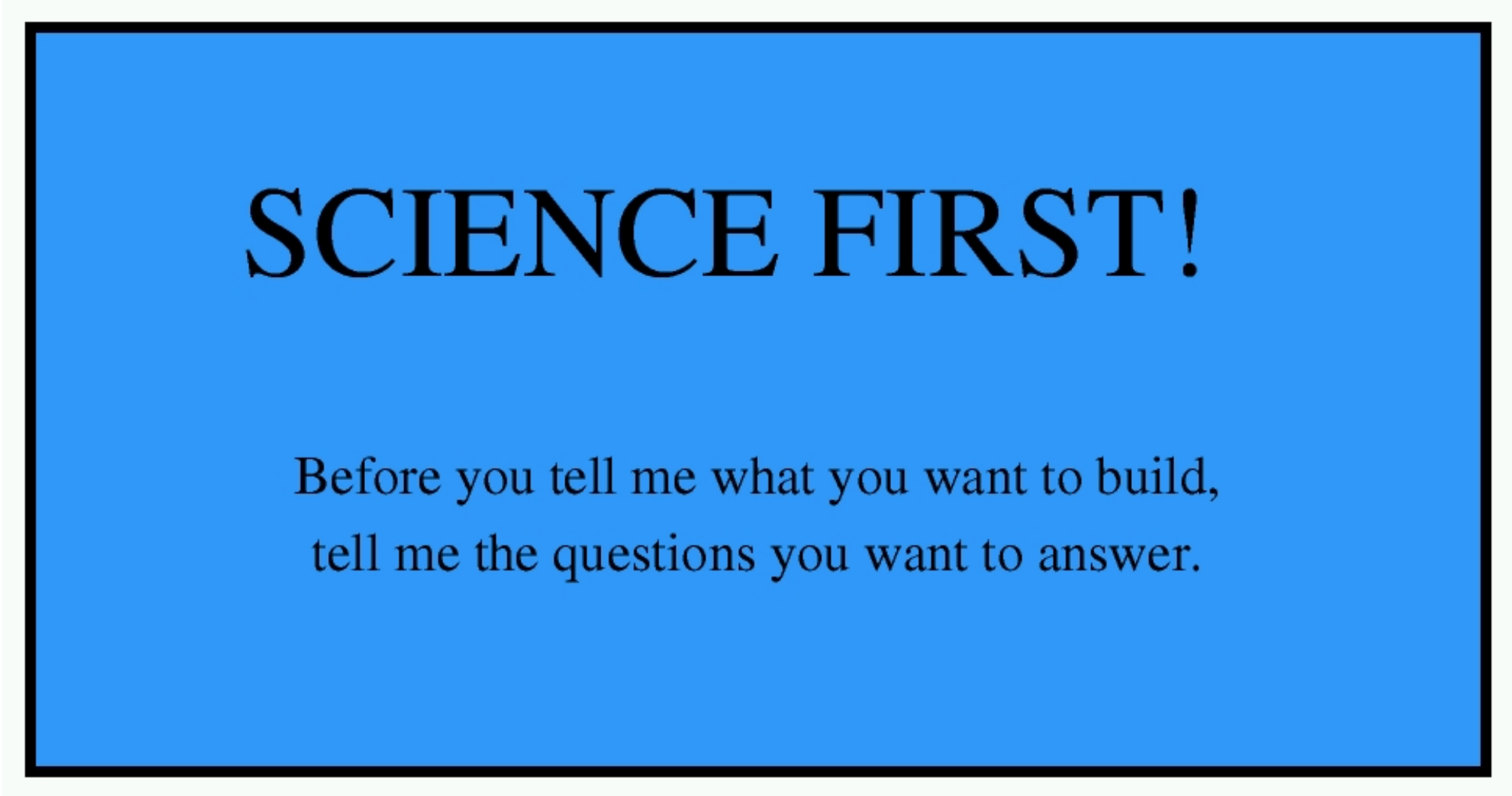
Deep Underground Science and Engineering Workshop

Eugene W. Beier

14 August 2004

Conclusions/Physics

Mike Turner's Exhortation



Solicitation 1:
Research Definition & Associated Infrastructure Requirements

- Define science and engineering research
  - Clearly articulate the program (initial suite of experiments, future program) and associated underground infrastructure requirements
  - Describe any associated requirements for instrumentation R&D
  - International context (partnering, duplication, …)
- Science and engineering organized into modules with common infrastructure needs
  - Describe the infrastructure needs for each Module, including depth, space, power, cooling, special safety features, etc.

