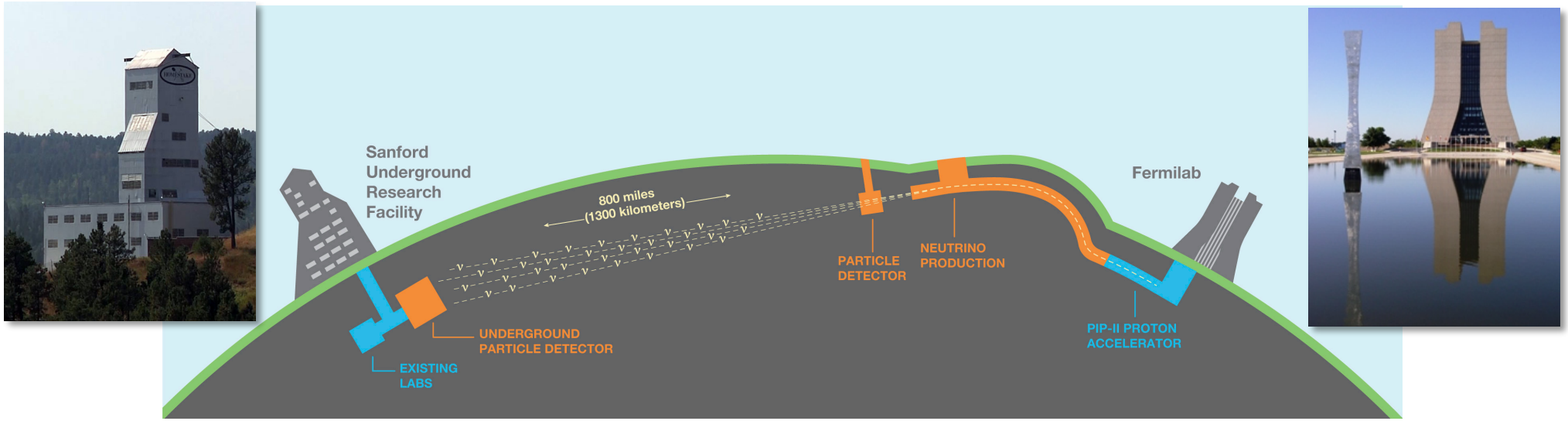

Status of DUNE: Deep Underground Neutrino Experiment

Ed Blucher

Stefan Söldner-Rembold

HEPAP Meeting

22 November 2019

THE UNIVERSITY OF CHICAGO

DUNE

P5 Recommendations

Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.

For a long-baseline oscillation experiment, based on the science Drivers and what is practically achievable in a major step forward, we set as the goal a mean sensitivity to CP violation[2] of better than 3σ (corresponding to 99.8% confidence level for a detected signal) over more than 75% of the range of possible values of the unknown CP-violating phase δ_{CP}. By current estimates, this goal corresponds to an exposure of 600 kt*MW*yr assuming systematic uncertainties of 1% and 5% for the signal and background, respectively. With a wideband neutrino beam produced by a proton beam with power of 1.2 MW, this exposure implies a far detector with fiducal mass of more than 40 kilotons (kt) of liquid argon (LAr) and a suitable near detector. The minimum requirements to proceed are the identified capability to reach an exposure of at least 120 kt*MW*yr by the 2035 timeframe, the far detector situated underground with cavern space for expansion to at least 40 kt LAr fiducial volume, and 1.2 MW beam power upgradable to multi-megawatt power. The experiment should have the demonstrated capability to search for supernova (SN) bursts and for proton decay, providing a significant improvement in discovery sensitivity over current searches for the proton lifetime.

Recommendation 13: Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest-priority large project in its timeframe.

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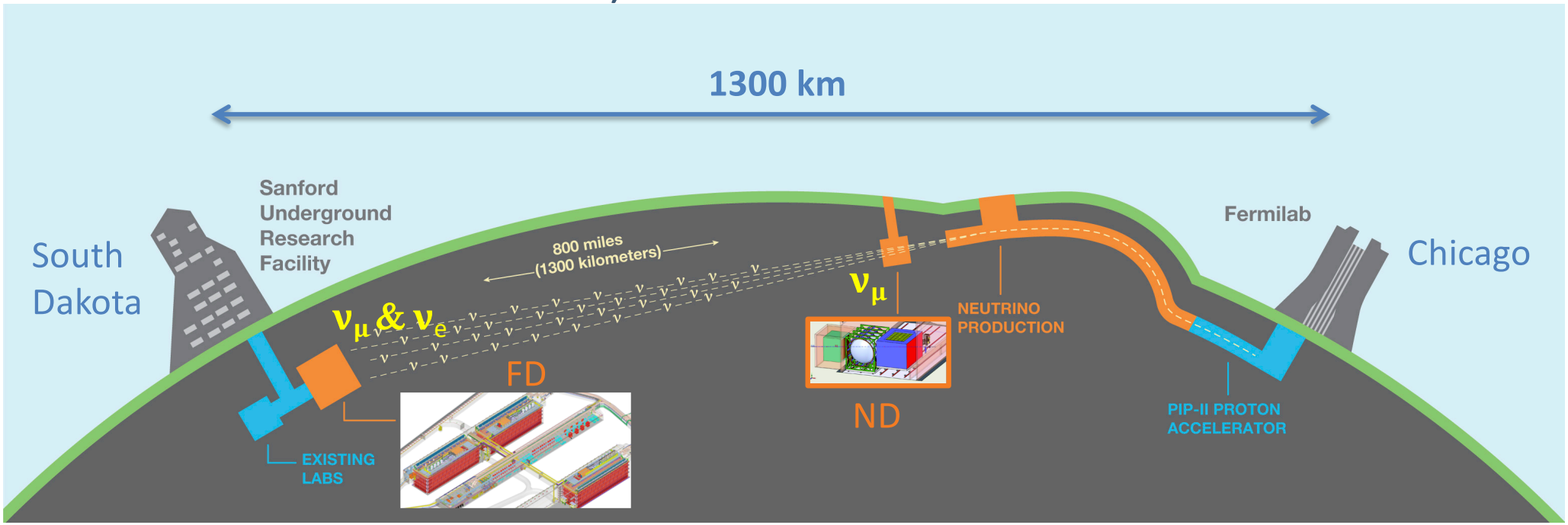
LBNF and DUNE are designed to meet the P5 goals.

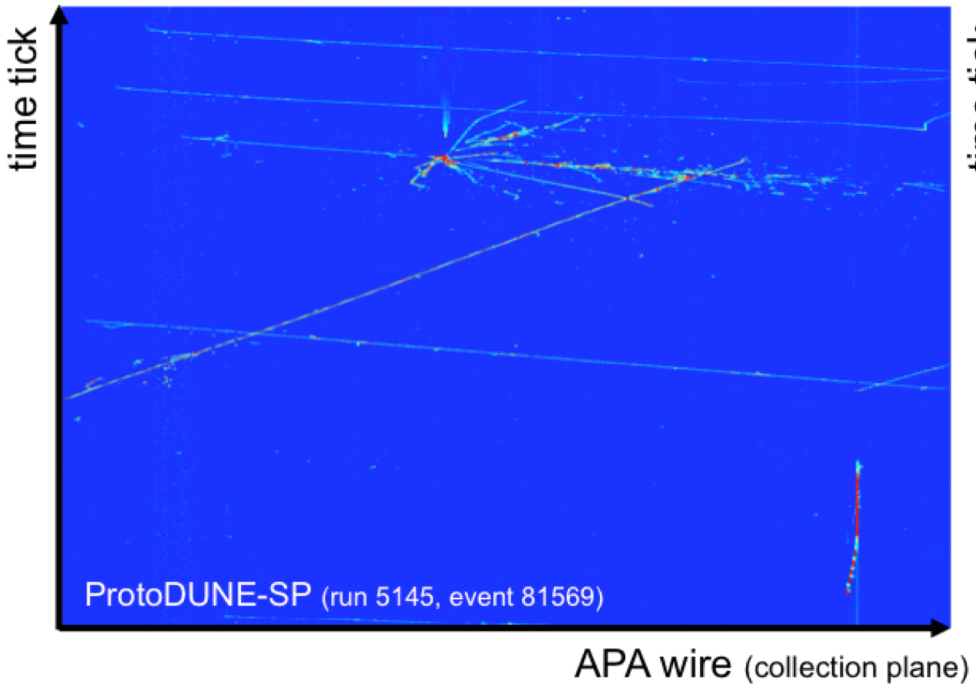
LBNF/DUNE Overview

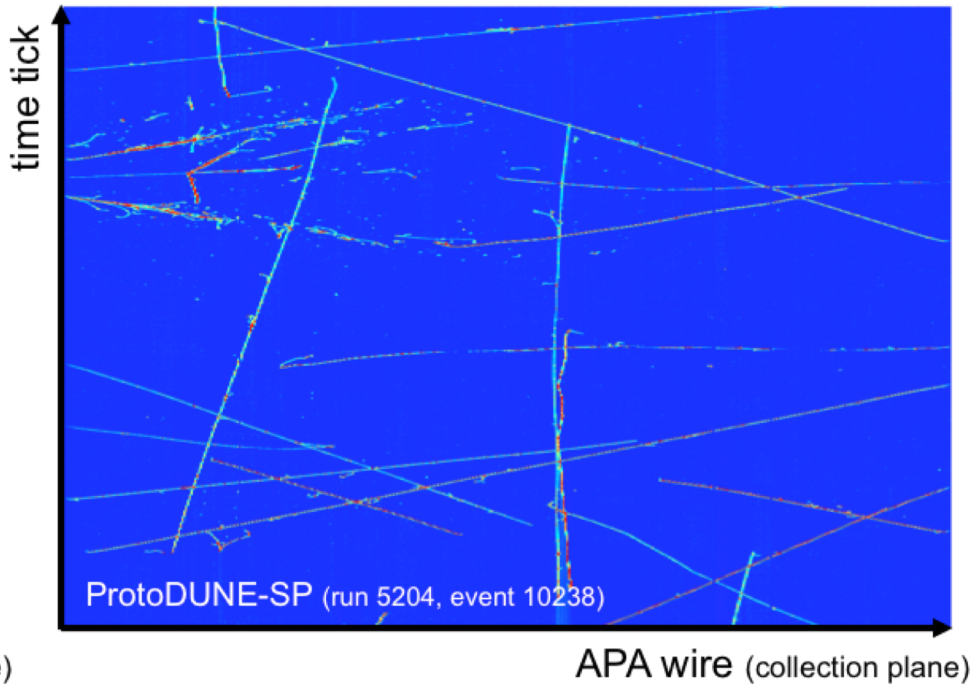
- Muon neutrinos/antineutrinos from high-power proton beam
  - 1.2 MW from day one; upgradeable to 2.4 MW
- Massive underground Liquid Argon Time Projection Chambers
  - 2 x 17 kt from day one; full DUNE scope is 4 x 17 kt (> 40 kt fiducial)
- Near detector to characterize the beam (100s of millions of neutrino interactions)



DUNE Science

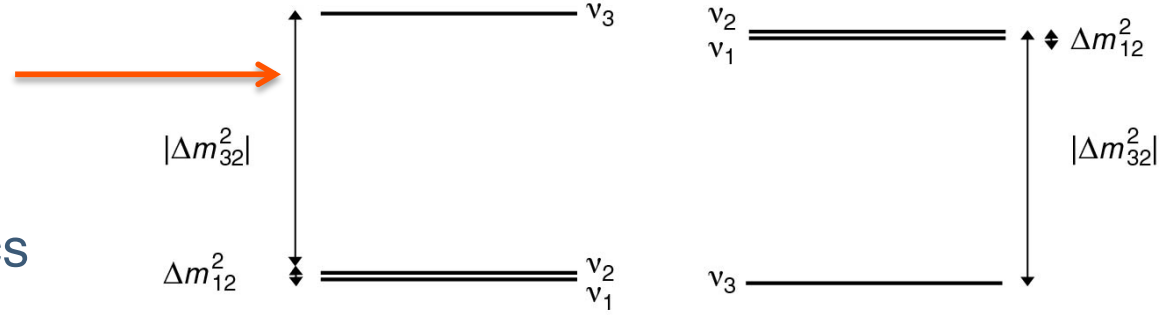
Unique combination of world's most intense wide-band neutrino beam, a deep underground site, and massive LAr detectors enables broad science program addressing some of the most fundamental questions in particle physics.





