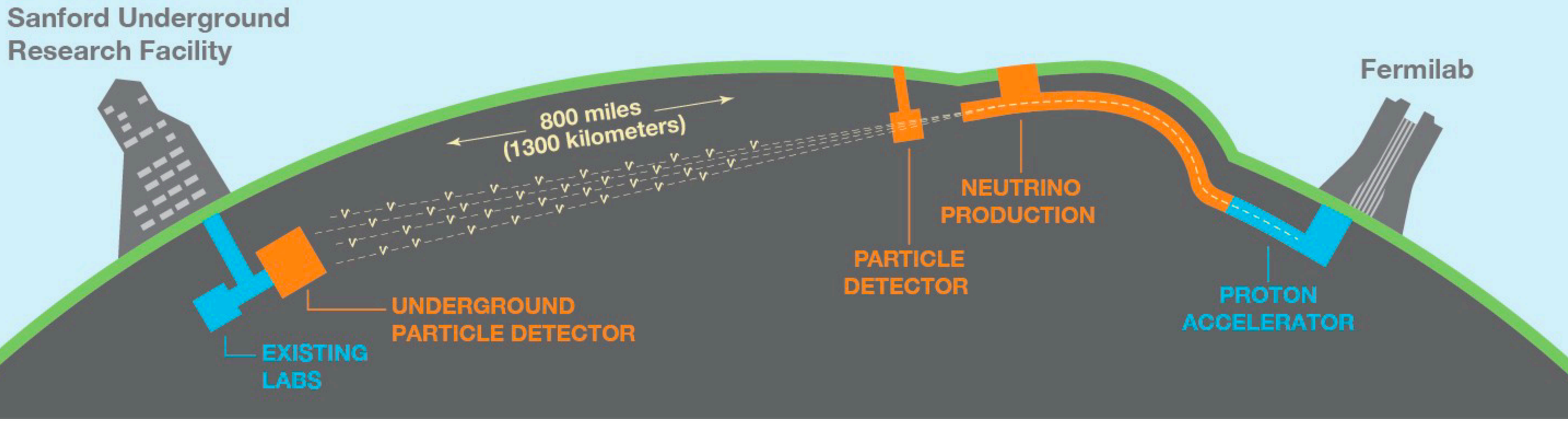
The Deep Underground Neutrino Experiment: a new era in precision neutrino physics

Jordi Capó

on behalf of the DUNE collaboration

Financiado por la Unión Europea NextGenerationEU
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES
Plan de Recuperación, Transformación y Resiliencia
GENERALITAT VALENCIANA Conselleria de Cultura, Educació, Universitats i Ocupació
GVANEXT
CSIC Consejo Superior de Investigaciones Científicas
Universitat de València
IFIC INSTITUT DE FÍSICA CORPUSCULAR
EXCELENCIA SEVERO OCHOA

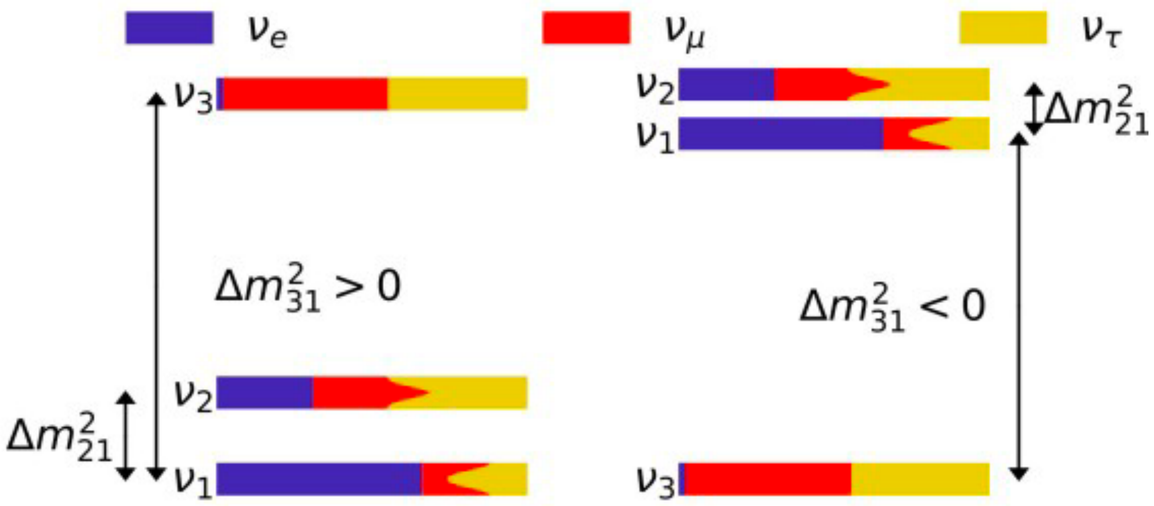
The Deep Underground Neutrino Experiment



- **DUNE** is a next-generation **long-baseline** neutrino oscillations experiment based in the US;
- It's **intense wide-band** (anti)neutrino beam, the use of the **LArTPC** as detection technology and its **long-baseline** will make of DUNE a world-leader in neutrino physics;

Big questions in Neutrino Physics

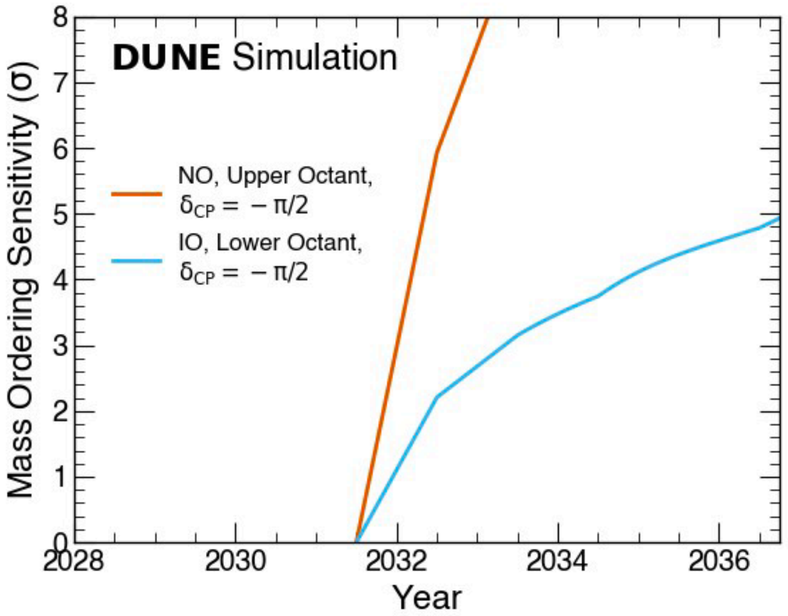
- What is the **origin** of neutrino mixing?
- Why do neutrinos have **mass**?
- Is the **neutrino-SM** complete? Is the 3-flavour picture correct?
- Which one is the **heaviest neutrino** mass eigenstate (mass ordering)?



