The Sudbury Neutrino Observatory

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What is SNO?

- From SNO themselves: "The goal of the observatory is to detect and study neutrinos emitted by the Sun and other celestial objects."
- A Heavy Water Cherenkov Detector
- Built in the Creighton Mine in Sudbury Ontario, 2km underground
- Largest underground cavity excavated at 2km depth

The Solar Neutrino Problem (SNP)

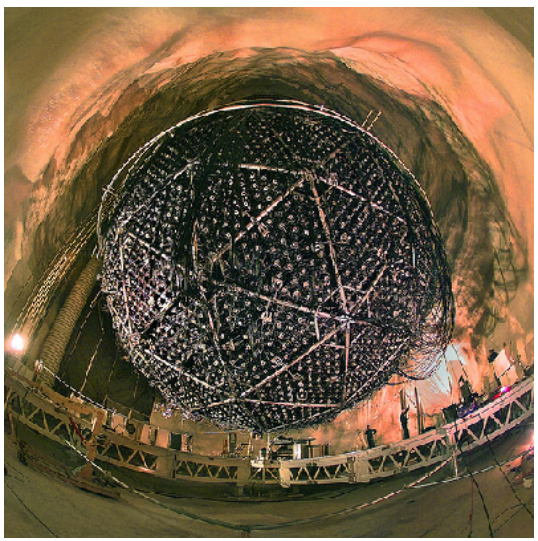
- Previous neutrino observation data was only $\frac{1}{3}$ of what was predicted, but the instrument was only sensitive to electron neutrinos ν_e.
- **Hypothetical Solution:** The neutrinos change flavor over the course of their journey from the Sun to the detector
- SNO's goal: verify this hypothesis

Rough Timeline

- 1985: Proposed solution to resolve the SNP via a Heavy-Water Cherenkov Detector
- 1989: US and Britain joins in on the project
- 1990: Construction begins
- November 1999: Construction completes, data collection (Phase I) begins.
  - May 2001: Phase II (NaCl $\rightarrow$ higher sensitivity)
  - February 2004: Phase III (Neutral Current Detector)
- November 2006: Data collection ends
- October 2015: Nobel Prize in Physics

Specs

- Spherical Chamber 12 m across
- 9456 Hamamatsu R4108 photomulplier tubes
- 1000 tons of Heavy Water (D_2O)
- 7000 tons of ultra-pure normal water



Detection Methods

Neutral Current (NC)

$$\nu_x + d \rightarrow p + n + \nu_x$$

selects for all neutrinos equally

Charged Current (CC)

$$\nu_e + d \rightarrow p + p + e^-$$

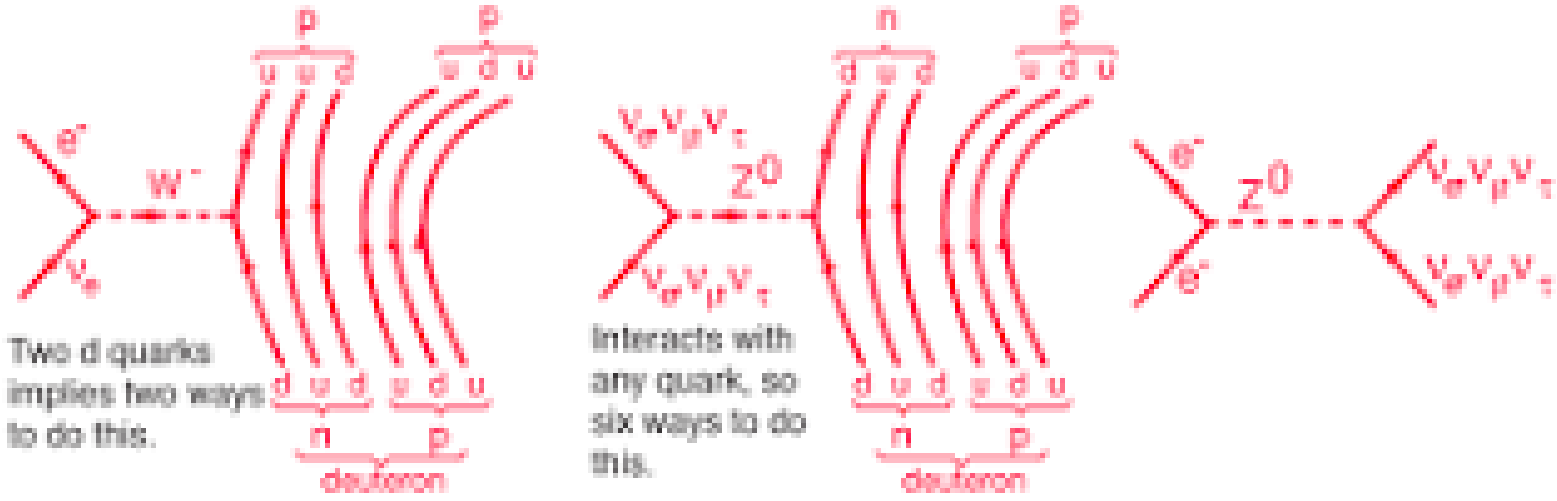
Only selects for electron neutrinos

Elastic Scattering (ES)

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

Selects for all neutrinos; ν_e selected 6x sensitivity

Feynman Diagrams



Charged current reaction, electron neutrinos only.

