Snowmass white paper planning meeting
Friday May 8, 2020, 1:00 PM

POF SiPM
Liquid Argon - Light Detection

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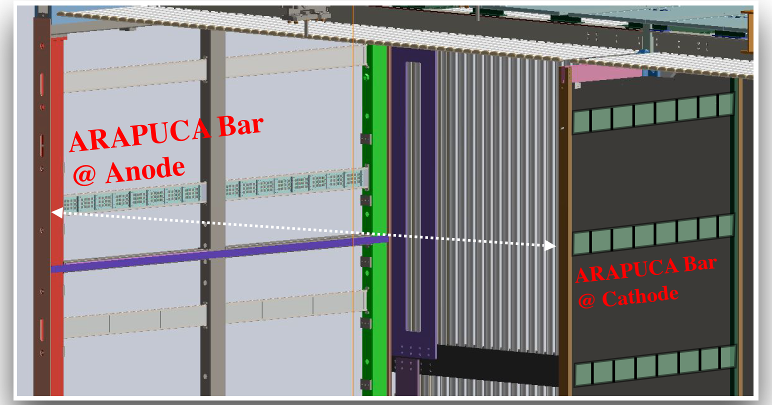


PhotoDetector technology in DUNE Module(s)

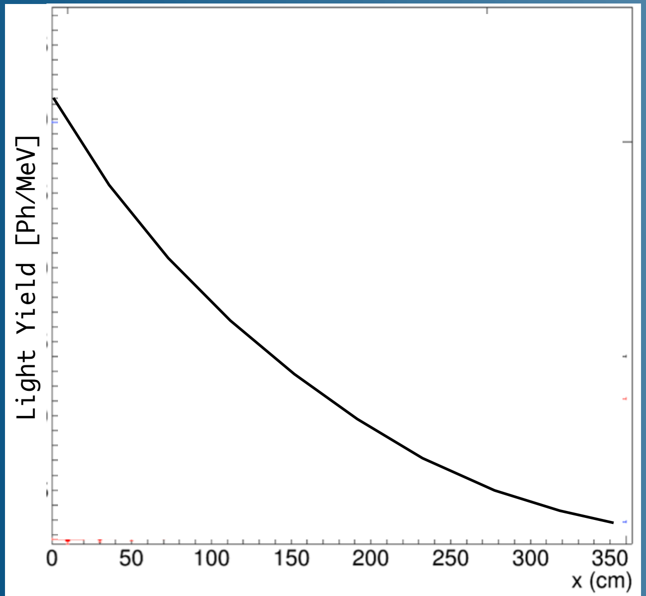
Technology choice: ARAPUCA - based on comparative results from protoDUNE-SP

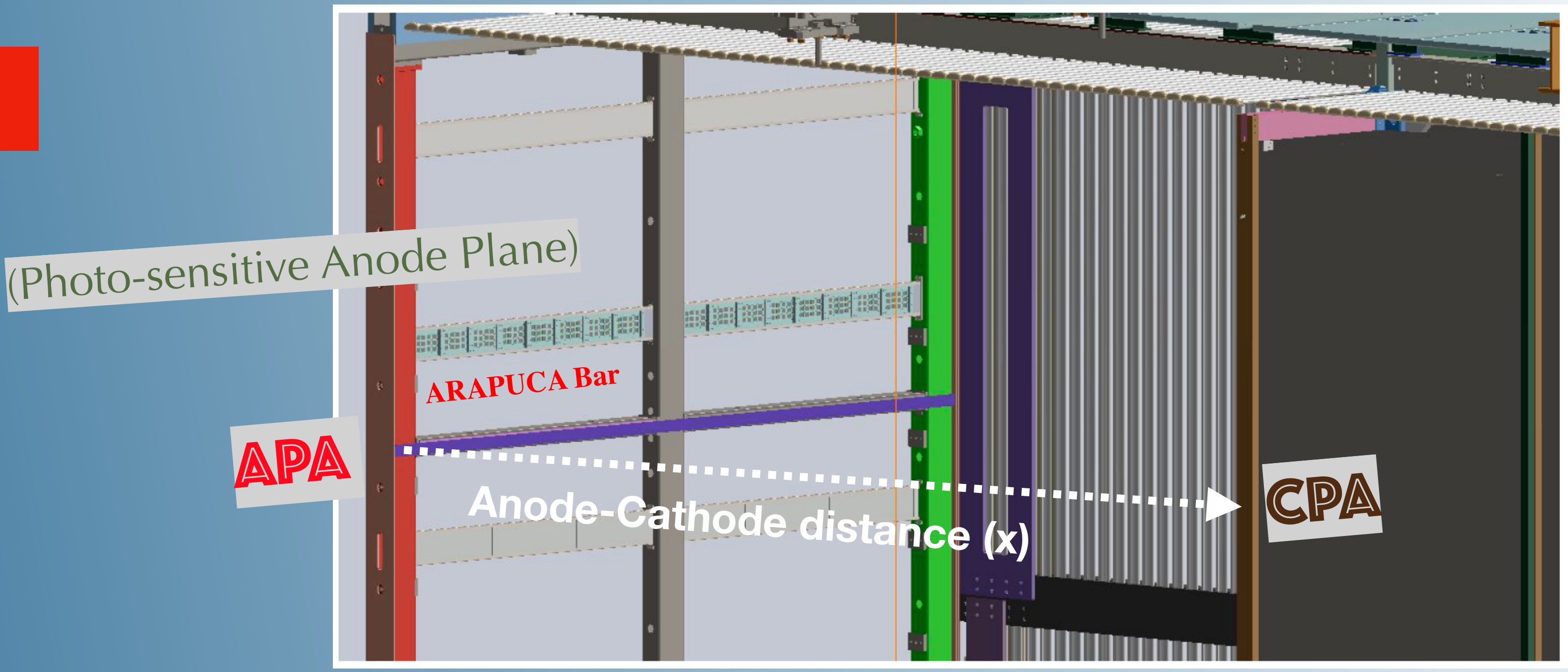
Main Features:

