DUNE FD-2 Photon Detector Workshop

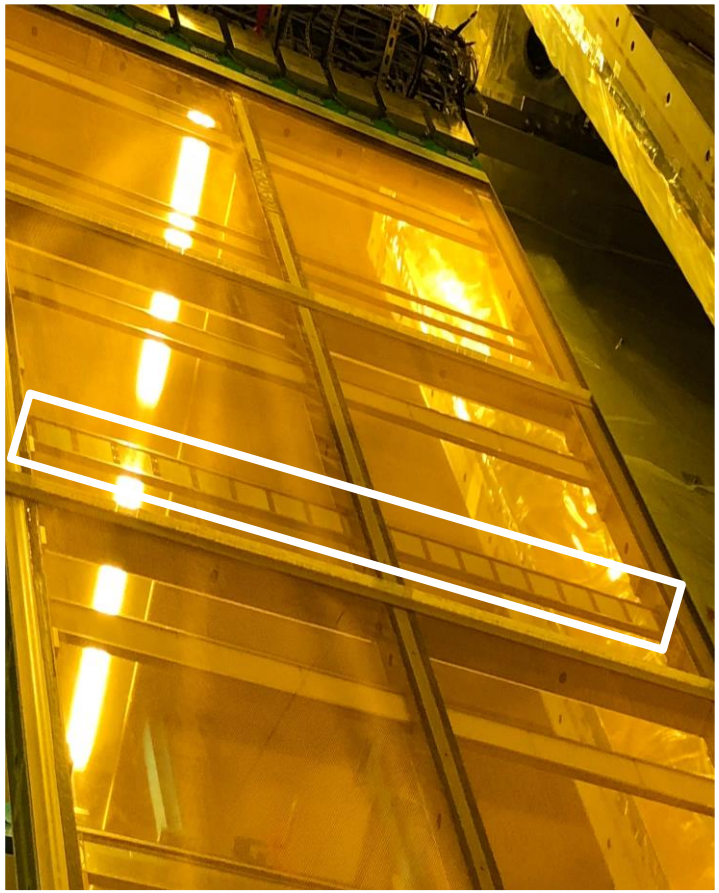
Ettore Segreto

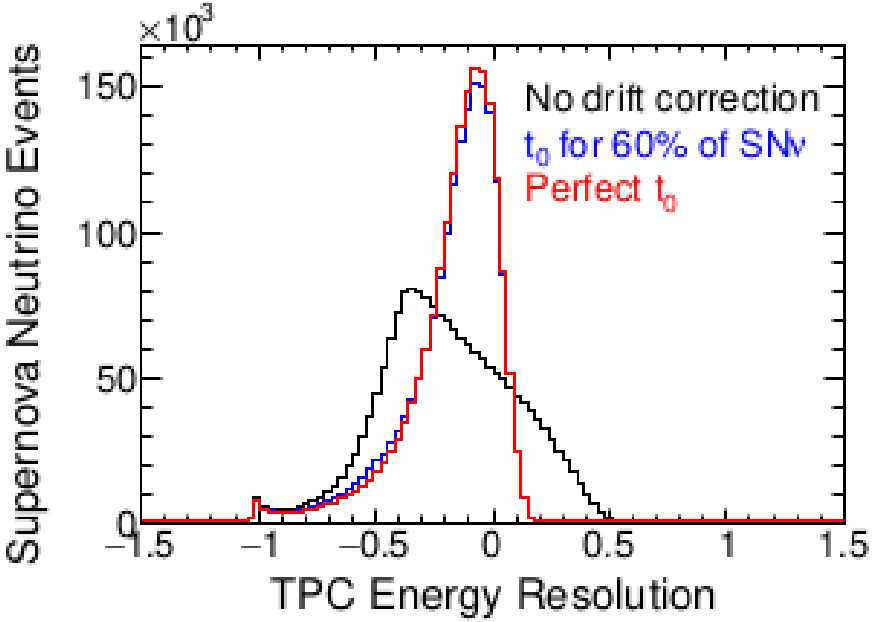
26th July, 2021

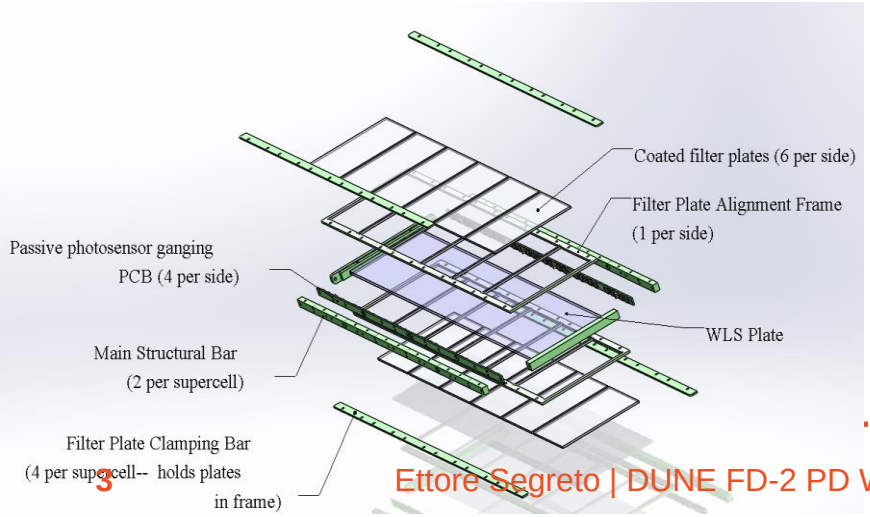
CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico
FAPESP FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO
IFGW UNICAMP
DUNE

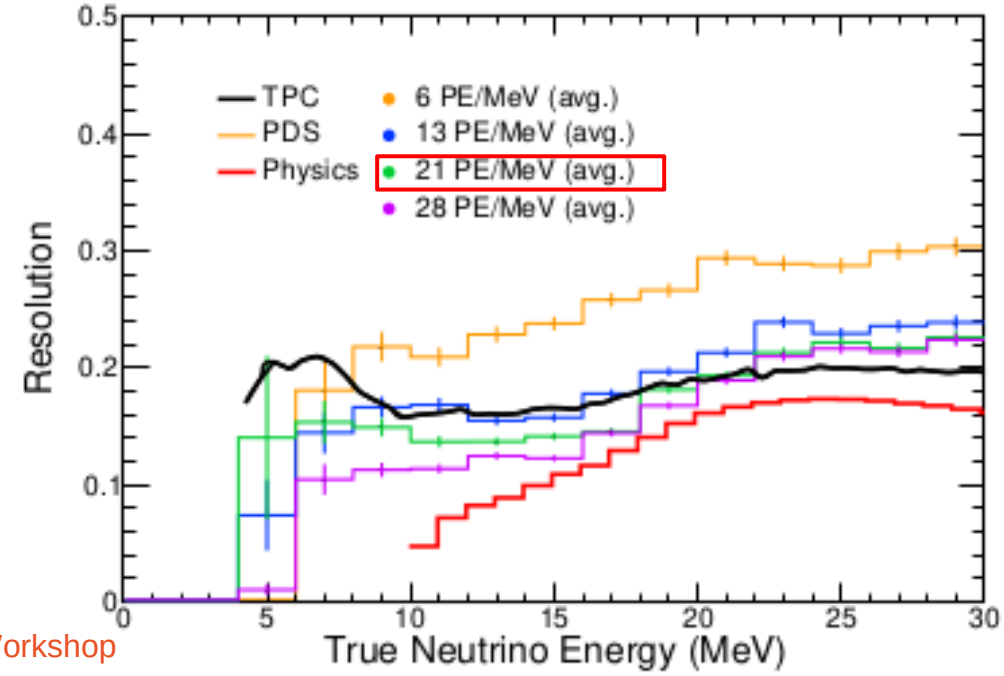
From FD-1 towards FD-2

- The Photon Detection Consortium of the DUNE Collaboration was formed in 2017 with the goal of designing, validating, constructing and installing the PD system of the first Far Detector module (FD-1) of DUNE;
- The PD Consortium has developed a solid design based on X-ARAPUCA light traps, SiPM read-out, cold SiPM ganging and warm read-out electronics (DAPHNE) which will be fully validated in the second Run of protoDUNE in 2022;
- Despite the mechanical constraints which had to be respected, the PD Consortium developed an excellent system. The Light Yield expected in the Time Projection Chambers, besides allowing to comfortably measure T_0 for non-beam events, will allow to enrich the physics program of the experiment at low energy;
- The energy resolution (with light) of events with visible energy below 10 MeV is competitive to what can be done with charge;
- The constraints of the shape and dimensions of the modules and the geometrical configuration of the TPC make the collection of light non-uniform and limit the maximum LY.




×10³
150
100
50
0
Supernova Neutrino Events
No drift correction
t0 for 60% of SNν
Perfect t0
−1.5
−1
−0.5
0
0.5
1
1.5
TPC Energy Resolution


Coated filter plates (6 per side)
Filter Plate Alignment Frame
(1 per side)
Passive photosensor ganging
PCB (4 per side)
WLS Plate
Main Structural Bar
(2 per supercell)
Filter Plate Clamping Bar
(4 per supercell-- holds plates
in frame)


0.5
0.4
0.3
0.2
0.1
0
Resolution
TPC
PDS
Physics
6 PE/MeV (avg.)
13 PE/MeV (avg.)
21 PE/MeV (avg.)
28 PE/MeV (avg.)
0
5
10
15
20
25
30
True Neutrino Energy (MeV)

