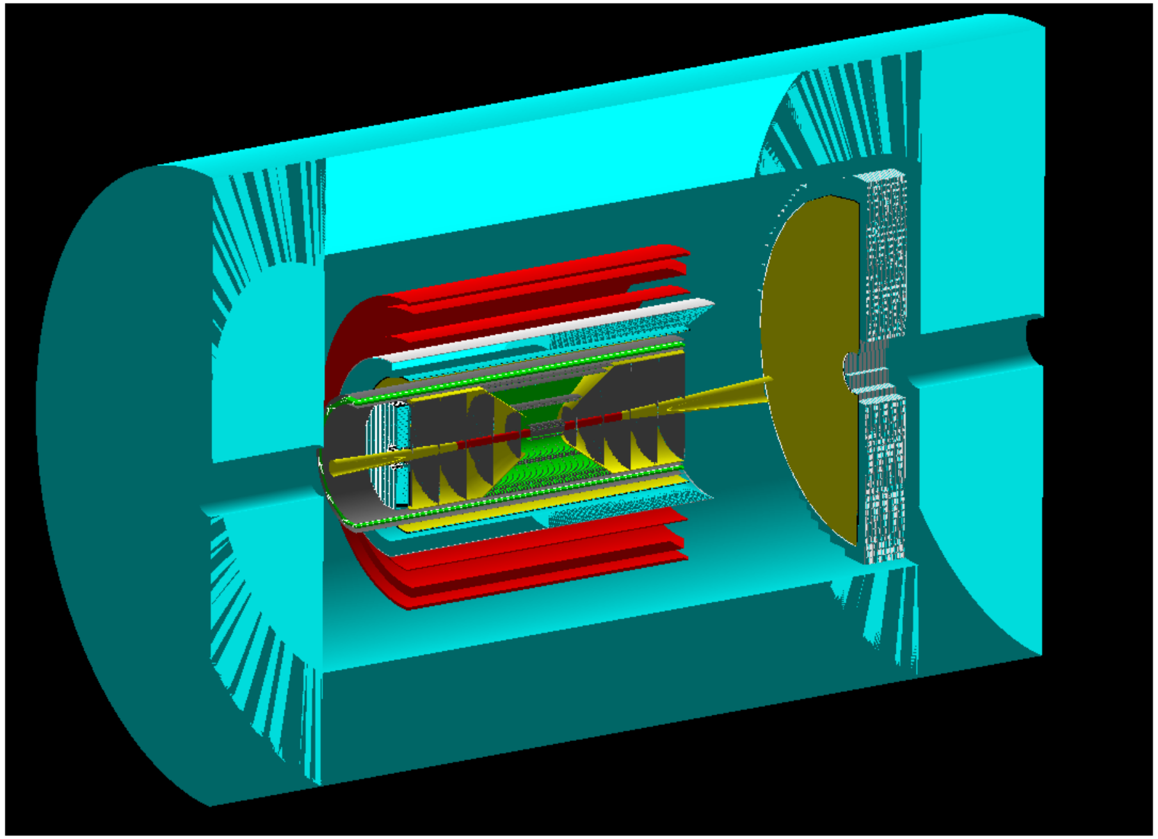
CORE: a COmpact detectoR for the EIC



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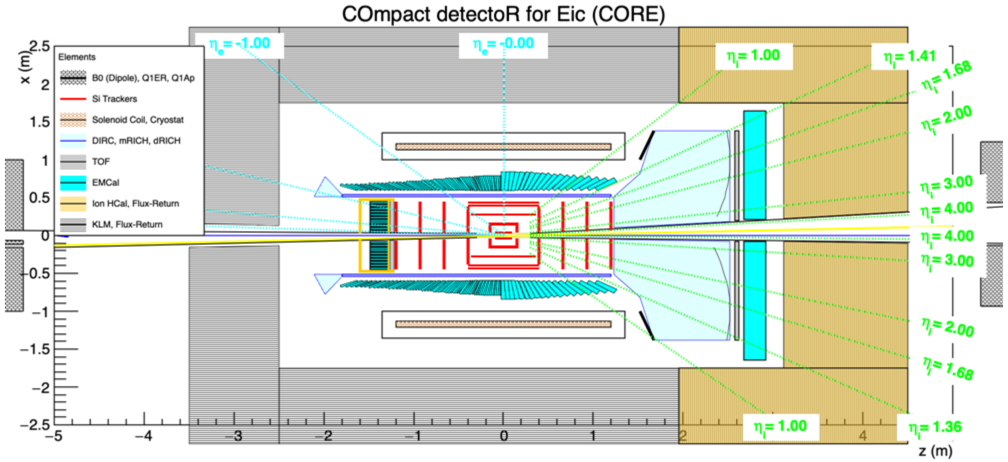
for the CORE pre-collaboration
(open to all users)

RHIC/AGS user meeting, June 9, 2021

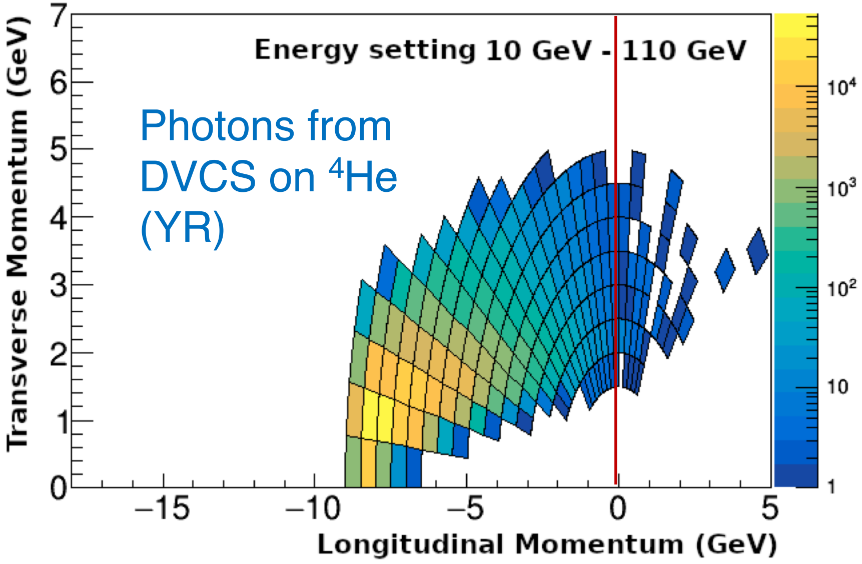
CORE physics

- CORE is a hermetic general-purpose detector that fulfills the EIC physics requirements outlined in the Yellow Report, White Paper, and other documents.
  - Inclusive, semi-inclusive, exclusive, jets, etc.

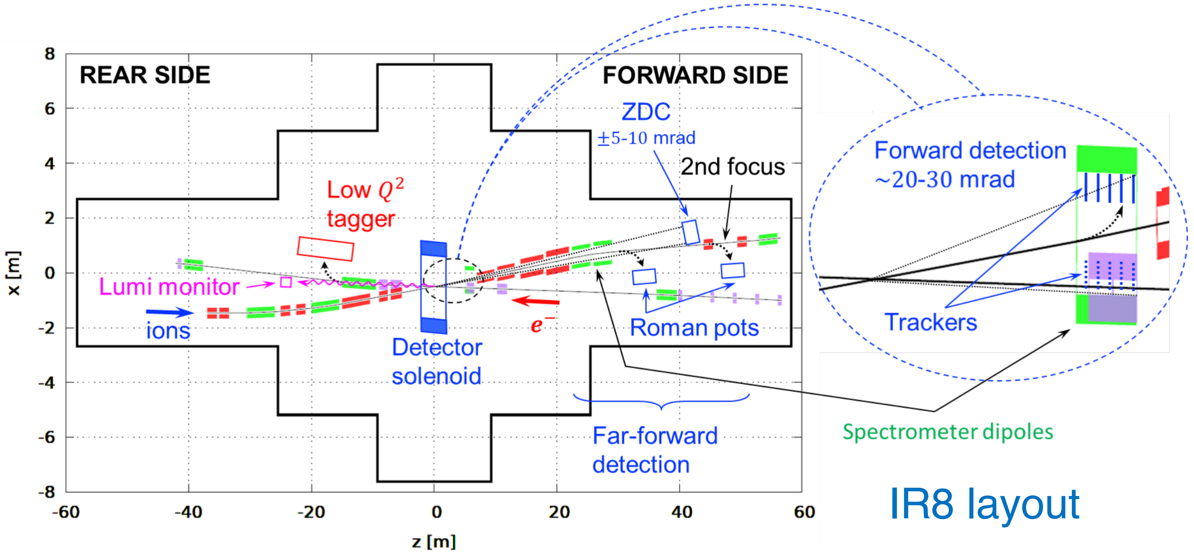


- The compact size of CORE (-3.5 m to +4.5 m) allows it to reach a higher luminosity for *all* c.m. energies.

- CORE aims to enhance capabilities for key unique EIC measurements such as DVCS on nuclei
  - A high-resolution EMcal in electron hemisphere makes it possible to reconstruct the t-distribution from the DVCS photon, which is important for nuclear beams.
  - The EMcal and the K_L-μ (KLM) system also offer improved lepton ID for exclusive reactions and jets.

