Very Low Energy Neutrino Interactions

A. How important are ν-processes in nucleosynthesis?

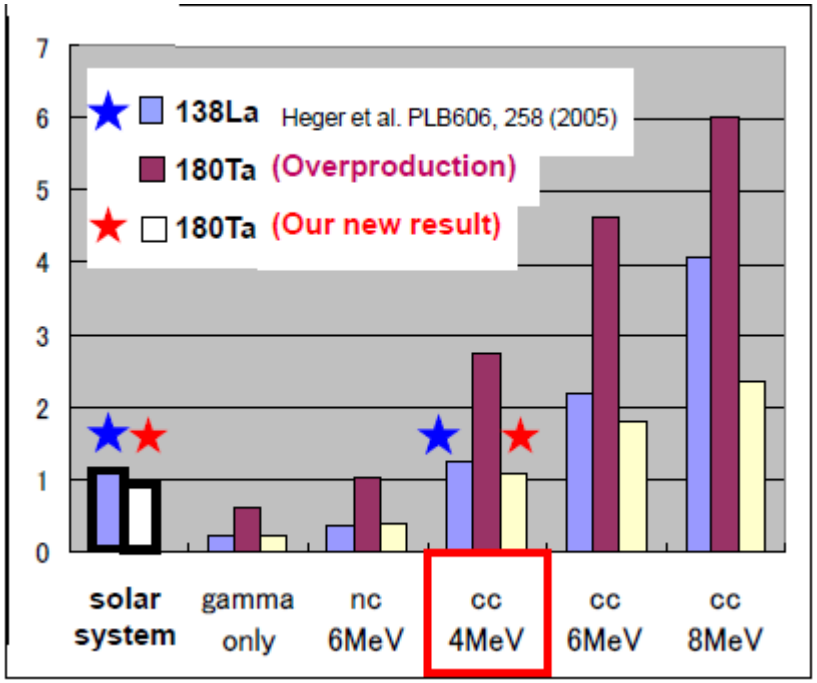
- Rare elements are made by ν-processes in supernova explosions (SNe): 7Li, 11B, 180Ta, 138La ….

★ To what extent do we know about SNν spectrum?

- R-process elements & 180Ta/138La

→ $T\nu e$ = 3.2 MeV,
Tanti-νe = 4 MeV

- Astron. GCE of light elements & 11B → $T\nu\mu$, = $T\nu\tau$ = 6 MeV (Kajino)



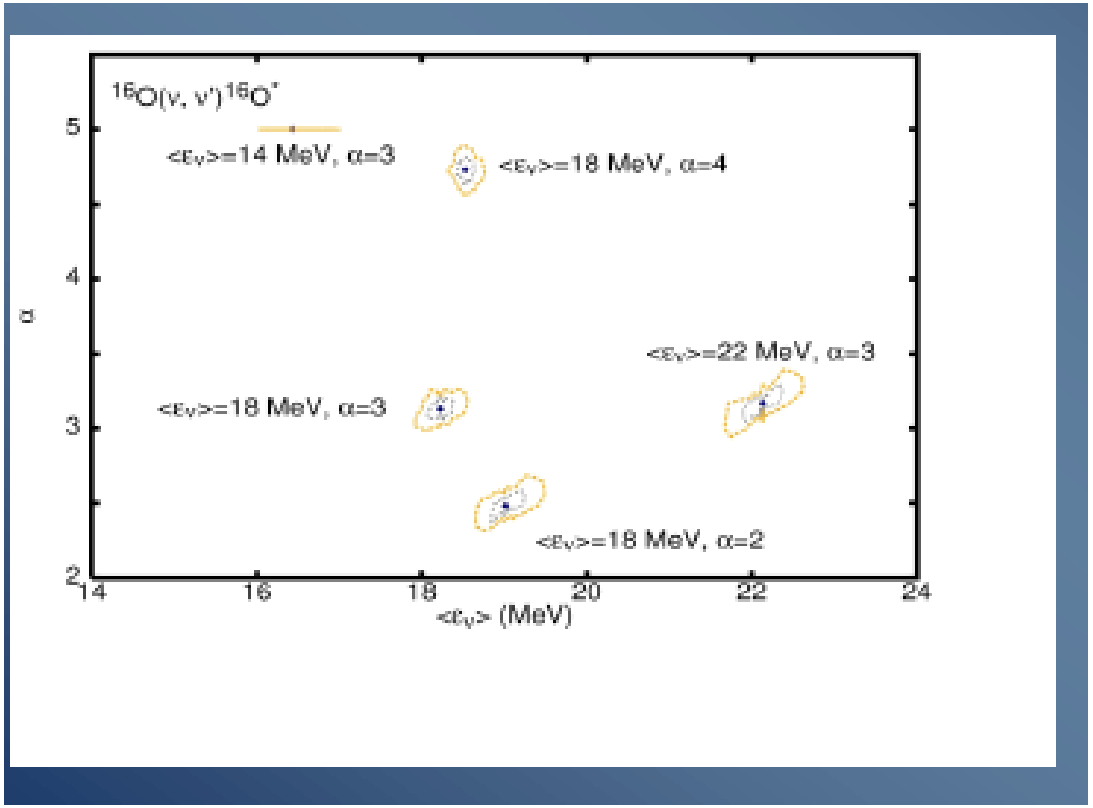
★ Shape of ν-spectrum?

