



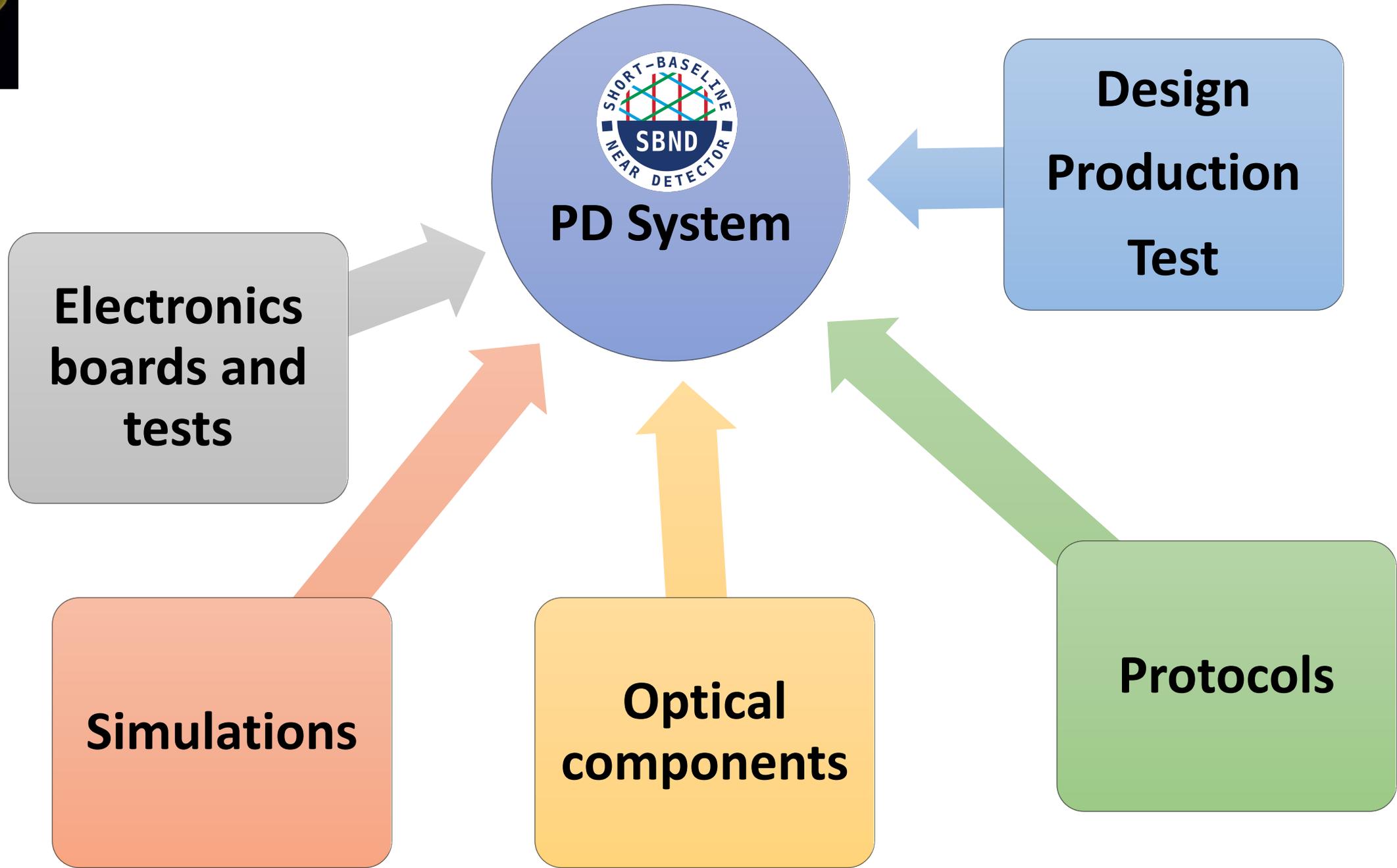
Sistema de fóton detecção do experimento SBND

Ana Machado





Brazilian Contribution



SBND is the near detector in the Short Baseline Neutrino (SBN) program at Fermilab



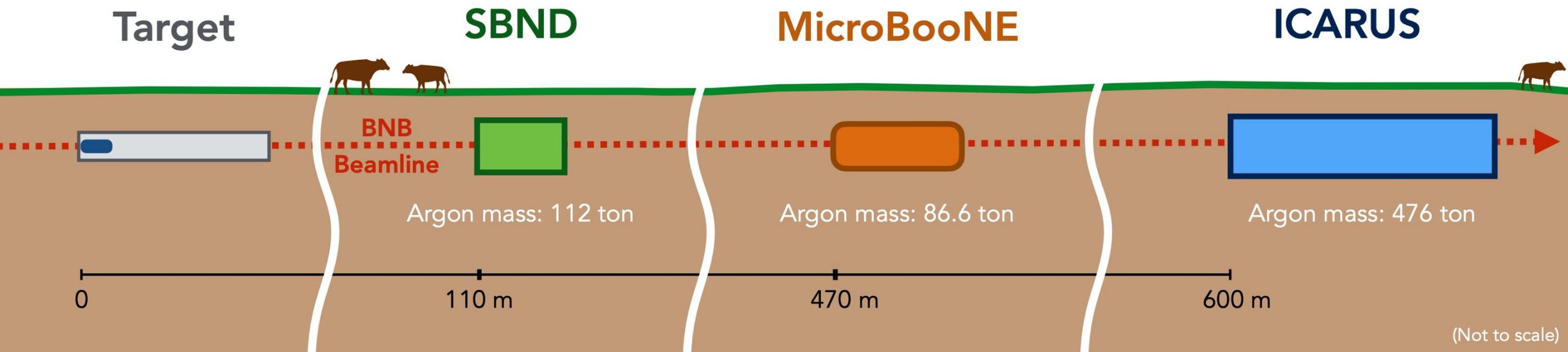
Three Liquid Argon Time Projection Chamber (LArTPC) detectors located along the Booster Neutrino Beamline (BNB) at Fermilab

Goals of the SBN program:

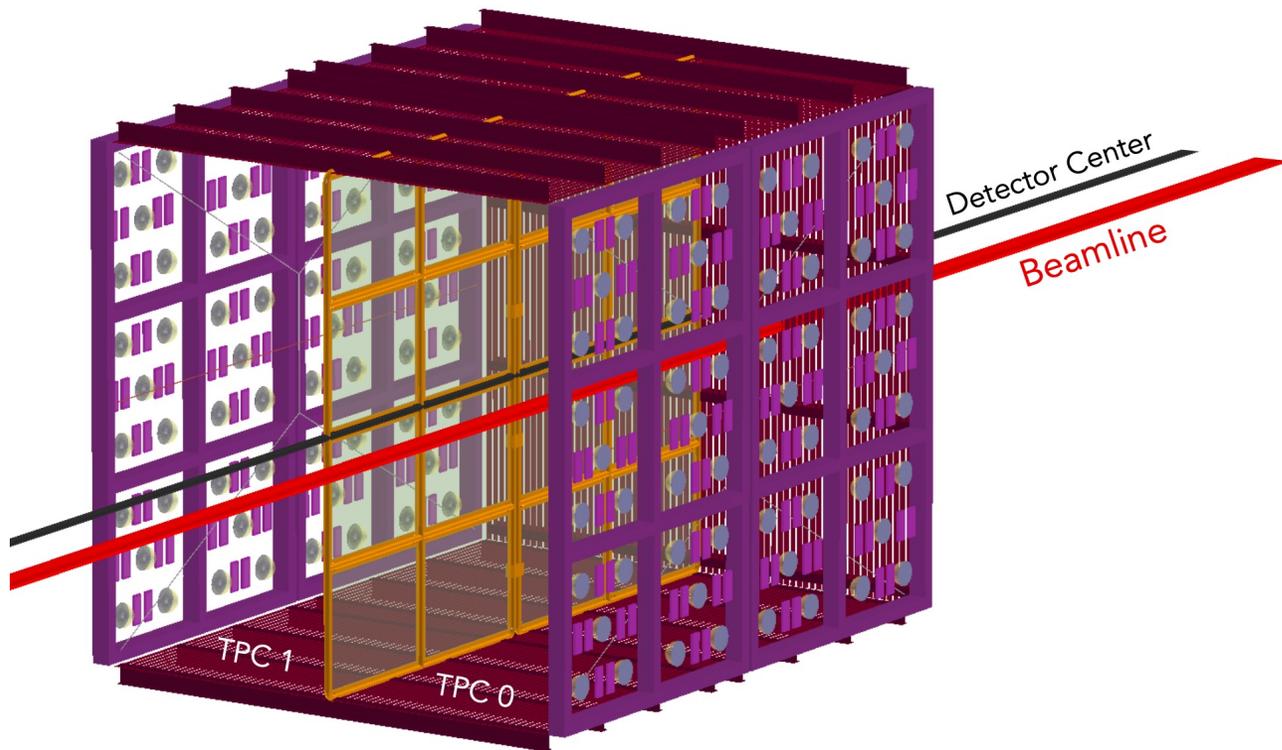
Search for eV mass-scale sterile neutrinos oscillations