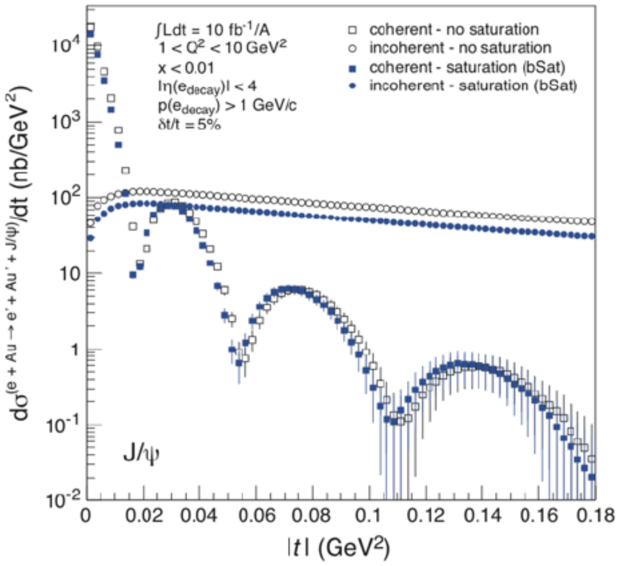


IR integration and physics opportunities



IR8 layout

Diffraction on nuclei (YR)

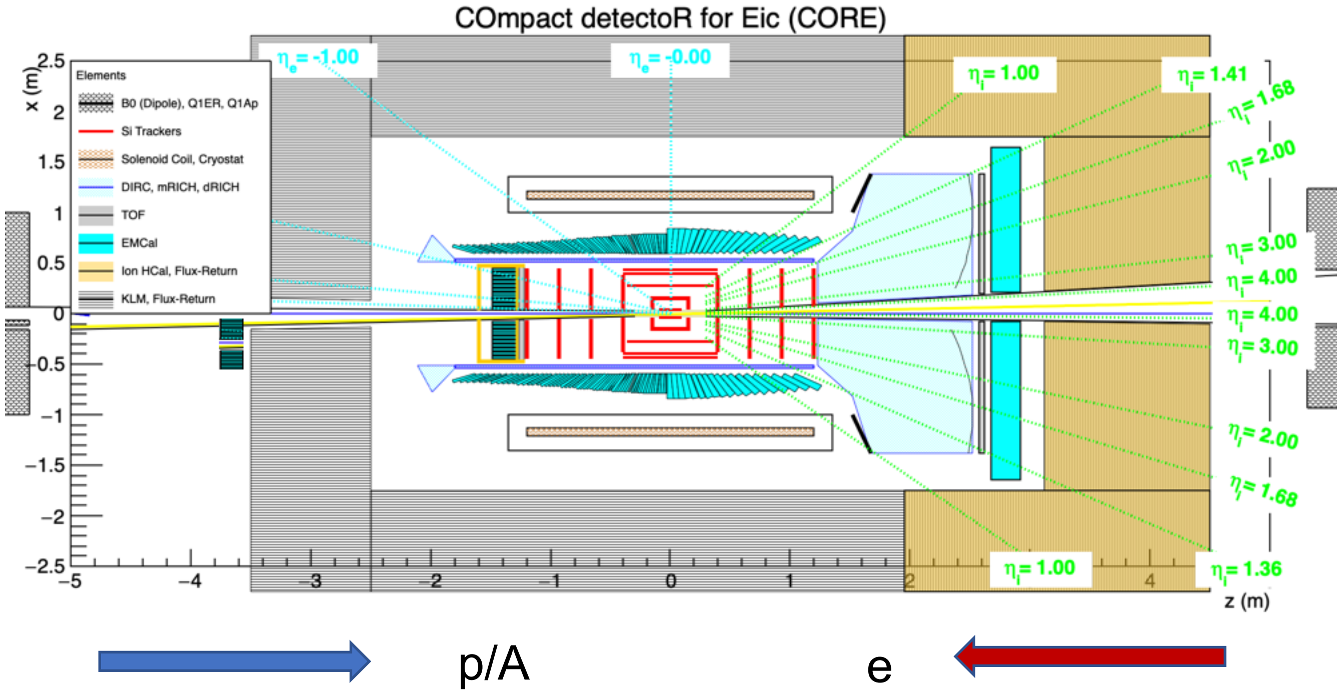


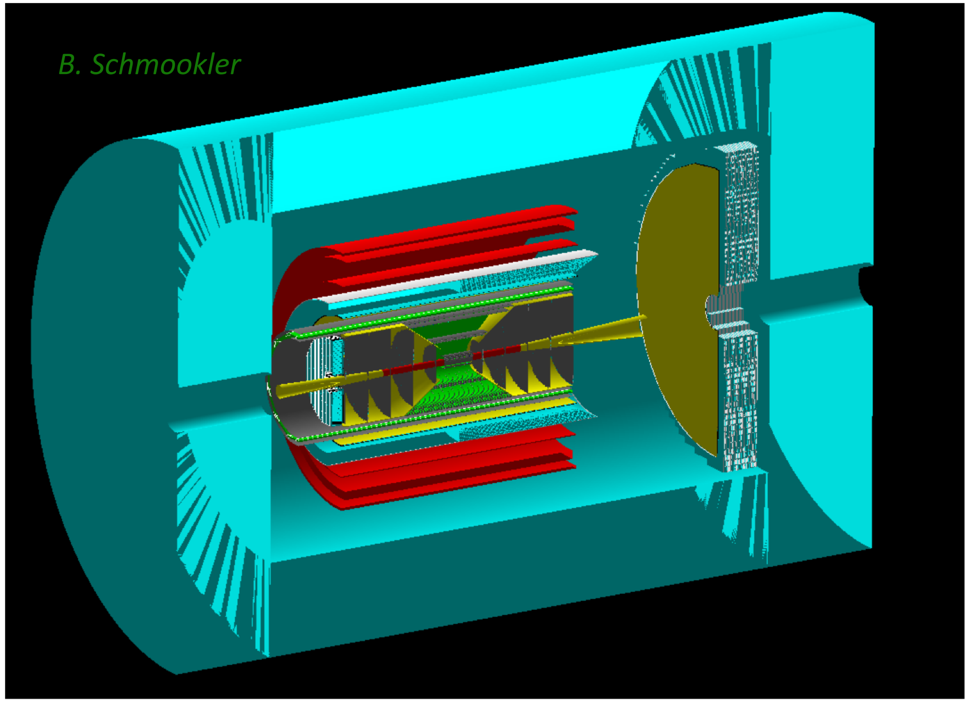
- CORE is compatible with both the IP6 (STAR) and IP8 (PHENIX) locations and all proposed IR layouts.

- An IR with a large, flat dispersion coinciding with an x-y focus (currently IR8) is preferred as it offers important physics capabilities:
  - Improved low-p_T acceptance for protons and light ions at low- and medium x.
  - Clean measurement of coherent diffraction on nuclei by tagging (vetoing) of the A-1 system
  - Measurement of the level structure of short-lived rare isotopes (complementary to FRIB)

a COmpact detectoR for the Eic (CORE)

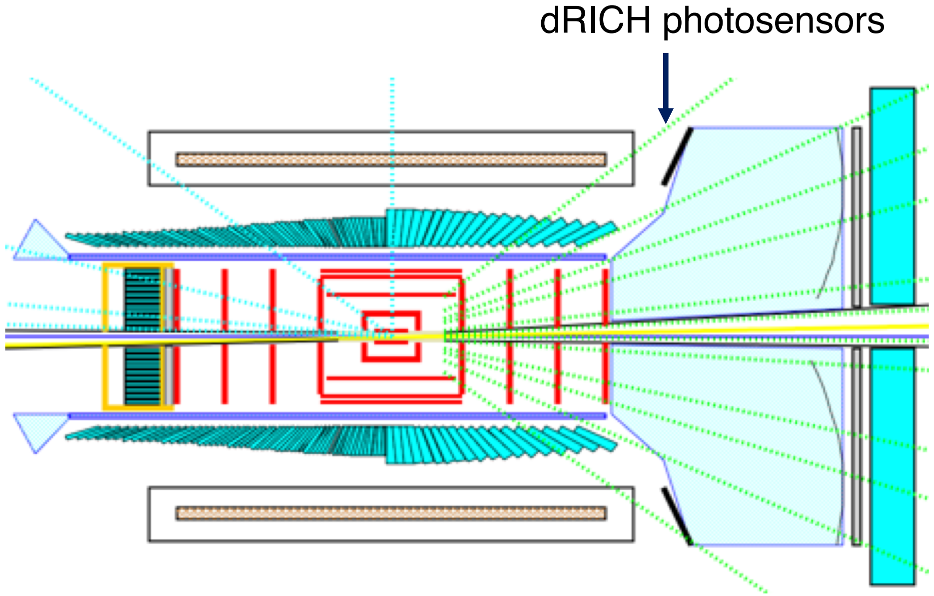
CORE in Geant (fun4all)