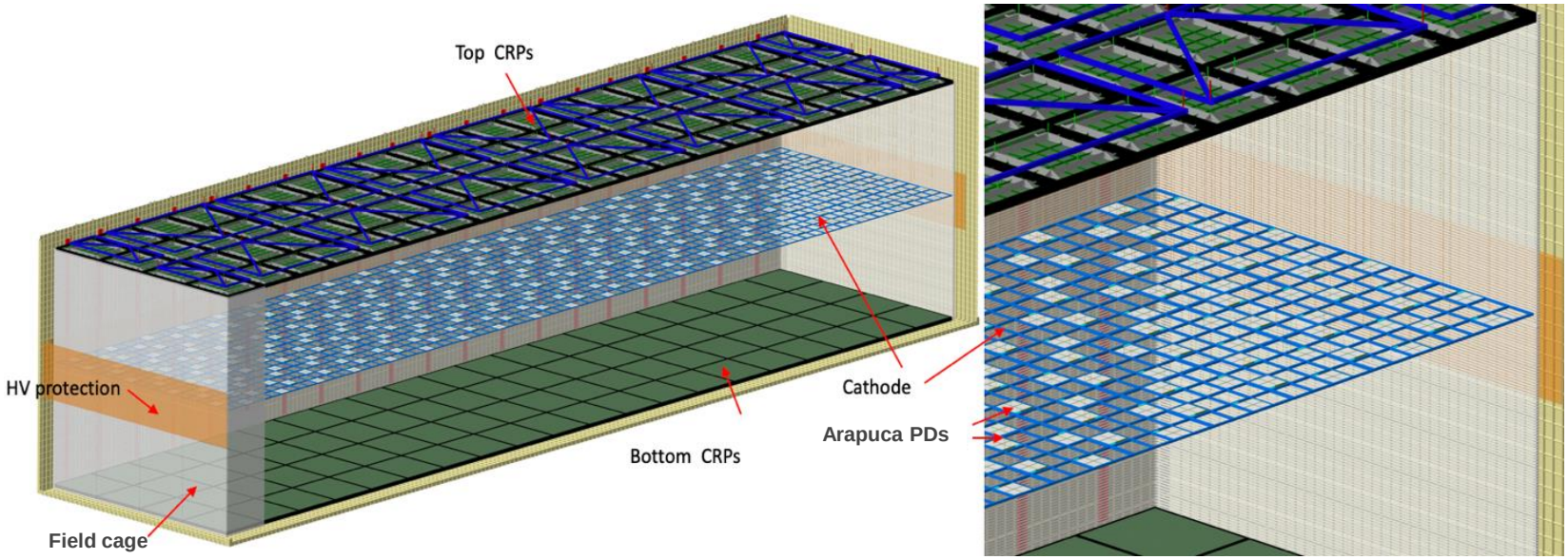
From FD-1 towards FD-2

- The PD system of FD-1 was brought to maturity by a highly International Consortium made of 47 Institutions, equally distributed among Latin America (17), North America (12) and Europe (17)
- The PD Consortium intends to found the PD system of FD-2 on these same solid bases in terms of technology and of International Collaborations
- FD-1 is the starting point for an improved, more efficient PD system for FD-2, which will meet the same minimal requirements but will be able to expand even more the physics reach of the experiment
- The system will be based again on the X-ARAPUCA technology but with substantial differences: Power over Fiber and Signal over Fiber (will hear a lot during the Workshop)

