
LBNE:
Long Baseline Neutrino Experiment
North Dakota
Minnesota
Lead, SD
South Dakota
Wisconsin
Michigan
Milwaukee
Iowa
Nebraska
Chicago
Illinois
Kansas
Missouri
Jim Strait
Engineers Week Presentation
16 Feb 2010
Image NASA
© 2008 Tele Atlas
Image © 2008 TerraMetrics
© 2008 Europa Technologies
Google
Pointer 43°03'56.44" N 95°10'42.53" WStreaming 100%
Eye alt 1108.62 km

Goals of LBNE

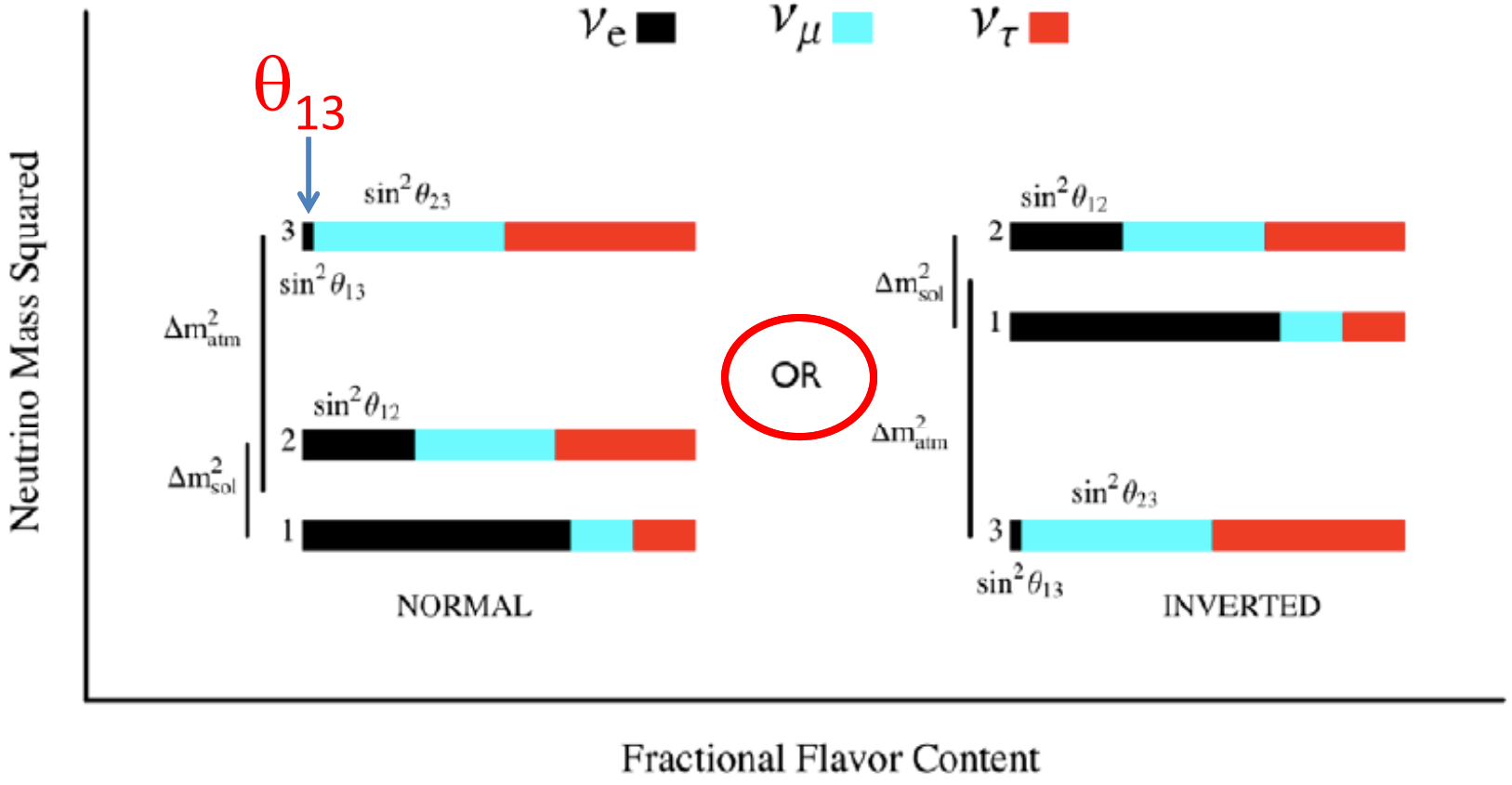
Measure ν_μ -> ν_e oscillations with sensitivity >> NOvA:

- Measure $\sin^2(2\theta_{13})$ to << 0.01
- Determine the mass hierarchy:
  Are ν_1 and ν_2 lighter or heavier than ν_3?
- Search for CP violation in the neutrino sector – Why is there matter but almost no anti-matter in the Universe?

Use very massive detector necessary for the oscillation physics for:

- Improved limits (or discovery!) of proton decay
- Measurements using astophysical neutrinos:
  - From cosmic ray interactions in the atmosphere
  - Solar neutrinos
  - Neutrinos from a supernova in (or near) our galaxy
  - Relic neutrinos from "all" past supernovas

Long Baseline Neutrino Oscillations



CP : P(ν) =P(ν-bar) ?

The sensitivities shown on the following series of plots are from Mark Dierckxsen, U of C

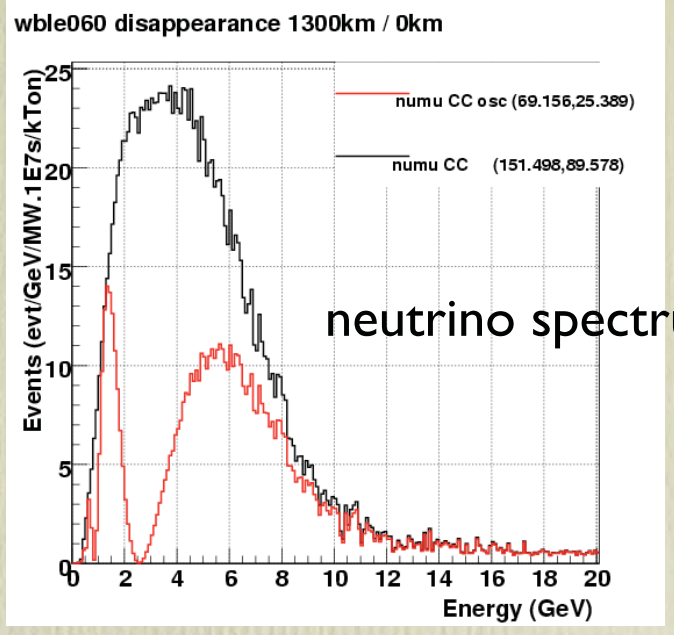
What do we want to be able to do this Experiment?

- A long baseline neutrino beam: 1000 km < L < 1500 km
  (MINOS = 735 km, NOvA = 810 km, T2K (Japan) = 295 km)
- A very massive detector:
  300 kT water Čerenkov detector (12 x Super-K)
  or
  50 kT LAr TPC (100 x ICARUS)
  (NOvA = 15 kT, Super-K (Japan) = 25 kT)
- Detectors at great depth, for cosmic ray shielding, especially for the non-accelerator based physics.
  (MINOS = 2200 mwe, NOvA ~ surface, Super-K = 2700 mwe)
- A high power neutrino beam of a few GeV energy, generated by a 2 MW proton beam.
  (MINOS ~ 0.3 MW, NOvA = 0.7 kW, T2K = 0.7 kW)
- A precision "near" detector to measure the un-oscillated beam as it leaves the source.

Event rate for FNAL to Homestake

Evt rate: 1 MW for 3 yrs ★

Event type	300kT, 120 GeV 0.5 deg.	300kT, 60 GeV 0 deg.
Numu CC no osc	161820	272693
Numu CC with osc	68220	124479



neutrino spectrum

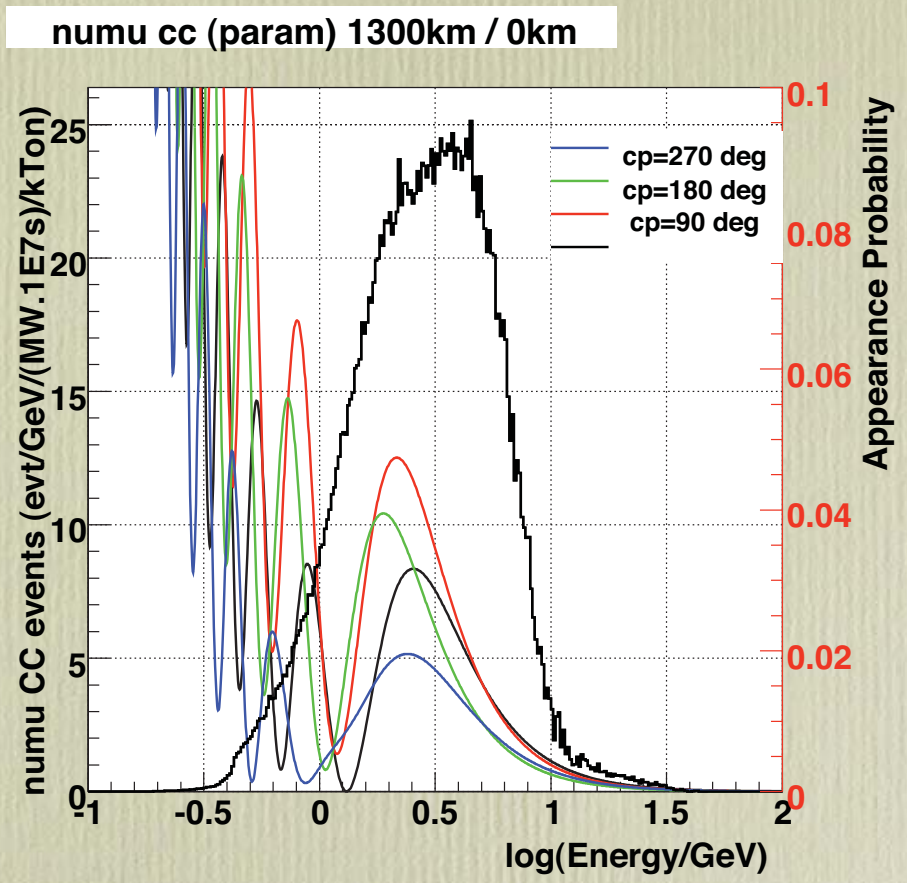
High precision $\sin^2 2\theta_{23}$, Δm^2_{32}

