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UNIVERSITÄT
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AEC
ALBERT EINSTEIN CENTER
FOR FUNDAMENTAL PHYSICS

LABORATORIUM FÜR HOCHENERGIEPHYSIK
LHEP
UNIVERSITÄT BERN

DEEP UNDERGROUND NEUTRINO EXPERIMENT



STATUS AND PERSPECTIVES OF THE **DUNE** EXPERIMENT

Antonio Ereditato, University of Bern, for the DUNE Collaboration

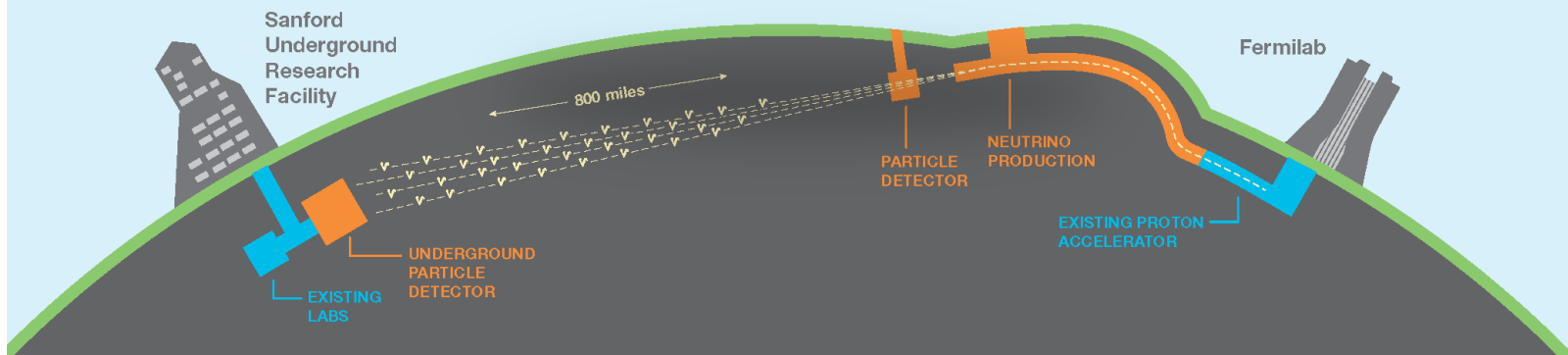


DUNE Experiment

DEEP UNDERGROUND **NEUTRINO** EXPERIMENT

Neutrino beam physics: study LBL ν_e **appearance** and ν_μ **disappearance** in a WBB to measure **MH**, **CPV**, and neutrino mixing parameters in a single experiment. Deep underground location reduces cosmogenic background and enables sensitivity to low-energy physics.

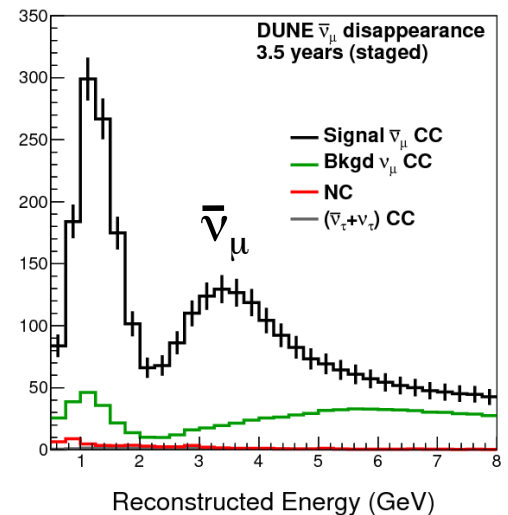
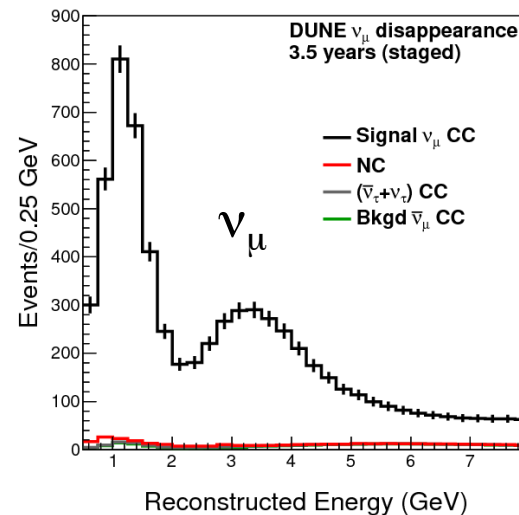
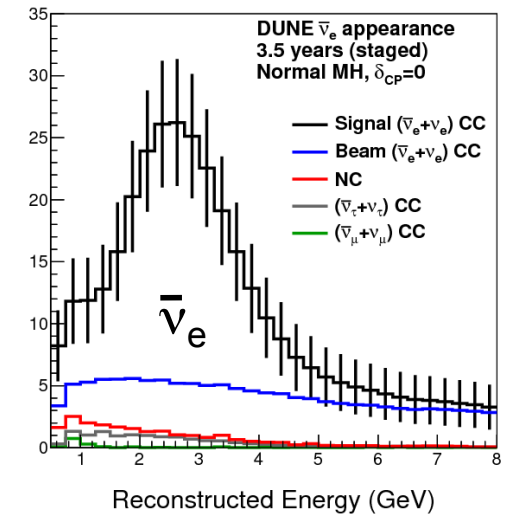
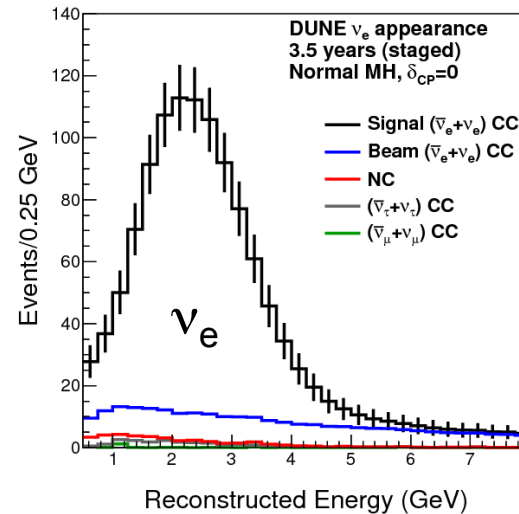
Underground neutrino observatory: unique opportunity for **matter instability** searches, **SN** neutrino detection, atmospheric neutrinos,...



Oscillation sensitivity

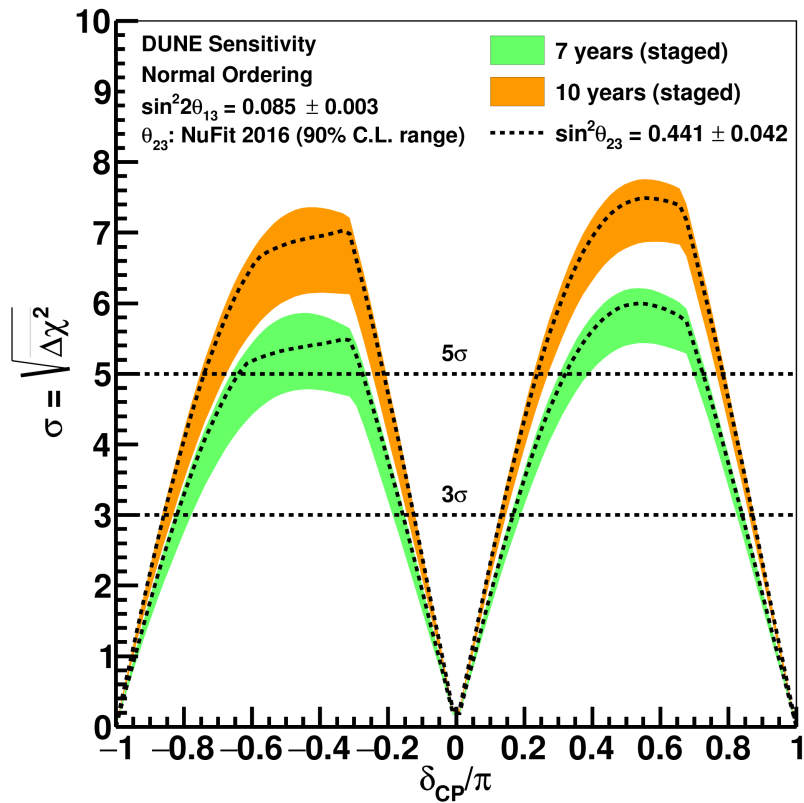
DUNE Conceptual Design Report (CDR)
arXiv:1512.06148

