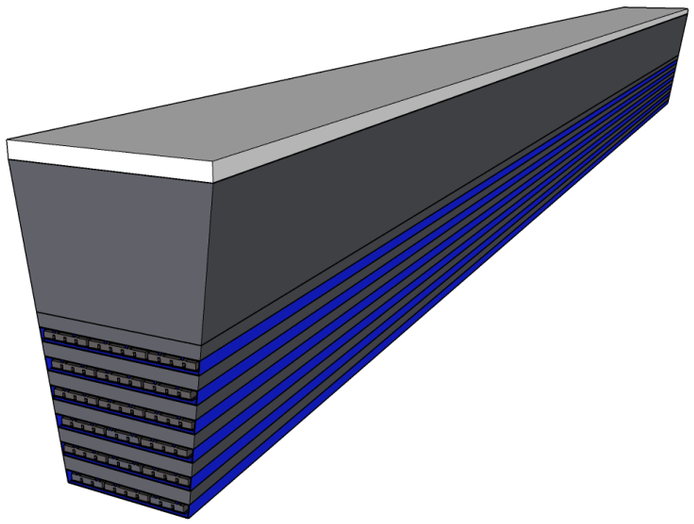
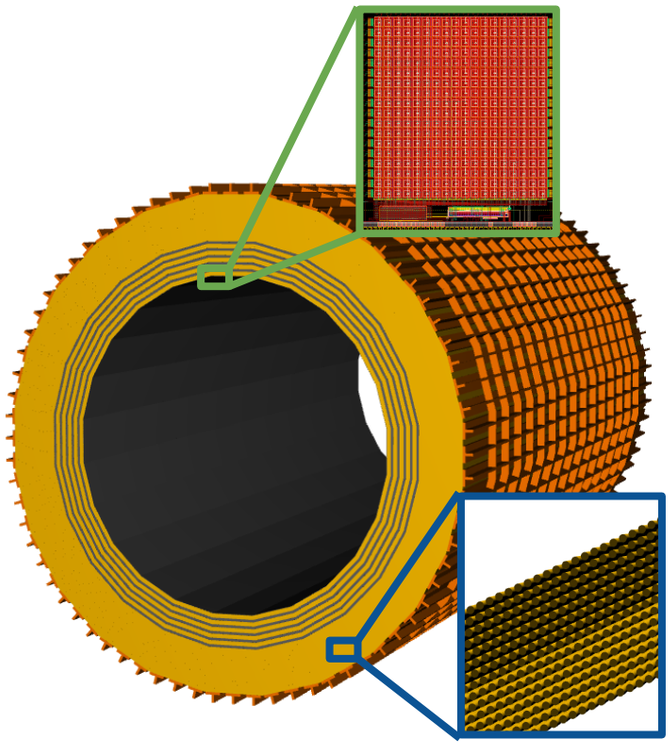




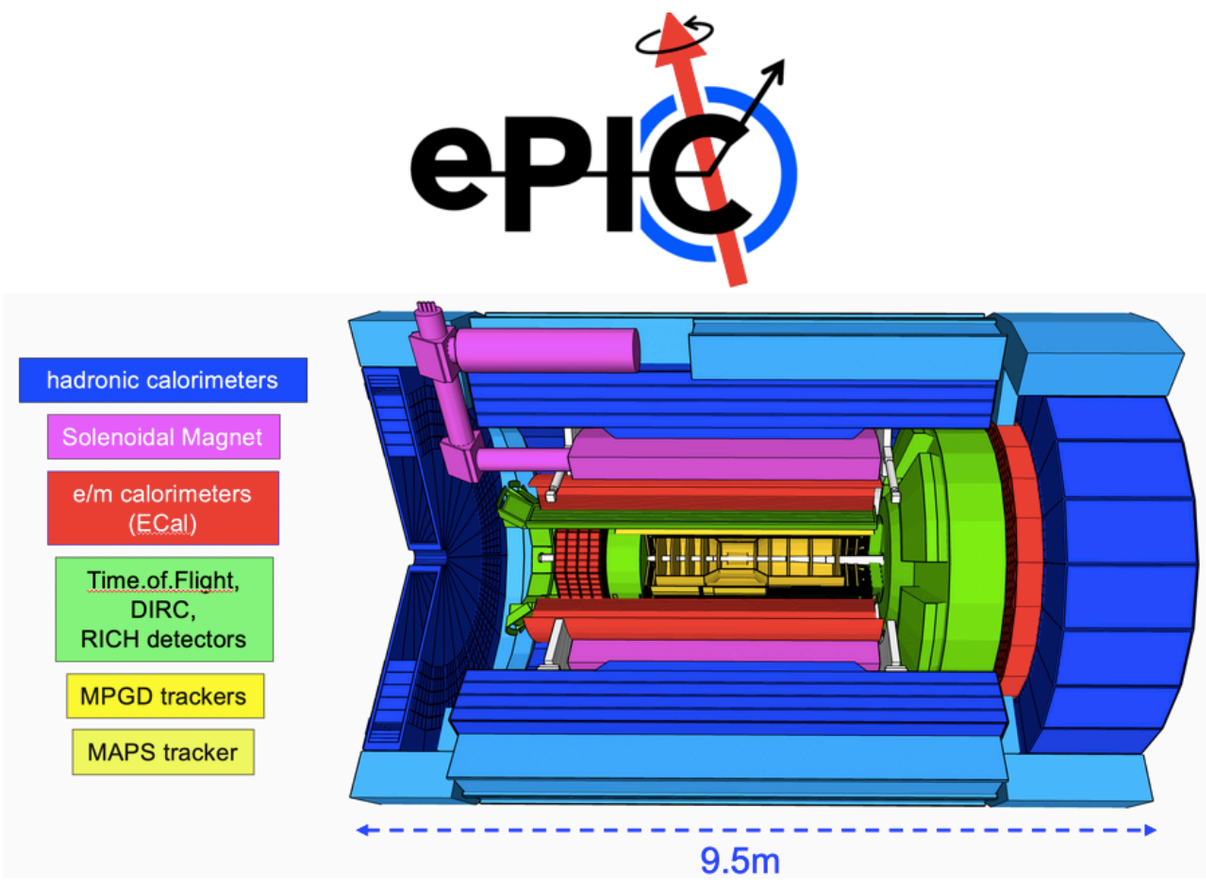
SciFi Review for ePIC/bECAL

Pre-Brief Slides

Z. Papandreou, M. Żurek, S. Joosten
for Imaging Barrel ECal DSC
September 13, 2023

Overview

- bECAL Consortium
- bECAL - Performance
- SciFi technology
- SciFi Assessment
- GlueX BCAL QA/QC
- Bottom Line



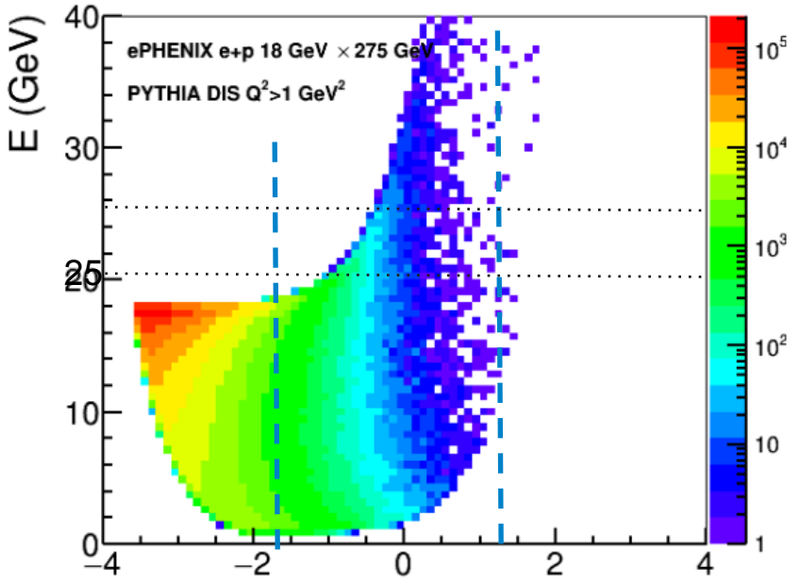
EIC Calorimetry Requirements

EIC Yellow Report requirements for bECAL:

