The DUNE Experiment

Ana Amelia Machado
for the DUNE Collaboration

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Outline

- Physics Motivation
- The P5 Recommendations
- DUNE - Deep Underground Neutrino Experiment
  - The Collaboration
  - Physics goals
  - DUNE Experiment
  - The Photon Detection System
- Latin America Contributions

Physics Motivation

Even if neutrinos are fundamental particles which have been detected ~ 70 years ago there **are still several open questions related to their properties**:

What we know
They are the second most abundant (identified) particle in the universe, after the photons
3 types (flavors) of ν, which interact with matter via the weak force
They oscilate in all 3 flavors
They have a mass
The oscillation is driven by a mixing matrix which links the flavor and mass states

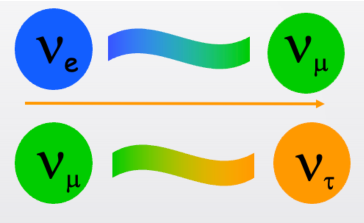
Atmospheric | Reactor & LBL | Solar

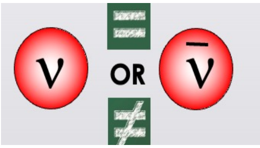
$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{-i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

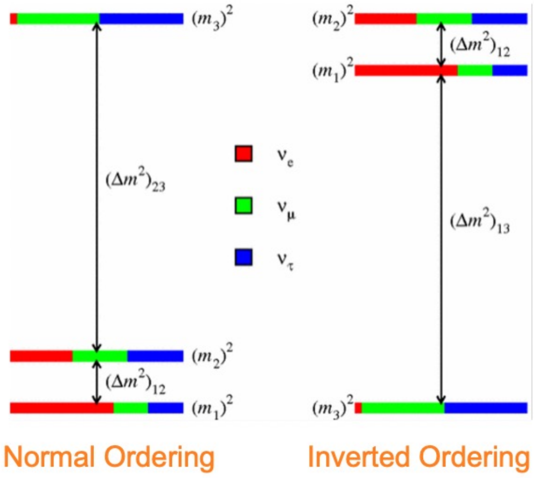
Physics Motivation

Even if neutrinos are fundamental particles which have been detected ~ 70 years ago there **are still several open questions related to their properties**:

What we don't know
Do neutrino and anti-neutrino oscillate differently?
How are the mass ordered ? (mass hierarchy)
What are the masses of neutrino?
Are there other neutrino types or interactions ?
Are neutrinos their own antiparticle ?







$\theta_{23} \sim 45°$ | $\theta_{13} \sim 9°$ $\delta = ?$ | $\theta_{12} \sim 33°$

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13} e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13} e^{-i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

δ_{CP} is a phase angle which has a value between 0 and 2π ;

CP is conserved → $\delta = 0$ or π
CP violation is max → $\delta = \pi/2$ or $3\pi/2$

P5 Science Drivers

- The **P**article **P**hysics **P**roject **P**rioritization **P**anel (**P5**) is a **scientific advisory** panel tasked with recommending plans for U.S. investment in **particle physics research over the next 10 years**, on the basis of various funding scenarios.

Chapter 3: The Science Drivers

https://www.usparticlephysics.org/wp-content/uploads/2018/03/FINAL_P5_Report_053014.pdf

P5 Science Drivers - Recommendation

4 Recommendations specific for accelerator neutrino program

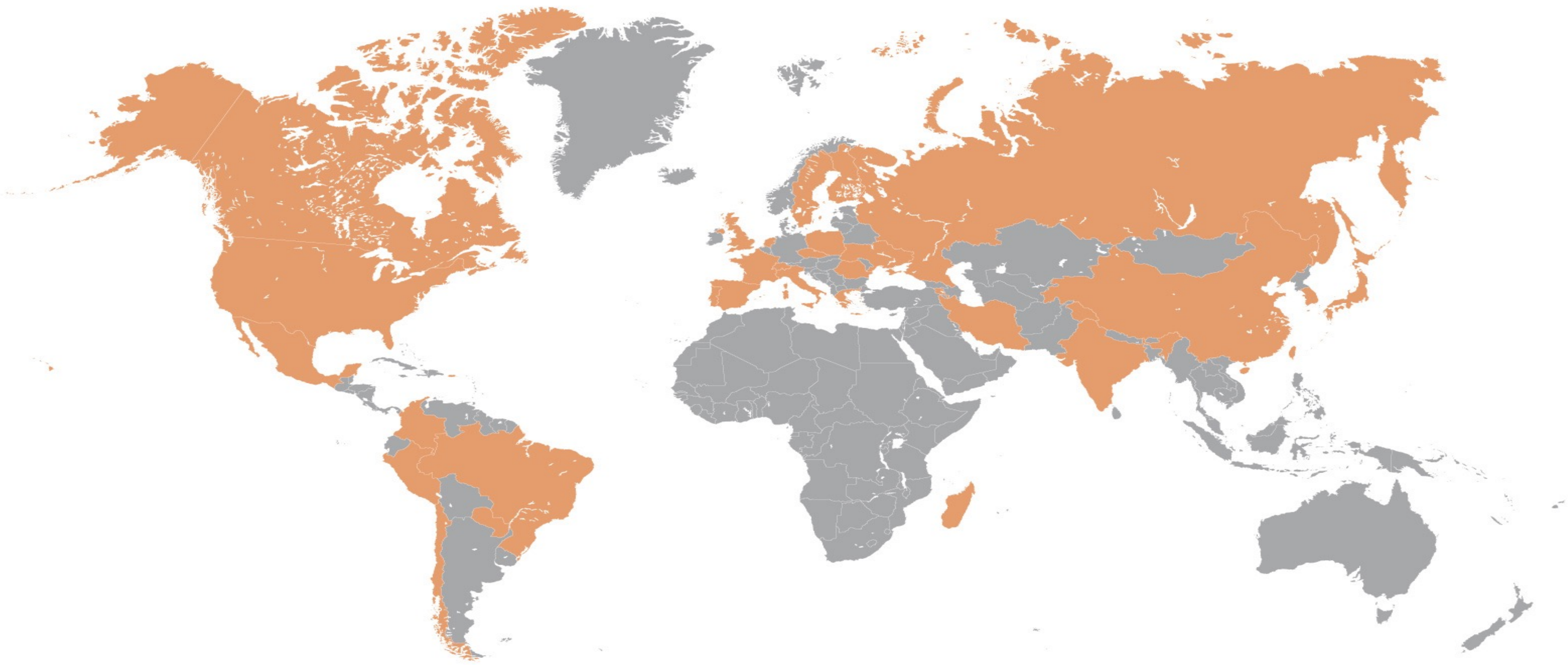
- **R12:** In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.
- **R13:** Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest- priority large project in its timeframe.
- **R14:** Upgrade the Fermilab proton accelerator complex to produce higher intensity beams. R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction, to provide proton beams of >1 MW by the time of first operation of the new long-baseline neutrino facility.
- **R15:** Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.

With a wideband neutrino beam produced by a proton beam with power of 1.2 MW, this exposure implies a far detector with fiducal mass of more than 40 kilotons (kt) of liquid argon (LAr) and a suitable near detector. **The minimum requirements to proceed are the identified capability to reach an exposure of at least 120 kt*MW*yr by the 2035 timeframe, the far detector situated underground with cavern space for expansion to at least 40 kt LAr fiducial volume, and 1.2 MW beam power upgradable to multi-megawatt power. The experiment should have the demonstrated capability to search for supernova (SN) bursts and for proton decay, providing a significant improvement in discovery sensitivity over current searches for the proton lifetime.**

https://www.usparticlephysics.org/wp-content/uploads/2018/03/FINAL_P5_Report_053014.pdf

DUNE – A Global Collaboration

1347 collaborators from 204 institutions in 33 countries + CERN



DUNE physics program

Origin of matter. Investigate leptonic CP violation.

Precision oscillation physics and test of 3-flavor oscillation

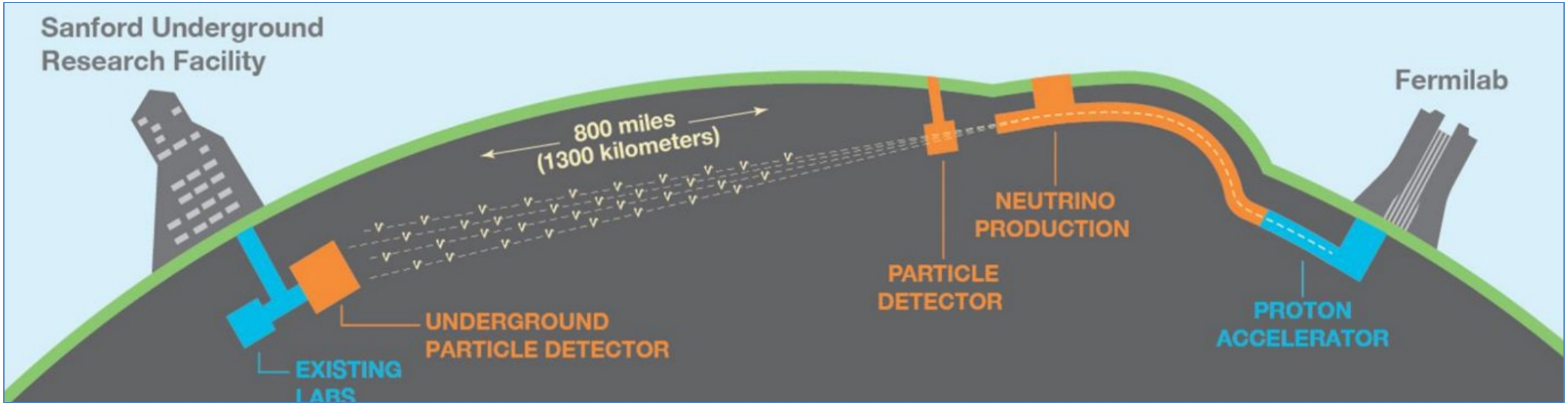
Neutrino mass hierarchy

Neutron star and black hole formation. Ability to observe neutrinos from supernova events and perhaps watch formation of black holes in real time.

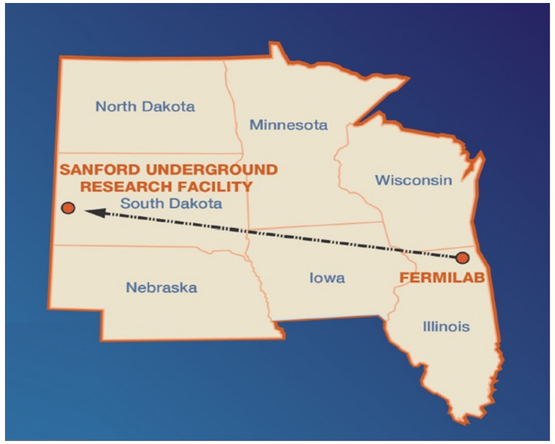
Unification of forces. Investigate proton decay, non standard interactions

Atmospheric and Solar neutrinos.

The DUNE Experiment



- High-power proton beam – 1.2MW upgradeable to **2.4MW**
- A high power, wide-band neutrino beam (~ GeV energy range)
- **Near detector** (**575m** from the ν source - 100s millions of ν interaction)
- **Far detector** in South Dakota **(~1300Km)** and 1,5Km deep underground
  - LArTPC → 4 modules - 17 kton each

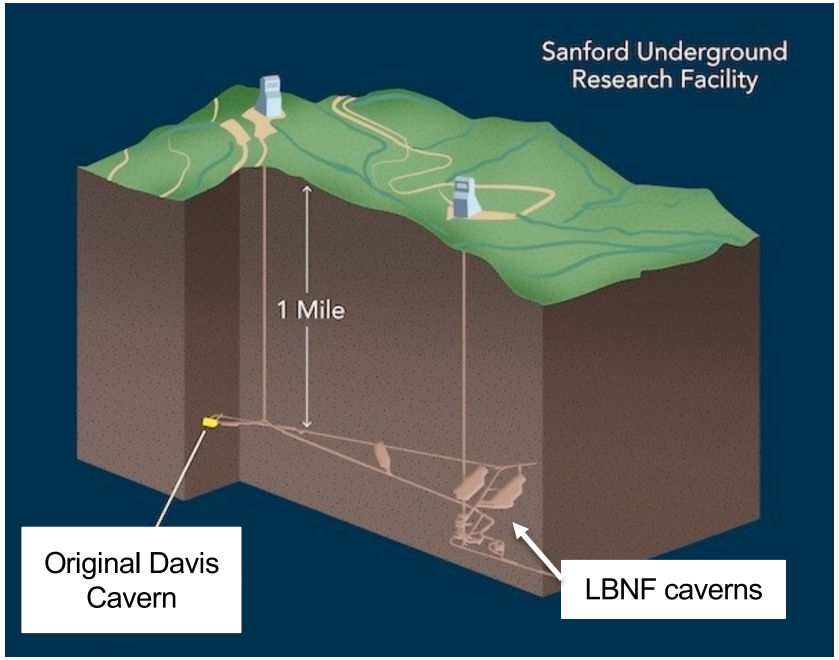


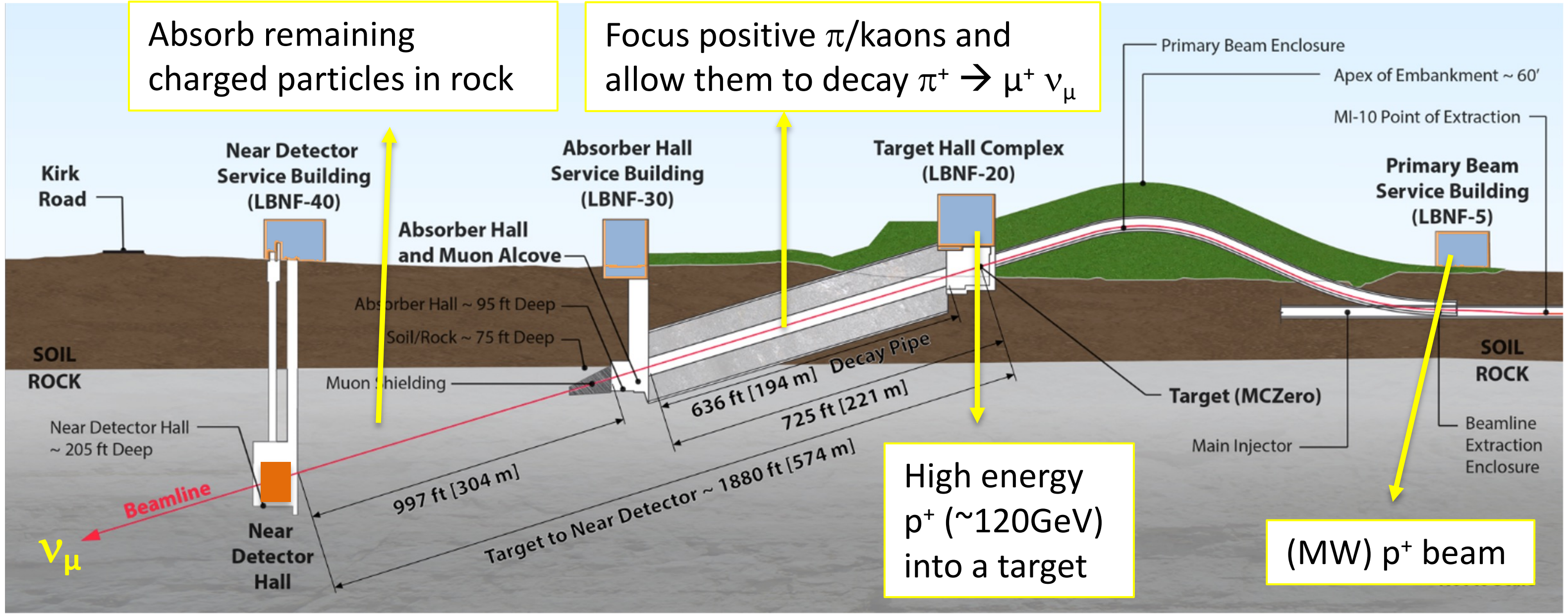
Long Baseline Neutrino Facility - LBNF

LBNF/DUNE : Illinois → underground in South Dakota

Illinois: ➔

- World's most powerful and advanced neutrino beamline
- DUNE near detector (ND)



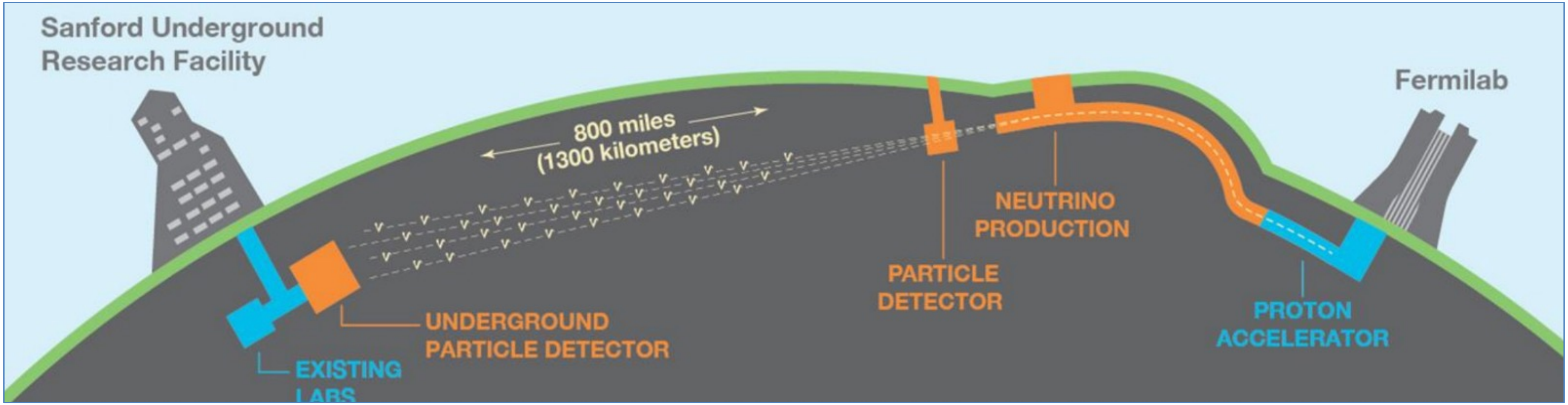


← South Dakota:

- Surface and underground facilities
- Cryostats - Massive membrane cryostats to hold liquid argon
- Cryogenic systems (Nitrogen and Argon)
- DUNE far detectors (FD) - 4 modules

