
Long Baseline Neutrino Experiment
North Dakota
Minnesota
Lead, SD
South Dakota
Wisconsin
Michigan
Milwaukee
Nebraska
Iowa
Chicago
Jim Strait
FRA Visiting Committee
18 March 2010
Illinois
Kansas
Missouri
Image NASA
© 2008 Tele Atlas
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Google
Pointer 43°03'56.44" N 95°10'42.53" WStreaming 100%
Eye alt 1108.62 km

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Yale: B.Fleming, M.Soderberg

44 Institutions, 154 Scientists
… and growing.

*Co-Spokes

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 astrophysical neutrinos:
  - Neutrinos from a supernova in (or near) our galaxy
  - Relic neutrinos from "all" past supernovas
  - From cosmic ray interactions in the atmosphere
  - Solar neutrinos

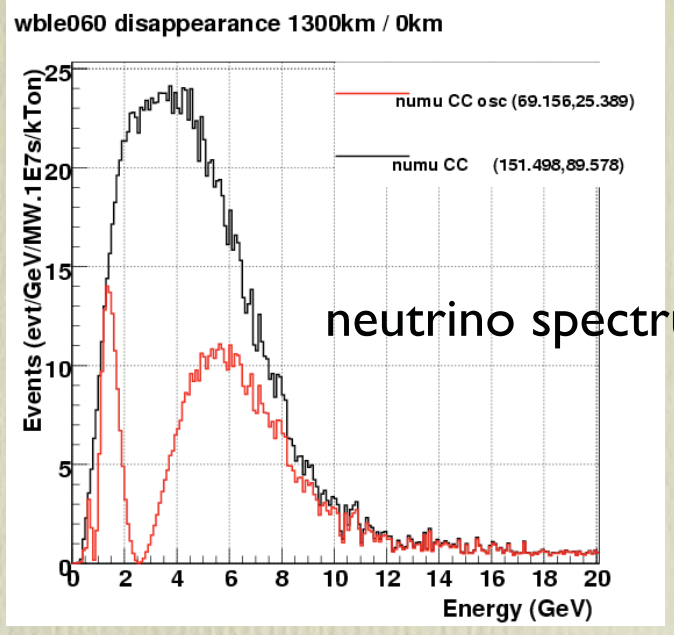
What do we want to be able to do this Experiment?

- 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 (80 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:
  ≥3000 mwe for p->$K^+\nu$; ≥4300 mwe for relic supernova neutrinos
  (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 MW, T2K = 0.7 MW)
- 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

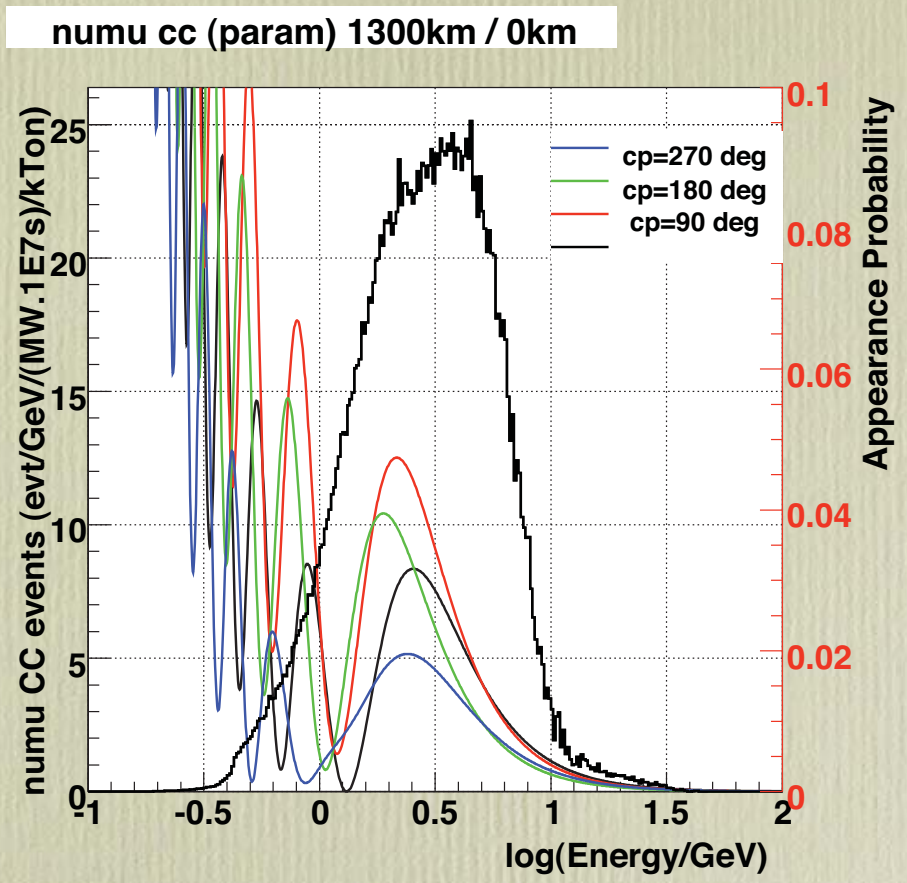
High precision $\sin^2 2\theta_{23}$, Δm^2_{32}