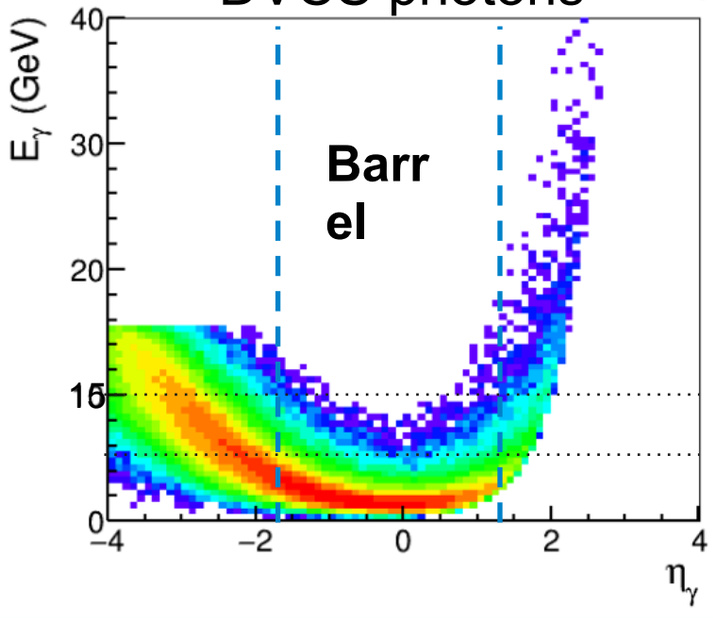
- Detection of electrons/photons to measure **energy and position**
- Require **moderate energy resolution** $10\%/\sqrt{E} \oplus (2-3)\%$
- Require **electron-pion separation up to 10^4** at low momenta in combination with other detectors
- Discriminate between **π^0 decays and single ɣ up to ~10 GeV**
- **Low energy photon** reconstruction ~100 MeV

Challenges: e/π PID, ɣ/π^0 discrimination, space

DIS electrons

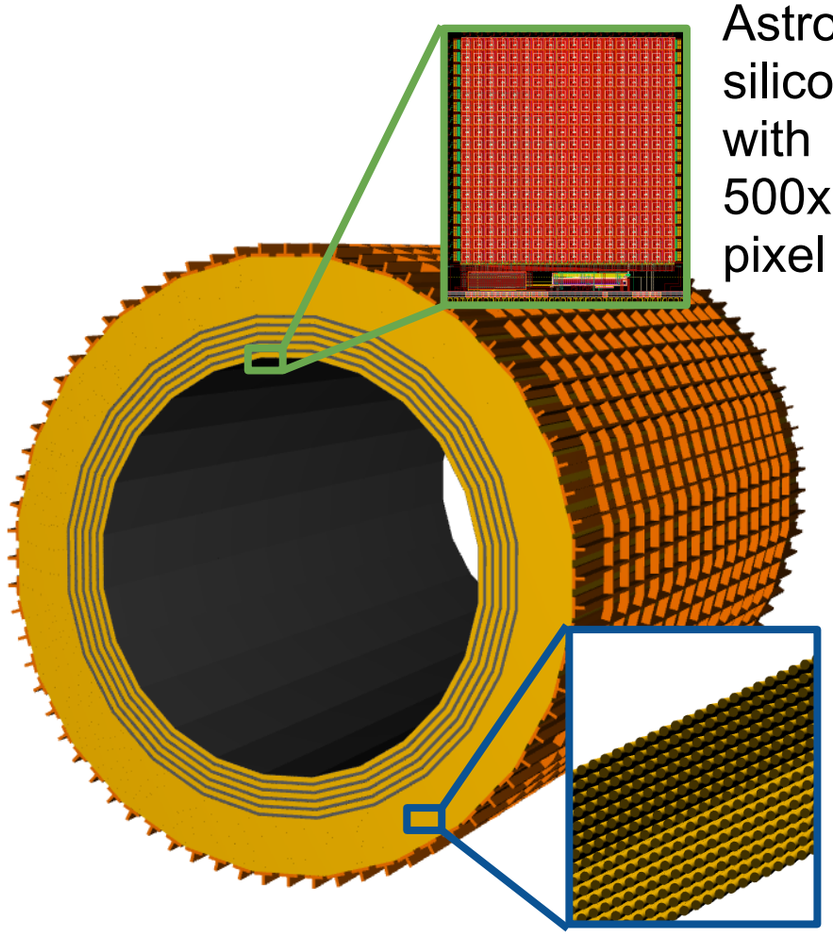


DVCS photons



bECAL Consortium

bECAL Performance

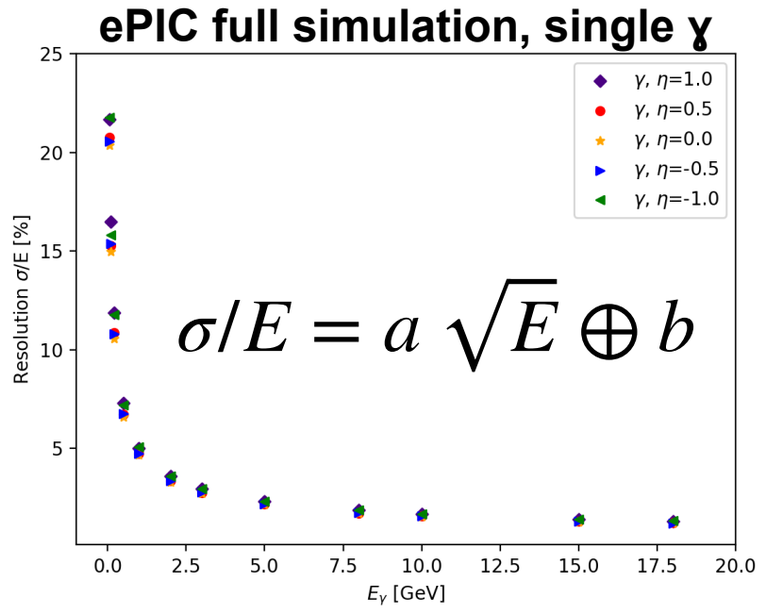


AstroPix: silicon sensor with 500x500μm² pixel size

SciFi Layers with **two-sided SiPM readout**

- Covers -1.71 < η < 1.31

- Total radiation thickness at η=0 ~17.1 X_0
- Sampling fraction (ΣE_{fibers} / E_{thrown}) ~10.3%



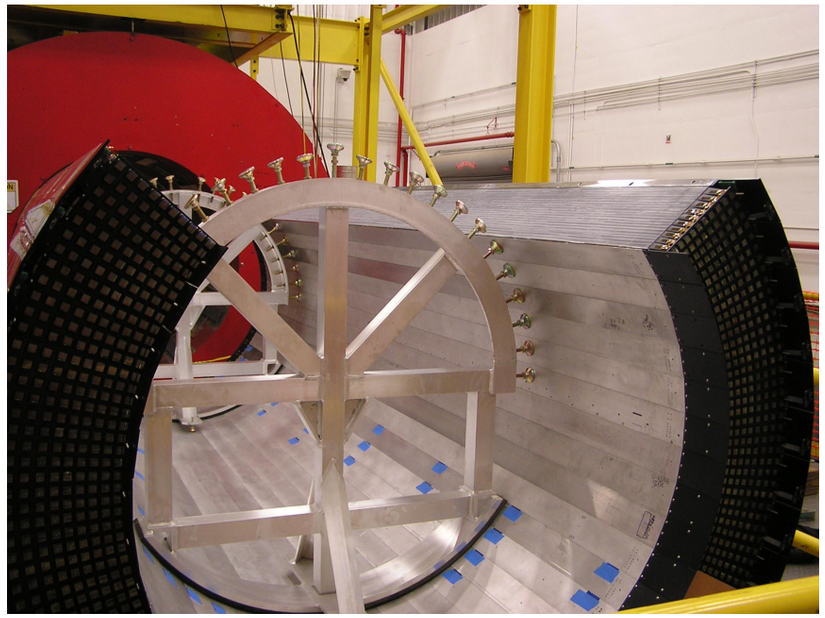
Fit parameters

η	a/√(E) [%]	b [%]
0	4.75(0.01)	1.02(0.02)

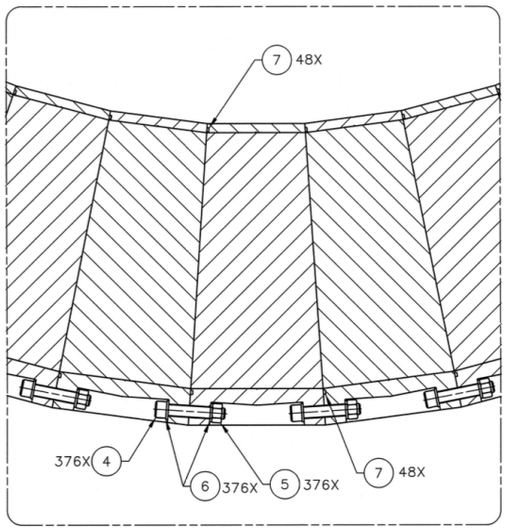
Energy resolution - Primarily from Pb/SciFi layers (+ Imaging pixels energy information)
Position resolution - Primarily from Imaging Layers (+ 2-side Pb/SciFi readout)

