Short-Baseline Plans at Fermilab

Steve Geer

European Strategy for Neutrino Oscillation Physics – II
May 14-16, 2012

U.S. DEPARTMENT OF ENERGY

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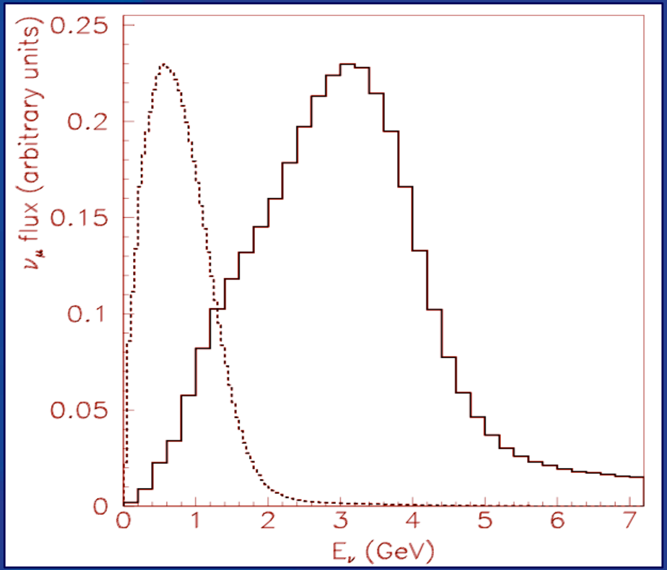
TWO NEUTRINO BEAMS AT FNAL

- **NuMI** (Neutrinos at the Main Injector)
  - 120 GeV protons from MI
  - 90 cm graphite target
  - 675 m decay region
- **BNB** (Booster Neutrino Beam)
  - 8 GeV protons from Booster
  - 71 cm beryllium target
  - 50 m decay region



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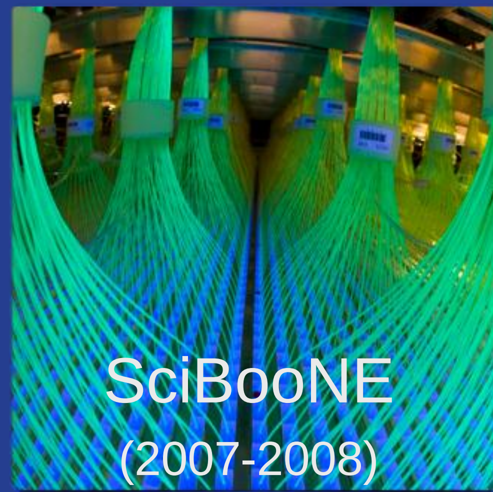
RECENT FNAL SBL EXPERIMENTS

Booster Beam Experiments (+ NuMI Off-Axis)



SciBooNE (2007-2008)

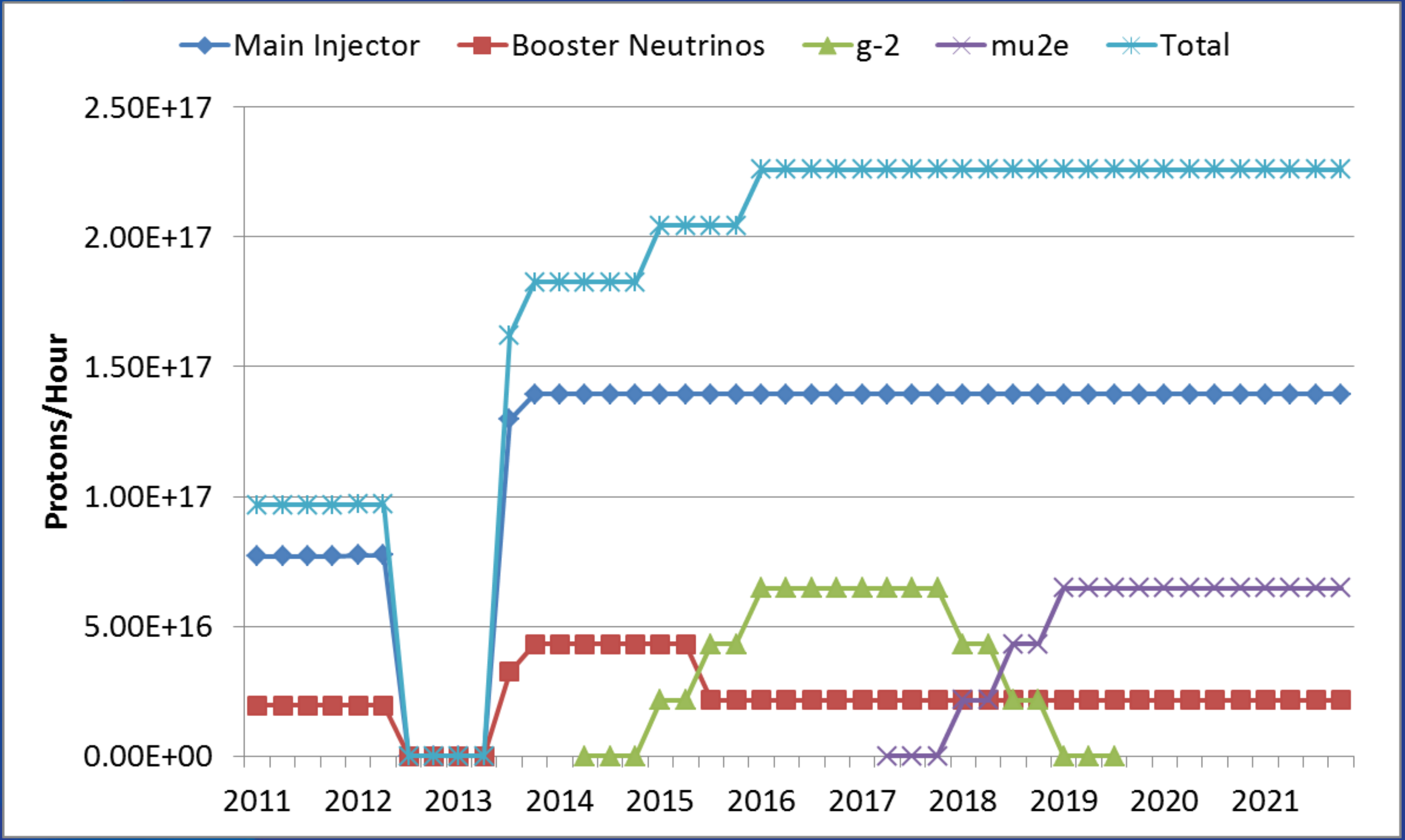
MiniBooNE (2002-2011)

