The Deep Underground Neutrino Experiment

Rhiannon Smith-Jones on behalf of the DUNE collaboration

NNN 2026

28th - 30th October 2026

Future Prospects for Next-Generation Neutrino Experiments



University of Sheffield

DUNE

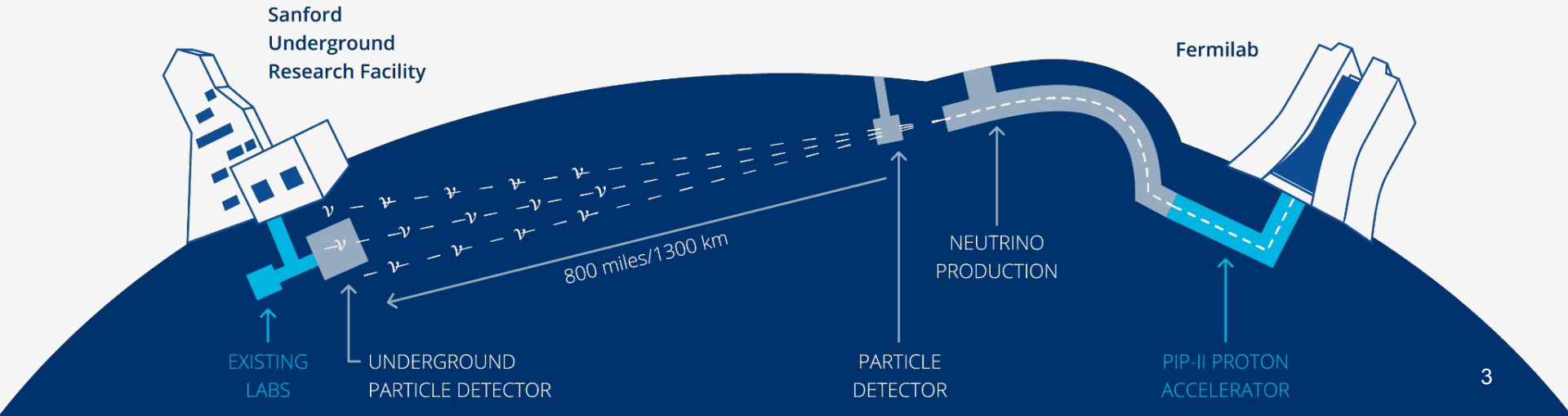
DUNE is the largest neutrino collaboration in history!

Overview

- The Deep Underground Neutrino Experiment.
- PIP-II Beamline.
- Far Detectors.
- Near Detectors.
- DUNE Science Program.
- Status.

Over 1500 collaborators from
220+ institutes in 38 countries.

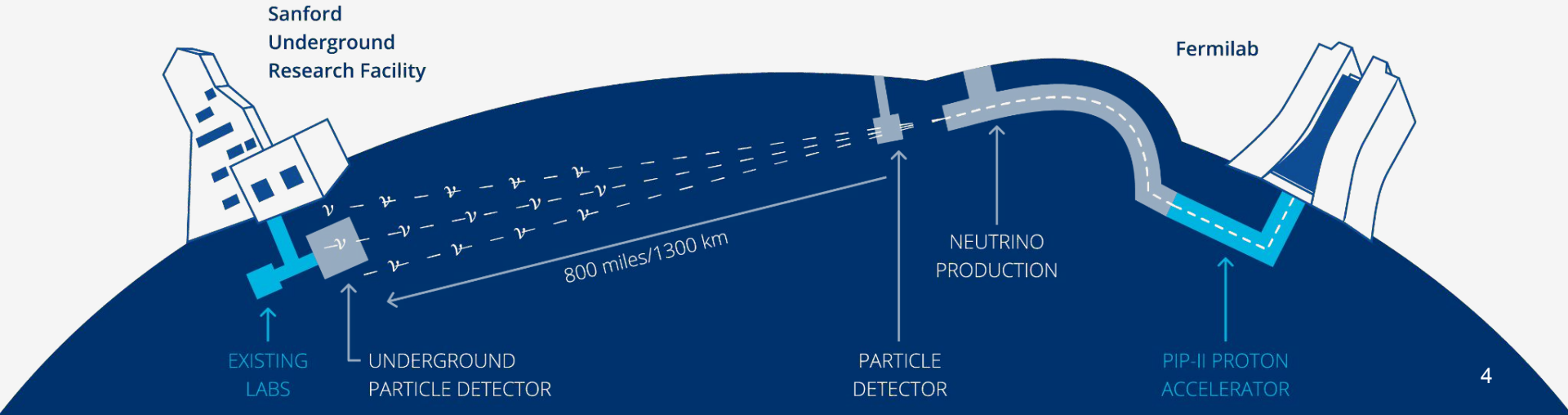
The Deep Underground Neutrino **Experiment**



LBNF

Locations: FNAL & SURF

- Delivering the world's most powerful neutrino beam,
  - Wideband spectrum.
- Huge caverns 1.5 km underground.
- 1,300 km baseline.



LBNF

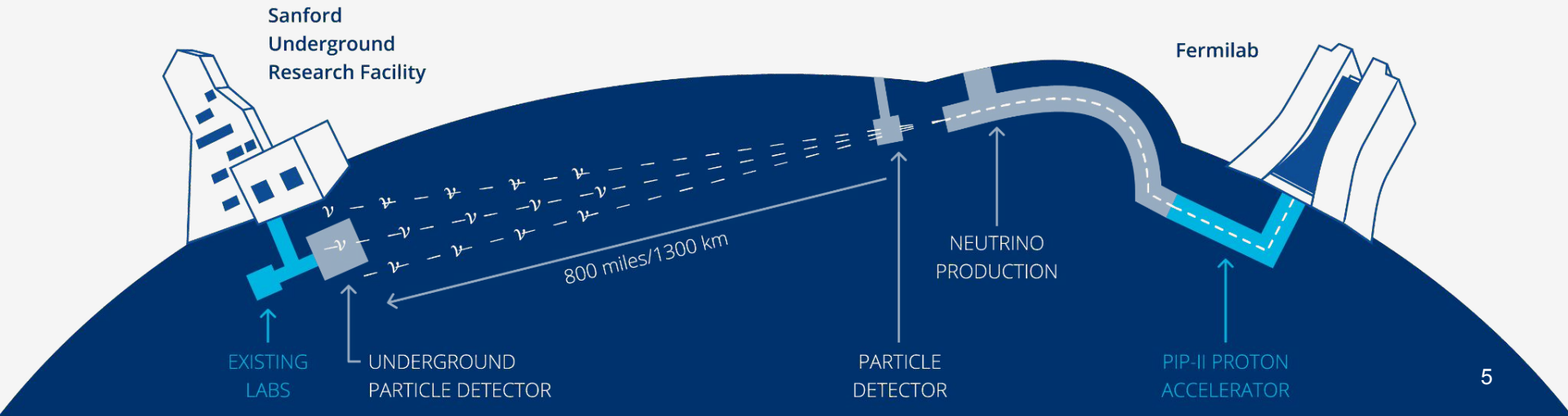
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DUNE FD

Location: SURF

- 4 of the largest ever LArTPCs (17 kton),
  - Built in 2 phases,
  - High-resolution.
- Horizontal & vertical drift technologies,
  - Variety of readout techniques.



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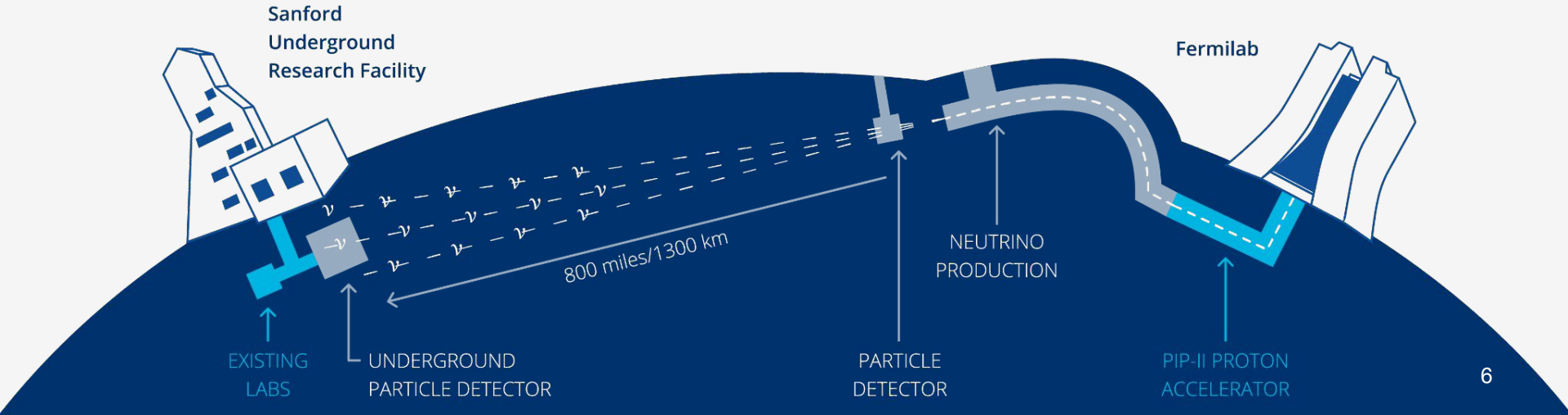
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DUNE ND

Location: FNAL

- 3-detector system,
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- Movable 'off-axis' via PRISM configuration.
- Beam monitoring & ν-Ar cross-section constraints.



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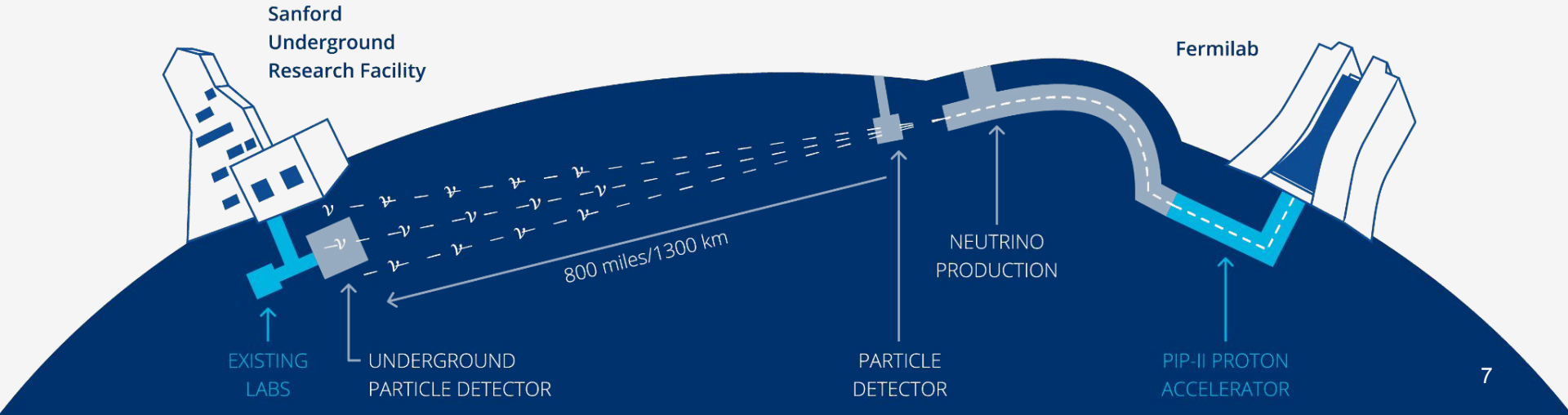
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Prototypes