DUNE will have a lot to say about these topics… its scientific program is broad and diverse

DUNE Physics Reach

Neutrino Oscillations

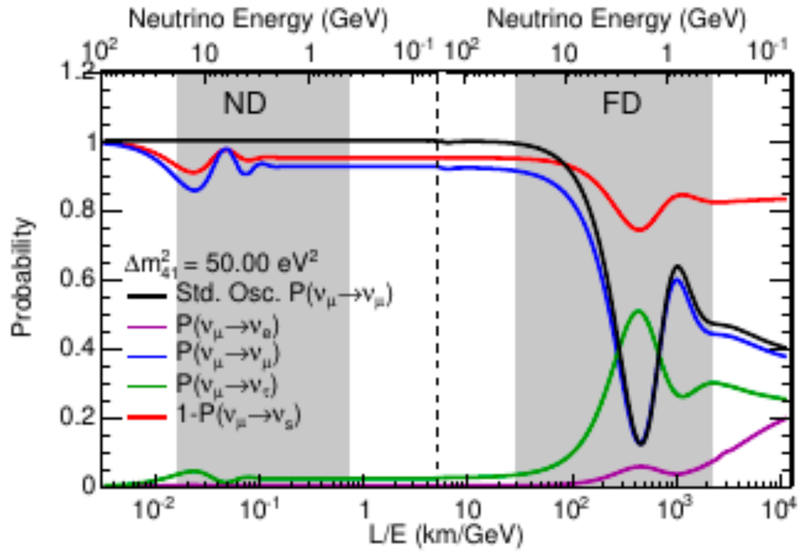


DUNE reaches **>5σ in MO** in about **5 years** *in the most pessimistic scenario*