NuMI Beam Experiments

Argoneut (2009-2010)

MINERvA (ongoing)

PROTON BUDGET: NEAR FUTURE



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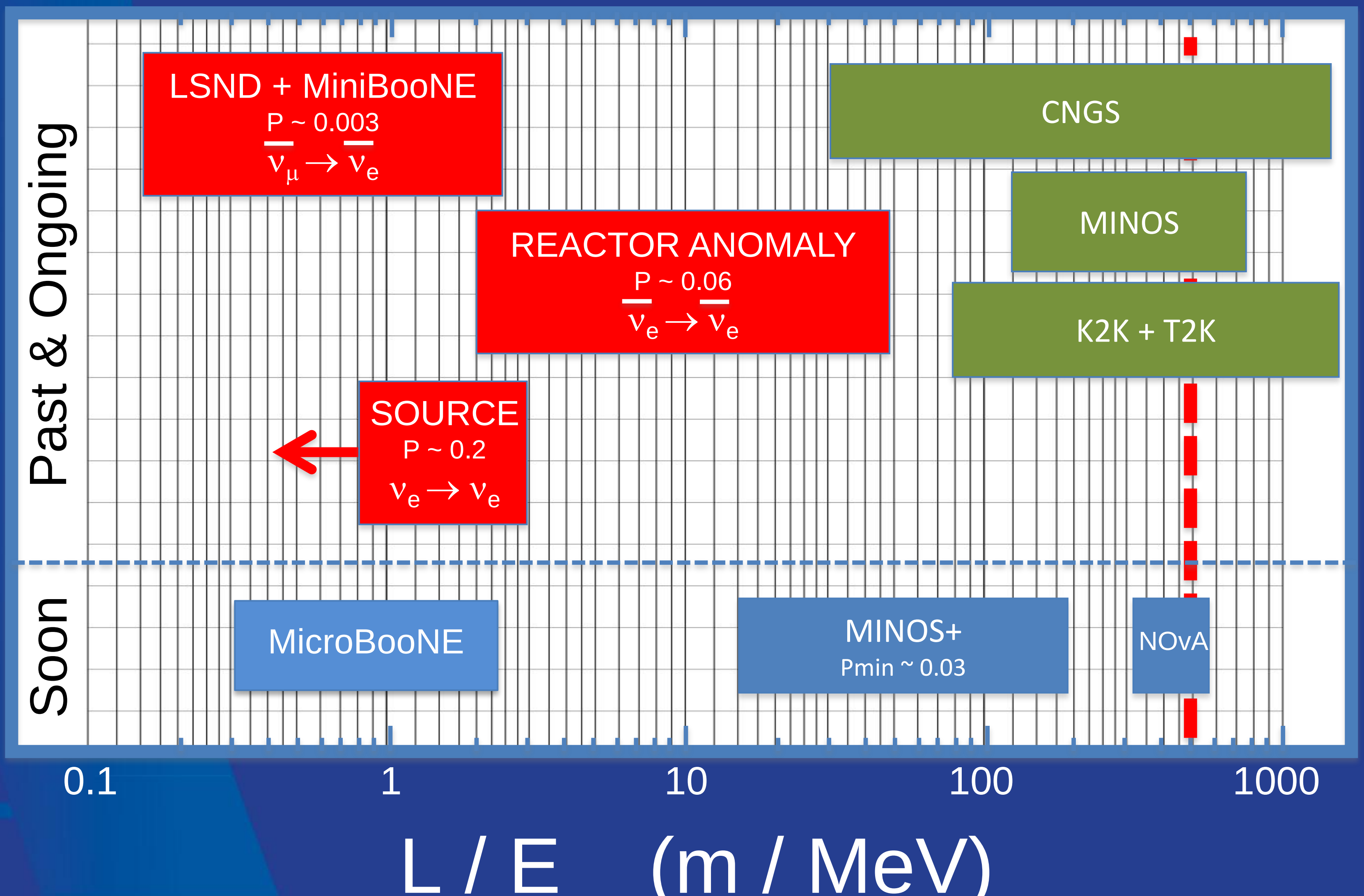
WHY DO WE NEED NEW SHORT-BASELINE EXPERIMENTS ?

