dRICH Interaction Tagger simulations

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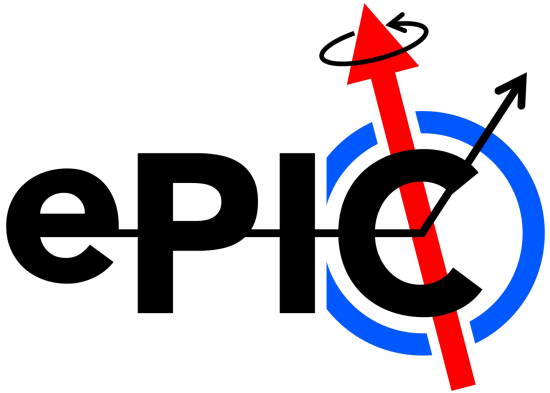


Motivation

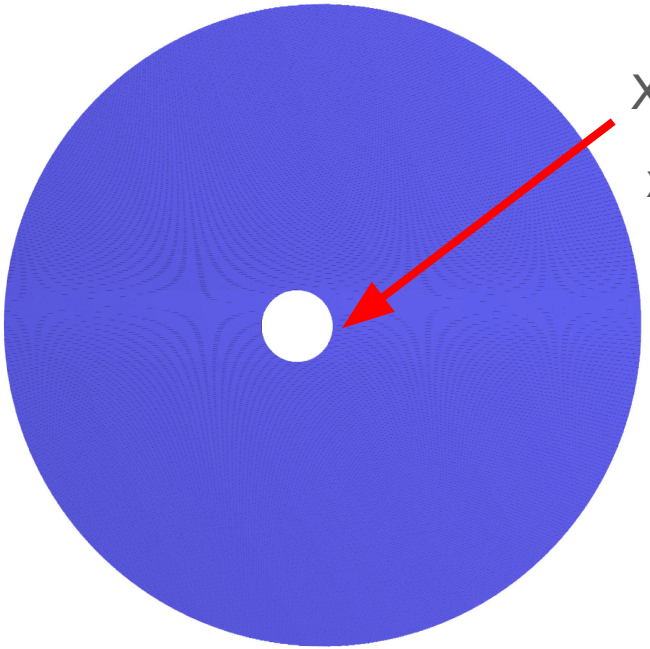
- dRICH is the ePIC sub-detector generating the highest FE data rate;
- thermal 1 p.e. background generated by SiPMs is irreducible at channel/RDO level;
- fast external trigger on hadrons crossing dRICH can reduce data rate;
- scintillator hodoscope in front of the aerogel was proposed as a possible solution;

Requirements:

1. high efficiency: double layer at 90 deg. (4*(0.02*2 mm+25 um)^2/(2 mm+25 um)^2)) = 1.1% inefficiency for normal tracks;
2. narrow coincidence: should be <10 ns of RF, on-line - fiber length <80 cm/20 cm/ns=4 ns + track uncertainty ~2 ns, off-line - resolution <0.1 ns;
3. thin: 2 layers x (2 mm SciFi + 3 mm supports CF) ~0.95+2.6=3.6%.

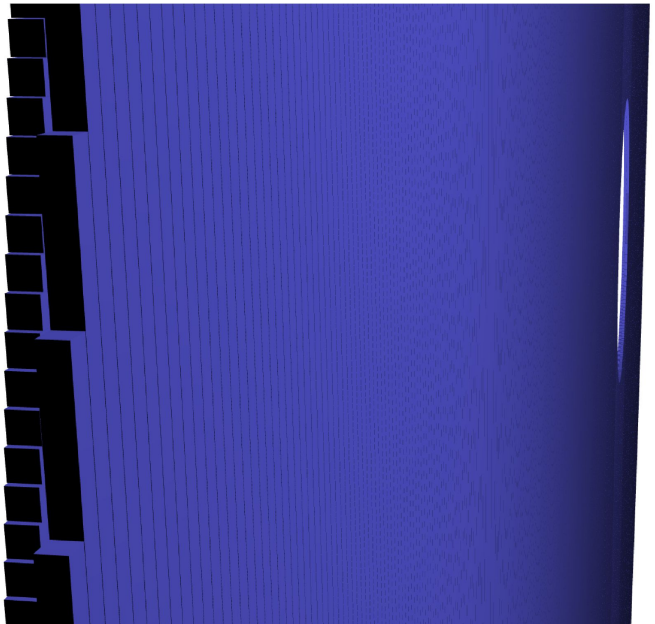
Tagger implementation in ePIC DD4HEP code

- two layers of 2 mm wide scintillation fibers, 2% cladding thickness, 25 um gap installed before dRICH aerogel at Z=ForwardRICHRegion_zmin + 2.86*cm;
- XY-directions, 956 fibers/layer, 1.23 km of fiber length/layer;
- 25 mr offset beam pipe hole in the center (one side reading for central fibers) with 85 mm radius (aerogel R_{min}=85 mm?).



