Forward Ecal Software Status and MC Validation

New coordinator : Akio Ogawa

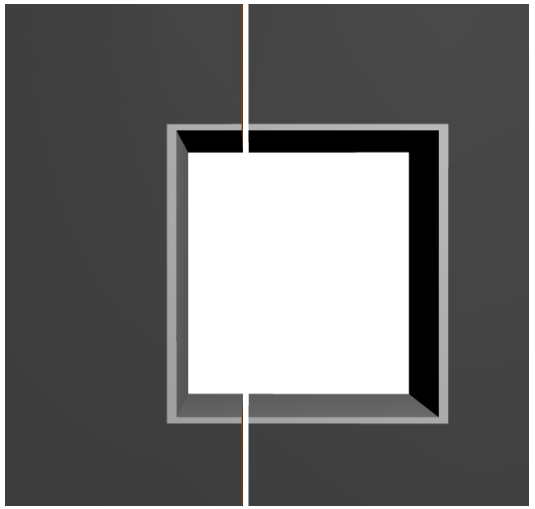
Coordinated : None

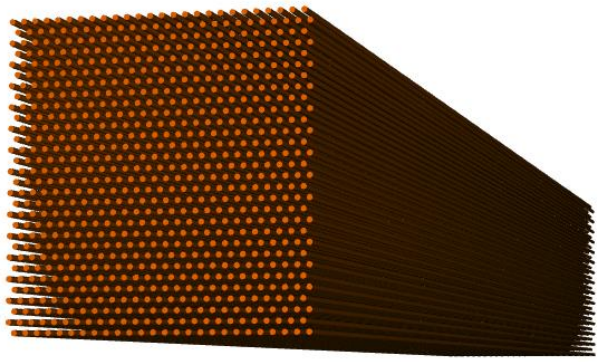
2025 Apr 23

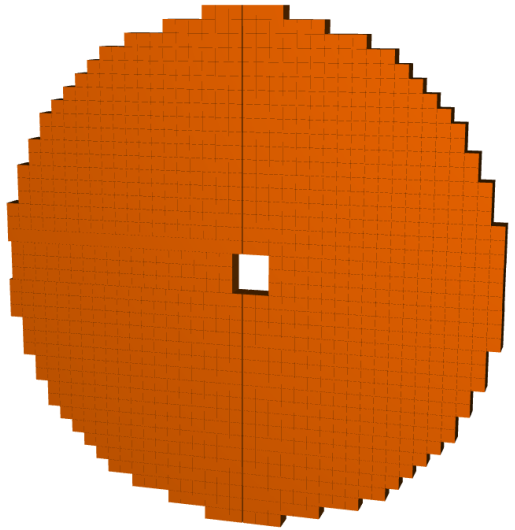
New Forward Ecal geometry implemented

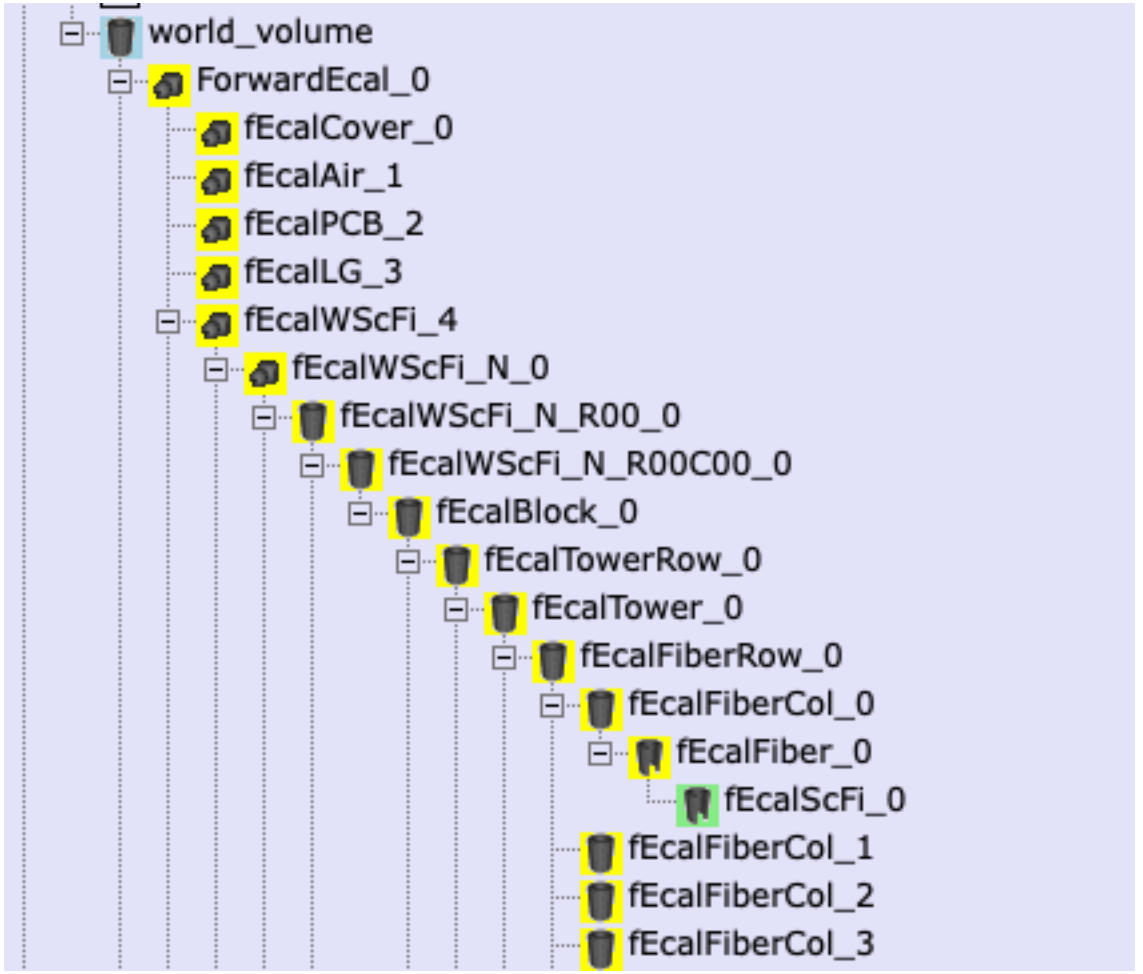
https://www.star.bnl.gov/~akio/epic/geometry/index.html

https://github.com/eic/epic/tree/fEcal_update









Two Geometry implementations

1. Homogeneous averaged/mixed material
   - epic/src/forwardEcal_geo.cpp
   - density (AvgTunhstenScFi) updated from 10.5 to 9.5 g/cm^3
   - Fast & "good enough" for most of studies with FastSim/resolution smearing https://wiki.bnl.gov/EPIC/index.php?title=File:Smearing_of_mixture_structure_for_EMCal.pdf
2. W powder & Scintillating Fibers
   - epic/src/forwardEcalScFi_geo.cpp
   - 36*40= 780 fibers (x25 more fibers than BIC)
   - BirksConsttant=0.126 mm/MeV
   - (Very) Slow and will be used to get Sampling Fractions, Resolutions, etc

