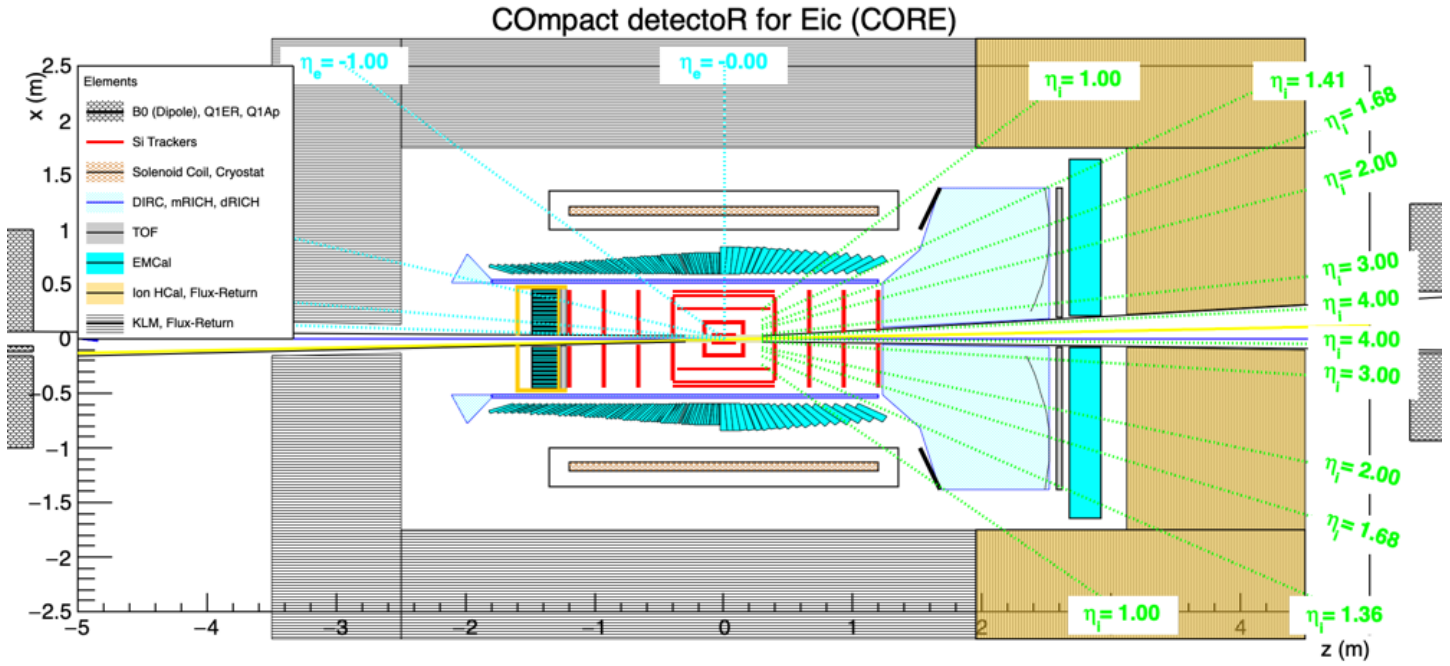
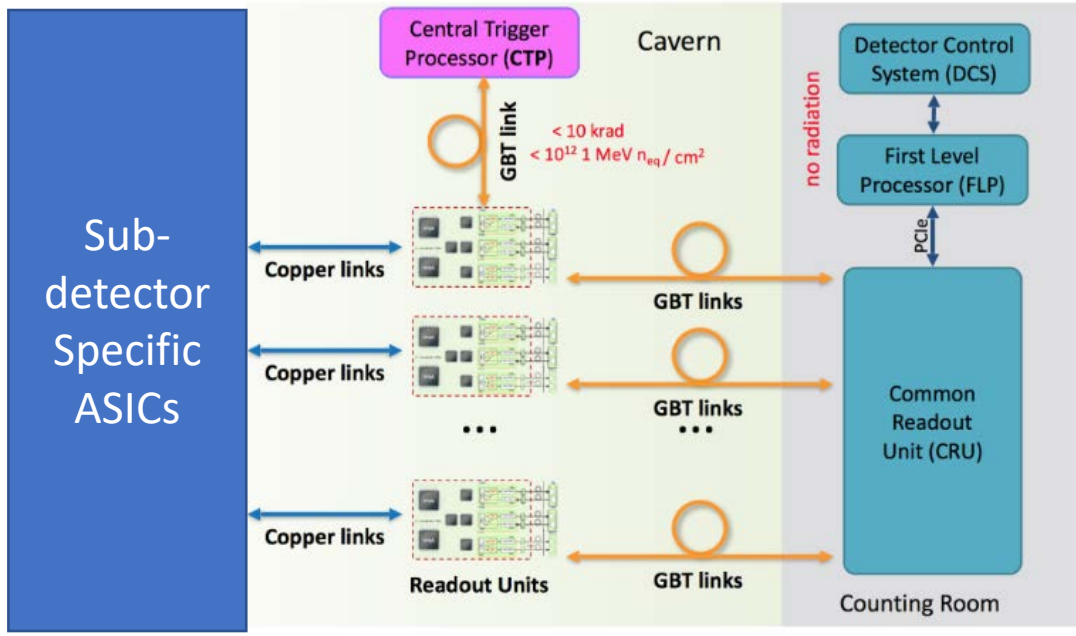
a COmpact detectoR for the Eic (CORE) Readout Initial plans





