Vertical Drift Photon Detector Tile Design

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Outline

The purpose of this talk is to demonstrate the conceptual possibility of a cathode-mount PD module which will fit within the constraints of the cathode modules. The detection efficiency of such a module is presented elsewhere in this review.

This concept allows us to develop costing for a VD-PD system, and to begin to schedule an R&D program for the system.

This design should be able to be easily modified for the cryostat membrane option, and with additional work perhaps for the field cage option.

Many people have contributed to this work (I am just collecting ideas!). I wish particularly to call attention to the contributions of Heriques Frandini at UNICAMP.

- Development transferrable from FD-1
- Module design concept
- Frame mounting concept
- Key upcoming development

HD PD Validation Results

Several key validation results for the HD Photon Detector are directly applicable to the VD system

- SiPM properties/aging
- Ganging studies
- Optical component performance (Detection efficiency)

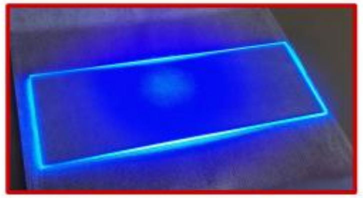
SiPM Cryogenic Testing

Model	#SiPM	PDE(%)	LN2 - First cycle		LN2 - Last cycle(20)		DIFF %
			After pulses (%)		After pulses (%)		
NUV-HD-Cryo	23	40	0.23	1.82	2.16	2.29	-25.93
		45	0.38	2.31	0.95	1.96	15.02
Triple Trench	29	40	0.68	1.77	0.08	1.24	30.08
		45	0.04	1.75	0.45	1.50	14.42

Model	#SiPM	PDE(%)	LN2 - First cycle		LN2 - Last cycle(20)		DIFF %
			Xtalk (%)		Xtalk (%)		
NUV-HD-Cryo	23	40	5.37	20.82	7.49	23.20	-11.42
		45	5.45	25.64	4.50	23.67	7.67
		50			2.69	26.72	
Triple Trench	29	40	0.03	10.65	2.27	10.65	0.03
		45	0.65	14.19	2.31	12.93	8.91

	NQ XA from pDune	XA with pDune EJ286	XA with EJ286	XA With FB-MiB
Vikuiti	On FR4 frame	On FR4 frame	On WLS Edges	On WLS edges
SiPMs	S13360 6050VE	S14160 6050HS	S14160 6050HS	S14160 6050HS
OV	+3 V	+2.7 V	+2.7 V	+2.7 V
S/N	5.3	WIP	7.6	7.3
Efficiency	1.8 (0.4) %		2.4 (0.2) %	3.7 (0.2) %

position	Increase of detected Light: FB w.r.t. Ej286	Increase of detected Light by Vikuiti on WLS
2,3,4	55 (5) %	38 (8) %
5	50 (5) %	30 (10) %
1	62 (5) %	40 (10) %



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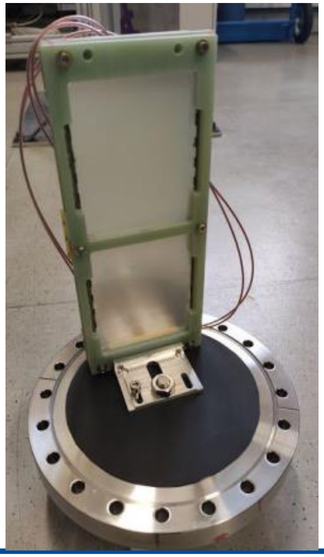
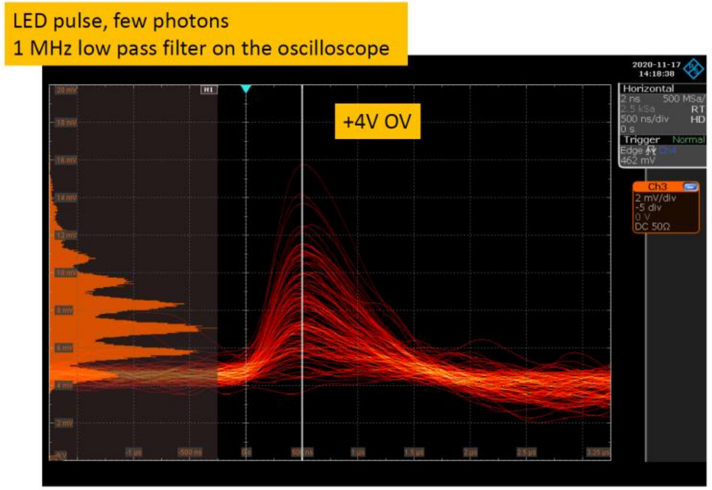
X-ARAPUCA Detection Efficiency (Glass to Power FB-118) MiB

