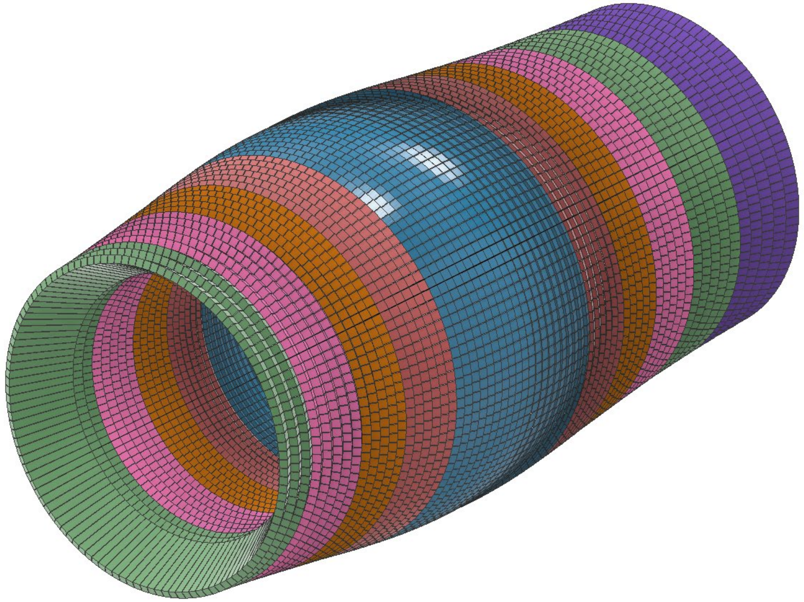
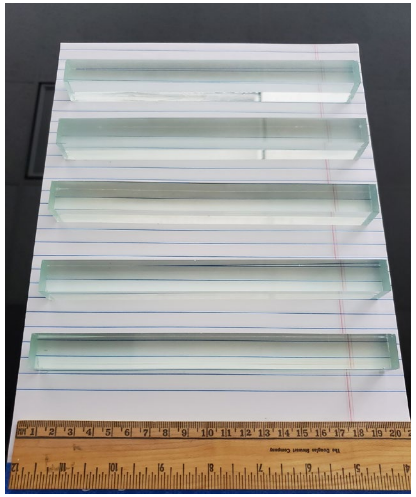
eRD105

SciGlass EM Calorimetry



A. Asaturyan, M. Battaglieri, V. Berdnikov, J. Bettane, M. Bondi, A. Celentano, J. Crafts, R. DeVita, T. Horn, G. Hull, M. Josselin, I.L. Pegg, S. Mayilyan, C. Munoz-Camacho, A. Mkrtchyan, H. Mkrtchyan, M. Murray, N. Pilleux, A. Shahinyan, P. Stepanov, V. Tadevosyan, R. Trotta, H. Voskanyan

A.I. Alikhanyan National Science Laboratory/Yerevan, Catholic University of America, The Vitreous State Laboratory, IJCLab-Orsay/France, INFN-GE, Jefferson Laboratory, U of Kansas



THE CATHOLIC UNIVERSITY of AMERICA
IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis
A. ALIKHANYAN National Laboratory
SCINTILEX
Jefferson Lab Thomas Jefferson National Accelerator Facility
INFN
KU THE UNIVERSITY OF KANSAS

Context: Detector-1 Barrel EMCal Reference Design

- Homogeneous EM calorimeter – typical materials in lepton induced hadron scattering: crystals and glass, a **well-established detector technology**
- Barrel EMCal readout electronics can be identical with the backward EM calorimeter → **no additional technology required**
- Experienced team of institutions (AANL, CUA, FIU, JMU, UK, MIT..) including **many early-career researchers** working on design, simulation, prototypes
- Opportunities for many early-career **in-kind contributions** for radiator, design/construction, simulation, readout
- **No long-lead items**

Report from the EIC Detector Proposal Advisory Panel

Conclusions for Detector Concept and Feasibility

Based on the careful study by the DAC and the information provided by the three proto-collaborations, the panel finds that ATHENA and ECCE satisfy the requirements to fulfil EIC's "mission need" statement based on the EIC community White Paper and the National Academies of Science (NAS) 2018 report. The more limited range of new technologies and the reuse of the BABAR Magnet and the sPHENIX HCAL make ECCE less expensive and more likely to be ready for data taking on time for Critical Decision 4A (CD-4A), the start of EIC accelerator operations, and therefore suitable as Detector 1. Core has provided a more conceptual, less fully developed design.

A. ALIKHANYAN National Laboratory

THE CATHOLIC UNIVERSITY OF AMERICA

University of Kentucky

FIU FLORIDA INTERNATIONAL UNIVERSITY

Massachusetts Institute of Technology

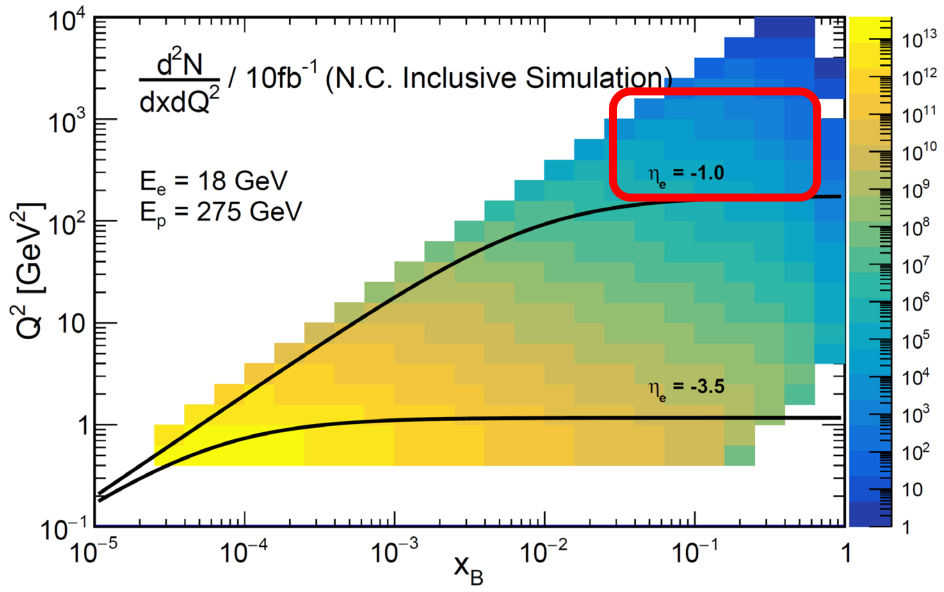
JMU JAMES MADISON UNIVERSITY

+ additional institutional interest

Introduction

Scattered electron kinematics measurement is essential at the EIC

- ❑ High precision, hermetic detection of the scattered electron is required over a broad range in η and over energy range from 0.1 to tens of GeV
  - ○ In the very backward direction high precision is required for electron kinematics measurement
  - ○ In backward and barrel region it is required for clean electron identification. In the barrel region, driven by high-x and high-Q^2 science drivers
- ❑ In ECCE SciGlass was chosen in the barrel as this provides excellent e/h separation due to its good energy resolution, matched to the backward region need, and its cost effectiveness



η	[-4 .. -1.75]	[-1.75 .. 1.3]	[1.3 .. 4]
Material	$PbWO_4$	SciGlass	Pb/Sc
X_0 (mm)	8.9	24-28	16.4
R_M (mm)	19.6	35	35
Cell (mm)	20	40	40
X/X_0	22.5	17.5	19
Δz (mm)	60	56	48

