The **L**ong-**B**aseline **N**eutrino **E**xperiment Project

LBNE

Bruce Baller (Fermilab)
for Jim Strait

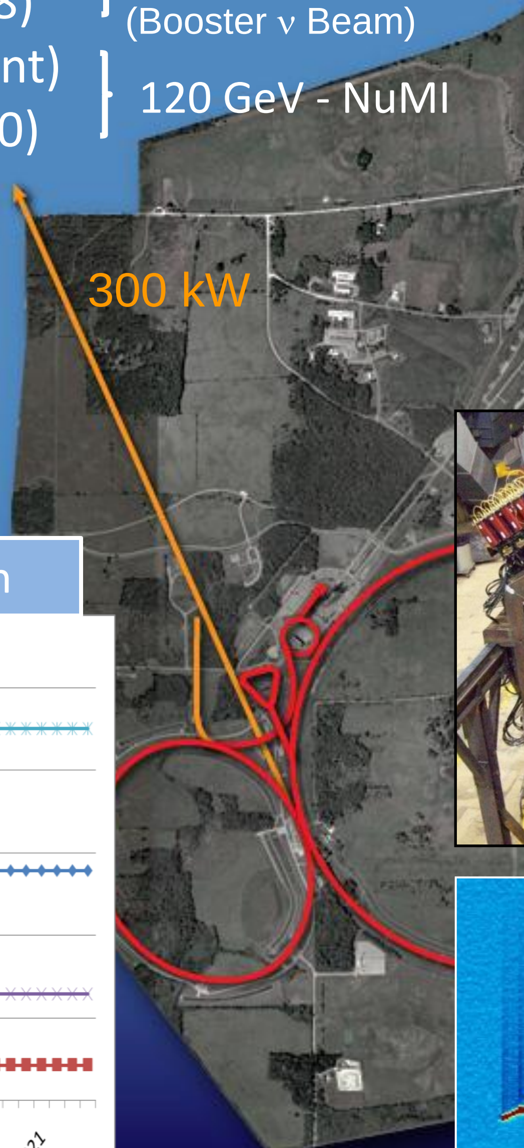
Outline

- Fermilab neutrino beams overview
- The Long Baseline Neutrino Experiment
- Staging scenarios with Project X
- Conclusions

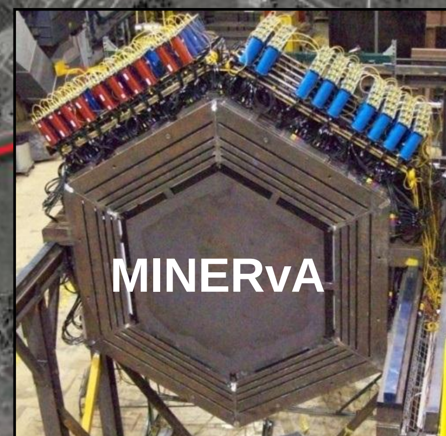
Short Baseline Neutrinos (Now)

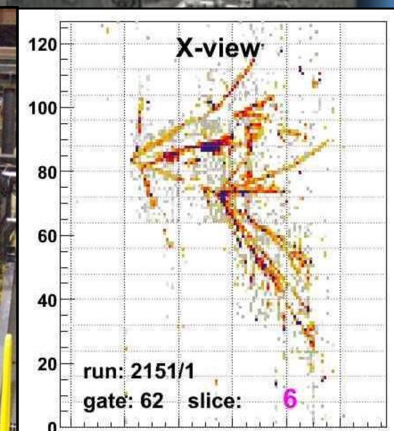
MiniBooNE (2002 – present)
SciBooNE (2007 – 2008)
} 8 GeV – BNB (Booster ν Beam)

MINERvA (2010 – present)
ArgoNeuT (2009 – 2010)
} 120 GeV - NuMI

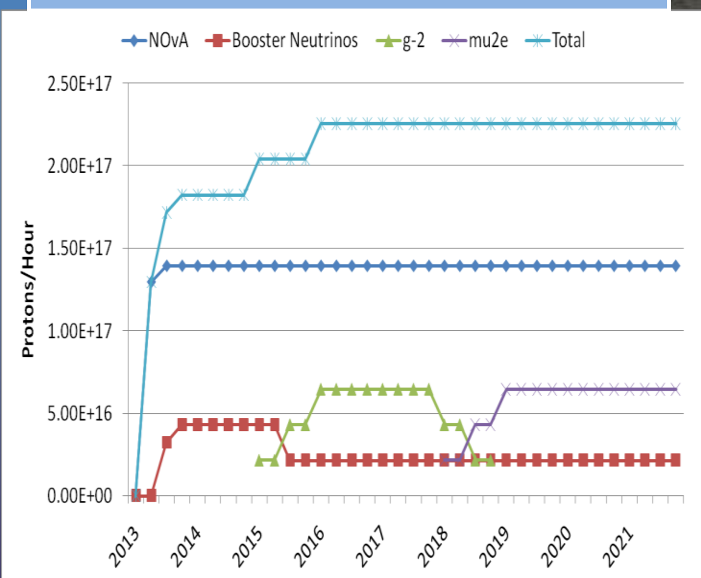


Liquid Argon Test Facility under construction → MicroBooNE

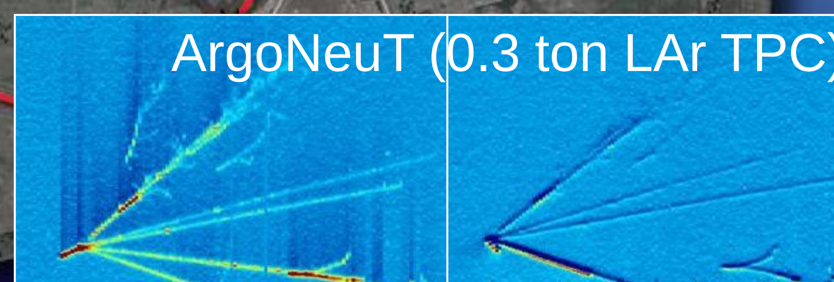




Proton Improvement Plan



ArgoNeuT (0.3 ton LAr TPC)

