Exploiting abundant LAr scintillation light *(complementary to ionization charge)* is the way to enhance/extend detection DUNE FD sensitivity in the low-energy range for rare UG events.

To this end **key point is to extend to 4π the PD Optical Coverage**
To embed a 4π PD into a LArTPC layout is a technological challenge

Operating PD on HV surface requires
electrically floating Photo-sensors and r/o Electronics
$\Rightarrow$ Power (IN) and Signal (OUT) transmitted via non-conductive cables

none of the commercially available technologies is rated to operate in Cold (at LAr Temperature)

A highly specialized R&D is ongoing
to validate existing technology in Cold
or develop Cold custom technology for this application

- “ $\sim 4\pi$ VD” solution for extending DUNE Physics Reach described in VD Proposal

- Fallback solution for minimizing technological risks (PD on cryostat walls) concept under development and initial MC simulations

- Very intense activity VD 4π PD R&D in US (at FNAL, BNL, UCSB, CSU), in Eu (at APC-Paris, Mi-Bicocca/INFN, ...) and in Br (at UNICAMP, UF ABC, UF SC). Progress & first Results

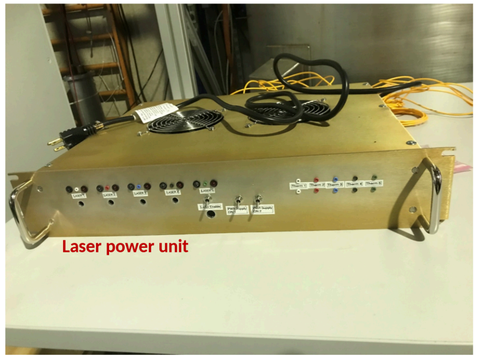
PoF (Power transmission over Fibre)

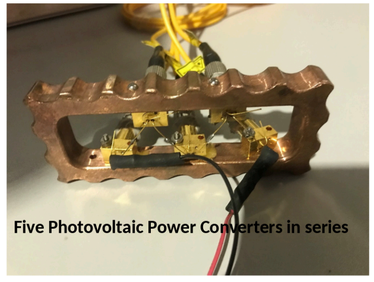
optimization for

- ✳ SiPM (higher voltage, very low current) and
- ✳ CE (low voltage, higher current)

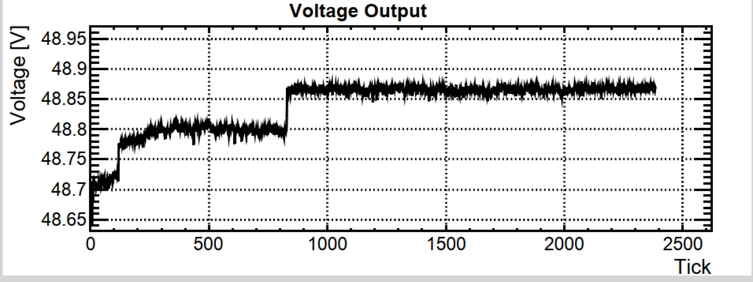
- First development (PoF concept) at FNAL:
- Prototype sent to CERN [Oct. 2020]:

Power over fiber system from Fermilab:





- Tests PoF for supply bias V SiPM board in LAr (CERN 50 lt test setup) [Nov-Dec.] - 60 V, 400 mA (Opto-Electric effic. 22% in cold)



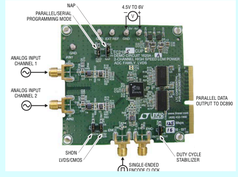
- Detected IR glow of fibre from optical pwr transmission (need fibre protection)

- Second development at FNAL (ongoing): new higher efficiency Pwr Converter found and tested (>30%).
- Prototype supply voltage (2-5 V) - high current for Cold Electronics in preparation

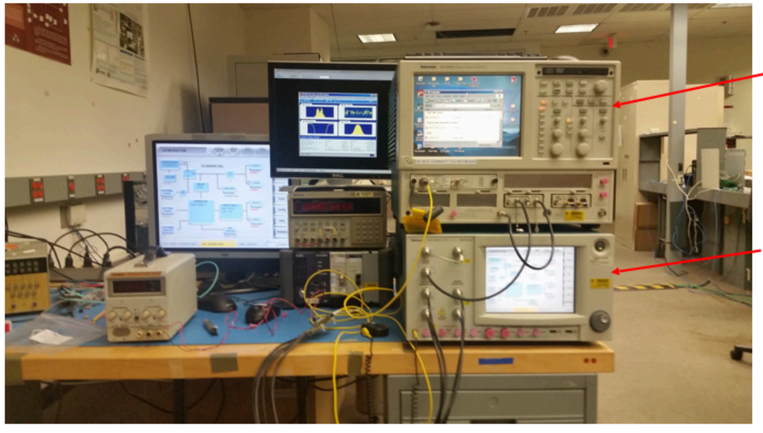
Cold Electronics & Digital Transceiver (Opto-Link for Signal Transmission)

- Specs & Design for fully Cold Electronics under development: Active Sum/Amplif. + ADC + FPGA Aggregator + OptoLink

- Cold ADC candidates selected, acquired and implemented in dedicated demo board - tests in cold to start



- Opto-Link: 12 **digital** OptoLink samples (adopted for CMS/ ATLAS) selected for tests in Cold (LN2) and procured.
- Optical Test stand re-assembled at FNAL/SCD.

