

eRD105 (SciGlass)

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On behalf of the eRD105 Team

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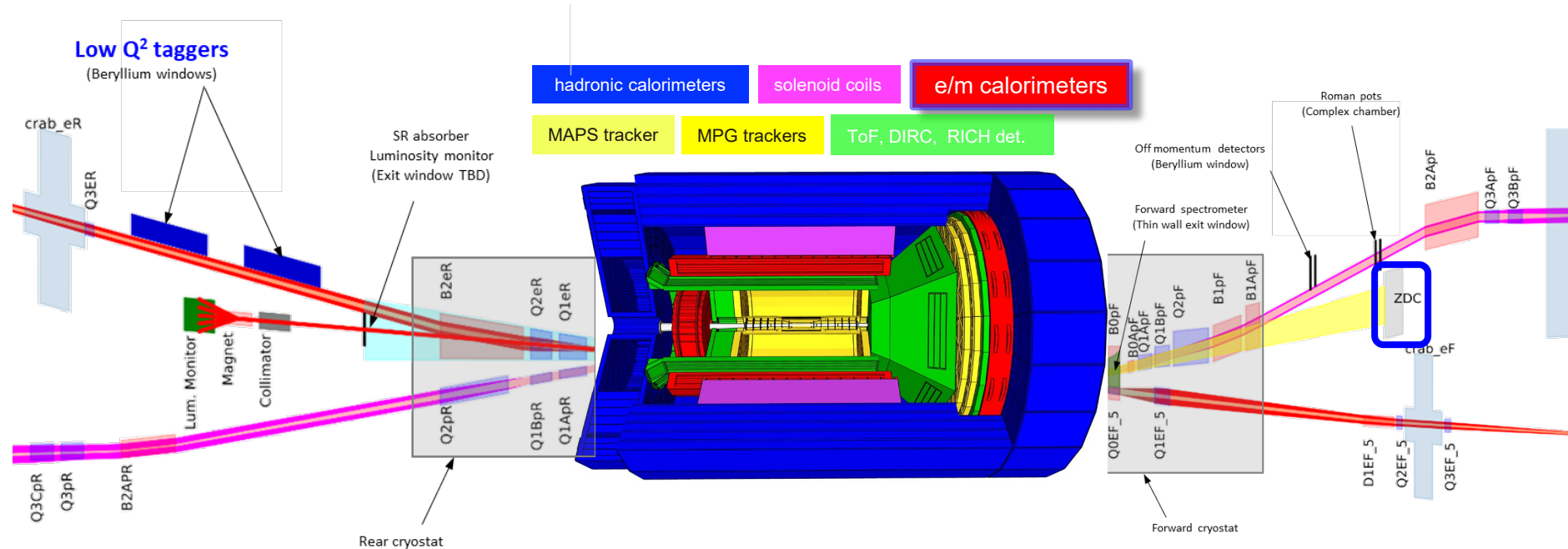
SCINTILEX

Jefferson Lab
Thomas Jefferson National Accelerator Facility



KU THE UNIVERSITY OF
KANSAS

Overview: Precision Calorimetry at the EIC

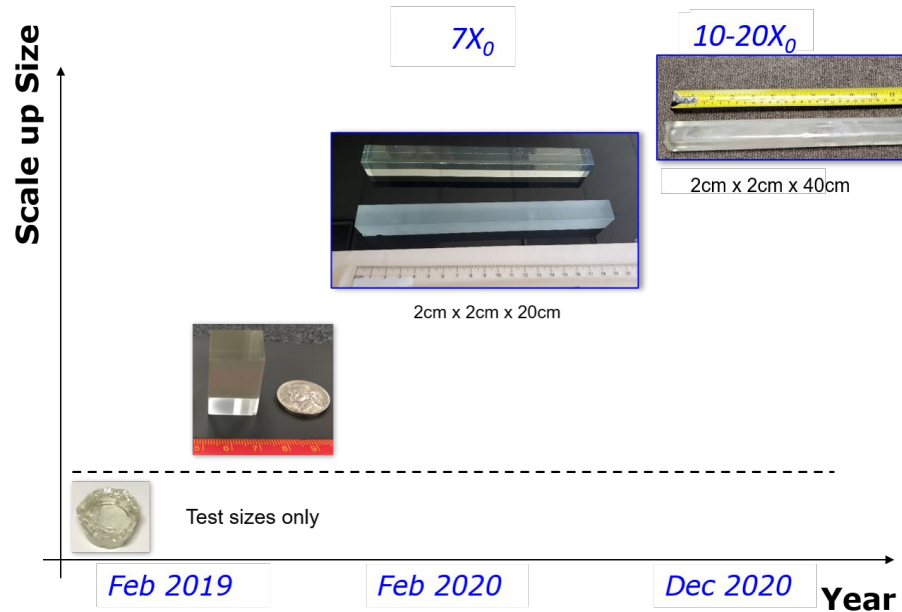


Topic from EIC Yellow Report	Requirement
Barrel PID e/π separation: up to 10^{-2} - 10^{-4} down to 0.2 GeV	Need good EMcal resolution; need additional e/π below 2 GeV
Backward e^- determination, e/p separation up to 10^{-4}	Need highest precision EM calorimetry
Auxiliary Detectors (ZDC, etc.)	Need good resolution EMCal