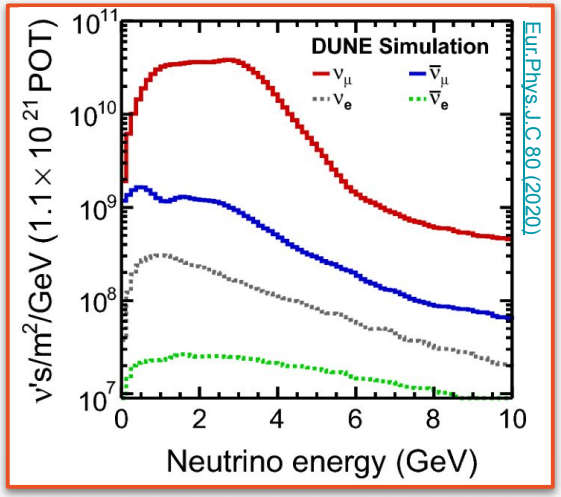
Locations: CERN & FNAL

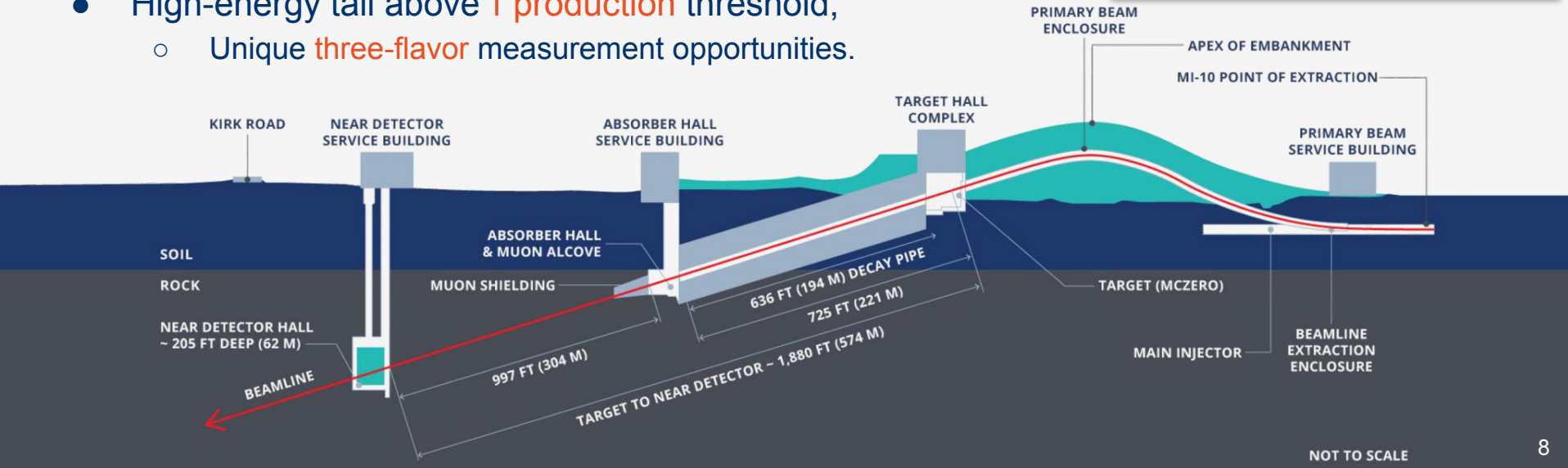
- Successful tests of FD LArTPC HD & VD technologies,
  - ProtoDUNE.
- Successfully tested ND LArTPC system,
  - 2x2 demonstrator.



PIP-II Beamline

- New accelerator doubles the proton flux for a 1.2 MW beam,
  - Upgradeable to >2 MW.
- DUNE will sit on-axis in a wideband beam (0.1-10 GeV),
  - Covers two oscillation maxima.
- High-energy tail above τ production threshold,
  - Unique three-flavor measurement opportunities.



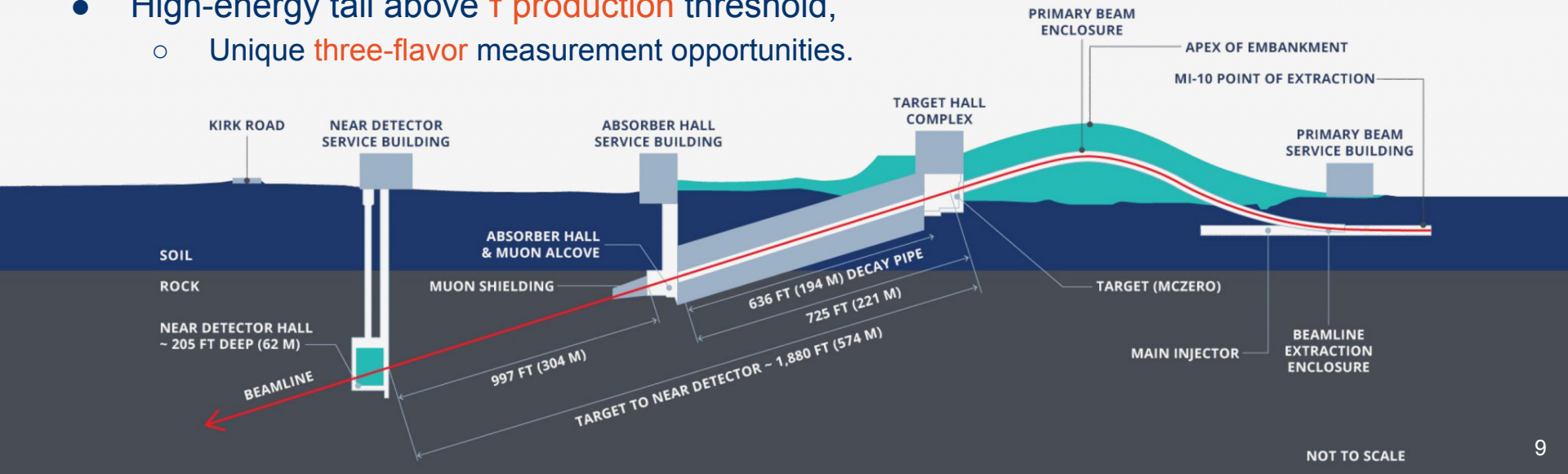


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Planned PIP-II Upgrades

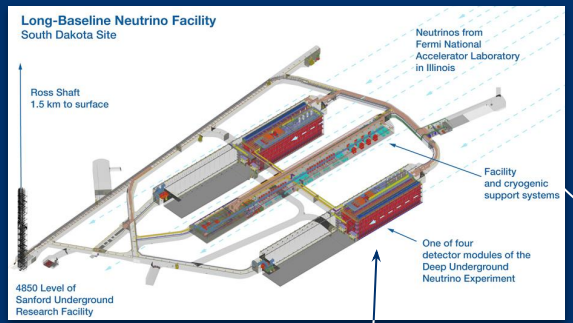
- 800 MeV LINAC,
- LINAC to Booster Transfer line,
- Upgraded Booster, Recycler and Main Injector,
- Conventional Facilities.

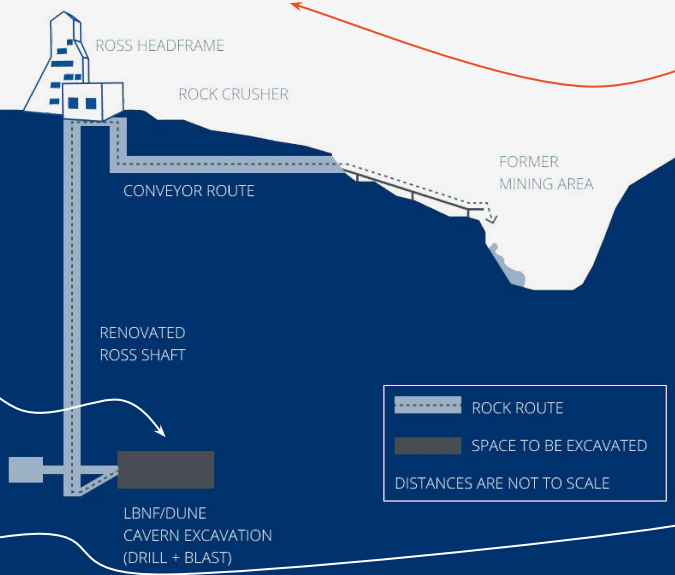


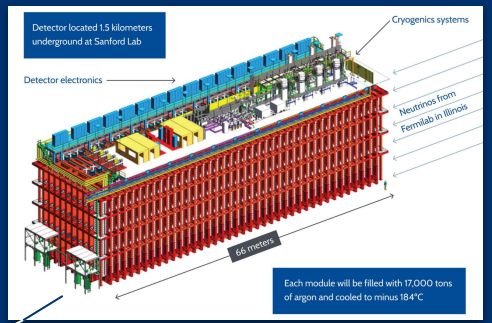
DUNE Far Detectors

- Comprise the largest (4 x 17 kton) LArTPCs ever to be constructed.
- **Phase I**: 2 FD modules (1 HD, 1 VD) → unambiguous mass ordering.
- **Phase II**: 2 additional FD modules → δ_{CP} discovery potential.

