Brazilian Community Report on Neutrino Program at FNAL

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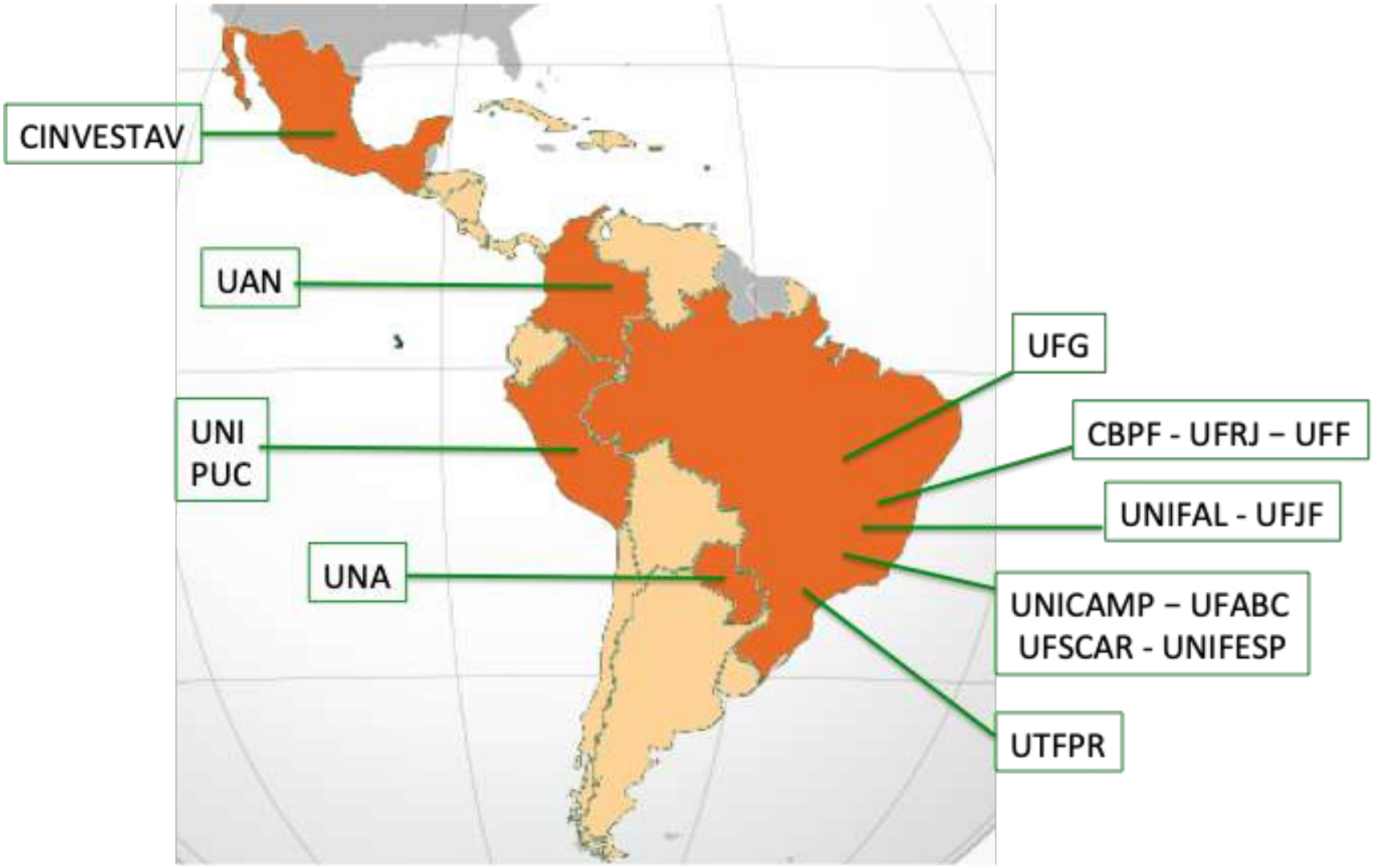
FAPESP
FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO
UNICAMP

