LBNE Near Detector Complex Plan

An attempt at a summary based on the following documents from the LBNE ND Review 10/4-5:

- C.Mauger, “Near Detector Overview”, LBNE-doc-2770-v1
- G.(Sam) Zeller, “ND Review 10/4: WBS 1.3.2 Measurement Strategy”, LBNE-doc-2771-v2
- G.Horton-Smith, “ND Review 10/4: Liquid Argon TPC”, LBNE-doc-2778-v1
- K.Lee, “ND Review 10/4: Liquid Argon TPC magnetization”, LBNE-doc-2779-v2
- G.Horton-Smith, K.Lee, and G.Zeller, “LAr Near Detector Physics Key Questions”, LBNE-doc-2821-v1.

The Long-Baseline Neutrino Experiment and Near Detector Complex

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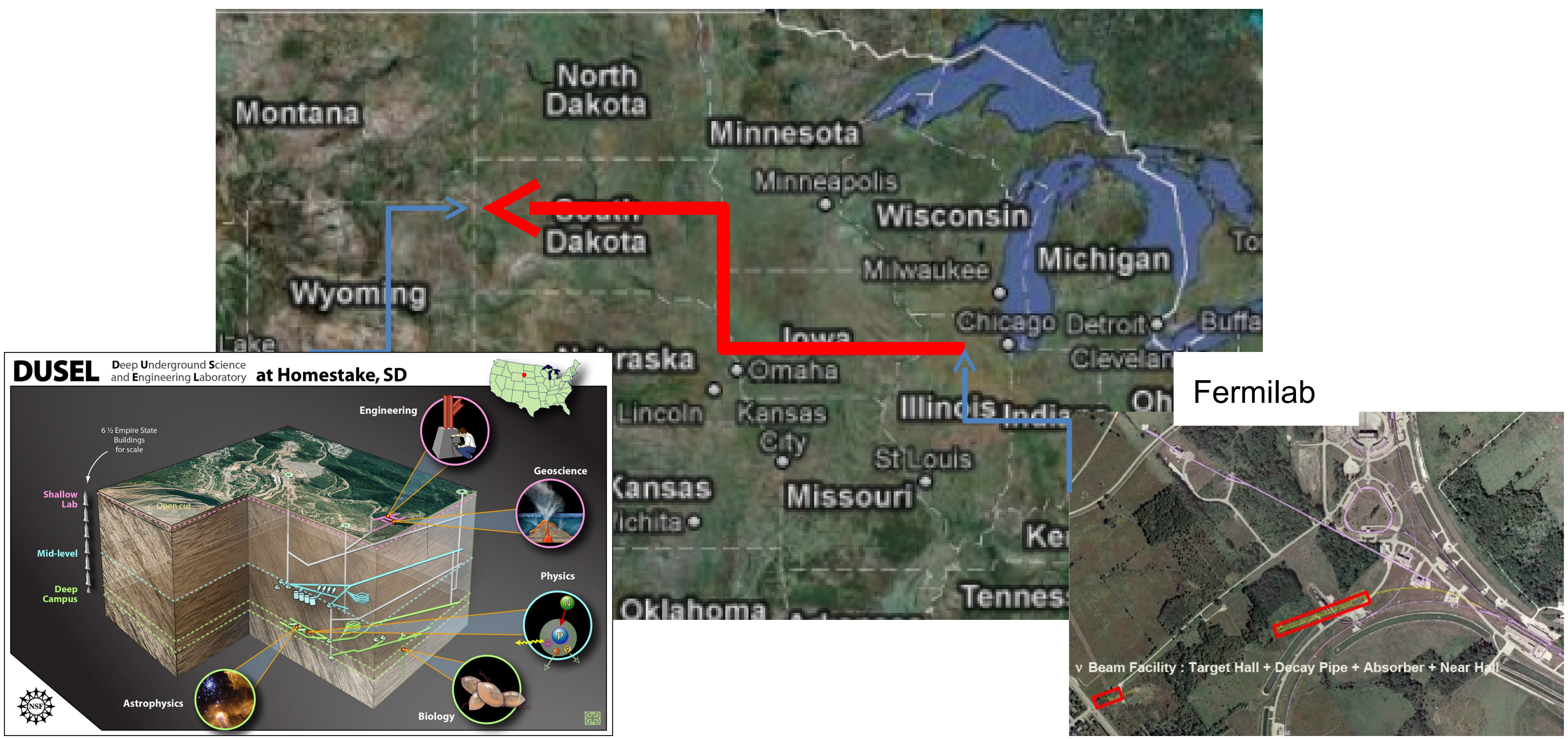
Primary Goals of LBNE

High-sensitivity measurement of ν_μ -> ν_e and $\bar{\nu}_\mu$ -> $\bar{\nu}_e$ oscillations, ν_μ , $\bar{\nu}_\mu$ disappearance

- Measure $\sin^2(2\theta_{13})$ to << 0.01
- Determine the mass hierarchy:
- Search for CP violation in the neutrino sector



Long-Baseline Neutrino Experiment Collaboration

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Kansas State: T. Bolton, G. Horton-Smith

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Minnesota: M. Marshak, W. Miller

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NGA: S. Malys, S. Usman

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Pittsburgh: D. Naples, V. Paolone

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Rensselaer: D. Kaminski, J. Napolitano, S. Salon, P. Stoler

Rochester: R. Bradford, K. McFarland

SDMST: X. Bai, R. Corey

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UCLA: K. Arisaka, D. Cline, K. Lee, Y. Meng, F. Sergiampietri, H. Wang

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Washington: S. Enomoto, J. Kaspar, N. Tolich, H.K. Tseung

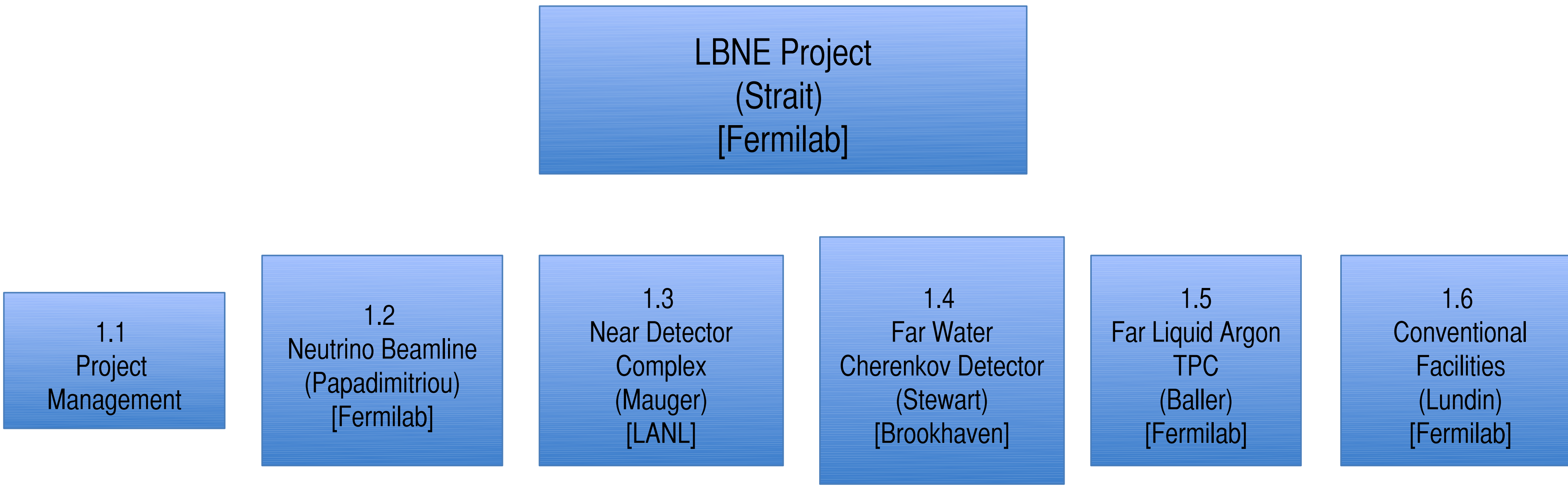
Wisconsin: B. Balantekin, F. Feyzi, K. Heeger, A. Karle, R. Maruyama, D. Webber, C. Wendt

Yale: B. Fleming, M. Soderberg, J. Spitz

262 Scientists and Engineers
59 Institutions
… And still growing!

4 June 2010

LBNE Project WBS

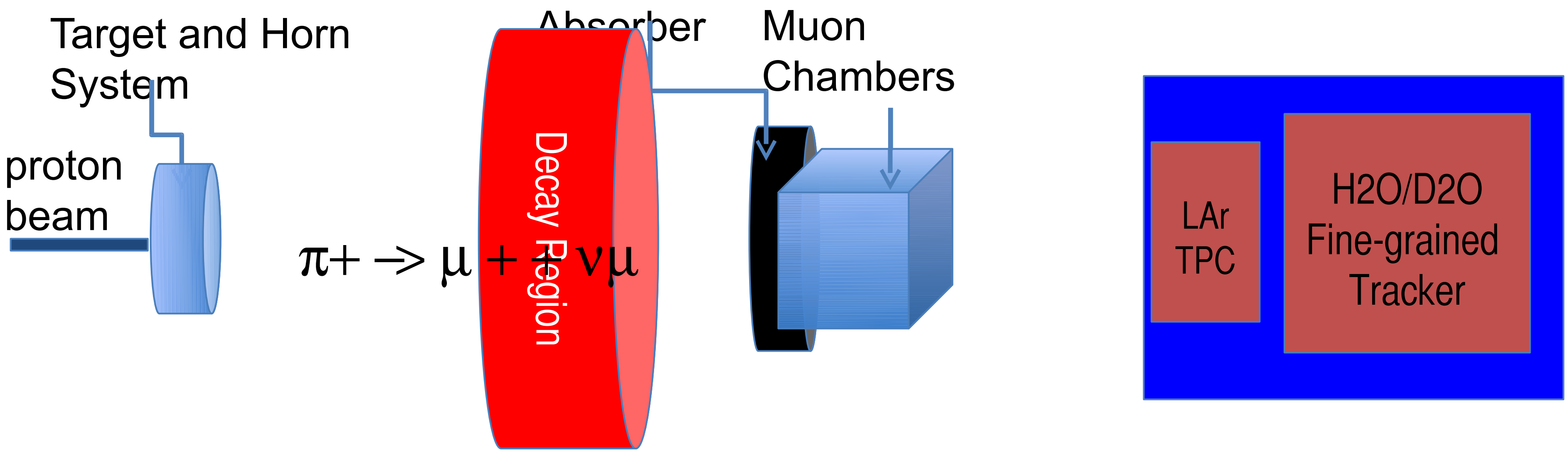


Scope of the Near Detector Complex (WBS 1.3)

Near Detector Complex Design Driven by

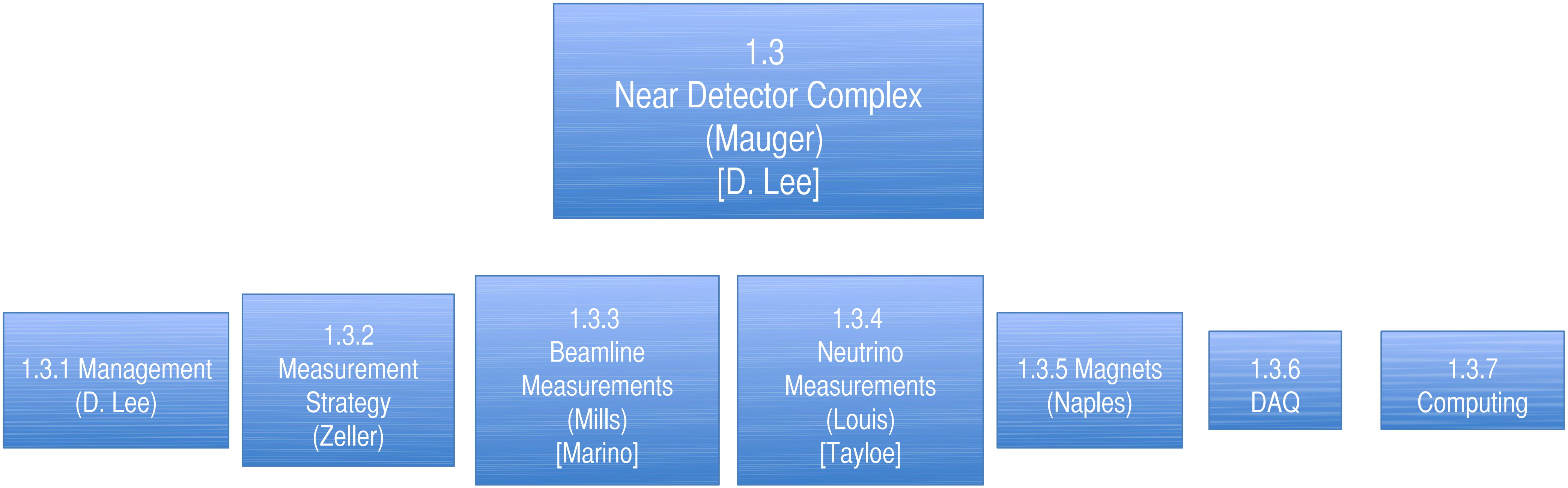
- What is needed for the oscillation analyses?
  - measurements of the neutrino fluxes: ability to predict the fluxes at the far site for any oscillation scenario
  - measurements of cross-sections/event rates of important processes: ability to predict signal and background rates and topologies
  - measurement of the stability of the neutrino beam
- How do we achieve this for the lowest cost?
- Basic Philosophy: NDC performance should not limit the sensitivity of the long-baseline experiment,
  - in the context of a ($1 billion), losing significant sensitivity to δCP to save a few $million on the NDC complex is unlikely to be a good bargain