Fermi-Dirac, Fermi-Dirac with chemical potential, or Polynomial-type

$$n_{SN[\langle\epsilon\rangle,\alpha]}(\varepsilon) = \left(\frac{\varepsilon}{\langle\varepsilon\rangle}\right)^{\alpha} e^{-(\alpha+1)\frac{\varepsilon}{\langle\epsilon\rangle}}$$

Construction of SNν spectrum from beta-beam measurement (Jachowicz)

$$n_{N\gamma}(\varepsilon_i) = \sum_{i=1}^{N} a_i n_{\gamma_i}(\varepsilon_i)$$



B. How ν-oscillations affect the nucleosynthesis?

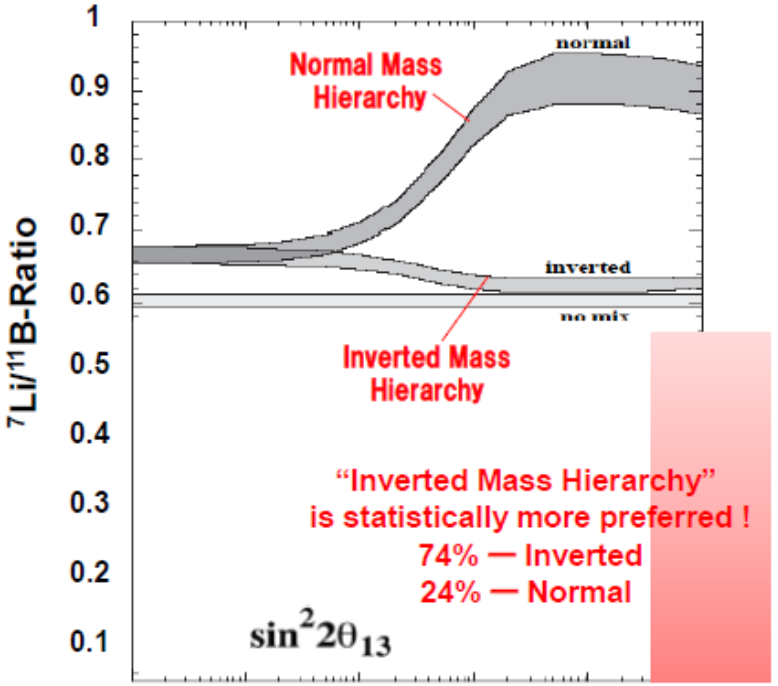
- MSW in He-O layer → enhances 7Li, 11B production
  7Li/11Be-ratio → θ_{13}, Mass Hierarchy (MH)

$$\sin^2 2\theta_{13} = 0.1$$

★ **Which MH is favored?**

Presolar grains (Murchison Meteorite, Si X grains) with Bayesian analysis → Inverted MH is favored (74% inverted) (Kajino)

Supernova X-Grain Coinstraint

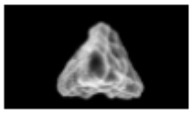


Mathews, Kajino, Aoki And Fujiya, Phys. Rev. D85,105023 (2012).

