dRICH Interaction Tagger simulations v.2

M. Osipenko

Motivation

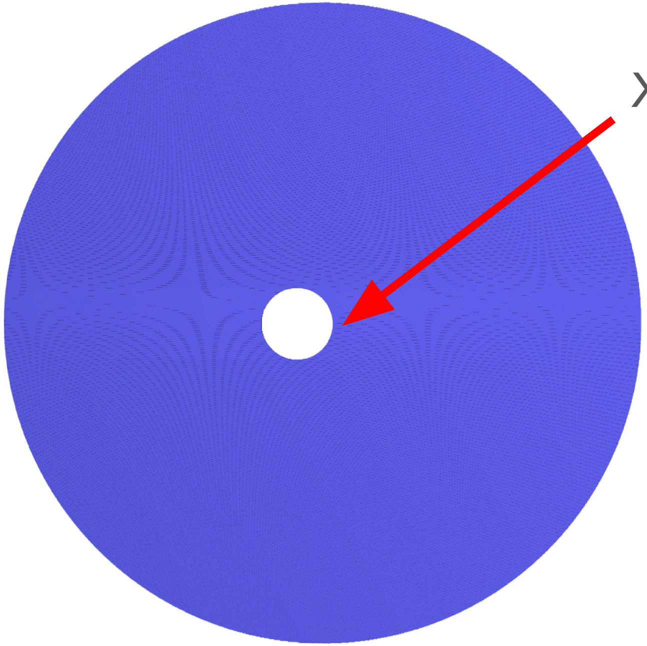
- dRICH is the ePIC sub-detector generating the highest FE data rate;
- thermal 1 p.e. background generated by SiPMs is irreducible at channel/RDO level;
- fast external trigger on hadrons crossing dRICH can reduce data rate;
- scintillator hodoscope in front of the aerogel was proposed as a possible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

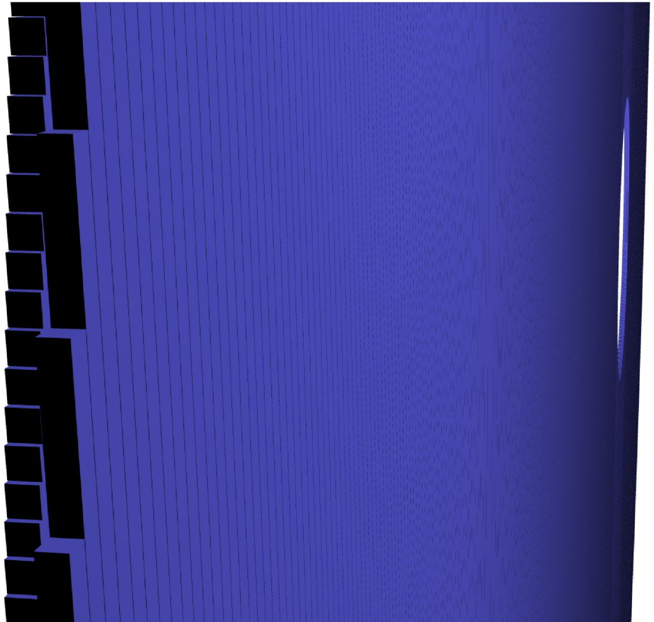
Tagger implementation in ePIC DD4HEP code

- two layers of 2 mm wide scintillation fibers, 2% cladding thickness, 50 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

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

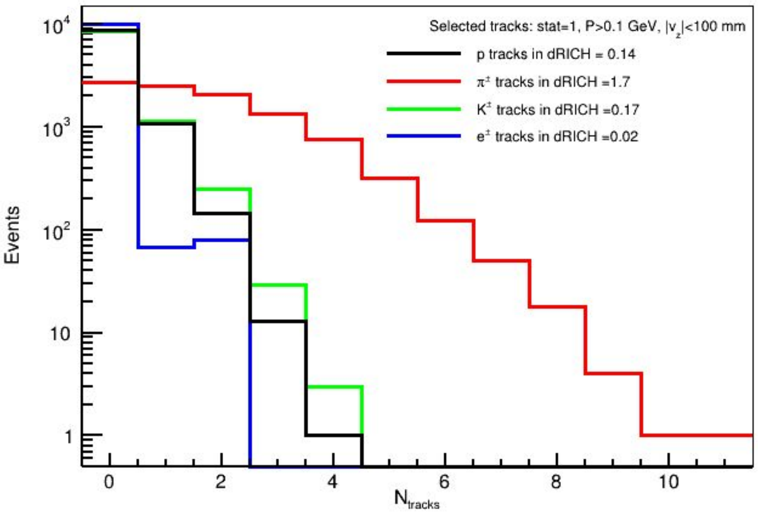


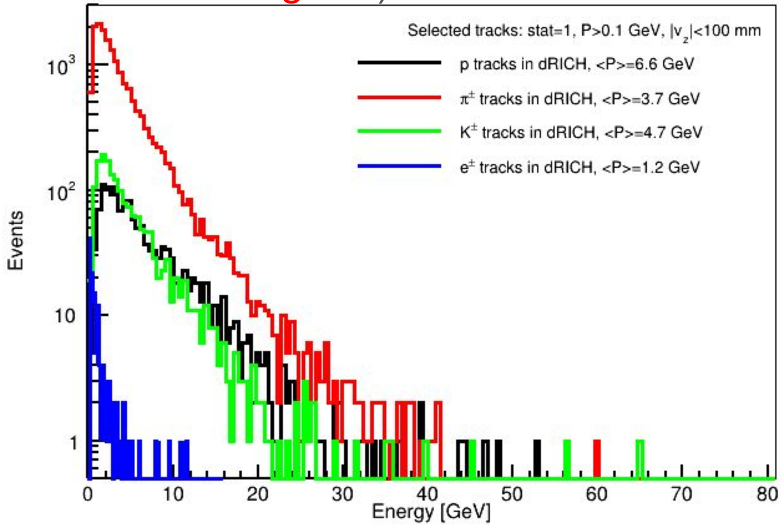
SIDIS simulations used for performance studies

pythia8NCDIS_10x100_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_vtxfix_1.hepmc (σ=0.556 μb):

$$Rate = \frac{N_{hits}}{N_{events}} \times \sigma_{gen}[\mu b] \times L[\mu b^{-1} s^{-1}]$$