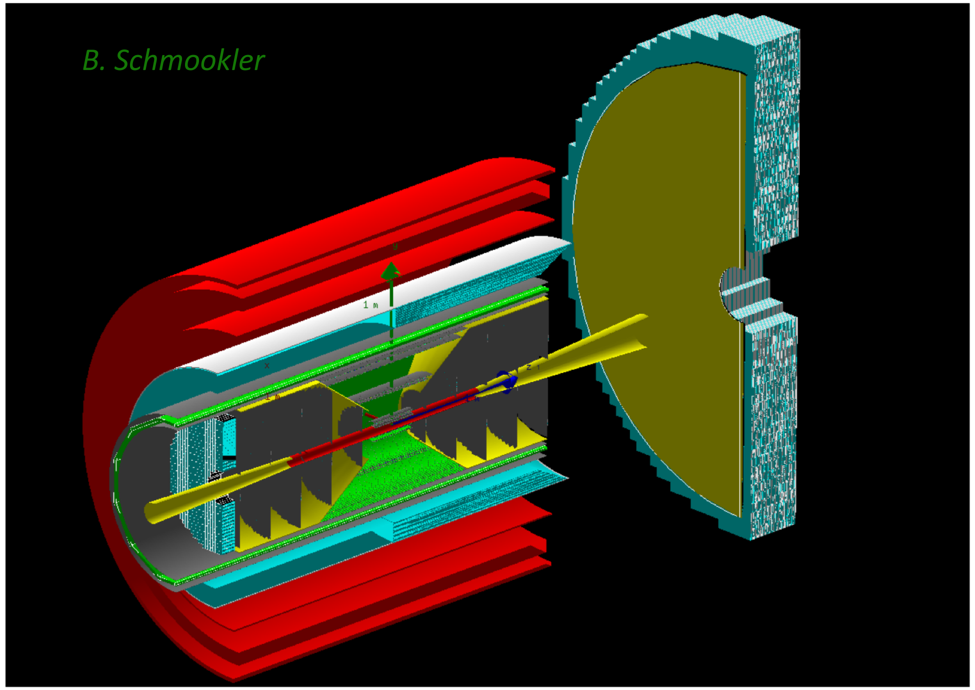


- Compact size reduces cost while allowing investment in critical components.
- Small central core leaves plenty of space within the flux return for support and services.
- Risk is minimized by utilizing subsystems from the Generic EIC R&D program

CORE systems



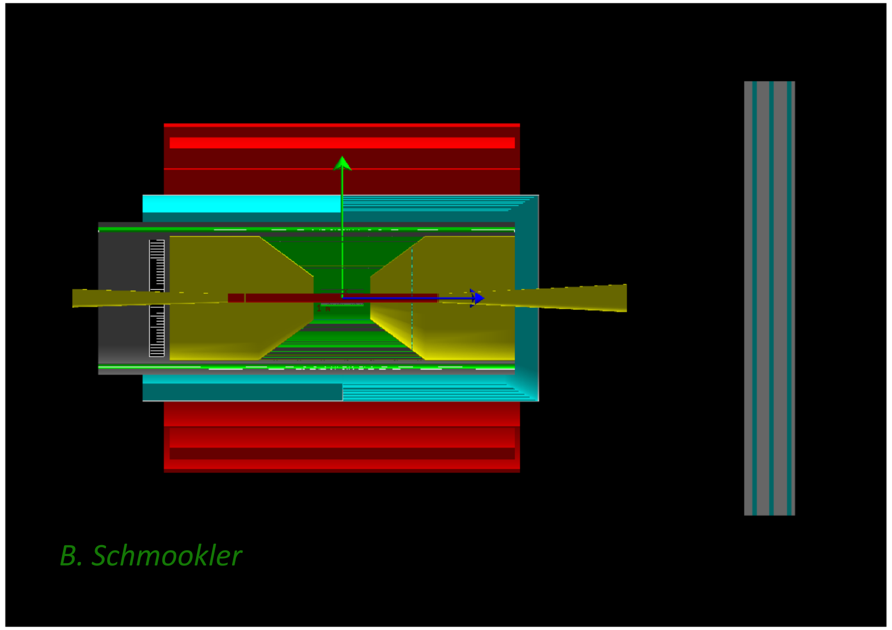
inner CORE in Geant (fun4all)



- New 2.5 T solenoid (2.5 m long, 1 m inner radius)
- Tracking: central all-Si tracker (eRD25) and h-endcap GEM tracker (eRD6)
- EMcal (eRD1): PWO for $\eta < 0$ and W-Shashlyk for $\eta > 0$
- Cherenkov PID (eRD14): DIRC (50 cm radius) in barrel and dual-radiator RICH in h-endcap
- TOF: LGADs in e-endcap (eRD29) and a simple TOF behind the dRICH
- Hcal / K_L-μ (KLM) detector integrated with the magnetic flux return

CORE solenoid

- The CORE solenoid is 2.5 m long with a 1 m inner radius
- CORE is compatible with any field in the 2 - 4 T range
- 2.5 T is the current baseline option



- A 1 m inner radius leaves 50 cm between the DIRC and solenoid

cost (2020 M$) = 1.8 x 0.458 x (stored energy)$^{0.7}$
M. A. Green and S. J. St. Lorant, Adv. Cryo. Eng. **39**

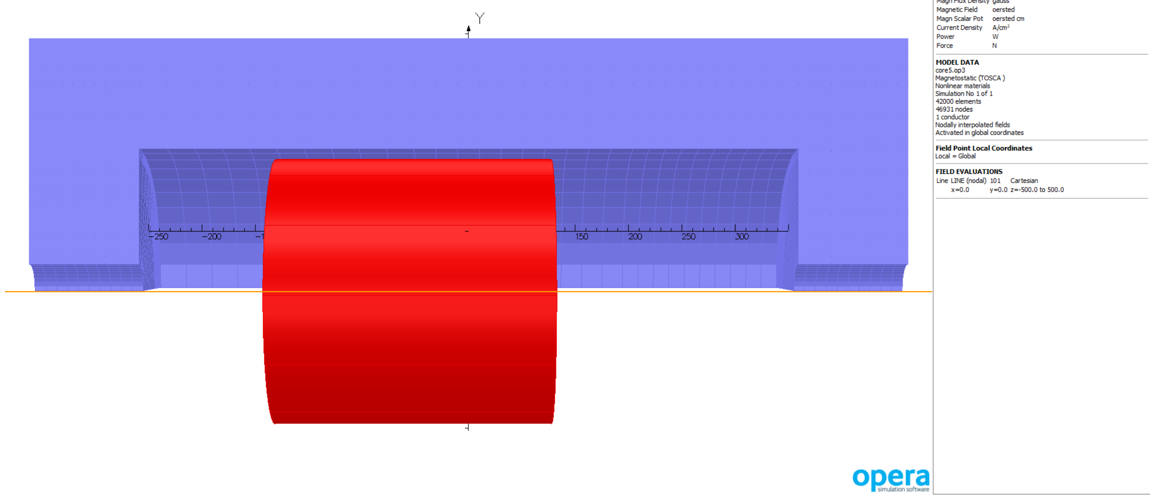
solenoid	field (T)	volume (m^3)	2020 cost (M$)
EIC-IP6	3	29	21
CORE	3	7.8	8.5
CORE	**2.5**	**7.8**	**6.6**
CORE	2	7.8	4.8

- Excellent projectivity for the field in the dual-radiator RICH.
- The field at the DIRC photosensors is less than 2 T, enabling use of MCP-PMTs:
  - best performance and low technical risk

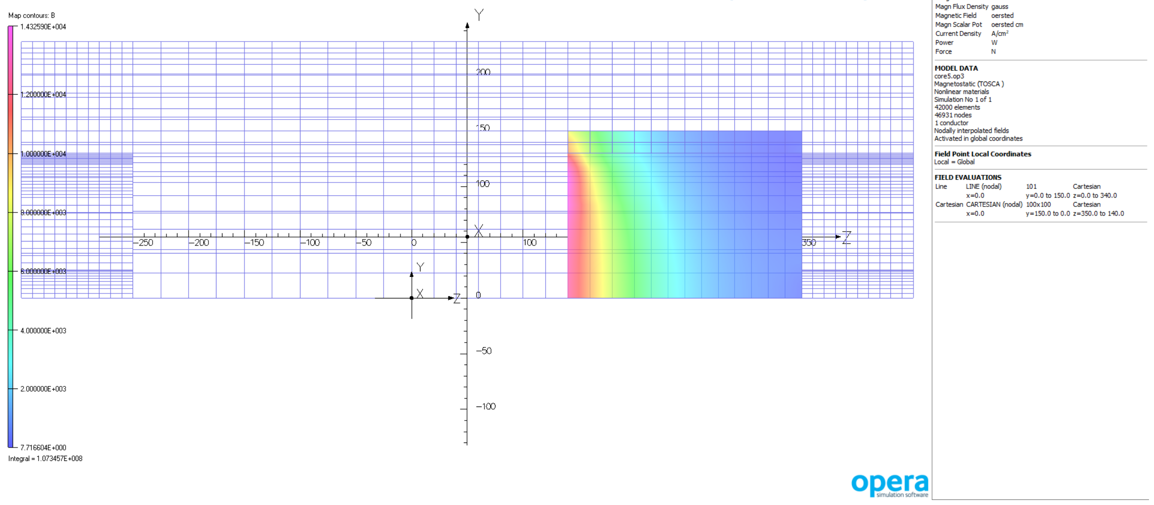
CORE solenoid in opera – 2.6 T on axis at IP