Detector	# of fibers	# of nodes/volumes in dd4hep
BIC (EcalBarrelScFi)	48 sectors * 12 layers * 5 grids * 288 fibers = 0.83M	3,816,963 nodes 52 volume
ForwardEcalScFi:	1714 blocks * 16 towers * 780 fibers = 21M	43,443,706 nodes 1269 volume

Speed and memory issue for fiber implementation

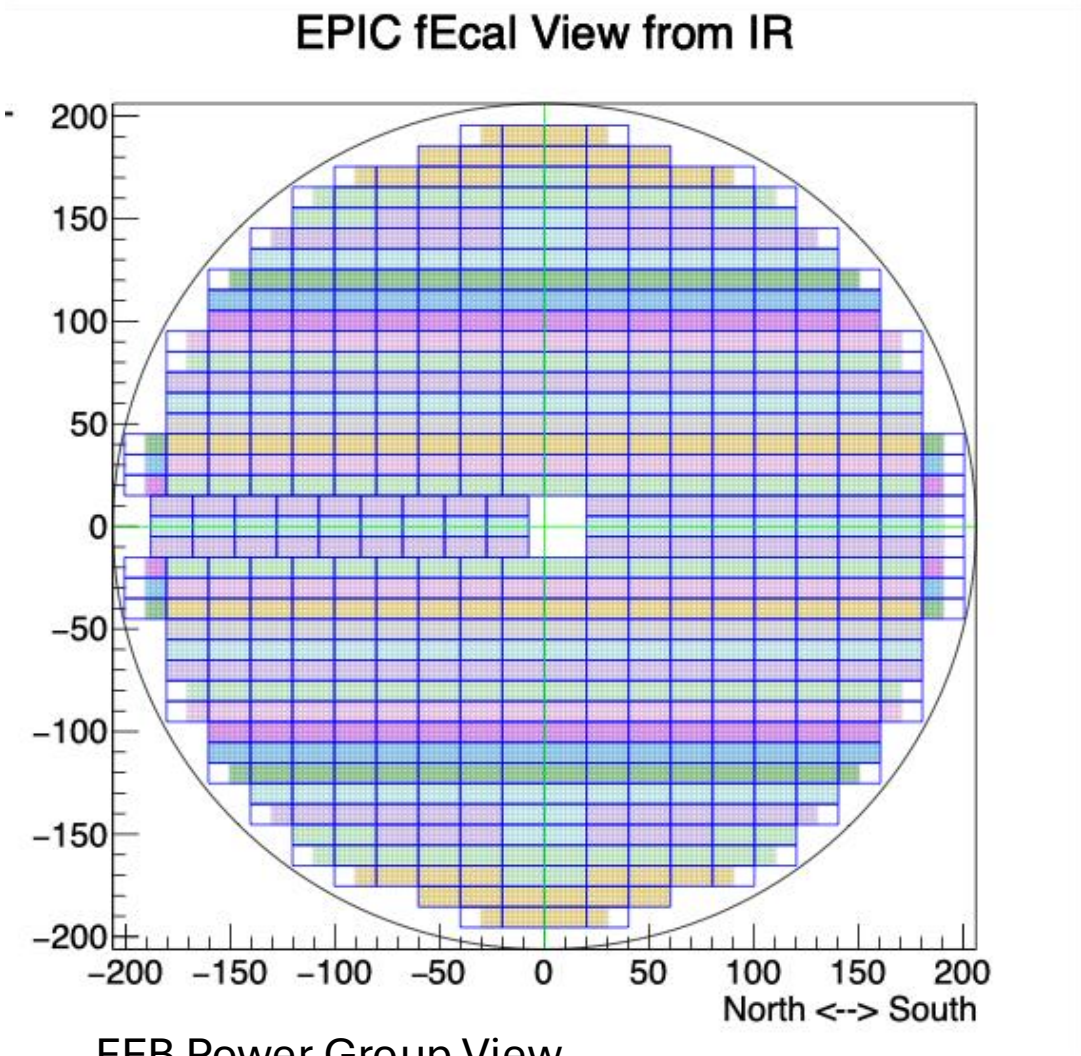
- Extra slow (>30min to startup) and taking huge memory
- Issue with dd4hep VolumeManager making PhysVolId →Sensitive Volume map?
  - Wants to define a hit for none-sensitive tower, not 21M sensitive fibers, but cannot
  - DD4Hep dev suggested “RegexSensitiveVolume”, but as slow to start up
  - ‘TREE’ and ’ONE’ modes in VolumeManager?
- https://chat.epic-eic.org/main/pl/d986i1r5f7f65yahxc5exfs7hy
- https://chat.epic-eic.org/main/pl/jt4ice1fkpnfdxpsx5ktebdm4y
- https://github.com/AIDASoft/DD4hep/issues/1419
- Temporally “fix” with fake CartesianGridX (>30min to ~3min startup)
- x35 more hits but ½ file size due to less “contributions” size

Speed comparison with 100 events of single 20GeV Gamma events

Code	StartUp Time	Event Processing	Avg # of hits	contributions@size	edm4hep file size
Homogeneous	7.6 sec	0.47 s/Event	79	47k	48M
Wpowder+ScFi	205.9 sec	2.62 s/Event	2855	15k	24M

Map and Numbering

https://www.star.bnl.gov/~akio/epic/map/index.html
https://github.com/eic/epic/blob/fEcal_update/src/forwardEcalMap.h



FEB Power Group View

Simple C++ class to convert between :

