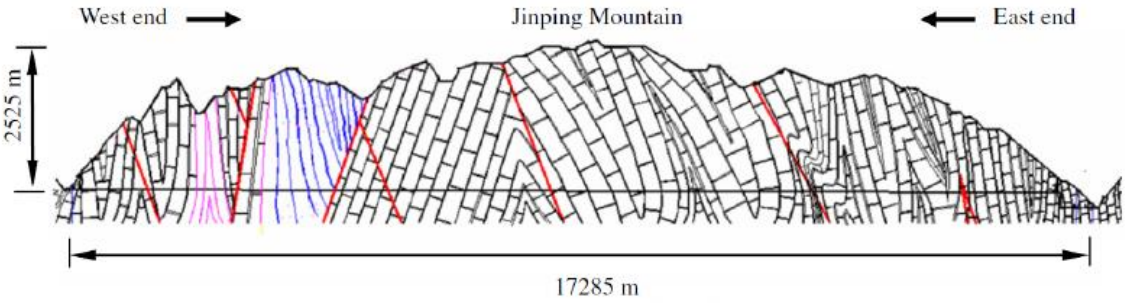

Development of LiCl aqueous solution for neutrino detection for Jinping Neutrino Experiment

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(for the research group)

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Contents

1. Jinping Neutrino Experiment(JNE) in plan
   Target volume, 500 m^3, at Jinping laboratory
   ---- Solar, Geo, Supernova neutrinos, etc.

2. Properties and development of LiCl aqueous solution as a neutrino target
   (organic luminescent material added)

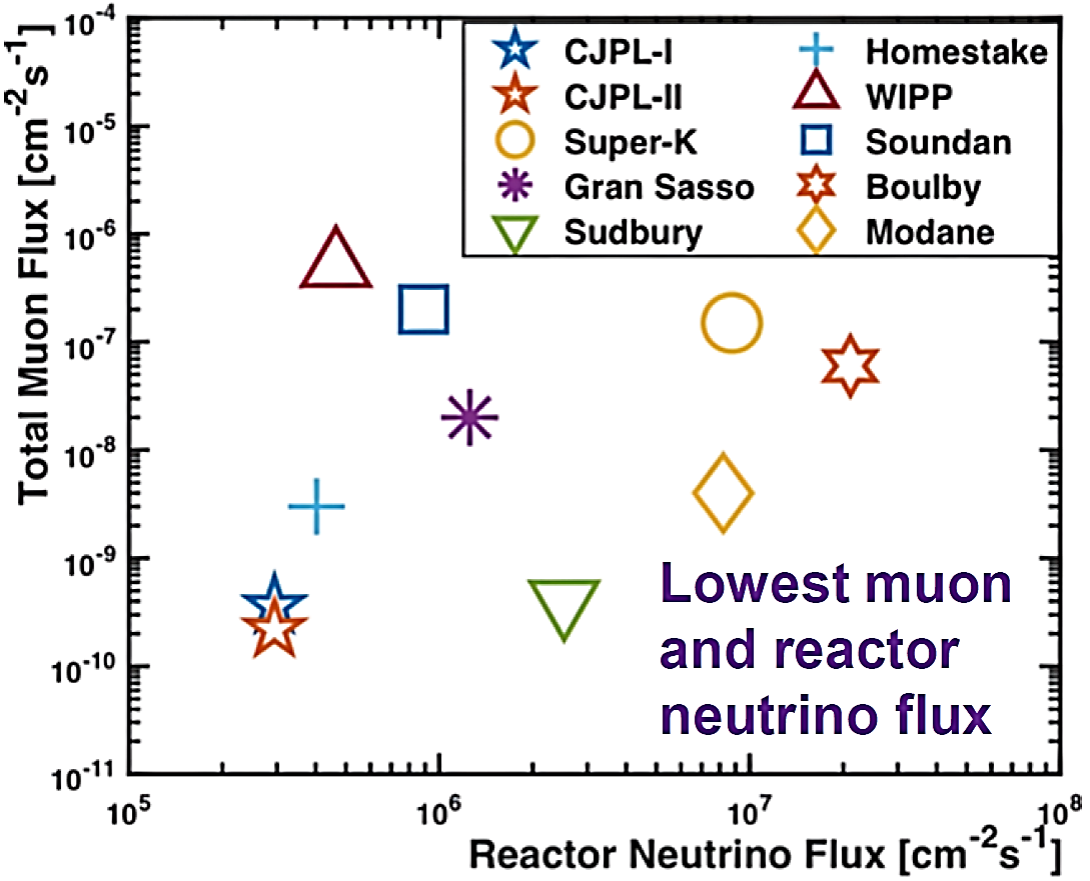
3. Sensitivity for solar neutrino upturn effect