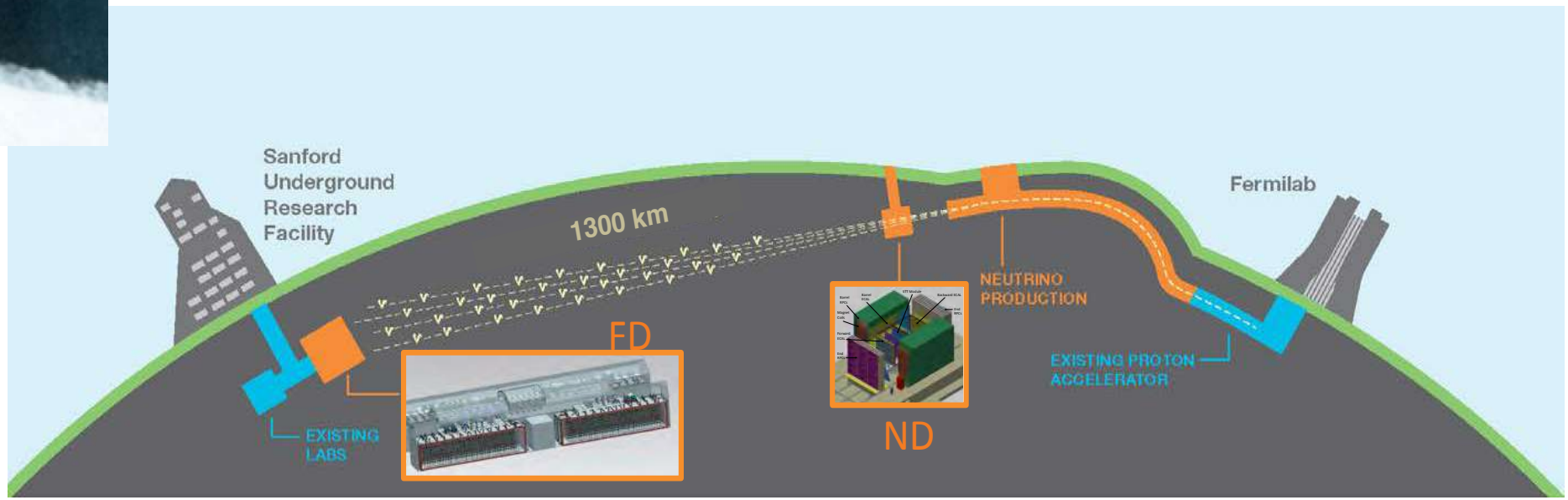
DUNE experiment

1132 collaborators from 188 institutions in 31 countries + CERN

DEEP UNDERGROUND NEUTRINO EXPERIMENT

DUNE in Latin America





Key DUNE features:

- High-intensity wide-band neutrino beam originating at FNAL
  - 1.2 MW proton beam upgradable to 2.4 MW
- Highly capable near detector to measure the neutrino flux
- A ~40 kt fiducial mass liquid argon far detector
  - Located 1300 km baseline at SURF's 4850 ft level (2,300 mwe)
  - Staged construction of four ~10 kt detector modules. First module installation starting in 2021.