- There are some indications that three-flavor mixing might not be the whole story. These indications come from:
  - Reactor anti-neutrino measurements at short distances
  - Radioactive source measurements
  - Accelerator-based neutrino & anti-neutrino measurements (LSND & MiniBooNE)
  - Cosmological measurements

- These tensions with 3-flavor mixing are at the level of 2 or 3 standard deviations. None of them are definitive. Some or all of them may be due to statistical fluctuations and/or systematic effects.

- However, taken together, the experimental evidence for the presence or absence of neutrino flavor transitions on a timescale characterized by L/E ~ 1 m/MeV is confusing, and needs experimental clarification.

L/E COVERAGE



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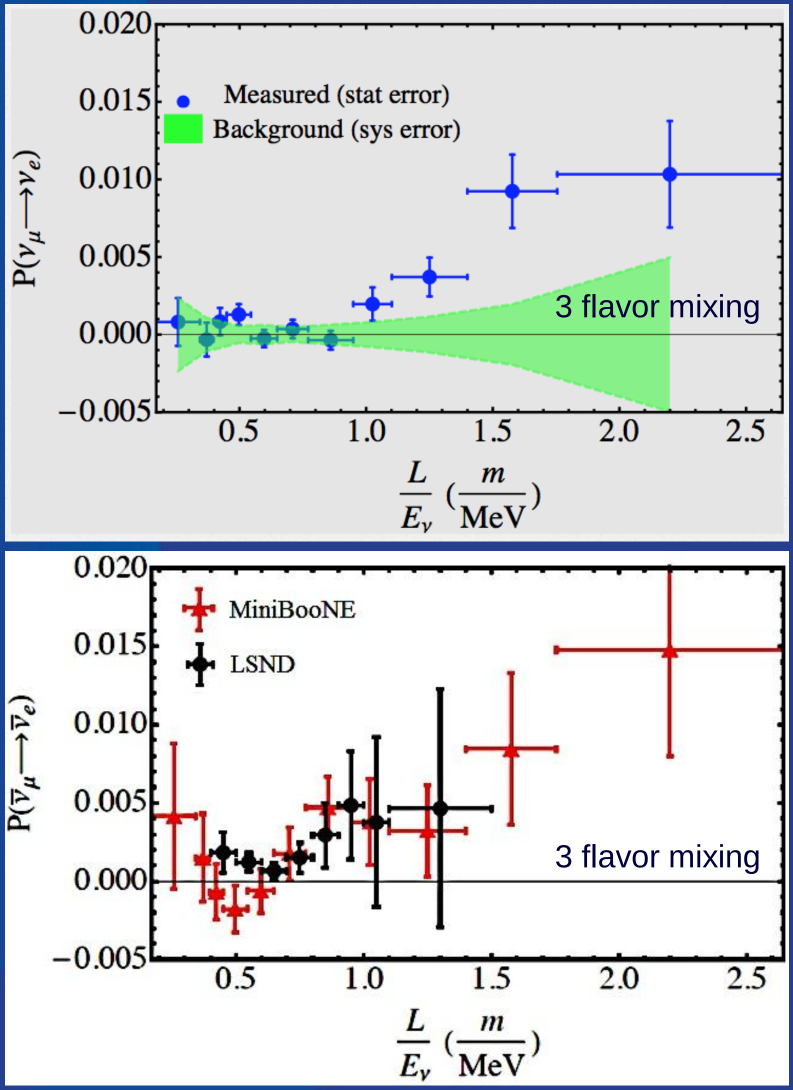
THE LSND + MINIBOONE CHALLENGE



An ~3σ excess of $\nu_\mu \to \nu_e$ events above background seen by MiniBooNE at low neutrino energies (E < 0.5 GeV) . At higher energies data consistent with background.

A >3σ excess of $\bar{\nu}_\mu \to \bar{\nu}_e$ events above background seen by LSND + MiniBooNE, corresponding to a transition probability O(0.003).

Are these "signals" statistical fluctuations ? Are the "electrons" really photons ?

MicroBooNE

- Short baseline experiment to explore the origin of the low energy excess reported by MiniBooNE, measure neutrino cross-sections, & develop liquid argon time projection (LArTPC) technology for future facilities.
- Will use a 170 ton LArTPC in the Booster Neutrino Beam (E=0.7 GeV) at a distance of L=0.5 km. It also sees the NuMI beam at a wide off-axis angle.
- European participation: Bern, Gran Sasso, L'Aquila