4. Prospects for geo and supernova neutrinos

China Jinping Underground Laboratory (CJPL) ----

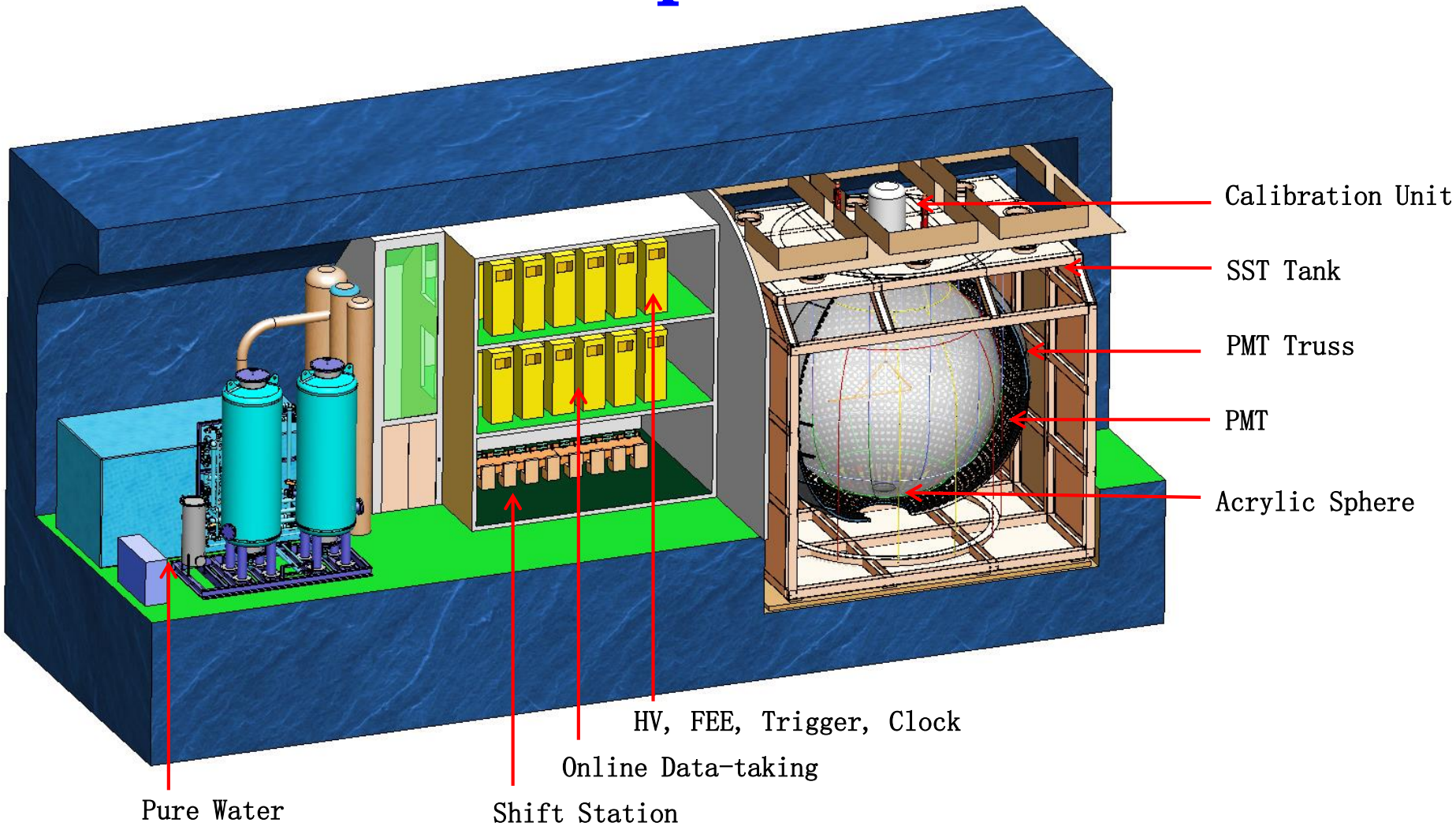
An ideal low background experiment site

2400 m overburden



1000 km to reactors

A 500 m^3 detector is planned at CJPLII



Target volume: 500 cubic meter

Goal of the Jinping Neutrino Experiment (JNE)

1. Solar neutrino
   B-8 neutrino spectrum, upturn effect
   (matter-induced survival probability increase)

2. Geo neutrino
   crust geo neutrino model study
   (Qinghai-Tibetan Plateau geoneutrino)

3. Diffuse supernova neutrino background (DSNB, aka supernova relic neutrinos)

4. Other new physics