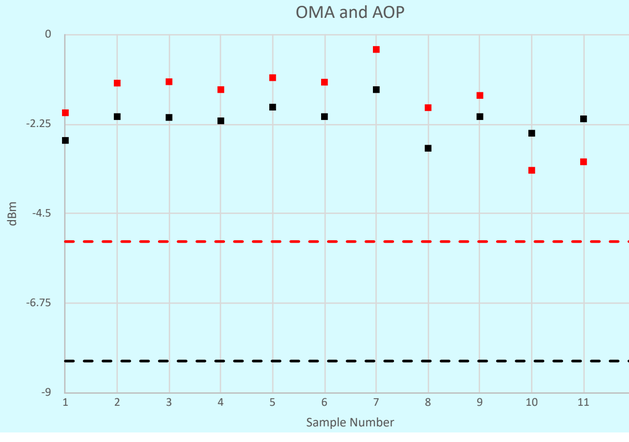


- The 12 samples fully benchmarked in Warm [eg Optical Modulation Amplitude (OMA) and Average Optical Power (AOP)]
- Ready to start Cold Test (in LN2 dewar). Unfortunately SCD management decided not to allow use LN2 in Feynman Center
- Now test stand is being moved to PAB - cold tests start expected very soon

Analog Transceiver

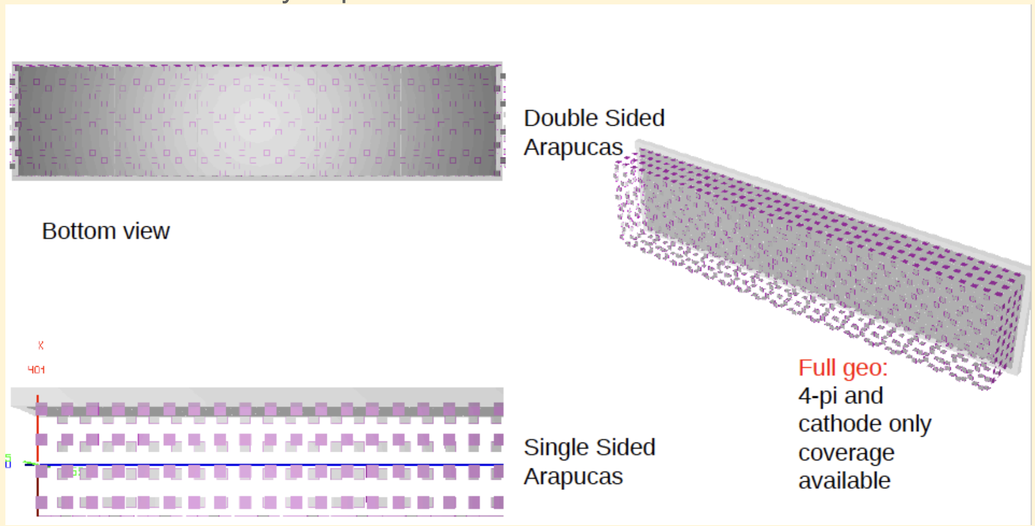
An alternative solution for Signal Transmission is provided by **Analog** opto-transmitter (as currently developed by DarkSide Collaboration)

Synergic efforts started by Eu Grps (in France and Italy) with DS on Analog opto-links development



VD 4π PD Simulation in LArSoft

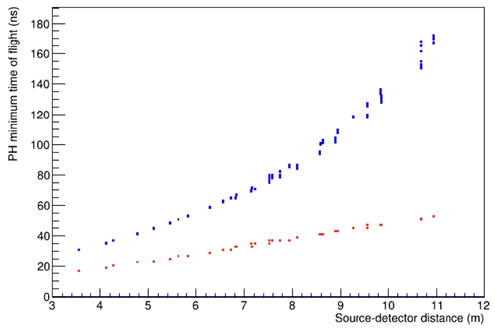
- VD PhDet Geometry implemented in LArSoft



- Ar+Xe features added based on protoDUNE results
- LY dependance on reflectivity of materials at LAr volume boundaries under study
- Simulation of Electronics Response
- Simulation of photon Timing and Time Resolution

