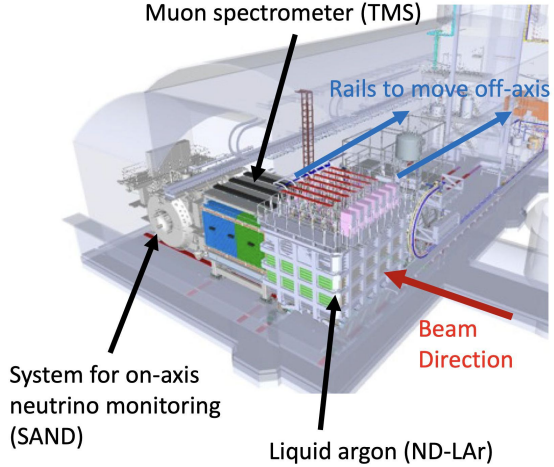
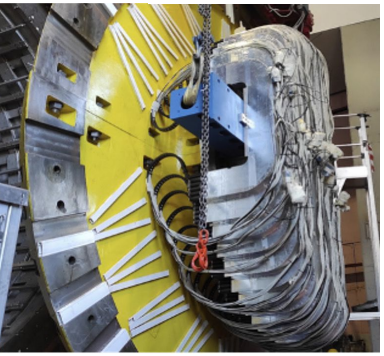
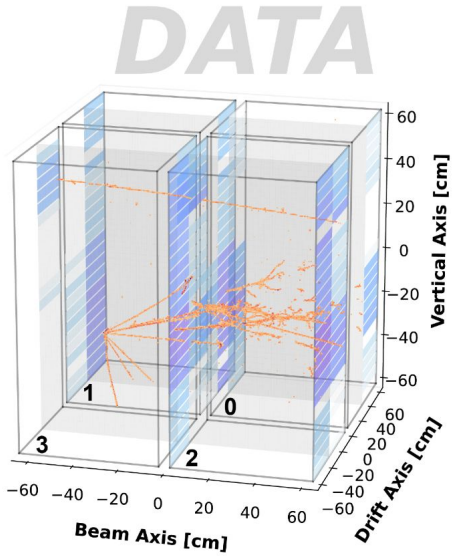








Los Alamos NATIONAL LABORATORY

Fermilab

DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

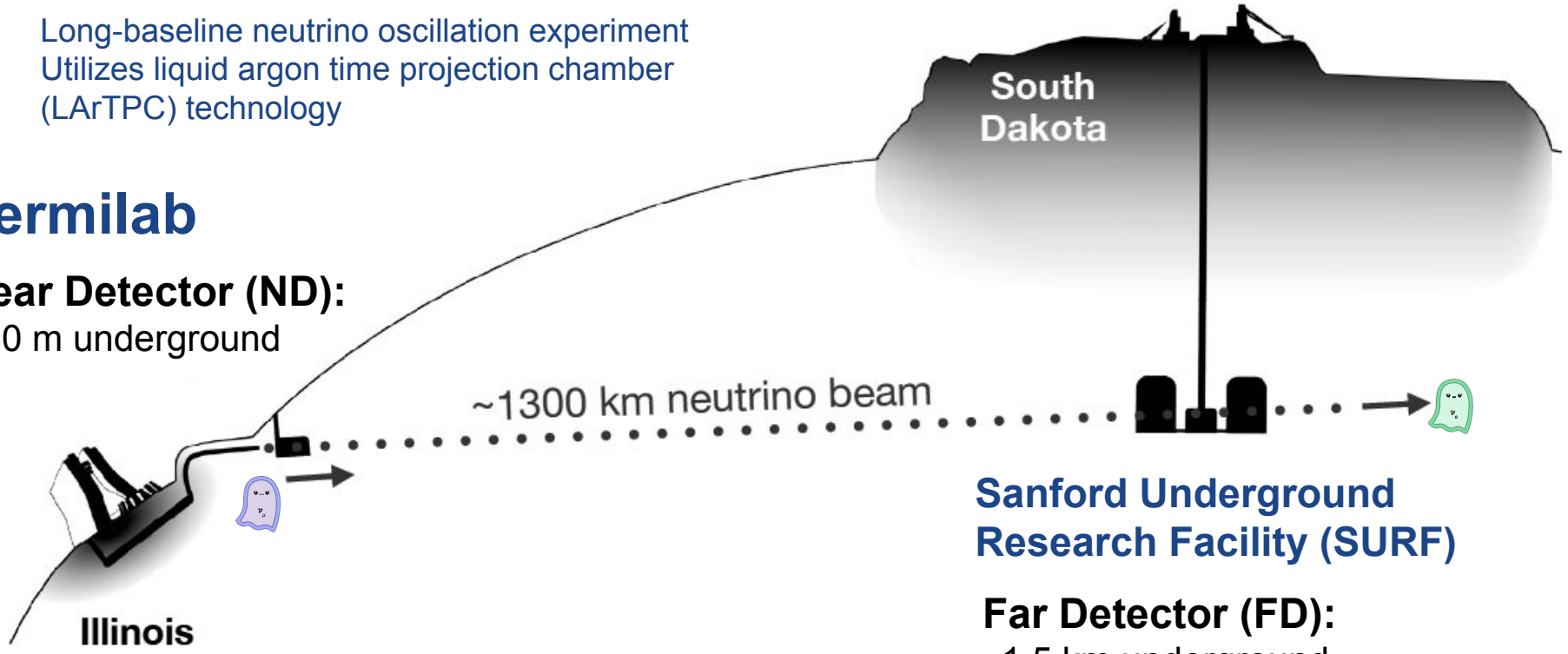
The DUNE Near Detector: Design and Current Status

Erin Yandel (LANL)
On Behalf of the DUNE Collaboration
eyandel@lanl.gov

NNN 2026
October 29, 2026

The Deep Underground Neutrino Experiment

- Long-baseline neutrino oscillation experiment
- Utilizes liquid argon time projection chamber (LArTPC) technology



Fermilab

Near Detector (ND):
~60 m underground

Sanford Underground Research Facility (SURF)

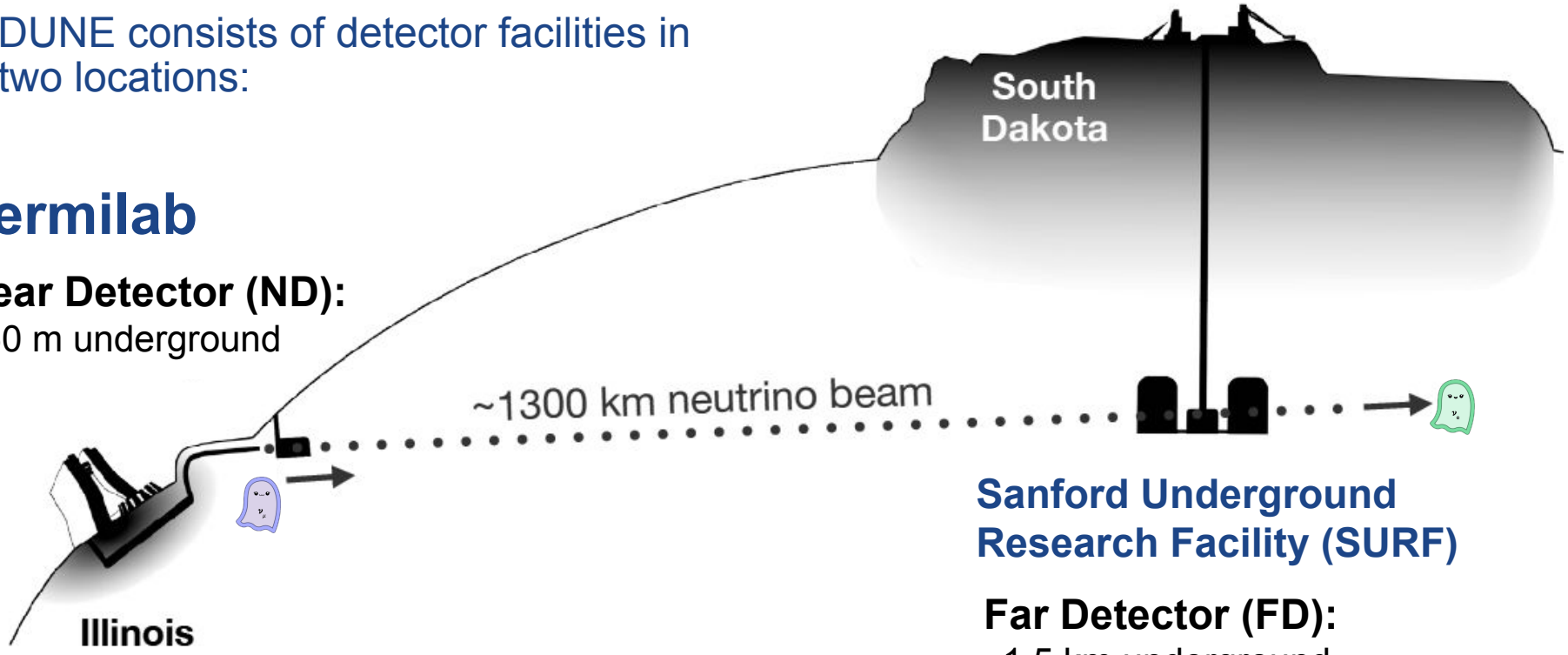
Far Detector (FD):
~1.5 km underground

DUNE Near Detector (ND)

DUNE consists of detector facilities in two locations:

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Near Detector (ND):
~60 m underground

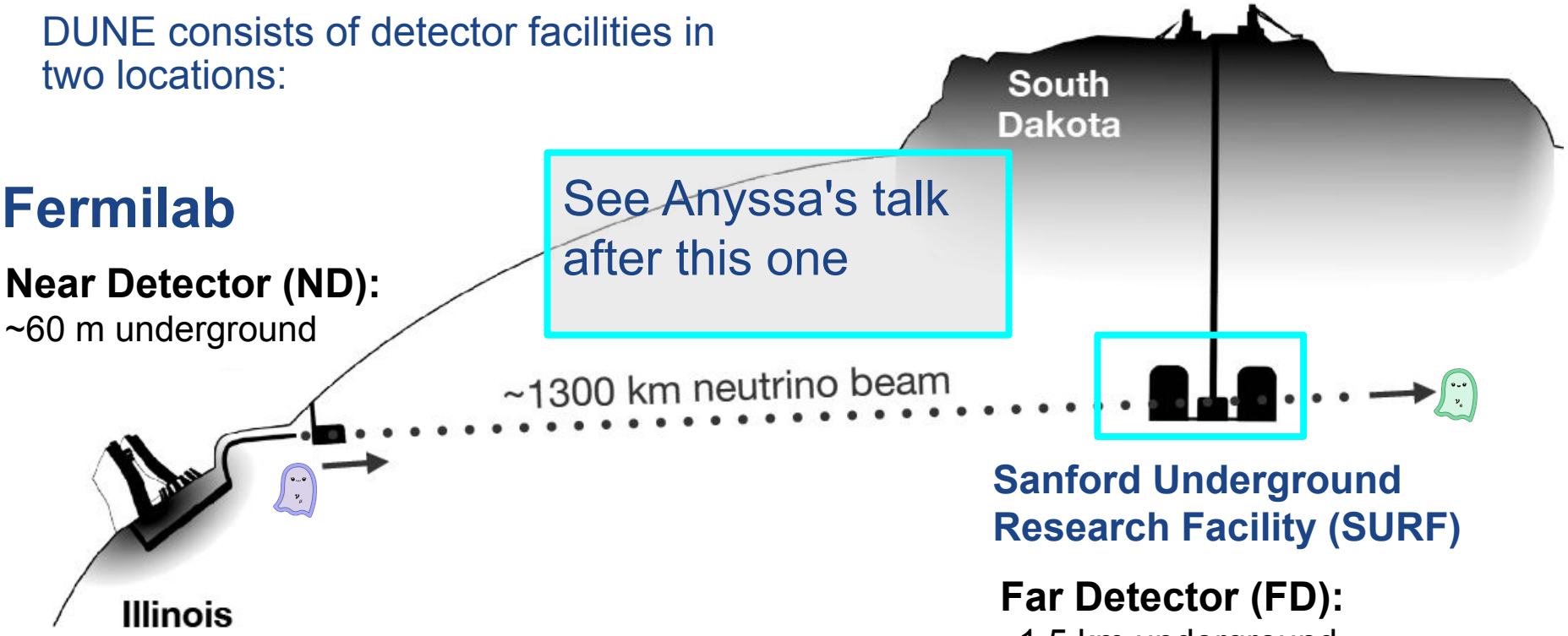


Sanford Underground Research Facility (SURF)

