Dip-coated Light Guide Bars

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DUNE Photon Detector Review
8/2/16

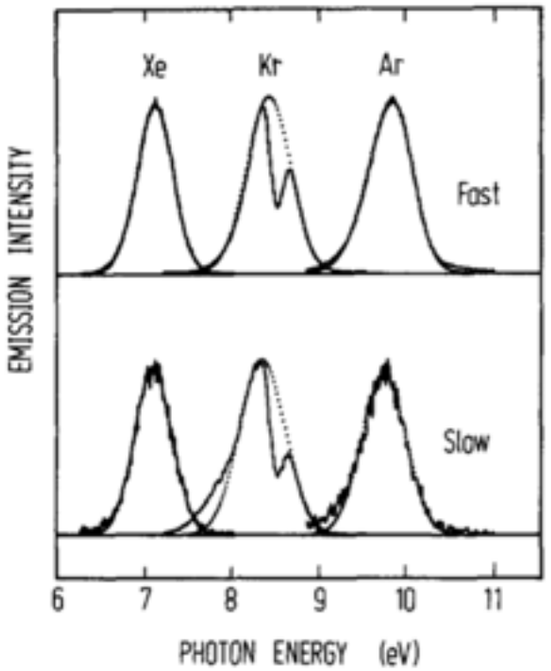
Outline

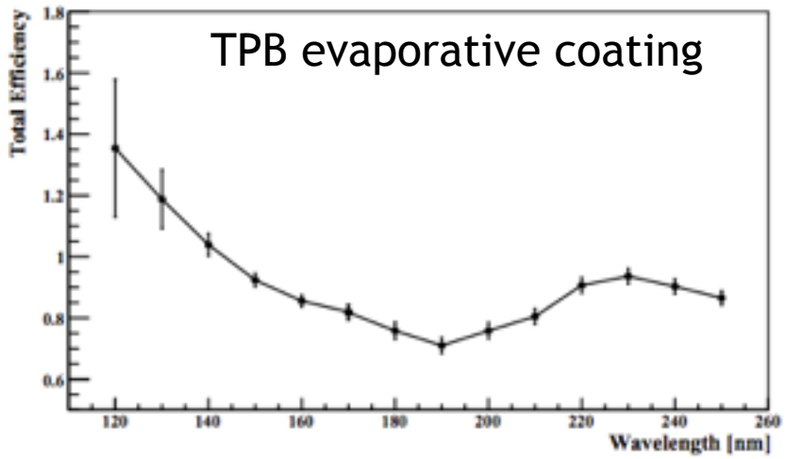
- Detector design
- Previous work at MIT
    - Existing setup and past performance
- Production at FNAL
- Conclusion

Light Guide Bar Detector Design

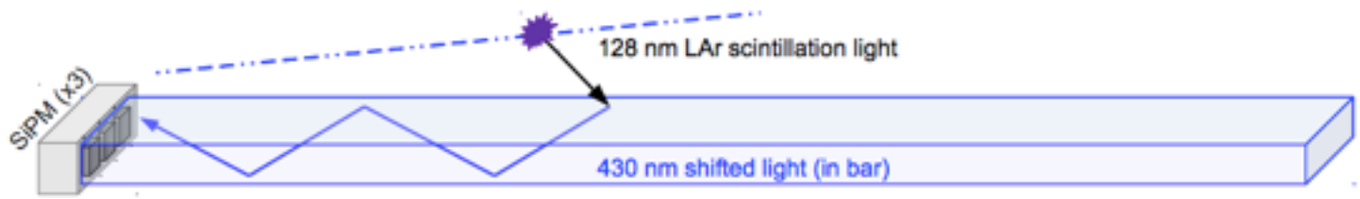
- LAr emits 128 nm scintillation photons
- Large area, thin profile acrylic bars coated with wavelength shifter (TPB) convert 128 nm light to 430 nm light
- Some re-emitted visible light is trapped in the acrylic bar and guided to the end
- Read out by array of SensL SiPMs whose peak wavelength sensitivity is well-matched to TPB

