# Solar Neutrinos

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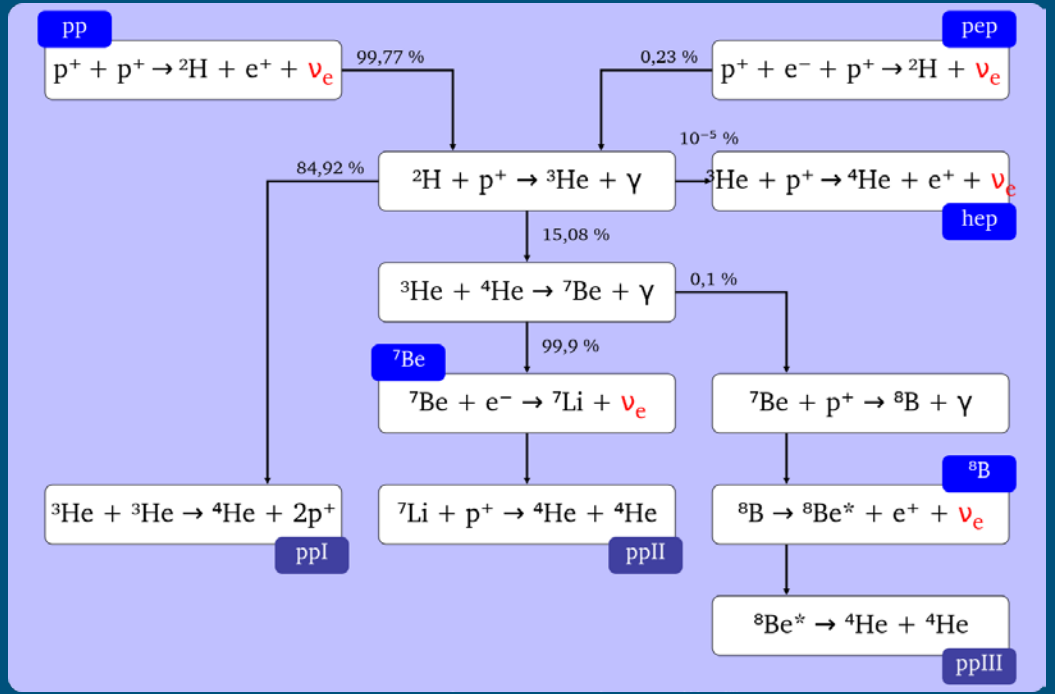
Presentation for Phys 564

# Source of Solar Neutrinos

- The Sun can only be powered by nuclear fusion at its core
- Relatively young star, with ~73% Hydrogen, ~25% Helium and ~ 2% metal



# Solar Neutrino Problem

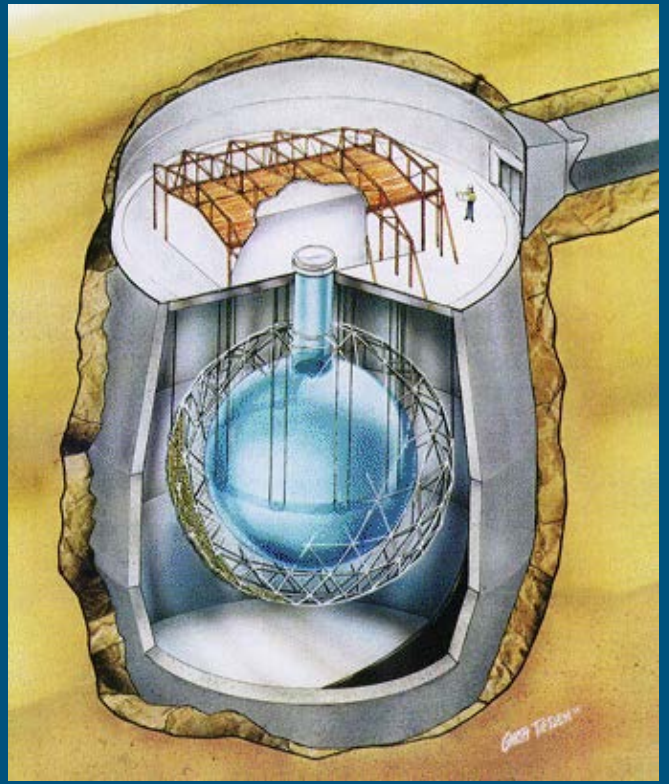
- Our sun only produces electron neutrinos
- We think we understand stellar structure well
  - Standard solar model (SSM)
- Theoretically expected electron neutrino flux does not match that has been observed (first noticed in the 1960s)
  - ~⅓ of the expected value is observed
  - XX, XX, XX (detectors that report this)
- Problem arise: why they do not match?