DUNE Physics Reach

Neutrino Oscillations

BSM Physics



DUNE's wide-band beam allows scanning **a large range of L/E**

DUNE Physics Reach

Neutrino Oscillations

BSM Physics

ν_τ Physics

DUNE's unique **imaging capabilities (LArTPC)** enables ν_τ physics in FD

DUNE Physics Reach

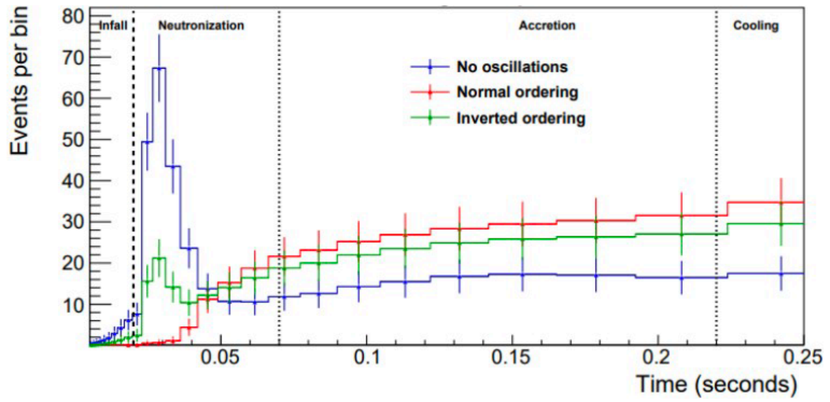
Neutrino Oscillations

BSM Physics

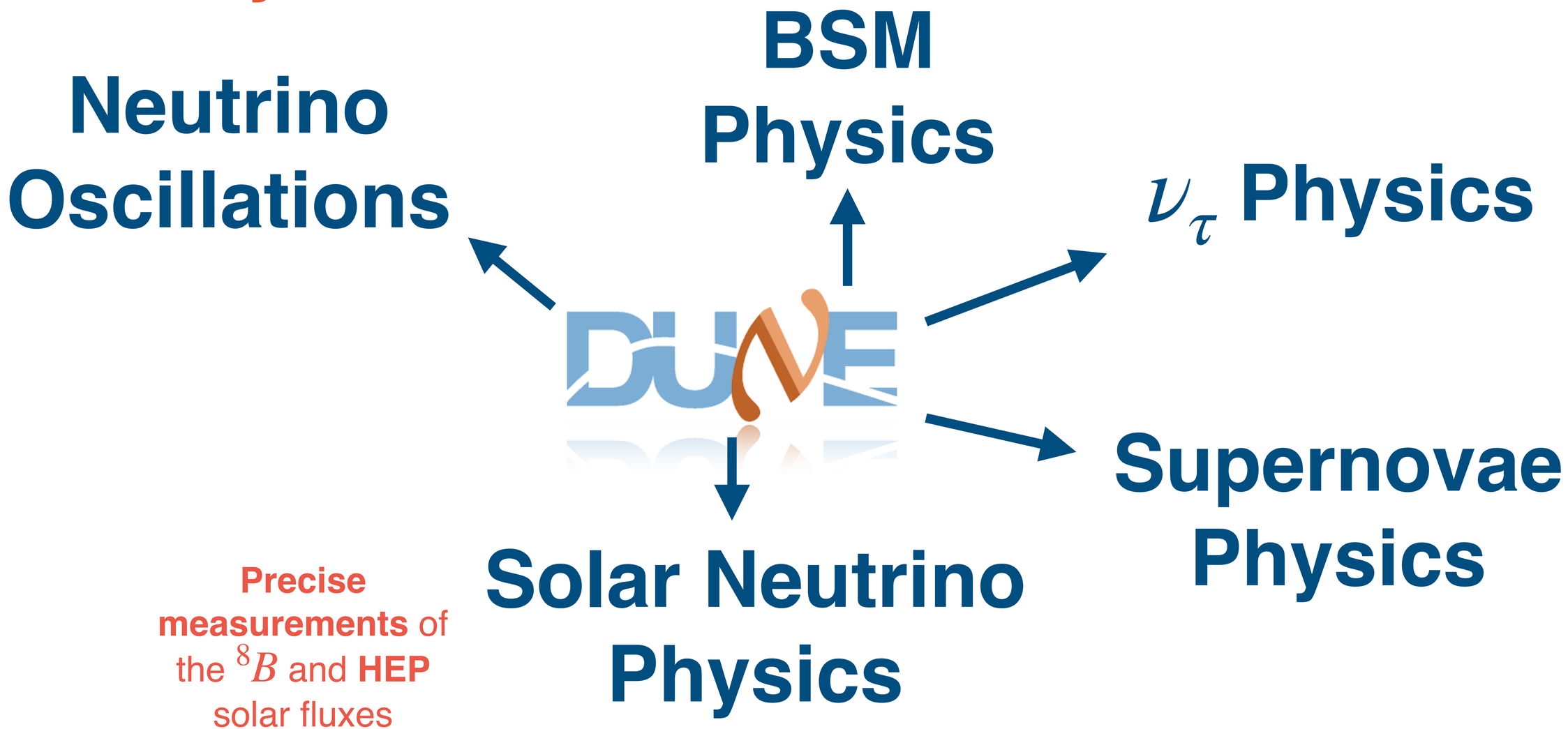
ν_τ **Physics**

Supernovae Physics

DUNE is uniquely **sensitive to MO** via **SNB** detection



DUNE Physics Reach



DUNE Physics Reach

Neutrino Oscillations

BSM Physics

ν_τ Physics

Neutrino Cross-Sections

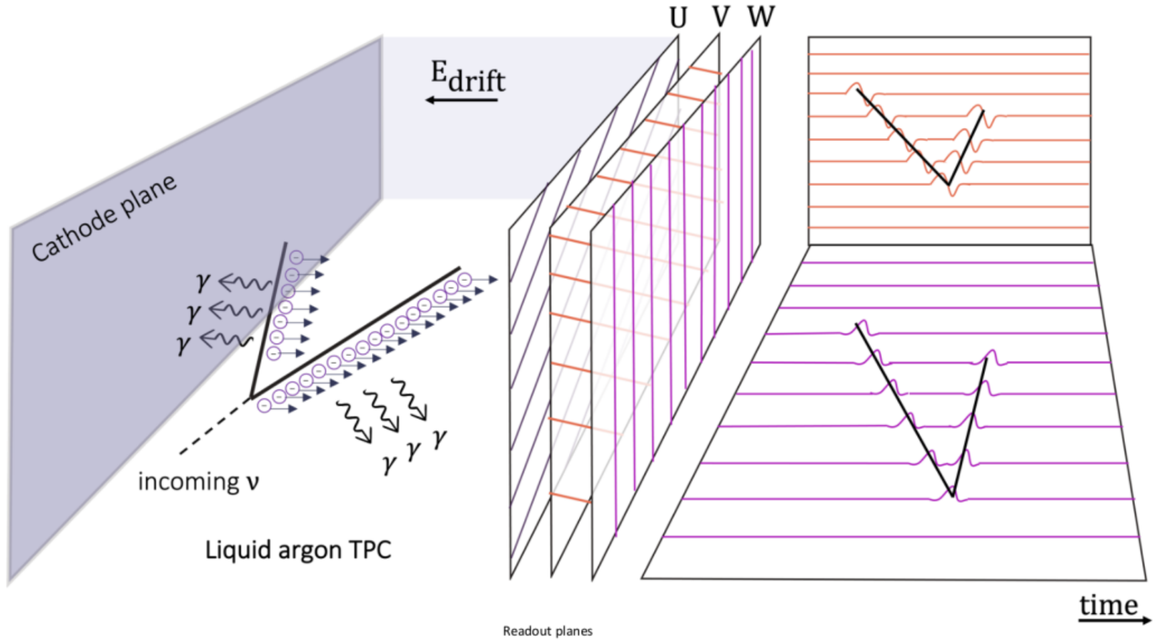
Supernovae Physics