E Morikawa et al., J Chem Phys vol 91 (1989) 1469





V. Gehman et al, NIM A 654, 116 (2011)



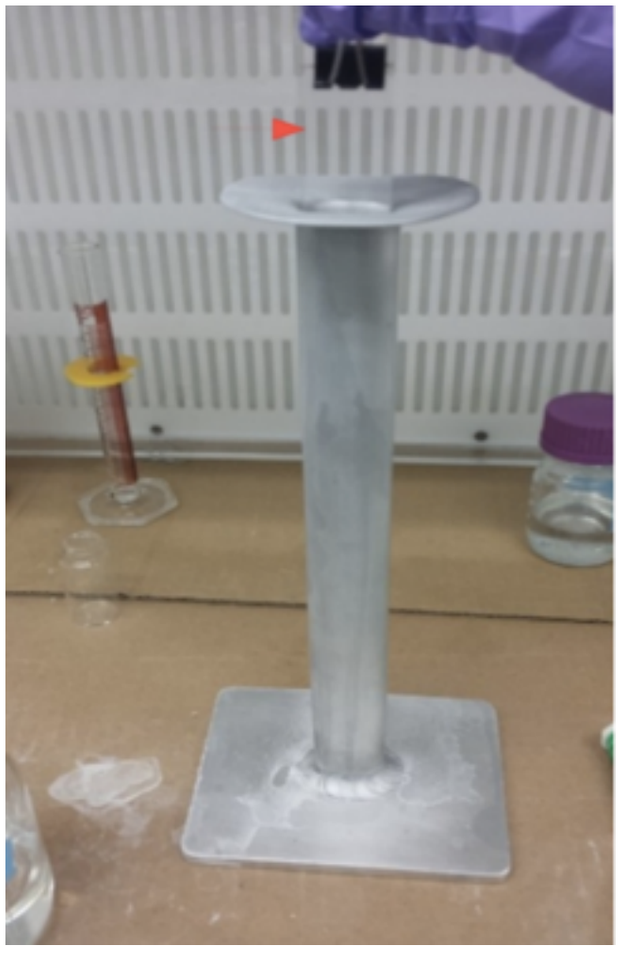
Dip-coated light guide bar illuminated by UV flashlight