Escavation progress

DUNE



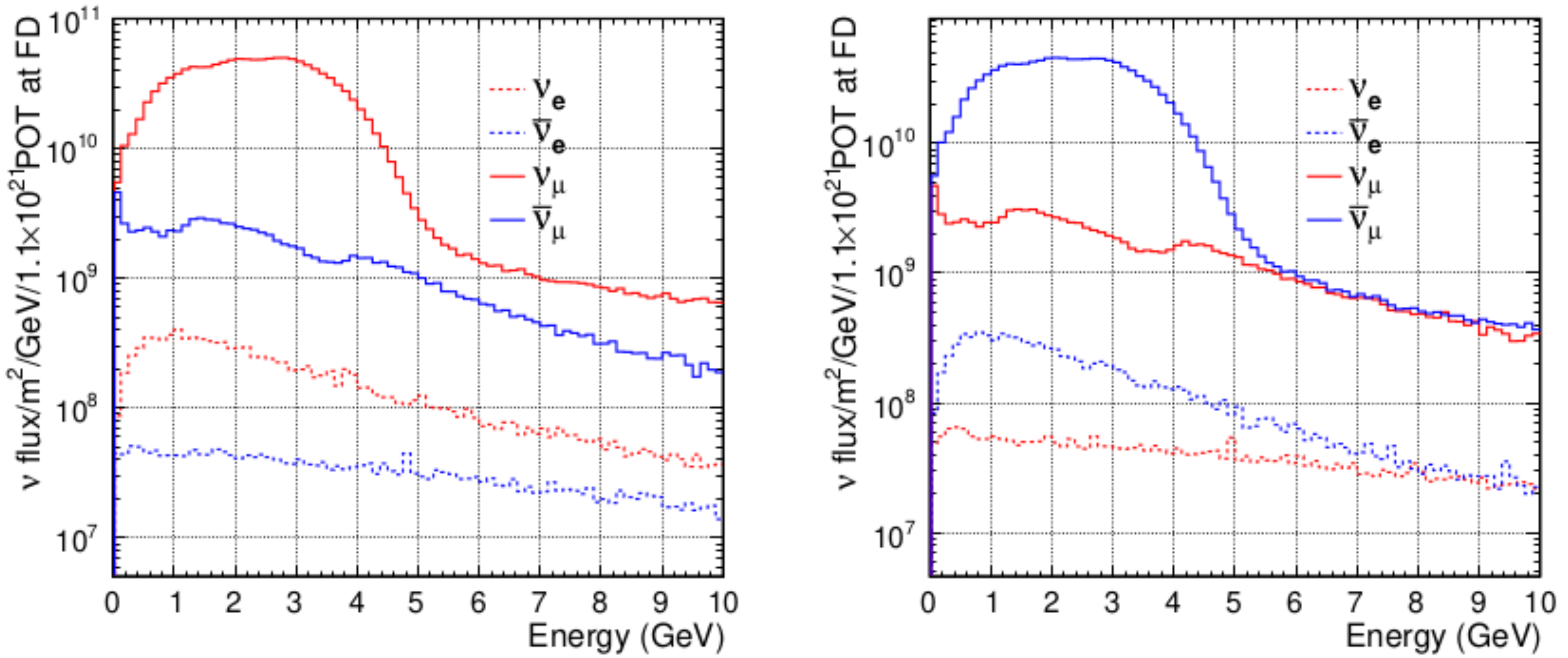
Near Detector : measurements of ν_μ **unoscillated** beam.

Far Detector: measurements of **oscillated** ν_μ & ν_e spectra

THEN repeat for antineutrinos – and compare oscillations of neutrinos and antineutrinos

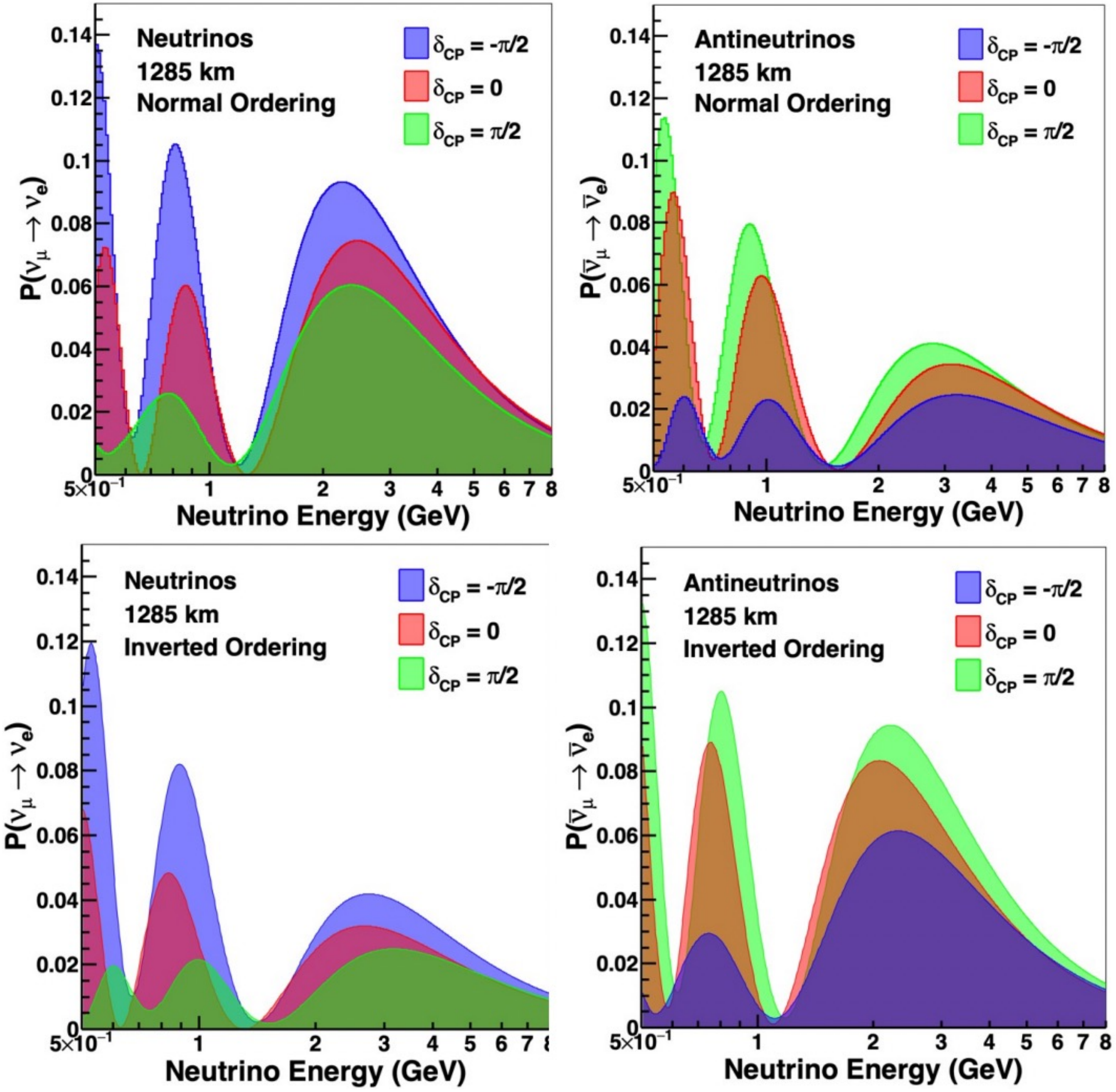
LBNF Beam

Neutrino fluxes at FD for: Neutrino mode & Antineutrino mode



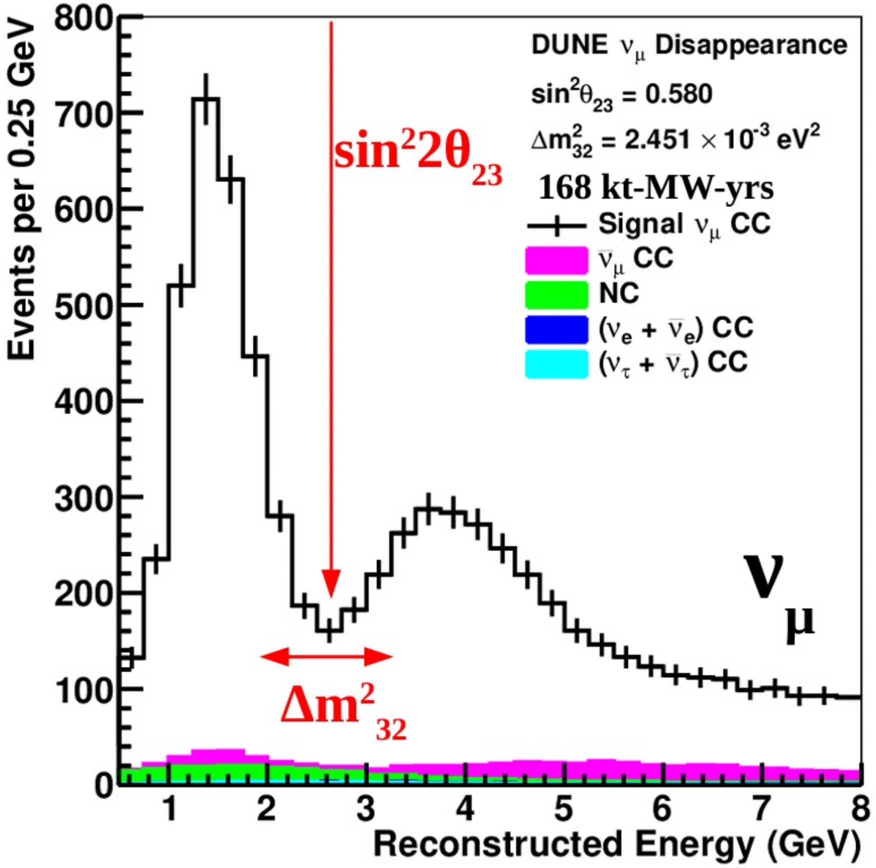
DUNE measures oscillation

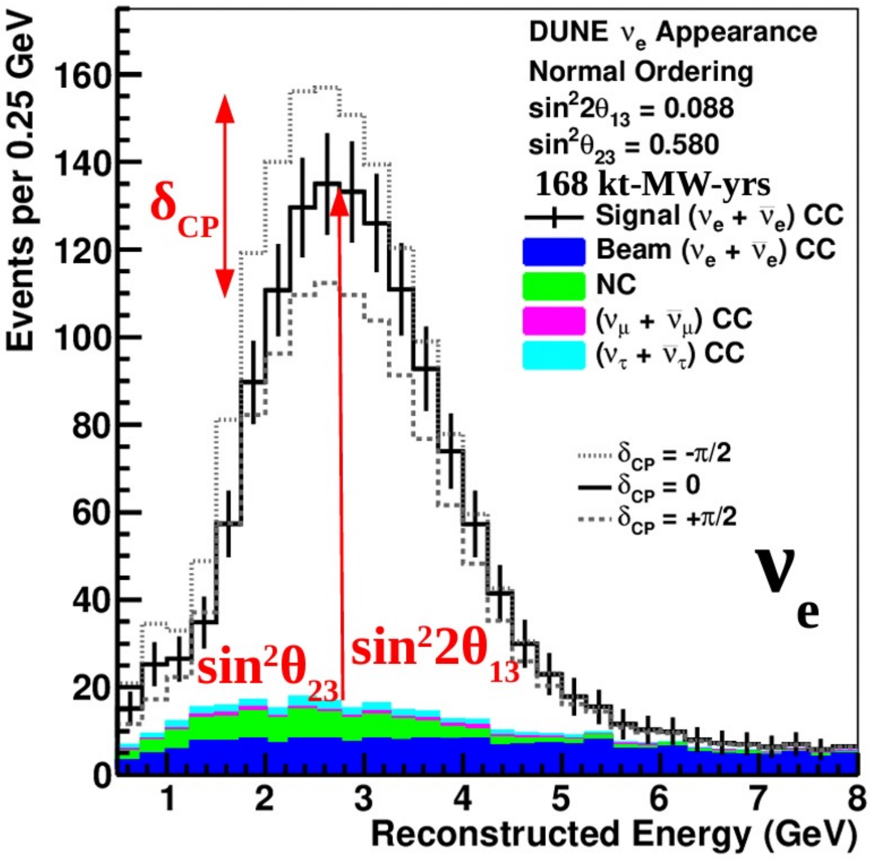
- Effect of mass ordering, CP violation, θ_{23} octant have different shape as a function of L/E
- Measuring oscillations as a continuous function of energy helps resolve degeneracies between oscillation parameters, and probing oscillations beyond the 3-flavor paradigm
- This requires that FD measure neutrino energy event by event



