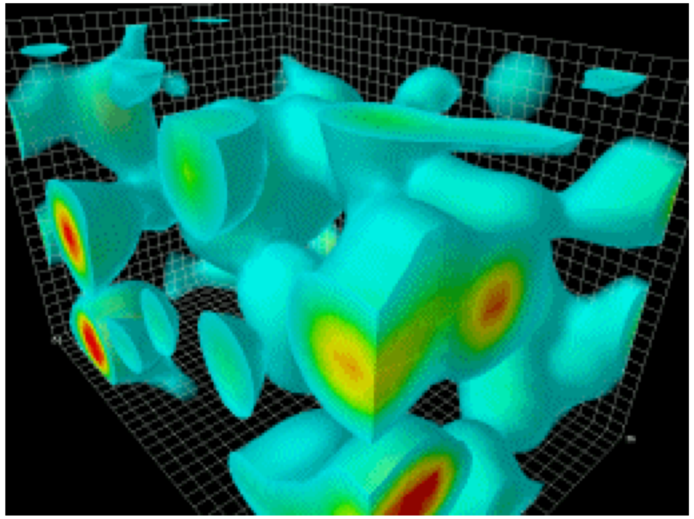
CORE: a COmpact detectoR for the EIC



The QCD vacuum

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Old Dominion University

for the CORE pre-collaboration

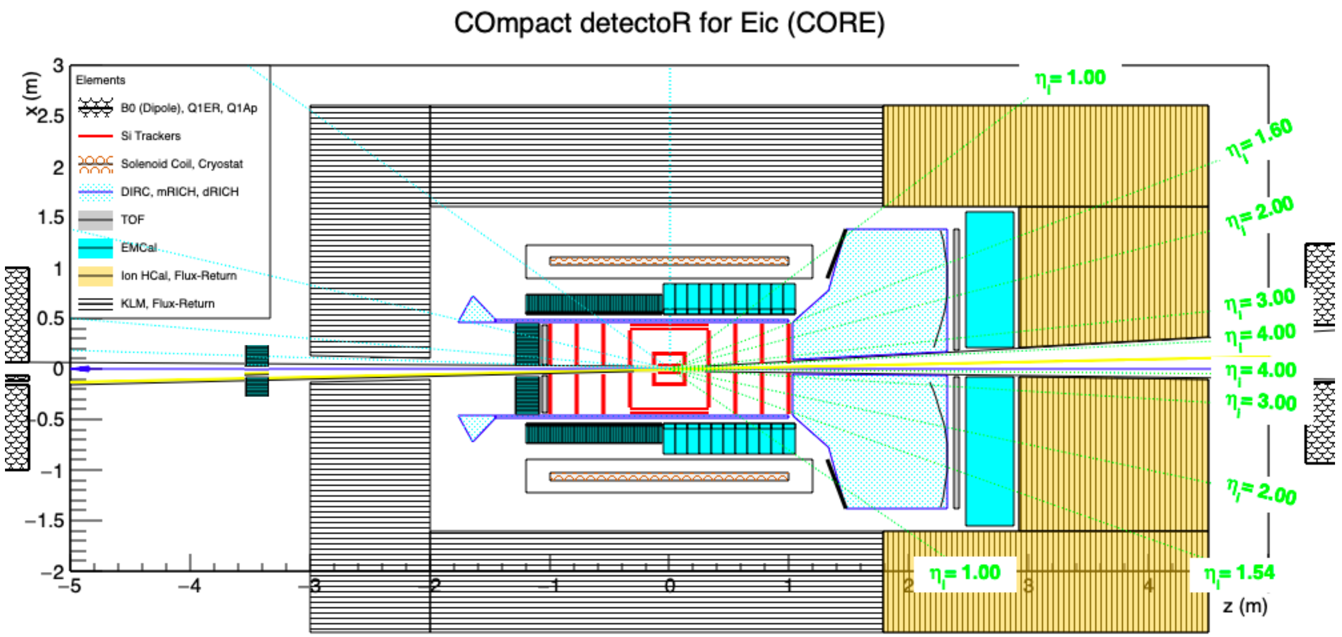
(open to all users)

IR2@EIC workshop, March 17-19, 2021

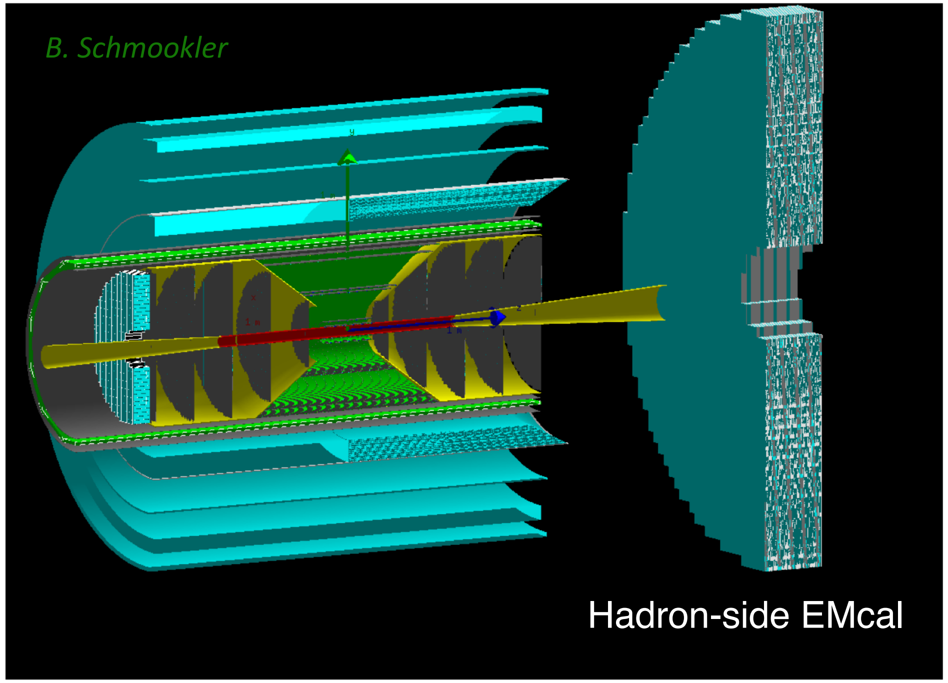
Participating institutions

- Catholic University of America
- Duke University
- Erlangen-Nuremberg University, Germany
- GSI, Germany
- Indiana University
- Old Dominion University
- Stony Brook University
- University of Hawaii
- University of South Carolina
- University of York, United Kingdom

a COmpact detectoR for the Eic (CORE)



inner CORE in Geant (fun4all)



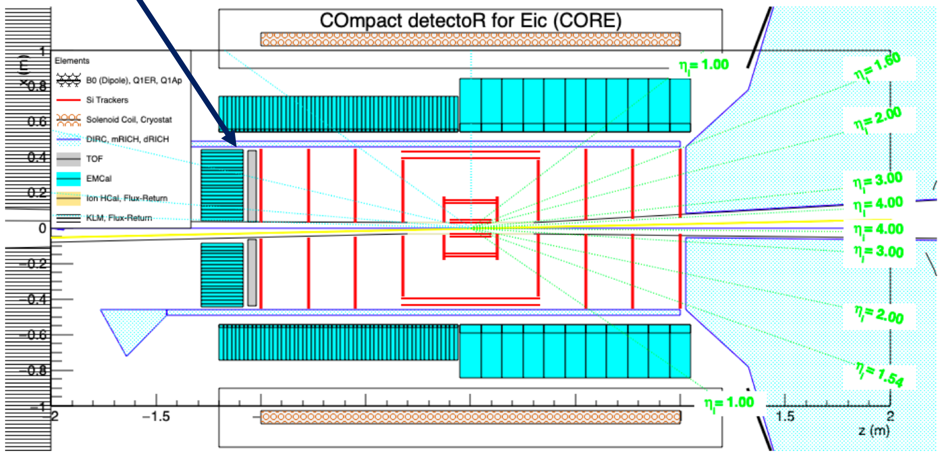
- A (nearly) hermetic general-purpose detector that fulfills the EIC physics requirements
- A small size, in particular of the inner systems, is cost-effective and allows:
  1. An overall reduction in cost without performance loss
  2. Improved performance in critical areas without large additional cost

  Balance can be optimized depending on funding.
- Risk is minimized by utilizing subsystems from the Generic EIC R&D program