Near Detector Complex Scope and Working Group



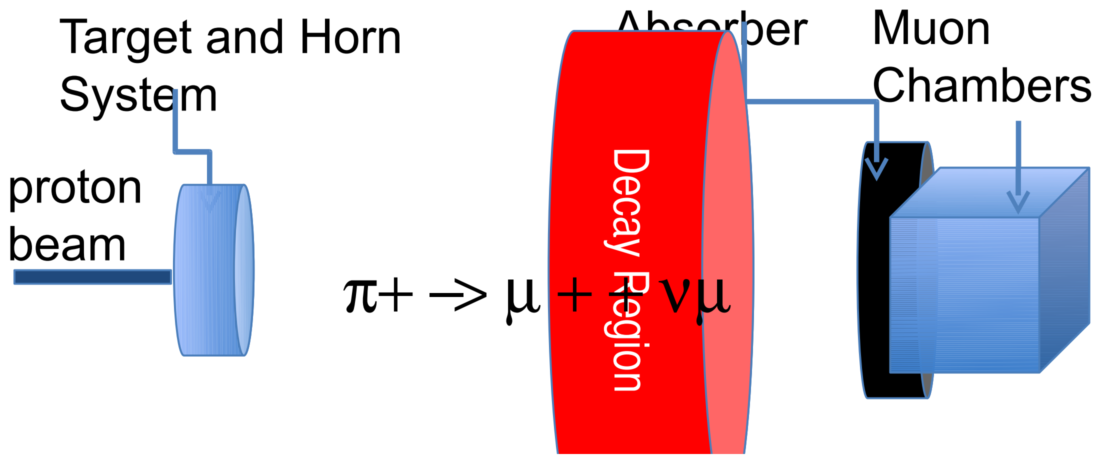
- BNL: Mary Bishai
- UCLA: David Cline, Kevin Lee
- Colorado: Alysia Marino, Eric Zimmerman
- Fermilab: Jorge Morfin, Ray Stefanski, Sam Zeller
- Indiana: Rex Tayloe
- Kansas State: Glenn Horton-Smith, Tim Bolton

NDC Organization and Staff ng



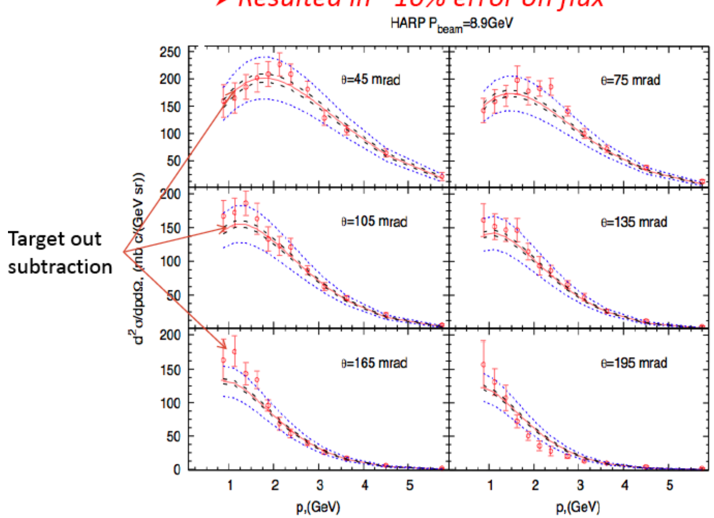
- LANL is the lead institution with strong university support
- Beamline Measurements and Neutrino Measurements are the primary technical elements
- Magnets separated out to ensure appropriate attention for potentially signif cant cost and schedule driver
- Measurement Strategy is funded off project but absolutely critical to our ability to reach CD-2

Beamline Measurements: Neutrino fluxes, neutrino beam monitoring



•Bottom Line:
- ~5% error on cross section
- *Resulted in ~10% error on flux*

HARP collaboration, hep-ex/0702024



Measurements to constrain the ν fluxes

- In-situ measurement
  - Particle fluxes extreme: > 108/cm2-spill
  - High precision unlikely
  - Currently, in-situ hadron measurements not being pursued
- External measurements
  - HARP (above π+ production for

Measurements to Monitor the ν beam

- Muon Ionization

Neutrino Measurements

- Due to large cross-section uncertainties in the few hundred MeV to few GeV neutrino energy regime on nuclear targets, we must measure event rates and topologies on whatever the nuclear targets are at the far site:
  - H2O
  - Argon
- Water
  - Reuse Minerva wholesale or with minor upgrades
  - Low-density, very fine-grained tracker – straw tubes (ATLAS-based design)
- Argon
  - Reuse MicroBooNE – or base design on MicroBooNE
  - New detector – smaller detector we could magnetize
- Neutrino flux measurement
  - few well-known cross-sections – quasielastic scattering at low momentum transfer on hydrogenic targets
  - Designing water targets for cross-section and event topology measurements – try H2O and D2O for this measurement

Measurement Strategy

- Deﬁne the measurements required at the near site to meet the goals of the long-baseline neutrino oscillation analyses
- How well must we measure and predict the neutrino ﬂuxes?
- How well must we predict signal and background rates and topologies?
  - what measurements must be made to accomplish these predictions?
  - charged current background and signal – extracting the neutrino ﬂux at the far site
  - neutral current background

Reference Design

- Philosophy: Choose designs with the maximum capabilities
- Beamline – include all three detection systems under consideration
  - Profile monitor
  - Threshold Cherenkov detector
  - Michel decay detector
- Neutrino – include both a water and liquid argon detector
  - Fine-grained tracker: straw-tube based tracker
  - Liquid Argon TPC: MicroBooNE design
- Cost: $55 million (~$72 million with contingency)

Risks

- As the RLS development continues, our list of risks will expand, but major risks are identified
- Major Risks:
  - Financial:
    - Non-costed labor required for the Measurement Strategy (requirements for preliminary design) and other parts of the sub-project (preliminary design)
  - Safety
    - Liquid Argon impact on Conventional Facilities – work getting underway to understand this, define our safety plan
  - Technical:
    - R&D required to validate methods to measure the neutrino fluxes
    - Will the far/near spectral ratio limit the sensitivity of LBNE?
  - Organizational
    - Availability of detector components from MicroBooNE, Minerva, MINOS

Major Interfaces

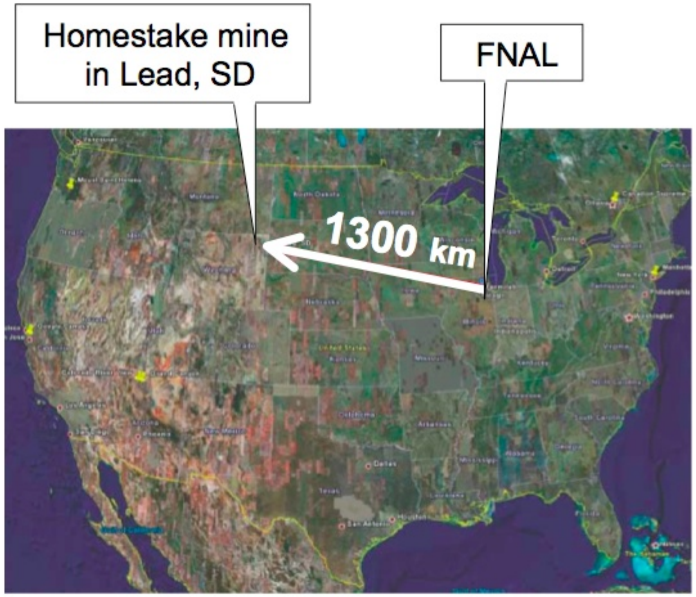
- Beamline Measurements – interface with Conventional Facilities and Beamline Sub-project (absorber)
- Neutrino Measurements – interface with Conventional Facilities
  - Safety impact on civil construction of the neutrino hall
    - Move to single shaft design?
    - Cryogenic safety
  - Power and other services requirements

Measurement Strategy
WBS 1.3.2

• encompasses the **physics studies** and simulations needed to **finalize the NDC requirements** & specifications for CD-2

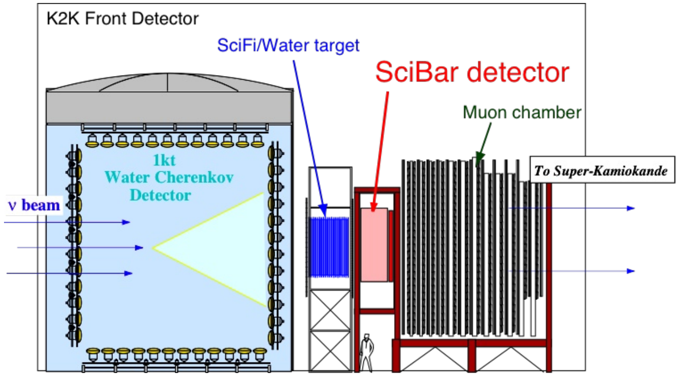
- serves as a point of connectior oscillation physics in the FD

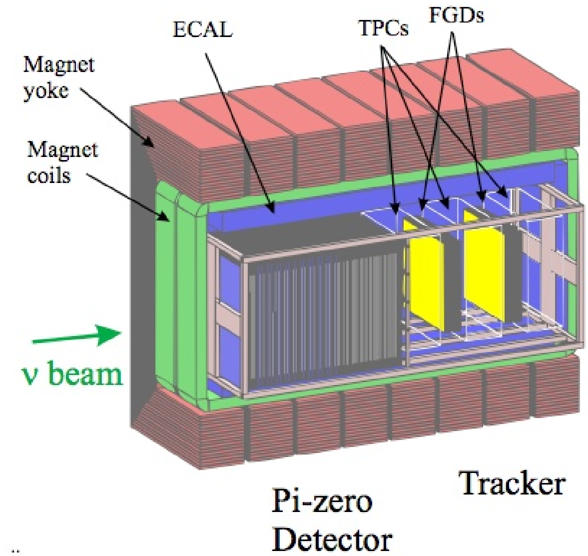
- somewhat unique to have this added as an explicit WBS element, but want a clear plan for how physics program will impact eventual CD-2 baseline ND design



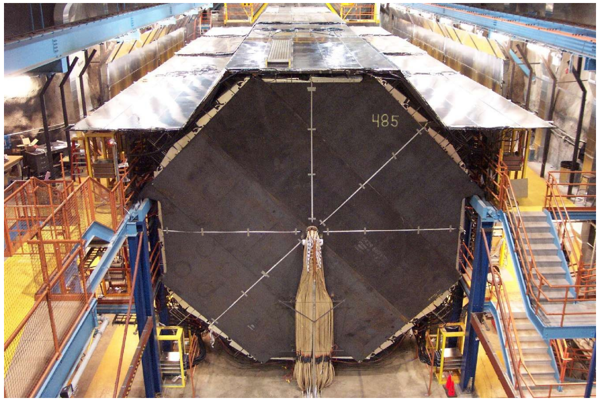
Other ν Experiments

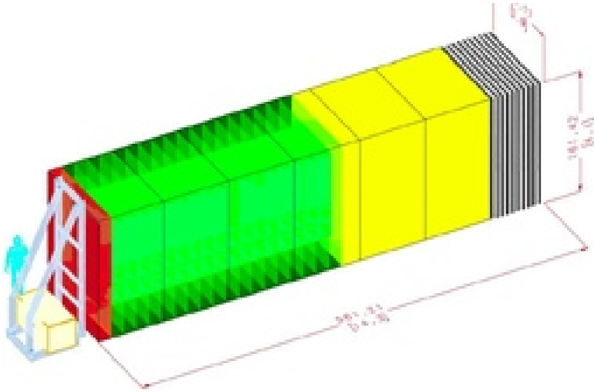
- K2K
- T2K





- MINOS
- NOvA





- strategies couple ν interaction and beamline measurements

LBNE

- demands on the LBNE near detector will be even greater
- level of ν oscillation precision to be achieved is much higher than will have been met prior to this (T2K, NOvA)