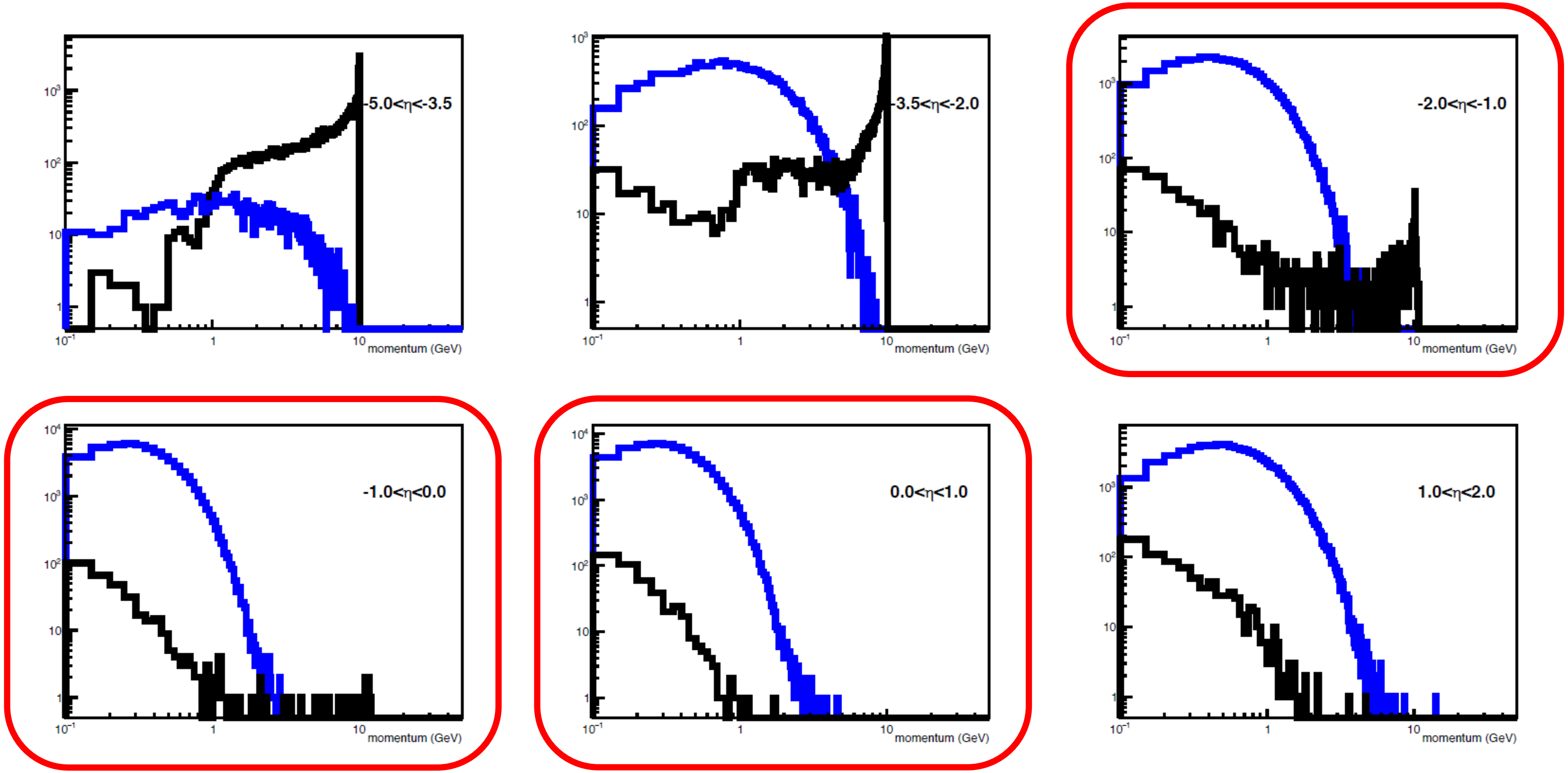
Requirements

- ❑ Good energy resolution
  - ○ e.g., region -2 < η < -1 requires ~7%/√E
- ❑ e/h separation up to 10^{-4}

e/π SEPARATION

NEEDS

ΔG needs pi/e 10^{-3}, A_{PV} needs pi/e 10^{-4} in η bins -2 to 1

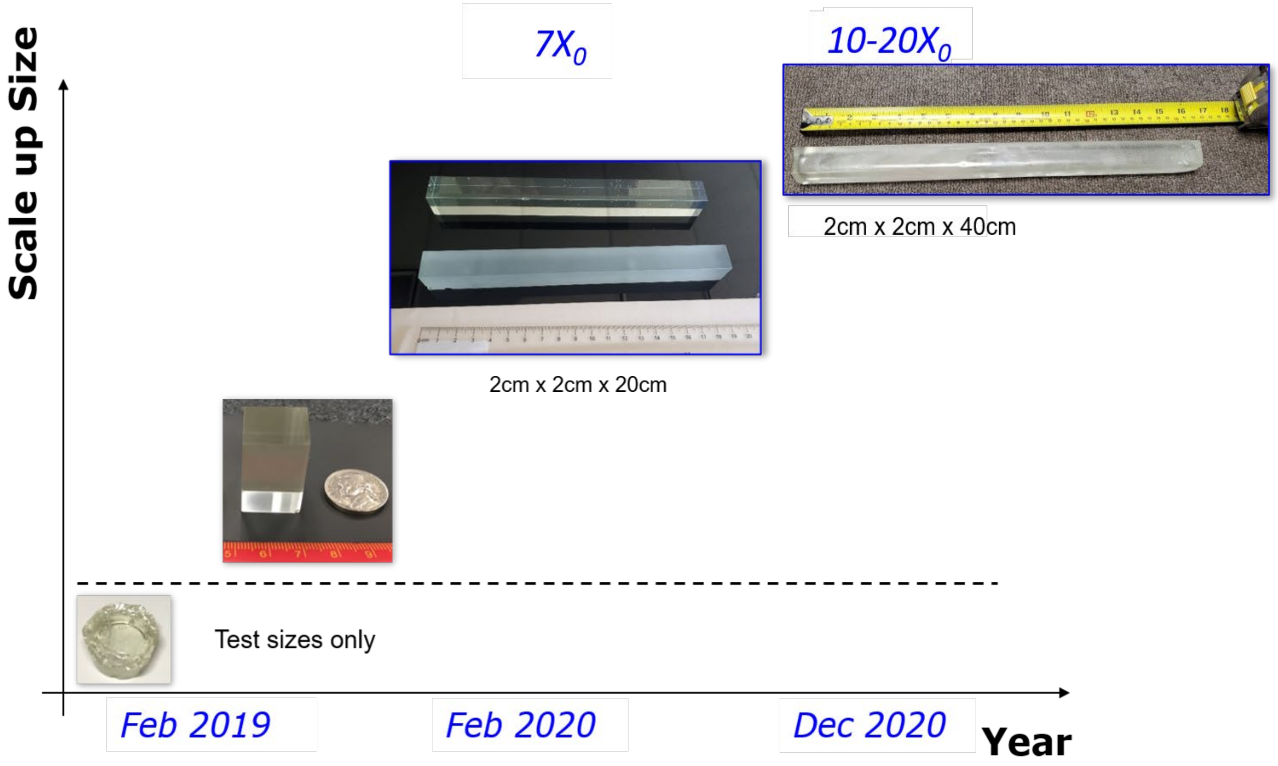


10 x 100 GeV Pion/e- Ratio (Work by **Hanjie Liu**)

Overview SciGlass

SCINTILEX

- SciGlass is a radiation hard material optimized to provide characteristics similar to or better than PbWO4.
  - Fabrication is expected to be cheaper, faster, and more flexible than PbWO4 crystals.
- SciGlass is being developed by Scintilex in collaboration with the Vitreous State Laboratory at CUA.



- Tremendous progress has been made in the formulation and production of SciGlass that improves properties and solves the issue of macro defects.

Previous Scintillating Glass Calorimeters

Scintillating Glass of different formulation has been used for beam tests and as EMCal in the 1980s

https://inspirehep.net/literature/261664

Performance of a scintillating glass calorimeter for electromagnetic showers, 1988

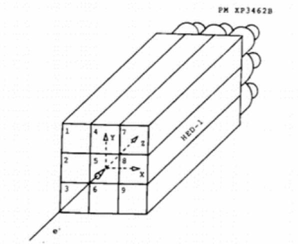


Fig. 3. Layout of the calorimeter setup in the test beam.

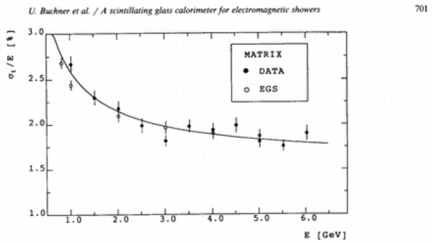


Fig. 12. Energy resolution as a function of the electron energy (black circles) and the EGS prediction (open circles). The line shows the parametrization (4) described in the text.

8x8x66 cm^3

1.46%/E+2.4%/sqrt(E)+1.63%

https://inspirehep.net/files/1299a6aa1e200e01f9d7f208800a81f6

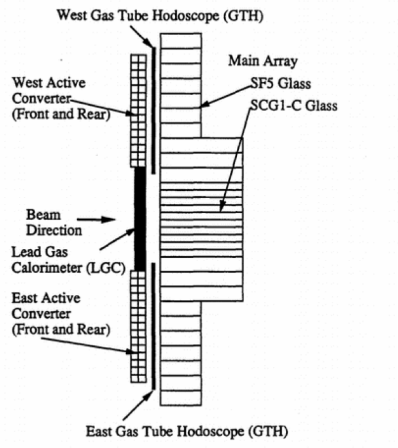


Figure 1. Plan view of the major components of the Experiment 705 calorimeter

	SCG1-C	SF5
Composition (by weight)	BaO 43.4% SiO2 42.5% Li2O 4.0% MgO 3.3% K2O 3.3% Al2O3 2.0% Ce2O3 1.5%	PbO 55% SiO2 38% K2O 5% Na2O 1%
Density	3.36 g/cm3	4.08 g/cm3
Radiation Length	4.25 cm	2.47 cm
Absorption Length (30-200GeV/c^2 pions)	45.6 cm	42.0 cm

Table 1. Properties of SCG1-C Scintillating and SF5 Lead Glass

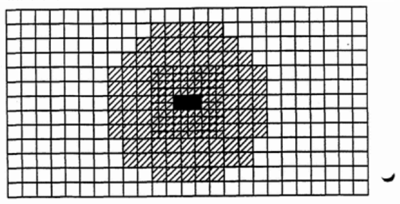


Figure 2. Beam view of the Main Array (SCG1-C scintillating glass is cross-hatched)

The Experiment 705 Electromagnetic Shower Calorimeter, 1993

15.x15.x89 cm^3
7.5x7.5x89 cm^3

Rad. Length 20.9 X0

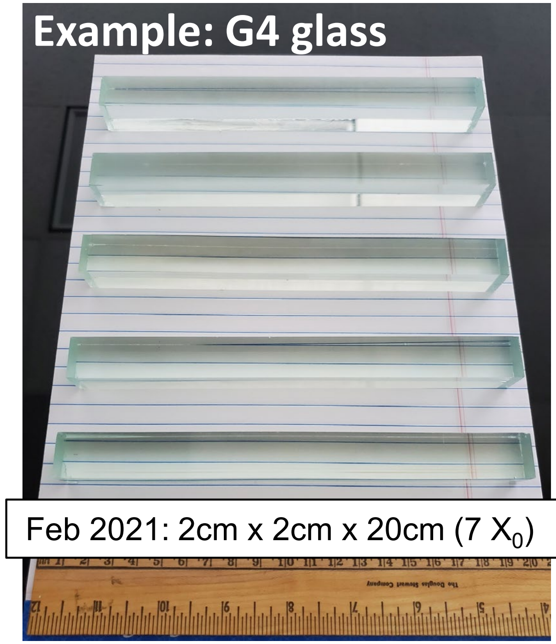
0.99%+4.58%/sqrt(E)

