DUNE FD PD Monitoring System Considerations

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Overview of Talk

From Jim Stewart

-Need to converge on the penetration pattern for the Far Detector cryostat.

-Need a "guess" for what penetrations are needed for calibration systems.

- To consider implementation of the UV-light calibration/monitoring system with the DUNE Far Detector we will need to describe how we designed the system for ProtoDUNE-SP

  -the system for ProtoDUNE is based on expertise acquired with building calibration/monitoring system for 35-ton DUNE prototype

- Description of 35-ton photon detector calibration system
- ProtoDUNE design
- Design considerations for DUNE Far Detector

35-ton DUNE Prototype

Recent Experience: 35ton DUNE Prototype

- The system has been designed, tested, installed, integrated, and operated with the 35-ton DUNE prototype detector

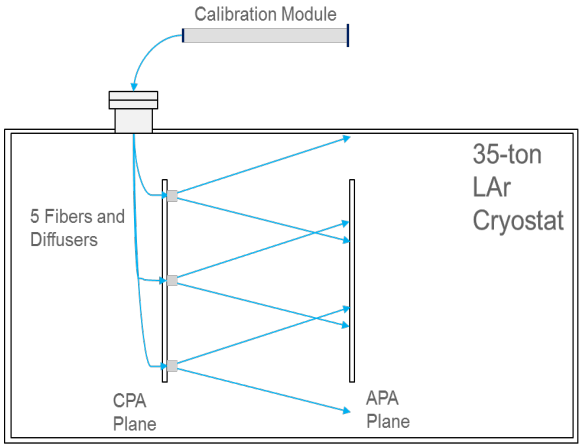
Photon Detector Calibration System Components

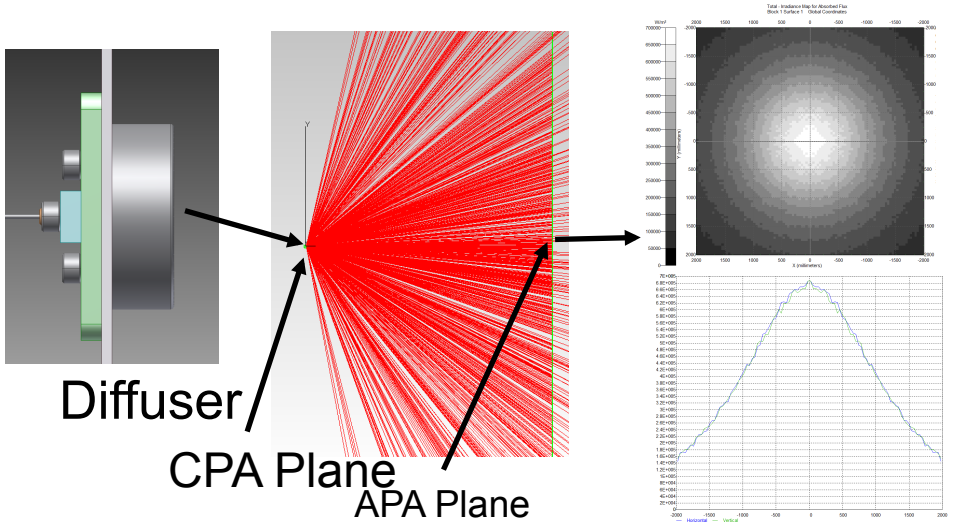
- Calibration module sources 5 UV LEDs (275nm)
- 275 nm light excites only wavelength shifter
- Quartz fibers deliver light to 5 diffusers mounted on CPA plane
- Diffusers distribute light onto photon detectors at APA plane
- One central Diffuser for Timing
- Four corner Diffusers for Uniformity/Gain

- Pulse widths from 5ns to 820ns
- Up to 25mW instantaneous optical power

Optical Simulation

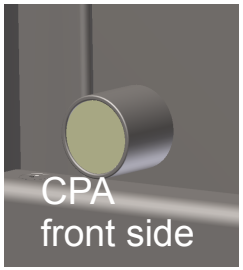
- TracePro used for optical system design, simulation, and optimization

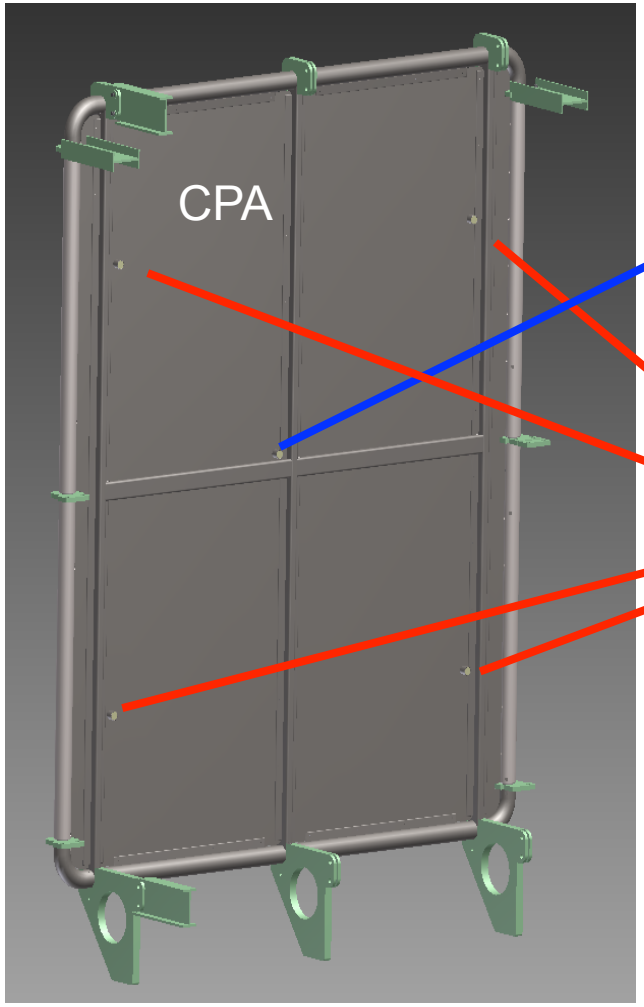




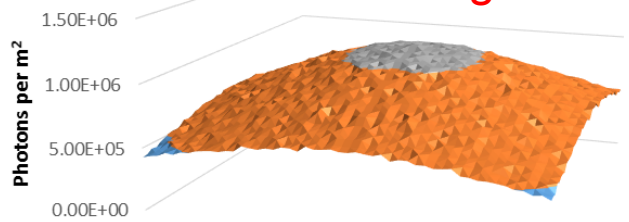
Optical Simulation of Single Diffuser at APA distance

Diffuser Implementation for 35-ton detector



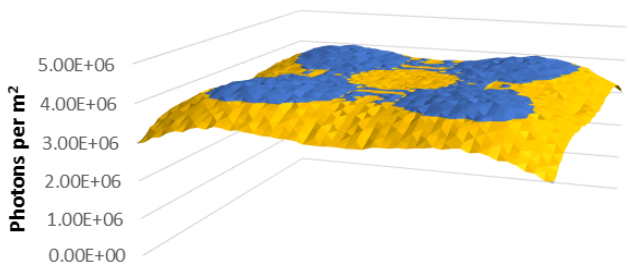


Central location timing calibration



Photon distribution on 2x2 m² APA Plane

Max	~5E+06 photons/m^2
Min	~2.5E+06 photons/m^2
Max/Min	~2



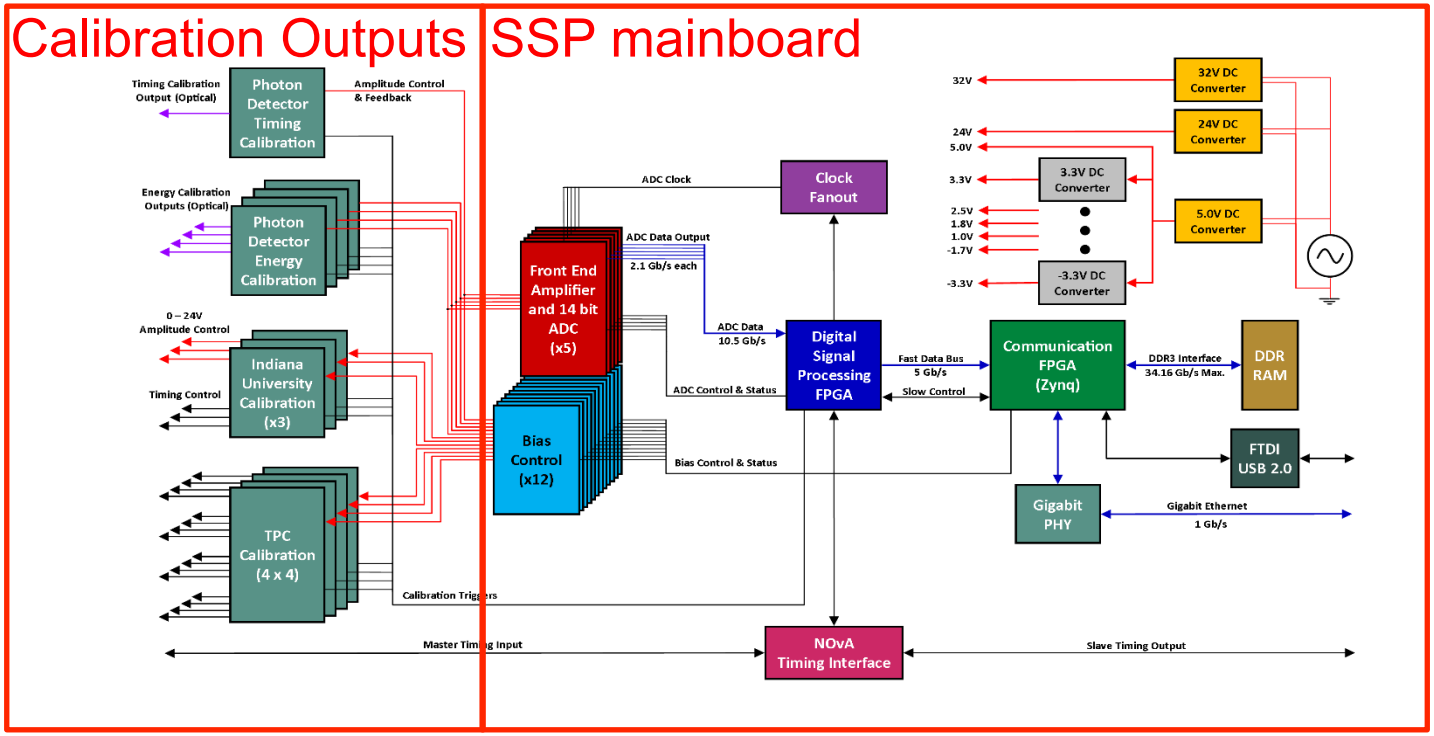
Photon distribution on 2x2 m² APA Plane

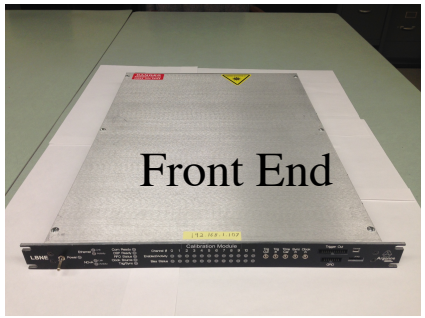
Max	~4.3 E+06 photons/m^2
Min	3.0 E+06 photons/m^2
Max/Min	1.44

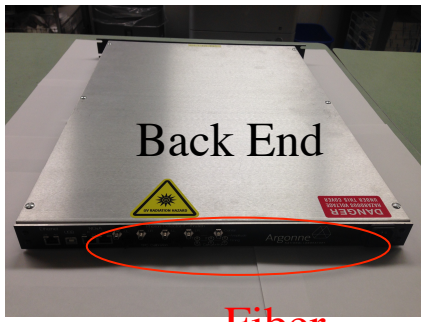
DUNE Calibration Module

- Utilizes the SSP mainboard as a controller

  Ethernet communication, timing control, internal/external triggering, etc.







