D0 Upgrade meeting

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Upgrade to Upgrade GEANT

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Outline

- GEANT based simulation framework for D0 Upgrade
  - CMS framework;
  - **D0geom**: definition of geometry, magnetic field and detector constants via TZ — GEANT Constant Definition Language;
  - **D0gen/ D0kin** : kinematics via Ntuples;
  - **D0sim**: tracking and hits, access to hits via GEANT structures;
  - **D0raw**: pile-up, noise, digitization;
  - **D0reco**: reconstructed hits;
  - Status of Upgrade D0 GEANT geometry in this scheme; Work to do ...
- Preliminary results on muon track reconstruction.
- Neutron background in the new scheme, comparison with previous calculations.

1 GEANT based simulation framework for D0 Upgrade

1.1 CMS framework

The CMS collaboration has accepted CMSim100 as the framework, based on standard CERN packages (GEANT 3 and ZEBRA), for the period of preparation of its Technical Design Reports (1996-1998). Herein I refer to this scheme as D0sim. It has the following features:

- The scheme contains a set of modules[1]:
  - D0geom — geometry description and constants;
  - D0gen, D0kin — kinematics;
  - D0sim — tracking;
  - D0raw — digitization;
  - D0rec — reconstruction; and
  - D0ana — analysis.
- The geometry, materials, rotations matrices, magnetic field, etc. are specified in the database (= GEANT rz-file) which uses as input title data cards which are read by the TZ (ZEBRA Titles) package. The result of this is an **RZ-file** which can be read for simulation or reconstruction.
- All communication among modules is done with ZEBRA structures, all of which are the structures available within GEANT.
- The interaction of the modules with each other is defined by FFREAD-control cards.
- The main ideas of this approach are
  - to simplify the interface with GEANT; and
  - to avoid doubling the constants information used for simulation and reconstruction.

[1] I replaced CM to D0 to make it more attractive.

1.2 D0geom

Geometry, materials, detector constants, magnetic field map are kept as formated text files of 80-column card-images (titles data cards) in the format of so-called **"GEANT Constant Definition language"** as ZEBRA Titles banks (TZ-banks).

D0GEOM interprets these TZ-banks and creates the GEANT description of the detector. In these titles is defined the detector structure.

The organization of work with the geometry, material and tracking media constants 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 element definitions 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 definitions include information to allow for **version selection**.

4. There is a **set of standard rotation matrices** defined by the ROT-M title bank with a 4-character keyword for each matrix. A standard rotation matrix is accessed by using this keyword. This set includes as **"NEXT" for any additional rotation matrix**. Access to the last-created rotation matrix is performed via keyword **"LAST"**. For additional rotation matrices an identifier number is given incremented by one from the largest number so far.

5. Material and tracking media are always refered to by their **names**.

1.2.1 TZ-banks

The tz-bank is presented as a formated text file of 80-column card-images, giving the titles one after the other. Normal mode is **"free-field format"** where the data are read line-by-line and the text interpreted. Each title bank starts with the **"title header line"** *DO ... A title-header line format is the following:

```
*DO  <idh>  <idn>  [-<opt><option text>] [#.comment]
where:
*DO     in cols 1-4 marks the header line;
<idh>   is the 4 character Hollerith bank ID;
<idn>   is the numeric bank ID, integer, if any;
<opt>   is a single optional letter;
<optx>  is optional text, if needed.
```

"idn" is used to identify the title bank version. The example presented below shows the description of the D0 detector as a box (where is defined the name of the volume, name of the mother volume, blank means no mother volume, name of the tracking medium [here it is air]). The symbols "#." mean start of comment which terminates by end of line or another of the same symbol.

```
*DO  GEAN   0 -U -A4CW -c1/80     #. D0 Main Detector volumes
 :D0      #. key volume name
 :volu  :D0    :BOX   "Air"     3  750.00     750.00    1000.00
 :mkpo             #. MaKe POlycone for  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
 :mkpo
 :VACP  :BEAM  "Vacuum"       -.5 3.     398.00  0.00       1.90
                                         398.00  0.00       2.5781
                                         645.16  0.00       2.5781
   ...
```