Resolution for mixed calorimeter (lead glass and SCG1-Glass)

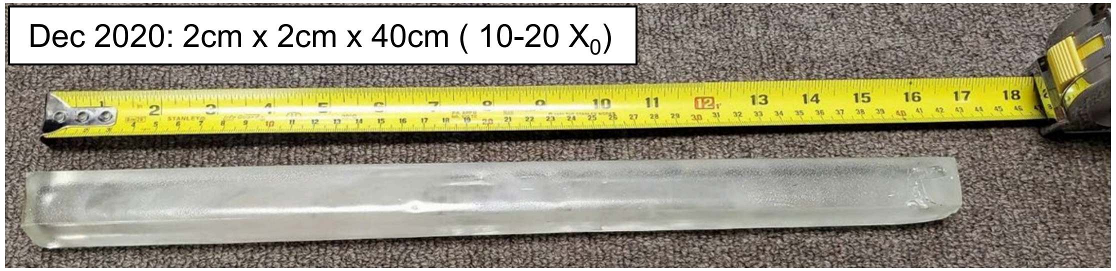
Results from 1980s scintillating glass calorimeters encouraging → Need to establish performance for SciGlass (different formulation)

SciGlass Status – June 2022

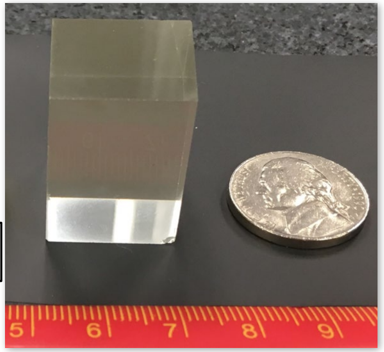
- SciGlass 20cm has been produced reliably; We tested a 3x3 20 cm SciGlass prototype detector in beam and measured its performance (ongoing R&D EEEMCAL consortium, eRD105)
- **Measured performance for 20cm SciGlass (7X_0) as per GEANT simulation**
- We have an SBIR phase-II to start large-scale production or larger blocks (40+ cm, rectangular and projective shapes)
- Received the first polished 40 cm SciGlass (15X_0) late 2021, more on the way



Feb 2021: 2cm x 2cm x 20cm (7 X_0)



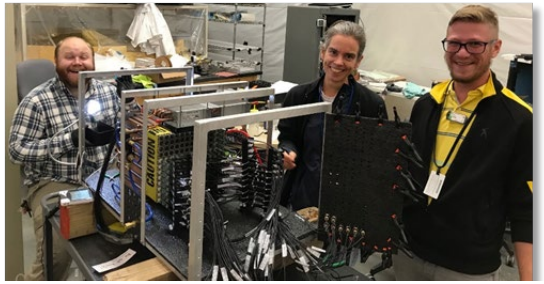
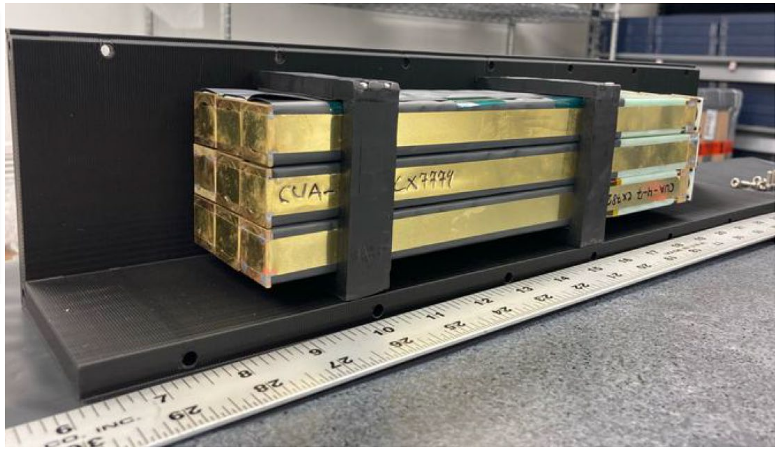
Dec 2020: 2cm x 2cm x 40cm (10-20 X_0)

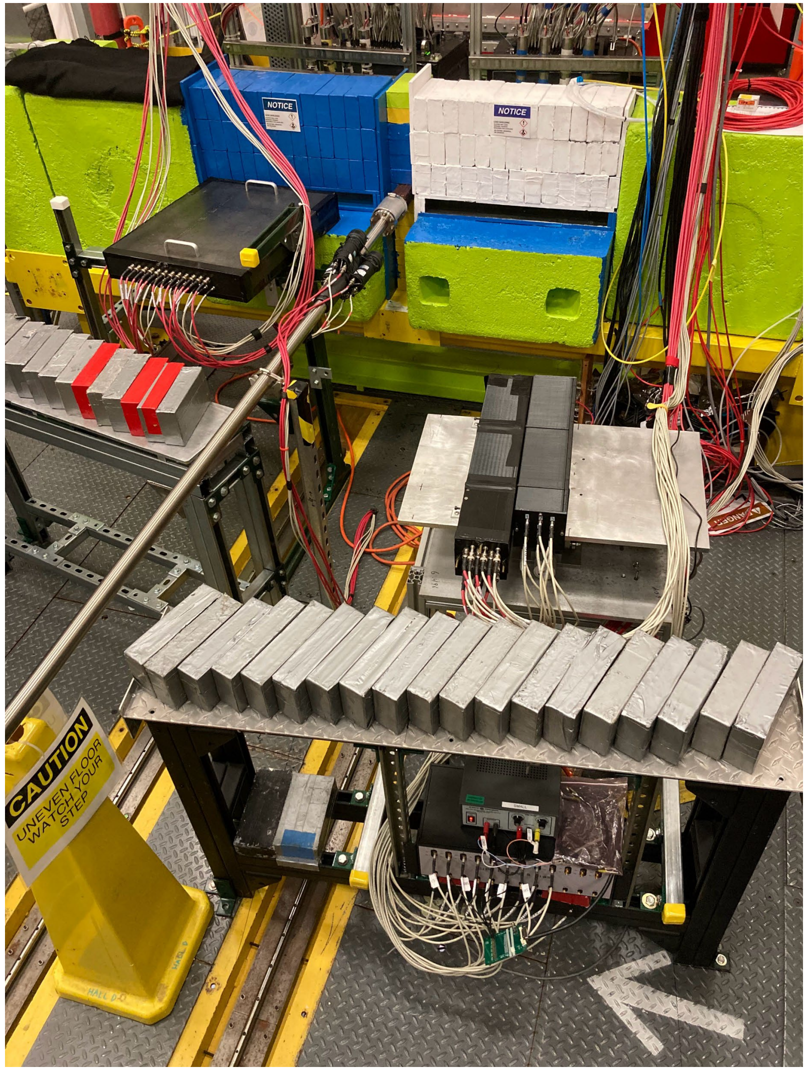


2019: 2cm x 2cm x 4cm

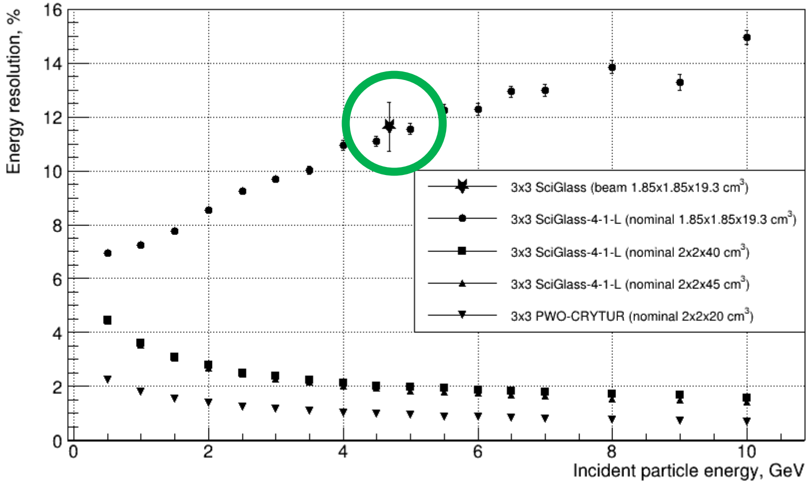
2018: 1cm x 1cm x 1cm

Ongoing Beam Tests



- ❑ Prototype 3x3 array installed and tested – energy resolution measured for three different beam energies
- ❑ **Results for ~7 X_0 blocks – matches with Geant4**
- ❑ **Plans for 2022: Test with ~15X_0 (40cm) long blocks**