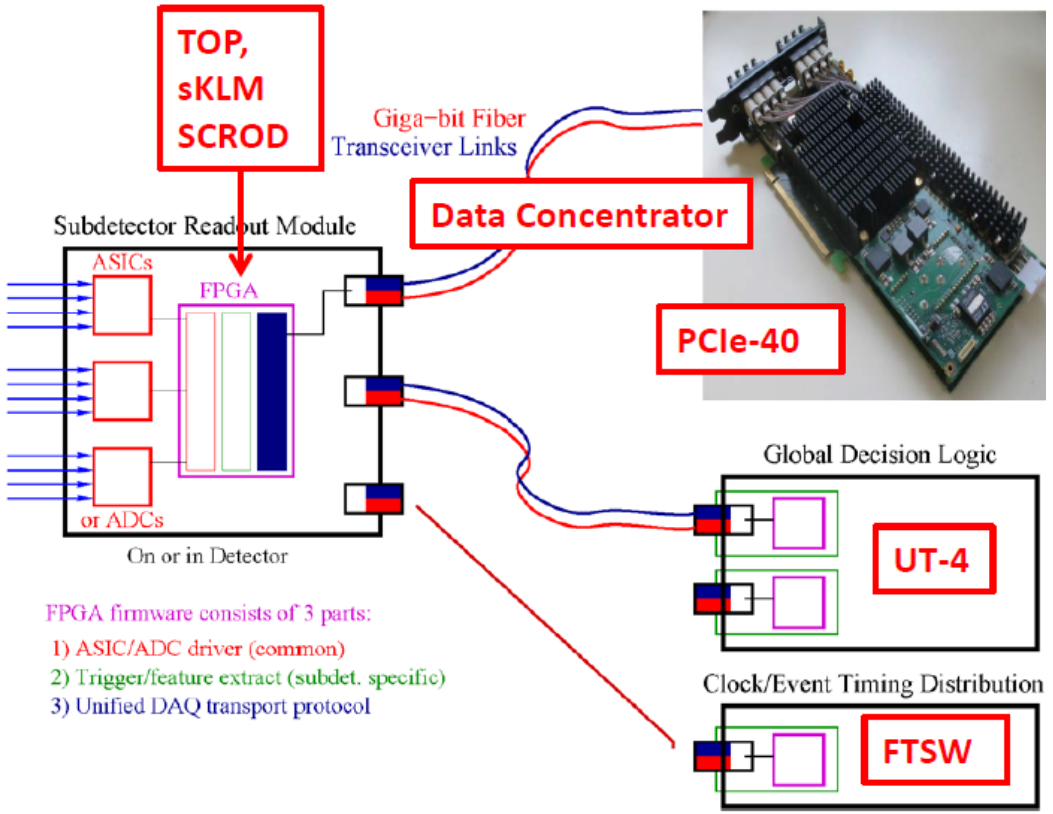
- Builds upon development efforts for LHC, Belle II
- Unified framework for all subdetectors
  1. Common Timing/Trigger distribution
  2. Cost baseline is FELIX for CRU
- Readout for subsystems from the Generic EIC R&D program

Gary S. Varner == 4-AUG-2021

University of Hawai'i Mānoa

General Readout Concept – an evolution of common implementations

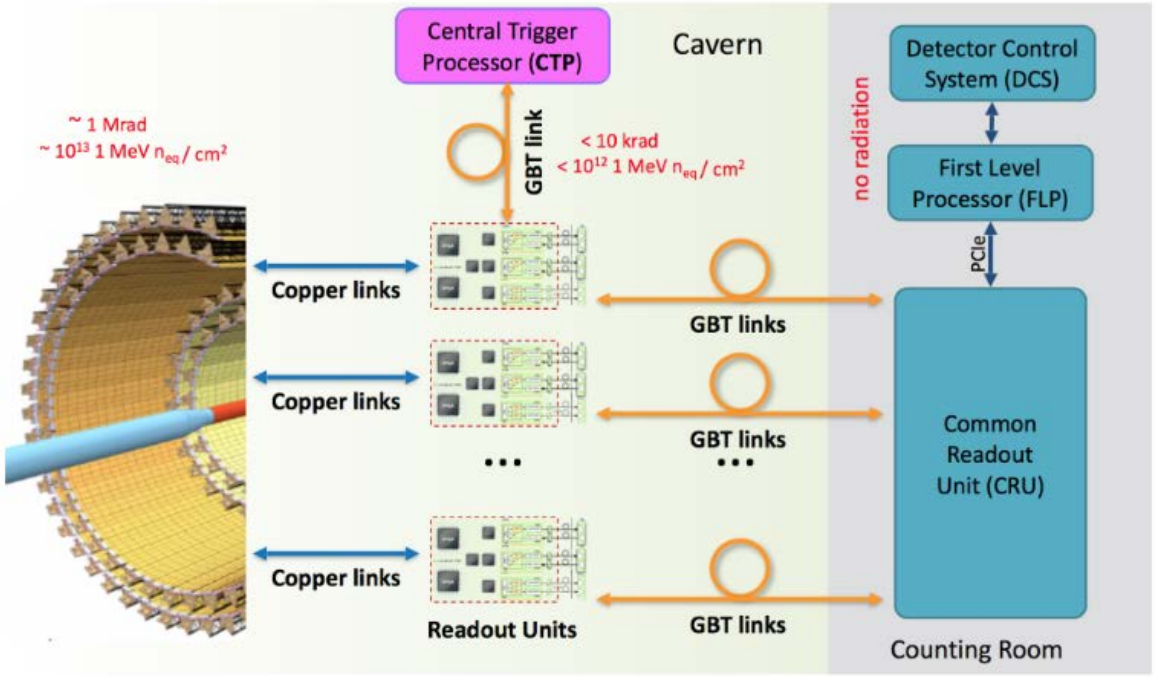
- Mixed RPC+scint readout (Data concentrator)
- >= 30kHz L1
- Gbps fiber Tx/Rx
- PCIe40 backend
- Super-KEKB clock/timing (FTSW)

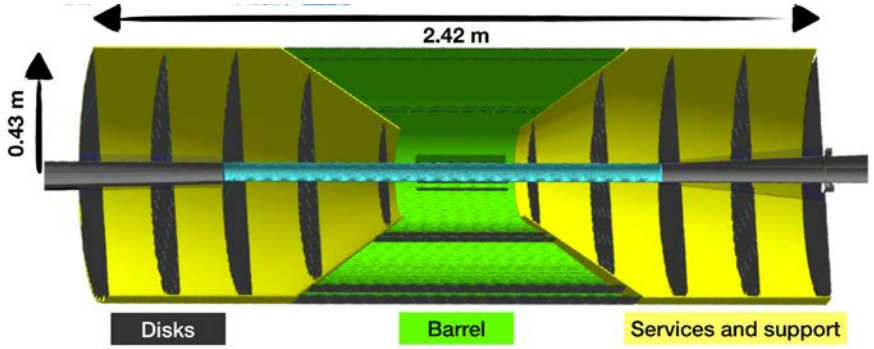


- Where possible, essentially triggerless DAQ
- Based upon above concept
- PCIe40 chosen as CRU, but FELIX was equally viable