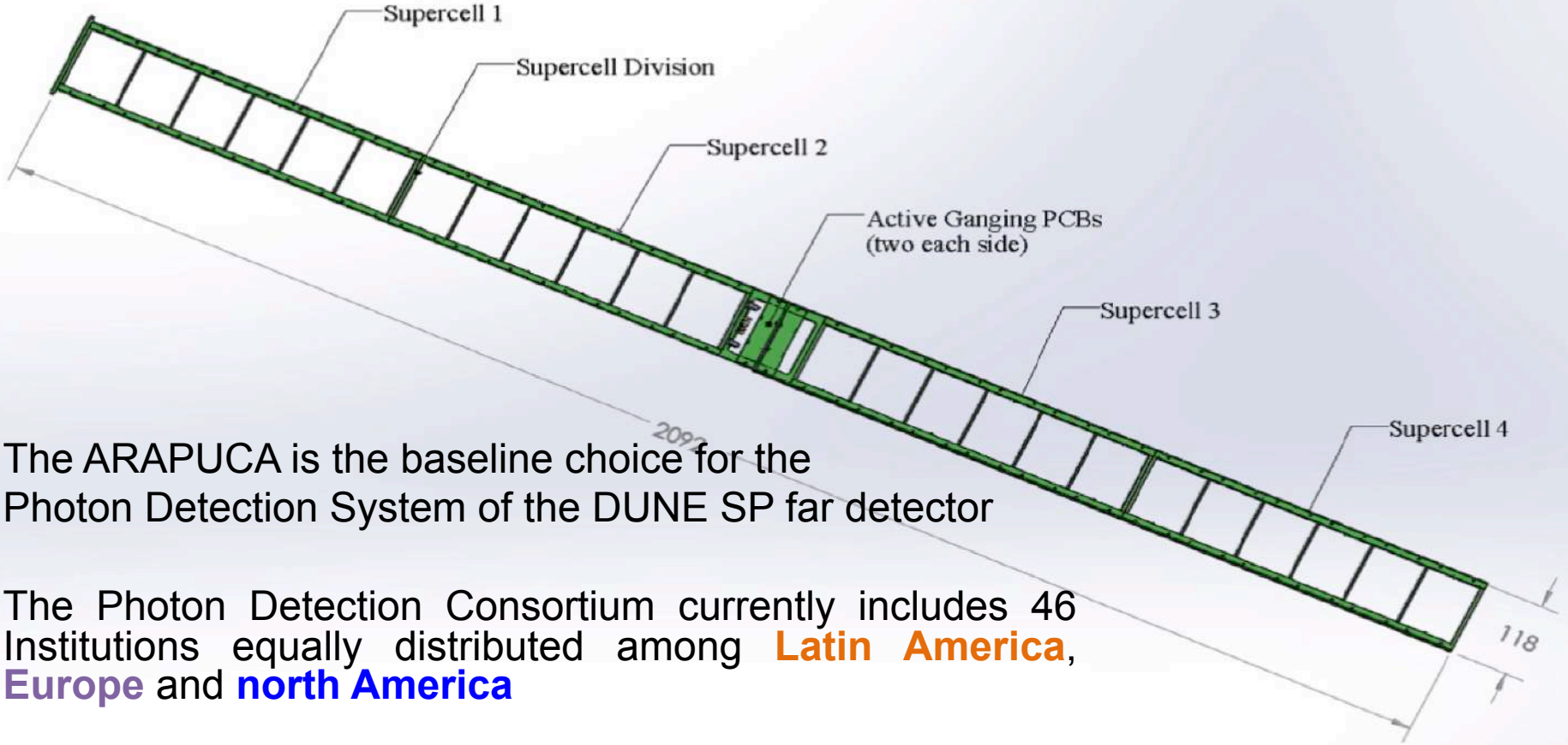
DUNE science program

- Fundamental open questions in particle and astroparticle physics:
  - ***Neutrino oscillation physics***
    - CP violation in the leptonic sector
    - Mass hierarchy
    - Precision oscillation physics to test 3-flavour paradigm
  - ***Nucleon decay***
    - Predicted in Beyond Standard Model theories [but not yet seen]
  - ***Supernova burst physics and astrophysics***
    - Galactic core collapse Supernova, unique sensitivity to ν_e

Neutrino Phenomenology
New Physics Models

- Brazilian groups are participating regularly in ***Beyond Standard Model*** activities inside the DUNE Collaboration
  - *large extra dimensions analysis*
  - *non-standard neutrino interaction analysis*
- Contributions also the ***Short Baseline Neutrino (SBN) program***:
  - *heavy neutrino decay analysis in SBN*

DUNE Photon Detection System
X-ARAPUCA



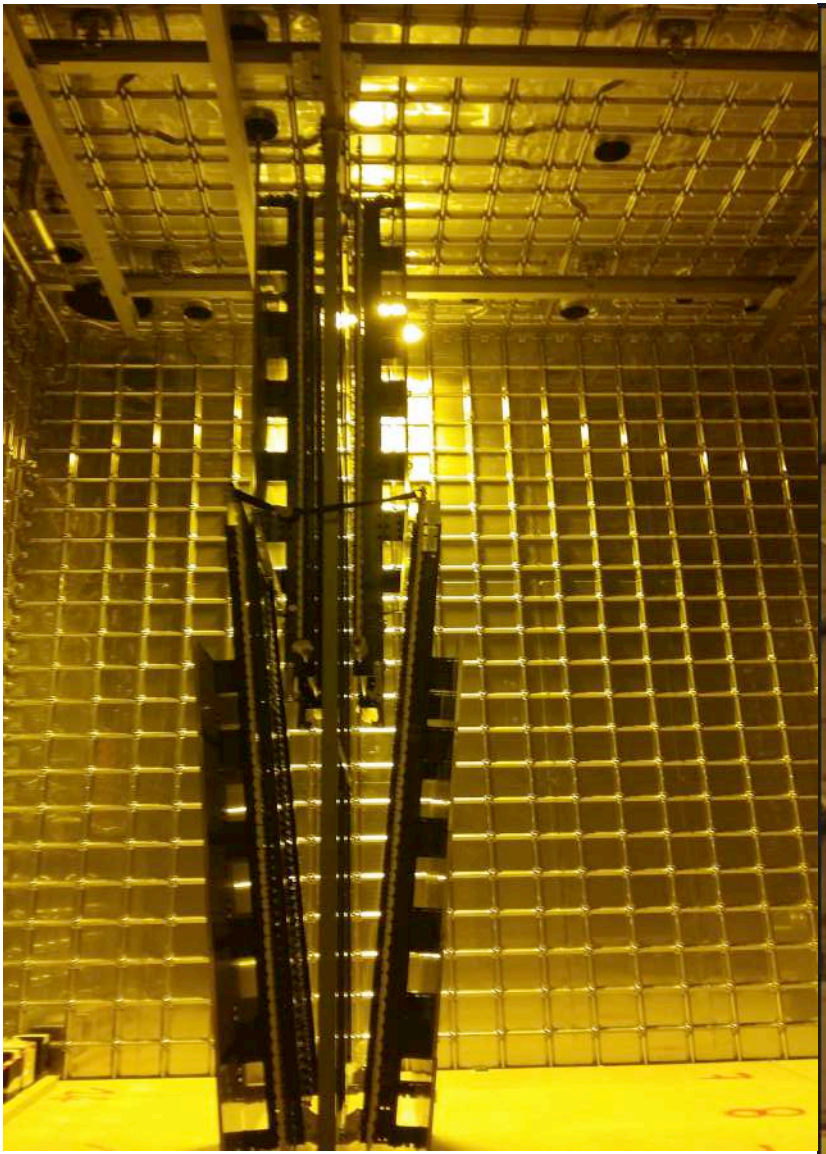
The ARAPUCA is the baseline choice for the Photon Detection System of the DUNE SP far detector