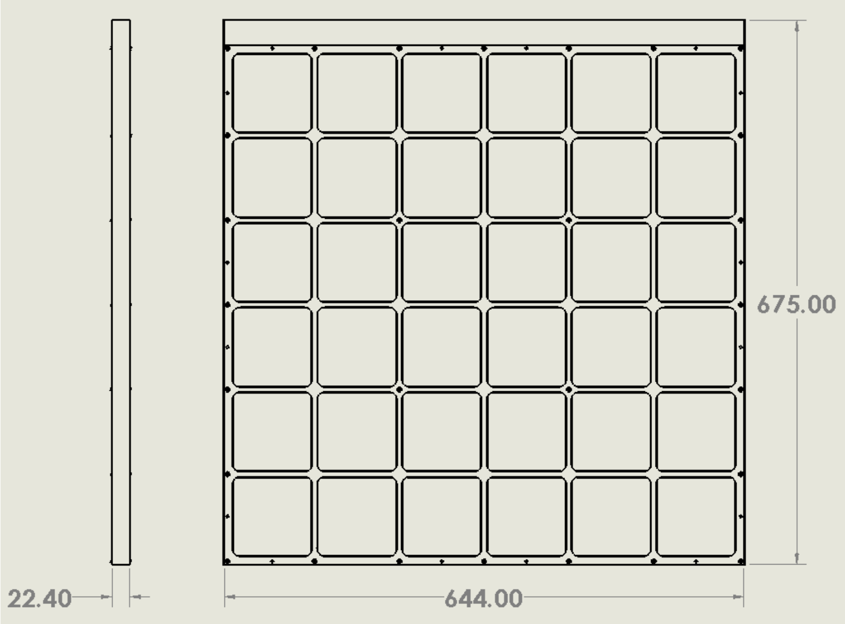


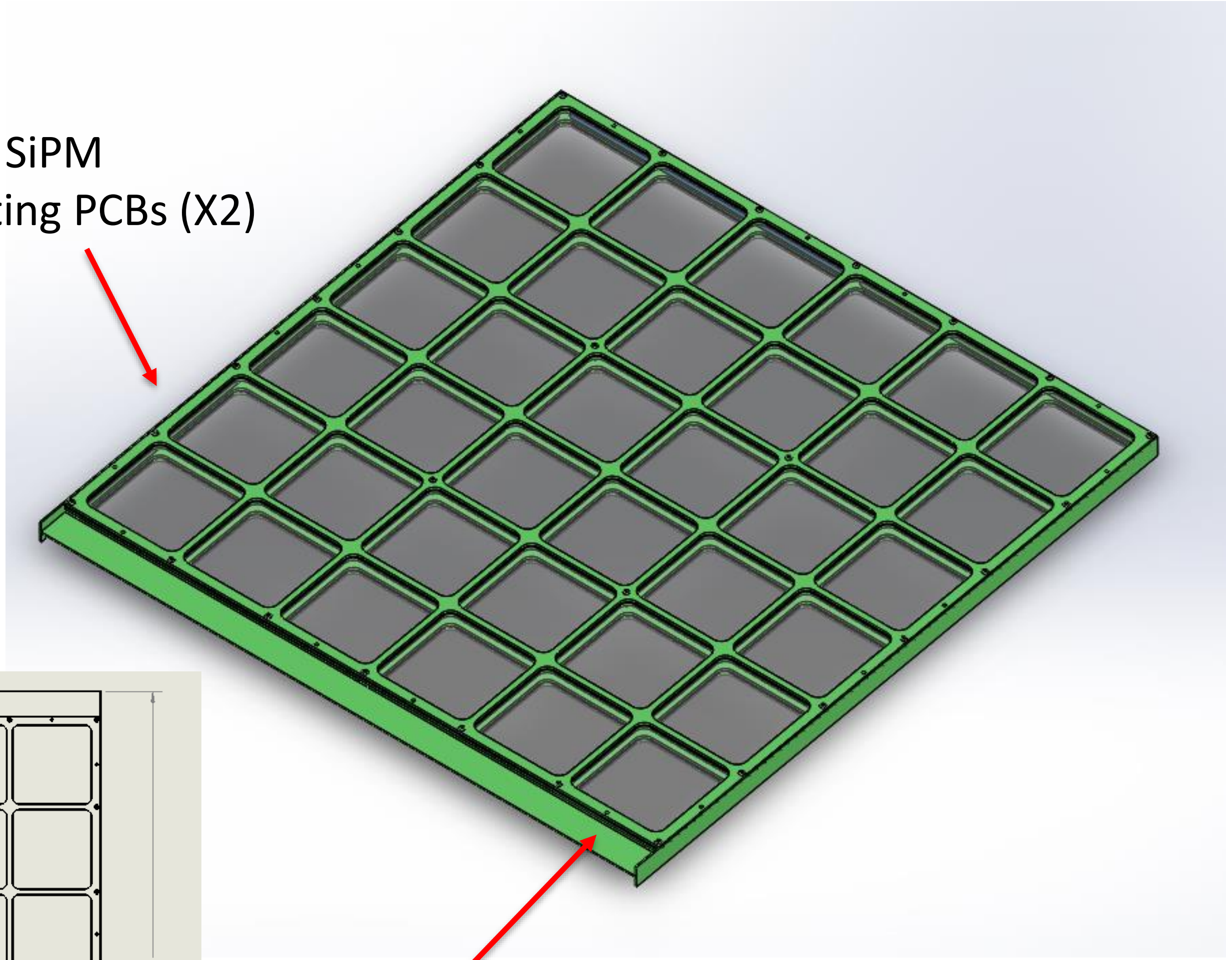


48 SiPM Active Ganging S/N > 5

Mechanical Frame (Concept)

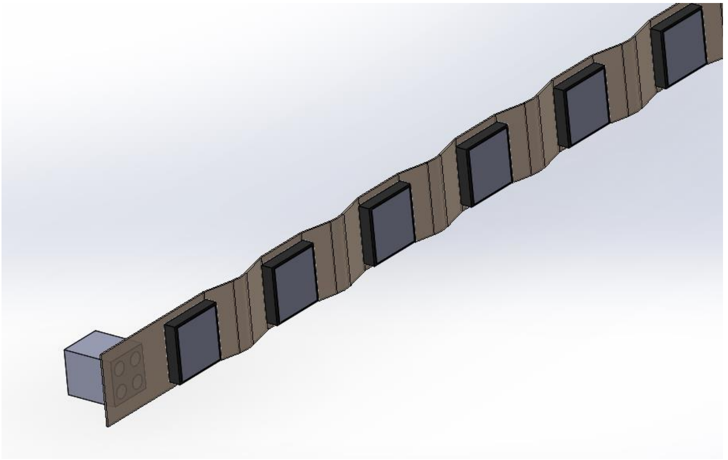
- Total active area ~3600mm^2 (X2 sides)
- Estimated mass ~5.5kg per tile
- 160 SiPMs (40 per side)
- FR-4 G-10 Frame components