DUNE Science Program

- Neutrino Oscillation Physics
  - **Search for leptonic (neutrino) CP Violation**
  - Resolve the mass ordering

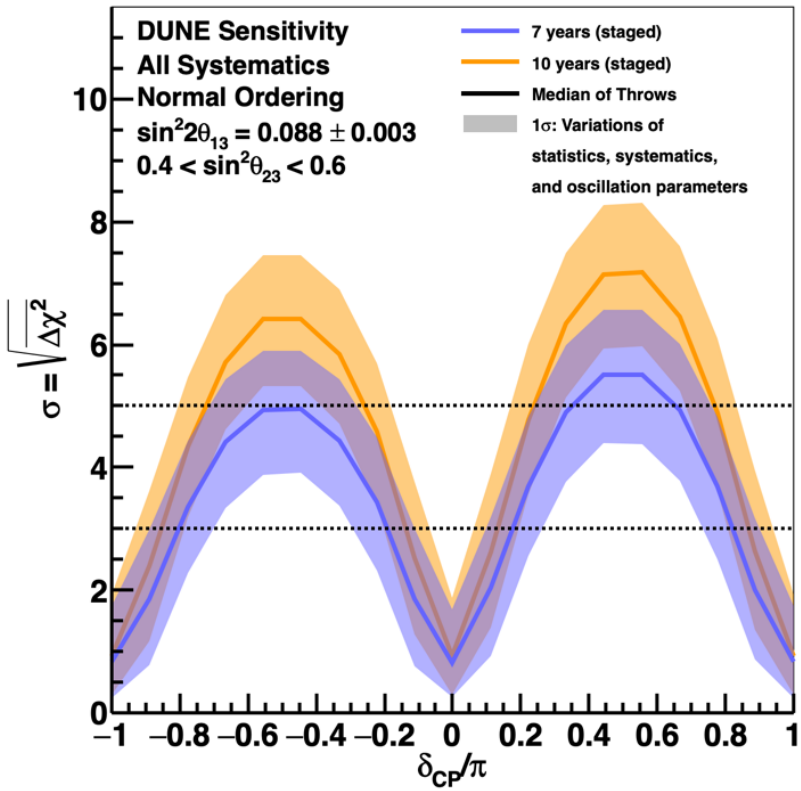


  ($m_3 > m_{1,2}$ or $m_{1,2} > m_3$)
  - Precision oscillation physics
    - Parameter measurements, θ_{23} octant
    - **Testing the current 3-neutrino model, non-standard interactions, …**
- Supernova burst physics and astrophysics
  - 3000 ν_e events in 10 sec from SN at 10 kpc
- Nucleon Decay

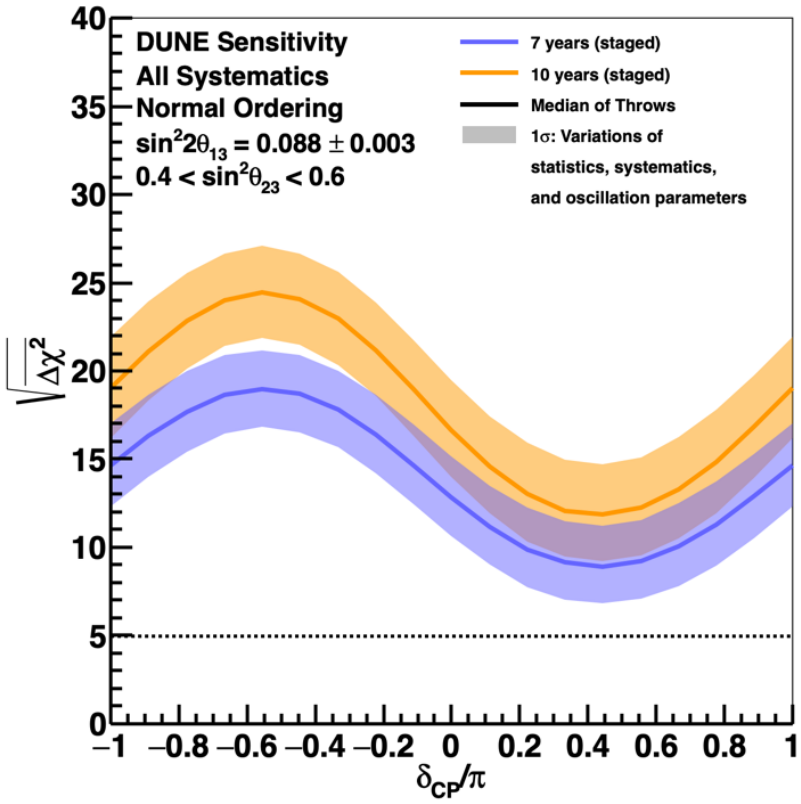
+ many other topics (ν interaction physics with near detector, atmospheric neutrinos, sterile neutrinos, WIMP searches, Lorentz invariance tests, etc.)

DUNE CP Violation and Mass Ordering

CP Violation Sensitivity



Mass Ordering Sensitivity

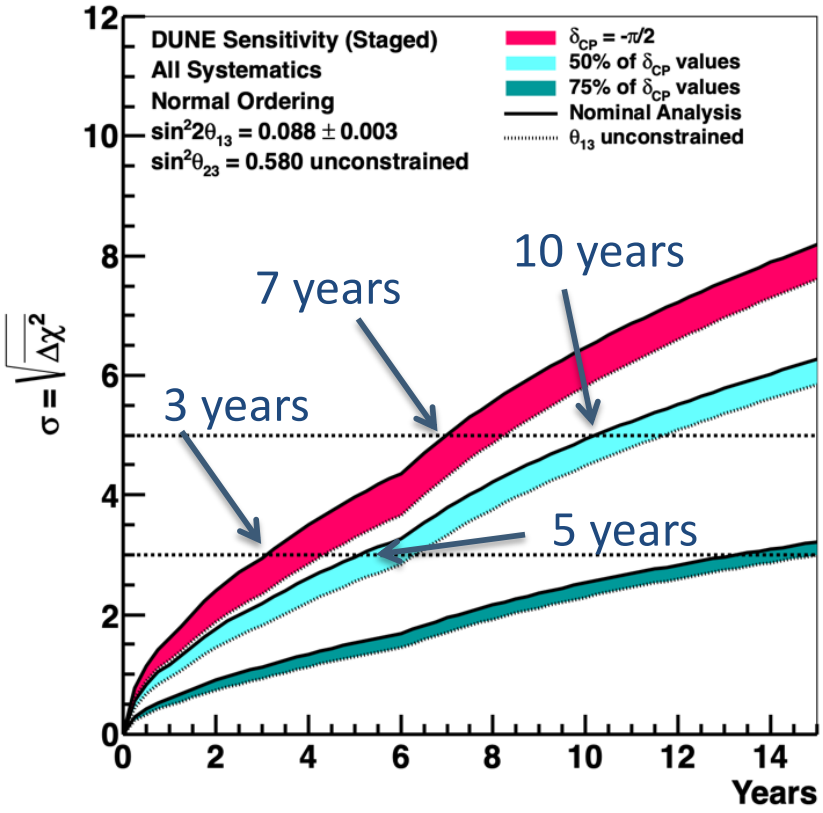


After 7 years (staged):

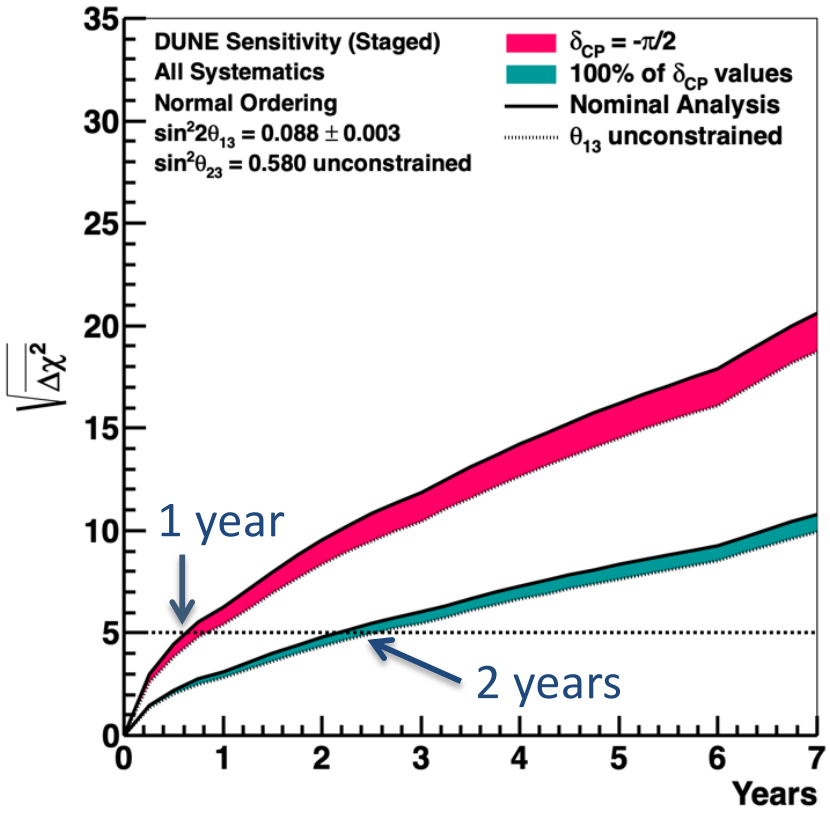
- CP Violation: 5σ if δ_{CP} near $\pm\pi/2$
- Mass hierarchy determination: > 5σ for all parameter values