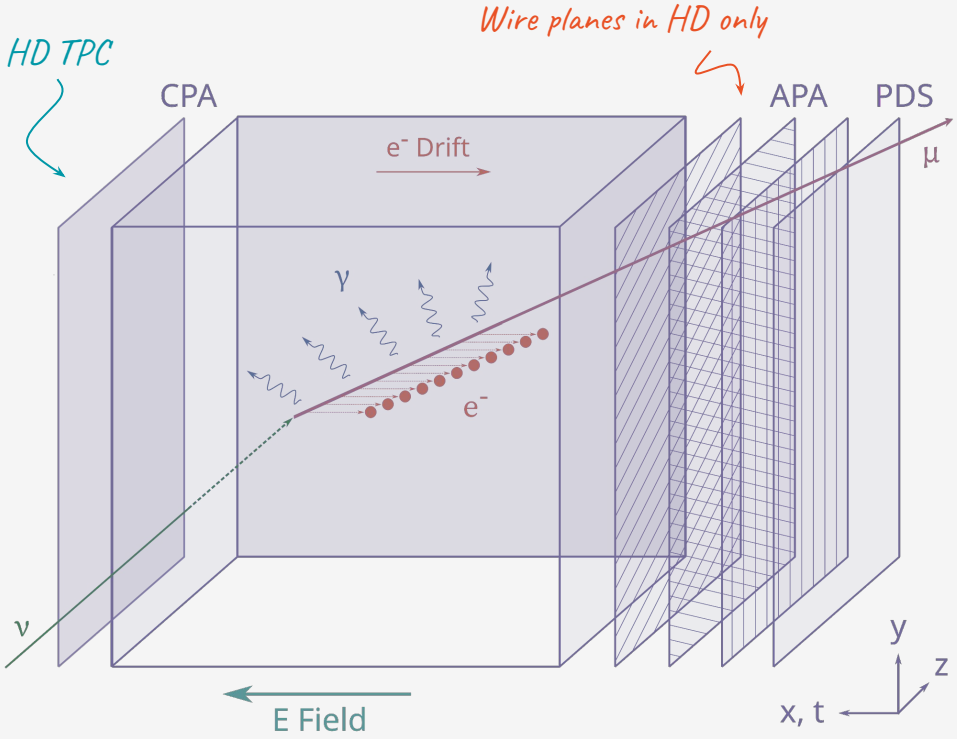
Talk yesterday by Anyssa Navrer-Agasson





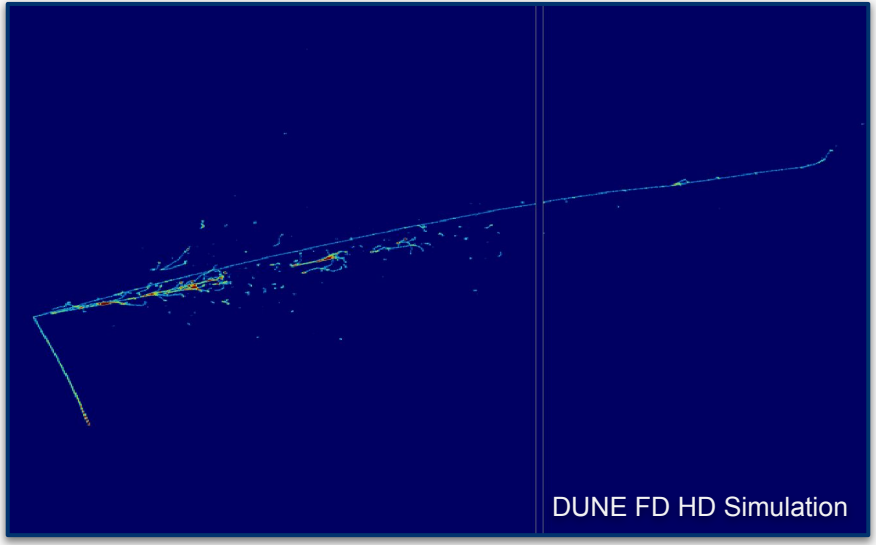


Liquid Argon Time Projection Chambers



low energy threshold

spatial & energy resolution



electron-photon shower separation

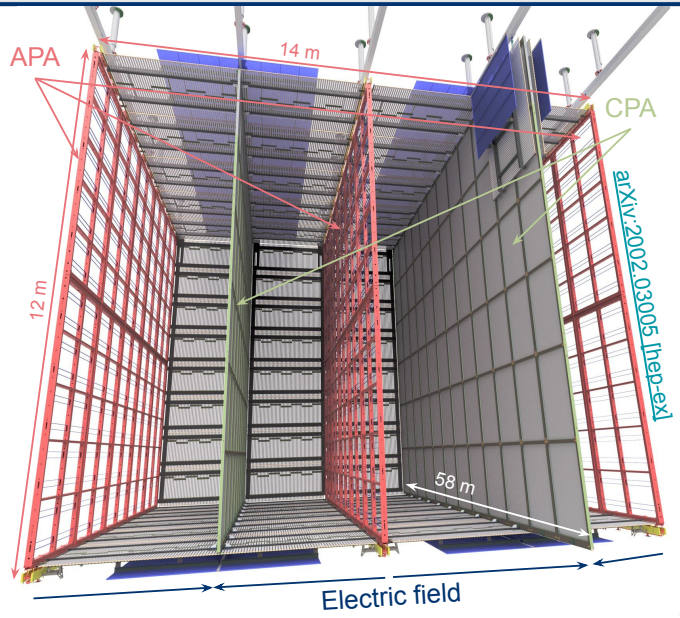
full 3D imaging

excellent particle identification

DUNE Horizontal & Vertical Drift FDs

Horizontal Drift: 150 APAs, 3.5 m drift distance, 500 V/cm field strength, ~5 mm wire pitch.

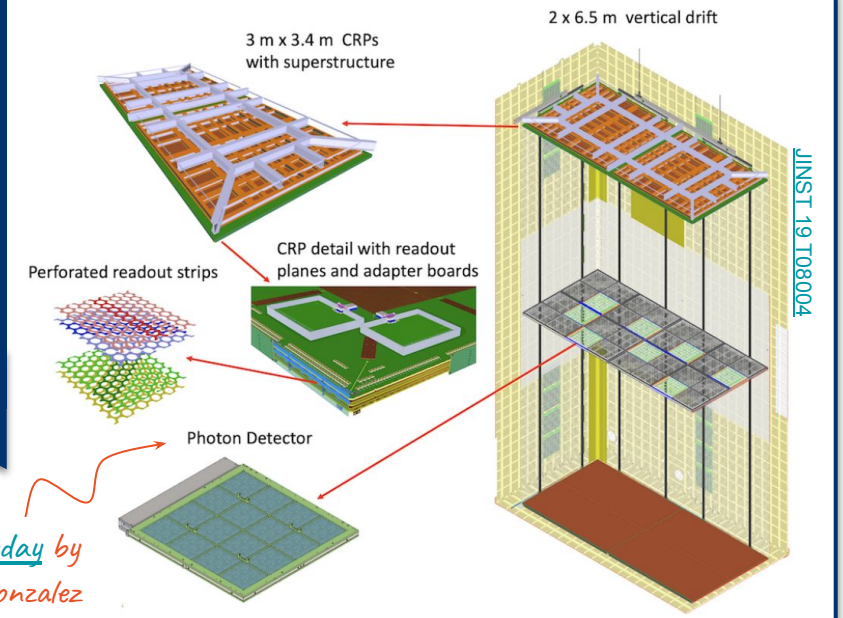
Vertical Drift: 160 CRPs, 6.5 m drift distance, 450 V/cm field strength, ~5-8 mm strip pitch.



APA: Anode Plane Assembly

CPA: Cathode Plane Assembly

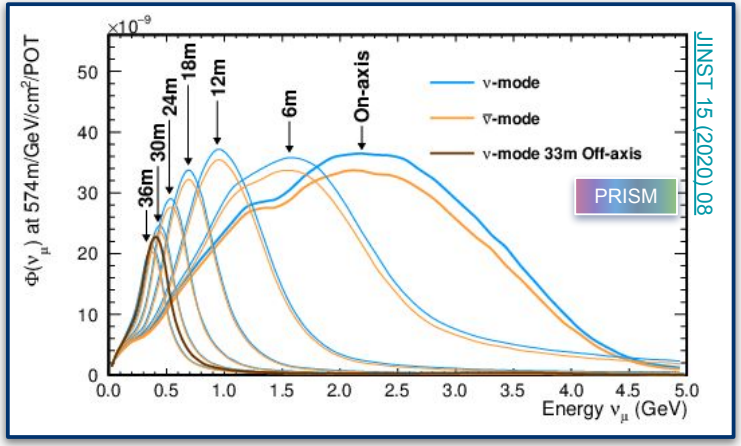
CRP: Charge Readout Plane



Talk yesterday by Maritza J. Delgado Gonzalez

Talk yesterday by Erin Yandel

DUNE Near Detectors



- Primary goals include,
  - Beam characterisation.
  - Systematic constraints,
  - Perform in a high-rate environment,
  - Standalone BSM searches.
- PRISM for off-axis measurement strategy,
  - Exploit the angular dependence of pion decay kinematics,
  - Use linear combinations to mimic the flux at the far detector,
  - Test energy dependence of interaction model.
- Located 60 m underground at a 574 m baseline to account for beam angle.

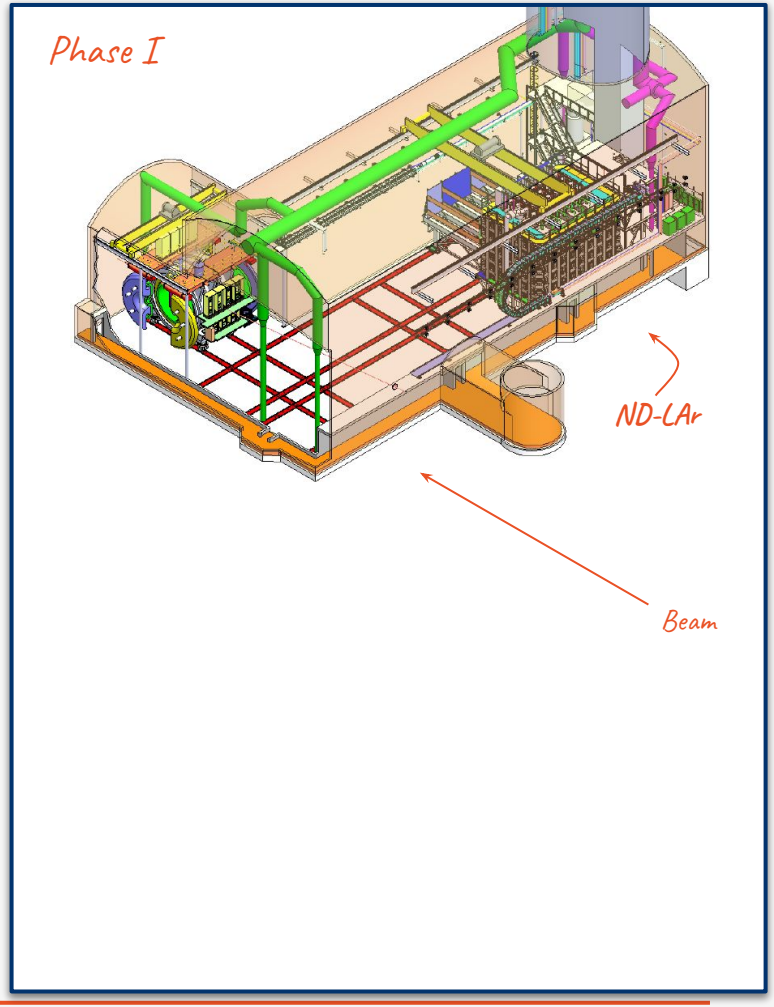
DUNE Near Detectors

PoS ICHEP2022 (2022)

ND-LAr (Phase I & II)

- Novel LArTPC with pixelated charge readout and 70 optically-isolated TPCs.
- Designed to cope with O(100) interactions per 1.2 MW spill.
- O(4 mm) resolution.

PRISM



DUNE Near Detectors

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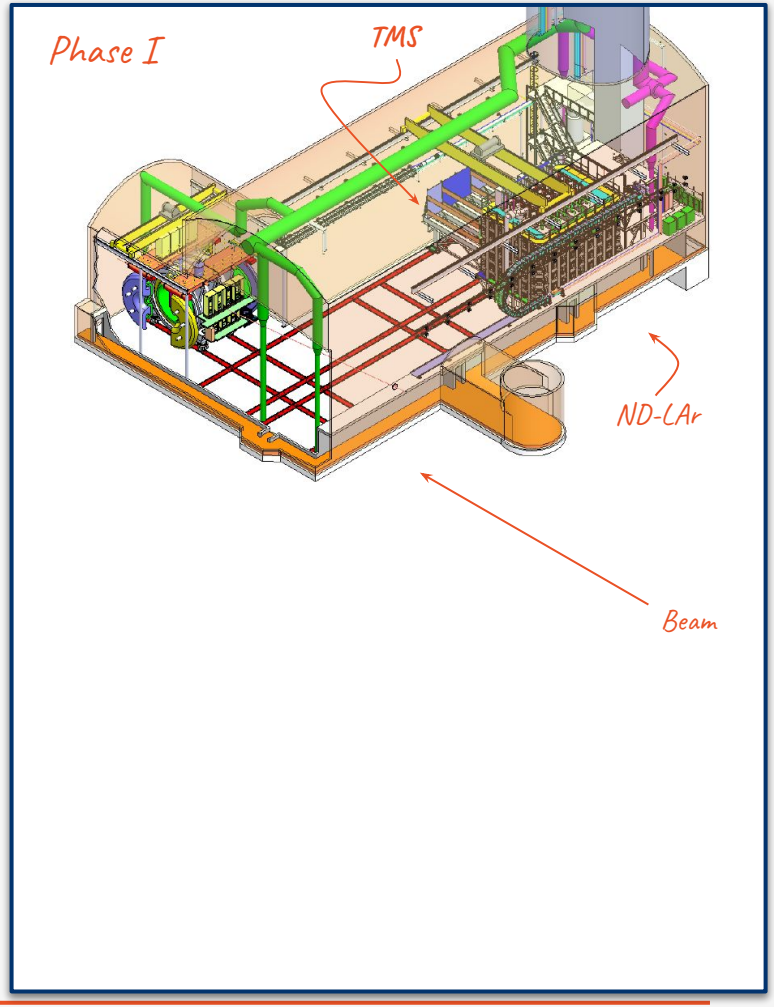
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PRISM

TMS (Phase I)

PRISM

- Muon spectrometer for those which exit ND-LAr.
- ~1 T solenoidal magnetic field,
  - Charge calculated from curvature.
- Alternating layers of steel and scintillator, ~3.5cm granularity.