# Solution: Neutrino Oscillation

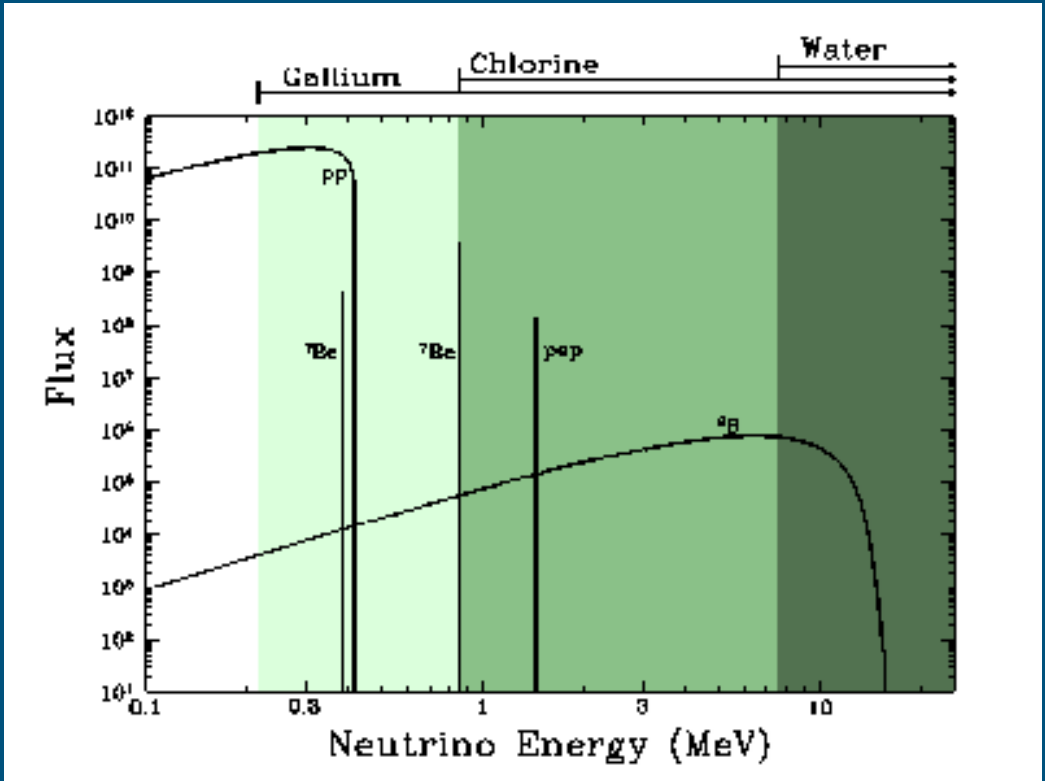
- Proposed by  Italian physicist Bruno Protecorvo in 1957
- The theory in short is, neutrinos have masses, and will change their flavors (e.g., transform from electron neutrino to  muon neutrino) after traveling distance
- SNP solved: electron neutrinos originally produced in the interior of the Sun changed into other neutrinos on their trip to the Earth
    - Confirmed by Super-K and SNO

# Sudbury Neutrino Observatory (SNO)

- Located 2100m underground in Ontario, Canada
- Using heavy water ($D_2O$) for detection
- Able to observe electron neutrinos alone and all three types of neutrino together
- Sensitive to neutrinos from $^8B$ decays