DUNE Sensitivity vs. time

CP Violation Sensitivity



Mass Hierarchy Sensitivity

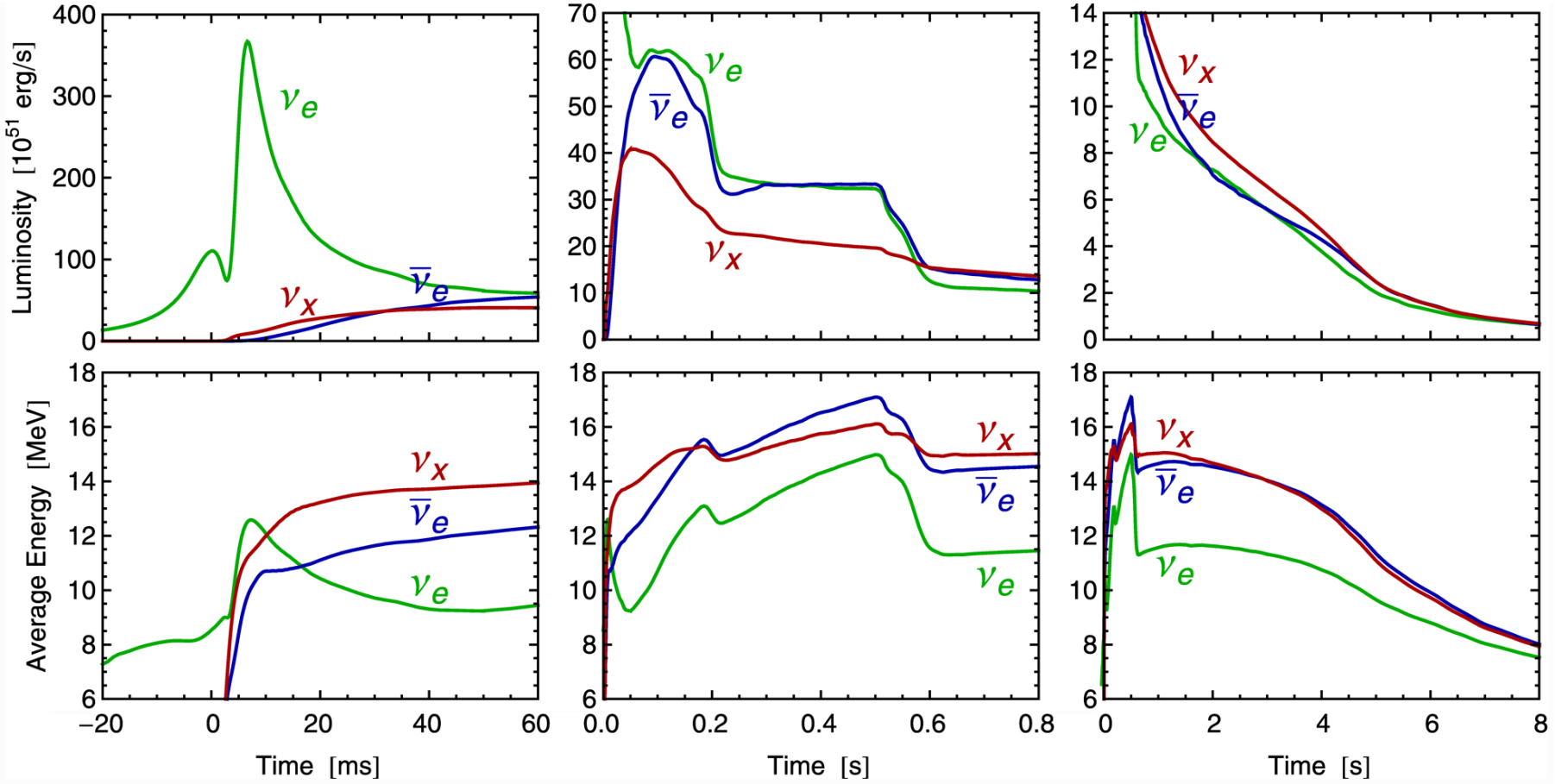


Important sensitivity milestones throughout beam physics program

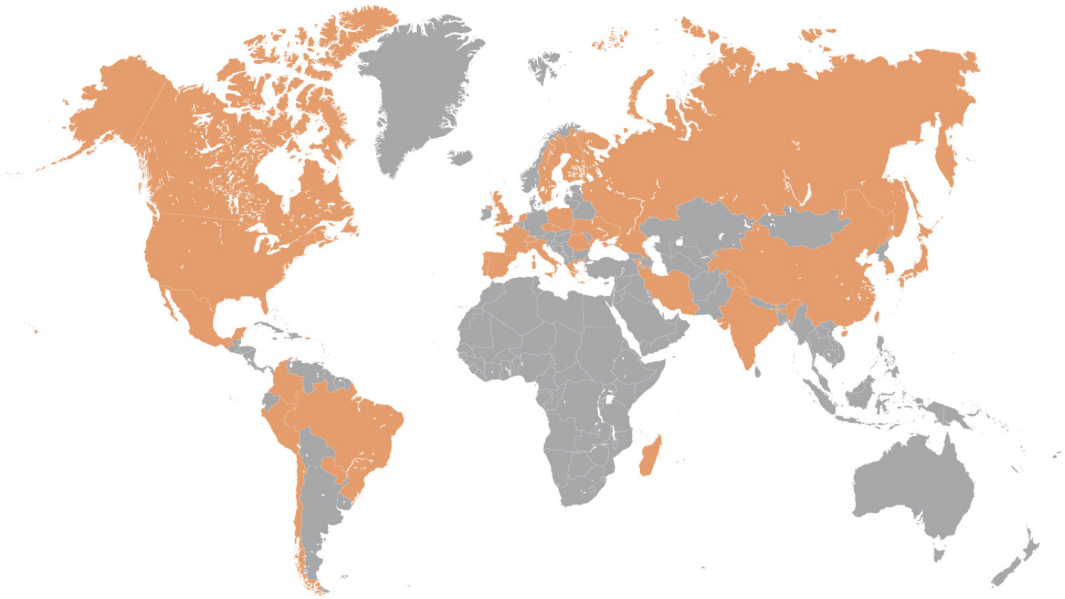
➡ Meets P5 goals

SN Neutrinos in DUNE

- LAr provides unique sensitivity to ν_e: $\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$
- About 3000 ν_e events in 10 sec from SN at 10 kpc



DUNE – a global collaboration



~1100 collaborators from
188 institutions in
31 countries + CERN

Continued growth, based on
exceptional science program

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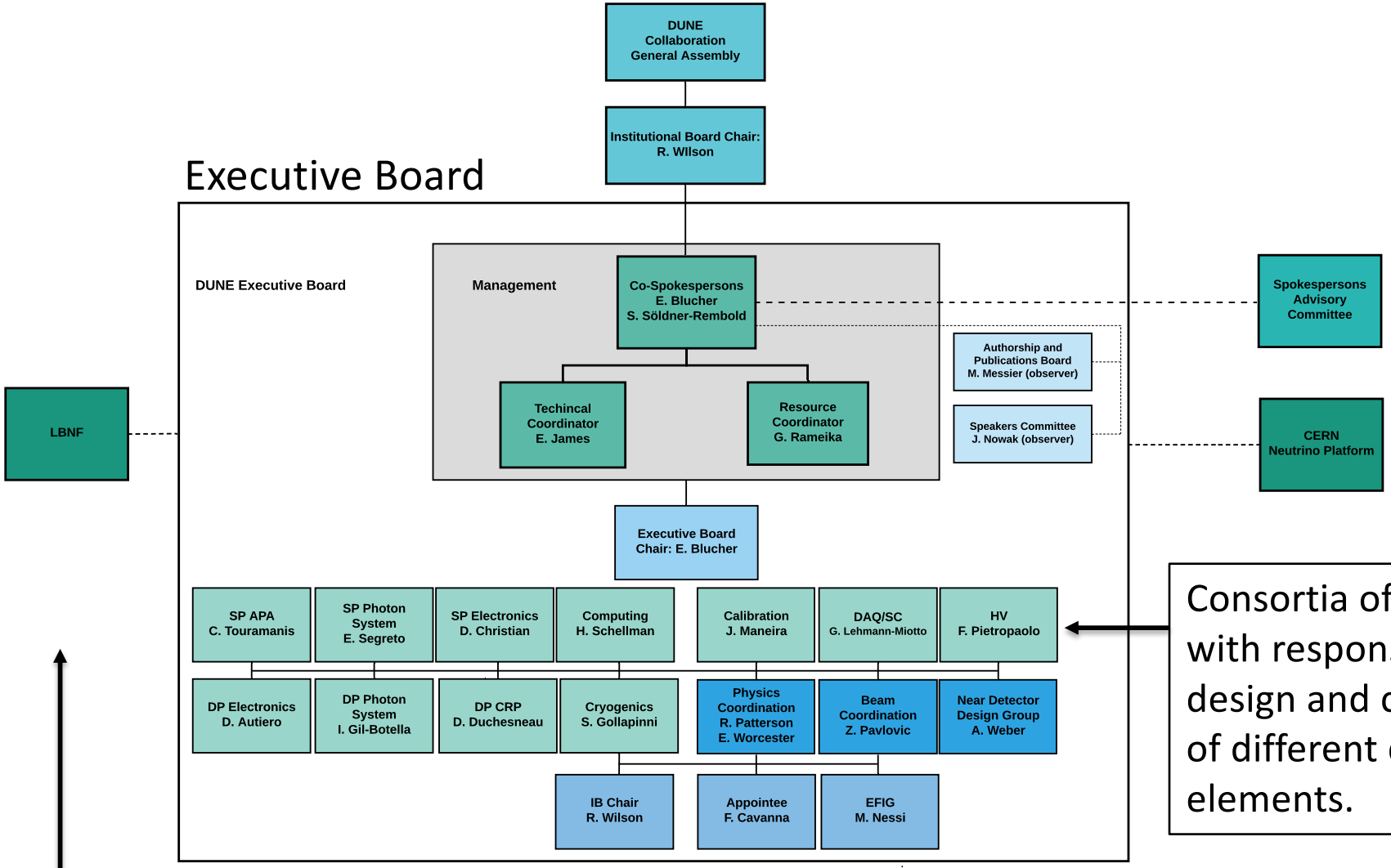
Collaboration Management



Consortia of institutions with responsibility for design and construction of different detector elements.