Goals of the workshop

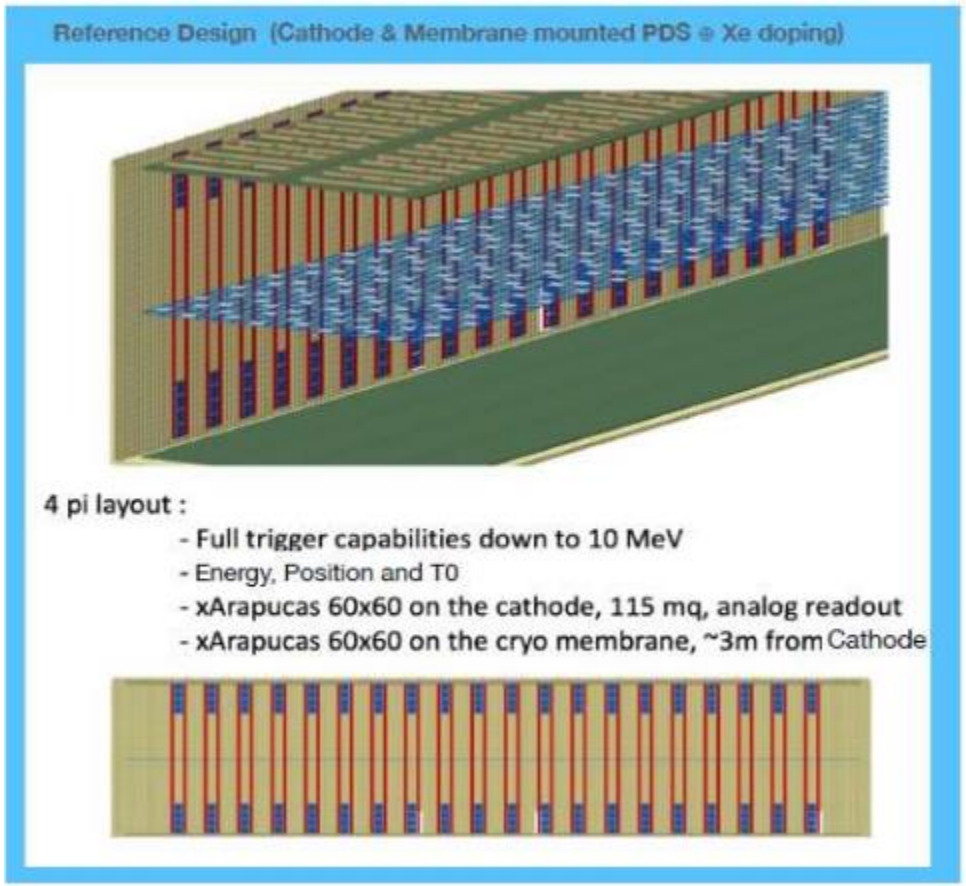
- The Consortium will show what the status of the PD system for FD-2 is;
- We want to disclose to the International Community the opportunities that our system offers in terms of design, validation and construction;
- We believe that the new technological challenges of the PDS for FD-2 can attract the interest of new groups from US, Europe and LA while keeping involved all the Institutions of the Consortium;
- We intend to replicate the successful model of FD-1 with a strong International involvement and a broad sharing of responsibilities.

Vertical Drift Concept



- Central cathode + two anode planes, one on the top and the other on the bottom
- Drift of the electrons along the vertical direction wrt to the floor
- Simpler design which allows to maximize the inner volume and to optimize the costs

FD-2 PDS Baseline Layout



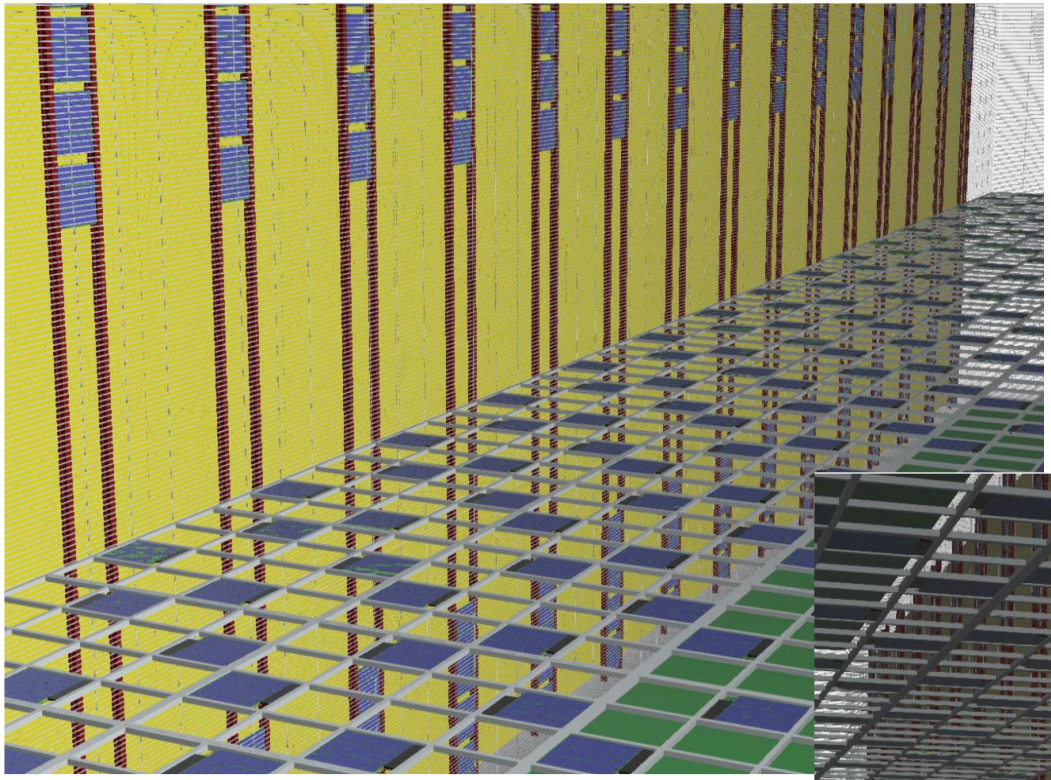
PD Active optical coverage on 3 sides: Cathode (sitting at high voltage) + long sides of the Cryostat walls (at ground)