Order 1000 ν_e appearance events in ~ 7 years of equal running in neutrino and antineutrino mode

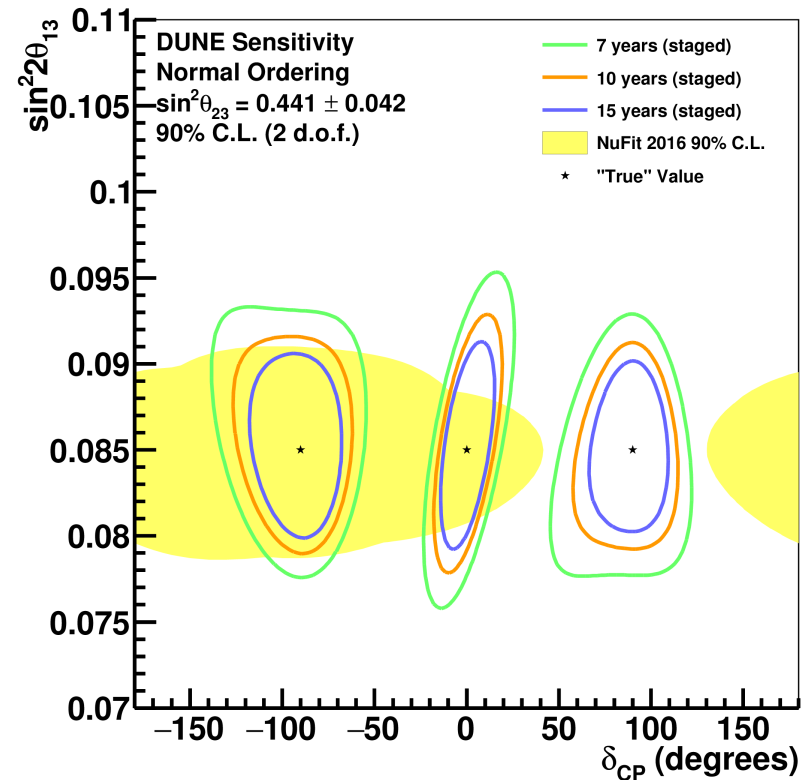


Sensitivity to CPV

CP Violation



Width of band indicates variation in possible central values of θ_{23}

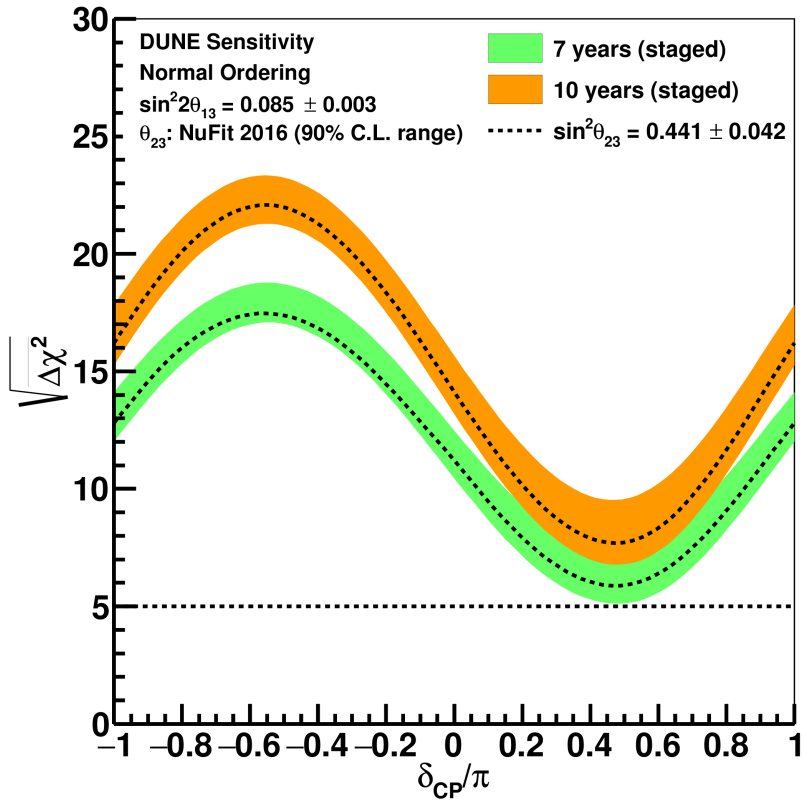


Simultaneous measurement of neutrino mixing angles and δ_{CP}

Other oscillation measurements

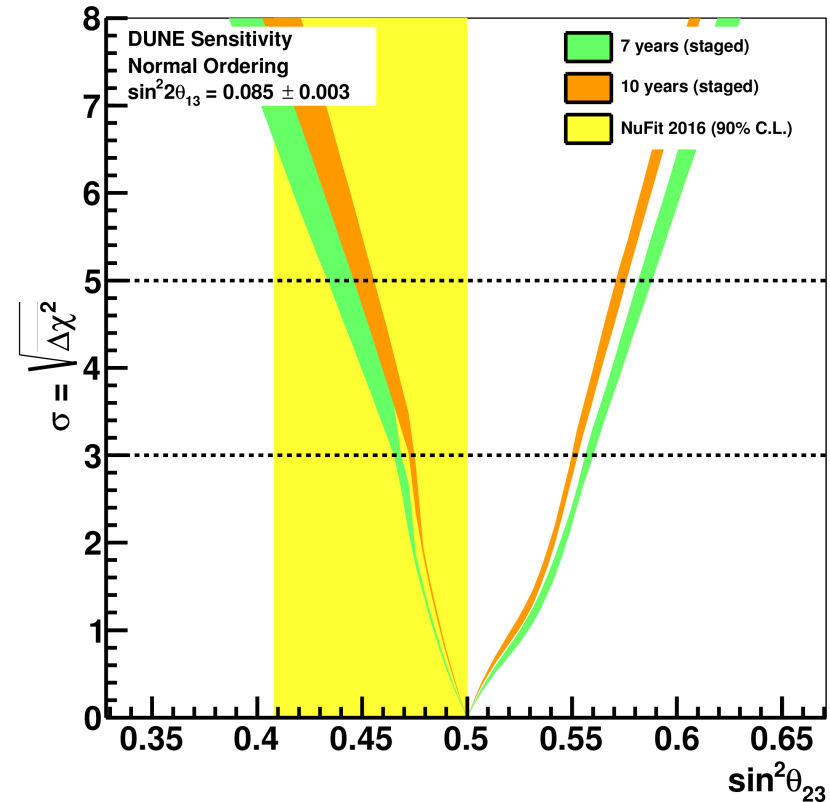
DUNE CDR

Mass Ordering



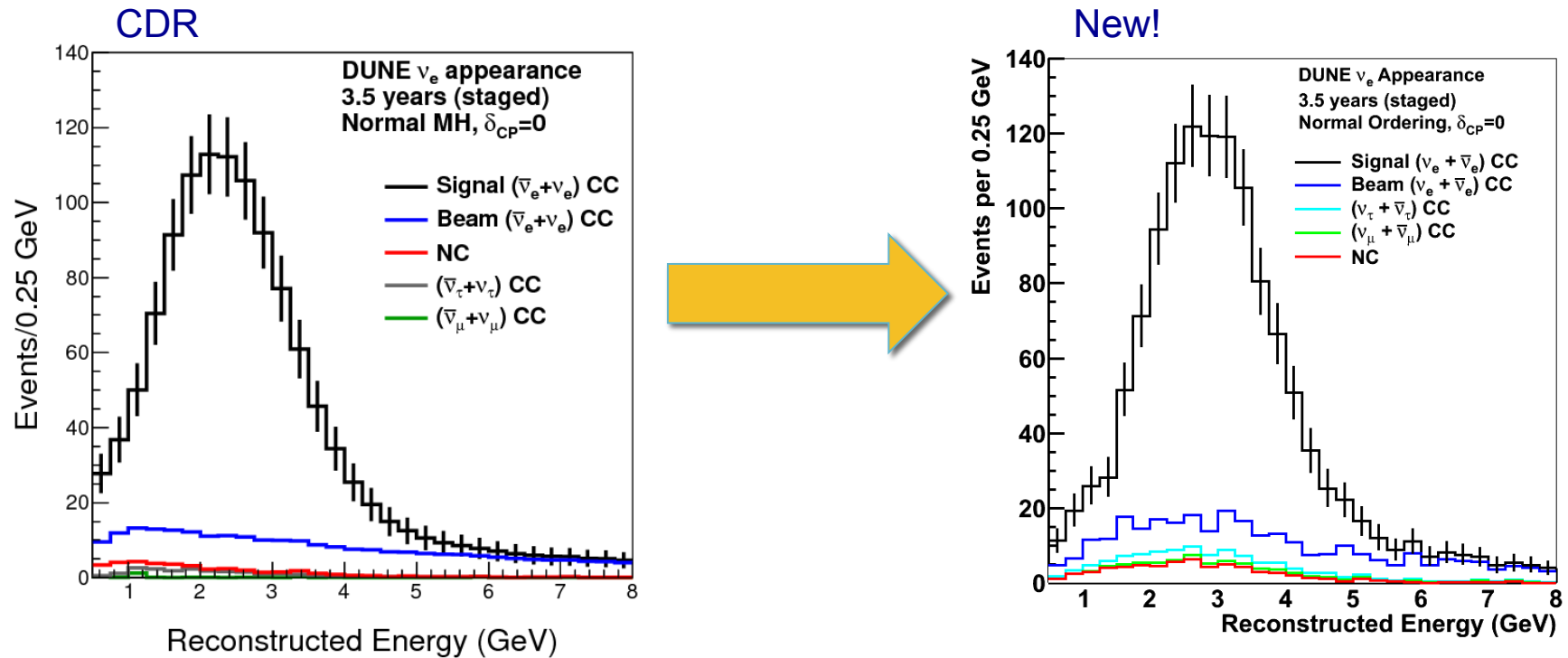
