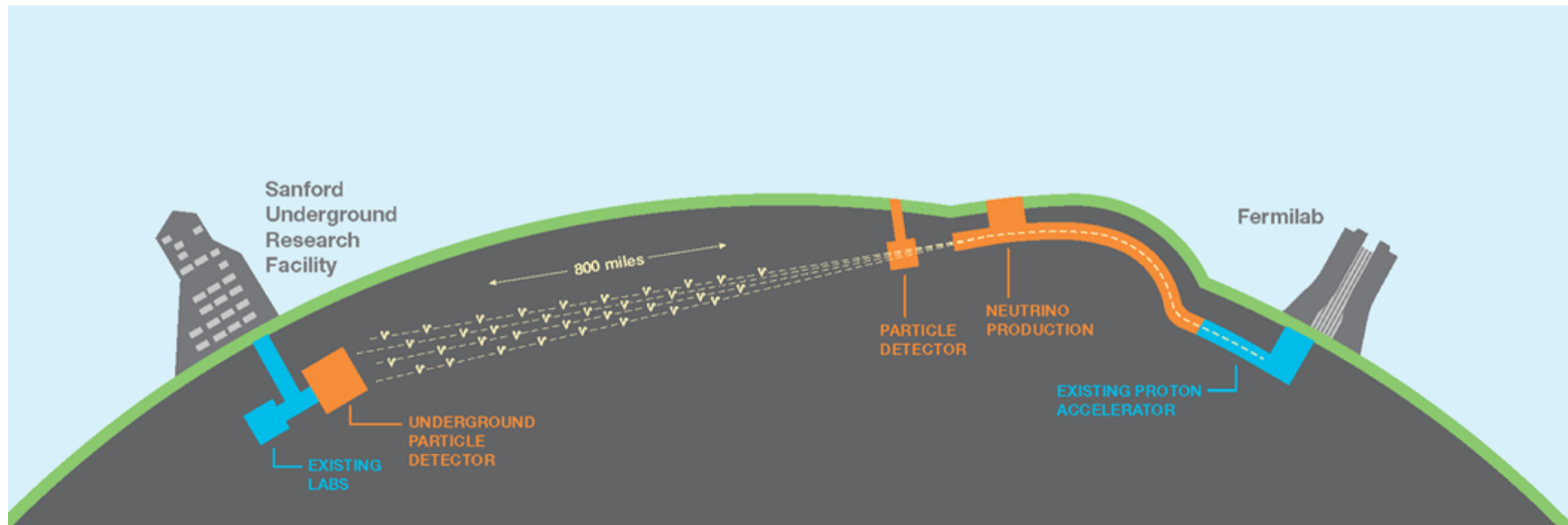


The DUNE Experiment



Alfons Weber

University of Oxford, STFC/RAL & CERN/EP-NU

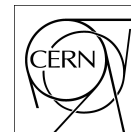
1-October-2018



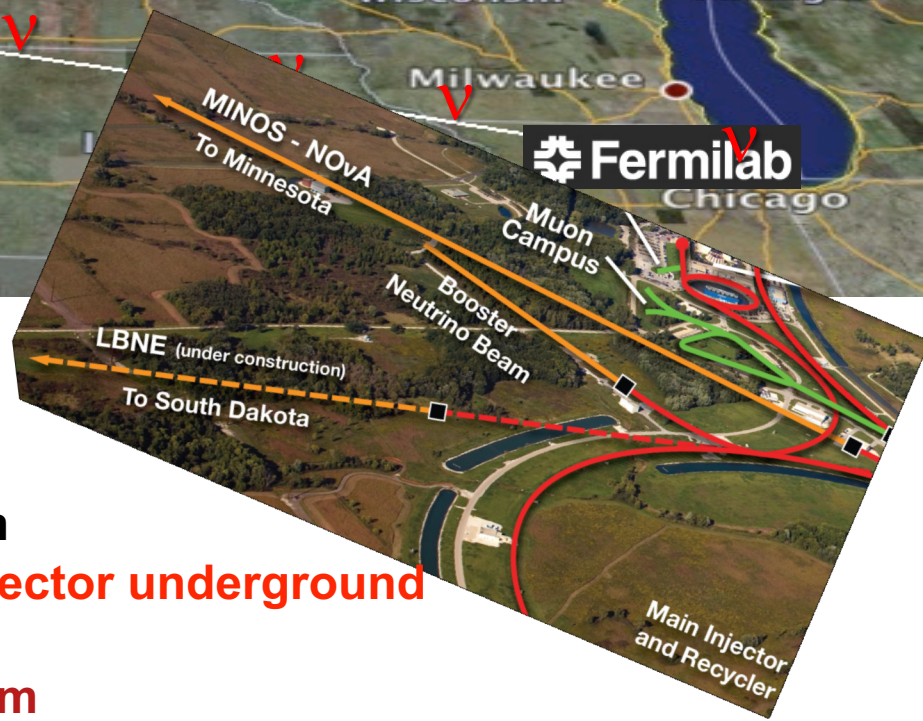
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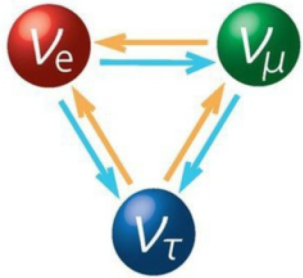


LBNF & DUNE



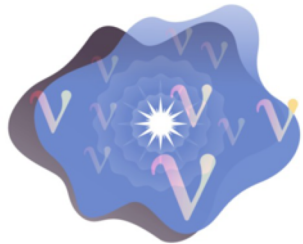
- **A new neutrino beamline over 1300 km**
- **Proton beam power assumption**
 - 1.2 MW → 2.3 MW
- **A highly-capable near detector system**
- **A >10 kt fiducial mass LAr TPC far detector underground at SURF**
- **A cavern for a full 40 kt detector system**

Physics Program



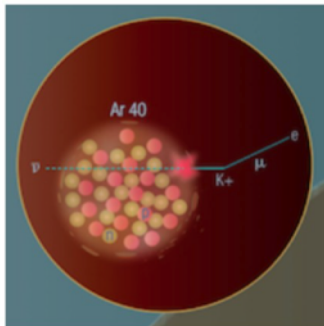
- Neutrino Oscillations

- Search for leptonic CP violation
- Determine neutrino mass ordering
- Precision PMNS measurements



- Supernova Physics

- Observation of time and flavour profile provides insight into collapse and evolution of supernova
- Unique sensitivity to electron neutrinos



- Baryon number violation

- Predicted by many BSM theories
- LAr TPC technology well-suited to certain proton decay channels (*e.g.*, $p \rightarrow K^+ \bar{\nu}$)
- $\Delta(B-L) \neq 0$ channels accessible (*e.g.*, $n \rightarrow \bar{n}$)

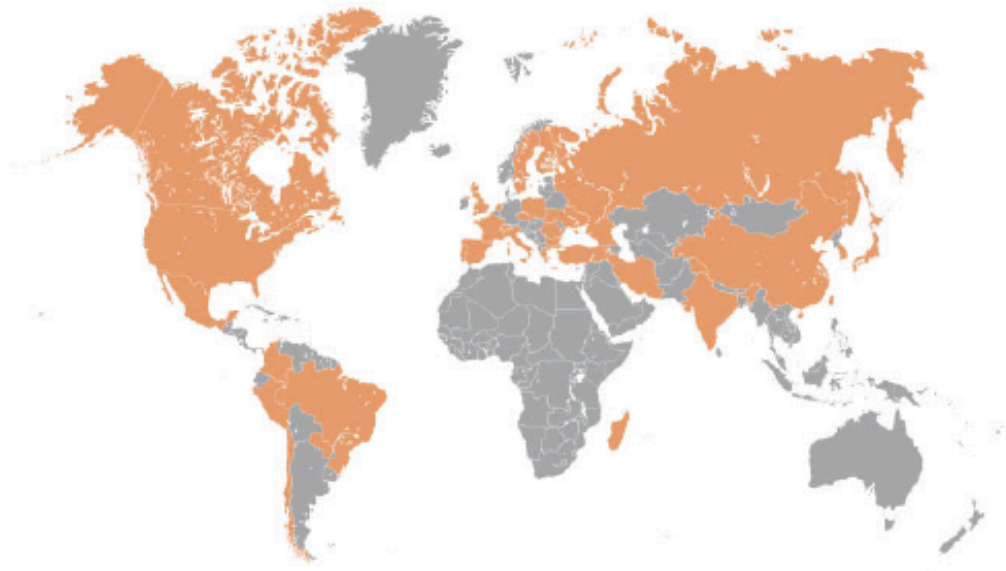
The DUNE Collaboration

- 1144 collaborators from 178 institutions in 32 countries
- 622 faculty/scientists, 191 postdocs, 106 engineers, 5 computing professionals, 220 PhD students
- Growing at a rate of about 100 collaborators/year



Collaborating Institutions

May 2018

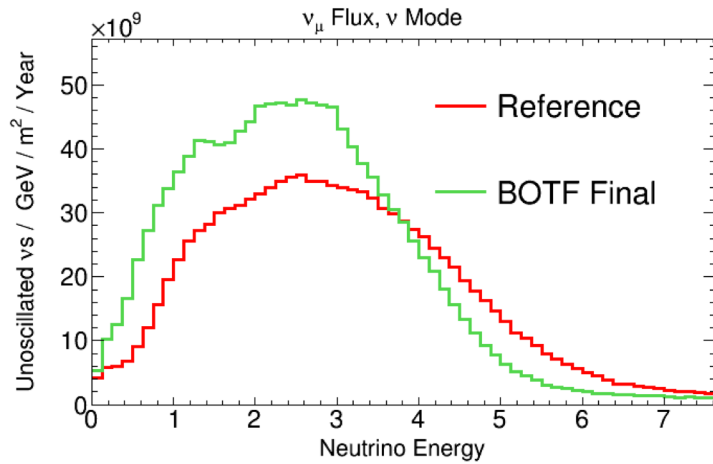


Armenia (3), Brazil (29), Bulgaria (1), Canada (1), CERN (32), Chile (3), China (5), Colombia (13), Czech Republic (11), Spain (34), Finland (4), France (23), Greece (4), India (45), Iran (2), Italy (63), Japan (7), Madagascar (8), Mexico (8), The Netherlands (4), Paraguay (4), Peru (8), Poland (6), Portugal (7), Romania (7), Russia (10), South Korea (4), Sweden (1), Switzerland (35), Turkey (2), UK (136), Ukraine (4), USA (621)