The main goal of this eRD105 R&D project is to demonstrate that SciGlass is a viable cost-effective solution as EIC calorimeter technology.

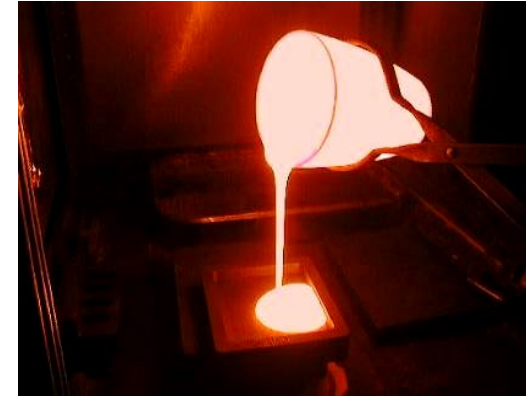
Overview: SciGlass

- ❑ SciGlass is a radiation hard material optimized to provide characteristics similar to or better than PbWO_4 .
 - Fabrication is expected to be cheaper, faster, and more flexible than PbWO_4 crystals.
- ❑ SciGlass is being developed by Scintilex, LLC 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.
- ❑ Scintilex has demonstrated a successful scaleup method and can now reliably produce glass samples of sizes up to ~ 10 radiation lengths.
- ❑ SBIR Phase-II: demonstrate scale up to block sizes $\geq 15 X_0$. Investigate the consistency of product quality over many repetitions of bar production - *ongoing*



The Vitreous State Laboratory – unique facility

- ❑ Designing, constructing and testing large glass production systems
 - VSL Joule Heated Ceramic Melter (JHCM) Systems:
 - The **largest array of JHCM test systems in the US**
 - The largest JHCM test platform in the US



PILOT SYSTEM SCALE-UP

DM10 and DM100 JHCM Systems at VSL



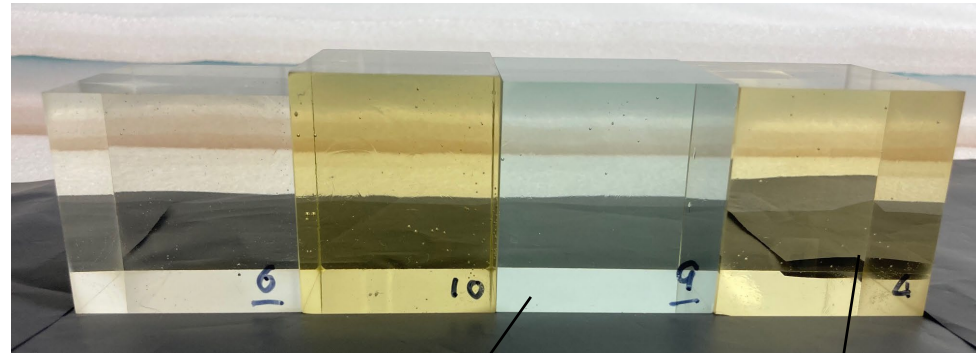
VSL DM1200 HLW Pilot Melter System



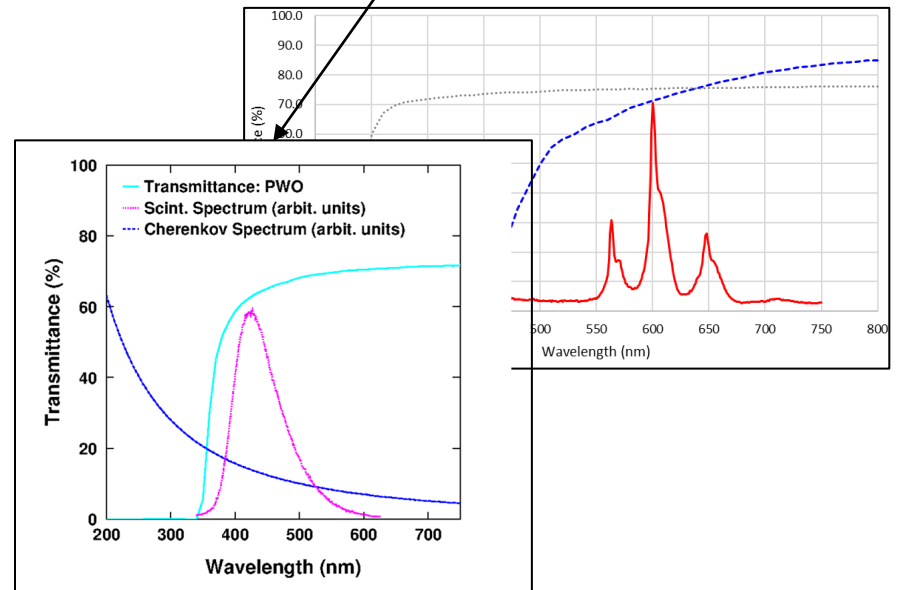
About 400,000 kg glass made
from about 1 million kg feed