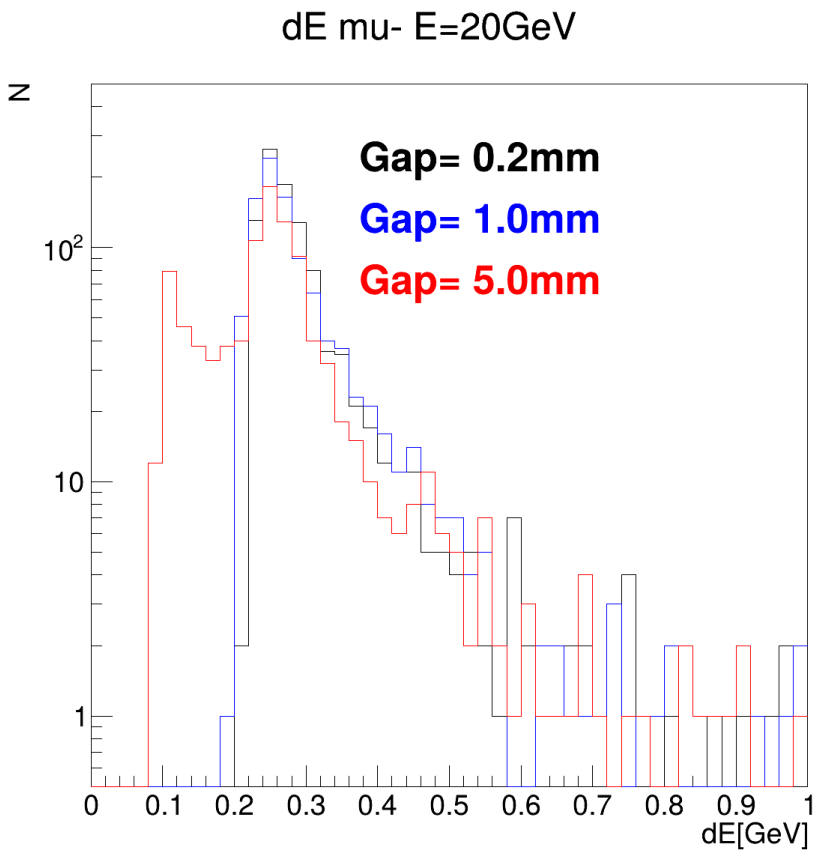
- Human readable Id (north/south, row, column)
- Human readable Id (north/south, block, tower)
- Local XY
- Global XYZ
- CellID in MC
- DAQ Id (ROC, FEB, SiPMBd, Ch…)
- Slow Control Id (Power Group, FEB Addr, SiPMBd…)

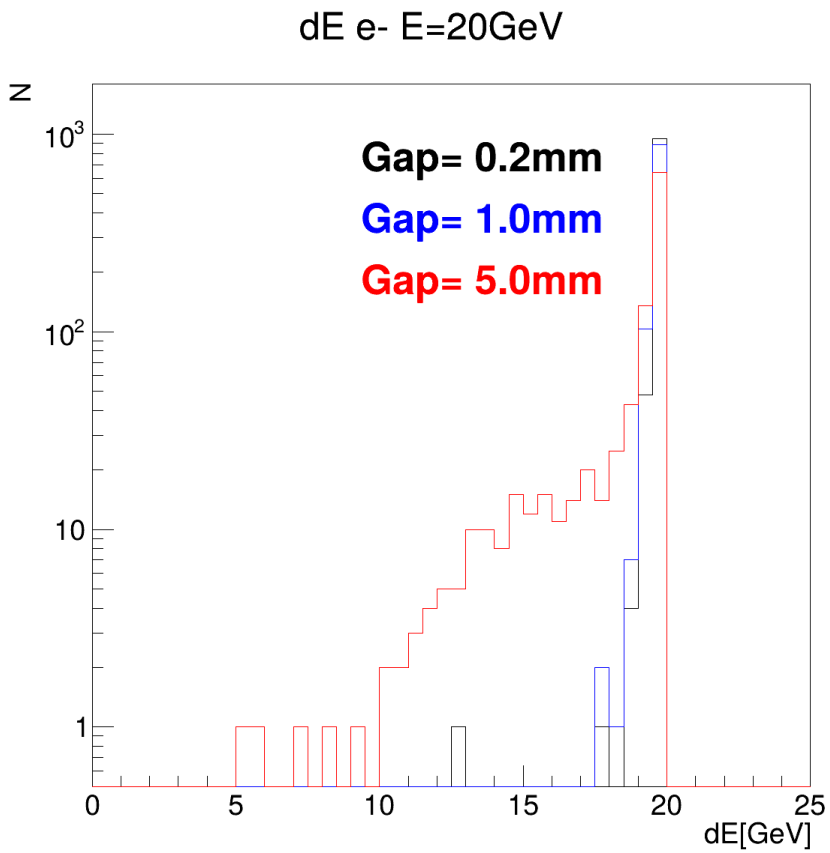
This also help to provide basic constants and functions for

- Drawings
- MC geometry
- Reconstruction
- QA plots

Block Gap Study

Shooting Muon/Electron towards +- 2cm of nearest to beam gap where gap effect is worst





From simple geometry :

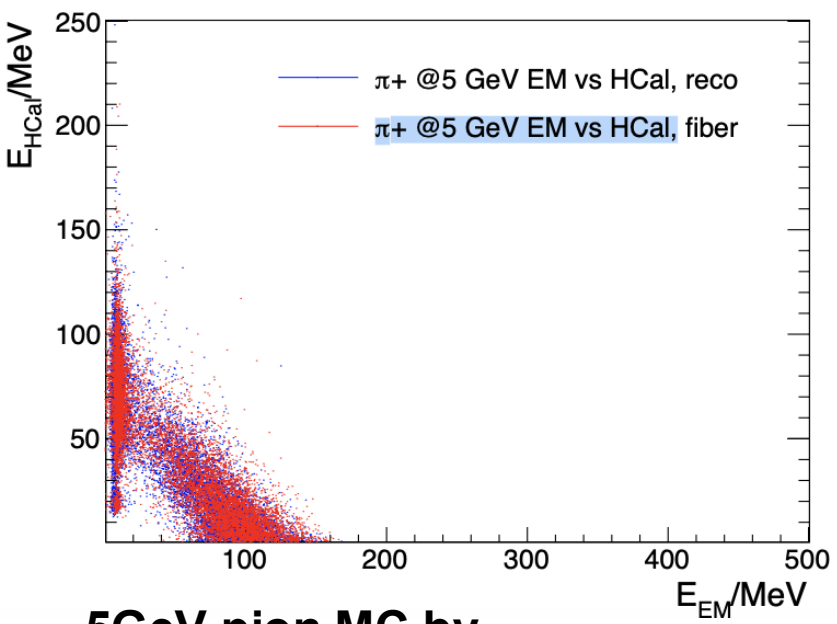
10mm gap make a region for a particle to miss up to 100% material

5mm gap make a region for a particle to miss up to 50% material

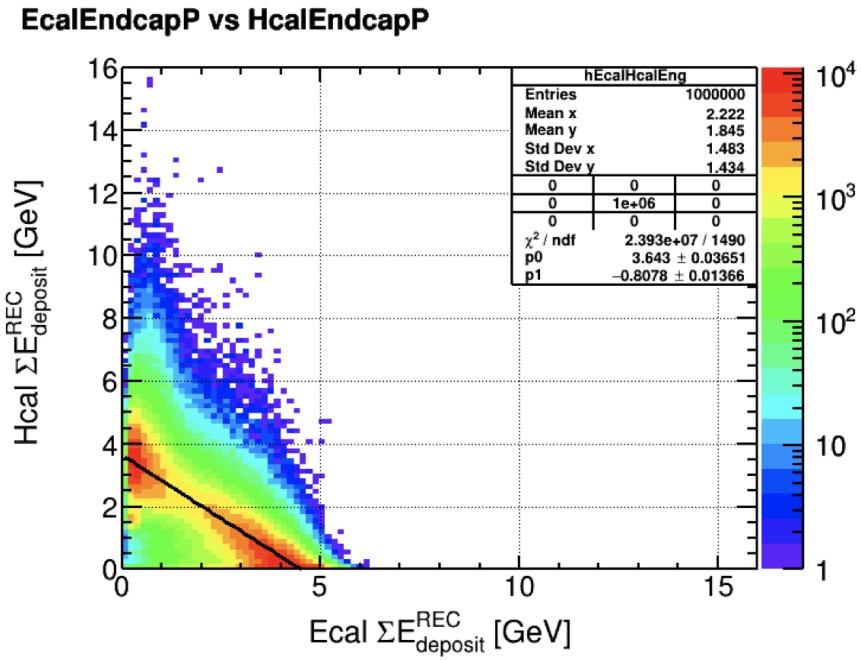
1mm gap make a region for a particle to miss up to 10% material

