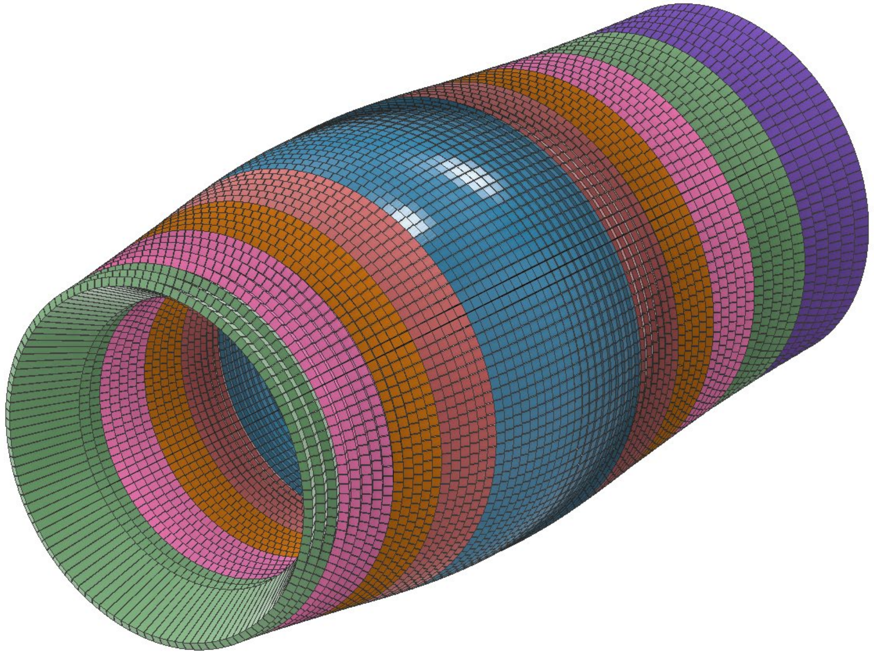
Electromagnetic Barrel Calorimetry



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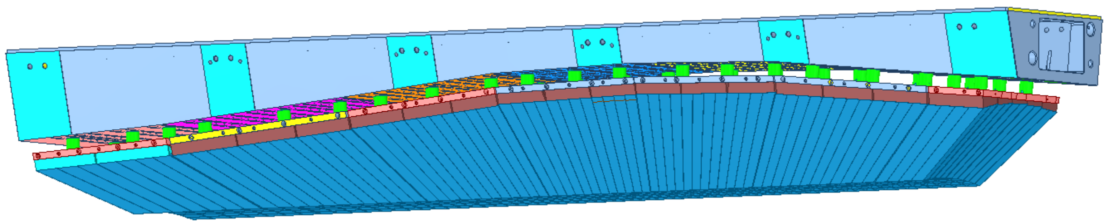
The Catholic University of America / Jefferson Lab



Ongoing Activities

- ❑ Pro-Con List for Calo WG
- ❑ Prototype beam test with 40cm long blocks – eRD105 (SciGlass) ahead of schedule with long block scale-up
- ❑ Further optimizations ongoing (e.g., to further minimize space between blocks and wedges)
  - O(1 mm) gap between blocks makes stacking easier (NPS choice: 0.5 mm).
- ❑ Simulations

Pro/Con List for SciGlass Barrel EMCal

From Calo WG meeting 9/1/22

Category	PRO	CON
Performance	• Well-established technology (homogeneous EM calorimeter) • Fulfills YR/NAS requirements even before optimization • Further optimizations ongoing (e.g., to further minimize space between blocks and wedges)	• O(1 mm) gap between blocks makes stacking easier (NPS choice: 0.5 mm).
Risk	• Main risks of developing high-quality SciGlass were addressed by DOE/SBIR grants and generic detector R&D program • Performance for 7X0 glass validated by prototype test • Several 15X0 (40 cm) blocks routinely produced now • Experienced team of institutions taking on the construction • 13 universities (10 US, 3 international)	• Delay of beam validation with 15 X0 glass in Hall D (scheduled Fall 2022)
Integration	• Matched to backward region needs • Requires no additional technology for readout electronics – can be identical to backward EMCal • Moderate number of readout channels • Advanced design concept built on PANDA precision homogeneous barrel EMCal design • Adding serviceability of individual wedges (24 or 12)	• Radial space need, would prefer 17 X0 (~45 cm) – addressed by ongoing work to optimize frame, serviceability and minimization of readout space need. • Gap of O(1 cm) between wedges
Cost	• SciGlass is cost-effective option for homogeneous calorimetry • 80% of labor provided in-kind – domestic and international • Opportunities for many early-career in-kind contributions • NSF/MSRI proposal discussed – additional in-kind for materials • No long-lead items	

Cost

- SciGlass is cost-effective option for homogeneous calorimetry
- 80% of labor provided in-kind – domestic and international
- Opportunities for many early-career in-kind contributions
- NSF/MSRI proposal discussed – additional in-kind for materials
- No long-lead items

SciGlass Barrel Cost from WBS06.10.05 (May 2022)

	N of towers	M&S, $	Labor, h
Barrel	**8800**	**$15,668,721**	**16,319**
e-endcap	3256	$7,103,707	36,249
h-endcap	53616	$4,272,708	17,276
Total	65672	$27,045,136	69,844

- ❑ Opportunities for many early-career **in-kind contributions** for radiator, design/construction, simulation, readout
- ❑ **80% of the labor hours are provided in-kind**.
- ❑ Based on previous experience these can be completed with students and postdocs, e.g., past experience with Q&A for order 1000 crystals.
- ❑ **Opportunity also for in-kind for M&S (NSF MSRI)**

NSF Proposal – additional in-kind for equipment

"Apparatus for the Detection and Identification of Electrons of the Electron-Ion Collider"

Will submit to FOA later in 2022

13 institutions, 10 US, 3 international

EIC-NSF Level XX (Draft)	Institution (Draft)	Major Funding	Major Team Member (Draft)
Mechanical Structure	IJCLab-Orsay MIT/MIT-Bates	International DOE	Carlos Munoz-Camacho Richard Milner
Radiator	Charles U./Prague CUA	International NSF	Miroslav Finger Tanja Horn
Front-end electronics	Lehigh U. FIU	NSF and DOE DOE	Rosi Reed Lei Guo
Back-end readout electronics, DAQ, full-chain tests	James Madison U. Ohio U. JLab	NSF NSF DOE	Ioana Niculescu Justin Frantz Vladimir Berdnikov
Prototyping, test stands, calorimeter assembly	AANL U. Kentucky Abilene Christian U.	International NSF DOE	Ani Aprahamian Renee Fatemi Jim Drachenberg
Simulation, reconstruction	W&M (also Ohio U.)	NSF and DOE	Cristiano Fanelli