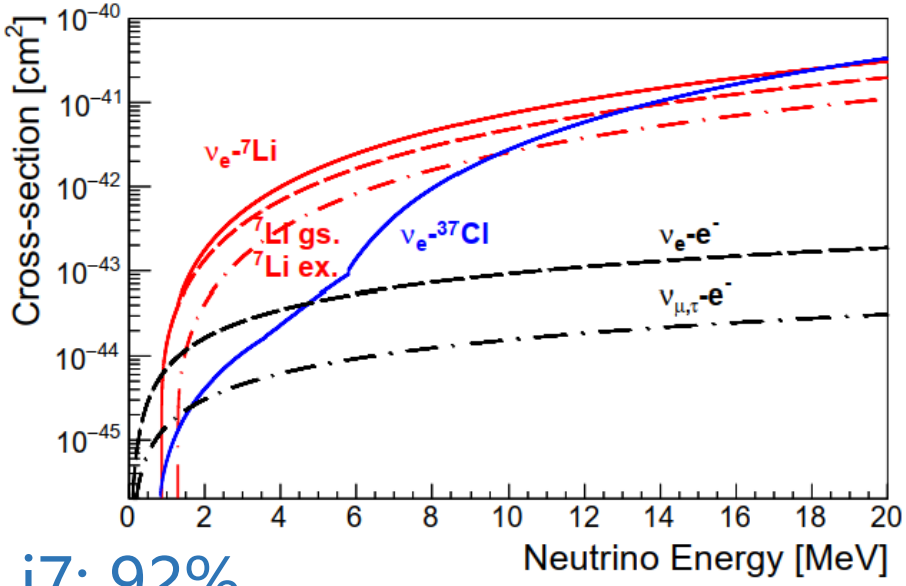
(Saturated) LiCl aqueous solution for neutrino det.

1. CC process for ν_e:

   $\nu_e + {}^7\mathrm{Li} \rightarrow {}^7\mathrm{Be} + e^- (+\gamma)$

   Measure neutrino energy
2. High cross-section:

   ν_e-Li7: 60 times of ν_e-e elastic for solar B8 neutrinos
3. High natural abundance of Li7: 92%
4. High solubility: 80 g LiCl in 100 g water



B8 Event rate/100 ton-year solution

	^{7}Li	^{37}Cl	All CC	e^-
Molarity (mol/L)	11	2.9	NA	610
Event rate (No Osci)	305	22.7	328	271
Event rate (Osci)	101	7.28	108	124
Event rate (Osci & >4 MeV)	94.5	7.24	102	48.0
Event rate (Osci & >5 MeV)	87.3	7.17	94.4	34.5