X=0 center

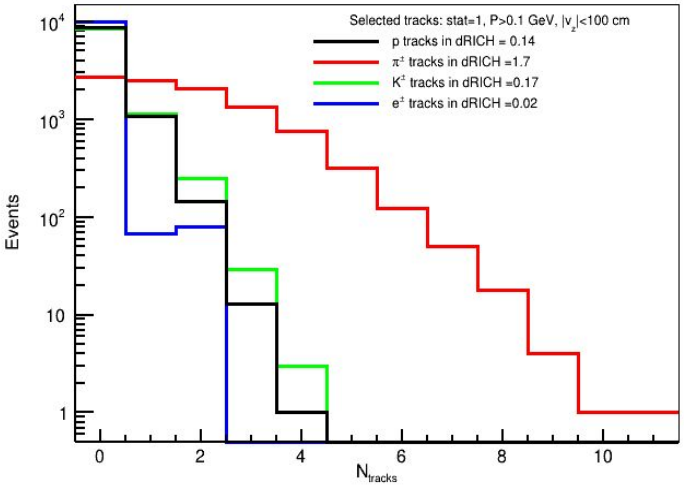
$x_0=-Z_{center}*\tan(25\ mr)$

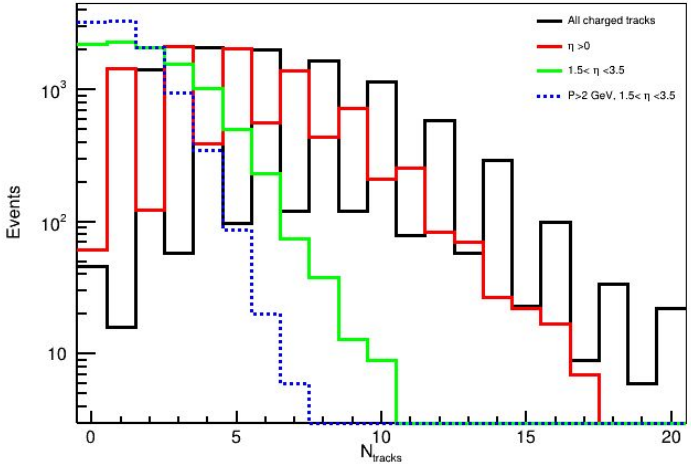


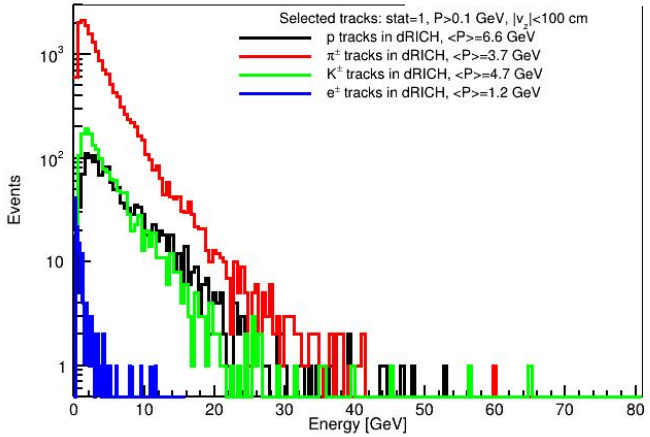
SIDIS simulations used for performance studies

pythia8NCDIS_10x100_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_vtxfix_1.hepmc, first 10,000 events:

- beams: e 10 GeV x p 100 GeV (early physics compatible), Q2>1 GeV2, beam angle effects;
- each event has about 2 charged tracks in dRICH acceptance;
- most of them are pions of 4 GeV;
- stat=1 - selects final state real particles (do we need others?);
- |Vz|<100 cm - selects particles created at IP (do we need others?).