Physics Topics

1. Solar Neutrinos $\rightarrow$ Low Energy Neutrinos
2. Double Beta Decay
3. Nucleon Decay/Atmospheric Neutrinos
4. Dark Matter
5. Low Background Counting Facilities and Prototyping

Physics Topics

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4. Dark Matter
5. Low Background Counting Facilities and Prototyping
6. Nuclear Astrophysics

Neutrino Questions

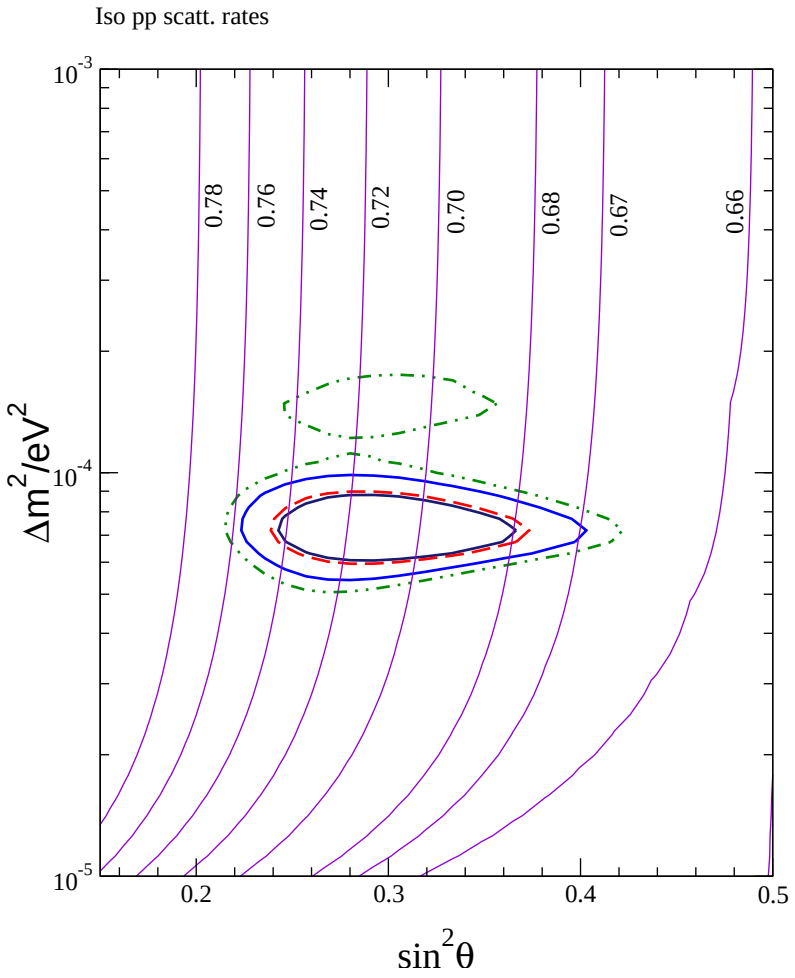
1. Why are lepton mixings large compared to quark sector?
2. How close is θ_{23} to maximal?
3. How small is θ_{13}? Why $\theta_{13} \ll \theta_{12}, \theta_{23}$?
4. What is the neutrino mass hierarchy?
5. Does the unitary triangle for neutrinos close (extra generations)?
6. Do neutrinos violate CP?
7. Does CP violation in neutrinos produce matter-antimatter asymmetry in universe (leptogenesis)?

Must measure θ_{13}, hierarchy, and especially CP!

Thanks to Eligio Lisi

Low Energy Neutrinos

- Solar Neutrinos: The SSM flux for *pp* neutrinos is known to 1%. Improve measurement of θ_{12}.