Chris Marshall slide

Neutrino Energy Spectra at FD

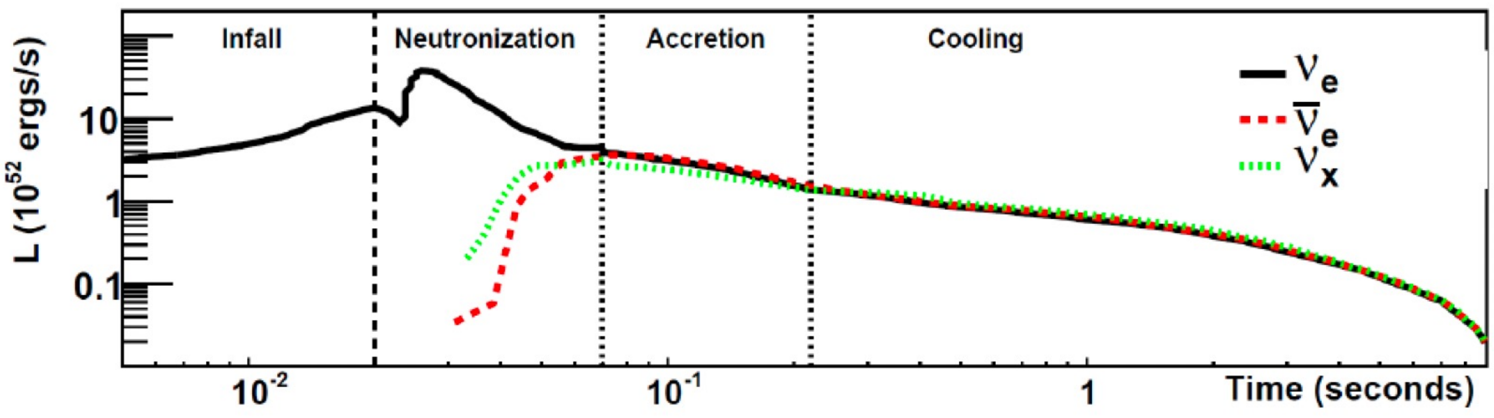


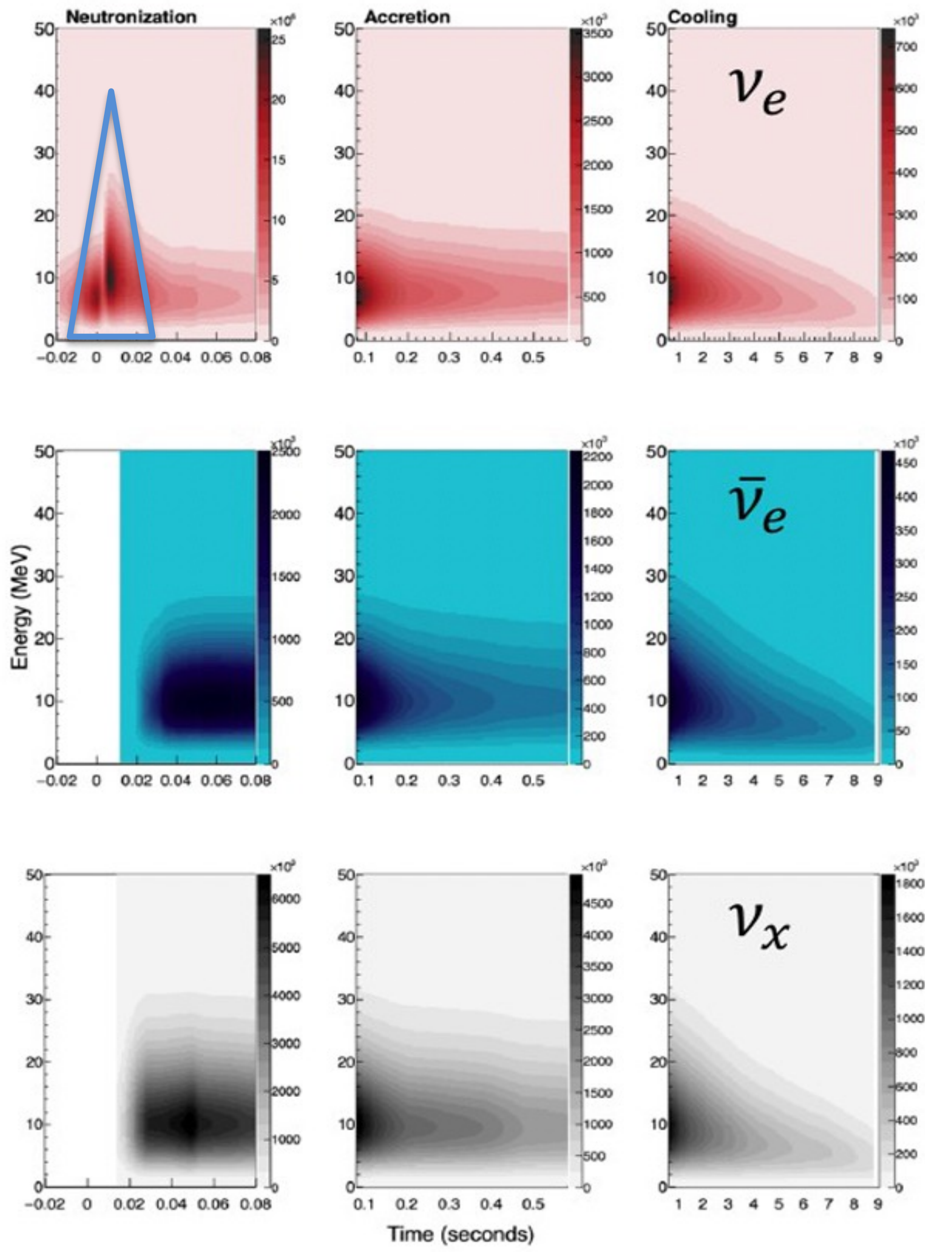


Critical range for oscillations is 0.5 to 5 GeV

Chris Marshall slide

Supernova neutrinos



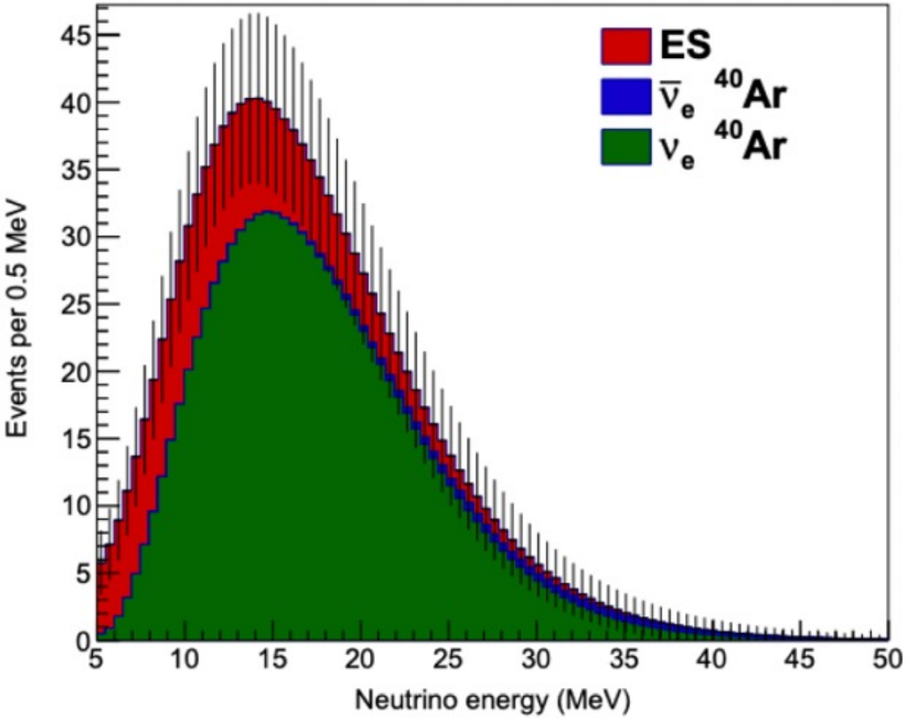


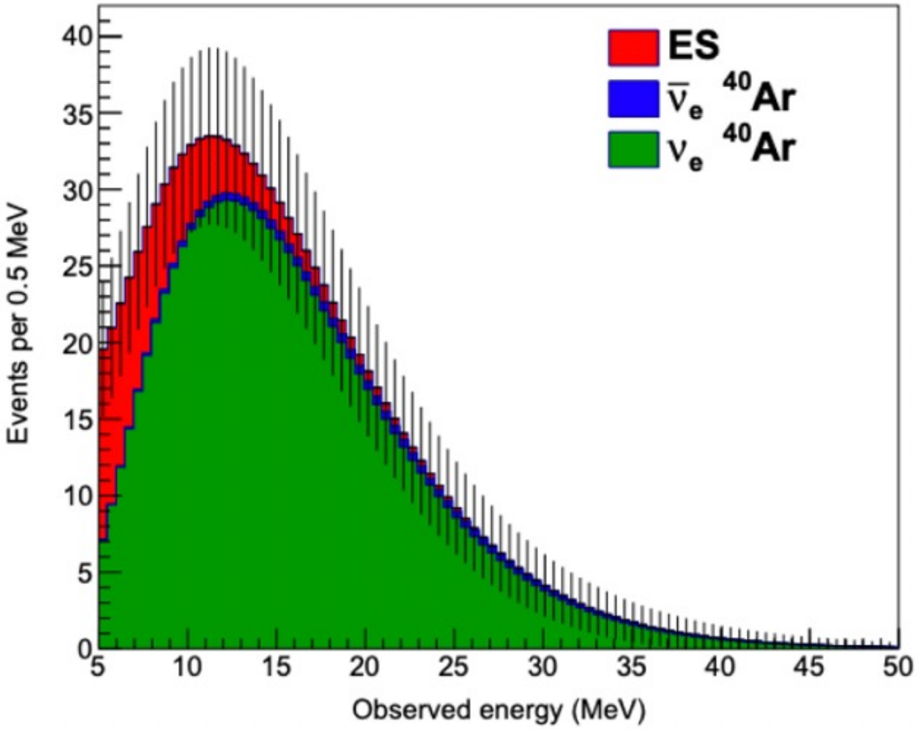
- DUNE Far Detector will be **sensitive to neutrinos from around 5 MeV to a few tens of MeV**
- DUNE's Ar target is sensitive mostly to ν_e → unique capability among existing and proposed supernova neutrino detectors (tipically sensitive to anti-ν_e through IBD)
- Possibility to observe the peak of neutronization

Expected Supernova burst signal

40 kton LAr & 10 kpc SN
"Garching model"
Computed with SNOwGLoBES

Channel	Garching
$\nu_e + ^{40}\text{Ar} \rightarrow e^- + ^{40}\text{K}^*$	882
$\bar{\nu}_e + ^{40}\text{Ar} \rightarrow e^+ + ^{40}\text{Cl}^*$	23
$\nu_X + e^- \rightarrow \nu_X + e^-$	142
Total	1047





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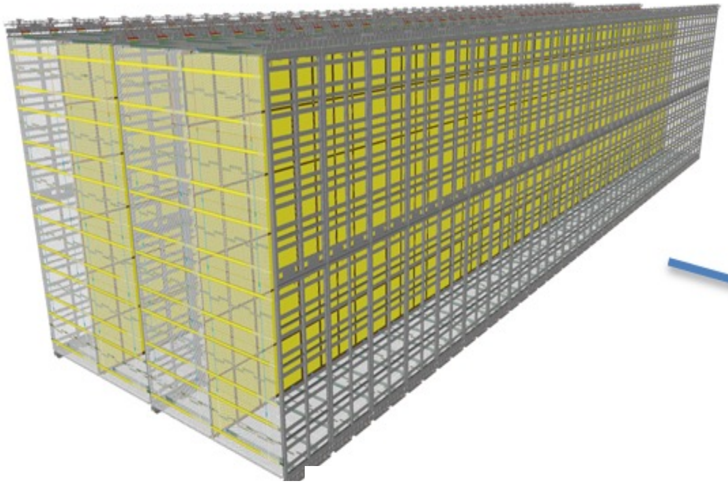
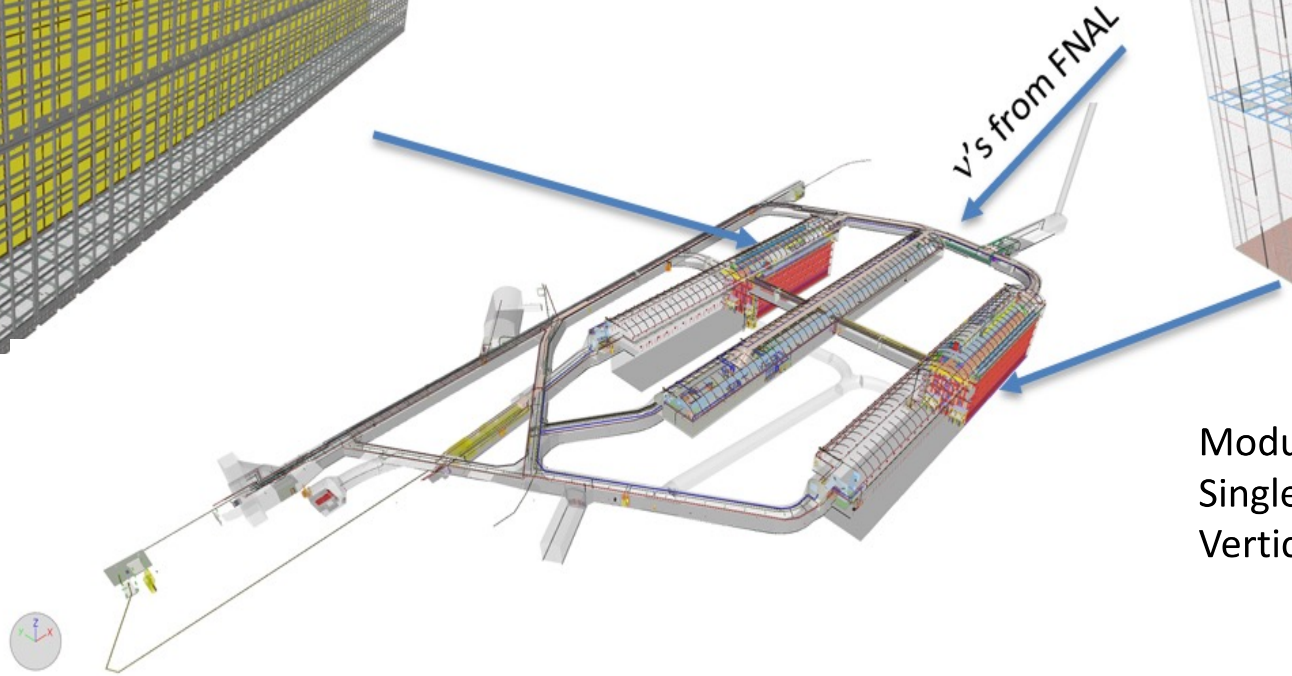
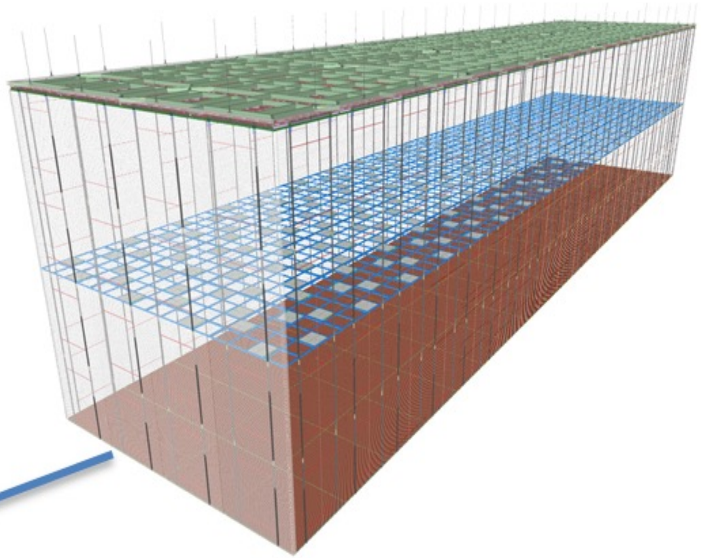
DUNE Phase I - Far Detector



Module 1 (FD1)
Single Phase
Horizontal Drift





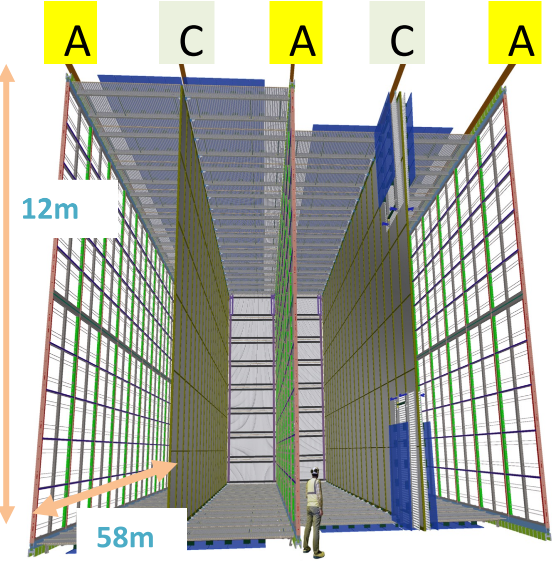
Module 2 (FD2)
Single Phase
Vertical Drift

APA: Anode Plane Assemblies

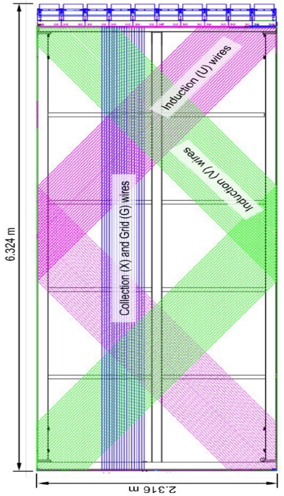
CRP: Charge Readout Planes

DUNE Far Detector (FD1 & FD2)

Horizontal Drift



- **4 drift volumes -** 3.6 m drift
- Electric field = 500 V/cm
  HV = -180 kV
- High-resistivity CPA for fast discharge prevention
- Anode: **150 APAs**, each with 4 wire planes (Grid, 2 x Induction, Collection)



- Photon Detectors: **X-ARAPUCA**
  10 modules / APA

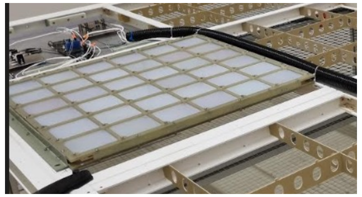
  Total of **1500 modules**

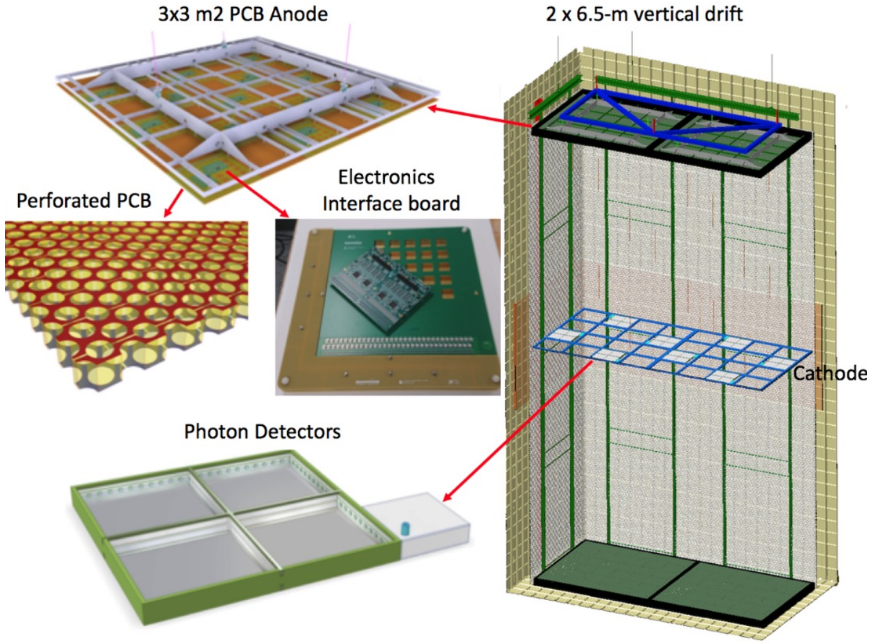
X-ARAPUCA module (212cm x 12cm)

Vertical Drift

- **2 drift volumes** (13.5 m x 6.5 m x 60 m) → 6.5m drift
- 2 Anode planes (top & bottom)
- Charge Readout Planes (CRP) → **perforated PCB**, fully immersed in LAr
- Cathode in the center at ~300kV

PD: Large size X-ARAPUCA tile (0.6 x 0.6 m^2)

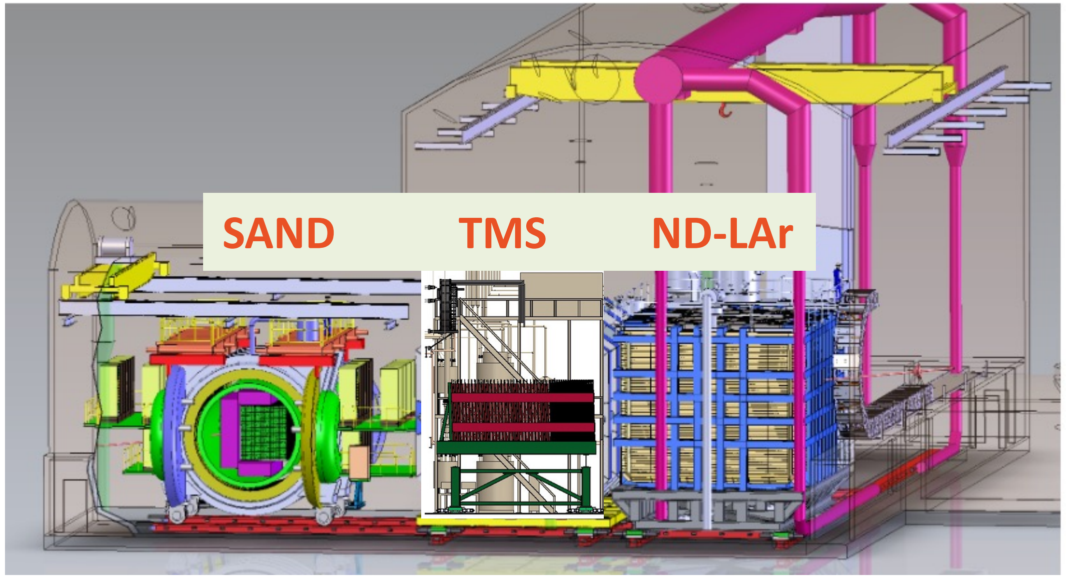




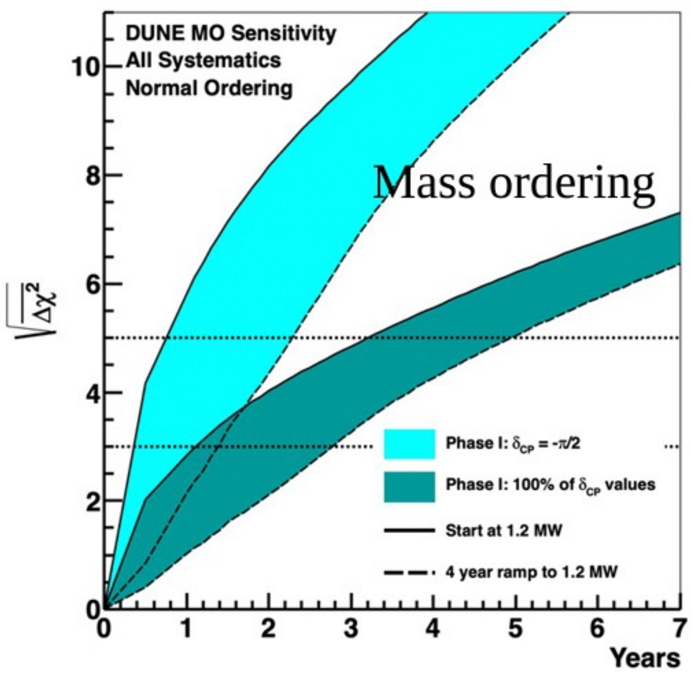
DUNE Phase I - Near Detector

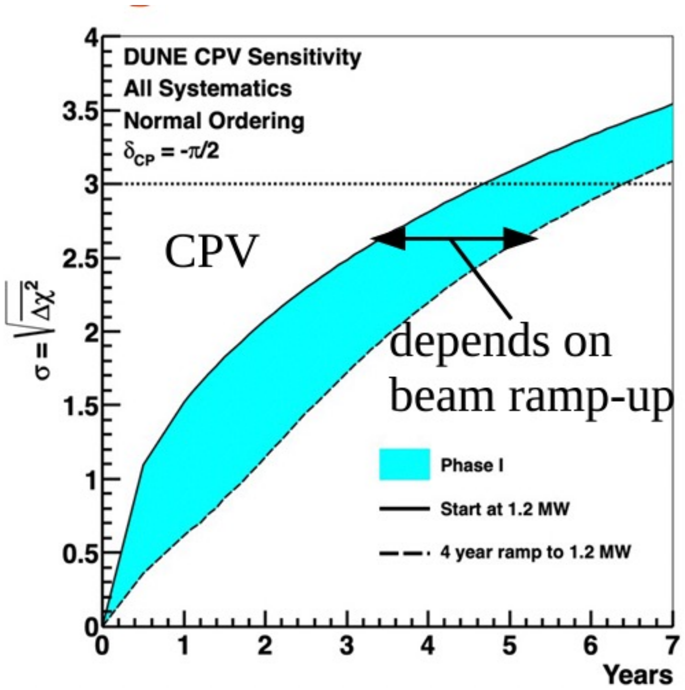
Allows for high statistic measurements of the initial neutrino flux