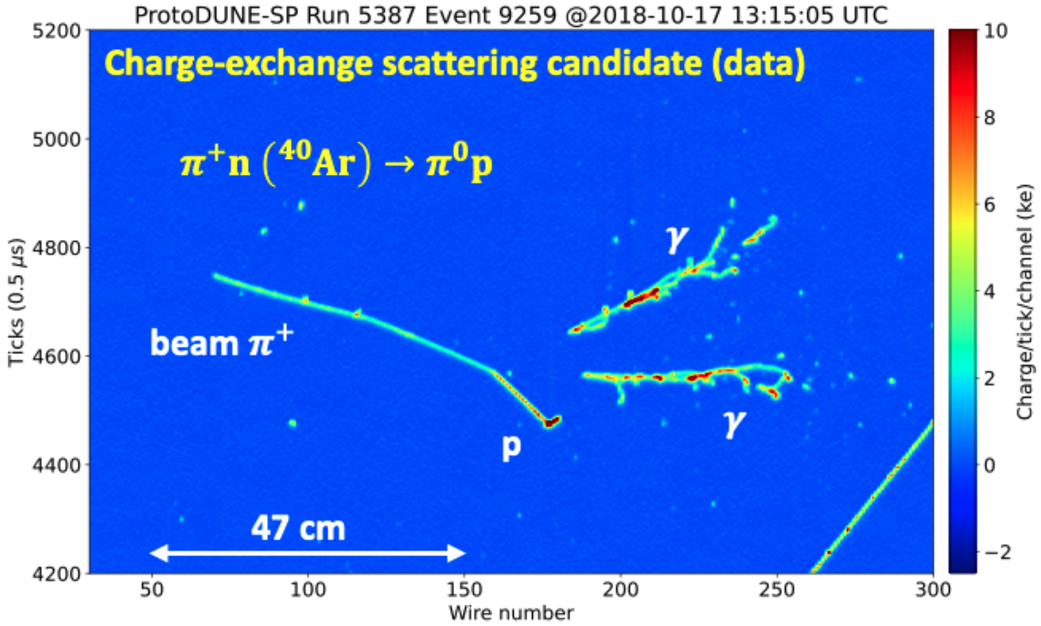
Solar Neutrino Physics

DUNE ND will provide world-class ν-X-sec measurements

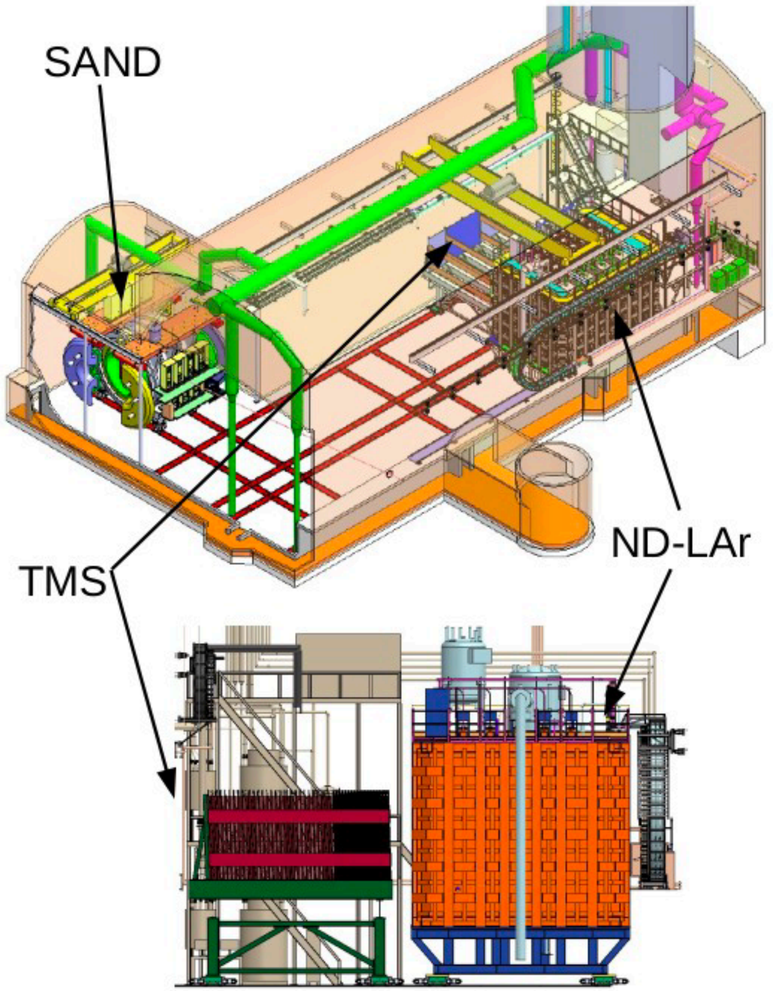
The Liquid Argon Time Projection Chamber (LArTPC)

- **Charged particles** travelling in LAr deposit their energy creating **ionisation** electrons and **scintillation** photons (~128nm);
- An **electric field** drifts electrons towards the anode where they are collected;
- A Photon Detection System (**PDS**) detects scintillation photons that can be used for **calorimetry** and for timing/**triggering**;

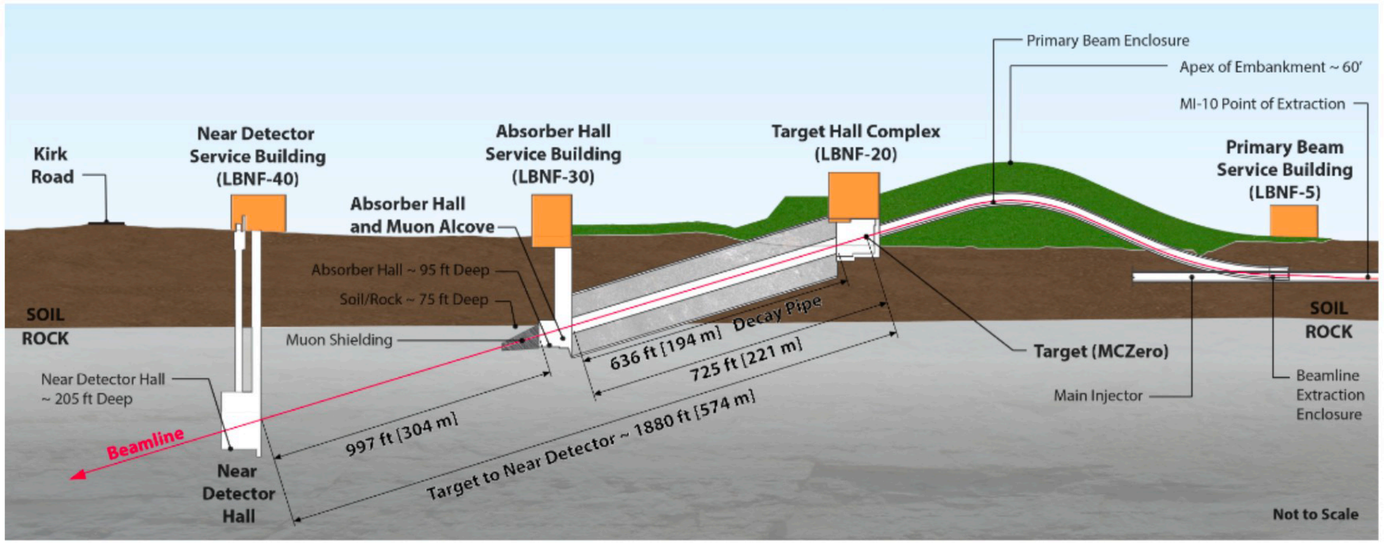




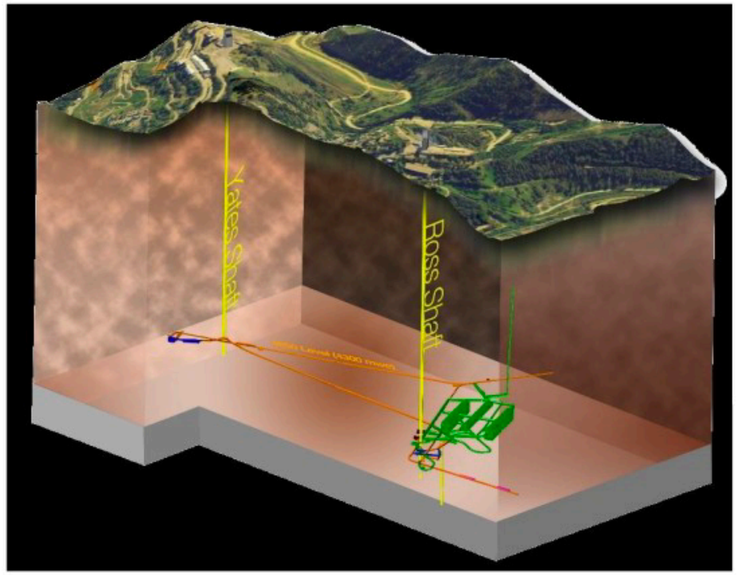
The beam line and the Near Detector complex