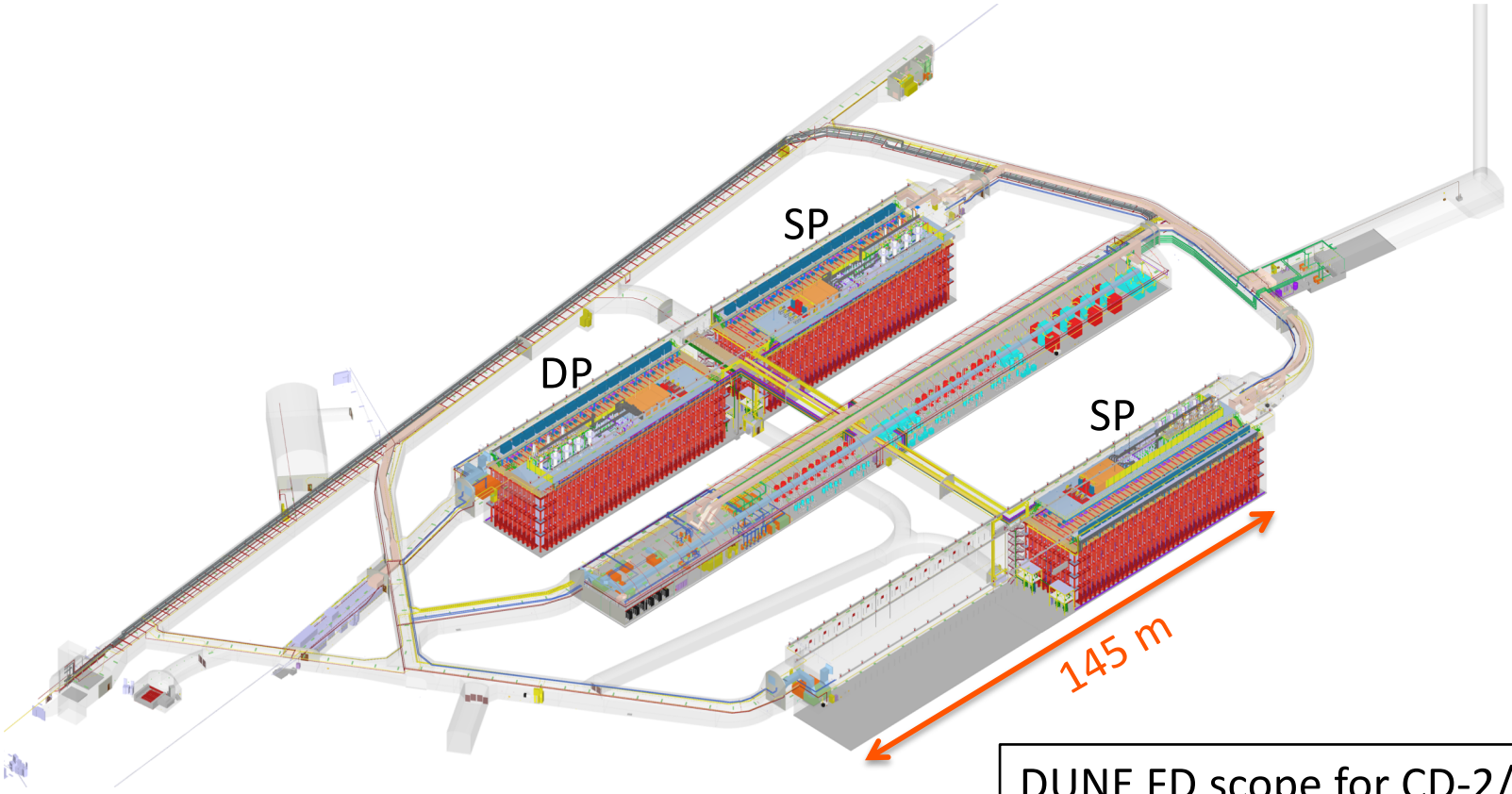
We work in close coordination with LBNF.

International Oversight

- DUNE Resources Review Board (RRB) (Chair: Alison Markovitz)
  - Established to provide coordination among funding partners and oversight of DUNE. Composed of representatives of all funding agencies that sponsor the project (including DOE).
- Long Baseline Neutrino Committee (LBNC) (Chair: Hugh Montgomery)
  - Charged by the Fermilab director to review the scientific, technical, and managerial progress, plans and decisions associated with DUNE. The committee chair reports to the Fermilab director. The LBNC is charged with reviewing DUNE TDRs and providing a recommendation on their endorsement to the Fermilab director and RRB.
- Neutrino Cost Group (NCG) (Chair: Steve Nahn)
  - Charged by the Fermilab director to review the cost, schedule, and associated risks for the DUNE experiment, and to provide regular reports to the Fermilab director and the RRB.

DUNE Far Detector (FD)

- Four separate 17 kt (> 10 kt fiducial) LAr TPCs
- 4 identically sized cryostats: 2 single phase (SP) + 1 dual phase (DP) +1 “opportunity” (this 2+1+1 plan is described in TDR)



DUNE FD scope for CD-2/3 review is two SP modules.

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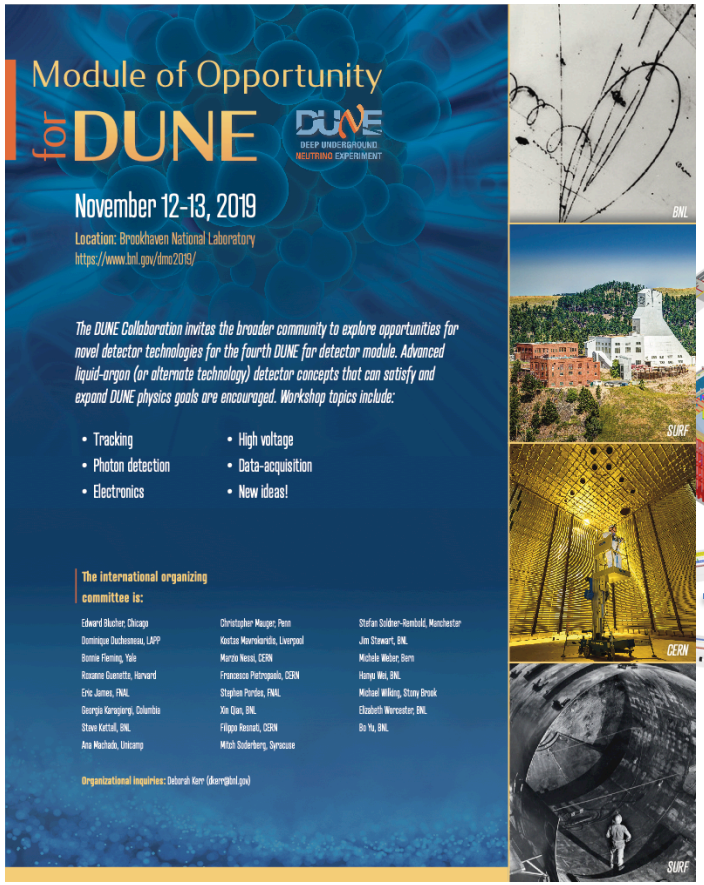

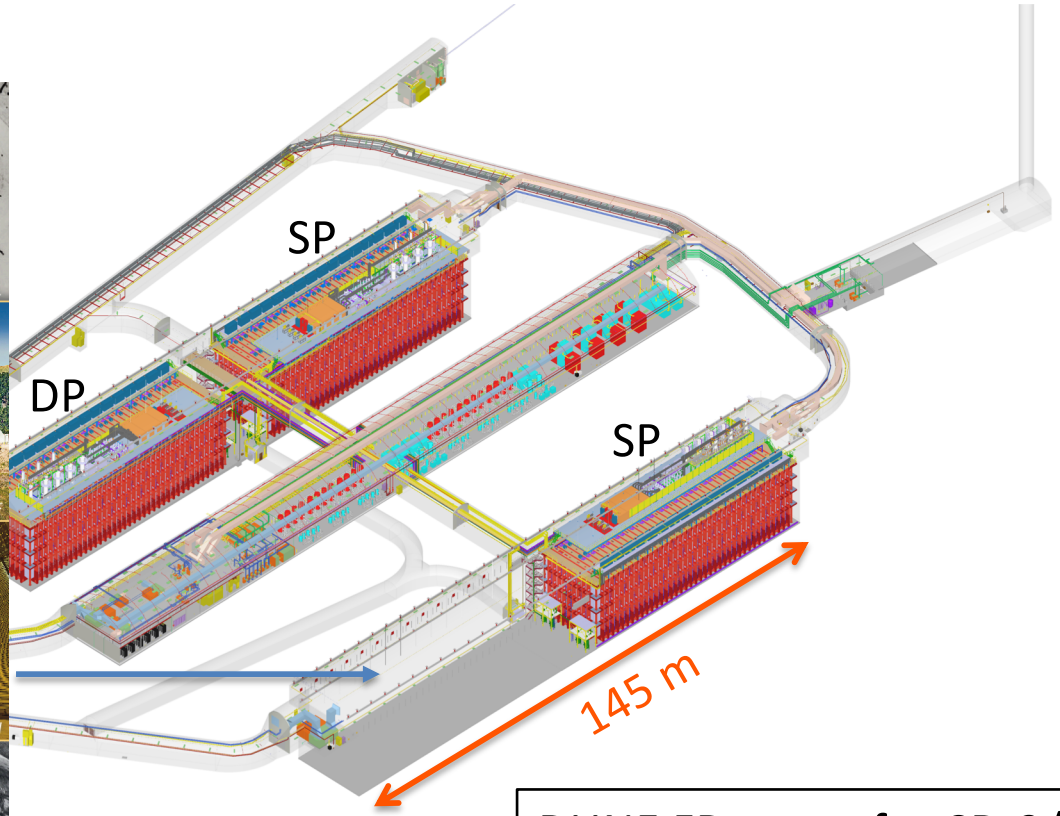

DUNE FD scope for CD-2/3 review is two SP modules.