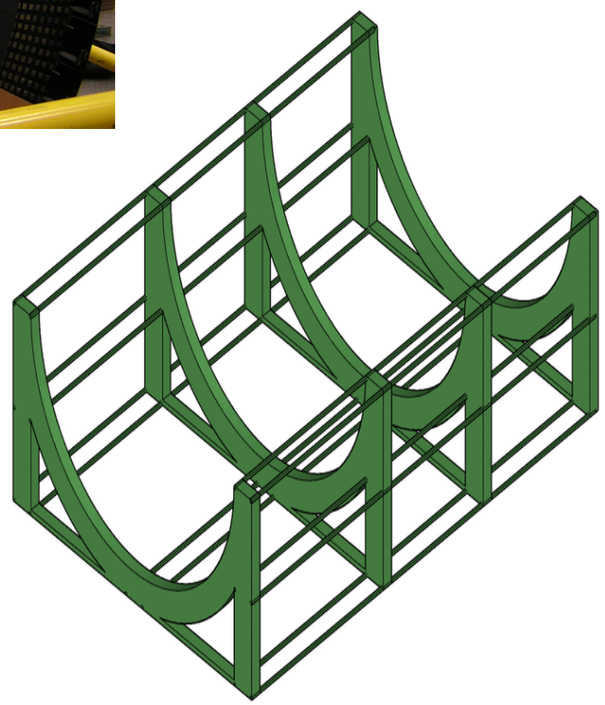
EM Barrel: ePIC v GlueX

GlueX self-supporting Arch



GlueX Stave Interconnections





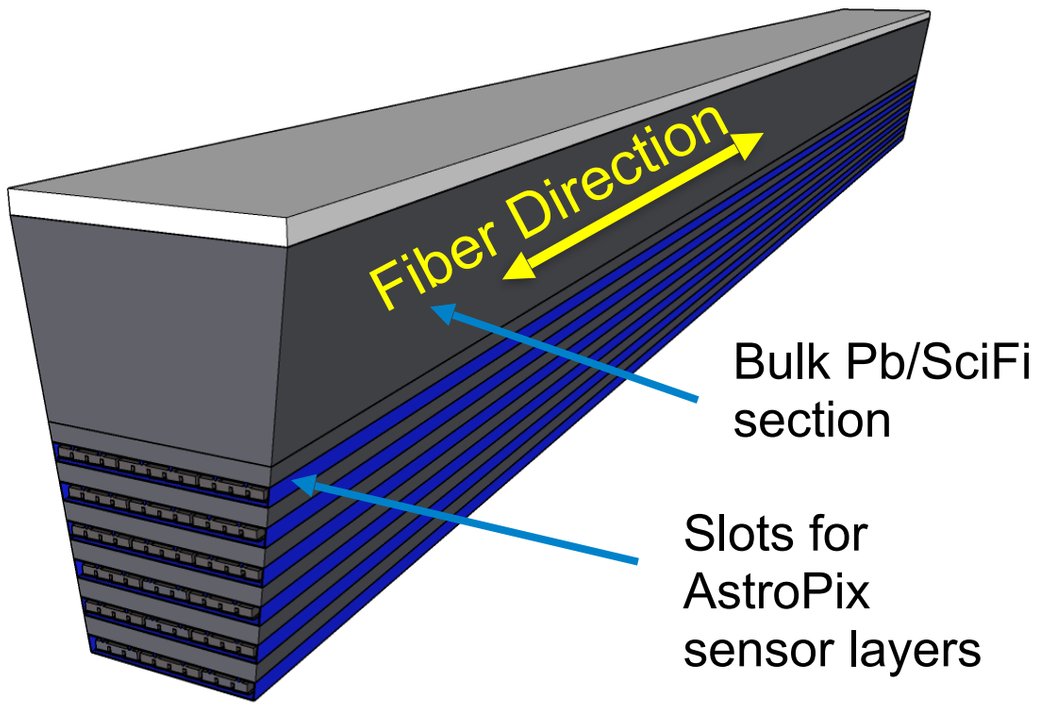
		ePIC	GlueX
Diameter (m)			
	Inner	1.62	1.3
	Outer	2.6	1.8
Length (m)		4.35	3.90
# Staves		48	48
Mass/stave (T)		1.1	0.58
Weight		36 tons	23 tons

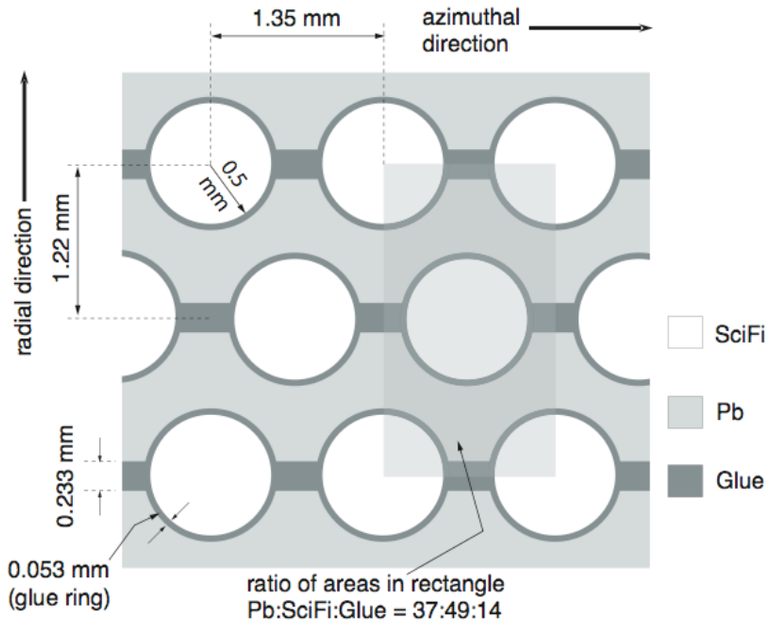
ePIC/bECAL & GlueX/BCAL

- Pb/SciFi construction
- 4,500 km vs 3,300km
- Hybrid vs Monolithic

bECAL Sector

Calorimeter Sector





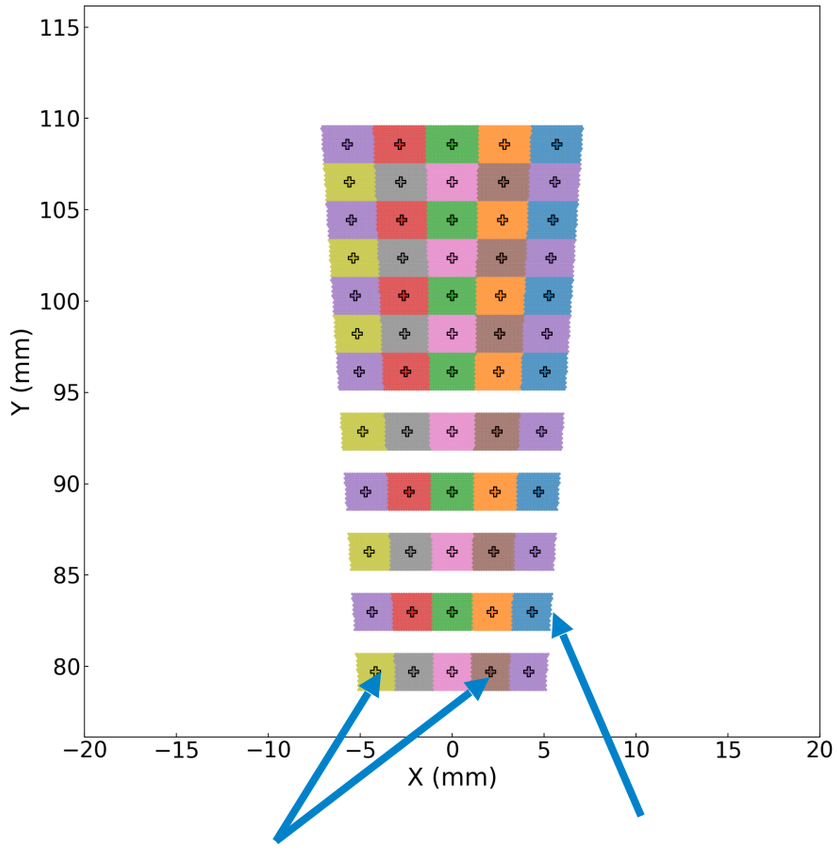
- 48 sectors:
  - Bulk at ANL
  - SFIL at Manitoba

- Inner: interleaved layers of imaging Si sensors with PbSciFi (SFIL- SciFi Imaging Layers)
- Outer: bulk Pb/SciFi section
- Light guides; optical cookie
- SiPMs as sensors

