Photon Detector Calibration/Monitoring System

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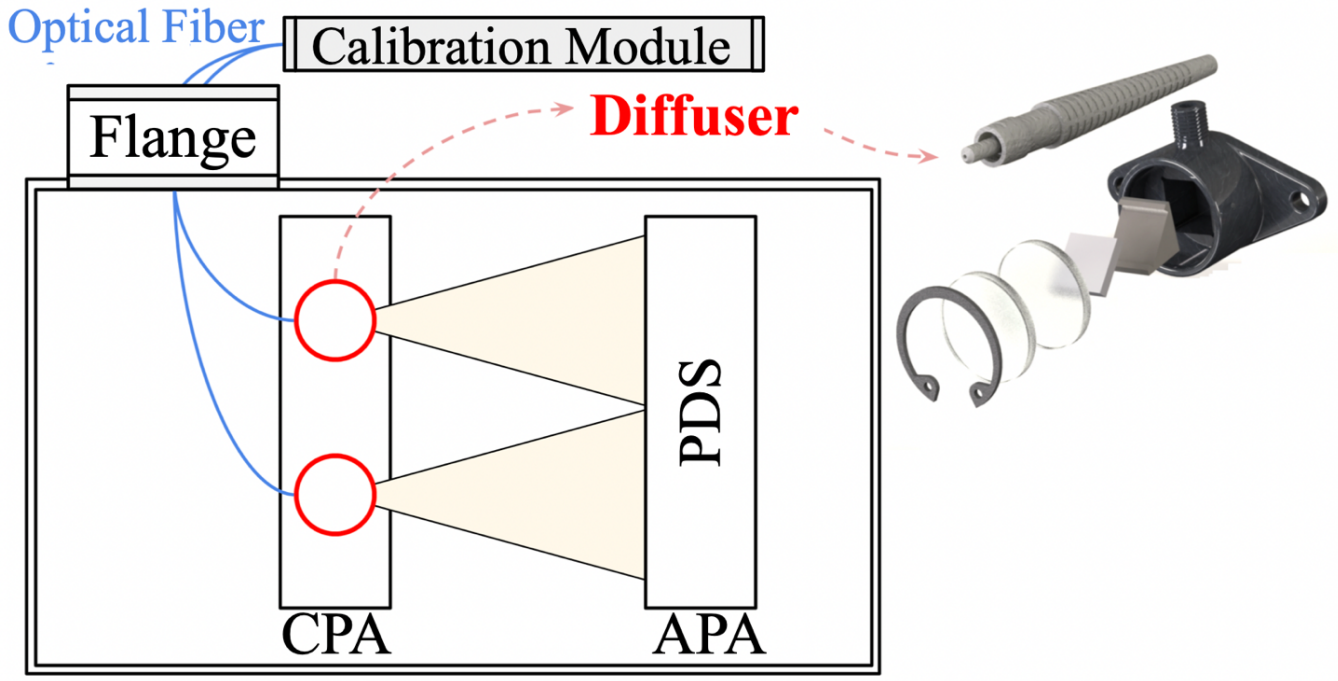
Outline

In this talk we will cover the following topics

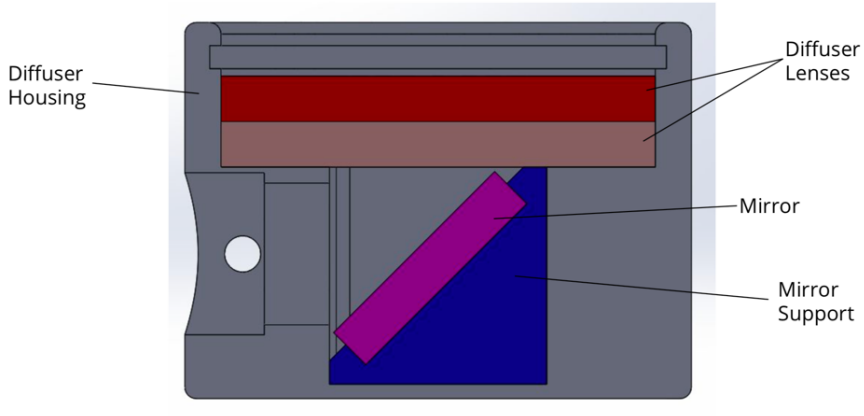
- Optical Diffuser Development Status
- Optical Fibers Routing and Testing
- Optical Feedthrough Status and Tests
- Electronics Hardware/Firmware Development
- Light Source Development



Optical Diffuser Development Status

Opto-mechanical components: Diffusers (previous update)

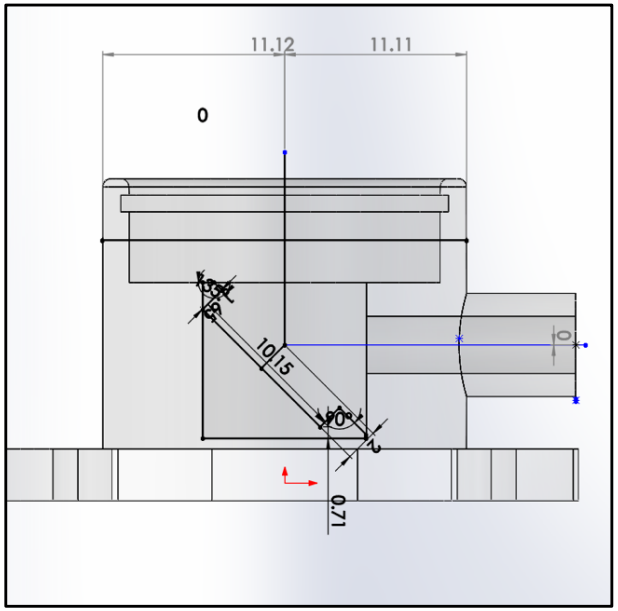
- 3D printed diffuser using PEEK (right)
  - Team formed at SDSMT (2 ME Senior Undergraduate students) to work on the final details for the diffuser housing design
  - SMA905 connection to the diffuser housing.
- Components of the diffuser purchased: 2 Diffuser glasses, UV mirror, and O-rings.



PEEK

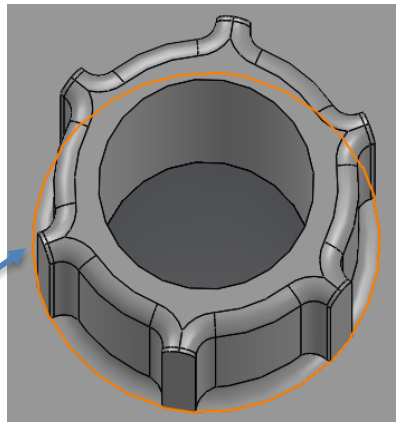
Opto-mechanical components: Diffusers (today)

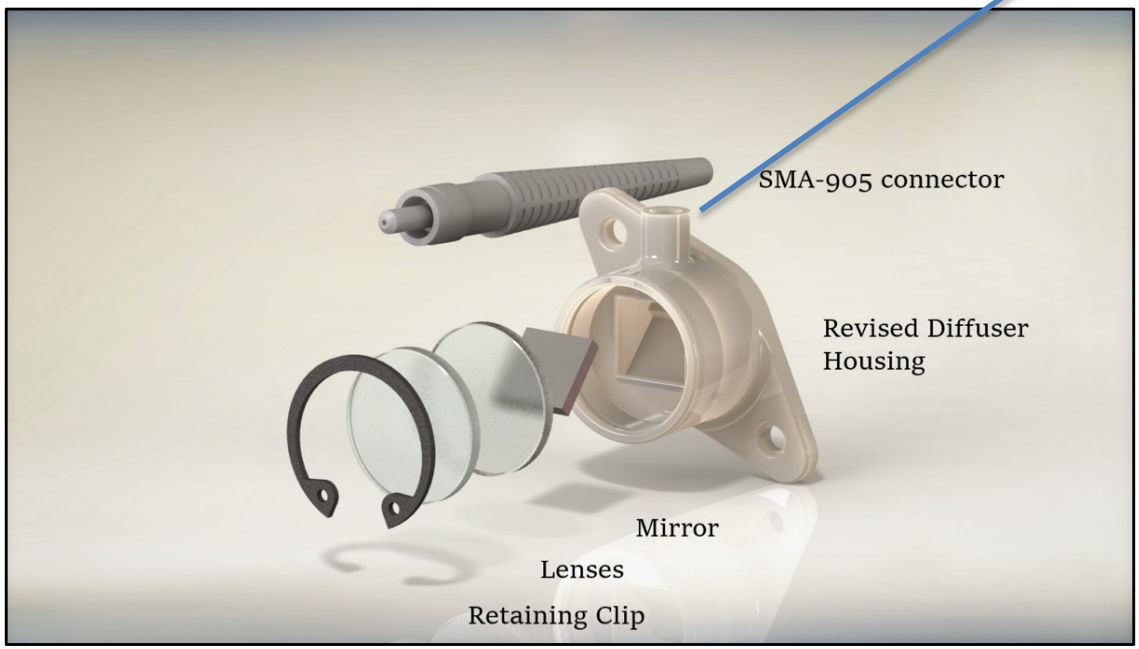
- Latest revision changes:
- Mirror support integrated into the diffuser
- Centered UV mirror in relation to the fiber optical cable
- Centered UV mirror in relation to the lenses
- Removed threads in the model
- Threads will be cut with a die or a treadless design

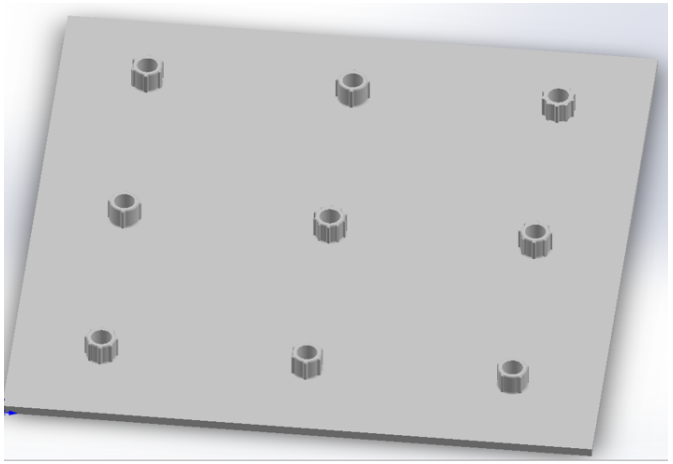


Opto-mechanical components: Diffusers (today)

- SMA connector research:
- Investigating thread-less connector design
  - Eliminate die cutting diffuser
  - Varying the geometry of the protrusions

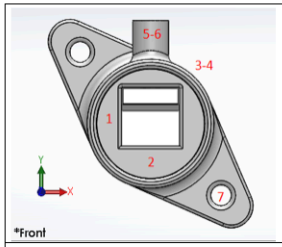
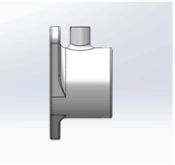
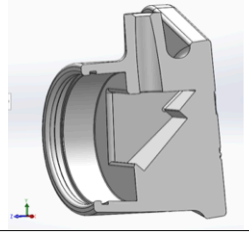
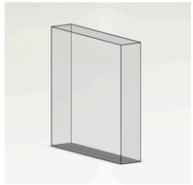






Opto-mechanical components: Diffusers (today)

- Comparison of 3D printed diffusers (PEEK and PLA) with respect to the designed model
- Variance in 3D-prints based on printer settings

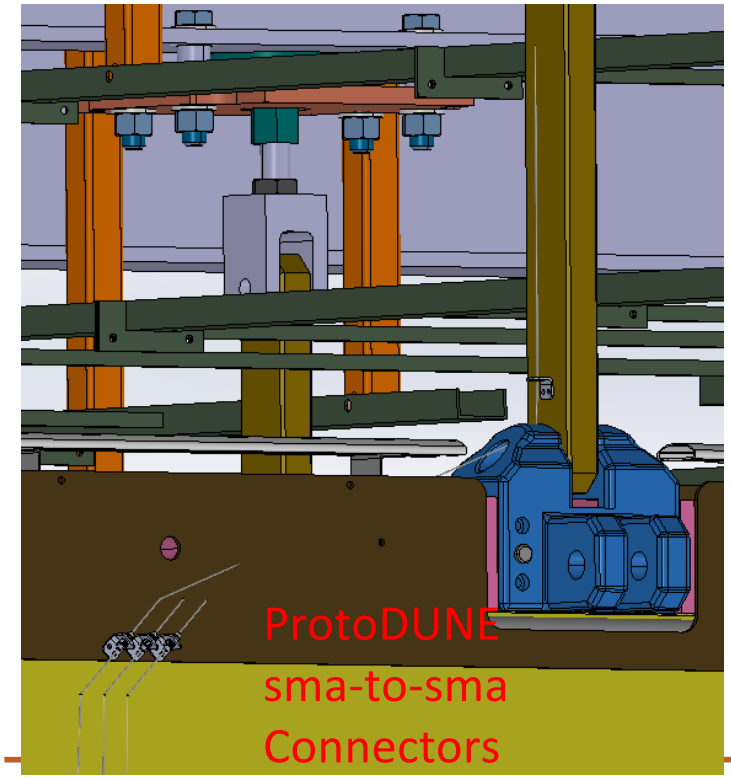
					
Location	Model (mm)	PEEK-v1 (mm)	PEEK-v2 (mm)	PLA (mm)	Mirror-Actual (mm)
1 - Mirror - Y	10.12	9.91	10.00	10.09	9.98
2 - Mirror - X	10.15	9.84	9.95	10.12	9.98
3 - Lense - outer	22.23	22.18	22.35	22.21	
4 - Lense - inner	19.05	18.57	18.65	18.89	
5 - Thread -outer	6.30	6.22	6.28	6.23	
6 - Thread - inner	3.50	3.39	3.36	3.38	
7 - Bolt hole diameter	3.60	3.33	3.34	3.54	