CORE in opera

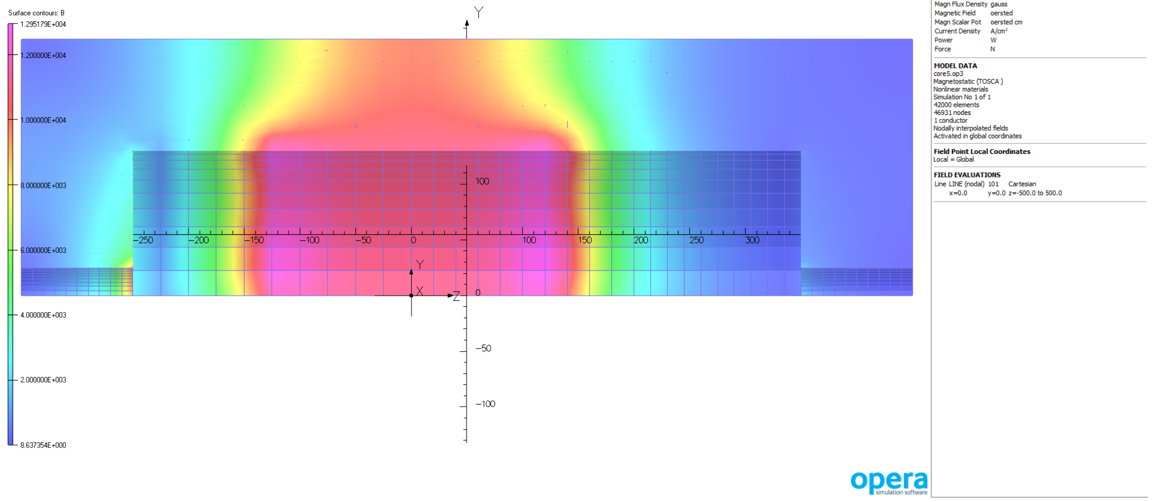
Paul Brindza

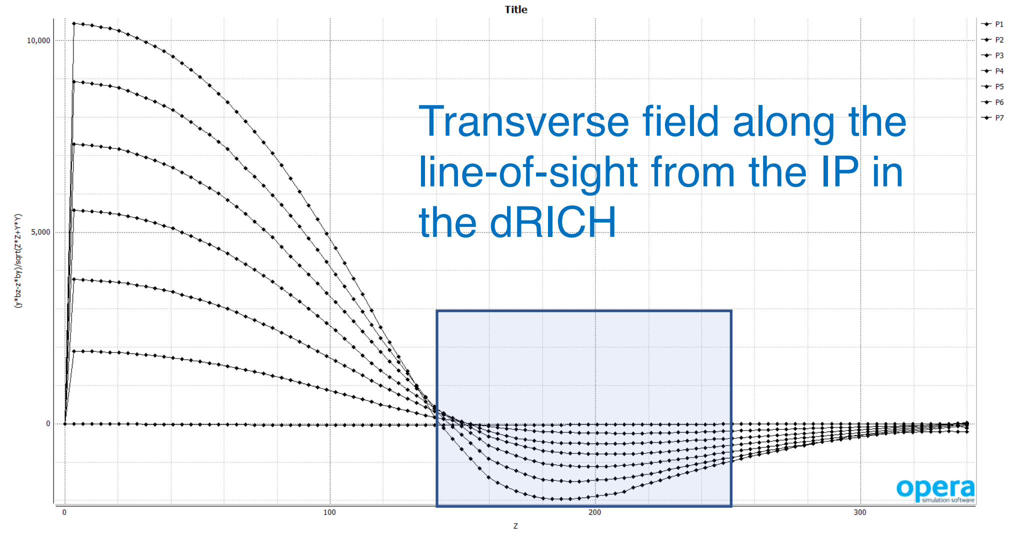


Field in the dual-radiator RICH (dRICH)



Field on iron surfaces

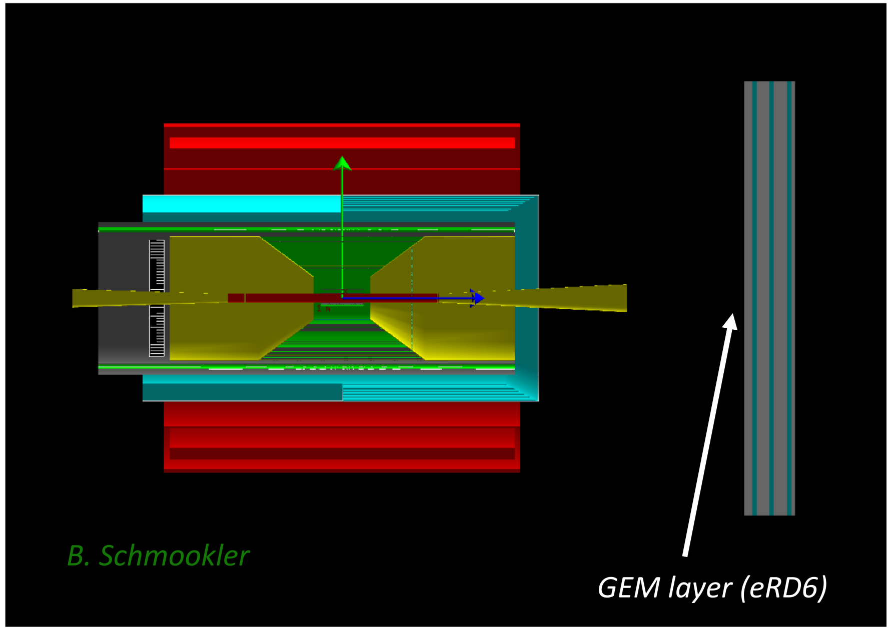




Central Si-tracker and h-endcap GEM

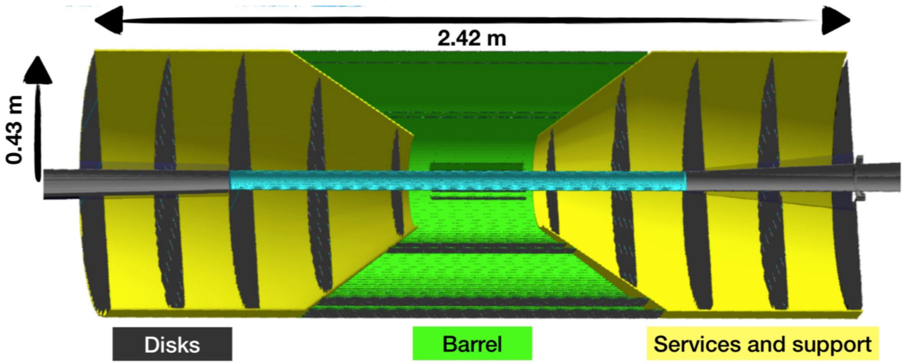
- The Si-tracker developed by eRD25 is a good geometric match for CORE, and an excellent staring point for simulations.

- The flexible geometry of the ALICE ITS3 technology could allow the vertex layers to take full advantage of an elliptic beam pipe.



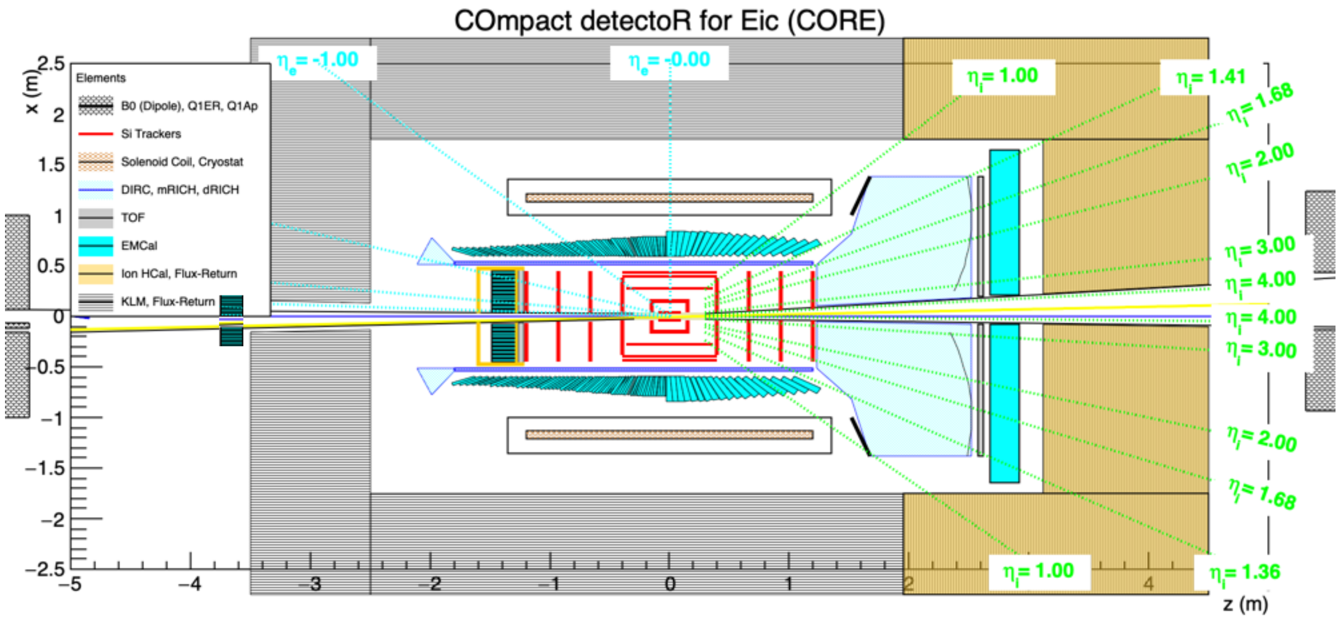
- In addition to the h-endcap GEM, MPGDs could also be used for post-DIRC tracking (if needed)