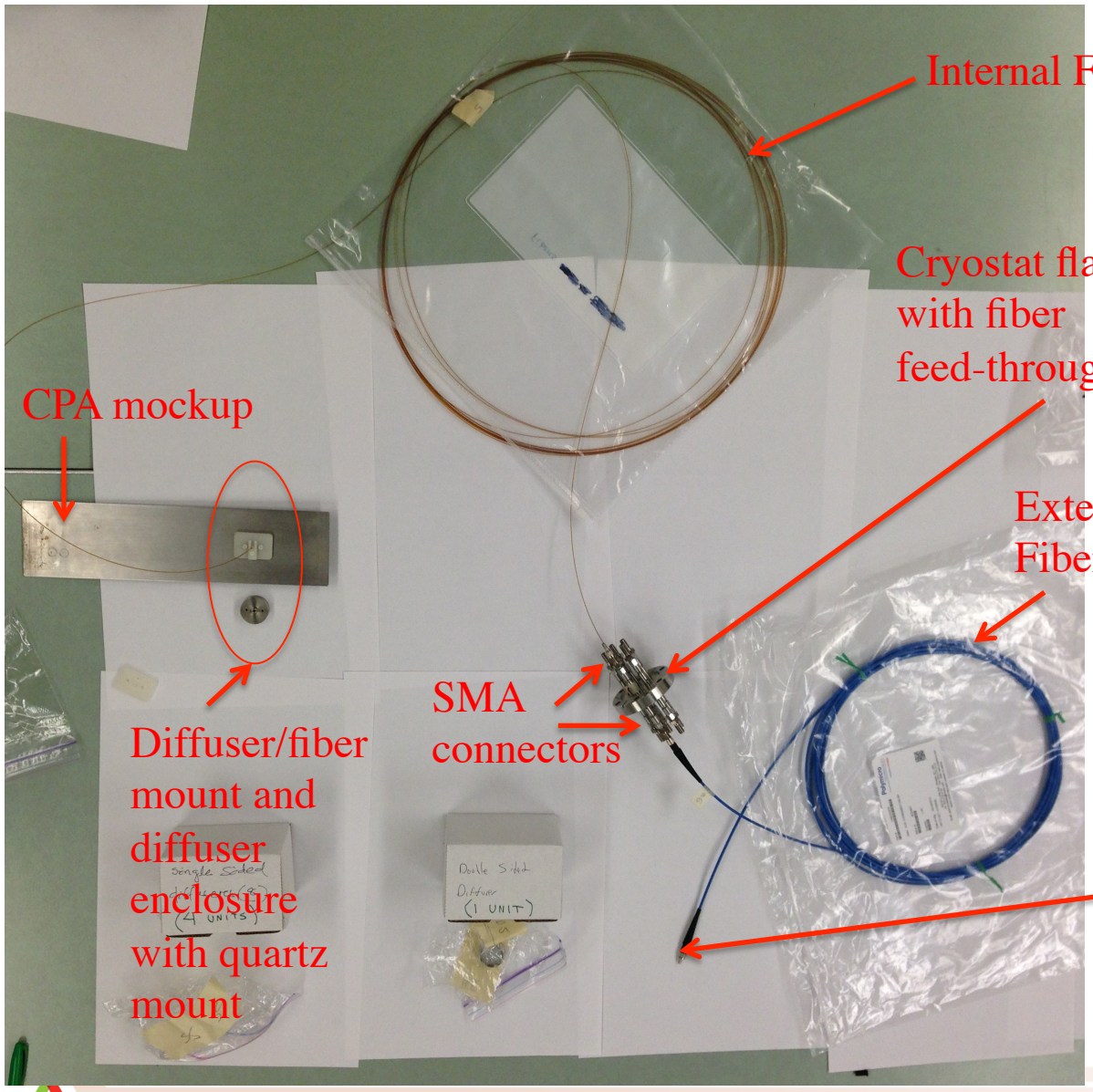
Fiber SMAs

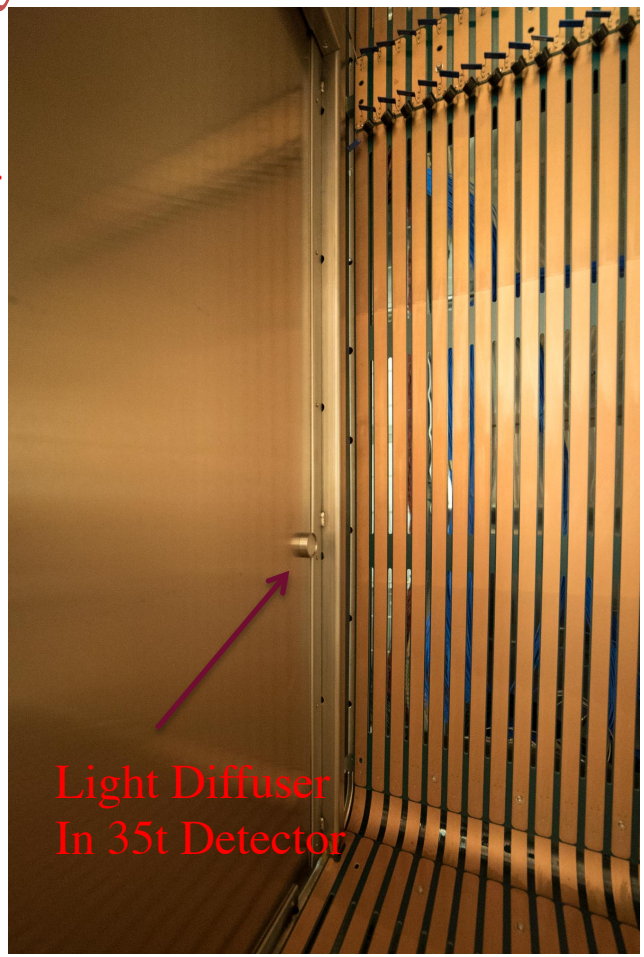
(also see the Backups)

Calibration Back-Panel

Components of the PD UV Calibration System

- Components installed with 35t DUNE prototype



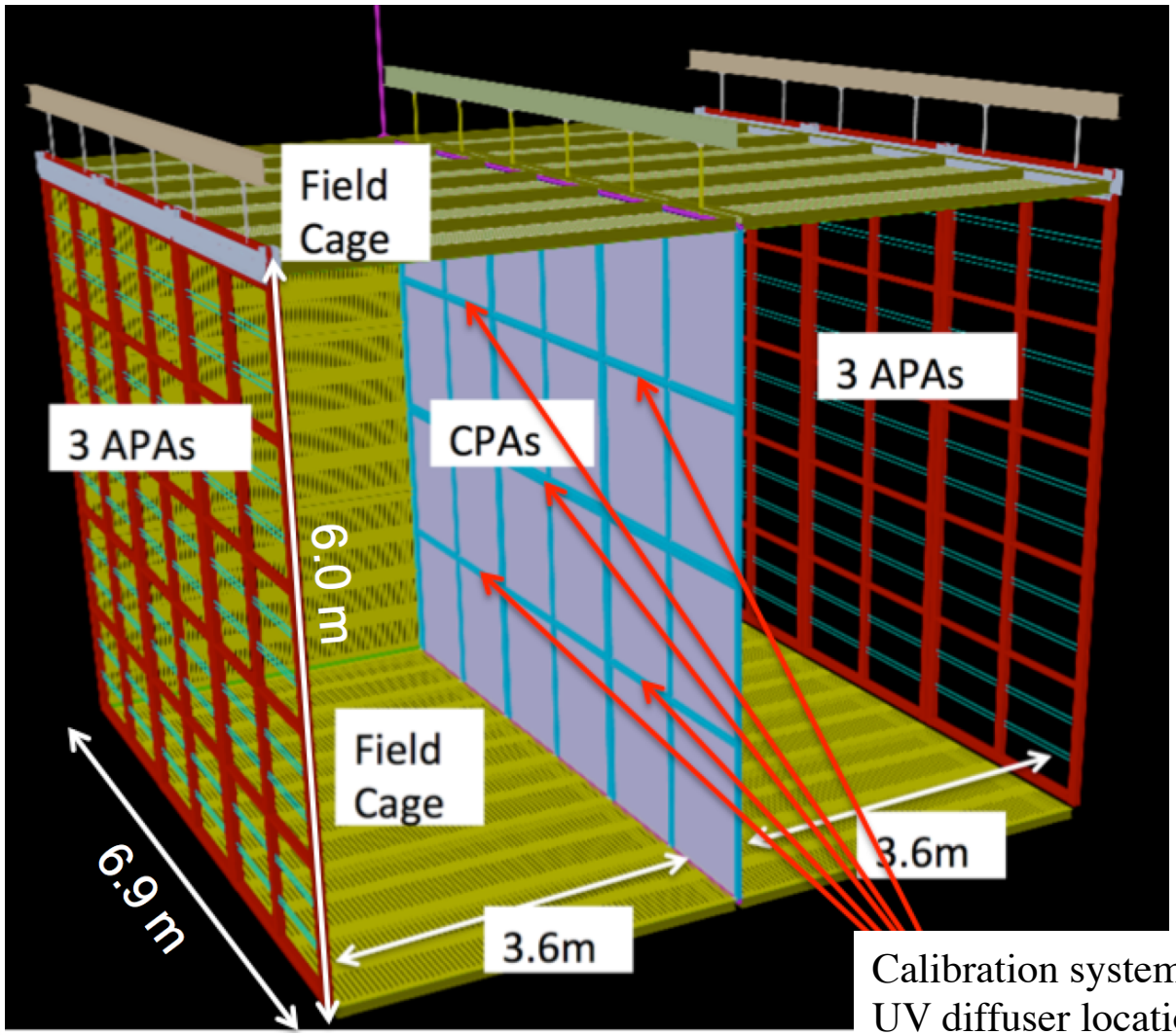


(more figures in Backups)