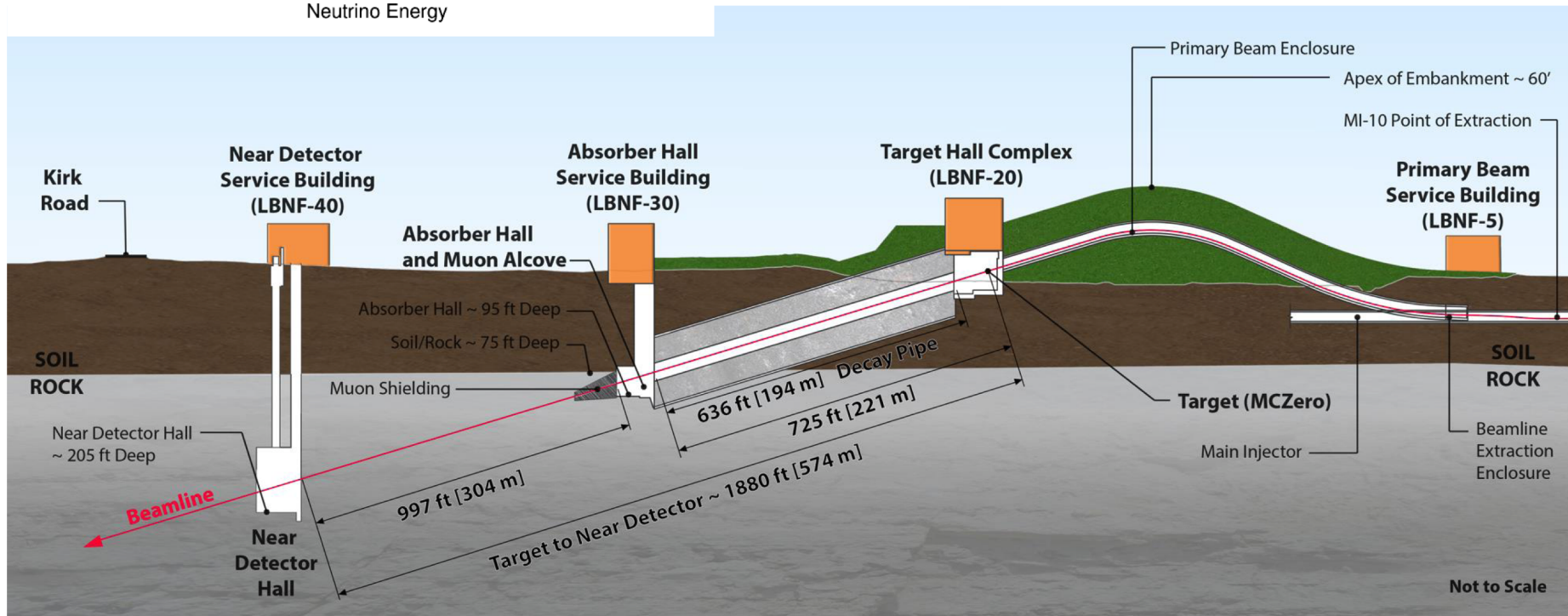
The DUNE Collaboration



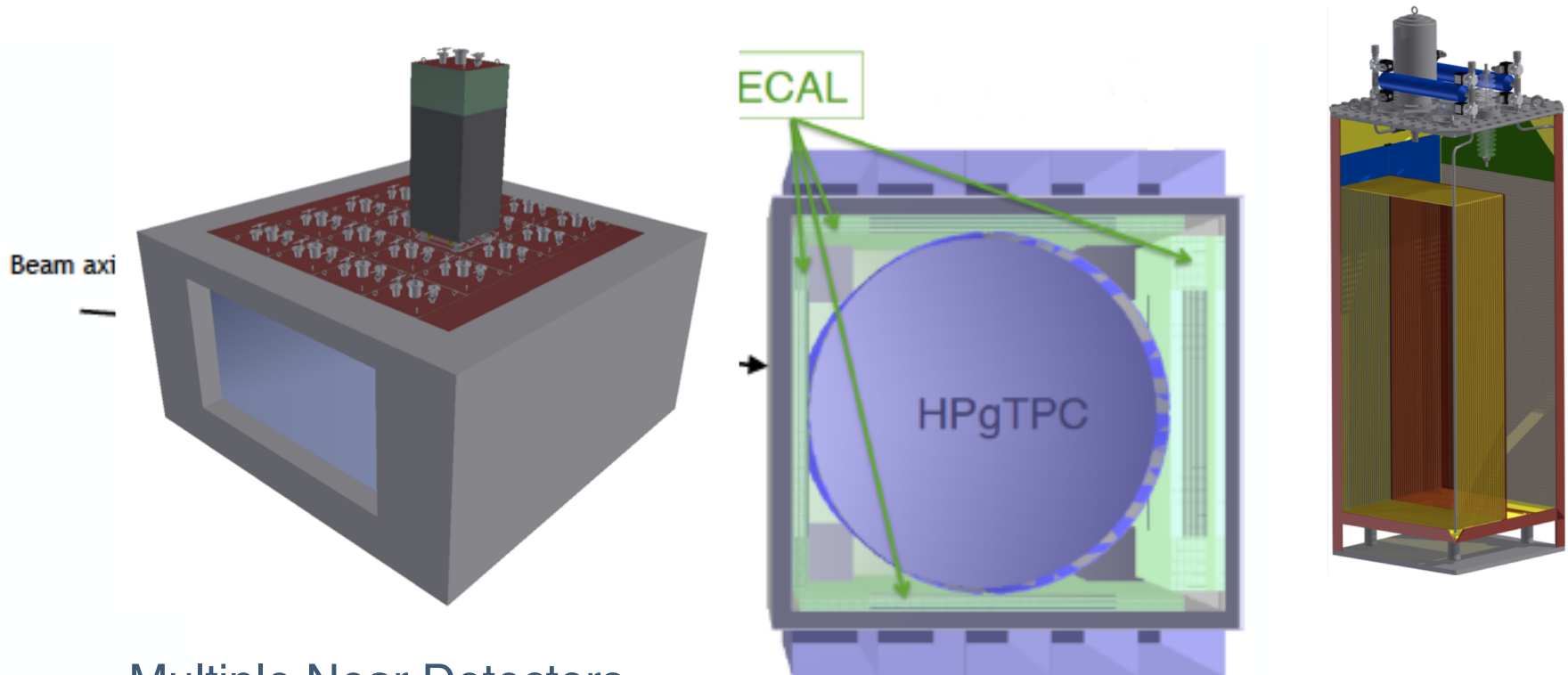
Beam



- Proton beam energy
60-120 GeV
- Power
1.2 MW \rightarrow 2.4 MW
- Neutrinos and anti-neutrinos

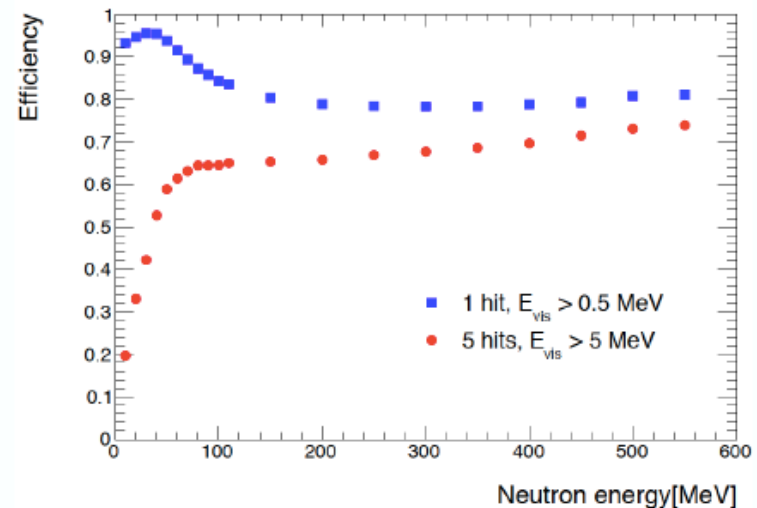
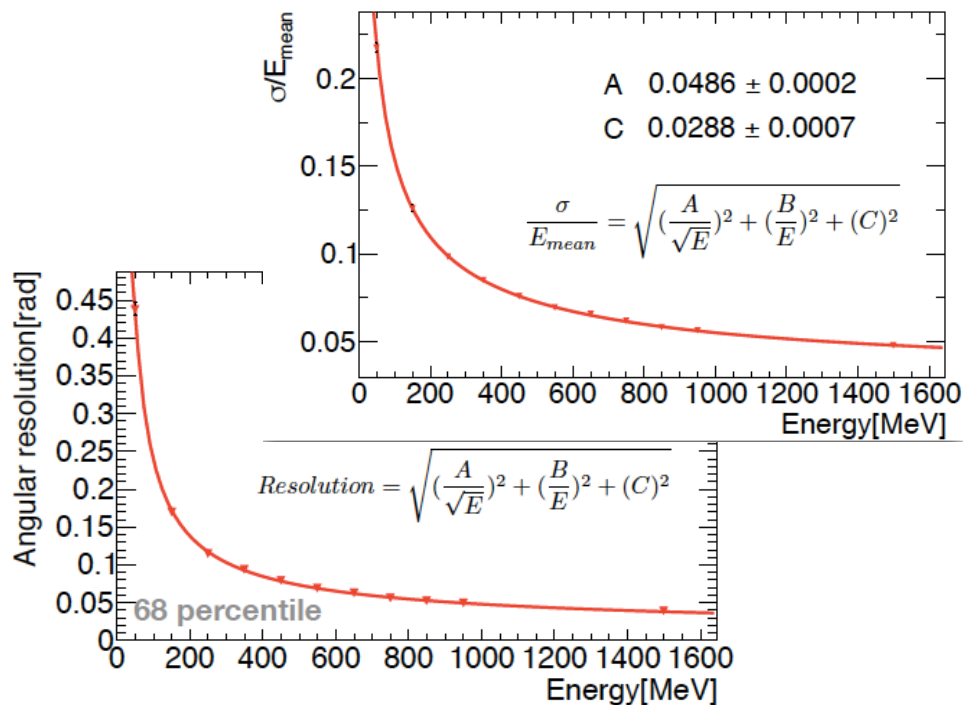
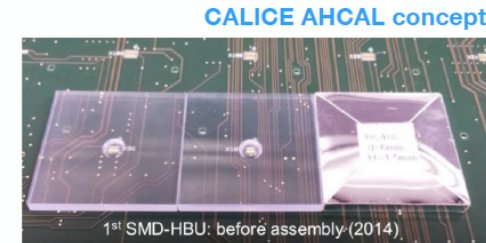
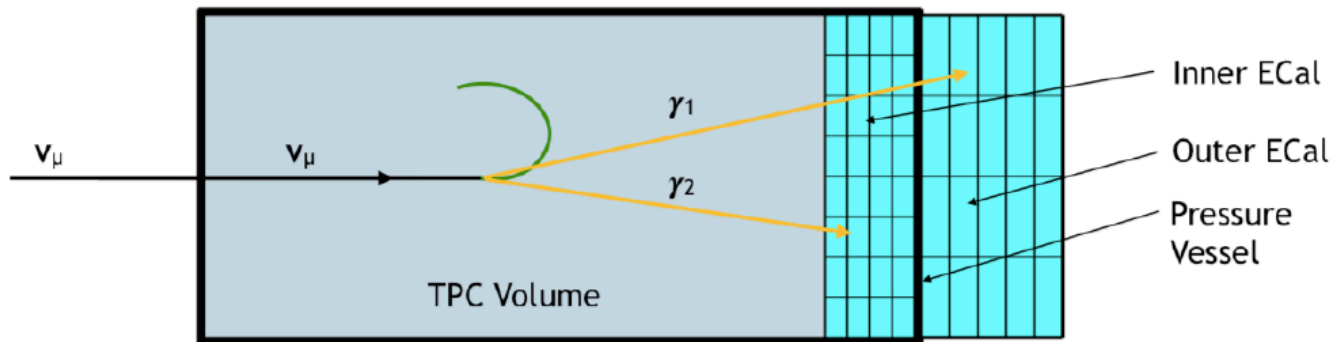


Near Detector Complex



- Multiple Near Detectors
 - characterise beam & neutrino interactions & detector response
 - LAr TPC (similar to FD)
 - High pressure gaseous argon TPC tracker
 - Calorimeter and muon systems

