



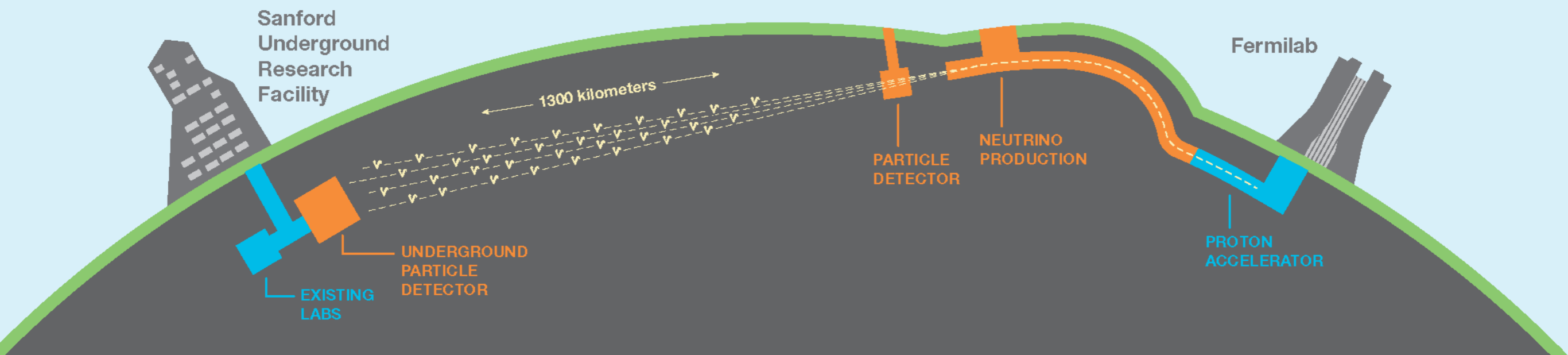
SENSITIVITY TO LONG-BASELINE OSCILLATION PHYSICS

Justo Martín-Albo (Oxford U.)
for the DUNE Collaboration

EPS Conference on High Energy Physics – Venice, 5th June 2017

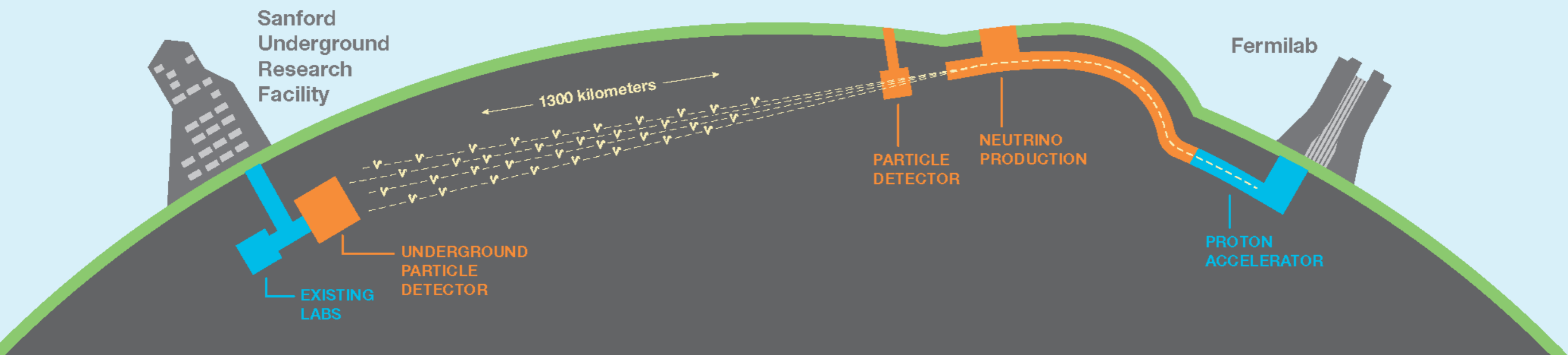
The *Deep Underground Neutrino Experiment* is a next-generation long-baseline oscillation experiment between Fermilab (Illinois) and the Sanford Underground Research Facility (South Dakota) consisting of

- a new MW-scale neutrino beamline (LBNF);
- a 4×10-kilotonne (fiducial) liquid argon far detector;
- a high-resolution, high-rate near detector.



The primary science program of DUNE includes:

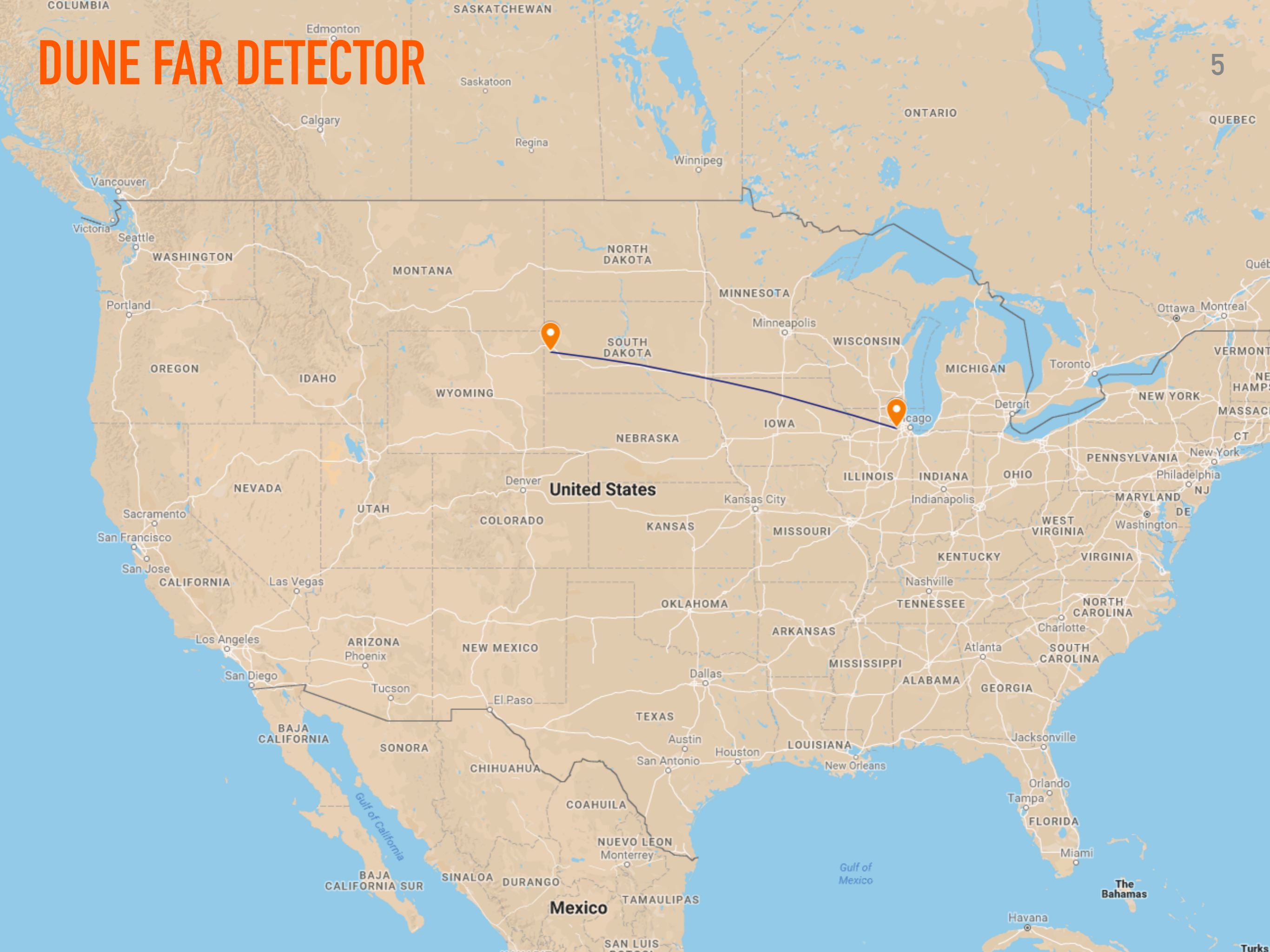
- Long-baseline neutrino oscillations
 - Leptonic CP violation
 - Neutrino mass ordering
 - Precision test of the 3-neutrino mixing framework
- Nucleon decay
- Neutrino astrophysics (e.g. core-collapse supernovae)



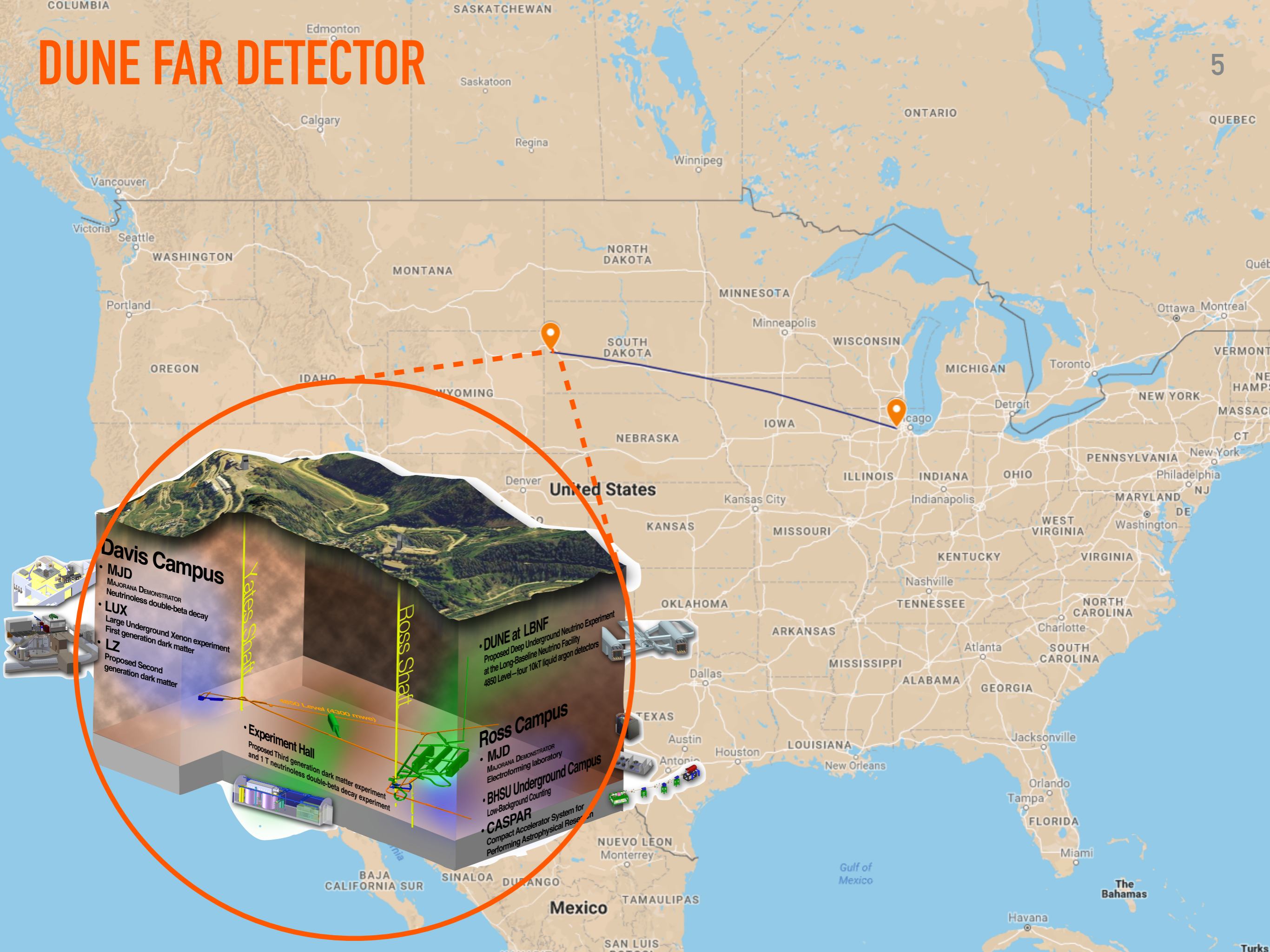
Title	Speaker	Session	Date and time
Astroparticle physics at the DUNE experiment	I. Gil Botella (CIEMAT)	Astroparticles	July 6, 14:30
Studying neutrino oscillations and searches for BSM physics with atmospheric neutrinos in DUNE	A. Higuera (Houston)	Neutrinos	July 6, 17:15
The ProtoDUNE-SP prompt processing system	M. Potekhin (BNL)	Detectors & Data Handling	July 6, 17:15
The DUNE far and near detectors	N. McConkey (Sheffield)	Detectors & Data Handling	July 6, 17:30
Automated reconstruction, signal processing and particle ID	M. Wallbank (Sheffield)	Poster	July 10, 18:00
Performance and physics measurements at protoDUNE-SP	S. Bordoni, L. Whitehead (CERN)	Poster	July 10, 18:00
The DUNE far detector	Diego García-Gómez (Manchester)	Poster	July 10, 18:00