- **Flexible design: Compatible with APA/LArTPC geometrical constraint of DUNE (1st Module)**
- **Demonstrated enhanced Efficiency (few % range) with possible further optimization (X-ARAPUCA)**
- **(Relatively) Large Light Yield: 1.9 photons/MeV from extrapolation to a PDS system consisting entirely of ARAPUCA modules for light signals at the farthest distance (CPA)**

Unresolved drawback of the design

large non-uniformity of the light response
as a function of drift distance

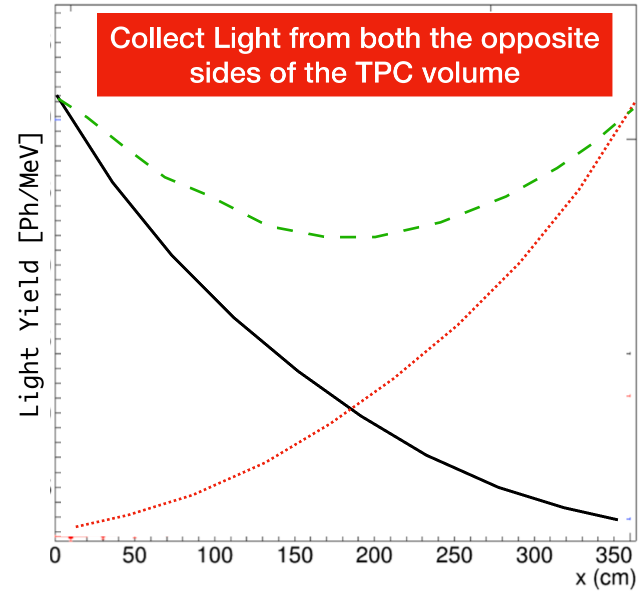


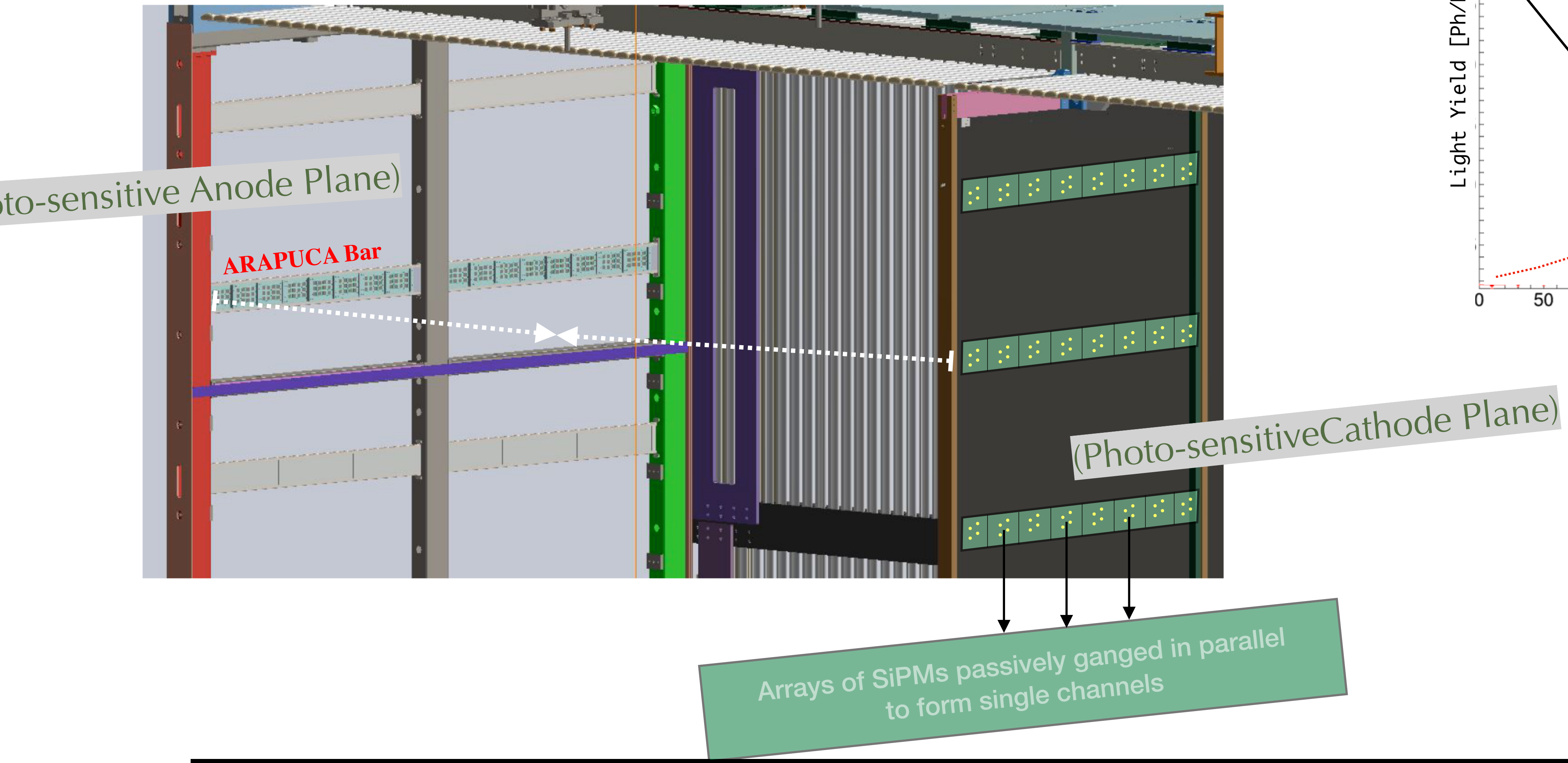


transform the CPA into a photo-sensitive cathode plane

W. Pellico - F. Cavanna (FERMILAB)

- Collect Scintillation Light from both the opposite sides of the TPC volume = **ideal solution** to:
  - make the response uniform across the detector
  - enhance the light yield
  - improve the pointing capability/space resolution of the PDS





Instrumenting with photo-sensors a surface at very large HV is a challenge that requires dedicated R&D

*the challenge is to **supply bias voltage** to the photo-sensors (in the range of 50 V or less) on the cathode plane and to **read-out the signal** out of the cathode plane at (nominal) 180 kV*

POF System – Two Parts

- Power to fiber
  - Convert electrical power to light
    - Four modules are required to generate 48 V
    - Each are **4 watt** laser systems
    - Individual adjustable output power
    - Interlocked – to protect laser/personnel
  - Transmit via fiber –
  - Fiber optic receivers
    - Four 48 volt receivers are tied in series
    - Typical conversion efficiency is 22 %

- SiPMs cold electronics module
  - Gang some number of SiPMs
  - Route signal to fiber transmitter
    - Convert electrical to light
    - Eleds – analog light transmitters
- SiPMs warm electronics module
  - Fiber to copper
  - Signal conditioning
  - Signal processing