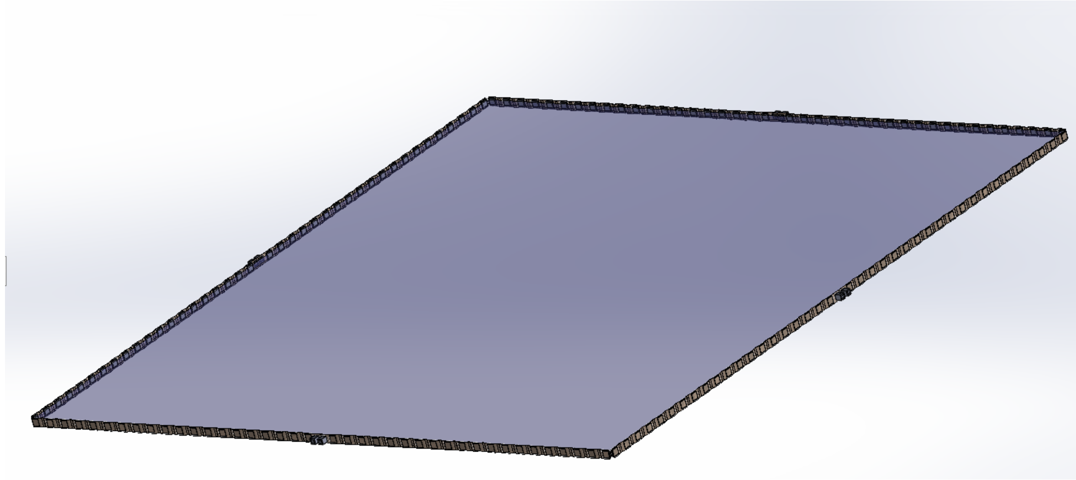


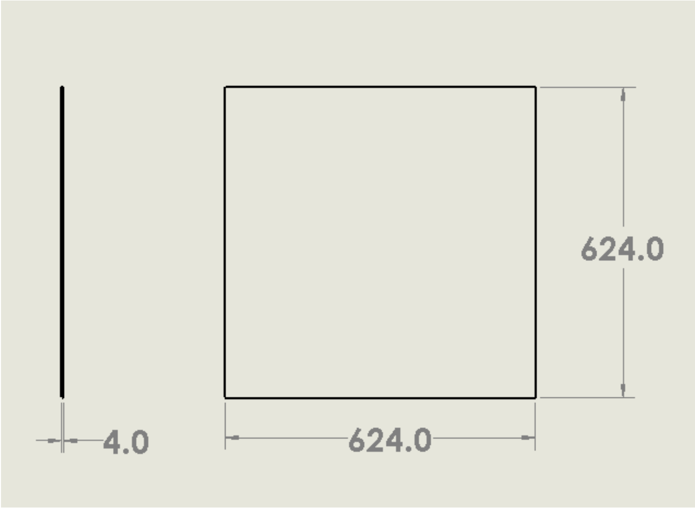


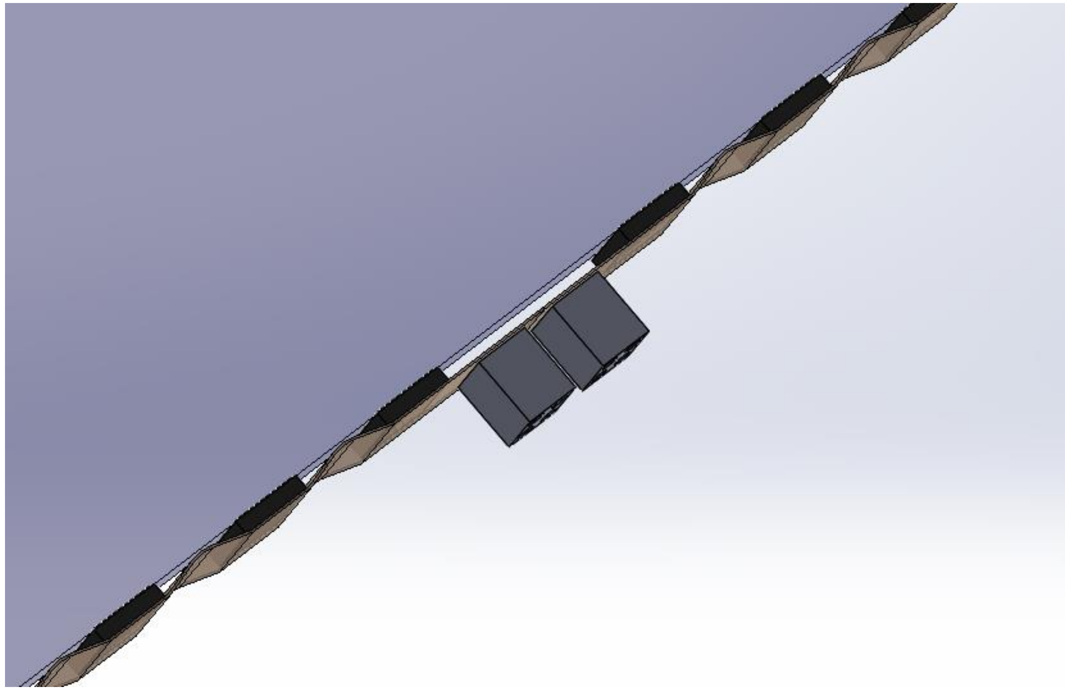
WLS Plate Assembly

- 160 SiPMs (40 per side)
  - Glued to WLS Bar for improved performance
- SiPMs mounted on Kapton flexi-PCB
  - Addresses relative thermal contraction of WLS plate/frame.
- Power-to-Glass FB-118 WLS plate (Milano)
- Concept new to VD PD--under development





