

QA testing of scintillating fibers of forward EM Calorimeter for EIC

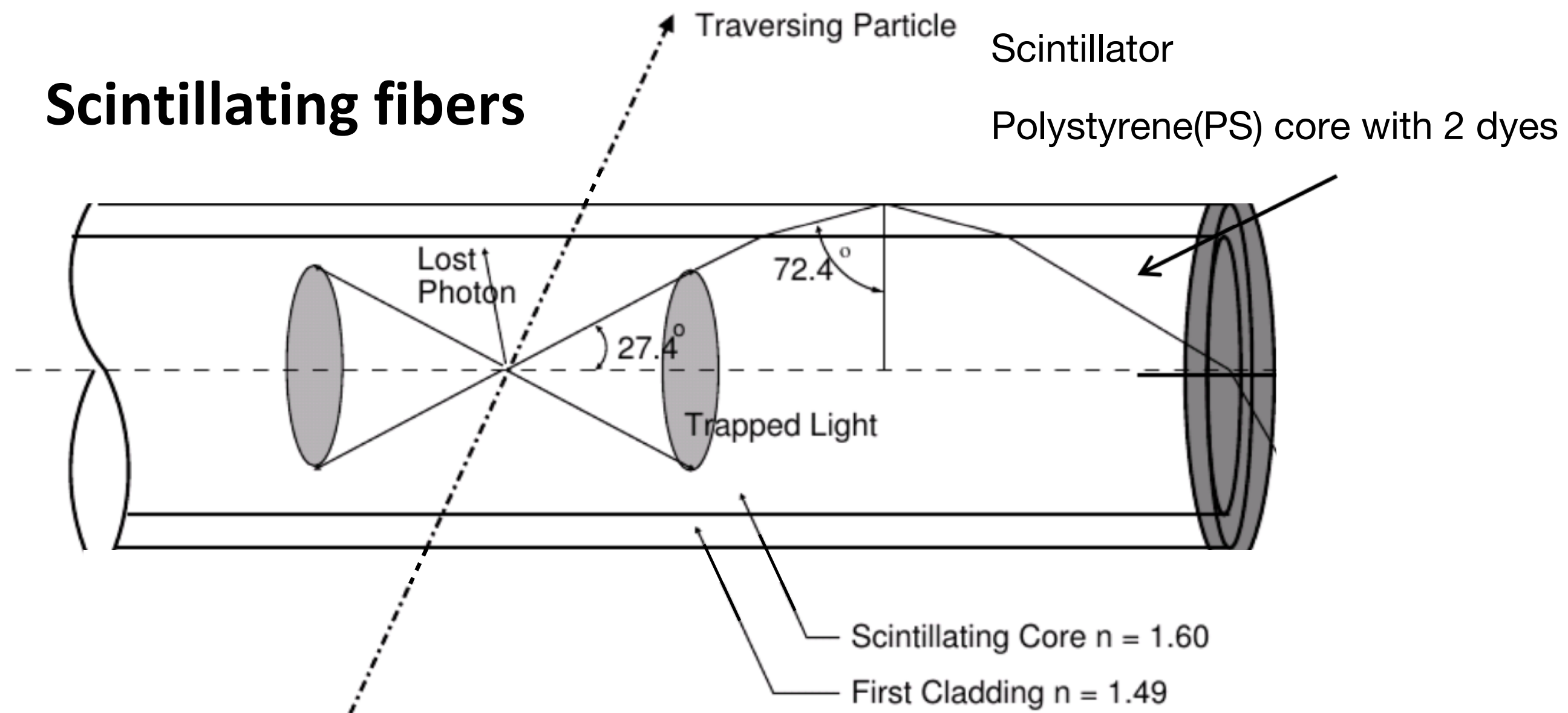
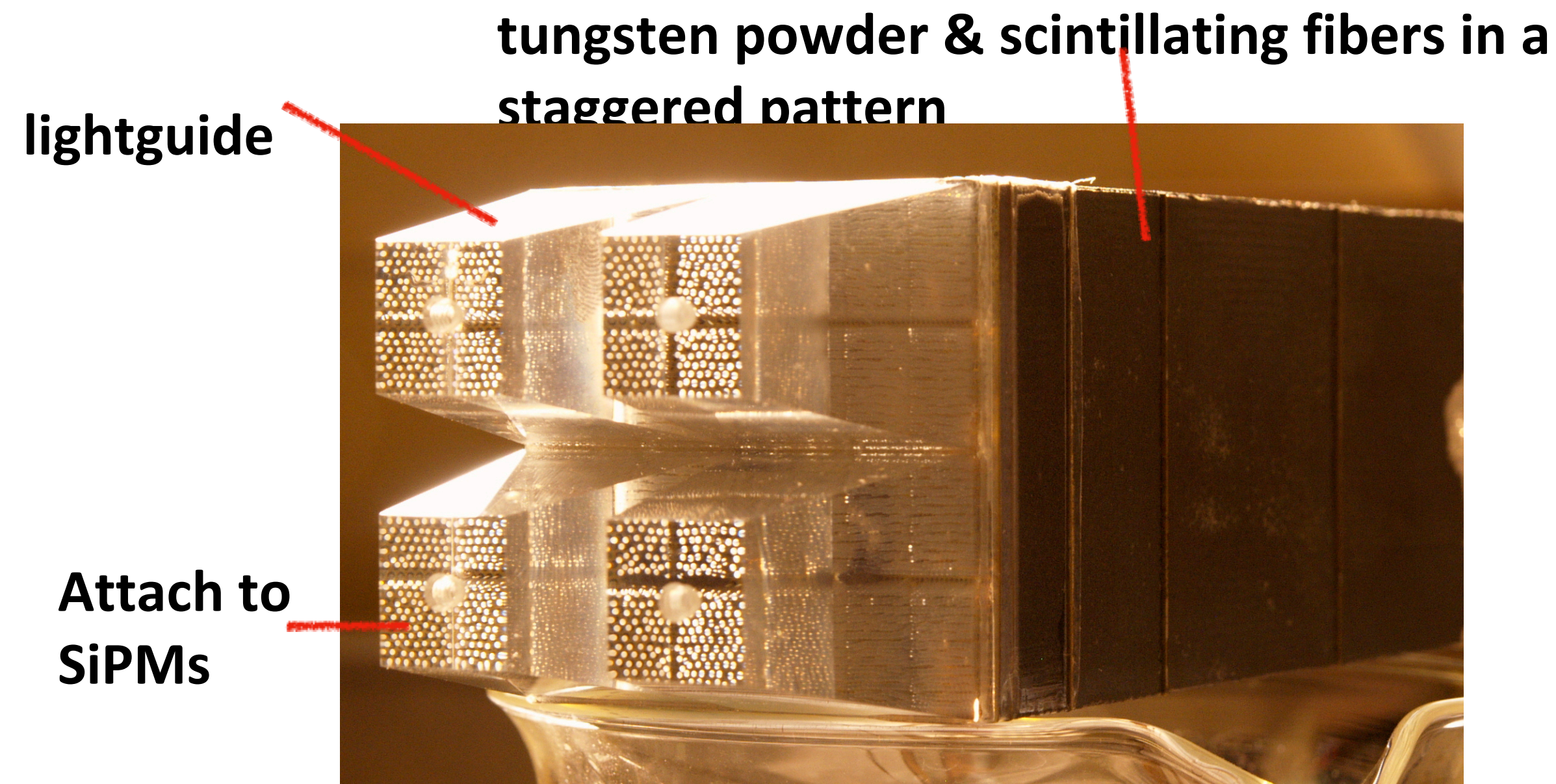
Yunshan Cheng