- measurement of $\nu_\mu \to \nu_e$ and $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations
  - $\sin^2 2\theta_{13}$ sensitivity down to 10^{-3}
  - ν mass ordering
  - CP phase measurement down to $\sim 20^0$

WBB, 1300km
200kt WCE
5+5 yrs $\nu + \bar{\nu}$
700 kW beam

- precise measurement of oscillation parameters in ν_μ and $\bar{\nu}_\mu$ disappearance
  - $\delta(\Delta m^2_{32})$ to few-%, $\delta(\sin^2 2\theta_{23}) < 1\%$ (both ν, $\bar{\nu}$)

Purpose

- main objective is to develop the <u>detailed requirements</u> for the functionality and performance of the NDC, as determined by the <u>scientific needs</u> of the experiment

- must <u>define how the ND data will be used</u> in the FD oscillation analysis in order to determine what the specific requirements for the NDC are

  - what do we need to measure
  - how well do we need to measure it?
  } FD dependent

- ensure that the FD is not systematics-limited

Generic Requirements

- ND will measure ν 's before they've had a chance to oscillate
- the ND should:

  - *possess sufficient containment, resolution, and tracking capability to separately identify classes of events of interest for the FD detector analyses as a function of energy*

    - ν_μ $\bar{\nu}_\mu$ $\bar{\nu}_e$ ν_e
    - *NC and CC*

  - *incorporate the same target material as the FD*
  - *include the means to separately identify* ν *and* $\bar{\nu}$
  - *be capable of accurately predicting differences in the* ν *energy spectra that are expected between the ND and FD*
  - *be able to uncover and quantify any background process that could interfere with the signal at the FD*

Questions

- these requirements lead to the following ND design questions:

  - *what is the required fiducial mass and material of the ND?*

  - *what, if any, is the required strength and extent of a magnetic field at the ND?*

  - *what is the required granularity/sampling and resolution of the ND?*

- we have a good idea of what we need to build and we have a variety of options

- next step: refine these requirements → final technical design

  - *treatment of systematic uncertainties in FD oscillation sensitivity projections has been fairly simple up to now*

- studies will directly couple FD oscillation analyses to ND design

Measurement Strategy Requirements

• identify specific sources of systematic uncertainty that must be addressed by the ND and quantify measurement accuracy

- intrinsic ν_e component of the beam
- NC π^0 and NC γ

} ν_e appearance

- un-oscillated ν_μ spectrum
- NC $\pi^{+/-}$ and CC π production

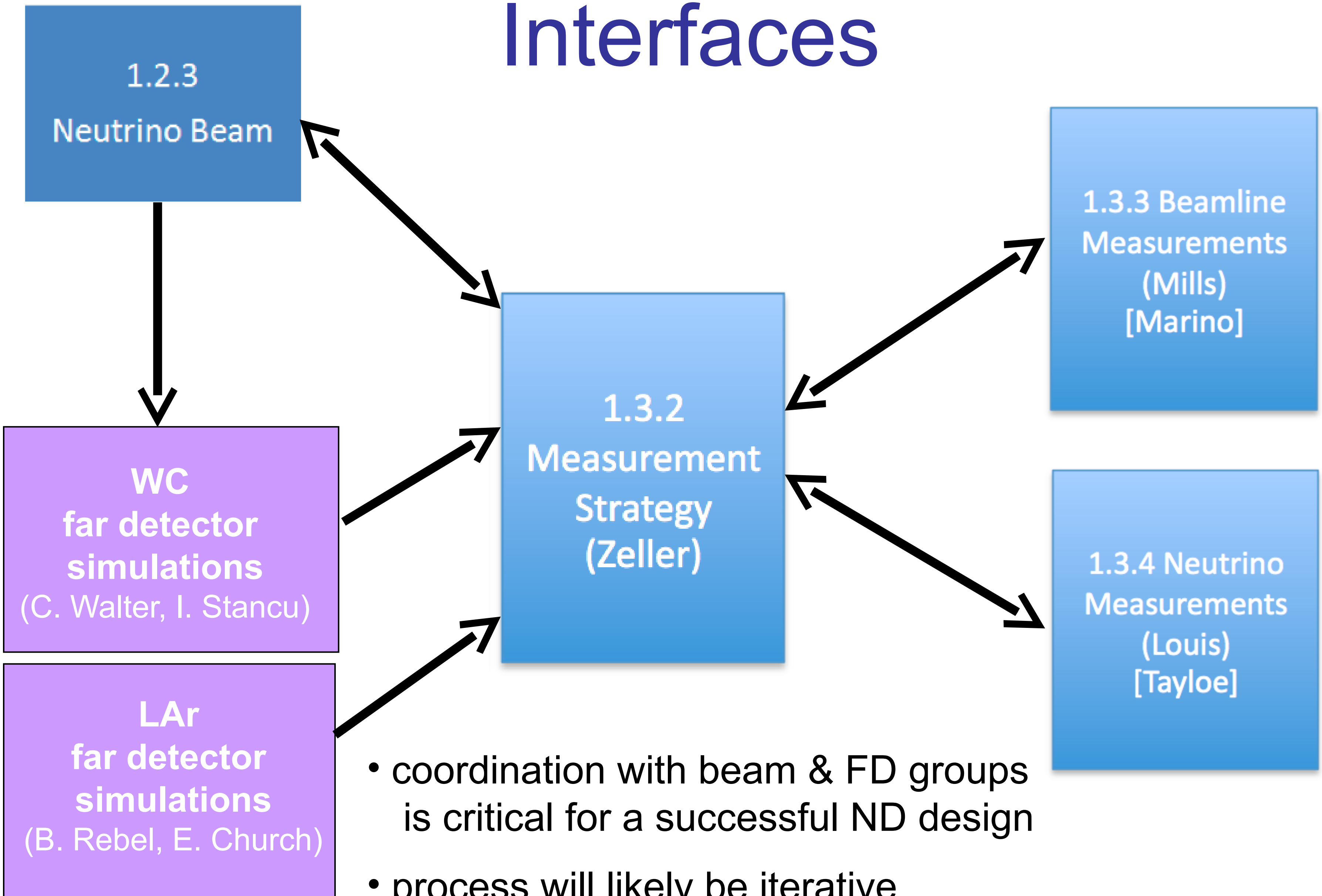
} ν_μ disappearance

- absolute neutrino flux $\longleftrightarrow$ $\sigma(\nu)$

} all of the above + spectral differences

• the performance of the FD & expected ν beam plays a crucial role in establishing what has to be measured and how well

Interfaces



- coordination with beam & FD groups is critical for a successful ND design
- process will likely be iterative

Overall Strategy

- the challenge of course is that the ND measures
  ν event rate = [ν flux] * [ν interaction cross section]

- ND measurement strategy couples:

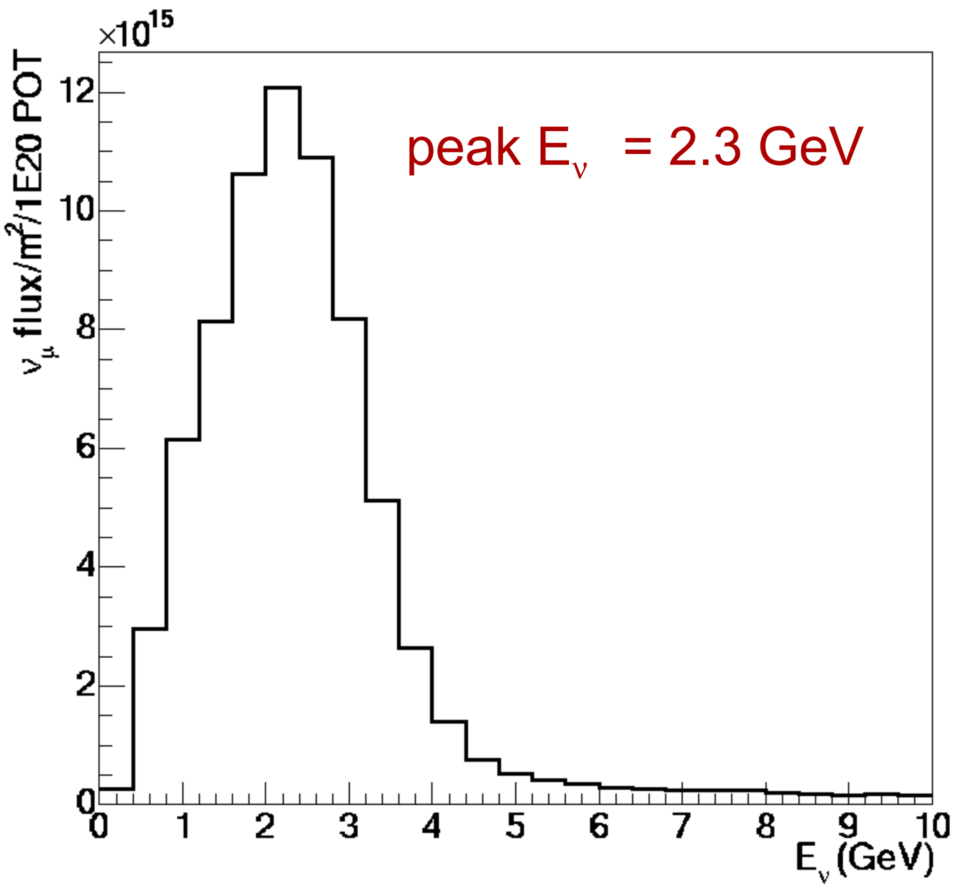
  - **dedicated ν flux measurements**
    - external hadron production measurements
    - in-situ beamline measurements
    - ν processes with well-known σ_ν

  - **ν interaction measurements**
    - ν & ν measurements on same nuclear targets as FD (H_2O, Ar)

1.3.3 Beamline Measurements
(Mills)
[Marino]

1.3.4 Neutrino Measurements
(Louis)
[Tayloe]

Near Detector Neutrino Flux



near detector event rates

	neutrino mode	antineutrino mode
ν_μ	92%	44%
$\bar{\nu}_\mu$	7%	55%
ν_e	1%	0.7%
$\bar{\nu}_e$	0.1%	0.5%

1% ν_e

- 99% muon-flavor beam
- in $\bar{\nu}$ mode, about a 50/50 mix of ν_μ and $\bar{\nu}_\mu$

