The SNO+ Experiment at SNOLab

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CAP Congress 2008

SNO+

6000 mwe overburden

850 tonnes LAB Scintillator

12 m Diameter Acrylic Vessel

1700 tonnes Inner Shield H_2O

Support Structure for 9500 PMTs, 60% coverage

5300 tonnes Outer Shield H_2O

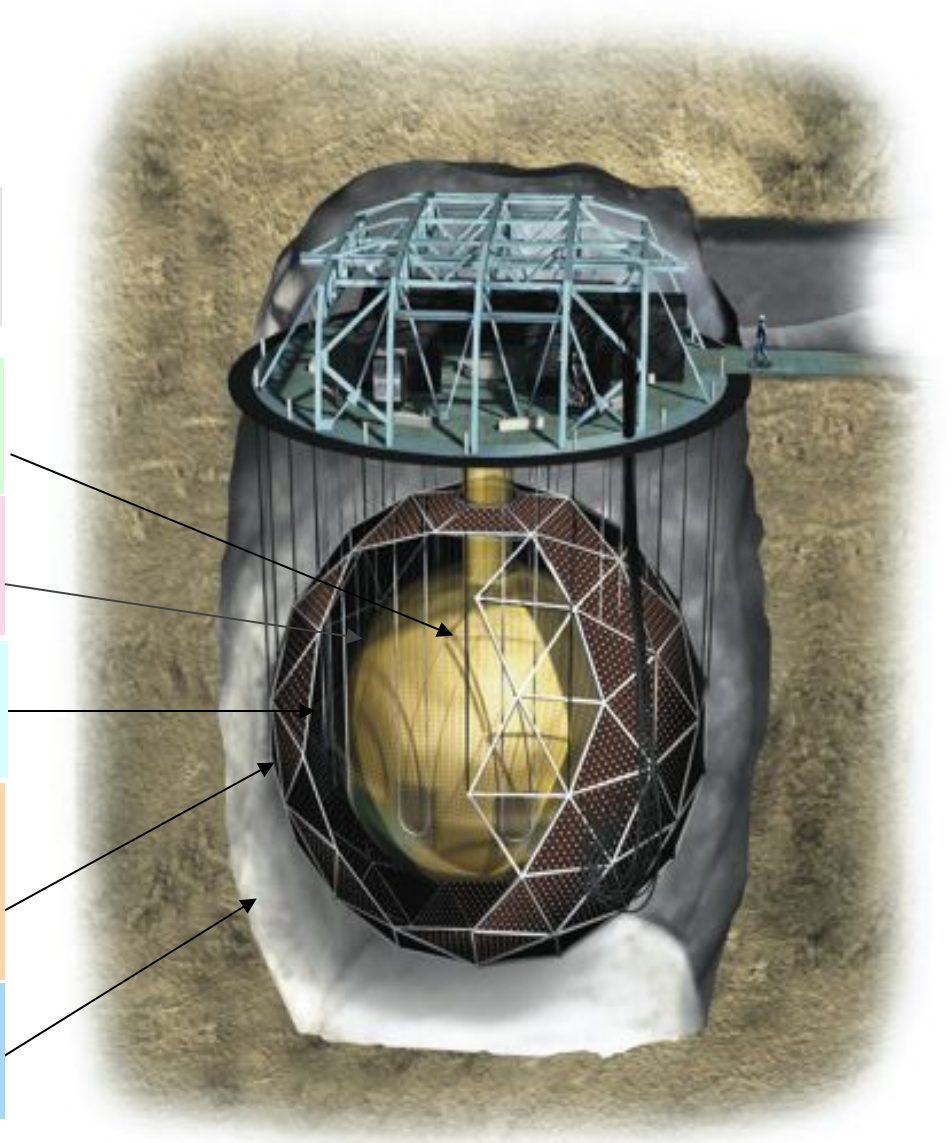


Image courtesy National Geographic

Changes between SNO and SNO+:

- Rope holddown for acrylic vessel
- Scintillator purification plant
- Improve calibration access

Neutrino interactions:

$$\nu_x + e^- \rightarrow \nu_x + e^-$$

$$\overline{\nu}_e + p \rightarrow e^+ + n$$

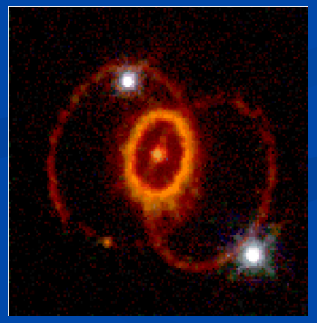
Deepest large scintillator experiment in the world!