Study of neutrino-argon interactions at the GeV energy scale

Search for new/rare physics processes in the neutrino sector and beyond



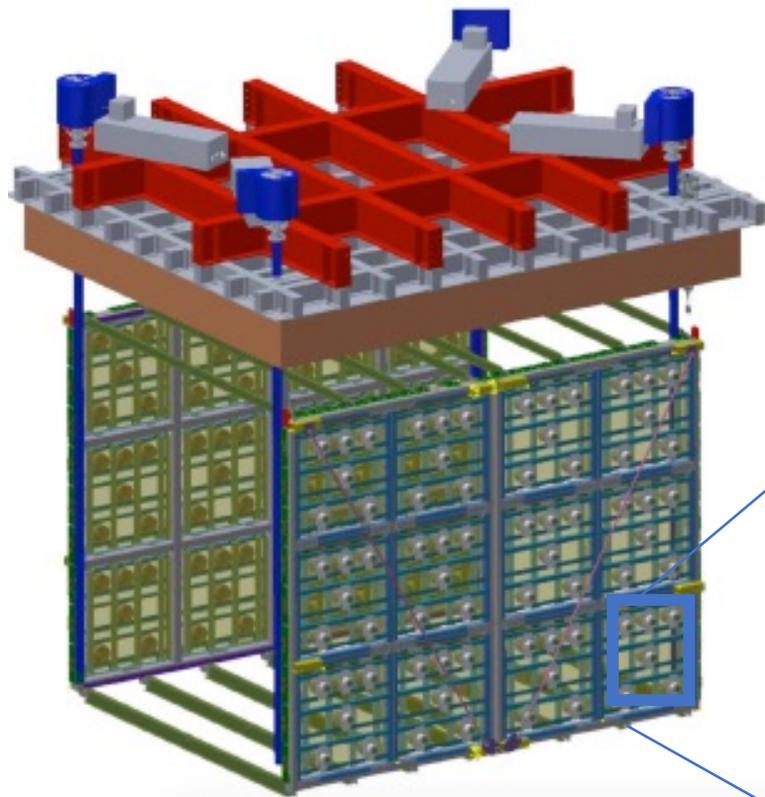
SBND DETECTOR



- LAr - Time Projection Chamber
- 112-ton - (4 x 4 x 5)m active volume
- Two drift volumes - Electric Field 500V/cm
- One central cathode Plane Assembles (CPA) –with wavelength shifter coated foils
- Two Anode Plane Assembles (APA) each one with three wire planes

The photon detection system is composed by PMT and X-ARAPUCA modules

Photon Detection System

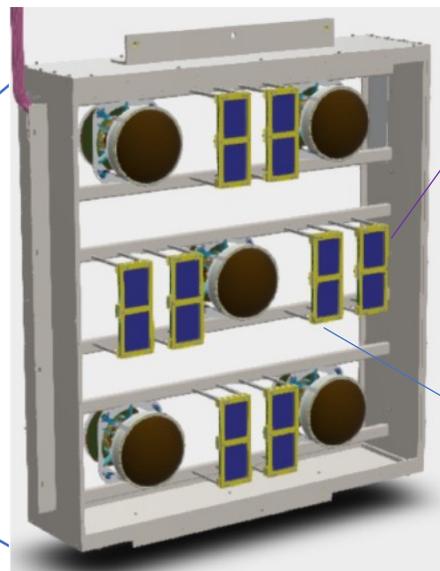


Hamamatsu
R5912-mod
(cryogenic)



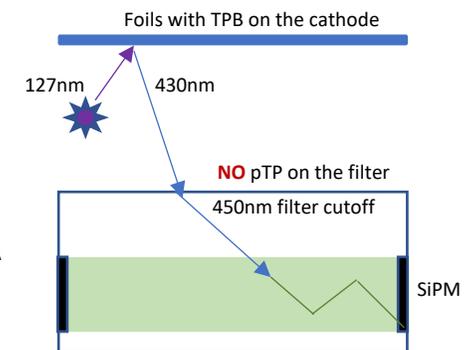
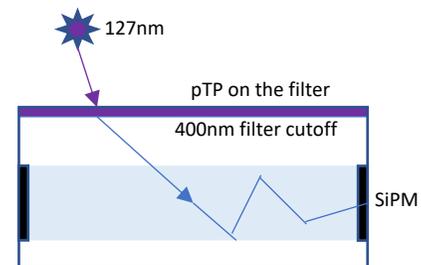
24 uncoated PMTs
96 coated PMTs

192 X-ARAPUCA modules

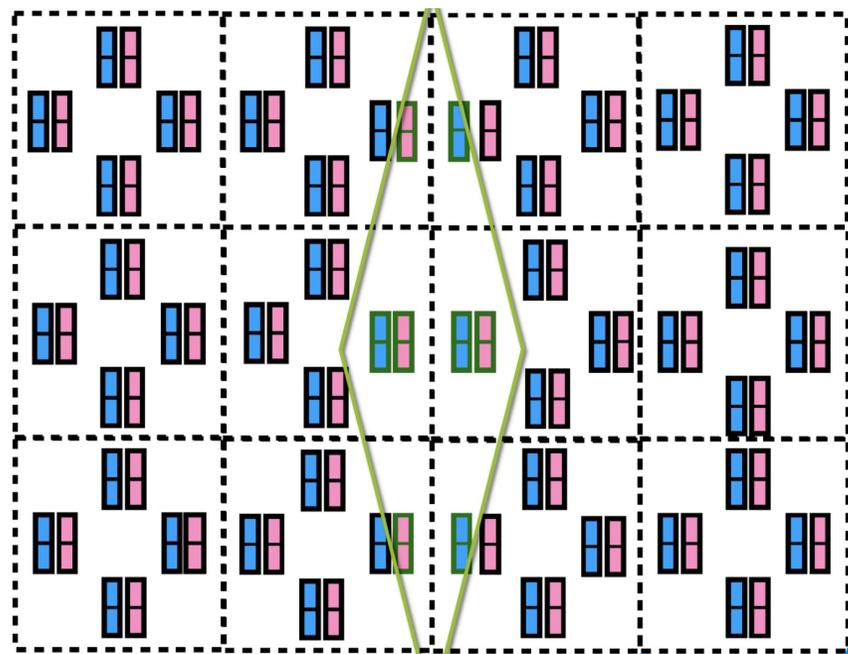
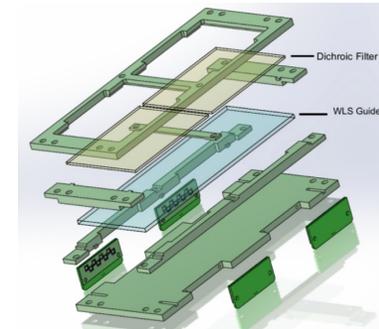