The Photon Detection Consortium currently includes 46 Institutions equally distributed among **Latin America**, **Europe** and **north America**

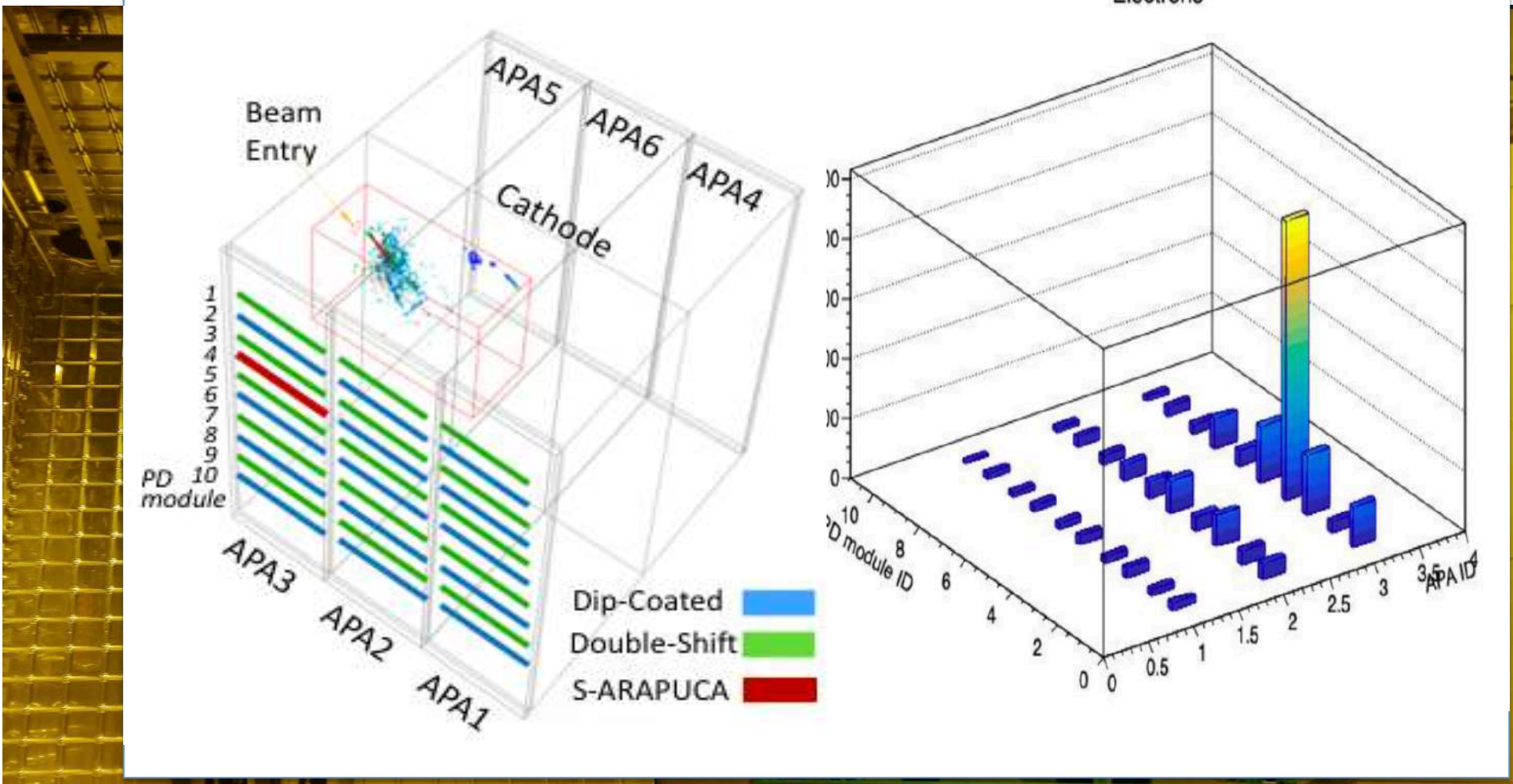
Optical components (optical filters and precison mechanics) developed by Brazilian Companies