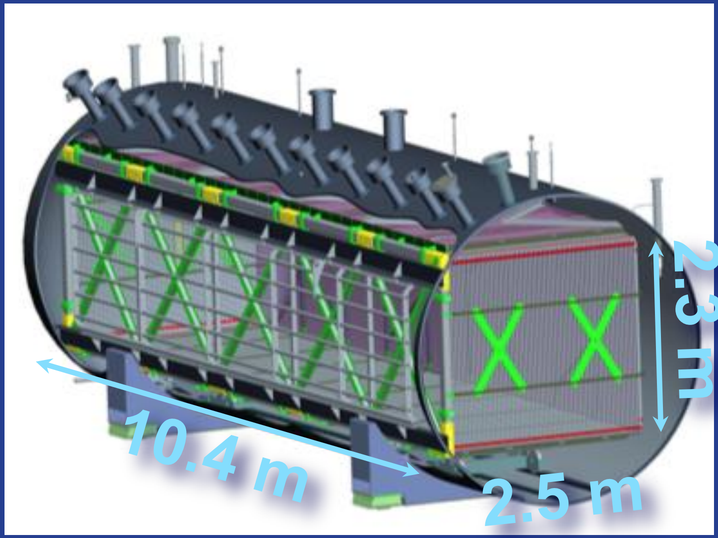
Data taking expected to start in 2014.

2-3 years run will yield 6×10^{20} POT and 10^5 neutrino events

TABLE 2. Summary of event rates in MicroBooNE's 60 ton volume by the neutrino mode BNB (6E20 POT), 468 m from the target.

production mode	formula	#evt ($\times 10^3$)
CC quasi-elastic	$\nu_\mu + n \to \mu^- + p$	66
NC elastic	$\nu_\mu + N \to \nu_\mu + N$	21
CC resonance π^+	$\nu_\mu + N \to \mu^- + N + \pi^+$	28
CC resonance π°	$\nu_\mu + n \to \mu^- + p + \pi^\circ$	7
NC resonance π°	$\nu_\mu + N \to \nu_\mu + N + \pi^\circ$	8
NC resonance $\pi^\pm$	$\nu_\mu + N \to \nu_\mu + N' + \pi^\pm$	3
CC DIS	$\nu_\mu + N \to \mu^- + X, W > 2$ GeV	1
NC DIS	$\nu_\mu + N \to \nu_\mu + X, W > 2$ GeV	0.5
CC coherent π°	$\nu_\mu + A \to \mu^- + A + \pi^+$	3
NC coherent $\pi^\pm$	$\nu_\mu + A \to \nu_\mu + A + \pi^\circ$	2
CC Kaon production	$\nu_\mu + N \to \mu^- + K + X$	~0.1
NC Kaon production	$\nu_\mu + N \to \nu_\mu + K + X$	<0.1
others		4
total		143

MicroBooNE

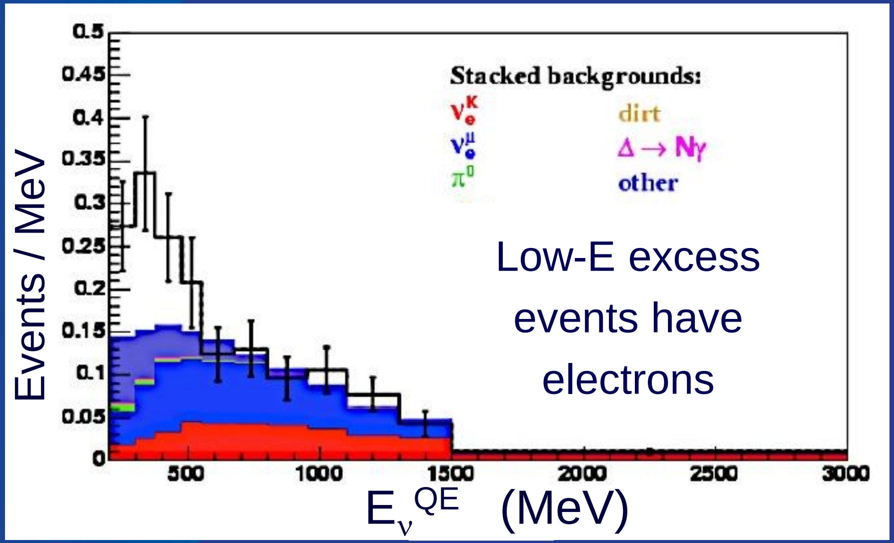


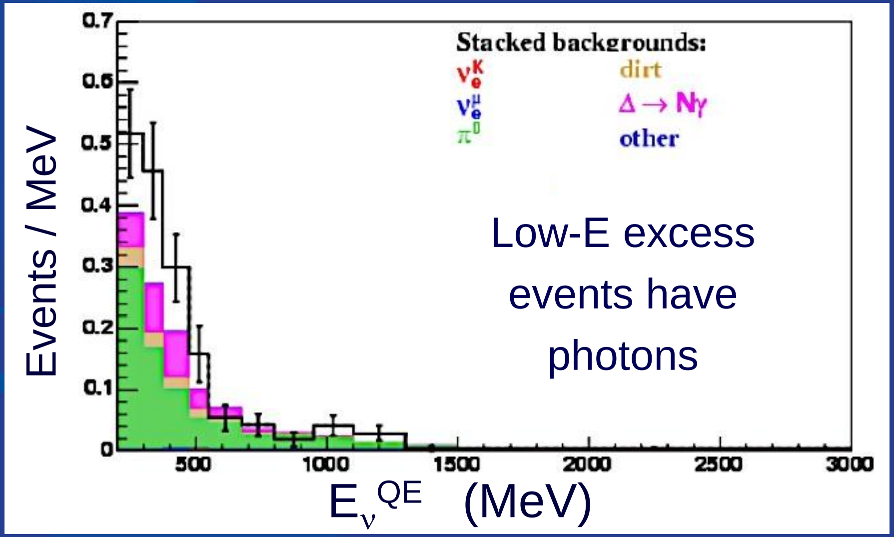
3D tracks with 3 mm resolution. Wires spaced with 3 mm pitch measure y-z coordinates. Drift time gives x. The 8256 wires arranged in planes at -60º, 0º, +60º wrt vertical.

