Fermilab Future Neutrino Program

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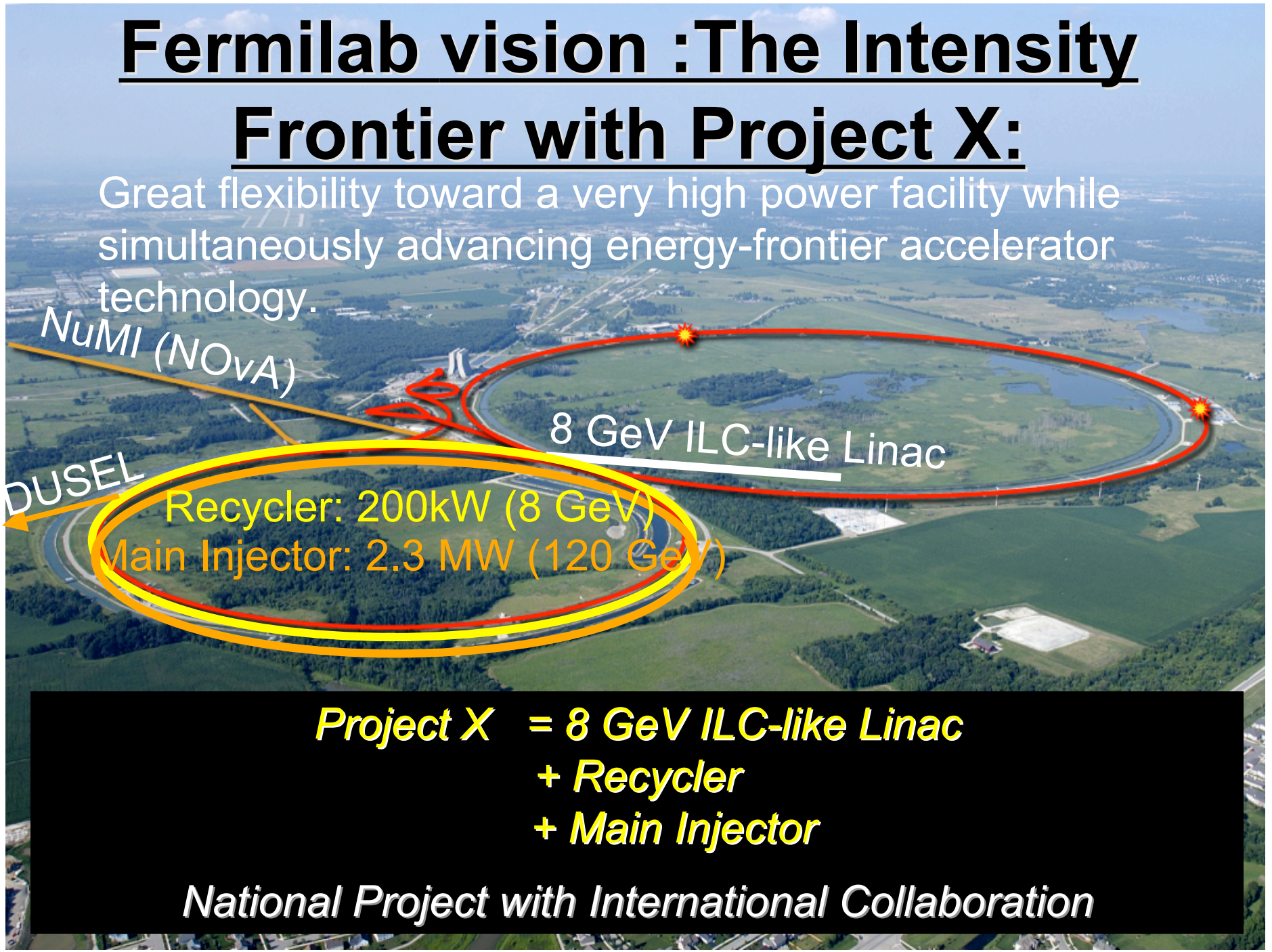
Outline

- The Fermilab vision
- Next generation long baseline experiments
  - Physics goals
  - Accelerator requirements
  - ν beam from Fermilab
  - Detectors
- Getting there - exploiting our existing facility
- Schedule for planning purposes
- Summary

Fermilab vision :The Intensity Frontier with Project X:

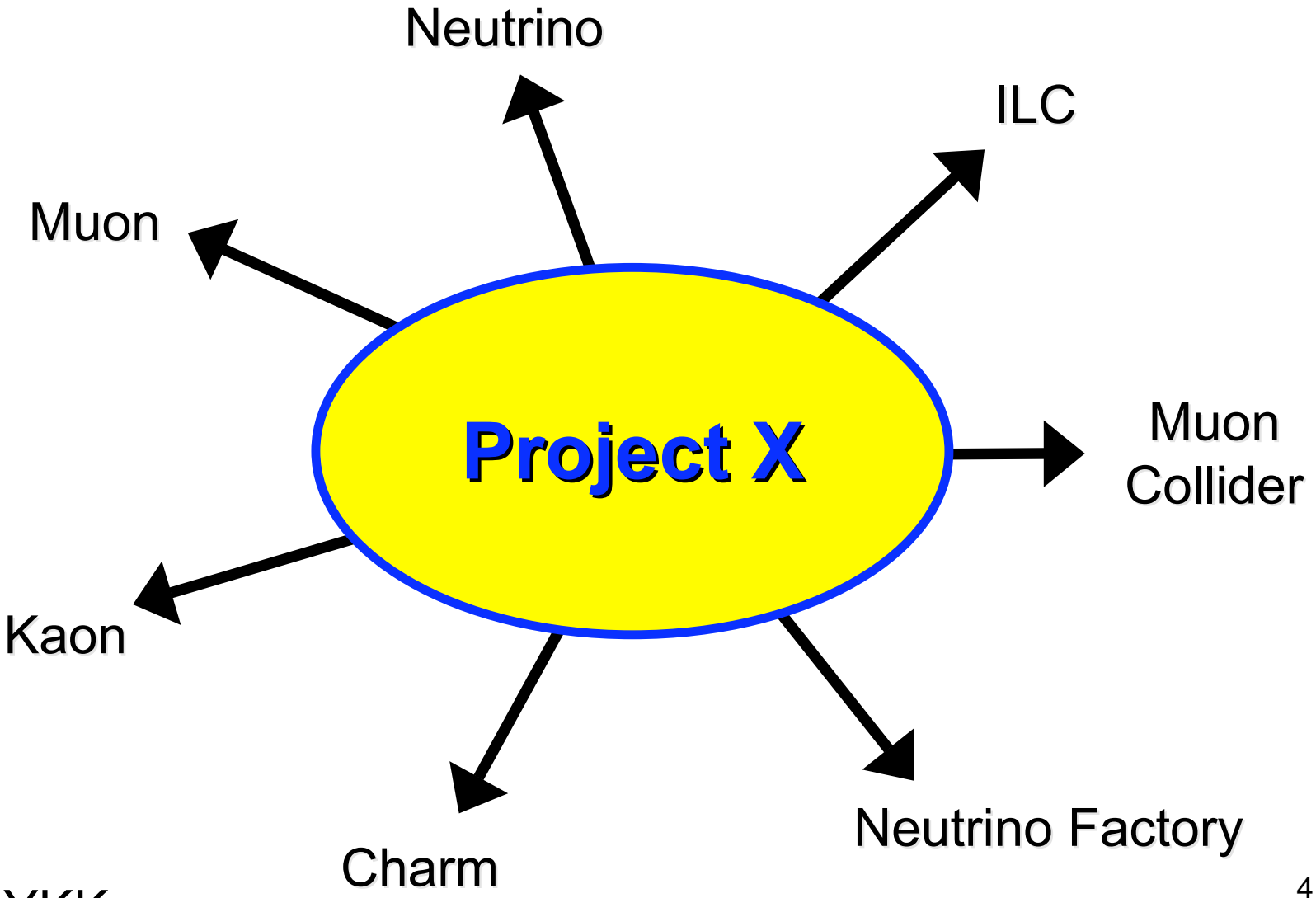
Great flexibility toward a very high power facility while simultaneously advancing energy-frontier accelerator technology.



