eRD105 (SciGlass)

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

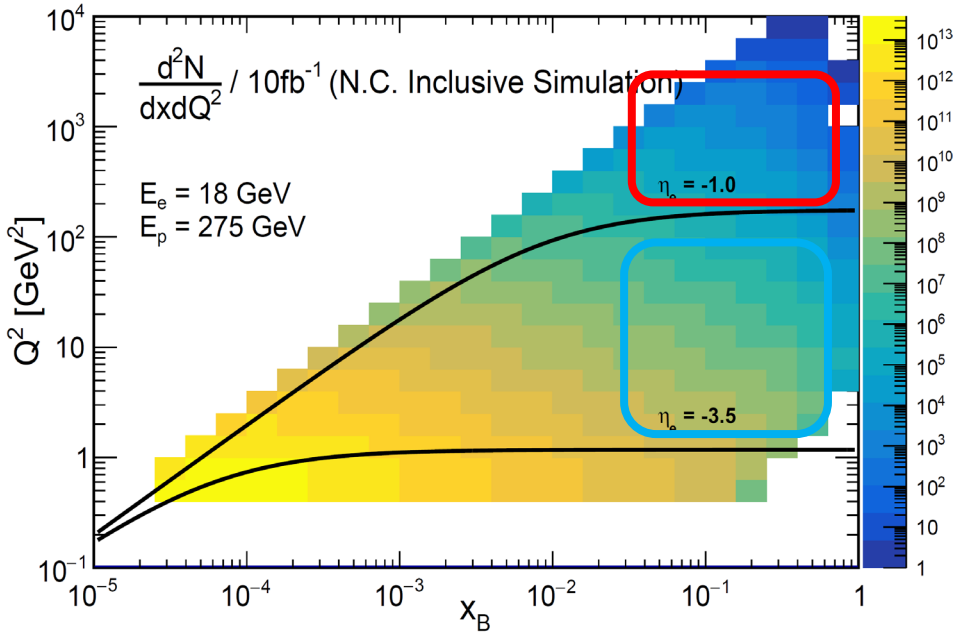
A.I. Alikhanyan National Science Laboratory/Yerevan, Catholic University of America, The Vitreous State Laboratory, IJCLab-Orsay/France, INFN-GE, Jefferson Laboratory, U of Kansas

Context: Precision EM Calorimetry

See Silvia's talk for details on EPIC

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
- SciGlass (developed with DOE/STTR) in the barrel 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
Dz (mm)	60	56	48

Requirements

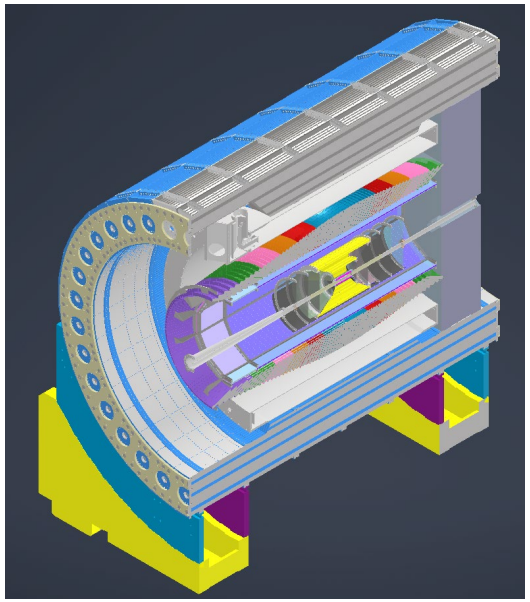
- Good energy resolution
  - e.g., region -2 < η < -1 requires ~7%/√E
- e/h separation up to 10^{-4}

Precision Electromagnetic Calorimetry

electron kinematics measurement is essential at the EIC

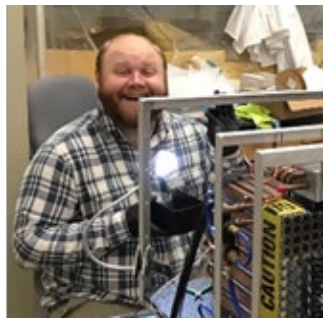
- Homogeneous EM calorimeter – typical materials in lepton induced hadron scattering: crystals and glass, a **well-established detector technology**
- Barrel EMCal readout electronics can be identical with the backward EM calorimeter → **no additional technology required**
- Experienced team of institutions (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

EEEMCAL











eRD105: SciGlass R&D

The main goal of this R&D project is to demonstrate that SciGlass is a viable cost-effective solution as EIC calorimeter technology

- The R&D effort benefits from a separately funded DOE SBIR/STTR Phase 2 providing facilities and resources for the glass fabrication and scale-up production

SCINTILEX

SBIR/STTR DE-SC0020619

- eRD105 made good progress in FY22 towards completion – albeit there are delays due to Covid19 and start of R&D funding
- The remaining R&D in FY23 aims at optimizing the readout matched to glass and comparison of different glass geometry shapes with prototypes and beam tests.

FY22 Milestones and Accomplishments

Milestones for FY22 - Beam test with small prototype

- ✓ **Task 1:** Leverage SBIR/STTR for SciGlass optimization and production of test samples
- ✓ **Task 2**: Receive ~25-50 test samples; initially 20 cm and 40 cm late in FY22
- ✓ **Task 3**: Characterize blocks at collaborating institutions including cross comparisons for systematic uncertainty
- ✓ **Task 4**: Construct a small 3x3 prototype and finalize readout infrastructure
- **Task 5**: Commission the 3x3 prototype
- **Task 6**: Carry out test beam program and validate readout concepts including streaming RO

Completed for 20-cm block, ongoing for 40cm blocks

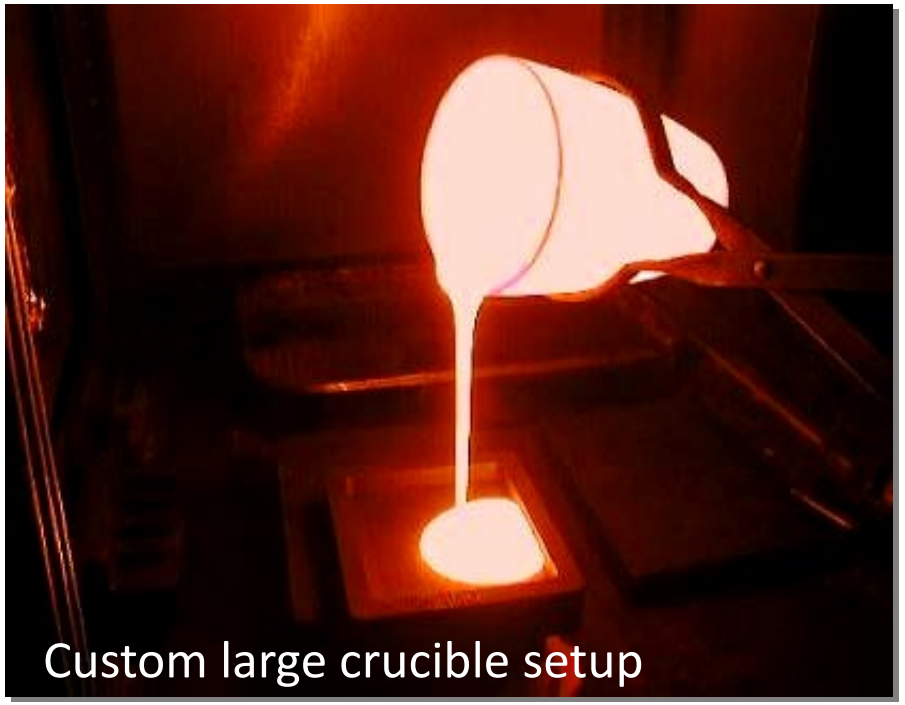
Task 1+2: SciGlass optimization and production

