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
...
```

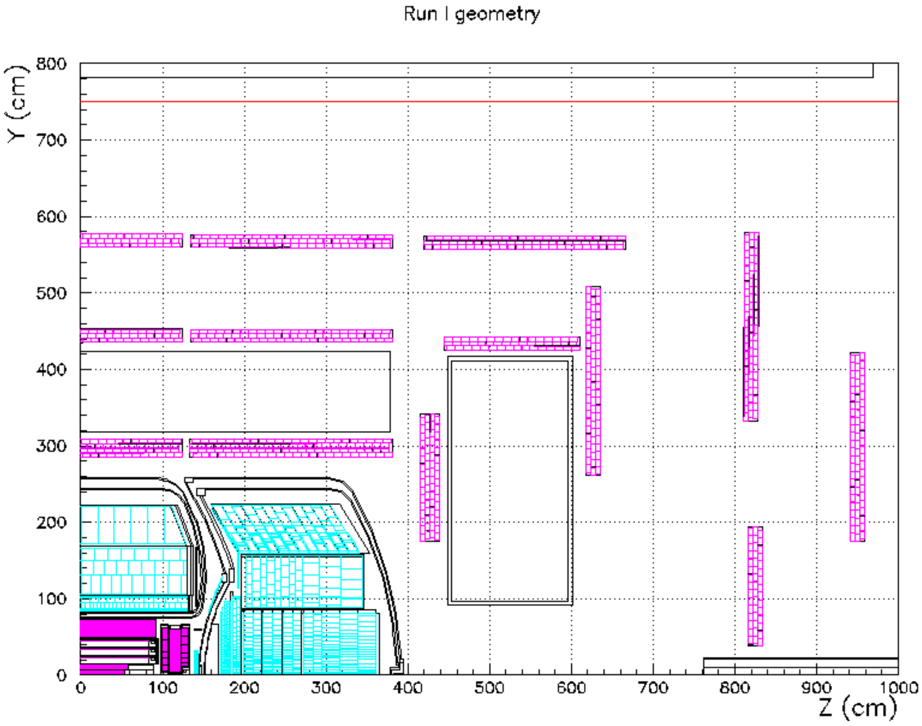

Figure 3.1: The DØ detector GEANT description for Run I.

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
```

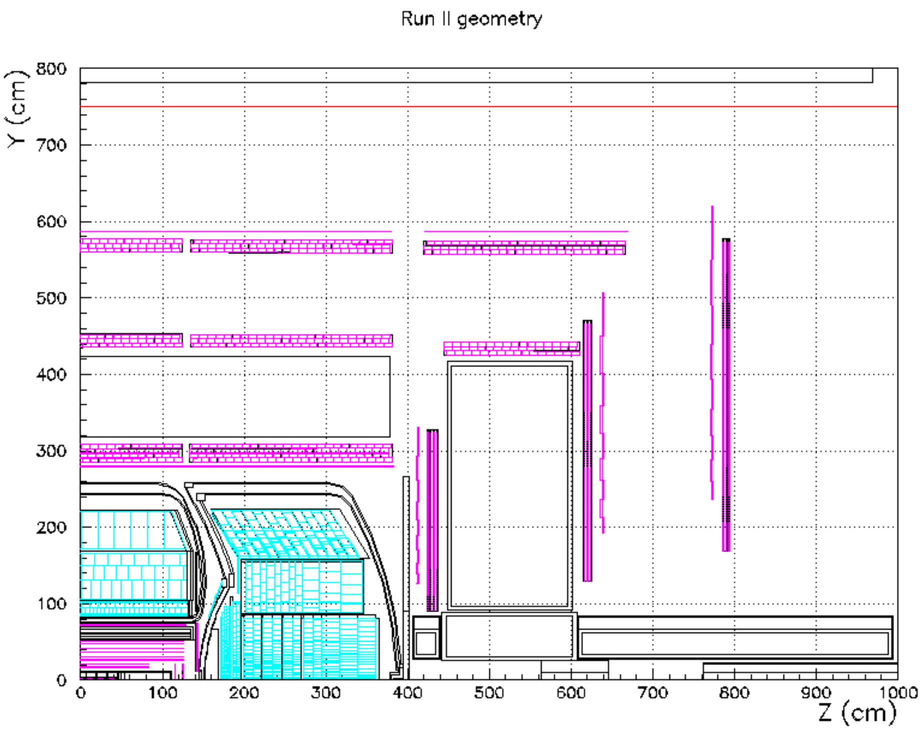

Figure 3.2: The DØ detector GEANT description for Run II.