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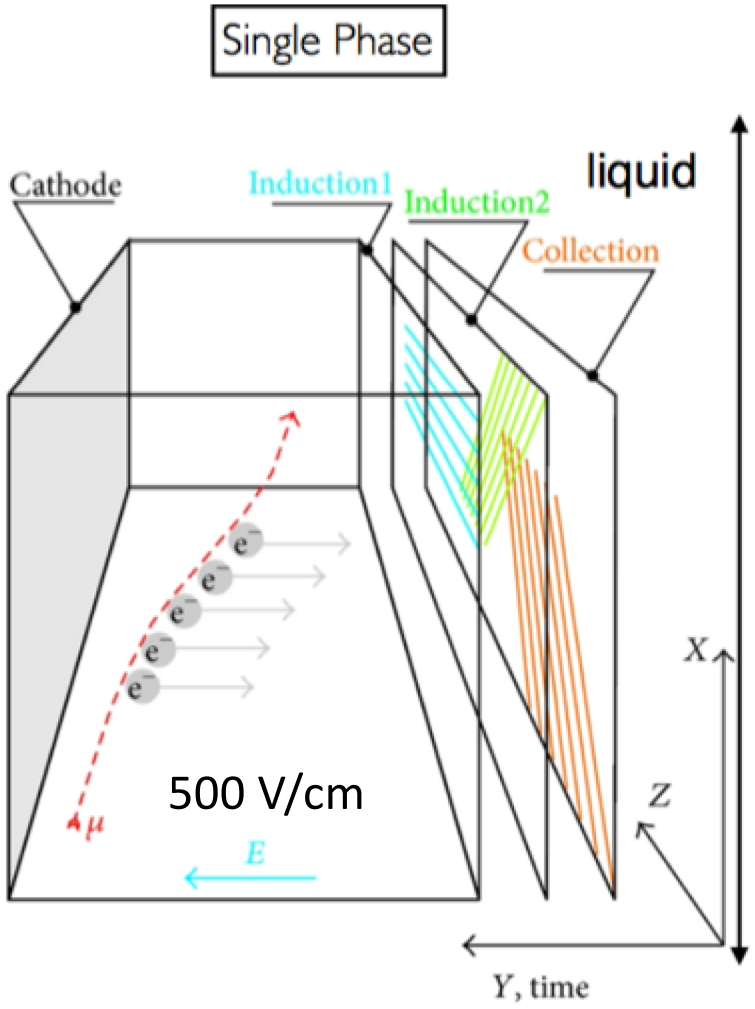
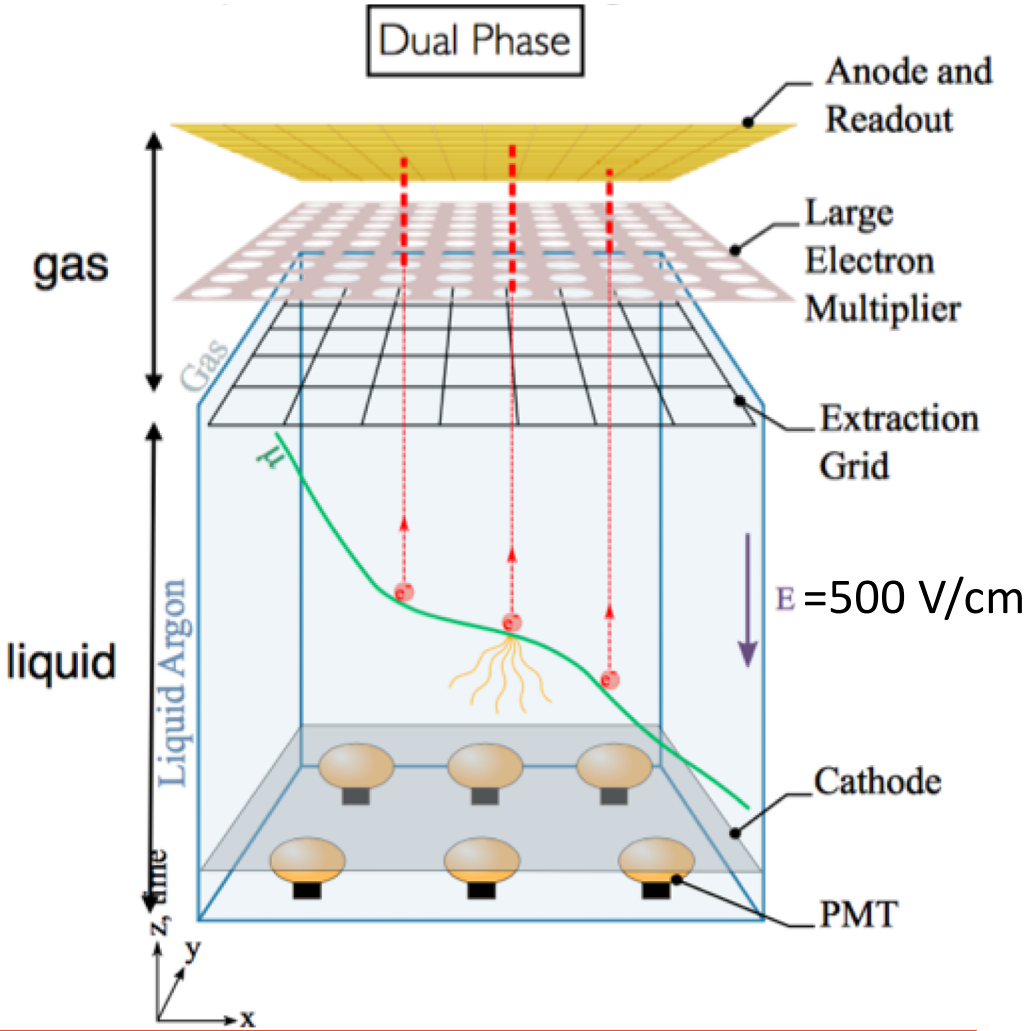
DUNE Far Detector Technologies

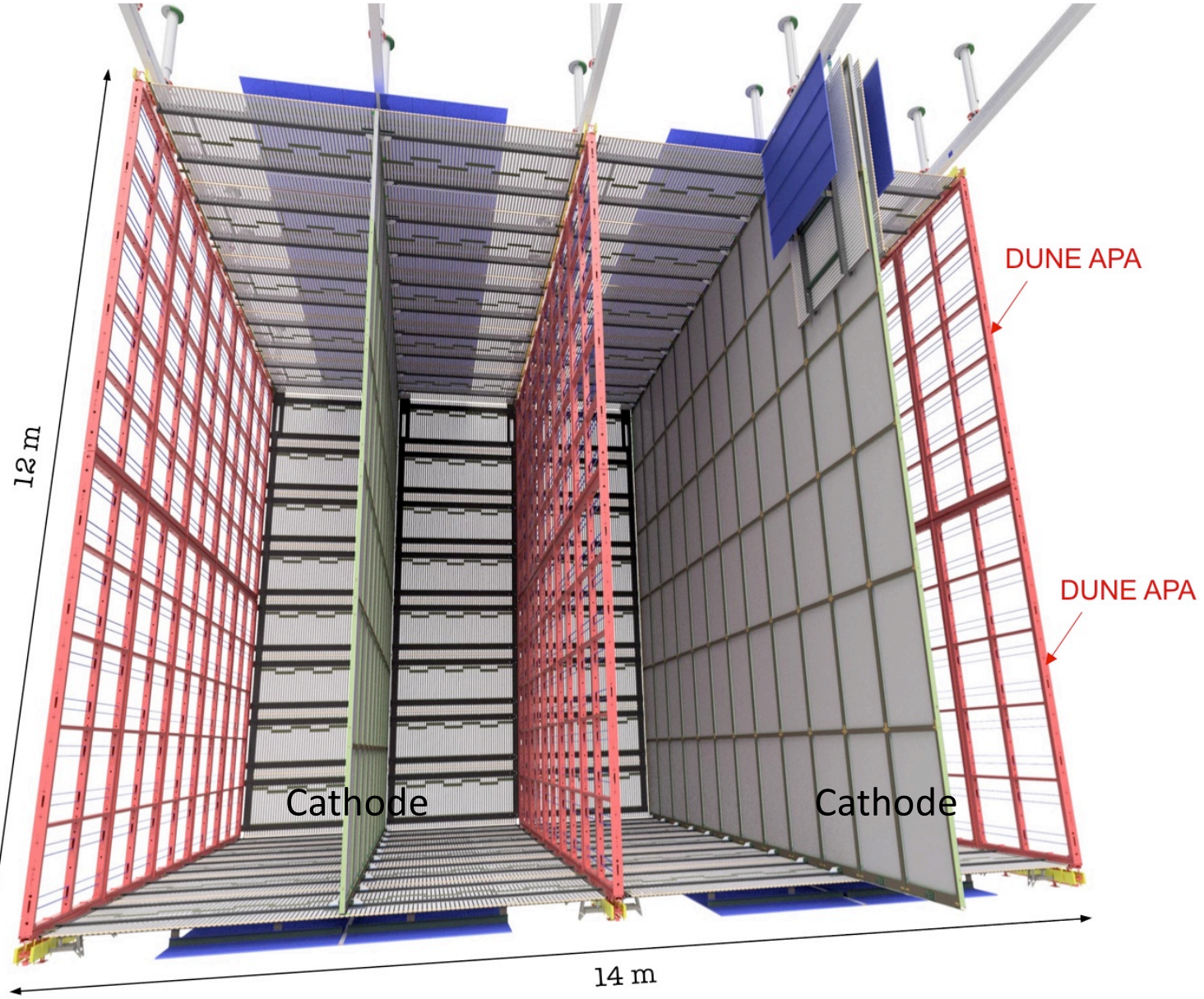
- Ionization charges drift horizontally and are read out with wires
- No signal amplification in liquid
- 3.5 m maximum drift



- Ionization charges drift vertically and are read out on PCB anode
- Amplification of signal in gas phase by LEM
- 12 m maximum drift



