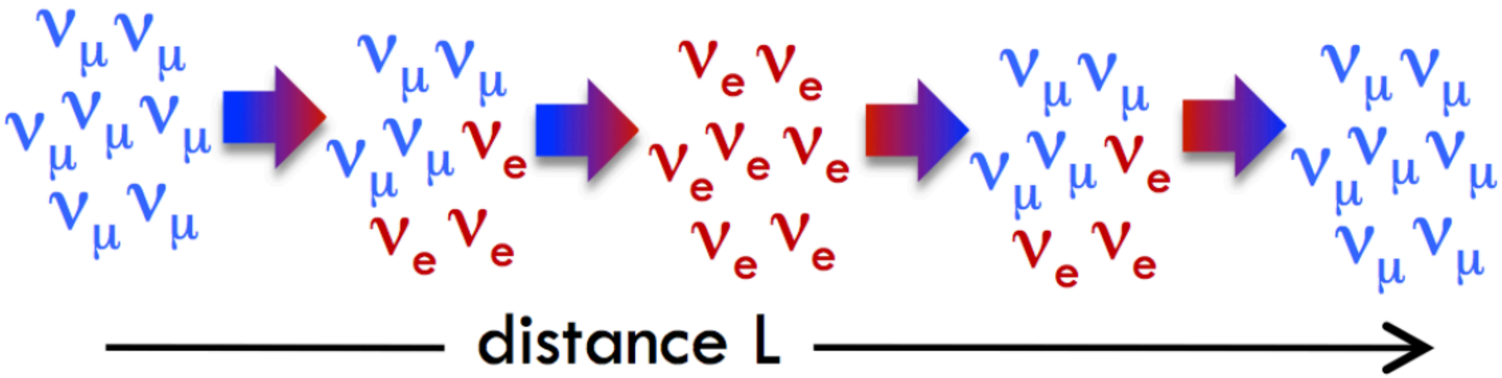
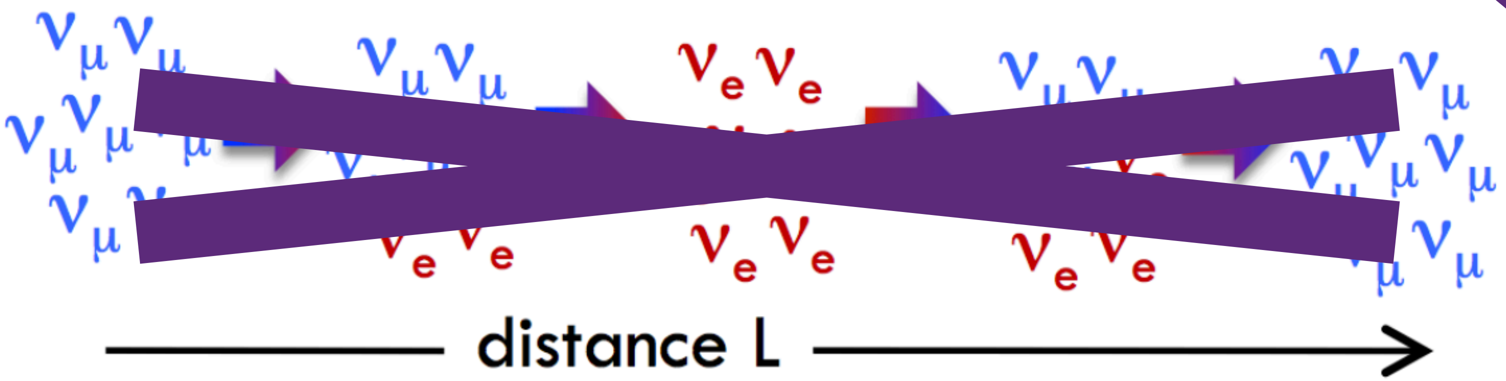
Scintillation Light Detection in SBND

Vincent Basque for the SBND Collaboration

Neutrino Oscillation

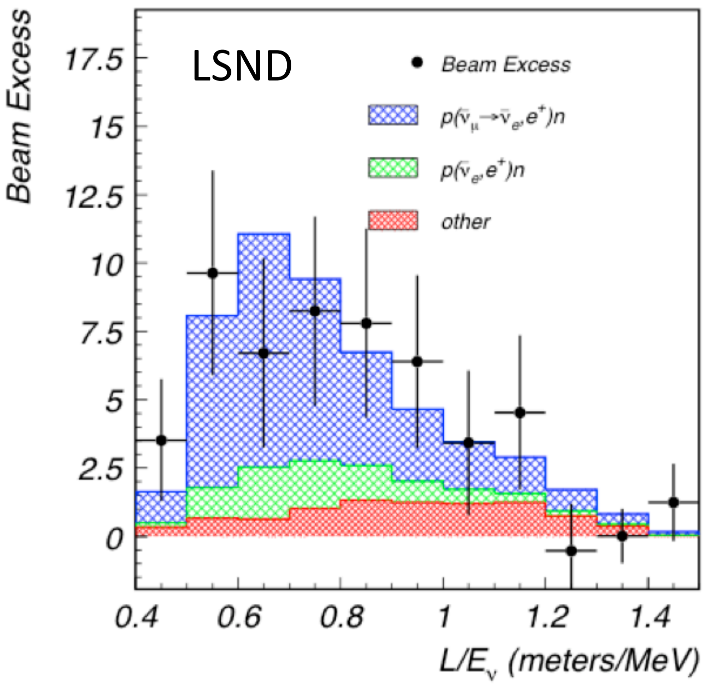


Neutrino Oscillation – Short-Baseline Anomalies

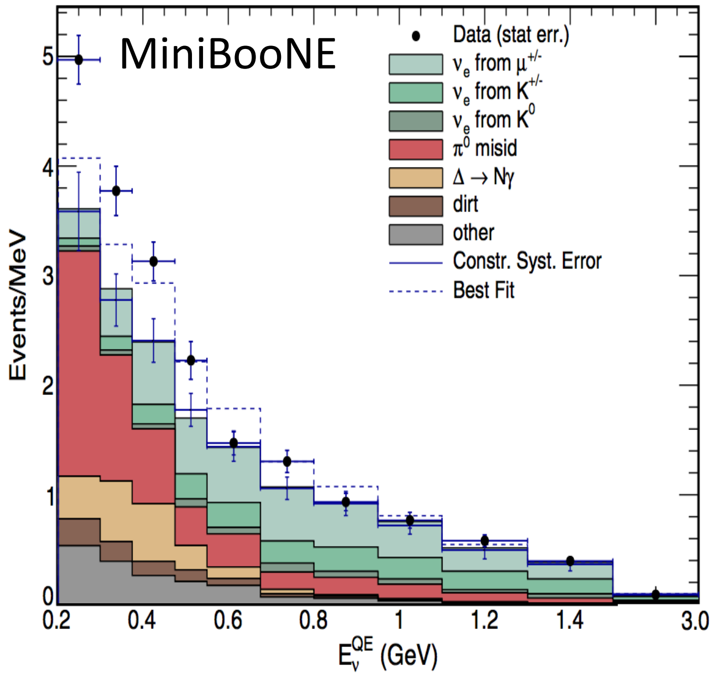


Lots of tension!

Phys. Rev. D64:112007, 2001



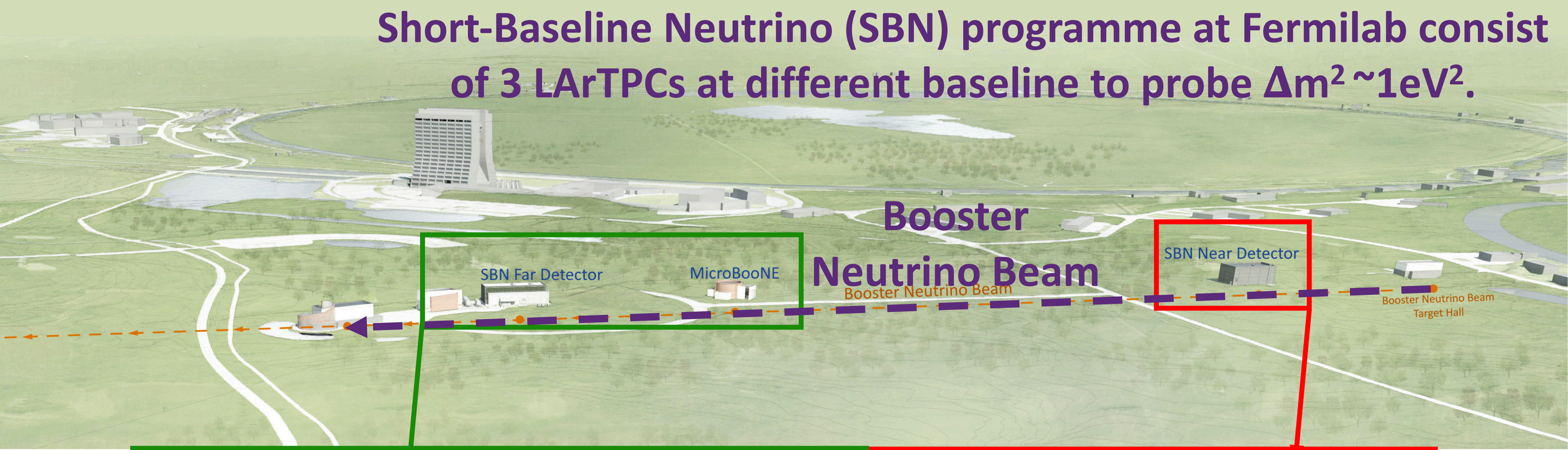
Phys. Rev. Lett. 121, 221801, 2018

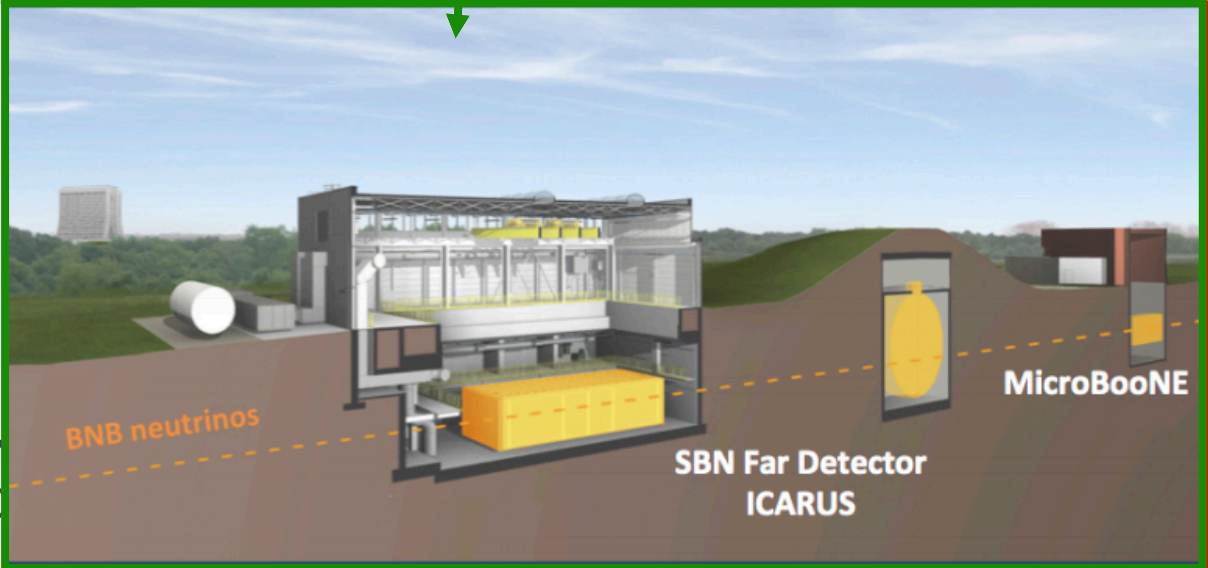


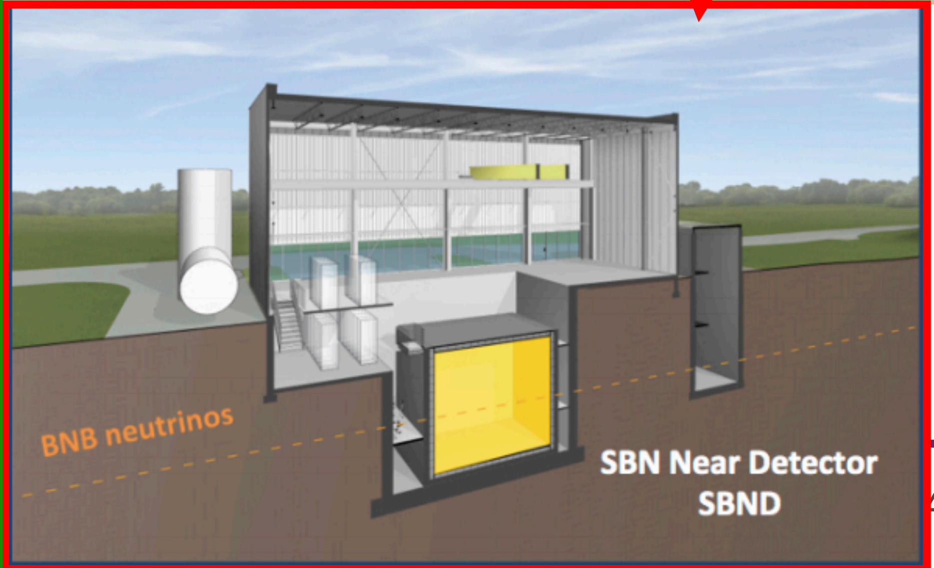
New (sterile) neutrino?