Neutral current reaction, all neutrinos.

Elastic scattering with any neutrino.

Results

- Total number of neutrinos detected matches theory $\rightarrow$ solves SNP
- Proves that Neutrinos have mass due to oscillations.

$$P_{\alpha\rightarrow\beta} = \sin^2(2\theta)\sin^2\left(\frac{\Delta m^2 L}{4E}\right)$$

  So $\Delta m > 0 \rightarrow$ neutrinos have mass!
- Data for solar mixing angle θ_{sol}

SNP Resolution

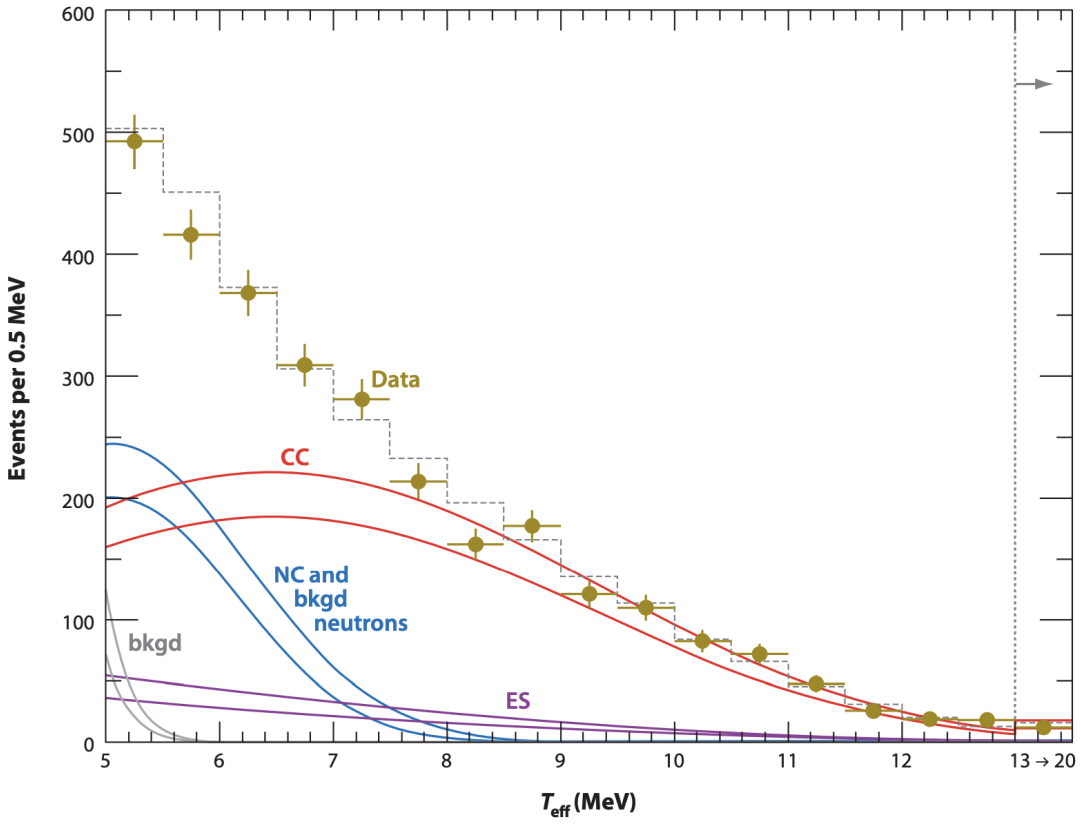


Figure: Events vs. effective kinetic energy