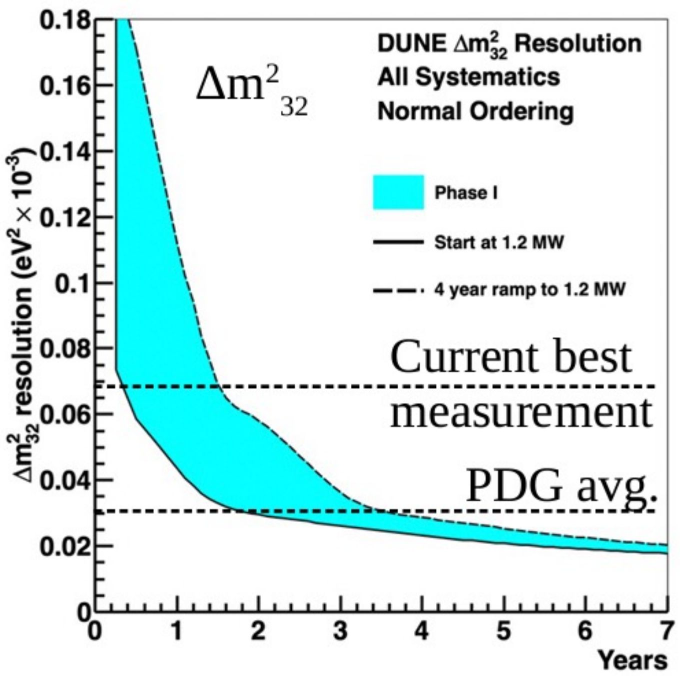
- ND-LAr → measurement of neutrino-nucleus interaction with the same target as the Far Detectors
- TMS → muon spectrometer for ND-LAr
- SAND → on axis; will make precision measurements of multiple channels of neutrino interactions, leading to better control of systematics ; monitors the beam stability when the ND-LAr+TMS are off-axis



Phase I



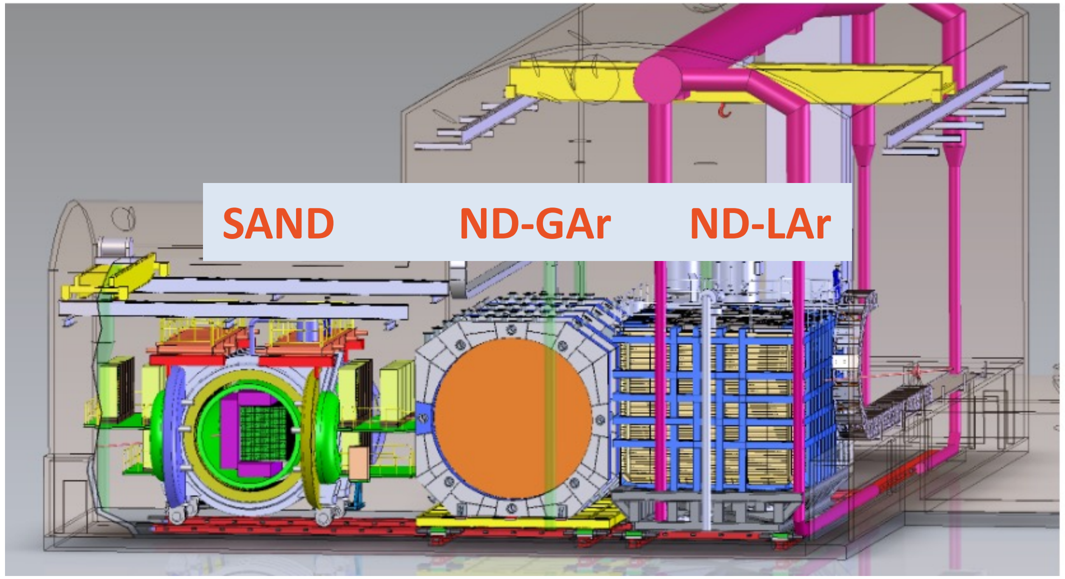




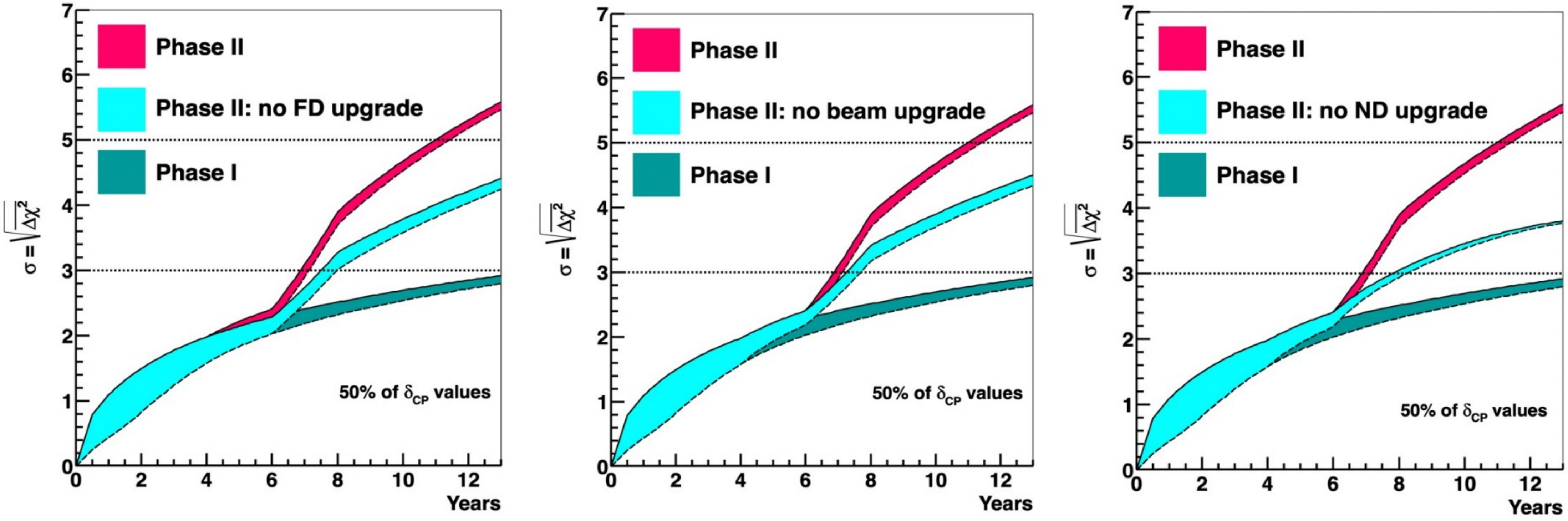
- DUNE will be able to establish ***the neutrino mass ordering at the 5σ*** level for 100% of δ_{CP} values
- ***CP violation*** can be observed with 3σ significance after about 7 years if $\delta_{CP} = -\pi/2$ and after about 10 years for 50% of δ_{CP} values.
- Δm^2_{32} can be measure with the resolution better than any other measurements after 2 years
- But Phase I cannot achieve all of the P5 goals

DUNE Phase II

- Beam power upgrade to 2.4MW
- Far Detector with 4 modules
- Near Detector : TMS replaced by ND-GAr
  - ND-LAr
  - ND-GAr → important for higher precison ν-Ar measurements and when the **statistics reach ~200 kt-MW-yrs**
  - SAND



DUNE evolution



To achieve all P5 goals it is need : Detector Mass 40 kton (4 modules) + Beam power upgrade to 2.4MW + Improved Systematics (Near detector upgrade)

LAr TPC - Technology

Charged particles in LAr **produce** free **ionization electrons** and **scintillation light (128nm)**

Ionization electrons drifts in a intense and uniform electric field(˜500V/cm) towards the readout wire-planes

↓

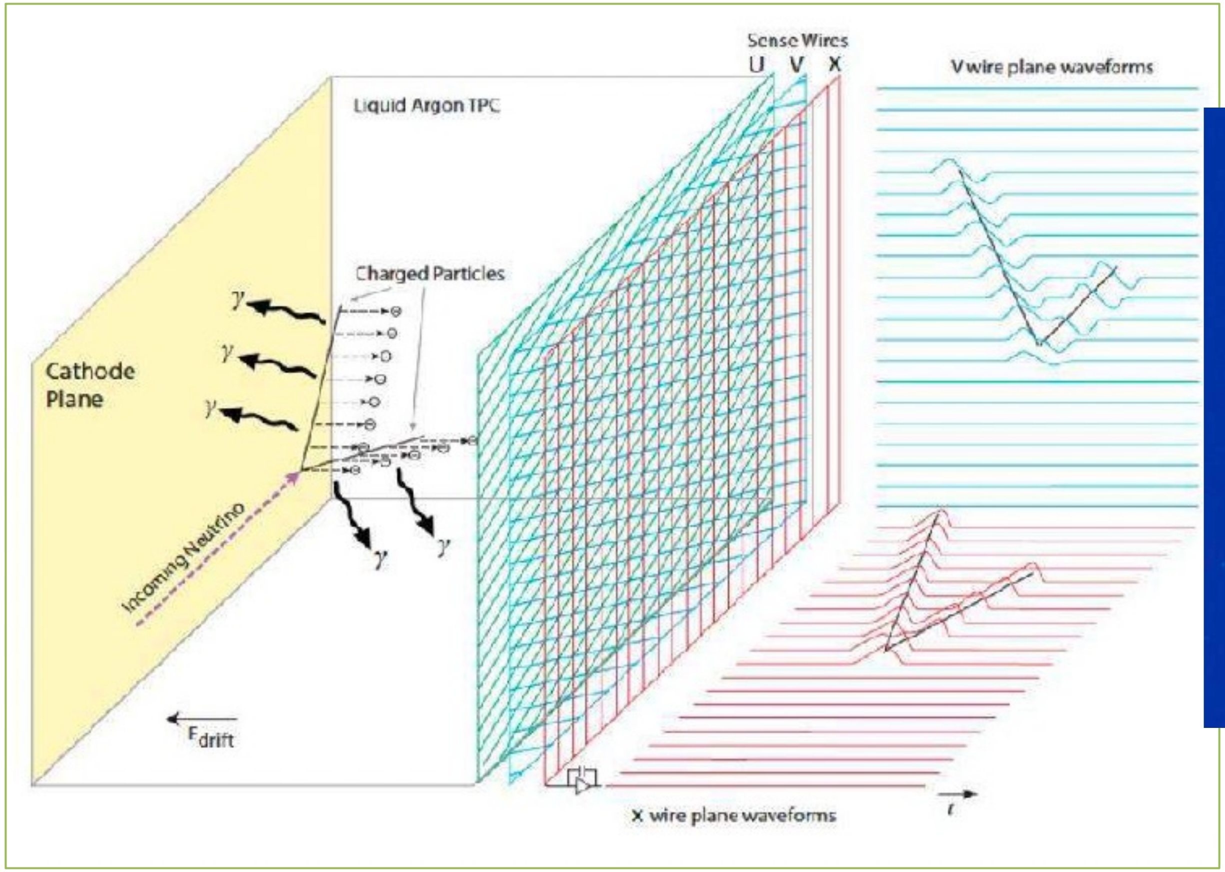
3D reconstruction + Calorimetric measurements

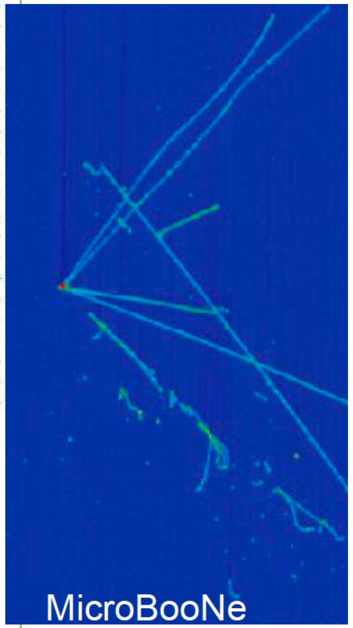
VUV photons propagate and are shifted into VIS photons

↓

Determination of $\mathbf{t_0}$ + Calorimetric measurements

Horizontal Drift



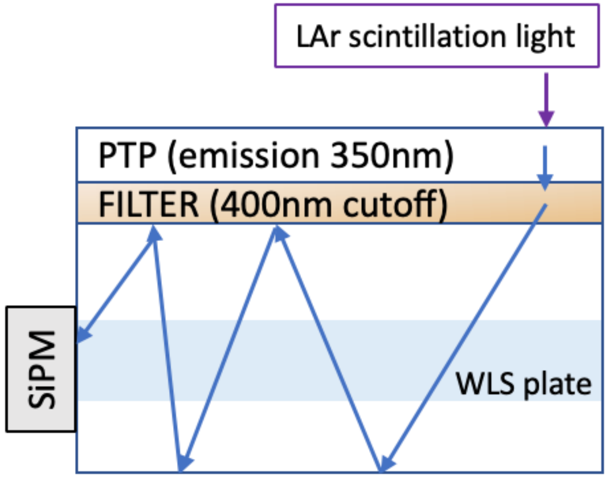


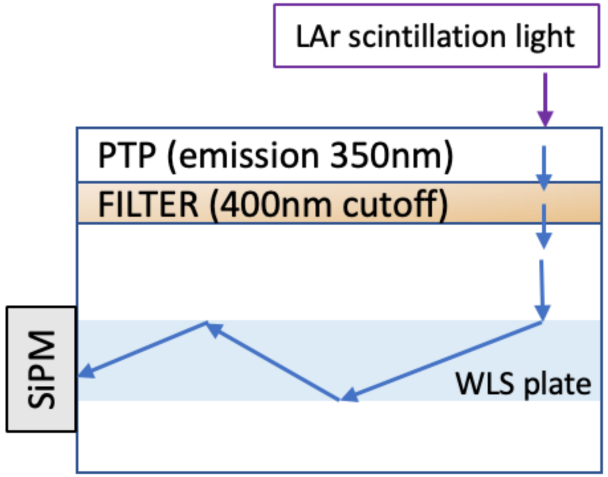
Photon Detection

The Photon detection system (PDS) of **module 1 and 2** is made by **X-ARAPUCA** devices

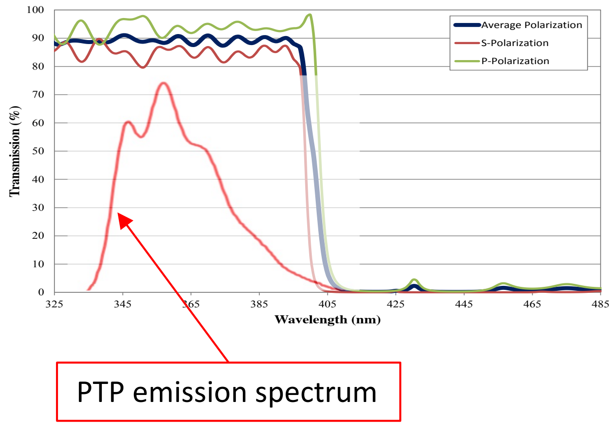
The **X-ARAPUCA is a light trap**; it makes use of SiPMs a photon collector for expanding the acceptance area and a trapping mechanism to give photons more than one chance of being detected

The trapping is done through the combination of a filter with a well defined cut off and two different wavelenght shifter

