Large Experiments/Facilities and the proposed timelines – Neutrino Frontier

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Snowmass Summer Study

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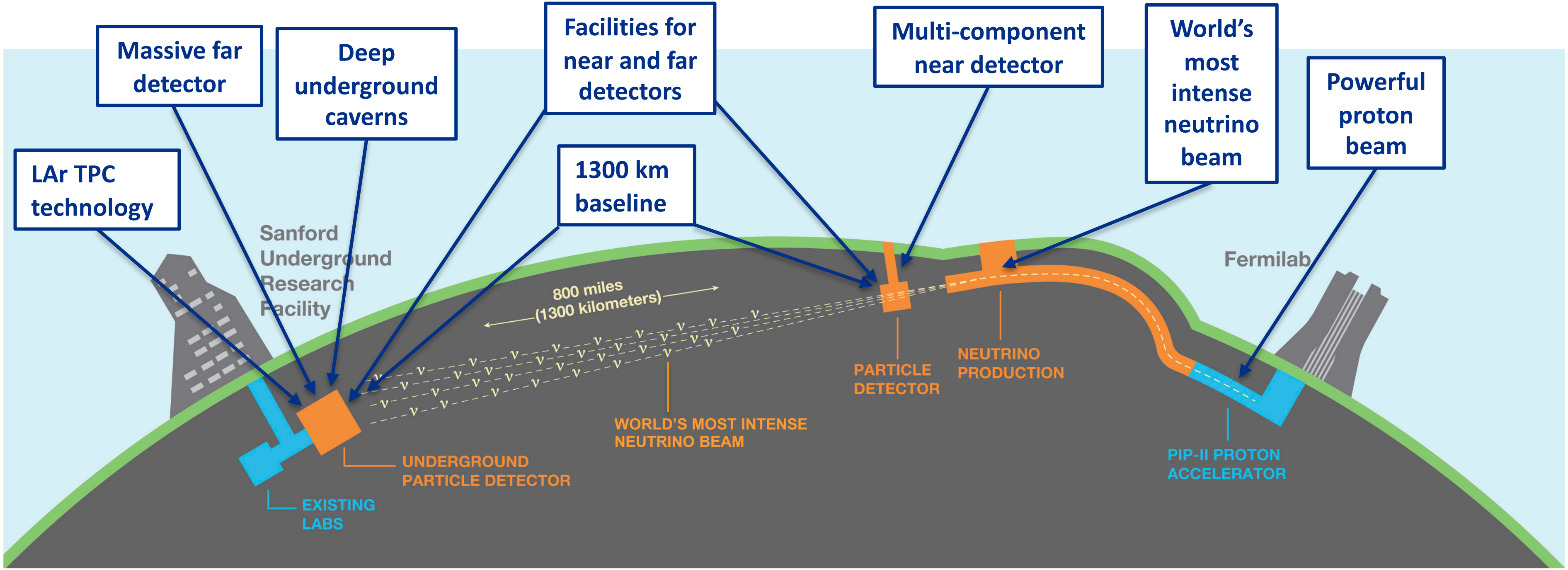
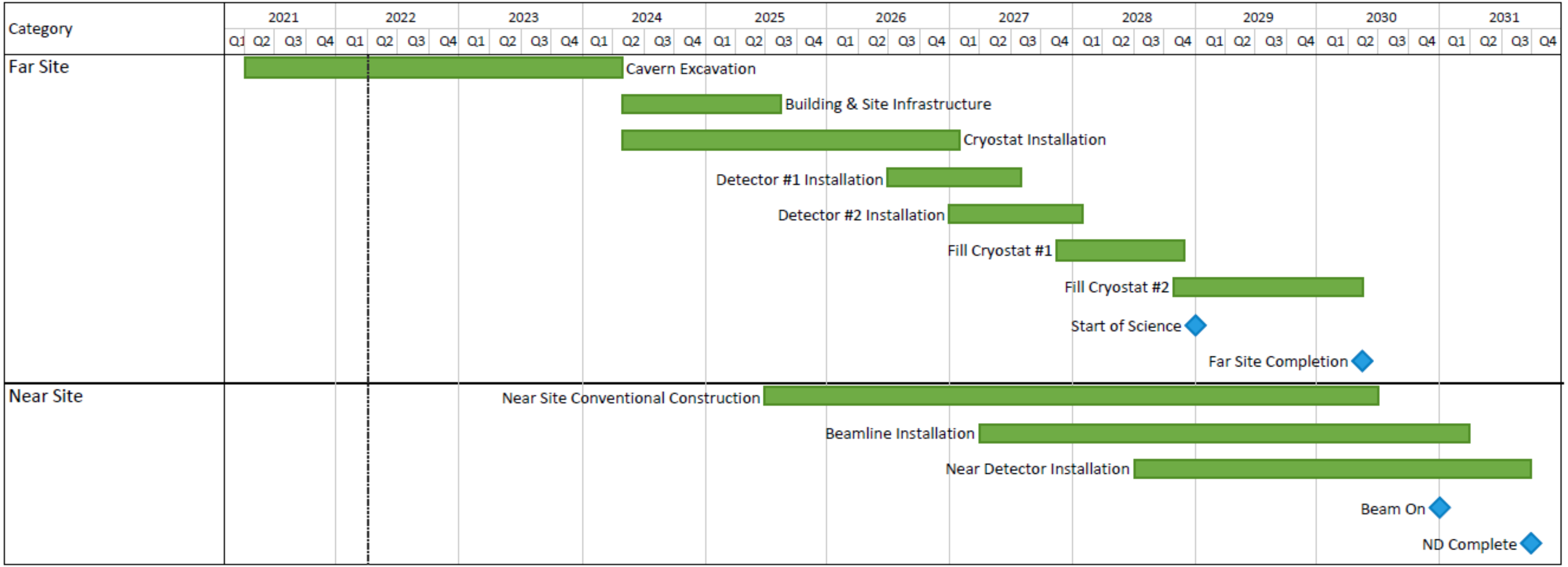
LBNF/DUNE