(S.Goswami, A.Bandyopadhyay, and S.Choubey,hep-ph/0312028)

Solar Neutrinos

- A *pp* rate measurement with better than 3% accuracy improves knowledge of $\sin^2\theta_{12}$.

- A *pp* rate measurement with better than 2% accuracy improves the experimental determination of the *pp* flux (using the luminosity constraint).

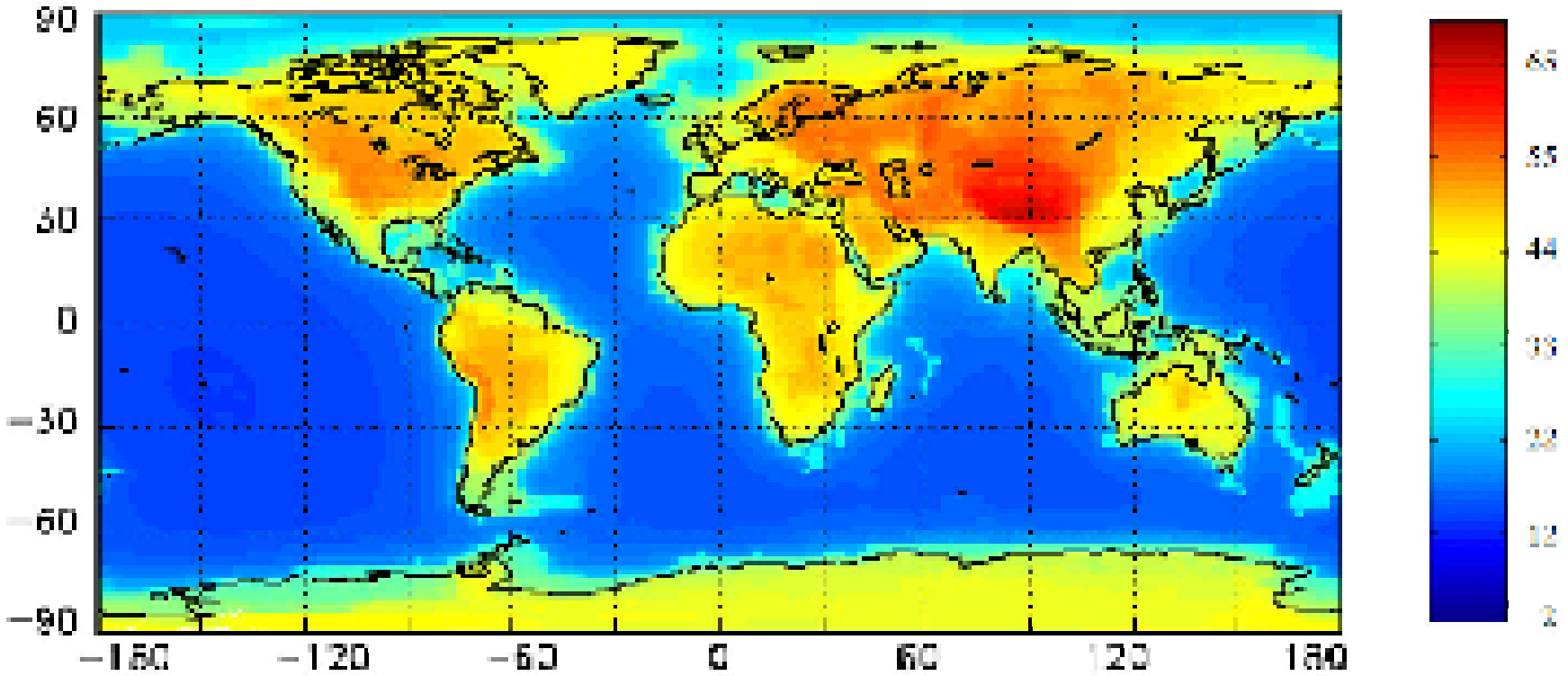
- Test luminosity constraint – Does L_{photon} imply $L_{neutrino}$?