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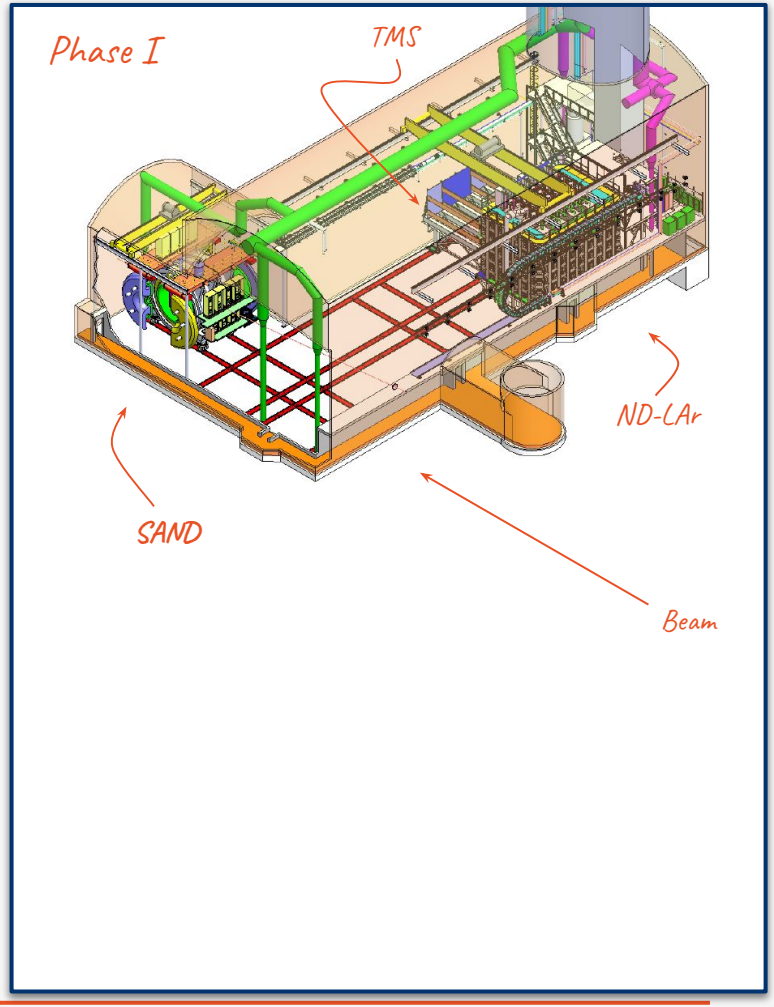
SAND (Phase I & II)

- Primarily a stability monitor,
  - Flux & cross-section constraints also possible.
- KLOE solenoid & ECAL with inner tracker and optically readout LAr target.
  - Superconducting magnet, 0.6 T.

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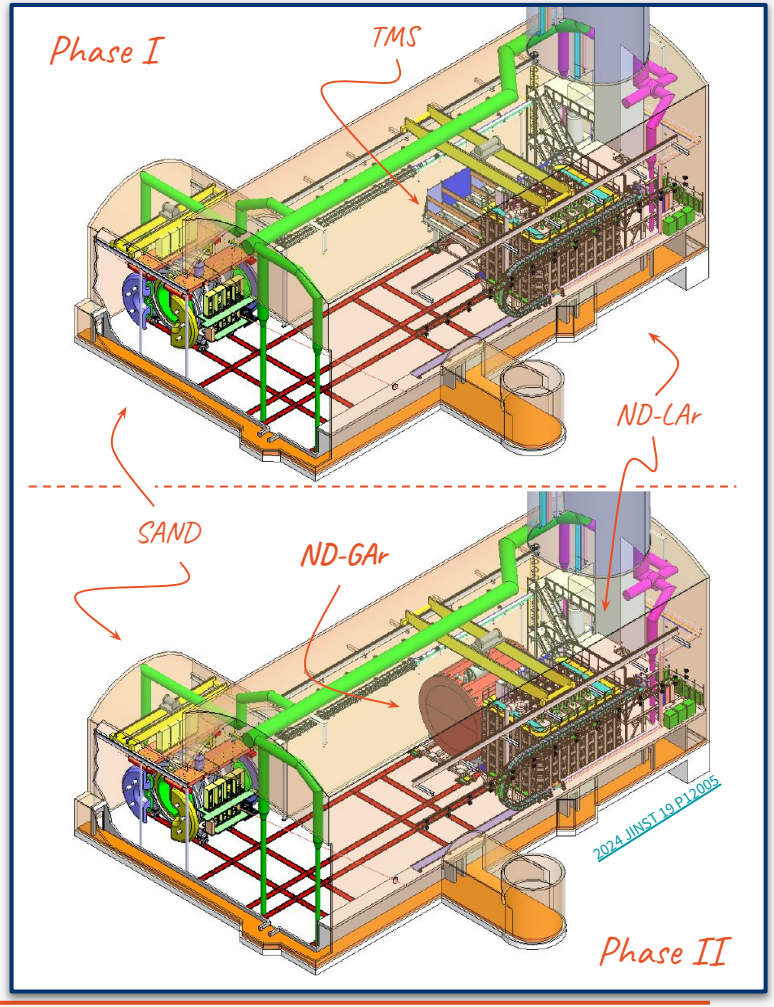
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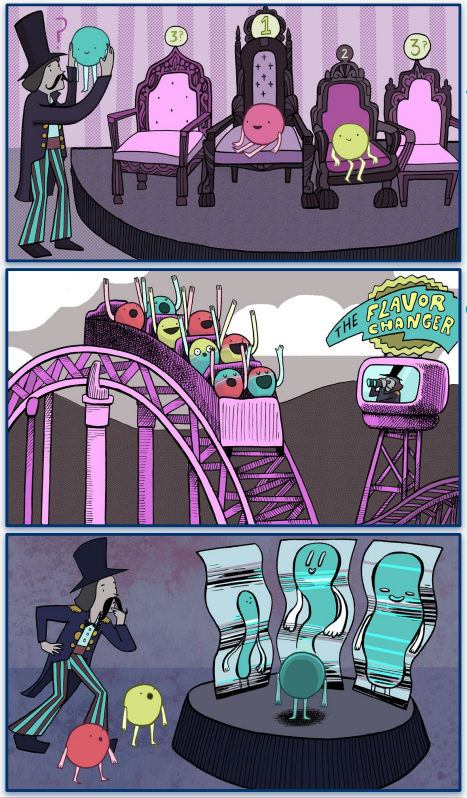
ND-GAr (Phase II)

PRISM

- Argon high pressure gas TPC,
  - Housed within an ECAL and 0.5 T superconducting magnet.
- Low momentum threshold for charged particle tracking,
  - Improved ν-Ar interaction models,
  - Muon spectrometer for ND-LAr,
  - BSM physics program.



DUNE Science Program



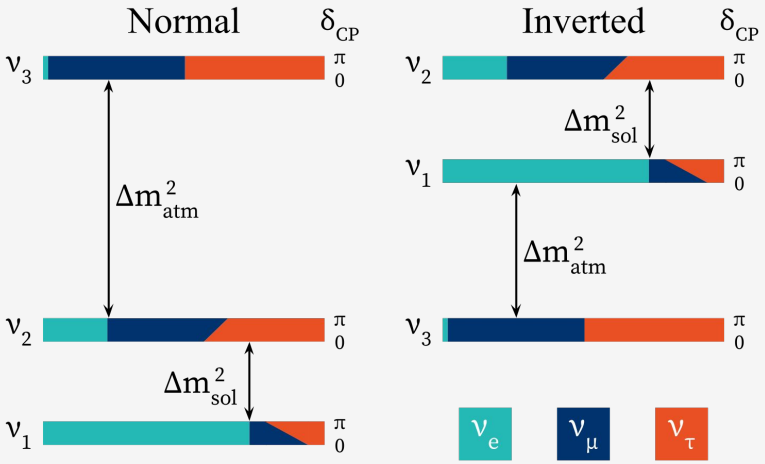
Artwork by Sandbox Studio, Chicago with Corinne Mucha & Ana Kova.



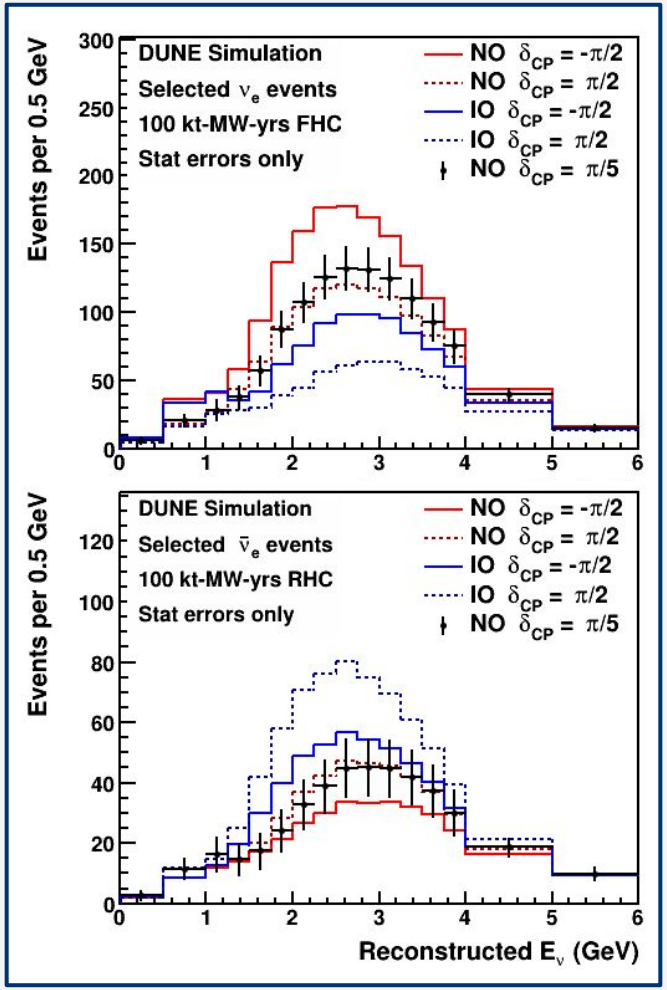
University of Sheffield

DUNE Science Program

- Neutrino mass ordering,
  - 5σ sensitivity to measuring the neutrino mass ordering for all values of δ_{CP} within the first 5 years.



Degeneracy breaking in Phase I

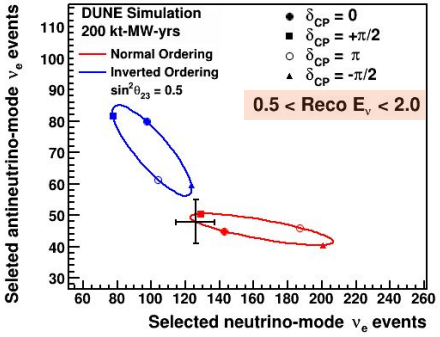


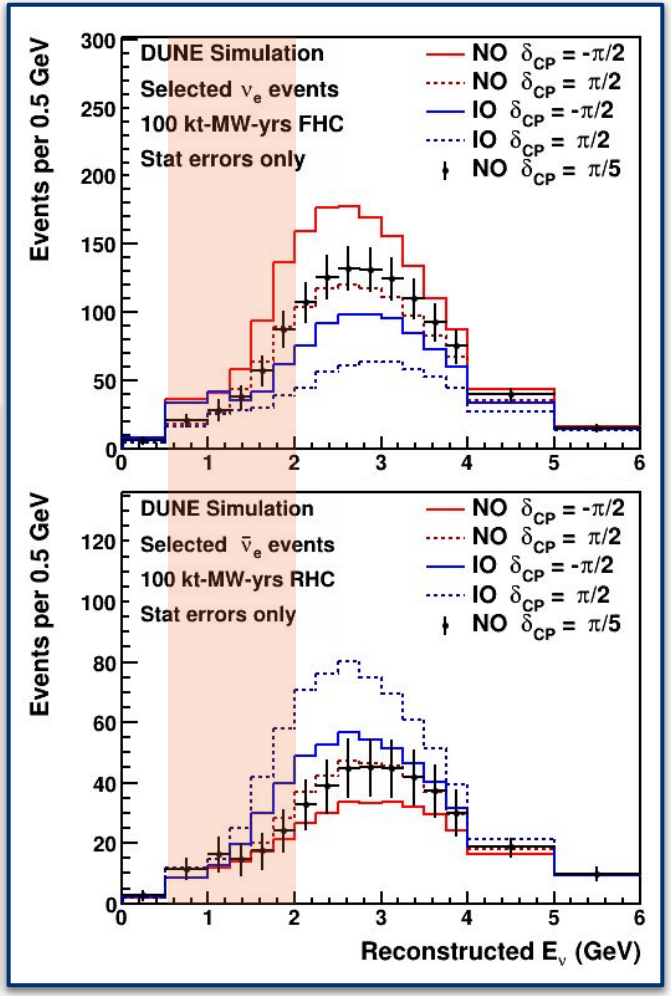
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Smallest MO separation.