SNO+ Physics

Low Energy Solar Neutrinos

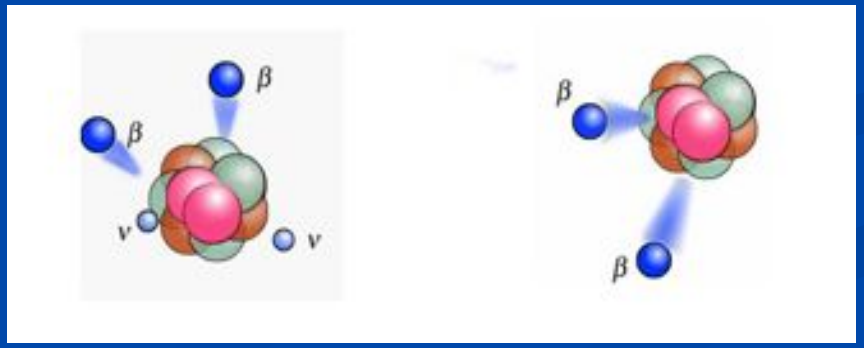
Reactor Antineutrinos

Geo-Neutrinos



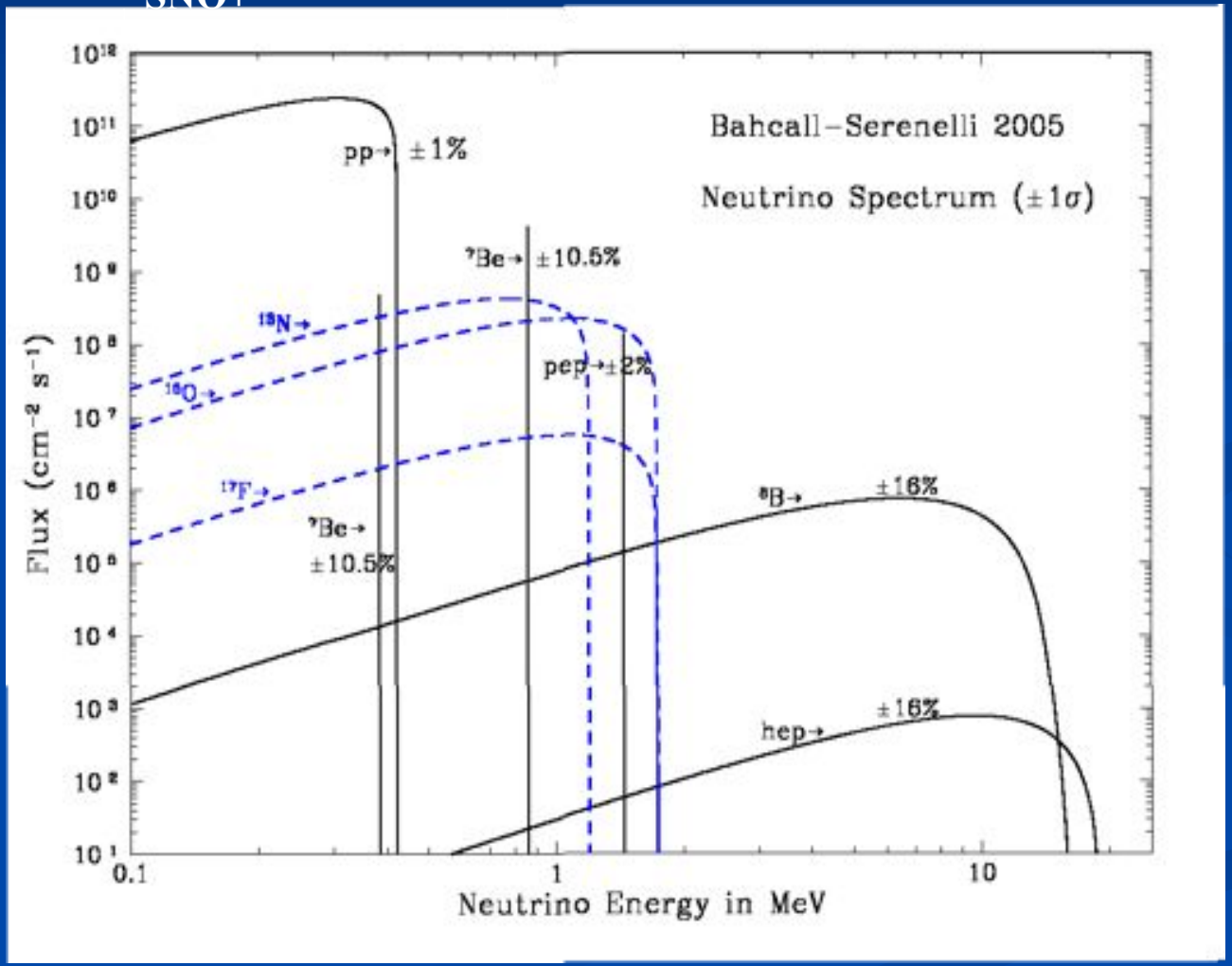
Supernova Neutrinos

Neutrinoless Double Beta Decay Search



Low Energy Solar Neutrinos

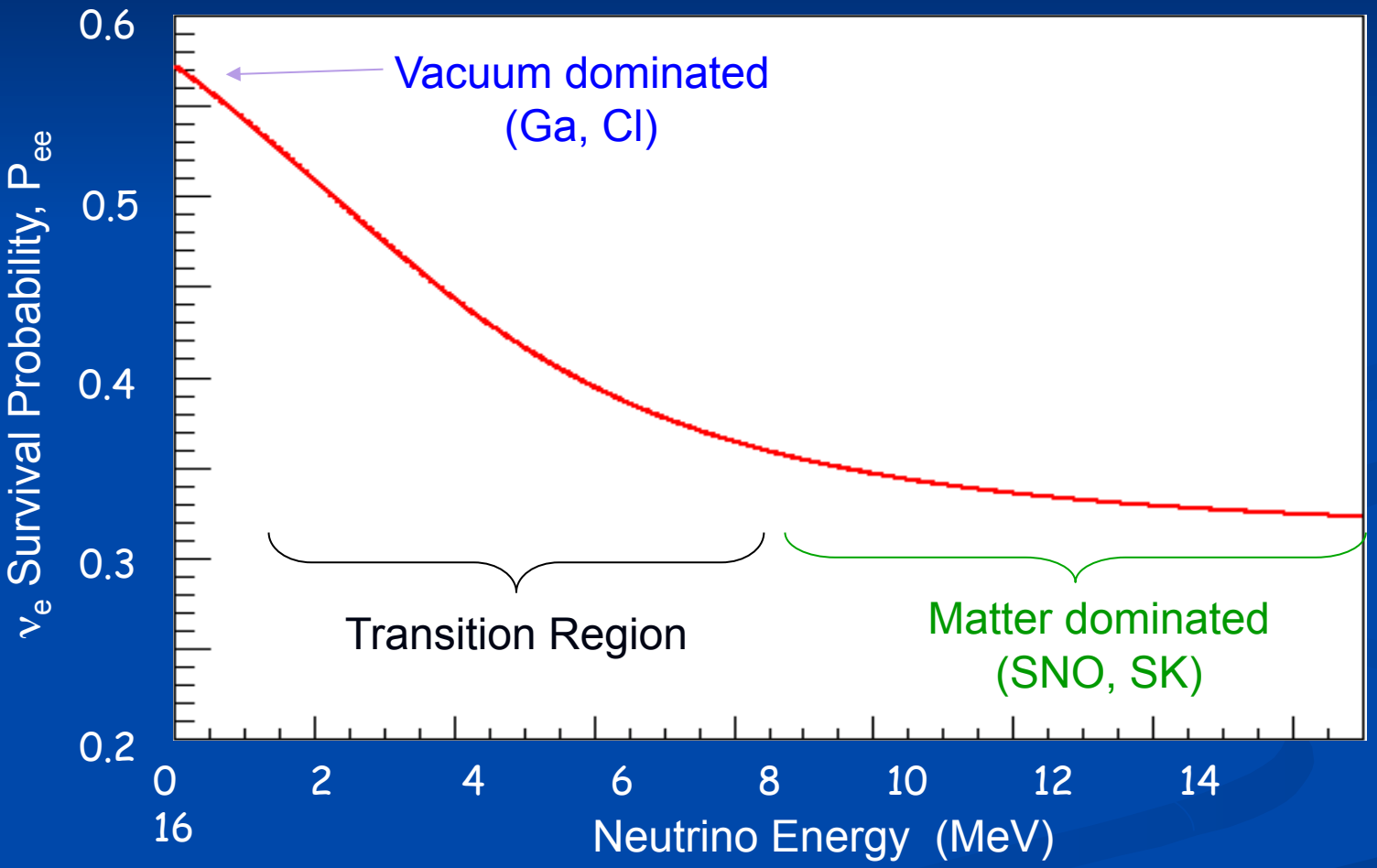
SNO+



SNO+ will study *pep*, CNO neutrinos.

