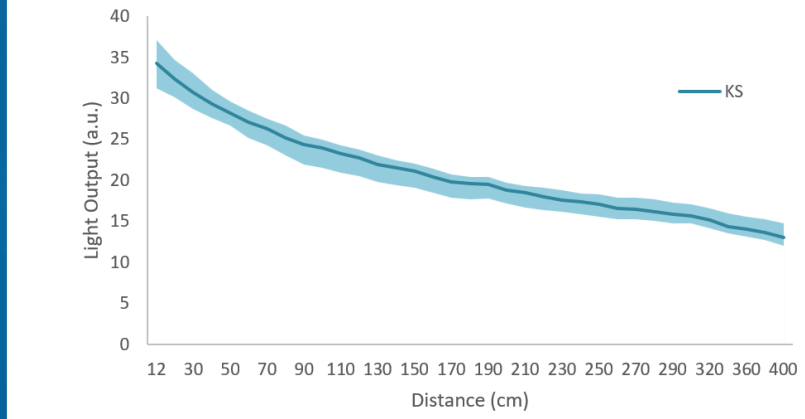
Barrel Imaging Calorimeter Preliminary Design Review

Scintillating Fibers



Tegan Beattie, Emily Pepper, Zisis Papandreou
University of Regina

BIC Workshop
June 16-18, 2026

ePIC

University of Regina | Faculty of Science

Fiber Tender Specifications

A. Light yield: the average response to a Sr-90 source shall be greater than 3.5 photoelectrons measured using a bialkali photomultiplier tube 200 cm from the source, and the opposite end blackened (assessed via methods mutually acceptable to the BSA and Contractor). **SiPM**

B. Diameter mean value and variation shall be 1.00 +/- 0.01 mm, RMS ≤0.02 mm. **Calliper**

C. Attenuation length for blue light > 4m. **Photodiode**

D. Batch to batch or lot to lot variation of light yield <15%.

E. Batch to batch or lot to lot variation of attenuation length <10%.

F. Emission spectrum in blue-green light **Spectrophotometer**

G. Scintillation decay time <3ns

H. Total length 4900 km

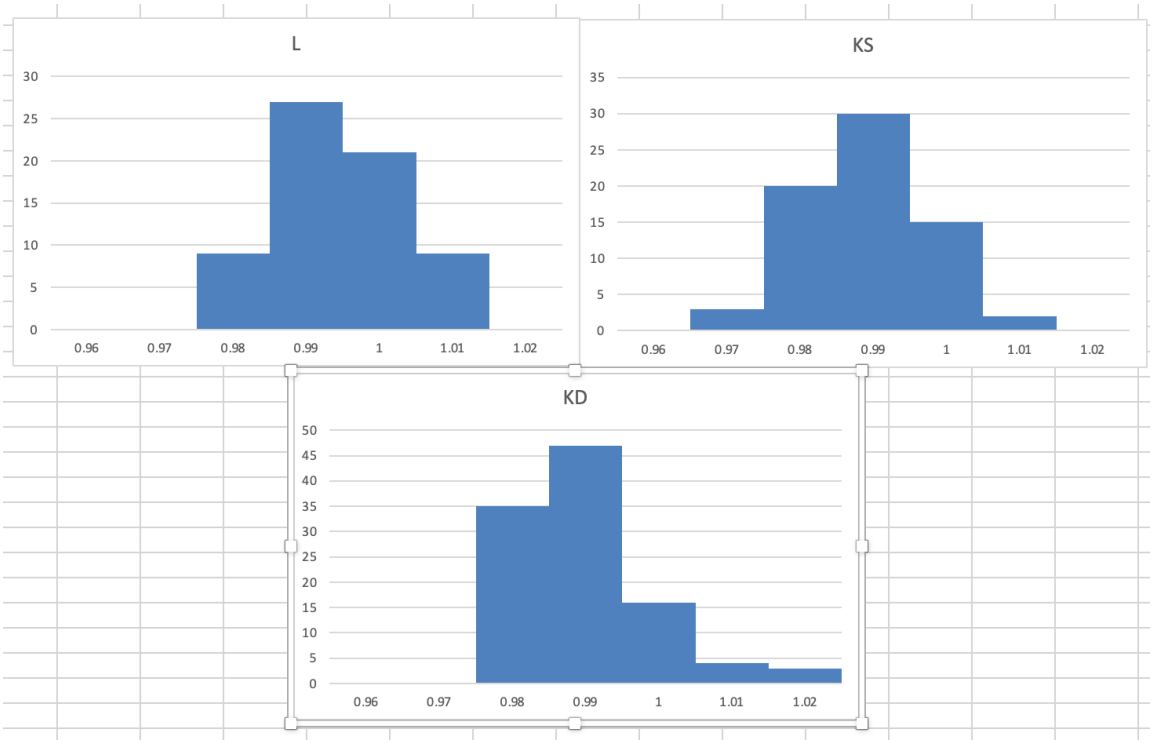
I. Delivery method in canes. Length of fibers 4.55 meters +/- 0.01m. **Tape measure**