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
        ...
```

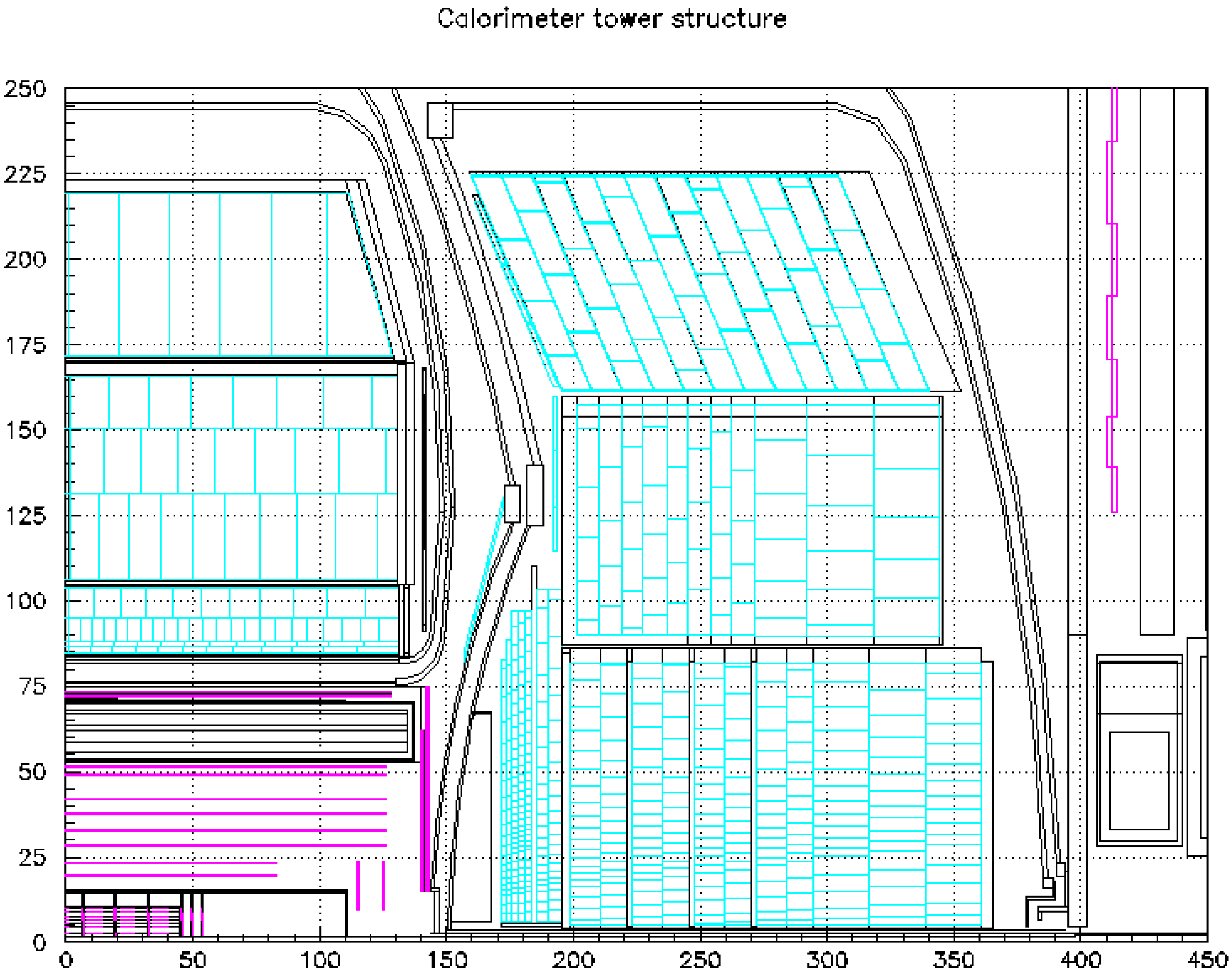

Figure 3.3: The DØ calorimeter tower structure.

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:

```
*DO  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:

```
*DO  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:

```
*DO  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:

```
*D0  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:

```
*D0  GEAN   0 -U -A4CW -c1/80     #. D0 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.