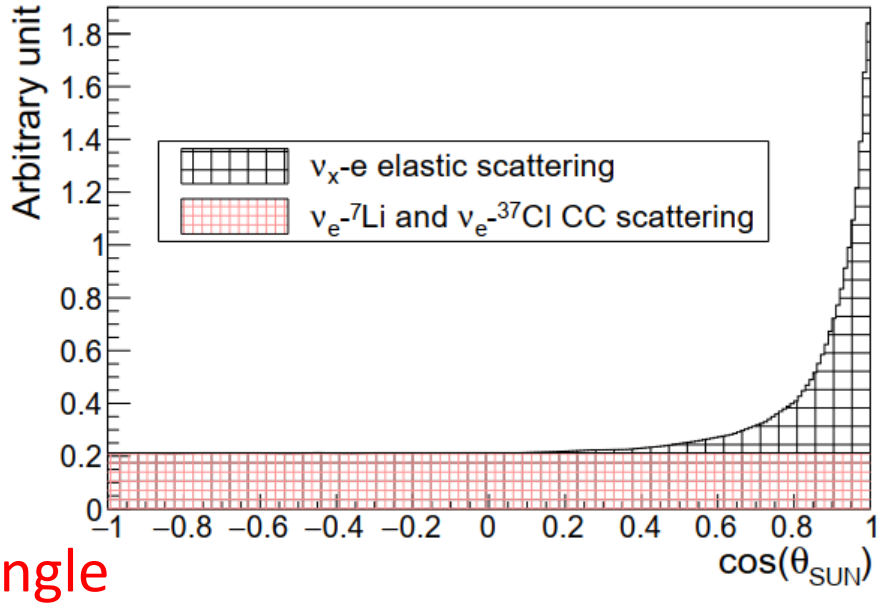
ν_e CC-Li7, ES, and $\bar{\nu}_e$ detection and separation