Short-Baseline Neutrino Programme

Short-Baseline Neutrino (SBN) programme at Fermilab consist of 3 LArTPCs at different baseline to probe $\Delta m^2 \sim 1eV^2$.

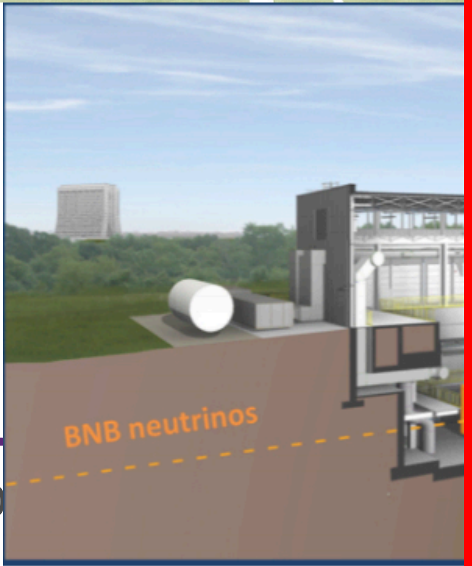


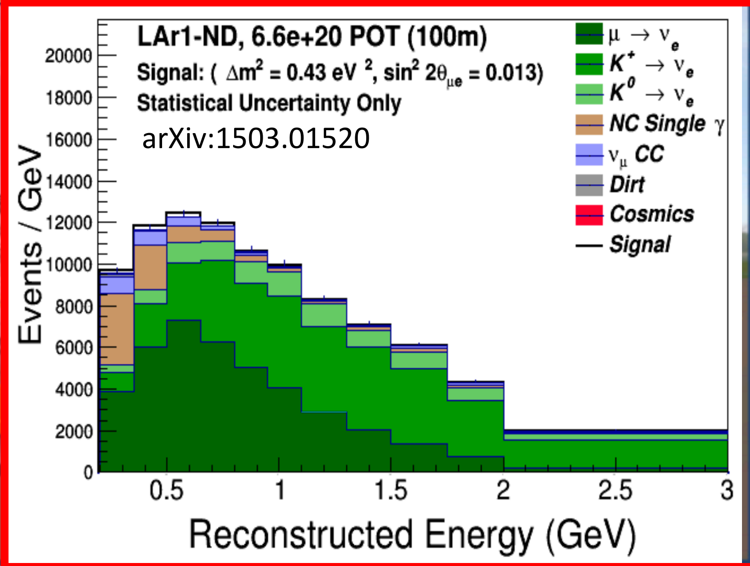


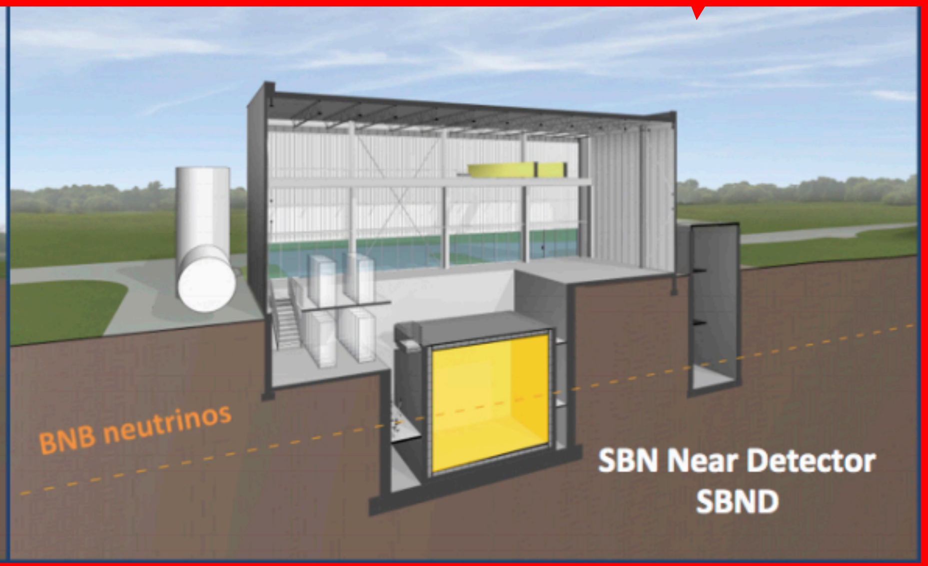


Short-Baseline Near Detector (SBND)

SBND → A 112 t active volume Liquid Argon Time Projection Chamber at 110 m from target



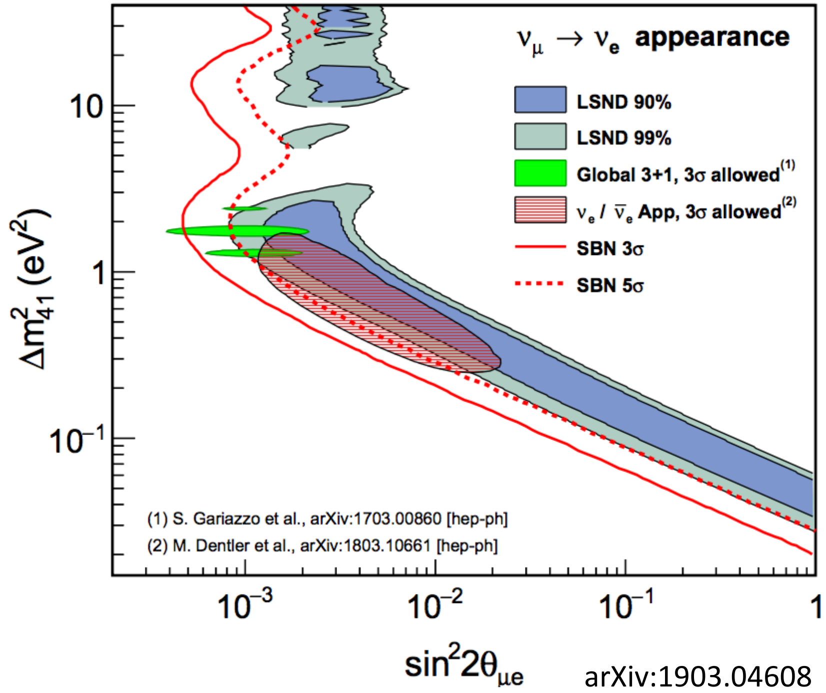




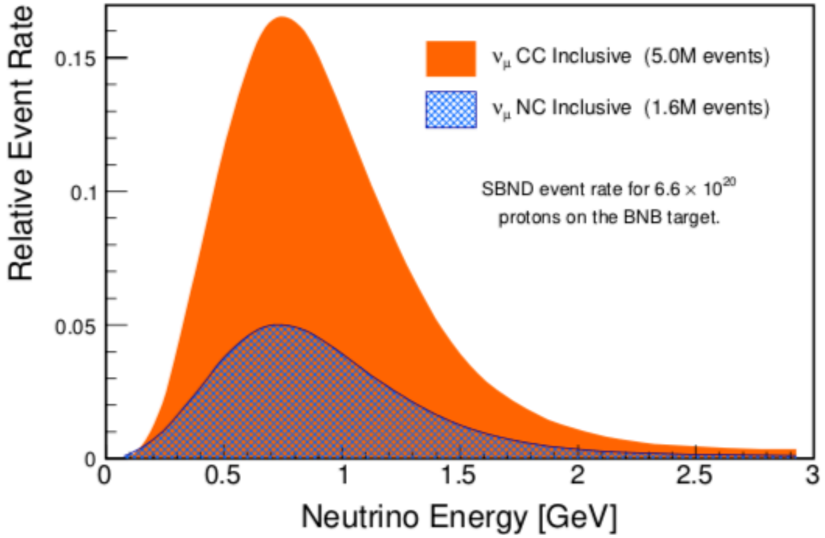
What Physics can SBND do?

- Measure unoscillated neutrino flux for SBN
  - Crucial for the sensitivity of oscillation measurement
  - Highly correlated interactions in near and far detectors (same detector technology and target)
  - Control systematic uncertainties for sterile neutrino search
- Become the world's highest statistics cross-section on LAr with ~7 Millions of ν_μ interactions in 3 years
  - Allows precision measurements of exclusive event topologies
  - Quantify nuclear effects in ν-Ar scattering
- BSM Physics (examples for SBND):
  - Sub-GeV Dark Matter (electron-scattering)
  - Neutrino and dark trident (arXiv:1406.2332)
  - Probing the Higgs Portal (arXiv:1909.1167)