DUNE FAR DETECTOR



DUNE FAR DETECTOR



Edmonton

Saskatoon

Regina

Winnipeg

ONTARIO

QUEBEC

5

Vancouver

Victoria

Seattle

WASHINGTON

Portland

OREGON

IDAHO

MONTANA

NORTH DAKOTA

MINNESOTA

SOUTH DAKOTA

WYOMING

NEBRASKA

IOWA

WISCONSIN

MICHIGAN

Toronto

Ottawa

Montreal

VERMONT

NEW HAMPSHIRE

MASSACHUSETTS

CONNECTICUT

PENNSYLVANIA

New York

MARYLAND

NJ

Washington

United States

KANSAS

MISSOURI

KENTUCKY

VIRGINIA

OKLAHOMA

ARKANSAS

TENNESSEE

NORTH CAROLINA

SOUTH CAROLINA

Dallas

MISSISSIPPI

Atlanta

ALABAMA

GEORGIA

TEXAS

Austin

Houston

LOUISIANA

New Orleans

Jacksonville

Orlando

Tampa

FLORIDA

Miami

The Bahamas

BAJA CALIFORNIA SUR

SINALOA

DURANGO

NUEVO LEON Monterrey

TAMAULIPAS

Mexico

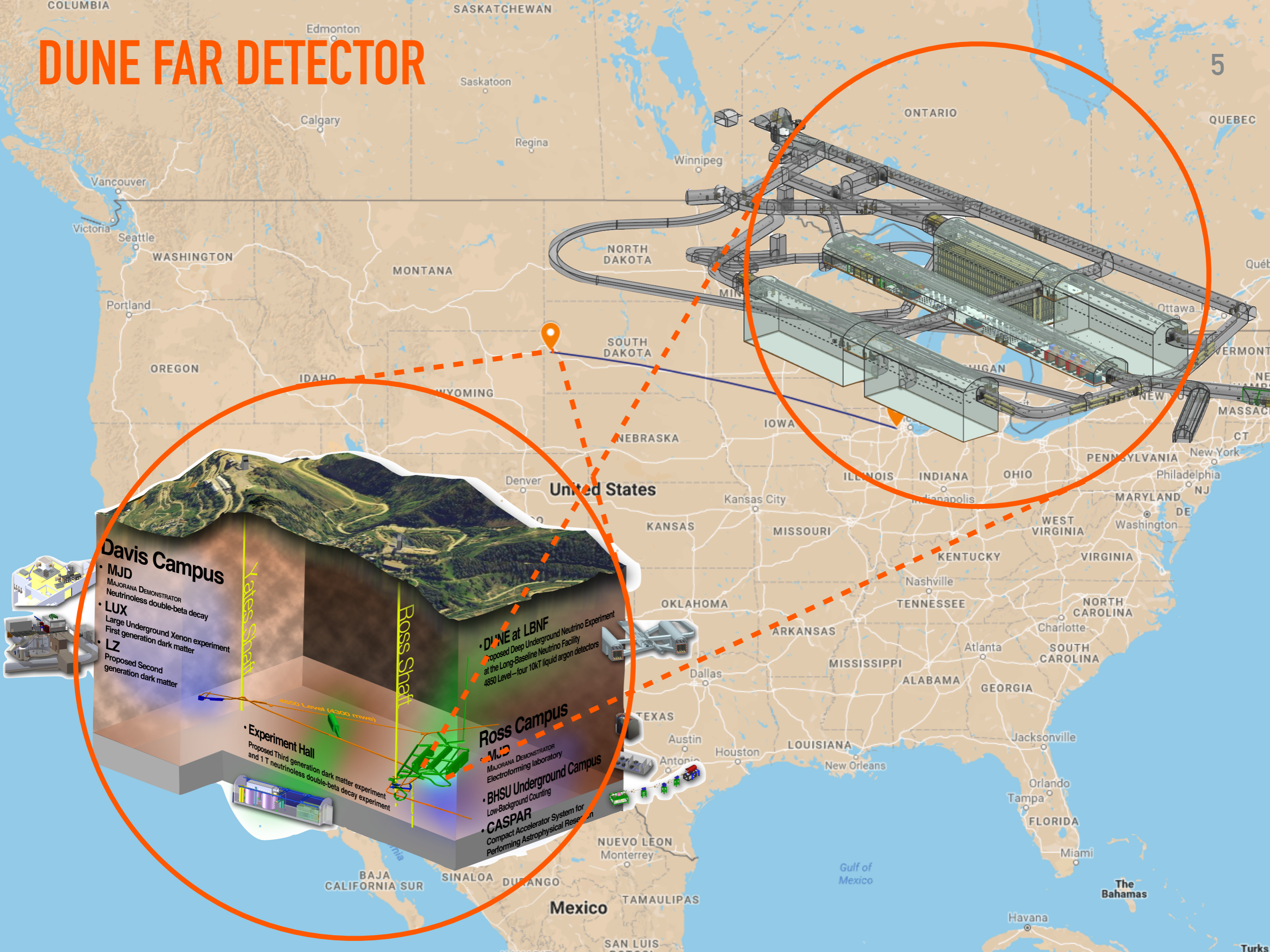
Gulf of Mexico

Havana

SAN LUIS

Turkey

DUNE FAR DETECTOR



Davis Campus

- MJD
MAJORANA DEMONSTRATOR
Neutrinoless double-beta decay
- LUX
Large Underground Xenon experiment
First generation dark matter
- LZ
Proposed Second
generation dark matter

Yates Shaft

Ross Shaft

Experiment Hall

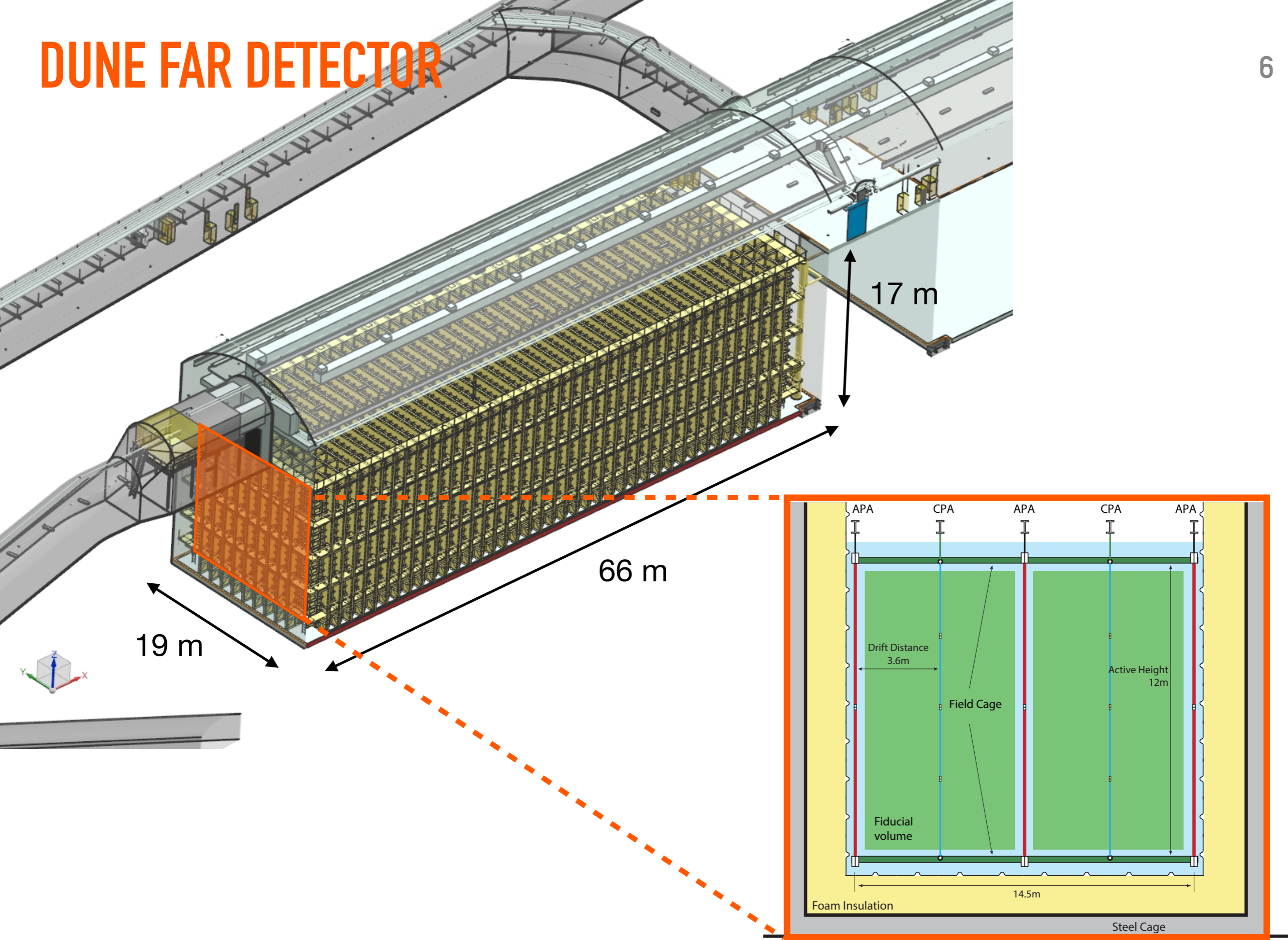
- Proposed Third generation dark matter experiment
and 1 T neutrinoless double-beta decay experiment