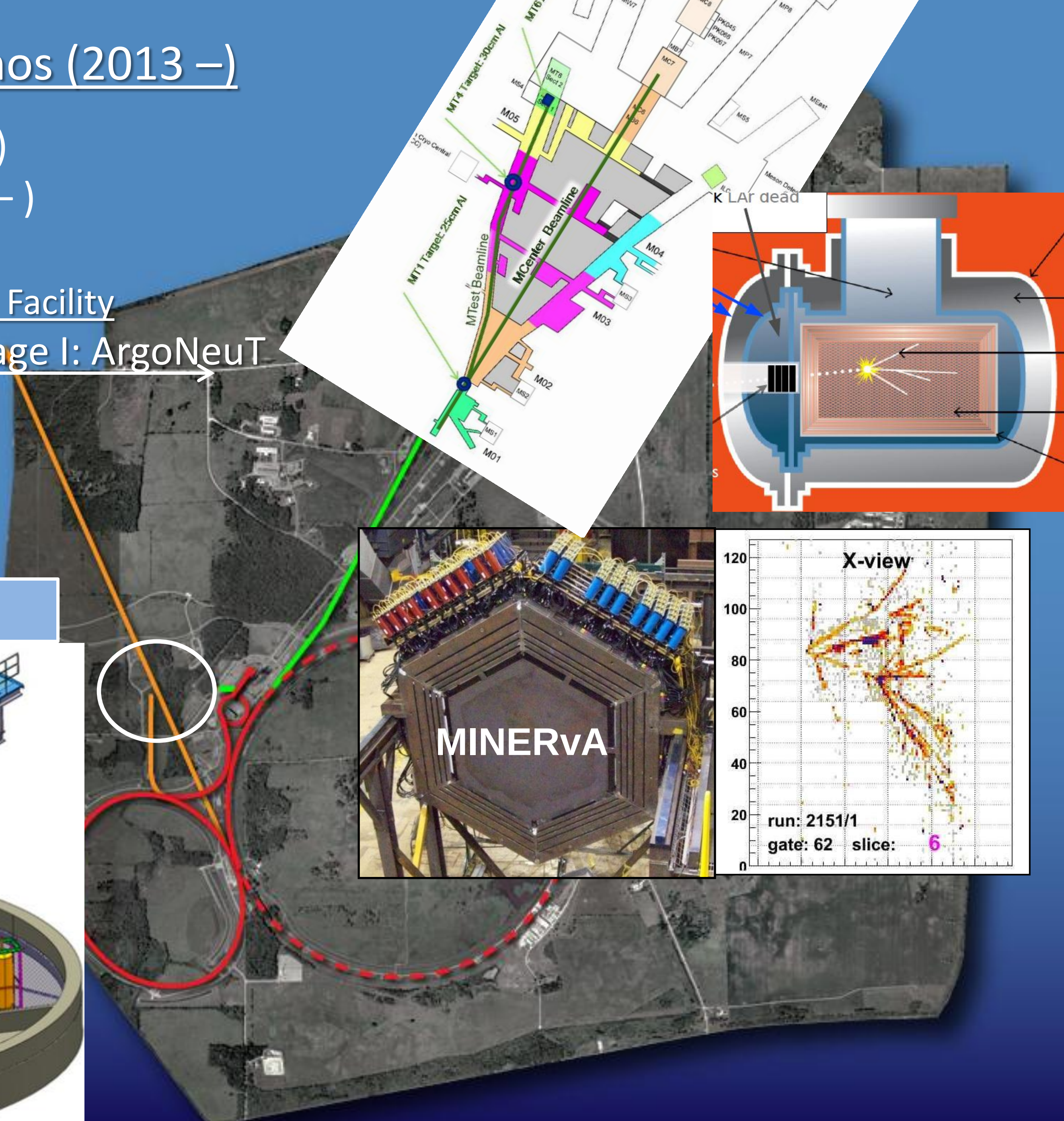


Short Baseline Neutrinos (2013 –)

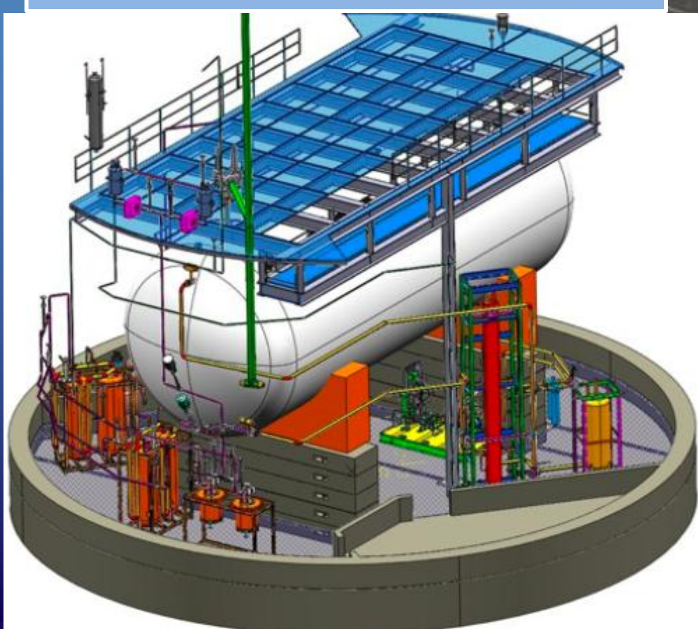
MINERvA (2010 –)
MicroBooNE (2013 –)

Fermilab Test Beam Facility

LAr Test Beam Program Stage I: ArgoNeuT

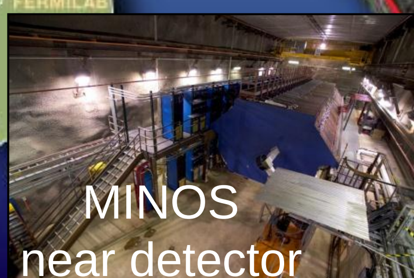


MicroBooNE



Long Baseline Neutrinos (Now)

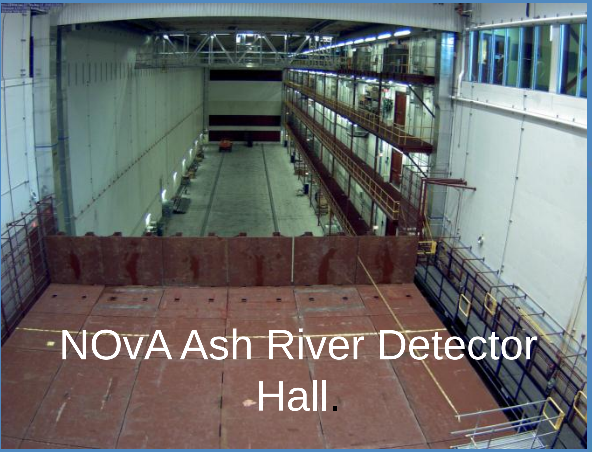
MINOS: on-axis (2006 – present) – 735 km