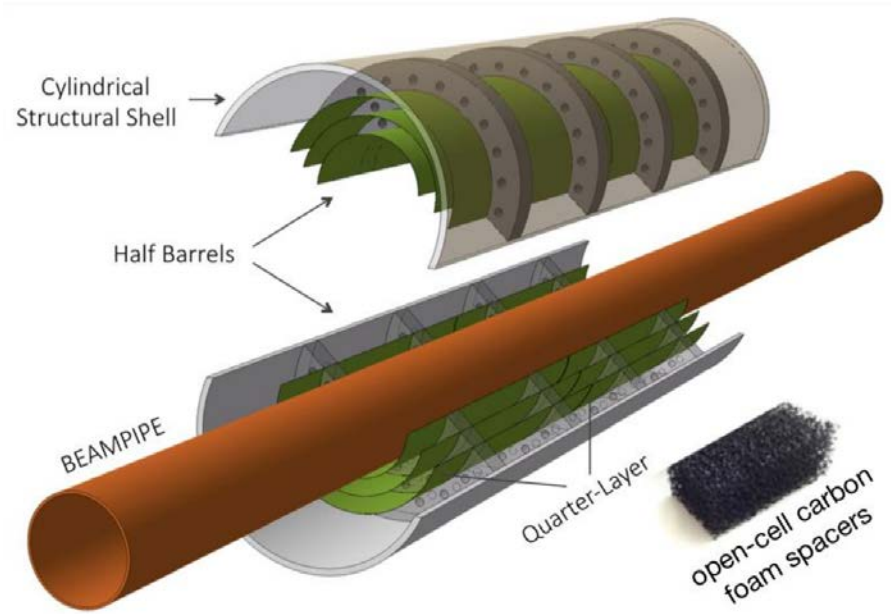
Central Si-tracker

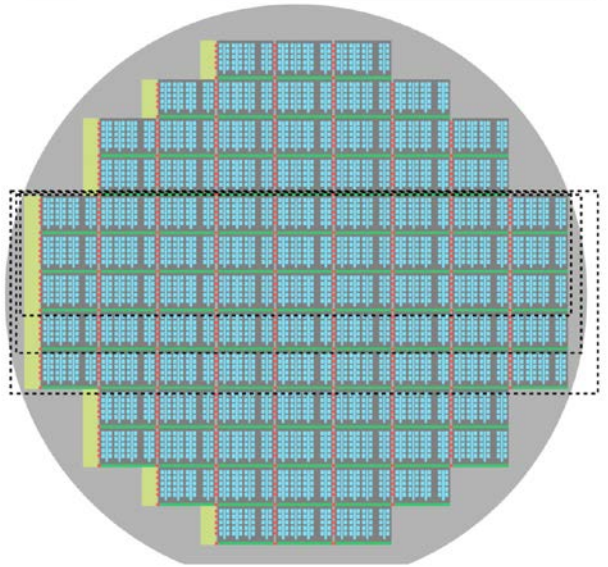
- A silicon tracker is compact, has a high resolution, and offers opportunities for future upgrades.
- The tracker developed by eRD25 uses ALICE ITS2/3 technology and is designed for the angular resolution requirements of the DIRC





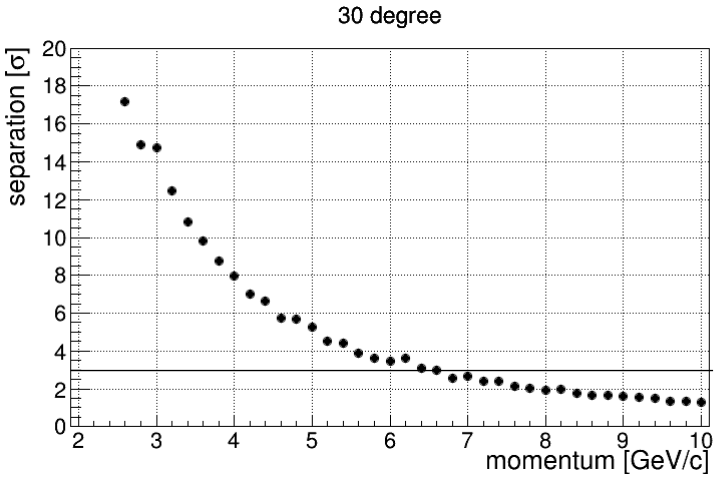
eRD25 tracker

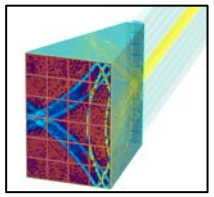


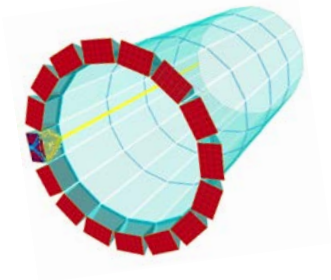


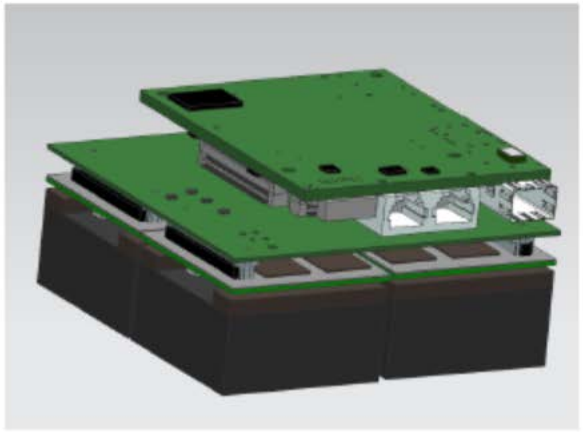
hpDIRC: hadron Identification in the barrel