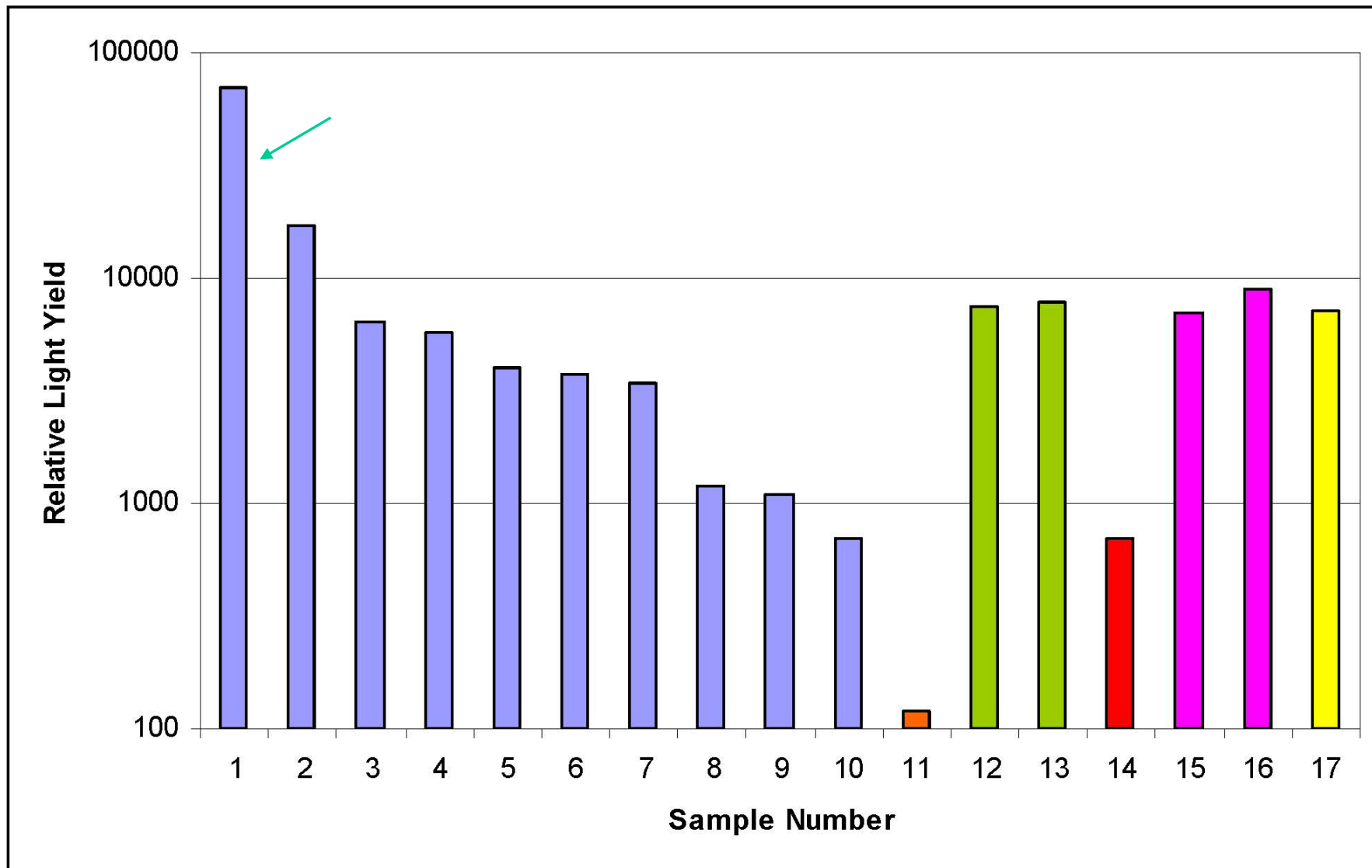
CSGlass

- ❑ 2019 – start of CSGlass R&D at Scintilex and VSL
 - Production of a few test size samples, but then focused on SciGlass
- ❑ Very high-density compared to nominal, emits at $>550\text{nm}$, good LY
- ❑ 2021 – resume CSGlass R&D at Scintilex and VSL
- ❑ CSGlass could be of interest for precision hadron calorimetry with dual readout, where Cherenkov and Scintillation light are detected in the same detector