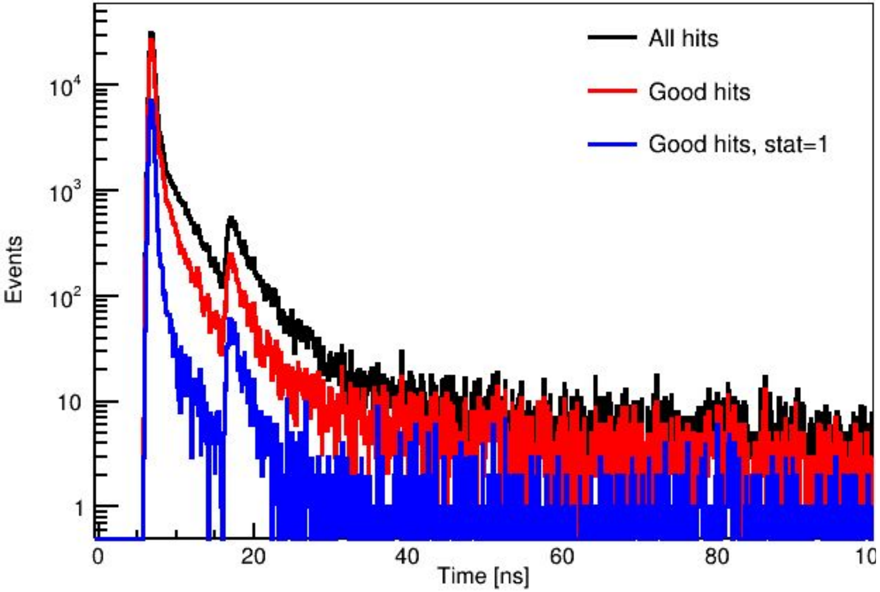
- beams: e 10 GeV x p 100 GeV (early physics compatible), Q^2>1 GeV^2, beam angle effects;
- each event has about 2 charged tracks in dRICH acceptance, most of them are 4 GeV pions;
- stat=1 - selects final state real particles (stat=0 for secondaries produced by Geant4);
- $|V_z|$<100 mm - selects particles created at IP (few primaries have larger Z).

