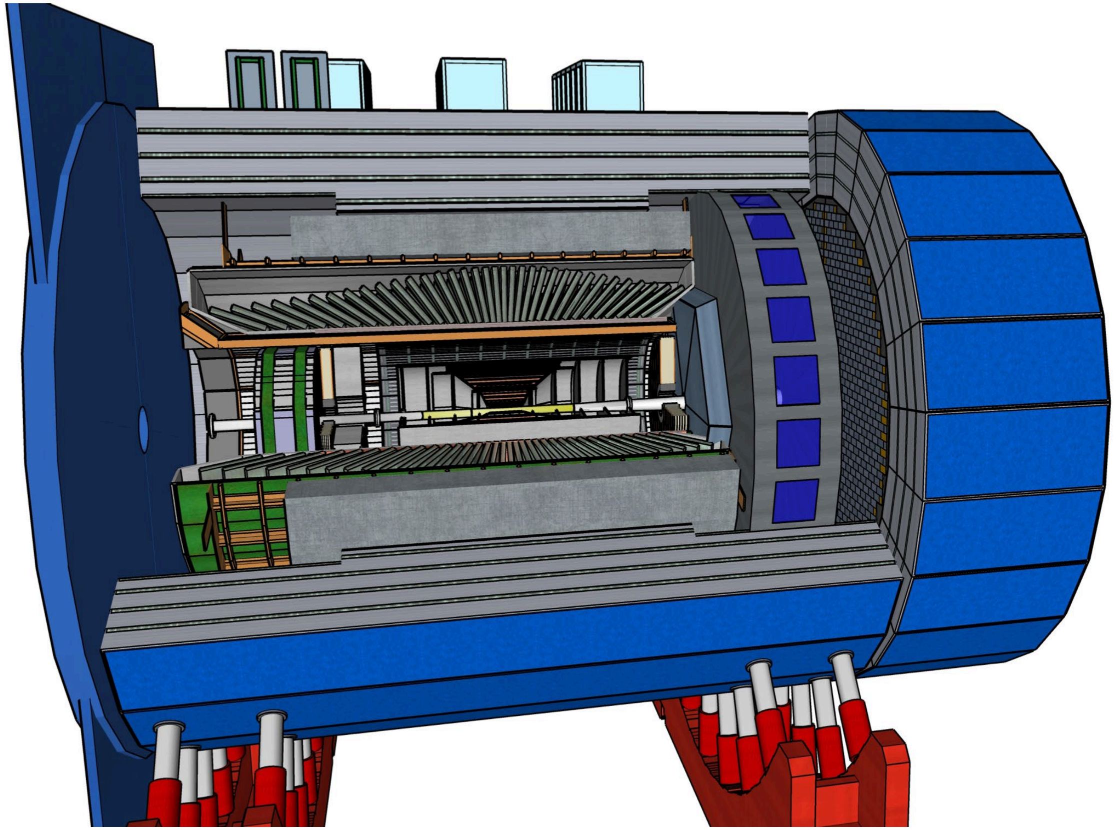
ECCE

EIC Comprehensive Chromodynamics Experiment



Detector Risk/R&D/Upgrades

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ECCE Risk associated with Detector Technologies

ECCE EIC Detector Preliminary Project Risk Log

Risk ID	Detector Subsystem	Primary Risk Impact Category (Dropdown)	Risk Title	Description	Risk Trigger
EIC-DR20	ECE06.10.05 - Electromagnetic Calorimetry	Schedule	SciGlass vendor	SciGlass is not yet commercially available. However, global manufacturers like Schott, St. Gobain, Corning International, Thermofisher, Asahi, etc. have the facilities to produce SciGlass on the large scale	Limited availability of SciGlass for EIC
EIC-DR22	ECE06.10.03 - Tracking	Cost	Silicon cost reduction	Massvie sensor purchase is required for the silicon tracker.	Early R&D, final values could change.
EIC-DR23	ECE06.10.03 - Tracking	Technical	Disk design	Ongoing R&D	Early R&D, final design could change
EIC-DR24	ECE06.10.03 - Tracking	Technical	MAPS ITS3	Risk similar to the EIC Si Consortium	Early R&D, final design could change
EIC-DR25	ECE06.10.03 - Tracking	Technical	GEM mRWELL with capacitive coupling	ongoing Jlab/CLAS12 and EIC R&D	
EIC-DR26	ECE06.10.04 - PID	Resources	Dual RICH - no direct expertise in collaboration		
EIC-DR27	ECE06.10 - Overall Project	Schedule	COVID/Pandemic Events	It is possible that project execution could be impacted by COVID or other pandemic events. Should these events occur, the projects execution could be disrupted. This would likely impact the projects cost and schedule.	Pandemic event impacts the project
EIC-DR28	ECE06.10 - Overall Project	Cost	Higher Overhead Rates	If the OH rates assumed in the cost estimate are higher than planned, the projects cost would be impacted.	OH rates are adjusted at an institution and are higher than expected.
EIC-DR29	ECE06.10 - Overall Project	Resources	Labor Resource Availability - Overall Project	Labor resources are not adequate to address project scope within the agreed-upon schedule.	Labor resources to execute the project are not available when needed
EIC-DR30	ECE06.10 - Overall Project	Cost	Escalation on Material/Higher Material Cost	Given current increases in inflation, it is possible that material cost in the future will be much higher than planned.	Material cost higher than anticipated to due higher esclation than expected.
EIC-DR31	ECE06.10 - Overall Project	Cost and Schedule	Contractor Availability	Current industry conditions suggest that contractor availability may be challenge for the project in the future. This could impact both cost and schedule due to limited options and delays in identifying and securing contractor support.	Contractors not readily available when needed.
EIC-DR32	ECE06.10 - Overall Project	Cost and Schedule	Equipment Failures	The project may experience some equipment failures during construction, assembly and intergration of the detector. Realization of such failures would result in cost and schedule impacts.	Equipment failures during project execution.
EIC-DR33	ECE06.10 - Overall Project	Technical	Unforeseen Technical Issues	Unknown technical challenges may arise during construction, assembly and intergration of the detector that are not accounted for within the planning.	Technical challenges realized.
EIC-DR34	ECE06.10 - Overall Project	Scope	Additional, Unforeseen Design Required	Additional, unforeseen design may be required for subsystems and/or components, beyond the design currently planned. If additional design is required then cost and schedule would be impacted.	Additional design of a subsystem of component required
EIC-DR35	ECE06.10.10 - Infrastructure and Integration	Scope	Unexpected Infrastructure and/or Facilites Issues	The project may be impacted by some unexpected cost associated with the facilities and/or infrastructure in order to incorporate the required infrastructure. Examples would be electrical power distribution issue not accounted for, issues with installing detector components in the space available, etc.	Unexpected, unplanned infrastructure needs identified.
EIC-DR36	ECE06.10 - Overall Project	Resources	The Loss of KEY Project Personnel	The loss of key technical experts would have an impact on the project. Typically, the loss of key personnel impacts the efficiency and continuity of the project and consequently impacts the schedule.	Loss of key project personnel.
EIC-DR37	ECE06.10 - Overall Project	Schedule	Procurement and Fabrication Delays	Procurement and fabrication delays occur quite often on projects of this nature. Should a significant procurement and/or fabrication delay be realized, if could impact the project cost and schedule.	Delays realized in procurements and/or fabrication.