Consortium: Electromagnetic Precision Calorimetry

(AANL, CUA, UKY, MIT, Lehigh, FIU and IJCLab had earlier meeting with NSF to pre-discuss) followed by meeting DOE-NSF-EIC PM

Abilene Christian University

A. Alikhanyan National Laboratory

The Catholic University of America

William & Mary
Chartered 1693

Massachusetts Institute of Technology

University of Kentucky

Ohio University
1804

Lehigh University

Charles University in Prague

FIU
Florida International University

IJCLab
Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

JMU
James Madison University

Jefferson Lab

+ possible additional institutional interest

University of Regina

University of Illinois Urbana-Champaign

University of Colorado Boulder

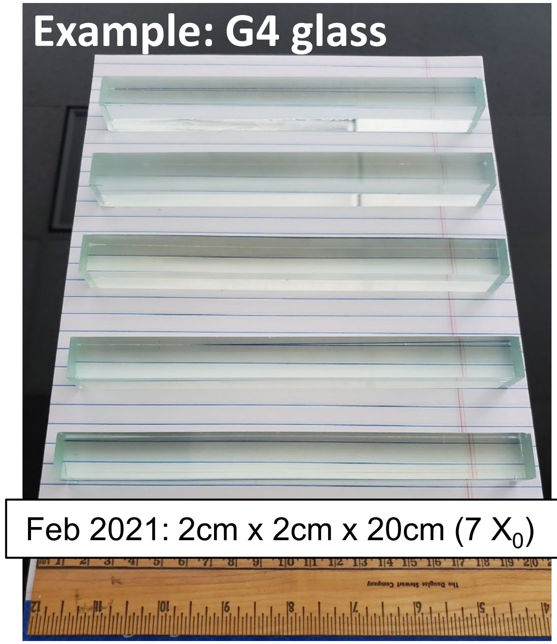
AU
Augustana University

Risk

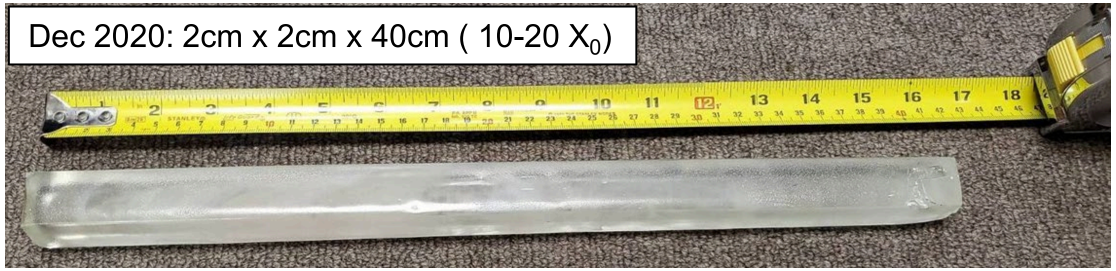
- Main risks of developing high-quality SciGlass were addressed by DOE/SBIR grants and generic detector R&D program
- Performance for 7X0 glass validated by prototype test
    - Delay of beam validation with 15 X0 glass in Hall D (scheduled Fall 2022)
- Several 15X0 (40 cm) blocks routinely produced now
- Experienced team of institutions taking on the construction
- 13 universities (10 US, 3 international)

Production: Radiator

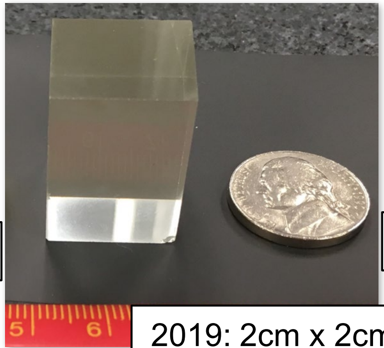
- SciGlass 20cm has been produced reliably; We tested a 3x3 20 cm SciGlass prototype detector in beam and measured its performance (ongoing R&D EEEMCAL consortium, eRD105)
- **Measured performance for 20cm SciGlass ($7X_0$) as per GEANT simulation**
- We have an SBIR phase-II to start large-scale production or larger blocks (40+ cm, rectangular and projective shapes)
- Received the first polished 40 cm SciGlass ($15X_0$) late 2021; issues identified and fixed
- SciGlass 40cm can now be produced routinely; received the first detector prototype 40cm SciGlass two weeks ago, eight more coming in the next few days



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



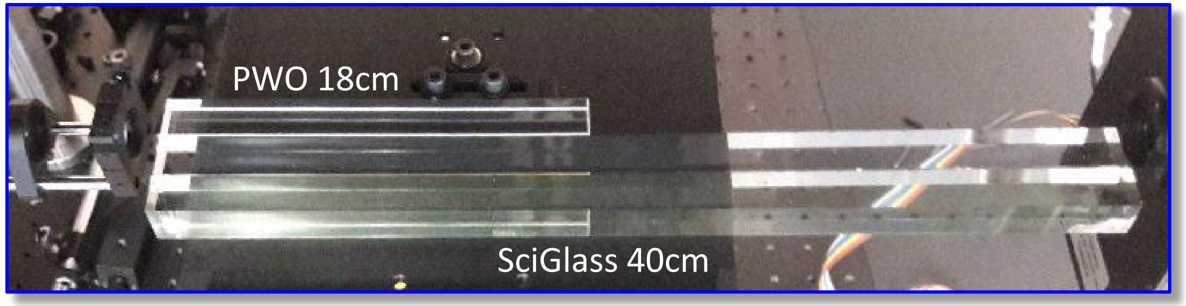
Dec 2020: 2cm x 2cm x 40cm (10-20 X_0)