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UCLA



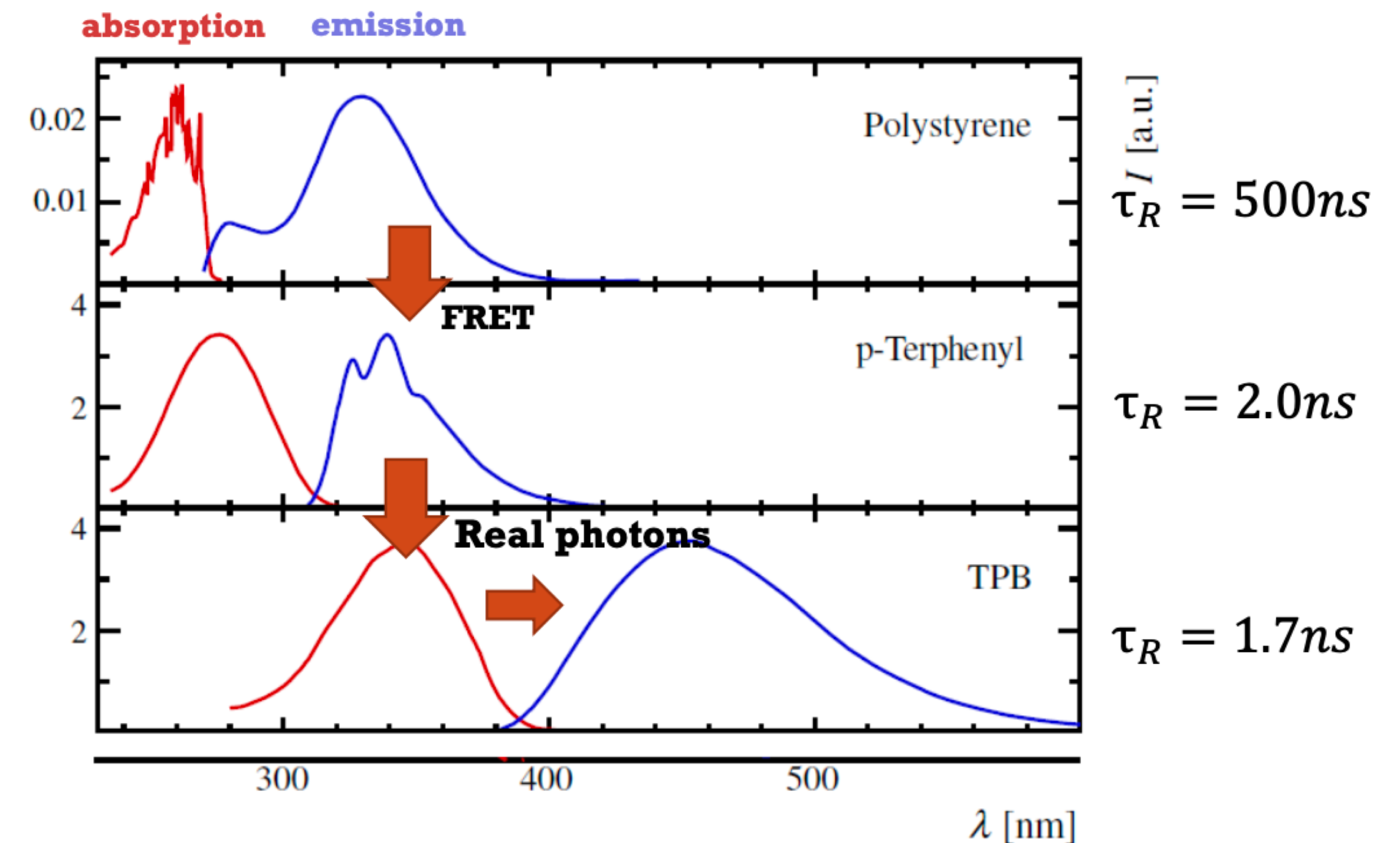
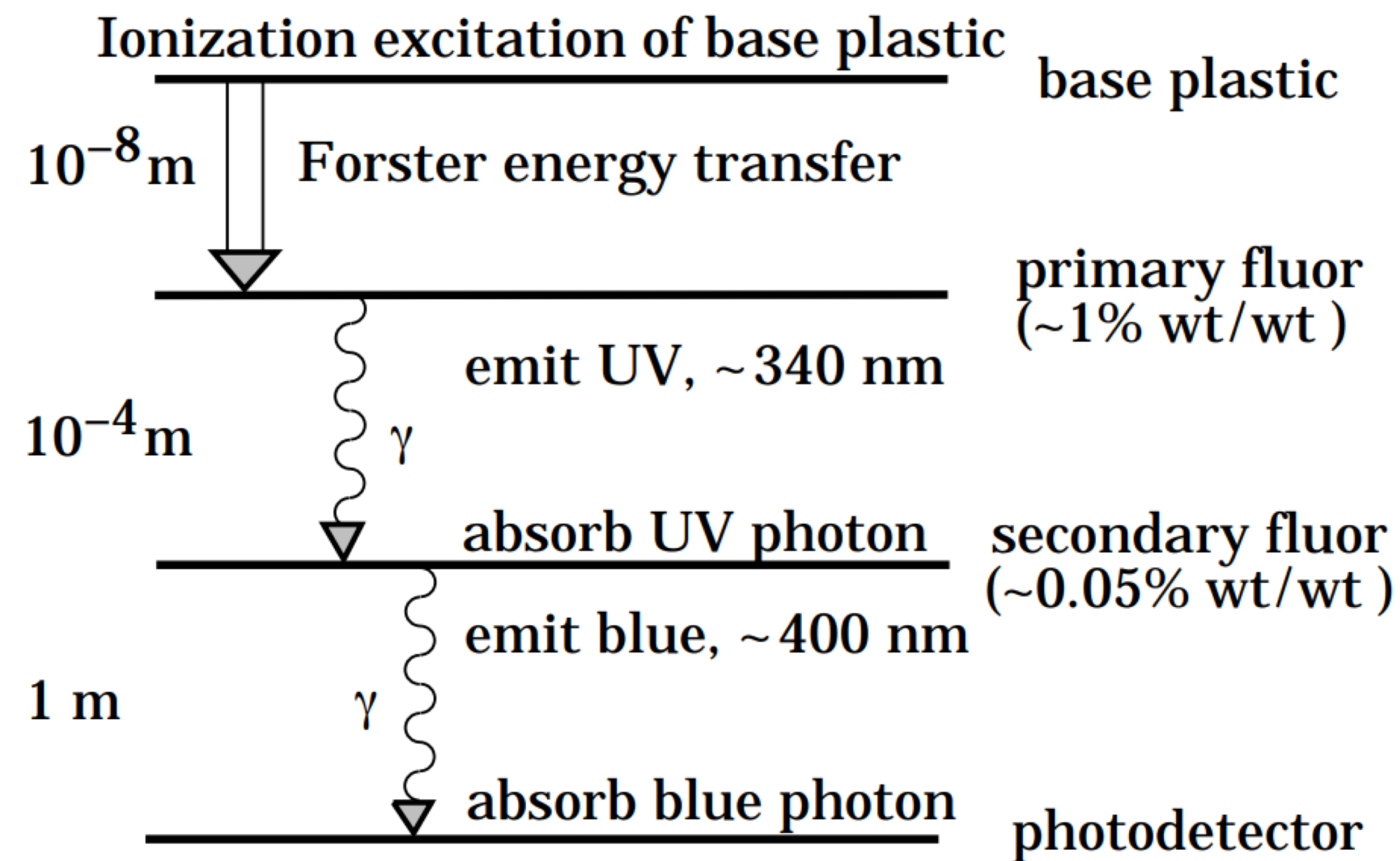
Introduction