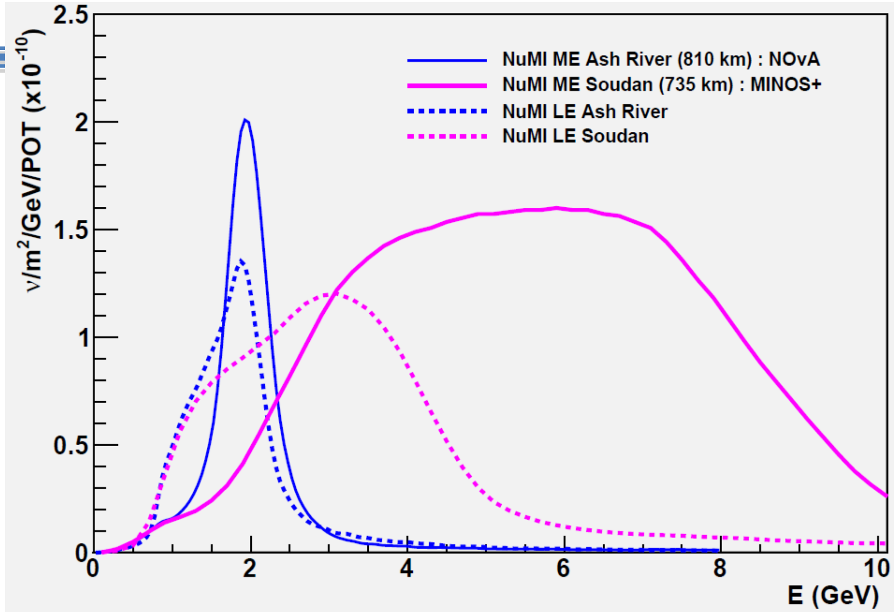
Long Baseline Neutrinos (2013 –)

NOvA: off-axis (2013 –) – 810 km

MINOS+: on-axis (2006 –) – 735 km



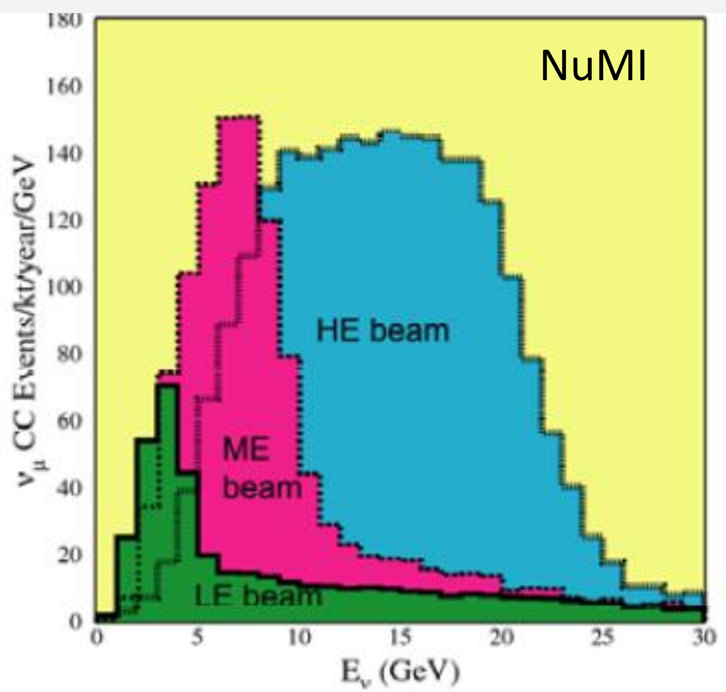
NuMI and Booster Neutrino Beam

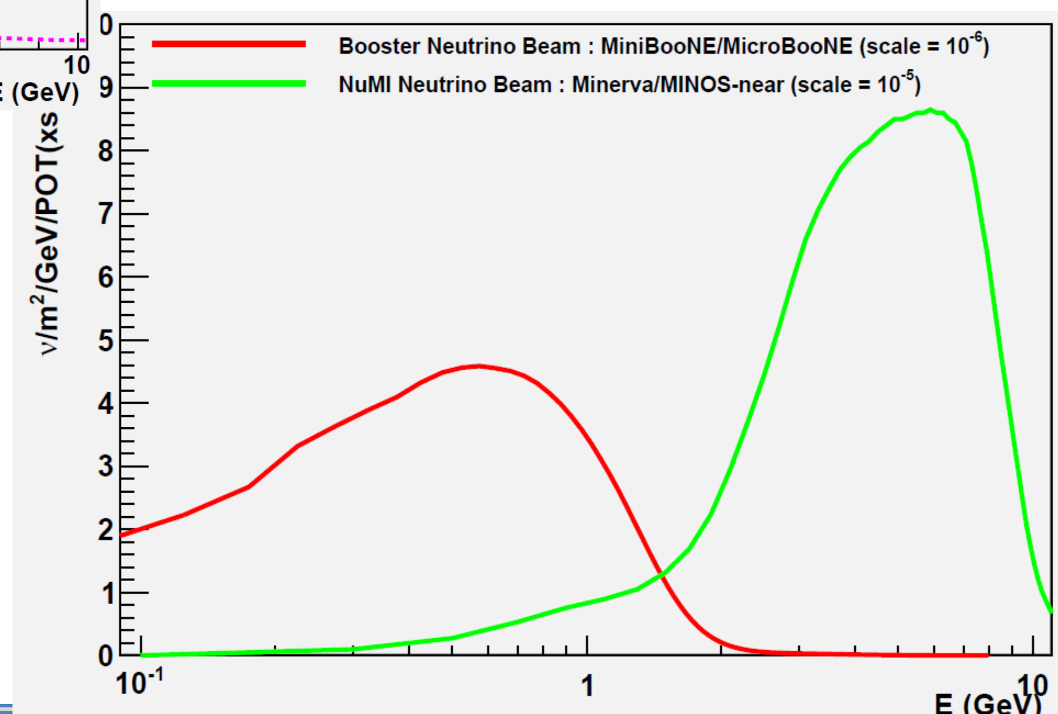


<u>BNB:</u> $0.1 < E_\nu < 1$ GeV

<u>NuMI - tunable</u>

- On-axis: $2 < E_\nu < 20$ GeV (Soudan)
- Off-axis ME beam: ~2 GeV (Ash River)





