Visualization: Detector Geometry and Events (Event Display)

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ePIC software tutorial

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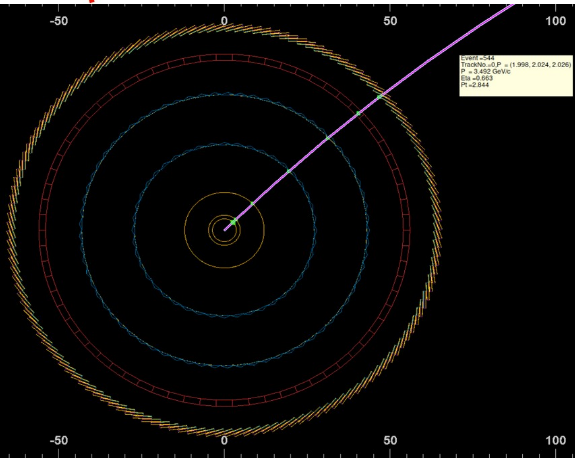
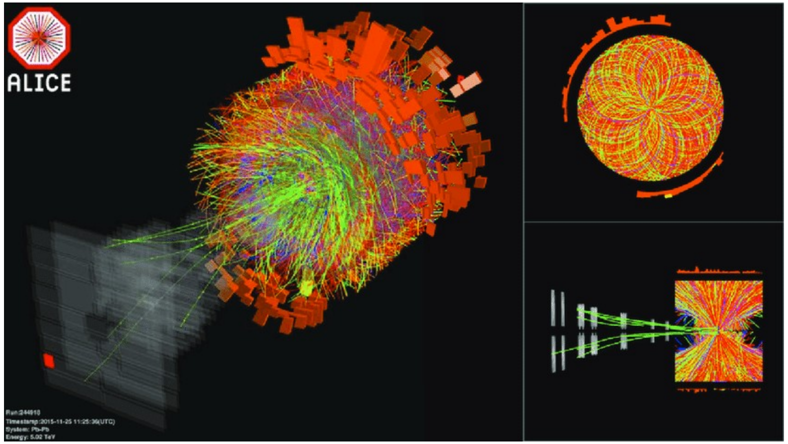
EPIC Event display



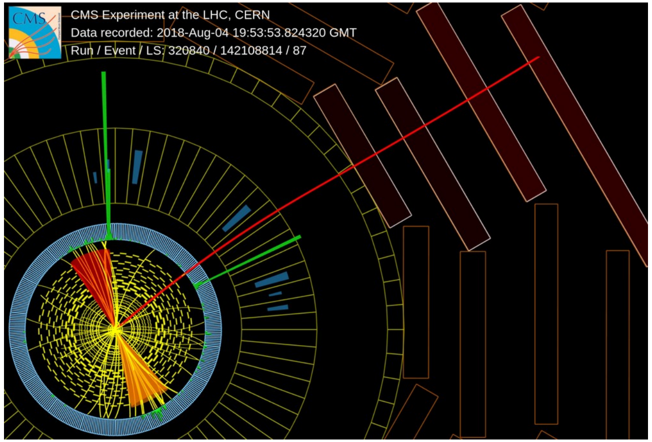
ALICE Event display

DOI: 10.1088/1742-6596/898/7/072008



CMS Event display

https://cms.cern/news/and-the-higgs-boson-said-let-there-be-light

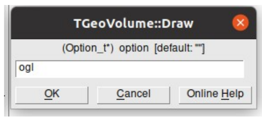


Visualization of Geometry

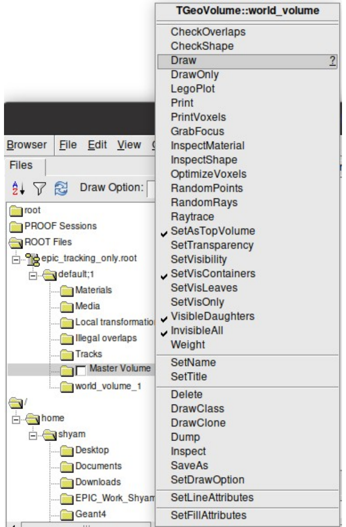
DD4HEP

(Detector Description for High Energy Physics)