2019: 2cm x 2cm x 4cm

2018: 1cm x 1cm x 1cm

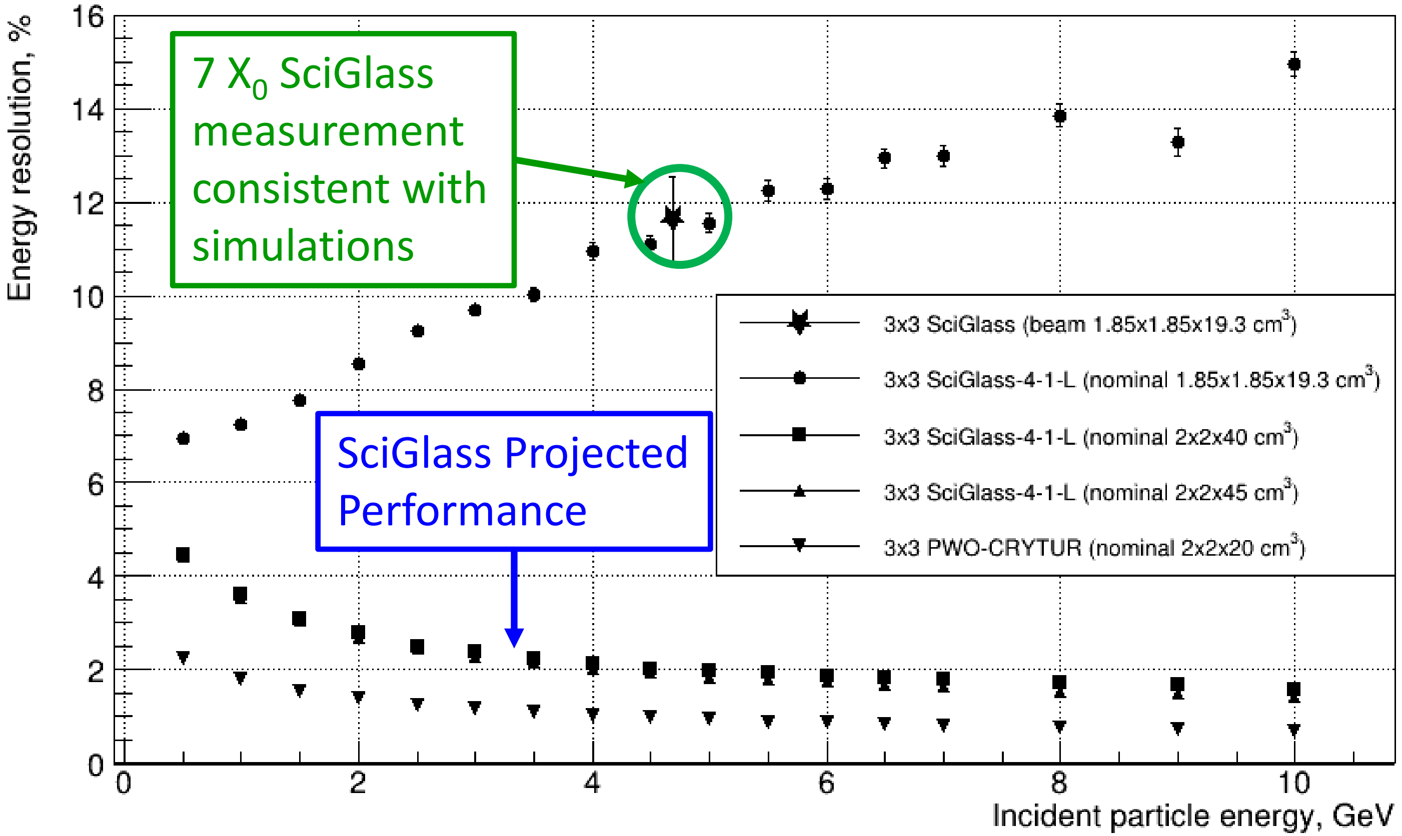
Summer 2022: 2cm x 2cm x 40cm (10-20 X_0) first detector prototypes