SciGlass Scale-up production

SCINTILEX

SBIR/STTR DE-SC0020619


Custom fabrication setup for 40cm SciGlass

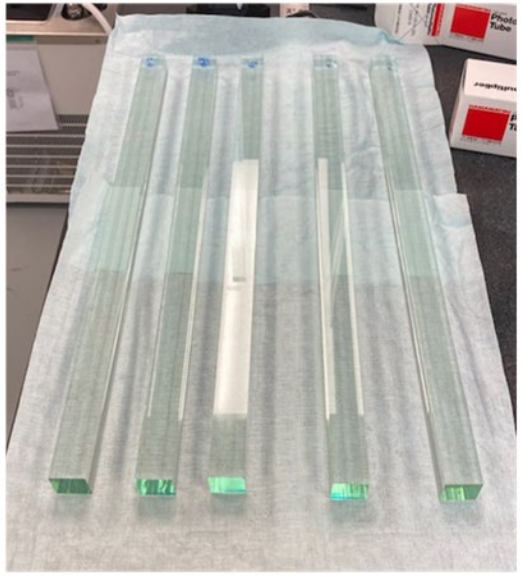

Custom large crucible setup

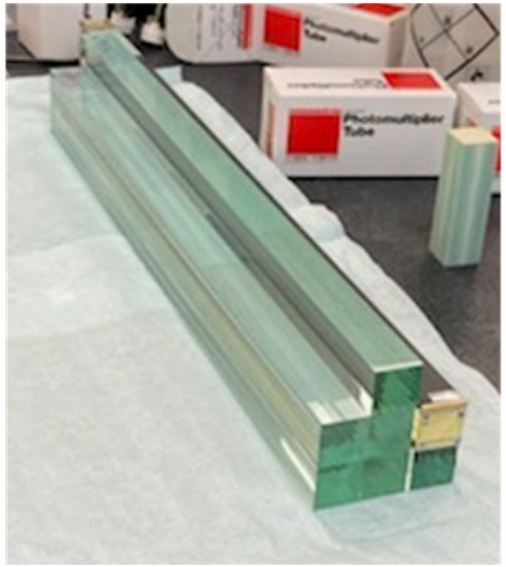

SciGlass 40cm before polishing

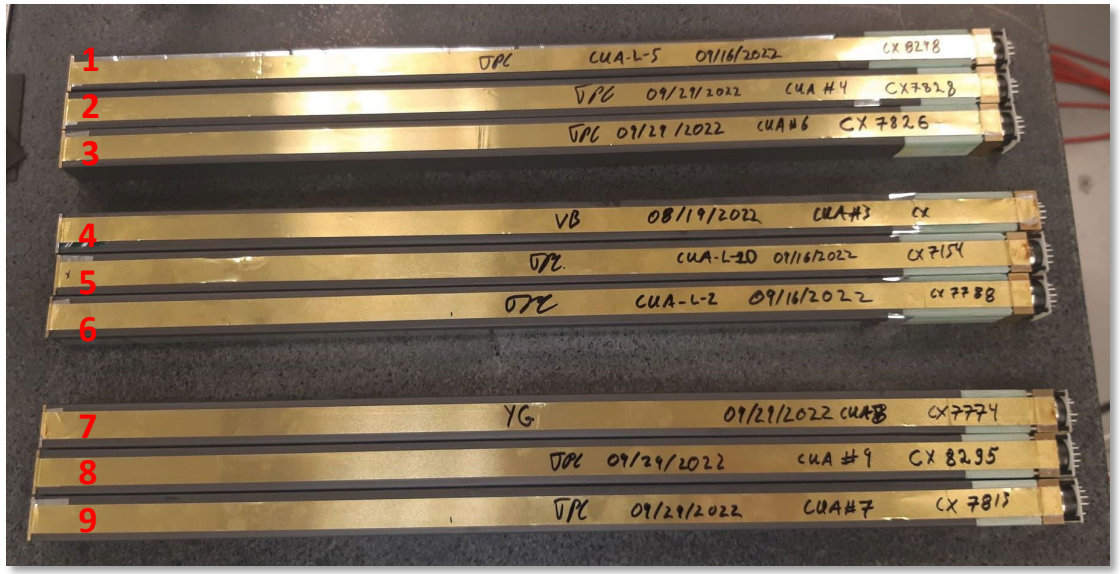
Task 1+2: SciGlass optimization and production

SCINTILEX

- SciGlass 20cm has been produced reliably and 40cm can now we produced routinely; We have an SBIR phase-II to start large-scale production of larger blocks (40+ cm, rectangular and projective shapes)
- A total of 25 SciGlass block test samples was produced over the last year - of these ten SciGlass blocks were of dimensions 20mm x 20mm x 400mm and fabricated with an optimized formulation – better transmittance
- An issue in the fabrication method was identified. A new setup is being constructed that has the potential to even further improve the transmittance of long glass blocks.



