# Photon Detector Calibration Monitoring System

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# Outline of Talk

- Goals of the photon-detector monitoring system
- 35-ton Detector Prototype of the system
- Going from 35-ton to ProtoDUNE
- Next Steps
- Summary

# Introduction

- **The Following Review Questions will be addressed (from the Charge):**

1. **Does the Photon Detector System design enable validation and refinement of the DUNE photon detector requirements?**
2. **Are Photon Detector System risks captured and is there a plan for managing and mitigating these risks?**
3. **Does the design lead to a reasonable production schedule, including QA, transport, installation and commissioning?**
4. **Does the documentation of the Photon Detector System technical design provide sufficiently comprehensive analysis and justification for the Photon Detector System design adopted?**
5. **Is the Photon Detector system scope well defined and complete? Are all Photon Detector System interfaces to other detector components: APA, cryostat and DAQ systems documented, clearly identified and complete? Do the electronics feedthrough port and TPC integrated 3D models adequately represent the mechanical, electrical and electronic interfaces to the Photon Detector System? Is the cabling, power and calibration well defined and understood? Is the grounding and shielding understood and adequate?**
6. **Are the Photon Detector System 3D model(s), top level assembly drawings, detail/part drawings and material and process specifications sufficiently complete to demonstrate that the design can be constructed and installed?**
7. **Are operation conditions listed, understood and comprehensive? Is there an adequate calibration plan?**
8. Are the Photon Detector System engineering analyses sufficiently comprehensive for safe handling, installation and operation at the CERN Neutrino Platform? Is the installation plan sufficiently well developed? Is the design for installation tooling adequate for installing the photon system?
9. **Have applicable lessons-learned from previous LArTPC devices been documented and implemented into the QA plan? Are the Photon Detector System quality control test plans and inspection regimes sufficiently comprehensive to assure efficient commissioning and adequate operational performance of the NP04 experiment?**



(Green = Will cover in this Talk; Blue = Will mention in this Talk)

# Photon Detector Calibration Monitoring System

- The goals of the photon-detector monitoring system:

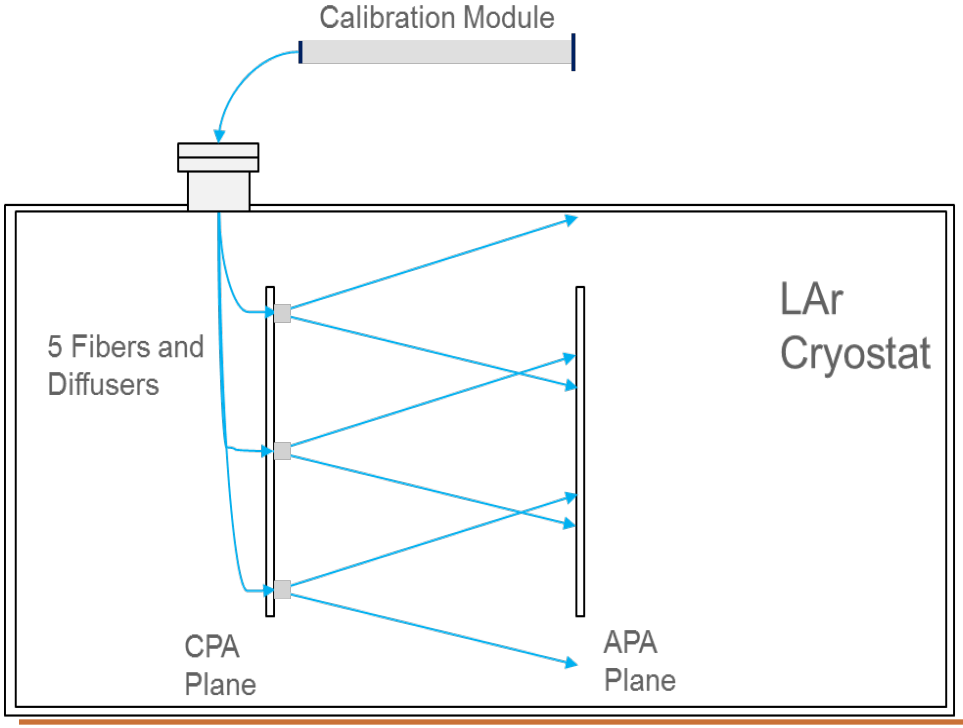
  a) Verify that the channels are functioning properly
  -after photon-detector installation, before LAr filled
  -after LAr filled
  b) Calibrate SiPM/SSP response
  c) Monitor the relative detector efficiency over time.
  d) Monitor relative timing performance of the system.

# 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

# Recent Status: 35ton DUNE Prototype

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

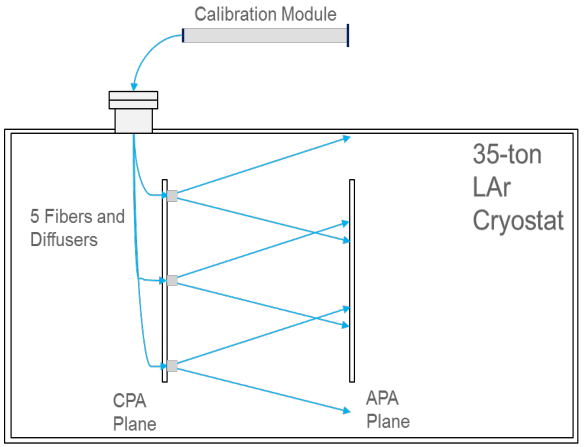
## Photon Detector Calibration System Components

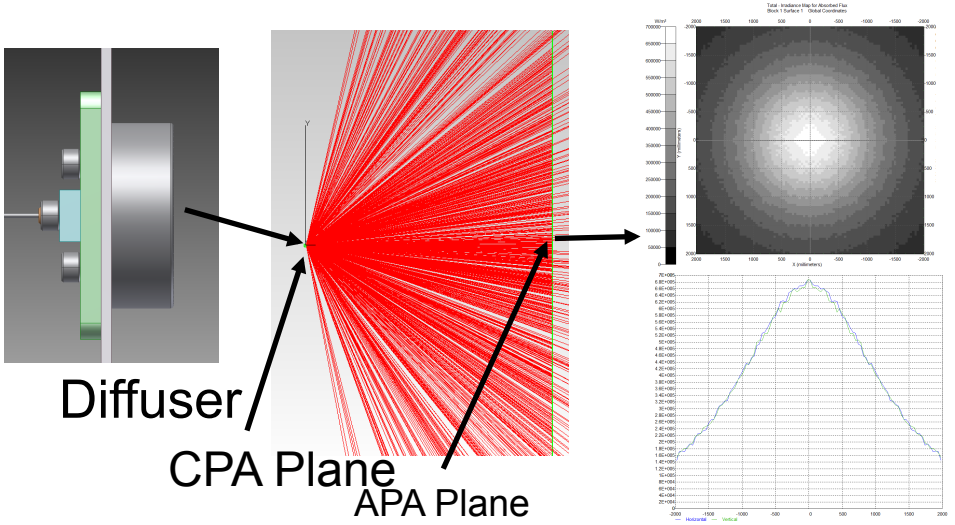
- Calibration module sources 5 UV LEDs (275nm)
- 275 nm light excites only wavelength shifter
- Quartz fibers deliver light to 5 diffusers mounted on CPA plane
- Diffusers distribute light onto photon detectors at APA plane
- One central Diffuser for Timing
- Four corner Diffusers for Uniformity/Gain

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

## Optical Simulation

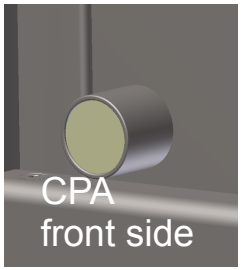
- TracePro used for optical system design, simulation, and optimization

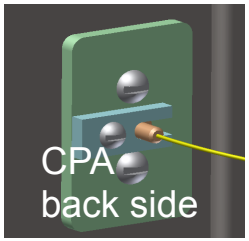


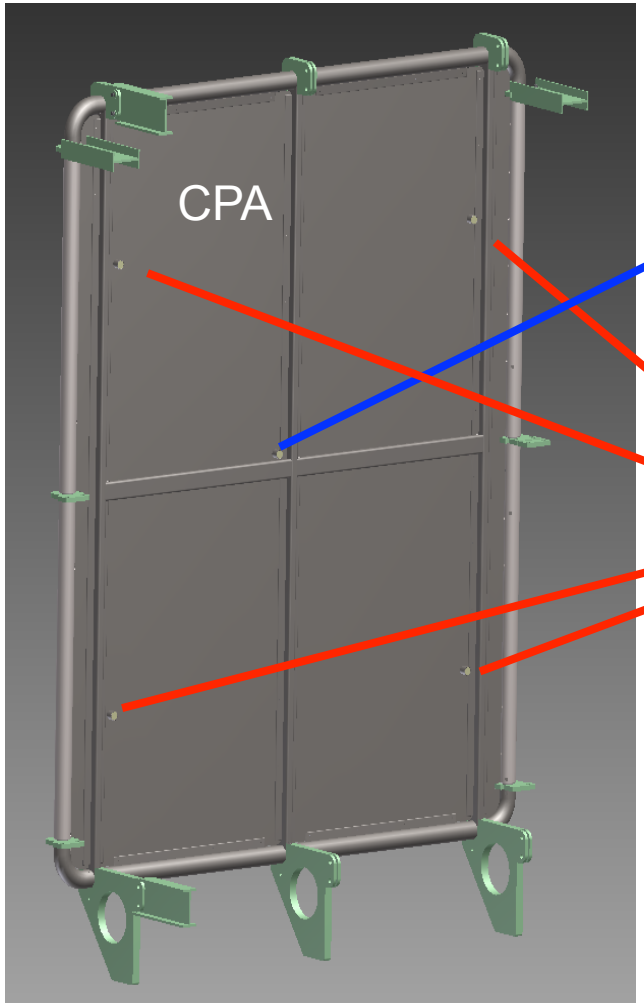




Optical Simulation of Single Diffuser at APA distance

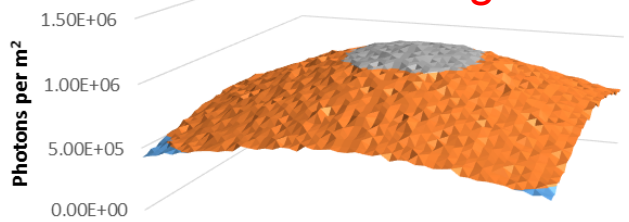
# Diffuser Implementation for 35-ton detector



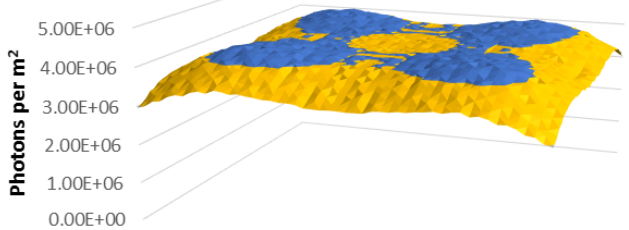

## Central location timing calibration




Photon distribution on 2x2 m² APA Plane

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

## 4 corner locations gain calibration



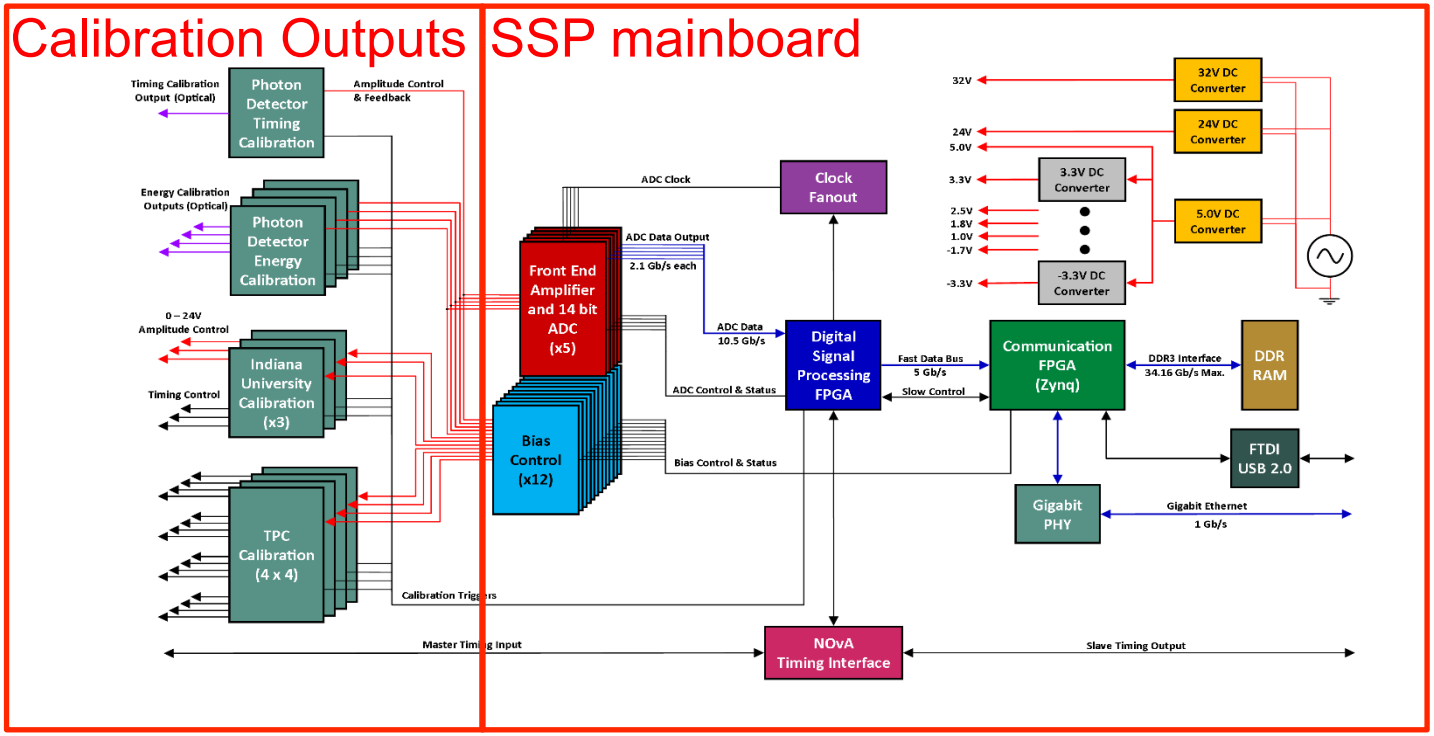

Photon distribution on 2x2 m² APA Plane

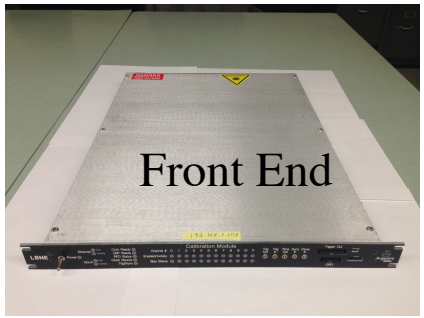
| | |
|---|---|
| Max | ~4.3 E+06 photons/m^2 |
| Min | 3.0 E+06 photons/m^2 |
| Max/Min | 1.44 |