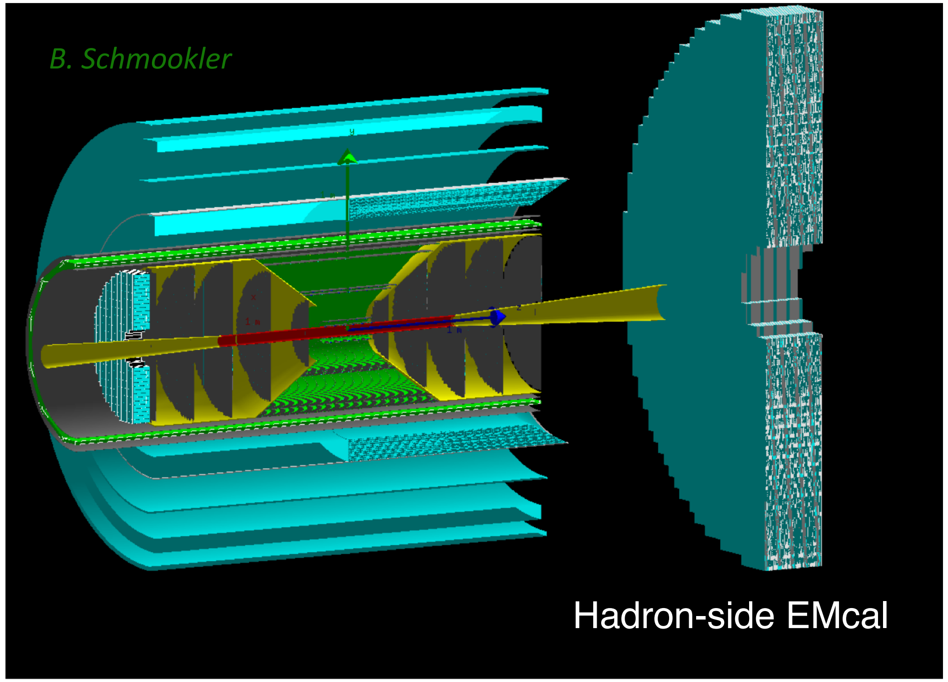
The core of CORE

No “gap” along line-of-sight from IP

dRICH photosensors



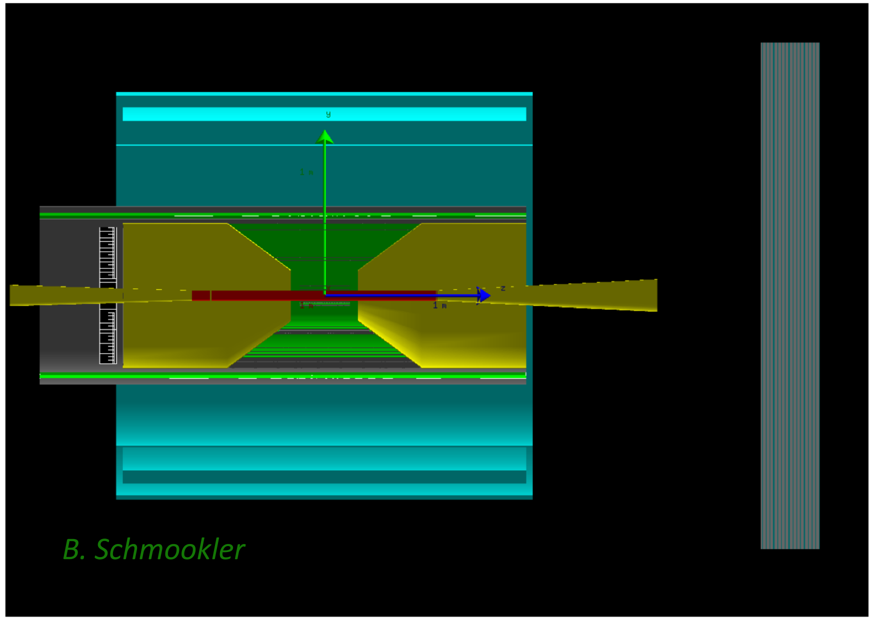
inner CORE in Geant (fun4all)



- Small central all-Si tracker (eRD25)
- Radially compact, high-performance barrel DIRC Cherenkov (eRD14)
- Dual-radiator RICH with *outward-reflecting* mirrors in the hadron endcap (eRD14)
- Extended PWO_4 EMcal coverage (2π, $\eta < 0$) on the electron side (eRD1)
- Small solenoid (2.5 m long, 0.9 m inner radius); could be new, but compatible with ZEUS

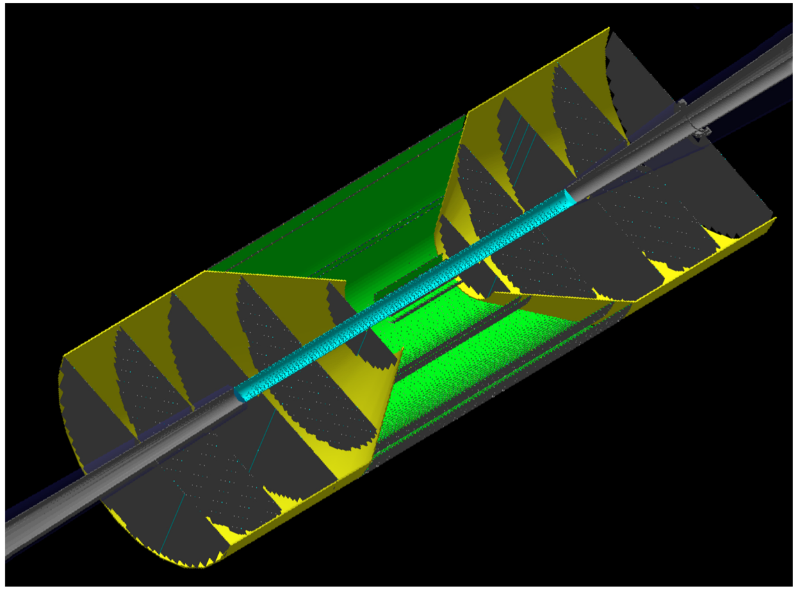
Solenoid and central Si-tracker

- The CORE solenoid is identical in size to the one used by ZEUS (2.5 m long and 0.9 m inner radius)
  - **22% of the volume** of the BaBar / sPHENIX solenoid or the proposed new large 3 T one.
- With a new small solenoid, CORE could support any field in the 1.4 – 3 T range, with 2 T being the preferred value
  - p_{min}, photosensors (MCP-PMTs / LAPPDs limited to 2 T)

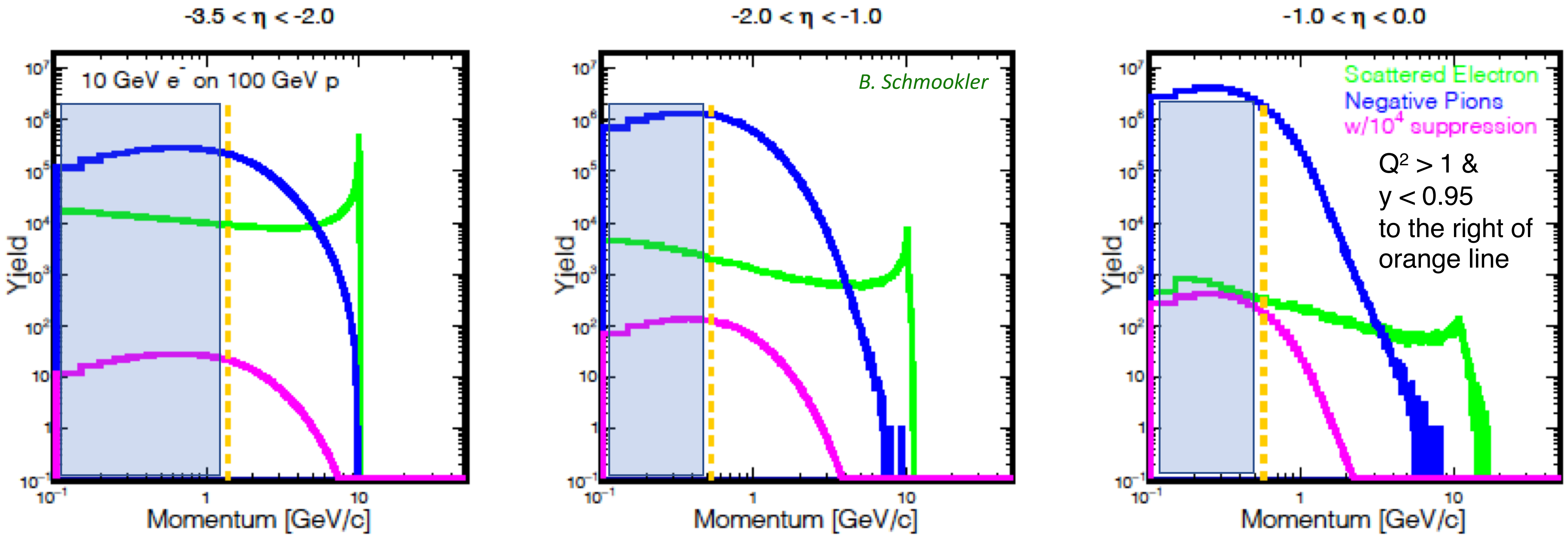


		$\delta p/p = Ap \oplus B$		$\mathrm{DCA}_z = A/p_T \oplus B$		$\mathrm{DCA}_T = A/p_T \oplus B$	
		A [%/GeV]	B [%]	A [μm GeV]	B [μm]	A [μm GeV]	B [μm]
$0.0 < \eta < 0.5$	B = 3.0T	0.018	0.369	26.6	3.24	25.0	4.87
	B=1.4T	0.038	0.816	27.1	3.33	26.2	3.88
$0.5 < \eta < 1.0$	B = 3.0T	0.016	0.428	36.8	3.79	28.5	4.49
	B=1.4T	0.035	0.898	35.1	3.79	31.2	4.04
$1.0 < \eta < 1.5$	B = 3.0T	0.016	0.427	55.9	5.89	33.1	5.46
	B=1.4T	0.035	0.921	56.2	5.41	35.2	5.10
$1.5 < \eta < 2.0$	B = 3.0T	0.012	0.462	108.2	8.74	39.1	5.46
	B=1.4T	0.026	0.997	106.3	8.36	39.8	5.21
$2.0 < \eta < 2.5$	B = 3.0T	0.018	0.719	207.3	19.77	45.1	9.54
	B=1.4T	0.041	1.548	201.8	21.50	46.3	9.31
$2.5 < \eta < 3.0$	B = 3.0T	0.039	1.336				
	B=1.4T	0.088	2.830				
$3.0 < \eta < 3.5$	B = 3.0T	0.103	2.428				
	B=1.4T	0.217	5.234				
$3.5 < \eta < 4.0$	B = 3.0T	0.295	4.552				
	B=1.4T	0.610	9.797				

