Detector-1 dRICH simulation status and update

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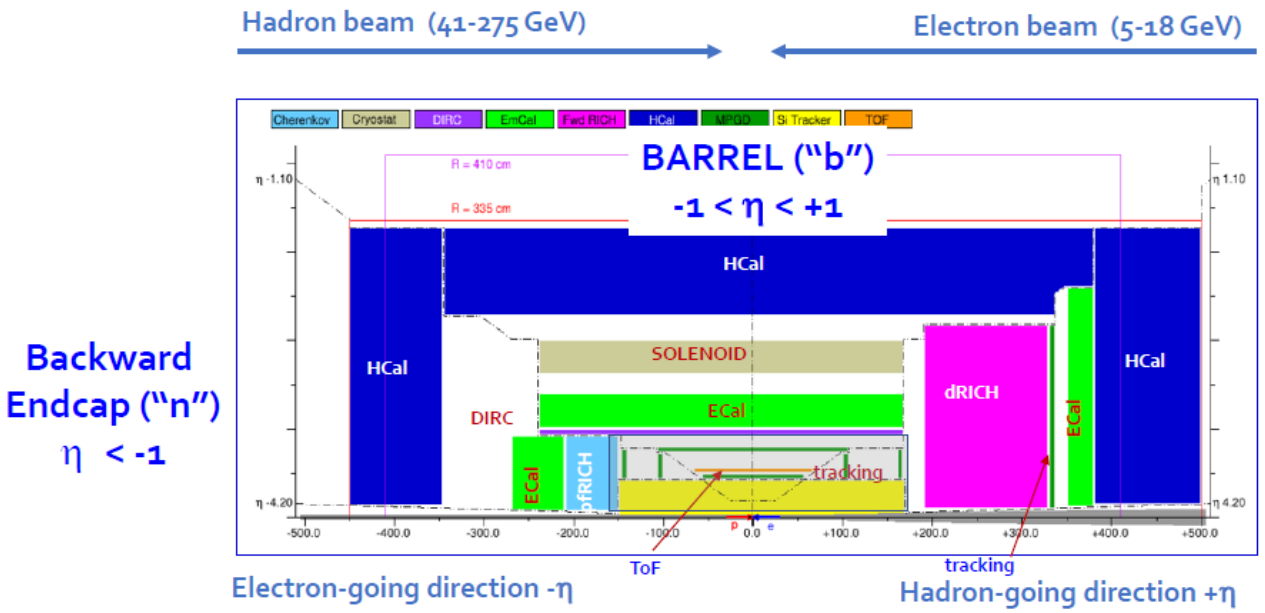
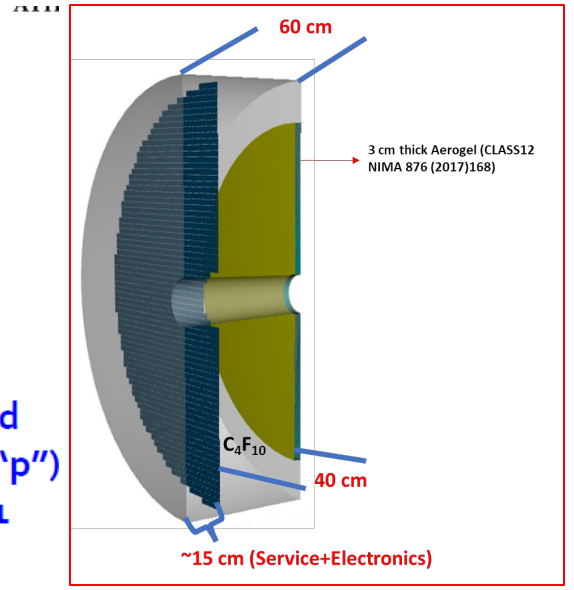
ON BEHALF OF THE DETECTOR-1 DRICH SIMULATION TEAM

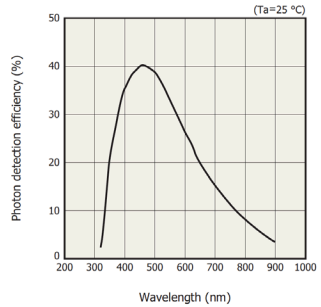
Outline :

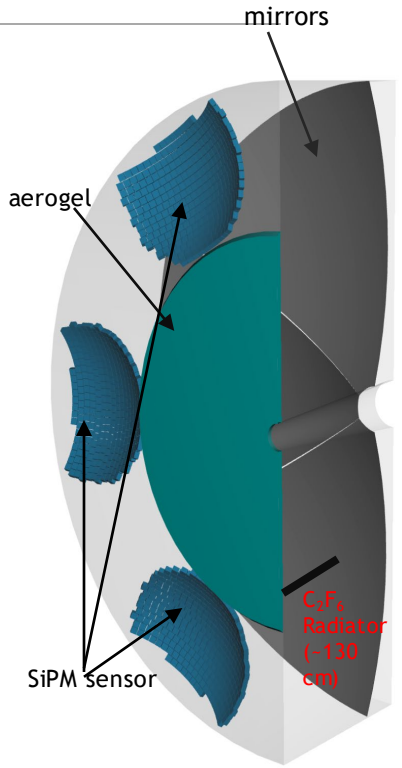
- A quick recapitulation of the work done for the ATHENA proposal submission
- Current situation of the simulation status
  - The dd4hep framework
  - The geometry
  - The reconstruction and analysis part
- General meetings to decide the path toward pattern recognition.
- Is the new magnetic field too different?
- Optimization of dRICH location and performance studies for the detector-1 scheme
  - Some numerical estimates of multiple scattering
- Timeline (Conservative)
- Conclusion

Recapitulations (Studies made for ATHENA proposal: Description of the RICHes)







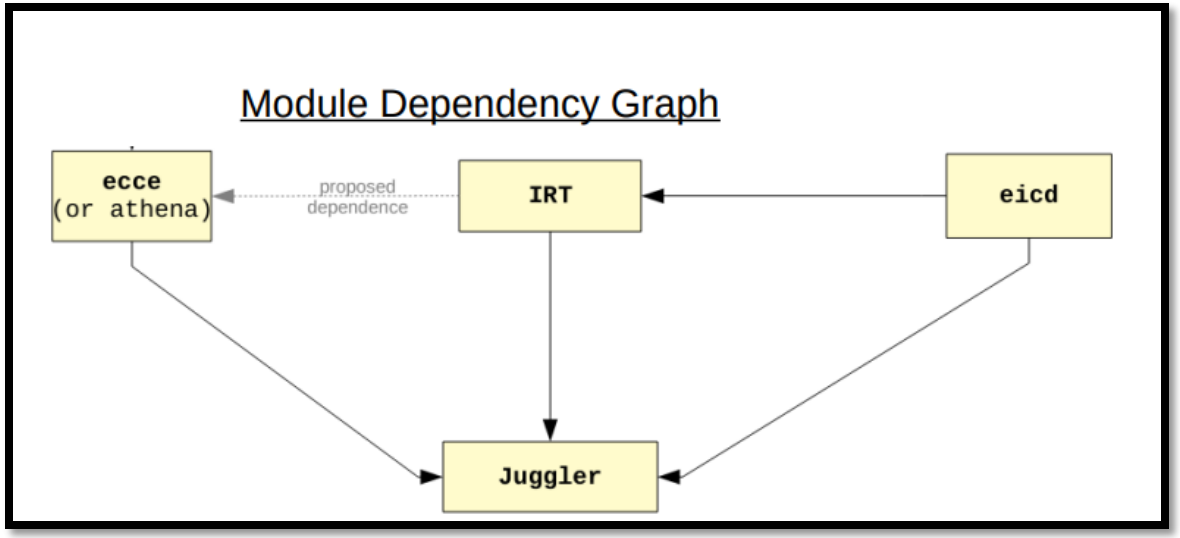


Aerogel Example (Same material for both pfRICH and dRICH):
Abs length->@ 400 nm 157 mm
Rayleigh->@ 400 nm ~40 mm
R_index->@ 400 nm 1.01933

