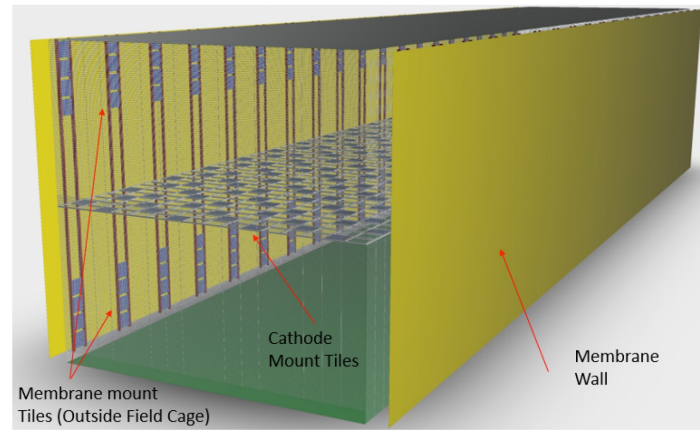
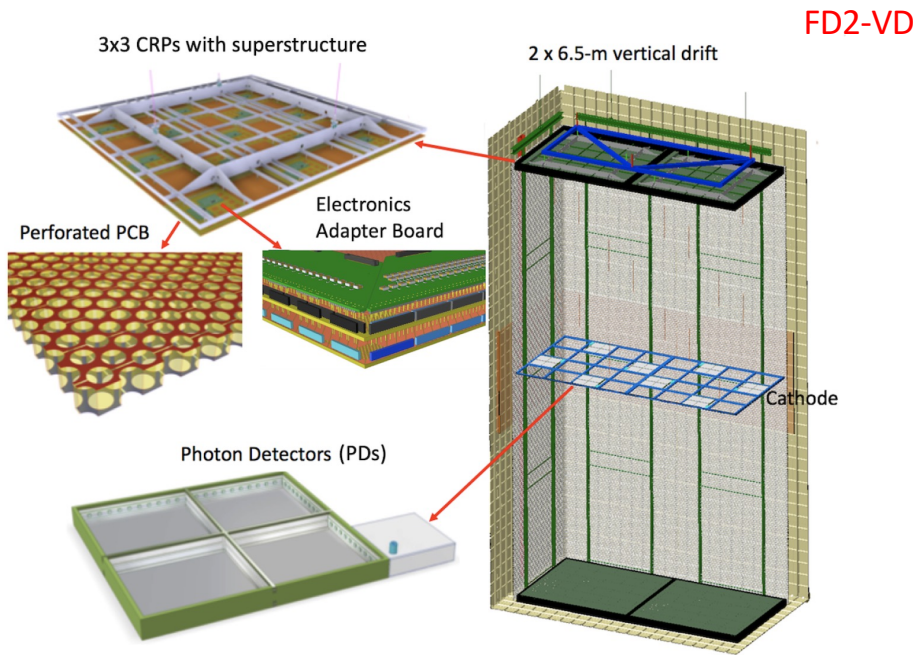


DUNE Far Detector Vertical Drift: PDS Calibration and Monitoring Status

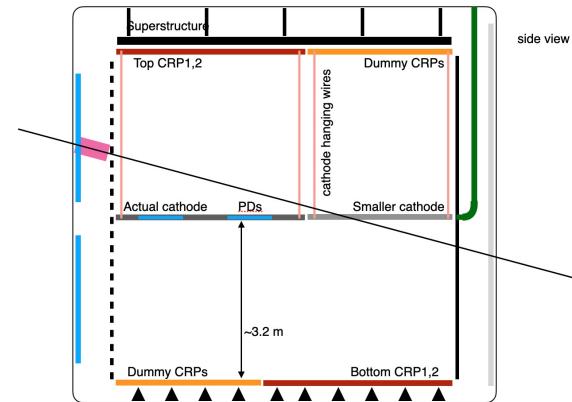
April 25, 2022 FD2-VD Design Meeting

Zelimir Djurcic, Aleena Rafique, David Martinez, Steve Magill et. al..