1.2.2 Hierarchy of keywords and geometry tree

Valid keywords to define the geometry (see GEOM data card description) and their hierarchy are defined through the title block **"SETU"**. The currently used version is shown below:

```
*DO  SETU   0 -u -A4CW -c1/80  #. SETUp selection keys
#. level
#.    0         1         2          3
#.   Genetic Detector type & No. of element in the given level
       #. central tracking    Idtype
:D0 1 4 :TRAK 10000 10 :SVTX 11100 0 #.Silicon
                       :SCFT 12100 0 #.fiber tracker
                       :DPRE 13100 0 #.Central preshower & magnet
                       :DFPS 13200 0 #. Forward preshower
                       :DLUM 14000 0 #.luminosity counter
                       :DVTX 15000 0 #.(Run 1) vertex drift chamber
                       :DCDC 16000 0 #.(Run 1) central drift chamber
                       :DFDC 17000 0 #.(Run 1) forward drift chamber
                       :DTRD 18000 0 #.(Run 1) TRD
                       :DATR 19000 0 #.? (obsolete)
       #. Calorimeters
        :CALO  20000 3 :CC   20100 3 #. Central calorimeter
                                    :UCEM  21100 0
                                    :UCFH  22100 0
                                    :UCCH  23100 0
                       :EC   20200 6 #. Endcap calorimeter
                                    :ECEM  21200 0
                                    :ECFH  22200 0
                                    :ECCH  23200 0
                                    :MFH   24200 0
                                    :MCH   25200 0
                                    :OCH   26200 0
                       :DICD 21000 0 #. Intercryostat detectors
       #. Muon system
        :MUON  30000 2 :MB   30100 3 #. Central muon system
                                    :MBPD 31100 0 #.drift planes
                                    :MBSC 32100 0 #.scintillator
                                    :DMUO 33100 0 #.Wamus (Run 1)
                       :MF   30200 3 #.Forward muon system
                                    :MFPD 31200 0 #.drift planes
                                    :MFPX 32200 0 #.scintillator
                                    :DSAM 33200 0 #.Samus (Run 1)
        :DTBM  40000 0 #. testbeam geometry
```

1.2.3 Program flow control cards

The program flow control cards refering to the above detector setup are listed below:

```
GEOM  'KEY1' N1   'KEY2'  N2      ...  (Detector geometry)
SETS  'KEY1' N1   'KEY2'  N2      ...  ((De)Activating detector)
DRAW  'KEY1' N1   'KEY2'  N2      ...  (drawing    )

HITS  'KEY1' N1   'KEY2'  N2      ...  (Hits)
PILE  'KEY1' N1   'KEY2'  N2      ...  (Pile-up == coherent noise)
NOIS  'KEY1' N1   'KEY2'  N2      ...  (Incoherent noise)
DIGI  'KEY1' N1   'KEY2'  N2      ...  (Digitization)
TRGP  'KEY1' N1   'KEY2'  N2      ...  (Trigger primitives)
RHIT  'KEY1' N1   'KEY2'  N2      ...  (Hit reconstruction)
RECO  'KEY1' N1   'KEY2'  N2      ...  (Reconstruction)

DBUG  'KEY1' N1   'KEY2'  N2      ...  (Debug level)
HBOOK 'KEY1' N1   'KEY2'  N2      ...  (histogram and Ntuples)
```

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 request.

Keywords in the above list are normally *subdetector* volume names. The value associated with the keyword is propagated to all lower levels and after that for all options except 'GEOM' the value for the keyword is set equal to the maximum value in the branch defined by this 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). 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  ' 0 'MUON' 3 'CALO' 1
```

switches off all detectors except the muon system and calorimeter which for the latter is taken the average (dead) version.

1.2.4 Magnetic field

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) :