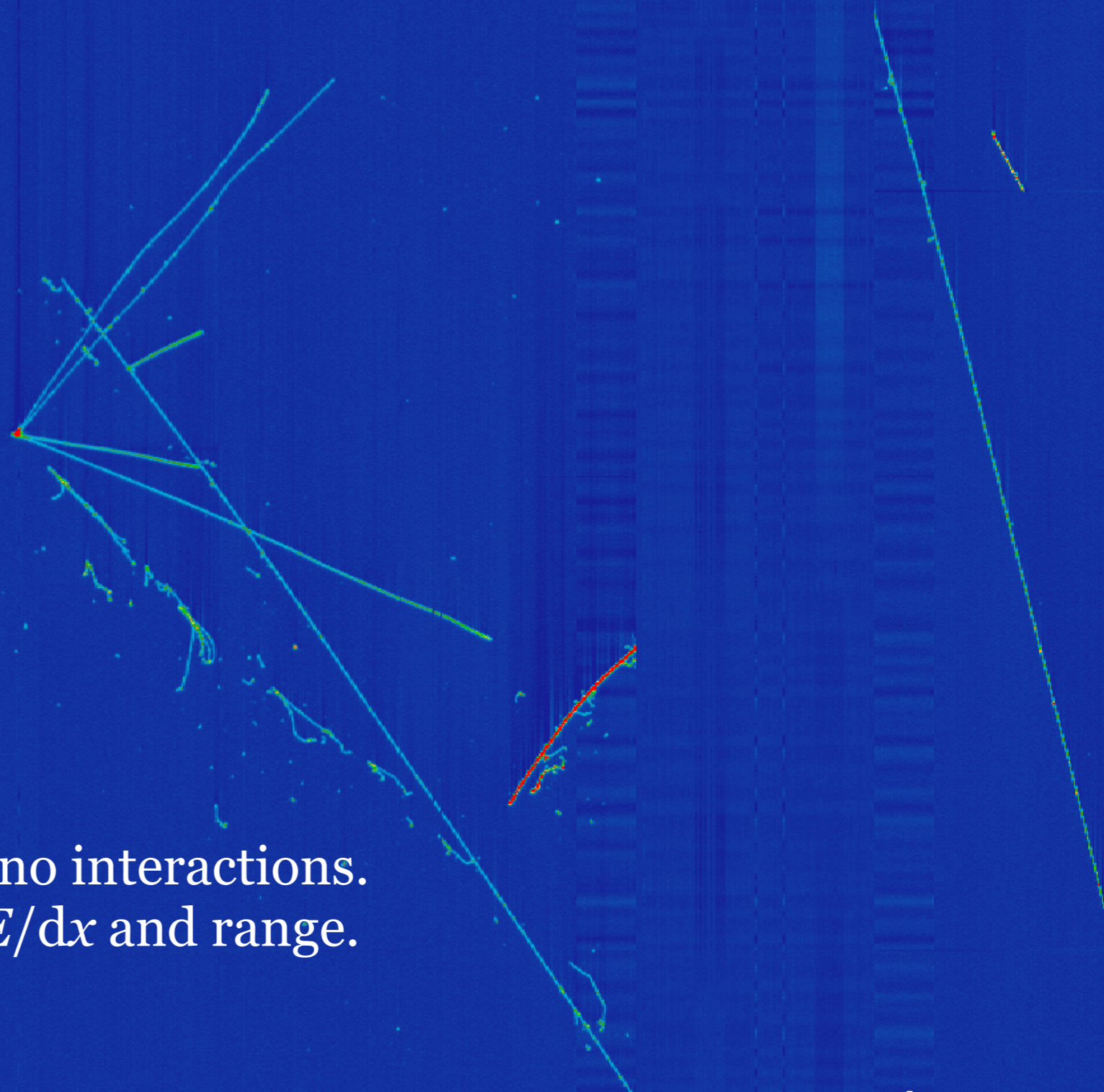
Ross Campus

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

- DUNE at LBNF
Proposed Deep Underground Neutrino Experiment
at the Long-Baseline Neutrino Facility
4850 Level—four 10kT liquid argon detectors

DUNE FAR DETECTOR





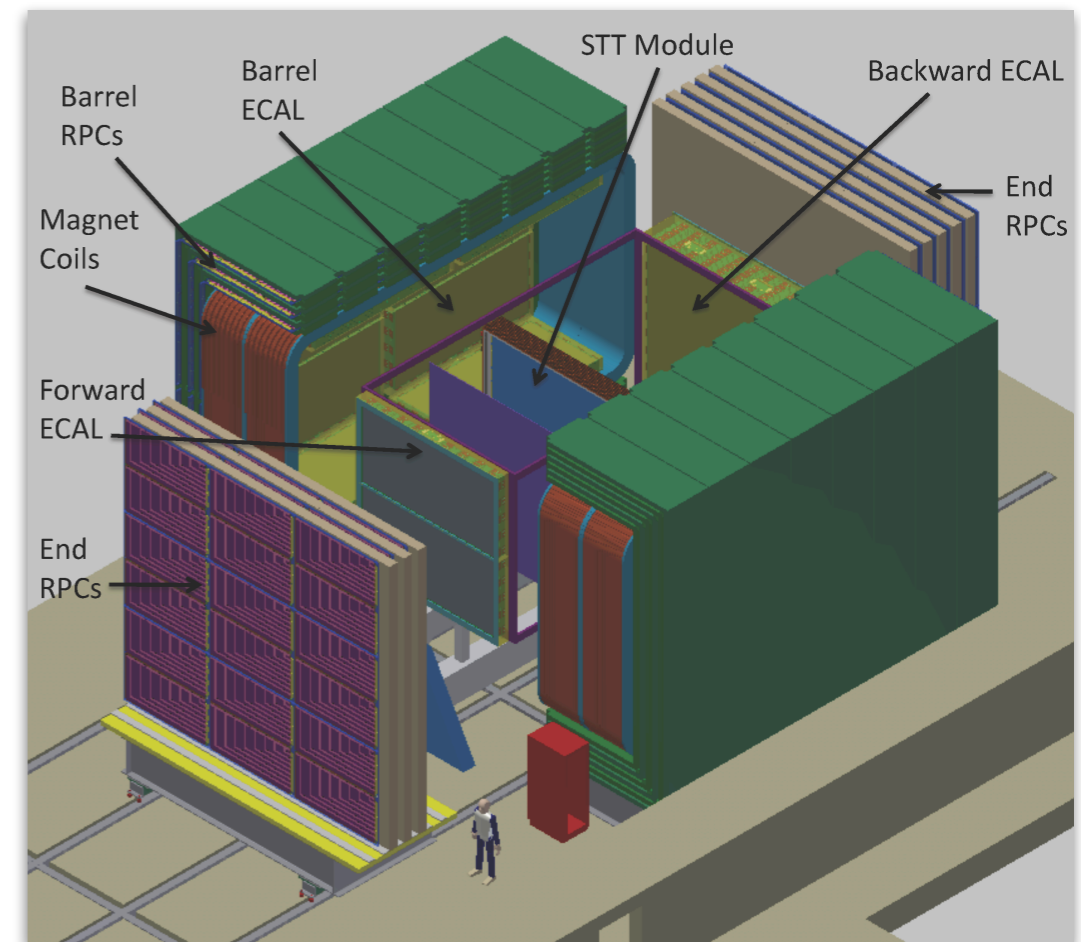
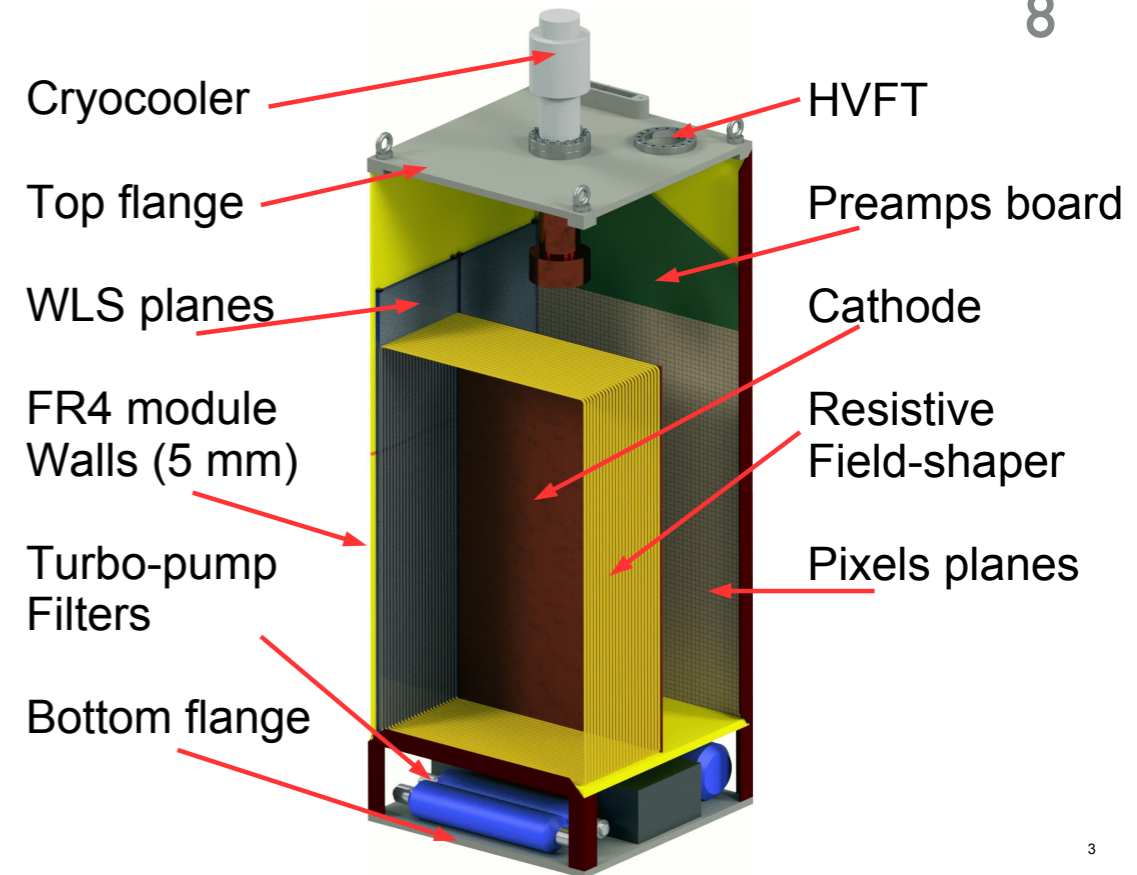
Fine-grained, 3D images of neutrino interactions.
Particle identification based on dE/dx and range.
Close to full acceptance.