Width of band indicates variation in possible central values of θ_{23}

Octant



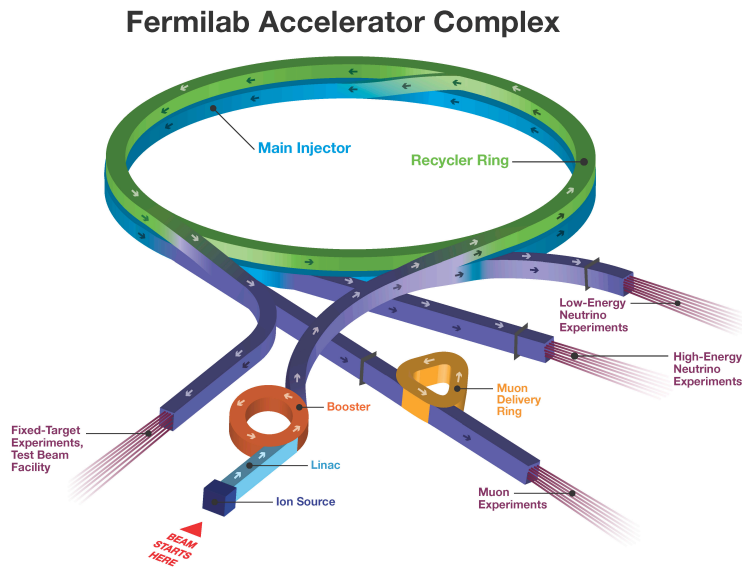
Width of band indicates variation in possible true value of δ_{CP}

Improved simulations (w.r.t. CDR)

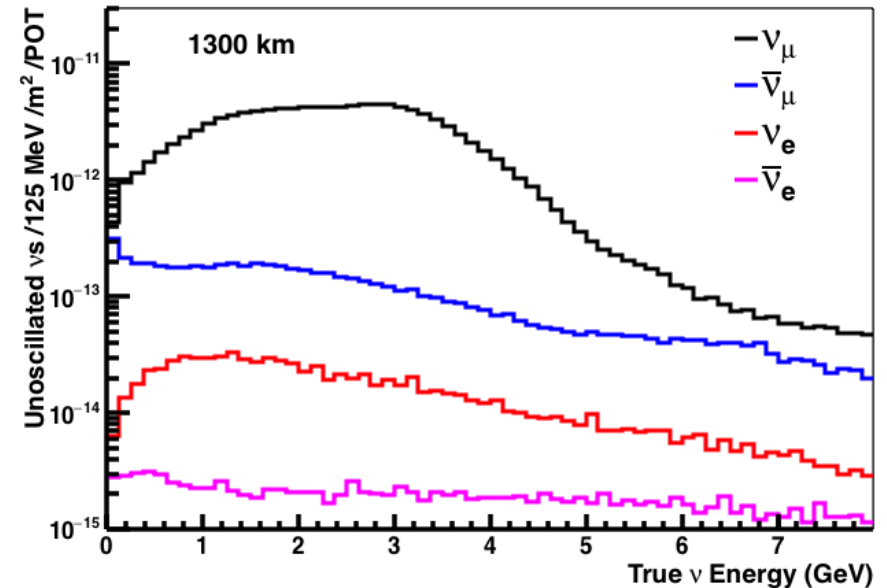


Sensitivity from MC-based analysis with automated reconstruction and event selection exceeds CDR sensitivity!

LBNF Beam



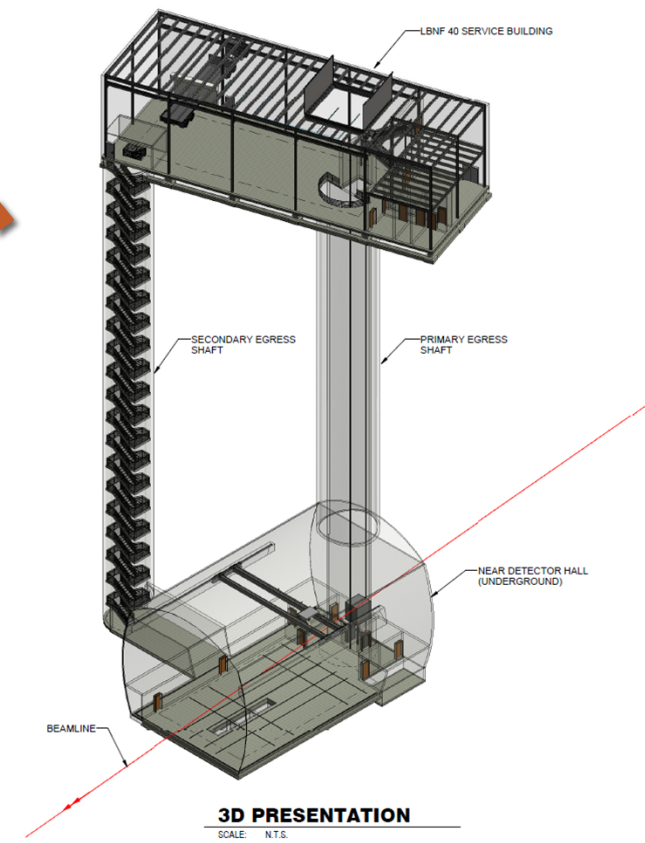
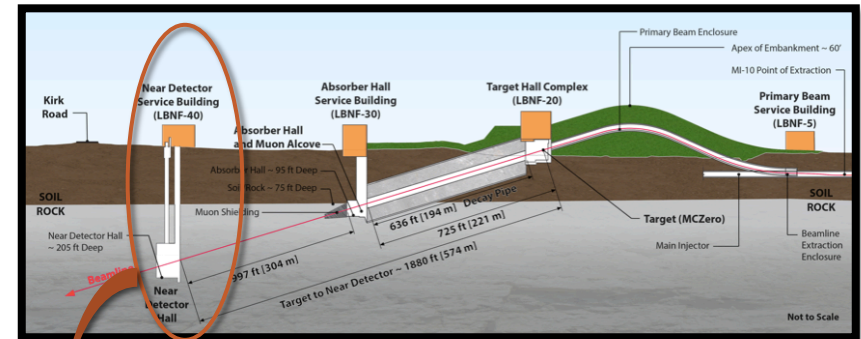
Neutrino Flux at 1300 km (CDR Optimized Beam)