ProtoDUNE-SP Photon Detector Monitoring System

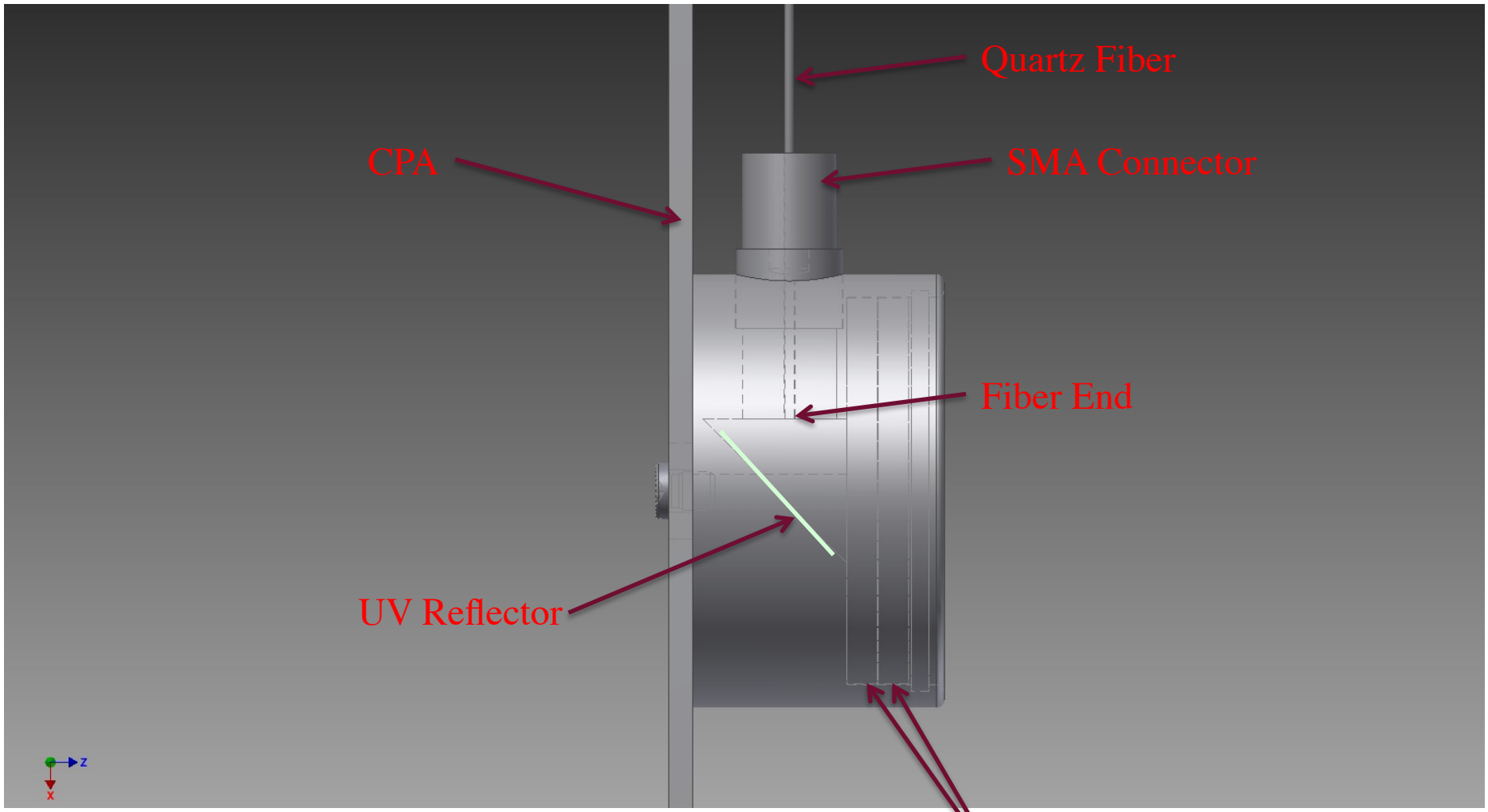
ProtoDUNE-SP Monitoring System

- Currently under fabrication for ProtoDUNE-SP



Calibration system
UV diffuser locations
At protoDUNE CPA

Diffuser Design for ProtoDUNE's CPA



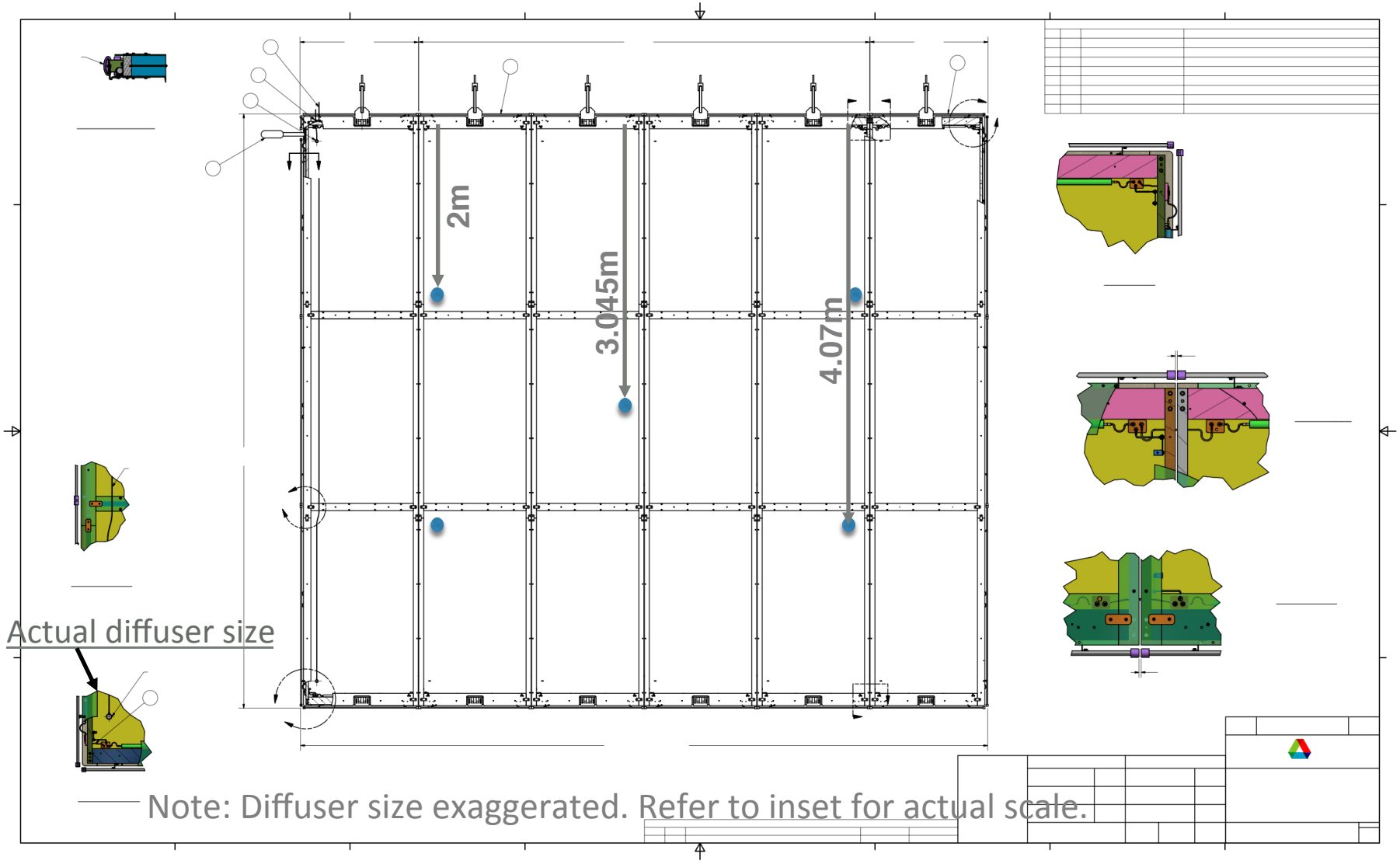
Diffuser Side View, based on older 3D model

Diffuser/Fiber Design for ProtoDUNE (Cont.)

- Diffusers Manufactured
  -Diffusers to be installed with CPAs in July/August

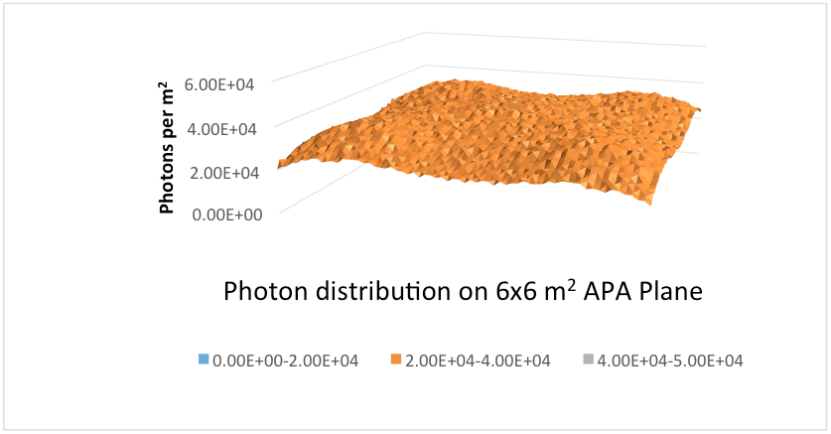
- Two sets of fibers will be fabricated
  -Fiber from a diffuser to CPA top frame
  -Fiber from CPA top frame to fiber feedthrough

Diffuser/Fiber Design for ProtoDUNE (Cont.)

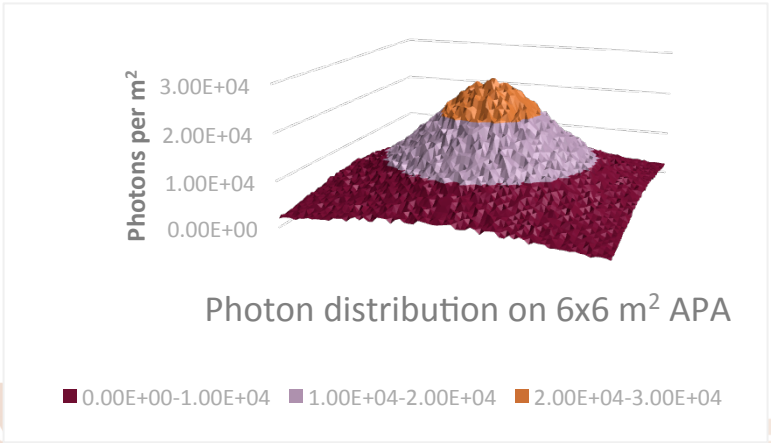


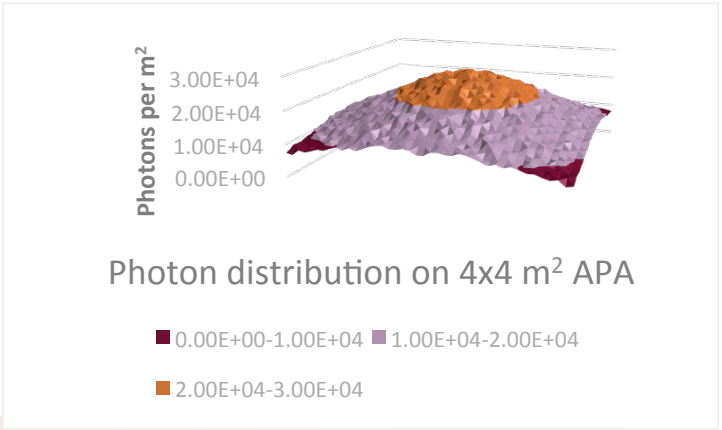
Diffuser/Fiber Design for ProtoDUNE (Cont.)

- Light distribution expected at APA surface from five diffusers at CPA (as described above)



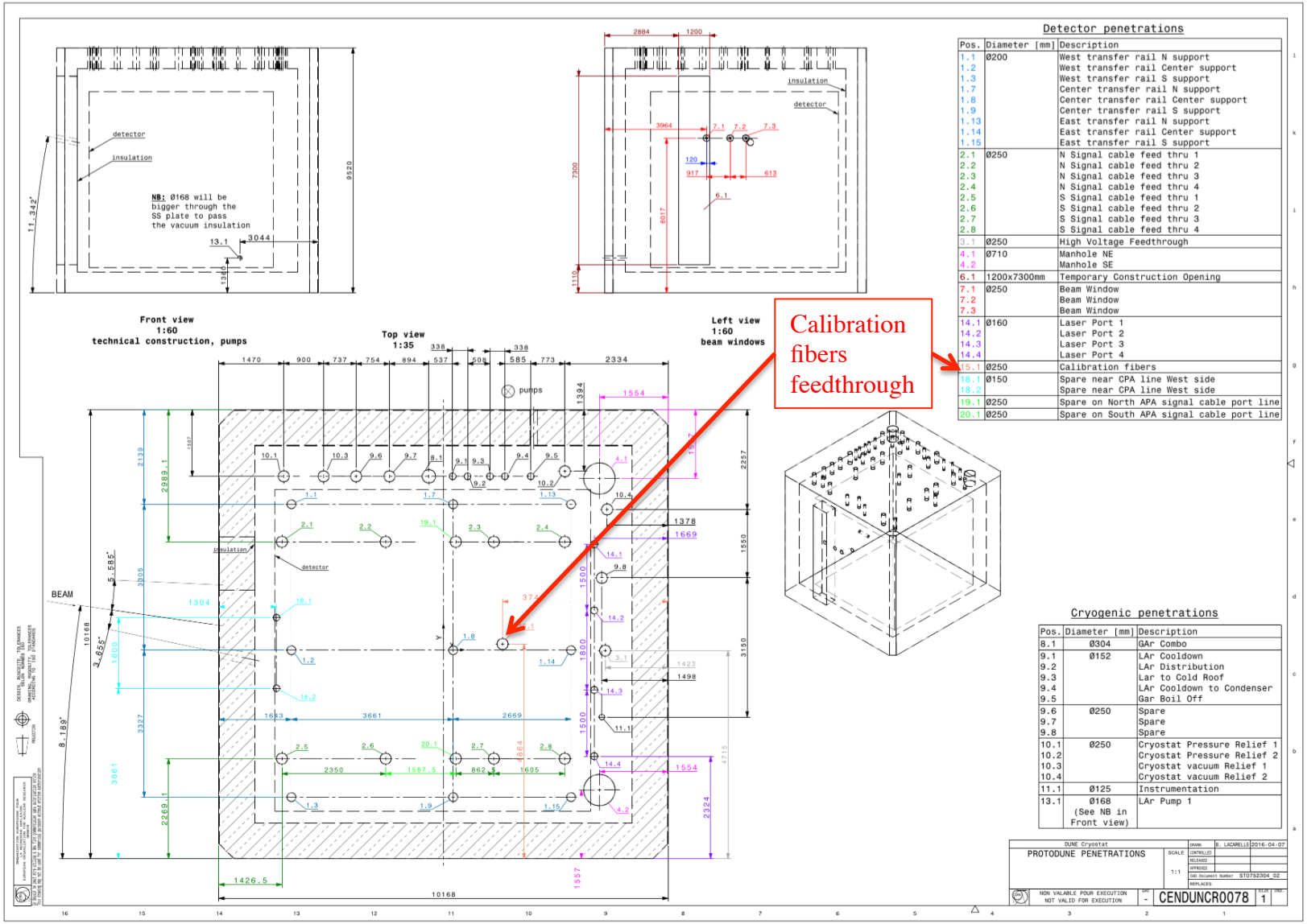
- Compare this light distribution to single diffuser covering 7m x 7m area (left) and 4m x 4m area (right):





ProtoDUNE penetrations drawing

- Fiber feed-through location shown



Detector penetrations

Pos.	Diameter [mm]	Description
1.1	Ø200	West transfer rail N support
1.2		West transfer rail Center support
1.3		West transfer rail S support
1.7		Center transfer rail N support
1.8		Center transfer rail Center support
1.9		Center transfer rail S support
1.13		East transfer rail N support
1.14		East transfer rail Center support
1.15		East transfer rail S support
2.1	Ø250	N Signal cable feed thru 1
2.2		N Signal cable feed thru 2
2.3		N Signal cable feed thru 3
2.4		N Signal cable feed thru 4
2.5		S Signal cable feed thru 1
2.6		S Signal cable feed thru 2
2.7		S Signal cable feed thru 3
2.8		S Signal cable feed thru 4
3.1	Ø250	High Voltage Feedthrough
4.1	Ø710	Manhole NE
4.2		Manhole SE
6.1	1200x7300mm	Temporary Construction Opening
7.1	Ø250	Beam Window
7.2		Beam Window
7.3		Beam Window
14.1	Ø160	Laser Port 1
14.2		Laser Port 2
14.3		Laser Port 3
14.4		Laser Port 4
15.1	Ø250	Calibration fibers
18.1	Ø150	Spare near CPA line West side
18.2		Spare near CPA line West side
19.1	Ø250	Spare on North APA signal cable port line
20.1	Ø250	Spare on South APA signal cable port line

Cryogenic penetrations

Pos.	Diameter [mm]	Description
8.1	Ø304	GAr Combo
9.1	Ø152	LAr Cooldown
9.2		LAr Distribution
9.3		Lar to Cold Roof
9.4		LAr Cooldown to Condenser
9.5		Gar Boil Off
9.6	Ø250	Spare
9.7		Spare
9.8		Spare
10.1	Ø250	Cryostat Pressure Relief 1
10.2		Cryostat Pressure Relief 2
10.3		Cryostat vacuum Relief 1
10.4		Cryostat vacuum Relief 2
11.1	Ø125	Instrumentation
13.1	Ø168 (See NB in Front view)	LAr Pump 1

DUNE Cryostat
PROTODUNE PENETRATIONS
SCALE 1:1
DRAWN B. LACARELLE 2016-04-07
CHECKED
RELEASED
APPROVED
DUNE Document Number ST0752304_02
REPLACES
NON VALABLE POUR EXECUTION / NOT VALID FOR EXECUTION
CENDUNCR0078 1

System Components: Parts/Materials

- Components known: fiber, SMA-connectors, flange design, SS and quartz diffuser materials for CPA flasher units
- Examples:

Polymicro TECHNOLOGIES
A Subsidiary of molex

Please address all Purchase Orders to:
MOLEX INCORPORATED
18019 North 25th Avenue, Phoenix, AZ 85023-1200
Tel: 602-375-4100 Web: www.molex.com/polymicro
Fax: 630-813-9995 E-Mail: gary.macdonald@molex.com

TO: Raquel C. Young
Argonne National Laboratory
Bldg. 362 RM E 245
9700 South Cass Avenue
Argonne, IL 60439-4815

Date 19-Feb-15
Quote # 27501GM
Telephone 630-252-6290 (direct)
Fax NA
E-Mail royoung@anl.gov

Estimated Lead Time 3-5 Weeks ARO | Ship Via | FCA Phoenix, AZ | Terms Net 30 Pending Approval

QUANTITY	UOM	Existing Part#	DESCRIPTION	UNIT PRICE USD	TOTAL*
7	Each	TBD	FOA, FVP600660710/8.5M Fiber Optic Assembly Fiber: FVP600660710 NA = 0.22 ± 0.02 Overall Length: 5m ± 10cm Proximal end finish: SMA 905 Distal end finish: SMA 905 Jacket: Black Hytrel Tubing		