1. CC-Li7 process for ν_e:

$$\nu_e + {}^7\mathrm{Li} \rightarrow {}^7\mathrm{Be} + e^- (+\gamma)$$

Measure neutrino energy

$$T = E_\nu - 0.862\ \mathrm{MeV}$$



2. Elastic scatter on e⁻:

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

CC-Li7, ES separated by solar angle

3. Delayed coincidence for $\bar{\nu}_e$:

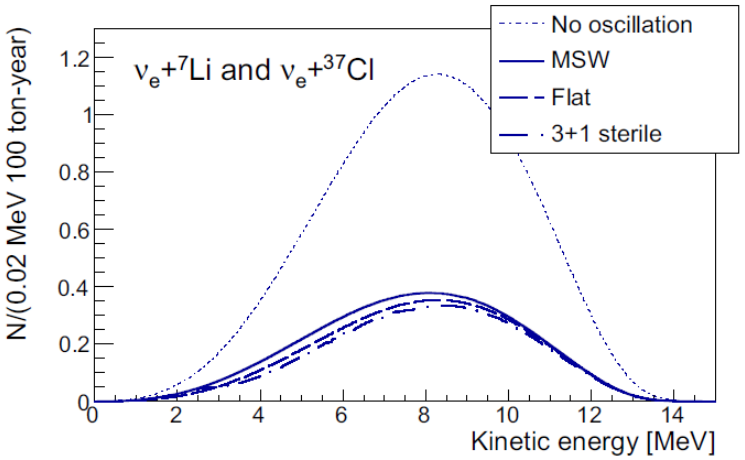
$$\bar{\nu}_e + p \rightarrow n + e^+$$

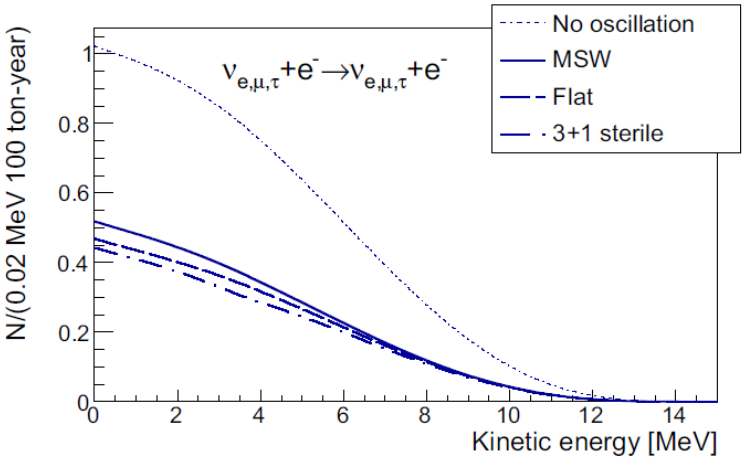
with neutron capture on H, Li6, and Cl35

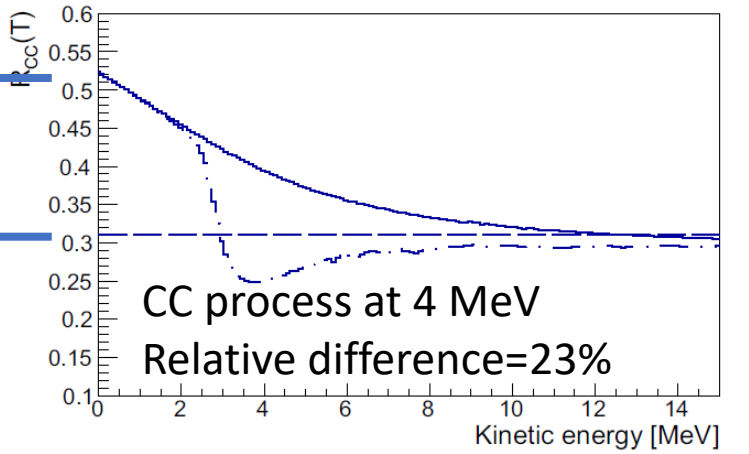
measure $\bar{\nu}_e$ energy

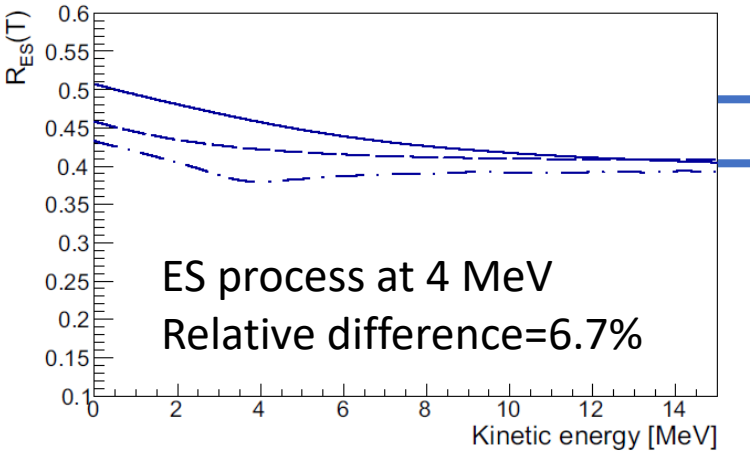
Spectrometer for ν_e and $\bar{\nu}_e$. Good chance for solar, geo, and supernova neutrinos.