- 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

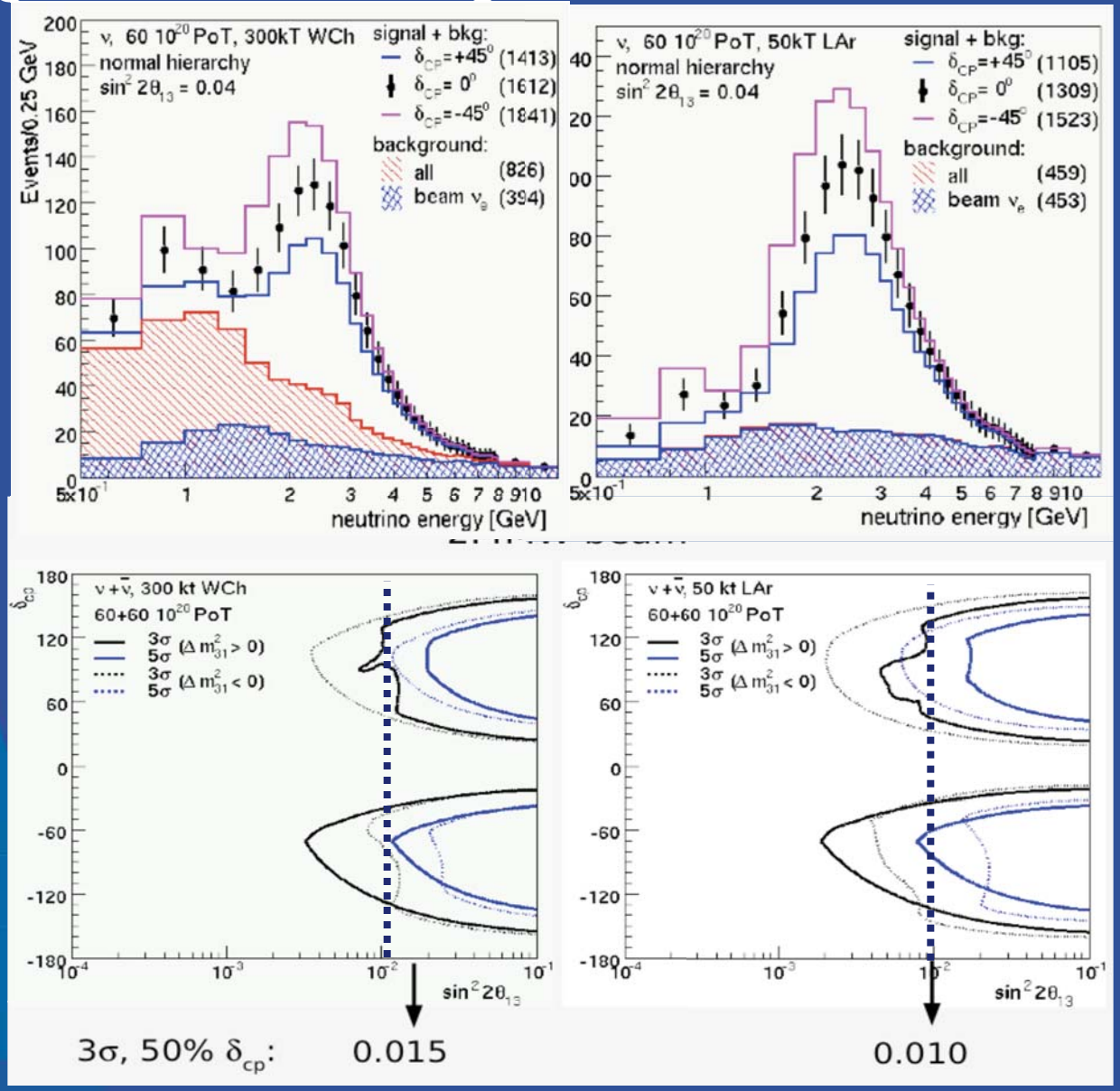
M.Diwan (BNL)
BNL Colloquium
24 Nov 2009

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



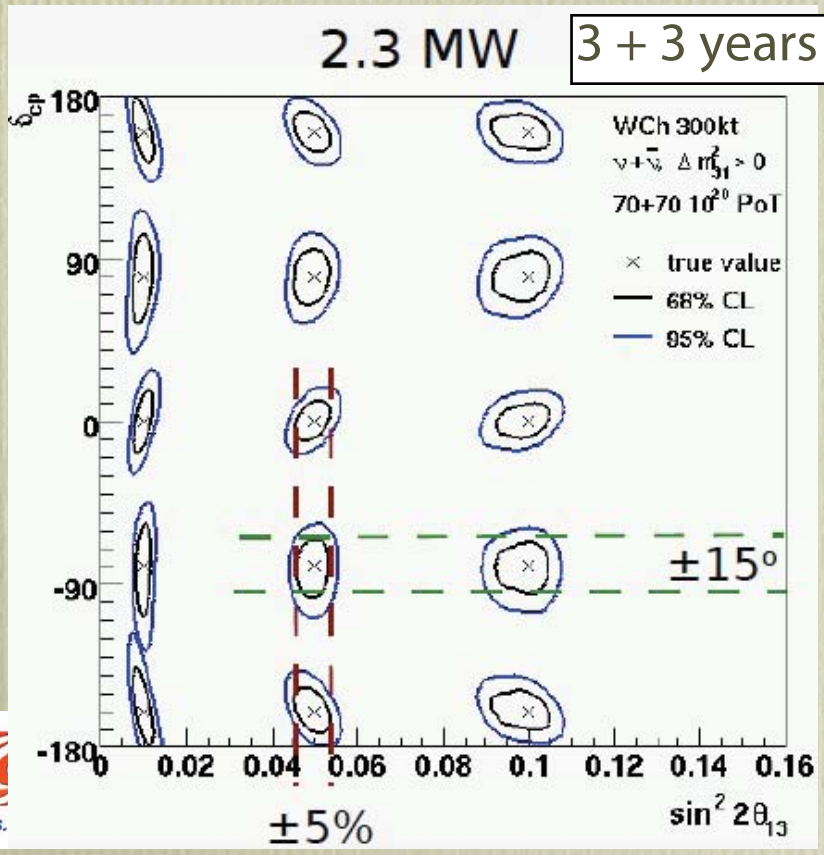
- 60 GeV at 0deg: CCrate: 14 per (kT*10^20 POT)

Signals and backgrounds for WC vs. LAr



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

=> x2 larger error bars . . .
or 4.5 x the running time to reach the same sensitivity

Project Scope

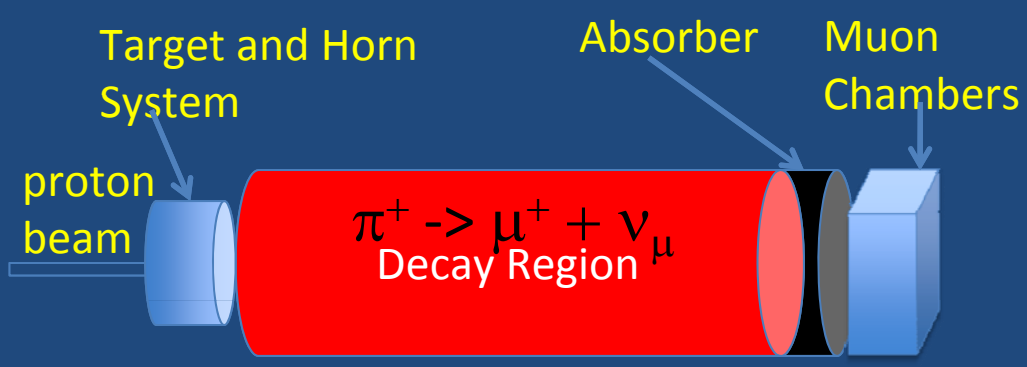
- WBS 1.1 – Project Management.
- WBS 1.2 - New neutrino beam at Fermilab:
  initial proton beam power = 0.7 MW, but facility to be capable of being upgraded to ≥2 MW.
- WBS 1.3 - Near detector capable of measuring neutrino beam properties and neutrino cross-sections with sufficient precision that the oscillation physics is limited by far detector statistics.
- A far detector complex of ≥ 200 kT Water Cerenkov equivalent:
- WBS 1.4 – Water Cerenkov far detector (100 kT "modules").
- WBS 1.5 – Liquid Argon TPC far detector (~20 kT "modules").
- WBS 1.6 – Conventional facilities:
  underground and surface facilities at the near and far sites.