Vendors submitted 100 fibers of 3 types: **2 single- and 1 double-clad**

Diameter Measurements - 2025

Digital Caliper

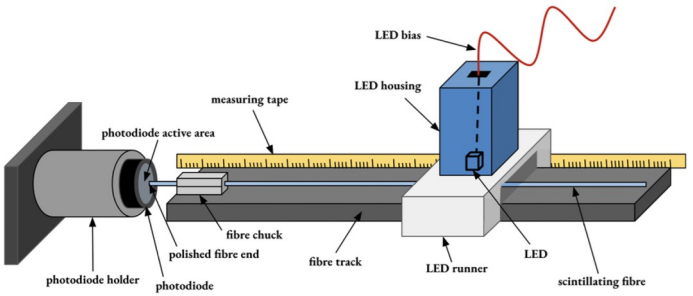
Number of fibers at each diameter:			
Diameter	L	KS	KD
0.96	0	0	0
0.97	0	3	0
0.98	9	20	35
0.99	27	30	47
1	21	15	16
1.01	9	2	4
1.02	0	0	3
	66	70	105



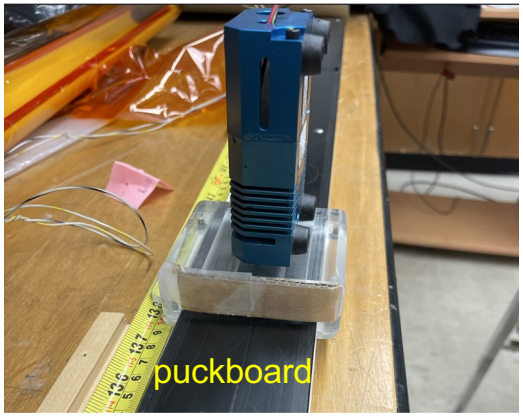
All fibers met diameter spec

Photodiode Station: Setup

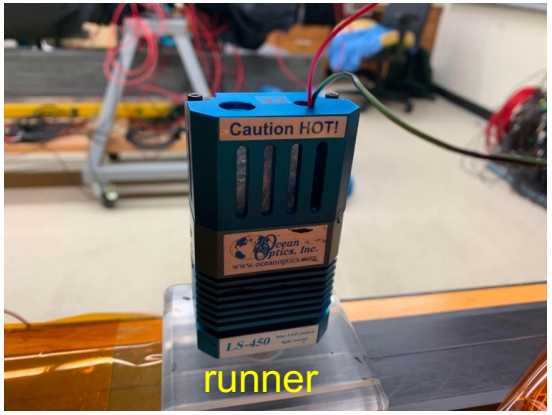
285 fibers tested; 15 with special end treatment



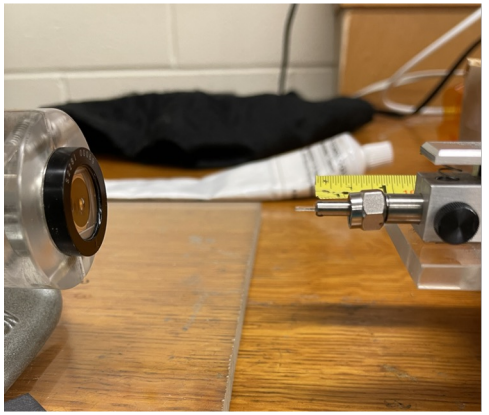
HAMAMATSU
PHOTON IS OUR BUSINESS



LED 370 nm; moves along puckboard



LED 370 nm; slides on acrylic runner



Optical grease at contact

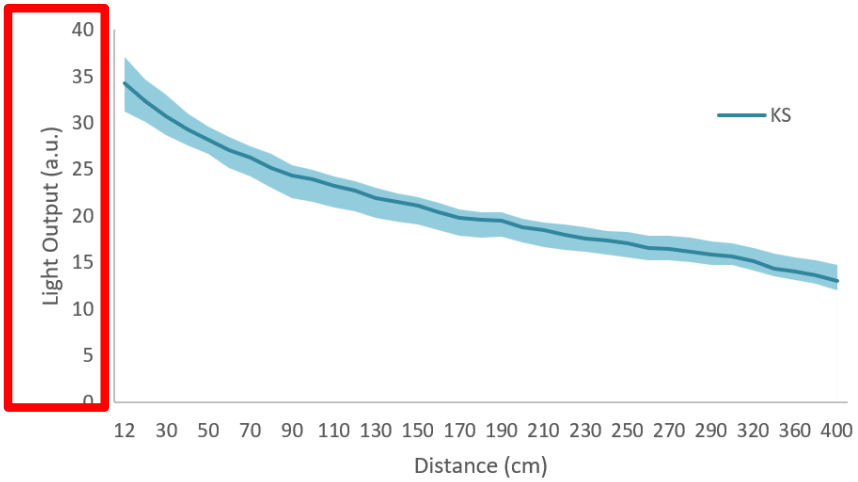
Photodiode Station: λ and light output

Table 2
Average Fit Parameters

Attenuation Length

	$I(x) = I_0(\alpha e^{-\frac{x}{\lambda_1}} + (1-\alpha)e^{-\frac{x}{\lambda_2}})$				$I(x) = I_0 e^{-\frac{x}{\lambda}}$ (>100 cm)	
Fibre	I_0	α	λ_1	λ_2	I_0	λ
L	21.5	0.4	44.1	343.2	13.9	315.5
KS	36.3	0.3	55.5	574.3	8.1	508.0
KD	39.8	0.3	139.7	750.7	36.2	539.1

Light output (a.u.)



