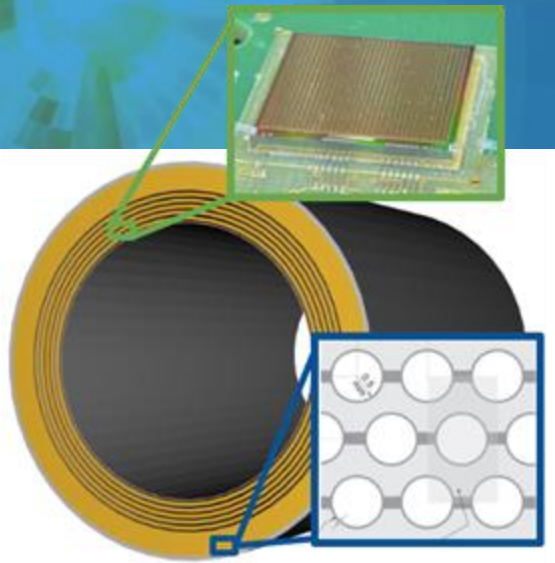
Barrel Imaging Calorimeter – presented to PDR2025

BIC Scintillating Fibers

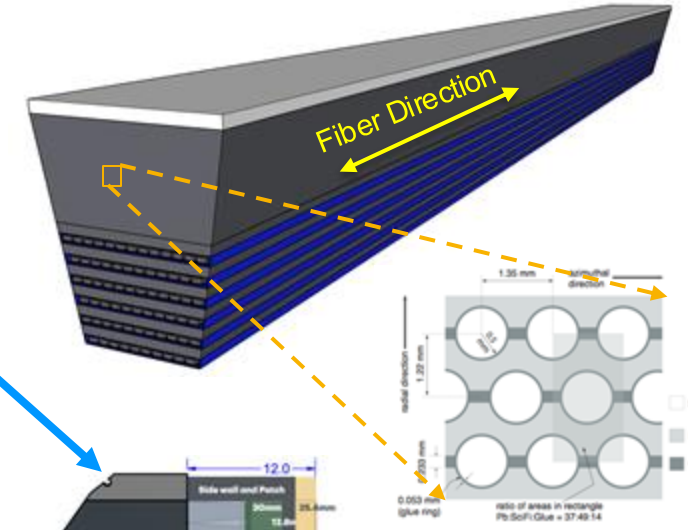


Zisis Papandreou
University of Regina
on behalf of the BIC DSC

TIC Meeting
October 6, 2025

Fiber Highlights

- 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/cookiess
- SiPMs
- CALOROC
- cooling