SiPM Readout

- **2-sided SiPM readout**
- **Lightguides** on sector sides
  - inner surface ~2×2 cm²
  - output face 1.3×1.3 cm²
- SiPMs that meet our requirements:
  - 4 x 6×6 mm² SiPMs (or equivalent) with 50 μm pixels (e.g. 4 x S14160-6050, or a pre-assembled S14161-3050-04 array)
  - same dimensions as GlueX but with better performance:
    - PDE = 50% (GlueX 33%)
    - Lower noise
- 12 layers x 5 cells x 2 sides x 48 sectors = **5760 channels**

ePIC Sector End View (x-y plane view), 17.1 X0

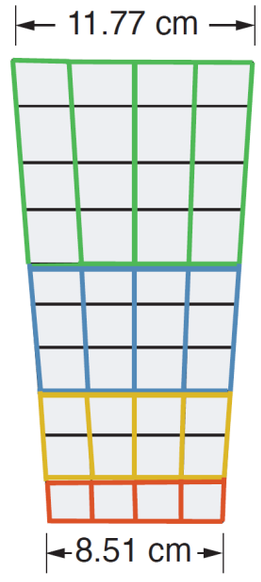


Readout **Cell**
The area 1 light guide is attached to
Layer = 5 cells

Pb/SciFi **Layer**

1 sector = 12 layers
1 layer = 17 fiber rows

GlueX Sector End View, 15.5 X0



Hamamatsu S12045(X)
4×4 array of 3×3 mm²
50×50μm² pixels

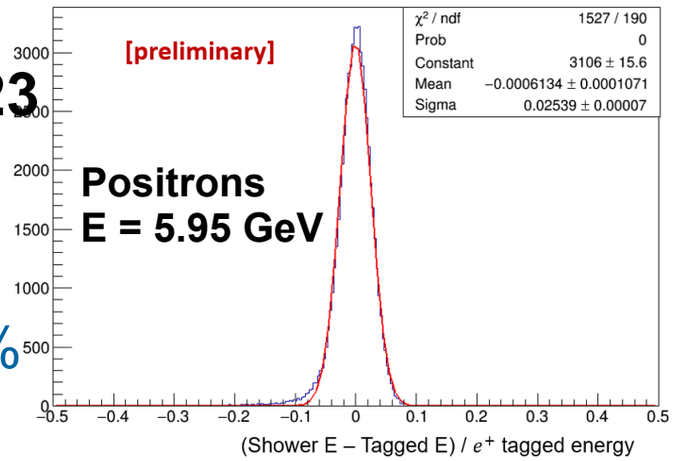
16 FADC per side
12 TDC per side

SciFi Technology

- Mature Technology: **GlueX**, KLOE EMCals
- Tested extensively for electromagnetic response in energies **E_γ < 2.5 GeV**
- **Energy resolution: σ = 5.2% /$\sqrt{E} \oplus$ 3.6%**[1)]
  - Newresults from Baby BCAL prototype in Hall D extend coverage to **6 GeV** and show that **constant term is < 2%**

Hall D, March 2023
Baby BCAL Test

Measured Resolution: ~ 2.5%

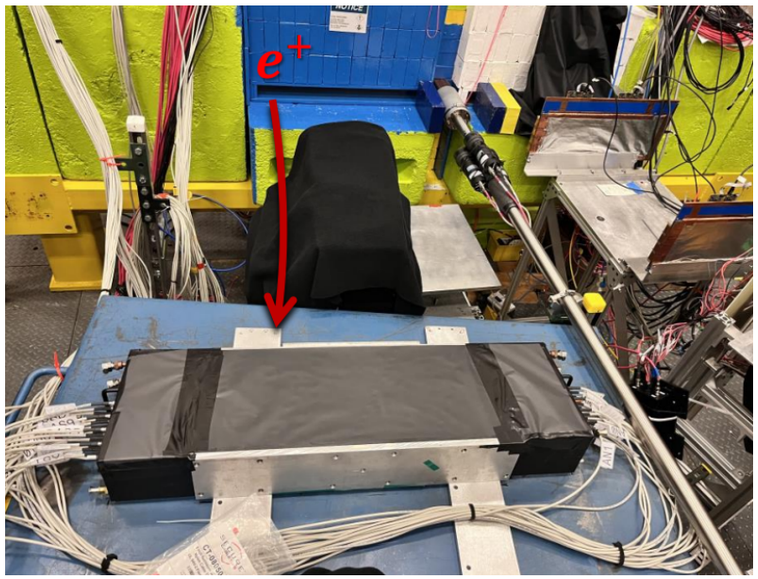


GlueX BCAL parameters

SiPMs: S12045(X) 4×4 array of 3×3 mm², 50μm pixel
https://ieeexplore.ieee.org/document/7161418,
https://www.sciencedirect.com/science/article/pii/S0168900213009042,
https://www.sciencedirect.com/science/article/pii/S0168900213017233

Lightguides: 8 cm long attached to the sector sides
https://halldweb.jlab.org/doc-public/DocDB/ShowDocument?docid=1784

Fibers: **double-clad** SCSF-78MJ

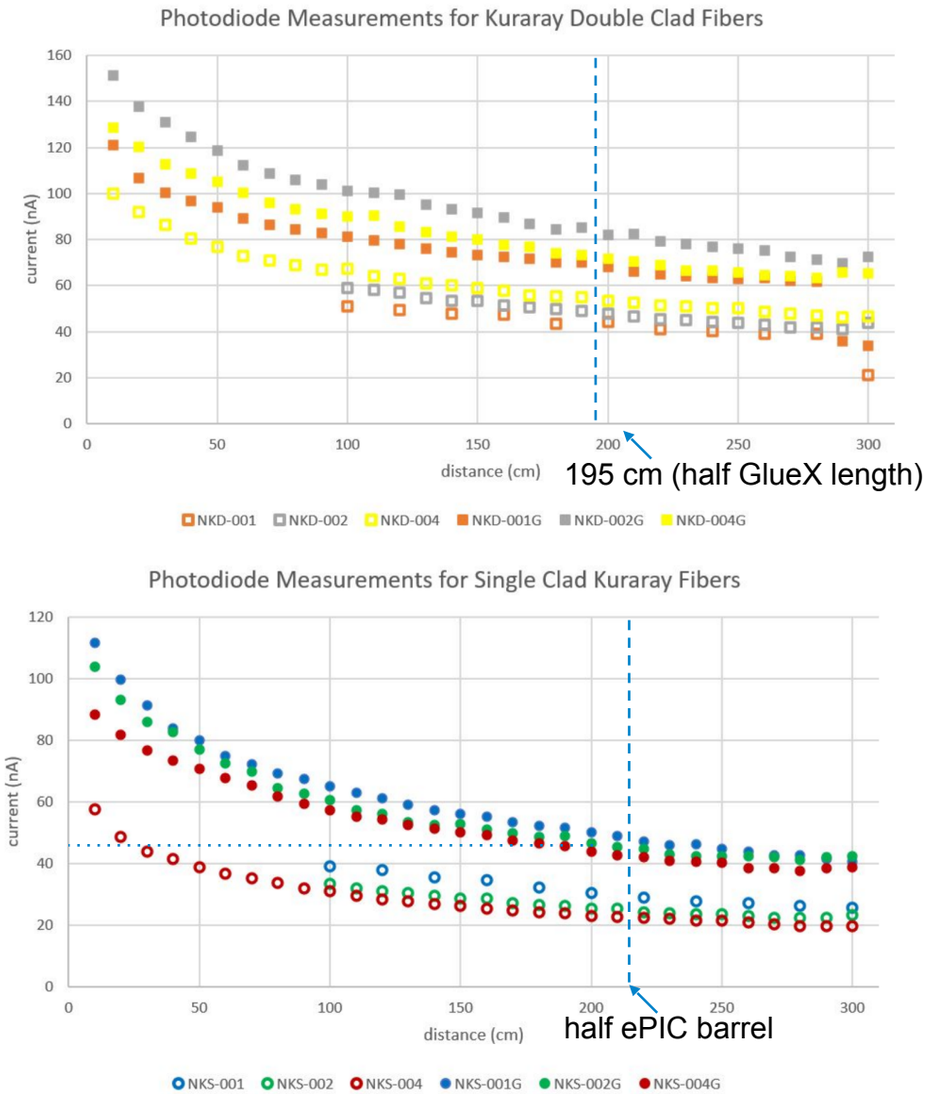


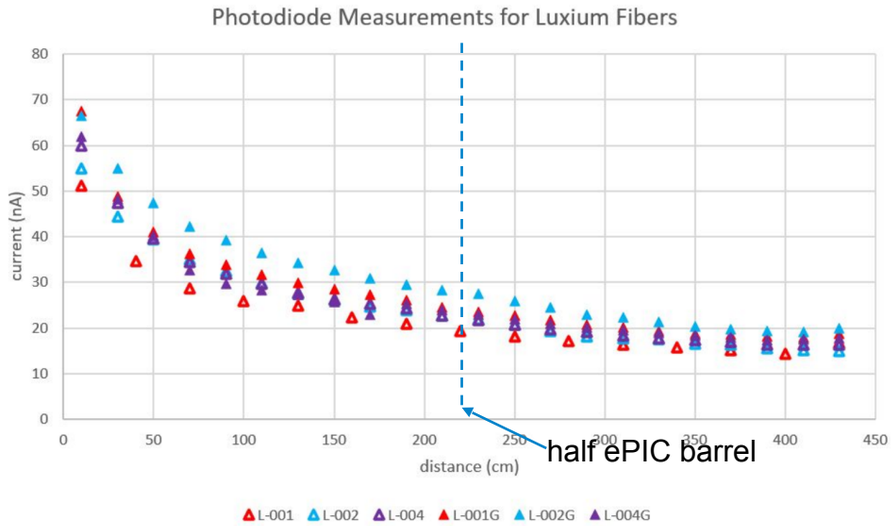
Baby BCAL 60 cm long, 15.5 X0, tested with e+, E ~ 3.6-6 GeV