- 60-120 GeV proton beam
- 1.2 MW, upgradeable to 2.4 MW
- Horn-focused neutrino beam optimized for CPV sensitivity
- Design of 3-horn focusing system based on optimized parameters (in progress)
- Neutrino and antineutrino modes

DUNE Near Detector

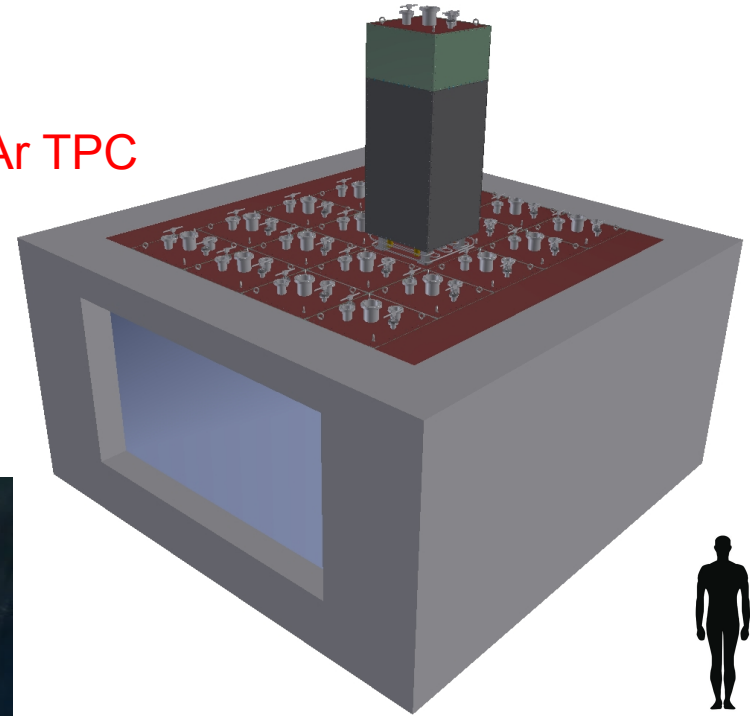
- Constrain systematics for long-baseline oscillation analysis: flux, cross-section, and detector uncertainties
- DUNE ND design concept near final (ND Design Group)
- Conceptual Design Report (CDR) planned for 2019
- DUNE ND design concept is an integrated system composed of multiple detectors:
 - Modular, pixel readout LAr TPC
 - Magnetized multi-purpose tracker
 - Electromagnetic calorimeter
 - Muon chambers
- Conceptual design will preserve option to move ND for off-axis measurements



Example the ArgonCube-like LAr TPC

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DUNE LAr TPC

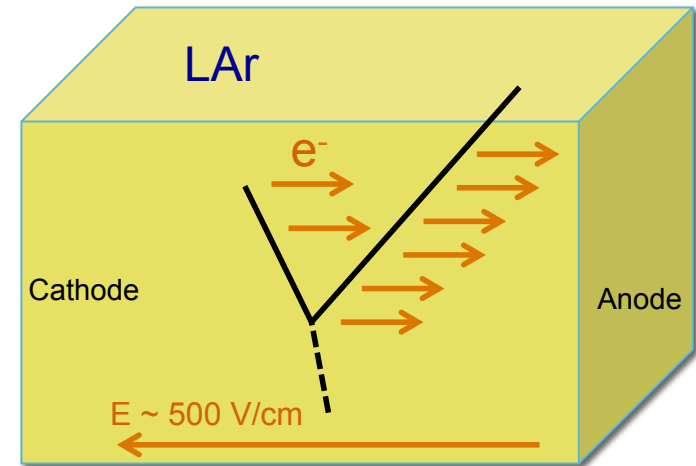


Detector prototypes in Bern

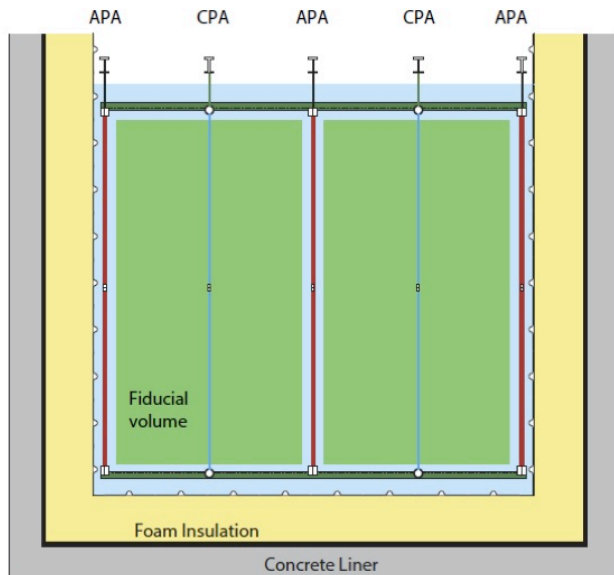


DUNE Far Detector

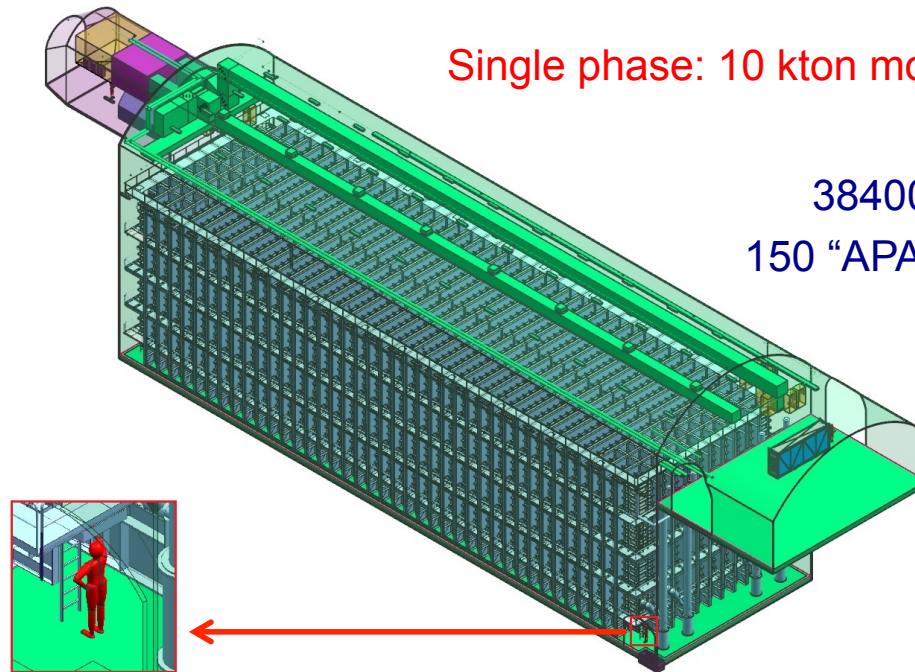
- 4 x 10-kton (fiducial) LAr TPC modules
- Single- and dual-phase detector designs
- Integrated photon detection
- Modules will not be identical