--> Highly integrated readout experience: Belle II iTOP detector









- The hpDIRC provides central acceptance π/K separation
- The minimum momentum for π/K ID in threshold mode is 0.2 GeV
- Readout has been an essential eRD14 activity (dualRICH, mRICH)

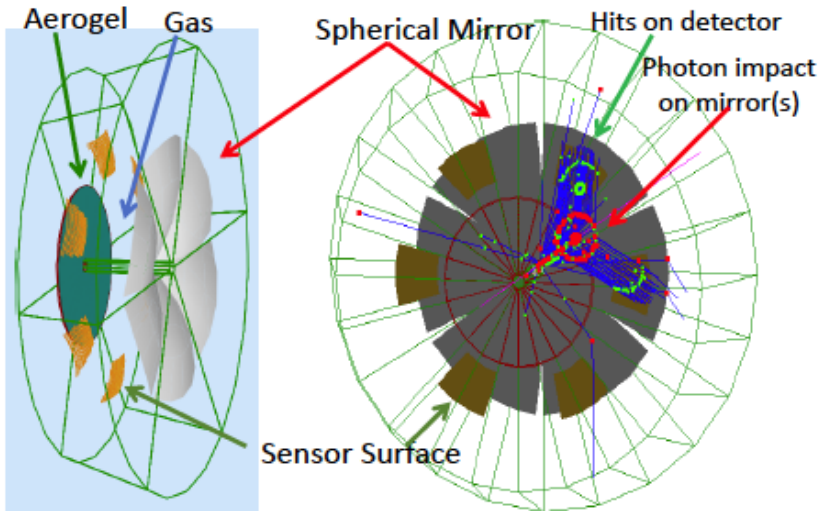
NALU SCIENTIFIC ENABLING INNOVATION

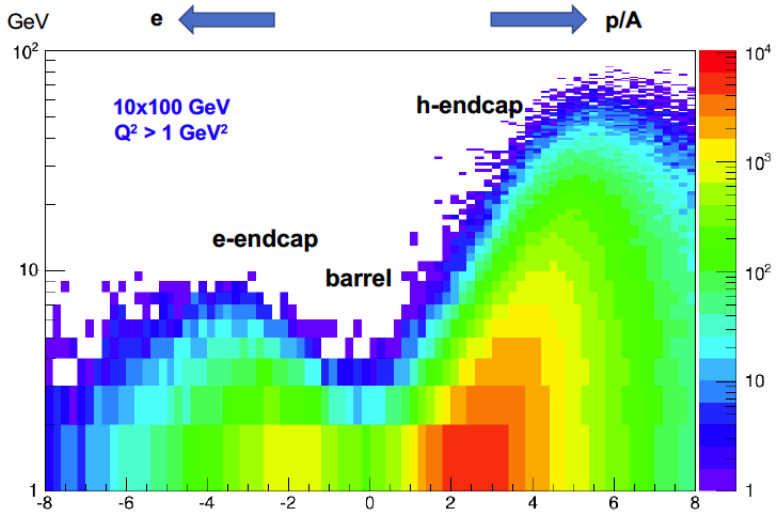
Current SoC-ASIC Projects

Project	Sampling Frequency (GHz)	Input BW (GHz)	Buffer Length (Samples)	Number of Channels	Timing Resolution (ps)	Available Date
ASoC	3-5	0.8	16k	4	35	Rev 3 avail
HDSoC	1-3	0.6	4k	64	80-120	Feb'21
AARDVARC	8-14	2.5	32k	4	4	Rev 3 avail
AODS	1-2	1	8k	1-4	100-200	Rev 1 avail

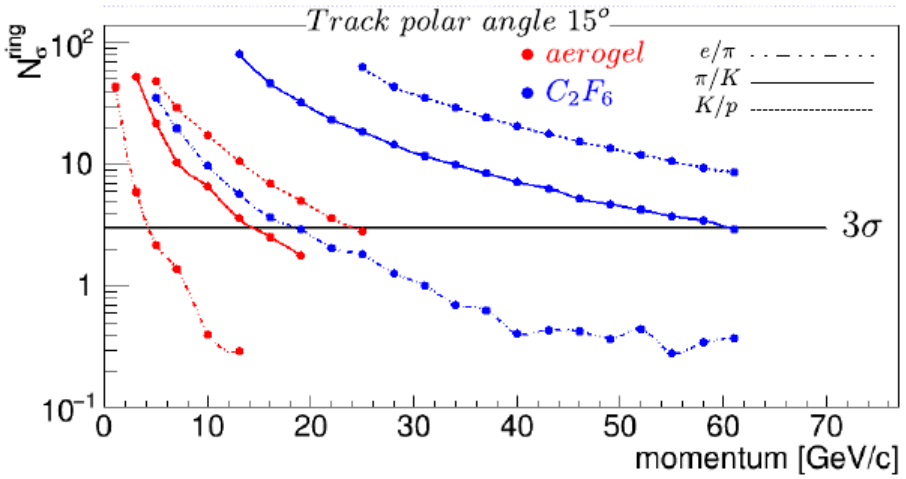
- **ASoC**: Analog to digital converter System-on-Chip
- **HDSoC**: SiPM specialized readout chip with bias and control
- **AARDVARC**: Variable rate readout chip for fast timing and low deadtime
- **AODS:** Low density digitizer with High Dynamic Range (HDR) option

dualRICH: hadron Identification in the hadron endcap





- 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

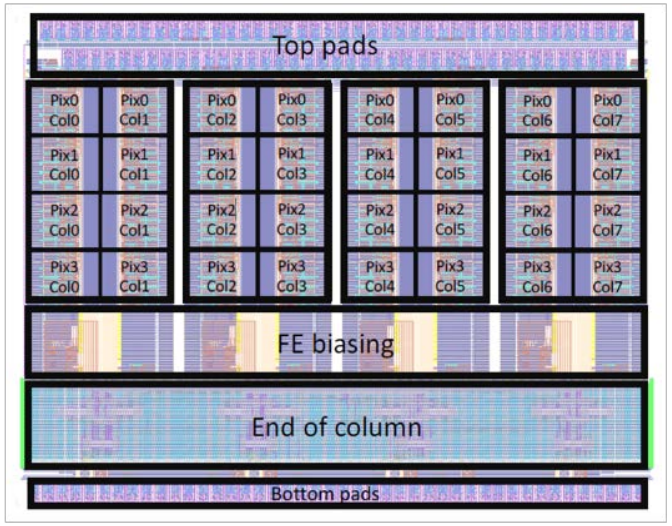


Development of a ToT readout based on ALCOR (F/E) + ARCADIA (DAQ)