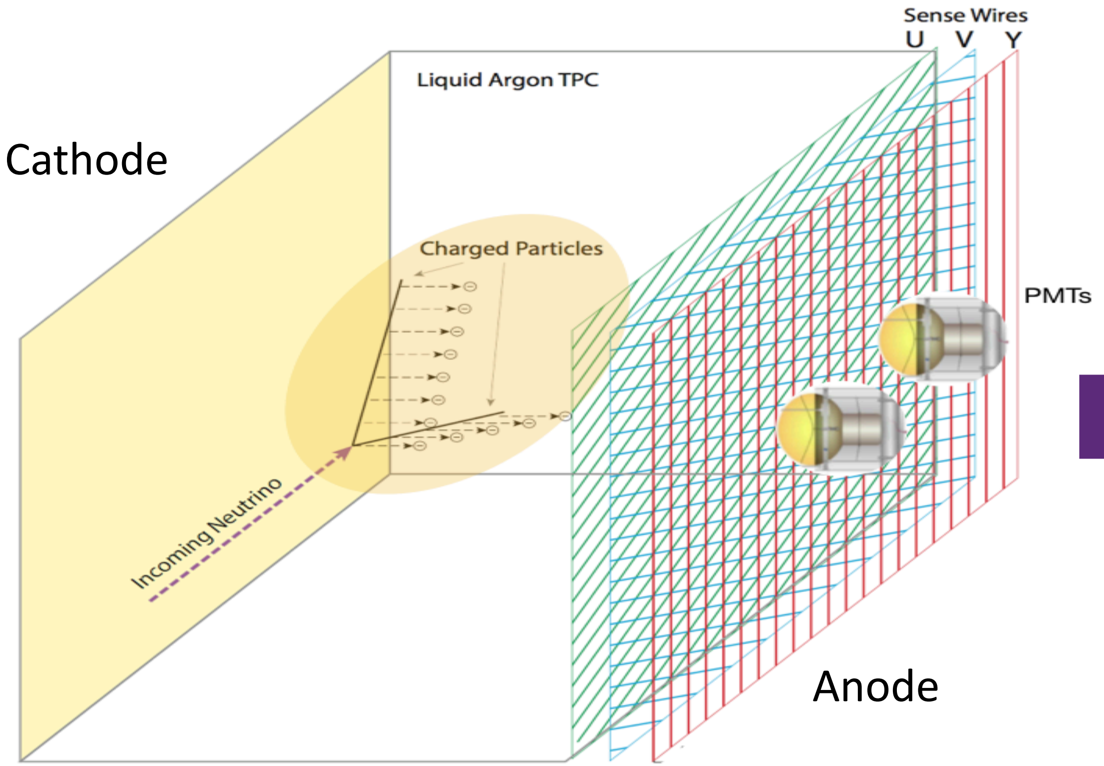
arXiv:1903.04608



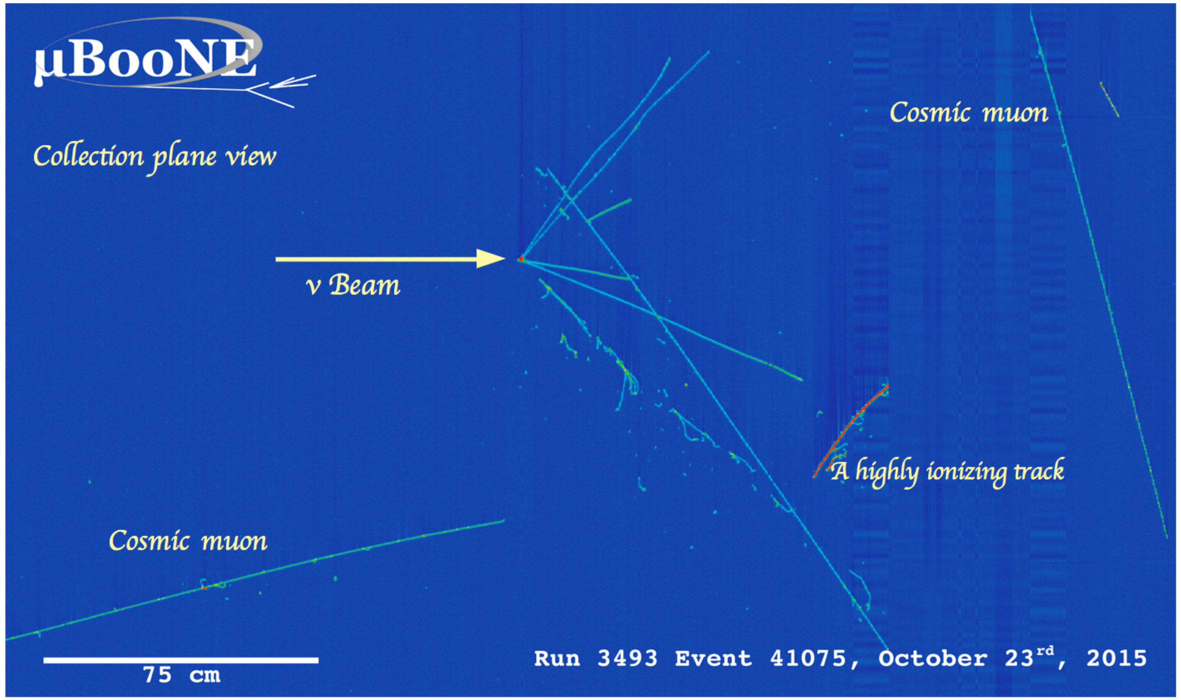
arXiv:1903.04608

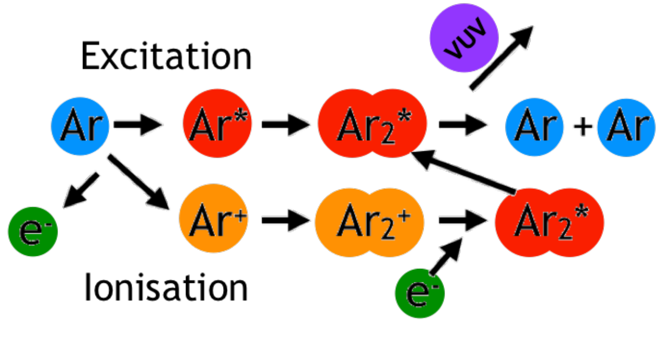


Liquid Argon Time Projection Chambers



Ionization signals:





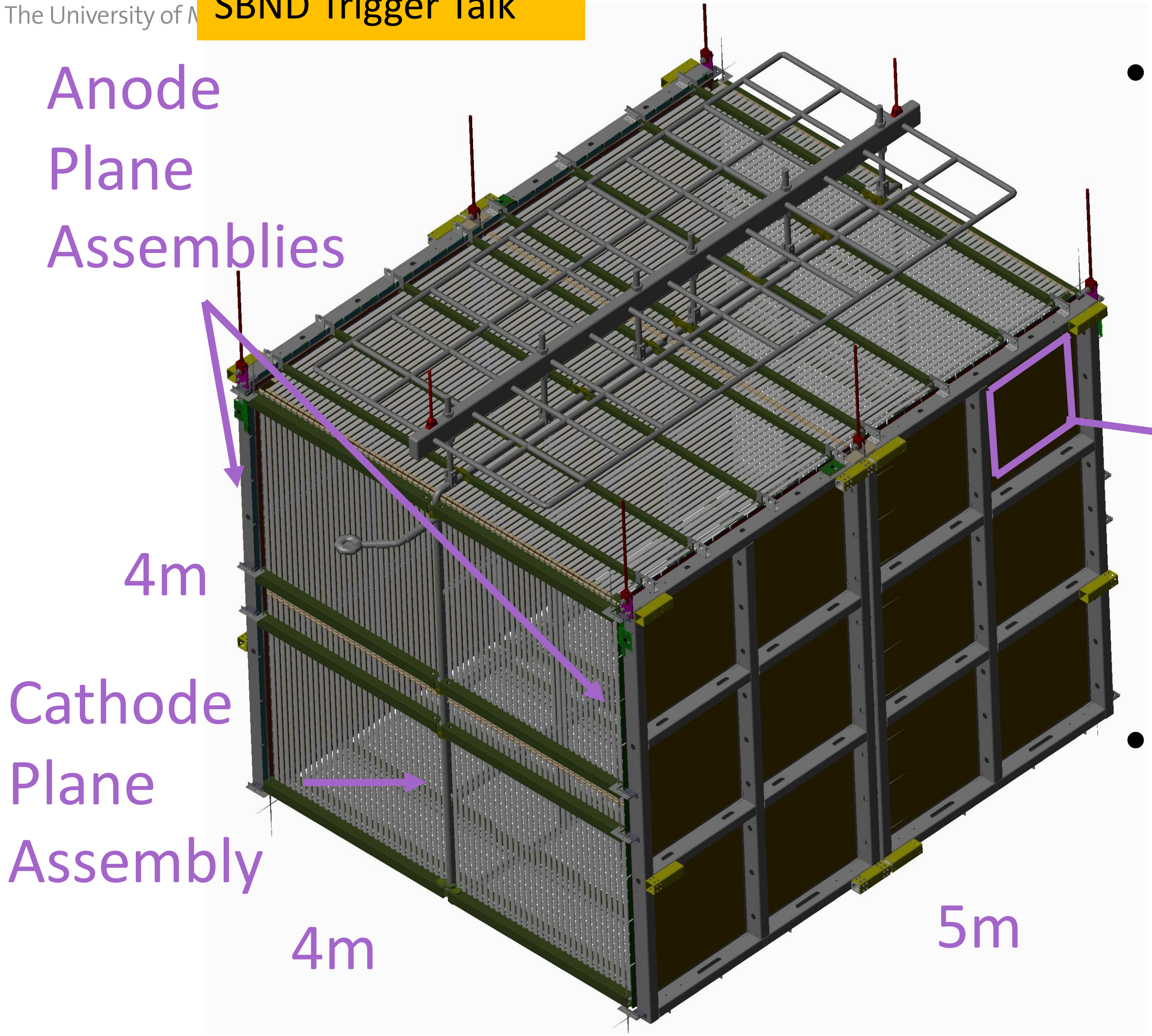
VUV scintillation emission pathways in LAr.

Scintillation signals:

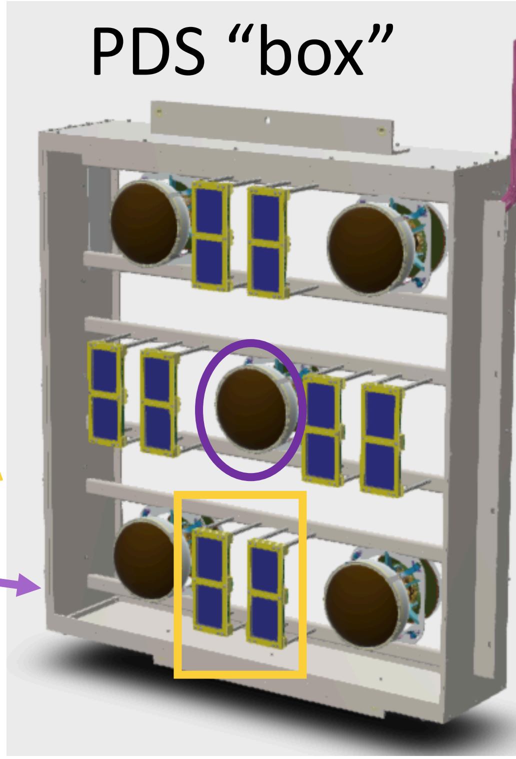
- Very good scintillator (40,000/MeV at E=0)
- Triggering (beam vs background events)
- Localizing neutrino events (MicroBooNE)

SBND Photon Detection System (PDS)

See David Rivera SBND Trigger Talk



- **Active elements:**
  - Baseline: 120 8" Hamamatsu PMT's (96 TPB coated)
  - R&D: X-ARAPUCA + ARAPUCA



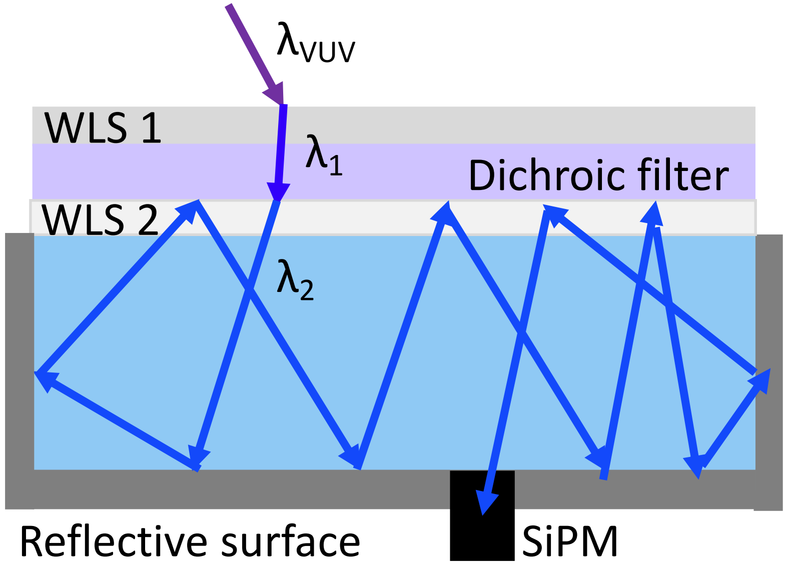
- **Passive element:**
  - Wavelength-Shifting Reflective foils.
  - Total **surface area of ~38 m^2** to cover on cathode(Largest area to date!)