- Important (esp. $\theta_{23} \sim 45$ deg.) with possibility of new physics.
- Either 120 GeV or 60 GeV beam can be used: two oscillation nodes.
- Measurement dominated by systematics (see hep/0407047) (~1%)

★ yr~2×10^7 sec

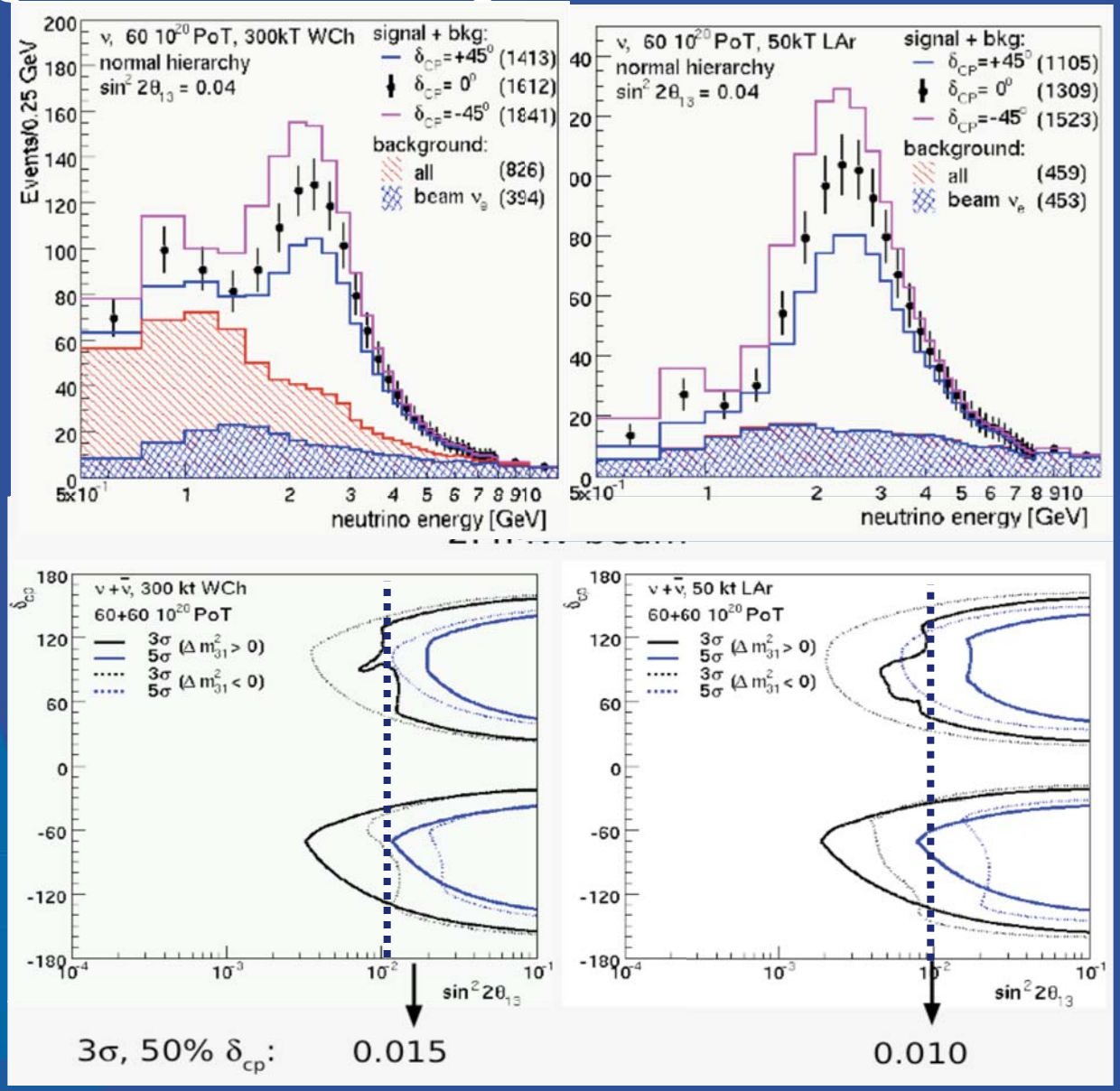
M.Diwan (BNL)
BNL Colloquium
24 Nov 2009

Spectra FNAL to DUSEL (WBLE:wide band low energy)



- 60 GeV at 0deg: CCrate: 14 per (kT*10^20 POT)

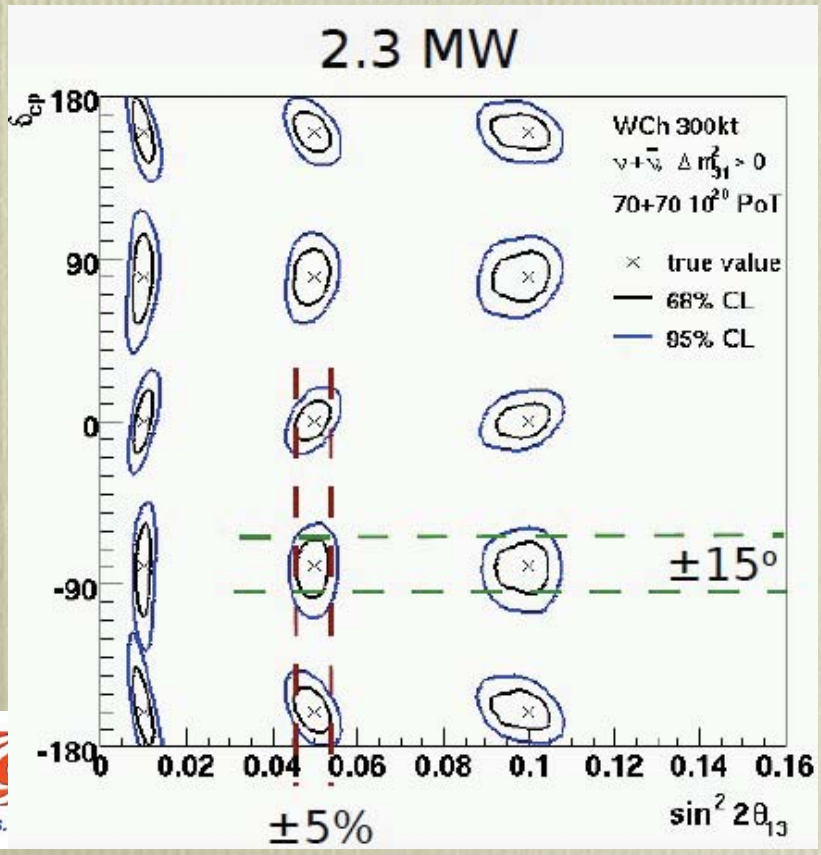
Signals and backgrounds for WC vs. LAr



Fermilab

Further science issues

- Program should lead to measurement of 3-generation parameters without ambiguities. (recall: CP measurement is approximately independent of θ13). Need large detector independent of θ13 value.
- A broad band beam is needed to get spectral information to resolve ambiguities. Spectrum down to 0.5 GeV important.



300 kT water Cherenkov detector @DUSEL
Measurement of CP phase and $\sin^2 2\theta_{13}$ at several points. All ambiguities and mass hierarchy are resolved.

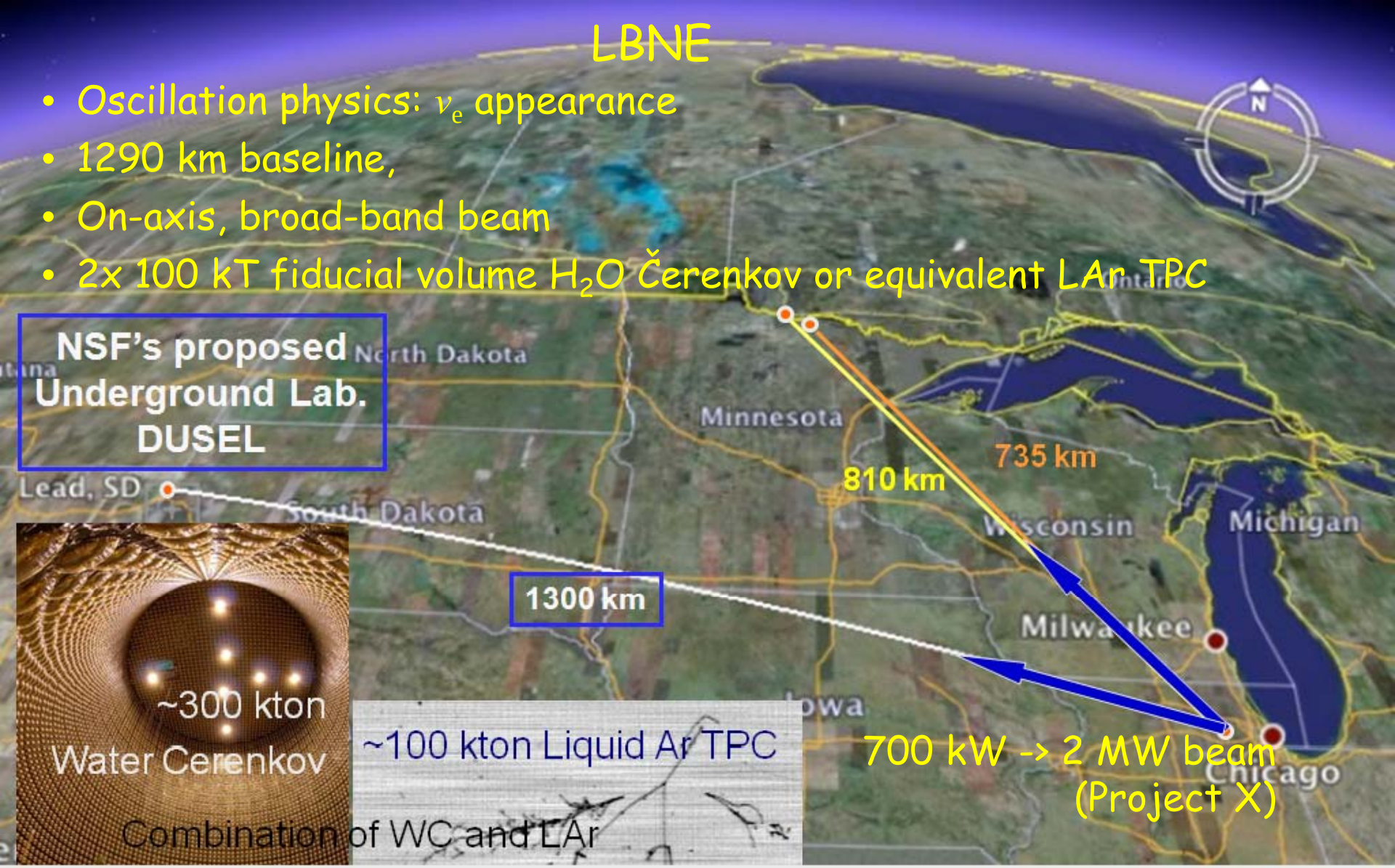
What are we planning for this experiment (reality intevenes)

- A new neutrino beam from Fermilab, aimed at the proposed DUSEL in the Homestake Mine in SD, baseline = 1290 km
- Two 100+ kT (fiducial volume) water Čerenkov detectors, *or*
  Two 17+ kT (fiducial) LAr detectors, *or*
  One of each.
- Detectors to be built at 4850 feet below the surface, *or*
  Possibly ~300 feet for the LAr detector
- A new neutrino beam line operating at 0.7 MW, *but*
  with infrastructure capable of 2 MW.
- A precision near detector just inside the Fermilab site boundary.