CC-Li7 vs ES for solar neutrino oscillation study



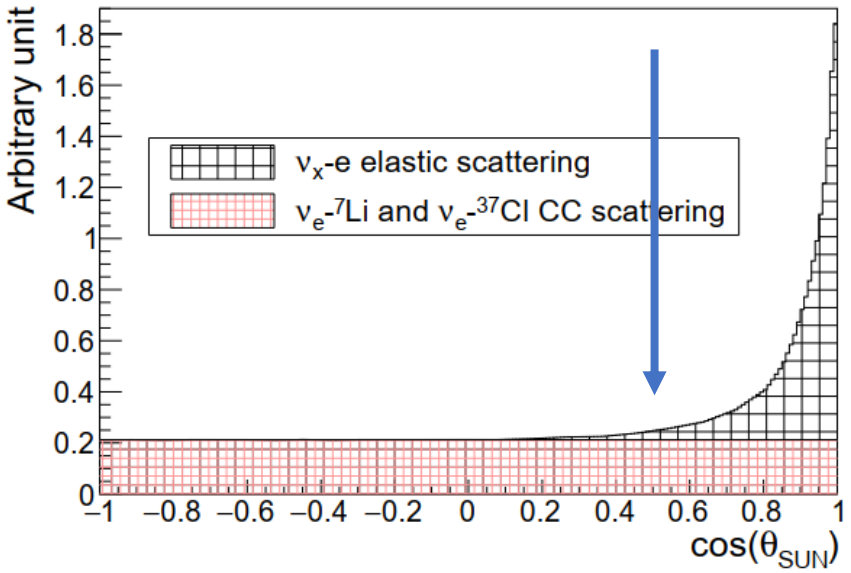


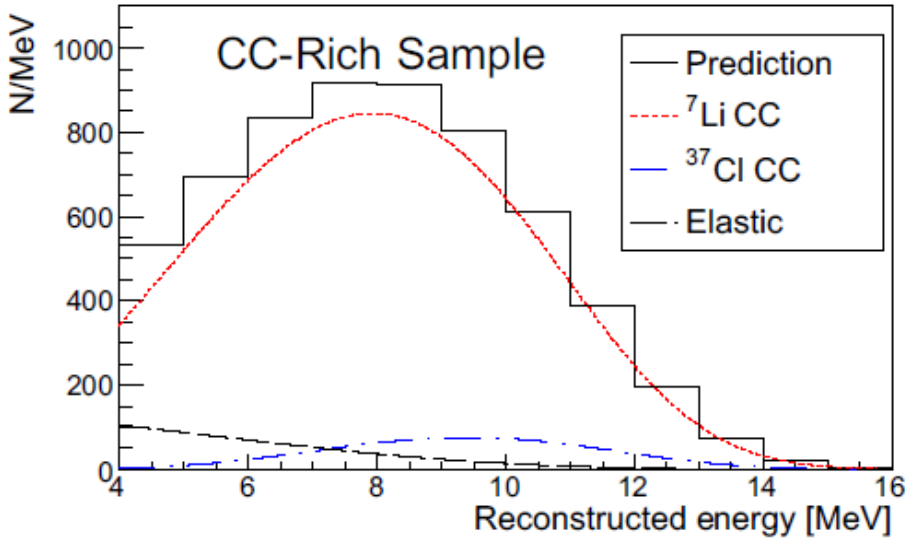




CC-Li7 process on nuclei is good to measure B-8 neutrino spectrum and any energy-dependent physics