- Detector Geometry: xml format (DD4HEP), gdml format, root format
- Geometry is handled by TGeoManager class in ROOT, gdml and root file can be visualized easily
- Convert xml (**epic_tracking_only.xml**) file to the root file (**epic_tracking_only.root**) using command below
  - dd_web_display --export -o **epic_tracking_only.root epic_tracking_only.xml**
  - geoConverter -compact2gdml -input **epic_tracking_only.xml** -output **epic_tracking_only.gdml**
- Geometry Visualization in ROOT (TGeoManager)
  - root [2] TGeoManager::Import("epic_tracking_only.gdml") // root or GDML file
  - root [2] gGeoManager->SetVisLevel(10) // Increase it to get more detailed geometry
  - root [2] gGeoManager->GetTopVolume()->Draw("ogl")
  - root [2] gGeoManager->Export("output.root"); // choose output.root
- ROOT Geometry using TBrowser




```
shyam@shyam:~/eic/epic$ root -l epic_tracking_only.root
root [0]
Attaching file epic_tracking_only.root as _file0...
(TFile *) 0x5570cb00bbb0
root [1] new TBrowser
(TBrowser *) 0x5570cb6e53c0
root [2] Info in <TGeoManager::CloseGeometry>: Geometry l
Info in <TGeoManager::SetTopVolume>: Top volume is world_
Info in <TGeoNavigator::BuildCache>: --- Maximum geometry
Info in <TGeoManager::CloseGeometry>: Voxelization retrie
Info in <TGeoManager::CountLevels>: max level = 5, max pl
Info in <TGeoManager::CloseGeometry>: 28430 nodes/ 102 vo
Info in <TGeoManager::CloseGeometry>: ---------------mod
```

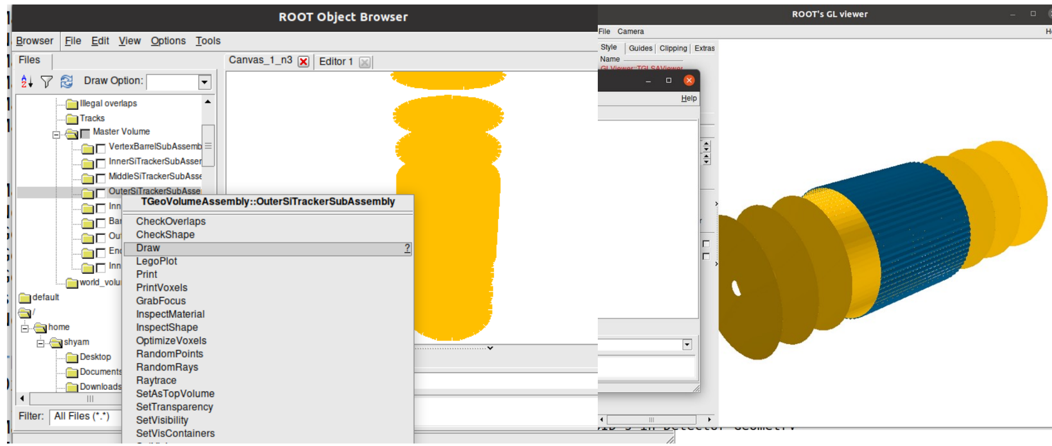


Very important check for geometries

root [2] gGeoManager->CheckOverlaps(0.01)
Info in <TGeoNodeMatrix::CheckOverlaps>: Checking overlaps for world_volume and daughters within 0.01
Warning in <TGeoMatrix::dtor>: Registered matrix InnerTrackerSupport_assembly_placement was removed
Warning in <TGeoMatrix::dtor>: Registered matrix Identity was removed
Warning in <TGeoMatrix::dtor>: Registered matrix Identity was removed
Check overlaps: [==========] 28430 [100.00 %]
Info in <TGeoNodeMatrix::CheckOverlaps>: Number of illegal overlaps/extrusions : 0

Visualization of Geometry

Press w, e, r, t..



Draw a specific Volume

Play with other options !!!