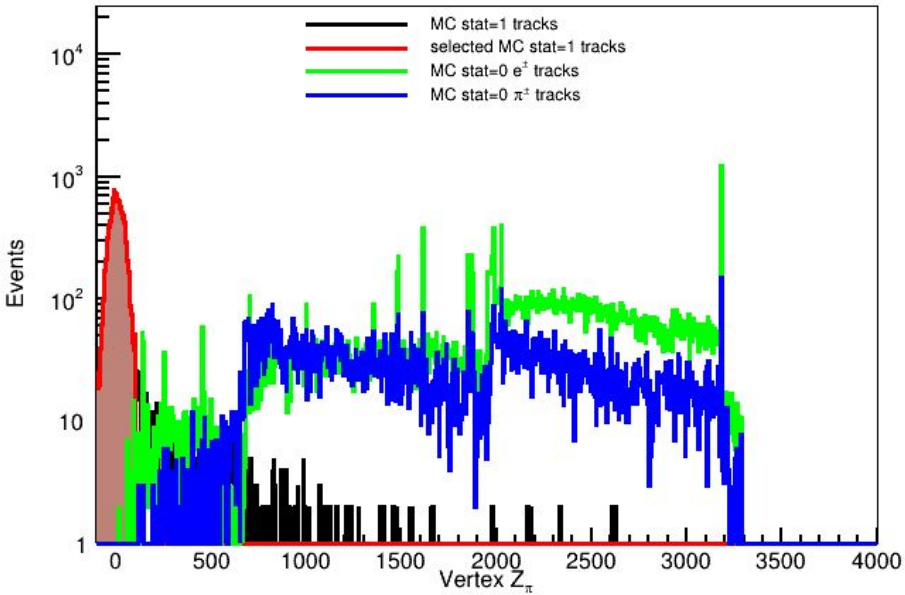


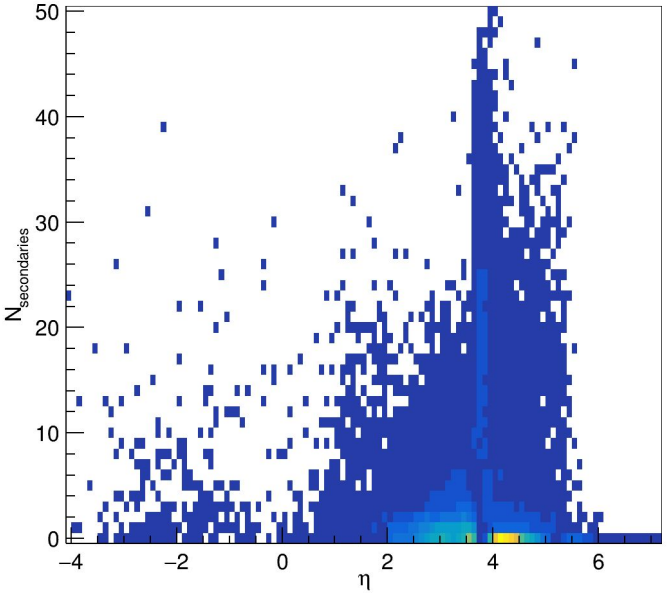




Z-vertex distribution and secondaries

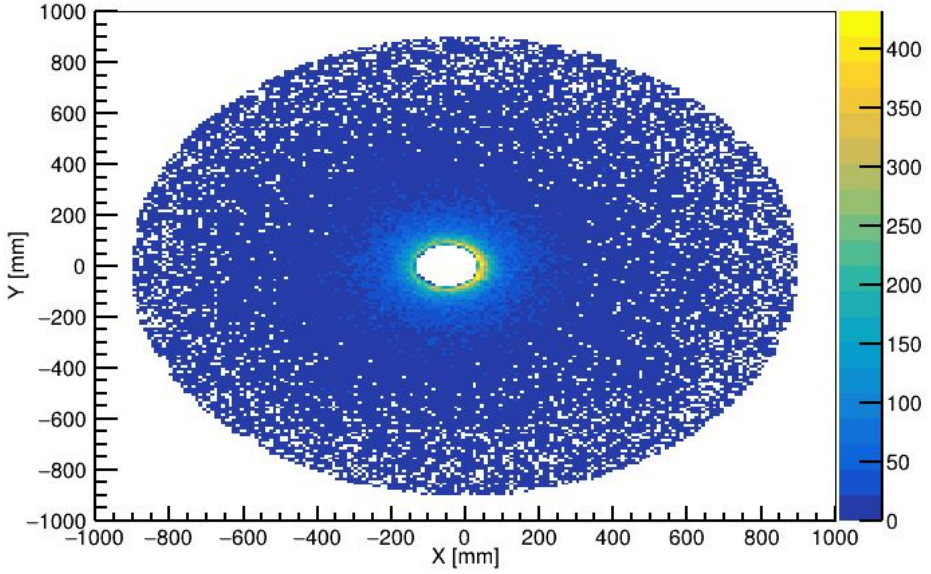
- 6% of stat=1 pions are produced at Z>100 mm;
- number of stat=0 pions is 1.13 times larger than stat=1;
- number of stat=0 e^{+-} is 2.3 times larger than stat=1 pions;
- secondary Z-vertex distributions have many peaks, largest at Z=3179 mm;