- The all-Si tracker developed by the eRD25 consortium is a good fit for CORE

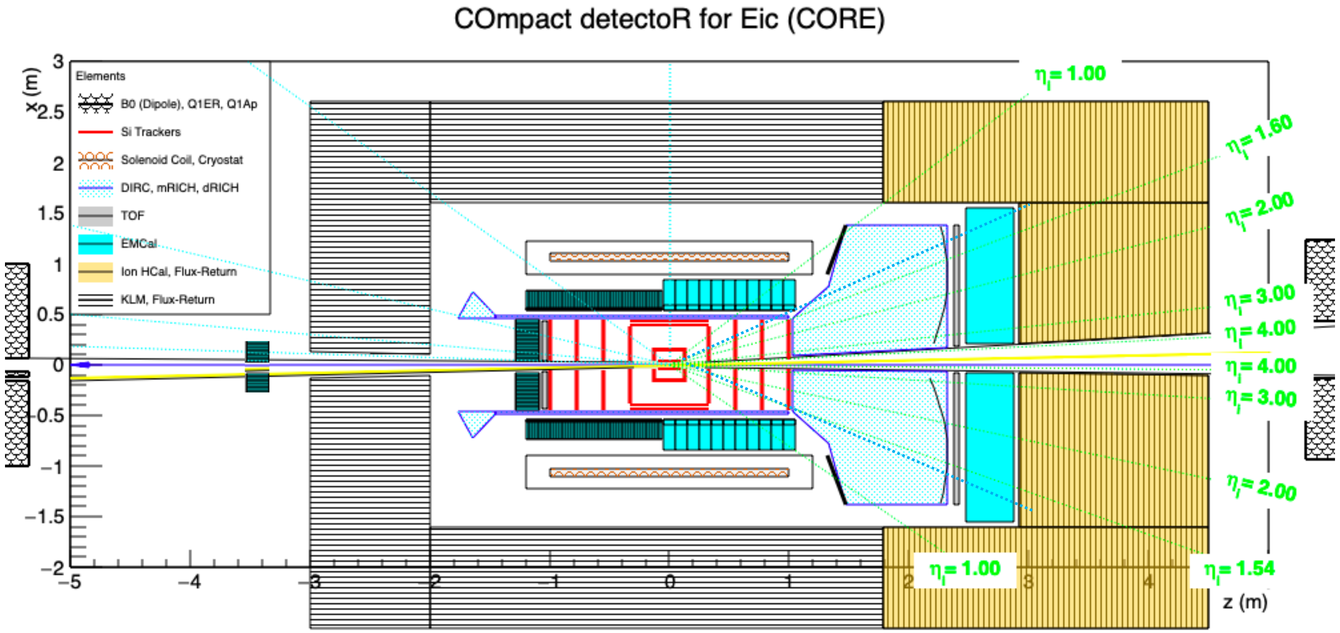


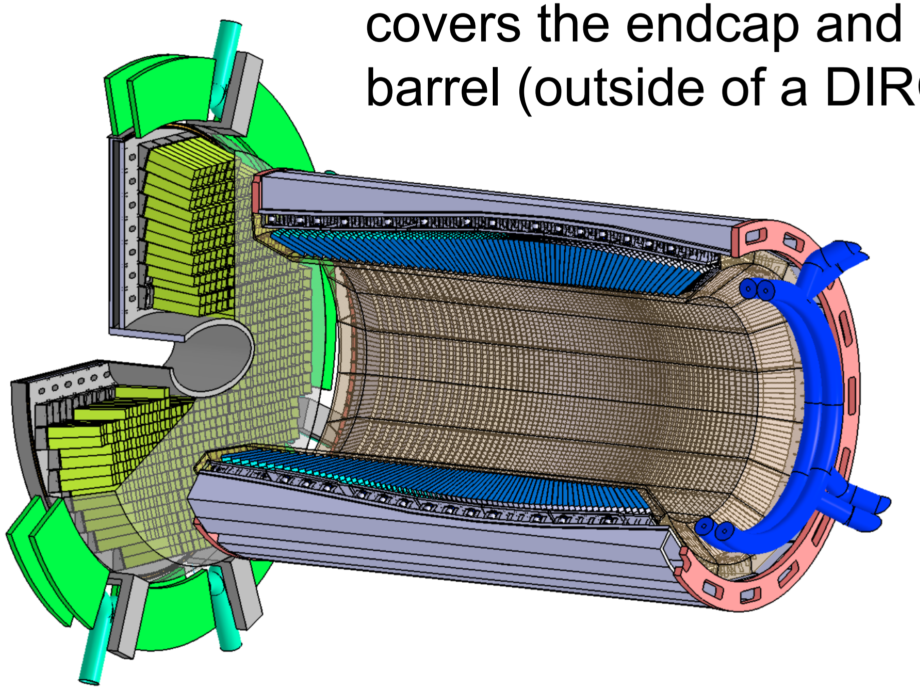
e/π identification requirements on the electron side



- For the EIC, a clean identification of the scattered electron is essential.
- Since the relative pion backgrounds rise with η, the most challenging region is -1 < η < 0.
- The best solution is to extend the PWO_4 EMcal coverage (η < 0).
  - This is only affordable in a relatively small detector
- Additional e/π suppression (at least 1:10 up to 1.2 GeV) can be provided by the DIRC

4π EMcal





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

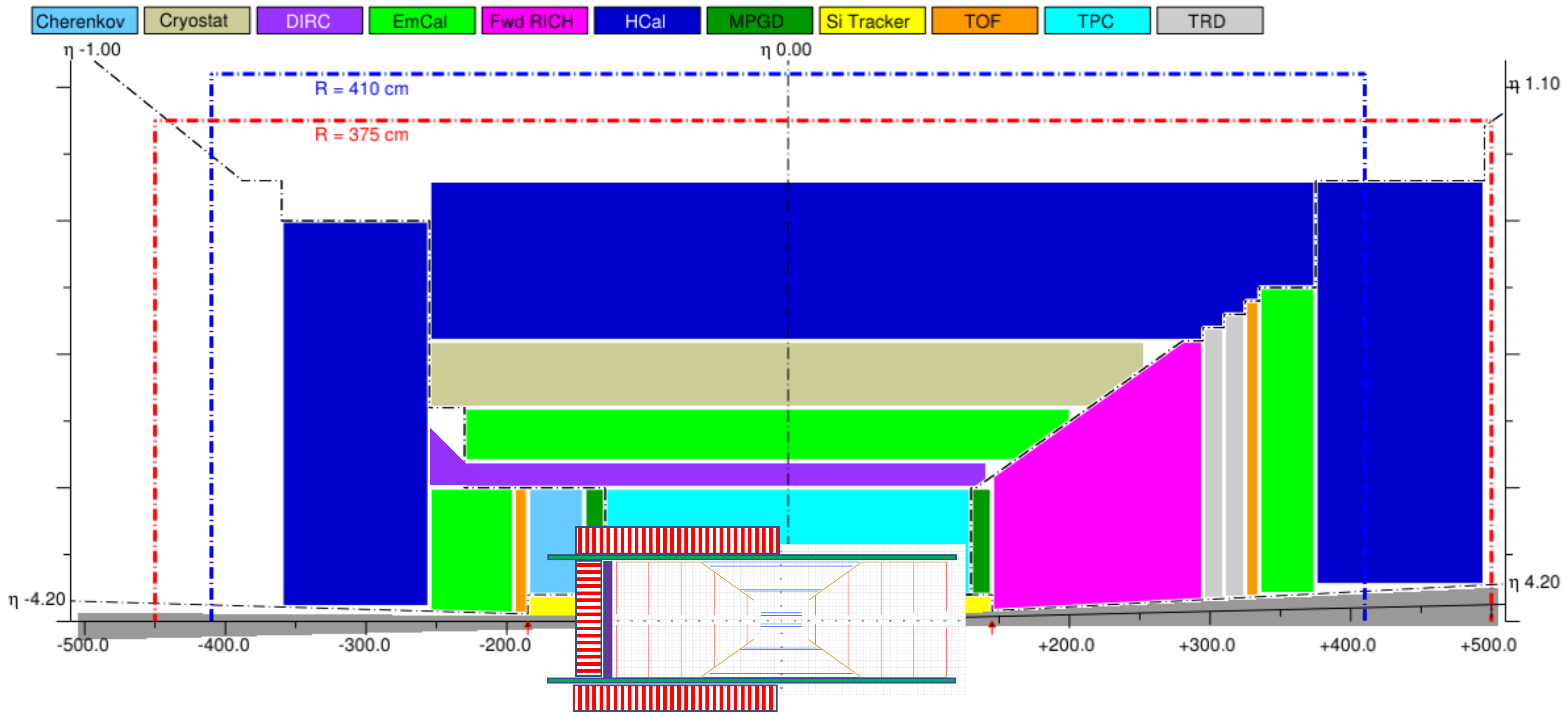
2π PWO_4 coverage

- The small size of CORE makes it affordable to extend the PWO_4 coverage to $\eta < 0$
  - The PWO_4 area will be half of that planned for PANDA, which is similar in size to CORE
- An additional small-angle PWO_4 EMcal can be placed behind the main detector endcap