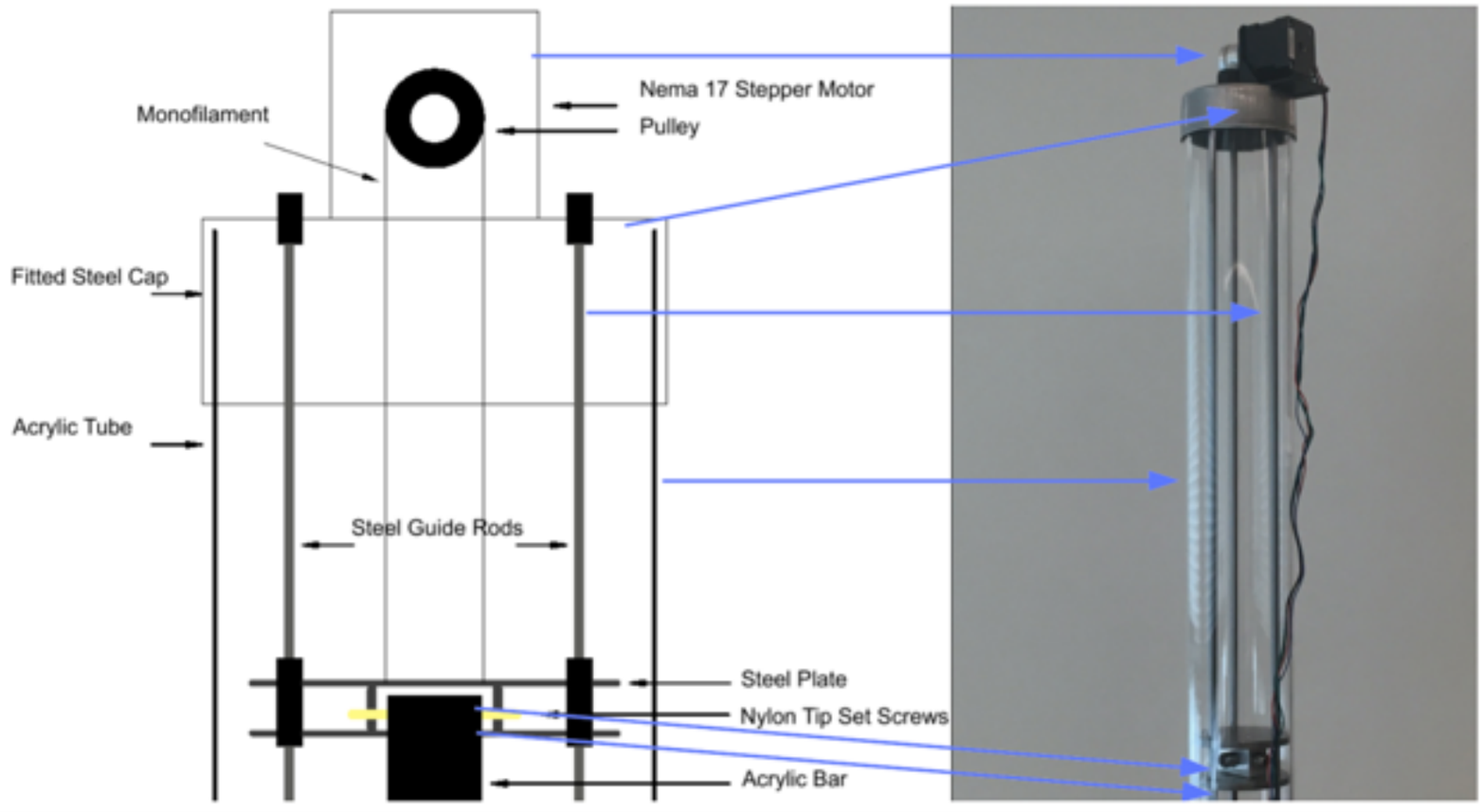
Dip-Coated Light Guide Bars

- Production method and quality control tests documented in JINST 10 (2015) P08017 and arXiv:1410.6256
  - UV-transmitting cast acrylic sheets, cut into bars, and polished on the ends
  - Bars are annealed to prevent crazing
  - TPB coating solution prepared from a mixture of toluene, TPB, UV-transmitting acrylic pellets, and ethanol
  - Bars are dipped in low humidity environment (<5% relative humidity) and hung in air to dry
  - Attenuation length tests are then performed in warm dark box

Quality Assurance: Humidity

Moved from “hand-dipping” bars to “mechanically-dipping” bars in low humidity enclosure (purged with dry nitrogen)