Read-out system designed by Colombian, Perviuan and Paraguayan Institutions

protoDUNE run1



protoDUNE run1



LAr Purifiction system

- Performing fluid-dynamic calculations, simulations and project conceptual design ***of the LAr circulation system of the far detector***
  - Testing and validating the *temperature monitoring of purification system*
  - Synthesis, characterization and test of candidate materials to be used as *purification media*
  - Design and test of the LAr and GAr purification and regeneration systems *in small scale prototypes*
  - Production and construction of *purity monitors* to be used on small scale prototypes
  - Contribution to *slow control development*

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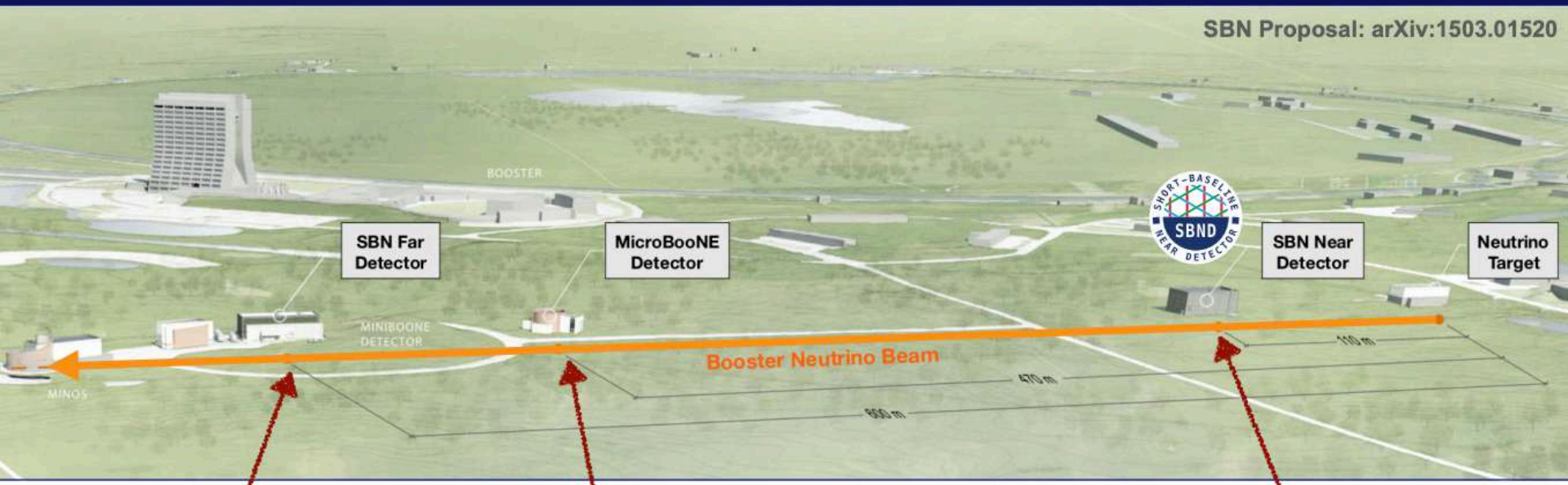
Great opportunity for Brazilian Companies