Neutrino Oscillations

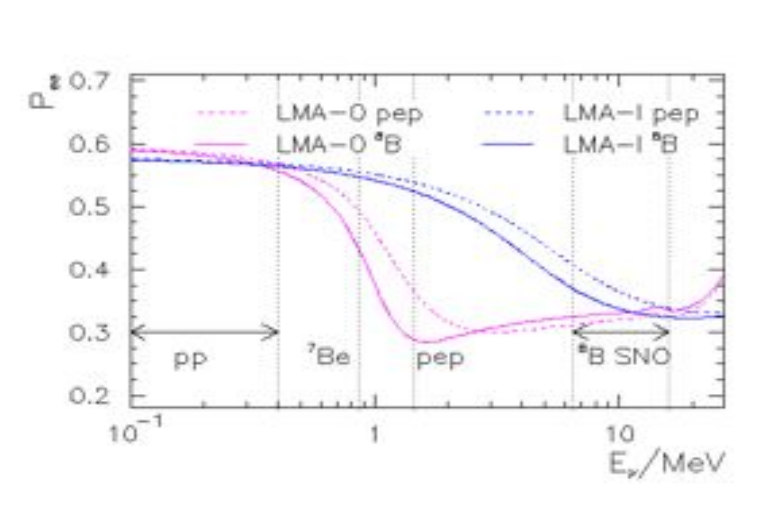
Solar electron neutrino survival probability changes with energy



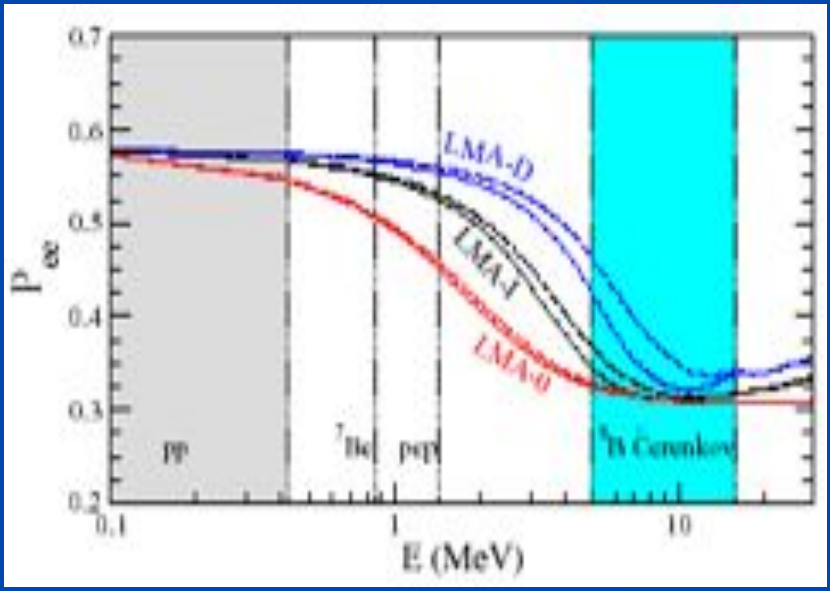
The vacuum and matter survival probabilities are well understood; it is transition region that is sensitive to details of the neutrino-matter interactions

Possible Transition Region New Physics

Non-Standard Interactions

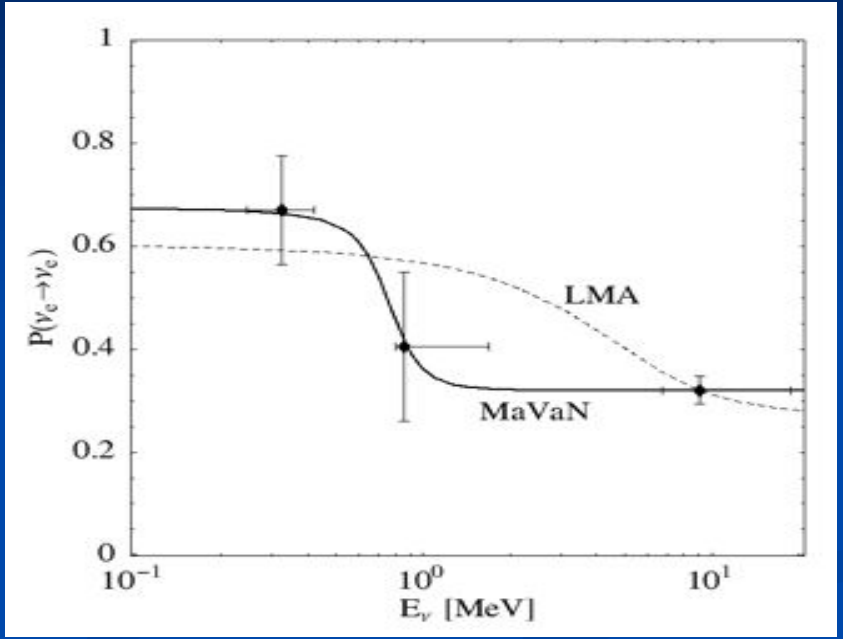


from Peña-Garay , hep-ph/0402266



from Miranda *et.al.*

Mass Varying Neutrinos



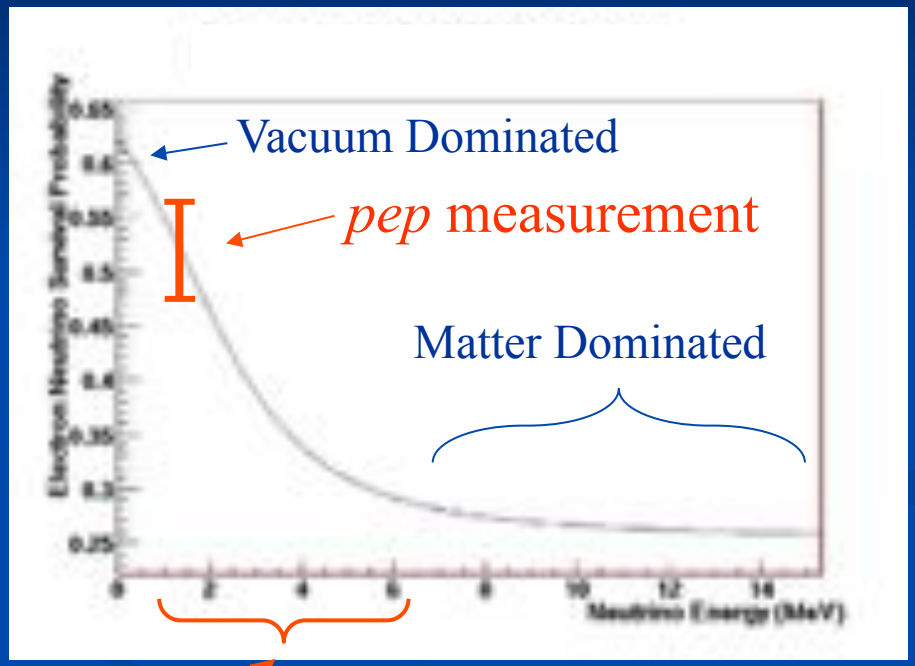
from Barger, hep-ph/0502196

Other Possibilities:

- CPT violations
- Large Θ_{13}
- Sterile neutrino admixture

pep Neutrinos: Probing Neutrino Oscillations

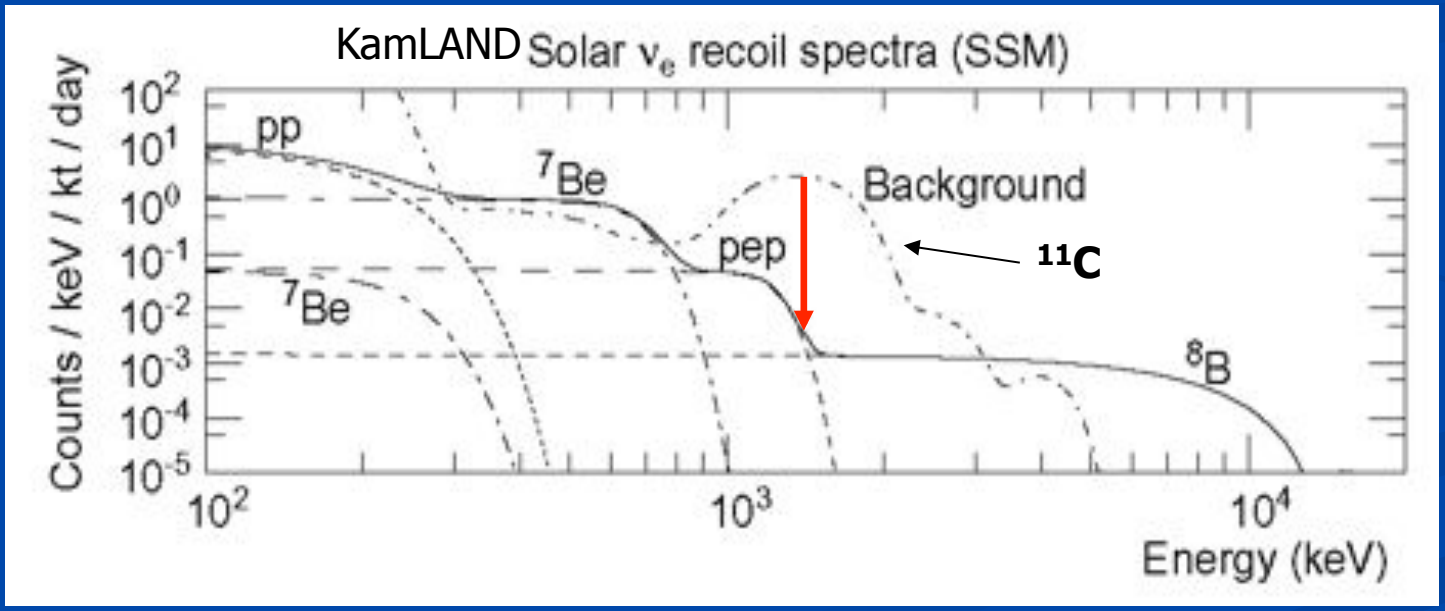
- *pep* neutrinos fall right in the transition region
- Have a small uncertainty on their predicted flux and a high enough rate to allow a precise measurement
- SNO+ can observe the rise in survival probability at low energy
  - Confirm MSW and that we know what's going on
  - Improve precision on Θ_{12} and solar only Δm_{12}^2
  - Look for new physics



Transition Region sensitive to the details of the neutrino-matter interactions

SNO+ *pep* Measurement Unique

- In other experiments, the *pep* signal is hidden by muon-produced ^{11}C decays
- SNOLAB is deep enough that ^{11}C will not interfere with the *pep* measurement in SNO+

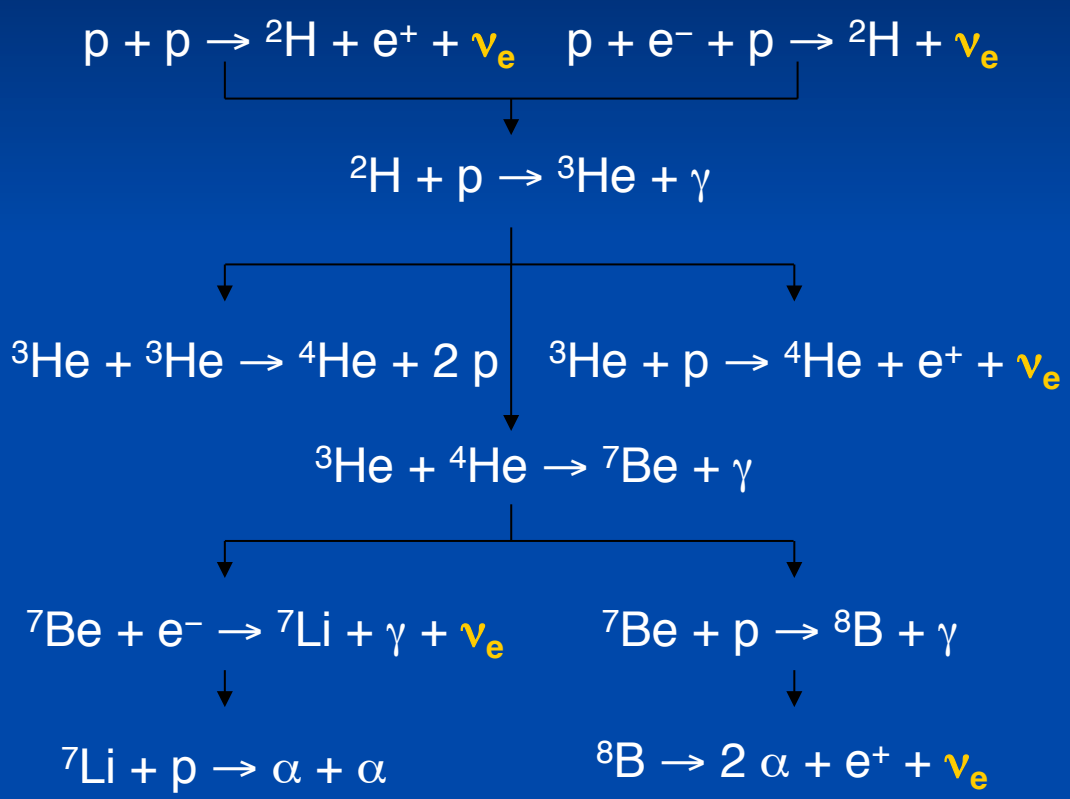


muon rate in KamLAND: 26,000 d^{-1} compared with SNO+: 70 d^{-1}

Image from the KamLAND proposal.

CNO Neutrinos

p-p Solar Fusion Chain



CNO Solar Fusion Cycle

$^{12}C + p \rightarrow {}^{13}N + \gamma$ $^{13}N \rightarrow {}^{13}C + e^+ + \nu_e$

$^{13}C + p \rightarrow {}^{14}N + \gamma$

$^{14}N + p \rightarrow {}^{15}O + \gamma$ $^{15}O \rightarrow {}^{15}N + e^+ + \nu_e$

$^{15}N + p \rightarrow {}^{12}C + \alpha$

CNO thought to provide ~2% of solar energy, but this has never been measured

SNO+ can measure the CNO contribution to solar energy generation!

