The Long-Baseline Neutrino Experiment: taking aim at the neutrino mass hierarchy, leptonic CP violation, and South Dakota

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LANL
DURA Annual Meeting
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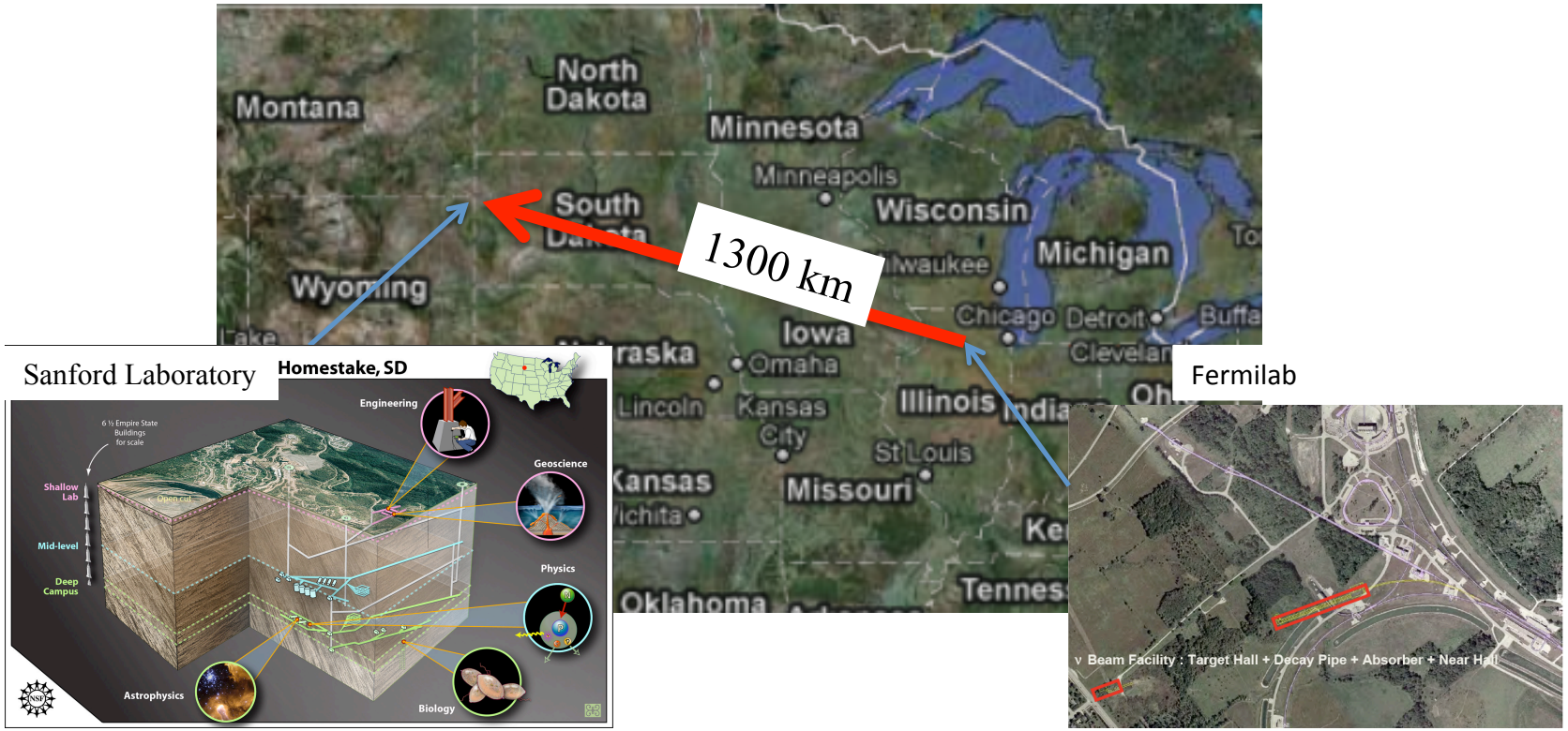
Outline

- LBNE Design
- Reconfiguration
- Physics Program
- Cost and Schedule
- Conclusions

Long-Baseline Neutrino Experiment



- Intense neutrino beam from Fermilab
- Near detector systems at Fermilab
- 34 kt liquid argon time-projection chamber (TPC) at Sanford laboratory at 4850 foot depth

Long-Baseline Neutrino Experiment Collaboration

Alabama: S. Habib, I. Stancu

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LBL: B. Fujikawa, V.M. Gehman, R. Kadel, D. Taylor

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Los Alamos: L. Bartoszek, J. Boissevain, S. Elliott, A. Friedland, G. Garvey, E. Guardincerri, T. Haines, D. Lee, W. Louis, C. Mauger, G. Mills, Z. Pavlovic, J. Ramsey, M. Ronquest, G. Sinnis, W. Sondheim, R. Van de Water, H. White, K. Yarritu

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Notre Dame: J. Losecco

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Rensselaer: J. Napolitano

Rochester: L. Loiacono, K. McFarland, G. Perdue

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Syracuse: M. Artuso, J. Asaadi, S. Blusk, T. Skwarnicki, M. Soderberg, S. Stone

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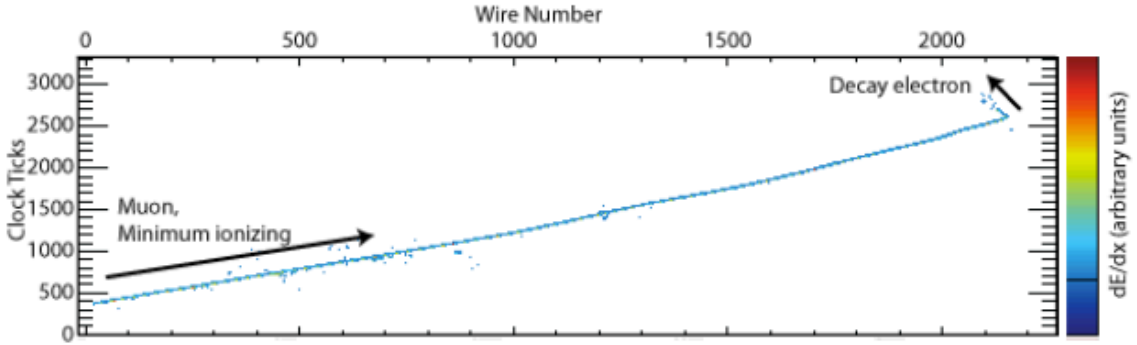
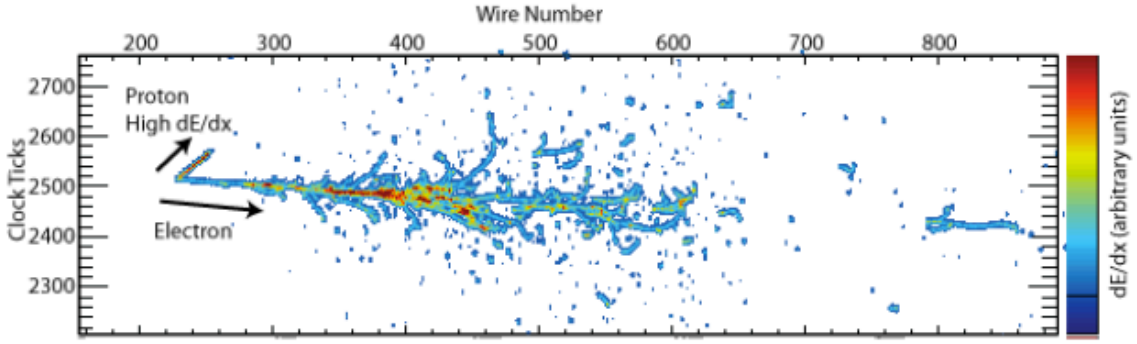
Yale: C. Adams, F. Cavanna, E. Church, B. Fleming, R. Guenette, O. Palamara, K. Partyka, A. Szelc