- Unambiguous, high precision measurements of Δm^2_{32}, δ_{CP}, $\sin^2\theta_{23}$, $\sin^2 2\theta_{13}$ in a single experiment
- Discovery sensitivity to CP violation, mass ordering, θ_{23} octant over a wide range of parameter values
- Sensitivity to MeV-scale neutrinos, such as from a galactic supernova burst
- Low backgrounds for sensitivity to BSM physics including baryon number violation

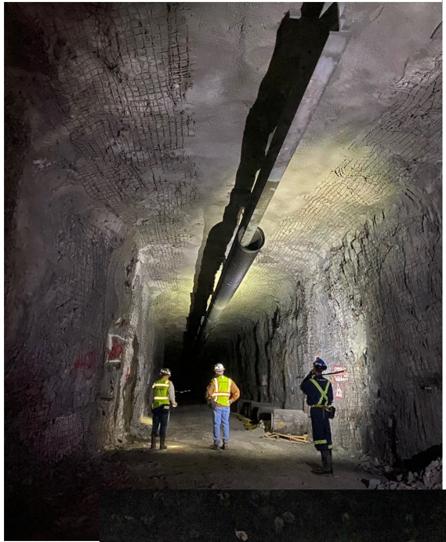


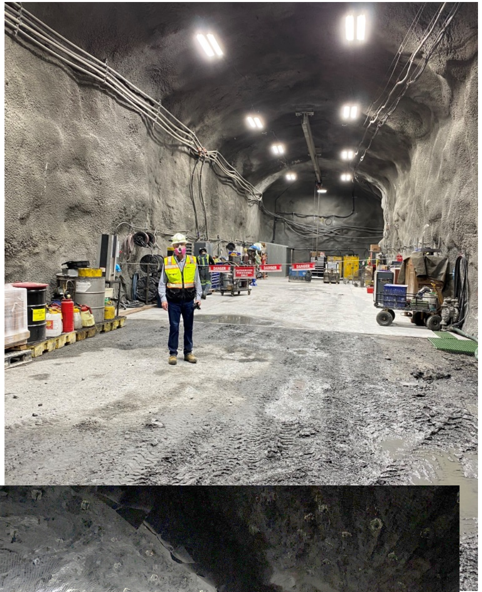
LBNF/DUNE Status and Timeline



LBNF & PIP-II Progress


PIP-II Construction May 2022

Installing and protecting South Cavern monorail


Permanent lighting installed in Maintenance Cavern



Panoramic view in North Cavern

Total Excavated Rock 35% as of 19 Jul 2022

LBNF/DUNE Phases I and II

From the 2014 P5 Report

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.**

Phase II (future):

- Increased mass at Far Detector
- More Capable Near Detector (MCND)
- Increased beam power by Booster replacement

Phase I (current):

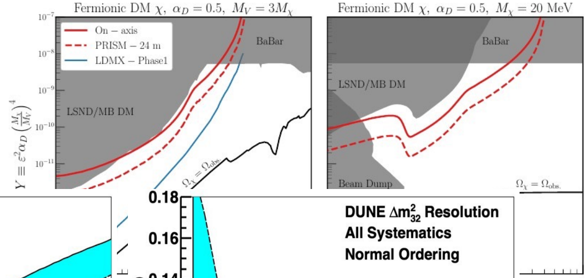
- Accomplished with PIP-II, LBNF/DUNE-US, and DUNE International Partners
- Meets P5 minimum requirements to proceed by 2035 timeframe
- Same project scope as proposed at CD-1R in July 2015

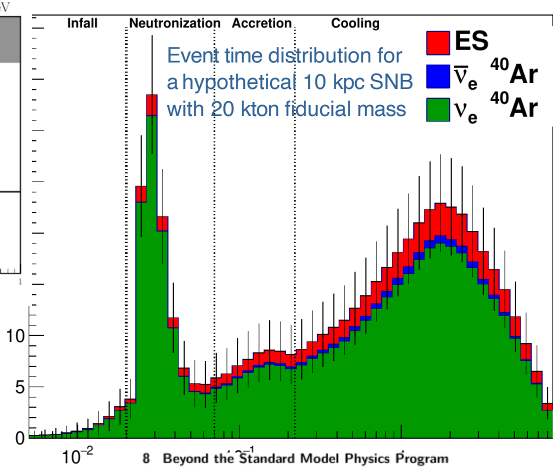
LBNF/DUNE-US Project + DUNE Int'l Project

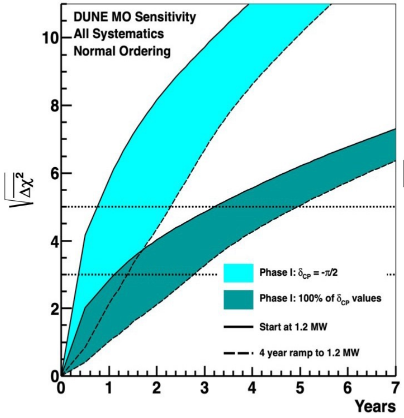
Capability Description	Phase I	Phase II
Beamline		
1.2MW (includes 2.4MW infrastructure)	X	
2.4MW		X[1]
Far Detectors		
FD1 – 17 kton	X	
FD2 – 17 kton	X	
FD3		X[2]
FD4		X[2]
Near Detectors		
ND LAr	X	
TMS	X	
SAND	X	
MCND (ND GAr)		X