Geo-Neutrinos

- Antineutrinos from β^- decay of K, U and Th in the earth's mantle and crust
- Models suggest that these decays are responsible for 40-100% of the earth's heat

Not well known!

- Use geoneutrinos to measure the earth's radiogenic heat and chemical composition

Geophysics with neutrinos!

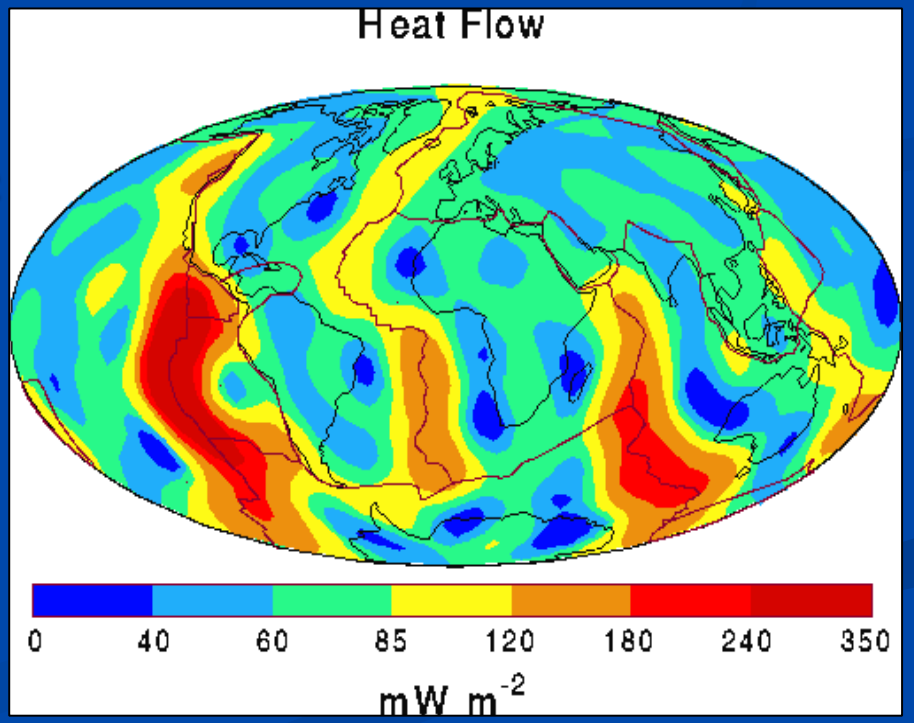
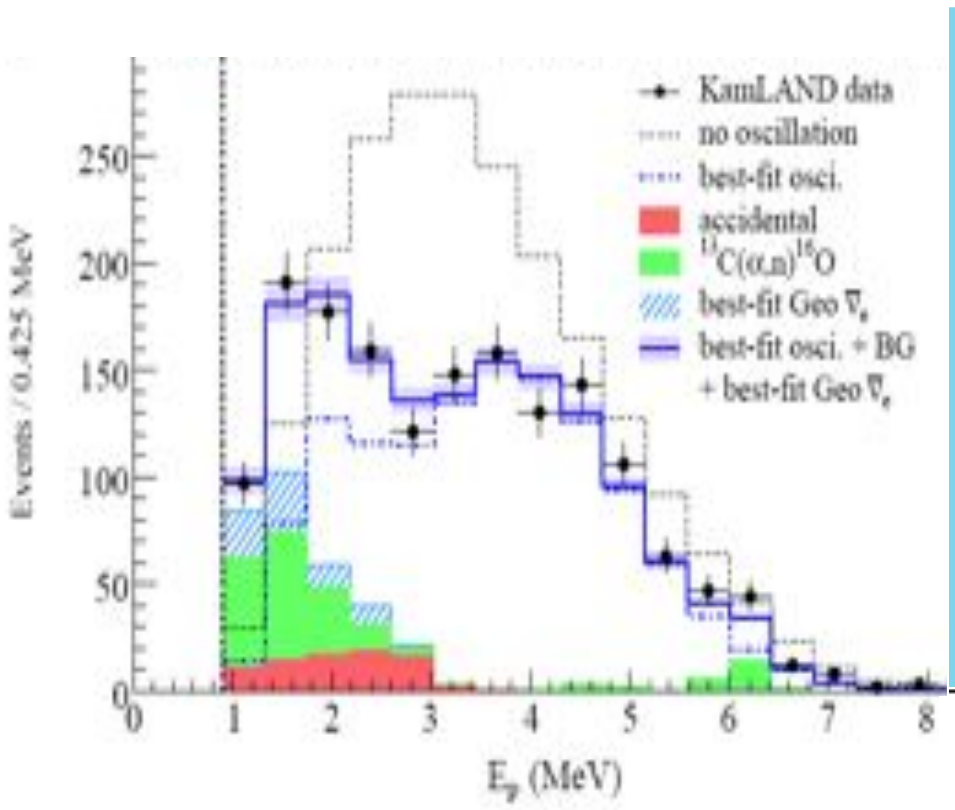


Image from H.N. Pollack, S.J. Hurter and J.R. Johnson, *Revie*
of Geophysics **31**(3), 267-280, 1993

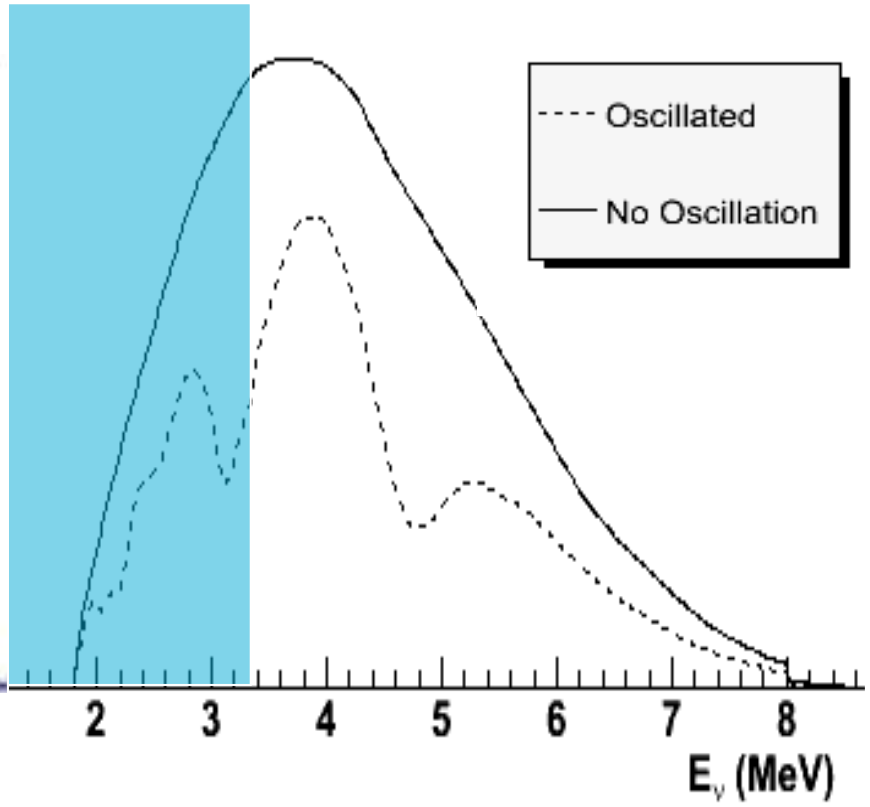
Reactor Antineutrinos

Allow precise study of neutrino vacuum oscillations.