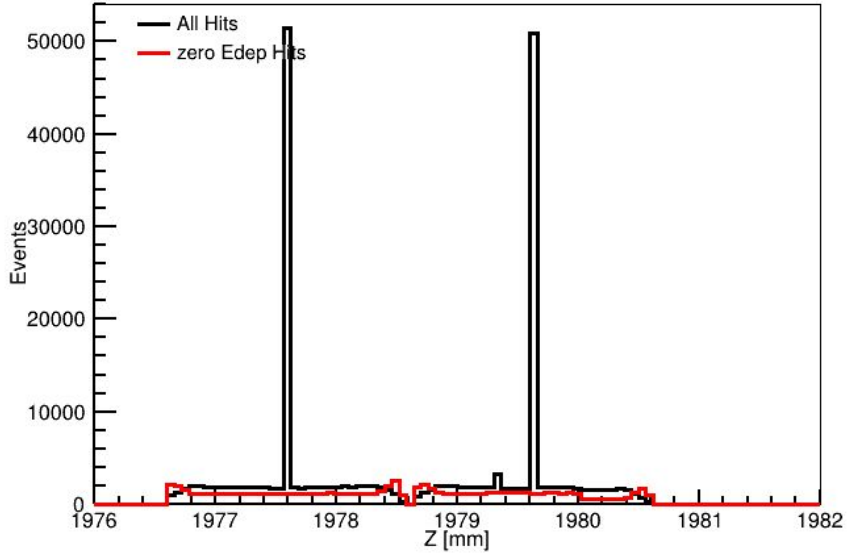




Tagger performance: spatial

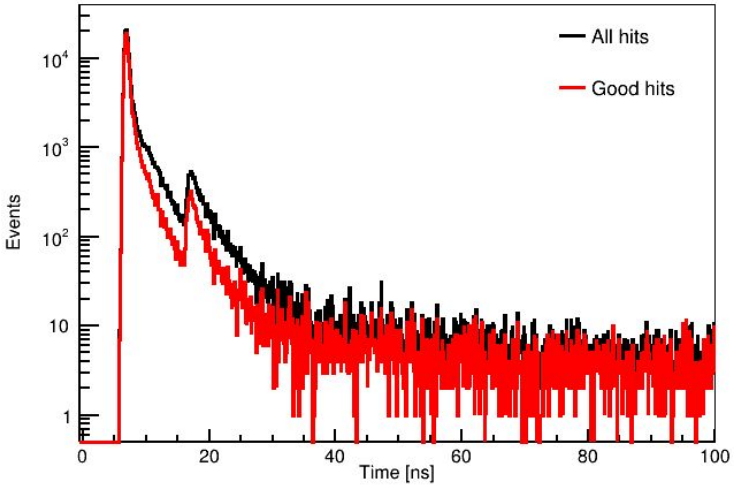
- dIT hits have cylindrical distribution around beam pipe;
- enhancement of rate around beam pipe is visible (asymmetric?);
- two layers in Z are clearly visible, hits outside of layers are low energy (how is it possible?);
- the two layers are found at Z=1977.59 mm and Z=1979.63 mm.

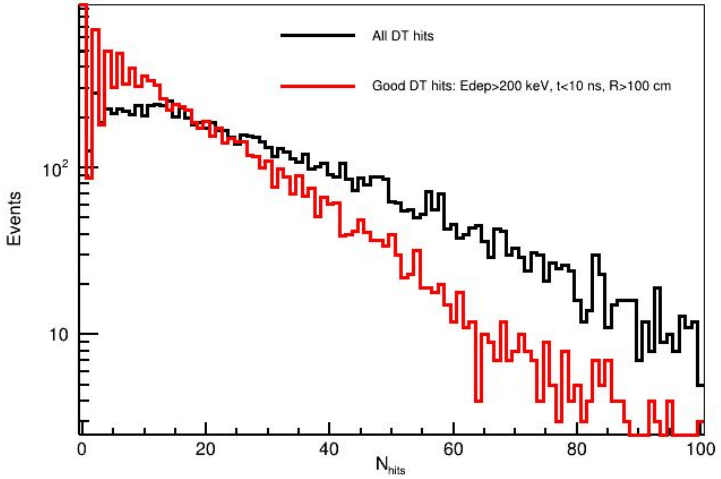


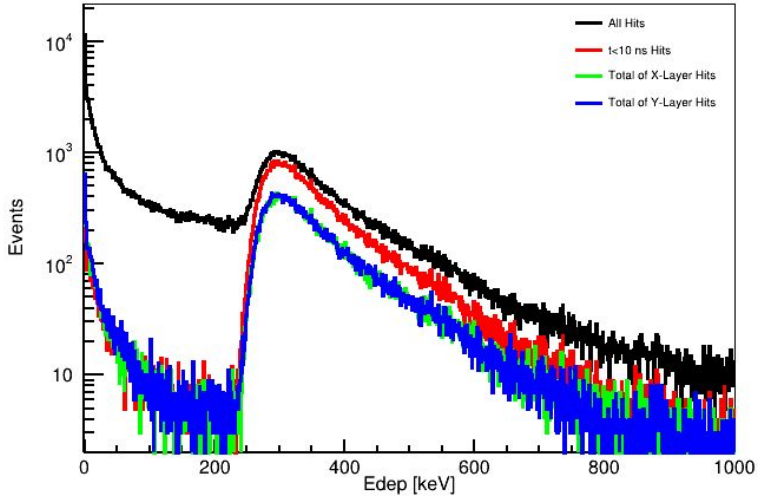


Tagger performance: time/edep

- mean number of dIT (>50 keV, <10 ns) hits =18, or about 9 hits/layer - looks high for 2 tracks? But only 1.4 hits/layer associated with stat=1 tracks!
- most probable deposited energy =300 keV/layer =2400 photons , assuming trapping efficiency of 4.2% (Kuraray) gives 50 photons/SiPM;
- time for 81% of hits within 2 ns , 89% in 10 ns -OK (doesn't include light propagation in fiber);