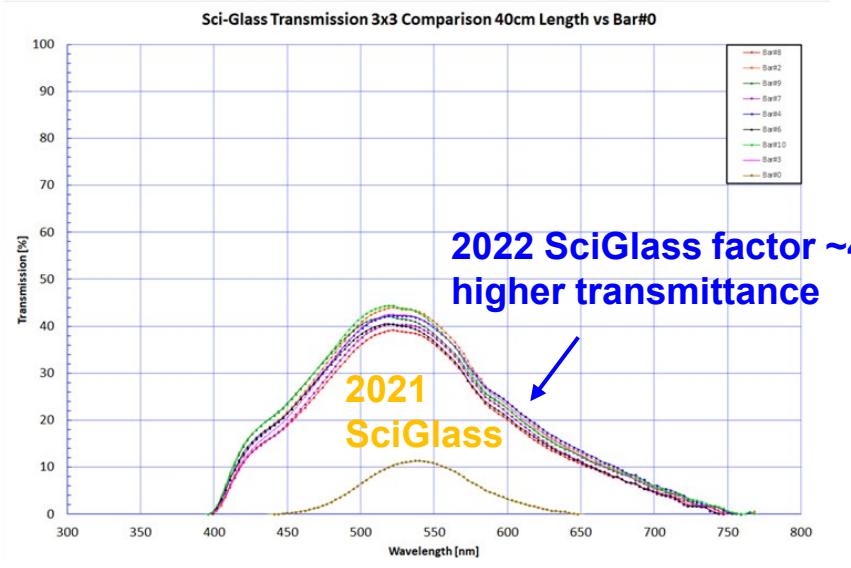


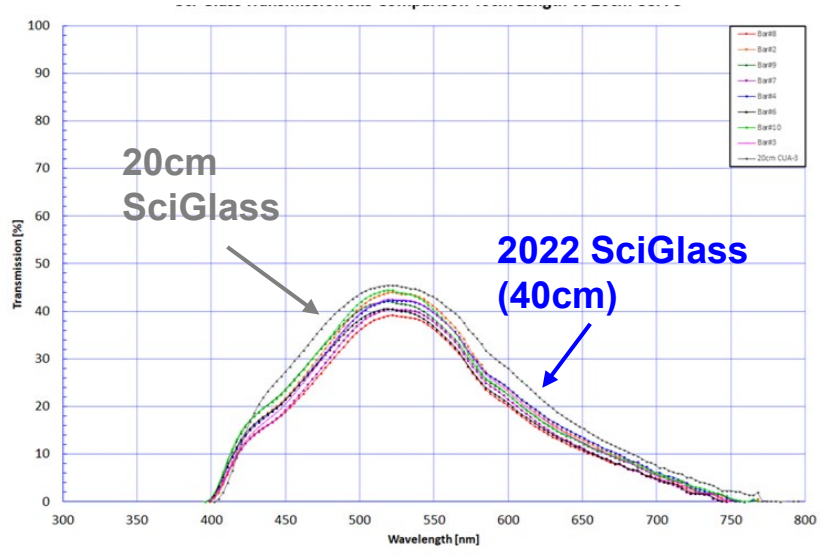


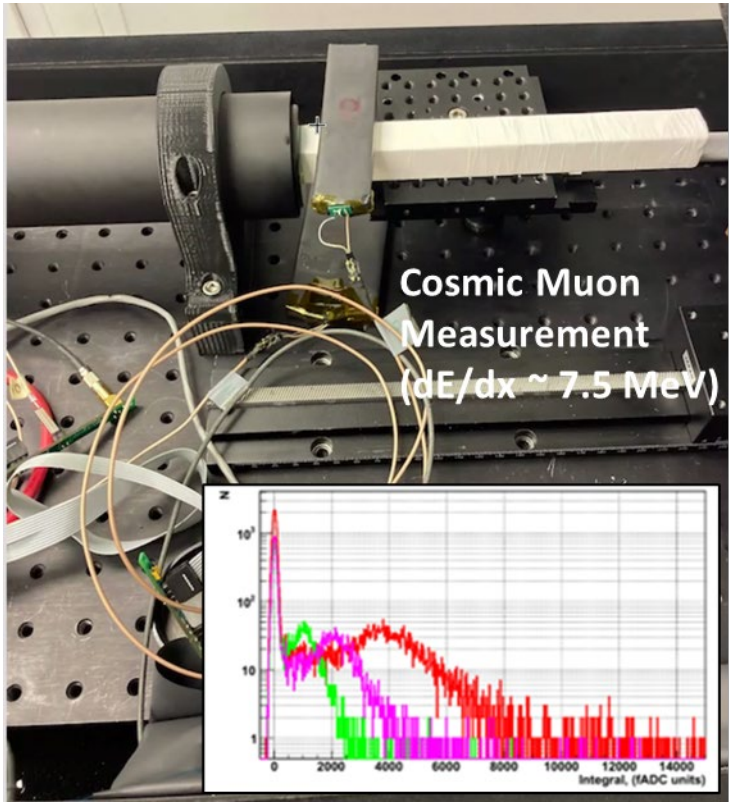
SBIR/STTR DE-SC0020619

Task 3: SciGlass Characterization

Longitudinal Transmittance of 40cm (and 20cm) long glass blocks







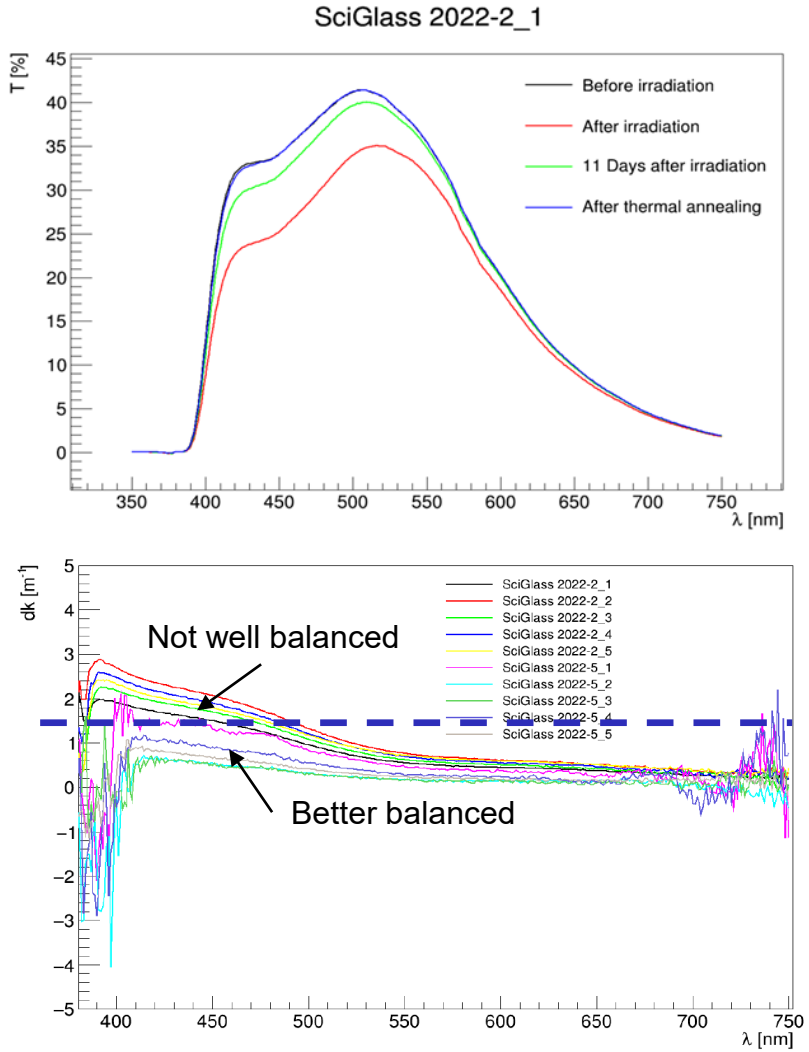
✔ **Significant improvements made in 40cm SciGlass performance within one year**

- ❑ Maintaining and optimizing optical properties is one of the biggest challenges in scale-up of scintillating glass for nuclear physics experiments
- ❑ Testbench: optical characterization and response to cosmics and radioactive sources to benchmark against specific experiment requirements and to prepare for detector prototype beam tests

✔ **Testbenches set up for rapid feedback loop on SciGlass**

Task 3: SciGlass Characterization

Irradiation of 20cm long blocks

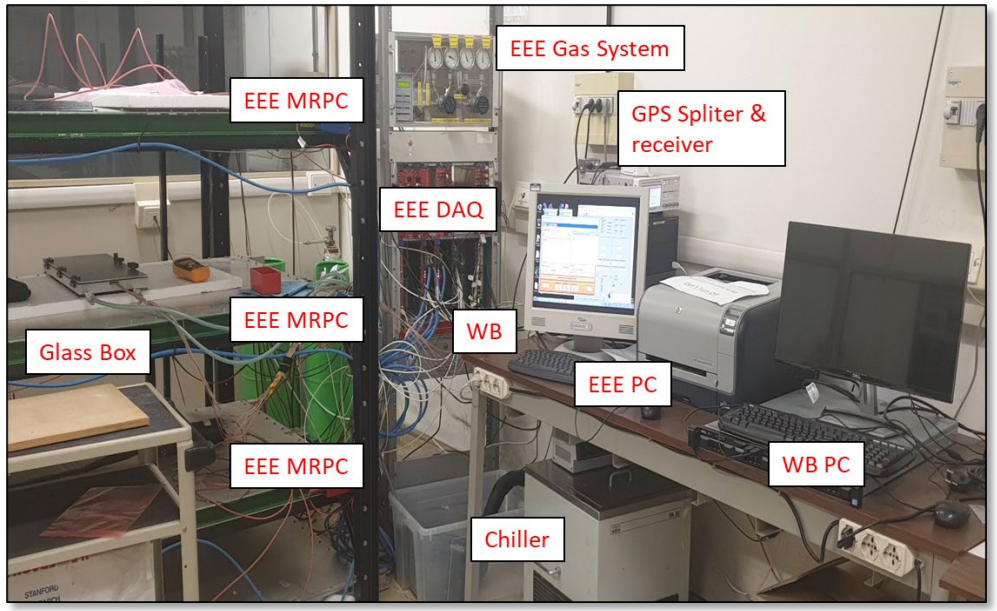


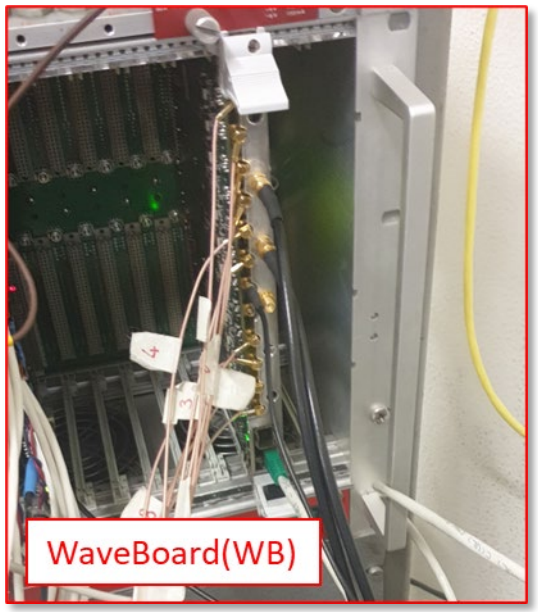
SciGlass overall consistent with specification

