Physics 491 Fall 2016
M. Gold

Friday Feature

The Nobel Prize in Physics 2015

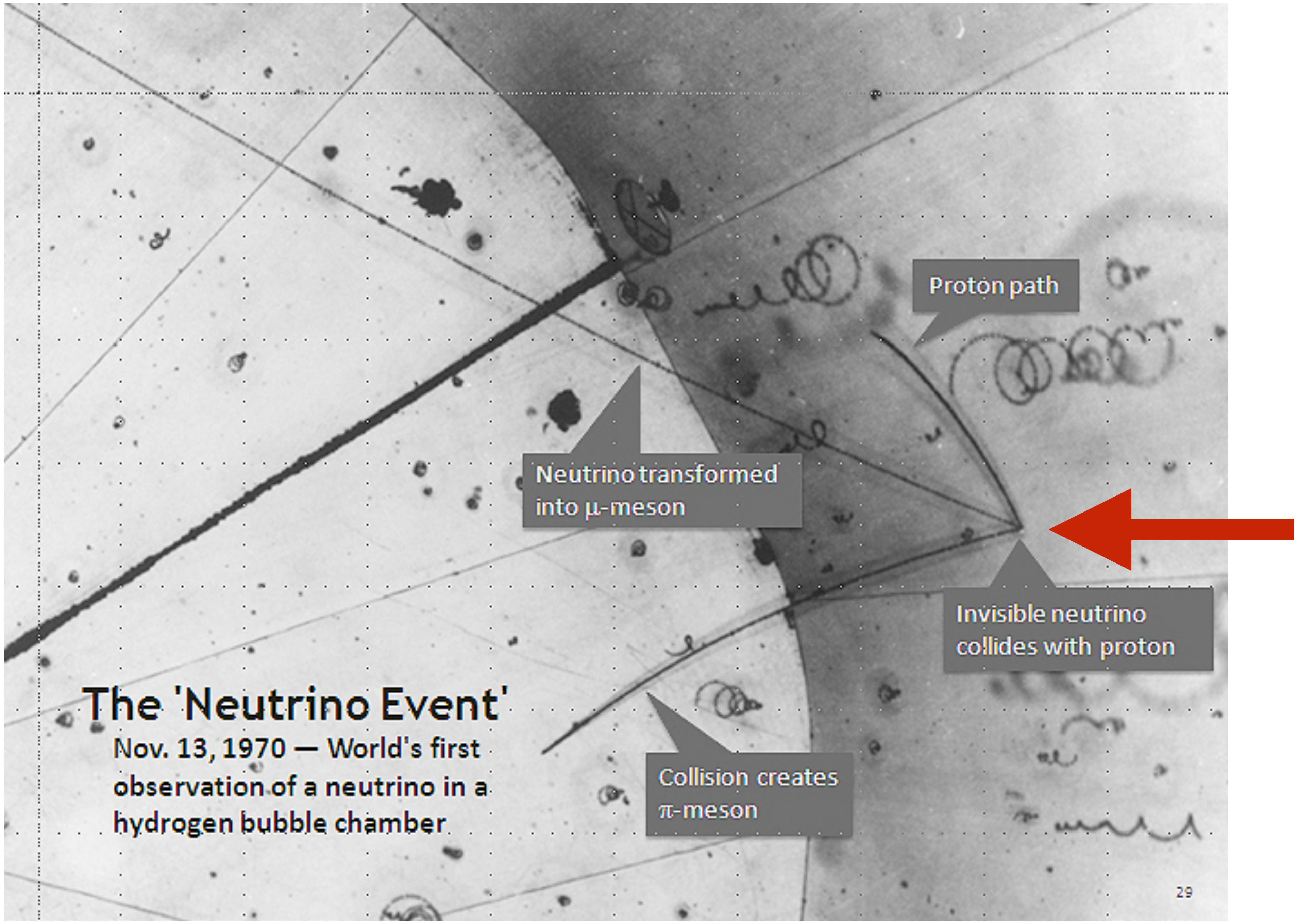
Takaaki Kajita and Arthur B. McDonald

*"for the discovery of neutrino oscillations,
which shows that neutrinos have mass"*

What is a neutrino?

beta-decay particle $n \rightarrow p + e^- + \bar{\nu}_e$

“weakly interacting” <free path> in water is 1600 light years!



why does the universe have it?