5cm x 5cm samples of with different level of C/S contributions





Formulation optimization: can control relative C/S light yield

Overview: 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

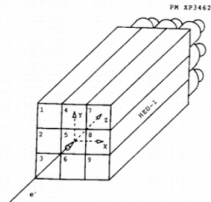


Fig. 3. Layout of the calorimeter setup in the test beam.

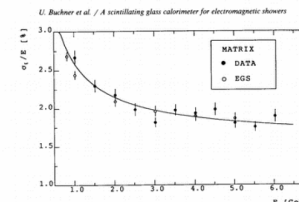


Fig. 12. Energy resolution as a function of the electron energy (black circles) and the EGS prediction (open circles). The line shows the parameterization (4) described in the text.

8x8x66 cm³

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

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

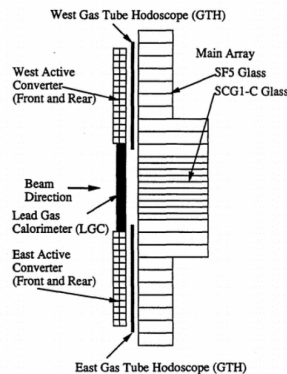


Figure 1. Plan view of the major components of the Experiment 705 calorimeter

	SCG1-C	SFS
Composition (by weight)	BaO 43.4% SiO ₂ 42.5% Li ₂ O 4.0% MgO 3.3% K ₂ O 3.3% Al ₂ O ₃ 2.0% CaO 0.5 1.5%	PbO 55% SiO ₂ 38% K ₂ O 9% Na ₂ O 1%
Density	3.36 g/cm ³	4.08 g/cm ³
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 SFS Lead Glass

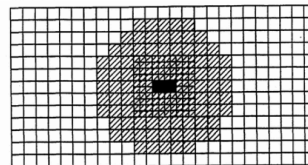


Figure 2. Beam view of the Main Array (SCG1-C scintillating glass is cross-hatched)

The Experiment 705 Electromagnetic Shower Calorimeter, 1993

15.x15.x89 cm³

7.5x7.5x89 cm³

Rad. Length 20.9 X0

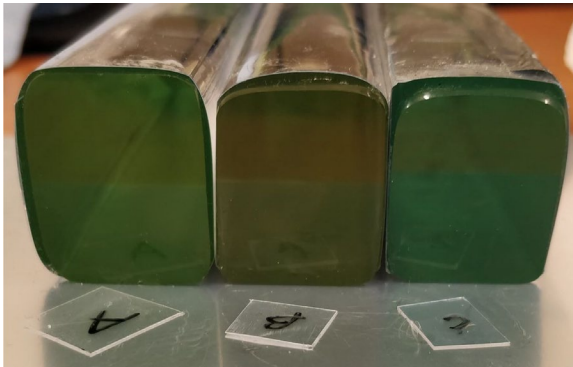
0.99%+4.58%/sqrt(E)

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 Testbench Results 2021

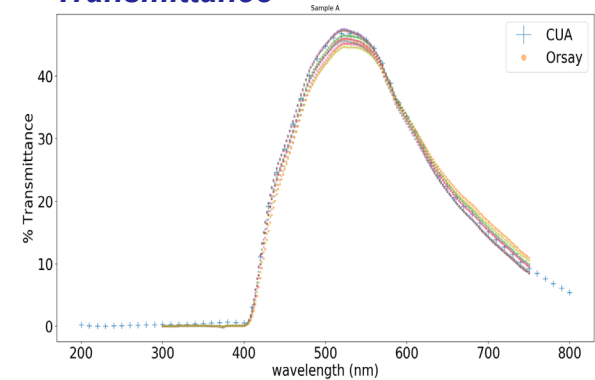
IJCLab-Orsay Activities 2021



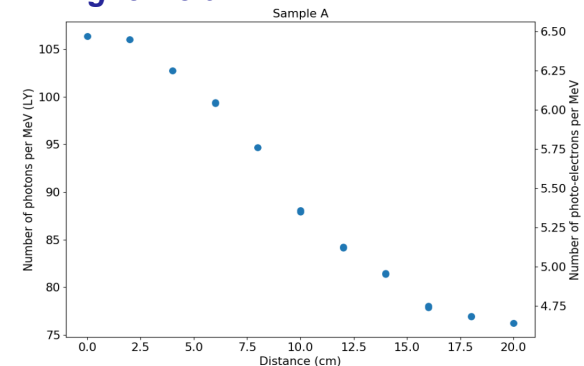
Glass samples
before polishing

- ❑ Three (3) SciGlass blocks of 20 cm length were produced and tested on the testbench at IJCLab-Orsay in Summer 2021
- ❑ Considerably improved transmittance (from 4% to 25-30% at 440nm); reasonable light yield as function of distance along the sample
- ❑ 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*

