DUNE Photon Detector Technology Developed at Indiana University

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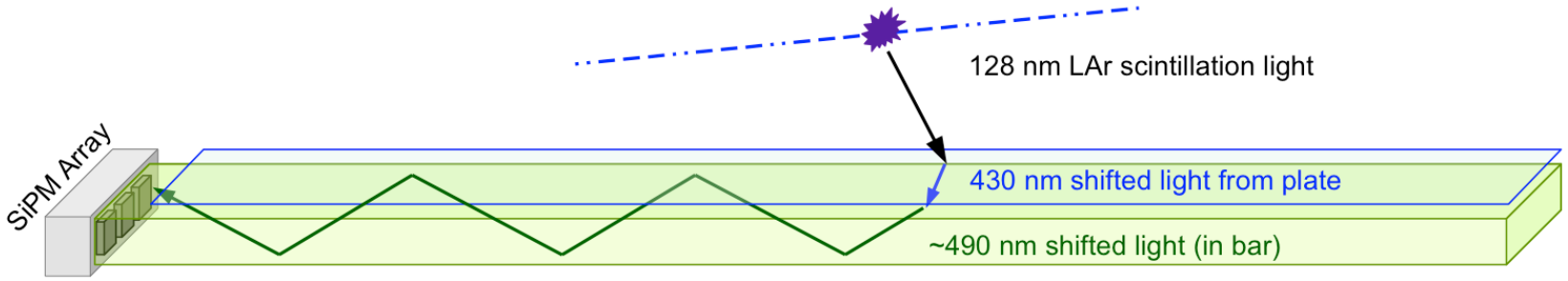
The IU Photon Detector Technology:

- The IU photon detector technology is based on commercial Eljen EJ-280 light guides with waveshifting plates made in our local lab
- 128 nm light VUV scintillation light is converted to 430 nm by the waveshifting plate
- 430 nm light is converted to 490 nm light by the Eljen light guide and is channeled to one end where it is viewed by SensL SiPMs



The underlying assumption:

The properties of the photon detectors are separable and can be studied/optimized independently.

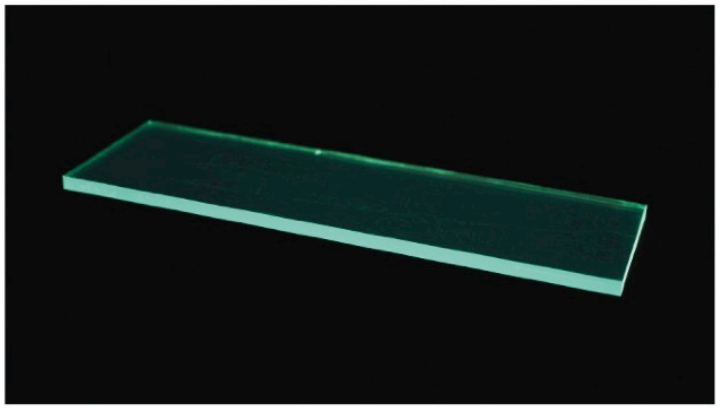
These properties include –

1. attenuation length
   a. Eljen light guides are a commercial product with uniformly excellent attenuation length (> 2m)
2. brightness
   a. relative brightness
      - optimization of wavelength shifting plates
   b. absolute brightness/efficiency
3. SiPM aging*
   a. reasonable performance in IU tests

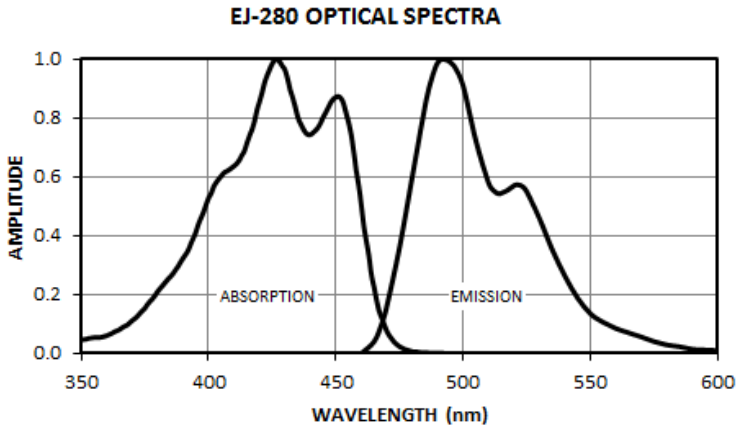
* later talk

Light Guides

- Based on commercial Eljen EJ-280 light guides custom cast in polystyrene
- Tested extensively in LN2 and LAr locally and in LAr at Fermilab
  - no crazing or degradation even after multiple thermal cycles