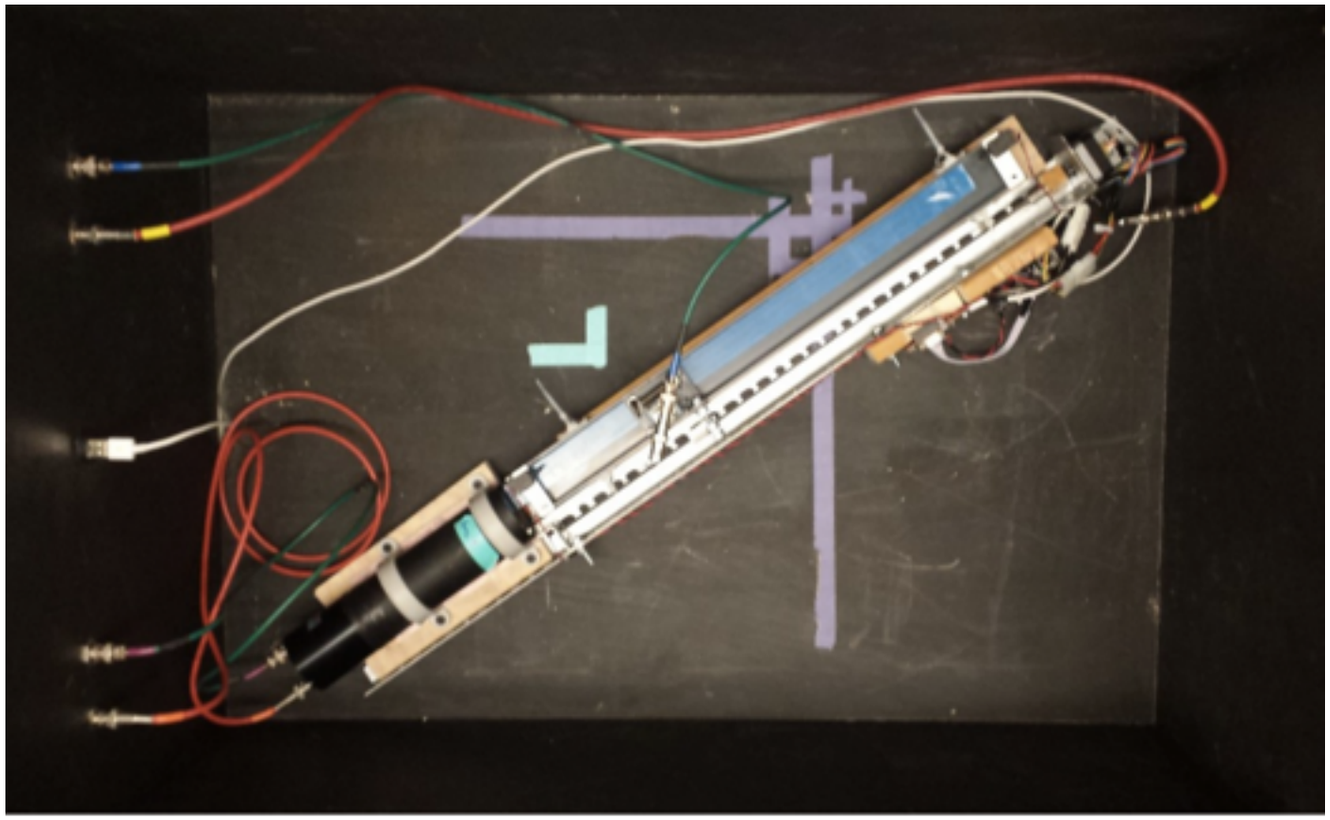


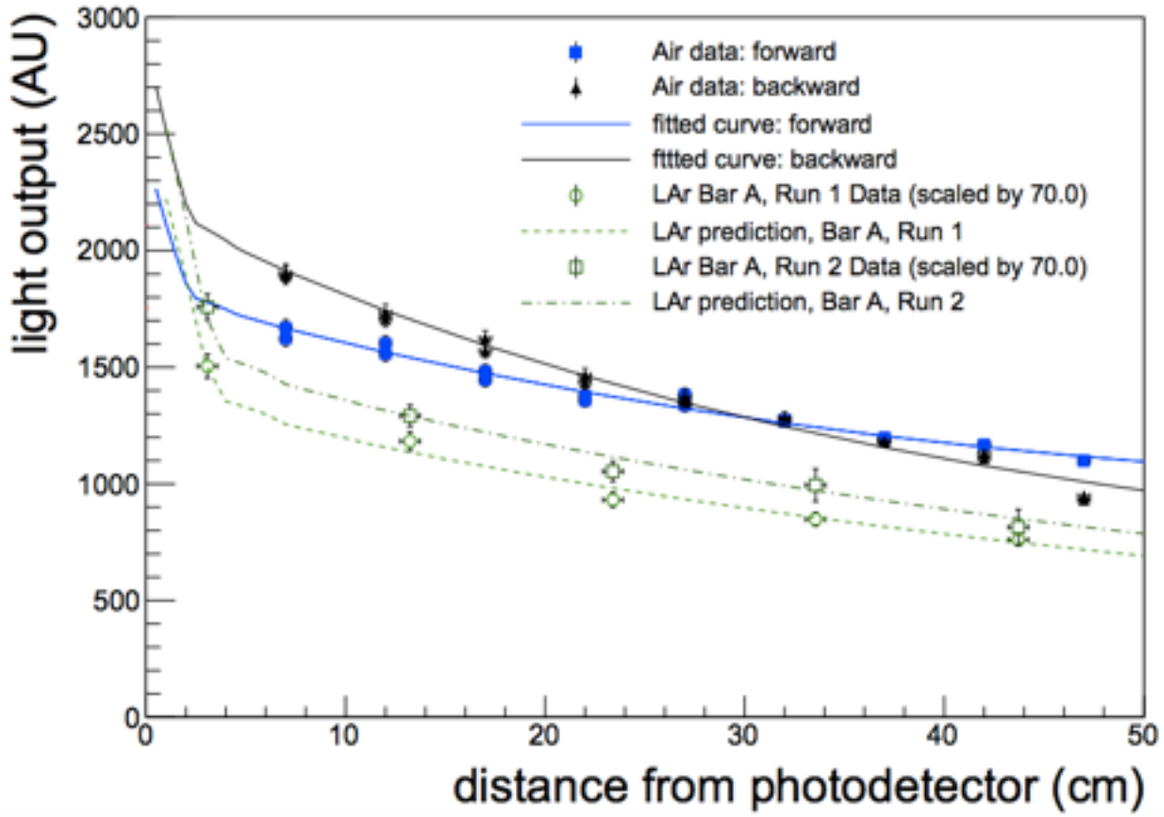


More details in arxiv:1604.03103

Quality Control: Attenuation Length

Dipped bars are measured in a dark box with UV LED, from which we can predict the behavior in LAr