Project X = 8 GeV ILC-like Linac
+ Recycler
+ Main Injector

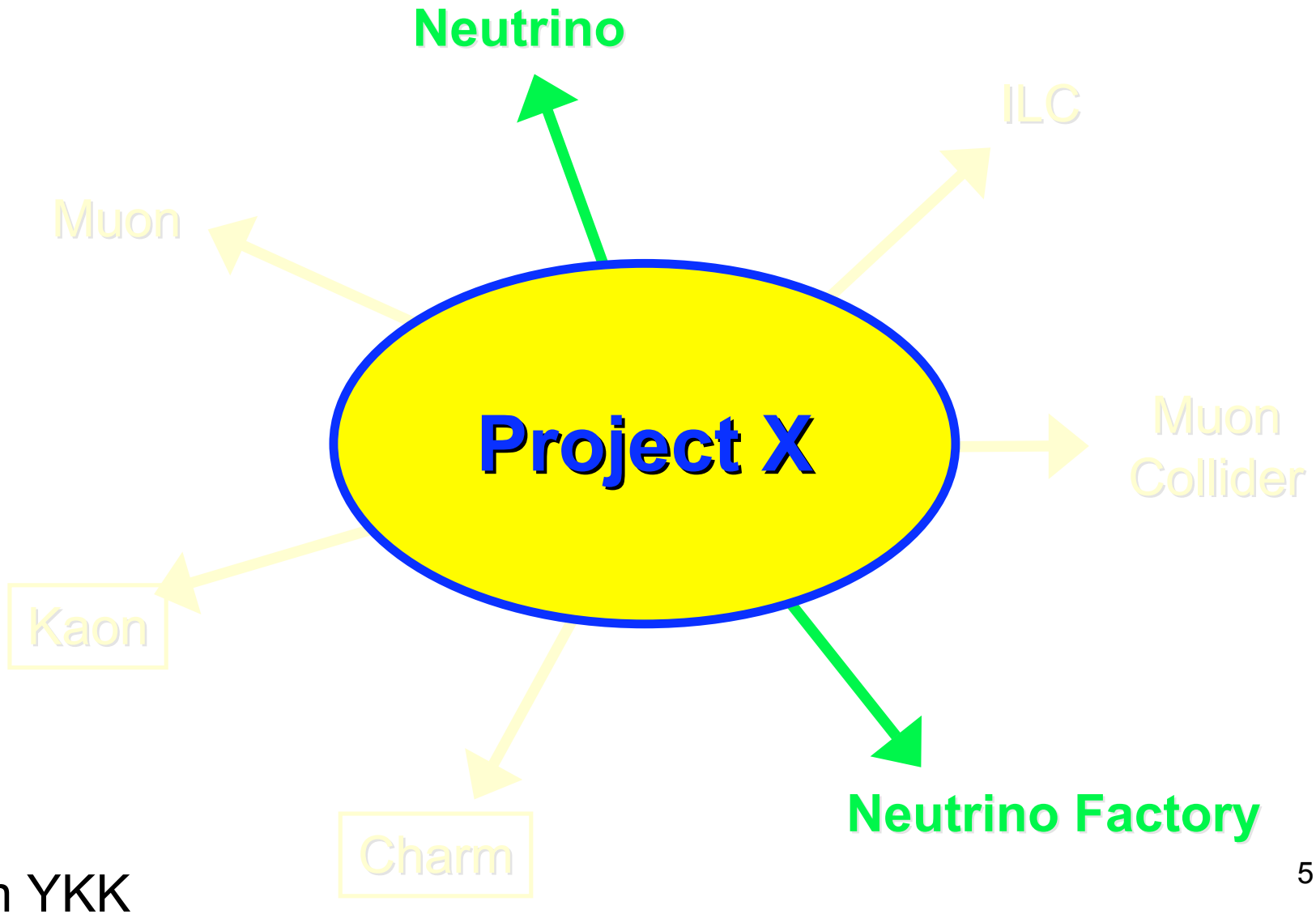
National Project with International Collaboration