Liquid Argon TPC Capabilities

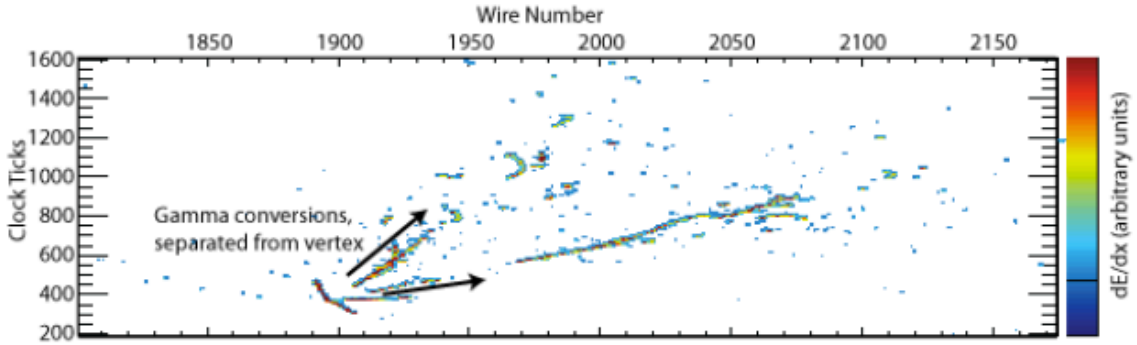
CC muon neutrino interaction



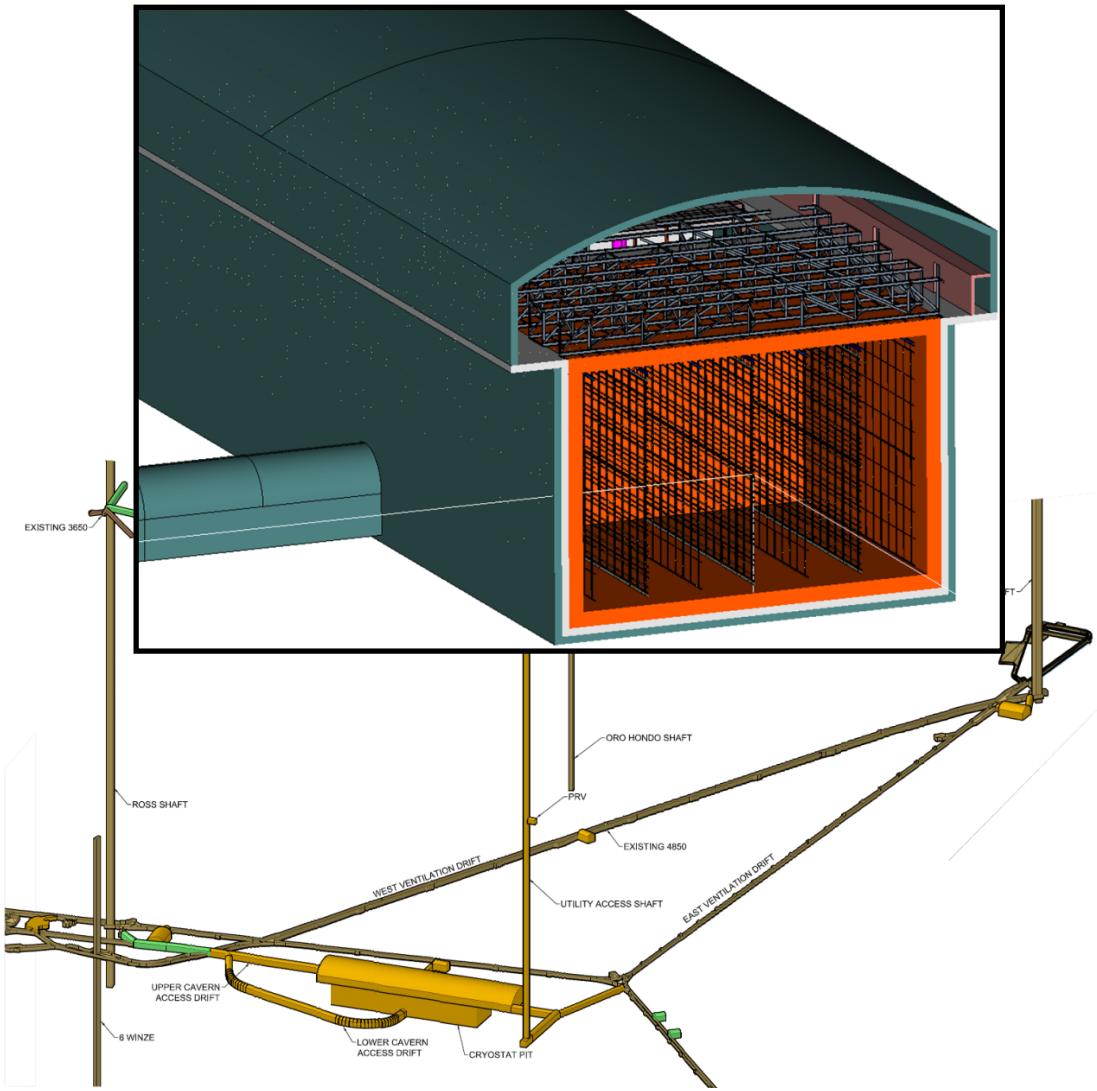
CC electron neutrino interaction



NC neutrino interaction

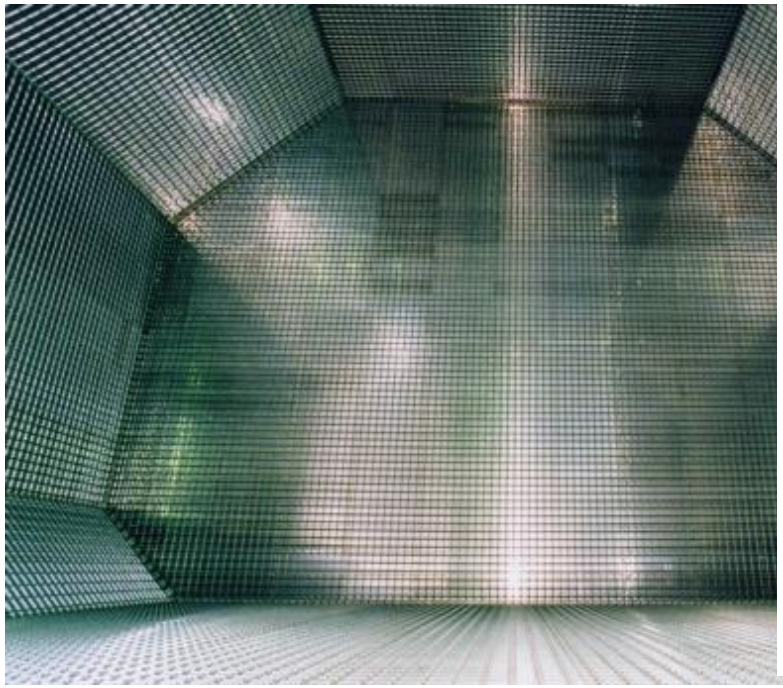


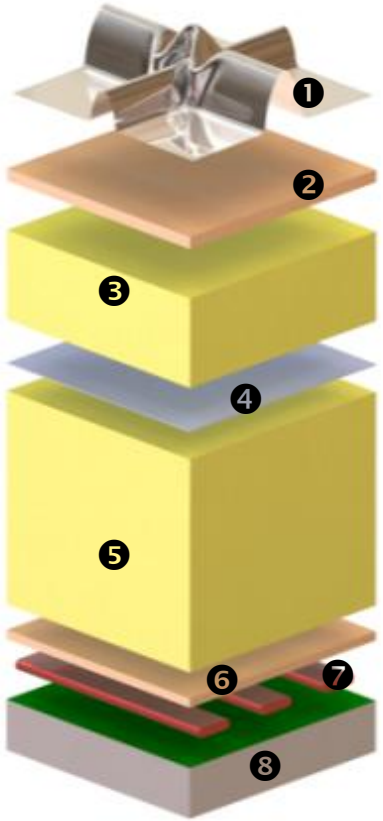
Far Detector



- Two detectors in a common cavern at 4850 ft. depth
- Active volume of each detector:
  22.4 x 14 x 45.6 m^3
- 33 kt fiducial mass
- TPC design:
  - 3.7 m drift length
  - 5 mm wire spacing
  - three stereo views