Giornata nazionale EIC_NET 2021 (20-21 December 2021): Timetable · Agenda (Indico) (infn.it)

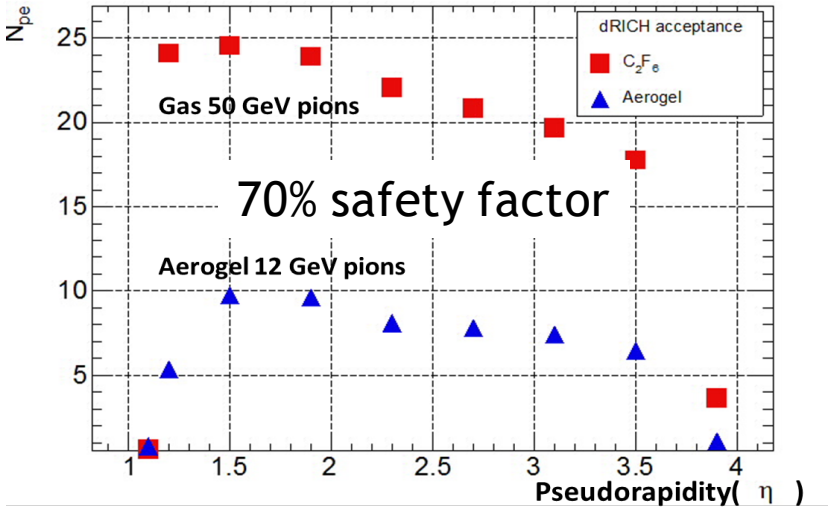
Recapitulations (Studies made for ATHENA proposal: The SW Chain)

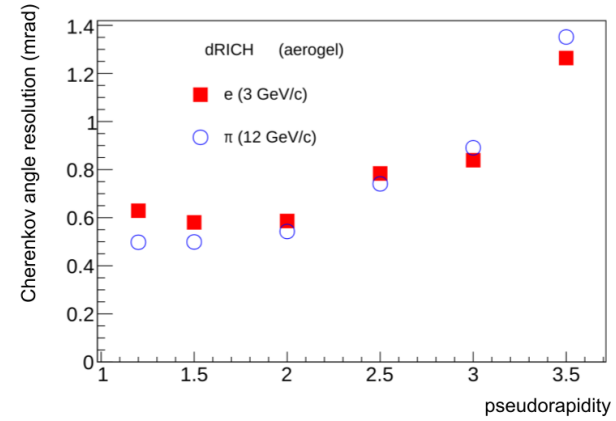
- ✓ We had generated simulated data using dd4hep framework. We had integrated a standalone Inverse Ray Tracing (IRT) algorithm in the reconstruction framework (juggler). The IRT algorithm has two capabilities:
  - A) Reconstruction of Cherenkov angles
  - B) Based on the rec. angles assignment of weights to a track for different particle hypothesis (e-pi-K-P)
- ✓ A frame independent C++ and ROOT based analysis code to study dRICH and pfRICH performances.

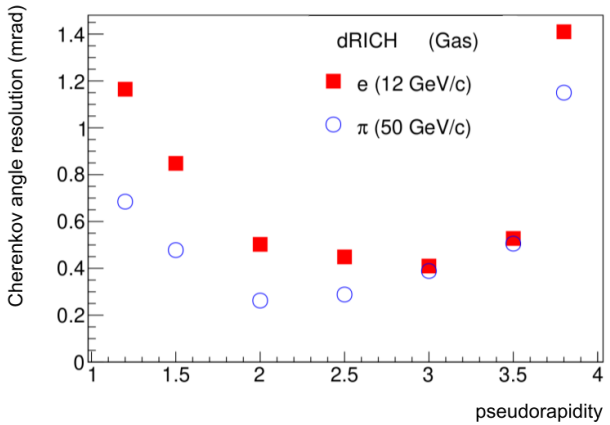


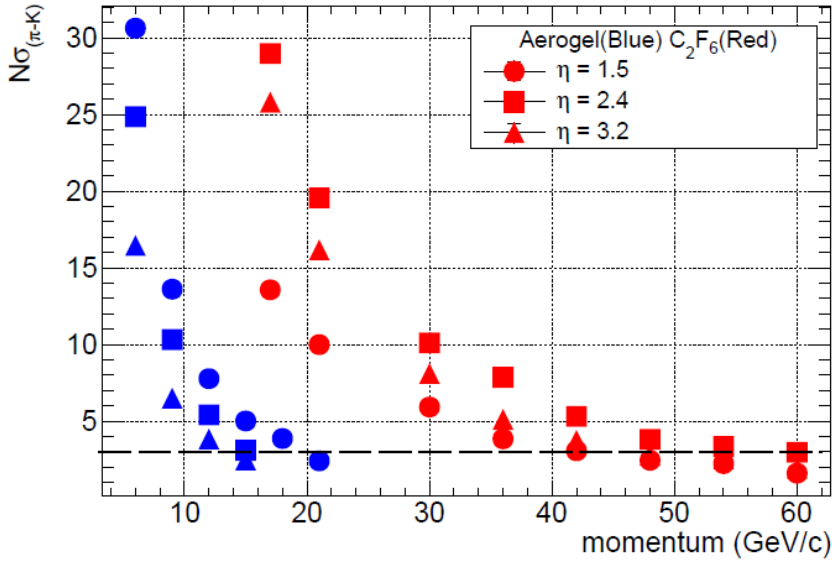
The real dependency is more complex!

Recapitulations (Studies made for ATHENA proposal: Performance plots dRICH)