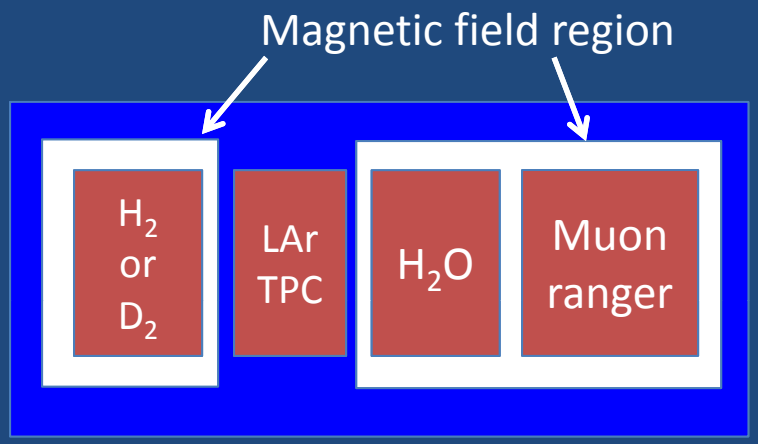
The Neutrino Beam Facility at Fermilab

Start with a 700 kW beam, and then take profit of the significantly increased beam power (2.3 MW) available with Project X

Primary beam energy (protons from the Main Injector) from 60 to 120 GeV

Near Detector Complex



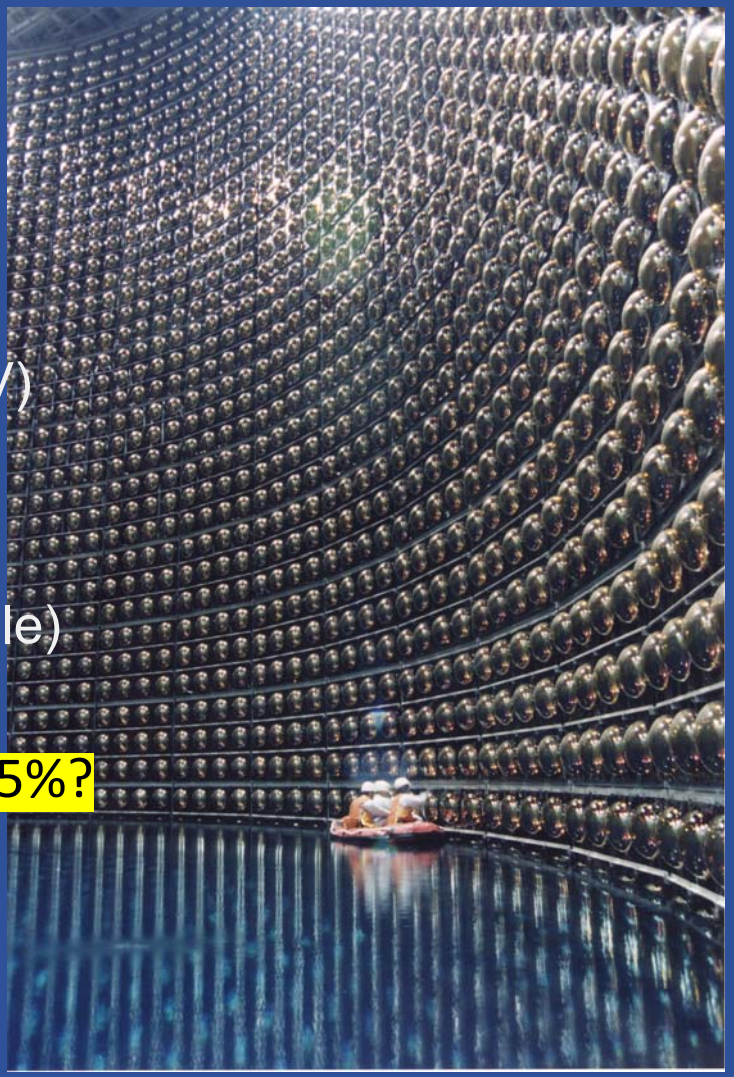


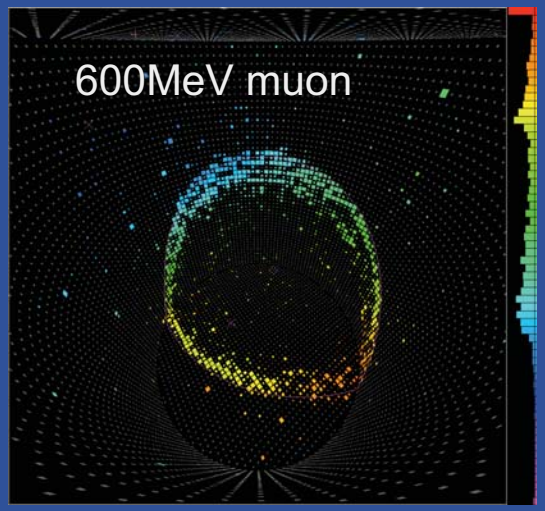
Scope of Work

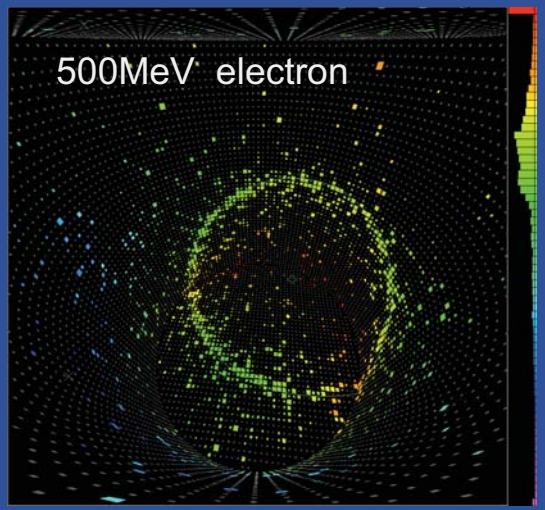
- Design a system of detectors and measurements to maximize the sensitivity of LBNE
  - Post-target hadron flux – extract neutrino flux
    - in-situ
    - external (eg MIPP, HARP, SHINE)
  - Post-absorber muon flux – neutrino flux information, spill-by-spill beam stability
  - Neutrino Hall
    - flux
    - interactions on same nuclear targets as far detector

Far Detector : Water Cerenkov

- Super-K
  - 13K 20” PMT
  - 40% coverage
  - 50 kT total mass (22 kT FV)
  - 39 m diameter
  - 42 m height
- LBNE (each module)
  - ~~60 K~~ 10” PMT 36K?
  - per 100kT FV module (~~25%~~ 15%?)
  - ~55 m diameter
  - ~60 m height