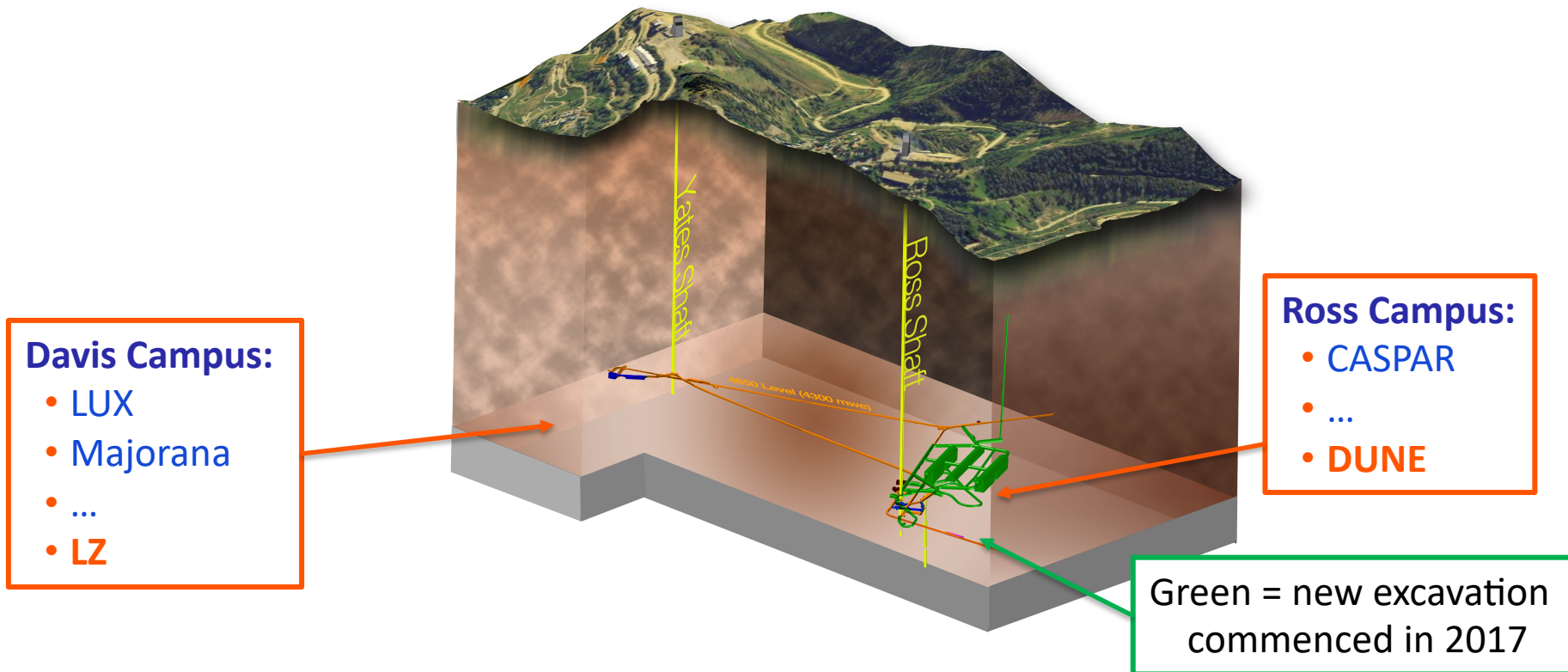
ECAL Concept



Underground Laboratory SURF

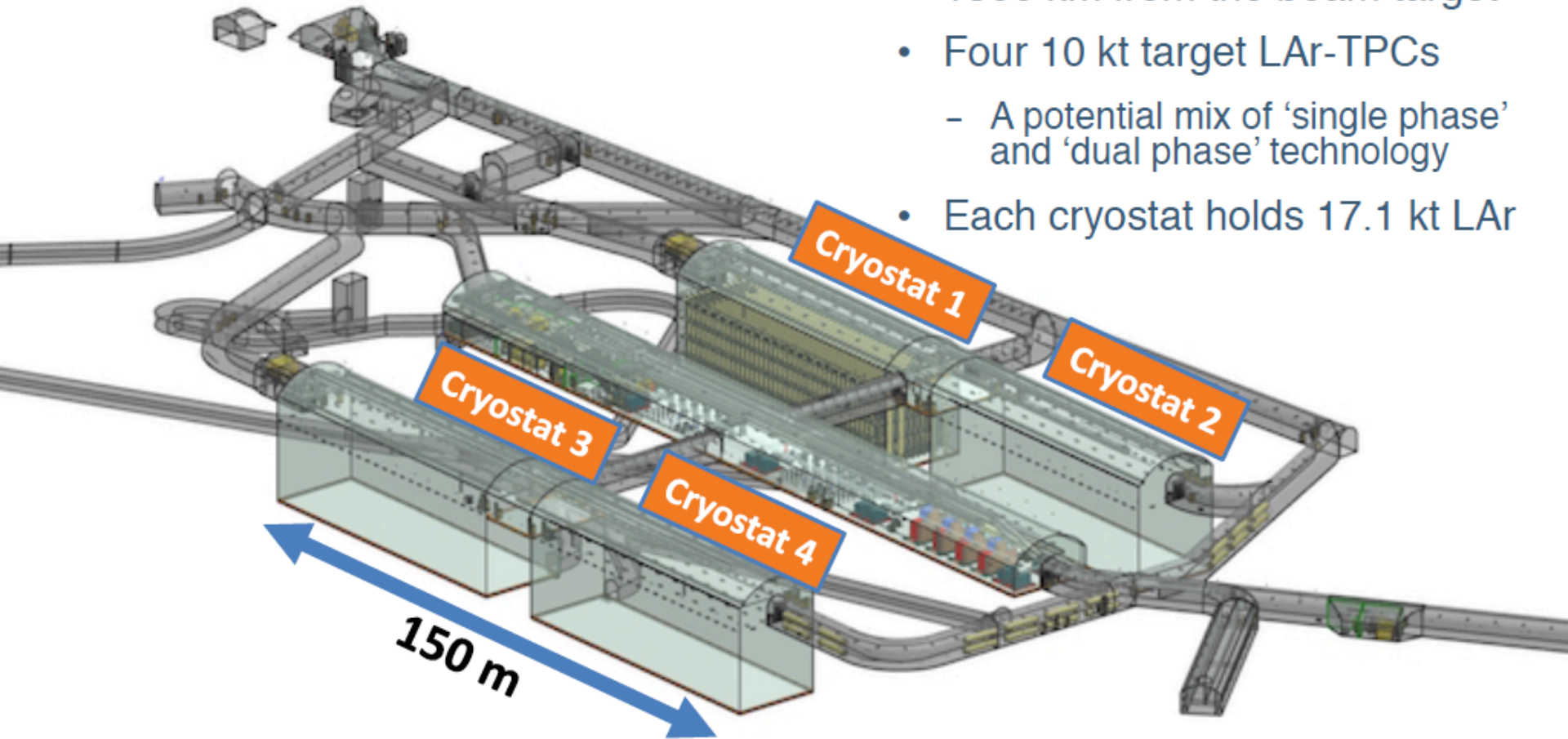
DUNE Far Detector site

- Sanford Underground Research Facility (SURF), South Dakota
- Four caverns on 4850 level (~ 1 mile underground)

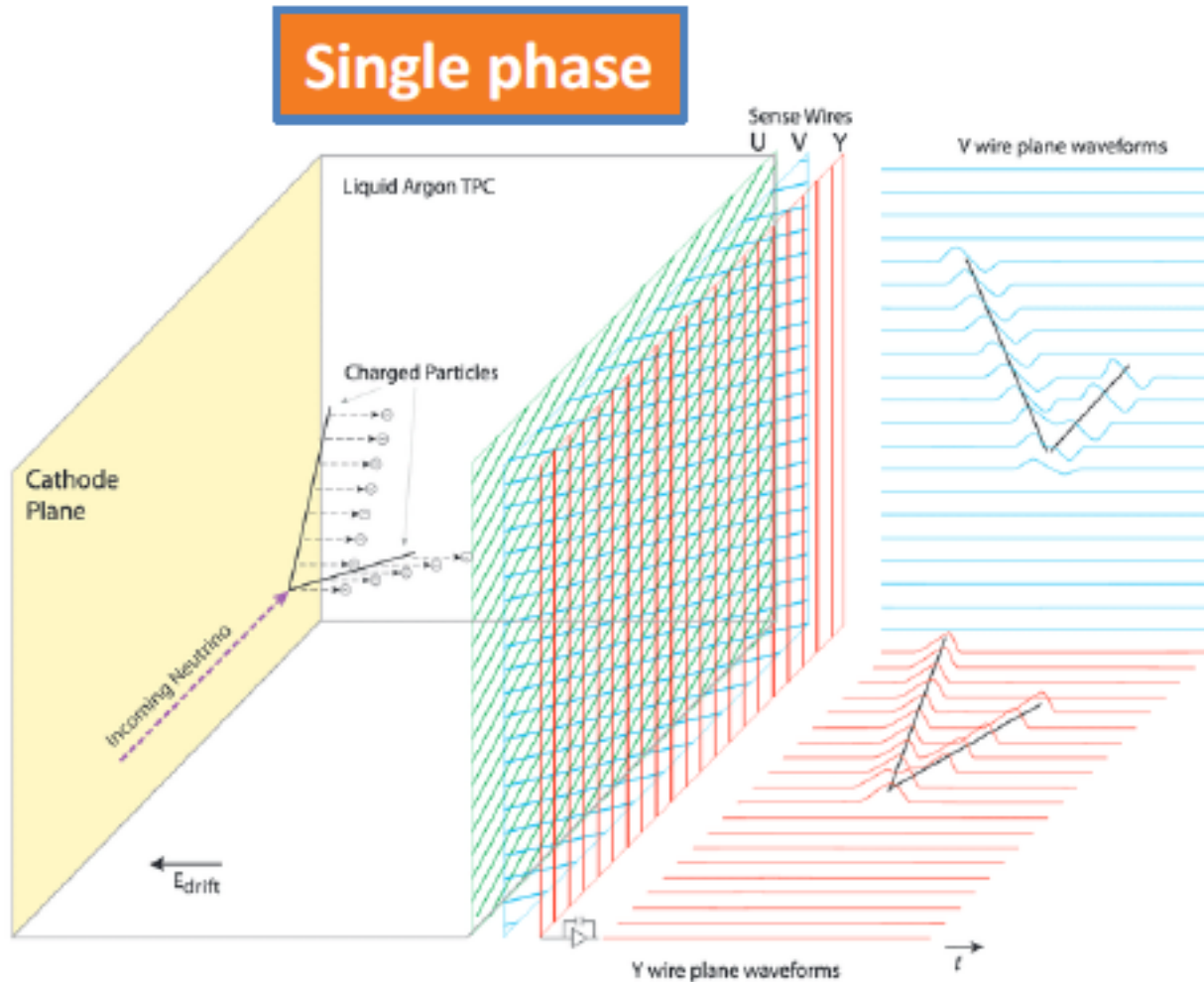


DUNE Far Detector

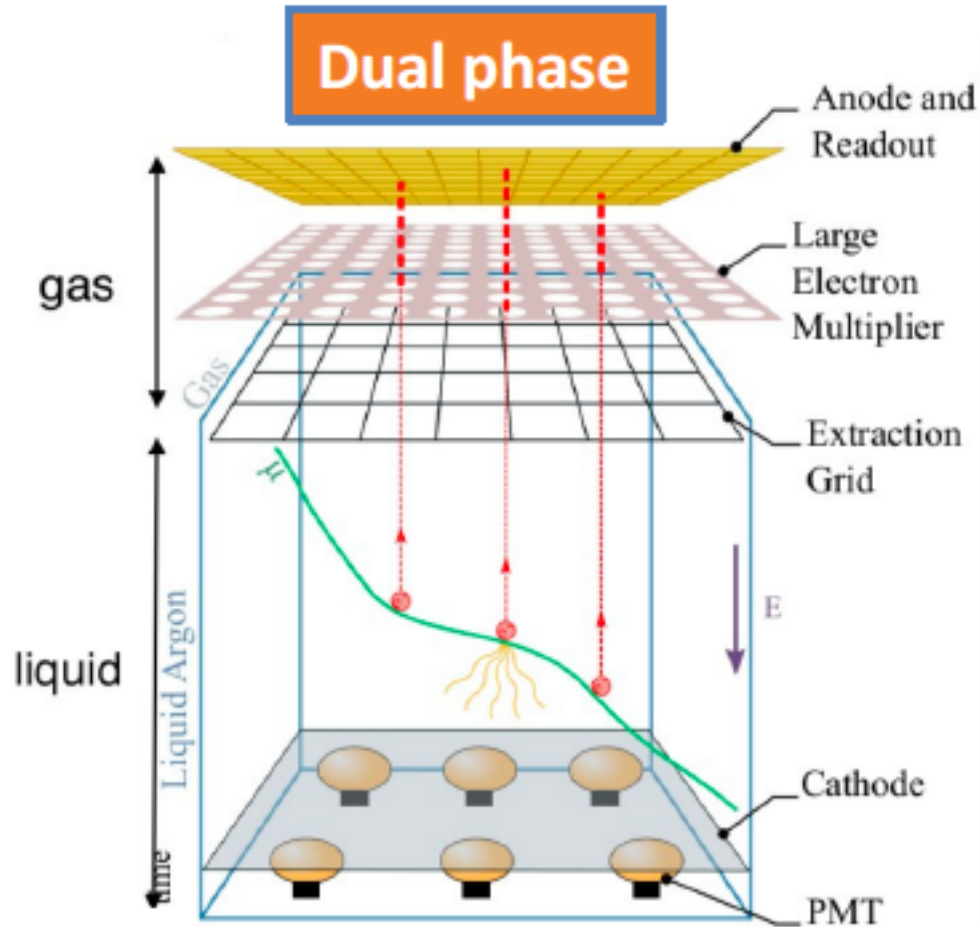
- 1478 m underground
- 1300 km from the beam target
- Four 10 kt target LAr-TPCs
 - A potential mix of 'single phase' and 'dual phase' technology
- Each cryostat holds 17.1 kt LAr