EJ-280

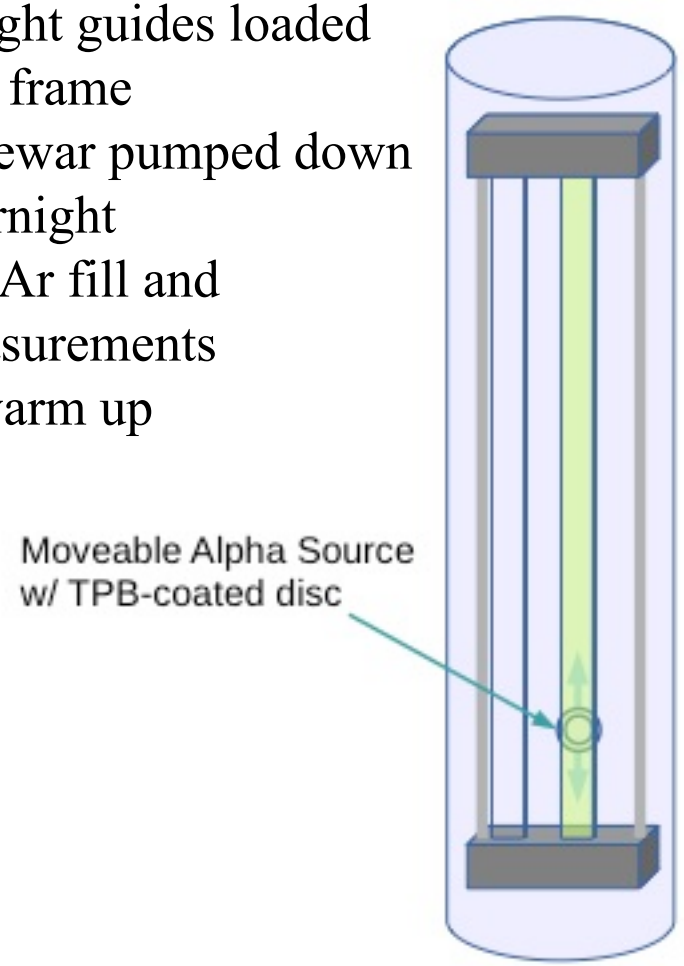


Light guides for protoDUNE ordered and set for delivery in two shipments in 12/16 and 3/17

Attenuation length measured in the IU dewar

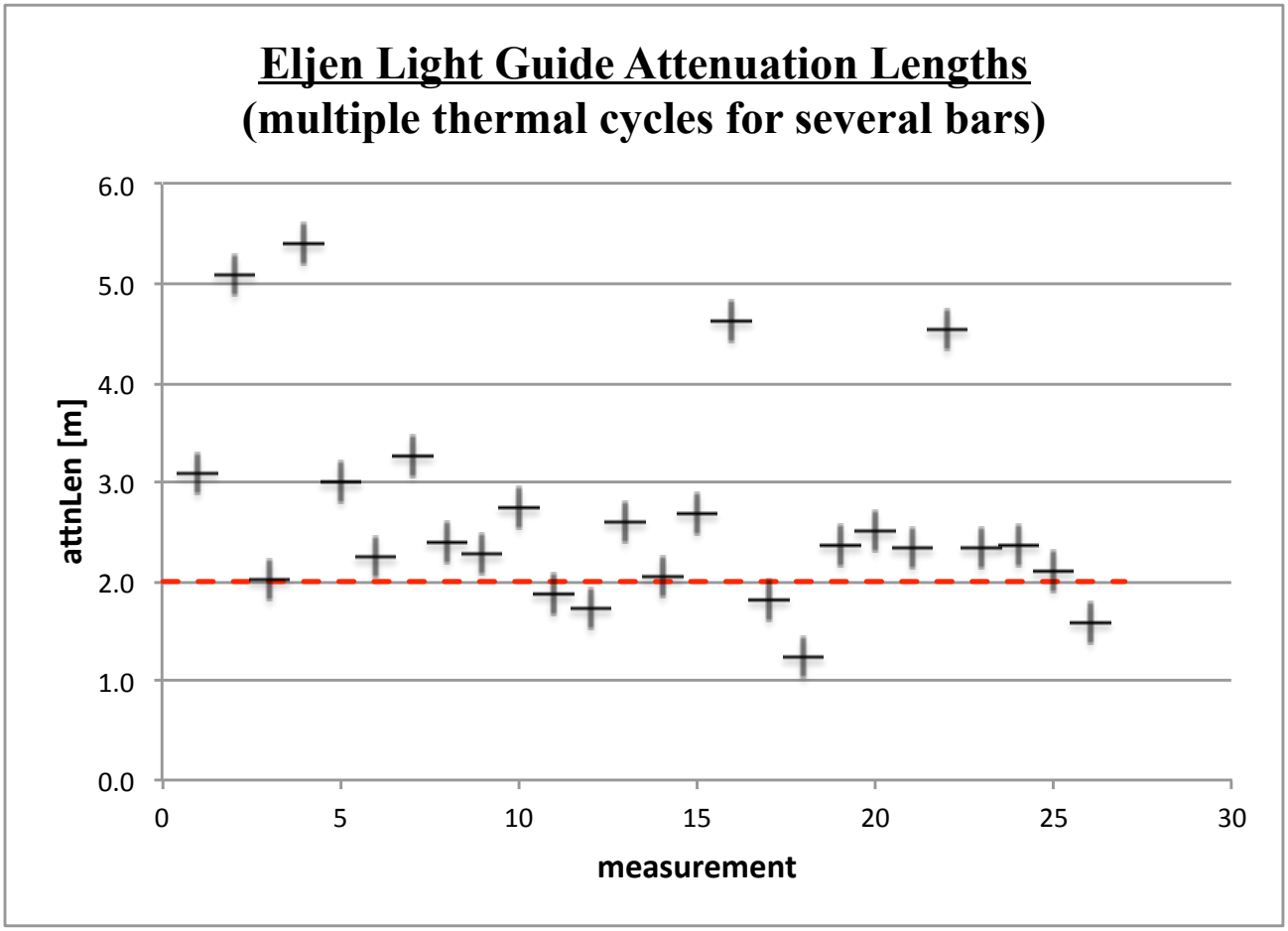
3-day turnaround

1. light guides loaded into frame
2. dewar pumped down overnight
3. LAr fill and measurements
4. warm up