- 500 kHz per channel
- 50 ps time binning

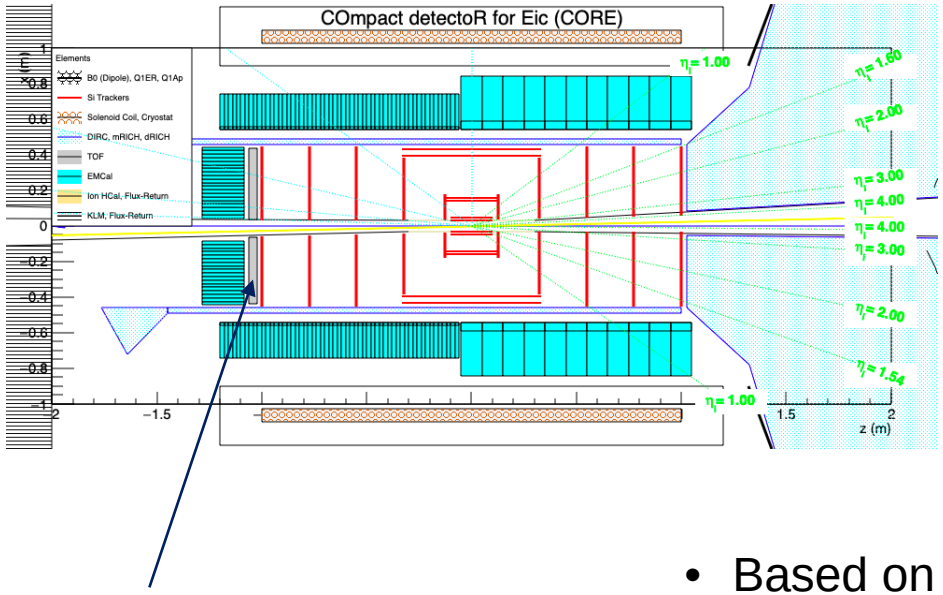
Chip under validation with a dedicated test board

Design of a readout chain dedicated to dRICH / SiPM



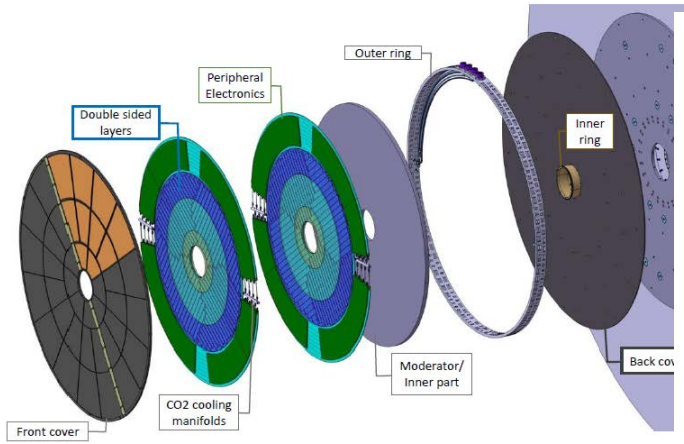
TOF: hadron Identification in the electron endcap

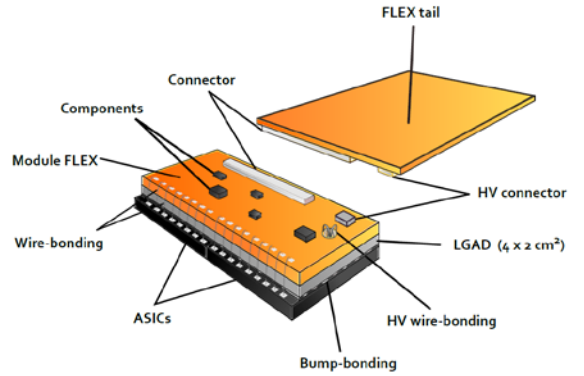
- While high-resolution TOF is not competitive with Cherenkov detectors in the central barrel (small radius), useful in the electron endcap.