Technology



Technology

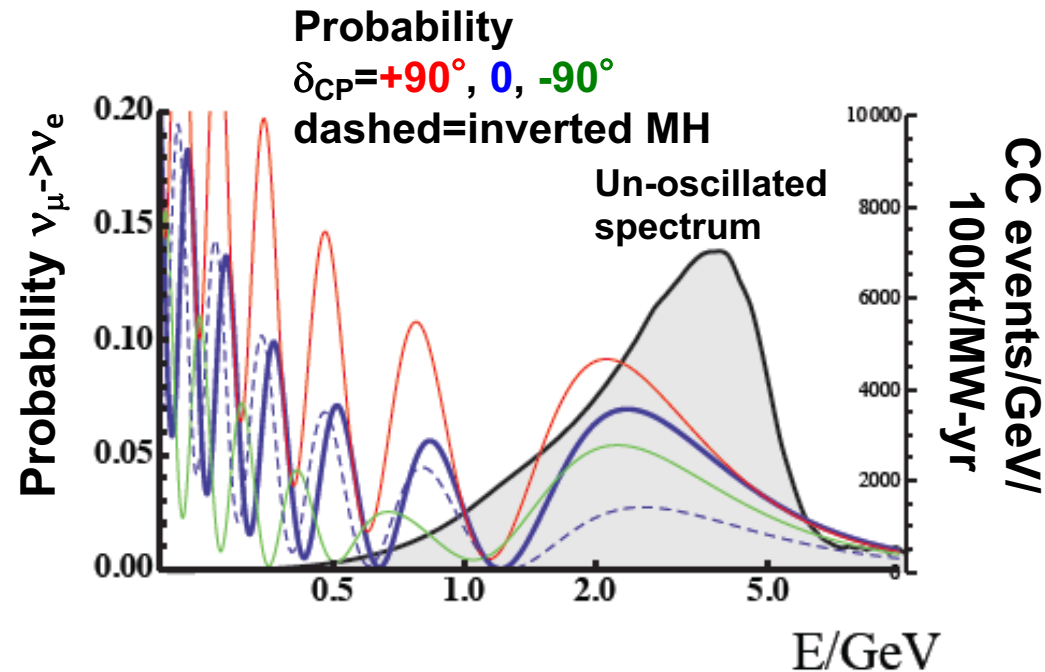


It's real!

21st July 2017: Ground breaking at SURF



Experimental Technique

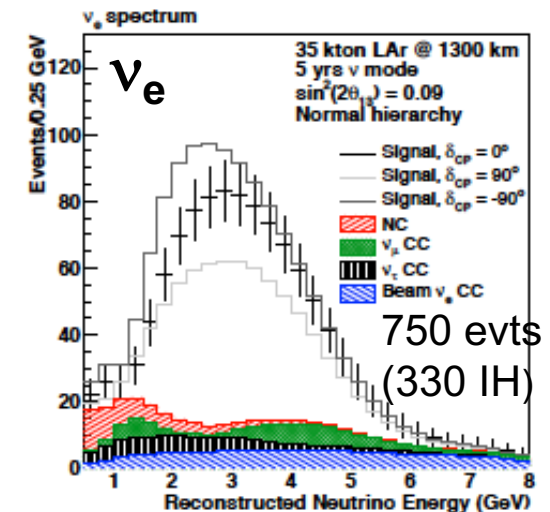
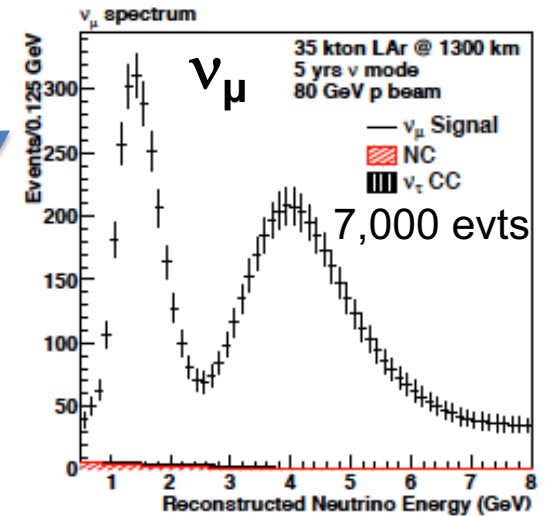


- Produce a pure wide band ν_{μ} muon-neutrino beam with energy spectrum matched to the 1st and 2nd oscillation maximum
- Measure spectrum of ν_{μ} and ν_e at a distant detector

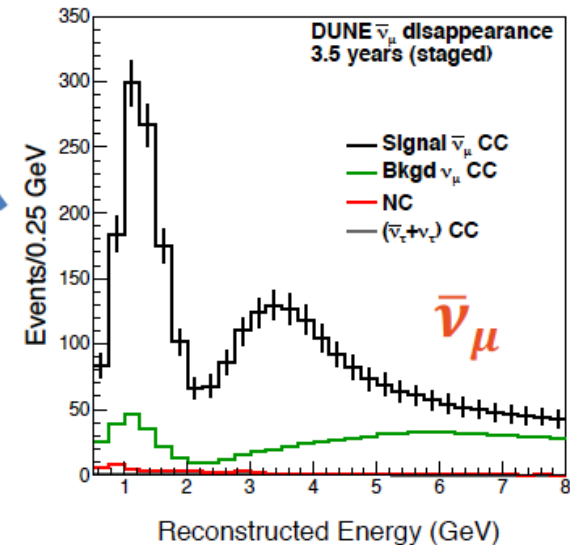
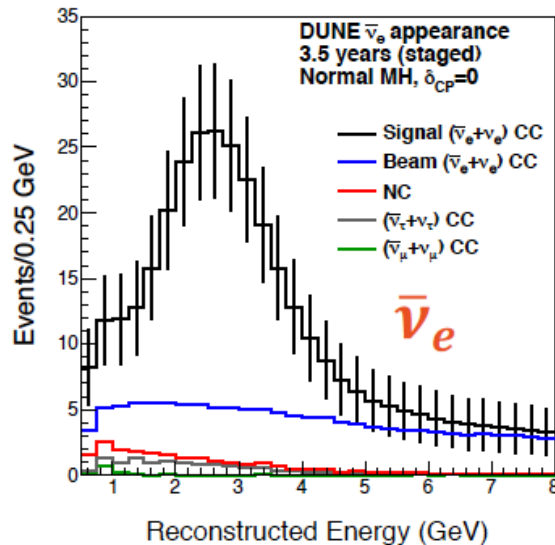
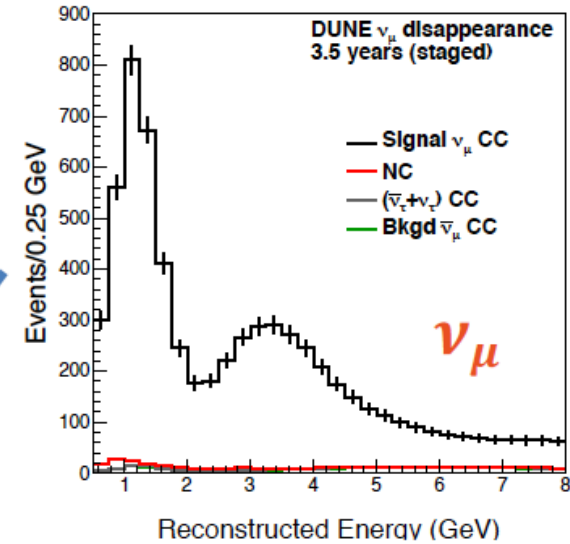
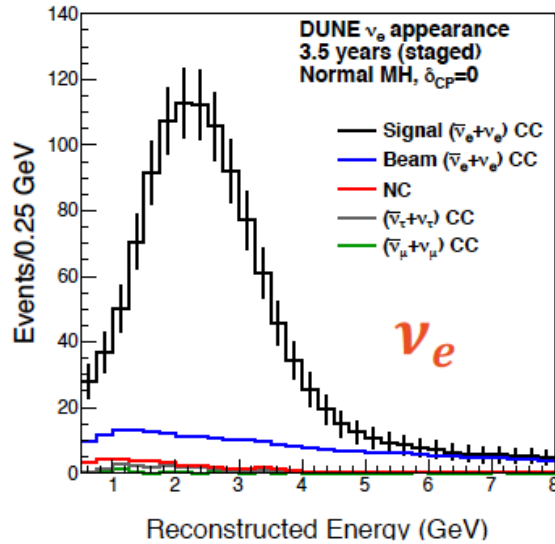
disappearance