Irradiation and test bench tests

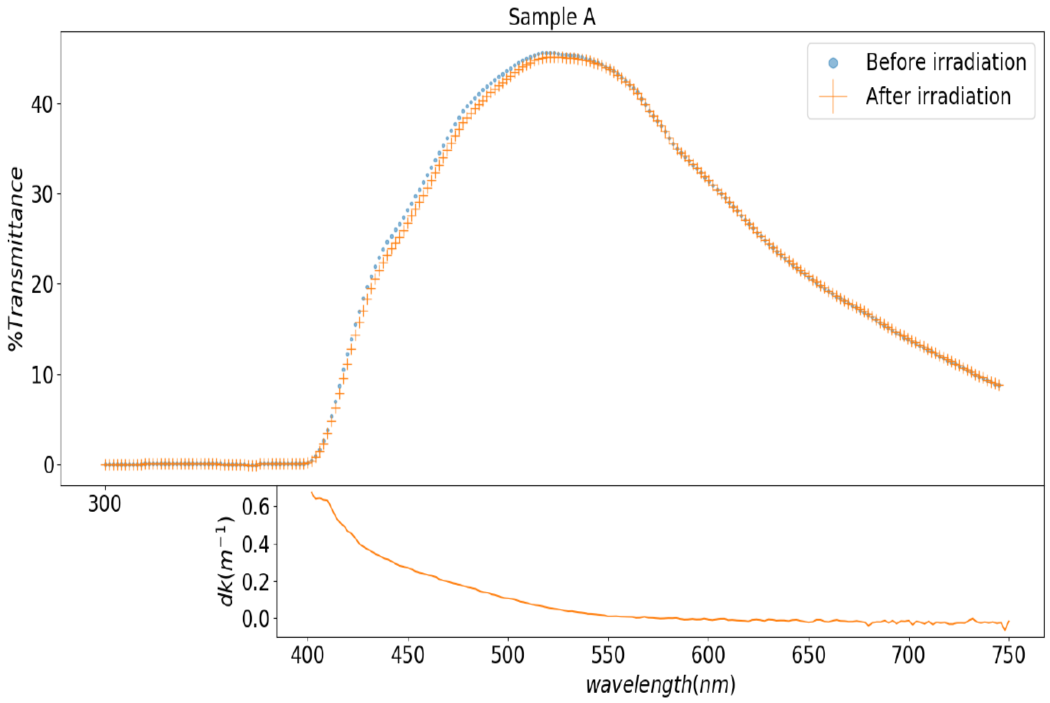
IJCLab-Orsay Activities 2021/22

- ❑ Three (3) SciGlass blocks of 20 cm length were produced and tested on the testbench at IJCLab-Orsay in Summer 2021

- ❑ Irradiation to a dose of 30 Gy (estimated dose for 1 year running at EIC) at a rate of 1 Gy/min → ***Samples are radiation hard***

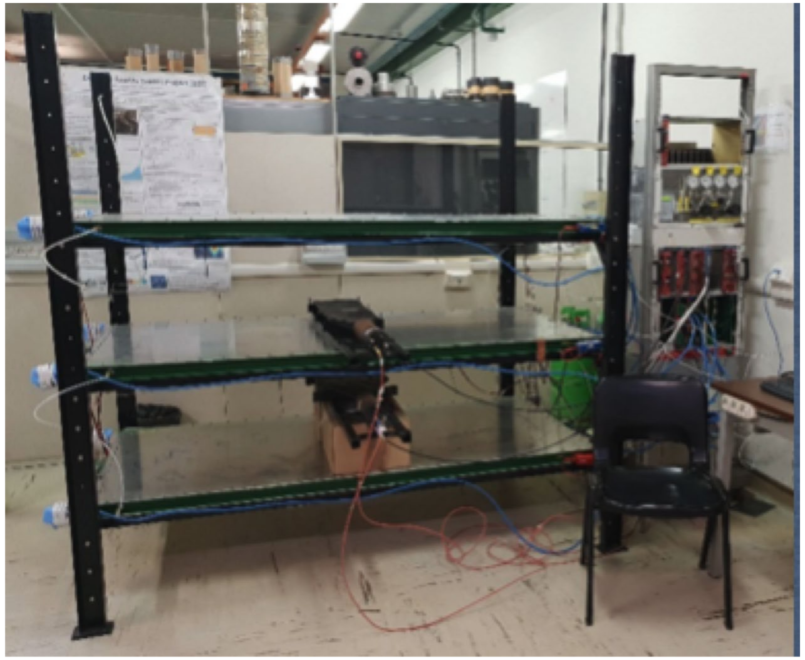
- ❑ More samples with optimized formulation on the way for 2022 tests

Radiation hardness

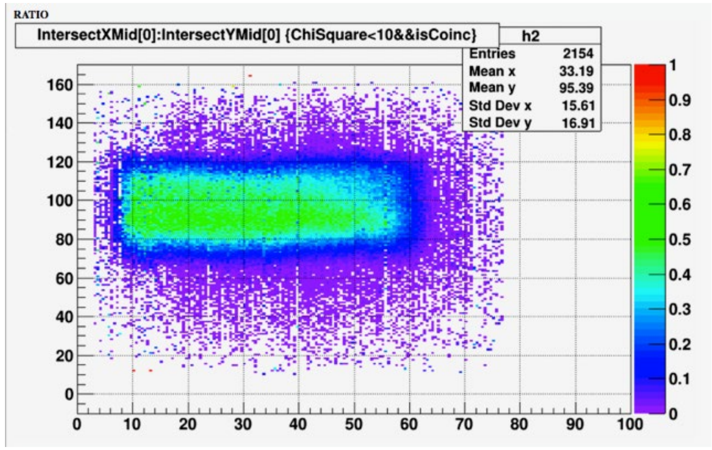


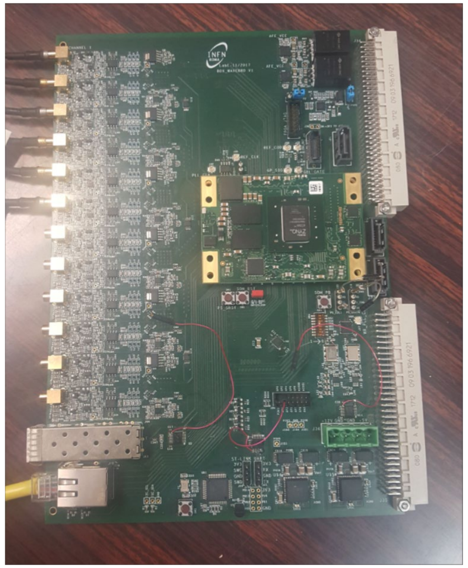
INFN-Genova 2021/2022 activities

As part of EIC eRD1 and eRD23, INFN-GE is contributing to the EIC calorimetry by supporting the R&D on PbWO and new Scintillating Glass readout (collaboration with CUA)



- Completion of the EEE/EIC facility in Genova to test large size detectors (up to 150x100x50 cm3) with streaming Read-Out DAQ for easy synchronisation
- Example of a plastic scintillator signals in coincidence with tracks detected by EEE telescope (off line analysis)
- The two detectors are read out independently
- A common GPS signals provides a common time reference