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

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

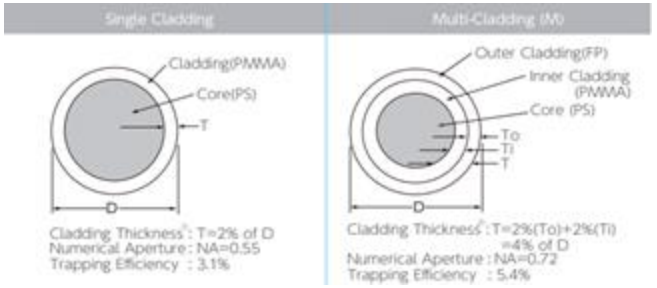
G. Scintillation decay time <3ns

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**

Task and Timelines



Workflow at U Regina

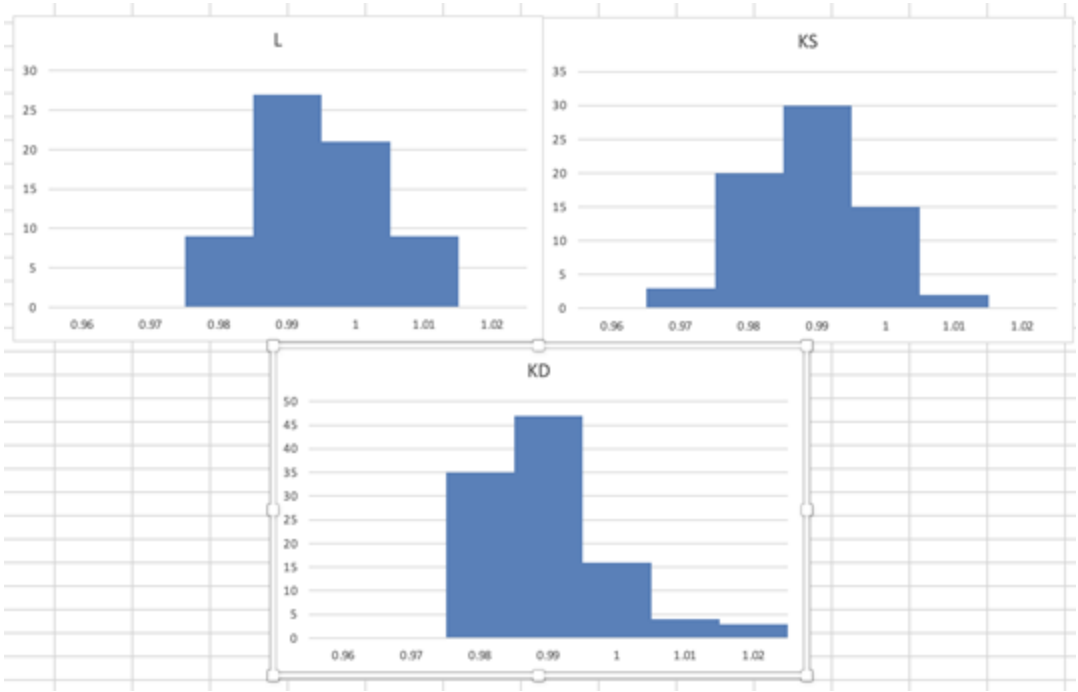
KD – Kuraray double-clad, **KS** – Kuraray single-clad
JS – BCAL Kuraray double-clad, **L** – Luxium single-clad

- 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
    - **Bid/Tender Assessment: 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**

Diameter Measurements

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

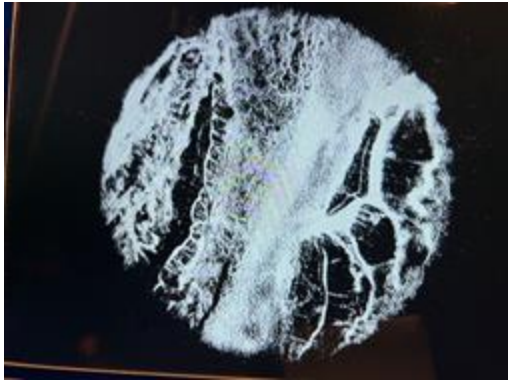


All fibers met diameter spec

Polishing Station: Polishing

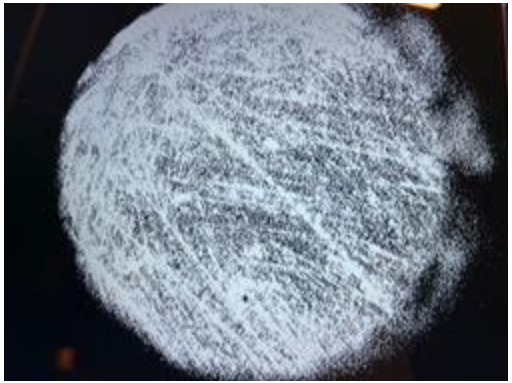
135 fibers both ends, 15 fibers initially only one end