The risk log includes 59 entries on items like magnet, detector systems/DAQ/electronics/computing, overall Project.

- Many of these risks can be mitigated by further design and understanding.
- Several risk items are related to the magnet based on a 2020 Jlab Engineering Risk Assessment (engineer: R. Fair) as reuse of the magnet presents moderate risk; The ECCE strategy is to plan for proactive maintenance, monitor magnet functionality during sPHENIX, and carry through E&D as schedule risk mitigation.
- Several risk items related to the detector technologies will be mitigated with detector R&D.

The risk log also contains 5 entries on opportunities, mainly opportunities to reduce number of sensors pending R&D.

ECCE Detector R&D Needs

See also EIC Detector R&D Document on https://indico.bnl.gov/event/10974/contributions/53172/

Table 5.2: Detector R&D costs evaluated specifically for the ECCE detector.

Equipment	In-Kind Value ($M)	On-Project Costs ($M)	Notes:
Cylindrical μRWELL	0.0	0.7	per ECCE experts
Si Sensor Development	6.0	3.9	per EICSC consortium
Si Additional R&D (Targeted)	1.0	1.8	per EICSC consortium
AC-LGADs	0.0	1.2	consistent with EIC R&D plan
PID	0.2	1.9	consistent with EIC R&D plan
EM Calorimetry (SciGlass and crystals)	0.2	0.2	consistent with EIC R&D plan in-kind from EEEMCal consortium
EM Calorimetry (Shashlik)	0.0	0.2	consistent with EIC R&D plan
Hadronic Calorimetry (forward)	0.0	0.4	consistent with EIC R&D plan
Electronics/ASICS	0.0	1.7	consistent with EIC R&D plan
Aux. Detectors	0.0	0.4	consistent with EIC R&D plan
TOTAL	**7.4**	**12.4**	

R&D discussed further in this talk

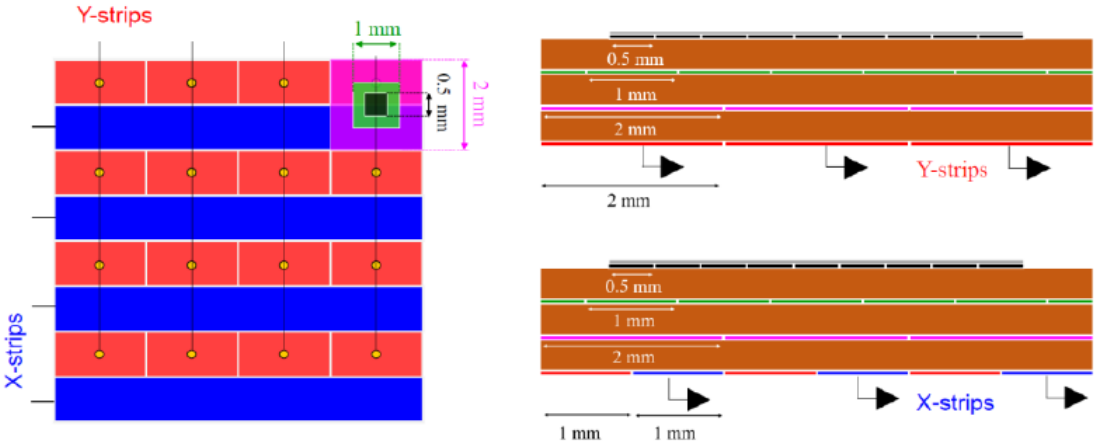
- ECCE developed a list with R&D needed to build the detector
  - Consistent with EIC R&D plans
- ECCE Consortium members are leading and/or actively contributing to many R&D consortia (e.g., EEMCAL, Silicon, ITS3 consortia) and EIC eRDnnn projects

Cylindrical muRWell (eRD108)

- Motivation:
  - Outer tracking layers
  - provide precise directional information to help seed the Cherenkov detector ring reconstruction (DIRC)

- Objective:
  - Demonstrate with a small prototype that cylindrical muRWell can be built and operated

Concept of capacitive-sharing strip readout

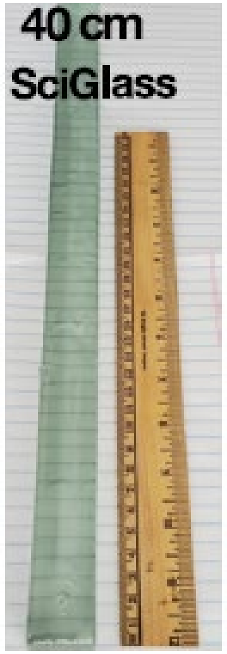


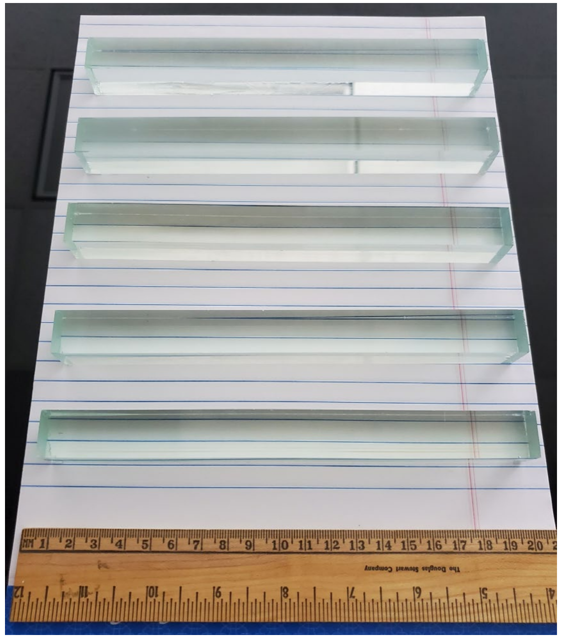
- R&D Plans for FY2022 & 2023
  - Design and fabricate the mechanics of the cylindrical muRWell prototype (FY22)
  - Design and procurement of muRWell amplification & readout composite foil (FY22)
  - Acquisition of a small VMM3a-SRS readout electronics (FY22)
  - Characterization of the prototype with Xray at BNL and beam at FNAL (FY23)