KamLAND



SNO+



KamLAND Collaboration, arXiv:0801.4589v2

SNO+ can confirm the KamLAND result and further constrain the neutrino mixing parameters.

Supernova Neutrinos

- Type II supernovae release ~99% of their gravitational binding energy as neutrinos
  - Burst detectable at galactic distances
- Neutrinos detection interesting to many areas of physics
  - SN1987a in the Large Magellanic Cloud
    - 24 events detected in 13s (Kamiokande, IMB, Baksan)
    - Papers on neutrino oscillations, neutrino mass, axion mass, the size of compact dimensions in the universe
- Neutrinos provide 'supernova early warning'

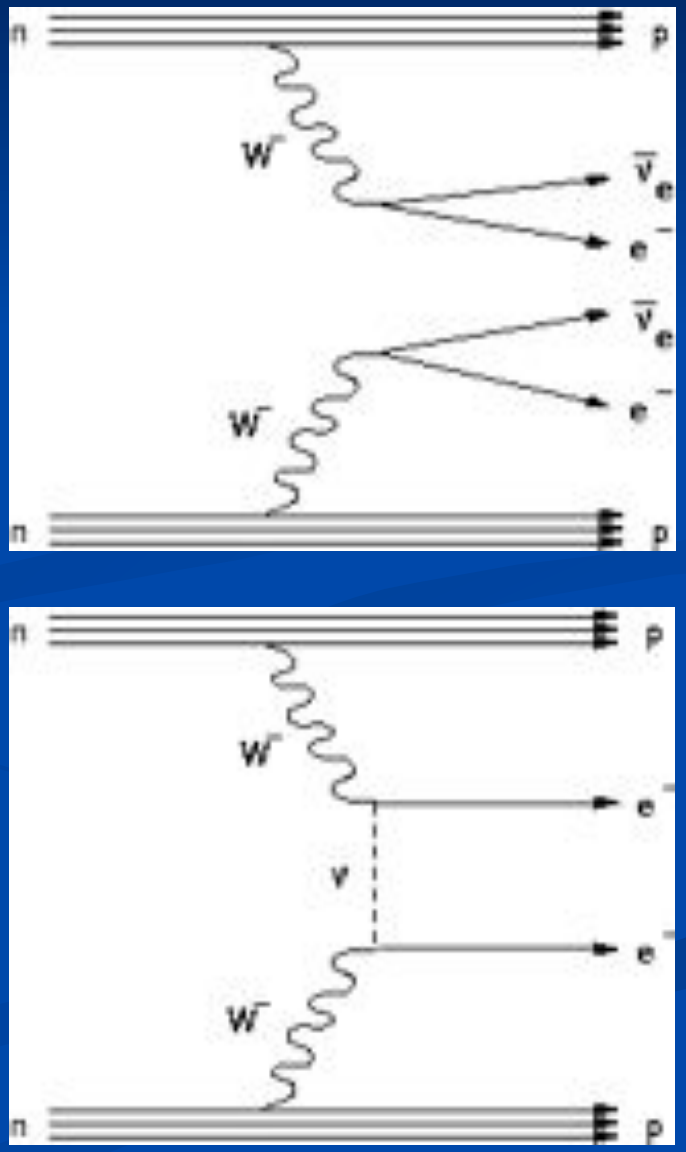
Neutrinoless Double Beta Decay

- Open question: are neutrinos Majorana or Dirac particles?
  - Are they their own anti-particles?
- In double beta decay, a nucleus releases two electrons and two antineutrinos:

$$(A, Z) \rightarrow (A, Z + 2) + 2e^- + 2\overline{\nu}_e$$

- If neutrinos are Majorana, sometimes neutrinoless double beta decay occurs:

$$(A, Z) \rightarrow (A, Z + 2) + 2e^-$$



Images from the NEMO collaboration.

Searching for neutrinoless double search involves looking for a tiny monoenergetic peak at the end of a large double beta decay continuum.