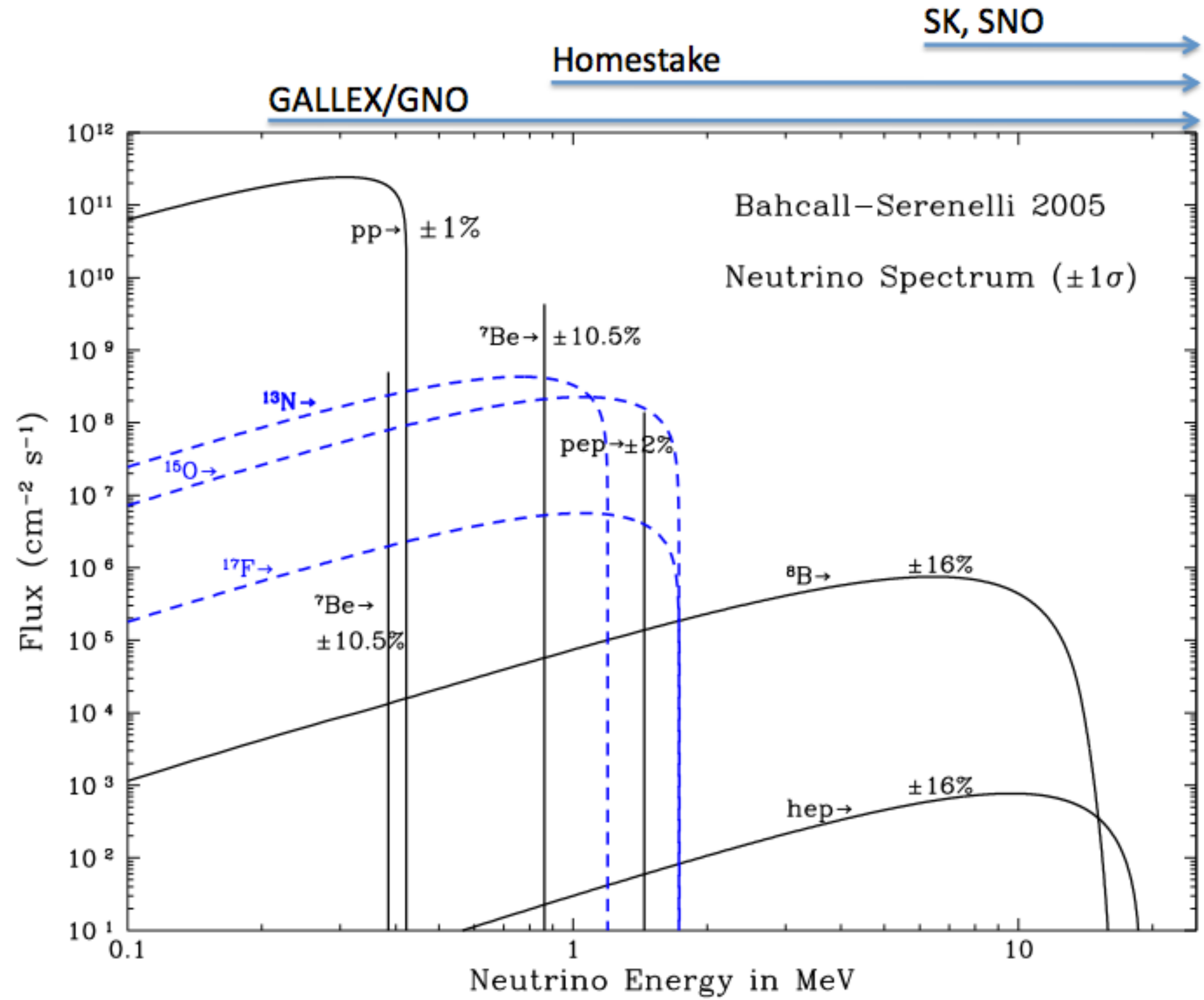


Figure 1: Neutrino fluxes (with percentage uncertainties) as predicted by the Bahcall-Serenelli solar model (BS05) [38], in cm^{-2} s^{-1} MeV^{-1} ($cm^{-2}s^{-1}$ for the lines). The arrows above the diagram indicate the energy ranges accessible to experiments. [From J.N. Bahcall's web site http://www.sns.ias.edu/~jnb/ with arrows added above the graph.]

Homestake (Davis 1968)

"solar neutrino problem"

100,000 gallons of cleaning fluid $\nu_e + {}^{37}Cl \rightarrow {}^{37}Ar + e^-$

...collect the Ar

The average value of the solar neutrino rate obtained by Homestake after more than 25 years of almost continuous measurement is

2.56 ± 0.16 (stat) ± 0.16 (sys) SNU

theoretically predicted**

8.5 ± 0.9 SNU

(One Solar Neutrino Unit, SNU, corresponds to one reaction per 10^{36} target atoms per second.)