Far Detector (FD):
~1.5 km underground

DUNE Near Detector (ND)

DUNE consists of detector facilities in two locations:



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Near Detector (ND):
~60 m underground

See Anyssa's talk after this one

Sanford Underground Research Facility (SURF)

Far Detector (FD):
~1.5 km underground

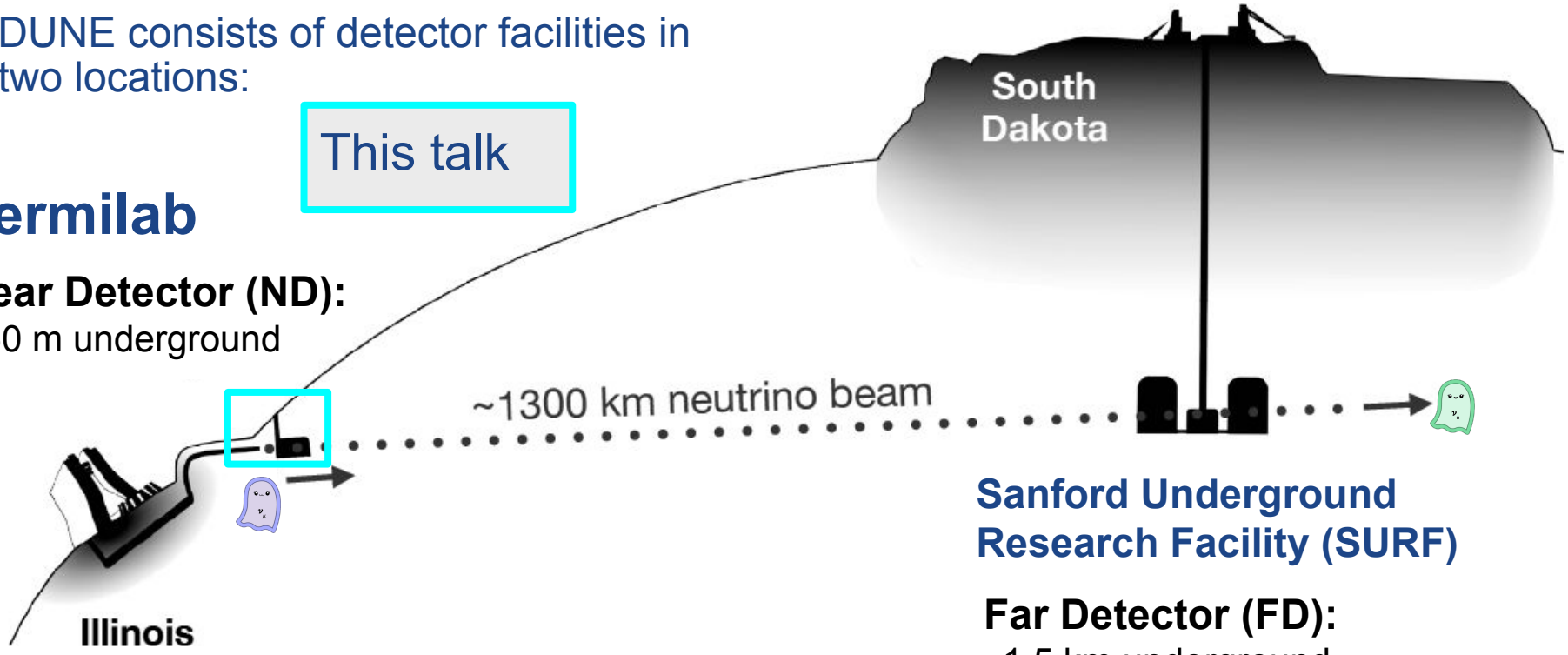
DUNE Near Detector (ND)

DUNE consists of detector facilities in two locations:

This talk

Fermilab

Near Detector (ND):
~60 m underground



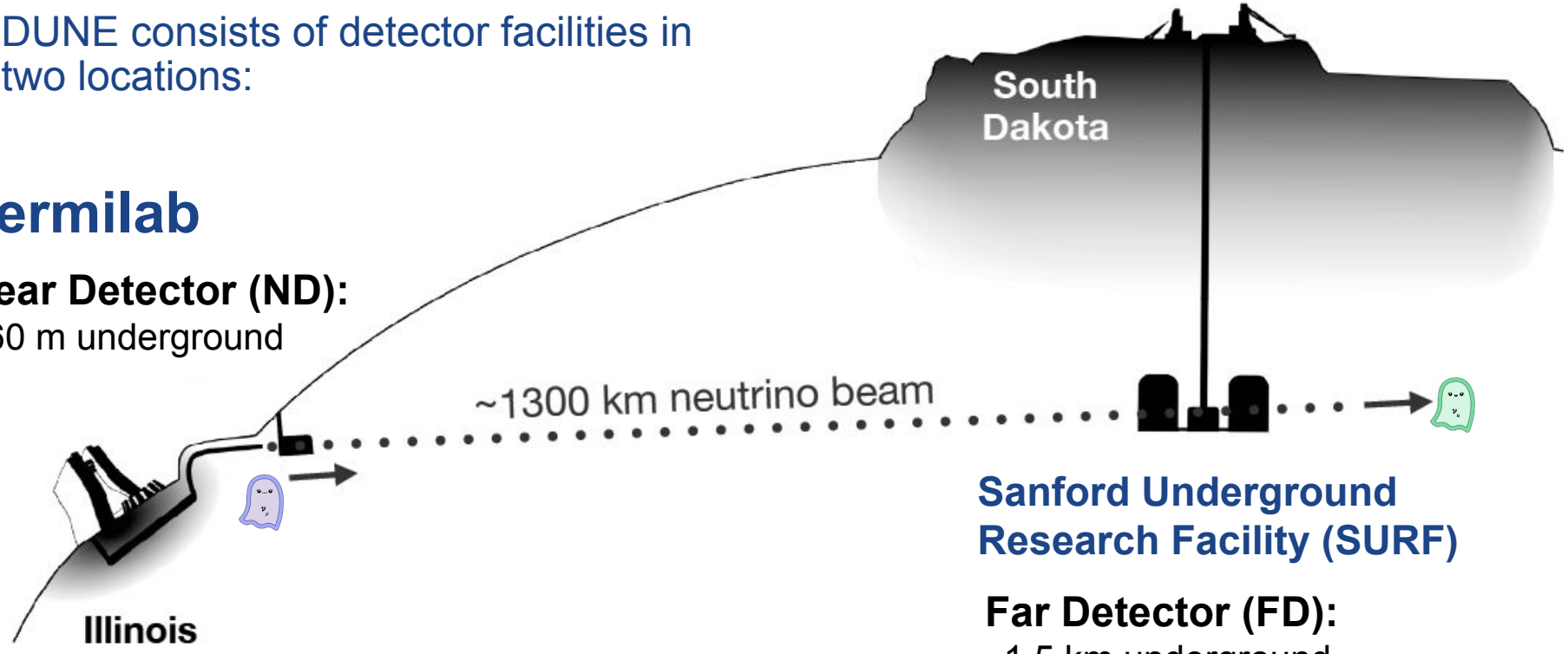
Sanford Underground Research Facility (SURF)

Far Detector (FD):
~1.5 km underground

DUNE Near Detector (ND)

See Rhiannon's talk tomorrow

DUNE consists of detector facilities in two locations:



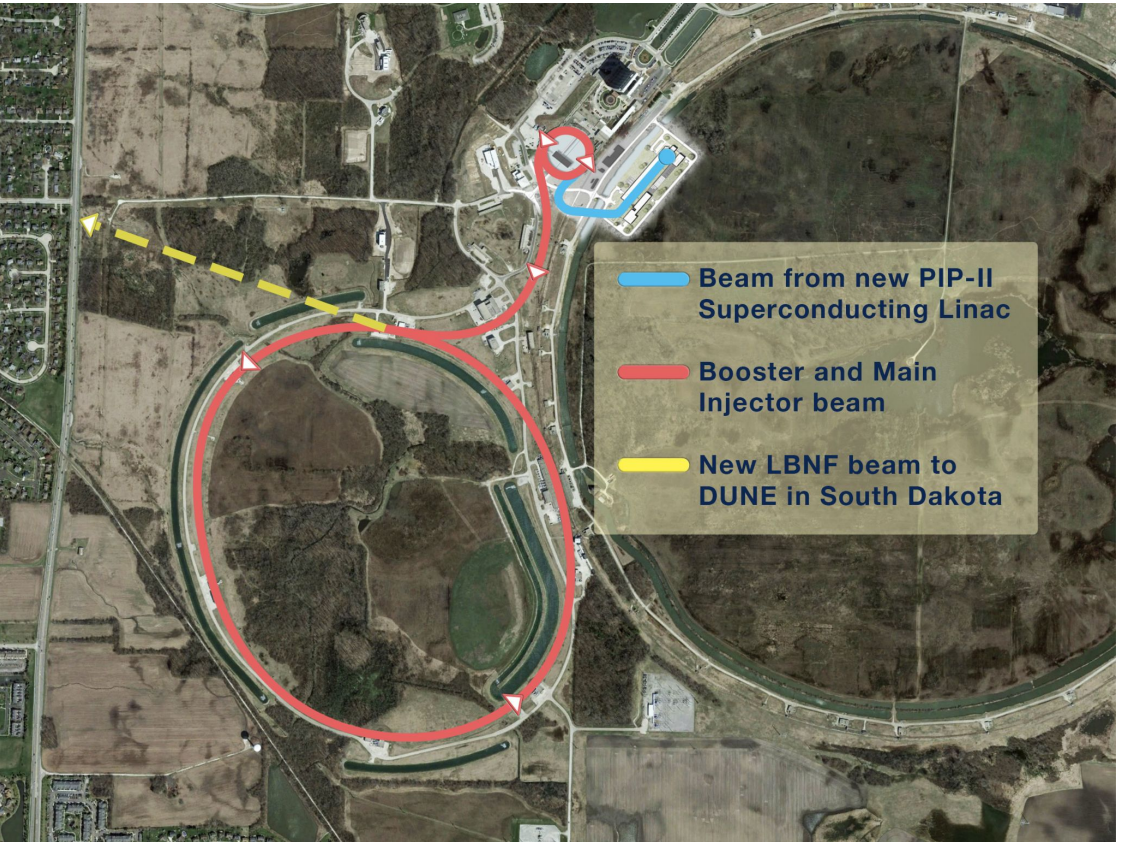
Fermilab

Near Detector (ND):
~60 m underground

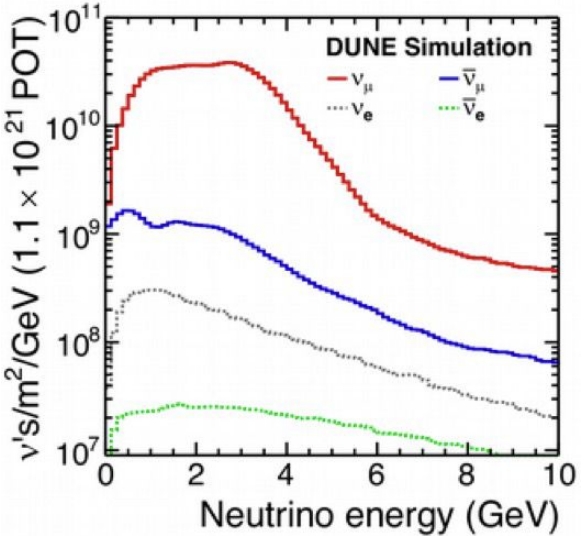
Sanford Underground Research Facility (SURF)

