Update on dRICH simulation studies

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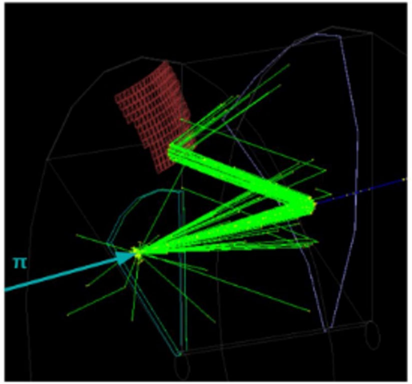
Outline

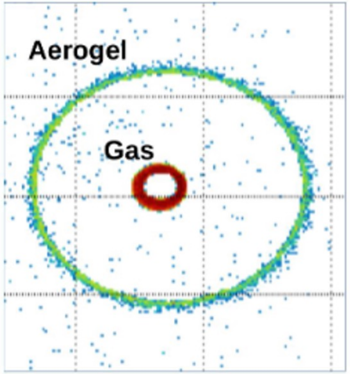
1. Recap
2. Look up tables
3. Studies related to aerogel parameter
4. Effect from upstream TOF detector
5. Effect of new magnetic field
6. A couple of words on timing
7. Conclusion

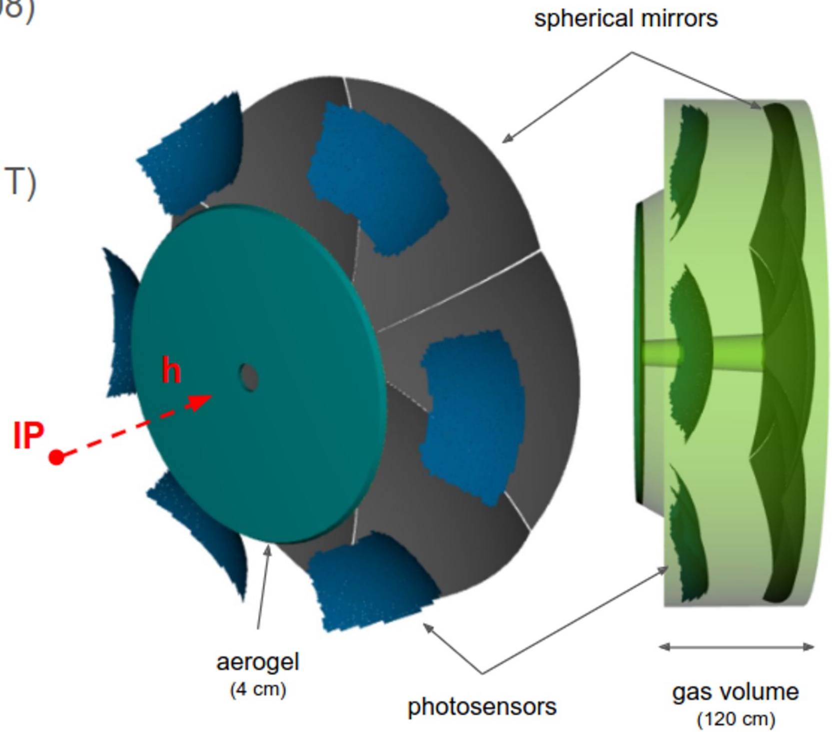
Recap: Detector description

- **radiators:** aerogel (n ~ 1.02) and C_2F_6 (n ~ 1.0008)
- **mirrors:** large outward-reflecting, 6 open sectors
- **sensors:** 3x3 mm^2 pixel, 0.5 m^2 / sector
  - single-photon detection inside high B field (~ 1 T)
  - outside of acceptance, reduced constraints
  - best candidate for SiPM option



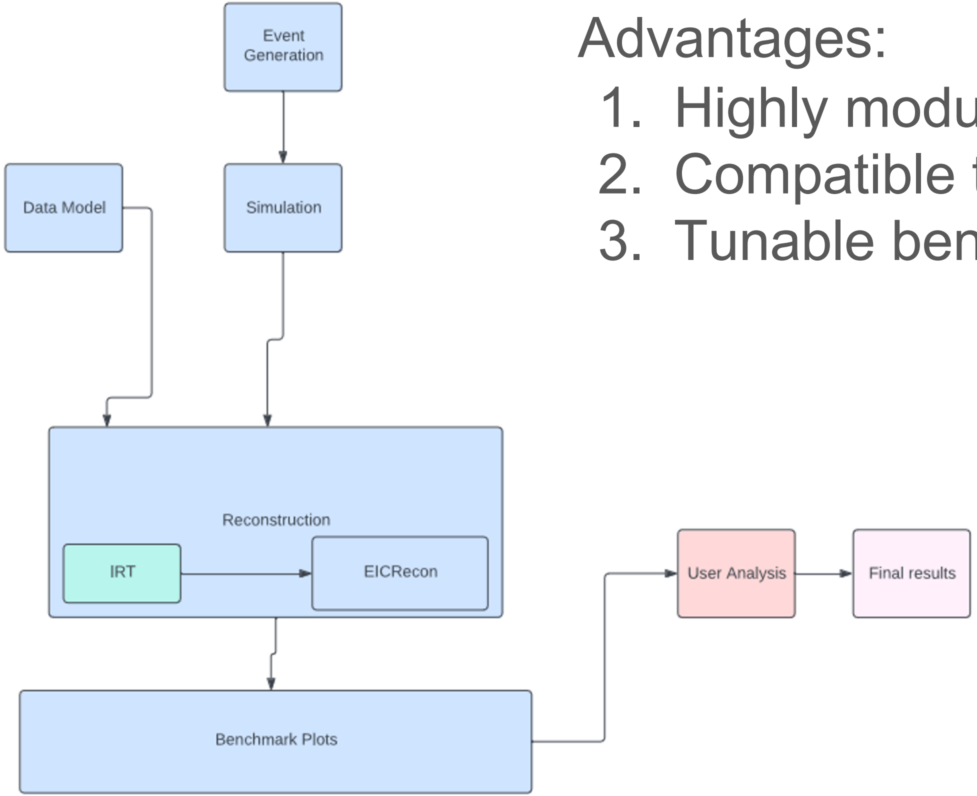
example event (accumulated hits)





Recap : Software stack

Once you ride the steep curve, the software stack is extremely friendly!