Membrane Cryostat





❶ Stainless steel primary membrane
❷ Plywood board
❸ Reinforced polyurethane foam
❹ Secondary barrier
❺ Reinforced polyurethane foam
❻ Plywood board
❼ Bearing mastic
❽ Concrete covered with moisture barrier

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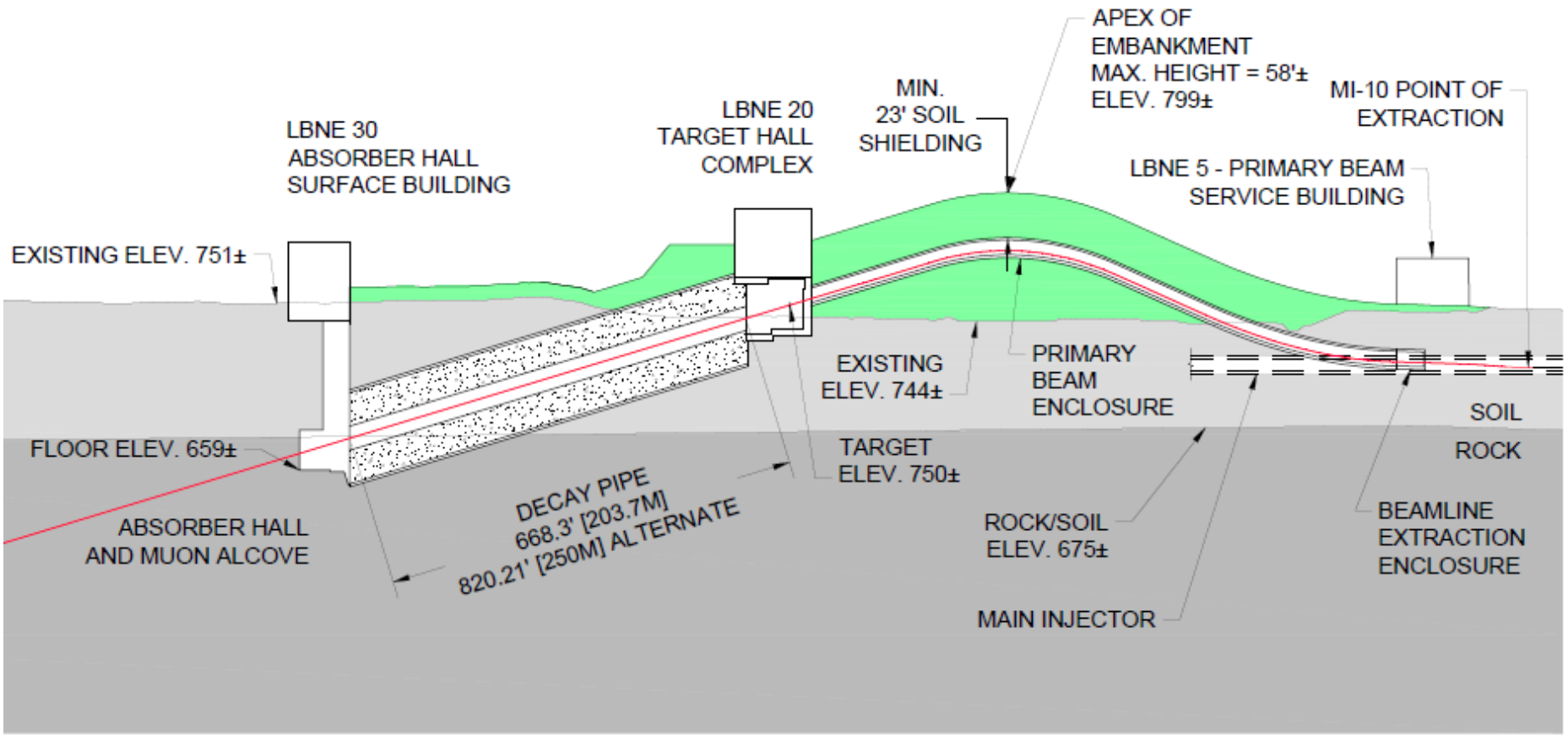
- Cost effective approach to the cryostat
- Used extensively in the liquid petroleum industry

Conventional Beam, New Approach

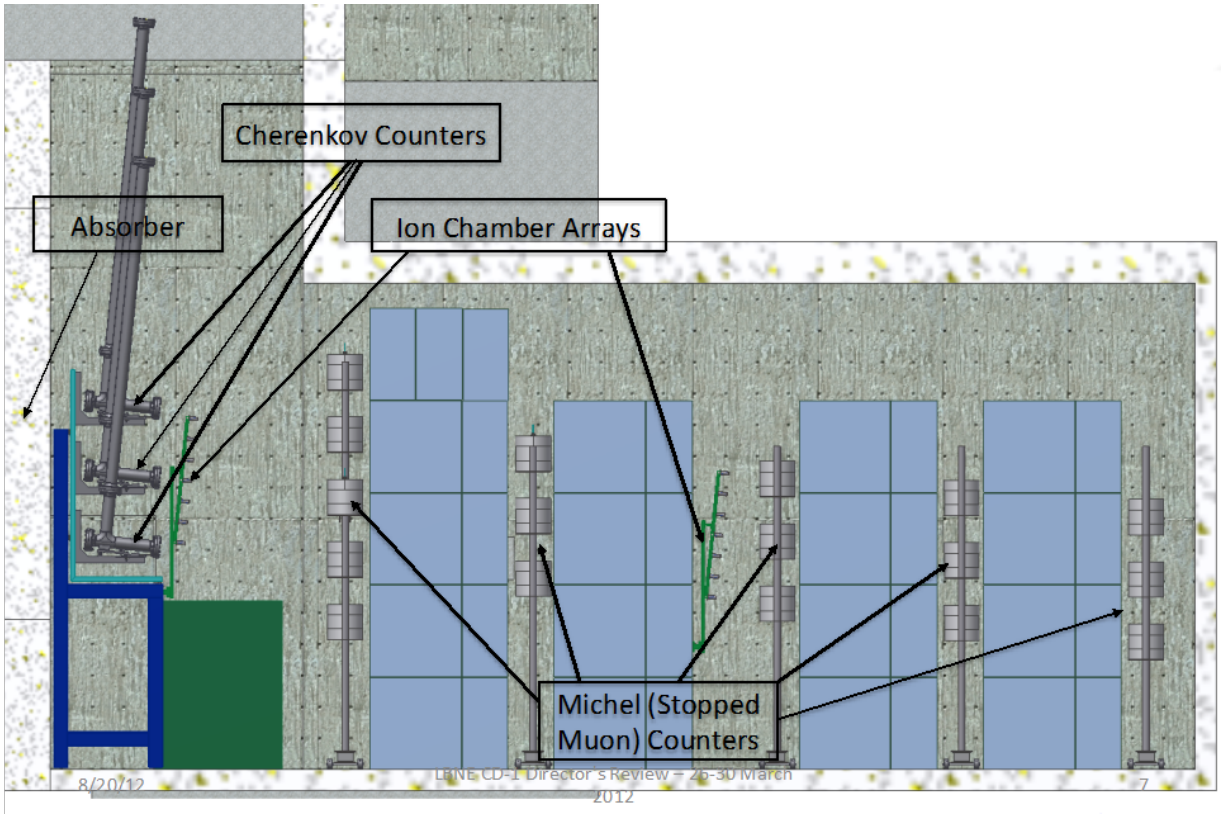


Measurements of muons post-absorber

Ionization Chambers:
- spill-by-spill beam profile

Cherenkov Detectors:
- measure all muons above a variable threshold
- constrains muon spectrum (correlated with E_ν)