Near Detector Events

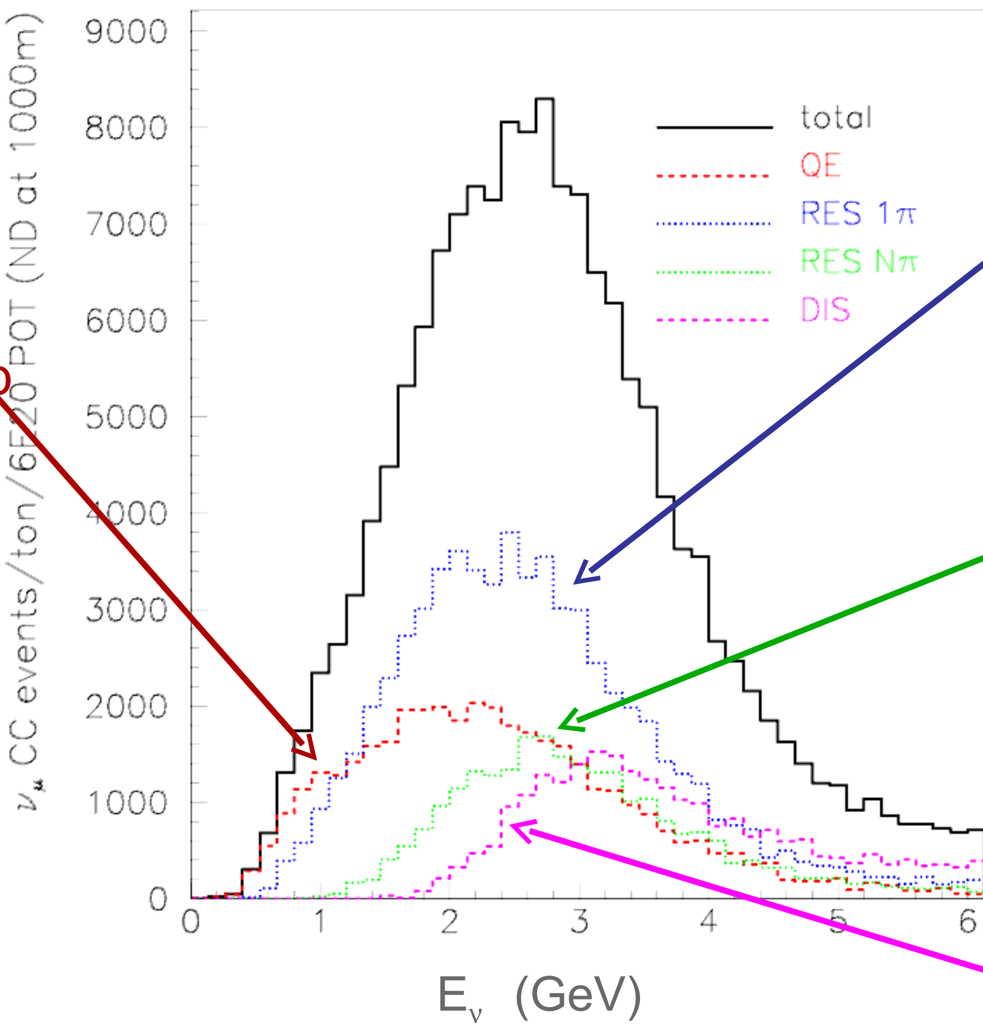
expected # ND events per ton H_2O
per $1x10^{20}$ POT in neutrino mode running

production mode	# ν_μ events	# $\overline{\nu}_\mu$ events
CC QE ($\nu_\mu n \to \mu^- p$ or $\overline{\nu}_\mu p \to \mu^+ n$)	18,977	1,336
NC elastic ($\nu_\mu N \to \nu_\mu N$ or $\overline{\nu}_\mu N \to \overline{\nu}_\mu N$)	7,094	436
CC resonant π^+ ($\nu_\mu N \to \mu^- N \pi^+$)	25,821	0
CC resonant π^- ($\overline{\nu}_\mu N \to \mu^+ N \pi^-$)	0	1,393
CC resonant π^0 ($\nu_\mu n \to \mu^- p \pi^0$ or $\overline{\nu}_\mu p \to \mu^+ n \pi^0$)	6,308	462
NC resonant π^0 ($\nu_\mu N \to \nu_\mu N \pi^0$ or $\overline{\nu}_\mu N \to \overline{\nu}_\mu N \pi^0$)	6,261	421
NC resonant π^+ ($\nu_\mu p \to \nu_\mu n \pi^+$ or $\overline{\nu}_\mu p \to \overline{\nu}_\mu n \pi^+$)	2,694	202
NC resonant π^- ($\nu_\mu n \to \nu_\mu p \pi^-$ or $\overline{\nu}_\mu n \to \overline{\nu}_\mu p \pi^-$)	2,325	163
CC DIS ($\nu_\mu N \to \mu^- X$ or $\overline{\nu}_\mu N \to \mu^+ X$, $W > 2$)	29,989	2,815
NC DIS ($\nu_\mu N \to \nu_\mu X$ or $\overline{\nu}_\mu N \to \overline{\nu}_\mu X$, $W > 2$)	10,183	1,109
NC coherent π^0 ($\nu_\mu A \to \nu_\mu A \pi^0$ or $\overline{\nu}_\mu A \to \overline{\nu}_\mu A \pi^0$)	790	87
CC coherent π^+ ($\nu_\mu A \to \mu^- A \pi^+$)	1,505	0
CC coherent π^- ($\overline{\nu}_\mu A \to \mu^+ A \pi^-$)	0	169
NC resonant radiative decay ($N^* \to N\gamma$)	41	3
NC elastic electron ($\nu_\mu e^- \to \nu_\mu e^-$ or $\overline{\nu}_\mu e^- \to \overline{\nu}_\mu e^-$)	11	2
IMD ($\nu_\mu e^- \to \mu^- \nu_e$)	6	0
other	17,023	1,355
all CC	94,948	7,144
total (NC+CC)	129,028	9,953
wrong-sign fraction		7.2%

- expect to collect about 1M total events/ton/yr in ν mode, 700 kW (~6M total/ton/yr in $\overline{\nu}$ mode)
- 0.1 events/ton/spill
- high event rates
- rate in 10 ton ND will be ~200x larger than the 200 kton FD

Event Composition

- operating in a complex energy region



QE (quasi-elastic)
$\nu_\mu n \rightarrow \mu^- p$

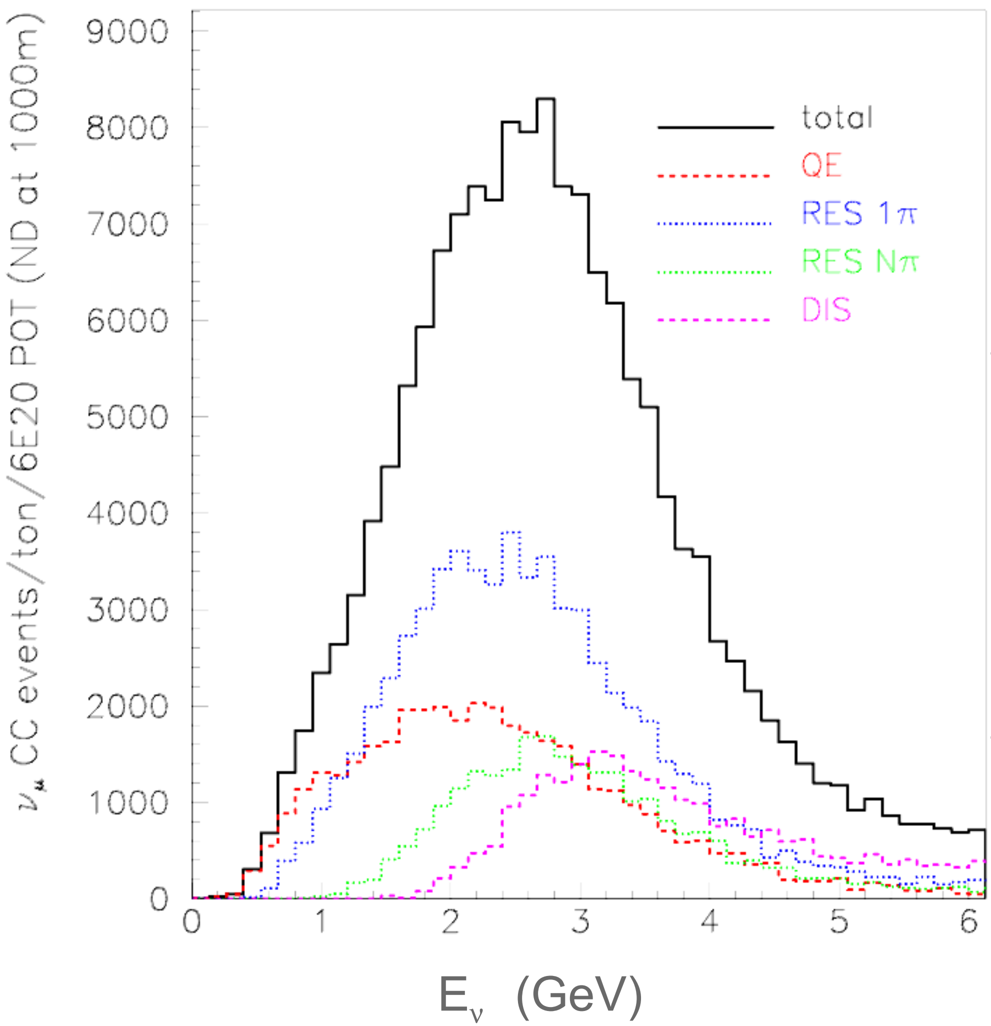
single pion production
$\nu_\mu p \rightarrow \nu_\mu N^*$, $N^* \rightarrow p \pi^0$

multi-pion production
$\nu_\mu n \rightarrow \nu_\mu N^*$, $N^* \rightarrow n \pi^0 \pi^0$

deep-elastic scattering
$\nu_\mu n \rightarrow \mu^- X$

Motivation

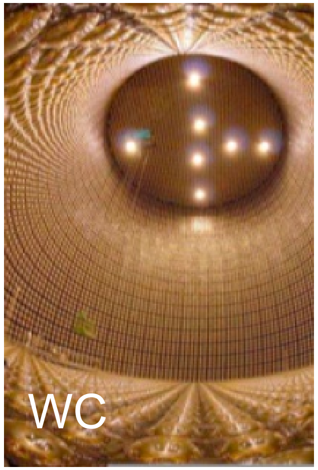
- operating in a complex energy region

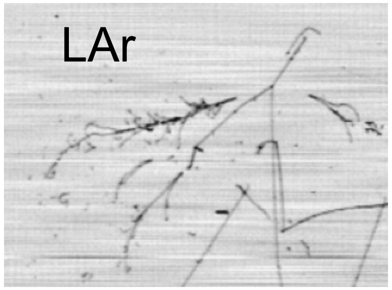


- large σ_ν uncertainties in this E range (~10-50%)
- complicated by transition region and nuclear effects!
- will have more information (MINERνA, μBooNE, T2K, NOvA)

Key Assumptions

- the driving physics considerations for the NDC are the LBL ν oscillation analyses



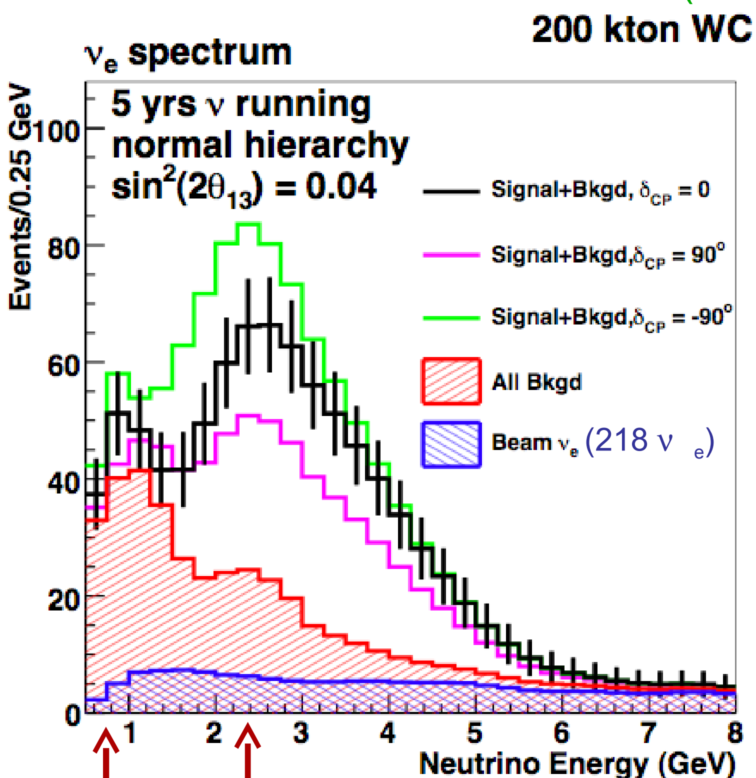


- the FD complex is composed of both a WC detector and a LAr TPC
- there will be 2 NDs: an upstream LAr detector for measuring ν interactions in argon and a downstream fine-grained tracker for measuring ν interactions in water.
- the NDC will be exposed to both ν and $\bar{\nu}$ mode beams

ν_e Appearance

- $\nu_\mu \rightarrow \nu_e$

(L. Whitehead)