SiPM POF System Concept

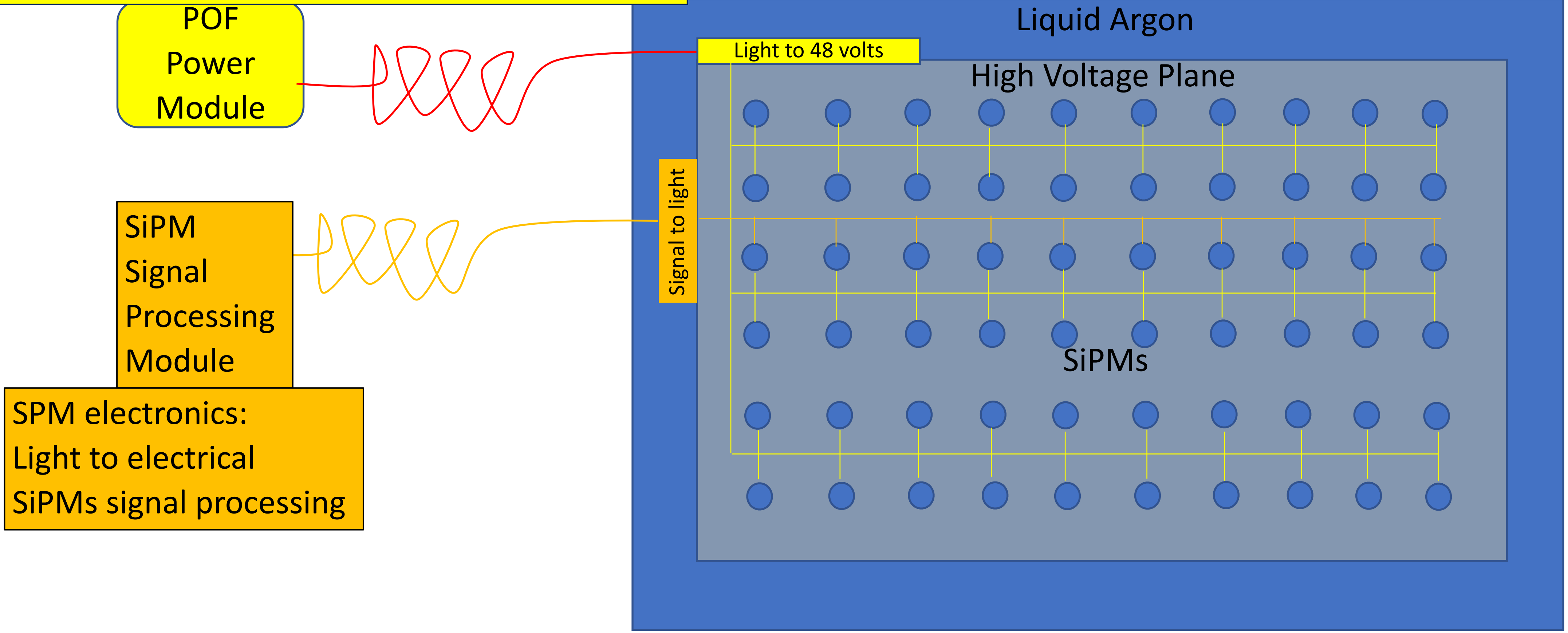
POF system:

1 Electronics box to house POF modules and Safety Interlocks

4 POF modules each capable of 4 watts

4 Light receivers summed on circuit board

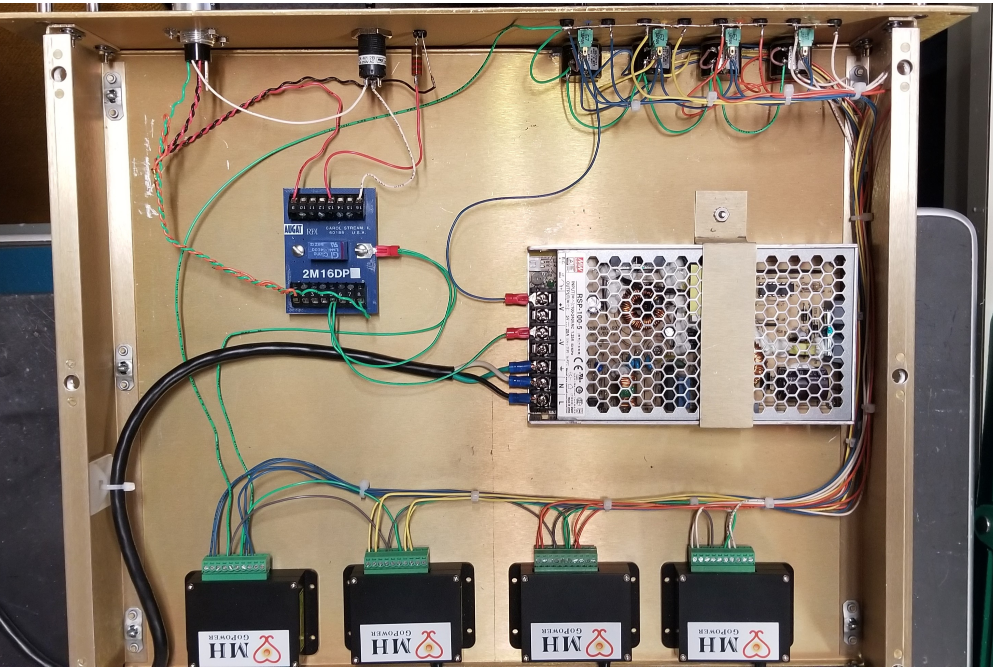
POF receiver resides inside detector on HV plane