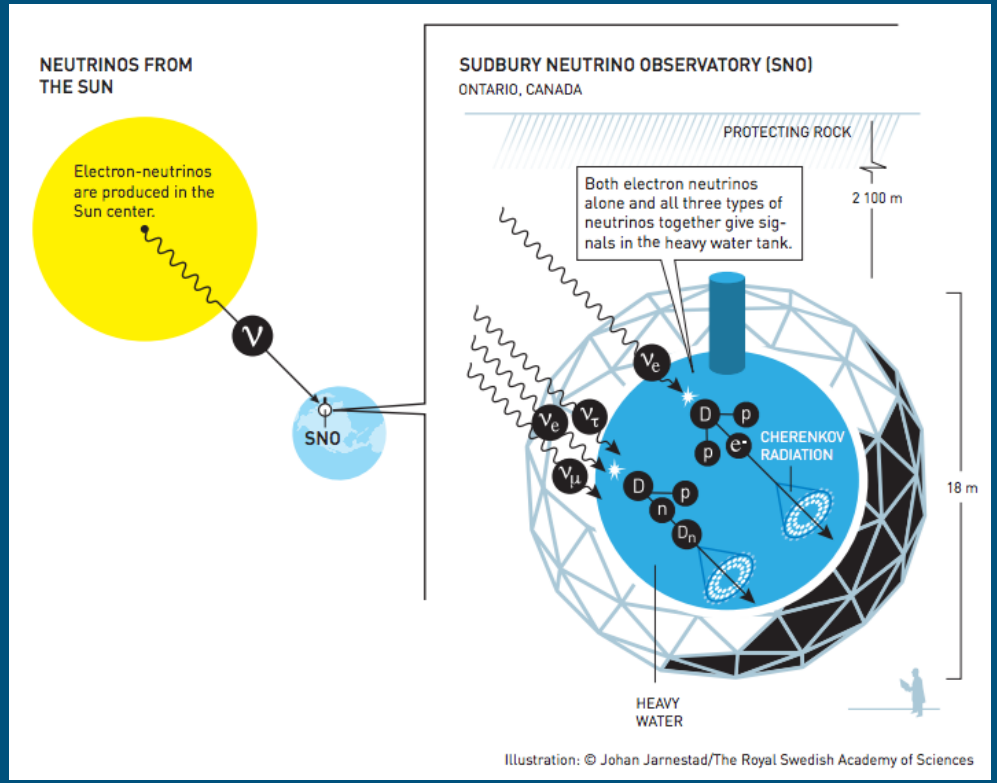
# Detectability of SNO



# Why Deuterium?

- Allows spontaneous measurements of two separate reactions:
  - $\nu_e + d \rightarrow p + p + e^-$, a charged current (CC) reaction that was sensitive only to electron neutrinos
    - determined by observing the Cherenkov light due to fast electrons
  - $\nu_x + d \rightarrow n + p + \nu_x$, a neutral current (NC) reaction that was equally sensitive to all neutrino types
    - determined by three methods in three phases in the program
  - $\nu_x + e^- \rightarrow \nu_x + e^-$, the elastic scattering (ES) of electrons by neutrinos, which is six times more sensitive to electron neutrinos than other flavors
    - Again determined by the Cherenkov light

# An illustration of how it works



# Charged Current (CC) Reaction

- $\nu_e + d \rightarrow p + p + e^-$
- W boson changed and most energy is transferred to electron, making it relativistic
- Fast moving electron exceed the speed of light in heavy water, causing Cherenkov effect
- The SSM predicts about 30 charged current events per day in SNO