- T2K, MINOS (2011)
- Double CHOOZ, Daya Bay, RENO (2012)

$\sin^2 2\theta_{13} = 0.1$

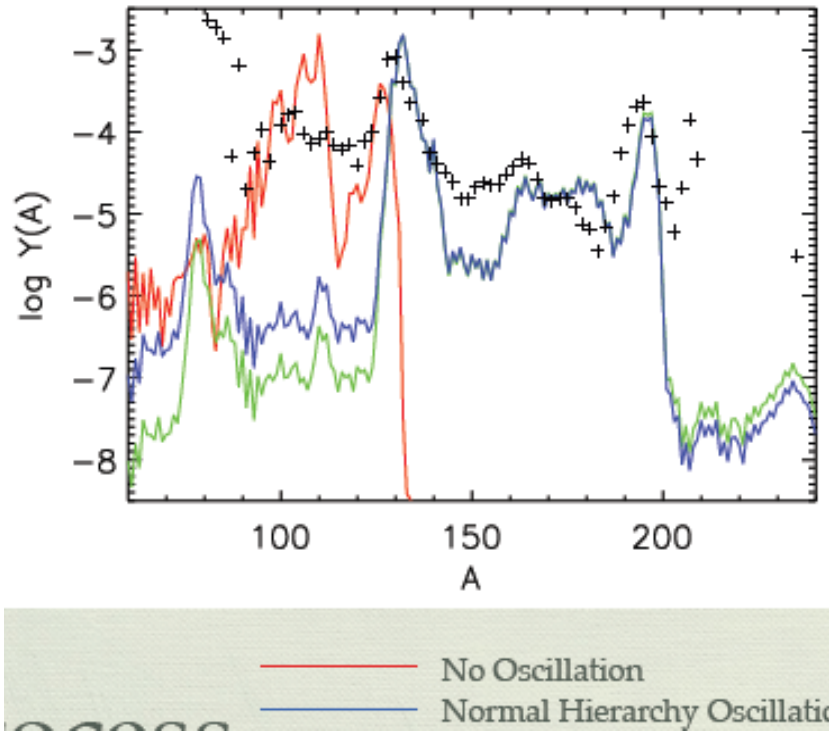
First Detection of ^{7}Li/^{11}B in SN-grains



W. Fujiya, P. Hoppe, & U. Ott, ApJ 730, L7 (2011).

- ν-ν interaction

A new type of ν oscillation from both ν-ν interaction and MSW can affect r-process nucleosynthesis above a BH accretion disk (Malkus)



★ **Effects of ν-ν interaction in nucleosynthesis?**

★ **Where are the r-process sites?**

Ye <0.5

ν-driven wind SNe Ye >0.5 ?

Neutron star mergers

MHD jet SNe

GRB (gamma-ray burst)

C. How accurately do we know ν-nucleus cross sections?

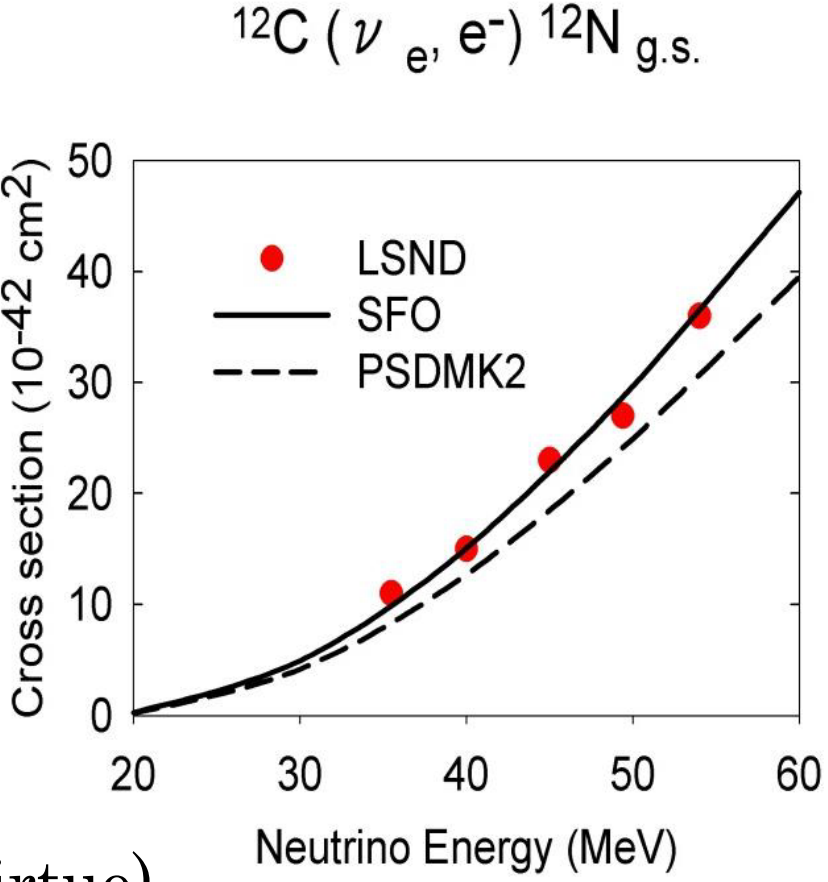
- Present shell-model (SM) calculations using interactions with proper tensor force, or SM+RPA, can reproduce experimental ν-nucleus cross sections in 12C and 56Fe at DAR energies.