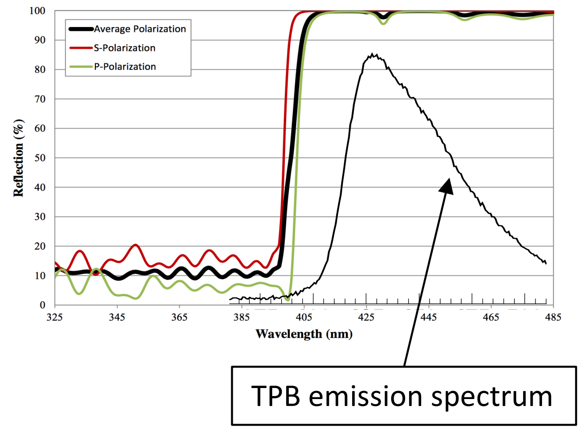




Dichroic filter transmission



Dichroic filter reflection

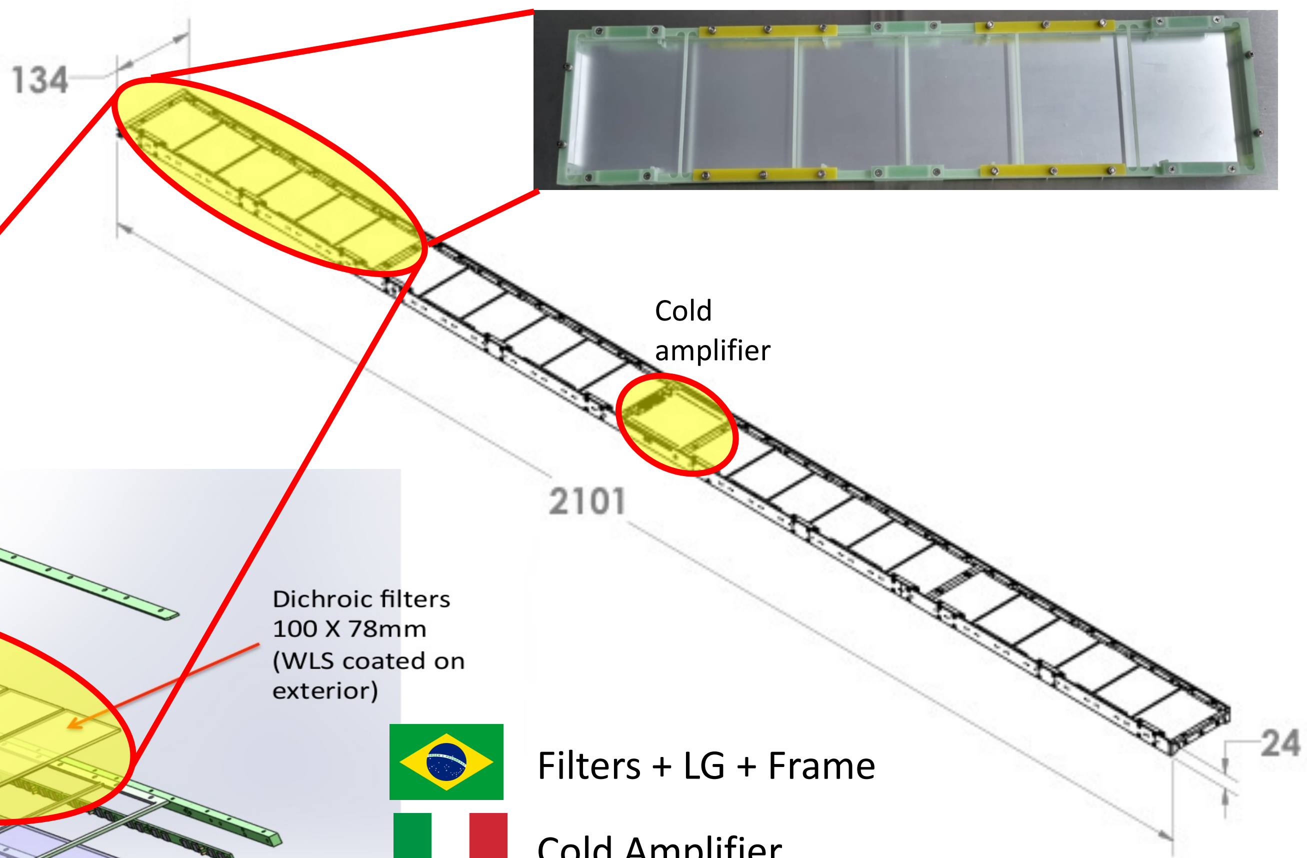


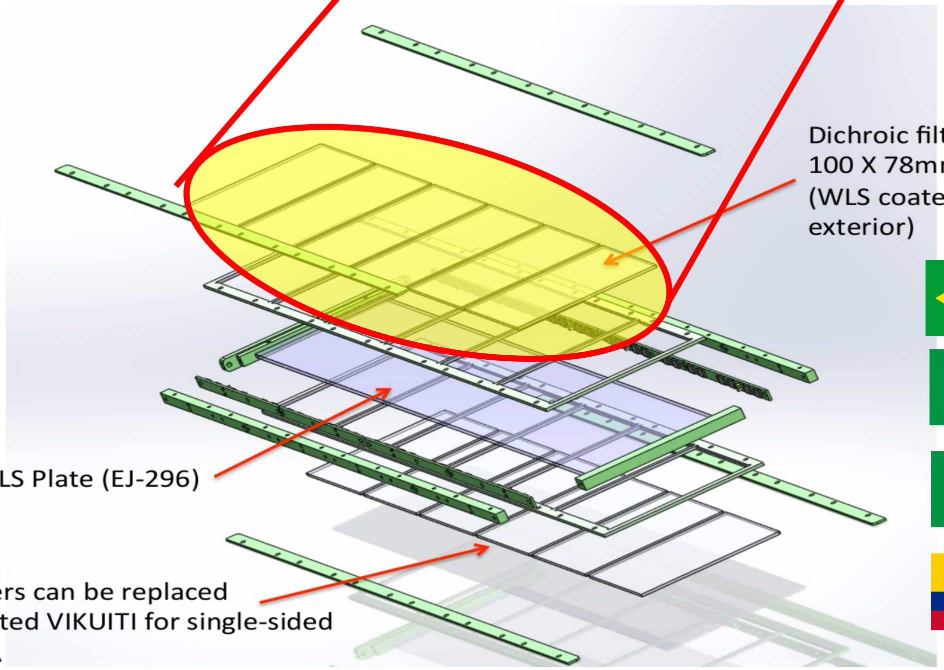
Photon detection system – horizontal drift

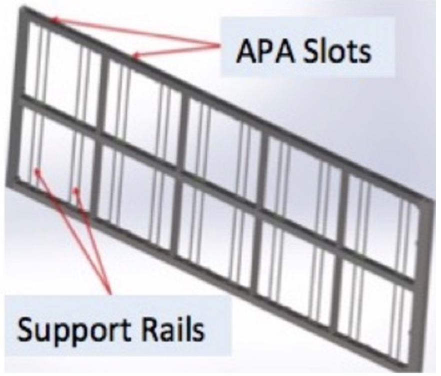
1 Module = 4 supercells

Supercell :

- 6 Dichroic Filters
- 48 SiPM
- 1 Light Guide







10 modules per APA

1500 in total

- 500 double sided
- 1000 single sided

Filters + LG + Frame

Cold Amplifier

SiPM

DAPHNE

Filters→ OPTO
LG→ Glass to Power
SiPM → Hamamatsu + FBK

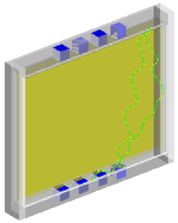
X-ARAPUCA small scale prototype TESTs

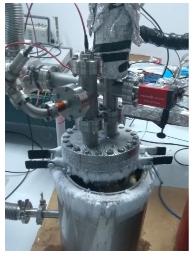
The X-ARAPUCA small scale prototypes have being used to measure the photon detection eficiency (DE) in LAr.

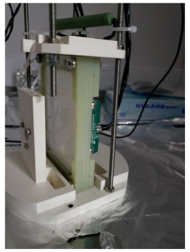
These measures was performed in three diferent laboratories to evaluate:

- Dichroic Filters : OPTO
- SiPM : Hamamatsu
- Light Guides : EJ286 and Glass to Power (G2P)

UNICAMP



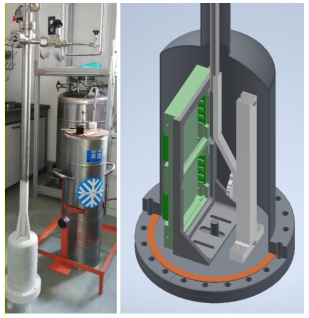


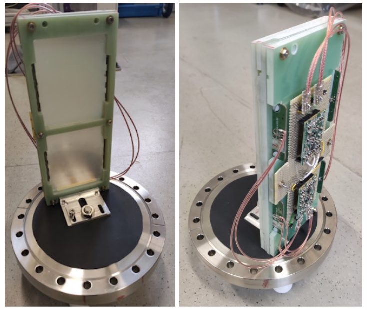


https://arxiv.org/abs/2106.04505

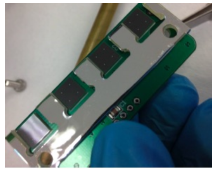
MIB

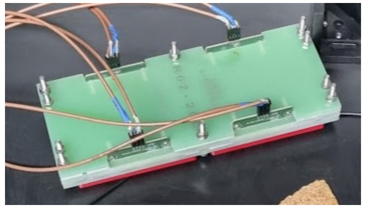
https://arxiv.org/abs/2104.07548

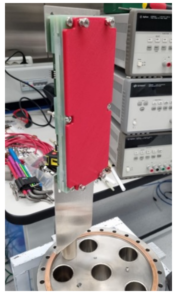




U.Napoli







Detec Eff measured:
OPTO + Hamamatsu +

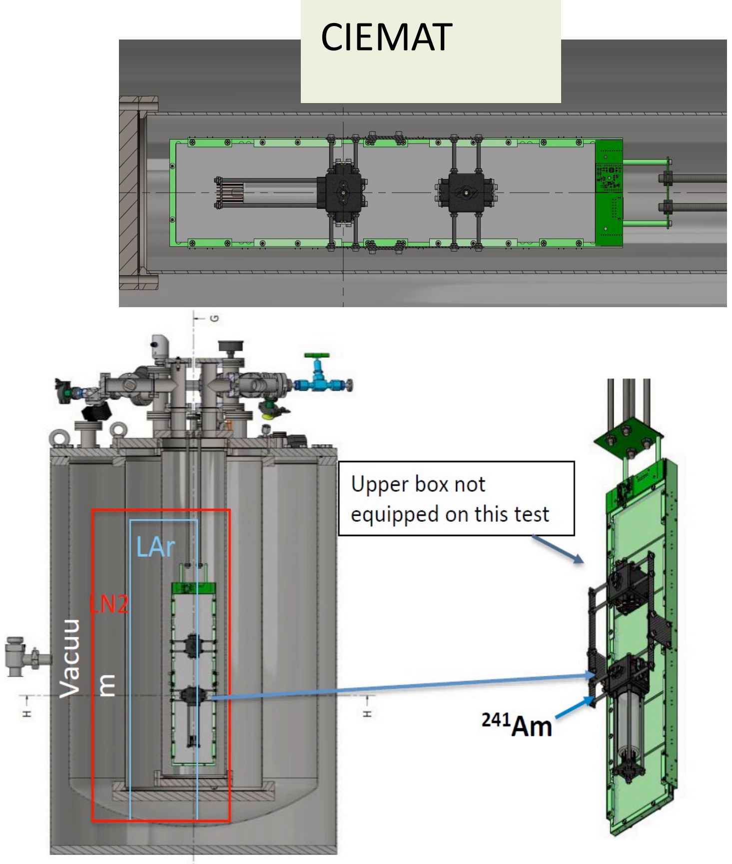
EJ286 → $2.2 \pm 0.5\%$

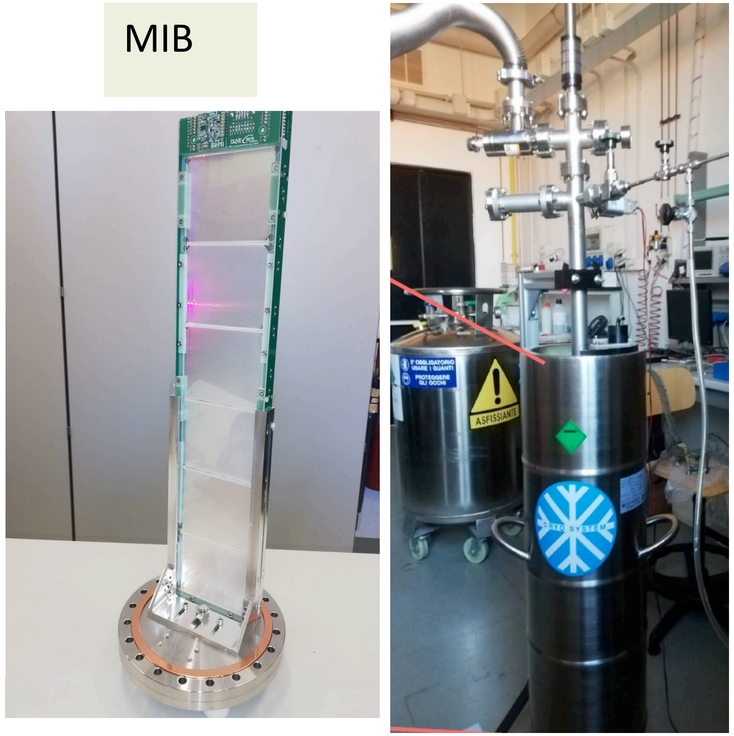
EJ286 → $1.8 \pm 0.1\%$
G2P → $2.9 \pm 0.1\%$

G2P → $2.7 \pm 0.3\%$

X-ARAPUCA Supercells Tests

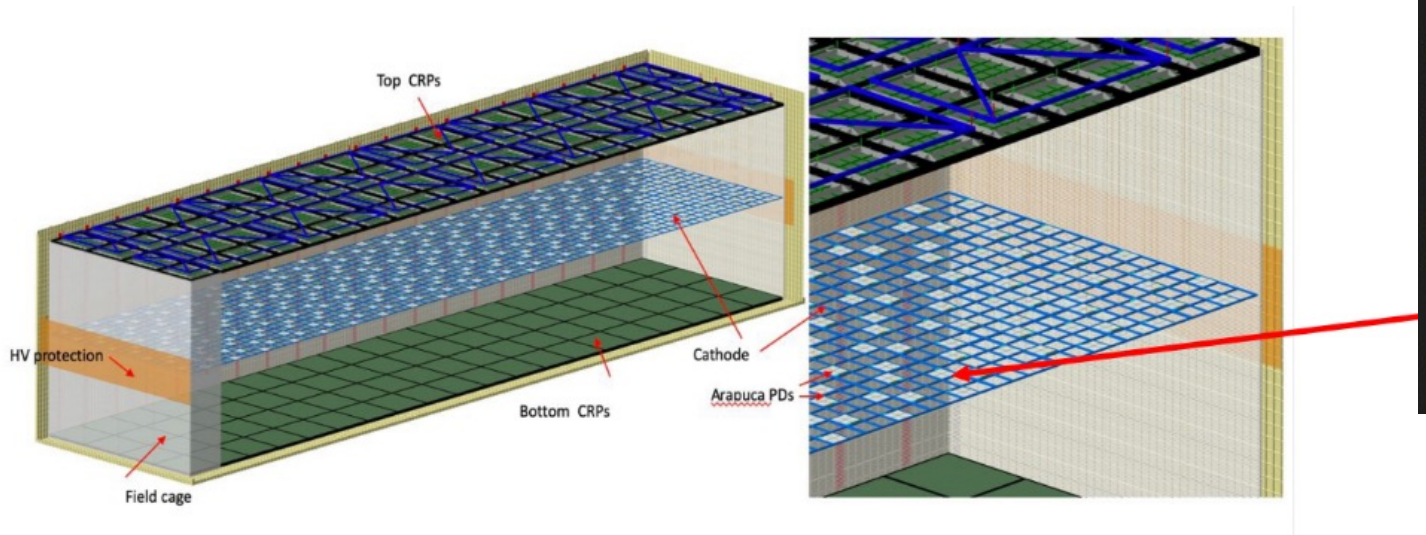
- Two independent tests were performed in order to measure the DE of the X-ARAPUCA supercells. One at CIEMAT and one at MIB
- Detection Efficiency **1.5% and 3%** depending on the combination of Sipm – WLS
- OPTO dichroic Filter
- Glass to Power (G2P) 20% > Eljen
- WLS-SiPM coupling to WLS bar → better for Hamamatsu than FBK bu about 10%

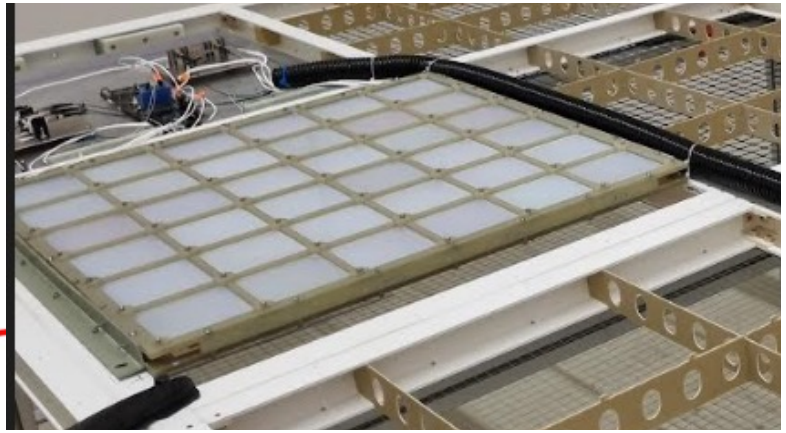




Photon detection system – vertical drift

- The Vertical Drift does not have the mechanical constrains of the Horizontal Drift for the X-ARAPUCA modules.
- They have been re-desingned with a square shape (60 x 60 cm^2) in order to maximize the **Light Collection**
- The basic Megacell module - single sided - has 36 dichroic filters with 97X97mm^2





Megacell: new version of the photon detection system

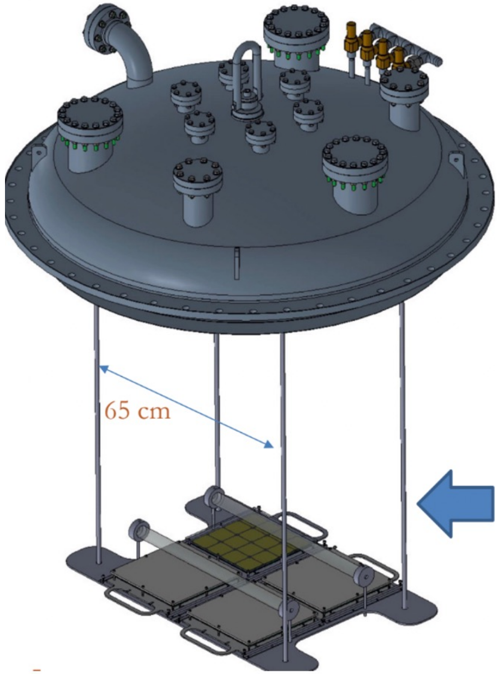
Test of XA-Megacell in Naples

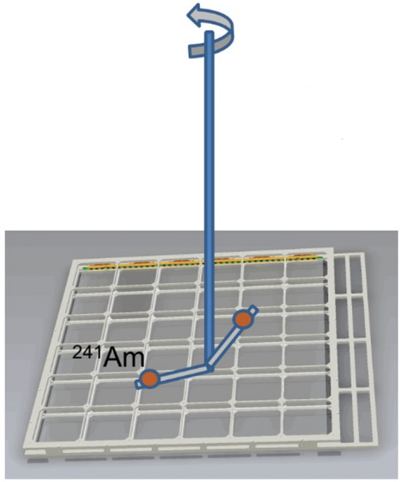
- Cryostat (1.15 m diameter – 1.57 m height)
- Equiped with PT1000 temperature/level meter sensors, pressure transducer and analog pressure indicator
- The cryostat is designed for automatic LN filling (7 hrs) and draining (15 hrs)
- A manipulator system will be installed with