Opportunities with Project X



From YKK

Opportunities with Project X



From YKK

The Current Neutrino Program

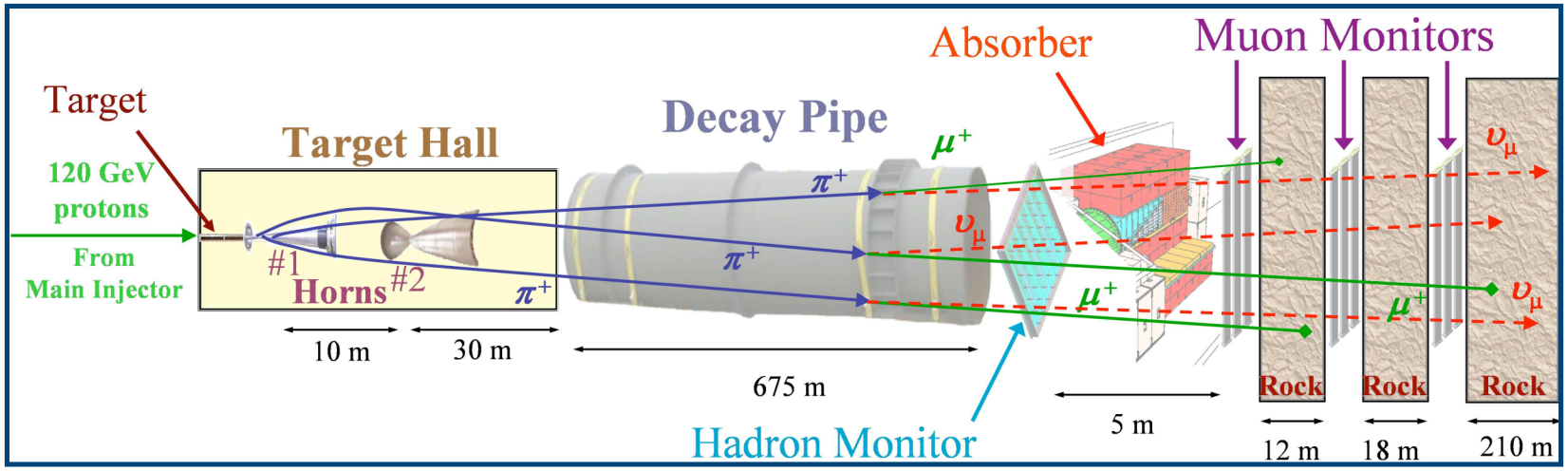
- 8 GeV protons from the Booster
  - Neutrinos from Booster Neutrino Beam (BNB)
    - To MiniBooNE (running)
    - To SciBooNE (running)

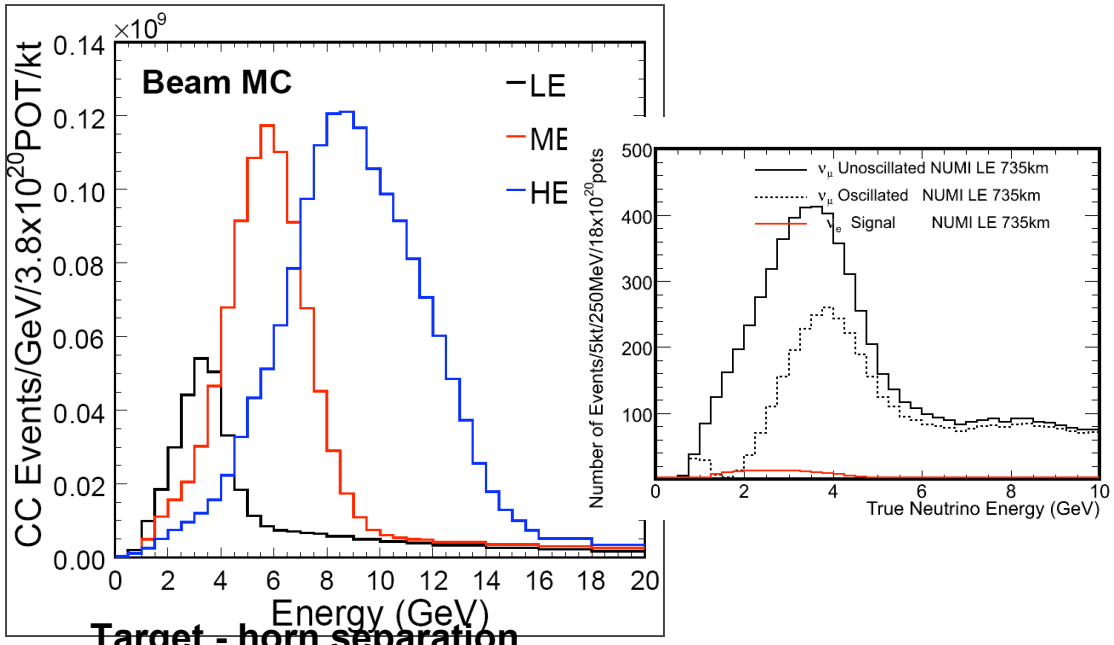
- 120 GeV protons from the Main Injector
  - Neutrinos from NuMI
    - To MINOS (running)
    - To emulsion and liquid argon detector tests (in progress)
    - To MINERvA (construction)
    - To NOvA (passed CD2/3a review; awaiting funding)

The Current Neutrino Program

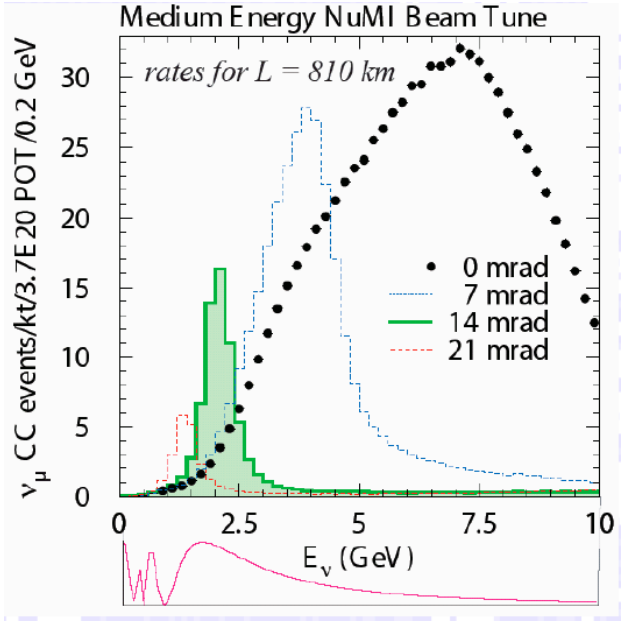
- 8 GeV protons from the Booster
  - Neutrinos from Booster Neutrino Beam (BNB)
    - To MiniBooNE (running)
    - To SciBooNE (running)
    - To MicroBooNE (proposed)
- 120 GeV protons from the Main Injector
  - Neutrinos from NuMI
    - To MINOS (running)
    - To emulsion and liquid argon detector tests (in progress)
    - To MINERvA (construction)
    - To NOvA (passed CD2/3a review; awaiting funding)
    - To LAr5 at SOUDAN (LOI under development)

The NuMI Beam





Target - horn separation sets the neutrino energy spectrum.