***note that prediction depends on detected spectrum*

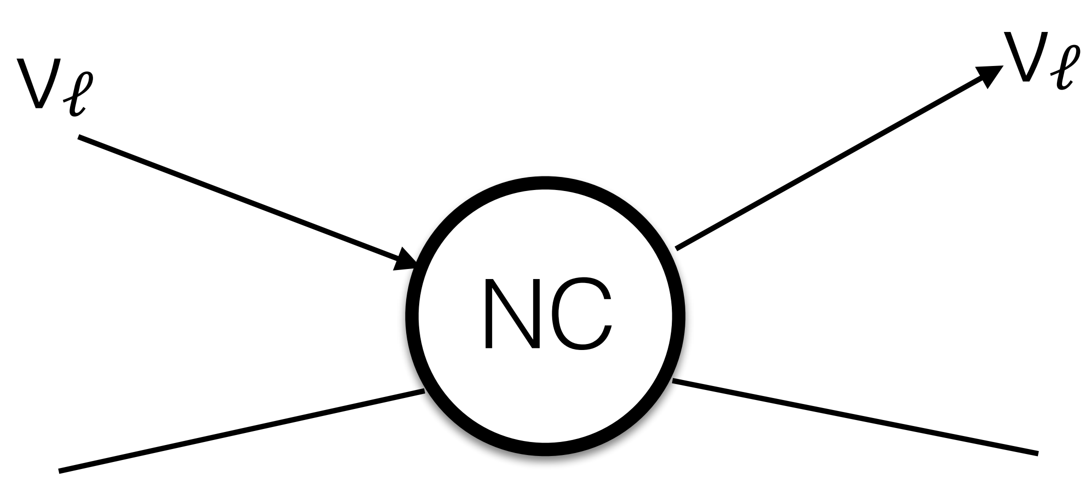
Homestake measured only electron-neutrino

