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U.S. DEPARTMENT OF ENERGY | Office of Science

Accelerator Neutrino Program in the U.S.

Regina Rameika – Fermi National Accelerator Laboratory

Neutrino Round Table – La Thuile, Italy

February 27, 2014

Outline

- Recent history and current program
- Plans for the future
  - Scientific planning process
  - LBNE and SBNE
  - How new construction projects get started in the U.S.
- Our plans in the global context
  - Merits
  - Competition
  - Collaboration

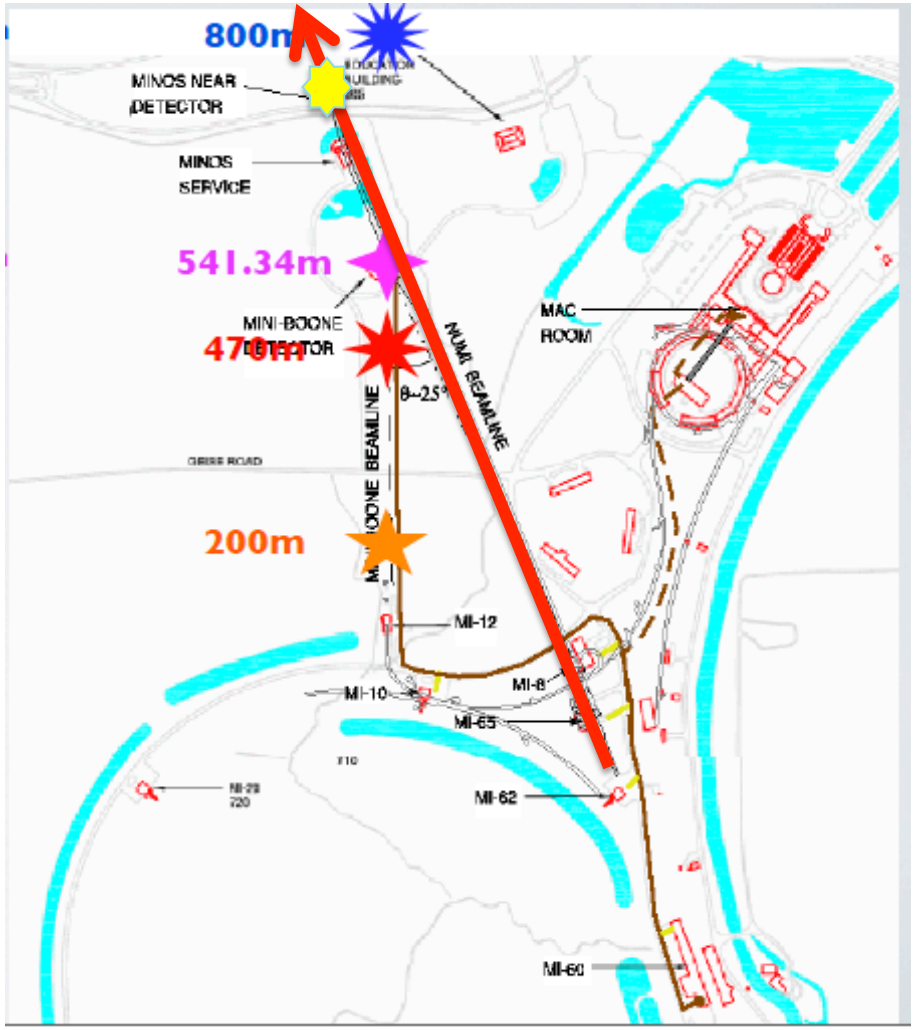
Fermilab Science Program Today

- CDF and D0 continue data analysis for ~2 years
- Test Beam Facility running well & at “over capacity”
- CMS
  - Analysis continues with present data sets
  - Near term upgrades proceeding
  - Data taking begins again in 2015 at ~14 TeV
- Cosmic experiments
  - Dark Energy Survey (telescope in Chile) taking data
  - Dark matter searches
- Neutrinos
  - MINOS+, MINERvA taking data
  - NOvA just about to commence data taking
  - MicroBooNE completing installation & will soon commence commissioning

Current Fermilab-based Neutrino Program

- **Operating** two neutrino beams : NuMI and BNB
  - NuMI : 3e20 POT/yr -> 6e20 POT/yr (700kW)
  - BNB : ~1 – 2 e20 POT/yr (depends on rate to NuMI)
- Collecting **DATA** from NOvA, Minerva, MINOS+ and MicroBooNE!
- **PHYSICS**
  - neutrino mass and mixing, mass hierarchy
  - cross-sections
  - sterile neutrinos
  - anomalies
- LAr **Technology Development** leading to VERY large detector for Long Baseline Neutrinos (LBNE)
  - Prototypes
  - Test beams
  - Intermediate detectors for physics