^{241}Am source gives monoenergetic 5.5 MeV α's

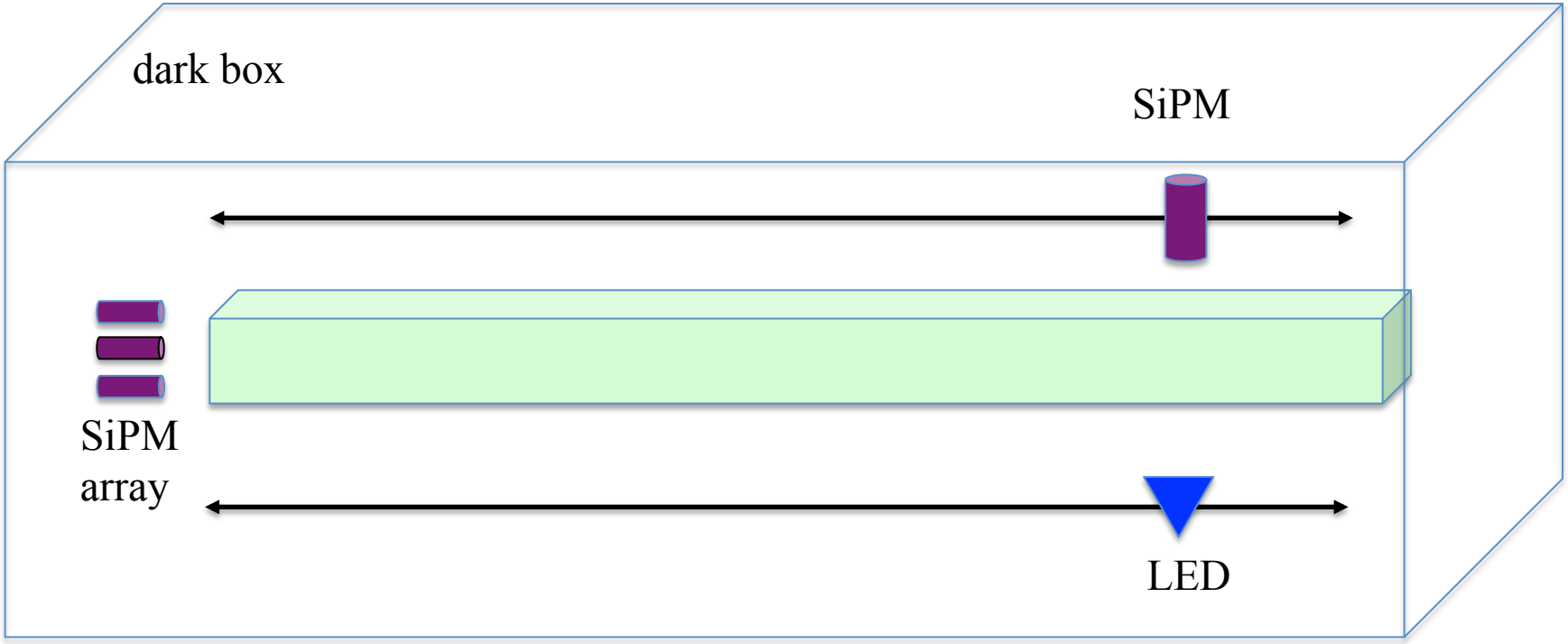
Multiple measurements over several months give confidence that Eljen light guides have > 2 m attenuation lengths, even after multiple thermal cycles