- Clad optical fiber is both a scintillator and a wavelength shifter.
- The fiber is drawn from a preform → cladding
- Interface between core and cladding has the highest possible uniformity and quality, so the signal transmission via total internal reflection has a low loss (long attenuation length).
- Attenuation length and LY is affected by: crystallinity of the base PS; quality of total internal reflection boundary and concentration of dyes as wavelength shifter.

How do scintillating fibers detect charged particles?

- Plastic molecules are energized by the ionizing radiation.
- The energy is transferred to fluors in a one or two step process, converting energy to optical wavelengths.



- Primary fluor: FRET significantly reduces decay time.
- Secondary fluor: Shift to longer wavelength \rightarrow better transmission \rightarrow longer attenuation length. Extends the difference between emitted and absorbed wavelength to mitigate self-absorption.

Fibers from Luxium

Requirements and Technical specifications for FEMC scintillating fibers
ePIC TDR Table 8.58

| Parameter | Requirements | Comments |
|-----------------------------|--|---|
| Light Yield (LY) | ≥ 8000 photons per MeV | Acceptance QA with Sr90 source Compared to a standard sample |
| Nominal Diameter | $0.47 \text{ mm} \pm 0.0094 \text{ mm RMS} \leq 0.02 \text{ mm}$ | QA sampled on 10% boxes 100% at ramp-up prod. stage |
| Attenuation Length | $\geq 3 \text{ m}$ | QA with UV LED |
| Batch-to-batch LY variation | $\leq 10\%$ | QA with Sr90 |
| Emission spectrum | Blue-green light | To match QE of SiPMs |
| Scintillation Decay Time | $\leq 3 \text{ ns}$ | Bunch structure at EIC |
| Delivery Method | In canes, length of fibers +2%, -0% | Length $\geq 1 \text{ m}$, increment 20 cm |