DUNE Single-phase TPC Design



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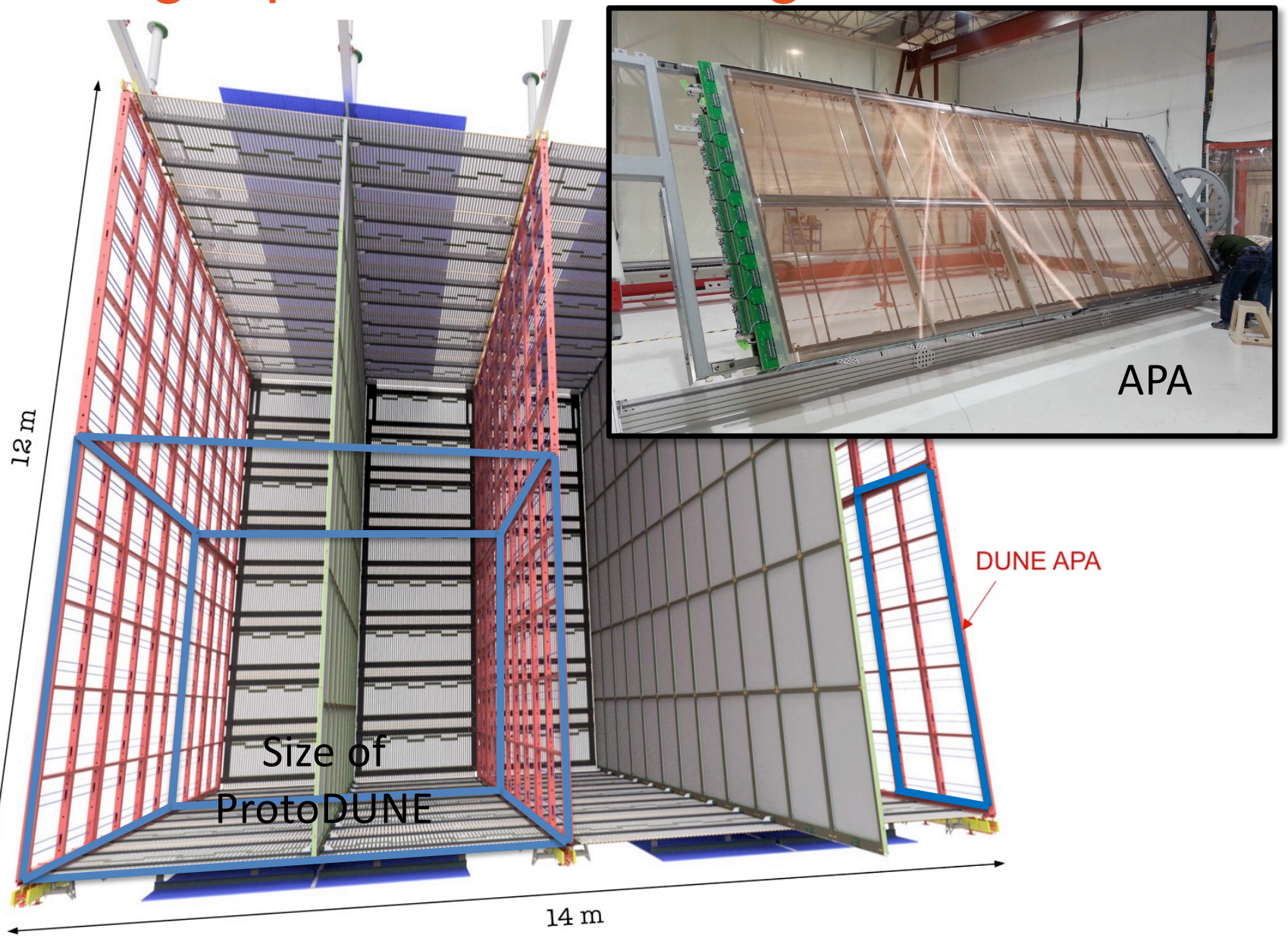
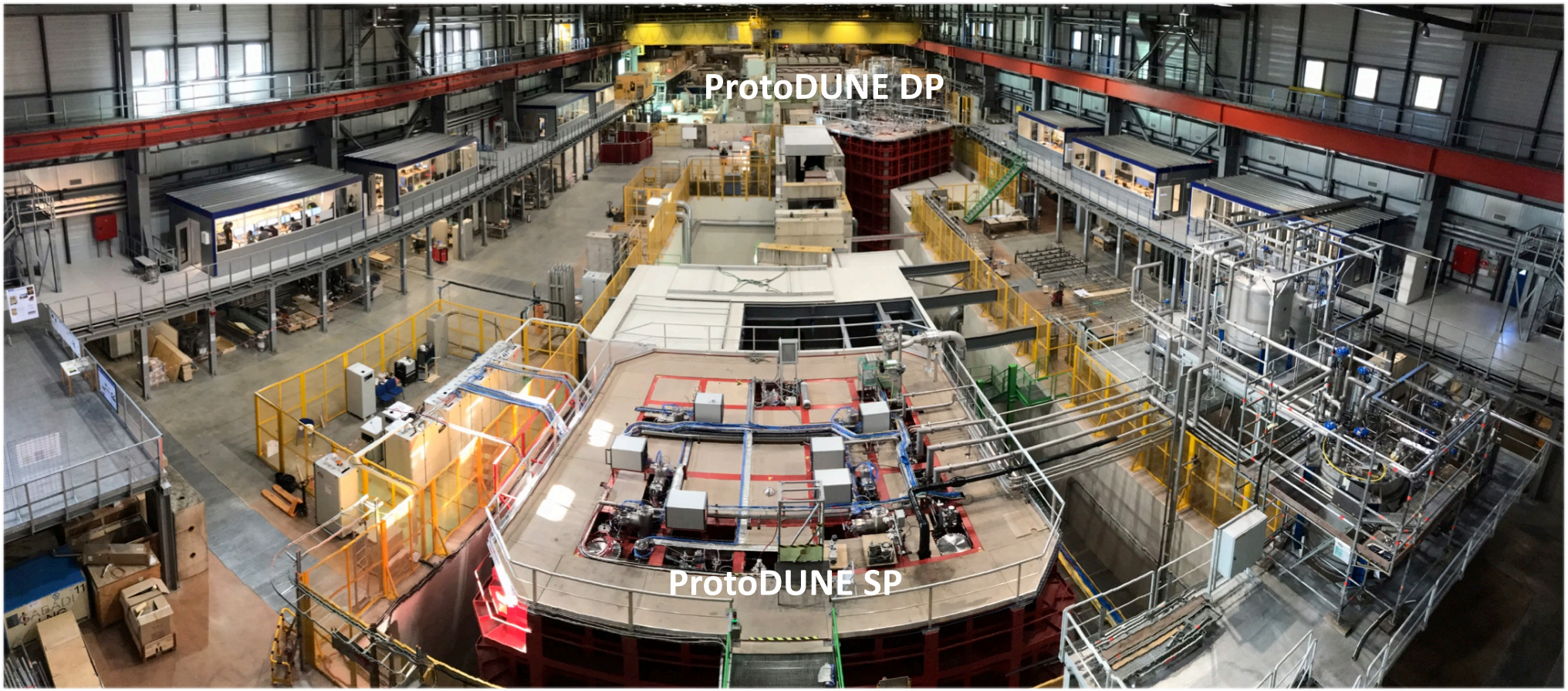
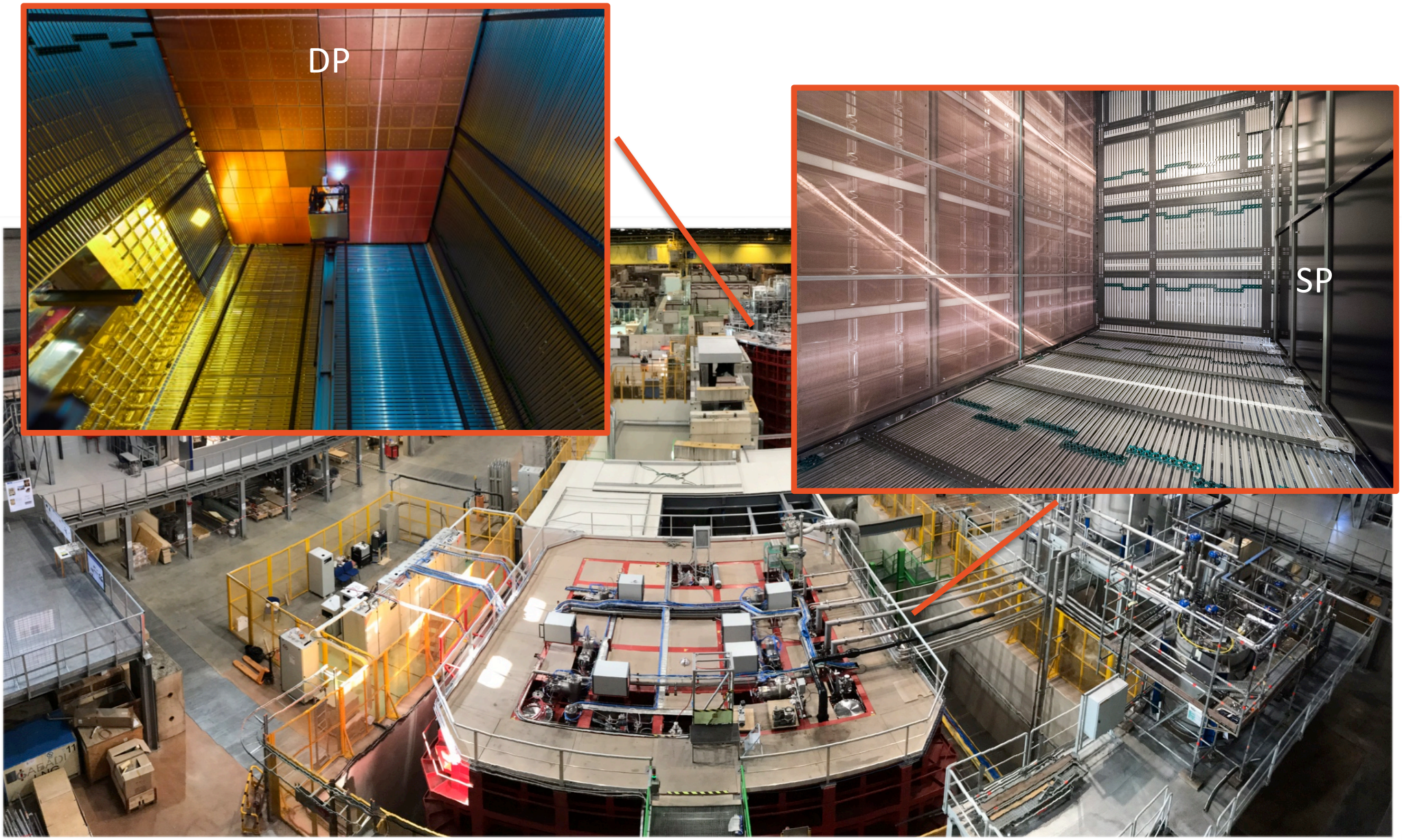


ProtoDUNEs

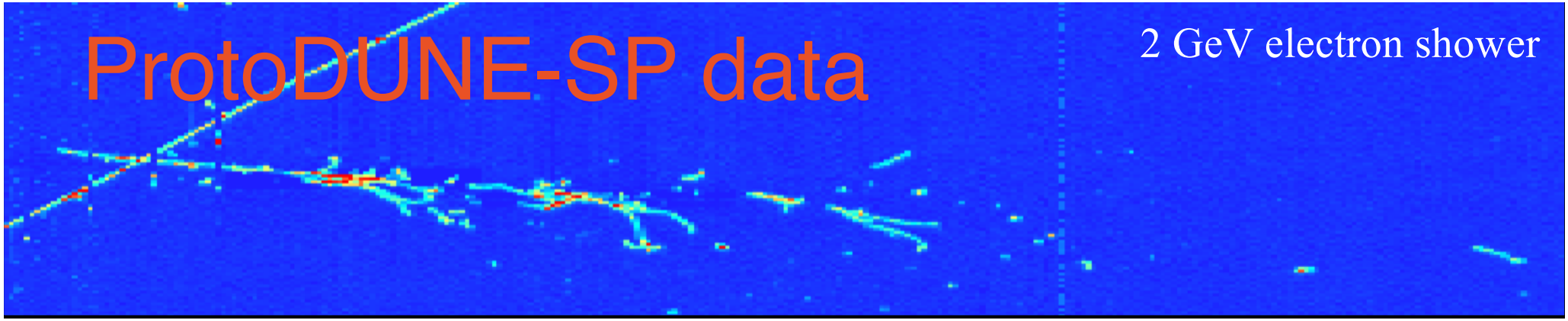
DUNE has constructed 1 kton-scale prototypes of LAr TPCs with single and dual phase readout at CERN