Far Detector (FD):
~1.5 km underground

The LBNF Neutrino Beam (PIP-II)

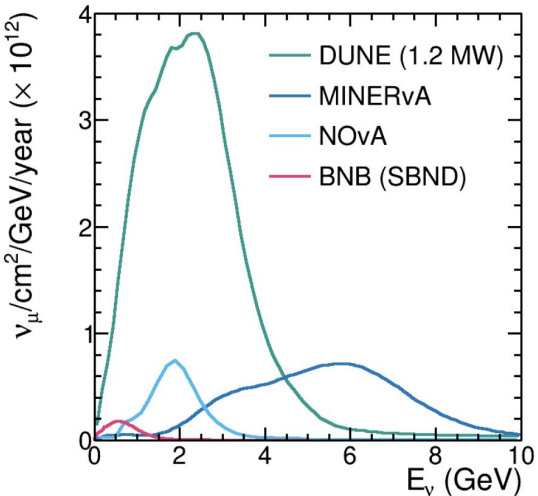


New PIP-II beam from Fermilab supplying 1.2 MW neutrino beam from 8 GeV protons

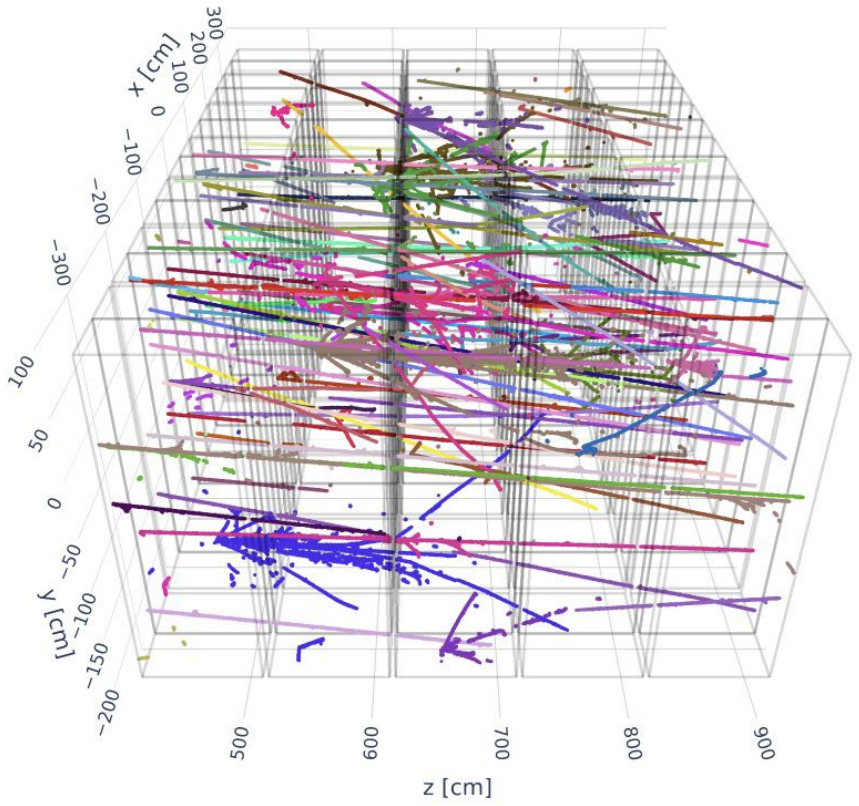


The Beam at ND

- 574 m from neutrino beam target
- ND will see about O(100) neutrino interactions per spill!
- Design optimized to detect and differentiate this unprecedented neutrino flux



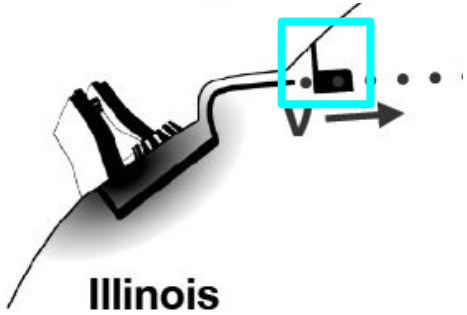
Simulation of one beam spill in ND-LAr

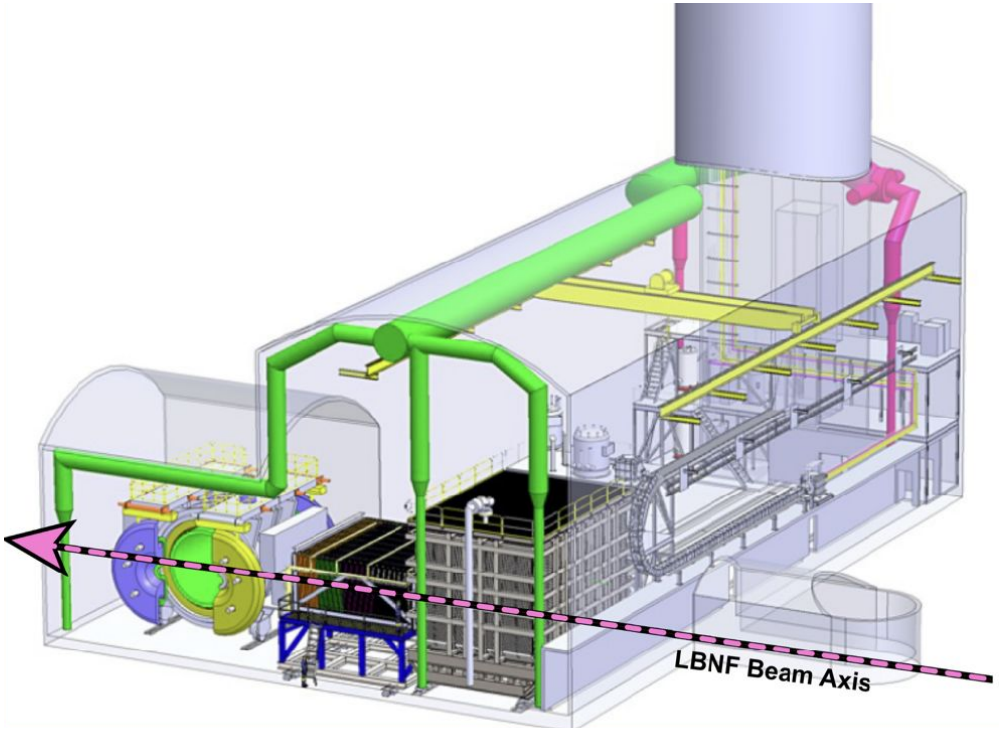


The Near Detector Complex

Consists of:

1. ND-LAr
2. TMS
3. SAND
4. PRISM

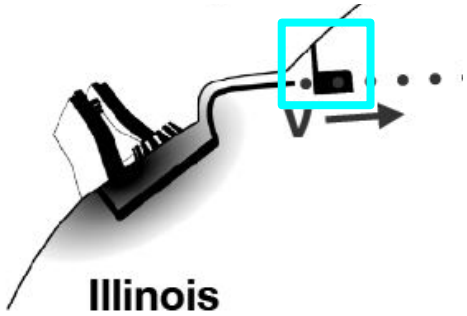


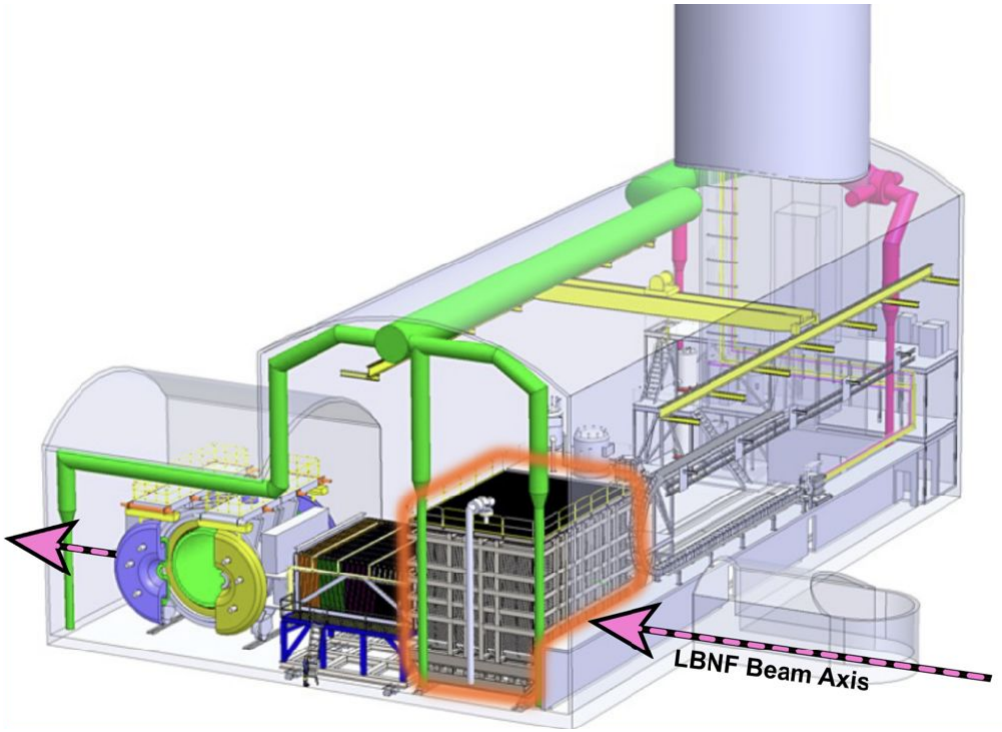


The Near Detector Complex

Consists of:

1. **ND-LAr**

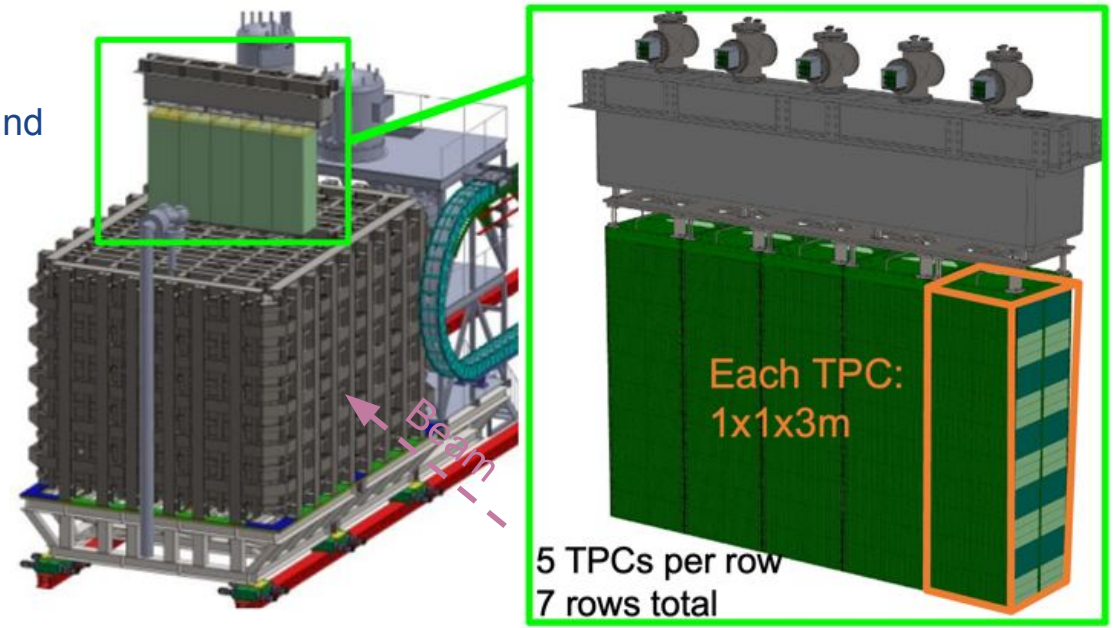




The ND-LAr Detector

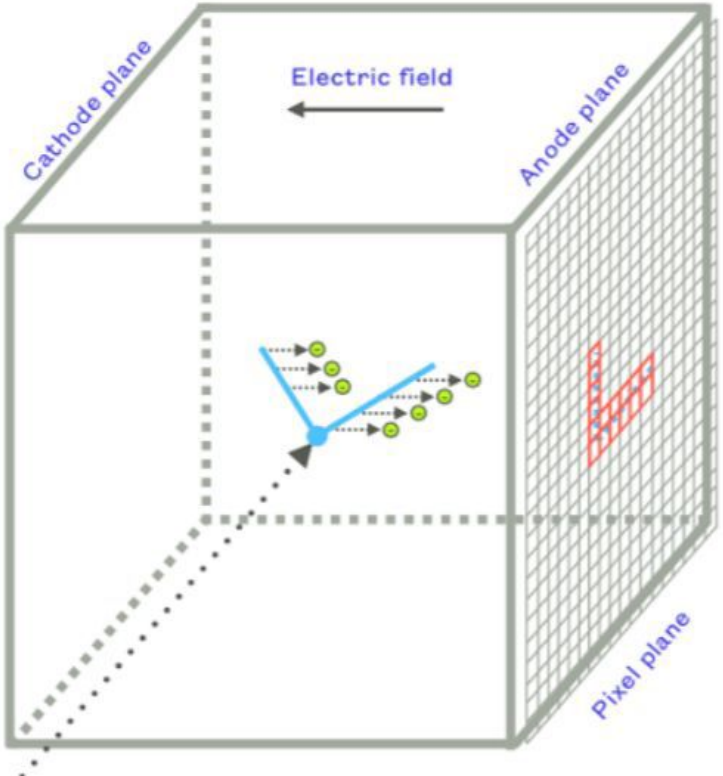
Novel design to handle unprecedented pile-up:

- Modularized detector with 35 optically isolated TPCs
  - Also allows for better background mitigation

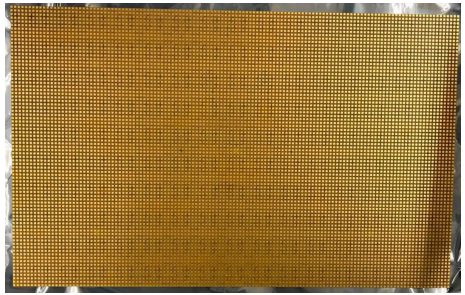


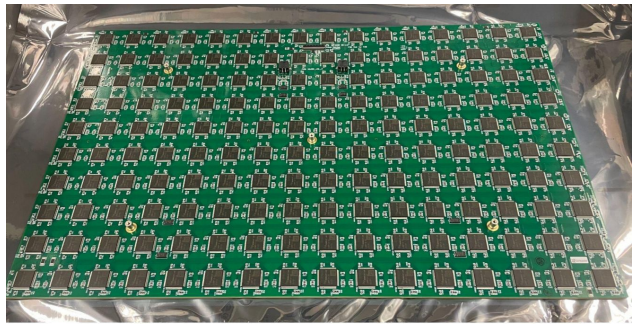
The ND-LAr Detector

Novel design to handle unprecedented pile-up:



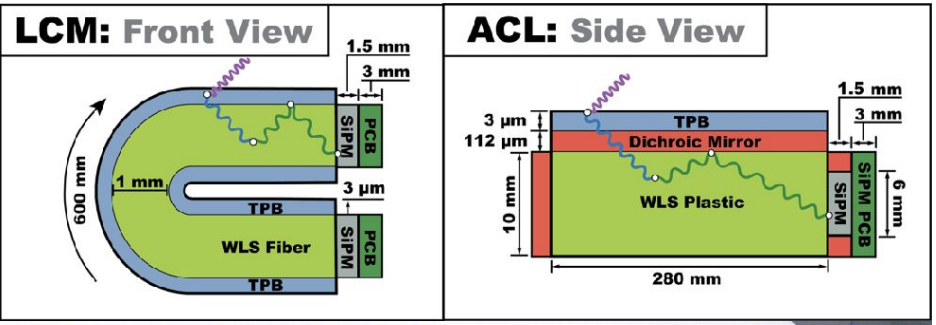
- Pixelated charge readout (LArPix) replacing traditional wires

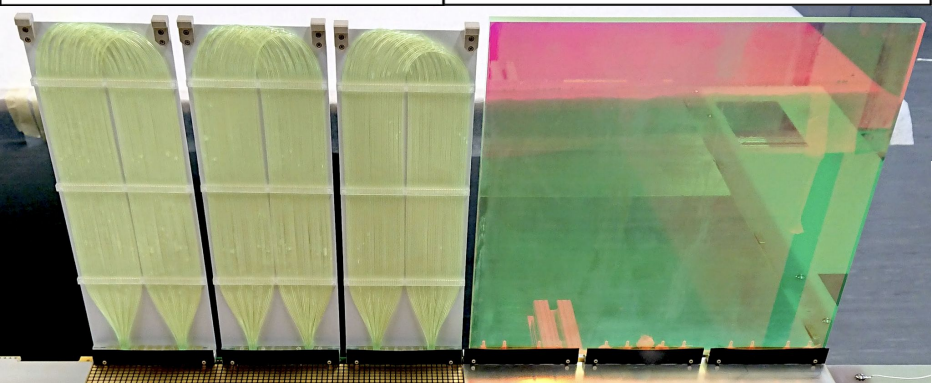




The ND-LAr Detector

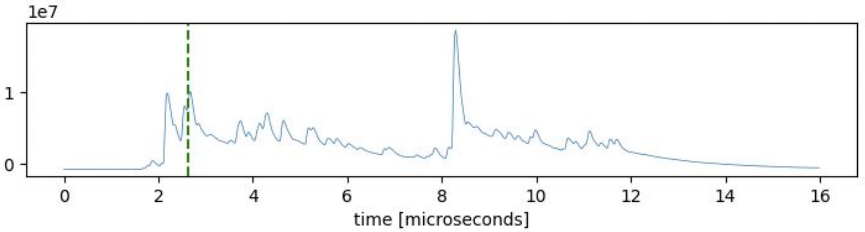
Novel design to handle unprecedented pile-up:





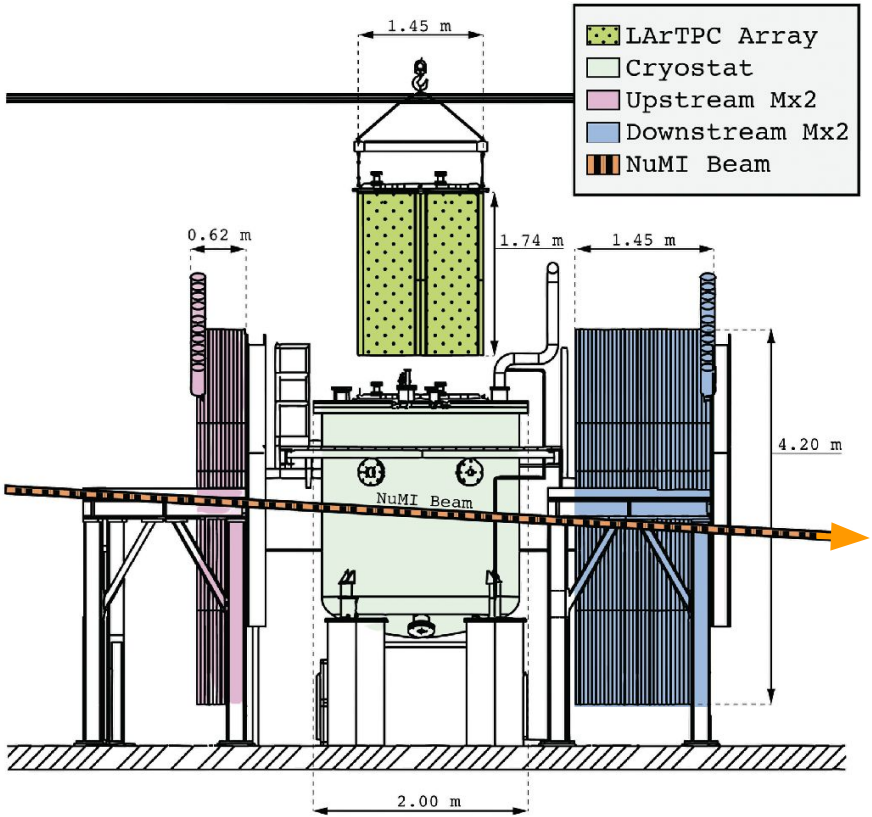
- Pixelated charge readout (LArPix) replacing traditional wires
- O(ns) timing light readout with vertical spatial resolution

Single beam spill light waveform pileup



ND-LAr Prototypes: The 2x2 Demonstrator

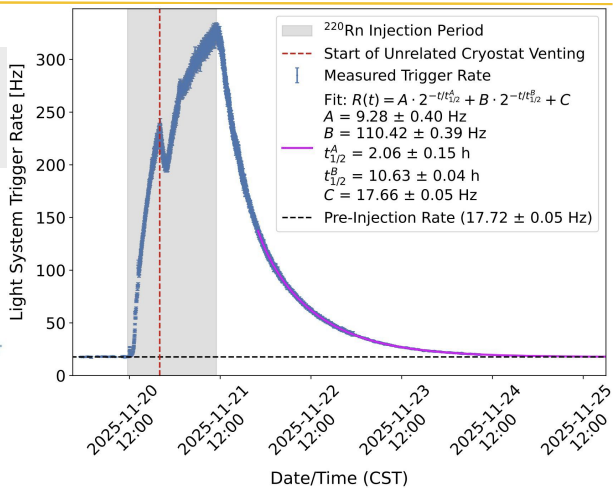
- Sits on-axis in Fermilab's Neutrinos at the Main Injector (NuMI) beam
  - Utilizes MINOS cavern and some MINERvA hardware
- 4 modules with 8 TPCs
  - 2x2 square design
- 2.4 tonne LAr active mass
- 30 cm drift length
- 384 SiPMs coupled to 128 light traps