Single phase: modular wire-plane readout



Single phase: 10 kton module

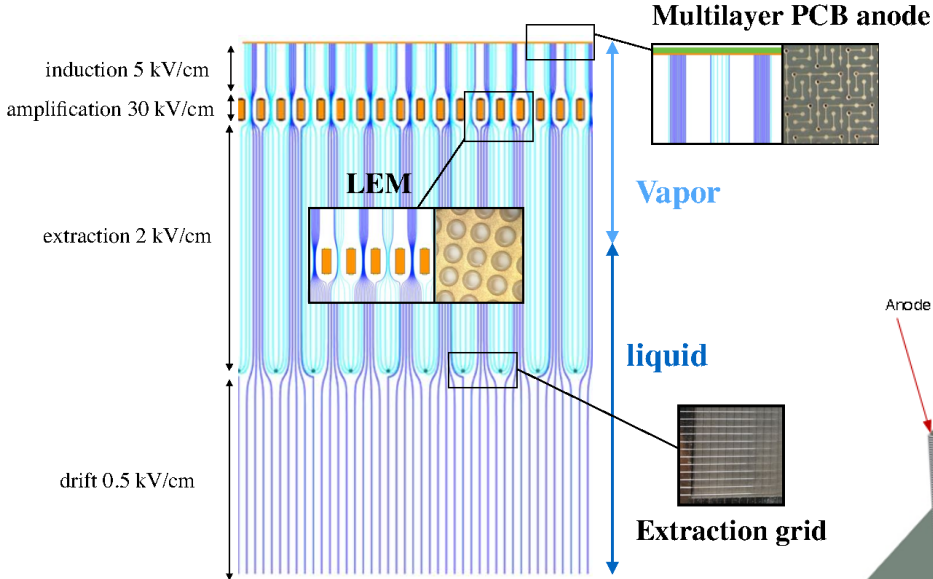
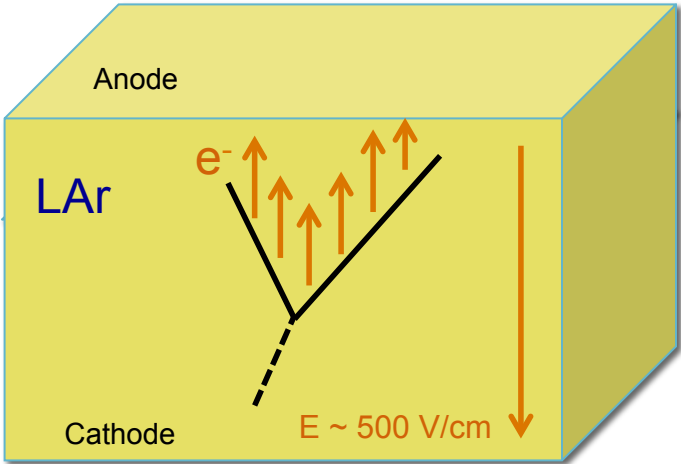


384000 readout wires
 150 "APAs" (2.3 m x 6 m)
 12 m high
 15.5 m wide
 58 m long