DUNE Far Detector: Vertical Drift Concept



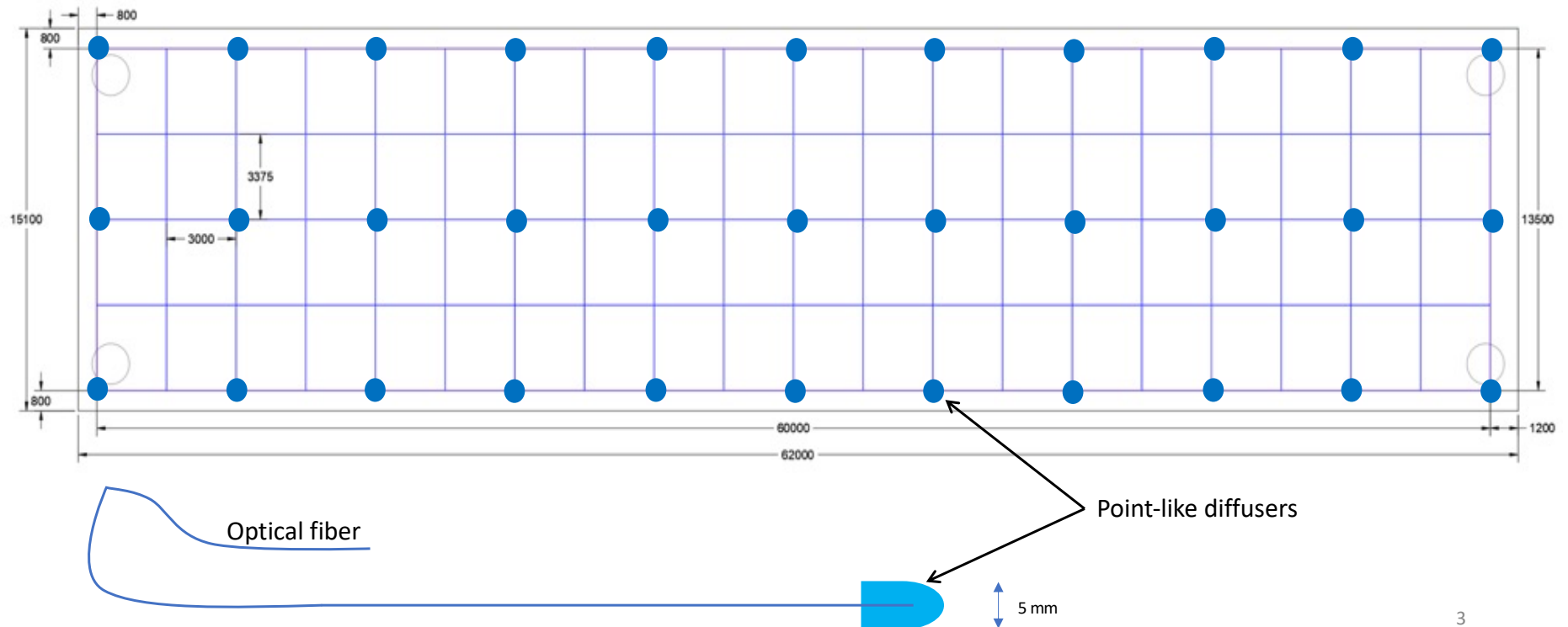
ProtoDUNE-II-VD



Calibration of Photon Detector System Stability, Gain, Time Resolution

- Point-like diffusers at top (and bottom) CRPs are considered (top Figure); A bare fiber-end or a single diffuser with ~ 5 mm diameter (bottom Figure) will transmit light transported via quartz fiber connected to the light source calibration module at cryostat top.

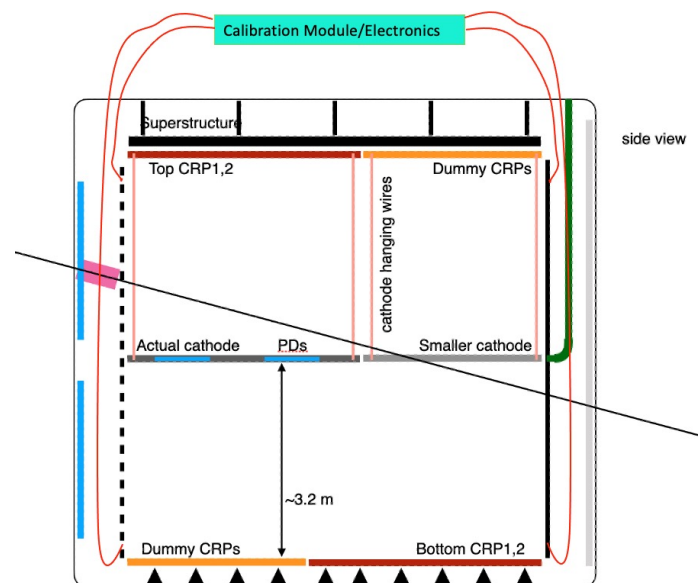
-Diffuser glass, optical fiber, fiber routing scheme, optical feedthrough components, and light source electronics are tested and fabricated for DUNE HD prototype ProtoDUNE-II-HD.

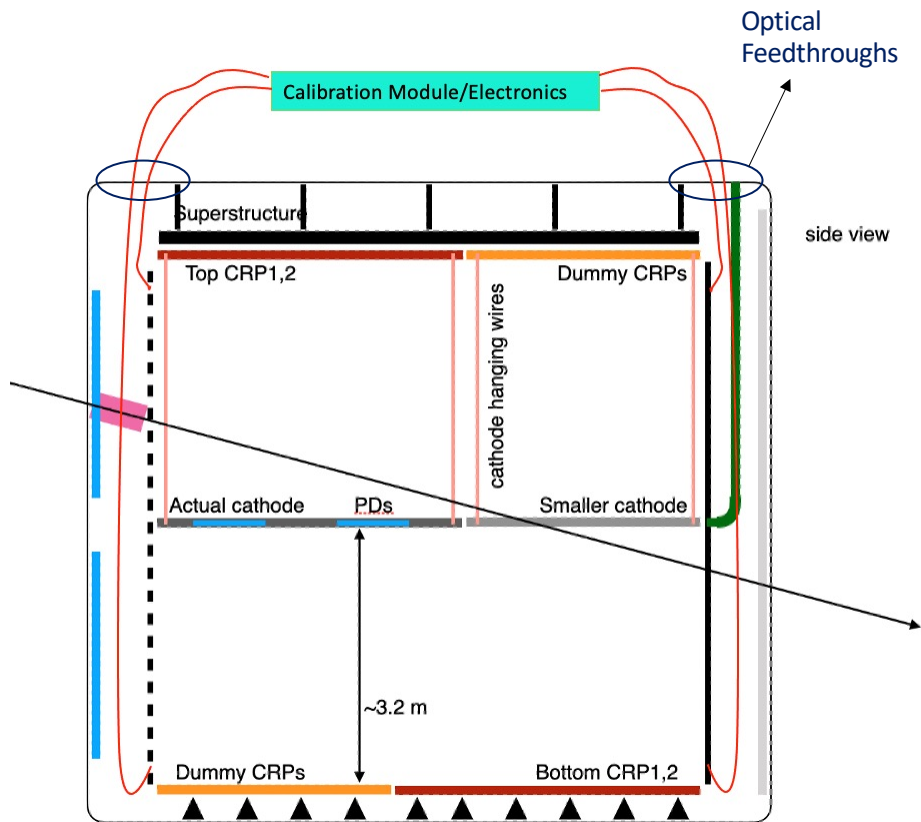


Calibration of Photon Detector System Stability, Gain, Time Resolution

What was done so far for FD2-VD?

- Provided the support by leveraging R&D effort for the FD1-HD (see recent Collaboration Meeting Talk): https://indico.fnal.gov/event/50215/contributions/232983/attachments/151278/195415/PDS_talk_collab_Jan2022_ZD_vs.pdf
 - Provided optical feedthroughs for VD tests at CERN and Fermilab.
 - Recycled fibers and diffusers from ProtoDUNE-SP-I and used these components in the VD cold box at CERN
 - Provided a single channel calibration pulser for the CERN cold box (extracted from the 12-channel design for DUNE)
 - Plan to build electronics calibration module for ProtoDUNE-II-VD based on FD2-HD solution that is now ready (based on recent design, prototyping, and the timing/DAQ test at CERN).
- Planned Next Steps:
 - Test/adopt new LED UV light source (wavelength, intensity).
 - Verify final calibration electronics board for the ProtoDUNE.
 - Build one calibration module board for ProtoDUNE-II-VD.
 - A rough plan on how to locate/install fibers and/or diffusers in ProtoDUNE-II-VD: eight light emission points at eight corners
 - Need the design/prototyping of optical fibers and its routing scheme for ProtoDUNE-VD and FD2-VD (similarly done for HD detectors)
 - Decide on fiber type (two major candidates) and on fiber routing.
 - Illuminate UV light from the bare fiber-end, or do we need a diffuser?
- Based on ProtoDUNE-II-VD fabrication and results: build the DUNE FD2-VD systems.