X-ARAPUCA
VUV light

X-ARAPUCA
Visible light



System Overview

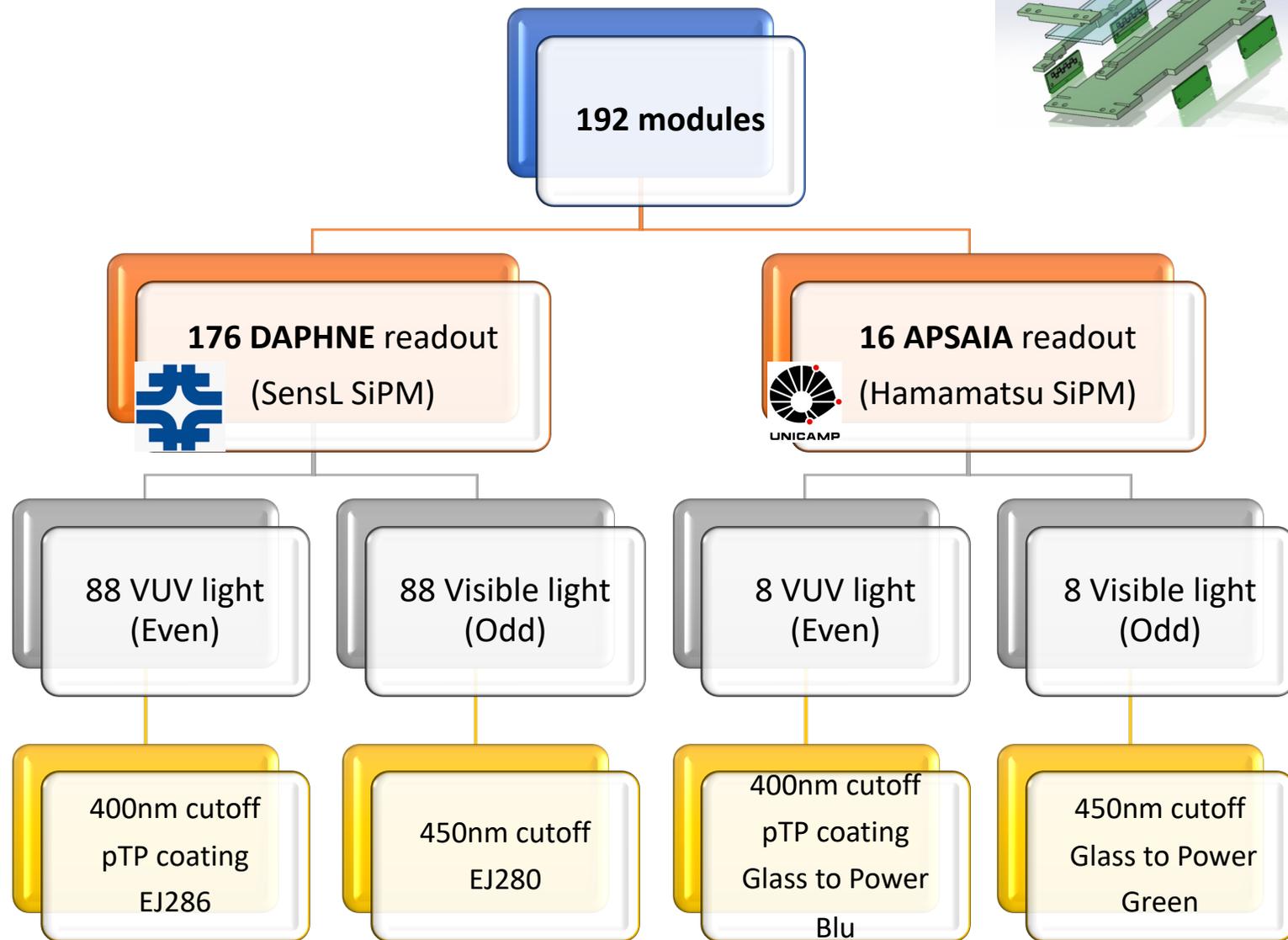


DAPHNE
 System
 Modules

 Labels:
020-195

APSAIA
 System
 Module

 Labels:
001-016



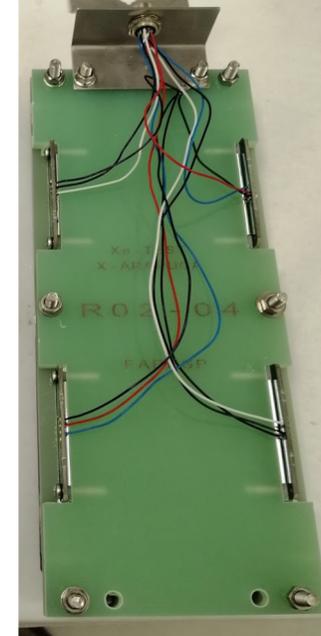
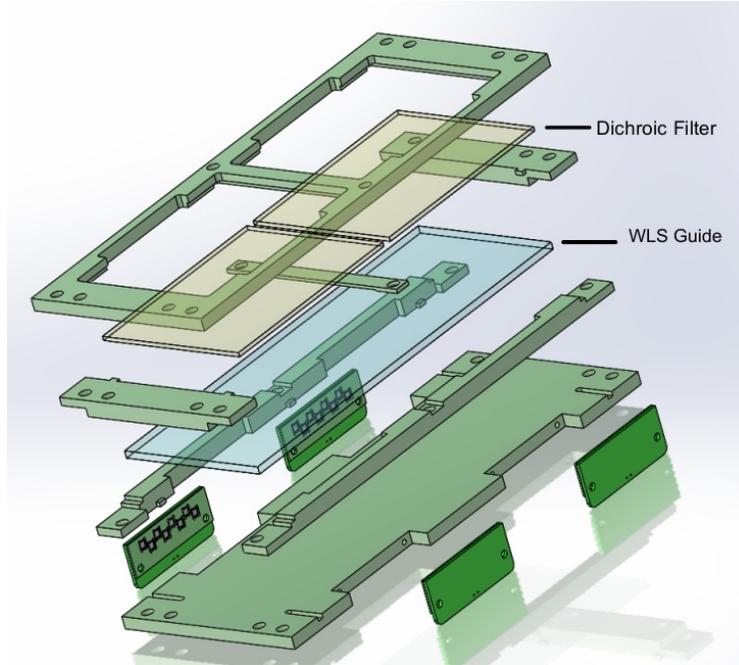
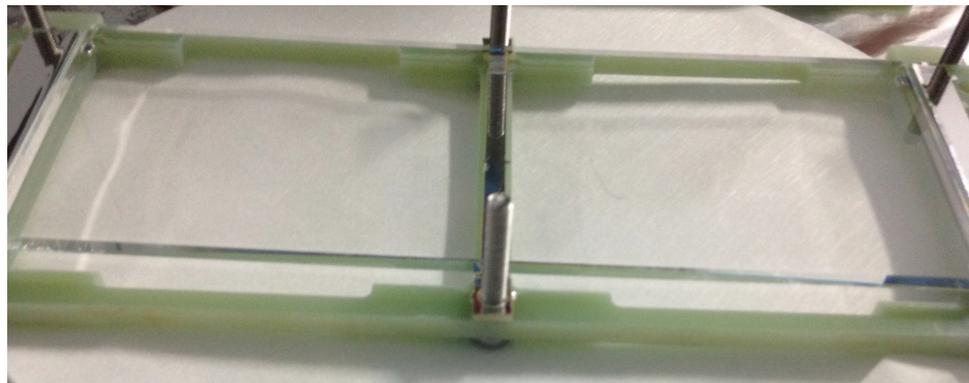
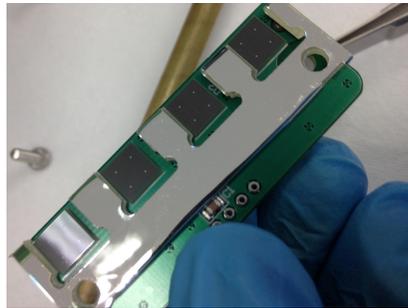
X-ARAPUCA Modules

Desing
Production
Test

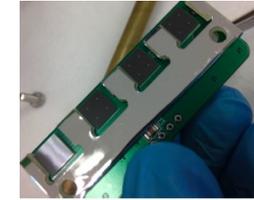
DAPHNE readout
SiPM sensL
3X3mm²



APSAIA readout
SiPM Hamamatsu
6X6mm²



Efficiency Expected



Two works published **this year**

- ▶ UNICAMP → Half SBND module was used for measurement of its efficiency in Lar
- ▶ <https://arxiv.org/abs/2106.04505>

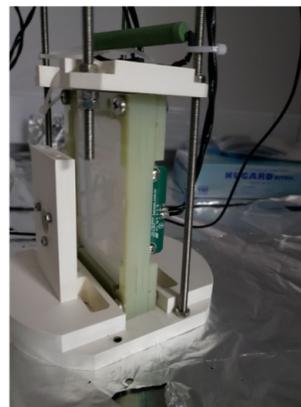
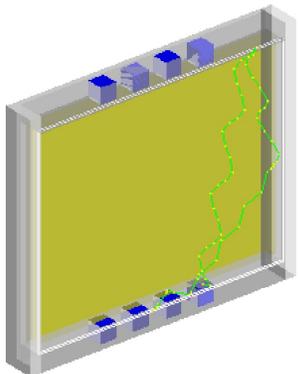
- ▶ Milano Bicocca group working on X-ARAPUCA for DUNE experiment.
- ▶ The Unicamp group provided the X-ARAPUCA module which is an SBND one
- ▶ <https://arxiv.org/abs/2104.07548>