170 tons total liquid argon / 86 tons instrumented / 60 tons fiducial

Field cage establishes 500 V/cm & drift velocity of 1.6 mm / μsec.

MicroBooNE





6×10^{20} pot in neutrino mode (2-3 year run, starting 2014)

If the MiniBooNE low energy excess is due to electrons, MicroBooNE expects a 5σ signal

If the MiniBooNE low energy excess is due to photons, MicroBooNE expects a 4σ excess

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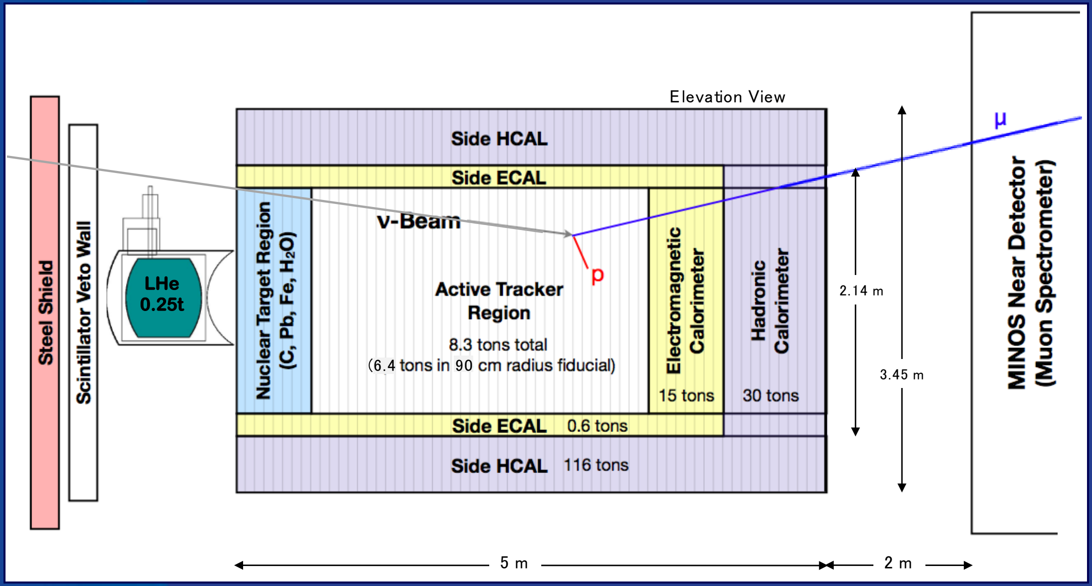
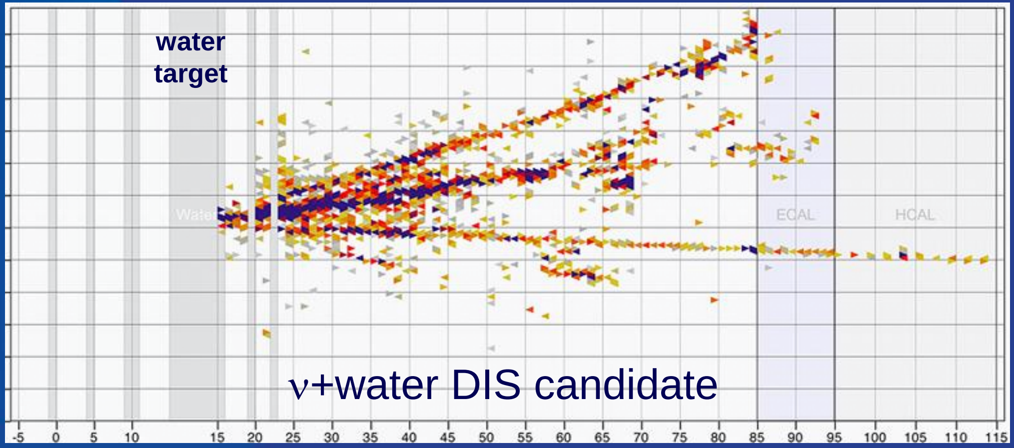
MINERvA





Finely-segmented, fully-active scintillator tracker surrounded by electro-magnetic & hadronic calorimetry

Studying neutrino-nucleus interactions in unprecedented detail on a range of nuclei (He, C, CH, H_2O, Fe, Pb)

Started data taking 2010 :

4.2×10^{20} POT (ν)

1.8×10^{20} POT (anti-ν)

European participation:

Athens, Dubna, Dortmund

WHAT IS THE SHORT-BASELINE PROGRAM AT FNAL BEYOND MINERvA & MicroBooNE ?