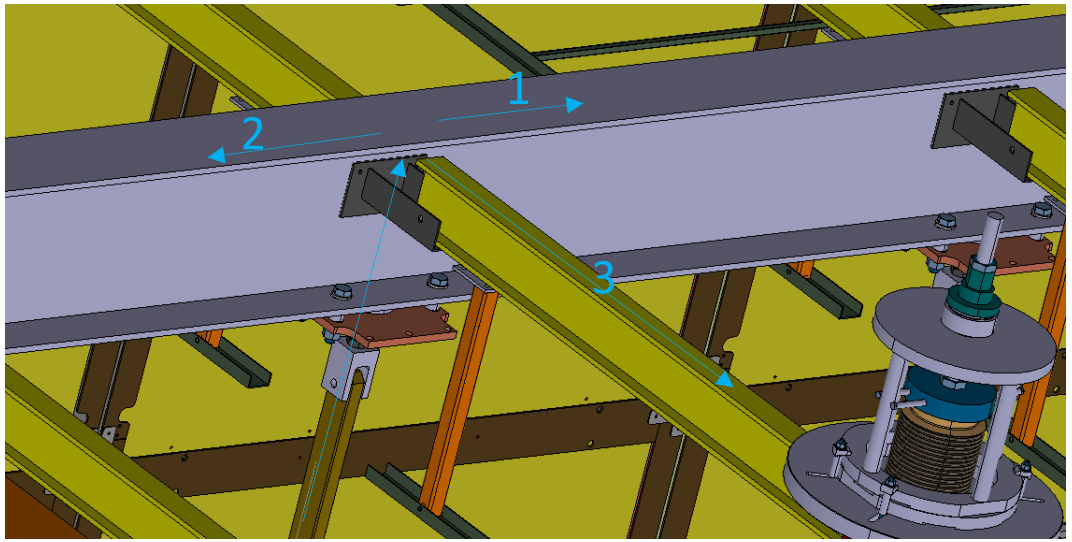
- PEEK-v2 is not as bad as the PEEK-v1 (first prototype).
  - Inner UV mirror dimensions and the lens dimension are a little off
  - **Next: We will sand down the PEEK-V2 diffuser so all the components fit properly and later submerged in Nitrogen**

Optical Fibers Routing and Testing

Opto-mechanical components: Optical Fiber Routing

- Developing a preliminary concept for optical fiber routing from the PDS flanges to the location of the diffusers in the CPA for DUNE soon to be ready.
  - -Using public DUNE detector models (STEP files) found at CERN Database EDMS (CPA, Ground Plane, DSS, Field Cage)
    - Updated to the last version of DSS
  - -Close work with the ANL team and Steve Magill (HVS/CPA lead).





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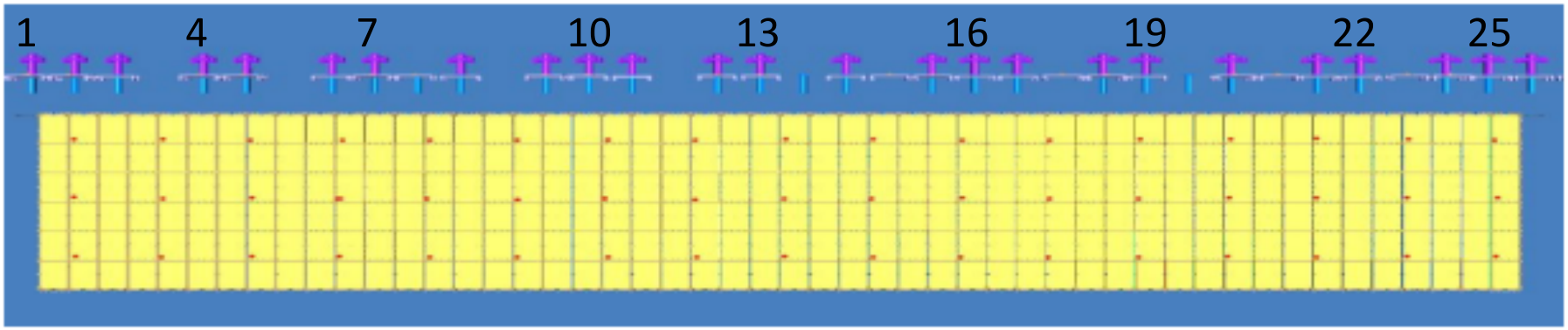
Opto-mechanical components: Optical Fiber Routing

-Front view of cathode plane assembly

- PDS Flanges: 1, 4, 7, 10, 13, 16, 19, 22, 25
- Red dots represent the light diffusers



Preliminary estimation (using Autodesk Viewer) of optical fiber length needed for 204 diffusers (51 diffusers per CPA side):
~ 3.2 km

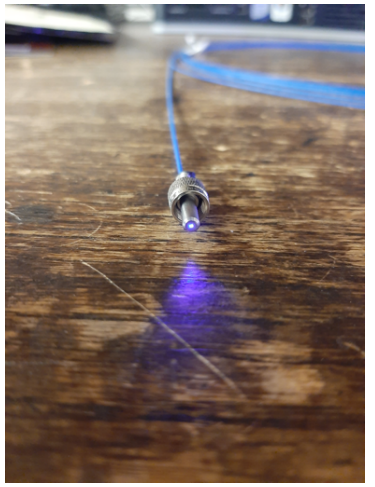
		Lengths of Fiber above CPA				
Diffuser Lines	Length of Fiber	Length of Fiber(3 Diffusers	Total length (6 Diffusers)	Total length (12 Diffuser	Inlet or Flange Number	
1	5.1	15.3	30.6	61.2	1	
2	5.5	16.5	33	66	4	
3	6.5	19.5	39	78	4	
4	5.5	16.5	33	66	7	
5	6.5	19.5	39	78	7	
6	6.5	19.5	39	78	10	
7	5.5	16.5	33	66	10	
8	6.5	19.5	39	78	13	
9	5.5	16.5	33	66	13	
10	7.5	22.5	45	90	16	
11	4.5	13.5	27	54	16	
12	6.5	19.5	39	78	19	
13	5.5	16.5	33	66	19	
14	7.5	22.5	45	90	22	
15	4.5	13.5	27	54	22	
16	7.8	23.4	46.8	93.6	25	
17	4.8	14.4	28.8	57.6	25	

One CPA Side
Two CPA Sides
Four CPA Sides

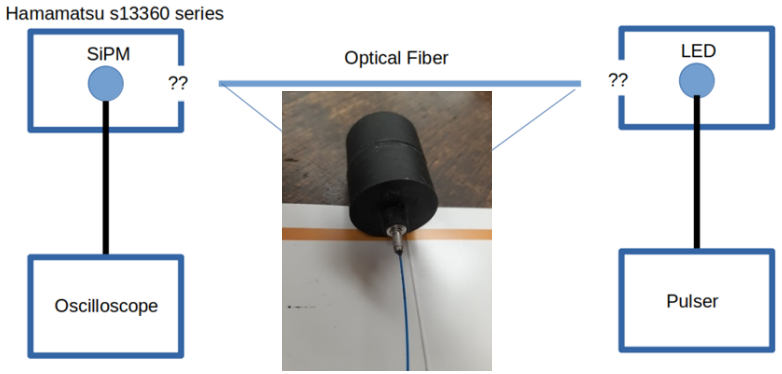
Note: Lengths estimated from measuring in Autodesk Viewer

		Total Length Above CPA=	1220.4 m
		w/10% increase=	1342.44 m
nternal CPA Lengths(3 Diffusers)	17.5216m	Total Length W/ Internal CPA Lengths=	2411.869 m
		w/10% increase=	2653.0559 m
Length of Inlet (m)=	2.5	Total Length W/ Inlets=	2921.869 m
Total # of Diffusers=	204	w/10% increase=	3214.0559 m
		Recommend=	3215 m

Opto-mechanical components: Fibers



- We are testing cryogenically optical fibers with different coatings (**previous update only one fiber**)
  - Assembled optical fibers: both ends with SMA905 connectors
  - Test light response of the optical fibers
  - Submerged in liquid nitrogen
- Table show some of the assembled fibers with their main characteristics.
- All coating materials are polymers with excellent dielectric insulation properties.



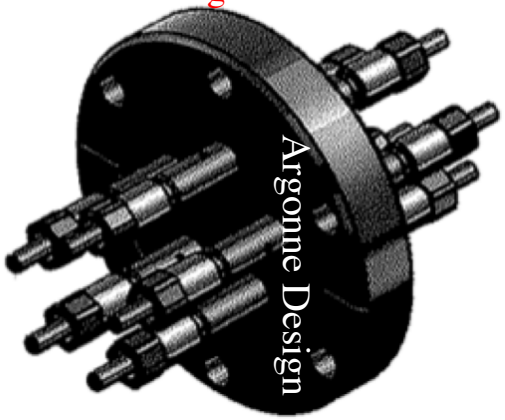
Optical Fiber Coating Material	Polyimide	Acrylate	Tefzel	Tefzel	Polyimide
Core diameter (um)	400	600	600	600	600
Coating diameter (um)	480	750	1040	1040	710
Operating Wavelength (nm)	250-1200	180-1200	400-2100	300-1200	250 - 1200
Test: # days in nitrogen	7	7	30	7	ProtoDUNE Run 1

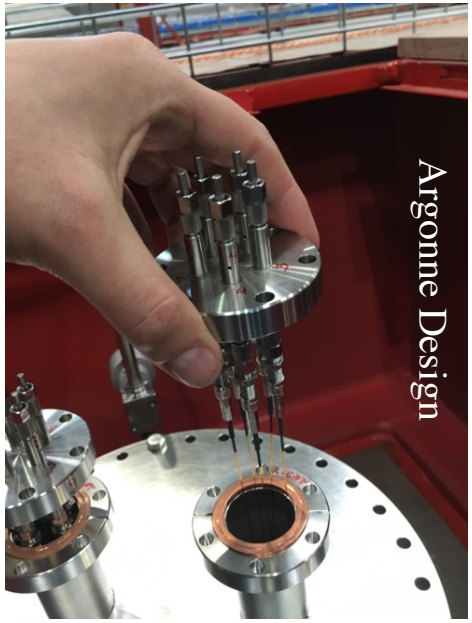
Optical Feedthrough Status

Optical Feedthrough Design and Production

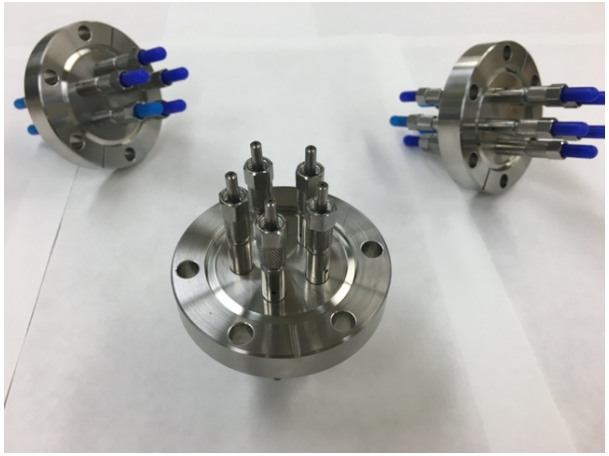
- Optical feedthrough design tested with ProtoDUNE-SP => Success.
  -Design adopted for DUNE HD-FD

Five channels optical fiber feedthrough



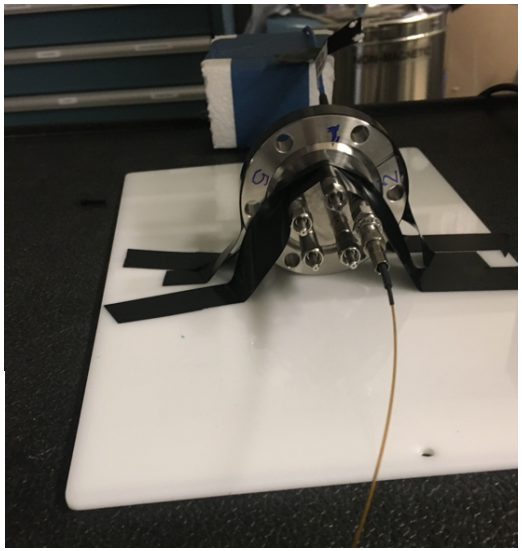


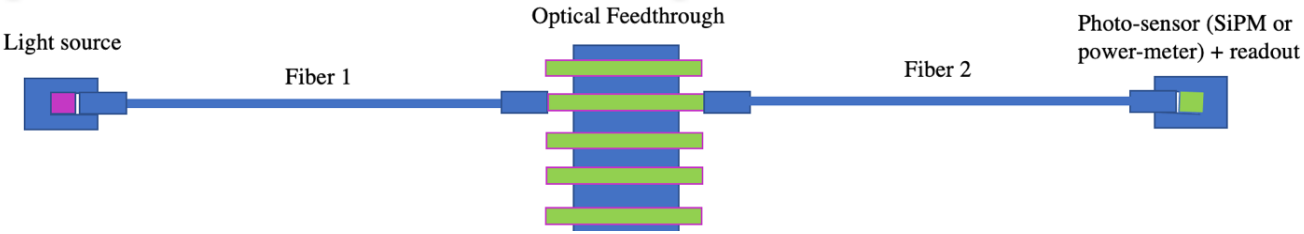
- Three five-channel feed-throughs came out from production by February
  -Optical tests underway
  -Test leakage (a vacuum test): to be organized over next few weeks.