Solar B8 neutrino extraction simulation



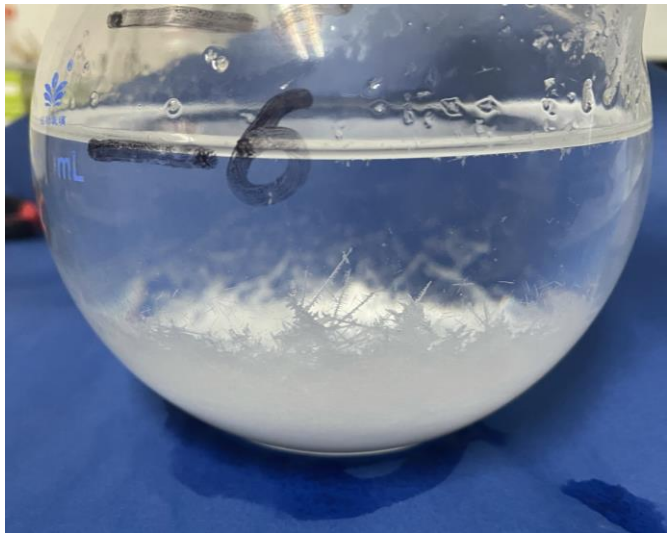


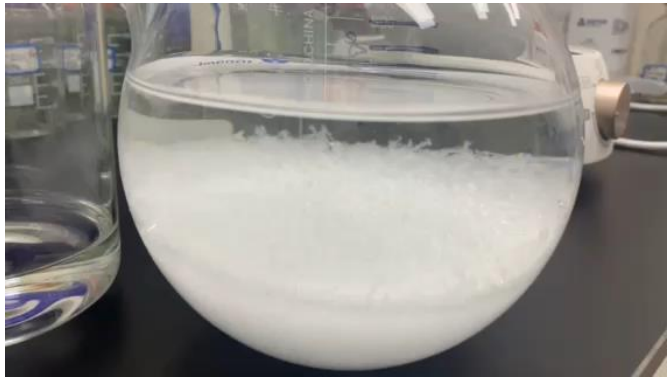
1. With a solar angle cut, CC-Li7 process signals can be clearly extracted.
2. JNE can serve as a solar neutrino spectrometer.

LiCl Water Solution Attenuation Length

LiCl water solution attenuation length improvement

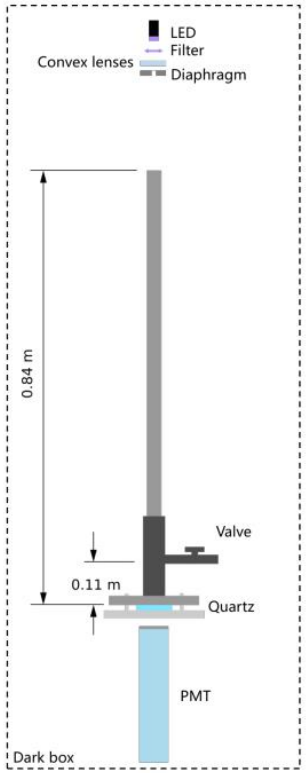
1. Absorption with powered activated charcoal
2. Thermal recrystallization