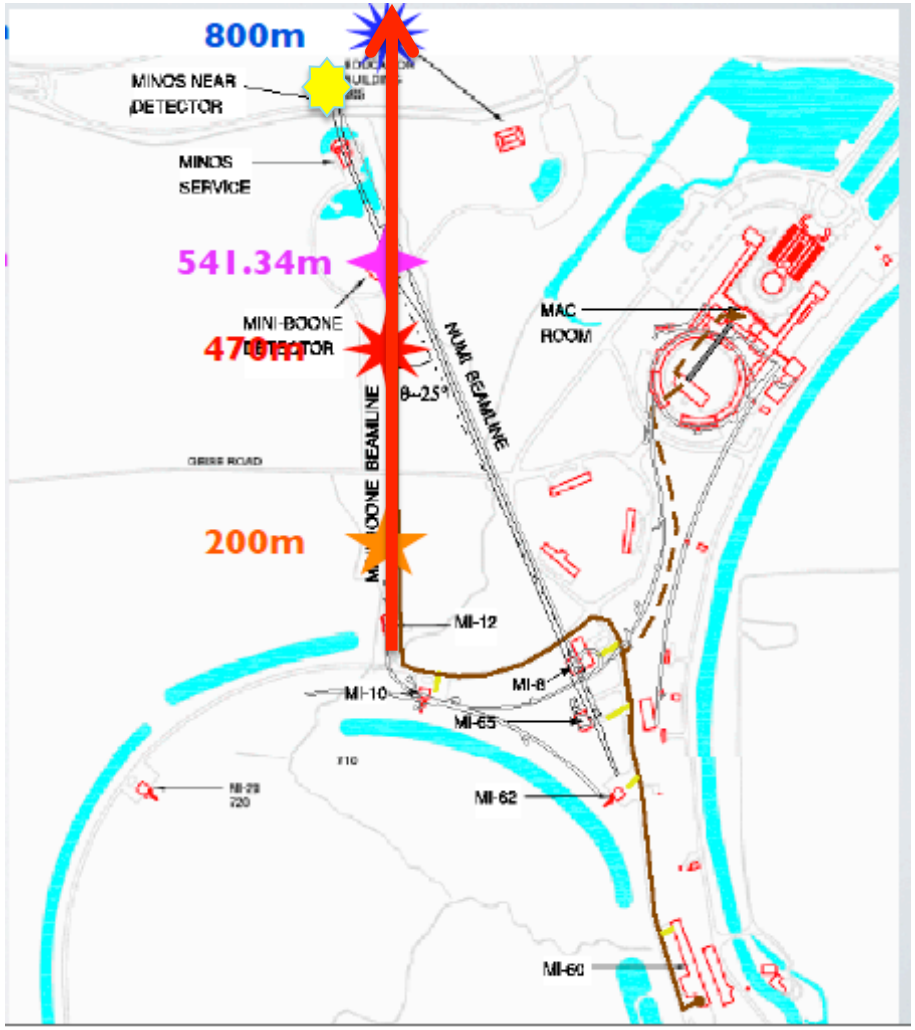
Two Neutrino Beams – multiple detector sites



NuMI Beam aims to Minnesota

Near detector hall ~100m below surface

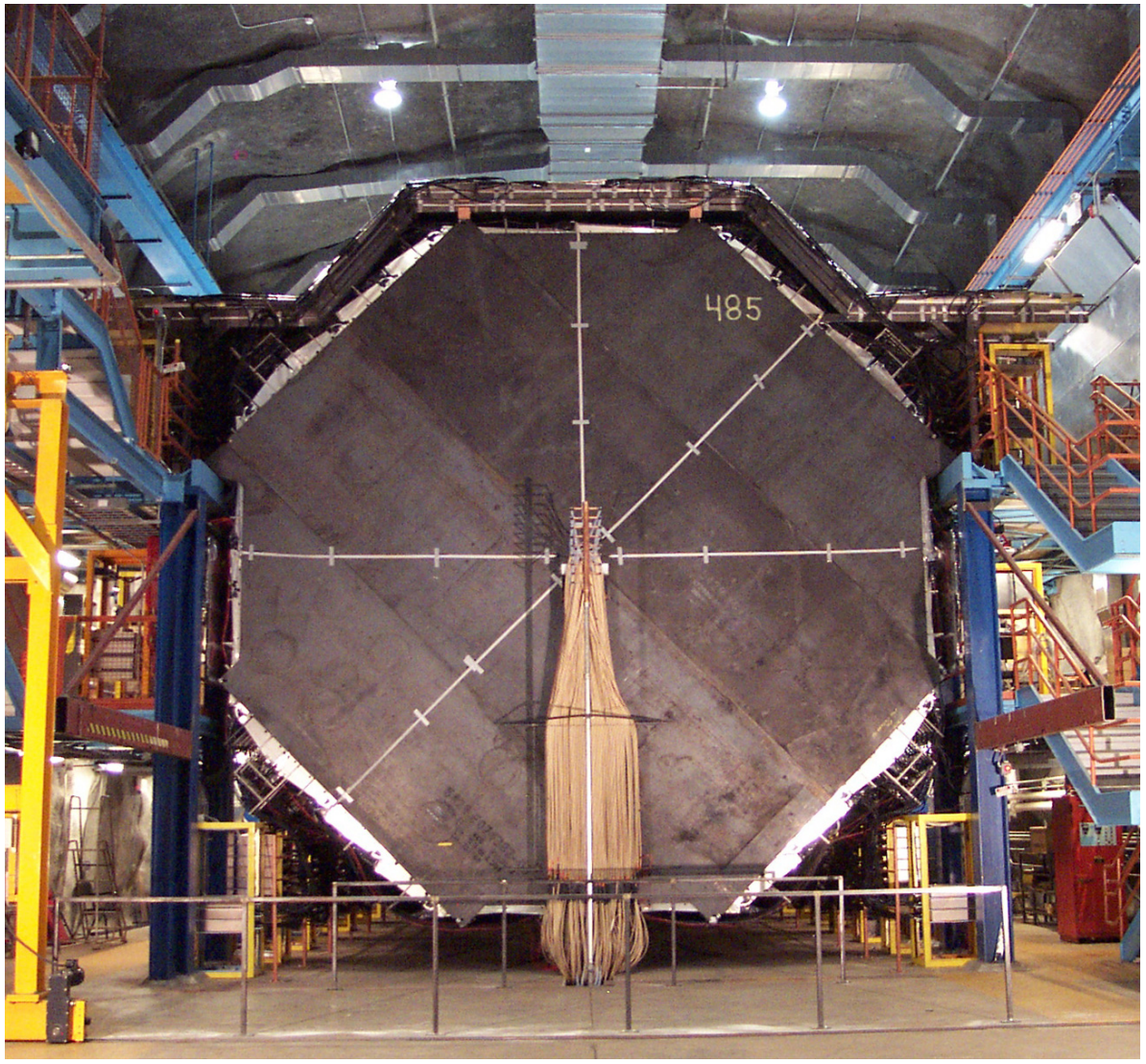
Two Neutrino Beams – multiple detector sites