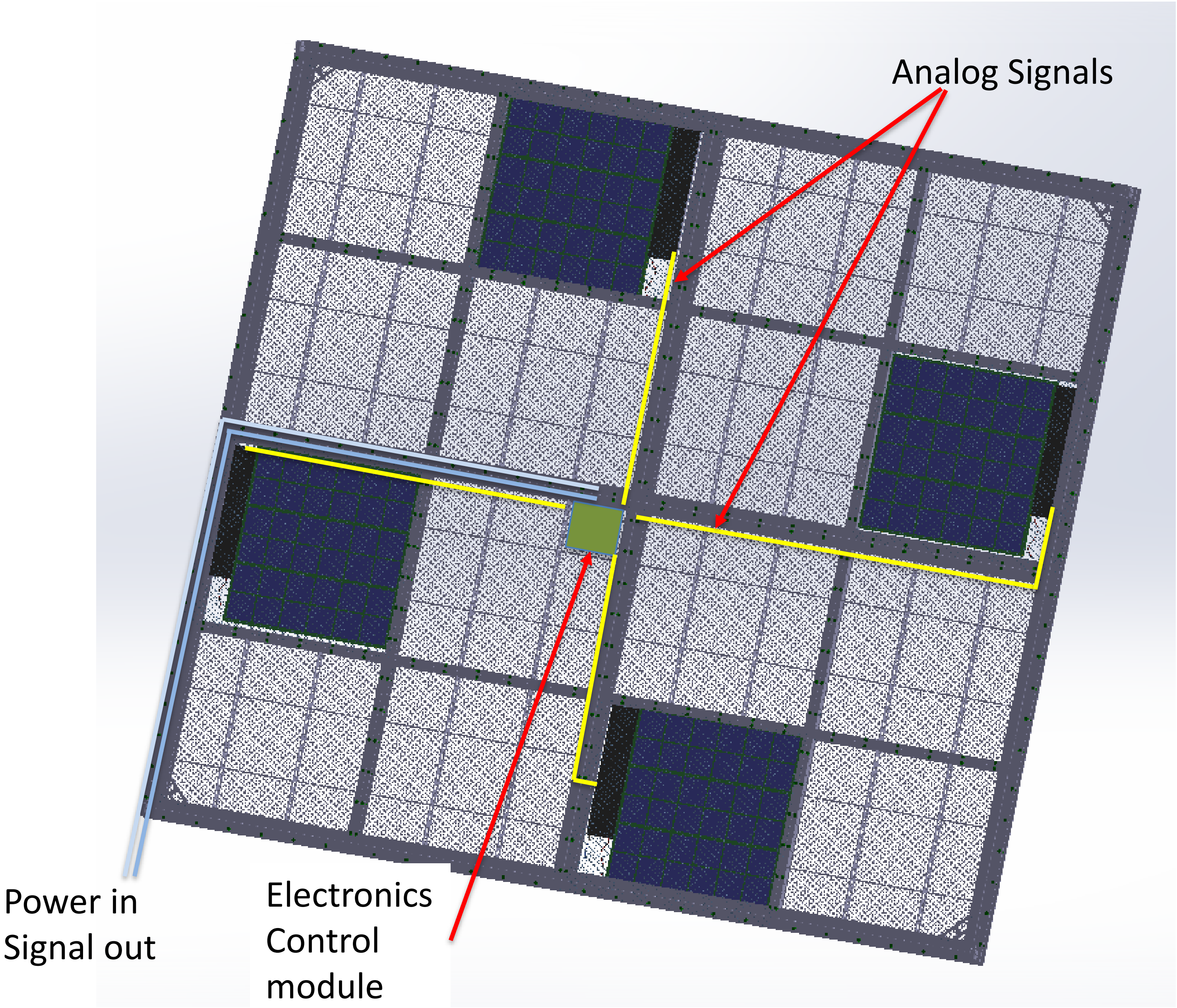




Frame mounting

- 4 modules per cathode module

- One readout electronics assembly per module
  - ~200mm^
  - Two PCBs in vertical stack: One analog board with amplifiers, (4 ADCs?) one digital board with signal readout, power, slow control



Upcoming (CY-21) Module R&D

- Complete preliminary cathode tile frame design (End of April 21)
  - Procure dummy filter plates/WLS bars for initial test
  - Assemble frame prototype and test in LN2 (Late May)
  - Revise mechanical design (July)
  - Fabricate 2 modules for cold box test (End of August)
  - Cold test (CSU? FNAL?) (End of September)
  - Cold box test CERN (October 21?)
- Procure optical filters
  - ~70 filters (July 21)
  - Coat filters & Assemble into modules (August 21)
  - Continue development of Xenon-optimized filter plates (Throughout 21, but not concluded in 21)
- Procure 3 WLS plates (Power to Glass) (July 21)
- Test Kapton flexi-PCBs for SiPM mounting (Summer 21)

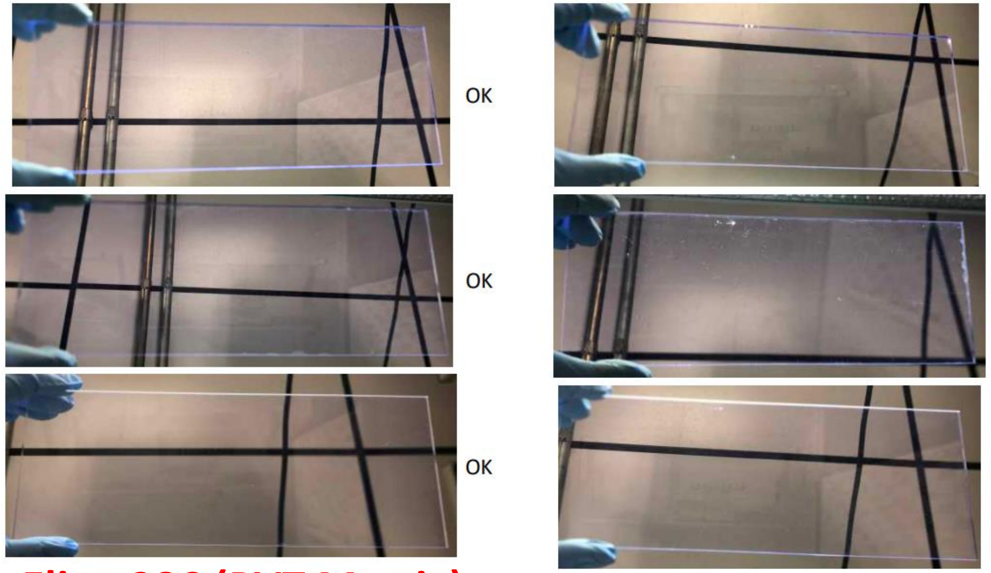
BACKUP

WLS Plates (EljenEJ286, FB118)