See Ettore/Ana's talk later today

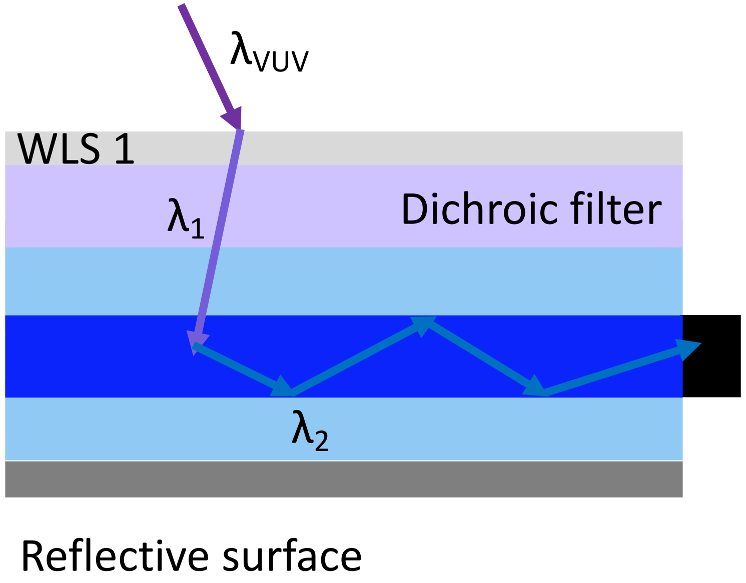
ARAPUCAs & X-ARAPUCAs

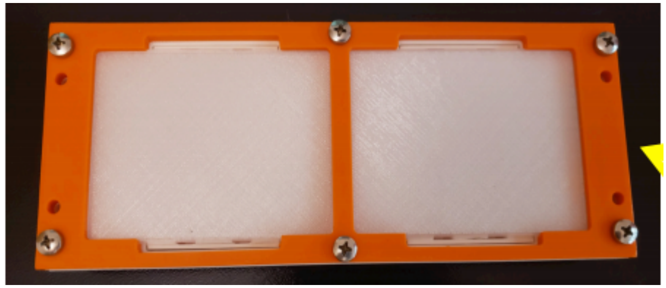
(X-)ARAPUCAS are light traps that increases the effective area of SiPMs using a combination of wavelength-shifters (WLS) and a dichroic filter

ARAPUCA



X-ARAPUCA

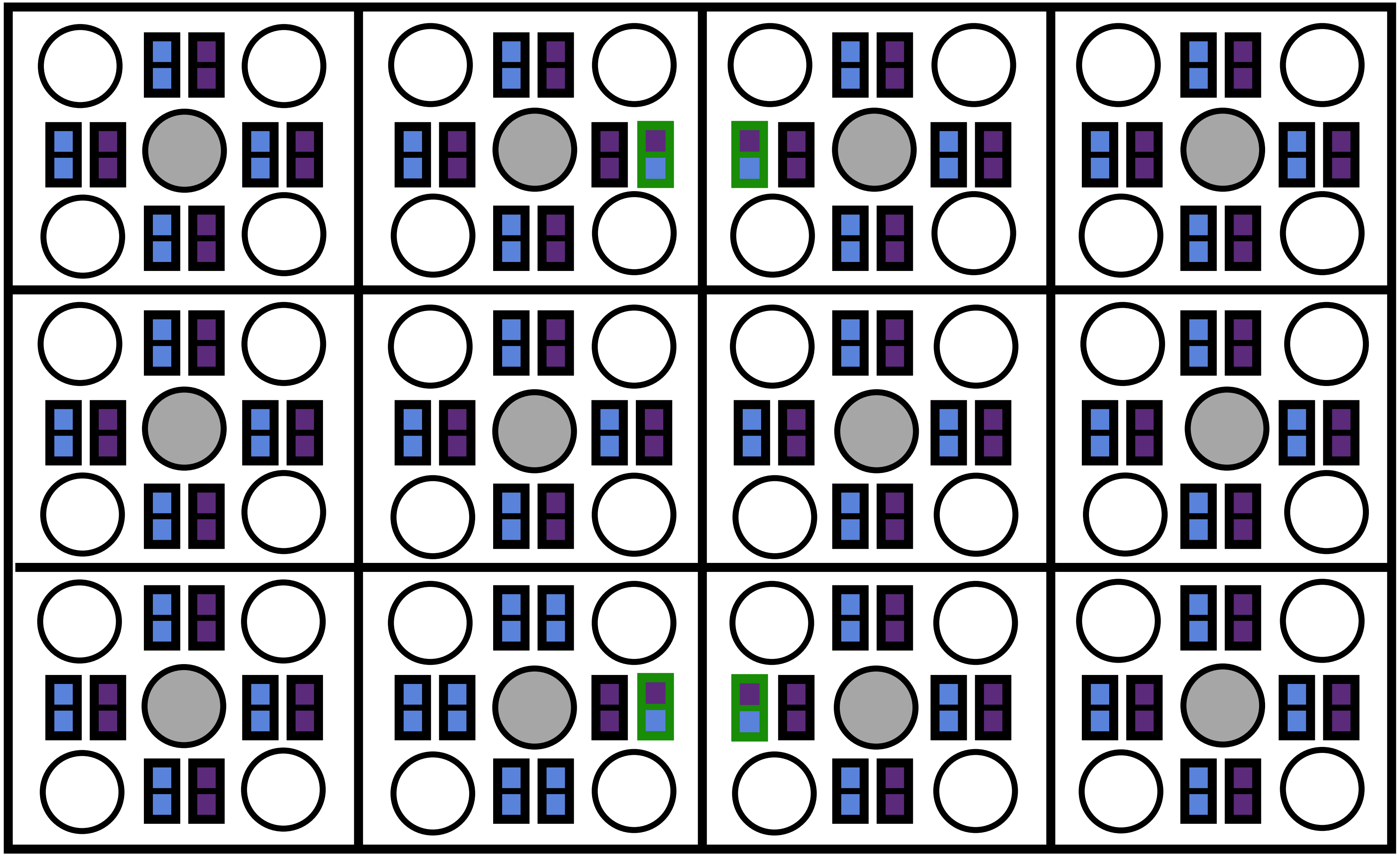




$$\lambda_{VUV} < \lambda_1 < \lambda_2 \text{ [nm]}$$

PDS Map

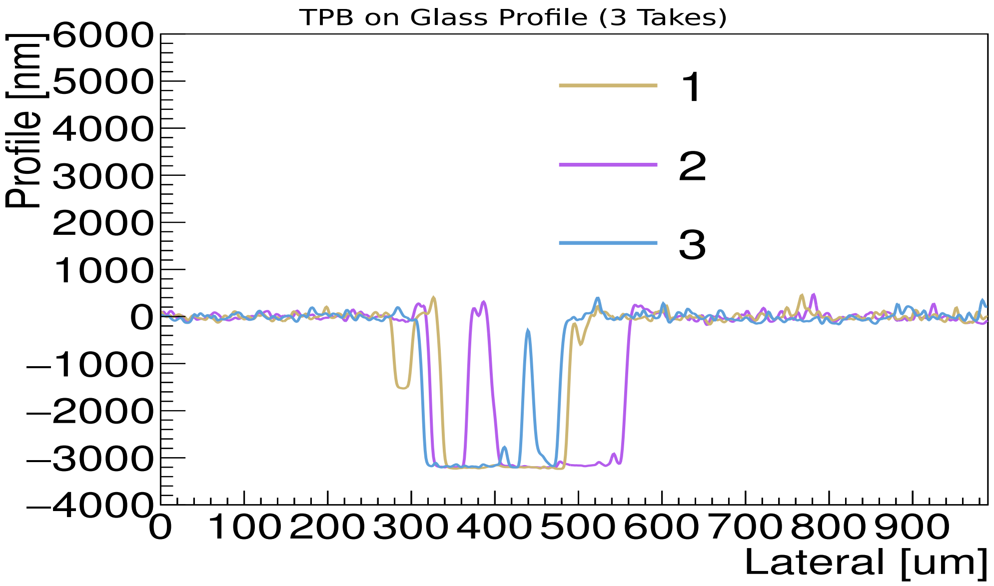
- PMT VUV + visible sensitive
- PMT visible sensitive
- X-ARAPUCA VUV sensitive
- X-ARAPUCA visible sensitive
- ARAPUCA (VUV sensitive)
- ARAPUCA (visible sensitive)



Wavelength-Shifting Reflective Foils

MANCHESTER 1824
The University of Manchester

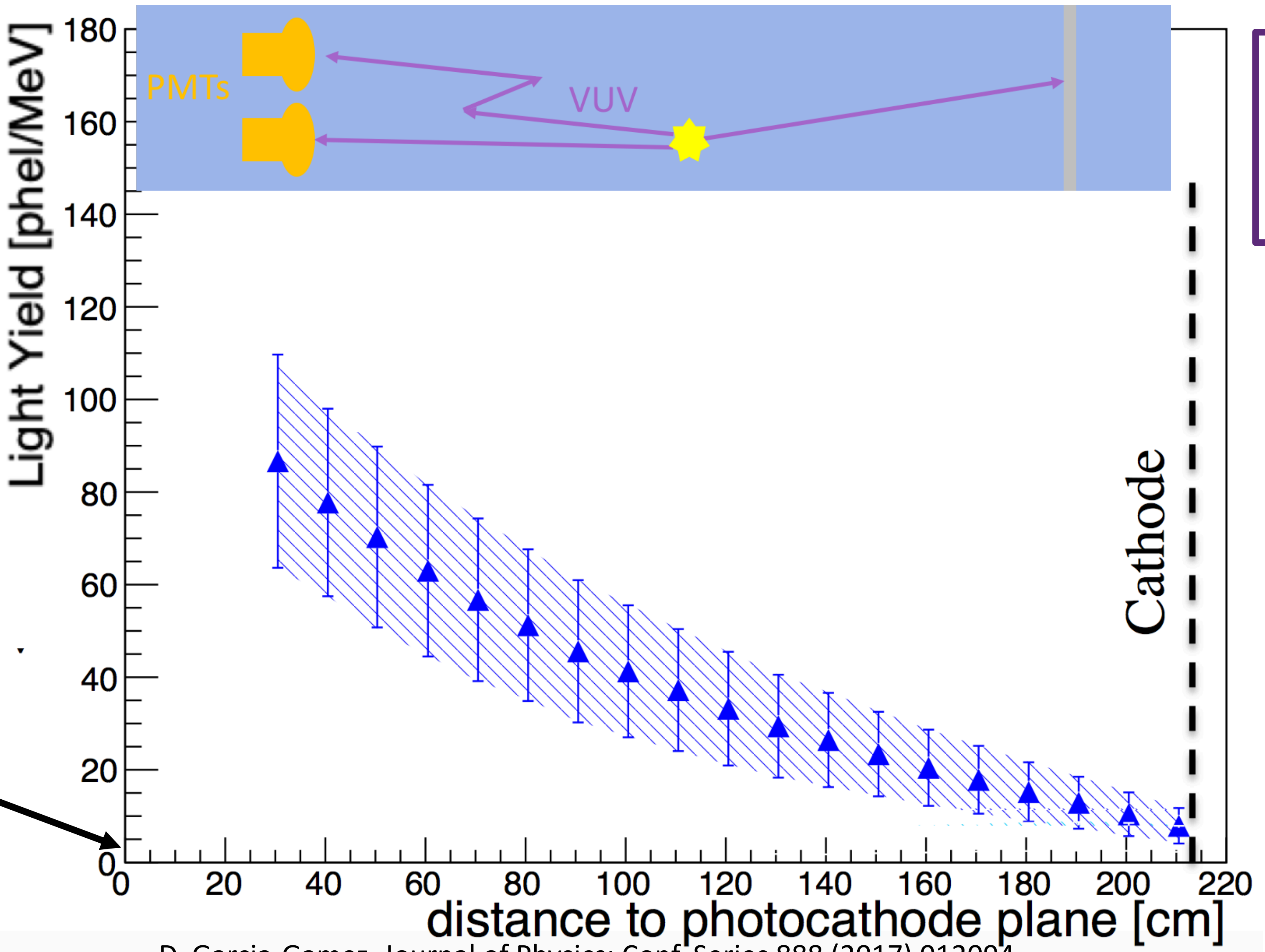
- 3M DF2000MA (38 um) laminated on 0.8 mm FR4 (lamination performed at IIT).
- 64 plates are required for SBND coverage (128 evaporations for double-sided)
- Evaporations split between Manchester and Unicamp.