Off-axis detector location sees a narrow band beam

NOνA

- With the current funding profile data taking can begin when several kilotons of mass and the accelerator project are ready, ~2012
- NOvA is a unique experiment
  - ν's from FNAL to Ash River experience significant matter effects
  - ν and $\overline{\nu}$ rates depend on θ_{13}, δ_{CP} **and** the mass hierarchy
- As measurements or limits on θ_{13} emerge, a run plan can be optimized to maximize sensitivity
- The physics program can be enhanced with intensity upgrades (Project X) and a complimentary on-axis detector (LAr5 at SOUDAN)

Neutrino Program Evolution

- Numerous studies over the past several years have laid out options for further exploring the neutrino sector
- i.e. BNL-FNAL US long baseline neutrino experiment study (March 2006-June 2007) explored
  - Beam options
    - NuMI , new Wide Band Beam
    - On and off axis detector locations
  - Detector technology options
    - Water cherenkov, liquid argon
- Several independent calculations of sensitivities give consistent results

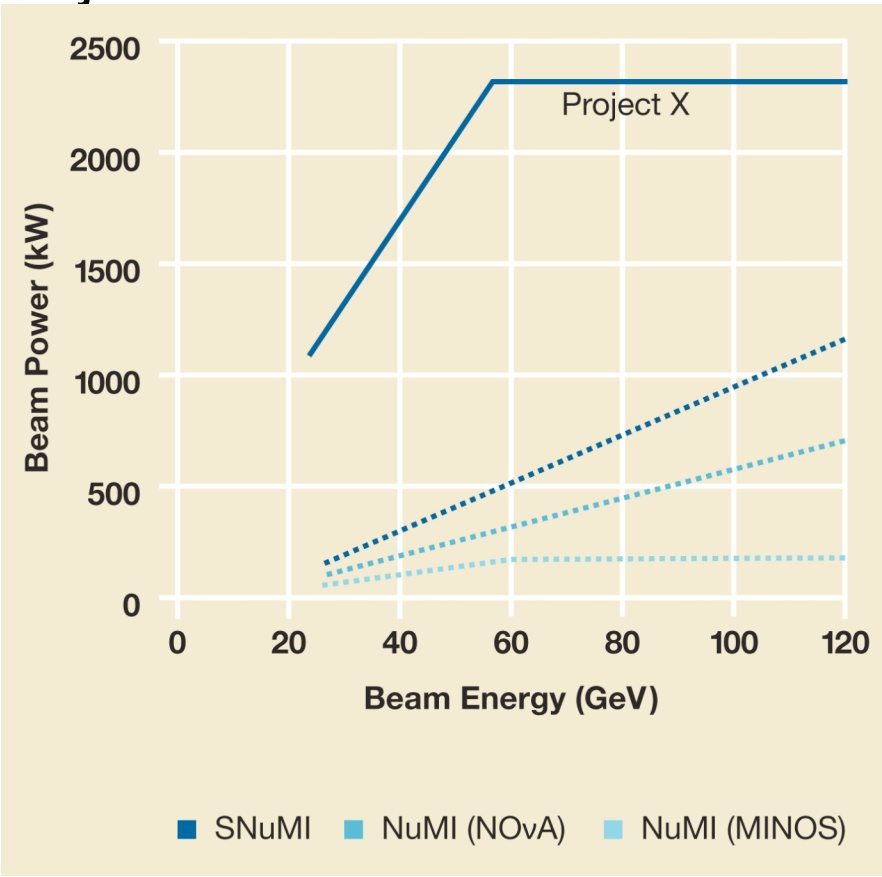
General Conclusions

- Future experiments using conventional* neutrino beams can be designed to have 3-5σ discovery potential for measuring $\sin^2 2\theta_{13}$,CP violation and the neutrino mass hierarchy for values of

  $0.001 < \sin^2 2\theta_{13} < 0.01$
- These sensitivities are reached assuming :
  - a **proton source** at the Megawatt level (or decades of running time)
  - a **neutrino beam** optimized to the oscillation probability (covering the 1st and 2nd oscillation maximum)
  - an **experiment baseline > 1000 km** (to improve the sensitivity to determine the mass hierarchy)
  - a **Detector** with effective mass (mass*efficiency) **> 100kT**
- *If nature has made θ_{13} very small we may need to move beyond conventional beams, i.e. **neutrino factory**

Options for the future Neutrino Program*

- 60 -120 GeV protons from the Main Injector fed by Project X



20-40x10^{20} POT/yr

10x10^{20} POT/yr

6x10^{20} POT/yr

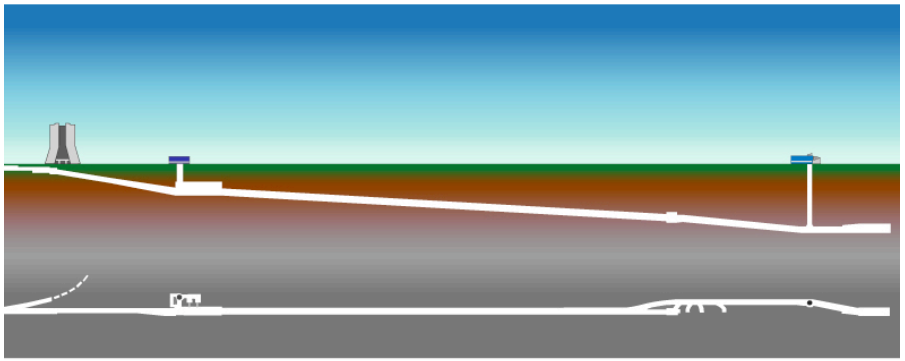
3x10^{20} POT/yr

Most recent sensitivity studies have been done for 120x10^{20} POT each ν and $\overline{\nu}$

*Also concepts for 800 GeV protons to fixed target (Heidi)

A ν beam project ….

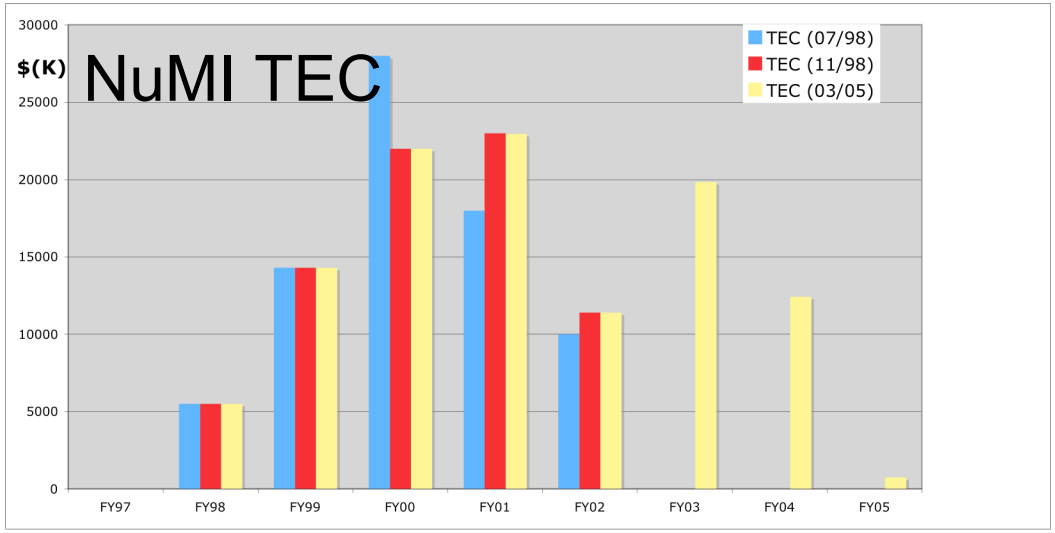
Cost and schedule can be based on our Fermilab underground construction **experience**….