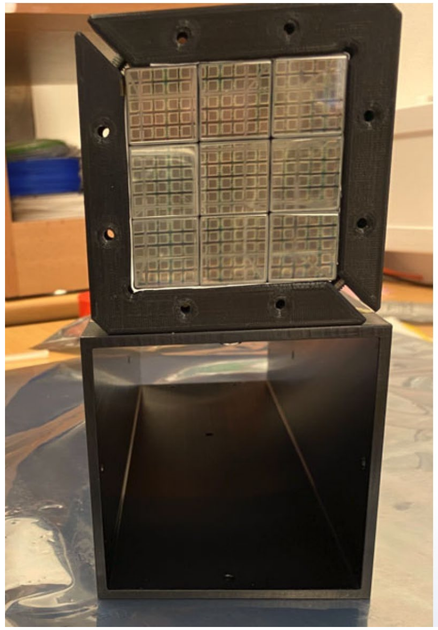
SciGlass R&D (eRD105)

- ❑ SciGlass of 20cm can be reliably produced
- ❑ SciGlass performance has been demonstrated with 20cm bars.
- ❑ Performance validation of longer blocks is part of the ongoing project EIC R&D (eRD105) – R&D is expected to be complete FY24
- ❑ Work towards large-scale commercial production is part of an ongoing Phase 2 SBIR/STTR

Item	Task	FY22				FY23				FY24			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Glass fabrication	Scale up to 4x4x45cm^3	■	■	■	■	■							
	Show uniformity and reproducibility		■	■	■	■	■						
	Fabrication process optimization			■	■	■	■	■					
	Process design verification to scale up						■	■	■				
	Large scale production study												
Glass Characterization	Optical characteristics	■	■	■	■	■							
	Irradiation	■	■	■	■	■							
Software	Prototype		■	■	■	■	■						
	Design options		■	■	■	■	■	■					
Prototype	Small prototype	■											
	Upgrade and commissioning		■	■	■		■	■	■				
	Readout		■	■	■		■	■	■				
Beam test	Beam test	■				■				■			
	Data analysis	■	■	■	■	■	■	■	■	■	■	■	







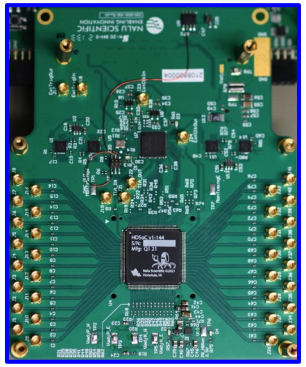
hpDIRC R&D (eRD103)

- ❑ Developed a very compact barrel EIC PID detector with extended momentum coverage, pushing both the π/K and e/π separation performance well beyond the state-of-the-art for DIRC counters
- ❑ Validated performance in detailed Geant4 simulation: 40-120 detected photons per particle, ≥ 3 s.d. π/K at 6 GeV/c
- ❑ Developed innovative 3-layer lens, build radiation-hard prototype, and validated properties on testbench and in DIRC prototype with particle beam

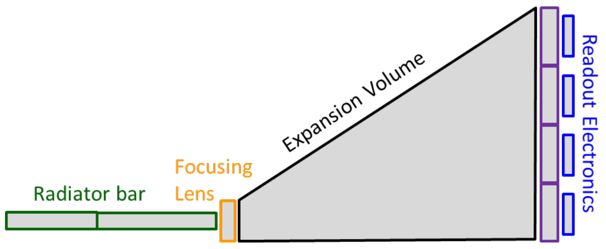
Remaining R&D:

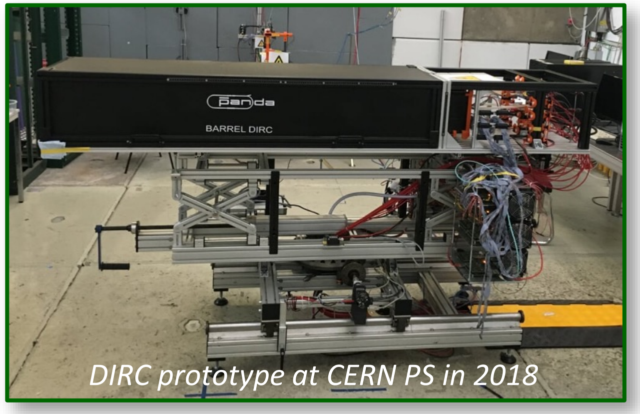
- ❑ To validate the PID performance of a cost-optimized hpDIRC design for the EIC detector with a vertical-slice prototype in a particle beam **by FY24**
- ❑ To minimize hpDIRC risks and to realize opportunities:
  - ➢ Technical risk: availability and performance of small-pixel MCP-PMTs and matching fast compact readout electronics
  - ➢ Opportunity: reuse of BaBar DIRC bars
  - ➢ Opportunity: investigate hpDIRC PID baseline design validation in particle beams
  - ➢ Opportunity: novel hybrid design with narrow bars and wide plate
  - ➢ Opportunity: cost/performance optimization (simulation and prototype)

Prototype readout stack at UH/Nalu

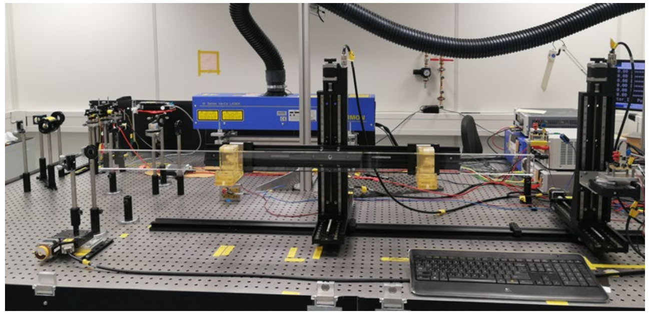


hpDIRC Key Components:

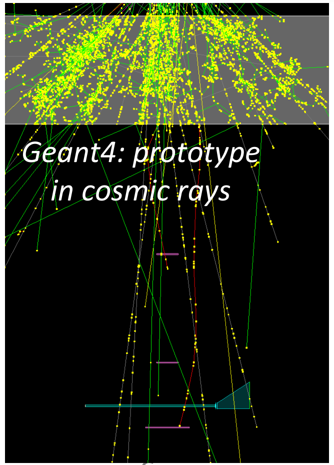




DIRC prototype at CERN PS in 2018



DIRC lab @ GSI

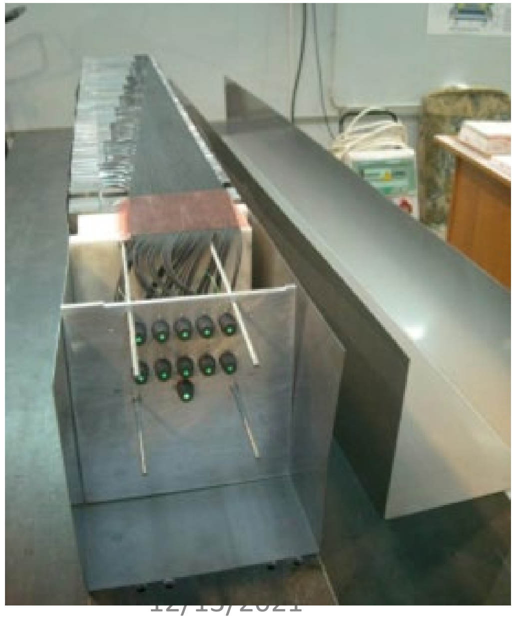


Geant4: prototype in cosmic rays

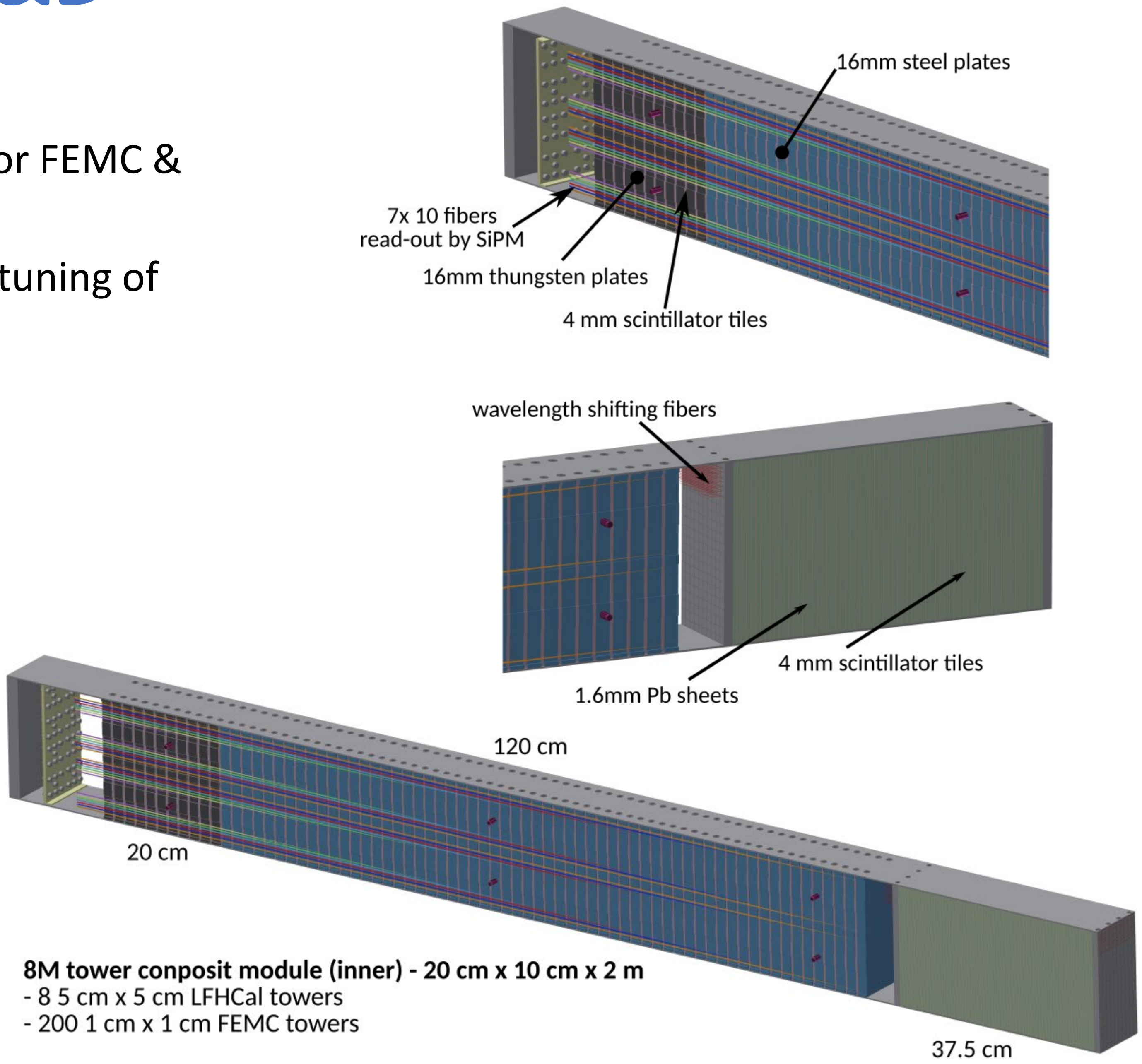
Forward Calorimeters R&D

- ❑ Verification of adapted integrated design for FEMC & LFHCAL with test beam
- ❑ Quantification of performance for reliable tuning of simulations

PSD-Calorimeter NA61



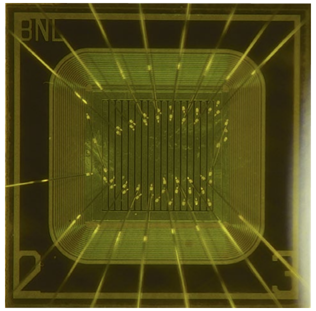
ALICE EMCal



AC-LGAD (eRD112)