High-resolution TOF using LGADs

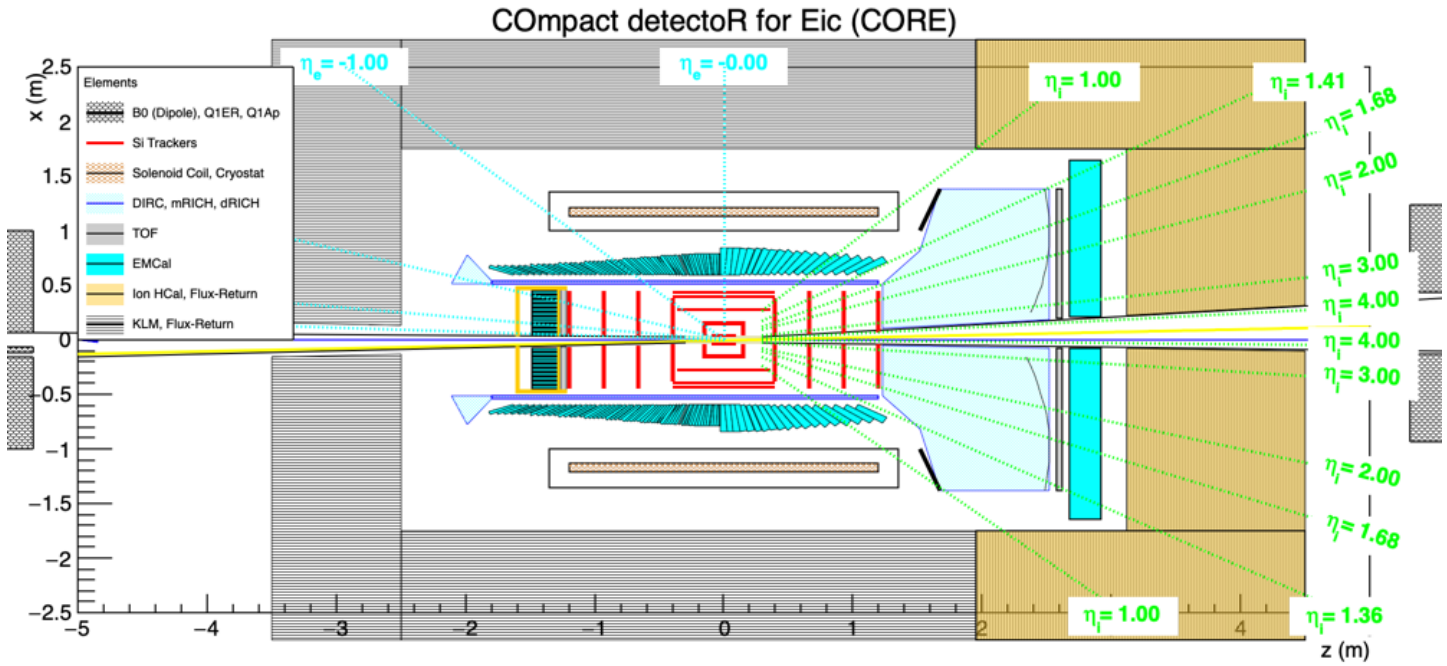
- 8043 4x2 cm^2 modules made of a LGAD sensor flip-chipped to two ASICs
- Pixel size 1.3x1.3 mm^2 (Cd ~4 pF)
- 225 channels / ASIC
- ASICs signals are wire bonded to a module flex.

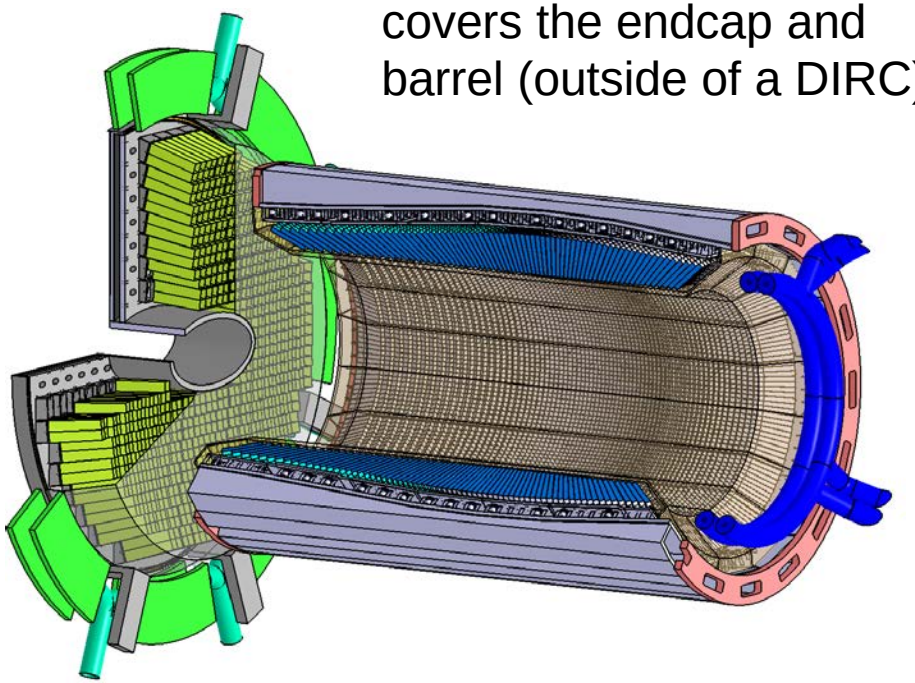




- Based on ATLAS High Granularity Timing Detector in the forward region made of two double-sided LGAD layers
- Read-out by ALTIROC

4π EMcal





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

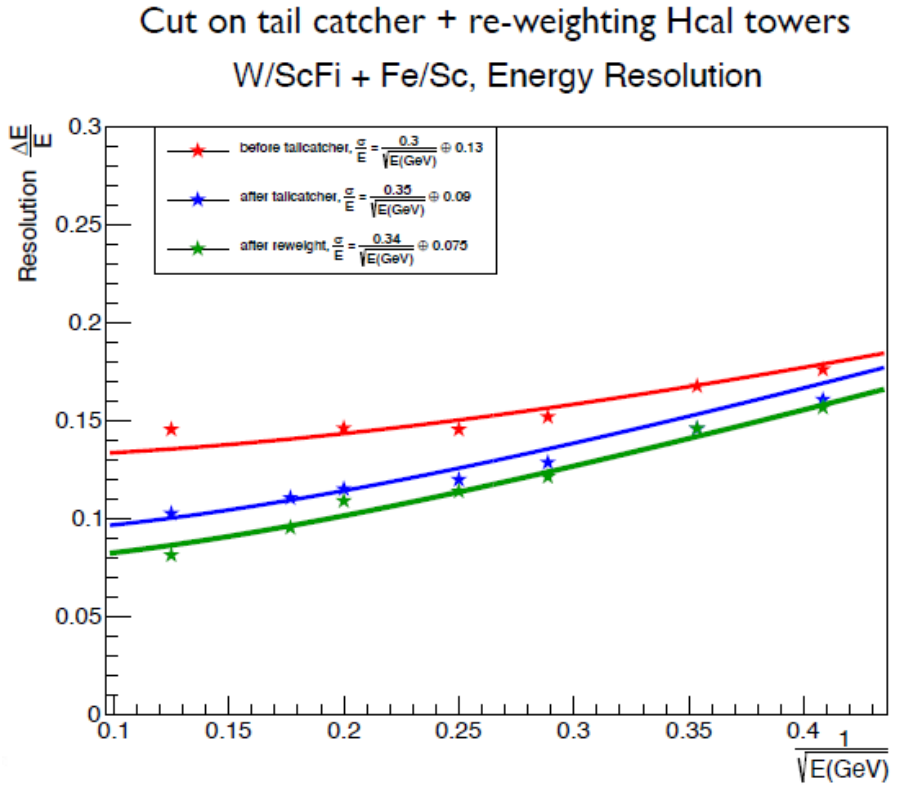
$\eta < 0$ coverage

- PWO_4 coverage up to 2π
  - The PWO_4 area will be half or less of that planned for PANDA
  - 14-bit 250 MSPS (or dual-range)