If we want to remove volumes (not comfortable): TEveManager makes things easier

➢ Geometry Visualization in ROOT (TEveManager)

```
void draw_geom()
{
The code can be used for any geometries
any others
TString rootfile="epic_brycecanyon_Shyam.root"; // Change geometry file name
TEveManager::Create();
gGeoManager = TGeoManager::Import(rootfile); // or use simply TGeoManager::Import(rootfile)
if (gGeoManager == nullptr) return;
TEveGeoTopNode *EPIC = new TEveGeoTopNode(gGeoManager,gGeoManager->GetTopNode()); // pass node here instead of
topnode
gEve->AddGlobalElement(EPIC);
gEve->FullRedraw3D(kTRUE);
}
```

If you have the root geometry file for any experiment use the macro to visualize

I attached macro with more advance options

Visualization of Geometry

- Geometry Visualization in DD4HEP
  - source /opt/detector/setup.sh
  - ddsim --**runType vis** --macroFile myvis_geo.mac --compactFile $DETECTOR_PATH/epic_tracking_only.xml

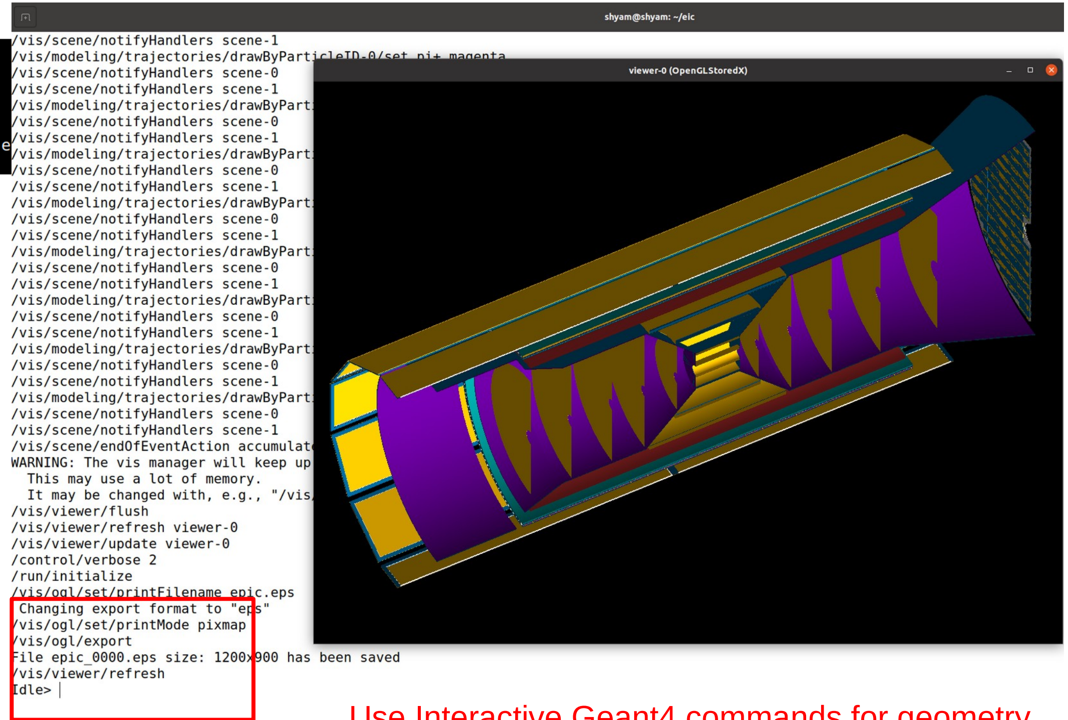
```
options:
  -h, --help            show this help message and exit
  --steeringFile STEERINGFILE, -S STEERINGFILE
                        Steering file to change default behaviour
  --compactFile COMPACTFILE [COMPACTFILE ...]
                        The compact XML file, or multiple compact files, if the last one is the close
  --runType {batch,vis,run,shell,qt}
```