Sensitivity to δ_{CP} value.





DUNE Science Program

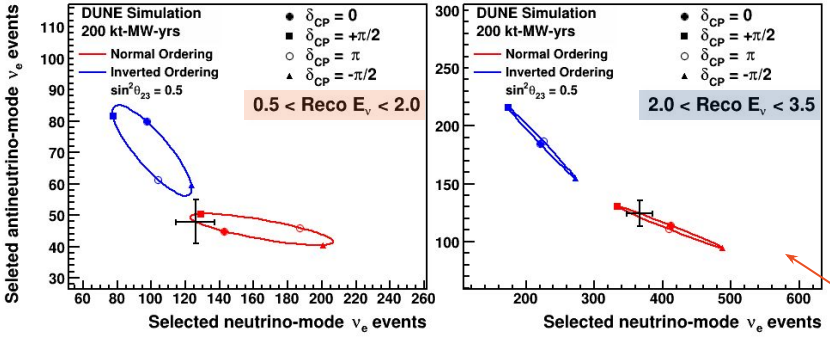
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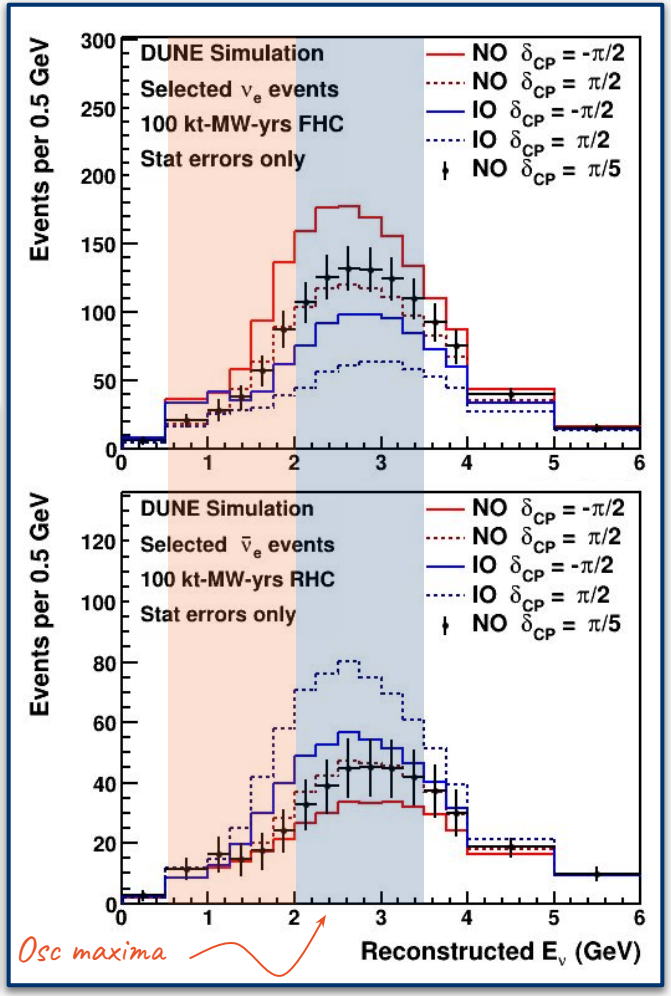
Smallest MO separation.

Sensitivity to δ_{CP} value.

Largest MO separation.

Insensitive to δ_{CP} value.





DUNE Science Program

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Smallest MO separation.

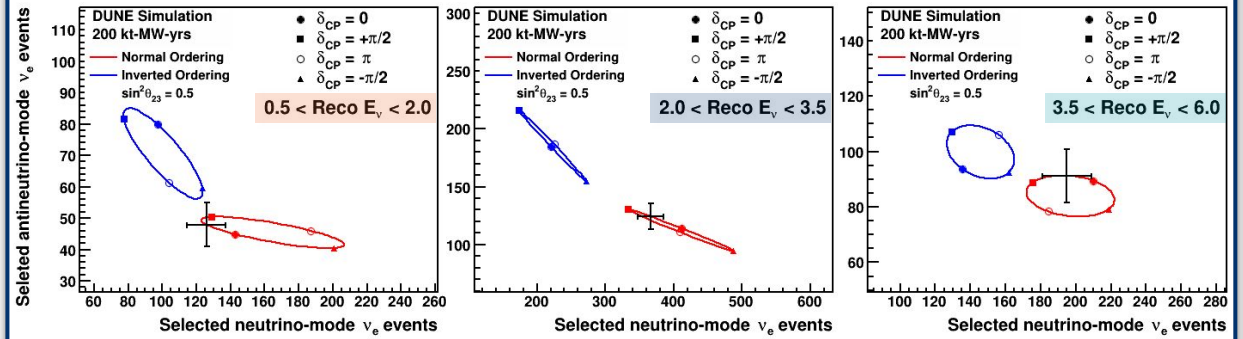
Sensitivity to δ_{CP} value.

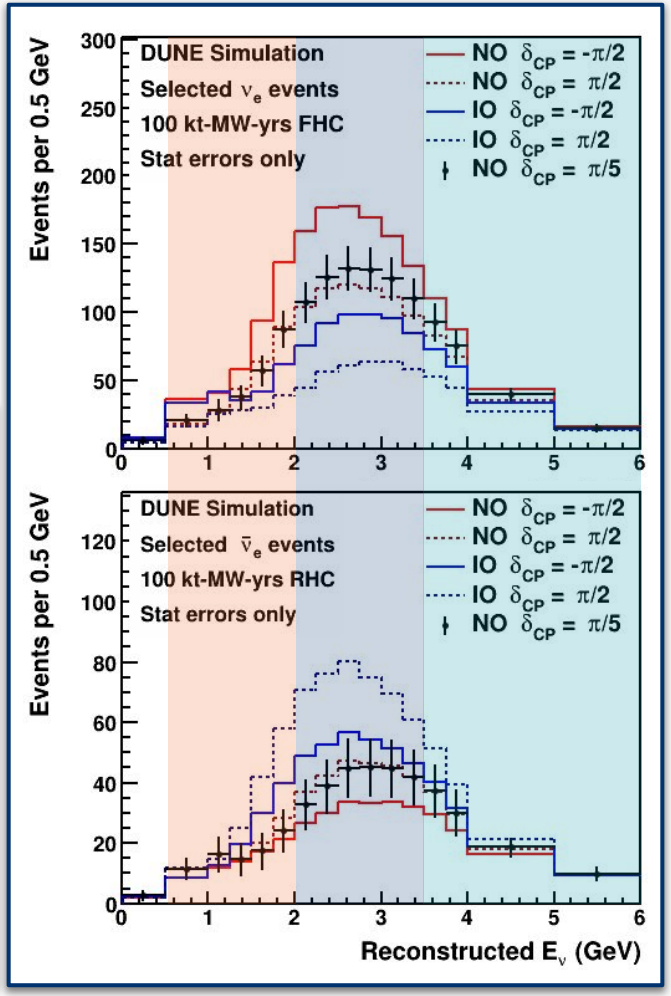
Largest MO separation.

Insensitive to δ_{CP} value.

Medium MO separation.

Sensitivity to δ_{CP} value.

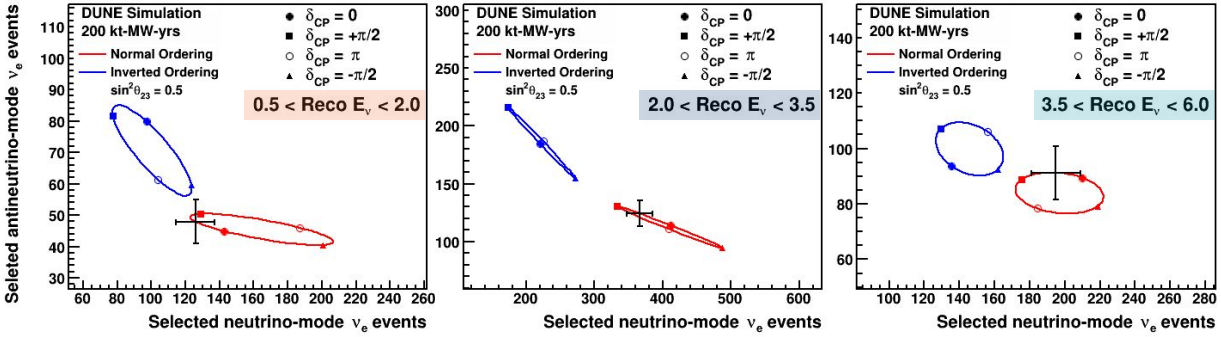


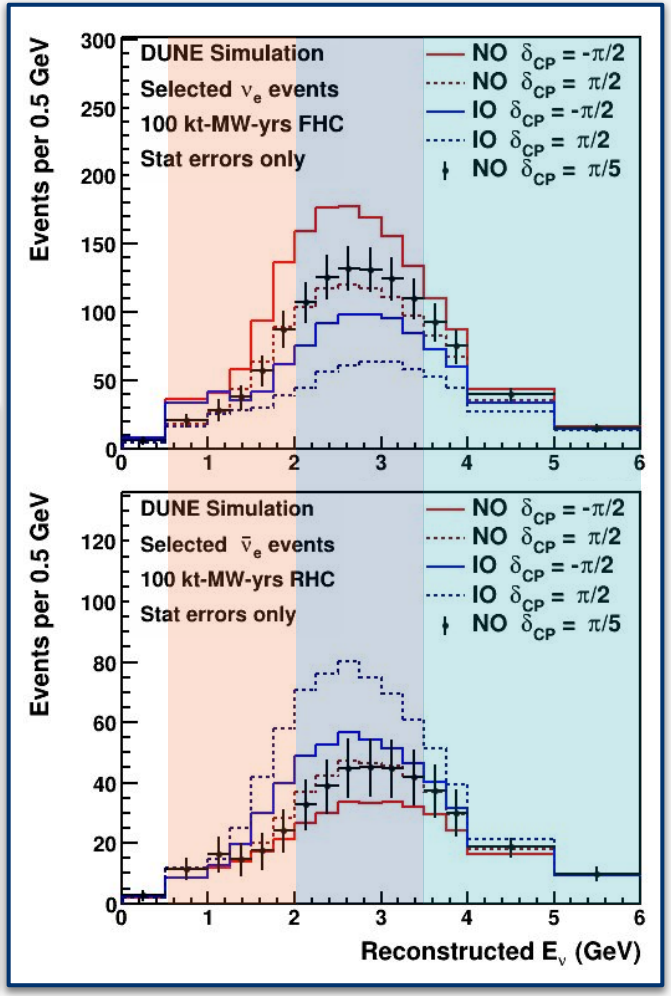


DUNE Science Program

- Neutrino mass ordering,
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Large matter effects induced by the long baseline combined with the breadth of the wide-band energy spectrum prevents any single incorrect choice of mass ordering and δ_{CP} from fitting the entire L/E range simultaneously.