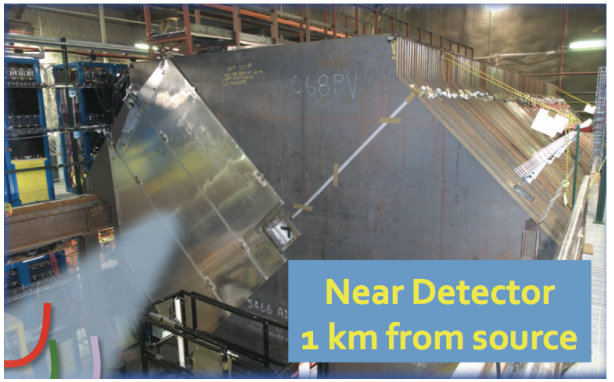


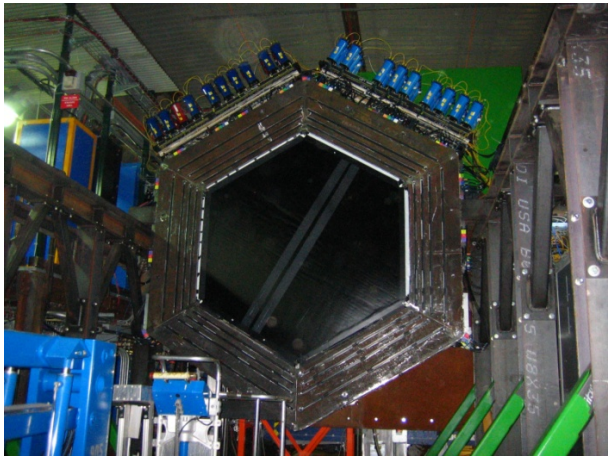
Booster Neutrino Beam is shallow

Detector halls ~10m below surface

MINOS+ : 5kTon Fe-Scintillator (NuMI on-axis @ 735km)