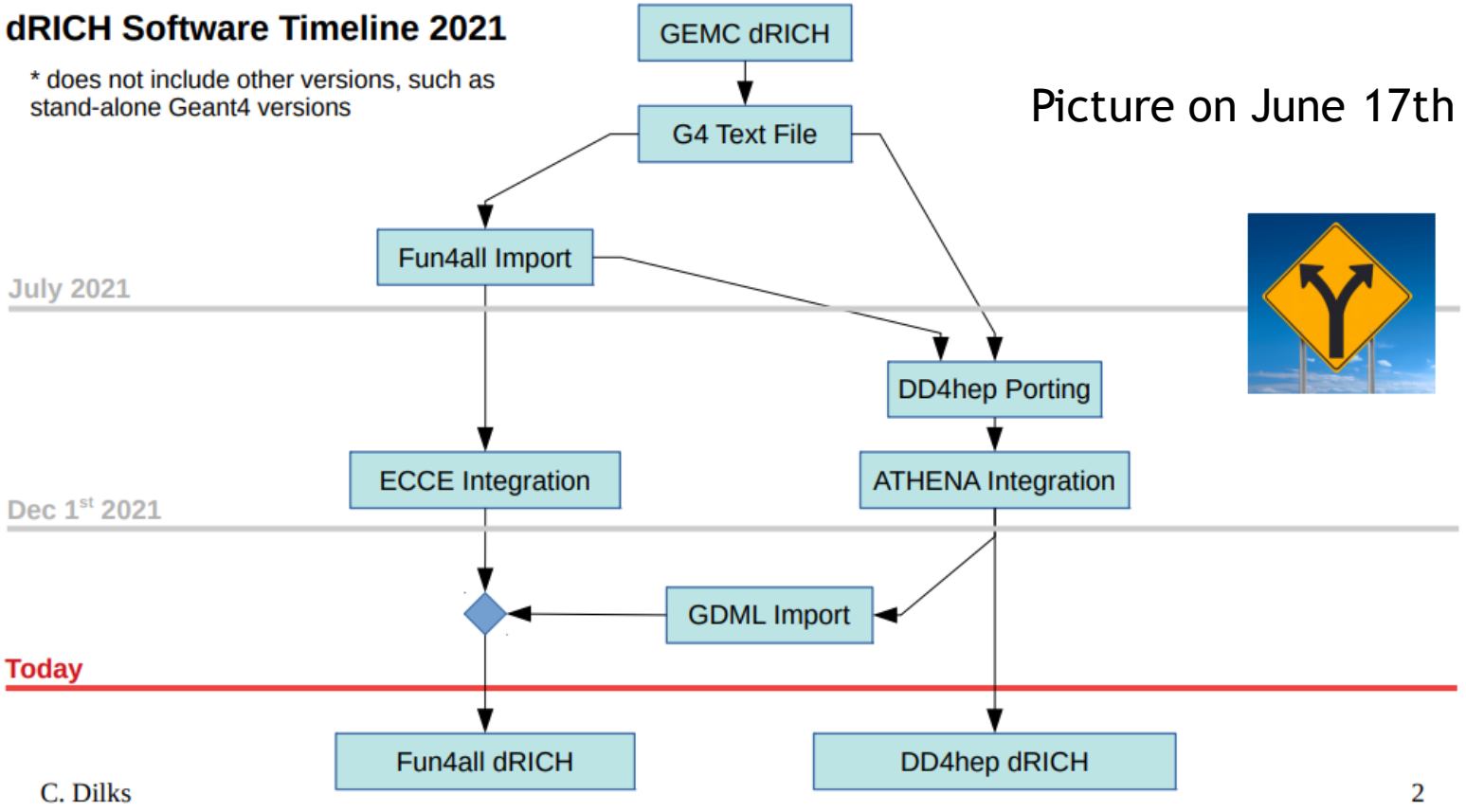




YR requirement: acceptance for the dRICH is $1.0 \leq \eta \leq 3.5$. These reference numbers were taken as a guidance for the ATHENA implementation.

Giornata nazionale EIC_NET 2021 (20-21 December 2021): Timetable · Agenda (Indico) (infn.it)

Current Situation of the simulation



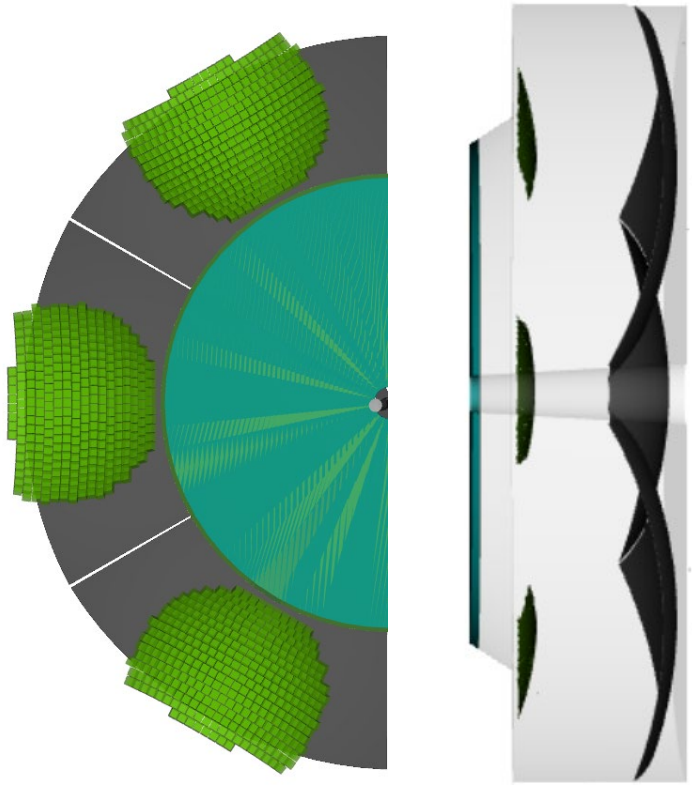
Picture on June 17th

drich-sw-update.pdf (bnl.gov)
Talk by C. Dilks (June 17th)

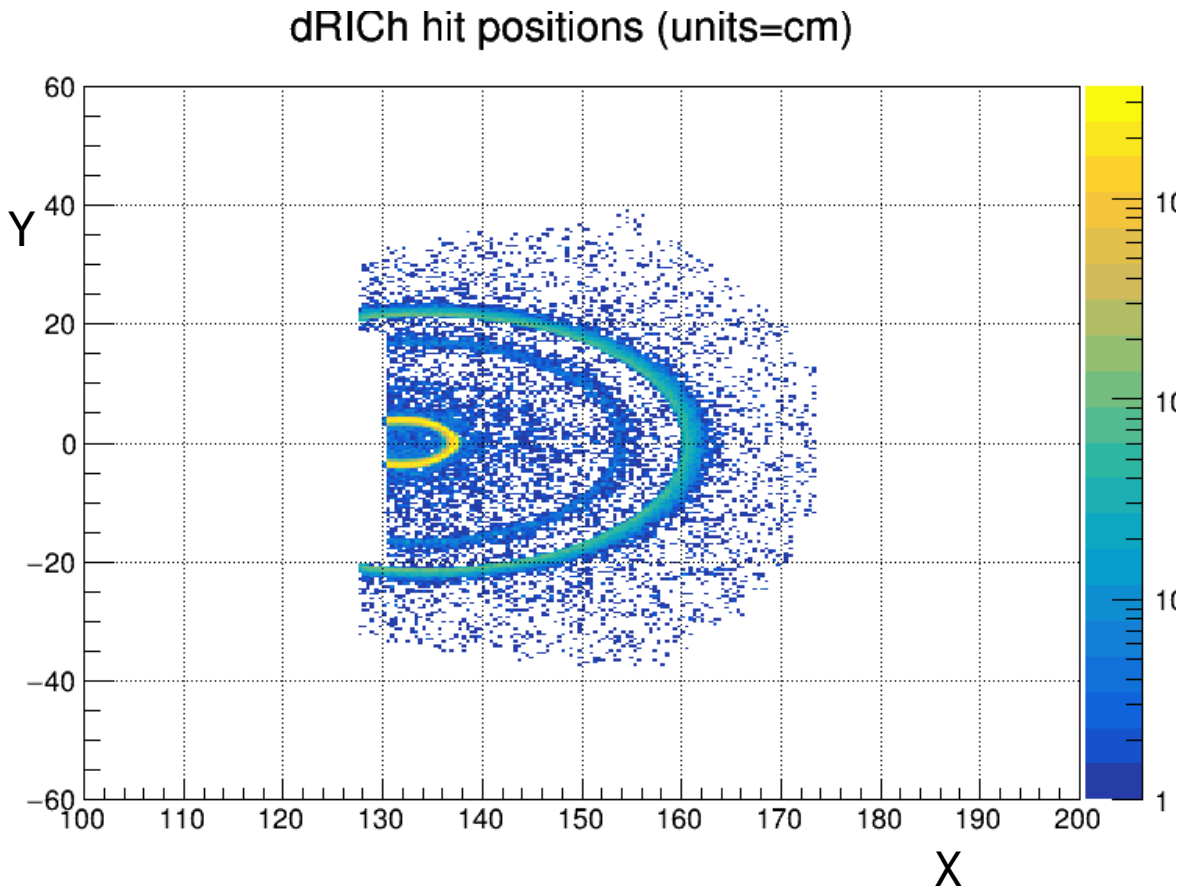
The dRICH parameters from ecce have been taken and DD4Hep dRICH is re-scaled