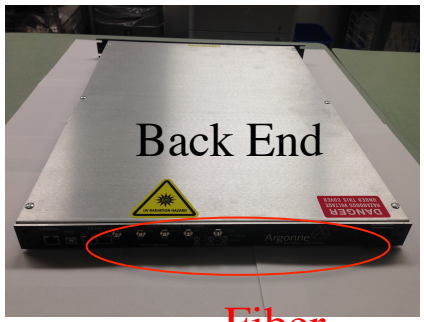
# DUNE Calibration Module

- Utilizes the SSP mainboard as a controller

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




Fiber SMAs

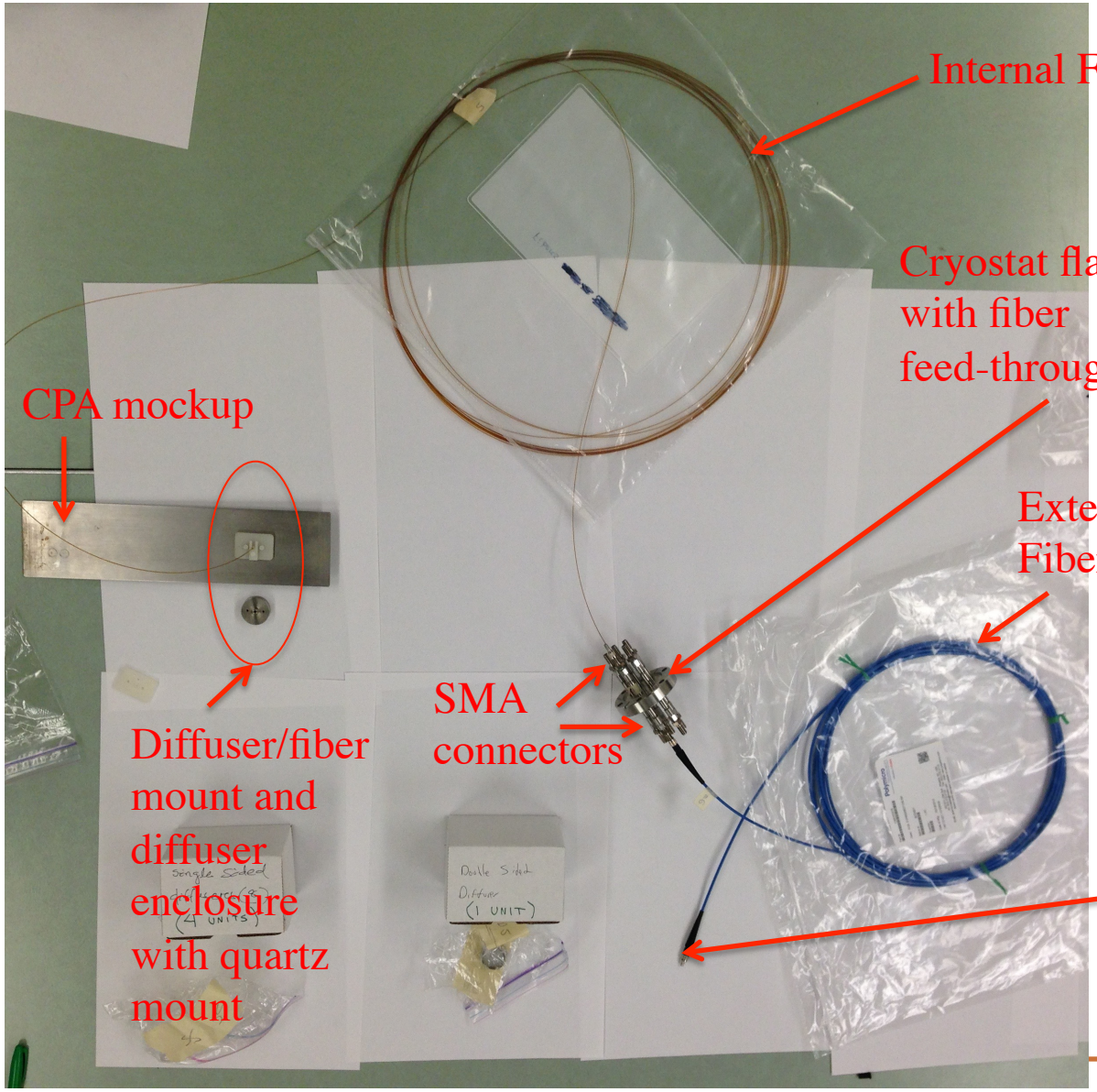
(also see the Backups)

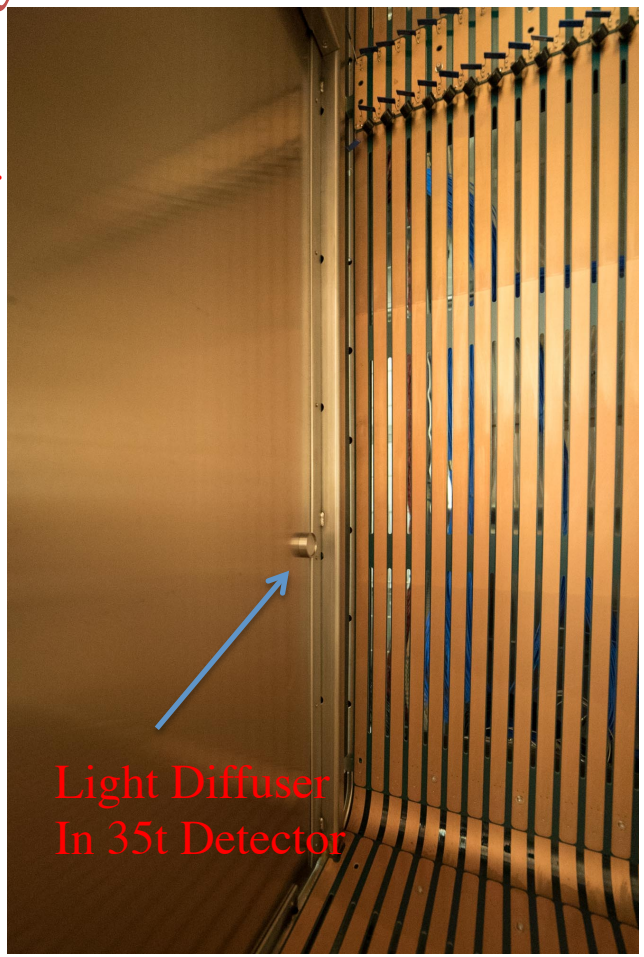


Calibration Back-Panel

# Components of the PD UV Calibration System

- Components installed with 35t DUNE prototype




(more figures in Backups)

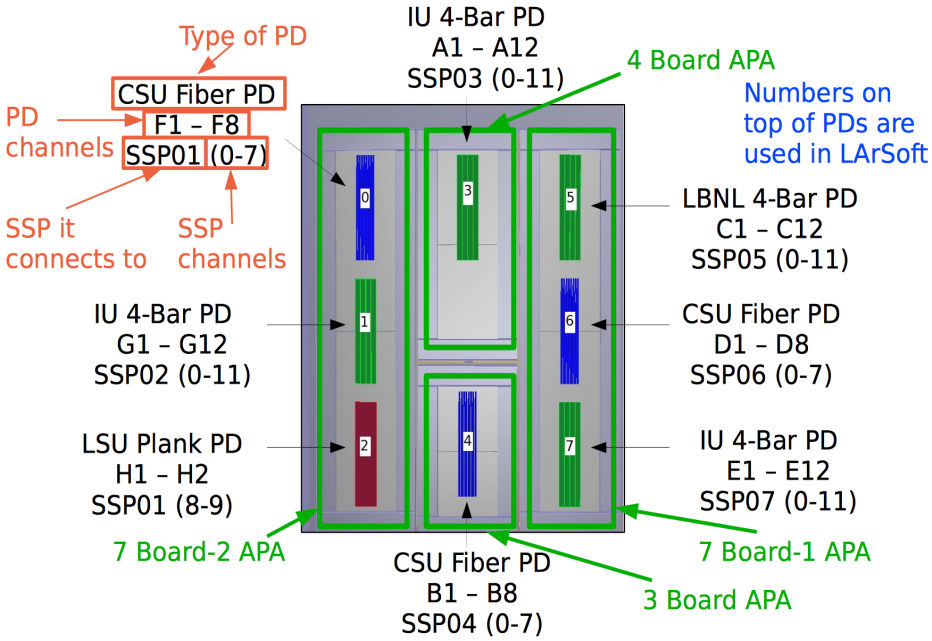
# 35-ton Experience

- 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

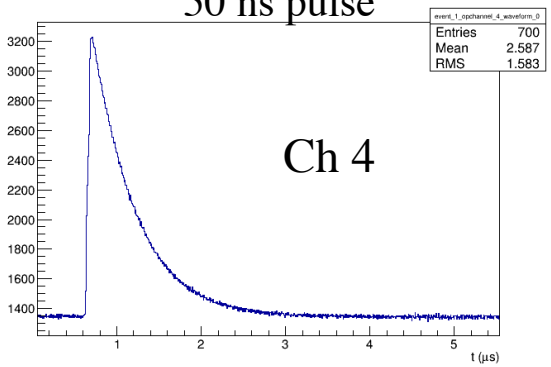
- Example of PD Calibration Runs in next two slides
  - -central diffuser only
  - -pulse width = 50, 10, 3.33 ns
  - -pulse amplitude 30 V
  - -pulse frequency 143 Hz



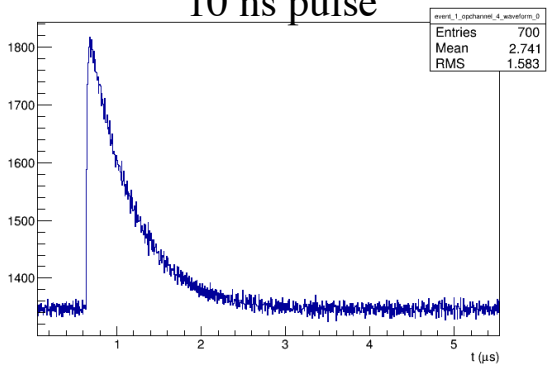
# PD Channels with Standard Response

- Standard Channels

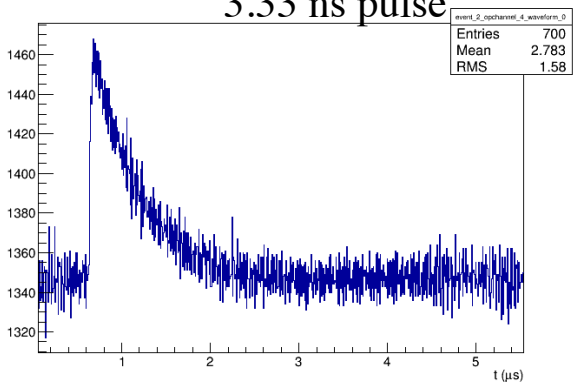
50 ns pulse

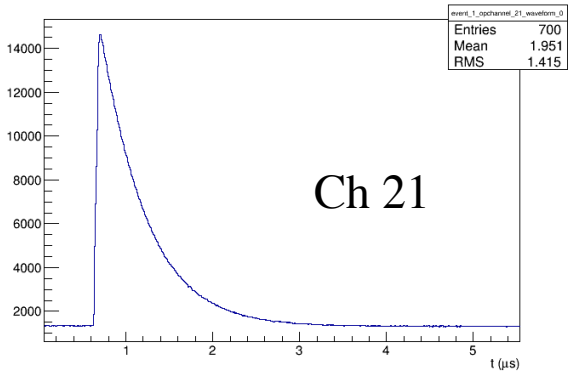


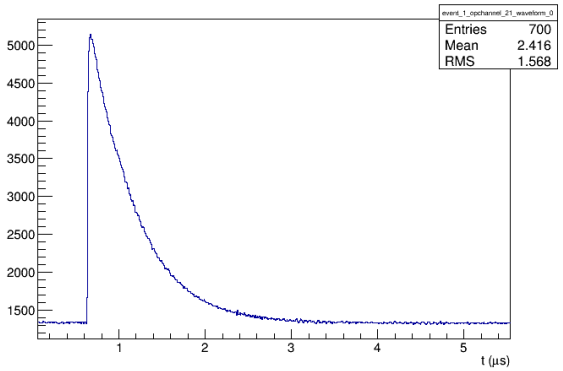

10 ns pulse

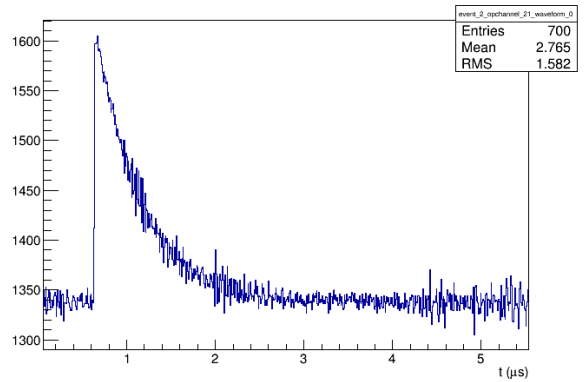


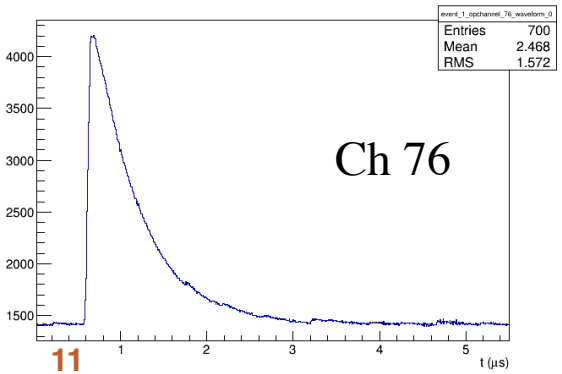

3.33 ns pulse

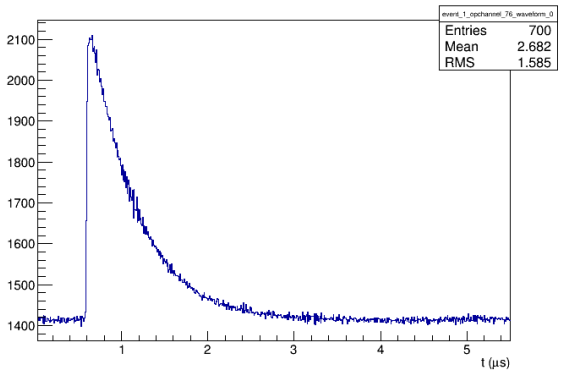


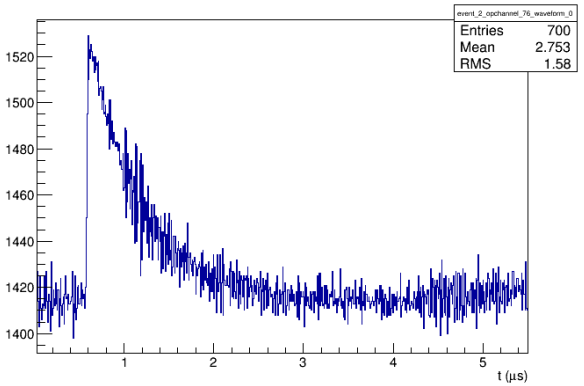



# Going from 35-ton to protoDUNE

- The prototype photon-detector UV-light calibration system has been implemented and tested with 35-ton detector