# Elastic Scattering (ES)

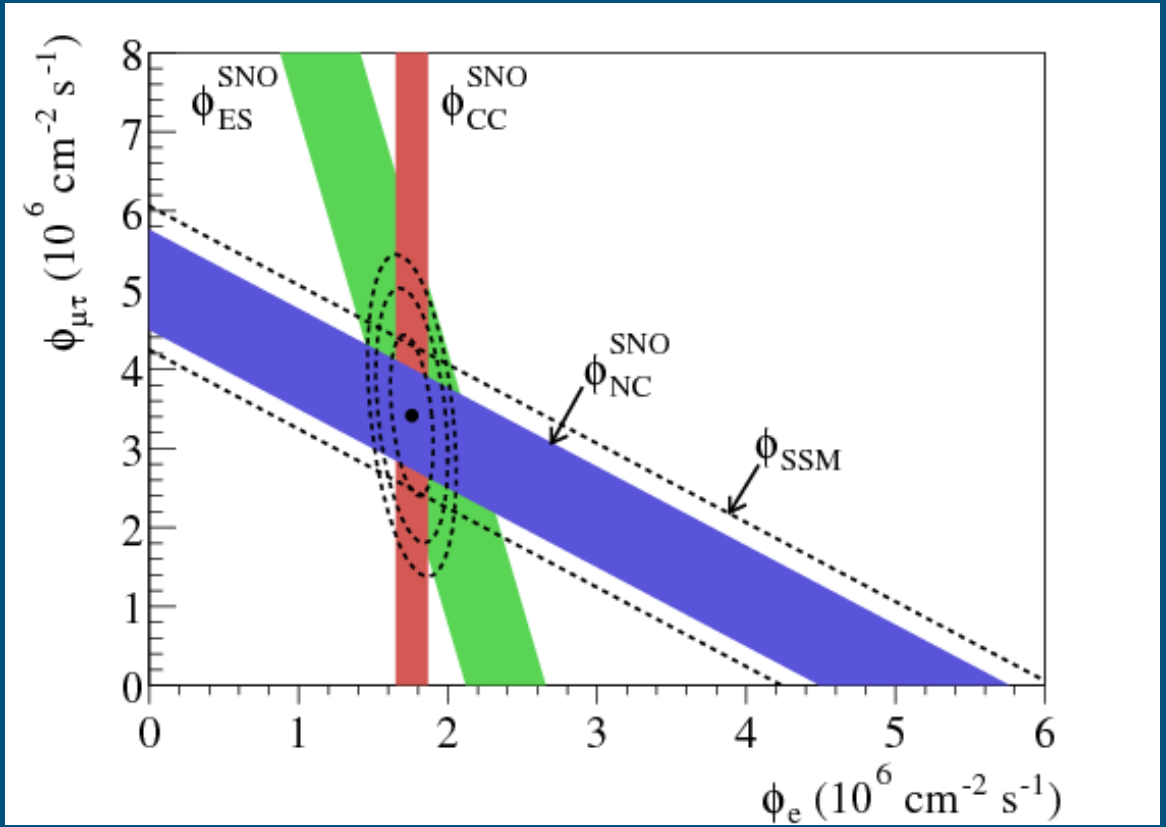
- $\nu_x + e^- \rightarrow \nu_x + e^-$
- Primary mechanism in other light water experiment
- All three flavors participate in this reaction by exchanging Z bosons
- Electron neutrino can exchange W boson as well, so it dominates the reaction of a factor of ~6
- Electron gains energy and produce Cherenkov light
- The SSM predicts about 3 charged current events per day in SNO

# Neutral Current (NC) Reaction

- $\nu_x + d \rightarrow n + p + \nu_x$
- Z boson is exchanged, and it has the same chance for all three flavors
- Phase - I
  - Pure heavy water
- Phase - II
  - With NaCl dissolved
- Phase - II
  - With 3He-filled neutron counters placed
- The SSM predicts about 30 charged current events per day in SNO

# Results

"Solar neutrinos from 8B decay have been detected at the Sudbury Neutrino Observatory ... Comparison of $\phi^{CC}(\nu_e)$ the Super-Kamiokande Collaboration's precision value of the flux inferred from the ES reaction yields a 3.3s difference, ..., providing evidence of an active non-ne component in the solar flux. The total flux of active $^8B$ neutrinos is determined to be $5.44 \pm 0.99 \times 10^6\ cm^{-2}\ s^{-1}$."



# References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# Thank you!