DØGSTAR

DØ GEANT Simulation of the Total Apparatus Response

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September 3, 1997

DØ note 3191 Revision A

Abstract

The purpose of this simulation package is to offer a central facility for Monte-Carlo studies of the DØ detector with different configurations. It allows a non-specialist to have a full GEANT simulation of the apparatus with a simple interface, while also providing the specialist with a full description of all the subdetectors. The package allows the user to run separately each of the different phases of detector simulation: event generation (**d0gen**), particle tracking in the detector with hit generation (**d0sim**), pile-up, signal and noise simulation (**d0raw**). It also includes simple reconstruction (**d0rec**) and analysis (**d0ana**) tools.

In order to provide a smooth transition from GEANT3 to GEANT4, we have made strenuous efforts to stay within the GEANT framework, especially in the treatment of hits. This Users' Guide contains general information on how to install, run, and control the DØ simulation package. The guide and the reference manual will be constantly updated. Sections of the document are maintained by the various people responsible. The Users' Guide is available on the web via the DØ software pages.

Recent updates:

Update for version v1_0			
Add ISAZEB as input kinematics	d0kine/iodb	Y.Fisyak	08.27.97
Clean up	All	Janelle Leger	08.18.97

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User's Guide

1.1 Introduction

1.1.1 General

The **D0GSTAR** simulation package relies heavily on the CERN package GEANT[1]. Features and properties of GEANT are used for simulating particle behaviour in the detector (detector simulation), for saving the hits, and for reconstruction and analysis (if desired).

D0GSTAR simulates the performance of the DØ detector for Run II at the Tevatron. The Run I detector geometry is also available within **D0GSTAR** but digitization is not handled at present.

In this document we will mainly pay attention to simulation in the "Global" context but we have tried to create a framework which includes also the requirements for "FAST" and "MIXTURE" level simulations.

1.1.2 Basic framework

The basic improvements in **D0GSTAR** over the old UPG_GEANT are as follows:

- The software is primarily organized on the basis of functionality and only secondarily on the basis of subdetectors:
  - All geometry definitions are in a single file, **detc**;
  - All constants to build the geometry are in data file(s);
  - Hit definitions for all tracking detectors – the Central (Inner) tracker and the Muon system (which is considered to be the Outer tracker) – are unified and the differences among the specific detectors appear only in the digitization and cluster reconstruction stages. The format of reconstructed hits is the same for all tracking detectors in DØ.
- The version selection mechanism has been changed.
- Naming conventions have been revised. The numbering convention is obsolete; no numbers for rotation matrices or materials need be used as access to all these values is done via character string.
- Pileup, including that from preceding and following beam crossings, is supported.

Details of the new conventions are described in the following sections. Information on administration and maintenance of the **D0GSTAR** system is given in Appendix 7.1.

1.1.3 Goals of the full simulation

D0GSTAR is the detector simulation package for the DØ experiment. Among the goals for **full DØ simulation** are the following:

- to create an adequate computer model of the detector;
- to simulate the detector response up to the level of the data that will be obtained from the DØ DAQ system;
- to provide a framework for reconstructing events as a debugging tool.

At least three levels of detail must be provided for different subdetector simulation models:

- fast simulation – geometrical acceptance + parametrical model for detector responses
- the so-called "mixture" level simulation – dead materials, background estimation and reconstruction
- full simulation – detailed event simulation up to the DAQ level accounting for event pile-up effects.

It is important to note that a consistent simulation must be provided at each of these different levels. An essential component of the computer model of the detector is the database consisting of the following elements:

- a description of the detector geometry
- the magnetic field map
- all material and tracking media definitions
- sensitive element definitions
- definitions of "hits" providing the information required for the digitization stage and event reconstruction
- the tools necessary to work with this database

1.2 Computing environment

1.2.1 DØ machines

At present the **D0GSTAR** simulation system is supported on the following platforms at **Fermilab** :

- d0sgi0 and d0cha/d0chb (DØ sgi cluster)
- d0tng (DØ dedicated Open VMS cluster)
- fnalu (**Fermilab** central **Unix** cluster)

The reference machine for code maintenance is d0sgi. The most up-to-date version of the **D0GSTAR** package is always found there and versions on other platforms should be just copies from d0sgi.

1.2.2 Code maintenance

The source code is maintained using CVS [2]. The ASCII data files, such as GEANT detector definition constants and magnetic field map, are also stored in CVS in the format accessible by the ZEBRA[4] TZ package (i.e. TZ titles) [5].

The public CVS source files are kept in the directory $CVSROOT[1]. The breakdown of these files in the directories is as follows:

```
Repository: /cvsroot/d0cvs
Module: d0gstar
          +---docs/        D0gstar documentation
          |   +---html/          (HTML files)
          |   +---tex/           (TeX, style and eps files)
          +---init/        set of environment variables initialization scripts
```

[1] The standard DØ CVS repository is cvsuserd0chb.fnal.gov:/cvsroot/d0cvs which can be defined by setup d0cvs

```
+---mgr/         set of scripts for compilation, linking and run
+---src/         top level directory for FORTRAN sources
|   +---d0si/    Simulation steering
|   +---detc/    Detector Constants
|   +---util/    general Utilities
|   +---gene/    Interface with PYTHIA, HERWIG, ISAJET
|   +---sys/     header files with D0 and CERNLIB machine definitions
|   +---trak/    central Tracker related codes
|   +---calo/    Calorimeter       -"-
|   +---muon/    Muon system       -"-
|   +---user/    Reconstruction    -"-
|   +---reco/    User specific     -"-
|   +---gcal/    GEANT-GCALor interface
+---d0db/        top level directory for the data
|   +---detc/    set of tz-files with detector constant description
|                and rz-files with GEANT databases
|   +---evsi/    event input files with event kinematics (Ntuples)
|   +---fz/      event input/output files (fz)
|   +---kine/    standard cards with particle properties definitions
|   +---rz/      output histograms and Ntuples
|   +---scan/
|   +---wrld/
+---bin/         examples of FFREAD cards for D0gstar run
|   +---openvms_v6_1/  executables for different platforms
|   +---sgi_53/
|   +---sun4x_55/
|   ...
+---lib/
|   +---openvms_v6_1/  libraries for different platforms
|   +---sgi_53/
|   ...
```

- **gene**— D0 standard physics generation steering package **d0gen**

- **d0si**— general DØ Simulation steering
  high level steering routines for event simulation
  high level steering for event reconstruction
  steering for kinematics
  steering for (full tracking) simulation
  steering for (re)digitization pass

- **detc**— Detector Constants — geometry related routines:
  general utilities for geometry, rotation matrices, materials, tracking media
  General Data cards interpretation, handling of GEAN and SETS data cards, etc...

- **user**— User 'hook' routines, mostly dummies by default

- **util**— general Utilities:
  Kinematics utility routines, simple generators and interfaces

Utility routines common to simulation and reconstruction of
simulated data
Magnetic field routines
Routines for random access events i/o
input/output file handling package (IODB)
Utilities for preparation of absorption and radiation
lengths plots, etc...
D0GSTAR versions of some GEANT routine

- **trak**— routines for digitization and hit reconstruction
  in the central Tracker ("TR")
- **calo**— ditto in the Calorimeter ("CA")
- **muon**— ditto in the Muon system ("MU")
- **reco**— steering and utilities for Reconstruction ("RE"):
  High level steering routines for event reconstruction
  Fanout and auxiliary routines for event reconstruction
  Utility routines for reconstruction
  User entry points in reconstruction, etc...
- **gcal**— the DØ version of GCALor[6].

1.2.3 DØ Unix environment

Upon login the variable pointing to the top level **D0GSTAR** directory should be set

```
setup d0gstar
```

to one of the machines group login scripts (d0dev, d0new, d0pro or d0old) are executed and several **D0GSTAR** environment variables are set:

$d0_path	– root directory of the public area
$d0_level	– level: old, pro, new or dev
$d0_ver	– version v000, v1_0, v1_0, v1_0
$d0_root	– root directory for the given version
$d0_src	– source directory for the given version
$d0_db	– data base directory
$d0_rz	– directory rz-files with histograms and Ntuples
$d0_fz	– directory with fz-files with events
$d0_evsi	– directory with Ntuples which defines kinematics
$d0_lib	– directory with compiled libraries for given architecture
$d0_libpath	– library path used in linking
$d0_bin	– standard directory with control cards to run **D0GSTAR**
$d0_exe	– directory which contains executables for given architecture
$d0_log	– directory log-files

The definition of some of these environment variables depends on the **D0GSTAR** version old/pro/new/dev being active. The user can change the **D0GSTAR** version via the following four commands:

- d0old → v000
- d0pro → v1_0
- d0new → v1_0
- d0dev → v1_0

The source code and the corresponding compiled libraries and executables are kept in the above directories.

If after execution of one of the above scripts (d0dev, d0new, d0pro or d0old) you don't get a message like

```
D0GSTAR version v1_0 has been initialized
```

```
with /tmp_root/1300/d0gstar/dev/d0gstar/bin/sgi_53
```

it means that you don't have the $D0GSTAR_DIR variable defined. You should define it as

```
setenv D0GSTAR_DIR /tmp_root/1300/d0gstar
```

and also define

```
alias d0dev "source $D0GSTAR_DIR/d0gstar/init/d0dev"
alias d0new "source $D0GSTAR_DIR/d0gstar/init/d0new"
alias d0pro "source $D0GSTAR_DIR/d0gstar/init/d0pro"
alias d0old "source $D0GSTAR_DIR/d0gstar/init/d0old"
```

and repeate initialization.

1.2.4 DØ VMS environment

On VMS we try to keep a one-to-one correspondence to the **Unix** environment. Upon login to VMS, the following group login scripts

```
$ d0_init  :=="@dafm02$dka300:[tmp1300.d0gstar.v1_0.d0gstar.init]d0_init.com"
$ d0dev    :=="d0_init dev"
$ d0new    :=="d0_init new"
$ d0pro    :=="d0_init pro"
$ d0old    :=="d0_init old"
```

are executed and several **D0GSTAR** logical names are set:

d0_path	– root directory of the public area
d0_level	– level: old, pro, new or dev
d0_ver	– version v000, v1_0, v1_0, v1_0
d0_root	– root directory for the given version
d0_src	– source directory for the given version
d0_db	– database directory
d0_rz	– directory rz-files with histograms and Ntuples

d0_fz	– directory with fz-files with events
d0_evsi	– directory with Ntuples which defines kinematics
d0_lib	– directory with compiled libraries for Open VMS
d0_bin	– standard directory with control cards to run **D0GSTAR**
d0_sys	– given architecture
d0_exe	– directory which contains executables for given architecture
d0_log	– directory log-files
d0_cfl	– command file to compile and create libraries
d0_vax	– top directory with VMS sources

1.2.5 DØ database

The **D0GSTAR** package uses a **Unix** directory/file-based database system. The database files are accessed by a special package called **iodb**. The iodb code resides in the `util/iodb` directory.

There are utility routines for opening and closing the files, defining logical units, etc. The unit numbers are defined implicitly so that the user need not worry about them. All the standard data files needed in the **D0GSTAR** simulation are given as defaults in fortran so that normally no system code (like link or assign) is needed in the job.

Instead of default files the user can define his/her own i/o files by using the FFREAD control cards CDIR and/or CFIL..

```
cdir 'EVTO' '../d0db/fz/neu_b '
cfil 'DETI' '../d0db/detc/geom_ini.rz '
     'EVSI' '../d0db/evsi/dtu2000evd0.ntpl '
     'EVTO' '../d0db/fz/d0_neu_c.fz '
     'HBKO' '../d0db/rz/d0_new_c.rz '
```

These cards (see section 1.5) are interpreted by the iodb package. The data base system is described in more detail in the reference manual section II.2.3.

1.2.6 Example job scripts

A standard procedure for working with the simulation package (on d0sgi's) comprises the following steps:

- define pass to **D0GSTAR** top level directory (see section 1.2.3)
- setup d0cvs, gtools
- setup **D0GSTAR** variables – d0dev
- create a directory for a version of the **D0GSTAR**

```
mkdir v1_0
cd v1_0
```

- checkout from CVS repository (if necessary) and execute

`$d0_mgr/d0boot`

```
   cvs checkout d0gstar
or
   mkdir d0gstar
   cvs checkout d0gstar/mgr
   cvs checkout d0gstar/src
   cvs checkout d0gstar/d0db
```

or just copy source files from $d0_src and/or from $d0_db where anybody can find the latest version of codes and titles • edit source

- compile with gmake (in d0gstar/v1_0)

```
d0boot production   # create production libraries
d0boot debug        # create debug libraries
```

- link with `$d0_mgr/d0gstar`

```
d0gstar             # for interactive version
d0gstar -p          # for interactive version with gpaw++
d0gstar -b          # for batch version
d0gstar -g          # for interactive debug version
d0gstar -b -g       # for batch debug version
d0gen               # d0gen
d0gen  -g           # d0gen debug version
```

In a d0gstar script, first of all files with fortran codes (*.F and *.f) are compiled in the current directory. The link path search includes the current directory, ./lib/d0_sys directory and $d0_lib. The executable module is created in the directory ./bin/d0_sys if it exists, otherwise the module is created in the current directory.

- run the job script (examples can be found in $d0_mgr/run*)

For each of these steps there are sample scripts in the public directory `$d0_mgr`. Notice that before accessing these files one should be sure that the **D0GSTAR** environment is properly set. For example, one gets the version v1_0, if one has applied the command d0new.

Thus the scripts and a related control card file are as follows:

- d0boot – compilation on **Unix**
- d0gstar – linking on **Unix**
- D0gstar.com – linking on VMS
- run – batch version of the simulation job
- d0vXXX.ttl – control card file for job

The file d0vXXX.ttl (XXX stands for version number) contains the FFREAD control cards.

1.3 Naming conventions

The naming convention for the source code is as follows: the routines of the package should in general start with the same two initials as the package itself, e.g. /detc/dcgeom. There may be exceptions from this rule especially in case of some utility routines which are in the **util** file.

The naming conventions for **GEANT** volumes, materials and media are described below.

1.3.1 Materials and tracking media naming conventions

We specify that any access to material or tracking media should be done only via a name (character string) instead by a hard-coded number. In general the name of the material and its related tracking media are the same with only one exception. For specific tracking media related to a given subsystem a prefix (a character plus underscore) is added as follows:

```
T_    --  for the tracker,
C_    --  for the calorimeter, and
M_    --  for the muon system.
```

Furthermore, if the material with this name does not exist, for example "*T_Air*", then the standard material will be used ("Air").

There is one special tracking medium that has the prefix "*Thick_*." This tracking medium is used to denote "thick" or "simple" (i.e., lacking internal structure) shielding materials and iron yokes for the purpose of reducing computer time. In volumes composed of this kind of medium, kinematical cuts are increased inside a sub-volume which is reduced from the mother volume by $3 \times x_0$ in all dimensions.

1.3.2 GEANT volume naming convention

The rule for the initial letter holds especially for the geometry volumes:

```
D  --  for general {D\O} volumes
B  --  for the beam region
T  --  for general tracker volumes
S  --  for the Silicon tracker
C  --  for the Scintillator fiber tracker
U  --  for the barrel calorimeter
E  --  for the endcap calorimeter
M  --  for the muon system
Q  --  for the low beta quadrupoles
```

Also "B" and "U" are devoted to barrel and "F","E" for endcaps. Their place in volume names is not fixed.

1.4 Program structure and data flow

1.4.1 General

The **D0GSTAR** simulation system includes the following phases:

- **d0gen**– standard DØ event generation package
- **d0geo**– creates GEANT geometry RZ-file from titles
- **d0kin**– kinematics for **D0GSTAR**
- **d0sim**– the DØ GEANT tracking and hits simulation
- **d0raw**– DØ raw data simulation, performs event pile-up and hit digitization
- **d0rec**– the DØ event reconstruction
- **d0ana**– the DØ event analysis

Each program phase can be run independently provided the output file from the previous phase is available. A component is controlled by FFREAD cards. The data flow diagram is presented in Fig.1.1. It uses GEANT and **CERN** library routines. It has the following features:

- The geometry, materials, rotation matrices, magnetic field, etc. are specified in the database (now just a GEANT RZ-file) which uses as input title data cards which are read by the TZ (ZEBRA Titles) package;
- All communication among modules is done with GEANT ZEBRA structures.

The result of this is an RZ-file which is used for simulation (**d0sim/d0raw**) or reconstruction (**d0rec**). **d0sim** fills the KINE structure, does tracking, and makes hits. **d0raw** performs pile-up of events from a given number of bunches and makes digitization. The structures are output using the FZ packages for later analysis (in **d0rec**) or in combinations with trigger events for simulation of pile-up effects. The following sections give specific details concerning the different parts of this system (**d0geo**, **d0sim** and **d0rec**).

The detailed program flow charts are presented in the Reference Manual.

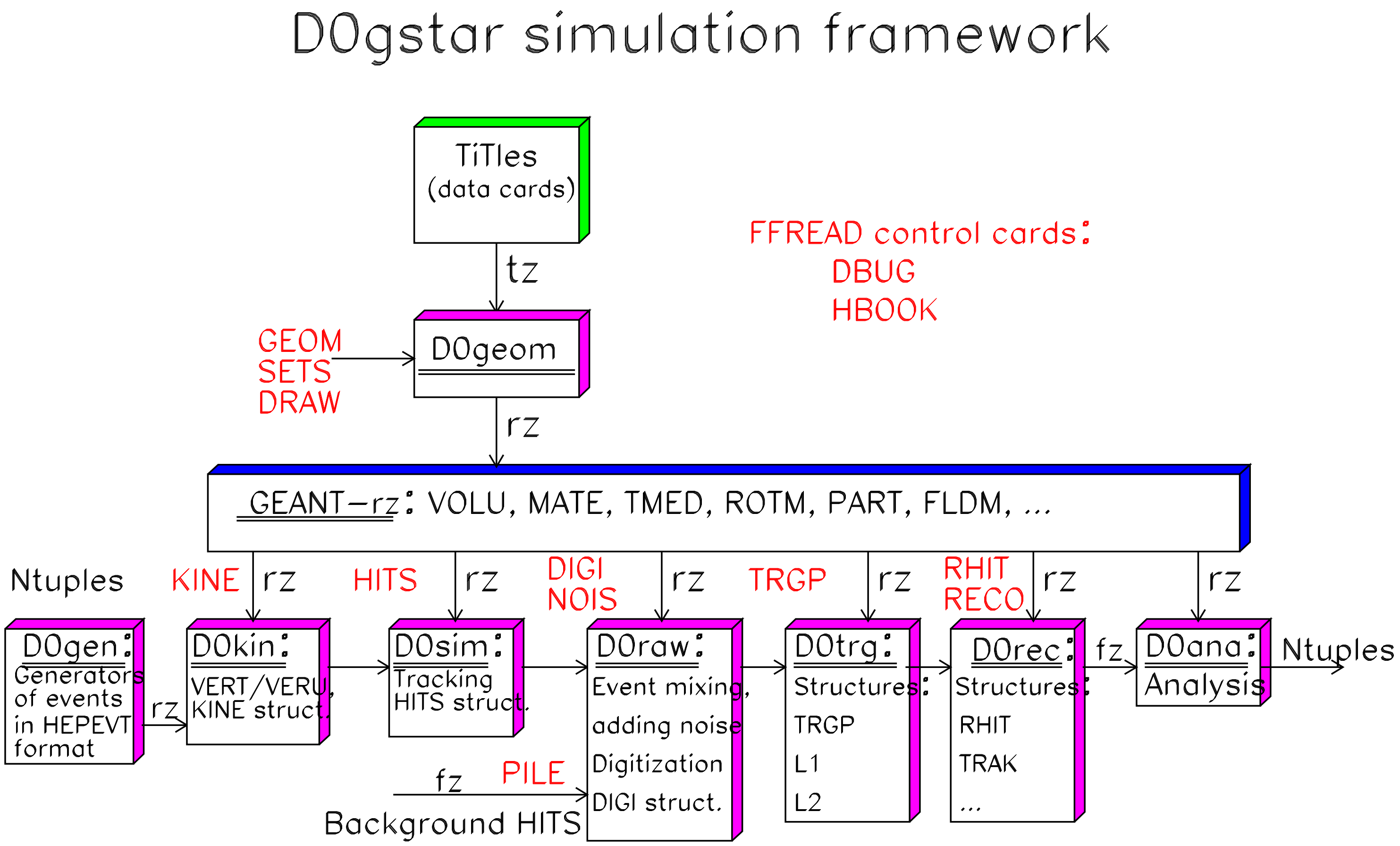

Figure 1.1: The **D0GSTAR** simulation program and data flow diagram.

1.4.2 Event generation – d0gen

The DØ detector simulation package follows the principle that the interface between the physics generators and GEANT kinematics goes via intermediate files which have a well defined format: column-wise Ntuples [8]. The Ntuple files are made by the DØ standard physics generation package **d0gen** which works in terms of the HEPEVT common where particle kinematics are stored as a **Column-Wise-Ntuple** (single precision):

```
******************************************************************
* Ntuple ID = 100    Entries = 2000      HEPEVT
******************************************************************
* Var numb * Type * Packing *    Range     *  Block   *  Name    *
******************************************************************
*      1   * I*4  *         *              * HEPEVT   * NEVHEP
*      2   * I*4  *         * [0,2000]     * HEPEVT   * NHEP
*      3   * I*4  *         *              * HEPEVT   * ISTHEP(NHEP)
*      4   * I*4  *         *              * HEPEVT   * IDHEP(NHEP)
*      5   * I*4  *         *              * HEPEVT   * JMOHEP(2,NHEP)
*      6   * I*4  *         *              * HEPEVT   * JDAHEP(2,NHEP)
*      7   * R*4  *         *              * HEPEVT   * PHEP(5,NHEP)
*      8   * R*4  *         *              * HEPEVT   * VHEP(4,NHEP)
******************************************************************
*  Block   *  Entries  * Unpacked * Packed *   Packing Factor    *
******************************************************************
* HEPEVT   *  2000     * 120008   * Var.   *    Variable         *
* Total    *    ---    * 120008   * Var.   *    Variable         *
******************************************************************
* Blocks = 1           Variables = 8       Max. Columns = 30002 *
******************************************************************
```

This provides the following benefits:

- files can be read on any system with **CERN** library installed
- in GUKINE only one interface code (HEPEVT→KINE) is needed
- events can be analysed with PAW, independent of GEANT

The HEPEVT standard is explained in ref. [9]. The event structure is in the common /HEPEVT/ shown below

```
      PARAMETER (NMXHEP=2000)
      REAL*4 PHEP, VHEP
      COMMON/HEPEVT/NEVHEP,NHEP,ISTHEP(NMXHEP),IDHEP(NMXHEP),
     &JMOHEP(2,NMXHEP),JDAHEP(2,NMXHEP),PHEP(5,NMXHEP),VHEP(4,NMXHEP)
```

containing information on particle status (ISTHEP), particle identifiers (IDHEP), mother-daughter relationships (JMOHEP, JDAHEP), particle 4-momenta (PHEP) and vertices (VHEP). For PHEP and VHEP we use single precision instead of PYTHIA's double precision.

HEPEVT is standard in PYTHIA. The STDHEP package [10] is used to interface the internal event structure of other physics generators with HEPEVT. The instructions for building and running **d0gen**can be found in Section 1.

1.4.3 GEANT detector description – d0geo

The GEANT detector description consists of the files

- **detc**— detector description code, and
- TZ titles for detector description and magnetic field maps — d0db/detc/*.tz.

The main steering routine is DCGEOM (in **detc**) and is called from UGINIT (in **d0si**).

Details of the detector description code and data may be found in the reference manual.

1.4.4 Kinematics – d0kin

The event generator kinematics are available only via the input Ntuples file. Run time generation (i.e. particle kinematics generation within **D0GSTAR**) is provided for simple events (IKINE=1-99) and Pythia events for **D0GSTAR** test purposes only.

For any other kind of generation, e.g. ISAJET generation at run-time, the user has to code his own USKIN9 routine which is called by GUKINE when IKINE=9.

The particle kinematics are controlled via the FFREAD control card "KINE" as follows:

```
KINE IKINE PKINE(1) ...  PKINE(10)
==============================================================================
 Valid kinematics definitions:
==============================================================================
KINE =  1 ==> Single particle event, with flat in the given eta, Phi and pT range
       PKINE(1)  = GEANT particle code (def. muon+)
       PKINE(2)  = eta_min
       PKINE(3)  = eta_max
       PKINE(4)  = Phi_min
       PKINE(5)  = Phi_max
       PKINE(6)  = pT_min
       PKINE(7)  = pT_max
       PKINE(8:10)= X & Y & Z of primary vertex
==============================================================================
KINE =  2 ==> the same as IKINE = 1 but  exponential distribution in the given pT range
==============================================================================
KINE =  3 ==> the scan with
       PKINE(1)  = GEANT particle code (def. muon+)
       PKINE(2)  = fixed pT            (def.  100.)
==============================================================================
KINE =  4 ==> the scan with
       PKINE(1)  = GEANT particle code (def. muon+)
       PKINE(2)  = fixed momentum      (def.  100.)
==============================================================================
KINE = 5  ==> Read ISAZEB file
==============================================================================
KINE = 11 ==> Single particle event, fixed momentum, Theta and Phi
       PKINE(1)  = GEANT particle code (def. muon+)
       PKINE(2)  = Theta (degree)      (def.   60.)
       PKINE(3)  = Phi (degree)        (def.   60.)
       PKINE(4)  = momentum (GeV/c)    (def.  100.)
       PKINE(5:7)= XYZ of primary vertex (def. 3*0)
       PKINE(8:10)= Sigma of X & Y & Z of primary vertex (def. 3*0)
```

```
================================================================================
KINE = 12 ==>  Multimuon event with fixed number of tracks
               in the given momentum and theta range
       PKINE(1)  = No. of muons        (def.     5)
       PKINE(2)  = P_min (GeV/c)       (def.    1.)
       PKINE(3)  = P_max (GeV/c)       (def.   50.)
       PKINE(4)  = Theta_min (degree)  (def.   10.)
       PKINE(5)  = Theta_max (degree)  (def.  170.)
       PKINE(6:8)= XYZ of primary vertex (def. 3*0)
       PKINE(9:10)= Sigma of X & Y of primary vertex (def. 3*0)
================================================================================
KINE = 13 ==>  Single track event
               in the given momentum and theta range
       PKINE(1)  = GEANT particle type (def. muon+)
       PKINE(2)  = p_min (GeV/c)       (def.    1.)
       PKINE(3)  = p_max (GeV/c)       (def.   50.)
       PKINE(4)  = Theta_min (degree)  (def.   10.)
       PKINE(5)  = Theta_max (degree)  (def.  170.)
       PKINE(6:8)= XYZ of primary vertex (def. 3*0)
       PKINE(9:10)= Sigma of X & Y of primary vertex (def. 3*0)
================================================================================
KINE = 15 ==>  Single particle event, fixed transverse momentum, Theta and Phi
       PKINE(4)  = Transverse momentum (GeV/c)    (def.  100.)
       PKINE(1:3),PKINE(5:7) - the same as for IKINE = 11
================================================================================
KINE = 16 ==>  Single track event
               in the given transverse momentum and theta range
       PKINE(2)  = p_T_min (GeV/c)     (def.    1.)
       PKINE(3)  = p_T_max (GeV/c)     (def.   50.)
       PKINE(1),KINE(4:8)  are the same as for IKINE = 12
================================================================================
KINE = 17 ==>  Single track event
               in the given transverse momentum and eta range
       PKINE(2)  = p_T_min (GeV/c)     (def.    1.)
       PKINE(3)  = p_T_max (GeV/c)     (def.   50.)
       PKINE(4)  = eta_min              (no def.)
       PKINE(5)  = eta_max              (no def.)
       PKINE(6:8)           are the same as for IKINE = 12
================================================================================
KINE = 19 ==>  User kinematics via uskin9
================================================================================
IKINE >99 ==>  LUND event with MSEL = IKINE - 100
               1x1 TeV proton-antiproton interaction
       PKINE(1)  = p_T_min (GeV/c)  of patron-parton interaction
================================================================================
```

KINE cards with any other IKINE will give the above printout.

1.4.5 GEANT tracking and HITS generation – d0sim

The GEANT hits are stored by the GUSTEP routine which is called by the GEANT system at each step of the particle's tracing in the detector. Hit information is stored when the particle goes through a detector sensitive volume and this volume is defined as a detector element. The format of this information is defined in the Reference Manual. The muon and tracker hits have the same format. GUSTEP calls a user routine USSTEP which is dummy by default.

The control of what daughter particles (secondaries) will be stored in the KINE structure is also controlled in GUSTEP. Daughters are stored in KINE, if

1. the interaction takes place in the tracker cavity and the mother has $p_t >$ pTcut, or
2. the interaction takes place for muon with $p_t > 5 \times$ pTcut, and the interaction mechanisms are one of the following: decay, Bremsstrahlung, pair production or hadronic interaction.

The value of pTcut is 1.0 GeV. The tracker limits are defined by the constants Rcut and Zcut which are set to 74 cm and 139 cm, respectively.