Low Energy Neutrinos

- Geo-Neutrinos

  Constrain models of earth's interior. (R. Davis)

Neutrino events from U, Th:

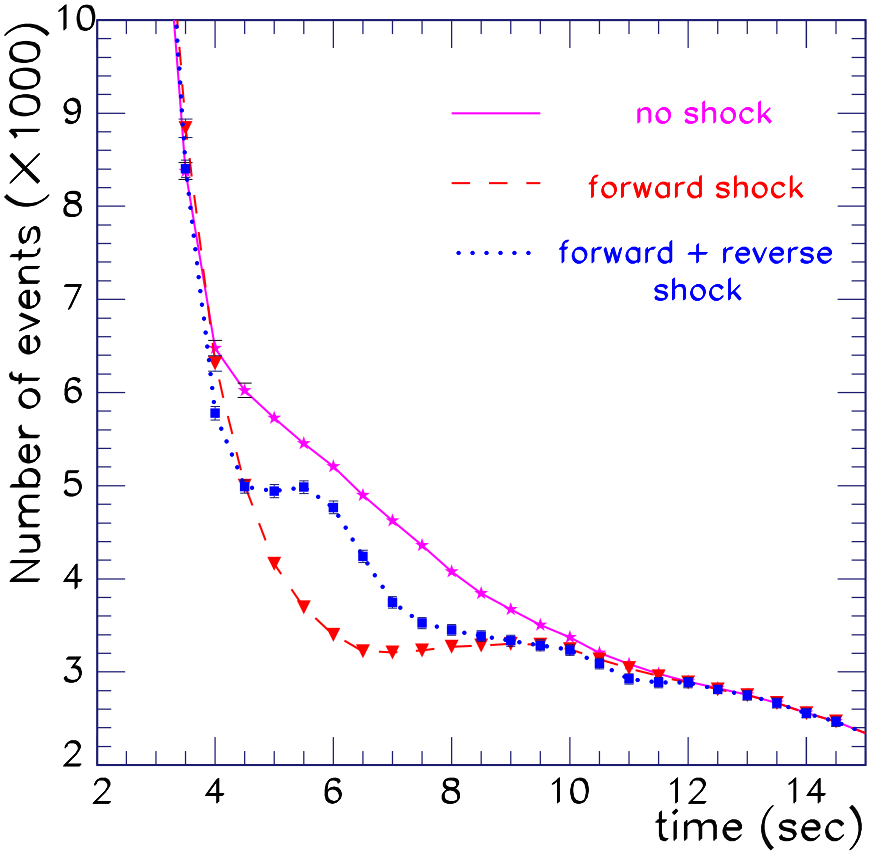


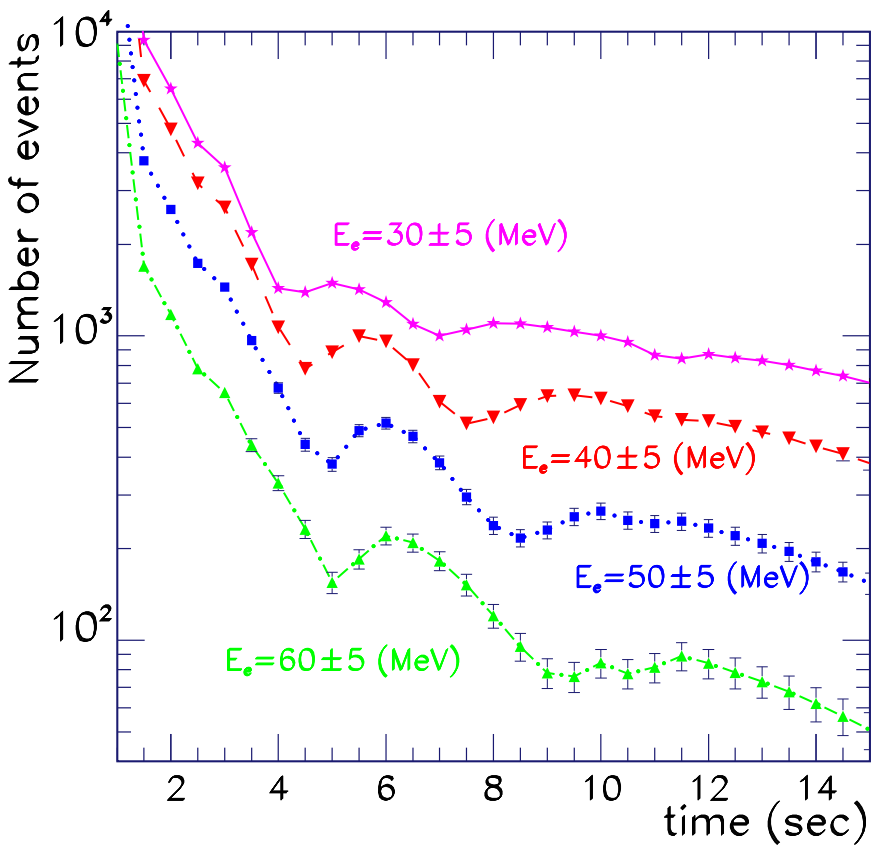
(Fiorentini, et al., PRD 69 (2004) 013001)