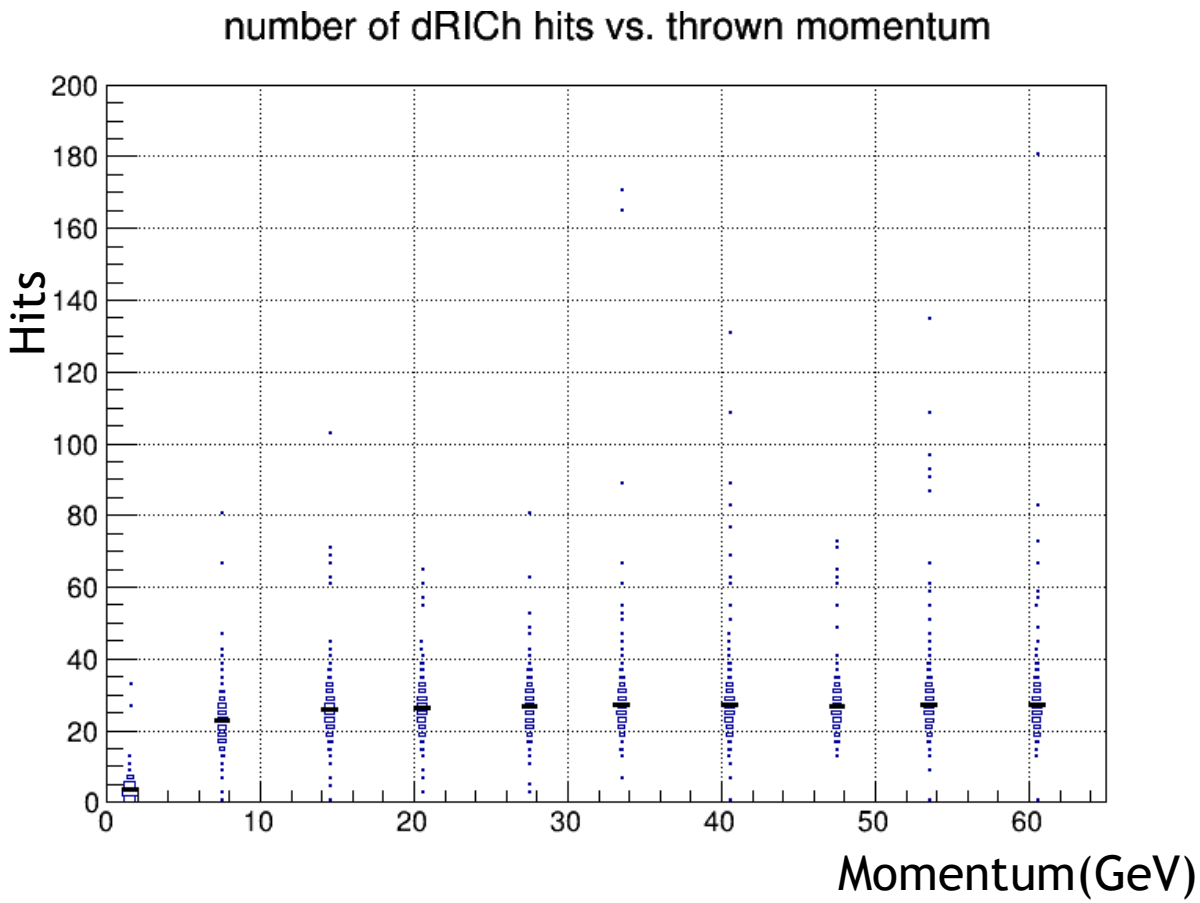
Current Situation of the simulation (dRICH rescaling, taking parameters from ecce)

- Occupies z from 180 – 280 cm (Radiator 100 cm at max.)
- Outer radius = 180 cm
- Snout parameters:
  - Length: 20 cm
  - Radii: projective to back-plane corner
  - Aerogel thickness = 4 cm
- Mirror parameters:
  - Center (z,x) = (79.19 cm, 125 cm)
  - Radius = 200 cm
- Sensor sphere parameters (extracted from spherical fit)
  - Center (z,x) = (71.93 cm, 124.98 cm)
  - Radius = 140 cm