Slide from David Schmitz

THE SBN PROGRAM @ FERMILAB



470t LArTPC, 600m from target

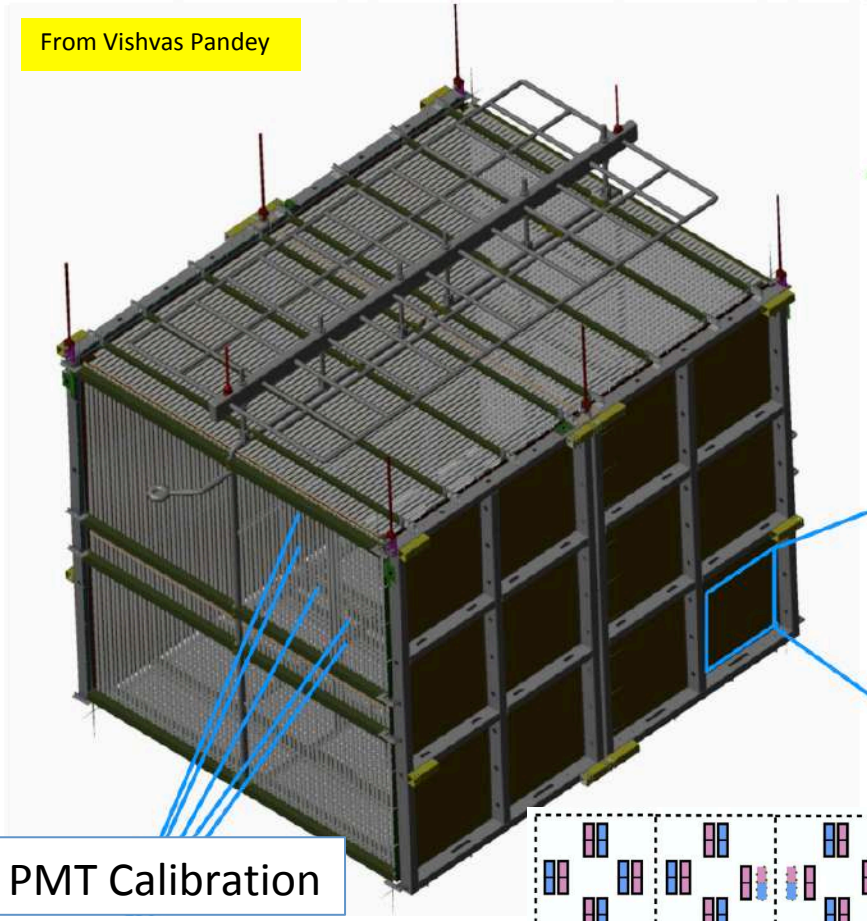
89t LArTPC
470m from target

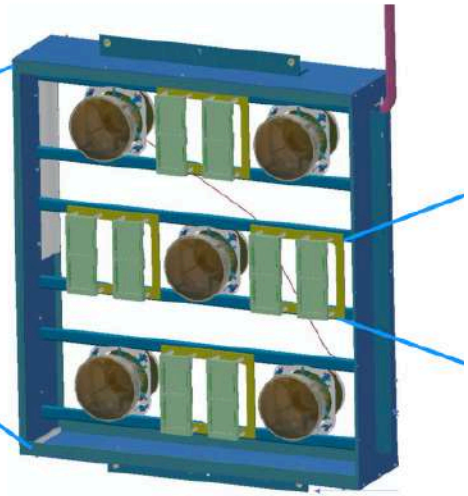
112t LArTPC, 110m from target

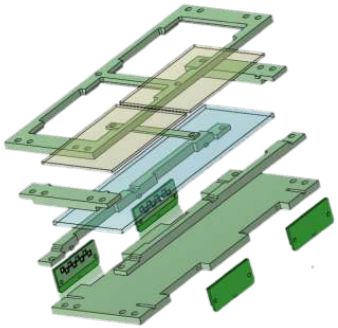
SBND Photon Detection System

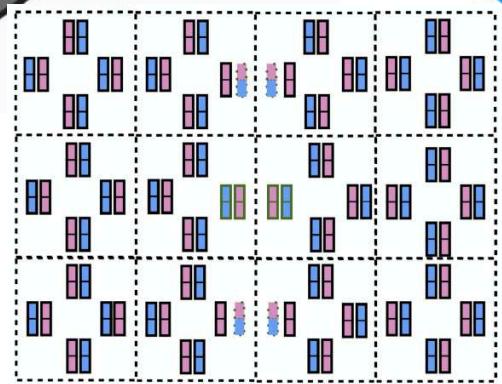
From Vishvas Pandey

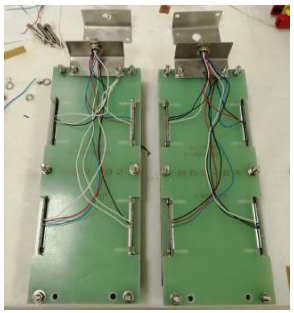
- **PMT System:** - Total 120 8” Hamamatsu PMTs
  - 5 PMTs (4 TPB coated + 1 uncoated) in each PDS box
- **ARAPUCA System:** - Total 192 (X-)ARAPUCA modules
  - 8 modules in each PDS box
- 12 PDS boxes mounted behind each APA wire frame











PMT Calibration

Software Development

- The development of a complete Monte Carlo simulation of the ARAPUCA device using the Geant4 framework
- Studies of the dependence of the collection efficiency as a function of the number and positioning of SiPMs, the device's geometry and optical properties of the materials (wavelength shifters and filter)
- Specific Monte Carlo codes for SBND and protoDUNE
- Improvement of the collaboration software for a better description of the light production and propagation mechanisms in Monte Carlo simulations.