1.4.6 Event pile-up, noise and digitization – d0raw

Event mixing and pile-up – gtrig

The event mixing with minimum bias (MB) background events is performed at the level of hits. "Physics" events and MB events are run separately event by event through **D0GSTAR** to produce HITS and intermediate files are output. The event mixing and pile-up are controlled by the following FF cards (see section 1.5).

Events containing the HITS structures are used in mixing using the CFIL card as follows:

```
CFIL  ...
      'FZIN'  'phevents.fz '     (input events must have HITS)
      'PILE'  'mbevents.fz '
or
      'EVSI'  'phevents.ntpl '   (GEANT tracking and HITS to be done)
      'PILE'  'mbevents.fz '
```

If an ntpl file (kinematics) is given as 'EVSI' input, one must have the card `KINE 0 ...` as well as SETS card set for the detector you want or use the SETS default (all detectors).

File names must be existing files or links pointing to existing files. Some sample files are in `$d0_db/fz` and `$d0_db/evsi` directories.

The number of mixed MB events per bunch is defined by the BEAM card and the number of bunches by the PILE card. With the PILE card one can define the number of bunch crossings before and after the crossing in which the physics event originated (the trigger crossing).

```
PILE  'Det1'  IF1  'Det2' IF2
```

The flag `IFi` is defined as

$$\mathrm{IFi} = 10N_{bc} + N_{ac}$$

where N_{bc} is the number of crossings before the trigger crossing, and N_{ac} is the number after. *The defaults for pileup flags are* -1 *which means that only the trigger crossing is simulated with no overlapping MB events.* For example the card

```
PILE  'TRAK'  10 'MUON' 31
```

would imply 5 crossings to be piled up for the **muon** detectors (3 before the trigger crossing and one after) and only 2 crossings (one before and the trigger) to be piled up for the tracker detectors. Another example:

```
PILE  'TRAK'  0 'MUON' 1
```

would simulate only the trigger bunch for the Tracker with MB background and for muon system one additional bunch collision after the trigger (1 is equivalent with 01).

The information on tracks responsible for the hits is saved along with the hit elements for the trigger event. For superimposed minimum bias events, vertex and track information is not stored. Consequently the track numbers in the hit structure are set to 9000 + event number.

Digitization – gudigi

Conversion of the energy deposits to detectable signals and digitization are steered by the routine GUDIGI. The steering control is given by the FFREAD card DIGI. For example the card

```
DIGI  'TRAK'  1 'DO ' 0
```

will enable digitization in the the trackers whereas no digitization will take place for the rest of the detectors.

1.4.7 Reconstruction – d0rec

The event reconstruction is steered by the routine D0RECO in the **d0si** package. The reconstruction in subdetectors takes place in the following order:

1. Reconstruction in calorimeters,
2. Reconstruction in muon chambers,
3. Reconstruction in the Tracker and
4. Global reconstruction.

The steering control takes place by the FF control card RECO. The reconstruction result is stored in the RECO bank structure which is linked to the D0MT master bank. The reconstruction structure as well as the simulation structures are all under the same root D0MT (see Appendix 'Bank Descriptions'). The top bank structure which supports different sub-detector reconstruction structures is shown in the figure below.

1.4.8 Utilities

I/O file handling

GEANT extensions

1.5 User hooks

1.5.1 General

The **GEANT** program uses the FFREAD package to transfer user data to the program. In addition to the standard **GEANT** data cards (see **GEANT** manual BASE040) there are a few specific data cards defined for the **D0GSTAR** program. The data cards are either inserted in the job script file (batch) or read from a separate ASCII file (interactive job).

The data cards which control sub-detector specific operations are normally of the following form:

```
FFID 'KEY1' N1  'KEY2' N2  ...
```

where the keywords KEYi are normally subdetector identifiers and the numerical flags Ni are normally used as switch off/on (0/1) indicators, detector options, or debug levels. The contents of this type of data card can be examined in the program by using the function ICFLAG as follows:

```
       Nx = ICFLAG ('KEYx','FFID')
```

where 'FFID' (in) is one of the defined FFREAD keys, 'KEYx' (in) is the (detector) identifier and Nx (out) is the numerical flag value.

Specifications of GEANT defined control cards can be found from the GEANT manual, section BASE040. Various DØ specific data cards are explained below together with some of the most common GEANT data cards.

1.5.2 Printing, histogramming and drawing control cards

The print/debug event range, the specific systems to be debugged, and GEANT structures to be printed can be controlled by the following data cards:

```
DEBU  IFIRST ILAST IDELTA                (Events to debug/print)
DBUG  'KEY1' N1  'KEY2' N2  ...          (Subsystems and levels to debug)
HBOOK 'KEY1' N1  'KEY2' N2  ...          (Subsystems to invoke HBOOK)
PRIN  'BNK1' 'BNK2' ...                  (Structures to print)
SWIT   N1 N2 N3 N4 ... N10               (Switches in interact. job)
```

Notice that the DEBU parameters control the DBUG, PRIN and SWIT flags, which become ineffective outside the event range determined by the DEBU card. The DBUG card controls subdetector specific debugs. For instance the control card

```
DBUG  'TRAK' 3  'MUON' 0
```

sets the tracker debug level to 3 with no debugging of the muon system.

Only the first four characters of the FF-keys are significant so that HBOO and HBOOK are equivalent on input cards. In the code only 4 characters should be used e.g.:

```
IVAL = ICFLAG ('TRAK','HBOO')
```

The HBOOK FF-card is used to control histograms and plots as well as Ntuples.

The DBUG and HBOOK data cards are designed to have some structure in the numerical flag values Nx. Nx is eight bits, each of which specifies the flag value at a given stage of the program. The eight stages are defined as

1. Program initialization (INIT, **d0geo**)
2. Creation of the event kinematics (KINE, **d0kin**)
3. Tracking and recording of hits (HITS, **d0sim**)
4. Event mixing and pile-up (PILE, **d0raw**)
5. Adding "junk" hits due to, for example, neutron background (JUNK, **d0raw**)
6. Digitization and trigger control (DIGI, **d0raw**)
7. Creation of reconstruction hits (RHIT, **d0rec**)
8. Reconstruction (RECO, **d0rec**)

and they correspond to the respective bits (starting from the least significant bit).

In interactive GEANT the SWITches N1, ... , N4 are used as follows: A GEANT routine GDEBUG is called from GUSTEP and GDEBUG calls specific Printing/Storing/Drawing routines according to the SWIT flag values as described below:

```
GDEBUG calls  GPKIN            if  SWIT(1) = 2
              GSXYZ                SWIT(2) = 1   or   SWIT(3) = 1
              GPCXYZ               SWIT(2) = 2
              GDCXYZ (all)         SWIT(2) = 3
              GDCXYZ (charged)     SWIT(2) = 3   and  SWIT(4) = 3
              GSXYZ+GDTRAK         SWIT(2) = 4
```

The routines GP... print the track parameters (GPKIN) or points when tracking. The routines GD... draw points on graphics window so that the tracks are seen as lines. In interactive session one can change the SWIT parameters by SWITCH command (see GEANT XINT002–29).

1.5.3 Events and structures i/o control cards

The following cards are used to control the i/o files and structures to be saved or read:

```
CDIR 'KEYW' 'directory '
CFIL 'KEYW' 'file '                     (space is significant)
SAVE 'KEY1' 'KEY2' ...
RSAV 'KEY1' 'KEY2' ...
GET  'KEY1' 'KEY2' ...
RGET 'KEY1' 'KEY2' ...
```

CDIR and CFIL cards are used to provide other than default DB files for the program.

The cards SAVE, RSAV, GET and RGET are standard GEANT control cards and they are used to control the structures (events) to be input/output in FZ or RZ format. They take as arguments standard GEANT structure names like 'KINE', 'VOLU', 'HITS' and 'DIGI'. Also non-standard GEANT structure identifiers like 'RHIT' and 'RECO' can be given as arguments. The keyword 'INIT' has a special meaning: it allows saving and retrieving of detector description files.

The control cards GET and RGET also affect the program flow: If a structure is requested from the input file, the processing request by the corresponding program control card will be overridden (see below).

1.5.4 Program flow control cards

The program flow control cards are listed below.

```
KINE  IKINE   PKINE(1)  PKINE(2)  ...   PKINE(8)
GEOM  'KEY1' N1   'KEY2'  N2      ...                (Detector)
SETS  'KEY1' N1   'KEY2'  N2      ...                (Hits)
PILE  'KEY1' N1   'KEY2'  N2      ...                (Pile-up)
DIGI  'KEY1' N1   'KEY2'  N2      ...                (Digitization)
JUNK  'KEY1' N1   'KEY2'  N2      ...                (Incoherent noise)
TRGP  'KEY1' N1   'KEY2'  N2      ...                (Trigger primitives)
RHIT  'KEY1' N1   'KEY2'  N2      ...                (Hit reconstruction)
RECO  'KEY1' N1   'KEY2'  N2      ...                (Reconstruction)
```

If a card is missing, default values are set for each keyword. Notice that the request by the above control card will be overridden if it is in contradiction with the GET/RGET card (see above).

The KINE card parameters go into the GEANT common /GCKINE/. It is used to control the kinematics input to GEANT. The meaning of the parameters is explained in section 1.4.4.

Keywords in the above list are normally *subdetector* volume names (see section II.3.5.1). The value associated with the keyword is propagated to all lower levels. After that, for all options except 'GEOM', the value associated with the keyword is set equal to the maximum value in the branch defined by the keyword.

The GEOM card is used to select geometry options. The 'KEYi' selection index Ni is defined as follows:

```
    Ni = ID + 10*IT
```

where IT is a technology index and ID is the level of detail. The default technology index is IT=0 (baseline proposal). The levels of detail are:

```
    ID = 3 .. detailed geometry (default)
         2 .. simplified geometry
         1 .. average geometry (no sensitive material)
```

For example, the GEOM card with the following contents:

```
GEOM 'DO  ' 3 'UC  ' -1
```

defines the default detector except that the barrel calorimeter will be completely switched off.

Different subsystems of the detector can be activated or deactivated. By default all subsystems are active. For example:

```
SETS 'DO ' 0 'WMUS' 1 'FMUS' 1
```

means that all detectors will be non-sensitive except the barrel and endcap muon chambers. The non-sensitive detector option means that there will be no HITS simulation.

Digitization, creation of trigger primitives, hit reconstruction, and event reconstruction are controlled by DIGI, TRGP, RHIT and RECO cards. The default values of the corresponding detector flags are = 1. The user can switch off the action in certain detectors by setting the corresponding value to 0, e.g.:

```
DIGI 'TRAK' 0
```

The flags can be used also to choose between different digitization and reconstruction options. More information may be found in the Reference Manual.

1.5.5 Other control cards

```
BEAM   X Y Z   dX dY dZ  Lum  NMB CROTIM XSECTN
(beam position and spread, luminosity, NMB, time between bunch crossings and
                                            total inelastic cross section)
```

The luminosity is given in units of $10^{32}\mathrm{cm}^{-1}\mathrm{s}^{-1}$. The mean number of events per bunch is calculated from:

$$\langle N_{MB}\rangle = L\sigma_T(p\bar{p})\tau_B.$$

where L is the luminosity and τ_B (= CROTIM) is the bunch crossing interval (ns). By default the actual number is generated according to Poisson statistics with the above mean. One can change this default by the parameter `NMB` which, when set to a positive value, implies a fixed number of mixed MB events. The BEAM card defines the nominal $p\bar{p}$ beam position and spread at the interaction point (in cm) as well as the luminosity in units of $10^{32}/cm^2/s$. The default values are $X = Y = Z = 0$ and $dX = dY = 50./\sqrt{2}$, $dZ = 30$ and $Lum = 1.$. The last parameters are optional and can be used to fix the number of MB events per bunch (see section 1.4.6), bunch crossing time and inelastic cross section.

Listed below is an example of control cards.

```
LIST
C    Nominal collision point and  sigmas(cm) Lumi/10**32  NmBunch CROTIM XSECTN
BEAM    0.    0.    0.   0.0050 0.0050 30.0    2.0             0    132.  61.5
C    *.ntpl no use   etamin etamax Phimin Phimax  pTmin pTmax
KINE   0      0.       -2.4    2.4      0.   360.    1.    9999.
TIME  5.   5.  1
RUNG  1   1                             (User run and first event number)
GEOM   'D0 ' 3  'CALO' 1   'MUON' 3     (Geometry options)
SETS   'D0 ' 1  'CALO' 0   'HCAL' 1     (HITS activation-deactivation)
CFIL  'HBKO' 'geant_hbook.hbook '       (Hbook output file)
      'META' 'geant.ps '                (Graphics output file)
      'EVTO' '$SCRATCH/minbias.fz '     (Events output file)
SAVE 'HEAD' 'HITS' 'KINE' 'VERT'        (Output structures selection)
PILE 'D0 ' 1                            (Pile-up control)
DIGI 'D0 ' 0                            (Digitization control)
RHIT 'D0 ' 0                            (Hits reconstruction control)
DBUG 'D0 ' 1  'TRAK' 3                  (specific debug levels)
DEBU  -1   100  1                       (first,last,frequency to debug)
PRIN 'KINE'                             (Structures to print)
SWIT   0  3  0  0  6*0                  (To see charged & neutrals)
STOP
END
```

1.5.6 Histogramming

To avoid clashes between different subsystems in **D0GSTAR** the following scheme is introduced for histogram subdirectories:

- directory /GEANT — contains histograms related to the GEANT processing of the events such as
  - time per event
  - time per deposited energy
  - memory used for event
  - total number of long life tracks per event
  - maximum stack size per event
  - ...
- directory /GENE — contains information about the generated (input) event: total and charged particle multiplicities, Z-coordinate of interaction, average energy versus pseudo-rapidity, p_T-distribution, ...
- directory /USER — contains histograms for the user

A directory structure closely following the structure defined in the SETUP title block (see section 3.5.1) is reproduced for the detector specific part. For example, the following subdirectories would be created:

- directory /TRAK — contains histograms for the central tracker

- directory /CALO — ditto for the calorimeter
- directory /MUON — ditto for the muon system
- directory /TRIG — ditto for the trigger

1.5.7 Hooks

The user can interface with **D0GSTAR** on a different level via a set of "USER HOOKS." The list of these hooks is presented below:

- USS_FFKEY — FFREAD control cards and other beginning initializations
- US_INITG — initializations after reading FF cards
- US_INITH — user definition of histograms
- US_INITU — user definition of Ntuples
- USKINE — user definition of kinematics called when IKINE 3 (see control card "KINE").
- USSTEP — user action in GUSTEP
- US_OUT — user action prior to event i/o
- USLAST — user termination.

Part II

Reference Manual

Chapter 1

Event generation - d0kin

The DØ simulation code, **D0GSTAR**, needs access to the particle kinematics produced from a number of distinct Monte Carlo generator programs. In general such programs have different ways of specifying the input parameters and a multitude of output event and file formats. The purpose of **d0gen** is to provide uniform input and output interfaces to the most common generators used by **D0GSTAR**. So far the only generator implemented within **d0gen** is Pythia.

To be consistent with **D0GSTAR** and CERNLIB we have adopted FFREADspecifying the input parameters to event generator programs.

Many event generators permit the conversion of the internal event format to the HEPEVT format. Moreover, the STDHEP package provides conversion routines to and from HEPEVT format for the Herwig, Jetset, Isajet, and QQ event generators. We have therefore adopted HEPEVT as the standard generator event format for **D0GSTAR**. **d0gen** is also a code repository of general event generator utilities which operate on the HEPEVT structure.

The output event file format adopted is the HBOOKcolumn-wise Ntuple format, which has a number of attractive features: it is system-independent and CERN-supported; it has a 1–1 mapping to Fortran COMMON blocks (*i.e.* HEPEVT); it is easy to read (by **D0GSTAR**, user programs, and PAW); and it supports transparently the packing of data.

1.1 d0gencode

The **d0gen** code is written in FORTRAN77. The source code may be found, on any machine with the DØ environment, in the CVS directory `d0gstar/src/gene`. While the **d0gen** code is part of the **D0GSTAR** software releases it is independent of the rest of the **D0GSTAR** code, apart from the use of standard IODB procedures (see `util/iodb`) to handle input/output files.

1.2 Creation of a HEPEVT Ntuple using d0gen

Event generation using **d0gen** has been implemented as follows:

1. the user modifies `GE_EVT_SEL` (if desired);
2. a standard script compiles, links to the **d0gen** library, and runs the program ;
3. the user controls the job with FFREAD data cards.

The following general data cards are understood by **d0gen**:

`DEBUG IDEMIN IDEMAX ITEST`
First event to debug, ast event to debug, Print control frequency — the same as used for **D0GSTAR**

`CFIL 'EVTO' 'higgs.ntpl '`
output HEPEVT event Ntuple file (N.B. a space after the file name and before the closing quotation mark is mandatory).

`KSEL i`
predefined DØ selection number `i` (`i=0` ⇒ call user selection routine `GES_USER`, the dummy version of which selects all events).

`ICUT i j k...`
INTEGER cut values (`KSEL`-dependent meaning).

`RCUT a b c...`
REAL cut values (`KSEL`-dependent meaning).

`TRIG n`
number of events to generate (e.g. `PYEVNT` calls).

`NSEL m`
number of events to be selected and written out.

`DECAY flag`
if true then **D0GSTAR**will provide decay for the particles known to it.

`Pythia flag frame beam target` $\sqrt{s}$
activate interface with Pythia (flag = true/false)

`HERWIG flag beam target` p_{beam} p_{taget} `process` p_{Tmin}
activate interface with Herwig (flag = true/false)

`ISAJET flag`
activate interface with ISAJET (flag = true/false)

`LUGIVE flag`
card to force reading Pythia parameters from the input via GE_FFUSER

`ISABEG flag`
card to force reading ISAJET parameters from the input via GE_FFUSER
In order to change parameters via GE_FFUSER a pair of the control cards should be used, for example,

```
*pythia true  'cms' 'p  ' 'p~  ' 2000.
lugive true
```

with "*" (star) in the first position of Pythia cards. During input it uses standard procedures of ISAJET (isaini) or Pythia (lugive) to read parameters for generators. Examples of jobs for different processes and with different generators are presented below:

- Generation of top production at Tevatron with Pythia. The block of the Pythia parameters is started with card "LUGIVE" and ends with "END". The "*" in the first position and "!" mean comments.

```
list
DEBUG  -1   100   1
cfil 'EVTO' '../d0db/evsi/pythia_top.ntpl '
decay true
*pythia true  'cms' 'p  ' 'p~  ' 2000.
lugive true
*---
*--- parameter setting for jetset
*--- set strangness supression & fragmentation p_T
*---
*
* default settings
*
* LUDAT1        <**********************************
MSTJ(104)=6      ! allow top-antitop production
* LUDAT2        <**********************************
PMAS(C6,1)=175.  ! top quark mass
* LUDAT3        <**********************************
MDCY(C111,1)=0   ! inhibit pi0 decays
* PYPARS        <**********************************
MSTP(2)=2        ! (D=1) calculation of alpha_strong at hard interaction
PARP(31) = 1.2   ! specifies a k factor = 1.2 (SDC)
* force decay modes
*23456123451234512345  (6x,6i5)
DECAY    24  -13   14                  ! W --> mu+ nu
*
CKIN(1)=30.
CKIN(3)=2.
MSEL=6            ! Top pair production
END
luexec true (force decays and remove comment lines)
ksel 0 (user selection)
nsel 10000
trig 10
stop
```

- Generation of hard hadron process with Herwig.

```
herwig true 'P' 'PBAR' 900. 900. 1500
luexec true
ksel 0 (user selection)
```

```
nsel 10000
trig 10
stop
```

- WW production job with ISAJET

```
*isajet true
isabeg
SAMPLE WPAIR JOB
1800,100,1,1/
WPAIR
BEAMS
'P','AP'
PT
50,100,50,100/
JETTYPE1
'W+','W-','Z0'/
JETTYPE2
'W+','W-','Z0'/
WMODE1
'E+','E-','NUS'/
WMODE2
'QUARKS'/
END
nsel 10000
trig 10
stop
```

1.3 Reading of HEPEVT Ntuples

Since the HEPEVT output events are in standard column-wise Ntuple format they can be used within PAW. They constitute the standard input format to **D0GSTAR** and can also be read from a standalone fortran program.

Chapter 2

Steering code — d0si

2.1 General

As mentioned in section I.1.4.1, there are six logical units in the DØ simulation software which have common initialization and termination stages:

- **d0geo**— creation of GEANT-RZ file which contains as GEANT structures all detector constants including geometry, materials, tracking media, magnetic field and subdetector parameters. The **util-** and **detc**-packages (see below) provide utilities for this operation.
- **d0kin**— read from Ntuple or create event kinematics and convert it into GEANT KINE/ VERT structure
- **d0sim**— the DØ detector simulation program which uses the GEANT structures provided by **d0geo** to
  - read or generate KINE structures for a given event
  - track all particles from this event through the detector elements
  - simulate detector hits
  - convert detector hits into digitization (i.e., the expected detector response).
- **d0raw**— the simulation of detector response
  - add hits from pile-up events
  - add "junk" – uncorrelated hits due to "neutron" background
  - convert detector hits into digitization (i.e., the expected detector response).
- **d0rec**— reconstruction of the event, including:
  - reconstruction of hits and showers from digitization
  - charged track pattern recognition
  - electromagnetic and hadronic shower reconstruction
  - ...
- **d0ana**— analysis of results

2.2 Initialization – uginit

The initialization for the batch version of the program is presented below[1]. This initialization stage program initializes ZEBRA and GEANT, sets and reads control cards (via FFREAD routines) and identifies the present versions of program and titles.

```
*
*   (*)  means  user code (not GEANT3 code)
*
* M A I N (*)   D0_GEANT3 Main Program
*  |
#if  defiend(D0_TRACE)
*  |->HANDLER(*)       condition handler
#endif
*  |
#if (defined(D0_MOTIF))&&(!defined(D0_BATCH))
   |->GPAWPP
#endif
#if (!defined(D0_MOTIF)&&(!defined(D0_BATCH))
   |->GPAW
#endif
#if  defined(D0_BATCH)
*  |->G Z E B R A      initialization of Zebra system
*  |->H L I M I T
#endif
*  |
*  |->U G I N I T (*)  user initialization routine for D0_GEANT3
*  |   |                                                        |
*  |   |                    =====================               |
*  |   |==================| Initialization phase|========================|
*  |   |                    =====================               |
*  |   |                                                        |
*  |   |->GINIT             GEANT initialization routine        |
*  |   |                    defines Simulation specific user data cards --|
*  |   |->FFSET                                                 |
*  |   |->D0_INITF (*)        General D0 initializations: FFKEYs etc..    u
*  |   |   |->IO_FFKEY (*)  Define data cards used for I/O and database  n
*  |   |   |->DC_FFKEY (*)  ...                    for DETC             r
*  |   |   |->D0_FFKEY (*)  ...                    for D0SI             .
*  |   |   |->TR_FFKEY (*)  Define user data cards for tracker,         a
*  |   |   |->CA_FFKEY (*)  ...                                         d
*  |   |   |->MU_FFKEY (*)  ...                                         .
*  |   |   |->US_FFKEY (*)  User specific                               |
*  |   |->GFFGO             Read FF data cards                          |
*  |   |->GZINIT            Initialize GEANT data structures            |
*  |   |->D0_INITG (*)      D0 initializations after reading FF cards   |
*  |   |   |->IO_INIT (*)  Initialize directories/files for I/O, database|
*  |   |   |->IO_OPEN_FILE (*)                                          |
*  |   |   |->UZINIT (*) Initialize user link area                      |
*  |   |   |->UTSELE (*) Interpretation of event selection FF card      |
*  |   |   |->TR_INITG (*)  Tracker Initialization                      |
*  |   |   |->CA_INITG (*)           ...                                |
```

[1] (*) means user code (not GEANT3 code)

```
*  |    |    |->MU_INITG (*)           ...                          |
*  |    |    |->US_INITG (*)  User Initialization                   |
```

2.3 DØ geometry preparation

The **d0geo** flow diagram is presented below. This part interfaces with UGINIT via a call to **DCGEOM** and tries to read the constants structure from the input GEANT.RZ file (using IODB key word “DETI” and “RGET” as a control card). If the requested file does not exist or there are any problems with the GEANT structure then the program recreates this structure using title data file(s) and saves them (structures) optionally as the output GEANT.RZ file (using IODB keyword “DETO” and “RSAV” as the control card).

```
*  |    |              ============================                |
*  |    |  ============|Data Base creation/reading|=======================|
*  |    |              ============================                |
*  |    |->DCGEOM   (*)  steering for reading of detector titles   |
*  |    |    |->DC_PINI (*)    particle table initialization       |
*  |    |    |    |->PYINIT           Use PYTHIA particle tables   |
*  |    |    |    |->LUGIVE           Use JETSET interpreter       |
*  |    |    |->IO_OPEN_FILE (*) Opens the input rz file           |
*  |    |    |->TZINIT    Read titles, initialize field map, creates |
*  |    |    |    |         D0 geometrical setup                   |
*  |    |    |    |->TZUSER (*)  Interprets the title banks and converts |
*  |    |    |        |          into GEANT structure              |
*  |    |    |        |->DCSETU (*)     Interpret SETUP data card  |
*  |    |    |        |    |->DC_SETUP (*)                         |
*  |    |    |        |        |->DCDECO (*)                       |
*  |    |    |        |        |->DC_FORM (*)                      |
*  |    |    |        |->DCONST (*)     Load material constants    |
*  |    |    |        |    |->DC_ACT (*)                           |
*  |    |    |        |        |->DCGMAT (*)                       |
*  |    |    |        |        |->DCGMIX (*)                       |
*  |    |    |        |        |->DCTMED (*)                       |
*  |    |    |        |        |->DCTPAR (*)                       |
*  |    |    |        |        |->DCROTX(*)   rotation matrices    |
*  |    |    |        |        |->DCSENS(*)                        |
*  |    |    |        |        |->DCMEDI(*)                        |
*  |    |    |        |->DCVALU (*) Test validity of the title block |
*  |    |    |        |->DCGEAN (*)                                |
*  |    |    |        |    |->DCVALU (*)                           |
*  |    |    |        |    |->CLTOU                                |
*  |    |    |        |    |->DC_ACT (*)                           |
*  |    |    |        |        |->DCGMAT (*)  Load material table  |
*  |    |    |        |        |->DCGMIX (*)  Load mixture table   |
*  |    |    |        |        |->DCTMED (*)  Load tracking medium table |
*  |    |    |        |        |->DCTPAR (*)  Load special TMED parameters |
*  |    |    |        |        |->DCCKOV (*)  Define constants for Cerenkov |
*  |    |    |        |        |->DCROTX (*)  Define rotation matrices |
*  |    |    |        |        |->DCSENS (*)  Declare sensitive medium |
*  |    |    |        |        |->DCMEDI (*)       ...             |
*  |    |    |        |        |->DCVOLU (*)  Create a new volume  |
*  |    |    |        |        |->DCDVN  (*)   Create division     |
*  |    |    |        |        |->DCDVN2 (*)       ...             |
*  |    |    |        |        |->DCDVT  (*)       ...             |
```

```
*  |   |   |       |       |->DCDVT2 (*)       ...                    |
*  |   |   |       |       |->DCDVX  (*)       ...                    |
*  |   |   |       |       |->DCNEAR (*)  Order the volumes           |
*  |   |   |       |       |->DCNEXT (*)       ...                    |
*  |   |   |       |       |->DCORD  (*)       ...                    |
*  |   |   |       |       |->DCPOS  (*)  Position the volumes        |
*  |   |   |       |       |->DCPOSP (*)        ...                   |
*  |   |   |       |       |->DCSATT (*)  Set attributes              |
*  |   |   |       |       |->DCDET  (*)  Declare sensitive detector  |
*  |   |   |       |       |->DCDETV (*)        ...                   |
*  |   |   |       |       |->DCDETA (*)  Declare an alias            |
*  |   |   |       |       |->DCDETH (*)  Define hit elements         |
*  |   |   |       |       |->DCDETD (*)  Define digit elements       |
*  |   |   |       |       |->DCDETT (*)  Define trigger primitives   |
*  |   |   |       |       |->DCDETU (*)  Define user words           |
*  |   |   |       |       |->DCHITS (*)  Standard hit banks          |
*  |   |   |       |       |->DCHITR (*)  Standard RHIT banks         |
*  |   |   |       |       |->DCPGON (*)                              |
*  |   |   |       |       |->DCTPNT (*)  Position two-point volumes  |
*  |   |   |       |->DCDRAW (*)     Interface to GDRAW routines      |
*  |   |   |       |->GGCLOS                                          |
*  |   |   |->IO_CLOSE_FILE (*)                                       |
*  |   |   |->DC_SATT (*)         Set special attributes              |
*  |   |   |->DCPART (*)         Complete particle table or           |
*  |   |   |->DCPARX (*)         Update particle table in memory      |
*  |   |   |->GGCLOS                                                  |
*  |   |   |->DCMEDI (*)         Special action for tracking media    |
*  |   |   |   |->GPHYSI                                              |
*  |   |   |->GLOOK                Print GEANT structures             |
*  |   |   |->GPMATE/GPTMED/GPROTM/GPVOLU/GPSETS/GPPART               |
*  |   |   |->DC_PRNT (*)          Print run conditions               |
*  |   |                                                              |
```