2nd osc max
0.8 GeV

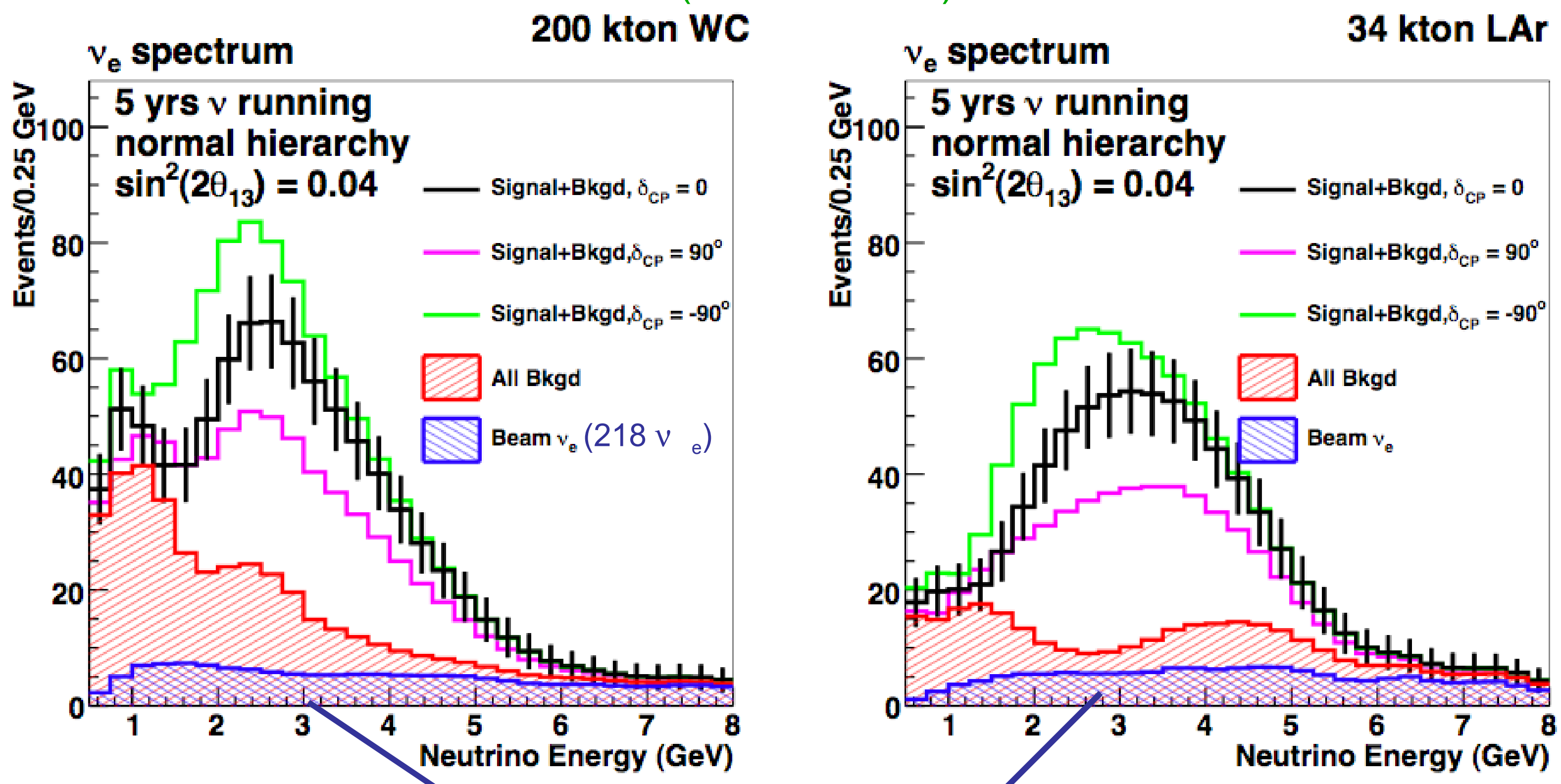
1st osc max
2.4 GeV

- θ_{13}
- ν mass ordering
- CP violation

ν_e Appearance

- $\nu_\mu \rightarrow \nu_e$

(L. Whitehead)

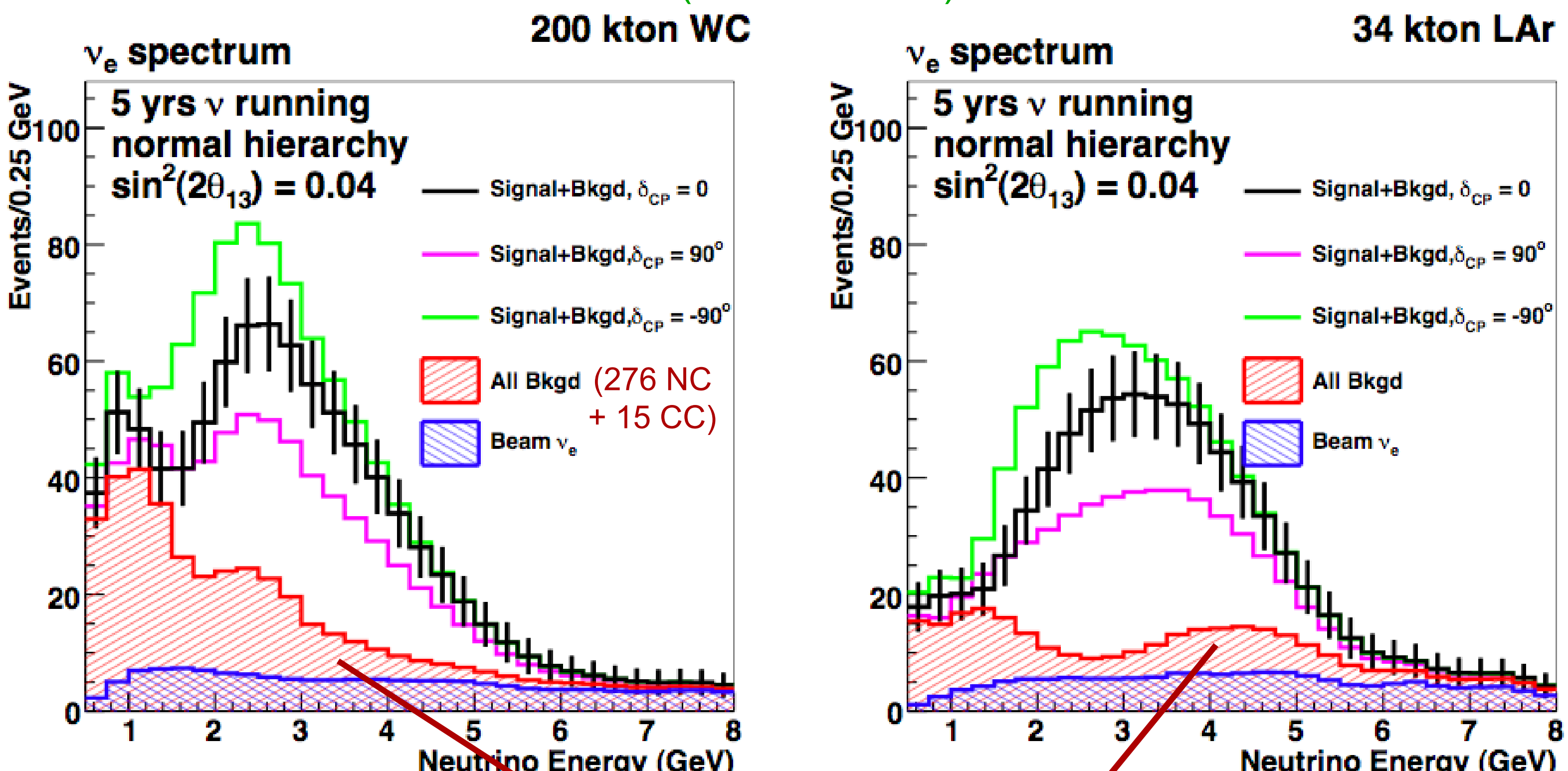


beam ν_e's
(irreducible)

ν_e Appearance

- $\nu_\mu \rightarrow \nu_e$

(L. Whitehead)



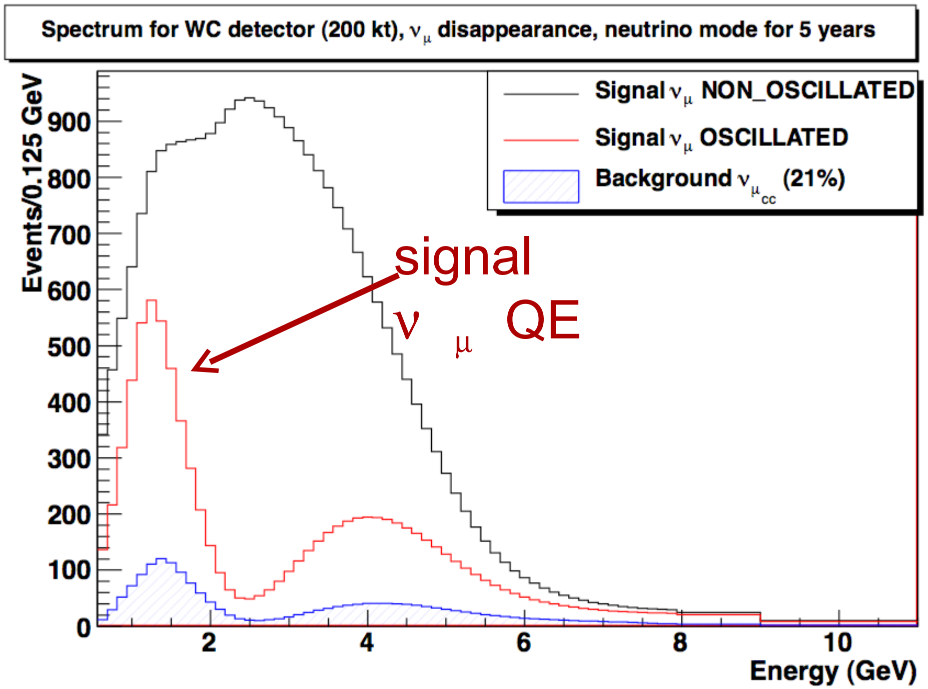
mis-identified ν_μ

- NC (π^0, γ)
- CC

ν_μ Disappearance

- $\nu_\mu \rightarrow \nu_x$

(R. Guenette)



- Δm^2_{32}
- $\sin^2 2\theta_{23}$

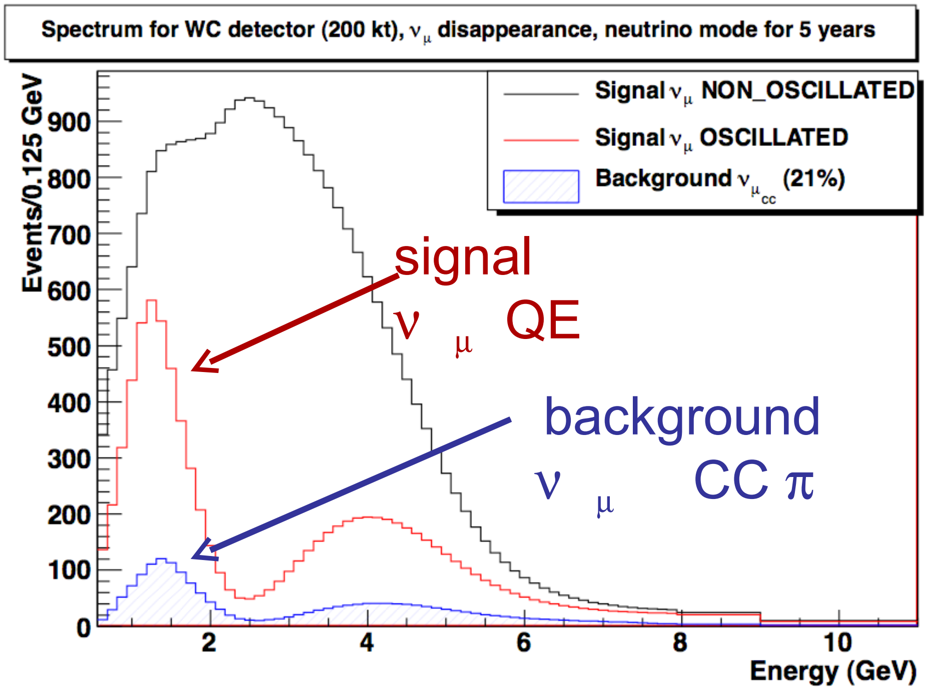
- typically ν_μ QE signal sample ($\nu_\mu n \rightarrow \mu^- p$)

$$E_\nu^{rec} = \frac{M_n E_\mu - 1/2(M_\mu^2 + M_p^2 - M_n^2)}{M_n - E_\mu + P_\mu \cos\theta}$$