$\eta > 0$ coverage (several options – including pre-showers for γ/π^0)

- The $\eta > 0$ barrel EMcal should to be relatively compact and projective
- The endcap EMcal needs to be affordable and work well with a high-resolution Hcal

CORE 2π PWO_4 EMcal superimposed on the "YR reference detector"

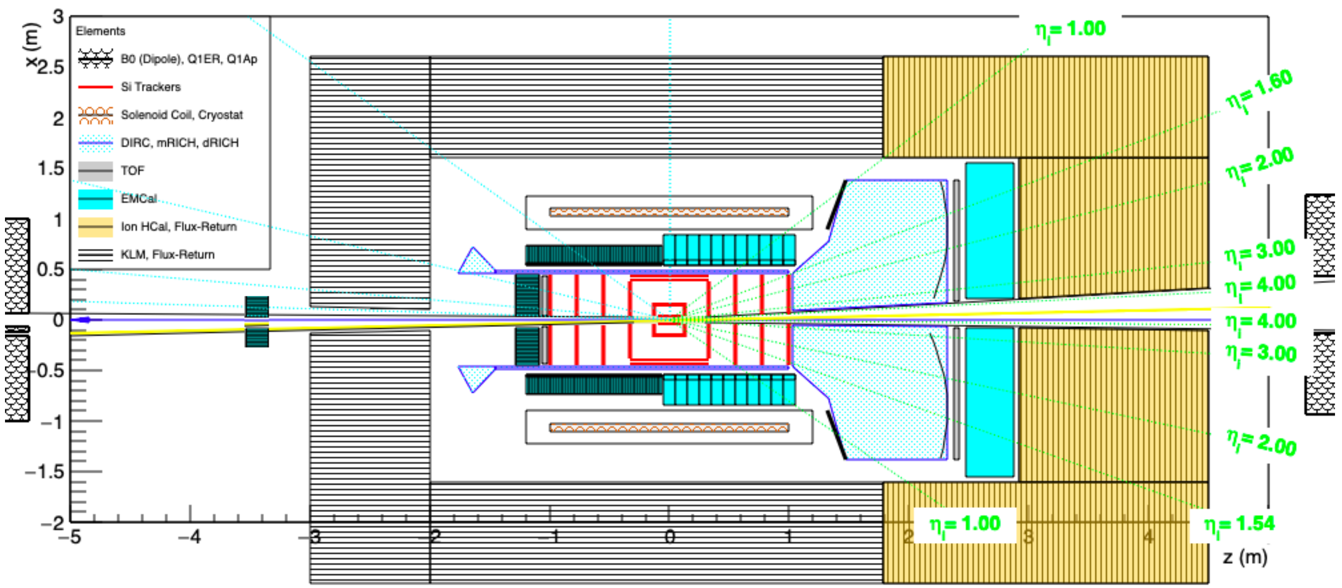


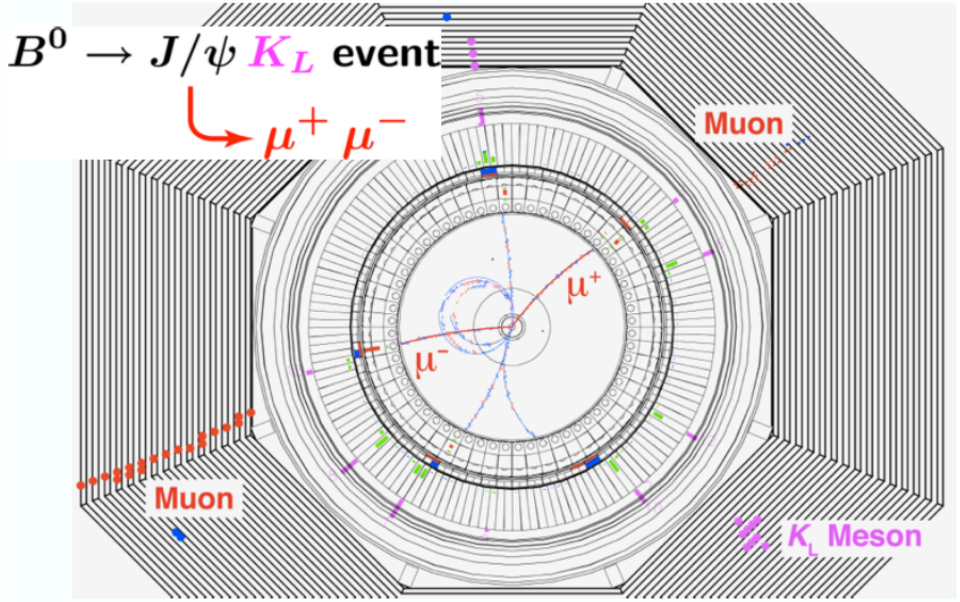
- In the "reference" detector, a PWO_4 EMcal in the barrel (green) would be much larger.

Hcal options

The Belle II μ-K_L (KLM) system

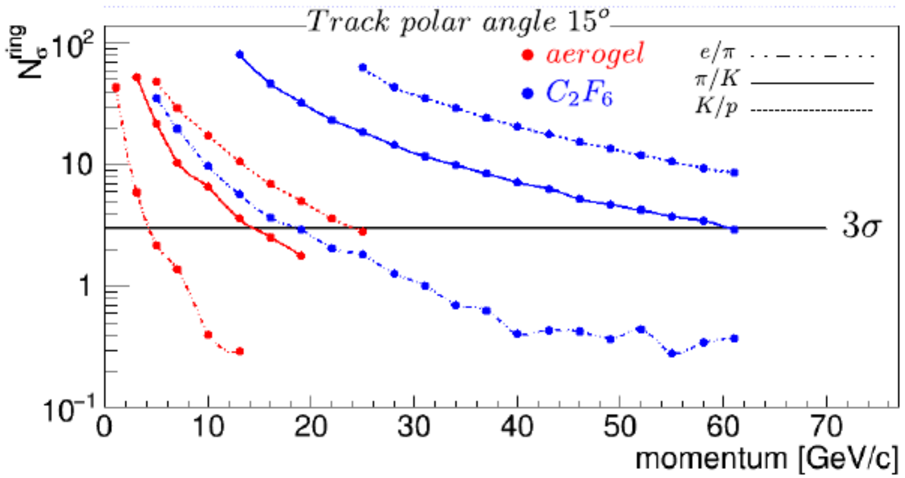
COmpact detectoR for Eic (CORE)

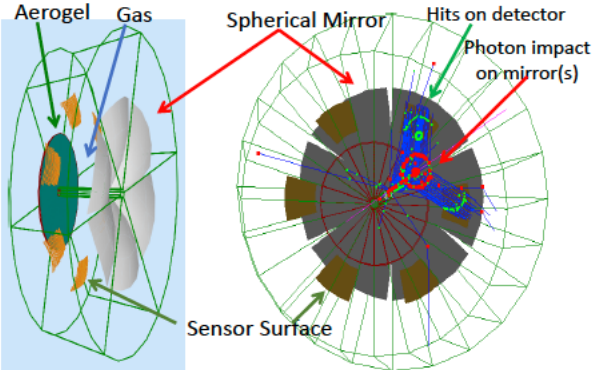




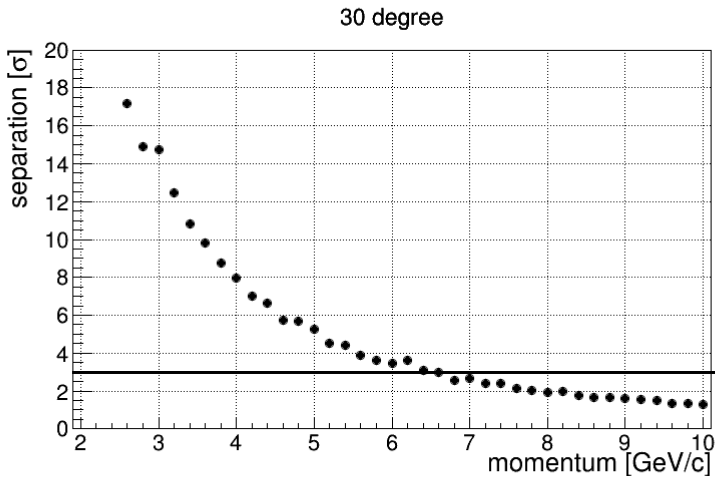
- The inner part of CORE is independent of the Hcal configuration.
- However, an attractive option is to emphasize different capabilities in different regions of rapidity..
- In the barrel and e-endcap, where jets are best reconstructed from individual tracks, one can trade energy resolution for better muon and neutral hadron ID, and lower cost (*cf.* Belle II KLM)
- In the hadron endcap, high energy, high multiplicity jets would benefit from an advanced Hcal (*e.g.*, as suggested by ANL, ORNL)

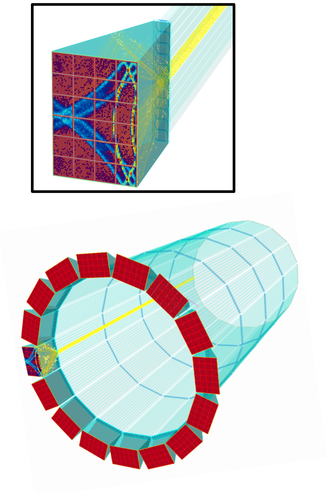
Hadron Identification in the barrel (hpDIRC) and hadron endcap (dRICH)