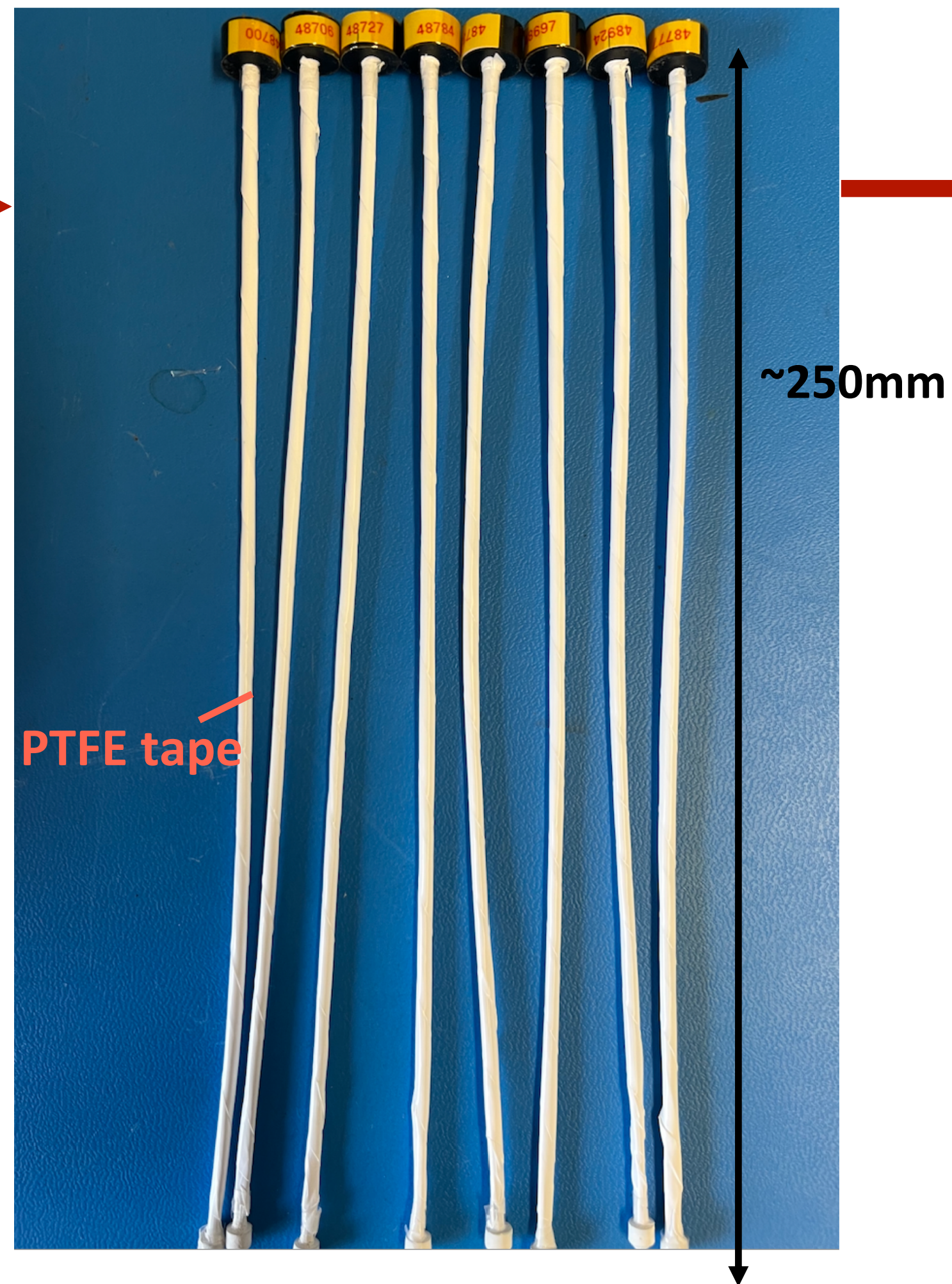
- There are 3,000 km of fibers in FEMC, which will be produced by Luxium during next three years.
- At **UCLA**, LY, diameter, and batch-to-batch variation are measured.
At **Luxium**, LY, attenuation length for fibers and batch-to-batch variation are measured on preforms, and on fiber bundles for first two shipments.

Fiber testing setup

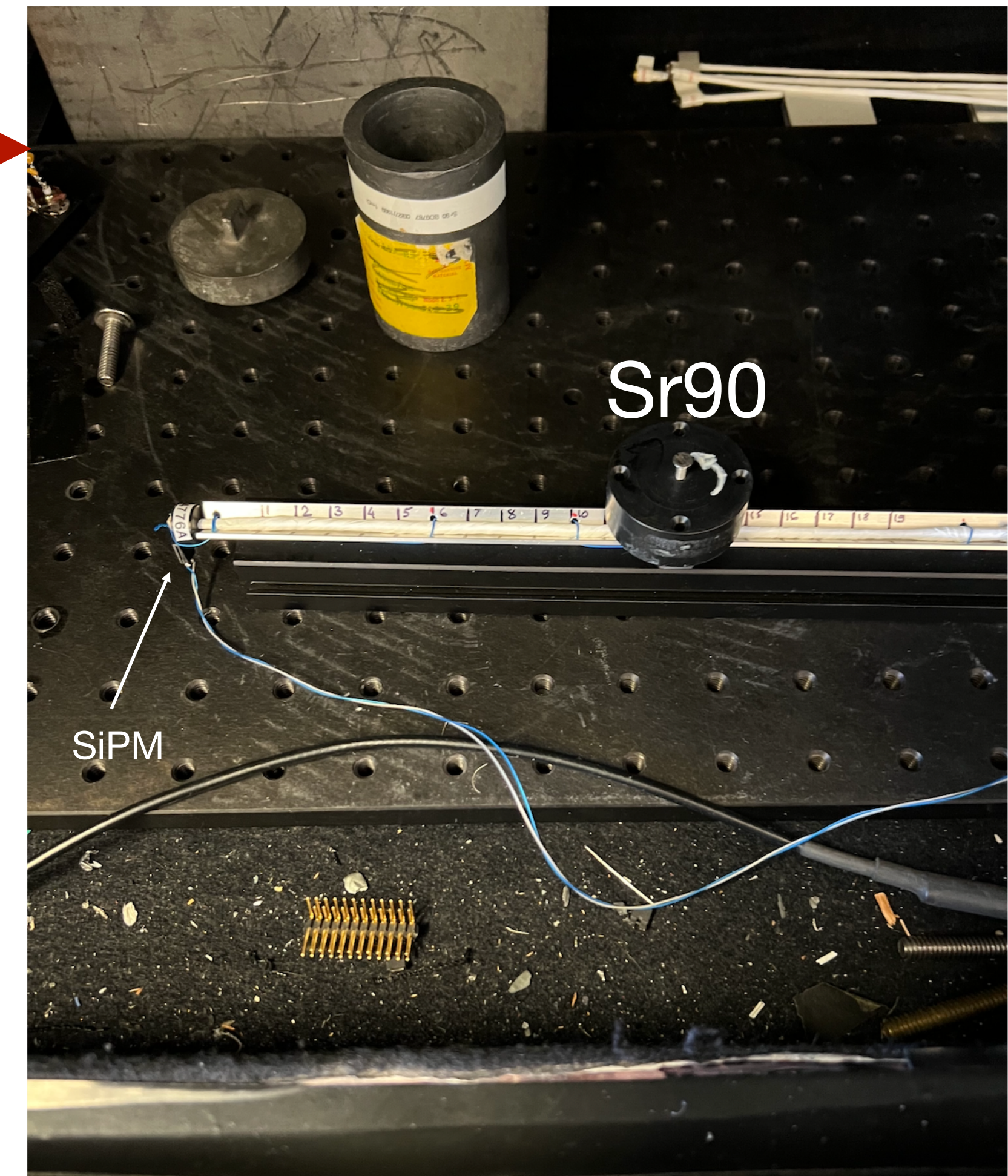
½ of the first shipment at UCLA,
~ 0.5% of total volume