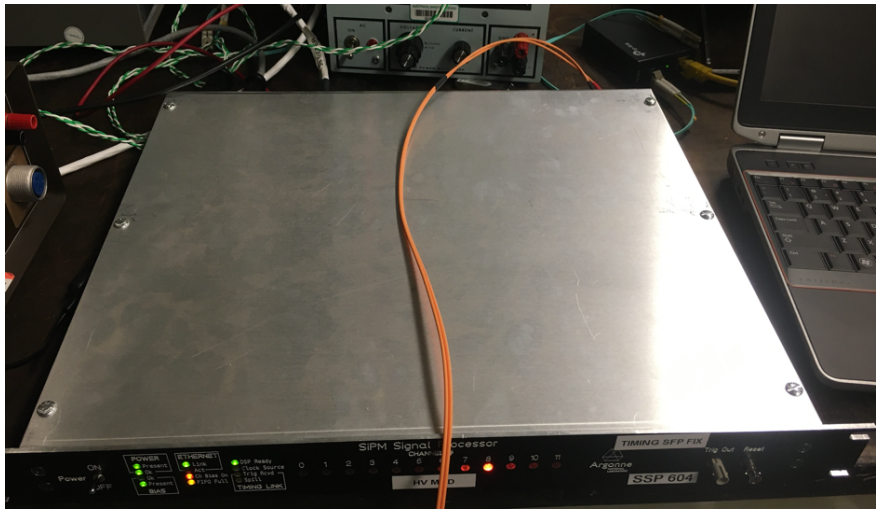


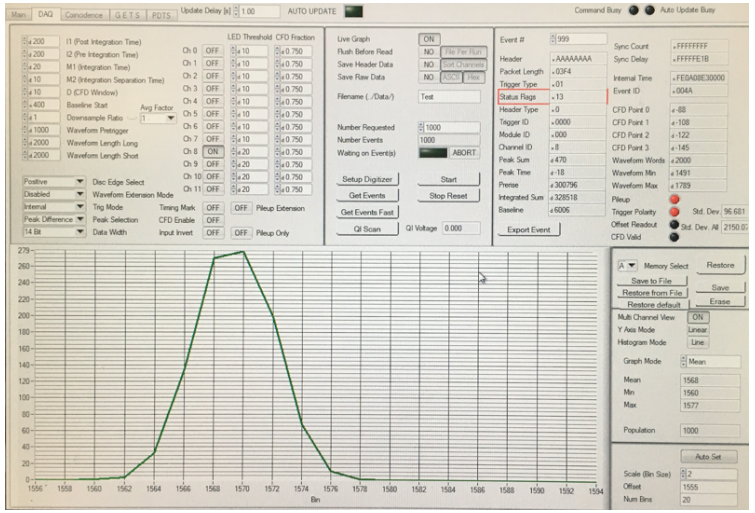
Optical Feedthrough Testing

- Test optical transparency and channel uniformity
  -ANL optical test stand
  -Feedthrough “Test” Measurements





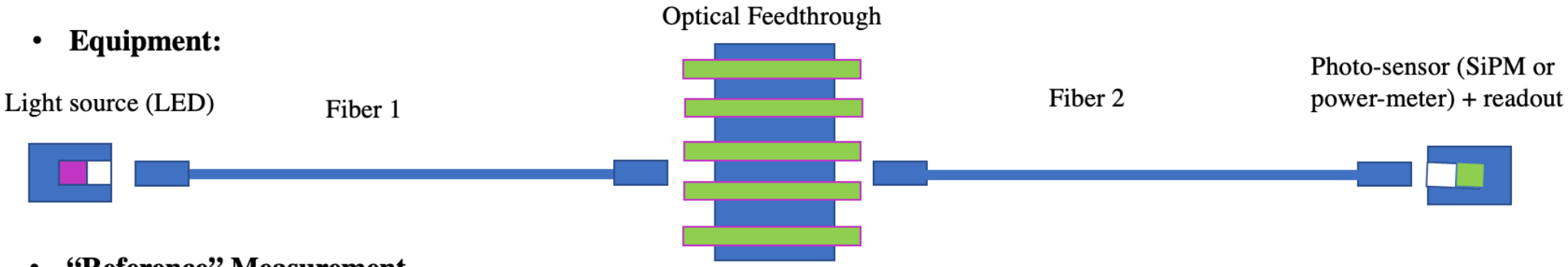




-Measurements performed with test stand above, using blue LED, show all channels respond in expected way.
-Will perform UV-light transparency measurement, quantify uniformity of feedthrough channels (schematics on next slide).

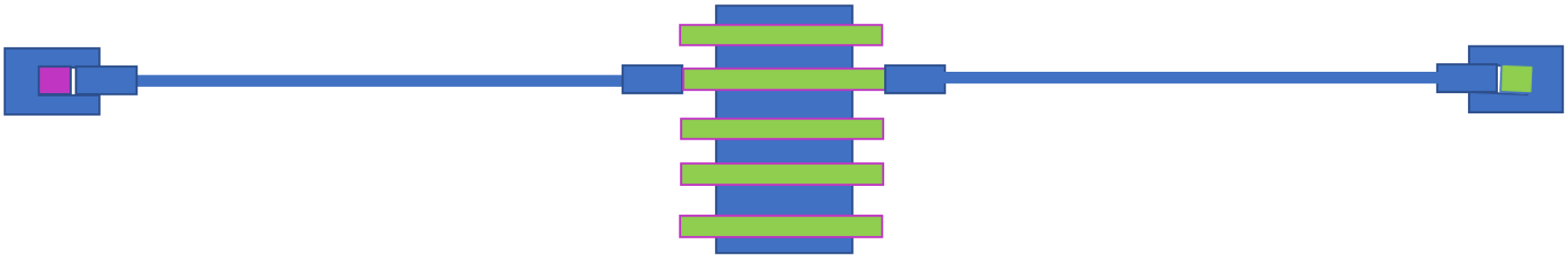
Optical Feedthrough Testing (cont.)

- **Equipment:**



- **"Reference" Measurement**
  - **-define measurement geometry**
  - **-get the "reference light intensity" at the end of two fibers**

- **Feedthrough "Test" Measurements**
  - **-measure light transparency of optical feedthrough channels with respect to "reference" measurement**



Electronics Hardware/Firmware Development

“New” Timing/DAQ Test Stand at ANL

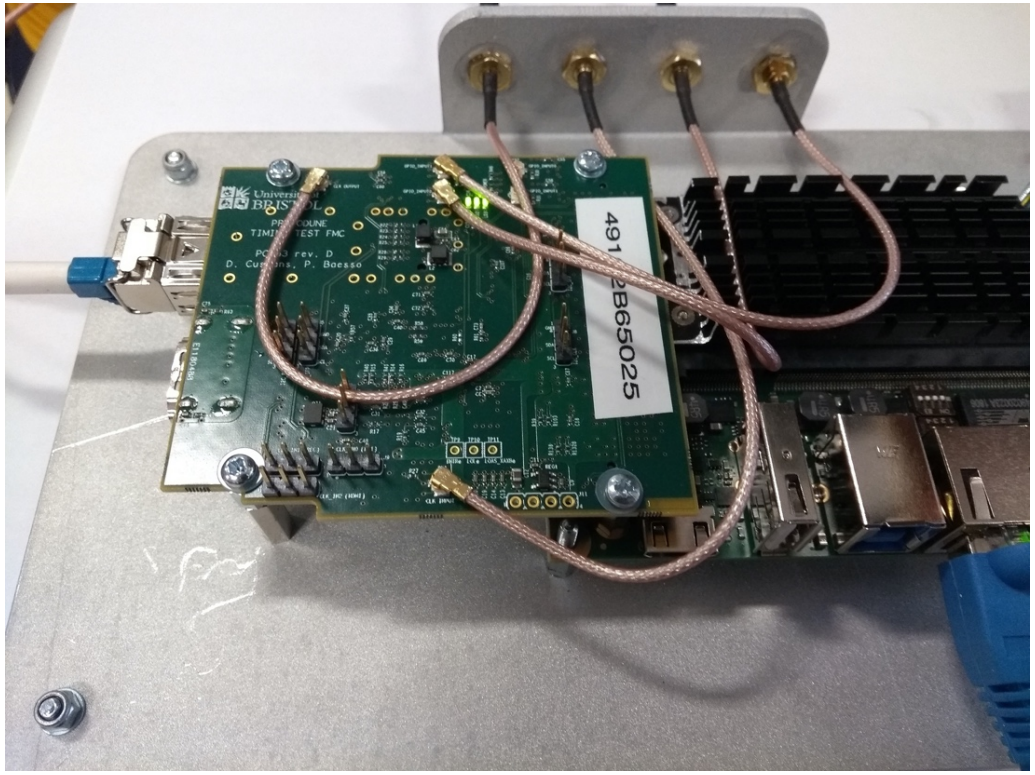
- “Old” timing test stand at ANL based on KC705 (but no plans to use the Kintex-7 in DUNE or PD-2 production hardware).
- Going forward requires Enclustra PM3 (base board) + AX3 (FPGA module) to act as a timing master for tests.
  -Calibration Module is end-point, to be tested with updated Firmware
  -We are proceeded with building the new test stand; ordered the following parts:

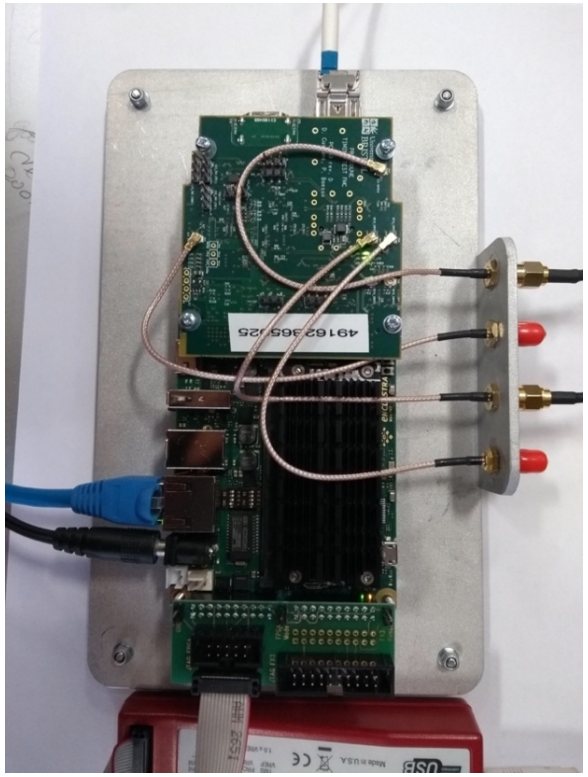
1	Ea.	MA-PM3-W https://www.enclustra.com/en/products/base-boards/mars-pm3/
1	Ea.	ACC-BASE-USB2.0-JTAG https://www.enclustra.com/en/products/base-boards/mars-pm3/
1	Ea.	MA-AX3-35-1I-D8 https://www.enclustra.com/en/products/fpga-modules/mars-ax3/
1	Ea.	HS-ZX-R1-Set

- DAQ group with David Cussans supplied a mounting plate which can mount an Enclustra PM3/AX3 together with a "reference timing hardware" FMC (**see next slide**).
- Once new endpoint FW timing version and the timing master is in hand, we will continue with the calibration module FW development to include
  -the timing loop (hardware fix already completed), and
  -add a new feature to slow-control to monitor stability of the light source.

“New” Timing/DAQ Test Stand at ANL (cont.)

