STUDY OF THE PHYSICS OF NEUTRINOS

www.interactions.org/neutrinostudy

Sponsored by the American Physical Society Divisions of —

- Particles and Fields
- Nuclear Physics
- Astrophysics
- Physics of Beams

Organizational meeting was held December 2003.

www.neutrinooscillation.org/studyaps/

Final report will be completed August 2004.

Our blessing —

Compelling evidence for neutrino mass and mixing.

Our opportunity —

To answer the neutrino questions raised by this discovery.

Our purpose —

To ensure that we make the best possible use of this opportunity.

Some of the Open Questions

- Is the matter-antimatter asymmetry of the Universe explained by the neutrino?
- Do neutrinos violate CP symmetry?
- Is the origin of neutrino mass different from that of the fundamental Dirac particles? Are neutrinos Majorana particles?
- How much of the dark matter is neutrinos? What are the masses of the neutrinos?
- Does the ordering of the neutrino mass eigenstates follow the pattern suggested by quark-lepton symmetry?

- Does the neutrino mixing matrix suggest an undiscovered (flavor) symmetry? Is the mixing of θ_{23} and θ_{13} maximal?
- Do sterile neutrinos exist?
- Will the direct observation of pp fusion neutrinos finally establish our detailed theory of the nuclear processes that power the Sun?
- What role do neutrino oscillations play in the physics of Type II supernovae, in particular as to the products of the r process?
- Will the observations of astrophysical neutrino sources open up a new window to the universe?

The Purposes of the Study

— Primary Purpose —

To move towards a coherent strategy for answering the open neutrino questions — a clear, unified plan that funding sources can easily consider and promote.

To this end, we will—

- Identify the most important questions
- Evaluate the physics reach of the proposed ways of answering them
- Examine how different facilities and experiments complement each other
- Create a decision tree
- Determine an intelligent sequence of facilities and experiments

Our findings will guide the creation of the future neutrino program.

To quote our Charge —

"The Study will lay scientific groundwork for the choices that must be made during the next few years."

— Secondary Purpose —

To explain to our colleagues in other areas of physics, our funding sources, and the general public why neutrino physics is now so exciting.

Charge to each Working Group

- Analyze the physics reach of your experimental approach.
- Consider what your approach can contribute to answering the open questions.
- Ensure that the relevant experiments are represented within your group.
- Provide independent technical evaluation of ideas.

The Structure of the Study

Chairmen

Stuart Freedman, Boris Kayser

Organizing Committee

Janet Conrad, Guido Drexlin,
Belen Gavela, Takaaki Kajita,
Paul Langacker, Keith Olive,
Bob Palmer, Georg Raffelt,
Hamish Robertson, Stan Wojcicki
Lincoln Wolfenstein

Working Groups — The Central Element

Each working group is defined by an experimental approach.

The groups and their leaders —

Solar and Atmospheric Neutrino Experiments

John Bahcall <jnb@ias.edu>, Josh Klein <jrk@physics.utexas.edu>

Reactor Neutrino Experiments

Gabriela Barenboim <gabriela@fnal.gov>, Ed Blucher <blucher@hep.uchicago.edu>

Superbeam Experiments and Development

Bill Marciano <marciano@bnl.gov>, Doug Michael <michael@hep.caltech.edu>

Neutrino Factory and Beta Beam Experiments and Development

Stephen Geer <sgeer@fnal.gov>, Michael Zisman <mszisman@lbl.gov>

Neutrinoless Double Beta Decay and Direct Searches for Neutrino Mass

Steve Elliott <elliotts@lanl.gov>, Petr Vogel <pxv@caltech.edu>

What Cosmology/Astrophysics and Neutrino Physics can Teach Each Other

Steve Barwick <barwick@HEP.ps.uci.edu>, John Beacom <beacom@fnal.gov>

Theorists participate in all working groups.

They will also discuss issues like how best to use future measurements to discriminate among theoretical models.

Coordinator of theoretical discussions:

Rabi Mohapatra
<rmohapat@physics.umd.edu>

Midcourse Meeting

(April 1-2 in Berkeley)

Purpose –

To assess the progress of the working groups, and to plan the rest of the study.

Participants –

The study organizing committee, and the working group leaders.

AGENDA FOR THE APS NEUTRINO STUDY
MIDCOURSE MEETING – April 1

Reports on the activities of the working groups.

1:00 Solar and atmospheric neutrino experiments
1:30 Reactor neutrino experiments
2:00 Superbeam experiments and development
2:30 Neutrino factory and beta beam experiments and development
3:00 Break
3:30 Neutrinoless double beta decay and direct searches for neutrino mass
4:00 What cosmology/astrophysics and neutrino physics can teach each other
4:30 Theoretical analyses
5:00 Discussion
6:00 Working dinner at LBNL

AGENDA FOR THE APS NEUTRINO STUDY MIDCOURSE MEETING – April 2

9:00 Assessment of the activities of the working groups, and provision of feedback from the organizing committee members to the working group leaders, and from the working group leaders to each other. Discussion leader: Paul Langacker

10:30 Break

11:00 Conclusion of assessment discussion

12:00 Lunch at LBNL

1:00 Coordination of the activities of the different working groups. Discussion leader: Stan Wojcicki

2:00 Planning of the June final general meeting of the study. Discussion leader: Stuart Freedman

2:30 Break

3:00 Outlining of the final report and discussion of the mechanics of creating it. Discussion leader: Hamish Robertson

3:45 Planning of a glossy popular brochure on neutrinos and a post-study neutrino-fest. Discussion leader: Janet Conrad

5:00 Adjourn

Findings and Conclusions –

- Working groups are working very hard.

They are making strong cases for the science their experimental approaches could pursue.

These should be integrated into **one coherent** case for the field.

• Some groups are grappling with the hard challenges of developing a sensible sequence of experiments, avoiding experiments that don't make fairly unique contributions, and identifying crucial enabling technologies.

Examples: A US superbeam program must add physics that will not be accomplished by the Japanese program.

Beyond NOvA, a proton driver will be an enabling technology.

• Some groups need encouraging to assess the physics reach of possible experiments.

Example: Never mind.

• Coordination among the working groups is crucial.

Example: The reactor and superbeam groups must coordinate their studies of how best to determine the small mixing angle θ_{13}, the normal or inverted character of the mass spectrum, and CP violation. To this end, a focus group has already been formed.

• The heart of our final report should not be the reports of the individual working groups, but a 30-page cross-cutting document highlighting the recent accomplishments in neutrino physics, identifying the most important open physics questions, and putting forward a coherent strategy for answering them. The working group findings will be inputs to the writing of this document, and the working group reports themselves will contain the many important technical details. A “writing group” is being formed.

• The final general meeting of the study will be June 28-30 in Snowmass. Both the working groups and the writing group will arrive with drafts of their reports. The meeting will allow the study participants to carry out the final coordination, and to work toward the final consensus. A tentative agenda with this aim has been prepared. The writing group will stay on for another 4-7 days to incorporate the results of the meeting into the final report.

• To convey the excitement in neutrino physics, we will create a glossy brochure, employing both physicists and a professional writer-illustrator. Ways of making this brochure informative and effective are being explored. We will also hold (in the fall or winter) a neutrino-fest/writer's workshop to tell journalists about the beautiful developments in the neutrino world, and to explain the open questions.