- 15 fibers bundle. Both ends epoxied with EpoTek 301-1 into black Delrin ferrules.
- Ends cut and hand polished.

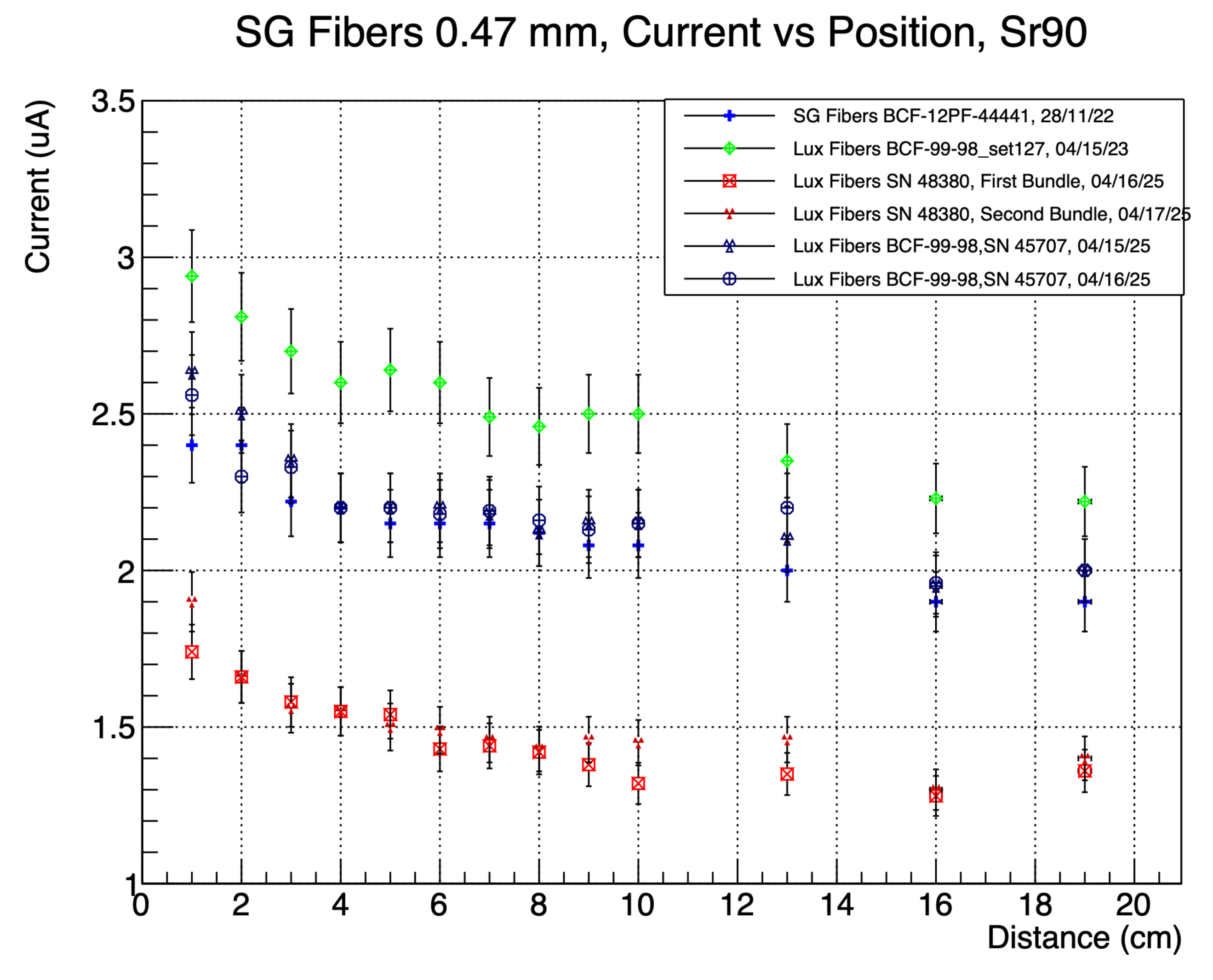


Dark box measurements



Measurements of the first shipment

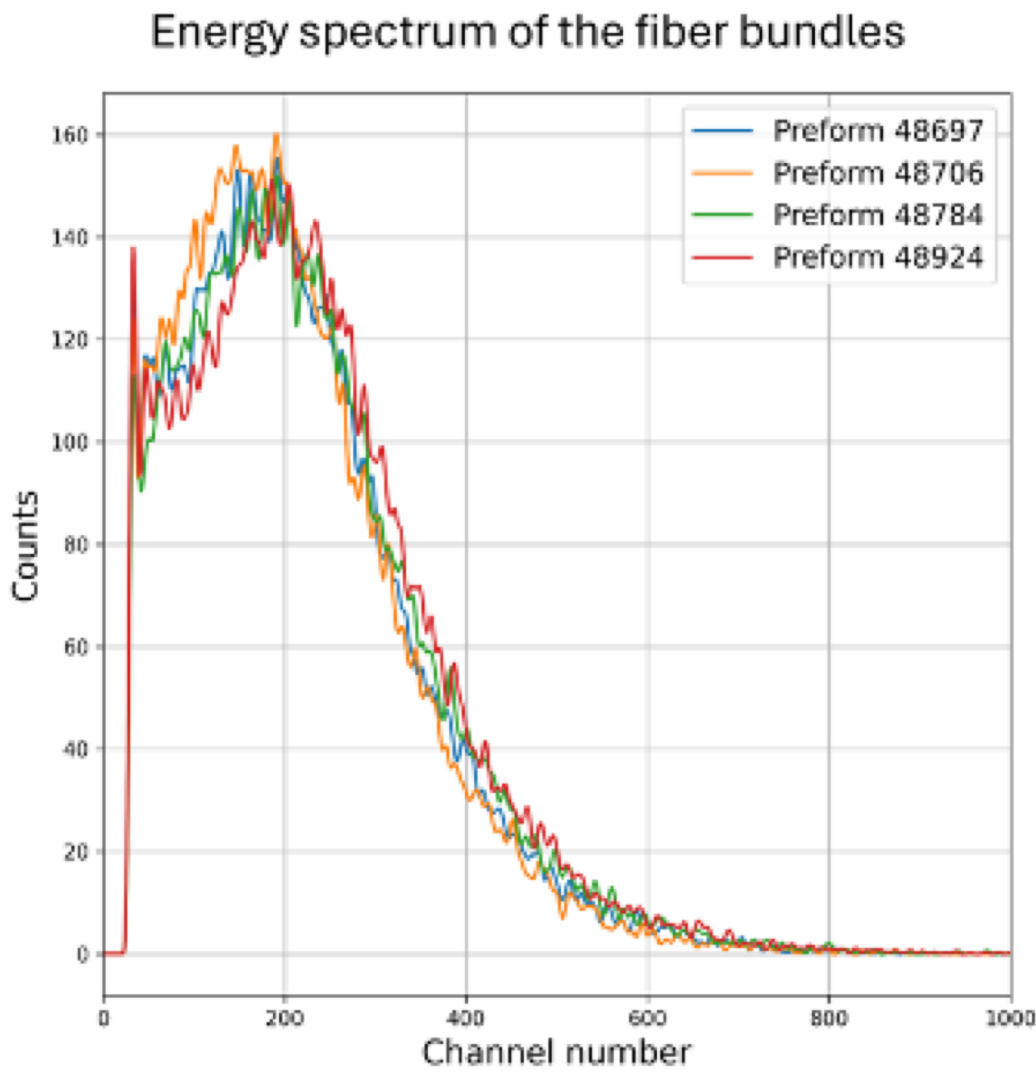
- First Article Fibers at UCLA at mid April 2025. **Did not passed QA**, LY is 40% lower than expected.
- Iterations of sample exchanges between Luxium and UCLA and weekly meetings with Luxium to address and resolve production issues.
- First two shipments will be more carefully tested at UCLA and Luxium.



Measurements of the first shipment

- Recent Luxium samples passed UCLA QA tests (half of first shipment, early July).
- Average LY identical to Ref. sample.
- Variation from preform to preform within +/- 10%.

| PMT current | |
|---------------|----------------------|