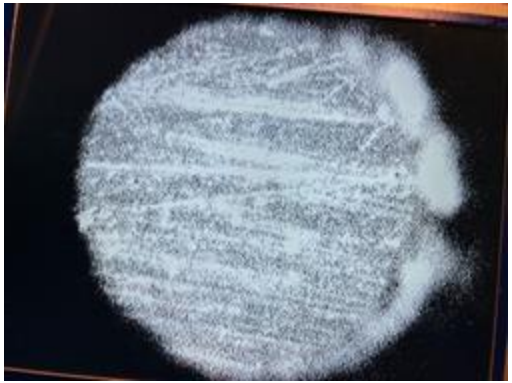
unpolished



polished

polished

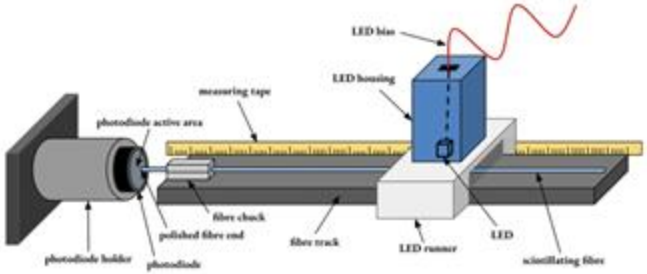


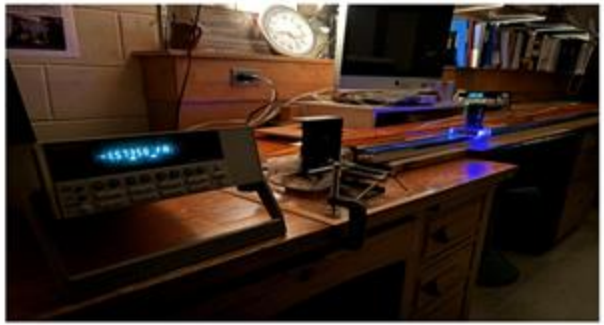


polished

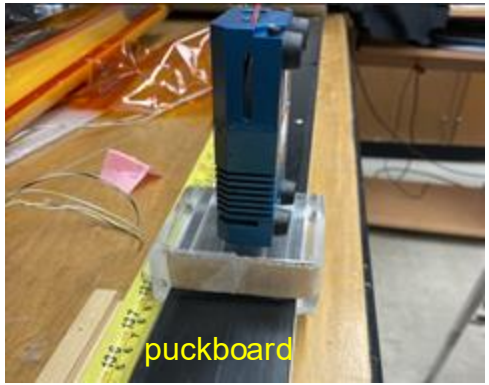
Photodiode Station: Setup

285 fibers tested; 15 with special end treatment

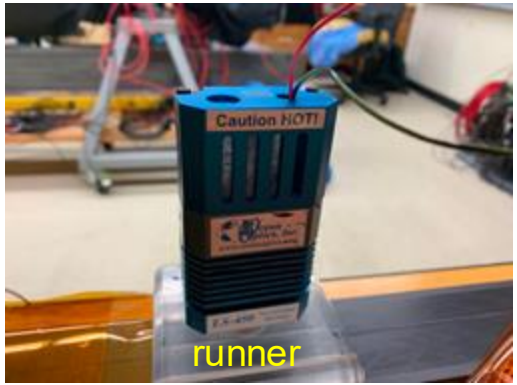




HAMAMATSU
PHOTON IS OUR BUSINESS



LED 370 nm; moves along puckboard



LED 370 nm; slides on acrylic runner

Optical grease at contact

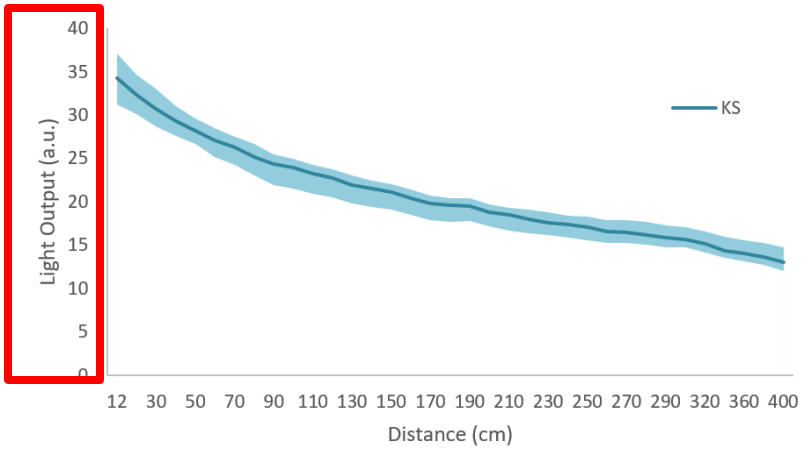
Photodiode Station: λ and light output

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

Attenuation Length: End Treatment

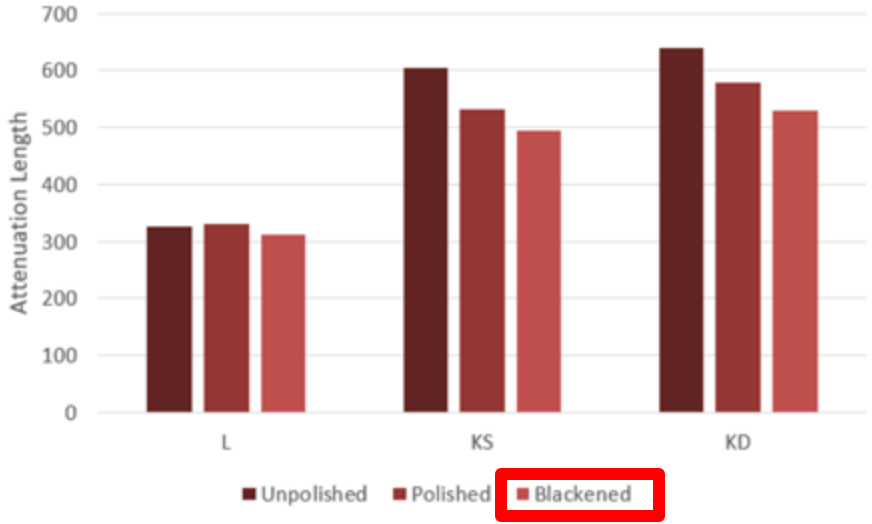


Figure 10. The attenuation length of each fibre at each stage of end treatment. The attenuation length comes from Eq. 2, from distances > 100 cm. As is visible, the attenuation length monotonically decreases as the fibre is polished and then blackened.