Eljen Bars



$2.2 \pm 0.5\%$



Eljen Bars

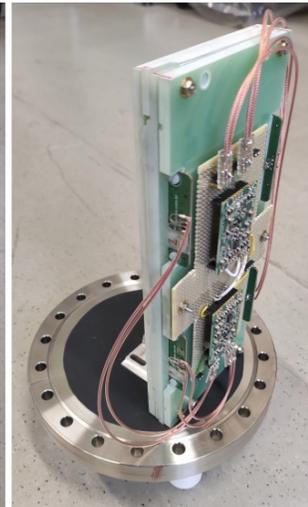
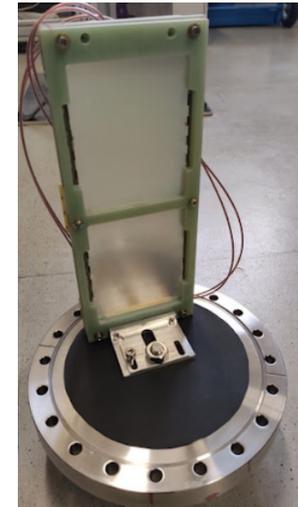


$(1.8 \pm 0.1)\%$

Glass to Power



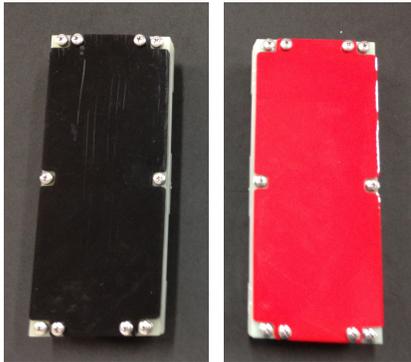
$(2.9 \pm 0.1)\%$

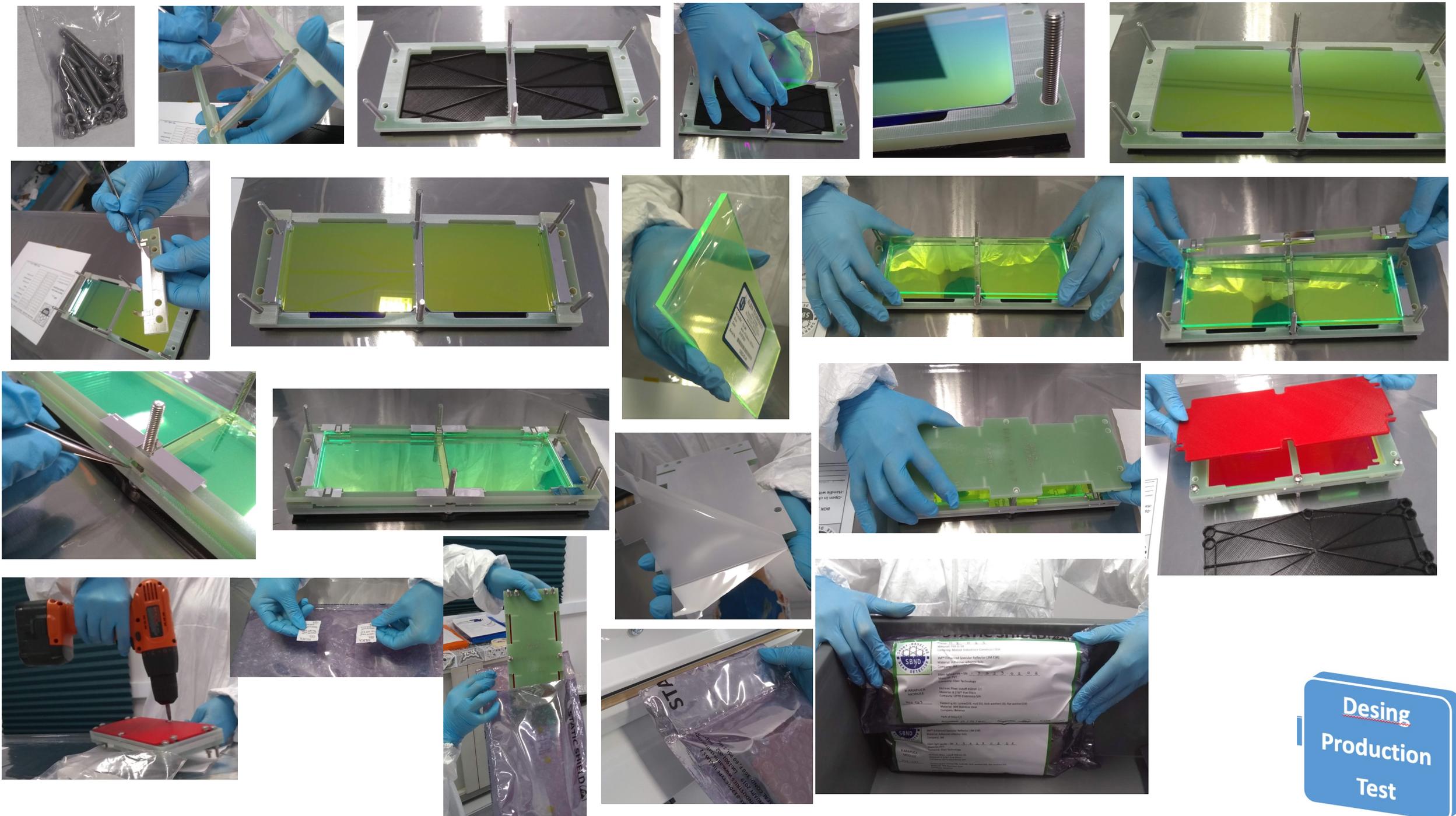


X-ARAPUCA ASSEMBLY



Desing
Production
Test



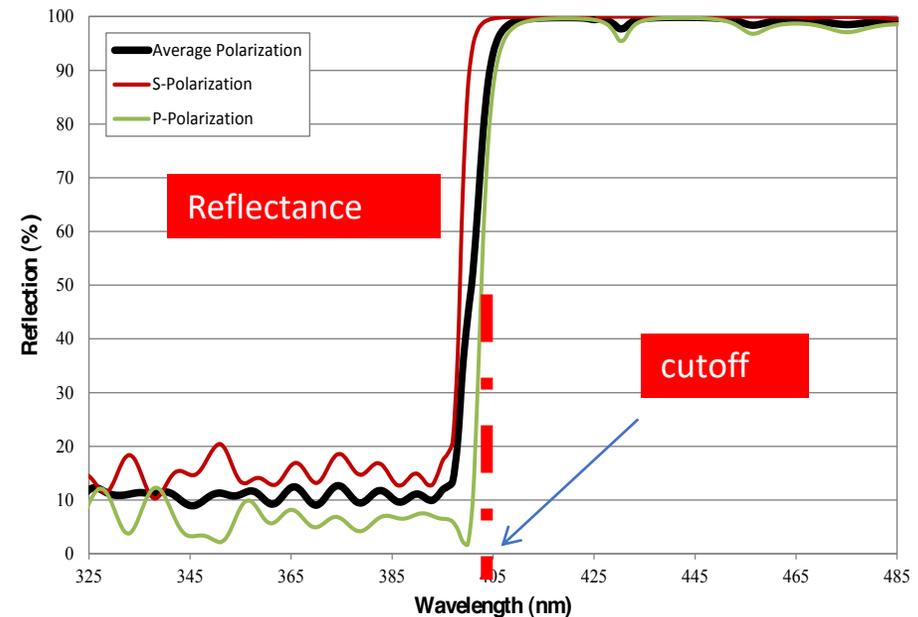
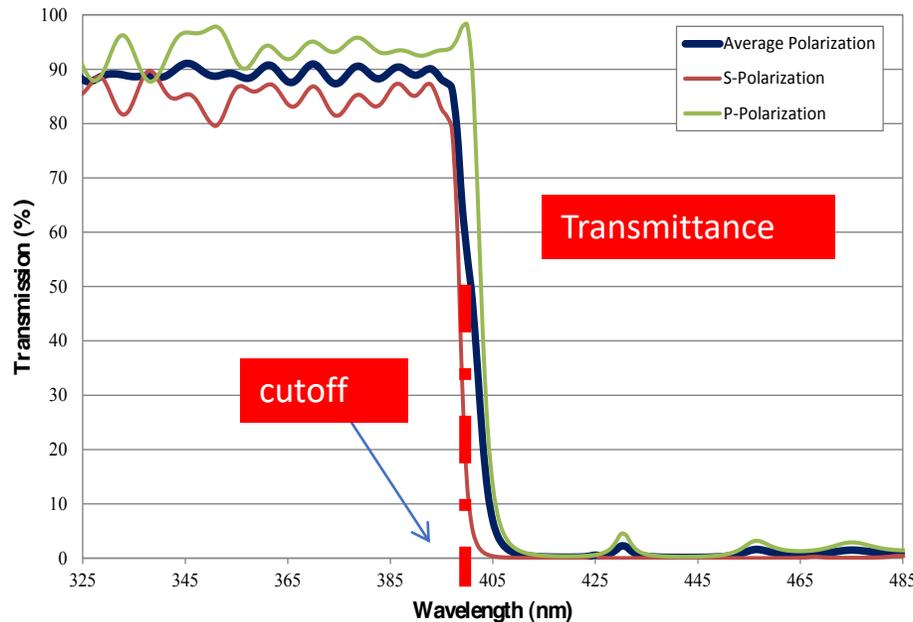