1) GlueX, Nucl. Instrum. Meth. A, vol. 896, pp. 24–42, 2018

Attenuation Length

Summer 2023 Measurements @Regina





Kuraray double-clad/Kuraray single-clad with grease

- at 10 cm: **~ 1.40**
- at 200 cm: **~ 1.65**

Kuraray double-clad/Luxium single-clad with grease

- at 10 cm: **~ 2.01**
- at 200 cm: **~ 2.80**

Kuraray single-clad 0cm - 216 cm: ~2-2.4
Luxium single-clad 0cm - 216 cm: ~2.7

Source: bECAL Fiber Tests @Regina - Update 5

QA & QC GlueX

BCAL Construction — Traveller version 1.0

Module No. **24** **Nonconformities:** Build & Machining — Fibres

Base Plate

Stamp/Segment No.	38	Drawing	RMS Traveller

Matrix Build

Date Start	10/26/2010	Fibre Shipment	12 & 13	Epoxy Used (g)	14495.2
Date End	11/18/2010	Fibre Lots (JS-)	322-325, 326-331, 333, 335-336, 338, 343-346, 350-354	Epoxy Lost (g)	484.5
No. of Layers	183			Pb Sheets Lost	2
No. of Builds	16				
Temp Range	21-22 C	AttenLen Means	393-399	Build Stats	
Humid Range	21-29%	Npe Means	6.73-7.46	Epoxy Stats	
		Fibres Used	15277	Procedures	
		Fibres Lost	0	Photos	

Top Plate

Stamp No.	24	Drawing	DC Rails: No

Machined Module

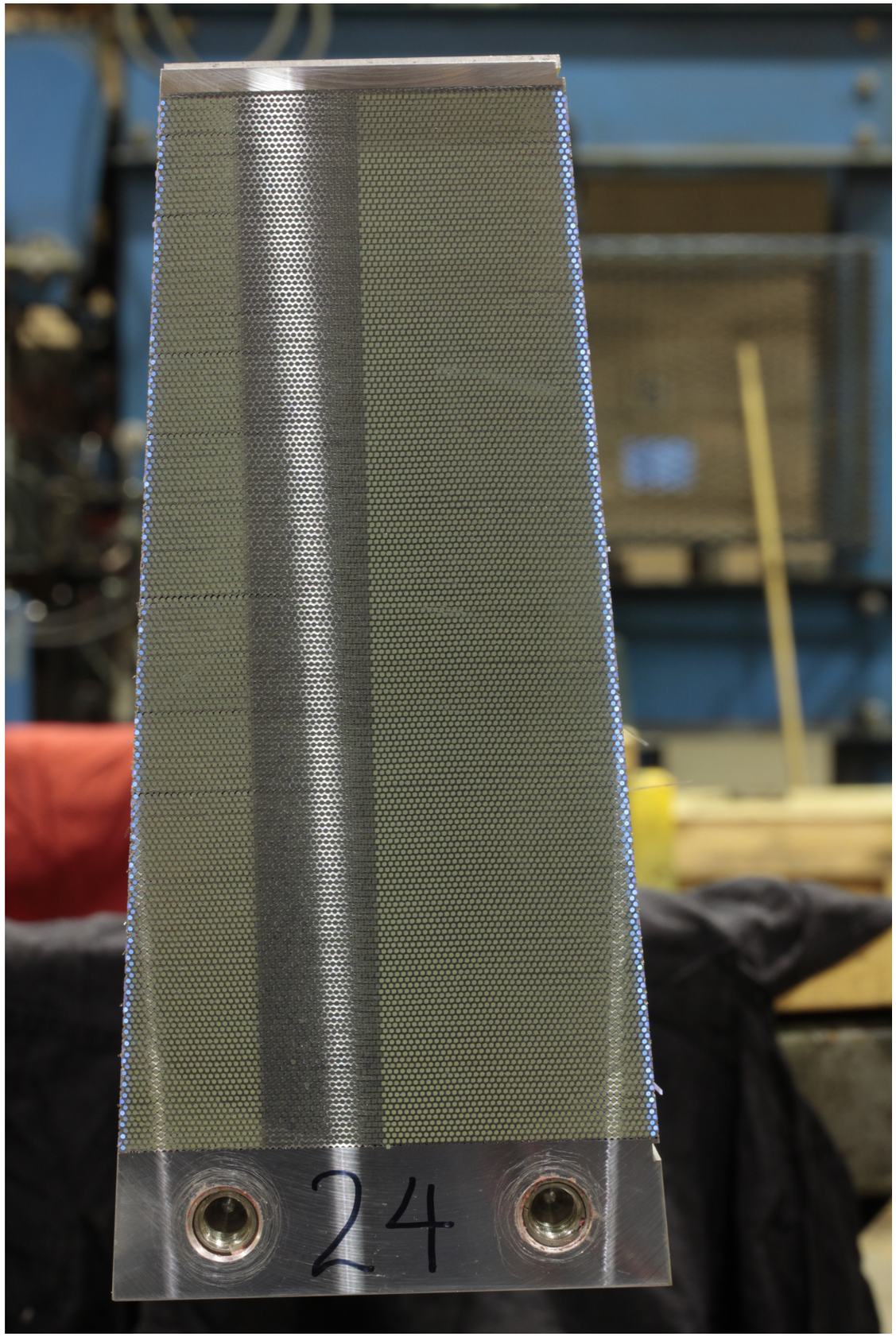
Module/Segment No.	24	Drawing	RMS Traveller

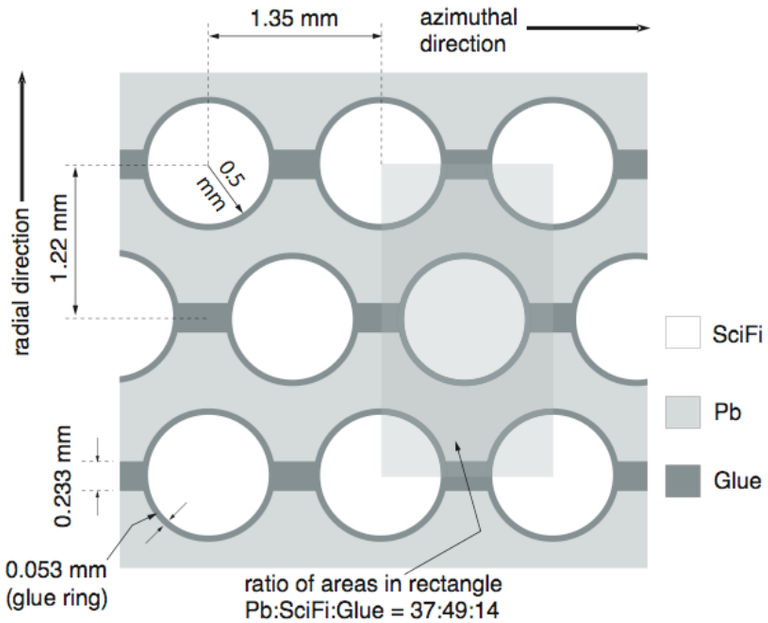
Transmission Uniformity

Light Source:	UV-LED	**Coupling:**	Air gap	
Coupler:	Winston Cone	**Readout:**	Winston Cone	End 1 Image

Last Updated: 1/20/2011 14:57

QA & QC GlueX


24


1.35 mm
azimuthal direction
radial direction
1.22 mm
0.5 mm
0.233 mm
0.053 mm (glue ring)
ratio of areas in rectangle
Pb:SciFi:Glue = 37:49:14
SciFi
Pb
Glue