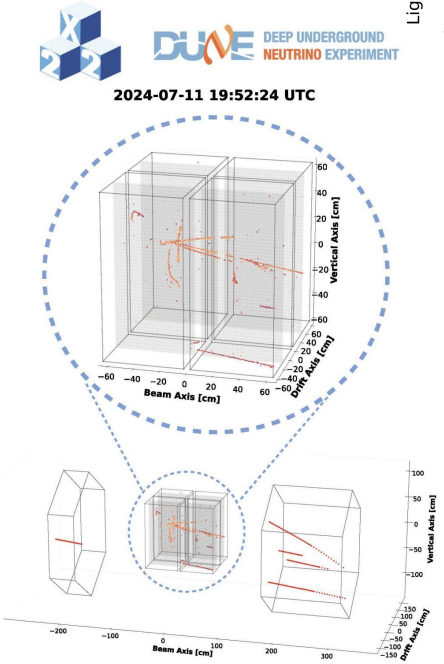
2x2 Demonstrator Status

- Run 1: 2024
  - 4.5 days of NuMI beam data
- Run 2: 2025
  - 3 months with gamma, alpha, and neutron sources
- Run 3: 2026
  - High voltage ramped on Sept. 28th
  - Expect ~12 weeks of beam, with possible extension up to 20 weeks
    - expected to record ~450k NuMI neutrino interactions
  - Currently taking cosmological and radiogenic data for cold commissioning

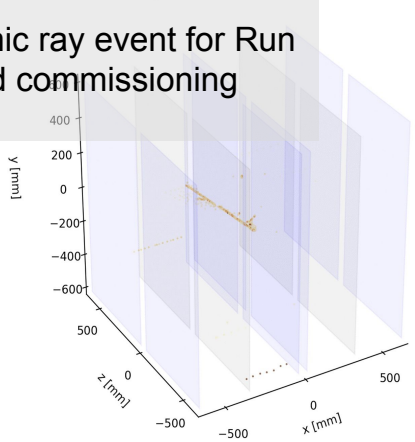
Radon injection study from Run 2 →



NuMI beam neutrino event from Run 1 ↓

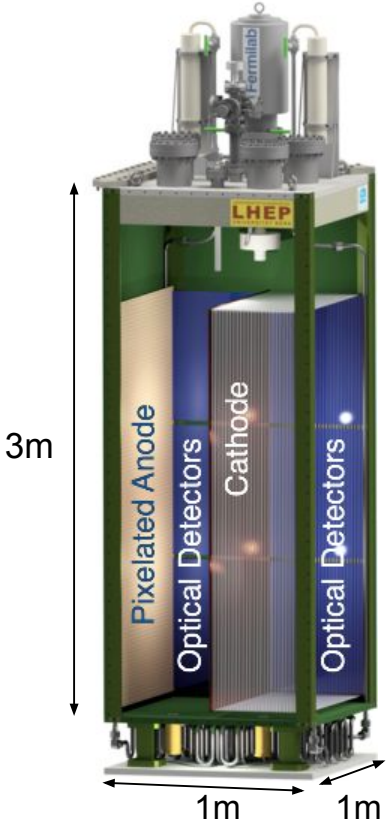


Cosmic ray event for Run 3 cold commissioning



Full Scale Demonstrator (FSD) Prototype

- 1st test of a full scale ND-LAr module
- Assembled and operated at Bern in 2024
- Collected ~70M cosmic-ray events over several weeks
- Took radioactive source data to measure low-energy scattering





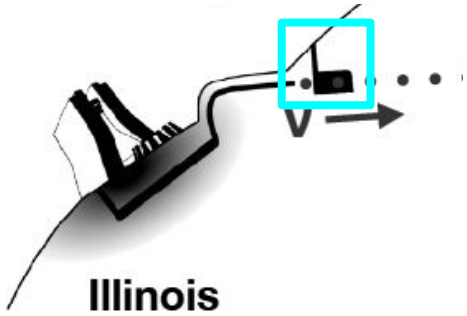


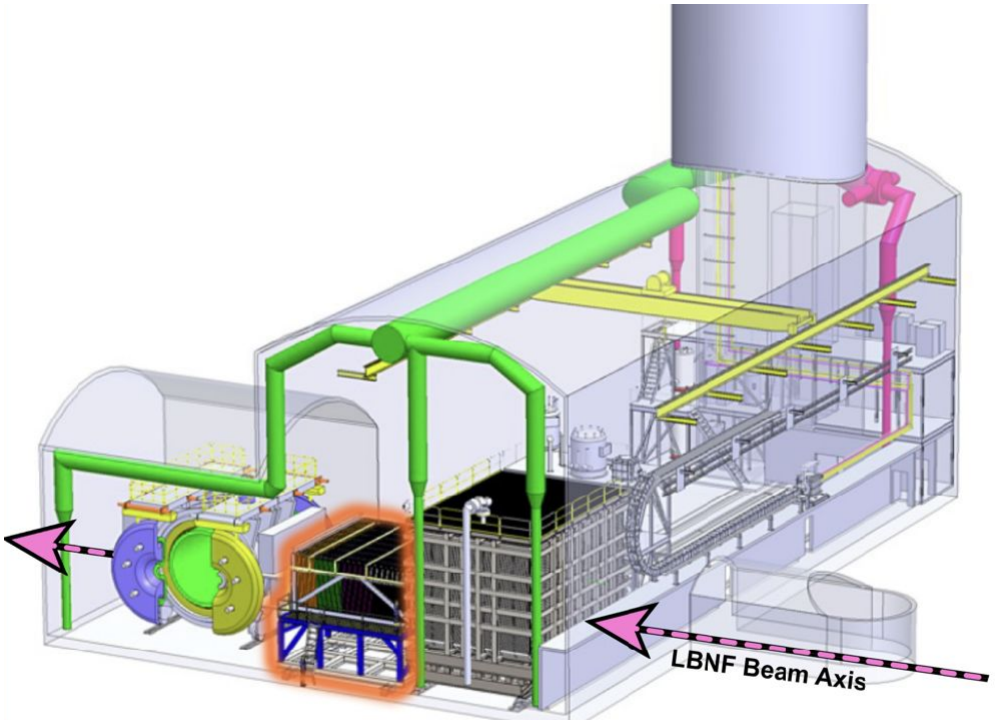


The Near Detector Complex

Consists of:

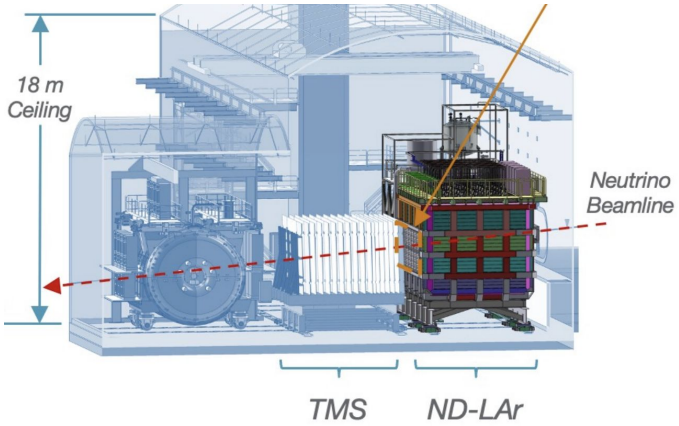
1. ND-LAr
2. **TMS**

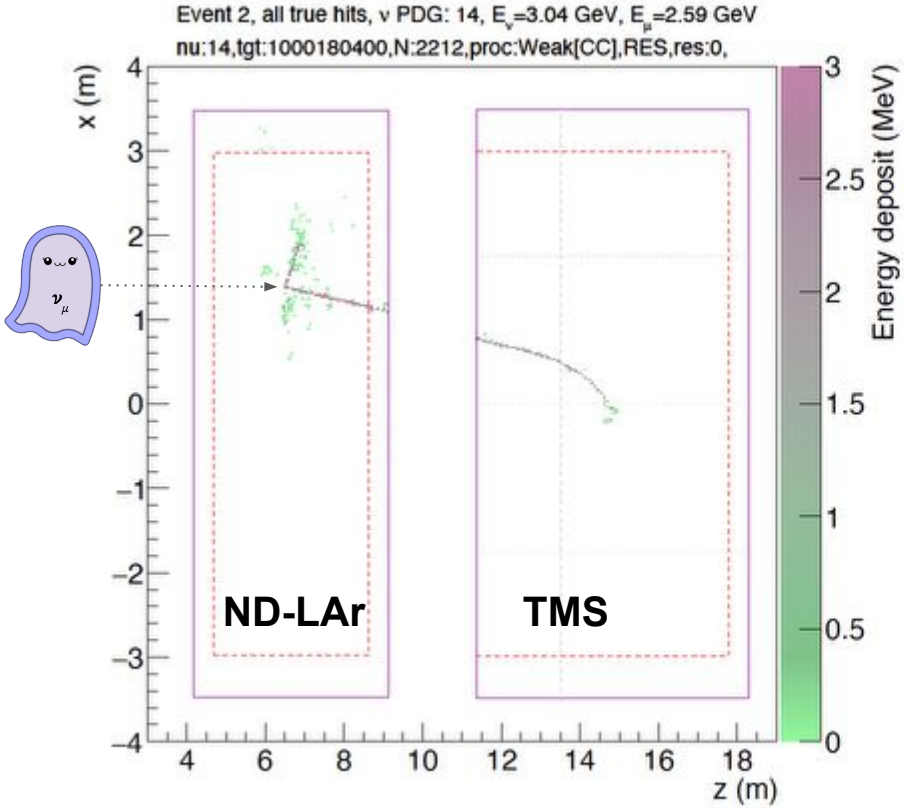




The Muon Spectrometer (TMS)

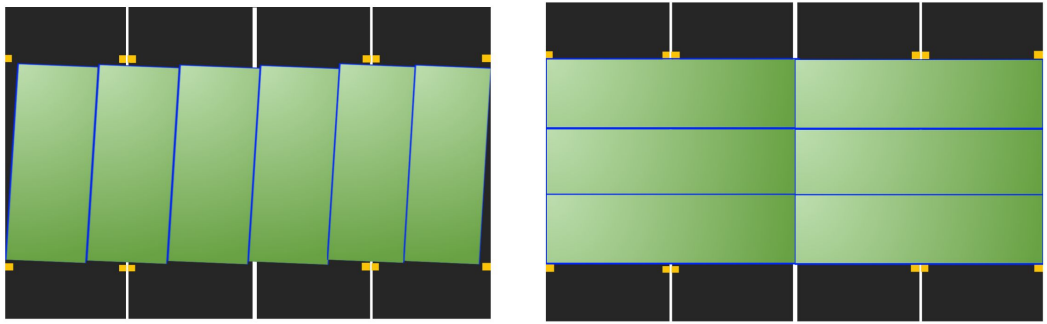
- ND-LAr will have many uncontained high-energy muons from numu CC interactions
- Goal: capture exiting muons for more accurate neutrino information
  - e.g. energy calculations



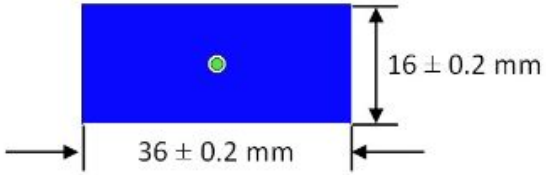


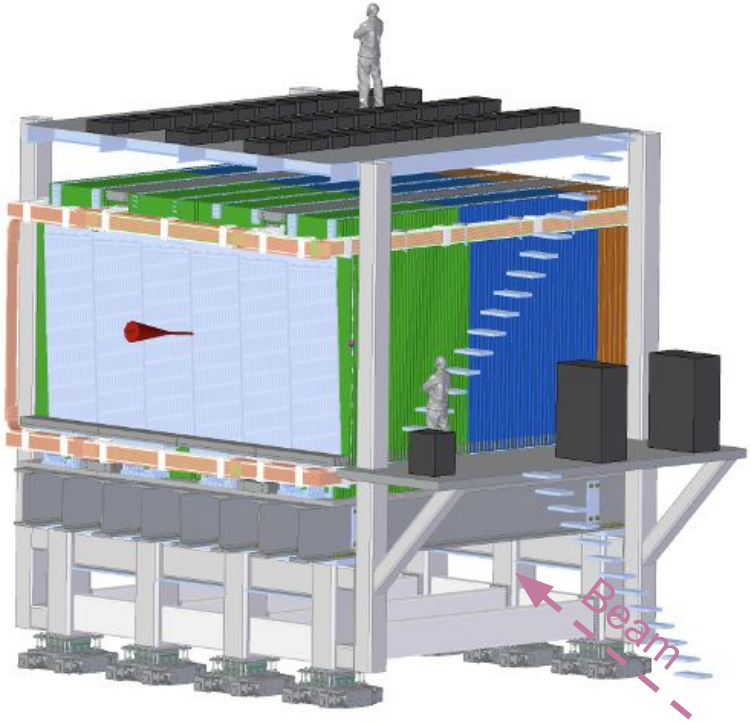
The Muon Spectrometer (TMS)