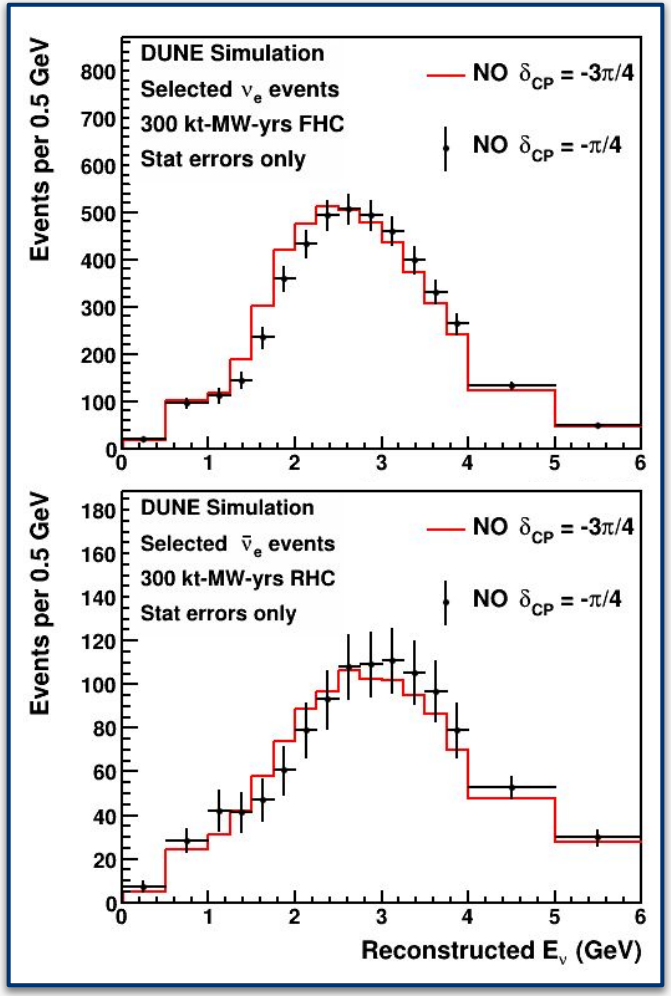




DUNE Science Program

- Neutrino mass ordering,
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- CP-phase, δ_{CP},
  - Significant CP violation discovery potential over a wide range of true δ_{CP} values within 10 years.

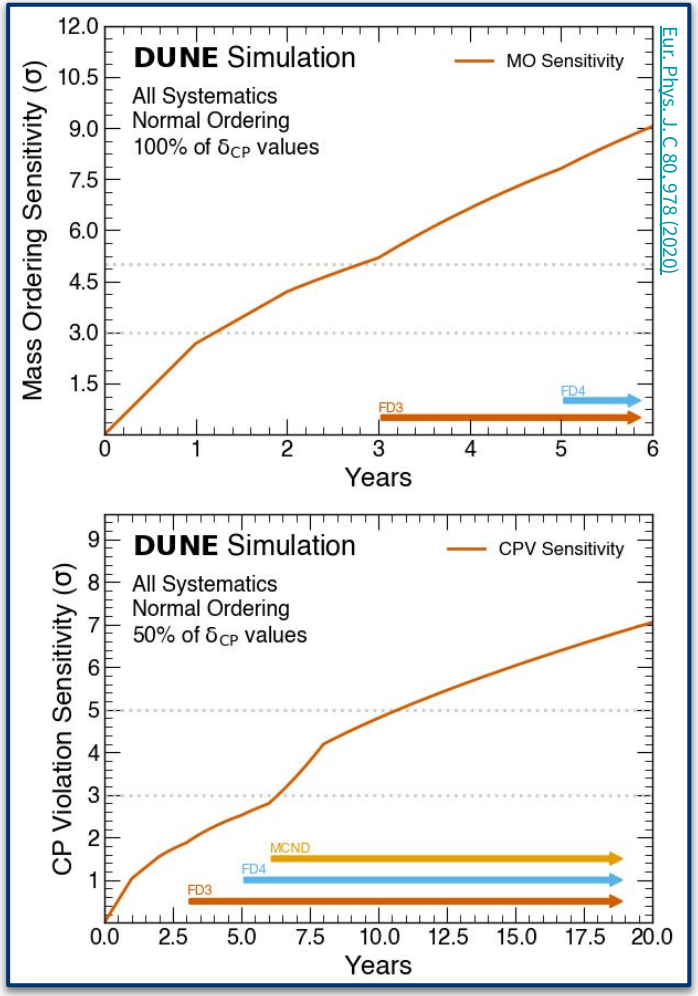
Degeneracy breaking through shape discrimination in Phase II



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Discovery potential

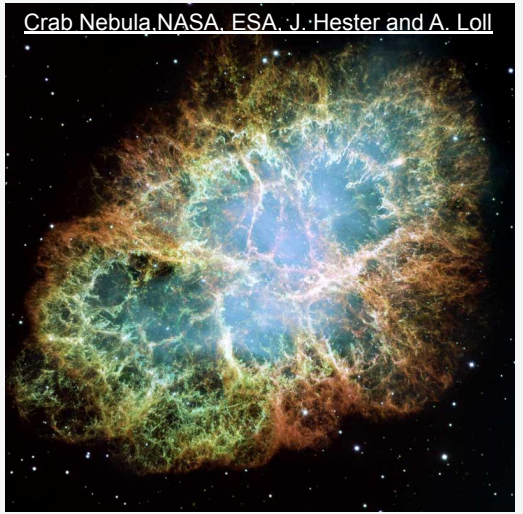


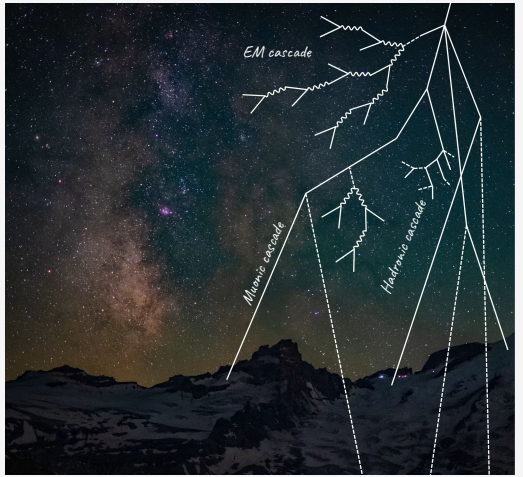
Eur. Phys. J. C 80, 978 (2020)

DUNE Science Program

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- 3-flavour neutrino oscillation paradigm constraints.
- Astrophysical neutrino searches,
  - Solar, supernova & atmospheric neutrino searches.

Precision physics

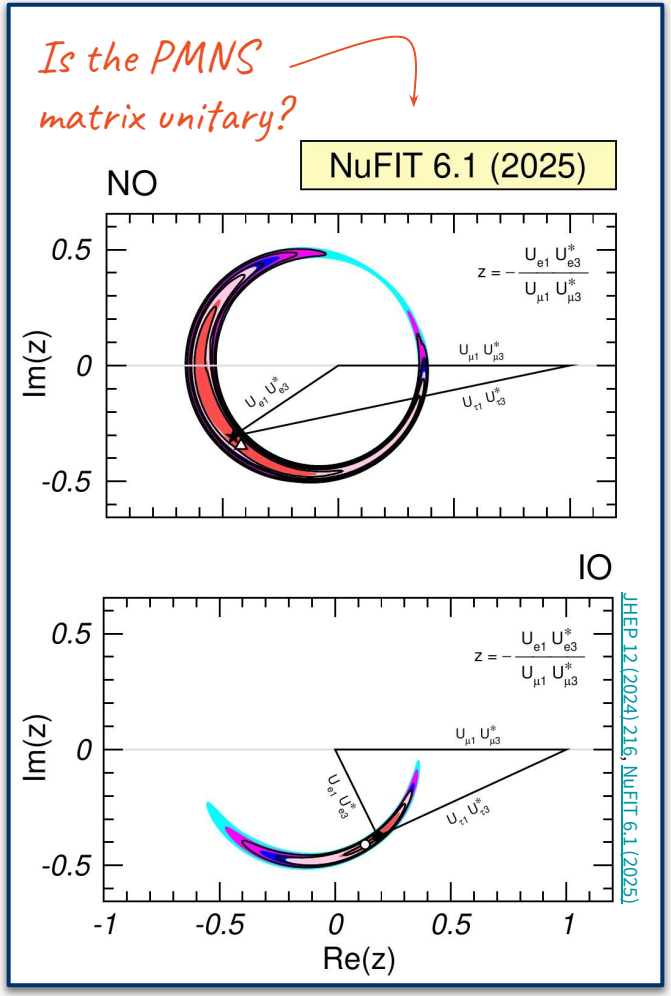

Crab Nebula,NASA, ESA, J. Hester and A. Loll



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- Astrophysical neutrino searches,
  - Solar, supernova & atmospheric neutrino searches.
- Beyond the Standard Model (BSM) searches,
  - Baryon-number-violating processes, steriles, HNLs, NSIs, dark matter candidates…

Discovery potential



DUNE Status



University of Sheffield

Status: Beamline

2019



Groundbreaking

2024

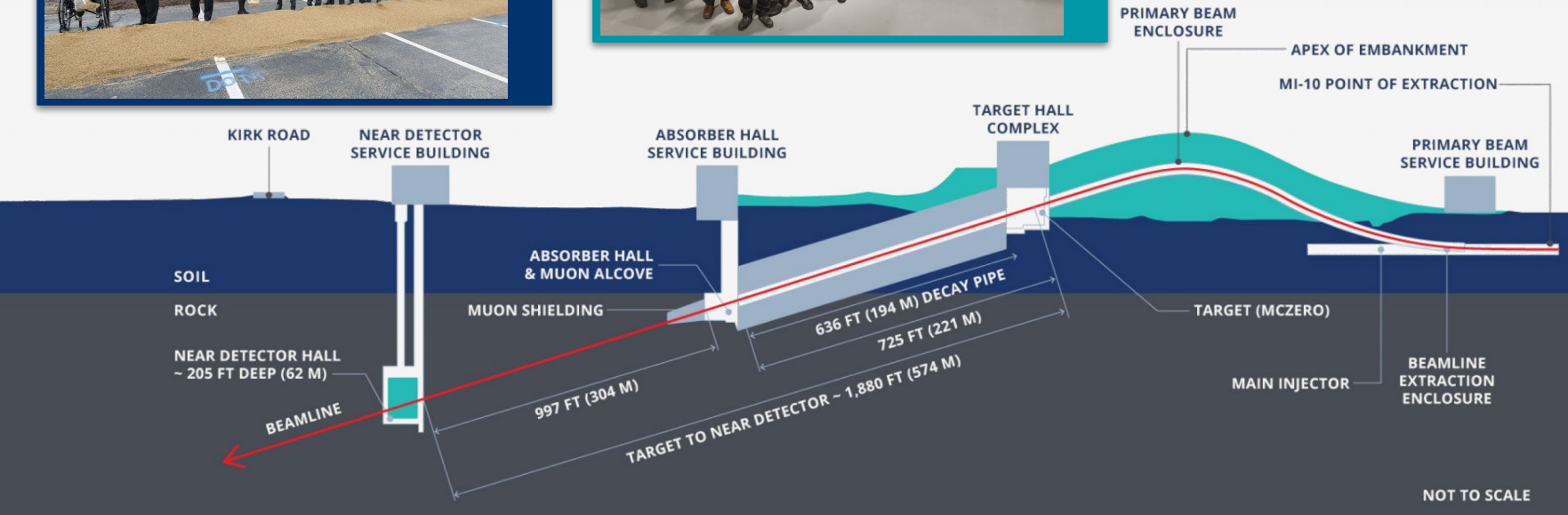


Cryo module prototype

2026

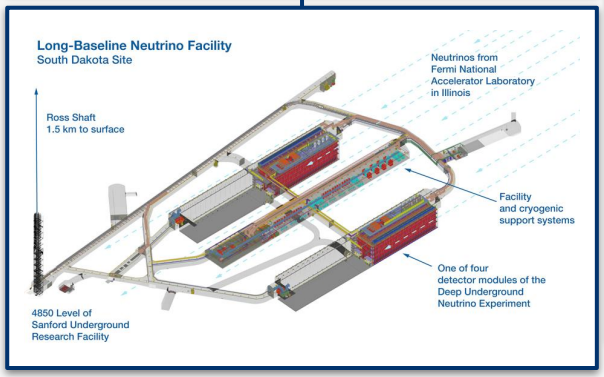


PIP-II Facility, Fermilab



Status: FD Cavern Excavation

- 800,000 tons of rock crushed and removed!
- Cavern outfitting complete,
  - Essential utilities ready to go.
- All cryostat material arrived in South Dakota,
  - Transported underground,
  - About to start cryostat assembly.