```
*DO  FLDM  -IF -E9508        #. Internal solenoid 2D-field map
   #. NR, NZ, DR, DZ, Rmin, Rmax , Zmin, Zmax, B_rho(NR*NZ),*B_z(NR*NZ
      50. 95. 2.0 2.0   0.0 100.0    0.0 190.0
#. B_r
       3*  0.000       8* -0.001       7* -0.002
...
#. B_z
 -19.973 -19.973 -19.974 -19.975 -19.976 -19.977 ...
```

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.   #.     d0map_sol.dat   -field. nx, ny, nz
    0.   70.  100.  120.  170.  220.  270.  310.  320.  330.  #. entx
...
 #. Bx
    1159*  0.000   0.001   0.001  -0.003         ...
 #. By
    1152*  0.000       7*  0.001   0.000   0.000 ...
 #. Bz
       9*  0.000  -0.057       6*  0.000  -0.064 ...
*DO  TORD  -IF -E110699      #. Toroid 3D-field map
             24.  48.  32.   #.     d0map_tor.dat   -field. nx, ny, nz
    0.   70.  100.  120.  170.  220.  270.  310.  320.  330.  #. entx
...
 #. Bx
  -0.022  -0.017  -0.013  -0.013  -0.007   0.006 ...
 #. By
   0.000  -0.015  -0.019  -0.022  -0.025  -0.022 ...
 #. Bz
   0.000      3*  0.001   0.002   0.001   0.001 ...
```

The ZEBRA-banks with these tables are kept along with other GEANT initialization structures and can be written to and read in from a standard GEANT RZ-file.

1.2.5 Materials and media definitions

The material is defined via the following procedure:

1. Use only external definitions via TZ title banks (GMAT and GMIX) for all materials.

2. Refer to by name (character string) and not by number.

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
```

A material with density ≤ 0 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
        ...
```

via pure materials and other mixtures. A negative fraction indicates that the fraction is by volume, otherwise the fraction is by weight. Some examples of mixture definitions are shown below:

```
*DO  GMIX   1    -A4CW -c1/50      #.          GMIX
  #.list of mixtures#
"Boron"                   2   2.34  #. comp.no.              dens     GMIX
          "Bor 10"            -.20  #. Volume (-) or Weight  (+) frac GMIX
          "Bor 11"            -.80  #. Volume (-) or Weight  (+) frac GMIX
"B_2 O_3"                 2   2.34  #. comp.no.              dens     GMIX
          "Boron"            -2.    #. Volume (-) or Weight  (+) frac GMIX
          "Oxygen"           -3.    #. Volume (-) or Weight  (+) frac GMIX
"Borated Polyethyl."      3   1.09  #. comp.no.              dens     GMIX
          "Polyethylene"      -.853 #. Volume (-) or Weight  (+) frac GMIX
          "Water"             -.108 #. Volume (-) or Weight  (+) frac GMIX
          "B_2 O_3"           -.039 #. Volume (-) or Weight  (+) frac GMIX


...
```

1.2.6 Tracking media

By default all the tracking medium parameters 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 the chosen media by using **"TMED"** title banks or keywords defined as in the example below:

```
*DO  TMED   1  -A4CW -c1/80      #. Media parameters
"Liquid Argon" 1 1  20.0  90.0   1.0   1.0    0.5E-1  0.2
```

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

```
*DO  MEDI   0 -U -A4CW -c1/80      #. Media flags
#. Media flag =  xy, where x = 0 calorimeter type media ILOSS = 2
#.                             = 1 track type media       ILOSS = 1
#.                y  = 1 for sensitive media
#.                y  = 0 for nonsensitive (default) media
 "Liquid Argon"          1
 "Silicon"              11
...
*DO  SENS   1  -A4CW -c1/80      #. Sensitive media
 "Scitil.PS"
 "EC EM1"
```

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
"Tungsten for SAMUS"       :CUTGAM    0.20
...
```

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, **"Liquid Argon"** and ITM is the corresponding internal GEANT medium number.

1.2.7 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 keyword and rotation parameters as defined for the input parameters for the routine GSROTM:

```
*DO  ROTM   0 -U -A4CW -C1/80  #.Title for D0 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)
: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)
...
```

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 yields a rotation matrix index IROTM of 0. The keyword **"NEXT"** reserves the next rotation matrix.

In the context of the **"GEAN"** style of defining parameters, the keyword **"ROTM"** followed by **"NEXT"** reserves the next rotation matrix and this will be used in subsequent **"POS"** or **"POSP"** requests which uses the keyword **"LAST"** for the last created rotation matrix.

1.2.8 GEANT geometry by TZ titles

D0geom offers a standard way of building subdetector GEANT geometries from TZ titles. This is performed by the routines DCGEAN which interpret the title blocks GEAN and make appropriate actions 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). The title block is selected if the requested action in GEOM data card for the subdetector keyword SDET matches with the numeric identifier of the block.

The following keywords can be used:

call	for calling specific detc 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)
hitr	for declaring standard reconstruction hit elements (gsdetr)
hits	for declaring standard hit elements (gsdeth)
medi	for declaring sensitive materials with special tracking media
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 constants which follow each keyword are the same as the call parameters required by the respective GEANT routine.

1.3 An example: geometry for the pixel detector