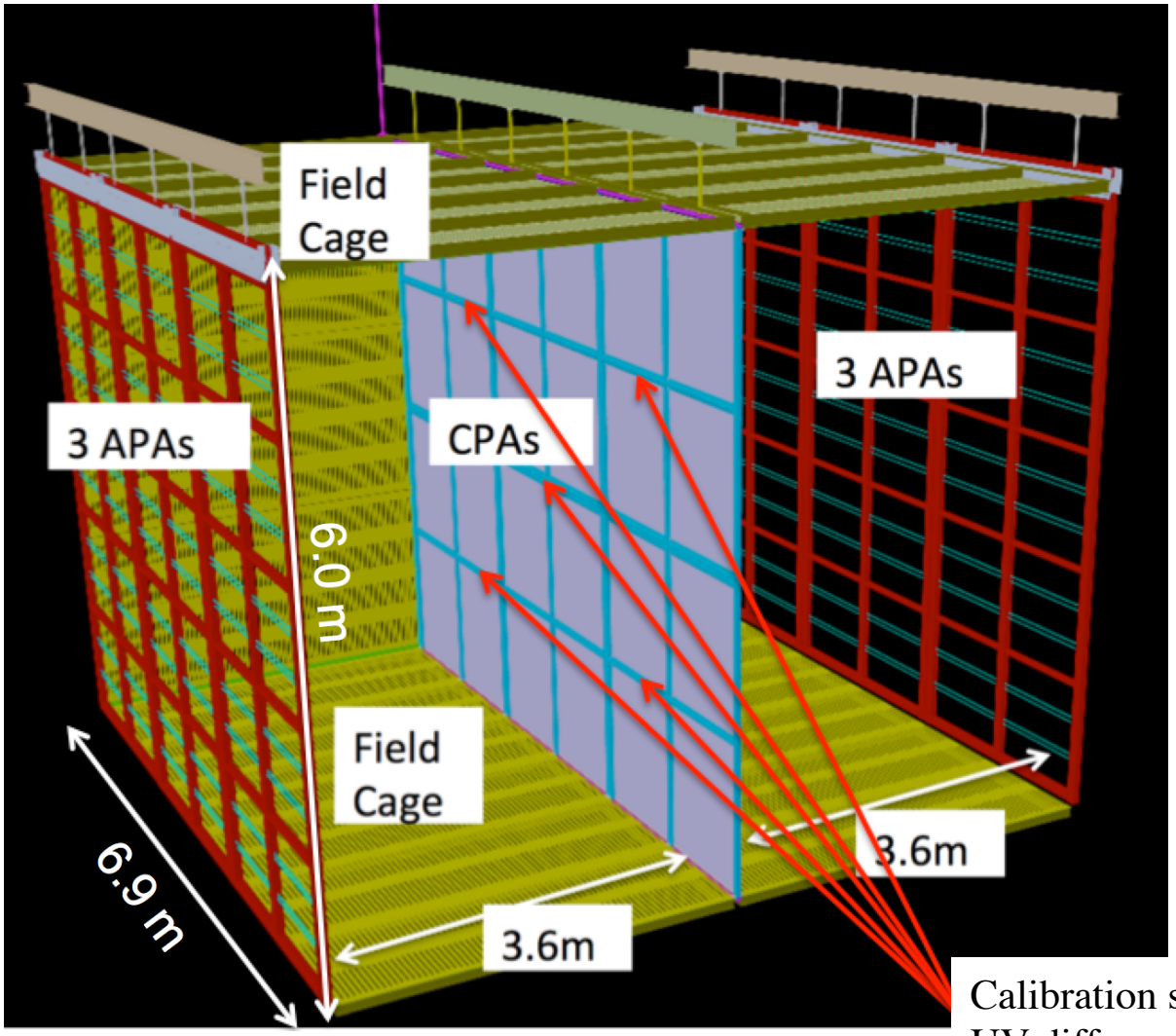
- Based on 35-ton experience we will re-design the system to used with the protoDUNE

- The system has been designed under following assumptions:
  -simple to implement (no active components within APA).
  -uniformly illuminates APA surface with the light diffused from CPA locations
  -has a potential to be adapted for deployment in a large Far Detector in the future

- In terms of technical requirements the system needs to:
  -uniformly illuminate the APA area of the detector
  -provide light levels down to a single P.E. at individual photon-detector channels, and higher light levels to study linearity of the readout
  -provide variable pulse width to test the time resolution of the photon- detector response

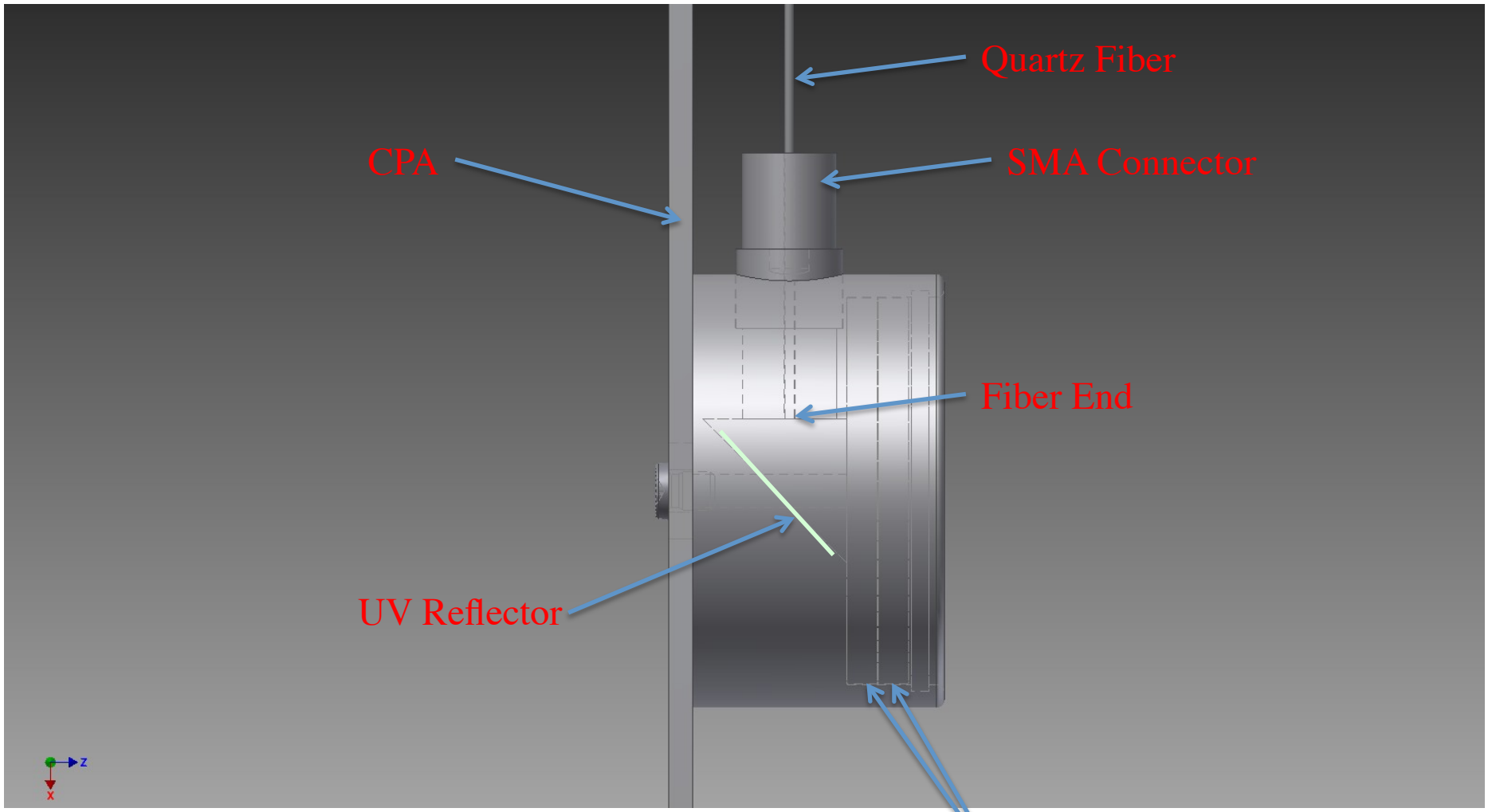
# Going from 35-ton to protoDUNE

- Based on the calibration system has been designed, tested, installed, integrated, and operated with the 35-ton DUNE prototype detector => adapt it for protoDUNE.