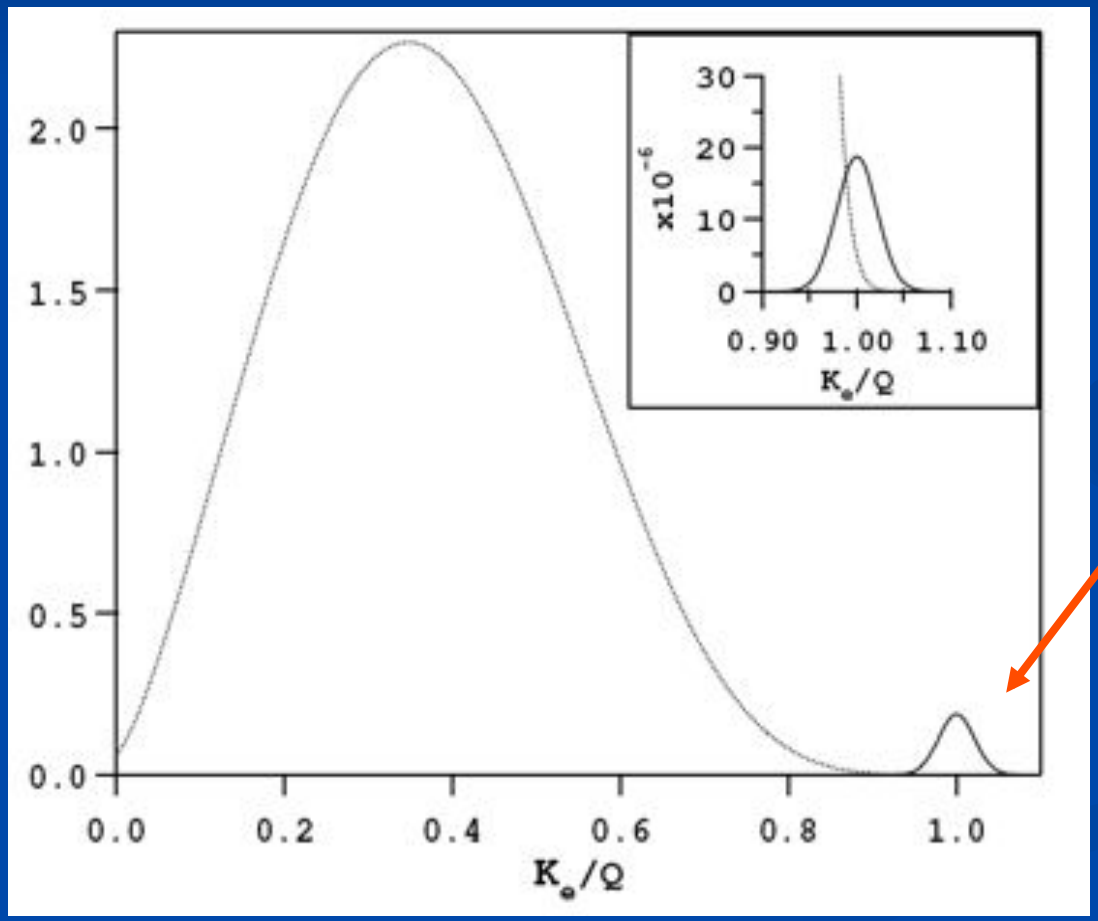
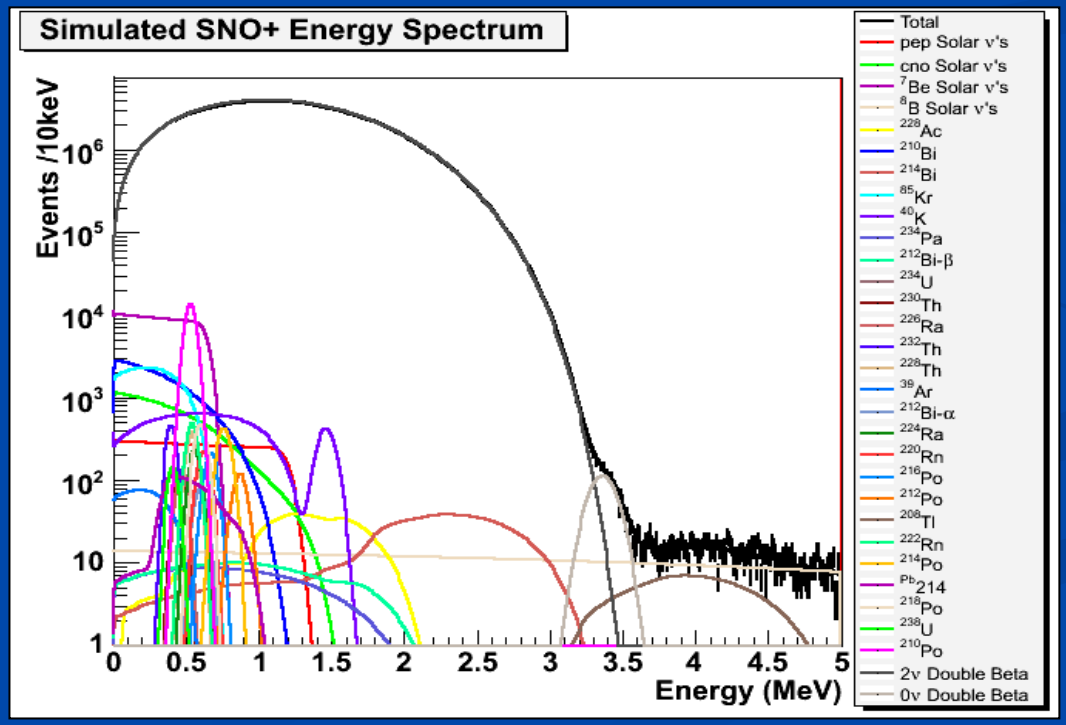


Image from Elliott and Vogel, hep-ph/0202254

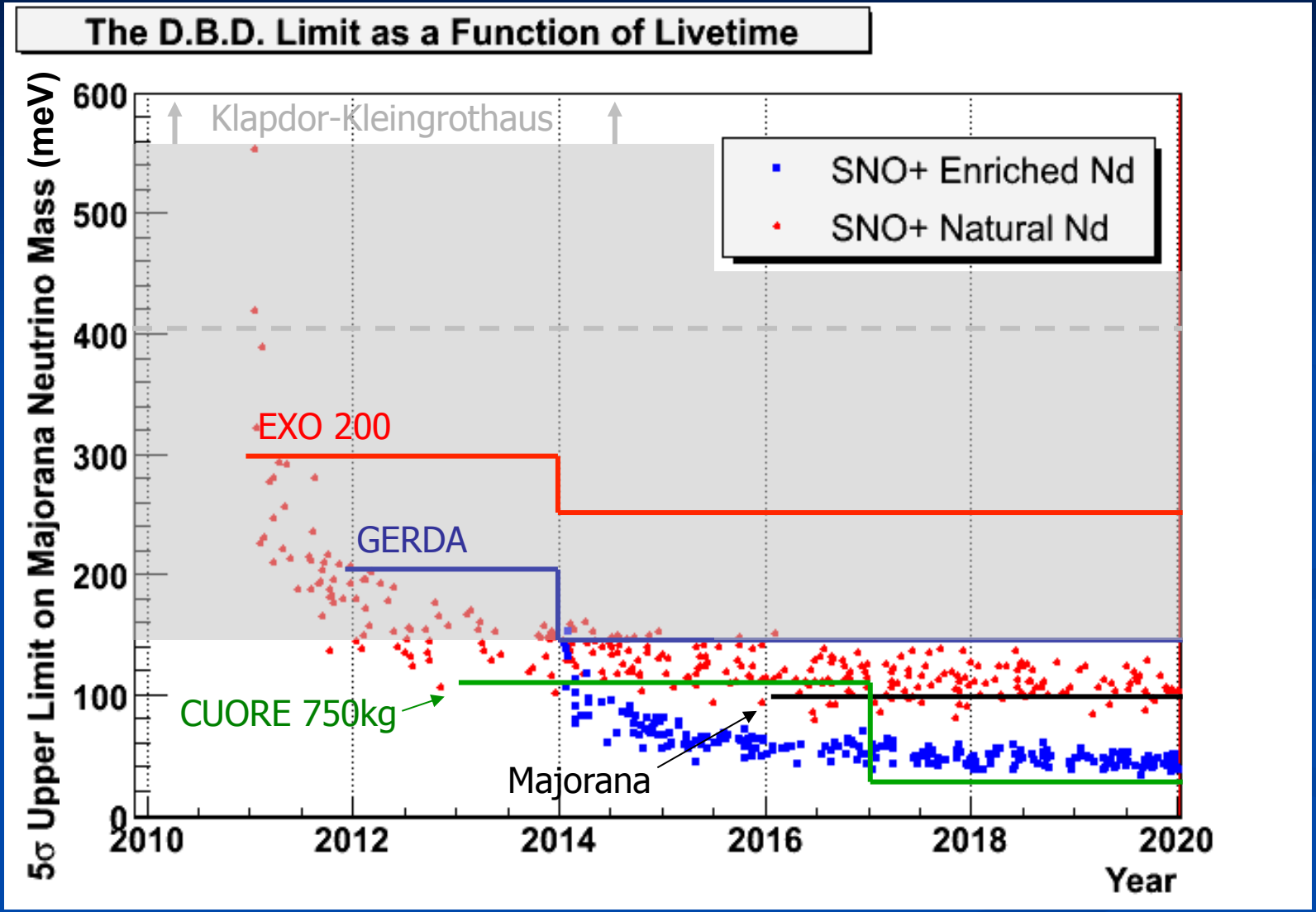
The size of the D.B.D. peak increases with the square of the neutrino mass!