QC: Eljen light guides

- attenuation length
- uniformity of manufacture

transmission
measures uniformity



pulse height vs
position measures
attenuation length

stepper motor moves
LED and SiPM

Wavelength Shifting Plates

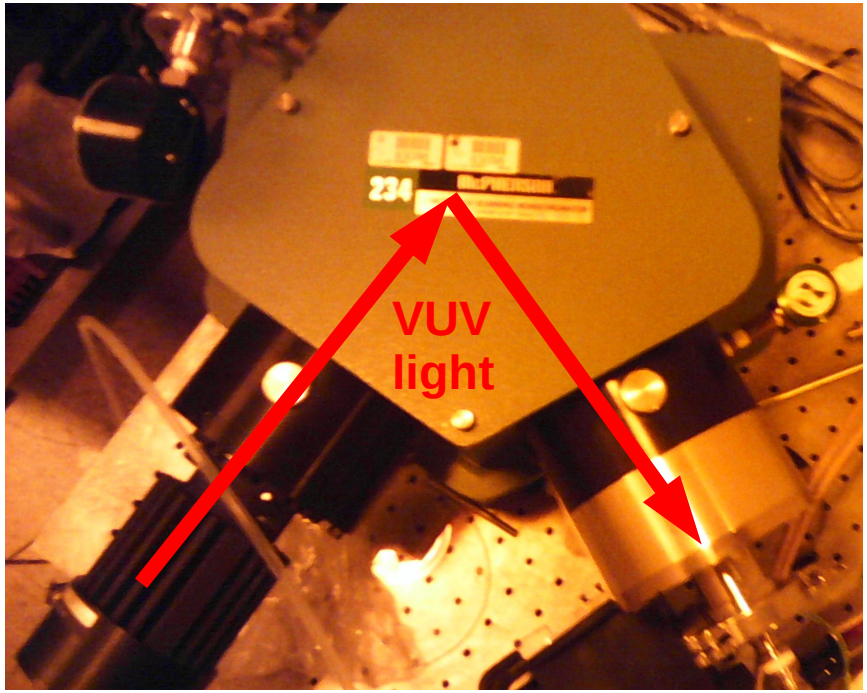
Search Matrix for optimal technology

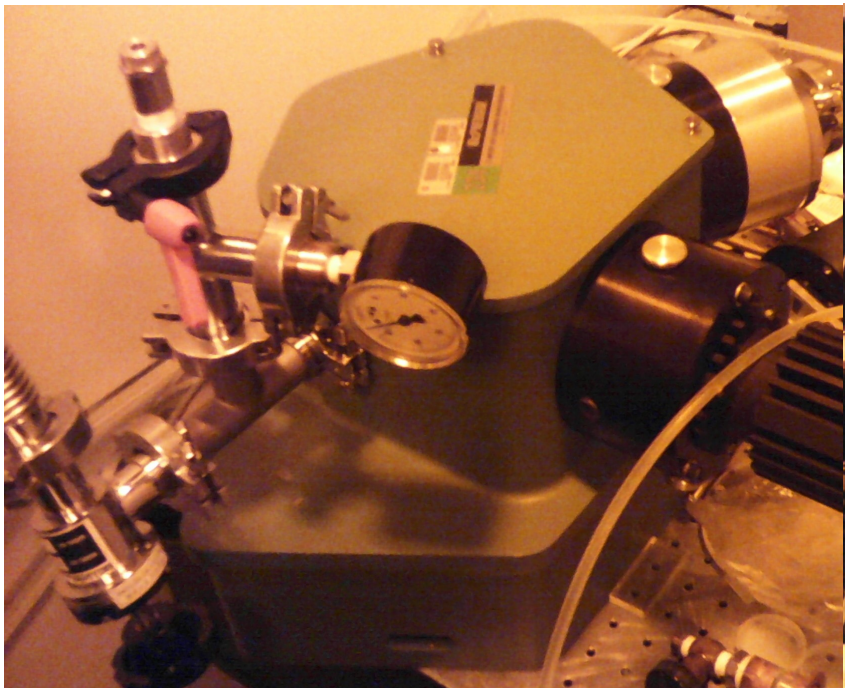
substrate	method of application	wavelength shifting solution
*acrylic 1/16" **	*spray/bake **	*IU basic **
polycarbonate 1mm	paint	IU variations
polycarbonate 0.004"	dip coated	MIT
heat shrink (Walmart)	spray	
heat shrink 0.001"	HVLP	
vinyl sheet	vacuum depostion	
vinyl 1/16"	by hand	
mylar 0.004"		
saran wrap		
fused silica		
crystal quartz		

* technology for plates used in Fermilab TallBo tests

QC Plate Testing with VUV Monochromator

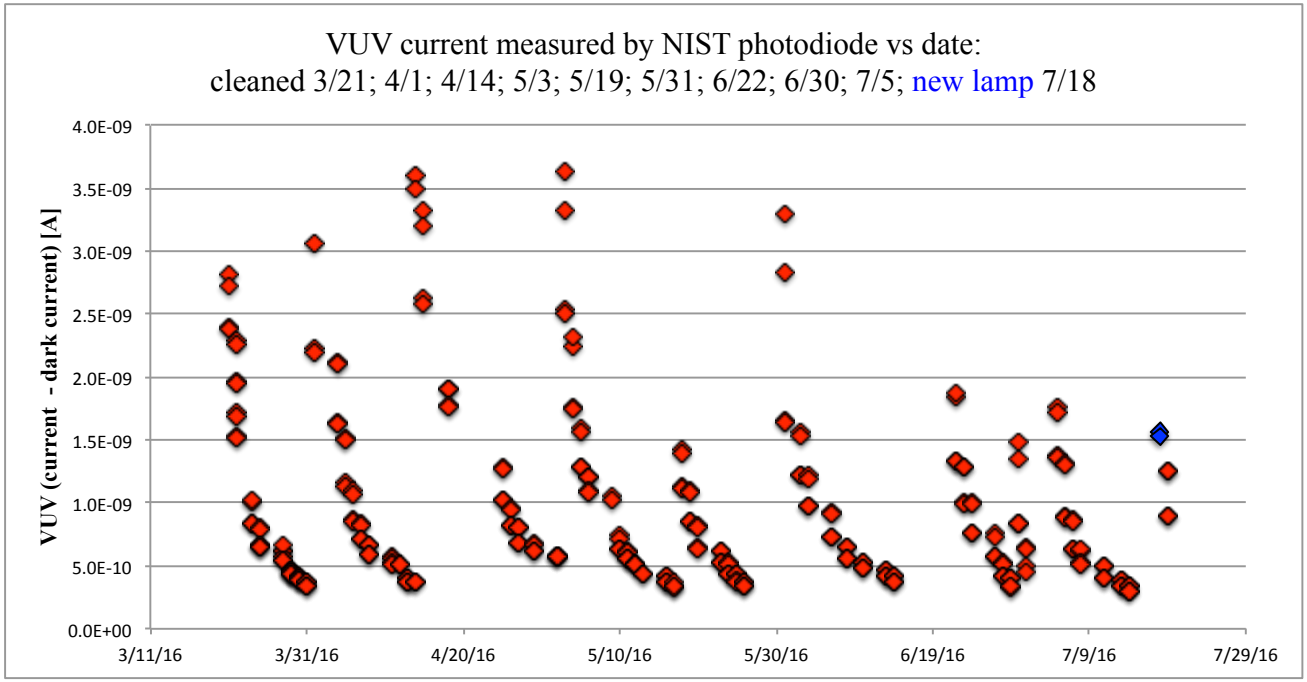
- McPherson VUV Monochromator with H_2 lamp
- Vacuum chamber filled with pure gaseous argon
- Vacuum chamber pumped down to purge residual N_2, O_2, H_2O
- H_2 lamp calibrated with NIST calibrated photodiode





QC metric:

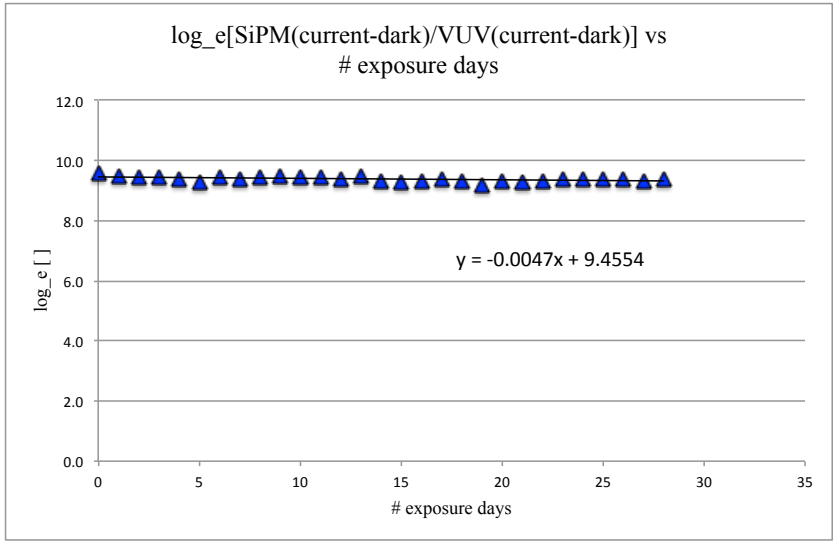
- MgF_2 window becomes less transparent with exposure to 128 nm light