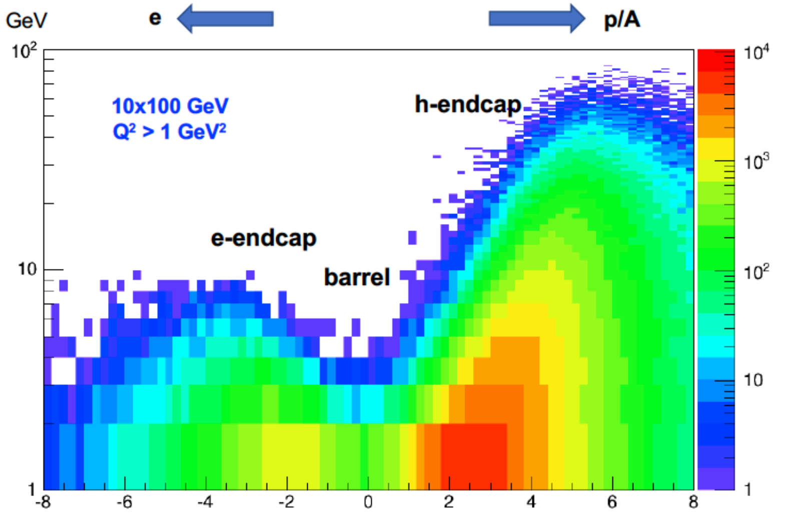


- Using aerogel and gas radiators with a single set of photosensors the dRICH provides *continuous* π/K separation of >3σ up to 60 GeV and excellent e/π separation
  - e/π: 10σ at 10 GeV





- 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



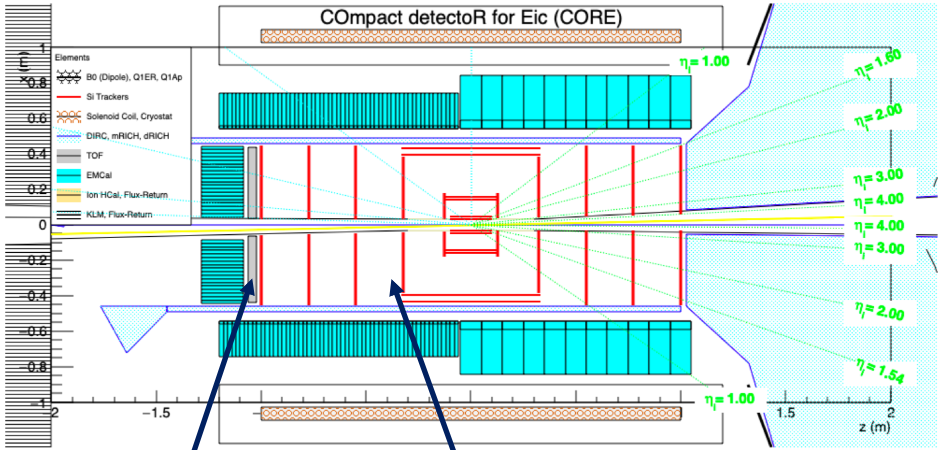
Hadron Identification in the electron endcap

- High-resolution TOF is not competitive with Cherenkov detectors in the hadron endcap (large particle momenta) and central barrel (small radius), but 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 at integrated with the Si-tracker.

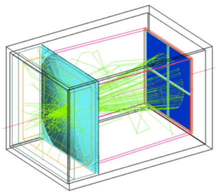
- The TOF installation is modest and resolution could improve through future upgrades.

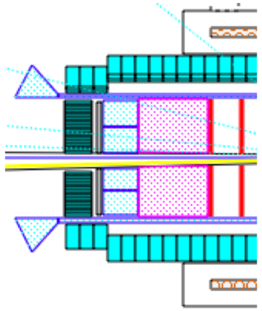
- However, CORE could also support an aerogel RICH (*e.g.*, the mRICH) by extending the endcap by 30 cm, for which there is plenty of space, although this would extend the length of the PWO_4 EMcal.



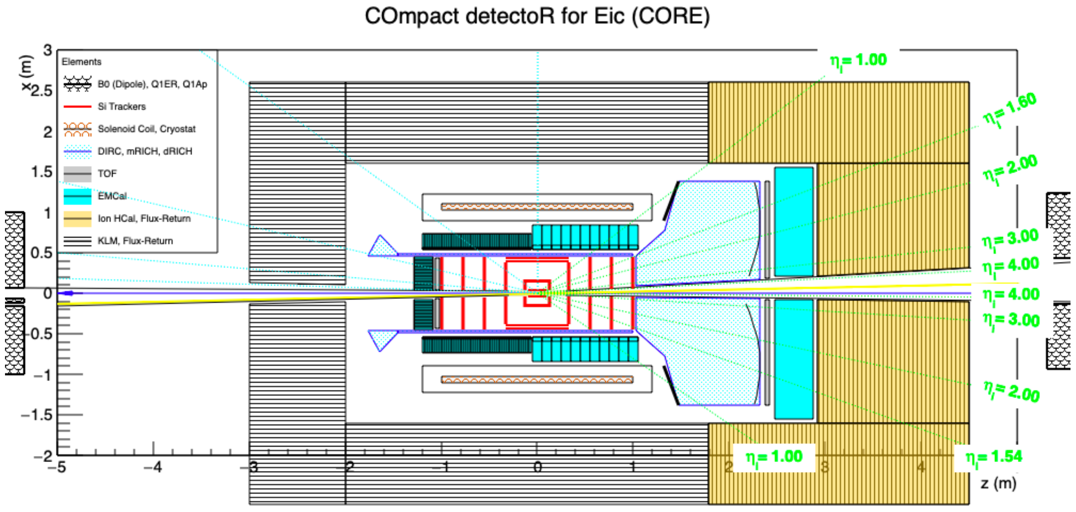
A Si timing "start" layer could be added behind one disk (ANL 5D?)

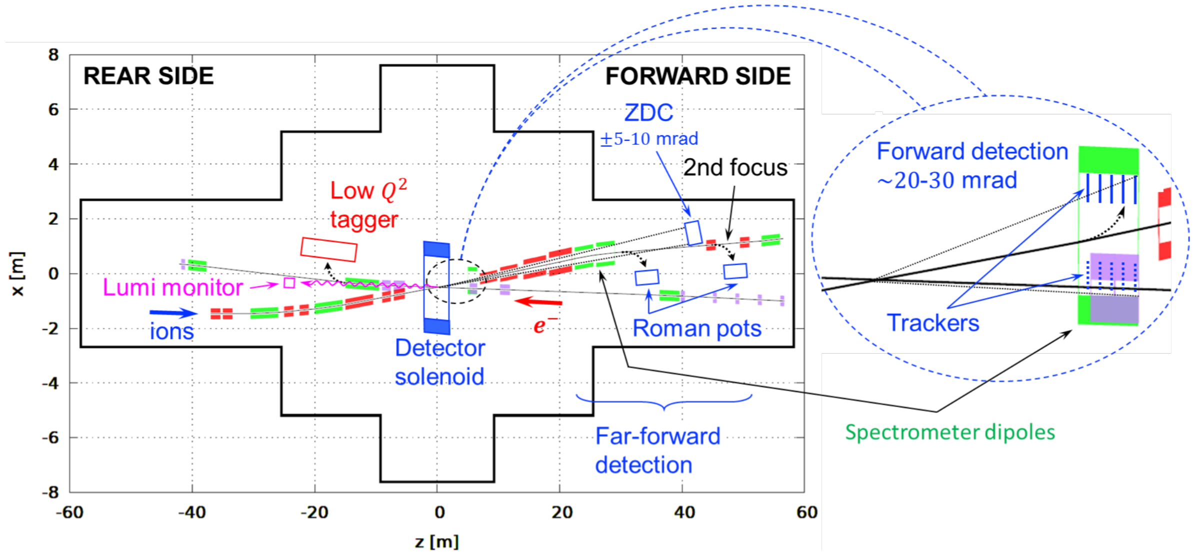
High-resolution TOF using LGADs or LAPPDs (which would not work at 3 T)





IR integration





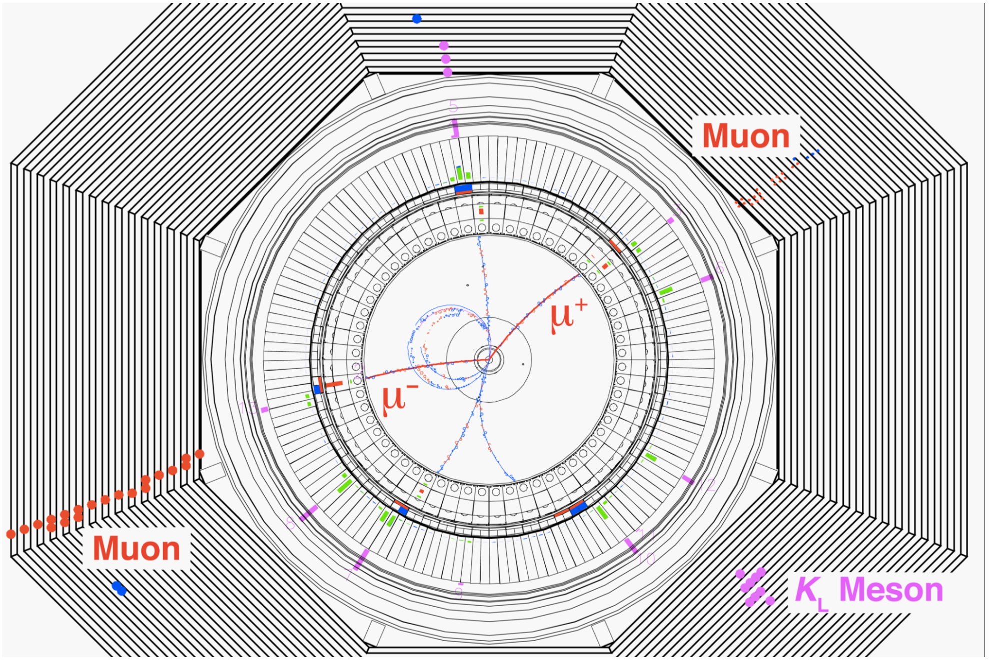
- Despite its compact size, CORE has a lot of space available for supports and services
- In its nominal configuration, CORE fits into a -3 m to +4.5 m IR space.
- If desired, the length on the hadron side could be reduced (or the electron side extended).
- CORE is compatible any crossing angle (which only affects forward acceptance in a narrow range of phi), and can fit into into both the IP6 (STAR) and IP8 (PHENX) halls.