eRD25 Si-tracker

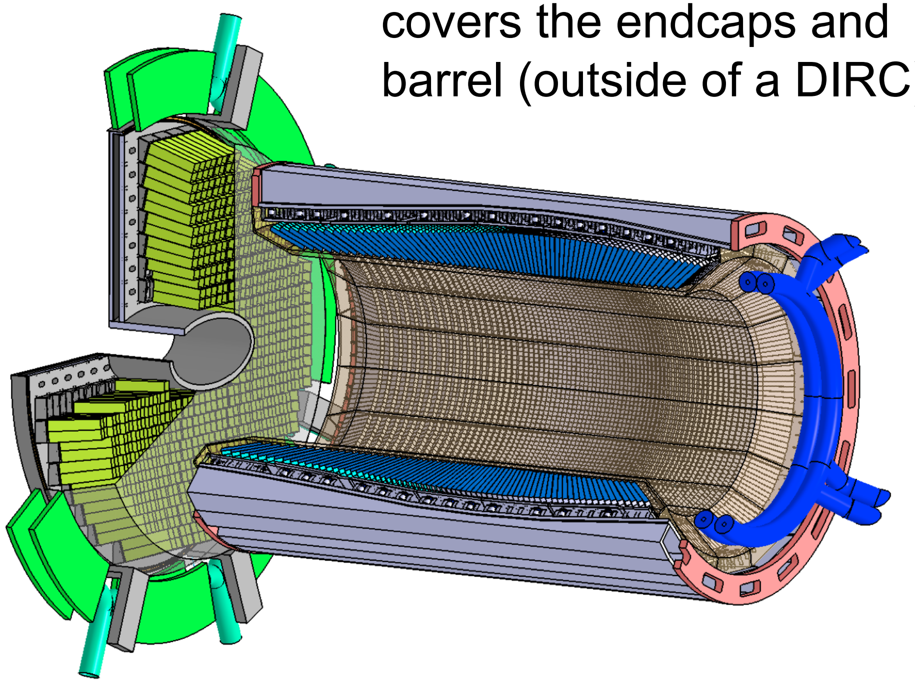


	ITS2/ALPIDE	ITS3
technology	180 nm	65 nm
pixel-size	27 x 29 μm	10 x 10 μm
thickness	50 μm	20-40 μm

4π EMcal



The PANDA PWO_4 EMcal covers the endcaps and barrel (outside of a DIRC)



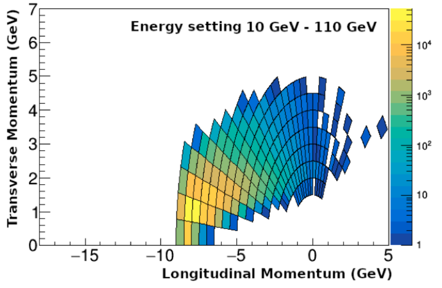
PWO (1-2%) for electron hemisphere: (up to 2π, $\eta < 0$ coverage)

- Both the endcap and barrel could be projective
- The small-angle EMcal could be SciGlass.

W-Shashlyk (6%?) for hadron hemisphere: ($\eta > 0$ coverage)

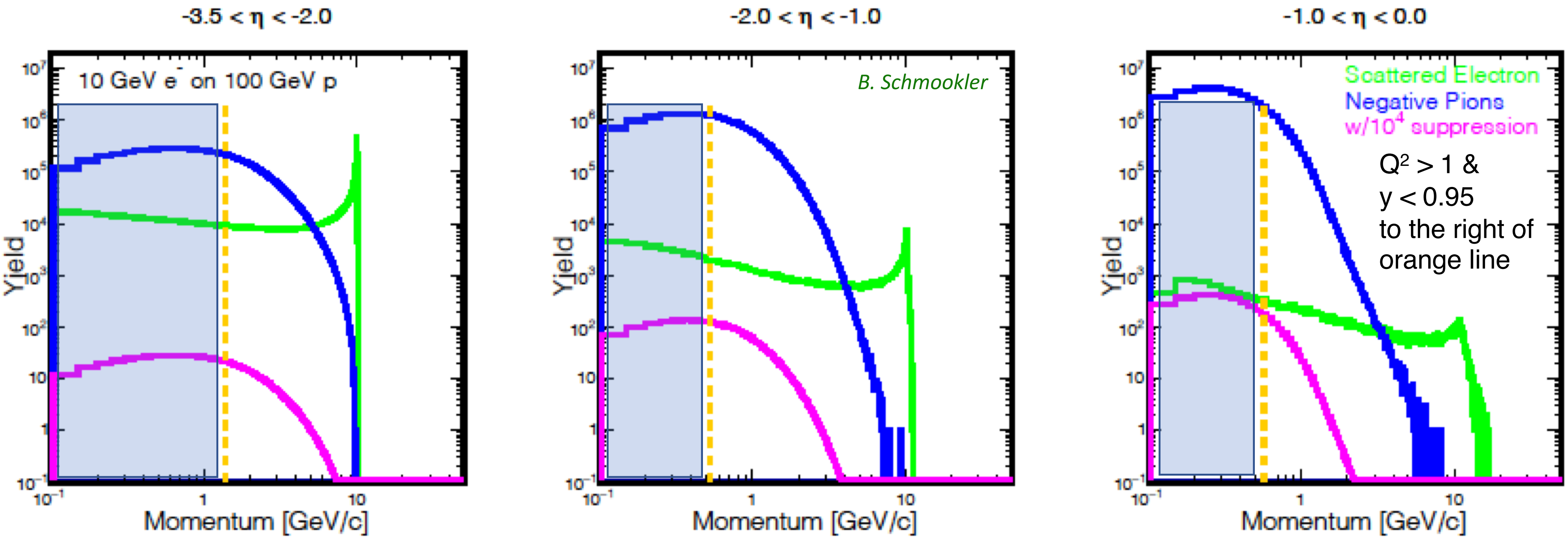
- Projective modules in the barrel
- Non-projective modules in the endcap

Important for eID and high-resolution photon detection (*e.g.*, DVCS on nuclei)



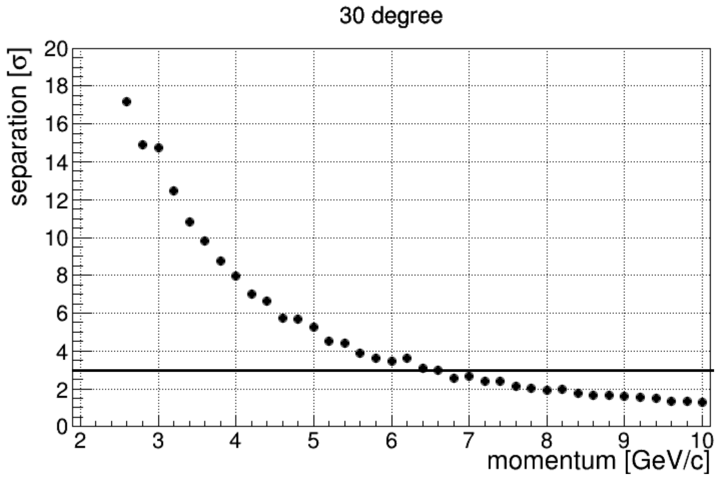
e/π identification in the electron hemisphere

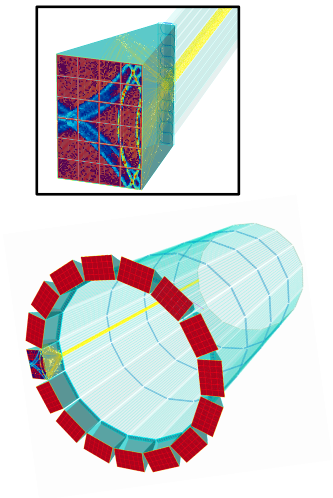
η = -ln(tan(θ/2))



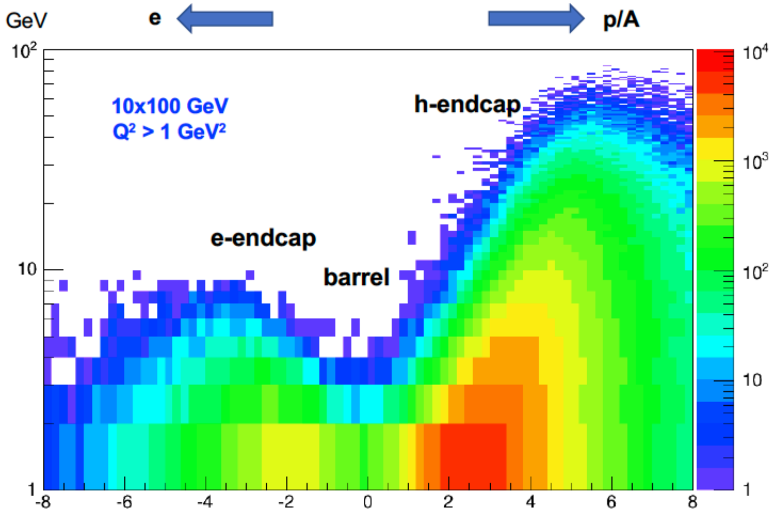
- For the EIC, a clean identification of the scattered electron is essential.
- The barrel region poses the greatest challenge and requires the best electron ID.
- CORE addresses this issue by extending the PWO EMcal coverage up to η < 0 (or possibly -0.5)
- Additional e/π suppression (at least 1:10 up to 1.2 GeV) is also provided by the DIRC.