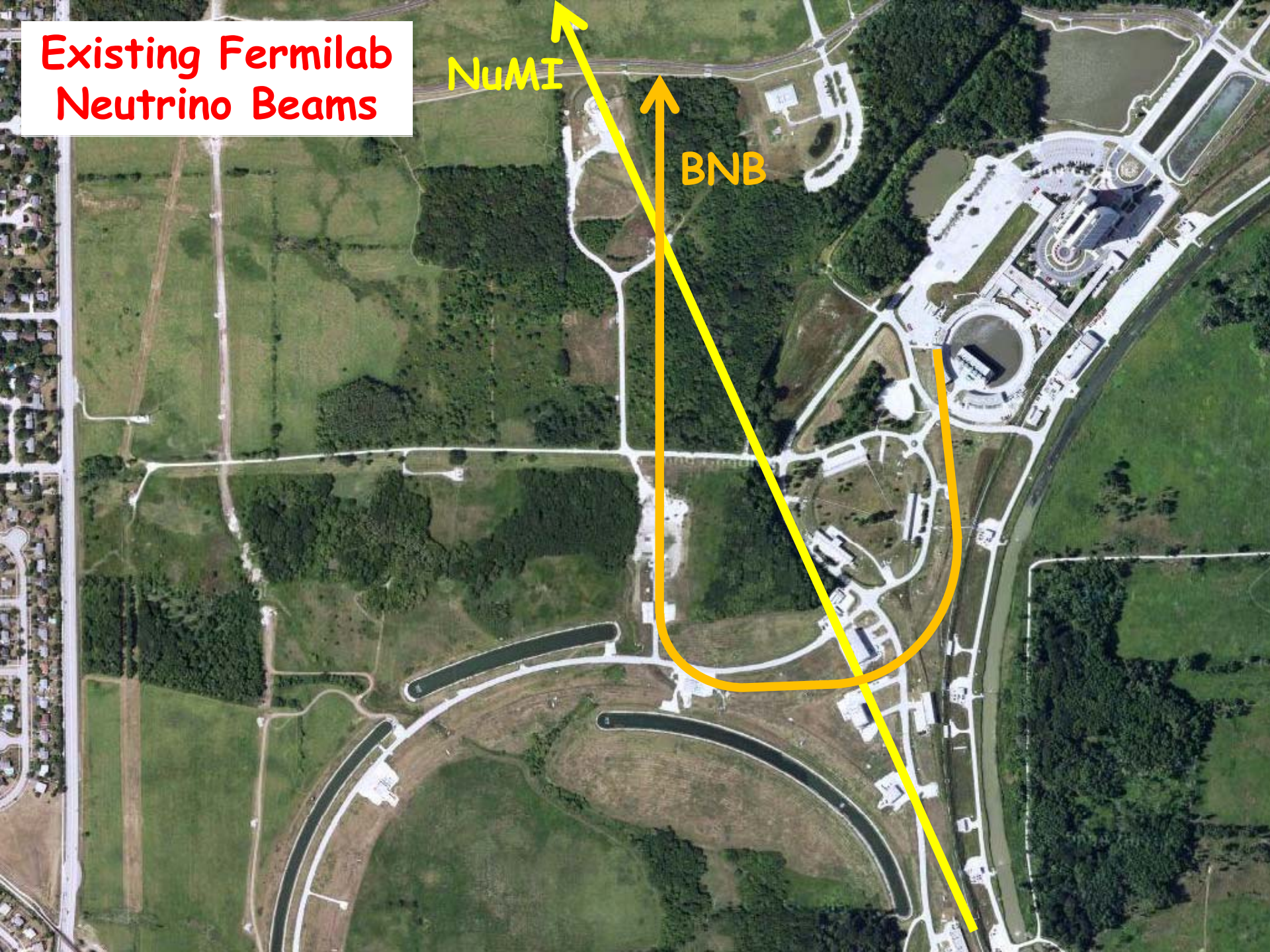
Note reduction in "exposure" :
2/3 the detector mass x 1/3 the beam power
=> require 4.5 x the running time to reach the same sensitivity

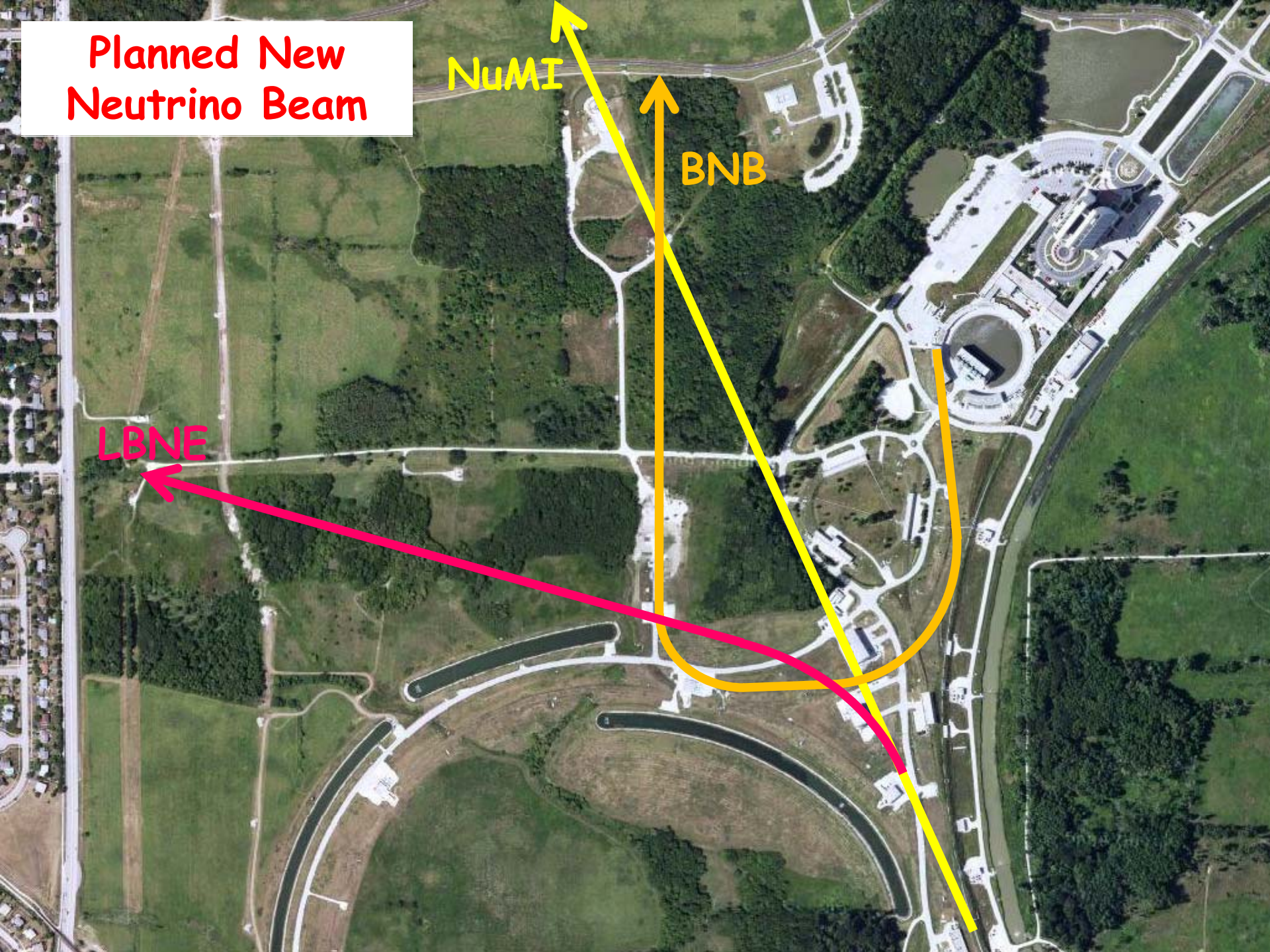
LBNE

- Oscillation physics: ν_e appearance
- 1290 km baseline,
- On-axis, broad-band beam
- 2x 100 kT fiducial volume H_2O Čerenkov or equivalent LAr TPC