^{241}Am alpha source

- Illumination system with optical feedthrough and light diffusers
- 405 nm laser available, procurement of UV

led source



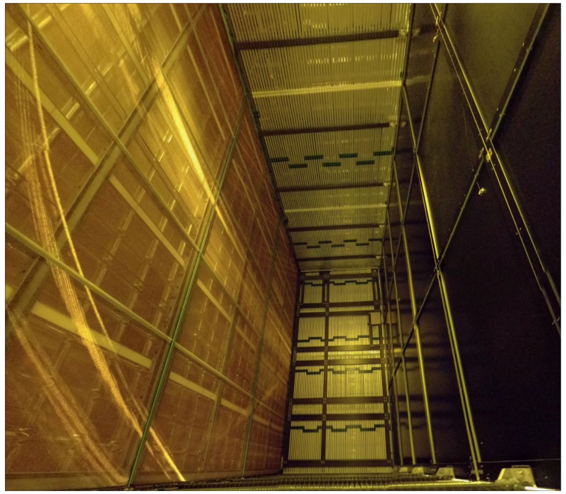


Credits: Francesco Di Capua

ProtoDUNE Run1 - HD

DUNE prototype at CERN

- Active Volume **419ton LAr**
- 2 Drift Volumes
- Max **drift length 3,6m**
- Run1 – 2018 to 2020 at CERN
- Beam of charged particles: pions,kaons, protons, muons and electrons with momenta in a range 0.3 GeV/c to 7 GeV/c
- **PDS system:** ARAPUCA, waveshifting light guides and double shift light guide



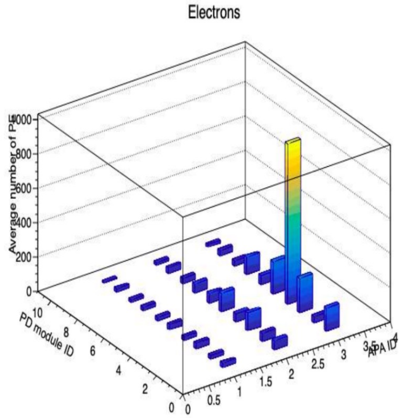
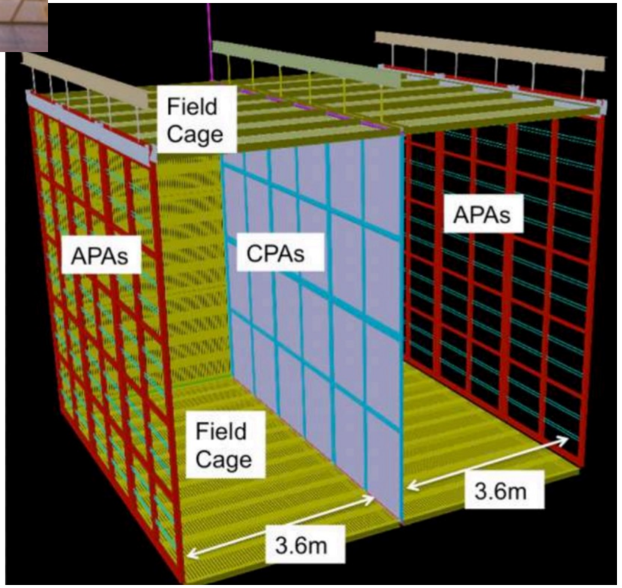
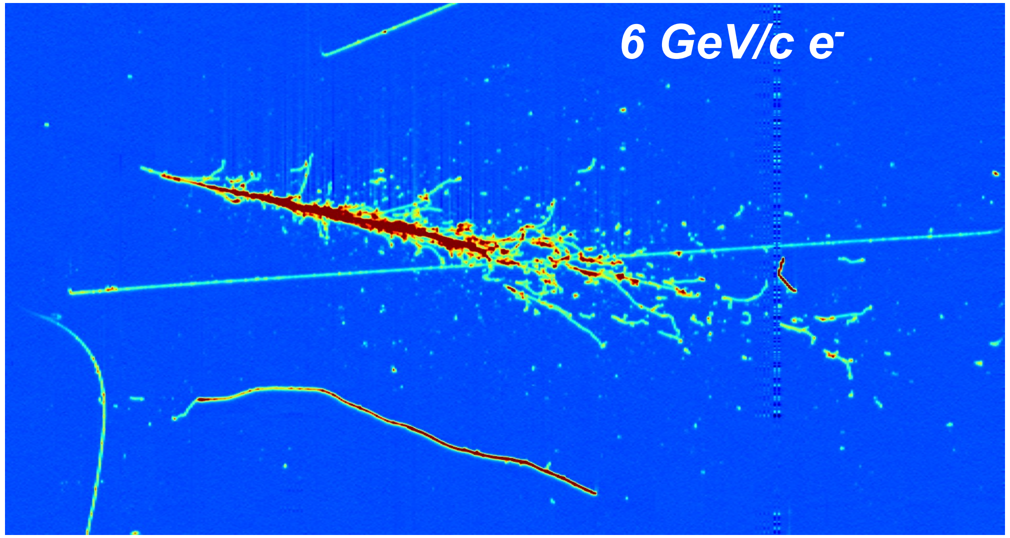


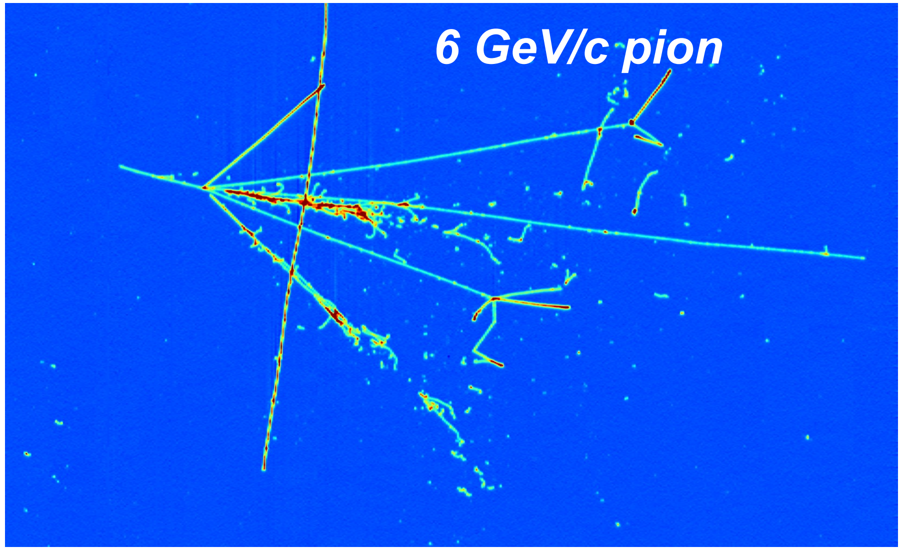
Figure 6: Average number of photons detected by the Photon Detection modules as a function of their position in the detector. The highest peak is the ARAPUCA signal.

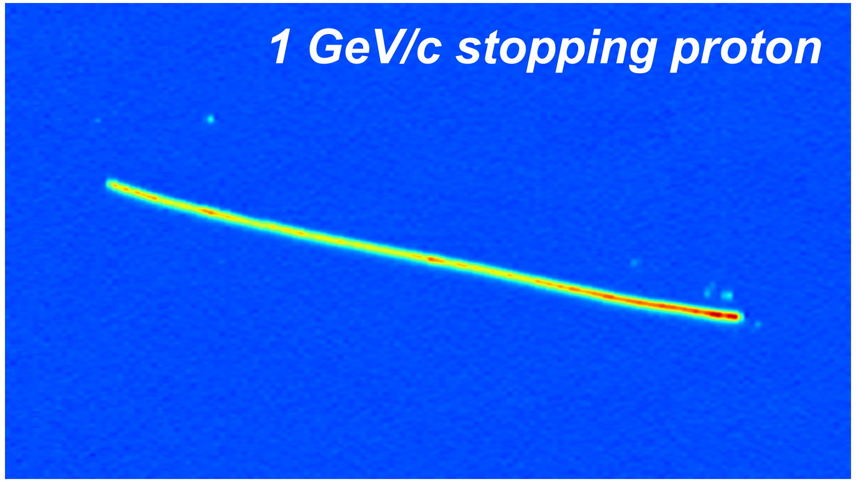


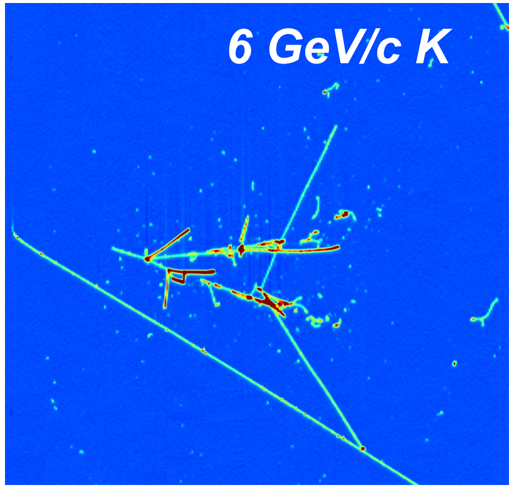
ProtoDUNE Run1 - HD - events

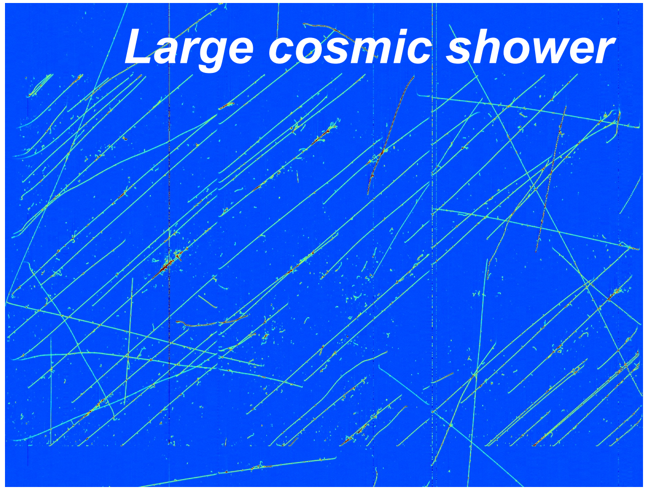
A talk of protoDUNE Run1 measurements (Neutron Inelstic cross section) will given by **David Rivera** today in parallel section





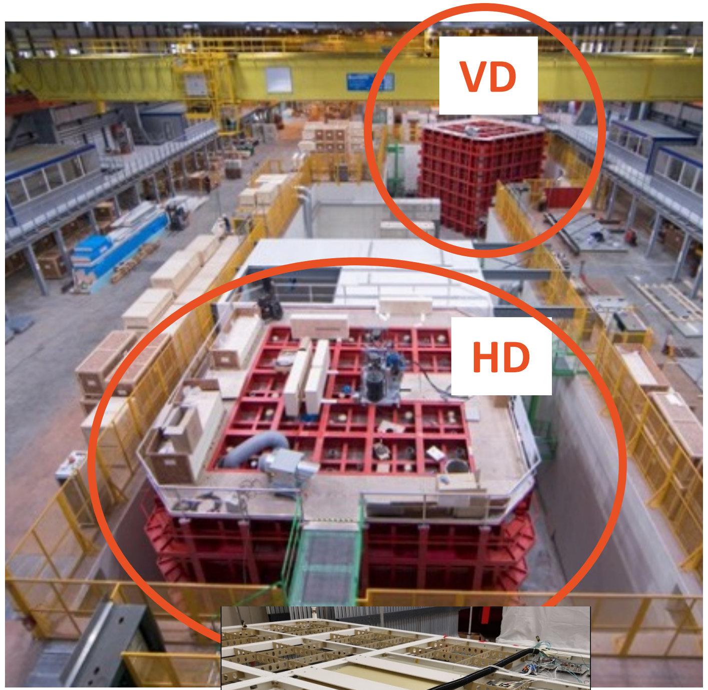






ProtoDUNE – HD & VD

We are preparing the run of **protoDUNE to test the final components** of Horizontal Drift and Vertical Drift far detector



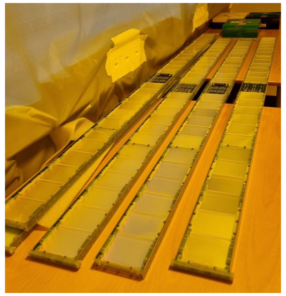
Horizontal Drift

- DUNE APA 2 top and 2 botom
- Photon Detection few different options are being evaluated

  Two different SiPM type (**Hamamatsu and FBK**)

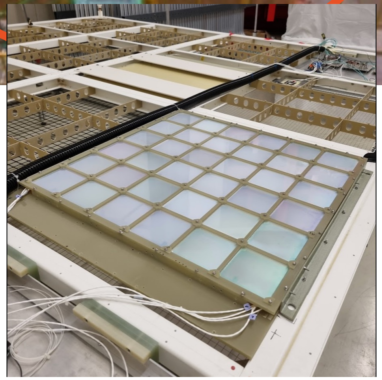
  Two different light guide (**ELJEN and GlastoPower**)

  Test of the electronics readout (**DAPHNE)**



Dichroic Filter dimensions

Size mm x mm	glass/batch #
97 x 97	25
202 x 97.5	14
150 x 150	12



Vertical Drift

PDS

- New X-ARAPUCA modules

  8 on the cathode (Power of Fiber)

  8 on the membrane

DUNE Far Detector - Module 3 and 4

DUNE Module of Opportunity Workshop 2 - 4 November 2022 – Valencia – Spain

→ The third and fourth modules provide opportunity for **further development of liquid-argon or alternate detector technologies** in support of the DUNE physics goals.

https://congresos.adeituv.es/dune_science/paginas/pagina_663_1.en.html

Technology

Liquid-argon

- Improved light detection based on VD PDS and ARAPUCA, metalenses.
- Ariadne: fast optical read-out
- SloMo: use underground argon in an acrylic vessel, reduce background.
- SoLAr/Q-Pix: pixel detector with integrated light system

Non-LAr options

- Water-based liquid scintillator (WbLS)
- Effective separation of Cherenkov and scintillation light with much better timing, dichroicons

Expanded physics scope

- Solar (and supernova) neutrinos
- Low-mass dark matter
- Neutrinoless double-beta decay

Contributions from LA to DUNE

Instrumentation

Simulation

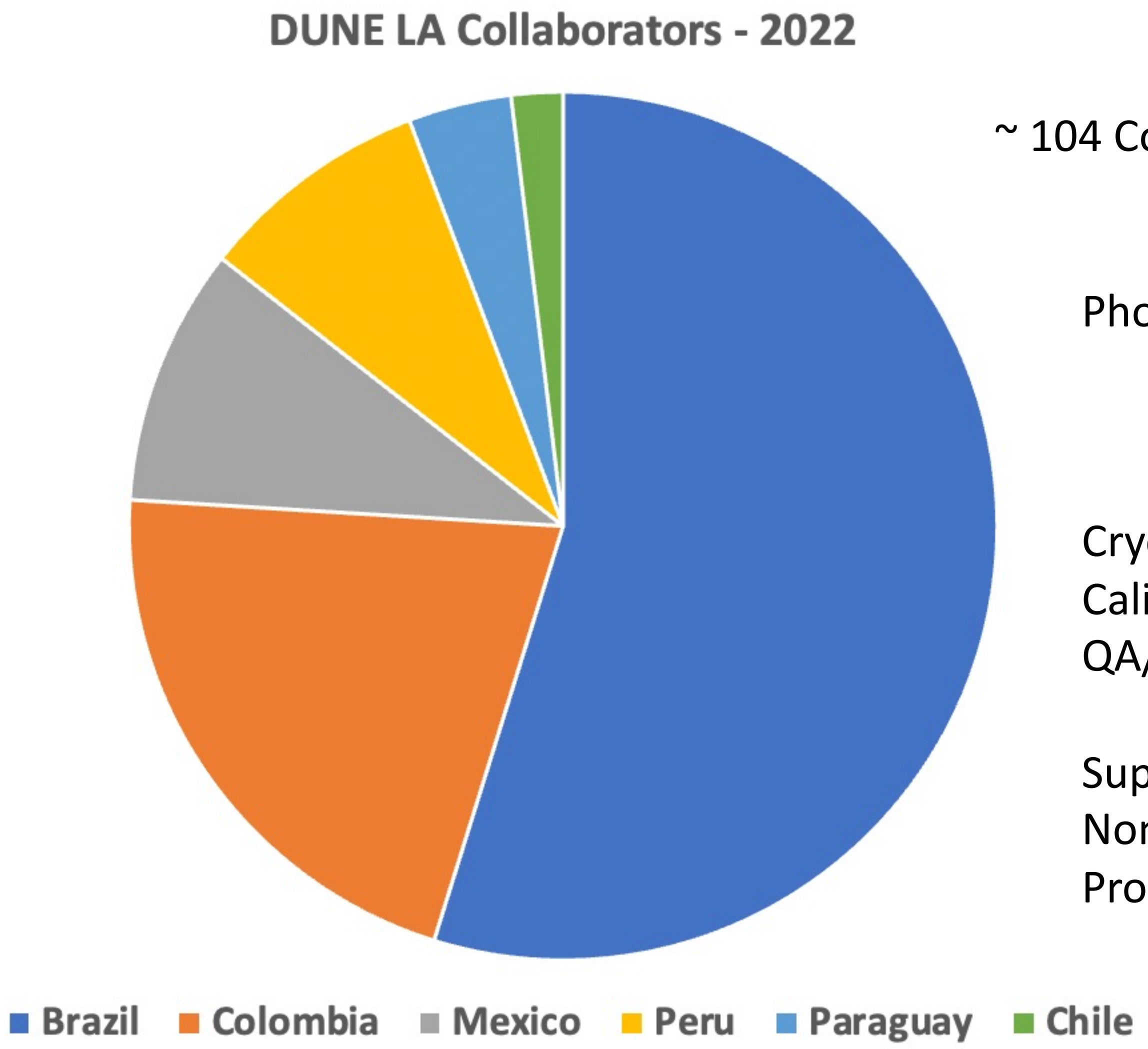
Softwear

Data Analysis

Phenomenology

Theory

Outreach

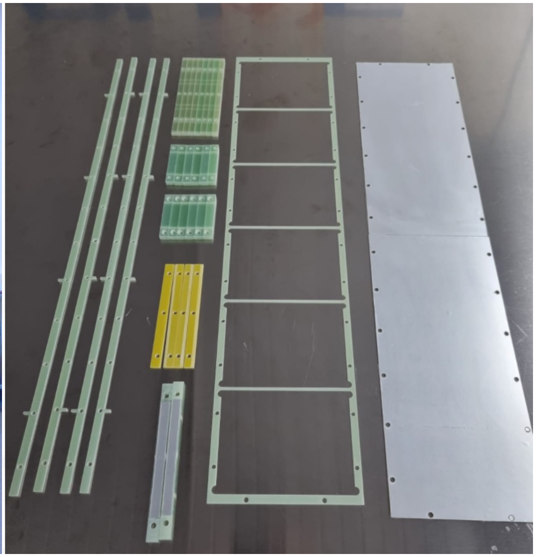


~ 104 Collaborators

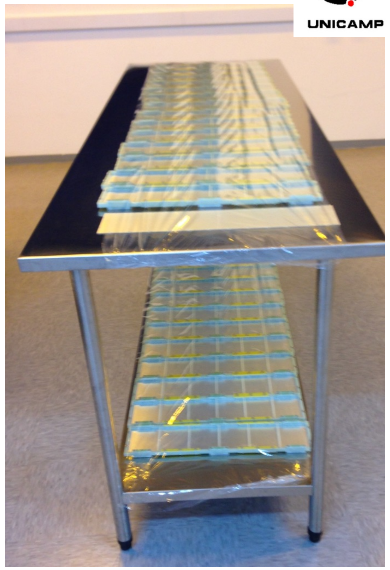
Photon Detection System
- Simulations
- X-ARAPUCA device
- DAPHNE read out electronics