ddsim -h

myvis_geo.mac

```
# $Id: vis.mac,v 1.4 2010/04/14 18:32:59 lindenle Exp $
#
# Macro file for the initialization phase of "exampleN03.cc"
/control/verbose 2
/control/saveHistory
/run/verbose 2
/vis/scene/create
/vis/open OGLSX 1200x900-0+0
#/vis/open OGL

# Draw geometry:
/vis/drawVolume
#
# Specify view angle:
/vis/viewer/set/viewpointVector -1 0 0
/vis/viewer/set/lightsVector -1 0 0
#
# Specify style (surface, wireframe, auxiliary edges,...)
/vis/viewer/set/style wireframe
/vis/viewer/set/auxiliaryEdge true
/vis/viewer/set/lineSegmentsPerCircle 100
# increase display limit for more complex detectors
/vis/ogl/set/displayListLimit 500000
#/vis/viewer/set/viewpointThetaPhi 240 -10
#/vis/viewer/set/viewpointThetaPhi 270 0 # Side view
#/vis/viewer/set/viewpointThetaPhi 270 -89.9 # Top-down view
/vis/viewer/set/viewpointThetaPhi 250 -50
```



Use Interactive Geant4 commands for geometry

You can add setting according to yours using standard Geant4 commands

Event Display (DD4HEP)

- Event Visualization in DD4HEP

source run_eve.sh

in Eve_GPS directory

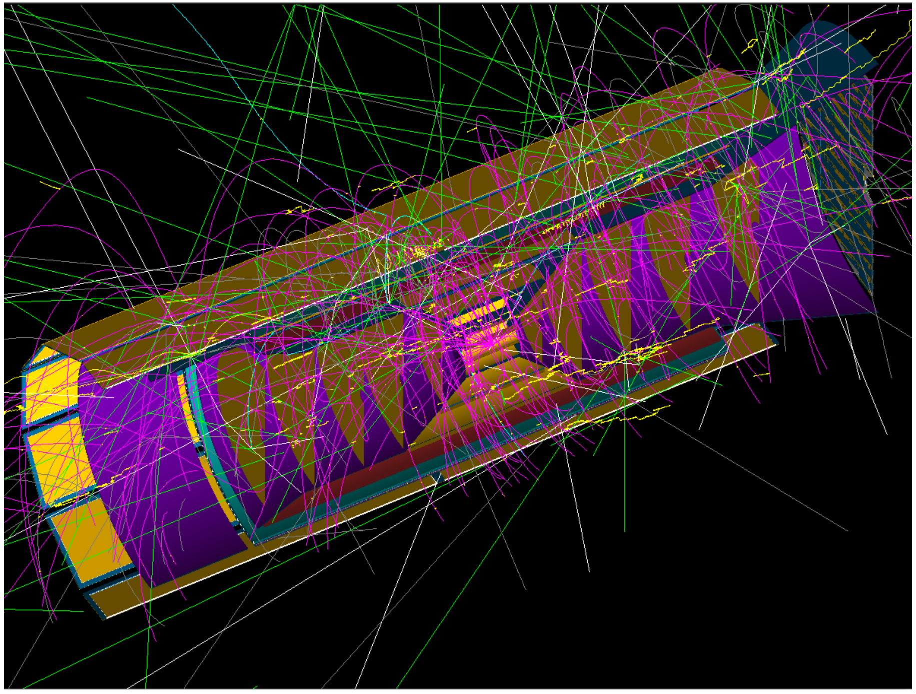
  - **General Particle Source (GPS) defined in myvis.mac**
  - source /opt/detector/setup.sh
  - ddsim --runType vis --**enableG4GPS** --macroFile myvis.mac --compactFile $DETECTOR_PATH/epic_tracking_only.xml --outputFile sim.edm4hep.root

Simulated Particle information stored in sim.edm4hep.root

Material Scan

/control/matScan/phi 360 0 360. deg
/control/matScan/theta 360 0 360. deg
/control/matScan/scan

accumulated events (Curling Tracks)



```
/vis/modeling/trajectories/drawByParticleID-0/set gamma green
/vis/scene/endOfEventAction accumulate
/vis/viewer/flush
/control/verbose 2
/run/initialize
/gps/verbose 2
/gps/particle pi-
/gps/number 1
/gps/ene/type Gauss
/gps/ene/mono  0.15 GeV
/gps/ene/sigma 0.01 GeV
/gps/position 0 0 0.0 cm
#/gps/direction 0 0.1 1.0
/gps/ang/type iso
/run/beamOn 100
/vis/ogl/set/printFilename epic.eps
/vis/ogl/set/printMode pixmap
/vis/ogl/export
```

myvis.mac

Event Display (DD4HEP)