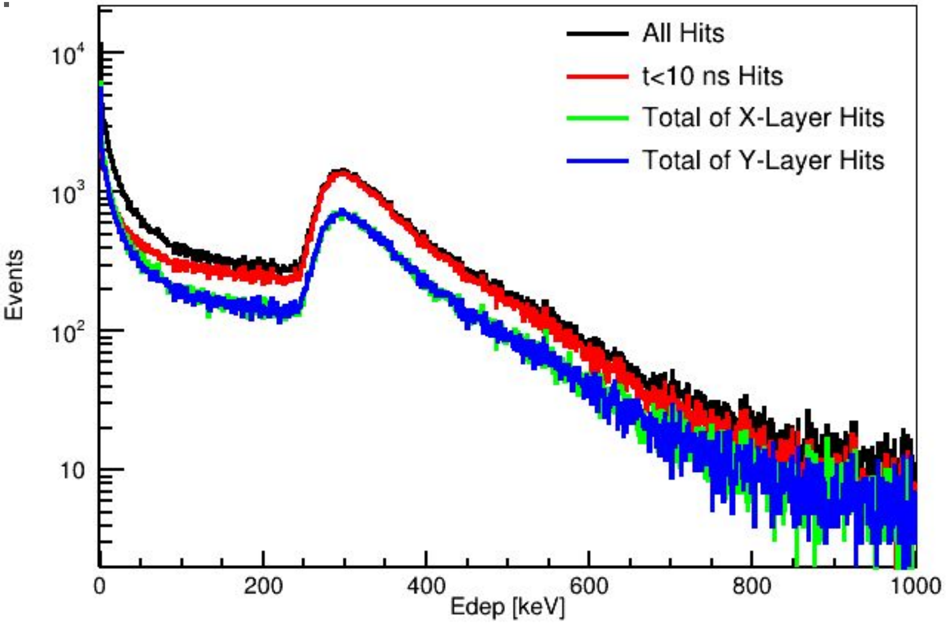




Tagger performance: energy deposited in scintillator

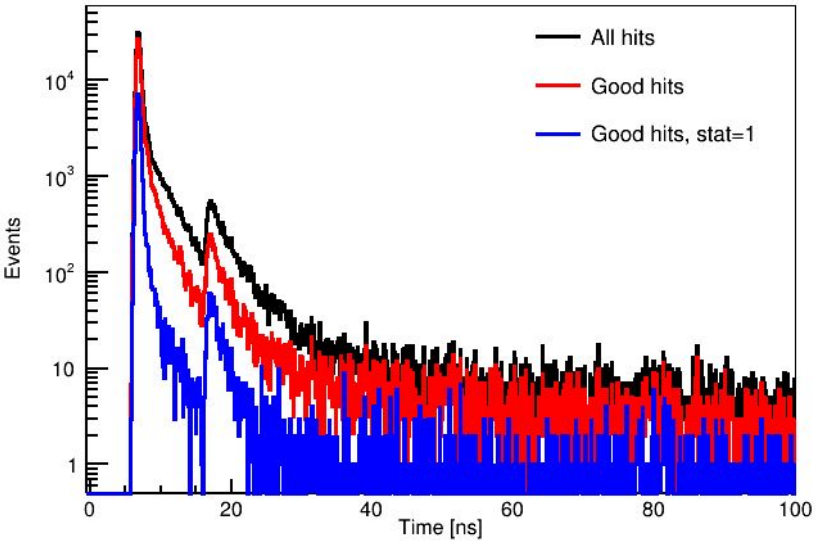
- most probable deposited energy =300 keV/layer =2400 photons;
- assuming trapping efficiency of 4.2% (Kuraray) gives 50 photons/SiPM;
- assuming SiPM PDE=40% (S13360-3050) gives 20 p.e./SiPM;
- threshold could be set at 100 keV~7 p.e./SiPM;
- expected Poisson inefficiency <0.1%.

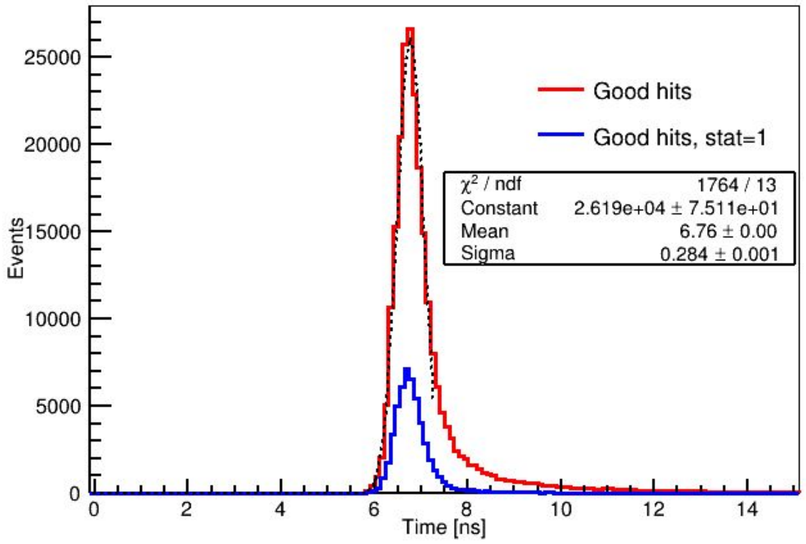




Tagger performance: time

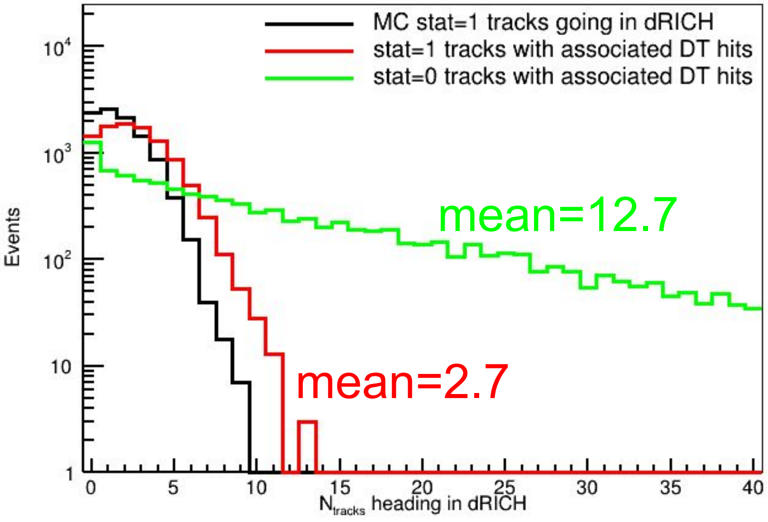
- hit time distribution has a Gaussian shape with a long r.h.s. tail;
- the tail is mostly generated by secondaries (stat=0);
- time for 85% of hits lies within 2 ns (t=6÷8 ns), 92% in 10 ns (doesn't include light propagation in fiber);
- mean number of good dIT hits (>100 keV, <10 ns) =20, or about 10 hits/layer; it will allow time correlations between fibers, improving "start" time.