- ➢ Initially observed thermal stress cracking of Eljen wavelength shifting plates traced to rate of cooling and improved by annealing
  - Samples of both PVT (EJ286) and Polystyrene (EJ286-PS) were tested through multiple cooling cycles at UNICAMP
  - No stress cracking observed with slow immersion in LN2.
  - Well within DUNE, ProtoDUNE fill rates

- ➢ Samples of both 1X (standard) and 4X WLS doping level WLS plates procured, will be tested in monochrometer (UNICAMP) and supercells (MIB, CIEMAT)

- ➢ New custom-fabricated WLS plates fabricated by Glass to Power with MIB (Cattadori) (Acryllic)
  - Early test results show significant improvement over standard-dopant concentration Eljen EJ286 bars



Eljen 286 (PVT Matrix)

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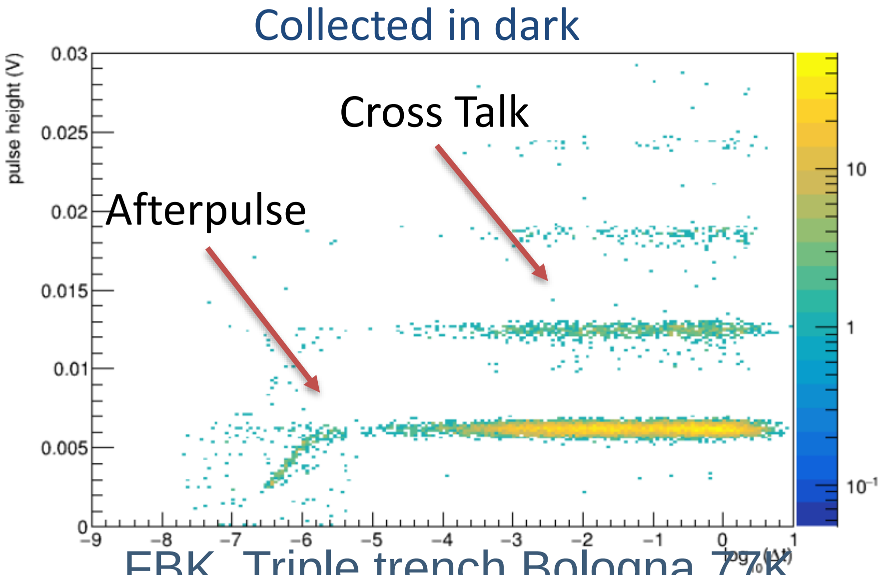
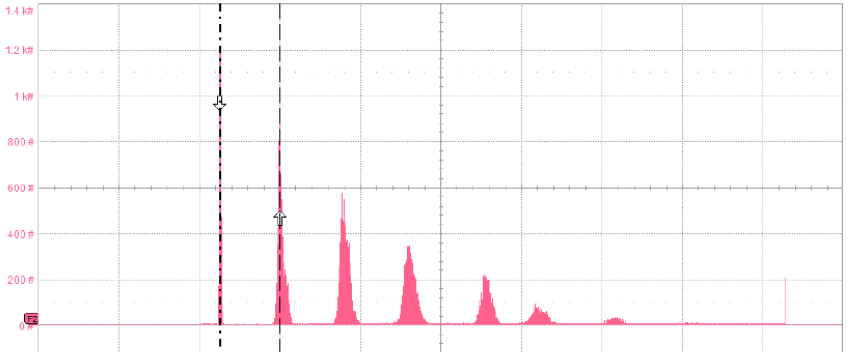
FB118 (Milano Bicocca)

Photosensors

- Initial SiPM tests performed for 6 candidate photosensors
  - 4X Hamamatsu
  - 2X FBK
- PDE, afterpulsing and crosstalk measurements performed before and after 20 cryogenic cycles
- Tests performed with redundancy (each type tested by at least 2 labs): Bologna, CIEMAT, Ferrara, Milano Bicocca, NIU, Prague, Valencia
- **No major issues observed**