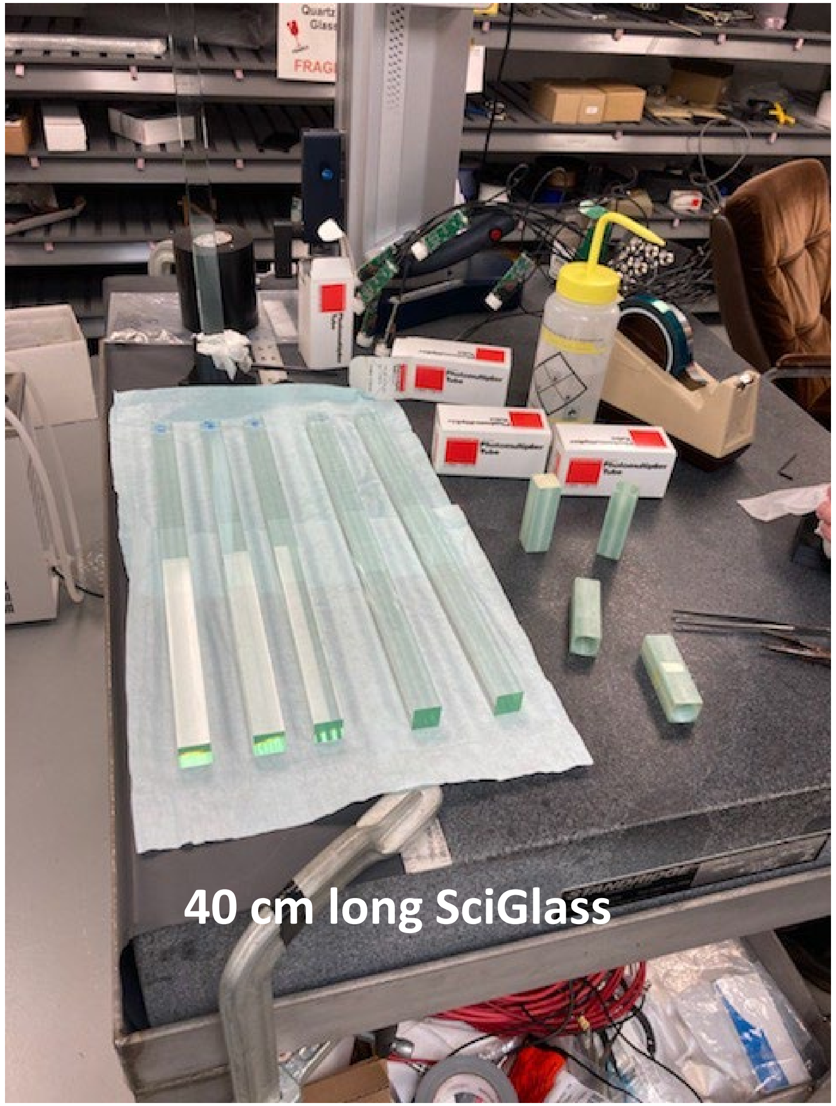
SciGlass Projected Performance

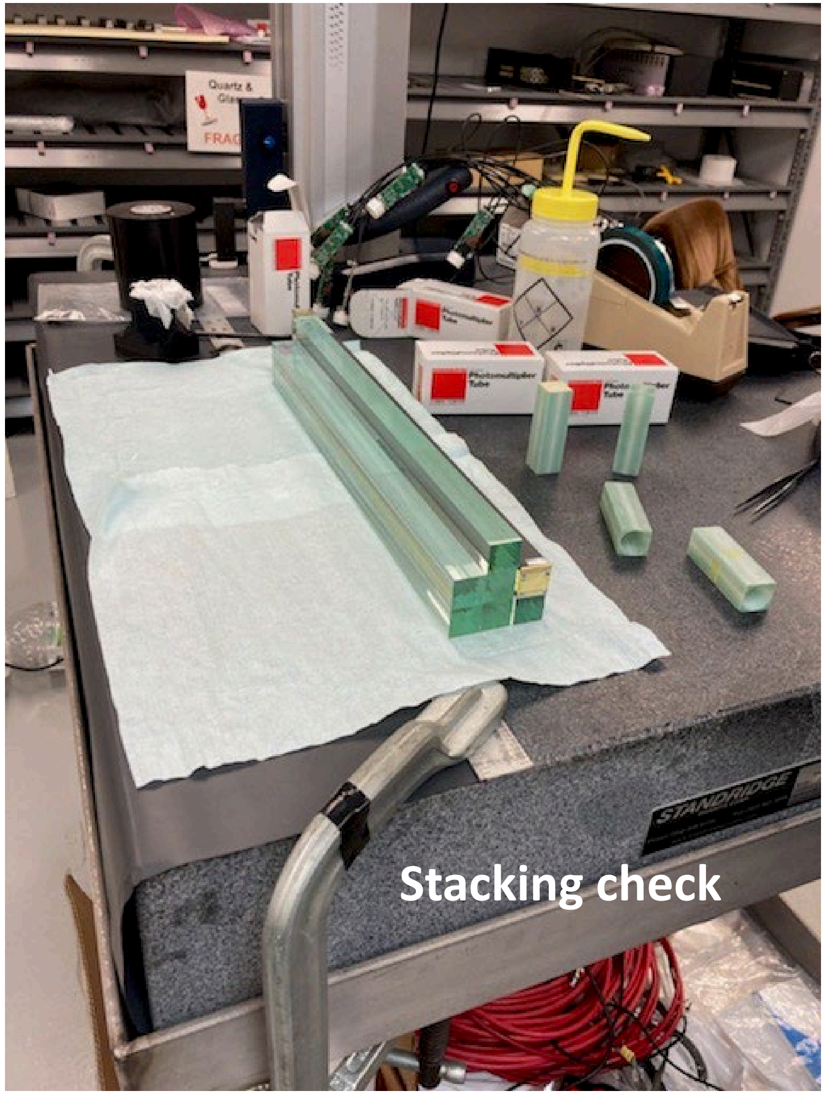
SciGlass development is supported by SBIR/STTR DE-SC0020619

