The Potential to Probe Solar Neutrino Physics with LiCl Water Solution

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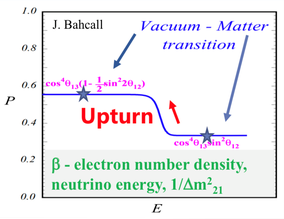
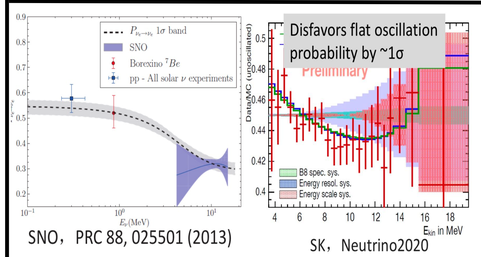
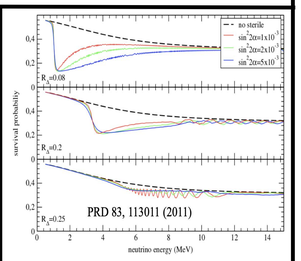
1. Solar Neutrino Physics Study

- In solar neutrino physics study, the MSW effect predicts that between the high- and low-energy regions, there is a smooth "upturn" of the survival probability curve.





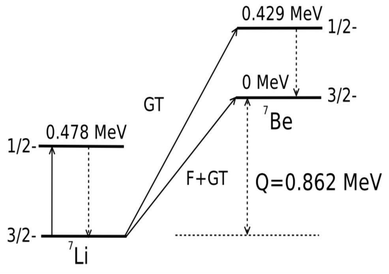


- There is no experimental confirmation about the upturn effect at present. So new physics may appear in this region, like NSI, or the weakly mixed light sterile neutrino model etc.

- The light sterile neutrino model can influence the upturn curve and make it "dip and wiggle".

2. Why LiCl Water Solution?

CC ($E_{th} = 0.862$ or 1.291MeV) :
$\nu_e + {}^7\mathrm{Li} \rightarrow {}^7\mathrm{Be} + e^- \ (+\gamma)$
NC : $\nu_x + {}^7\mathrm{Li} \rightarrow \nu_x + {}^7\mathrm{Li} + \gamma\ (0.478\mathrm{MeV})$



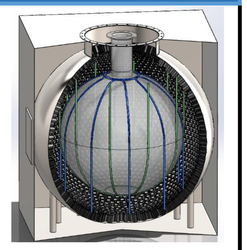
- The effective kinetic energy of the final eletron after the charged-current (CC) interaction directly reflects the neutrino energy, which stands in sharp contrast to the plateau structure of recoil electrons of the elastic scattering (Elas) process.

- CC interaction cross-section of ν_e on ^{7}Li and ^{37}Cl weighted by the solar ^{8}B electron neutrino spectrum is 3.759×10^{-42} cm^2, which is about 60 times that of Elas process. And LiCl has high solubility in water at 10°C and ^{7}Li has high natural abundance.

Channel	$\sigma(^8\mathrm{B})$ (10^{-42}cm^2)
^{7}Li total	3.759
^{37}Cl total	1.069
e^-	0.061

3. Detector with LiCl water solution

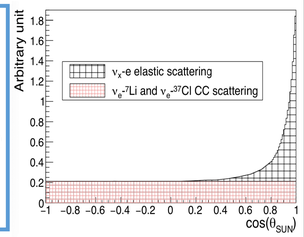
- The measured attenuation length of 11 ± 1 m at 430 nm shows that the LiCl solution is practicable for a 10-m diameter detector. This neutrino detector proposal is suitable for Jinping Neutrino Experiment (JNE) detector with 320 tons fiducial mass.