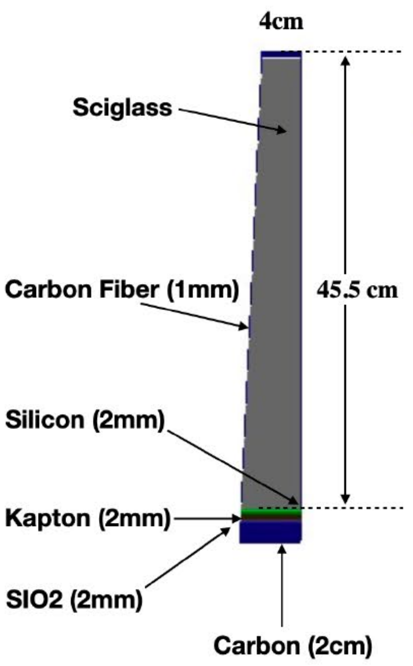


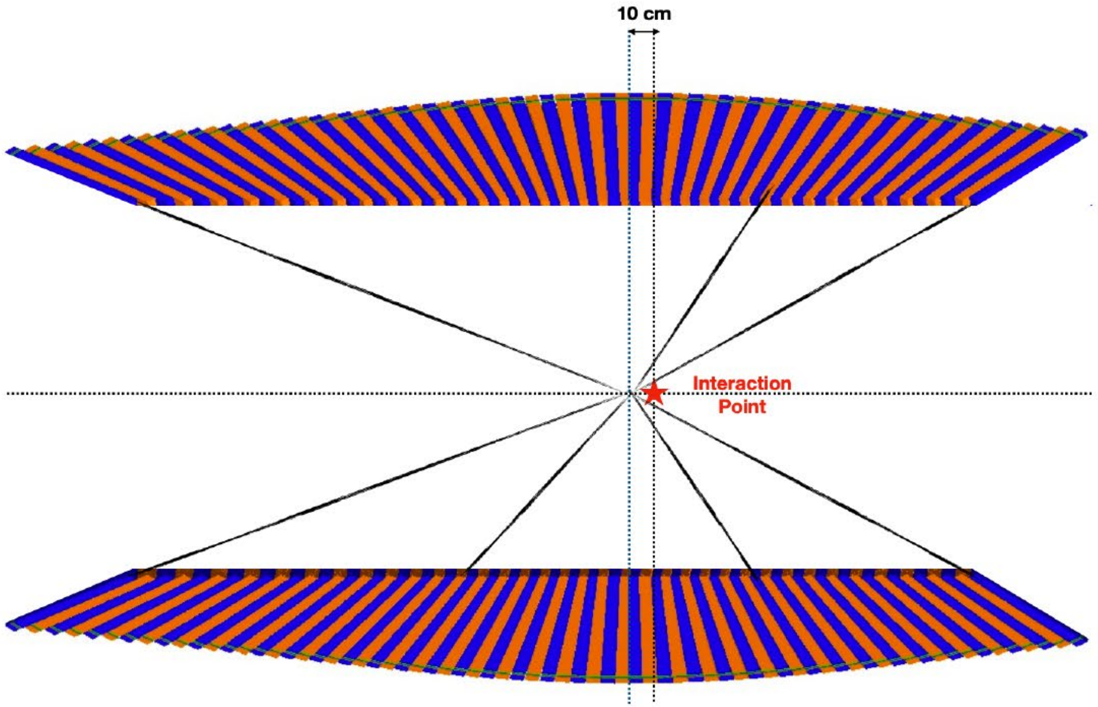


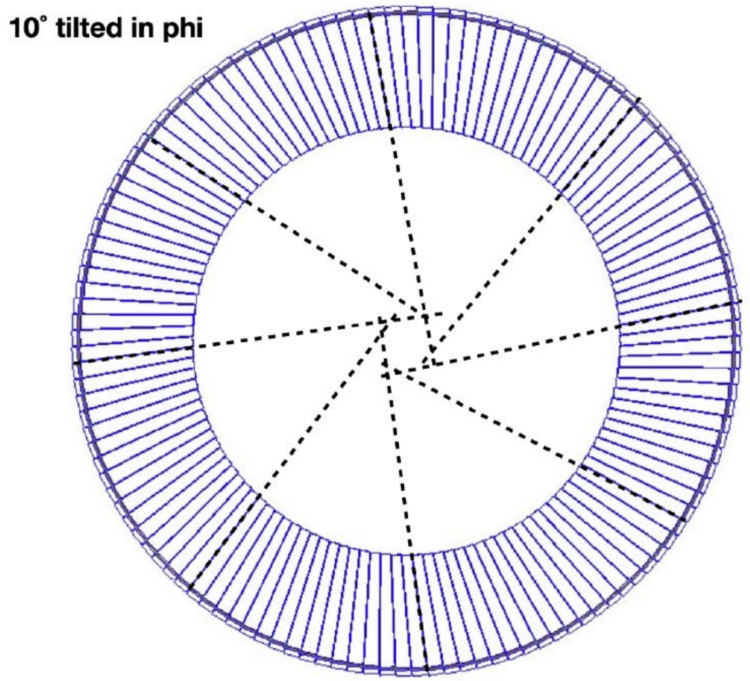
INFN digitiser (WaveBoard 2.0) used in the streaming RO tests in Genova

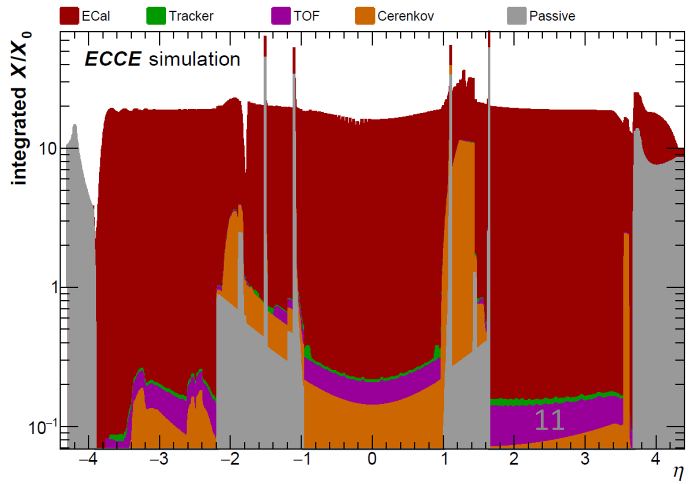
- Few SciGlass samples at INFN-GENOVA
- SIPM RO and FE electronics available
- RO/DAQ in streaming mode tests planned for 2022
- MC simulations of SciGlass and PbWO EM calorimeter

SciGlass Barrel EMCal in Simulations





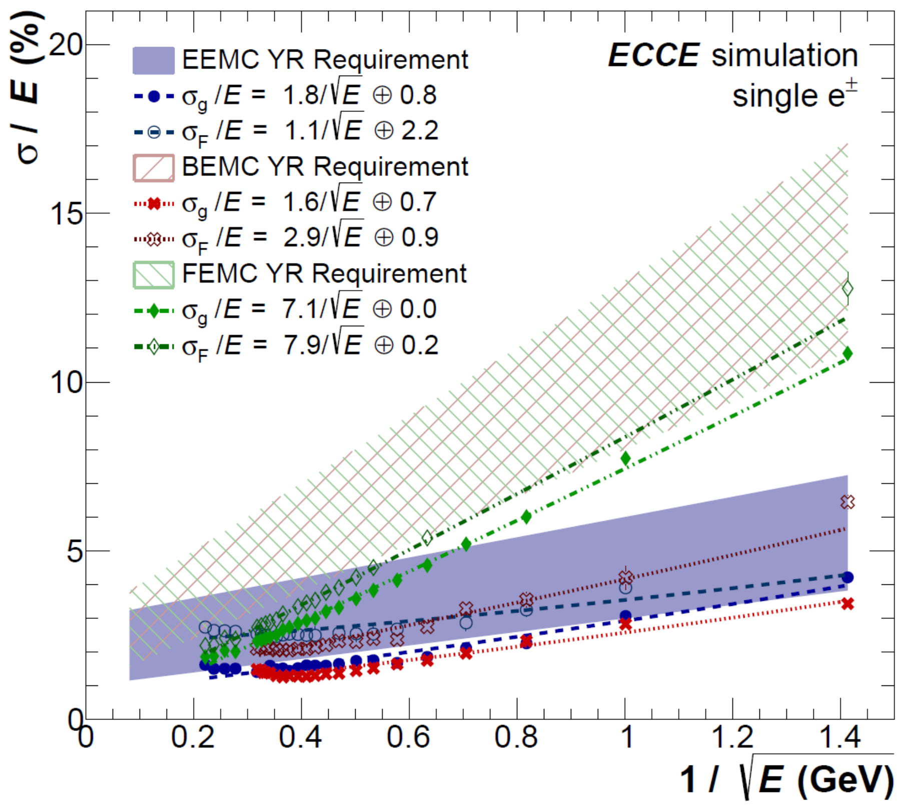




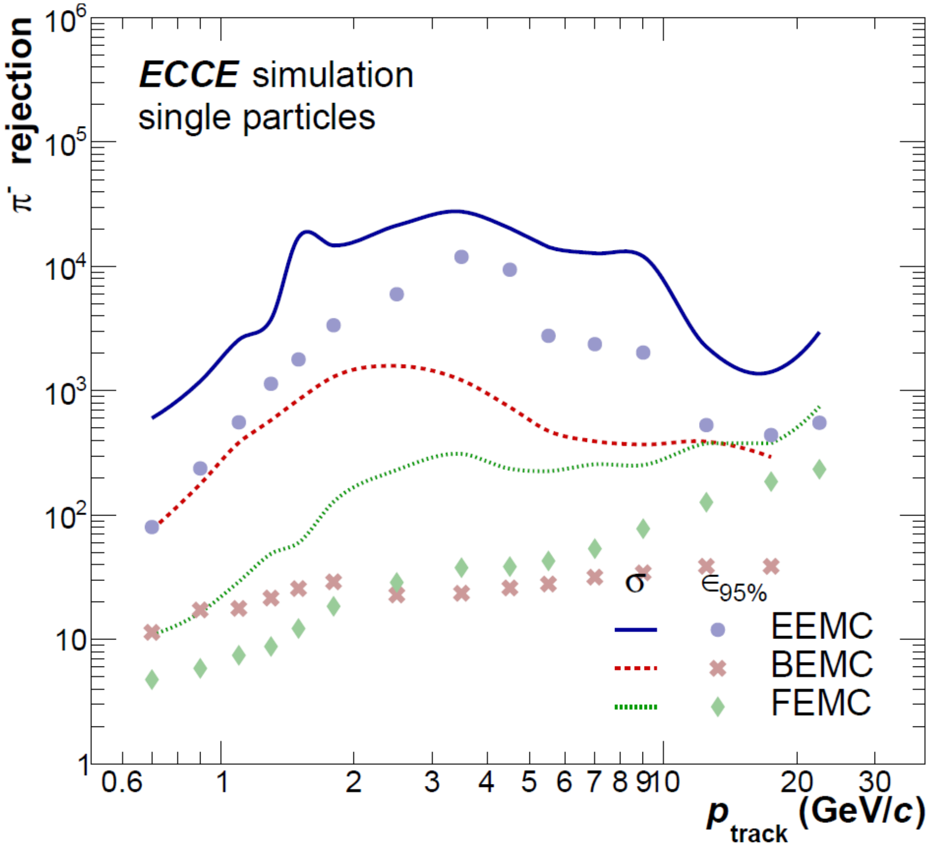
- ❑ Assumes 45.5cm long blocks ($17X_0$) – close to 40cm prototype
- ❑ Implemented with the active components and support structures
- ❑ Also important to consider materials in front of the EM calorimeter as it impacts performance (resolution, rejection, etc.)