Solid line shows the average of all measured fibers; shaded line shows the spread

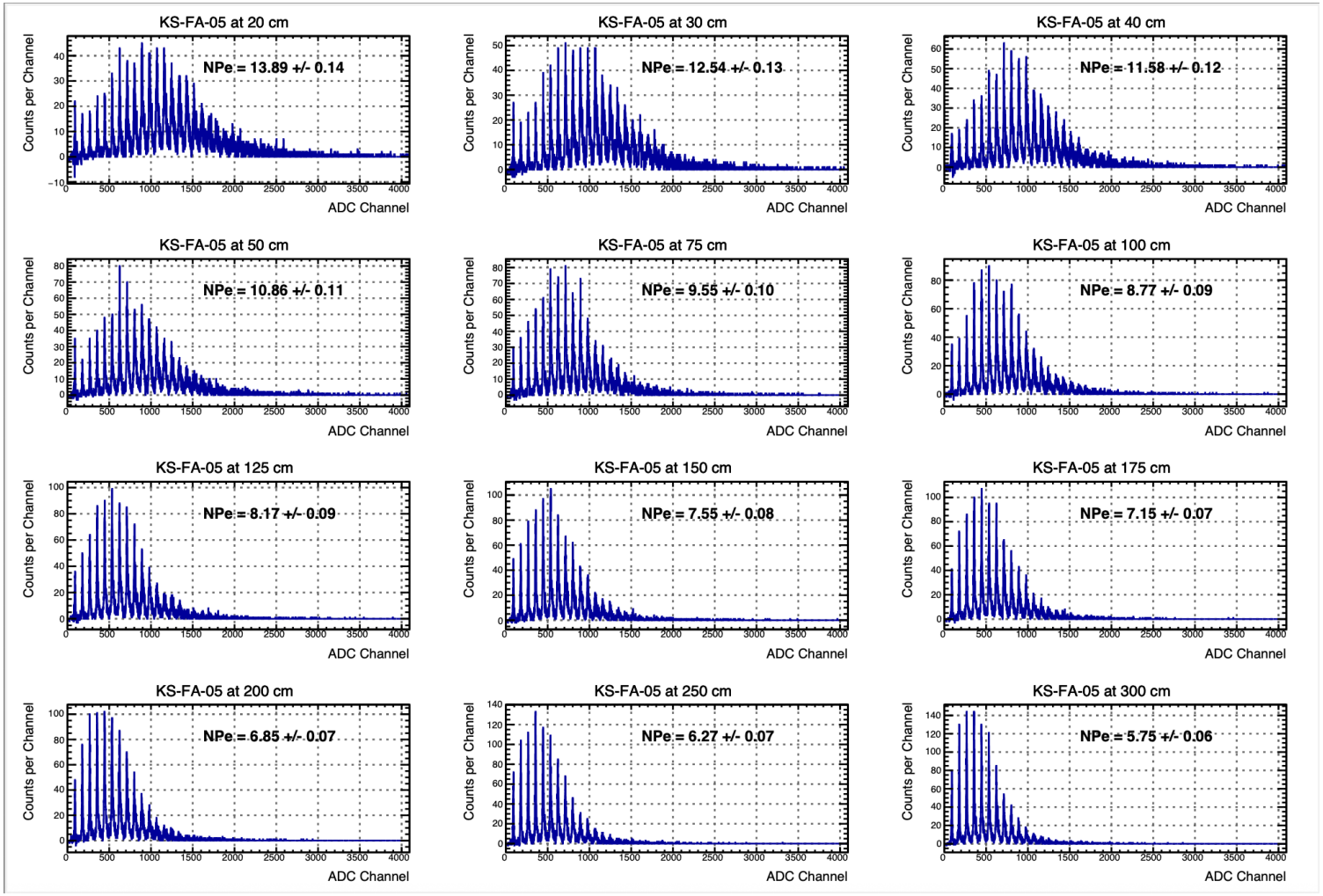
Kuraray KS selected; met spec for both λ and light output