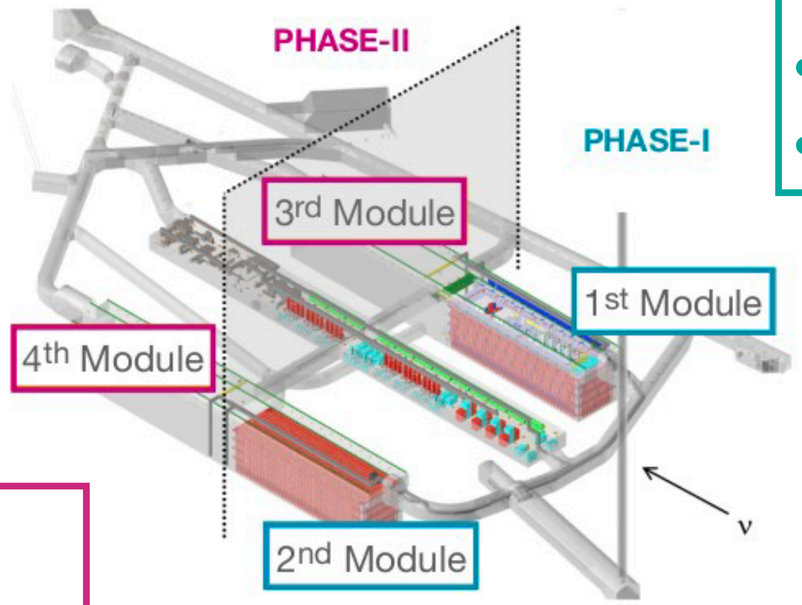
- **1.2MW** neutrino beam upgradeable to **2.4MW**;
- Near Detector (**ND**) at 574m that measures the **un-oscillated flux**, constrains **systematics** and predicts far detector event rate;
- ND-LAr is a **modular** LArTPC with **pixelated** readout;
- ND-LAr+TMS moves (**PRISM** technique)



A massive Far Detector at SURF



- **~70kt** of LAr deployed in **4 modules** in two massive caverns **1.5km** underground and **1300km** away from FNAL;

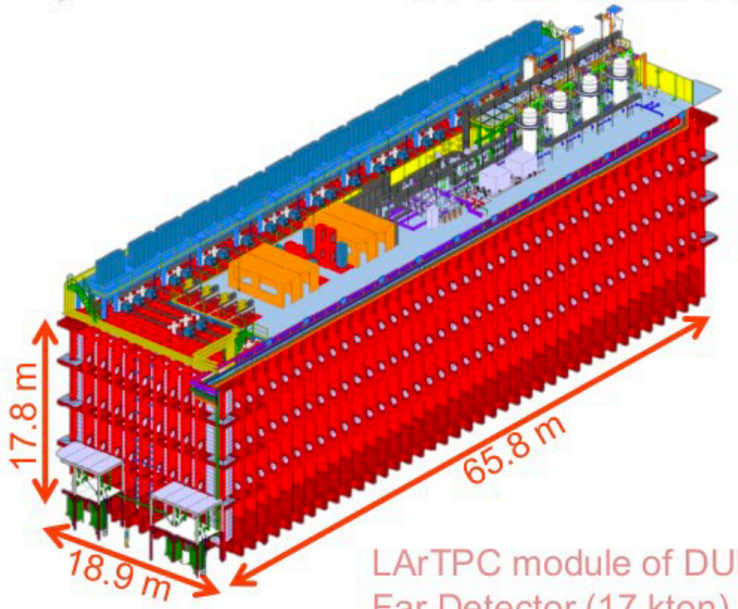


Phase-I

- Full ND and two FD modules;
- 1.2MW neutrino beam line;

Phase-II

- Two additional FD modules;
- Beam line upgraded to >2MW;
- A more capable ND;

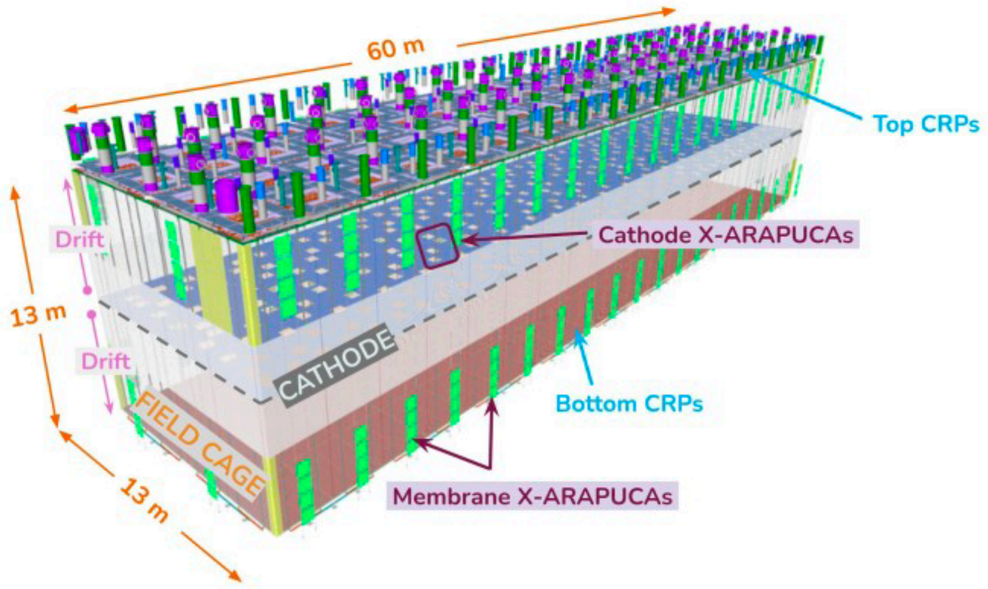


LArTPC module of DUNE Far Detector (17 kton)