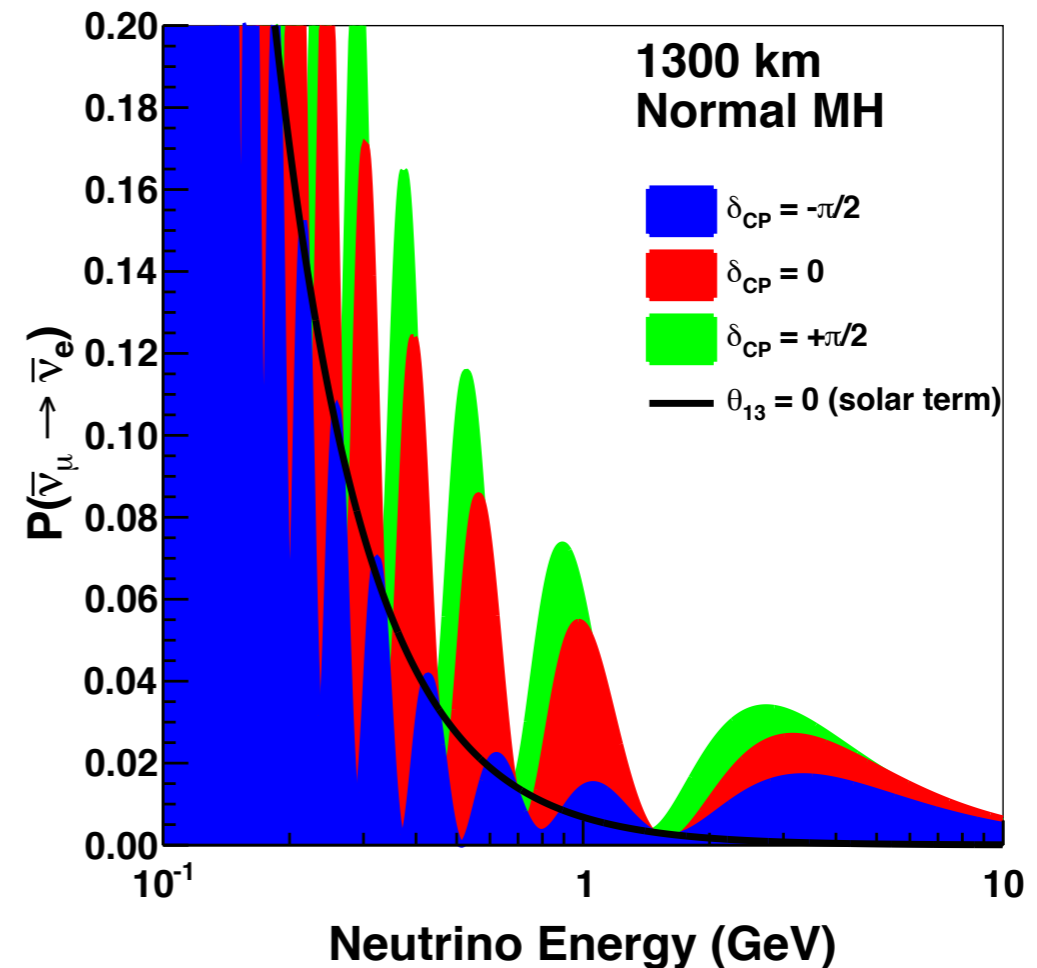
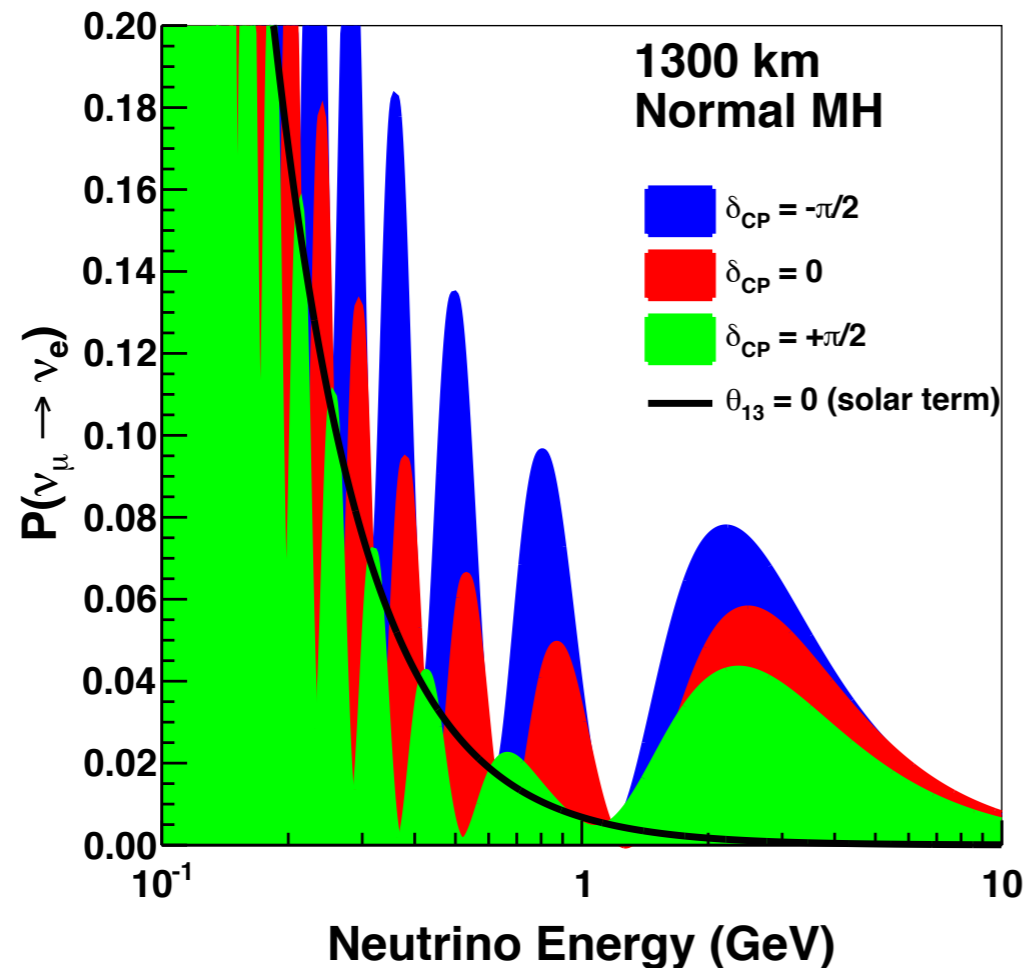
75 cm

Run 3493 Event 41075, October 23rd, 2015

DUNE NEAR DETECTOR

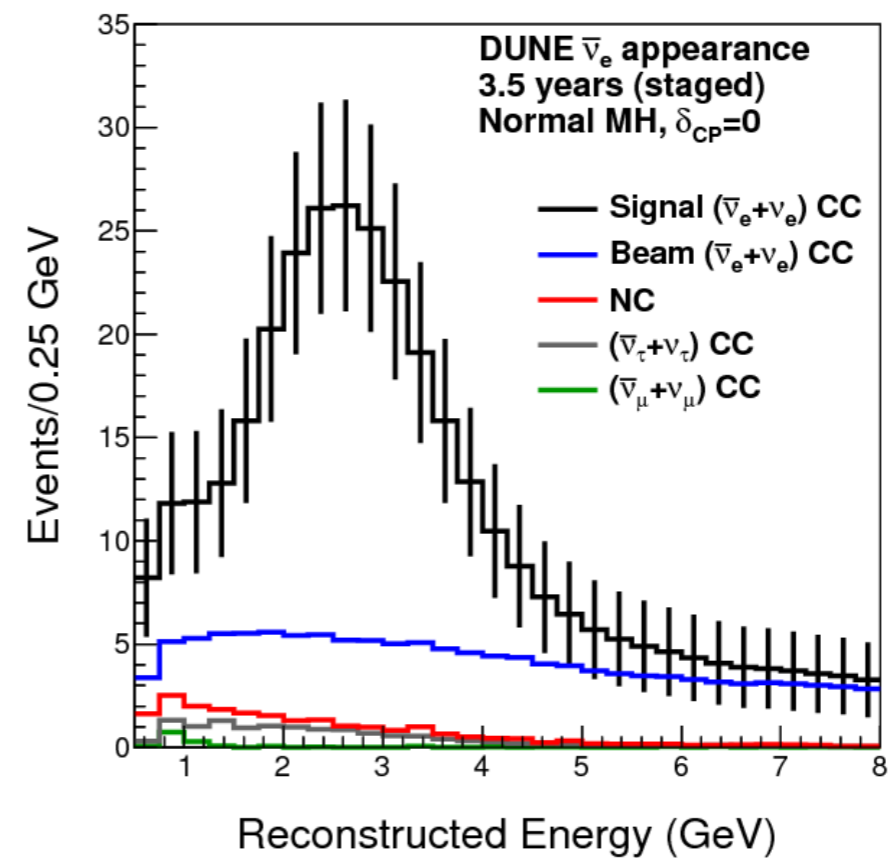
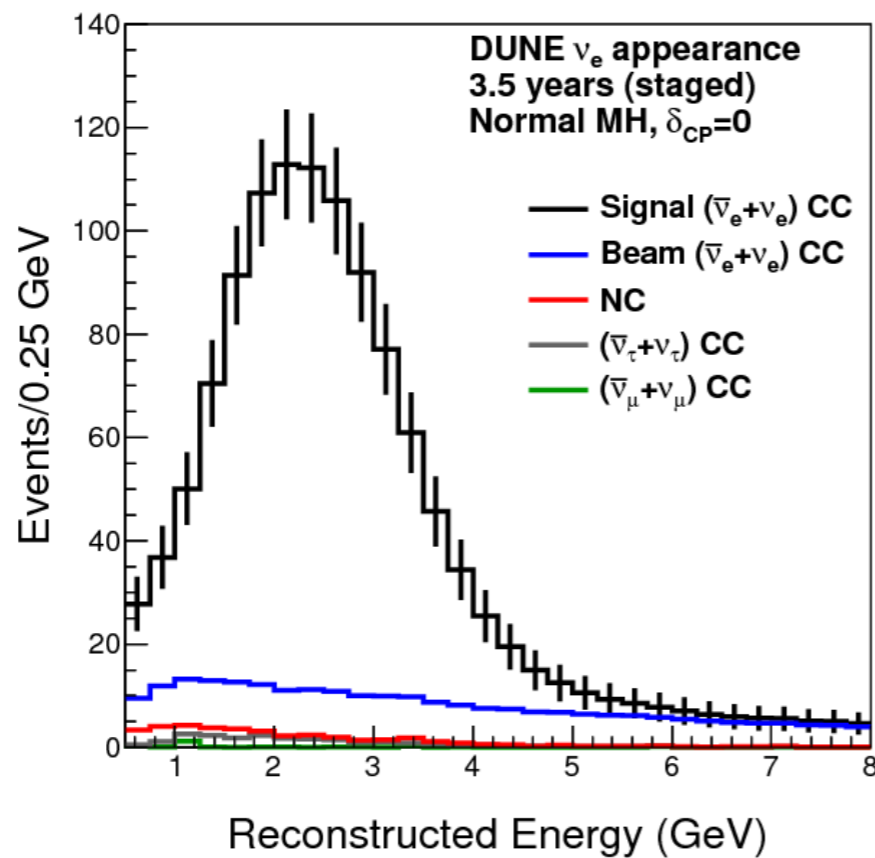
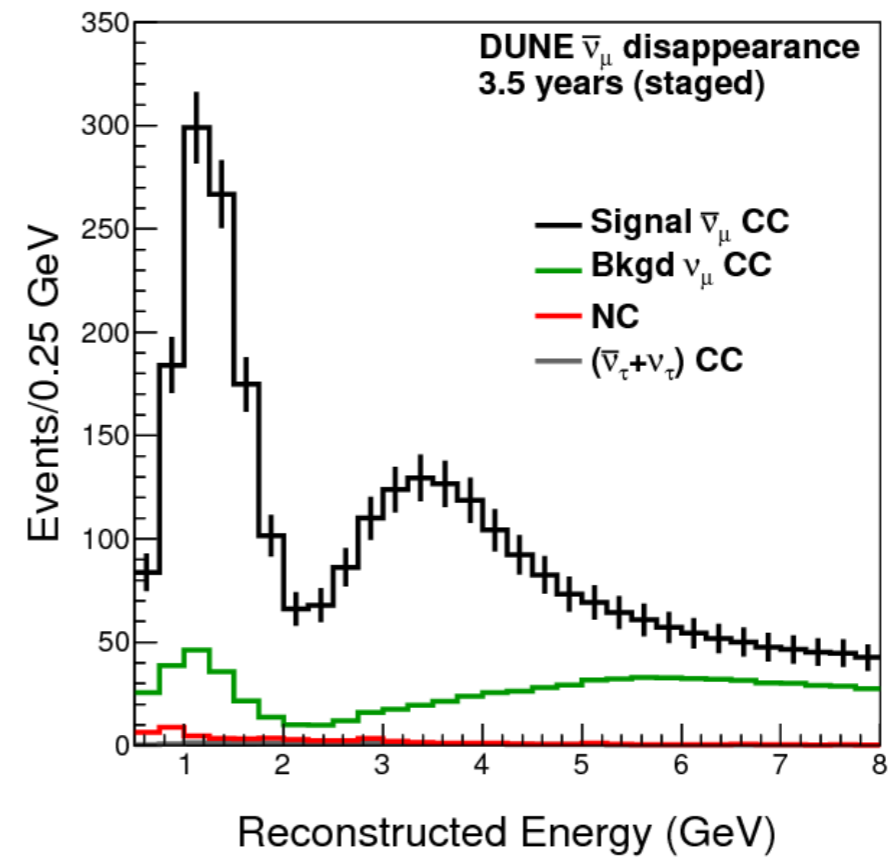
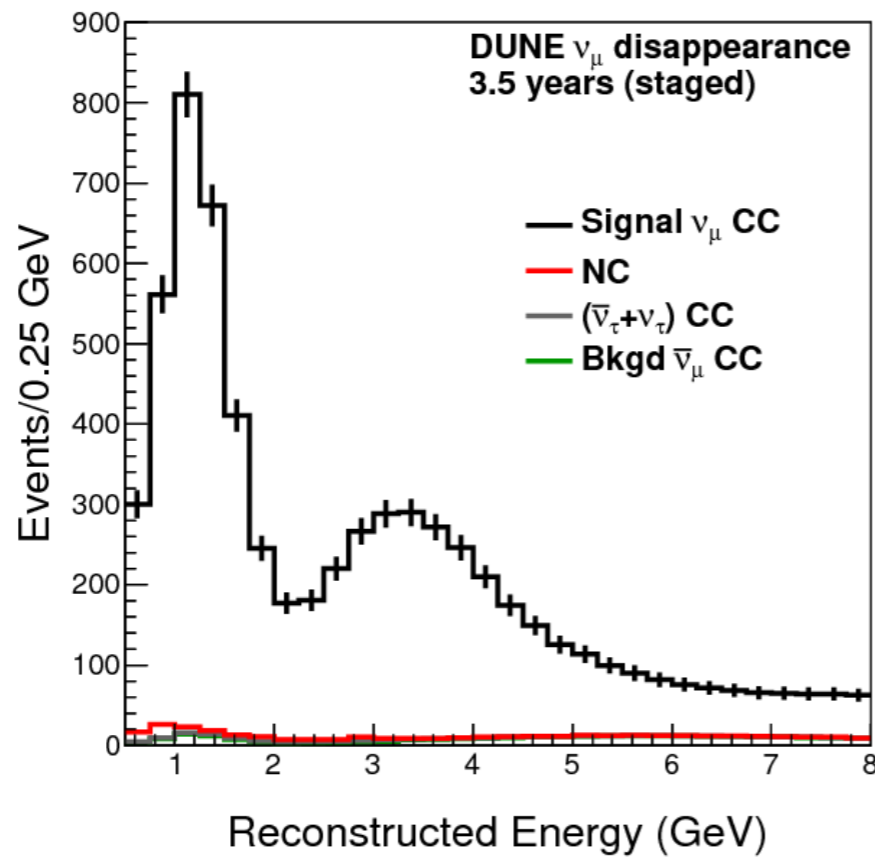
- ND has fundamental role for LBL physics, constraining systematic uncertainties through the measurement of neutrino flux and interaction cross sections.
- It will record largest sample of neutrino interactions ever collected.
- Also sensitive to new physics (e.g. heavy sterile neutrinos).
- DUNE ND currently under design. Conceptual design ready by 2018.
- It will likely feature a modular liquid argon TPC and a magnetised, high-resolution tracker.