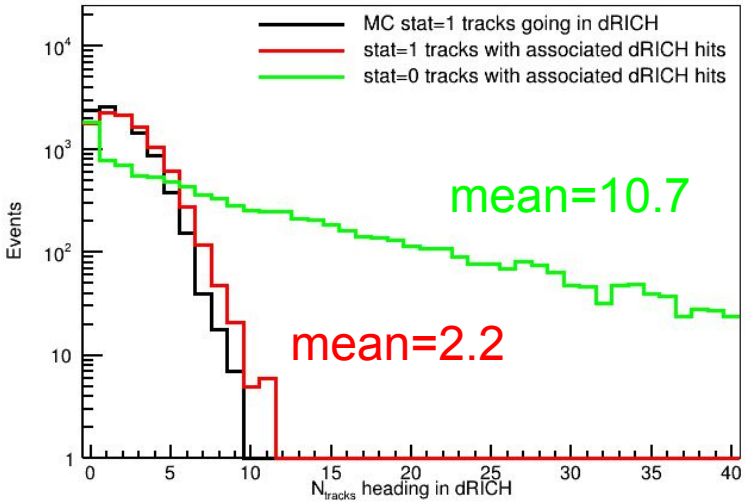


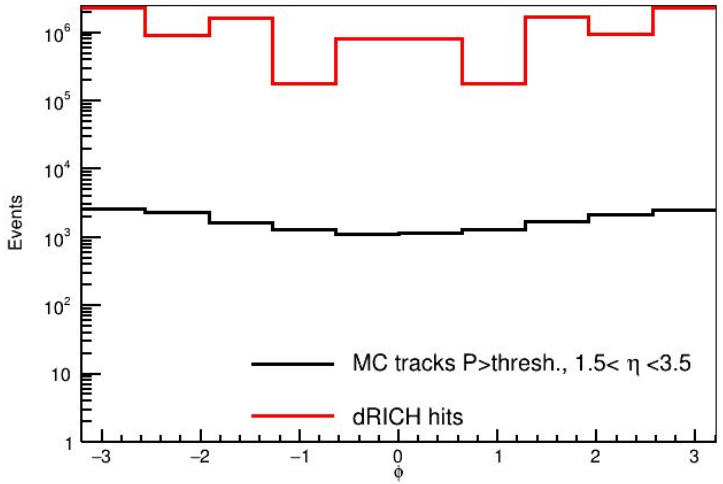


dRICH performance

- dRICH hits are associated with different kinds of MCParticles tracks (not photons?):
- stat=1 tracks - almost equal to generated MC tracks (few with wrong Z-vertex or initial η direction)
- stat=0 tracks (mostly e^{+-}, but there are also pions) - 5 times hits than stat=1.

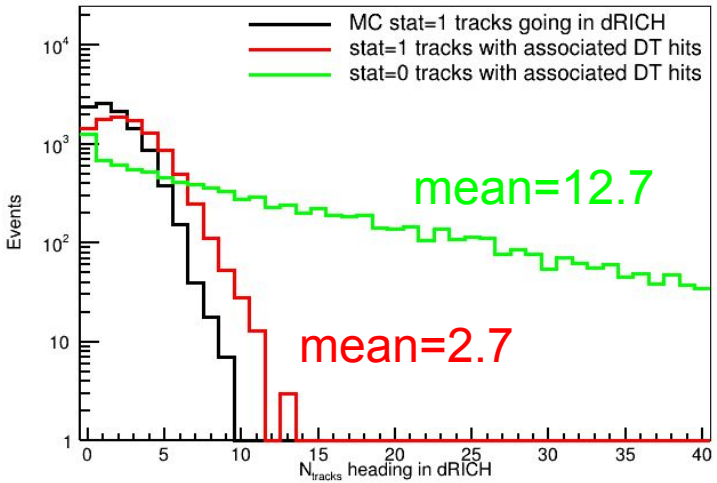
```
stat = MCParticles.generatorStatus[_DRICHHits_MCParticles.index[DRICHHits.cellID index]]
```