Advantages:

1. Highly modular
2. Compatible to plugin multiple algorithms
3. Tunable benchmark plots

Caveats:

1. Cutting edge software: requires dedicated efforts to learn the software architecture.
2. Bleeding edge: need to make sure, your stack is always updated.

Recap : Software stack (simulation outcome)

```
branch: DRICHHits                10237785
branch: _DRICHHits_MCParticle    294560
branch: EcalBarrelImagingHits     71667
branch: _EcalBarrelImagingHits_contributions     22791
branch: EcalBarrelImagingHitsContributions     63834
branch: _EcalBarrelImagingHitsContributions_particle     23172
branch: EcalBarrelScFiHits     1419869
branch: _EcalBarrelScFiHits_contributions    146268
branch: EcalBarrelScFiHitsContributions    991752
branch: _EcalBarrelScFiHitsContributions_particle     88737
branch: EcalEndcapNHits          75867
branch: _EcalEndcapNHits_contributions     28571
branch: EcalEndcapNHitsContributions    100082
branch: _EcalEndcapNHitsContributions_particle     25785
branch: EcalEndcapPHits        2013162
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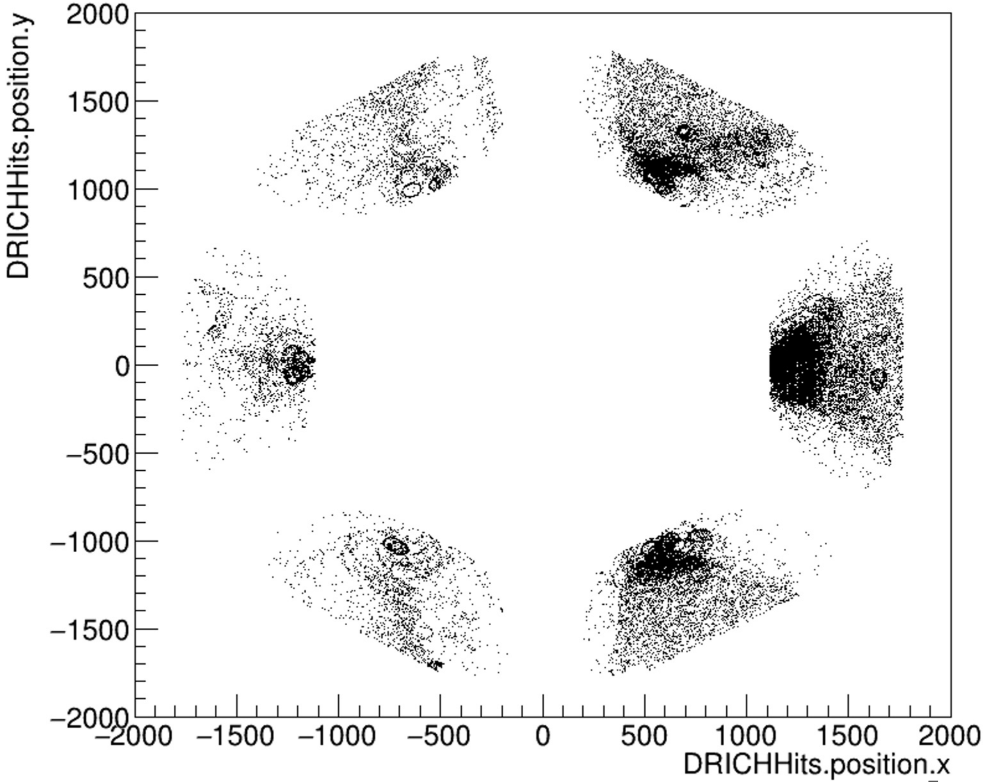
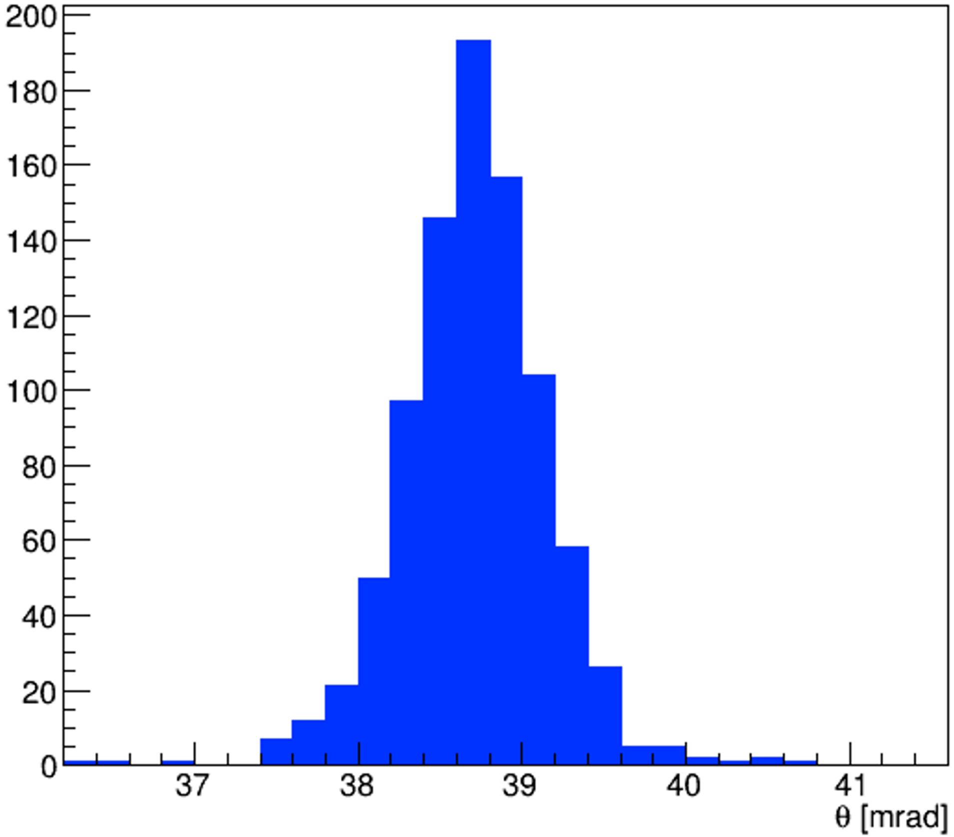
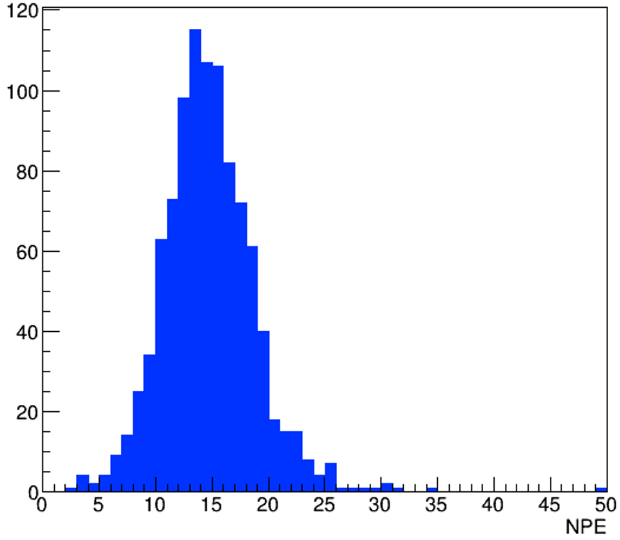


Recap : Software stack (recons. and analysis outcome)





Information related to single photon hits are also stored!

Studies for the look-up table

What is a look-up table (LUT)?