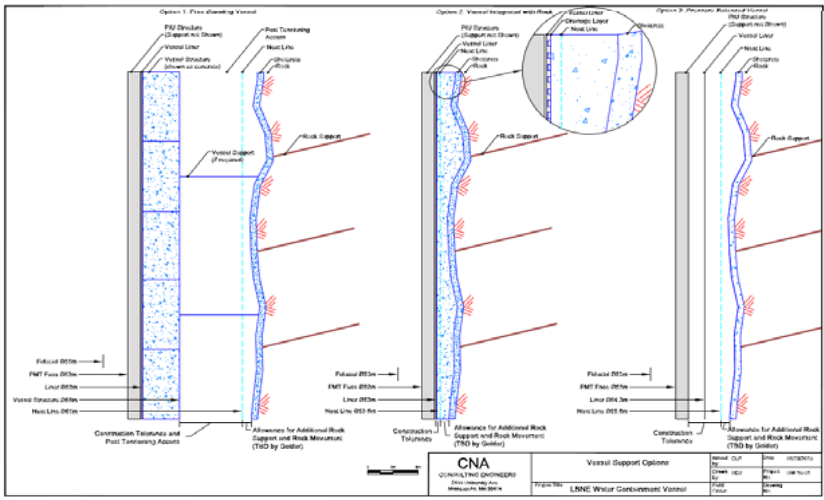


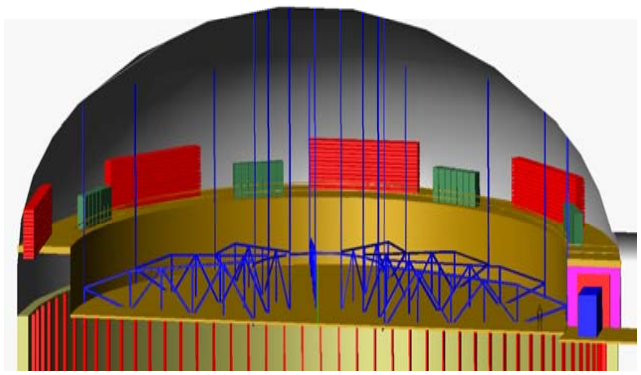


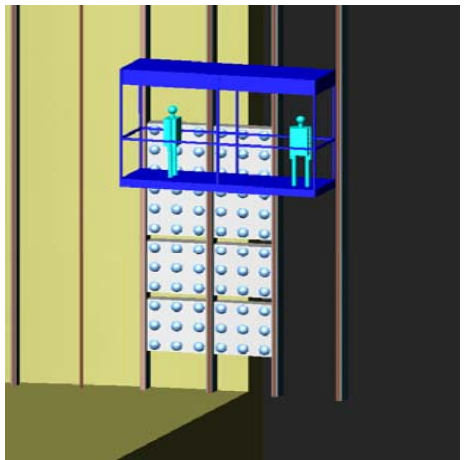


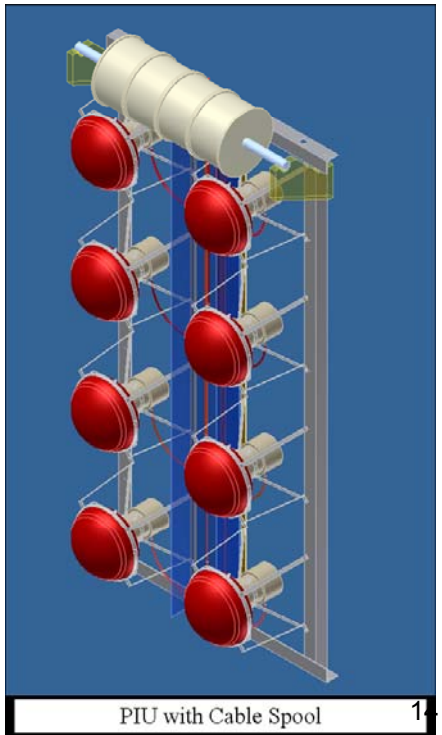
1.4.2 Vessel/Liner (F. Feyzi and B. Paulos)

- Vessel: Consortium of A&E companies evaluating vessel options
  - Select primary option March 9-10
  - 4 months to develop design, cost, and schedule for CD-1
- Deck: Three concepts being developed
  - Select primary option in April
  - Need time after vessel option select
- PMT mounting
  - Numerous options
  - Select best and alternate in April
  - Depends on deck decision



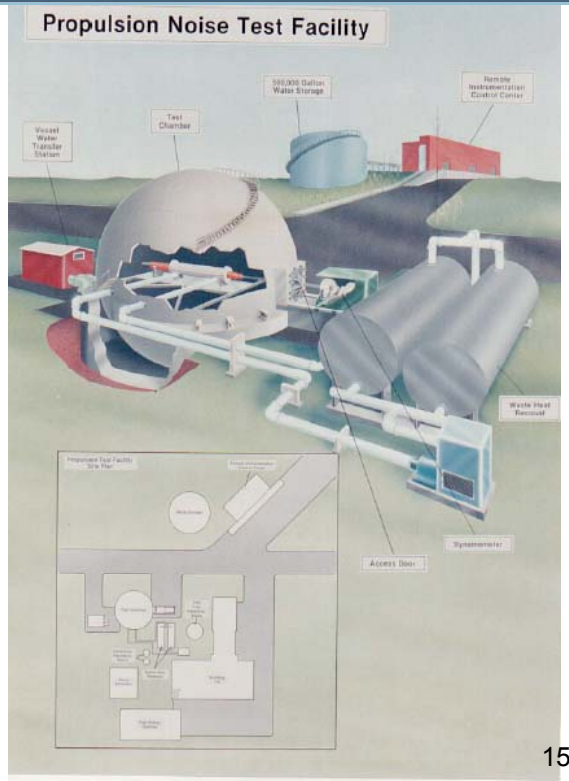






1.4.3 PMTs (P. Mantsch)

- PMT Procurement.
  - Request for Information RFI to photon detector vendor
    - 2 Vendors responded Hamamatsu and ETL
    - Source Selection Panel will be used for procurement
- Detailed plan for PMT testing and characterization under development.
- PMT protection.
  - Contract with Navy to bring testing facility online
    - ½ Million gallon – 50’ diameter tank
    - Will have engineering plan and proven test facility for CD-1
- Light collection studies in planning stage.
- PMT assembly plan developed at Wisconsin.