2021





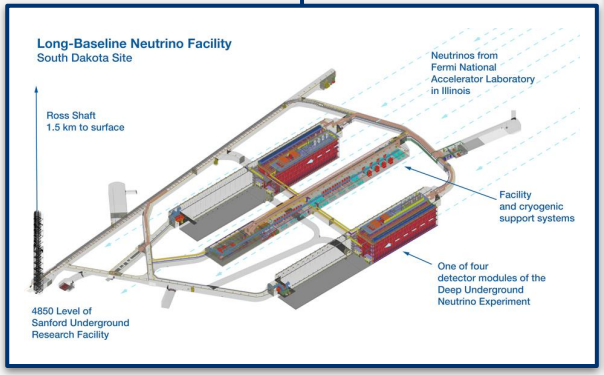
2025





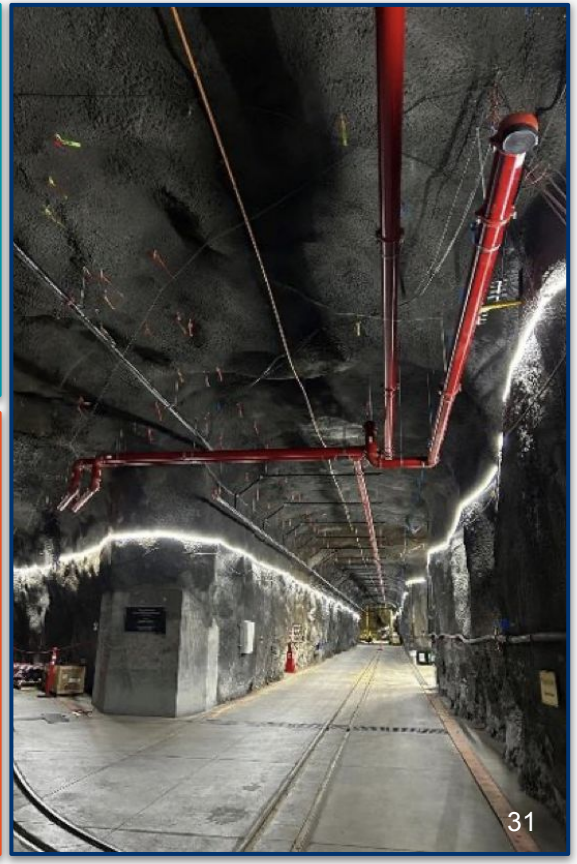
Status: FD Cavern Outfitting

- 800,000 tons of rock crushed and removed!
- Cavern outfitting complete,
  - Essential utilities ready to go.
- All cryostat material arrived in South Dakota,
  - Transported underground,
  - About to start cryostat assembly.



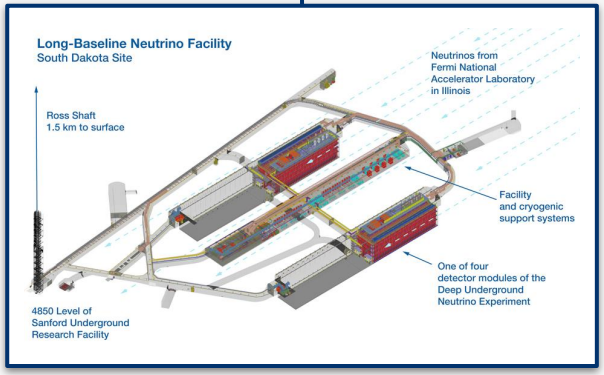






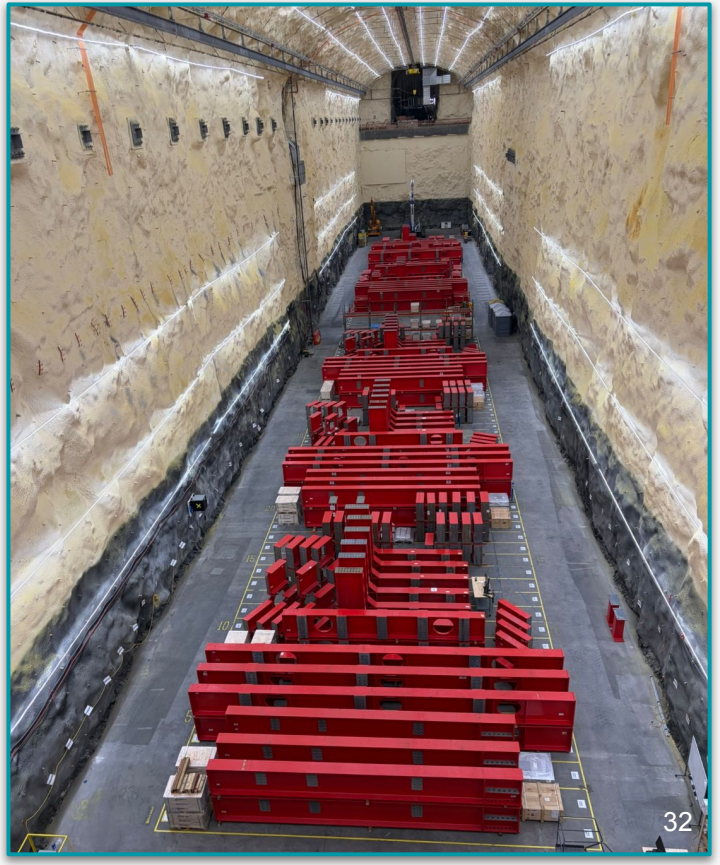
Status: FD Cryostat Transport

- 800,000 tons of rock crushed and removed!
- Cavern outfitting complete,
  - Essential utilities ready to go.
- All cryostat material arrived in South Dakota,
  - Transported underground,
  - About to start cryostat assembly.





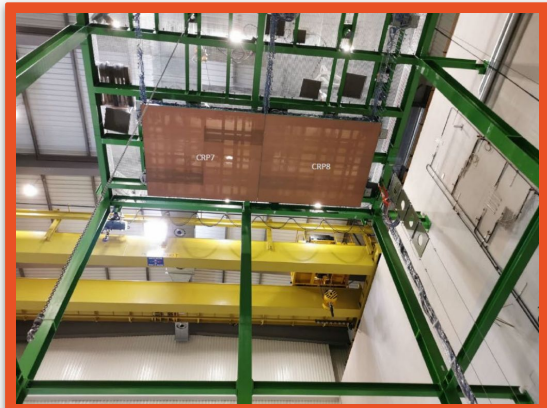
Cryostat material underground



Status: FD VD Charge Readout Planes



CERN Cold Box Testing

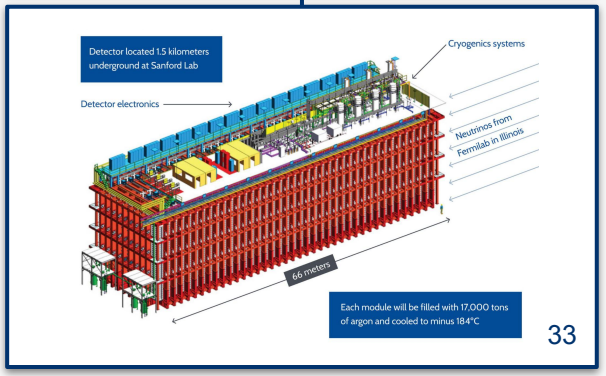


Support Frame Load Tests

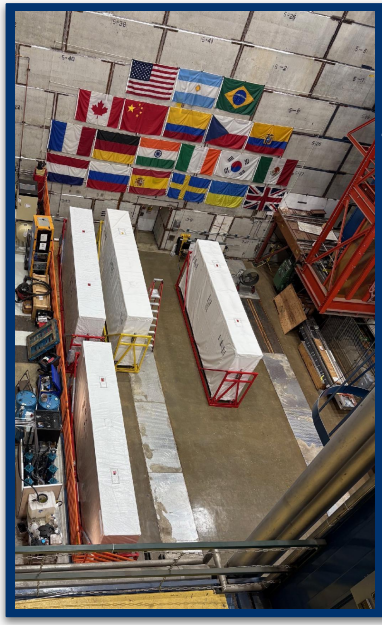


Support Frame Load Tests

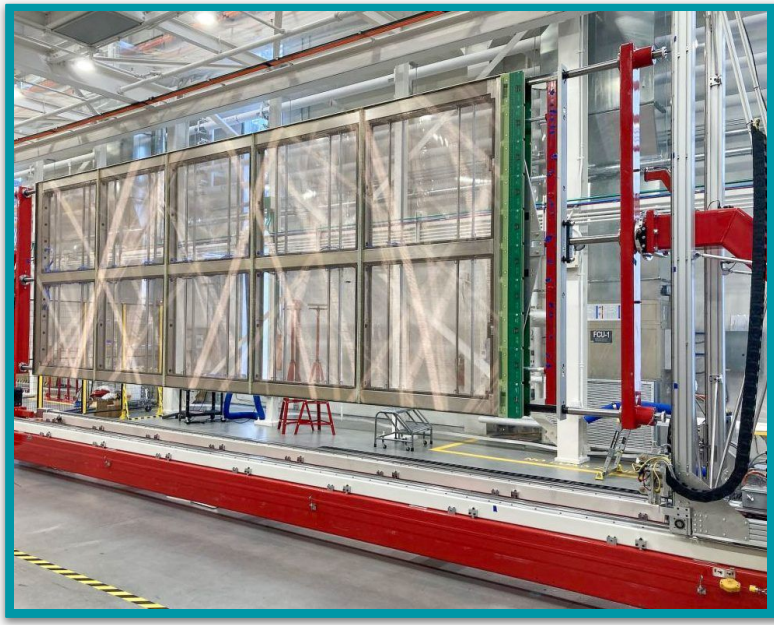
- The DUNE Vertical Drift FD will utilise a novel perforated PCB CRP readout technology.
- Installation test stand & cold tests in operation at CERN.
- Construction of 160 CRPs underway at Grenoble, Yale & CERN.



Status: FD HD Anode Plane Assembly

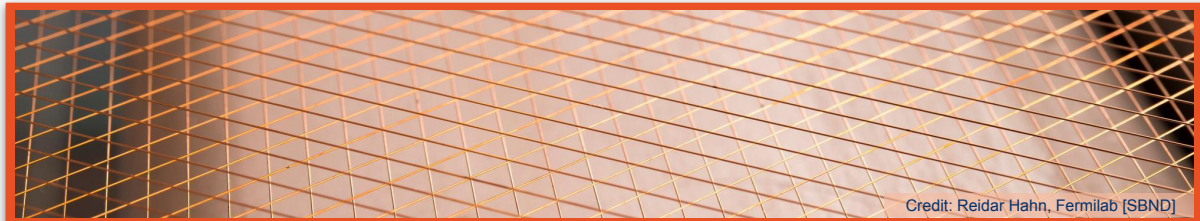


APA Shipments: UK → US



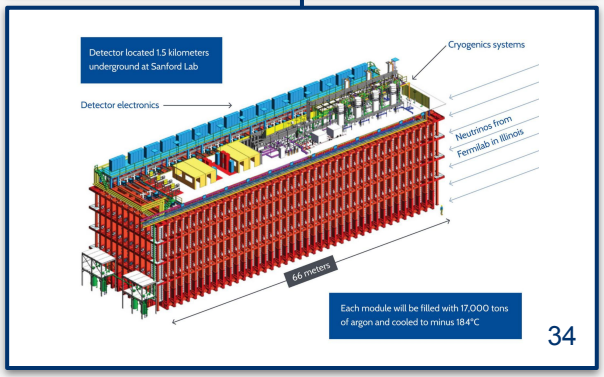
APA Construction: Wire Winder

- The DUNE Horizontal Drift FD will utilise the tried-and-tested wire plane readout technology.
- 150 **6.1 x 2.3 m** APAs in total,
  - 137 will be constructed in the UK,
  - 13 will be constructed in the US,
  - Half of the 137 UK APAs have completed construction.