Phase-I FD Technologies

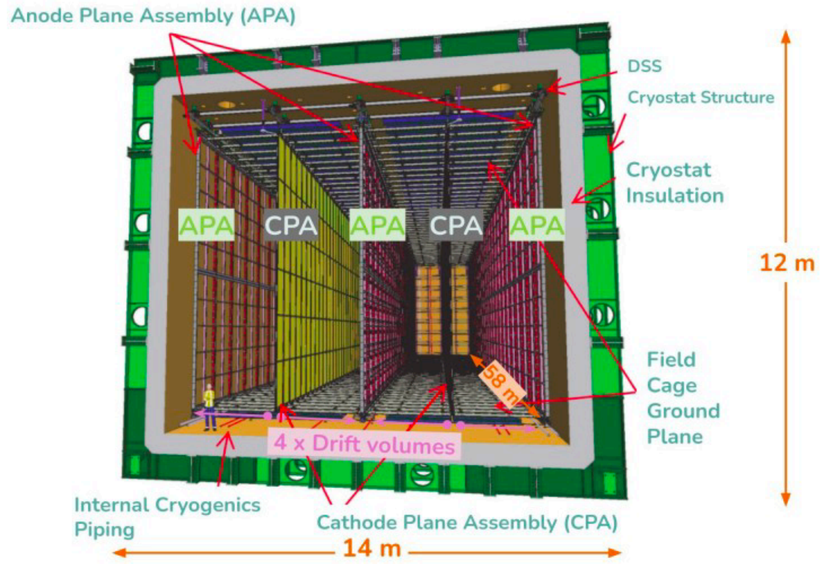
FD Vertical Drift (VD)

- 2 vertical drift volumes (2 anode planes + 1 cathode plane);
- Charge readout: perforated PCBs;
- PDS on the cathode and membrane walls;



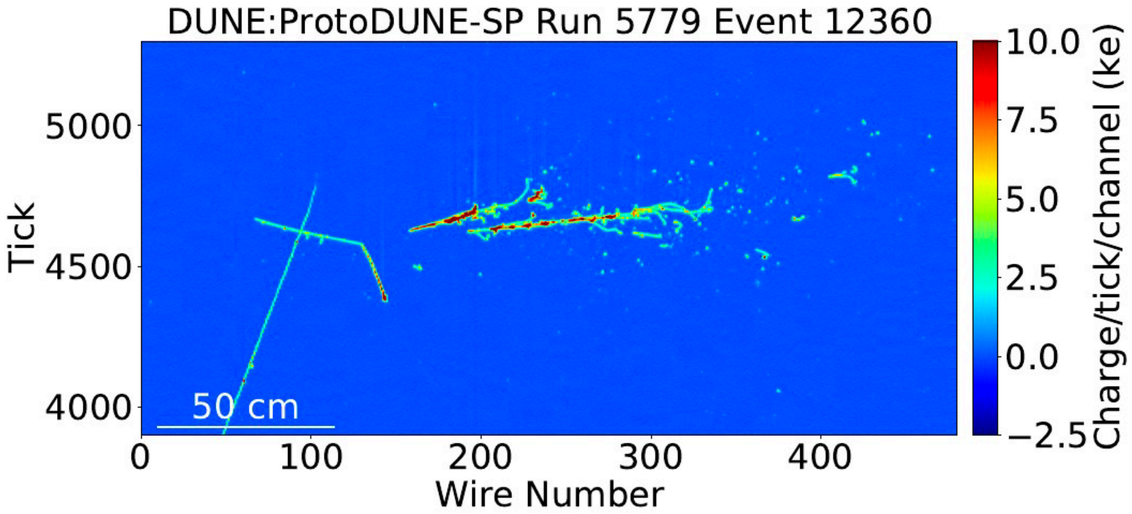
FD Horizontal Drift (HD)

- 4 horizontal drift volumes (3 anode planes + 2 cathode planes);
- Charge readout: 3 wire planes;
- PDS on the Anode Plane Assemblies (APA);