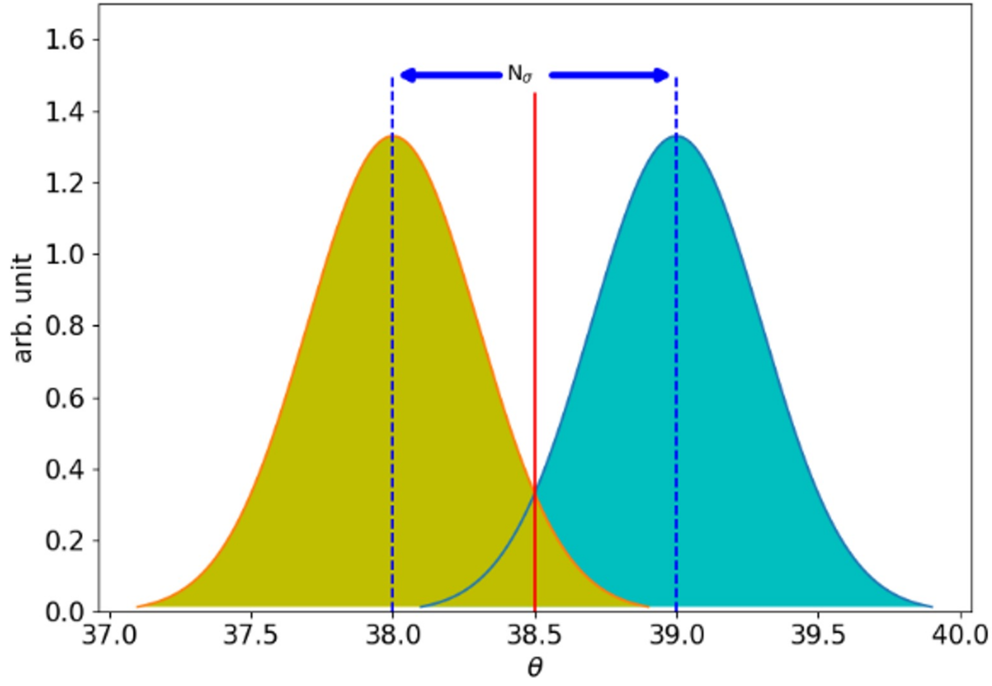
- A look-up table comprises a set of probabilities of a PID detectors performance.
- Not a final PID probability coming out of complete PID reconstruction algorithm.
- It is a temporary solution to use the PID detector information in a predetermined tabular form to use a random generator to smear the true MC PID information.

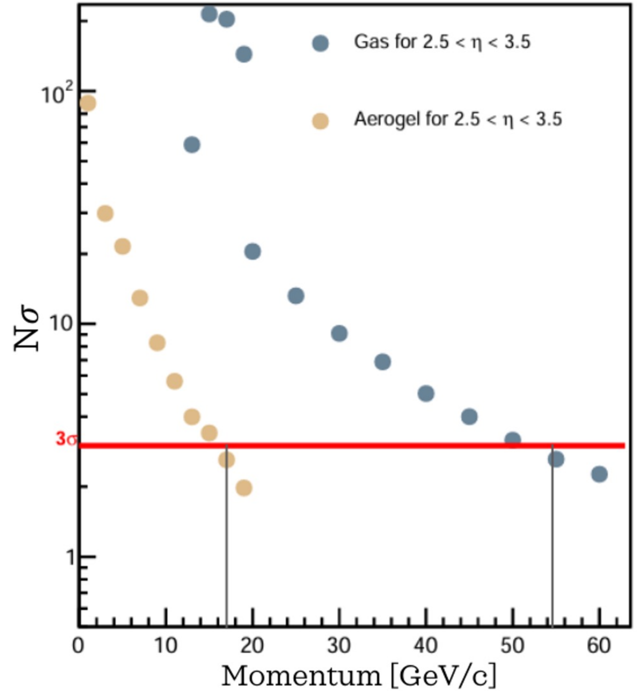
$$\epsilon(j \to i) = \frac{N(j \to i)}{N(j)}$$

$$M_{RICH} = \begin{pmatrix} \epsilon(\pi \to \pi) & \epsilon(\pi \to K) & \epsilon(\pi \to p) & \epsilon(\pi \to X) \\ \epsilon(K \to \pi) & \epsilon(K \to K) & \epsilon(K \to p) & \epsilon(K \to X) \\ \epsilon(p \to \pi) & \epsilon(p \to K) & \epsilon(p \to p) & \epsilon(p \to X) \end{pmatrix} \qquad \vec{T}_h = M_{RICH}^{-1} . \vec{I}_h$$

Similar to a standard PID matrix, the LUT table will be used for smearing the true MC information.