Npe Station: Setup

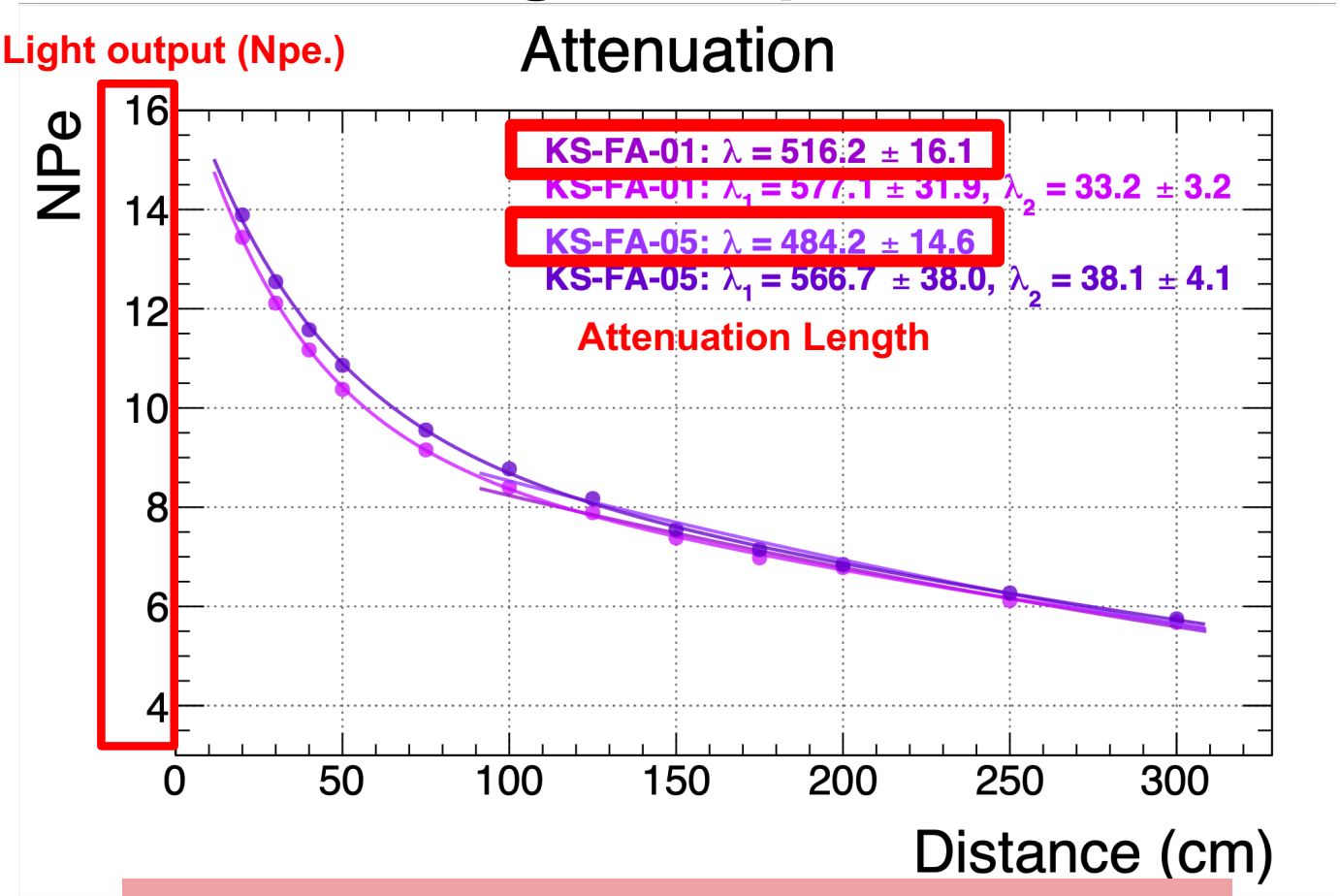
^{90}Sr source

- Complete darkness
- Two 3x3mm^2 SiPMs
- Fiber along plank
- Coincidence with SiPM
- ^{90}Sr with trigger scintillator
- Scan ^{90}Sr from 20-300cm, but routine @20/@200cm
- Fit spectrum extract Npe

Npe Station: Peaks



Npe Station: λ and light output



Kuraray KS selected; met spec for both λ and light output

QC for Fibers

Procedures

QC Procedure - from BCAL; updated for BIC

Evaluate (ca. 0.5-1%?) random fibers to meet BIC specifications

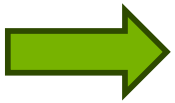
Spectrum, diameter uniformity, long attenuation length, light output

Fiber usage in the build: batch variation does not affect build

ePIC-BIC Scintillating Fiber Specifications Assessment Protocol

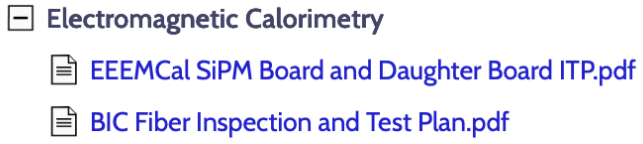
Tegan Beattie, Aram Teymurazyan, Zisis Papandreou
Department of Physics, University of Regina, Regina, SK S4S 0A2 Canada
April 2025

A description of the handling and assessment protocols for first article scintillating fibers for the BIC at the University of Regina, including the equipment used, setup, and step-by-step instructions for measuring the attenuation lengths, NPe, scintillation spectra, and diameters of optical fibers.



Scintillating Fiber Inspection and Test Plan

Sylvester Joosten / Zisis Papandreou
Argonne National Lab, USA / University of Regina, Canada