ν_μ Disappearance

- $\nu_\mu \rightarrow \nu_x$

(R. Guenette)



- Δm^2_{32}
- $\sin^2 2\theta_{23}$

- typically ν_μ QE signal sample ($\nu_\mu\, n \rightarrow \mu^- p$)

$$E_\nu^{rec} = \frac{M_n E_\mu - 1/2(M_\mu^2 + M_p^2 - M_n^2)}{M_n - E_\mu + P_\mu \cos\theta}$$

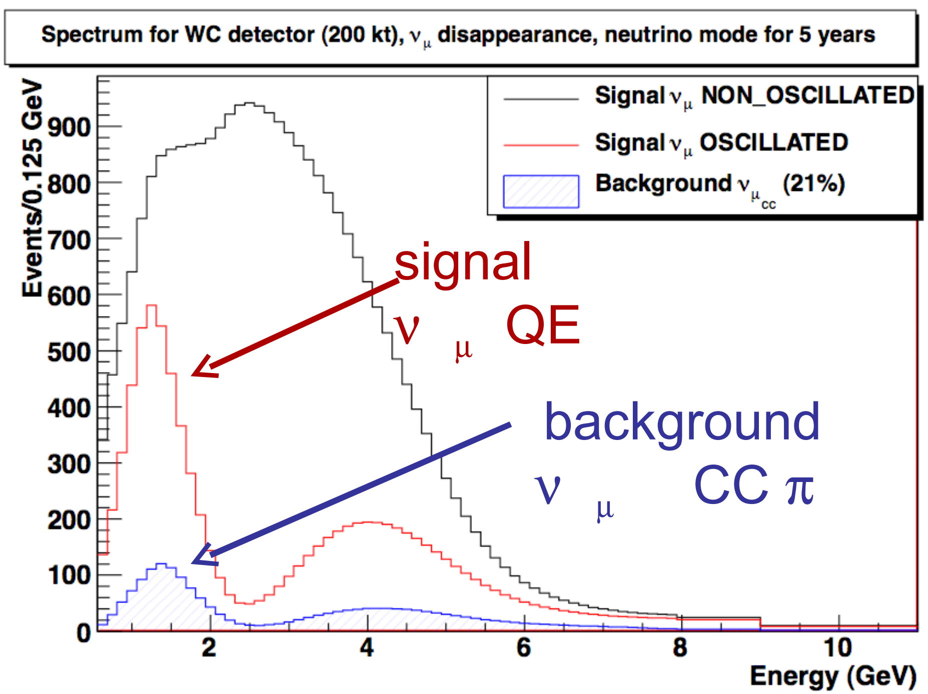
- there will always be bkgs from other types of ν ints, when reconstructed with QE kinematics, these events will give an incorrect E_ν

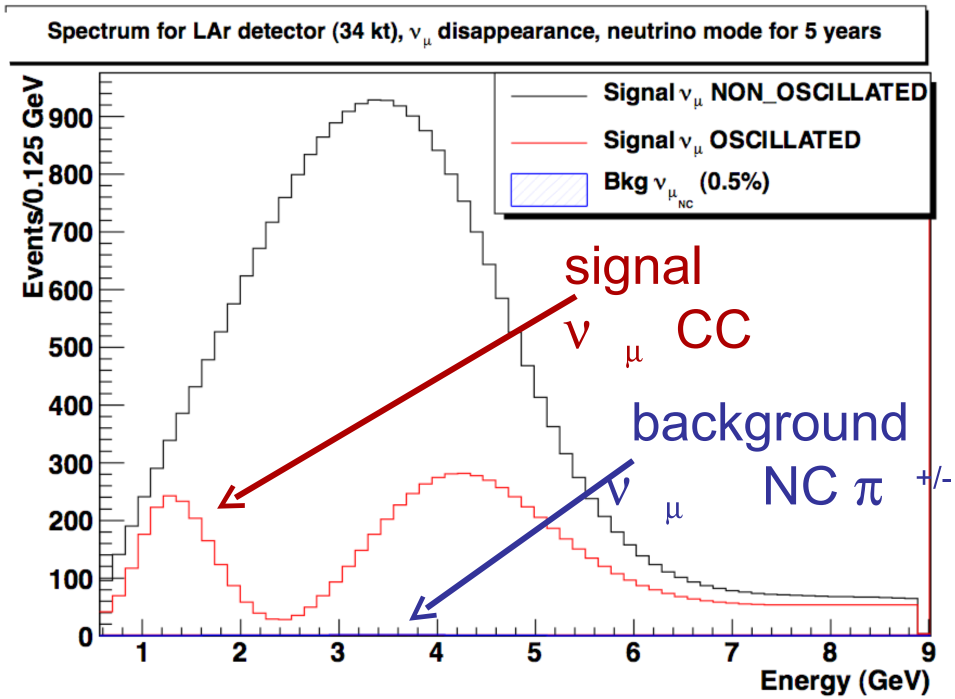
- need to carefully measure # of non-QE in the sample

ν_μ Disappearance

- what ND will need to measure will depend on FD strategy

(R. Guenette)





E_ν ~ 0.5 - 6 GeV

LAr TPC Near Detector

Glenn Horton-Smith

LBNE Near Detector Review
Breakout Session
2010/10/05

Contents

- Scientific context: what we know, why we need this
- Details of the conceptual design
- R&D plans
- Resource Loaded Schedules *(RLS)*
- Risk

Things we know

- LAr TPC w/ 3 mm wire spacing provides 3 mm or better 3-d spatial resolution, better than an unsegmented water-Cerenkov.
- This is the resolution required to properly identify pi-0 and gammas from neutrino interactions, important for eliminating background to nu-e appearance.
- For these reasons, a very large LAr TPC is seen as a good option for the far detector. (Reference plan.)
- There are uncertainties in all cross-sections on both LAr and H2O (see Sam Zeller's talk).
- Therefore, **we plan to measure beam-flux-times-cross-section at the near detector in the same materials as used at the far detector**.

Differences between H2O vs LAr, near vs. far

- An unsegmented LAr TPC near detector can get the resolution required to separate nu-e interactions from nu-mu with π^0, γ final states. With H2O, the near and far detectors are less similar.
- Size of the near detector is limited by interaction rate and near hall size: unlike far detector, near LAr TPC won't fully contain many muons.
- Near hall will have a fine-grained tracker downstream of the LAr TPC, unlike far detector.
- Magnetization is possible at near detector, either of LAr TPC itself (UCLA design) or of downstream tracker.

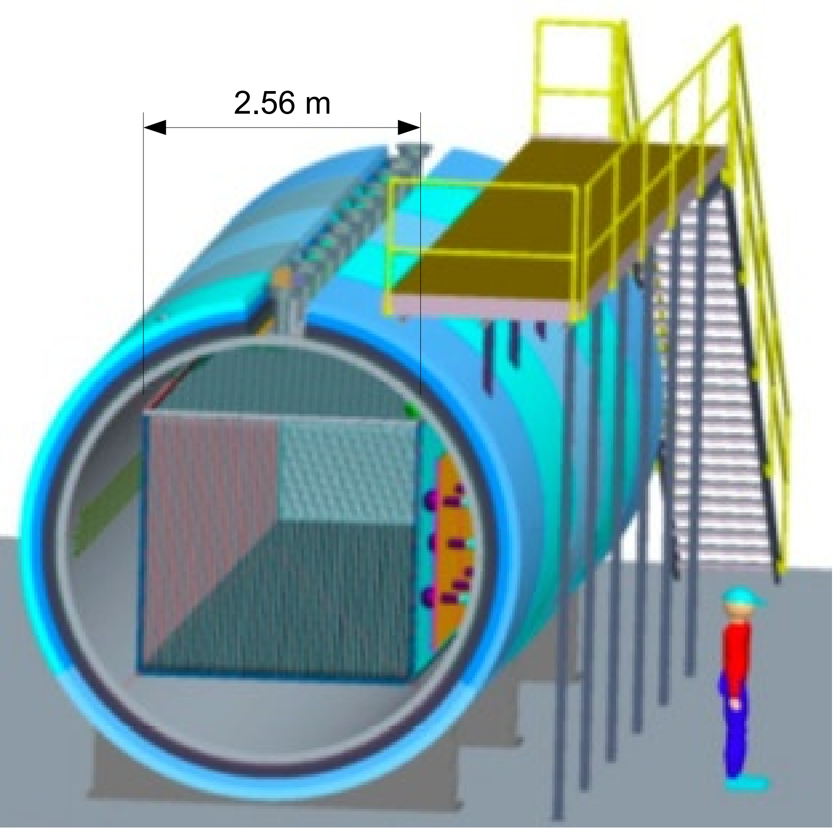
Concept

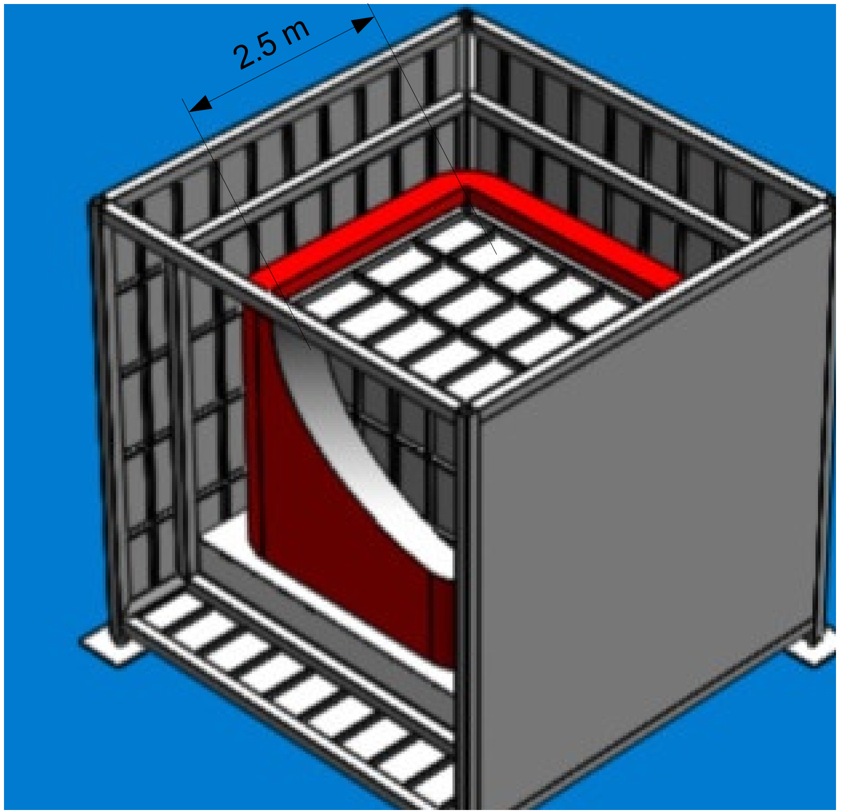
- Two main options in CDR:

  (1) “70 ton unmagnetized” (MicroBooNE design)

  (2) “20 ton magnetized” (UCLA design)

- “Reference design”: (1) “70 ton unmagnetized”