FOCUS GROUP

Short-Baseline Neutrino Focus Group was convened by the Fermilab Directorate end of CY11 with the following charge:

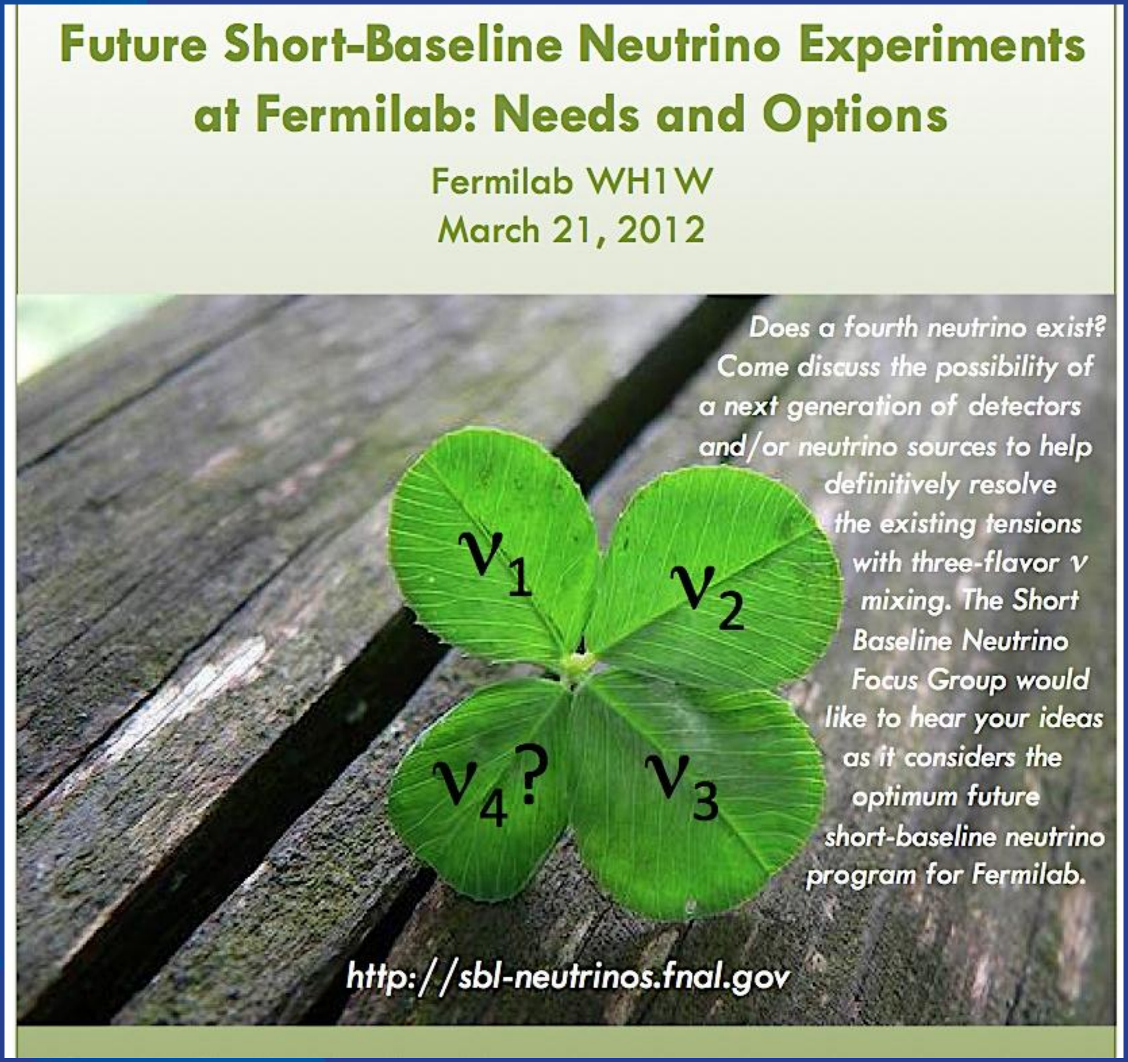
Several neutrino oscillation experiments have produced results that exhibit, at the level of a couple of standard deviations, a tension with the simple three-flavor mixing framework. These tensions might be purely statistical in origin, or might arise from one or more unidentified systematic effects, or from new physics. Together with the laboratory and the community, we would like to ask you to consider new generation detectors and/or new types of neutrino sources that would lead to a definitive resolution of the existing anomalies. With this in mind:

1. Evaluate to what extent the ongoing and planned neutrino experiments will be able to resolve the origin of each of the couple of sigma tensions with three-flavor mixing. Identify any additional measurements that might be needed, and options for making these measurements.

2. Compare with competing facilities the future capabilities at Fermilab for supporting a short baseline neutrino program to definitively resolve the present anomalies, and suggest what the optimal short baseline neutrino program might be beyond the presently approved and running experiments.

➔First meeting of the Focus Group was Jan 9, 2012.