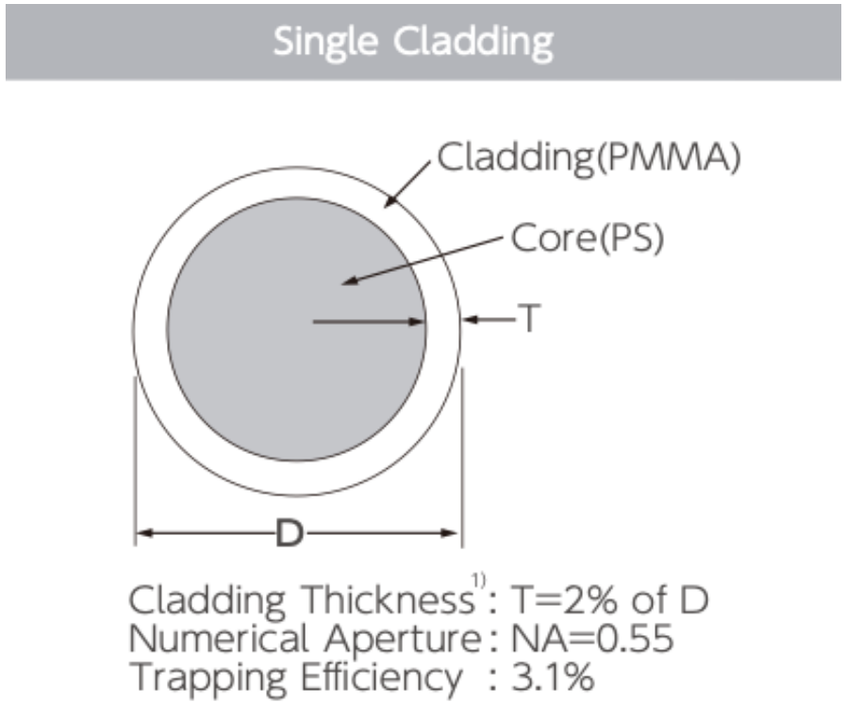
ES&H

- Scintillating fibers (polystyrene) are flammable.
- The total mass of fibers for bECAL is 3.5 tons.
- Fibers will be received, stored and processed into PbSciFi matrices at ANL/Canada (U Manitoba).
- Full assembly of each sector at ANL. Integration of all sectors at BNL.
- Adequate safety measures are needed to store this mass of fibers. Handling and storage areas require with standard fire extinguishing systems.

Fiber Specs

bECAL detector

1. Double or Single clad fibers, round cross section
2. diameter 1.0 mm
3. diameter tolerance shall be less than 2%, <20 μm
4. Single clad: cladding thickness ~2% of diameter,
   Double-clad: cladding thickness ~4% of diameter
5. attenuation length for blue light >3.5 m
6. emission spectrum of blue-green light
7. light yield > 7000-8000 ph/MeV
8. scintillation decay time < 3ns
9. delivered in spools or canes
10. total length 4500 km.
11. delivery schedule: ~3 years



Communicated to Kuraray & Luxium (May 2023); both indicated delivery in ~ 4 yrs (with fECAL 3,000km SciFi)

Long Lead Procurement

Comparison to GlueX

- **Fiber specs:**
  - single-clad, 435-cm long, shipped in coils
  - performance and cost (value engineering: higher PDE, optical coupling for double- vs single-clad)
    - otherwise same specs as GlueX
- **PbSciFi construction:**
  - Bulk section: identical
  - Layer 2-cm-slices: similar; minimal risk
- **Production & assembly:** two lines at ANL, one in Canada, sector assembly at ANL, barrel at BNL

Bottom Line

- **bECAL baseline comparison is to GlueX/BCAL**
- GlueX/BCAL
  - PbSciFi Construction successful
  - SciFi: Kuraray **double-clad** met GlueX specs
- ePIC/bECAL
  - Longer (432.5 cm vs 390 cm), fibers may come in a spool - elastic memory, tooling and procedure needed
  - Vendors: **single-clad** Kuraray ($1.4/m) and Luxium ($1.1/m) should be adequate. Kuraray has better performance to Luxium.
  - Both vendors appear to be able to meet LLP timeline.

Backups

λ_{atten} Measurements

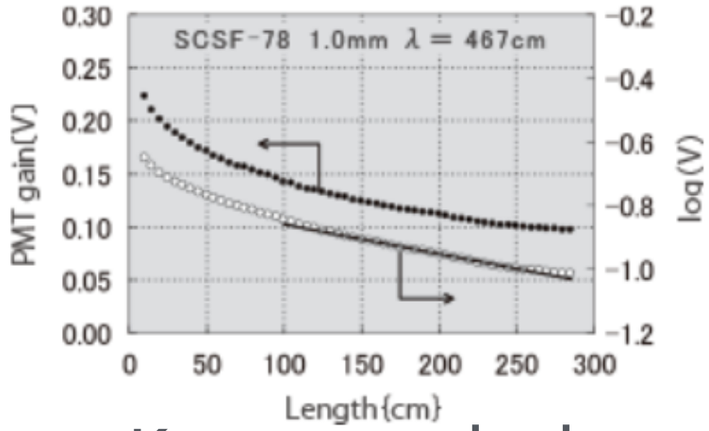
Kur-S

Lux-S

Kur-D

NKS-00i	λ (cm)	L-00i	λ (cm)	NKD-00i	λ (cm)
001	431±17	001	412±17	001	620±41
002	480±22	002	386±13	002	528±24
003	486±16	003	377±8	003	505±21
004	441±46	004	406±8	004	544±17
005	460±13	005	439±8		
001G	432±27	001G	425±8	001G	641±67
002G	532±42	002G	407±9	002G	529±41
004G	449±17	004G	567±66	004G	531±29