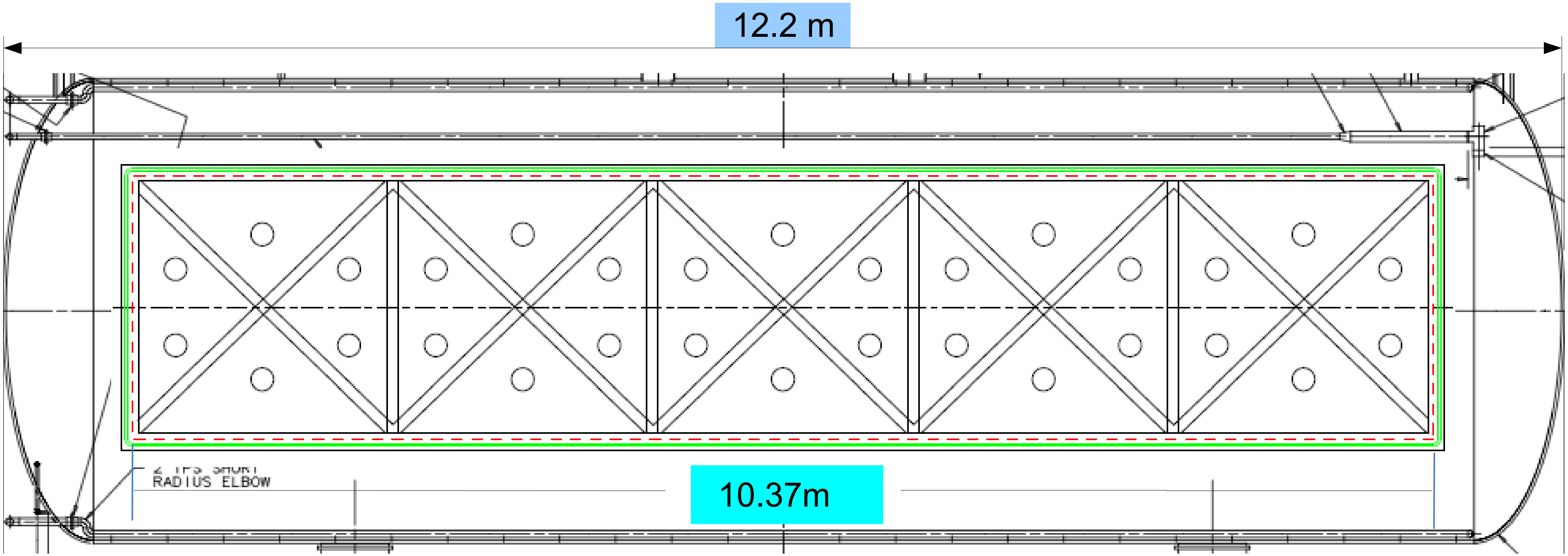


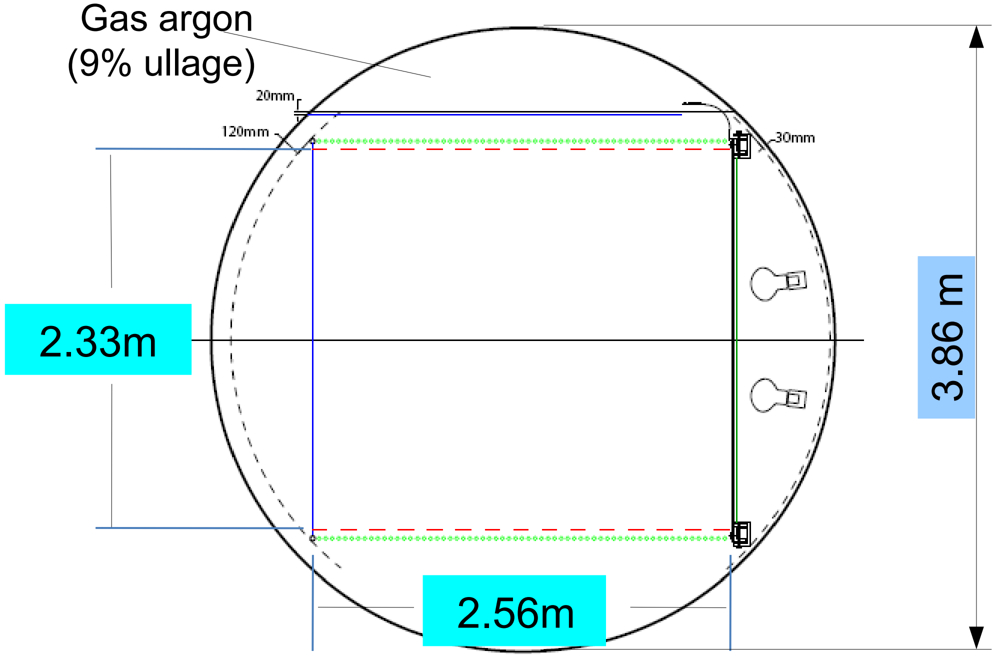
Range of options

		70-ton				20-ton
		unmagnetized			magnetized	
	MicroBooNE (original)	Move MicroBooNE	**Reuse MicroBooNE, new cryostat**	**All new MicroBooNE (reference)**	µBooNE-scale TPC, modular cryostat	**Modular, magnetized TPC**
Cryo systems	☺	~0	~0	new HW	new HW	new HW
Cryostat	☺	0	new HW	new HW	**all new**	**all new**
TPC	☺	0	0	new HW	**all new**	**all new**
Digit+DAQ	☺	0	0	new HW	new HW	new HW
De-install/move	-	**all new**	**all new**	**-**	-	-
Magnet	-	-	-	**-**	**all new**	**all new**

- The table above shows the two options in a larger spectrum.
- “New HW”: new hardware using MicroBooNE engineering&design.
- “All new”: new hardware with new engineering and design.
- If MicroBooNE itself completes its program prior to start of near detector construction, some cost savings may be realized.

Basic MicroBooNE Parameters



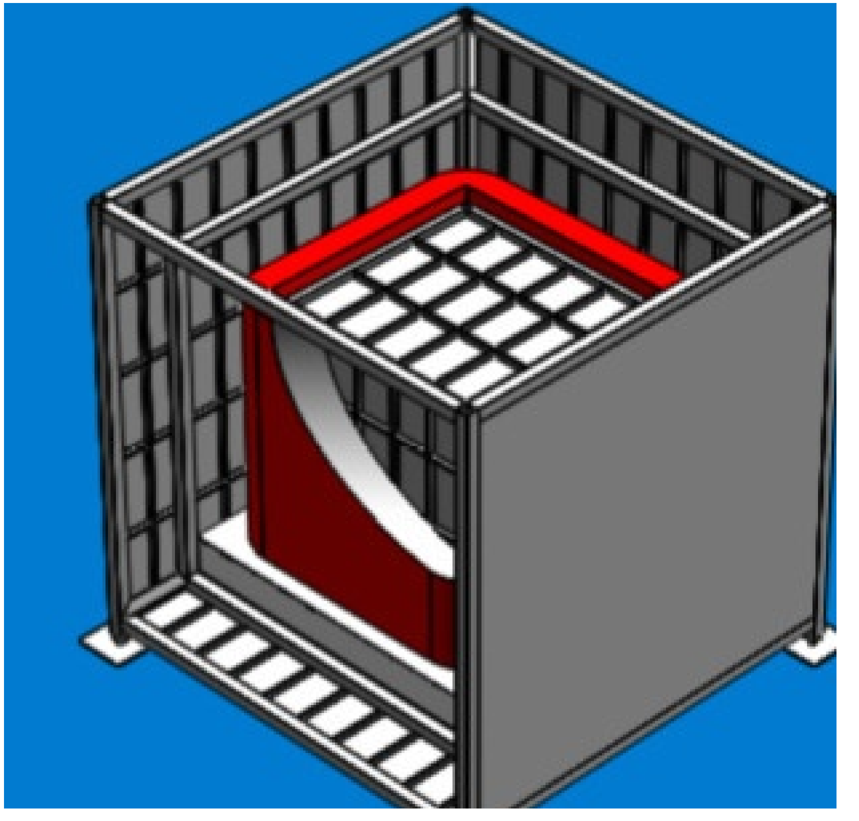


- 3 mm wire spacing
- Number of Wires:
  - Y: 3456
  - U, V: 2400 each
  - Total: 8256
- LAr in cryostat: 118 m^3
- Nominal fid. mass: 70 t

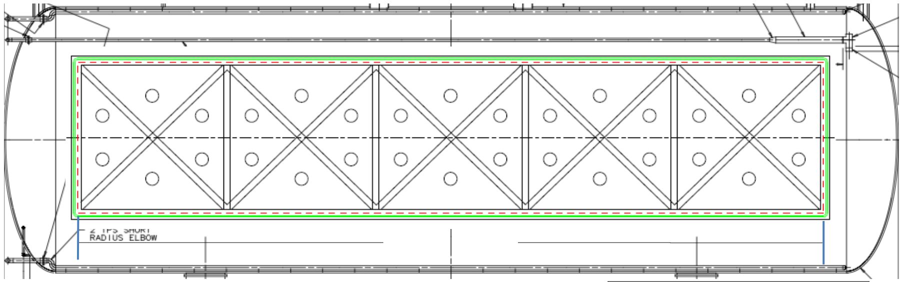
Note: These parameters current as of refs [1] and [2].

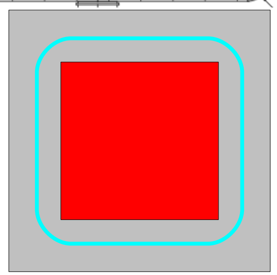
Basic 20-ton Parameters

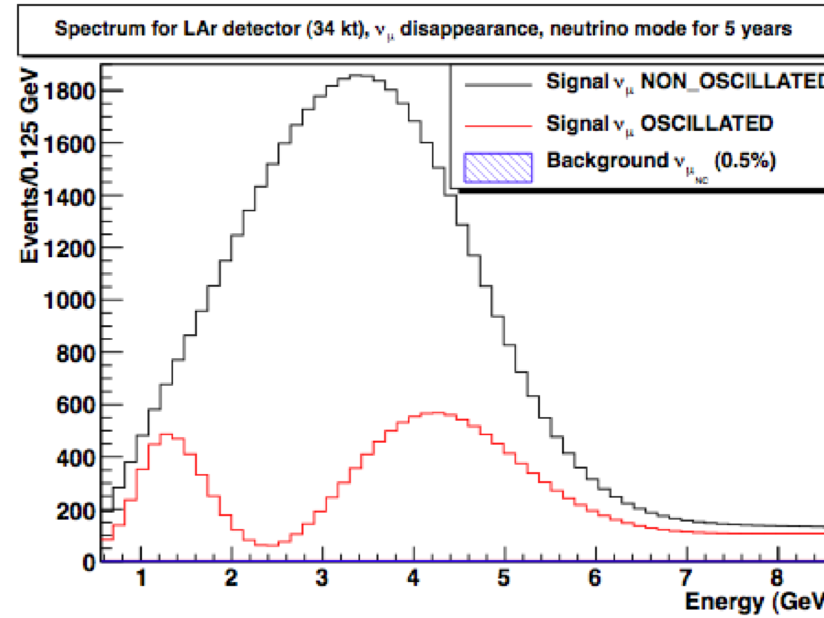
- Active TPC volume 2.5 m x 2.5 m x 2.5 m.
- 3 mm wire spacing.
- ~3100 wires.
- LAr in cryostat: 16 m^3
- Fiducial mass: 20 tons.



Some Other Parameters

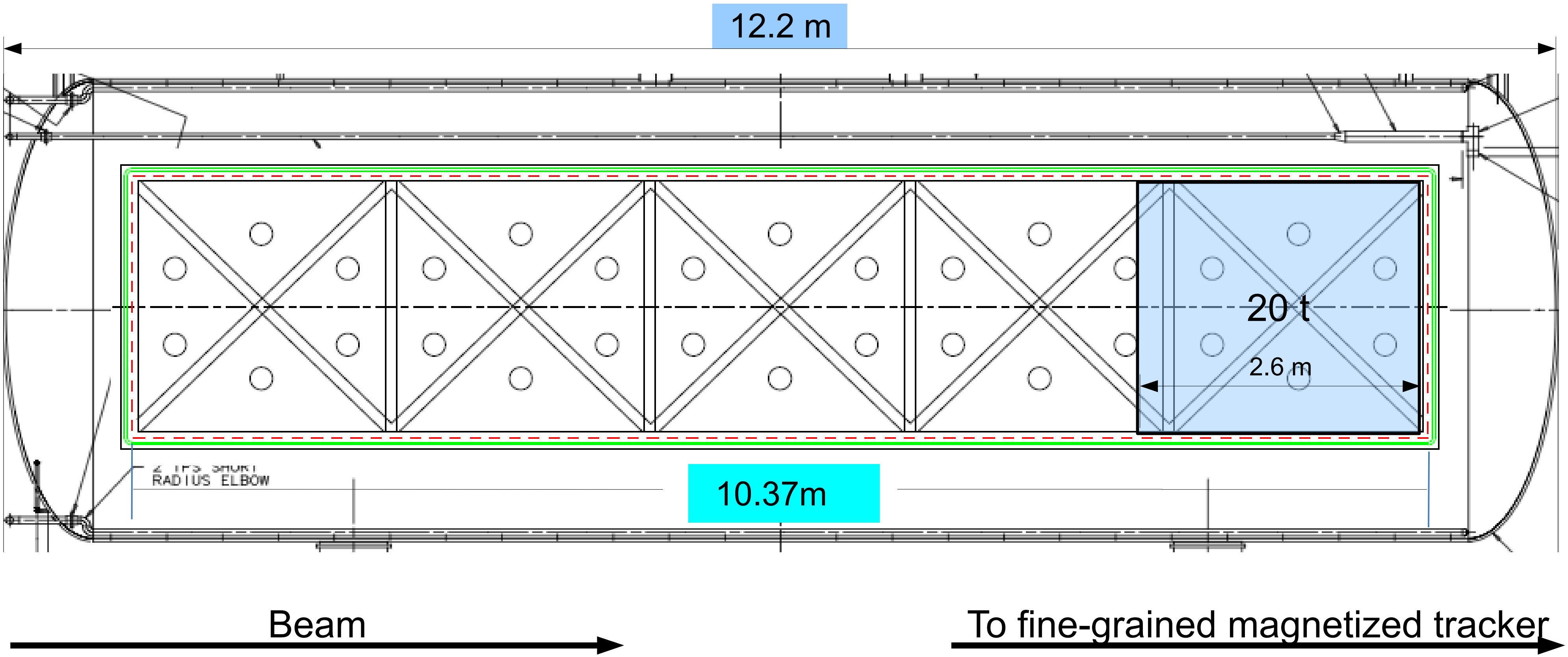






- 0.063 events/spill/ton @ 670 m for 700 kW, 120 GeV beam
  - 4/spill/(70 tons), 1/spill/(20 tons).
  - Entering event rate needs evaluation with hall design
- e- drift velocity: 1.6 mm/µs (500 V/cm), drift time 1.6 ms
- Muon range in LAr: 8.6 m for 2 GeV muon
- 20 mrad (1°) mult. scatt. for 2 GeV muon after 1 m LAr (calculated from the standard equation)

70-t LAr TPC as a 20-t LAr TPC
with a 50-t LAr TPC upstream



- Extra mass doesn't hurt physics.
- Extra length helps contain muons and identify entering b.g.
- 20-t can be magnetized, helps ID those tracks that don't escape into downstream tracker. ==> Physics studies needed.