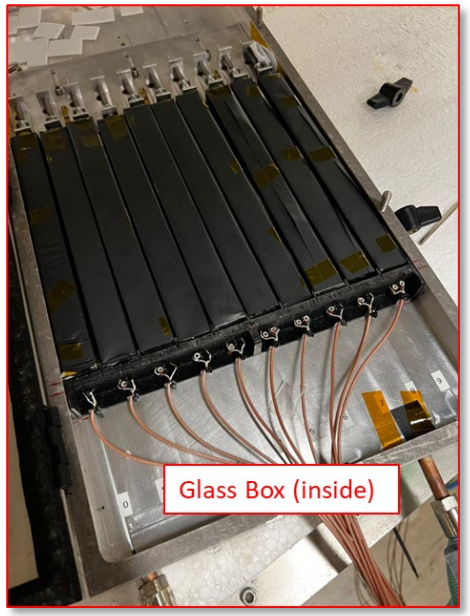
Figure 3: *Measured transmittance of a recent 20-cm-long SciGlass sample before and after 30 Gy of radiation at 1 Gy/min. The formulation of this block had an imbalance of the radiation-protecting Cerium ionization state compared to the one that increases the light yield. However, even with the relatively reduced transmittance the observed radiation damage is within the acceptable limit of the EIC. Further tests are anticipated with the 40cm blocks.*

	2_1	2_2	2_3	2_4	2_5
Length (cm)	1.95	1.92	2.00	2.00	2.00
Width (cm)	1.85	1.95	2.00	2.00	2.00
Height (cm)	19.90	19.70	20.00	19.55	19.95

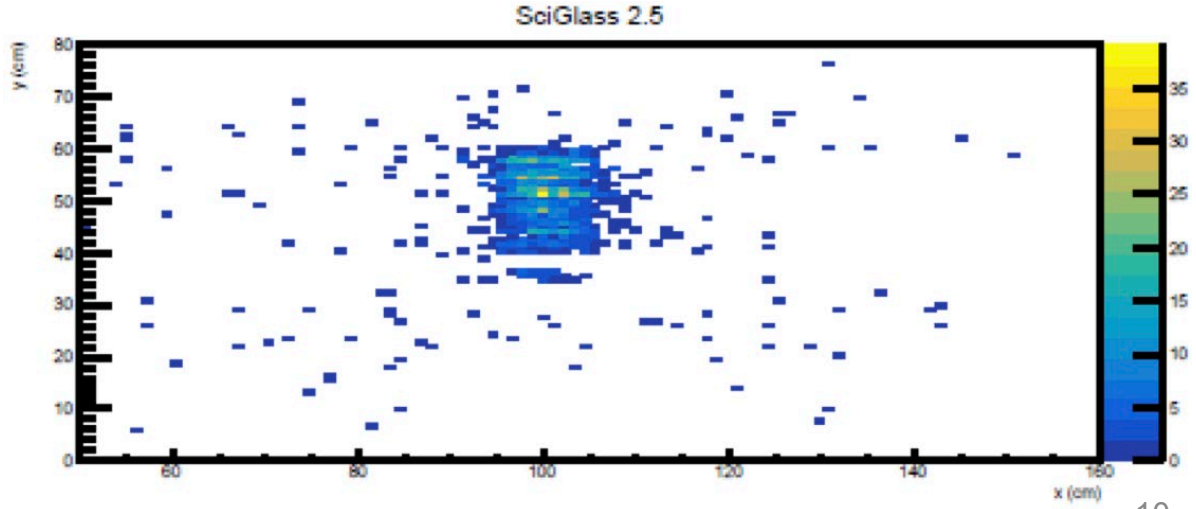
Task 3: Testbench Initial Measurements with SiPM







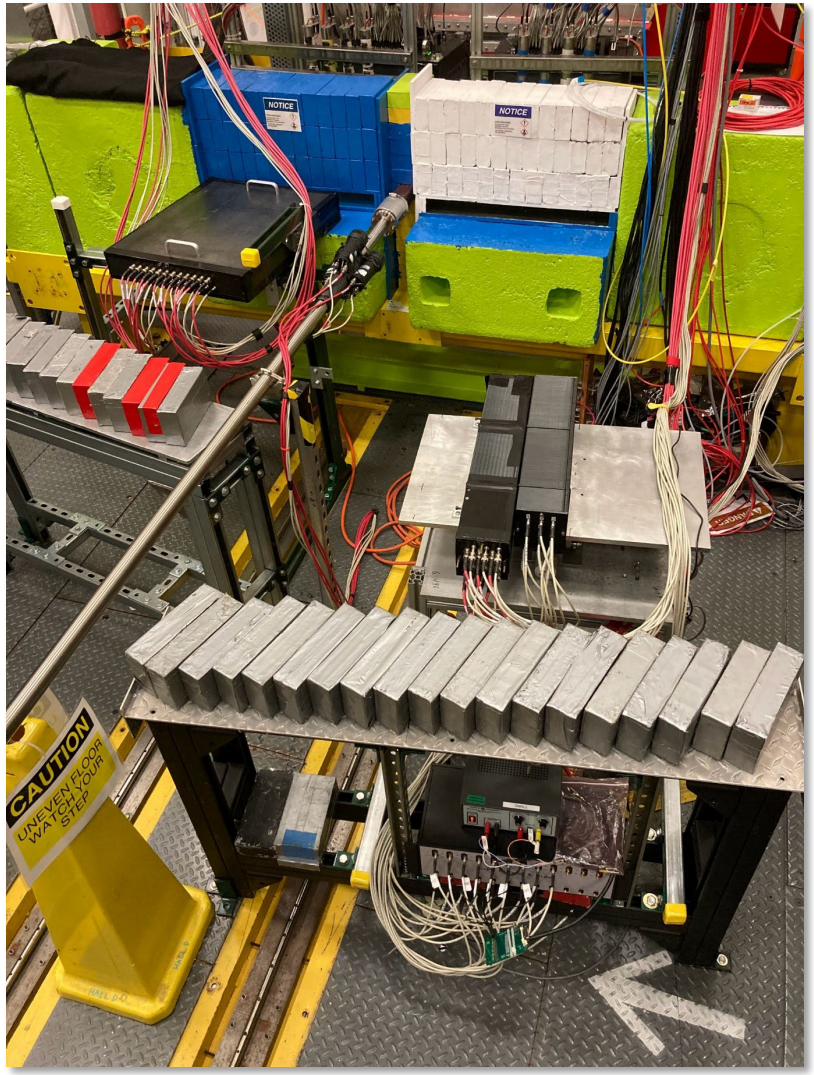
- Cosmic muon trajectories are tracked by three EEE Multi-gap RPC ALICE-like
- Signals are collected by 10 WaveBoard (triggerless mode) channels.
- Online event filtering: wWaveforms are collected only if a trigger from EEE DAQ branch is present.
- EEE data and WB data have a GPS timestamp for (absolute) synchronization.