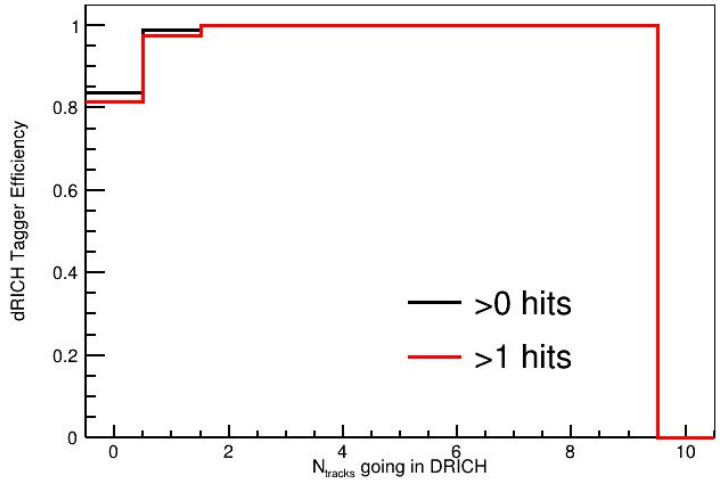




Tagger performance: efficiency

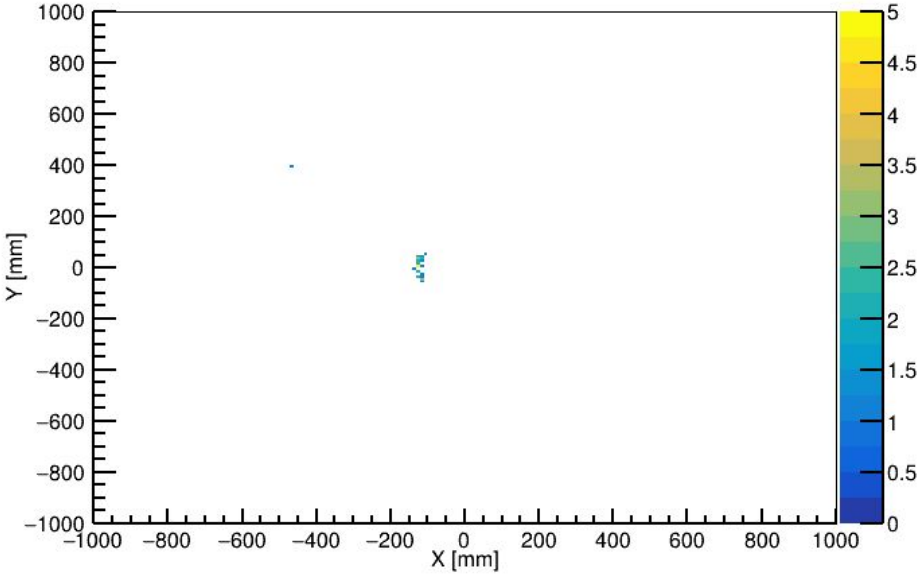
- observed slightly larger number of tracks with associated DT hit;
- efficiency was estimated as a ratio of events with charged tracks having DT hits over the number of events having dRICH hits;
- expected overall 99% efficiency, observed for >0 MC tracks heading into dRICH: 99-100% (99% for 1 MC track) overall value (from >0 MC tracks) 99.6%.
- 4.7 times more stat=0 track hits than stat=1.

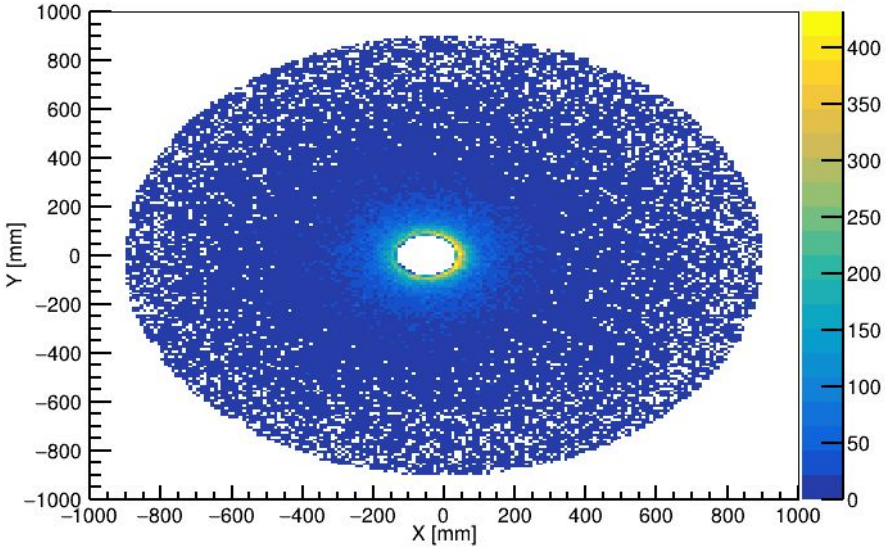




Tagger performance: inefficiency (1 MC track in dRICH)

- MC tracks not detected in Tagger crosses tagger plane at X=-120 mm, Y=0 (extrapolated from vertex, magnetic field swimming not accounted);
- this corresponds to the left edge of the beam pipe (pipe center is computed incorrectly? x_ip_off=-DT_Zmin*0.025).