Matter – Antimatter Asymmetry with Neutrinos
Proton Decay
Supernovae Neutrinos


Existing Fermilab
Neutrino Beams
NuMI
BNB


Planned New
Neutrino Beam
NuMI
BNB
LBNE

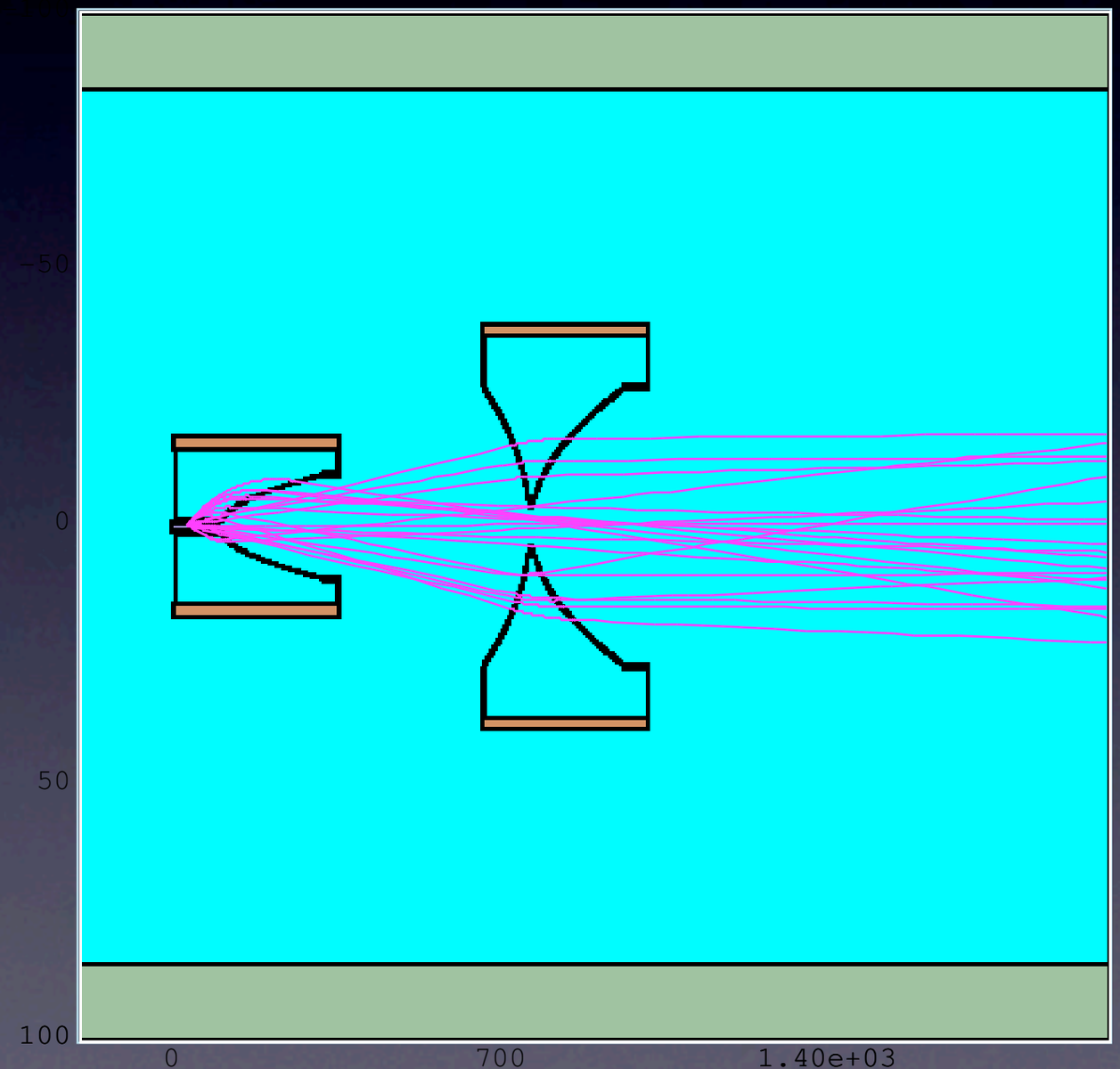
LBNE

Civil Construction

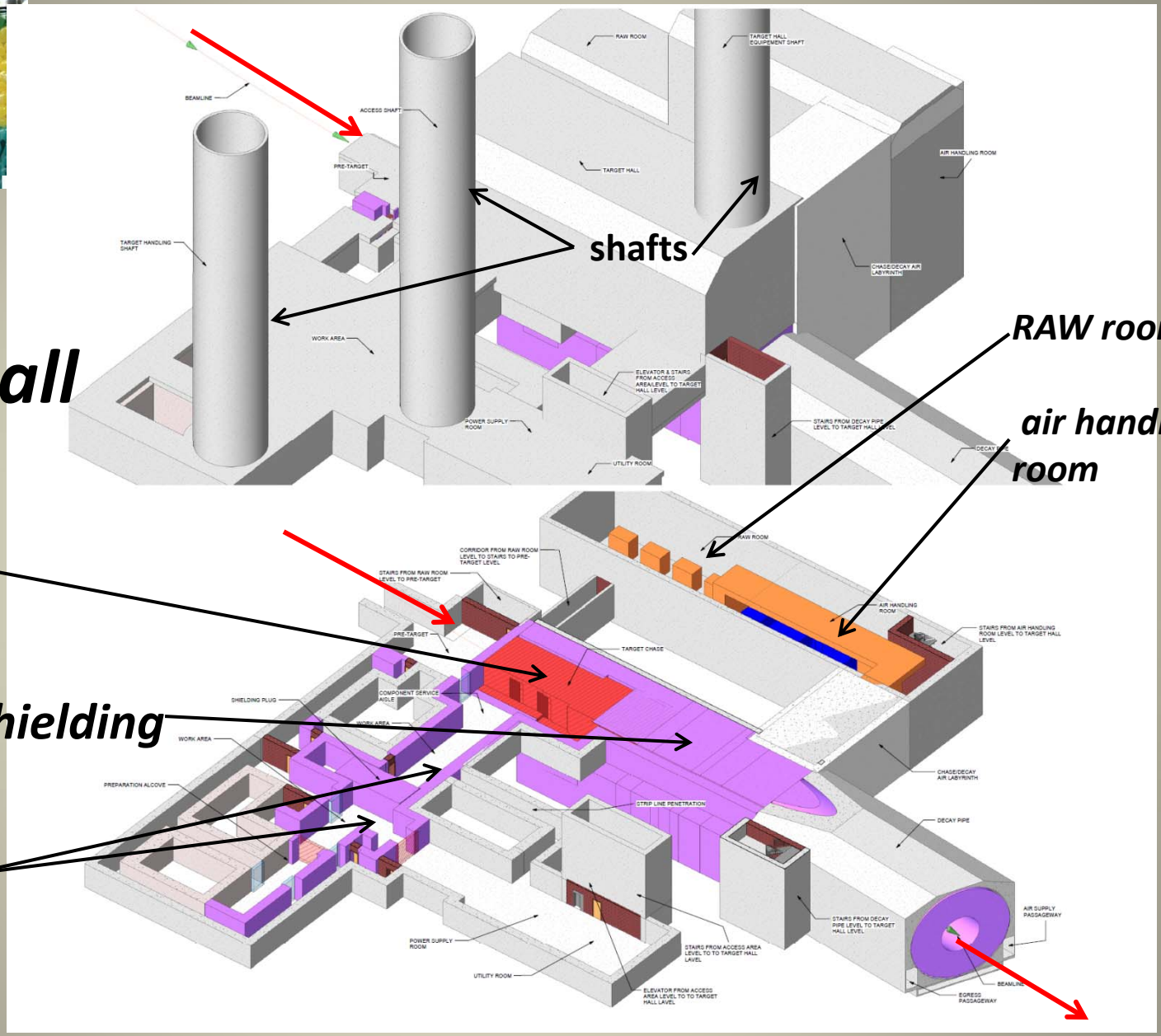
Tim Wyman, P.E.
FNAL FESS/Engineering

Visualization

5 GeV



Target Hall

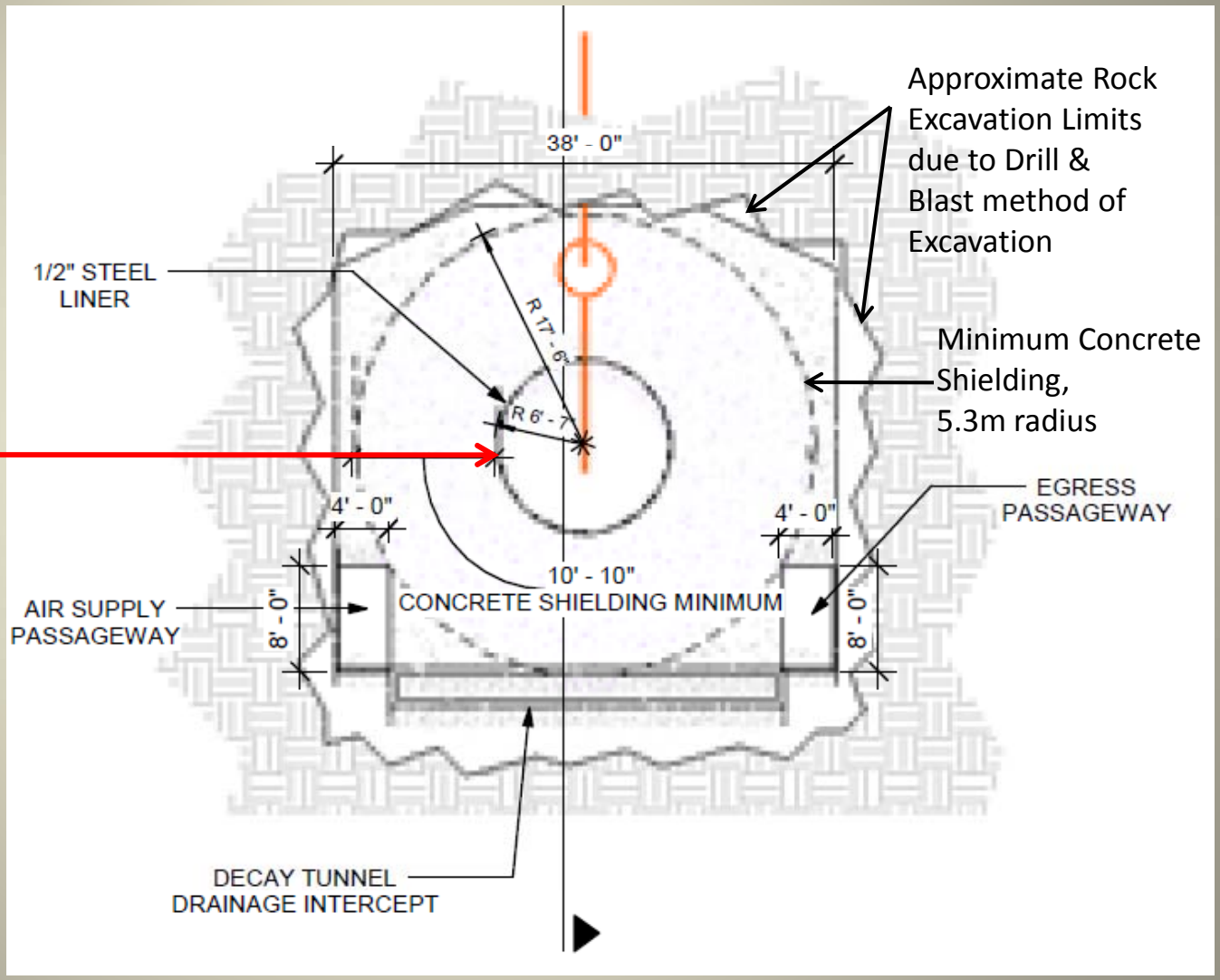

shafts
RAW room
air handling room
target chase
target pile/shielding
work areas

Decay Tunnel / Pipe

4m dia.