FBK, Triple trench Bologna 77K
Dark and correlated noise



Hamamatsu LQR 50mm Prague 77K
Gain, S/N of 1 sensor

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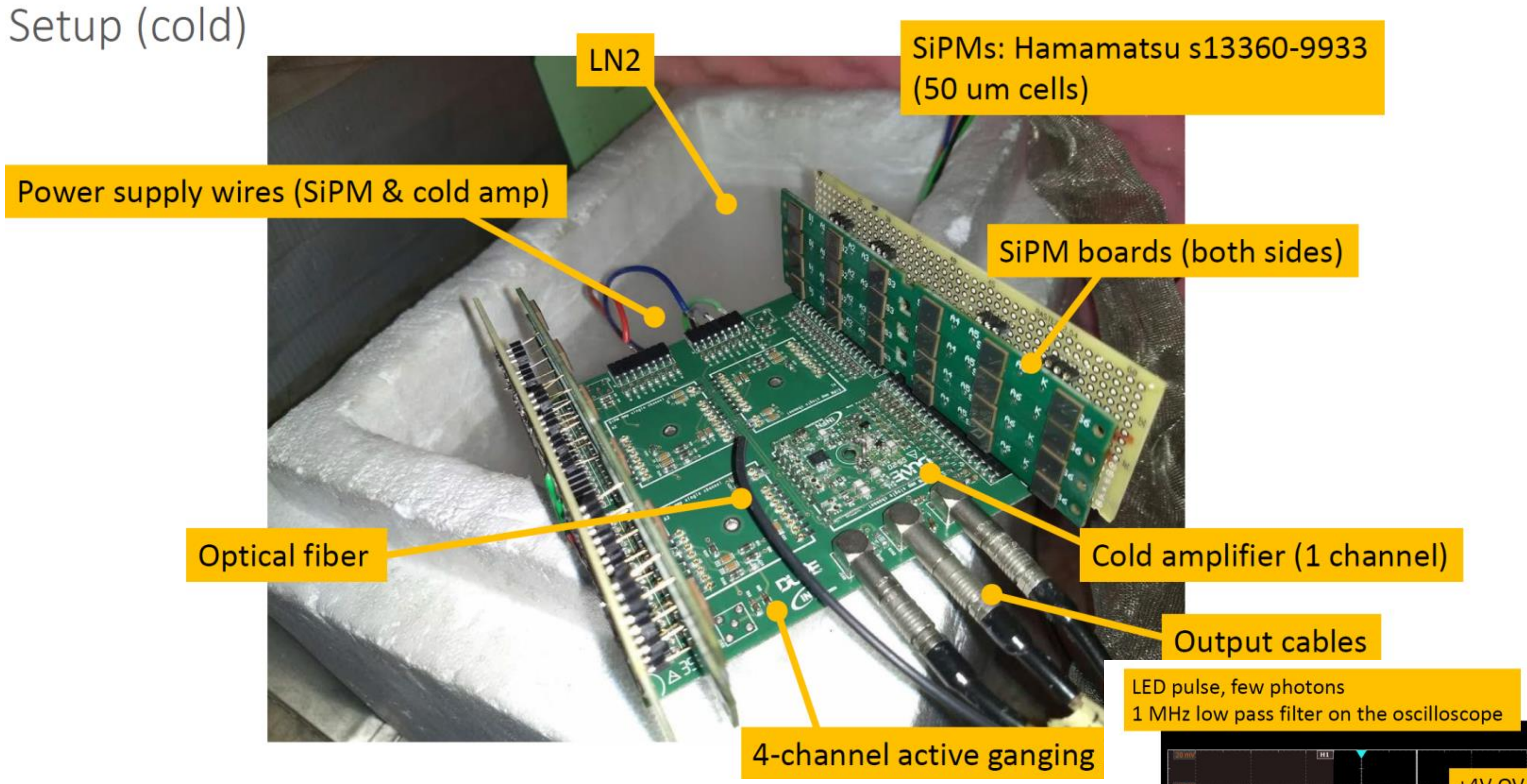
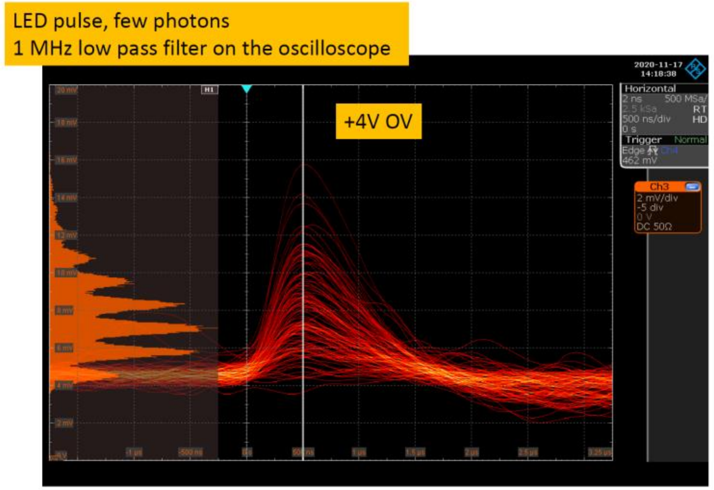
Active Ganging (i)

- Groups of 48 Hamamatsu and FBK SiPMs have been operated cryogenically at Bicocca

- S/N ratio >5 observed (exceeding PD system requirements)
  - Even better performance with optimized filtering