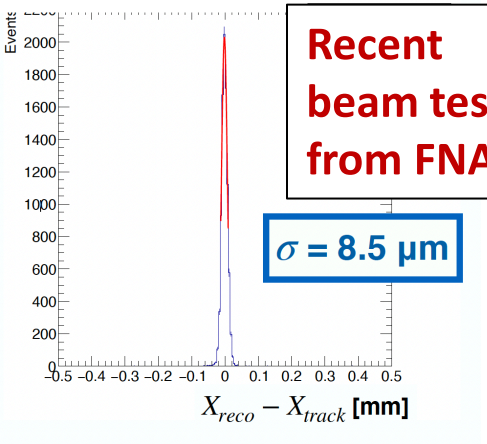
(AC)-LGAD

Strip AC-LGADs fabricated at BNL



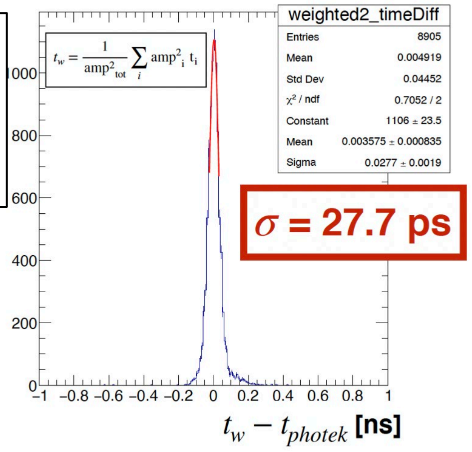
100µm pitch, 20µm gaps

Position resolution



Recent beam tests from FNAL

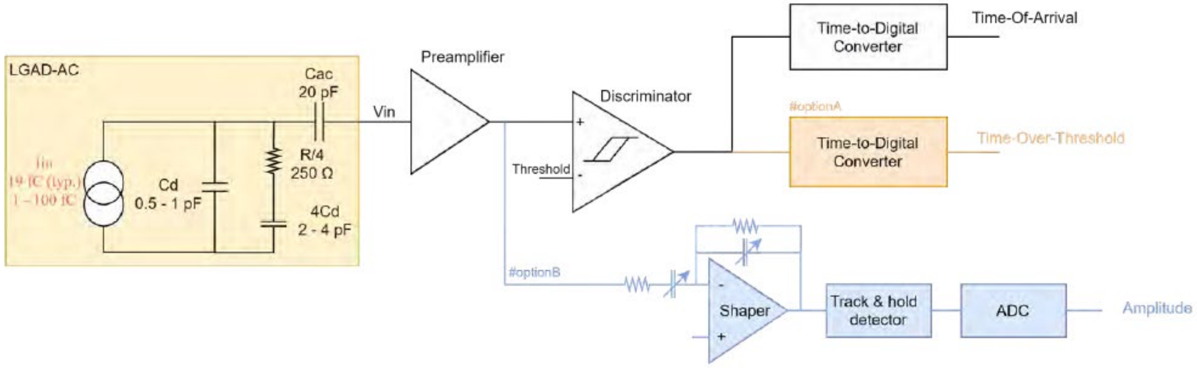
Time resolution



C. Madrid et. al., LGADs Consortium meeting, Nov. 1, 2021

- Detectors can provide <20ps / layer
- AC-coupled variety gives 100% fill factor and potentially a high spatial resolution (dozens of microns) with >1mm large pixels

(ASIC)



- Goal: 15-20 ps jitter with minimal (1-2 mW/ch) power consumption, match AC-LGAD sensors for EIC
- Continue the ASIC prototyping effort for RPs by IJCLAB/Omega (1st submission by in-kind funding)
- Utilize the design and experience in ASICs for fast-timing detectors from ATLAS and CMS. Investigate common ASIC design and development for RPs and TOF.

mRICH (eRD101)

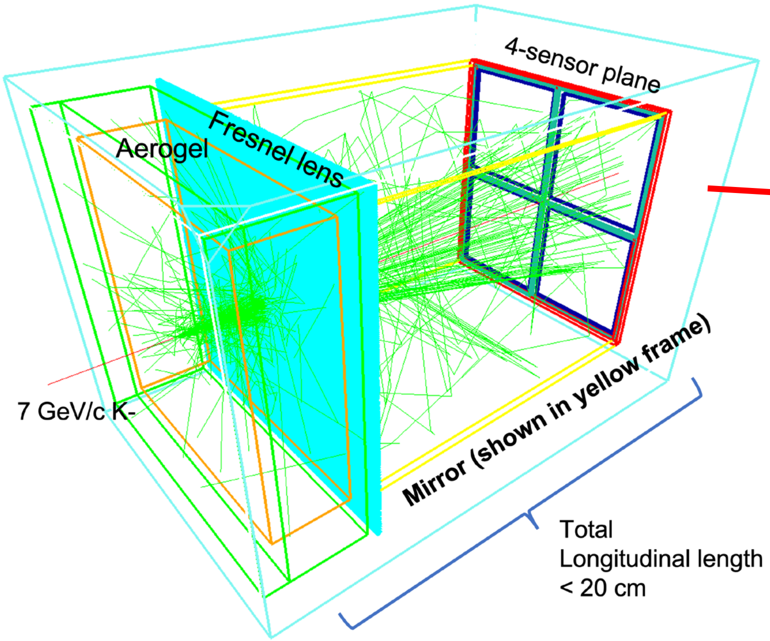
- ❑ mRICH JLab test (2021) data analysis for extracting single photon angle resolution (before 2/1/22)
- ❑ Fine tuning mRICH GEANT4 simulation to match performance from test data (ongoing)
- ❑ Engineering design: optimizing detector coverage and optical components & assembly (ongoing)
- ❑ Build new prototype toward its final design for array installation (by the end of 2022)

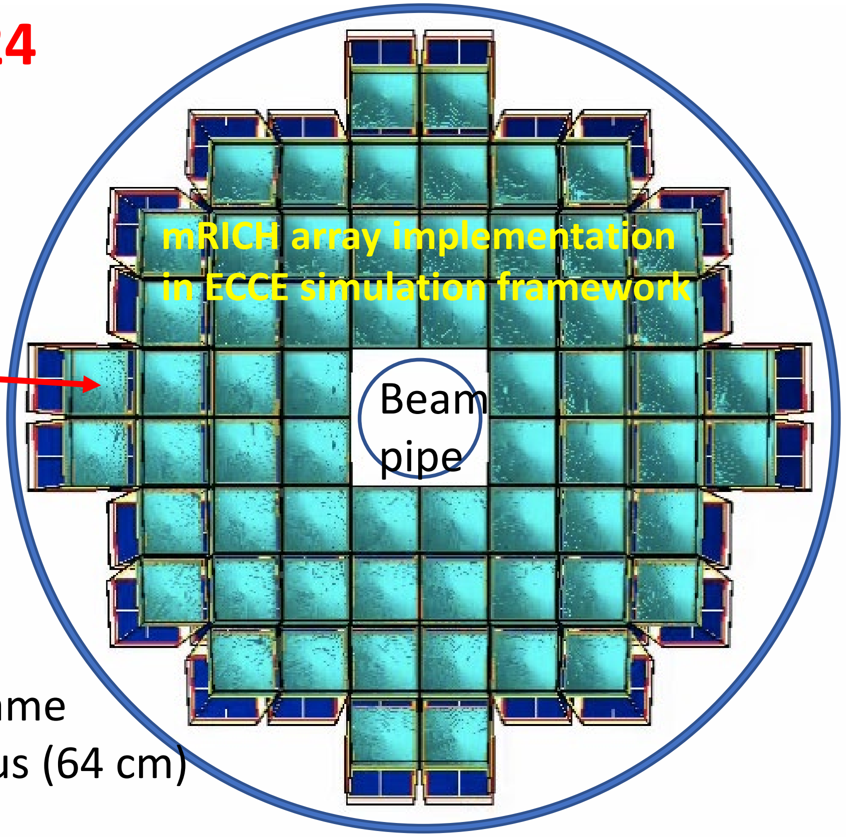
FY 22

- ❑ mRICH performance tests with the new prototype
- ❑ mRICH tests with new photosensors