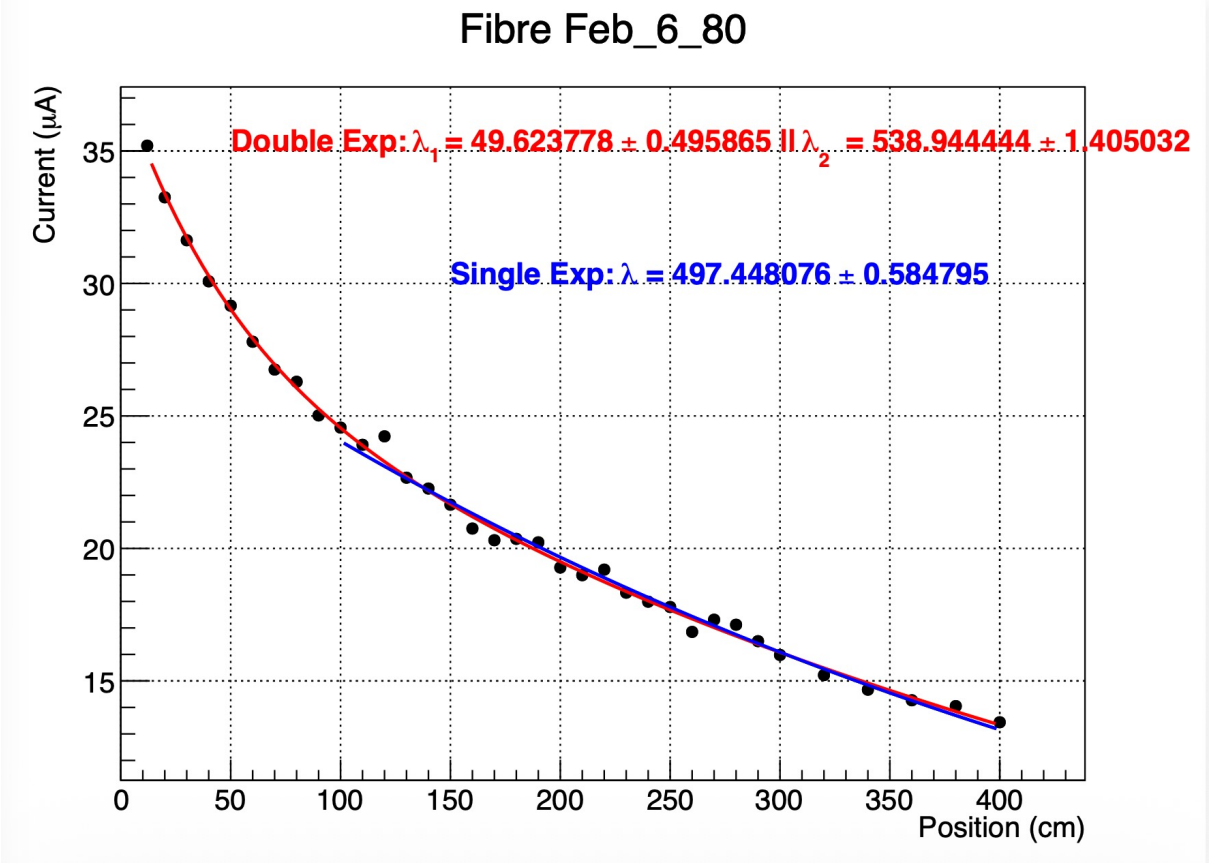


EEEMCal SiPM Board and Daughter Board ITP - Larry Isenhower.

Barrel Imaging Calorimeter Scintillating Fiber ITP - Sylvester Joosten and Zisis Papandreou.

ANL Production Fibers

Re-checked at URegina



Summary

2025 tests: KD, KS and L (first article) and JS (old GlueX)

- Diameters: all fibers met spec
- Spectrum: all fibers met spec
- Fiber comparison for λ and light output
  - Photodiode: λ_{KS}>4m
  - Npe: λ_{KS}>4m (all λ shift somewhat to larger numbers)
- Technical report almost done; proceed to publication

2026 Kuraray shipments (28k fibers each) started Feb 2026

QC at ANL: <1.0% of fibers atten len, <<1.0% for spectrum

Occasional cross-checks with at URegina

Attenuation Length: End Treatment

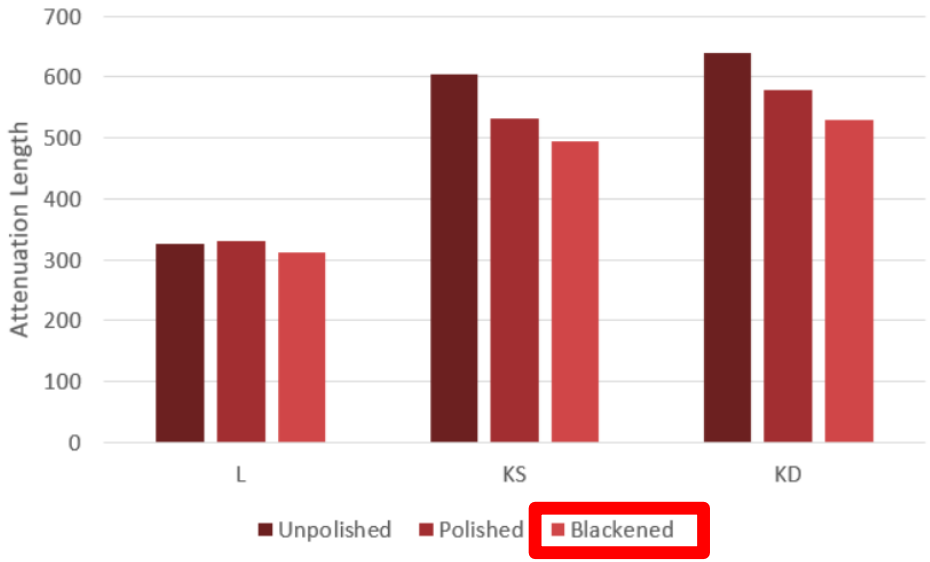


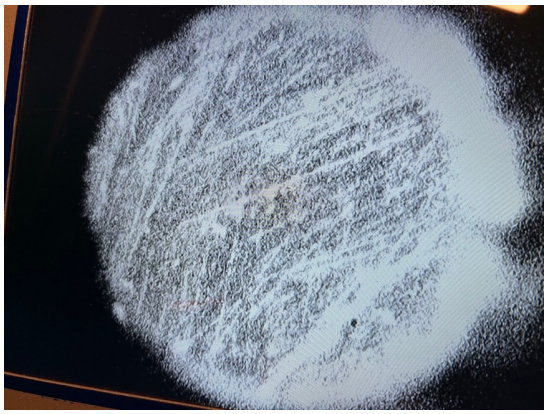
Figure 10. The attenuation length of each fibre at each stage of end treatment. The attenuation length comes from Eq. 2, from distances > 100 cm. As is visible, the attenuation length monotonically decreases as the fibre is polished and then blackened.

