

Previous lecture

- Neutrino Oscillations, see handout lecture 8
 - ▶ Mass and weak eigenstates not the same
- Two-flavour mixing formula

$$\text{Probability}(\nu_e \rightarrow \nu_\mu) = \sin^2 2\theta \sin^2(1.27 \Delta m^2 L/E)$$

- ▶ L (km), Δm^2 (eV²), E (GeV)
- ▶ Single mixing angle, θ (ensures matrix is unitary)
- ▶ θ a parameter of nature, fixed, no relation to angular variable
- ▶ θ defines size of mixing
- ▶ $\Delta m^2 (= m_2^2 - m_1^2)$ gives dependence of oscillations on L/E
- ▶ $(E/1.27 \Delta m^2)$ defines an oscillation length scale
- Generalisation to 3 neutrino flavours
 - ▶ 3 mixing angles, θ_{12} , θ_{13} , θ_{23}
 - ▶ 3x3 "MNS" matrix
- Direct analogy with quarks ("CKM" mixing matrix)

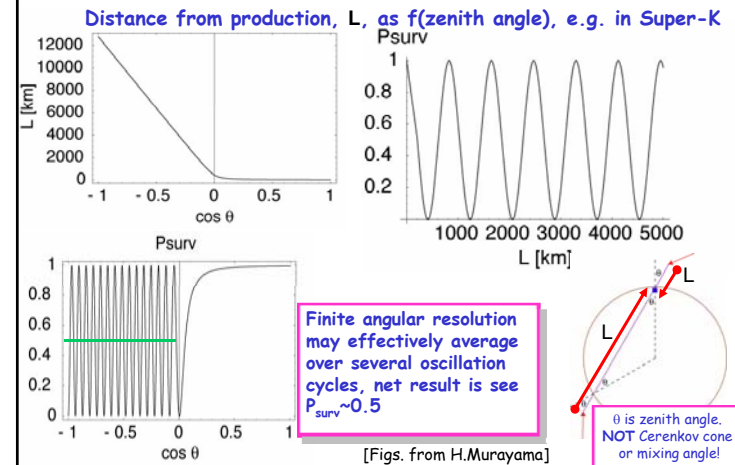
Lecture Content

- Approx. lecture content
 1. PP intro
 2. PP intro.
 3. v props 1: strong/e.m./weak, no. neutrino generations
 4. v props 2: lepton no., v existence
 - Examples of decay/production
 5. Neutrino mass
 - Fermi-Kurie plot
 - Phase space kinematics/4-momentum
 6. Parity and CP violation... (why so important in lepton sector?)
 - Wu et al., ⁶⁰Co experiment
 7. Detection & observation
 - Liquid, solid, bubble chamber
 - "Direct" methods (DONUT)
 8. Atmospheric neutrinos
 - Cerenkov detectors
 - SuperKamiokande experiment
 9. Atmospheric neutrino data and oscillations
 - Interpretation of atmospheric v data
 - Two-flavour neutrino oscillation formalism
 10. Solar neutrinos and SSM
 - SNO experiment and data
 - NBDB (NEMO, etc.)
 11. Implications for cosmology
 - Open vs. closed scenarios: various m, regions
 - v as DM candidate?
 - Subject outlook (JPARC, MICE, Neutrino Factory, SK, SNO, KAMLAND, CHOOZ, MINOS, miniBOONE, JPARC, vF, ...)

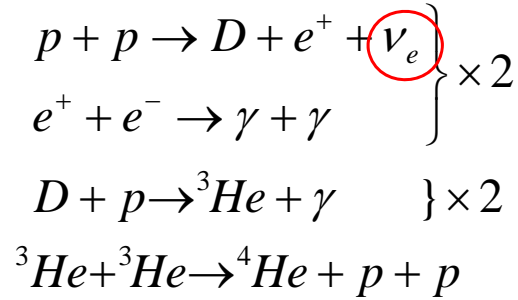
Today

- Discussion of neutrino oscillations - See Winter 2.4.6
- "Solar neutrino problem" - See Winter, Sec. 6.1.x
- SNO
 - ▶ What it measures

"Survival" Probability

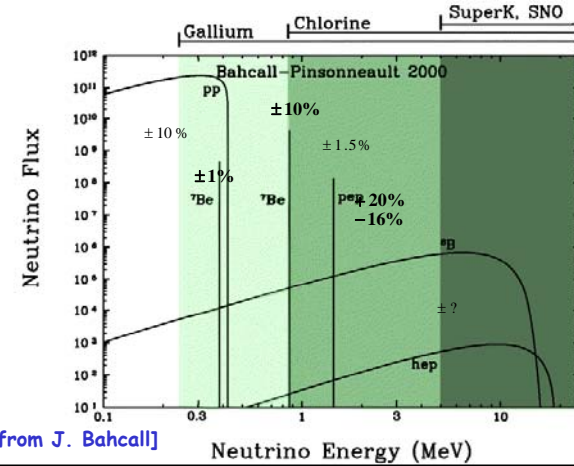


Solar fusion: the p-p mechanism



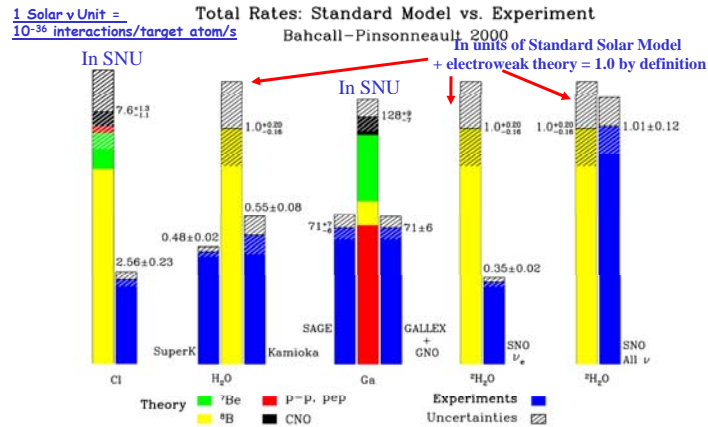
Protons fuse, ultimately form an alpha particle, net release of 26.7 MeV/event

ν_e Solar Neutrino Spectrum



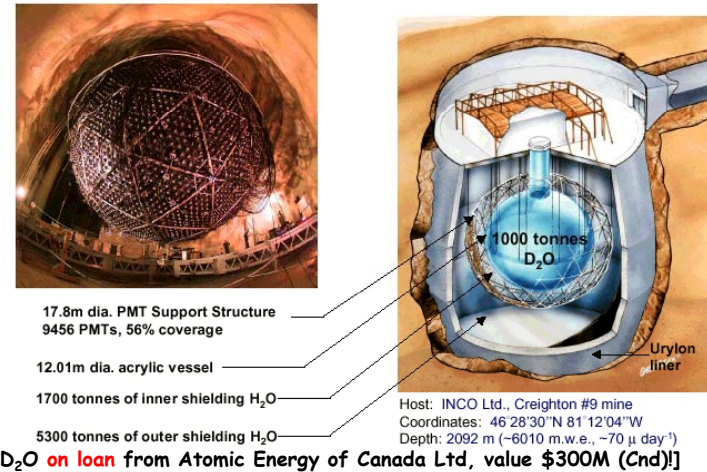
[Fig. from J. Bahcall]

Solar ν : Data vs. Theory



[Fig. from J. Bahcall]

SNO (Sudbury Neutrino Observatory)



SNO lab