SBND Light Yield

- VUV scintillation (128 nm) is absorbed by most material (except liquid argon itself).
- Rayleigh scattering (~55 to 110 cm). and absorption (~30 m).

PDS is here



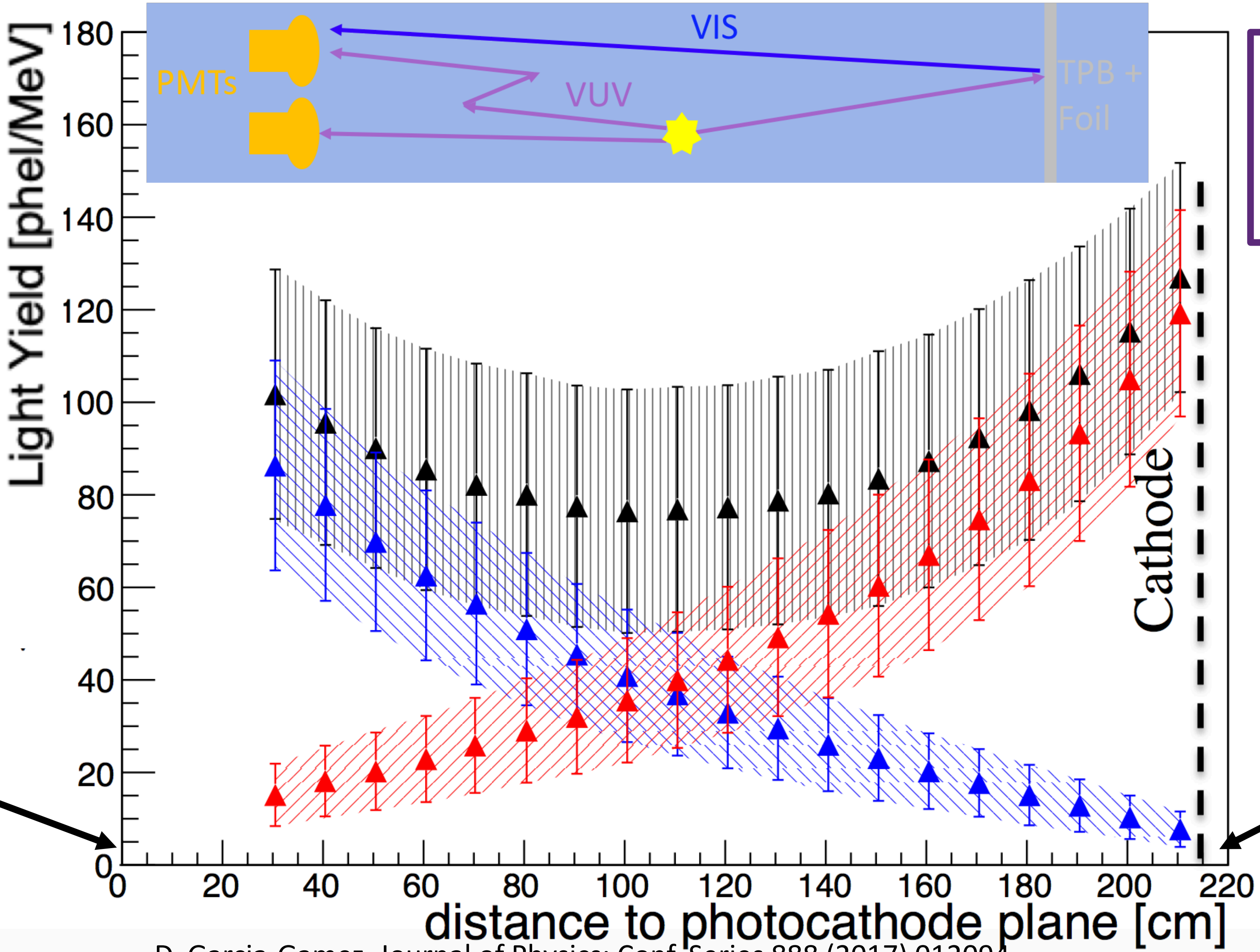
D. Garcia-Gamez, Journal of Physics: Conf. Series 888 (2017) 012094

VUV direct light

No foils.

SBND Light Yield

Rayleigh scattering of visible light is longer than VUV.



D. Garcia-Gamez, Journal of Physics: Conf. Series 888 (2017) 012094

VUV direct light
VIS reflected light
Total (VUV+VIS)

PDS is here

Cathode (only) covered with WLS+foil.

Foils are here.

SBND High Light Yield + Coverage Physics

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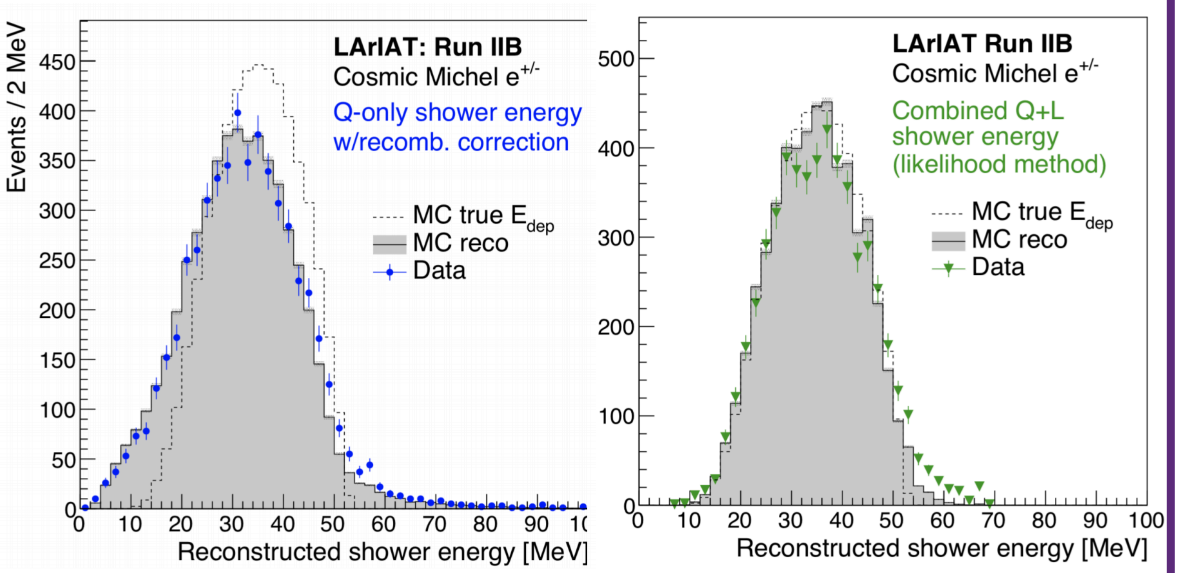
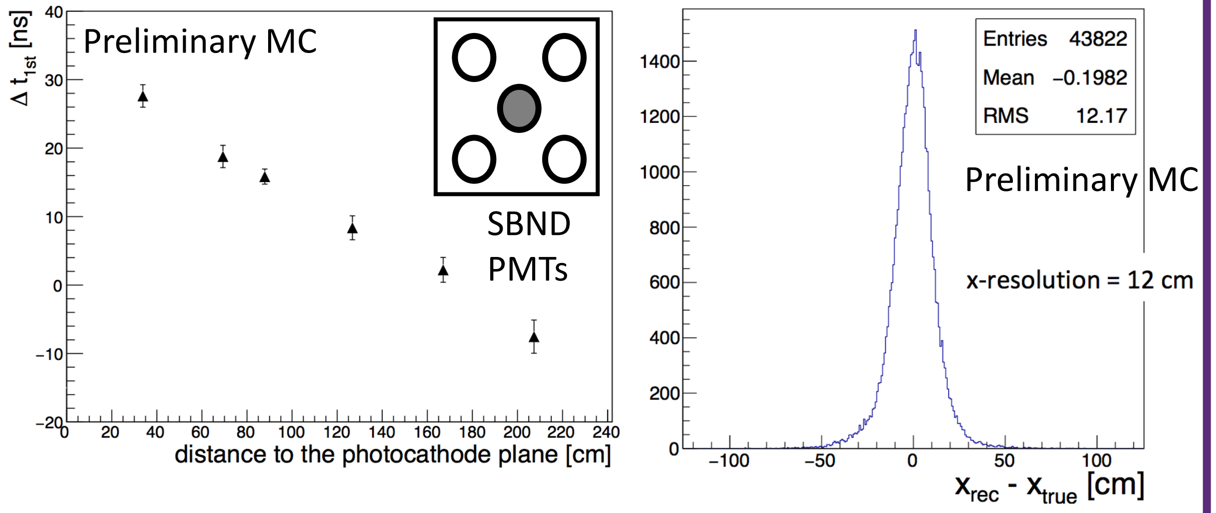
The University of Manchester

W. Foreman, LIDINE 2019



Improve energy resolution and calorimetry (ionization + scintillation)

D. Garcia-Gamez, LIDINE 2017



Determine position in drift direction at the trigger time using both light (only)

Improve cosmic rejection

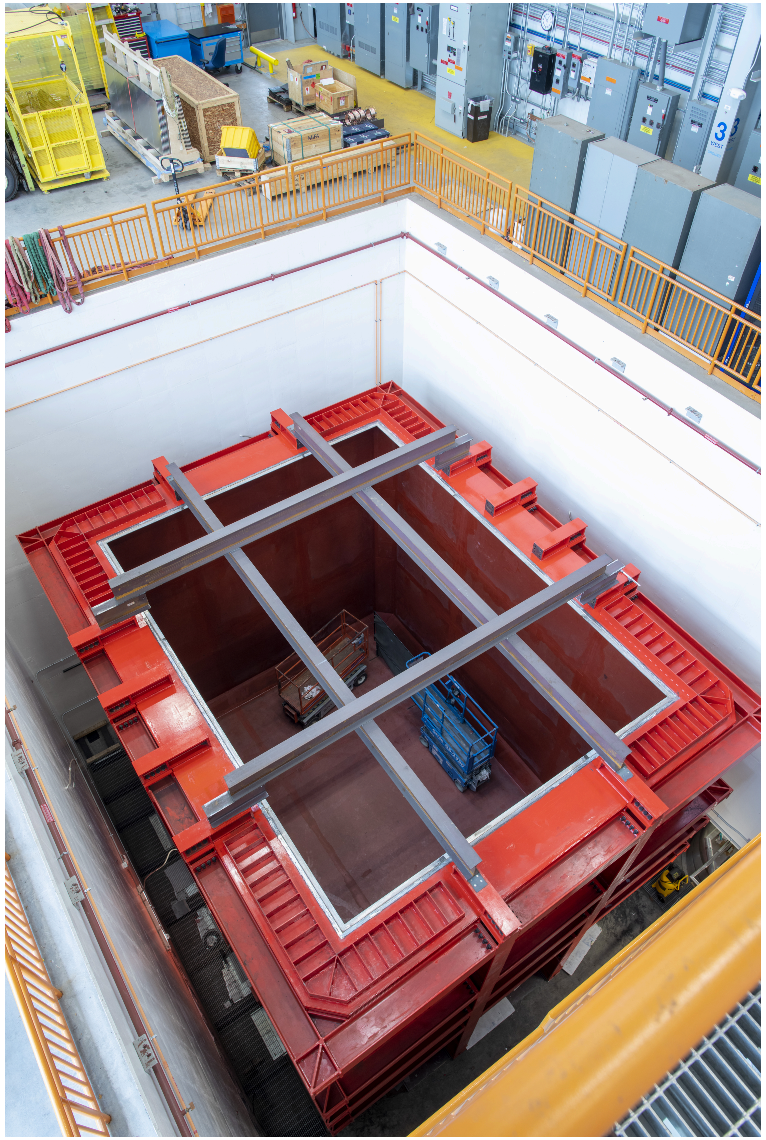
Perform calibration and particle identification