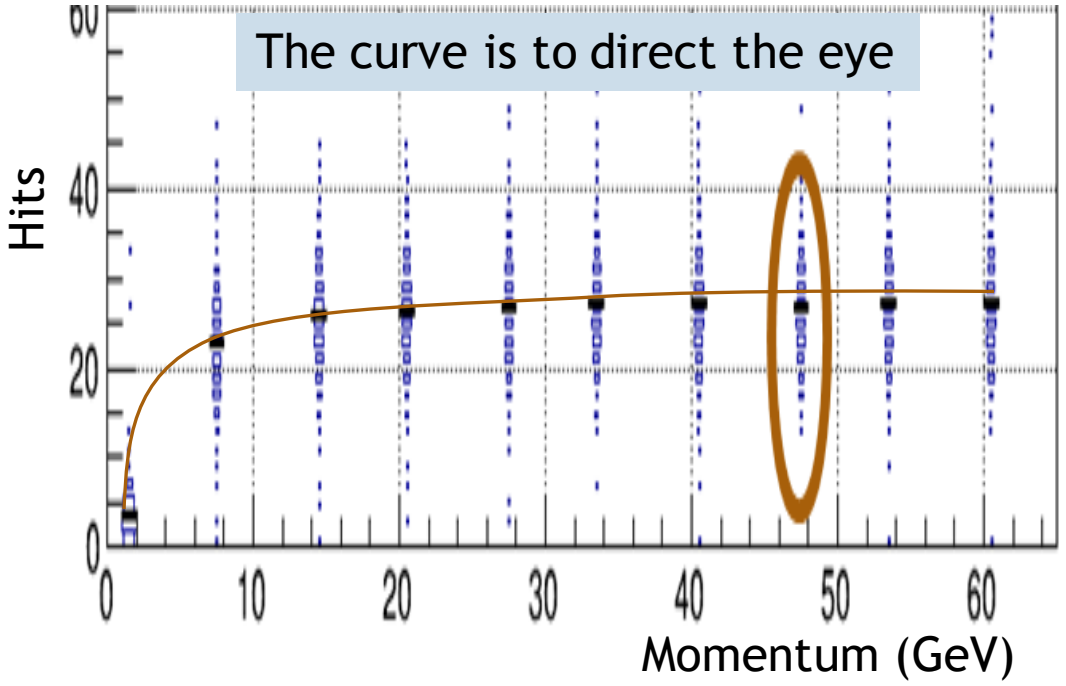


Simulation results





Evaluation of the re-scaling

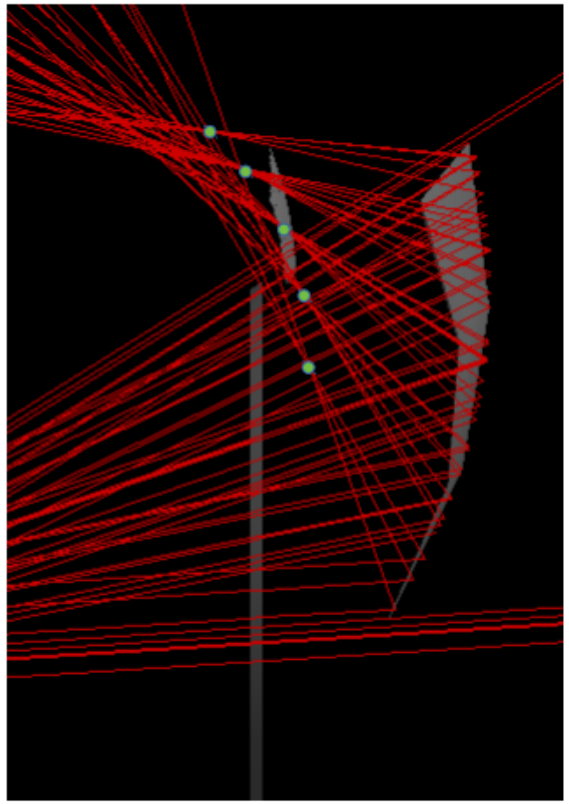


First-order: rescaling effect seen

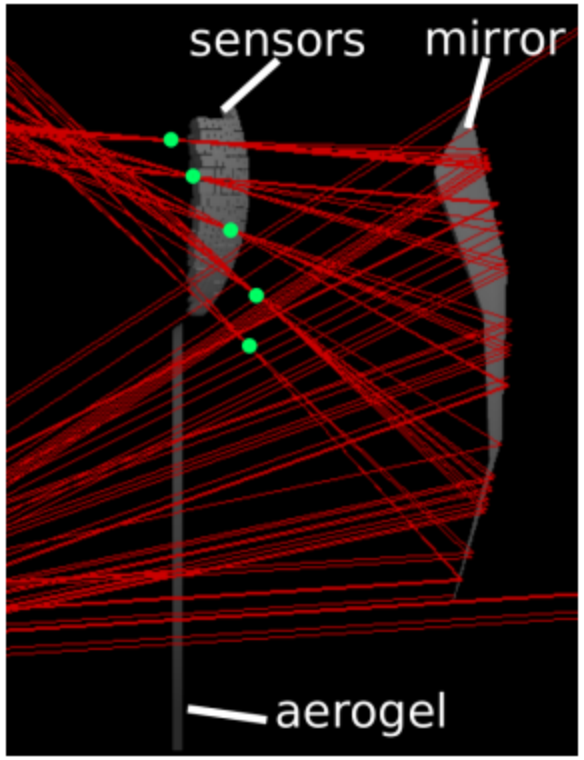
1. We are shooting single particles with no added noise the distribution of hits can be assumed as Cherenkov photons generated by particles.
2. The hits are not treated with the safety factor. For example, the mean of the hit distribution 47.5 GeV is (25*0.7 ~17). Which is at 30% loss compared to what we observed in ATHENA studies.
3. Envelope has lost about 40cm of length compared to the 140 cm (ATHENA). Of course, the entire length is not filled with the radiator gas, we have gaps of the mirror near the beam, aerogel, sensor etc. Similarly, not all particles will travel parallel to the beam pipe. So on average, the ratio of 100/140 is what we are having as the scale of radiator size. Which is around 70%. **We are sacrificing 30% in the radiator and losing 30% in counted photons**.

Collimated photon beam focalization (point to point)

New DD4hep ECCE version

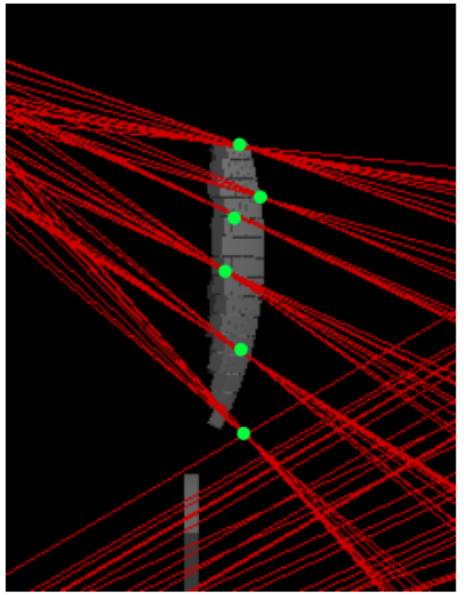


DD4hep ATHENA version



tuned for maximum polar acceptance

DD4hep ATHENA dual mirror test configuration



still plenty of room for improvement!!

Sensors tiled on a sphere may not be ideal...

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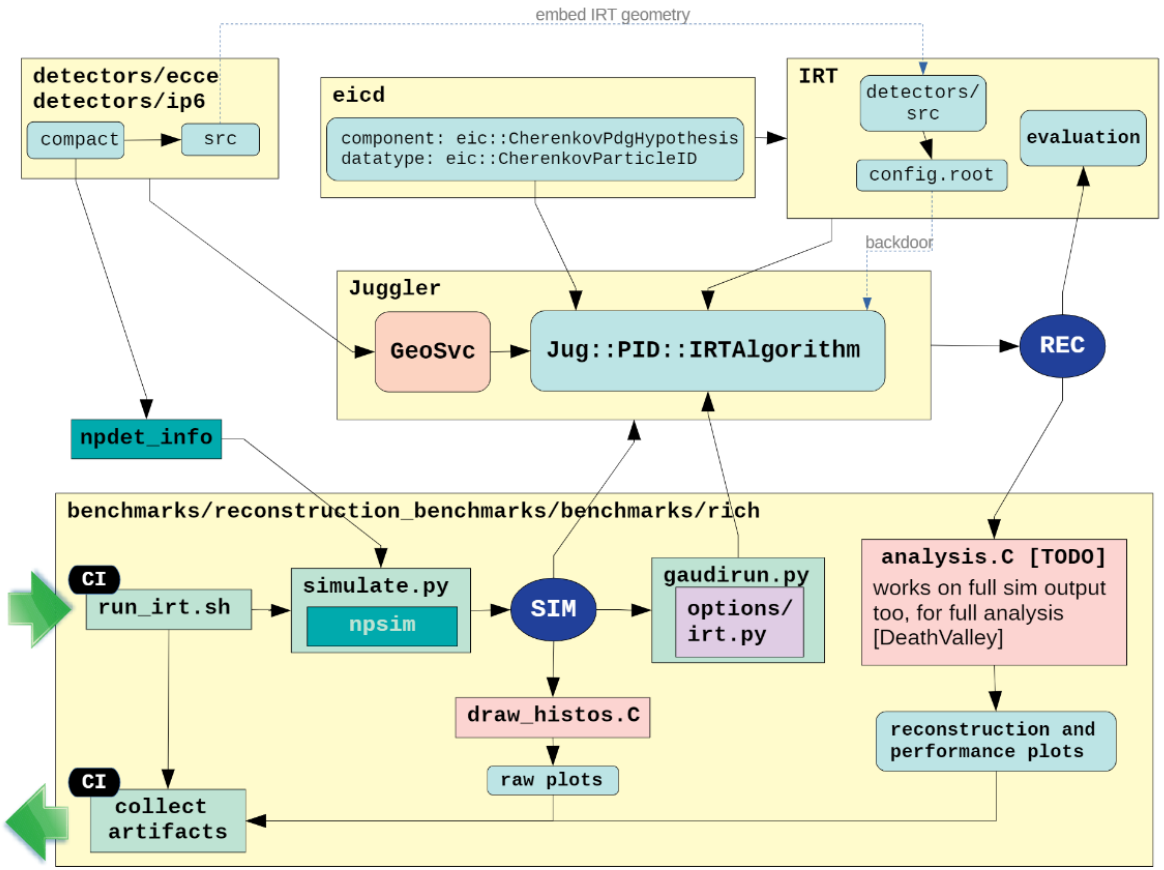
[drich-rescaled.pdf (bnl.gov)]

Files · irt-init-v01 · EIC / irt · GitLab (anl.gov)

Status of the IRT reconstruction software

Dependence of the IRT algorithm to eicd:
The IRT algorithm depends on the eicd (eic data model).
The IRT has two primary modules.
a) Reconstruction (Single Cherenkov Photon angle)
b) Evaluation (Evaluation of hypothesis of a particle (MC or Reco)
)
Both steps depend on the EIC data Structure.
Dependence of the Juggler algorithm to eicd:
The Juggler depends in many folds:
a) The IRT part within juggler (eicd dependence)
b) Other associations (JugTrack,JugReco ..) in juggler to IRT
(internal eicd dependence).
Several changes in upstream eicd due to new formalism of EDM4hep.
IRT does not work in the new scheme.
IRT needs to be refactored→ bottleneck.
Currently, **only hit-level evaluations are possible** directly from simulated data
→Restoring the reconstruction part in the sim chain should be of high priority.
Nevertheless, the situation is in an evolving stage.
Several refactoring and modifications are foreseen in the future.