Initialization of histograms and Ntuples.

```
*  |   | =============  Initialization of HBOOK ======================== |
*  |   |                                                              |
*  |   |->D0_INITH (*)                                                |
*  |   |   |->HTITLE                                                  |
*  |   |   |->IO_OPEN_FILE (*) Open hbook file if any                 |
*  |   |   |->D0_INITU (*)     Initialize Ntuples                     |
*  |   |   |   |->TRE_INITU (*)  for Tracker                          |
*  |   |   |   |->CA_INITU  (*)  for CALO                             |
*  |   |   |   |->US_INITU  (*)  for Muon system                      |
*  |   |   |   |->RE_INITU  (*)  for reconstruction                   |
*  |   |   |   |->US_INITU  (*)  for user                             |
*  |   |   |->HMDIR                                                   |
*  |   |   |->G_INITH (*) book GEANT standard histograms              |
*  |   |   |->TR_INITH (*) initialize subsystem  histograms           |
*  |   |   |->CA_INITH (*)                                            |
*  |   |   |->MU_INITH (*)                                            |
*  |   |   |->US_INITH (*)                                            |
*  |   | ============ Initialization of input/output fz-files  =========|
*  |   |                                                              |
*  |   |->IO_OPEN_FILE (*)     Open fz-file for input/output:         |
```

```
*  |   |->ZPHASE(1)        Flag end of initialization stage              |
*  |                                                                     |
```

2.4 Simulation steering

Simulation steering is provided for

- at the level of the run — definition via FFREAD-cards of the run parameters, kinematics, cuts, level of simulation (hits and digitization), choice and initialization of input/output files fz-files for trigger event, pile-up events and output of the simulation results; initialization of HBOOK Ntuples and histograms (see section about creation of histograms)
- at the level of the event — event reading, selection, processing and writing, execution error trapping
- at the level of the step — creation of hits, histogramming. In this step there is also special treatment of particle decays (see the section describing kinematics and particle definitions).

and includes:

- initialization of input/output fz-files for trigger event, pile-up events and output of the simulation results
- initialization of HBOOK Ntuples and histograms. It is essential that at this stage different directories are created for different subsystems in order to avoid interference among them.
- loop over requested number of events, create hits and fill histograms.

```
*  |->Q N E X T E      loops over events                                 |
*  | (G R U N)                                                           |
*  |   |                                                                 |
*  |   |->TIMEX            gets time left after initialization           |
*  |   |                                                                 |
*  |   |<-------------------------------------------------------------|
*  |   |                                                                 |
*  |   |->GTRIGI             initialization for event processing         |
*  |   |-> GTRIG (*)         event processing                            |
*  |   |   |->GSCANK/GUTREV/GSCANO  geantino SCAN if any                 |
*  |   |   |->TIMED                                                      |
*  |   |   |->GCFIN (*)      try to read information from FZ file        |
*  |   |   |->UTEVSL (*)     select event from FZ-file                   |
*  |   |   |                                                             |
*  |   |   |========== d0kin                                    ========|
*  |   |   |                                                             |
*  |   |   |->GUKINE (*)     generates or reads event input kinematics   |
*  |   |   |                                                             |
*  |   |   |========== d0sim                                    ========|
*  |   |   |                                                             |
*  |   |   |->GUTREV (*)     controls tracking of a complete event       |
*  |   |   |                                                             |
*  |   |   |========== d0raw       ======================================|
*  |   |   |========== pile-up     ======================================|
```

```
*  |   |   |->D0_PILE (*)                                                  |
*  |   |   |   |->GPOISS                                                   |
*  |   |   |   |->IO_OPEN_FILE(*)open file with pile-up events             |
*  |   |   |   |->GCFIN (*)      read Pile-up event hits if any            |
*  |   |   |   |->UTPRNT(*)                                                |
*  |   |   |   |->IO_CLOSE_FILE (*)                                        |
*  |   |   |   |->GFHITS                                                   |
*  |   |   |   |->GSAHIT (*)                                               |
*  |   |   |========== junk        =====================================|
*  |   |   |->D0_JUNK   (*)                                                |
*  |   |   |   |->TR_JUNK  (*)                                             |
*  |   |   |   |   |->TR_RATE (*)  rate versus Z and R                     |
*  |   |   |   |->MU_JUNK  (*)                                             |
*  |   |   |   |   |->M_RATE (*)  rate versus Z and R                      |
*  |   |   |   |->TIMED                                                    |
*  |   |   |   |->UTPRNT (*)                                               |
*  |   |   |->GRLEAS                                                       |
*  |   |   |========== digitization  ===================================|
*  |   |   |->GUDIGI (*)     fan-out routine for digitization              |
*  |   |   |   |->D0HITL(*) get list of hitted detector elements           |
*  |   |   |   |->GFPARA    fetch detector element volume parameters       |
*  |   |   |   |->GFDETU    fetch detector element user parameters         |
*  |   |   |   |->GFPATH    get volume list from path                      |
*  |   |   |   |->GLVOLU    load the given volume position in /GLVOLU/     |
*  |   |   |   |->GFHITS    fetch hits                                     |
*  |   |   |   |->TSH2D (*) digitization for Silicon                       |
*  |   |   |   |->TCH2D (*)     -"-      for Sci.Fiber                     |
*  |   |   |   |->CAH2D (*)     -"-      Calorimeter                       |
*  |   |   |   |->MUH2D (*)     -"-      Muon system                       |
*  |   |   |   |->TIMED                                                    |
*  |   |   |========== Trigger primitives ===============================|
*  |   |   |->D0D2T (*)      fanout for trigger primitives                 |
*  |   |   |   |->GFDETU                                                   |
*  |   |   |   |->MUD2T (*)  Muon trigger primitives                       |
*  |   |   |->GPTRGP (*)  Print trigger primitives if any                  |
*  |   |   |========== 1 Level Trigger    ===============================|
*  |   |   |->D0L1_TRG (*)     L1 Trigger reconstruction                   |
*  |   |   |========== 2-nd Level trigger ===============================|
*  |   |   |->D0L2_TRG (*)                                                 |
```

2.5 Kinematics — d0kin

2.5.1 Kinematics data structure

The GEANT KINE and VERT data structures are used for the track and vertex kinematics. These structures can be read in **D0GSTAR** as a column-wise Ntuple. The essential point is that all particles from Table 3.1 above which decay via weak or electromagnetic interactions are declared stable at the event generation stage. All decays and secondary interactions are treated by GEANT. Thus the kinematics input information contains only one vertex and KINE-structure which corresponds to one primary proton-antiproton interaction. Information about the primary interaction is stored in HEP-format for each primary vertex in the user VERU-bank with cross references to the KINE structure.

During the processing of this event in **D0GSTAR**, new vertices are created corresponding to decays and secondary interactions of particles. The GEANT protocol provides the complete history of each particle generated in any step. The criteria under which secondary particles are selected for storage into a VERT/KINE structure are the following:

- the interaction takes place in the tracker cavity and if the mother has $p_t > 1$ GeV/c, or
- the interaction takes place for muon with $p_t > 5$ GeV/c, and if the interaction mechanisms are one of the following: decay, Bremsstrahlung, pair production or hadronic interaction.

For tracker studies it is important to store the V^0 and flavour decay secondaries, and for muon decay background studies it is important to store all the $K \to$ **muon** and $\pi \to$ **muon** decays which would potentially reach the muon system.

2.5.2 Vertex fluctuation

The primary vertex nominal position and sigmas for fluctuation are defined by the FFREAD card BEAM which is defined on page 1.5.5. The routine VTXGEN is used for the vertex fluctuation.

Fixed vertex position can be obtained by setting the BEAM card parameters 4,5 and 6 to 0. 0. 0. which implies no vertex fluctuation.

The standard GUKINE flow chart looks as follows:

```
*  |   |   |========== d0kin                                     ========|
*  |   |   |->GUKINE (*)     generates or reads event input kinematics   |
*  |   |   |   |                                                         |
*  |   |   |   |->D0NTUP (*) kinematics read from Ntuples                |
*  |   |   |   |   |->D0NT_READ (*)                                      |
*  |   |   |   |   |   |->D0_HEPC (*)                                    |
*  |   |   |   |   |   |->LULIST                                         |
*  |   |   |   |   |->D0_HEPG (*)                                        |
*  |   |   |   |       |->VTXGEN (*)                                     |
*  |   |   |   |       |   |->GRANOR                                     |
*  |   |   |   |       |->GSVERT                                         |
*  |   |   |   |       |->D0PYTIDG (*)                                   |
*  |   |   |   |       |->GSKINE (*)                                     |
*  |   |   |   |->D0SIMPLE (*) single particle event with fixed theta,   |
*  |   |   |   |   |          phi, p_T                                   |
*  |   |   |   |   |->VTXGEN (*)                                         |
*  |   |   |   |   |->TRAMUL (*)                                         |
*  |   |   |   |   |->PARTYP (*)                                         |
*  |   |   |   |   |->GIVEPT (*)                                         |
*  |   |   |   |   |->GSVERT                                             |
*  |   |   |   |   |->GSKINE                                             |
*  |   |   |   |->USKINE (*)  user kinematics                            |
*  |   |   |   |   |->USKIN1 (*)                                         |
*  |   |   |   |   |->USKIN2 (*)                                         |
*  |   |   |   |   |->USKIN3 (*)                                         |
*  |   |   |   |   |->USKIN6 (*)                                         |
*  |   |   |   |   |->USKIN7 (*)                                         |
*  |   |   |   |   |->USKIN8 (*)                                         |
*  |   |   |   |   |->USKIN9 (*)                                         |
*  |   |   |   |   |->USLUND (*)                                         |
```

```
*  |    |    |    |    |->LULIST                                          |
*  |    |    |    |->GPVERT                                               |
*  |    |    |    |->GPKINE                                               |
```

For cuts defined by the KINE card one uses the integer function ICKREJ which takes the particle momentum as an input argument and returns 1, if the particle is outside the cuts.

2.6 GEANT tracking — d0sim

This section presents the steering of the GEANT tracking

```
*  |    |    |========== d0sim                                    ========|
*  |    |    |                                                            |
*  |    |    |->GUTREV (*)     controls tracking of a complete event      |
*  |    |    |    |                                                       |
*  |    |    |    |->GTREVE                                               |
*  |    |    |         |-> store initial tracks in stack                  |
*  |    |    |         |                      (-> GFKINE,GSSTAK,GUSKIP)   |
*  |    |    |         |                      ( loop over tracks )        |
*  |    |    |         |->GLTRAC   prepare commons for tracking           |
*  |    |    |         |      | ->GMEDIA          finds current volume    |
*  |    |    |         |                                                  |
*  |    |    |         |->GUTRAK (*)       calls GTRACK                   |
*  |    |    |             |                                              |
*  |    |    |             |->GTRACK            controls tracking of current |
*  |    |    |                  |               track                     |
*  |    |    |                  |                                         |
*  |    |    |                  |->GTMEDI           finds current volume  |
*  |    |    |                  |                                         |
*  |    |    |                  |  GTGAMA or                              |
*  |    |    |                  |  GTELEC           extrapolation of particle |
*  |    |    |                  |  GTNEUT                                 |
*  |    |    |                  |->GTHADR           track  by  one  step  |
*  |    |    |                  |  GTNINO                                 |
*  |    |    |                  |  GTMUON                                 |
*  |    |    |                  |   |->GUDCAY (*)   decay of particles    |
*  |    |    |                  |       |->LU1ENT                         |
*  |    |    |                  |       |->LUEXEC                         |
*  |    |    |                  |           |->LUDECY                     |
*  |    |    |                  |                                         |
*  |    |    |                  |->GFINDS           Compute SET and DET number|
*  |    |    |                  |                   if volume is sensitive |
*  |    |    |                  |                                         |
*  |    |    |                  |->GUSTEP (*)       special operations at the |
*  |    |    |                      |               step                  |
*  |    |    |                      |->GSCANU (*)                         |
*  |    |    |                      |   |->GSSCAN (*)                     |
*  |    |    |                      |->GDEBUG                             |
*  |    |    |                      |->D0MTHIT (*)   stores hits             |
*  |    |    |                      |   |           for current detector  |
*  |    |    |                      |   |->GMTOD                          |
*  |    |    |                      |   |->GSAHIT (*)                     |
*  |    |    |                      |   |->UTPRNT (*)                     |
```

```
*  |   |   |                  |->D0CHIT (*)                          |
*  |   |   |                  |   |->GSCHIT (*)                      |
*  |   |   |                  |->USSTEP (*)   user action on this step |
*  |   |   |                  |->GSKING       Store any secondary    |
*  |   |   |                                  particles generated during|
*  |   |   |                                  step                   |
```

2.6.1 Reconstruction steering

This section presents the steering for muon track reconstruction.

```
*  |   |   |========== d0reco                                    ========|
*  |   |   |========== Hit reconstruction ===============================|
*  |   |   |->D0RHIT(*)         create RHIT structure                    |
*  |   |   |   |->GFATT                                                  |
*  |   |   |   |->GFPARA                                                 |
*  |   |   |   |->GFDETU                                                 |
*  |   |   |   |->D0D2R (*)                                              |
*  |   |   |   |   |->D0DIGL (*)                                         |
*  |   |   |   |   |->GFPATH                                             |
*  |   |   |   |   |->GLVOLU                                             |
*  |   |   |   |   |->GFDIGI                                             |
*  |   |   |   |   |->TSD2R (*) Si   reconstructed hits from digi.       |
*  |   |   |   |   |->TCD2R (*) SCFT    -"-                              |
*  |   |   |   |   |->CAD2R (*) CALO    -"-                              |
*  |   |   |   |   |->MUD2R (*) MUON    -"-                              |
*  |   |   |   |->D0H2R (*)   smeared hits                               |
*  |   |   |   |   |->D0HITL (*)                                         |
*  |   |   |   |   |->GFPATH                                             |
*  |   |   |   |   |->GLVOLU                                             |
*  |   |   |   |   |->GFHITS                                             |
*  |   |   |   |   |->D0H2R1 (*)                                         |
*  |   |   |   |   |->GSRHIT                                             |
*  |   |   |   |->TIMED                                                  |
*  |   |   |->GPRHIT                                                     |
*  |   |   |========== Reconstruction ===================================|
*  |   |   |->D0RECO (*)                                                 |
*  |   |   |   |->REEFIT (*)    Find em clusters                         |
*  |   |   |   |->REJFIT (*)    Find jets                                |
*  |   |   |   |->REMFIT (*)    Muon Track fit                           |
*  |   |   |   |   |->REGETM (*)  Read hits                              |
*  |   |   |   |   |   |->REINIT (*)                                     |
*  |   |   |   |   |   |->GFDETU    Get detector parameters              |
*  |   |   |   |   |   |->D0HITL (*) Get list on hitted elements         |
*  |   |   |   |   |   |->GFPATH    Detector element geometrical         |
*  |   |   |   |   |   |->GLVOLU    parameters                           |
*  |   |   |   |   |   |->GFRHIT (*) Get RHIT                            |
*  |   |   |   |   |   |->GFHITS (*) Get HITS (for debug only)           |
*  |   |   |   |   |   |->REFMEA (*) transformation of RHITs  into       |
*  |   |   |   |   |   |       |        measurement structures           |
*  |   |   |   |   |   |       |->LGPRED (*) Parameters of measurement plane |
*  |   |   |   |   |->RETSEG (*)     Find Track segments                 |
*  |   |   |   |   |->REFNTK (*)     Find Tracks from Track segments     |
*  |   |   |   |   |->REFITK (*)     Track fit                           |
```

```
*  |    |    |    |    |->RETPIP (*)     Transport track parameters in IP    |
*  |    |    |    |    |    |->RETGLB (*)                                     |
*  |    |    |    |    |->RETKID (*)                                          |
*  |    |    |    |    |->REPRNT (*)                                          |
*  |    |    |    |->RETFIT (*)                                               |
*  |    |    |         |->REGETM (*)                                          |
*  |    |    |         |->REFITK (*)                                          |
*  |    |    |         |->RETPIP (*)                                          |
*  |    |    |         |->RETKID (*)                                          |
*  |    |    |         |->REPRNT (*)                                          |
*  |    |    |         |->HFNTB                                               |
```

2.6.2 Event summary

```
*  |    |    |->GUOUT (*)                                                     |
*  |    |    |    |->C_OUT (*)                                                |
*  |    |    |    |    |->HFNTB                                               |
*  |    |    |    |    |->GFVERT                                              |
*  |    |    |    |    |->GFATT                                               |
*  |    |    |    |    |->GFHITS                                              |
*  |    |    |    |->TR_OUT (*)                                               |
*  |    |    |    |->CA_OUT (*)                                               |
*  |    |    |    |->MU_OUT (*)                                               |
*  |    |    |    |->US_OUT (*)                                               |
*  |    |    |    |->GCFOUT (*)                                               |
*  |    |    |    |    |->FZOUT                                               |
*  |    |    |    |->UTPRNT (*)                                               |
*  |    |    |->DOFHIS (*)    Fill standard GEANT histograms                  |
*  |    |    |->DOHSAV (*)    save histograms if needed                       |
*  |    |                                                                     |
*  |    |->GTRIGC   Clear event partition                                     |
```

2.7 Termination phase

The termination phase is standard; histograms are saved and files closed.

```
*  |                                                                          |
*  |============= Run termination ========================================|
*  |                                                                          |
*  |->UGLAST (*)     User termination                                         |
*  |    |->USLAST(*)  User entry point                                        |
*  |    |->IO_CLOSE_FILE (*) Close IO Buffers                                 |
*  |    |    |->IO_FIL_KADDR (*)                                              |
*  |    |    |->IO_UNIT (*)                                                   |
*  |    |    |    |->IO_FIL_KADDR (*)                                         |
*  |    |    |->IO_FILE (*)                                                   |
*  |    |    |    |->IO_FIL_KADDR (*)                                         |
*  |    |    |->HREND                                                         |
*  |    |    |->FZENDI                                                        |
*  |    |    |->FZENDO                                                        |
*  |    |    |->HROUT                                                         |
*  |    |->DOHSAV (*)                                                         |
```

```
*  |   |   |->PYSTAT                                                 |
*  |   |   |->HPAKE                                                  |
*  |   |   |->IO_UNIT (*)                                            |
*  |   |   |->IO_FILE (*)                                            |
*  |   |   |->HRFILE                                                 |
*  |   |   |->HROUT                                                  |
*  |   |   |->HREND                                                  |
*  |   |->IO_UNIT (*)                                                |
*  |   |->HPLEND                                                     |
*  |   |->GDCLOS                                                     |
*  |   |->GLAST                                                      |
*  |                                                                 |
* STOP ==============================================================|
```

Chapter 3

Detector description code and constants — detc

3.1 General

The organization of the geometry, material and tracking media constants in **D0GSTAR** is based on the following principles:

1. All detector geometry related constants are defined in external files. TZ (ZEBRA Title package format) titles are used as initial storage for these constants. The detailed format of the title banks may be detector dependent.

2. The constants are considered first of all as instructions for direct filling of the corresponding GEANT structures — volumes, materials and tracking media, rotation matrices, detector elements definition and detector dependent information for description of the corresponding detector element response. At this stage title constants define objects corresponding to GEANT entities with parameters as attributes of these objects.

3. The geometry defined by these titles (GEAN banks) is built with the TZ utility routines in the **detc** source file. The experimental hall, master-volumes for all subsystems, as well as volumes not belonging to a specific subsystem (e.g., quadrupoles, shielding, etc) are defined in the same way.

4. The geometry definitions include information to allow for version selection.

5. There is a set of standard rotation matrices defined by the ROTM title bank with a 4-character keyword for each matrix. A standard rotation matrix is accessed by using this keyword in a call to a utility routine. This set includes as "NEXT" for any additional rotation matrix. For the additional rotation matrices an identifier number is given incremented by one from the largest number so far.

6. Material and tracking media are always referred to by their names.

This approach has been introduced and discussed in detail in a CMS technical note[12]. As has been pointed out above, in **D0GSTAR** all the experimental setup related code and constants (geometry, materials, rotations, hits-formats, magnetic field map, user-defined detector parameters, ...) are centralized into the three following sources (see flow diagram in section 2.3):

- The source file **detc** (GEANT Detector Constant Definition Language) with FORTRAN routines which contain all non-trivial parametrical models for all subsystem (detector) descriptions.
- The title files in d0db/detc (title information for the detector) which contains in the ZEBRA Title Package format (TZ-format) all constants and user parameters for the above models.

The non-trivial part is an interface between the titles data banks and the FORTRAN codes (from Detector Constant package) describing the model for a specific subdetector. To establish that we define title banks of two types:

- Title banks which contain parameters
- Title banks of specific formats for volume definitions which are interpreted by specific utility routines of the **detc** package. The style of format definitions which is used:
  - "GEAN" style contains a bunch of trivial GEANT instructions like creation of volume, its positioning, hit definition, detector set definition, setting an attribute to the volume, and so on.

  Only these types of title banks have assignment to keywords and version numbers which have been discussed in the version selection mechanism (see section 1.5).

As examples, shown in Fig.3.1, Fig.3.2 and Fig.3.3 are drawings of the DØ detector obtained in GEANT using the above title banks for Run I and Run II configurations and the calorimeter tower structure. The formats of the title banks will be described in detail below.

3.2 Magnetic field

The field map(s) is placed in the d0db/detc/fmap.tz file in TZ format. The ZEBRA-bank with this table is kept along with other GEANT initialization structure and can be written to and read in from standard GEANT RZ-file. The field maps used for the linear interpolation are placed in the three following title banks for the **2D** solenoid magnetic field map inside the solenoid (FLDM)

```
*--                                                 10/25/96  Ryuji Yamada
*-- D0 Upgrade Magnetic Field Map for Whole D0 Detector "d0fieldmap.grid"
*-- Geometry : Base   + 2T Solenoid    4643.705 x 1.0223 = 4747.26 A
*--                  + Toroidal Magnets  CF + both EF  1500 A
*--                                      both SAMUS       0 A
...
*DO  FLDM -IF -E15360       #. Internal solenoid 2D-field map
   #. NR, NZ, DR, DZ, Rmin, Rmax , Zmin, Zmax, B_rho(NR*NZ),*B_z(NR*NZ
     76. 101. 2.0 2.0   0.0 150.0    0.0 200.0
#. B_r
      44*  0.000       6* -0.001      29*  0.000       4* -0.001       6* -0.002
...
#. B_z
 -19.999 -20.000 -20.000 -20.001 -20.001 -20.002 -20.003 -20.005 -20.006 -20.008
...
```

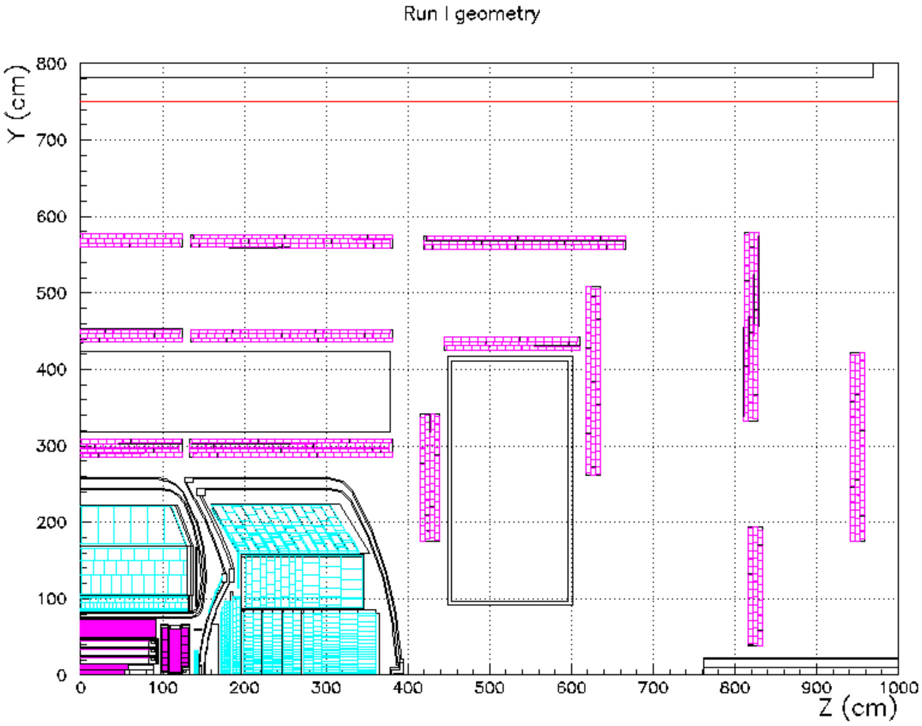

Figure 3.1: The DØ detector GEANT description for Run I.

and two **3D** magnetic field maps for the solenoid (SOLN) and toroid (TORD) (due to their different symmetry) outside of the solenoid

```
*DO  SOLN -IF -E110699      #. External solenoid 3D-field map
            24.  48.  32.   #.     SOLN-field. nx, ny, nz
    0.   70.  100.  120.  170.  220.  270.  310.  320.  330.  #. entx
  340.  350.  360.  370.  380.  390.  400.  410.  420.  430.
...
 #. Bx
      21*  0.000   ...
#. By
      23*  0.000   ...
#. Bz
  -0.003  -0.003       4* -0.002  -0.002  -0.001  -0.001  -0.316       6* -0.001
...
*DO  TORD -IF -E110699      #. Toroid 3D-field map
            24.  48.  32.   #.     TORD-field. nx, ny, nz
    0.   70.  100.  120.  170.  220.  270.  310.  320.  330.  #. entx
...
 #. Bx
  -0.022  -0.018  -0.016  -0.013  ...
#. By
   0.000  -0.009  -0.012  -0.013  ...
#. Bz
```

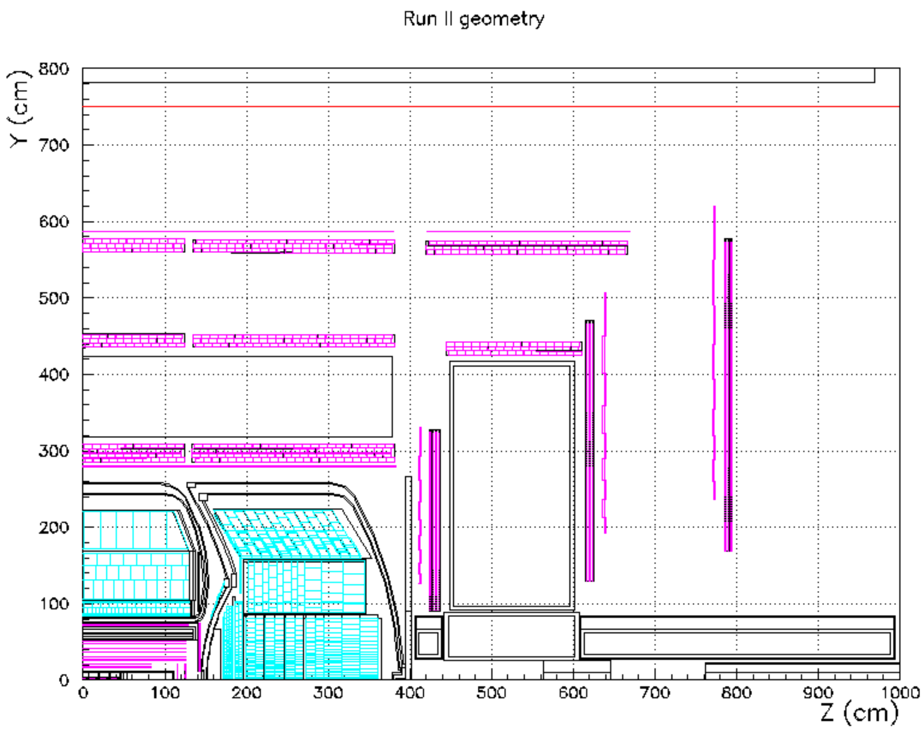

Figure 3.2: The DØ detector GEANT description for Run II.

3.3 Materials and media definitions

In **D0GSTAR** we follow the following procedure for material definitions:

1. Use only external definitions via TZ title banks for all materials.
2. Refer by name (character string) and not by number.
3. Use title banks GMAT and GMIX for material and mixture definitions.

Materials are defined by the GMAT titles as shown in the example for a few materials below:

```
*DO  GMAT   1    -A4CW -c1/80      #.          GMAT
  #.list of pure materials
  #.            A        Z       dens          X_0          abs_l
"Vacuum"       1.E-16   1.E-16   1.E-16       1.E16        1.E16
"Hydrogen"     1.00794  1.0     0.70800E-01  865.54       717.51
"Deuterium"    2.01     1.0     0.162        756.79       337.65
```

The full list of pure materials used (GMAT-bank) is given in Appendix 7.2.

A material with density zero can be defined but may be used only in a mixture definition.