- Event Visualization in DD4HEP

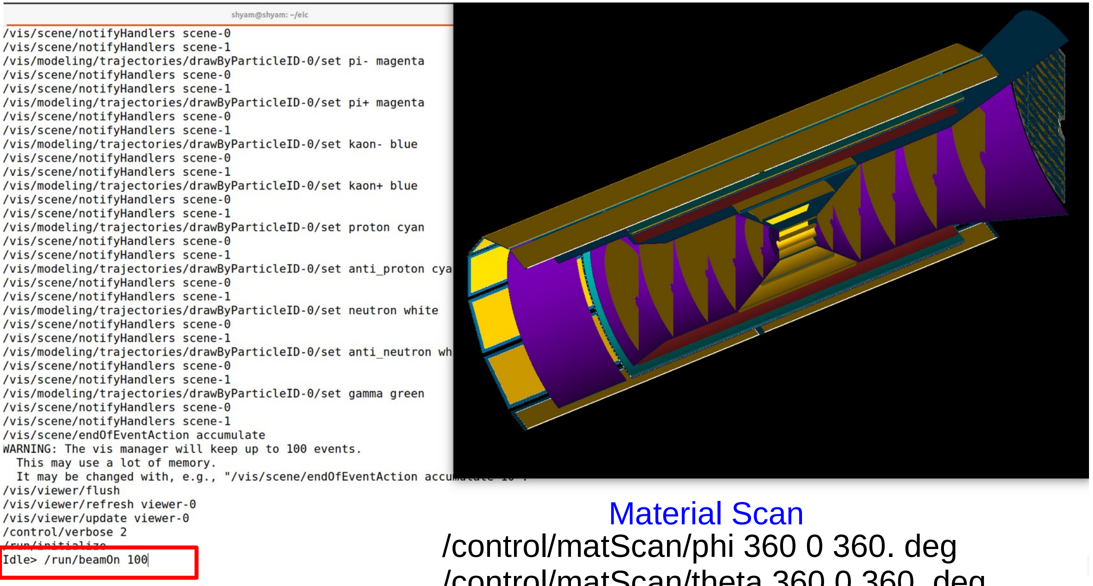
source run_eve.sh

in Eve_Gun directory

  - **Using Particle Gun**
  - source /opt/detector/setup.sh
  - ddsim --runType vis --macroFile myvis.mac --compactFile $DETECTOR_PATH/epic_tracking_only.xml --enableGun --gun.particle pi+ --gun.momentumMin 0.1*GeV --gun.momentumMax 10.*GeV --gun.thetaMin 3*deg --gun.thetaMax 177*deg --gun.distribution uniform --outputFile sim.edm4hep.root