$$I = I_0 \cdot e^{\frac{-x}{\lambda}}$$

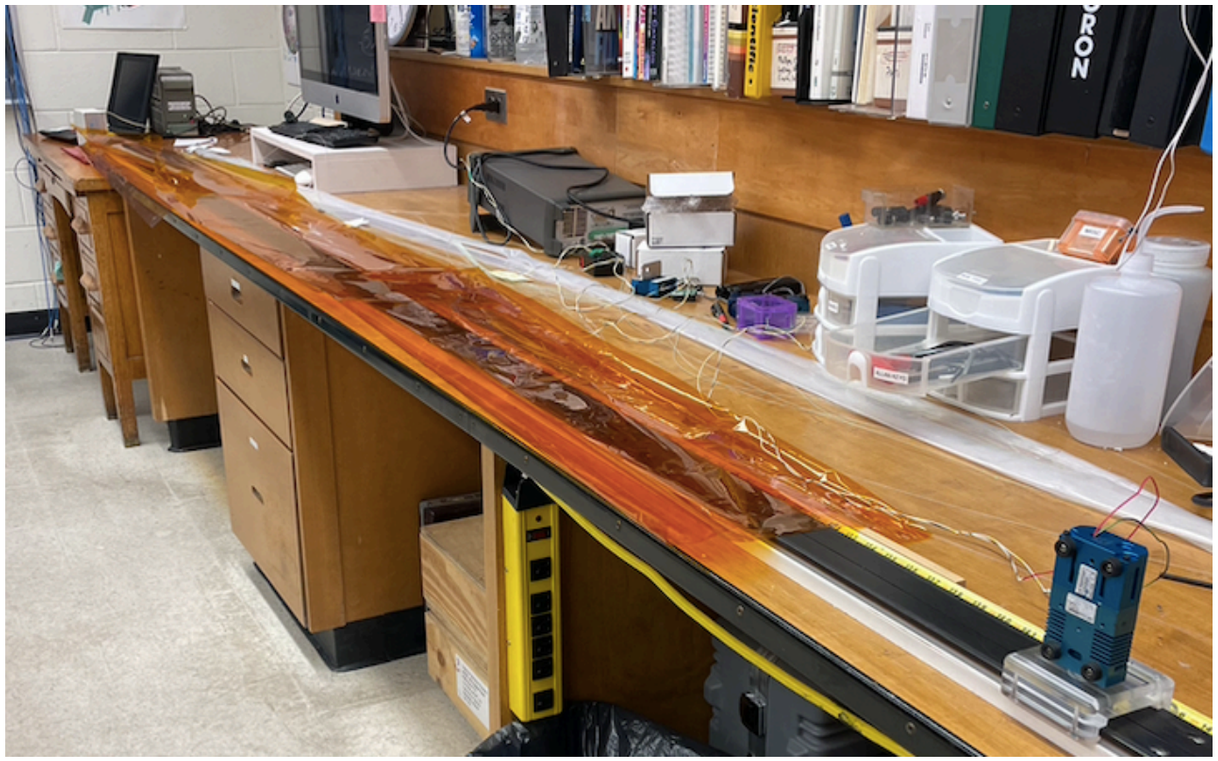


Kuraray method: 100-300cm fit

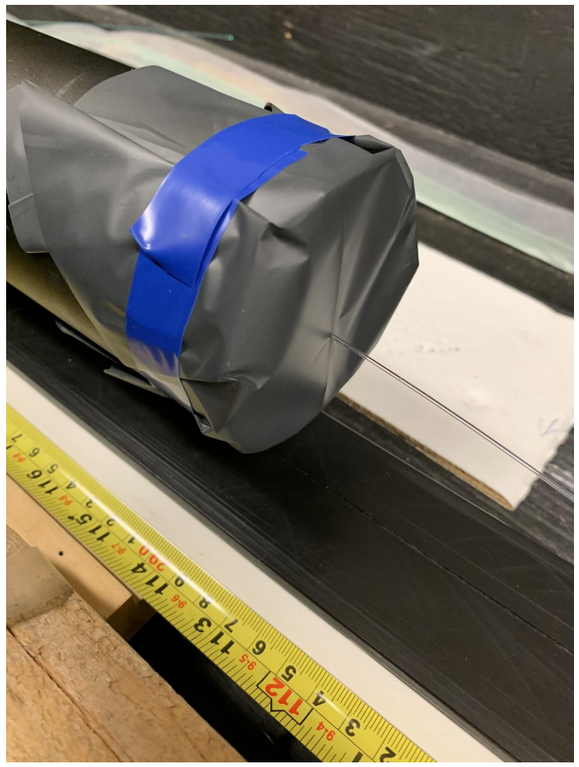
- All attenuation lengths > 400 cm

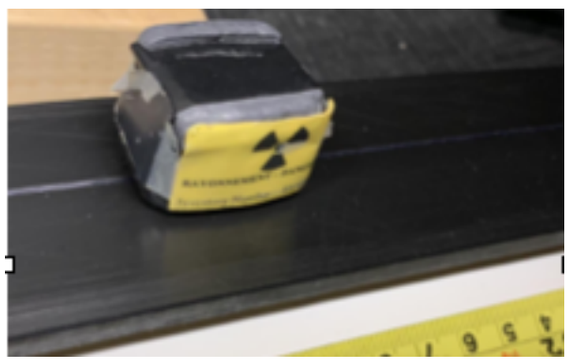
Fiber Measurements

Photodiode Station



Npe Station (soon)

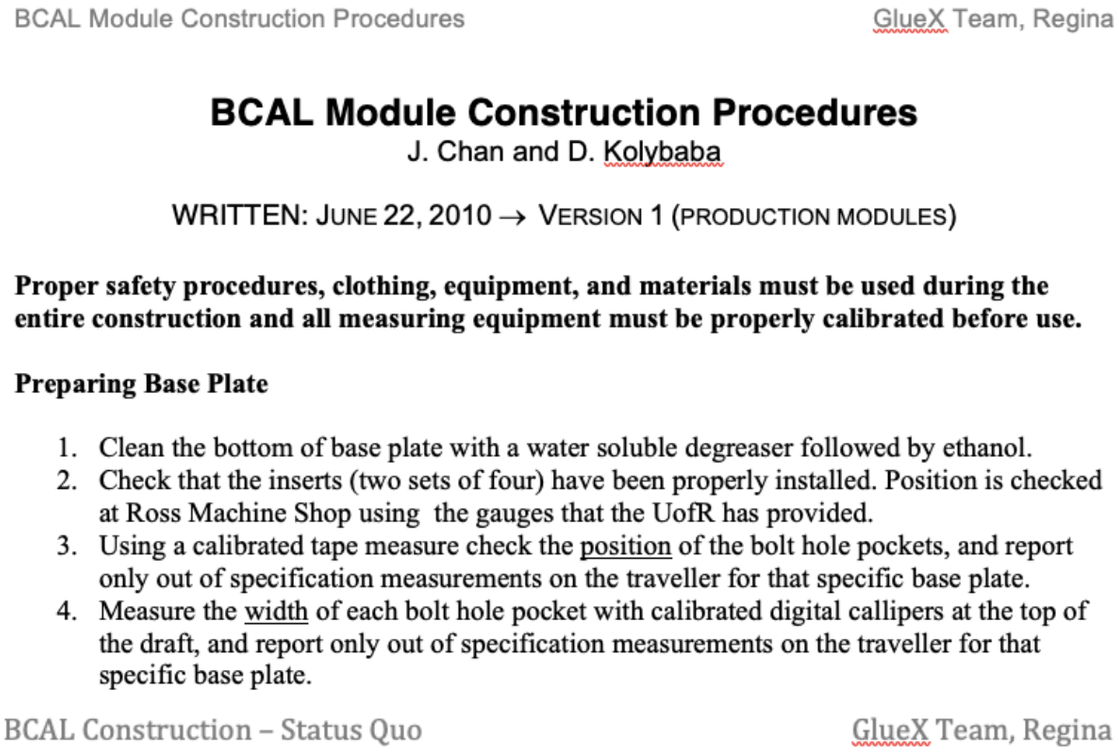




90Sr source
SiPM-PMT coinc

BCAL Testing & Construction

- Detailed step-by-step manuals on construction and fiber testing (1% of fibers, randomly selected)
- Eight different check lists
- Detailed spread sheets for tracking fibers, lead, epoxy, builds & module height
- Inspections & QA: in reports
- Condition/packaging/visual inspection/photos
- Diameter at 3 locations along each fiber
- Wavelength spectrum measured
- Attenuation length and light output measured


BCAL Module Construction Procedures GlueX Team, Regina

BCAL Module Construction Procedures

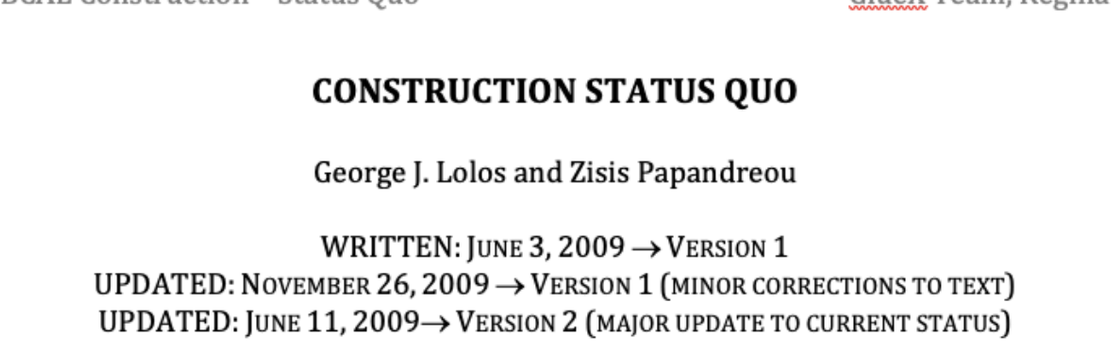
J. Chan and D. Kolybaba

WRITTEN: JUNE 22, 2010 → VERSION 1 (PRODUCTION MODULES)

Proper safety procedures, clothing, equipment, and materials must be used during the entire construction and all measuring equipment must be properly calibrated before use.

Preparing Base Plate

1. Clean the bottom of base plate with a water soluble degreaser followed by ethanol.
2. Check that the inserts (two sets of four) have been properly installed. Position is checked at Ross Machine Shop using the gauges that the UofR has provided.
3. Using a calibrated tape measure check the position of the bolt hole pockets, and report only out of specification measurements on the traveller for that specific base plate.
4. Measure the width of each bolt hole pocket with calibrated digital callipers at the top of the draft, and report only out of specification measurements on the traveller for that specific base plate.