- 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**



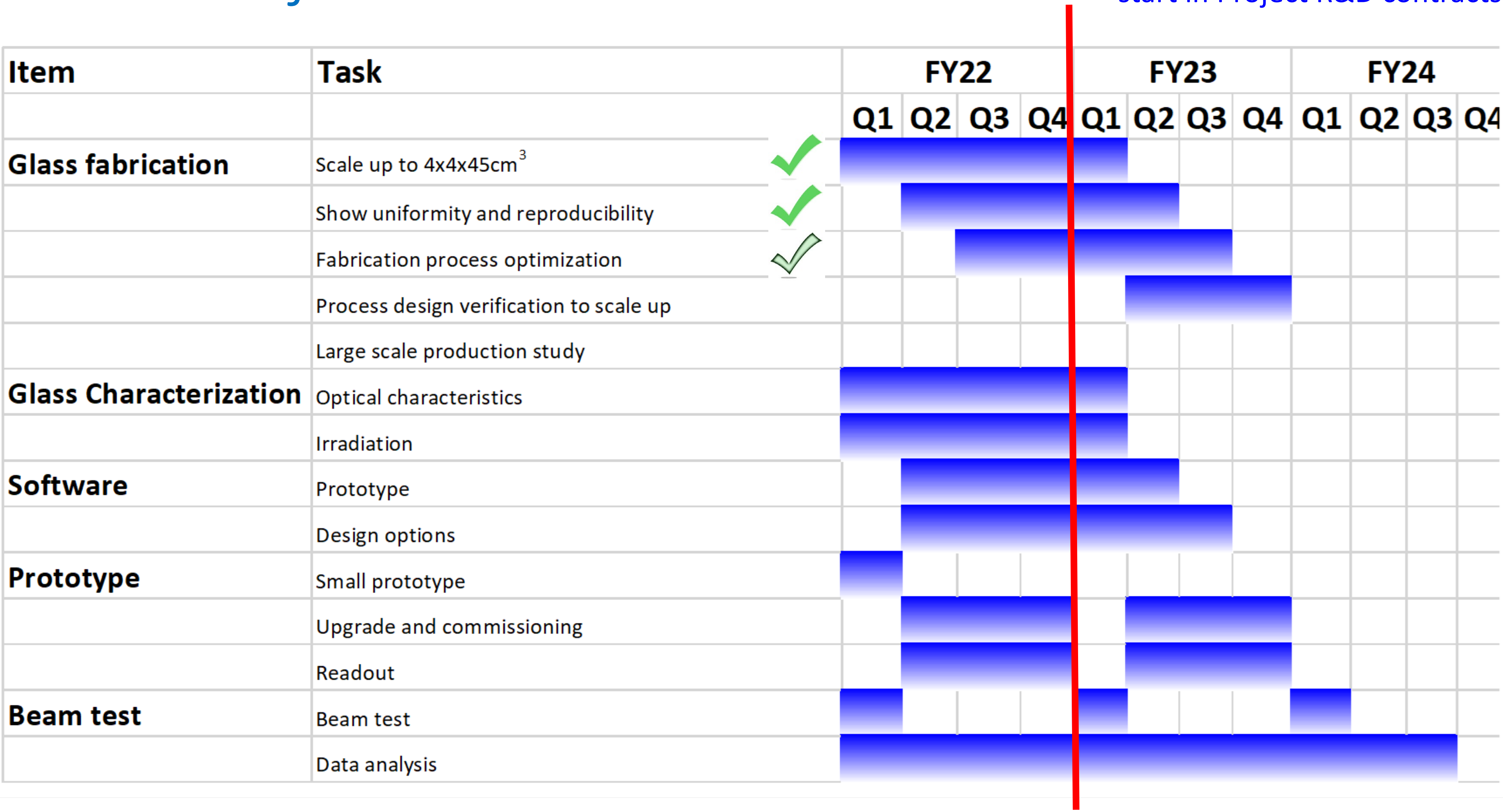
Preparations for Prototype Test





eRD105 Project R&D Timeline

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



Integration

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  - Radial space need, would prefer 17 X0 (~45 cm) – addressed by ongoing work to optimize frame, serviceability and minimization of readout space need.
- Requires no additional technology for readout electronics – can be identical to backward EMCal
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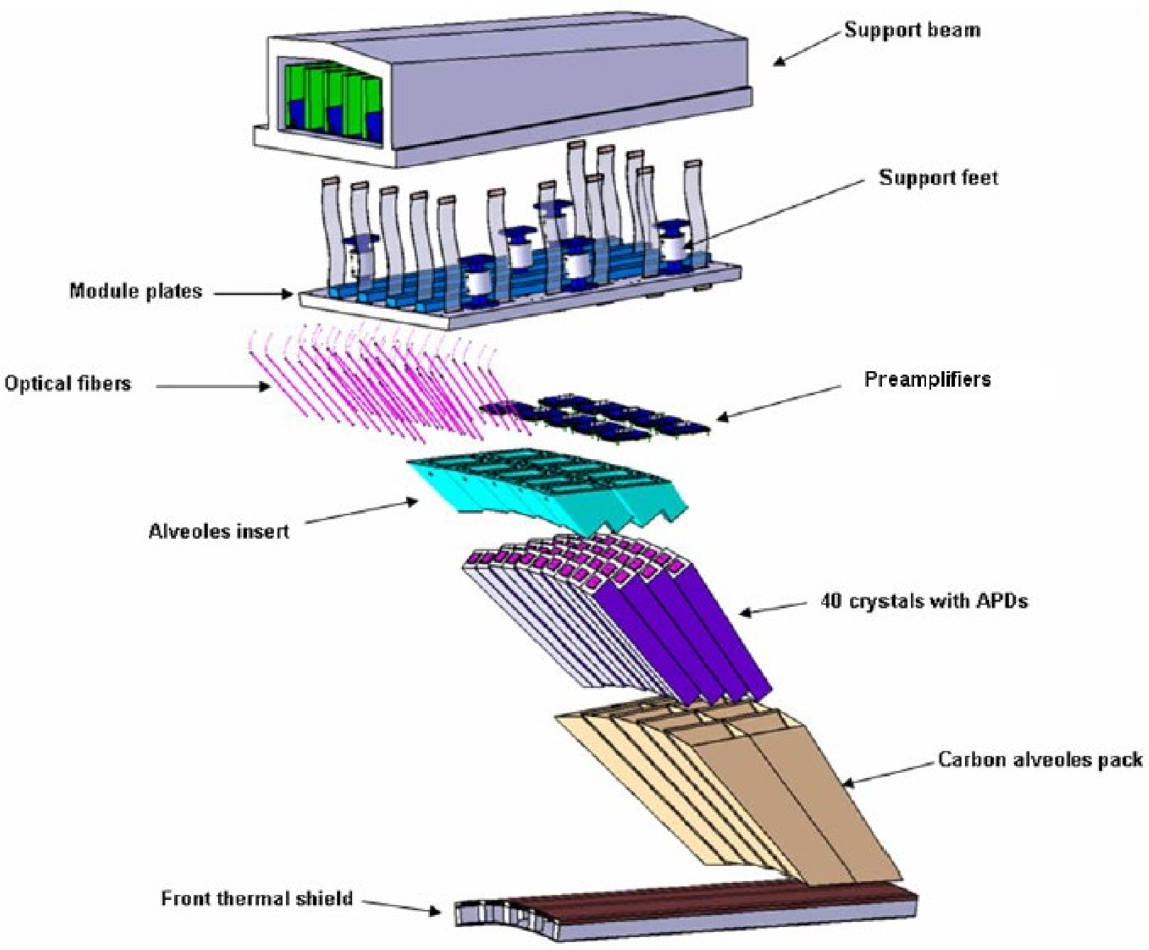
  - Gap of O(1 cm) between wedges