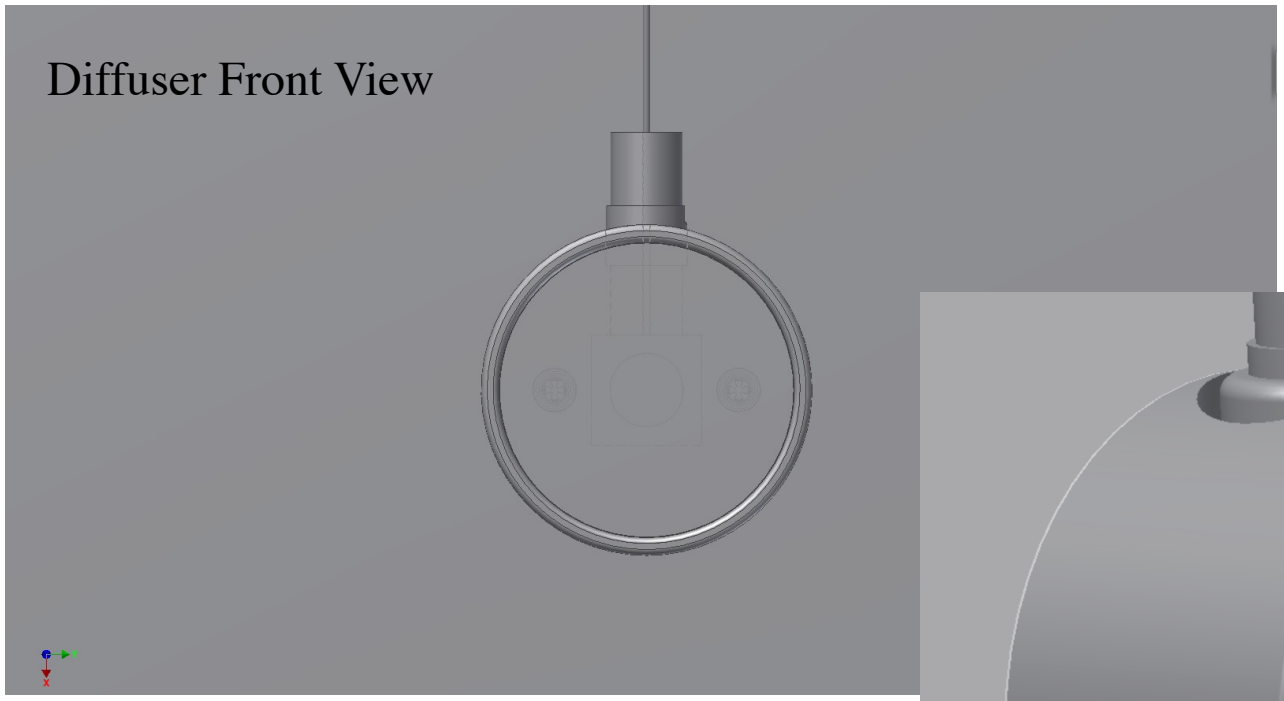

Calibration system
UV diffuser locations
At protoDUNE CPA

# Diffuser Design for protoDUNE's CPA



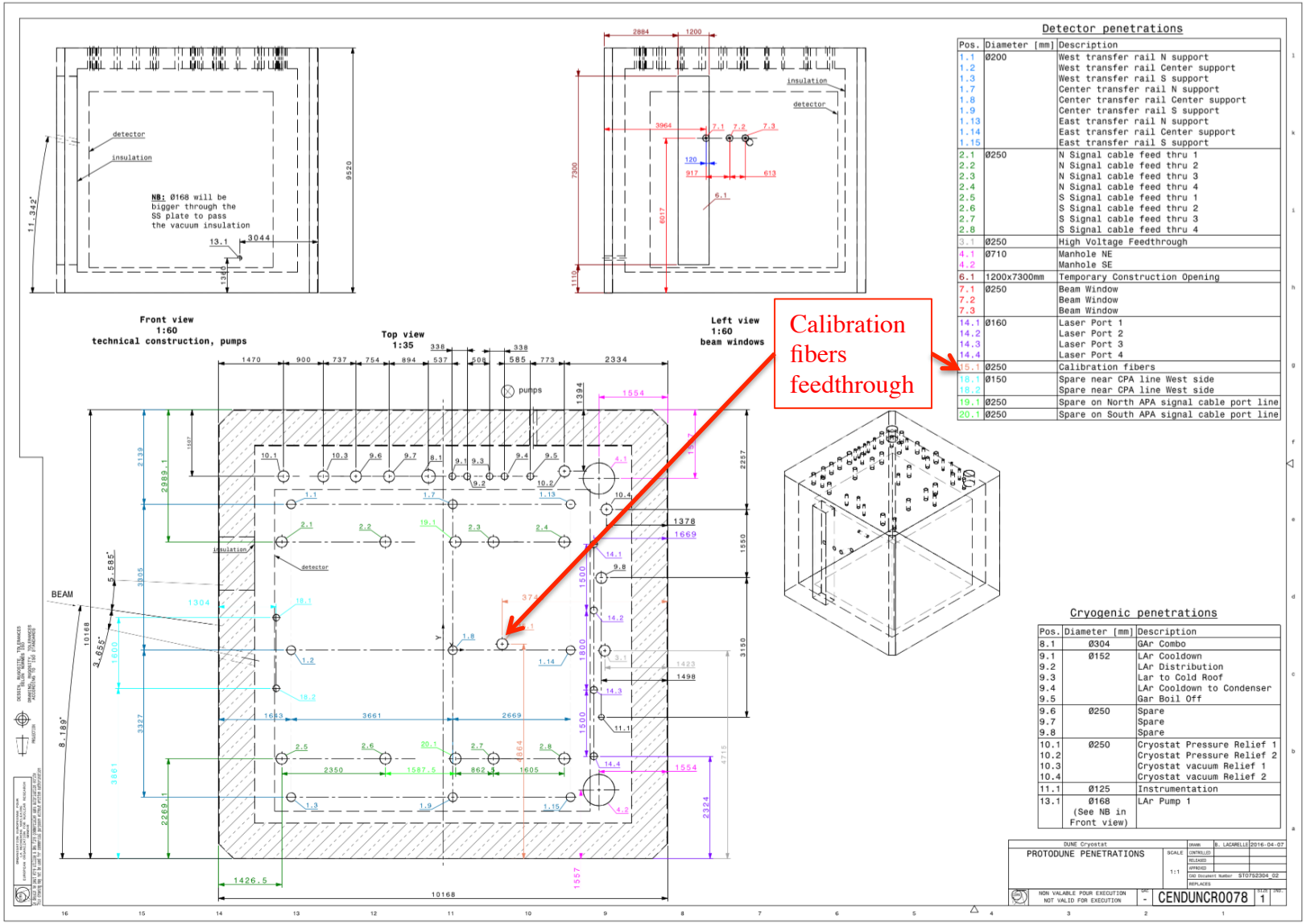

Diffuser Side View, based on existing 3D model

# Diffuser Design for protoDUNE's CPA




# 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 |

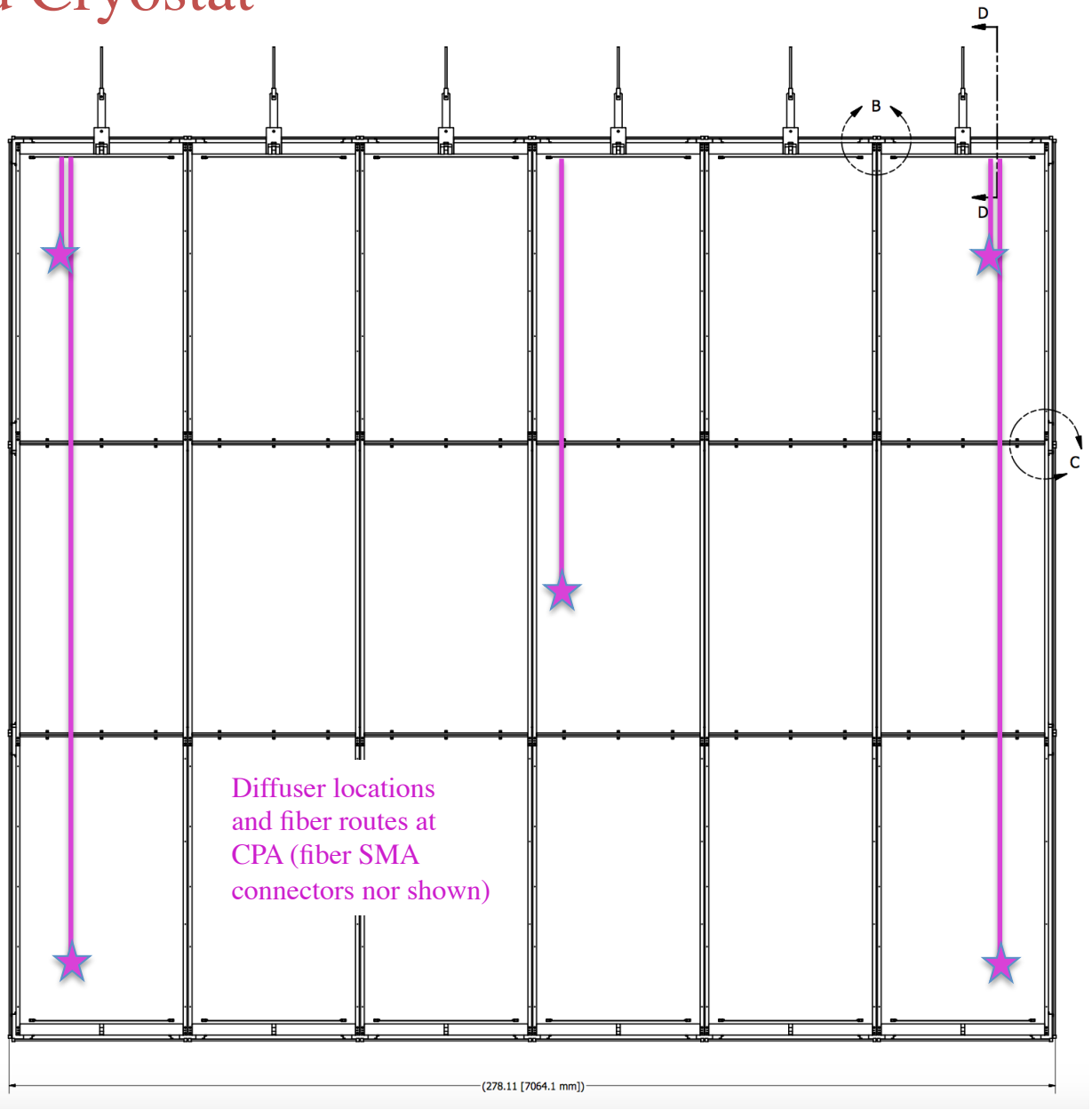
Cryogenic penetrations

| 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 — B. LACARELLE 2016-04-07 — CENDUNCR0078

# Interface to CPA and Cryostat

- Calibration components to be incorporated to CPA design
  - -diffusers
  - -fibers
- Provided 3D model to CPA group
  - -calibration components being added in current iteration of drawings
- Will use identical fiber feed-through developed with 35-ton
- Identical quartz fiber will be used
  - -length between 13 and 18m
- Discussion underway with Grounding/Shielding
  - -decide calibration module location (SSP-like)



# Interface to CPA and Cryostat (see more in Backups)

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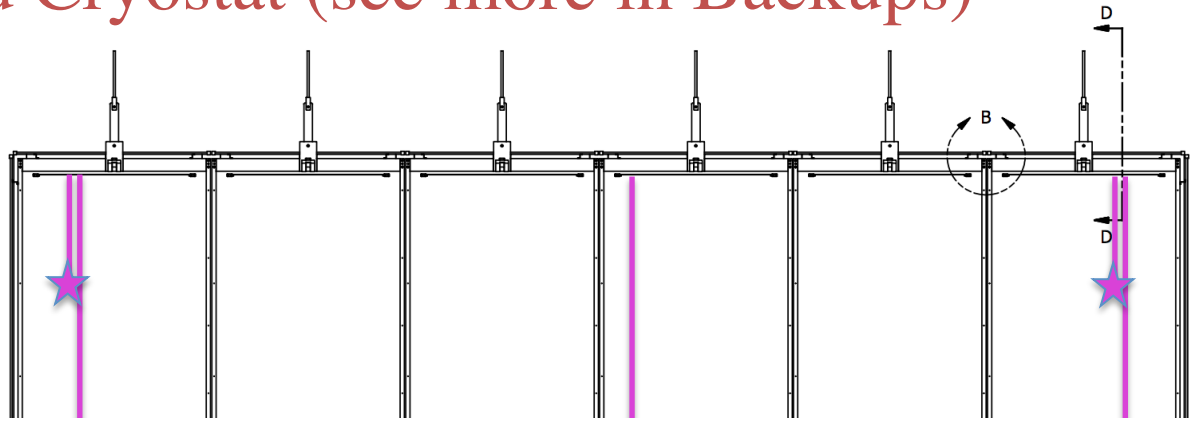


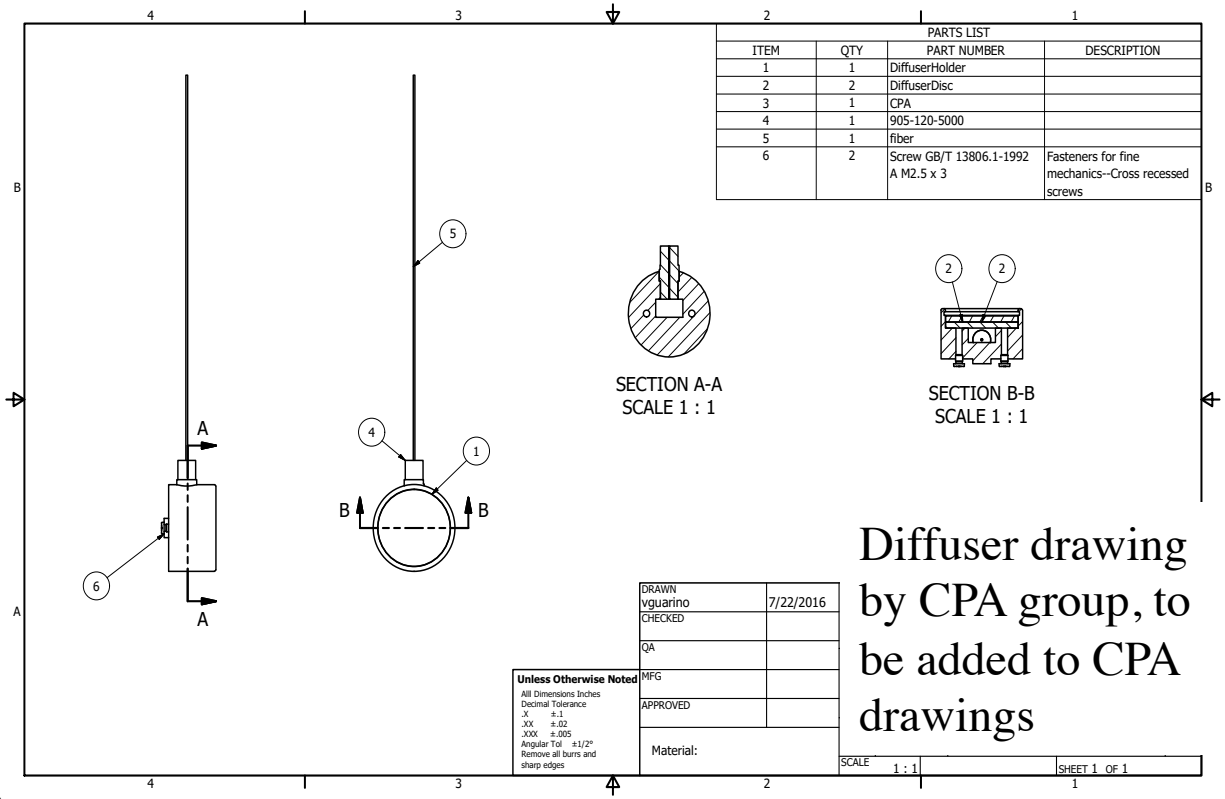


Diffuser drawing by CPA group, to be added to CPA drawings

# System Components: Parts/Materials

- Components identified
  -based on 35-ton prototyping: adopt same fiber, SMA-connectors, flange design, SS and quartz diffuser materials for CPA flasher units
- Examples:

Polymicro TECHNOLOGIES
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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

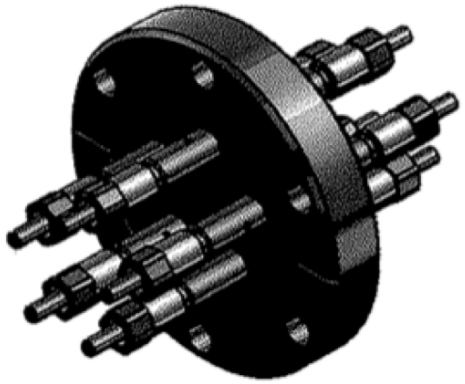
**SILICA/SILICA Optical Fiber** **FV** Fibers
• High -OH

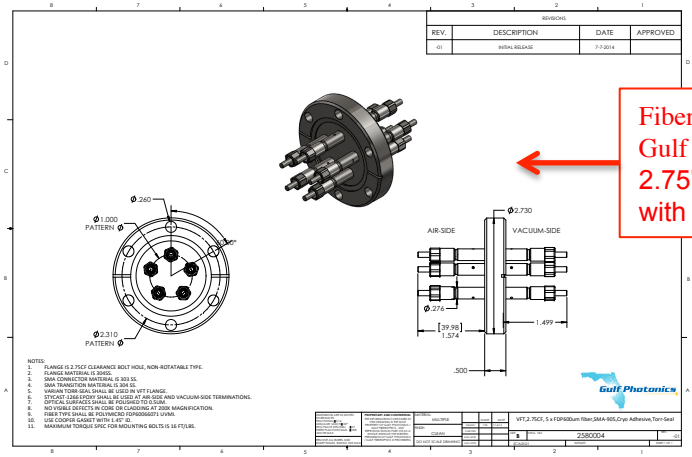
*Characteristics*
- Step Index
- Numerical Aperture: 0.22 ± 0.02
  Full Acceptance Cone: 25.4 degrees
- UV-Vis-NIR Transmission, 180nm to 1,150nm
- Superior Radiation Resistance
- High Laser Damage Threshold
- Sterilizable & Bio-compatible – USP Class VI*
- High -OH Silica Core, Doped Silica Clad
- Polyimide 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 |
| FVA1000105012250*** | 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

Discussion to decide
2 x 5-fiber-feedthrough, or
1 x 10-fiber-feedthrough

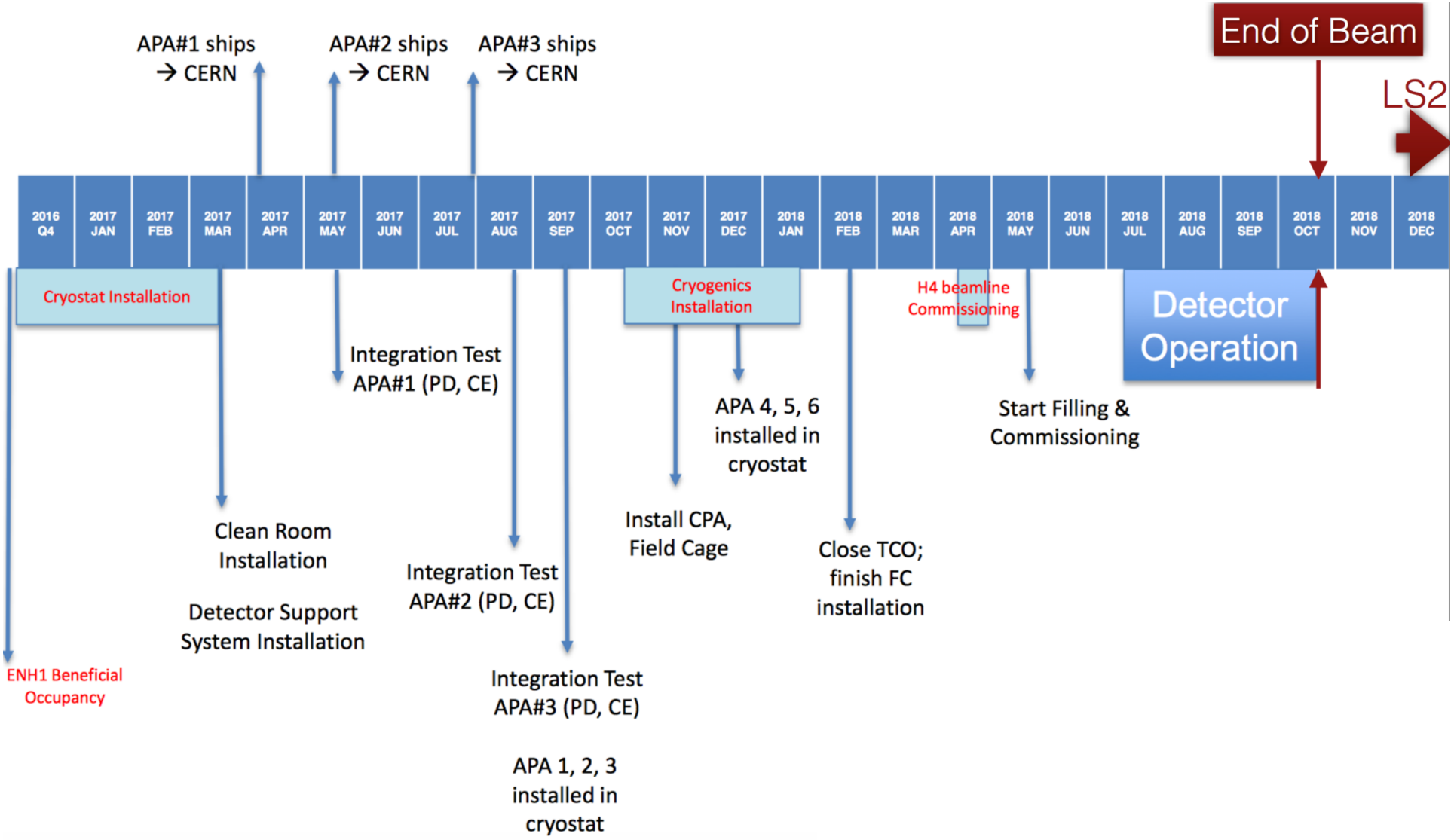
# Next Steps

- Procure and fabricate components of the UV-light calibration system
  - -Ten calibration channels (5 diffusers at each CPA side)
  - -External and Internal fibers
  - -Fiber feed-through
  - -Diffusers at CPA