```
*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
```

1.3.1 Detector specific parameters

The standard GEANT geometry information and material parameters usually are not enough to describe the behaviour of the detector element. For example, to describe signals from PDT's it is needed to know the drift velocity, resolution and so on. Sometimes it is **possible** but **not reasonable** to do that. In order to store this information (UPAR(1:NUPAR) into the standard constant data GEANT structure and to retrieve it in D0sim 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 barrel detector:

```
....
#.
 :detu   :SVTX  :SBL*  15 #. No. of words
           0.010 #. Precise coordinate resolution
           0.100 #. Coarse  -"-
           50.   #. APPV   applied voltage
           40.   #. DEPV   depletion voltage
         1500.   #. VMUE   electron drift vel.
          600.   #. VMUH   hole drift vel.
         2.25E-2 #. VTEE   electron temp.
         3.75E-2 #. VTEH   hole temp.
         1350.   #. HME    electron hall mobility
          310.   #. HMH    hole hall mobility
            0.   #. SLOPE  noise slope
            3.   #. CAPIN  input capacitance
         1500.   #. PARAL  parallel strip noise
            2.   #. NNOIS  noisy strips to a cluster
            0.   #. NCORS  correlated strips
#.
...
```

1.3.2 HITS, Detector Sets and Detector elements

D0sim adopts the standard definition of detector elements which groups into detector sets. The detector set definitions for the given list of detector elements depend only on the convenience of their handling — activating and disactivating by the mechanism proposed above via the FFREAD control card **"SETS"**. Thus here we define detector sets corresponding to the subsystem hierarchy. A detector superset, for example for the whole muon system, is defined by an alliance of sets of base detector types (IDTYPE). The following structure of the detector types is used:

```
*
* ***  D0  Detector IDentifiers:
*
*      idtype = XYZUV
*               X  --  subsystem identifier:
*                      1 - track system, 2 - calorimeters, 3 - muon system
*                Y  -  detector type (technology)
*                      1/2/3   - Pixels/ Silicon / MSGC for tracker
*                      1/2/3   - E.M. calorimeter/Hadron/Forward for
*                                calorimeters
*                      1/2/1/2 - DTBX/RPC/CSC/PPC for muon barrel and endcap
*                 Z -  1/2/3   - for barrel/endcap/tail
*                  UV          - superlayer/sublayer number, user dependent
*
*Superset        set             subset          detector element
*TRAK = 10000 -> SVTX = 11000 -> SVTB = 11100 -> SBL1 = 11110
*                                             -> SBL2 = 11120
*                             -> SVTF = 11200 -> SDWL = 11210
*                SCFT = 12000 -> SCFT = 12100 -> SF** = 121**
*
...
```

(see above SETU title bank).

GEANT provides:

- a mechanism (routine GSDETV) of **unique identification** of the different detector elements of the same type;
- in HITS package **this identifier is stored** in the hit-bank together with identifier of track which produces this hit and 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.

1.4 Hit format for the tracker and muon system

Due to the similarity of the tracking and muon detectors in D0sim it is used the same detector elements and hit definitions. The common hit format of the GEANT hits (detector impact points) is defined in the title bank TKHT (TracK HiT):

```
*DO  TKHT  0    -c4/60  #.TracKer /Muon hit definition
     17                         #.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 :DIRX      1.0  1.E9    0   #.VECT(4) at volume entrance
  5 :DIRY      1.0  1.E9    0   #.VECT(5) at volume entrance
  6 :DIRZ      1.0  1.E9    0   #.VECT(6) at volume entrance
  7 :P         0.0  1.E6    0   #.VECT(7) at volume entrance
  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   #.(LCS)
 11 :Zin     250.0  1.E6    0   #.
 12 :XOUT    250.0  1.E6    0   #.(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
 17 :RADL      0.0  1.E6    0   #.Material transversed (in X0)
```

The **"HITS"** instructions which includes detector set and detector element names in the **"GEOM"** TZ-bank, for example for WAMUS PDT detector element and hit definition one can use