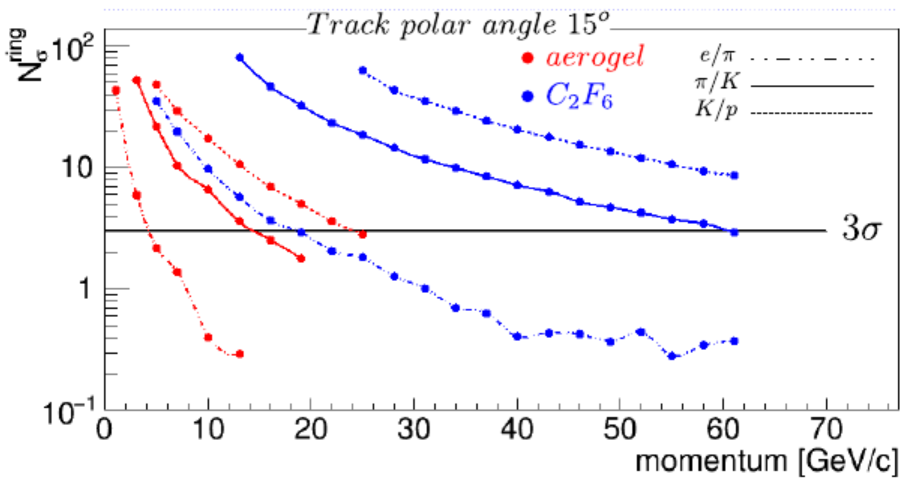
Charged hadron ID in the barrel (hpDIRC) and hadron endcap (dRICH)

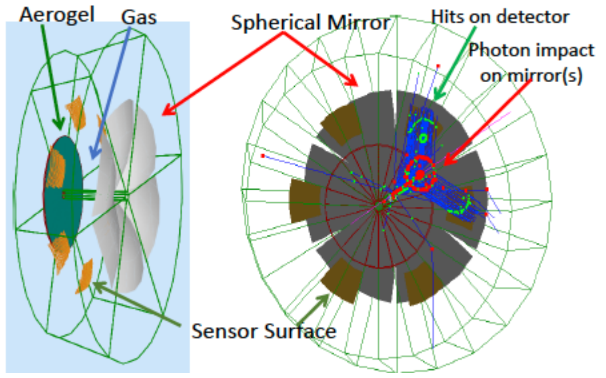




- The hpDIRC has a π/K separation of >4σ up to 6 GeV (and 2σ at 8 GeV).
- The minimum momentum for π/K ID in threshold mode is 0.2 GeV (**no TOF needed**)

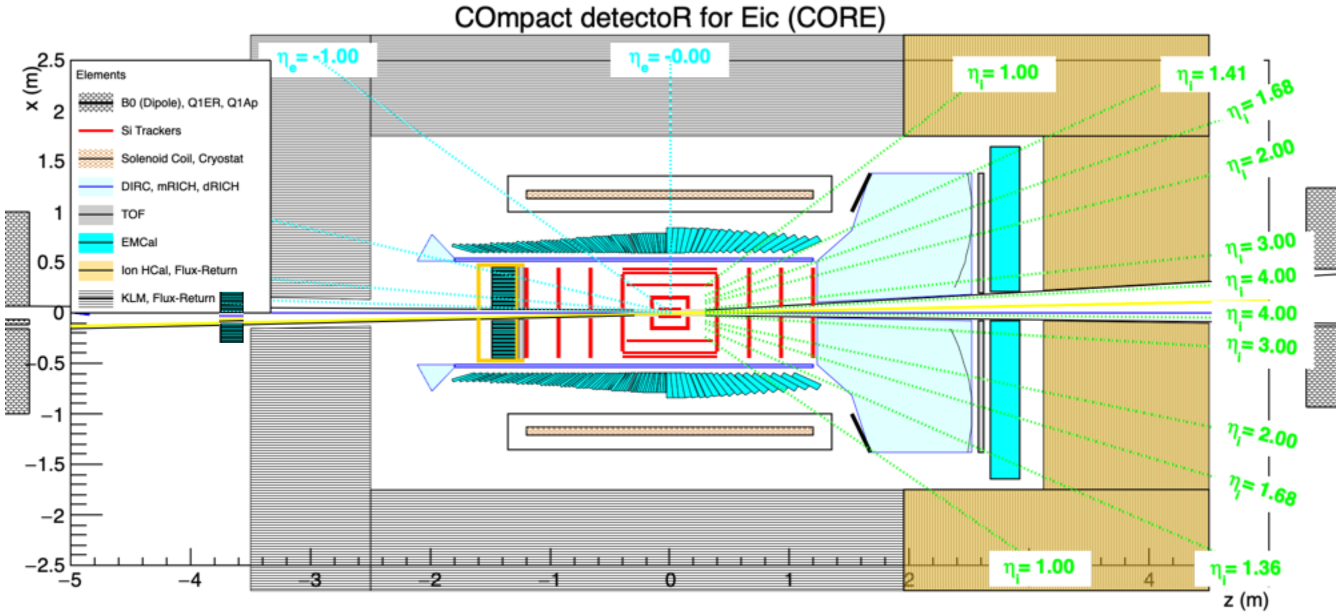




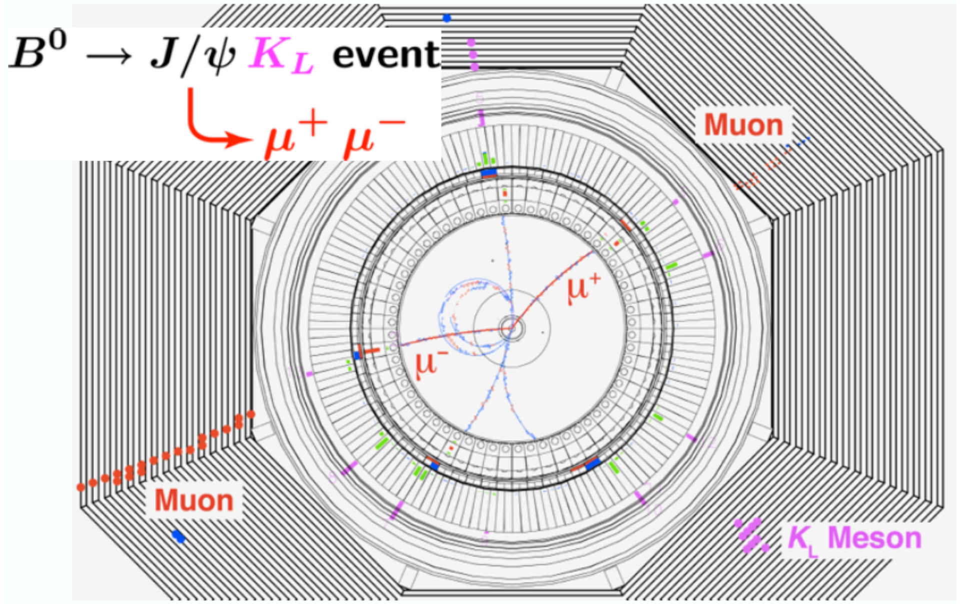


- Using aerogel and gas radiators with a single set of photosensors the dRICH provides *continuous* π/K separation of >3σ up to 60 GeV and an excellent e/π separation (**no TRD needed**).
  - e/π: 10σ at 10 GeV