Status of the IRT reconstruction software

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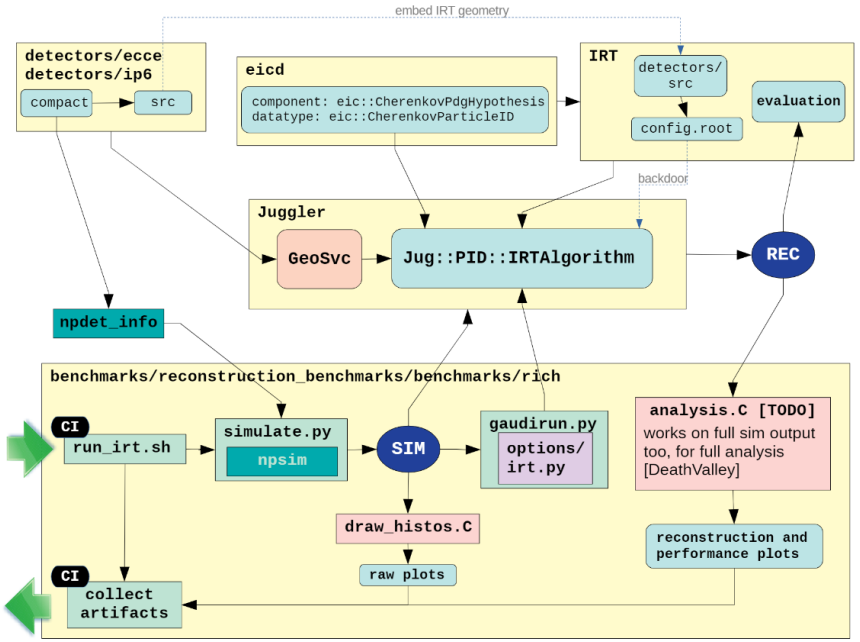


Work had been started with **high priority** and discussions are ongoing with SW experts!
→ Nevertheless, the discussion is ongoing on an alternative to Juggler/Gaudi. (Refactoring juggler will make no sense in this case) Revival of juggler independent IRT?

General meetings to decide the path towards pattern recognition.

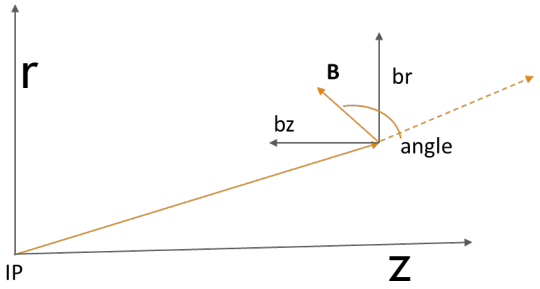
RICH Pattern Recognition Challenges (6 April 2022) · Agenda (Indico) (infn.it)

Suggestions from the discussions:

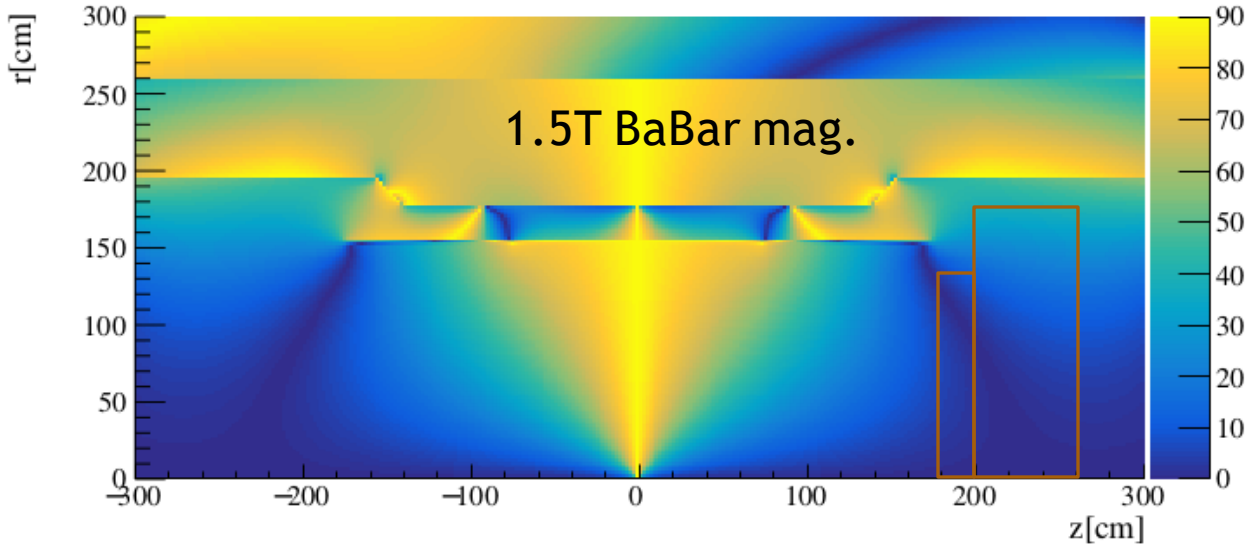
a. To have a **robust** and **intuitive** PID based on pattern recognition for construction purpose.
b. Keep the option open for more sophisticated PID algorithms.
c. The possibility to have dRICH-related options to store more information for debugging and construction purposes.

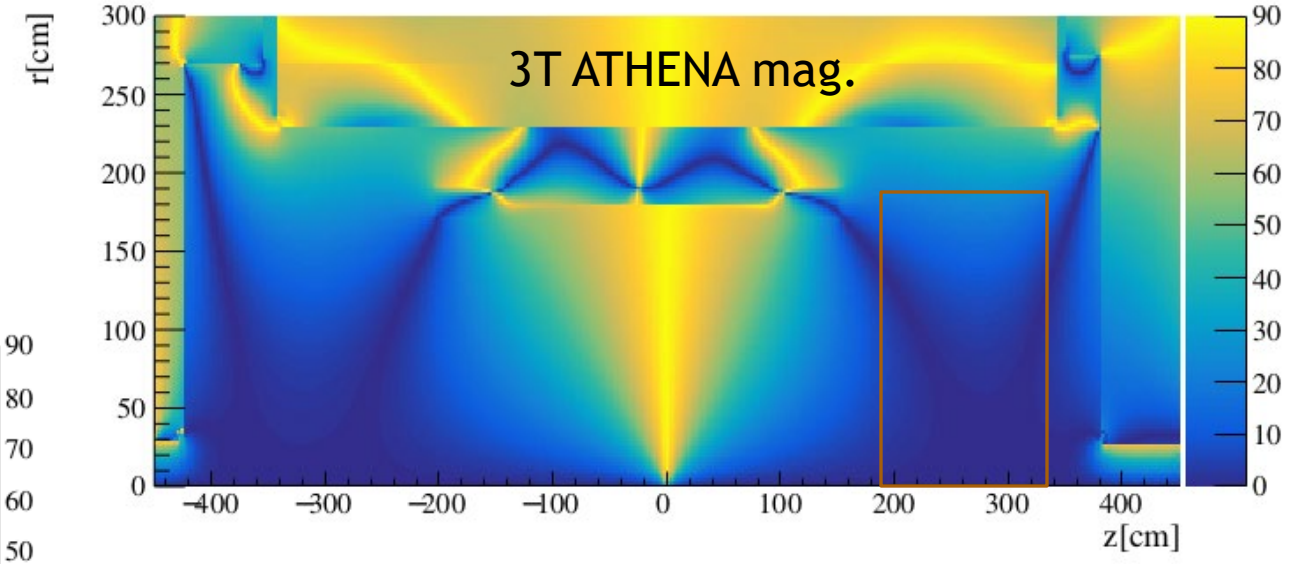
These requirements require to have a **different data model** with the features to add more dRICH associated variables and use them in the Reconstruction code, relatively easily.

