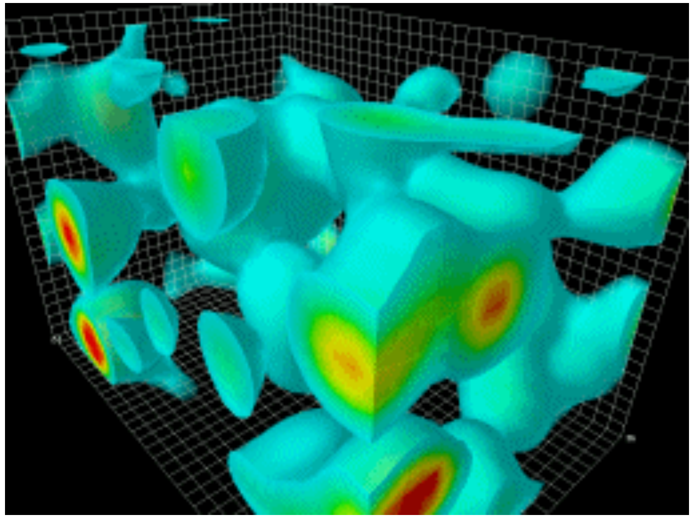
EIC@IP6 meeting, March 12-13, 2021

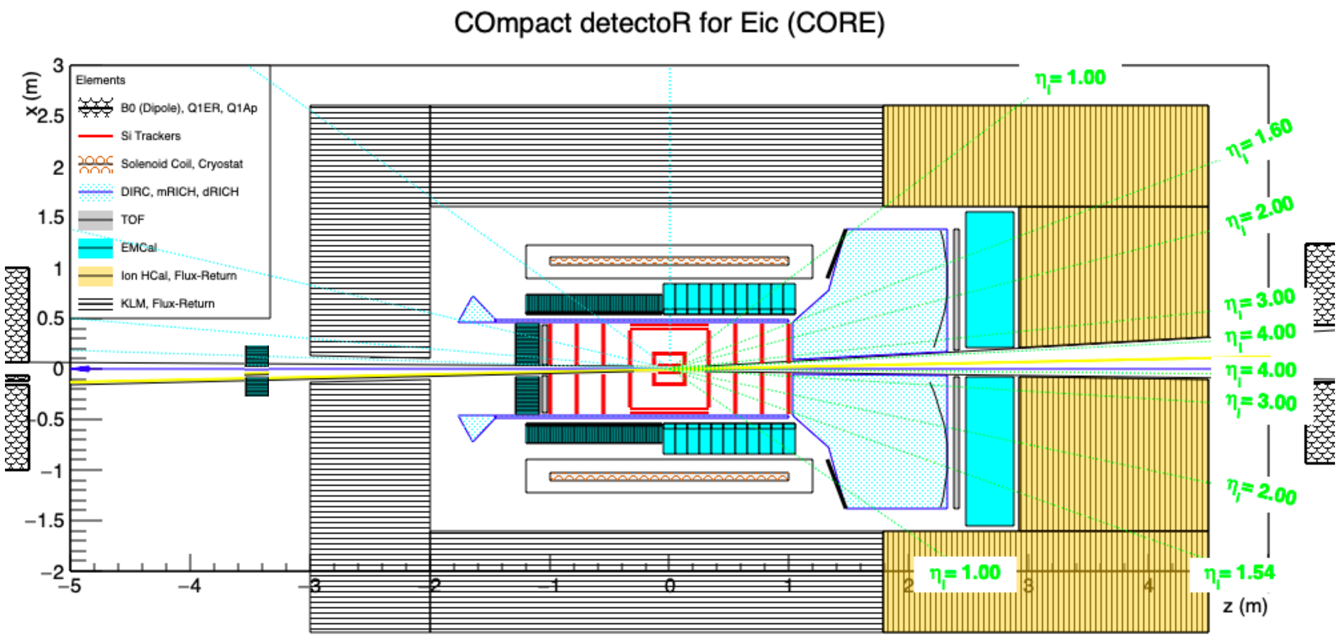
CORE: a COmpact detectoR for the EIC


The QCD vacuum

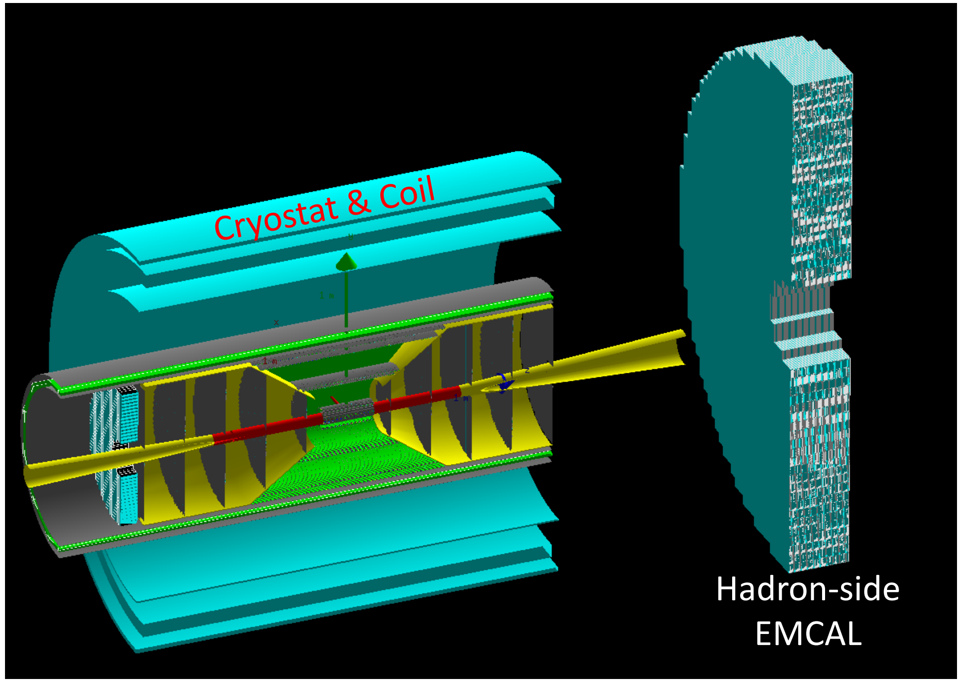
Charles Hyde
Old Dominion University

Pawel Nadel-Turonski
Stony Brook University

a COmpact detectoR for the Eic (CORE)



inner CORE in Geant (fun4all)