| Fiber preform | Net PMT current (nA) |
| 48697-A | 1.83 |
| 48697-B | 1.97 |
| 48706-A | 1.77 |
| 48706-B | 1.75 |
| 48784-A | 1.87 |
| 48784-B | 1.85 |
| 48924-A | 1.74 |
| 48924-B | 1.89 |



Luxium QA

| Preform ID | LY | % to Ref. Sample | | |
|------------|------|------------------------------------|--|--|
| 44776A | 1.84 | Reference Sample | | |
| 48706 | 1.68 | 91% | | |
| 48733 | 1.73 | 94% | | |
| 48924 | 1.96 | 107% | | |
| 48697 | 1.88 | 102% | | |
| 48727 | 1.8 | 98% | | |
| 48784 | 1.86 | 101% | | |
| 48700 | 1.84 | 100% | | |
| 48777 | 1.92 | 104% | | |
| Average LY | | 99.60% with respect to Ref. sample | | |



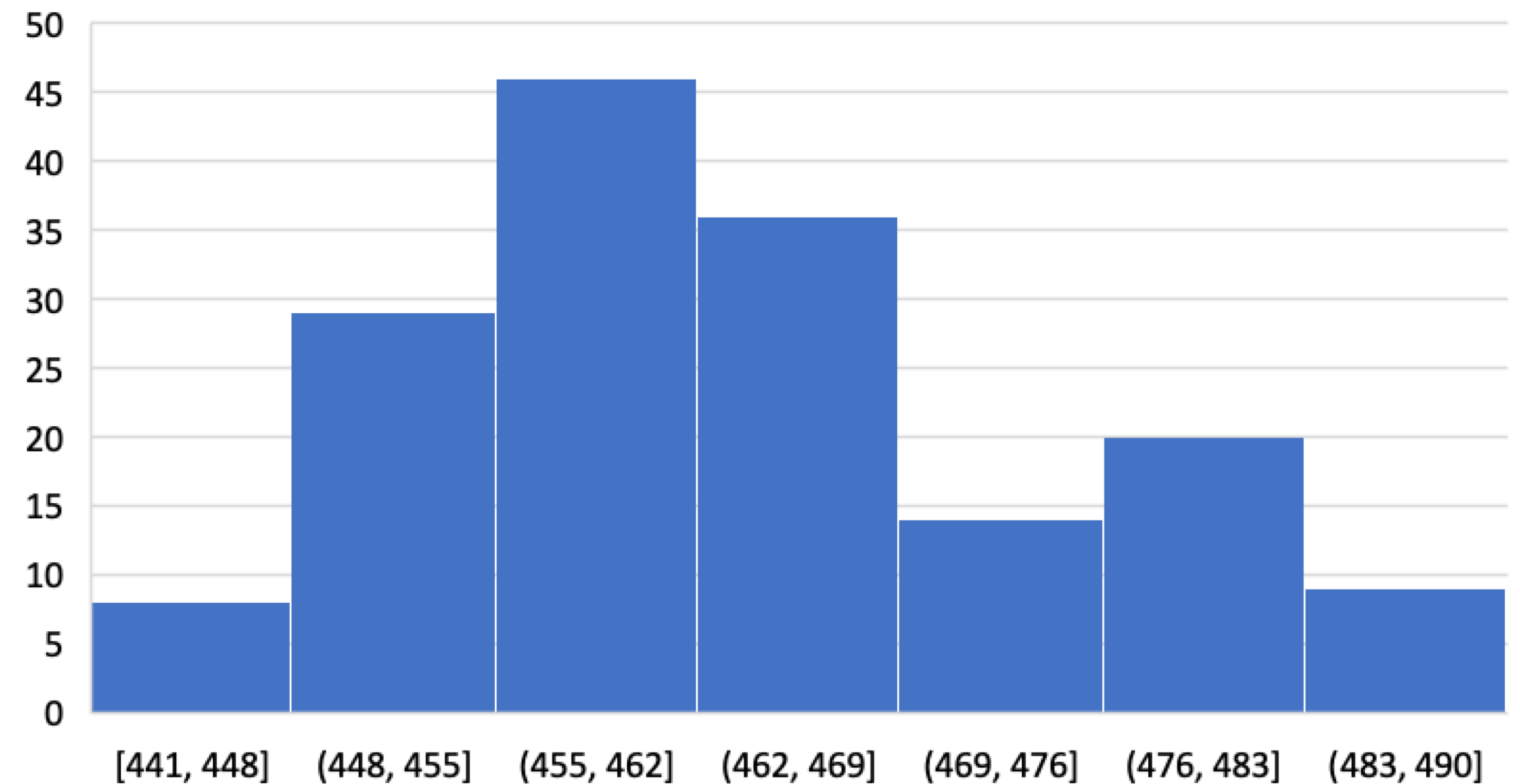
| | |
|----------------|--------------------------|
| Drawing Number | 200-8663 |
| Model | BCF9998XLS-D0.47 X 1m, R |
| Lot ID | 48697 |