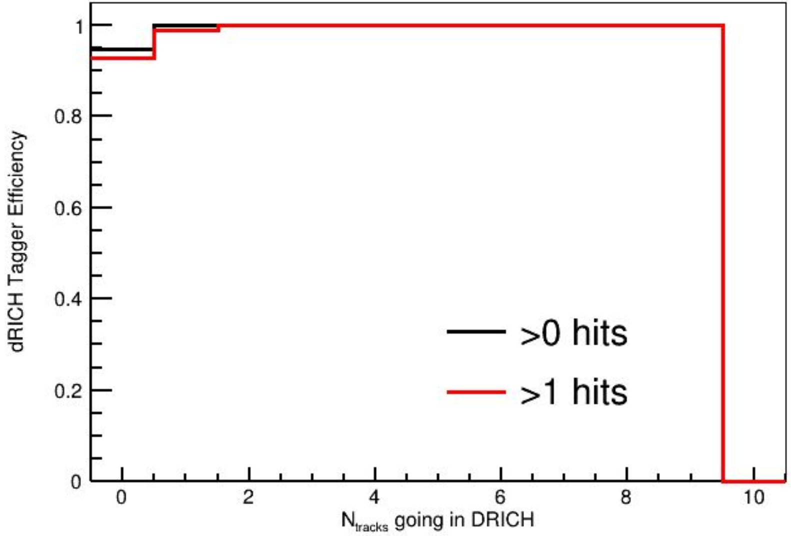




Tagger performance: efficiency

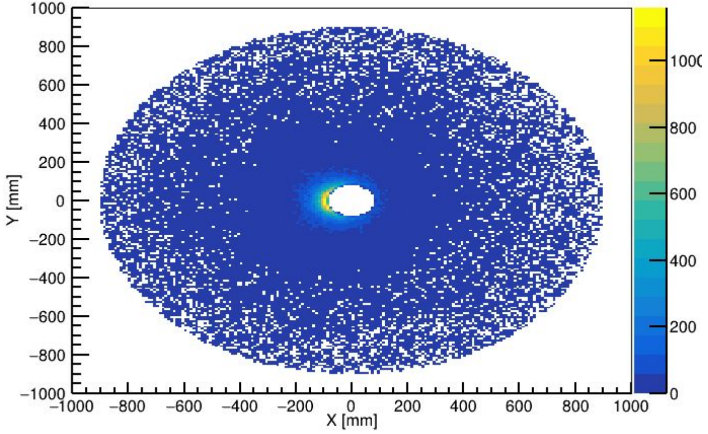
- observed in average 15 tracks/event with associated DT hits;
- efficiency was estimated as a ratio of events with charged tracks having DT hits over the number of events having dRICH hits;
- expected overall 99% efficiency, observed for >0 MC tracks heading into dRICH: 99-100% (99% for 1 MC track) overall value (from >0 MC tracks) 99.97%.
- 4.7 times more stat=0 (secondary) track hits than stat=1.





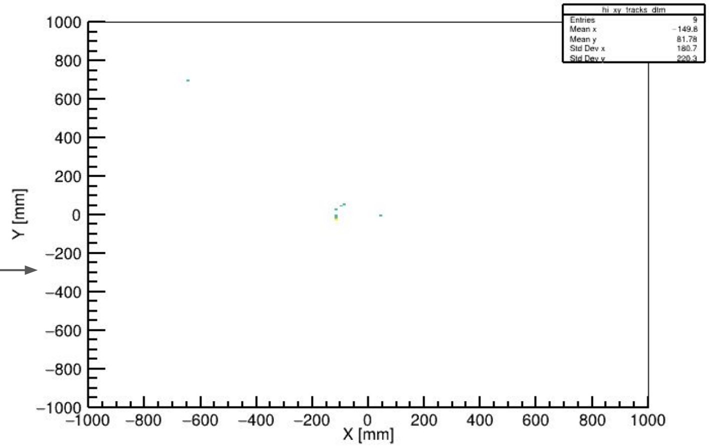
Tagger performance: inefficiency

- 0 MC tracks means that there are no tracks with $|V_z|<100$ mm and $1.5<\eta<3.5$;
- most of 0 track events have dRICH hits from tracks having $\eta>3.5$ (3.5-3.7), and high (10-50 GeV) momenta, few events have tracks $V_z>100$ mm;
- missing tracks cross DT-plane just around beam pipe;
- 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^o)~3 mm?].



tracks without DT hits

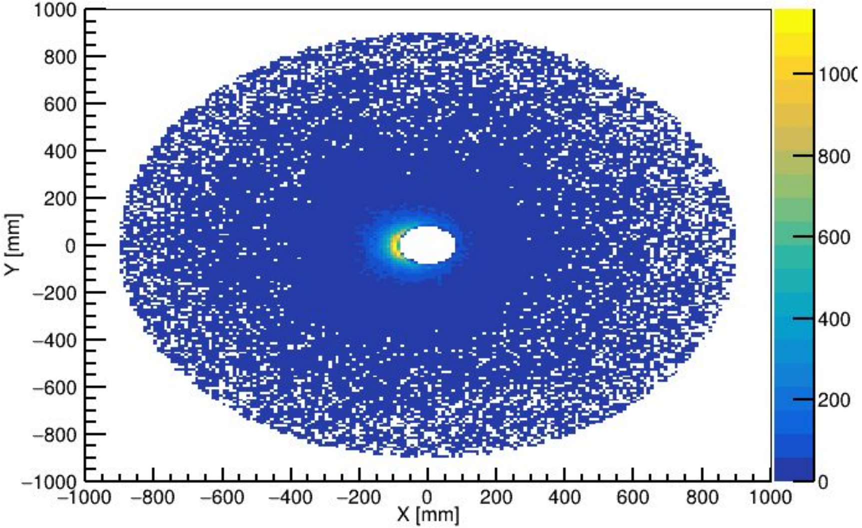
-7% at 0 MC



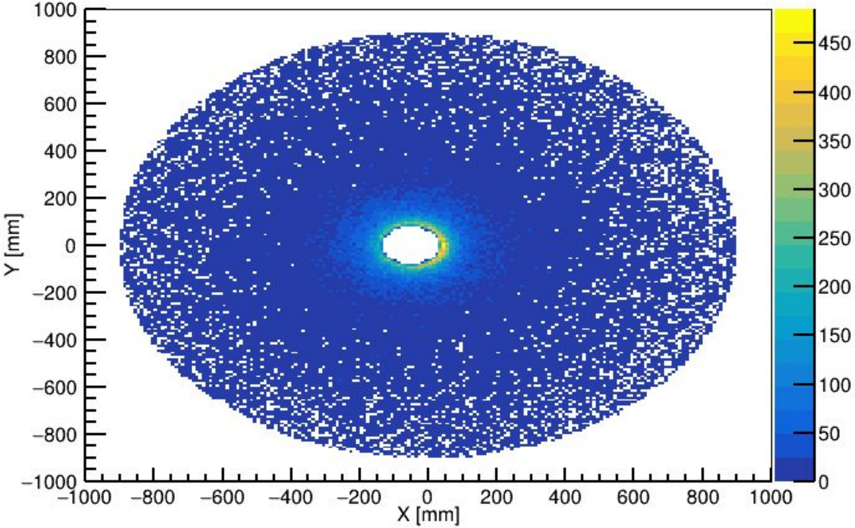
Beam pipe offset

- beam pipe is not located at the IP center (X=0,Y=0);
- but presently dRICH aerogel in DD4HEP simulations has centered hole;
- since our DT efficiency is defined relative to dRICH we must use central hole for consistency;
- clear asymmetry of hit distributions, probably produced by the secondaries (primaries must be symmetric).