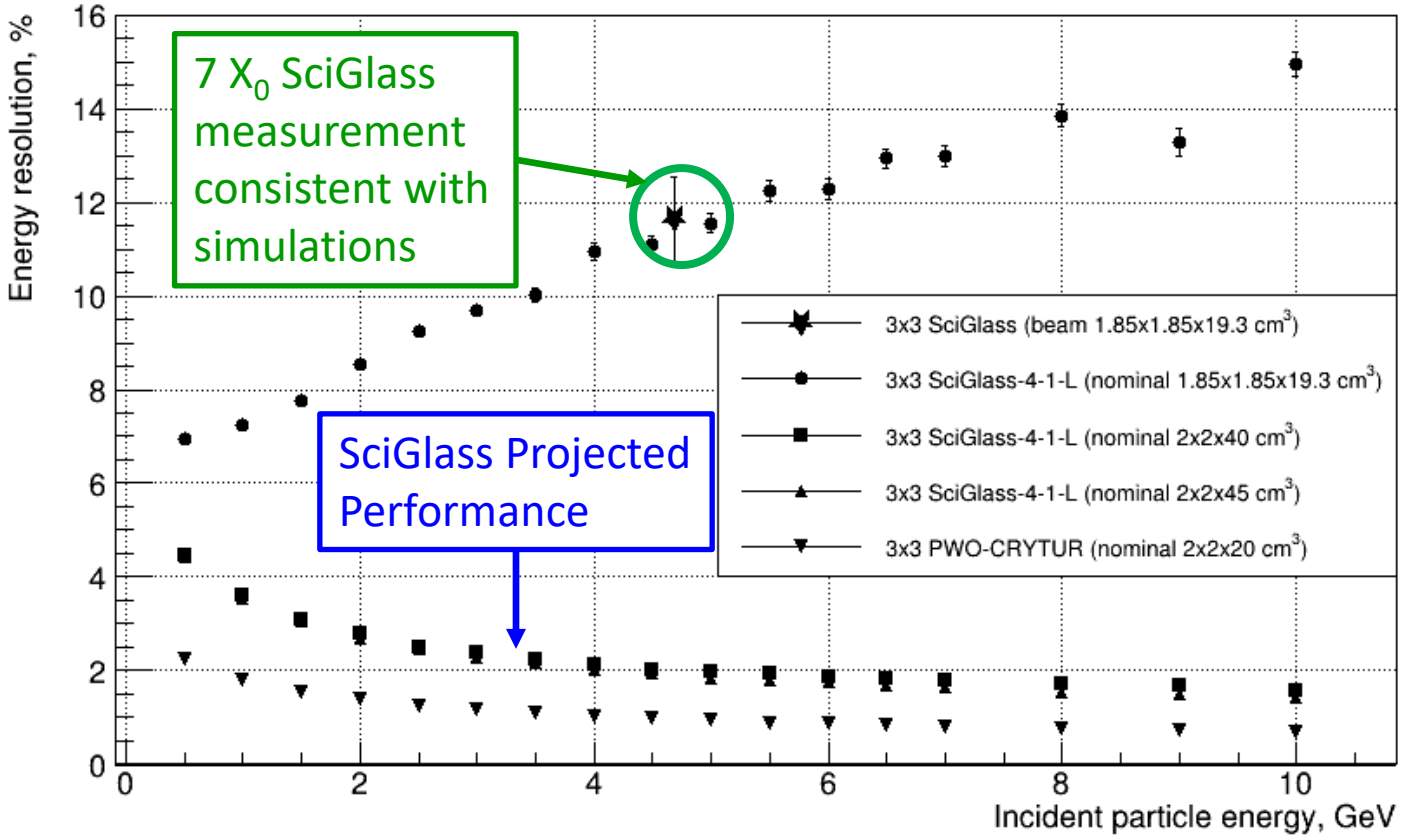
Response of a Sciglass block to cosmic muon

Task 4: 3x3 Prototype tests: 20cm

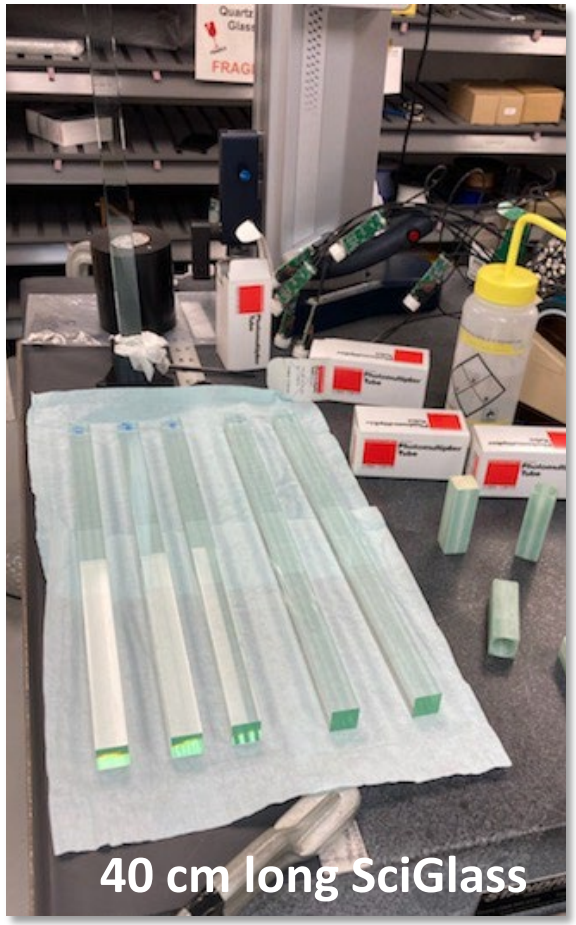
SciGlass development is supported by SBIR/STTR DE-SC0020619