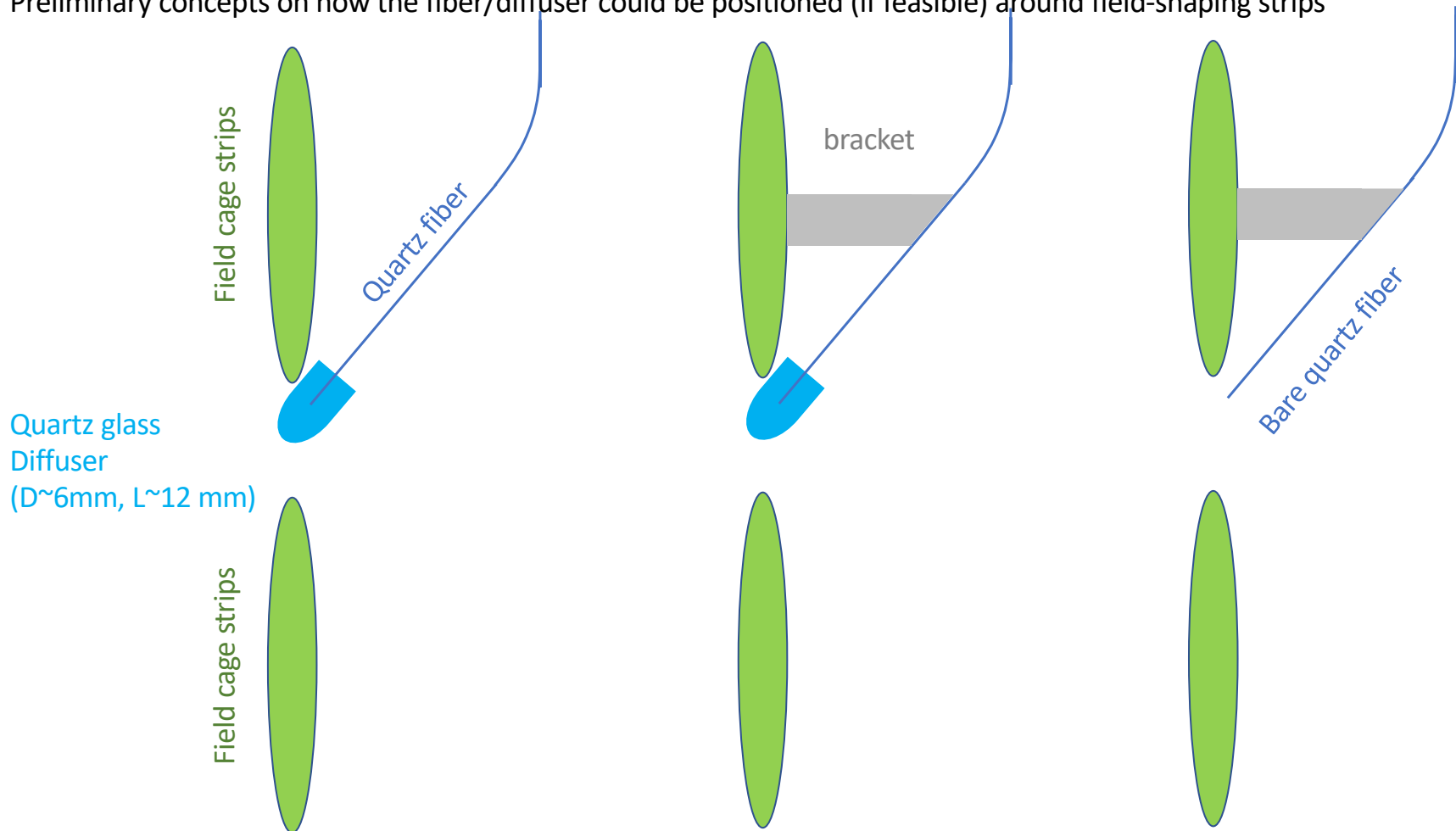




- Use ProtoDUNE-VD to prototype and qualify the calibration system for DUNE FD2-VD.
- A tentative plan is to order enough material to equip 16 calibration fiber ends at ProtoDUNE-VD:
 - All the corners of the cube inside the volume (8)
 - All the corners of the cube outside the active volume (8).
- Preliminary DUNE FD2-VD considerations (discussion with Ryan):

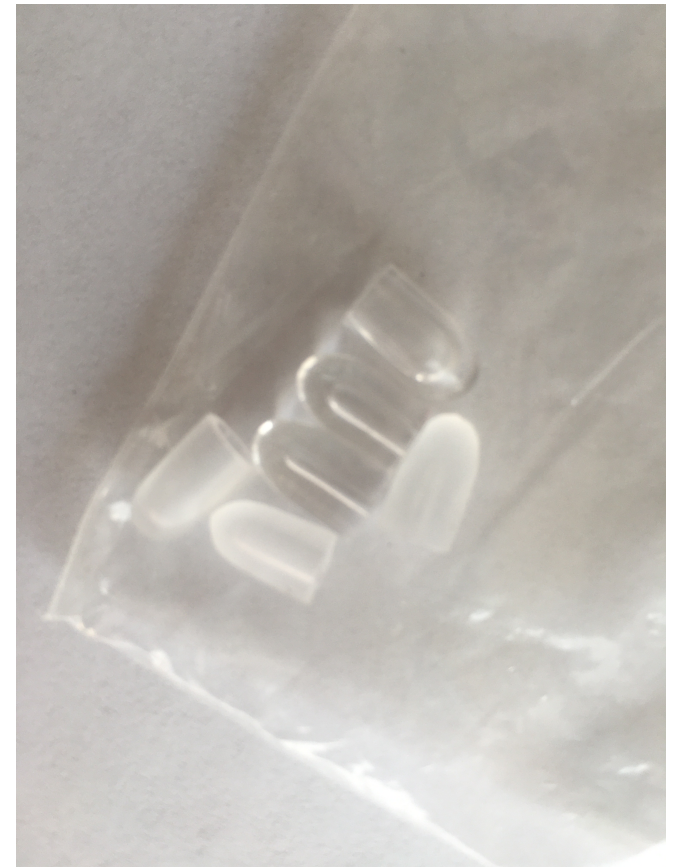
The DUNE plan would be 12 calibration fiber ends per 2x3 cathode section (3 above and 3 below in the active volume + 3 above/below outside active volume, or maybe 2 above/below would be enough -- would be 8 calibration fiber ends). There are 12 such sections of 2x3 cathode,.. which would mean 144 calibration fibers. The best idea we had was to attach the fiber ends to our conduit so we own it and do not have to interface with the anode folks. The fibers would also run to our 40 flanges.