R&D

Two main topics:

- Much being done in context of other projects
- LAr "Integrated Plan" by Baller, Fleming, et al.
  - ArgoNeut
  - LArSoft
  - MicroBooNE
- There are some additional physics questions that need answers.
- In addition, the magnetization option needs significant R&D in both how to do it and how to use it. (See Kevin Lee's presentation.)

R&D relevant to ND in “Integrated Plan”

- Integrated Plan: LBNE-doc-2113-v1, November 2009.
- Near detector physics study component: see the “University Proposal”, LBNE-doc-380-v23, July 2010.
  - Analysis tools. (LArSoft)
  - Operate and produce publishable physics results with a large experiment operated on/near surface. (MicroBooNE)
  - Some LBNE-specific physics studies.

LBNE-specific LAr studies in the "University Proposal"

- Optimization studies of the LArTPC detectors, simulation of cosmic ray events, and related sensitivity studies with updated efficiency and background assumptions.
- Do we need a LAr TPC calibration test in a test beam?
  ("No LArTPC has been calibrated in a test beam to allow measurement of electromagnetic and hadronic showers...")

General questions to for overall physics program

- Energy resolution and energy scale are key - need better estimates
- Also need signal efficiency and background acceptance
- Effect of CC cross-section uncertainty on result – to what extent do they really cancel given near detector?
- See also Sam Zeller's talk.

Additional physics questions

- Does the LAr ND need side trackers for
  - external neutral B.G. rejection? (fraction of events?)
  - tracks leaving TPC sideways? (fraction of events?)
- To what extent does lepton sign id really help us id nu vs antinu? (Many factors here.)
- Can lepton sign tag be used to “calibrate” the “vertex activity” signatures? Multiple scattering signature?
  - Is magnetic field in TPC necessary for this, or is a downstream tracker sufficient?
- What could ArgoNeut, Icarus, and MicroBooNE tell us?

Resource Loaded Schedule Details

- The .mpp file currently shows “Kansas State” labor doing everything as a “placeholder”.
- As far as I know, no institution has commitments for actual construction or installation yet.
  - Certainly K-State has no money for this.
  - Work for the “reuse MicroBooNE” option might be done by the same people who did it the original MicroBooNE.
  - For now, we assume the same tasks by the same kind of people, using K-State labor costs and overhead.
- All R&D is off-project, and mostly managed under other projects, as previously explained. (Only exception: support for G. Horton-Smith's travel expenses for some L4 manager duties.)

Risk Assessment Status

- Identification of risks for the LAr system is underway.
- We can also draw from the MicroBooNE risk registry.
  - Many risks on the MicroBooNE risk registry are specific to the initial construction and operation of MicroBooNE.
  - However, they give ideas of the cost, schedule, and technical risks generic to any other LArTPC detector.
- **Cryogenic/ODH issues underground are particularly significant.**
  - A conceptual design for mitigating this risk is being developed.

Risk Details (LAr TPC specific)

Without sufficient funding and personnel, the **R&D**, design, construction, and assembly of the near detectors will not be completed.

The reference design includes cryogenics **(liquid argon)** in the underground near detector hall. The safety issues associated with the underground cryogenics and ODH hazards must be fully understood and mitigated.

The reference design includes high power (>1 MW) **and high voltage (128 kV)** in the underground near detector hall. The engineering and safety issues associated with underground power must be fully understood and mitigated.

Complete **simulations of the different detector options** are required in order to complete the designs of the near detectors.

Wire breakage: a single broken wire can disable the entire detector (true for any TPC). MicroBooNE R&D shows this to be very low probability in their design, to be mitigated further by adding secondary wire holder mechanism.

MicroBooNE project canceled before R&D and design complete (low risk?) -- would have to continue any remaining 70-ton R&D and design on LBNE project funds.

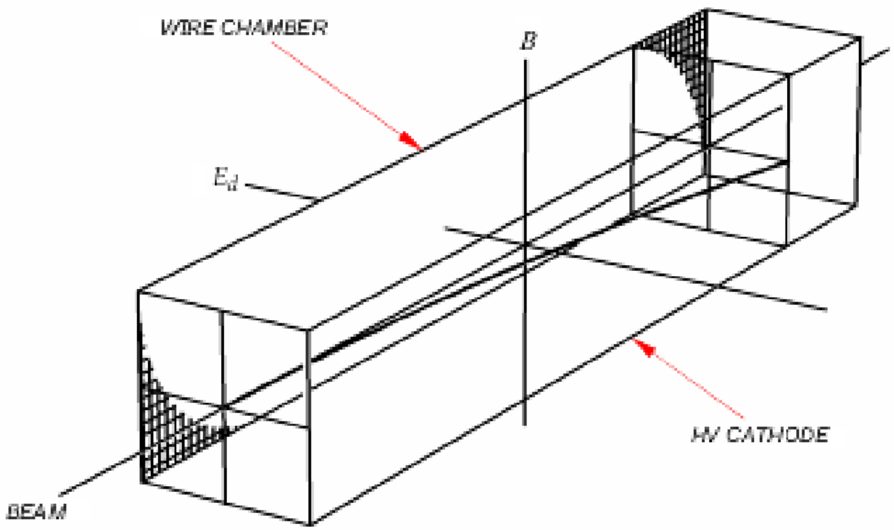
Conclusion

- Reference design: “New MicroBooNE”
  - Cost-savings if old MicroBooNE is reused.
  - 20-ton magnetized TPC is a not-less-preferred option.
- There are a number of physics questions to address.
  - Physics measurement group working with LAr group to specify specific detector simulations to perform.
- Mature RLS and BoE for most subsystems of reference design adapted from MicroBooNE.
- Risk assessment is proceeding.

ND Review 10/4: Liquid Argon TPC 2

D. Cline
K. Lee
F. Segiampietri
H. Wang
UCLA

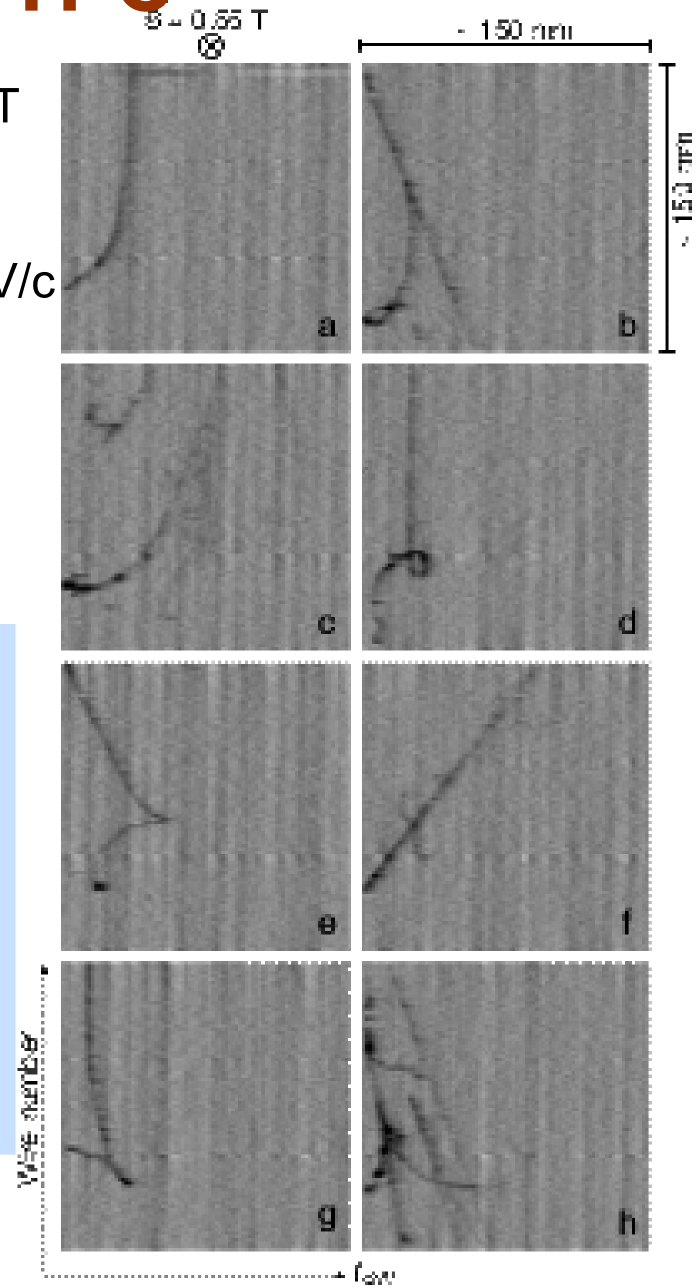
Magnetized LAr TPC



B = 0.55 T

R ~ 5 cm

p ~ 7 MeV/c



Momentum measurement:

$$\frac{\Delta p}{p} \approx \frac{0.14}{B(Tesla)\sqrt{(x(m))}\,\cos\lambda}$$

x=track length

λ=pitch angle

Required field for 3σ charge discrimination:

$$B \geq \frac{0.2\,(Tesla)}{\sqrt{x(m)}\,\cos^3\lambda}$$

e^-

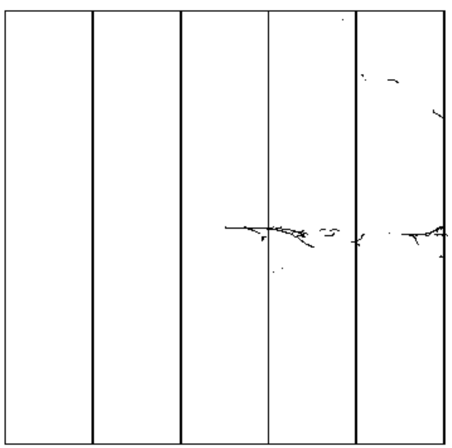
2.5 GeV

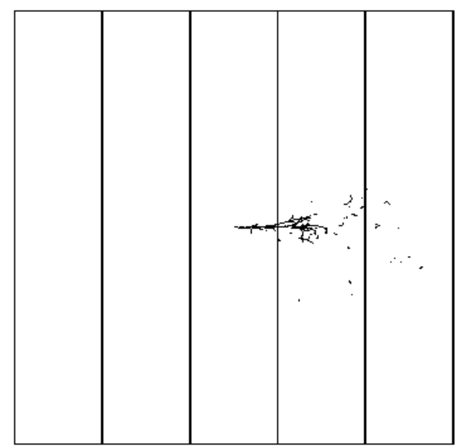
Simulated electron shower in magnetic field B=1T

Impact Event Simulations in 0.5 T Field

2.5 m × 2.5 m × 2.5 m LAr
Volume

0.5 GeV





1.0 GeV

positron
s

electron
s