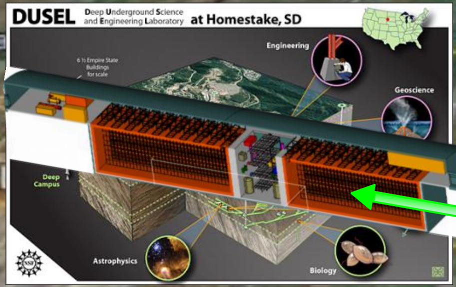
Long Baseline Neutrino Experiment

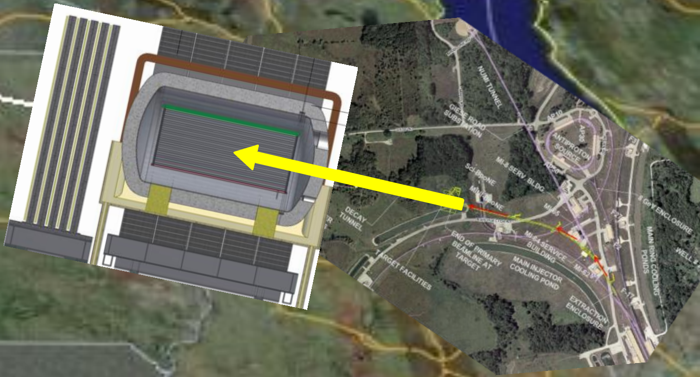
New Neutrino Beam at Fermilab…

Precision Near Detector on the Fermilab site

Directed towards a distant detector

33 kton Liquid Argon TPC Far Detector at a depth of 4850 feet (4300 mwe)





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337 Members
61 Institutions
25 US States
5 Countries

13 April 2012 (337)

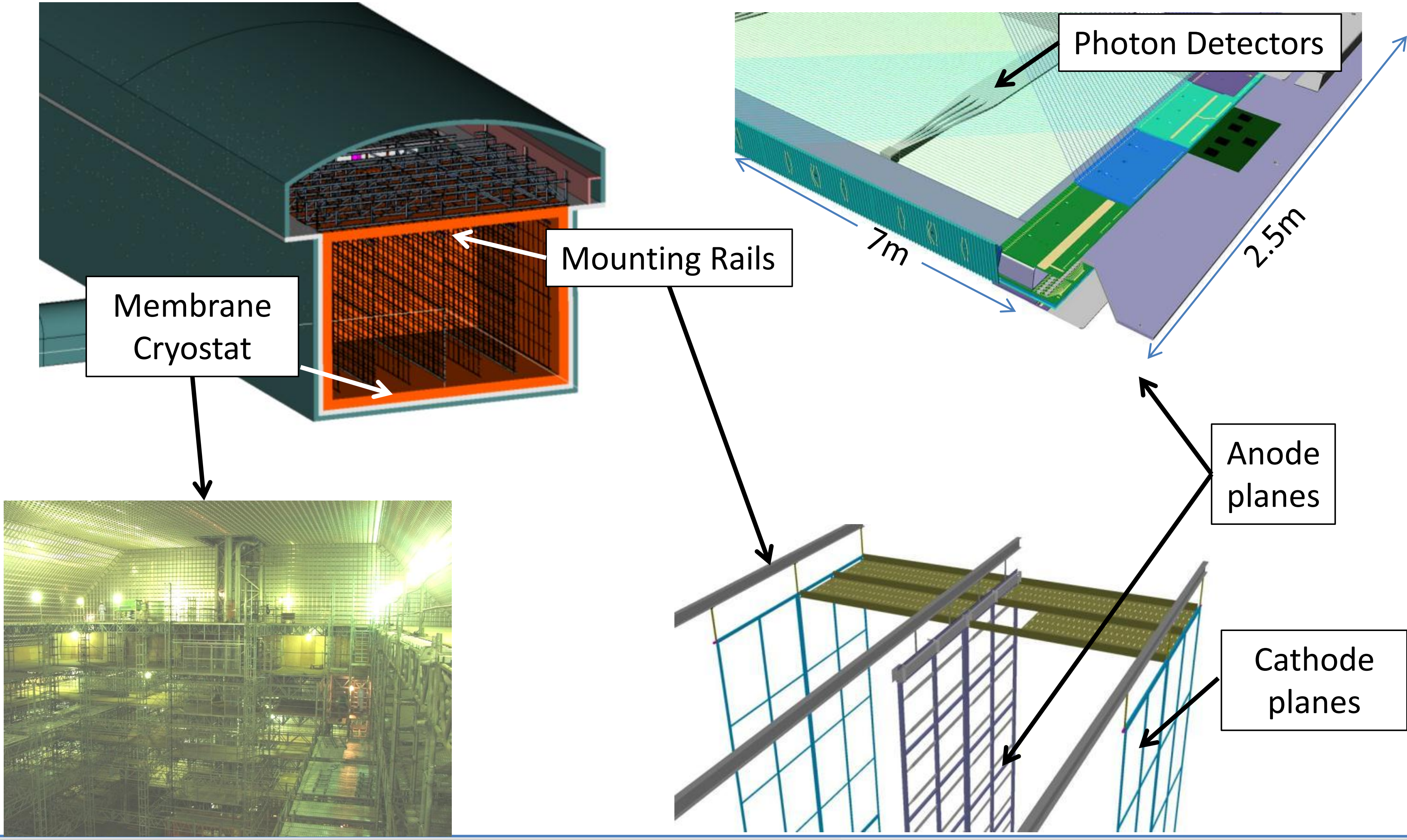
LBNE – Neutrino Oscillations

- LBNE plans a comprehensive program to measure neutrino oscillations
- With its 1300 km baseline, high-power beam, and precision detector, it will:
  - Measure full oscillation patterns in multiple channels, precisely constraining mixing angles and mass differences
  - Cleanly separate matter effects from CP-violating effects
  - Search for CP violation both by measuring the parameter δ_{CP} and by observing differences in ν and $\bar{\nu}$ oscillations.