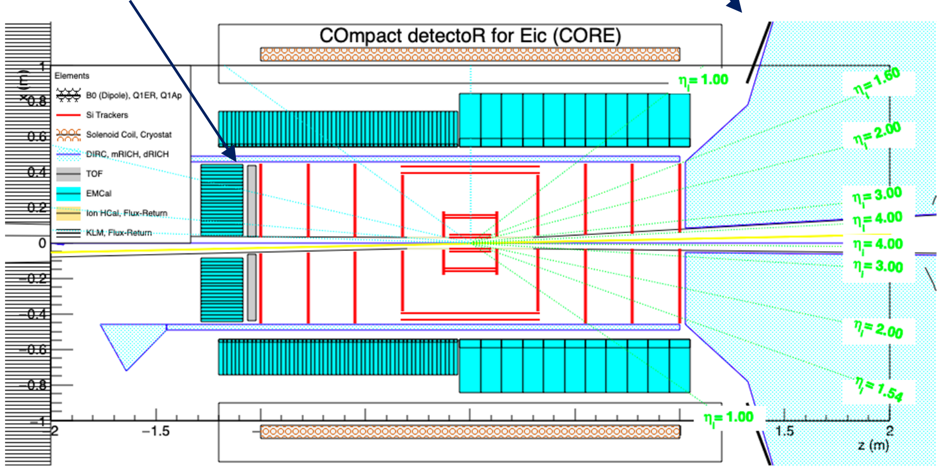
- A (nearly) hermetic general-purpose detector that fulfills the EIC physics requirements
- Small size, in particular of the inner systems, is very cost-effective, allowing:
  1. An overall reduction in cost without performance loss
  2. Improved performance in critical areas without large additional cost
- Risk is minimized by utilizing subsystems from Generic EIC R&D program

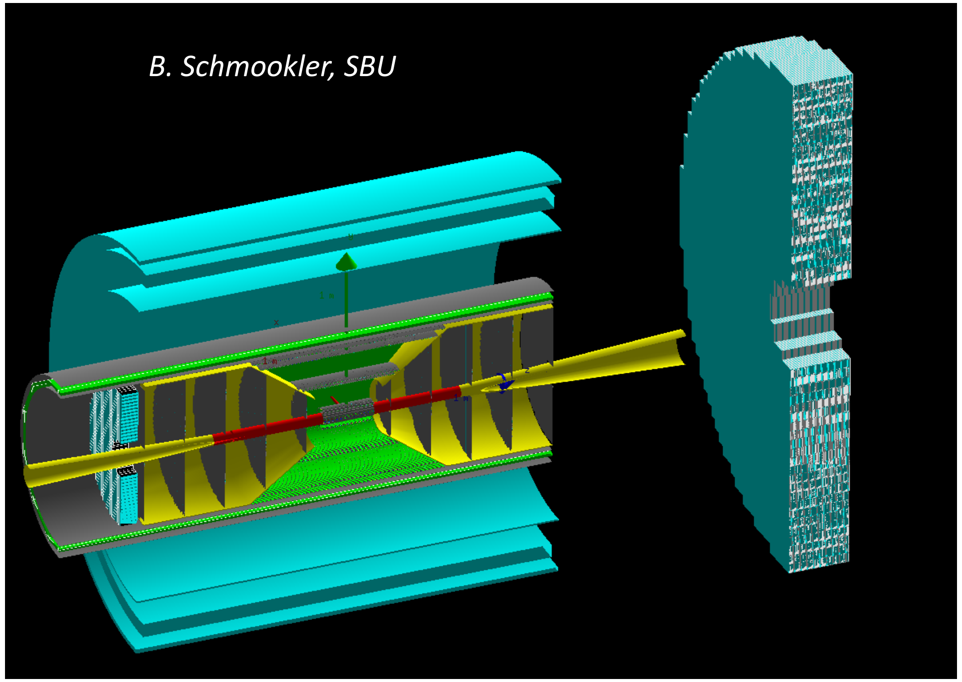
Core concepts of CORE

central CORE in Geant (fun4all)

No “gap” along line-of-sight from IP

dRICH photosensors

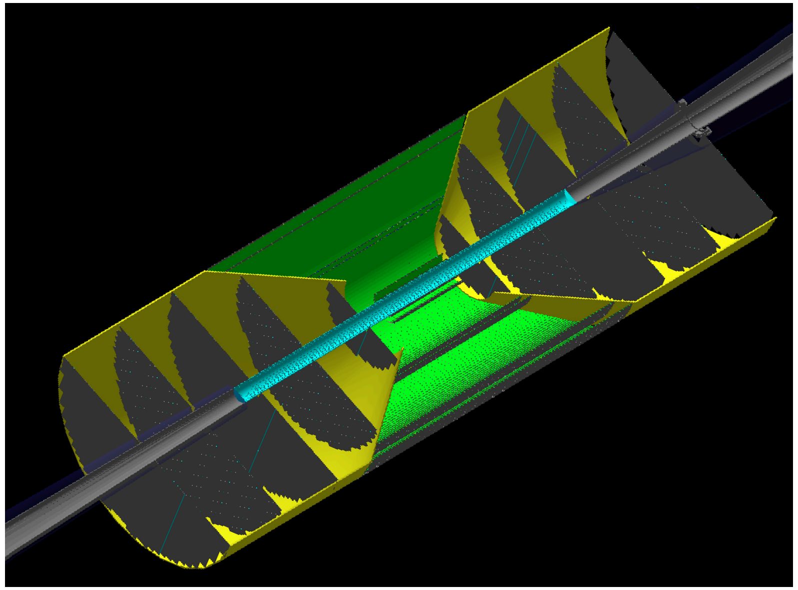




- Small central all-Si tracker (eRD25)
- Radially compact, high-performance barrel DIRC Cherenkov (eRD14)
- Dual-radiator RICH with *outward-reflecting* mirrors in the hadron endcap (eRD14)
- Extended PWO_4 EMcal coverage (2π, $\eta < 0$) on the electron side (eRD1)
- Small solenoid (2.5 m long, 0.9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