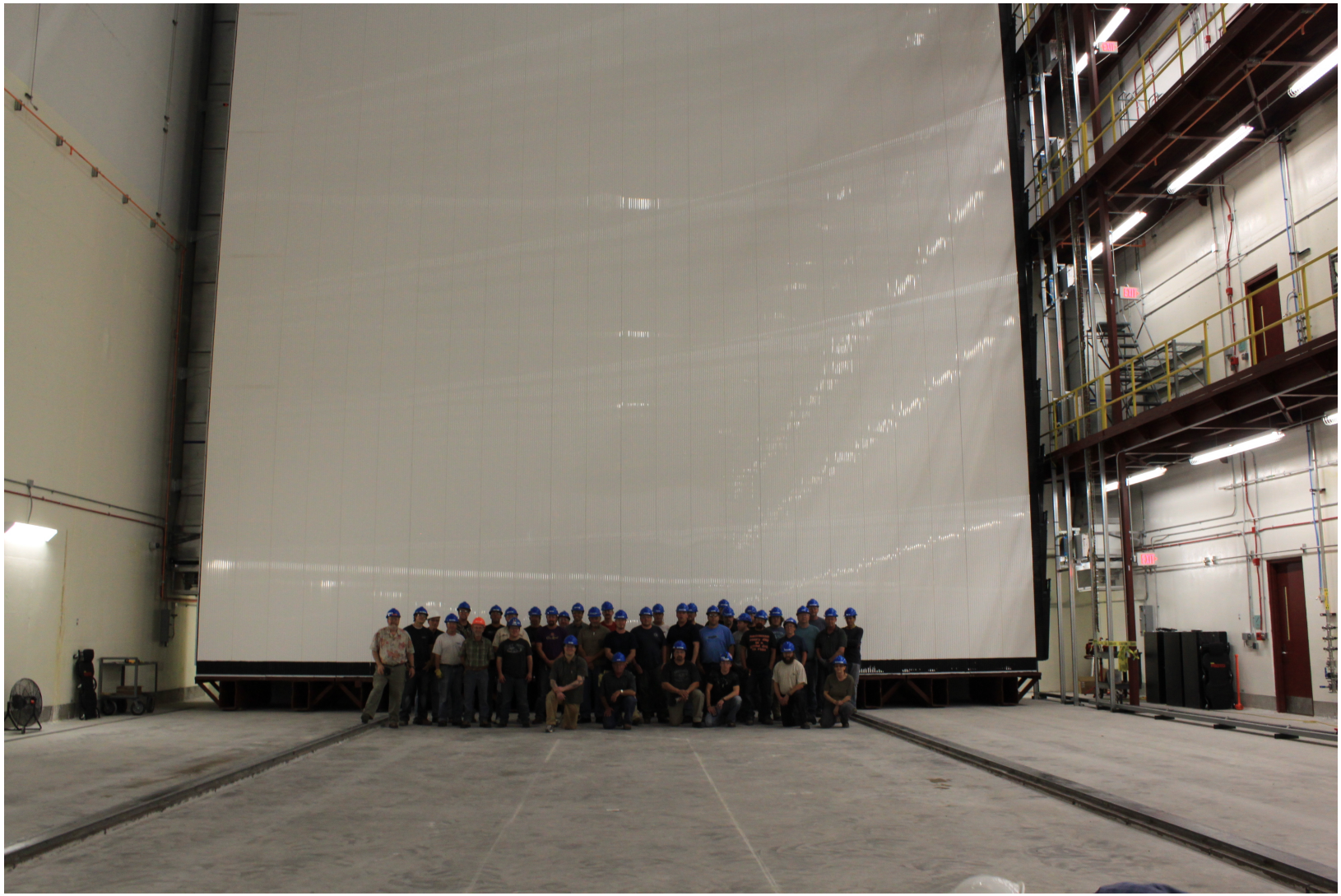






Minerva installed in Front of MINOS ND

NOvA 14 kTon Liquid Scintillator Far Detector (810km – NuMI off-axis)



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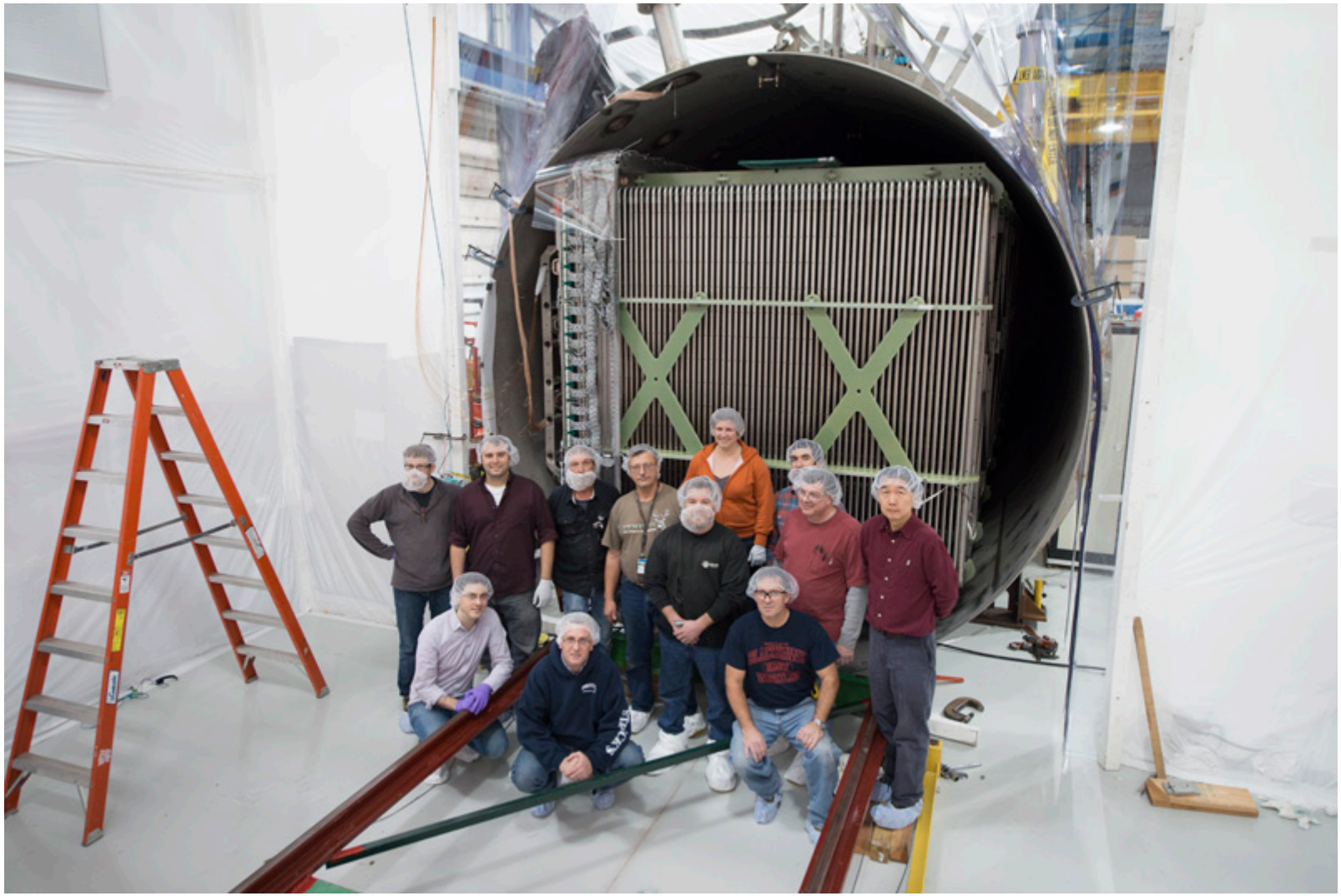
MicroBooNE 170-ton Liquid Argon TPC to be installed in Booster Neutrino Beam this spring



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Planning for the future

- The U.S. particle physics community has identified many exciting, well-motivated, new or upgraded experiments to pursue
- The Snowmass Process
  - Hundreds of pages of white papers and reports
  - General support and enthusiasm from all frontiers for all frontiers
- Funding is not available to do everything -> P5 Prioritization Process currently underway
- There are three regions internationally which host major facilities : Europe, Asia and the Americas
  - Large programs are expensive and will require global planning and collaboration