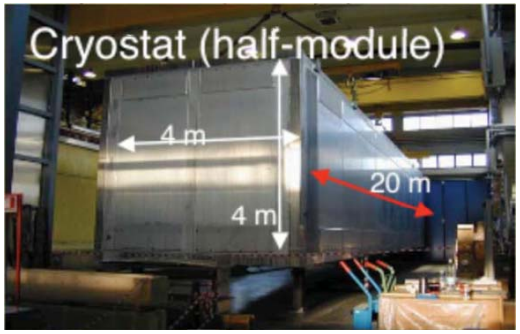
Far Detector : Liquid Argon TPC

LAr potential:

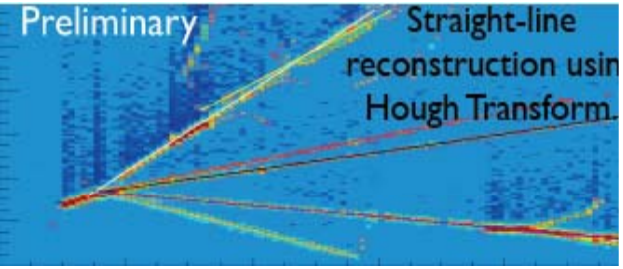
- Efficiency for ν_e ~80%
- e / π°/ γ identification – low NC bkgd

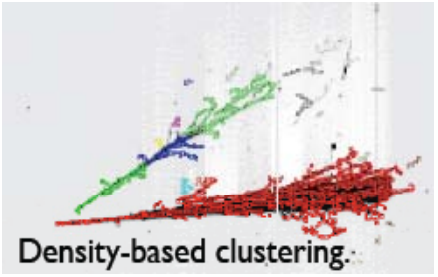
Proof of Principle:

- ICARUS (600 T)



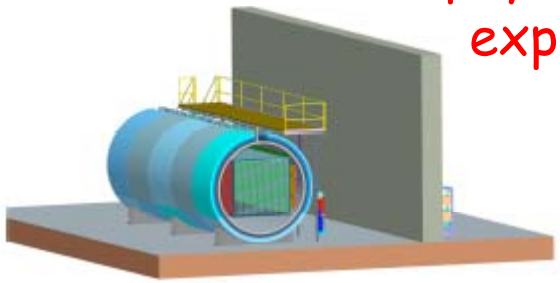
- ArgoNeuT: event reconstruction





R&D program:

- MicroBooNE – ν physics exp.