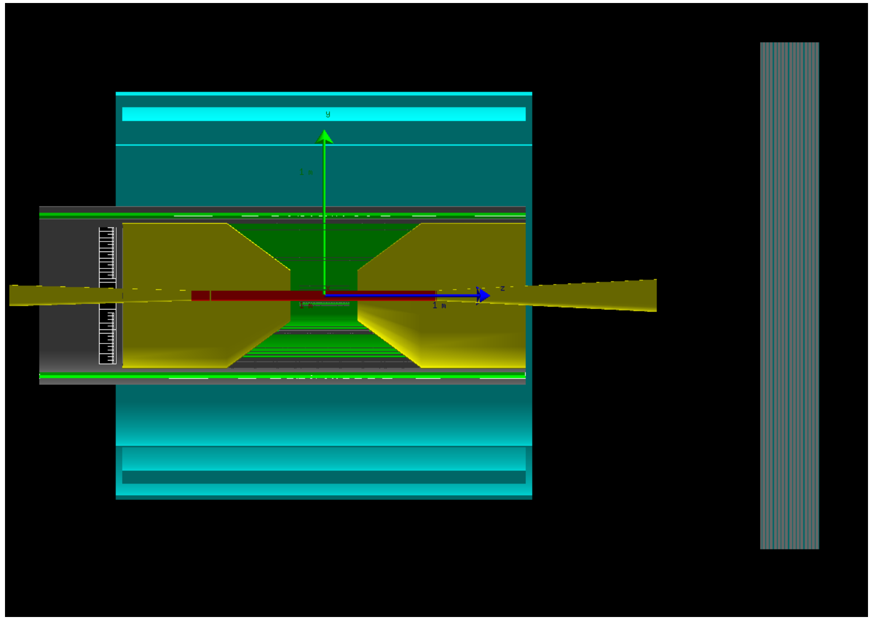
Solenoid and central Si-tracker

- The CORE solenoid is identical in size to the one used by ZEUS (2.5 m long and 0.9 m inner radius), or about 1/3 the volume of the BaBar / sPHENIX solenoid.
- If a new solenoid is built, CORE could support any field in the 1.4 – 3 T range, with 2 T (the geometric mean) being the preferred value (p_{min}, photosensors, etc).

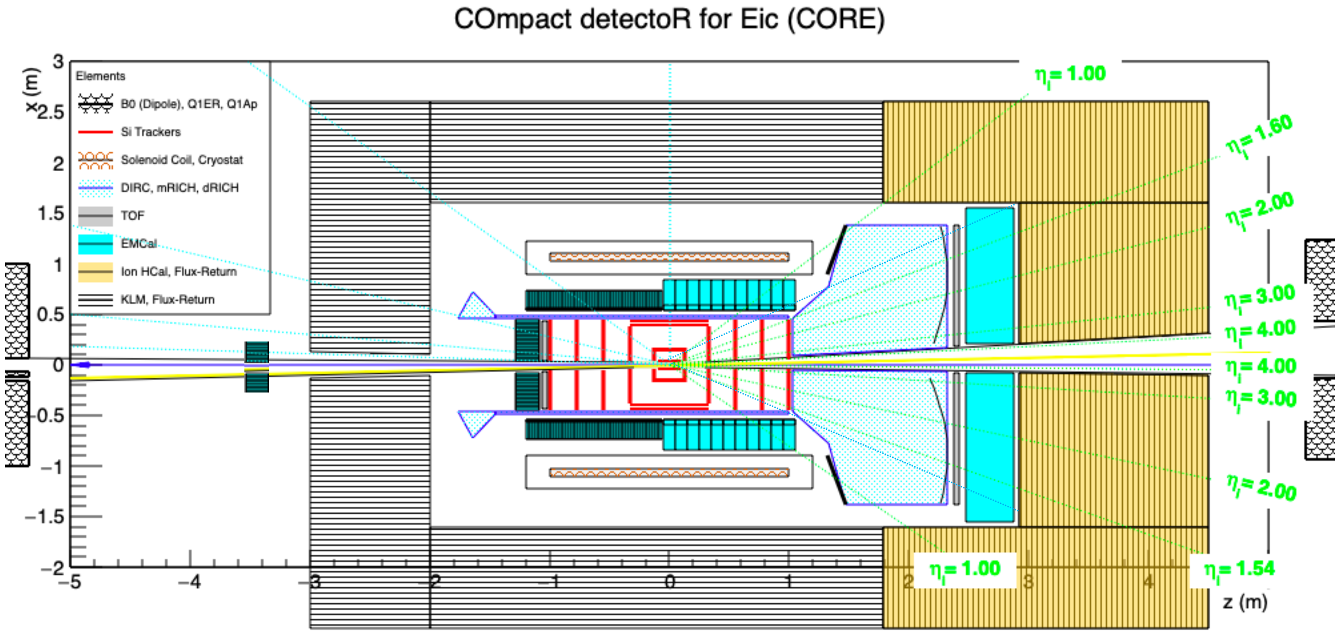


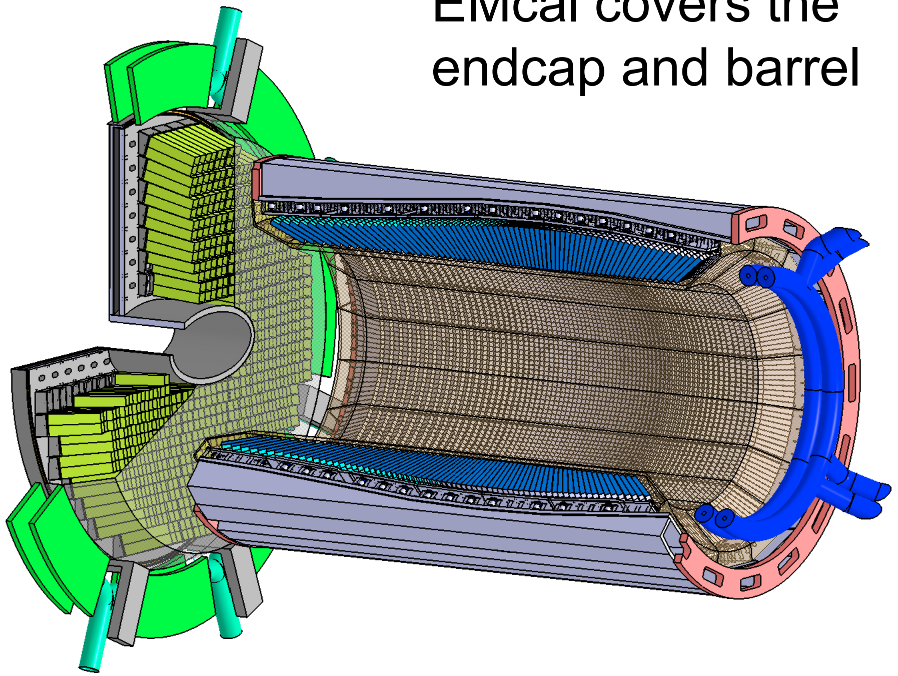
- The all-Si tracker developed by the eRD25 consortium is a very good fit for CORE