  12C (ν, e⁻) 12N (1^+, g.s.)
  56Fe (ν, e⁻) 56Co DAR
  56Ni (e⁻, ν) 56Co
  (Suzuki)

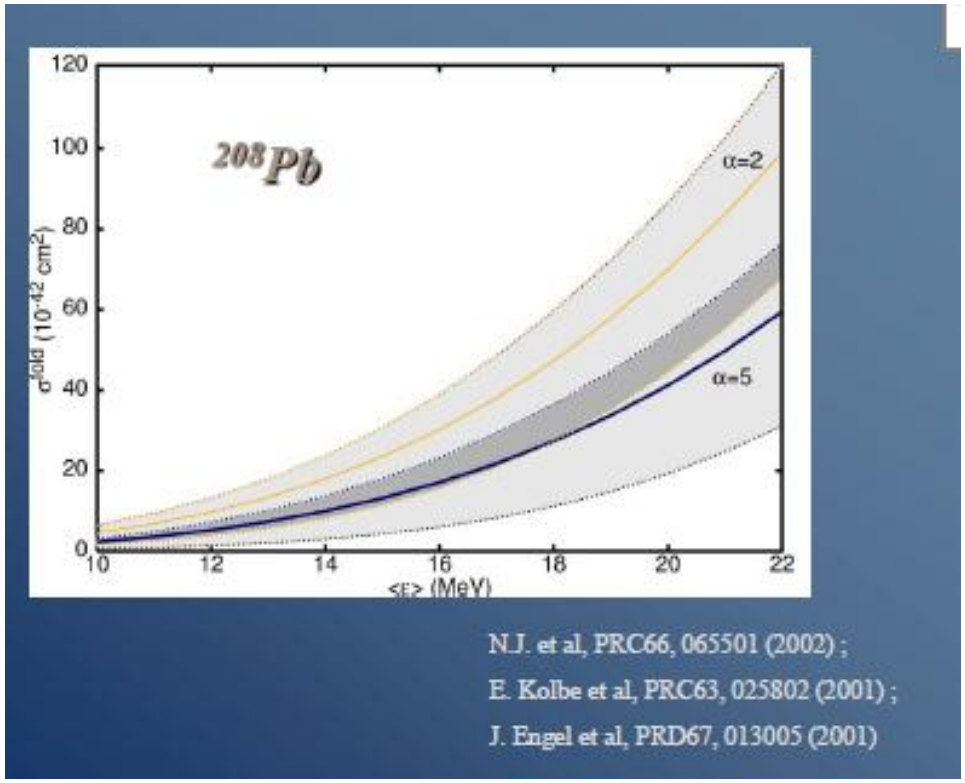
- Important targets for SNν detection: 40Ar, 208Pb

★ **Direct measurements of cross sections for these nuclei are possible by SNS and LArTPC, HALO.**

40Ar (ν, e⁻) 40K
208Pb (ν, e⁻) 208Bi
208Pb (ν, ν') 208Pb (Cavanna, Virtue)



Cross sections for 40Ar (ν, e-) 40K: calc. by Suzuki, Langanke
Cross sections for 208Pb (ν, ν') 208Pb and 208Pb (ν, e-) 208Bi:



(Jachowicz)

★ More accurate theoretical evaluation of ν-208Pb cross sections is necessary.

Inclusion of spreading in the GT strength due to coupling to 2p-2h states is important.

▪ ν scatttering from isoscalar targets

○ Coherent elastic scattering:

Challenging experiment: (Jongee Yoo, Moroni)

removal of backgrounds

detection of recoil-nucleus at keV eneregy region

★ **What can we know about reactor anti-ν_e?**

total flux, energy spectrum

existence or non-existence of sterile ν ?

○ Effects of strangeness content of nucleon

★ **Can we obtain information on strange quark content of nucleon?**

Cross sections can be sensitive to g_A^s (Jachowicz)

Scattering cross sections from proton and neutron tend to cancel. Measurement of (ν, ν' p) and (ν, ν' n) is favored.

→ quasi-elastic region

cf. 12C (ν, ν') 12C (1+, T=0) (Suzuki, Kohyama, Yazaki)

Isospin mixing effects are important

Cross section was too small.