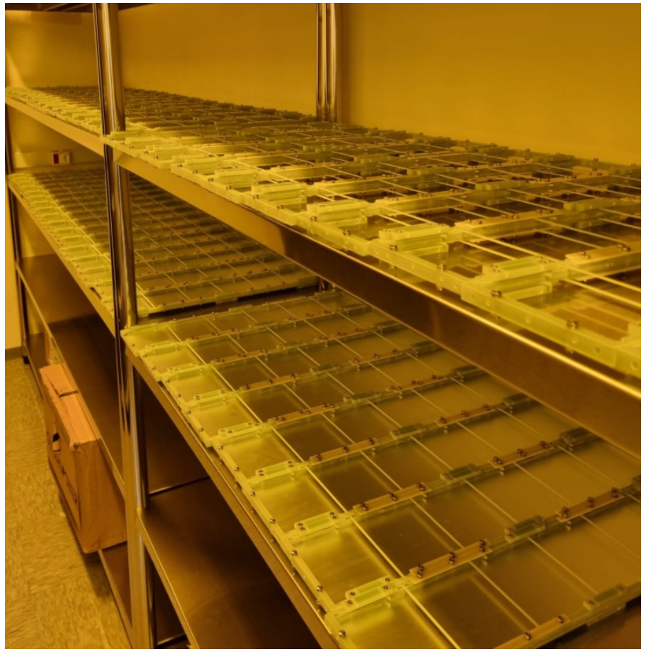
Cryogenic Midia Purification
Calibration
QA/QC

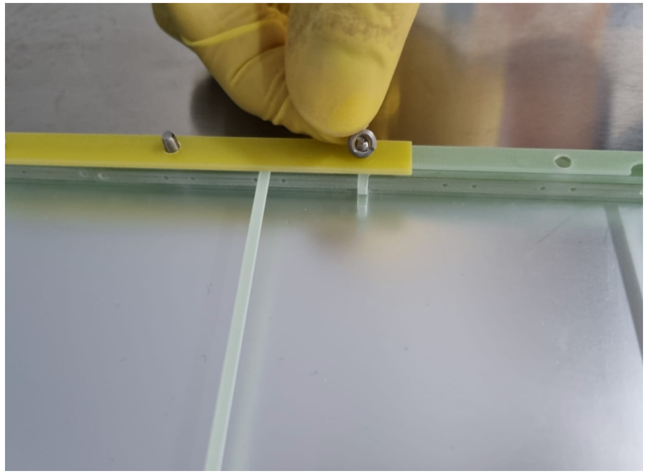
Supernova / Solar / Atmospheric / Non Standard Interactions / Proton decay / DarkMatter

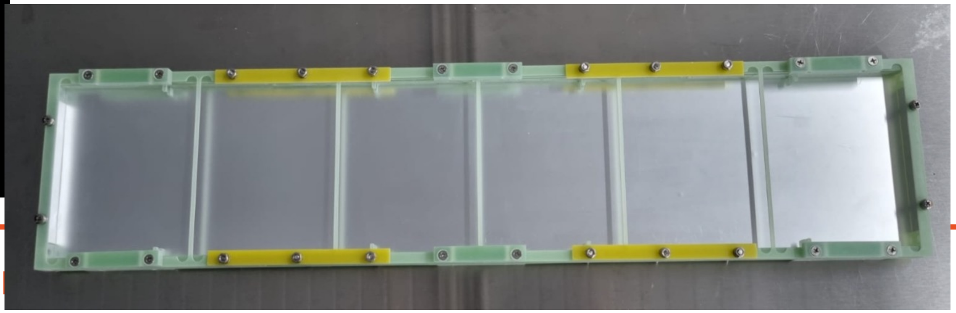


200 supercells produced in Brazil and pre-assembled at UNICAMP

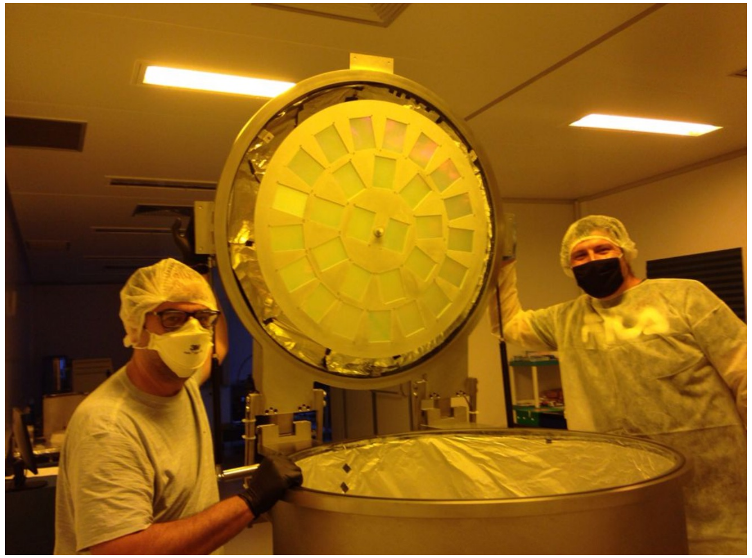


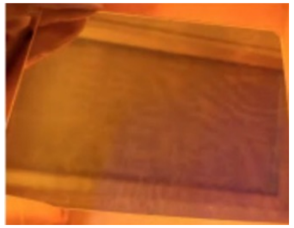


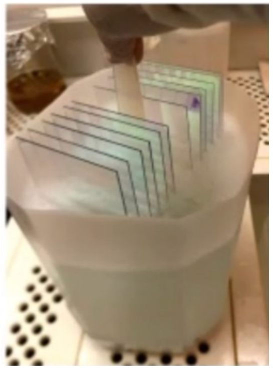




Assembly team at Unicamp:
R. Aguiar, P. Duarte, L.Pagliuso, V. Andreossi, G.Botogoski, F. Demolin, A.Machado, E.Segreto

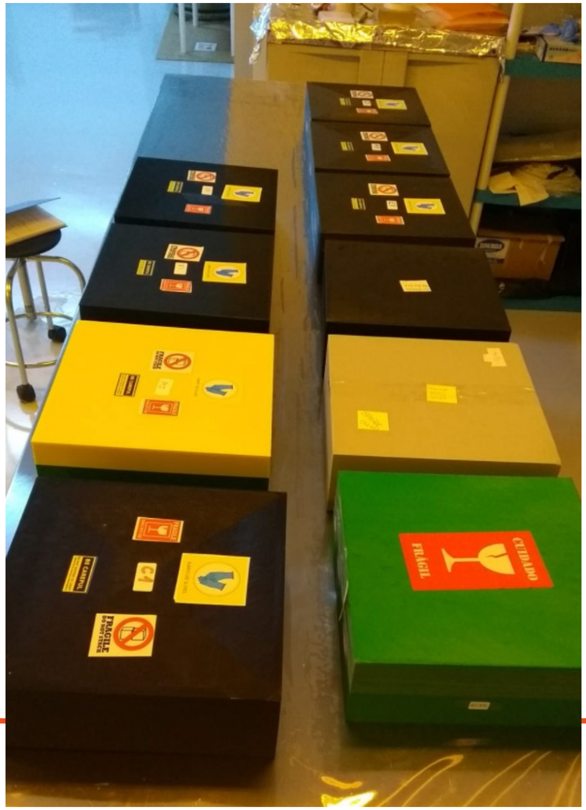






1400 Short pass dichroic filters
Produced by OPTO company (Brazil) .

All Filters have been shipped to CERN.



Cleanning of the filters performed at CTI (Brazil) - M.C.Bazetto and V.Pimentel

Centro de Tecnologia da Informação Renato Archer
UNIDADE DE PESQUISA DO MCTI

1100 Filters coated with ptp at clean room of lab leptons at Unicamp. Special boxes for storage and transportation of filters designed and 3d printed at Unicamp.

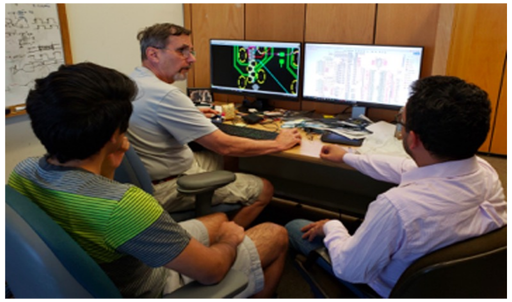
Team at Unicamp: F. Marques, R. de Merlo, R. Aguiar, P. Duarte, A. de Mendonça, F. Demolin, M.Adames, A.Machado, E.Segreto

LAB. LEPTONS

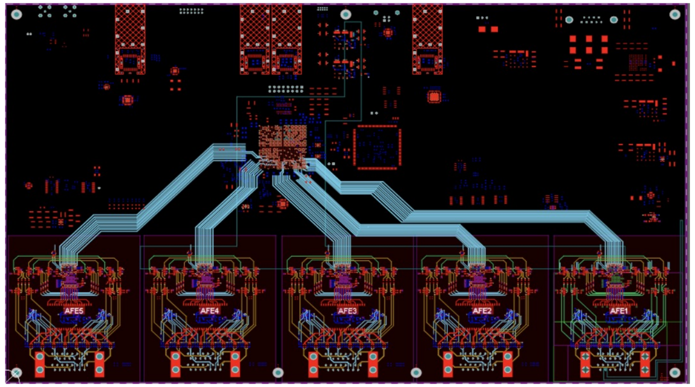
UNICAMP FAPESP DUNE

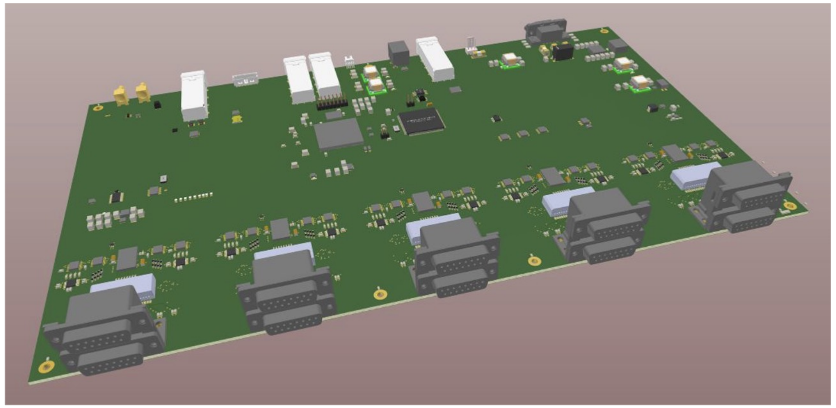
DAPHNE PDS Electronics Readout

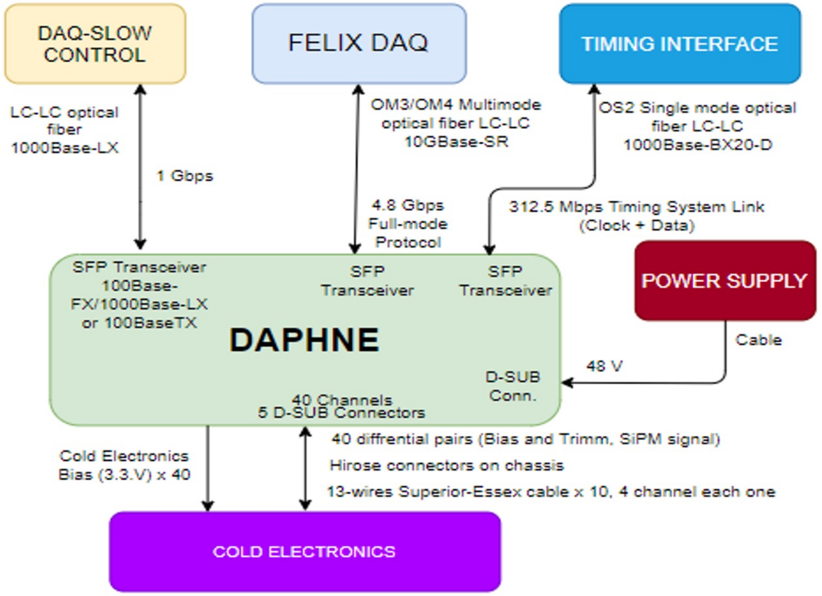
- **D**etector electronics for **A**cquiring **PH**otons from **NE**utrinos
  - Warm readout electronics for the DUNE SP-PD



- Developed as a **partnership between FNAL and Latin America** based of the FNAL design of the Mu2e cosmic ray veto FEB
  - **2019 →** Visits to FNAL by Javier Castaño and Juan Vega Martinez
  - **2020 →** Schematic and Layout has been finalized and reviewed



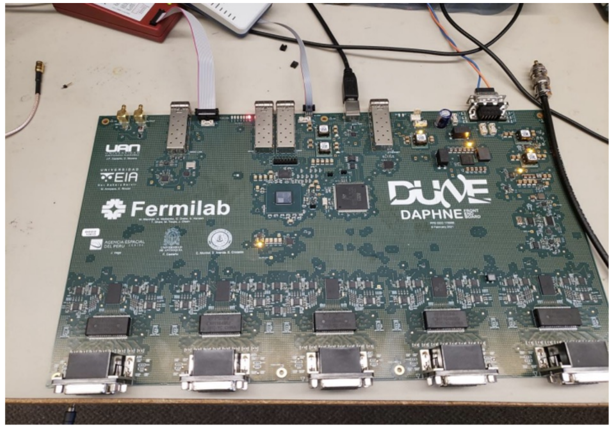




Credits: Deywis Moreno

DAPHNE PDS Electronics Readout

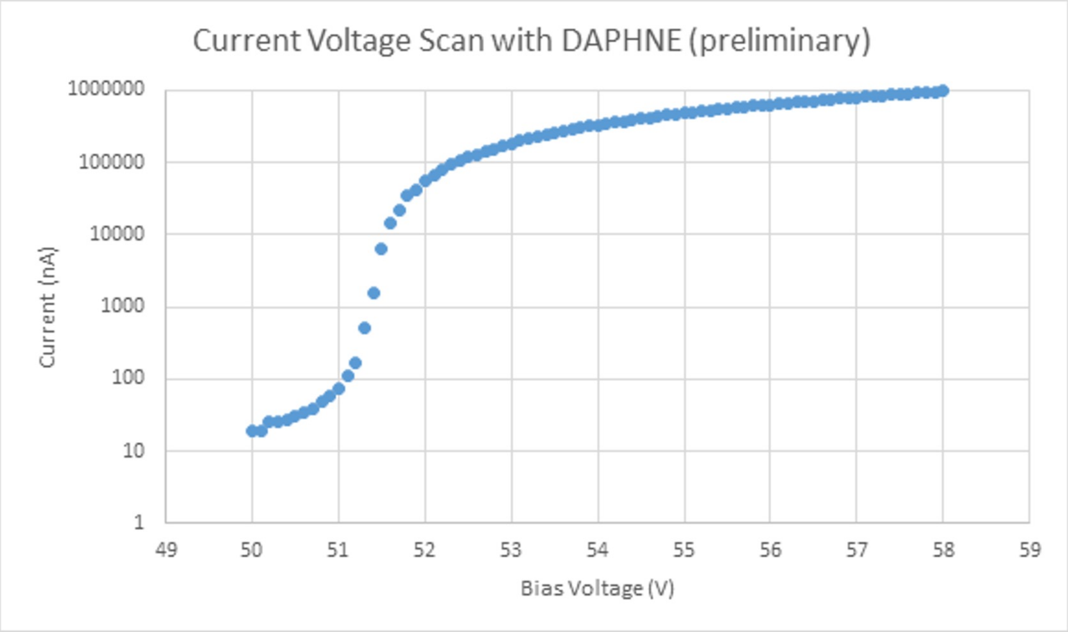
- **2021** → Production of bare PCBs ; Assembly vendor selected; Chassis design complete. Prototype testing plan & docs being developed.
- Hardware test starts at Sep 2021



Current Monitoring (Juan Vega (CONIDA)., Kurt Francis(NIU), Fabian Castaño (UdeA) and Miguel Marchan (FNAL)

Current/Voltage scan using a DAPHNE board with one of the custom MPPCs for the down select (S13360 75um pixel High quenching resistance) at room temperature.