Allow lower trigger thresholds

MANCHESTER 1824
The University of Manchester

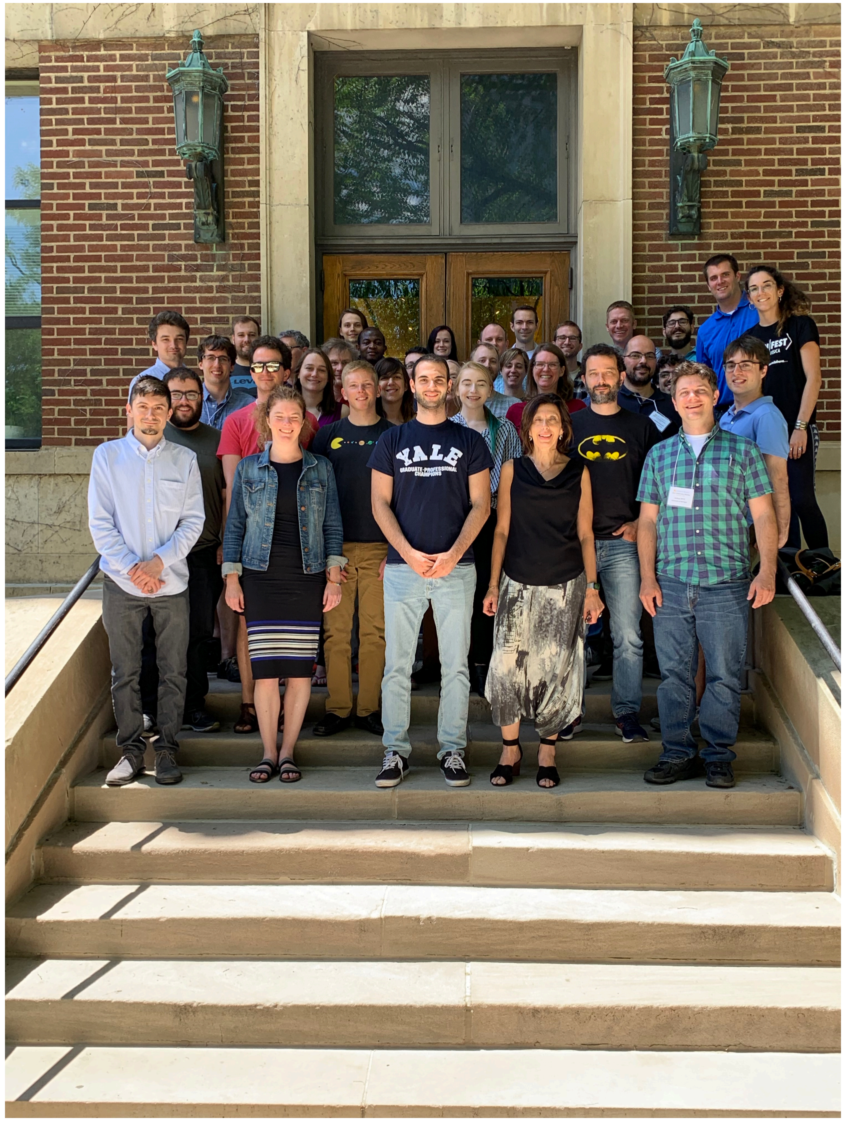
SBND Current Status

- Warm cryostat steel structure installation: November
- TPC assembly: ongoing winter/spring 2020
- Membrane cryostat installation: begin spring 2020
- Moving and installing detector: fall 2020
- Filling and commissioning: 2021



Summary

- SBND's high coverage diverse photon detection system will have a large impact to both SBN physics and R&D for future LArTPCs in a neutrino beam.
- Sensitivity to both VUV direct and VIS reflected light through PDS + Wavelength-shifting foils.
- SBND's PDS status:
    - PMTs tested at LANL and will be on their way early 2020
    - ARAPUCA/X-ARAPUCA are in production and will be installed with PMTs
    - Wavelength-shifting reflective plates and mesh assemblies are ready for installation on cathode.
- Busy next year(s) for SBND!



Backup

244 Total Collaborators

198 Scientific Collaborators **(faculty/scientists, postdocs, PhD students)**

39 Institutions

23 US Institutions

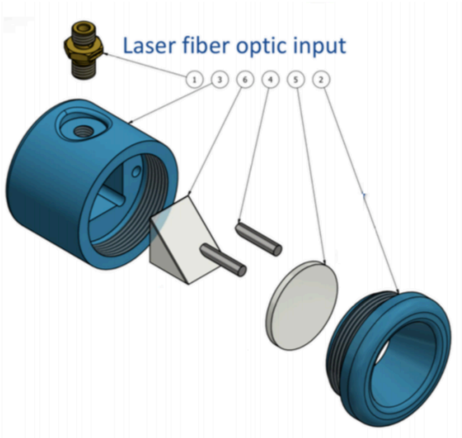
- 4 DOE national laboratories
- 19 US universities

16 International Institutions

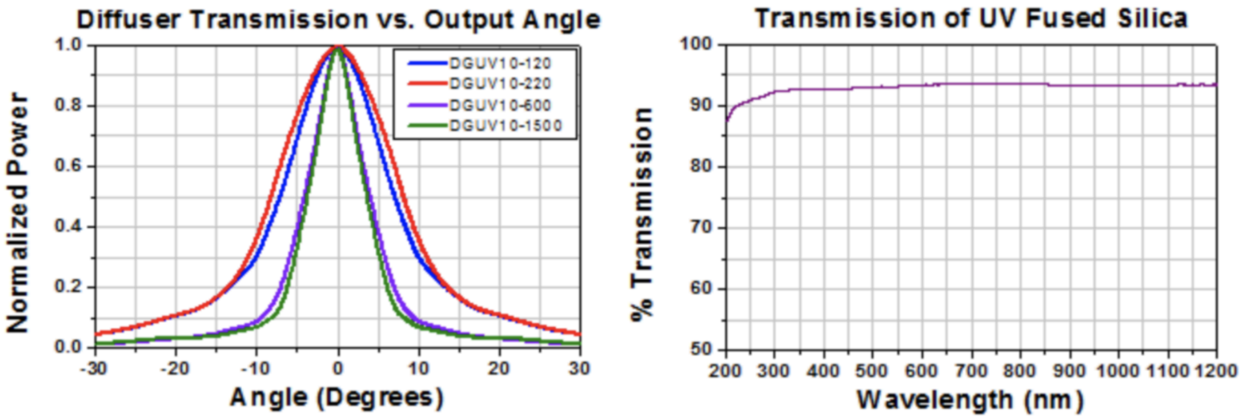
- 5 Brazilian universities
- 1 Paraguayan university
- 1 Spanish university, 1 national lab
- 1 Swiss university
- 6 UK universities
- CERN

SBND PDS Calibration System

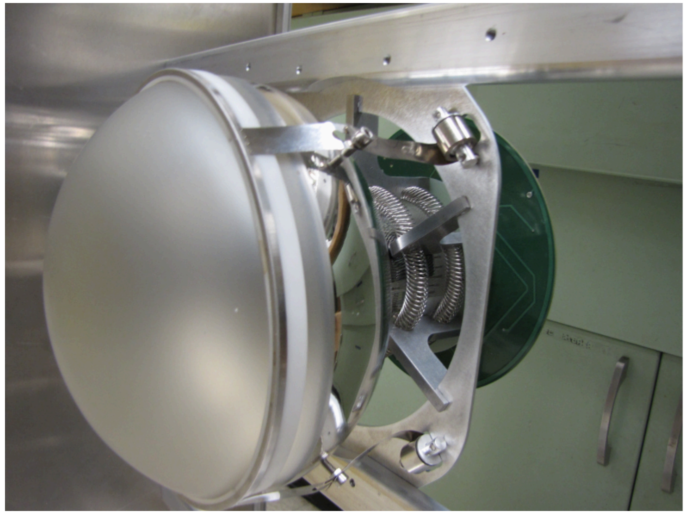
- A diffuser system installed at the cathode using a laser (Q1-B semiconductor laser class 3B) with two wavelengths (211 nm and 537 nm) will be used to calibrate the PDS.



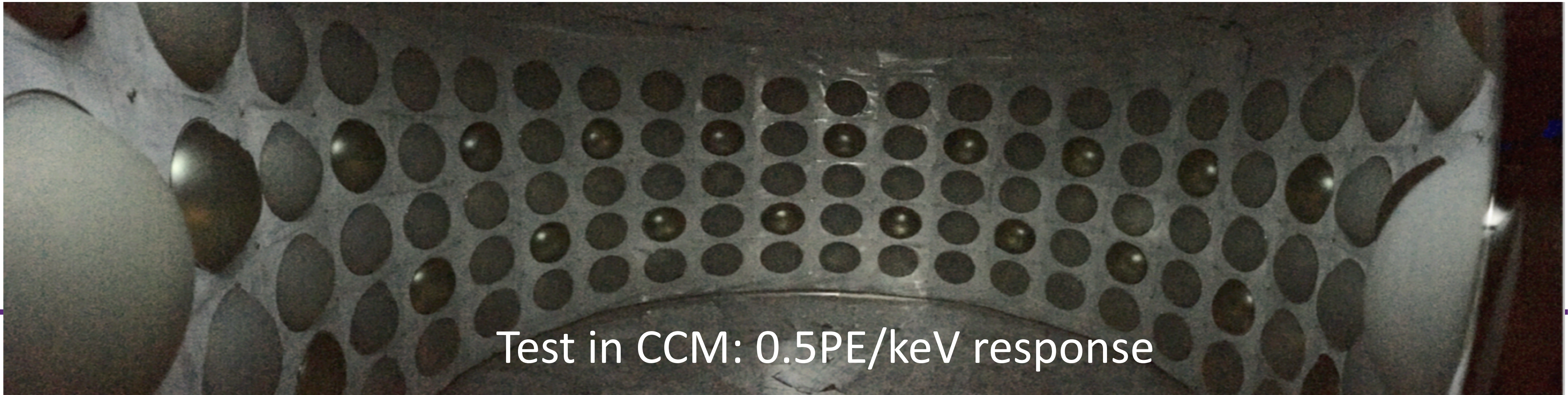
Parameter	Specified	Measured
Laser pump current	INFO	170 A
Pulse energy @532 nm	INFO	2.1 mJ at 170 A
Pulse energy @213 nm	0.5 mJ	0.55 mJ at 170 A
Energy stability @ 532 nm	<2.5 % RMS	2.1 % RMS
Energy stability @ 213 nm	<3.5 % RMS	3.3 % RMS



SBND PMTs



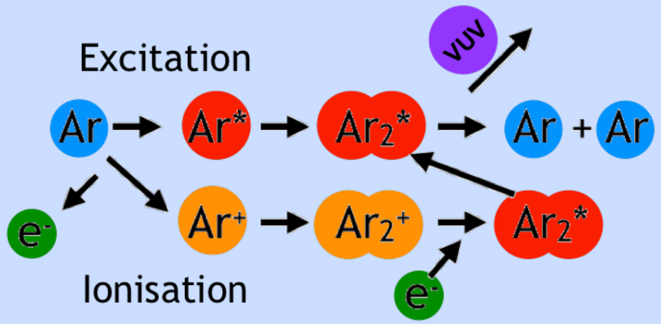
- 120 sandblasted 8” Hamamatsu R5912-mod PMTs readout by CAEN V1730 will make the primary PDS of SBND (60 per TPC side).
- 96 are covered with TPB to wavelength shift VUV light (sensitive to both VUV and VIS).
- 24 are non-coated making them only sensitive to visible reflected light.