- 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**

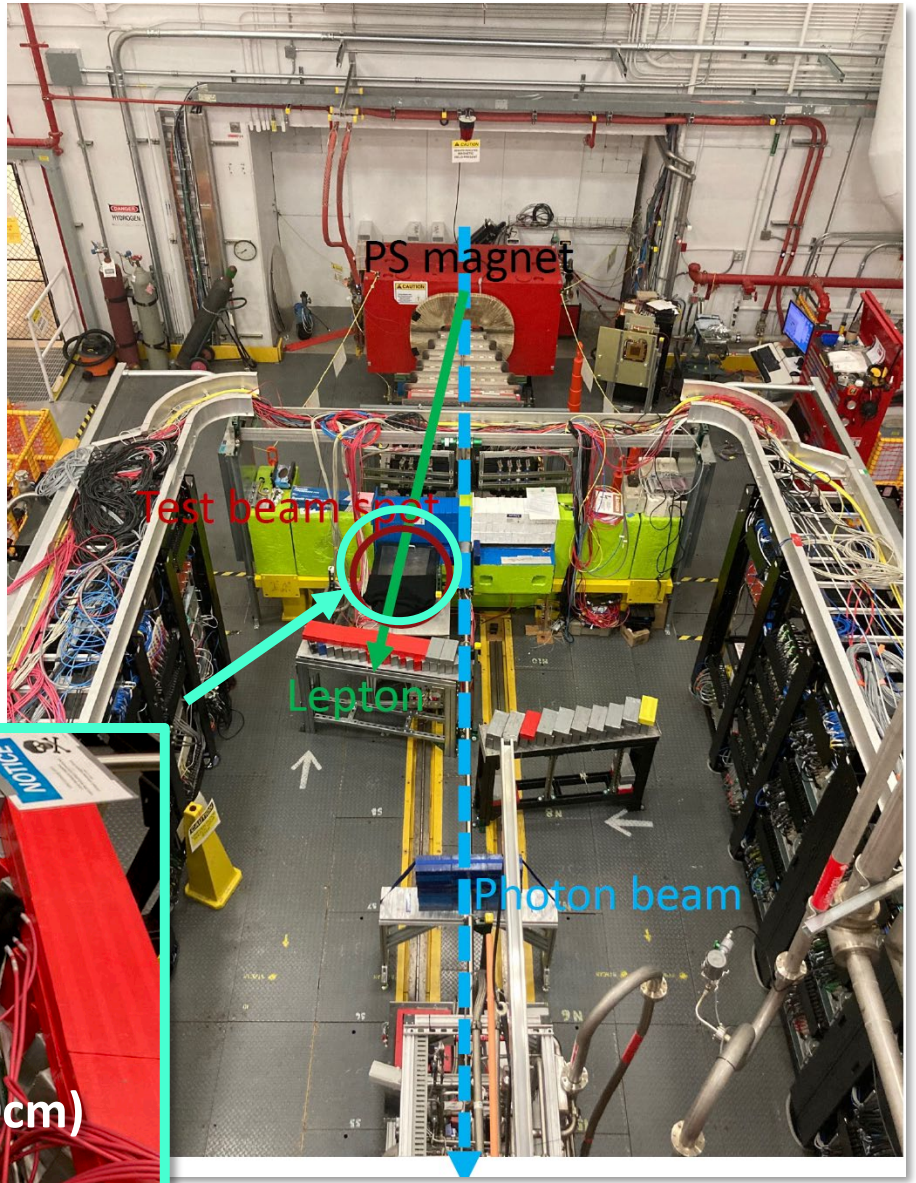


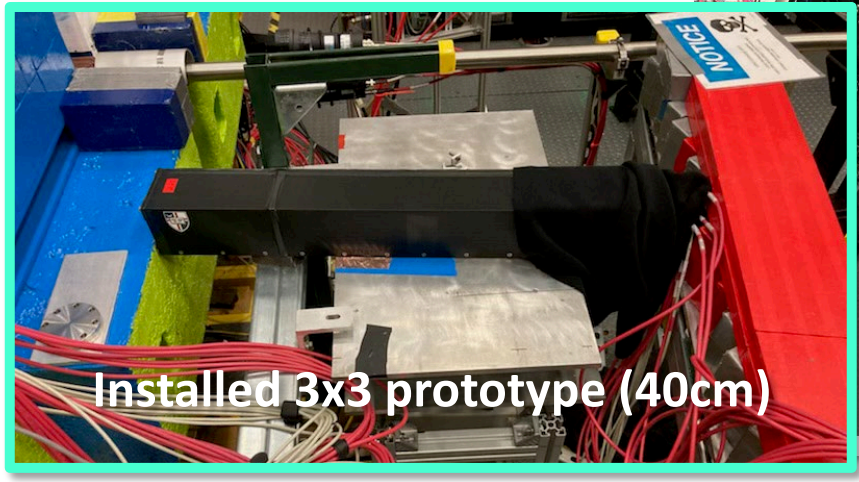
Preparations for Prototype Test – 40cm



Preparations for Prototype Test – 40cm

Installation of the 3x3 (40cm SciGlass) prototype in the beamline at Jefferson Lab

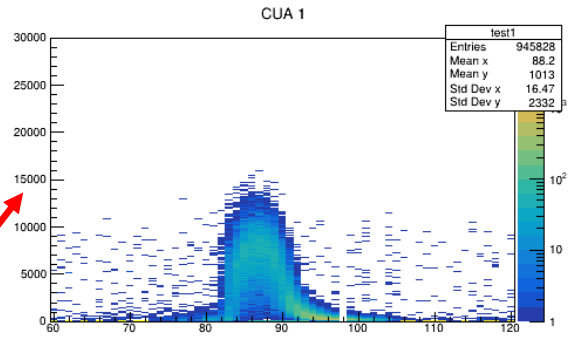


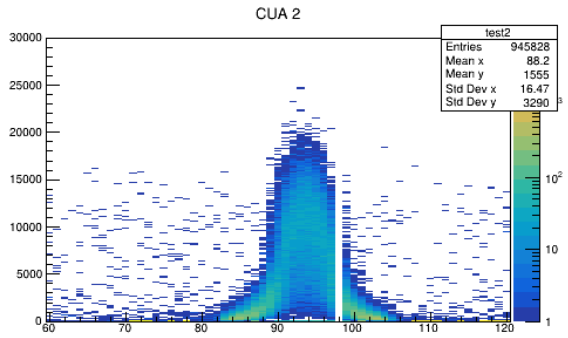


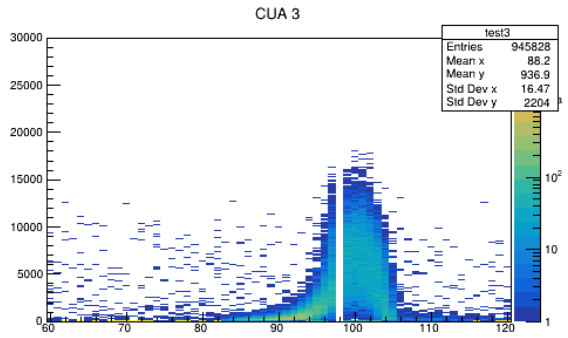
First Data from Prototype Test – 40cm

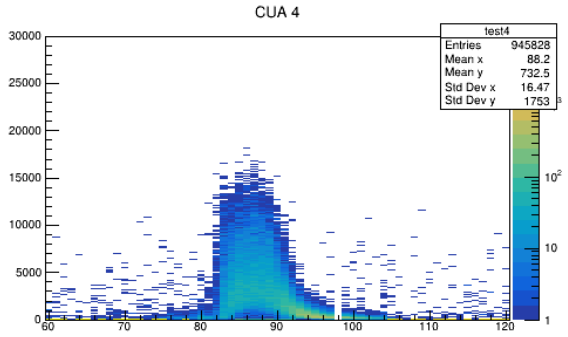
Top row: CUA-1, CUA2, CUA3;
Middle: CUA4, CUA5, CUA6;
Bottom: CUA7, CUA8, CUA9