JINST 10 (2015) P08017

Warm Dark Box Test Stand Data

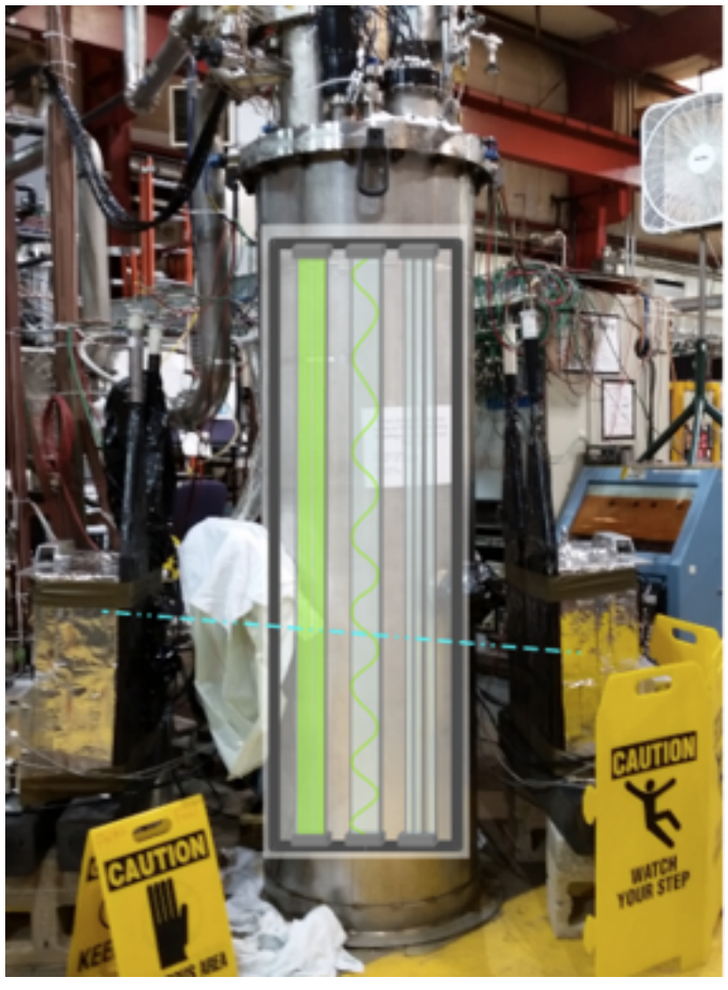
Consistently producing light guide bars showing good performance

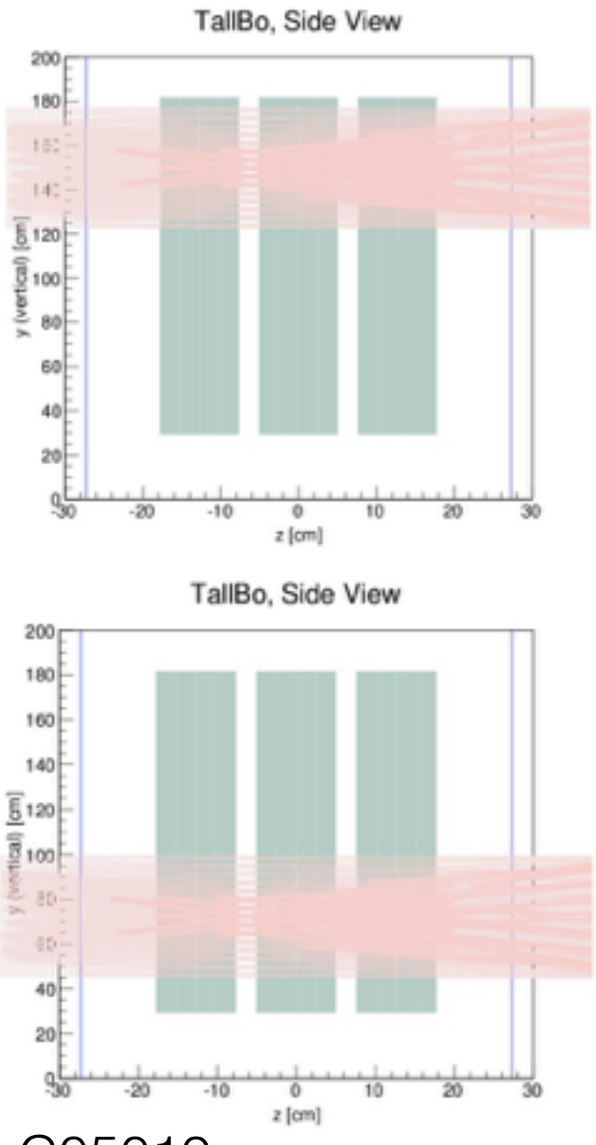
Technique	λ, Attenuation length (cm)	C, Increase in thickness (%/cm)	N, Normalization (arbitrary units)
Mechanically-Dipped	229	0.80	17.6
	286	0.84	18.9
	179	0.77	20.3
	201	0.69	20.9
	213	0.64	20.7
	217	0.84	20.3
mean (std. dev)	220 (36)	0.76 (0.08)	19.8 (1.3)
Hand-Dipped	259	0.57	23.0
	339	0.50	21.0
	257	0.45	23.6
	306	0.87	21.0
	205	0.49	23.2
	232	0.28	25.1
	251	0.10	26.8
mean (std. dev)	264 (45)	0.45 (0.25)	23.7 (2.7)