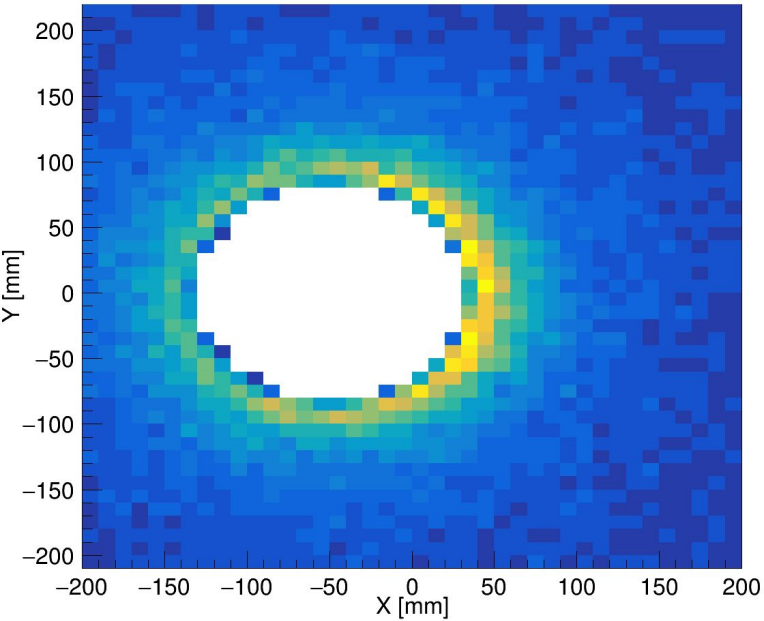




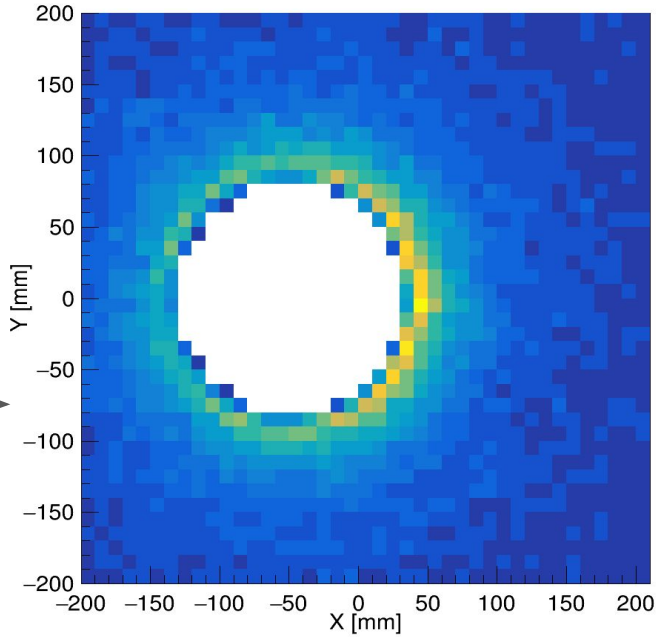
Beam pipe centering

- moving beam pipe hole by +5 mm from nominal produces more symmetric hit distribution, but perhaps further offset is necessary - why?

$x_0 = -Z_{center} * \tan(25\ mr)$

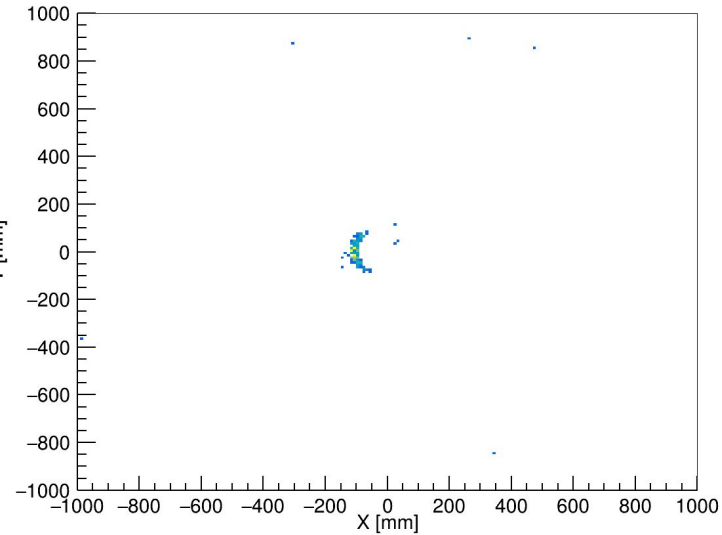


dx=+5 mm



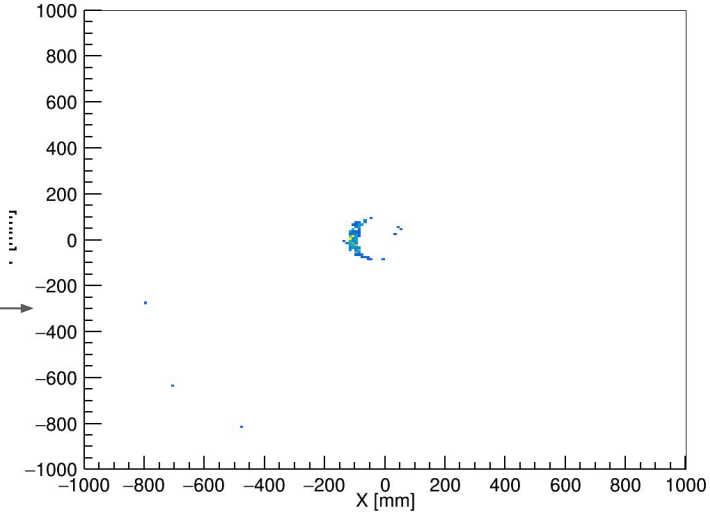
Tagger performance: inefficiency (0 MC track in dRICH)

- 0 MC tracks means that there are no tracks with |Vz|<100 mm and 1.5<η<3.5;
- most of 0 track events have dRICH hits from tracks having η>3.5 (3.5-3.7), and high (10-50 GeV) momenta, few events have tracks V_z>100 mm;
- perhaps we need to reduce lower radius of fibers to cover the projected lowest edge of the most distant edge of aerogel [dZ*tan(3.46°)~3 mm?].