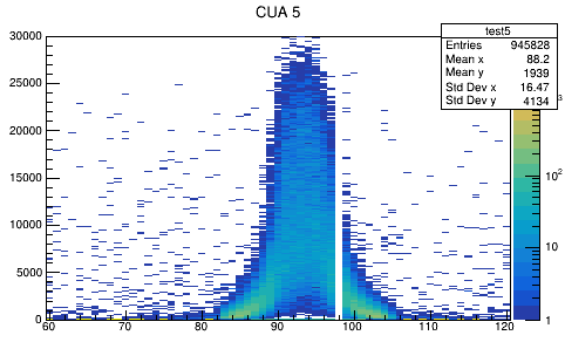
10/17/2022

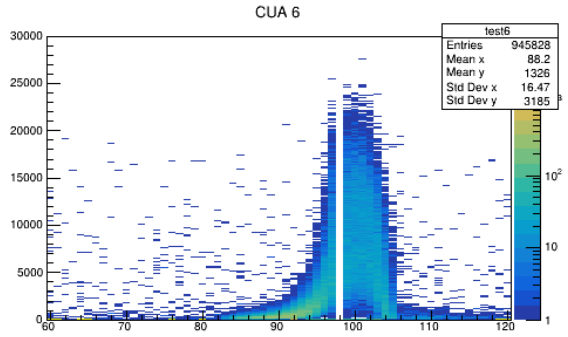


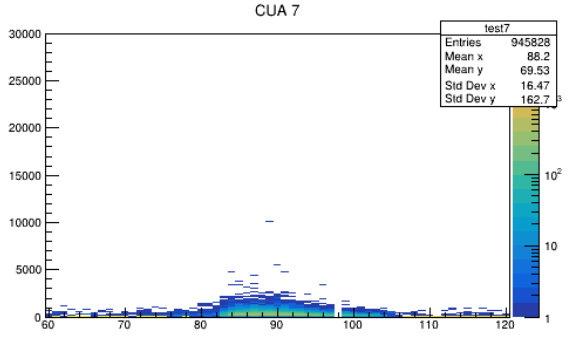


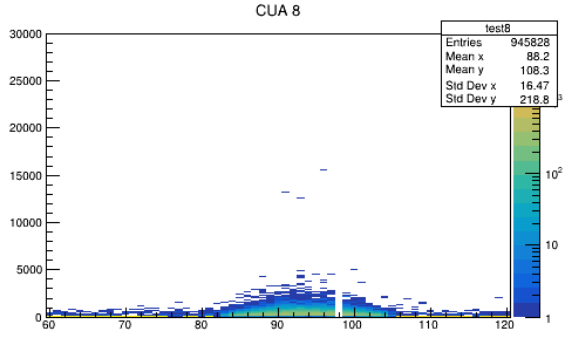


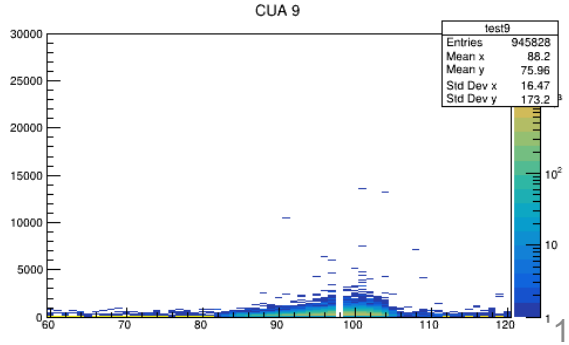








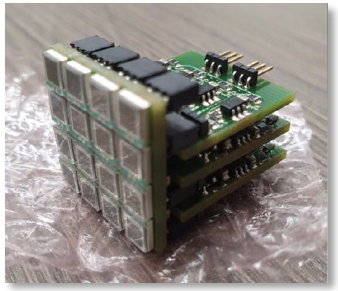


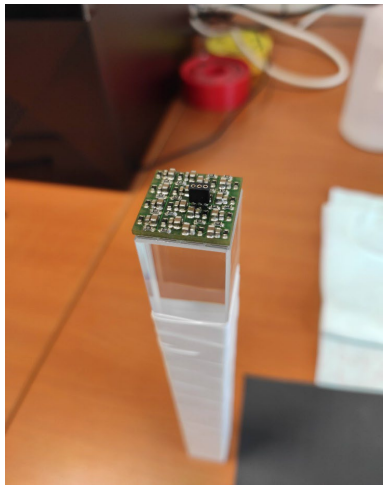


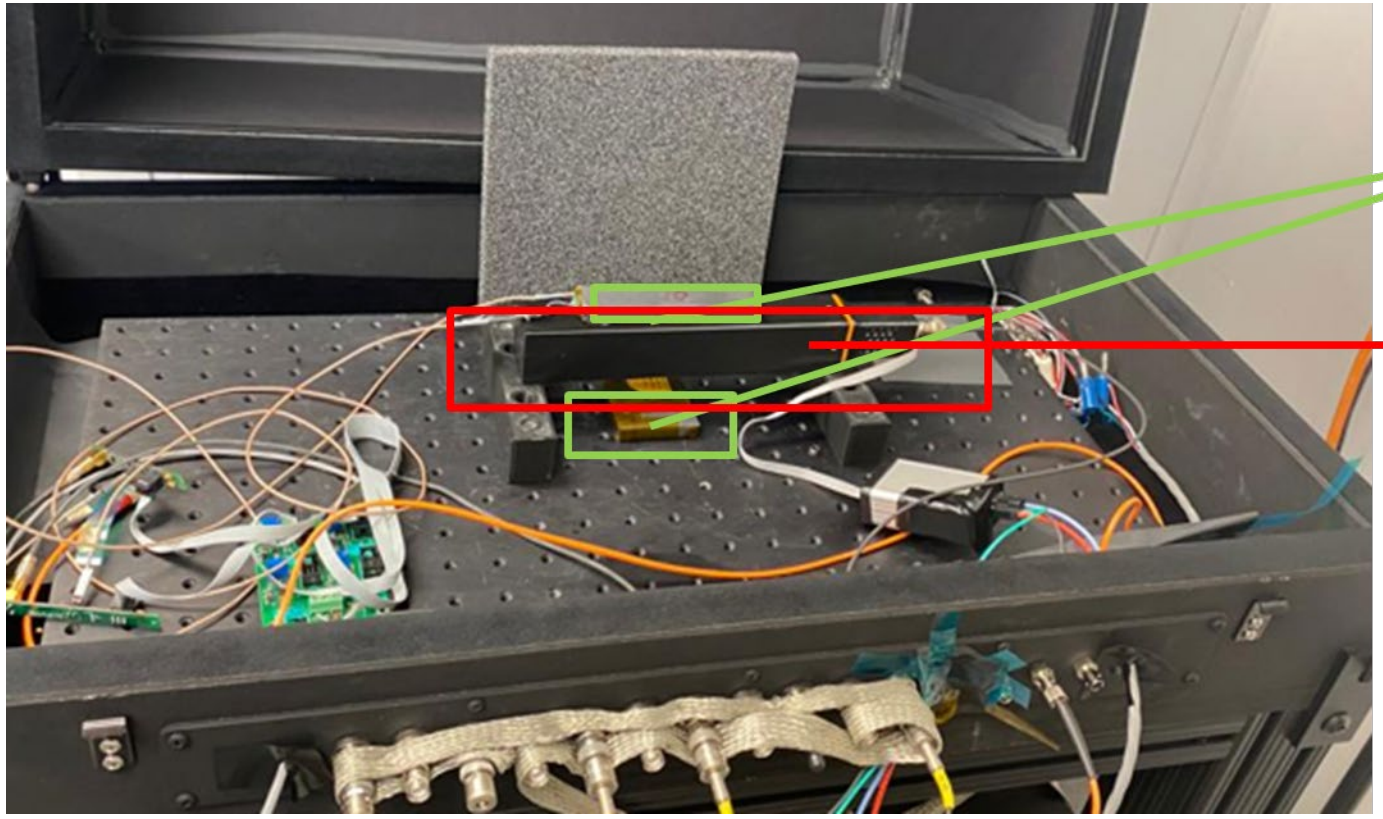
- See signals (amplitude spectra) from all blocks
- Beam is not fully centered → need to re-align the detector (next few days)

Spin-off: SiPM Prototype Tests with Crytur USA

Goal of the tests: Optimize and test SiPM matrix readout chain with new generation PWO crystals