- **DAPHNE Board provides the Bias Voltage for the SiPMs**.
- The current is monitored by DAPHNE software



Credits: Deywis Moreno

DAPHNE @Colombia Dec 2021

DAPHNE Board at UAN
Javier Castaño

- DAPHNE Board arrived to University EIA the first week of November.
- Edgar Rincon and Manuel Arroayave

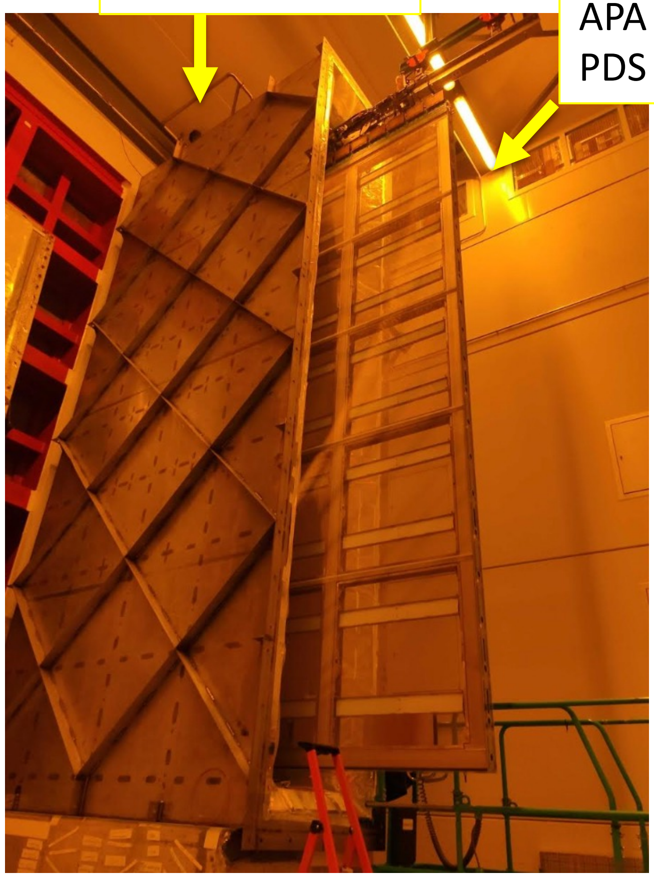
Credits: Deywis Moreno

DAPHNE status 2022

- Test ongoing in different labs. (CERN, Milano, EIA, Fermilab, NIU).
- FPGA firmware that enables external and self trigger options and 40 Channels acquisition is ready and tested .
- Integration of DAPHNE into the DAQ system is progressing.
- **DAPHNE working @ CERN in ProtoDUNE 2 (Cold Box Test)**

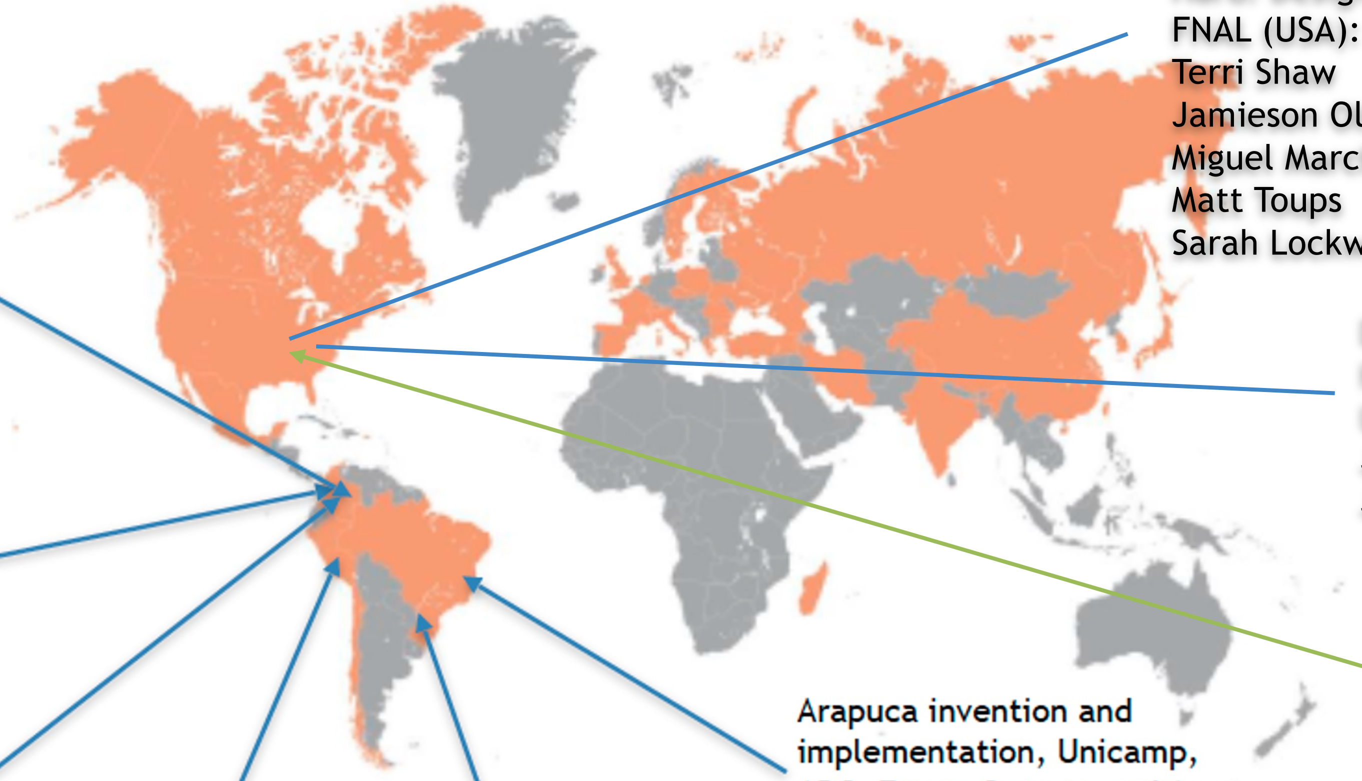
ProtoDune HD Cold Box

APA PDS



Credits: Deywis Moreno

DAPHNE Team Members



DAPHNE dev,
Hard. Design
FNAL (USA):
Terri Shaw
Jamieson Olsen
Miguel Marchan
Matt Toups
Sarah Lockwitz

DAPHNE dev,
Hard. Design
UAN (Col):
Deywis Moreno,
Javier Castaño

DAPHNE dev,
Hard. Design
U. Mich (USA):
Josh Spitz
Jon Ameel

DAPHNE dev,
Firw./Software
EIA (Col):
Amalia Betancur,
Edgar Rincon
Manuel Arroyave

DAPHNE Testing and Int.,
NIU (USA):
Kurt Francis
Vishnu Zutshi

Arapuca invention and implementation, Unicamp, ABC, Ettore Segreto and Ana Machado

DAPHNE dev,
Firw./Software
UdeA (Col):
Jaime Osorio,
Jorge Lopez
Fabian Castaño

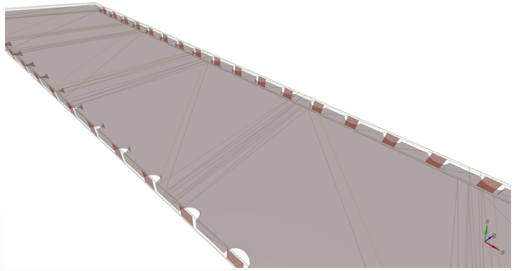
DAPHNE dev,
Hard./Software
CONIDA (Peru):
Cesar Castromonte
Luis Otiniano
Juan Vega

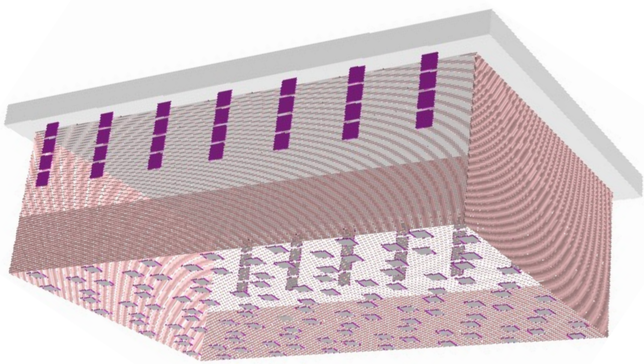
DAPHNE dev,
full-mode 4.8 Gbps link
FIUNA (Paraguay):
Jorge Molina,
Esteban Cristaldo
Carlos Montiel
Diego Aranda

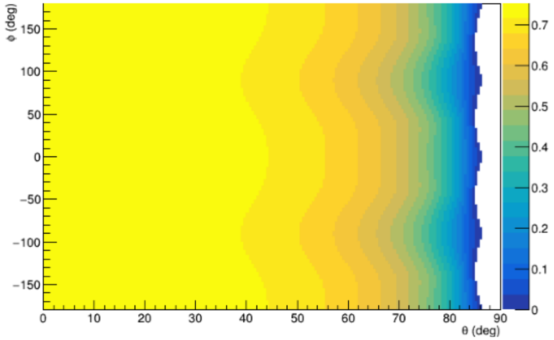
Credits: Deywis Moreno

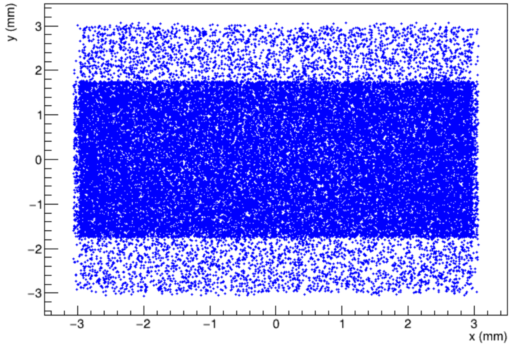
Softwear - LA contribution PDS

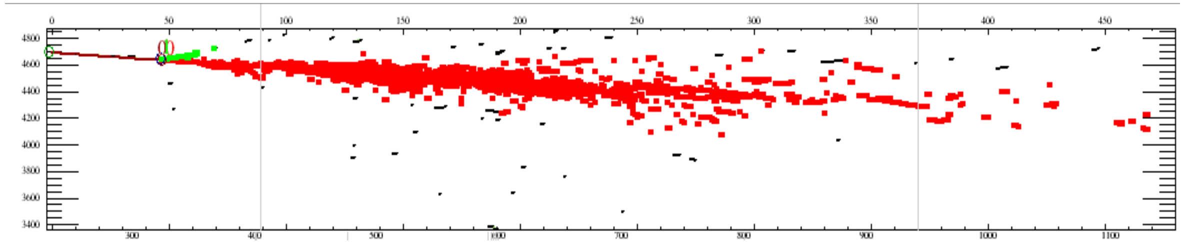
- Simulation and data analysis of light detectors
- Modeling production and propagation of scintillation light in LAr
- Simulation and data analysis of (Proto)DUNE detectors and PDS
- Computational structure for light simulation (performance and data analysis)

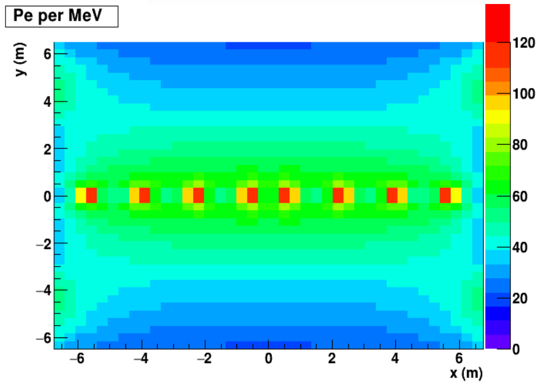


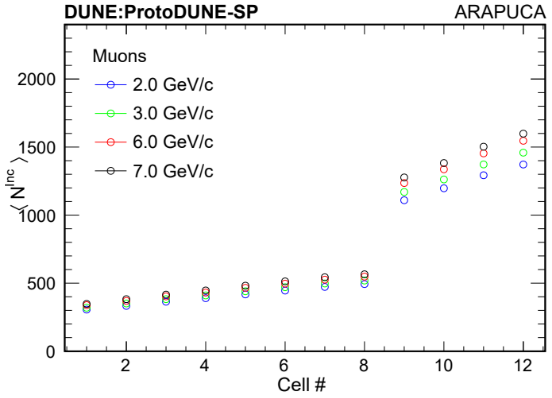








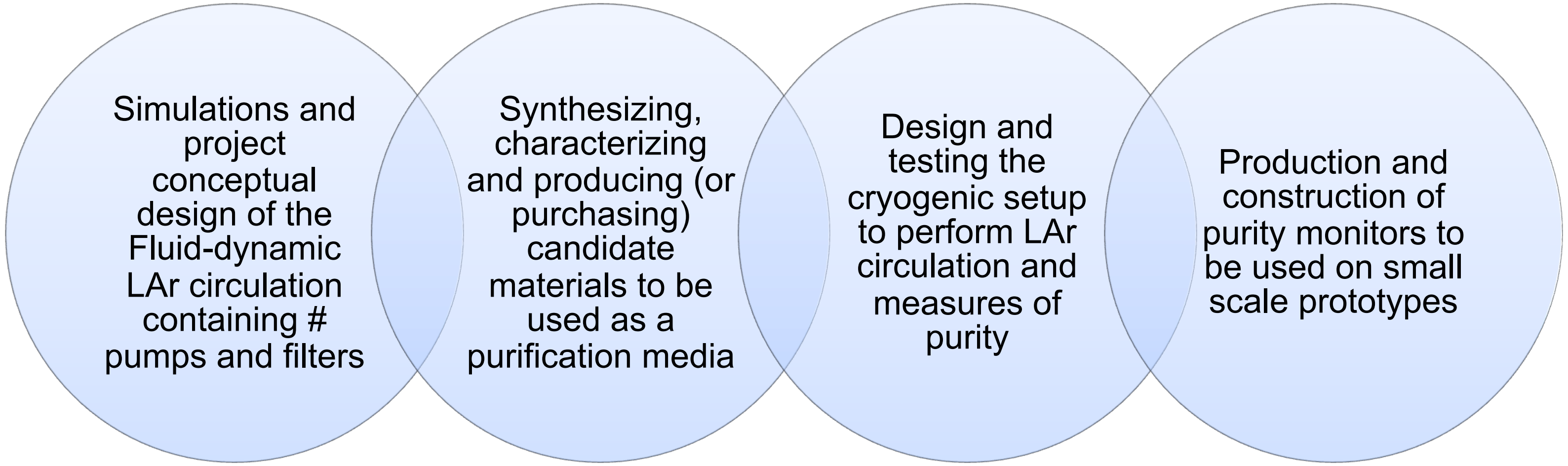




UFABC – ITA – UTFPR - UNIFESP

PULArC – Purification LAr Cryostat

- The PULArC is a cryogenic setup to test new solutions for new LAr purification media
- This project is in collaboration between UNICAMP and FERMILAB, and represents the **phase I** for the contribution of **Liquid Argon purification and recirculation system for DUNE.**
- The project was divided in 4 groups: Fluid dinamics simulation, synthesis and material characterization, design the cryogenic chamber, production of purity monitor.



PULArC – Purification LAr Cryostat

PURIFICATION LIQUID ARGON CRYOSTAT

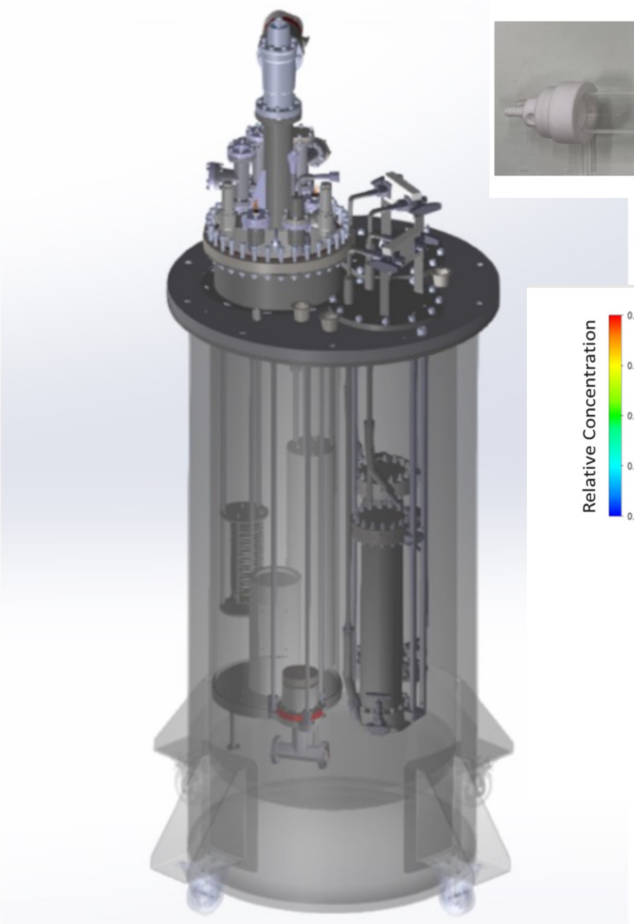
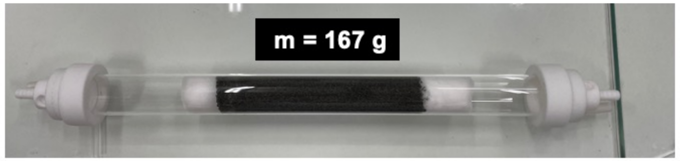
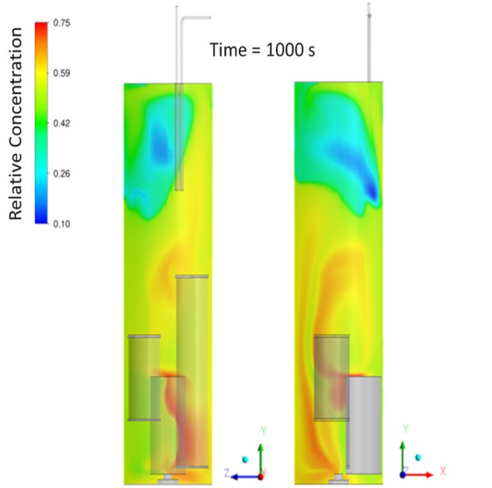
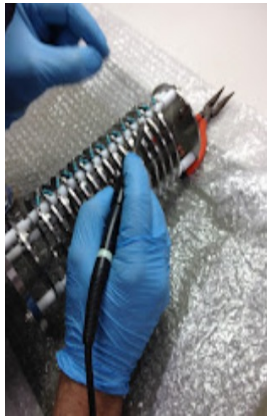


FIG. 6. UNILArC

Media Activation Cu-0226S – BASF (reference)







Summary

- DUNE will resolve the neutrino mass ordering, and measure δ_{CP} with CP violation sensitivity over a broad range of parameter space
- DUNE will precisely measure θ_{13}, θ_{23}, and Δm^2_{32}
- DUNE has unique sensitivity to low-energy neutrinos from a galactic supernova burst
- DUNE has competitive sensitivity to a wide range of physics beyond the Standard Model
- ProtoDUNE run 2 will take data in the second half of 2023, and will validate the technological choices for FD1 and FD2
- Latin America will give a big contribution to DUNE, mainly the photon detection system for FD1 and FD2

Muchas GRACIAS

Muito OBRIGADA

Acknolegement

For financial support in the research of the DUNE experiment, through the projects

- 2021/13538-5
- 2020/02544-1
- 2020/01609-2
- 2019/11557-2
- 2017/13942-5
- 2016/09084-0
- 2016/01106-5
- 2016/01106-5