$\eta > 0$ coverage

- Baseline W-Shashlik dual gain-range amplification
  - 14-bit 250 MSPS (or dual-range)

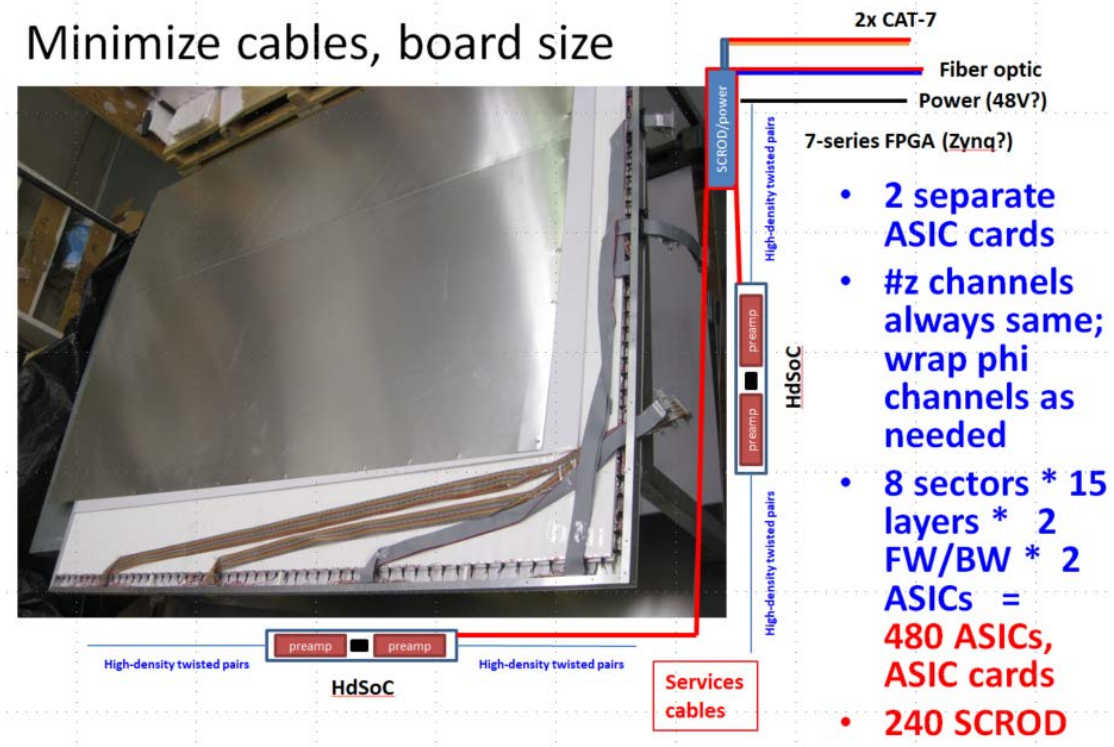
Hadron Calorimeter: 10cm x 10cm towers, 6 SiPMs/tower

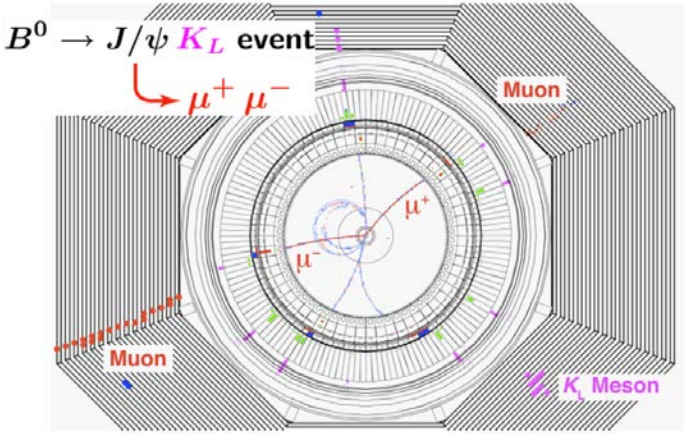


- Relatively simple readout requirements
  - 80 MSPS probably enough
  - 8-bits resolution

Muon ID

Basis: Belle II K_L-μ (KLM) system





Baseline cost estimate with preamplification on HDSoC ASIC.

Phase	Resource	Basis of estimate	Total (k$)
Pre-production	Carrier+SCROD Engineering	0.5 FTE Andrew	70
	DatCon Engineering	0.5 FTE Kunkler	89
	Carrier+SCROD Test system	1.0 Postdoc	65
	Carrier+SCROD Testing labor	1.0 Graduate RA	50
	HDSoC ASIC procurement	Nalu Scientific	50
	Carrier+SCROD PCB + parts procurement	Engr est.	21
	DatCon PCB + parts procurement	Engr est.	15
	Carrier+SCROD PCB assembly	Engr est.	14
	DatCon PCB assembly	Engr est.	8
Production	Engineering	0.25 FTE Andrew	35
	DatCon Engineering	0.25 FTE Kunkler	44
	Carrier+SCROD Test system	1.0 Postdoc	65
	Carrier+SCROD Testing labor	1.0 Graduate RA	50
	HDSoC ASIC procurement	Nalu Scientific	150
	Carrier+SCROD PCB + parts procurement	Engr est.	121
	DatCon PCB + parts procurement	Engr est.	115
	Carrier+SCROD PCB assembly	Engr est.	75
	DatCon PCB assembly	Engr est.	25
	LV Power System + cable ass'blies	Engr est.	80
	LV Power System + cable ass'blies design	0.1 FTE Visser	20
Commissioning	Carrier+SCROD Engineering support	0.2 FTE Andrew	28
	DatCon Engineering support	0.2 FTE Kunkler	36
	Installation support / analysis	1.0 Postdoc	65
	Installation support	1.0 Graduate RA	50
	HDSoC ASIC support	Nalu Scientific	80
	LV Power System + cable ass'blies integration	0.1 FTE Visser	20
Total			1,441 k$