The mixtures are more varied and are defined as

```
‘‘Name of mixture’’     ‘‘No. of components’’  density
      ‘‘component name’’   fraction
        ...
```

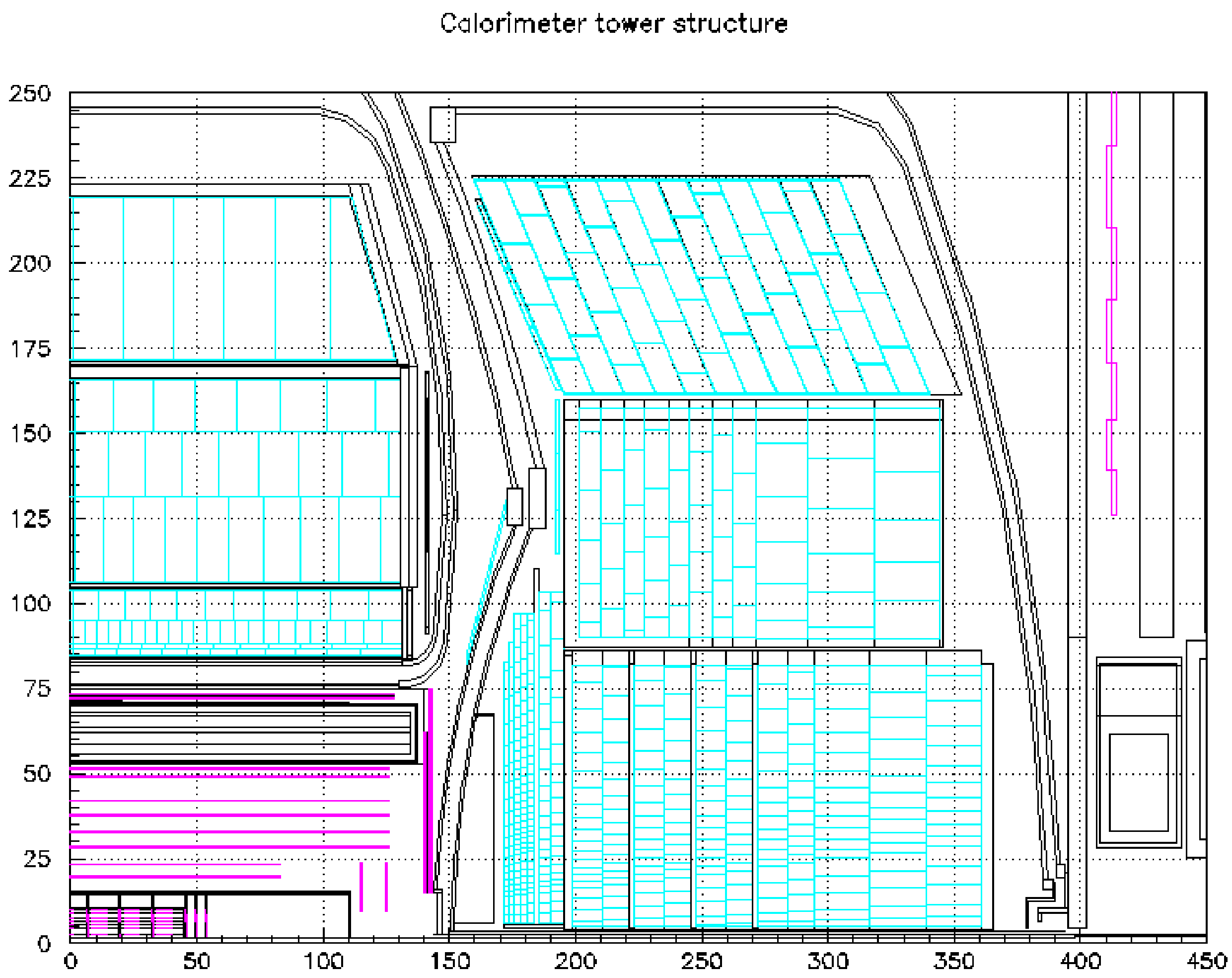

Figure 3.3: The DØ calorimeter tower structure.

via pure materials and other mixtures.

- A negative fraction indicates that the fraction is the "**Atomic**" fraction (for example used to create a given molecule),
- negative "No. of components" and negative fractions mean fraction by **volume**; i.e. defined via densities of their components,
- otherwise the fraction is by **weight**.

Some examples of mixture definitions are shown below:

```
*DO  GMIX   1    -A4CW -c1/50      #.     GMIX
  #.list of mixtures
"Epoxy"                      3      1.3   #. comp.no. dens     GMIX
          "Carbon"                -15.    #. Atomic fraction
          "Hydrogen"              -44.    #. Atomic fraction
```

```
          "Oxygen"                -7.0   #. Atomic fraction
...
"PDT gas"                   -3    -1.0   #.
          "Argon"                 -0.8   #. Volume fraction
          "C F_4"                 -0.1   #. Volume fraction
          "Methane"               -0.1   #. Volume fraction

...
"Stand.Concrete"        9     2.35
          "Hydrogen"          0.6       #. Weight fraction
          "Carbon"            3.0       #. Weight fraction
          "Oxygen"           50.0       #. Weight fraction
          "Sodium"            1.0       #. Weight fraction
          "Aluminum"          3.0       #. Weight fraction
          "Silicon"          20.0       #. Weight fraction
          "Potassium"         1.0       #. Weight fraction
          "Calcium"          20.0       #. Weight fraction
          "Iron"              1.4       #. Weight fraction

...
```

A more complete example is shown in Appendix 7.3 and the full list of available mixtures can be found in d0db/detc/gtit.tz file.

In general all media have the same name and number as the corresponding materials. Introduced also are special media for the same materials due to difference in the tracking through them (precision, turning angle, special cutoff values, etc.). There are also special tracking media and materials which have the prefix "*Thick_*" which means that kinematical cuts for these media are increased (usually to 100 MeV for electrons and to 10 MeV for hadrons). The "thick" material and tracking medium are generated automatically from standard one by any access to this medium.

By default all the tracking media have the following parameters:

```
                ISVOL IFIELD FIELDM  TMAXFD  STEMAX  DEEMAX   EPSIL STMIN
                  0    -1      20.      90.    0.1     0.1     0.5   0.1
```

These default parameters can be changed for chosen media by using "TMED" title banks or keywords defined as in the example below:

```
 :tmed  "PDT gas" 1    -1      20.      10.     10.     0.1  0.001  0.005
```

A tracking medium can be declared sensitive using the title block (or keyword) "SENS". There one specifies the names of the media chosen as explained in the example below:

```
*DO  SENS   1  -A4CW -c1/80      #. Sensitive media
 "LiquidArgonDetector"
...
```

Some special tracking medium parameters (various cuts and physics flags) can be changed through the title block "TPAR". There one supplies the name of the medium, the parameter to be changed and the value as in the example below:

```
*DO  TPAR   1  -A4CW -c1/80      #. Special tracking medium parameters
 "LiquidArgonDetector" "ILOSS" 2. #. Change ILOSS = 2
```

A material/medium number can be found in the fortran code by the following call:

```
CALL DCMATM (CMATE, ITM*)
```

where CMATE can be, for example, "PDT gas" and ITM is the corresponding internal GEANT medium number.

3.4 Rotation matrices

There is a standard set of rotation matrices which are defined by ROTM titles as shown in the example below. The definition includes a keyword and rotation parameters as defined for the input parameters for the routine GSROTM:

```
*D0  ROTM   1 -A4CW -C1/80  #.Title for D0 8 created on 940722 at 1159
      #. Thet1   Phi1  Thet2   Phi2  Thet3   Phi3
:000D     90.0    0.0   90.0   90.0    0.0    0.0 #.    (x,y,z) => ( x, y, z)
:180X     90.0    0.0   90.0  -90.0  180.0    0.0 #.    (x,y,z) => ( x,-y,-z)
:XZXD     90.0    0.0   90.0  270.0    0.0    0.0 #.    (x,y,z) => ( x,-y, z)
   ...
```

The full list of available standard matrices with their definition is given in Appendix 7.4.

Access to the index of a standard matrix can be done via call

```
CALL DCROTM (CNAME, IROTM*)
```

where CNAME is the keyword specifying the rotation matrix to be chosen. The key word "NULL" is reserved for the null rotation which gives the rotation matrix index IROTM the value 0. The keyword "NEXT" reserves the next rotation matrix.

In the context of the "GEAN" style of defining parameters (see next section), the keyword "ROTM" followed by "NEXT" reserves the next rotation matrix which will be used in subsequent "POS" or "POSP" requests which uses the keyword "LAST" for the rotation matrix.

3.5 Detector geometry

3.5.1 Hierarchy of keywords and geometry tree

The detector structure — **valid names** of **subdetectors** which also correspond to the **names of tz-files** and **valid keywords** to define the geometry (see the GEOM data card description) and their hierarchy — and detector type identifier (IDTYPE) are defined through the title block "SETU". The currently used version for Run II is shown below:

```
*D0  SETU   0 -u -A4CW -c1/80  #. SETUp selection keys RUN 2 (default)
#. level
#.    0         1         2          3
#.   Genetic Detector type & No. of element in the given level
         #. Central Tracker
:D0 1 1 :RUN2 0 5 :TRAK 10000 3 :SVTX 11100 0 #. Silicon
                                :SCFT 12100 0 #. fiber tracker
                                :DPRE 13100 0 #. Central preshower & magnet
                  #. Calorimeters                     Central calorimeter
```

```
                  :CALO 20000 2 :UC   20100 4 :UCEM 21100 0 #. Electromagnetic
                                              :UCFH 22100 0 #. Fine Hadronic
                                              :UCCH 23115 0 #. Coarse Hadronic
                                              :UCGH 24108 0 #. Coarse Hadronic
                                :EC   20200 9 #. Endcap calolrimeter
                                              :ECEM 21200 0 #. Electromagnetic
                                              :ECIH 22200 0 #. Inner Fine
                                              :ECGM 23210 0 #. Endcap massless gap
                                              :ECMF 24200 0 #. Middle Fine Hadronic
                                              :ECMC 25200 0 #. Middle Coarse Hadronic
                                              :ECOH 26200 0 #. Outer Coarse Hadronic
                                              :DICD 27209 0 #. Intercryostat detectors
                                              :DFPS 13200 0 #. Forward preshower
                                              :CASH     0 0 #. Run 2 shielding
                  #. Muon system
                  :MUON 30000 2 :WMUS 30100 2  #. Wide angle MUon System
                                              :WMPD 31100 0 #. drift planes
                                              :WMSC 32100 0 #. scintillator counters
                                :FMUS 30200 2  #. Forward MUon System
                                              :FMPD 31200 0 #. drift planes
                                              :FMPX 32200 0 #. scintillator counters
                  :D0AB     0 0 #. D0 experimental hall
                  :QUAD     0 0 #. D0 Low Beta Quadrupoles
```

The Run I detector structure is the following:

```
*D0  SETU   1 -u -A4CW -c1/80  #. SETUp selection keys RUN 1
#. level
#.    0         1         2          3
#.   Genetic Detector type & No. of element in the given level
                       #. Central Tracker
D0 1 1 :RUN1 0 5 :TRAK  10000  4 :VTX  15000 0 #. (Run 1) vertex drift chamber
                                 :CDC  16000 0 #. (Run 1) central drift chamber
                                 :FDC  17000 0 #. (Run 1) forward drift chamber
                                 :TRD  18000 0 #. (Run 1) Transition rad. det.
                 #. Calorimeters
                 :CALO  20000  2 :UC   20100 4 #. Central calorimeter
                                               UCEM 21100 0 #. Electromagnetic
                                               UCFH 22100 0 #. Fine Hadronic
                                               UCCH 23115 0 #. Coarse Hadronic
                                               UCGH 24108 0 #. Coarse Hadronic
                                 :EC   20200 8 #. Endcap calolrimeter
                                               ECEM 21200 0 #. Electromagnetic
                                               ECIH 22200 0 #. Inner Fine
                                               ECGM 23210 0 #. Endcap massless gap
                                               ECMF 24200 0 #. Middle Fine Hadronic
                                               ECMC 25200 0 #. Middle Coarse Hadronic
                                               ECOH 26200 0 #. Outer Coarse Hadronic
                                               DICD 27209 0 #. Intercryostat detectors
                                               L0   14000 0 #. luminosity counter
                 #. Muon system
                 :MUON  30000  3 :WMUS 30100 1 #. Wide angle MUon System
                                               WMPD 31100 0 #. drift planes
                                 :FMUS 30300 1 #. Forward MUon System
                                               AMPD 31300 0 #. drift planes
```

```
                              :SMUS 30400 0 #. Samus (Run 1)
              :D0AB      0 0 #. D0 experimental hall
              :QUAD      0 0 #. D0 Low Beta Quadrupoles
```

In order to switch from Run II to Run I geometry it is needed to set FFREAD card

```
RUN1 true
```

3.6 GEANT geometry by TZ titles

D0GSTAR offers a standard way of building subdetector GEANT geometry from TZ titles. This is performed by the routine DCGEAN which interpret the title block GEAN and makes the appropriate actions (instructions) requested by these titles.

The title block for GEAN has the following structure:

```
*DO  GEAN  <idn>   -A4CW -c1/80     #. title header line
 :SDet          #. Subdetector keyword name (e.g. TRAK)
   ...
  followed by blocks of data with a 4-character keyword and values
   ...
```

The numeric identifier <idn> contains packed information with the level of description (in the least significant digit) and the alternate version number if any (in the higher digit). Zero in the least significant digit specifies that the title is valid for all levels of description (simple, average or detailed). “-c1/80” defines a readable column range in the title card. The maximum number of readable columns is 240.

The title block is selected if the requested action in “GEAN” data card for the subdetector keyword SDet matches with the numeric identifier of the block.

The following instructions can be used:

call	for calling specific dc routines to take action
ckov	for loading parameters for Cerenkov generation (gsckov)
det	for sensitive detector declaration (gsdet)
deta	for sensitive detector declaration (gsdeta)
detd	for detector digitization specification (gsdetd)
deth	for detector hits specification (gsdeth)
dett	for trigger primitive declaration (gsdett)
detu	for detector user word specification (gsdetu)
detv	for sensitive detector declaration (gsdetv)
dvn	for volume divisioning (gsdvn)
dvn2	for volume divisioning (gsdvn2)
dvt	for volume divisioning (gsdvt)
dvt2	for volume divisioning (gsdvt2)
dvx	for volume divisioning (GSDVX)
gmat	for pure material definition (gsmate)
gmix	for mixture/compound (gsmixt)
hits	for declaring standard hit elements (gsdeth)
rhit	for declaring standard reconstruction hit elements (gsdetr)
medi	for declaring sensitive materials with special tracking media
matu	for material user word specification
medu	for media user word specification
mkpo	for special polygon/polycone creation
near	for search techniques (gsnear)
next	for search techniques (gsnext)
ord	for search techniques (gsord)
pos	for volume positioning (gspos)
posp	for volume positioning (gsposp)
rotm	for rotation matrix (gsrotm)
satt	for volume attributes (gsatt)
sens	for declaring sensitive materials
tmed	for tracking medium parameters (gstmed)
tpar	for special tracking medium parameters (gstpar)
tpnt	for positioning two point volumes
volu	for volume parameters (gsvolu)
2pnt	for positioning two point volumes

The above instructions are not case sensitive.

The constants which follow each instruction are the same as the call parameters required by the respective GEANT routine with the exception that the material and media are defined by a character sequence instead of a number.

The parameters which follow each instruction are defined as follows:

- call - a key word indicating the routine to be invoked
- ckov
  - material name
  - number of bins in the table NPCKOV

- photon momenta (PPCKOV), absorbtion coefficients (ABSCO), detection efficiencies (EFFIC) and refractive indices (RINDEX)

- detv/det /deta
  - set name
  - detector name, followed by routine specific parameters:
  - number of volumes, IDTYPE, NWHI, NWDI, list of (volume names, NBITS) (GSDet)
  - **or** IDTYPE, NWHI, NWDI (GSDetV)
  - **or** alias name, NWHI, NWDI (GSDetA)

- deth/detd/detu
  - set name
  - detector name, followed by routine specific parameters:
  - number of hit elements, their name, origin, factor, # of bits (GSDetH)
  - **or** number of digit elements, their names and # of bits (GSDetD)
  - **or** number of user elements, the user array (GSDetU)

- dvn /dvn2/dvt /dvt2/dvx
  - volume name (character string)
  - name of the mother (character string)
  - followed by division related parameters:
    * NDIV, IAXIS (GSDVN)
    * NDIV, IAXIS, C0, Material name (GSDVN2)
    * STEP, IAXIS, material name, NDVMX (GSDVT)
    * STEP, IAXIS, C0, Material name, NDVMX (GSDVT2)
    * NDIV, IAXIS, STEP, C0, Material name, NDVMX (GSDVX)

- gmat - the same constants as in gmat titles (see above)

- gmix - the same constants as in gmix titles

- hits/rhit
  - set name
  - detector name, the hit elements being taken from the standard banks

- near/next/ord
  - name (character string) and routine specific information:
  - number of content (IN), Length of list, list of neighbours (GSNEAR/GSNEXT)
  - **or** IAXIS (GSORD)

- pos /posp
  - volume name (character string)
  - copy number

  - name of the mother volume (character string)
  - name of rotation matrix (character string, NULL if no rotation matrix, "NEXT" if the last rotation matrix of the detector type or one standard matrix)
  - ONLY/MANY specification (string)
  - x, y, z coordinates and optionally (for GSPOSP) number of parameters and parameter list.

- rotm - the same constants as in rotm titles
- satt
  - volume name (character string)
  - attribute name
  - attribute value
- sens/medi
  - name of the material which is to be declared as sensitive
- tmed
  - tracking medium name (character string) followed by:
  - ISVOL, IFIELD, FIELDM, TMAXFD, STEMAX, DEEMAX, EPSIL, STMIN
- tpar
  - tracking medium name (character string)
  - parameter name (string)
  - its new value
- volu
  - volume name (character string)
  - shape (character string)
  - medium (character string)
  - number of parameters plus parameter list
- 2pnt
  - volume name (character string)
  - name of the mother (character string)
  - the ONLY attribute (character string)
  - number of 2-point volumes to be positioned
  - parameter list of the mother volume
  - coordinates of the first and the last point

The instruction "mkpo" is used to creation of nested polygone/polycone. Each block contains the names of the current volume and the mother volume, the material content of the current volume, number of edges (0 for polycones), number of xy-planes and for each plane, the position with inner and outer radii. In the example

```
 :mkpo            #. Beam Pipe
 :BEAM  :D0    "Beryllium"    -.5 3.    398.00  0.00       1.95
                                        398.00  0.00       2.667
                                        645.16  0.00       2.667
```

a beryllium tube BEAM is positioned inside the volume DØ. The volume BEAM is constructed making use of a polycone defined through two planes at z = 0 and at z = 75 with inner and outer radii of 5.85 and 6.00 respectively.

As an example we present in Appendix 7.5 a full description of the geometry for the pixel detector.

3.7 Detectors and hit formats

3.7.1 Detector Sets and Detector elements

In **D0GSTAR**we have adopted the standard definition of detector elements which groups them into detector sets. The detector set definitions for a given list of detector elements depend only on convenience of their handling — activation and deactivation is by the above mechanism via the FFREAD control card "SETS". Thus here we define detector sets corresponding to the subsystem hierarchy in section 1.5. The detector supersets, for example for the whole muon system, is defined by alliance of sets on the basis of detector types (IDTYPE). The following structure of the detector types (see sequence **d0did**) is used:

```
* D0 Detector IDentifiers
*
* d0did.inc
*
* ***  D0 Detector IDentifiers:
*
*      idtype = XYZUV
*              X  --  subsystem identifier:
*                     1 - track system, 2 - calorimeters, 3 - muon system
*               Y  -  detector type (technology)
*                     1/2     - Silicon / Scintillator fibers for tracker
*                 Z -  1/2     - for barrel/endcap
*                  UV          - superlayer/sublayer number, user dependent,
* *** define D0 detector element idetifiers
*
      INTEGER        IDTRAK
      INTEGER               IDSVTX, IDSCFT, IDDPRE                  ! RUN 2
      INTEGER               IDVTX , IDCDC , IDFDC, IDTRD            ! RUN 1
*
* *** TRAK
*
      PARAMETER (IDTRAK = 10000)
      PARAMETER (IDSVTX = 11100, IDSCFT = 12100, IDDPRE = 13100)
      PARAMETER (IDVTX  = 15000, IDCDC  = 16000, IDFDC  = 17000,
     &           IDTRD = 18000)
*
* *** CALO
*
      INTEGER IDCALO, IDUC, IDEC,
```

```
     &                IDUCEM, IDUCFH, IDUCCH, IDUCGH,
     &                IDECEM, IDECIH, IDECGM, IDECMF, IDECMC, IDECOH,
     &                IDDICD, IDDFPS, IDLUM
      PARAMETER      (IDCALO = 20000)
      PARAMETER      (IDUC   = 20100, IDEC   = 20200)
      PARAMETER      (IDUCEM = 21100, IDUCFH = 22100, IDUCCH = 23115,
     &                IDUCGH = 24108)
      PARAMETER      (IDECEM = 21200, IDECIH = 22200, IDECGM = 23210,
     &                IDECMF = 24200, IDECMC = 25200, IDECOH = 26200,
     &                IDDICD = 27209, IDDFPS = 13200, IDLUM  = 14000)
*
* *** MUON
*
      INTEGER        IDMUON, IDWMUS, IDFMUS
      INTEGER                IDWMPD, IDAMPD, IDSMUS,        ! RUN 1
     &                               IDWMSC, IDFMPD, IDFMPX ! RUN2
      PARAMETER     (IDMUON = 30000, IDWMUS = 30100, IDFMUS = 30200)
      PARAMETER                     (IDWMPD = 31100, IDAMPD = 31300)
      PARAMETER                                     (IDSMUS = 30400)
      PARAMETER                     (IDWMSC = 32100)
      PARAMETER                     (IDFMPD = 31200, IDFMPX = 32200)
```

The four letter convention (xxxx) used above is adopted in **D0GSTAR**as a mnemonic for the detector element type identifier IDTYPE = IDxxxx and the above numbers a set via PARAMETER statement in the sequence **d0did**. Of cause it is supposed that any access to those detector element type identifiers will be done only via IDxxxx but not via numbers.

GEANT provides:

- a mechanism (routine GSDETV) for uniquely identifying the different detector elements of the same type;
- in the HITS package this identifier is stored in the hit-bank together with the identifier of the track which produced this hit and of the hit itself;
- There is a mechanism (GFPATH/GLVOLU) for using this detector element identifier to obtain the detector element parameters, for example, the position of the detector element in the global coordinate system.

These features of GEANT are very heavily used for the tracker and muon system hit handling.

3.7.2 Hit format for the tracker and muon system

Due to the similarity of the tracking and muon detectors in **D0GSTAR** we use the same detector element and hit definitions. The common hit format for the GEANT hits (detector impact points) is defined in the title bank TKHT (TracK HiT):

```
*DO  TKHT   0          -c4/60      #. TracKer /Muon hit definition
     16                           #.No. of hit elements
   #. NAMESH  ORIG  FACT  NBITSH
  1 :X_G    2000.0  5.E5    0     #.VECT(1) at volume entrance
  2 :Y_G    2000.0  5.E5    0     #.VECT(2) at volume entrance
  3 :Z_G    2000.0  5.E5    0     #.VECT(3) at volume entrance
  4 :p_X       1.0  1.E9    0     #.p_X     at volume entrance
```

```
  5 :p_Y       1.0  1.E9    0     #.p_Y     at volume entrance
  6 :p_Z       1.0  1.E9    0     #.p_Z     at volume entrance
  7 :step      0.0  1.E6    0     #.step    in the detector element
  8 :TYPE      0.0  1.0     0     #.particle type
  9 :Xin     250.0  1.E6    0     #. enter point in detector element
 10 :Yin     250.0  1.E6    0     #.(detector element coordinate system: LCS)
 11 :Zin     250.0  1.E6    0     #.
 12 :XOUT    250.0  1.E6    0     #.exit  point from detector element (LCS)
 13 :YOUT    250.0  1.E6    0     #.
 14 :ZOUT    250.0  1.E6    0     #.
 15 :dEdX      0.0  1.E9    0     #.deposited energy,
 16 :T_OF      0.0   10.    0     #.time_of_flight
```

The **"HITS"** instructions include detector set and detector element names in the **"GEAN"** TZ-bank, for example for WAMUS PDT detector element and hit definition the following instructions are used:

```
*DO  GEAN   0 -U -A4CW -c1/80     #. DO PDT hits
 :MBPD    #. key volume name
                   #. IDtype  Nwhi Nwdi
 :detv :MBPD    :APDT  31110  1000 100 #. DETV
 :detv :MBPD    :BPDT  31120  1000 100 #. DETV
 :detv :MBPD    :CPDT  31130  1000 100 #. DETV
 :hits :MBPD    :*PDT
 :rhit :MBPD    :*PDT
 :detu :MBPD    :*PDT  2 0.070   0.30  #. Precise/Coarse resolution
```

...

3.7.3 The digitization format

The digitized hits format should in principle simulate the detector readout format which may be different for different detectors. But for practical reasons below we present a digitization bank format for Silicon detector:

```
...
     #. Silicon detector DIGItization definition
:detd :SVTX  :SBL*  4    #. no. of digitization elements for coarse coordinate
      :SIDE       1      #. 0 = normal plane, 1 = stereo plane (if any)
      :STRP      10      #. strip (0..1023)
      :TIME       9      #. time
      :ADC       12      #. charge (ADC)
...
```

The DIGI bank will be filled by the GEANT DIGI package:

```
          GSDIGI (ISET, IDet, LTRA, NTRA, NUMBV, KDIGI, IDIG)
```

which sets up the references to the KINE structure (via a list of tracks LTRA(1:NTRA) which caused this digitization) so that for each digitized response one can find the track(s) responsible.

3.7.4 User parameters for detector element

The standard GEANT geometry information and material parameters usually are not enough to fully describe the behaviour of a detector element. For example, to describe the signals from a Silicon detector it is necessary to know the voltage, strip width and so on. Sometimes it is not possible or reasonable to do that. For example, the readout of the calorimeter towers in η and ϕ is not matched with the physical geometry of uranium plates or modules. In order to store this information (`UPAR(1:NUPAR)`) into the standard constant data GEANT structure and to retrieve it in **D0GSTAR** we use routines:

```
        GSDetU (IUSET, IUDet, NUPAR, UPAR)
and     GFDetU (IUSET, IUDet, NUPAR, UPAR)
```

This information is detector dependent. As an example below we present the user information used for the Silicon detector:

```
....
#. barrels ladder section
#. layer 1
 :detu   :SVTX  :SBL1
  37            #. number of params
  0.010         #. 1.     Precise coordinate resolution
  0.100         #. 2.     coarse  coordinate resolution
  1.            #. 3. direction that axial strips (1st phi index)face
                #. 1/2=outward/in.
  0. 4*1. 0.    #. 4-9.   stereo flag by barrel 0/1 = single/dble sided
  0. 90.        #. 10-12. THST  stereo angle by type p-axial/n-streo
  0.0050 0.0156 #. 12-14  SIPIT pitch  by type       p-axial/n-stereo
  384. 768.     #. 14-16  SIACT number of strips     p-axial/n-stereo
...
```

3.8 Particle descriptions

In **D0GSTAR**we use the extended list of particles which is given in the following table 3.1: The main reason for this extension is to provide the possibility for the weak decay of particles, including the simulation of their decay vertex inside GEANT via a call to GUDCAY / LU1ENT / LUEXEC / LUDECY (see program flow in section 2.4).

3.9 D0GSTAR Database

All constants that have been discussed in this chapter (including the field map) are stored in an RZ-file and this file is considered an entity of the DØ database. The detailed description of access to this database is given in section 4.2.

3.10 How to change GEANTdescription of the detector in D0GSTAR

The detector constants are defined via hierarchy of title files (see section 3.5.1). This hierarchy is defined in setup.tz file via SETU title bank. The access sequence to these files are the following:

Table 3.1: The list of particles used in **D0GSTAR**.

No.	name	No.	name	No.	name	No.	name
1	gamma	2	e+	3	e-	4	neutrino
5	mu+	6	mu-	7	pi0	8	pi+
9	pi-	10	K_L0	11	K+	12	K-
13	n0	14	p+	15	p -	16	K_S0
17	eta	18	Lambda0	19	Sigma+	20	Sigma0
21	Sigma-	22	Xi0	23	Xi-	24	Omega-
25	n 0	26	Lambda 0	27	Sigma -	28	Sigma 0
29	Sigma +	30	Xi 0	31	Xi +	32	Omega +
33	tau+	34	tau-	35	D+	36	D-
37	D0	38	D 0	39	D_s+	40	D_s-
41	Lambda_c+	42	W+	43	W-	44	Z0
45	Deuteron	46	Triton	47	Alpha	48	Geantino
49	He3	50	Cerenkov	51	E.M.shower	52	Had.shower
53	J/psi	54	Upsilon	55	Lambda_c -	56	B0
57	B 0	58	B+	59	B-	60	B_s0
61	B_s 0	62	B_c+	63	B_c-	64	T+
65	T-	66	T*+	67	T*-	68	T*_2+
69	T*_2-	70	T0	71	T 0	72	T*0
73	T* 0	74	T*_20	75	T*_2 0	76	T_s+
77	T_s-	78	T*_s+	79	T*_s-	80	T*_2s+
81	T*_2s-	82	T_c0	83	T_c 0	84	T*_c0
85	T*_c 0	86	T*_2c0	87	T*_2c 0	88	T_b+
...	...	...	...	...	...	...	...
293	T*_1b-						

- first the current directory is checked for the given title file and if it exists in the current directory it will be read;
- if this file does not exist in the directory then it will be taken from the standard place ($d0_db/detc).