NuMI Civil construction : $75M
NuMI Technical components : $30M
AY$ at project completion 03/05

2001 re-baseline added
*$33M to the TEC**
More recent projects have been required to incorporate larger initial contingency

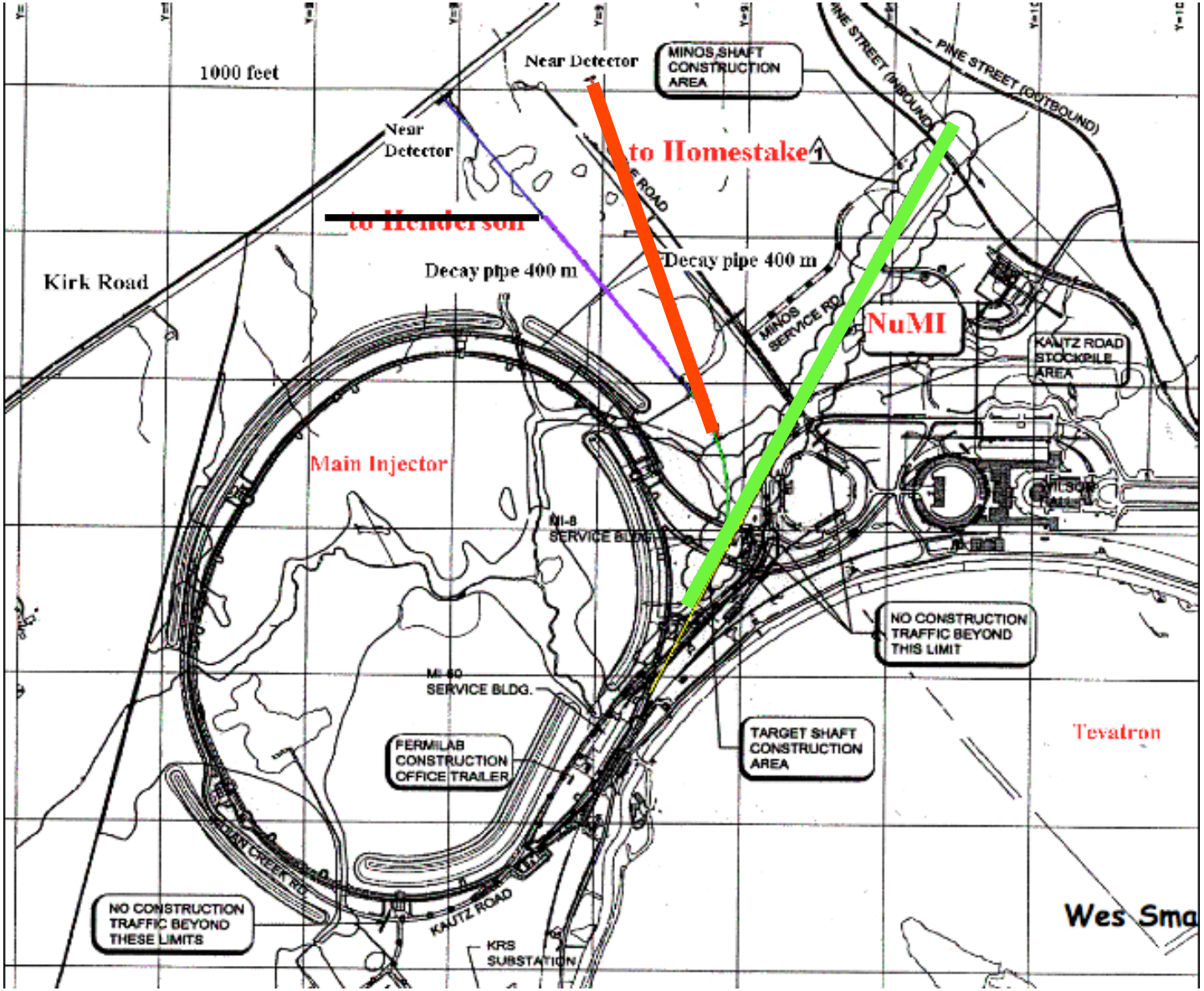
Civil construction included:
2 access shafts
Target & absorber halls
2m diameter x
675m shielded decay tunnel
By-pass tunnel
Near Detector hall



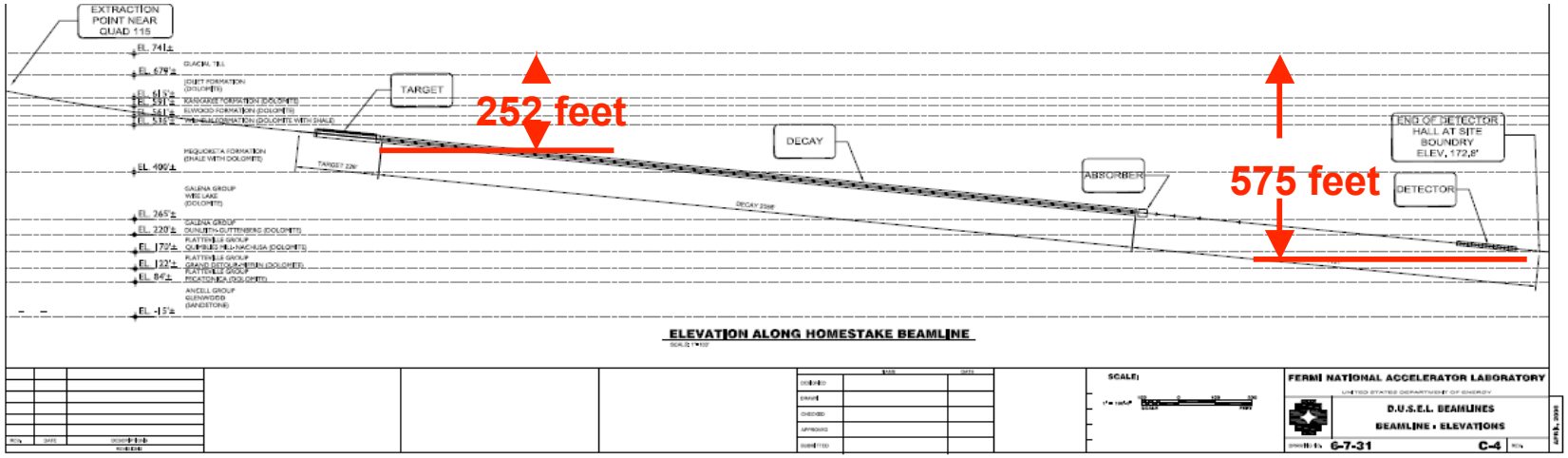
**OPC was only slightly adjusted to match re-baseline schedule*