KLM: K_L and Muon detector subsystem at the EIC

EIC EOI #26

Will Jacobs (IU), Pawel Nadel-Turonski (SBU), Gary Varner (UH), Anselm Vossen (Duke)

- High efficiency and purity μ detection and ID
  - Important for di-lepton production, including J/ψ and time-like Compton scattering (TCS)
- Identify K_L and neutrons in jets
  - Focus on PID and position rather than energy, which cannot be precisely determined for a single few-GeV neutral hadron with any Hcal
- The Belle II KLM provides a good starting point for developing a similar system for the EIC
  - More details on the Belle II KLM can be found in the backup slides.



$B^0 \rightarrow J/\psi + K_L$

Thank you!

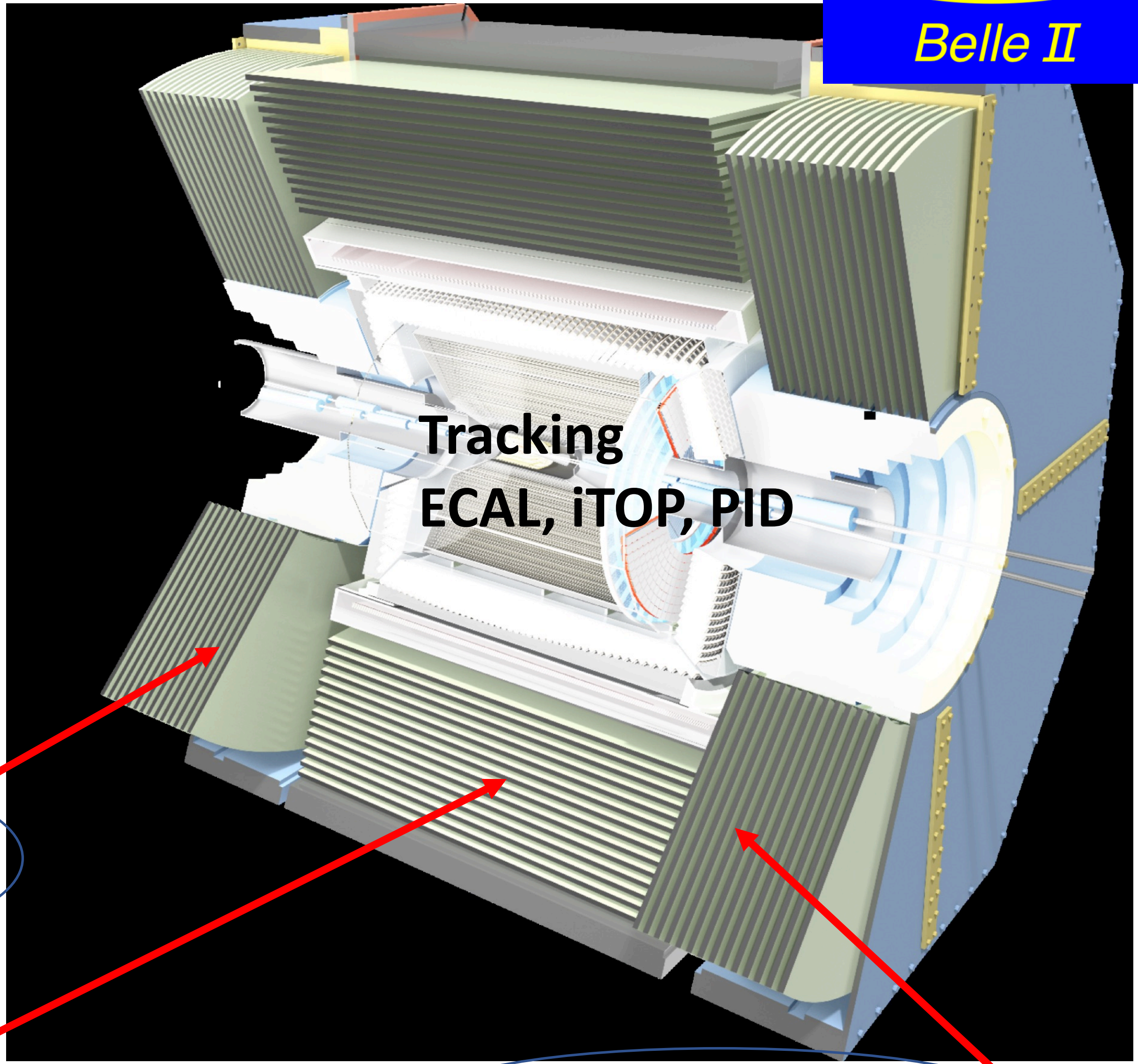
Open collaboration kick-off meeting March 29-30
Save the date! All are welcome!

Example: upgraded Belle II detector at Super KEKB

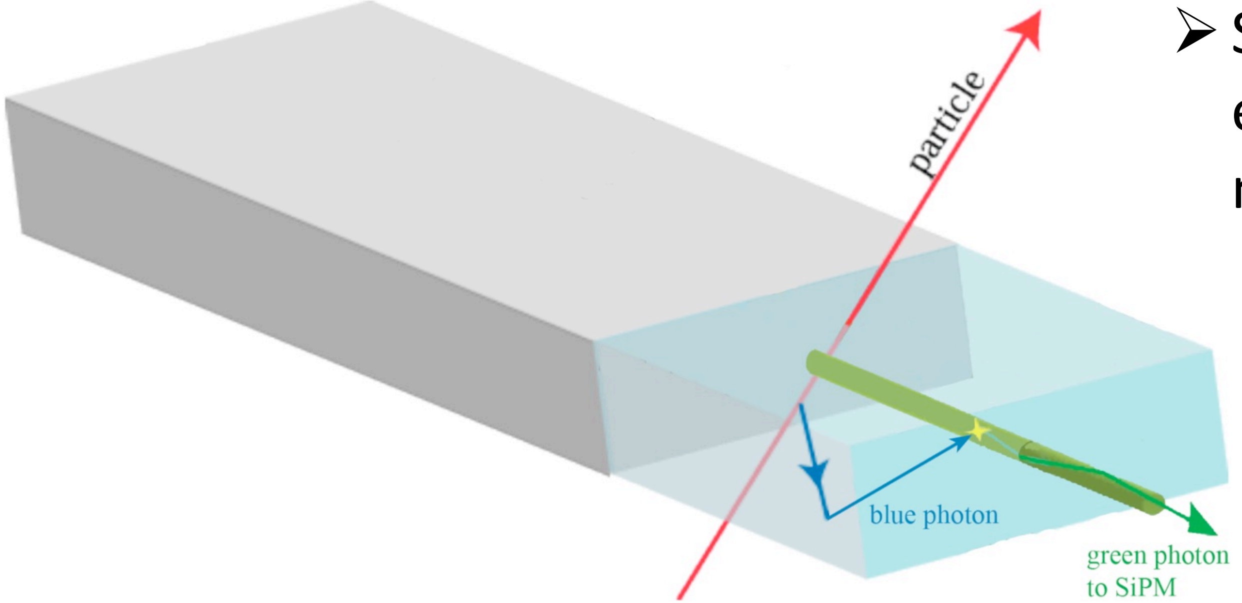
- Active readout elements interleaved with 1.5 T solenoid magnet return steel
- Configuration optimized primarily for μ and K_L detection and ID
- Relatively inexpensive, technically simple construction and robust operation
- It is not a full-fledged/proper EM or Hadron calorimeter

Octagonal Iron yoke structures:

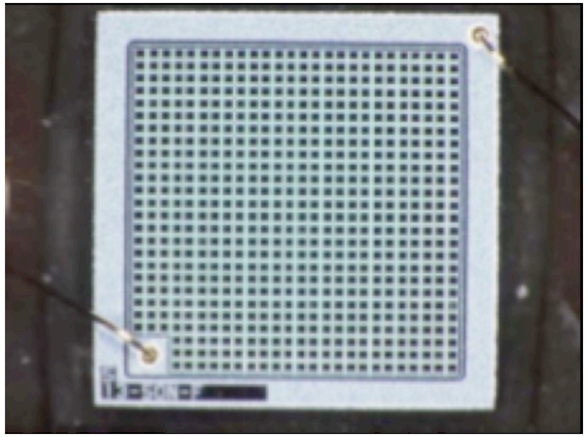
- 14 layers of ~ 47 mm thick steel plates
- ~ 40 mm thick air slots => 15 barrel, ~ 14 Forward , ~ 14 Back instrumented for readout