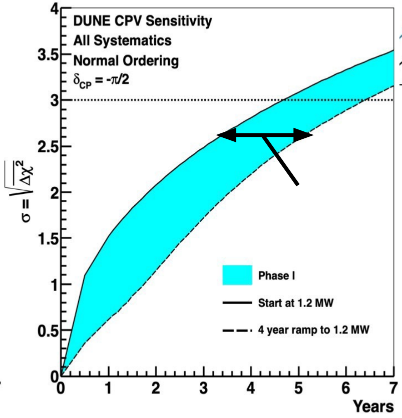
Note 1: requires upgrades to LBNF neutrino target and upgrades to Fermilab accelerator complex. The LBNF facility is built to support 2.4MW in Phase I.
Note 2: Caverns and cryo-infrastructure built in Phase 1

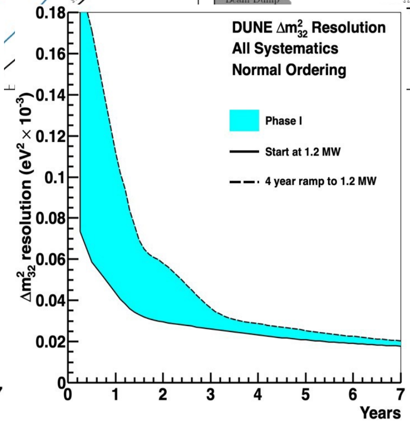
DUNE Phase I Physics







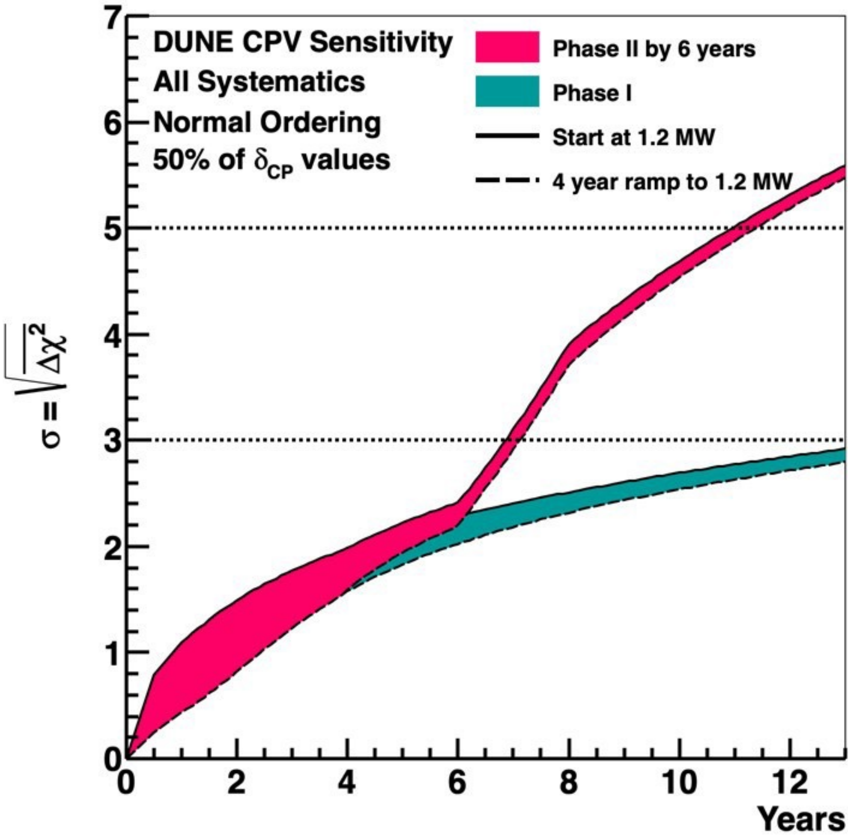




Phase I will do world-class physics:

- Only experiment with 5σ mass ordering capability regardless of true parameters
- Discovery of CPV at 3σ if CP violation is large
- High precision disappearance parameters, (e.g. surpass current Δm^2_{32} error in ~2-3 years)
- DUNE is already very sensitive to a galactic supernova burst with Phase I
- DUNE is an excellent BSM physics experiment in Phase I
- Phase I Near Detector has world leading sensitivity to DM produced in beamline