appearance

700 kW beam



Measurement Strategy

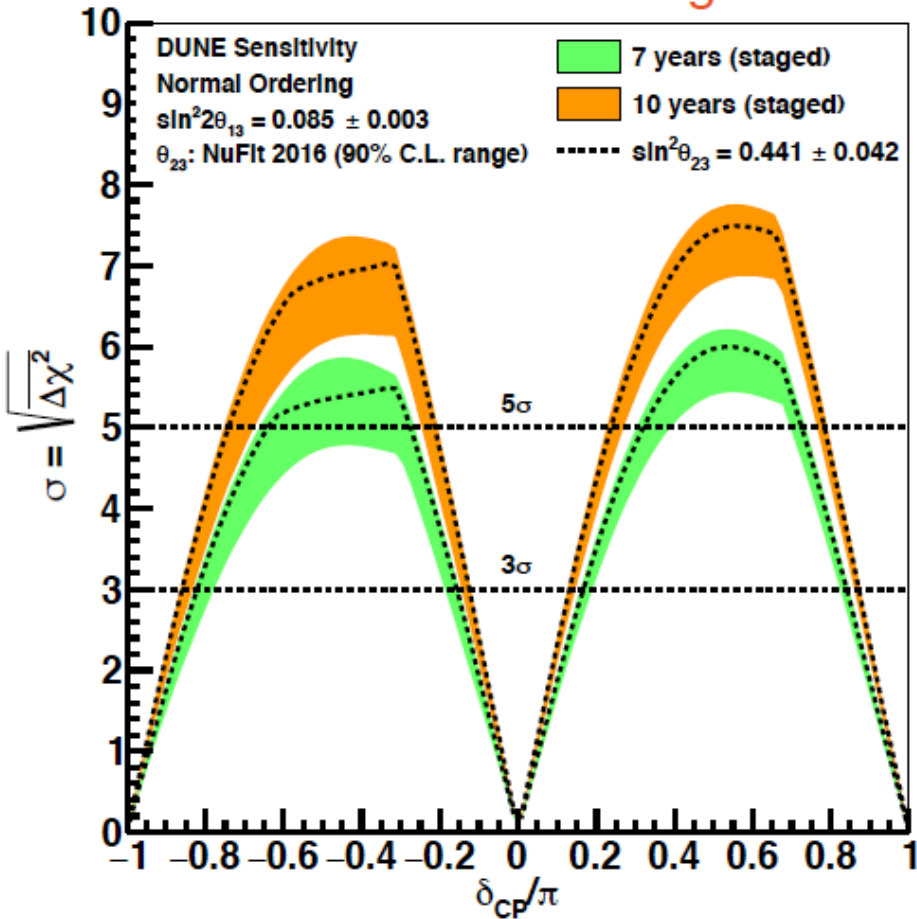


4 sample fit

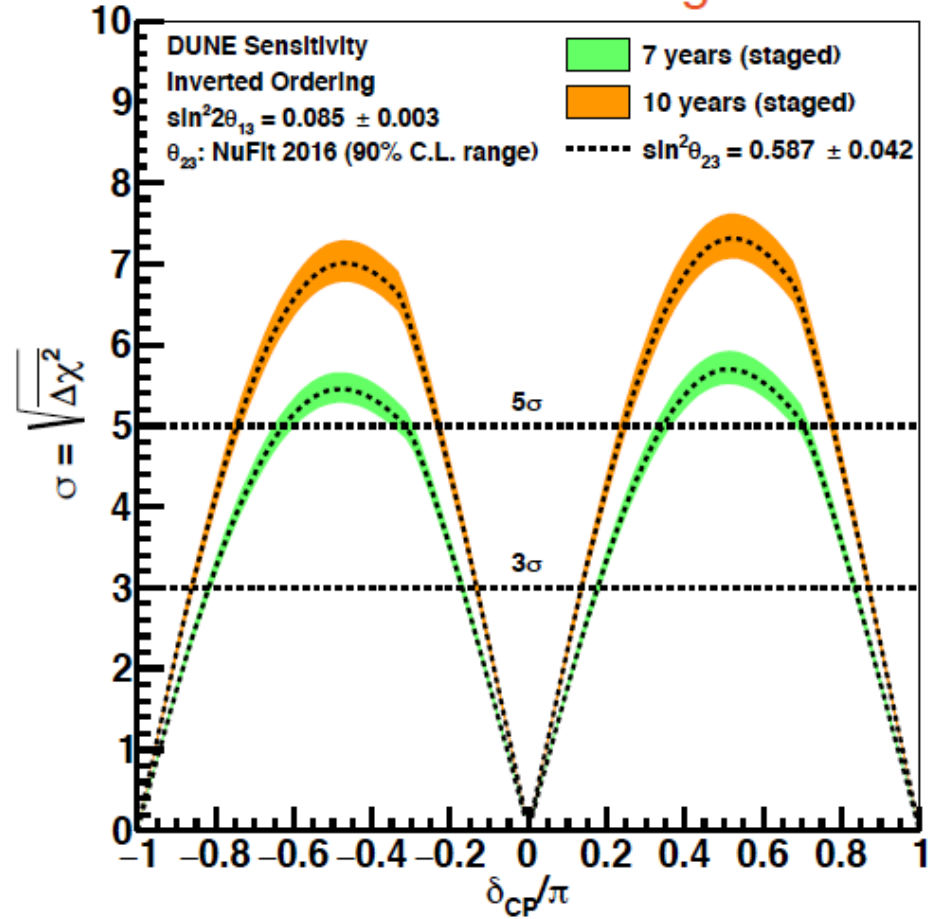
Oscillation parameters

CP Sensitivity

Normal ordering



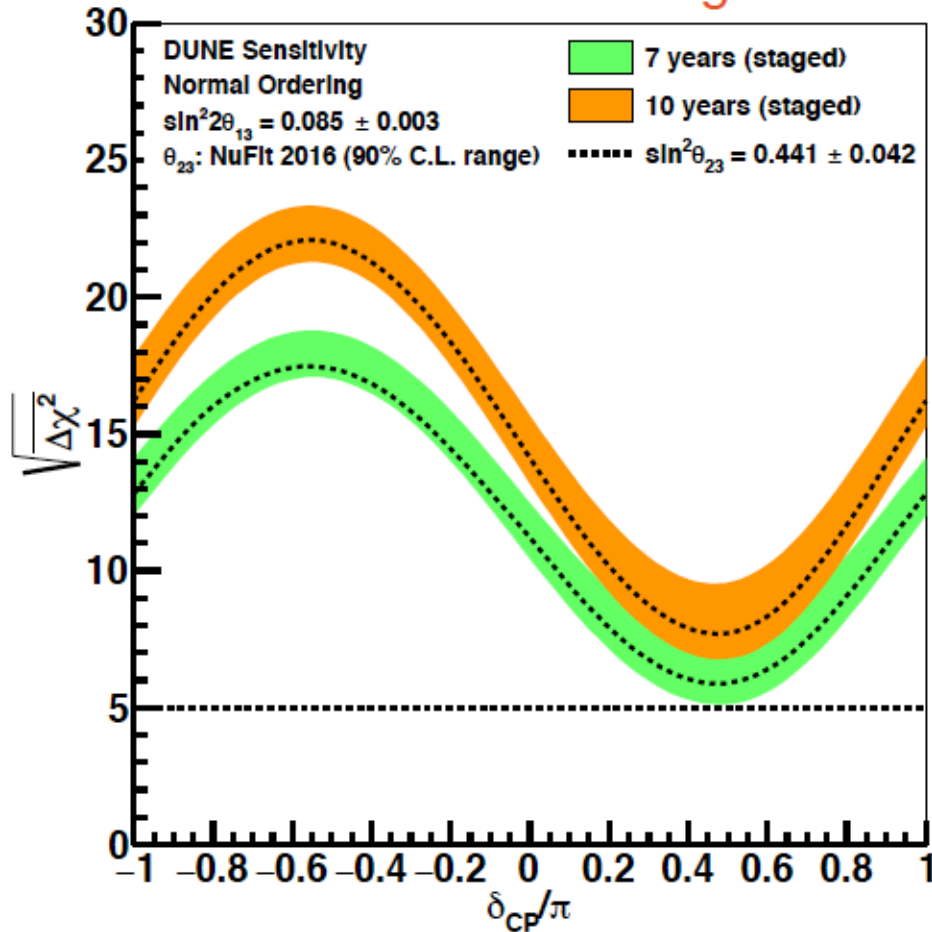
Inverted ordering



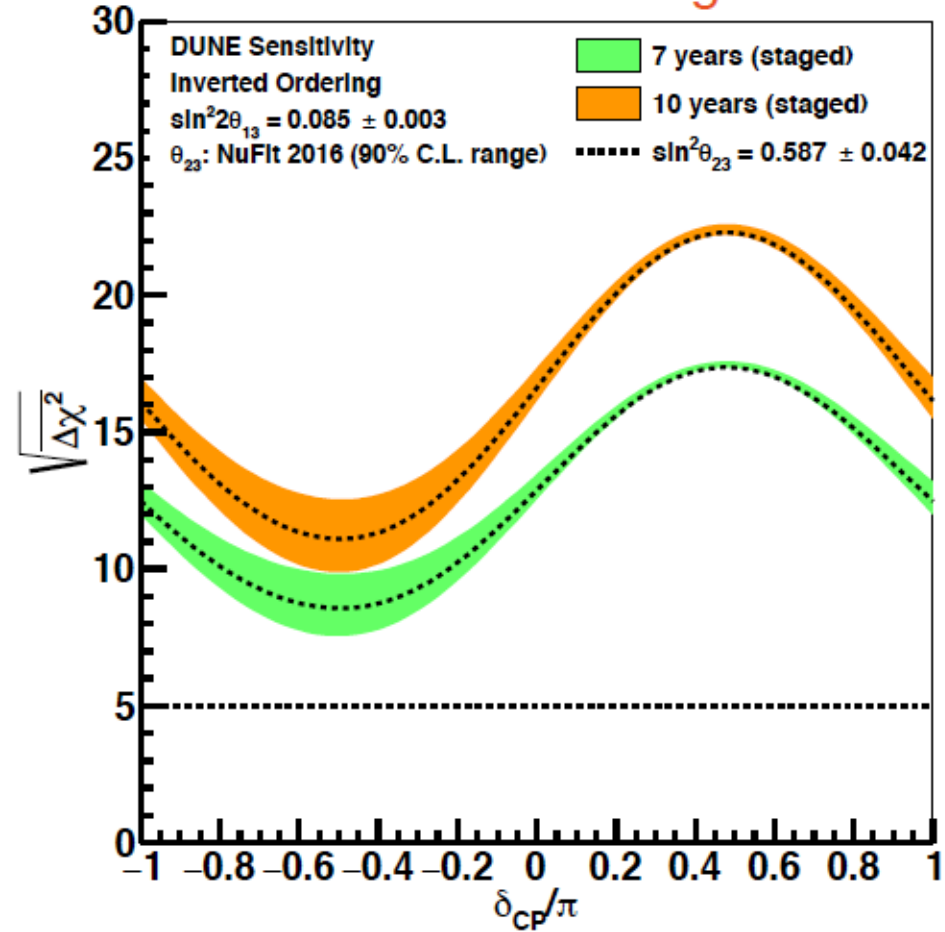
The upper and lower boundary of each band refers to the the input θ_{23} maximum and minimum respectively

Mass Ordering

Normal ordering



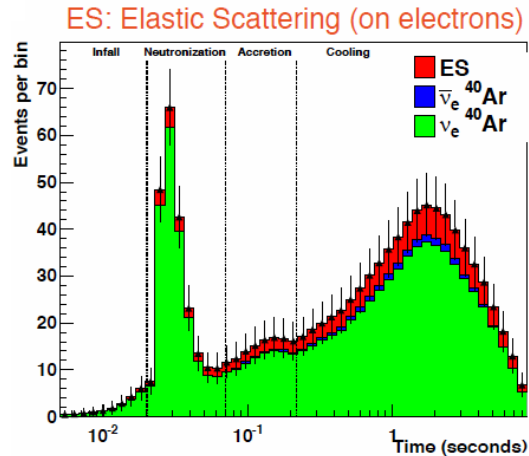
Inverted ordering



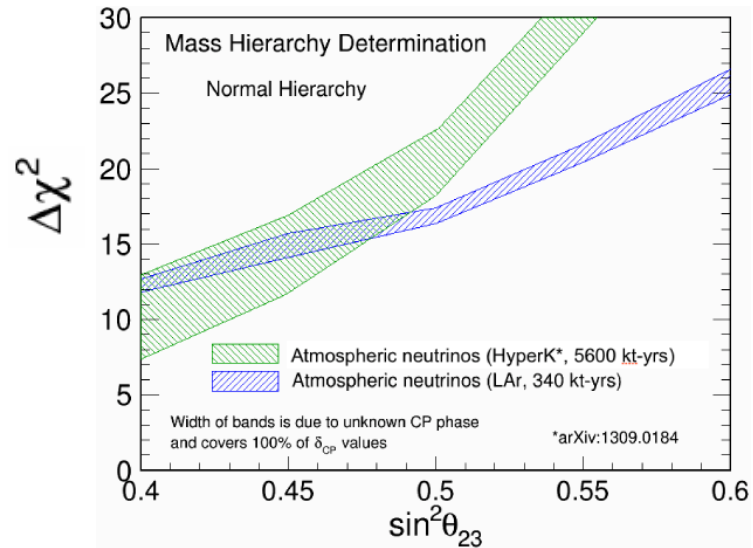
The upper and lower boundary of each band refers to the the input θ_{23} maximum and minimum respectively

Other Physics

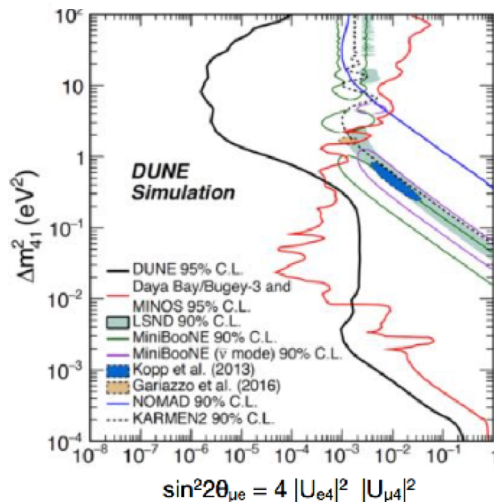
supernova



atmospherics



atmospherics



- Dark matter
- Large extra dimensions
- Dark photons
- NS interactions

An Incredible Journey ProtoDUNE

[Dec. 12, 2015] □



[Sept. 21, 2018]