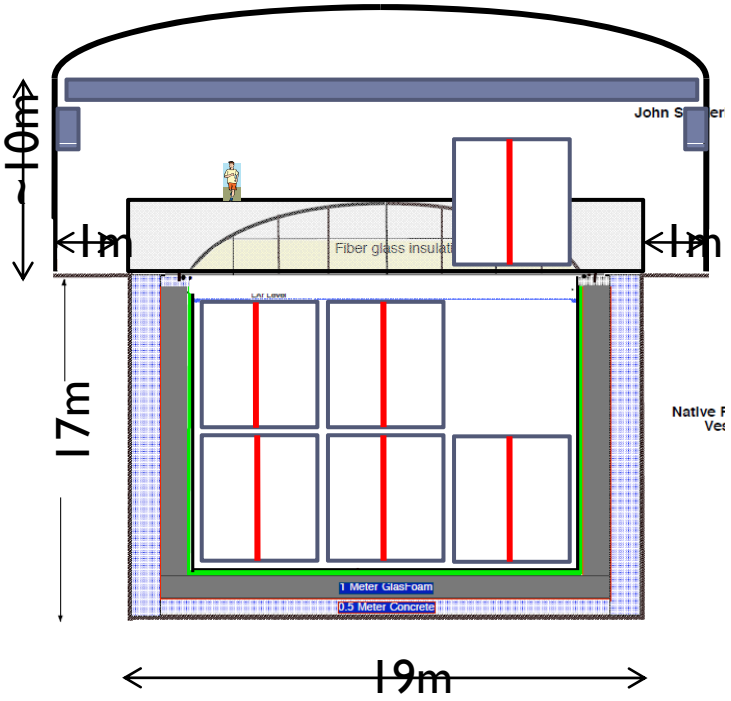


- LAr Purity Demonstrator

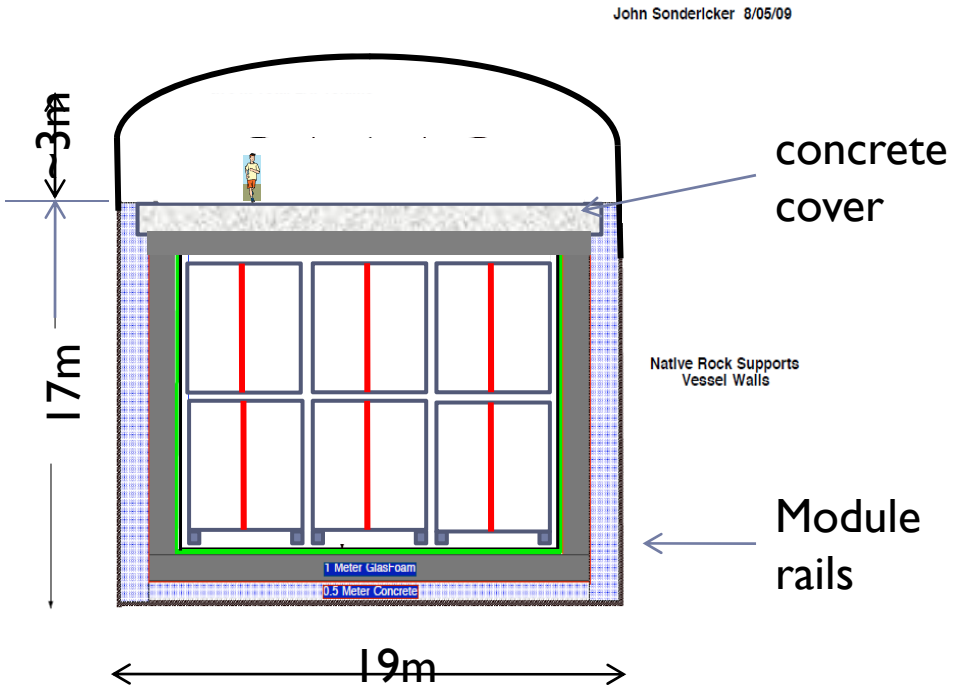
- And more

Membrane Cryostat
TPC Module/Cavern Concepts

Top Loading with Bridge Crane
Deep Option



End Loading on Rails
Shallow Option



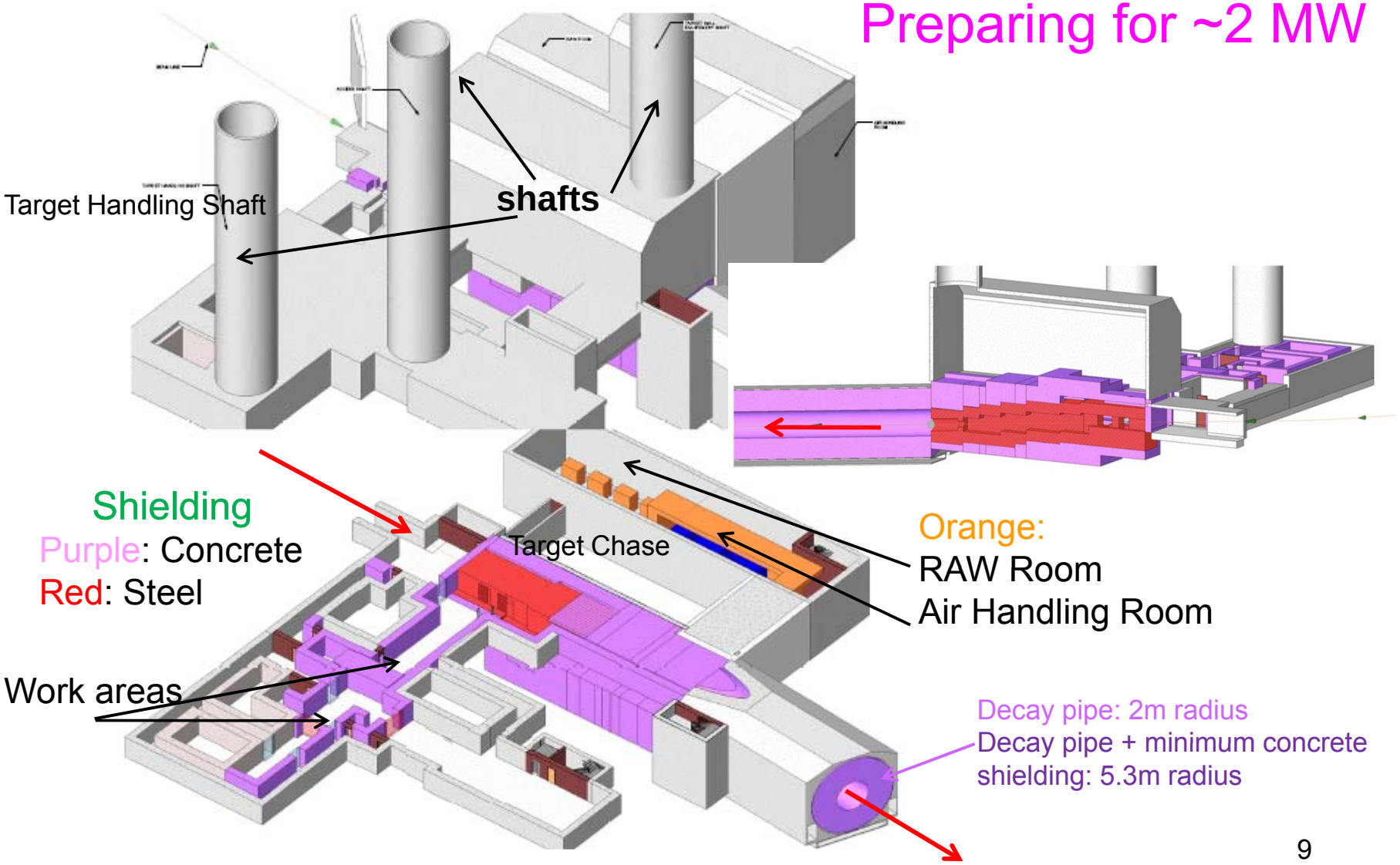
Reference Design1a shown – Bo Yu will present other options

Conventional Facilities Scope

- CF at Fermilab
  - Tunnel for Primary Beam