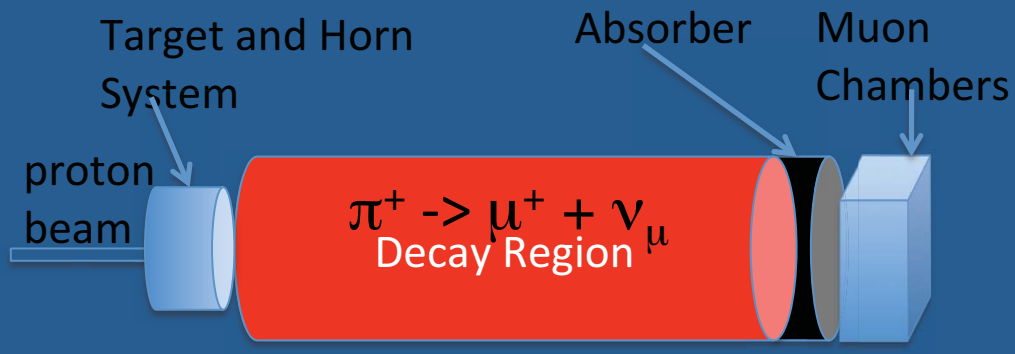
Decay Pipe

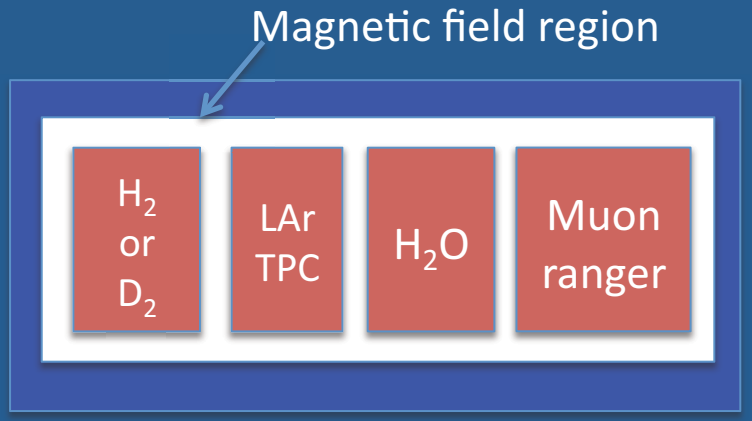
(vs. NuMI 2 m dia.)



Near Detector – Early Conceptual Stage

Anticipated Measurements





Beamline Measurements

Geoff Mills Talk

- In-situ meson measurements
- HARP/MIPP/SHINE external hadron production measurements
- muon measurements/ monitoring

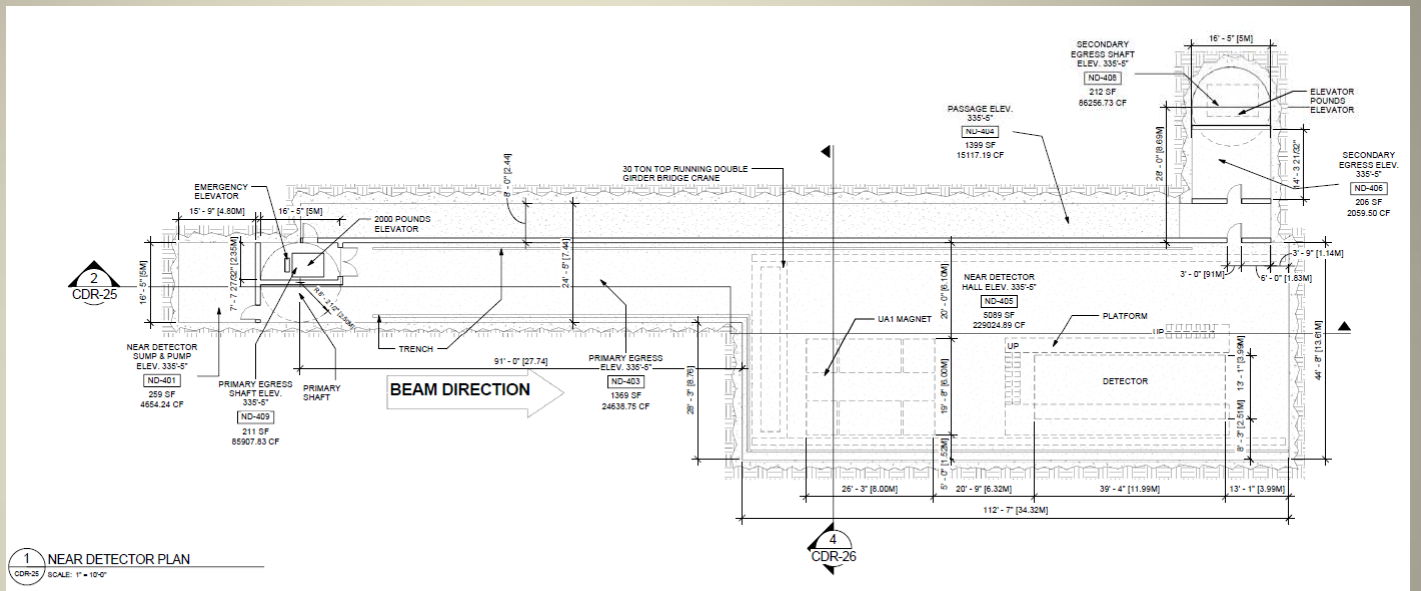
Neutrino Hall Measurements

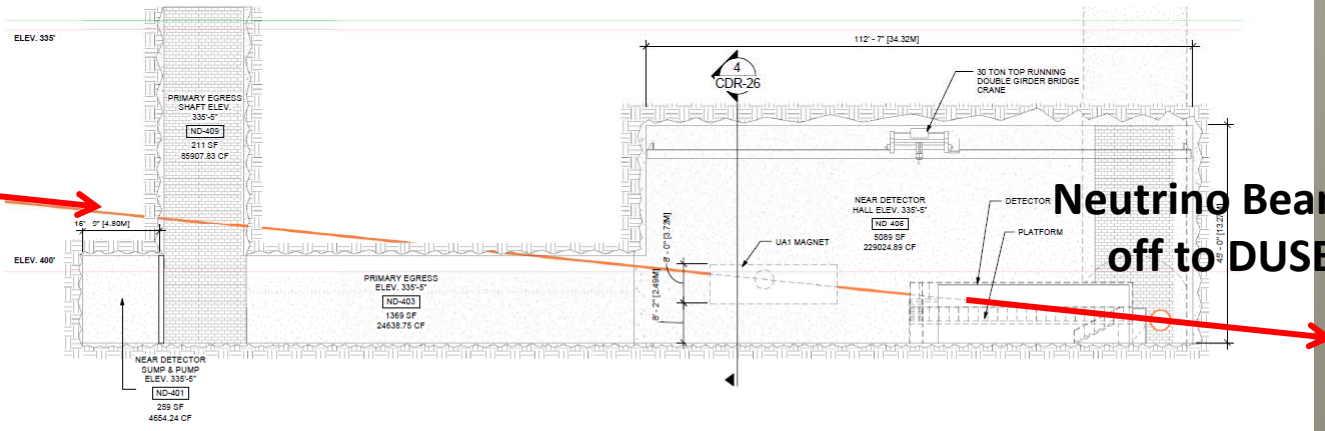
Bill Louis Talk

- Flux measurement
- Precision event rate/cross-section measurements on H_2O and argon
- Muon momentum measurements
- Charge/flavor separated neutrino spectrum measurement

C. Mauger (LANL)
Collaboration Mtg
28-31 Jan 2010

Near Detector Hall





LBNE

Beamline

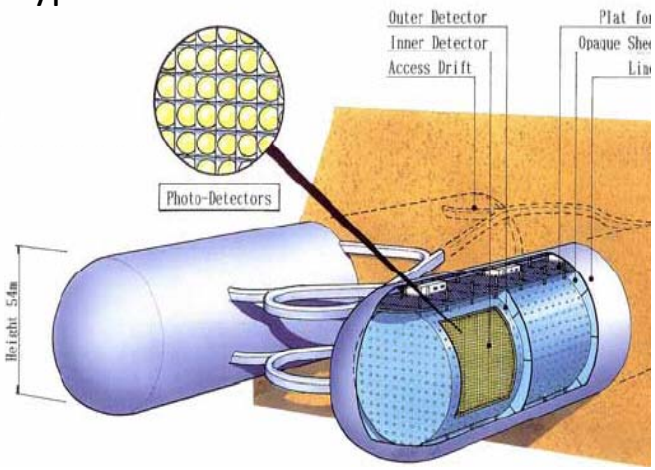
Neutrino Beam off to DUSEL

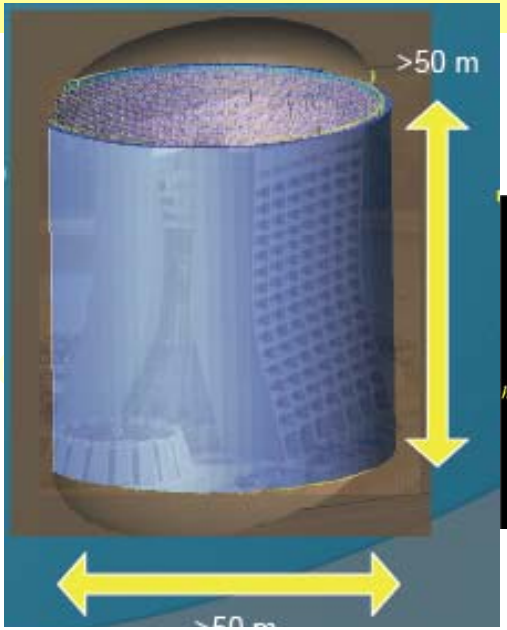
T. Wyman (FESS)
Collaboration Mtg
28-31 Jan 2010

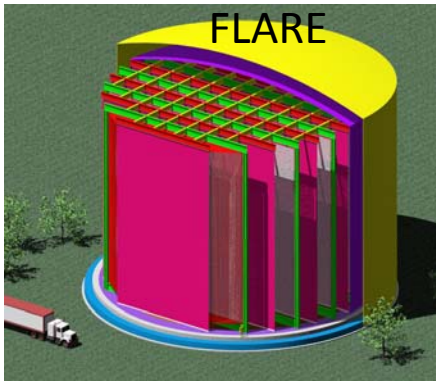
World Wide Concepts for Large Detectors

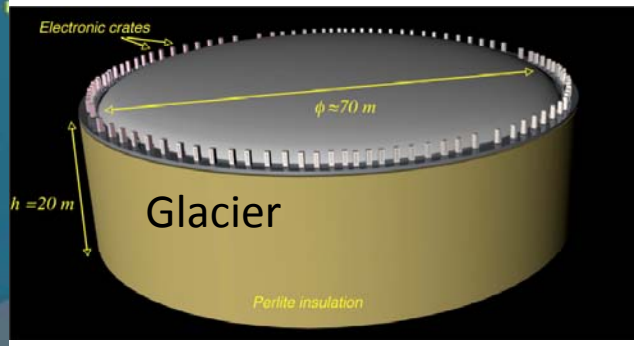
Water Cerenkov
Liquid Argon
Liquid Scintillator