COMMUNITY MEETING



112 Participants

19 Talks

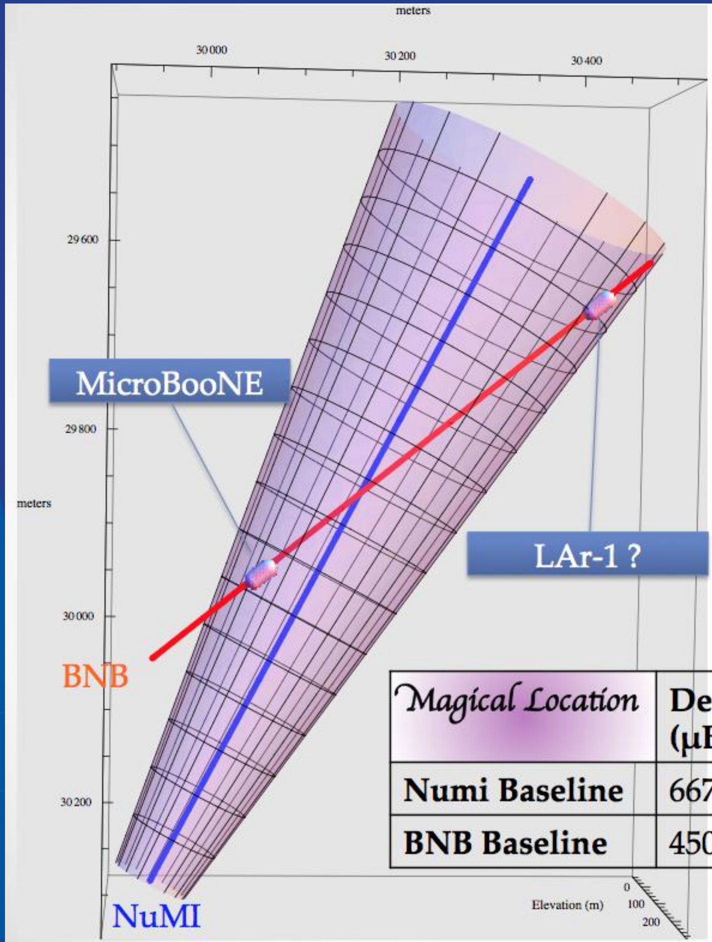
Depending on how you count, 10-20 different experiments concepts presented/discussed

IDEAS FROM THE COMMUNITY FOR FUTURE SHORT-BASELINE EXPERIMENTS

RADIOACTIVE SOURCES	
ELASTIC SCATTERING	Borexino (nu and anti-nu), SNO+Cr
CHARGED CURRENT	LENS, Baksan, Ce-LAND, Borexino, Daya Bay
COHERENT SCATTERING	RICOCHET using bolometers
REACTORS	
SMALL CORE	SCRAAM (Bugey, SONGS, ATR), Stereo
COHERENT SCATTERING	RICOCHET using bolometers
ATMOSPHERIC NEUTRINOS	
Fe CALORIMETER	ICAL, INO
OTHER	LAr Detector, IceCube
ACCELERATORS: DECAY AT REST	
LSND-LIKE	OscSNS (ORNL or FNAL), LSND Reloaded (Super-K + cyclotron)
COHERENT SCATTERING	RICOCHET using bolometers
ACCELERATORS: DECAY IN FLIGHT	
PION-DECAY	BooNE, MicroBooNE+LAr (LArLAr), NOvA short-baseline, SciNOvA
MUON DECAY	Muon decay ring (VLENF), Entry-level Neutrino Factory, Full NF
Nu-tau APPEARANCE	With L/E ~ 1 m/MeV
OTHER MEASUREMENTS	
HADRON PRODUCTION	MIPP-Upgrade, NA61/Shine

EXAMPLE IDEA - 1

Two detectors at “magic” locations using 2 beams with same off-axis angle (hence neutrino spectrum) for off-axis beam.



Two Detectors & Two Neutrino Beams

Locate a far detector for μ BooNE such that it is:

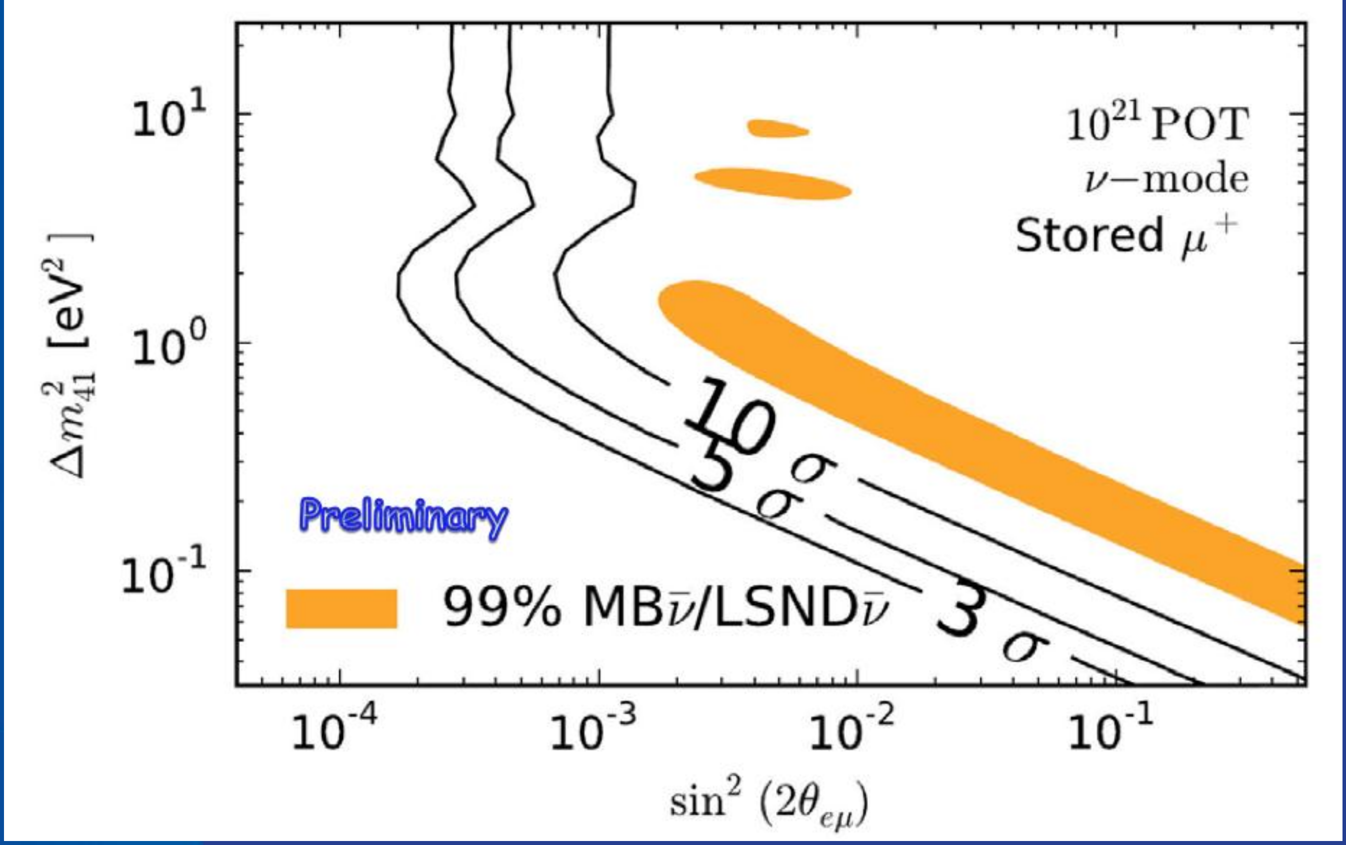
- on-axis for the BNB
- at the same off-axis angle

Magical Location	Detector 1 (μBooNE)	Detector 2 (LAr-1)
Numi Baseline	667 m	1110 m
BNB Baseline	450	925

Geoff Mills

EXAMPLE IDEA - 2

Simple muon storage ring to generate anti-ν_e beam



Alan Bross

SUMMARY

- There's an enthusiastic short-baseline community with lots of ideas.
- The near-term short-baseline experimenents at Fermilab are MINERvA and MicroBooNE.
- The Short-Baseline Neutrino Focus Group at Fermilab is looking at how possible experiments at FNAL, beyond the currently approved program, might contribute to a definitive resolution of the current tensions with 3 flavor mixing, particularly the LSND/MiniBooNE effects. There are some promising ideas. Conclusions will be presented to the June PAC meeting.

BACKUP SLIDES

EVOLUTION OF FACILITIES

Program:	Stage-0: Proton Improvement Plan	Stage-1: 1 GeV CW Linac driving Booster & Muon Campus	Stage-2: Upgrade to 3 GeV CW Linac (MI>70 GeV)	Stage-3: Project X RDR (MI>60GeV)	Stage-4: Beyond RDR: 8 GeV power upgrade to 4MW
MI neutrinos	470-700 kW**	515-1200 kW**	1200 kW	2300 kW	2300-4000 kW
8 GeV Neutrinos	15 kW + 0-50 kW**	0-40 kW* + 0-90 kW**	0-40 kW*	85 kW	3000 kW
8 GeV Muon program e.g, (g-2), Mu2e-1	20 kW	0-20 kW*	0-20 kW*	85 kW	1000 kW
1-3 GeV Muon program	-----	80 kW	1000 kW	1000 kW	1000 kW
Kaon Program	0-30 kW** (<30% df from MI)	0-75 kW** (<45% df from MI)	1100 kW	1100 kW	1100 kW
Nuclear edm ISOL program	none	300 kW	300 kW	300 kW	300 kW
Ultra-cold neutron program	none	300 kW	300 kW	300 kW	300 kW
Nuclear technology applications	none	300 kW	300 kW	300 kW	300 kW
# Programs:	4	8	8	8	8
Total* power (mean):	660 kW	2020 kW	4210 kW	5490 kW	11300kW

Steve Holmes, March 21st, 2012 meeting

FOCUS GROUP

Steve Brice	FNAL
Bonnie Fleming	Yale
Steve Geer (chair)	FNAL
Andre de Gouvea	Northwestern
Debbie Harris	FNAL
Patrick Huber	Virginia Tech
Boris Kayser	FNAL
Geoff Mills	LANL
Koichiro Nishikawa	KEK
Stephen Parke	FNAL
Chris Polly	FNAL
Andre Rubbia	ETH Zurich
Bob Tschirhart	FNAL
Richard Van de Water	LANL
Bob Zwaska	FNAL
Sam Zeller	FNAL