Thus by copying and modifying the file with the description of any subsystem the **GEANT** description of the detector can be easily changed. Also the SETU bank which defines the above hierarchy can be changed.

Chapter 4

Utilities

4.1 The GEANT extensions

4.2 The IODB file-based database system

D0GSTAR requires access to a number of external files. These have a variety of formats and different opening, reading, writing, and closing requirements. In order to have easily-maintainable and reliable code, a coherent system for file storage, maintenance, and access is required which supports a variety of formats and multiple versions of the same file in a system-independent way.

IODB[13] was designed to meet these needs. IODB uses the standard Unix file system and a small number of Fortran routines to access the files required by **D0GSTAR** in a uniform and transparent way. All files within **D0GSTAR** are now handled by IODB, the defaults of which can be overridden using FFREAD data cards, as described below.

The IODB package consists of two parts: the input/output files and the code required to manage them. The latter may be found in the directory `//UTIL/IODB`. Within **D0GSTAR**, the files are organized in a *logical* directory structure which corresponds closely, but not exactly, to the the *physical* Unix directory structure. The use of a *logical* structure facilitates the porting of the code to non-Unix platforms.

The files are located in two *logical* directories:

- the `d0db` directory tree contains input constants files, such as GEANT geometry file, *etc.*;
- the `work` directory tree is used for input and output user files, such as event files, GEANT metafiles, *etc.*

Inside each of these "top-level" directories is one level of subdirectories which in turn contain the files required. Within **D0GSTAR** each directory, sub-directory, and file is assigned a unique keyword which is used in all file handling operations so that the actual *physical* name need be specified only once. This keyword thus serves as a *logical* name which is translated in a hidden way into a reference to a *physical* file.

D0GSTAR assigns default values for *physical* directory and file names. The user may over-ride the default directory and file names using FFREAD data cards if desired, as described below. To avoid conflicts, logical unit number assignments are managed exclusively by IODB Fortran routines.

This scheme ensures that all *physical* file names are in one place and that the details of file handling are concealed from the user, whether the files be plain text, formated binary, RZ, FZ, *etc.* Moreover, should a more complex database be implemented at a later stage, the required changes are largely localized to the IODB Fortran routines.

4.2.1 The IODB directory structure

Table 4.1 describes the IODB directory structure. The first column contains the keyword used

Keyword	Logical location	Default physical value	Description
`D0DB`	(Top-level)	`$d0_db`	Top level D0DB directory
`WORK`	(Top-level)	. (current directory)	Top level working directory
`DETC`	`D0DB`	`$d0_db/detc`	Detector geometry & materials
`KINE`	`D0DB`	`$d0_db/kine`	Kinematics files (ISAJET cards, *etc.*)
`EVSI`	`D0DB`	`$d0_db/evsi`	Event (signal) (rz or ntpl) input files
`FZIN`	`D0DB`	./. (current directory)	Event (signal, fz) input files
`ISAZ`	`D0DB`	`$d0_db/evsi`	Event (isazeb, fz) input files
`PILE`	`D0DB`	`$d0_db/fz`	Event (background, fz) input file
`EVTO`	`WORK`	./. (current directory)	Event (fz/ntpl) output files

Table 4.1: The IODB directory structure.

by **D0GSTAR**and FFREAD to refer to the directory; the second shows the *logical* location of the corresponding directory; the third gives the corresponding default *physical* directory name; the fourth describes the purpose of the directory, *i.e.* the type of files which should be contained within it.

The top-level IODB directory is defined by the `$d0_db` environment variable which usually has the value `$d0_root/d0db`. Its value may differ between machines but the IODB routines in **D0GSTAR** read this variable and take it into account.

To clarify the table take, for example, the directory referred to by the **detc** keyword. It is *logically* contained within IODB and its default *physical* value is `$d0_db/detc` (*i.e.* it is also *physically* within the `d0db` directory). If the *physical* value for IODB is overridden using a data card, as described below, then all directories *logically* contained within IODB will also change, including **detc**. If only the default value of **detc** is overridden then IODB is of course unchanged.

4.2.2 The IODB file structure

Table 4.2 describes the IODB file structure. The first column contains the keyword corresponding to the file; the second gives the *logical* directory within the IODB structure, in which the file resides; the third gives the *physical* location of the file in the Unix file-system; and the fourth gives a brief description of the file and marks whether it is an input or an output file.

4.2.3 Overriding the IODB default directory and file names

For debugging purpose, it is useful to be able to change the *physical* names of directories and files associated to given keywords. Similarly, users will in general wish to specify their own event and graphics files.

Keyword	Logical location	Default physical location	Description	I/O?
FMAP	d0db/detc	$d0_db/detc/fmap.tz	field map	i
GTIT	d0db/detc	$d0_db/detc/gtit.tz	tz detector description	i
DETI	d0db/detc	$d0_db/detc/geom_ini.rz	rz detector description	i
DETO	work/detc	./geom_out.rz	rz detector description	o
ISAC	d0db/kine	$d0_db/kine/isajet.cards	ISAJET cards	i
PYTC	d0db/kine	$d0_db/kine/pythia.cards	PYTHIA cards	i
ISAD	d0db/kine	$d0_db/kine/isajet.dat	ISAJET data	i
EVSI	d0db/evsi	$d0_db/evsi/dtu2000evd0.ntp	rz events signal	i
FZIN	work/fz	./fzin.fz	fz events signal	i
ISAZ	d0db/evsi	$d0_db/evsi/psi_mumu.isa	fz events signal(isazeb)	i
PILE	d0db/fz	$d0_db/fz/pile_up.fz	fz events background	i
EVTO	work/evto	./fzout.fz	fz or rz/ntpl	o
HBKO	work/usro	./hbook	user hbook	o

Table 4.2: The IODB file structure.

Two new FFREAD data cards have been defined which enable the defaults to be overridden. The `CDIR` data card changes directory names while the `CFIL` data card changes file names, for example:

```
CDIR 'IODB'  '/user/tom/private '           ! top level db directory
     'WORK'  '/user/dick/data '             ! top level work directory

CFIL 'FMAP'  '/user/joe/test.fieldmap '     ! input magnetic field map file
```

The first argument of each line (*e.g.* `'IODB'`) is the keyword while the second is the new *physical* value (the exclamation mark and the trailing text are comments here and should not be included). Only one `CDIR`(`CFIL`) card is specified for multiple directory(file) changes. The directory/file name should in all cases be an absolute path name and must be terminated by a space before the trailing single quote. If a file name is changed using the `CFIL` data card, then this takes precedence over a change of the corresponding directory via the `CDIR` data card (*i.e.* the latter is ignored for this particular file). If the directory corresponding to the keyword IODB or WORK is changed then the names of those directories *logically* contained within them are changed accordingly.

Chapter 5

Tracker codes

Chapter 6

Calorimeter codes

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Chapter 7

Appendices

7.1 Code Administration

7.1.1 Code and title file administrators

For **D0GSTAR** there is a general or **D0GSTAR** file administrator who is responsible for the coordination and synchronization of different pieces of the code. The general (or **D0GSTAR**) administrator is also responsible for the source file which contains the principal **D0GSTAR** steering routines (the **d0si**).

For each source file the code administrator and a few deputies from each related system is appointed by the DØ software coordinator and coordinator of the subsystem. The list which is presented below has to be discussed.

```
Package        LIBRARIAN         DEPUTY(IES)

D0SI            Y.Fisyak    J.Womersley
DETC            Y.Fisyak    J.Womersley
UTIL            Y.Fisyak    J.Womersley
TRAK            TBD         TBD
CALO            S.Linn      TBD
MUON            TBD         TBD
RECO            TBD         TBD
GCAL            Y.Fisyak
G320            Y.Fisyak
```

The administrators are also responsible for the documentation being as up-to-date as possible. For each source file there is a directory *xx*docu for documentation where *xx* stands for the two initial letters of the file. The most important files like **d0si**, **detc**, **trak**, **calo**, **muon**etc contain a User Guide.

7.1.2 Code submission and update policy

Persons who want to submit new code or corrections to **D0GSTAR** must contact the administrator in question.

7.2 List of Pure Materials

```
*DO  GMAT   1    -A4CW -c1/80      #.          GMAT
  #. list of pure materials
  #.            A         Z        dens          X_0           abs_l
"Vacuum"       1.E-16   1.E-16   1.E-16       1.E16         1.E16
"Hydrogen"     1.00794  1.0     0.708E-1      865.54        717.51
"Deuterium"    2.01     1.0     0.162         756.79        337.65
"Helium"       4.0026   2.0     0.125         754.56        520.80
"Lithium"      6.9410   3.0     0.534         154.98        137.45
"Beryllium"    9.0122   4.0      1.8480       35.276        40.690
"Bor 10"       10.      5.0      2.34         21.0209       0.0
"Bor 11"       11.      5.0      2.34         23.1229       0.0
"Carbon"       12.011   6.0      2.2650       18.850        38.102
"Nitrogen"     14.007   7.0     0.808         47.017       108.660
"Oxygen"       15.999   8.0     0.143E-2      23944.        63636.
"Fluorine"     18.998   9.0      1.1080       29.925        0.0
"Neon"         20.180   10.      1.2070       23.977        80.033
"Sodium"       22.990   11.      0.969        28.8675       0.0
"Magnesium"    24.305   12.      1.735        0.0           0.0
"Aluminium"    26.980   13.      2.7          8.8926        39.407
"Silicon"      28.090   14.      2.33         9.3648        45.494
"Phosphor"     30.974   15.      1.82         0.0           0.0
"Sulfur"       32.066   16.      2.07         0.0           0.0
"Chlorine"     35.450   17.      1.56         0.0           0.0
"Argon"        39.948   18.     0.16390E-2    10983.      65842.69
"Potassium"    39.098   19.      0.860        0.0           0.0
"Calcium"      40.078   20.      1.55         0.0           0.0
"Scandium"     44.956   21.      2.98         0.0           0.0
"Titanium"     47.880   22.      4.53         3.5617        27.511
"Vanadium"     50.941   23.      6.10         0.0           0.0
"Chromium"     51.996   24.      7.18         0.0           0.0
"Manganese"    54.938   25.      7.43         0.0           0.0
"Iron"         55.850   26.      7.87         1.7585        16.760
"Cobalt"       58.933   27.      8.90         0.0           0.0
"Nickel"       58.693   28.      8.876        0.0           0.0
"Copper"       63.546   29.      8.96         1.4353        15.056
"Zinc"         65.390   30.      7.112        0.0           0.0
"Gallium"      69.723   31.      5.877        0.0           0.0
"Germanium"    72.610   32.      5.3230       2.3013        26.395
"Arsenic"      74.922   33.      5.72         0.0           0.0
"Selenium"     78.960   34.      4.78         0.0           0.0
"Bromine"      79.904   35.      3.11         0.0           0.0
"Krypton"      83.8     36.      2.60         0.0           0.0
"Rubidium"     85.4678  37.      1.529        0.0           0.0
"Strontium"    87.62    38.      2.54         0.0           0.0
"Yttrium"      88.9059  39.      4.456        0.0           0.0
"Zirconium"    91.22    40.      6.494        0.0           0.0
"Niobium"      92.906   41.      8.55         0.0           0.0
"Molybdenum"   95.940   42.      10.20        0.0           0.0
"Technetium"   98.0     43.      11.48        0.0           0.0
"Ruthenium"    101.07   44.      12.39        0.0           0.0
"Rhodium"      102.9055 45.      12.39        0.0           0.0
"Palladium"    106.42   46.      12.00        0.0           0.0
```

```
"Silver"       107.87   47.      10.48       0.0         0.0
"Cadmium"      112.41   48.      8.63        0.0         0.0
"Indium"       114.82   49.      7.30        0.0         0.0
"Tin"          118.69   50.      7.31        1.2066      22.30
"Antimony"     121.75   51.      6.679       0.0         0.0
"Tellurium"    127.60   52.      6.23        0.0         0.0
"Iodine"       114.82   53.      7.30        0.0         0.0
"Xenon"        131.29   54.      3.057       2.7740      55.28
"Cesium"       132.9054 55.      1.870       4.52        0.0
"Barium"       137.33   56.      3.50       29.581    9999.0
"Lanthanum"    138.9055 57.      6.127       0.0         0.0
"Cerium"       140.12   58.      6.637       0.0         0.0
"Praseodymium" 140.9077 59.      0.0         0.0         0.0
"Neodymium"    144.24   60.      0.0         0.0         0.0
"Tungsten"     183.85   74.      19.3       0.35         9.5855
"Gold"         196.97   79.      18.85       0.0         0.0
"Lead"         207.19   82.      11.350     0.56120      17.092
"Bismuth"      208.98   83.      9.37        0.0         0.0
"Uranium"      238.03   92.      18.950     0.31662      10.501
```

7.3 Examples of Material Mixtures

```
*DO  GMIX   1    -A4CW -c1/50      #.          GMIX
  #.list of mixtures                                                GMIX
"Boron"                  2     2.34          #. comp.no.            dens     GMIX
          "Bor 10"             -.20          #. Atomic fraction
          "Bor 11"             -.80          #. Atomic fraction
"B_2 O_3"                2     2.34          #. comp.no.            dens     GMIX
          "Boron"             -2.            #. Atomic fraction
          "Oxygen"            -3.            #. Atomic fraction
"Al_2 O_3"               2    -1.0           #. comp.no.            dens     GMIX
          "Aluminium"         -2.0           #. Atomic fraction
          "Oxygen"            -3.0           #. Atomic fraction
...
"Air"                    4    1.214e-3       #. Air 18 degr.C and 58% humidity
          "Nitrogen"         74.94           #. Weight fraction
          "Oxygen"           23.69           #. Weight fraction
          "Argon"             1.29           #. Weight fraction
          "Hydrogen"          0.08           #. Weight fraction
...
"FrontEnd Electronics"      -3    -1.0       #. comp.no.            dens     GMIX
          "Air"                 -0.750       #. Volume fraction
          "Silicon"             -0.200       #. Volume fraction
          "Lead"                -0.050       #. Volume fraction



...

"NEMA G10 plate"            3     1.7        #.
          "Si O_2"              -0.773       #. Atomic fraction
          "Epoxy"               -0.147       #. Atomic fraction
          "Chlorine"            -0.080       #. Atomic fraction
"NEMA FR4 plate"            4     1.025      #.
```

```
          "Si O_2"              -0.613      #. Atomic fraction
          "Epoxy"               -0.147      #. Atomic fraction
          "Bromine"             -0.080      #. Atomic fraction
          "Oxygen"              -0.160      #. Atomic fraction
...
"Liquid Argon"             1      1.39      #. comp.no.            dens     GMIX
          "Argon"                -1.0       #. Atomic fraction
...
"Silicon Detector"         1      2.3300
          "Silicon"               -1.000    #. Atomic fraction
...
"ColdAluminium"      1    2.722  "Aluminium"      1.0 #. Weight fraction
"ColdStainlessSteel" 1    7.935  "StainlessSteel" 1.0 #. Weight fraction
```

... and

7.4 List of Standard Rotation Matrices

```
*DO  ROTM   1  -A4CW -C1/80  #.Title for {D\O} 8 created on 940722 at 1159
  #. Thet1   Phi1  Thet2   Phi2  Thet3   Phi3
:000D   90.0    0.0   90.0   90.0    0.0    0.0  #.    (x,y,z) => ( x, y, z)
:XYZD  -90.0    0.0   90.0   90.0    0.0    0.0  #.    (x,y,z) => (-x, y, z)
:XZXD   90.0    0.0  -90.0   90.0    0.0    0.0  #.    (x,y,z) => ( x,-y, z)
:YZXD  -90.0    0.0  -90.0   90.0    0.0    0.0  #.    (x,y,z) => (-x,-y, z)
:180X   90.0    0.0  -90.0   90.0  180.0    0.0  #.    (x,y,z) => ( x,-y,-z)
:180R   90.0    0.0   90.0   90.0  180.0    0.0  #.    (x,y,z) => ( x, y,-z)
:180D  -90.0    0.0   90.0   90.0  180.0    0.0  #.    (x,y,z) => (-x, y,-z)
:180Y   90.0   90.0  -90.0    0.0  180.0    0.0  #.    (x,y,z) => ( y,-x,-z)
:180Z   90.0   90.0  -90.0    0.0    0.0    0.0  #.    (x,y,z) => ( y,-x, z)
:Z180  -90.0   90.0   90.0    0.0    0.0    0.0  #.    (x,y,z) => (-y, x, z)
:ZSXD   90.0   90.0  180.0    0.0   90.0    0.0  #.    (x,y,z) => ( y,-z, x)
:90ZD  -90.0    0.0    0.0    0.0   90.0   90.0  #.    (x,y,z) => (-x, z, y)
:90XD   90.0   90.0    0.0    0.0   90.0    0.0  #.    (x,y,z) => ( y, z, x)
:90DX  -90.0   90.0  180.0    0.0   90.0    0.0  #.    (x,y,z) => (-y,-z, x)
:20XD   90.0   70.0    0.0    0.0   90.0  -20.0  #.    (x,y,z) => ( ?, z, ?)
:60XD   90.0  110.0    0.0    0.0   90.0   20.0  #.    (x,y,z) => ( ?, z, ?)
:90YZ  -90.0   90.0  180.0    0.0   90.0    0.0  #.    (x,y,z) => (-y,-z, x)
:90YD    0.0    0.0   90.0    0.0   90.0   90.0  #.    (x,y,z) => ( z, x, y)
:90XY    0.0    0.0  -90.0   90.0   90.0    0.0  #.    (x,y,z) => ( z,-y, x)
:90YX  180.0    0.0   90.0   90.0   90.0    0.0  #.    (x,y,z) => (-z, y, x)
:YXZ2   90.0   90.0    0.0    0.0   90.0    0.0  #.    (x,y,z) => ( y, z, x)
:YXZ3  -90.0   90.0   90.0    0.0  180.0    0.0  #.    (x,y,z) => (-y, x,-z)
:YXZ4  -90.0   90.0   90.0    0.0    0.0    0.0  #.    (x,y,z) => (-y, x, z)
:YXZ5  -90.0   90.0  -90.0    0.0  180.0    0.0  #.    (x,y,z) => (-y,-x,-z)
:YXZ6   90.0   90.0   90.0    0.0    0.0    0.0  #.    (x,y,z) => ( y, x, z)
:R000   90.0    0.0   90.0   90.0    0.0    0.0  #.    (x,y,z) => ( x, y, z)
:R005   90.0    5.0   90.0   95.0    0.0    0.0  #.    (x,y,z) => ( ?, ?, z)
...
:R355   90.0  355.0   90.0   85.0    0.0    0.0  #.    (x,y,z) => ( ?, ?, z)
:R360   90.0  360.0   90.0   90.0    0.0    0.0  #.    (x,y,z) => ( x, y, z)
:000T   90.0    0.0   90.0   90.0  180.0    0.0  #.    (x,y,z) => ( x, y,-z)
:005T   90.0    5.0   90.0   95.0  180.0    0.0  #.    (x,y,z) => ( ?, ?,-z)
...
```

```
:355T   90.0  355.0   90.0   85.0  180.0    0.0  #.    (x,y,z) => ( ?, ?,-z)
:360T   90.0  360.0   90.0   90.0  180.0    0.0  #.    (x,y,z) => ( x, y,-z)
:C001   90.0   11.25   0.0    0.0   90.0  281.25 #.    (x,y,z) => ( ?, z, ?)
:C002   90.0   22.50   0.0    0.0   90.0  292.5  #.    (x,y,z) => ( ?, z, ?)
...
:C063   90.0    0.00   0.0    0.0   90.0   90.0  #.    (x,y,z) => ( x, z, y)
:Z1YX   90.0   90.0    0.0    0.0   90.0    0.0  #.    (x,y,z) => ( y, z, x)
:Z2XY   90.0    0.00 180.0    0.0   90.0   90.0  #.    (x,y,z) => ( x,-z, y)
:Z3XY  -90.0    0.00   0.0    0.0   90.0   90.0  #.    (x,y,z) => (-x, z, y)
:Z4YX   90.0   90.0  180.0    0.0  -90.0    0.0  #.    (x,y,z) => ( y,-z,-x)
:Z5YX  -90.0   90.0    0.0    0.0  -90.0    0.0  #.    (x,y,z) => (-y, z,-x)
:Z6XY  -90.0    0.00 180.0    0.0  -90.0   90.0  #.    (x,y,z) => (-x,-z,-y)
:Z7XY   90.0    0.00   0.0    0.0  -90.0   90.0  #.    (x,y,z) => ( x, z,-y)
:Z8YX  -90.0   90.0  180.0    0.0   90.0    0.0  #.    (x,y,z) => (-y,-z, x)
:XXZY   90.0    0.0  180.0    0.0   90.0   90.0  #.    (x,y,z) => ( x,-z, y)
:XZXY   90.0  180.0  180.0    0.0   90.0  -90.0  #.    (x,y,z) => (-x,-z,-y)
:YZXZ   90.0   90.0   90.0    0.0  180.0    0.0  #.    (x,y,z) => ( y, x,-z)
:XXYZ   90.0  180.0   90.0  -90.0    0.0    0.0  #.    (x,y,z) => (-x,-y, z)
```

7.5 Geometry Title Examples

7.5.1 An example: geometry for the pixel detector

The pixel detector GEANT description created by the following instruction is shown in Fig.7.1

```
*DO  GEAN   0 -U -A4CW -c1/80     #. D0 pixel Detector  volumes 1st layer
 :MFPX    #. key volume name
#. rings eta = array(13,1.9-0.76); r1 = 412./sinh(eta);
#.                                 r2 = 638./sinh(eta);
#.                                 r3 = 772./sinh(eta);
#. The first ring:               r11      r12  dz    phi1   phi2
 :volu  :MR1A :TUBS "Air" 5 126.0647 139.2952 1.0  -92.25 267.75
 :volu  :MR2A :TUBS "Air" 5 139.2952 154.0735 1.0  -87.75 272.25
...
 :volu  :MRHA :TUBS "Air" 5 374.7213 427.8096 1.0  303.75 321.75
#. The second ring:
 :volu  :MR1B :TUBS "Air" 5 126.0647 139.2952 1.0  -87.75 272.25
 :volu  :MR2B :TUBS "Air" 5 139.2952 154.0735 1.0  -92.25 267.75
...
 :volu  :MRHB :TUBS "Air" 5 374.7213 427.8096 1.0  308.25 326.25
 :satt  :MR*A :SEEN 0  :satt  :MR*B :SEEN 0
#. Rings positioning
:pos :MR1A 1 :MFZA :NULL :ONLY 0. 0. 0.
:pos :MR2A 1 :MFZA :NULL :ONLY 0. 0. 0.
...
:pos :MRHA 1 :MFZA :NULL :ONLY 0. 0. 0.
:pos :MR1B 1 :MFZB :NULL :ONLY 0. 0. 0.
:pos :MR2B 1 :MFZB :NULL :ONLY 0. 0. 0.
...
:pos :MRHB 1 :MFZB :NULL :ONLY 0. 0. 0.
#.                    Ndiv Iaxis
 :dvn   :MP1A   :MR1A  40 2   :dvn   :MP1B   :MR1B  40 2
 :dvn   :MP2A   :MR2A  40 2   :dvn   :MP2B   :MR2B  40 2
```

```
...
 :dvn   :MPHA   :MRHA   2 2   :dvn   :MPHB   :MRHB   2 2
#. Pixel
 :volu  :PXLA   :TRD1 "Scintillator"  0
 :volu  :PXLB   :TRD1 "Scintillator"  0
...
#. 1-st A                             x y  z     dx1  dx2 dy   dz
 :posp :PXLA 1 :MP1A :90XD :ONLY 132.62 0. 0. 4 4.95 5.46 1. 6.56
 :posp :PXLA 1 :MP2A :90XD :ONLY 146.62 0. 0. 4 5.47 6.04 1. 7.32
...
 :posp :PXLA 1 :MPHA :90XD :ONLY 401.10 0. 0. 4 14.7 16.7 1. 26.3
#. 1-st B
 :posp :PXLB 1 :MP1B :90XD :ONLY 132.62 0. 0. 4 4.95 5.46 1. 6.56
 :posp :PXLB 1 :MP2B :90XD :ONLY 146.62 0. 0. 4 5.47 6.04 1. 7.32
...
 :posp :PXLB 1 :MPHB :90XD :ONLY 401.10 0. 0. 4 14.7 16.7 1. 26.3
```

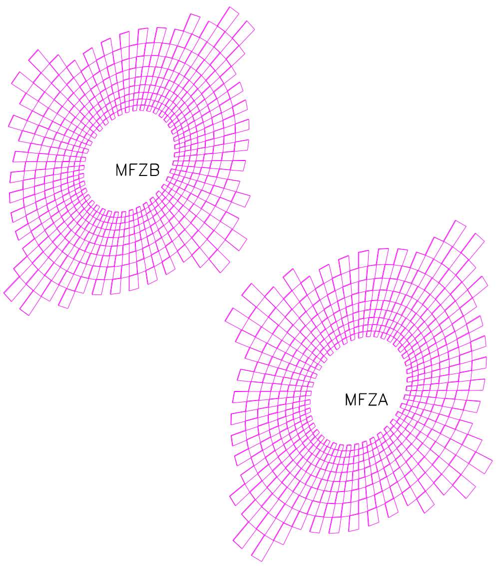
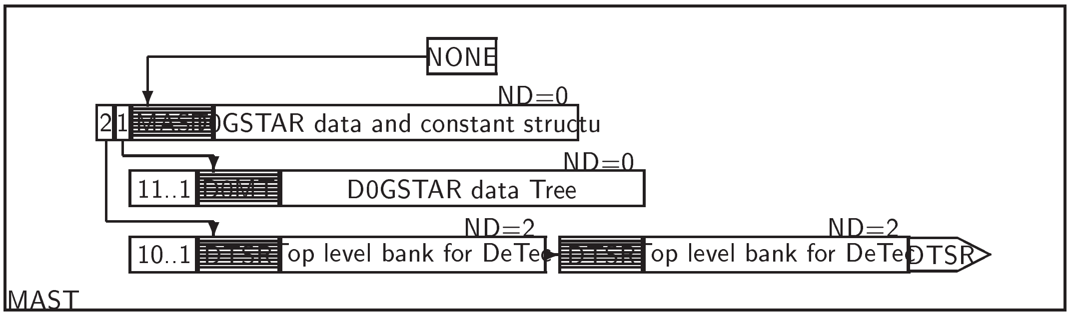


Figure 7.1: Pixel detector

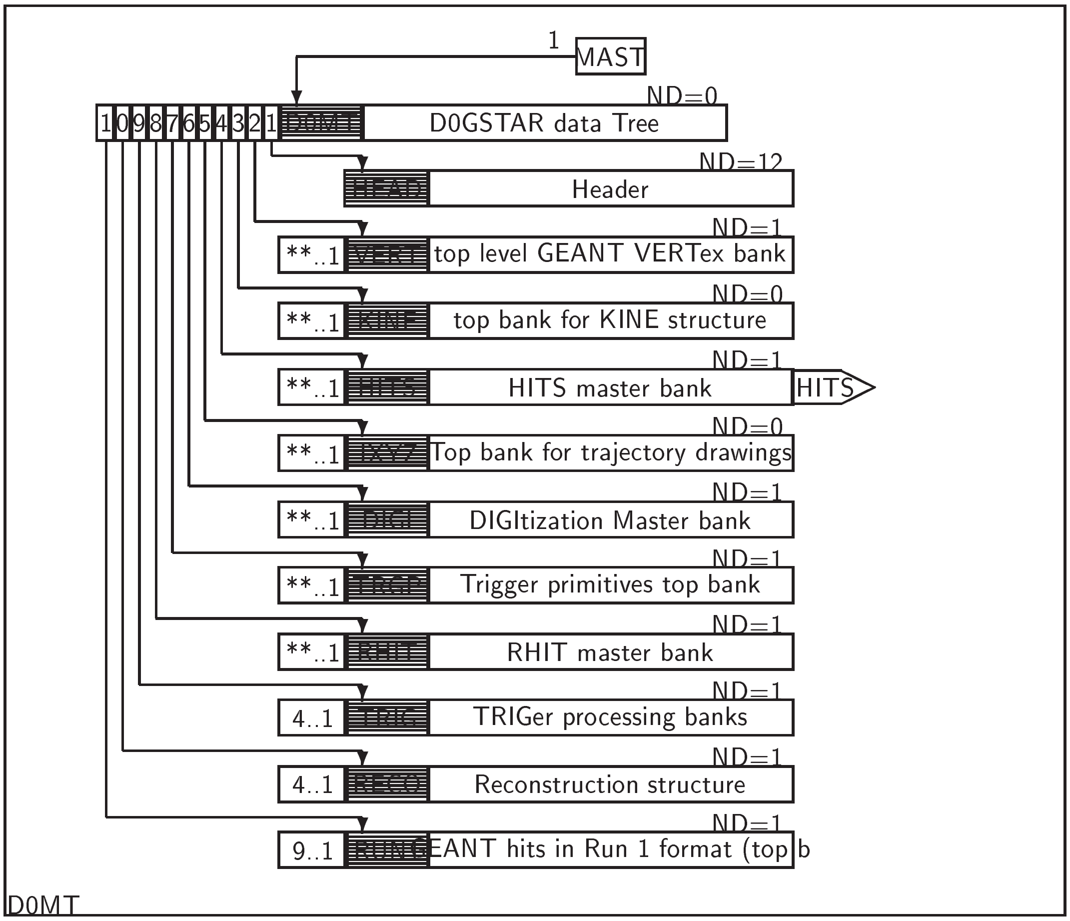
7.6 Bank Descriptions

For documentation of the ZEBRA structure used for data store and database, we adopted the DZEDIT/DZDOC package. As an example, the reconstruction bank descriptions are presented below.