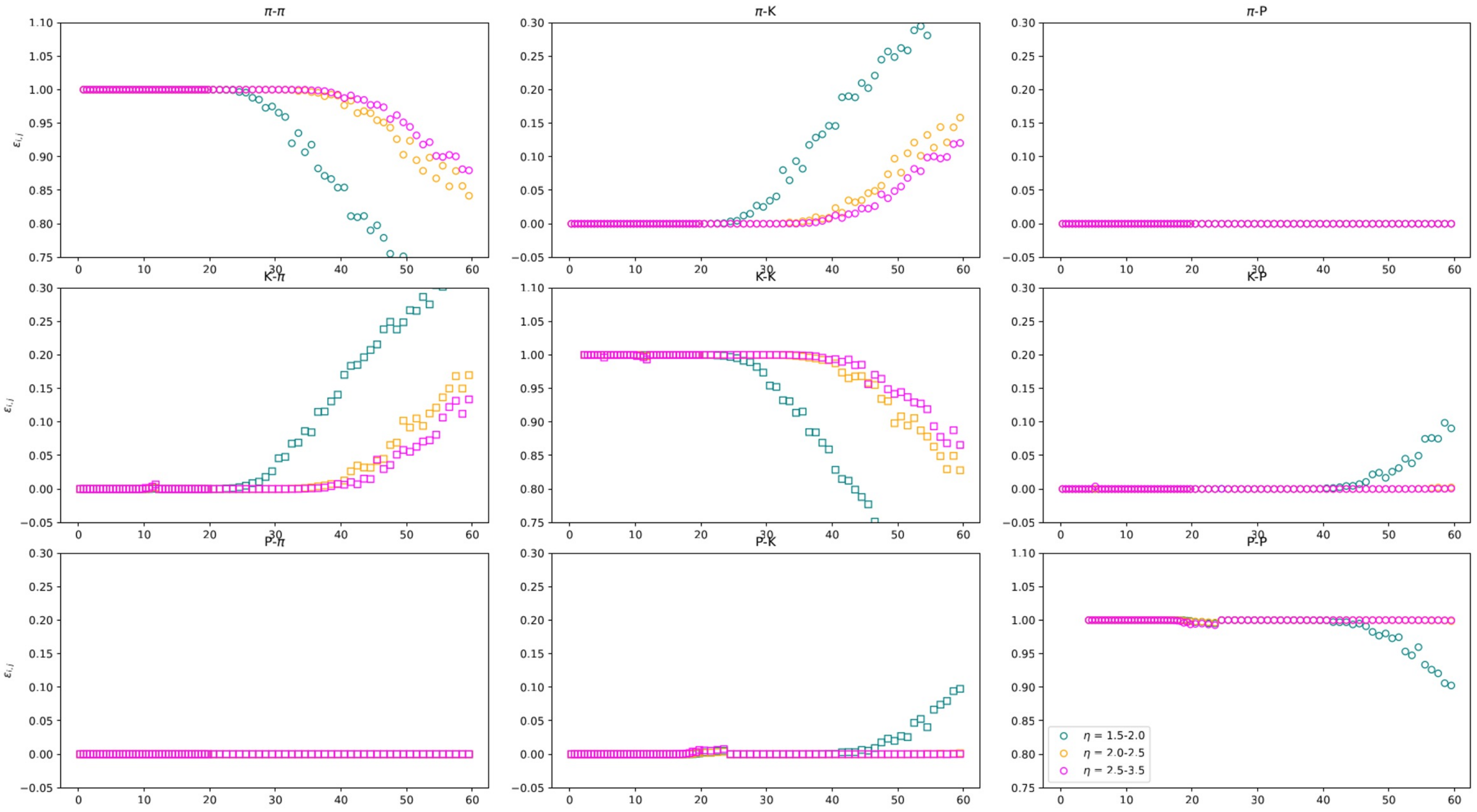
How is a LUT is computed for dRICH



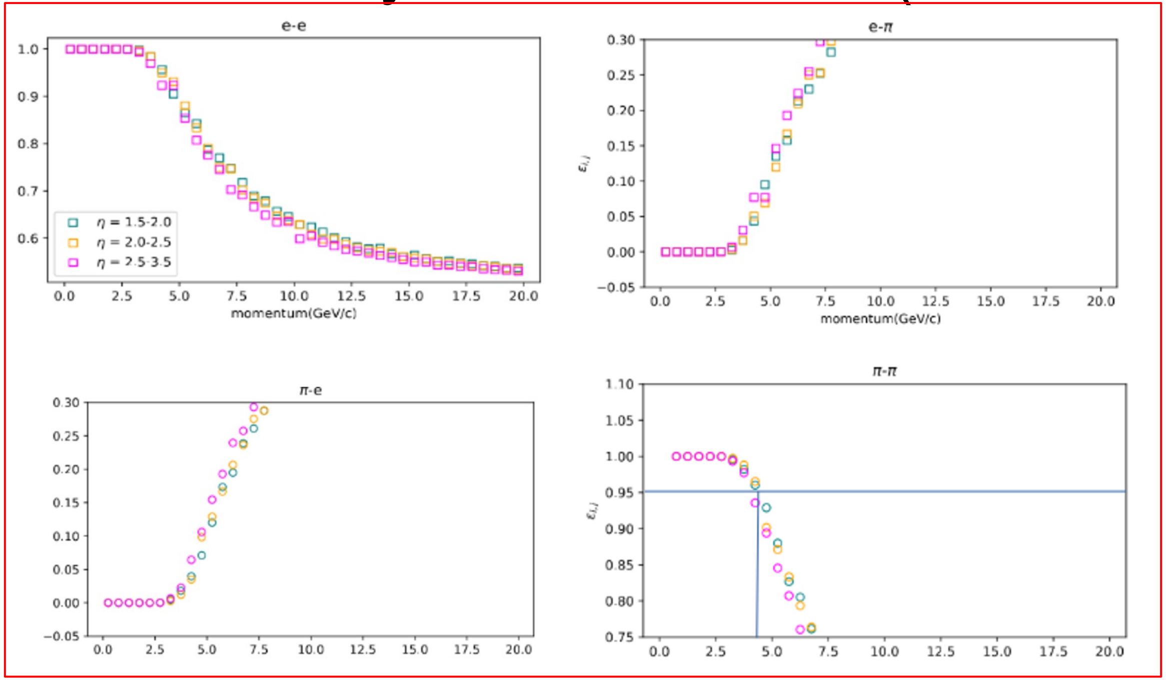


LUT→ Translate Number of sigma separation to a probability under the curve

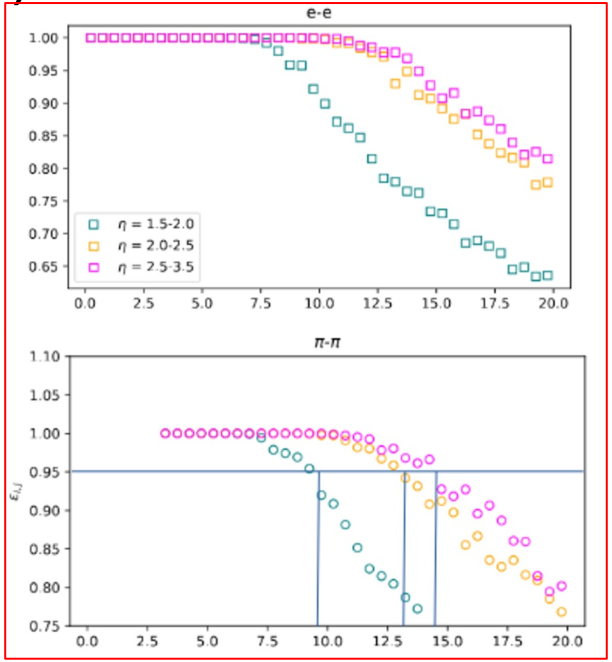
Preliminary LUT for dRICH (merged aerogel and gas info)



Preliminary LUT for dRICH (electron pion)



Aerogel

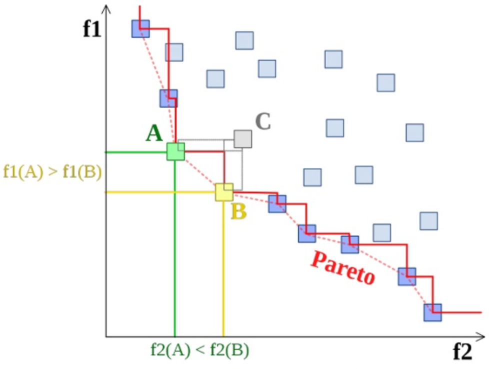


Gas

A couple of words on AI/ML based dRICH geometric optimization (Studies by Connor Pecar Duke U)

Multi-objective Bayesian optimization (MOBO)

- Can optimize a multi-objective space, with the objective of finding the set of best possible designs and tradeoffs between objectives
- Aiming to construct best possible estimate of the Pareto front
- For dRICH: performance in different p/η ranges as separate objectives



https://en.wikipedia.org/wiki/Pareto_front

Duke