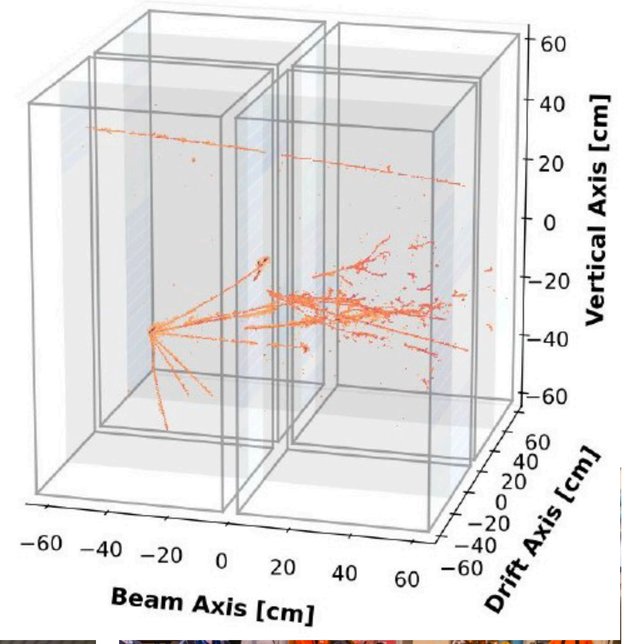


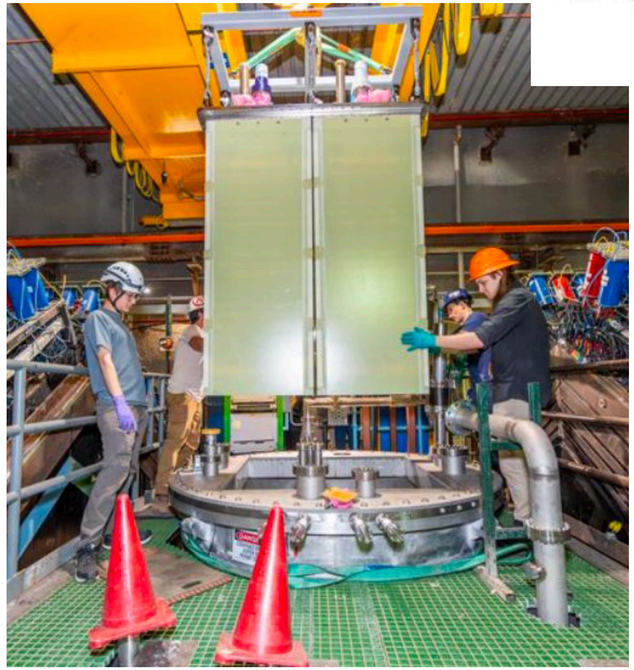
DUNE collaboration. JINST 15 (2020) T08010

DUNE Prototypes: CERN & FNAL



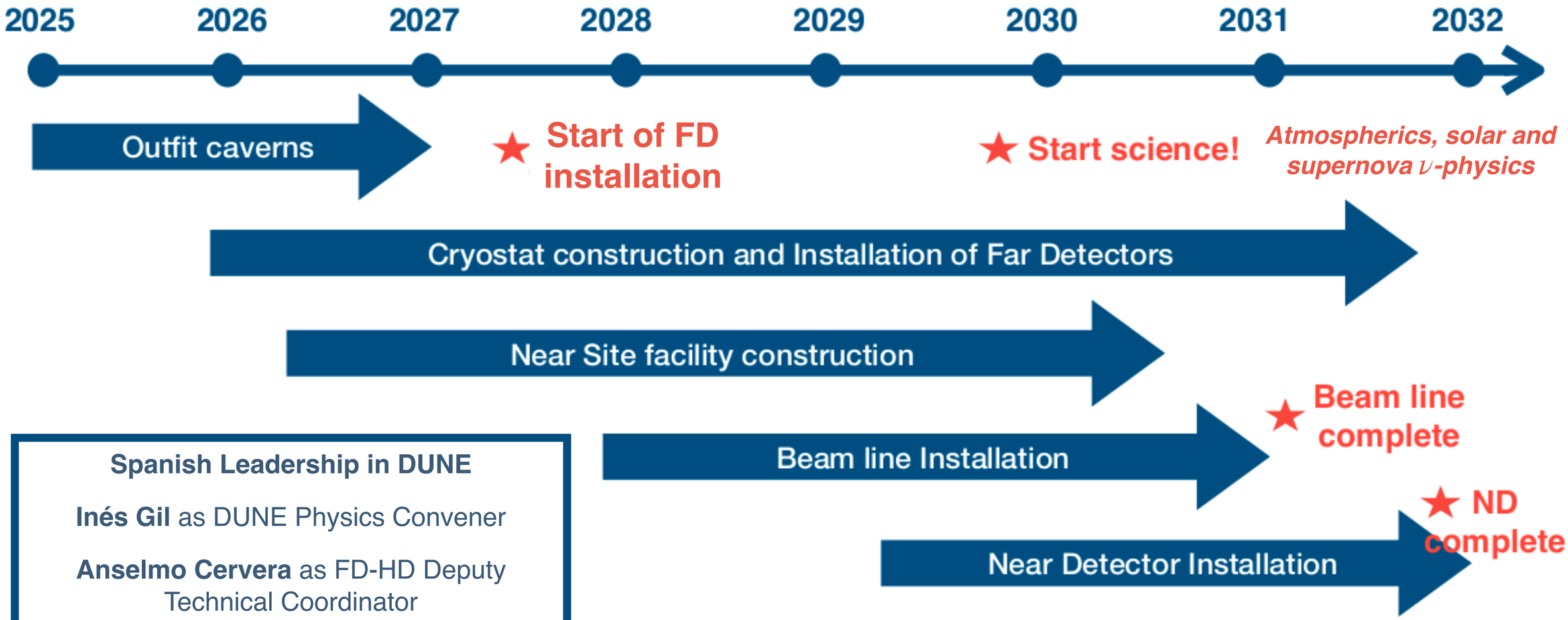
2x2 analysis ongoing, additional beam run planned for 2026 (NuMI beam)





LBNF/DUNE caverns excavated

LBNF/DUNE project timeline



Spanish Leadership in DUNE

Inés Gil as DUNE Physics Convener

Anselmo Cervera as FD-HD Deputy Technical Coordinator

Michel Sorel as Phase-II Deputy Coordinator

Summary

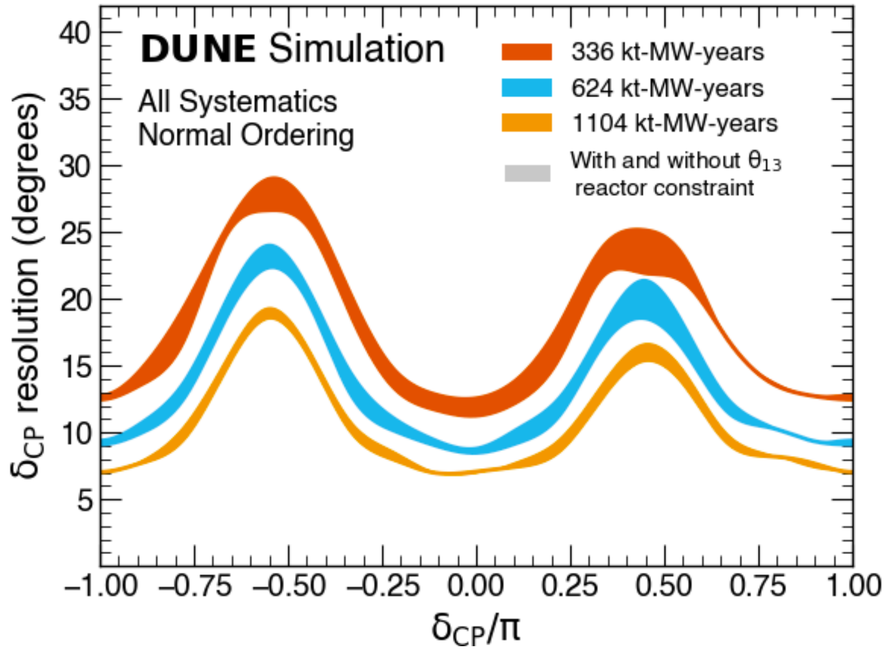
- DUNE is designed to test the **3-flavour neutrino paradigm** and search for new physics in neutrino oscillations;
- DUNE will make the **most precise measurements** of neutrino oscillation parameters;
- DUNE has unique **low-E and BSM** reach;
- **Caverns** are **excavated** and the first cryostat will start to be assembled in May 2026;
- Detector components and infrastructure are **being built** all over the world, including CERN;