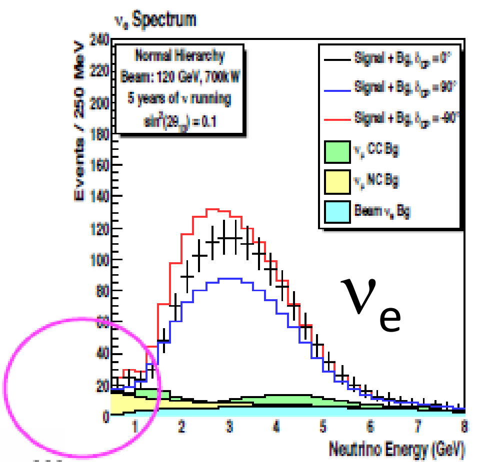
LBNE – Non-Accelerator Physics

- With a large precision detector underground, LBNE can
  - Search for (and perhaps discover) baryon number violating phenomena in channels not easily accessible to existing detectors (e.g. $p \rightarrow K^+\nu$)
  - Measure the ν_e spectrum from a galactic supernova, complementary to the $\bar{\nu}_e$ measured by other detectors
  - Make measurements with unprecedented energy and angular precision with atmospheric neutrinos

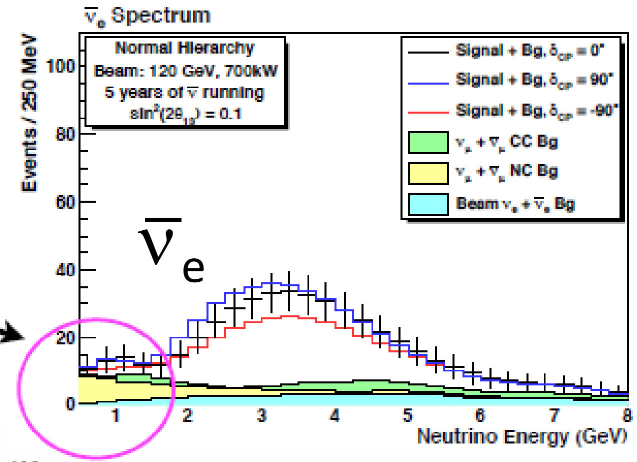
Liquid Argon TPC Far Detector



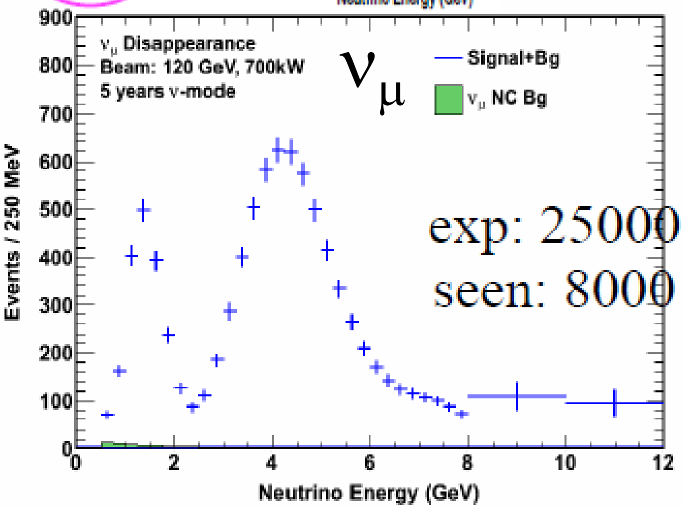
1300 km expectation

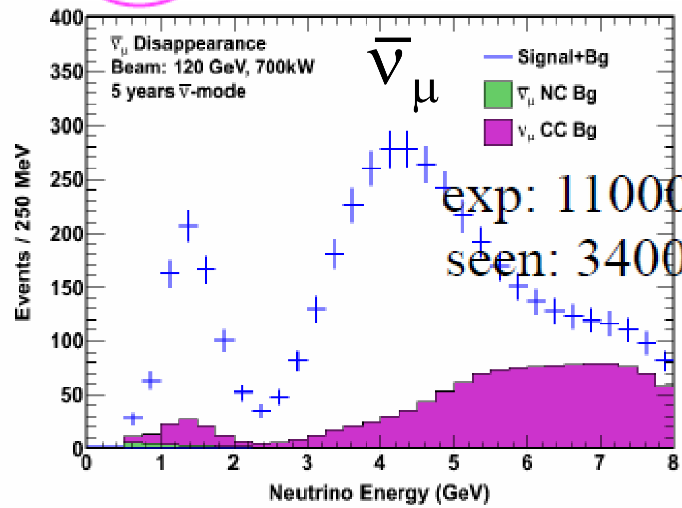


These events are very important



For each bin, conversion fraction of electrons can be calculated. Matter effect can be substracted to obtain explicit CP signal.





Potential surprises:

Matter effect is not what is expected !

CPV does not have the proper energy 1/E dependence.

- With 1300 km the full structure of oscillations is visible in the energy spectrum. This spectral structure provides the unambiguous parameter sensitivity in a single experiment.

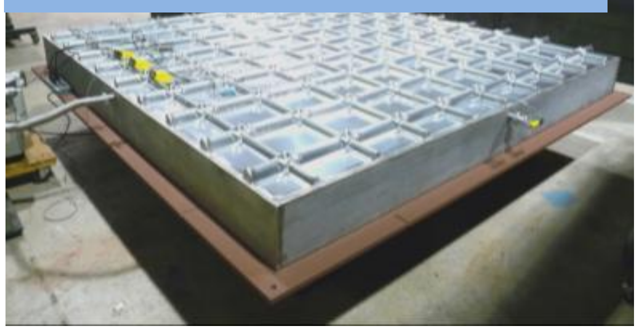
Liquid Argon Test Stands and Prototypes

LAr Materials Test Stand

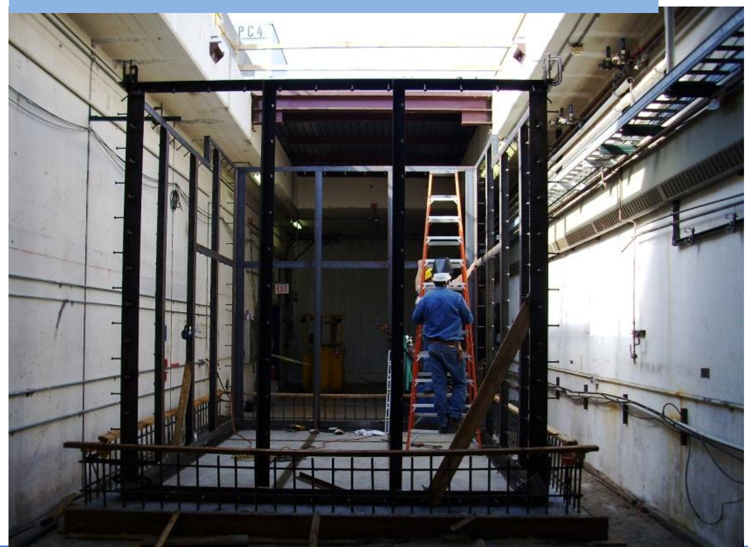
Liquid Argon Purity Demonstrator

First test successful
Testing complete in 2012

Membrane cryostat wall section



35 ton prototype – Membrane Cryostat



In construction.
Operate in 2013
Phase 2 w TPC

LBNE – Project Design

- A robust conceptual design has been developed for all elements:
  - Beam optimized for this physics, upgradeable to >2 MW
  - Precision near detector: LAr TPC or straw-tube tracker.
  - Simple, scalable design for a large LAr TPC far detector.
  - All of the extensive civil engineering required to construct the beam and experiment.
- The engineering design and the project plan have been thoroughly reviewed and found to be sound.
- The project is ready to complete design and construction.