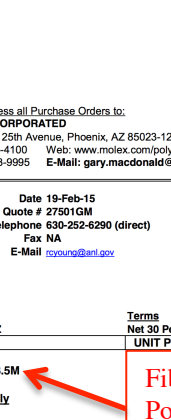
Fiber part:
Polymicro
FVP60060710

SILICA/SILICA Optical Fiber **FV** Fibers
• High -OH

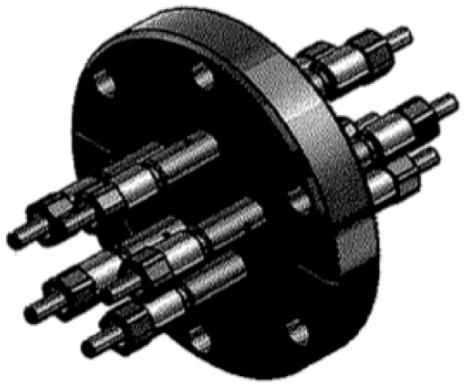
Characteristics
- Step Index
- Numerical Aperture: 0.22 ± 0.02
  Full Acceptance Cone: 25.4 degrees
- UV-Vis-NIR Transmission, 180nm to 1,150nm
- Superior Radiation Resistance
- High Laser Damage Threshold
- Sterilizable & Bio-compatible – USP Class VI*
- High -OH Silica Core, Doped Silica Clad
- Polyimide Buffer Standard; Silicone, Acrylate, High-Temperature Acrylate also available.
- Polyimide Concentricity ≤ 3µm
- Sizes for Bundling
- Tighter Tolerances Available
- Temperature: Operating –65°C to +300°C Intermittent, up to 400°C
- Proof Tested to 100kpsi

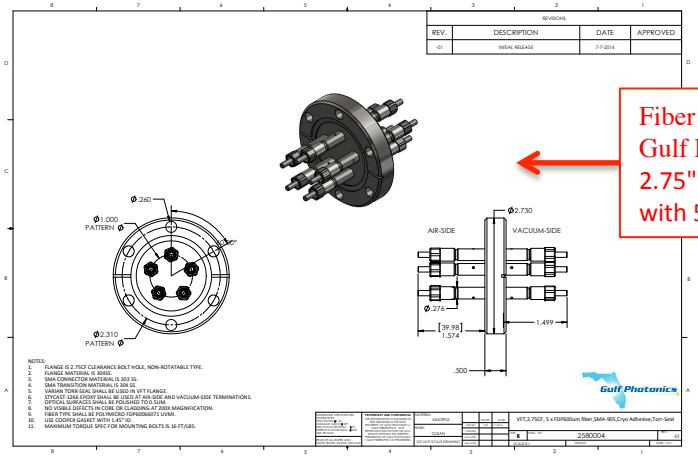
Product Descriptor	Core (µm)	Clad (µm)	Buffer (µm)
FVP050055065*	50 ± 2	55 ± 2	65 ± 2
FVP100110125**	100 ± 3	110 ± 3	124 ± 3
FVP150165195	150 ± 3	165 ± 3	195 ± 5
FVP200220240	200 ± 4	220 ± 4	239 ± 5
FVP300330370	300 ± 6	330 ± 7	370 ± 10
FVP400440480	400 ± 8	440 ± 9	480 ± 7
FVP600660710	600 ± 10	660 ± 10	710 ± 10
FVA8008801100***	800 ± 20	880 ± 15	1100 ± 30
FVP100120140	100 ± 3	120 ± 3	140 ± 4
FVP200240280	200 ± 4	240 ± 4	275 ± 5
FVP320385415	320 ± 8	385 ± 8	415 ± 10
FVA1000105012500***	1000 ± 20	1050 ± 15	1250 ± 40

* Recommended for UV wavelengths only. Availability varies.



Note: The items listed in this table are standard configurations and sizes. Other configurations may be available on request. Please let us know what we can do to help satisfy your project requirements.





Fiber feedthrough part:
Gulf Photonics:
2.75" diameter Conflat flange
with 5 SMA 905 fiber connectors

For ProtoDUNE decided
2 x 5-fiber-feedthrough

15

Note on Expected Light Yield

- Light yield expected in ProtoDUNE when compared to the 35-ton detector
  -Back of envelope calculation

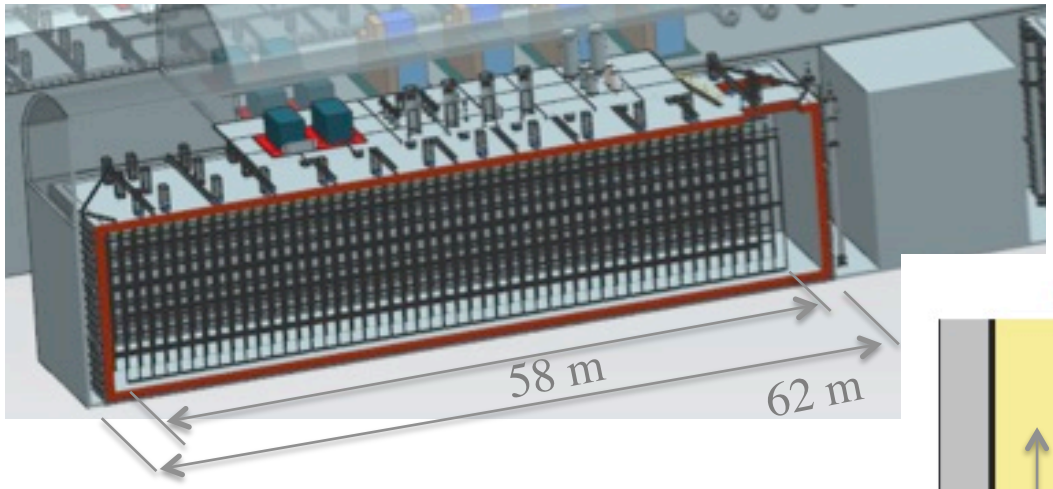
- Assume the following
  -ProtoDUNE LEDs will emit 2 x light of the 35 ton LED
  -ProtoDUNE PD light collection and conversion efficiency
  is expected improve by a factor ~2 over 35ton.
  -Single photon readout channel at pD gangs together 3 SiPMs (compared so 35t single SiPM readout per channel)
  -In protoDUNE the light is emitted over volume defined by CPA to APA distance of 3.6m, compared to 2.2 m drift in 35t

⇒ LY (ProtoDUNE) / LY(35t) ~ (0.7 to 1.6) per SiPM, (~2 to 5) for 3 ganged together
⇒ We may expect more light per readout channel in ProtoDUNE PDS;
⇒ Applies to DUNE FD

- See the Bonus Material on the light yield in 35-ton detector (from central diffuser alone)

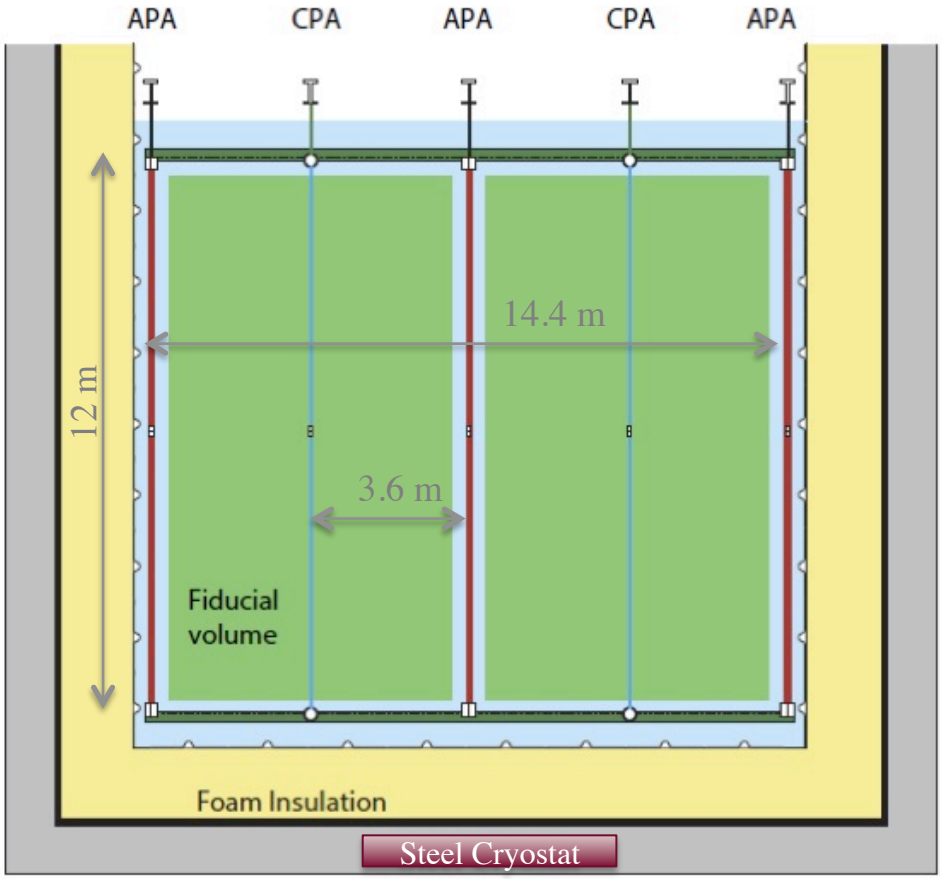
Going forward to DUNE

Nominal 10 kt Detector Design



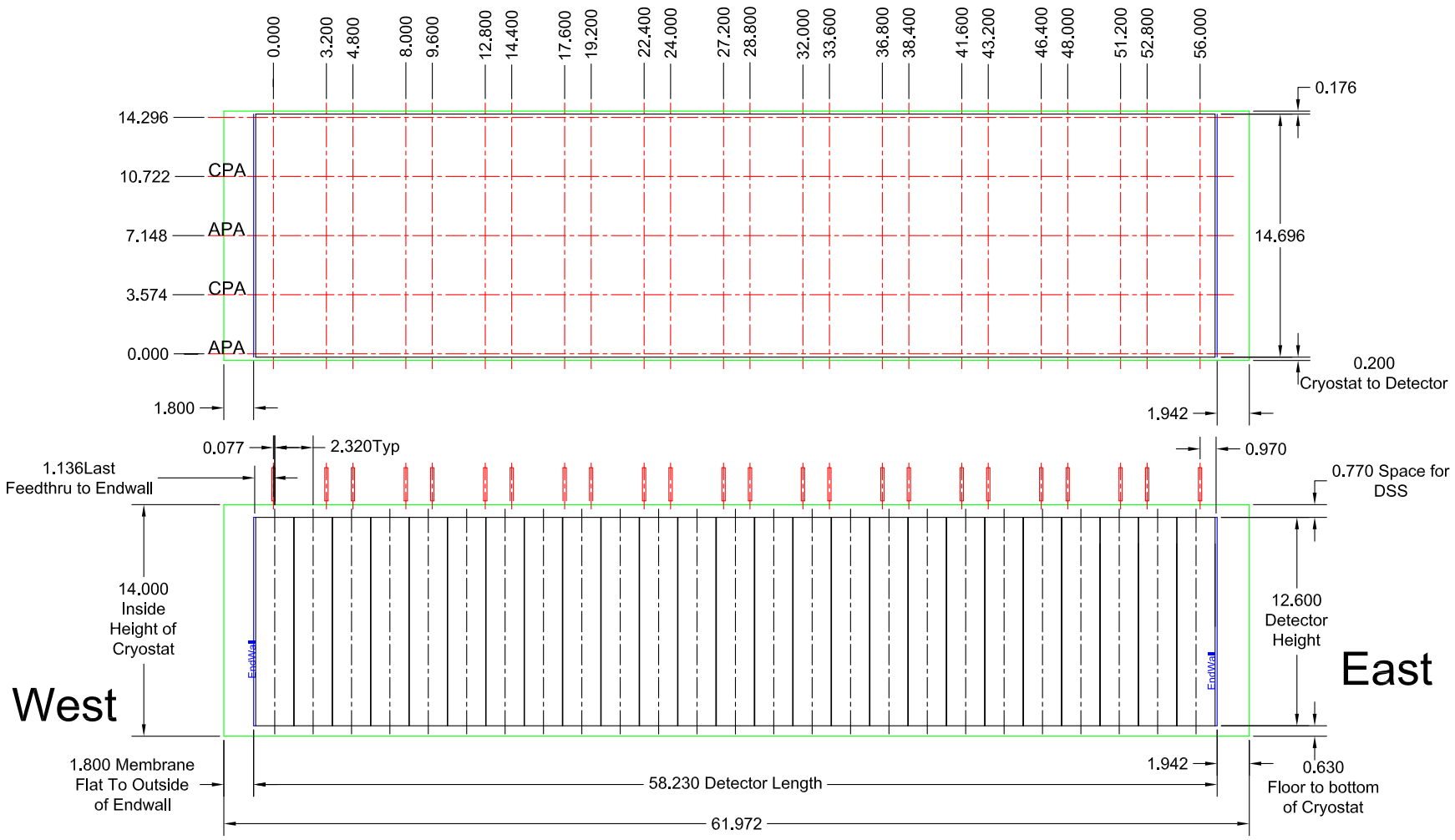
Detector Module Characteristics

- 17.1/13.8/11.6 Total/Active/Fiducial mass
- 3 Anode Plane Assemblies (APA) wide
  - 3.6 m max drift length
- Cathode planes (CPA) are internal
- 58m long - 12m high - 14.4m active width