Hyper-Kamiokande

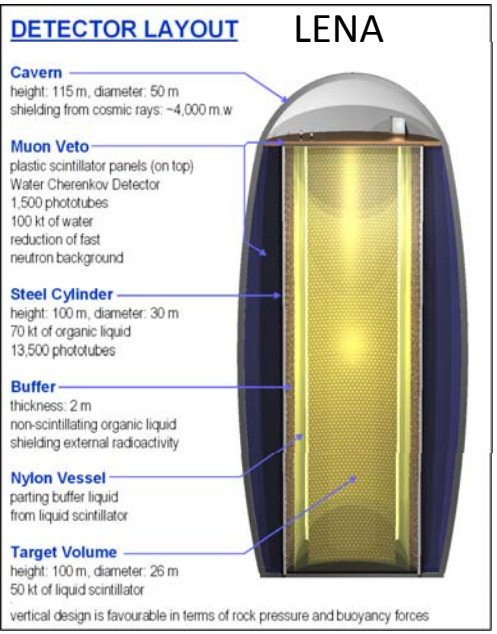


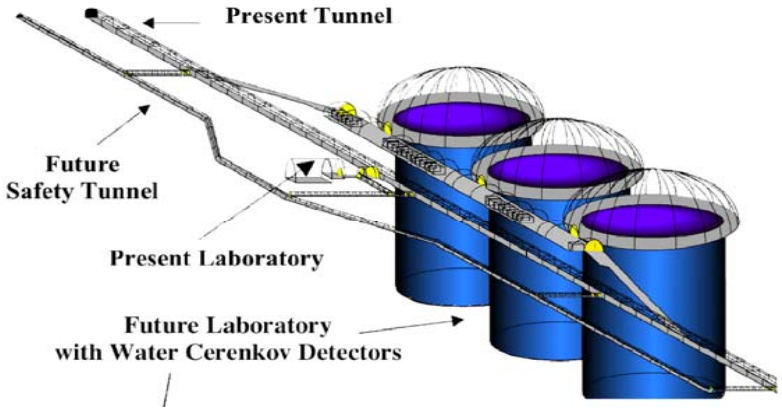


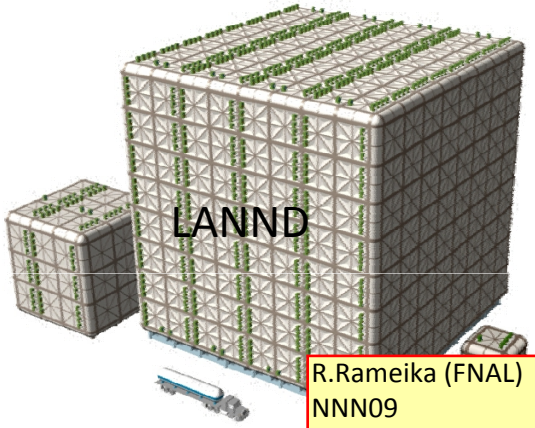




LENA



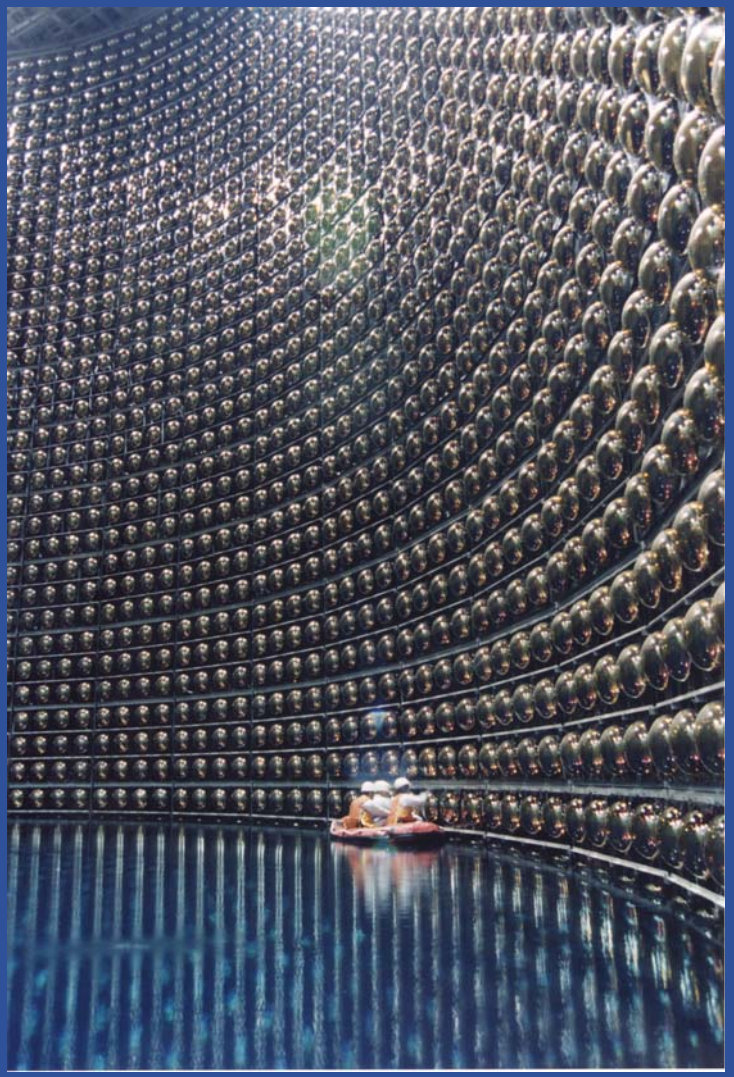


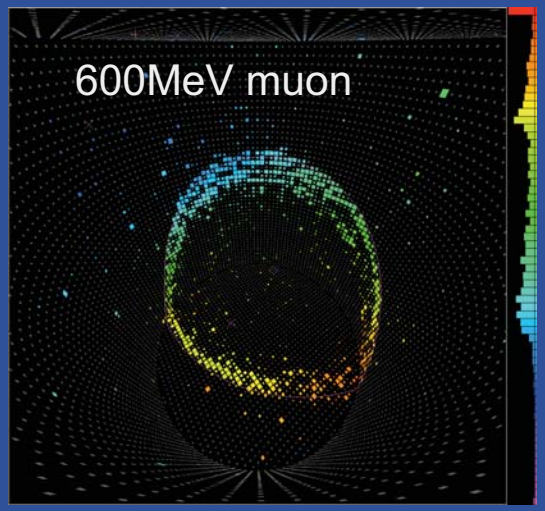


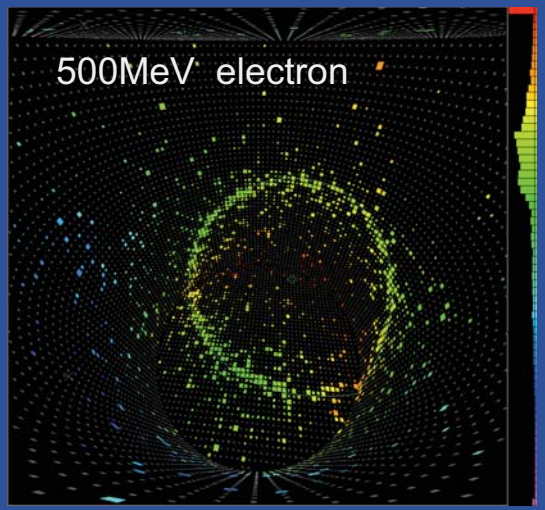
R.Rameika (FNAL)
NNN09
10 Oct 2009

Far Detector : Water Cerenkov

- Super-K
  - 13K 20” PMT
  - 40% coverage
  - 50 kT total mass
  - 39 m diameter
  - 42 m height
- LBNE
  - 60 K 10” PMT per 100kT FV module (25%)
  - ~55 m diameter
  - ~60 m height