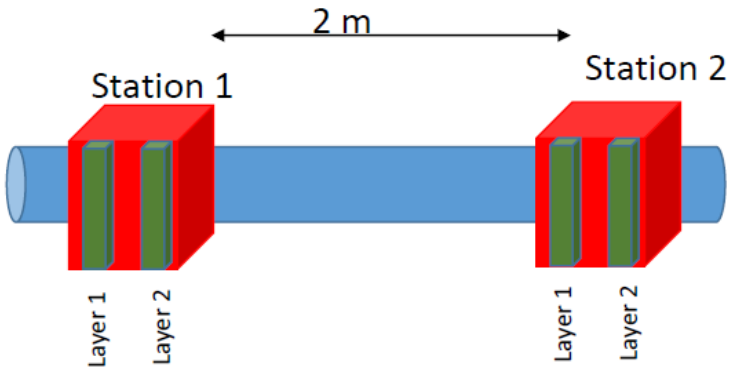
- Detailed costing numbers from recent upgrade exercise (DOE Belle II Operations Review)
- At the EIC, mid-rapidity muons have relatively low momenta (placing a muon detector behind an Hcal is not feasible).
- Since jets are best reconstructed from individual tracks, one approach is to trade energy resolution for better muon and neutral hadron (K_L) ID, and lower cost (*cf.* Belle II KLM)

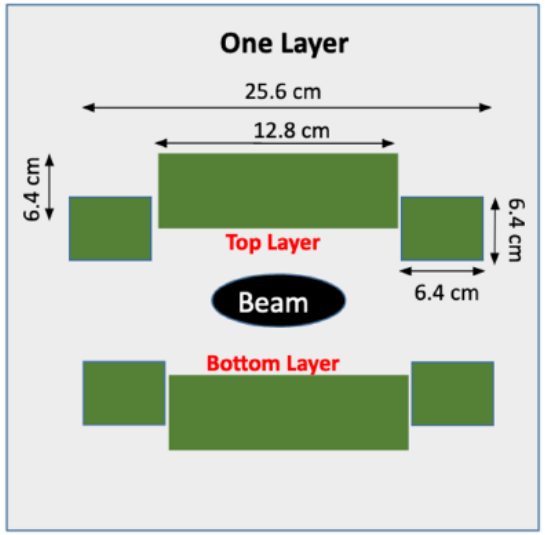
Forward/Far-Forward/Far-Backward detectors: many concepts

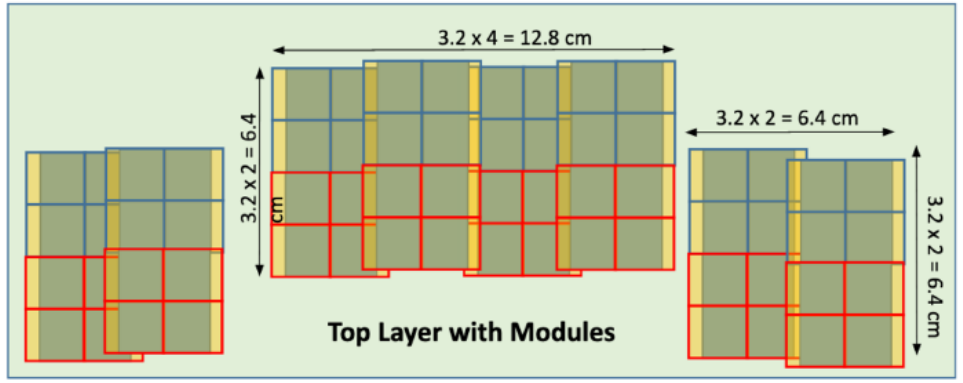
Ion Forward: B0			
Si-Tracker	AC-LGAD or MAPS		
Decay Tracker	SC Nanowires	Future R&D/upgrad	
Ion Far-Forward			
RP@45m	AC-LGAD		
Off-momentum	MPGD	JLab / COMPASS/ PHENIX	
ZDC-EM	PbWO4		Rad-Hard
ZDC-Hcal			
Far-Backward		(electron Far Forwad)	
Pair Spec	MPGD		
0deg Tagger	AC-LGAD		
	PBWO4		

- Fine spatial and timing resolution, radiation hardness
- AltiROC or CMS variant

- Updated strawman layout with current design for LGAD sensor + ASIC.







AC-LGADs are the baseline for detectors in EIC Roman Pot

CORE Readout Summary Table

Subsystem	Sensor	ASIC(s)	# Channels	RU status	# FELIX	Comments
Si-Tracker	MAPS	ITS2, ITS3	30 G	Reuse?	12 ?	eRD25
hpDIRC	MCP-PMT	AARDVARC	49 k	**baseline**	4	eRD14, Nalu Scientific
Dual RICH	SiPM	ALCOR	65 k	**baseline**	4	eRD14, INFN
TOF (eEndcap)	DC-LGAD	ALTIROC	2 M	needed	8	
EMCal –PbWO4	SiPM/APD	COTs ADC	20 k	needed	2	
EMCal – W-Shashlik	SiPM/APD	COTs ADC	30 k	needed	3	
Ion HCal	SiPM	COTs ADC	50 k ?	needed	4	
KLM (mu/Hcal)	SiPM	HDSoC	30 k	**baseline**	1	Belle II, Nalu Scientific
Far-Forward/Backward	AC-LGAD	ALTIROC?	TBD	needed	2 ?	

- Skeleton for WBS estimation of what needed (however a lot of work needed)
- Additional Forward, Far-Forward detectors possible