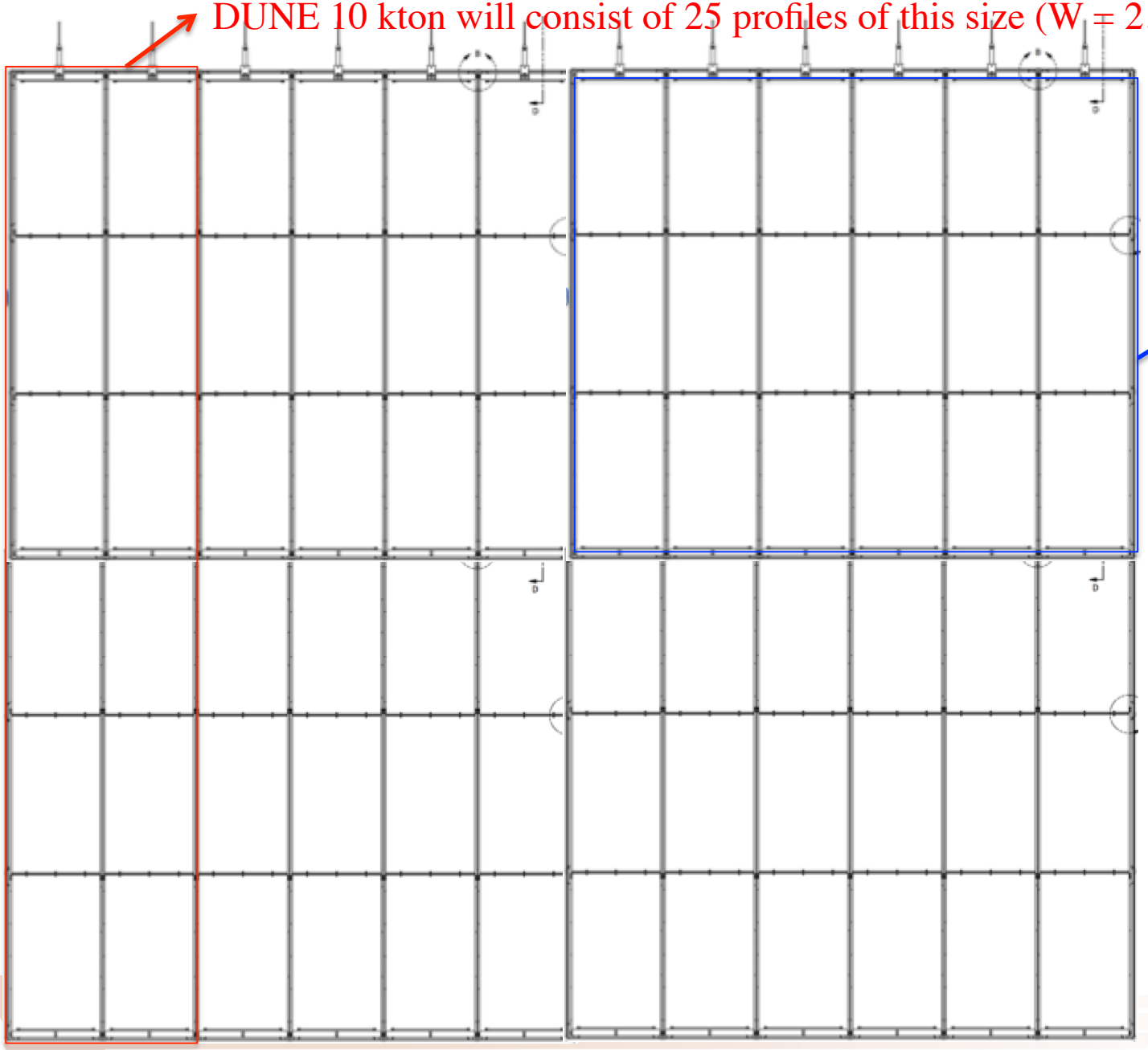


Nominal 10 kt Detector Design

-This is GSS related drawing but provides dimensions

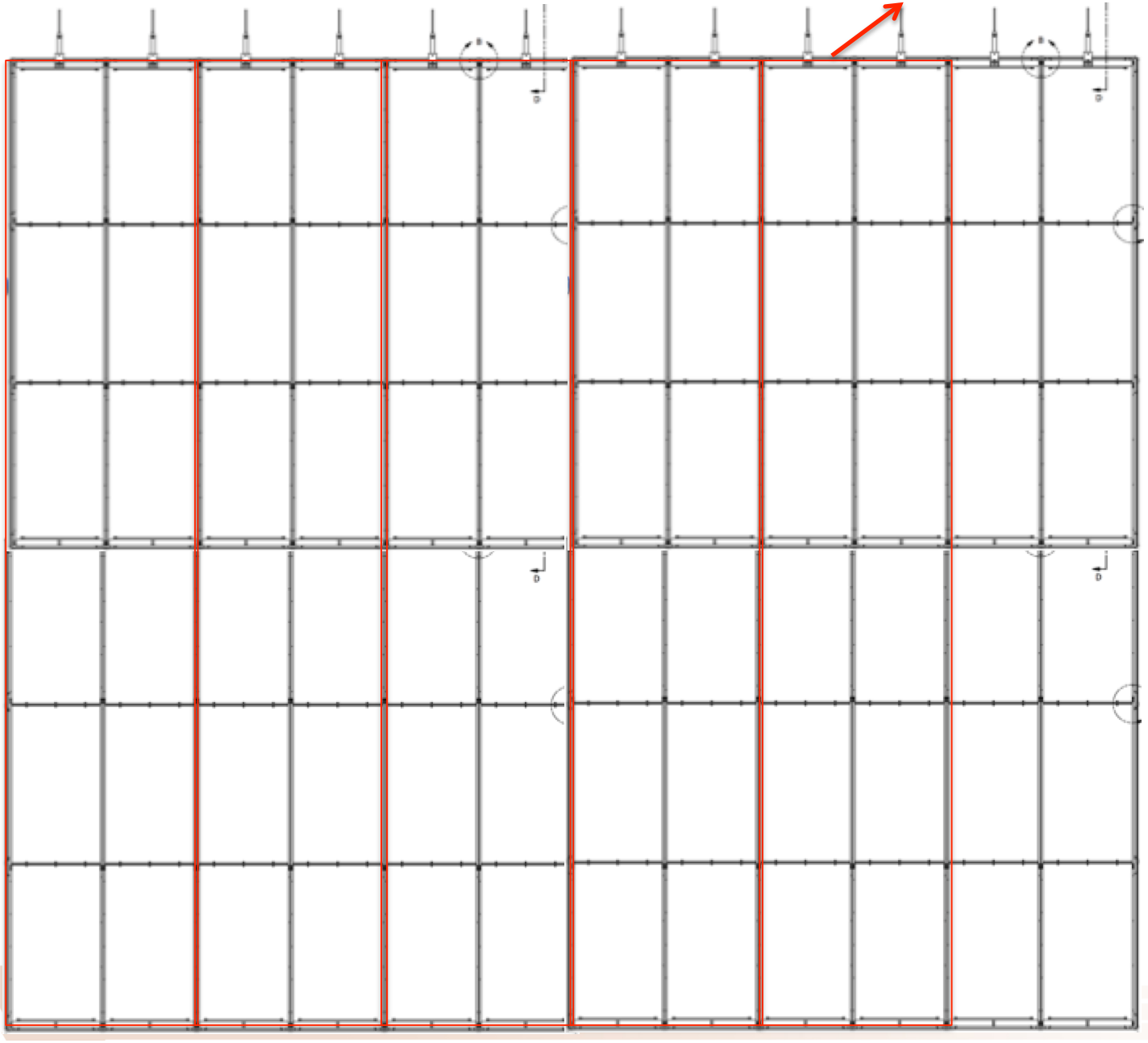


Nominal 10 kt Detector Design



Nominal 10 kt Detector Design

Total red area is now ~11.6m x 12m ie ~ symmetric;
Divides
Full CPA
Into five
sections



UV Light Calibration System in 10 kt DUNE detector

- More from Jim:

  "The main purpose here is to understand how many penetrations are needed in the cryostat roof for fibers for a light flashing system. In protoDUNE we have 5 fibers on the face of the CPA. It is unclear how this scales up. Can we put 5 fibers on a 14m by 12m surface of the cathode or do we need to keep the same fiber density and have 20 fibers on the same area? If we want 40 fibers every 14 meters this will be a fairly big flange where only 10 fibers will fit on a small flange."

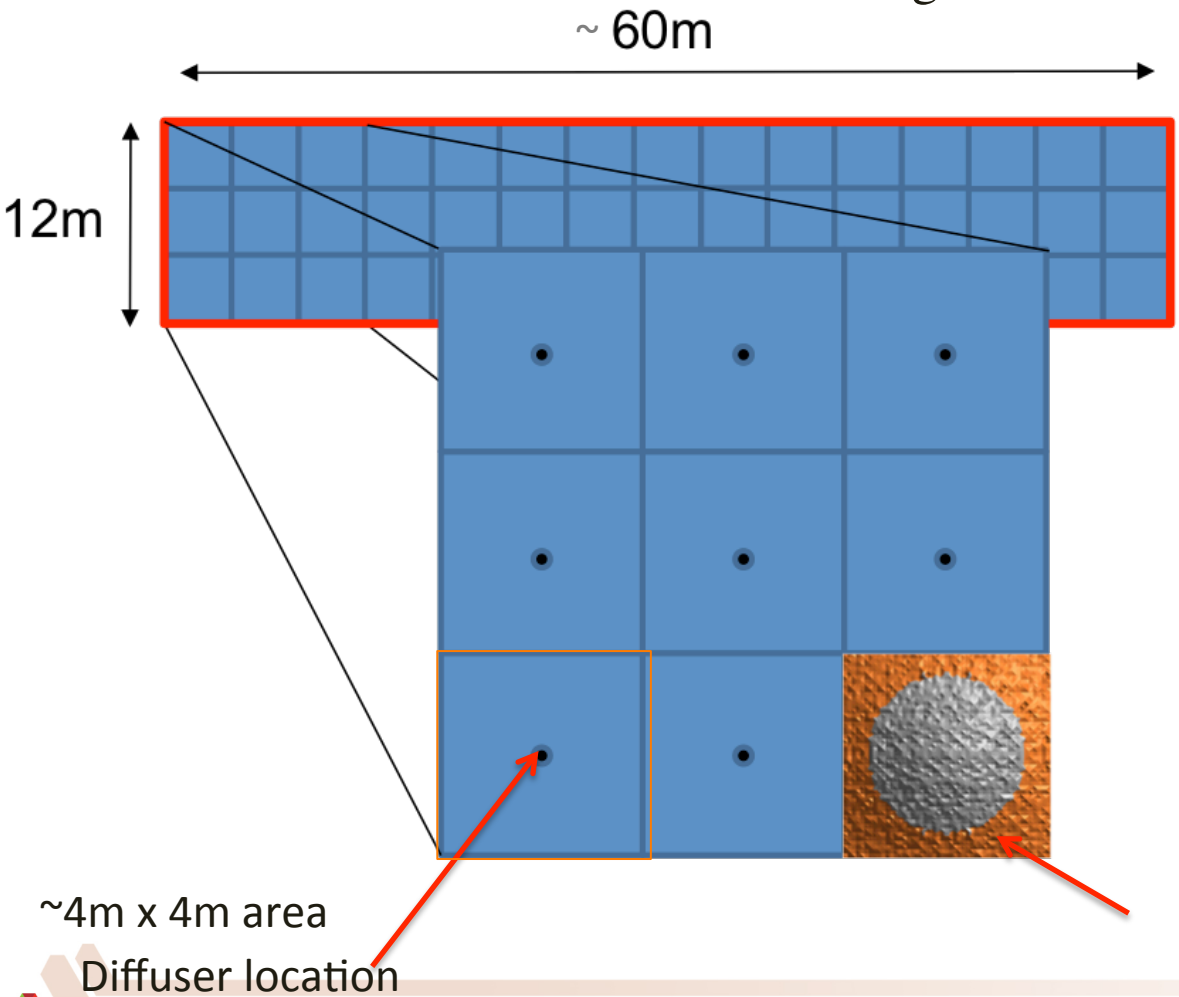
- What we considered:

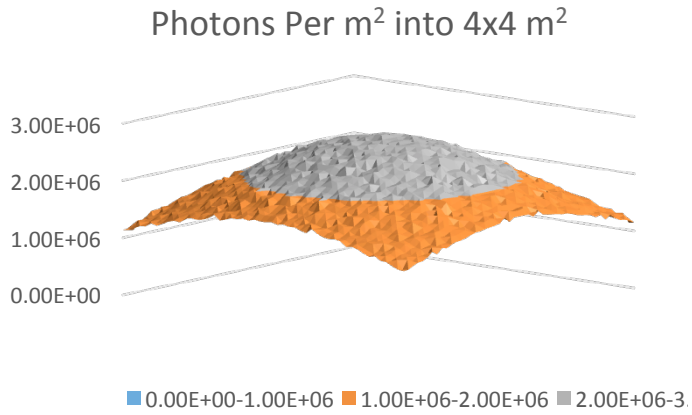
  A) One fiber per 4m x 4m area: this option will translate in 9 fibers for ~12m x 12m area.