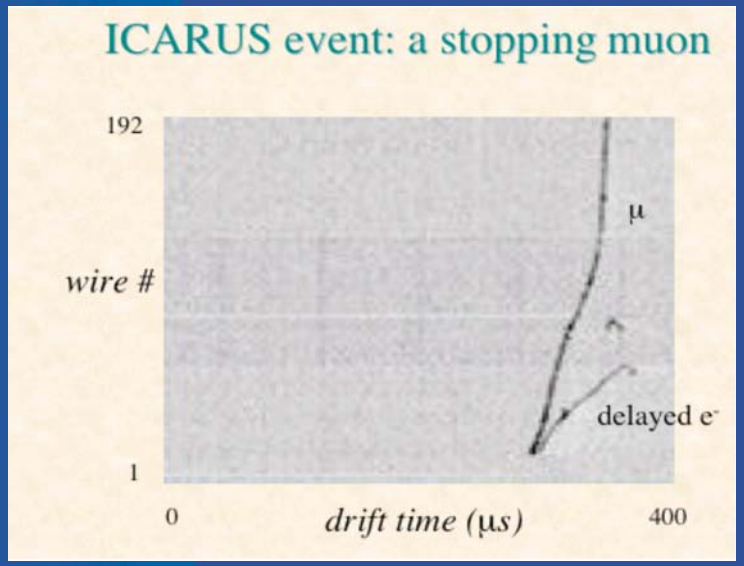


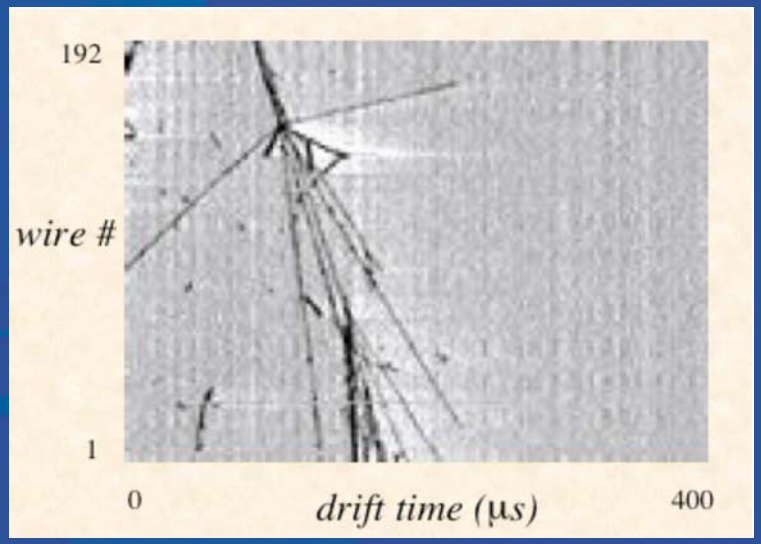




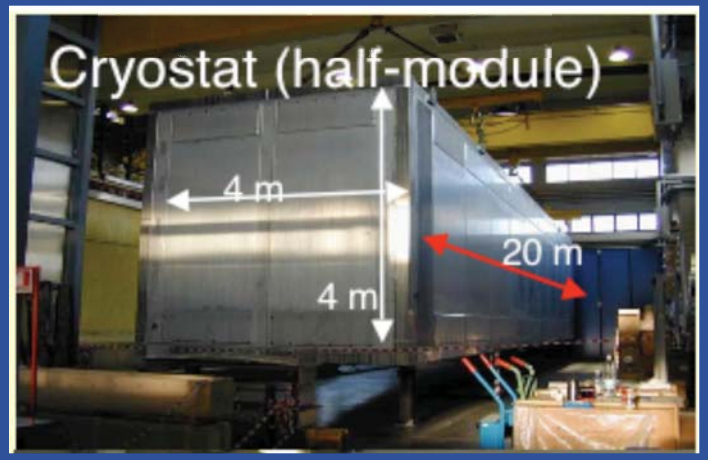
Fermilab

Far Detector : Liquid Argon



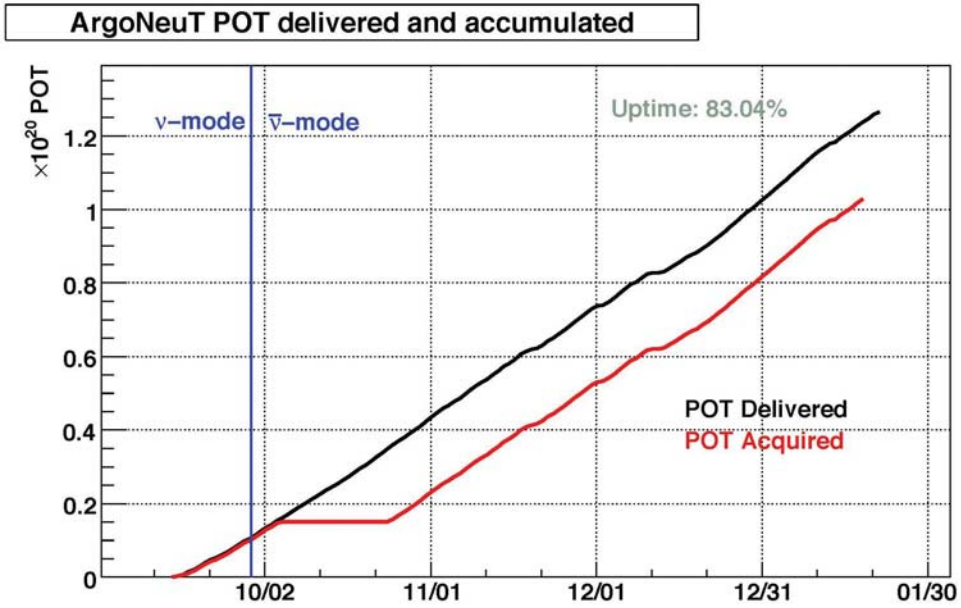


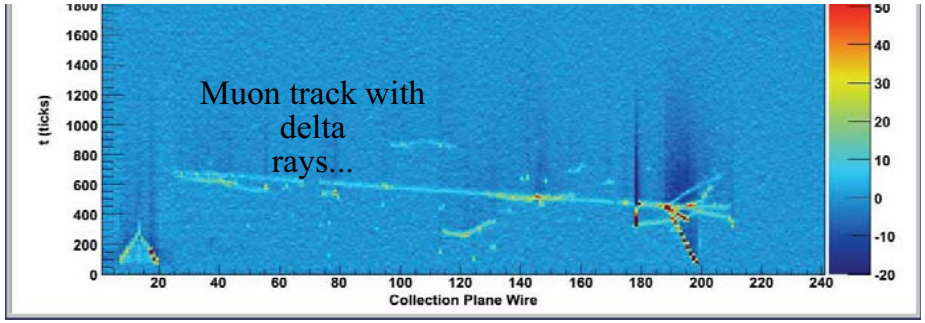
- LAr potential
  - Efficiency ~80%
  - $e/\pi^0/\gamma$ identification – low NC bkgd
- Proof of Principle at large scale lacking
  - ICARUS T-300 x 2
  - Many challenges

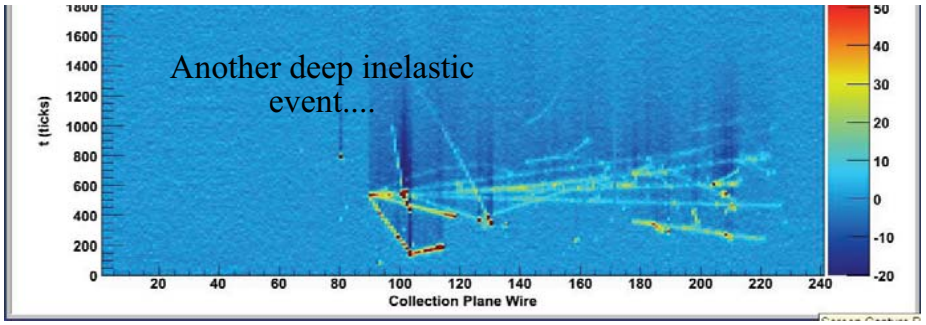


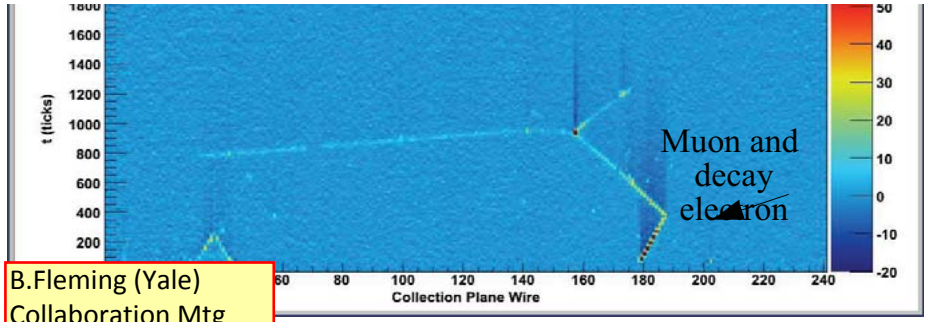
Fermilab

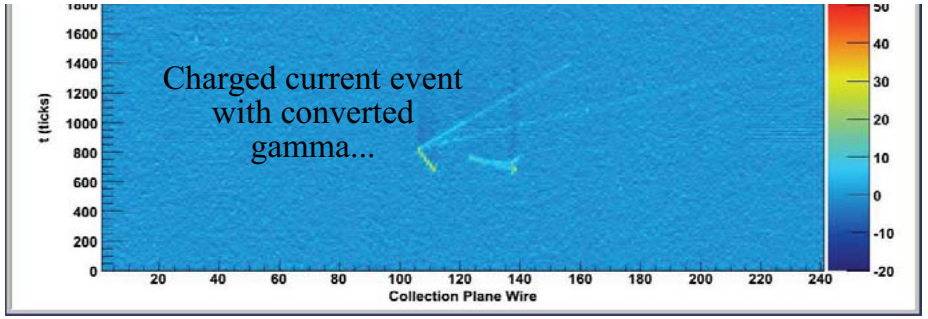
Progress on these components...