central beam hole in DT



X-offset beam hole in DT

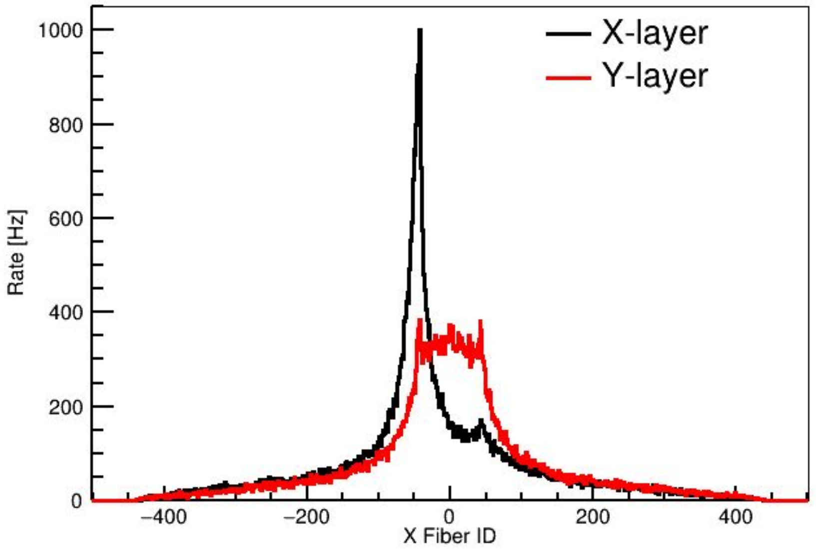


DT rates at nominal luminosity

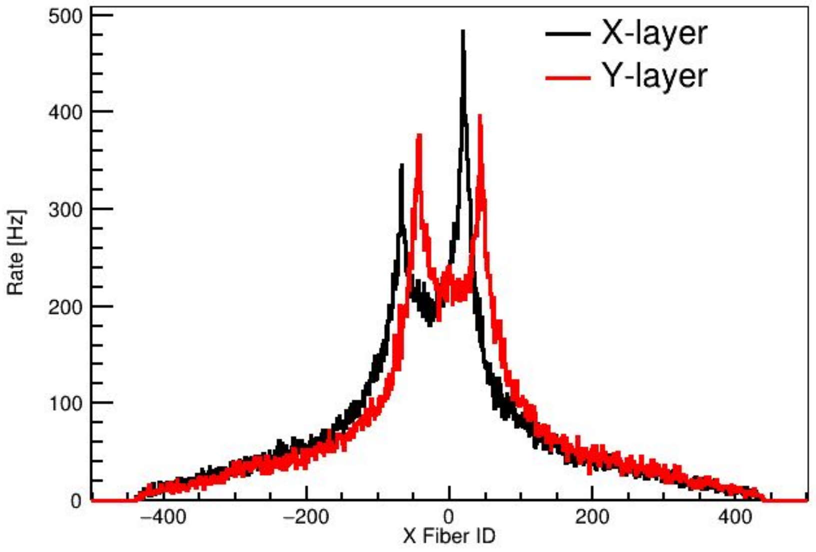
- we assumed the maximum nominal ePIC luminosity of 10^{34} 1/cm^2/s;
- observed fiber rate are not exceeding 1 kHz (70 kHz total), rendering probability of accidental coincidences negligible;

$$Rate = \frac{N_{hits}}{N_{events}} \times \sigma_{gen}[\mu b] \times L[\mu b^{-1} s^{-1}]$$