Increase gap between blocks from 0.6mm to 1mm

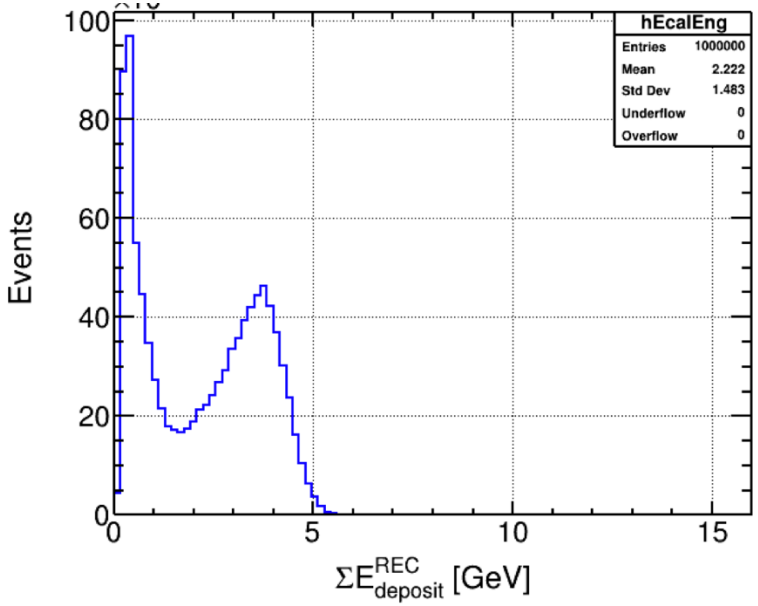
Response to low energy hadron



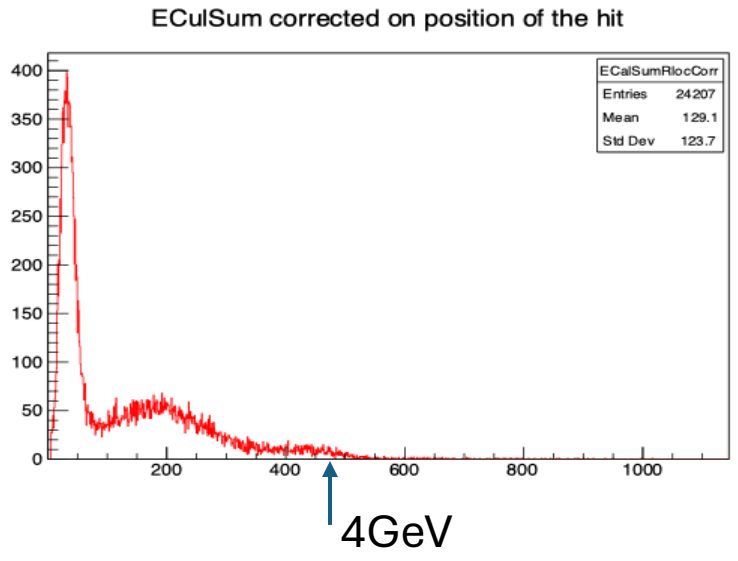
5GeV pion MC by Zhiwan Xu, Ryan Milton



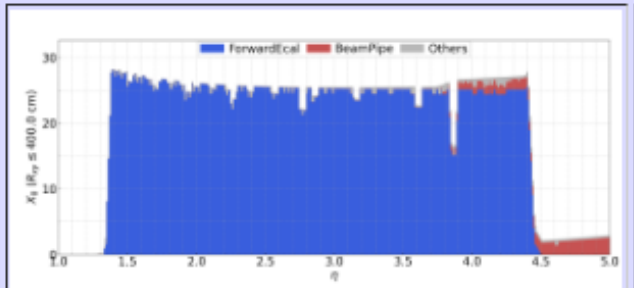
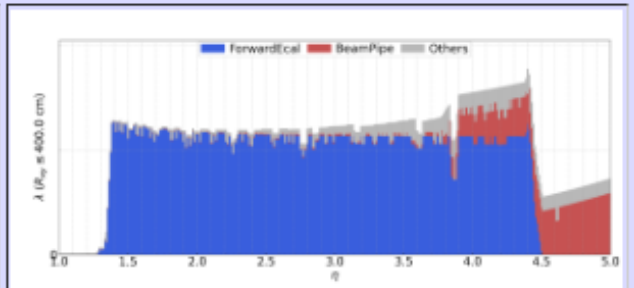
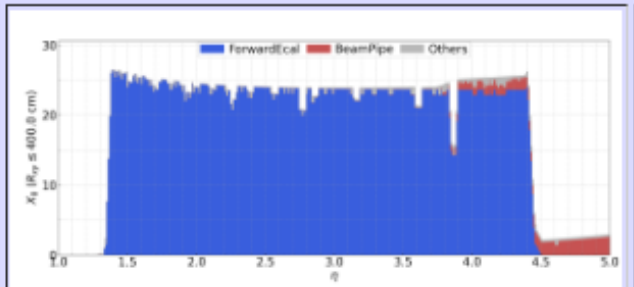
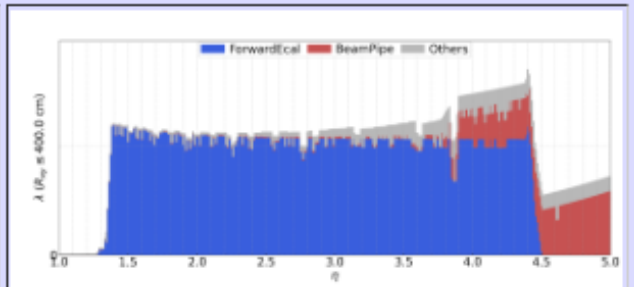
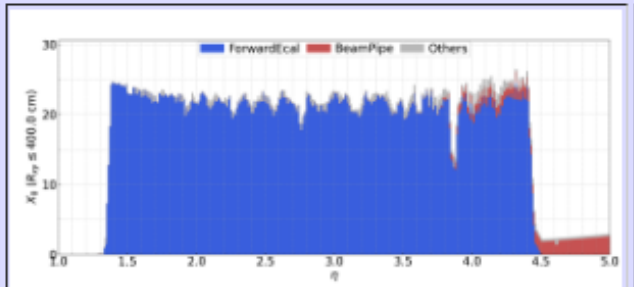
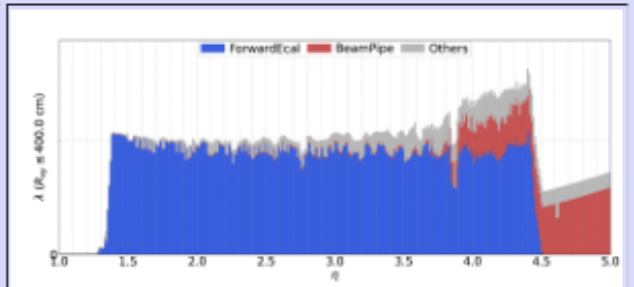
5GeV Pion MC by Jihee Kim