Field cage with 70% transparency

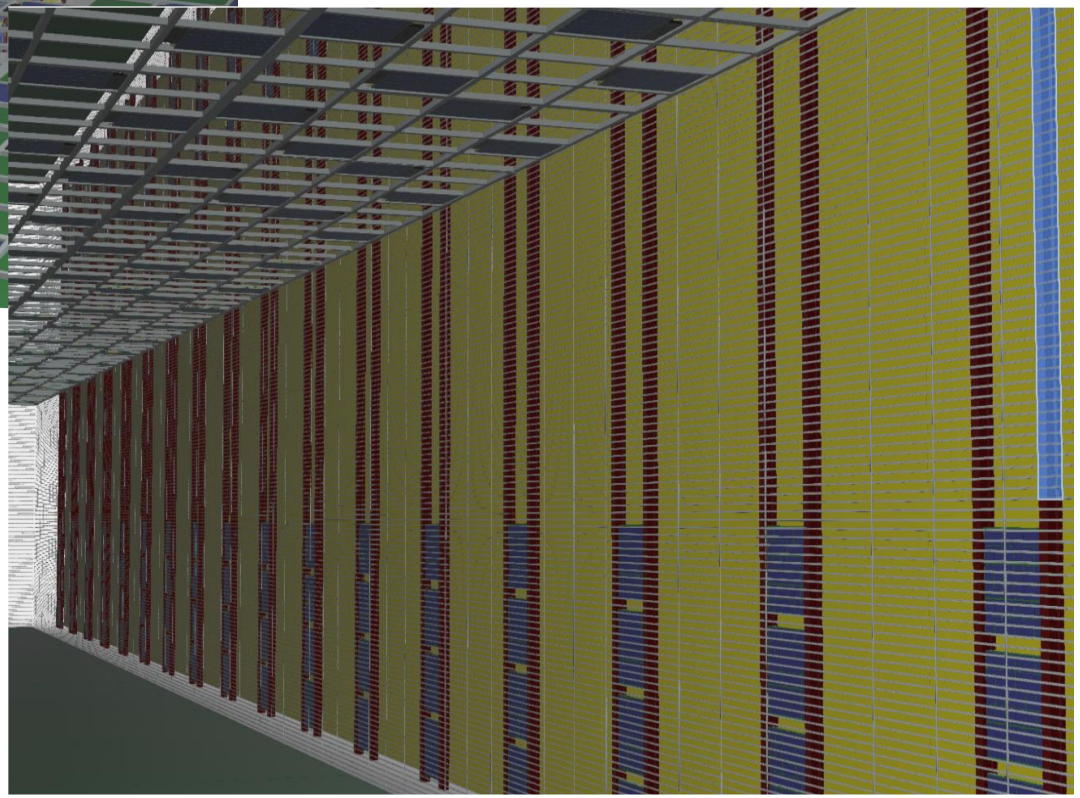
Xenon doping at 10 ppm level

- This configuration ensures a good uniformity in light collection -> increased Rayleigh scattering length wrt to pure argon
- Low detection threshold
- Enhanced energy and position resolution

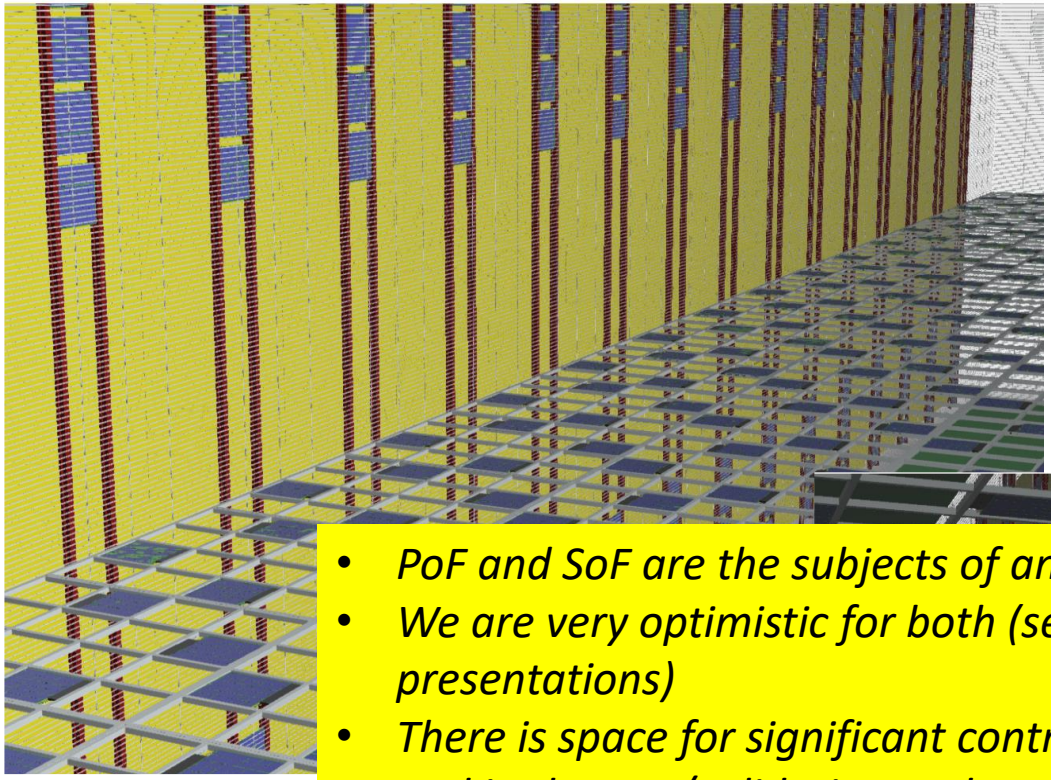
Average LY ~ 40 PE/MeV assuming the same detection efficiency for X-ARAPUCAs as in FD-1 and same coverage.