central beam hole in DT



X-offset beam hole in DT



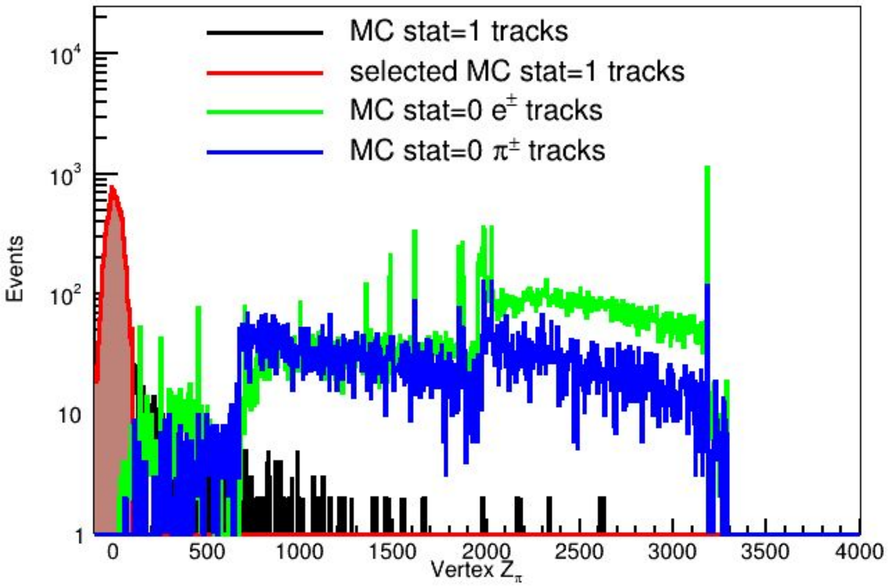
Conclusions

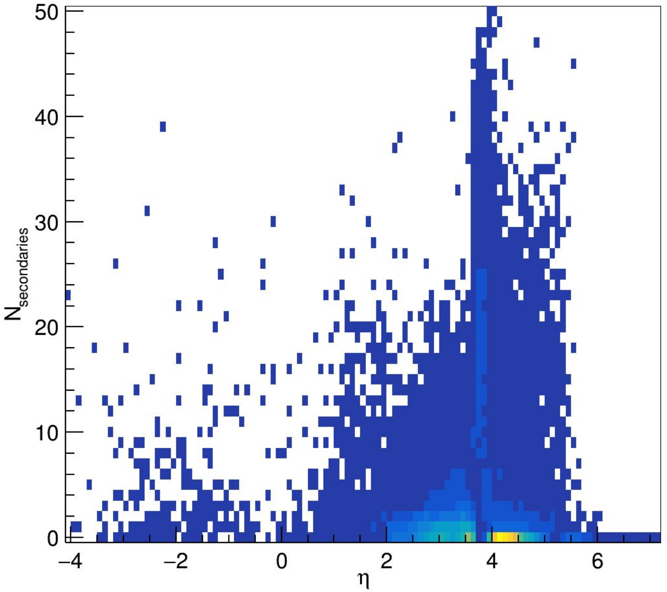
- dRICH Tagger was implemented in DD4HEP code of epic software;
- observed reasonable deposited energy and time distributions;
- number of hit groups in Tagger is similar to dRICH;
- efficiency w.r.t. dRICH seems to be about 99.9%;
- observed number of secondaries 3 times larger than primaries;
- number of hits from secondaries is 5 times larger than from primaries;
- Tagger rate in each fiber is not exceeding 1 kHz at maximum ePIC luminosity.

BACKUP

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;

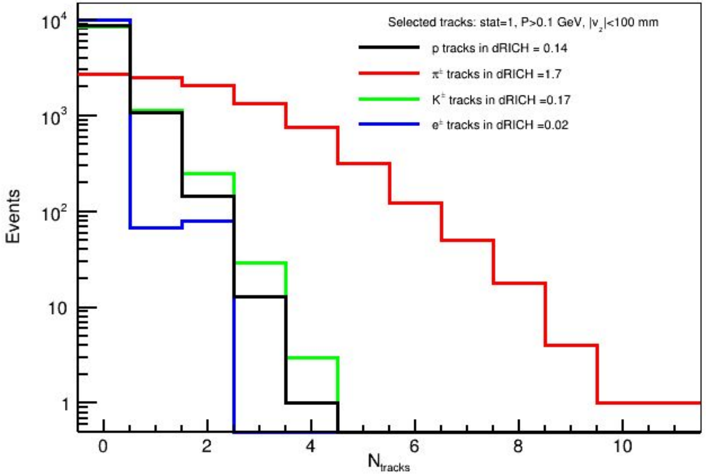


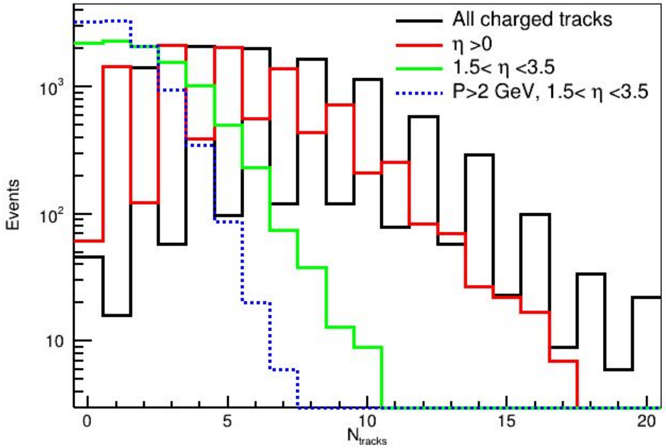


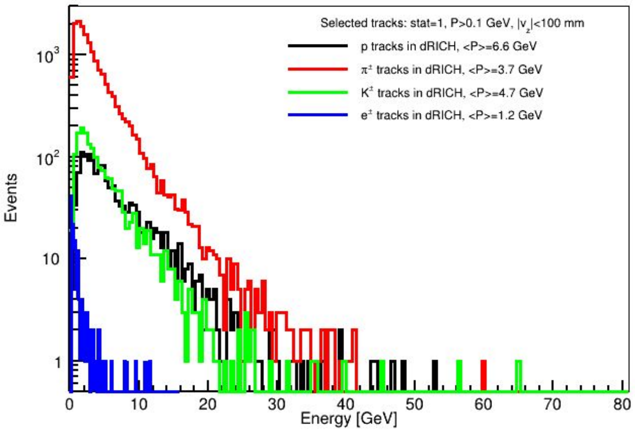
SIDIS simulations used for performance studies

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), Q^2>1 GeV^2, 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 (stat=0 - secondaries);
- $|V_z|$<100 mm - selects particles created at IP (few primaries lost).