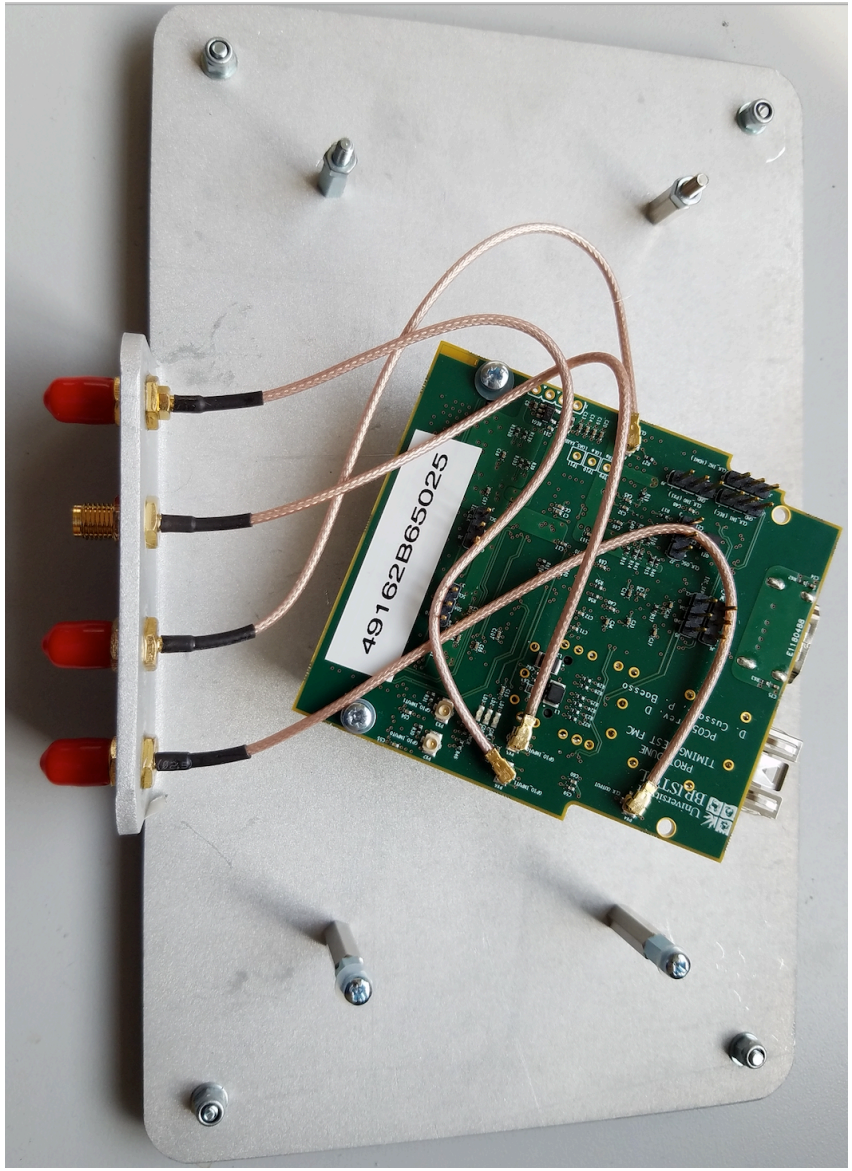
- David Cussans et. al. shipped a mounting plate with timing FMC
  -Photos showing the arrangement of Enclustra-AX3/PM3 + timing FMC on the mounting plate.





- Test Stand construction is underway
  -Once complete will be used for timing firmware/software implementation/tests.

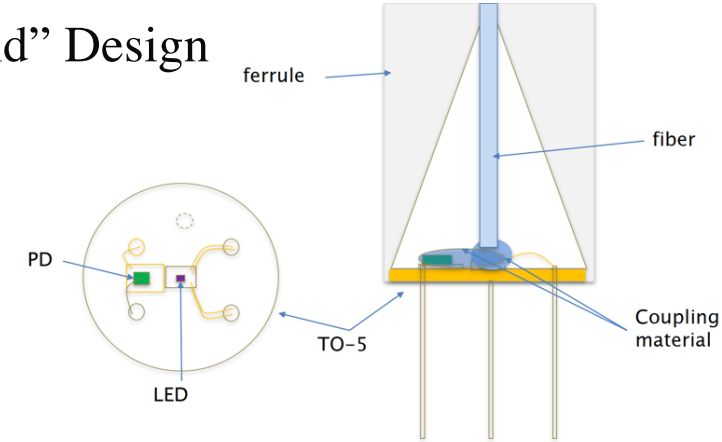
“New” Timing/DAQ Test Stand at ANL (cont.)



- FMC + mounting plate arrived this morning (from Bristol: thank you David Cussans!)

Calibration Light Source Development

"Old" Design



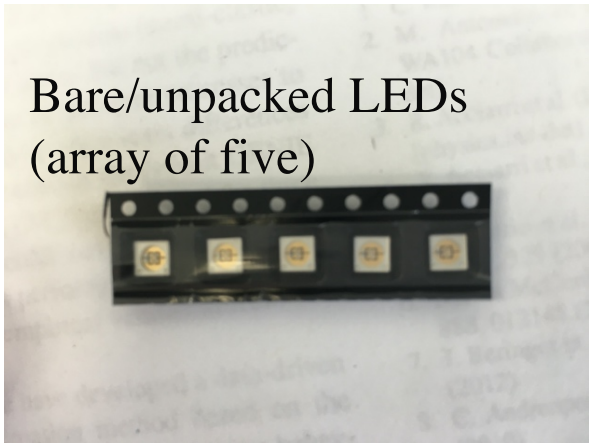
- Selection of new LED for DUNE Calibration Module light source
  - -We have selected six LED types for testing.
  - -Now in hand.

SETi Proprietary and Confidential

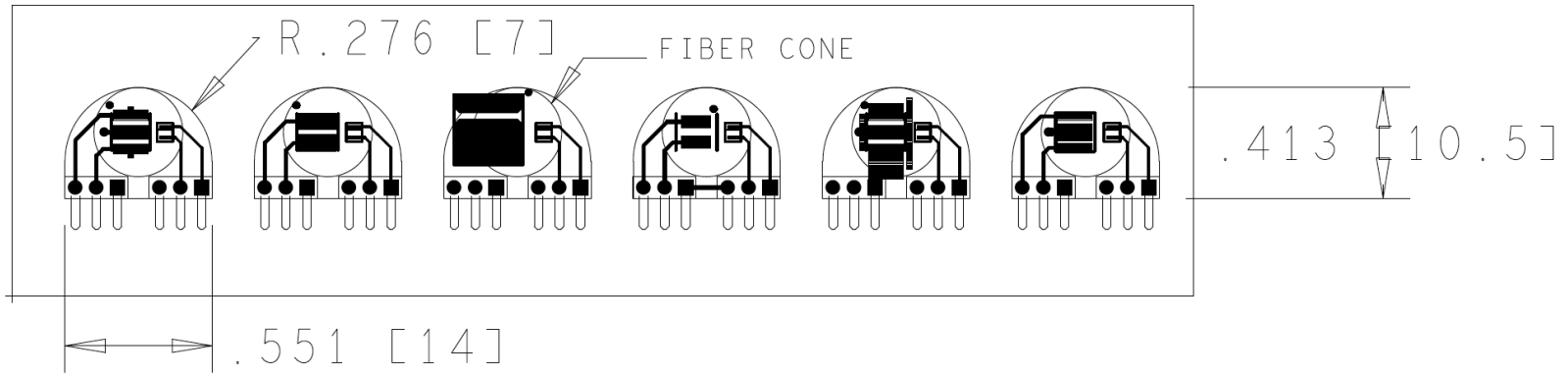
Name	Series	Wavelength (nm)
IN-C39CTKU1	IN-C39(X)TK UVC	275
CUD7GF1B	N/A	275
XST-3535-UV-A60-CE275-00	XST-3535-UV	275
E275-3 UVC LED Chip	N/A	275
XZVS160S-A	N/A	365
NDU1104ESE-365-TR	N/A	365

Calibration Light Source Development (cont.)

- Example: one of 6 LED types we selected for testing



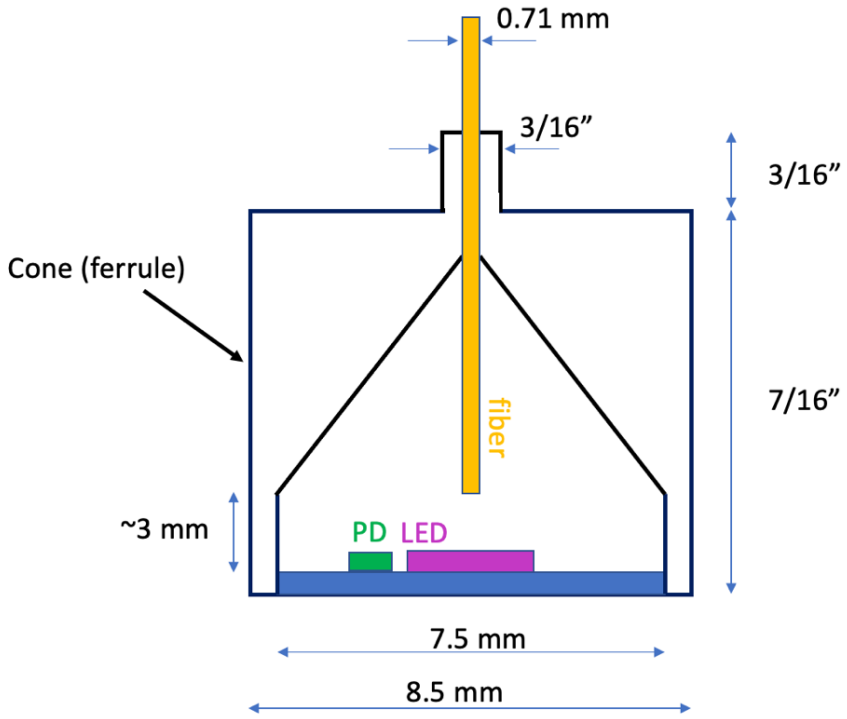
- Design of test board and PCB light-source board underway



- Enclosed is a picture of a single strip of the LED/Photodiode circuit boards.
  - -The Fiber cone will need to be around 8.25mm ID to fit these parts inside.
  - -We will get multiple strips of these boards on a panel for testing.
  - -Need add a fixture that these will plug into similar to the main Calib. Mod. board.

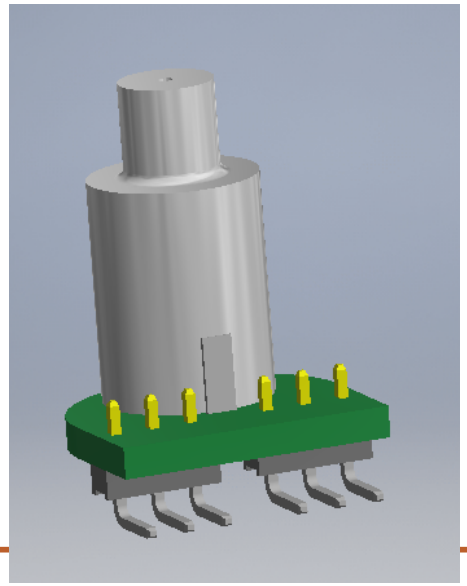
Calibration Light Source Development

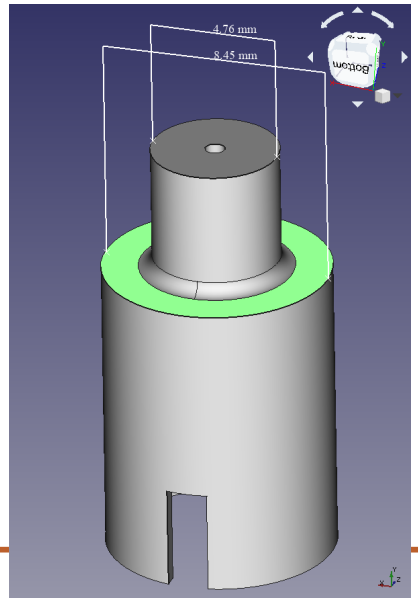
➢ This is a rough sketch of the light source:



- The fiber O.D. is 710 +/- 10 um.
- The cone needs to have an O.D. of 8.5mm and an I.D. of 7.5mm at the base.
  - -The ID needs to stay at 7.5mm for a minimum of 2.54mm above the board for components clearance inside the cone.
  - -The top of the taper shall have a .71mm hole to support the fiber.
  - -Add two screws for mounting the outer shape.
  - -If plastic it could be 3D printed at APS/PHY/HEP.