- Electron-neutrino appearance amplitude depends on θ_{13} , θ_{23} , δ_{CP} and matter effects. All four can be measured in a single experiment.
- Broadband beam and long baseline break degeneracy between CPV and matter effects.

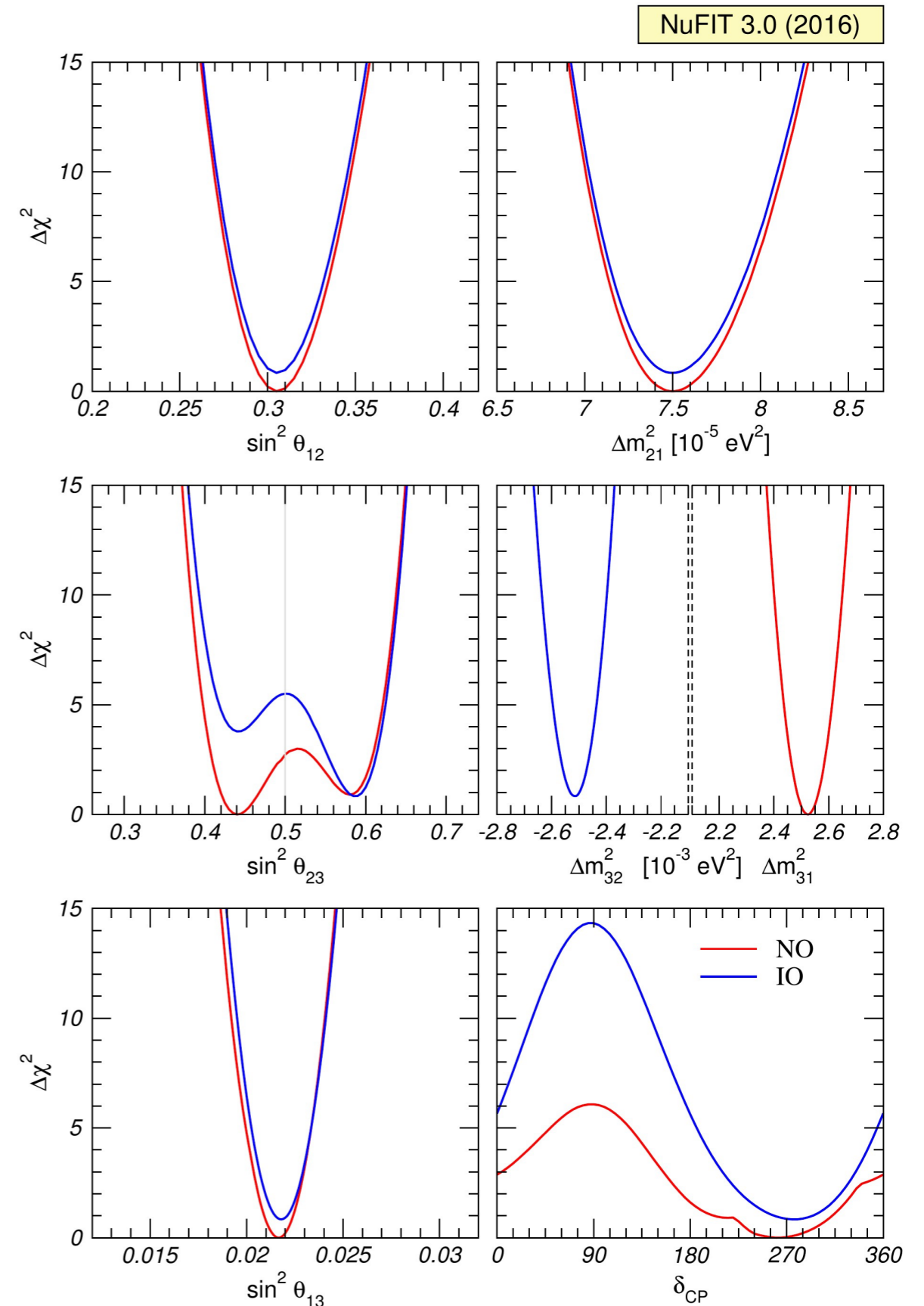
LBL EXPERIMENTAL STRATEGY



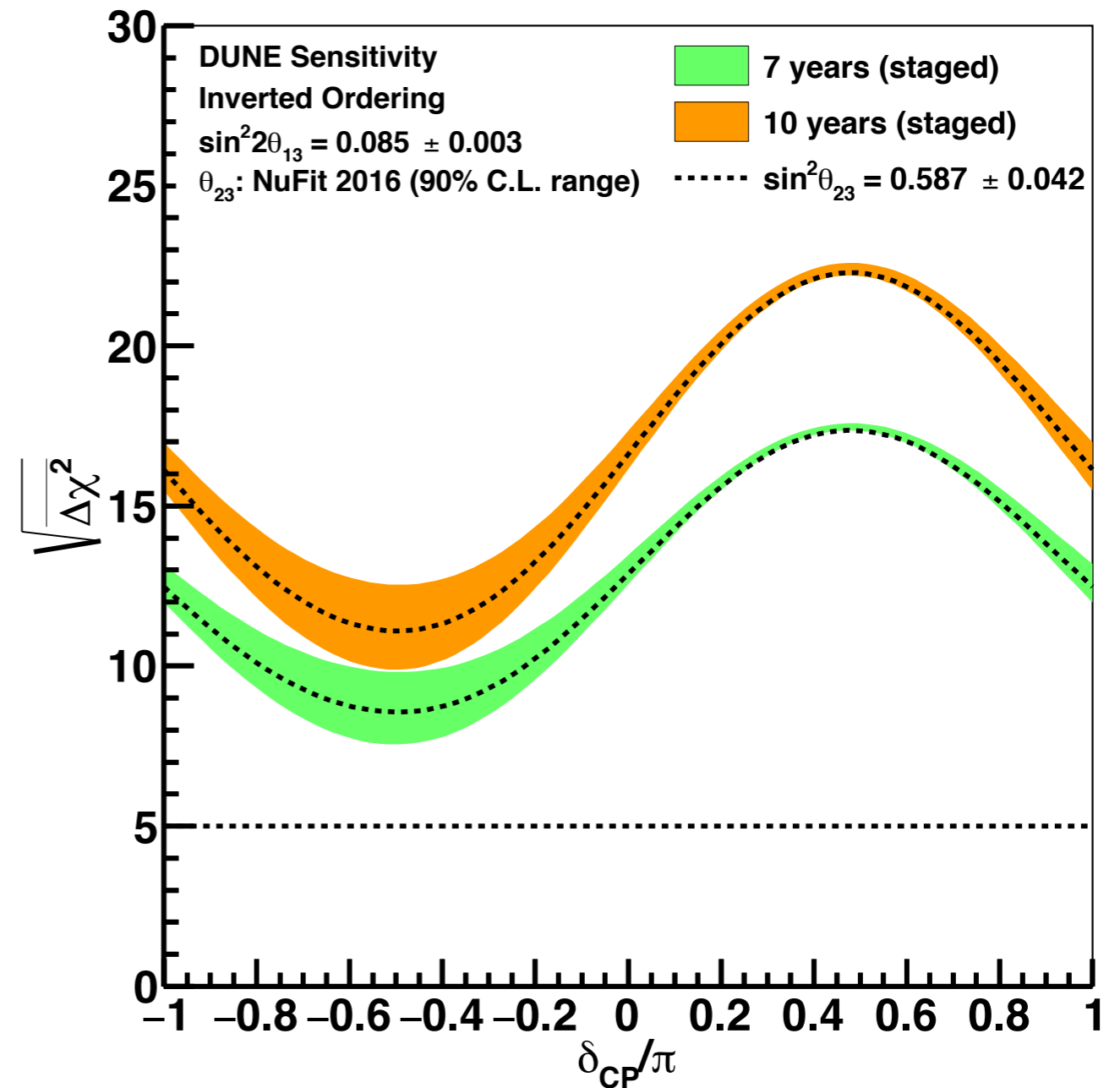
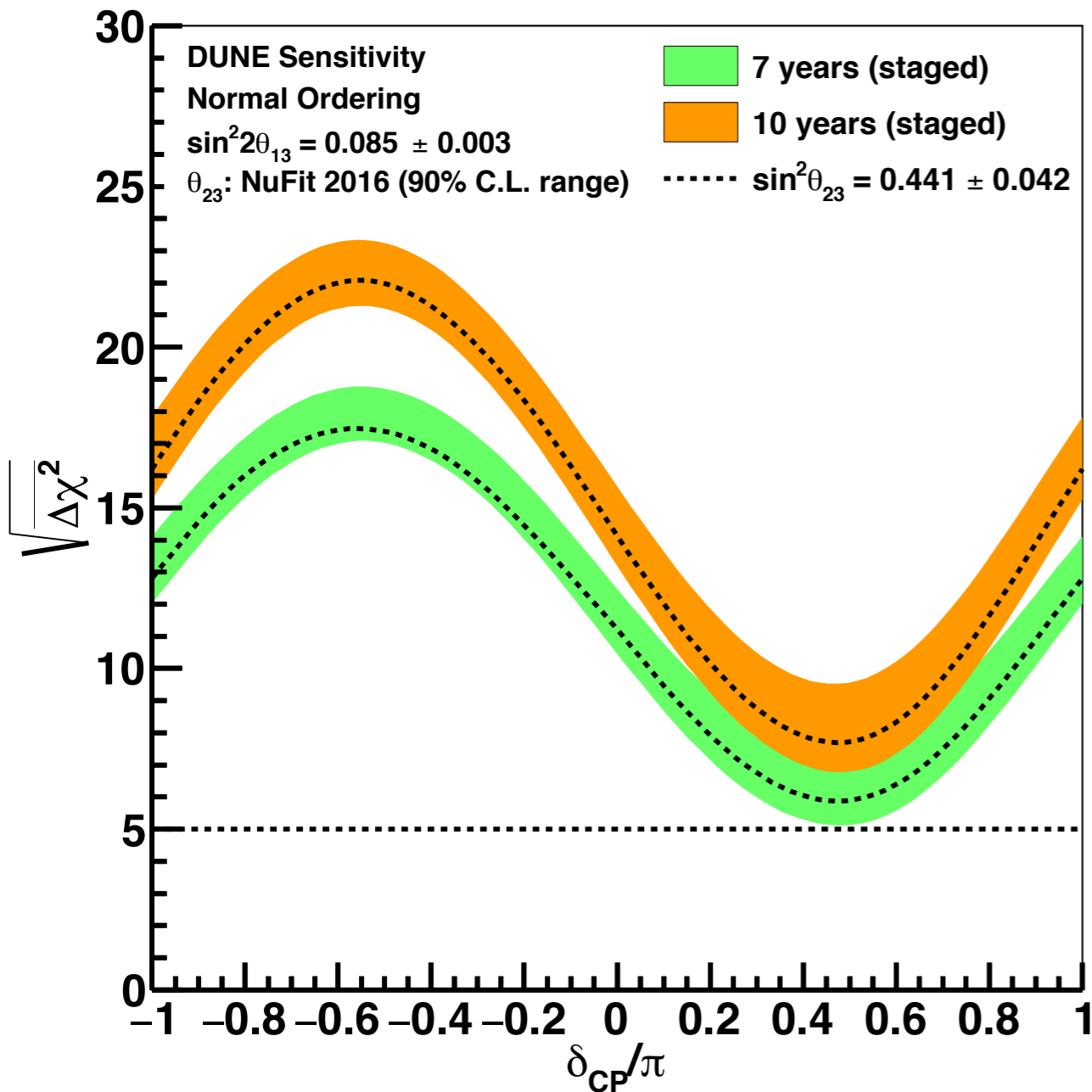
LBL EXPERIMENTAL SENSITIVITIES