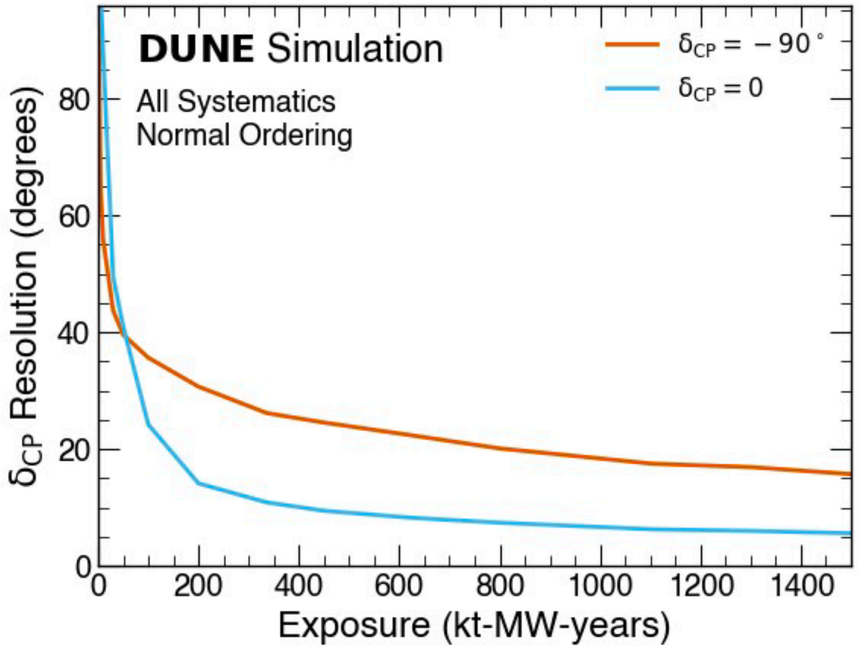

DUNE Collaboration Meeting Valencia - September 2025

Backup

δ_{CP} resolution

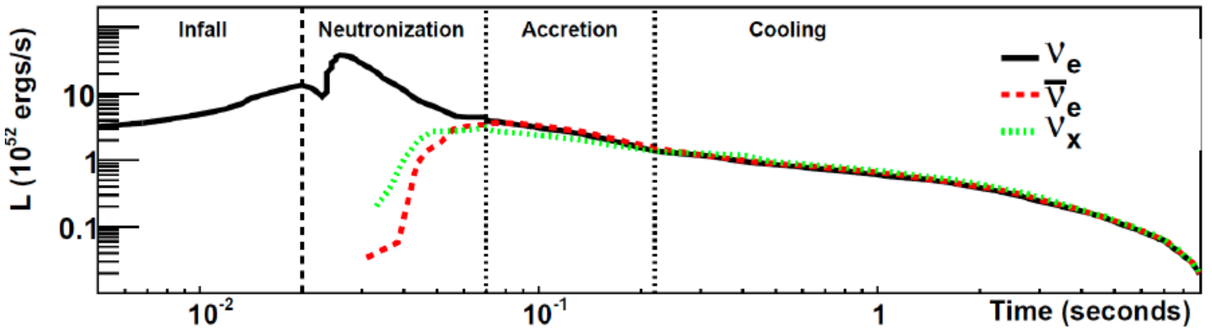
- DUNE has the best ultimate δ_{CP} resolution, especially if CP is violated;
- DUNE can resolve degeneracies between different values of δ_{CP} with broad L/E spectrum;

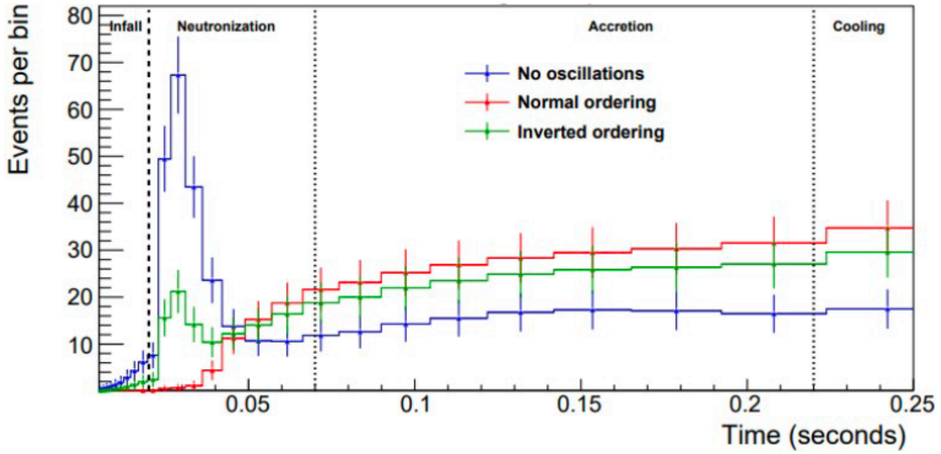




Supernova Physics

- ~5º pointing resolution depending on SNB location;
- Only DUNE measures ν_e due to Ar target
- DUNE is uniquely sensitive to MO via SNB;





	ν_e	$\bar{\nu}_e$	ν_x
DUNE	89%	4%	7%
SK[1]	10%	87%	3%
JUNO[2]	1%	72%	27%

[1]Super-Kamiokande, *Astropart. Phys.* **81** 39-48 (2016)
[2]Lu, Li, and Zhou, *Phys Rev. D* **94** 023006 (2016)