FY 23/24

Note: There will be synergic efforts in mitigating the risk factors associated with Aerogel procurement and photosensor choices with dRICH R&D (eRD102).





hpDIRC frame
Inner radius (64 cm)

ECCE Detector – Added Capabilities

CENTRAL

Dual Readout Calorimetry

- Improved energy resolution in the forward region for measurements of SIDIS hadrons, TMDs with jets, and the ability to reconstruct event kinematics using hadron remnants

Muon Chambers

- Add muon chambers to enable improved detection and tagging of semi-leptonic decays of heavy flavor

Hadron Arm High-Rapidity Tracking Layer

- Add small, high-rapidity AC-LGAD layers in front of the forward calorimeters to improve track momentum resolution at very high momentum – benefits the deconvolution of overlapping clusters in the forward calorimeters

Backward Hadronic Calorimeter

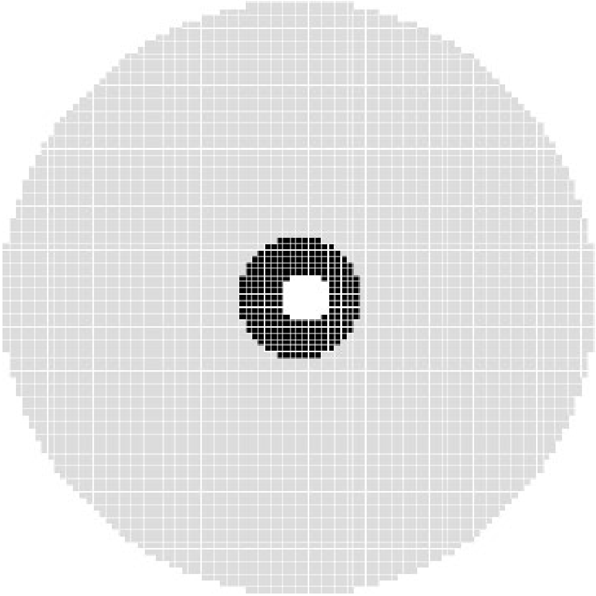
- Add a hadron calorimeter in the electron-going direction contributes to reconstruction of event kinematics by the double-angle JB method at high y, and electron identification. Could be based on the STAR FCS Fe/Sc with partial re-use

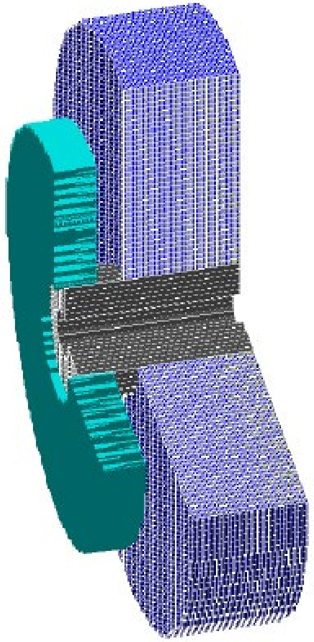
FAR FORWARD – FAR BACKWARD

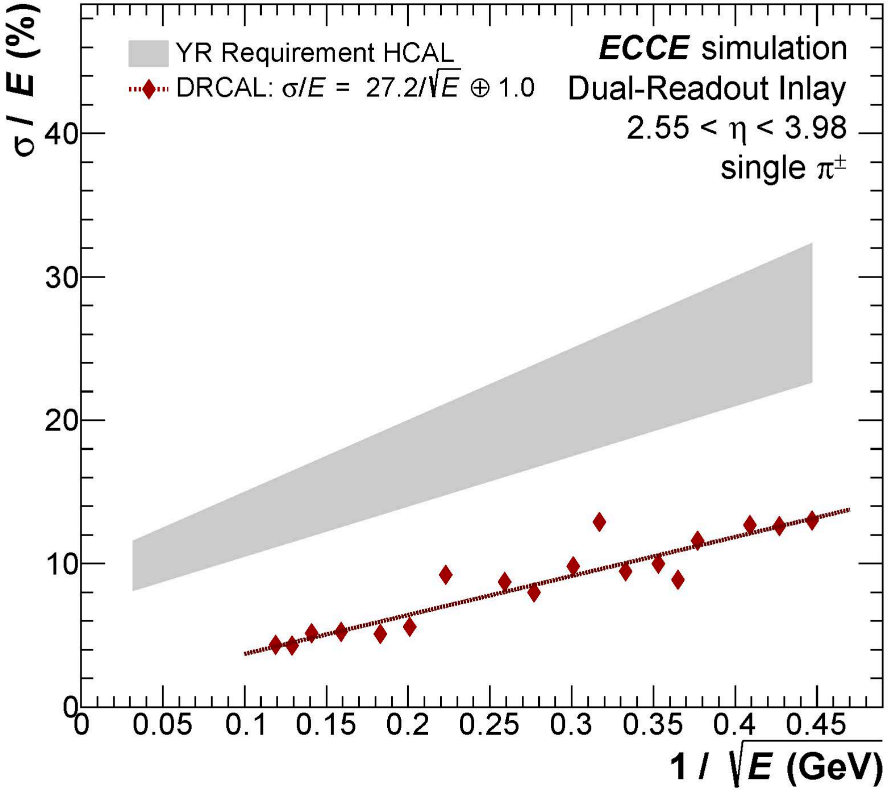
- None foreseen at present

Dual Readout Calorimeter

- Upgrade path for the forward region to enable jet performance to very high rapidity
- Would replace the integrated FEMC+LFHCAL
- Dual readout provides maximal information from a single detector: shower resolution, depth and timing information, particle identification
- Material optimization is one of the ongoing R&D areas