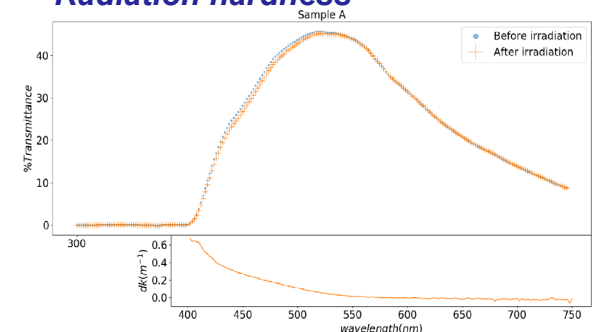
Transmittance



Light Yield



Radiation hardness



Prototype Test Preparations (1)



- Improved prototype with new SiPM based assembly
- Same size 3D printed frame as PMT based version
- Two piece SiPM holder concept developed
- Holders are 3D printed (PLA plastic)
- PEEK plastic will be used in real detector
- Silicon based glue for frame, no SiPM glueing to crystal
- SiPM soldered to circuit board with SMA connector
- 25um cell SiPM for beam tests installed (75um second option)
- LEMO output at the detector patch panel
(BIAS/Preamp or Waveboard application)

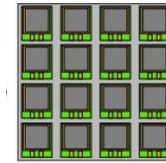
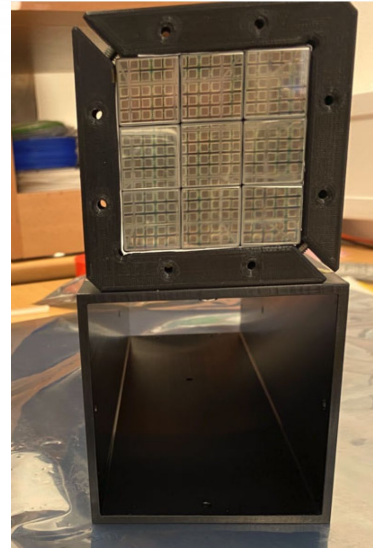


Small prototype was installed in Hall D at Jefferson Lab (USA)

Prototype Test Preparations (2) – in collaboration with CRYTUR USA

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

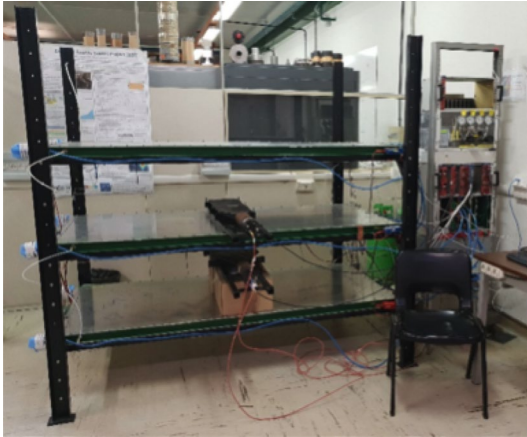
- CRYTUR USA concept
- 9 CRYTUR crystals
- 16 SiPMs per crystal
- $3 \times 3 \text{ mm}^2$ SiPMs
- $\sim 90\text{k}$ cells per SiPM
- Plug-n-play prototype
- First working RO version for EIC



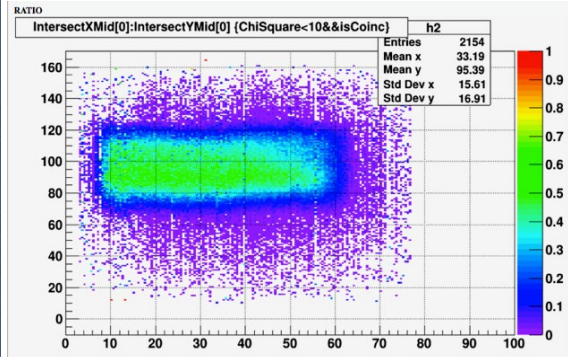
- Direct performance comparison with 3x3 PMT version, INFN SiPM version
- Energy resolution studies
- Noise studies
- Light collection studies
- Linearity studies
- Threshold studies