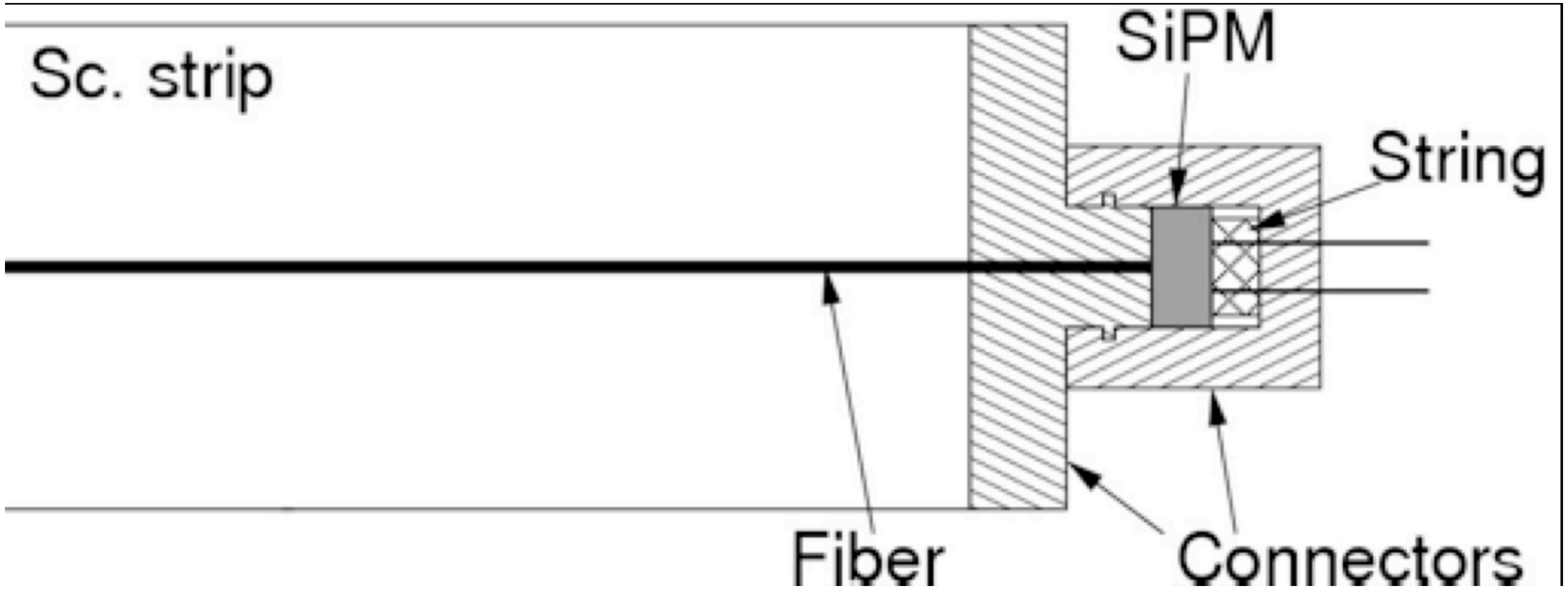
Now: Endcap and first 2 Barrel layers are scintillator based



- Scintillator strips: barrel ~ 1x2.5 cm^2 xsec extruded with fiber hole (endcaps ~ 0.7x4 cm^2 machined w/ cut)
  - Hamamatsu SiPM attached to fiber (mirrored at far end)

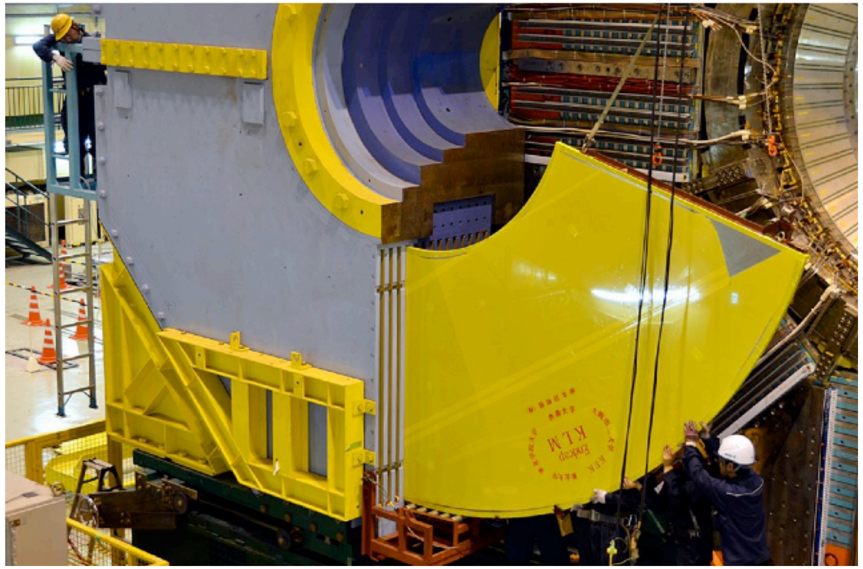


~ 1.3 x 1.3 mm2
667 pixels



- 1.5 T field operation
- rad-hard (est. >10-year lifetime @ Belle II)
- 8-pixel threshold => >99% efficiency

