MeV electron- neutrino and antineutrino spectrometer with LiCl and GaCl

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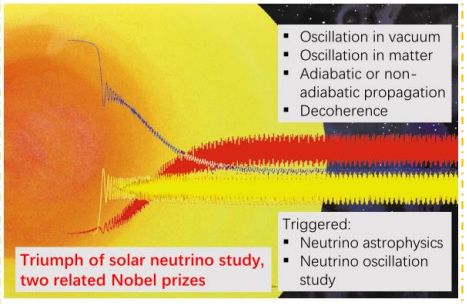
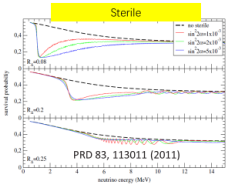
Solar Neutrino Oscillation



Light sterile neutrino



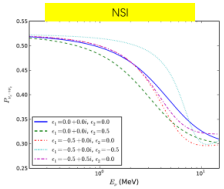
$$R_\Delta \equiv \frac{\Delta m^2_{01}}{\Delta m^2_{21}}$$

$$\Delta m^2_{01} \sim (0.2\text{–}2)\times 10^{-5}\ \text{eV}^2$$

Light sterile neutrino is compatible with the current experimental measurements

Special for solar neutrino oscillation:
Its parameter range is different than reactor anomaly, Gallium anomaly, LSND anomaly (Δm^2 ~1 eV^2)

Non-standard interaction



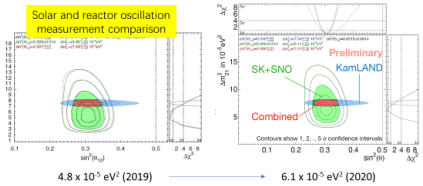
$$\mathcal{H} = \sqrt{2}G_F n_e \begin{pmatrix} 1+\epsilon_{ee} & \epsilon^s_{e\mu} & \epsilon^s_{e\tau} \\ \epsilon_{e\mu} & \epsilon_{\mu\mu} & \epsilon^s_{\mu\tau} \\ \epsilon_{e\tau} & \epsilon_{\mu\tau} & \epsilon_{\tau\tau} \end{pmatrix}$$

Light sterile neutrino is compatible with the current experimental measurements

NSI can present at neutrino production, propagation, and detection

Experimental data is expected on this regard

Neutrino anti-neutrino symmetry

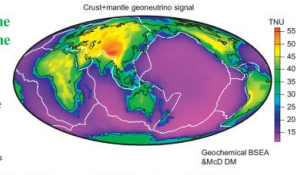


- Solar ν_e oscillation parameter is not fully compatible with ground $\bar{\nu}_e$ measurement. Best CC result from SK and SNO
- Best NC result is from SNO, which limits the future improvement of solar oscillation parameter measurement

Geoneutrino detection at Jinping Laboratory

Radiogenic heat is one key power to drive the Earth evolution

Tibet Plateau is predicted to have the largest geo neutrino flux



- Can provide interesting link for seismology-predicted density and geochemics-predicted composition.
- Facilitate the mantle geo-neutrino determination

Note: "$\bar{\nu}_e$" for geo neutrino

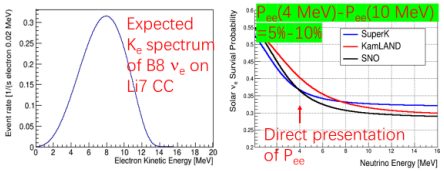
ν_e and Li7 interaction (Fermi & Super GT)

CC: $\nu_e + {}^7\text{Li} \rightarrow {}^7\text{Be} + e^-$ (E_{th}=0.862 or 1.291 MeV)

Angular dist.: $1+\alpha\cos\theta$, α=-0.02 for 5< E <10 MeV

Energy: one-to-one correspondence

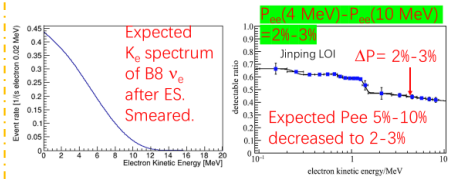
NC: $\nu_x + {}^7\text{Li} \rightarrow \nu_x + {}^7\text{Li} + \gamma$ (0.478 MeV) (E_{th}=0.478)



Better than: ν-electron elastic scattering

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

1. Compton-plateau like E_e after the ES process
2. Strong solar angle correlation
3. A mixture of CC+NC



Li7 CC, ES and other features

ν_e-^{7}Li CC(E_{th}=0.86 MeV)
$\nu_e + {}^7\text{Li} \rightarrow {}^7\text{Be} + e^-$
1. 3.5×10^{-42} cm2
2. ^{7}Li NA: 92.4%
3. solubility (10°C)
   75 g LiCl/100 g H_2O

- No enrichment for Li
- High cross-section
- High solubility
- LiCl Cheap, 20k yuan/ton

Good for Exp.