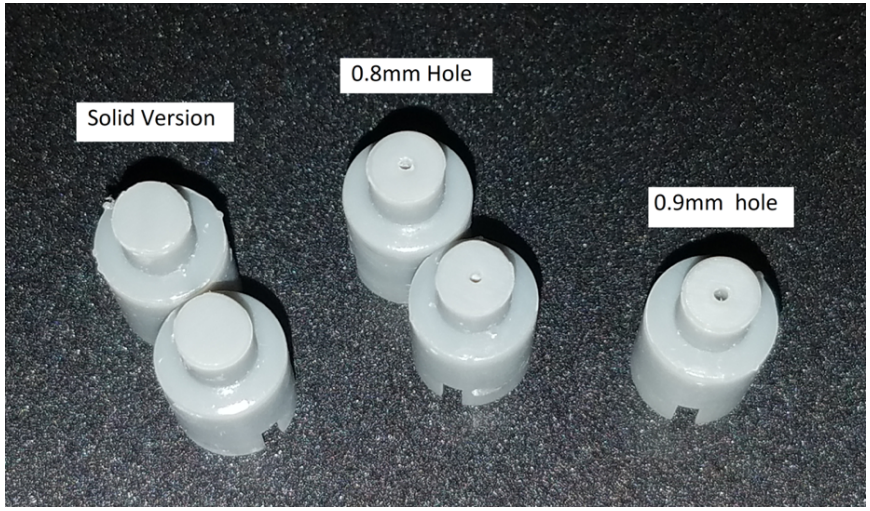
➢ This is real design work:

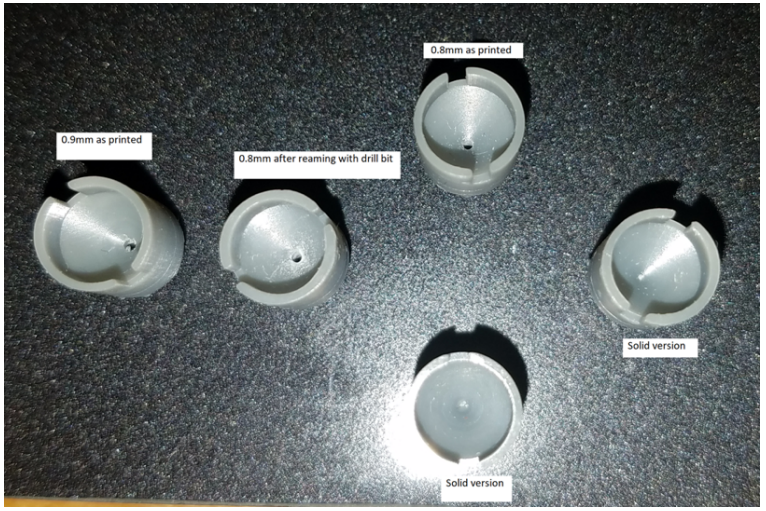




Calibration Light Source Development

- Cone prototypes 3D-printed at Argonne





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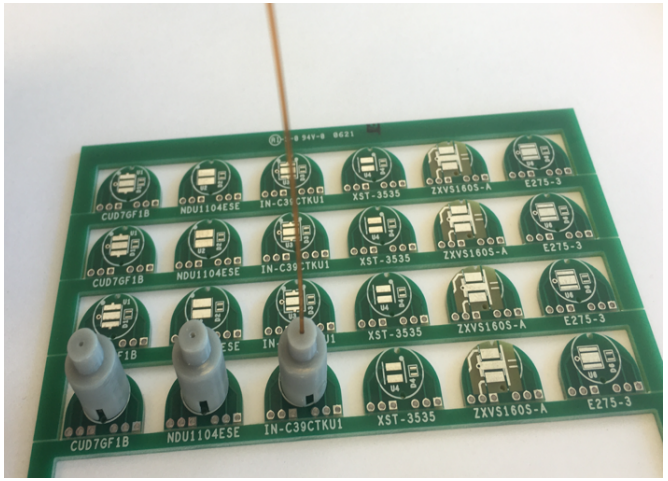
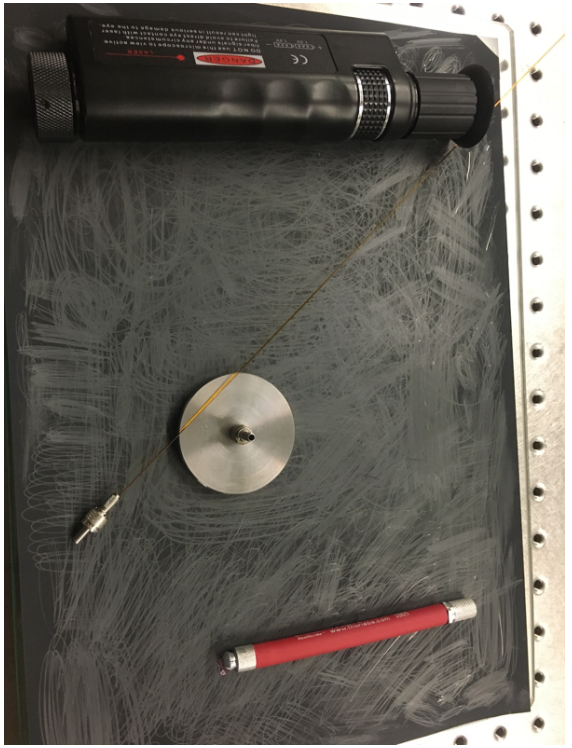
Calibration Light Source Development

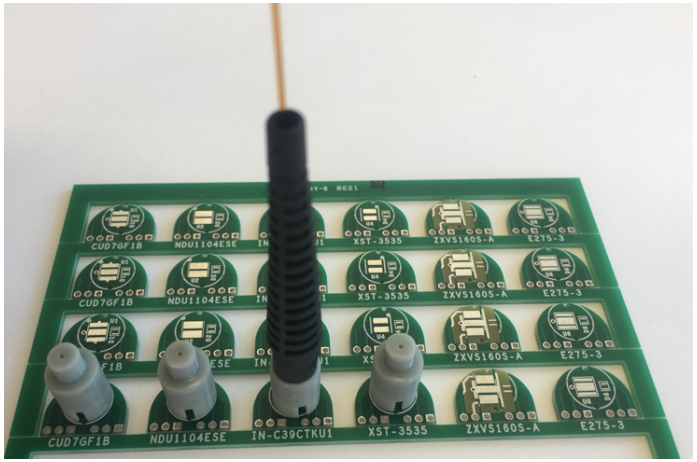
- LED printed circuit boards after production



- Optical fiber cutter/polisher

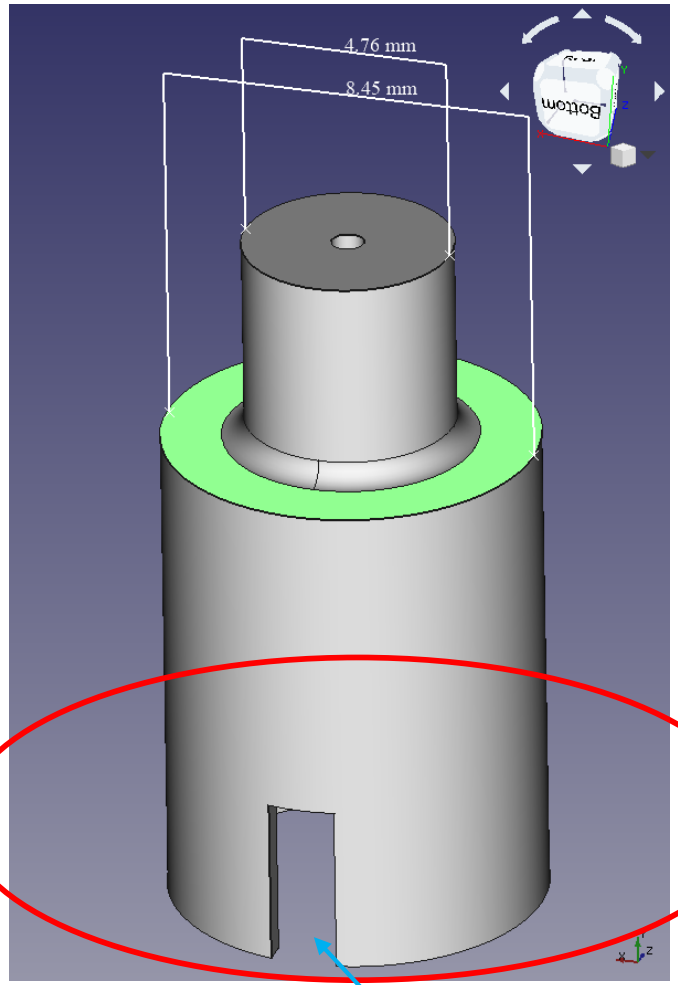


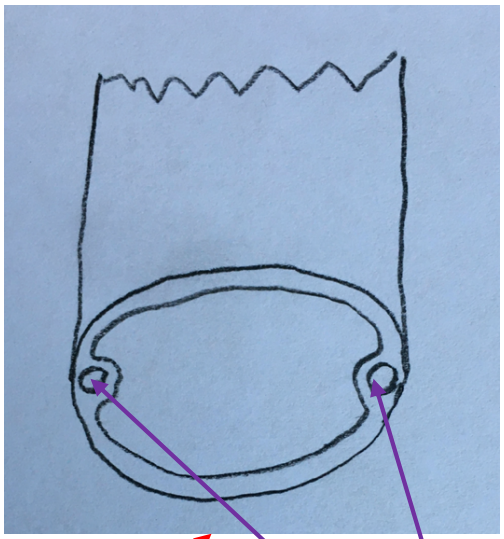
- Tests with light source housing ("cone") after initial production



Calibration Light Source Development

- Working on iteration of light source mechanical design to add pins to attach cone to PCB





This would be a rough sketch of bottom part of the cone

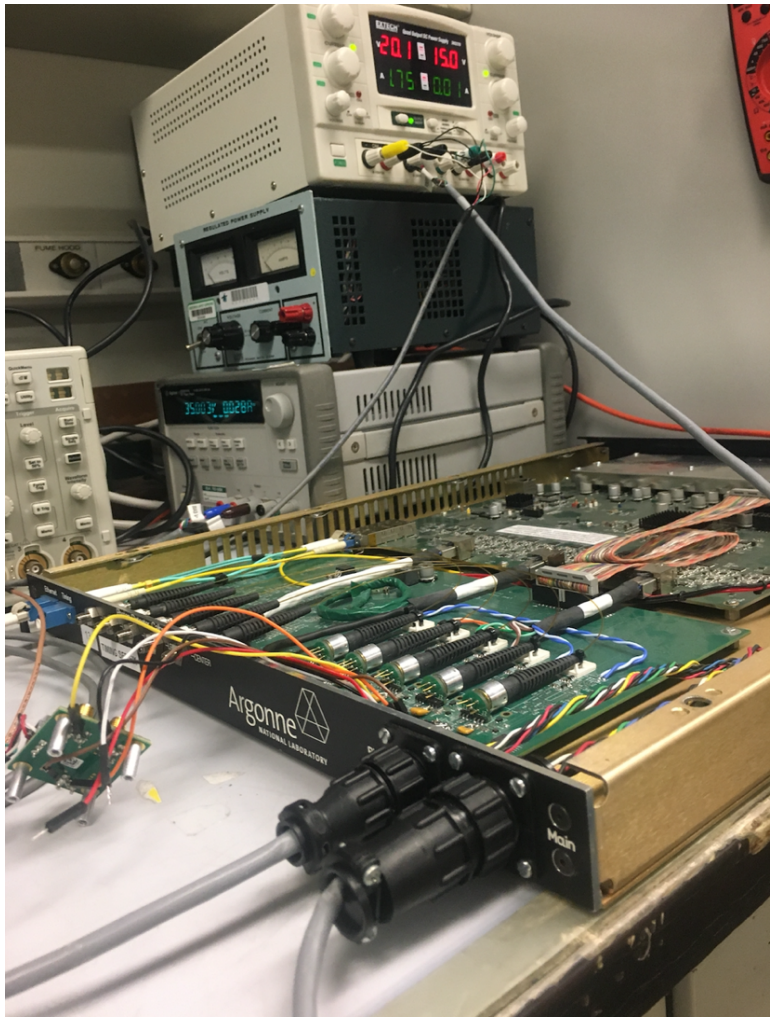
Anticipated pinholes that match PCB board holes

Will add pinholes to the model i.e. here.