Our planning is with a global view of the future

Fermilab Recommendations to P5

- **We recommend the following elements as priorities for the U.S. Particle Physics Program**
  - U.S. High Energy Physics community continues to play a leading role in LHC operations and upgrades
  - Fermilab hosts a world-class **accelerator-based neutrino program**
    - **Full scope** LBNE, deep underground with >1MW beam power
    - Active program in short baseline LArTPC experiments
  - The next generation rare process experiments will take place within this decade
  - Continue to explore new particles and forces with a community selected set of experiments in the cosmic frontier
  - Participation in the ILC as an international partner when the concept matures to the appropriate level
  - Plans for an upgrade of the accelerator complex to deliver multi-megawatt beam power are developed
  - Work with the world community on longer term accelerator technology options

  Requires major investments by non-DOE and international partners

Long Baseline Neutrino Experiment

- LBNE will be a world-class accelerator-based neutrino experiment for CP violation searches and more!
  - **Baseline** of 1300 km
    - For the determination of the mass hierarchy AND measuring the CP violating phase
  - **Wide-band neutrino beam** of 0.5 – 5GeV
    - Enough statistics to fit event spectra for both neutrinos AND anti-neutrinos
  - **Underground Liquid Argon Detector** of >30kT mass
    - Excellent signal efficiency and background rejection
  - **High Resolution Near Detector**
- The combination of these components make LBNE a very effective way to get to neutrino CP-violation physics
- Underground leads to extended physics capabilities (supernova, proton decay, ….)

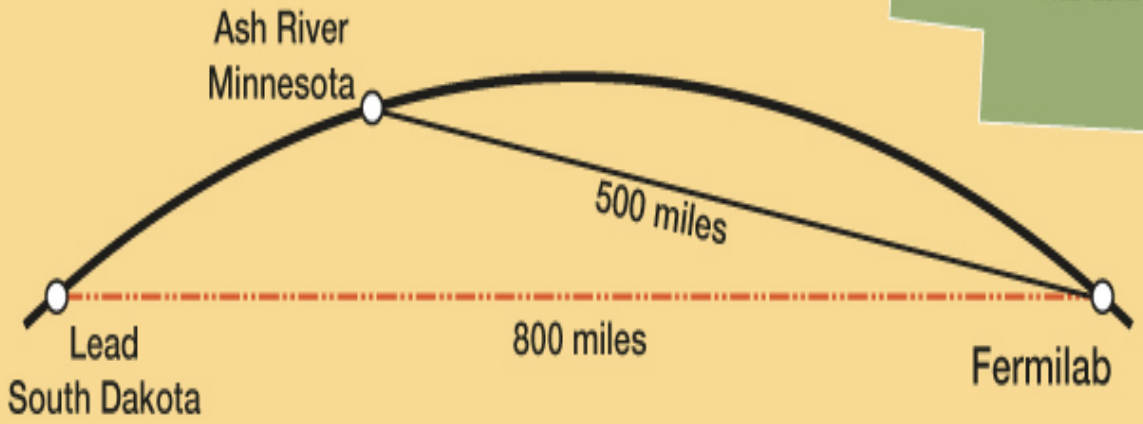
Full scope may need to be achieved in stages

Longer Baseline than existing NuMI Beam

Straight Through the Earth

MINOS	Soudan Mine, MN	2340 ft deep
NOvA	Ash River, MN	Surface level
LBNE	Homestake Mine, SD	4850 ft deep

35ktons liquid argon deep underground



Fermilab accelerators and neutrino beams

Starting new construction projects in the U.S.

- Step 1 : Collaboration and/or Laboratory develops a plan for a new experiment or project
  - Go through internal approval process
  - Perhaps endorsement from a panel like P5….
- Step 2 – 5 : The DOE "CD" Process
  - CD-0 : "Approval of Mission Need"
  - CD-1 : "Alternative Selection and Cost Range" (Conceptual Design Report)
  - CD-2 : "Set Project Baseline" : Total Project Cost set (Technical Design Report)
  - CD-3 : "Approval to start construction"; construction funding available