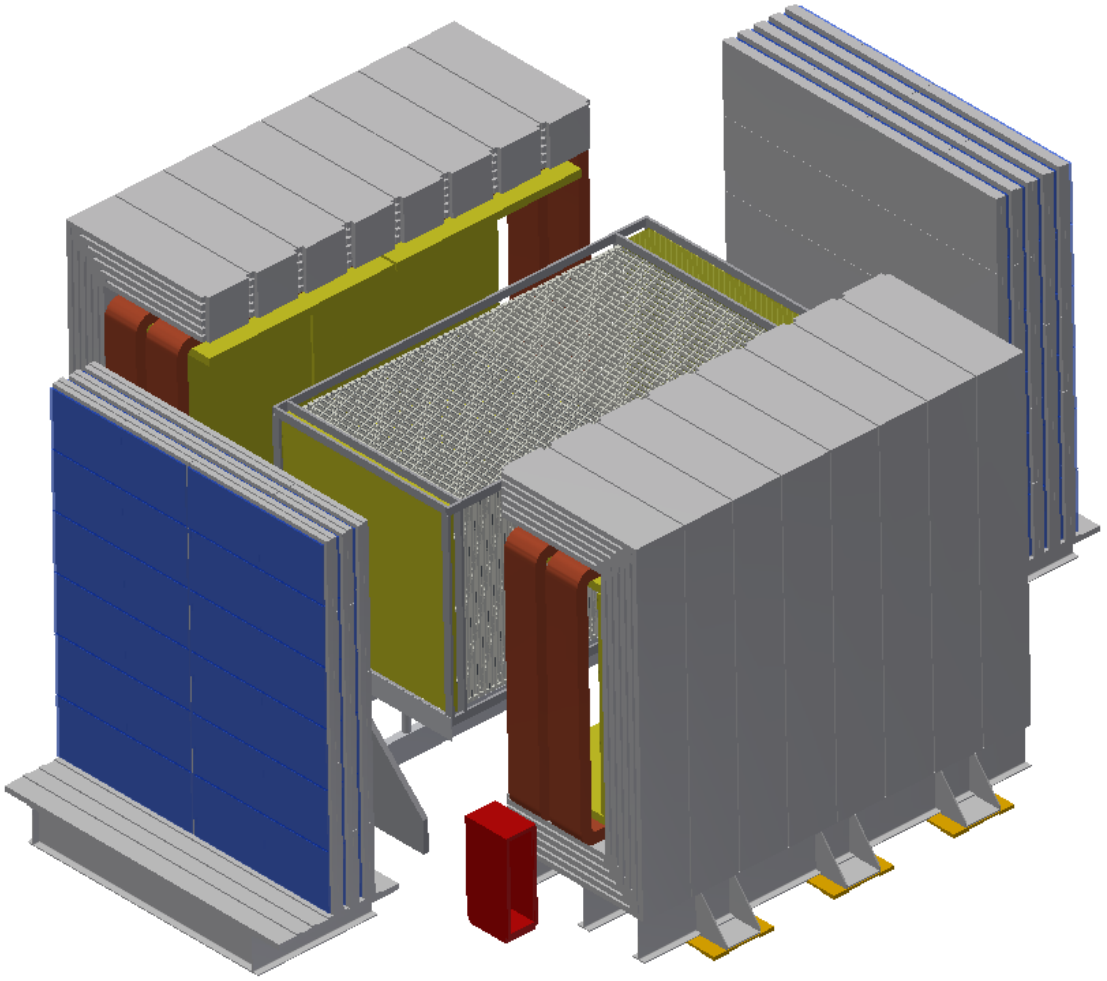
Michel Decay Detectors:
- measure muons that stop at a given depth in material
- constrains muon spectrum
- may give absolute flux constraint



Includes planning measurements of hadron production in external beamlines on materials from which the target and horns are composed

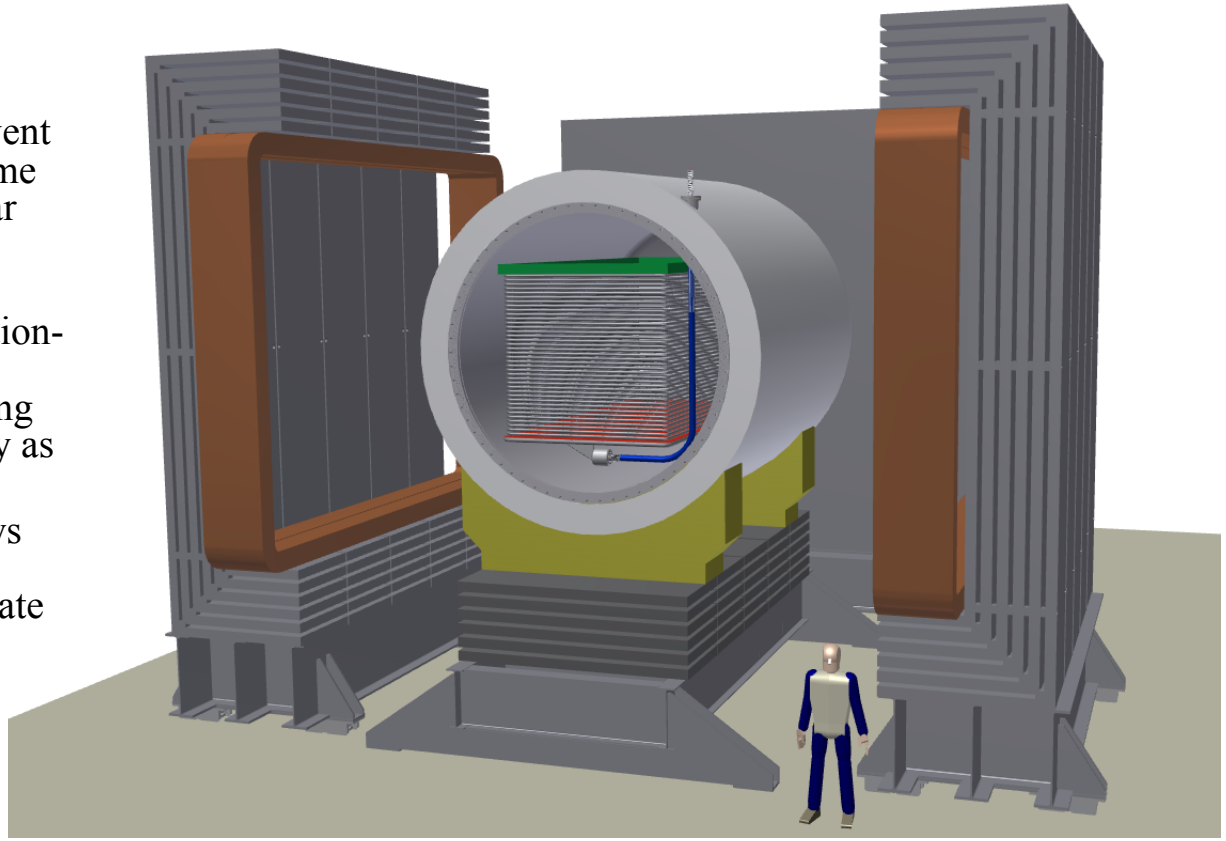
Two options for near neutrino detector

- High precision straw-tube tracker with embedded high-pressure argon-gas targets
- Philosophy
  - make high-precision, high-statistics measurements of neutrino interactions with argon (far detector target nucleus)
  - measure inclusive and exclusive cross-sections to build and constrain models to predict the event signatures at the far site *and correlate them with true neutrino energy*
  - make detailed studies of electron (and muon) neutrino and anti-neutrinos separately