Blackened end emulates fiber reponse in BIC

Polishing Station: Polishing

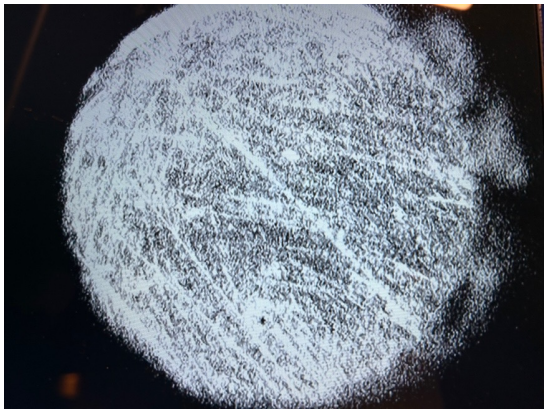
135 fibers both ends, 15 fibers initially only one end

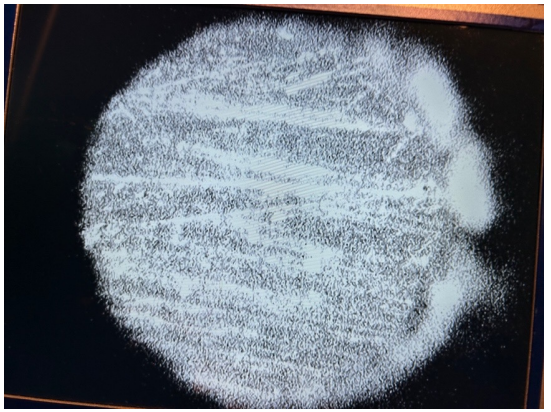
unpolished



polished

polished





polished

EH&S for Fibers

Procedures

Safety standards and documentation from BCAL → 2025 code

Fibers:

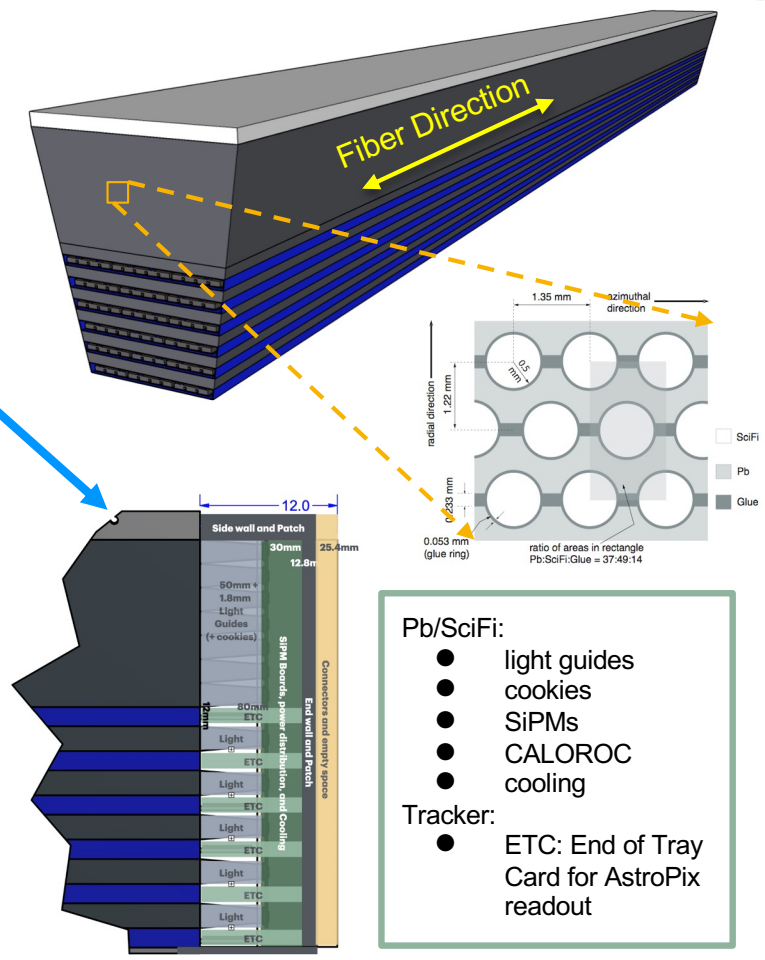
- Scintillating fibers (polystyrene) are flammable.
- The total mass of fibers for BIC is 3.9 tons. Adequate safety measures are needed to store this mass of fibers.
- Fibers will be received, stored and processed into PbSciFi matrices at ANL.