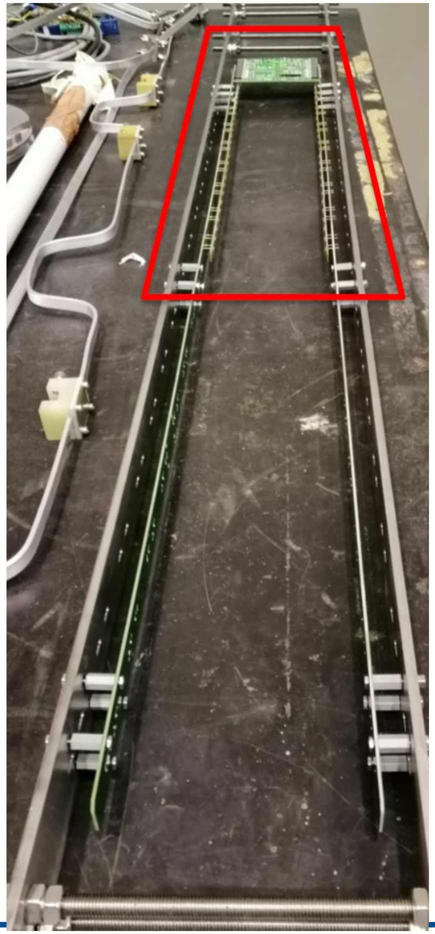


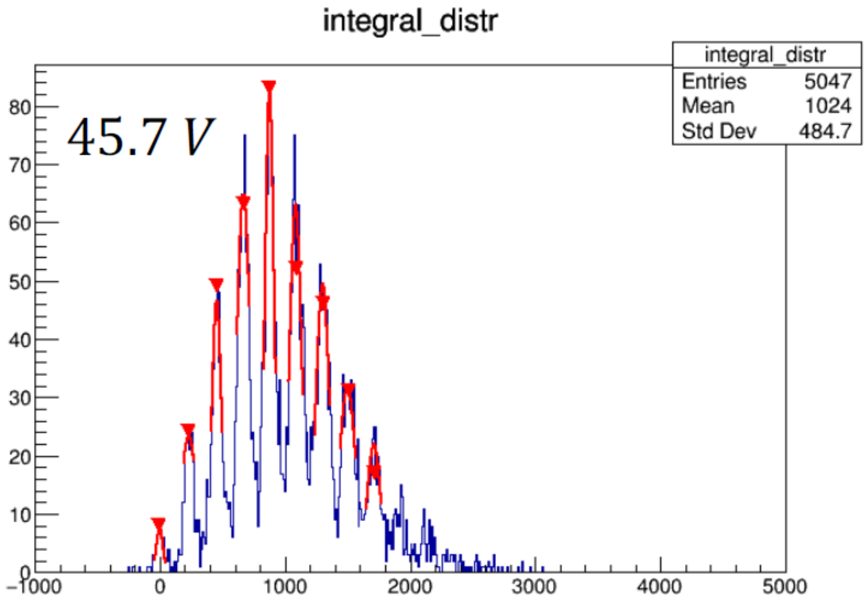


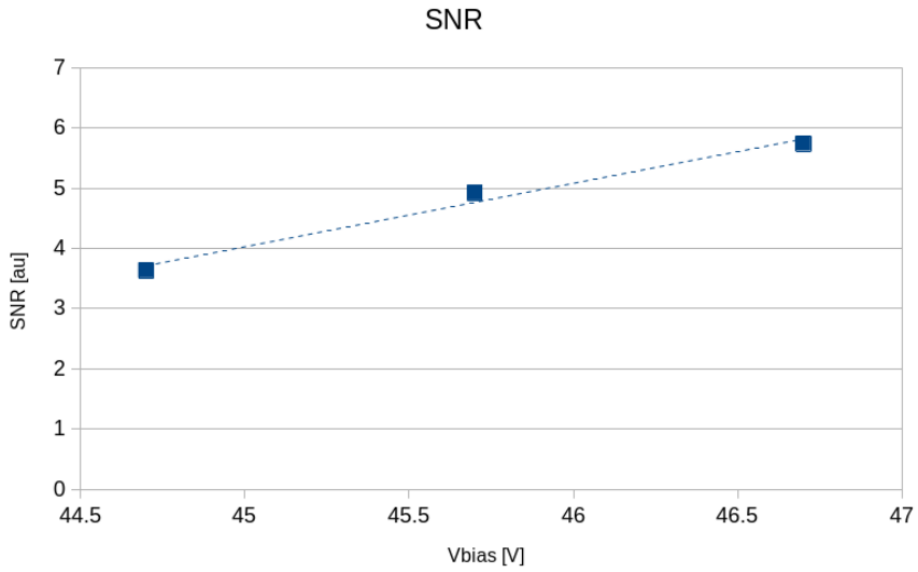
Ganging achieved (S/N>5) in November in a table-top design (Hamamatsu) and in January (FBK)
All measurements at 77 K.

Active Ganging (ii)

- End-to-end readout of 48 SiPMs demonstrated at Milano Statale with Hamamatsu SiPMs
- S/N ratio >5 observed (exceeding PD system requirements)