| Test Type | Data | Unit |
|---------------|-----------|------------|
| Att_Length | 353 | Meter |
| LF_cm_100 | 6.47E-011 | Light Flux |
| LF_cm_200 | 4.91E-011 | Light Flux |
| LF_cm_300 | 3.58E-011 | Light Flux |
| PH Cs-137 E/O | 152 | Channels |

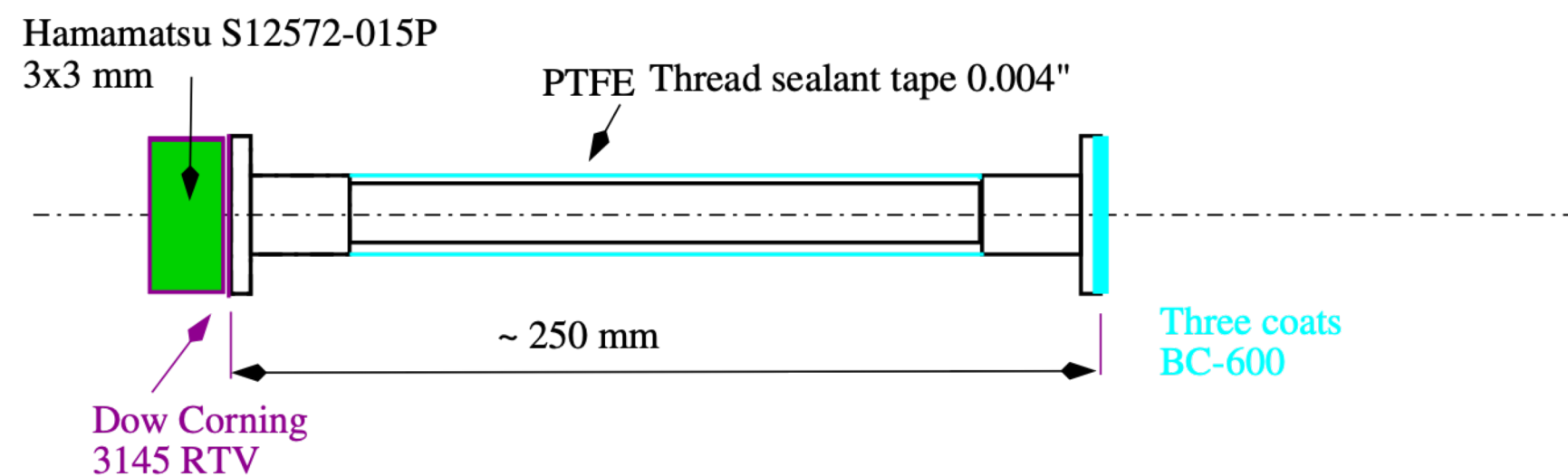
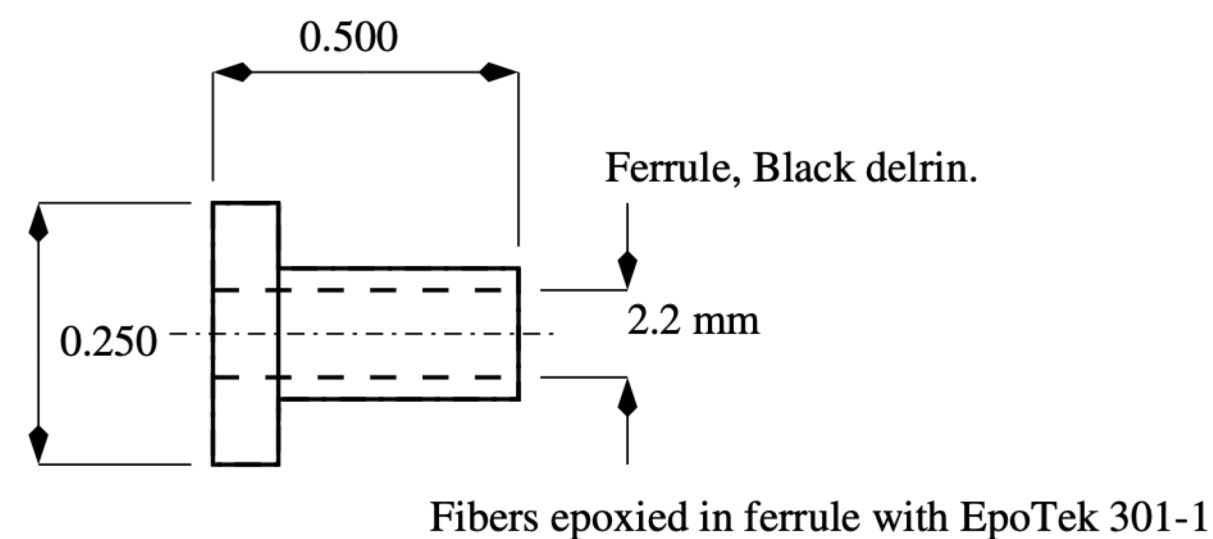
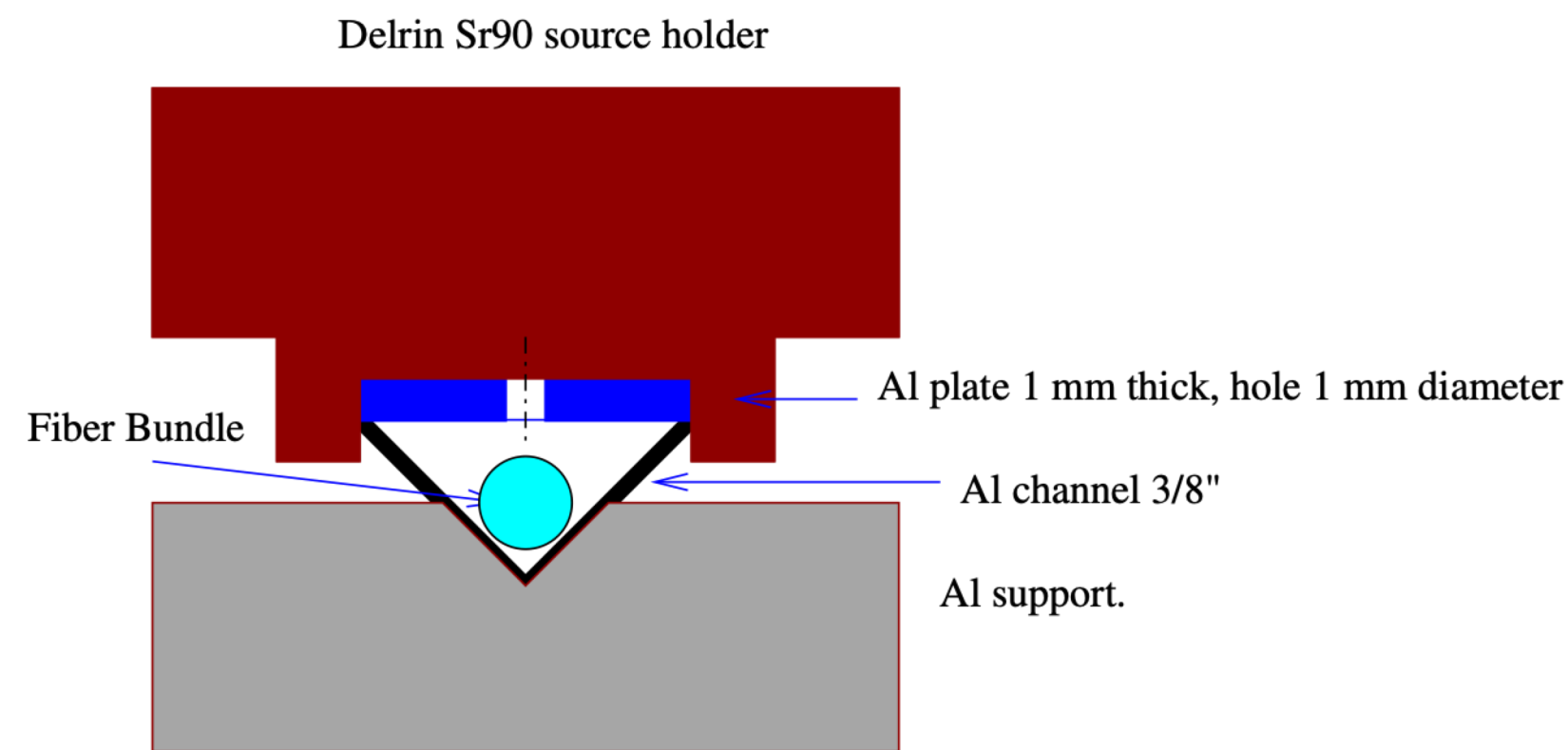
Measurements of the first shipment

- Fiber diameter (162 measurements):
 $\overline{D} = 464 \mu m$, $\sigma(D) = 10.9 \mu m$.
It is supposed to be 0.47 ± 0.0094 mm.
- The variance of fiber D is wider than expected because fibers' roundness is not perfect.
 - Not a problem in terms of FEMC performance (energy resolution)
 - May slow down staffing meshes with fibers.
- Expect the second half of first shipment at the end of July. Discussed with Luxium and hope to see the fibers will be more round.



The BCF-9998XL fibers will be supplied in the form of precut canes, 0.47 mm nominal diameter ± 0.0094 mm acceptable range, RMS ≤ 0.02 mm. The pulling towers at Luxium Solutions use a laser micrometer to measure diameter in real time as the fiber is drawn. Feedback from the measurement is routed to the tower controller to maintain size within specification....<- Luxium Technical Proposal.

Backups



Power Supply - Agilente 6614C (Bias 42.53 V)
Picoammeter - Keithley 487 (Dark current 43 nA)

Details of UCLA setup.

O.Tsai 05/08/25

- 15 fibers bundle. Both ends epoxied with EpoTek 301-1 into black Delrin ferrules.
- Ends cut and hand polished.
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- Optical contact with SiPM with Dow Corning 3145 RTV.
- Far end – three coats of BC-600
(both steps assures imperfections in polishing does not affects measurements)
- Fiber bundle loosely wrapped with PTFE ¼" wide 0.004" thick tape.
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- Measurements made in the dark box, ambient temperature is ~20 degrees C.