GLUEX EXPERIMENT DOCUMENT 1573-V4

- Fibre Attenuation Length Measurement Procedures (FibreProcedures-AttenLen_v2.pdf, 71.3 kB)
- Fibre Number of Photoelectron Measurement Procedures (FibreProcedures-Photoelectrons_v2.pdf, 89.7 kB)
- Lead Handling and Swaging Procedures (LeadHandling-Instructions_v2.pdf, 108.2 kB)
- Quality Assurance Plan (QAPlan_v4.pdf, 227.4 kB)
- Risk Assessment/Safety (Construction-RiskAssessment_v1.pdf, 73.6 kB)
- Updated Construction Manual (Draft) (Updated Construction Manual (Draft).doc, 145.2 MB)

Fiber Highlights - 2025

- Attenuated signals from showers reach both ends
  - Pb/SciFi layers **probe shower radially** (essentially a 3D profile but AstroPix gives 3D much more precisely)
  - **Read both ends with light-guides and SiPMs** enclosed in end-of-sector box (**ESB**)
  - Shower position extracted from both ends' TOA (in addition to AstroPix position information)
- First Article fibers testing at **U Regina**
  - Attenuation length, light output, spectral response, diameter
- **Shifting to ANL**
  - Testing procedures and QA/QC now at ANL
  - 4 Fiber test stations now at ANL

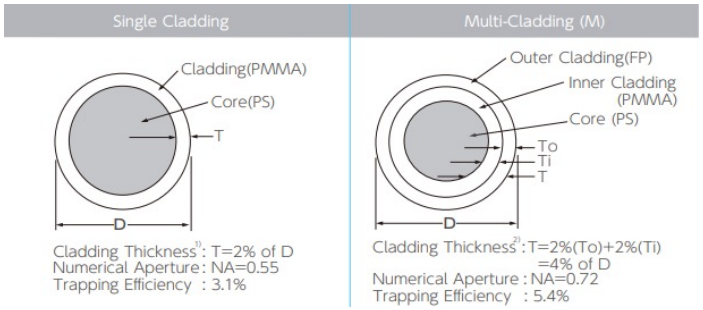


Pb/SciFi:
- light guides
- cookies
- SiPMs
- CALOROC
- cooling

Tracker:
- ETC: End of Tray Card for AstroPix readout

Task and Timelines

Workflow at U Regina



KD – Kuraray double-clad, **KS** – Kuraray single-clad
JS – BCAL Kuraray double-clad, **L** – Luxium single-clad

- Mar 20: **285 fibers arrive at Regina from ANL (95 KD, 95 KS, 95 L)**
- Mar 21, 24: **Polishing station**: 135 fibers double-ended, 15 single-ended

  Mar 25: **Spectrophotometer station**: 8 fibers (2 of each + 2 JS), 35 points; no grease

  Mar 26: 45 **Caliper**: diameter measurements at 75, 150, 225, 300, 375cm

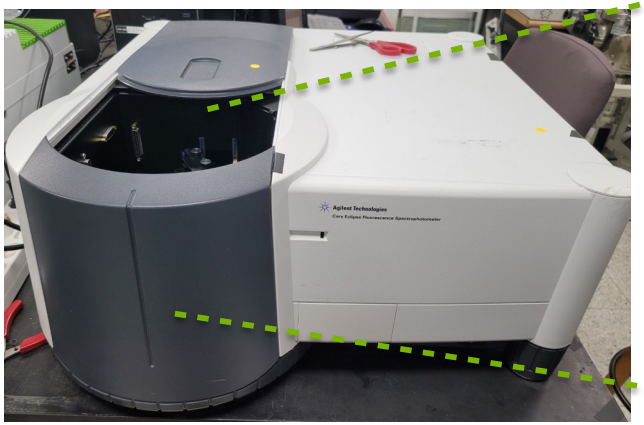
  Mar 26-28: **Photodiode station**: 30 fibers (10 of each) + 5 JS

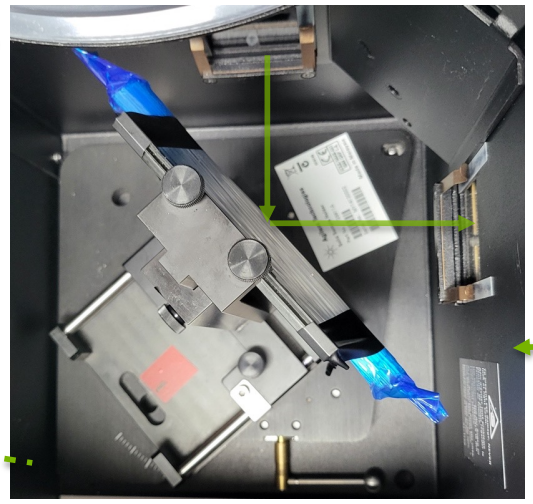
  Measured **12-400 cm**, every 10cm to 300cm, then every 20cm, 35 points; optical grease
  - Opposite end polished and blackened
  - **Tender Measurement: single-exp fit 100-300cm**
- Apr-May: **Npe station**: two 3x3mm^2 SiPMs on fiber end and for 90Sr trigger; no grease
- June-July:
  - All fibers completed on photodiode, end-treatment, repeatability cross checks
  - Single- & double-exp analysis
  - Sample of fibers measured with spectrophotometer
  - **Fibers returned to ANL; technical report to Zenodo this fall**