Low Energy Neutrinos

- Supernova Neutrinos

  Learn about the equation of state of dense nuclear matter.





(R. Tomas, et al.,astro-ph/0407132)

↑ Reverse shock

Low Energy Neutrinos

- Relic Supernova Neutrinos

  Learn about the cosmological history of star formation.

Neutrinoless Double Beta Decay

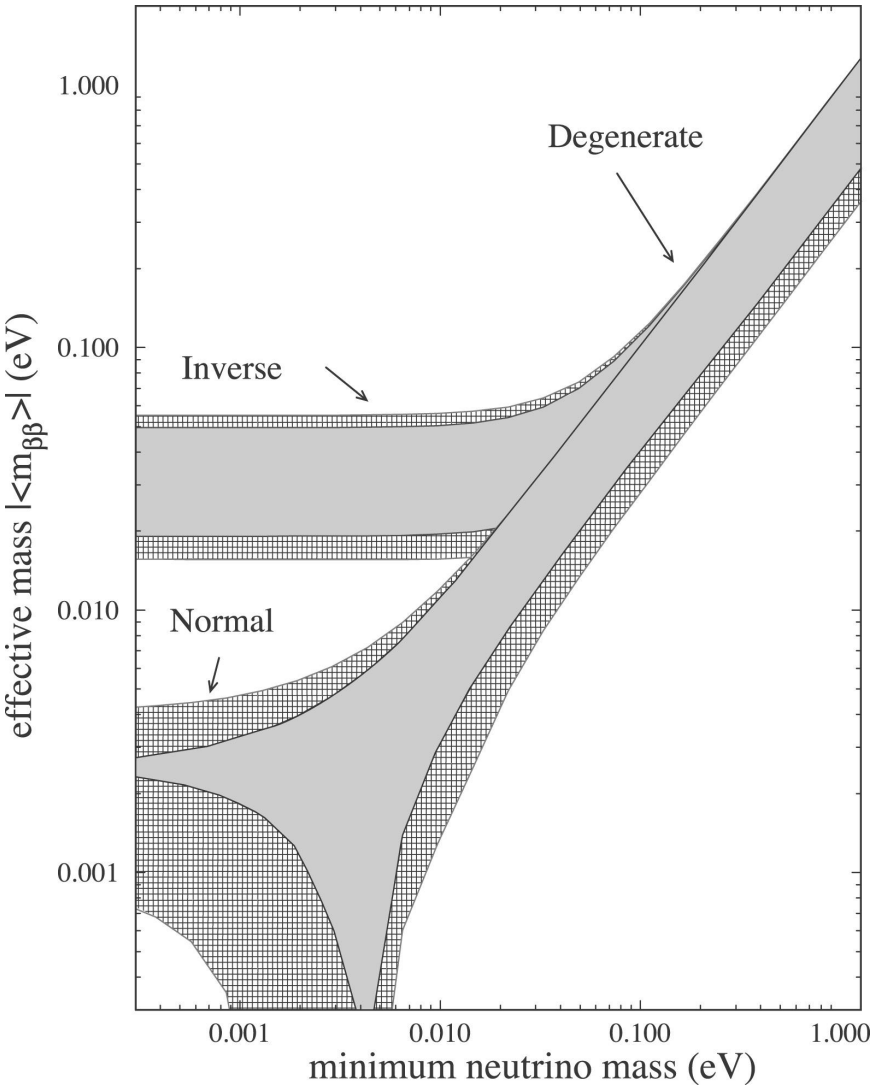
- Are neutrinos their own anti-particles?