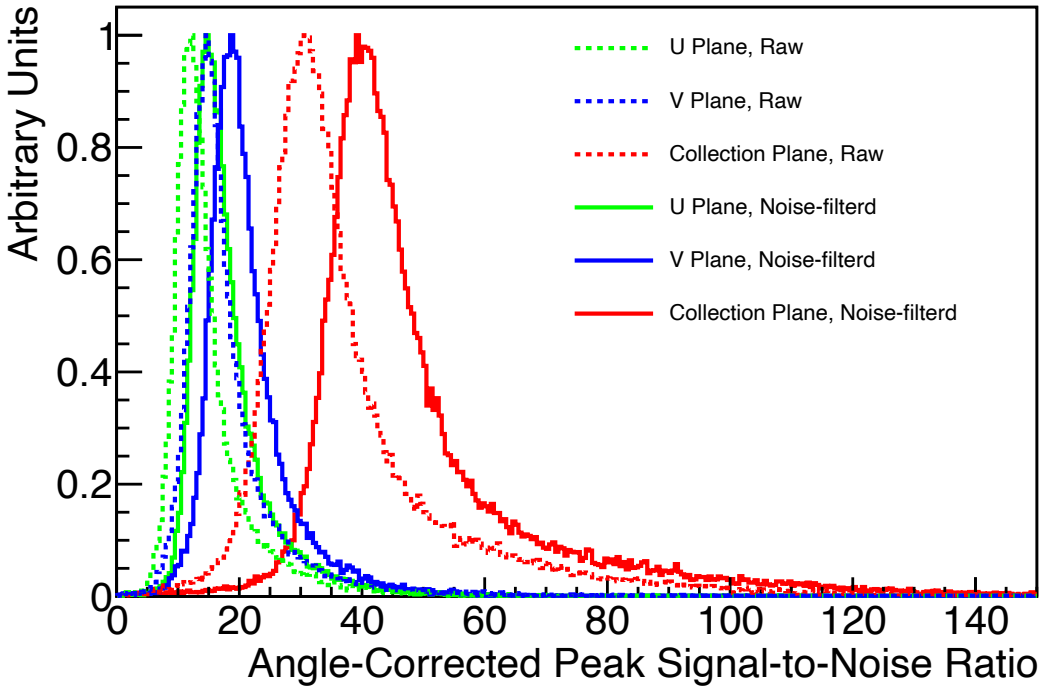
ProtoDUNEs

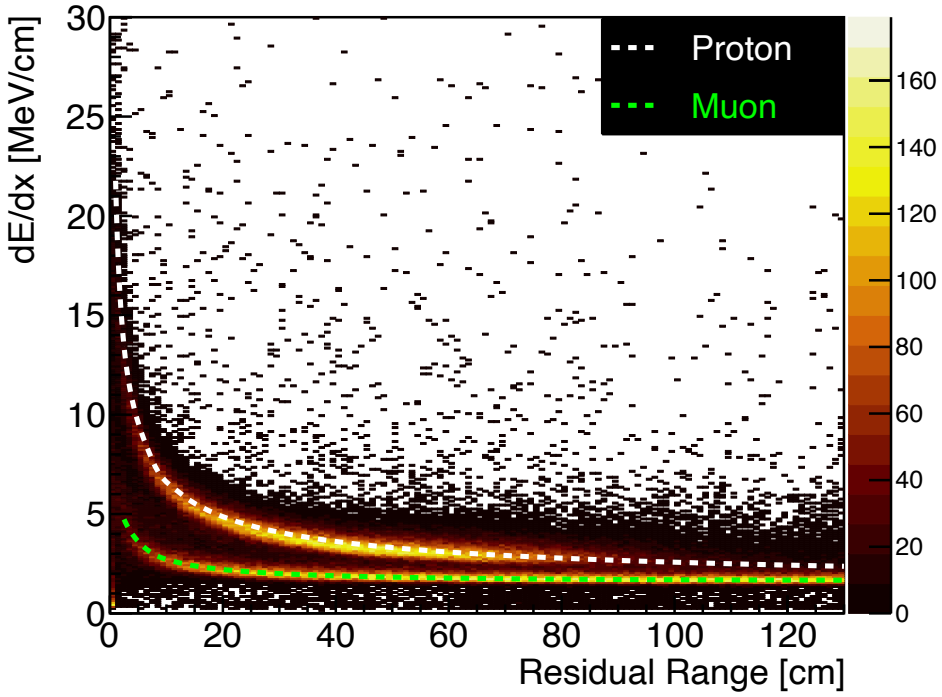


ProtoDUNE-SP data



- > 1 year of stable data taking, including 2 months of beam data
- Excellent performance: HV, liquid argon purity, and signal-to-noise
- First publication in preparation





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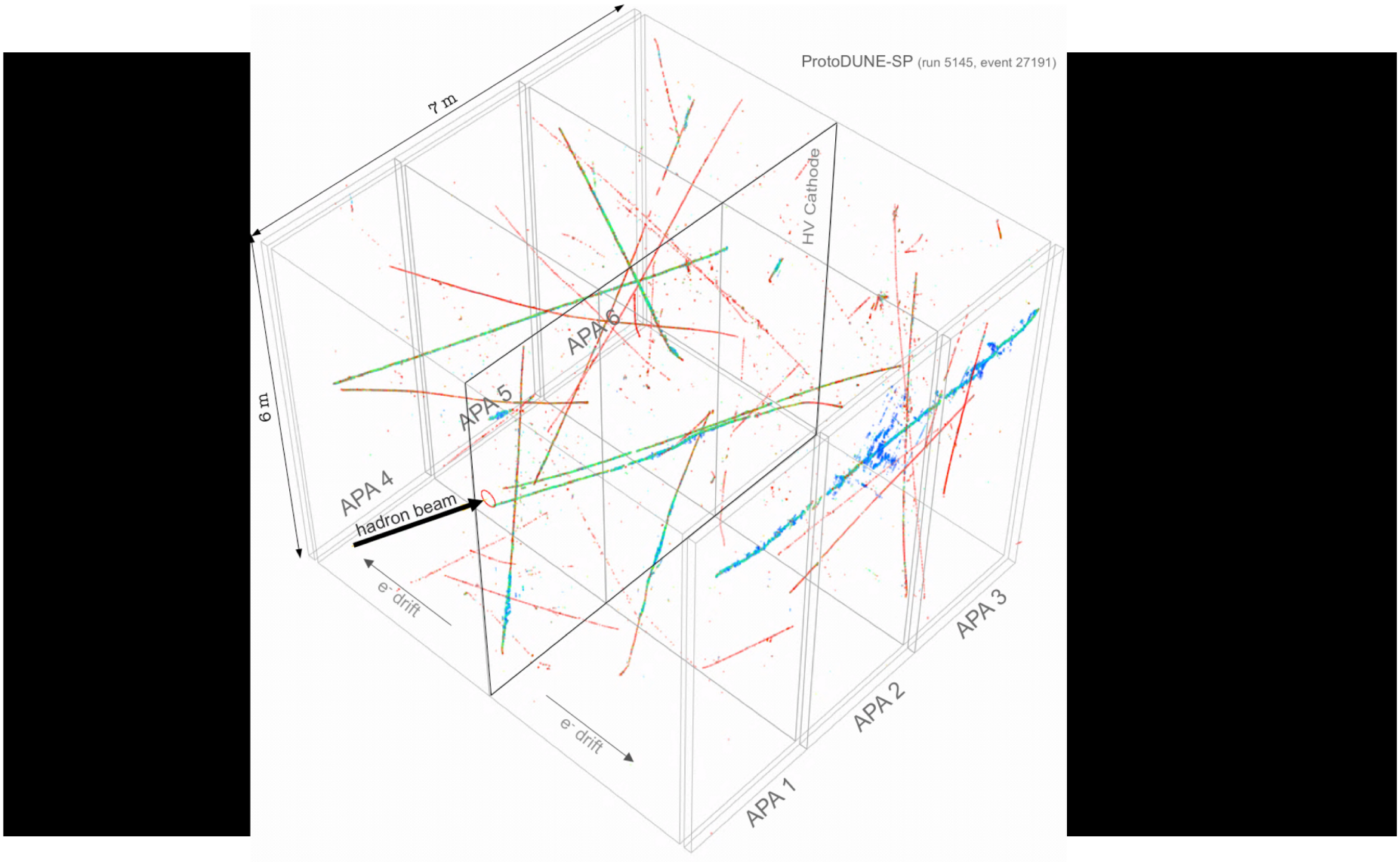
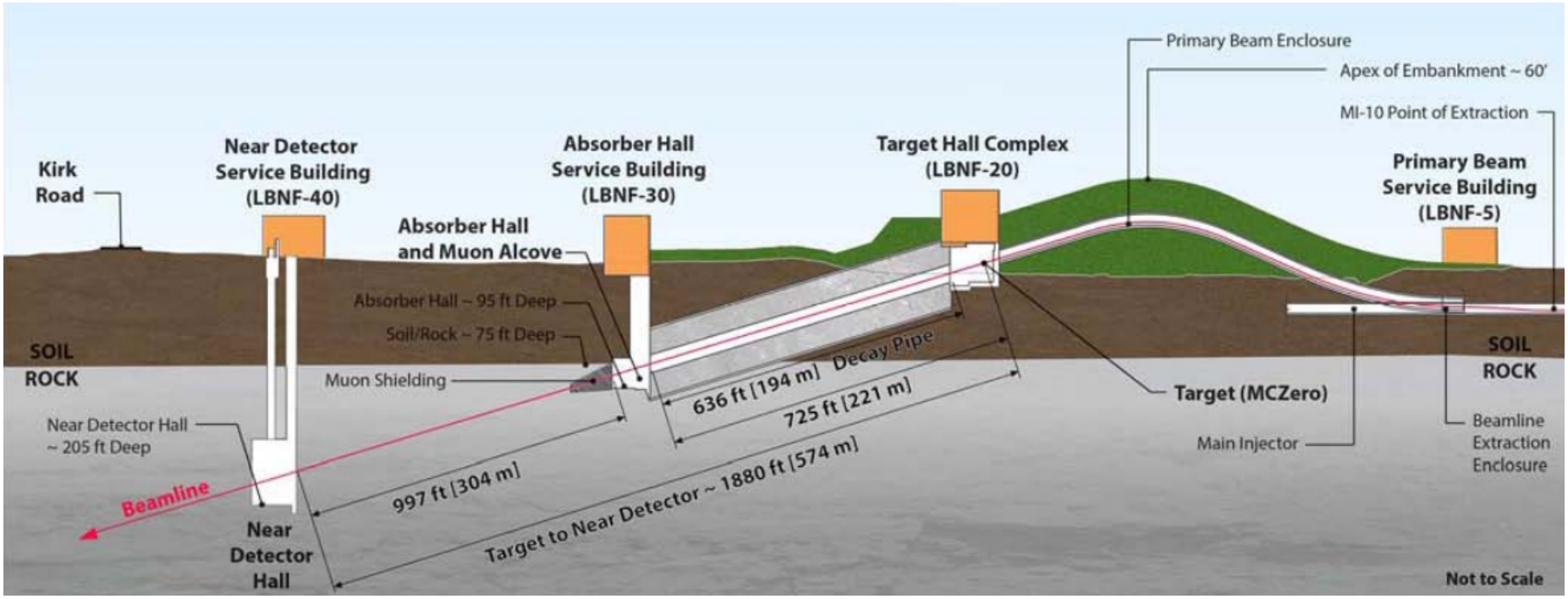
ProtoDUNE-SP Data