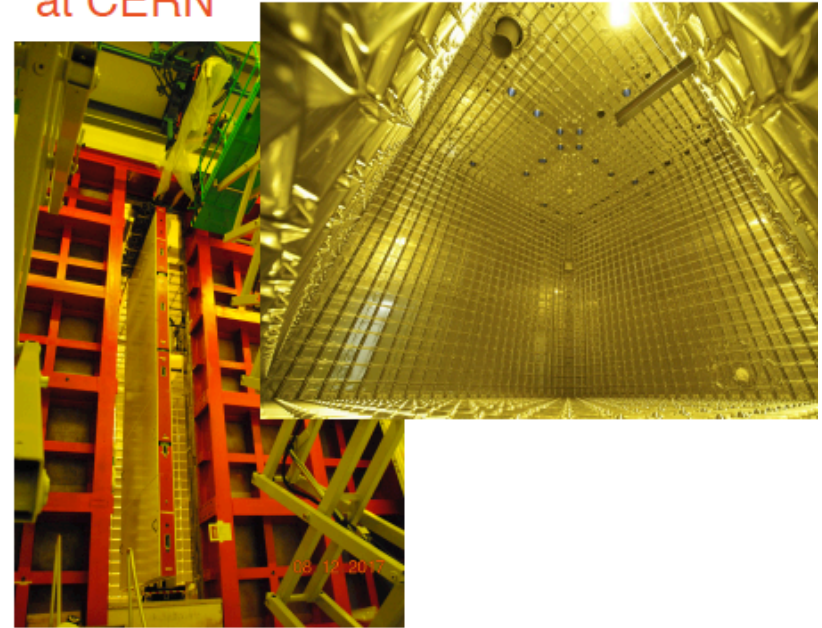


ProtoDUNE @ CERN

Components are being constructed and shipped to CERN



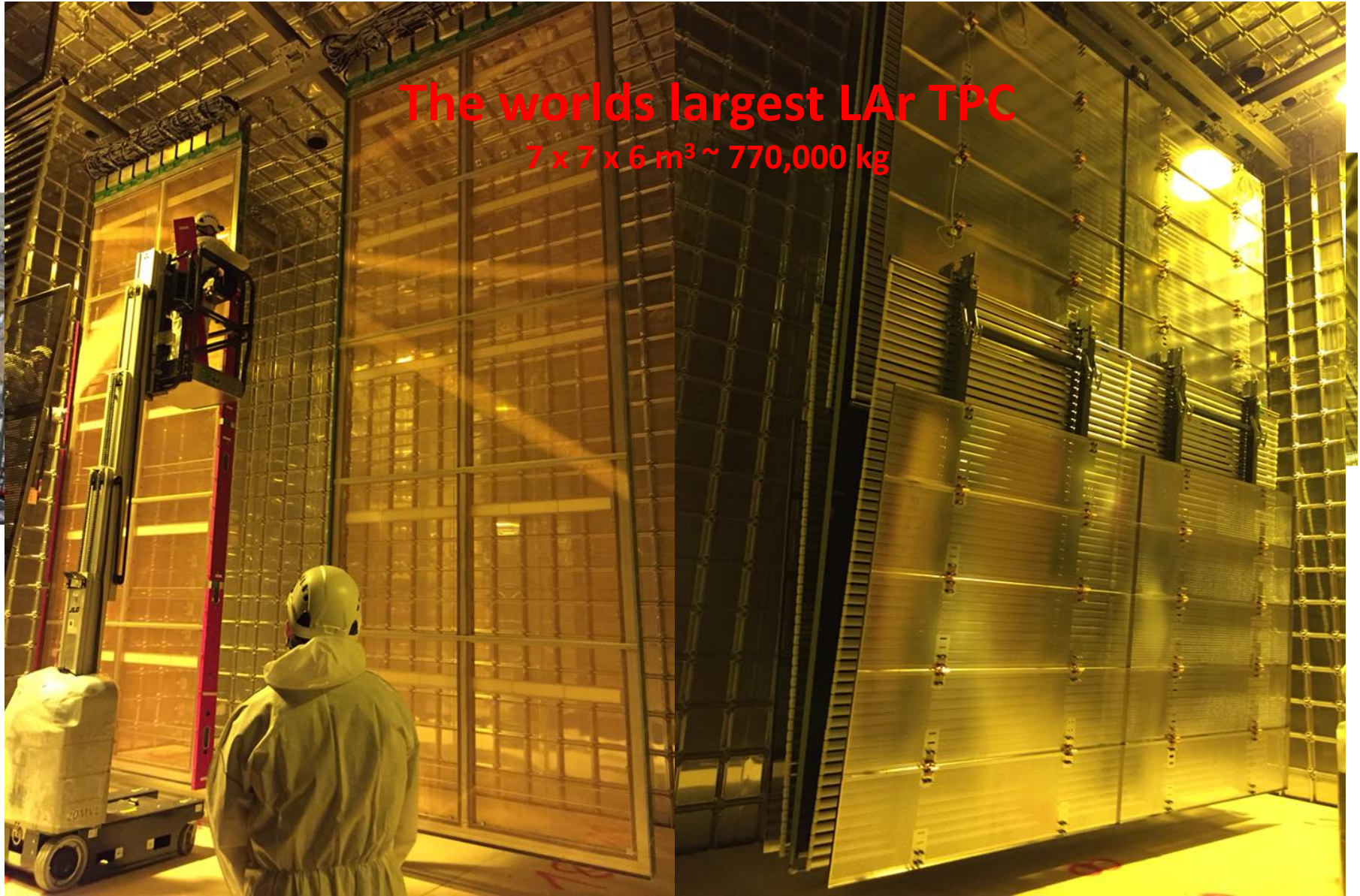
Construction is taking place in EHN1 at CERN



On track for 2018 data taking

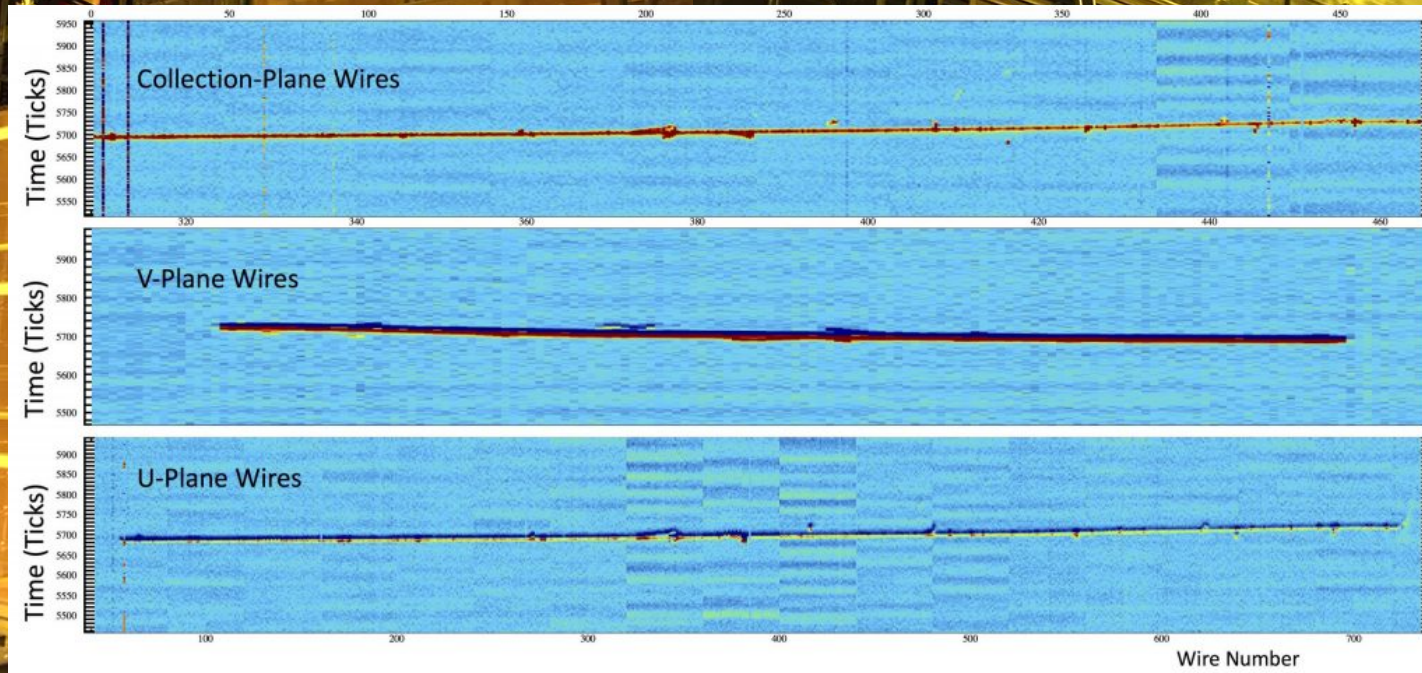
ProtoDUNE @ CERN

The worlds largest LAr TPC
 $7 \times 7 \times 6 \text{ m}^3 \sim 770,000 \text{ kg}$

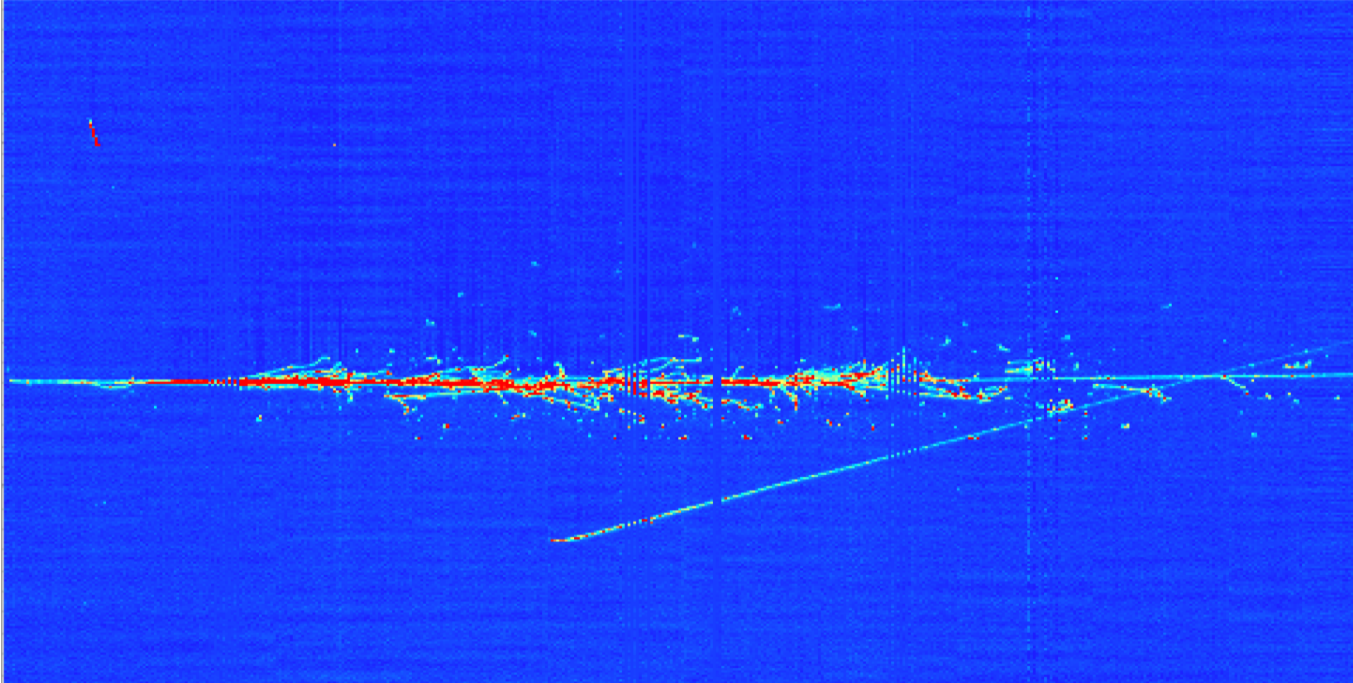


ProtoDUNE @ CERN

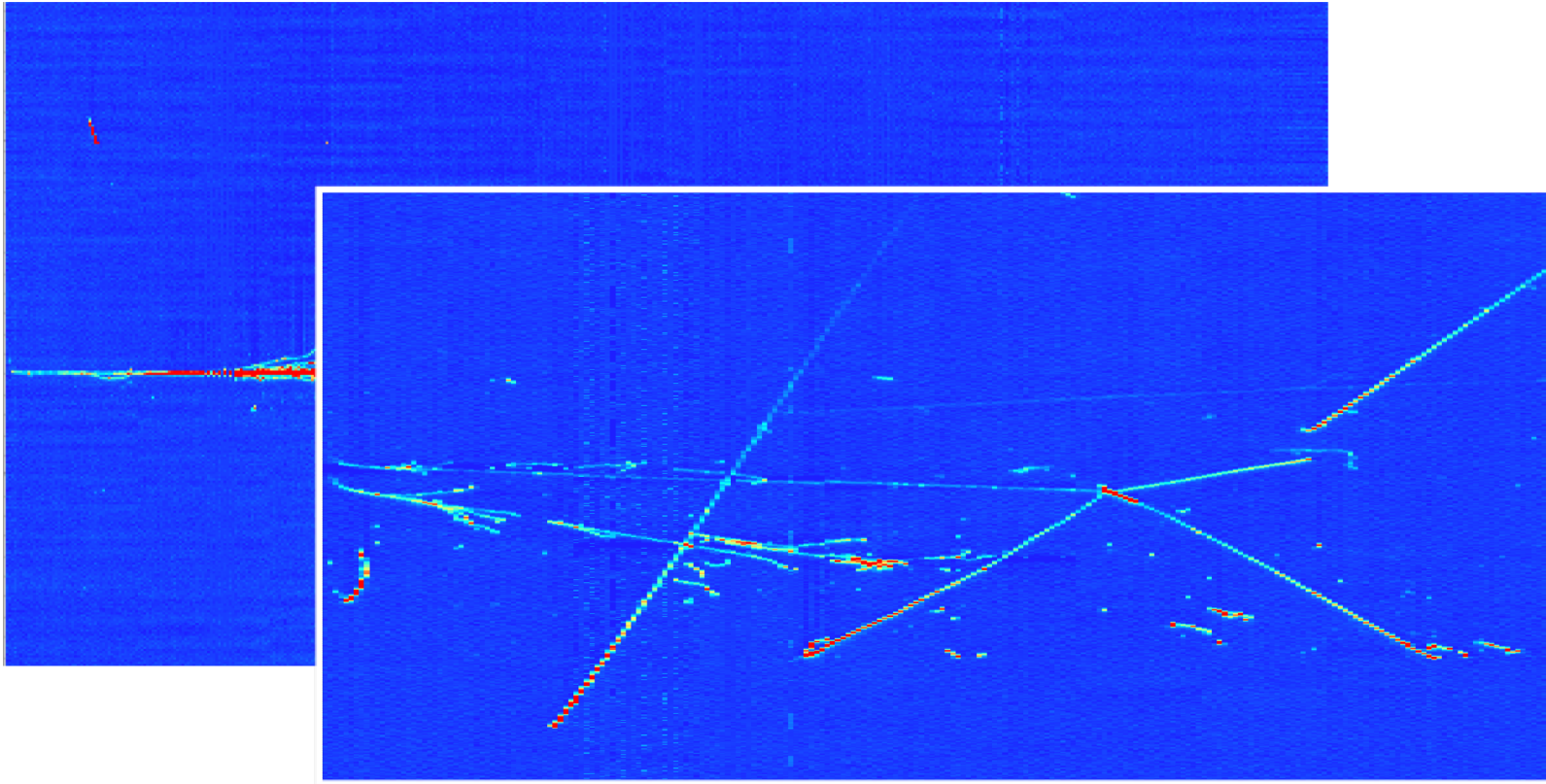
The worlds largest LAr TPC
 $7 \times 7 \times 6 \text{ m}^3 \sim 770,000 \text{ kg}$