4GeV Pion Test Beam (Oleg)

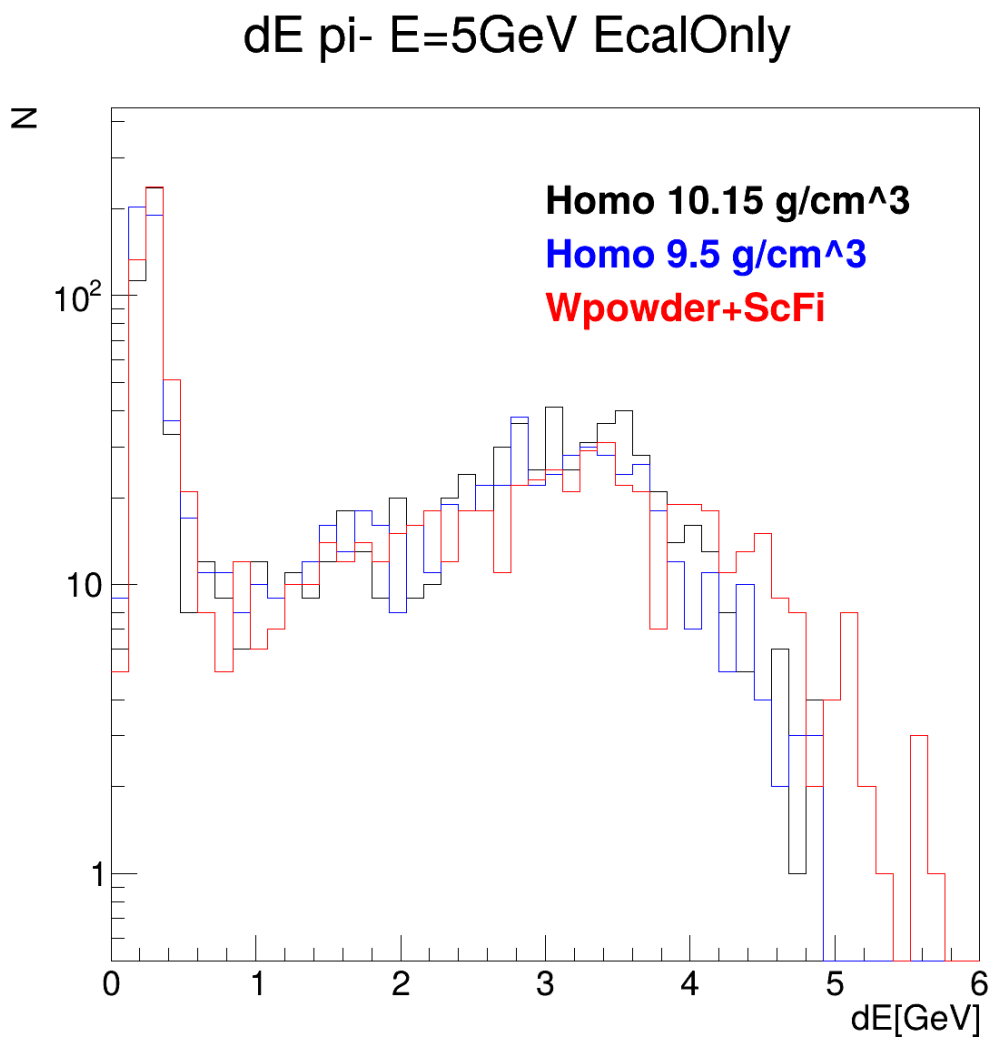


G4 Material Scan

material average density	Radiation Length	Interaction Length (1tick=1.0)
Mixed 10.15 g/cm^3		
Mixed 9.50 g/cm^3		
W powder + ScFi		

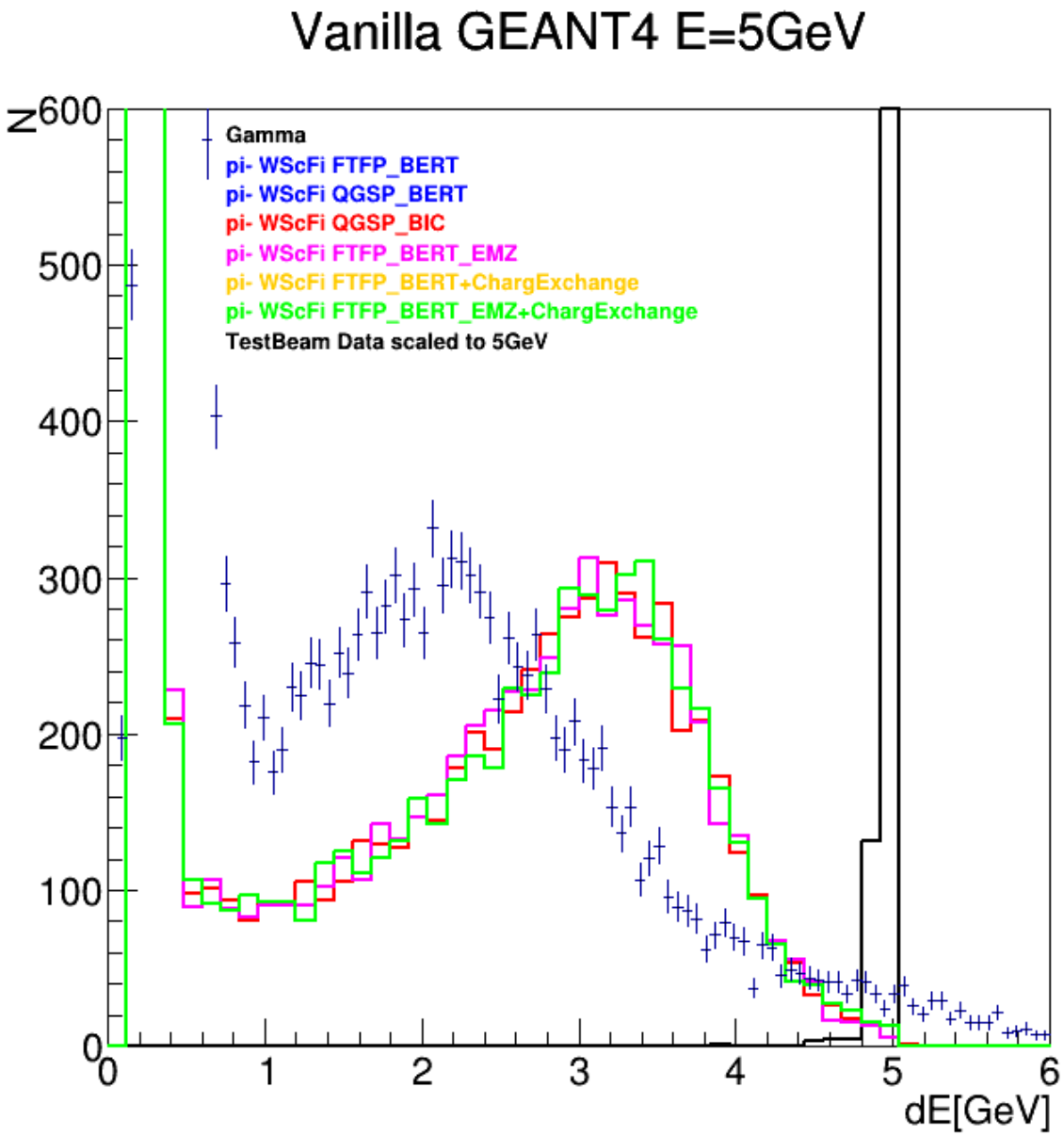
~23 radiation length and ~1.1 interaction length as expected