Tiles on the cathode are double sided -> have dichroic filters on both sides. Biased (Power over fiber - PoF) and read-out (Signal over fiber - SoF) through optical fibers.



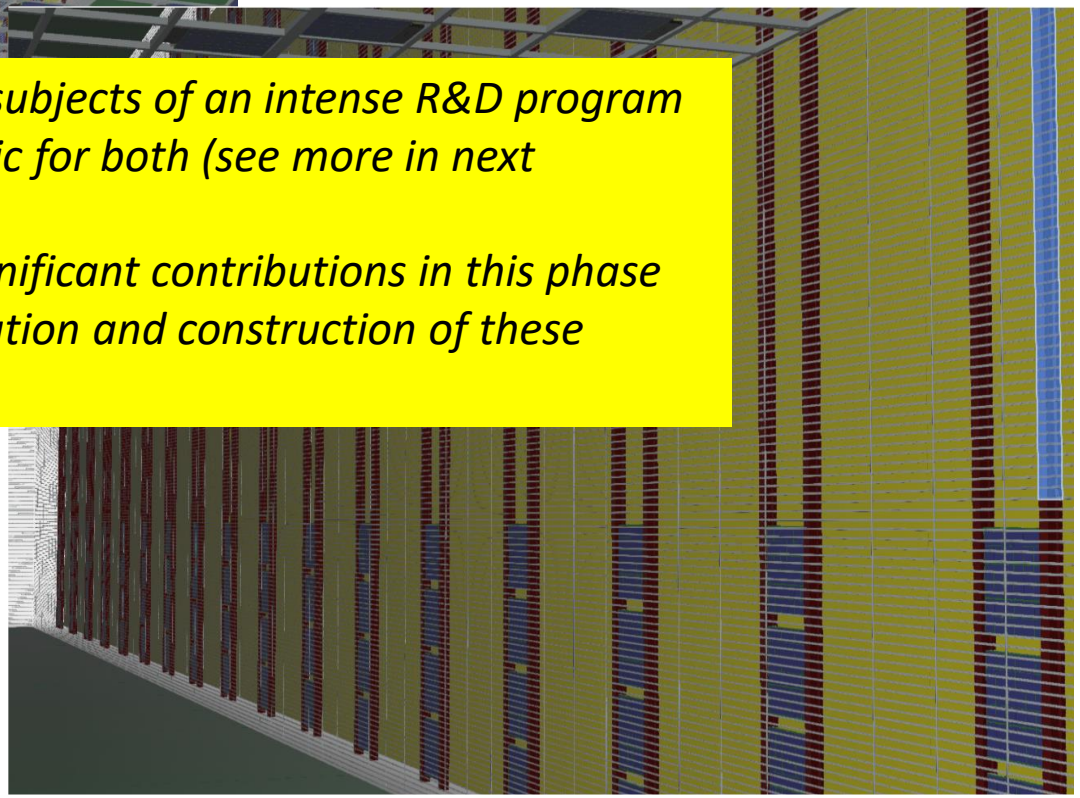
Tiles on the cryostat walls are single sided. Can be biased and read-out through traditional wires