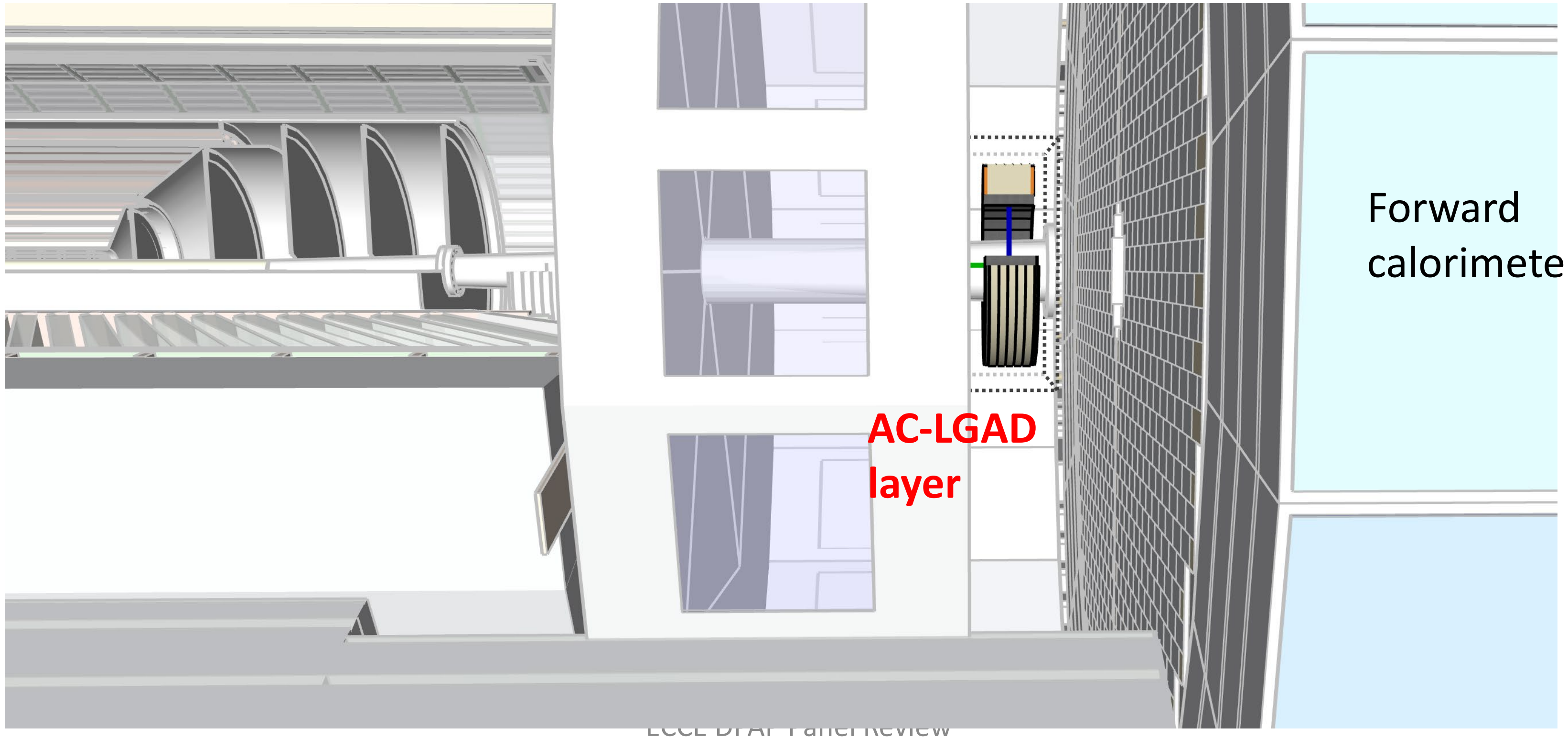




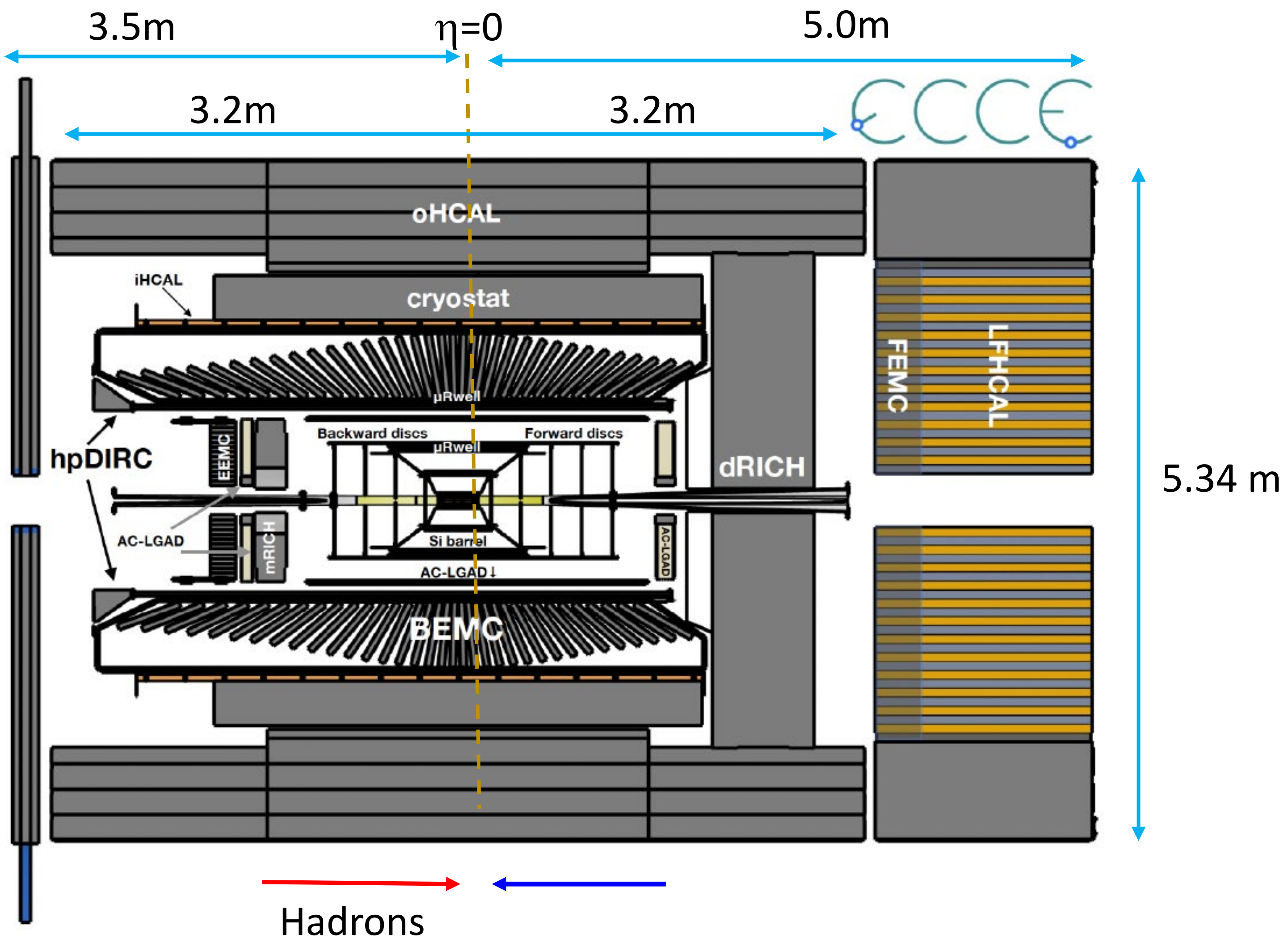


Hadron Arm High-Rapidity Tracking Layer

- Add small, high-rapidity AC-LGAD layer ($3.0 < \eta < 3.5$) in front of the forward calorimeters to improve track momentum resolution for very high momentum ($p_T > 20$ GeV/c) charged tracks
- Also allows the detection of those hadrons that enter the forward calorimeters from outside the acceptance of the inner tracker (beyond $\eta = 3.0$). Multiple layers would allow complete tracking to η~4.0
- Beneficial for the deconvolution of overlapping clusters in the forward calorimeters as a necessary component to implementing a particle flow algorithm for the reconstruction of forward jets.



Muon Detectors



- The ECCE detector radius is 2.7 meter, with the RCS beam at 3.35 meters → space available for additional detectors
- Adding muon chambers would enable improved detection and tagging of semi-leptonic decays of heavy flavor
- Also reduces ambiguity with scattered electron for deep exclusive processes; J/Psi→e^+e^-, J/Psi→$\mu^+\mu^-$