SciGlass Barrel EMCal Performance

Energy resolution

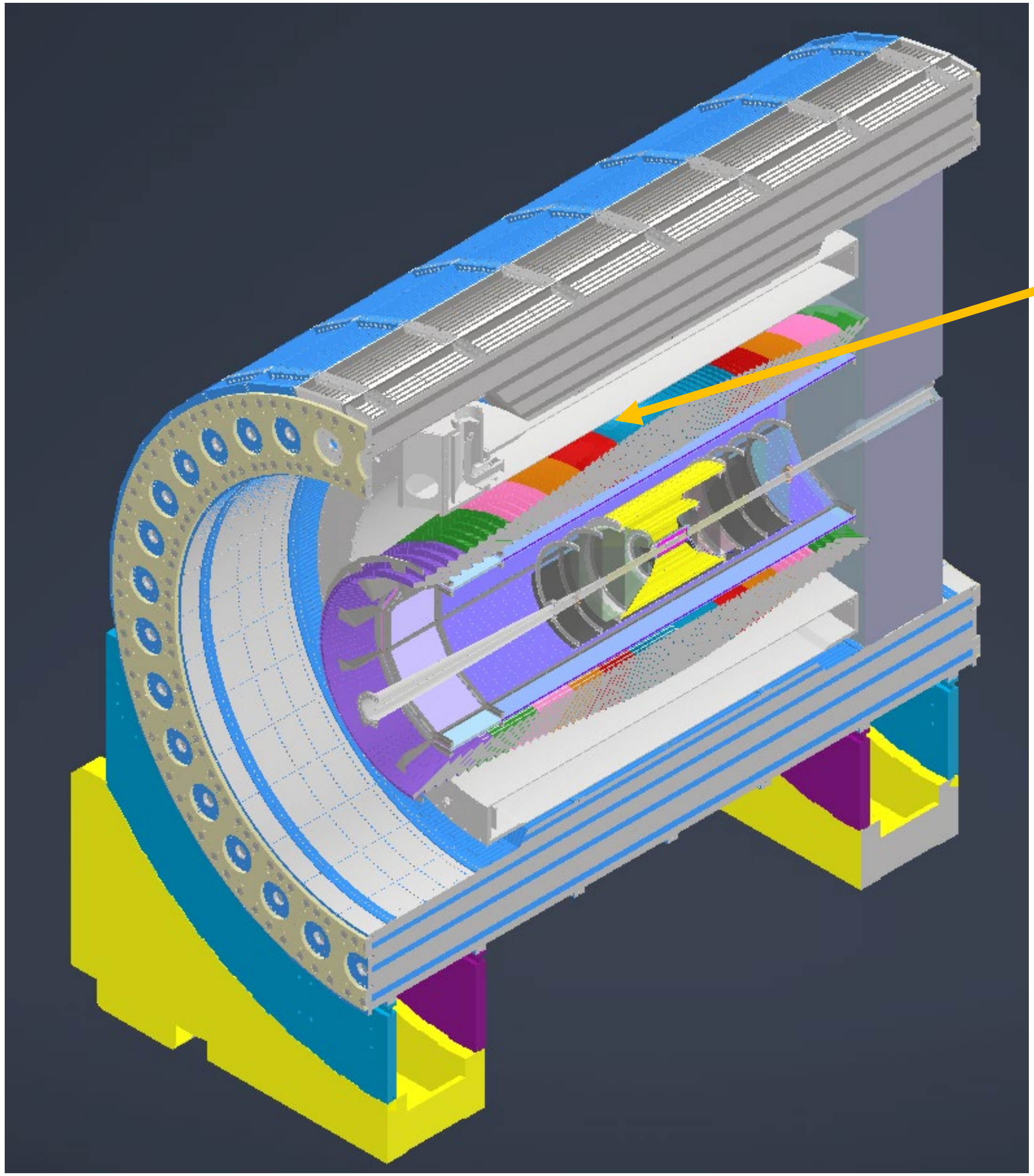


Pion Rejection



Exceeds requirements from Yellow Report

SciGlass barrel EMCal in the EIC Reference Detector



Barrel ECAL(BEMC)

Homogeneous, projective calorimeter based on SciGlass, cost-effective alternative to crystals

- ❑ The barrel is one of the largest sub-detectors with 8000 homogeneous scintillator blocks of 45.5cm length (and ~10cm radial readout space)
- ❑ It is extended in the negative rapidity direction (with η coverage from -1.75 to +1.3) to provide hermeticity with the backward ECal.
- ❑ In the backward direction hermeticity is provided by the combination of barrel, backward ECals, and mRICH complements (3σ e/h up to 2 GeV) . Readout and supply lines are included.
- ❑ In the forward direction the barrel EMCal faces much higher range of particle rates across the acceptance of the forward endcap

Homogeneous Design based on PANDA

PANDA

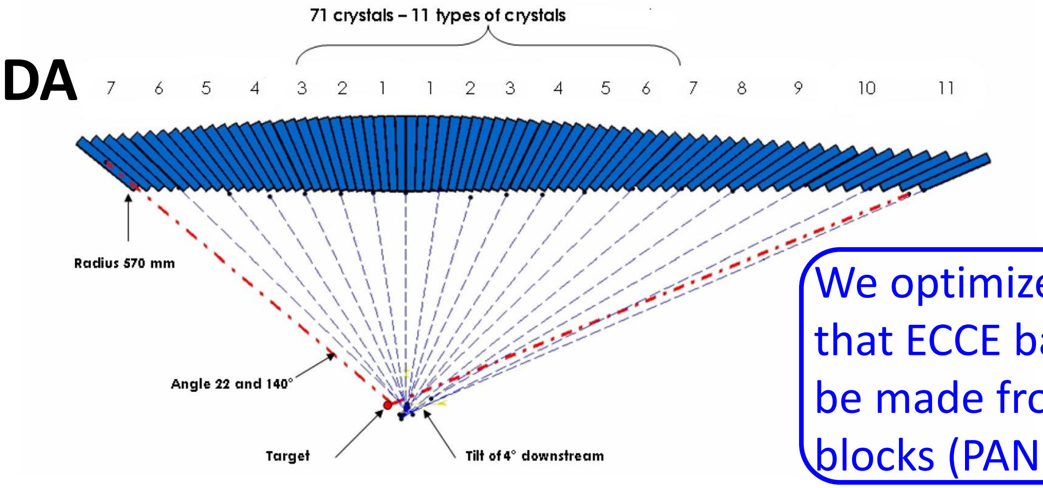
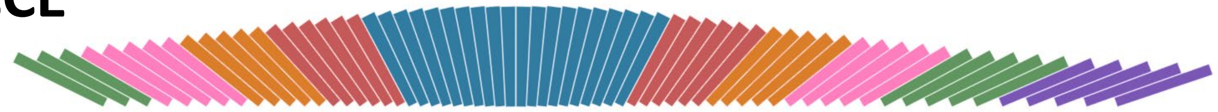
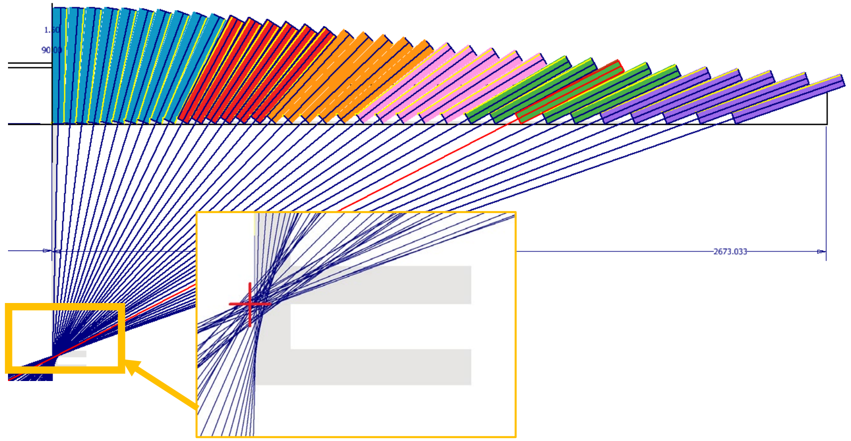


Figure 5.4: Crystal arrangement of the barrel along the beam axis. Positions of the different crystal types are indicated. Due to the mirror symmetry, 11 types are sufficient instead of 18.

ECCE

Based on realistic CAD design (CUA)





We optimized the geometry so that ECCE barrel calorimeter can be made from 6 families of blocks (PANDA has 11 families)

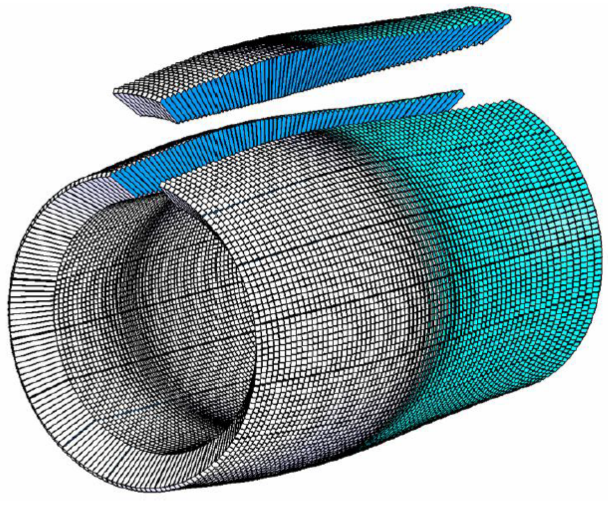
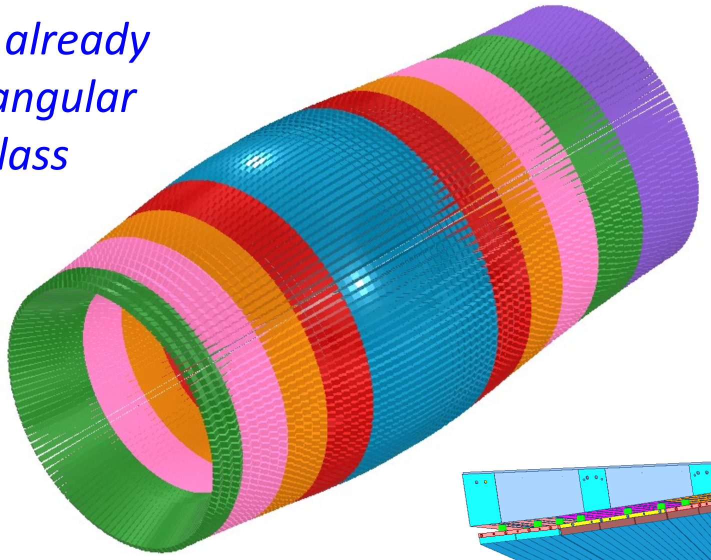
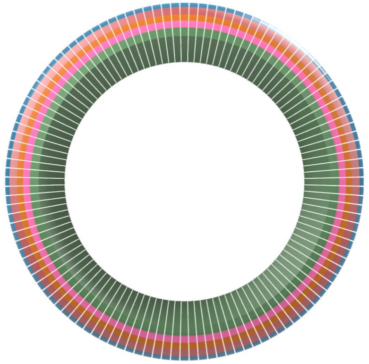
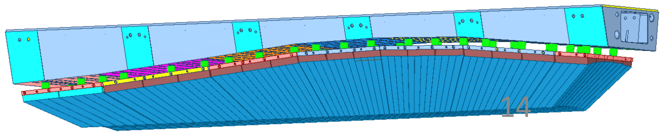