```
*DO  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
```

the case when this detector set is a member of a tracking detector superset (TRAK+MUON) will cause access to **"TKHT"** and its use for creating a hit format bank for this particular detector element.

The bank will be filled by the GEANT HITS package and hence the reference to the track in kinematics structure which caused the hit can be found by GEANT facilities. The reference to the sensitive volume parameters, such as rotation matrix and the detector user parameters, is provided by the GEANT system.

Using this common definition for GEANT hits (detector impact points) we have in the GUSTEP the same code for muon and tracker simulation. This allows also us to use the same code for track pattern recognitions.

The calorimeter hit definition is given by CAHT title bank:

```
*DO  CAHT   0    -c4/60  #.Calorimeter hit definition
      2                               #.No. of hit elements
   #. NAMESH  ORIG  FACT  NBITSH
  1 :ELSE      0.0  1.E5    0.        #.E.M.Energy deposited
  2 :ELSH      0.0  1.E5    0.        #.Energy deposited
```

1.5 D0gen

D0sim itself has some very simple event generation facilities (for example, single particle) but by default the **input** in the D0sim is defined as a **Column-Wise-Ntuple** which contains a dump of COMMON/HEPEVT/ (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 *
*****************************************************************
```

D0gen is an external procedure for D0sim. This allows to use any generators as input to D0sim and also provide easy control on the input. You can always check with PAW: What do you have as an input?

1.6 D0kin

D0kin creates **VERT**- and **KINE**-GEANT structures. The input event (COMMON/HEPEVT/) can be kept in VERT-structure as **VERU**-bank.

The FFREAD-card **KINE** defines the input kinematics. The particle kinematics is controlled via the FFREAD control card **"KINE"** as follows:

```
 Kinematics definition:
================================================================================
IKINE = 0 ==>  Events are input from file (Ntuples)
        PKINE(1)    = not used
        PKINE(2-3)  = Etamin-Etamax
        PKINE(4-5)  = Phimin-Phimax (deg)
        PKINE(6-7)  = Ptmin -Ptmax  (GeV)
        PKINE(8)    = 1. if copy of HEPEVT wanted in VERT user bank
================================================================================
IKINE = 1 ==> Single particle event
        PKINE(1)    = GEANT particle code
        PKINE(2-7)  = (as above)
================================================================================
IKINE = 2 ==> Simple MB event
        PKINE(1)   = (not used)
        PKINE(2-7) = (as above)
================================================================================
IKINE = 9 ==>  GUKINE calls user own taste generation USKINE
================================================================================
```

The Ntuple files are made by the D0 standard physics generation steering package D0gen which works in terms of the **"world standard" HEPEVT** common where particle kinematics are stored.

1.7 D0sim

D0sim performs GEANT tracking and create HITS-structure (control by **HITS** control card).

1.8 D0raw

1.8.1 Pile-up

The event mixing with minimum bias background events is performed at the level of hits. Physics events and MB events are run separately event by event through D0sim to produce HITS and intermediate files are output. The event mixing and pile-up are controlled by FF cards.

The number of mixed MB events per bunch are defined by the BEAM card and the number of bunches by the PILE card.

```
c     (Beam position and spread, luminosity, NMB, cross time &
section)
BEAM   X Y Z   dX dY dZ  Lum  NMB tau_B  sigma_T
PILE  'DET1'  IF1  'DET2' IF2
```

The luminosity is given in units of $10^{34}\mathrm{cm}^{-1}\mathrm{s}^{-1}$. The mean number of events per bunch is calculated from:

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

where L is the luminosity and τ_B is the bunch crossing interval. By default the actual number is generated from 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.