Preliminary concepts on how the fiber/diffuser could be positioned (if feasible) around field-shaping strips



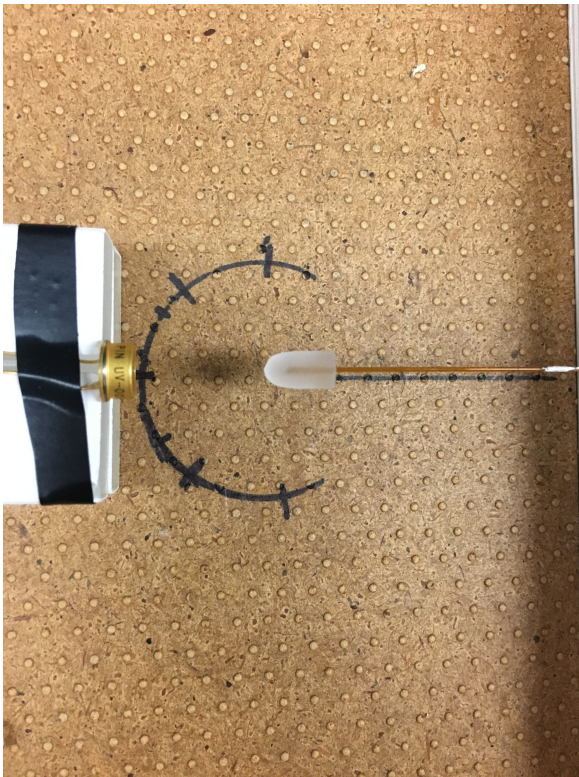
-Dimensions and shapes are arbitrary here; quartz fiber mass is ~1.5g/m; Diffuser mass ~3.0g (D~6mm, L~12 mm)

First Diffuser Prototype to be tested



First Diffuser Prototype Tests

- Initial Tests performed at ANL
 - evaluation of uniformity

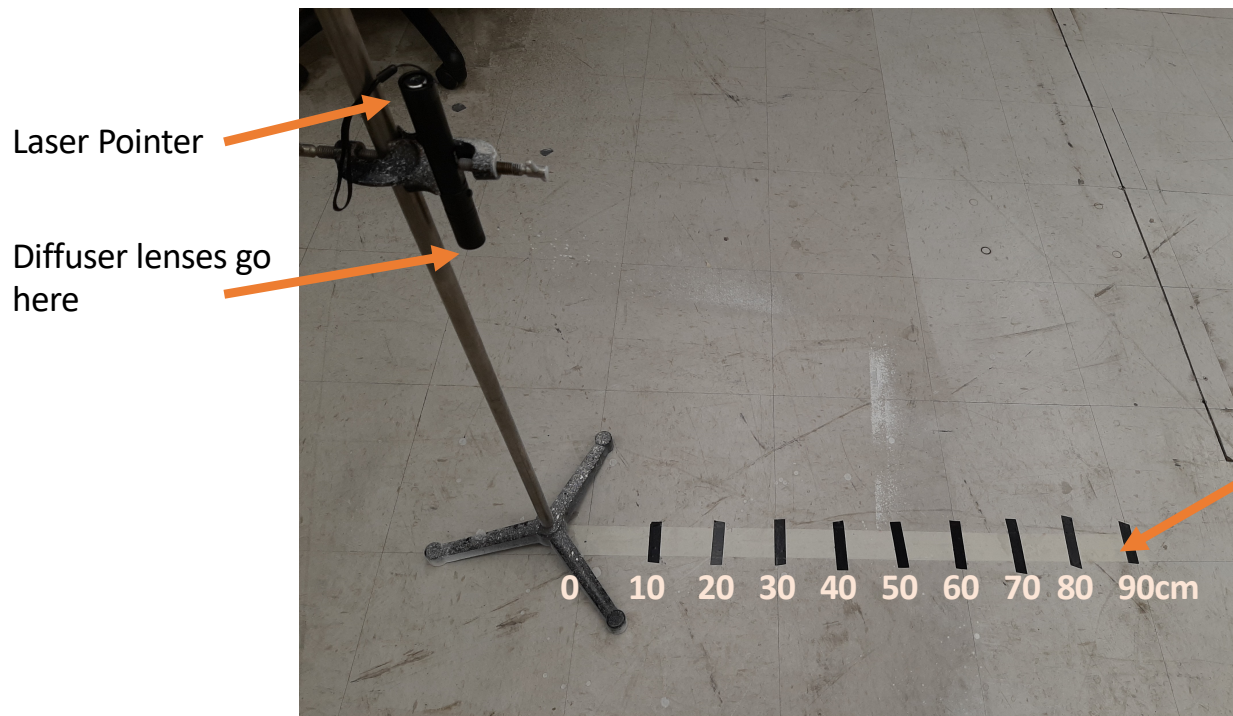


- Preliminary test shows a uniform light distribution within 45 degrees cone around the fiber axis
 - More detailed test at South Dakota with a dedicated setup (next slide); samples of diffuser shipped and arrived to SDSMT
 - Expertise in fiber routing distribution from ProtoDUNE-DP;

First Diffuser Prototype Tests (cont.)