  B) Five fibers per 12m x 12m area; very similar to covering five fibers per 14m x 12m area (= 4 ProtoDUNE's CPAs)

UV Light Calibration System in 10 kt DUNE detector

- **Option A**:
- Potential approach for DUNE 10 kton detector
  -install light diffusers at CPA
  -cover 4m x 4m APA area with a single diffuser





% STDEV	19%
Max	2.74E+06
Min	1.13E+06
Max/Min	2.425982247
Average	1.96E+06

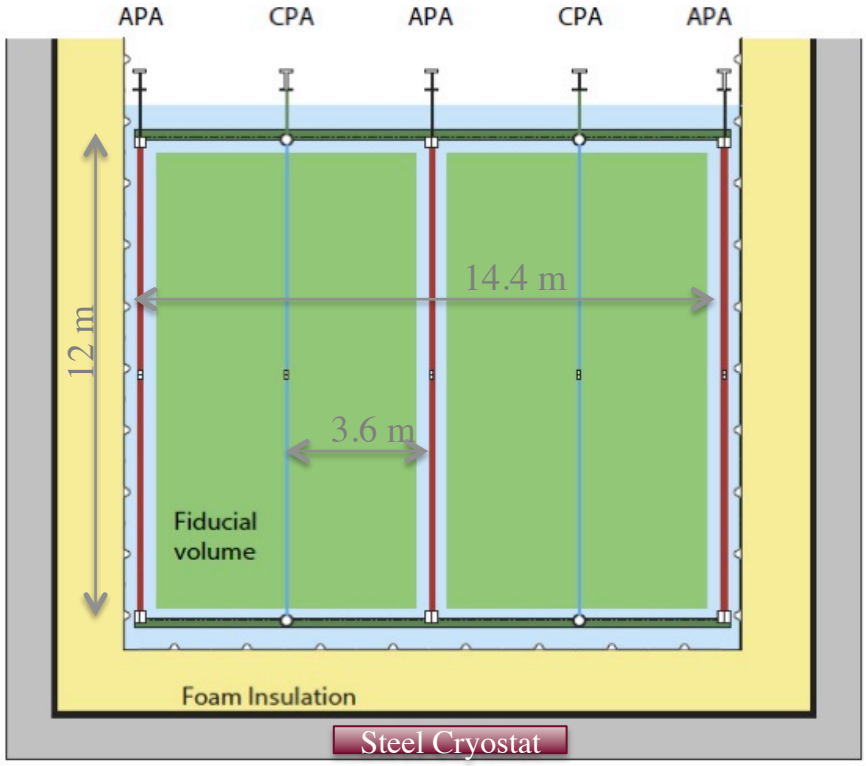
Simulated light response
at APA 4m x 4m area

UV Light Calibration System in 10 kt DUNE detector

- **Option A**:

-Leads to (9 fibers) x (5 sections) = 45 fibers per CPA side
-Doable in terms of penetrations: use 1 feed-through for 9 fibers
=> Five feed-throughs per CPA side

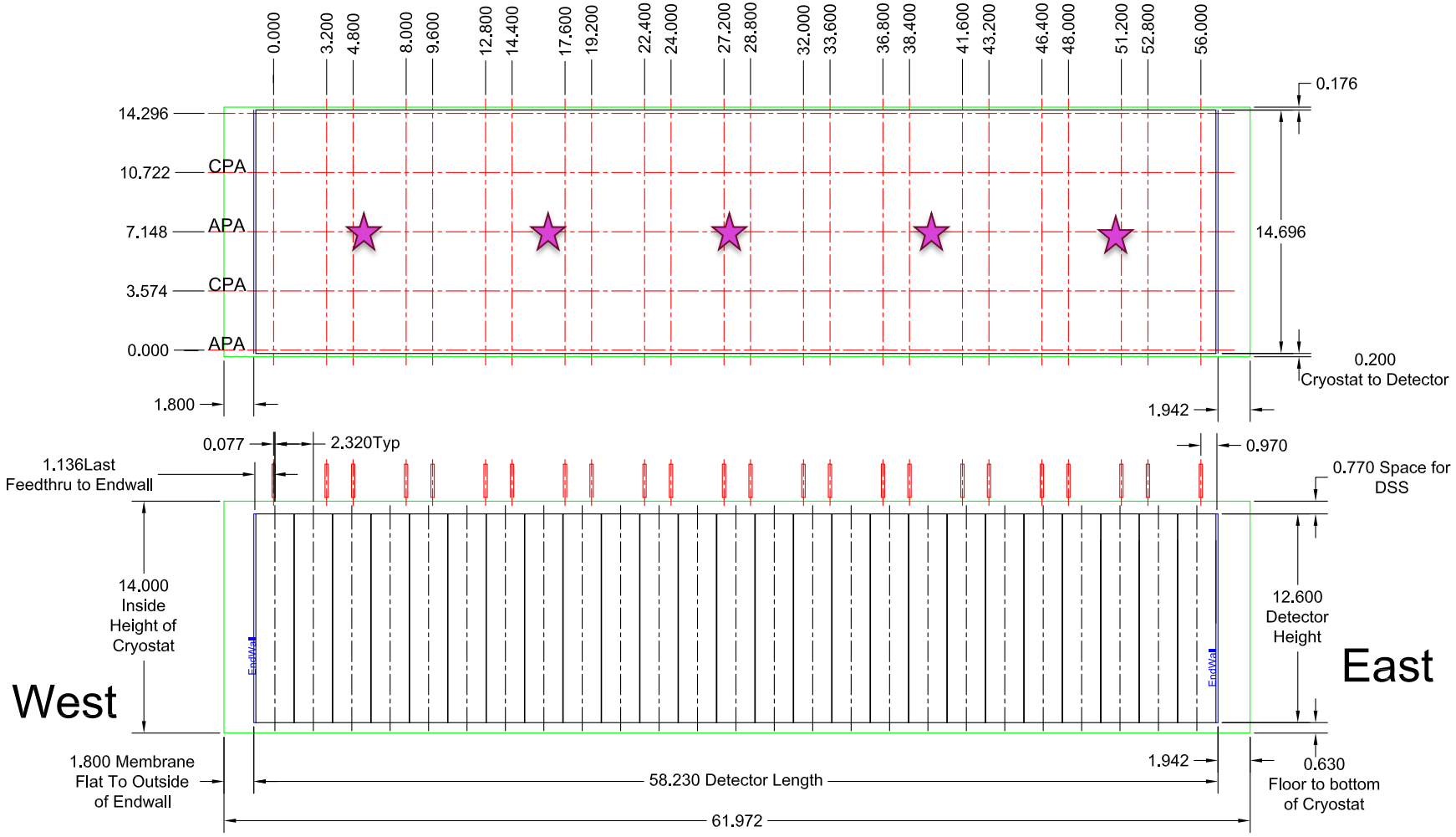
-Need cover 3 or 4 CPA sides?
=> with 3 sides covered:
need a total of 135 fibers
= 27 fibers in each of 5 sections



UV Light Calibration System in 10 kt DUNE detector

- **Option A**:

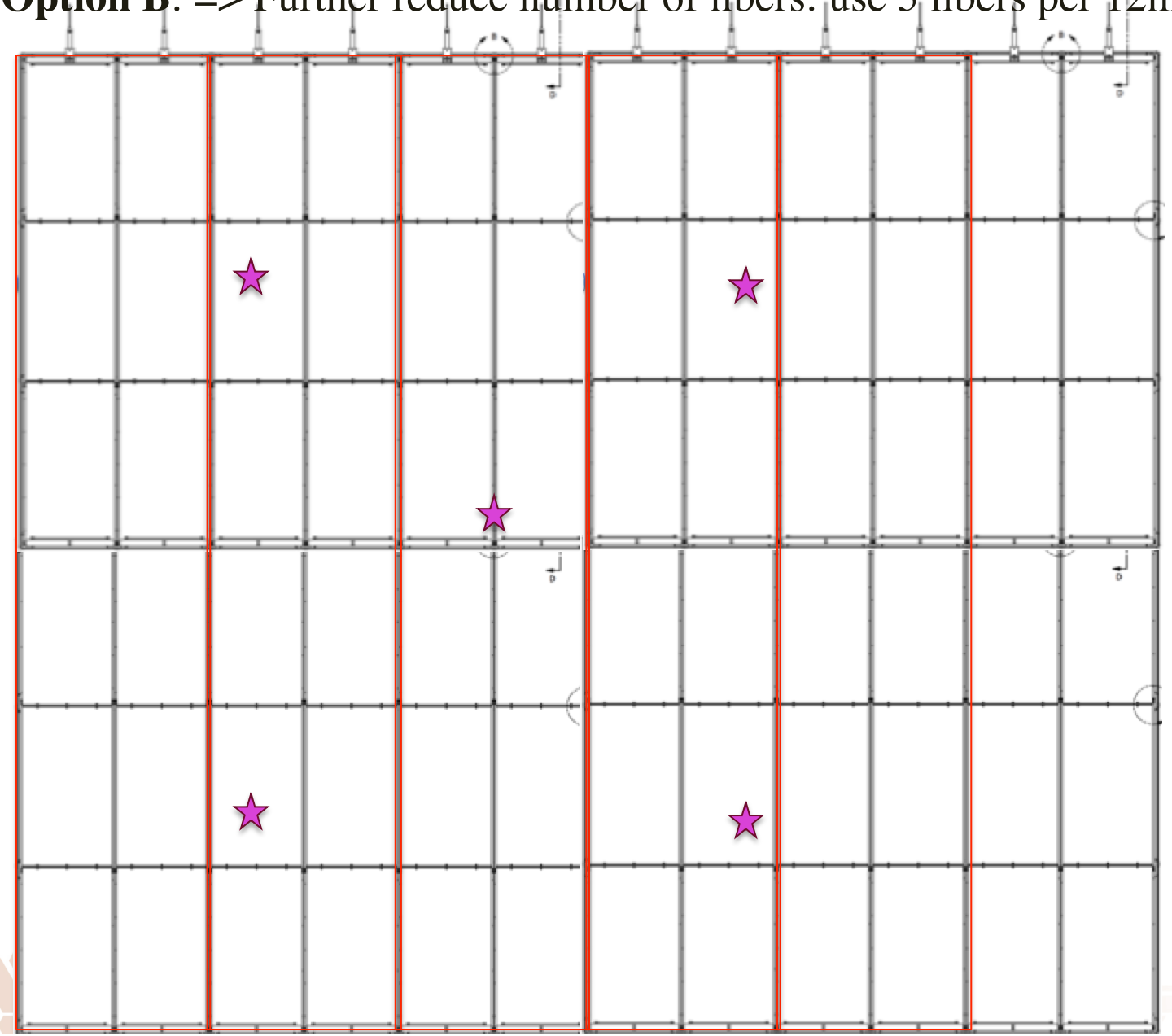
Five penetrations with 27 fibers each? Feasible?
Or Double number of penetrations (various ways possible)?



Modified 7/18/17

UV Light Calibration System in 10 kt DUNE detector

- **Option B**: => Further reduce number of fibers: use 5 fibers per 12m x 12m area



Potential diffuser Locations would be studied further (use ProtoDUNE Data)

UV Light Calibration System in 10 kt DUNE detector

- **Option B**:
  => Further reduce number of fibers: use 5 fibers per 12m x 12m area

  -Leads to (5 fibers) x (5 sections) = 25 fibers per CPA side
  -Doable in terms of penetrations:
  => may decide to use 1 feed-through for 5 fibers
  Five feed-throughs per CPA side
  => or use smaller number of feedthrus where each feedthru may cary more fibers

  => For 3 CPA sides one gets a total of 75 fibers
  5 penetrations, each one with 15 fibers?

- Note: when both sides of CPA are equipped with fibers/diffusers then the number doubles for same CPA
  => with option B this would lead to (10 fibers) x (5 sections)
  => may decide to use 1 feed-through for 5 fibers

DUNE FD Monitoring System

- At this point we may only sketch of what such a system would look like for DUNE FD

- We will use ProtoDUNE calibration system and PD data to study optimal distribution ie coverage of these diffusers.
  -We will test if the central diffuser alone could cover an area of ~4m x 4m vs ~6m x 6m

Bonus: 35-ton Experience

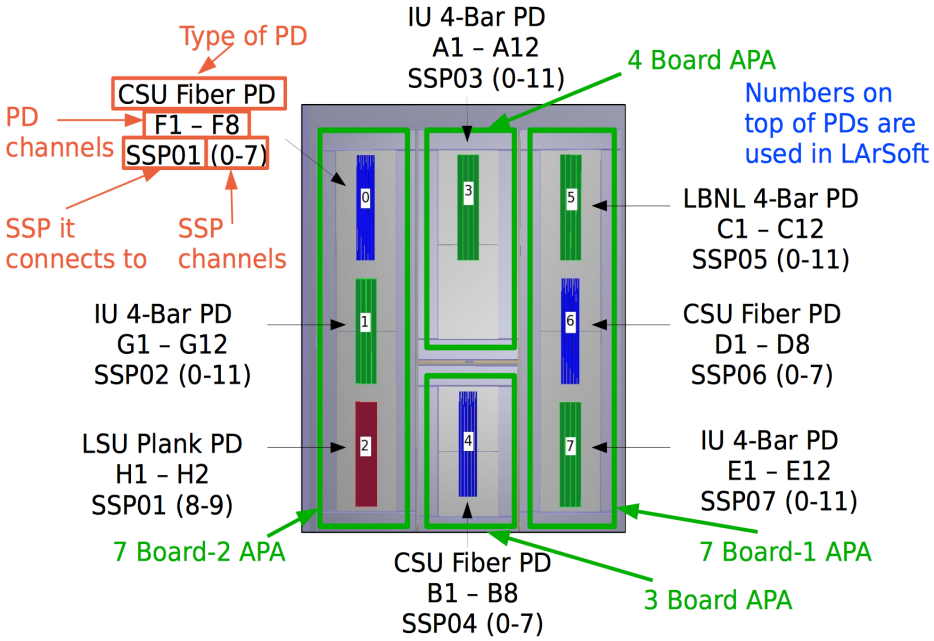
35-ton Experience

- PD UV calibration system has been operational before the end of 35-ton run

- Collected calibration data demonstrated functionality of the calibration system and examined the functionality of the photon-detector channels
  - -observe normal channels (i.e. standard response)
  - -discover noise channels
  - -discover malfunctioning PD channels

- We have collected data with all five UV-light diffusers with different pulse lengths and pulse heights
  - -analysis underway