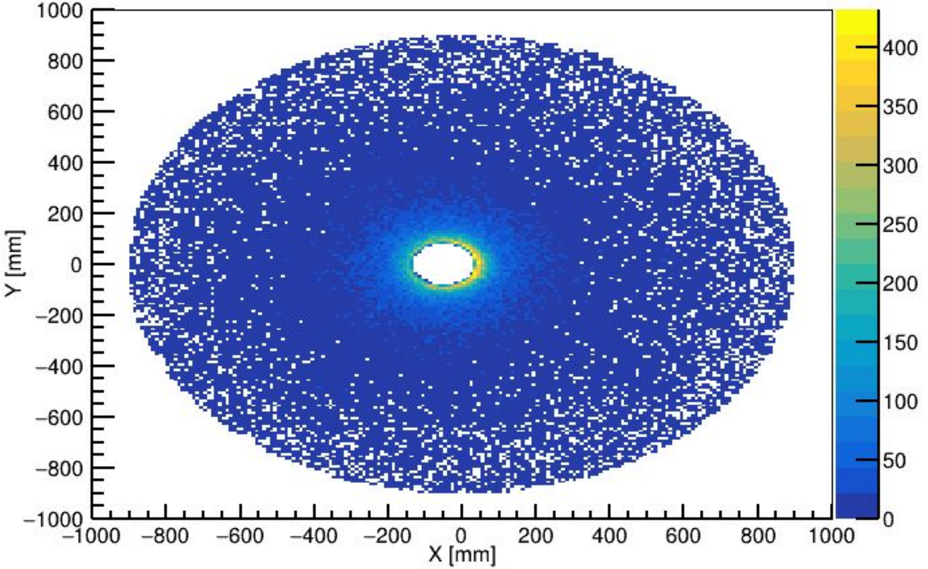


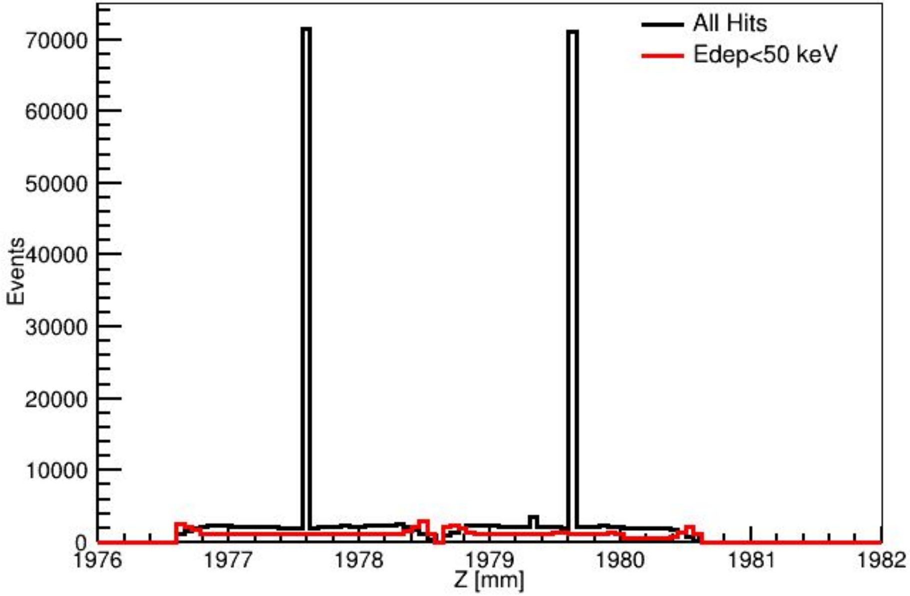




Tagger performance: spatial

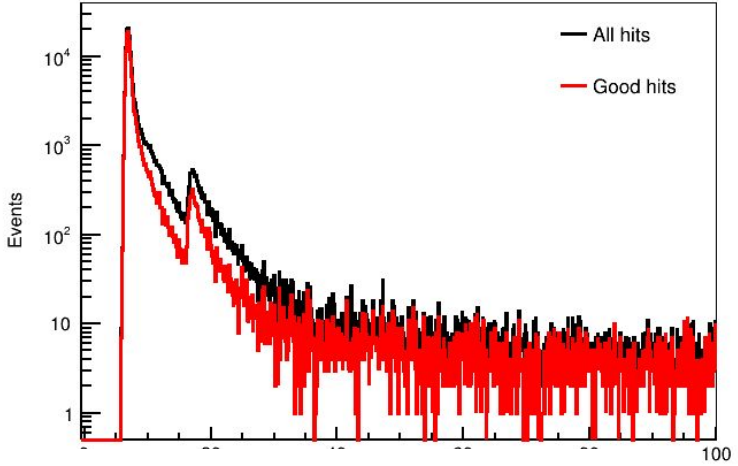
- dIT hits have cylindrical distribution around beam pipe;
- enhancement of rate around beam pipe is visible (asymmetric?);
- two layers in Z are clearly visible, hits outside of layers are low energy (how is it possible?);
- the two layers are found at Z=1977.59 mm and Z=1979.63 mm.