All the following sensitivity plots consider these assumptions:

- Oscillation parameters from NuFit2016.
- Staging scenario with equal running in neutrino and antineutrino modes:
 - Year 1 (2026): 20-kt FD with 1.07 MW beam.
 - Year 2 (2027): 30 kt FD.
 - Year 4 (2029): 40 kt FD.
 - Year 7 (2032): upgrade to 2.14 MW beam.
- GLoBES-based fit to the FD samples, with parameterised detector response.

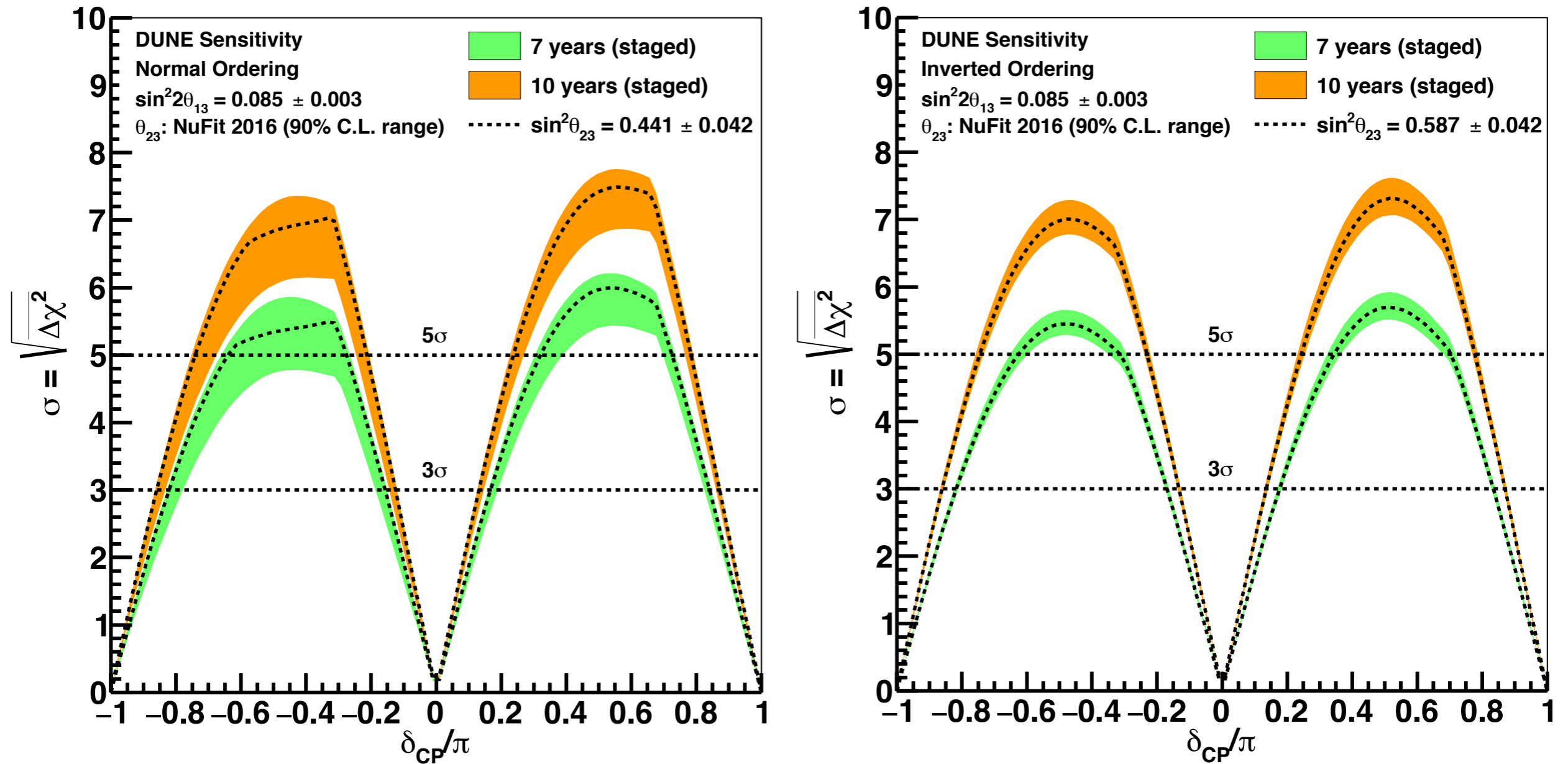


SENSITIVITY TO MASS HIERARCHY



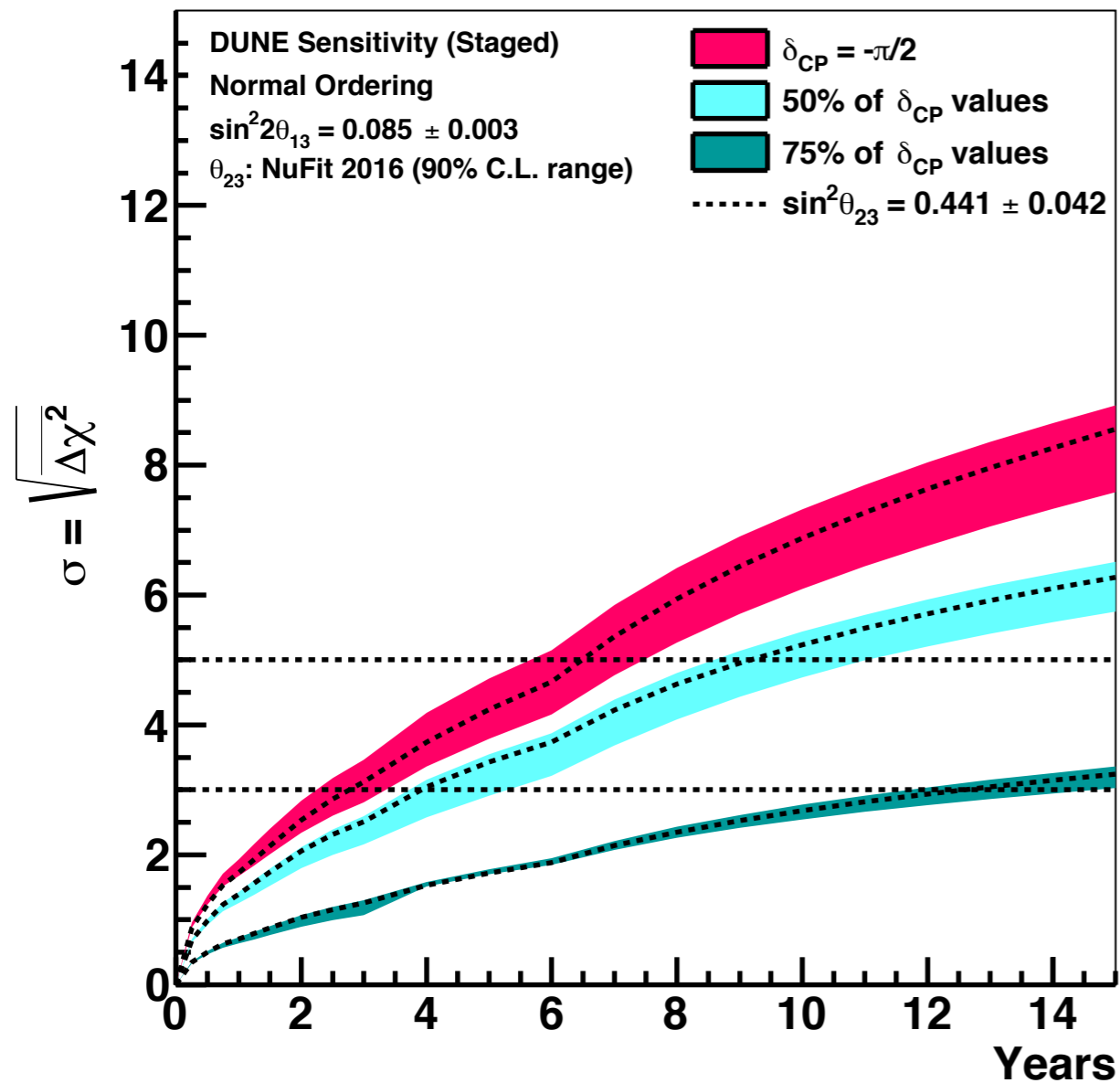
Width of bands represents range of sensitivities for the 90% CL region in θ_{23} values.
Sensitivity increases with increasing θ_{23} .