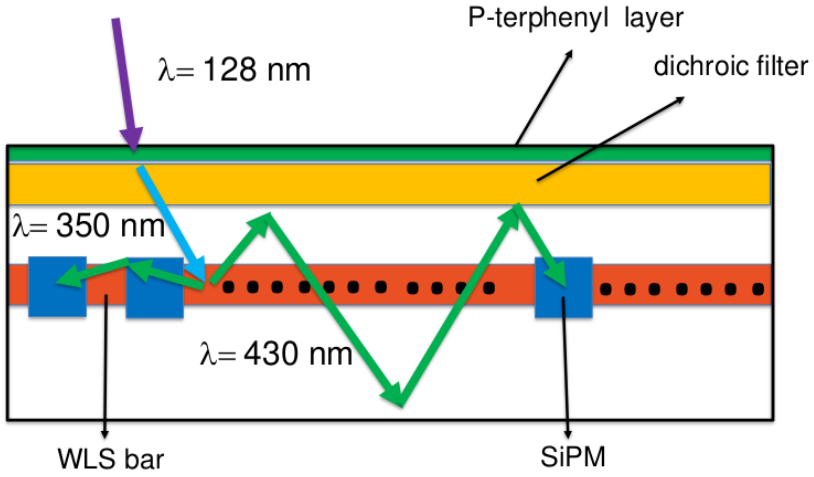
Tiles on the cathode are double sided -> have dichroic filters on both sides. Biased (Power over fiber - PoF) and read-out (Signal over fiber - SoF) through optical fibers.

- *PoF and SoF are the subjects of an intense R&D program*
- *We are very optimistic for both (see more in next presentations)*
- *There is space for significant contributions in this phase and in the test/validation and construction of these systems*

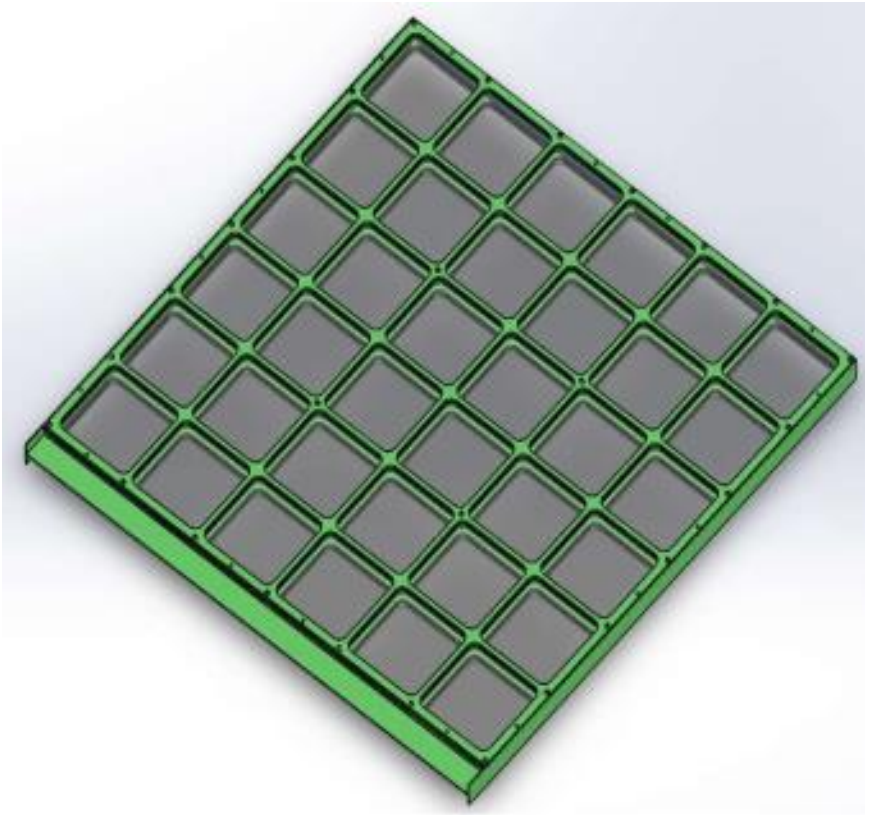
Tiles on the cryostat walls are single sided. Can be biased and read-out through traditional wires



X-ARAPUCA tile for FD-2

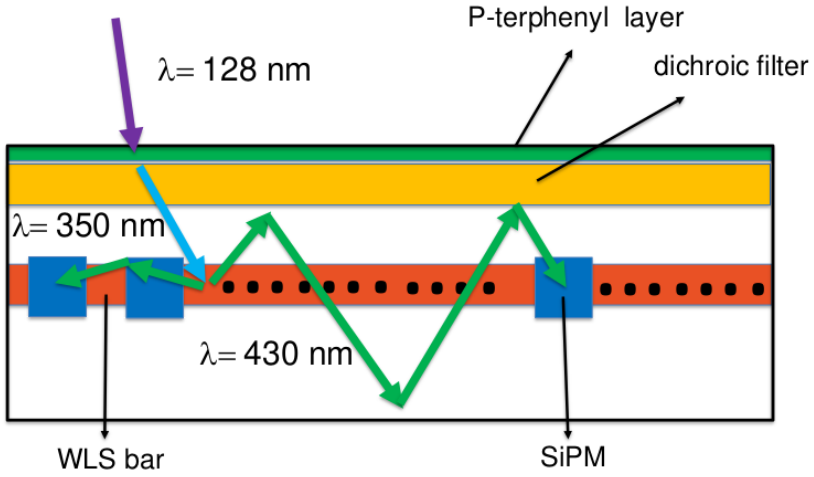


Credits: F. Terranova



- Tiles with ~ 60x60 cm^2 area
- One wave-shifting plate of the same size
- SiPM mounted on the lateral surfaces of the plate
- For the tiles sitting on the cathode the biasing and read-out of the SiPM arrays are done through optical fibers