Figure 5.5: View of the total barrel volume with a separated single slice of 710 crystals. A slice covering 1/16 of the barrel volume.

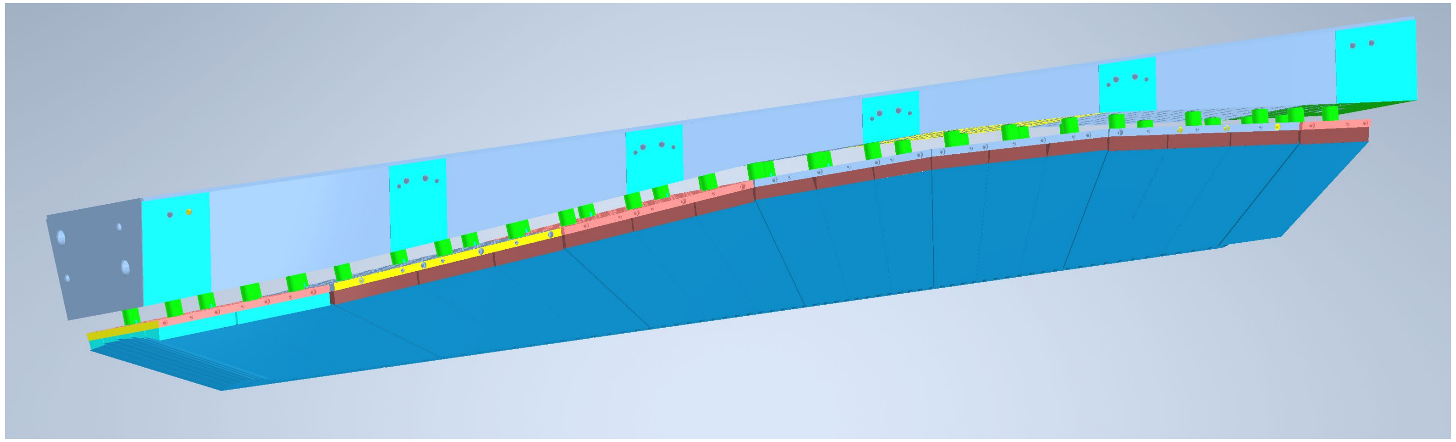
With these families we already reduced any gap both angular and radially between glass blocks to <5mm

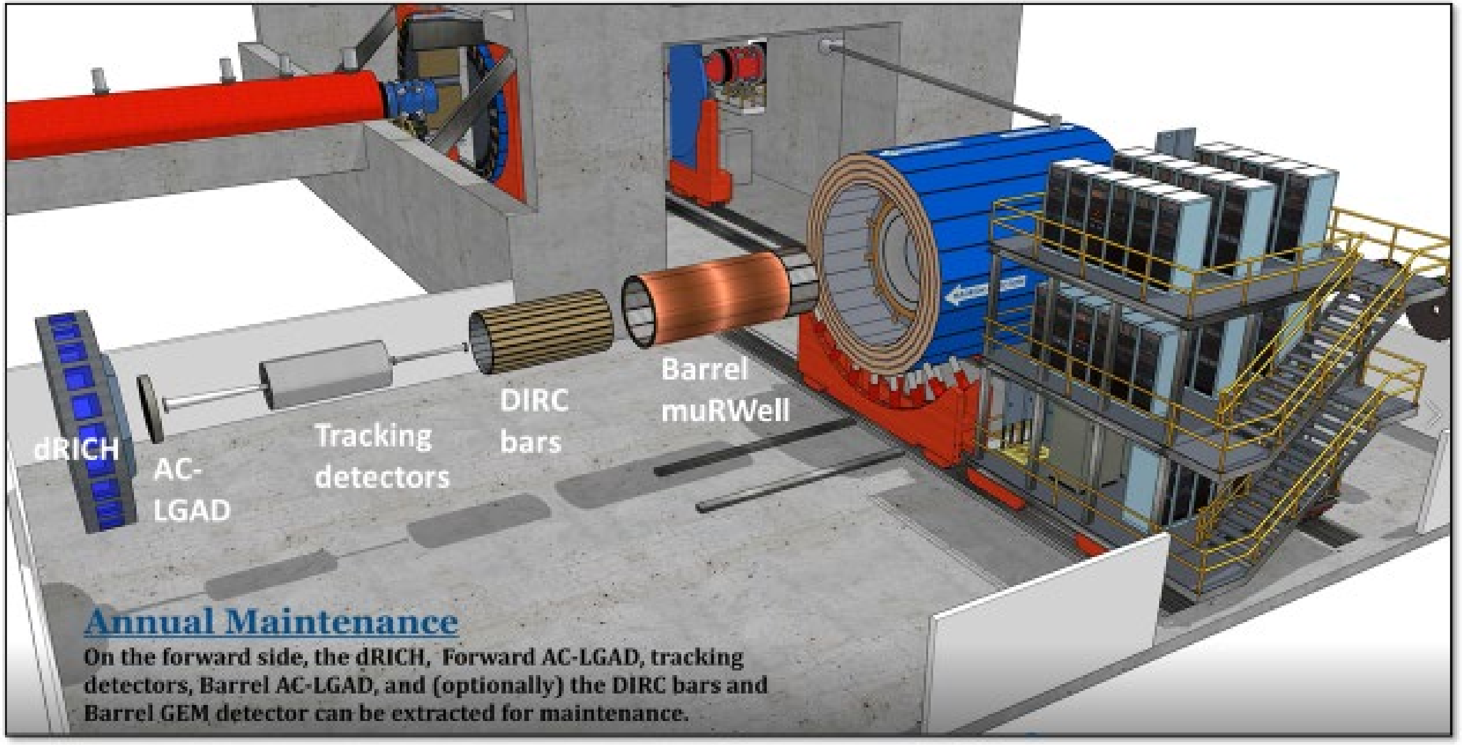


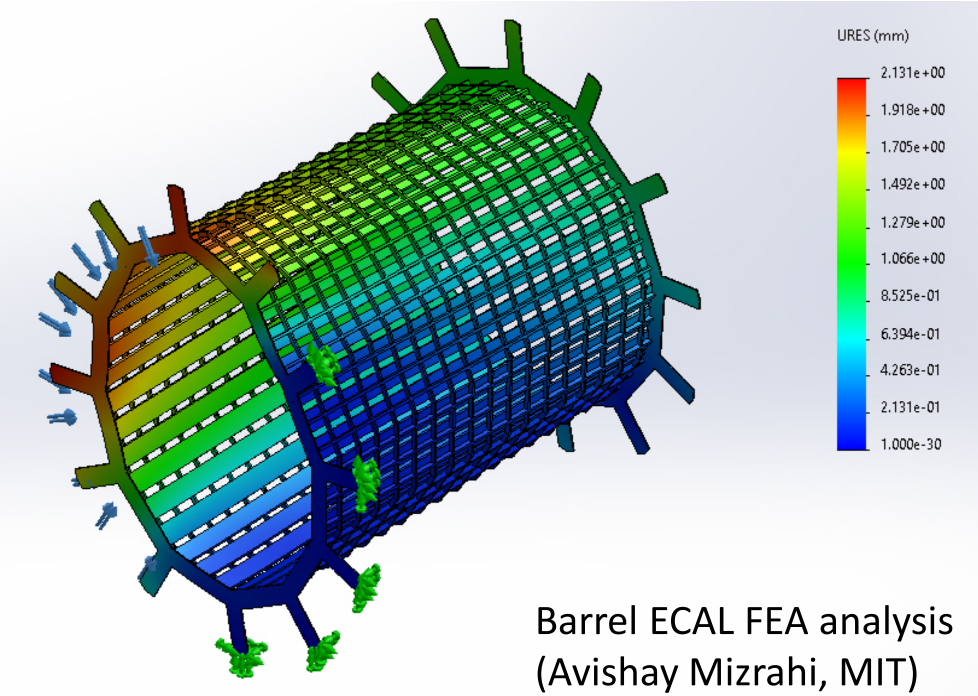




Advancing the Design (making use of work already done at PANDA)