K_0 ID



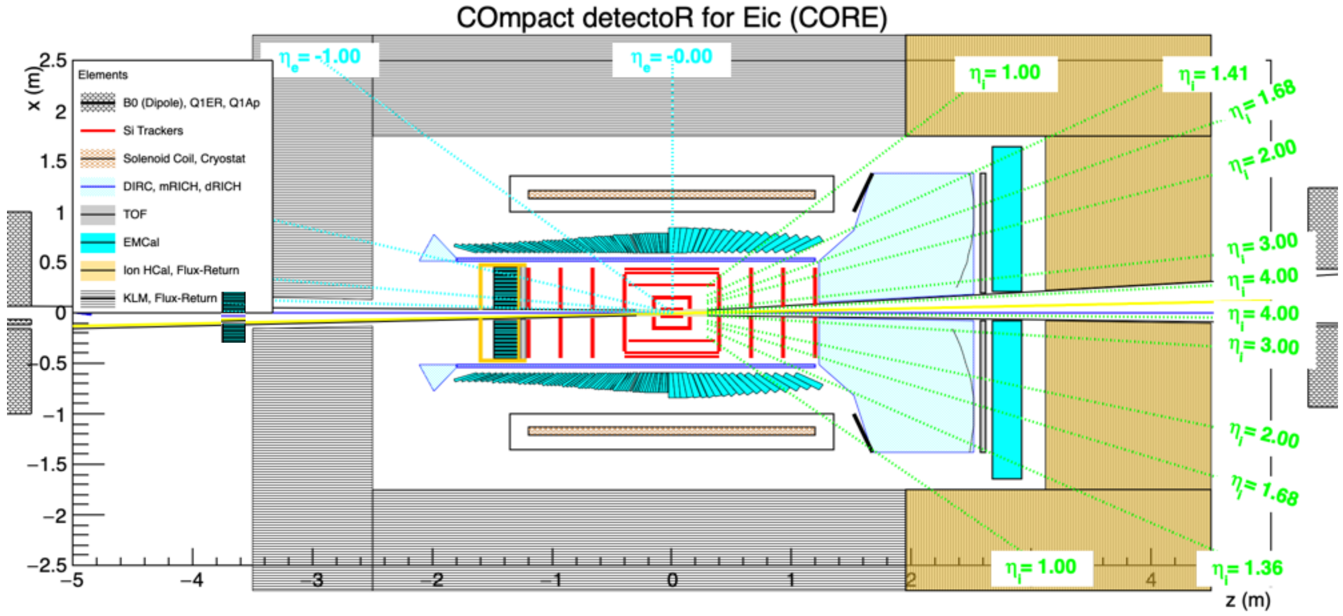
The Belle II K_L-μ (KLM) system

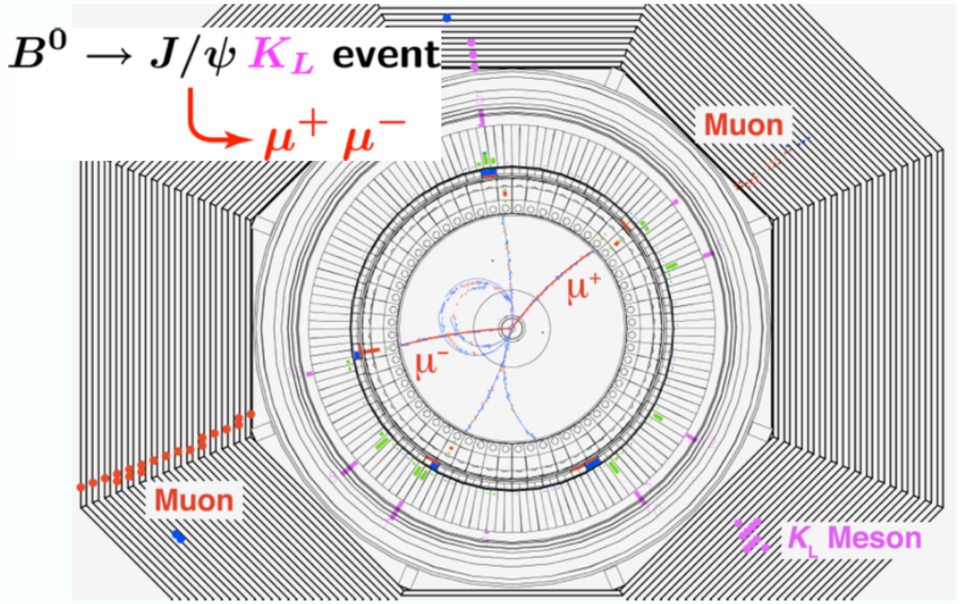


- $K_s \to \pi^+\pi^-$ decays ($c\tau$ = 2.68 cm) can be measured in the outer part of the tracker.
  - K_s with all momenta can be measured, but the efficiency will drop with momentum.
  - p/π^+ ID in the DIRC will distinguish $K_s \to \pi^+\pi^-$ from $\Lambda \to p\pi^-$.
- K_L will be detected in the KLM system, which will provide a precise angular measurement
  - p_T for a single neutral hadron can be obtained from p_T balance
  - For a single neutral hadron, n/K_L ID can be obtained from hermeticity and baryon conservation (all target baryons stay in the beam pipe)

Muon ID

The Belle II K_L-μ (KLM) system

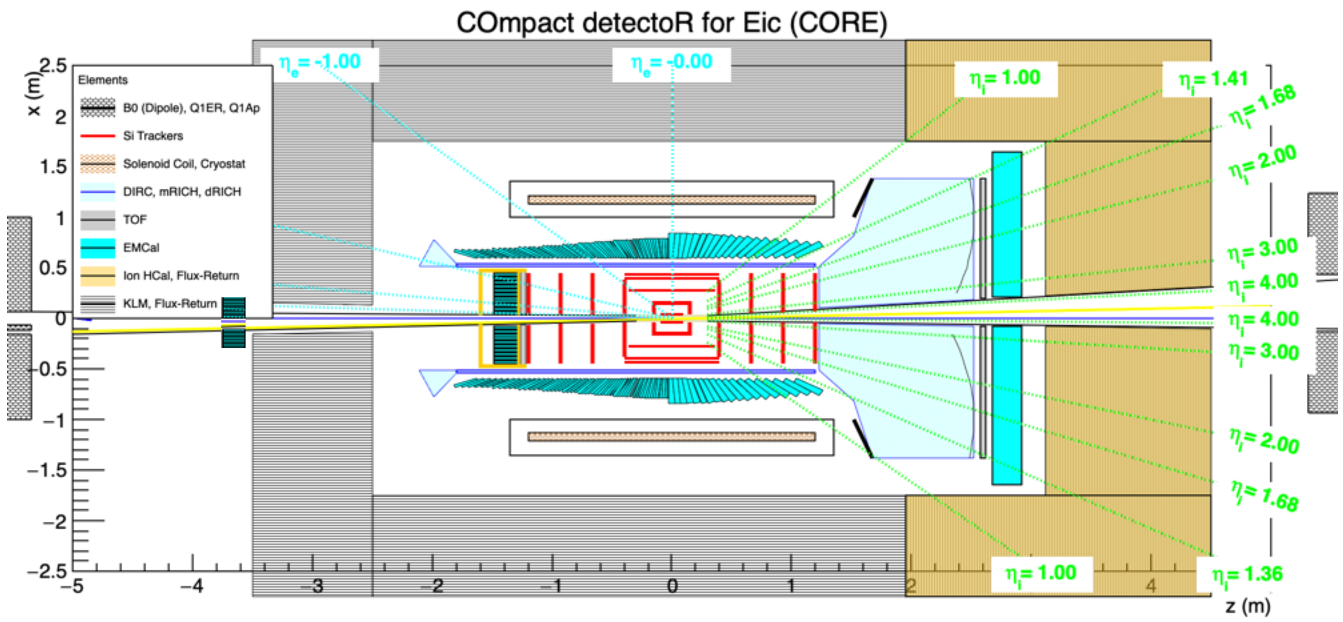




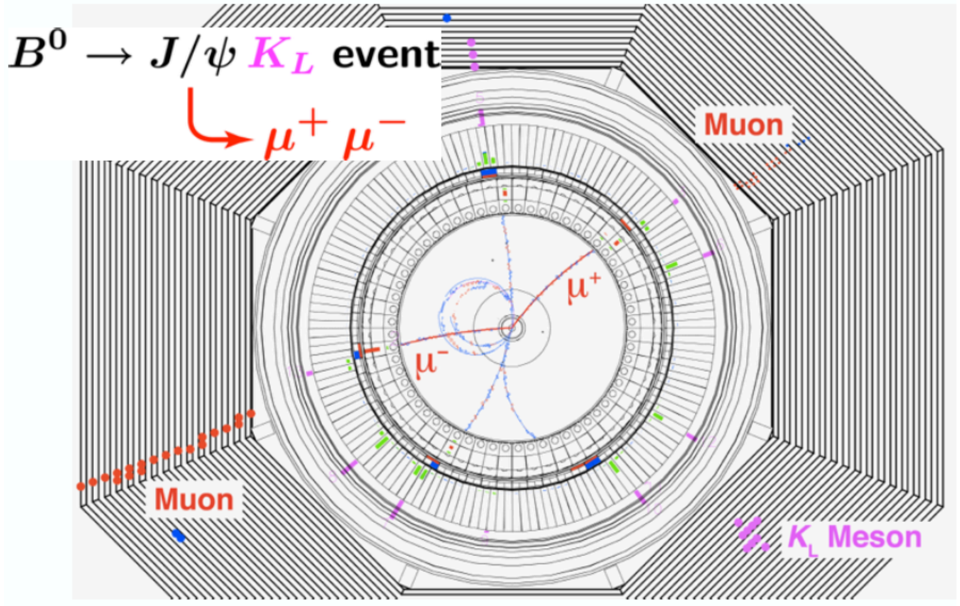
- At the EIC, mid-rapidity muons have relatively low momenta. The Belle KLM (K_L-μ) detector, which is integrated with the flux return, can ID muons down to 0.6 GeV/c.