MAST D0GSTAR data and constant structure MASTer bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAST     D0GSTAR data and constant structure MASTer bank
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL               2
NS               2
Up        NONE     0
Origin    NONE
IO-Charac          2
             ---------- Description of the links  ----------
1         D0MT     D0GSTAR data Tree
2         DTSR     D0GSTAR DeTector costant StRucture
```



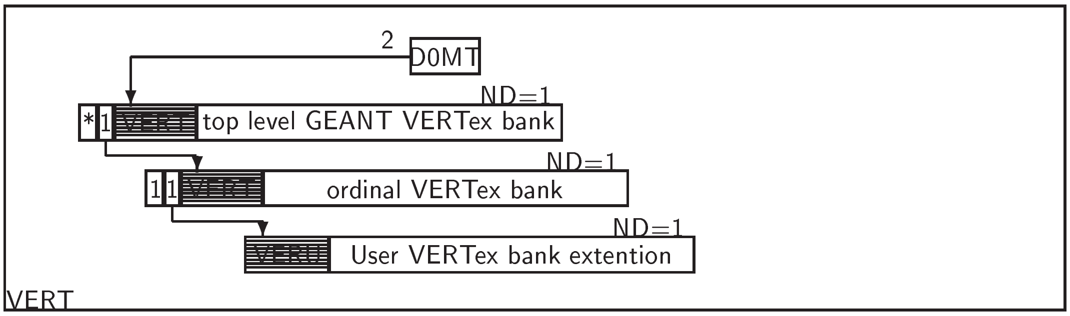
D0MT D0GSTAR data Tree

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DOMT     DOGSTAR data Tree
Author             Yu.Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL              11
NS              11
Up        MAST     -1
Origin    MAST
IO-Charac          2
NZERO     -1
             ---------- Description of the links  ----------
1         HEAD     Header
2         VERT     Simulated VERTex bank
3         KINE     Simulated GEANT KINE bank
4         HITS     Simulated HITS
5         JXYZ     Graphics
6         DIGI     Simulated GEANT digitization
7         TRGP     Trigger primitives
```

```
8         RHIT     Reco hit structure
9         TRIG     Trigger bank structures
10        RECO     Event reconstruction bank structures
11        RUN1     GEANT hits in Run 1 format (former GEAN bank)
```

HEAD Header

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  HEAD     Header
Author             GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
ND              12
Up        D0MT     -1
Origin    D0MT
IO-Charac          2
             ---------- Description of the data words   ----------
1         Run      number
2         Event    number
3         Random   number seed 1 at beginning of event
4         "        "
5         Random   number seed 1 at end of generator
6         "        " phase
7         Random   number seed 1 at end of tracking
8         "        " phase
9         Random   number seed 1 at end of digitization
10        "        " phase
11        No.      of vertices
12        No.      of tracks
13        GEOD0    GEOM data structure identifier
14        SETD0    SETS data structure identifier
```



VERT top level GEANT VERTex bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  VERT     top level GEANT VERTex bank
Author             : GEANT
```

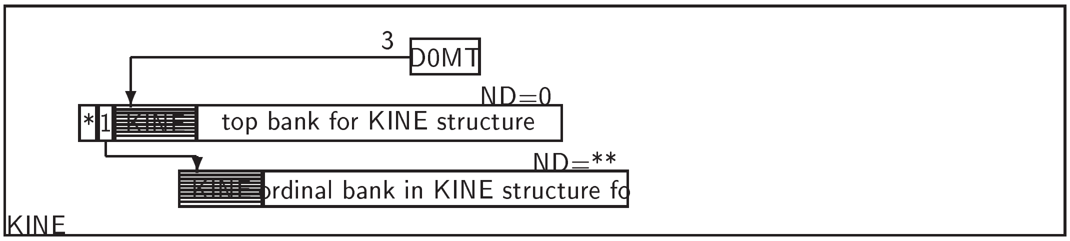
```
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NVERT
NS        NVERT
ND               1
Up        DOMT     -2
Origin    DOMT
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NVERT
    1       VERT
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         NVERT    No. of vertices
```

VERT ordinal VERTex bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  VERT     ordinal VERTex bank
NumericId NVTX
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               1
NS               1
ND               1
Up        VERT     -1
Origin    VERT
IO-Charac          3
             ---------- Description of the links  ----------
1         VERU
             ---------- Description of the data words   ----------
1         X
2         Y
3         Z
4         TOFG
5         NTBEAM
6         NTTARG
7         NTRACK
--REP level=1  NTRACK
    8       ITRACK
--REP level=1 -- End --
```

VERU User VERTex bank extention

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  VERU     User VERTex bank extention
Author             : Yu.Fisyak
Version            1.0
Store     IXSTOR
Division  IXDIV
ND               1
Up        VERT     -1
Origin    VERT
IO-Charac          3
             ---------- Description of the data words   ----------
1         N1       FIRST PARTICLE NUMBER FROM /HEPEVT/
2         N2       LAST  PARTICLE NUMBER FROM /HEPEVT/
--REP level=1  (N2-N1+1)
    3       ISTHEP(j status code
    4       IDHEP(j) particle identity
    5       JMOHEP(1 pointer to mother
    6       JMOHEP(2 pointer to second mother
    7       JDAHEP(1 pointer to the first daugther
    8       JDAHEP(2 pointer to the last daugther
    9       PX(j)
    10      PY(j)
    11      PZ(j)
    12      E(j)
--REP level=1 -- End --
```



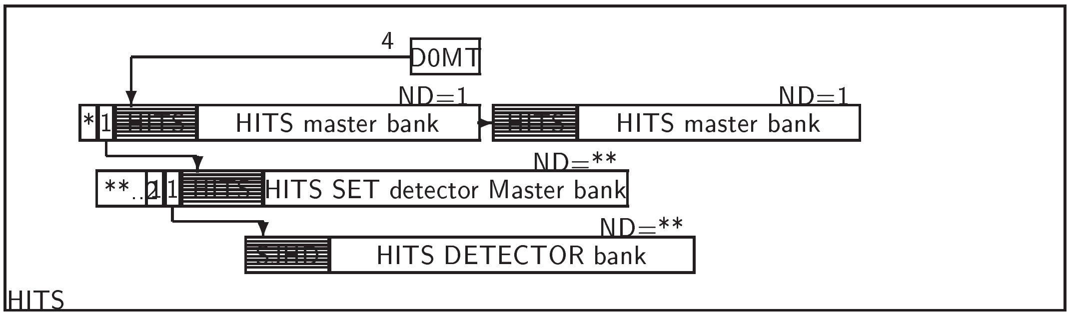
KINE top bank for KINE structure

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  KINE     top bank for KINE structure
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NTR
NS        NTR
Up        DOMT     -3
Origin    DOMT
IO-Charac          3
             ---------- Description of the links  ----------
--REP level=1  NTR
```

```
    1       KINE
--REP level=1 -- End --
```

KINE ordinal bank in KINE structure for each particle

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  KINE     ordinal bank in KINE structure for each particle
NumericId particle no. in VERU bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
ND        6+NV
Up        KINE     -1
Origin    D0MT
IO-Charac          3
             ---------- Description of the data words   ----------
1         PX
2         PY
3         PZ
4         E
5         PART     particle type
6         NV       No. of vetices
--REP level=1  NV
    8       IVERTEX
--REP level=1 -- End --
```



HITS HITS SET detector Master bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  HITS     HITS SET detector Master bank
NumericId Bunch    no.
Author             GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NDET
NS        NDET
```

```
ND        NDET
Up        HITS     -ISET
Origin    HITS
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NDET
    1       SJHD     HITS bank for the detector element
--REP level=1 -- End --
             ---------- Description of the data words   ----------
--REP level=1  NDET
    1       ILAST    last word used in SJHD bank
--REP level=1 -- End --
```

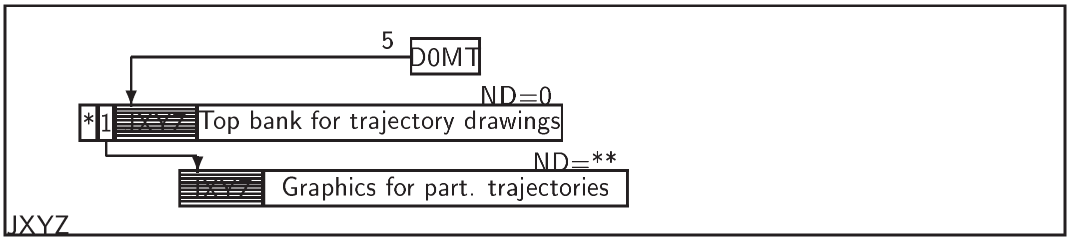
SJHD HITS DETECTOR bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SJHD     HITS DETECTOR bank
NumericId 1000*ISET+IDET
Author             GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
ND        NWHI
Up        HITS     -IDET
Origin    HITS
IO-Charac          /2B 6F
             ---------- Description of the data words   ----------
--REP level=1  NHIT*(NV+NH+1)
    1       ITRA     track number
    2       packed   volume (NV) and hits parameters (NH)
--REP level=1 -- End --
```

HITS HITS master bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  HITS     HITS master bank
NumericId Event    no. (=1 for trigger one)
Author             GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NSET
NS        NSET
ND               1
Next      HITS
Up        DOMT     -4
Origin    DOMT
```

```
IO-Charac          3
             ---------- Description of the links  ----------
--REP level=1  NSET
    1       HITS     Detector Set Master bank
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         Bunch    time (ns, trigger event = 0)
```



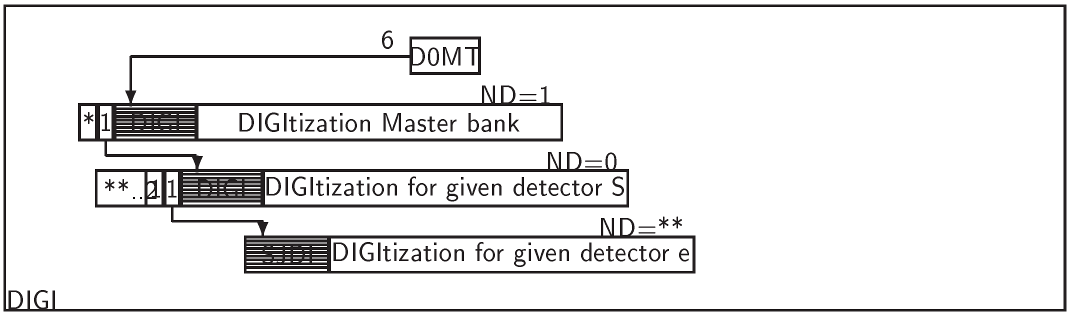
JXYZ Top bank for trajectory drawings

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  JXYZ     Top bank for trajectory drawings
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NCKINE
NS        NCKINE
Up        DOMT     -5
Origin    DOMT
IO-Charac          3
             ---------- Description of the links  ----------
--REP level=1  NCKINE
    1       JXYZ     for each ITRA
--REP level=1 -- End --
```

JXYZ Graphics for part. trajectories

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  JXYZ     Graphics for part. trajectories
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
ND        NCJXYZ
Up        JXYZ     -ITRA
Origin    JXYZ
IO-Charac          3
             ---------- Description of the data words   ----------
1         NCJXYZ-2
```

```
2          3.
--REP level=1  NPOINT
    3       IPOINT
    4       IPART
    5       X
    6       Y
    7       Z
--REP level=1 -- End --
```



DIGI DIGItization Master bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DIGI     DIGItization Master bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NSET
NS        NSET
ND               1
Up        DOMT     -6
Origin    DOMT
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NSET
    1       DIGI
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         dummy
```

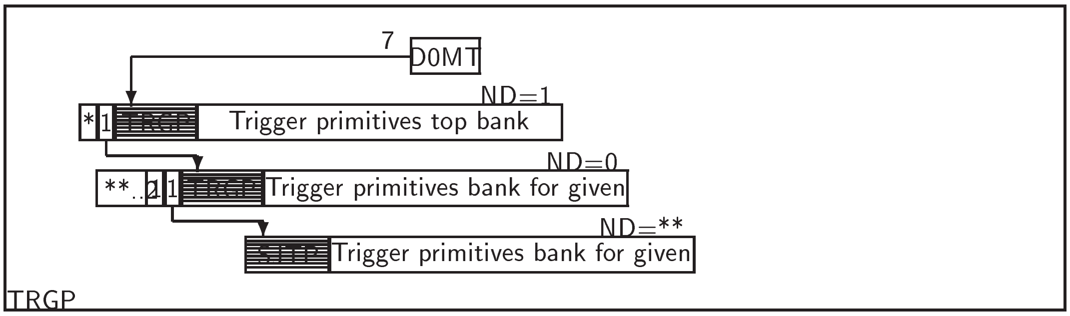
DIGI DIGItization for given detector SET

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DIGI     DIGItization for given detector SET
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
```

```
NL        NDET
NS        NDET
Up        DIGI     -ISET
Origin    DIGI
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NDET
    1       SJDI
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         dummy
```

SJDI DIGItization for given detector element

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SJDI     DIGItization for given detector element
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
ND        NWDI
Up        DIGI     -IDET
Origin    DIGI
IO-Charac          1
             ---------- Description of the data words   ----------
--REP level=1  NWD
    1       tracks   numbers, volumes numbers and digits
--REP level=1 -- End --
```



TRGP Trigger primitives top bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TRGP     Trigger primitives top bank
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NSET
```

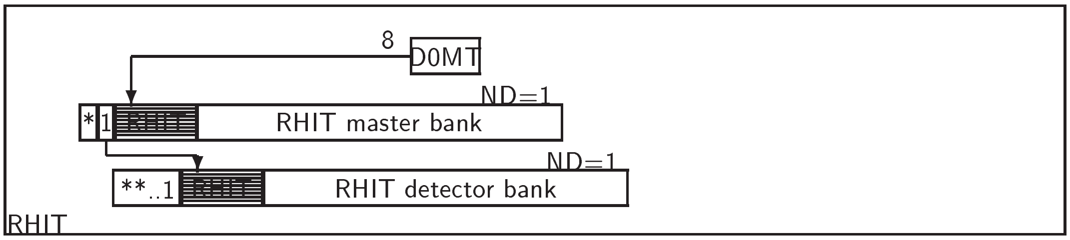
```
NS        NSET
ND               1
Up        DOMT     -7
Origin    DOMT
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NSET
    1       TRGP
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         dummy
```

TRGP Trigger primitives bank for given detector SET

```
----------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TRGP     Trigger primitives bank for given detector SET
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NDET
NS        NDET
Up        TRGP     -ISET
Origin    TRGP
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NDET
    1       SJTP
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         dummy
```

SJTP Trigger primitives bank for given detector element

```
----------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SJTP     Trigger primitives bank for given detector element
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXDIV
ND        NWD
Up        TRGP     -IDET
Origin    TRGP
IO-Charac          1
             ---------- Description of the data words   ----------
--REP level=1  NWD
    1       tracks   numbers, volumes numbers and trigger primitives
--REP level=1 -- End --
```

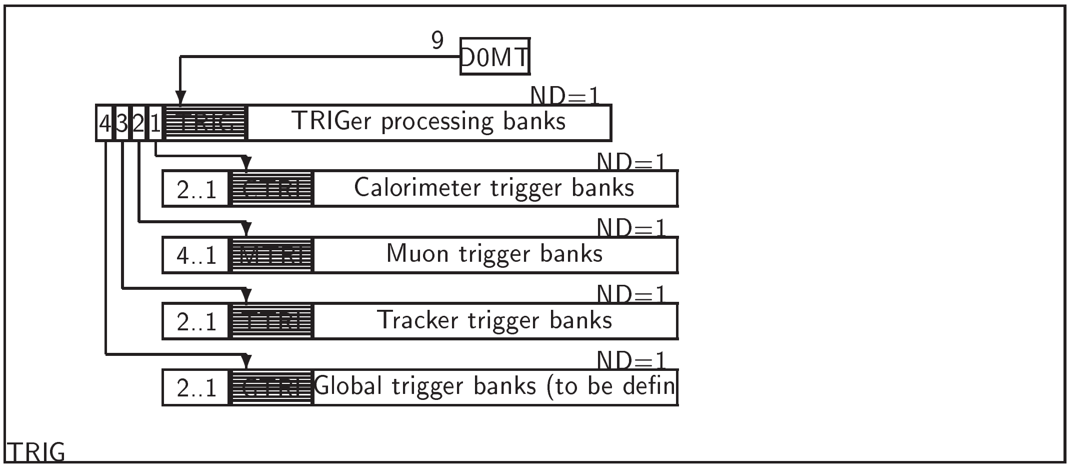


RHIT RHIT master bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  RHIT     RHIT master bank
Author             Y.Fisyak
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NSET
NS        NSET
ND               1
Up        DOMT     -8
Origin    DOMT
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NSET
    1       RHIT     Detector bank
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         dummy
```

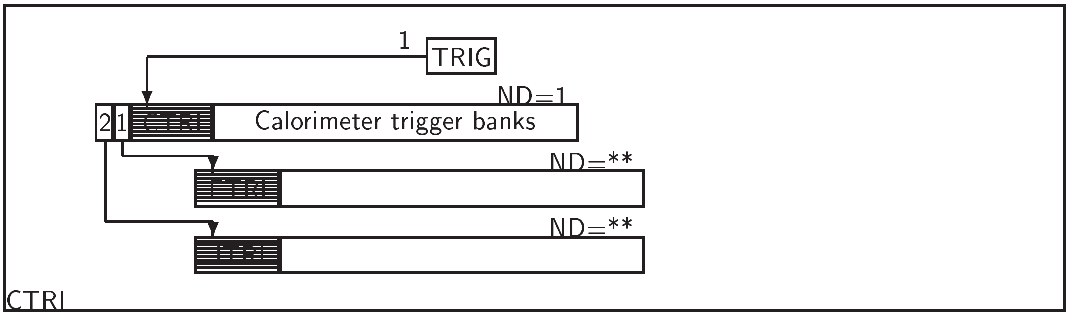
RHIT RHIT detector bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  RHIT     RHIT detector bank
Author             Y.Fisyak
Version            1.0
Store     IXSTOR
Division  IXDIV
NL        NDET
NS        NDET
ND               1
Up        RHIT     -ISET
Origin    RHIT
IO-Charac          2
             ---------- Description of the links  ----------
--REP level=1  NDET
--REP level=1 -- End --
```



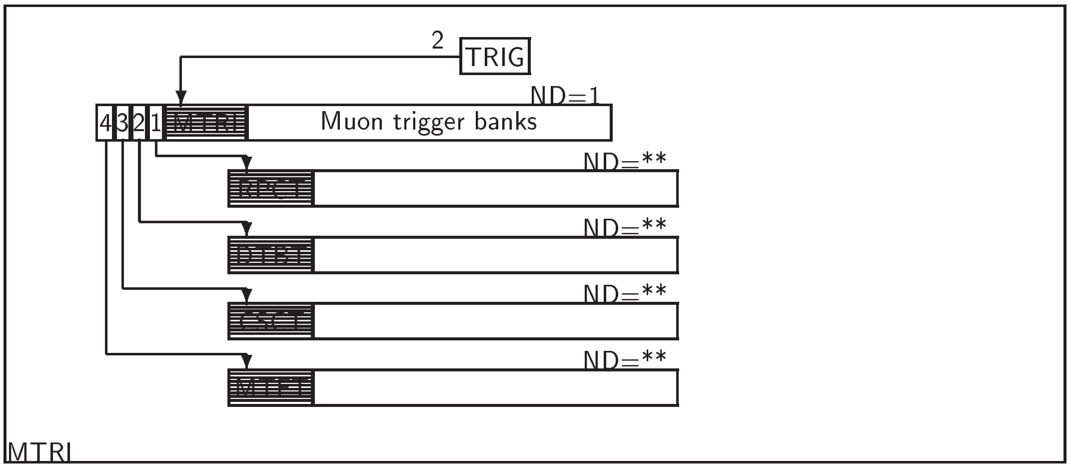
TRIG TRIGer processing banks

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TRIG     TRIGer processing banks
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL                4
NS                4
ND                1
Up        DOMT     -9
Origin    DOMT
IO-Charac          2
NZERO             1
             ---------- Description of the links  ----------
1         CTRI     Calorimeter trigger structure
2         MTRI     Muon trigger
3         TTRI     Tracker trigger (filter)
4         GTRI     Global trigger
             ---------- Description of the data words   ----------
1
```



CTRI Calorimeter trigger banks

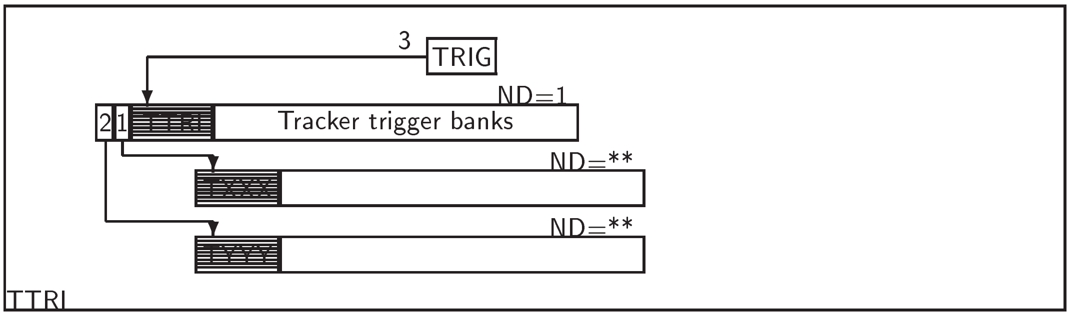
```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  CTRI     Calorimeter trigger banks
Author             NN
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               2
NS               2
ND               1
Up        TRIG     -1
Origin    TRIG
IO-Charac          2
NZERO            1
             ---------- Description of the links  ----------
1         ETRI     EM trigger
2         JTRI     Jet trigger
             ---------- Description of the data words   ----------
1


ETRI/CTRI No doc


JTRI/CTRI No doc
```



MTRI Muon trigger banks

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MTRI     Muon trigger banks
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               4
NS               4
```

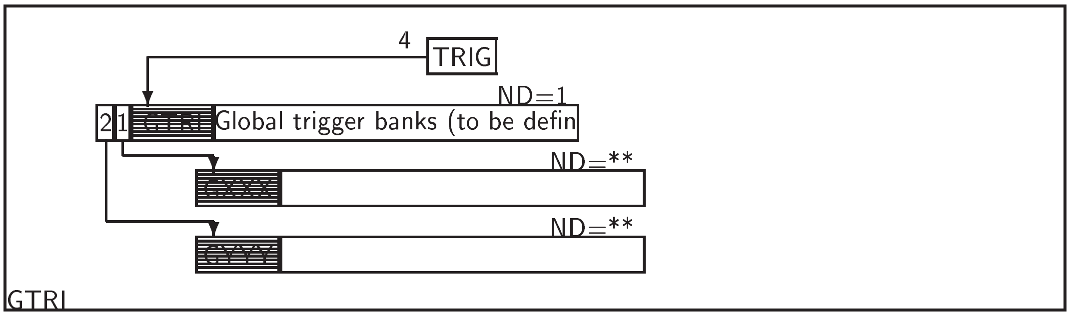
```
ND                 1
Up         TRIG      -2
Origin     TRIG
IO-Charac            2
NZERO              1
             ---------- Description of the links  ----------
1          RPCT      RPC Trigger
2          DTBT      DTBx Trigger
3          CSCT      CSC Trigger
4          MTFT      Muon Track Finder for Trigger
             ---------- Description of the data words   ----------
1


RPCT/MTRI No doc


DTBT/MTRI No doc


CSCT/MTRI No doc


MTFT/MTRI No doc
```



TTRI Tracker trigger banks

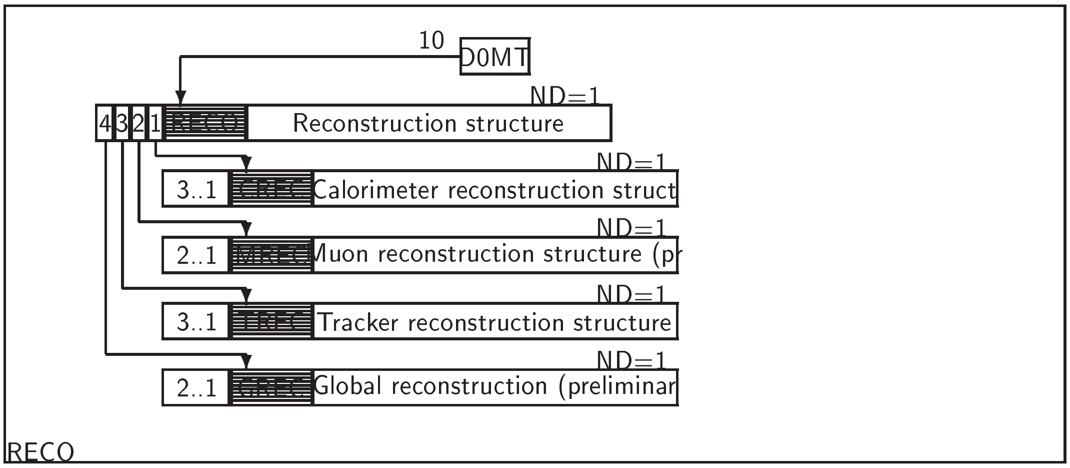
```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH   TTRI      Tracker trigger banks
Author               NN
Version              1.0
Store      IXSTOR
Division   IXDIV
NL                 2
NS                 2
ND                 1
Up         TRIG      -3
Origin     TRIG
IO-Charac            2
```

```
NZERO            1
             ---------- Description of the links  ----------
1         TXXX     To be defined
2         TYYY     To be defined
             ---------- Description of the data words   ----------
1


TXXX/TTRI No doc


TYYY/TTRI No doc
```



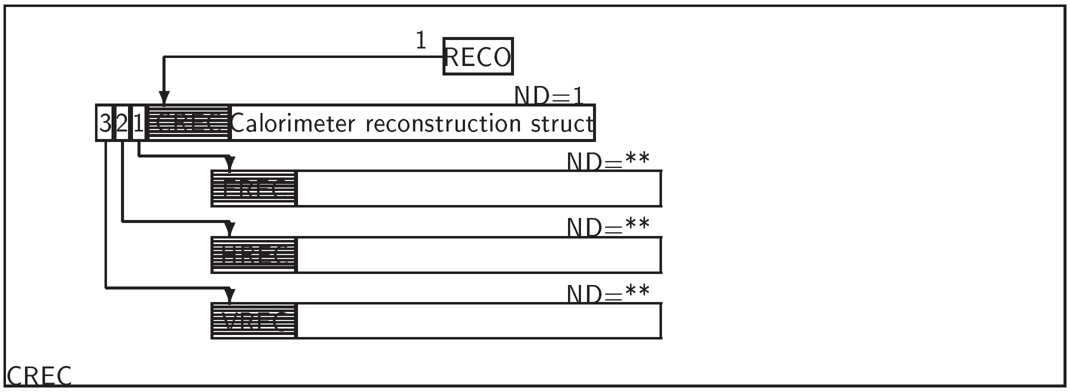
GTRI Global trigger banks (to be defined)

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  GTRI     Global trigger banks (to be defined)
Author             NN
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               2
NS               2
ND               1
Up        TRIG     -4
Origin    TRIG
IO-Charac          2
NZERO            1
             ---------- Description of the links  ----------
1         GXXX     To be defined
2         GYYY     To be defined
             ---------- Description of the data words   ----------
1


GXXX/GTRI No doc


GYYY/GTRI No doc
```