Desing
Production
Test

Dichroic Filter studies

The optical filters must have these characteristics:

- Transparent for wavelengths below the filter cutoff
- Reflective for wavelengths above the filter cutoff
- Designed for the incidence angle of 45 degrees



Substrate Analysis

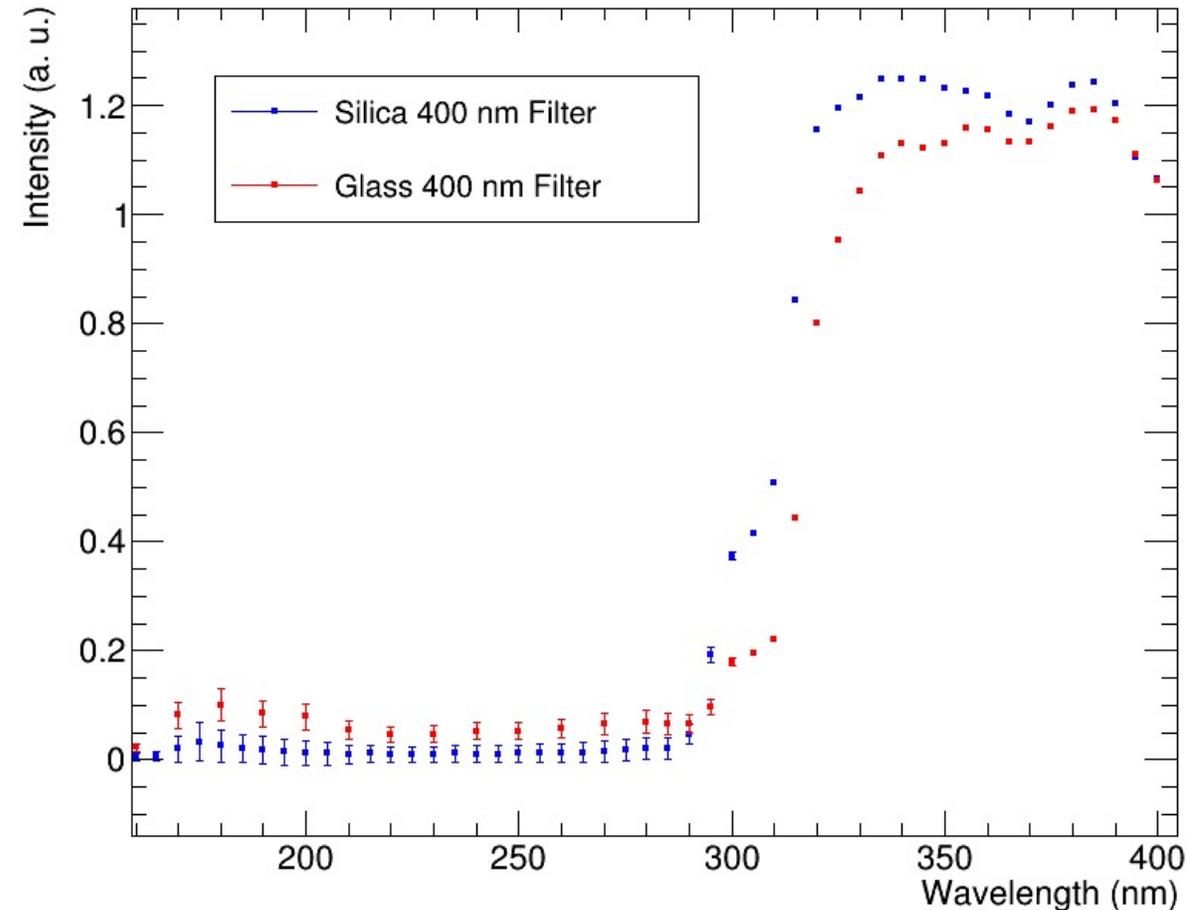
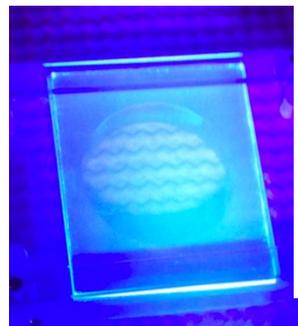
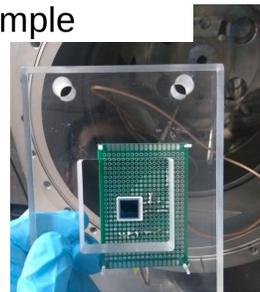
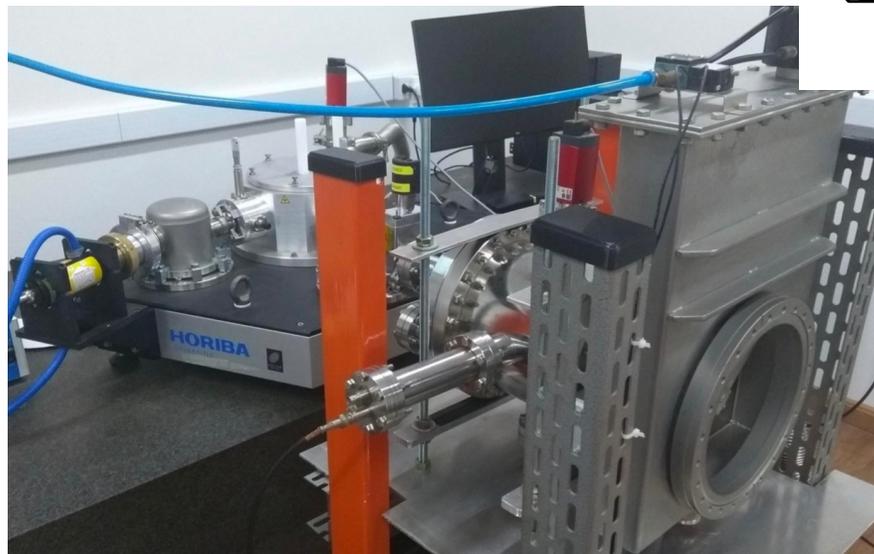
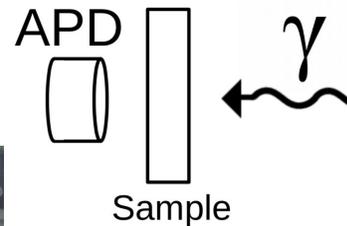


Results

Fused Silica and a **Optical Glass (B270)** were tested using a Deuterium light source monochromator (emission 120 -/400nm) and a Si APD S8664-1010 (Q.E. 320nm -/ 1000nm) Cutoff 300nm
Calibration: direct light to APD

Above 350nm the transmittance spectrum of the two samples is similar.

- The choice of B270 is conveniente because it is much cheaper

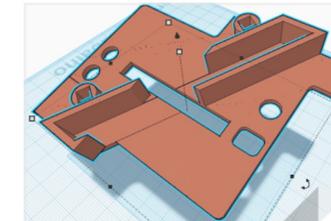
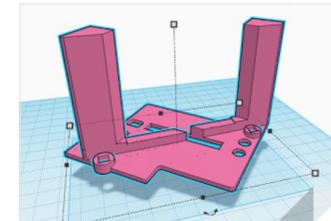
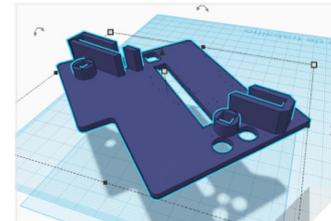


Transmittance measurements

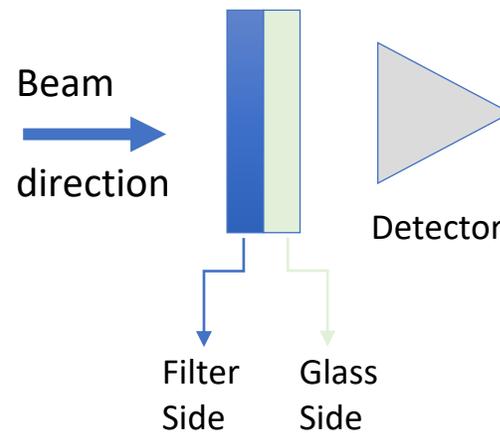


UV-VIS spectrometer Perkin-Elmer

- Reflectivity (8° angle from incidence beam)
- Transmittance (different angles) : 3D print support