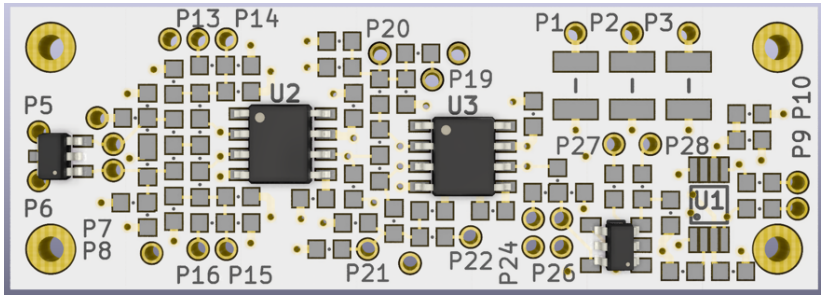
25

Electronics Development: Monitoring light source feedback loop

- Adding a photodiode preamp to the design
  -A success in testing preamp and seeing photodiode signal in calibration module ADC



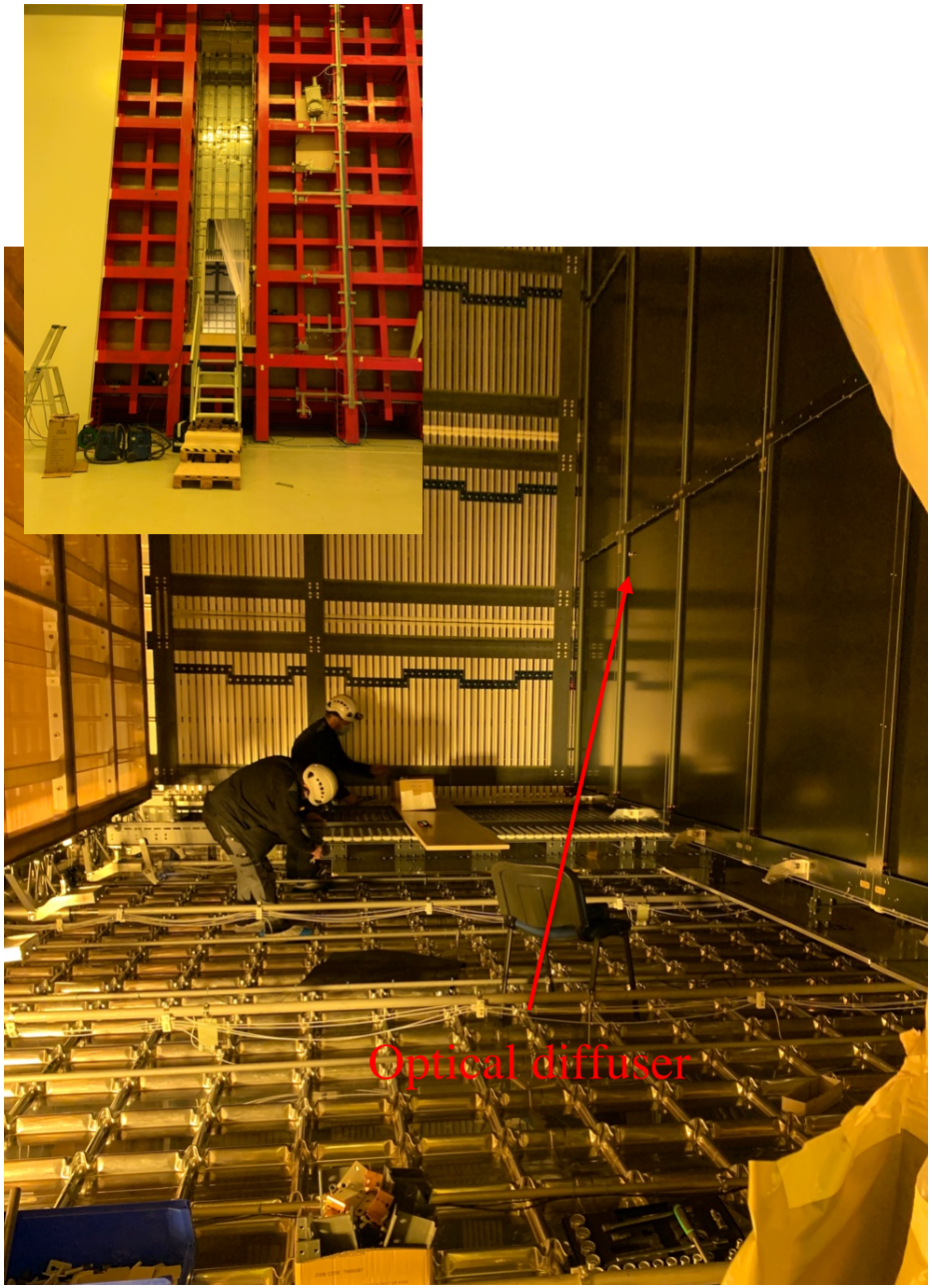
- There is a PCB designed as a small configurable amplifier.
  -It has a couple of op-amps and can be equipped with a differential output driver.
  -The board is only 0.7" x 2", so a stack of 5 of them should fit in the chassis without any problem.
  -They will need to be assembled, with the following
    2 ICs
    ~12 0603/1210 SMDs



ProtoDUNE-SP Decommissioning

ProtoDUNE-SP Phase-I Decommissioning Efforts

- ProtoDUNE-SP phase I successfully completed
  -decommissioning started
- Some of the system components may be recovered for additional tests.
- We wanted the cold fiber/diffusers carefully removed
  -Want to observe any visible changes caused by cryogenic operation
  -Look for fractures/cracks
  -Want to save fibers for a measurement of optical transparency (attenuation) to probe potential aging/deterioration.
  -Useful for further studies in general
- We also want feedthroughs and warm fibers (in black jackets) above cryostat saved for further use and testing.
  -Perform retests
  -Optical transmission
  -Mechanical properties
- In discussion with decommissioning team.



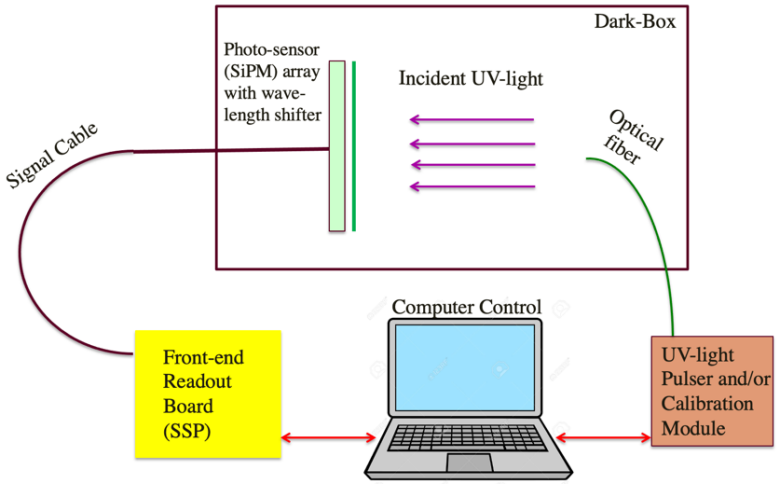
Summary

- Optical Diffuser Development Status
  - -Preliminary design of optical diffuser fabricated and tested
  - -New iteration of design underway.
- Optical Fibers Routing and Testing
  - -New DUNE Far Detector DSS design available to us
  - -Adding fiber routes to the design
  - -Preliminary calculation of fiber length completed.
- Optical Feedthrough Status and Tests
  - -New series of three optical feedthroughs fabricated
  - -Testing started.
- Electronics hardware/Firmware development
  - -Timing system implementation underway
  - -Monitoring capability of light source being added to the design
  - -Next step is incorporation of new firmware to include timing system communication and monitoring capability.
- Light Source Development
  - -All components of new calibration light source under design/testing
- Working with CERN ProtoDUNE-SP team to salvage original calibration system
  - -Idea is to retest existing component for aging signatures.
- Calibration System group is following the development timescale discussed at recent collaboration meeting.

Backup Slides

ANL Lab Status

- Our limited operations request has been granted by ANL/DOE, so we are back to lab hands-on work (from mid-December, what effectively meant January).
- First step was to build/re-establish test stands

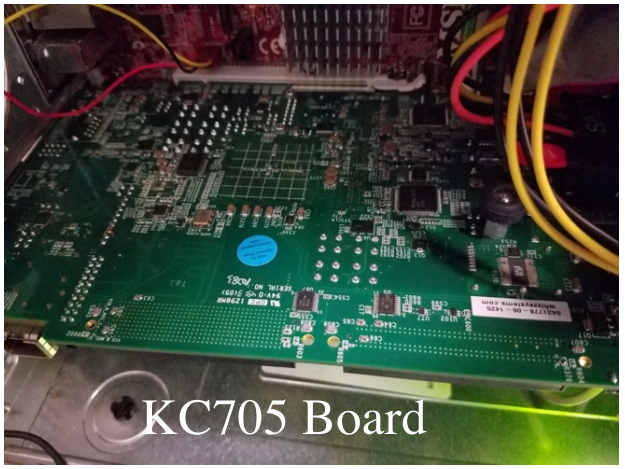


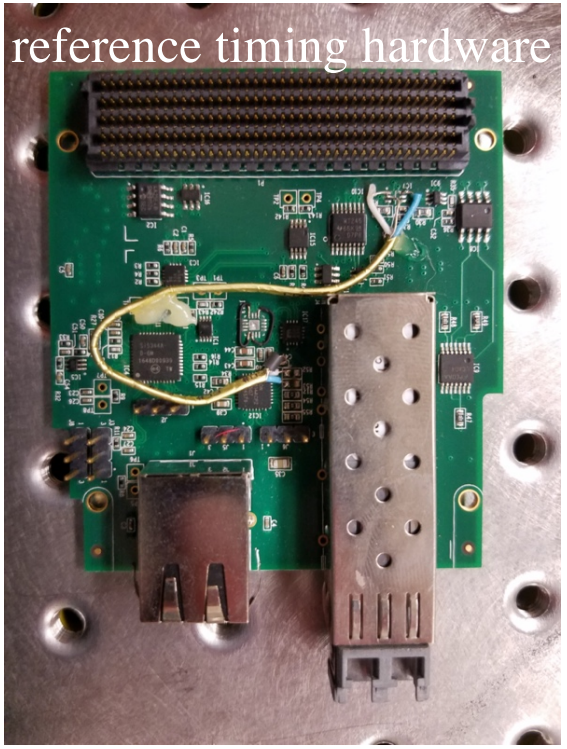
1) Calibration Electronics test stand
   -needed to test new light sources
   -follow-up on FW development/updates

2) Timing-system/DAQ test stand
   -timing system emulator with a timing master
   -needed to integrate timing FW with Calibration Modules

“Old” Timing/DAQ Test Stand at ANL

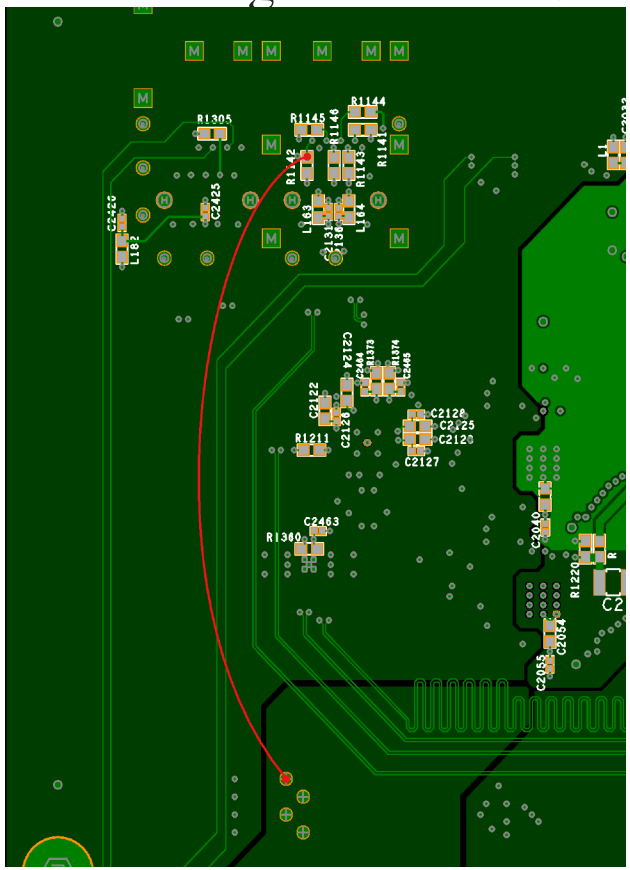
- As we returned part-time to the lab, we inspected ANL timing/DAQ test-stand
  -Originally built for ProtoDUNE-I





Module Design Updates

- Next Step with the Calibration Module
  -connect the TX interface's disable signal from the timing interface's SFP to the FPGA, for dynamic control.