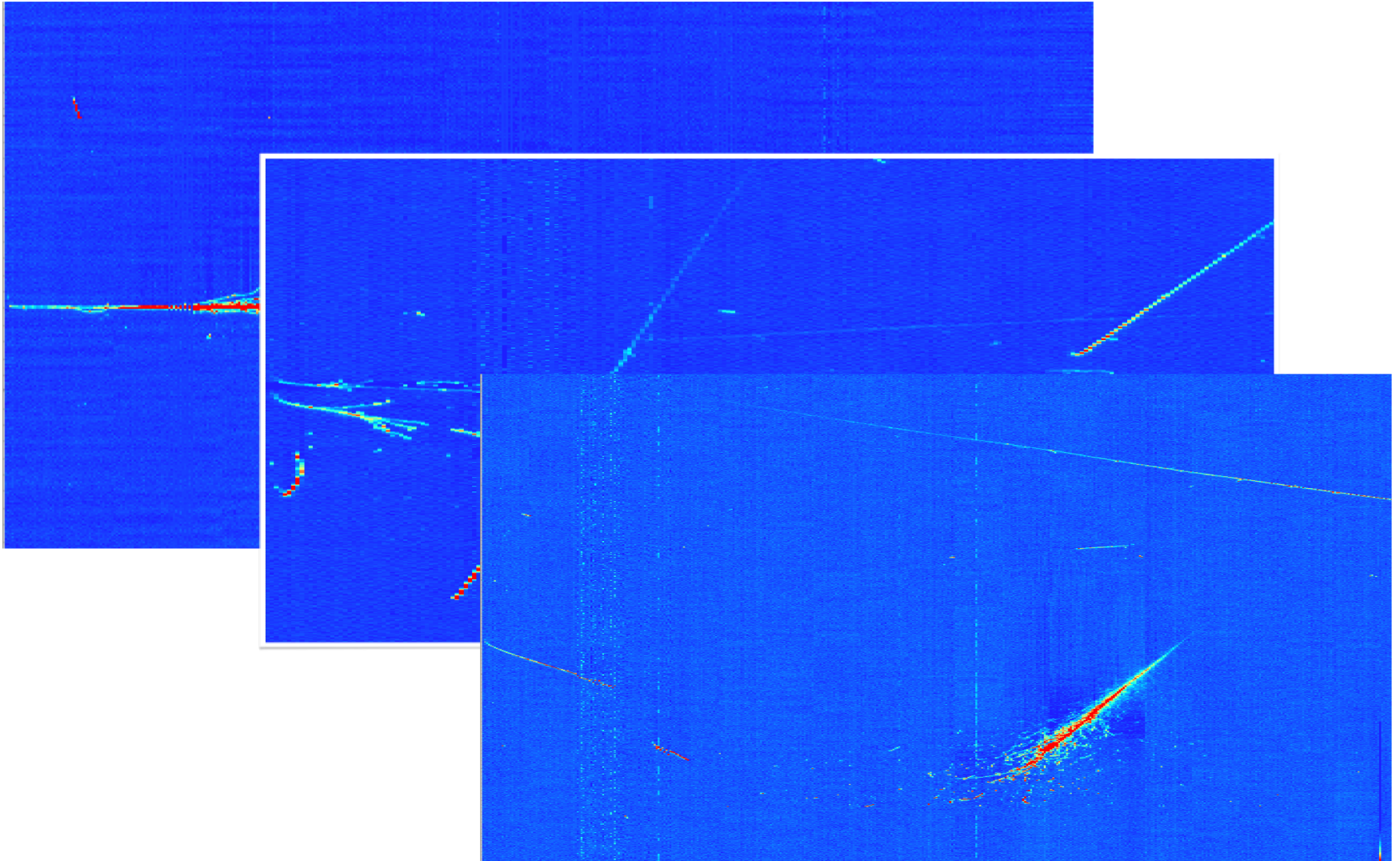
Real Events



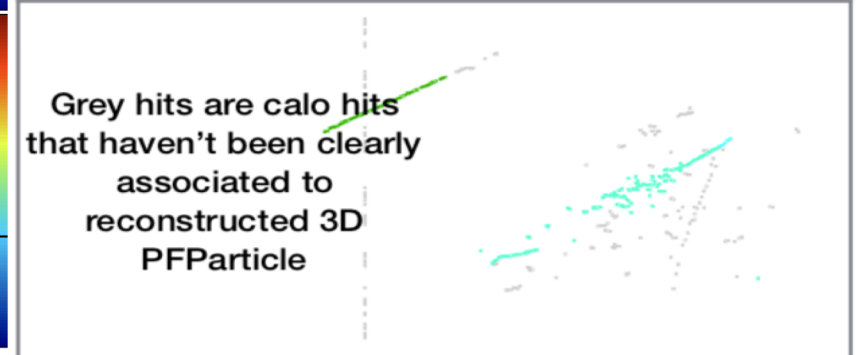
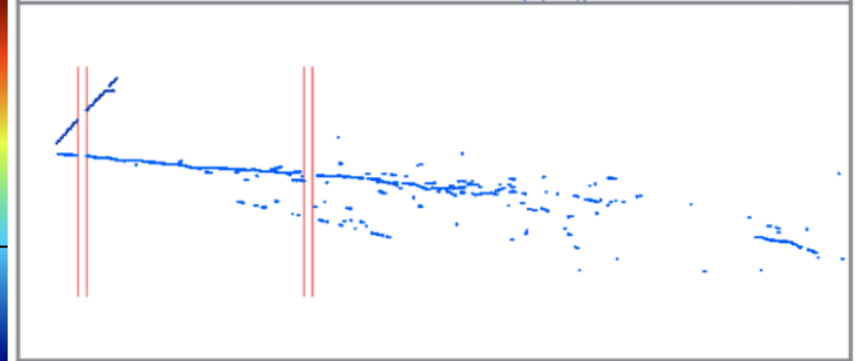
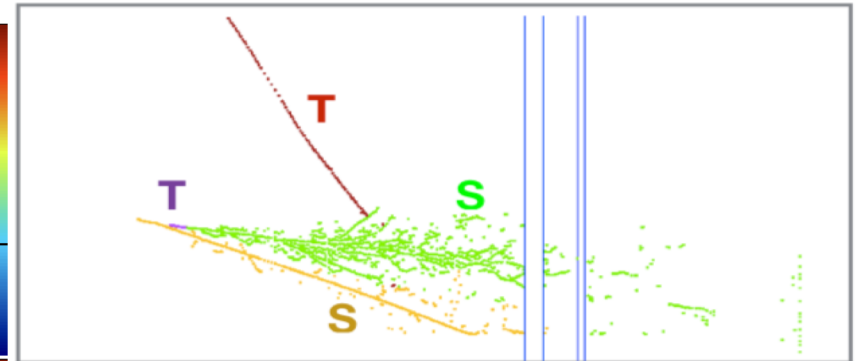
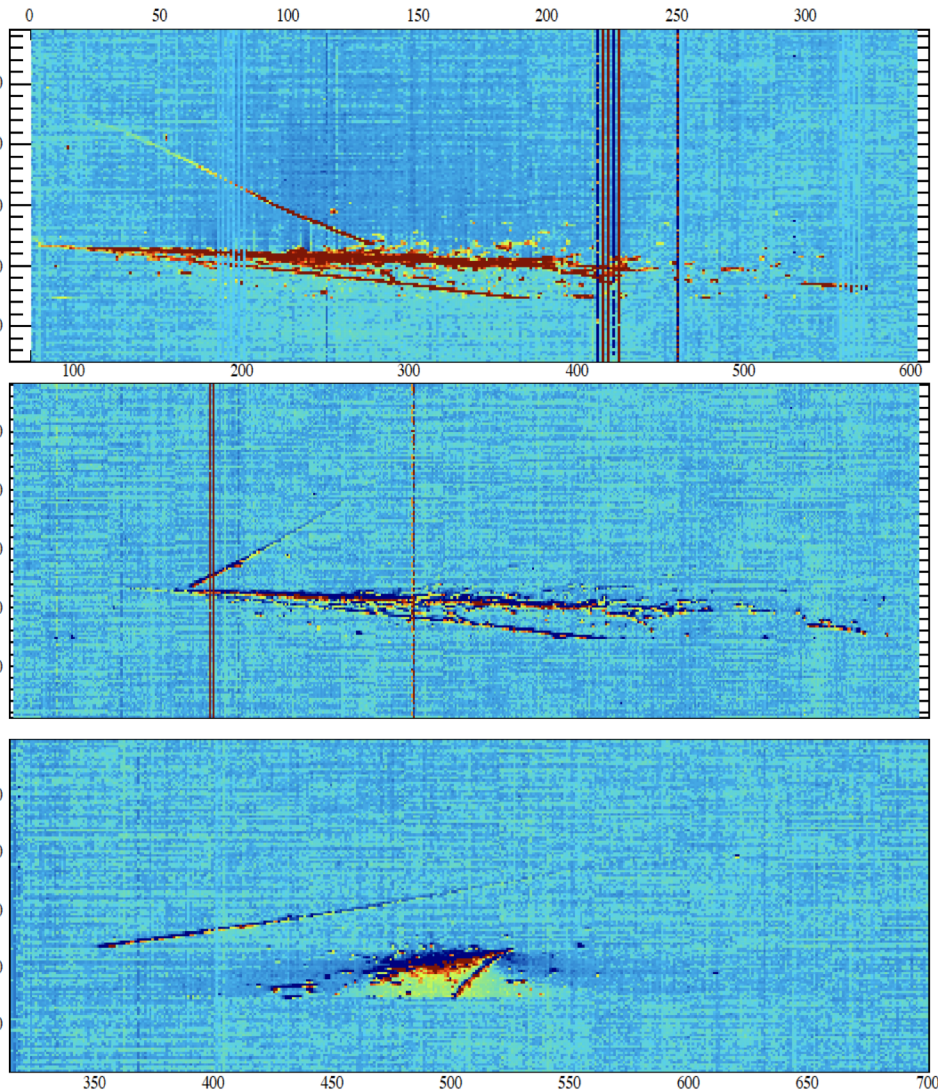
Real Events



Real Events



Automatic Reconstruction



Summary and Conclusion

- DUNE has an ambitious physics program
 - Precision oscillation parameter measurements
 - CPV, mass ordering
 - Nucleon decay, SN
- Truly international project with strong support
 - US & internationally
- Technology is well understood
 - Prototyping and verifications are well underway
- DUNE is the neutrino physics of the future