arxiv:1604.03103

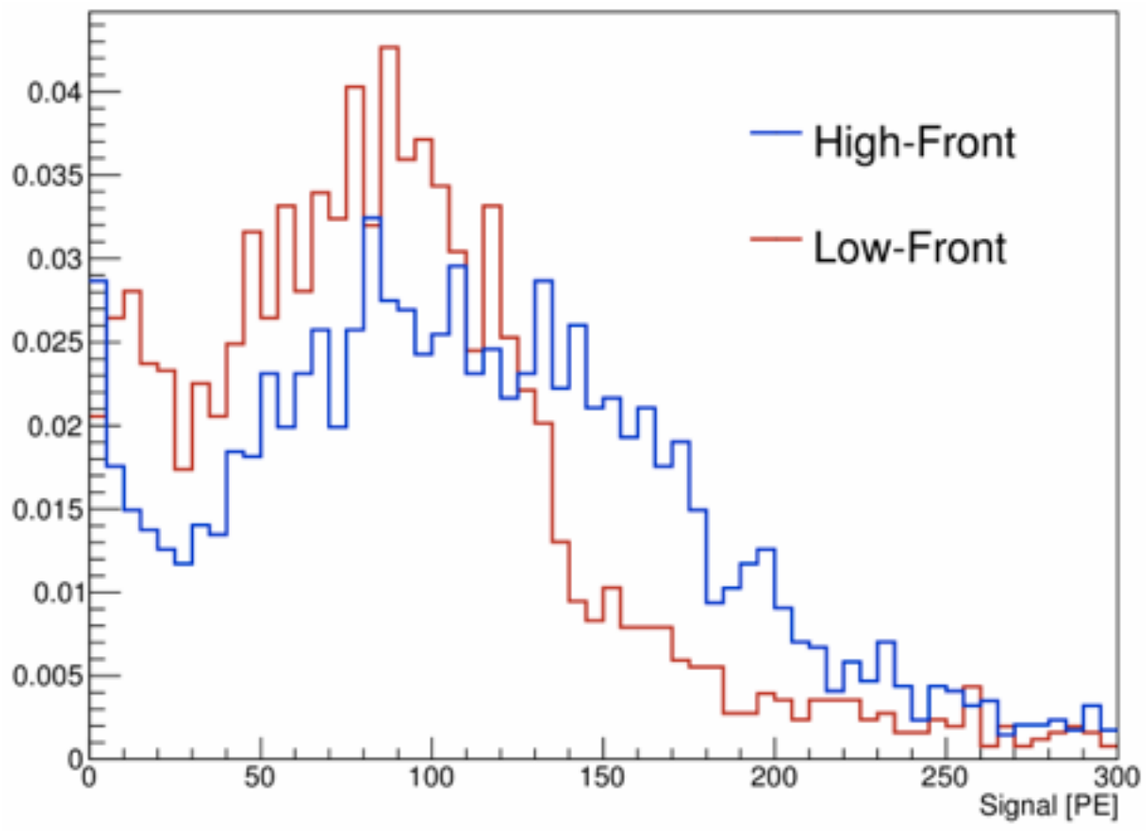
LAr Test Stand ("TallBo") Data

Best light guide attenuation length and brightness performance for TallBo runs in 2015 & 2016





Area normalized PE distribution



Attenuation length > 185 cm

D. Whittington, JINST 11 (2016) C05019

Moving Production to FNAL

- MIT lab cannot accommodate dipping protoDUNE-sized bars
- Technology/knowledge transfer to FNAL and assistance setting up and operating production facility to accomplish this
  - FNAL scientist formerly at MIT deeply involved in dip-coated light guide bar development
  - FNAL postdoc sent to MIT to learn technique
  - MIT grad student expert on dip-coated light guide bars permanently in residence at FNAL
  - MIT technician in residence at FNAL this summer