- Develop protoDUNE Calibration Plan with PD, Calibration, Monitoring groups

- Components of the calibration plan
  - -Initial “Dry” Run
  - -Initial LAr Run to verify functionality of PD channels
    - -set SiPM gains
  - -Periodic runs to monitor stability of the system
    - -relative performance of PD channels
    - -time resolution

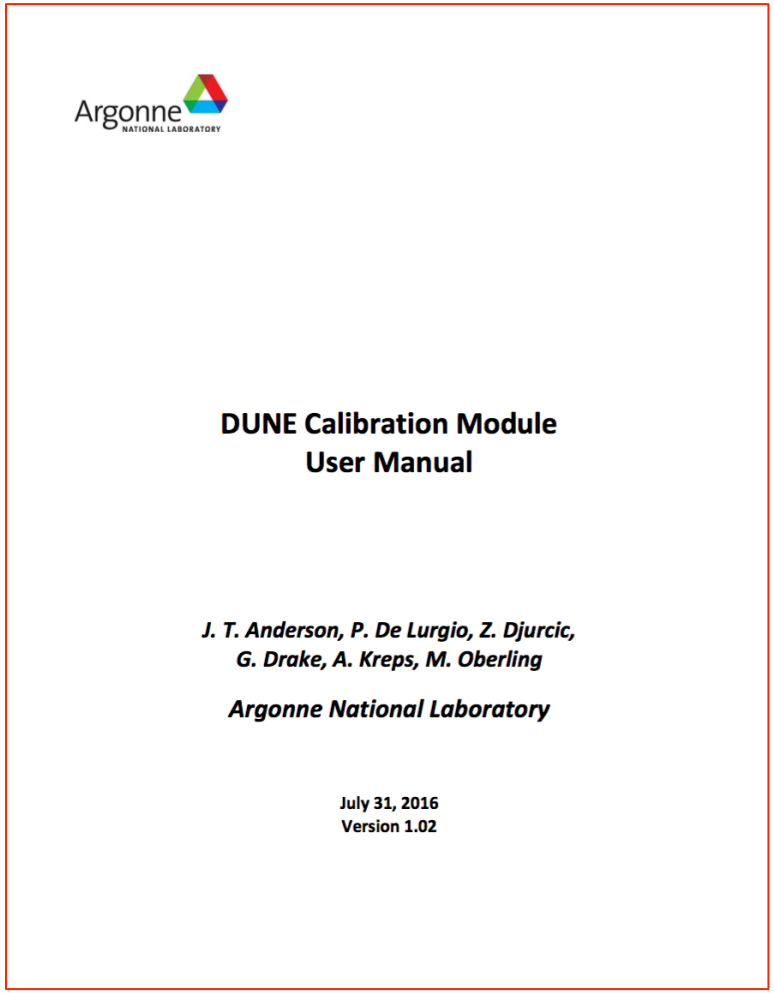
# Schedule of Activities at CERN




- Schedule of activities at CERN has been developed
- PD calibration installation activities start with CPA installation at CERN in October 2017.

# Summary

- UV Light Calibration system designed for protoDUNE detector.
- Diffuse light from CPA to photo-detectors at APA.
- Prototype calibration module and fiber distribution systems built, tested, and operated in 35-ton detector
- The system is being re-designed for protoDUNE
  - -Large time and amplitude dynamic range with good uniformity
- Development will be continued toward 10 kt DUNE.
  - -Next Step: protoDUNE Calibration
- The calibration plan under developed with calibration and monitoring groups


Argonne NATIONAL LABORATORY

**DUNE Calibration Module**
**User Manual**

*J. T. Anderson, P. De Lurgio, Z. Djurcic,*
*G. Drake, A. Kreps, M. Oberling*

*Argonne National Laboratory*

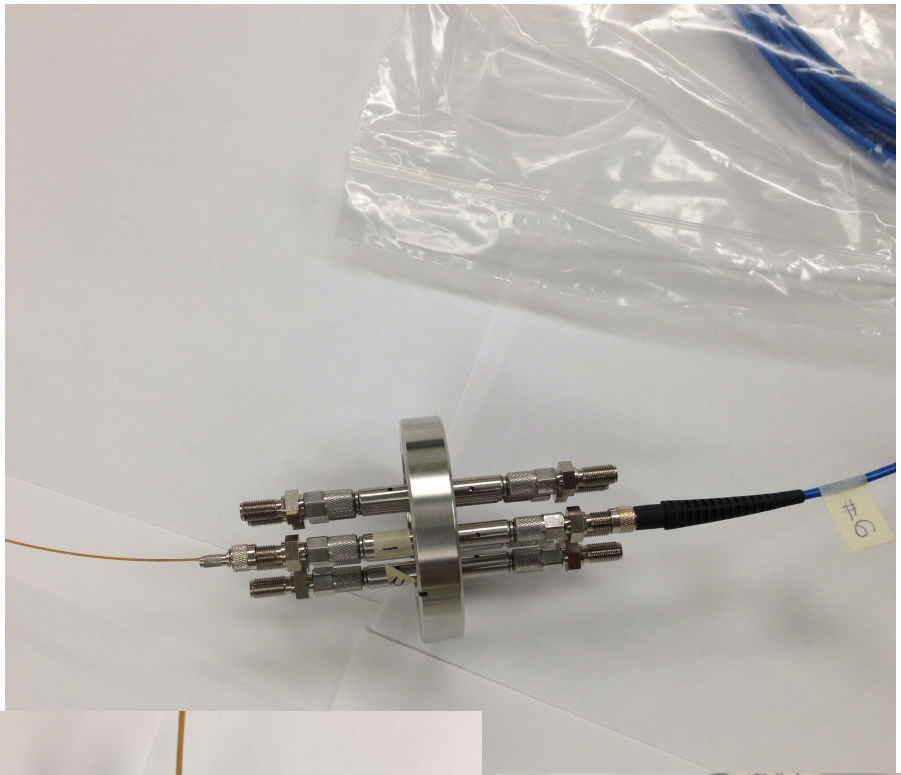
July 31, 2016
Version 1.02

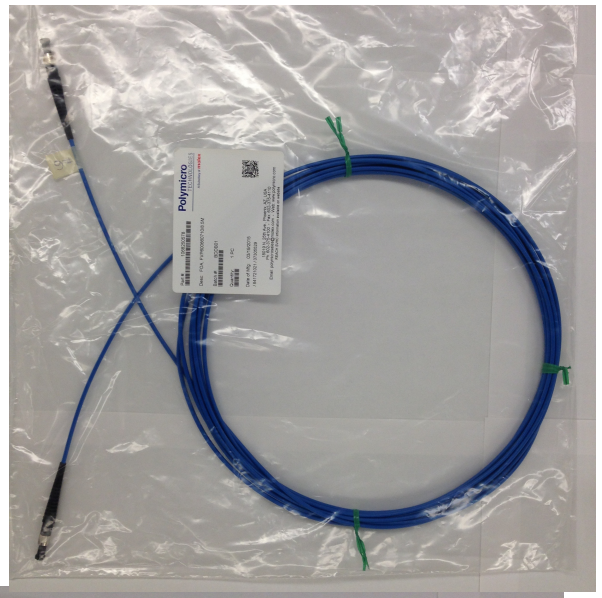
DUNE docdb-1572

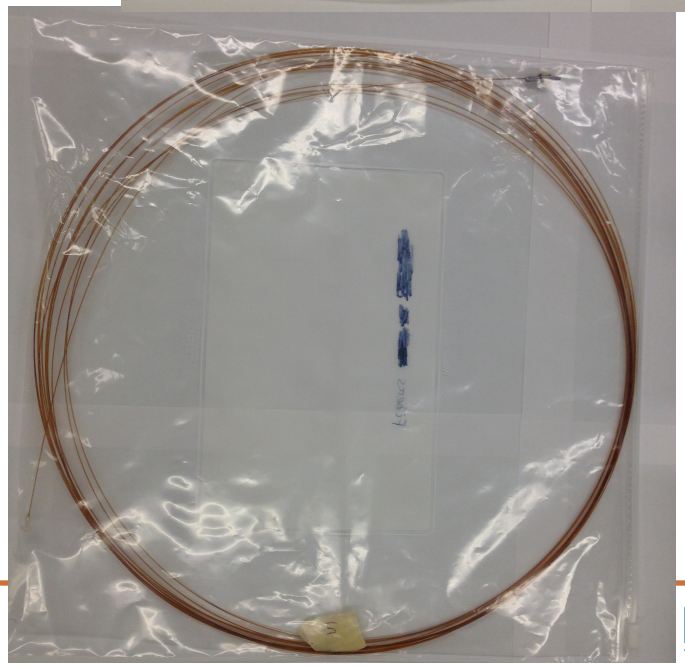
# Backups

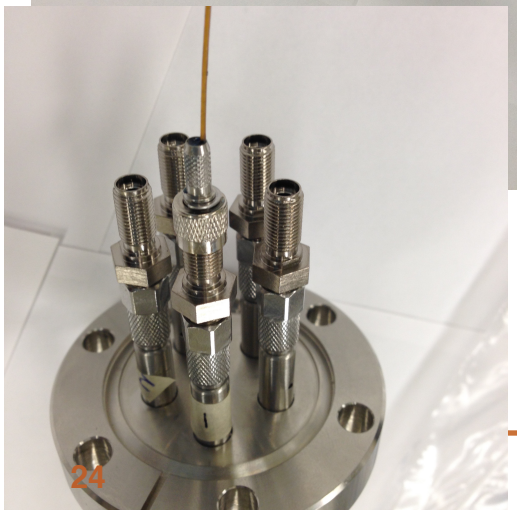
# Components of the PD UV Calibration System

- Components installed with 35t DUNE prototype



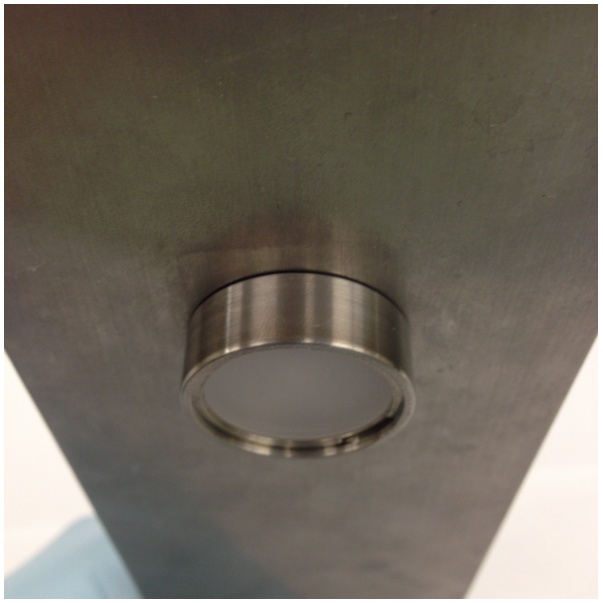


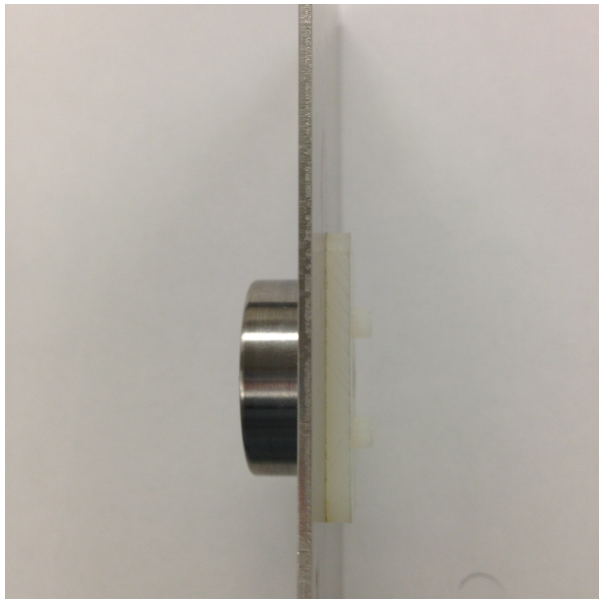



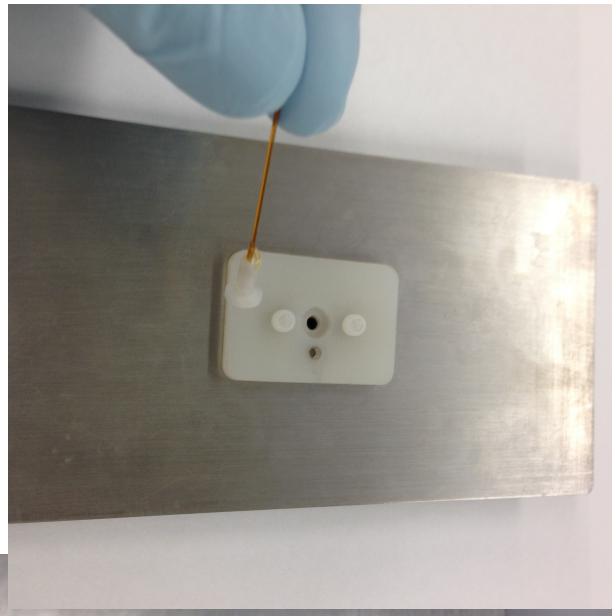


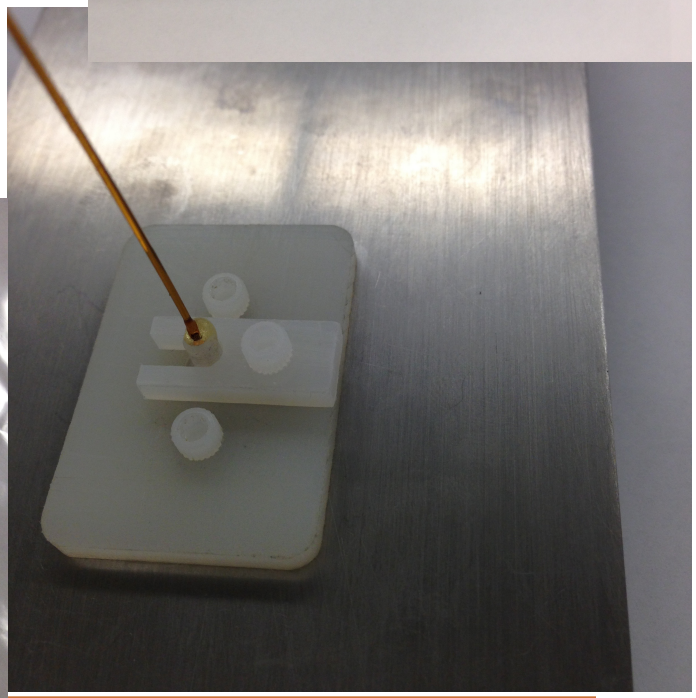
# Components of the PD UV Calibration System

