Medium-term neutrino program in the US

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INPAC 2007, Doubletree Berkeley Marina
ongoing

• SNO is over, NCD data still being analyzed
• Mini-BooNE at odds with LSND @ 98%CL
• Mini-BooNE anti-neutrino run
• MINOS
• SuperK, KamLAND (solar), Borexino
• Sci-BooNE
• MINERνA
ongoing

- SNO is over, NCD data still being analyzed
- Mini-BooNE at odds with LSND at 98%CL
- MINOS
- SuperK, KamLAND (solar), Borexino
- Sci-BooNE
- MINER
Measures low-E neutrino cross sections in the T2K region
MINERνA

- DOE CD-1, 2, 3a March 2007
- NSF MRI, June 2007 $750K
- TPC=$16.8M, below P5 cutoff
What I know

- I don’t have any insider information
- I basically reiterate P5 recommendations Oct 2006, and add some updates
What are the masses of the neutrinos? Does the neutrino mass spectrum resemble the charged-lepton and quark spectra, or is it an inverted version of those other spectra?

What is the pattern of neutrino mixing? How large is $\theta_{13}$, the centrally important but presently-unknown mixing angle? Is the atmospheric mixing angle, known to be very large, maximal?

Are neutrinos their own antiparticles?

Do neutrinos violate the matter-antimatter CP symmetry? Are neutrinos the key to understanding the matter-antimatter asymmetry of the universe?

Are there sterile neutrinos — neutrinos that do not experience any of the known forces of nature except gravity?

What can neutrinos tell us about the models of New Physics beyond the Standard Model?

What has been the role of neutrinos in shaping the universe? What would an understanding of this role tell us about the universe and about neutrinos?

What can neutrinos, acting as messengers, reveal about astrophysical phenomena?

What totally unanticipated further surprises do neutrinos have in store?
P5 Report
Simplified

• normal or inverted hierarchy?
• How large is $\theta_{13}$? Is $\theta_{23}$ maximal?
• Majorana?
• CP violation? Leptogenesis?
• Are there sterile neutrinos?
• Neutrinos and models of New Physics?
• Did neutrino mass affect galaxy formation?
• Using neutrinos to learn astrophysics?
• Any more surprises?
Daya Bay

Far site
1600 m from Ling Ao
2000 m from Daya
Overburden: 350 m

Mid site
~1000 m from Daya
Overburden: 208 m

Ling Ao Near
500 m from Ling Ao
Overburden: 98 m

Daya Bay Near
360 m from Daya Bay
Overburden: 97 m

Entrance portal

Empty detectors: moved to underground halls through access tunnel.
Filled detectors: swapped between underground halls via horizontal tunnels.

Total tunnel length: ~2700 m
Daya Bay

- US cost ~$20M
- A detailed review of the Daya Bay project should be carried out as soon as possible. This review should focus particularly on the feasibility of the approach. It should evaluate the basis of estimates of the systematic uncertainties, along with the additional systematic uncertainties induced by moving the detectors. Conditional on a favorable review, we recommend proceeding with planning and construction.
- going ahead with Chinese funding
- passed CD-1 (April 2007), CD-2 in October
• ~$200M, with accelerator upgrade ~$30–40M
• Proceed with the 20 kt-scale NOvA experiment. Due to long operations required, construction should not be stretched out significantly with respect to the roadmap described in Chapter VI.
• We encourage T2K and NOvA to communicate to maximize the complementarity of the two programs. We recommend a modest level of U.S. participation in T2K. We encourage international participation in NOvA Phase I.
• CD-I April 2006, CD-II Lehman review July 2007
T2K vs NO\(\nu\)A

- LBL \(\nu_\mu \rightarrow \nu_e\) appearance
- Combination of
  - \(\sin^2 2\theta_{13}\)
  - Matter effect
  - CP phase \(\delta\)

95\%CL resolution of mass hierarchy
$3\sigma$ sensitivity on $\sin^2 2\theta_{13}$
Accelerator vs Reactor

Reactor experiments can help in Resolving the $\theta_{23}$ degeneracy

(Example: $\sin^2 2\theta_{23} = 0.95 \pm 0.01$)

McConnel & Shaevitz, hep-ex/0409028
The three techniques to measure neutrino-less beta decay, CUORE, EXO, and Majorana should be investigated vigorously, leading to a selection of one technique for an experiment at the 1-10 ton scale. One possible decision point is after the parallel EXO efforts in barium tagging and in the EXO-200 double beta decay search are complete. This might be as early as 2010. Should success of the techniques be demonstrated, an upgrade to the full experiment with either a 1-ton or a 10-ton detector should be considered in the context of the other possibilities available at that time and with advice from the appropriate body (i.e., NuSAG). By around 2011-2013 more information is also expected to be available on the feasibility of a larger scale version of the $^{76}$Ge and $^{130}$Te experiments.
750g $^{130}$Te O$_2$
$\langle m_{\nu} \rangle_{ee} > 20$-$60$meV

200 kg $^{136}$Xe, aiming at 10t
The DUSEL is an intriguing scientific possibility for physics and astrophysics. We recommend that the DUSEL planning and evaluating process continue.
Long-term

- No recommendation, only possibilities
- 2nd NOvA detector @ further off-axis
- FNAL beam to ~Mt H$_2$O, LAr in DUSEL
- T2KK, CERN SPL to Fréjus/Modane
- muon storage ring
Sensitivity to mass hierarchy

4MW
T2KK: 0.27Mt×2
T2K-II: 0.54Mt
4+4yrs v+vbar

1.0° OA
1.5° OA
2.0° OA
2.5° OA

Kamioka only
2 and 3 σ curves

Fanny Dufour
4MW
T2KK: 0.27 Mt \times 2
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4+4 yrs $\nu+\nu\bar{\nu}$

1.0° OA
1.5° OA
2.0° OA
2.5° OA

Kamioka only
2 and 3 $\sigma$ curve

Fanny Dufour
Medium-term US

- SuperK, KamLAND, Borexino
- Cross section measurements
- SciBooNE and MINERvA
- Accelerator-based oscillation physics
- Mini-BooNE (?), MINOS, T2K, NOvA
- Reactor $\theta_{13}$: Daya Bay
- $0\nu\beta\beta$: CUORE, Majorana, EXO
Medium-term US (UC)

- SuperK, KamLAND, Borexino
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- SciBooNE and MINERvA
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