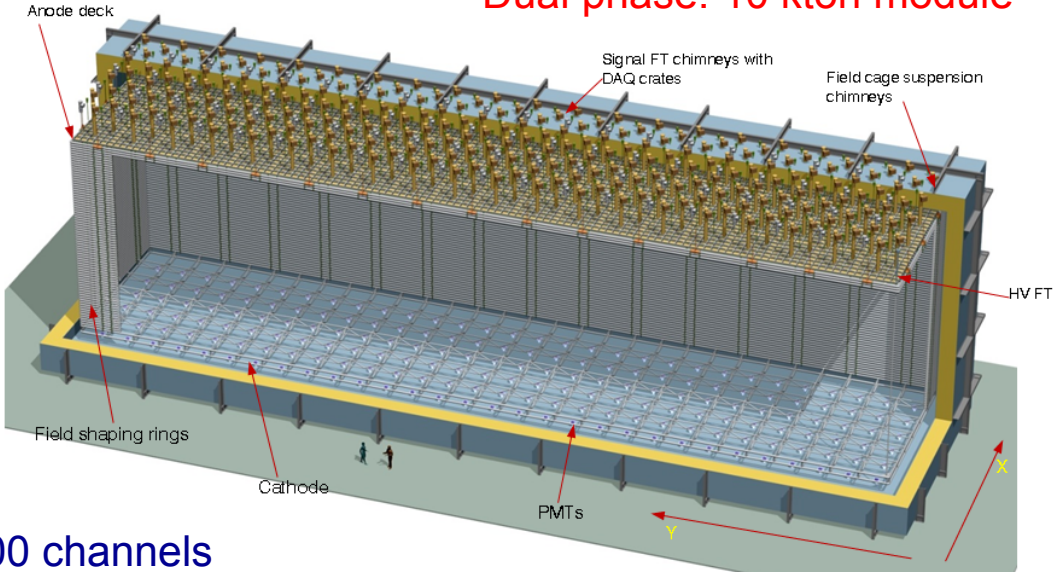
DUNE Far Detector

Dual phase: signal extracted and amplified in gas phase

DEEP UNDERGROUND NEUTRINO EXPERIMENT



Dual phase: 10 kton module

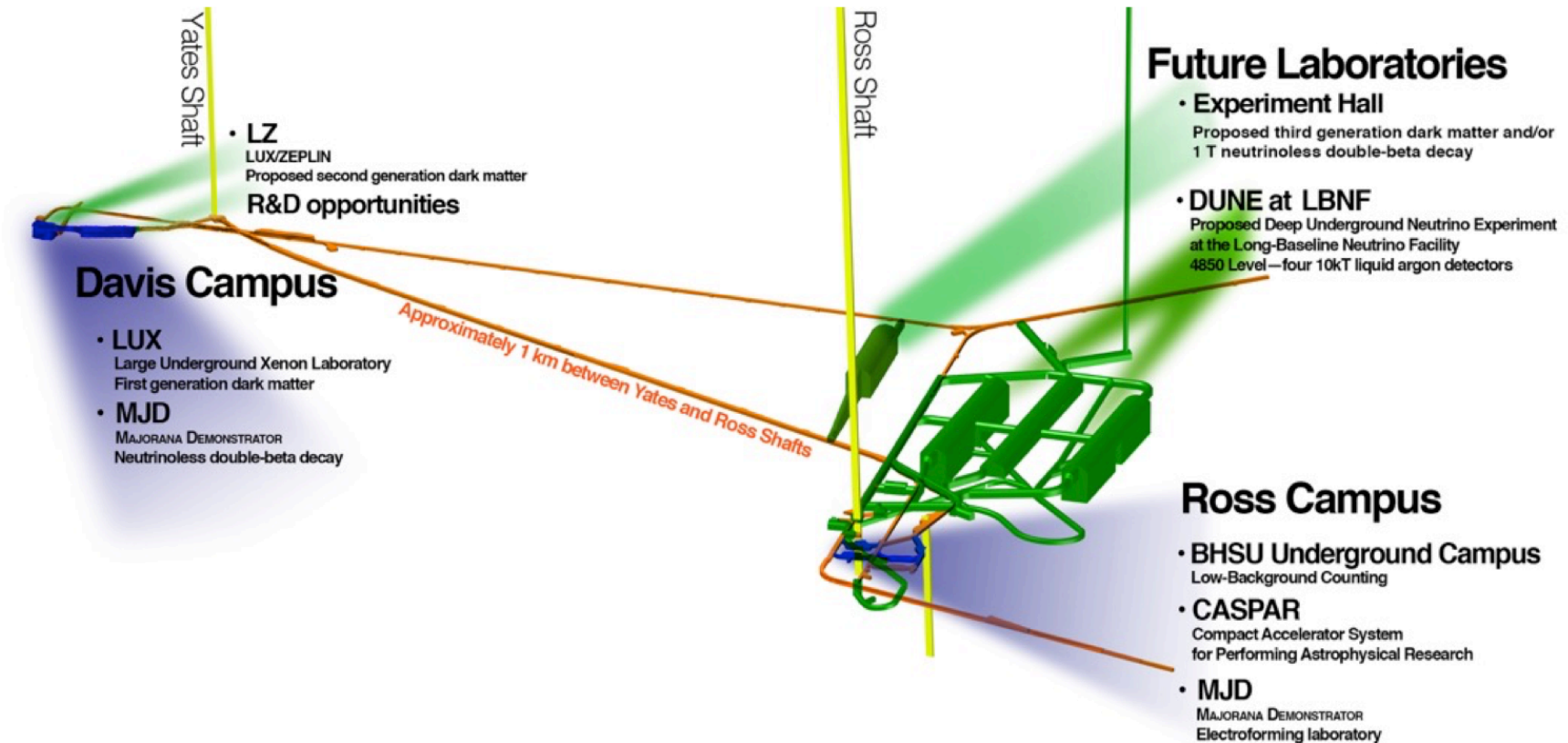


153600 channels
80 3x3 m² "CRPs" (Charge Readout Planes)

SURF

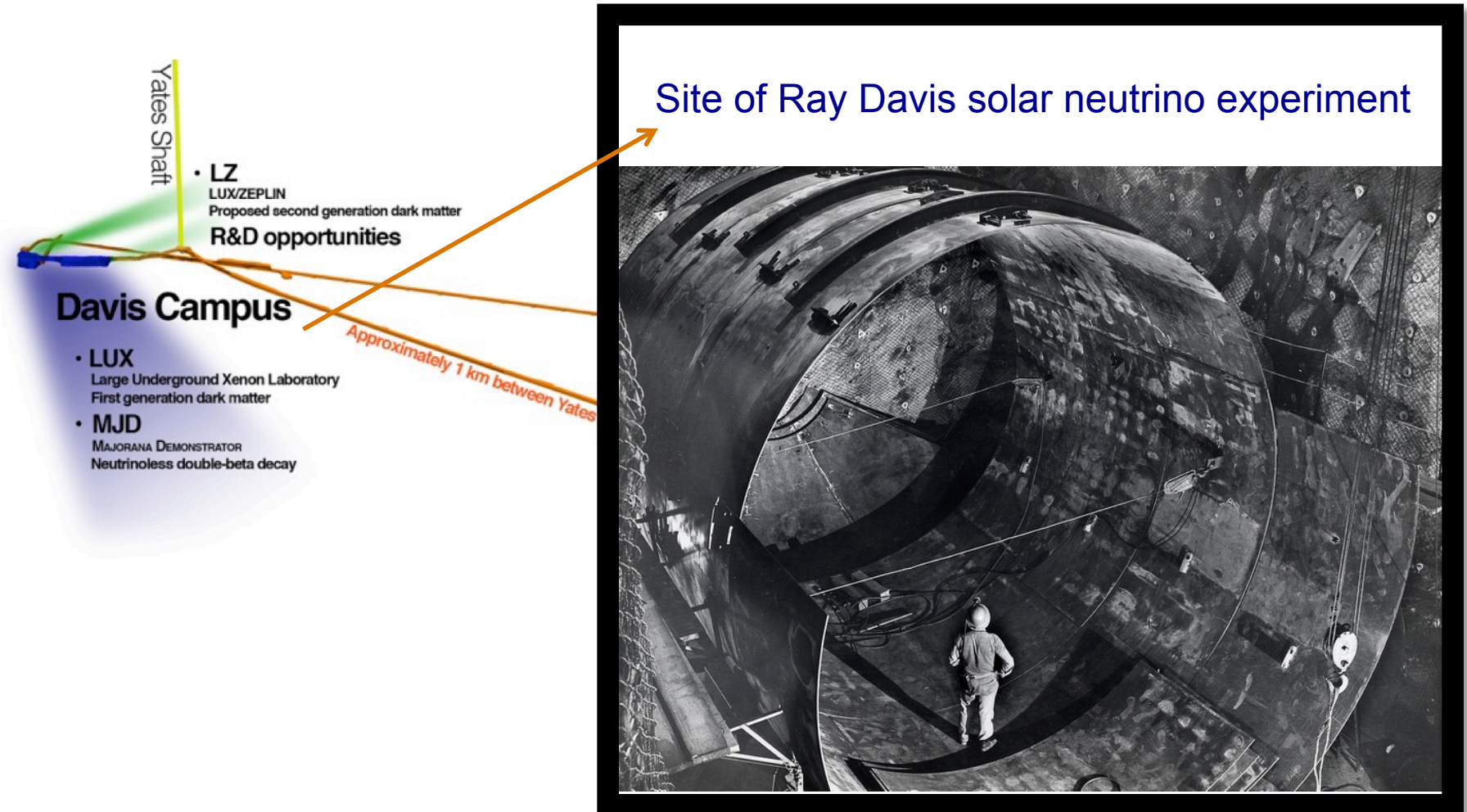
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Sanford Underground Research Facility (Lead, SD)



SURF

Sanford Underground Research Facility (Lead, SD)

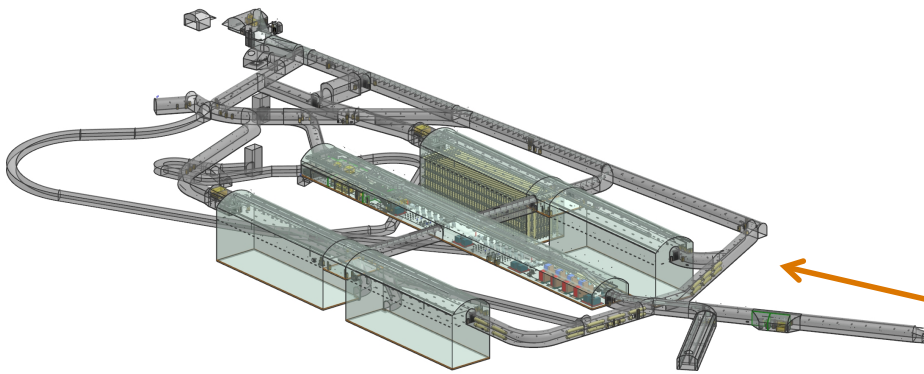


SURF

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Sanford Underground Research Facility (Lead, SD)

LBNF Facilities for DUNE Detectors



Future Laboratories

- **Experiment Hall**
Proposed third generation dark matter and/or 1 T neutrinoless double-beta decay
- **DUNE at LBNF**
Proposed Deep Underground Neutrino Experiment at the Long-Baseline Neutrino Facility
4850 Level—four 10kT liquid argon detectors