DUNE Phase II Physics



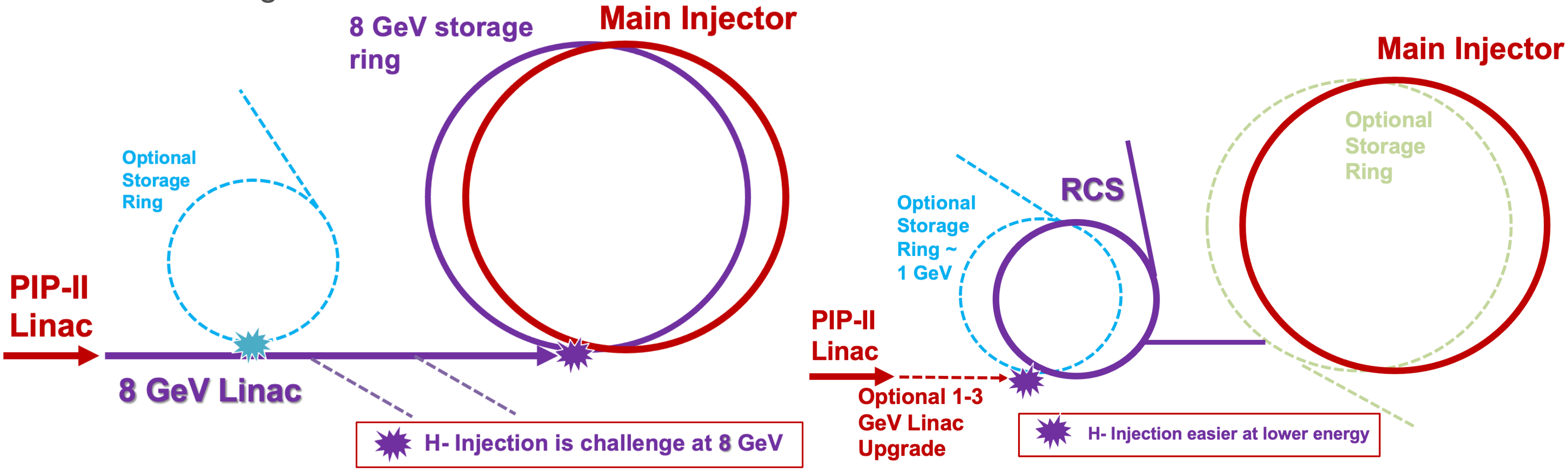
- DUNE needs full Phase II (FD3&4, 2,4MW, MCND) scope to achieve precision physics goals defined in P5 report.
- CPV sensitivity for 50%of δCP values shown
  - Precision measurements are similarly affected
- Timescale for precision physics is driven by achieving full scope on aggressive timescale, early ramp-up is not as relevant
- Many BSM searches at the Near Detector will benefit from the beam upgrade:
  - Neutrino tridents, Milicharged particles, Heavy neutral leptons, Light dark matter, Anomalous ν_τ appearance etc.

2.4MW with the Booster Replacement

PIP-II provides a platform for an extended physics program and future facility upgrades.

Booster replacement scenarios are developed informed by input from Snowmass/P5

- Cost-effective and fastest path to increased power to 2.4MW for LBNF in the 2030's
- Capture options for additional medium and small scale experiments
- Enable long-term vision



Takeaways

- DUNE Phase I should be realized in this decade
- Realization of the full DUNE Phase II should be the highest priority
  - Pursue upgrades aggressively such that the full DUNE scope is achieved in the 2030s
- R&D work to design detectors that broaden the physics scope while fulfilling the core goals of DUNE should be supported
- There are unique opportunities for NF to contribute to leadership of a cohesive, HEPwide strategic approach to DEI and community engagement, which is urgently needed.
  - As the flagship domestic experiment DUNE should be at the center of these efforts
- A healthy portfolio of small and midscale NF experiments is vital to the field and to the success of DUNE (C.F. SBN and DUNE)