- In the hadron endcap, both jet and muon energies are large, and additional muon detectors can be placed behind the Hcal (yellow).

Jets



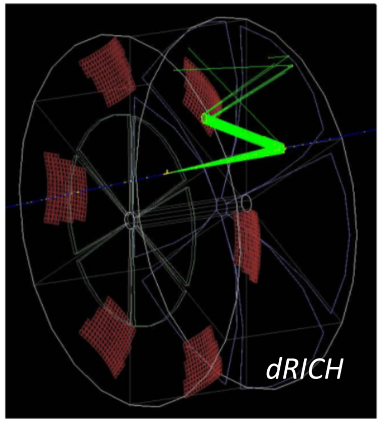
The Belle II K_L-μ (KLM) system



- Except for the forward-hadron direction, jets at the EIC are best reconstructed from individual tracks (giving a better jet energy resolution than an Hcal could provide).
  - About 1/3 of jets have a neutral hadron, which can be detected in the K_L-μ (KLM) system
- In the hadron endcap, a high-resolution Hcal (yellow) is important for high-energy, high-x jets
  - An h-side Hcal is also important for kinematic reconstruction (JB and DA methods)
  - Note that the Hcal / KLM transition at η ~ 1 is somewhat arbitrary and can be adjusted

Simulation status

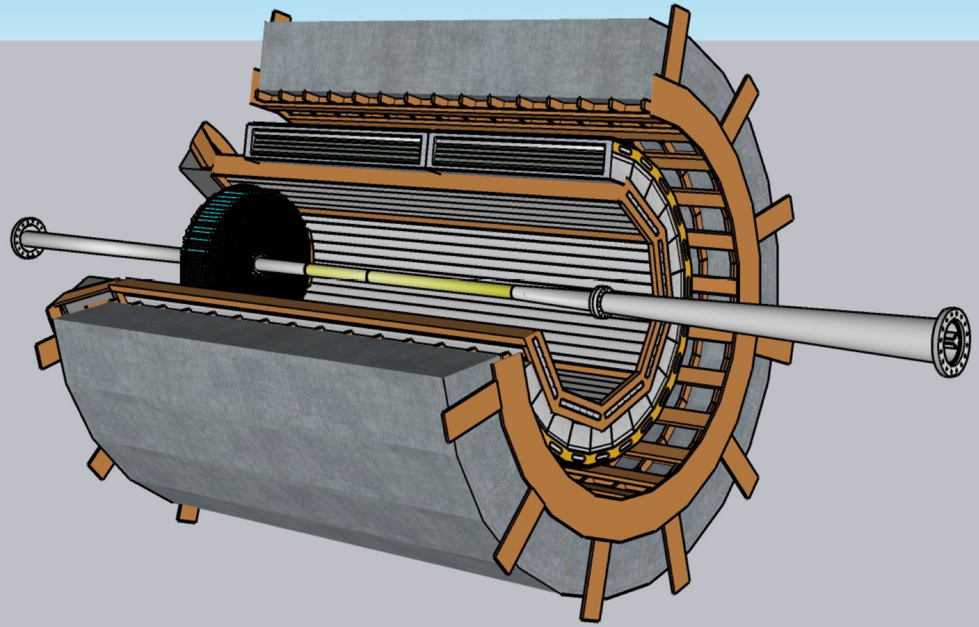
- The CORE configuration is well defined and stable
- Solenoid field map.
  - Ready; will soon be implemented in fun4all
- Geant4 (fun4all)
  - All major subsystems are implemented – but not all are yet fully functional.
  - dRICH is currently implemented separately but will be added soon



Geometry in Fun4All

- Implementation in fast MC
  - eic-smear: CORE model is almost complete. PID is currently being added
  - Delphes: implementation ongoing
- Users will soon be able to start full physics simulations with CORE!

Thank you!



How to get involved

All users are welcome to join CORE and participate in CORE activities!

Bi-weekly meetings

- Mondays at noon
  - Time may change due to conflicts with other meetings

Wiki and mailing lists

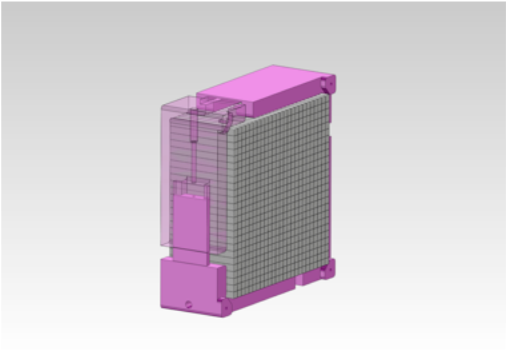
- Wiki: https://eic.jlab.org/core
- Mailing lists:
  - eic-core@jlab.org
  - eic-core-det@jlab.org
  - eic-core-phys@jlab.org

Pre-showers for γ/π^0 separation

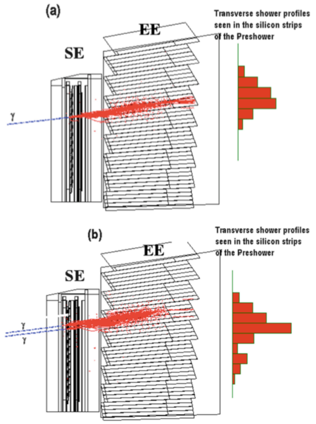
- W-Shashlyk may be have sufficient intrinsic position sensitivity not to require a separate pre-shower
  - R&D will determine optimal configuration.
  - No separate pre-shower needs to be implemented in simulation at this point

- PWO crystals can provide γ/π^0 separation at lower energies, but a pre-shower will improve separation and increase the energy range
  - Would PWO alone be sufficient for the EIC?
- Several PWO pre-shower options exist.
  - Simplified configuration in simulation?

A LYSO pre-shower from the RD2012-13 proposal with fiber readout could be an interesting option.



The CMS PWO pre-shower uses cooled 6 mm Si-strip detectors in-between an initial layer and the main PWO blocks



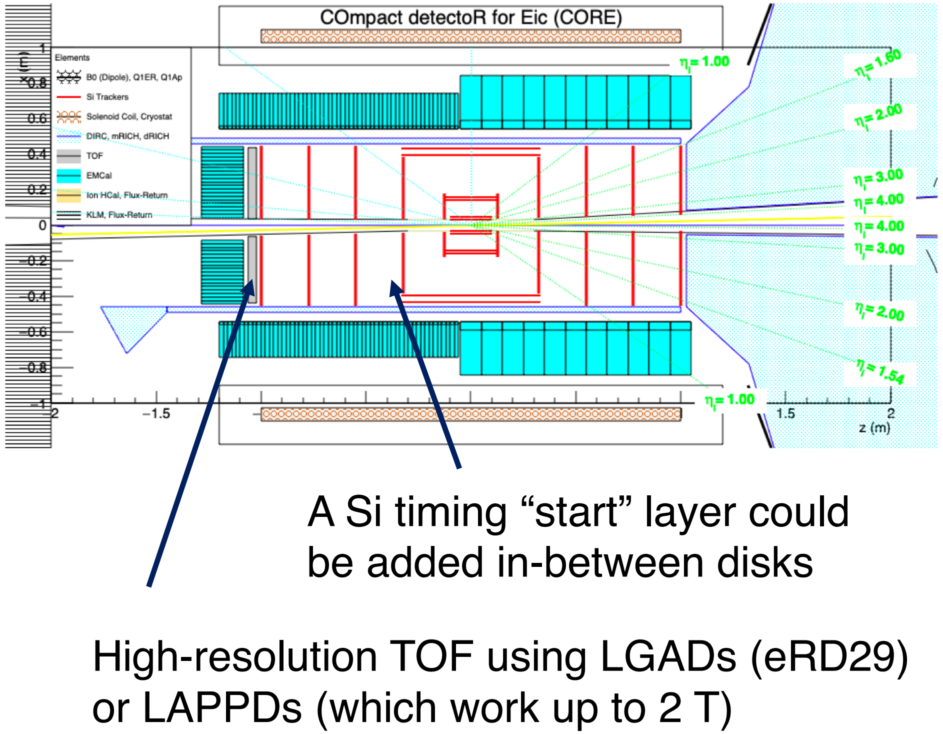
Hadron Identification in the electron endcap

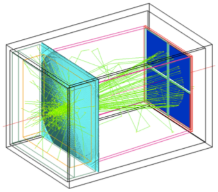
- While high-resolution TOF is not competitive with Cherenkov detectors in the central barrel (small radius), it could be a good solution for the electron endcap.

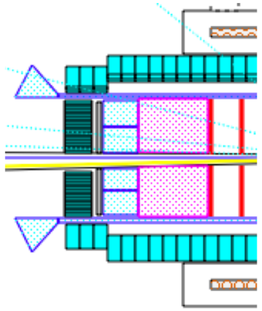
- t_0 can be obtained using an electron scattered into the endcap and/or a separate ”start” layer integrated with the Si-tracker.

- The TOF installation is modest and resolution could improve through future upgrades.

- Alternatively, CORE could also support an aerogel RICH (*e.g.*, the mRICH) by extending the endcap by 30 cm, for which there is plenty of space - although this would also extend the length of the PWO_4 EMcal.







Complementarity?