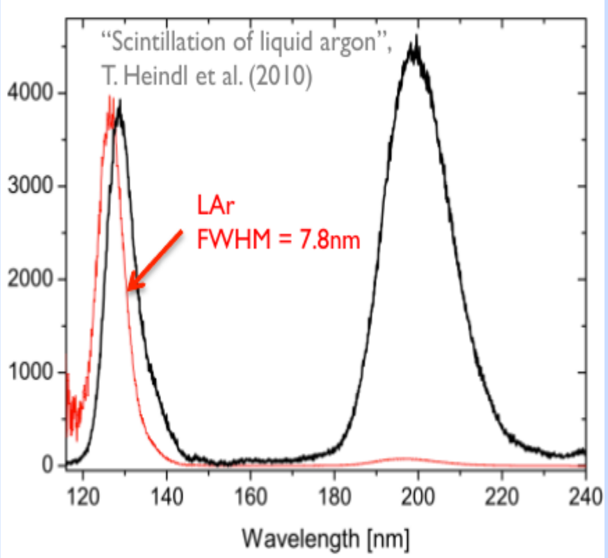


Summary of scintillation light in liquid argon

1. Emission:

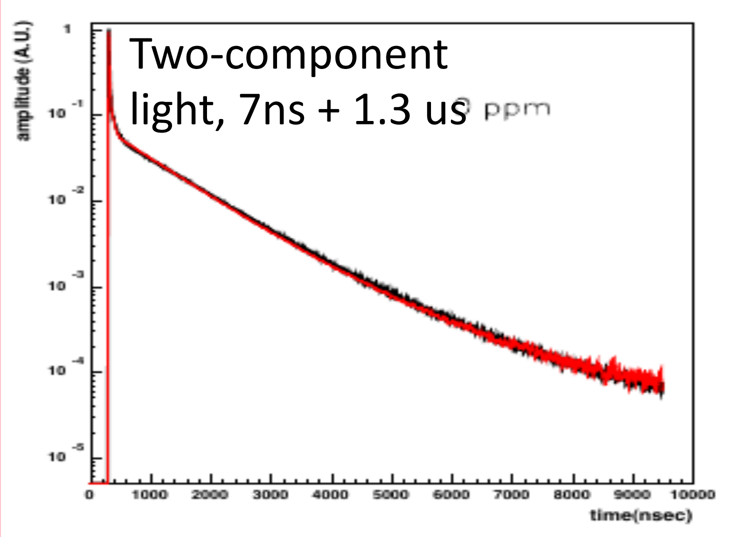
- Excited argon dimer dexcites to emits 128 nm photons (VUV).





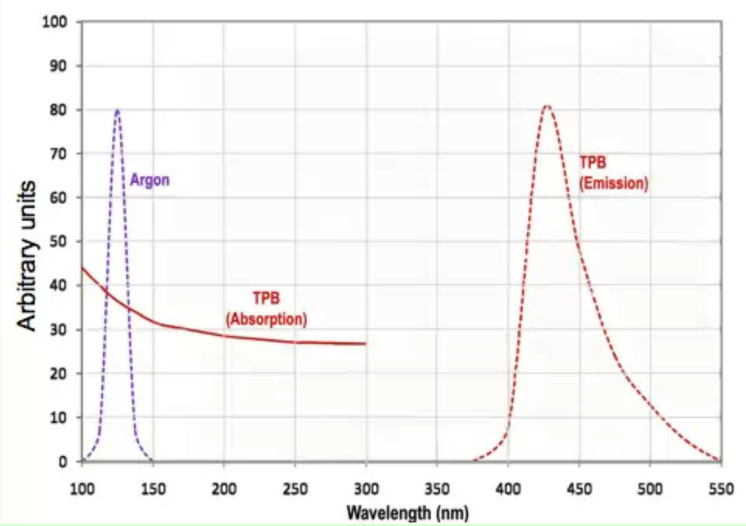
2. Propagation:

- VUV scintillation is absorbed by most material (except liquid argon itself).
- Rayleigh scattering (~55 to 110 cm) and absorption (~30 m).

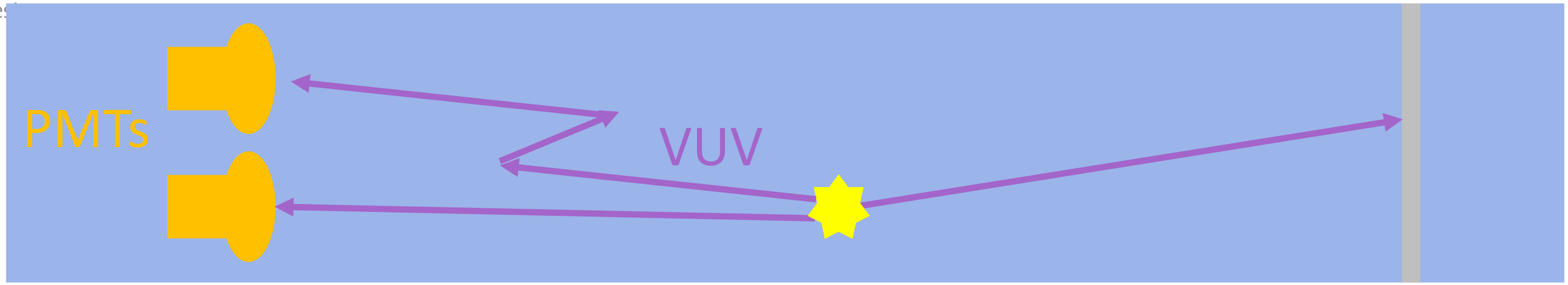


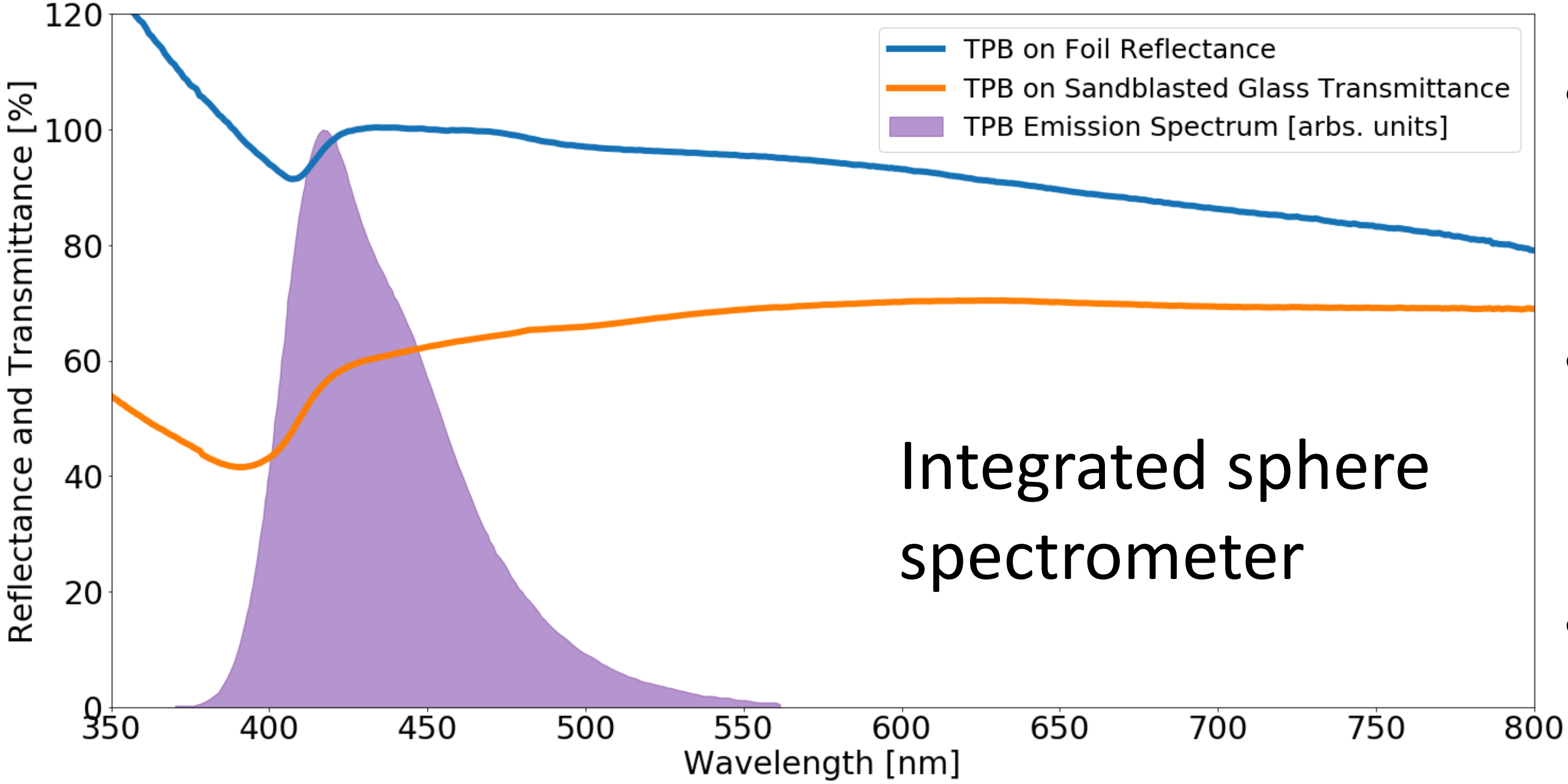
3. Detection:

- Typical PMTs and SiPMs are blind to VUV scintillation which makes the detection challenging.
- Solution? use Wavelength shifting compounds, like Tetra-Phenyl Butadiene (TPB).



Transmittance and reflectance with TPB



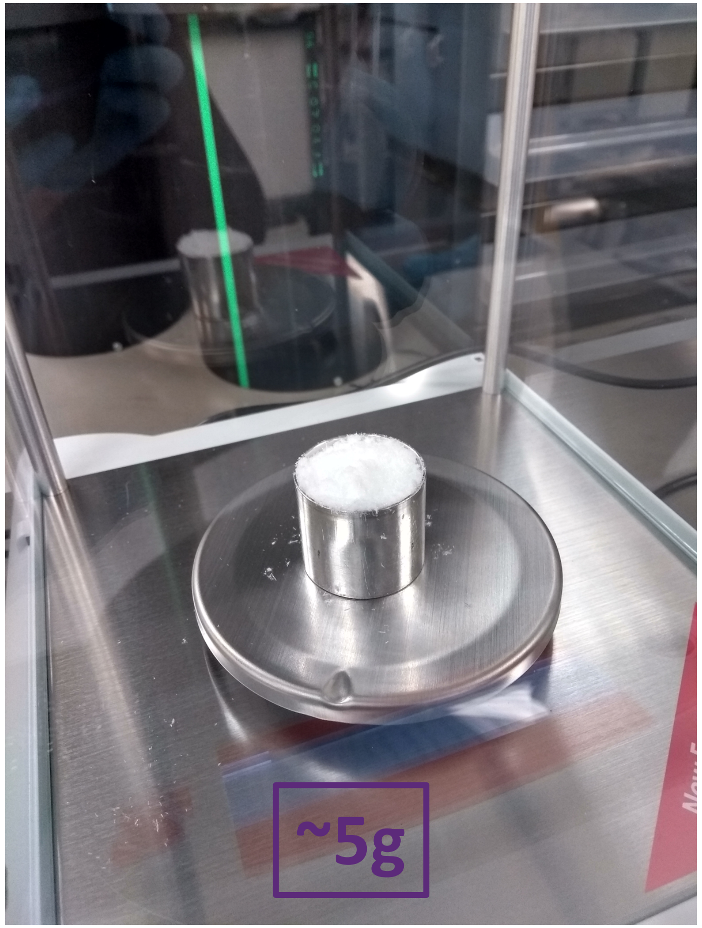


Integrated sphere spectrometer

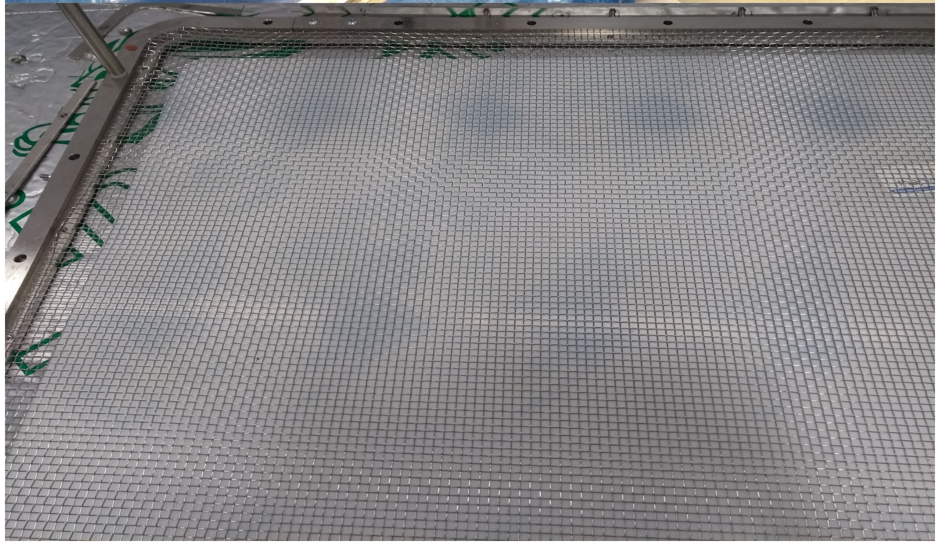
- Light travelling to the TPB coated cathode will be remitted and reflected.
- That light will will travel to the PMTs and transmit through the glass window.
- ~60% of the blue light will transmit.