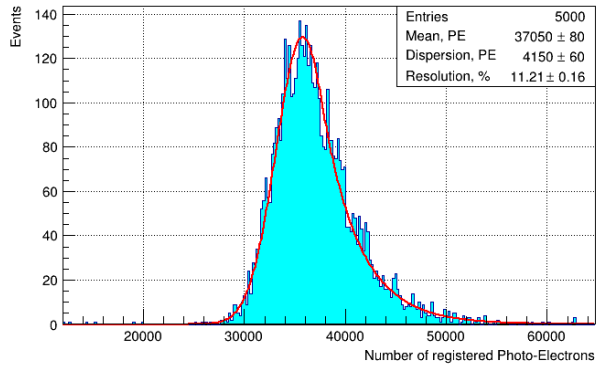
Trigger Scintillator

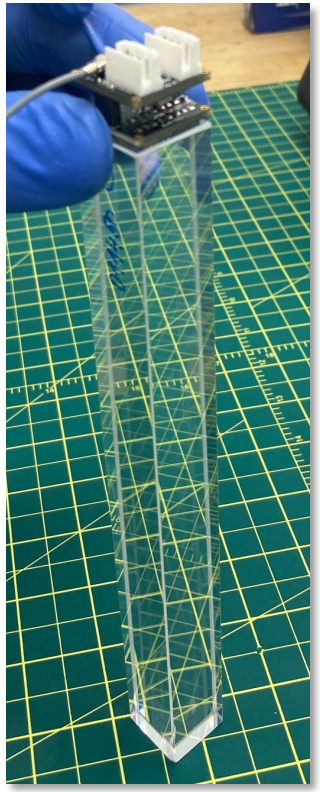
Crytur prototype 2.0

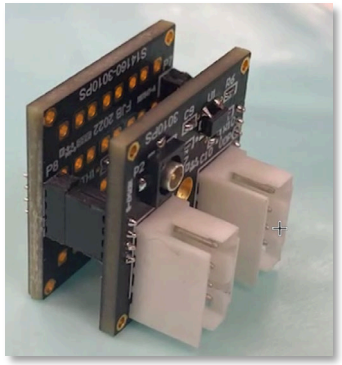
eRD105 R&D Plan for FY23

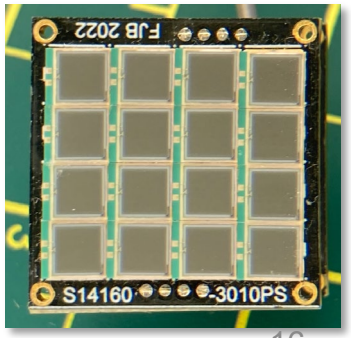
The R&D plan for FY23 focuses on the full block optimized for the calorimeter

- ❑ Characterization of the transverse shower development
- ❑ Optimization of the readout (SiPM matrix and services)
- ❑ Measurement of the ratio of fast and slow components of the scintillating glass – an important input for the electronics optimization
- ❑ Implementation of the process production and performance comparison of different glass geometry shapes.









Milestones for FY23 and outlook

- **FY23: Scale-up to 40 cm complete**
  - Receive ~25 test samples
  - Beam test with 3x3 (5x5) prototype with 40+ cm. (CUA, AANL, JLab)
    - HallD Jlab beam test logistic: installation, safety, DAQ etc. (JLab)
    - Beam test preparation and data analysis (CUA, AANL)
  - Develop and implement a SiPM-based readout (INFN-GE)
  - Design and test an optimized streaming RO chain (INFN-GE)
  - Sciglass blocks characterization, including Irradiation (IJCLab-Orsay, Kansas U.)
  - Implement process for different geometries (CUA)

SCINTILEX

- FY24: Final test of different geometries
  - projective SciGlass as required for barrel EMCal application
  - optimization of reflector and impact of a carbon fibre inner support structure for the glass blocks on calorimeter performance

eRD105 Request and Responsibilities

	FY23 Request
CUA/VSL/Scintilex	**14,854**
Technical Support	7,549
Fringe	1,793
Materials	0
Equipment	0
Travel	0
Indirect Cost	5,512
IJCLab-Orsay	**13,750**
Student Support	7,500
Materials	
Equipment	
Travel	
Indirect Cost	
INFN-GE	
Student Support	
Equipment	
Travel	
Indirect Cost	

	FY23 Request
AANL	**13,500**
Student Support	5,000
Fringe	1,500
Materials	2,000
Travel	5,000
Indirect Cost	0
Kansas U.	**6,396**
Student Support	3,000
Fringe	900
Materials	0
Travel	0
Indirect Cost	2,496
TOTAL	**60,000**

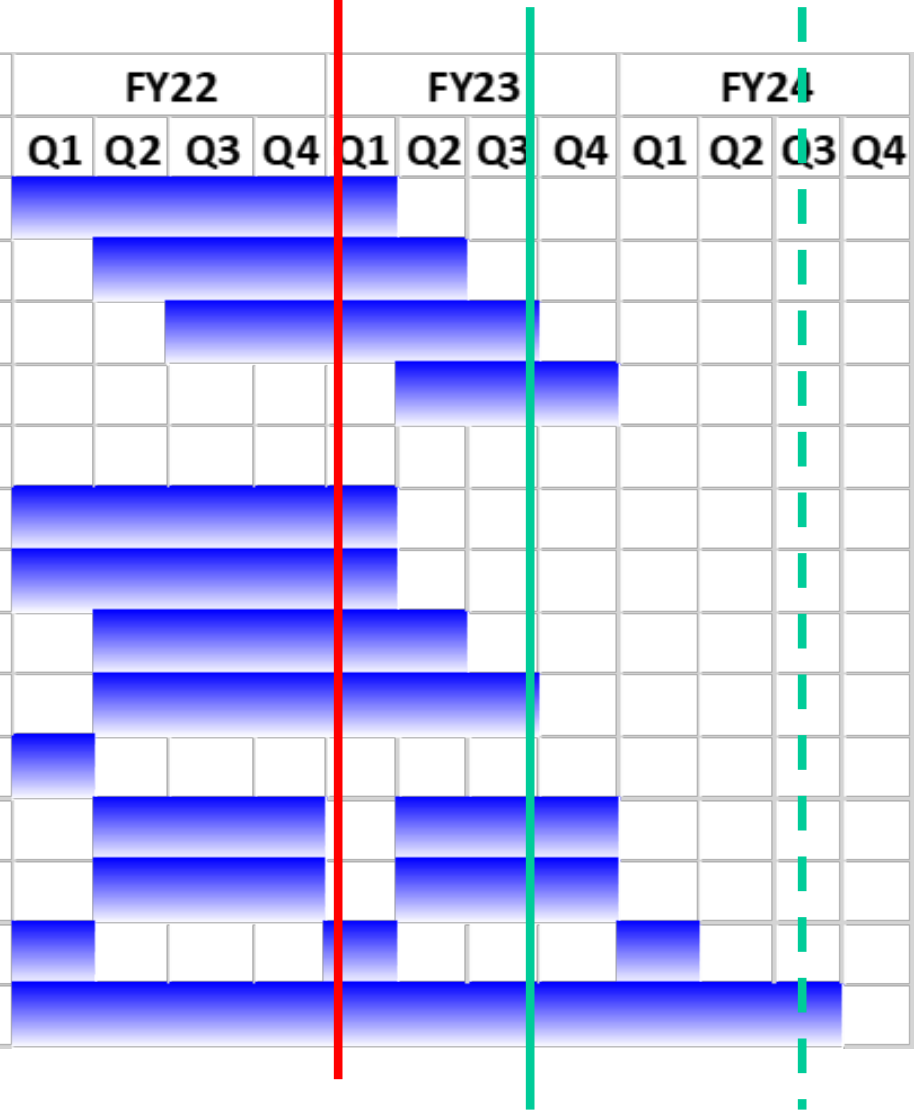
- **CUA/VSL:** coordinate the overall project; SciGlass production and organization of the beam tests, including construction of prototypes; further develop simulations to support the beam tests.
- **IJCLab-Orsay:** perform characterization of the produced large (40+cm) SciGlass blocks, evaluate the radiation hardness from low to high doses, produce analysis software, and contribute to mechanical designs, prototype construction, and beam tests as possible
- **INFN-GE:** optimize the readout framework and developing matched SiPM matrices and services for the beam tests including boards and communication/analysis software, and in particular for SRO tests
- **U. Kansas:** characterization of the produced glass blocks and analysis software development.
- **AANL:** scintillator characterization, prototyping, simulation development, etc.,
- **JLab (unfunded):** contribute to organizing and maintaining the beam test program

R&D nearing completion. Modest request with large fraction of resources contributed by the institutions

eRD105 Timeline

October 2022

Item	Task
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



Not yet taking into account delayed start in Project R&D contracts

Good progress towards completing the R&D – some items complete ahead of schedule