dx=+5 mm

-12%



Tagger performance: number of hits

- **Two hits per each track:**

DT-Hit: 0 , Edep= 429.848 , X,Y,Z,t= -25.5122 420.961 1977.58 7.0294 , index= 10 , size= 52, MCpart= 211, Stat= 1, P= 2.53549, V_Z= -42.4842, Eta= 2.2667

DT-Hit: 1 , Edep= 391.202 , X,Y,Z,t= -25.5762 421.384 1979.63 7.0364 , index= 10 , size= 52, MCpart= 211, Stat= 1, P= 2.53549, V_Z= -42.4842, Eta= 2.2667

DT-Hit: 2 , Edep= 309.036 , X,Y,Z,t= 8.36265 -592.355 1977.71 7.30487 , index= 16 , size= 52, MCpart= 211, Stat= 1, P= 0.746503, V_Z= -42.4842, Eta= 1.87898

DT-Hit: 3 , Edep= 338.409 , X,Y,Z,t= 8.59101 -592.862 1979.63 7.31213 , index= 16 , size= 52, MCpart= 211, Stat= 1, P= 0.746503, V_Z= -42.4842, Eta= 1.87898

DT-Hit: 4 , Edep= 341.901 , X,Y,Z,t= -521.465 345.569 1977.58 7.19027 , index= 17 , size= 52, MCpart= -211, Stat= 1, P= 4.21484, V_Z= -42.4842, Eta= 1.88967

DT-Hit: 5 , Edep= 388.259 , X,Y,Z,t= -521.986 345.951 1979.63 7.20039 , index= 17 , size= 52, MCpart= -211, Stat= 1, P= 4.21484, V_Z= -42.4842, Eta= 1.88967

DT-Hit: 6 , Edep= 175.342 , X,Y,Z,t= -521.424 345.332 1977.93 7.19326 , index= 49 , size= 52, MCpart= 11, Stat= 0, P= 0.00348498, V_Z= 1977.33, Eta= 1.90419

DT-Hit: 7 , Edep= 518.119 , X,Y,Z,t= -521.185 344.923 1979.63 7.20051 , index= 49 , size= 52, MCpart= 11, Stat= 0, P= 0.00348498, V_Z= 1977.33, Eta= 1.90419

DT-Hit: 8 , Edep= 6.16968 , X,Y,Z,t= -573.632 349.438 1977.89 7.428 , index= 48 , size= 52, MCpart= 11, Stat= 0, P= 0.0053879, V_Z= 1962.26, Eta= 1.1515

DT-Hit: 9 , Edep= 0.85571 , X,Y,Z,t= -557.074 371.786 1980.54 7.33314 , index= 48 , size= 52, MCpart= 11, Stat= 0, P= 0.0053879, V_Z= 1962.26, Eta= 1.1515

DT-Hit: 10 , Edep= 364.977 , X,Y,Z,t= -560.299 149.708 1977.58 7.15301 , index= 14 , size= 52, MCpart= -211, Stat= 1, P= 3.15382, V_Z= -42.4842, Eta= 1.95427

DT-Hit: 11 , Edep= 297.461 , X,Y,Z,t= -560.858 149.91 1979.63 7.16013 , index= 14 , size= 52, MCpart= -211, Stat= 1, P= 3.15382, V_Z= -42.4842, Eta= 1.95427

Cell ID issue

- simulation prints a lot of warnings:

```
Geant4VolumeManager INFO  +++   Bad volume Geant4 Path: DRT_17/AV_8590!fiber_ass_X_6#6!fiber_core_n_325#325
Geant4VolumeManager INFO  +++   Bad volume Geant4 Path: DRT_17/AV_8588!fiber_ass_Y_4#4!fiber_core_n_258#258
Geant4VolumeManager INFO  +++   Bad volume Geant4 Path: DRT_17/AV_8588!fiber_ass_Y_4#4!fiber_core_n_567#567
```

- used similar to dRICH code to form Cell ID:

```
pssPV.addPhysVolID("layer", 0).addPhysVolID("fiber", n_fibers).addPhysVolID("sipm", 0);
auto sensorID = encodeSensorID(pssPV.volIDs());
DetElement pssDE(det, "sensor_de_" + sensorIDname, sensorID);
<id>system:8,layer:3,fiber:12,sipm:6,x:32:-16,y:-16</id>
```

from geo.cpp (printed with cout):

: 00000000000000000000000000000000000000000000110000000000000000

in the simulated edm4hep root file becomes:

: 11111111110100110000000000000010000000000000000000000000000000

Conclusions

- dRICH Tagger was implemented in DD4HEP code of epic software;
- observed reasonable deposited energy and time distributions;
- number of hit groups in Tagger is similar to dRICH;
- efficiency w.r.t. dRICH seems to be about 99.6%;
- observed number of secondaries 3 times larger than primaries;
- number of hits from secondaries is 5 times larger than from primaries;
- need help to resolve issues with warnings and Cell ID.