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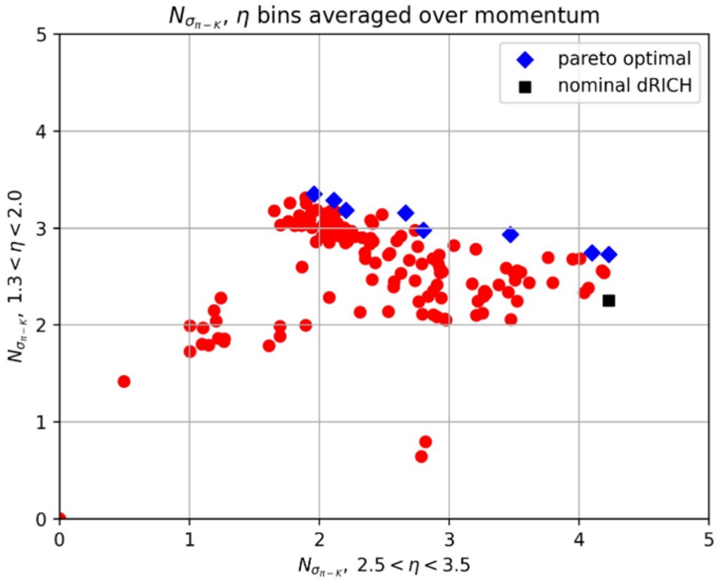
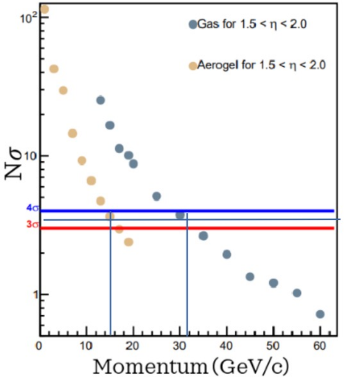
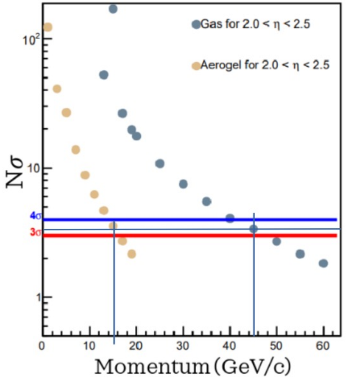
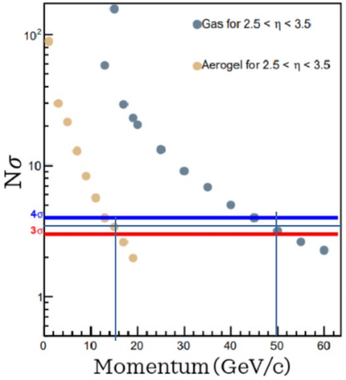


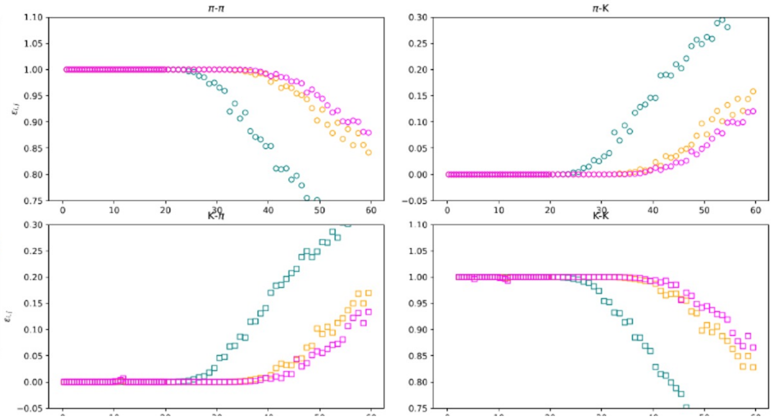
- ❑ In a single mirror optics, large angle and small angle tracks can not be optimized.
- ❑ Nominal dRICH geometry falls in the region the Pareto Optimization indicates.
- ❑ Considering spectrometer constraints we are almost there!

Consistency of Number of sigma separation and LUT





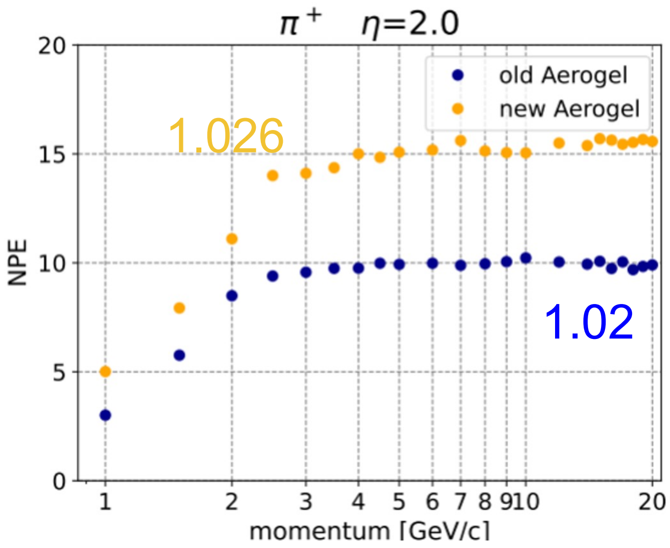




→ Number of sigma separation and LUTs are compatible and consistent!
→ The parameters used for dRICH are nominal ones!
→ Preliminary LUT! Optimization of aerogel optical parameters ongoing. Soon new LUT will be released.

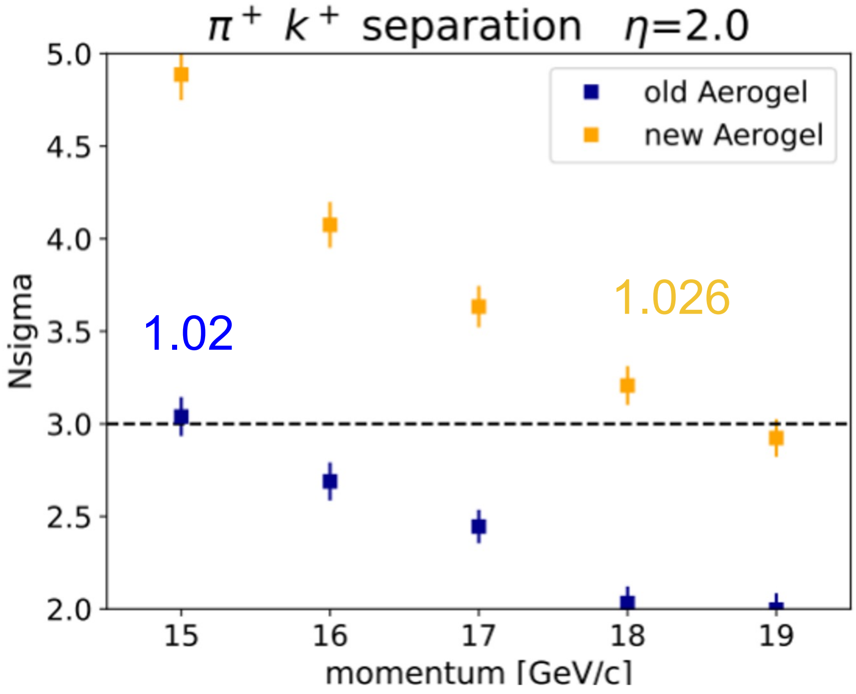
Exploration of different Aerogel Parameters.