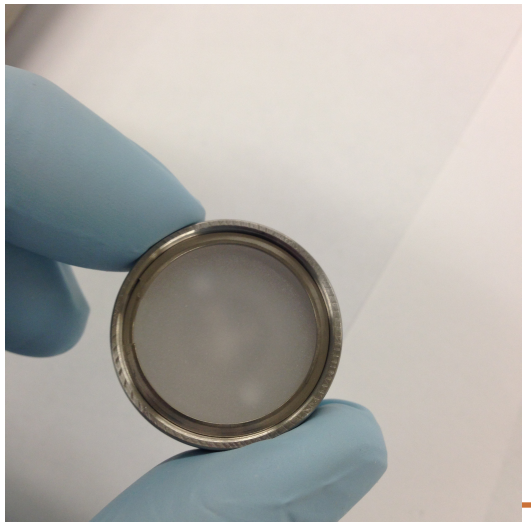
- Components installed with 35t DUNE prototype





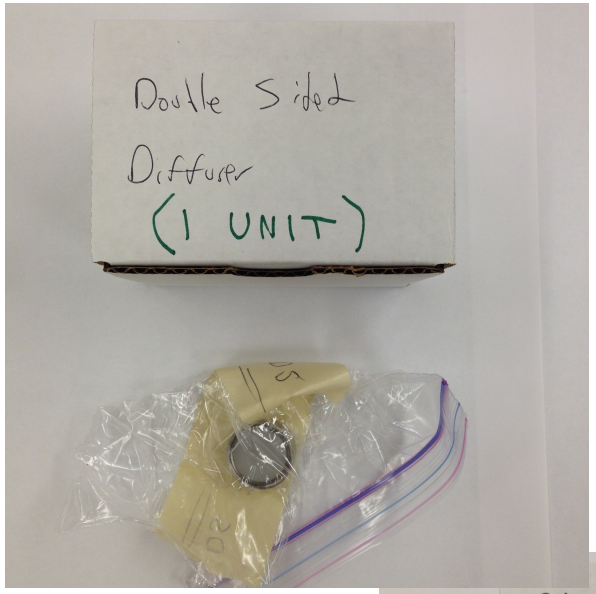


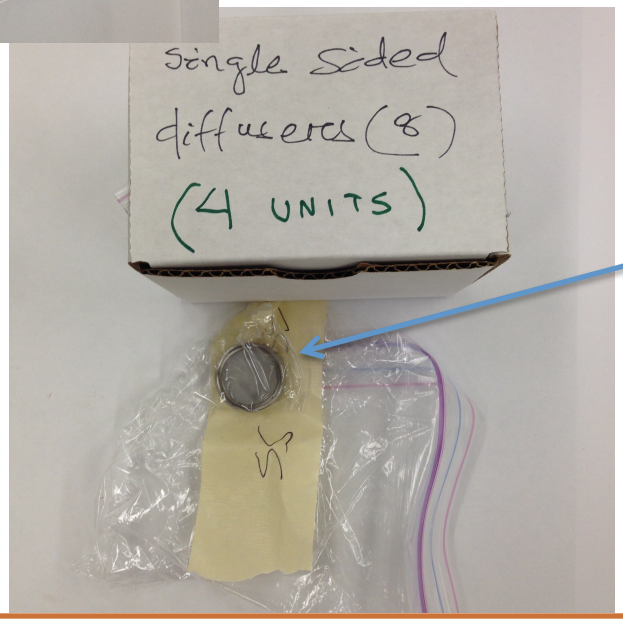




# Components of the PD UV Calibration System

- Components installed with 35t DUNE prototype

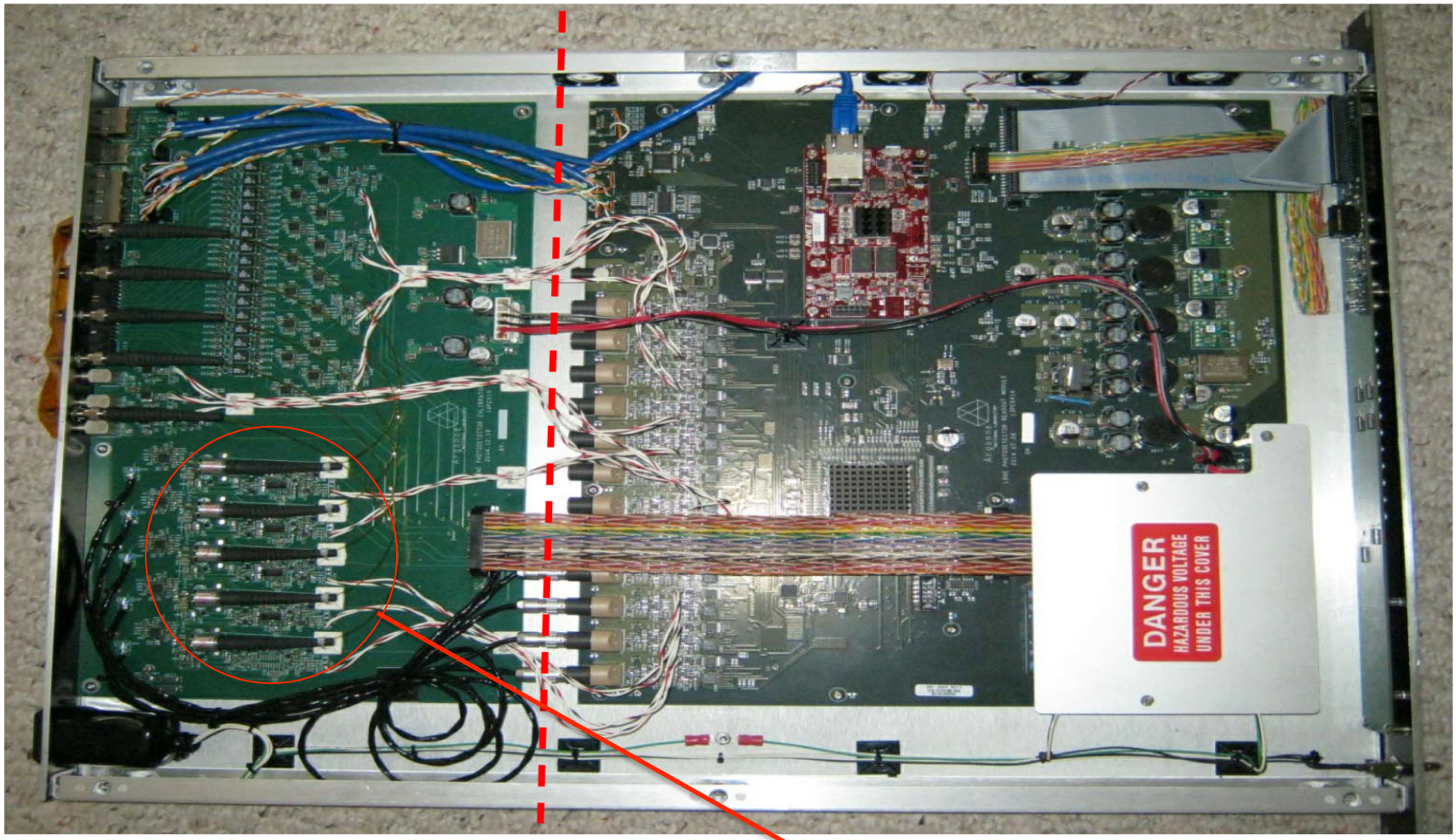


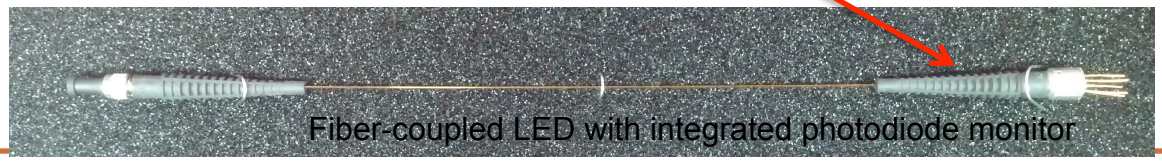




# DUNE Calibration Module

Calibration Board

SSP mainboard

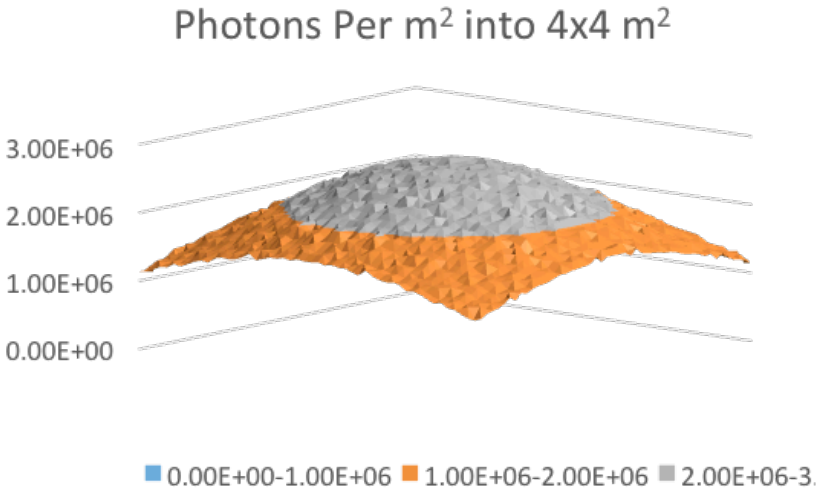


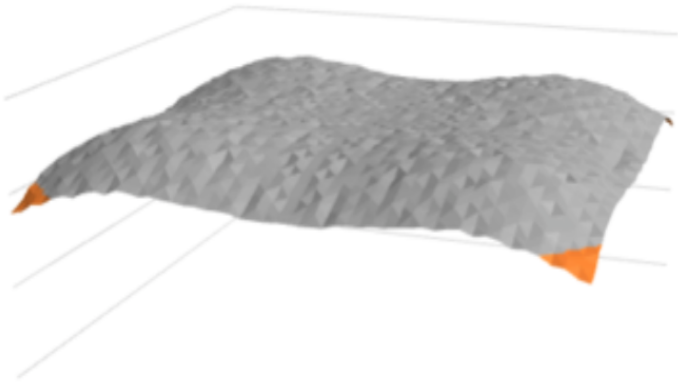



Fiber-coupled LED with integrated photodiode monitor

# Expected Light Profile

- Simulated light distributions of at the APA location for the cases of the VUV light emitted by either
  -central diffuser only (left figure), or
  -outer four diffusers simultaneously (right figure).
- The simulation estimate has been obtained for 35-ton detector and scaled to 3.6 m CPA - APA distance at protoDUNE.



# Reflective mirror for CPA diffuser

Edmund optics | worldwide

TECHSPEC® 10 x 10mm UV Enhanced Aluminum, λ/4 Mirror

**Stock No.** #45-723

**$42.00**

1 - 5 for $42.00 each.
6 - 25 for $34.00 each.

## Specifications

| | |
|---|---|
| Dimensions (mm) | 10.0 x 10.0 |
| Dimensional Tolerance (mm) | ±0.25 |
| Clear Aperture (%) | 85 |
| Thickness (mm) | 2.0 |
| Thickness Tolerance (mm) | ±0.25 |
| Surface Flatness | λ/4 |
| Surface Quality | 60-40 |
| Edges | Ground, 0.75 mm Maximum Full Width Bevel |
| Substrate | BOROFLOAT® |
| Coating Specification | $R_{avg}$ >85% @ 250 - 700nm |
| Typical Energy Density Limit | 0.5 J/cm² @ 355nm, 10ns |
| Wavelength Range (nm) | 250 - 700 |
| Wavelength Range (µm) | 0.25 - 0.7 |
| Type | Flat Mirror |
| Coating | UV Enhanced Aluminum |
| RoHS | C |

# 10-fiber feed-through quote

- Being developed with Gulf Photonics (ANL specs)

Gulf Photonics
A DIVISION OF GULF FIBEROPTICS

Quality Fiber Optic Solutions

Gulf Photonics, Inc.
640 Brooker Creek Blvd.
Suite 460
Oldsmar, FL 34677
United States

**Invoice and shipping address:**
Argonne National Laboratory
9700 S. Cass Avenue
B109
Lemont, IL 60439
United States
630.252.2000

Argonne National Laboratory
9700 S. Cass Avenue
B109
Lemont, IL 60439
United States

## Quotation N° SO718

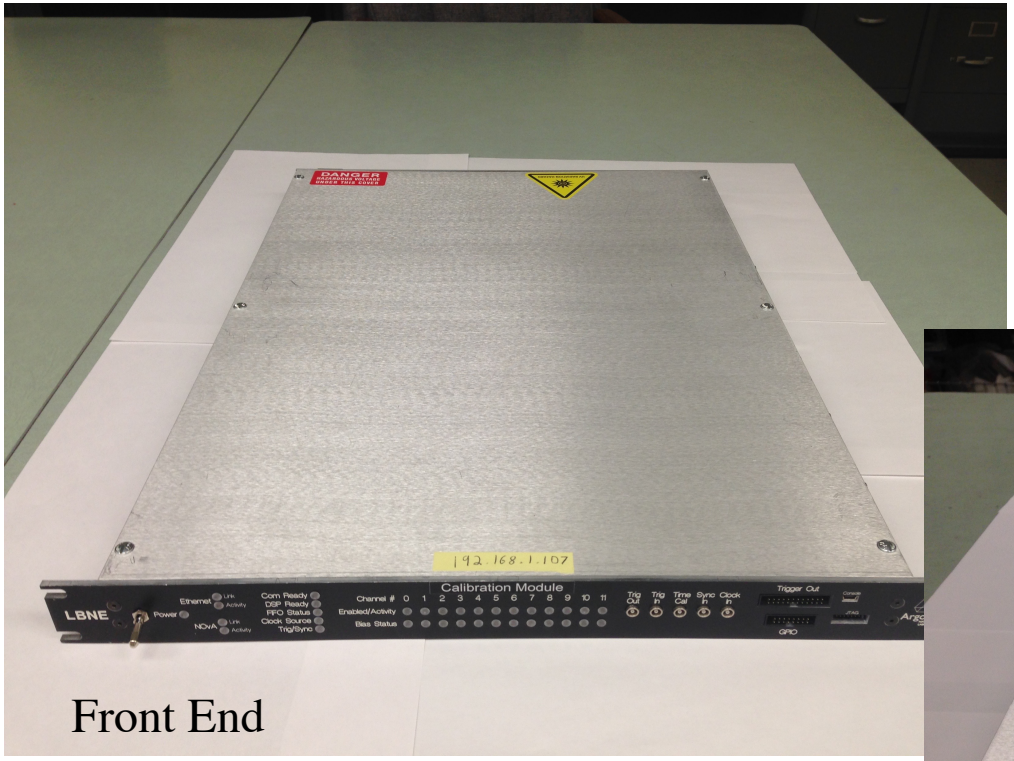
| Your Reference: | Quotation Date: | Salesperson: | Payment Term: |
|---|---|---|---|
| RFQ 02 MAR 2016 | 03/02/2016 15:30:38 | Craig Vogeley | Net 30 |

| Description | Taxes | Quantity | Unit Price | Price |
|---|---|---|---|---|
| [2580013] VFT,8"CF-Non Rotatable Unthreaded Flange, 10 x FDP600um fiber,SMA-905,Cryo Adhesive,Torr-Seal | Exempted Tax (Sale) | 1.00 Unit(s) | 1320.00 | $ 1320.00 |