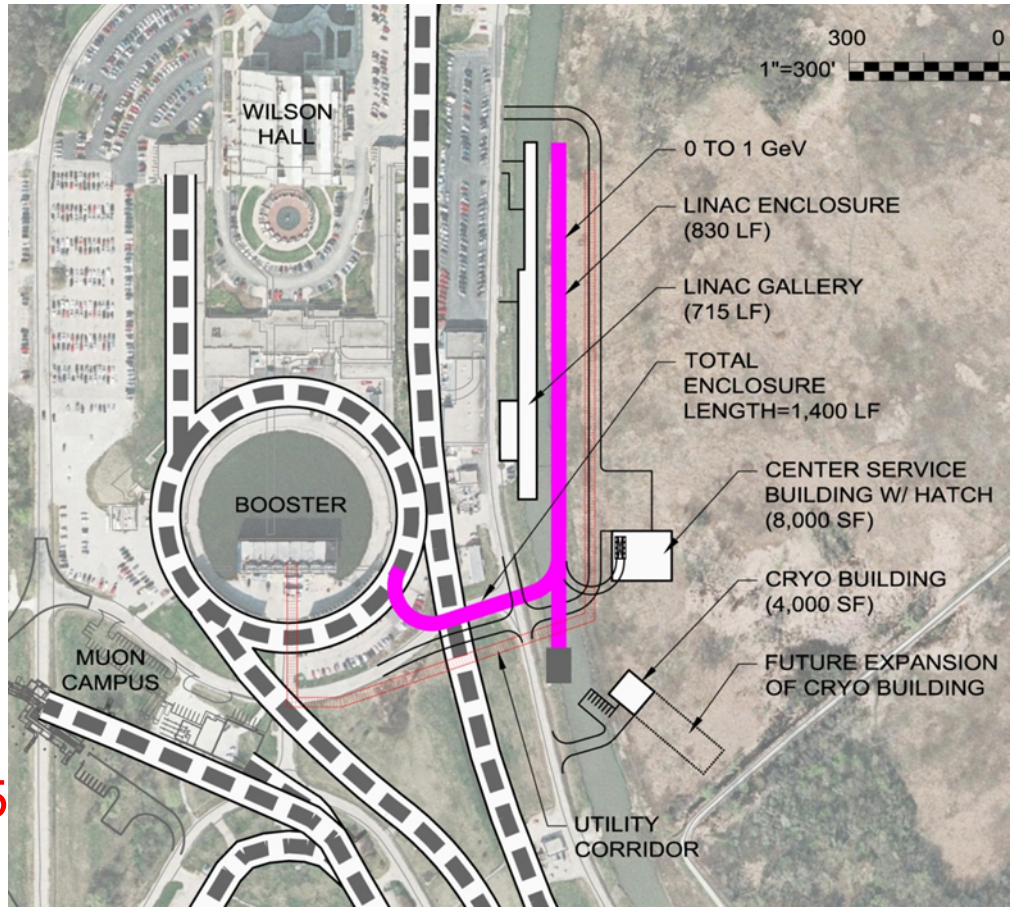
The LBNE Project has CD-1

Protons for Neutrinos

- For a number of years Fermilab had been developing plans for an upgrade to the complex based on superconducting rf technology which would include a cw linac up to 3 GeV, and high power beams at 8 GeV and 60-120 GeV (2.3 MW)
  - The cost of this Project X was large and we are unable to fund it in a timely way along with the rest of the program
- We have decided to reorient the Project X program to the Proton Improvement Plan-II (PIP-II) to have a goal of delivering 1.2MW for LBNE operations when it starts

Protons for Neutrinos : PIP-II

- To achieve >1MW an upgrade to the proton complex is required
  - Start by upgrading the linac
  - Develop high power target capability
  - Build a platform for multi-megawatt future
- PIP-II is first step in modernizing the accelerator complex
  - Aiming for CD-0 in spring 2015
  - 800 MeV SRF linac injecting into Booster



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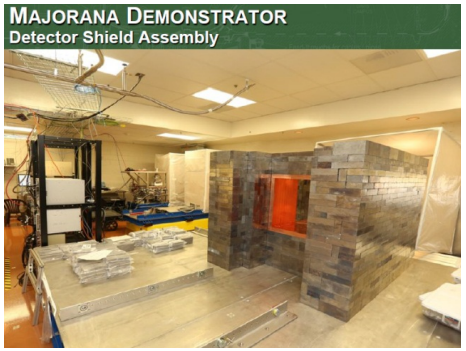
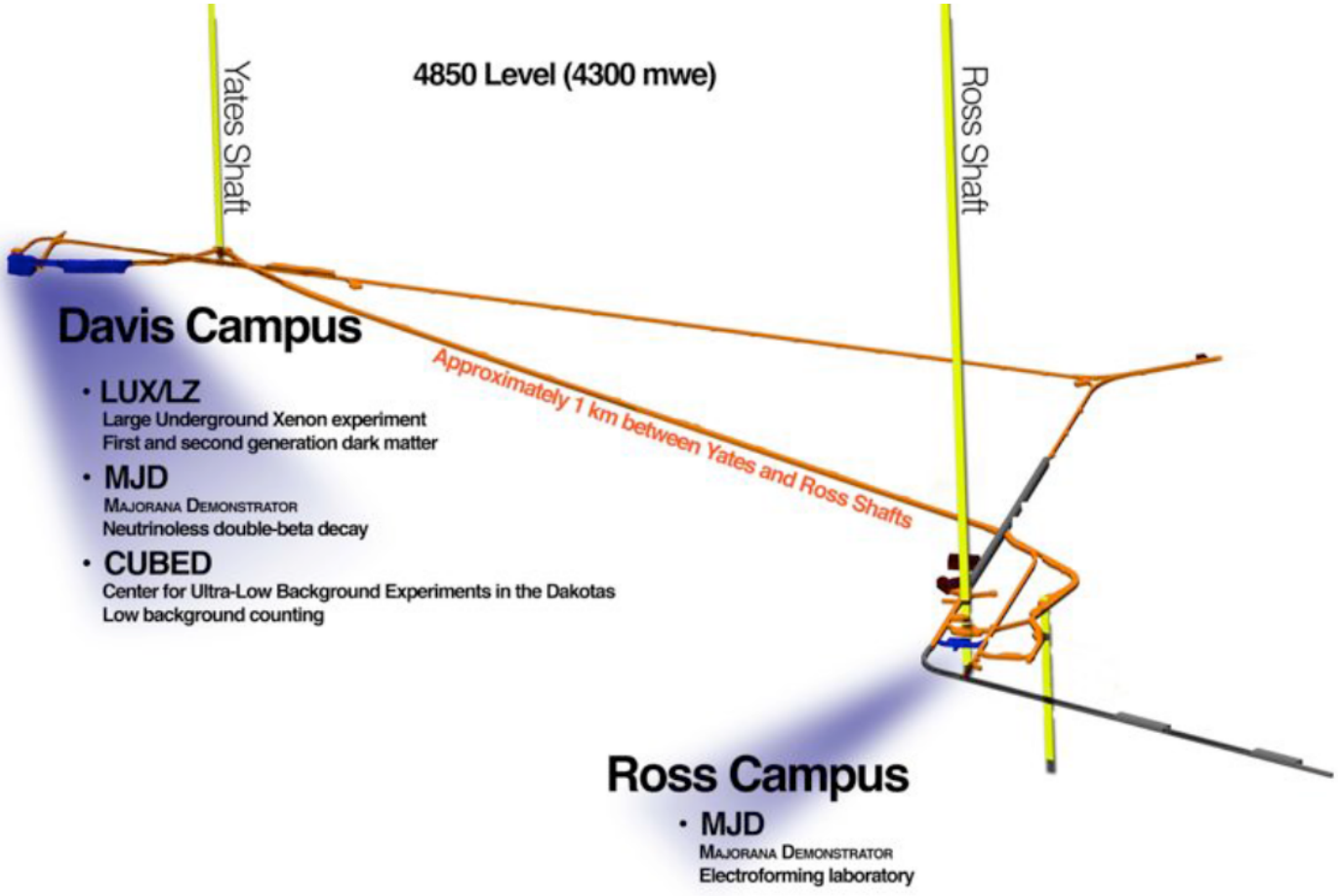
Merits of the FNAL neutrino program