		$\delta p/p = Ap \oplus B$		$\mathrm{DCA}_z = A/p_T \oplus B$		$\mathrm{DCA}_T = A/p_T \oplus B$	
		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				



4π EMcal





The PANDA PWO_4 EMcal covers the endcap and barrel

2π PWO_4 coverage

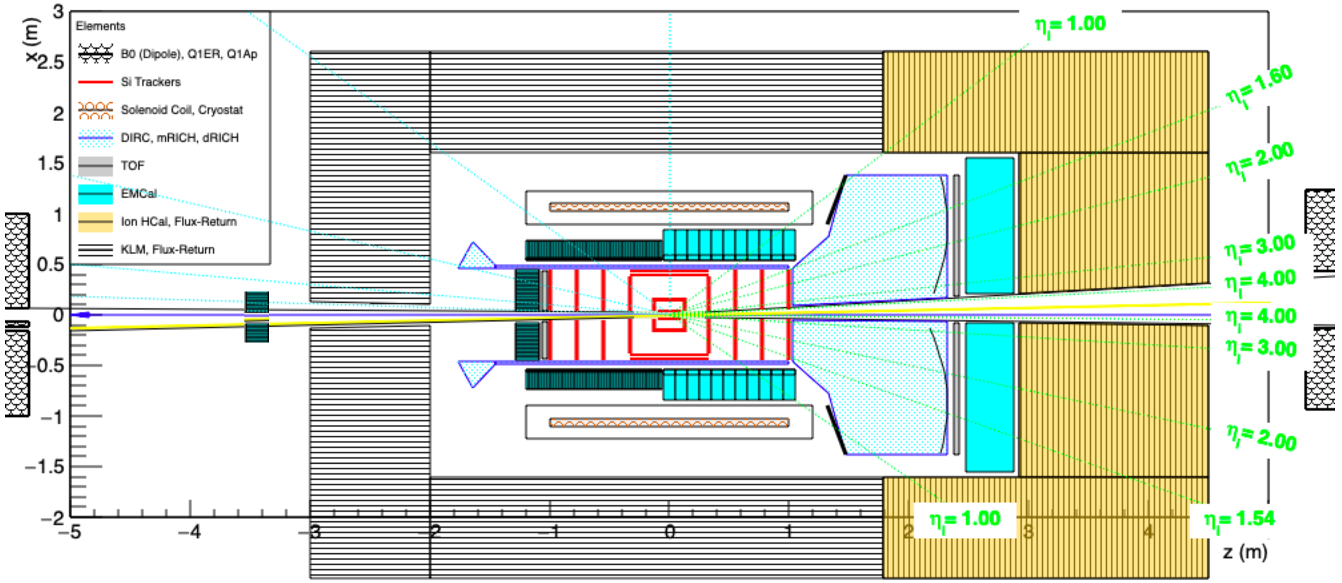
- The small size of CORE makes it affordable to extend the PWO_4 coverage to $\eta < 0$
  - The PWO_4 area will be half of that planned for PANDA, which is similar in size to CORE
- An additional small-angle PWO_4 EMcal can be placed behind the main electron endcap

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

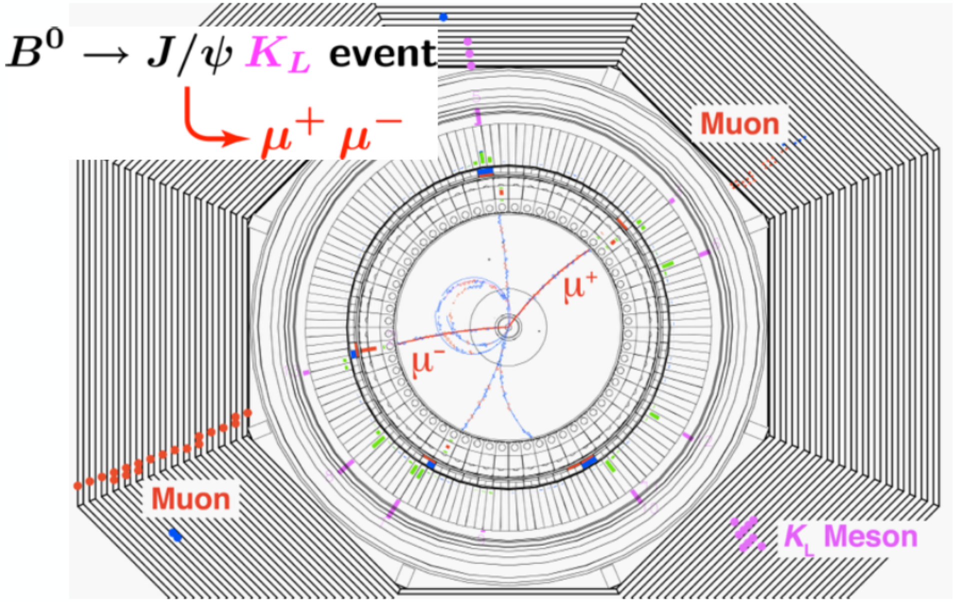
- The $\eta > 0$ barrel EMcal should be relatively compact (~30 cm radial) and projective
- The endcap EMcal needs to be affordable and work well with a high-resolution Hcal

HCal options

COmpact detectoR for Eic (CORE)