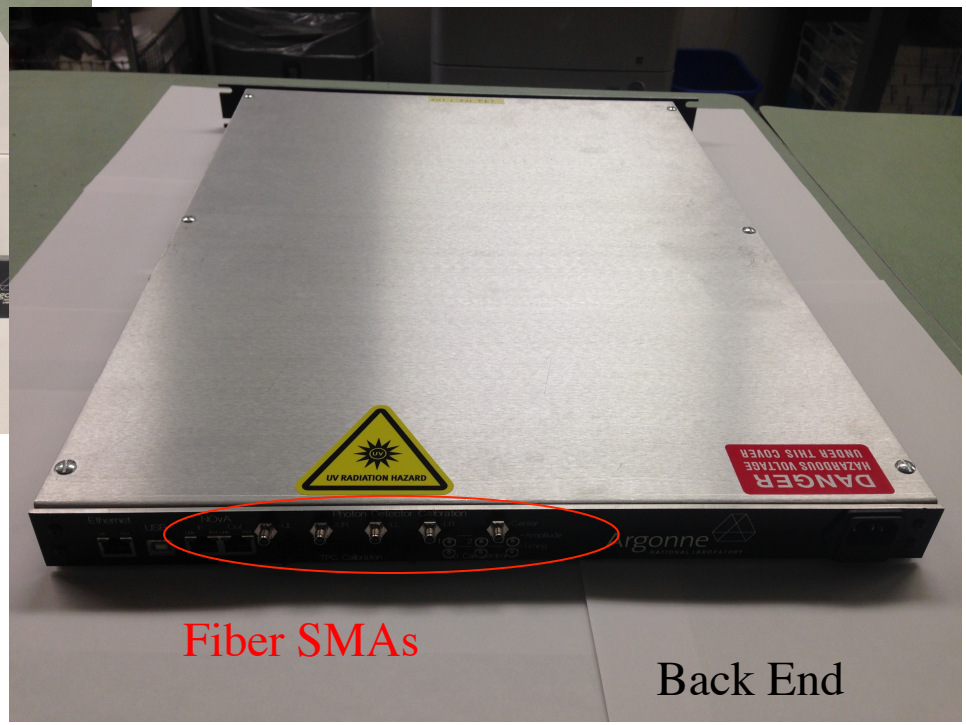
| | |
|---|---|
| **Total Without Taxes** | $ 1320.00 |
| Taxes | $ 0.00 |
| **Total** | $ 1320.00 |

Shipping Terms: Ex Works
Estimated Lead Time: 5 weeks ARO + approved drawing
Thank you for the opportunity to provide this quotation!

# DUNE Calibration Module



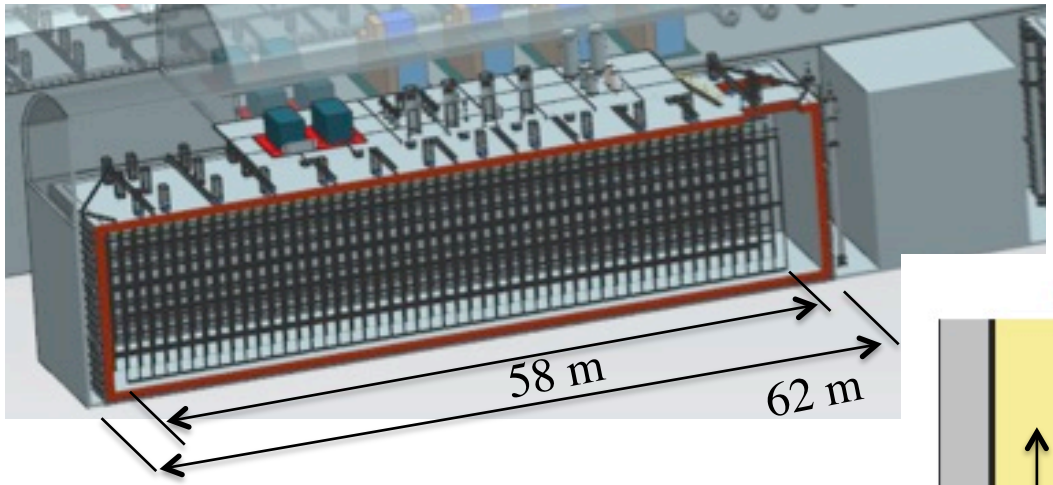

Front End




Fiber SMAs

Back End

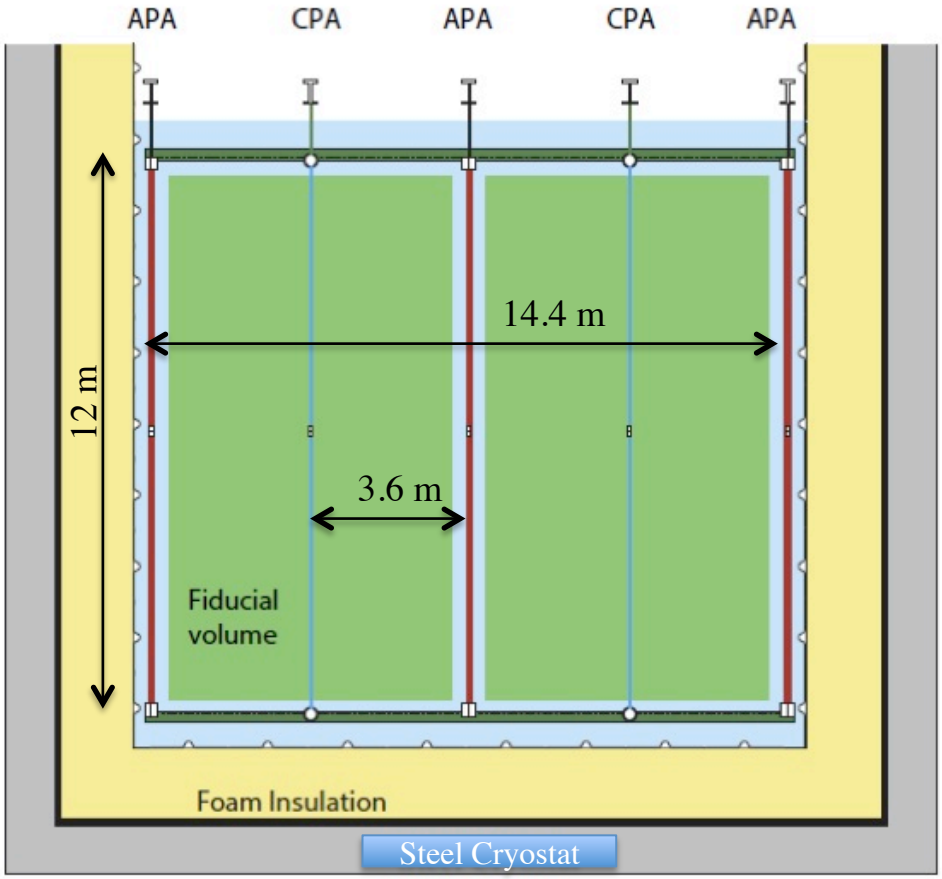
# Nominal 10 kt Detector Design




(slide from Jim Stewart)

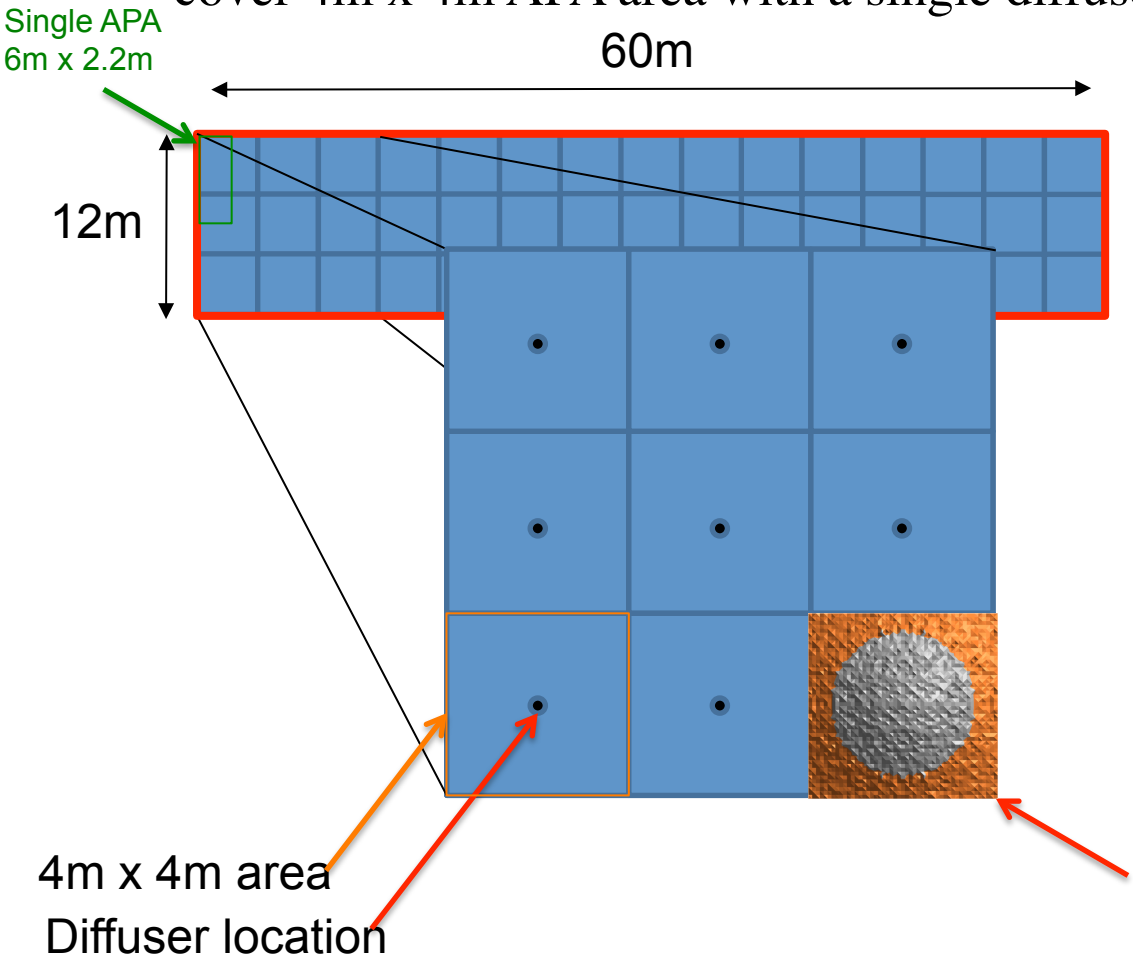
## Detector Module Characteristics

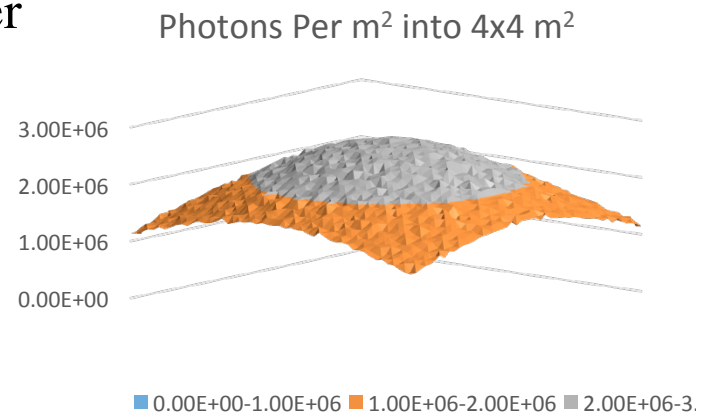
- 17.1/13.8/11.6 Total/Active/Fiducial mass
- 3 Anode Plane Assemblies (APA) wide
  - 3.6 m max drift length
- Cathode planes (CPA) are internal
- 58m long - 12m high - 14.4m active width



# UV Light Calibration System in 10 kt DUNE detector

- Approach for DUNE 10 kton detector
  -install light diffusers at CPA
  -cover 4m x 4m APA area with a single diffuser

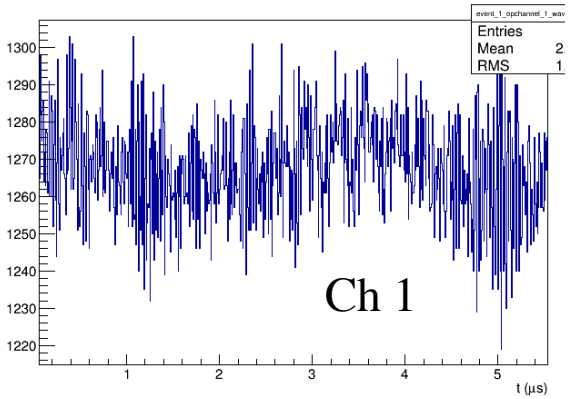


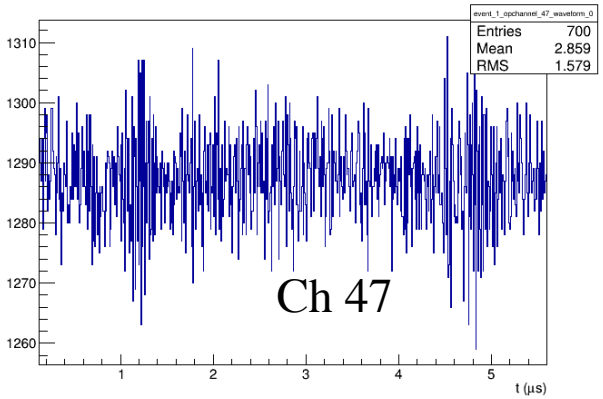



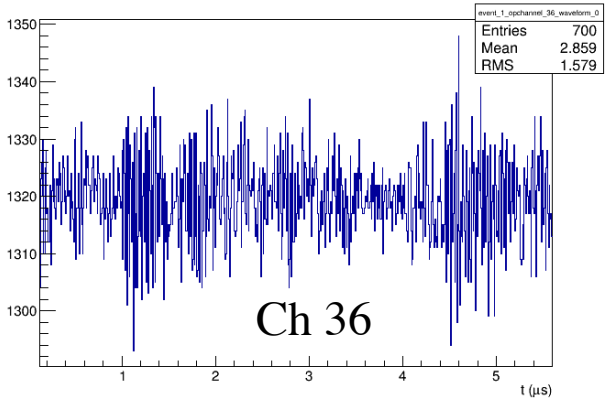

| | |
|---|---|
| % STDEV | 19% |
| Max | 2.74E+06 |
| Min | 1.13E+06 |
| Max/Min | 2.425982247 |
| Average | 1.96E+06 |