Two options for near neutrino detector

- Smaller (than the far detector) liquid argon TPC
- Philosophy
  - make high statistics measurements of event signatures in the same technology of the far site
  - try to minimize detector/reconstruction-related systematic uncertainties by using the same technology as the far site
  - magnetization allows for charged muon separation for separate neutrino and antineutrino studies



LBNE Reconfiguration

- March of 2012, Dr. Brinkman charged Fermilab to lead a process to build LBNE in stages
- In this process, phase I was defined as the beam at Fermilab, a 10 kton liquid argon TPC at the surface near Homestake, with the move underground and a near neutrino detector to come later. CD-1 for this scope was approved in December of 2012.
- The *goal* for the first phase from the DOE, Fermilab management, the project and collaboration is to construct a broadband beam capable of 2.3 MW operation, a highly capable near detector, and a far detector underground with greater than 10 kt of fiducial mass
- The collaboration and project are actively seeking non-DOE contributions that would enable the goal for the first phase

Scientific Challenges with Phase I

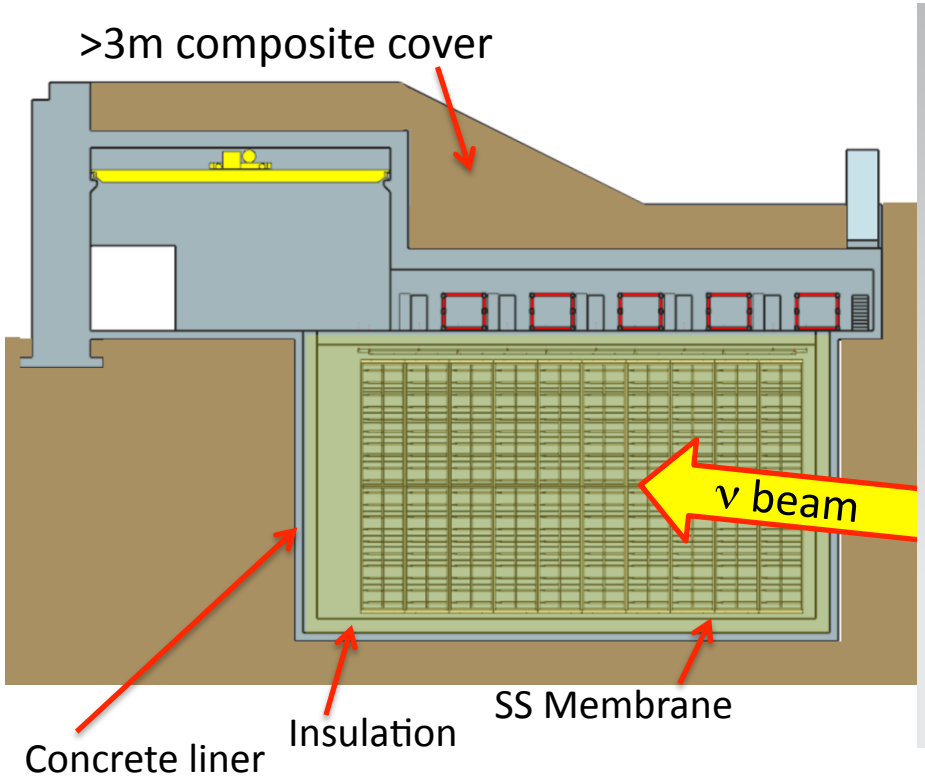
Cosmic Ray backgrounds in a near-surface far detector.

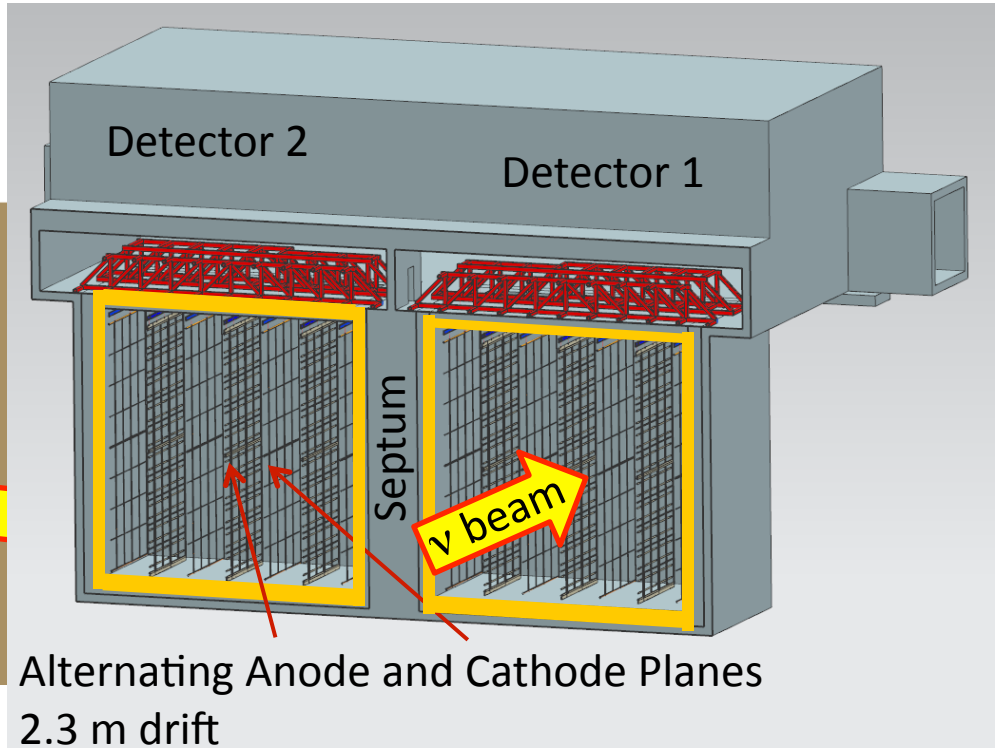
- On-going simulations indicate that a combination of passive shielding and the precise pattern recognition provided by the LAr TPC can reject backgrounds to at most a few events per year.
- Timing from Ar scintillation can reduce background by additional x100.
- A recent independent review concluded that the analysis is sound and the risk is manageable.
- Going underground is critical for the full scientific agenda of LBNE