SENSITIVITY TO CP VIOLATION

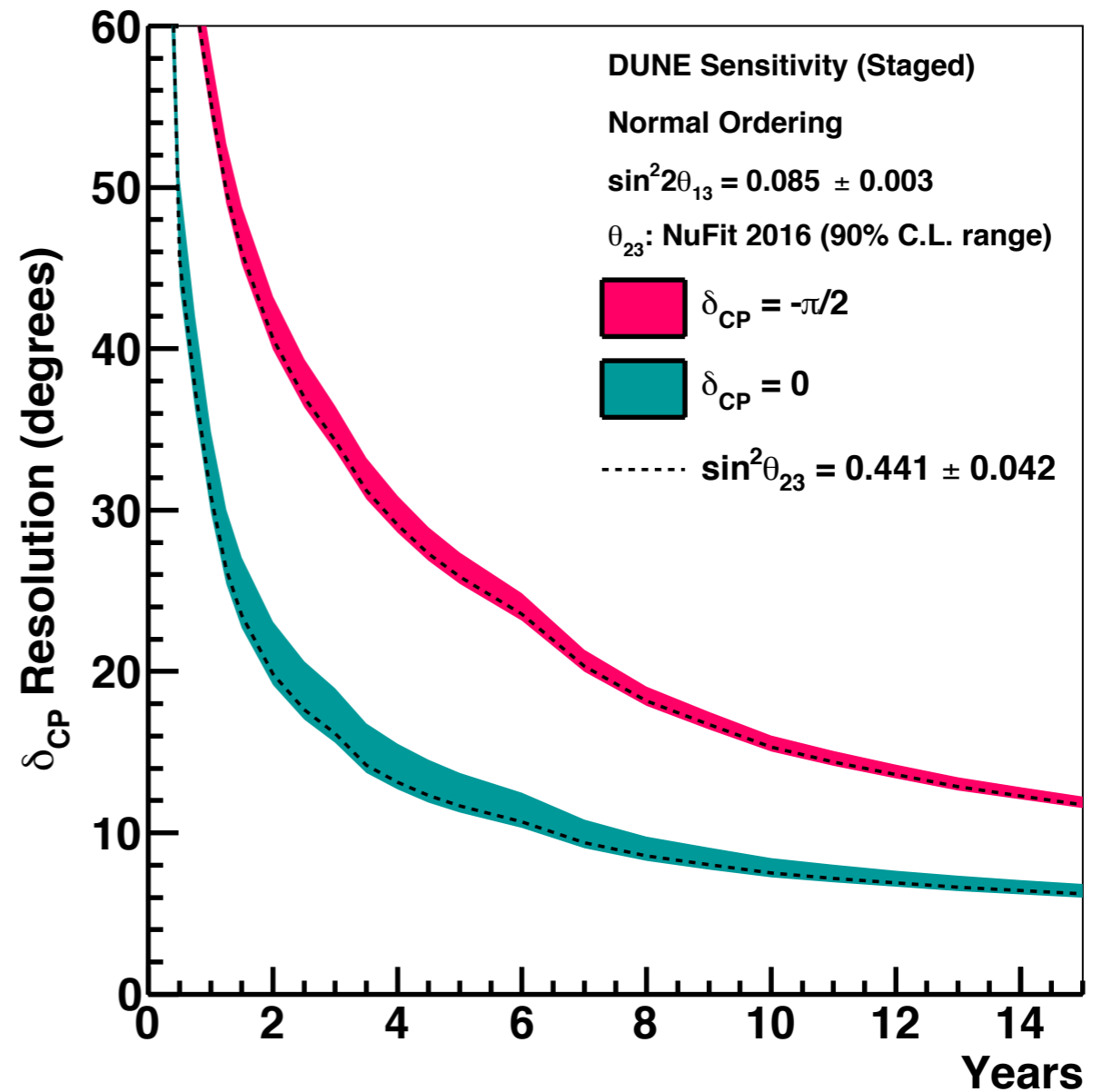


Width of bands represents range of sensitivities for the 90% CL region in θ_{23} values.
Sensitivity decreases with increasing θ_{23} .