Protectiveness of magnetic field- lines around dRICH region (read from field maps)



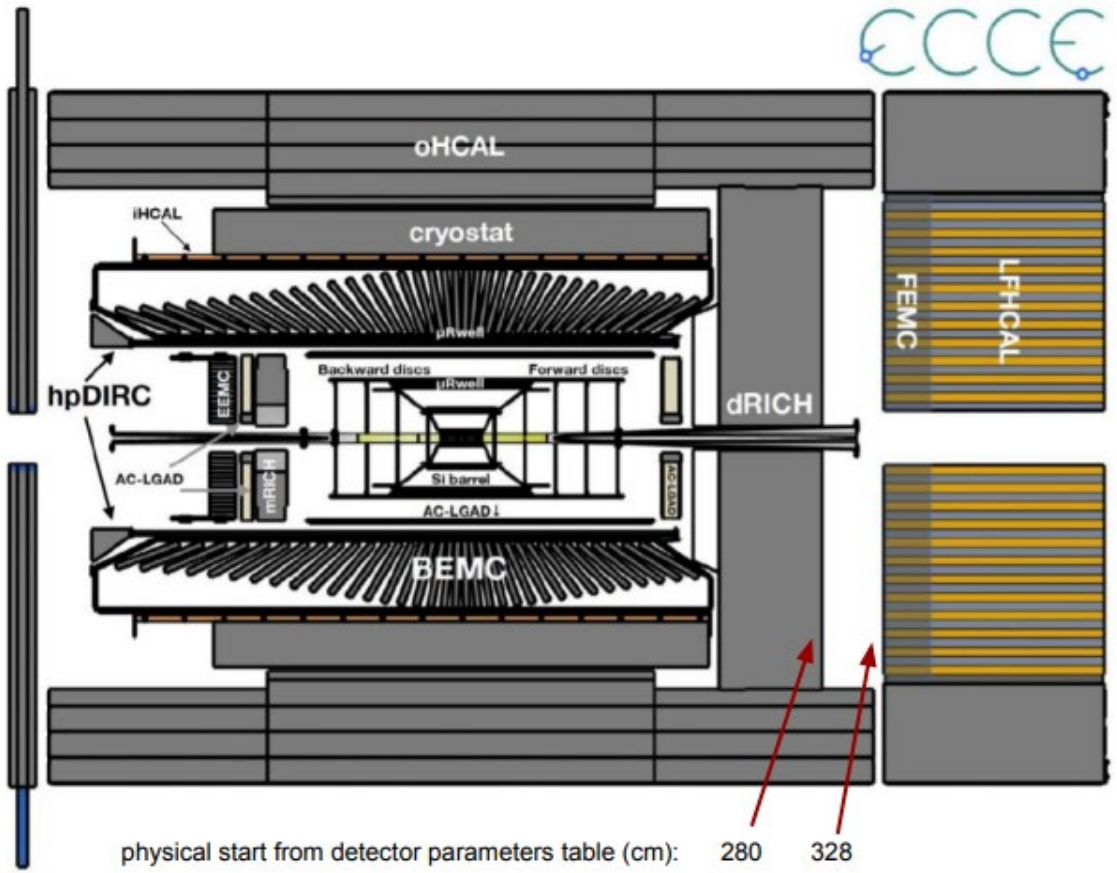
Estimate of projectivity→ Angle between the direction vector and the Field vector





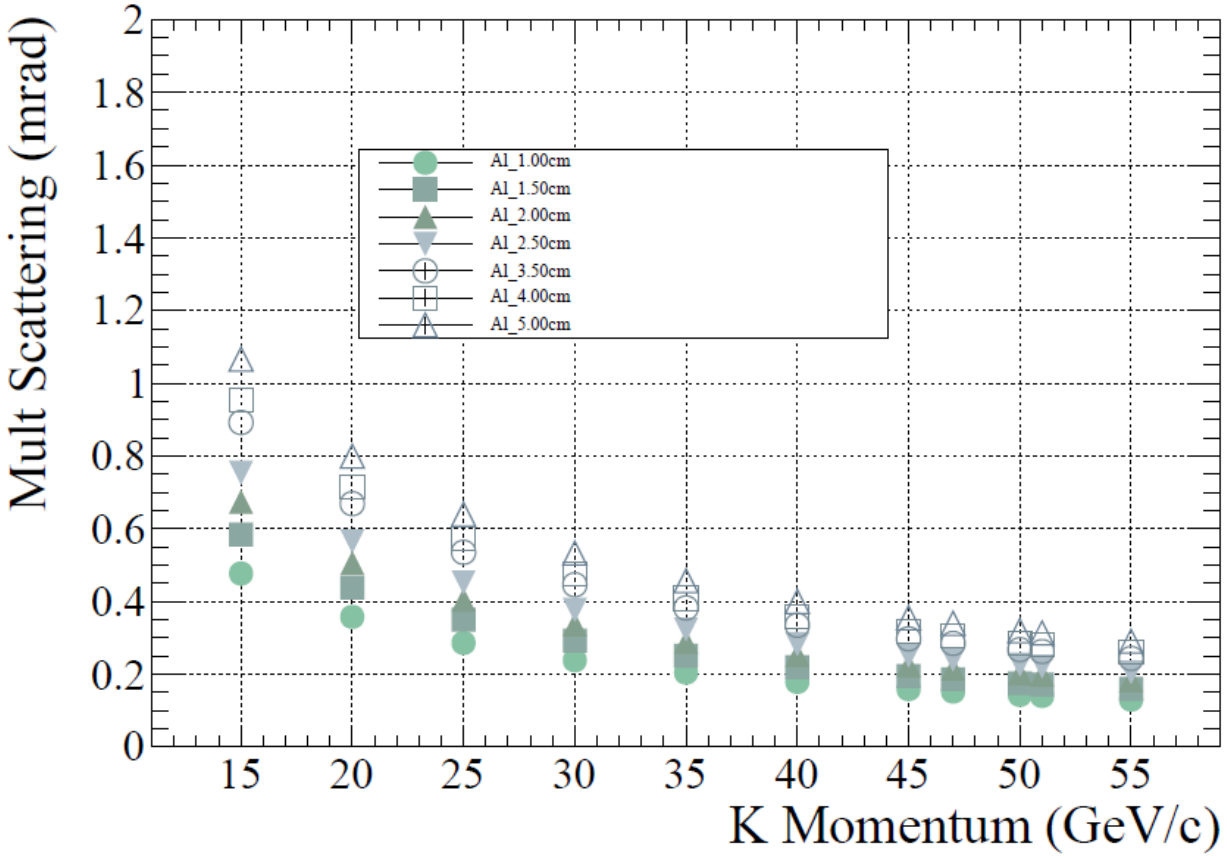
A complete analysis will tell us the full story!
→ First look does not show major difference.

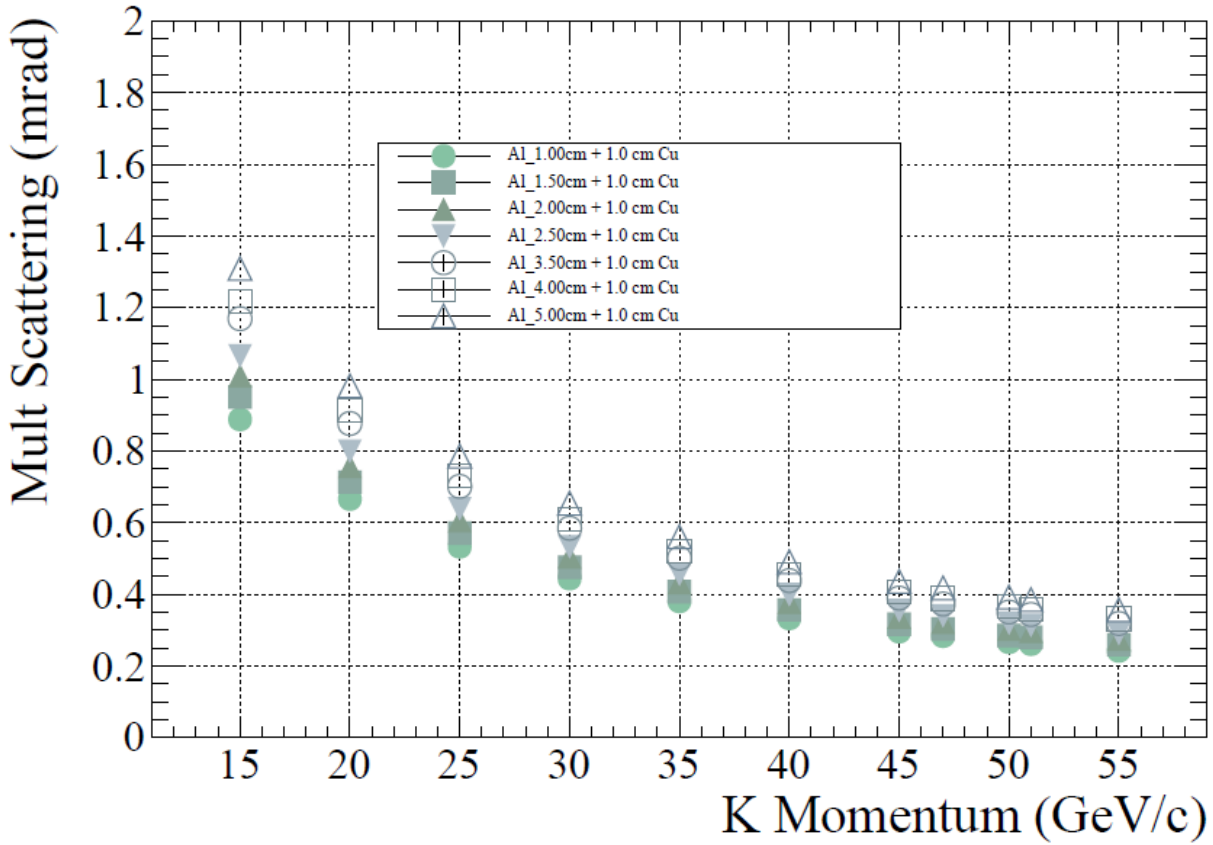
Optimization of the dRICH location and size