Staged or Alternative Approaches

- The total cost of LBNE is too large for us to implement all at once
  - We are examining ways to stage its construction, or alternative ways to reach the same physics goals.
- Integrating LBNE plans with a staged implementation of Project X → more beam power for LBNE.

We welcome international collaboration in the development of options

U.K. Institutions and Fermilab Collaboration
on Proton Accelerators and Sciences

Letter of Intent signed
between STFC (UK Science and Technology Facilities Council) and Fermilab

Staged Options Considered

- Initial construction of the neutrino beam (700 kW) from the Main Injector and a far detector on the surface, followed by
  - a larger underground detector
  - Or upgraded beam power
- Initial construction of a large underground detector, followed by
  - construction of the beam from the Main Injector and near detector.

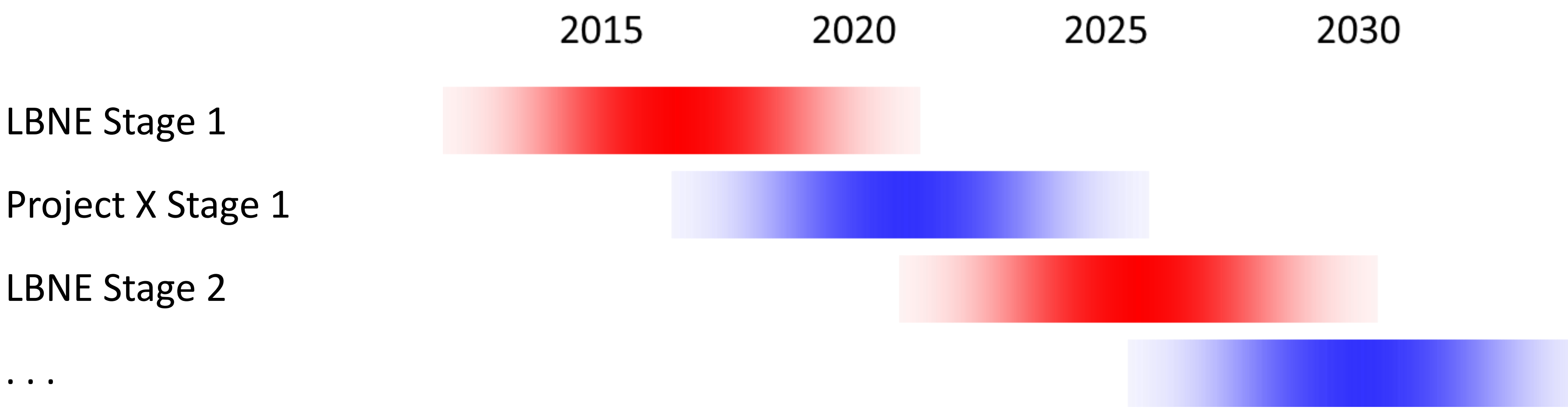
Alternate Approaches to LBNE

- Alternatives to the LBNE approach are being examined utilizing the existing NuMI beamline.
  - Large detector on the surface:
    - On-axis at Soudan Lab (MINOS location), 735 km baseline
    - Off-axis at Ash River (NOvA location), 810 km baseline
  - Small detector underground at Soudan (2100 mwe)
- Advantage: beamline exists → larger initial detector
- Disadvantages:
  - Shorter baseline
  - Beam spectrum not optimal for shorter baseline
  - Beamline not upgradeable to high beam power

Feasible Scenarios

Scenario A – 1300 km:

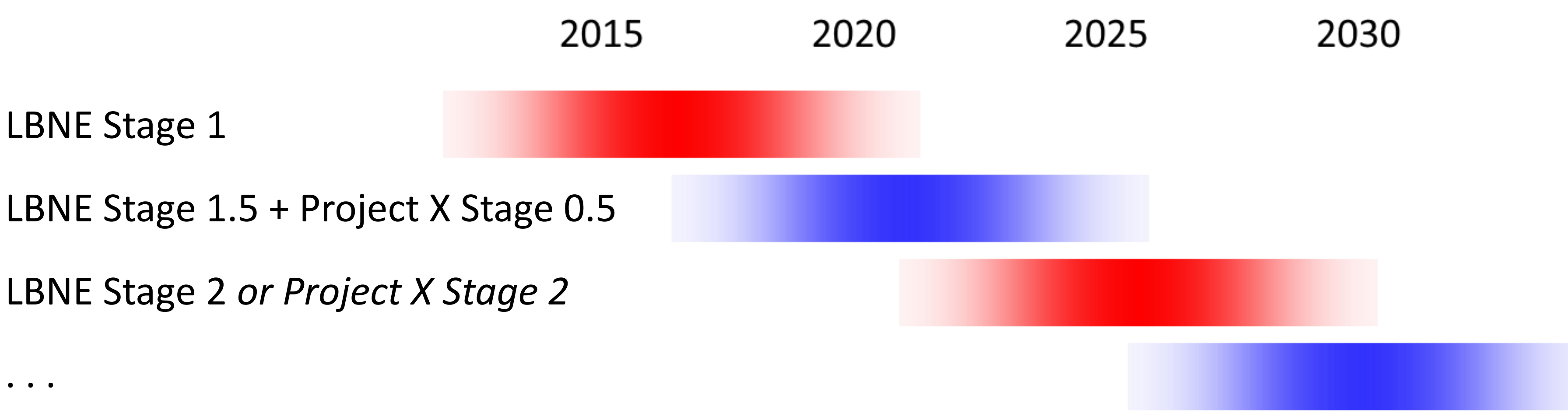
1) 10 kt LAr detector on surface at Homestake + LBNE beamline (700 kW)
2) Project X stage 1 → 1.1 MW LBNE beam
3) Additional 30 kt detector on surface or ~15 kt deep underground (4300 mwe)



Feasible Scenarios

Scenario B – 1300 km:

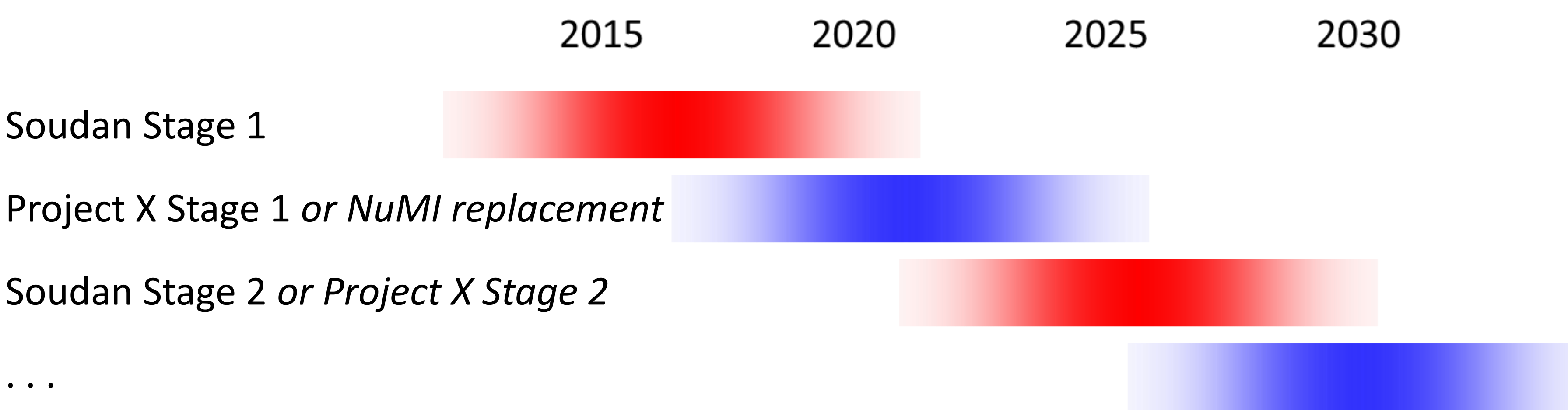
1) ~15 kt LAr detector underground at Homestake
2) LBNE beamline *and* Project X “stage 0.5” (1 GeV pulsed linac)
   → 1.1 MW for LBNE
3) Additional ~25 kt detector underground at Homestake
   or Project X stage 2



Feasible Scenarios

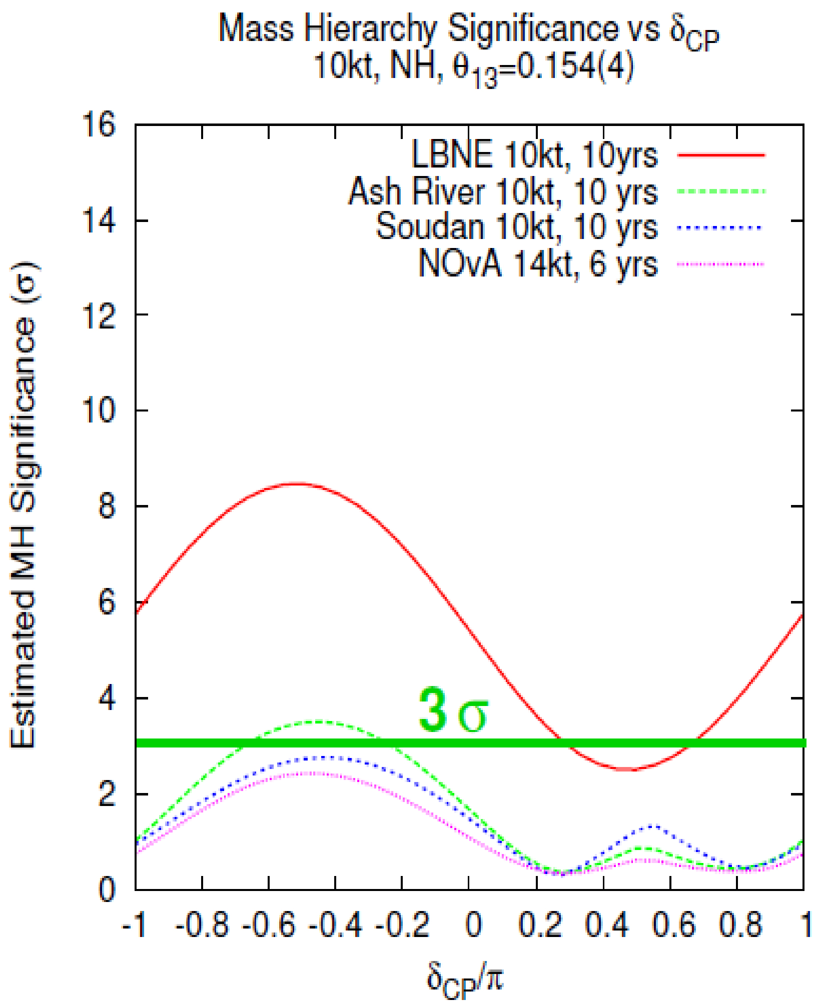
Scenario C – 735 km:

1) ~30 kt detector on surface *or* ~15 kt detector underground (2100 mwe) at Soudan (735 km baseline)
2) Project X stage 1 => 1.1 MW NuMI beam
   or build new beamline with lower energy and higher beam power and Project X "stage 0.5"
3) Additional ~15 kt detector underground *or Project X stage 2*