- Design finalized
- Alternating planes of steel and scintillator
- Located downstream of ND-LAr
- Stop muons from neutrino interactions up to ~5 GeV



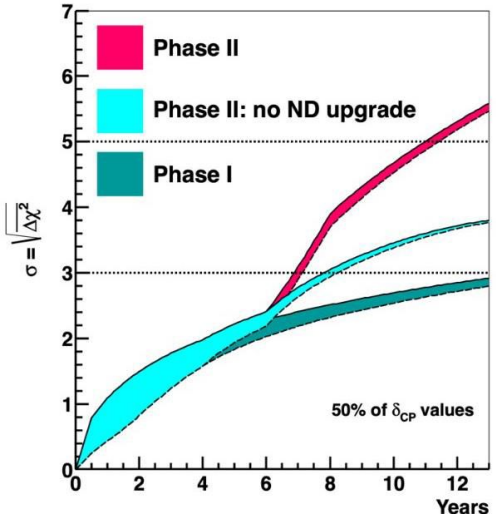
Scintillator Bar

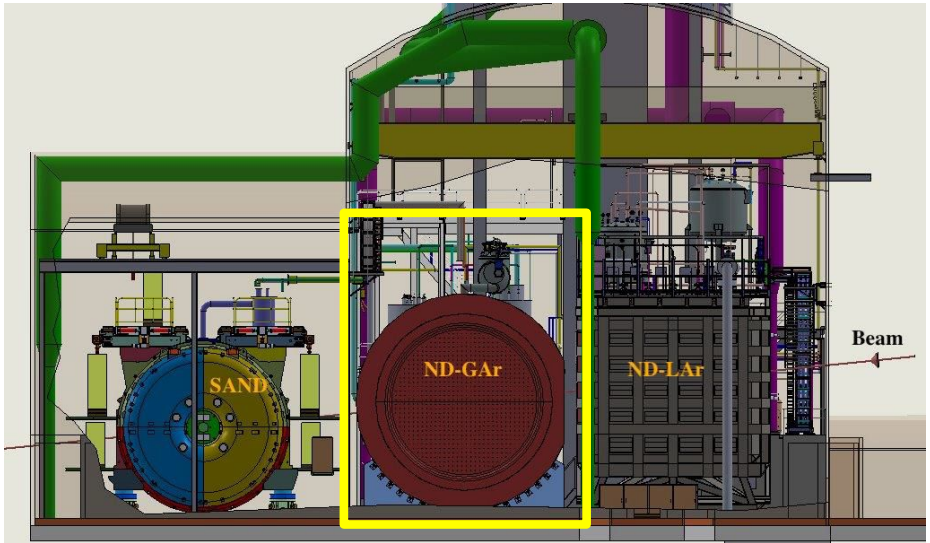


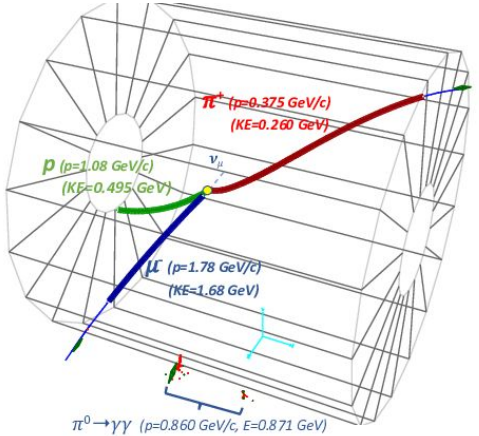


Phase II Upgrade: ND-GAr

- Upgrade TMS to argon gas detector (ND-GAr)
  - Using gaseous argon lowers energy thresholds
  - ND-GAr able to detect hadrons down to ~tens of MeV
- R&D and prototyping currently underway



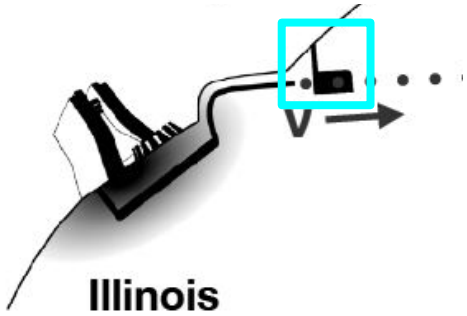


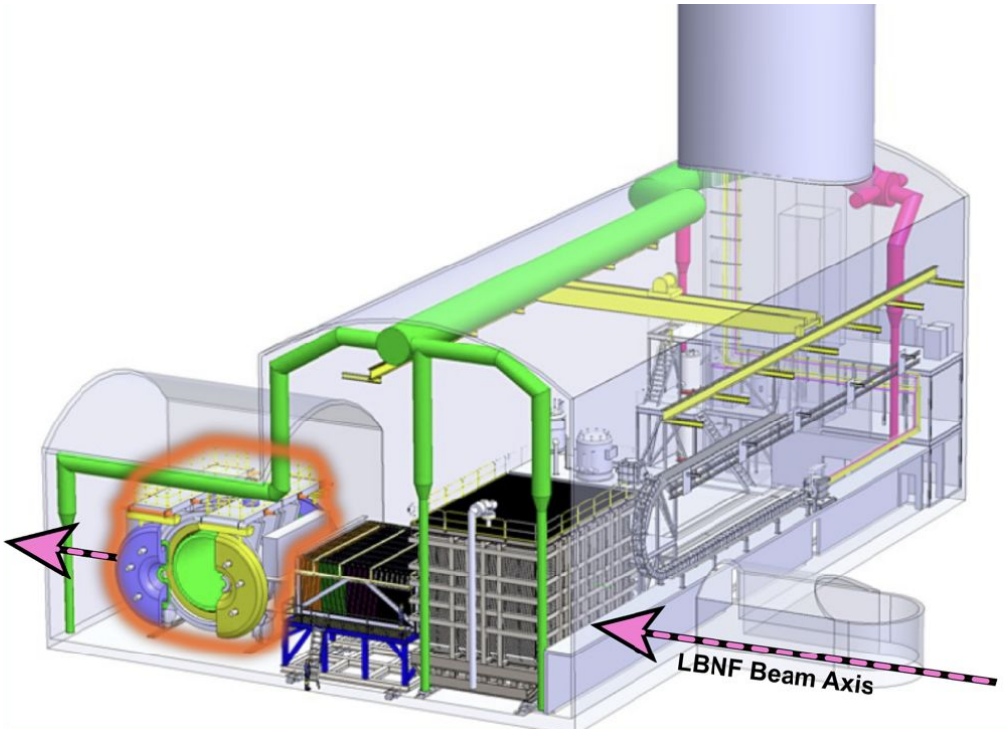


The Near Detector Complex

Consists of:

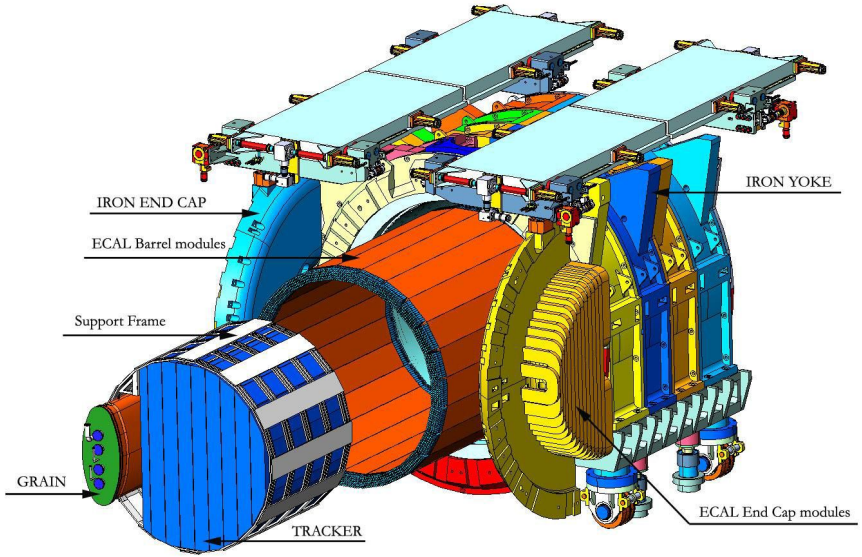
1. ND-LAr
2. TMS
3. **SAND**

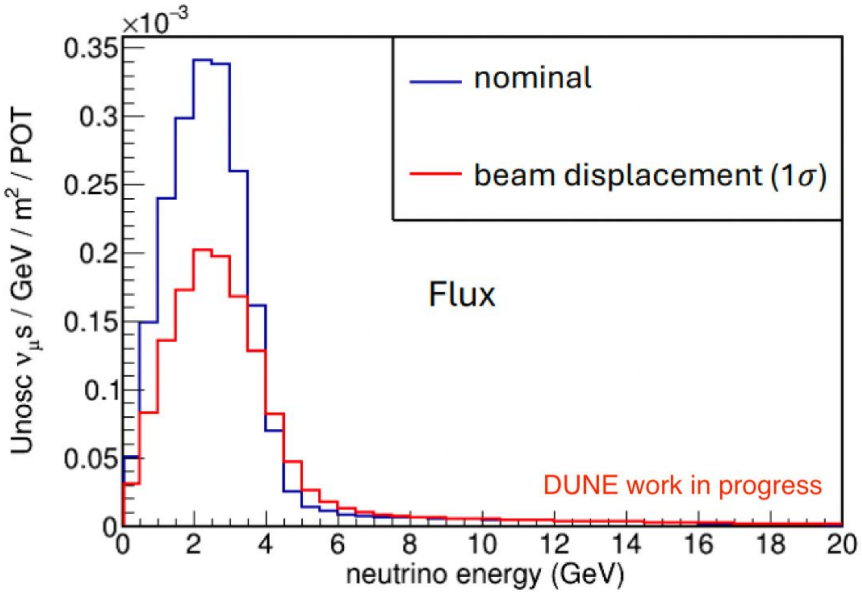




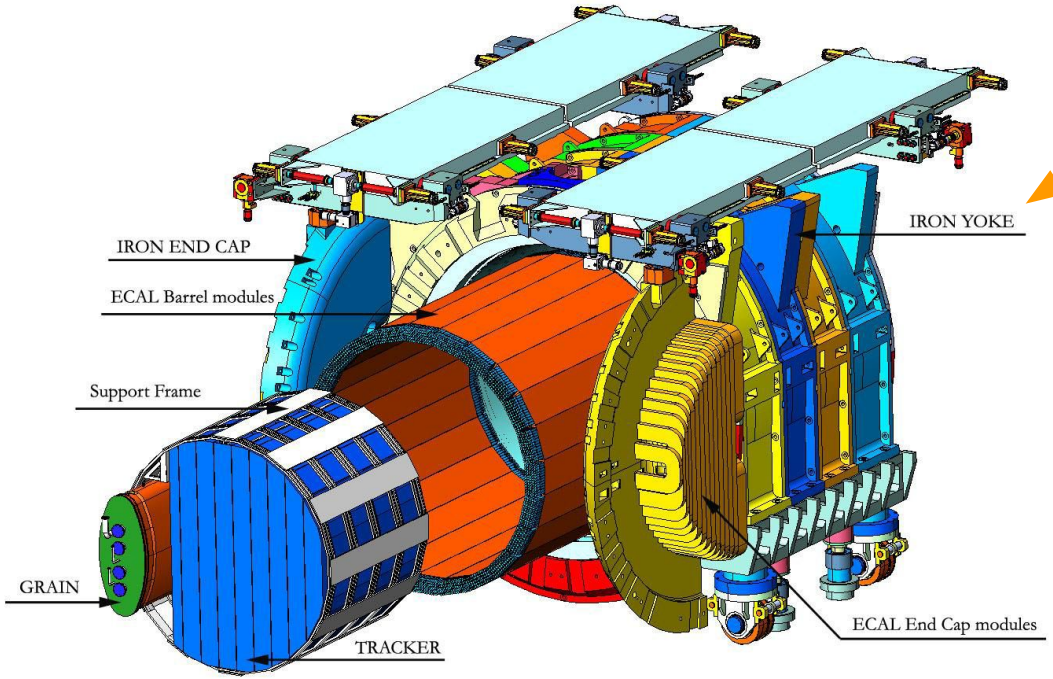
System for on-Axis Neutrino Detection (SAND)