➤ Detailed Tests to performed at SDSMT

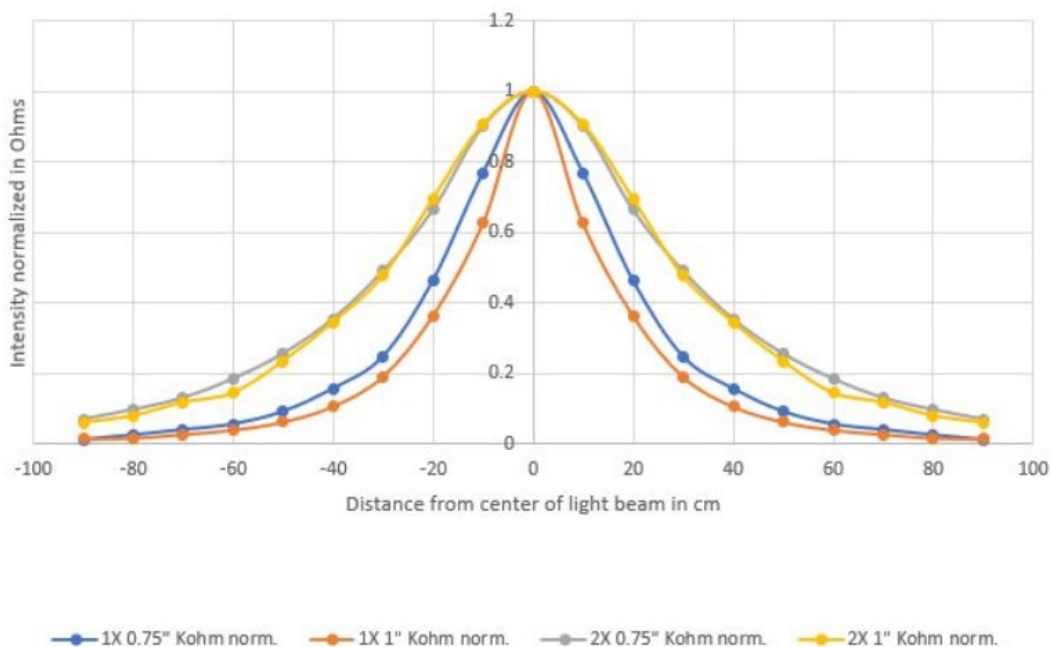
- Evaluation of uniformity in 3D
- Measure Intensity at each 10cm interval to get the function of intensity over distance
- Data was taken both in Lux and in Ohms, then normalized to 1



First Diffuser Prototype Tests (cont.)

- Example measurement performed with DUNE FD1-HD diffusers
 - Will perform a set of measurements with the ProtoDUNE-VD candidate diffusers.

0.75 vs. 1 inch diffuser, with one and two lenses OHM version

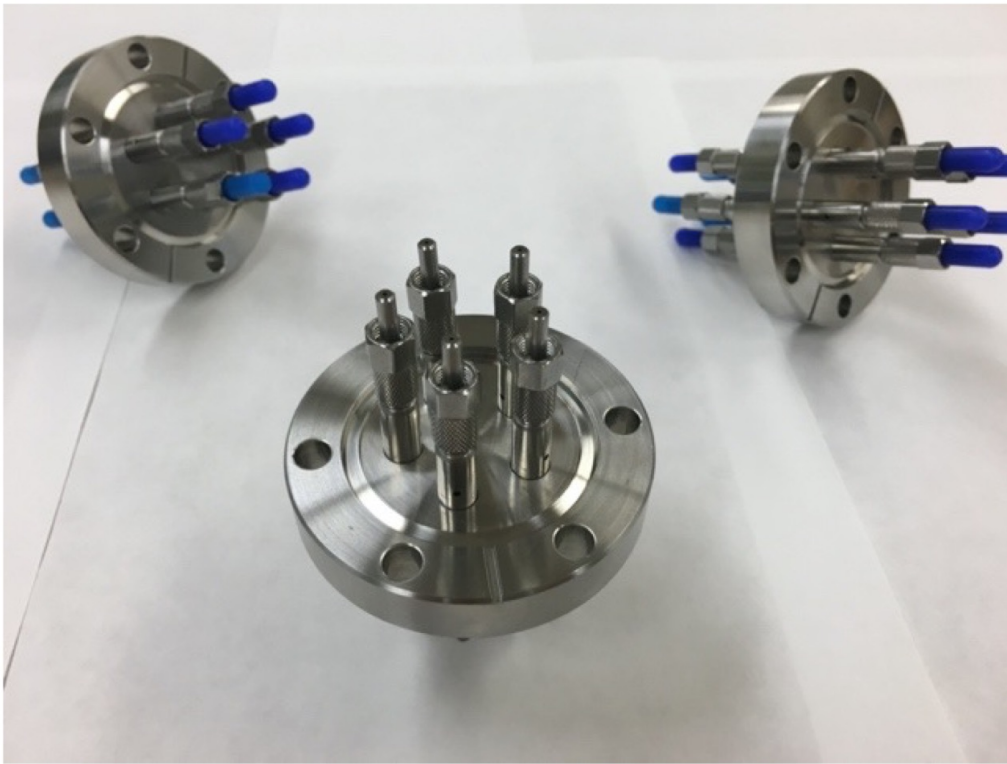


- Shows the relationship between both the number of diffuser glass layers vs. their intensities over distance
- Shows the relationship between the size of the diffuser glass vs. their intensities over distance

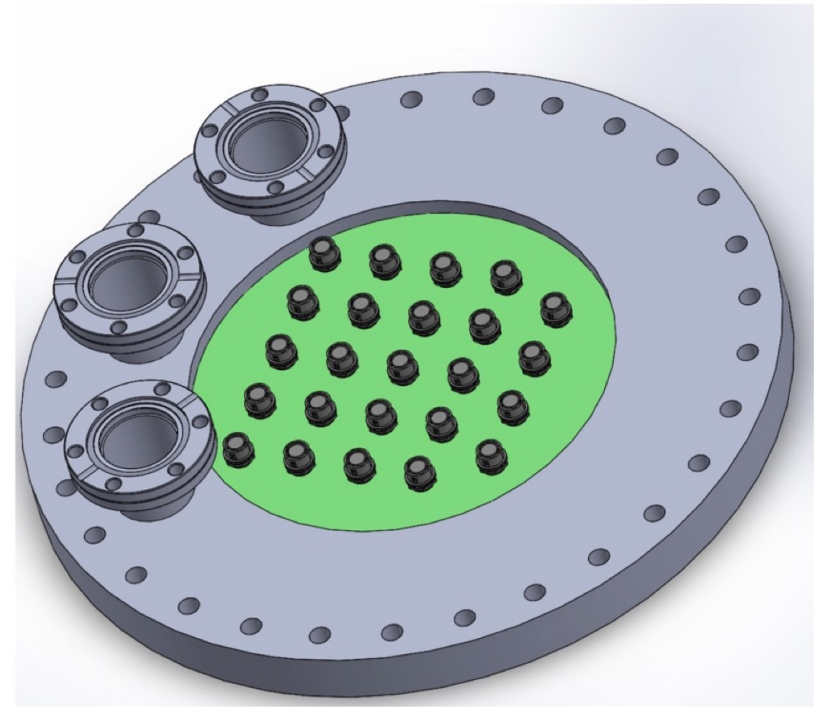
Next Steps in Calibration System Fiber Routing

- Discussed April 25/22:
 - Complete tests of fibers/diffuser diffusion as described above
 - Consider fiber mount at top and/or bottom CRP (information from Bo Yu)
 - Provide optical fiber specs and/or samples to the design team (Dave Pushka, Vishnu Zushi et al.)