FNAL Production Overview

- 30 light guide bars will be delivered for protoDUNE
  - Planning to produce 52 total light guide bars in addition to small test bars
- FNAL & MIT postdocs as well as MIT grad students (see title slide) available for this effort
- Schedule for this has been developed and is updated regularly

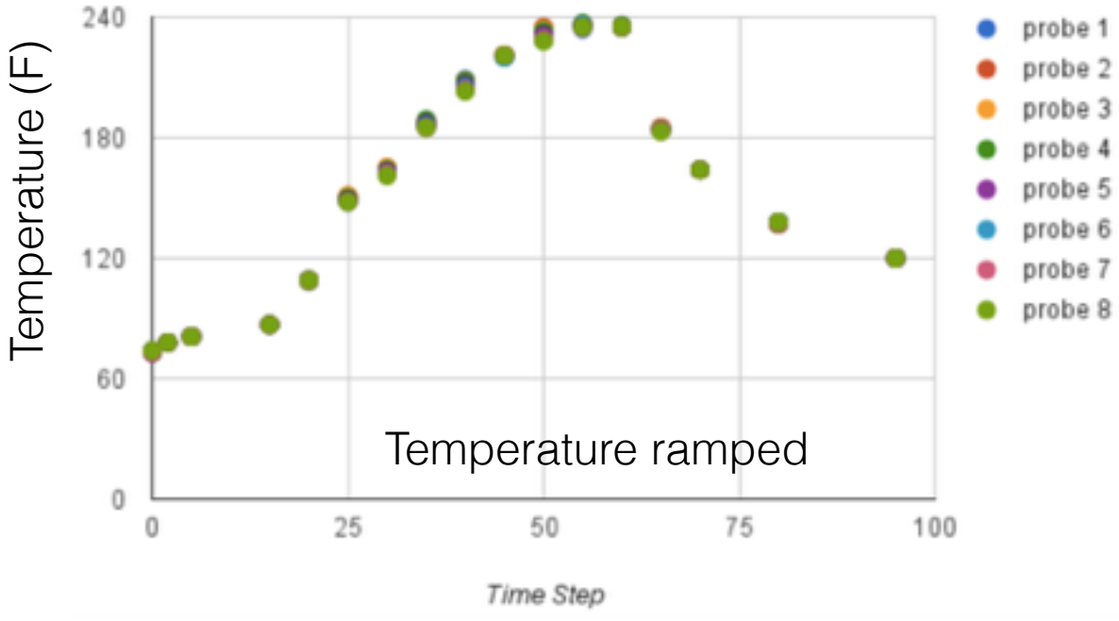
FNAL Production: Acrylics and Wavelength Shifting Solution

- Using same acrylic (UTRAN), supplier (EMCO), and finish (high-end polish) as used in the past
  - Placed initial order of 13 full-sized bars and 18 small test bars
    - Small bars will be used to vet new facilities at FNAL
- Solution will use same ingredients as before
  - Will be mixed in 8 ft wide fume hood approved for use with flammables in FNAL's Lab 6
  - Solution and ingredients stored in chemical storage cabinet