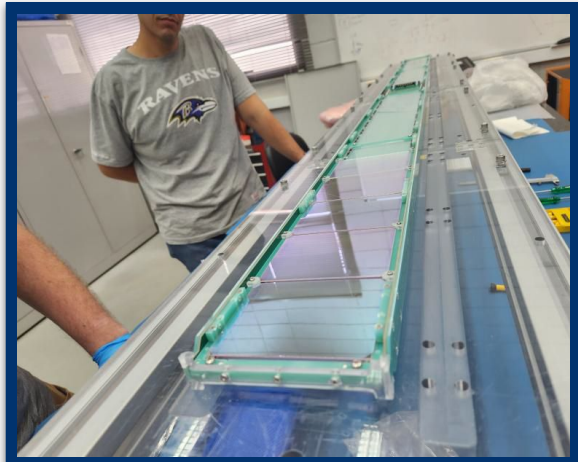


Credit: Reidar Hahn, Fermilab [SBND]

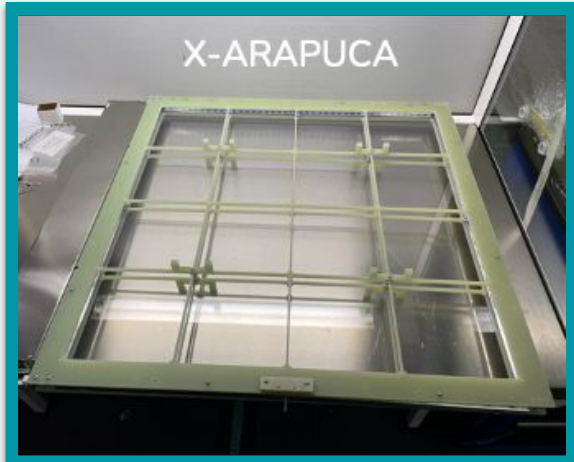
Wire plane



Status: FD Photon Detection Systems

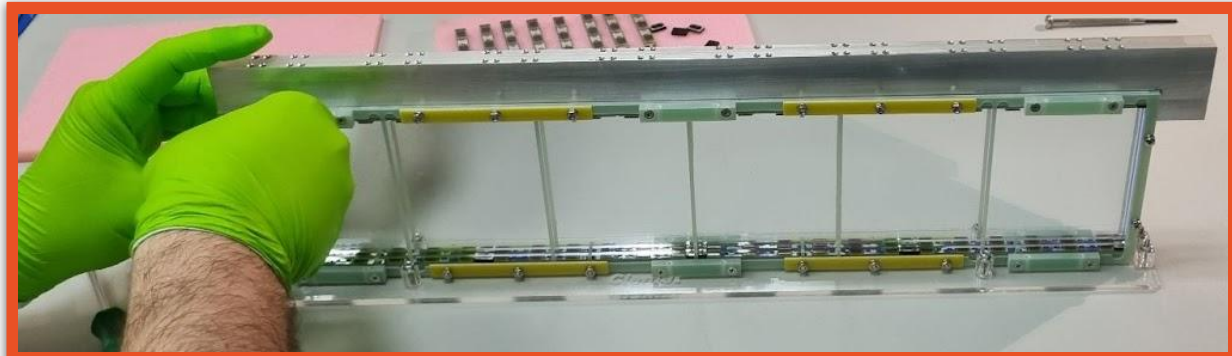


HD X-ARAPUCA Module

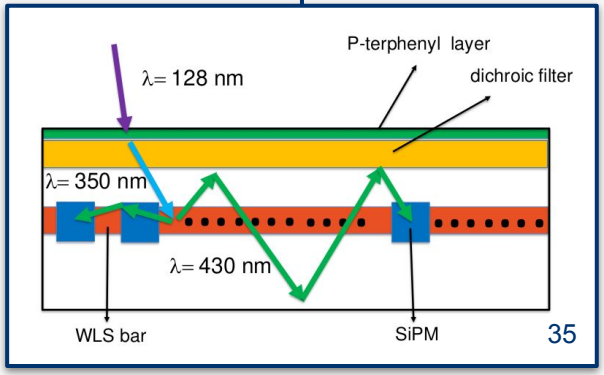


VD X-ARAPUCA Module

- Both the HD & VD FDs will use the X-ARAPUCA technology for their photon detection systems (PDS),
  - Designed & developed in Brazil,
  - Implementation variations in HD/VD.
- Component production, module assembly, tests & simulation developments are underway,
  - Global effort for full PDS modules.

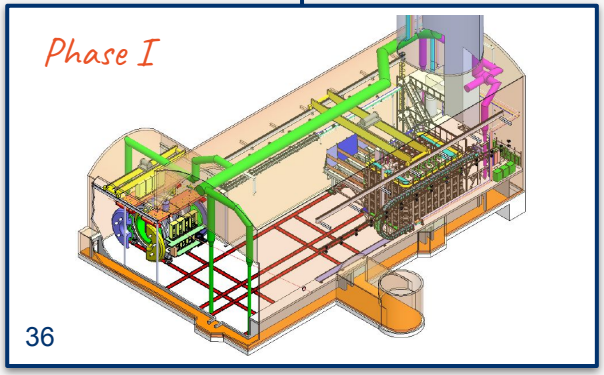


HD X-ARAPUCA Module



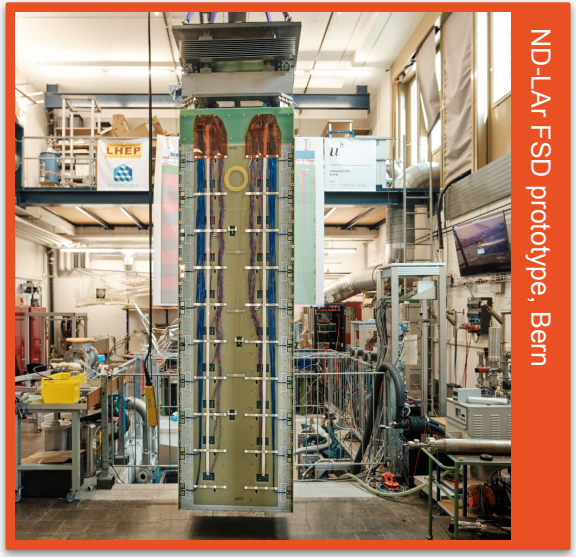
Status: Near Detectors

- ND test/prototype program extremely successful.
- Facility design nearly complete, TDR in preparation.
- Lab for cryogenic tests progressing well, getting ready for construction.





Test cryostat, FNAL



ND-LAr FSD prototype, Bern



SAND integration tests, INFN



PRISM tests, Minnesota

Status: FD Prototypes

Neutrino Platform at CERN has so far hosted 3 prototypes for the DUNE FD technologies.

Charged-particle test beam and cosmic data runs have been taken for all 3 detectors.

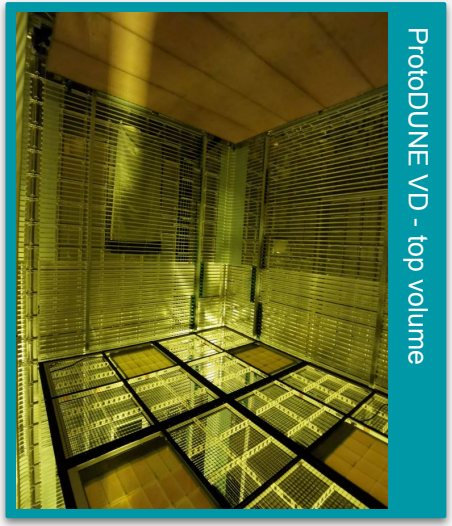
PD-SP: (2018 - 2020) tested the largest ever LArTPCs with full-scale FD components.

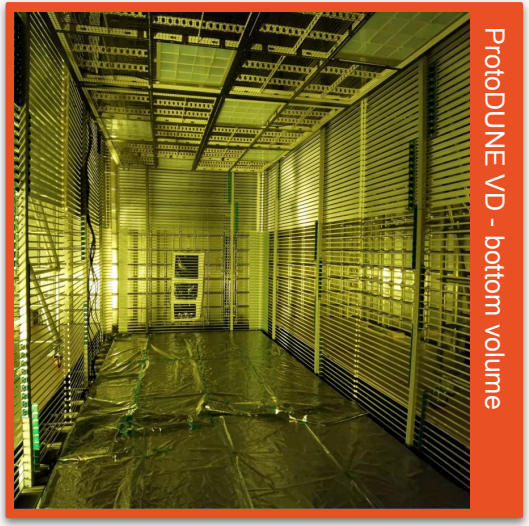
PD-HD: (2024 -) Testing components of the final horizontal drift design.

PD-VD: (2025 -) Testing components of the final vertical drift design.

PD-III proposed to test Phase-II components.







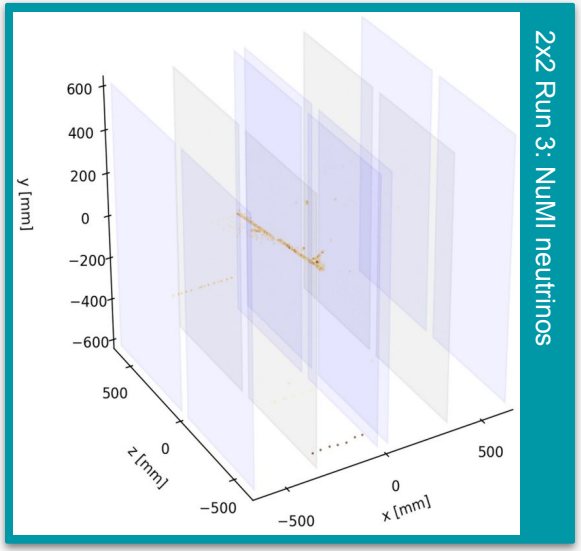
Status: ND Prototypes

The 2x2 Demonstrator tests the modular LArTPC configuration which will be employed by ND LAr.

Run 1: NuMI antineutrino beam data, 4.5 days in 2024, Instruments 2026, 10, 18.

Run 2: Beam-off data, Oct. - Dec. 2025, detector upgrades implemented and 3 calibration systems deployed.

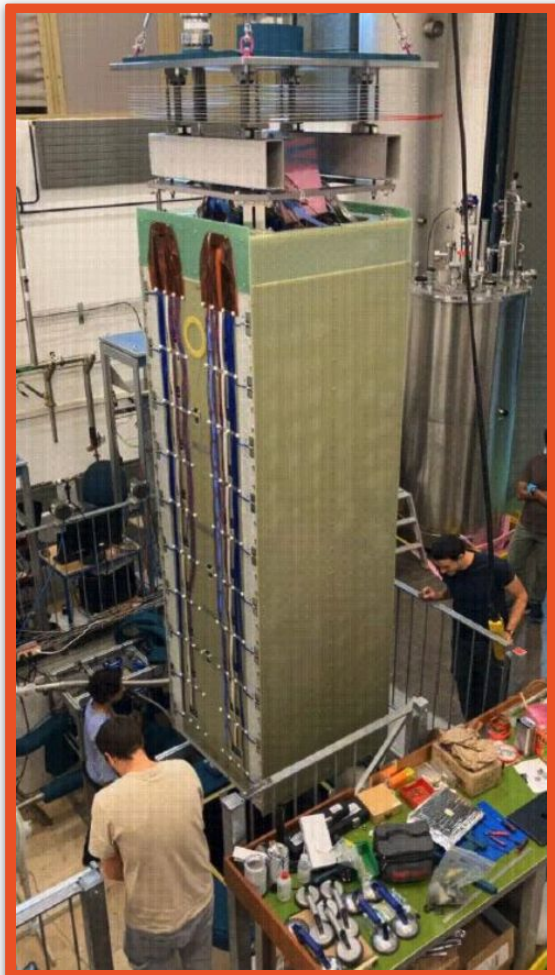
Run 3: Currently taking data with the brand new NuMI beam run.



2x2 Run 3: NuMI neutrinos

The Full Scale Demonstrator tests a full-sized ND LAr module at Bern.

Run: Cosmic-ray & radioactive source data, 2024.



Full Scale Demonstrator (FDS), Bern

Outlook

The DUNE experimental design will facilitate a broad and ambitious neutrino physics program spanning multiple decades,

- World's most intense neutrino beam,
- Long (1,300 km) baseline,
- ND PRISM.

DUNE is rapidly checking off construction milestones towards first data at the end of the decade.

Thank you!



DUNE Collaboration, May 2026, SD



DUNE Collaboration, September 2026, UNICAMP