Optical Feedthroughs

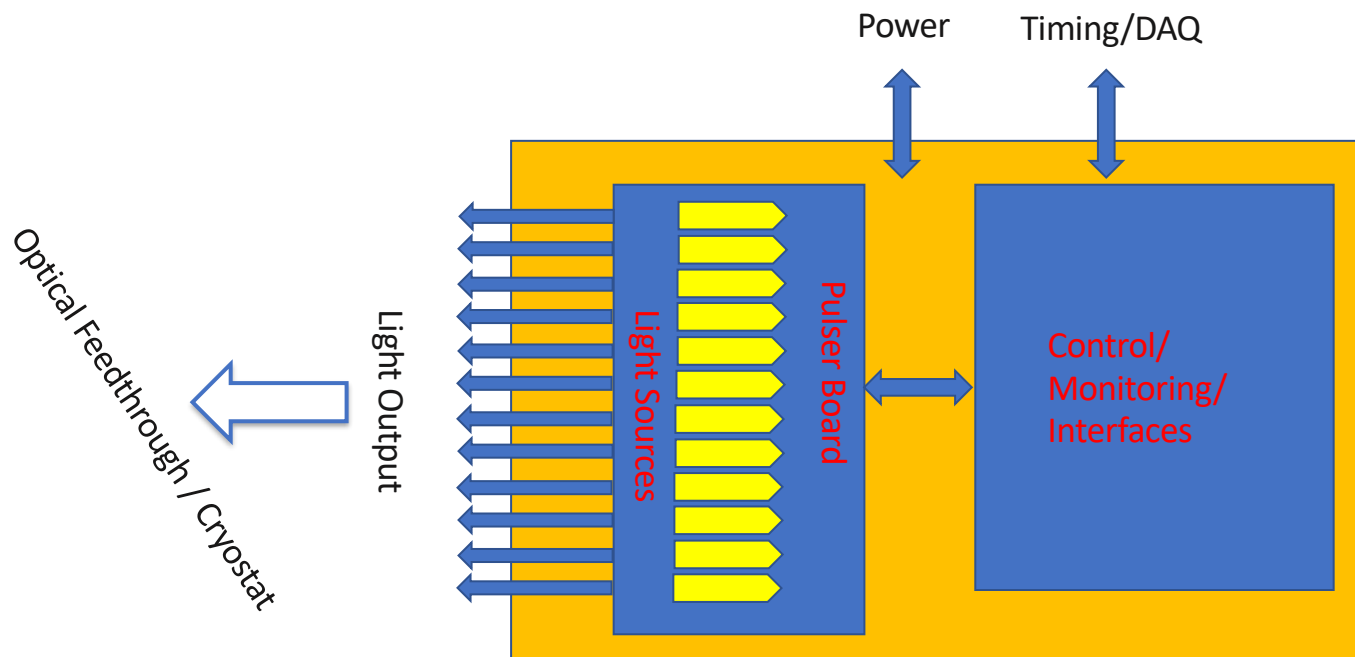


PDS Signal + Optical Flange



Electronics Boards

- Board schematics: control/interface board, pulser board, light sources, power supplies



Electronics Boards

- Summary of recent Prototyping and testing at CERN



- Able to initialize and configure the module through DAQ interface
- We communicate with the ProtoDUNE timing system
 - Running state of the module (the module is locked to the timing master),
 - Measure the round-trip time (timing master -> end-point (calibration module) -> timing master.
 - Set timing delays.



- Recent Light Source Design and Tests

-Based on initial LED/PD testing/selection

-One of the design steps was to produce pulser board and light source prototypes for VD cold box

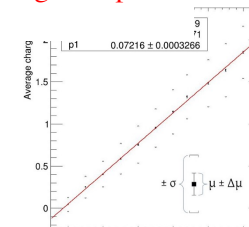
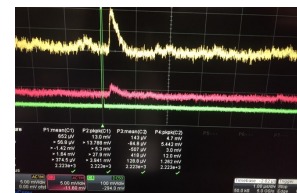
PDS calibration at CERN

-Fibers and diffusers from ProtoDUNE-I



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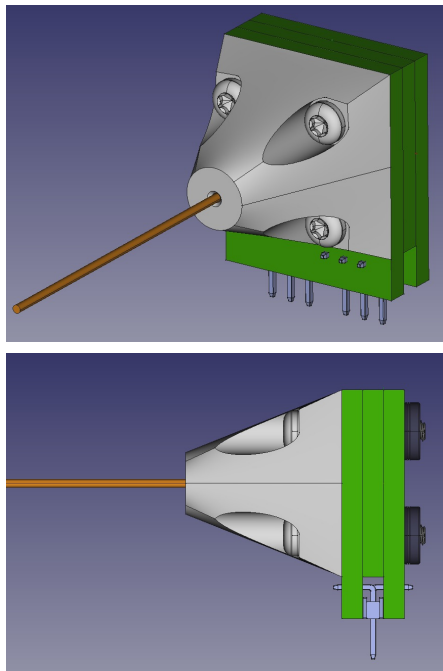
Measurements at CERN: light response, linearity.



Results:
Sabrina,
Dante

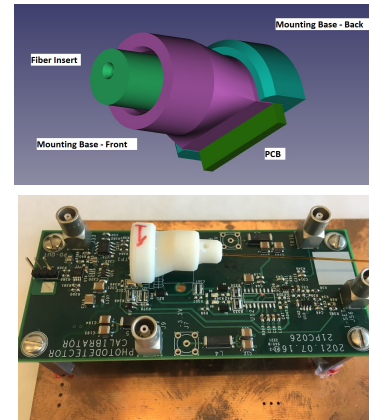
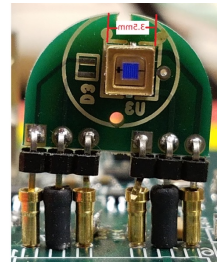
Electronics Boards

- LED and PD PCB/assembly
 - Fiber holder/insert
 - LED and PCB assembly
- bolts to hold the fiber holder on PCB housing
 - Components 3D-printed