The Belle II μ-K_L (KLM) system



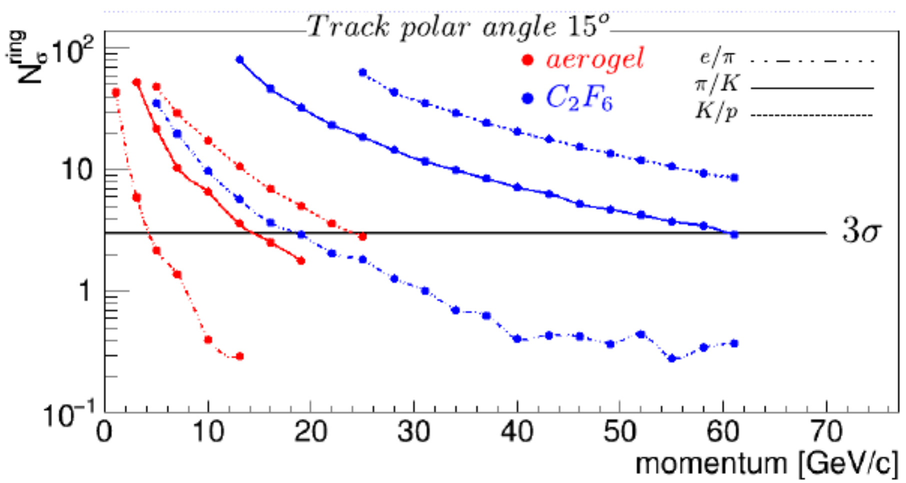
- The inner CORE is independent of the Hcal, leaving many options for the Hcal
- One choice is to emphasize different capabilities in the central and ion-forward regions.
- In the barrel and e-endcap, where jets are well reconstructed from individual tracks (lower multiplicity), one can trade energy resolution for better muon and neutral hadron ID, and lower cost (c.f. 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)

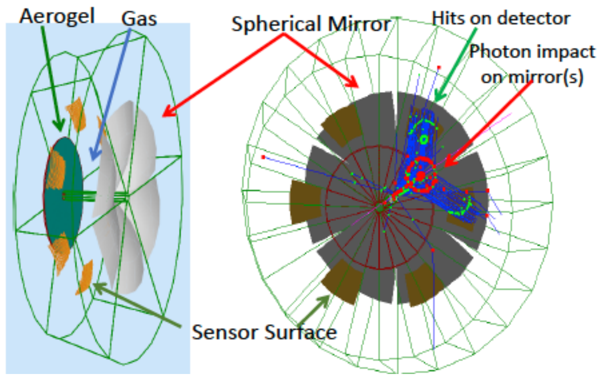
Planning for an open collaboration Kick-off meeting March 29-30:
Save the date! All are welcome!

- Current Participating Institutions
  - Catholic University of America
  - Duke University
  - GSI, Helmholtz Centre
  - Indiana University
  - Old Dominion University
  - Stony Brook University
  - University of Hawaii
  - University Erlangen-Nuremberg
  - University of South Carolina
  - University of York

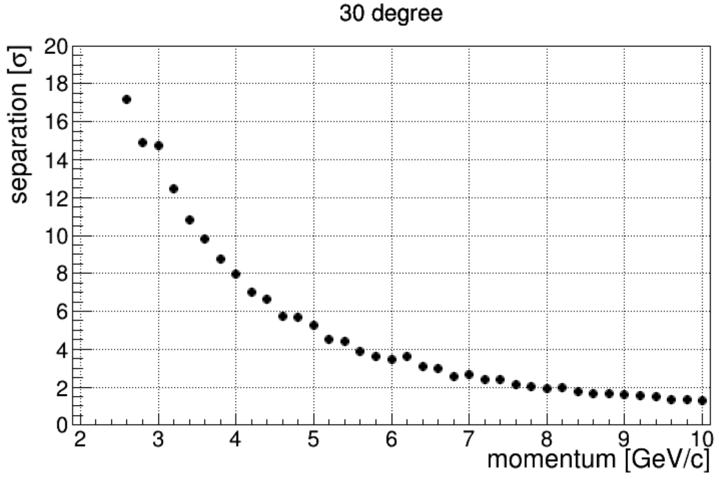
Thank you!

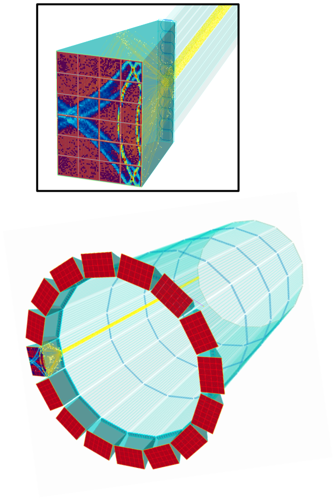
Hadron Identification in the barrel (hpDIRC) and hadron endcap (dRICH)



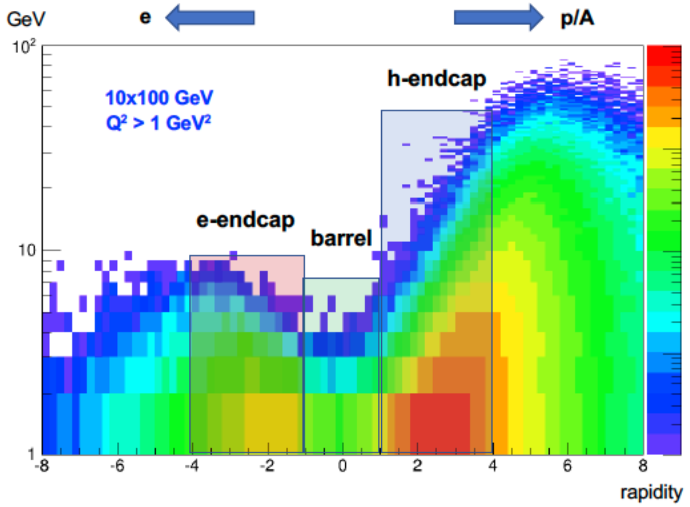


- Using aerogel and gas radiators with a single set of photosensors the dRICH can provide *continuous* π/K separation up to 60 GeV (3σ) and excellent e/π separation
  - e/π: 10σ at 10 GeV





- The hpDIRC aims for 3σ π/K separation up to 6-7 GeV and (2σ at 9 GeV).