Acknowledgement

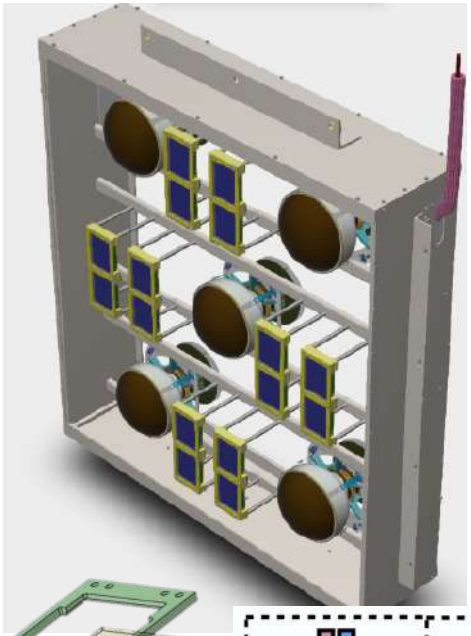
This work is supported by FAPESP through the processes:

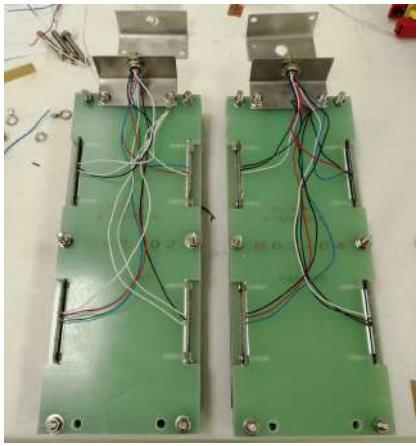
2014/19164-6 Thematic Project Challenges in XXI in Neutrino Physics
2016/01106-5 LAr program at UNICAMP
2019/11557-2 Sistema de detecção de luz para o experimento DUNE X-ARAPUCA
2017/13942-5 Caracterização numérica do ARAPUCA: uma nova tecnologia detectora de cintilação em líquidos nobres
2018/18544-0 - O instrumento ARAPUCA e seu impacto na sensibilidade do detector longe de DUNE para eventos de baixa energia
2019/00938-5 SPRINT agreement UNICAMP-DUKE UNIVERSITY: Supernova physics in DUNE
2016/00272-9 PhD of Gabriela Stenico: SBN

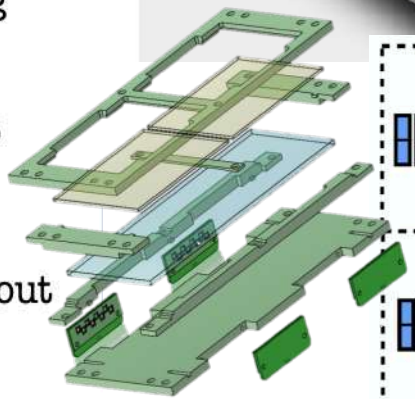
Back-up

SBND Photon Detection System

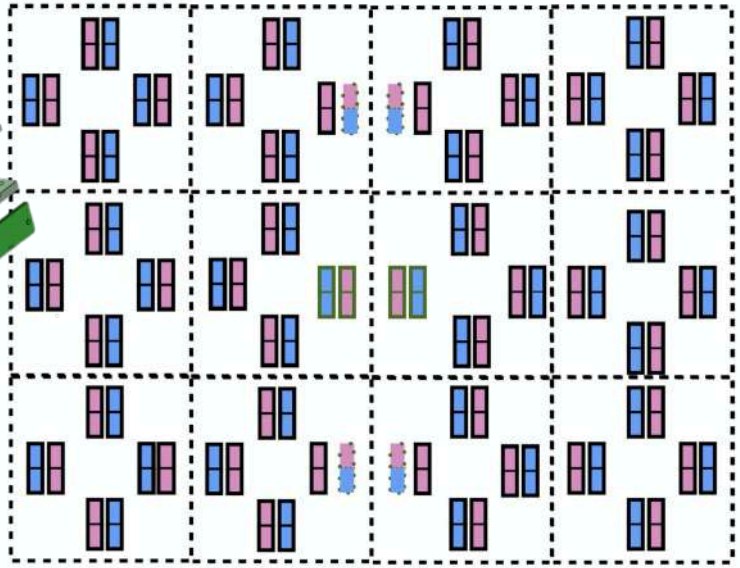
- Composite photon detection system that enhances the amount of light collected and provides R&D opportunities
  - Detect both direct scintillation light (VUV) and visible light (Cherenkov or reflected)
- 24 photon detector modules mounted behind the Anode Planes
  - **120 8" Hamamatsu PMTs**
    - 96 coated with wavelength-shifting Tetraphenyl Butadiene (TPB)
    - 24 uncoated for seeing visible light
  - **192 ARAPUCA light collectors**
    - 8 ARAPUCA + 8 X-ARAPUCA read out by CAEN SiPM readout electronics
    - 176 X-ARAPUCA + DAPHNE SiPM readout electronics, adapted from Mu2e cosmic veto system