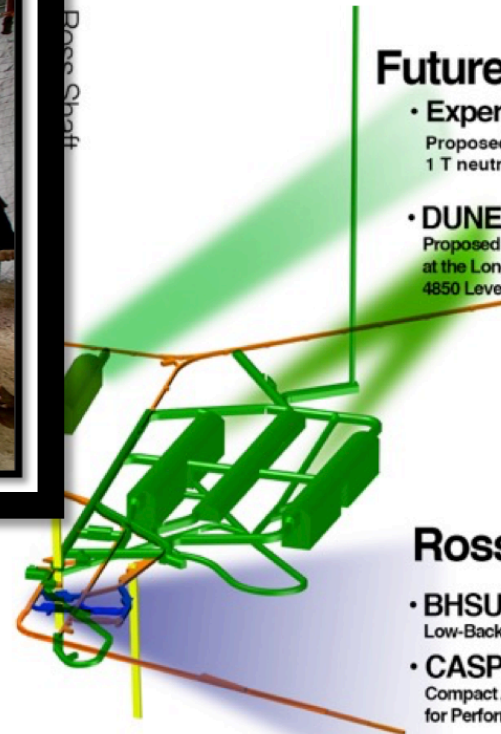
Ross Campus

- **BHSU Underground Campus**
Low-Background Counting
- **CASPAR**
Compact Accelerator System for Performing Astrophysical Research
- **MJD**
MAJORANA DEMONSTRATOR
Electroforming laboratory

SURF

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Sanford Underground Research Facility (Lead, SD)



Future Laboratories

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Ross Campus

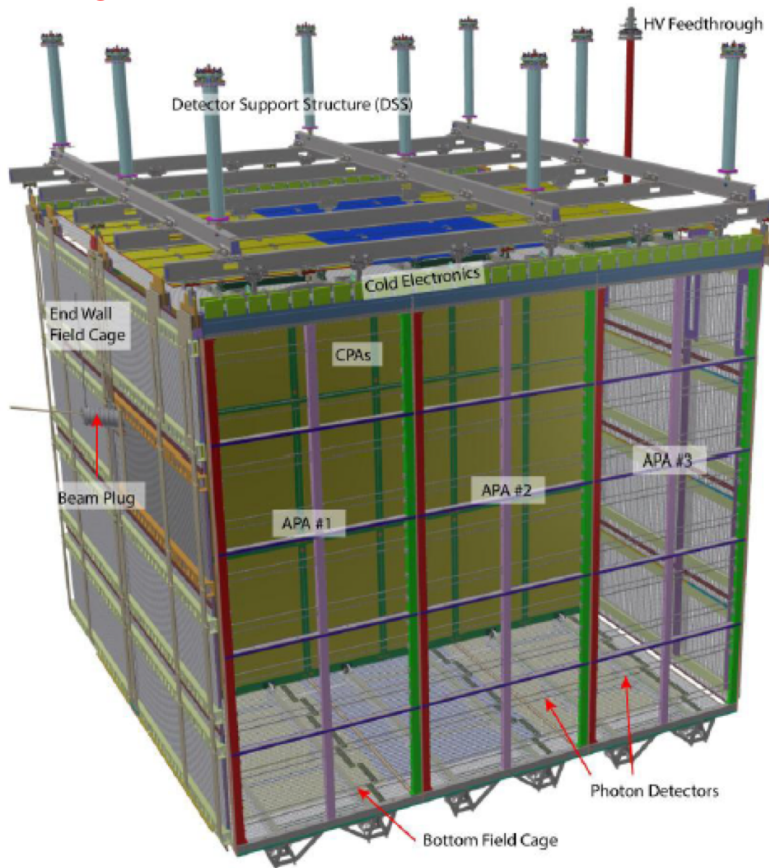
- **BHSU Underground Campus**
Low-Background Counting
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Compact Accelerator System for Performing Astrophysical Research
- **MJD**
MAJORANA DEMONSTRATOR
Electroforming laboratory

Single- and dual-phase prototypes

Enabled by CERN Neutrino Platform

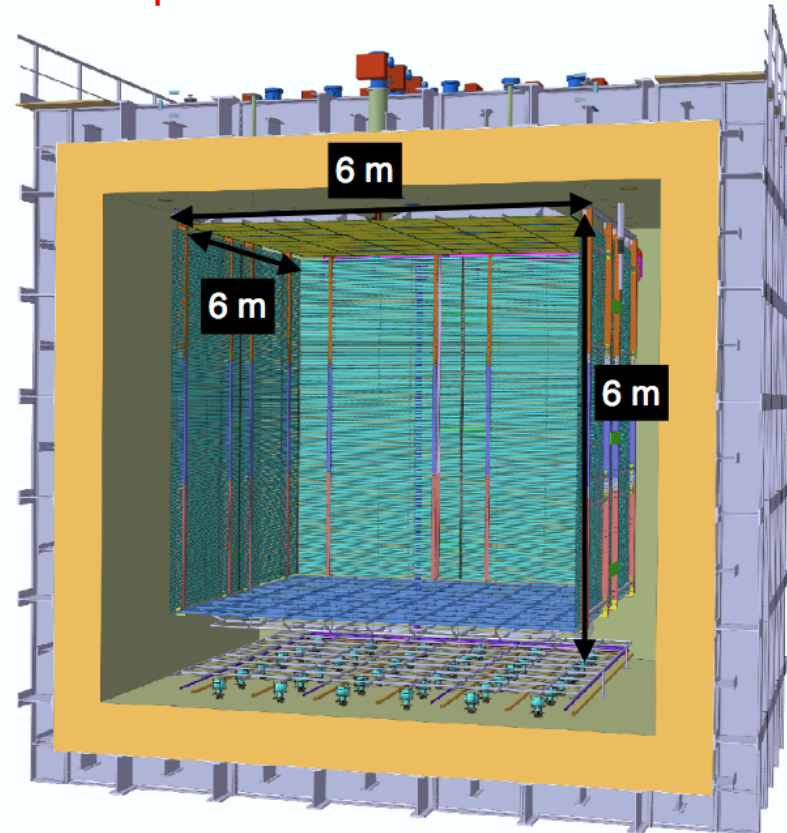
See Matt Worcester's slides for more details