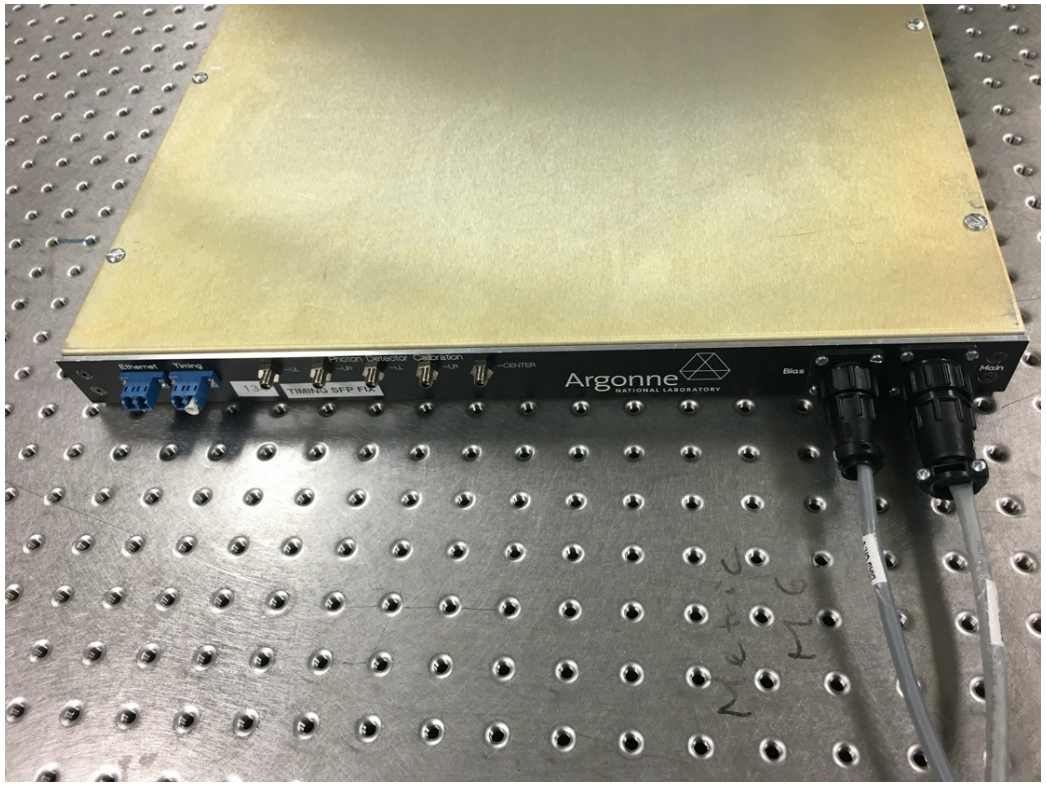


  -This will repurpose the unused TX Fault
  (pin 2) pullup to escape the TX Disable
  (Pin 3) signal from the SFP cage.
  -Then a wire will connect this to
  the FPGA via a FPGA test point.

- After this is in place, we will look to updating Calibration module's timing interface firmware to enable control of TX features.

- Second modification: monitoring feedback loop
  -Feed PD output to ADC input to measure average pulse amplitude/RMS.
  -Firmware will enable to deliver these values as registers to be read out via SC.

Information on LV Cables/Power-Supplies



Bias Cable (powers LEDs)

LV Cable (powers electronics circuitry)

Engineering Note on Power Cables (by Gary Drake)

1. LV Cables

-Power source: Wiener MPOD MPV8030, 8 channel, 0-30V, 0-2.5A max, remote sensing

-Power connector on MPV8030: SPC15230, male pins

-Current rating of pins: 5 A

-Wire: Alpha Wire 78194, 4 pairs, 20 AWG (3.5 Amp rating)

-Configuration for each channel: 3 pairs for power & return; 1 pair for remote sensing

-Nominal Current by the SSP: 1.5 A @ 20V

-Voltage drop: 1V (each direction)

-Power connectors on Calibration Module: AMP 206708-1

-Current rating of sockets: 13 A

2. Bias Cables

-Power source: Wiener MPOD MPV8060, 8 channel, 0-60V, 0-1A max, remote sensing

-Power connector on MPV8060: SPC15230, male pins

-Current rating of pins: 5 A

-Wire: Alpha Wire 5474L, 4 pairs, 24 AWG (1.4A rating)

-Configuration for each channel: 3 pairs for power & return; 1 pair for remote sensing

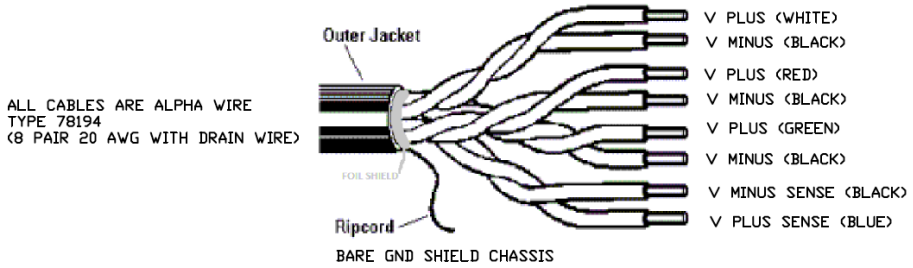
Nominal Current by the module: < 100 uA @ 30V

-Voltage drop: ~0 V

-Power connectors on SSP: AMP 206485-1

Current rating of pins: 7.5 A

LV Power Cable / Power Supply Scheme



CABLE A

9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
1	White	20	V plus output
2	Black	1	V Minus output
3	Red	21	V Minus output
4	Black	2	V plus output
5	Bare Gnd	19	Shield Chassis
6	Black	3	V Minus output
7	Green	22	V plus output
8	Black	4	V Minus Sense Input
9	Blue	23	V plus Sense Input

CABLE B

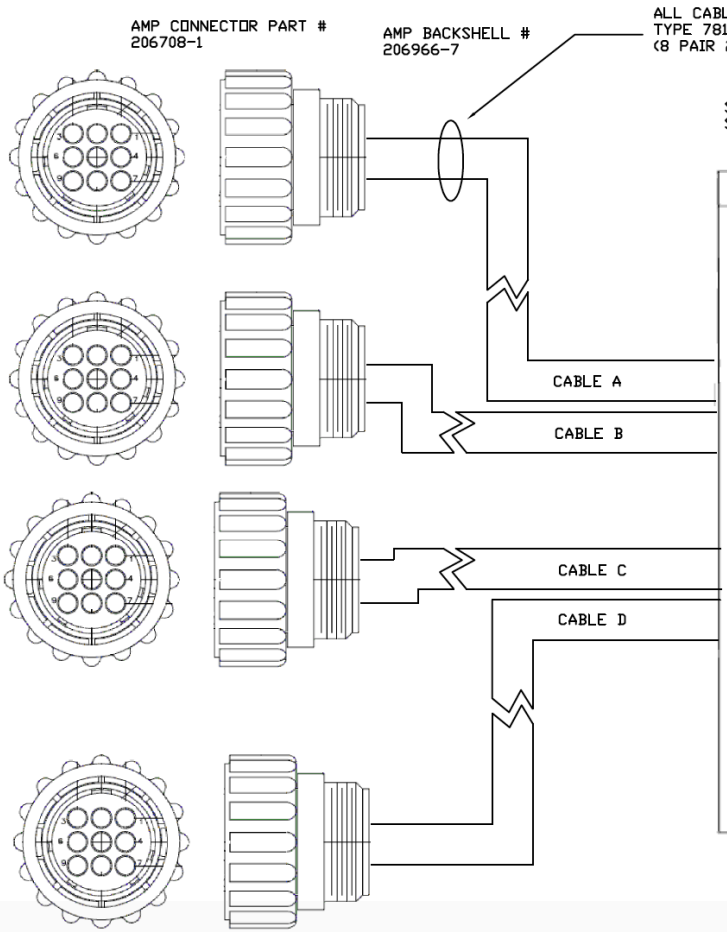
9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
1	White	24	V plus output
2	Black	5	V Minus output
3	Red	25	V Minus output
4	Black	6	V plus output
5	Bare Gnd	19	Shield Chassis
6	Black	7	V Minus output
7	Green	26	V plus output
8	Black	8	V Minus Sense Input
9	Blue	27	V plus Sense Input

CABLE C

9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
1	White	28	V plus output
2	Black	9	V Minus output
3	Red	29	V Minus output
4	Black	10	V plus output
5	Bare Gnd	19	Shield Chassis
6	Black	11	V Minus output
7	Green	29	V plus output
8	Black	12	V Minus Sense Input
9	Blue	20	V plus Sense Input

CABLE D

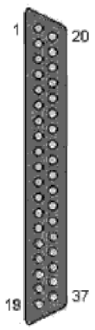
9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
1	White	32	V plus output
2	Black	13	V Minus output
3	Red	33	V Minus output
4	Black	14	V plus output
5	Bare Gnd	19	Shield Chassis
6	Black	15	V Minus output
7	Green	34	V plus output
8	Black	16	V Minus Sense Input
9	Blue	35	V plus Sense Input



SPC CONNECTOR # SPC15230

SPC METAL HOOD # SPC15310

DSUB37 female (Channel 0..3)	Pin	Signal	TOP Connector
	1	U0-	Channel 0 negative output
	20	U0+	Channel 0 positive output
	2	U0-	Channel 0 negative output
	21	U0+	Channel 0 positive output
	3	U0-	Channel 0 negative output
	22	U0+	Channel 0 positive output
	4	S0-	Channel 0 negative sense input
	23	S0+	Channel 0 positive sense input
	5	U1-	Channel 1 negative output
	24	U1+	Channel 1 positive output
	6	U1-	Channel 1 negative output
	25	U1+	Channel 1 positive output
	7	U1-	Channel 1 negative output
	26	U1+	Channel 1 positive output
	8	S1-	Channel 1 negative sense input
	27	S1+	Channel 1 positive sense input
	9	U2-	Channel 2 negative output
	28	U2+	Channel 2 positive output
	10	U2-	Channel 2 negative output
	29	U2+	Channel 2 positive output
	11	U2-	Channel 2 negative output
	30	U2+	Channel 2 positive output
	12	S2-	Channel 2 negative sense input
	31	S2+	Channel 2 positive sense input
	13	U3-	Channel 3 negative output
	32	U3+	Channel 3 positive output
	14	U3-	Channel 3 negative output
	33	U3+	Channel 3 positive output
	15	U3-	Channel 3 negative output
	34	U3+	Channel 3 positive output
	16	S3-	Channel 3 negative sense input
	35	S3+	Channel 3 positive sense input
	17	INTERLOCK0	Optional interlock input: The four channels of this connector are
	36	INTERLOCK1	enabled only if a signal is applied here
	18	LOOP0	Safety Loop, LOOP0 and LOOP1 are connected to each other, no
	37	LOOP1	connection to other potentials
	19	CHASSIS	Connected to chassis / front panel



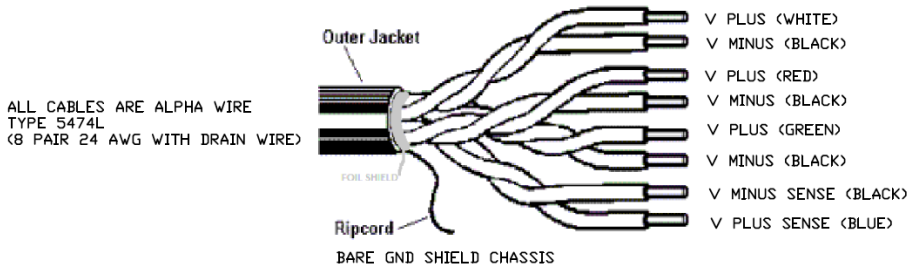
CABLE A

CABLE B

CABLE C

CABLE D

Bias Power Cable / Power Supply Scheme



CABLE A

9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
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9	Blue	23	V plus Sense Input

CABLE B

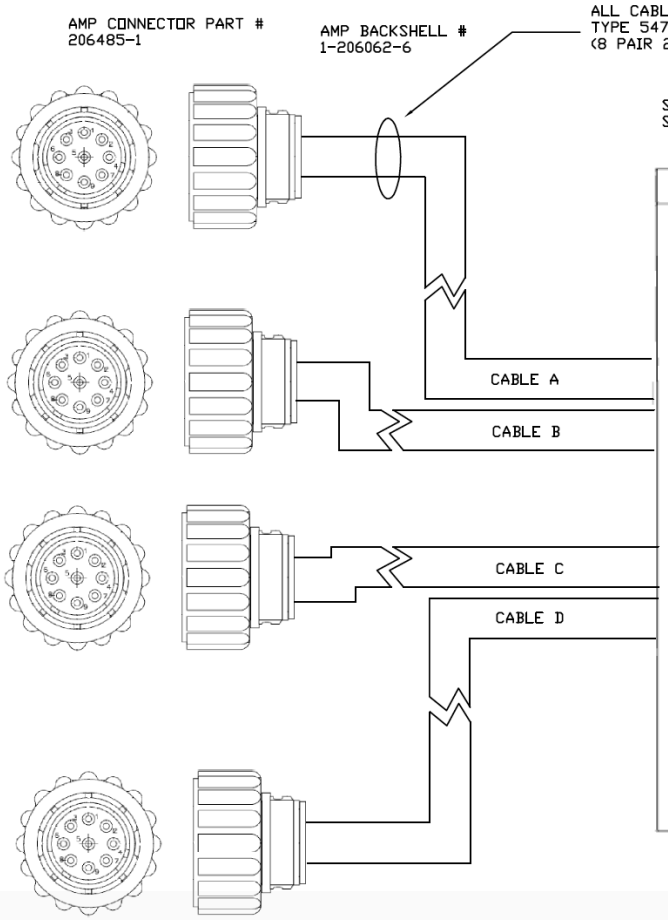
9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
1	White	24	V plus output
2	Black	5	V Minus output
3	Red	25	V Minus output
4	Black	6	V plus output
5	Bare Gnd	19	Shield Chassis
6	Black	7	V Minus output
7	Green	26	V plus output
8	Black	8	V Minus Sense Input
9	Blue	27	V plus Sense Input

CABLE C

9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
1	White	28	V plus output
2	Black	9	V Minus output
3	Red	29	V Minus output
4	Black	10	V plus output
5	Bare Gnd	19	Shield Chassis
6	Black	11	V Minus output
7	Green	29	V plus output
8	Black	12	V Minus Sense Input
9	Blue	20	V plus Sense Input