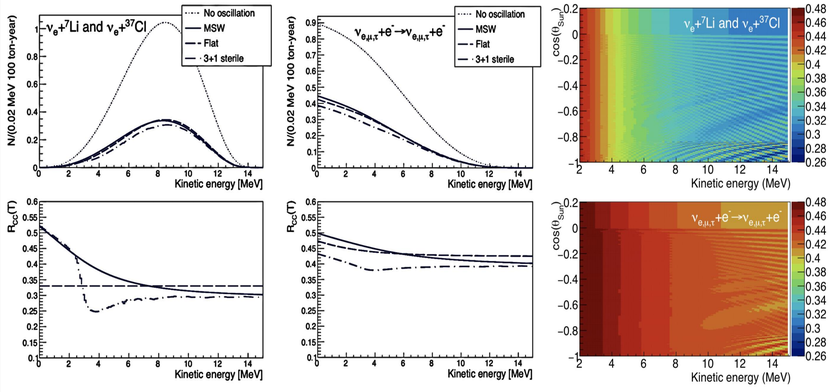
- The CC event rates of ^{7}Li, ^{37}Cl, and the Elas event rate are calculated with the ^{8}B ν_e spectrum in different situation.

	Molarity (mol/L)	Event rate No osci. (/100 ton-year)	Event rate Osci. (/100 ton-year)	Event rate Osci. &>5MeV (/100 ton-year)
^{7}Li	11	305	101	87.3
^{37}Cl	2.9	22.7	7.28	7.17
All CC		328	108	94.4
e^-	610	271	124	34.5

- The CC and Elas events can be separated with a reconstructed solar angle cut. Applying a solar angle cut at 60 degrees, a CC-rich sample (most are CC events) and an Elas-rich sample (most are Elas events) are obtained.



4. Advantages in Solar Neutrino Physics Study

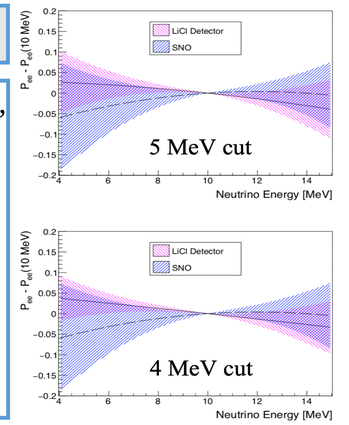


- The rich structure information of the upturn signal, the light sterile neutrino signal in energy spectrum and the original rich pattern in the survival probability plot of ν_e are well repeated in the CC plot but is almost smeared out in the Elas plot. So LiCl has clear advantages in solar neutrino study.

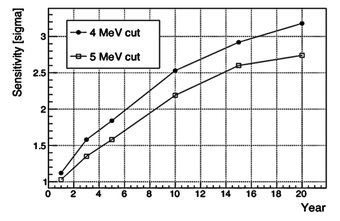
5. Sensitivity Study for Upturn Effect

$$P_{ee}(E_\nu) = c_0 + c_1(E_\nu - 10) + c_2(E_\nu - 10)^2$$

- By using a quadratic function of E_ν, We give the best fit and rms spread of the function for the LiCl water solution detector with the exposure of 320×5 ton-year. The result from the SNO is also overlaid for comparison. A significant improvement with the compact LiCl detector can be expected.



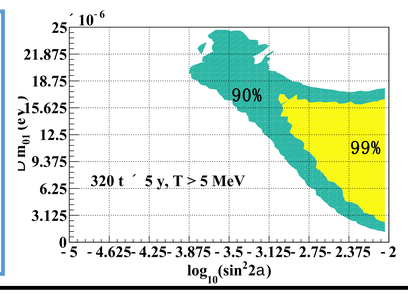
$$P_{ee}(E_\nu) = c_0 + c_1(E_\nu - 10)$$



- We use a simple linear function to quantify the sensitivity of rejecting no upturn effect.
- The sensitivity of rejecting no upturn effect versus the number of data-taking years for a 320-ton LiCl water solution is shown.

6. Sensitivity Study for Light Sterile Neutrino

- We use the Feldman-Cousin method to determine the exclusion sensitivity of a detector with the exposure of 320×5 ton-year. We shows the sensitivity contours with a 5 MeV cut.



7. Conclusion

- LiCl water solution has advantages in solar neutrino physics:
  - measuring the solar neutrino upturn effect,
  - the search for light sterile neutrinos,
  - the study of the Earth matter effect.
- The sensitivity of probing the upturn and sterile neutrinos with the detector proposal is presented.

Acknowledgement

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