- On-axis beam monitor downstream in ND complex
  - monitor the stability and composition of the neutrino beam
  - constrain systematic uncertainties





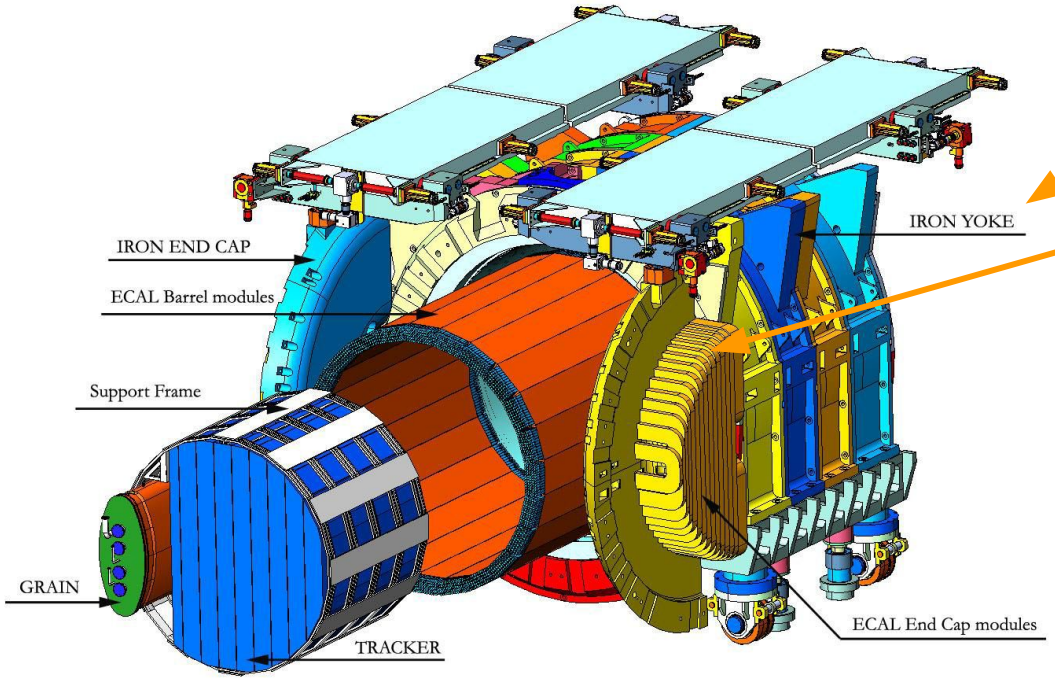
SAND Design



Consists of:

- a superconducting magnet

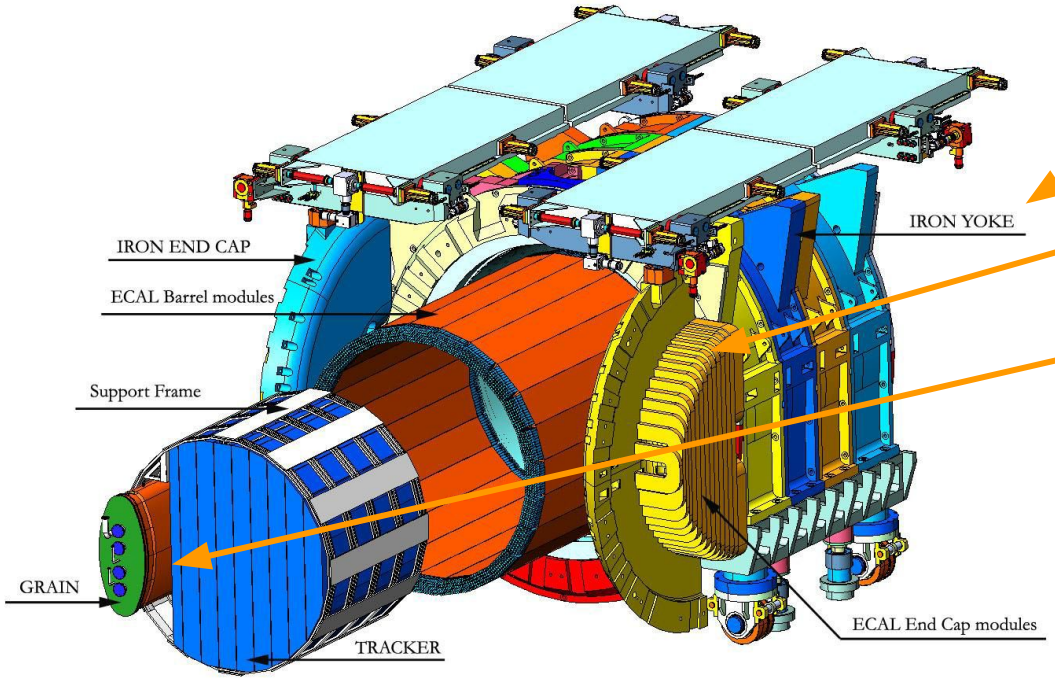
SAND Design



Consists of:

- a superconducting magnet
- an electromagnetic calorimeter (ECAL)

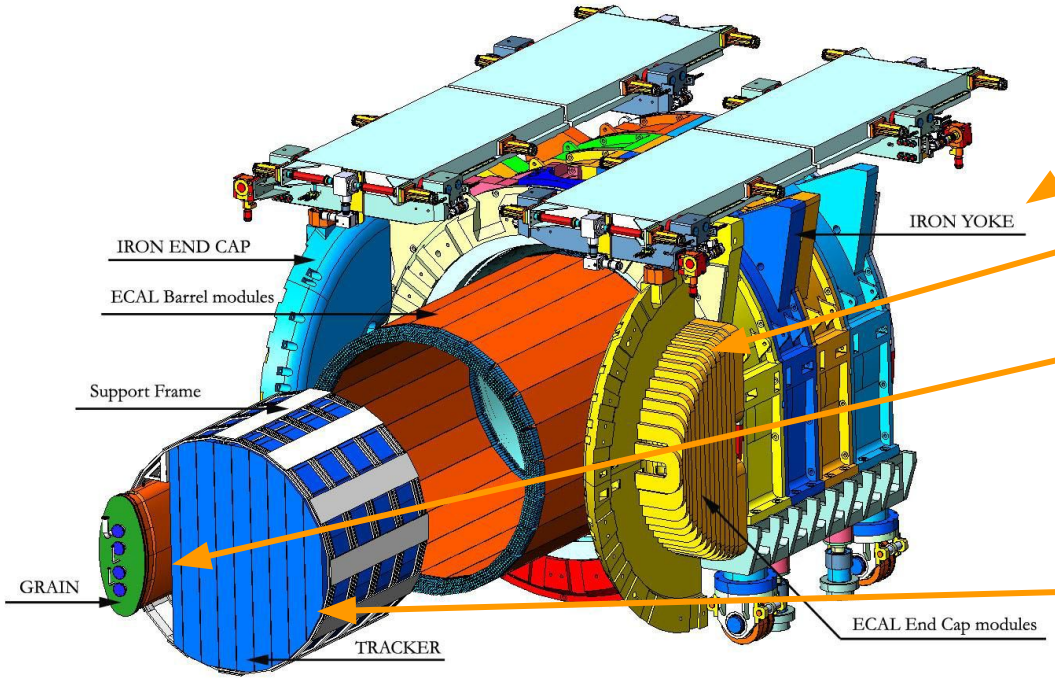
SAND Design



Consists of:

- a superconducting magnet
- an electromagnetic calorimeter (ECAL)
- a LAr active target + scintillation-based tracker
  - GRanular Argon for Interaction of Neutrinos (GRAIN)

SAND Design



Consists of:

- a superconducting magnet
- an electromagnetic calorimeter (ECAL)
- a LAr active target + scintillation-based tracker
  - GRanular Argon for Interaction of Neutrinos (GRAIN)
- a modular low-density gaseous inner volume

SAND Status

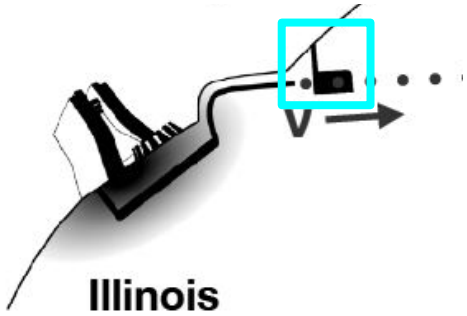
- Magnet and ECAL will be reused from KLOE experiment
  - being refurbished
- GRAIN optical systems being developed
  - 2 systems being explored: lenses vs. coded aperture masks
- Inner Tracker R&D underway
  - Base design uses a Straw Tube Tracker
  - Drift Chamber being explored as backup
- Integration tests ongoing →