- Constrain the total mass scale by measuring

$$|\langle m_{\beta\beta}\rangle|^2 = \left|\sum_i m_i U_{ei}^2\right|^2 .$$

- Sequence of difficult experiments:
  Sensitivity to:

Degenerate - now (200 kg)
Inverted - before DUSEL? (1000kg)
Normal - in a decade? (10,000 kg)



(Particle Data Group)

Long Baseline Neutrino Experiments

Measure θ_{13}, δ_{CP}, and the sign of Δm^2_{13}

Need:

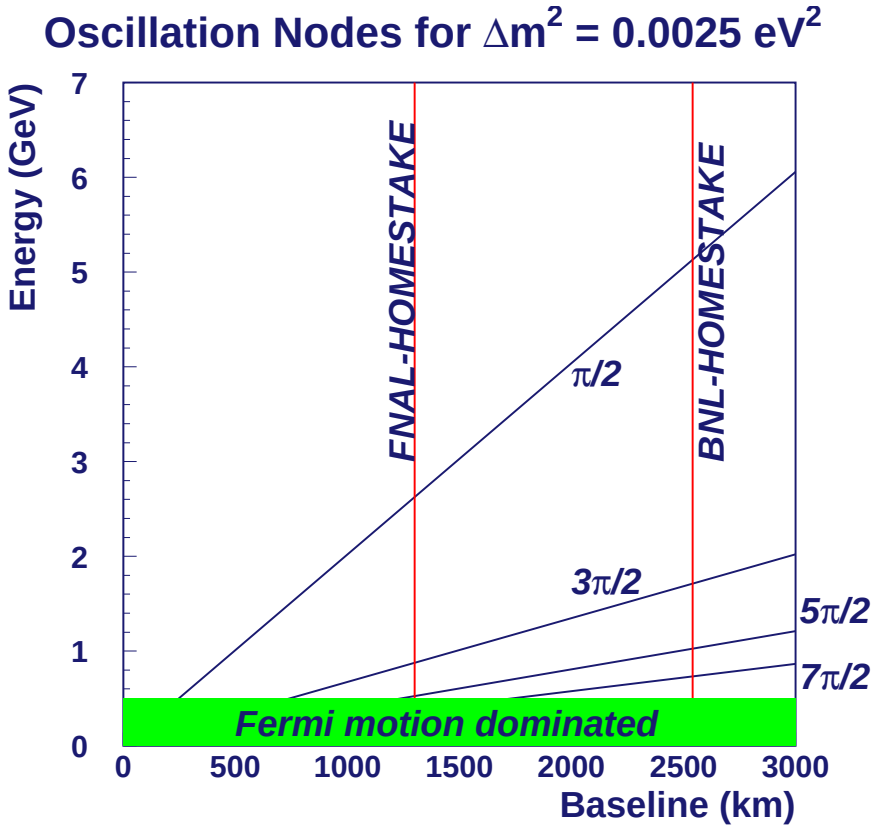
$>$1000 km baseline.

$>$100 kilo-ton detector.

(Depending on technology)

Does it need DUSEL?

Stay tuned...



(M. Diwan, hep-ex/0407047)

Nucleon Decay/Atmospheric Neutrinos

Are forces of nature unified at high energy?