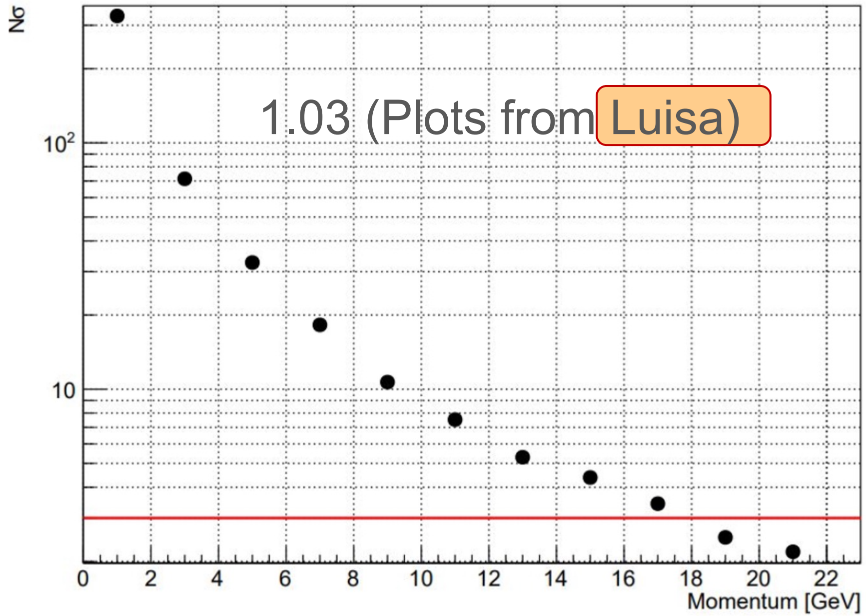
- New aerogel parameters are under evaluation.
- The first impression from simulation studies indicates baseline aerogel parameters are not optimal.
- Different aerogel materials are getting tested.
- Optimal aerogel parameter will be implemented in the simulation scheme to compute refined LUT.



Performance of different Aerogels

Tiziano's talk GM 22nd March





Effect of forward Time of Flight detector in dRICH resolution

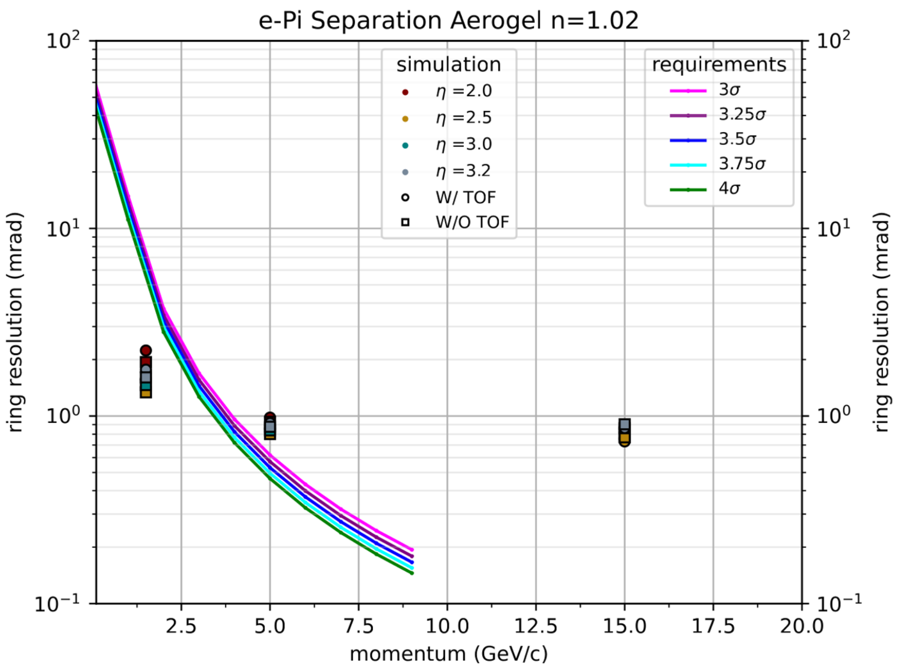
- Forward TOF consists ~3% X/X0; where as Barrel composes 1% X/X0.
- The effect of FTOF for dRICH resolution has been estimated. Running similar events w/ and w/o FTOF detector.

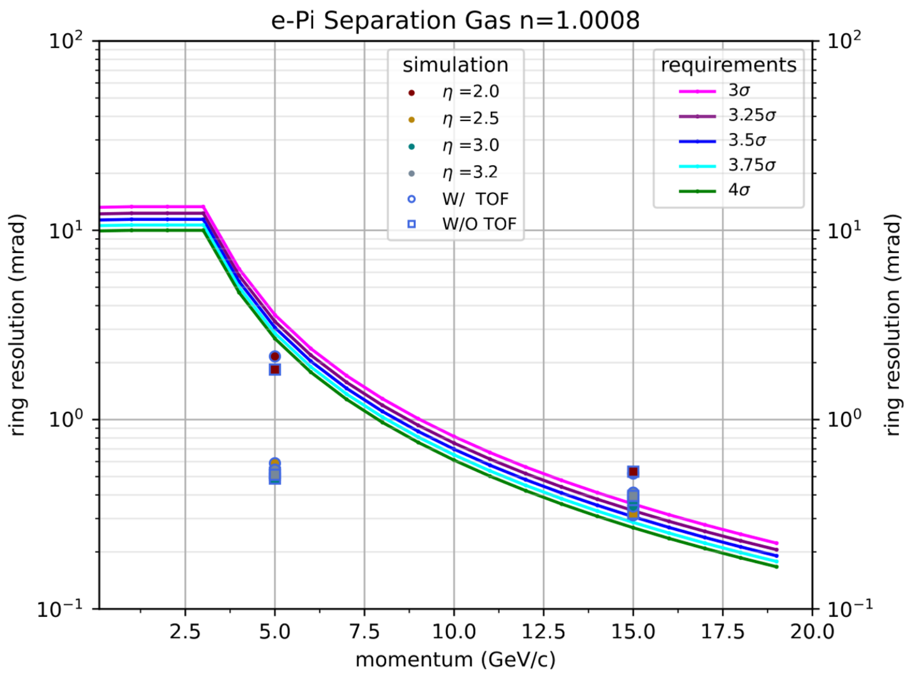
FTOF requirements and R&D progress

Current requirements (presented at FY23 EIC Project R&D - DAC Meeting)

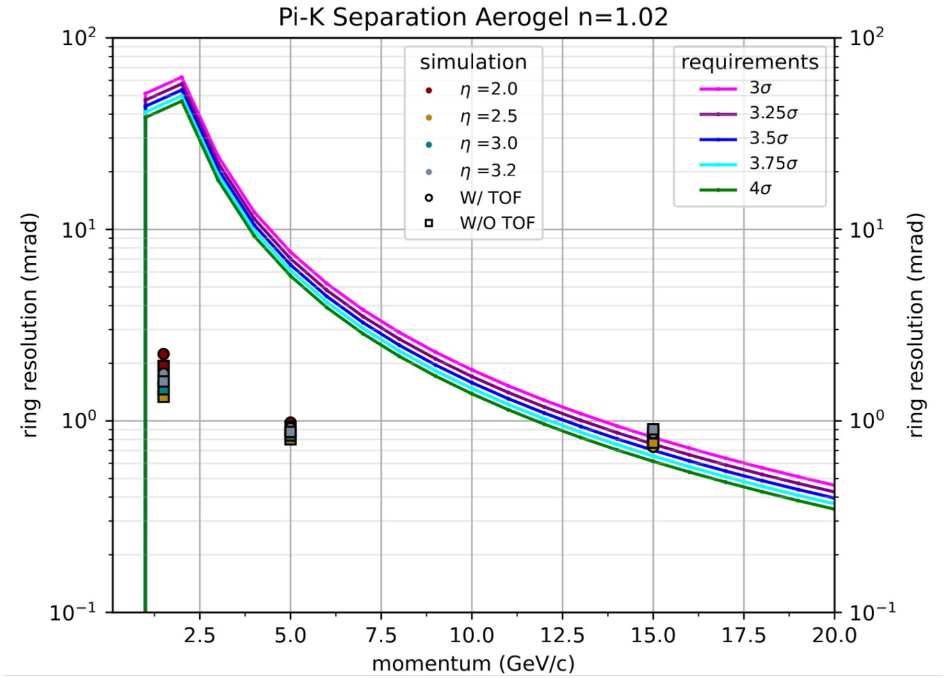
	Area (m^2)	Channel size (mm^2)	# of Channels	Timing Resolution	Spatial resolution	Material budget
Barrel TOF	10	0.5*10	2.4M	30 → 35 ps	30 μm in $r \cdot \varphi$	0.01 X_0
Forward TOF	1.4	0.5*0.5	5.6M	25 ps	30 μm in x and y	0.08 → 0.025 X_0
B0 tracker	0.07	0.5*0.5	0.28M	30 ps	20 μm in x and y	0.01 → 0.05 X_0
RPs/OMD	0.14/0.08	0.5*0.5	0.56M/0.32M	30 ps	140 μm in x and y	no strict req.