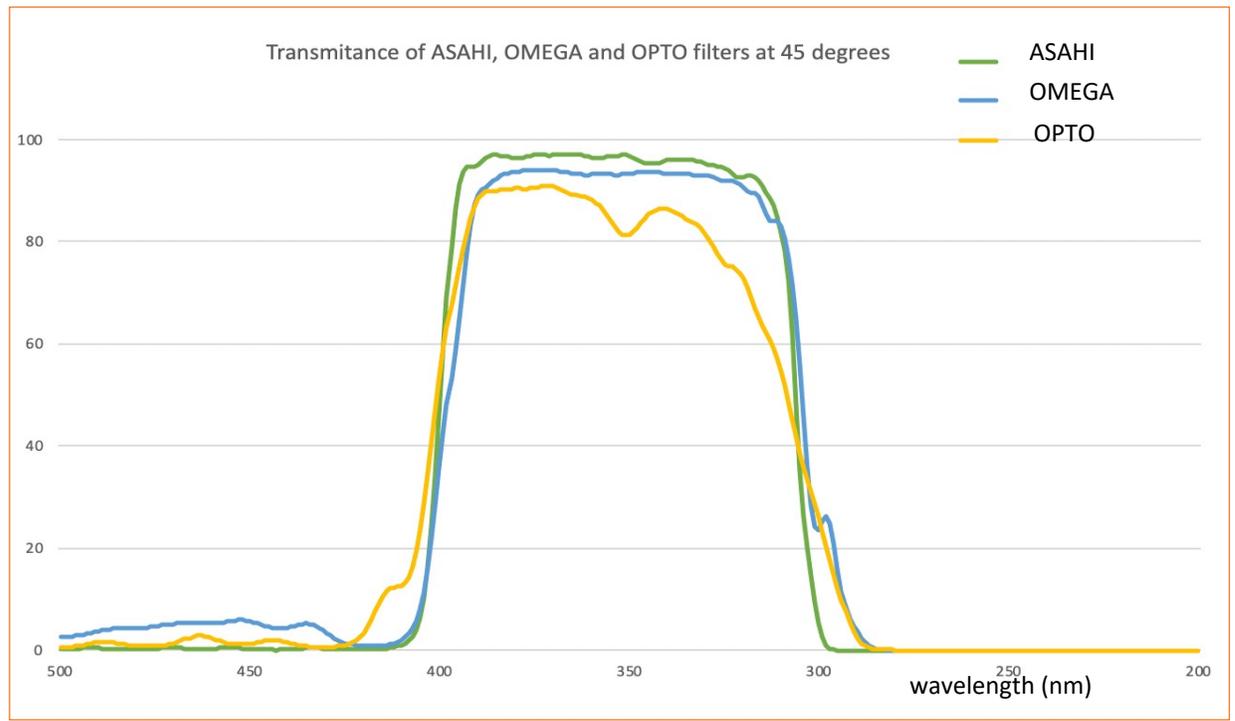
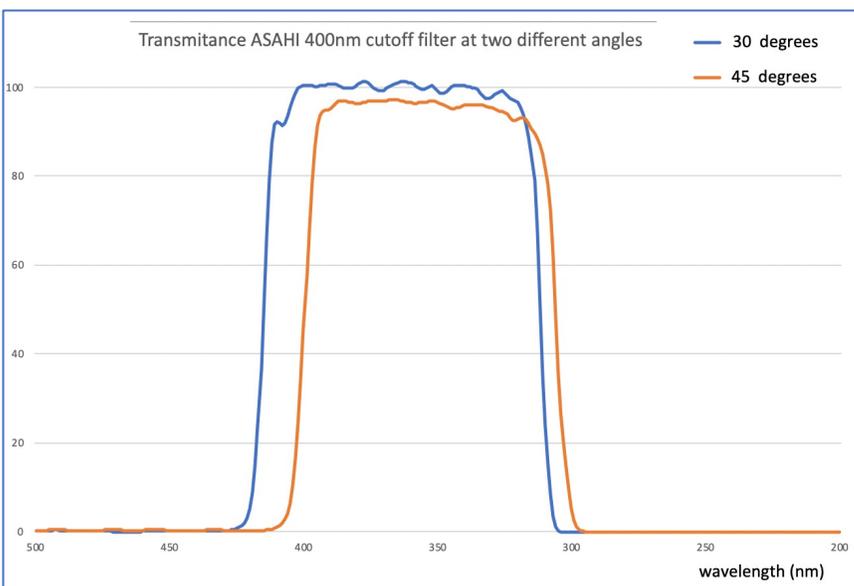
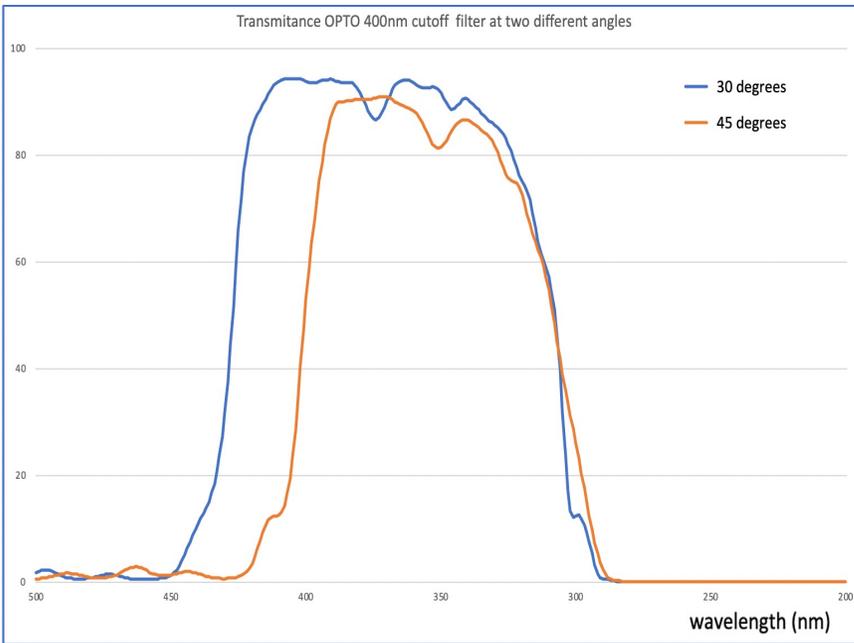
Courtesy of Frederico DeMolin



- Humidity and Temperature controlled
- Samples:
- Filters from OPTO, OMEGA and ASAHI
400nm cutoff

Transmittance

- Check the angular dependence
- Comparison with other producers
 - ASAHI and OMEGA (Fused sílica substrate)
 - OPTO (Optical Glass substrate)