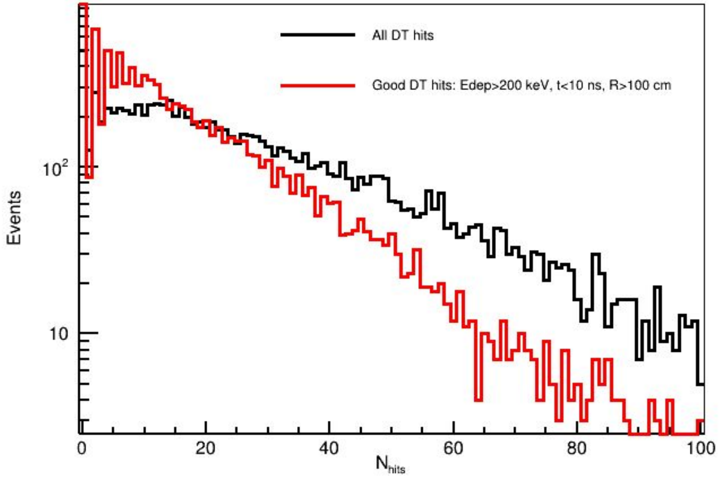


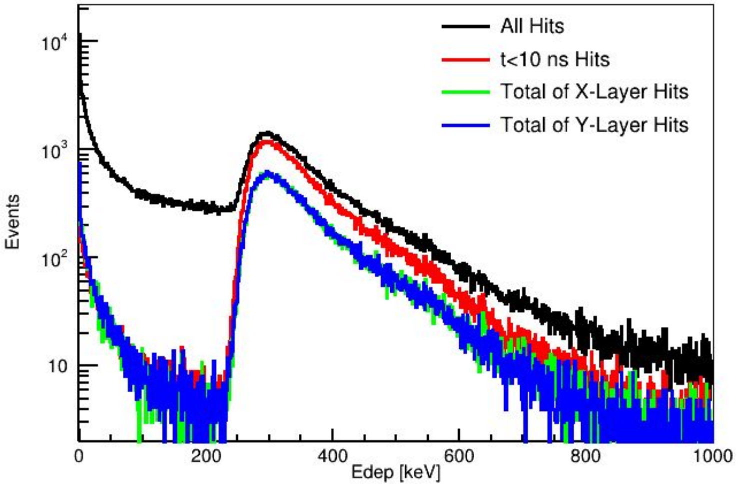


Tagger performance: time/edep

- 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);



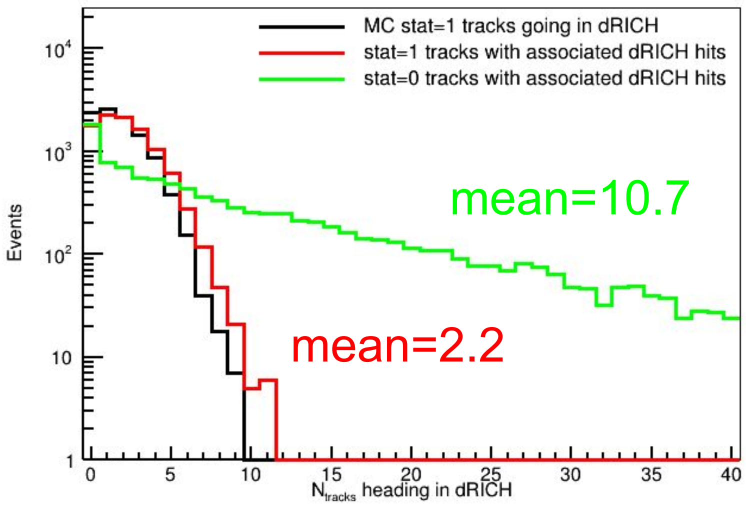


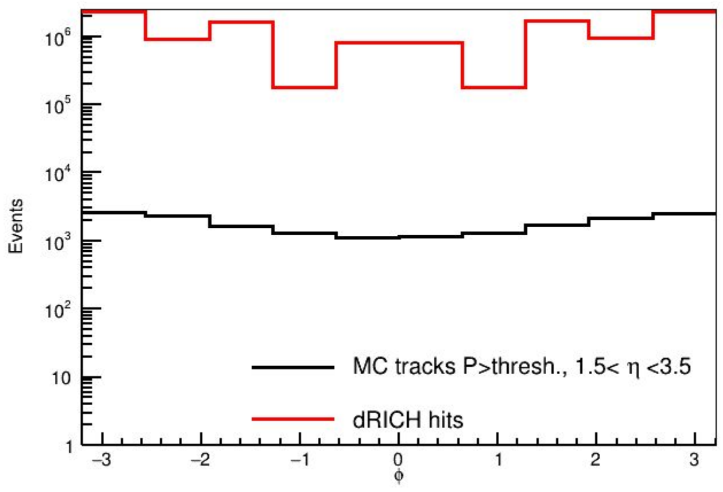


dRICH performance

- 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]]
```

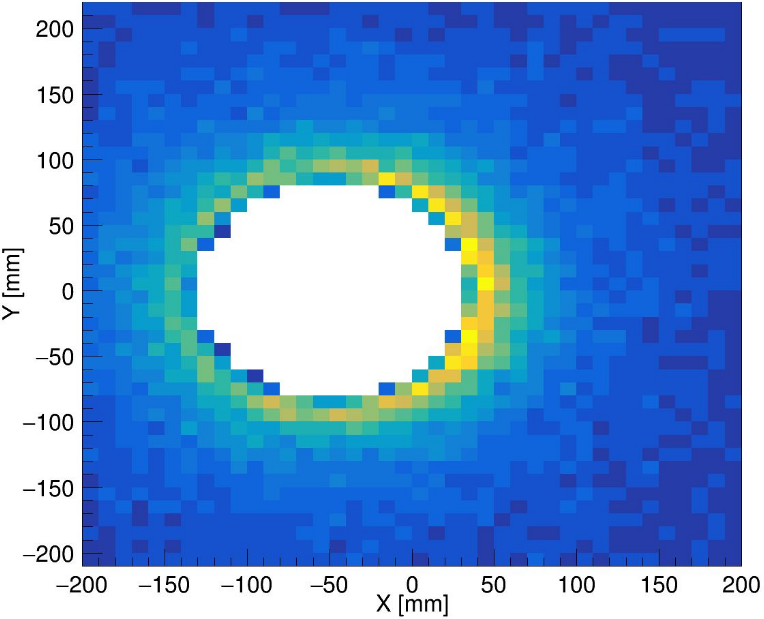




Beam pipe centering

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

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



dx=+5 mm