Simulated Particle information stored in sim.edm4hep.root

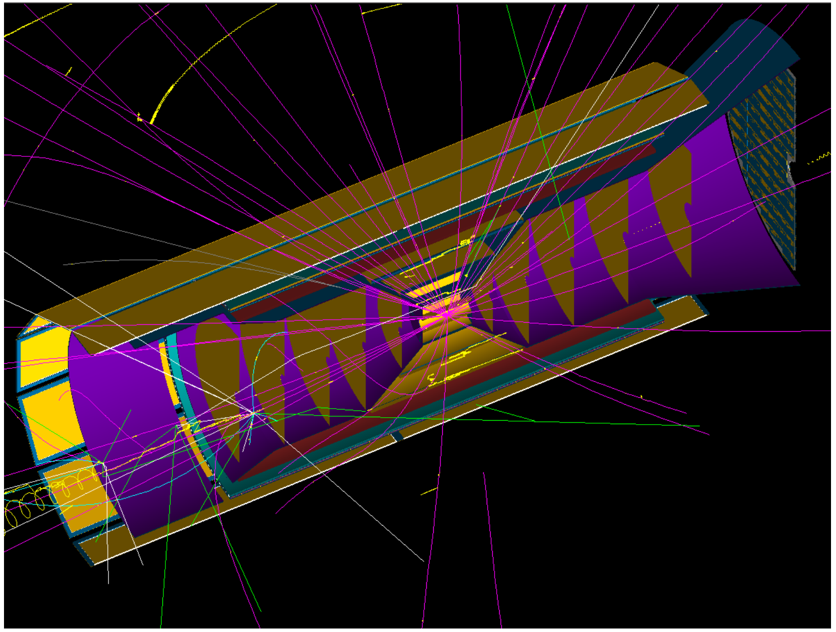
100 events



Material Scan

/control/matScan/phi 360 0 360. deg
/control/matScan/theta 360 0 360. deg
/control/matScan/scan

100 events



Material Map

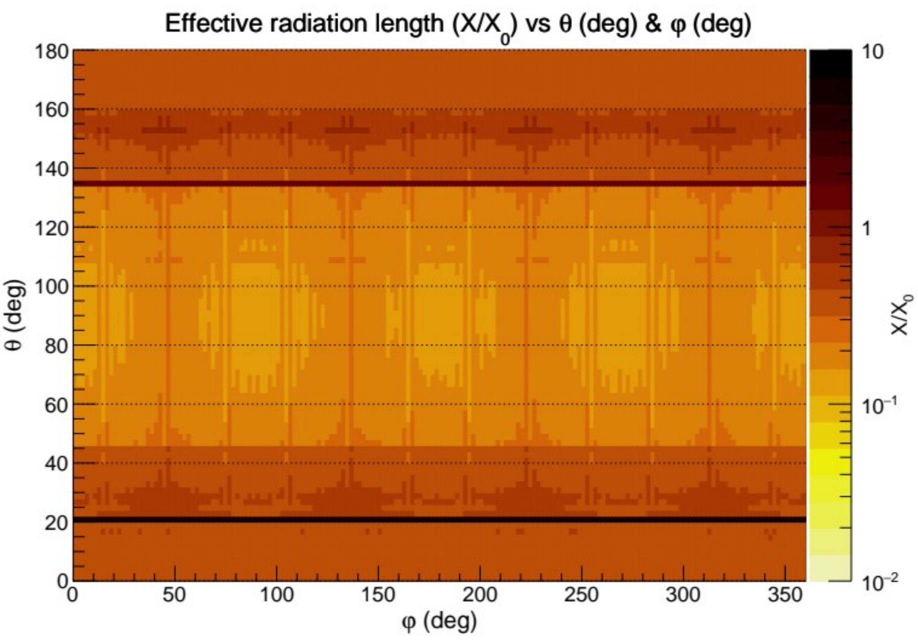
run1.mc

```
/run/initialize
/control/matScan/phi 360 0 360. deg
/control/matScan/theta 360 0 360. deg
/control/matScan/scan
```

- Material Map as a function of Theta and Phi in DD4HEP
  - **Using Material Scan Geant4**
  - source /opt/detector/setup.sh
  - npsim --runType run --macroFile run1.mac --compactFile $DETECTOR_PATH/epic_tracking_only.xml >output.txt &