INFN-GENOVA 2021-22 activity

INFN-GE activity



- 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



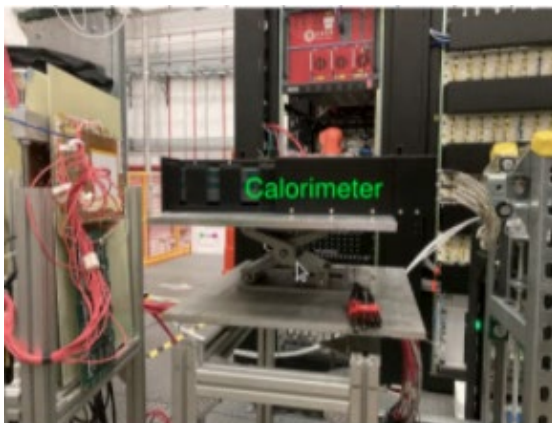
- Example of a plastic scintillator signals in coincidence with tracks detected by EEE telescope (off line analysis)
- The two detectors are read out independently
- A common GPS signals provides a common time reference



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

- Few SciGlass samples sent from IJCLab-Orsay to 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

Jefferson Lab activity

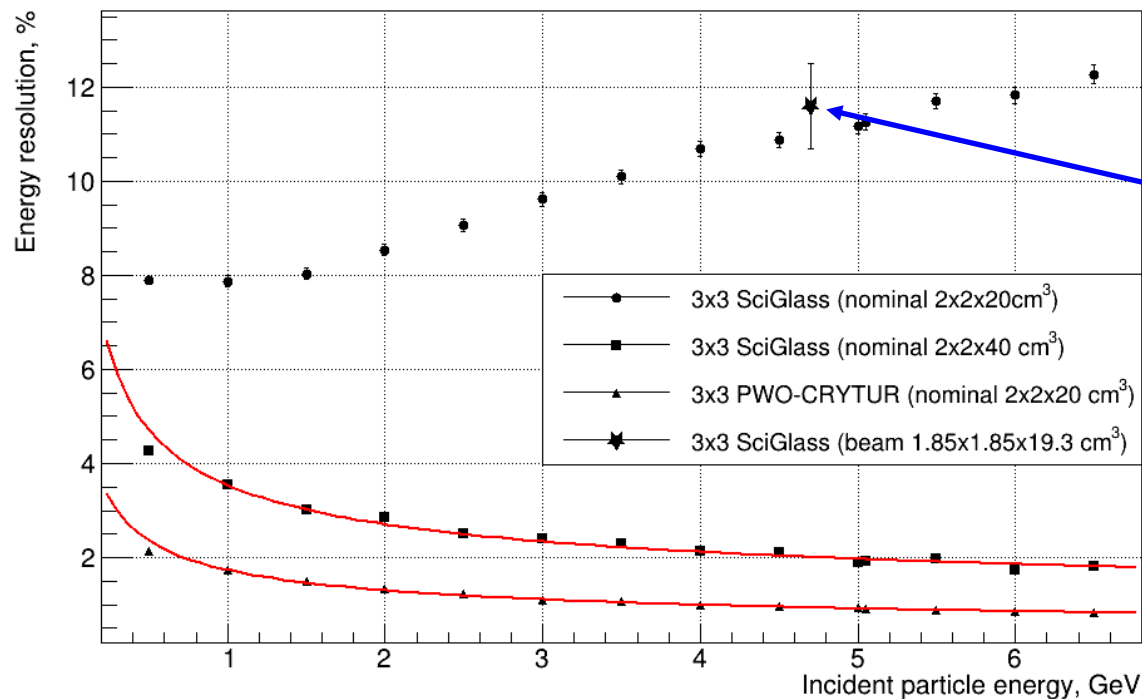
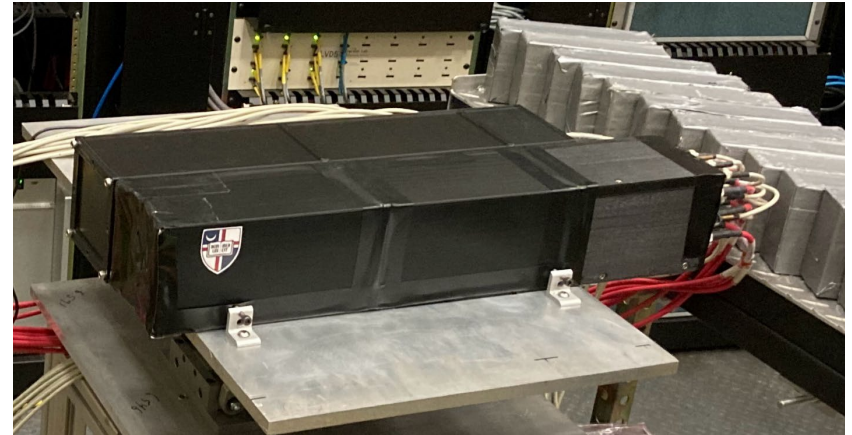
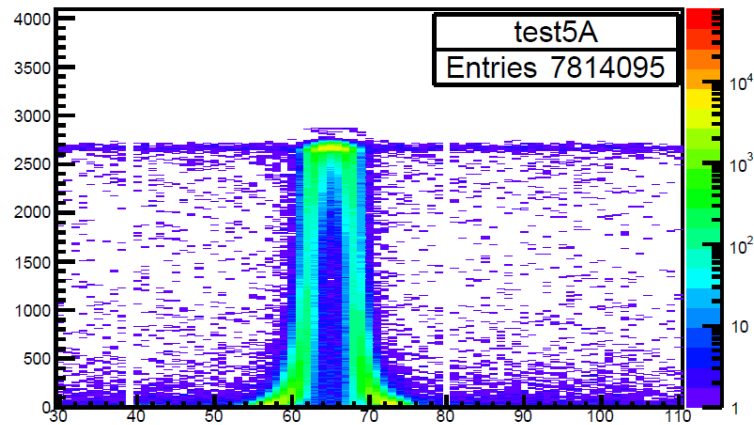