Barrel ECAL FEA analysis (Avishay Mizrahi, MIT)

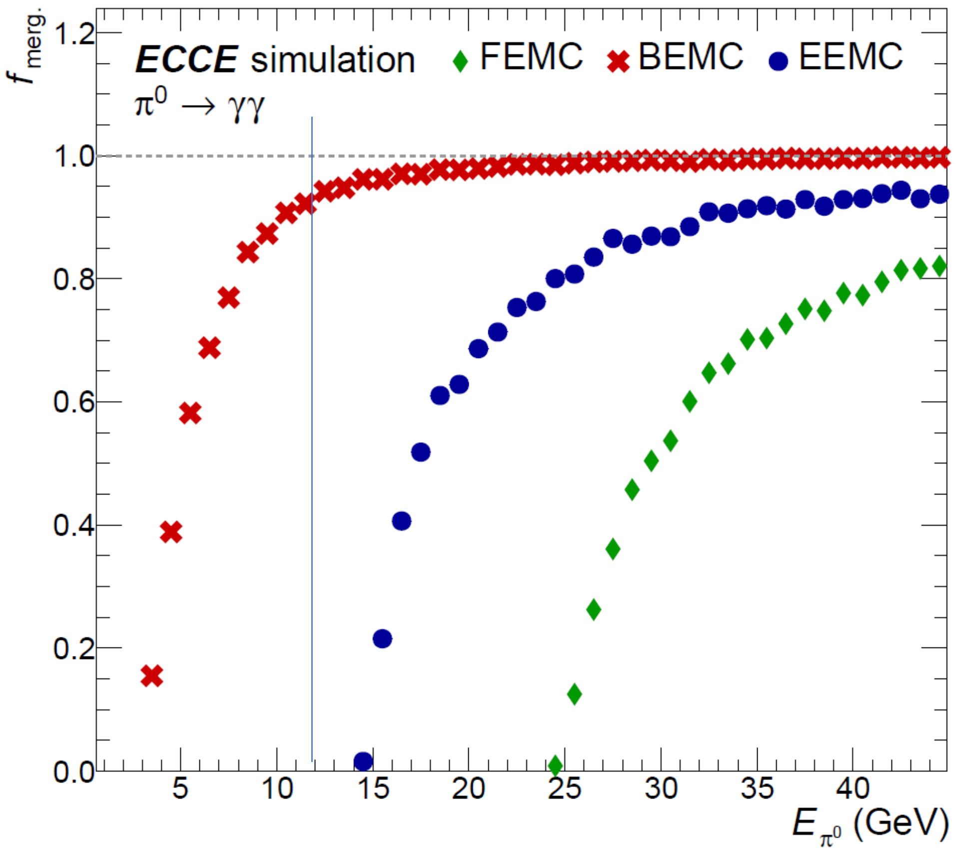
- ❑ Slice/supermodule details – also cooling, cabling, etc.
  - Ongoing studies (CUA/MIT)
- ❑ Support structure optimization
  - Ongoing studies (MIT)
- ❑ Access and maintenance
  - Add thin Teflon layer to avoid friction when removing wedge

Outlook

- ❑ EEEMCAL will enable unique detector capabilities for scattered electron detection and identification at EIC
  - SciGlass in the barrel provides excellent e/h separation due to its good energy resolution, matched to the backward region need, and its cost effectiveness
- ❑ Detector performance validations with beam data is a key piece of information
  - Method of calorimetry beam tests at Jefferson Lab Hall D established with series of successful tests
- ❑ Prototype 3x3 SciGlass array has been installed and tested – energy resolution measured for three different beam energies
- ❑ **Results for ~7 X_0 blocks – matches with Geant4**
- ❑ **Plans for 2022: Test with ~15X_0 (40cm) long blocks**
- ❑ Readout using SiPM matrix being developed for beam test

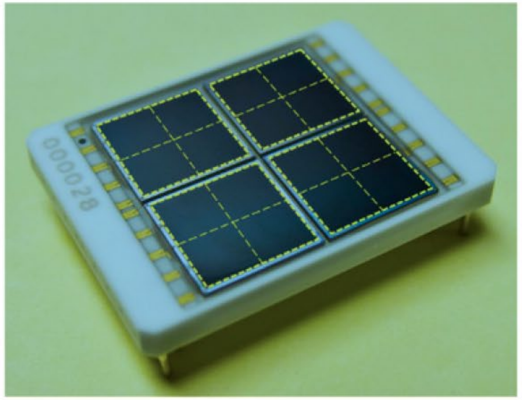
Barrel EMCal Complementarity

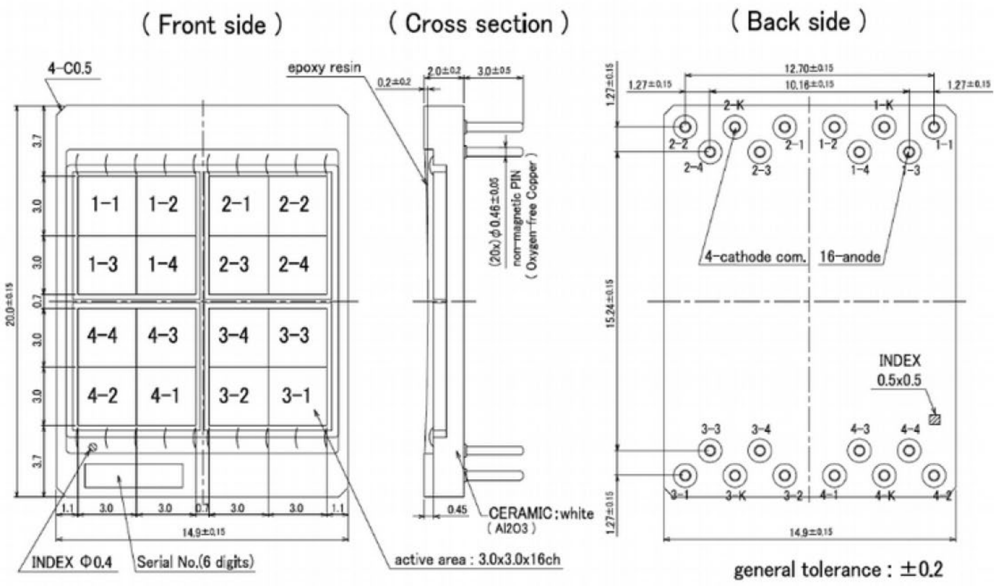
Pi0 merging fraction

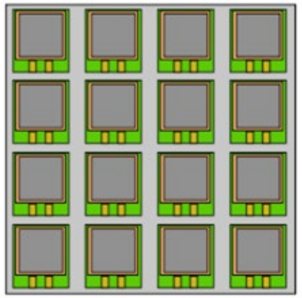


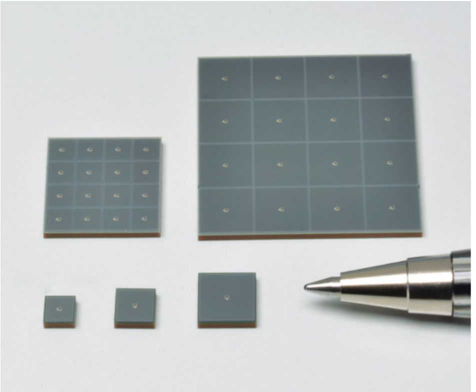
- ECCE emphasized electron detection from YR requirements
- Jet measurements might benefit from good 1photon/pi0 separation
- A good reason for 2 complementary EIC detectors

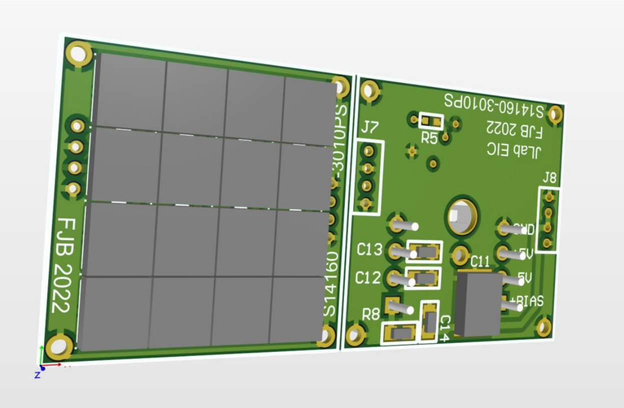
SiPM Readout Option

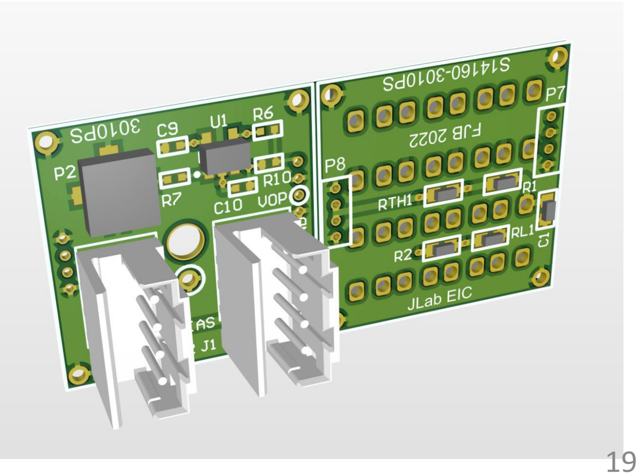












Considerations:

- SiPMs with (15-50)um pixel pitch and good PDE
- Use of light guides (potential light loss) versus big sensitive surface matrix of SiPMs.