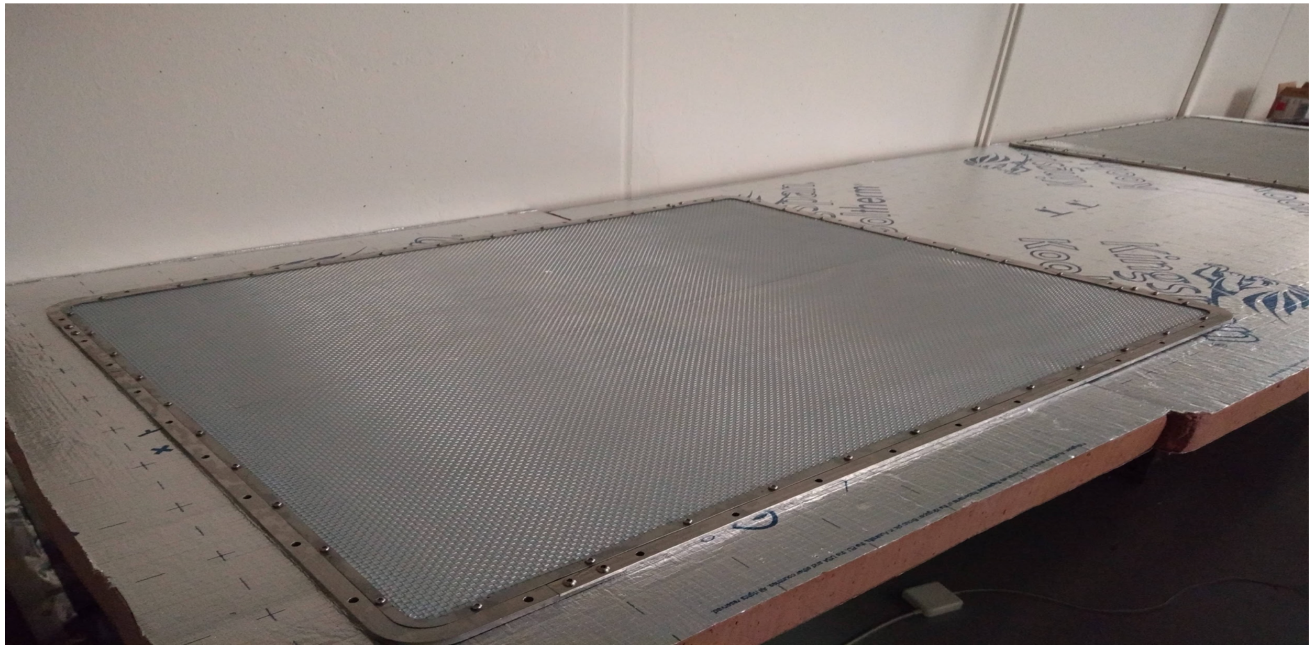
TPB evaporation

- 64 plates are required for SBND coverage (128 evaporations for double-sided) + spares.
- Heating up slowly the TPB filled cup up to 245°C and evaporate on plate.
- Manchester and Unicamp have split the task (both have the same evaporation setup).



Assembly

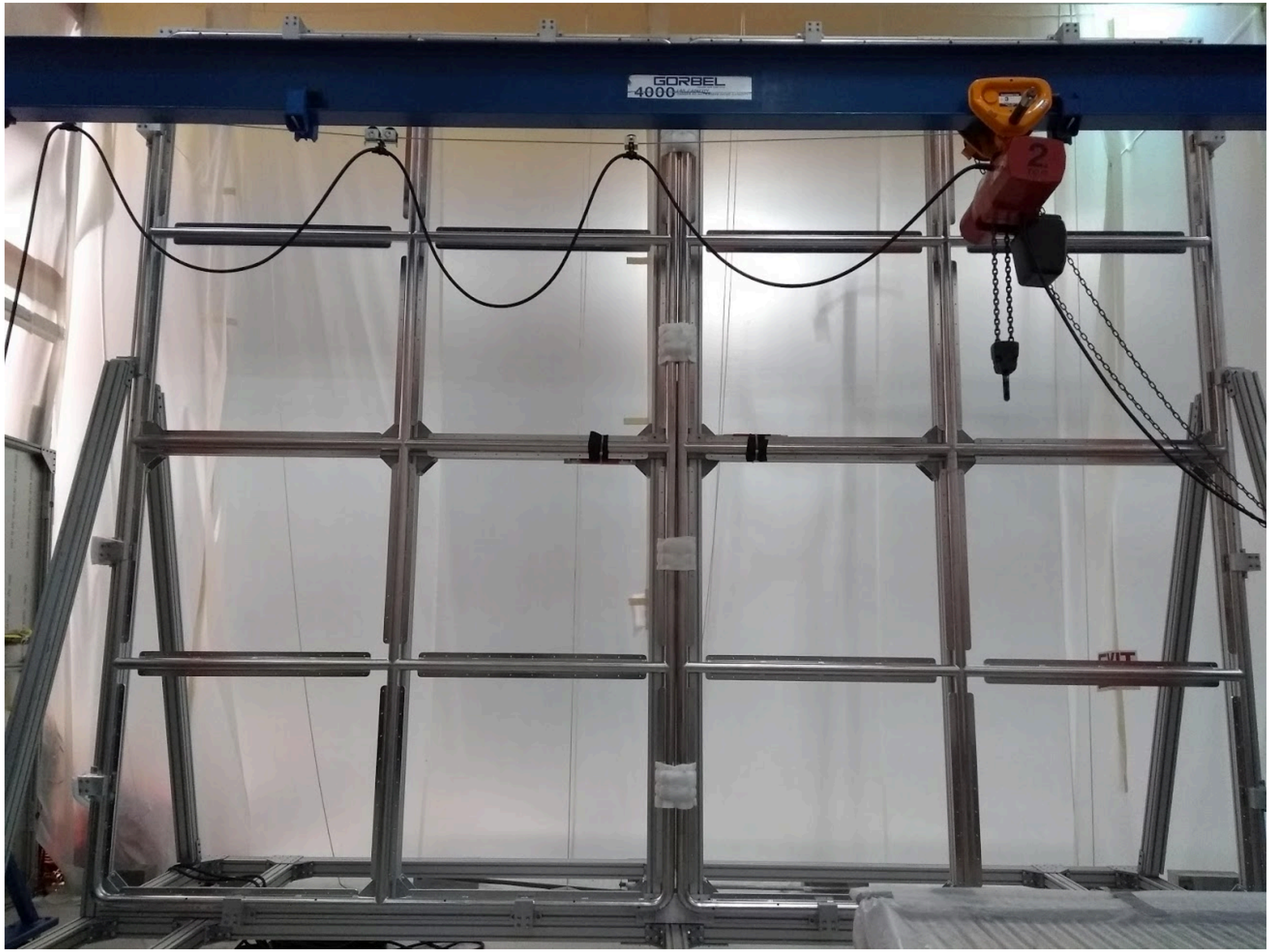


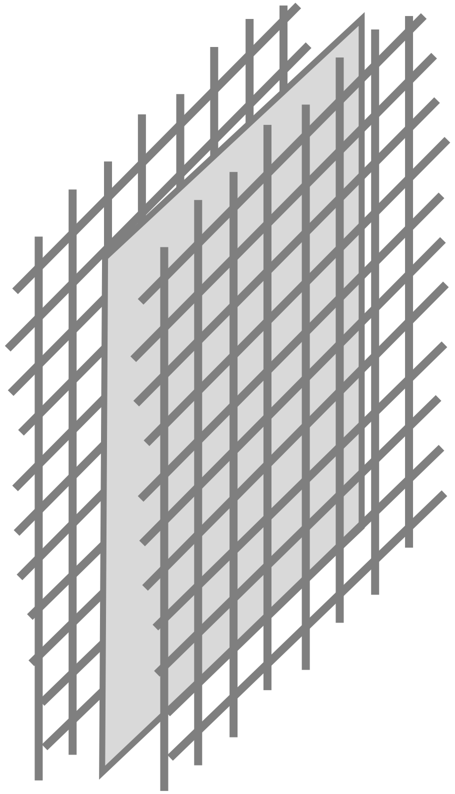


- Cool down (with LN2) the frame to shrink.
- Screw the mesh-foil-mesh configuration in before before subframes warms up.
- Let the assembly expand and lock in place.

Repeat 16 times!

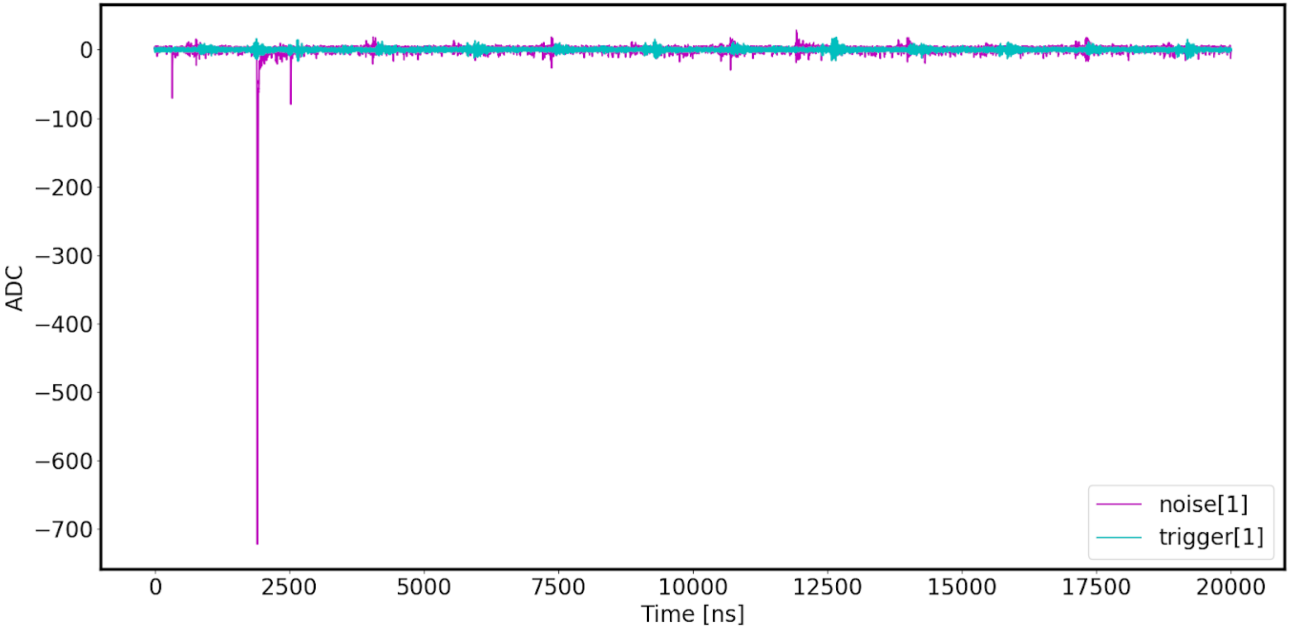
Installation on SBND cathode





- Metal mesh to keep electrical field uniform and constant.

QC setup



- N6.0 argon with alpha source in vacuum chamber with a PMT.
- Foil sample located above the PMT.