WLS Studies

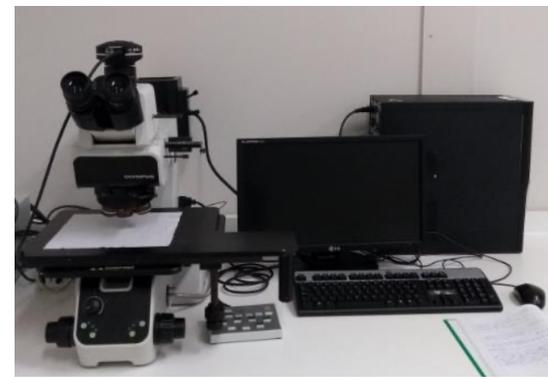


Thermo-Hygrometer



Optical components

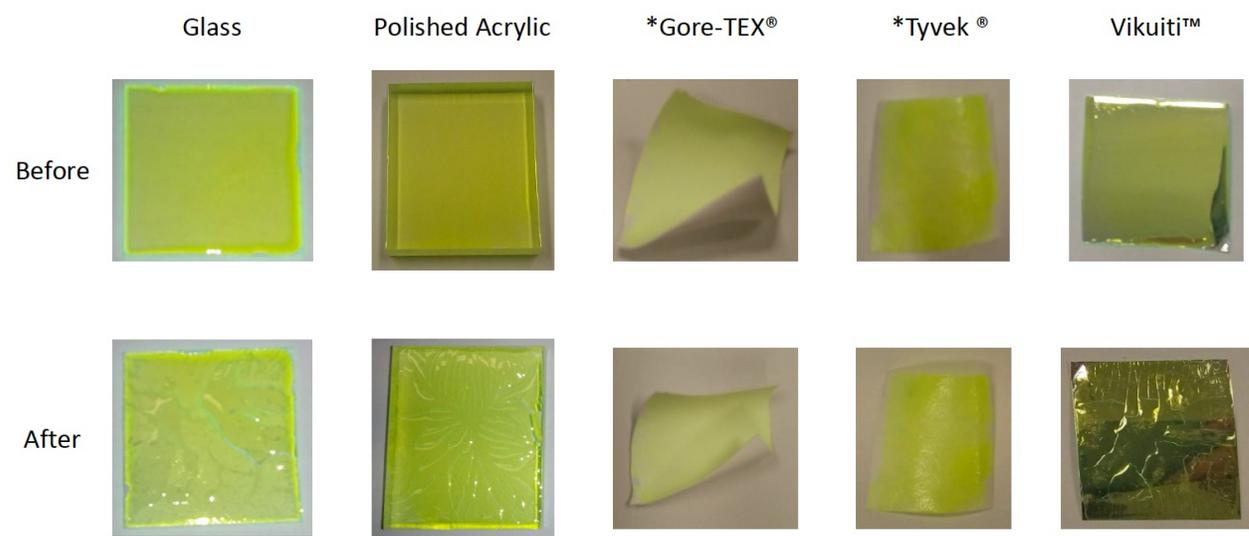
Optical Microscopy - Olympus



Fluorometer/Spectrometer - Horiba



CRYOGENIC ADHESION TESTS IN DIFFERENTS SUBSTRATES



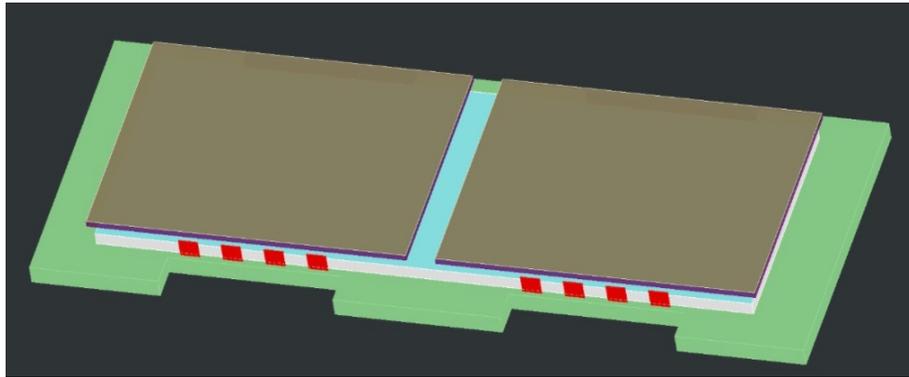
Tests consisted of:

- "speed" of 2cm/min
- room temperature
- relative humidity
- bars/plates immersion on Arapuca frame

Before and After LN₂ immersions were taken:

- Optical Microscope images
- Transmittance
- Fluorescence (emission and excitation spectras)

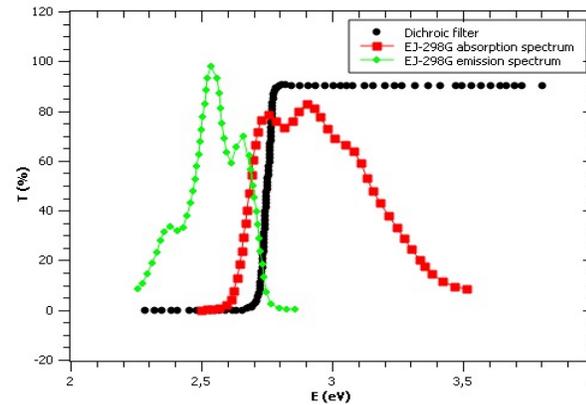
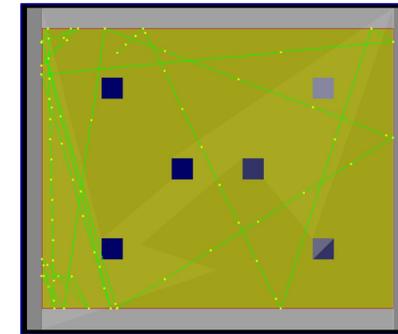
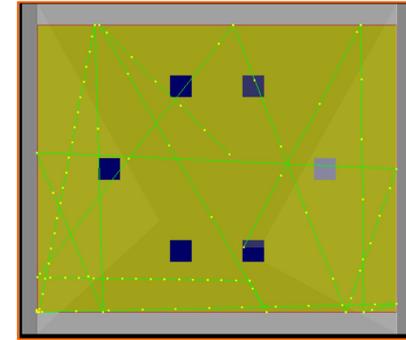
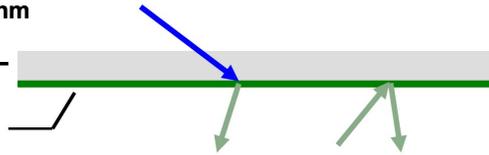
Simulation Contributions to SBND



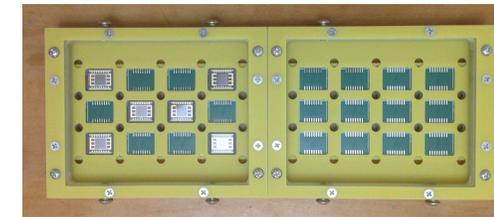
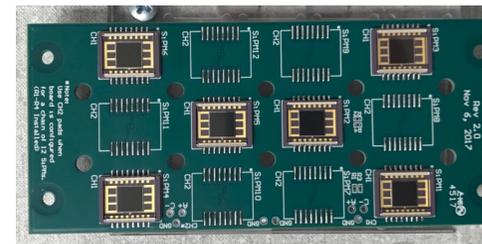
Studies on optical window

Filter cutoff at 460 nm

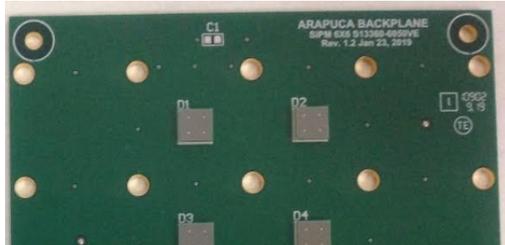
EJ-298G



● pnt_coated
 ● pnt_uncoated
 ■ xarapuca_vis
 ■ xarapuca_uv

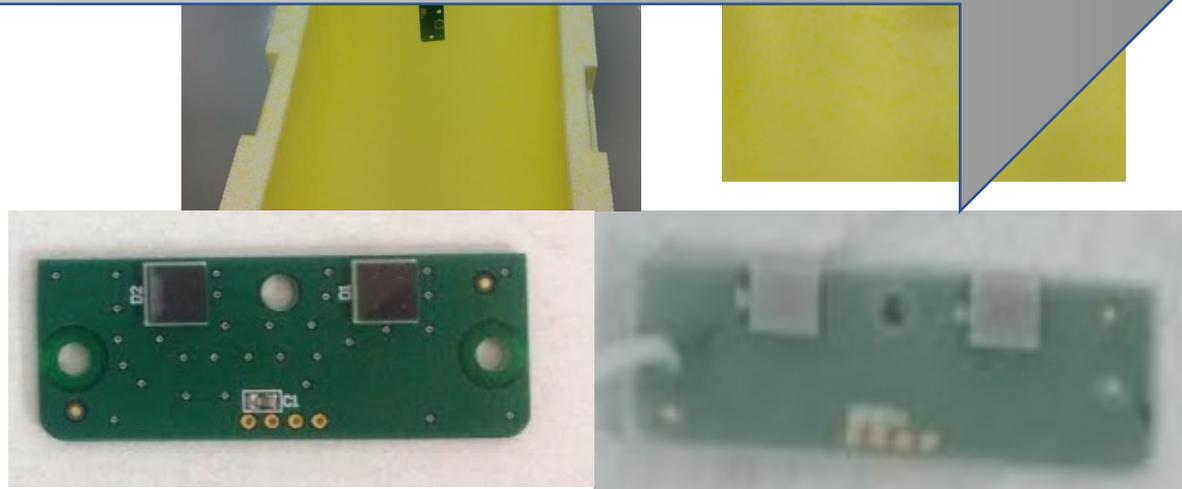
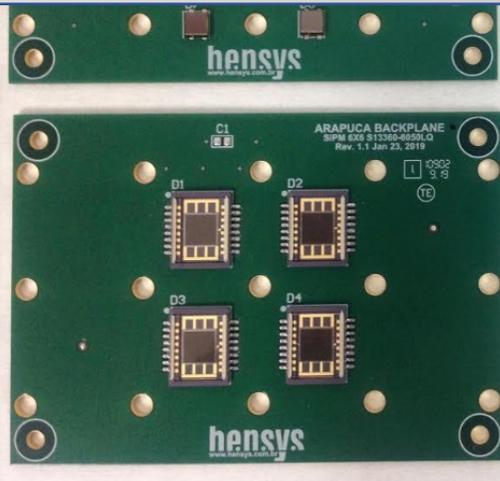