# Malfunctioning and non-standard PD Channels

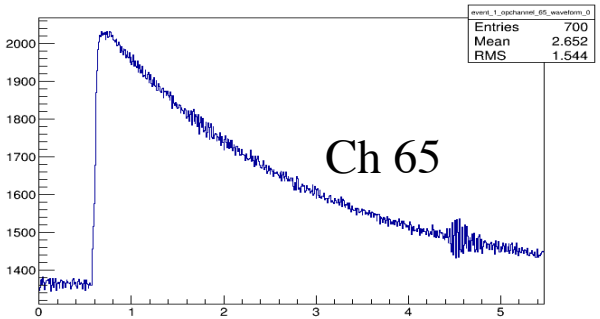
- Malfunctioning Channels

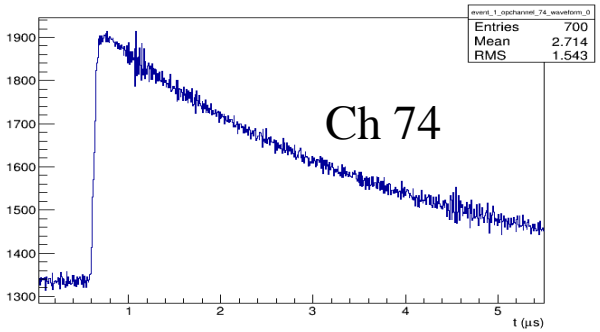


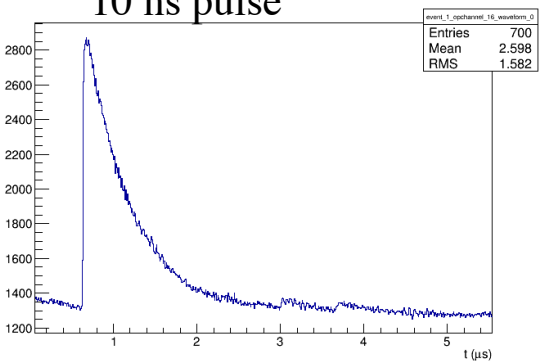

- "Slow" PD Channels



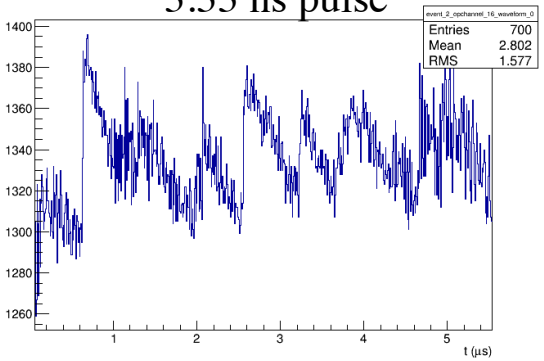




- Channels with p.e.-like noise

10 ns pulse

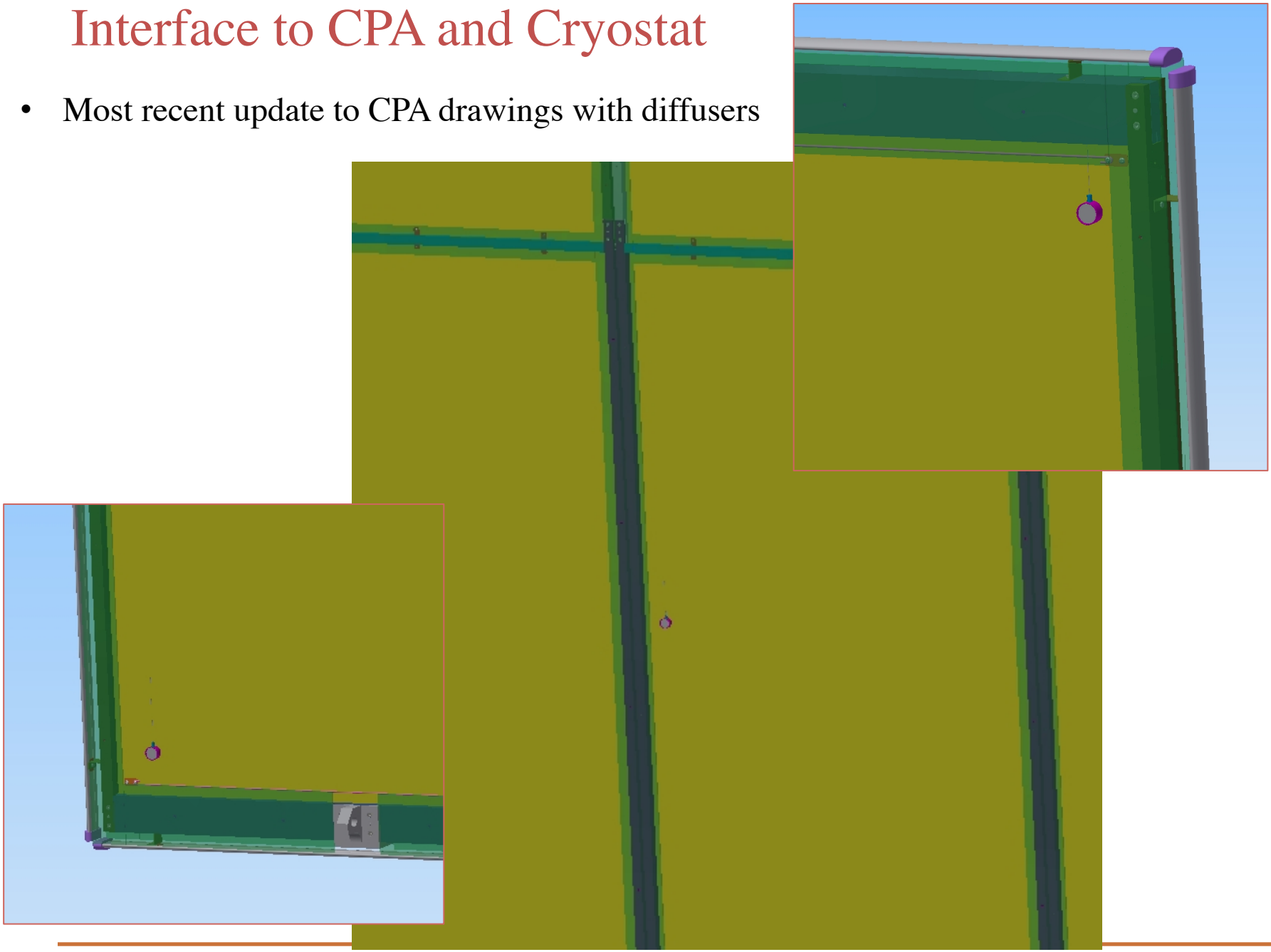



3.33 ns pulse



# Interface to CPA and Cryostat

- Most recent update to CPA drawings with diffusers



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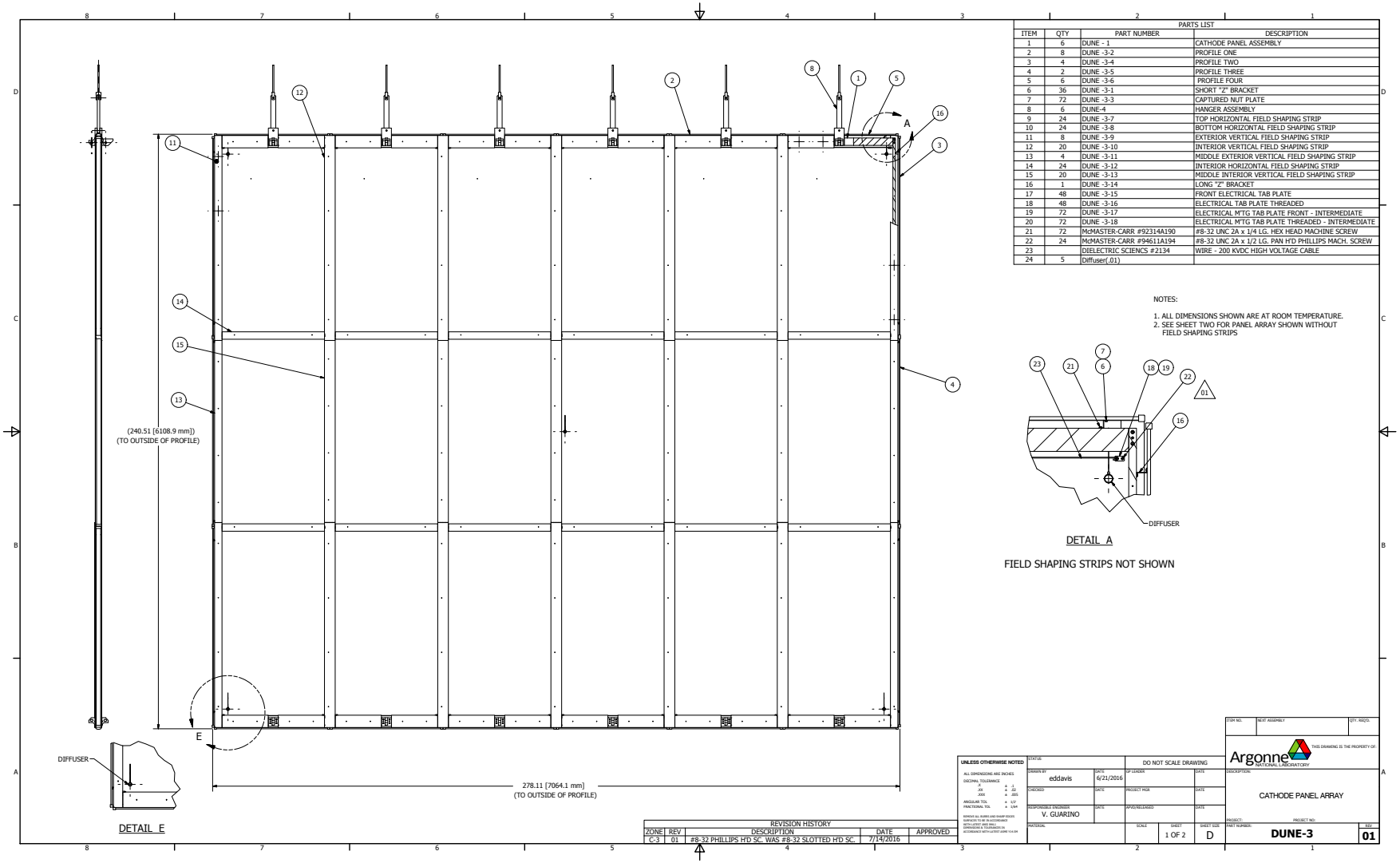

PARTS LIST

| ITEM | QTY | PART NUMBER | DESCRIPTION |
|---|---|---|---|
| 1 | 6 | DUNE - 1 | CATHODE PANEL ASSEMBLY |
| 2 | 8 | DUNE -3-2 | PROFILE ONE |
| 3 | 4 | DUNE -3-4 | PROFILE TWO |
| 4 | 2 | DUNE -3-5 | PROFILE THREE |
| 5 | 6 | DUNE -3-6 | PROFILE FOUR |
| 6 | 36 | DUNE -3-1 | SHORT "Z" BRACKET |
| 7 | 72 | DUNE -3-3 | CAPTURED NUT PLATE |
| 8 | 6 | DUNE-4 | HANGER ASSEMBLY |
| 9 | 24 | DUNE -3-7 | TOP HORIZONTAL FIELD SHAPING STRIP |
| 10 | 24 | DUNE -3-8 | BOTTOM HORIZONTAL FIELD SHAPING STRIP |
| 11 | 8 | DUNE -3-9 | EXTERIOR VERTICAL FIELD SHAPING STRIP |
| 12 | 20 | DUNE -3-10 | INTERIOR VERTICAL FIELD SHAPING STRIP |
| 13 | 4 | DUNE -3-11 | MIDDLE EXTERIOR VERTICAL FIELD SHAPING STRIP |
| 14 | 24 | DUNE -3-12 | INTERIOR HORIZONTAL FIELD SHAPING STRIP |
| 15 | 20 | DUNE -3-13 | MIDDLE INTERIOR VERTICAL FIELD SHAPING STRIP |
| 16 | 1 | DUNE -3-14 | LONG "Z" BRACKET |
| 17 | 48 | DUNE -3-15 | FRONT ELECTRICAL TAB PLATE |
| 18 | 48 | DUNE -3-16 | ELECTRICAL TAB PLATE THREADED |
| 19 | 72 | DUNE -3-17 | ELECTRICAL M'TG TAB PLATE FRONT - INTERMEDIATE |
| 20 | 72 | DUNE -3-18 | ELECTRICAL M'TG TAB PLATE THREADED - INTERMEDIATE |
| 21 | 72 | McMASTER-CARR #92314A190 | #8-32 UNC 2A x 1/4 LG. HEX HEAD MACHINE SCREW |
| 22 | 24 | McMASTER-CARR #94611A194 | #8-32 UNC 2A x 1/2 LG. PAN H'D PHILLIPS MACH. SCREW |
| 23 | | DIELECTRIC SCIENCS #2134 | WIRE - 200 KVDC HIGH VOLTAGE CABLE |
| 24 | 5 | Diffuser(.01) | |

NOTES:

1. ALL DIMENSIONS SHOWN ARE AT ROOM TEMPERATURE.
2. SEE SHEET TWO FOR PANEL ARRAY SHOWN WITHOUT FIELD SHAPING STRIPS

DETAIL A

FIELD SHAPING STRIPS NOT SHOWN

(240.51 [6108.9 mm])
(TO OUTSIDE OF PROFILE)

278.11 [7064.1 mm]
(TO OUTSIDE OF PROFILE)

DETAIL E

| REVISION HISTORY | | | | |
|---|---|---|---|---|
| ZONE | REV | DESCRIPTION | DATE | APPROVED |
| C-3 | 01 | #8-32 PHILLIPS H'D SC. WAS #8-32 SLOTTED H'D SC. | 7/14/2016 | |

UNLESS OTHERWISE NOTED

DRAWN BY: eddavis 6/21/2016
RESPONSIBLE ENGINEER: V. GUARINO
DO NOT SCALE DRAWING
Argonne NATIONAL LABORATORY
THIS DRAWING IS THE PROPERTY OF:
CATHODE PANEL ARRAY
SCALE: SHEET: 1 OF 2 SIZE: D
PROJECT:
PART NUMBER: DUNE-3
REV: 01