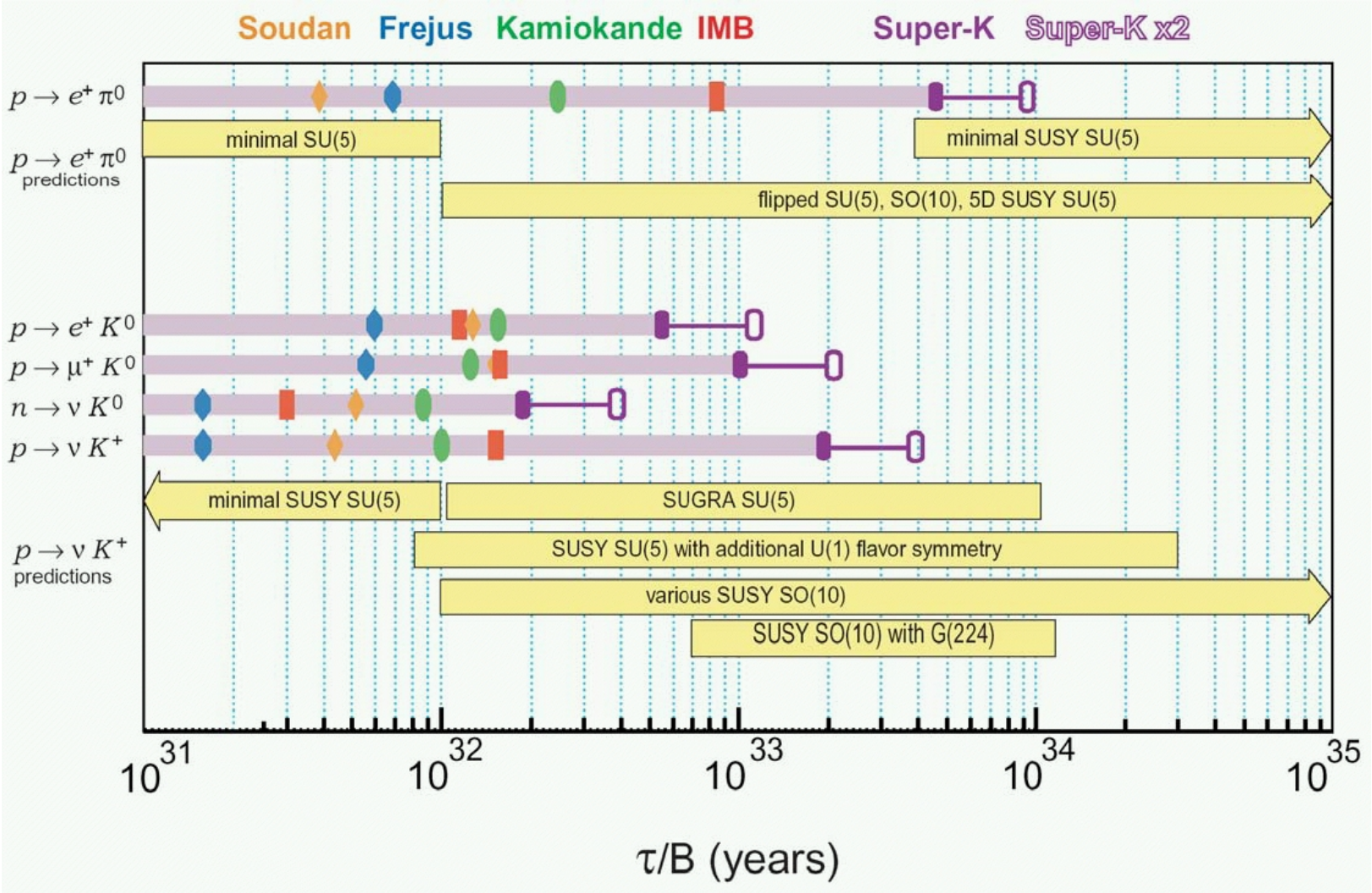
Nucleon Decay/Atmospheric Neutrinos

Are forces of nature unified at high energy?

A positive nucleon decay result would be an achievement comparable to those of Newton and Maxwell...

Nucleon Decay

Can we make it to the end of this picture?



Multi-purpose Nature

- Possible long baseline target.
- If a supernova occurs at 10kpc, expect ~ 150,000 anti-$_e$ events…about a factor of 10 more than all other detectors combined. This varies with detector design.
- Geophysical neutrino measurements can resolve the long-standing issue of the Earth's heat budget
  - requires sensitivity to neutrinos in the range 0.5-2.6 MeV
- Integrated flux from distant SN should produce an isotropic constant flux of $_e$
  - implications for stellar formation rate
  - SK has published limits which are a factor of five above most optimistic models
  - ~200 background events from "stealth" muons and other atmospheric neutrino interactions