Fiber Emission Measurement

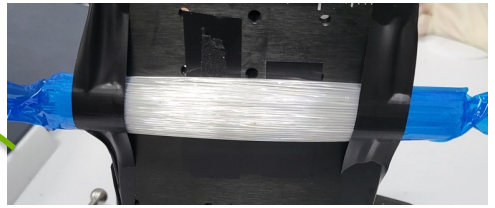
Wavelength Response – KNU

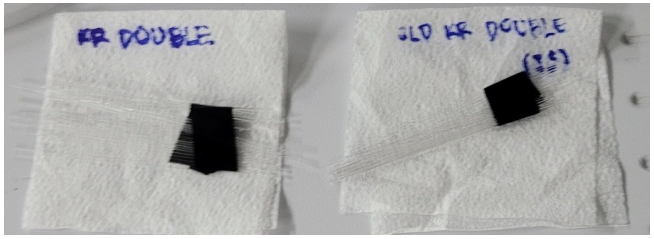
Cary Eclipse Fluorescence Spectrometer

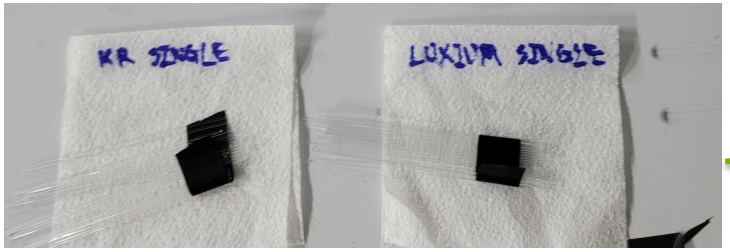




~150 fibers bundled for measurement



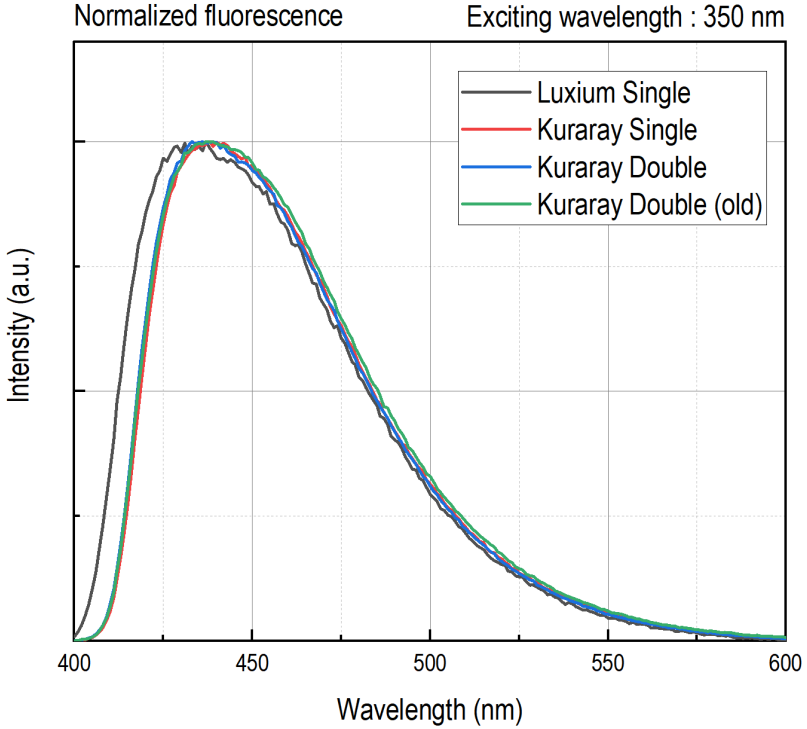




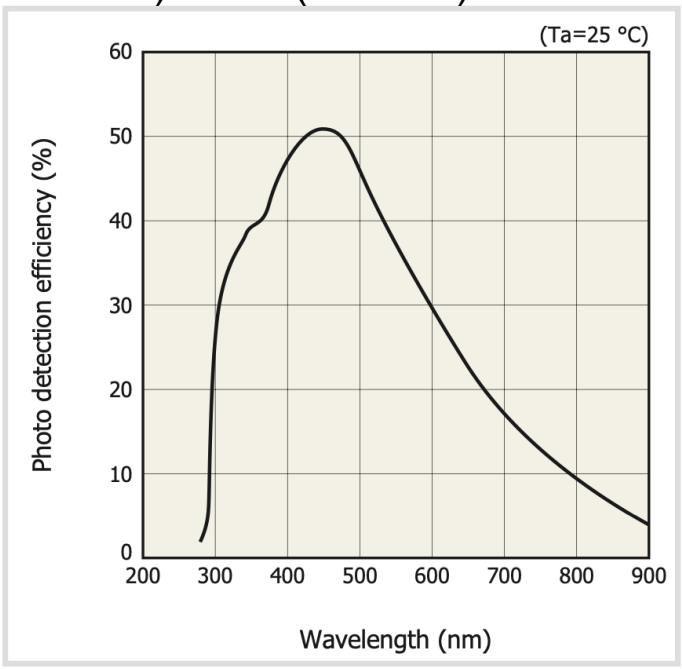
Kuraray (double-cladding) Kuraray (double-cladding) Kuraray (single-cladding) Luxium (single-cladding)

Fiber Emission Spectra

Wavelength Response – KNU



Cf) SiPM (S14161) PDE



- Fiber emission spectra match well with SiPM PDE, with no significant dependence on manufacturer or cladding type.

Fiber spectra met wavelength spec