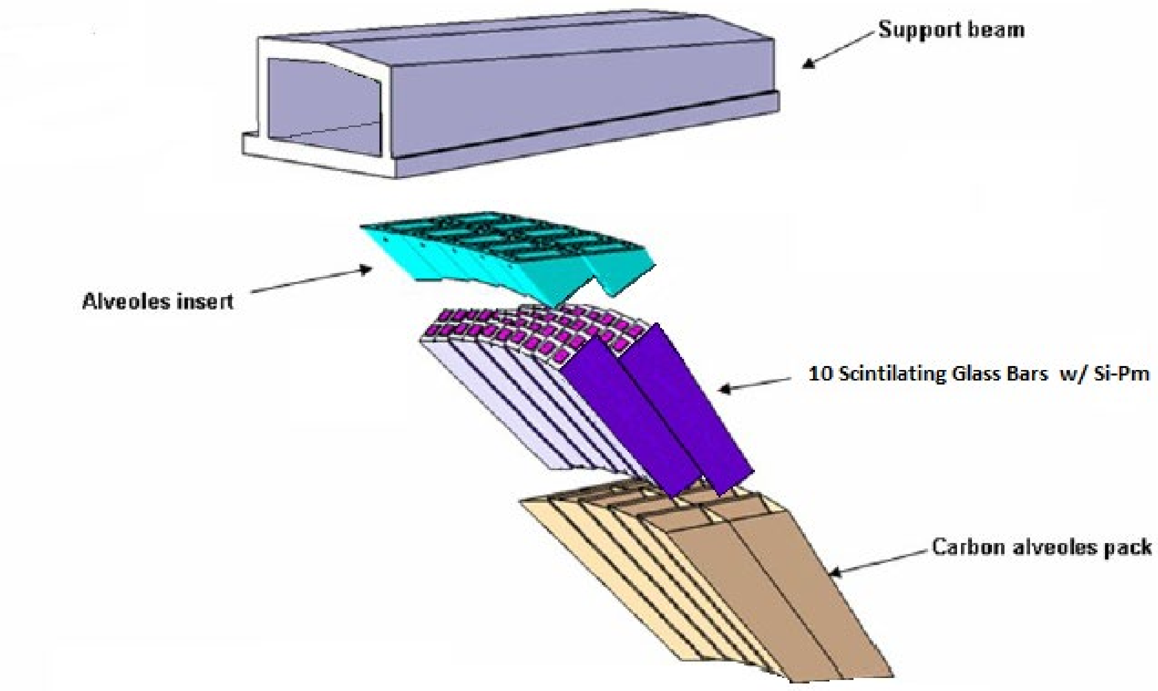
Design optimizations

Optimizations to optimize frame, serviceability and minimization of readout space

PANDA



EIC



EIC variant would omit the module plate and support feet layer and attach the alveoli’s inserts directly to the support beam as well as omitting the front thermal shield.

Ongoing Activities

- **Simulation – updating the Barrel EMCal model (U. Kentucky, FIU, AANL)**
  - DD4HEP (Dmitry Kalinkin, Renee Fatemi (U. Kentucky) with help from Wouter et al.)
  - Fun4All (Taya Chetry (FIU), Hamlet Mkrtchyan et al. (AANL), MIT, with help from Friederike, Nico et al.)
- **Mechanical – advancing the design (Josh Crafts, CUA and Avishay M., MIT, Rahul Sharma, BNL)**
  - Slide/supermodule details – also cooling, cabling, etc.
  - Attachment to support structure and optimization
  - Access and maintenance – Thomson slides integrated in frame or Teflon coating
- **Electronics/Readout – fully compatible with PbWO4 choices**
  - Geant simulation if similarly do not need light guides for SciGlass
- **Prototype beam tests Fall 2022 (Vladimir Berdnikov, JLab)**
  - 3 x 3 prototype of SciGlass 40cm
  - SiPM readout with 10um - 50um pixel pitch matrices – also relevant for PWO

Homogeneous Design based on PANDA

PANDA

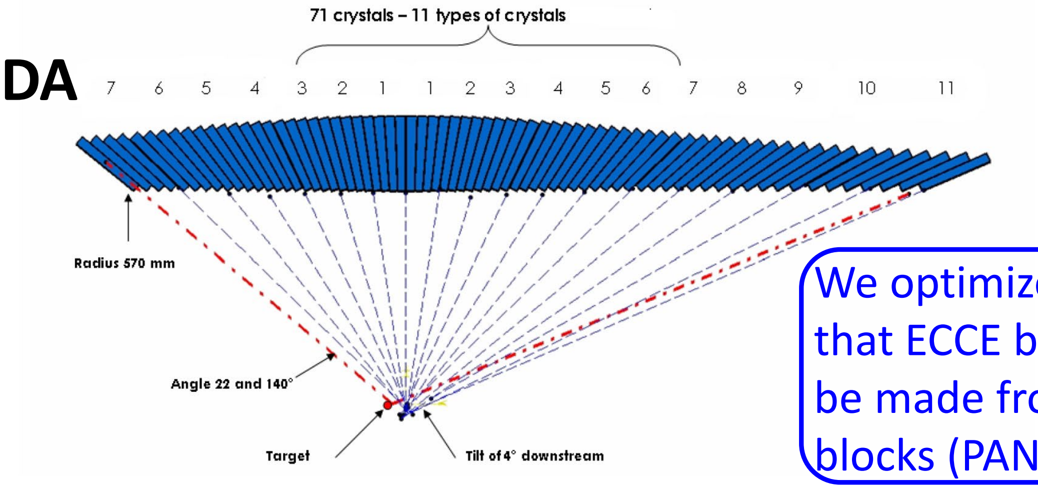


Figure 5.4: Crystal arrangement of the barrel along the beam axis. Positions of the different crystal types are indicated. Due to the mirror symmetry, 11 types are sufficient instead of 18.

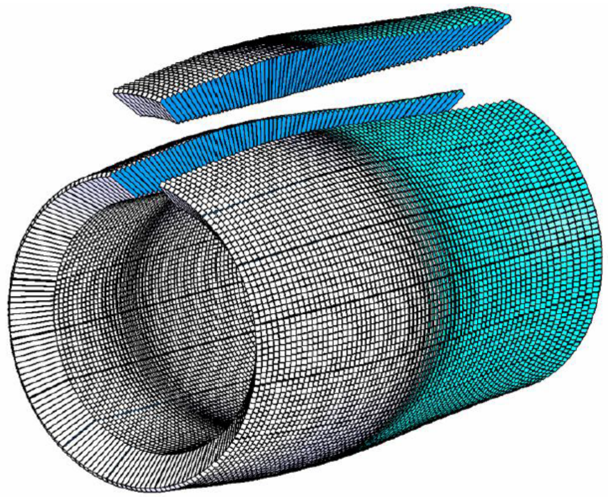
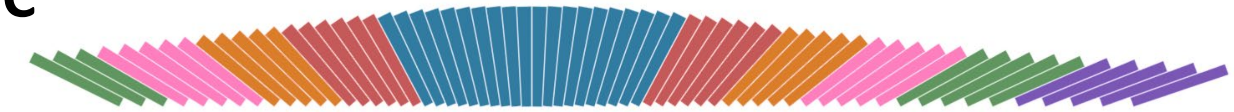


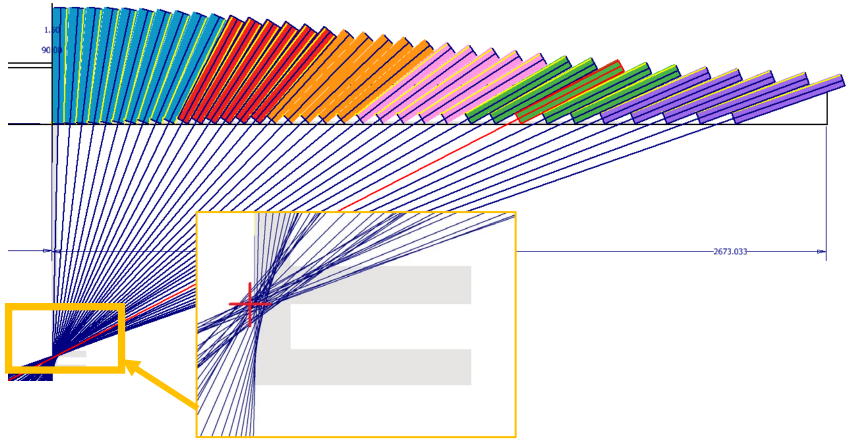
Figure 5.5: View of the total barrel volume with a separated single slice of 710 crystals. A slice covering 1/16 of the barrel volume.