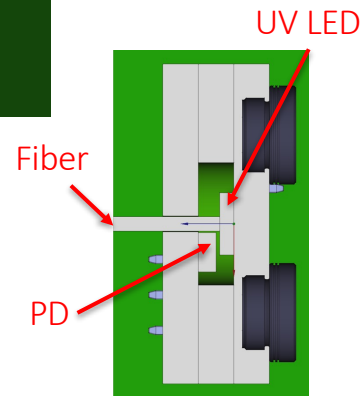
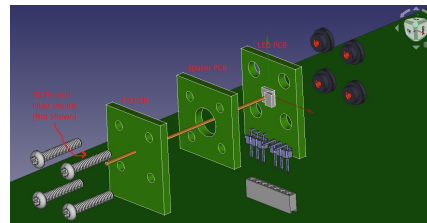


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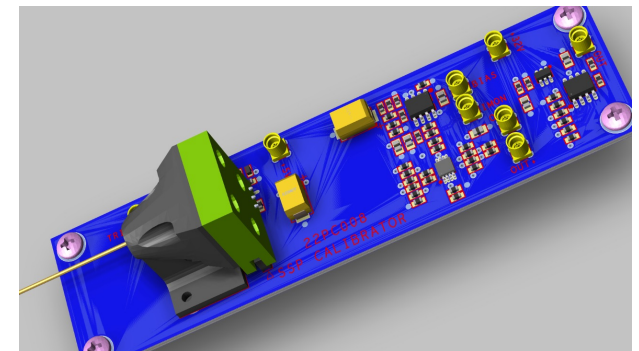
Initial implementation



New implementation

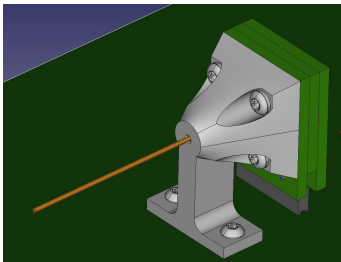


Final Single channel

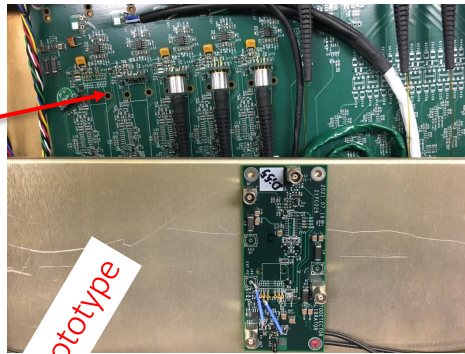


Electronics Boards

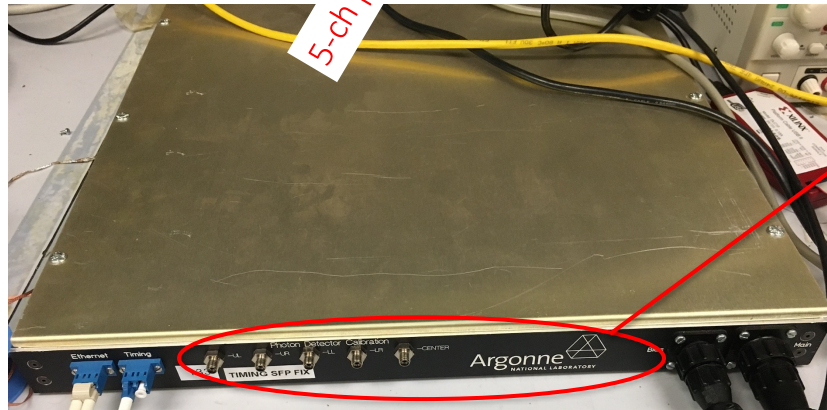
- New design of pulser board and light source effectively converts 5-ch prototype design to final 12-ch module (aside from motherboard HW/FW updates)