Lack of near Neutrino Detector

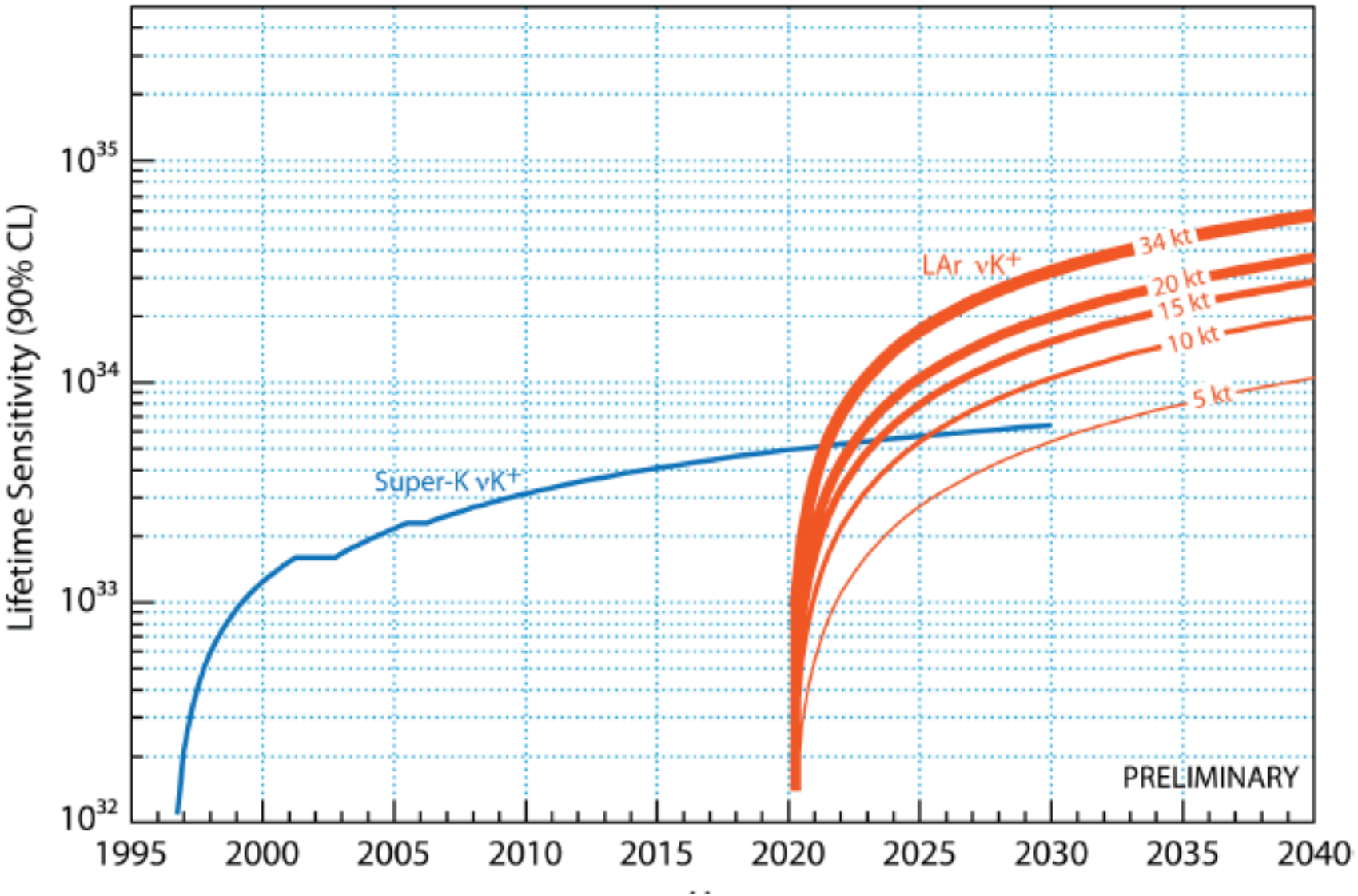
- Using a) data from the very similar and well-understood NuMI beam, b) new target hadron production data, c) precise muon flux measurements, we expect to understand the LBNE flux to $\lesssim$10%.
- Using the oscillated ν_μ flux at the far detector, we should be able to predict the unoscillated flux for the ν_μ -> ν_e analysis to 5%.
- A full near detector complex is necessary in the long term to achieve the full scientific agenda of LBNE.