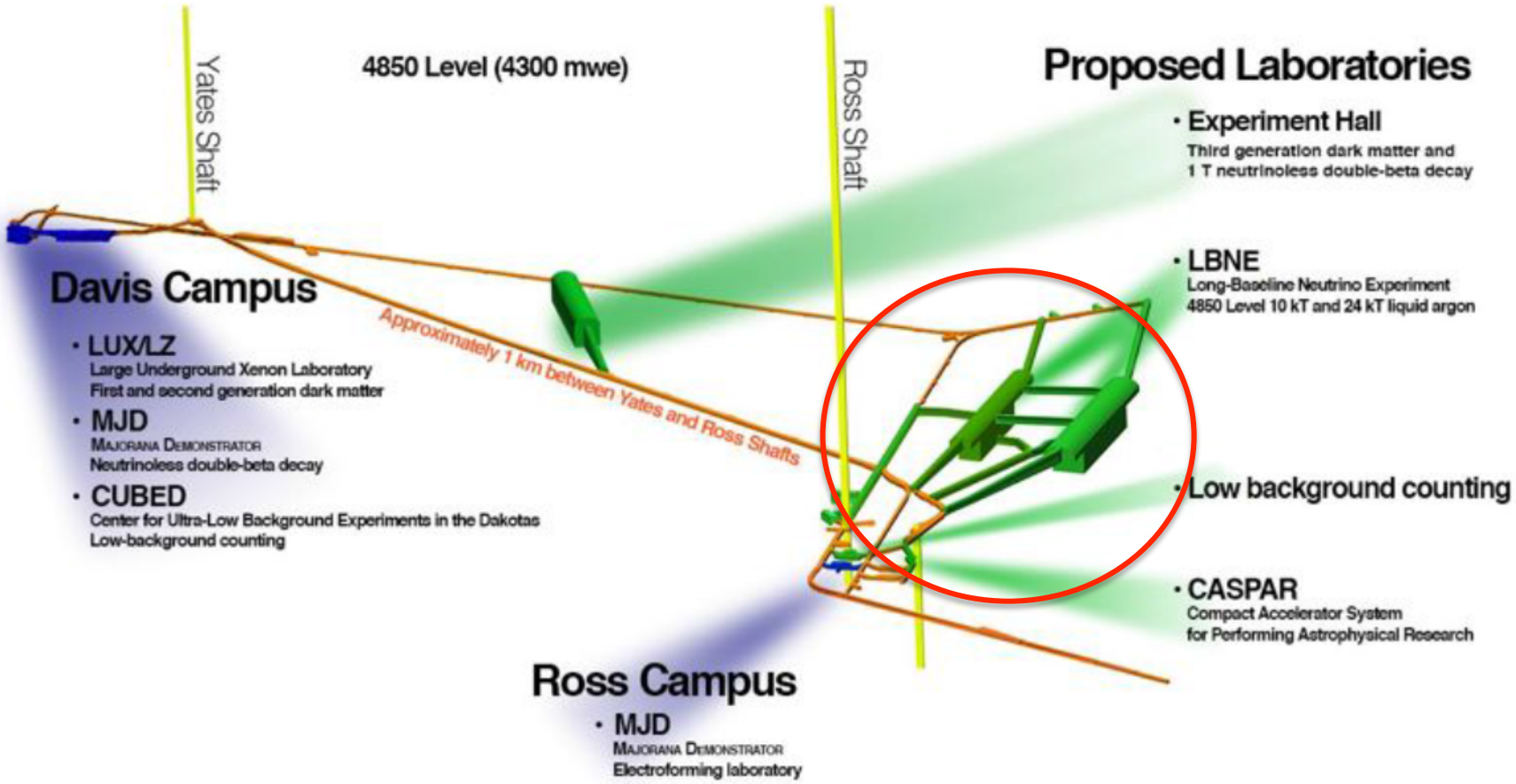
- Short and Mid-Term : Short- and Long-baseline experiments
  - **Running**, efficient neutrino beamlines
  - Exploiting **existing** detectors, beams and infrastructure
  - **Adding** detectors with new technologies
  - **Continuous** physics output while building for the future
- Long term : Long-baseline (LBNE)
  - Planning from the Department of Energy will provide ~2/3 of the needed **funding** ($~900M)
    - CD-1 approval, significant funding for design efforts in this year
  - **Operating**, **underground laboratory** for the site of the far detector (SURF in South Dakota)
  - **Growing**, international collaboration with the vision and commitment to carry out the program