- We have around 48 cm of available space after the dRICH.
- There are proposals to increase the dRICH length by 30 cm. This will increase the number of photons and larger lever arm to improve the focalization.
- Will we need a tracker behind the dRICH to improve the track resolution? → A detailed simulation is needed → IRT will be needed.
- How much contribution will come from multiple scattering for a 50 GeV Kaon? We need around 0.5 mrad of Cherenkov angle resolution at 50 GeV pi-K separation.
- How much contribution from the AC-LGAD services etc before dRICH?
- Thicker radiator vessel for pressurized non CF gases?
  → Detailed Simulation to be done in coming days

Kaon track deflection due to multiple scattering (numerical calculations)





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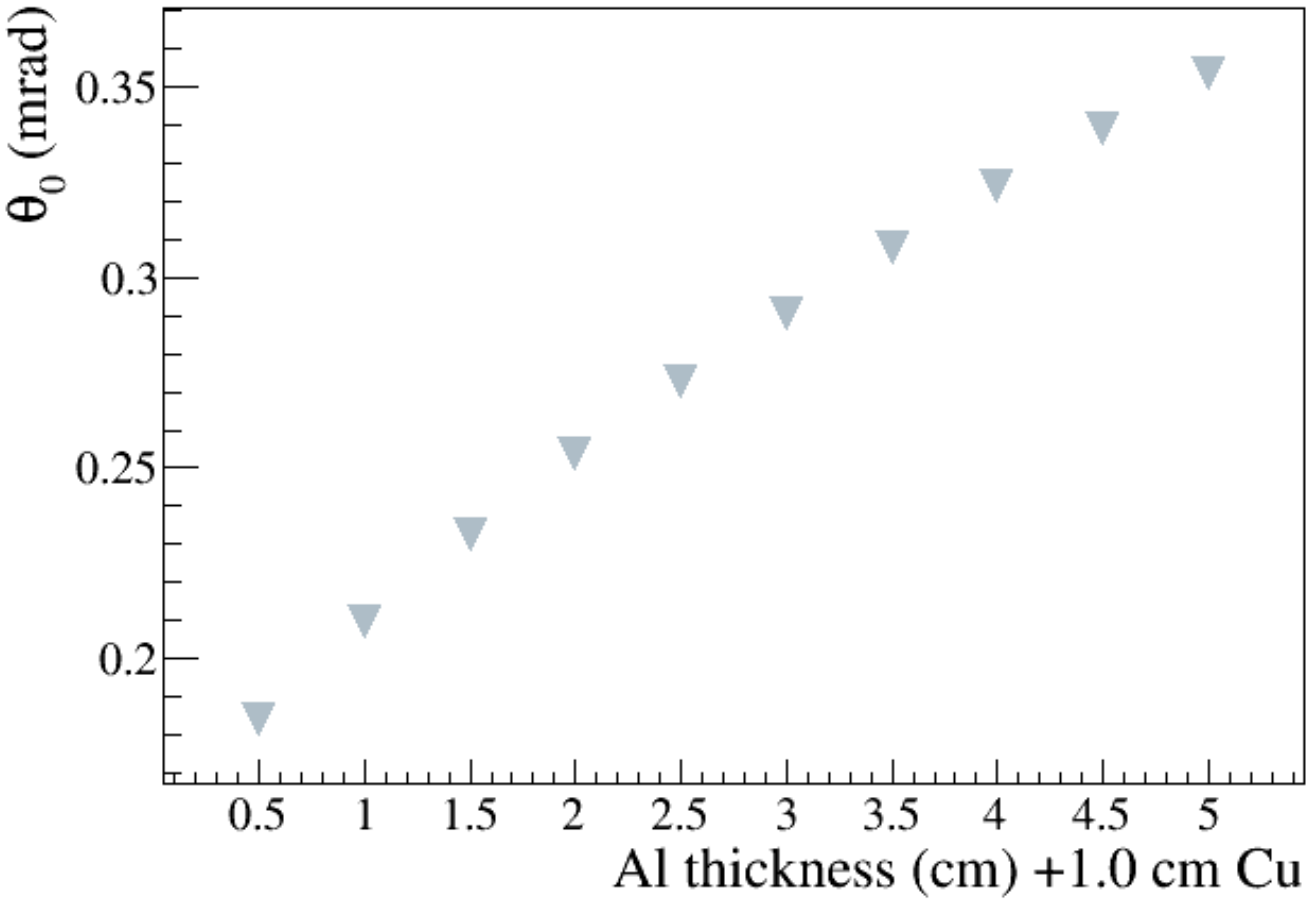

1) Even if we implement 5 cm of Aluminum and 1 cm of Cu (cabling contribution), we probably are less than the required Cherenkov angle resolution.
2) A simulation (even if standalone) can be beneficial.
3) On the dRICH side: how much material is needed for the vessel for pressurized non-CF gases?
4) A dRICH PID performance can be estimated w/ and w/o a tracker after the dRICH.

Contribution from radiator gas and aerogel is negligible ~0.035 mrad

Timeline (conservative estimate)

Milestones

- High priority:
  - Envelope updates – awaiting guidance from GD/I group
- Data model – Summer/Fall 2022*
  - Addition of components / datatypes for IRT, and other algorithms – try to keep them ‘common’
  - Revisions to existing components / datatypes
    - Members
    - Relations
    - Any extra code
  - Add “extra” information helpful for dRICH development, that could be turned on/off with a switch
- IRT integration – Fall/Winter 2022/3
  - Relation of charged tracks to sensors
  - IRT merged, with benchmarks
  - Compare to previous performance

Juggler/Gaudi?

- Alternate algorithms – Fall/Winter 2022/3
  - Apart from the robust chi2 algorithm
  - Help needed, development could be in parallel with IRT integration

* time estimates are approximate and conservative, to account for unexpected delays, e.g., refactoring needs to keep up with upstream changes

Timeline (conservative estimate)

Milestones

- Optimization of optics – Summer/Fall 2022
  - Model focal points for sensor placement guidance
  - Dual / Multi Mirrors
  - Re-align with the proton beam?
- Update materials – Summer/Fall 2022
  - Sensors update is ongoing
  - Need help with other materials
  - Consider non-CF gas options (pressure, vessel updates, …)
  - Automate generation of material tables (integrate the shared optics header)

Conclusion

- The workflow has been slowed down but progressing.
- The refactoring of the IRT algorithm is on the high priority task list.
  - By the end of October (extreme conservative estimate), we believe to have again the Full simulation chain ready.
  - The full reco. path is evolving… To be understood.
- The rescaling of the dRICH in detector-1 is done→ First order appearance is consistent.
- Several optimizations are foreseen in existing scenarios. A more realistic sensor description, and a dual mirror configuration study will be done.
- dRICH position and size optimization are better to be done in a realistic simulation.
- PID algorithm has to be initiated and a working team to be identified. → A quick survey has been made.