Far Detector with 10 ktons



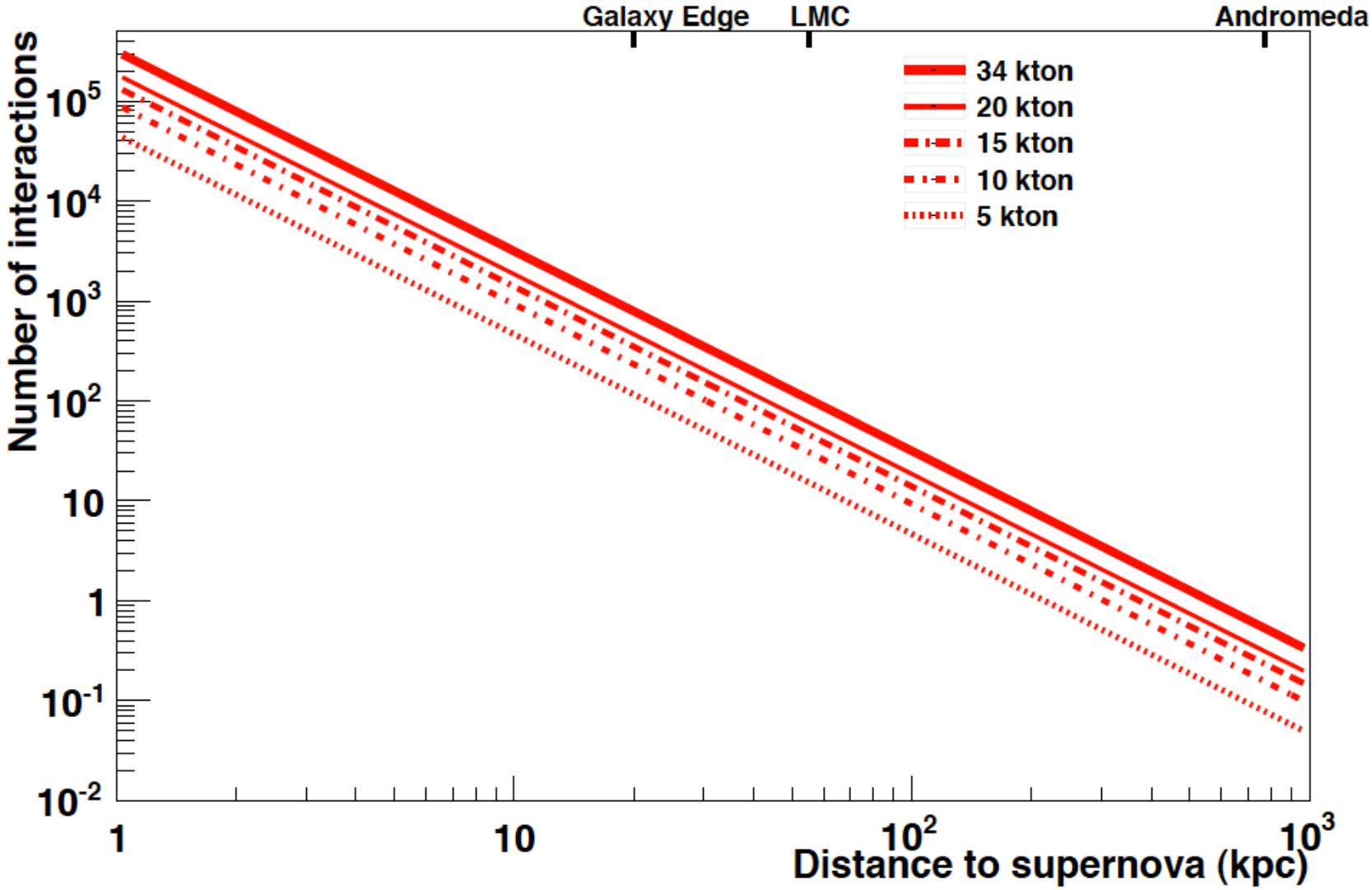


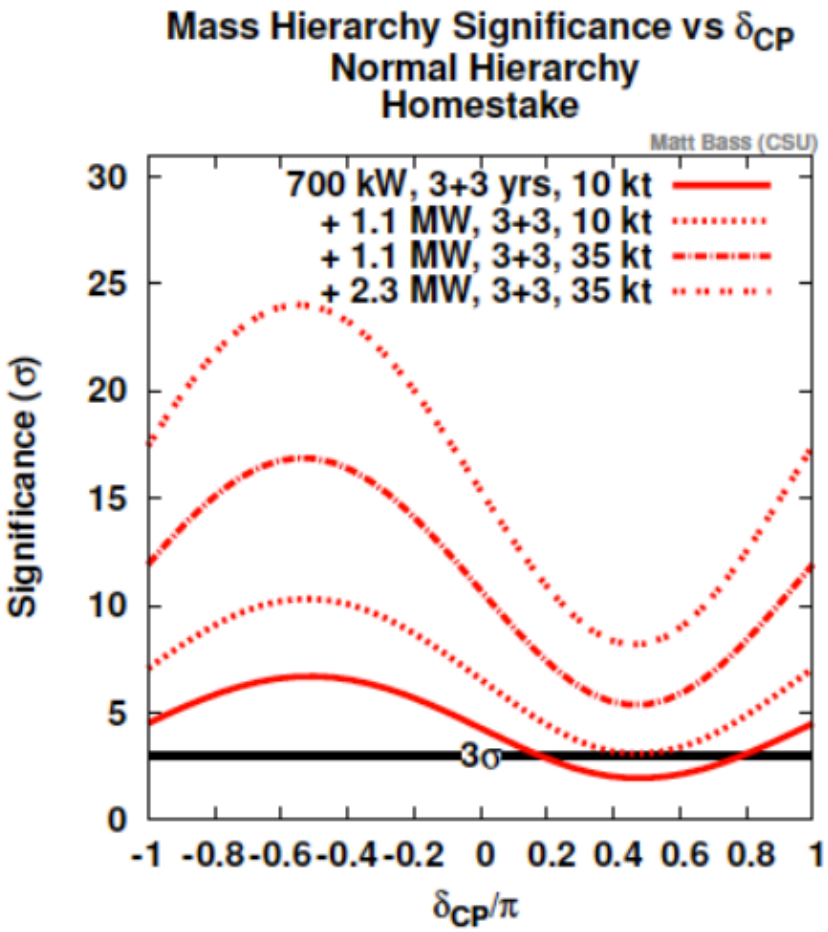
Nucleon decay with a liquid argon TPC

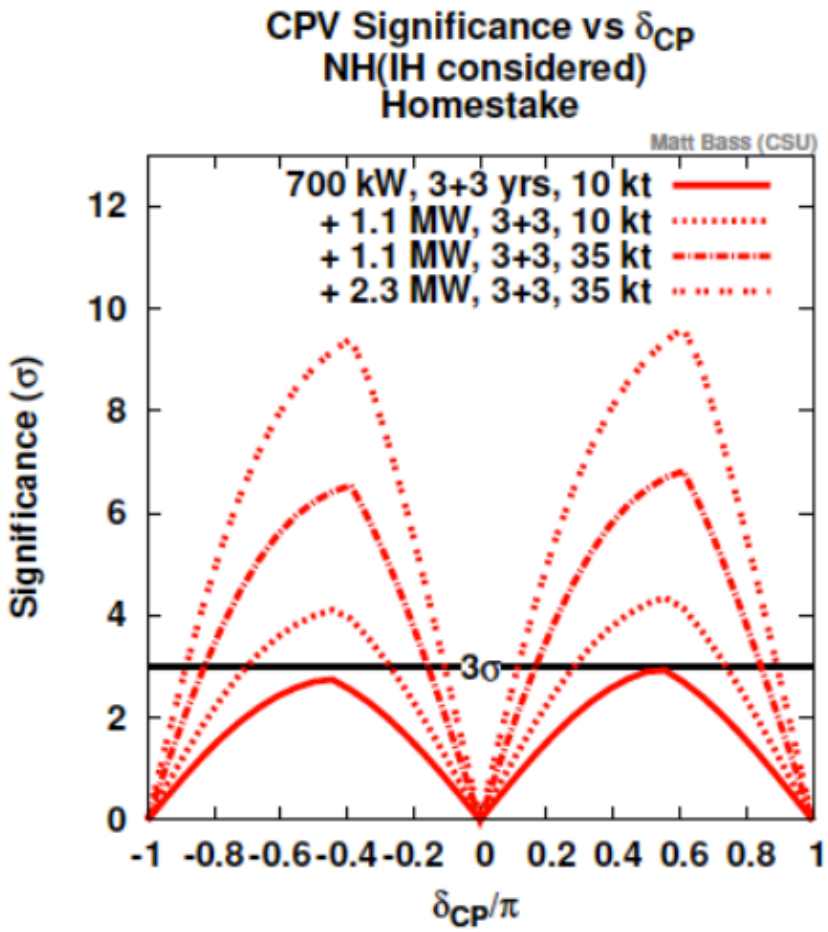


Jen Raaf

Burst Supernova Neutrino Events





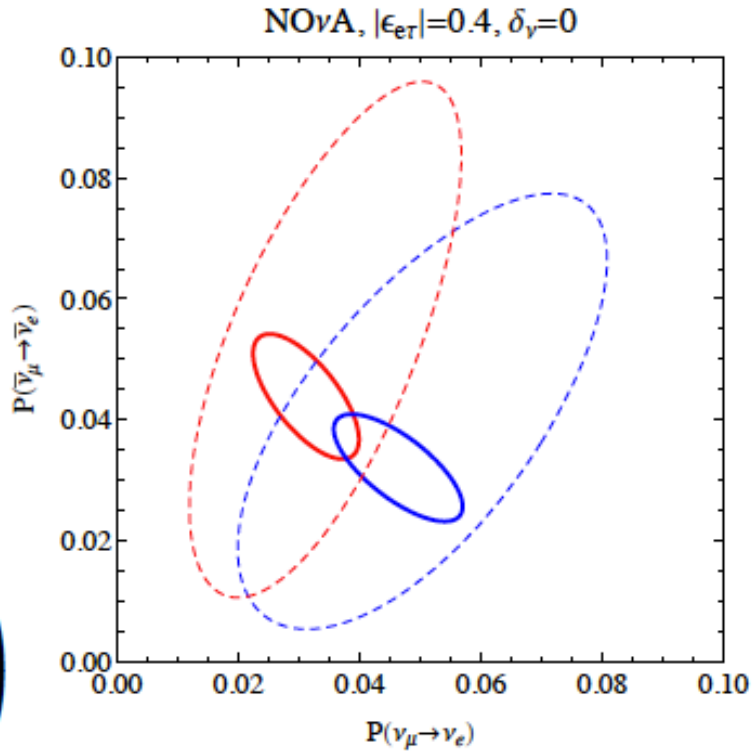


LBNE sensitivity will grow with exposure

Non-Standard Interactions (NSI)

- Simplifying framework:
  - a single term: a flavor changing qq $\nu_e \nu_\tau$ interaction
  - subdominant to the SM weak interactions

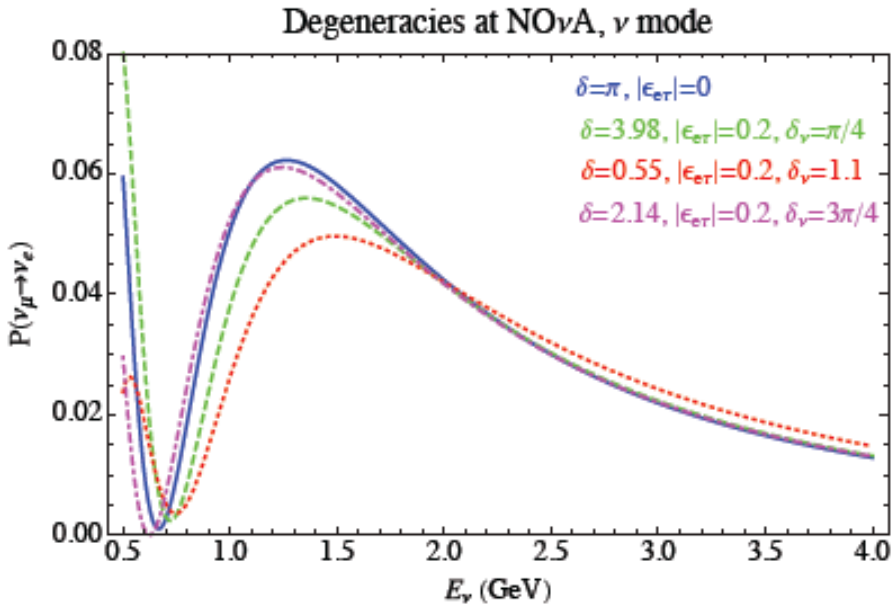
$$H_{mat}^{flav} = \sqrt{2} G_F n_e \begin{pmatrix} 1 & 0 & |\varepsilon_{e\tau}| e^{-i\delta_\nu} \\ 0 & 0 & 0 \\ |\varepsilon_{e\tau}| e^{i\delta_\nu} & 0 & 0 \end{pmatrix}$$