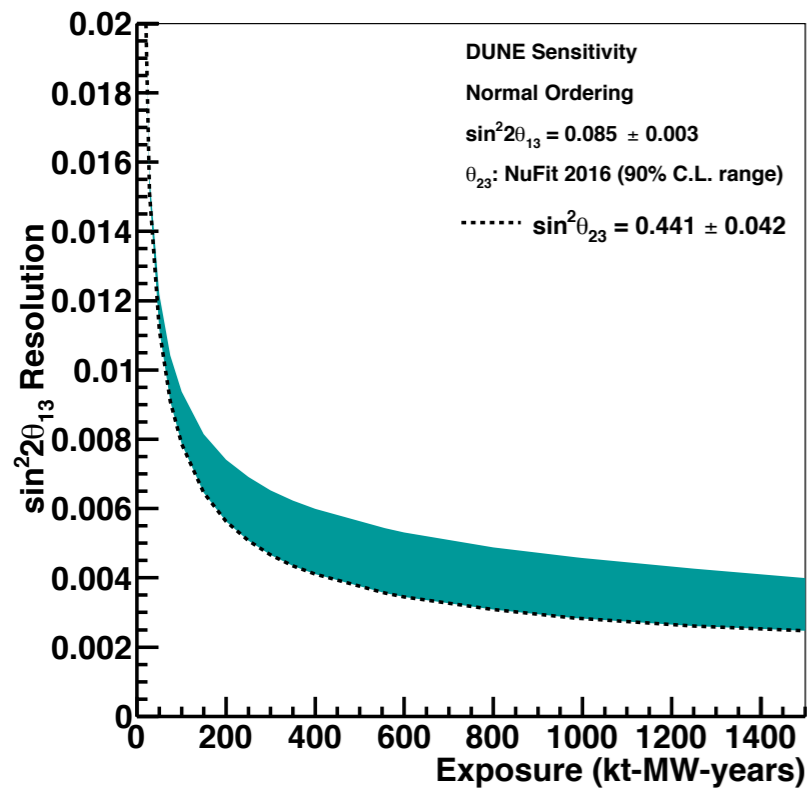
CP Violation Sensitivity



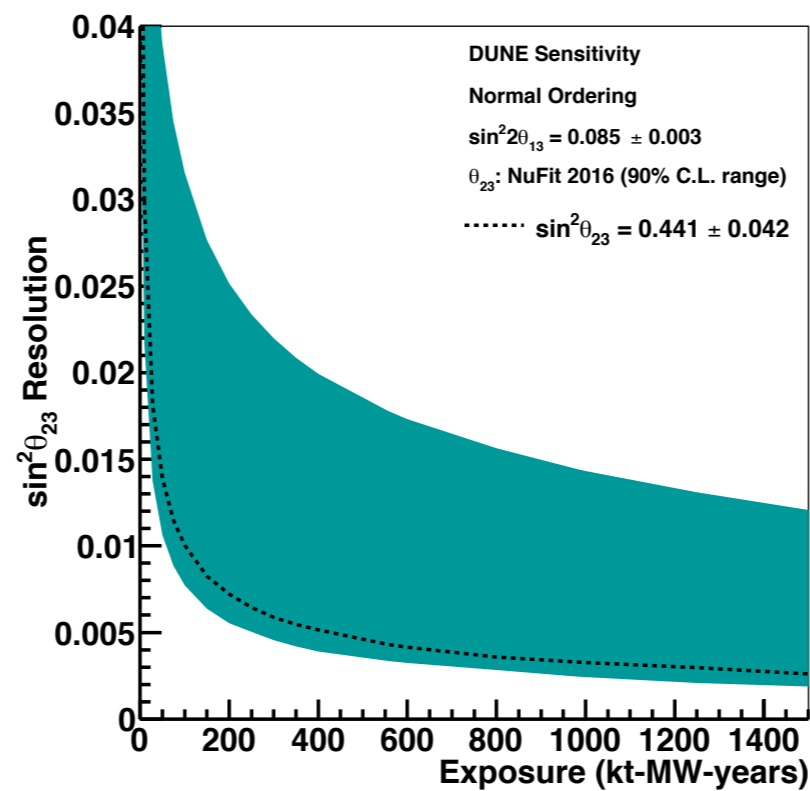
δ_{CP} Resolution



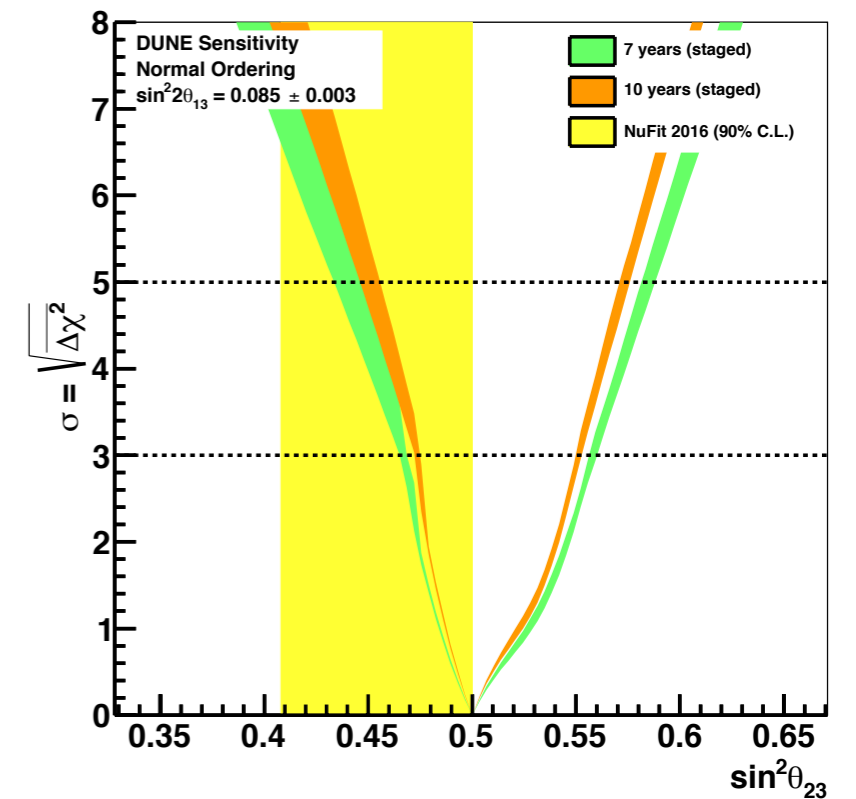
$\sin^2 2\theta_{13}$ Resolution



$\sin^2 \theta_{23}$ Resolution

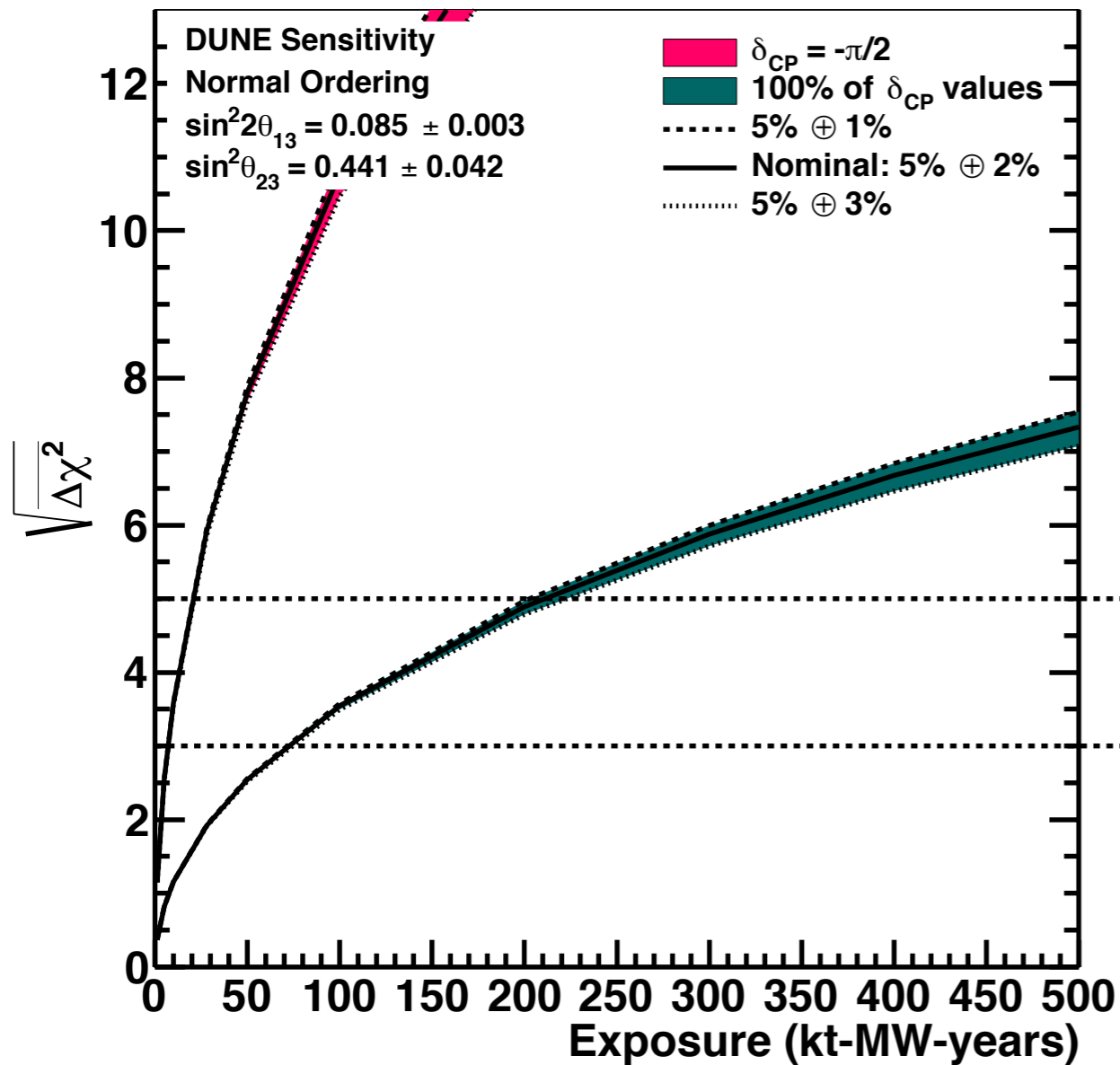


Octant Sensitivity

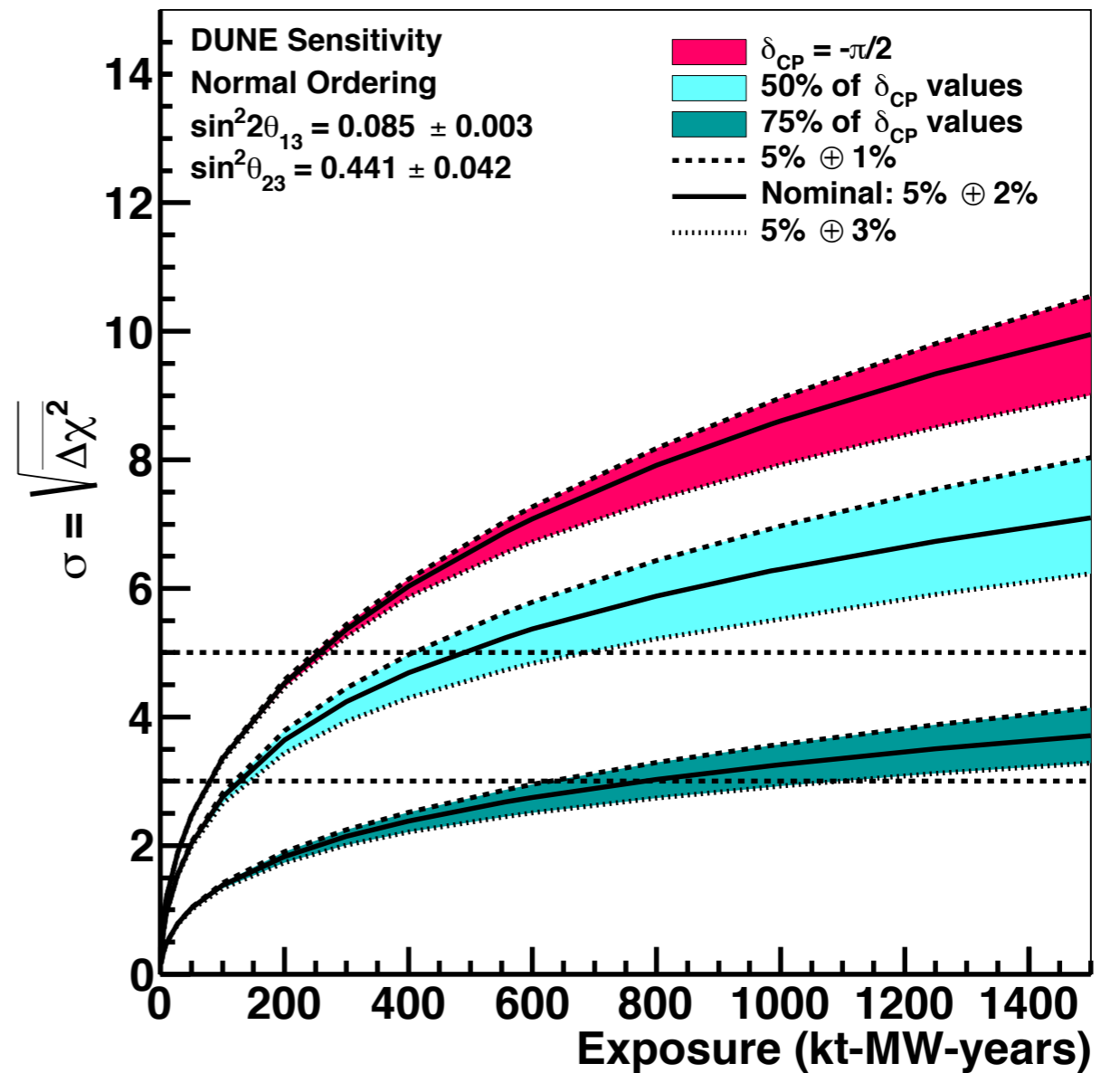


Long-baseline experiments will approach the resolution of reactor experiments in the measurement of the mixing angles.

MH Sensitivity



CP Violation Sensitivity



The difference between 1% and 3% normalisation uncertainty in the electron neutrino sample translates into a factor of 2 in exposure.

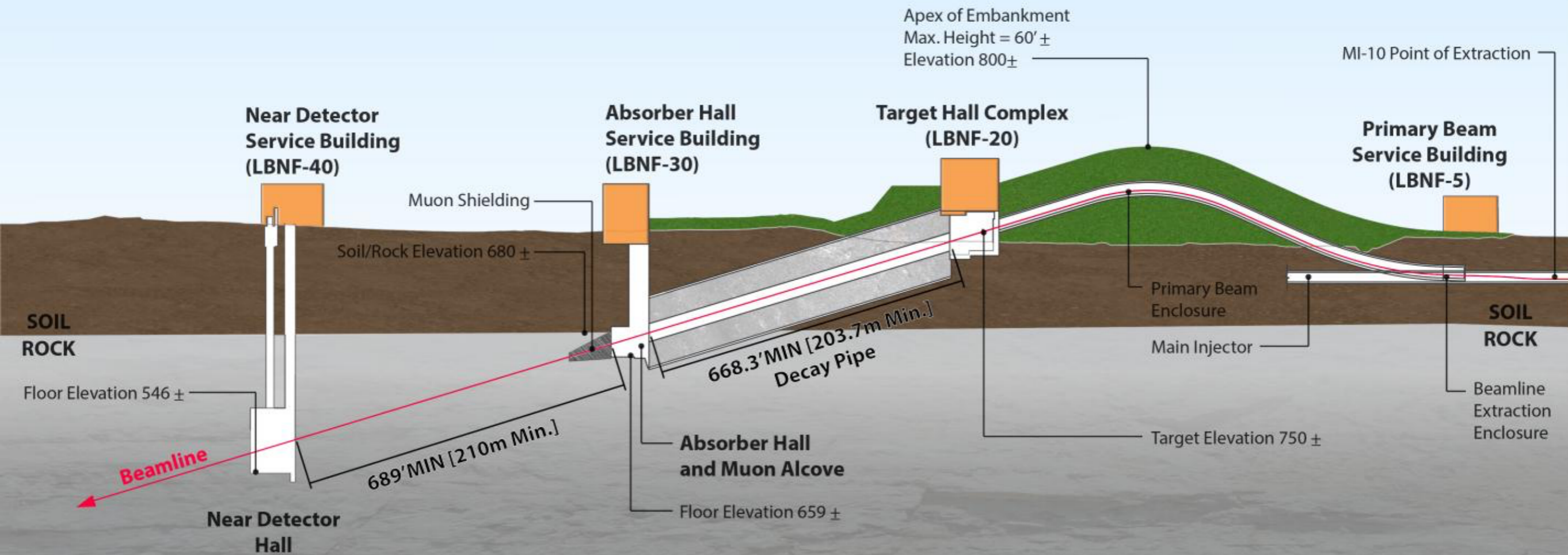
- DUNE will use a broadband beam and a long baseline (1300 km) to make a precise, simultaneous measurement of the mass ordering, the CP-violation phase and the neutrino mixing angles.
 - Comparison to other oscillation channels allows unitarity test.
 - Sensitive as well to new physics affecting oscillation probabilities.
- The mass, high granularity and deep underground location of the DUNE far detector provide good sensitivity to baryon non-conservation and supernova burst neutrinos.
- DUNE physics program will produce interesting results at each stage of 20+ year operation.

BACKUP SLIDES

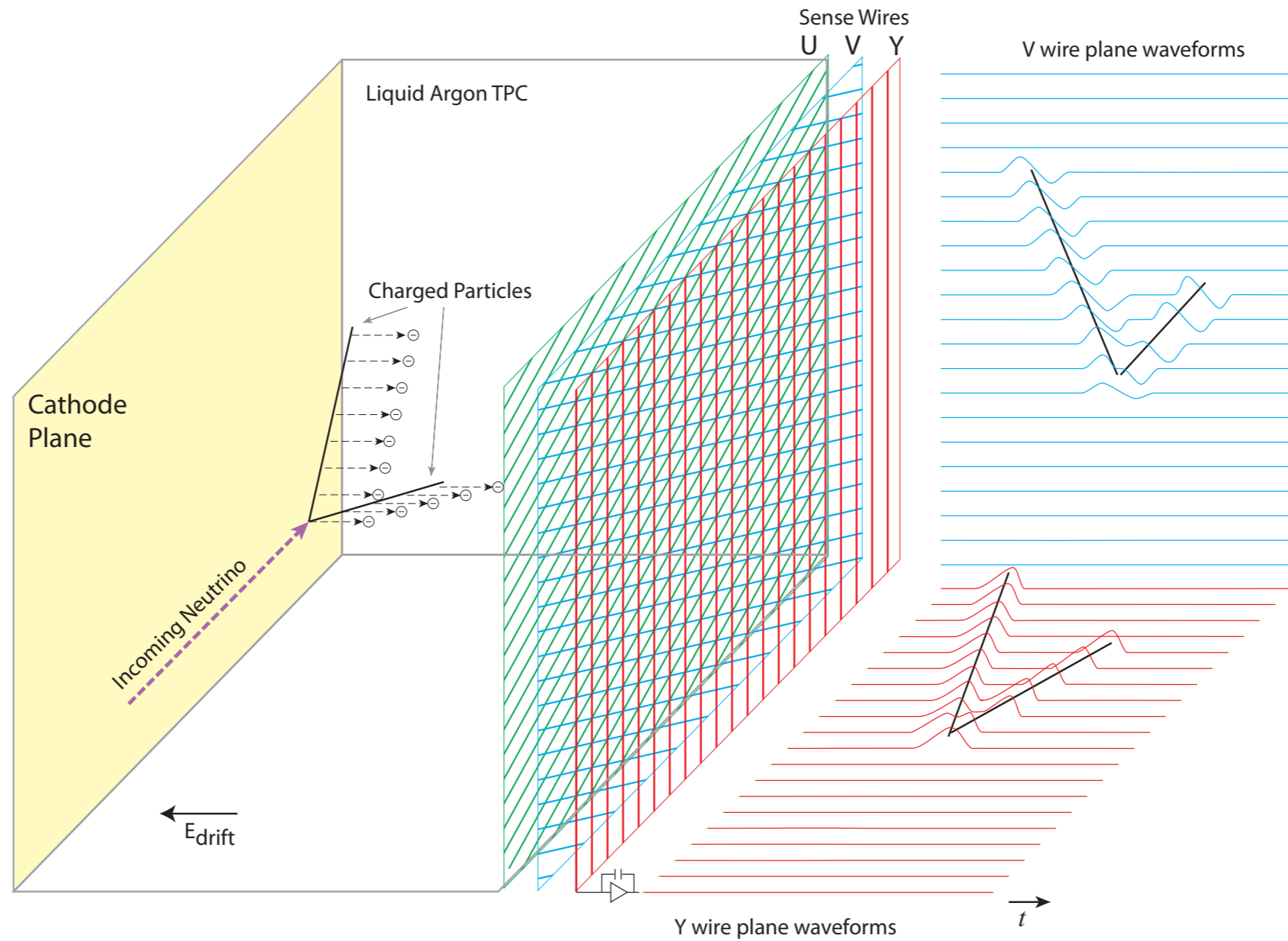
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LBNF NEUTRINO BEAMLINE

- 60-120 GeV protons from Fermilab Main Injector.
- Wide energy spectrum covers the 1st and 2nd oscillation maxima.
- Initial upward pitch, 101 mrad pitch to point to South Dakota.
- Initially 1.2 MW, upgradeable to 2.4 MW.



DUNE FAR DETECTOR: LIQUID ARGON TPC



Working principle of a (single phase) liquid argon time projection chamber.