X-ARAPUCA distribution



Prototype system for DUNE

From David Schmitz

DUNE science program

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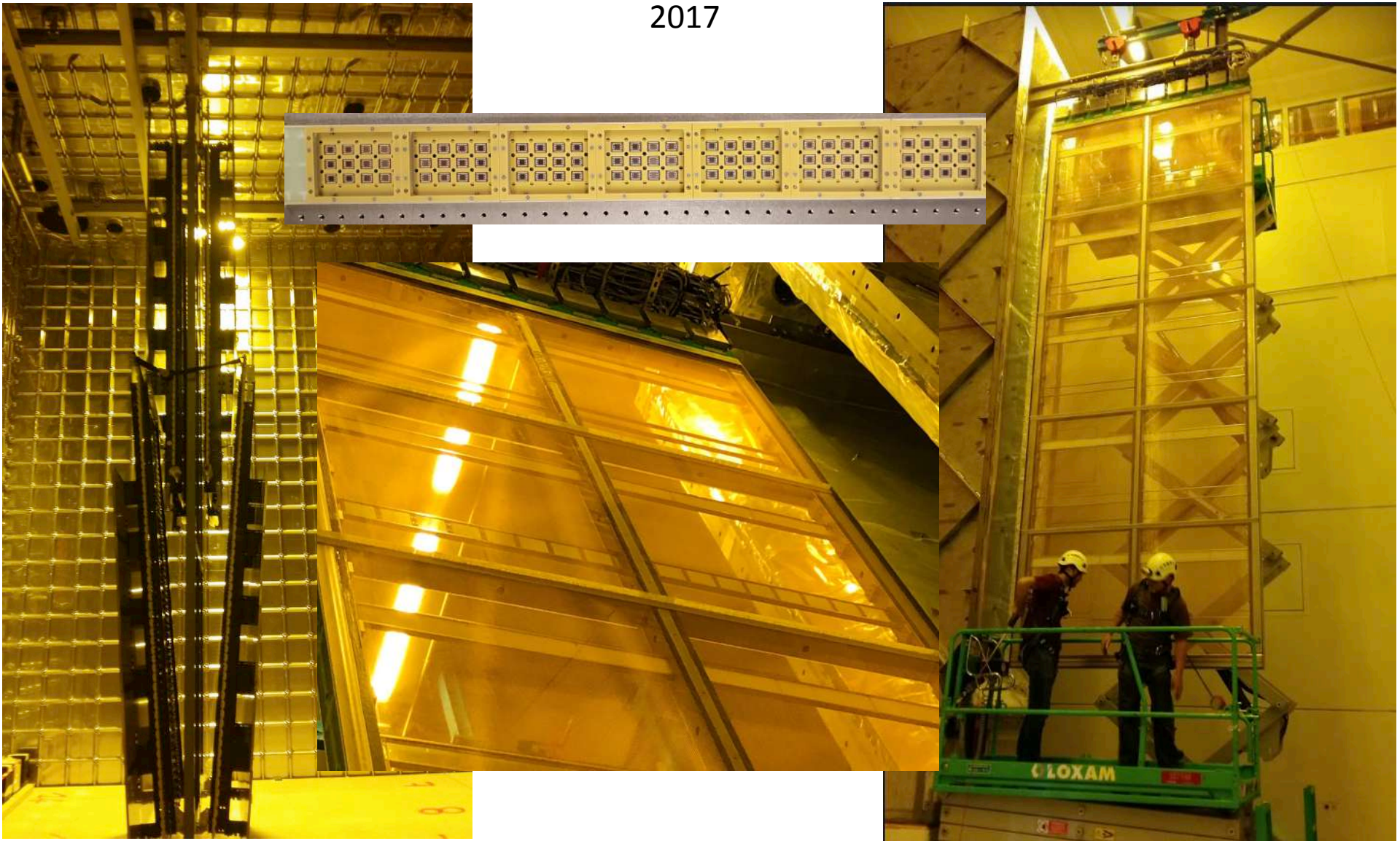
- Neutrino oscillation physics
  - ✓ CP violation in the leptonic sector
  - ✓ Mass hierarchy
  - ✓ Precision oscillation physics to test the 3-flavour paradigm
- Nucleon decay
  - ✓ Predicted in beyond the Standard Model theories [but not yet seen]
  - ✓ e.g. the SUSY favored mode: $p \rightarrow K^{+}\overline{\nu}$
- Supernova burst physics and astrophysics
  - ✓ Galactic core collapse Supernova, unique sensitivity to ν_e

protoDUNE run1

2017



protoDUNE results