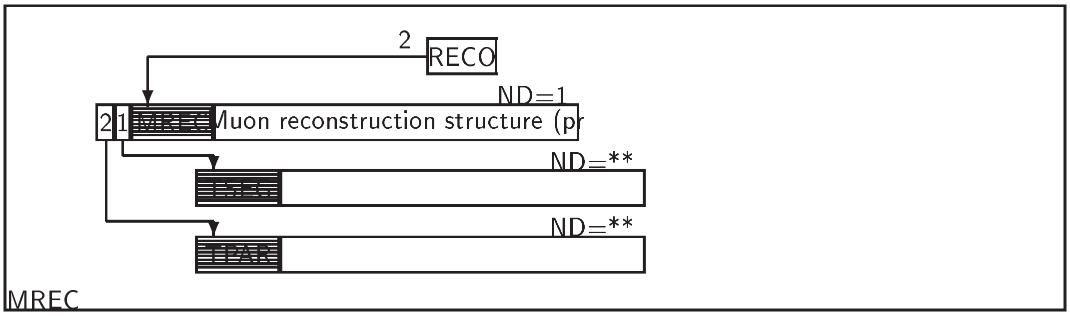
RECO Reconstruction structure

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  RECO     Reconstruction structure
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               4
NS               4
ND               1
Up        DOMT     -10
Origin    DOMT
IO-Charac          2
NZERO            1
             ---------- Description of the links  ----------
1         CREC     Calorimeter reconstruction structure
2         MREC     Muon reconstruction
3         TREC     Tracker reconstruction
4         GREC     Global reconstruction
             ---------- Description of the data words   ----------
1
```



CREC Calorimeter reconstruction structure (preliminary)

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  CREC     Calorimeter reconstruction structure (preliminary)
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               3
NS               3
ND               1
Up        RECO     -1
Origin    RECO
IO-Charac          2
NZERO            1
             ---------- Description of the links  ----------
1         EREC     ECAL reconstruction
2         HREC     HCAL reconstruction
3         VREC     VCAL reconstruction
             ---------- Description of the data words   ----------
1


EREC/CREC No doc


HREC/CREC No doc


VREC/CREC No doc
```



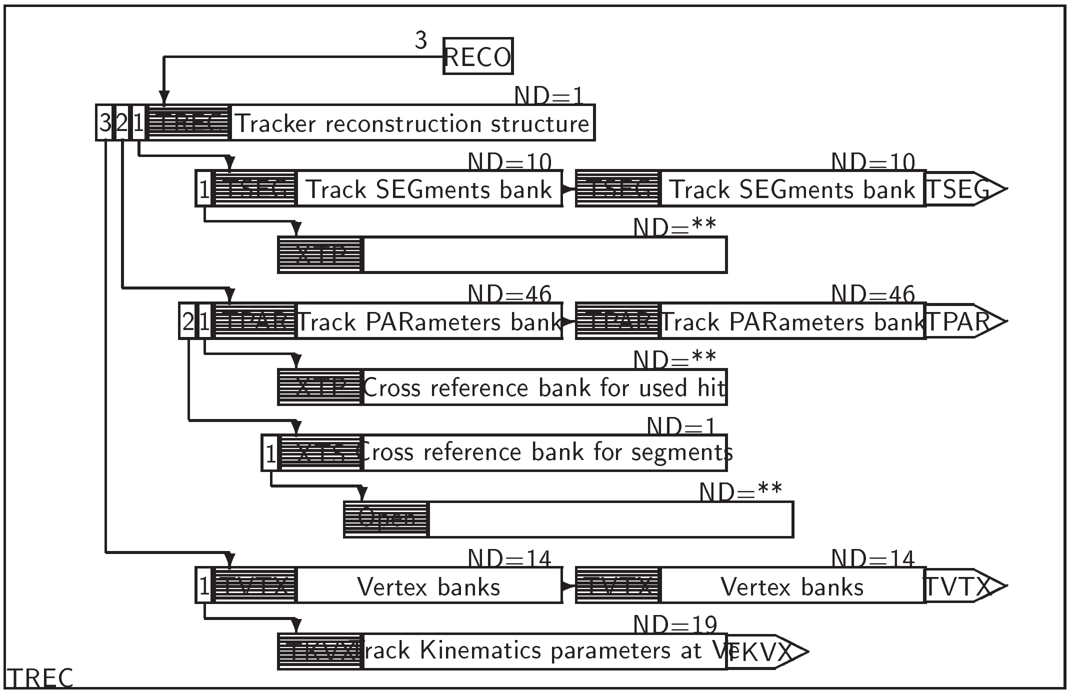
MREC Muon reconstruction structure (preliminary)

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MREC     Muon reconstruction structure (preliminary)
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
```

```
NL                2
NS                2
ND                1
Up        RECO      -2
Origin    RECO
IO-Charac           2
NZERO             1
             ---------- Description of the links  ----------
1         TSEG     Track segments
2         TPAR     Track parameters
             ---------- Description of the data words   ----------
1
```

TSEG/MREC No doc

TPAR/MREC No doc



TREC Tracker reconstruction structure

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TREC     Tracker reconstruction structure
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL                3
NS                3
```

```
ND               1
Up        RECO     -3
Origin    RECO
IO-Charac          2
NZERO            1
             ---------- Description of the links  ----------
1         TSEG     Track segment banks
2         TPAR     Track parameters banks
3         TVTX     Vertex banks
             ---------- Description of the data words   ----------
1


XTP /TSEG No doc
```

TSEG Track SEGments bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TSEG     Track SEGments bank
Author             : V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               1
NS               1
ND              10
Next      TSEG
Up        TREC     -1
Origin    TREC
IO-Charac          3I -F
NZERO           10
             ---------- Description of the links  ----------
1         XTP      Cross reference bank for hits used
             ---------- Description of the data words   ----------
1
2
3
4
5
6
7
8
9
10
```

XTP Cross reference bank for used hits

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  XTP      Cross reference bank for used hits
Author             : V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
ND        1+3*NRHIT
Next      NONE
Up        TPAR     -1
Origin    TPAR
IO-Charac          -I
             ---------- Description of the data words   ----------
1         NRHIT    Number of hits
--REP level=1  NRHIT
    2       ISET     GEANT set identifier
    3       IDET     GEANT detector identifier
    4       IXRHIT   The hit number in RHIT bank
--REP level=1 -- End --
```

XTS Cross reference bank for segments

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  XTS      Cross reference bank for segments
Author             : NN
Store     IXSTOR
Division  IXDIV
NL               1
NS               1
ND               1
Next      NONE
Up        TPAR     -2
Origin    TPAR
IO-Charac          -I
             ---------- Description of the links  ----------
1         Open     - to be defined
             ---------- Description of the data words   ----------
1         Open     - to be defined


Open/XTS  No doc
```

TPAR Track PARameters bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TPAR     Track PARameters bank
Author             : V.Karimaki
Version            1.0
```

```
Store     IXSTOR
Division  IXDIV
NL               5
NS               2
ND              46
Next      TPAR
Up        TREC     -2
Origin    TREC
IO-Charac          3I -F
NZERO           46
             ---------- Description of the links  ----------
1         XTP      Used hits cross reference bank
2         XTS      Track segments cross reference bank (for DTBX)
             ---------- Description of the Reference links  ----------
1         TPAR     Ref link to TPAR in TREC structure (for global mu-fit)
2         TPAR     Ref link to TPAR in MREC structure (for global mu-fit)
3         Ref      link to e.m. cluster (for global e-fit)
             ---------- Description of the data words   ----------
1         IDTK     Track (+ vx) identifier = IDTR + 1000*IDVX
2         IDMC     MC track and vertex no = ITRA + 1000*IVER
3         NDF      Number of degrees of freedom
4         CHI      Chi squared
5         X        ) Global coordinates (cm)
6         Y        ) (X,Y) is a point of DCA to (X-beam, Y-beam)
7         Z        ) (X,Y,Z) is on the trajectory
8         Q/p      Signed inverse momentum (1/GeV)
9         DIP      Dip angle = $\pi$/2 - polar angle (rad)
10        PHI      Azimuth angle in global system (rad)
--REP level=1        15
11        Covarian matrix of Q/p,dip,phi,y$_t$,z$_t$ (lower diagonal)
--REP level=1 -- End --
26        X        ) Global coordinates at the first measurement (cm)
27        Y        ) (X,Y,Z) is on the trajectory at the detector
28        Z        ) plane of the first measured point
29        Q/p      Signed inverse momentum (1/GeV)
30        DIP      Dip angle = $\pi$/2 - polar angle (rad)
31        PHI      Azimuth angle in global system (rad)
--REP level=1        15
32        Covarian matrix of Q/p,dip,phi,y$_t$,z$_t$ (lower diagonal)
--REP level=1 -- End --
```

TKVX Track Kinematics parameters at VerteX

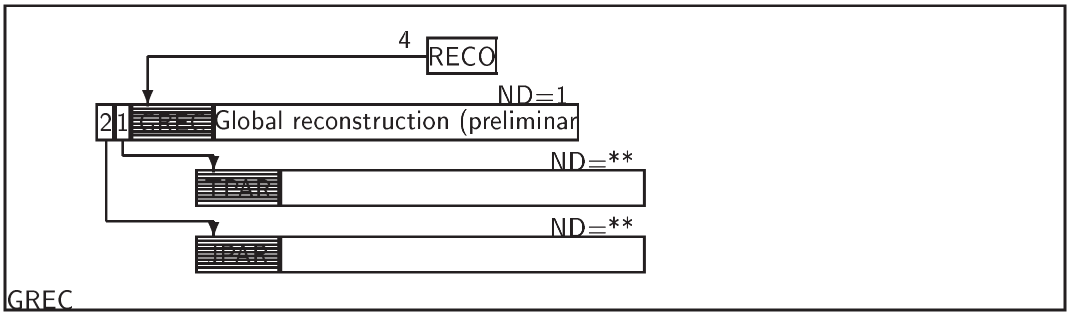
```
------------------------------------------------ entered file at  1-Aug-97 14: 0
Bank IDH  TKVX     Track Kinematics parameters at VerteX
Author             : V.Karimaki
Version            1.0
Store     IXSTOR
```

```
Division  IXDIV
NL               1
ND              19
Next      TKVX
Up        TVTX     -1
Origin    TVTX
IO-Charac          3I -F
NZERO           17
             ---------- Description of the Reference links  ----------
1         TPAR     ref link to TPAR bank
             ---------- Description of the data words   ----------
1         Track    Id (as in TPAR)
2         Flag     0 (1), if track was not used (was used) in vertex fit
5         q/p      charge*track inverse momentum (GeV)
6         dip,     angle between track and the xy-plane (rad)
7         phi      (rad)
--REP level=1         6
8         Covarian Matrix (lower diagonal)
--REP level=1 -- End --
14        dxy,     impact parameter in xy (cm)
15        sxy,     its error (cm)
16        dz,      impact parameter in z (cm)
17        sz,      its error (cm)
```

TVTX Vertex banks

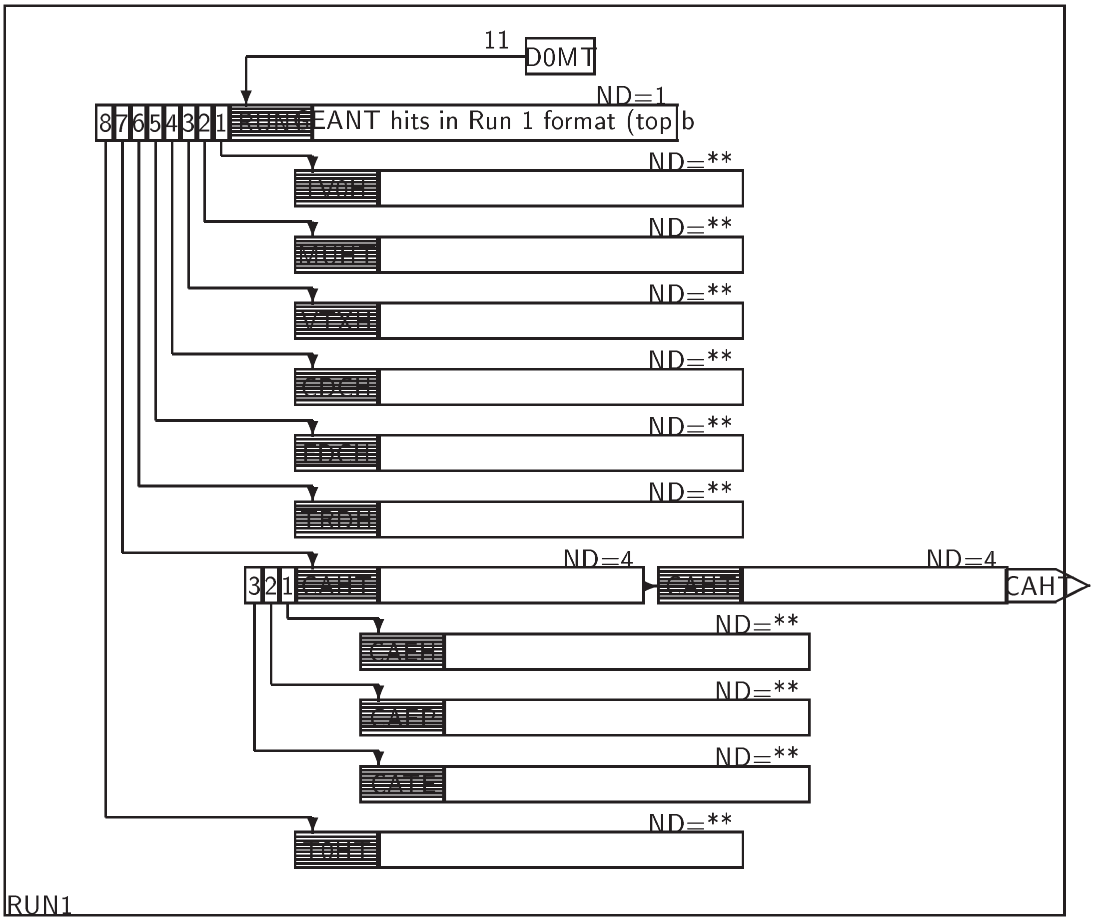
```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TVTX     Vertex banks
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               2
NS               1
ND              14
Next      TVTX
Up        TREC     -3
Origin    TREC
IO-Charac          4I -F
NZERO           14
             ---------- Description of the links  ----------
1         TKVX     Outgoing tracks TKVX banks
             ---------- Description of the Reference links  ----------
1         TKVX     Ref link to incoming track (or 0)
             ---------- Description of the data words   ----------
1         Vertex   ID
2         MC       vertex no
3         No.      of associated tracks
```

```
4          No.      of tracks used in fit
5          Chisq
6          X
7          Y
8          Z
9          C(XX)    Covariance matrix elements (lower diagonal)
10         C(XY)
11         C(YY)
12         C(XZ)
13         C(YZ)
14         C(ZZ)
```



GREC Global reconstruction (preliminary)

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  GREC     Global reconstruction (preliminary)
Author             V.Karimaki
Version            1.0
Store     IXSTOR
Division  IXDIV
NL               2
NS               2
ND               1
Up        RECO     -4
Origin    RECO
IO-Charac          2
NZERO            1
             ---------- Description of the links  ----------
1         TPAR     Global track fit parameters
2         JPAR     Global jet parameters
             ---------- Description of the data words   ----------
1


TPAR/GREC No doc


JPAR/GREC No doc
```



RUN1 GEANT hits in Run 1 format (top bank, former HITS)

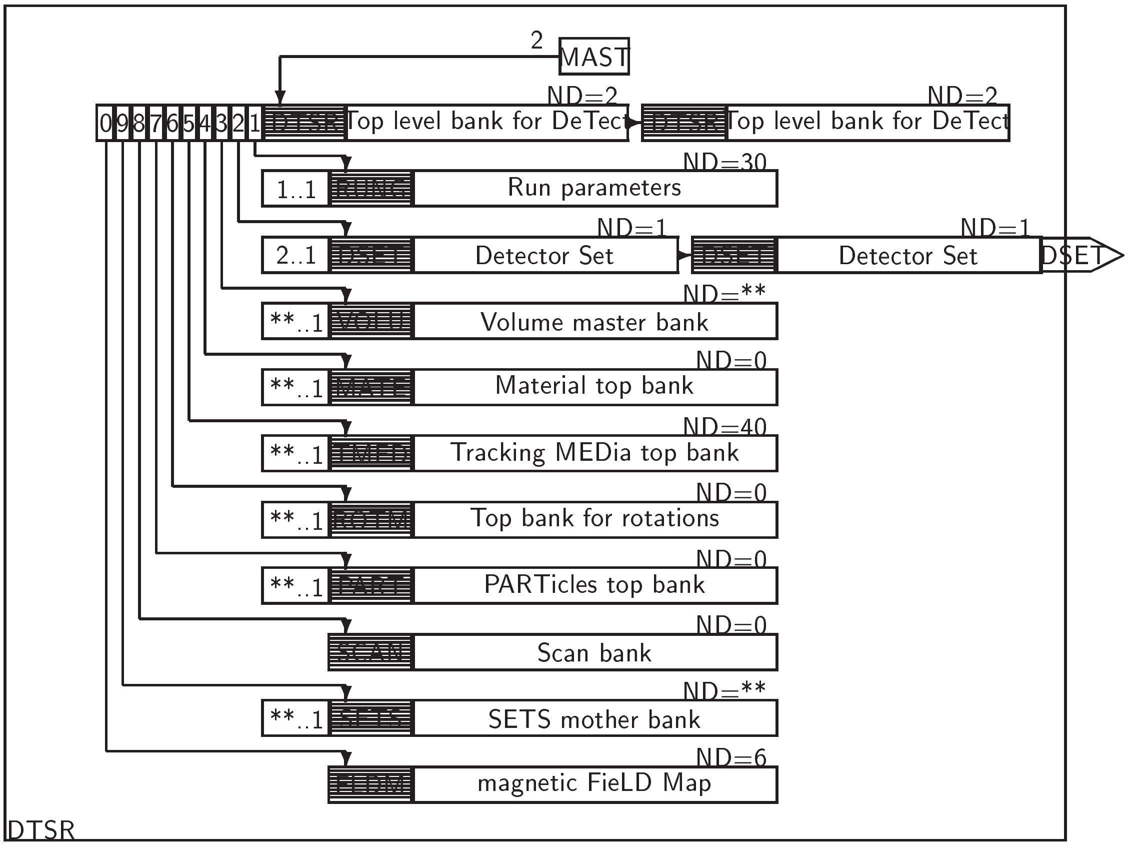
```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  RUN1     GEANT hits in Run 1 format (top bank, former HITS)
Author             : Yuri Fisyak
Version            3.0
Store     IXSTOR
Division  IXDIV    {mnemonic of the division}
NL               9 {number of links}
NS               9 {number of structural links}
ND               1 {number of data words}
Up        DOMT     {UPID: Id of Up-banks, JB is the link offset of bank}
Origin    DOMT     {ORID: Id of Origin-bank}
IO-Charac          3 {IO characteristics}
NZERO     -1       {number of data words preset to zero}
             ---------- Description of the links  ----------
1         LV0H     (level 0 hits header)
2         MUHT     (muon drift ch. hits header)
3         VTXH     (vertex chamber hits header)
4         CDCH     (central " " " " )
5         FDCH     (forward drift ch. hits header)
6         TRDH     (TRD hits header)
```

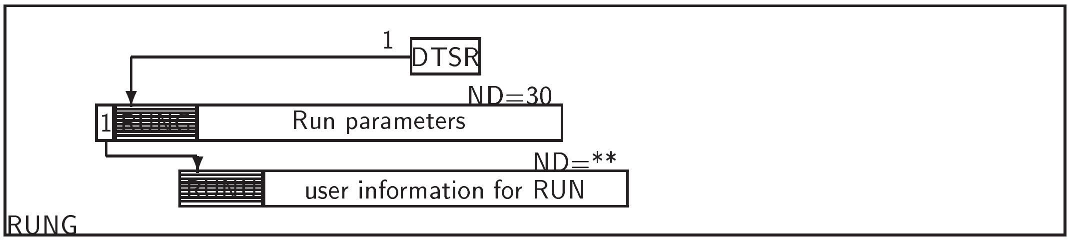
```
7         CAHT     (cal. hits header)
8         T0HT     (T0 detector hits)
             ---------- Description of the data words   ----------
1         version  number=3


LV0H/RUN1 No doc


MUHT/RUN1 No doc


VTXH/RUN1 No doc


CDCH/RUN1 No doc


FDCH/RUN1 No doc


TRDH/RUN1 No doc


CAEH/CAHT No doc


---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  CAEP
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXDIV    {mnemonic of the division}
NL               1 {number of links}
NS               1 {number of structural links}
ND        NR*NCH+3 {number of data words}
Up        CAHT     -2 {UPID: Id of Up-banks, JB is the link offset of bank}
Origin    CAHT     {ORID: Id of Origin-bank}
IO-Charac          3I/1I1F {IO characteristics}
NZERO     -1       {number of data words preset to zero}
             ---------- Description of the data words   ----------
1         I        Bank version number
2         I        NR=2 repetition number
3         I        NCH number of channels
--REP level=1  NCH
    4       B        packed address in bytes (BYTE B(4) in VAX)
                     B(4)=ieta,B(3)=iphi,B(2)=l
    5       R        Energy in GeV
--REP level=1 -- End --
```

CATE/CAHT No doc

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  CAHT
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXDIV    {mnemonic of the division}
NL               4 {number of links}
NS               3 {number of structural links}
ND               4 {number of data words}
Next      CAHT     {NXID: Id of possible next banks}
Up        RUN1     -7 {UPID: Id of Up-banks, JB is the link offset of bank}
Origin    RUN1     {ORID: Id of Origin-bank}
IO-Charac          I 3F {IO characteristics}
NZERO     -1       {number of data words preset to zero}
             ---------- Description of the links  ----------
1         CAEH
2         CAEP
3         CATE
             ---------- Description of the Reference links  ----------
1         HSRT
             ---------- Description of the data words   ----------
1         I        bank version (= 2)
2         R        Cryostat correction factor, ECN
3         R        Cryostat correction factor, CC
4         R        Cryostat correction factor, ECS
```

T0HT/RUN1 No doc





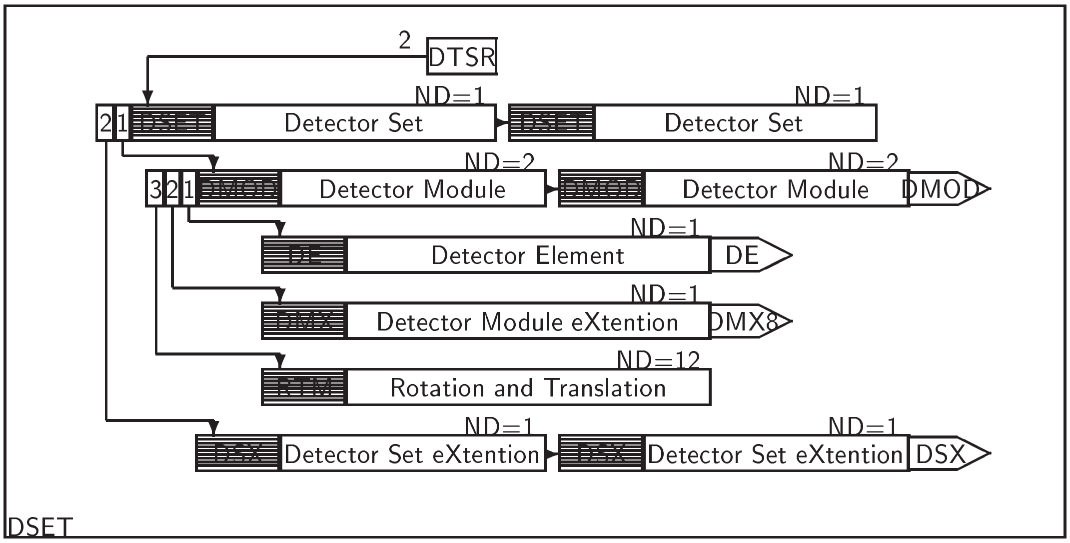
RUNG Run parameters

```
--------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  RUNG     Run parameters
NumericId        1
Author             GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
NL               1
NS               1
ND              30
Up        DTSR     -1
Origin    DTSR
IO-Charac          20I -F
            ---------- Description of the links  ----------
1         RUNU     USER information
```

```
             ---------- Description of the data words   ----------
1          Run      number
2          GEODO    GEOM data structure identifier
3          SETDO    SETS data structure identifier
--REP level=1         7
4          Reserved for user applications
--REP level=1 -- End --
11         creation date for 'INIT' data structures
12         creation time for 'INIT' data structures
13         creation data for 'KINE'
14         creation time for 'KINE'
15         creation data for 'HITS'
16         creation time for 'HITS'
17         creation data for 'DIGI'
18         creation time for 'DIGI'
19         Random   number seed 1 in GTRIGC
20         Random   number seed 2 -"-
21         GEANT    version number when 'INIT' created
22         ZEBRA    version number when 'INIT' created
23         GEANT    version number when 'KINE' created
24         ZEBRA    version number when 'KINE' created
25         GEANT    version number when 'HITS' created
26         ZEBRA    version number when 'HITS' created
27         GEANT    version number when 'DIGI' created
28         ZEBRA    version number when 'DIGI' created
--REP level=1         2
29         free
--REP level=1 -- End --
```

RUNU user information for RUN

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  RUNU     user information for RUN
Author             : Y.Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2+2*NOKEYV+5*NOVALL
Up        RUNG     -1
Origin    RUNG
IO-Charac          (2+2*NOKEYV+4*NOVALL)I (NOVALL)H
             ---------- Description of the data words   ----------
1          NOKEYV   no. of key Volumes
2          NOVALL   no. of volumes
--REP level=1  NOKEYV
    3        Key      volume start index
--REP level=1 -- End --
```



DE Detector Element

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DE       Detector Element
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND                1
Next      DE
Up        DMOD     -1
Origin    DMOD
IO-Charac          2
             ---------- Description of the data words   ----------
1         IDTYPE   detector element Type
```

DMX Detector Module eXtention

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DMX      Detector Module eXtention
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND                1
Next      DMX8
Up        DMOD     -2
Origin    DMOD
IO-Charac          2
             ---------- Description of the data words   ----------
1         IDTYPE   detector Module eXtention Type
```

DMX8 Dead element description

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DMX8     Dead element description
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        NDEAD+1
Next      DMX8
Up        DMOD     -2
Origin    DMOD
IO-Charac          2
             ---------- Description of the data words   ----------
1         8
--REP level=1  NDEAD
    2       IDEAD    dead element identifier
--REP level=1 -- End --
```

RTM Rotation and Translation

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  RTM      Rotation and Translation
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND              12
Up        DMOD     -3
Origin    DMOD
IO-Charac          2
             ---------- Description of the data words   ----------
--REP level=1         9
1         Rotation Matrix
--REP level=1 -- End --
--REP level=1         3
10        Translat vector
--REP level=1 -- End --
```

DMOD Detector Module

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DMOD     Detector Module
NumericId 1000*ISET+IDET
Author             : Yuri Fisyak
Version            1.0
```

```
Store     IXSTOR
Division  IXCONS
NL              4
NS              3
ND              2
Next      DMOD
Up        DSET     -1
Origin    DSET
IO-Charac          2
             ---------- Description of the links  ----------
1         DE       Detector Element
2         DMX      Detector Module Extention
3         RTM      Rotation matrix and transormation
             ---------- Description of the data words   ----------
1         IDTYPE   detector Module Type
```

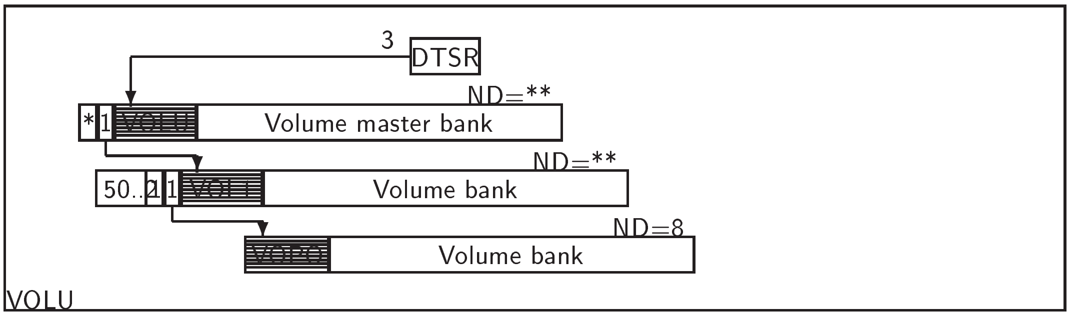
DSX Detector Set eXtention

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DSX      Detector Set eXtention
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND              1
Next      DSX
Up        DSET     -2
Origin    DSET
IO-Charac          2
             ---------- Description of the data words   ----------
1         IDTYPE   detector Set eXtention Type
```

DSET Detector Set

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DSET     Detector Set
NumericId ISET     {Set number}
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL              2
NS              2
ND              1
Next      DSET
Up        DTSR     -2
Origin    DTSR
```

```
IO-Charac          2
             ---------- Description of the links  ----------
1         DMOD     Detector Module
2         DSX      Detector Set Extention
             ---------- Description of the data words   ----------
1         IDTYPE   detector Set Type
```



VOLU Volume master bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  VOLU     Volume master bank
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL        NVOLUM
NS        NVOLUM
ND        NVOLUM
Up        DTSR     -3
Origin    DTSR
IO-Charac          5
             ---------- Description of the links  ----------
--REP level=1  NVOLUM
    1       VOL1
--REP level=1 -- End --
             ---------- Description of the data words   ----------
--REP level=1  NVOLUM
    1       VOLUME   NAME
--REP level=1 -- End --
```

VOL1 Volume bank

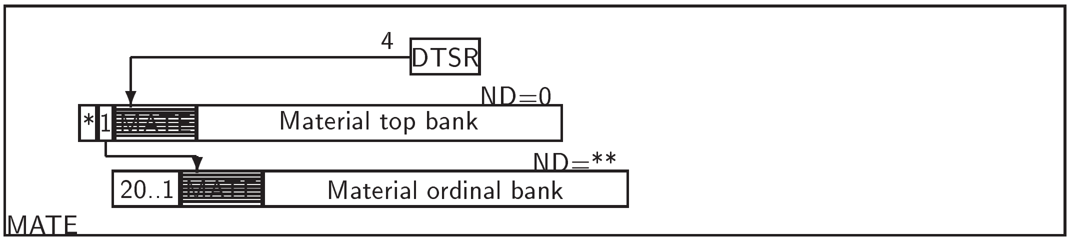
```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  VOL1     Volume bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
```