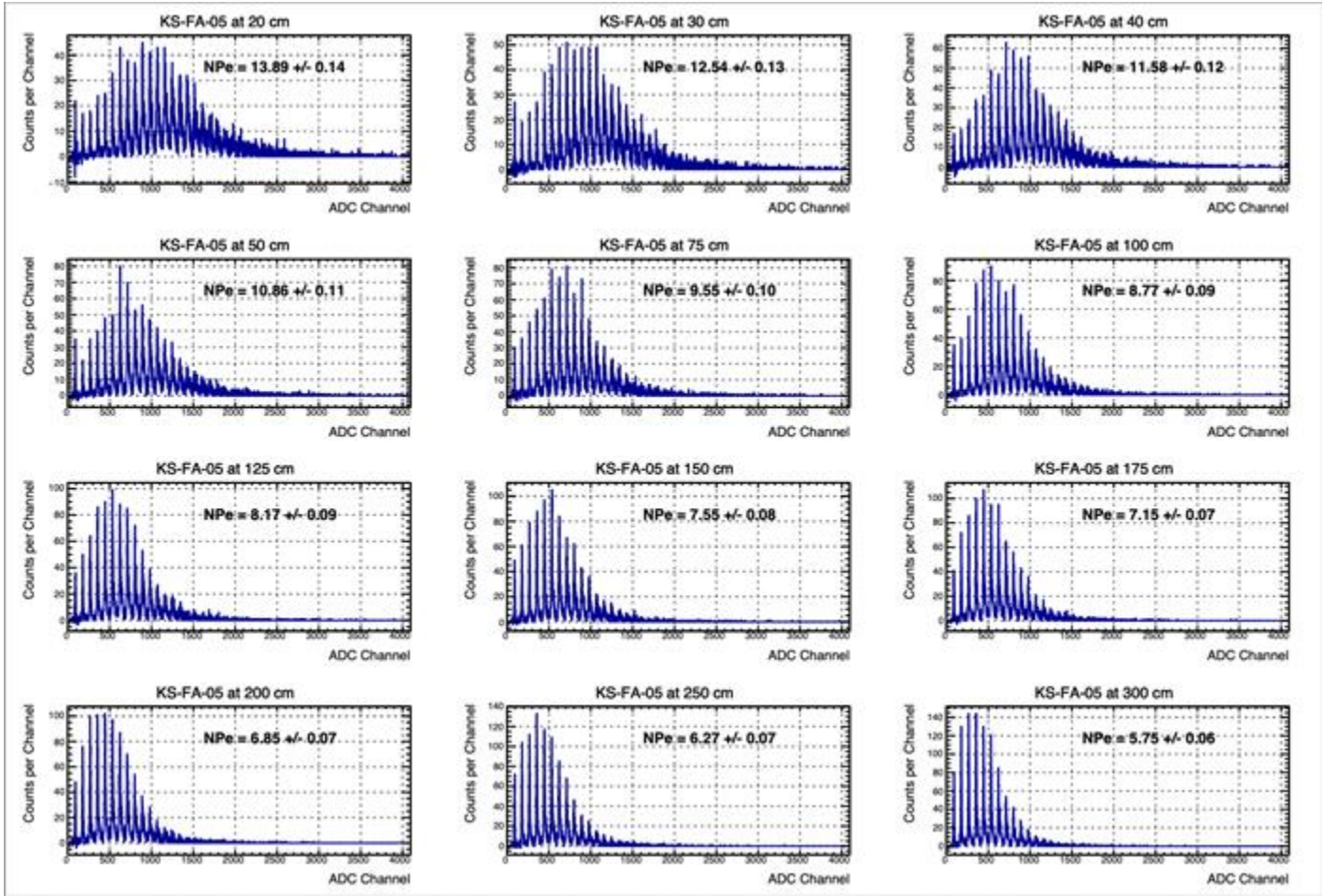
Blackened end emulates fiber reponse in BIC

Npe Station: Setup

^{90}Sr source

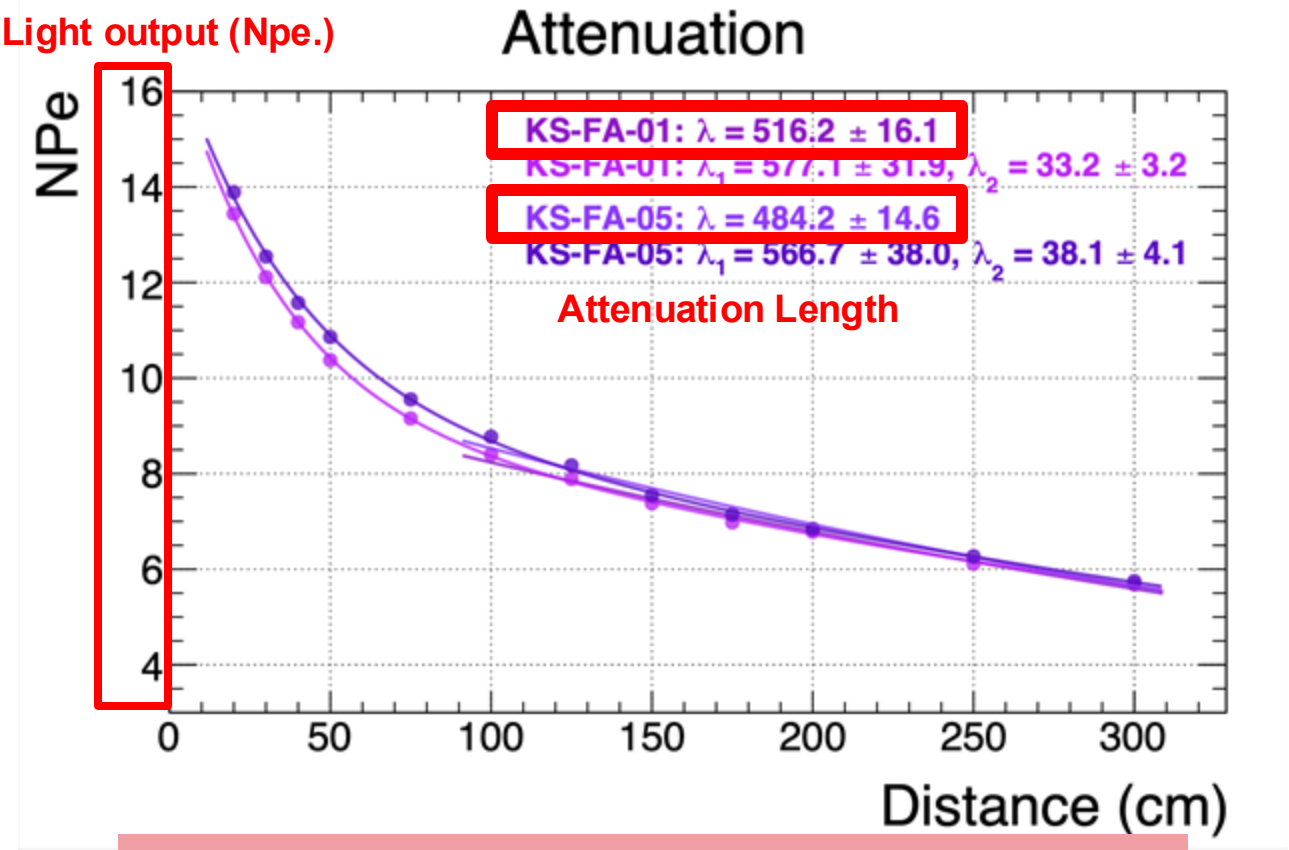
- Complete darkness
- Two 3x3mm^2 SiPMs
- Fiber along plank
- Coincidence with SiPM
- ^{90}Sr with trigger scintillator
- Scan ^{90}Sr from 20-300cm
- Fit spectrum extract Npe