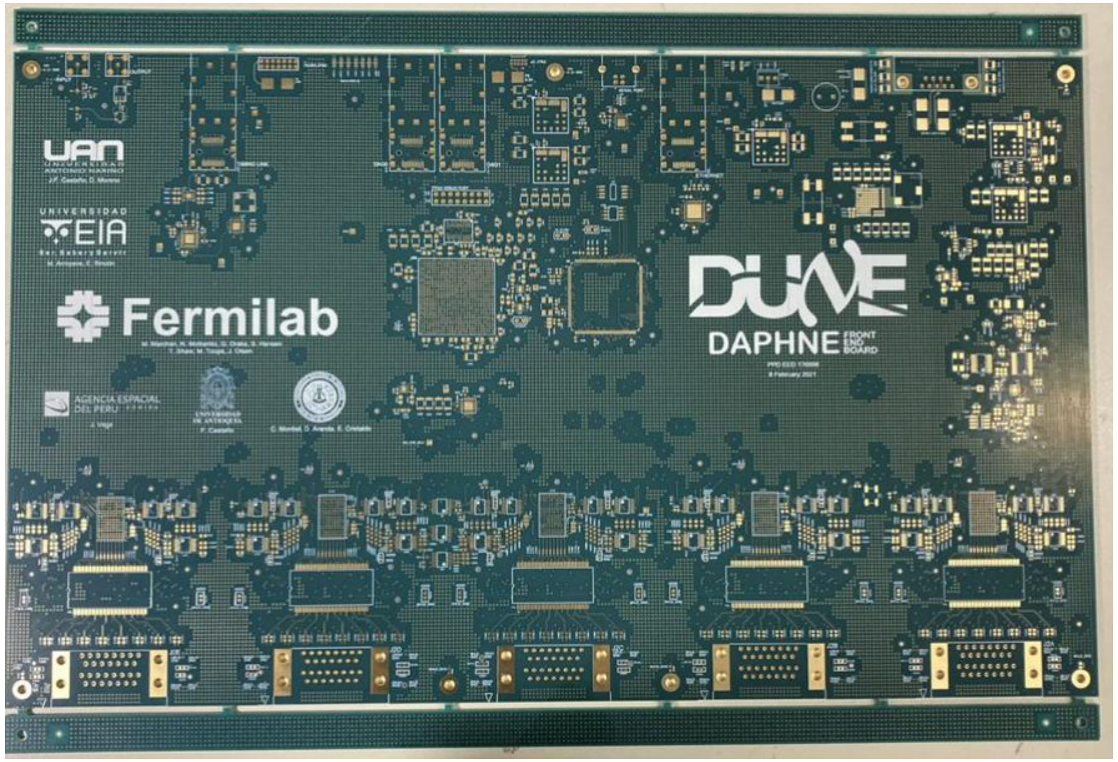






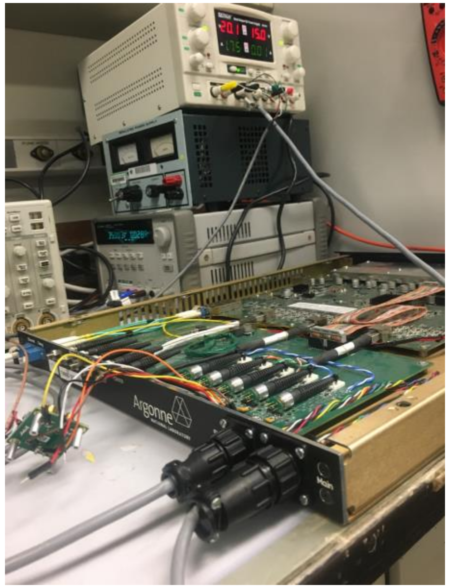
Warm Electronics (DAPHNE)

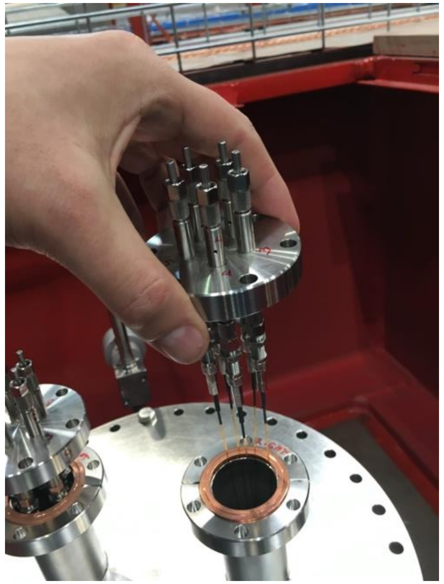
- Bare PCBs arrived March 3
- Visual inspection & review of testing documentation satisfactory March 4
- Boards sent out for assembly March 4
  - Expected back ~March 15
- Chassis design complete and order in place
  - Delivery expected ~March 15
- Prototype testing plan, software, firmware & docs being finalized.
- **DAPHNE prototypes will be distributed approximately April 3.**
  - **FNAL, 2**
  - **Colombia, 2**
  - **Italy 2**
  - **Spain 1**
  - **CERN 1**
  - **CSU 1**
  - **UNICAMP/FIUNA 1**

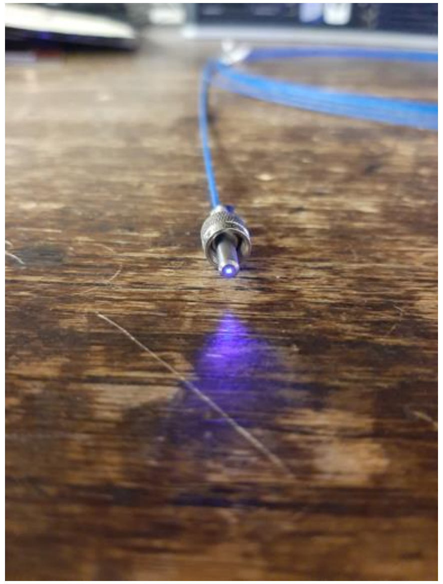


Monitoring System

- Molded plastic diffuser design complete
- 3D printed diffusers fabricated (PEEK)
- Value engineering of fiber candidate underway
- Custom 5-fiber vacuum feedthrough fabricated & under test.
- Modifications of SSPs into monitoring system drivers underway
- Value engineering of monitoring system LEDs and on-board calibration underway.







Optical Coating Stability Studies

- Stability Studies of optical coatings were hampered by COVID-19 in both Syracuse and UNICAMP
- Syracuse testing is re-opening now, and additional filter plates are being sent to allow additional testing
- ProtoDUNE 1 data will be used to study stability as well
  - Monitoring system data
  - Mean PE per channel during running
  - Examination of PD modules following removal from cryostat

<u>Optical Coating Test Status & Plans</u>

- Completed first test of two filter plates 11/2020

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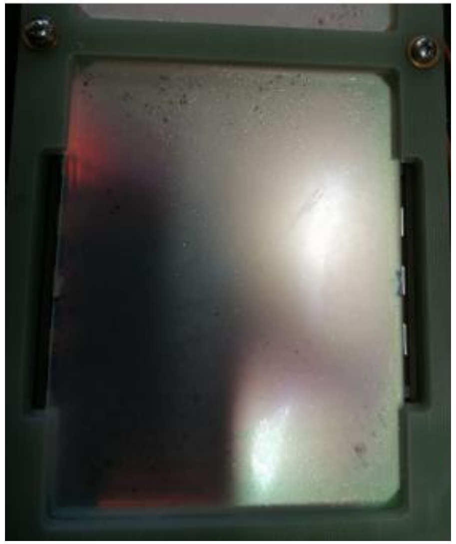
- Improve test stand procedures, specifically slower cool-down.
- Investigate adding a filter on sampling port for pTP solubility study.
  - See 10.1088/1748-0221/14/02/P02021
- Begin series of one-week runs with new filters from Campinas.
- Extended run beginning ~March 2021 with latest filter lot from Campinas.

Coating after 3 cycles (MIB)



ARAPUCA performance during run