Time information

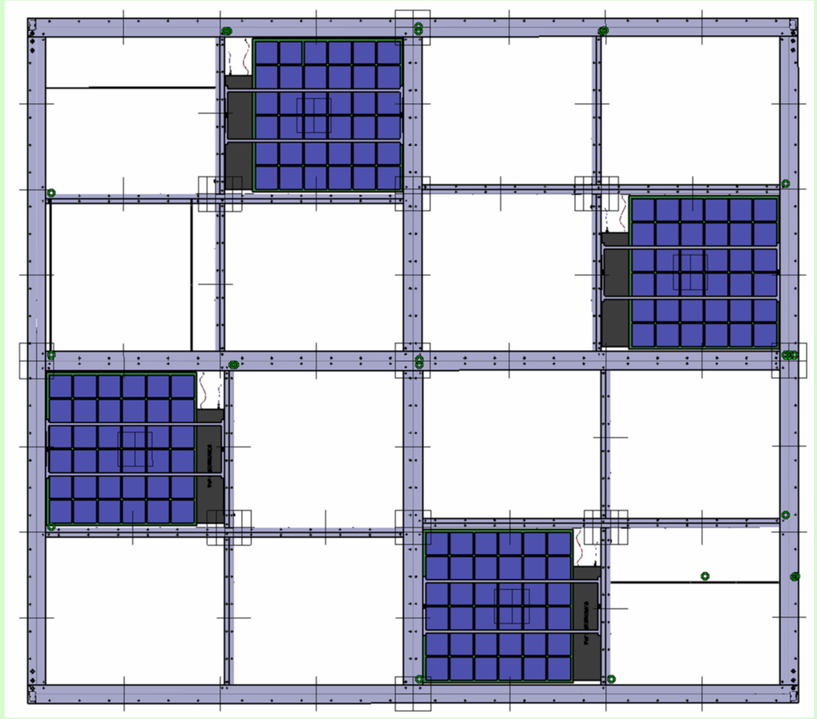
Argon vs Xenon comparison

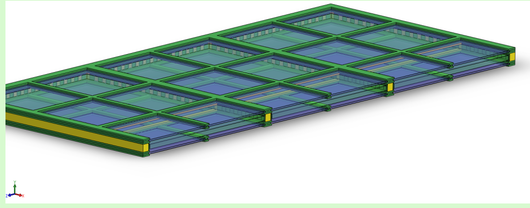


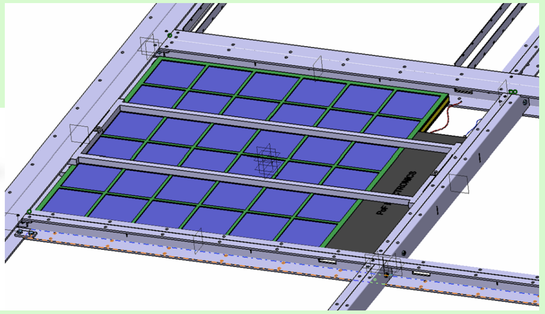
- FLUKA simulation for VD PD fallback Option (confirm MC results for **4π PD**

xARAPUCA detector design and integration

- Progress in xARAPUCA detector design and integration in Cathode mechanical Structure - in collaboration with LAL Orsay - IN2P3







The VD PD Fallback design

a PD scenario with no critical technological risk associated

- Operate PD on surfaces at Ground:

PD Active coverage distributed onto the 4 vertical sides of the Membrane Cryostat (outside the FC)

+

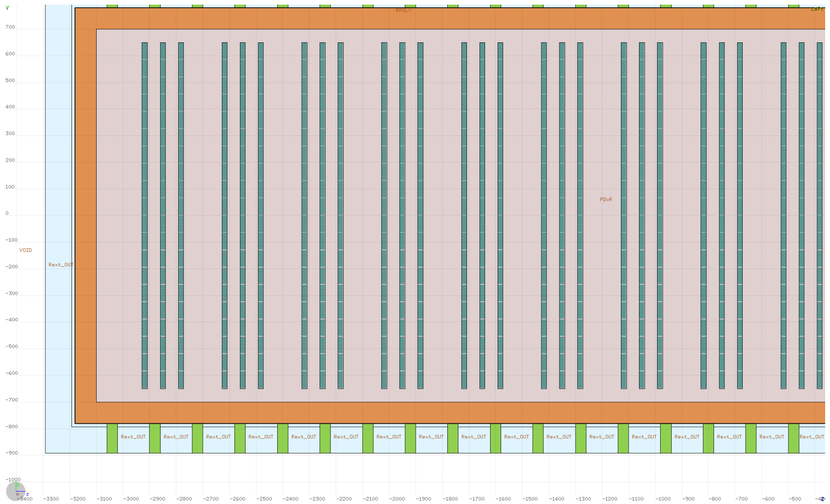
Modify Field Cage design (thinner profiles & wider gaps btw. profiles to increase FC transparency)

+

Xe doping (minimize Rayleigh scatter for light at far distance)

Simulation in progress

Implemented geometry: Megacells on the Cryo inner surface: side view



P. Sala

No critical R&D required - just re-design existing ARAPUCA Technology
no need of new electronics and power/signal transmission

On the other hand

reduced performance compared to the $\sim 4\pi$-PD is expected $\Rightarrow$
no expanded physics scope, no reduced fabrication cost