EIC

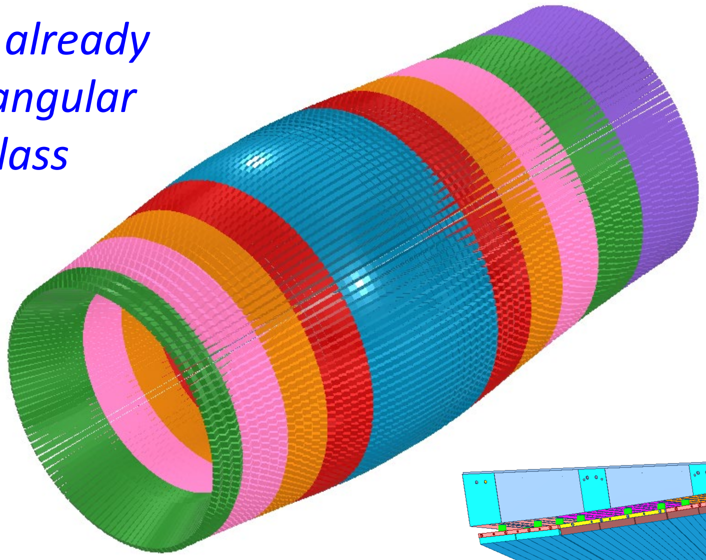
Based on realistic CAD design (CUA)

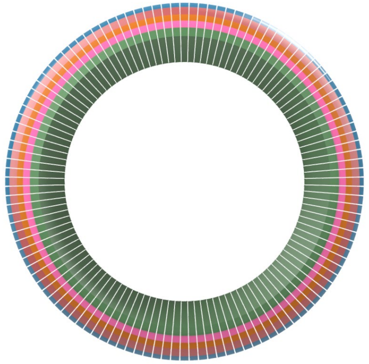


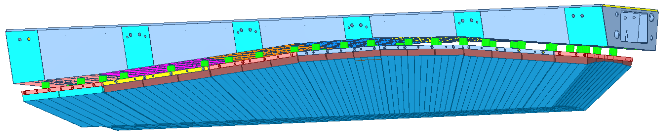
We optimized the geometry so that ECCE barrel calorimeter can be made from 6 families of blocks (PANDA has 11 families)



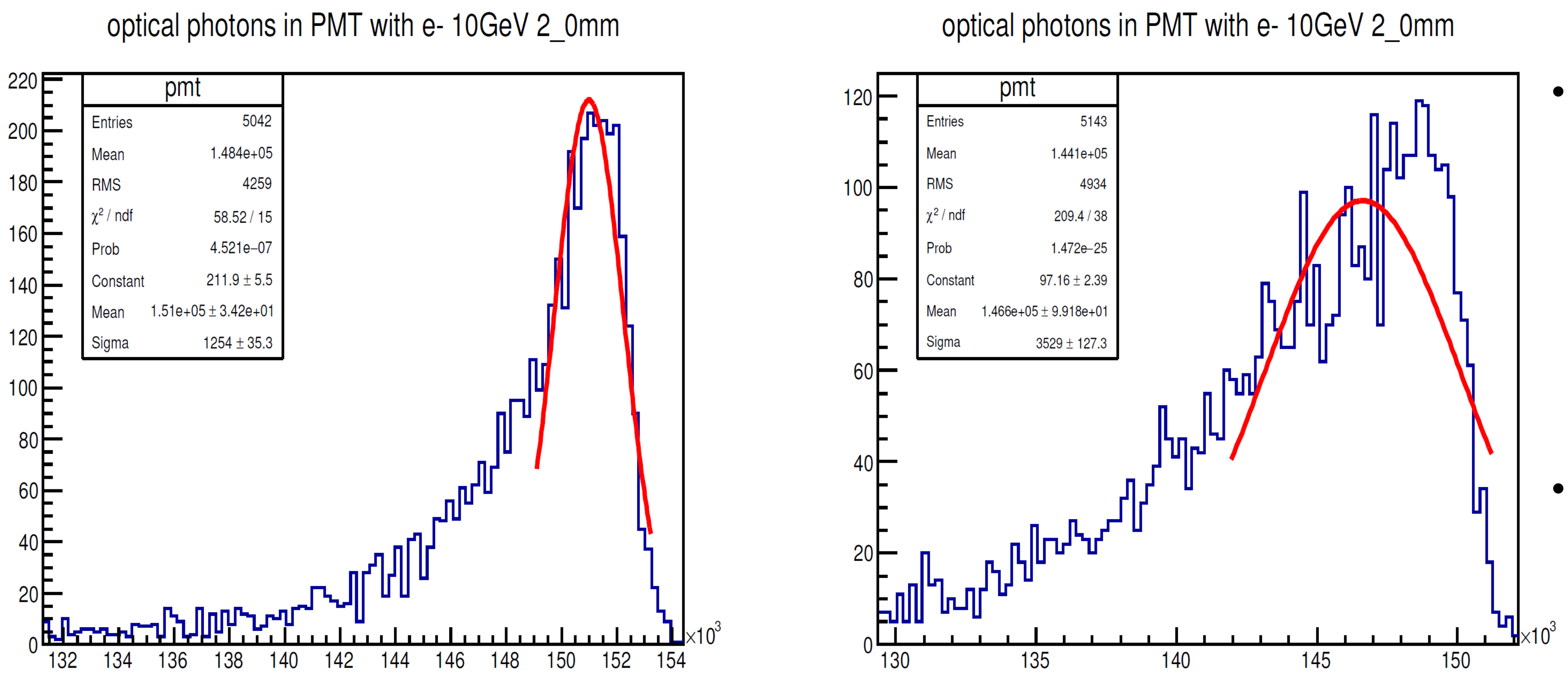
With these families we already reduced any gap both angular and radially between glass blocks to O(1mm)