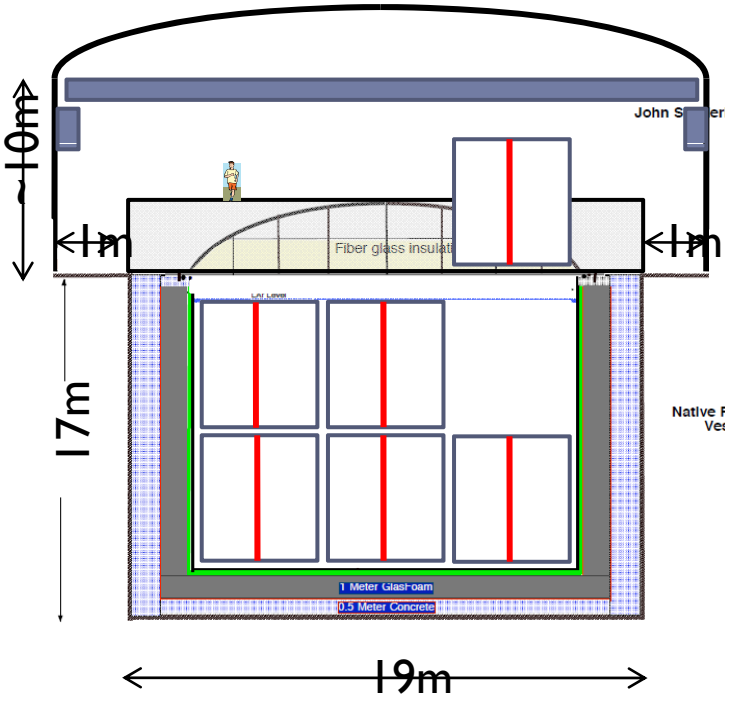


B.Fleming (Yale)
Collaboration Mtg
28-31 Jan 2010

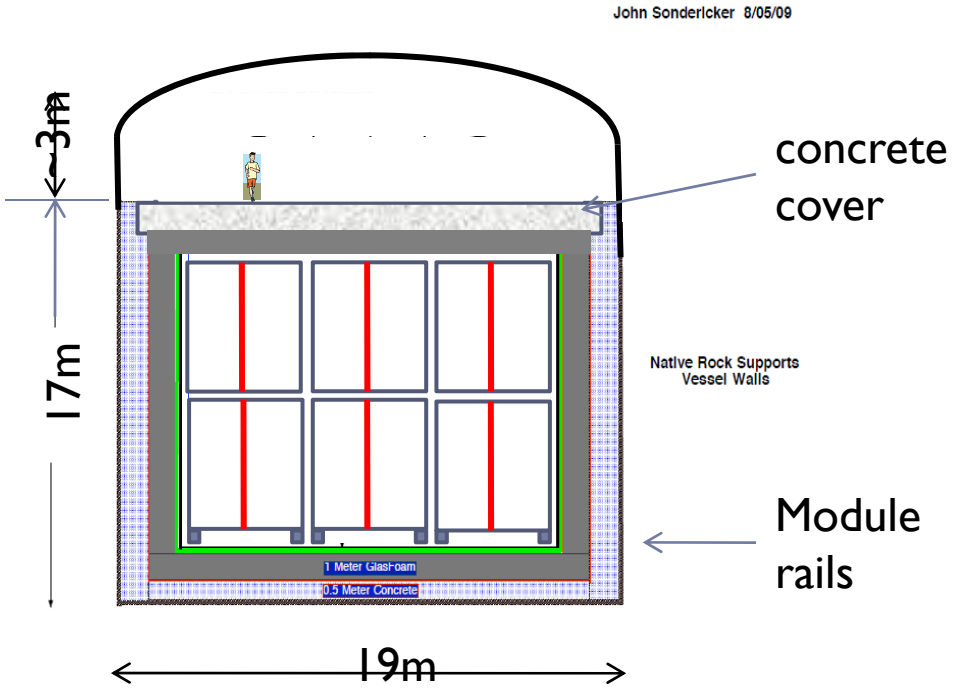
See M. Soderberg's talk

Membrane Cryostat
TPC Module/Cavern Concepts

Top Loading with Bridge Crane
Deep Option

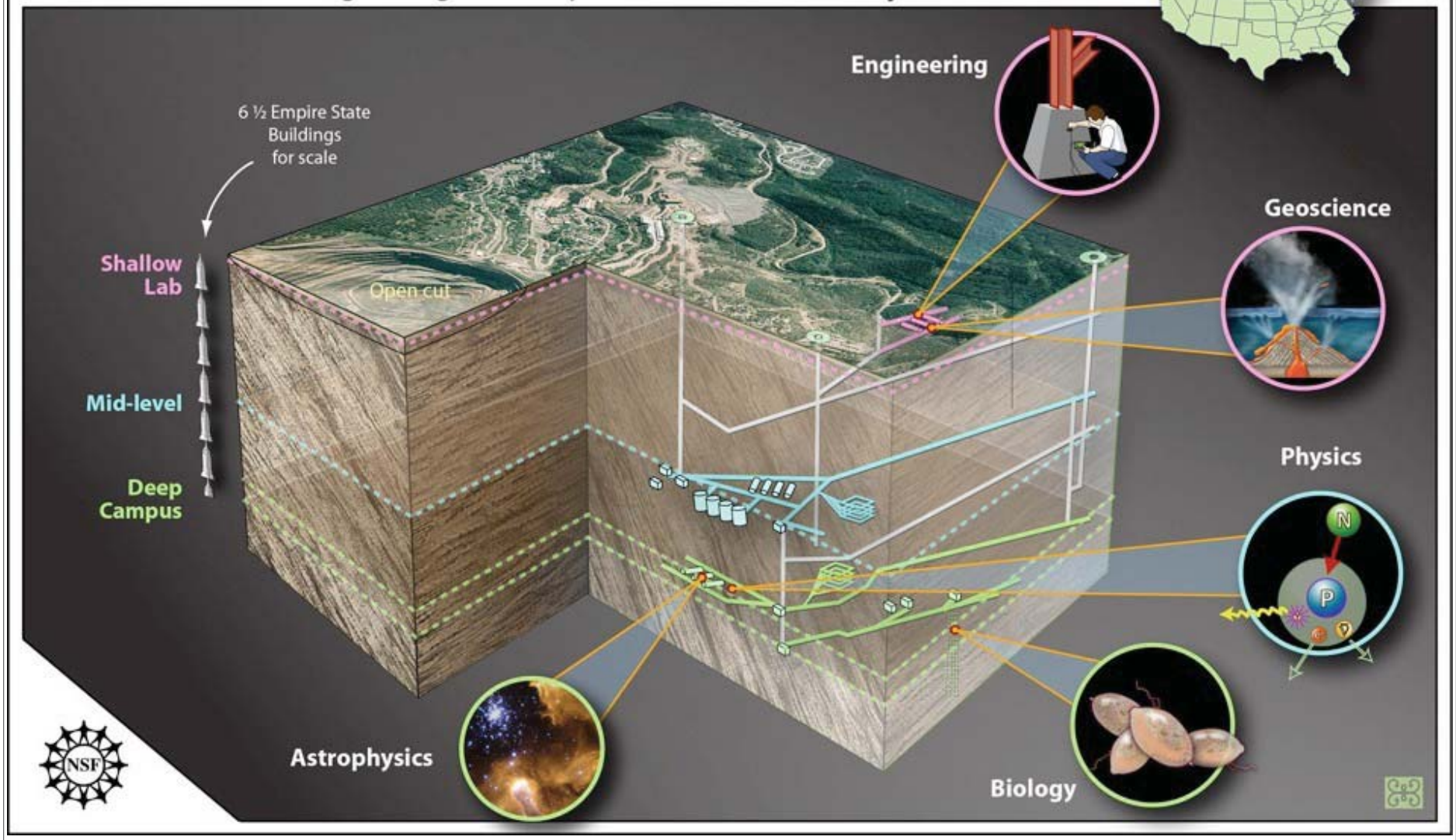


End Loading on Rails
Shallow Option



Reference Design1a shown – Bo Yu will present other options

DUSEL Deep Underground Science and Engineering Laboratory at Homestake, SD



NSF site decision on advice from a 22 member unanimous panel.

Office of Science
U.S. DEPARTMENT OF ENERGY

M.Diwan

M.Diwan (BNL)
BNL Colloquium
24 Nov 2009

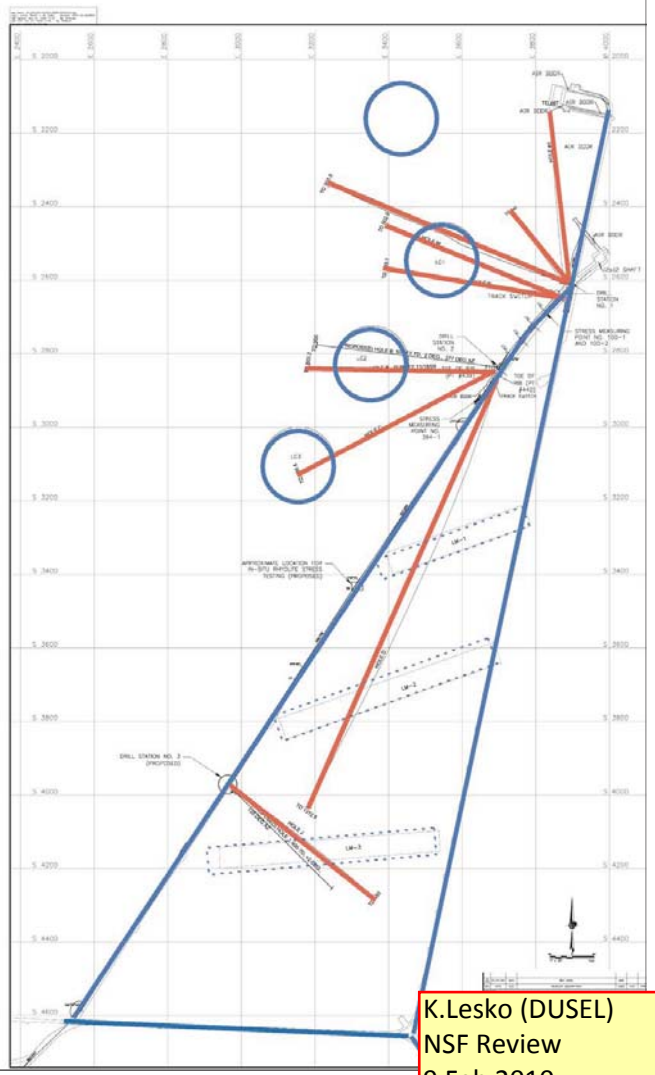
BROOKHAVEN NATIONAL LABORATORY

M.Diwan (BNL)
BNL Colloquium
24 Nov 2009

Completed Critical Geotechnical Investigations

- 4850 Level Mapping - Completed
- Geological Model - Developed
- Coring and Logging - Completed
  - holes 1, 2, 3: Sanford Lab
  - holes 3, M, N: LC 1
  - holes B, C: LC 2, LC3
  - holes D, J: 4850 Lab Modules
  - 4363.1 feet of core
- *In situ* testing - Completed
- Laboratory testing - Completed

Good news: Little Water, Good to Very Good Rock Quality



K.Lesko (DUSEL)
NSF Review
9 Feb 2010

Challenges are Everywhere!

Neutrino Beam capable of taking a 2 MW proton beam on target

- Target / Horn system
- Radiation Issues: material survivability, remote handling, ground water protection, tritium, . . .
- Underground construction
- Underground safety
- Etc.

Near Detector needs clever design

- Cannot just be miniature version of far detector
- Needs to be compact and cost effective
- Underground construction
- Underground safety
- Etc.

Challenges are Everywhere!

Water Čerenkov Detector

- Unprecedented size and number of PMTs
- Water pressure effects on PMTs
- Water tank and water system design
- Electronics and data handling
- All done underground
- Underground safety!
- Etc.

Challenges are Everywhere!

Liquid Argon Detector

- 50x scale-up from largest LAr TPC ever made.
- Argon purity at < ppb level over huge volume.
- Large cryogenic system deep underground.
- Electronics design and data handling!
- Event reconstruction from huge amount of information.
- Underground safety!!!
- Etc.

Challenges are Everywhere!

Underground Construction

- Complex Target Hall, Decay Pipe, and Hadron Absorber construction on Fermilab site.
- Near Detector hall at 400 feet depth.
- Large Cavity for water Čerenkov detector is of unprecedented size and depth.
- Underground safety!!!
- Etc.

We are only just starting . . .

. . . and need all the help we can get!

For more information, ask:

About the whole project: Gina Rameika, Elaine McCluskey or me

About the nu beam: Vaia Papadimitriou, Pat Hurh, Bob Zwaska

About water Čerenkov: Paul Mantch, Mark Kaducek (PMTs);
Del Allspach, Tom Junk (water systems)

About Liquid Argon: Bruce Baller (overall), Rich Schmitt (cryogenics),
Ray Yarema (electronics)

About Civil Construction: Tim Wyman (on-site);
Chris Laughton (DUSEL)

The fun has just begun!