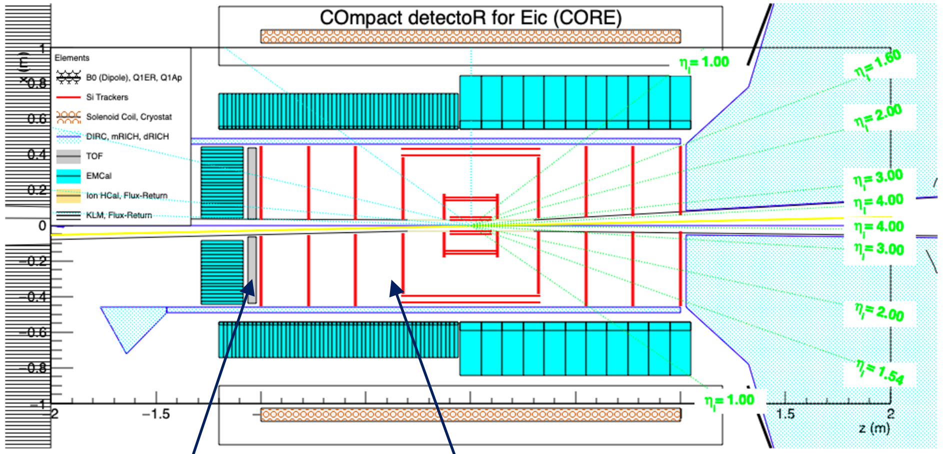
Hadron Identification in the electron endcap

- 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.

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

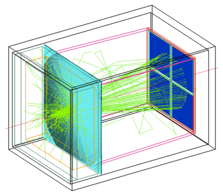
- The TOF installation is modest and resolution could improve though future upgrades.

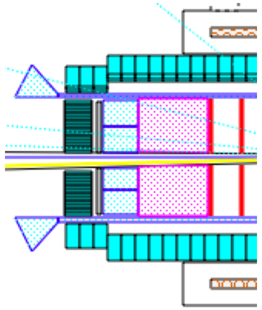
- However, CORE could also support an aerogel RICH (e.g., the mRICH) by extending the endcap by 30 cm, for which there is plenty of space, although this would extend the length of the PWO_4 EMcal.



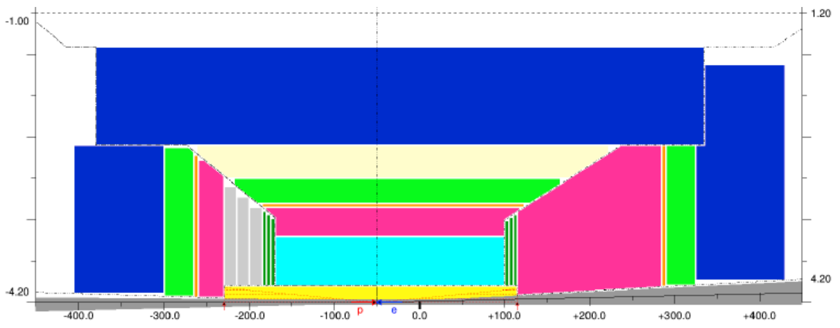
A Si timing “start” layer could be added behind one disk (ANL 5D?)

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

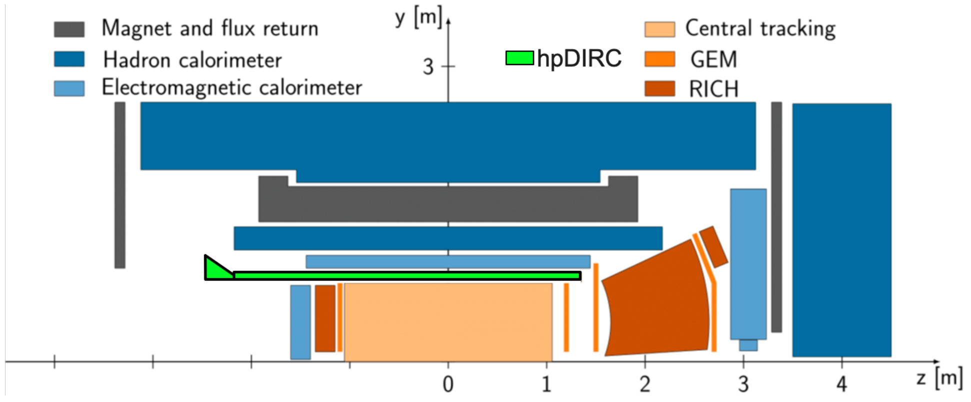




A two detector scenario?



2020 Yellow Report “Reference Detector”



EIC-sPHENIX from 2018 LOI

- To realize a two-detector scenario, we need cost-effective detector concepts
- This can be accomplished by
  - A new detector that can satisfy the EIC physics goals within a moderate budget
  - A detector that save costs by re-using suitable existing components
    - (e.g., magnet, barrel Hcal, and TPC from sPHENIX).
- There also needs to be a meaningful complementarity between the two detectors
  - The Yellow Report “reference detector” is, however, generally similar in size and layout to the “EIC-sPHENIX” proposal from 2018.
  - The main differences is that ”reference detector” has an electron-side Hcal, and envisions using more expensive subsystems, possibly including a new 3T solenoid

EIC EOI #26 Pawel Nadel-Turonski et al.