Impact of Gaps Between Blocks – Example PWO



(a) Air gap

(b) Carbon gap

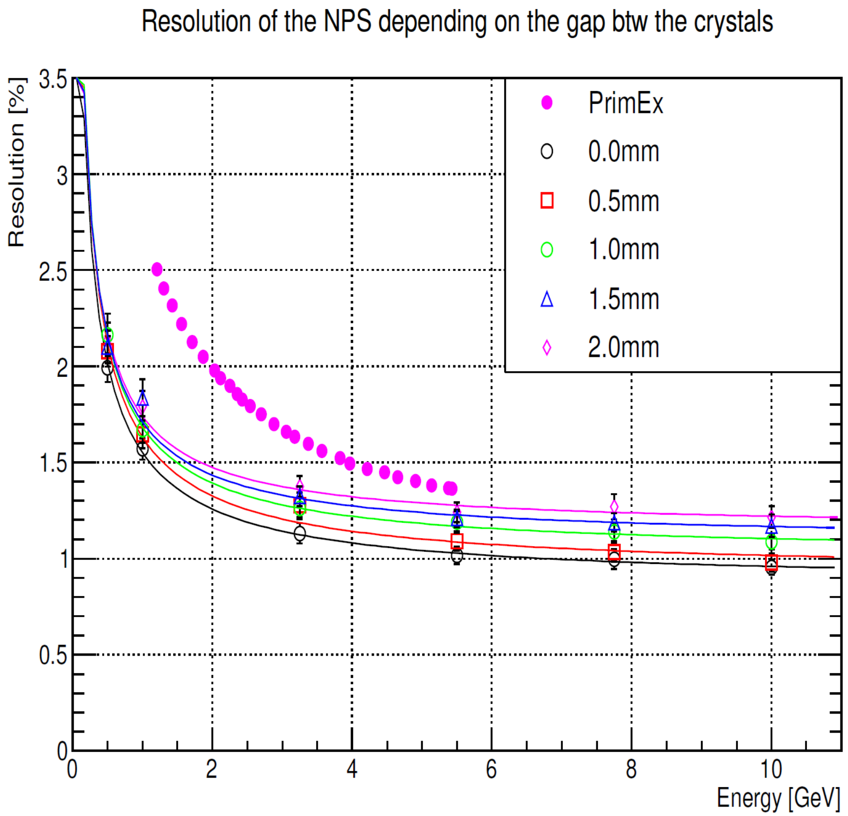
Figure 6: Comparison of the 10GeV gamma energy deposition histogram

Gap : 2mm

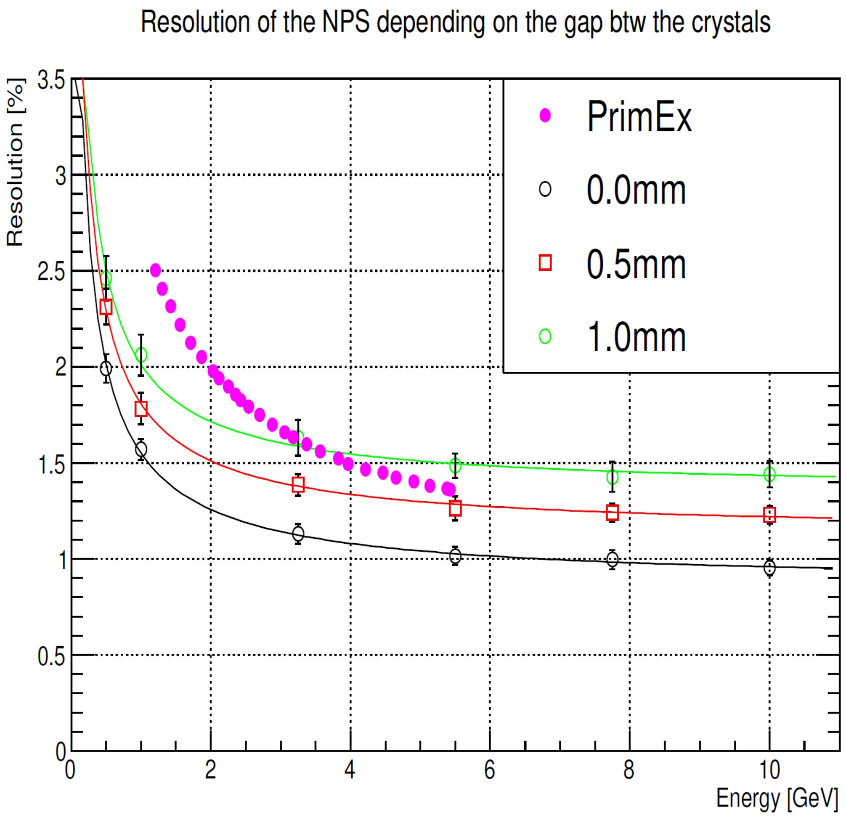
- *Note that in the limit of no or very small gaps the energy resolution and pion rejection will be 1 to 1 correlated.*
- *If gaps become larger (or one has material in front) then one creates tails and the e/h separation gets worse.*

For the 2 x 2 x 20 cm3 PbWO4 crystals the impact of a 2 mm air or carbon gap has been well studied

Impact of Gaps Between Blocks – Example PWO



(a) Air gap



(b) Carbon gap

Figure 7: Comparison between the air gap & carbon gap. 1% miscalibration.

For the 2 x 2 x 20 cm^3 PbWO4 crystals the impact of an air or carbon gap has been well studied.
→ A gap of 2 mm air gives about the same performance as a gap of 0.5 mm carbon.

- For NPS the choice became a 0.5 mm air gap with only a small piece of carbon in front and back of the crystal to hold them as compromise between resolution and ease of installation.
- The impact of gaps for SciGlass needs to be similarly understood – resolve by updating the barrel EMCal model in simulation. Mechanically, we have found that with six families of 4 x 4 x 45 cm^3 SciGlass blocks we can already limit to a < 3 mm air gap (flaring from < 1 mm in the front to ~2.5 mm in the back). Further mitigation is possible (more families, look at interaction region) As with NPS we likely would use a small piece of carbon in front and back of the glass to hold them, but the main gap will be air. Between the supermodule wedges (each containing 5 x 65 glass blocks) there would be of O(1 cm) gap for stainless housing, needed for ease of wedge removal.
- For SciGlass with block size 4 x 4 x 45 cm^3 we are now investigating the effect of these gaps in simulations.