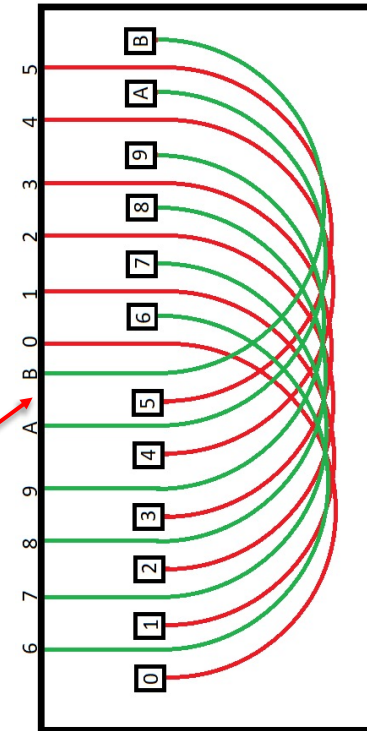
New light source design



5-ch prototype



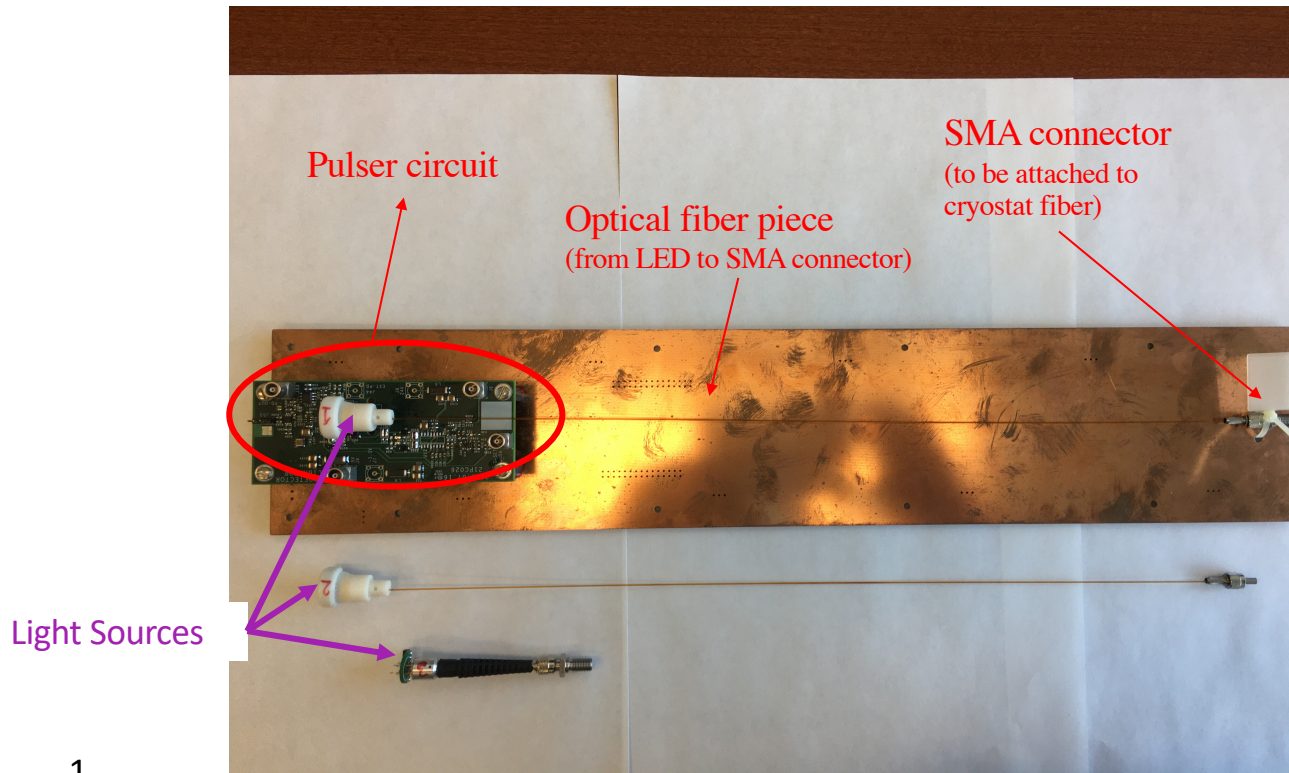
TIMING BFP FIX



12-ch design

Light Source Prototype Testing at CERN

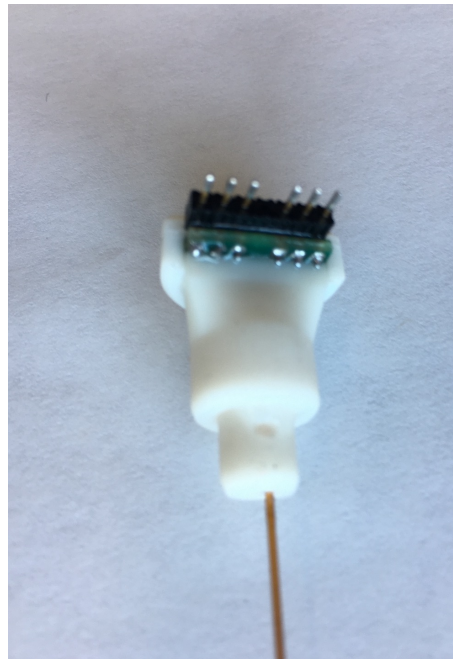
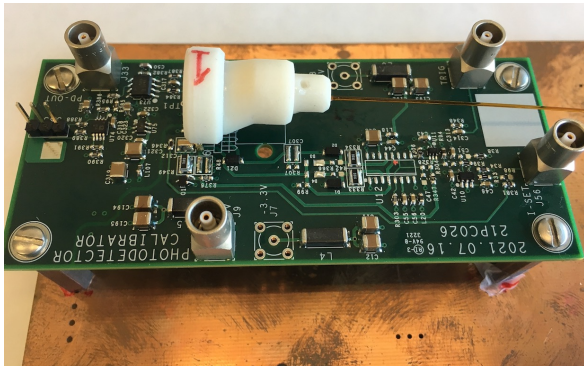
- Used one of the first new light source and new pulser board prototypes to CERN with PDS-VD Cold Box
 - Three light sources are added (LED#1, LED#3 @ 275nm, LED#2 @ 365nm)
 - Already test results by Sabrina, Dante, Flavio.



Show cold box,
Fibers, diffusers

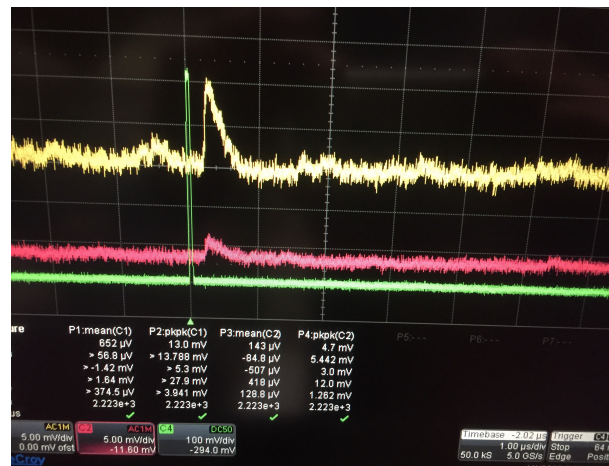
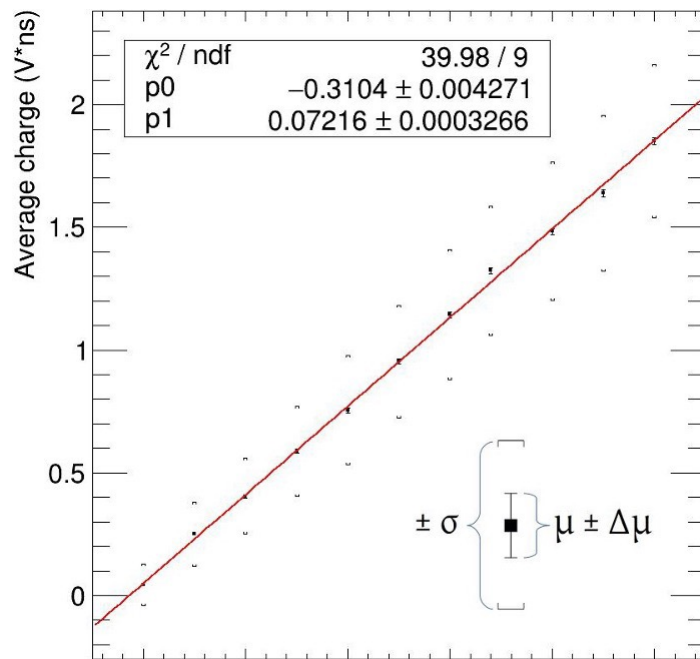
LED Pulsar Test at CERN: Description

- Light sources are attached to the pulser board, via six pin connector
 - Light sources may be de-attached/attached to the board
 - Fiber is fragile (quartz) and need to be handled with care



LED Pulsar Test at CERN: Description

- Measurements at CERN: light response, linearity.
 - Prototype pulser used to verify linear response of the SiPMs (x-ARAPUCA tested at CERN) to calibration LED signal of increasing amplitude.



From Sabrina, Dante

BACKUP SLIDES