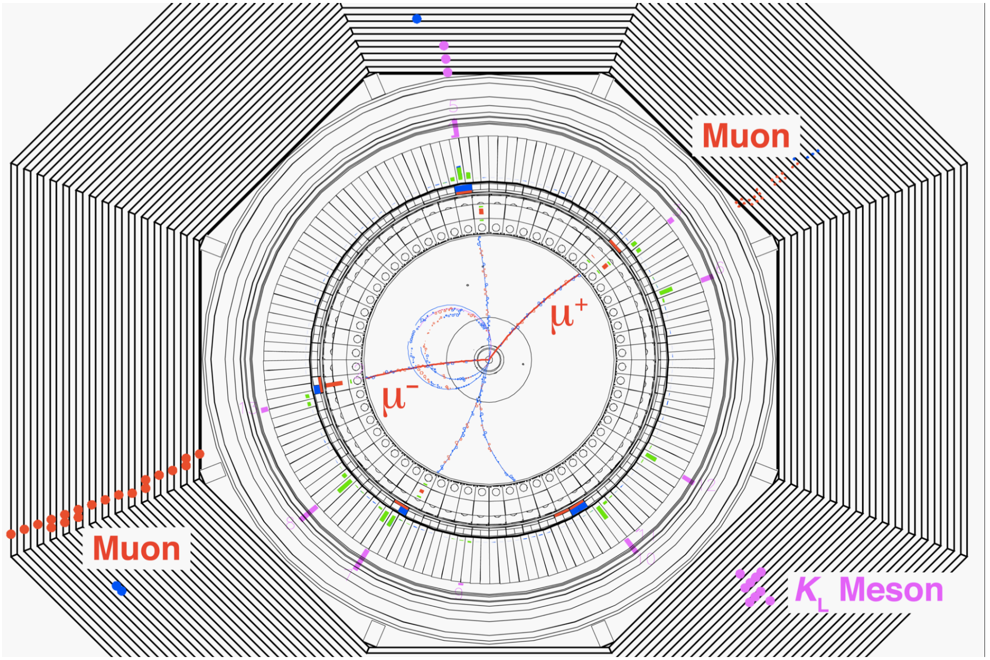
KLM: K_L and Muon subDetector at the EIC

- High efficiency and high purity μ detection and ID: for di-lepton production (J/ψ) and time-like Compton scattering processes

- Identify K_L and other neutral particles in jets

- Provide additional detector coverage for verification or veto.