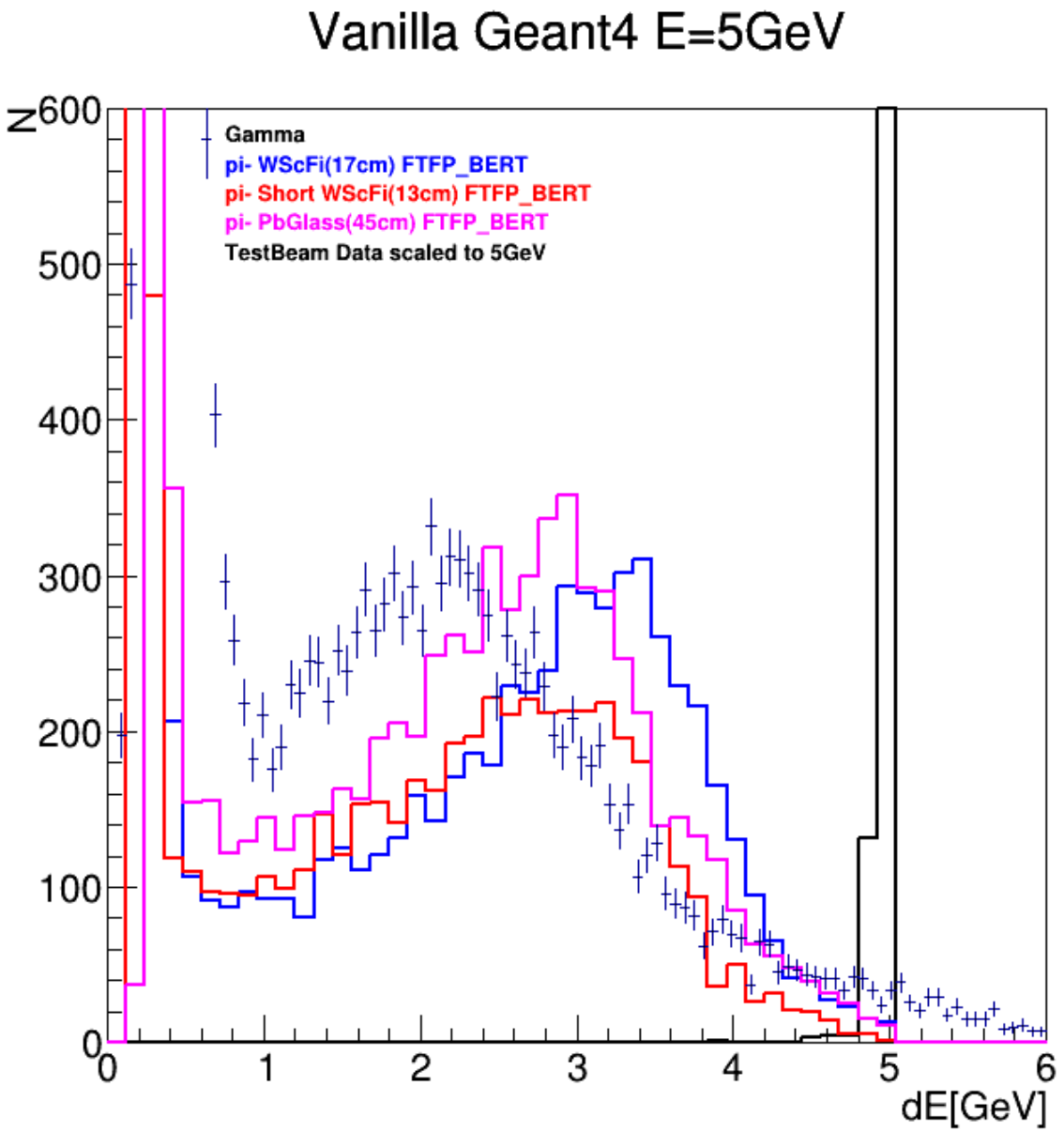
Reproduced high energy(>1/2 full energy) peak with both Homogeneous and WScFi geometries