  - Target Hall complex
  - Decay Pipe and Absorber
  - Near Detector Hall
  - Surface Buildings and Infrastructure
- CF at Far Site
  - Caverns for WC and LAr detectors
  - Infrastructure and surface facilities as required

Target Hall Isometric Views

Preparing for ~2 MW



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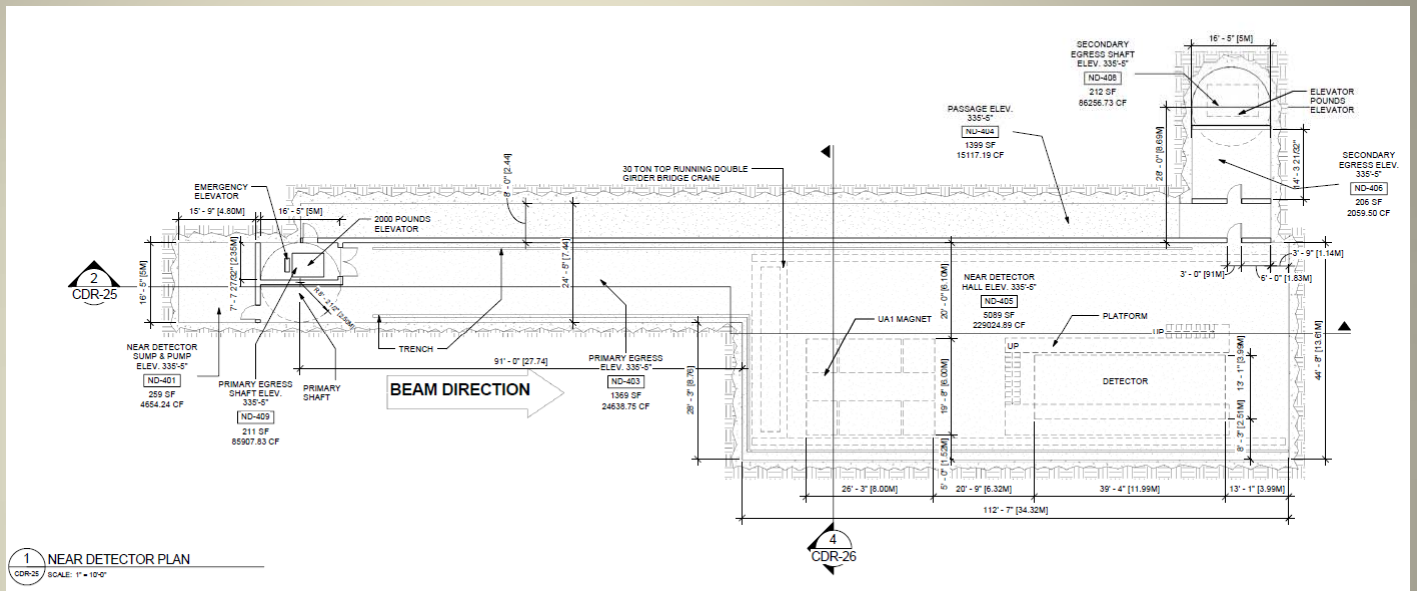
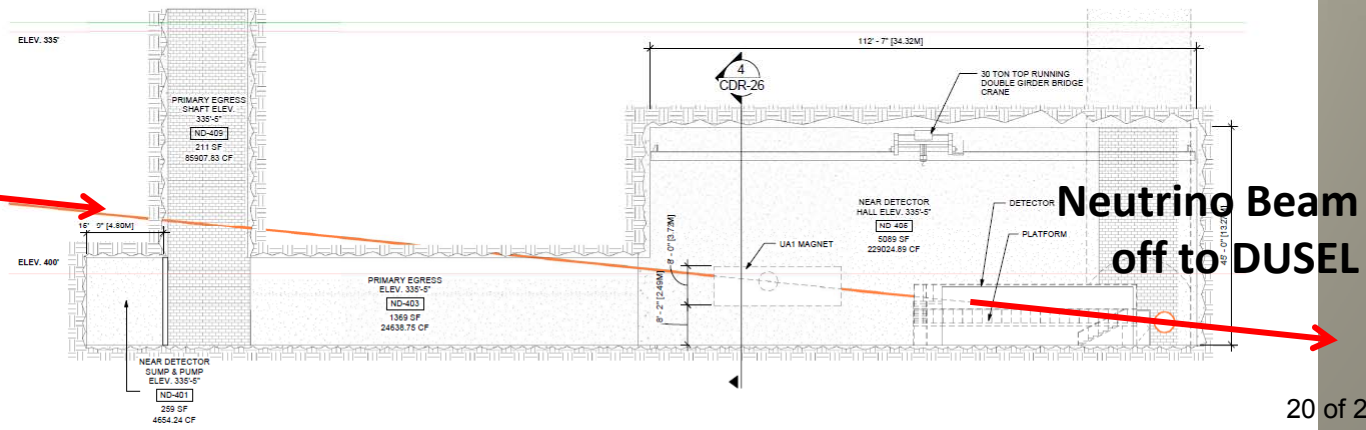
Near Detector Hall