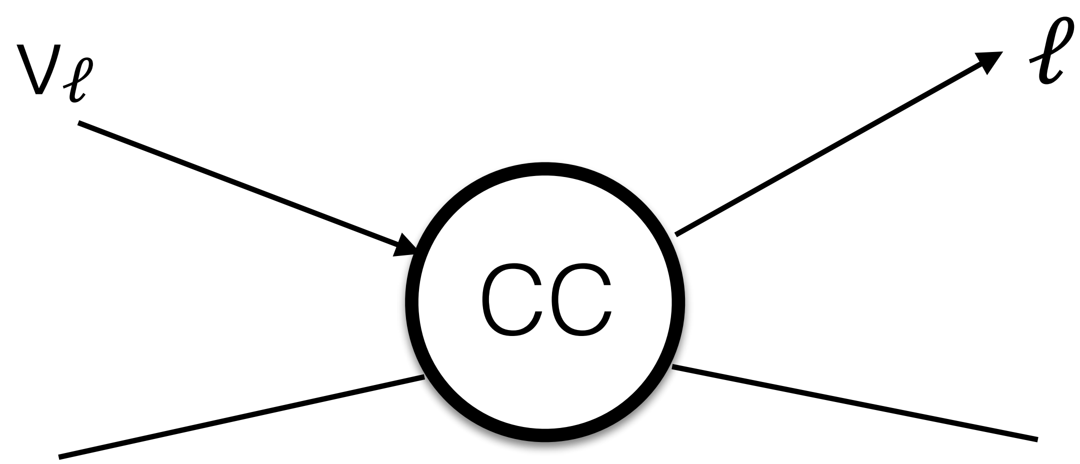
3 flavors of neutrinos: ℓ=e,μ,τ

m_{e}= 0.5 MeV

m_{μ}=106 MeV

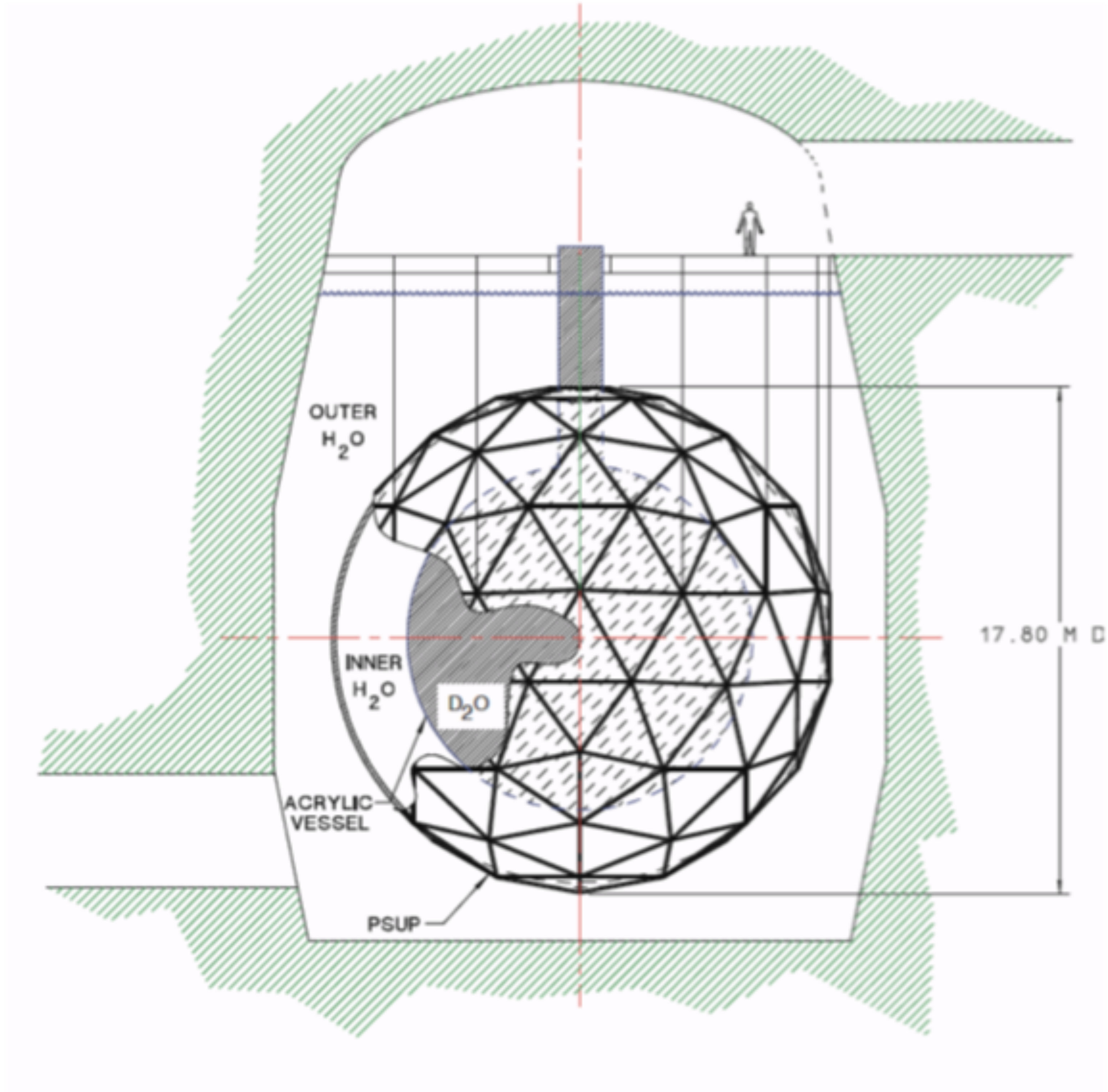
m_{τ}=1777 MeV





CC interaction tags flavor

Layout of SNO



SNO detected ^{8}B solar neutrinos via the reactions

$$\nu_e + {}^2H \rightarrow e^- + p + p \quad \text{(CC)}$$
$$\nu_x + {}^2H \rightarrow \nu_x + p + n \quad \text{(NC)}$$
$$\nu_x + e^- \rightarrow \nu_x + e^- \quad \text{(ES)}$$

ES mostly measures ν_e

Combined measurement

The ^{8}B neutrino flux from the final fit to all reactions is

$\phi=\phi(\nu_e)+\phi(\nu_\mu)+\phi(\nu_\tau)=5.25\pm0.16(\text{stat}) + 0.11\text{-}0.13\ (\text{sys})\times10^6\ \text{cm}^{-2}$

in very good agreement with the theoretically expected

5.94 (1 ± 0.11) [SSM BPS08] or

5.58 (1 ± 0.14) [SSM SHP11]

The flux of muon- and tau-neutrinos deduced from the results

$\phi(\nu_\mu)+\phi(\nu_\tau)=(3.26\pm0.25^{\pm0.40})\times10^6\ \text{cm}^{-2}\text{s}^{-1}$

Solar neutrino problem solved, but what are neutrinos telling us?