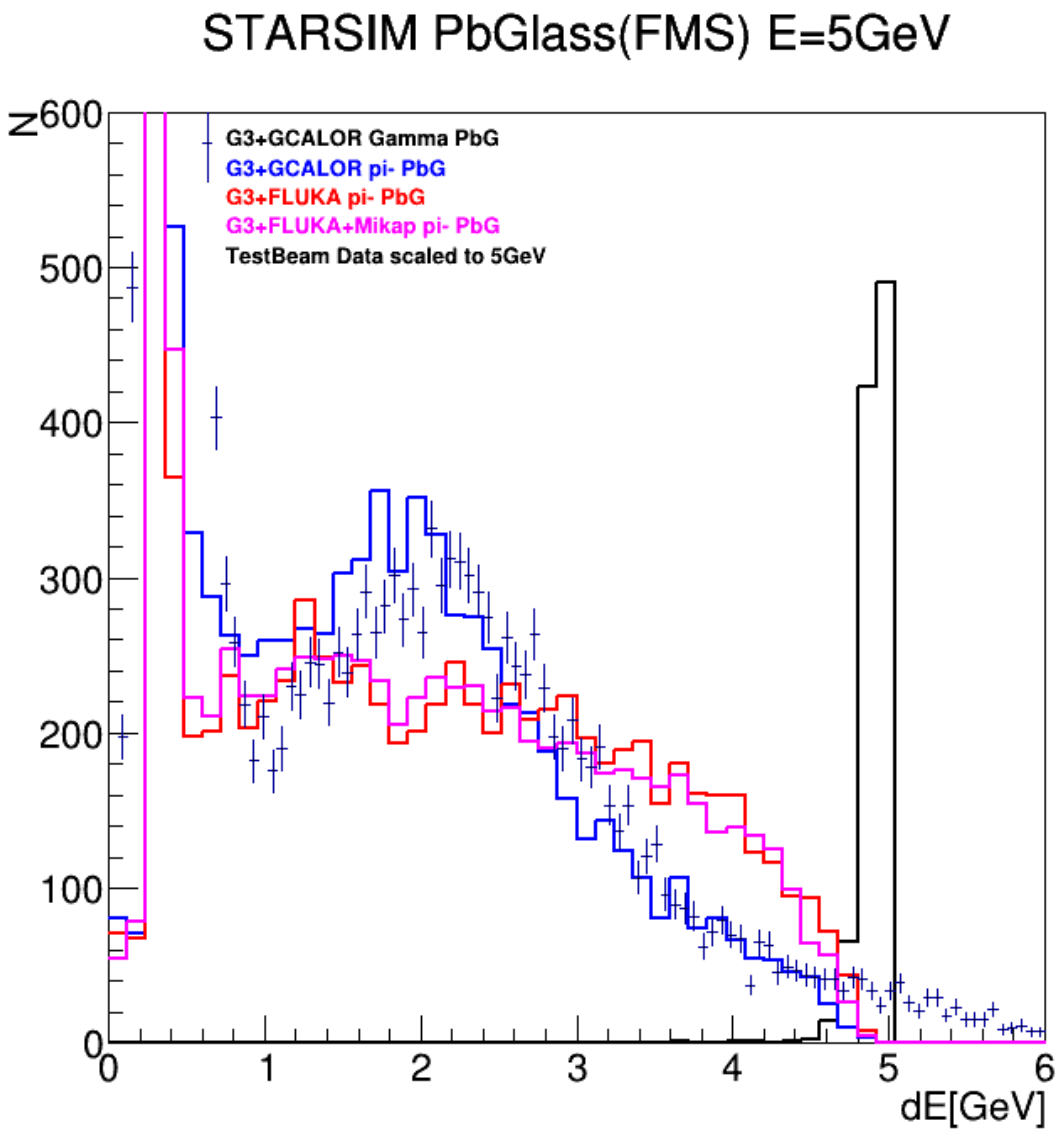
SF = 0.03 for WScFI

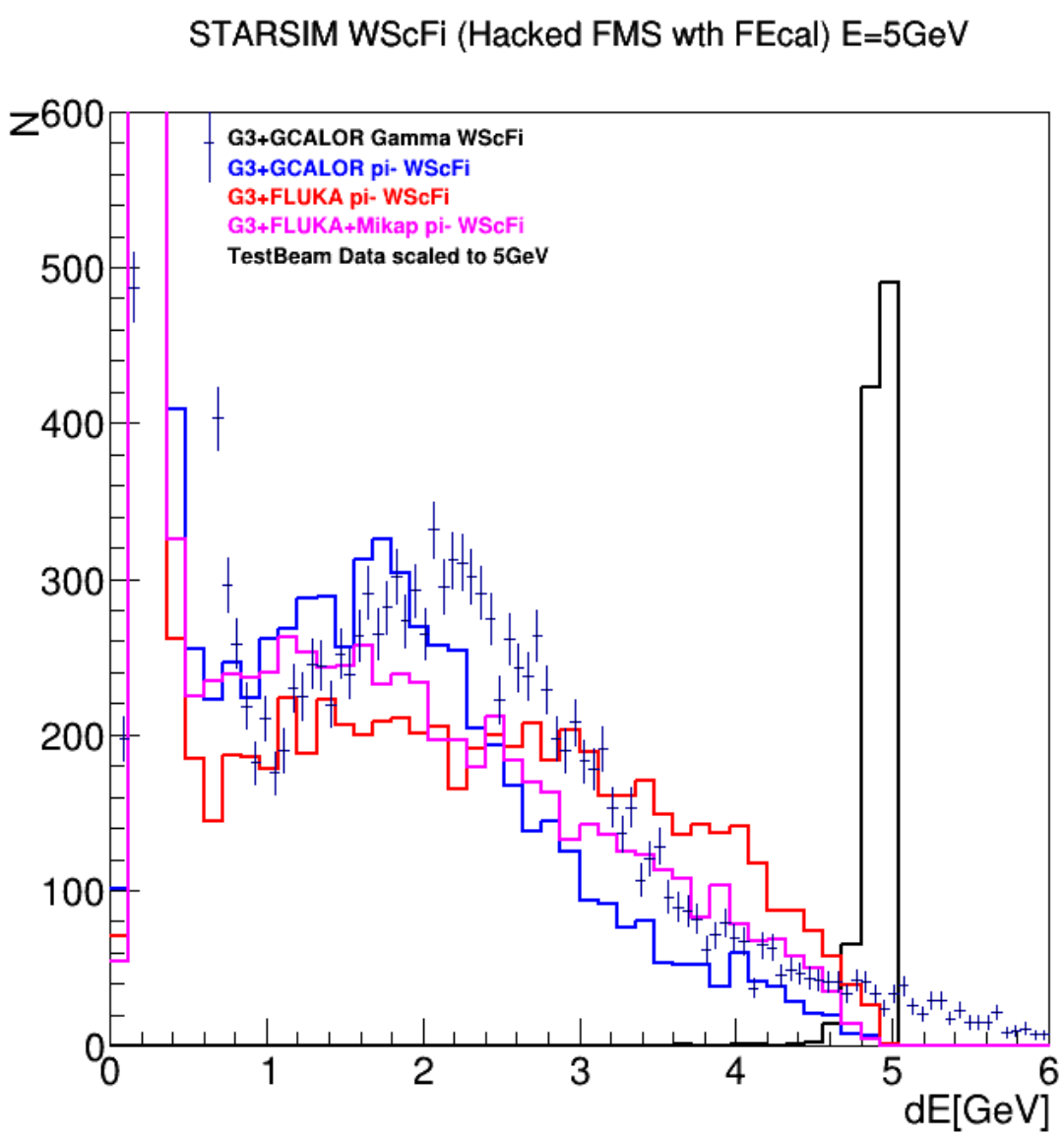
Vanilla Geant4 with different Physics List and Materials





Geant3 (STARSim)