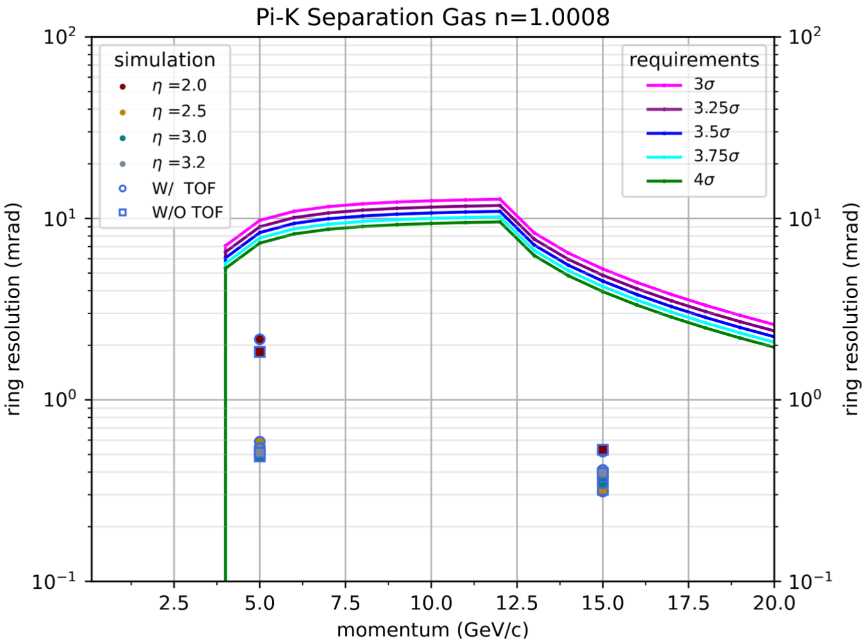
Performance of dRICH w/ and w/o TOF





Performance of dRICH w/ and w/o TOF

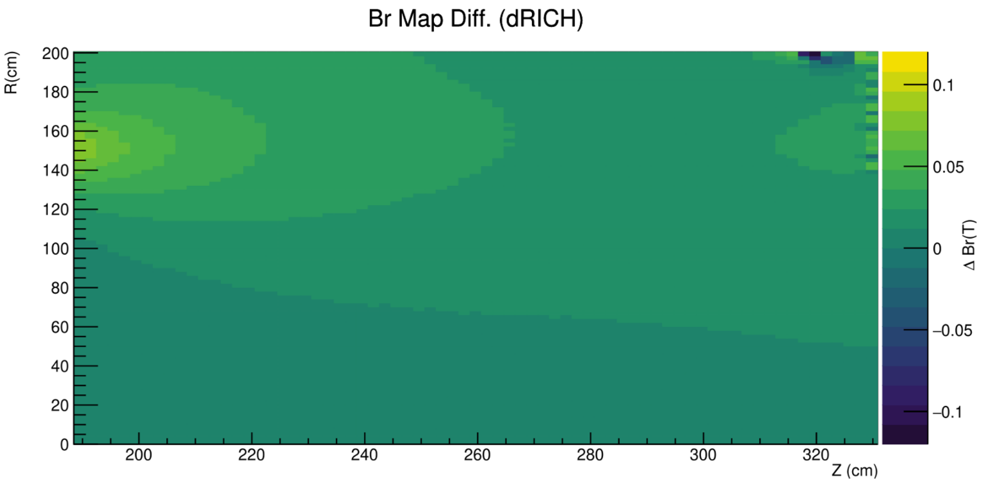




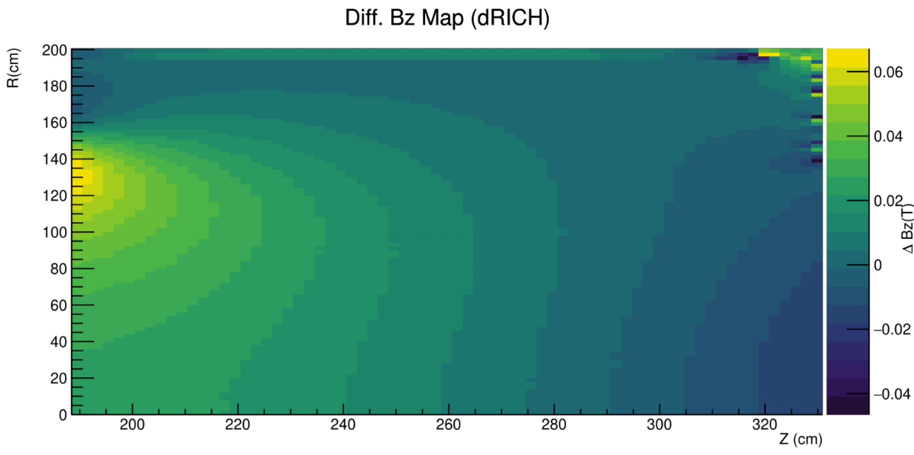
Performance of dRICH w/ and w/o TOF

- With ***existing material budget*** for FTOF, the performance limit for electron pion separation in aerogel (n=1.02) may be limited to a slightly lower momentum.
- The Upper limit can be way above 10 GeV (EIC YR requirement).
- The pion kaon separation are unaffected.
- In case of change in the material budget and also with the final aerogel parameters, the effect will be rechecked.