Backward Hadronic Calorimeter

On average the energy in an eHCAL is quite low in DIS events, @ Q^2>1 GeV^2, W^2>10 GeV^2 , 0.01<y<0.95:

13% of DIS events have E_{eHCAL}>1.0 GeV
3% of DIS events have E_{eHCAL} >1.0 GeV from neutral hadrons

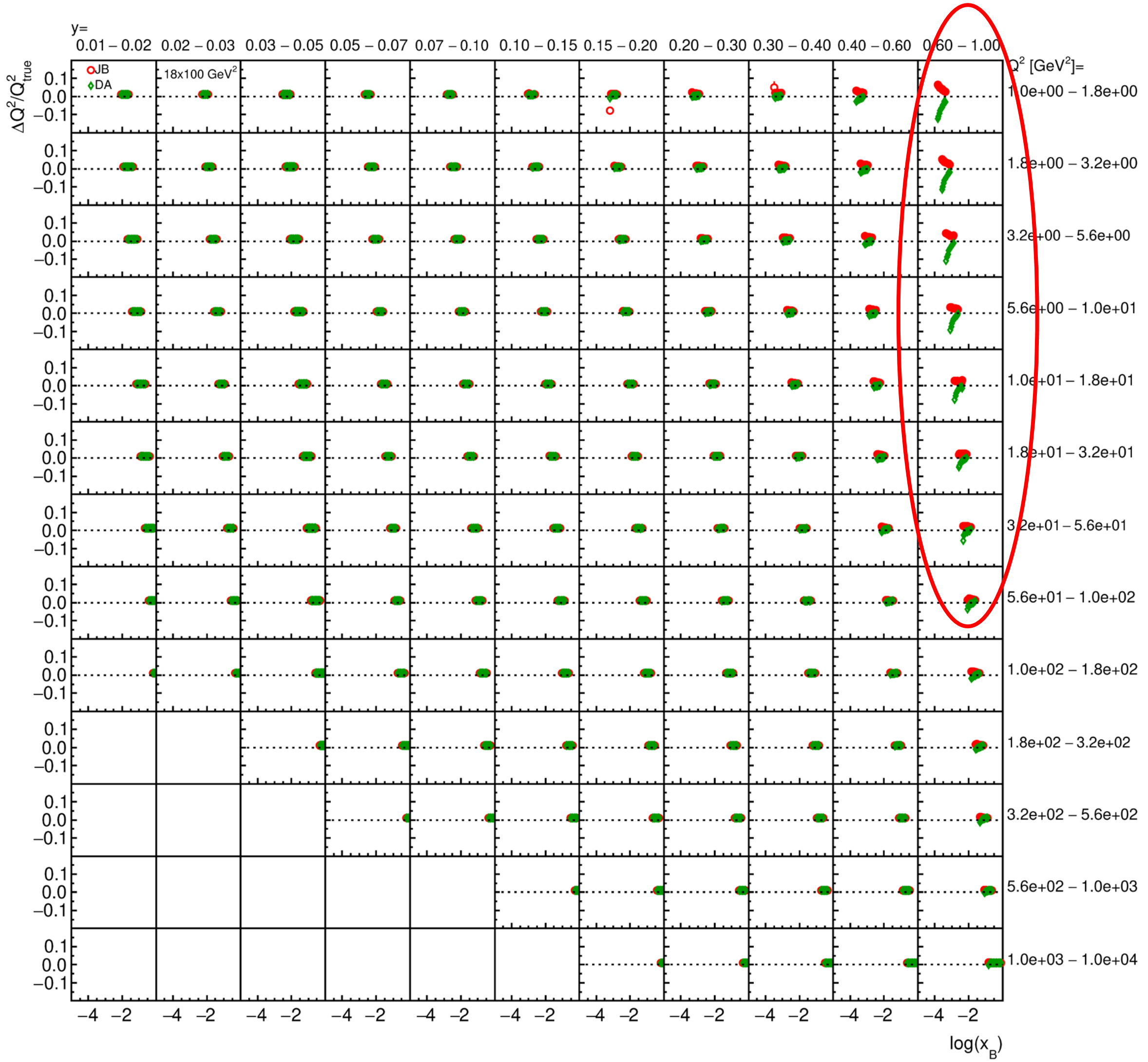
8% of DIS events have E_{eHCAL}>1.5 GeV
1.7% of DIS events have E_{eHCAL} >1.5 GeV from neutral hadrons

The eHCAL has an influence on the reconstruction of the DIS variables in the regions of low Q^2 and high y. *However, these are exactly the regions where the reconstruction of DIS variables using the scattered-lepton information is superior to the Jacquet-Blondel and double-angle method*.

Hence, from this point of view, an eHCAL is not needed.

Conversely, science interest in a low Q^2 and high y region for use of the J-B method or complementarity reasons may lead to an eHCAL upgrade. Could be based on the STAR FCS Fe/Sc with partial re-use

DIS Kinematics Reconstruction



Backup