LBNE

Beamline

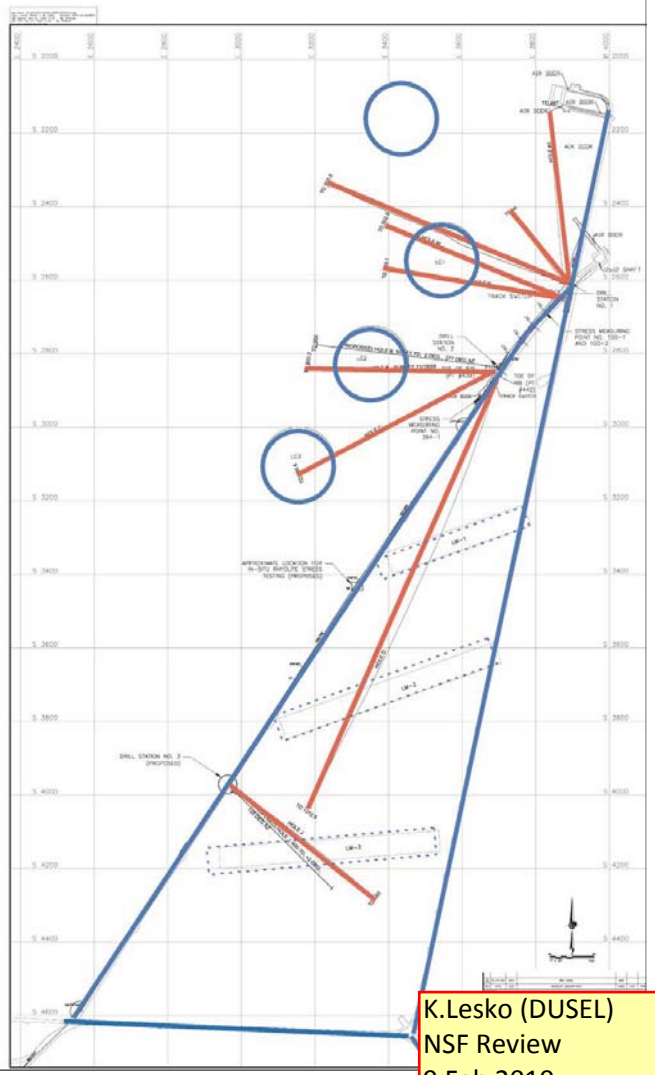
Neutrino Beam off to DUSEL

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

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

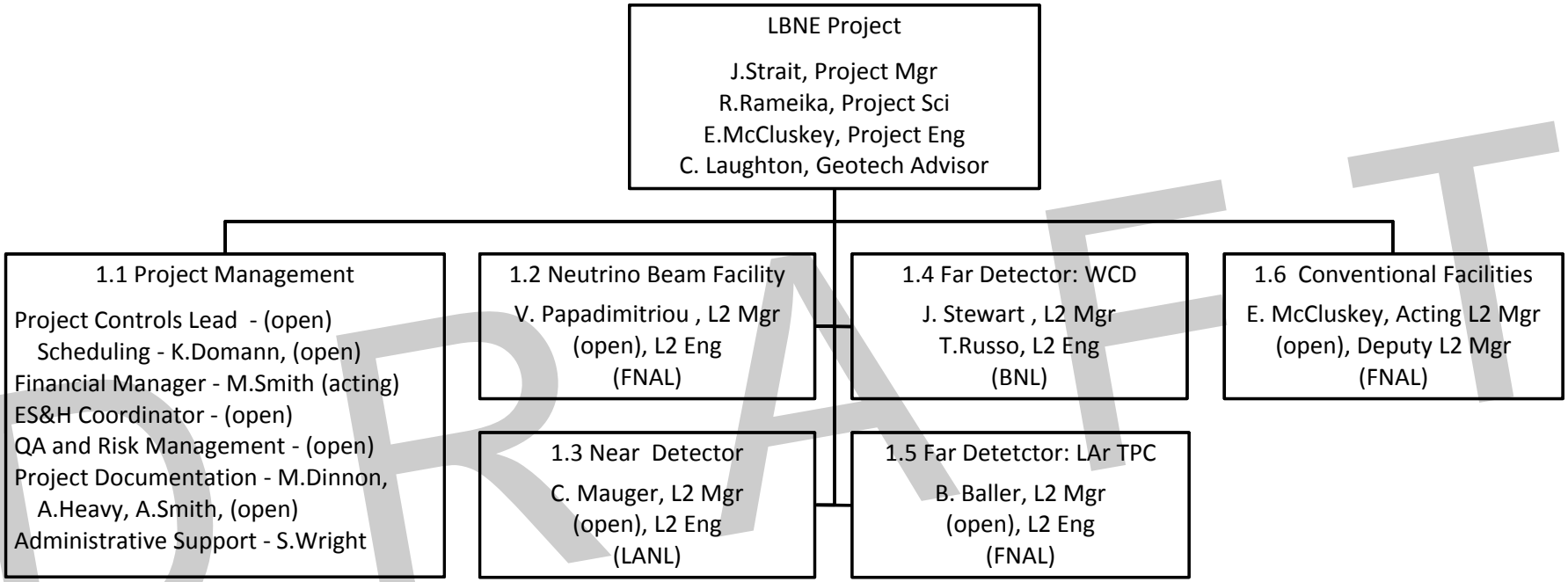


K.Lesko (DUSEL)
NSF Review
9 Feb 2010

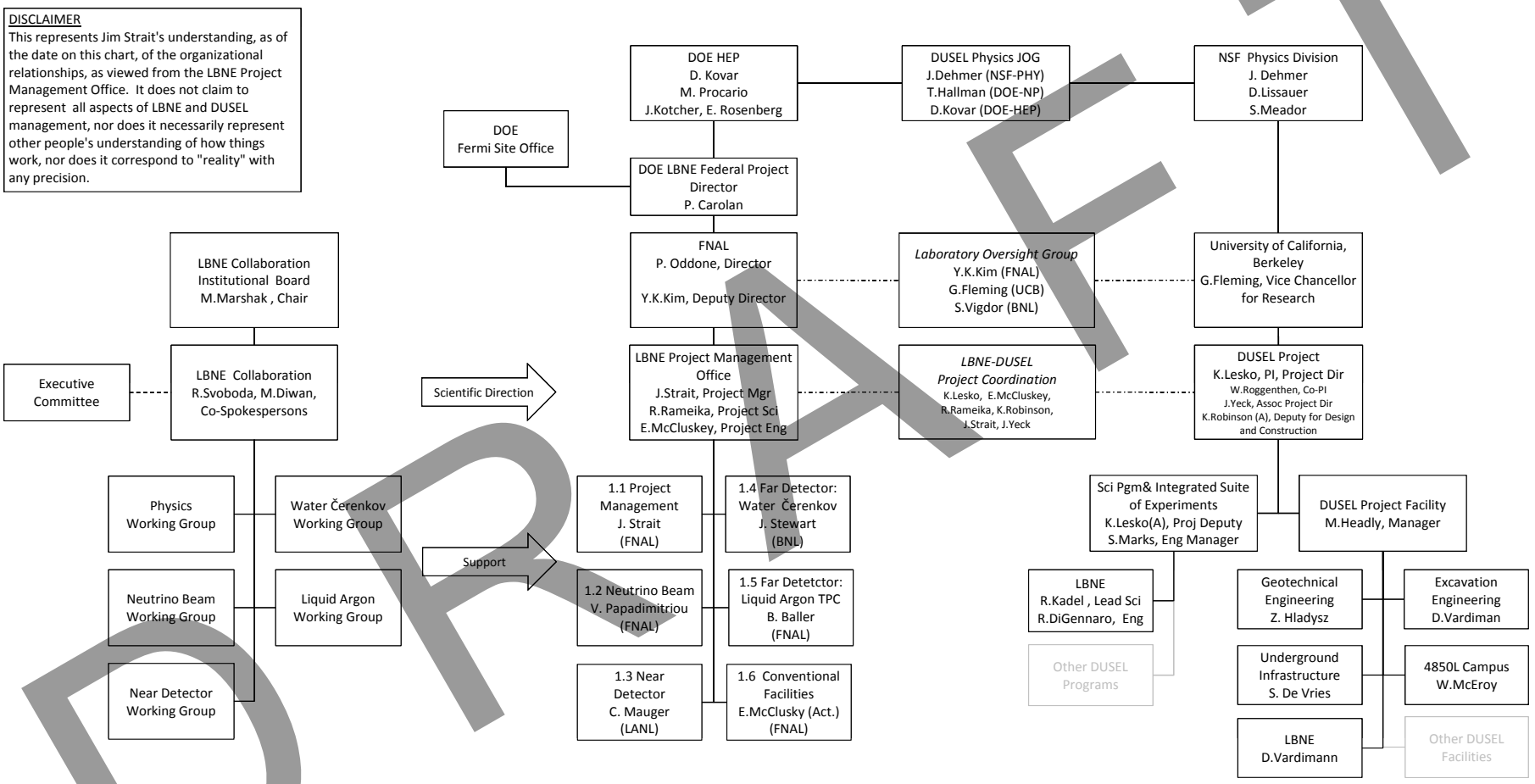
Conventional Facilities Issues

- Management and conceptual work for CF @ Far Site is not part of CD-1 budget plan.
- CF at Far Site is an LBNE responsibility (but an overlap of DUSEL MREFC scope) in DUSEL-owned area – will be working to answer: who is owner of facility, who leads design, who holds contracts, who's responsible for safety, who makes field decisions during construction?
- The challenge to describe CF at Far Site for all detector configurations under development, and be clear about scope, cost and schedule at CD-1.

LBNE Project Office
Organization and Staffing



Organizational Relationships and Interfaces (as I understand them)



Preparing for CD-1

We are aiming at a CD-1 Lehman Review in December 2010.

Conceptual design development is focused on the technical, cost and schedule drivers.

Beam

- o Primary beam – conventional design, well understood
- o Neutrino beam
  - technically challenging, but at the same level as NOvA
  - challenge to design facility to be upgradeable to 2+ MW, without overdoing it.

Near Detector

- o Still developing physics requirements to drive the design
- o Overall scale "1~2 x MINERvA" => not a cost or schedule driver
- o Will probably have several configuration options as of CD-1 => cost range

Preparing for CD-1

Water Cherenkov Detector

- Main drivers (technical, cost, schedule) are water tank, water system, and PMTs – conceptual designs and cost estimates are being developed with industrial consultants.
- Electronics, DAQ, calibrations are getting less attention, but are not technical, cost or schedule drivers for the conceptual design.

Liquid Argon TPC

- Cryostat and cryogenic system designs are being developed with industrial consultants.
- TPC and electronics are the focus of the lab and university groups
- Trigger/DAQ, photon detectors getting less attention, but are not technical, cost or schedule drivers for the conceptual design.

Preparing for CD-1

Conventional Facilities

- Design of on-site (Fermilab) facilities proceeding rapidly.
  => in good shape for Dec
- Will rely on / start from work done by DUSEL for LC1;
  no serious work yet on LC2 and associated excavations and infrastructure.
- Industrial contract in place to make conceptual designs for LAr cavity at 4850L or shallow depth.
- Far site facilities are our major concern for reaching CD-1 quickly:
  - Just defining precisely what this job is for us . . . deteriming LBNE-DUSEL boundaries of responsibilities.
  - No L2 or L3 manager for this task yet.

(Draft) Calendar of Events Towards CD-1

- Detailed outline of CDR – 10 May
- Initial draft sub-project Resource Loaded Schedules – 25 June
- Intermediate draft CDR – 25 June
- Readiness check for CD-1 (internal review) – week of 12 July
- Subproject RLS delivered for compilation by PMO – 16 August
- Final draft CDR, ready for final editing – 13 September
- CD-1 Directors Design Review – week of 20 September
- CD-1 Directors Cost, Schedule and Management Review – week of 25 October

Lehman Review (IPR) – first half of December.

Summary

- LBNE is an ambitious experiment aimed at
  - discovering and measuring CP violation in the neutrino sector
  - proton decay and neutrino astrophysics

- A strong Physics Collaboration and a strong Project Team are being formed to build and execute this experiment, with Fermilab in a leadership position.

- We are aiming for a CD-1 Lehman Review at the end of this year.