New Magnetic field map (Changes in the dRICH region)



Radial Component



Longitudinal Component

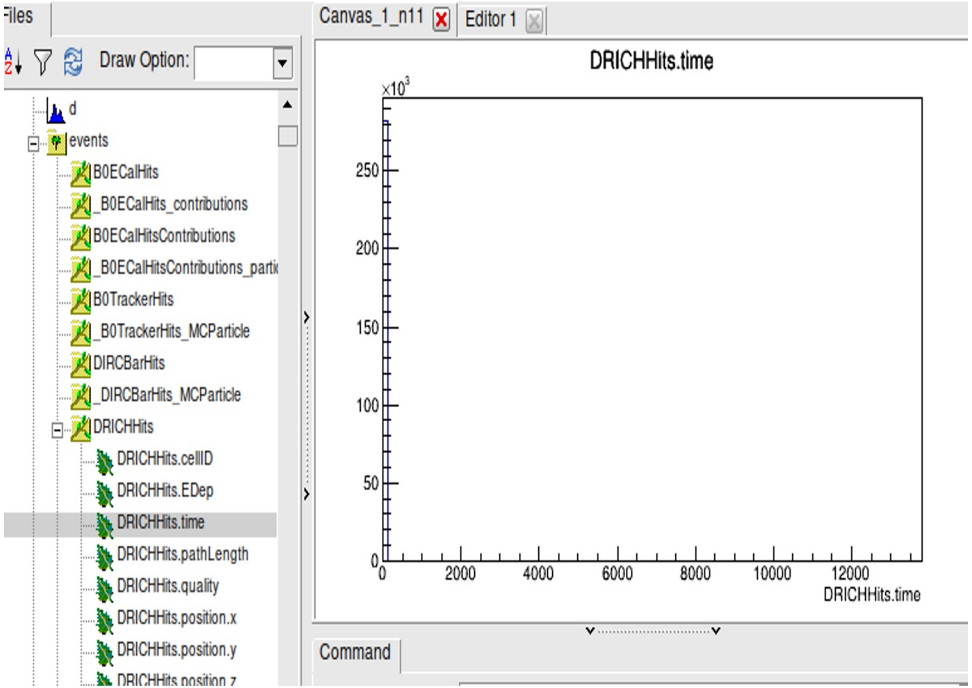
- ❑ Marginal change has been seen in the dRICH region.
- ❑ Nominal resolutions are preserved.
- ❑ No look up table needed to be prepared only to account the new field map.

Couple of words on time (rough expectation)

The dRICH sits 1.95 m from the IP,
The particles travelling close to the speed of *c* (but not exactly). Then the photons emitted (let’s assume in the very first point) and then reflected by the mirror to the sensor plane.

Total path traversed by tracks (for gas photons):
1.95m + 5 cm (with aerogel and vessel wall)
+2.3 m (by the photon including reflection)~ 4.3 m path.
Estimated time 4.3 m/c ~ 14 ns!

Couple of words on timing (preliminary)

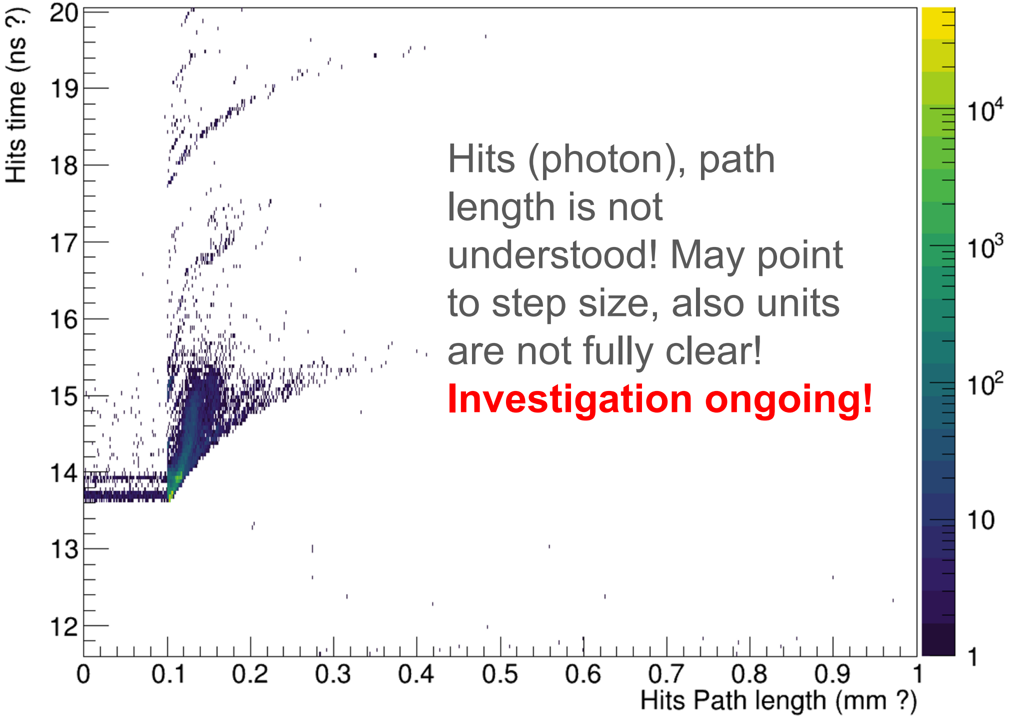


1. Included time info for the hits!
2. Include path length for the hits as well!

On the first look the information seemed not physical!

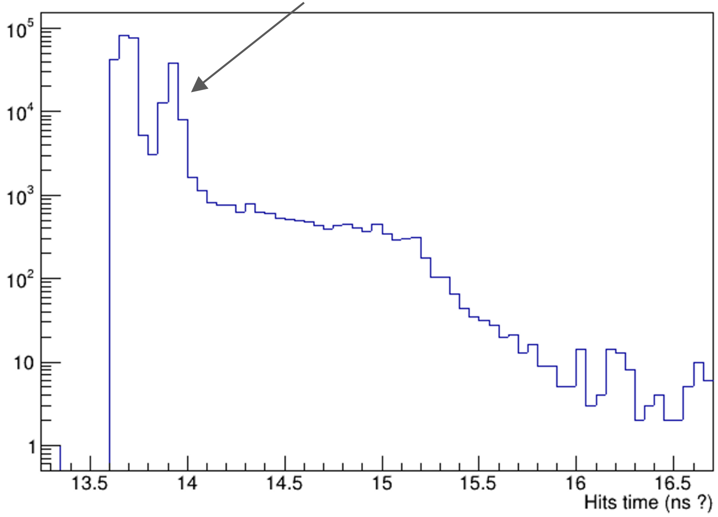
But…

Couple of words on timing with some meaningful binnings (preliminary)



Hits (photon), path length is not understood! May point to step size, also units are not fully clear!
Investigation ongoing!

<u>This could be the time recorded from the IP to the hits!!</u>



Further accomplished and ongoing activities

- ❑ dRICH does provide EIC YR requirements.
- ❑ dRICH sensor petals are rotated according to engineering design.
- ❑ The sensor box extrusions are made in more realistic way.
- ❑ The current physical locations are made according to latest positions from the project.
- ❑ Geometrical and optical tunings are close to finalization.
- ❑ Parameterization of the acrylic filter (placed after the aerogel) will be implemented.
- ❑ Extreme priority in the next months on optimization of reconstruction algorithm.

Summary

- ❑ Performance of dRICH consistent with EIC YR requirements.
- ❑ The optimization is promising and at the final phase.
- ❑ Preliminary Look Up Table has been provided with merged information for physics studies. Final table will be provided soon.
- ❑ New magnetic field map has minimal changes in dRICH region.
- ❑ Current TOF material, has some minimal effect mostly for electron pion separation.
- ❑ Constant simulations work ongoing for finalization of detector design.
- ❑ Effort will be given to improve reconstruction algorithm and PID performance studies.