Npe Station: Peaks



Npe Station: λ and light output

Light output (Npe.)

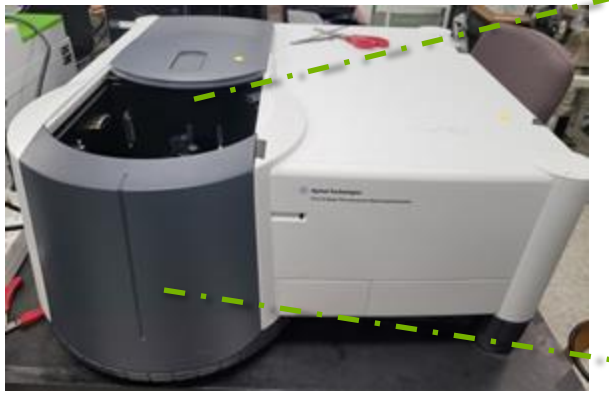


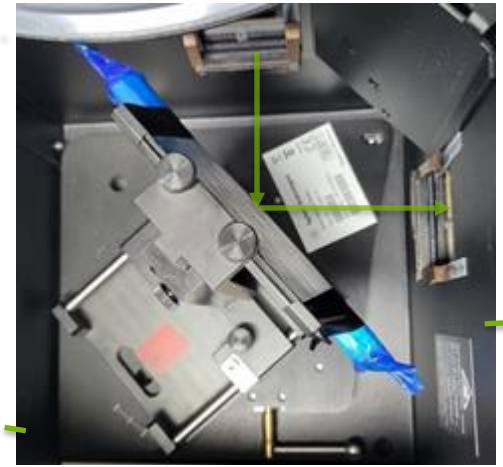
Kuraray KS selected; met spec for both λ and light output