    - Good starting point may be Belle II KLM for a EIC similar system



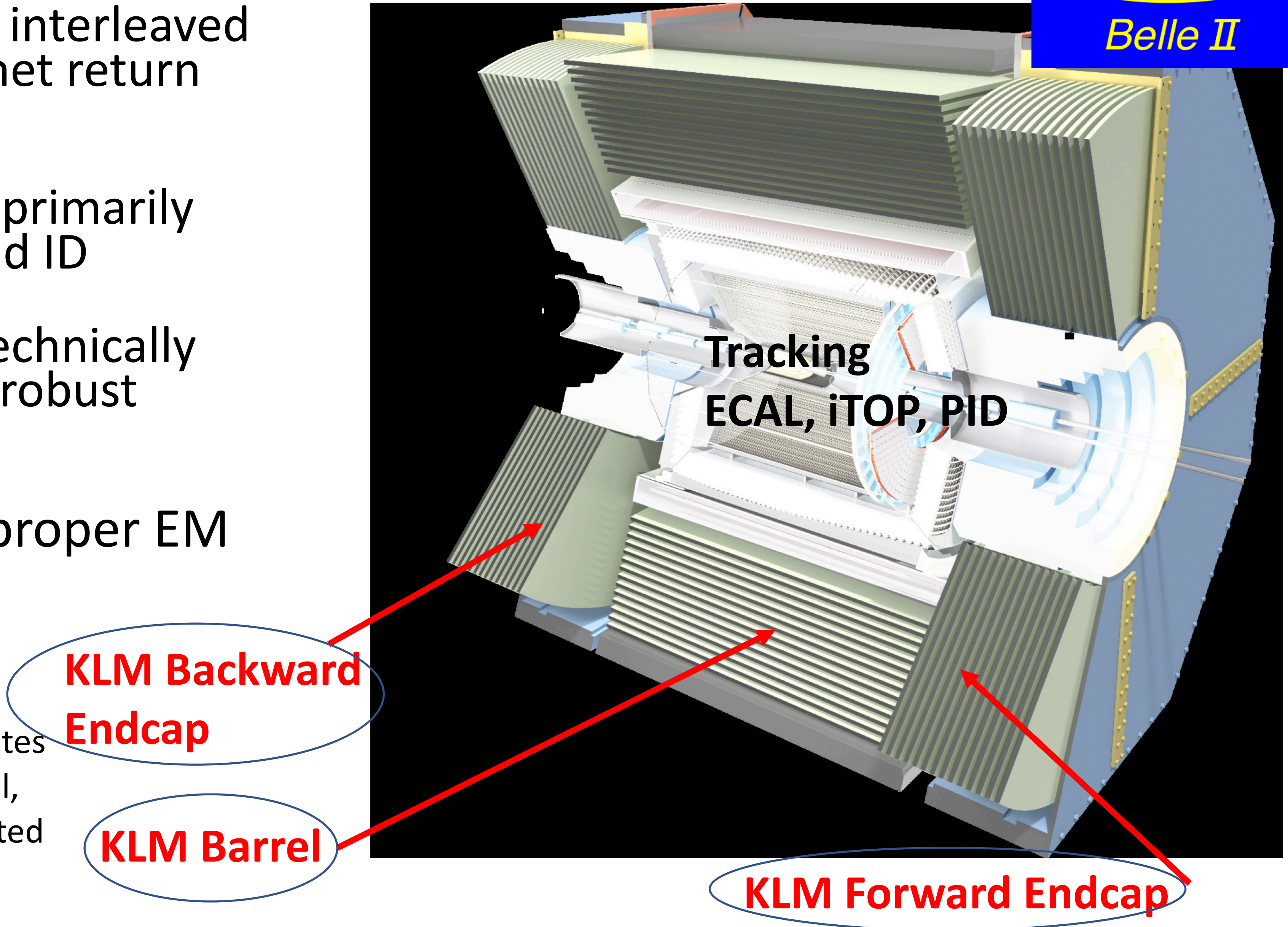
$B^0 \rightarrow J/\psi + K_L$

Example: upgraded Belle II detector at Super KEKB

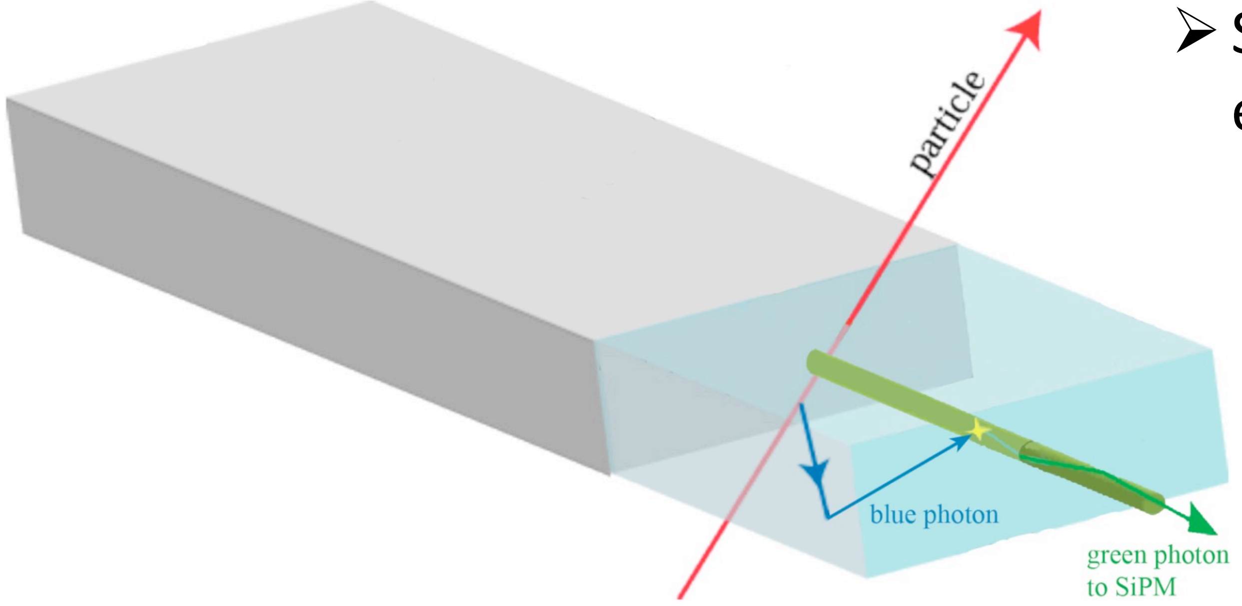
- Active readout elements interleaved with 1.5 T solenoid magnet return steel
- Configuration optimized primarily for μ and K_L detection and ID
- Relatively inexpensive, technically simple construction and robust operation
- It is not a full-fledged/proper EM or Hadron calorimeter

Octagonal Iron yoke structures:

- 14 layers of ~ 47 mm thick steel plates
- ~ 40 mm thick air slots => 15 barrel, ~ 14 Forward , ~ 13 Back instrumented for readout

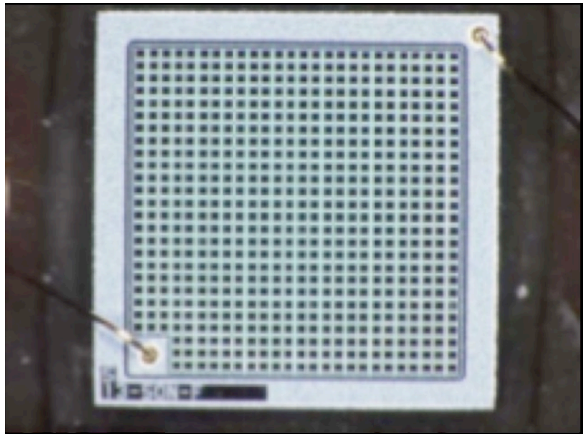


Now: Endcap and first 2 Barrel layers are scintillator based

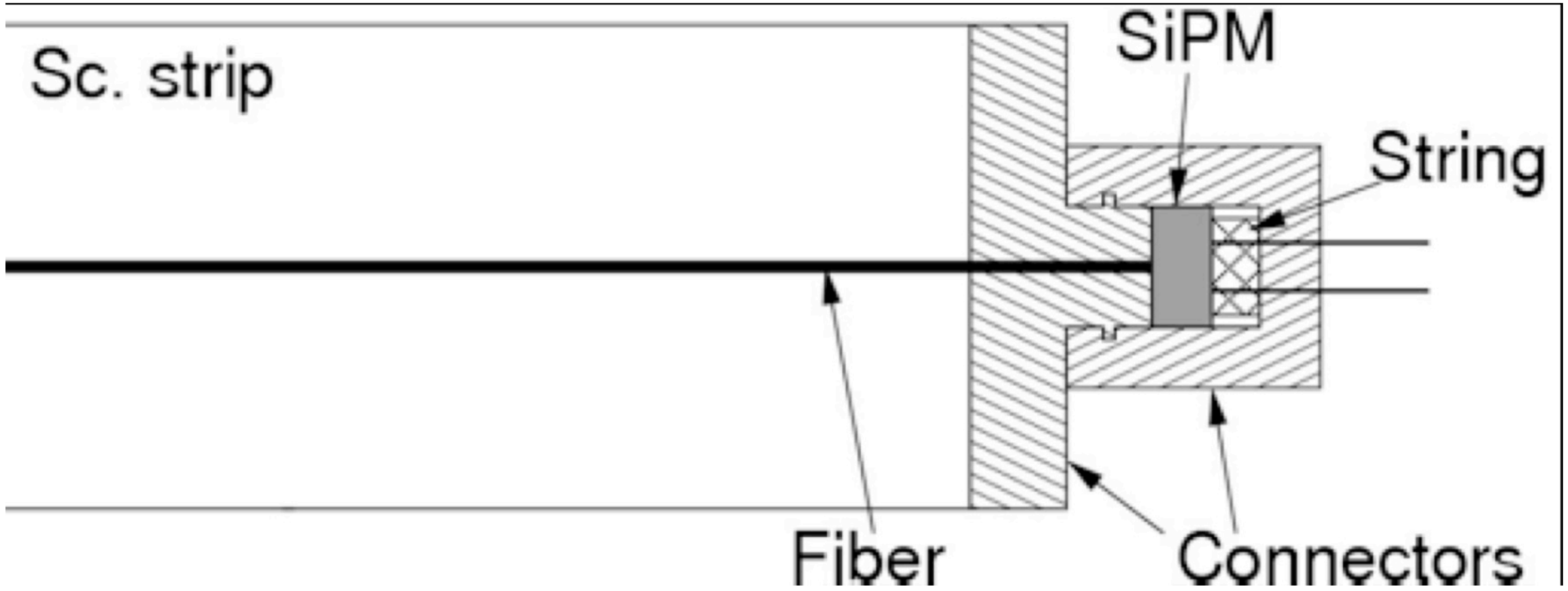


- Scintillator strips: ~ 1x2 cm cross section extruded with fiber hole or machined w/ cut

- 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