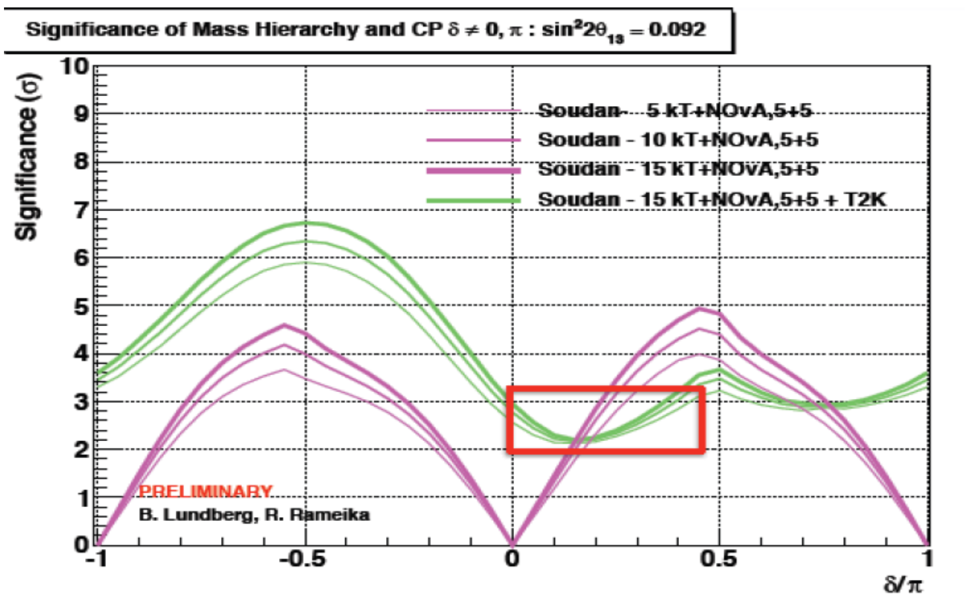


Mass Hierarchy Significance

Scenario A, Stage 1

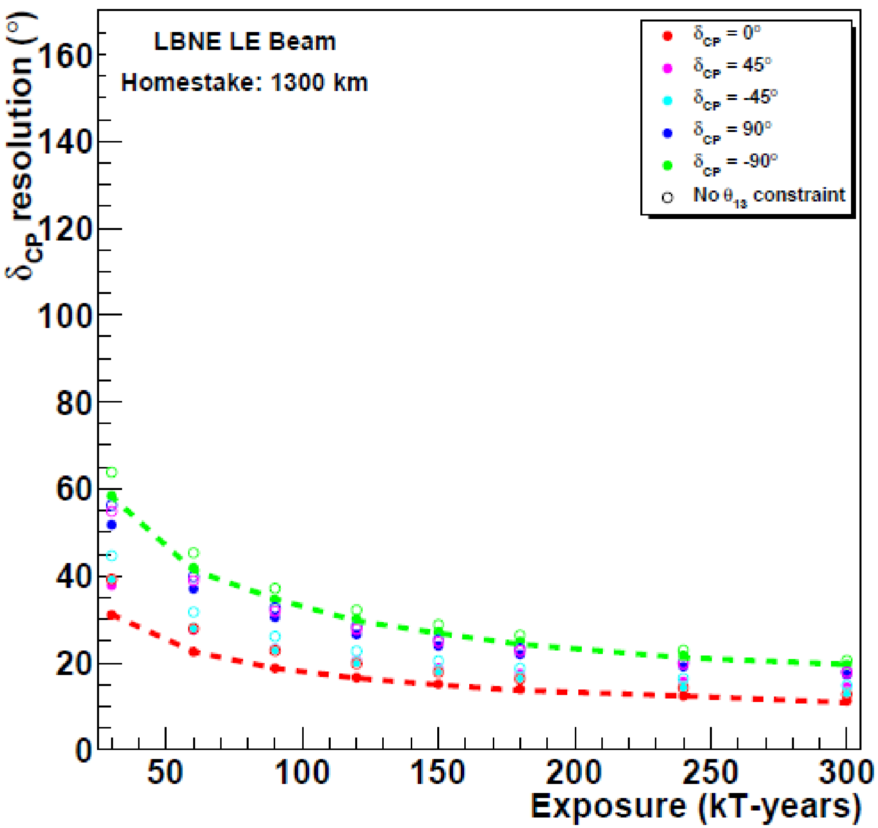


Scenario C, Stage 1

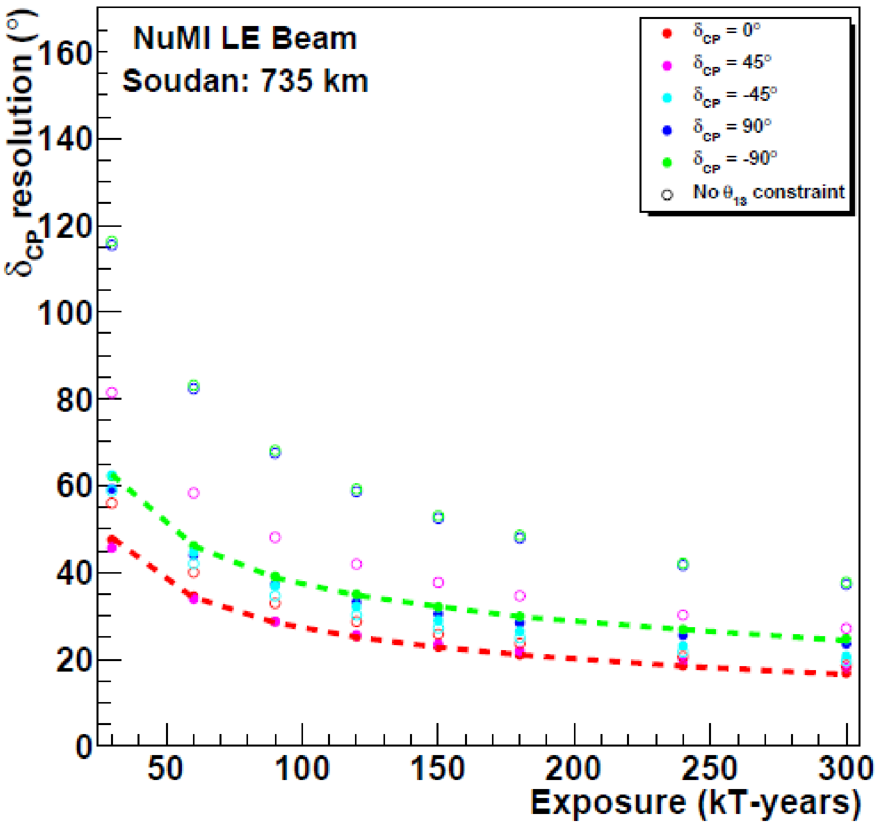


δ_{CP} Resolution vs Exposure

Scenario A, Stage 1



Scenario C, Stage 1



Completing the Staging Studies

- Report on staging/alternative scenarios is being prepared and will be submitted to DOE at the end of this month.
- Work on physics, engineering and cost estimating will continue into the summer:
  - Physics capabilities of each scenario
  - Reducing cost of underground options
  - Understanding technical limitations of NuMI beam
- Decision on which path to follow by the end of the summer.

Conclusions

- Fermilab currently has a powerful and diverse neutrino program
  - Upgrade to double the NuMI beam power is taking place now
- LBNE science goals are
  - Understanding CP violation
  - Nucleon decay and neutrino astrophysics studies when detectors are located underground
- Ready to move towards construction from a technical perspective but the funding climate requires rethinking the one-step approach
- We are now developing a phased program which builds on our current facilities to yield steady increases our understanding of neutrinos
- This exciting program would come to fruition more rapidly with expanded collaboration