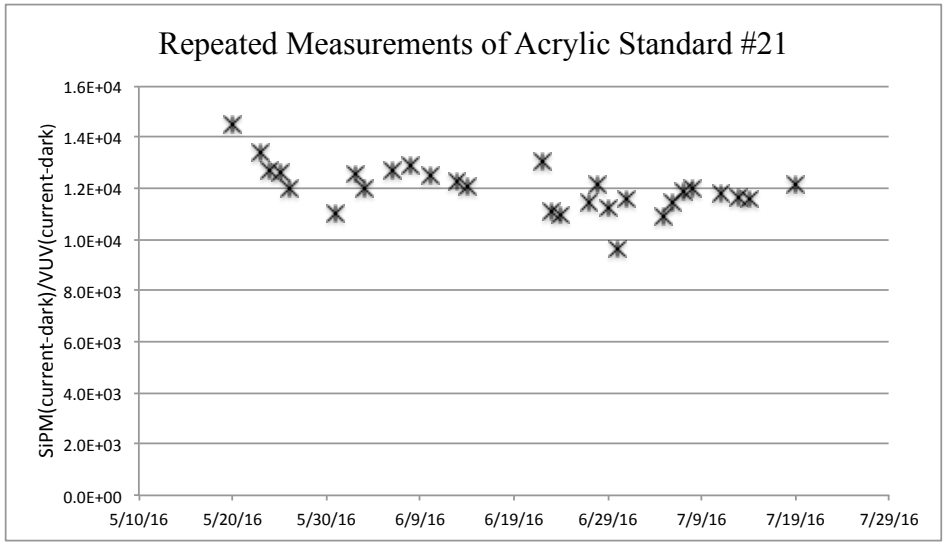


- characterize plate performance with metric:

(waveshifted optical light as measured by SiPM)/
(128 nm light as measured by NIST photodiode)

- Performance of VUV monochromator was monitored by continuously measuring a standard wavelength shifting plate: sprayed/baked acrylic plate, similar to proposed protoDUNE plates





degradation from VUV light expected to go like

exp(-exposure)

no degradation seen

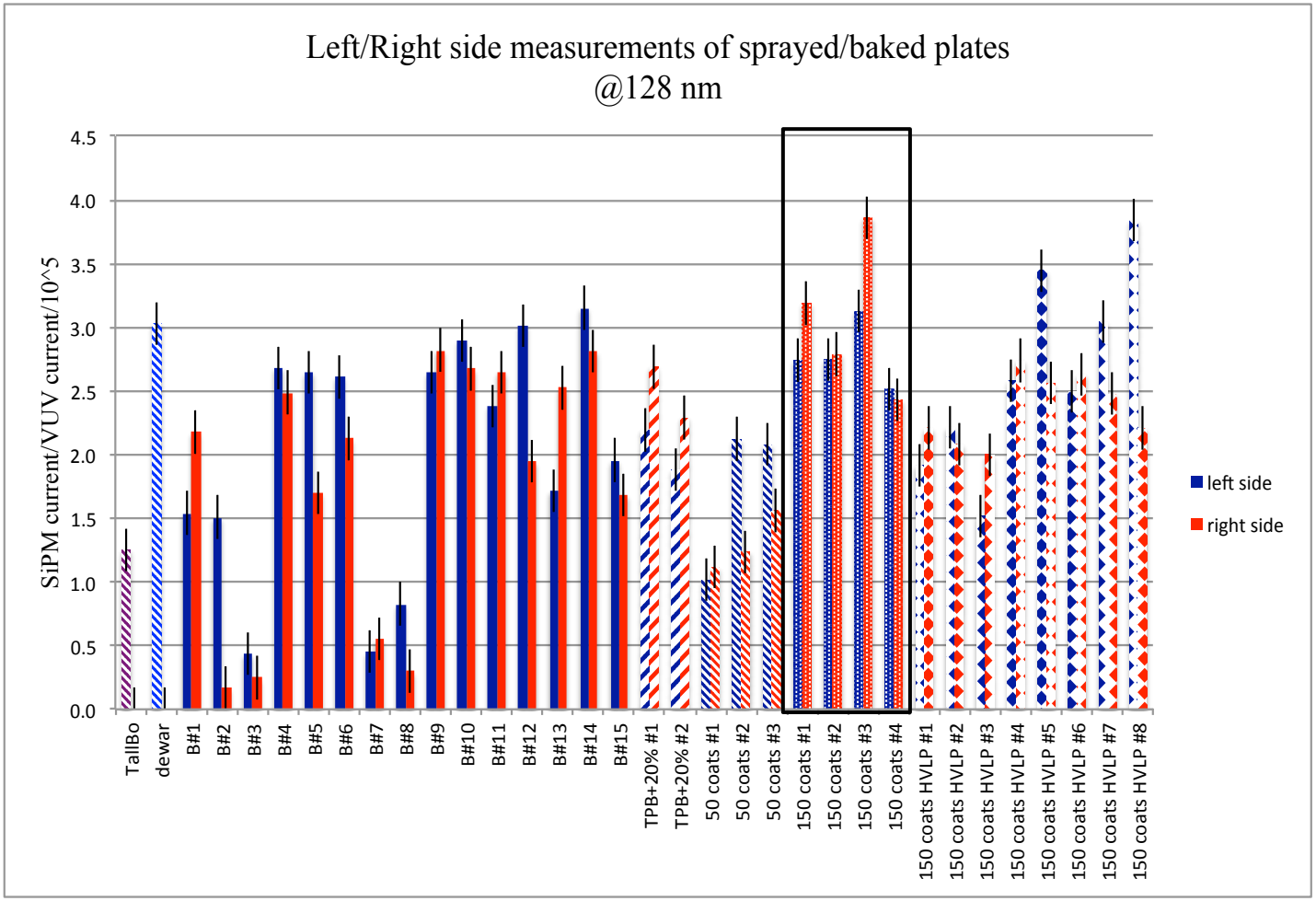
fluctuations about the mean of the measurements give systematic error