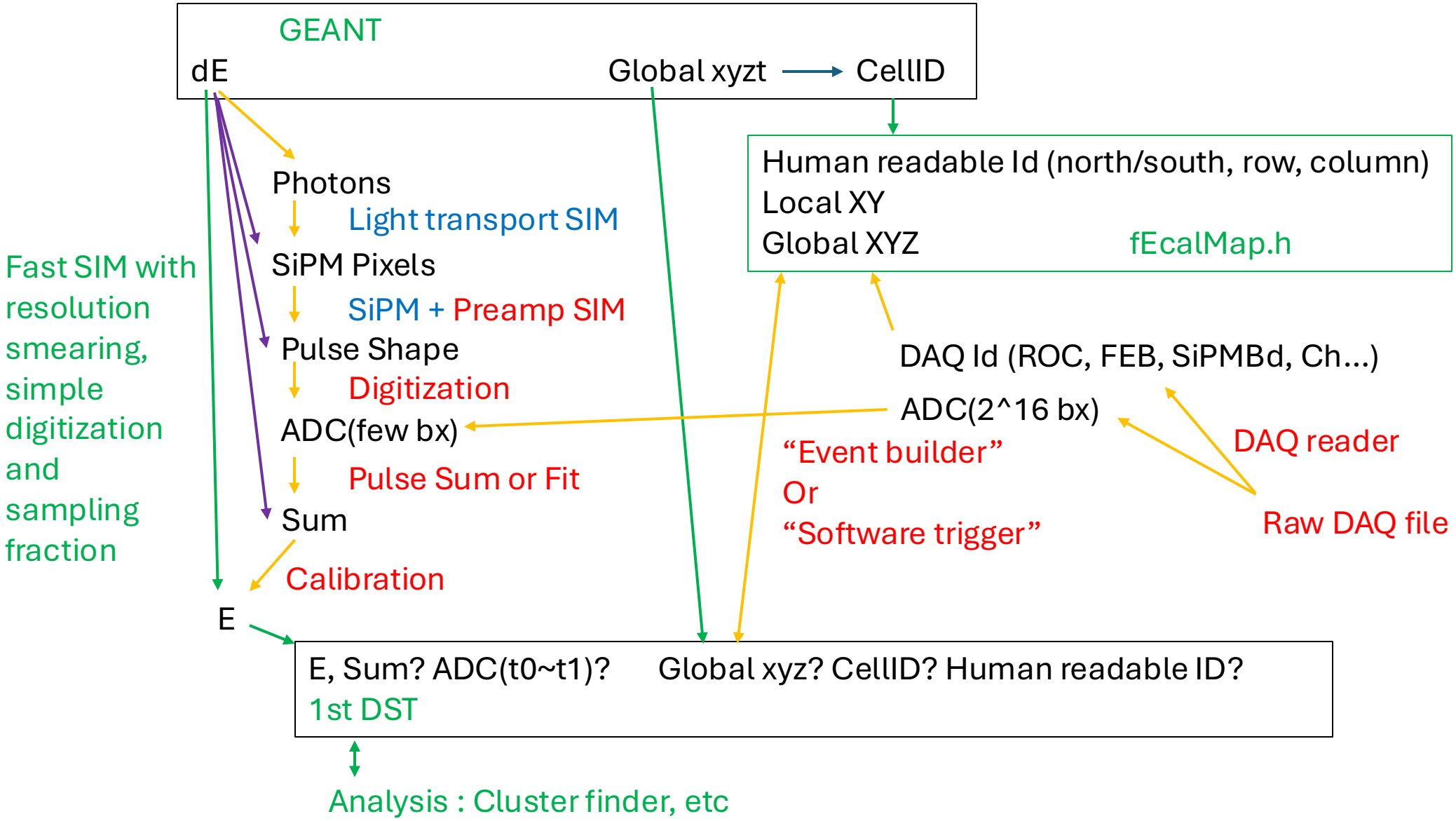
After GEANT…

- Fast Sim with just energy dependent resolution smearing

- Light Transport Sim – if we know significant position dependence in light correction efficiency
  - Test beam data shows ~5%…. Not significant enough?
- SiPM Sim – Radiation damage and noise, Saturation…
  - Noise ~10MeV below 15MeV digitization threshold… Not significant?
- Preamp Pulse Shaping Sim
  - Simple pulse shape parametrized to a function
- Time binning and Digitization
- At what stage do we add
  - energy dependent resolution smearing in case of mixed material model
  - Embedding noise or early/late overlapping events

- Time bin sum or fit
- Calibration

- I think we should consider
  - Independent studies of each effect, parametrize if needed
  - Flexible path : Fast sim to slower and slower sim depending on purpose


GEANT
dE
Global xyzt
CellID
Human readable Id (north/south, row, column)
Local XY
Global XYZ
fEcalMap.h
Photons
Light transport SIM
SiPM Pixels
SiPM + Preamp SIM
Pulse Shape
Digitization
ADC(few bx)
Pulse Sum or Fit
Sum
Calibration
E
Fast SIM with resolution smearing, simple digitization and sampling fraction
DAQ Id (ROC, FEB, SiPMBd, Ch…)
ADC(2^16 bx)
"Event builder"
Or
"Software trigger"
DAQ reader
Raw DAQ file
E, Sum? ADC(t0~t1)?
Global xyz? CellID? Human readable ID?
1st DST
Analysis : Cluster finder, etc

Summary

- New Forward Ecal Geometry with current design with both :
  - Fast Homogenous model
  - Slow W powder + 780 ScFi model
  - https://www.star.bnl.gov/~akio/epic/geometry/index.html
  - https://github.com/eic/epic/tree/fEcal_update

- Unresolved : ScFi model has speed & memory issue in DD4hep (VolumeManager?)

- Unresolved : Low energy hadron response does not agree with test beam data
  - It does NOT look like issue of
    - Geometry code & material (interaction length is as expected)
    - Homogeneous vs Fiber model
    - EIC/DD4hep (Vanilla Geant4 is same)
    - Different Geant4 Physics Lists give same
  - G3 looks agree with test beam data better
  - Barrel Ecal MC with DD4hep/G4 agree with their test beam data, look like fEcal test beam data and G3

- Next step : Update FastSim … then PreAmpSim?

CAD drawinings from Harvey, Joshua

Part Number	Component
1	8-36 Screws
2	Mounting Plate – Top
3	Mounting Plate – Bottom
4	Titanium Dioxide Epoxy
5	Tungsten Sci-Fi Block
6	Light Guide Face
7	Light Guide
8	SiPM (Hidden behind SiPM Board)
9	SiPM PCB
10	Connector MA01R030VABBR600
11	Connector MA01F030VABBR300
12	¼” Copper Tube
13	Aluminum Heat Sink
14	Thermal Pad
15	Pre-Amp PCB
16	Bia PCB
17	Ethernet 615008145121