X-ARAPUCA tile for FD-2



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- SiPM mounted on the lateral surfaces of the plate
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Lot of optimizations and opportunities here:

- *New tiles -> Improve transparency and light conversion*
- *Coupling of the SiPMs to the tile to improve the transmission of the photons from the tile to the SiPMs*
- *Optimize dichroic filters to improve trapping efficiency*

WORKSHOP PROGRAM

Day one – 26/07/2021

08:00	**Introduction (Scope of the WS) + FD2 (VD) PDS: Concept & Goals**	*Ettore Segreto* 08:00 - 08:15
	FD2 (VD) PDS: Detector Implementation, Layout, Module Design	*Flavio Cavanna* 08:15 - 08:30
	FD2 (VD) PDS: Features and Potentialities for DUNE LowEn Physics	*Laura Paulucci Marinho* 08:30 - 08:45
	FD2 (VD) PDS: Current (Reference) Design, Deliverables, Budget, Plan (WBS)	*Ryan Rivera* 08:45 - 09:00
09:00	**FD2 (VD) PDS: European proposed contribution to VD PDS**	*Ines Gil-Botella* 09:00 - 09:15
	Break	09:15 - 09:30
	PDS Mechanical Design, Layout and Fabrication (Cathode Mount and Membrane Mount)	*David Warner* 09:30 - 09:55
10:00	**PDS Electrical/Electronics Layout Overview (Cathode Mount and Membrane Mount)**	*Ryan Rivera* 09:55 - 10:15
	Power-over-Fiber (HV-LC, LV-HC)	*William Pellico*
	Discussion	10:35 - 10:50
	PhotoSensors	*Francesco Terranova* 10:50 - 11:05
11:00	**SiPMs Ganging**	*Dante Totani* 11:05 - 11:20
	Dichroic Filters and WLS film	*Ana Amelia Machado* 11:20 - 11:35
	WLS Plates & SiPM Mounting	*Carla Maria Cattadori* 11:35 - 11:50
	Remarks - Perspectives/Opportunities	11:50 - 12:10
12:00		

Day two – 26/07/2021

08:00	CE Analog Readout & Transmission (Tx&Rx)	*Sabrina Sacerdoti et al.*	08:00 - 08:20
	CE Digital Readout Transmission (Tx&Rx)		08:25 - 08:45
09:00	Immersed WE Option (CryoSub)for Digital Readout, Aggregation & Transmissio	*David Cussans et al.*	08:50 - 09:05
	Warm Electronics: (Warm Rx, ADC), DAQ interface		09:10 - 09:25
	Discussion		09:30 - 09:45
10:00	Other Ph.detection Item(s) ?: SiPM readout (at FNAL)	*Paul Rubinov*	09:50 - 10:05
	PDS Monitoring and Calibration System		10:10 - 10:25
	Break		10:30 - 10:45
11:00	Contributions at NIU	*Vishnu Zutshi*	10:50 - 11:05
	Contribution plans at the University of Iowa	*Yasar Onel*	11:05 - 11:15
	Contribution plans at CSU	*John Harton*	11:15 - 11:30
	Harvard U - Fiber Modulators	*Neil Sinclair*	11:30 - 11:45
	UIUC - GaAs Photovoltaic Laser Power Converters	*Lee Lawrence*	11:45 - 12:00
12:00	Opportunity for Contribution at CINVESTAV (Mexico)	*Marco Ayala-Torres*	12:00 - 12:10
	Opportunity for contributions from UF Rio de Janeiro	*Joao Torres de Mello Neto*	12:10 - 12:20
	Opportunity of Contributions at CTU Prague		12:20 - 12:30
	Remarks - Perspectives/Opportunities	*Francesco Terranova*	12:35 - 12:55
13:00	End of the Workshop		12:55 - 13:01

Conclusions

- The PDS of FD-2 is being founded on the solid bases of the one of FD-1
- Baseline design allows to increase the overall Light Yield with almost the same active coverage of FD-1. Enlarged physics scope
- System based on the X-ARAPUCA light trap, but with new technological challenges. Especially in the area of SiPM biasing (PoF) and SiPM read-out (SoF)
- There is space for substantial contributions in many areas and new contributors are highly welcome