http://www.hep.ph.ic.ac.uk/~yoshiu/COMET/comet_g4HTMLdoc/_control_matScan_.html

Later format data using format_data.sh and do root -l Plot_MaterialMap.C in directory Material_Map/




```
G4cout << "        Theta(deg)     Phi(deg)  Length(mm)          x0     lambda0" << G4endl;
G4cout << G4endl;
for(G4int iPhi=0;iPhi<nPhi;iPhi++)
{
 G4Event* anEvent = new G4Event(iEvent++);
 G4double phi = phiMin;
 if(iPhi>0) phi += G4double(iPhi)*phiSpan/G4double(nPhi-1);
 eyeDirection = G4ThreeVector(std::cos(theta)*std::cos(phi),
                              std::cos(theta)*std::sin(phi),
                              std::sin(theta));
 theRayShooter->Shoot(anEvent,eyePosition,eyeDirection);
 theMatScannerSteppingAction->Initialize(regionSensitive,theRegion);
 theEventManager->ProcessOneEvent(anEvent);
 G4double length = theMatScannerSteppingAction->GetTotalStepLength();
 G4double x0 = theMatScannerSteppingAction->GetX0();
 G4double lambda = theMatScannerSteppingAction->GetLambda0();

 G4cout << "        "
        << std::setw(11) << theta/deg << " "
        << std::setw(11) << phi/deg << " "
        << std::setw(11) << length/mm << " "
        << std::setw(11) << x0 << " "
        << std::setw(11) << lambda << G4endl;
 aveLength += length/mm;
 aveX0 += x0;
 aveLambda += lambda;
}
if(nPhi>1)
{
 G4cout << G4endl;
 G4cout << " ave. for theta = " << std::setw(11) << theta/deg << " : "
        << std::setw(11) << aveLength/nPhi << " "
        << std::setw(11) << aveX0/nPhi << " "
        << std::setw(11) << aveLambda/nPhi << G4endl;
}
```

Look at the below for details

G4MaterialScanner.cc
G4MaterialScanner.hh
G4MSSteppingAction.hh
G4MSSteppingAction.cc

https://indico.bnl.gov/event/17080/contributions/68330/attachments/43302/72915/EPIC_Tracking_Meeting_Shyam.pdf

Event Display (ROOT Based)

- DD4HEP event display: Moving geometry and adding some information is not easier
- Event Visualization in ROOT (More user friendly-my code)
  - Event display (Visualizing Tracks with track information) quite easy
  - Helix Propagator (Uniform magnetic field) and RK Propagator (Non-uniform magentic field) (Supported)
  - Quite easy to add hits (Currently added for Lumi also)

THelix ROOT (Parameterization)

THelix has two different constructors.

q = +/-1 VTX (x,y,z) Momentum (px,py,pz) dir (0,0,1)-Z axis

If a particle with charge q passes through a point (x,y,z) with momentum (px,py,pz) with magnetic field B along an axis (nx,ny,nz), this helix can be constructed like:

```
THelix p(x,y,z, px,py,pz, q*B, nx,ny,nz);
(nx,ny,nz) defaults to (0,0,1).
```

Particle propagation (ACTs): https://acts.readthedocs.io/en/latest/tracking.html#particle-propagation

In case of a homogeneous magnetic field, and in the absence of material interaction, the particle follows a helical trajectory. Such a helix can be calculated purely analytically.

Often, Magnetic fields are not homogeneous, however. In the presence of such changing fields, the corresponding differential equations of motions need to be solved using numerical integration techniques.

In ACTS, numerical integration is done using the Runge-Kutta-Nyström (RKN) method.

Genfit also uses Runge-Kutta extrapolation

Event Display (ROOT Based)

Event_display_example.C

Reconstruction of Helix:

Simulated Tracks

VTX_{MC}: (0.,0.,0.)

$Momentum_{MC}$: (px, py, pz)