SiPM Boards



- The SiPM boards for ARAPUCA and X-ARAPUCA have been produced
- Was performed connectivity test at room and cryogenic temperature

The design of ARAPUCA in SBND was replaced by X-ARAPUCA
BUT
a lot of instrumentation work has been developed at LABLEPTONS





QA/QC documentation

- Cleaning Procedure:
 - X-ARAPUCA frames
 - X-ARAPUCA Dichroic Filters
 - X-ARAPUCA Dichroic filters visual inspection
 - X-ARAPUCA light guides visual inspection
 - X-ARAPUCA Fastening
 - Clean room → Controlled Environment



- Labels
- Evaporation Procedure
- Assembling Procedure
- Shipment document
- Incident/Issues document
- Traveler

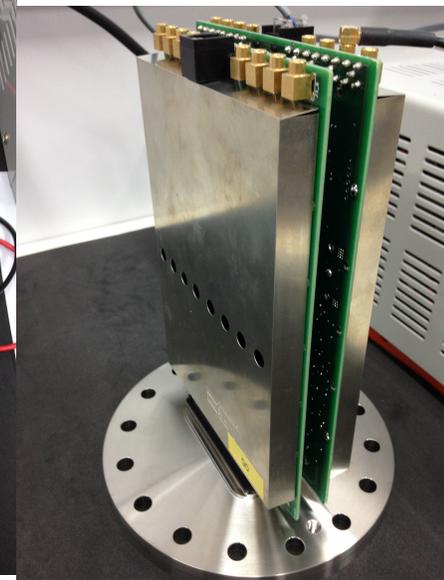
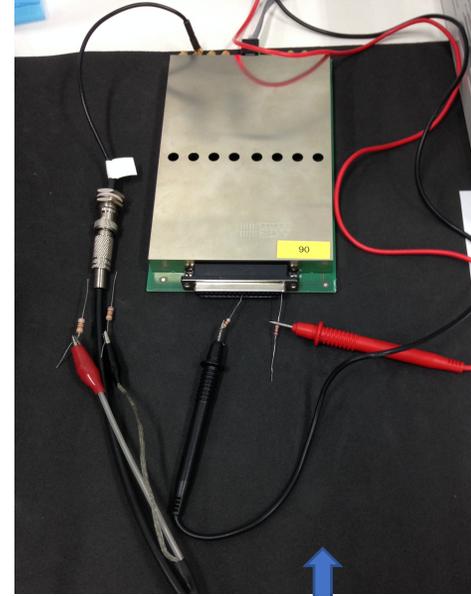
<p>BOX _____</p> <p>-Open in clean area</p> <p>-Handle with gloves</p>	Dichroic filter; cutoff 400nm		Material: B 270™ Flat Glass		Company: OPTO Eletrônica S/A		OPTO delivered to UNICAMP:	
	1-	///	16-	///			Delivered to CTI:	
	2-	///	17-	///			Cleaned:	
	3-	///	18-	///			Returned to UNICAMP:	
	4-	///	19-	///			Resp.: _____	
	5-	///	20-	///				
	6-	///	21-	///				
	7-	///	22-	///				
	8-	///	23-	///				
	9-	///	24-	///				
	10-	///	25-	///				
	11-	///	26-	///				
	12-	///	27-	///				
	13-	///	28-	///				
	14-	///	29-	///				
15-	///	30-	///					

<p>X-ARAPUCA MODULE</p>	Dichroic filter; cutoff 400nm (2)		Material: B 270™ Flat Glass		Company: OPTO Eletrônica S/A	
	Frame:					
	Material: TVE G-10					
	Company: Matos Indústria e Comércio Ltda.					
	Eijen light guide - SN: _____					
	Material: PVT					
	Company: Eijen Technology					
	3M™ Enhanced Spectral Reflector (3M ESR)					
	Material: Adhesive reflector foils					
	Company: 3M					
Fastening kit: screw (20), nut (20), lock washer (10), flat washer (20)						
Material: 304 Stainless steel						
Company: Belenus do Brasil Ltda.						
Pack of Silica (2)						
Assembled: ___/___/___ Responsible: _____						

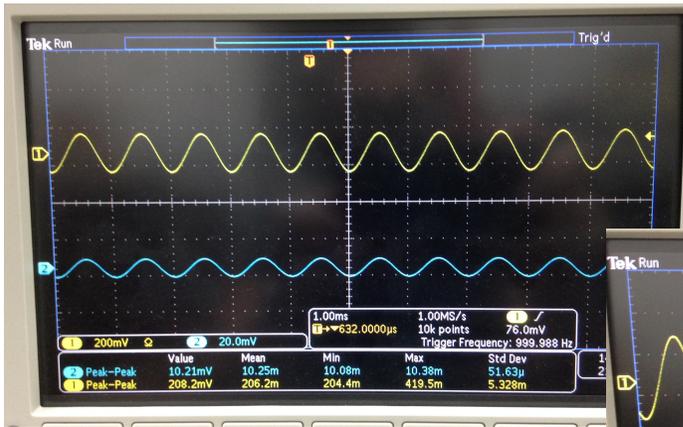
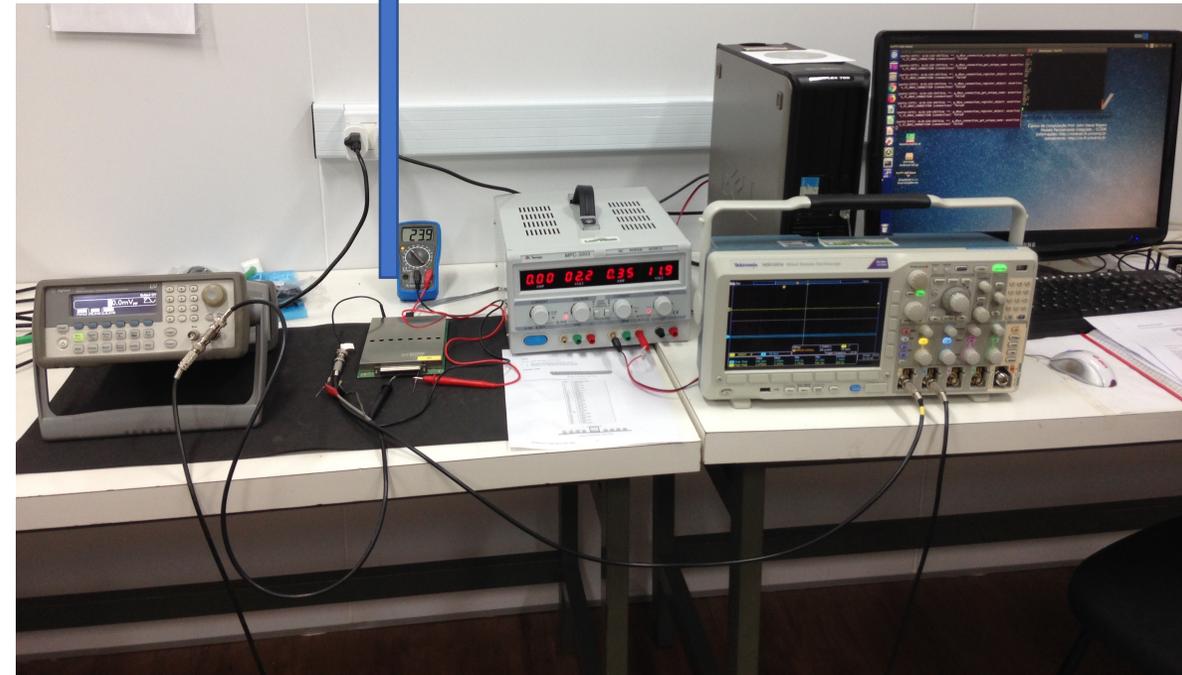


APSAIA board tests

- 4 APSAIA boards will be used to bias the MPPCs, readout and amplify the signals for 16 X-ARAPUCA modules.
- Each APSAIA board has 8 channels
- The gain can be tuned to be 20x or 40x



Electronics boards and tests





Summary

- Since the ARAPUCA system was approved to be installed in SBND, a huge **instrumentation work has been developed here in Brazil**, at UNICAMP and CTI.
- **Brazilian companies** are working together for the production of the modules, dichroic filters and also the electronics.
- Simulations studies of ARAPUCA and X-ARAPUCA modules have been done by UFABC, UFSCAR and UNIFAL groups
- There are more contributions of the brazilian groups in SBND in instrumentation (**purity monitors, câmeras and RTD**), and also in **phenomenology**.

Muito Obrigada



2016/09084-0

2017/13942-5

2014/19164-6

2016/01106-5

2015/25121-0

2019/11557-2