st.dev./mean = 7.8×10^{-2}

Technology for protoDUNE:

- computer controlled spraying of TPB/DCM solution
- baked overnight at 80 C
- cut to size after baking

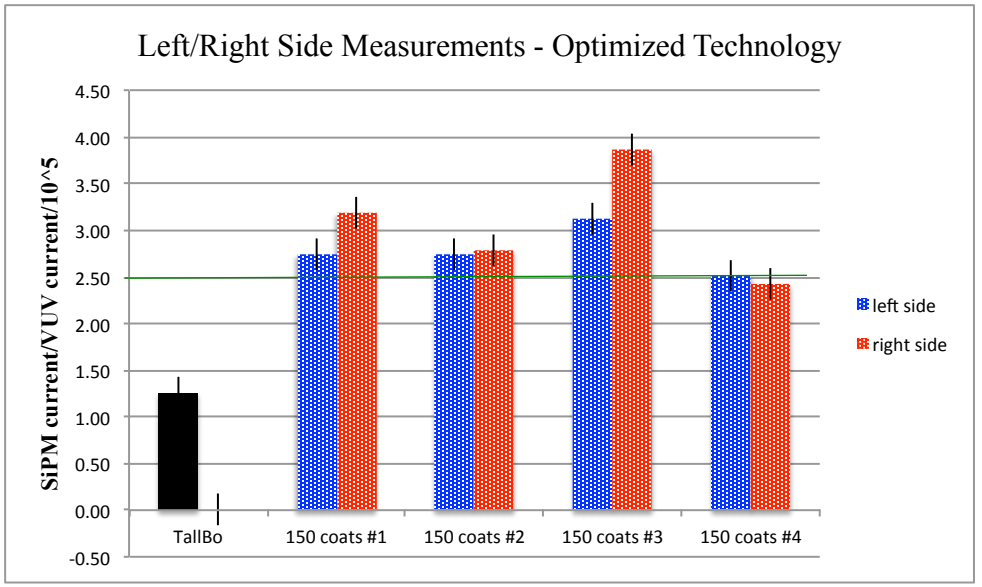
optimization studies:



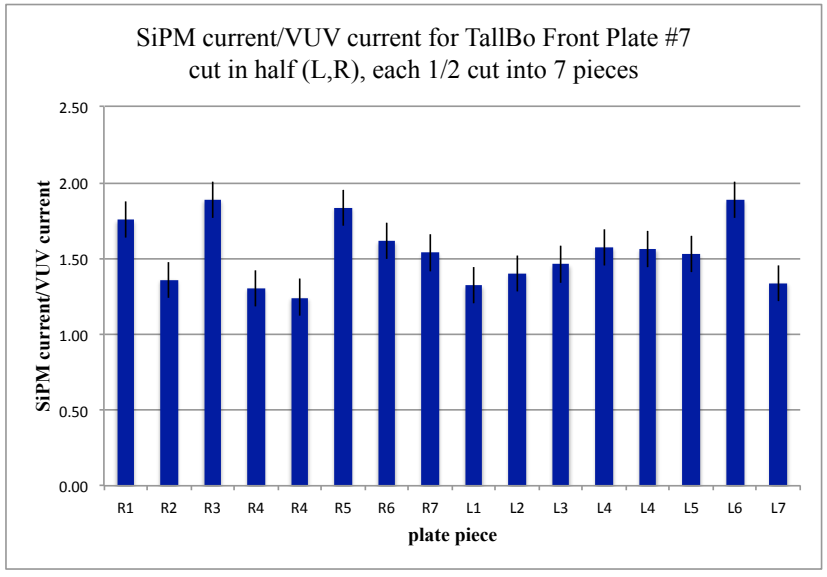
requirement/yield:

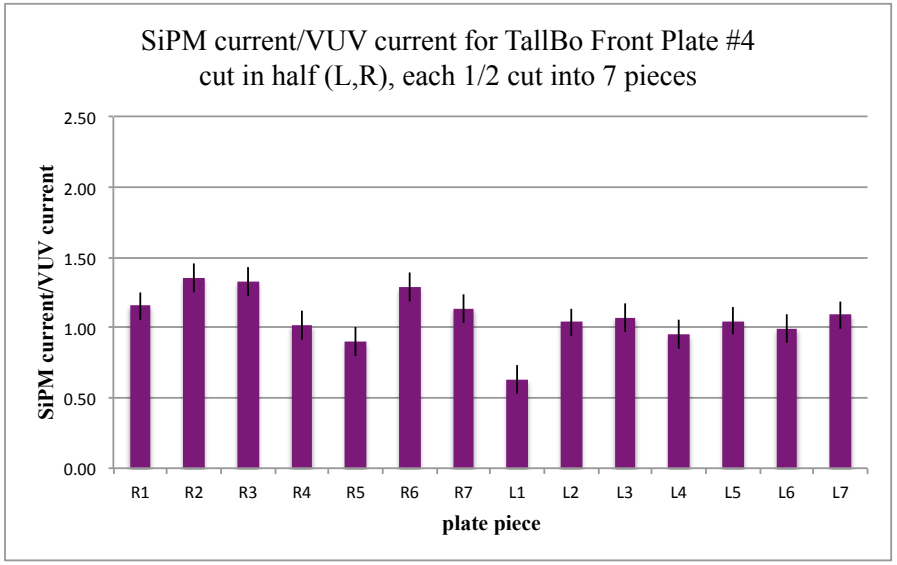
- 2x as bright as TallBo plates* metric = 2.5
- yield ~75%