Evidence of Δm

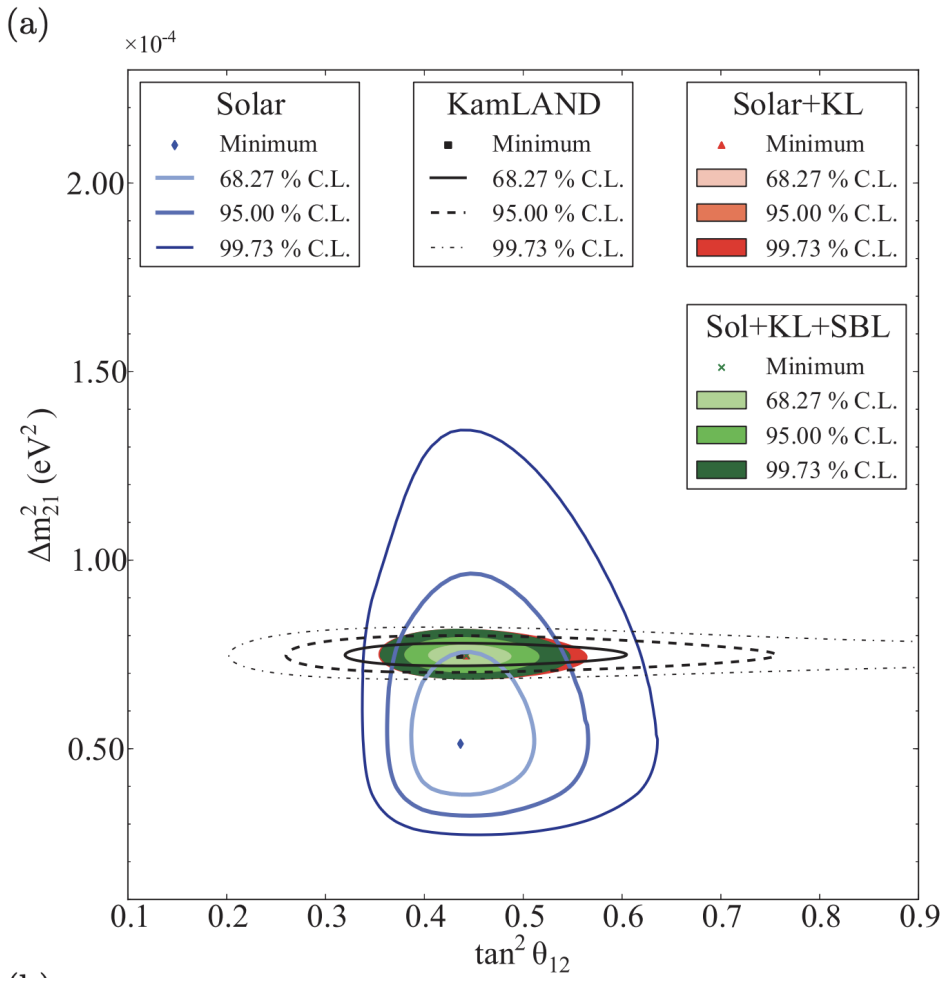


Figure: Mixing angle $\tan^2\theta_{12}$ vs. Δm^2_{21}

SNOLAB and Beyond

Since SNO, the mine was expanded to accomodate for more experiments, creating SNOLAB.

- SNO+: World's largest scintillator experiment
- SuperCDMS: Dark matter searches using Si and Ge crystals
- REPAIR: Effect of radiation on living organisms

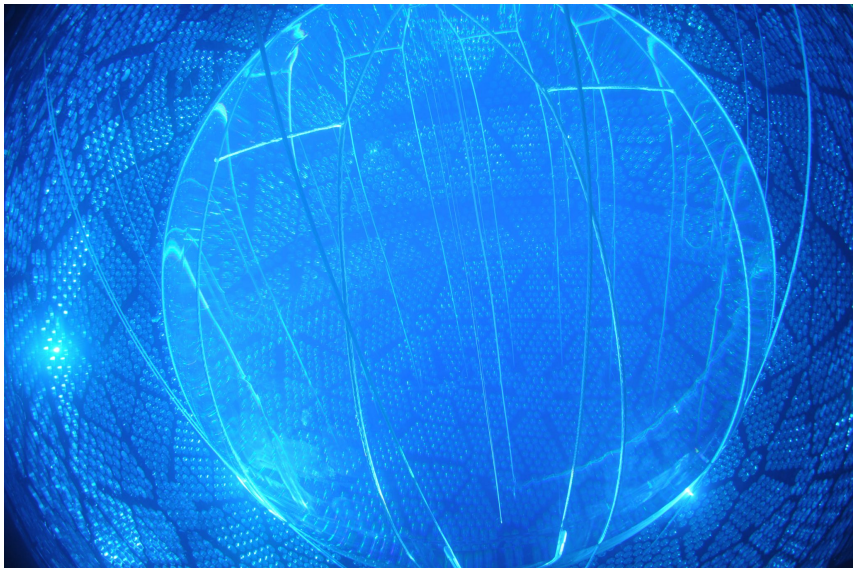


Figure: SNO+ detector

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