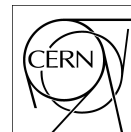
Backup



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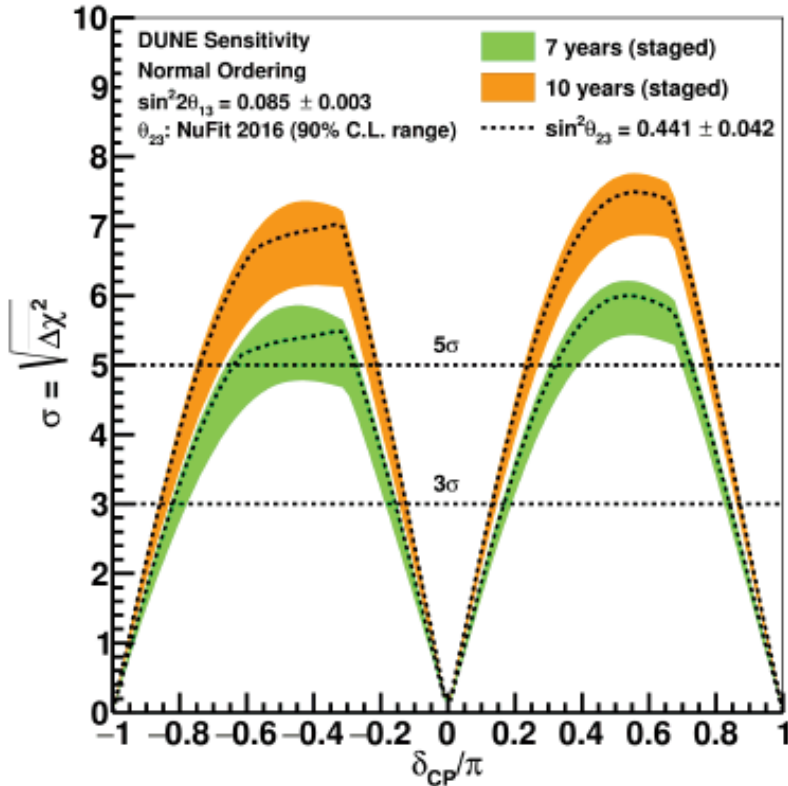


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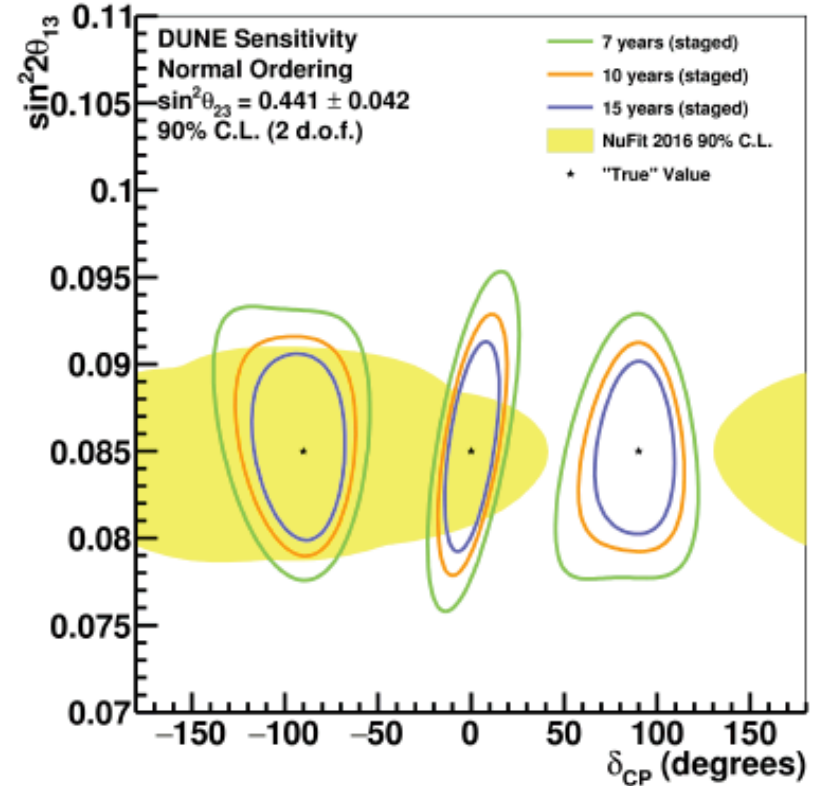


Oscillation Highlights (I)

CP Violation



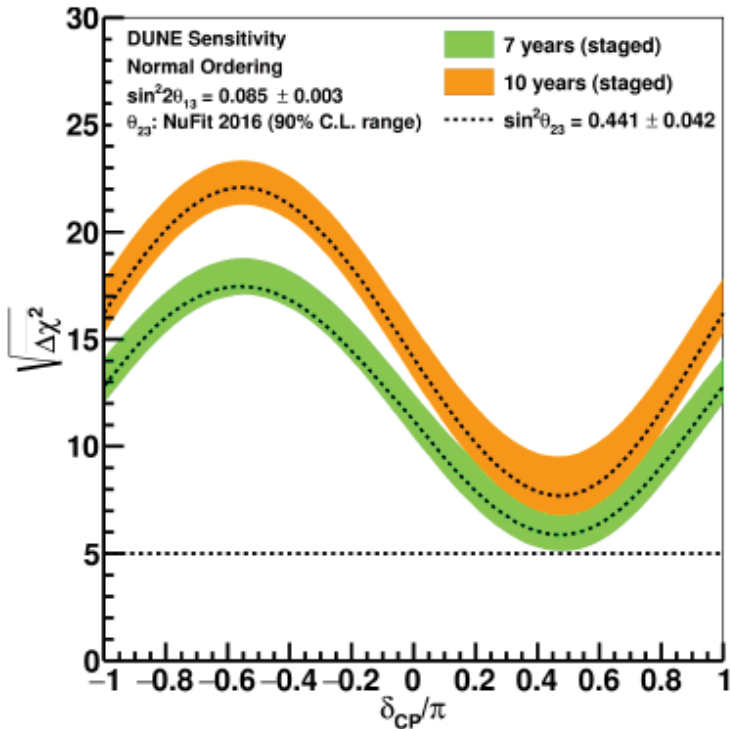
Width of band indicates variation in possible central values of θ_{23}



Simultaneous measurement of neutrino mixing angles and δ_{CP}

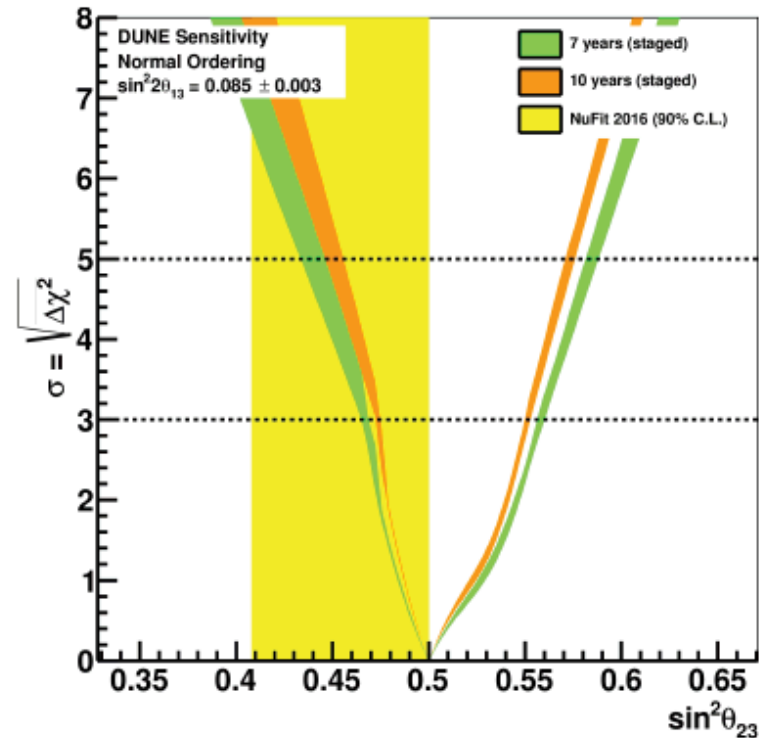
Oscillation Highlights (II)

Mass Ordering



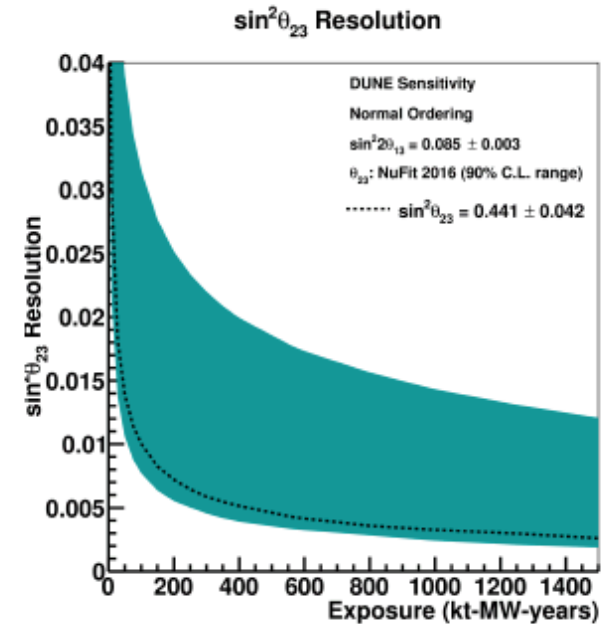
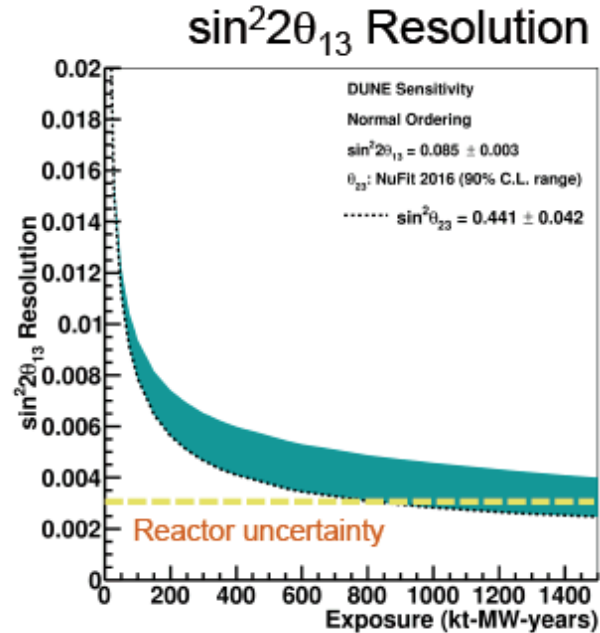
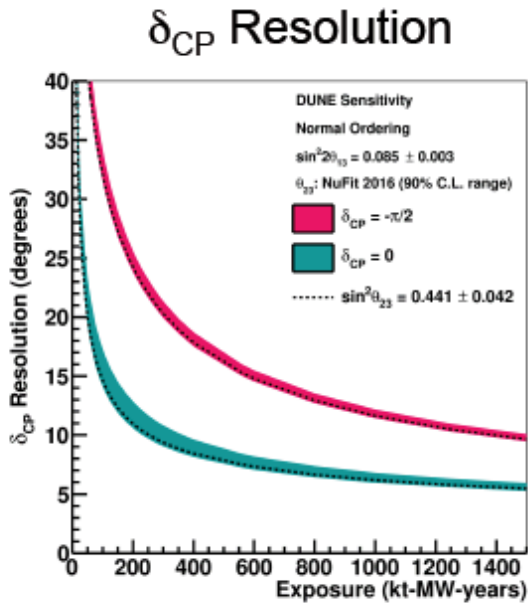
Width of band indicates variation in possible central values of θ_{23}

Octant



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

Oscillation Highlights (III)



Schedule/Timeline

★ Costs and technical schedule are understood

- Multiple independent reviews
- FD excavation started

★ Schedule based on a realistic funding profile

- DOE planning line (including large contingency)
- Planned CERN contributions
- Anticipated international contributions

★ International Key Milestones:

- **2017:** start of construction at SURF
- **2018:** operation of two large-scale prototypes at CERN
- **2019:** International approval of DUNE funding matrix
- **2021:** start of installation of first 17-kt far detector module
- **2024:** start of operation of 17-kt far detector module
- **2026:** start of beam operation (1.2 MW) with two 17-kt FD modules