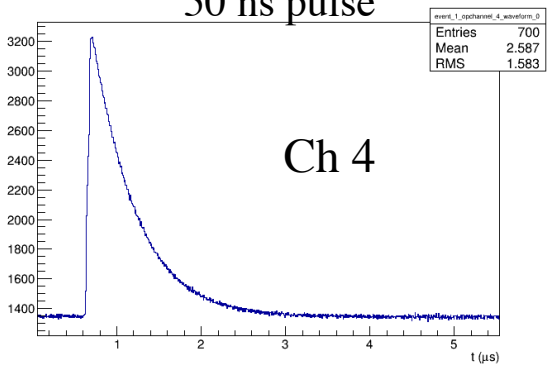
- Example of PD Calibration Runs in next two slides
  - -central diffuser only
  - -pulse width = 50, 10, 3.33 ns
  - -pulse amplitude 30 V
  - -pulse frequency 143 Hz



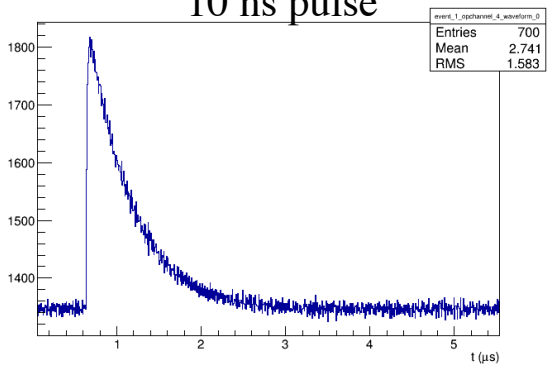
PD Channels with Standard Response

- Standard Channels

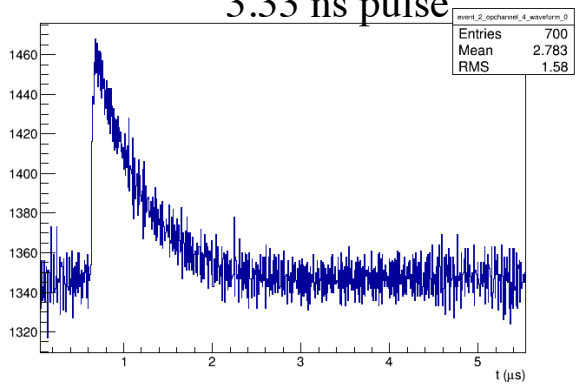
50 ns pulse

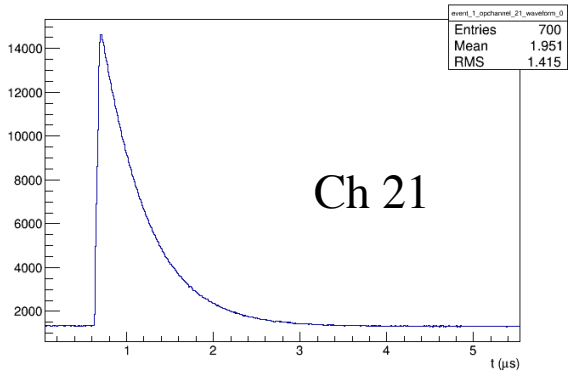


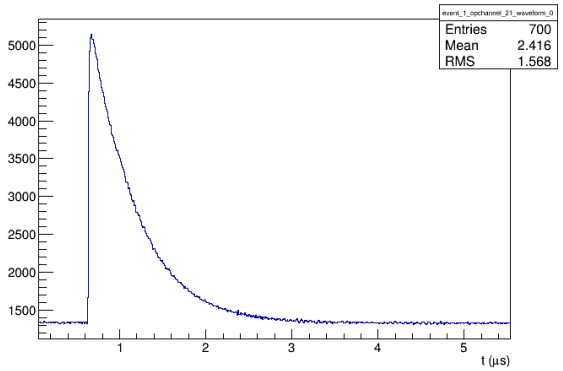
10 ns pulse

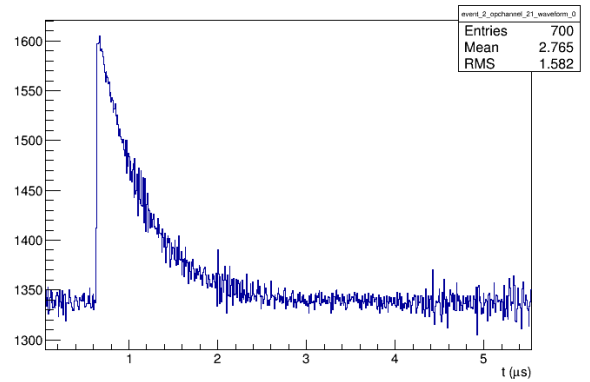


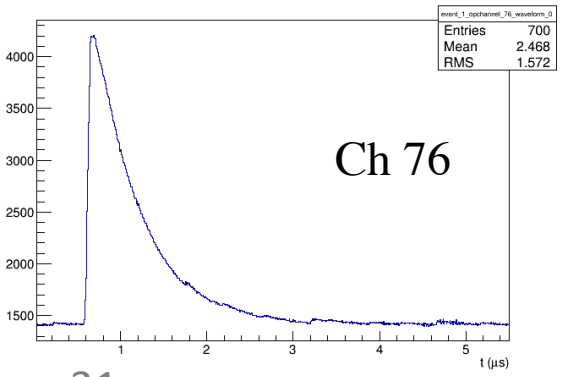
3.33 ns pulse

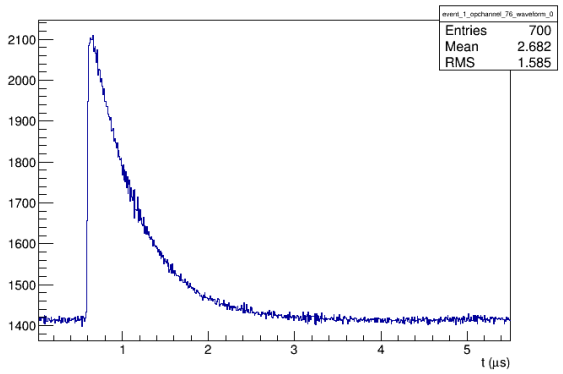


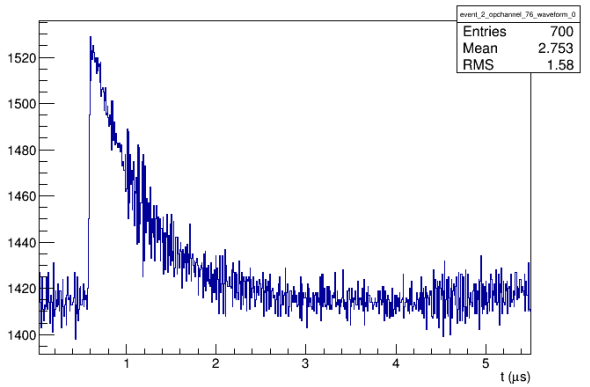












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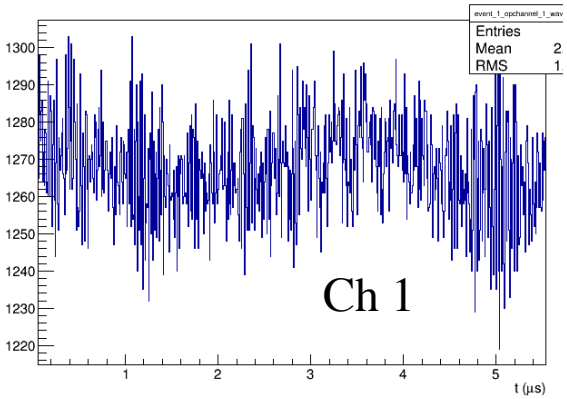
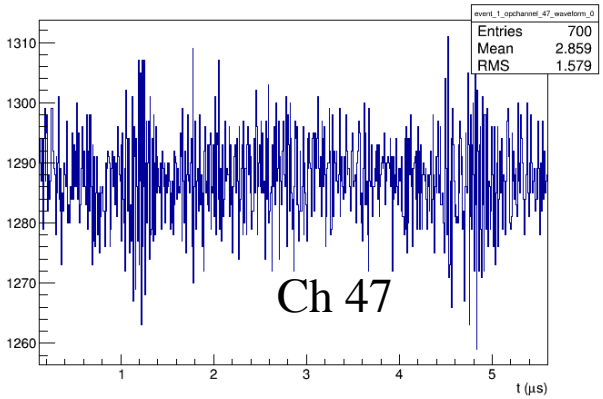
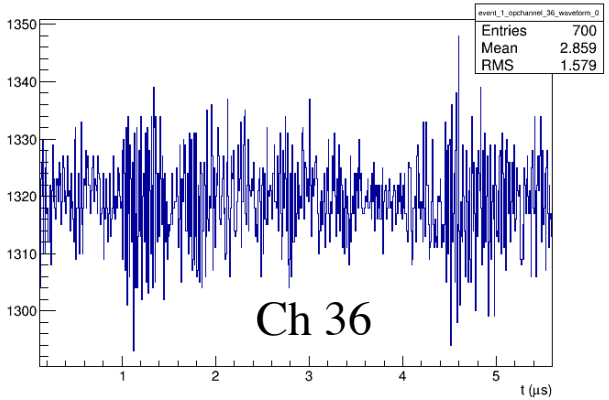
Malfunctioning and non-standard PD Channels