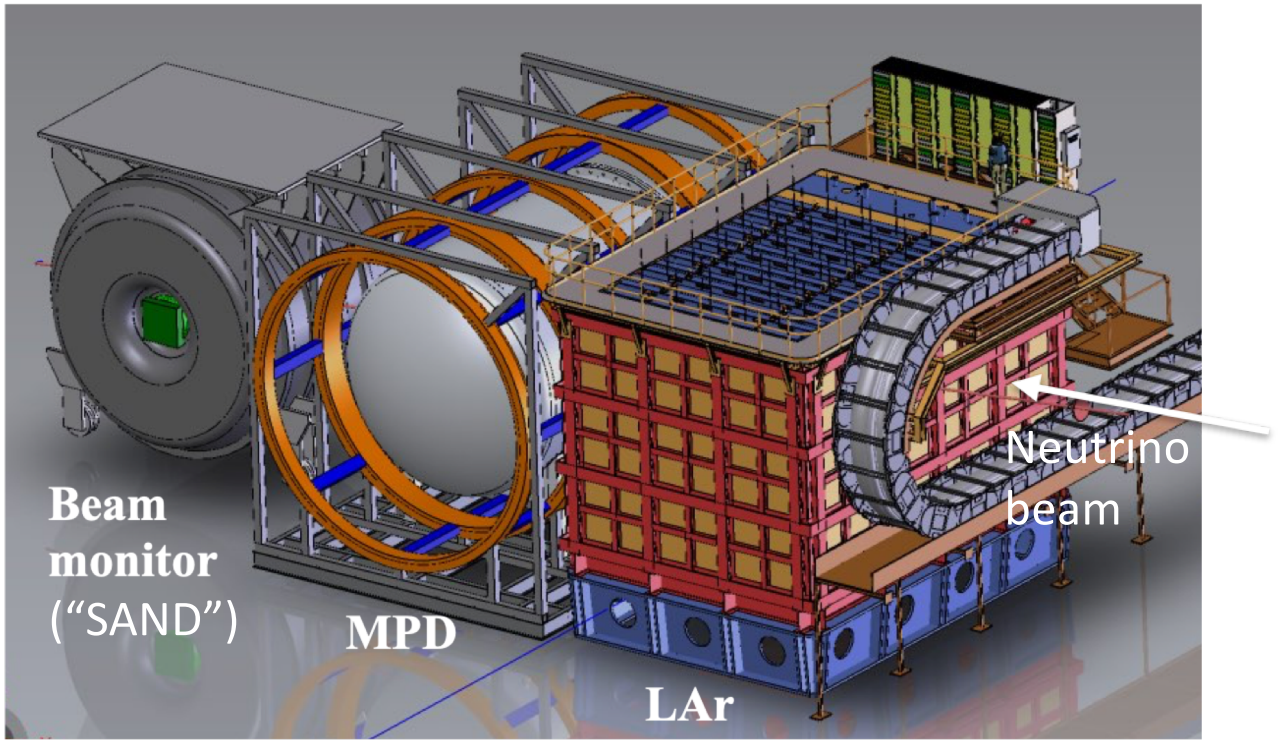
DUNE Near Detector



Goals:

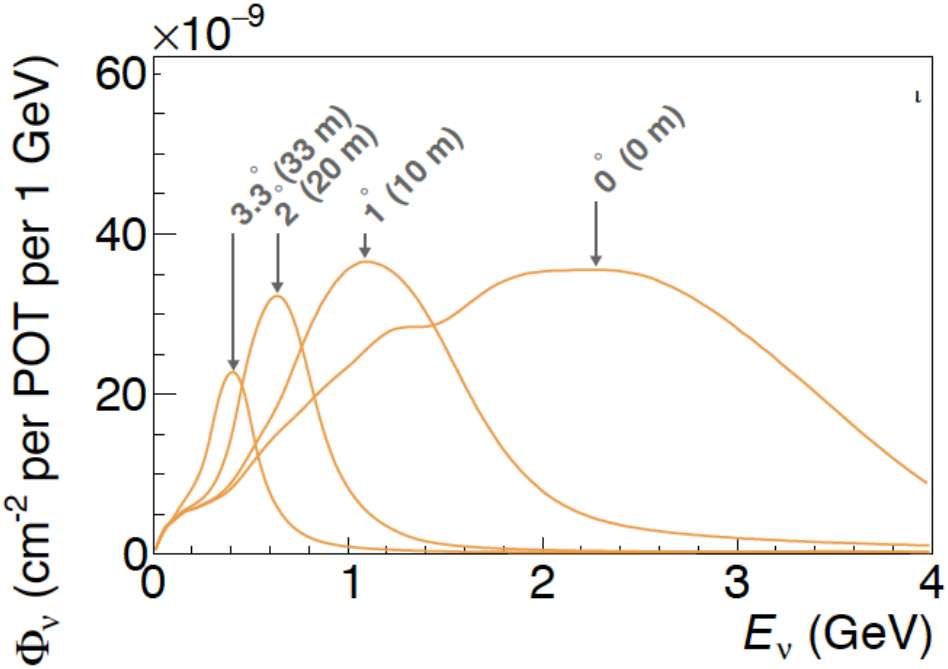
- Measure the neutrino beam rate and spectrum to predict un-oscillated event rates in the far detector
- Constrain systematic uncertainties for oscillation measurements
  - minimize differences between near and far detectors
  - measure neutrino interactions on same nuclei

DUNE Near Detector

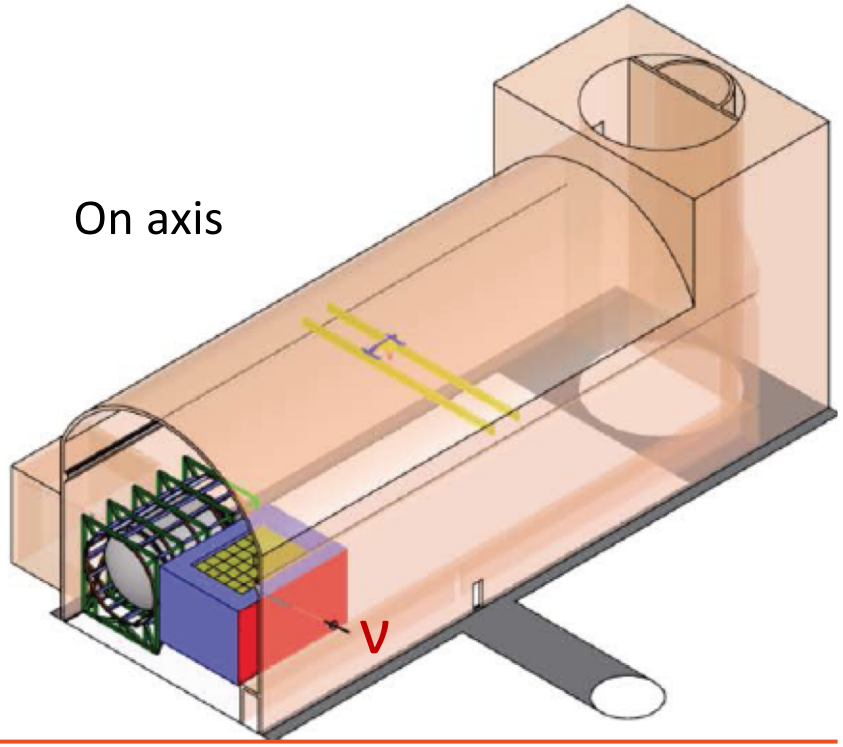


- LAr: Highly segmented LAr TPC (ArgonCube)
- MPD (Multi-purpose detector): High Pressure Gas Argon TPC, Calorimeter, and muon system magnetized by superconducting coils
- SAND beam monitor: High density plastic scintillator detector with tracking chambers and calorimetry in KLOE magnet
- DUNE-PRISM: Movement of LAr+MPD transverse to the beam, sampling different E_ν

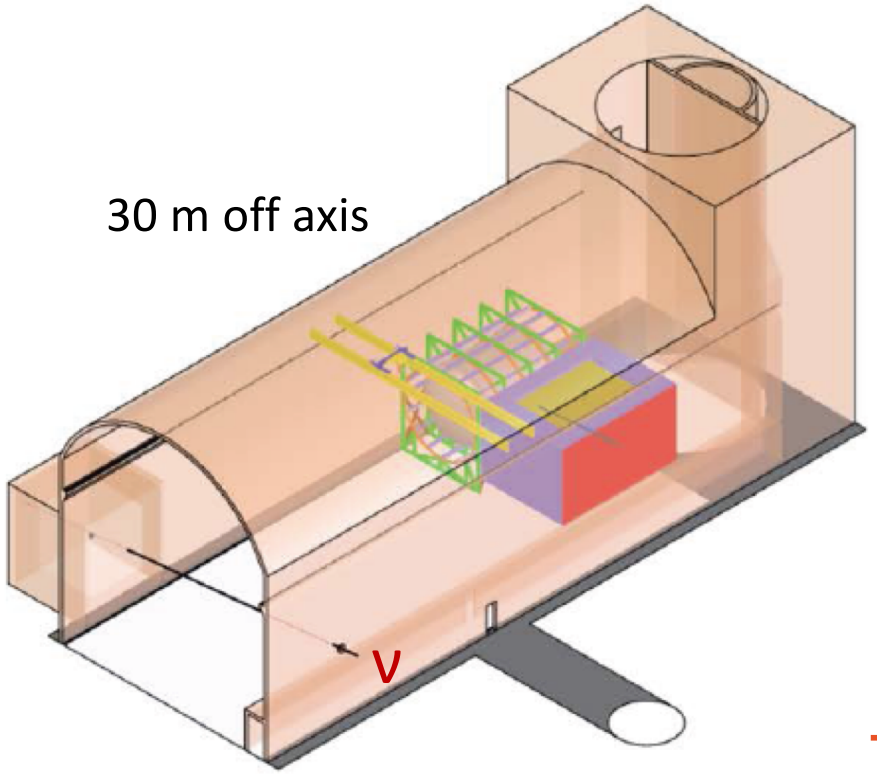
DUNE-PRISM



On axis



30 m off axis



DUNE Technical Design Report

A major milestone for the collaboration

- Submitted final versions for LBNC approval on Nov. 8.; approval expected in next couple of weeks.
- The DP volume will be completed based on input from ProtoDUNE-DP.

- Thank you to Mont and all of the LBNC members and consultants for their careful review of the TDR

Schedule

- For planning of DUNE activities, we have adopted the following working schedule:

Start of Module 1 Installation: August 2024

Start of Module 2 Installation: August 2025

- Baselining of US project in 2020 will define final schedule.
- Physics data will start as soon as first module is complete – start of an exciting long-term physics program

Summary

- DUNE will be a world-leading neutrino experiment with the potential for groundbreaking discoveries in particle physics, astrophysics, and cosmology.
- TDR documenting the DUNE-SP far detector design and physics case is complete. Ready to baseline.
- ProtoDUNE program has been a great success, and has demonstrated the maturity of the SP far detector design and the Collaboration's ability to execute a complex detector construction project.
- We have developed a near detector reference design, and are working toward CDR in late 2019 and TDR in 2020. Ready to baseline at end of 2020.
- The Collaboration is functioning well, and will be ready to install detectors at the earliest availability of caverns.