Continue: Goals of the PDK/ATMnu Working Group

Requirements

- Draw on the requirements from the currently existing proposals/ideas
  - limit discussions on how best to do the experiment or on particular choice of the detector technology
- Some of the critical requirements
  - depth
  - size (rock quality/stability)
  - total volume (rock removal rate)
  - access (time, component size, component weight)
  - back ground level (radon, etc.)
  - safety/environmental control (cryogenics, hazardous materials)
  - electric power, water
  - maximum cost, desired schedule

Dark Matter

- The Earth is not the center of the universe. (Copernicus)

- The Sun is not the center of the universe. We are in a galaxy.

- The matter of the Earth and stars is not the dominant form of matter in the universe. Dark matter is.

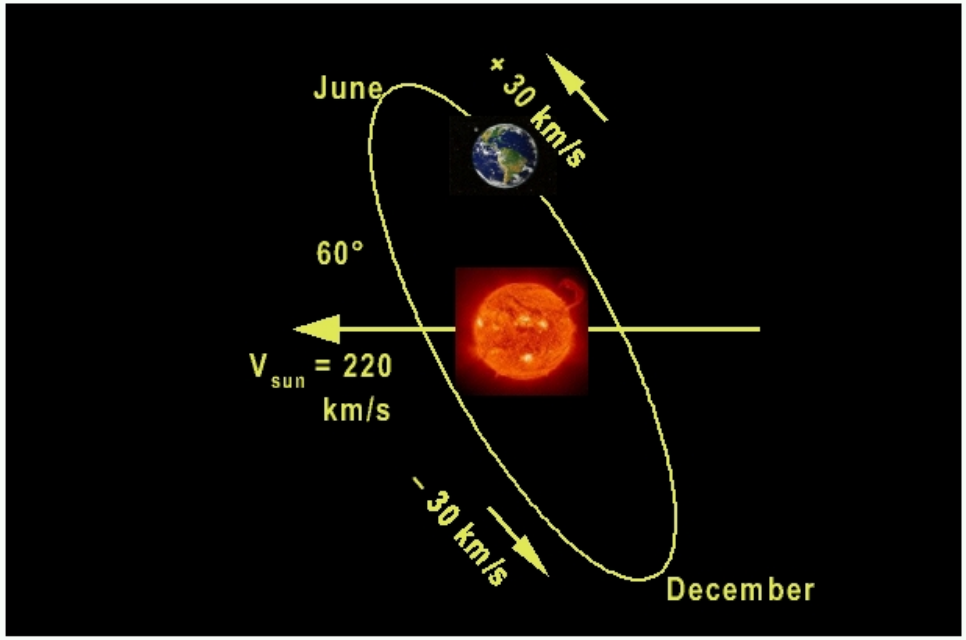
- What is Dark Matter?

- A prime candidate for dark matter is WIMPs – Weakly Interacting Massive Particles.

- Detector Technologies - different way of rejecting gammas/betas
  - CDMS: phonons (~heat) and ionization
  - Edelweiss: heat and ionization
  - LXe: light and ionization
  - Cresst: heat and light
  - Drift: track topology in gas
  - Superheated: immune

- The CDMS story, parts 1 and 2 illustrate the issues of background rejection and the neutron/depth question -- common to all WIMP dark matter searches

- Signatures
  - Calorimetry
  - Annual modulation
    - Variation of earth's motion through galactic halo
  - Directional modulation
    - Earth's rotation



Low Background

- Important support work for a large variety of physics experiments.

Nuclear Astrophysics

- No report here - this science is missing from current DUSEL program.

Modules

- Modules are groups of experiments sharing a common infrastructure.

1. Long Baseline Neutrino experiments and Nucleon decay – can share to the extreme - they can be done in the same multi-purpose detector.

2. Low energy neutrinos, neutrinoless double beta decay, dark matter have much infrastructure in common.

Conclusions

- There is an exciting program of physics experiments to start in the first decade of DUSEL.

- We can't see the second decade clearly yet, but among long baseline experiments, proton decay, double beta decay, dark matter,... there are certain to be some experiments we will be doing in the second decade.

The DUSEL physics program is strong!