- Preparation of new tests of a PbWO 3x3 EM Cal prototype instrumented with SIPMs, fast FE preamplifiers and bias boards
- Developing the interface to JLab fADC250 boards trough VTP-readout
- Developing the backend in collaboration with ERSAP Group at JLab and TRIDAS at INFN CNAF/BO
- Developing AI-supported unsupervised cluster-finding algorithms for real-time tagging/filtering
- On-beam tests in Hall-D in Fall 2021

Prototype 2021 Beam Tests Overview

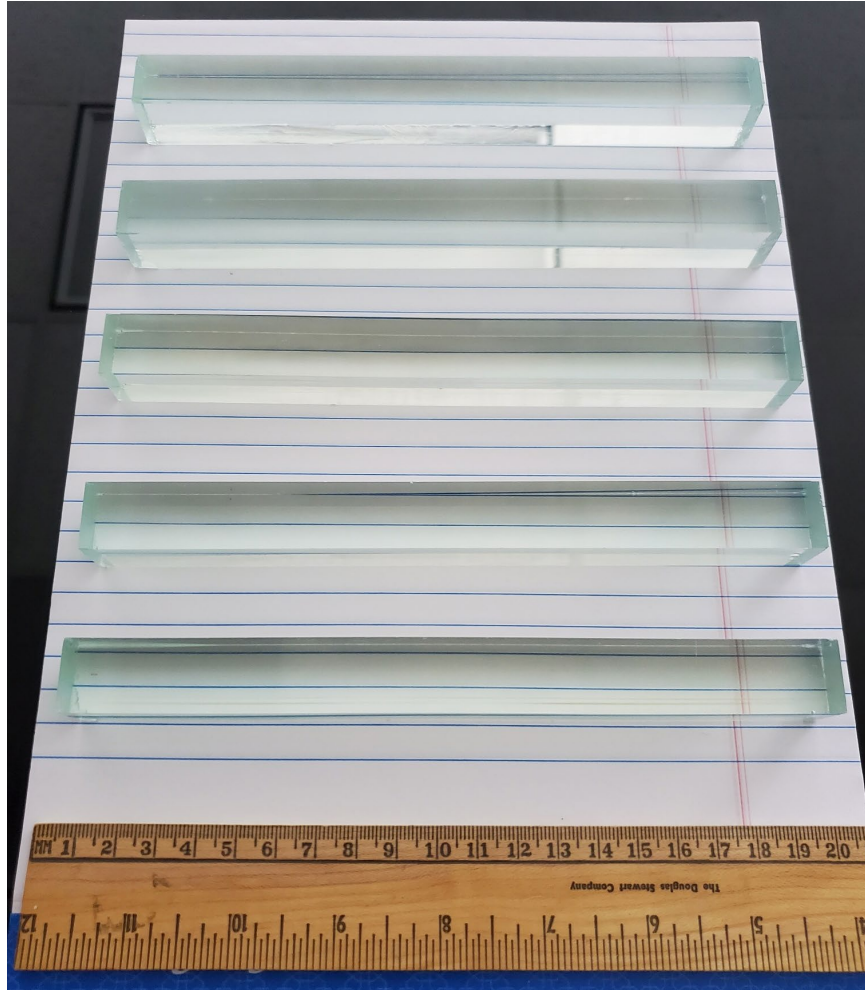
N	Configuration	Photosensor	GlueX Run	Energy, GeV	ER, % raw	ER, % calib
1	PWO+PMT	PMT Hamamatsu R4125-01	81386	4.698+-0.013	2.1%	1.8%
2	PWO+SiPM (INFN RO)	SIPM Hamamatsu S13360-6025CS	81518	4.698+-0.013	2.3%	2.1%
3	PWO+SiPM (CRYTUR RO)	SIPM Hamamatsu	-	-	-	-
4	Glass+PMT+Amp	PMT Hamamatsu R4125-01	81489	4.698+-0.013	10%	9.1%
5	Glass+PMT without Amp	PMT Hamamatsu R4125-01	81526	4.698+-0.013	12.3%	11.6%
6	Glass+PMT without Amp	PMT Hamamatsu R4125-01	81564	3.918+-0.013	12.5%	12.2%
7	Glass+PMT without Amp	PMT Hamamatsu R4125-01	81594	5.504+-0.013	11.1%	10.6%