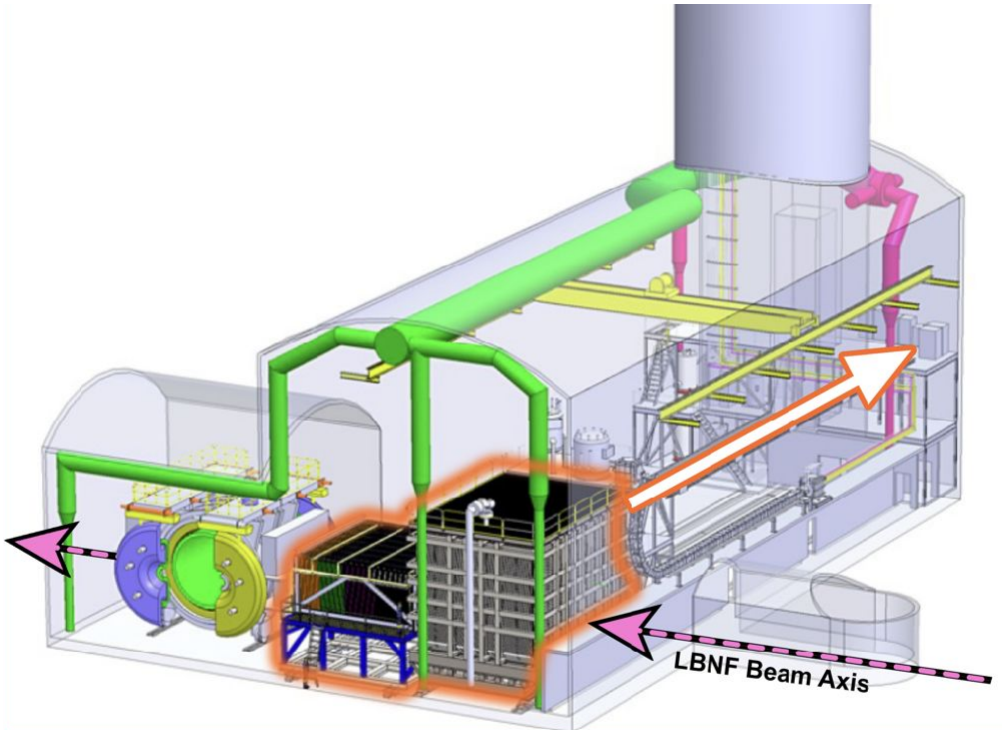


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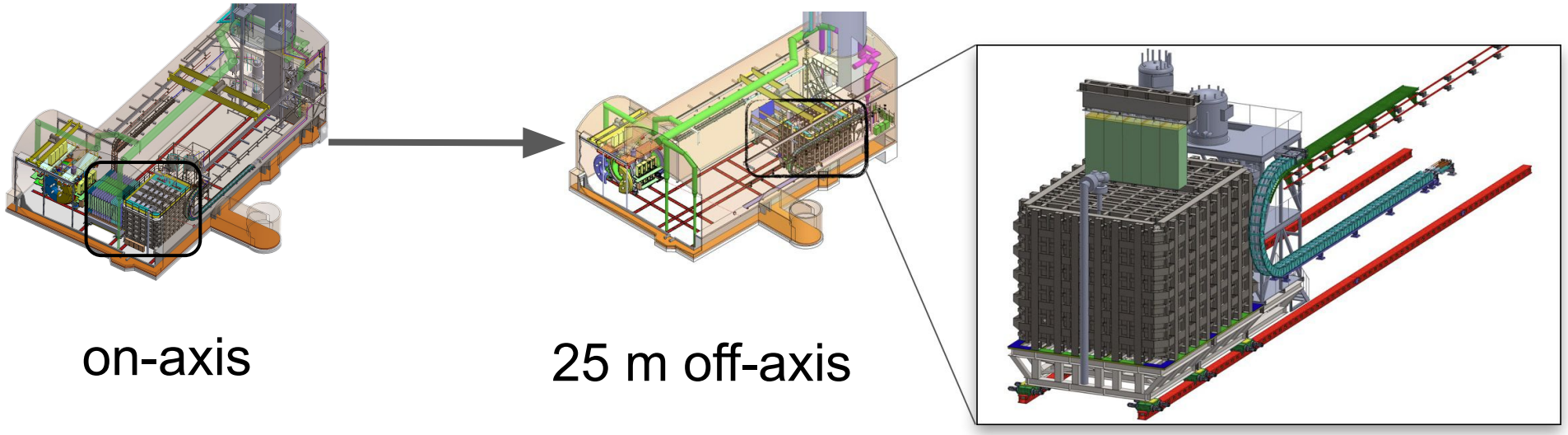
1. ND-LAr
2. TMS
3. SAND
4. **PRISM**





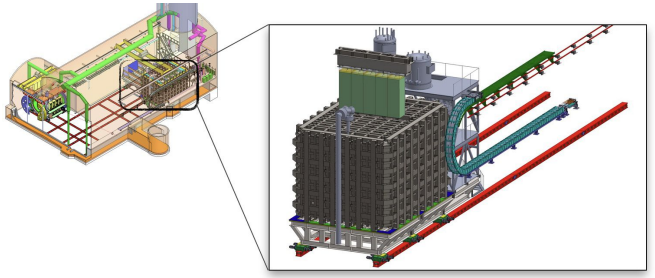
PRISM

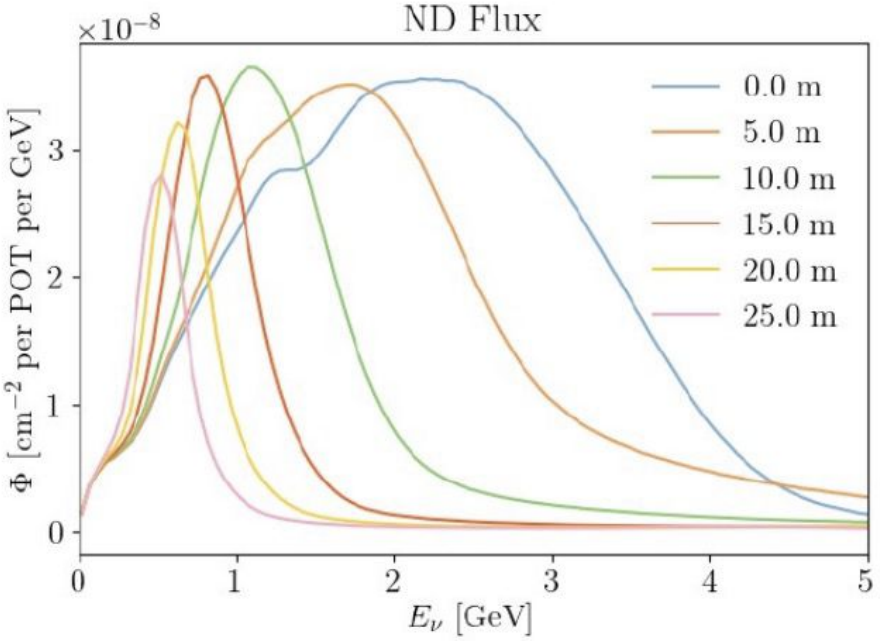
ND-LAr and TMS can move up to 28.5 m off-axis



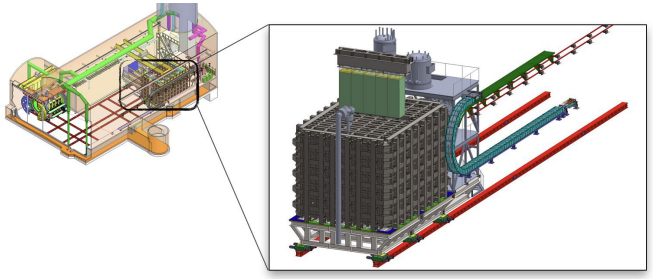
PRISM

- ND-LAr and TMS can move up to 28.5 m off-axis
- Allows for observations of varied beam spectra
  - ND flux changes with angle due to pion decay kinematics
- Constrain energy dependence of neutrino cross sections → build oscillation analysis with minimal interaction modeling





PRISM



- ND-LAr and TMS can move up to 28.5 m off-axis
- Allows for observations of varied beam spectra
  - ND flux changes with angle due to pion decay kinematics
- Constrain energy dependence of neutrino cross sections → build oscillation analysis with minimal interaction modeling
- Testing underway in Minnesota →



DUNE Near Site Status

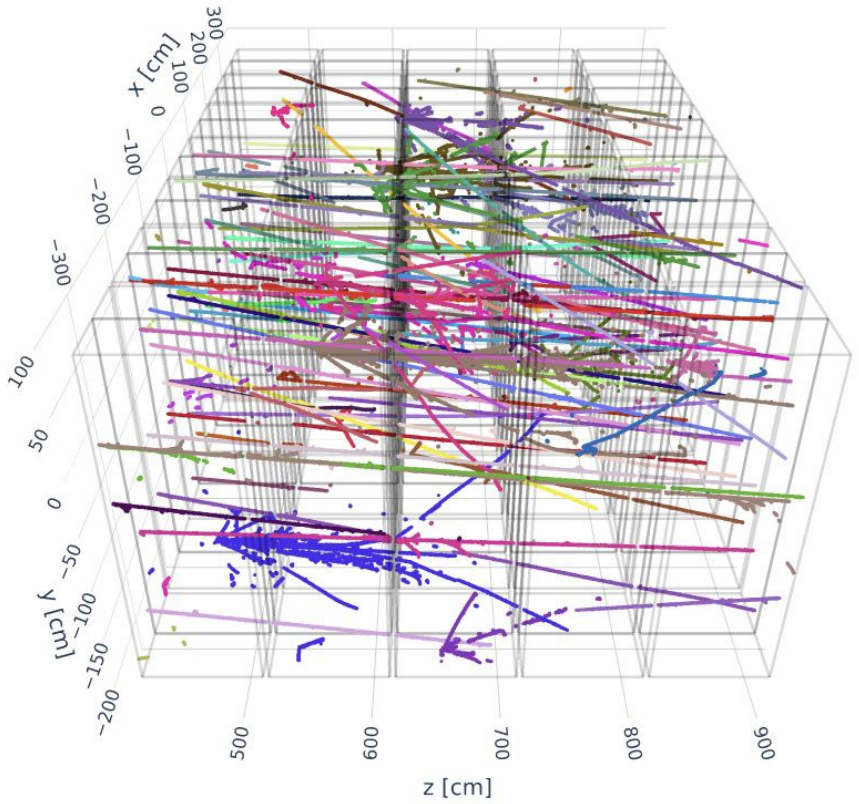
- DUNE Near Detector Facility steadily moving towards final designs
  - a Technical Design Report (TDR) is in preparation
- DUNE Cold lab – Material Assembly Test Facility (MATF) – at Fermilab progressing well and received the first test equipment

DUNE Cold lab at Fermilab



Summary

- The DUNE Near Detector is essential to reaching DUNE's physics goals
- The ND has been designed to handle an unprecedented neutrino flux from the LBNF beam
- DUNE ND detector and facility designs are mostly finalized
- A number of R&D and prototyping efforts are underway and showing good results
- The DUNE ND plans for first beam physics data in 2032



Thank You!

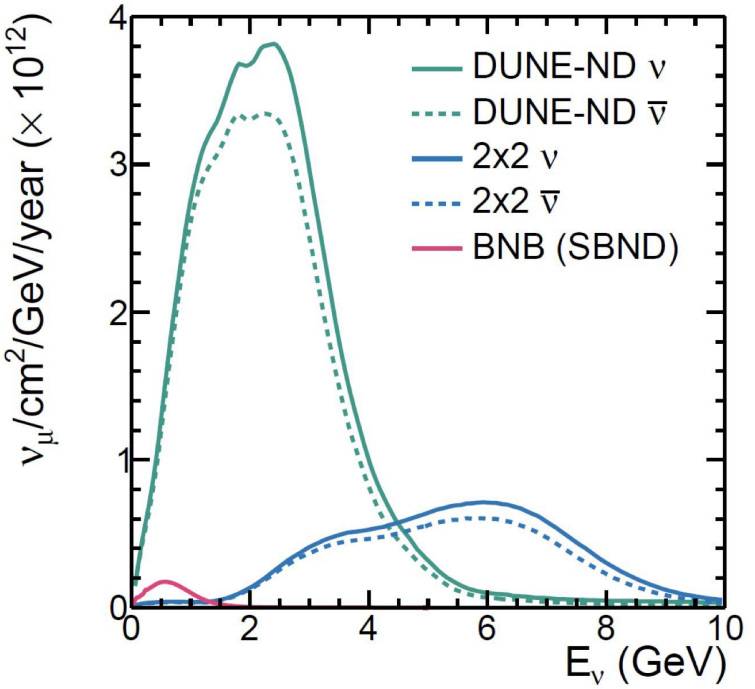


Backup

2x2 Demonstrator Analyses

Neutrino Analyses:

- Neutron Production
- Mesonless with muon antineutrino
- Neutral Pion Production
- NC Elastic



Comparisons of NuMI on-axis flux to BNB and DUNE (LBNF) fluxes.

2x2 Demonstrator Analyses

Other Analyses:

- Gamma Pointing
  - Gamma emitters: Co60, Y88, Na22
- Neutron Captures
  - Neutron sources: AmBe and DTG
- Radon Injection
  - Rn220
  - Beta and alpha decays
- Activation of detector components