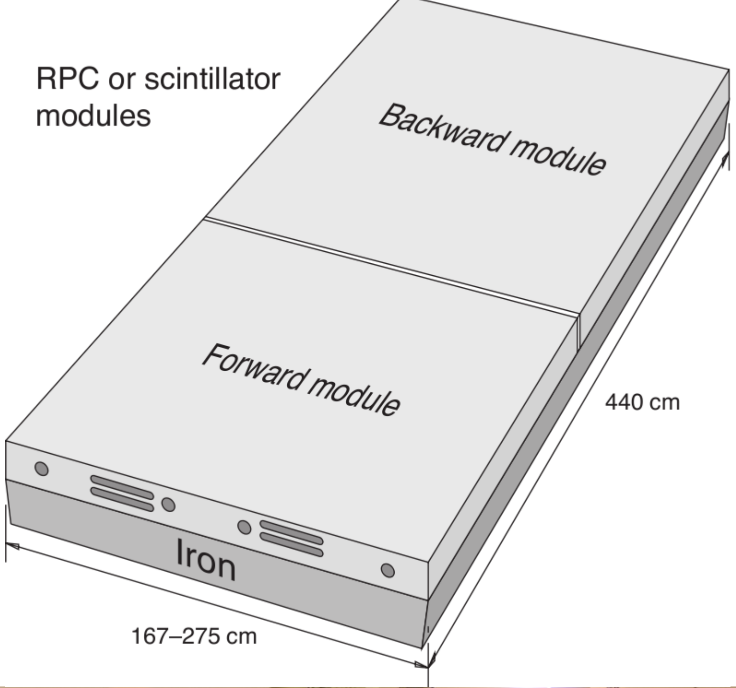
Belle II detector KLM components

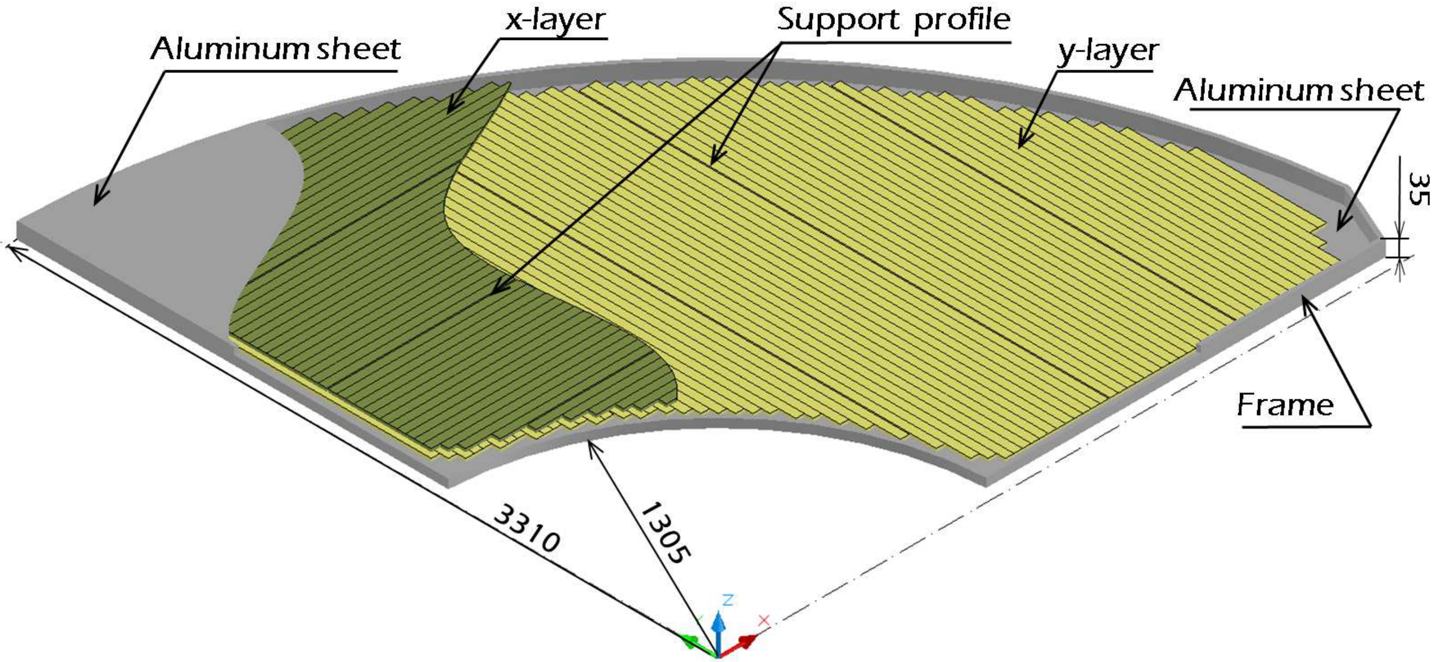


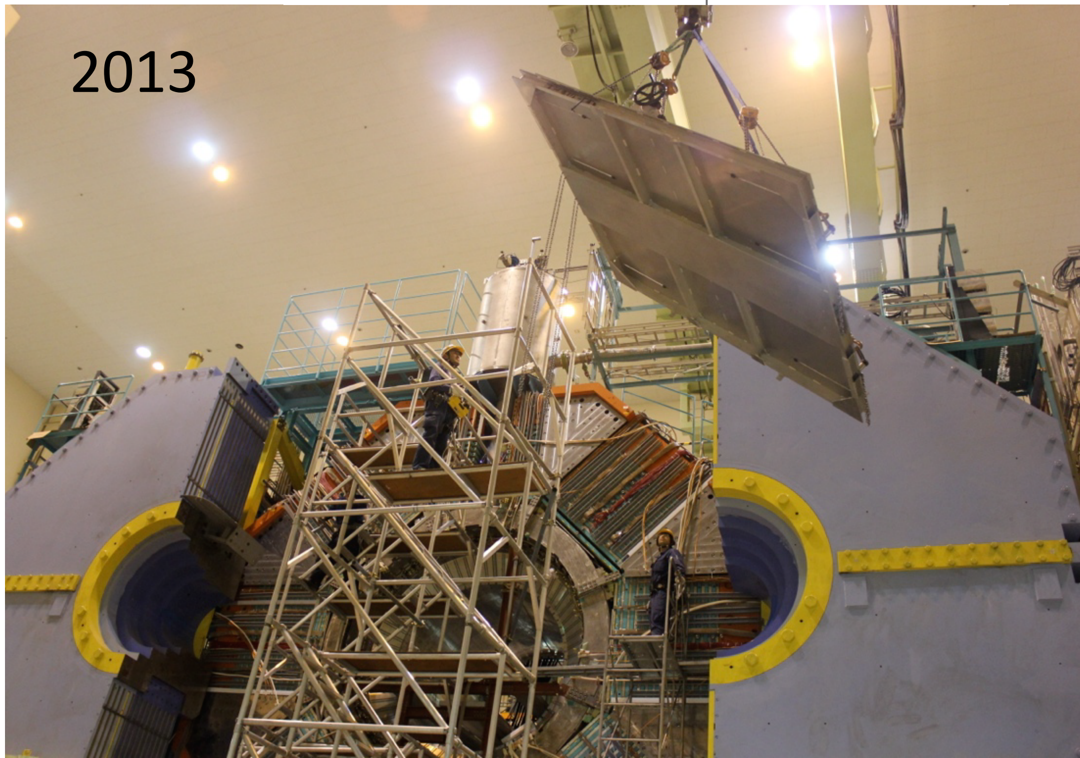
Endcap

2014

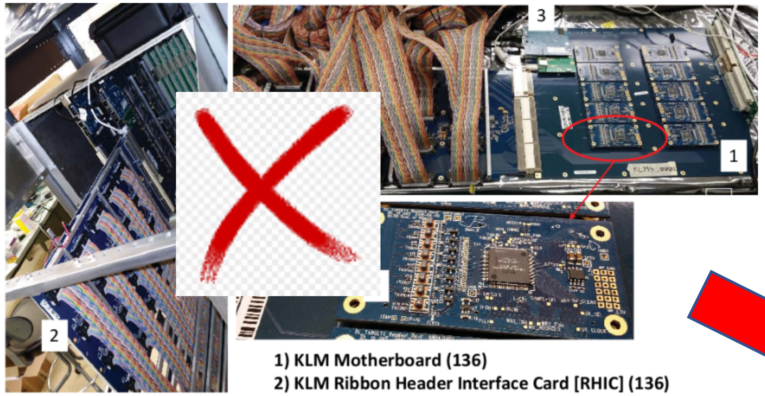
Barrel







Plans (EOI to Belle II): replace 13 remaining Barrel RPC layers



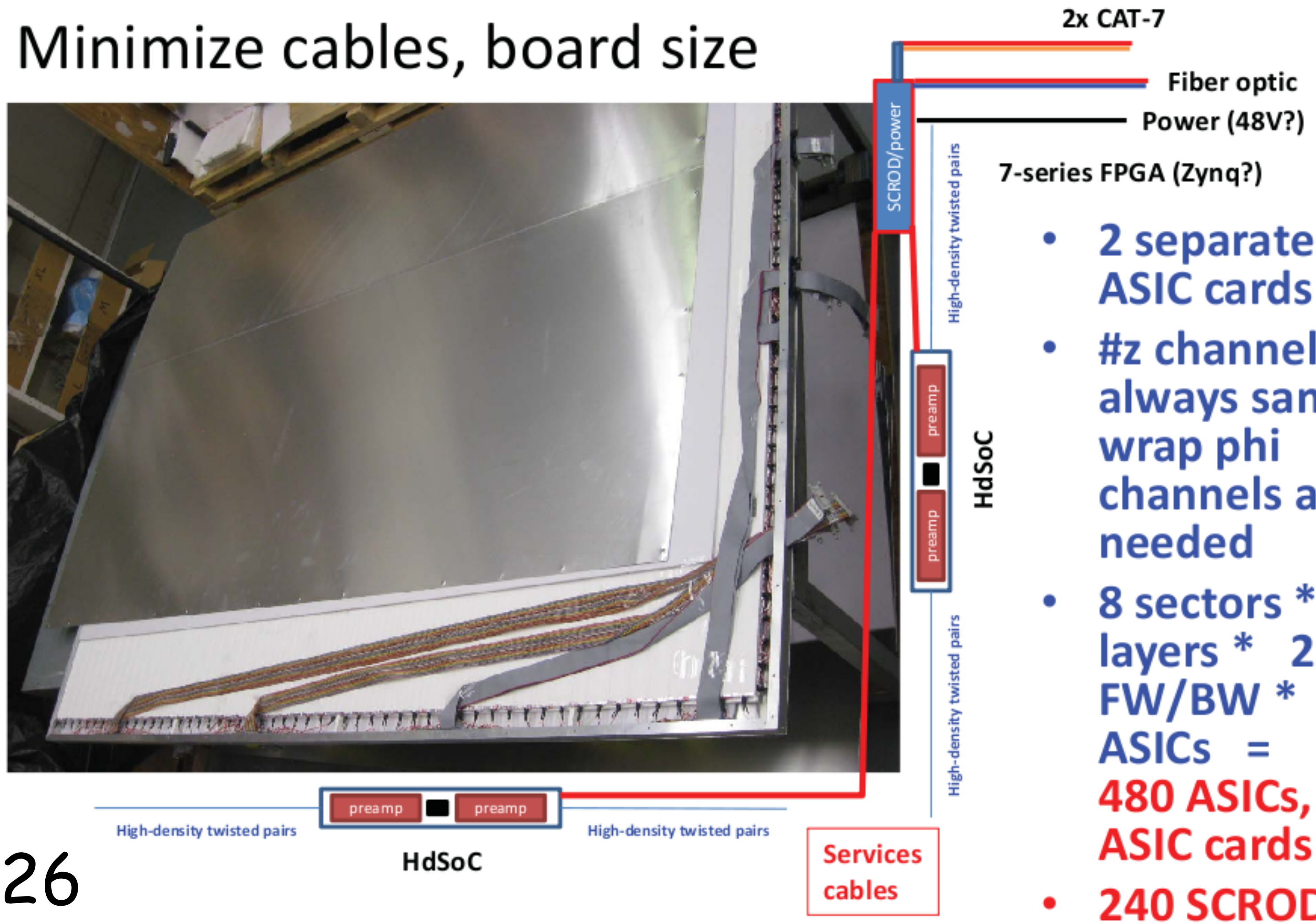
104 Endcap sets
32 Barrel

1) KLM Motherboard (136)
2) KLM Ribbon Header Interface Card [RHIC] (136)
3) KLM SCROD Rev A (136)
4) TARGETX Daughtercards (1288)

- Fabricate the new scintillator layers
- Redesign scintillator readout for all 15 layers

- Move digitizing front end electronics into detector panel
- Developments: embedded ASIC; compact SCROD; 64-chn readout; several different preamp options
- K_L time-of-flight?

Minimize cables, board size



- 2 separate ASIC cards
- #z channels always same; wrap phi channels as needed
- 8 sectors * 15 layers * 2 FW/BW * 2 ASICs = 480 ASICs, ASIC cards
- 240 SCROD

Expected installation ~ 2026