Fiber Emission Measurement

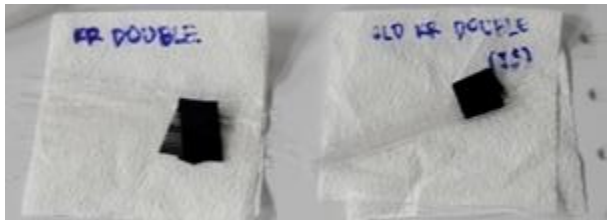
Wavelength Response – KNU

Cary Eclipse Fluorescence Spectrometer





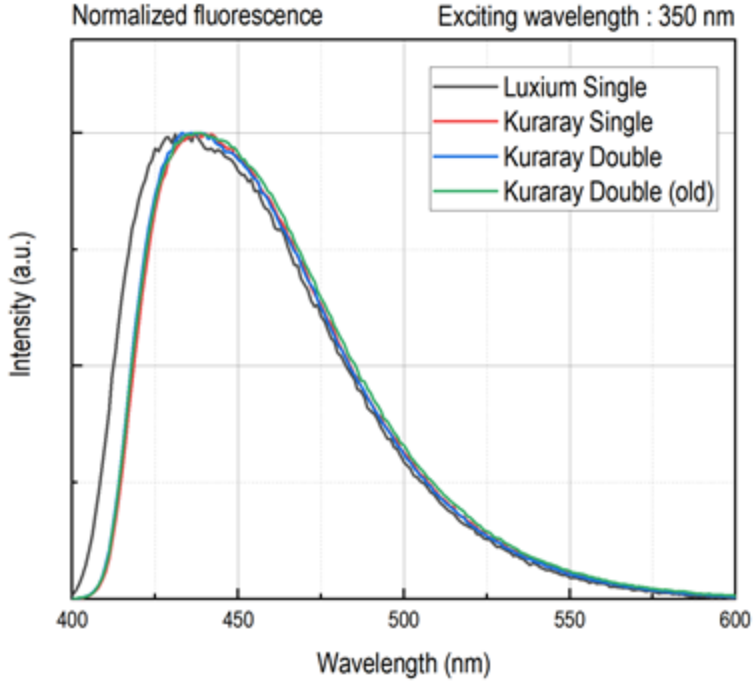
~150 fibers bundled for measurement



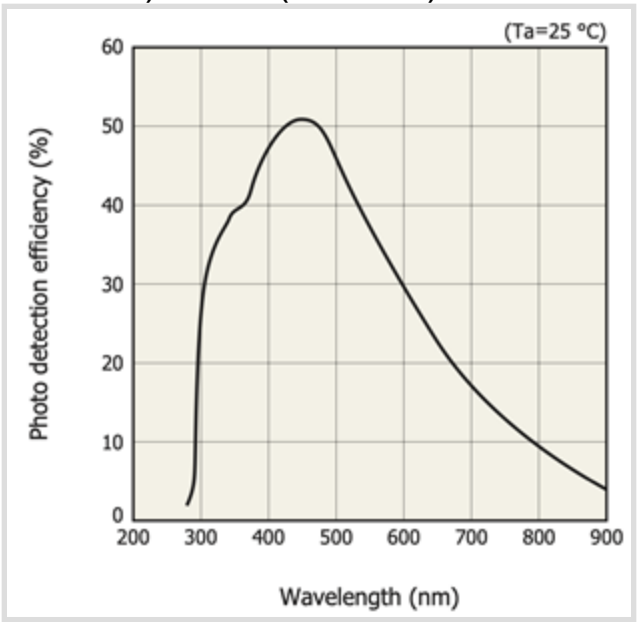
Kuraray (double-cladding) Kuraray (double-cladding) Kuraray (single-cladding) Luxium (single-cladding)

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

QC for Fibers

Procedures

- QC Procedure - from BCAL; updated for BIC by **U Regina**
- Evaluate (ca. 1%?) random fibers to meet BIC specifications
- Spectral shape, 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 R... ...or measuring the a... ...ers.

Recommendation: finalize QA/QC procedures before the start of full component production.
Response: completed

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)

Summary

- Extensively tested 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 in progress
- **Kuraray SCSF-78 contract expected to be signed in October.**
- Fiber QC/Safety: extensive testing QA/QC protocols; sent to ANL
- Setup and procedures established at the production site ANL