Sanford Underground Research Facility, Lead, South Dakota





Planned location of caverns for LBNE detectors



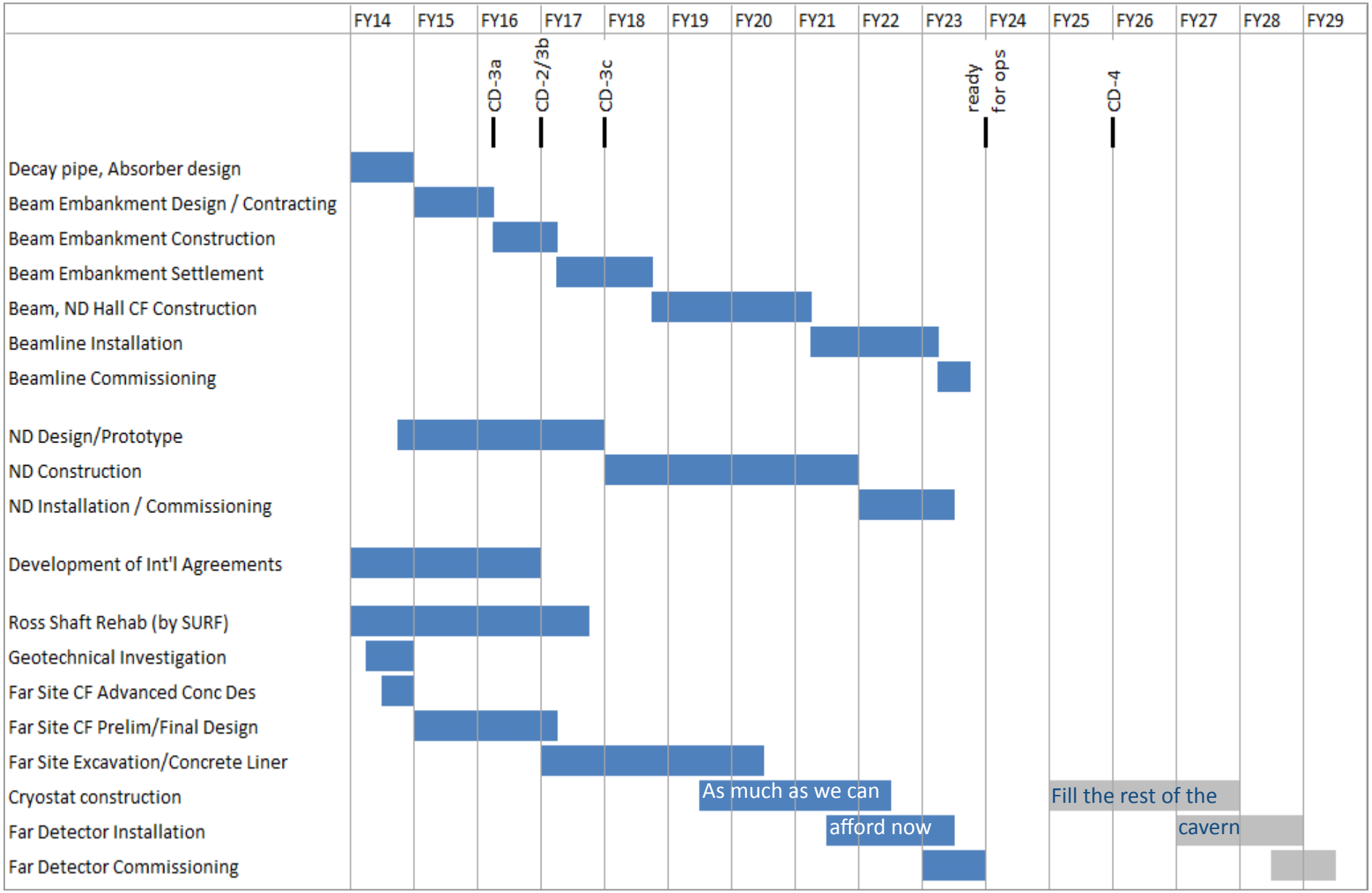
This Program in the World-wide Context

- Following the completion of Tevatron operations Fermilab has concentrated its efforts on the accelerator based domestic program towards experiments that can benefit from the high intensity proton sources from the Booster and Main Injector.
- Fermilab is planning an upgrade to the accelerator complex to produce an even more powerful proton source that will enable world class neutrino experiments at very long baseline.
- In the context of the accelerator program operating in Europe and future planning for an ILC in Japan and perhaps even more ambitious collider projects being discussed, the Fermilab accelerator is an ideal place to host world class neutrino experiments.

Round Table Questions

- *Do you consider this to be part of a balanced world-wide effort?*
  - Currently T2K + NOvA will make major contributions towards our understanding of what the mass hierarchy is, and may even give us a hint as to the value of δ_{CP}
  - At the present time the Fermilab program is the only operating accelerator based search for sterile neutrinos
    - In concert with other efforts at reactors and with sources, we should begin to get more insight as to the nature of the observed anomalies
    - With this insight the world wide accelerator neutrino community can contemplate what the next best step might be
- *Would you prefer to merge the effort and collaborate with other labs?*
  - Many efforts on R&D for detectors and high power neutrino beams would benefit from collaboration and consolidation, in particular when building new infrastructure is required
  - We welcome new collaborators to both our on-going and planned experiments and R&D activities

A planning schedule for LBNE



Conclusion

- Fermilab and the U.S. neutrino community are committed to focus their efforts on hosting the program that I have outlined.
- We look forward to working with international partners in both the short and long-baseline experiments to develop the facilities and detectors needed to realize the exciting physics results that await.