By PILE card one can define the number of bunches before and after the actual bunch. The flag `IFi` is defined as

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

where N_{bc} (N_{ac}) are number of bunches before (after) the actual collision. For example the card

```
PILE  'TRAK'  10 'MUON' 205
```

would imply 26 bunches to be piled up for MUON detectors (20 before, the actual one and 5 after) and only 2 (one before and the actual one) to be piled up for Silicon and Scintillator Fiber detectors.

The information on tracks responsible for the hits are 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 refreshed.

1.8.2 Noise

Procedure of adding uncorrelated noise to detector elements is controlled by FF-card

```
NOIS  'TRAK'  1  'D0  ' -1
```

1.8.3 Digitization – GUDIGI

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

```
DIGI  'TRAK'  1 'D0  ' 0
```

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

1.9 D0trg

The steering control for reconstruction of trigger primitives is given by the FFKEY card TRGP. For example the card

```
TRGP  'MUON'  1 'D0  ' 0
```

will enable reconstruction of trigger primitives only for the the muon system whereas.

1.10 D0rec

The steering control for reconstruction of hits primitives is given by the FFKEY card RHIT. For example the card

```
RHIT  'MUON'  1 'DO  ' 0
\par
The steering control for reconstruction tracks and calorimeters
clusters
 is given by the
FFKEY card RECO. For example the card
\begin{verbatim}
RECO  'MUON'  1 'DO  ' 0
```

1.11 D0ana

At this stage the analysis is concluded by filling histograms and Ntuples.

To avoid clashes between different subsystems in D0sim the following scheme is introduced for histogram subdirectories:

- Ntuples are created in the top level directory
- directory /GEANT — contains histogram related to GEANT processing of the events such as
  - time per event
  - 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 pseudorapidity, p_T-distribution, ...
- directory /USER — contains histogram for the user

A directory structure closely following the structure defined in the SET-UP title block (see section 1.2.2) is reproduced for the detector specific part. For example, the following subdirectories would be created:

- directory /TRAK — contains histogram for the Central tracker
- directory /CALO/CC — contains histogram for the barrel calorimeters
- directory /CALO/EC — ditto for the endcap calorimeters
- directory /MUON — ditto for the Muon system
- directory /TRIG — ditto for the trigger
- ...

1.12 Status of Upgrade D0 GEANT geometry in this scheme

This version of Upgrade GEANT is installed on FNALD0 and d0sgi:

`/exports/usr/people/fisyak/upg_geant/vd0/`

The present version keeps package as cmz- or Patchy car-files. Next release of CMsim will be done in CVS. This is a reason why I keep it as it is. The other reason is that for me it is not clear how we can use CVS with VMS.

The present geometry of the standard Upgrade GEANT is already done in the new scheme.

Because existing magnetic field map for toroids is calculated for their positions shifted towards IP by 10 cm in the presented version geometry it is used this **"uncorrect"** position. By the end of August R.Yamada has promised to provide a new magnetic field and these position have to be corrected.

It is need some work to install there the plate version of calorimeter geometry.

The hits are defined.

There is a question about digitization. The natural way is to use the same approach as for hits i.e. GEANT defined detector element identification and access to this detector element parameters via

```
GFPATH/GLVOLU/GFDETU.
```

This means rewriting of digitization part.

The same question exists about reconstructed hits.

How we can proceed with this stuff? Should we wait until somebody writes a C++ version reconstruction or do something now?

2 Preliminary results on the muon track reconstruction

This version of Upgrade GEANT has been used for muon track reconstruction. In the reconstruction it was used Kalman filter approach. For these calculation simulated hits have been smeared with $\sigma_x = 700\ \mu$m and $\sigma_z = 3$ mm for precise and coarse coordinates for WAMUS PDTs and $\sigma_x = 1.4$ mm for precise coordinate for the muon endcap Iarocci Tubes.

- Geometrical coverage.
- Track segment reconstruction efficiency.
- Momentum resolution for $p_T = 10$, 25 and 100 GeV/c;
- Momentum resolution versus eta.

It is needed some work for tuning of the fit procedure, especially track segment reconstruction.

3 Neutron background in the new scheme

This version has been used to process 1000 minimum bias (DTUJET-93) events to estimate the situation with backgrounds. For neutron transport in GEANT it has been used GCALOR.

This is just first look what is going on in new geometry but there are some disagreement which might be attribute the mentioned above position of the endcap toroids.