Prototype 2021 Beam Tests First Results



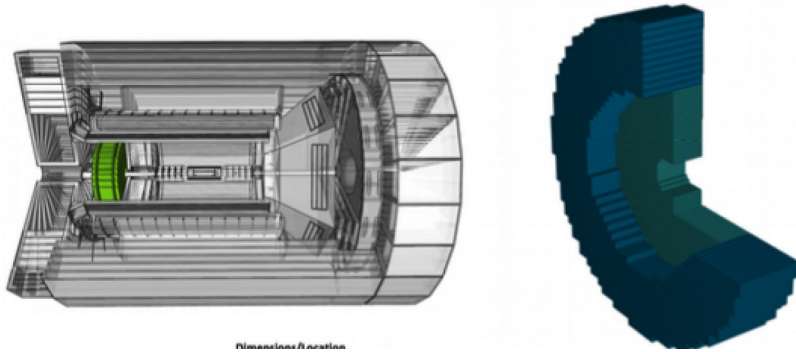
Data point from
beam test

SciGlass Status – November 2021



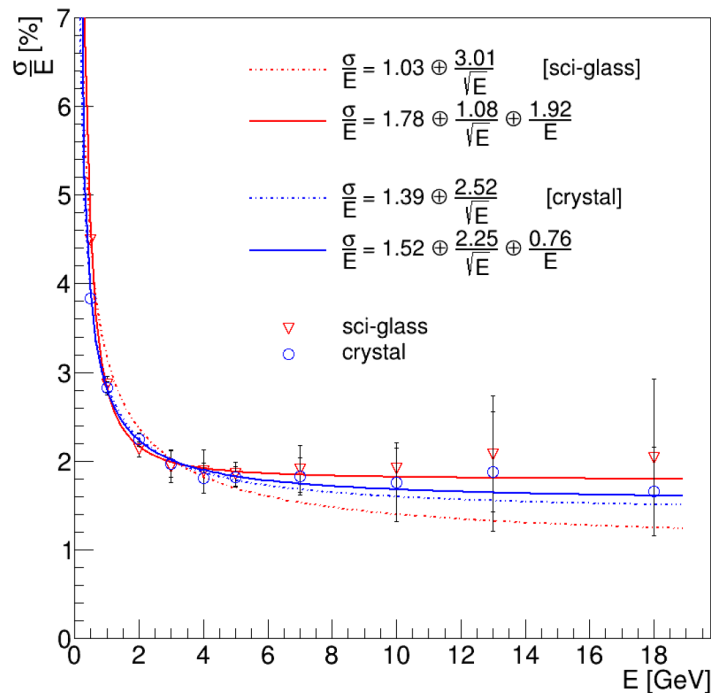
- ❑ Nine (9) SciGlass blocks of 20 cm length were produced for the small prototype beam test – uniformity looks promising
- ❑ The method for producing lab scale size samples (10-20) of length 20cm is now well established – performance needs to be tested with beam
- ❑ Samples of length up to 40cm have been made – optimization of the fabrication method for QA ongoing
 - FY22: Aim to demonstrate optimized method
 - FY22/23: Test first samples with beam

SciGlass – Preliminary Projections in EIC Detector



- High-resolution homogeneous EM calorimetry is part of all three proto-collaboration detector proposals.
- Encouraging: Initial simulations of SciGlass in EIC framework suggest a similar performance for 40 cm SciGlass with PbWO₄ crystals.

E resolution of inner[crystal] and outer[sci-glass]



Pion rejection factor inner[crystal] and outer[sci-glass]