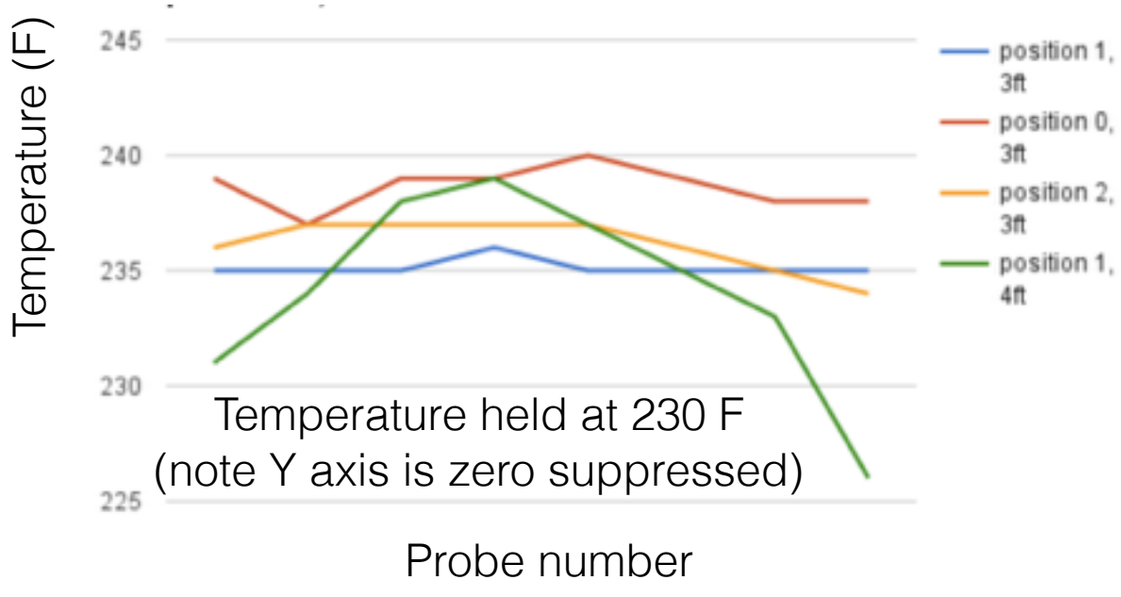
FNAL Production: Annealing

- Large annealing oven identified at FNAL
- Measurements of temperature profile indicate that it will be acceptable to anneal many bars at once on a rack inside the oven

Rod with probes along distributed along oven depth

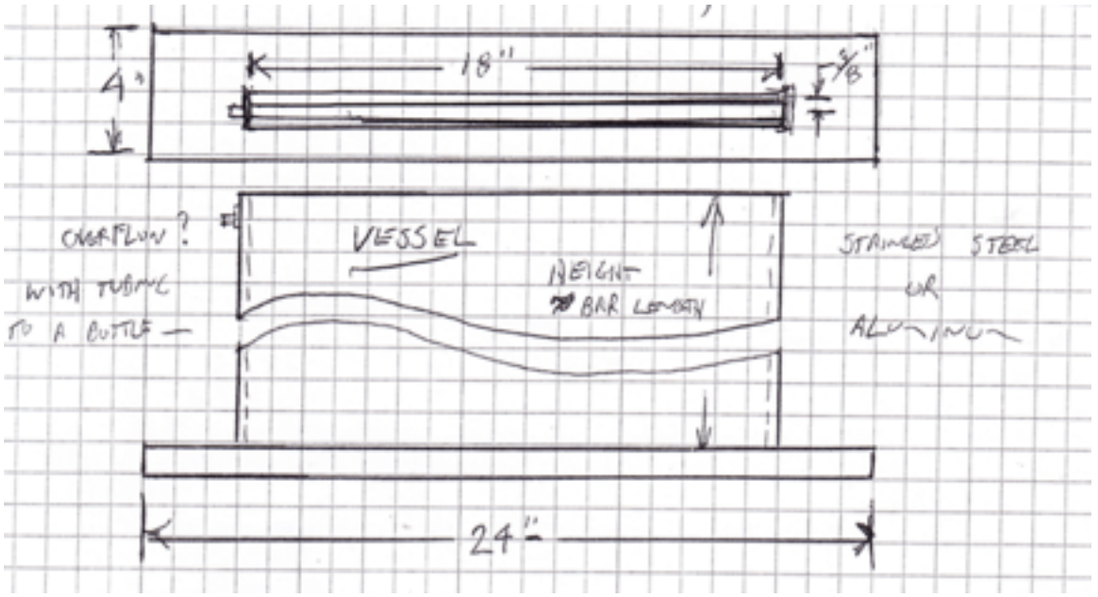


Rod with probes displaced side to side and upwards



FNAL Production: Dipping

- Dipping vessel based on extending original MIT design
- Space (15’ x 15’ x 20’) identified in FNAL’s Lab 7 for dip-coated bar production
- Writing Technical Scope of Work to address relevant safety requirement after meeting with ES&H



FNAL Production: Quality Control

- Acrylic bar tolerances are +/- 0.05” on length and width and +/- 0.024” on thickness

- Measurements will be made at the 5 mount points along the length of each acrylic bar with a caliper

- In addition attenuation length measurements performed in warm dark box on each dipped bar

  - Dark box has been built and materials ordered for attenuation length setup

Conclusion

- Excellent light guide performance demonstrated using dip-coating method pioneered at MIT
- Credible plan based on past experience to move light guide bar production to FNAL
- Experienced team committed to carrying out this effort