```
 NL             50
 NS             50
 ND        9+NPAR+NATT
 Up        VOLU     -IVOLU
 Origin    VOLU
 IO-Charac          3
              ---------- Description of the links  ----------
 --REP level=1  NCOPIES
     1       VOPO
 --REP level=1 -- End --
N+1        NDW
N+2        SCO
              ---------- Description of the status bits ----------
 1         Content  of the volume has been ordered by GSORD
 2         Content  of the volume has been developed by GGDVLP
 3         Volume   is convex
 4         User     routines GSNEAR or GSNEXT have been called
 5         Bit      used to exclude a volume from the search in the geometrical
                    tree.
              ---------- Description of the data words   ----------
 1         ISEARC   search flag (=0 vol. pos. order by GSNEXT/GSNEAR; <0 binary
                    searc
 2         ISHAPE   system shape number
 3         NIN      number of volumes imbedded in the mother volume. If it is
                    negativ
 4         NMED     medium number for the volume
 5         NPAR     number of shape parameters
 6         NATT     number of drawing attributes
 --REP level=1  NPAR
     6       PAR      array of shape parameters
 --REP level=1 -- End --
 --REP level=1  NATT
   6+NPAR   IAT      array of drawing attributes
 --REP level=1 -- End --
```

VOPO Volume bank

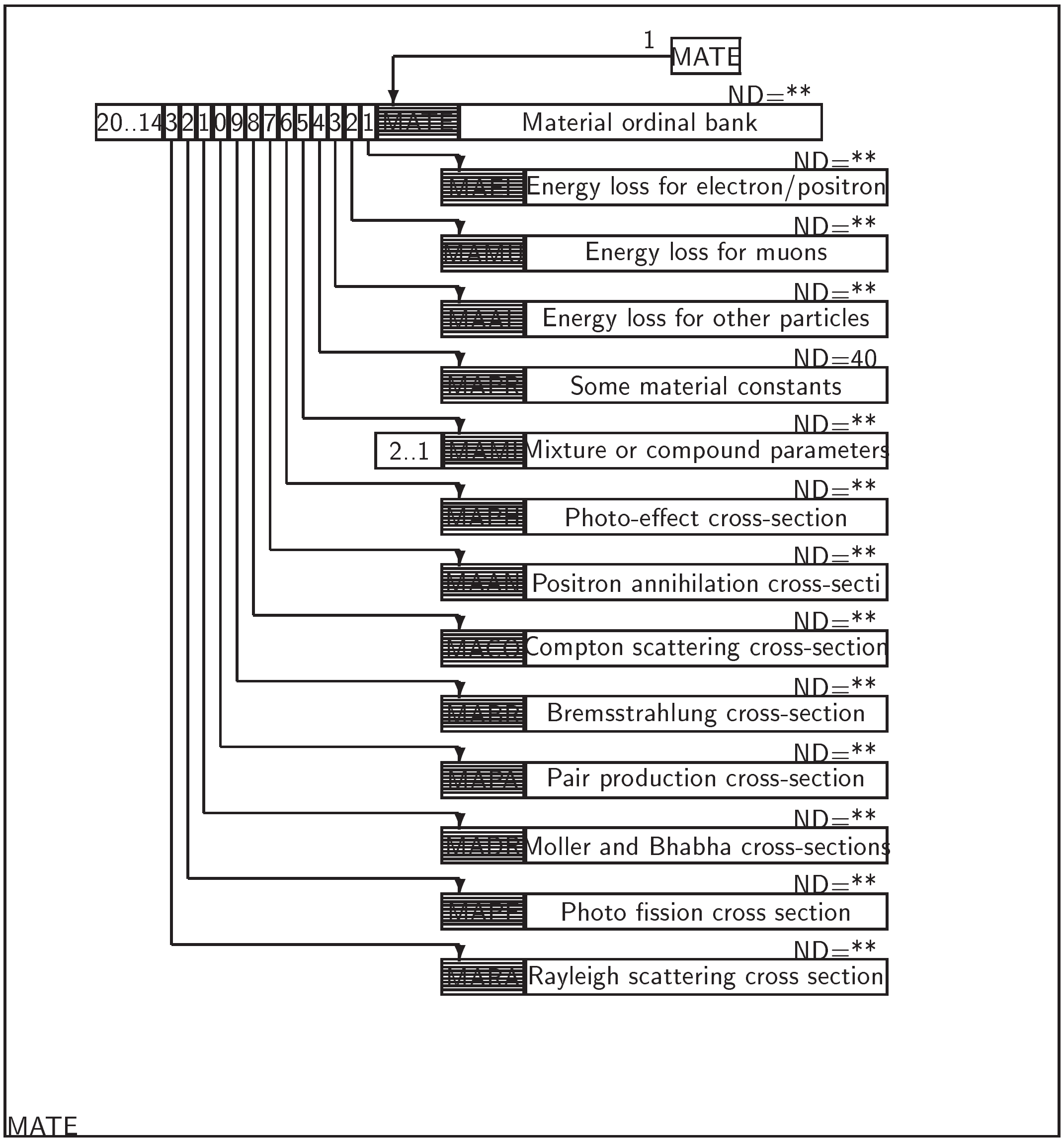
```
 ---------------------------------------------- entered file at  1-Aug-97 14: 0
 Bank IDH  VOPO     Volume bank
 NumericId 100*IVO+ICOPY
 Author             : GEANT
 Version            1.0
 Store     IXSTOR
 Division  IXCONS
 NL             1
 NS             1
 ND             8
 Up        VOL1     -ICOPY
```

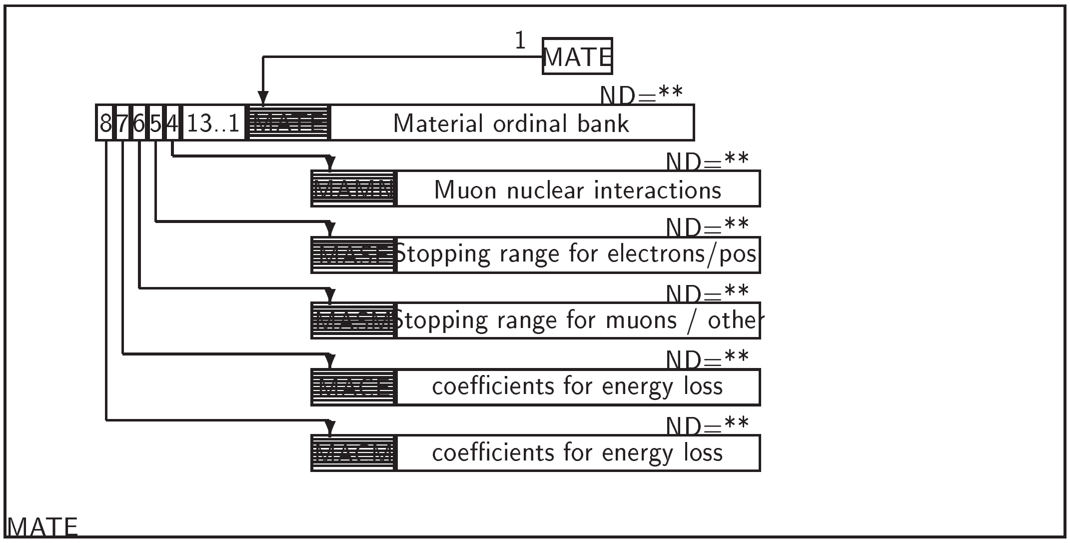
```
Origin    VOL1
IO-Charac          3
             ---------- Description of the data words   ----------
1         NENTRY
2         VOLUME   NUMBER
3         USER     NUMBER
4         IROT
5         X
6         Y
7         Z
8         ONLY
```



MATE Material top bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MATE     Material top bank
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL        NMATE    {No. of materials}
NS        NMATE
Up        DTSR     -4
Origin    DTSR
IO-Charac          3
             ---------- Description of the links  ----------
--REP level=1  NMATE
    1       MATE
--REP level=1 -- End --
```


1
MATE
ND=**
20..14 3 2 1 0 9 8 7 6 5 4 3 2 1
Material ordinal bank
ND=**
Energy loss for electron/positron
ND=**
Energy loss for muons
ND=**
Energy loss for other particles
ND=40
Some material constants
ND=**
2..1
Mixture or compound parameters
ND=**
Photo-effect cross-section
ND=**
Positron annihilation cross-secti
ND=**
Compton scattering cross-section
ND=**
Bremsstrahlung cross-section
ND=**
Pair production cross-section
ND=**
Moller and Bhabha cross-sections
ND=**
Photo fission cross section
ND=**
Rayleigh scattering cross section
MATE


1
MATE
ND=**
8 7 6 5 4 13..1
Material ordinal bank
ND=**
Muon nuclear interactions
ND=**
Stopping range for electrons/pos
ND=**
Stopping range for muons / other
ND=**
coefficients for energy loss
ND=**
coefficients for energy loss
MATE

MATE Material ordinal bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MATE     Material ordinal bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
NL              20
NS              20
ND        11+NWBUF
Up        MATE     -IMATE
Origin    MATE
IO-Charac          5H -F
             ---------- Description of the links  ----------
1         MAEL     Energy loss for electron/positron
2         MAMU     Energy loss for muons
3         MAAL     Energy loss for other particles
4         MAPR     Some material constants
5         MAMI     Mixture or compound parameters
6         MAPH     Photo-effect cross-section
7         MAAN     Positron annihilation cross-section
8         MACO     Compton scattering cross-section
9         MABR     Bremsstrahlung cross-section
10        MAPA     Pair production cross-section
11        MADR     Moller and Bhabha cross-sections
12        MAPF     Photo fission cross section
13        MARA     Rayleigh scattering cross section and atomic form factor
14        MAMN     Muon nuclear interactions
15        MASE     Stopping range for electrons/positrons
16        MASM     Stopping range for muons / other particles
17        MACE     coefficients for energy loss
18        MACM     coefficients for energy loss
             ---------- Description of the data words   ----------
--REP level=1         5
1         Material name
--REP level=1 -- End --
6         A
7         Z
8         DENS
9         RADL
10        ABSL
11        1.
--REP level=1  NWBUF
    12      UBUF
--REP level=1 -- End --
```

MAEL Energy loss for electron/positron

```
------------------------------------------------ entered file at  1-Aug-97 14: 0
Bank IDH  MAEL     Energy loss for electron/positron
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -1
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1       Energy   loss for electron/positron
--REP level=1 -- End --
```

MAMU Energy loss for muons

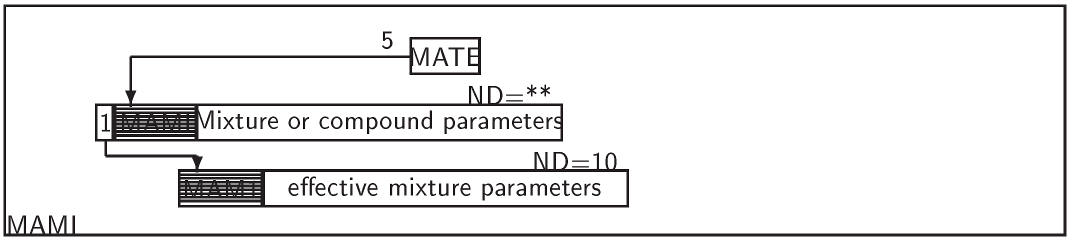
```
------------------------------------------------ entered file at  1-Aug-97 14: 0
Bank IDH  MAMU     Energy loss for muons
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        NEK1
Up        MATE     -2
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  NEK1
    1
--REP level=1 -- End --
```

MAAL Energy loss for other particles

```
------------------------------------------------ entered file at  1-Aug-97 14: 0
Bank IDH  MAAL     Energy loss for other particles
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        NEK1
Up        MATE     -3
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  NEK1
    1
--REP level=1 -- End --
```

MAPR Some material constants

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAPR     Some material constants
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND              40
Up        MATE     -4
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1        40
1
--REP level=1 -- End --
```



MAMI Mixture or compound parameters

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAMI     Mixture or compound parameters
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
NL               2
NS               2
ND        4*NLM
Up        MATE     -5
Origin    MATE
IO-Charac          3
             ---------- Description of the links  ----------
1         MAM1
             ---------- Description of the data words   ----------
--REP level=1  NLM
    1       1/X0
--REP level=1 -- End --
--REP level=1  NLM
    2       WMIX
--REP level=1 -- End --
```

```
--REP level=1  NLM
    3       Z
--REP level=1 -- End --
--REP level=1  NLM
    4       A
--REP level=1 -- End --
```

MAM1 effective mixture parameters

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAM1     effective mixture parameters
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND              10
Up        MAMI     -1
Origin    MAMI
IO-Charac          3
             ---------- Description of the data words   ----------
2         AEFF/AMO
3         ZEFF/ZMO
```

MAPH Photo-effect cross-section

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAPH     Photo-effect cross-section
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        NEK1
Up        MATE     -6
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  NEK1
    1
--REP level=1 -- End --
```

MAAN Positron annihilation cross-section

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAAN     Positron annihilation cross-section
Author             : GEANT
Version            1.0
```

```
Store     IXSTOR
Division  IXCONS
ND        NEK1
Up        MATE     -7
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  NEK1
    1
--REP level=1 -- End --
```

MACO Compton scattering cross-section

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MACO     Compton scattering cross-section
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        NEK1
Up        MATE     -8
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  NEK1
    1
--REP level=1 -- End --
```

MABR Bremsstrahlung cross-section

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MABR     Bremsstrahlung cross-section
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -9
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1
--REP level=1 -- End --
```

MAPA Pair production cross-section

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAPA     Pair production cross-section
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -10
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1
--REP level=1 -- End --
```

MADR Moller and Bhabha cross-sections

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MADR     Moller and Bhabha cross-sections
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        3*NEK1
Up        MATE     -11
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  3*NEK1
    1
--REP level=1 -- End --
```

MAPF Photo fission cross section

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAPF     Photo fission cross section
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -12
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1
--REP level=1 -- End --
```

MARA Rayleigh scattering cross section and atomic form factors

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MARA     Rayleigh scattering cross section and atomic form factors
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -13
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1
--REP level=1 -- End --
```

MAMN Muon nuclear interactions

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MAMN     Muon nuclear interactions
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -14
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1
--REP level=1 -- End --
```

MASE Stopping range for electrons/positrons

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MASE     Stopping range for electrons/positrons
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -15
Origin    MATE
IO-Charac          3
```

```
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1
--REP level=1 -- End --
```

MASM Stopping range for muons / other particles

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MASM     Stopping range for muons / other particles
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*NEK1
Up        MATE     -16
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  2*NEK1
    1
--REP level=1 -- End --
```

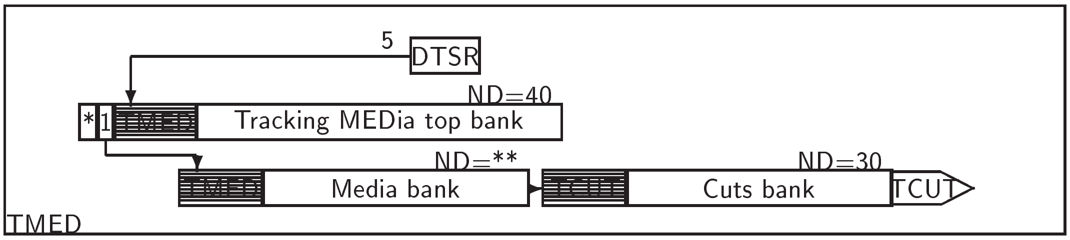
MACE coefficients for energy loss

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MACE     coefficients for energy loss
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        6*NEK1
Up        MATE     -17
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  6*NEK1
    1
--REP level=1 -- End --
```

MACM coefficients for energy loss

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  MACM     coefficients for energy loss
Author             : GEANT
Version            1.0
Store     IXSTOR
```

```
Division  IXCONS
ND        6*NEK1
Up        MATE     -18
Origin    MATE
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  6*NEK1
    1
--REP level=1 -- End --
```



TMED Tracking MEDia top bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TMED     Tracking MEDia top bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
NL        NTMED    {No. of medias}
NS        NTMED
ND              40
Up        DTSR     -5
Origin    DTSR
IO-Charac          3
             ---------- Description of the links  ----------
--REP level=1  NTMED
    1       TMED
--REP level=1 -- End --
             ---------- Description of the data words   ----------
1         CUTGAM
2         CUTELE
3         CUTNEU
4         CUTHAD
5         CUTMUO
6         BCUTE
7         BCUTM
8         DCUTE
9         DCUTM
10        PPCUTM
11        IPAIR
12        ICOMP
```

```
13        IPHOT
14        IPFIS
15        IDRAY
16        IANNI
17        IBREM
18        IHADR
19        IMUNU
20        IDCAY
21        ILOSS
22        IMULS
23        IRAYL
24
25
26
27
28
29
30
31        ILABS
32        ISYNC
33        ISTRA
34
35
36
37
38
39
40
```

TMED Media bank

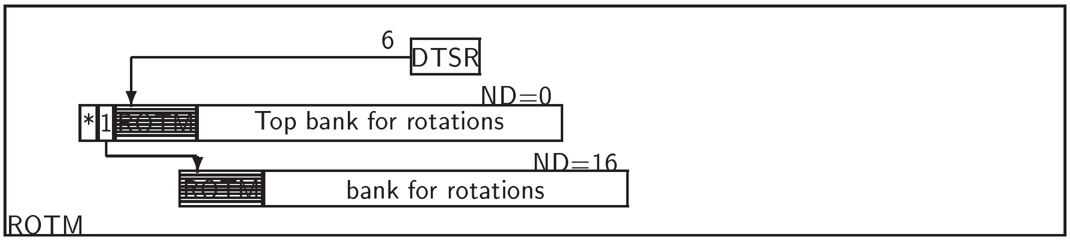
```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TMED     Media bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
NL              10
NS              10
ND        14+NWBUF
Next      TCUT
Up        TMED     -ITMED
Origin    TMED
IO-Charac          5H -F
             ---------- Description of the data words   ----------
--REP level=1          5
1         MEDIA    NAME
--REP level=1 -- End --
```

```
6         NMAT
7         ISVOL
8         IFIELD
9         FIELDM
10        TMAXFD
11        SM
12        DE
13        EPS
14        ST
--REP level=1  NWBUF
    15      UBUF
--REP level=1 -- End --
```

TCUT Cuts bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  TCUT     Cuts bank
NumericId ITMED
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND              30
Up        TMED     -ITMED
Origin    TMED
IO-Charac          3
             ---------- Description of the data words   ----------
1         CUTGAM
2         CUTELE
3         CUTNEU
4         CUTHAD
5         CUTMUO
6         BCUTE
7         BCUTM
8         DCUTE
9         DCUTM
10        PPCUTM
11        PAIR
12        COMP
13        PHOT
14        PFIS
15        DRAY
16        ANNI
17        BREM
18        HADR
19        MUNU
20        DCAY
21        LOSS
```

```
22        MULS
23        RAYL
26        GHCOR1
27        GHCOR2
28        GHCOR3
29        GHCOR4
27        BIRK1
28        BIRK2
29        BIRK3
30
31        ILABS
32        ISYNC
33        ISTRA
34
35
36
37
38
39
40
```

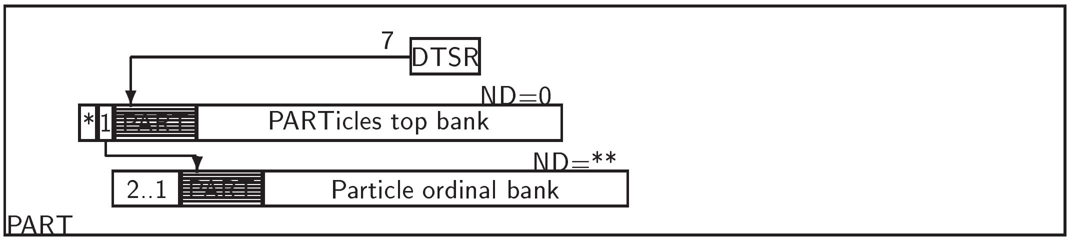


ROTM Top bank for rotations

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  ROTM     Top bank for rotations
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
NL        NROTM
NS        NROTM
Up        DTSR     -6
Origin    DTSR
IO-Charac          3
             ---------- Description of the links  ----------
--REP level=1  NROTM
    1       ROTM
--REP level=1 -- End --
```

ROTM bank for rotations

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  ROTM     bank for rotations
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND              16
Up        ROTM     -IROTM
Origin    ROTM
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1         9
1         GROTM
--REP level=1 -- End --
10        IP1      + 10*IP2 + 100*IP3
11        THETA1
12        PHI1
13        THETA2
14        PHI2
15        THETA3
16        PHI3
```



PART PARTicles top bank

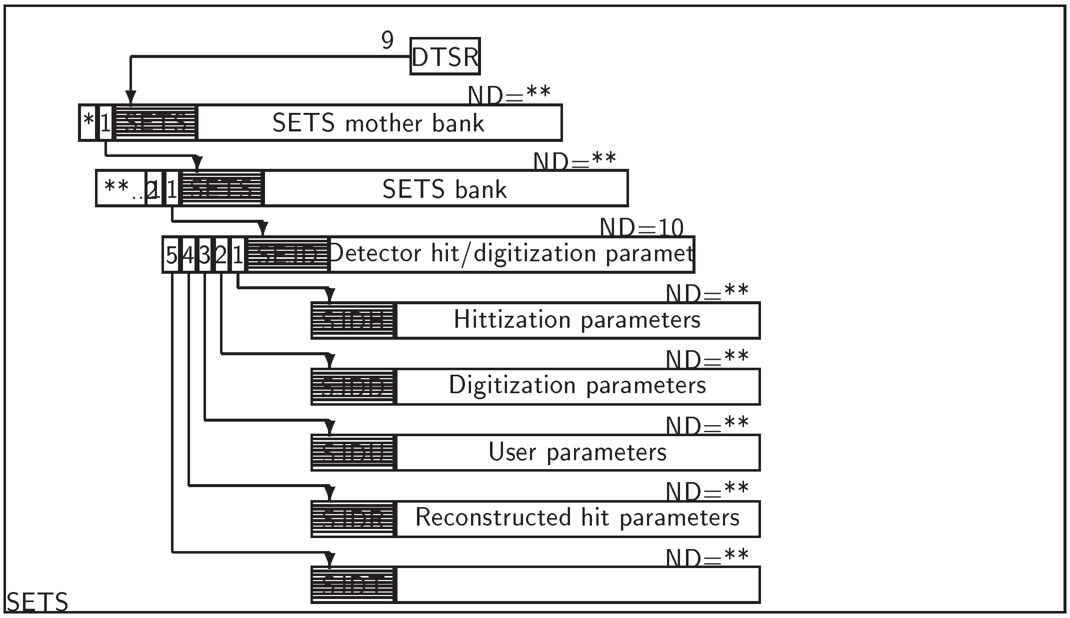
```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  PART     PARTicles top bank
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL        NPART    {No. of particles}
NS        NPART
Up        DTSR     -7
Origin    DTSR
IO-Charac          3
             ---------- Description of the links  ----------
--REP level=1  NPART
    1       PART
--REP level=1 -- End --
```

PART Particle ordinal bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  PART     Particle ordinal bank
NumericId KF       JESTET particle code
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
NL               2
NS               2
ND        NWBUF+9
Up        PART     -IPART
Origin    PART
IO-Charac          5H -F
             ---------- Description of the data words   ----------
--REP level=1         5
1         Particle Name
--REP level=1 -- End --
6         ITRTYP
7         AMASS
8         CHARGE
9         TLIFE
--REP level=1  NWBUF
    10      UBUF
--REP level=1 -- End --
```

SCAN Scan bank

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SCAN     Scan bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
Up        DTSR     -8
Origin    DTSR
IO-Charac          2
```



SETS SETS mother bank

```
----------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SETS     SETS mother bank
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONST
NL        NSET
NS        NSET
ND        NSET
Up        DTSR     -9
Origin    DTSR
IO-Charac          5
             ---------- Description of the links  ----------
--REP level=1  NSET
    1       SETS
--REP level=1 -- End --
             ---------- Description of the data words   ----------
--REP level=1  NSET
    1       SET      name
--REP level=1 -- End --
```

SETS SETS bank

```
----------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SETS     SETS bank
Author             : GEANT
Version            1.0
```

```
Store     IXSTOR
Division  IXCONST
NL        NDET
NS        NDET
ND        NDET
Up        SETS     -ISET
Origin    SETS
IO-Charac          5
             ---------- Description of the links  ----------
--REP level=1  NDET
    1       SEJD
--REP level=1 -- End --
             ---------- Description of the data words   ----------
--REP level=1  NDET
    1       DET      name
--REP level=1 -- End --
```

SEJD Detector hit/digitization parameters

```
----------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SEJD     Detector hit/digitization parameters
NumericId 10*ISET+IDET
Author             : Y.Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL               5
NS               5
ND              10 + 2*NV
Up        SETS     -ISET
Origin    SETS
IO-Charac          10I / 1H 1I
             ---------- Description of the links  ----------
1         SJDH     hit parameters
2         SJDD     digitization parameters
3         SJDU     user parameters
4         SJDR     reconstructed hit parameters
5         SJDT     trigger primitives parameters
             ---------- Description of the data words   ----------
1         NW       Total number of words to store packed volumes
2         NV       Number of volumes in the list
3         NwH      Number of words required per simulated hit
4         NwR      Number of words required per reconstructed hit
5         NwD      Number of words required per digit/trigger primitives
                   (16bits)
6         ND       Number of different digit types/trigger primitives (16bits)
7         NWHI     Number of words allocated for simulated hit
8         NWDI     -"- digitization/ the same for trigger primitives
```

```
9         NSOL     Number of paths through the JVOLUM tree for DETV otherwise 0
10        For      an alias only, IDET of main detector
--REP level=1  NV
    11      name     of volume
    12      number   of bits/volume
--REP level=1 -- End --
--REP level=1  NSOL*NLEVs
   JD+2*NV+1LINAM(N)
   JD+2*NV+1LIMUL(N) / NLEV for N = 1
--REP level=1 -- End --
```

SJDH Hittization parameters

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SJDH     Hittization parameters
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        4*NH
Up        SEJD     -1
Origin    SEJD
IO-Charac          /1H 1I 2F
             ---------- Description of the data words   ----------
--REP level=1  NH
    1       NAMH
    2       NBIT     = 0 )
    3       ORIG     = 0 ) dummy
    4       FACT     = 1 )
--REP level=1 -- End --
```

SJDD Digitization parameters

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SJDD     Digitization parameters
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        2*ND
Up        SEJD     -2
Origin    SEJD
IO-Charac          / 1H 1I
             ---------- Description of the data words   ----------
--REP level=1  ND
    1       NAME
    2       NBITS
--REP level=1 -- End --
```

SJDU User parameters

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SJDU     User parameters
Author             : GEANT
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        NUPAR
Up        SEJD     -3
Origin    SEJD
IO-Charac          3
             ---------- Description of the data words   ----------
--REP level=1  NUPAR
    1       UPAR
--REP level=1 -- End --
```

SJDR Reconstructed hit parameters

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  SJDR     Reconstructed hit parameters
Author             : Y.Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND        NH
Up        SEJD     -4
Origin    SEJD
IO-Charac          5
             ---------- Description of the data words   ----------
--REP level=1  NH
    1       NAMESH
--REP level=1 -- End --


SJDT/SEJD No doc
```

FLDM magnetic FieLD Map

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  FLDM     magnetic FieLD Map
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
ND               6 + 2*NR*NZ
```

```
Up        DTSR     -10
Origin    DTSR
IO-Charac          3
             ---------- Description of the data words   ----------
1         NR       (float)
2         NZ       (float)
3         DRHO
4         DZ
5         RHOMAX
6         ZMAX
--REP level=1  2*NR*NZ
    7       B$_{\rho and B$_Z$
--REP level=1 -- End --
```

DTSR Top level bank for DeTector constant StRucture

```
---------------------------------------------- entered file at  1-Aug-97 14: 0
Bank IDH  DTSR     Top level bank for DeTector constant StRucture
Author             : Yuri Fisyak
Version            1.0
Store     IXSTOR
Division  IXCONS
NL              10
NS              10
ND               2
Next      DTSR
Up        MAST     -2
Origin    MAST
IO-Charac          2
             ---------- Description of the links  ----------
1         RUNG     Run parameters
2         DSET     Detector Set
3         VOLU     GEANT constants
4         MATE     -"-
5         TMED     -"-
6         ROTM     -"-
7         PART     -"-
8         SCAN     -"-
9         SETS     -"-
10        FLDM     FieLD Map
             ---------- Description of the data words   ----------
1         Min.     time validity
2         Max.     time validity
```

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