Double Beta Decay in SNO+

- Loading ^{150}Nd into the SNO+ scintillator gives a huge amount of isotope
- SNO+ can fit for the spectral shape of the neutrinoless d.b.d. peak, rather than counting events in a bin
  - Much less sensitive to energy resolution, background
- SNO+ can stage a competitive next generation double beta decay experiment



SNO+ D.B.D. Sensitivity



SNO+ Estimate:

- Natural Nd in 2011
- Enriched Nd in 2014
- 50% fiducial volume
- 75% livetime

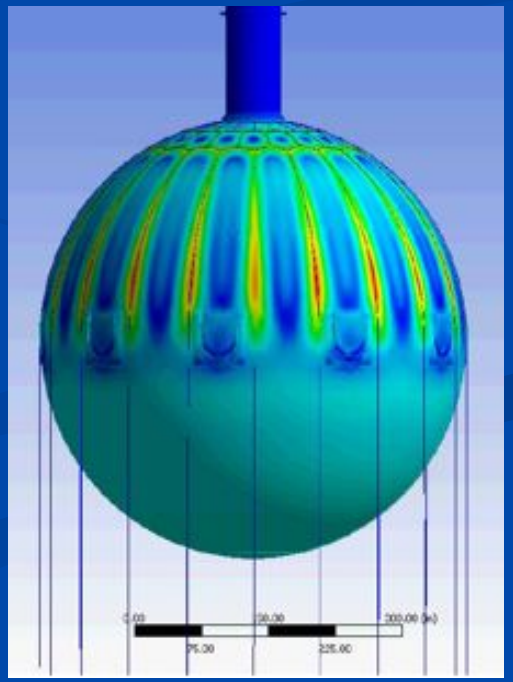
Physics Summary

- Particle Physics
- Solar Physics
- Geo-Physics
- Supernova Physics

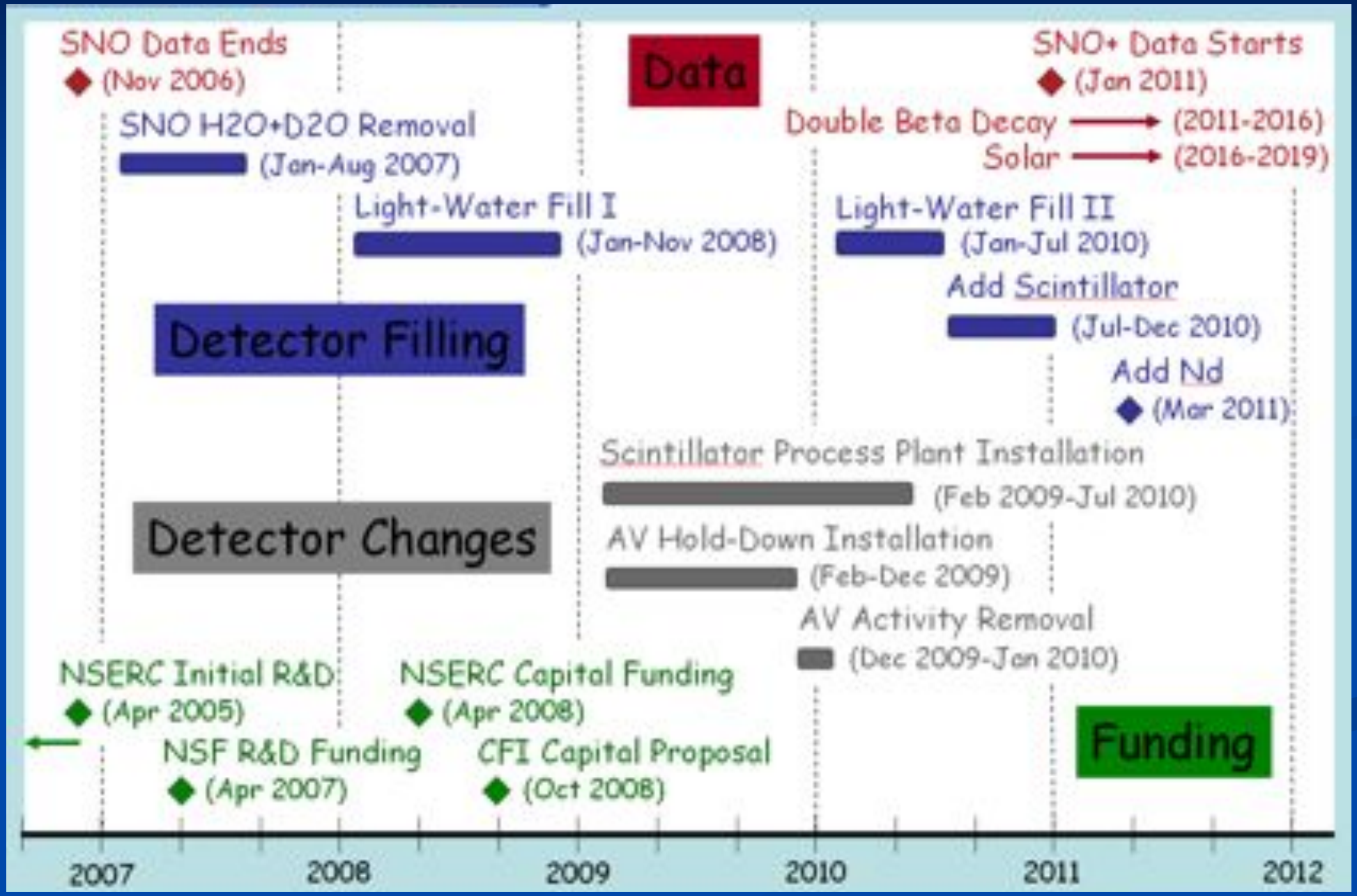
SNO+ will contribute to man different disciplines in physics!

SNO+ Status

- Cavity and acrylic vessel are currently filled with light water
  - Testing fiber optic calibration system
  - Performing calibrations to monitor the state of the PMTs/electronics
  - Working on DAQ upgrades/remote operation
- Scintillator purification plant quote expected in a few months
- Acrylic vessel holddown design is being finalized
- Techniques are being developed to clean radon daughters from the inside surface of the AV



SNO+ Schedule and Milestones



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