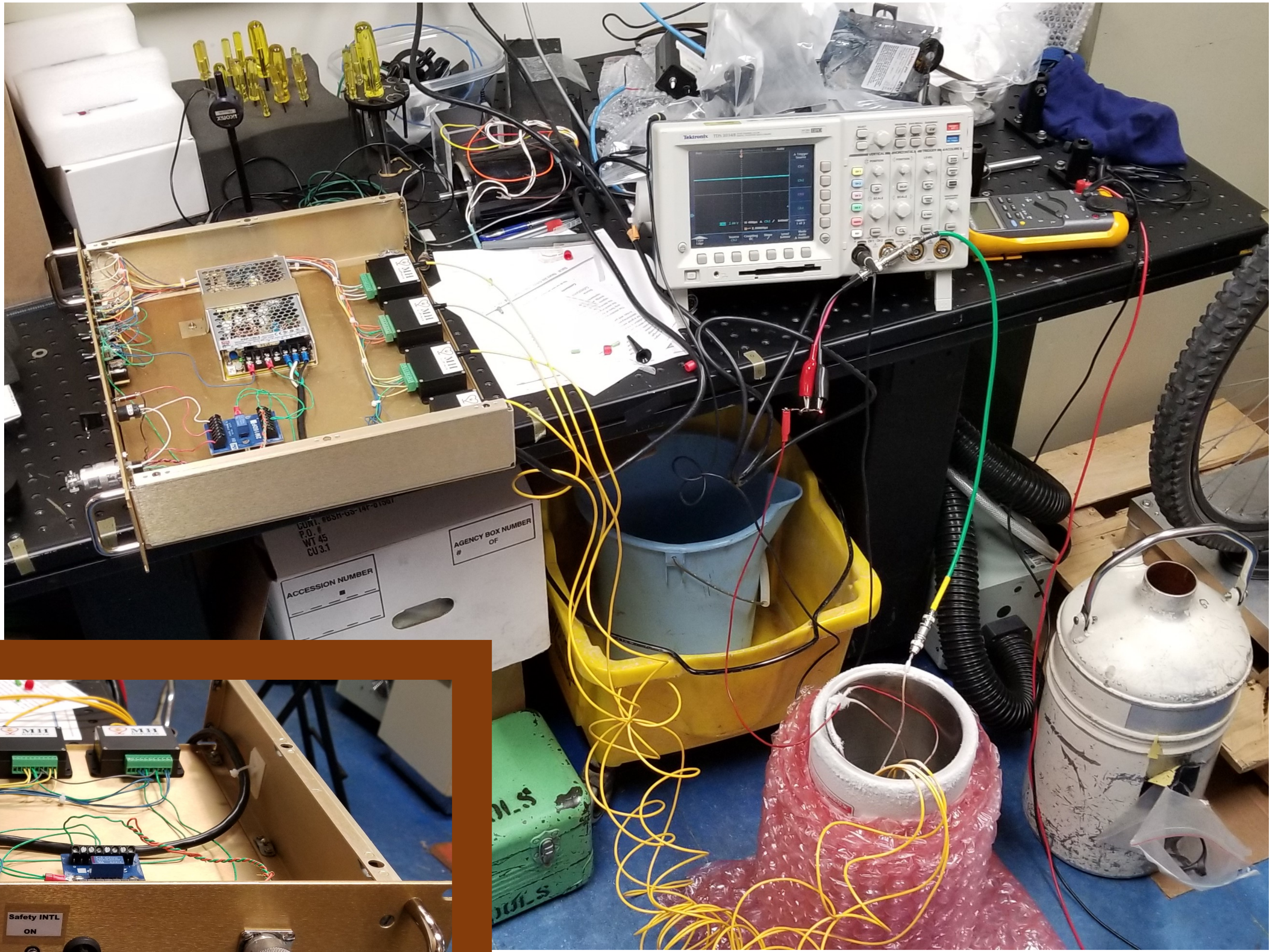


Work Done

- Investigated several vendors – found a suitable POF product and purchased 4 units
    - Each Laser POF system is capable of about 12 Volts, several mA at room temperature.
- Built a module to house the laser drivers, power supply, hardware interlocks and safety controls
- Tested individual units to verify specifications
- Built a simple board that ganged the four laser/fiber receivers together to reach the required 48 volts.
- Tested the POF 4 receiver system in at room temperature and then in LN
- The receiver module has tap points to monitor voltages and current – used for testing in LN
- Ran simple first tests with SiPMs (two) to verify they responded to pulsed light in LN

All testing has gone well – meeting design values - LN tests look good





Testing of POF with SiPM module in LN

Measured voltages/current of POF

Verified SiPM operations

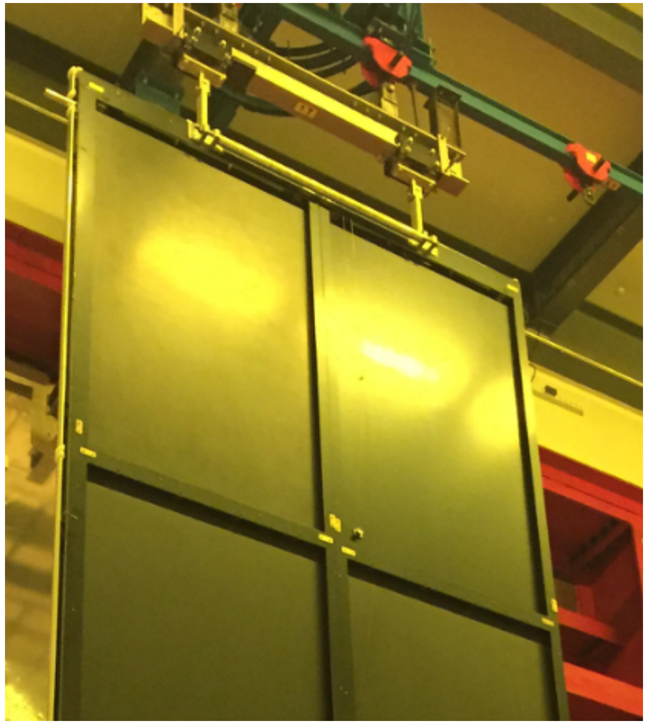
Work to be done & Issues

- Verify gang of SiPM works
  - Calibrate SiPM response
    - Take POF system out to PAB and perform calibration of system
    - Verify the Si
- Reliability of system – long test runs
- Cold electronics – transmitters – Only tested simple Eleds
  - This is difficult due to lack of verified electronics
  - Which Eleds/electronics to use to convert electrical SiPM signal to fiber
  - How many signals are to be combined
  - What is the power needed (POF has some power overhead but is it sufficient
  - Do we need a separate POF to power the E2Fiber electronics
    - First guess is may not be necessary but only back of the envelop numbers

Further steps towards implementation in actual photo-detector system(s):

- Test and certify functionality of a *multi-SiPM board (passive ganging) with PoF Receivers (power-in) and ELeds Transmitter (signal-out*) on a HV plane immersed in Liquid Argon [at FNAL: Lab tests + PAB tests]

- Design and develop/optimization of a multi-SiPM board with PoF Receiver/Transmitter suitable for installation onto DUNE CPA panel (including fibers routing) & Test in LAr [at CERN, CryoLab with available CPA panels].



- Further development can explore implementation of **photo collectors** embedded in the cathode plane: the **ARAPUCA design** looks adaptable to this purpose [final test, after approval, in protoDUNE-SP Phase 2 - currently expected in 2022]