* see Whittington talk



Uniformity:



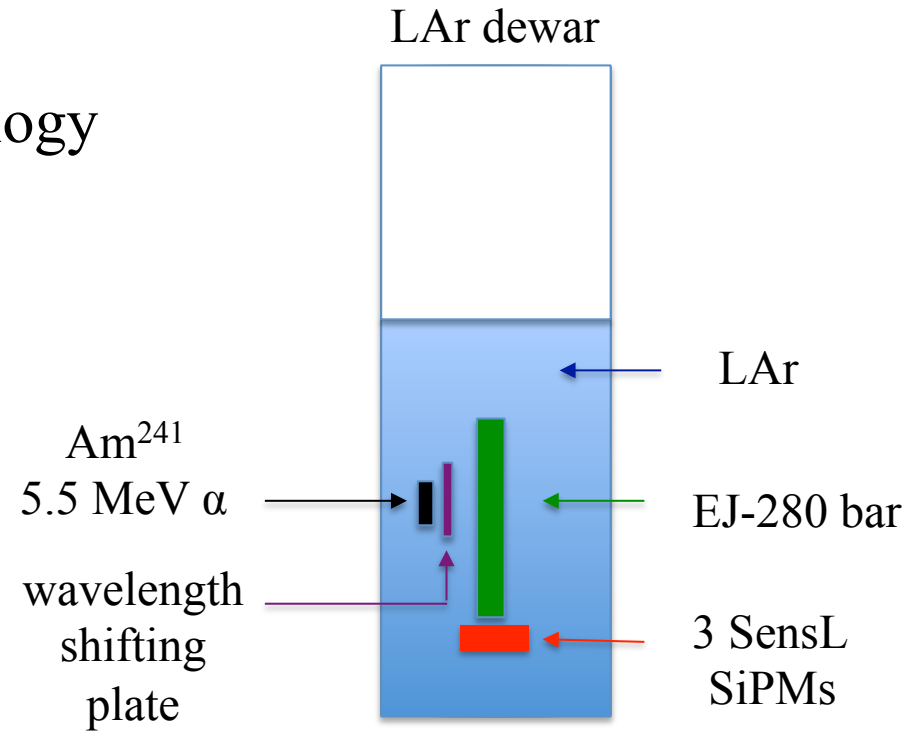


It is important to demonstrate that the chosen technology's performance in the VUV monochromator correlates with its performance in liquid argon

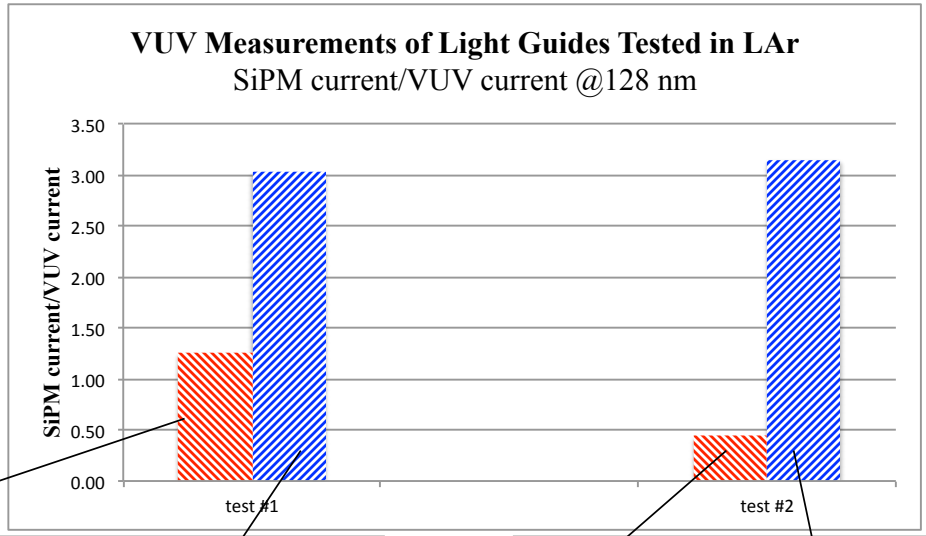
We tested sprayed/baked technology with setup shown:

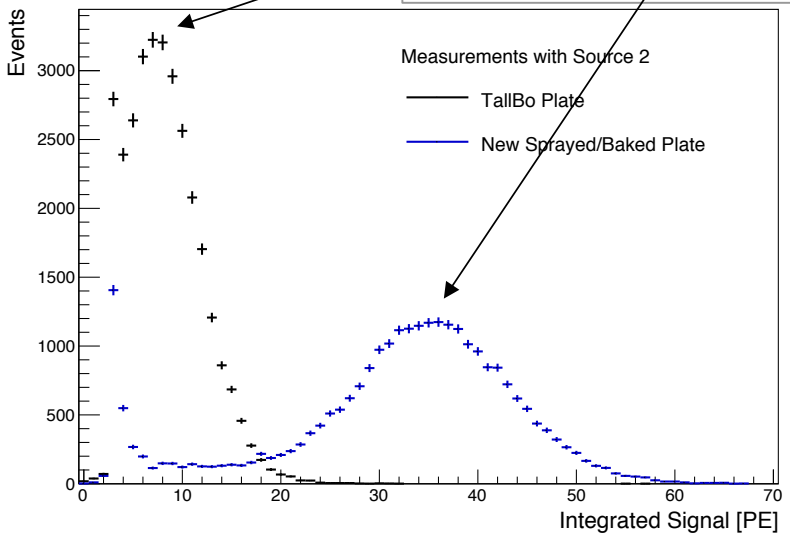
- local dewar at IU dewar lab:
- geometry:

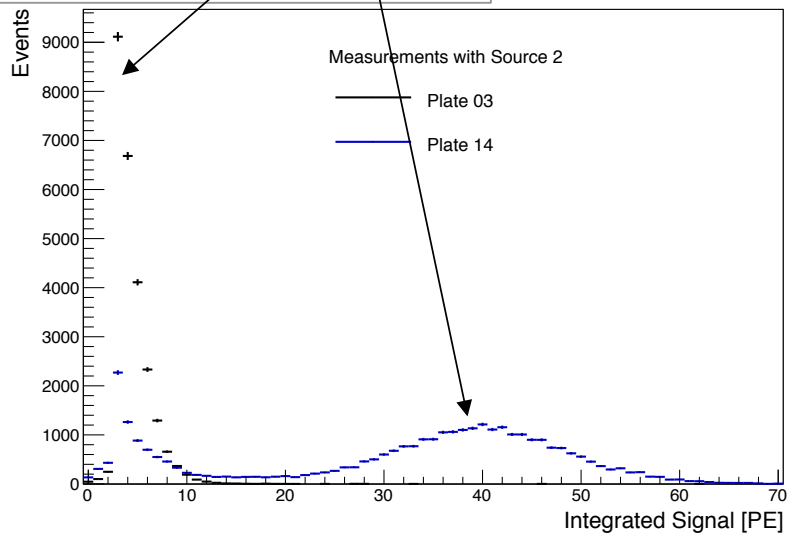
α source/plate technology/ /EJ-280 bar/3 SiPMs



- two sets of plates measured
- after first test, the plate positions were reversed and plates retested







performance in VUV correlates with performance in LAr

Production:

- plates required = 36 PDs x 13 plates/PD (1 spare/PD) = 468
- production rate = 4 plates/day
- production time = 8 months @ 75% yield
- schedule: starting 9/16, completed 6/17
- labor required: 1 tech, 1 scientist (as is done now)

ES&H

Summary

Environmental Health and Safety Managers were asked to evaluate engineering controls for the … Mufson lab. ES&H Mangers requested a dichloromethane exposure assessment to evaluate spraying and dipping activities with current engineering controls.

Shonna McCracken, Neil Toth and Thomas Thrasher conducted the IH Assessment on May 9th, 2016. Dichloromethane sampling was conducted during spraying and dipping activities. Integrated sampling was conducted to obtain a reliable estimate of the worker's exposure during a normal work shift.

For each sampling activity, personal and ambient, airborne contaminants were collected onto a medium placed at the breathing zone of the employee. Sample were submitted to Galson Laboratory for analytical analysis.

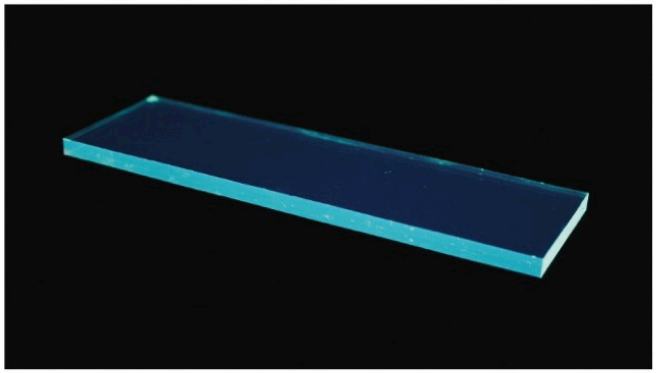
Summary of Findings

Spraying and Dipping

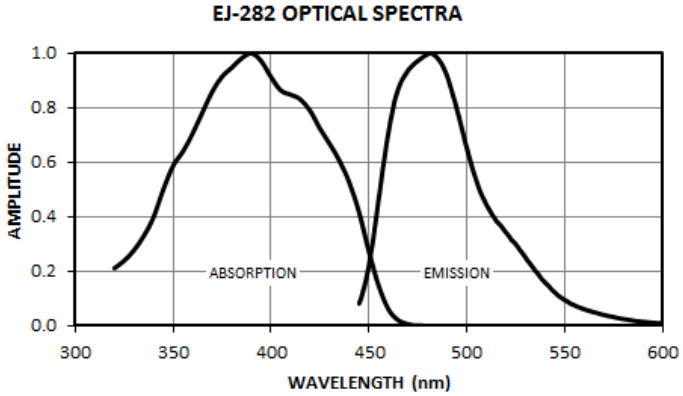
Analytical analysis verified spraying and dipping operation controls are satisfactory in controlling dichloromethane exposure in both the ambient and personal samples. Ambient exposure levels were 4.8ppm, which is below both the PEL (25ppm) and AL (12.5ppm). However this activity was conducted for a time period of 31 minutes. If the production time increased, OSHA PEL and AL exposure levels could be exceeded.

Moving Forward: Value Engineering

- a simpler spraying technique with higher potential yield – High Volume Low Pressure (HVLP) – is being investigated
- New product line from Eljen may better match SensL SiPM QE



EJ-282



- The waveshifter bisMSB may provide a better match to the EJ-280 waveshifter

Summary:

Eljen light guides:

- commercial product, if made correctly, will work
- attenuation length measured > 2m multiple times at room temperature and in LAr
- QC: test in dark box at room temperature

Wavelength shifting plates:

- demonstrated that VUV monchromator wavelength performance at room temperature correlates with performance in LAr