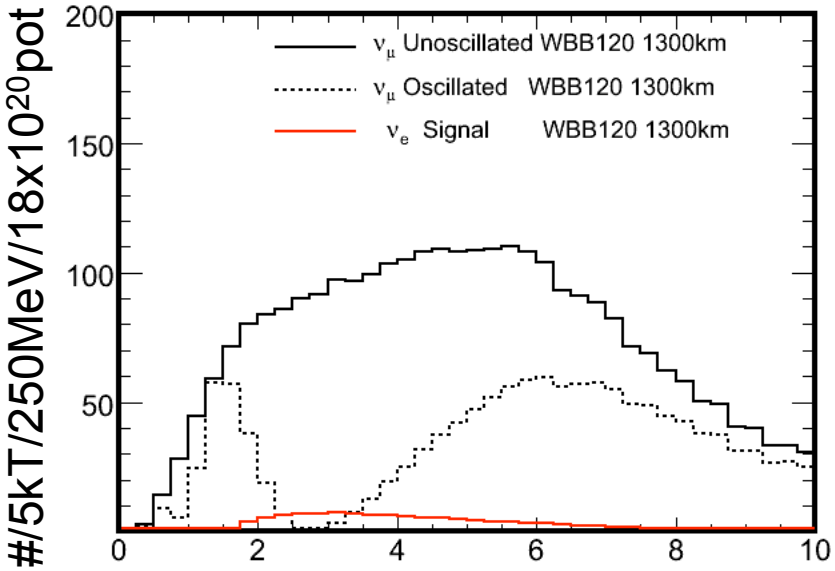
Beam to DUSEL

Laid out in Spring 2006



A beam to DUSEL : shorter & wider than NuMI

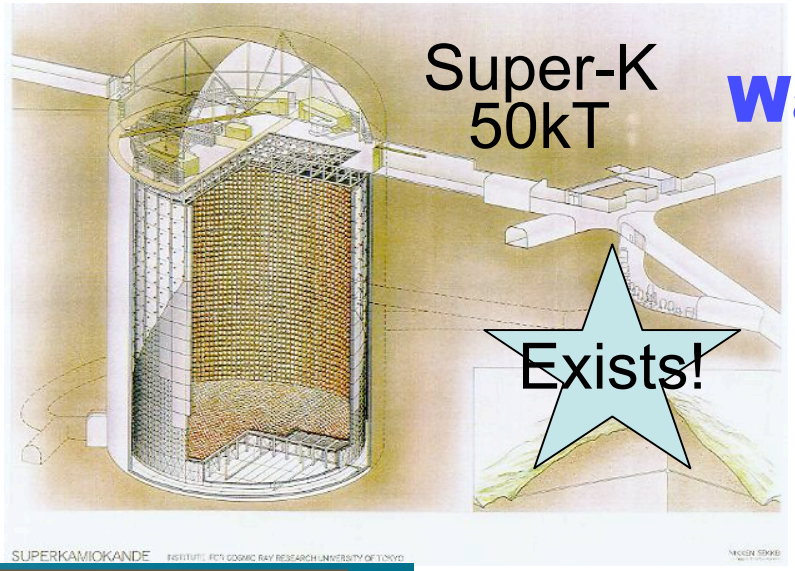




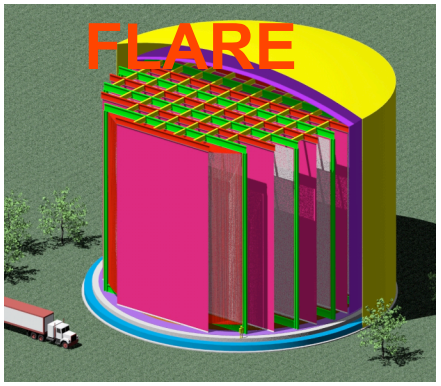
High power issues:
groundwater activation,
radioactive air emissions,
target stress,radiation damage,
decay pipe stress….

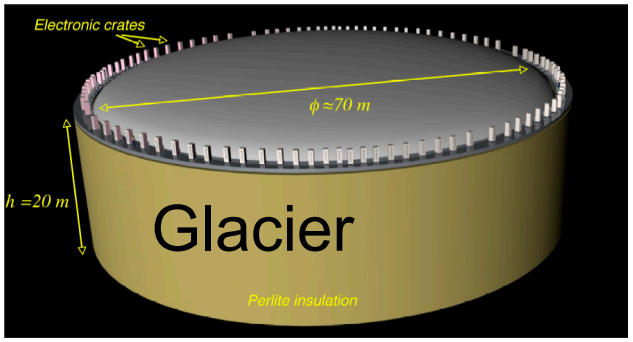
A super beam needs a super detector ….