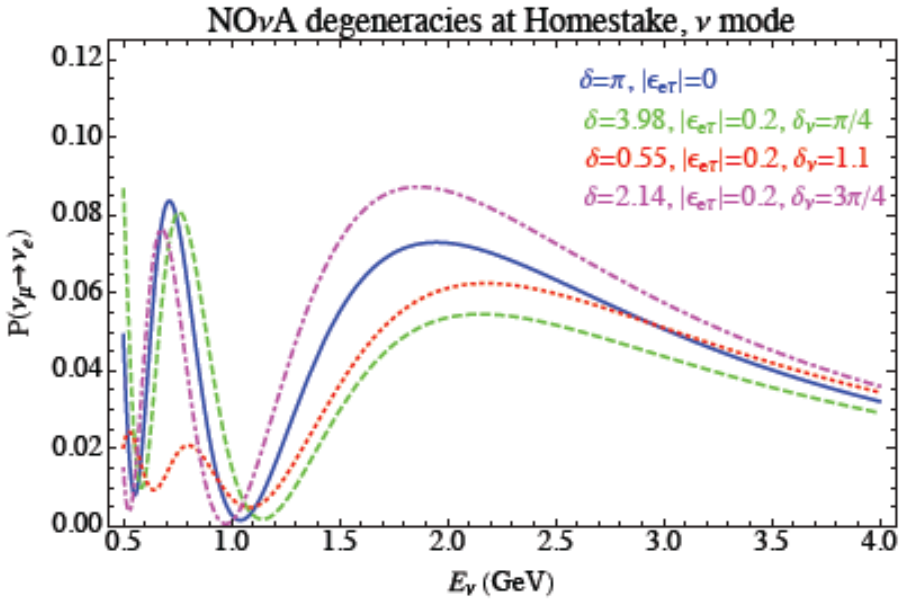


Alex Friedland

NSI: Breaking degeneracy

- LBNE spectral measurements can break the degeneracy



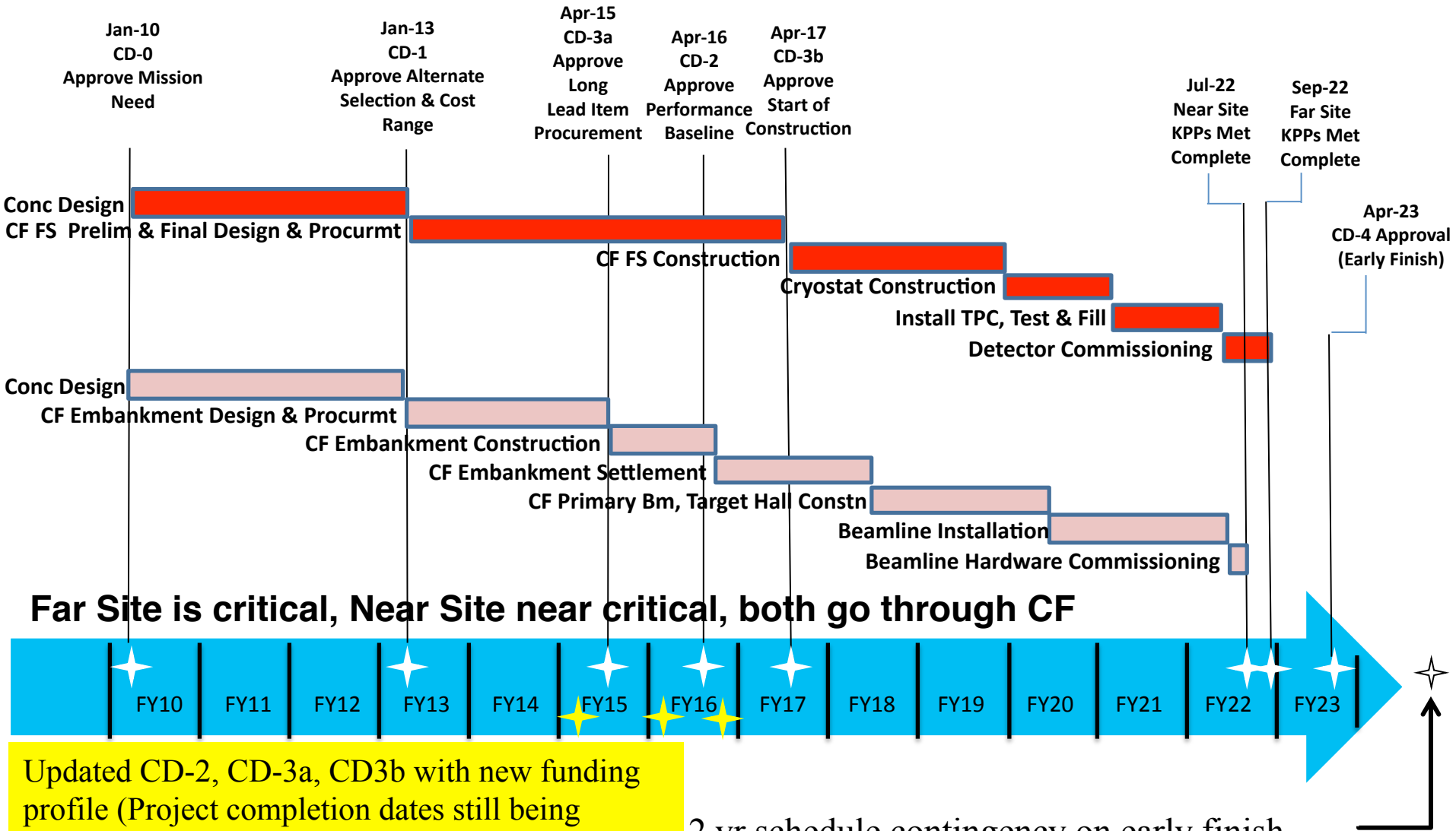


LBNE CD-1 Cost Summary

LBNE Cost Estimate in At-Year k$	Base Cost k$	Contingency		TPC k$	cost to date thru 6/2012
		k$	% of cost to go		
130.01 Proj Office	57,014	16,099	32%	73,113	6,987
130.02 Beamline	129,370	35,311	29%	164,680	7,422
130.03 NDC	11,815	10,748	148%	22,563	4,558
130.04 WCD	11,178		0%	11,178	11,178
130.05 LAr FD	181,347	71,767	41%	253,114	7,775
130.06 CF	241,191	71,600	31%	312,790	6,872
Top-down Contingency		30,000	5%	30,000	
Grand Total	631,914	235,525	40%	867,439	44,792

slide from Jim Strait

LBNE (phase 1) Critical Path Schedule Summary



Updated CD-2, CD-3a, CD3b with new funding profile (Project completion dates still being developed under the new profile)

2 yr schedule contingency on early finish

slide from Jim Strait

Summary

- LBNE is program designed to address many critical questions in particle physics
- Despite the challenging funding situation, we are moving forward as quickly as possible to develop the full scope of LBNE