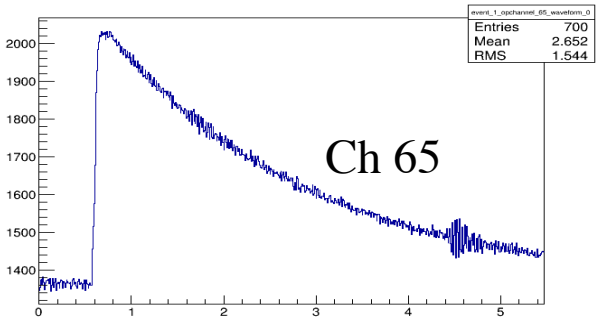
- Malfunctioning Channels

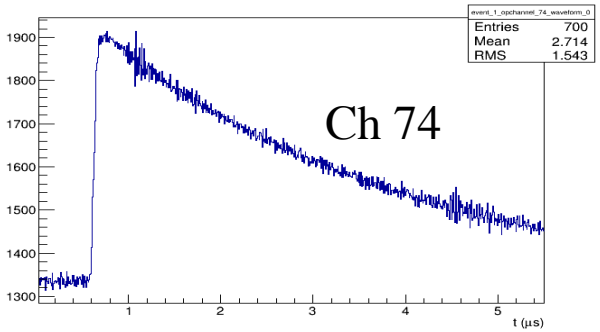






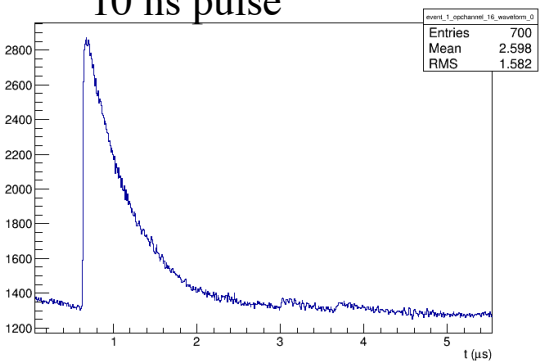
- "Slow" PD Channels



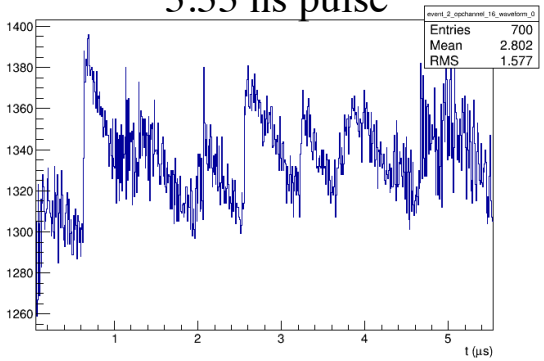


- Channels with p.e.-like noise

10 ns pulse

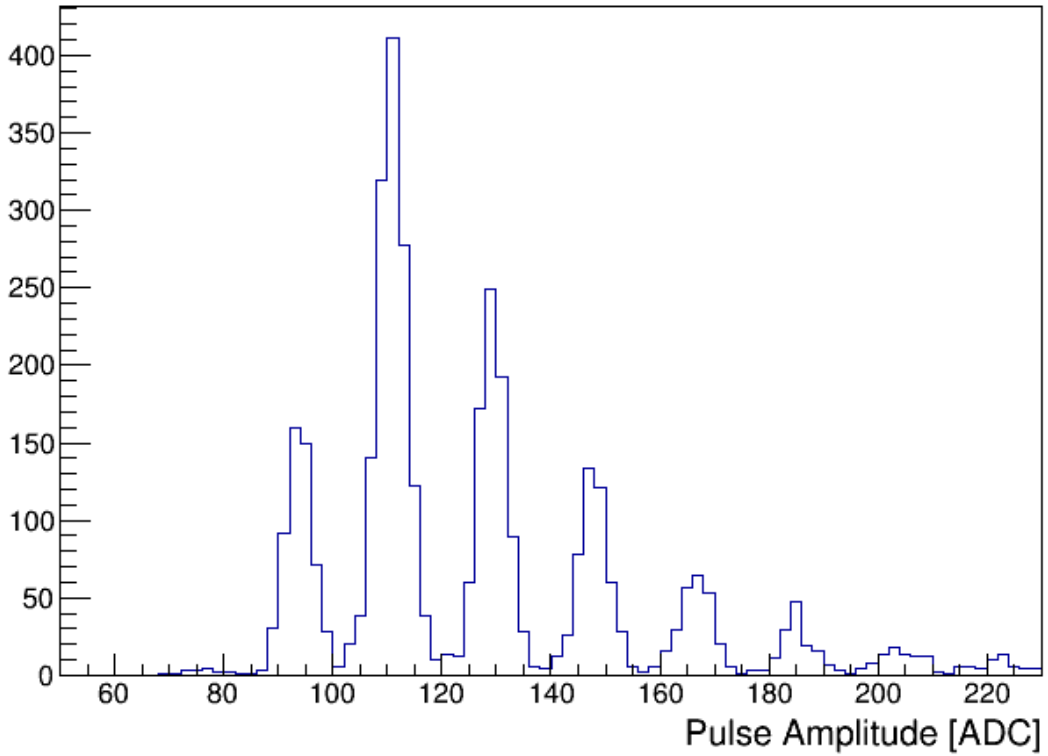


3.33 ns pulse



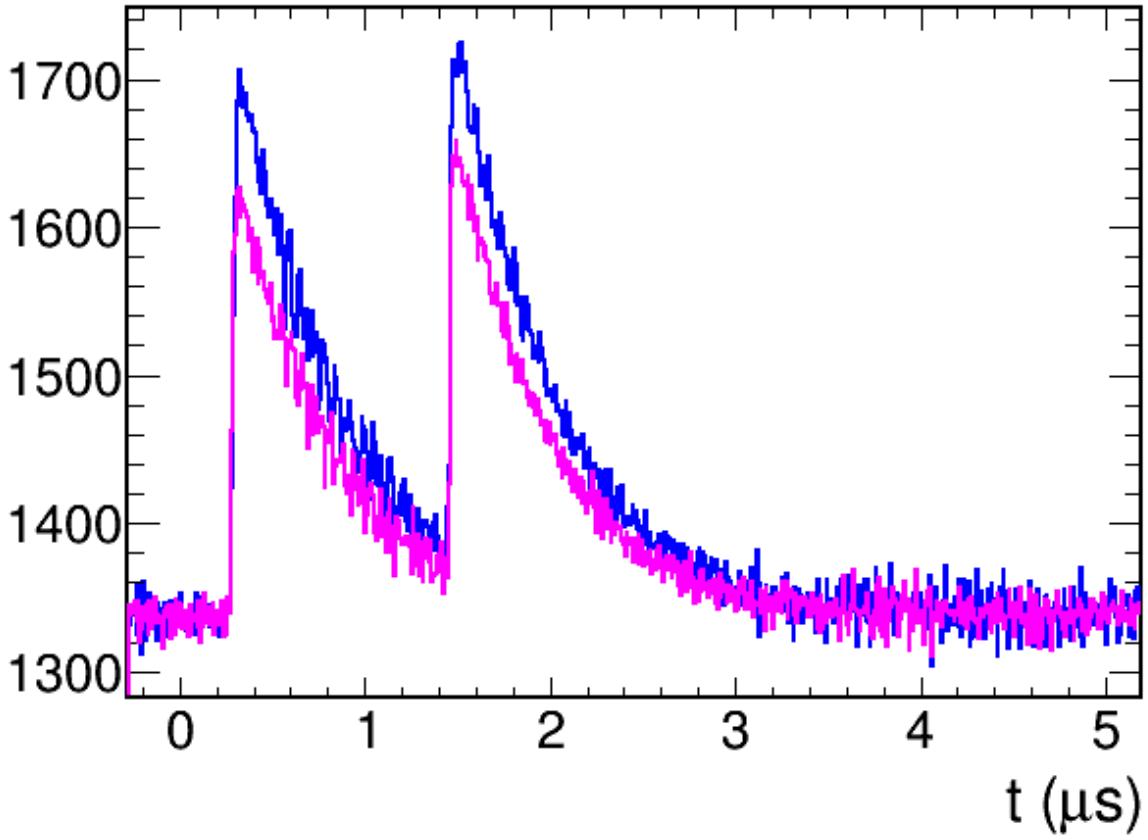
35-ton Data Analysis

- Typical photo-electron distribution from one of photon-detector readout channels
  -From this distribution we find SiPM gain to be 18 counts per single photo-electron (calibration of the signal strength to N_{PE})



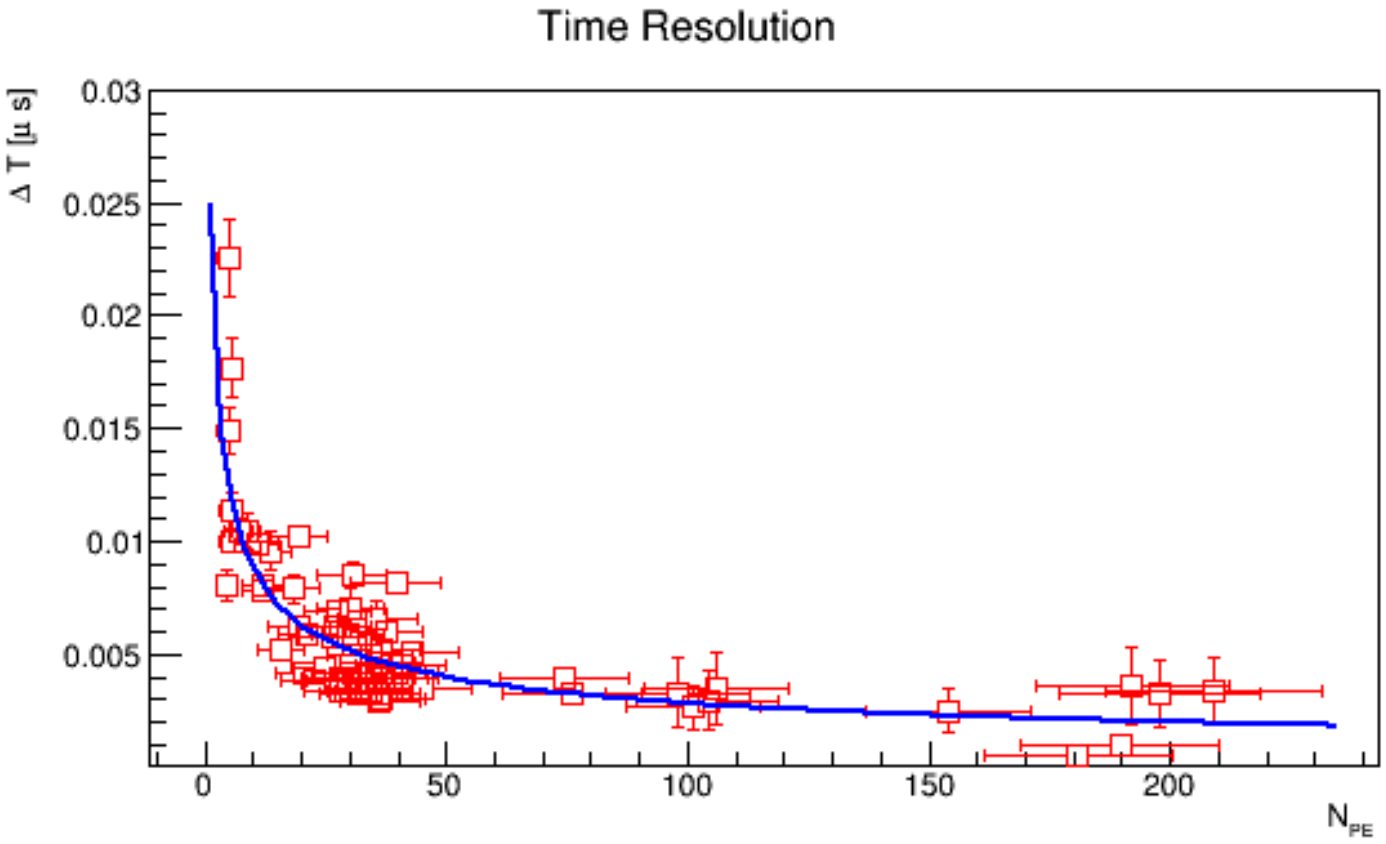
35-ton Data Analysis (Cont.)

- Typical example of double-pulse pairs emitted by calibration system and observed by photon-detectors
  -We looked for the time difference $T_{12} = t_2 - t_1$



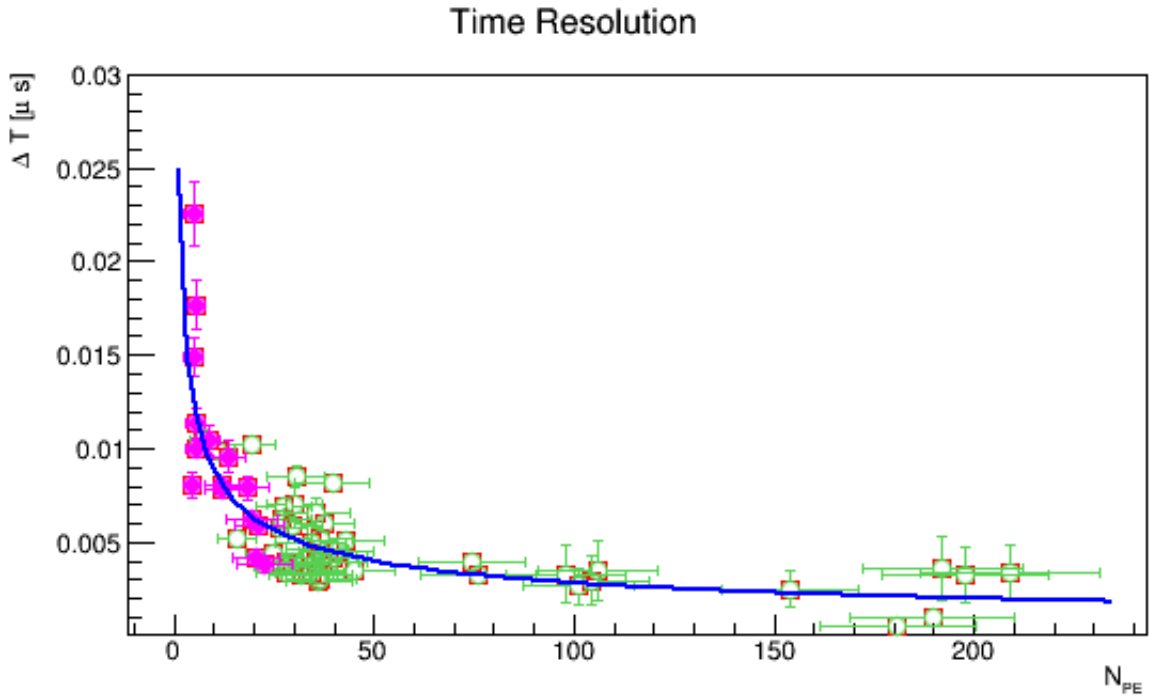
35-ton Data Analysis (Cont.)

- Time resolution plots as a function of pulse height in units of N_{PE}



35-ton Data Analysis (Cont.)

- Time resolution plots as a function of pulse height (of the second pulse) in units of N_{PE}
  -magenta points represent the run collected with 3.9 ns wide pulses,
  -green points represent the run collected with 11.7 ns wide pulses

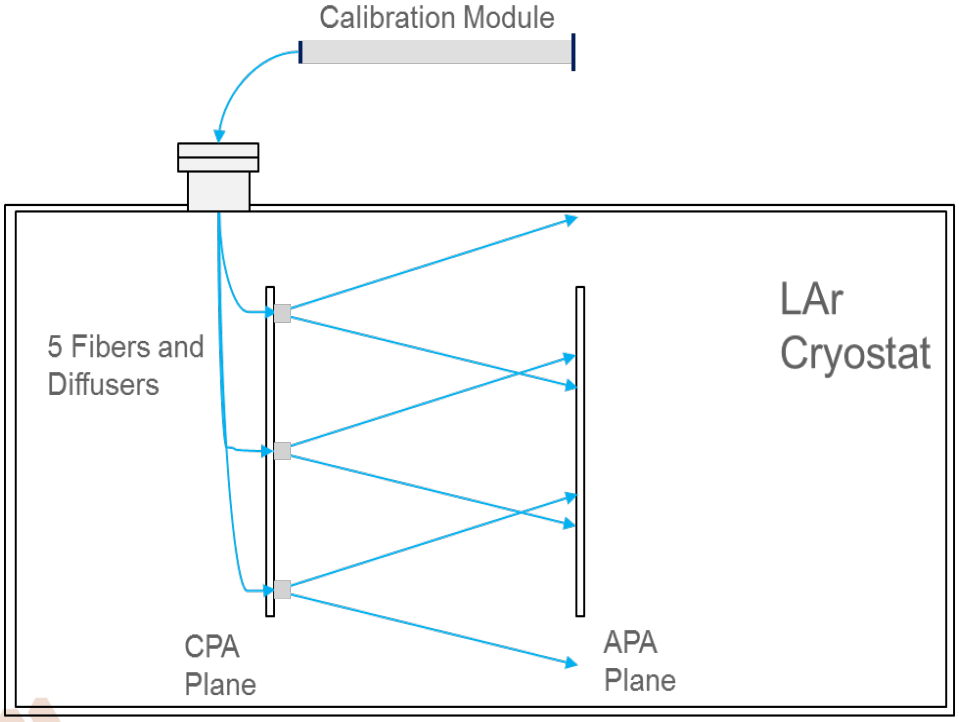


BACKUP SLIDES

UV Light Calibration System

- Photon Detector Calibration Monitoring System has been realized in a form UV-light flasher calibration system

- UV light calibration system design:
  -transports light from 275 nm UV LED sources through quartz fibers to the TPC volume
  -diffuse light to the photon detection system light collection elements
  -use UV light (will be wavelength shifted) to mimic physics of LAr scintillation light
  -observe SiPM response to shifted light.



- Outer Components:
  -Optical quartz fiber
  -Calibration Module with 275nm LEDs

- Inner Components:
  -Light diffusers at CPA plane
  -Optical quartz fiber
  -Flange with fiber feed-through

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