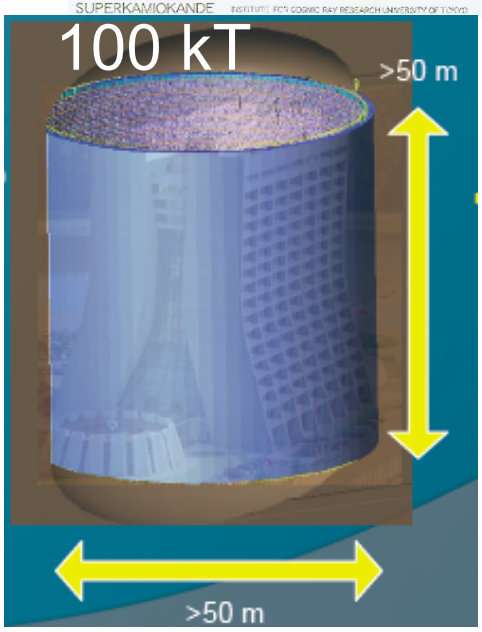
Large Detector Concepts

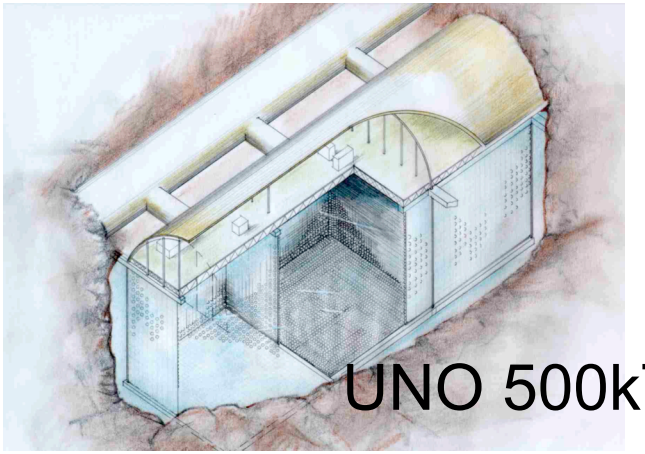


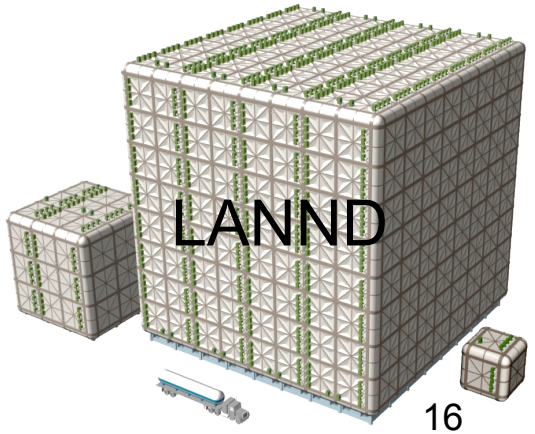
Water Cerenkov And Liquid Argon











Large Detector Issues

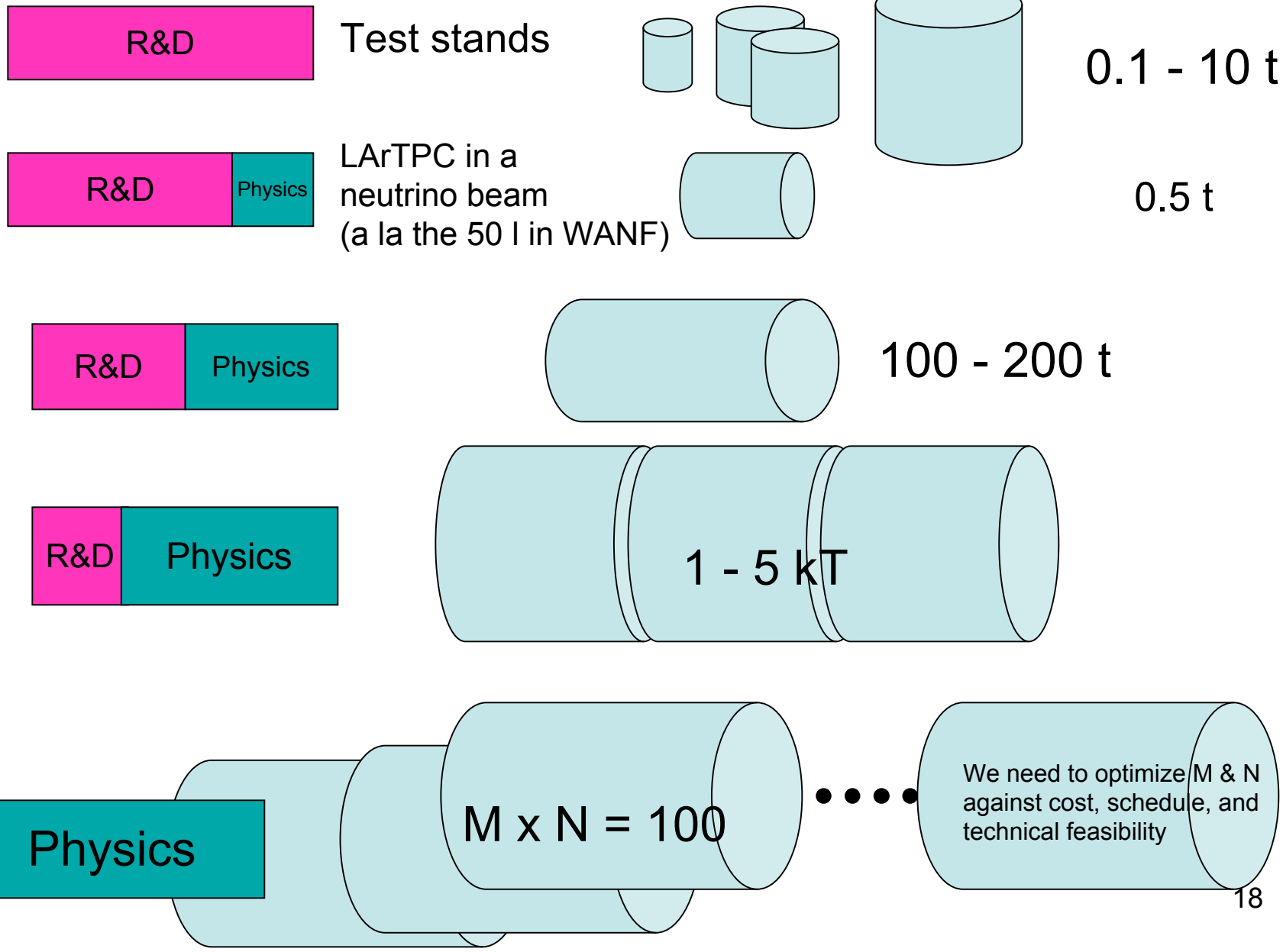
- Independent of technology
  - Cavern excavation technical risks and cost*
- Water Cherenkov
  - Risks associated with cavern size
  - PMT production and delivery schedules
- Liquid Argon
  - Demonstration of performance in a real experiment
  - Cost per unit mass
  - Determine the optimum modular configuration

*Data point:

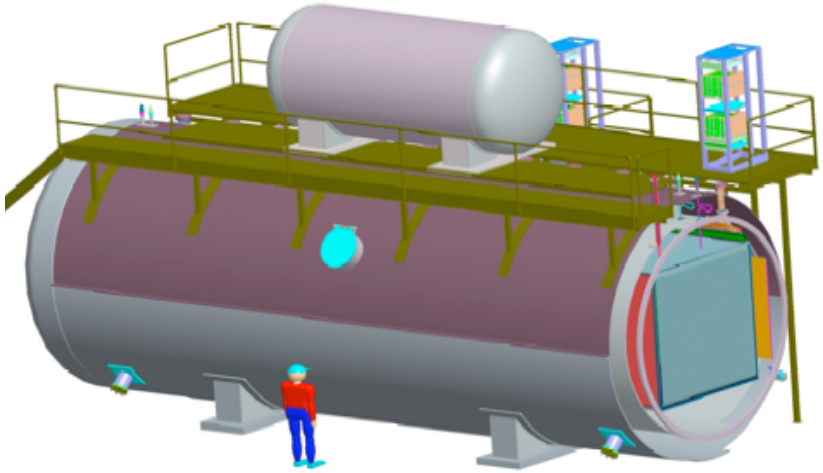
- MINOS cavern at SOUDAN
  - Rock Excavation only :
    - 1994 Proposal estimate : $3.3M
    - FY2000 actual : $7M for 11,500 m^3
    - Escalate to FY08 → $780/ m^3

Development of the LAr technology is well suited to the ***Fermilab accelerator program****…*

Evolution of a Liquid Argon Physics Program



MicroBooNE and LAr5

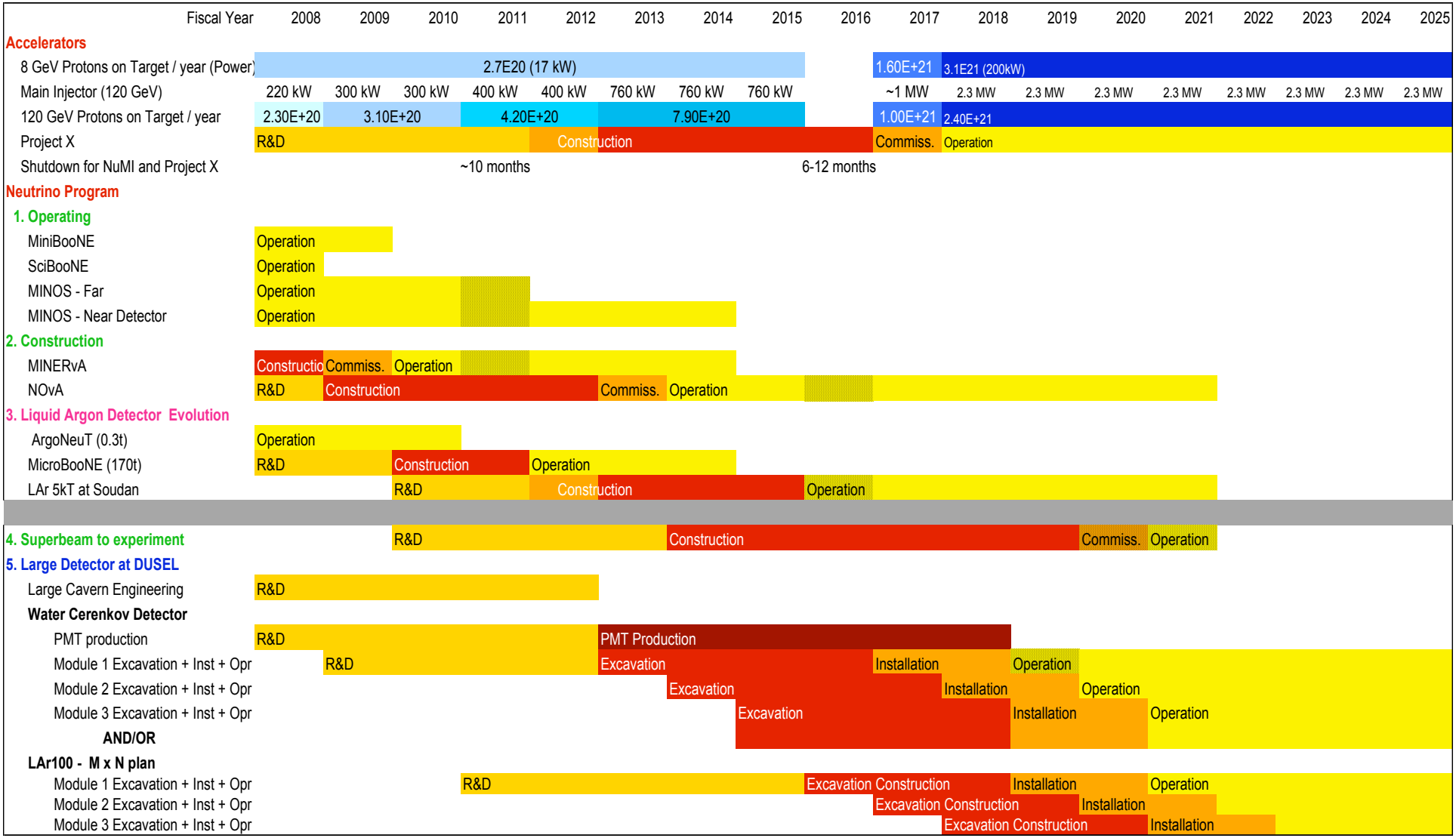


- R&D towards LAr5
- Physics opportunity
  - e/π/γ separation
  - MiniBooNE low E excess
  - Neutrino cross sections

- R&D towards LAr100
- Considering feasibility of magnetizing (S.Geer)
- Physics opportunity
  - θ_{13} and mass hierarchy

Exploit existing facilities : BNB, NuMI, Soudan Underground Lab

Program Evolution



Short and long term planning

- **Booster Program**
  - Move aggressively towards a final design for the MicroBooNE detector so that it can be constructed and operated as soon as possible
  - Design MicroBooNE to be wholly or in part the LAr5 near detector
- **NuMI Program**
  - Determine feasibility and cost of LAr5 in SOUDAN
- Future Longer Baseline Experiment Configuration decisions depend on :
  - Status of DUSEL
  - Cavern and beam costs and constructability issues
  - Feasibility of staging detectors (water cherenkov and LAr)
  - Detector costs, technical feasibility and performance in multi-GeV region

Conclusions

- Fermilab currently has a world-leading neutrino program
- The existing Fermilab neutrino beams are unique
  - We should continue to fully exploit them by aggressively completing our approved projects and initiating new ones that are directly applicable to a long term vision which includes a new super beam and super detectors
- This program meets the criteria of :
  - Exciting physics
  - Maintains options for the future
  - Is not dependent on huge jumps in funding
  - It can be carried out incrementally in bite size pieces
  - It supports a path to gain a large machine at the energy frontier
- Aggressive support is needed for the R&D issues related to the super beam and super detectors