BCAL Construction – Status Quo GlueX Team, Regina

CONSTRUCTION STATUS QUO

George J. Lolos and Zisis Papandreou

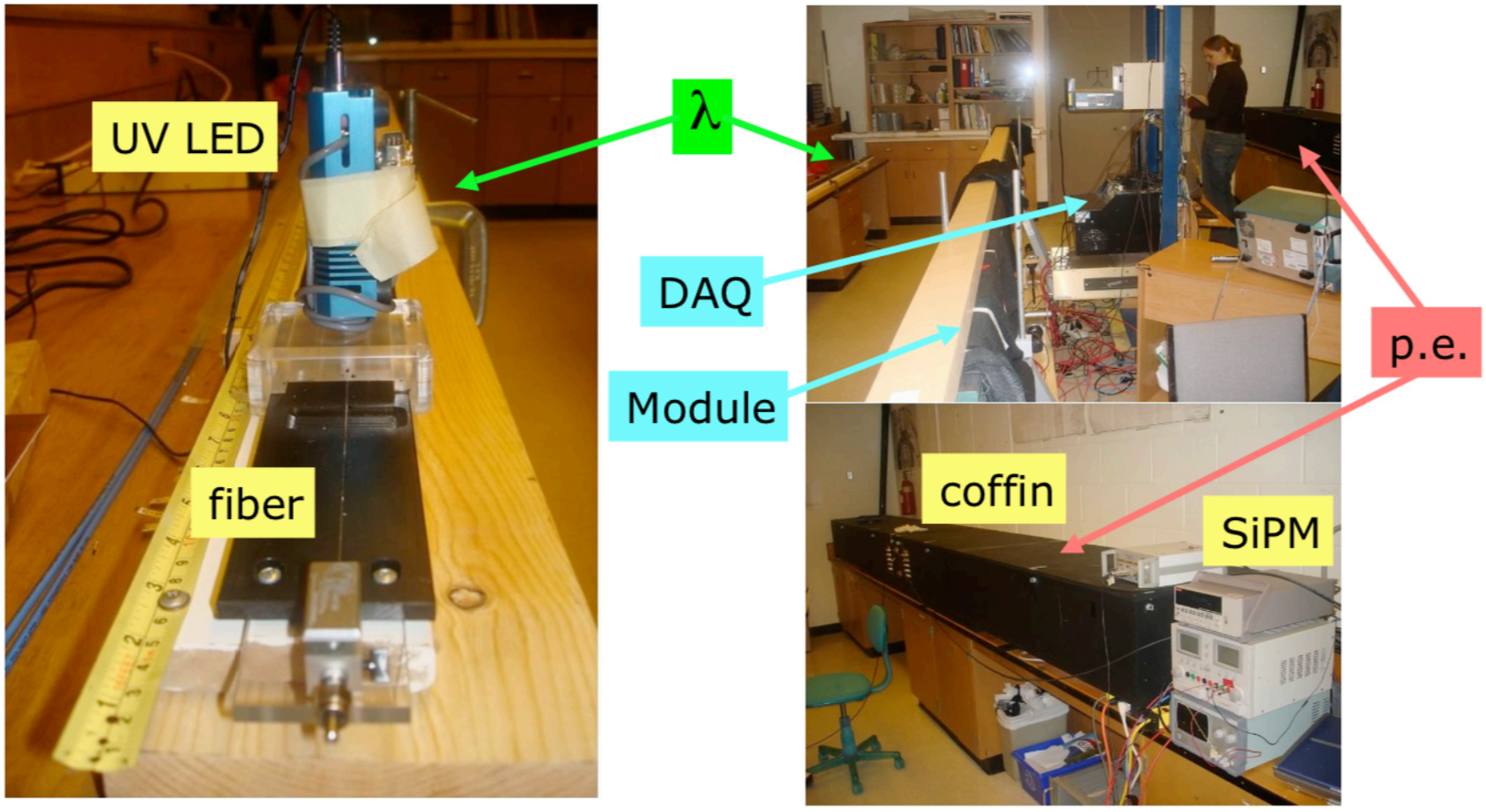
WRITTEN: JUNE 3, 2009 → VERSION 1
UPDATED: NOVEMBER 26, 2009 → VERSION 1 (MINOR CORRECTIONS TO TEXT)
UPDATED: JUNE 11, 2009→ VERSION 2 (MAJOR UPDATE TO CURRENT STATUS)

1. Introduction

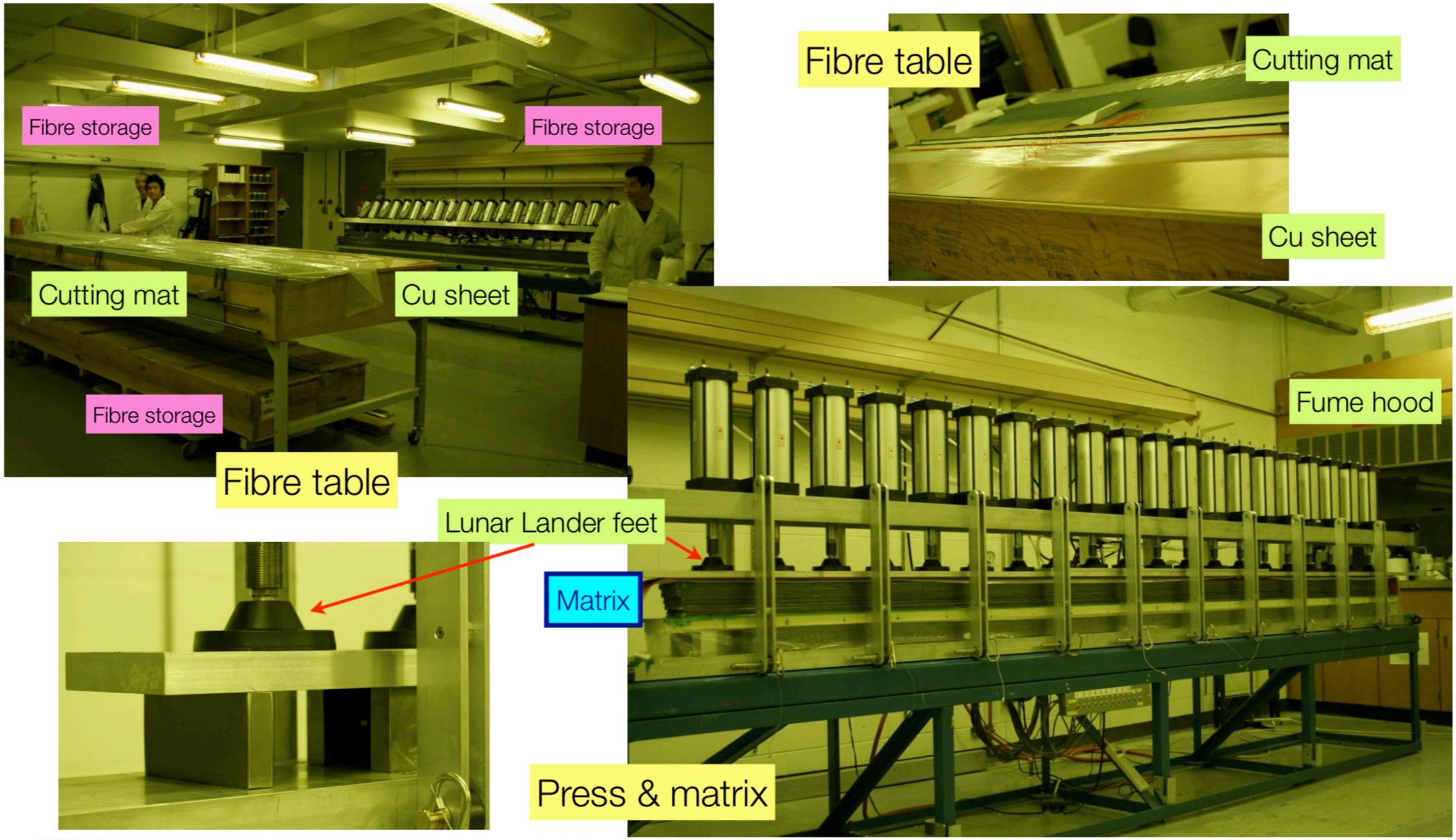
The construction status quo of the 48 BCAL modules, as budgeted for in subcontract JSA 09-R280857-CR (for the construction of the Barrel Calorimeter – BCAL) and in Appendices 1 and 2, is described herein.

Fibre Testing lab

- First article
  - Regina data
  - JLab data
  - GlueX-doc-1317
  - Bench Reference
- Production (Regina)
  - ☑ Condition/packaging
  - ☑ Diameter
  - ☑ Attenuation length: LED, photodiode current
  - ☑ N_{pe} at 200cm: ^{90}Sr, PMT, external trigger

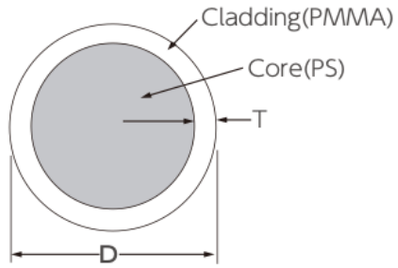


Matrix construction progress - panoramic



ePIC Fiber Contenders

Single Cladding



Cladding Thickness[1]: T=2% of D
Numerical Aperture: NA=0.55
Trapping Efficiency : 3.1%

Description	Emission			Decay Time [ns]	Att.Leng.[2] [m]	Characteristics
	Color	Spectra	Peak[nm]			
SCSF-78	blue	See the following figure	450	2.8	>4.0	Long Att. Length and High Light Yield
SCSF-81	blue		437	2.4	>3.5	Long Attenuation Length
SCSF-3HF(1500)	green		530	7	>4.5	3HF formulation for Radiation Hardness

1) Test fibers are Non-S type, 1mmϕ.
2) Measured by using bialkali PMT and UV light(254nm).
Quality control is made by another measurement of the transmission loss every batch.

Specific Properties of Standard Formulations

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	# of Photons per MeV**	Characteristics / Applications
BCF-10	blue	432	2.7	~8000	General purpose; optimized for diameters >250µm
BCF-12	blue	435	3.2	~8000	Improved transmission for use in long lengths