Single phase



Active volume $6.9 \times 7.2 \times 6 \text{ m}^3$

Dual phase



Active volume $6 \times 6 \times 6 \text{ m}^3$

EHN1 AT CERN

Dual
phase
cryostat

Single
phase
clean
room
and cold
box

Single
phase
cryostat



ProtoDUNE-DP Field Cage

Field Cage complete: April 2018

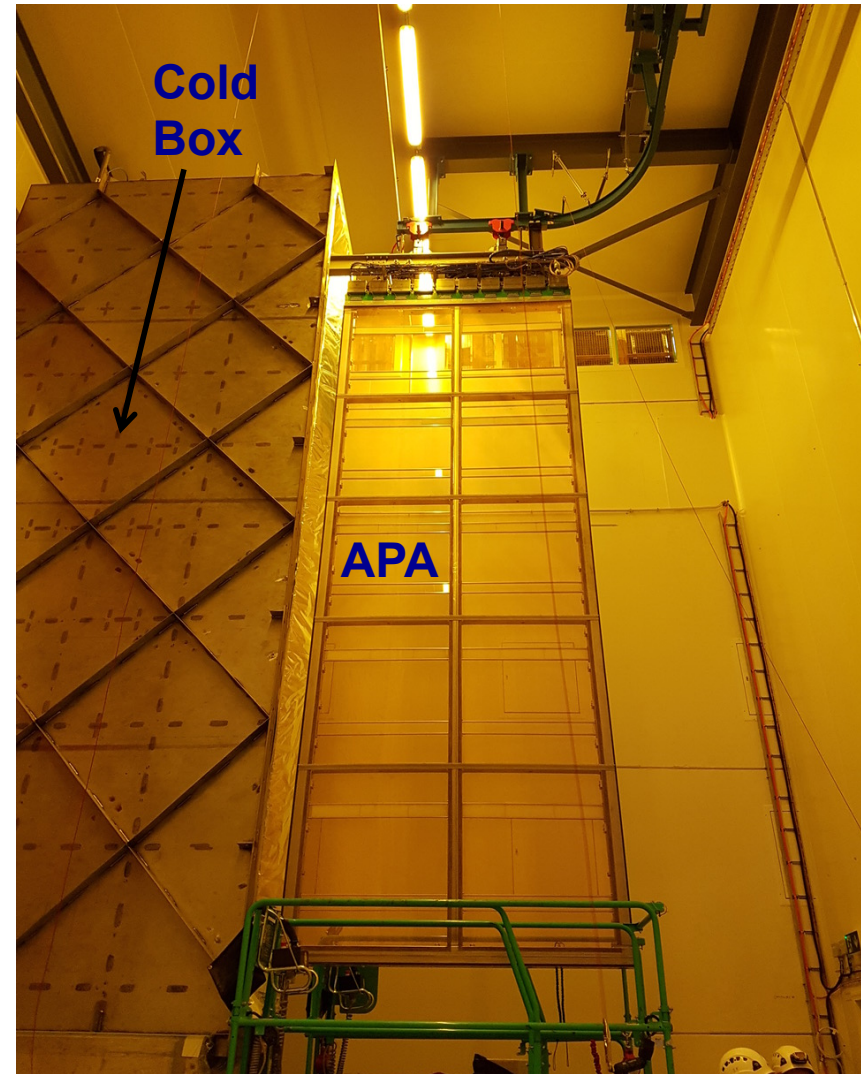


Successful test at 150 kV

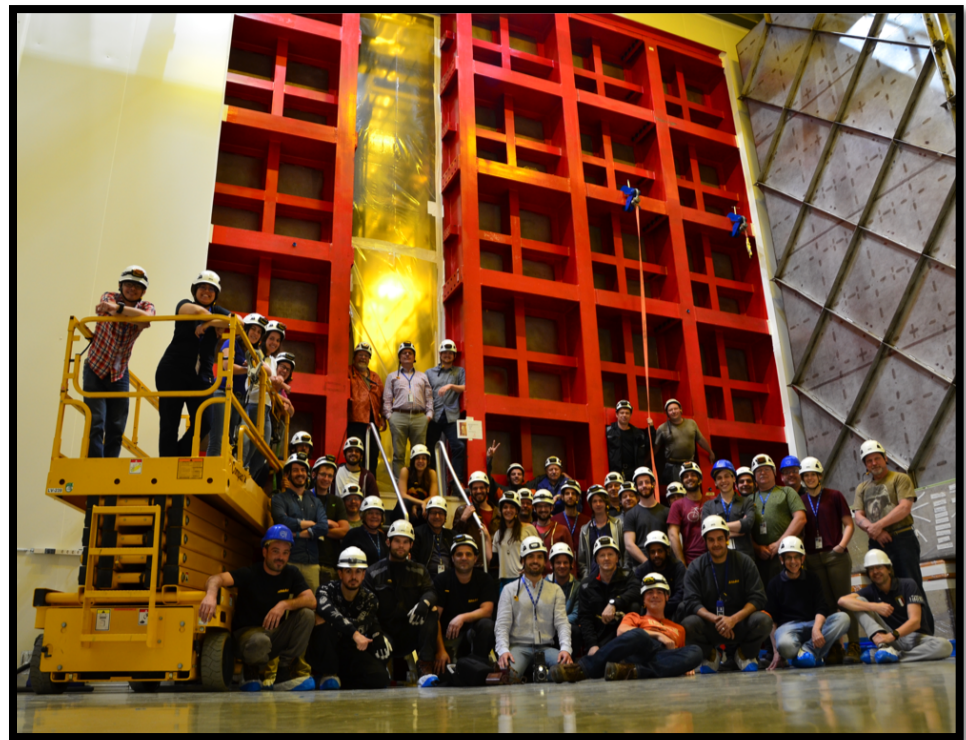
ProtoDUNE-SP Cold Box

Testing of assembled APA and electronics before installation into protoDUNE cryostat

Filled with cold nitrogen gas for testing at “cool” temperature (~160 K)



ProtoDUNEs: status and plans



A. Ereditato - Rencontres du Vietnam - August 2018

DUNE general timeline



2018: ProtoDUNE_s at CERN



2019: Technical Design Report



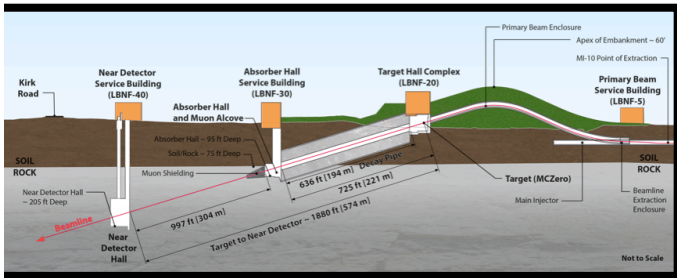
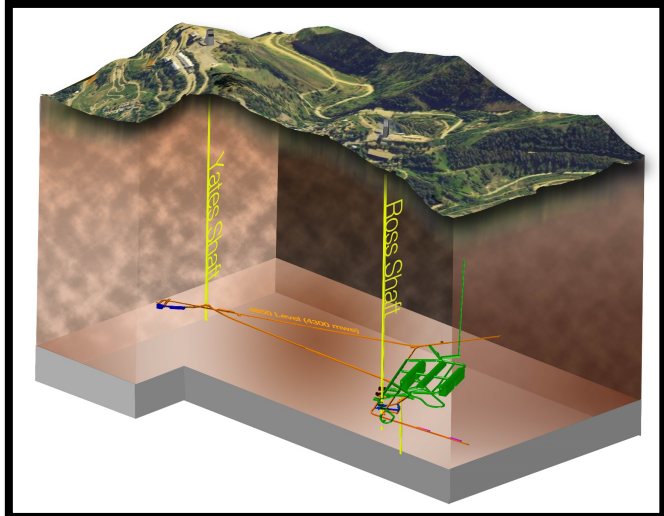
2019: Far site primary excavation begins



2022: First module installation begins



2026: Neutrino beam available

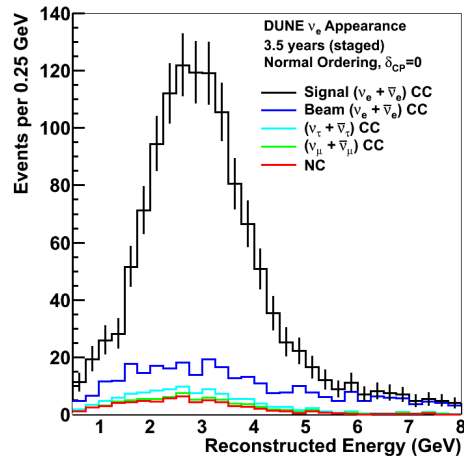


Physics data as soon as 1st module complete

- Atmospheric ν
- SNB and solar ν
- Matter instability
- Detector calibration

Conclusions

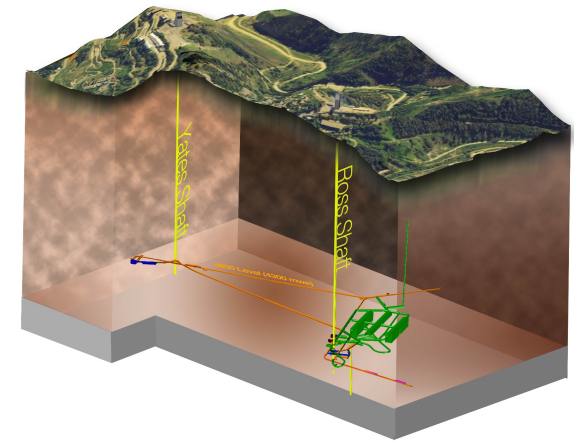
New estimates



R&D and ProtoDUNEs



Coming soon...



LBNF/DUNE: the ultimate neutrino facility/observatory

LBNF and **DUNE** progressing on facility construction, detector design, R&D and physics studies

ProtoDUNEs: scaling up towards 40 kton LAr TPC

2019: **DUNE** TDR, Near Detector CDR and **ProtoDUNEs** results

Expect first **DUNE** FD data in ~2024.