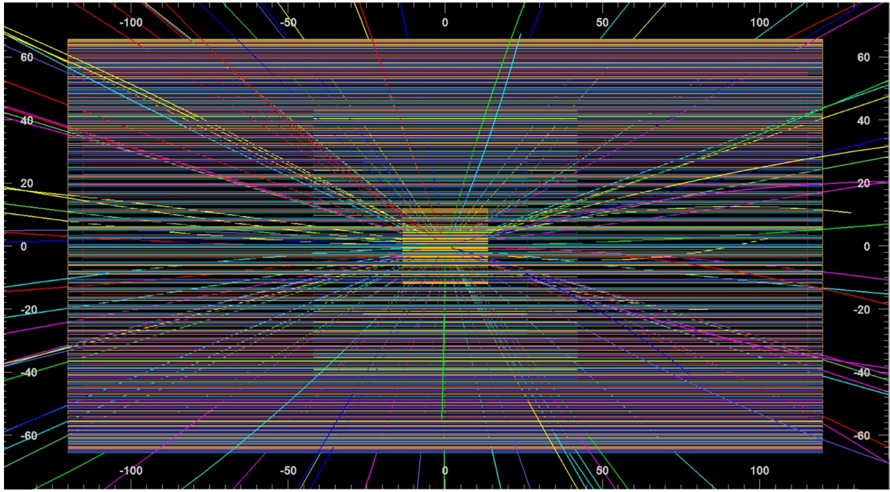
Charge: +/-1

dir (0,0,1)-Z axis

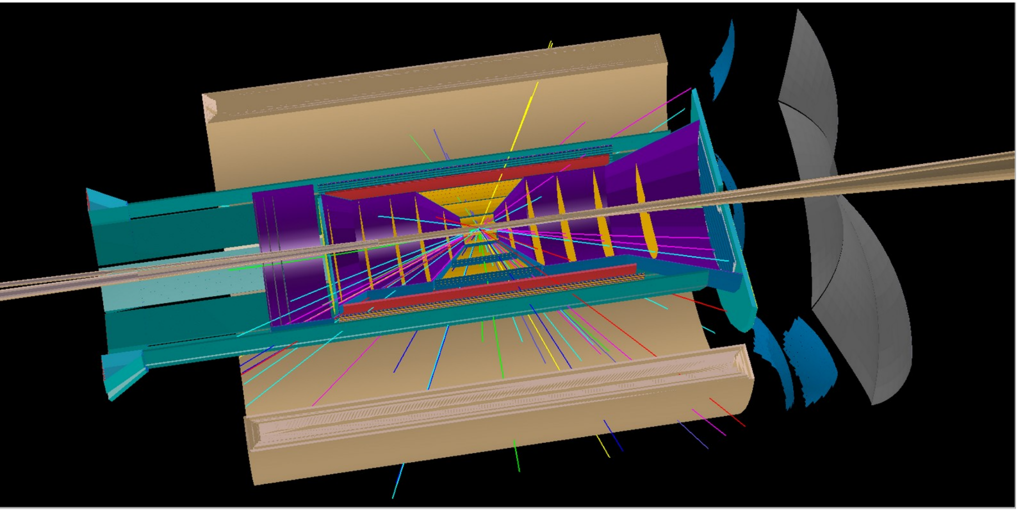
B = 1.7

If we need any feature for detector debugging, please contact me!!!

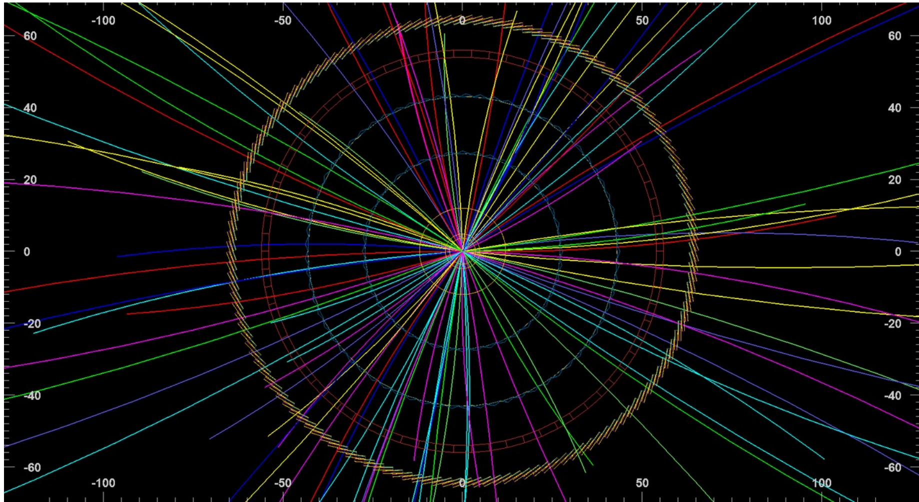
R-Z View



3D View



R-Phi View



Event Display (ROOT Based) Few Pictures

From my slides

run: root -l epic_display.C

https://indico.bnl.gov/event/17924/contributions/72265/attachments/45681/77134/EPIC_Tracking_Meeting_Shyam26Jan2023.pdf