CABLE D

9 Pin Connector #	Color	DB37 Pin Connector #	Wire Name
1	White	32	V plus output
2	Black	13	V Minus output
3	Red	33	V Minus output
4	Black	14	V plus output
5	Bare Gnd	19	Shield Chassis
6	Black	15	V Minus output
7	Green	34	V plus output
8	Black	16	V Minus Sense Input
9	Blue	35	V plus Sense Input



DSUB37 female (Channel 0..3)	Pin	Signal	TOP Connector
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	4	S0-	Channel 0 negative sense input
	23	S0+	Channel 0 positive sense input
	5	U1-	Channel 1 negative output
	24	U1+	Channel 1 positive output
	6	U1-	Channel 1 negative output
	25	U1+	Channel 1 positive output
	7	U1-	Channel 1 negative output
	26	U1+	Channel 1 positive output
	8	S1-	Channel 1 negative sense input
	27	S1+	Channel 1 positive sense input
	9	U2-	Channel 2 negative output
	28	U2+	Channel 2 positive output
	10	U2-	Channel 2 negative output
	29	U2+	Channel 2 positive output
	11	U2-	Channel 2 negative output
	30	U2+	Channel 2 positive output
	12	S2-	Channel 2 negative sense input
	31	S2+	Channel 2 positive sense input
	13	U3-	Channel 3 negative output
	32	U3+	Channel 3 positive output
	14	U3-	Channel 3 negative output
	33	U3+	Channel 3 positive output
	15	U3-	Channel 3 negative output
	34	U3+	Channel 3 positive output
	16	S3-	Channel 3 negative sense input
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	17	INTERLOCK0	Optional Interlock Input. The four channels of this connector are
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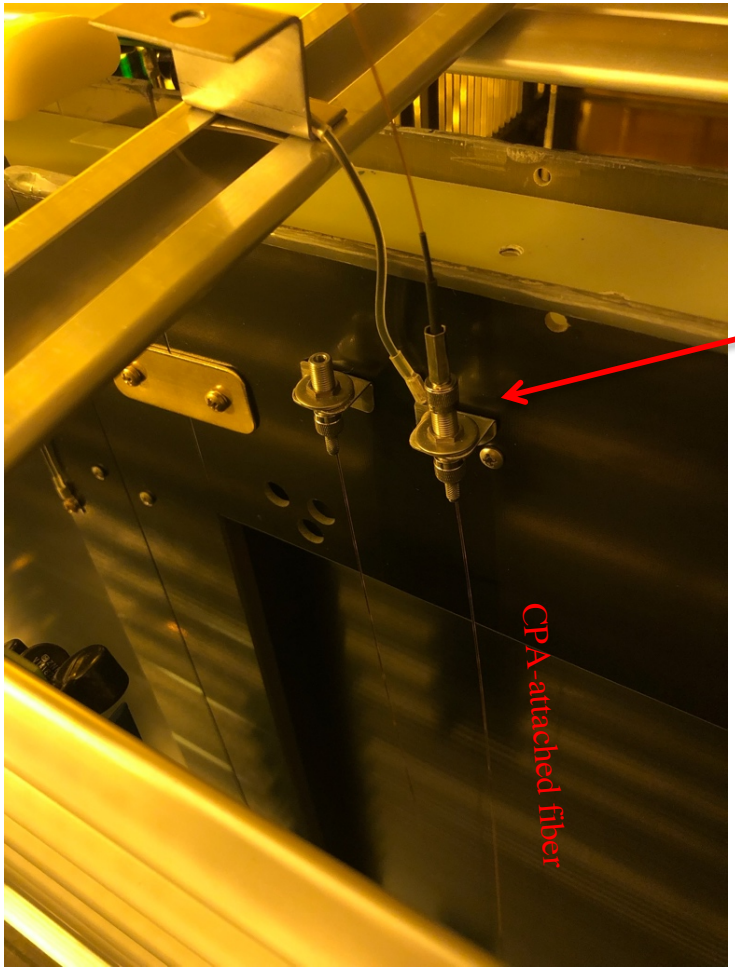
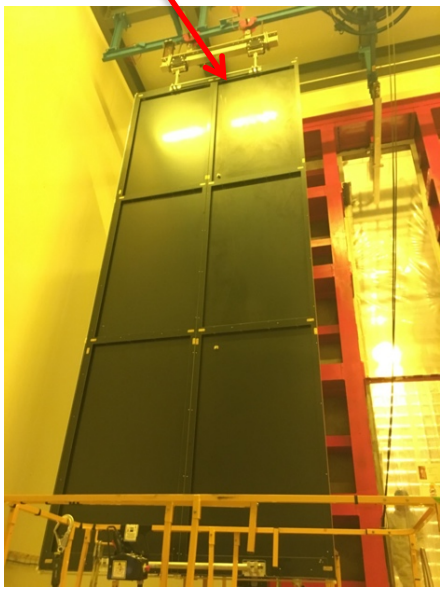
	18	LOOP0	Safety Loop, LOOP0 and LOOP1 are connected to each other, no
	37	LOOP1	connection to other potentials
	19	CHASSIS	Connected to chassis / front panel

CABLE A
CABLE B
CABLE C
CABLE D

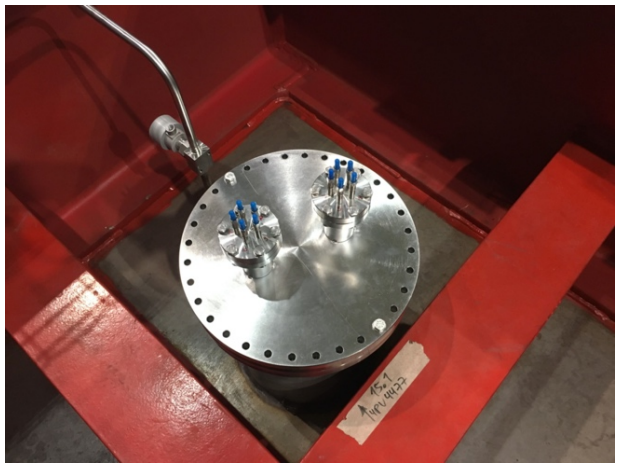
(ProtoDUNE) Installation of the top fibers

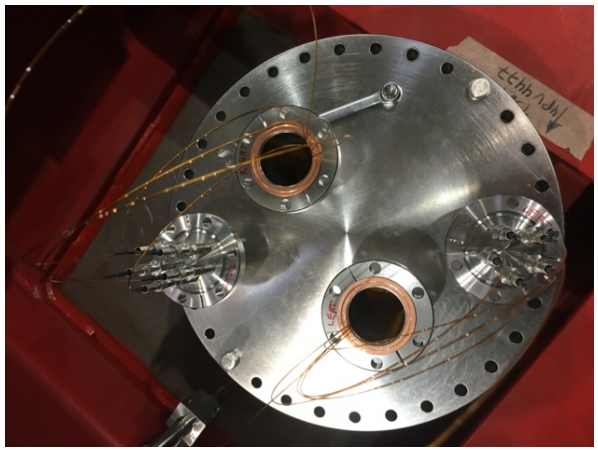
- Using this slide to illustrate the following
  -fiber installation (CPA fiber pre-installed with CPA, upper fiber pre-routed awaiting CPA)

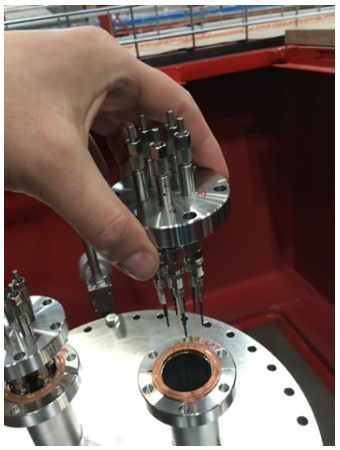


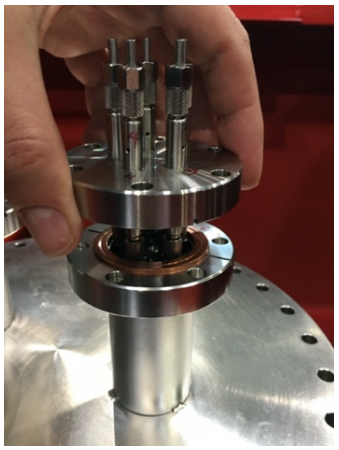


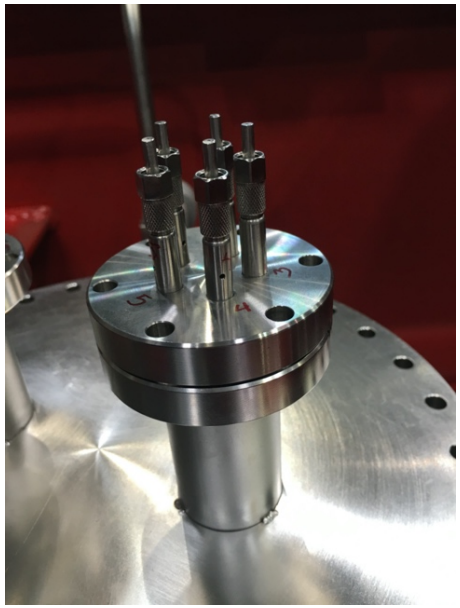
Optical Feedthroughs

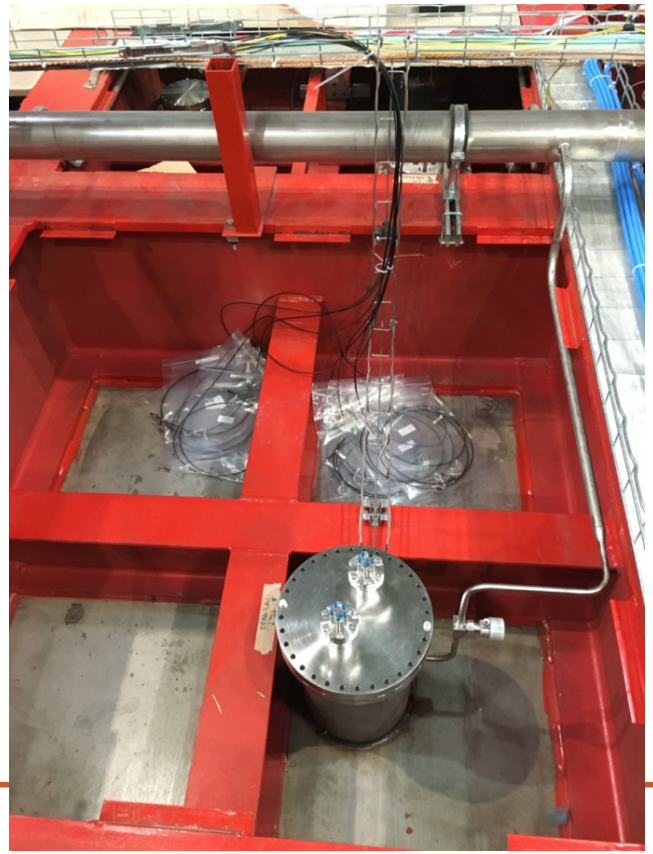


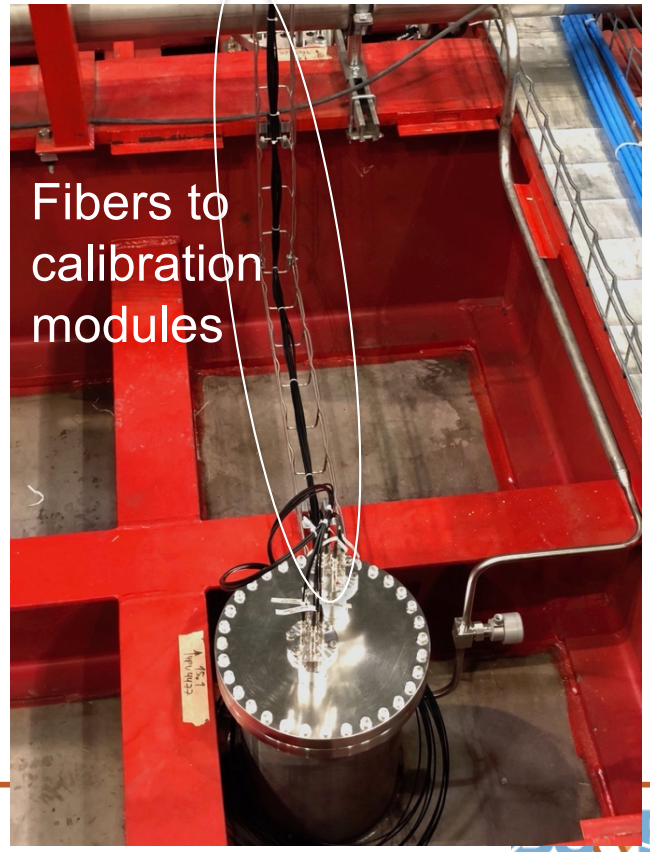












Calibration Modules

- Electronics modules with integrated UV-LEDs