ν_e-e elastic scattering:
$\nu_x + e^- \rightarrow \nu_x + e^-$
1. 0.061×10^{-42} cm^2

ν_e's CC and NC on D (SNO):
$\nu_x + D \rightarrow \nu_x + p + n$
$\nu_e + D \rightarrow e^- + p + p$
1. E_{th}(NC)=2.22 MeV
2. E_{th}(CC)=1.42 MeV
   ~0.61×10^{-42} cm^2

ν_e's CC on Ar (DUNE):
$\nu_e + {}^{37}\text{Ar} \rightarrow e^- + {}^{37}\text{Cl}$
1. E_{th}(CC)=3.79 MeV
   Cross-section<Li7

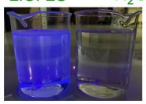
Geo "$\bar{\nu}_e$" can be detected in LiCl aqua solution

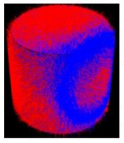
- $\bar{\nu}_e + p \rightarrow e^+ + n$ n capture on H: 0.3 barn
- Delayed signal 1:
  $n + {}^6\text{Li} \rightarrow t\ (2.73\ MeV) + \alpha\ (2.05\ MeV)$, ~0.55 MeV
  ^{6}Li NA is 7.59%, σ is 940 barn
  H. K. M. Tanaka, H. Watanabe, SCIENTIFIC REPORTS 4 : 4708 (2014)
- Delayed signal 2:
  $n + {}^{35}\text{Cl} \rightarrow {}^{35}\text{Cl}^* \rightarrow {}^{35}\text{Cl} + \gamma's$ (8.6 MeV, 2.5 $\gamma's$)
  ^{35}Cl NA is 75.76%, σ is 44 barn
  SNO, PhysRevC.72.055502(2005)
- ~30% n captured on ^{35}Cl, High delayed energy, Easy to identify
- ~70% n captured on ^{6}Li, Challenging to identify

New LiCl aqua solution Cherenkov scintillator

- Li mass fraction 7%
- Identify Cherenkov and scintillation Identify Li CC electron
- Purification through recrystallization
- LiCl aqua solution, attenuation length>11m

LiCl LS H_2O

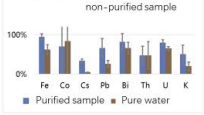




Cherenkov – B
Scintillation – R

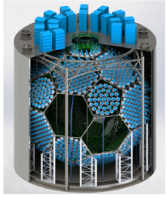
ν_e ES direction reconstruction and Li7 CC separation

Purification result

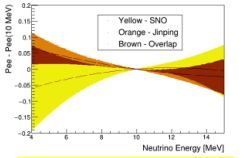


Sensitivity with LiCl aqua solution

LiCl aqua solution in 5 hundred ton 10 year plan



1. Exclude downturn assumption (99% CL)

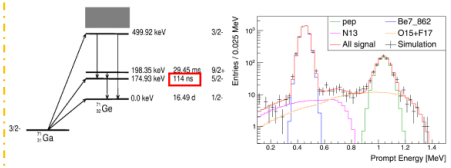


2. Discover geoneutrino from Himalaya's if at Jinping Underground Lab

Delayed coincidence in ν_e CC capture on Ga

$$\nu_e + {}^{71}_{31}\text{Ga} \rightarrow {}^{71}_{32}\text{Ge}_{ex} + e^- \rightarrow {}^{71}_{32}\text{Ge}_{1st} + e^- + (\gamma's),$$

$${}^{71}_{32}\text{Ge}_{1st} \rightarrow {}^{71}_{32}\text{Ge}_{gs} + \gamma\ (174.94\ \text{keV}),\ \tau = 114\ \text{ns}.$$



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