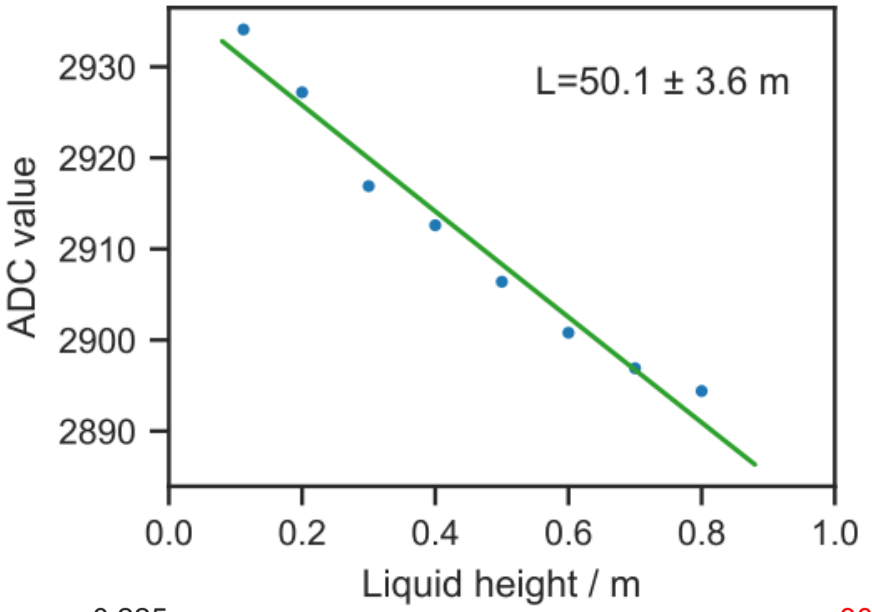
LiCl Water Solution Attenuation Length

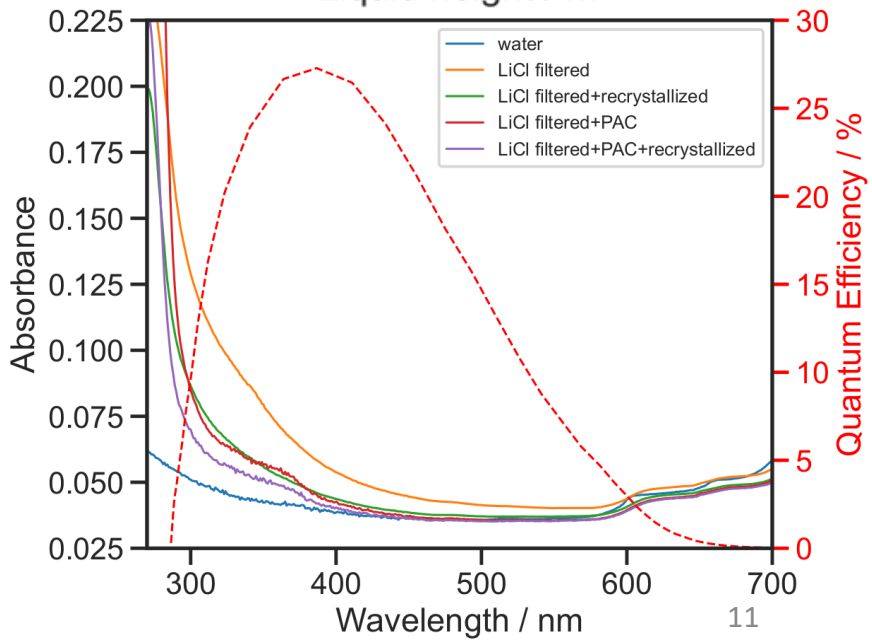
50 m attenuation length achieved.



(a)

(b)

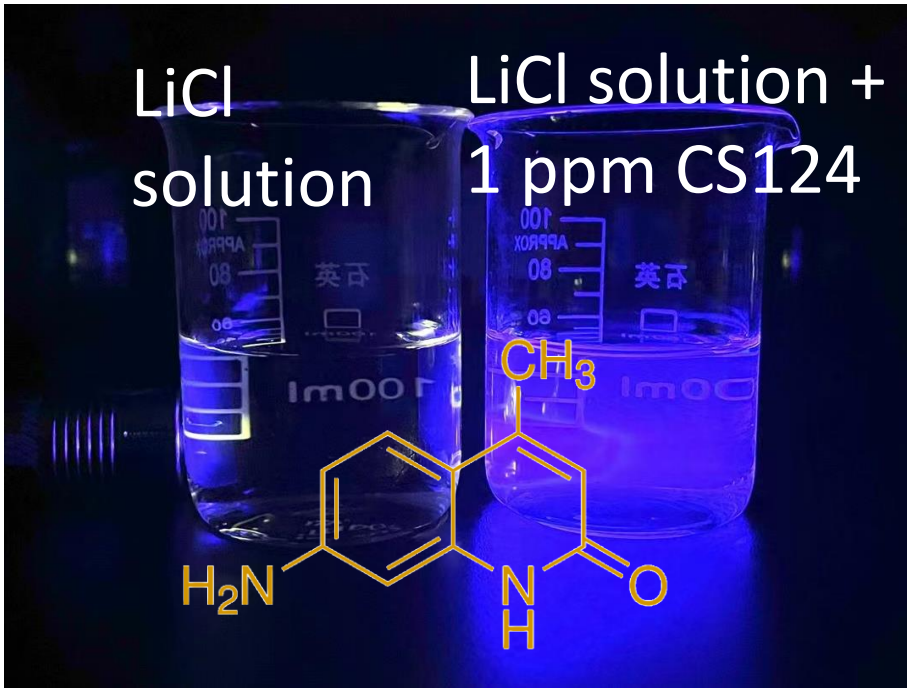


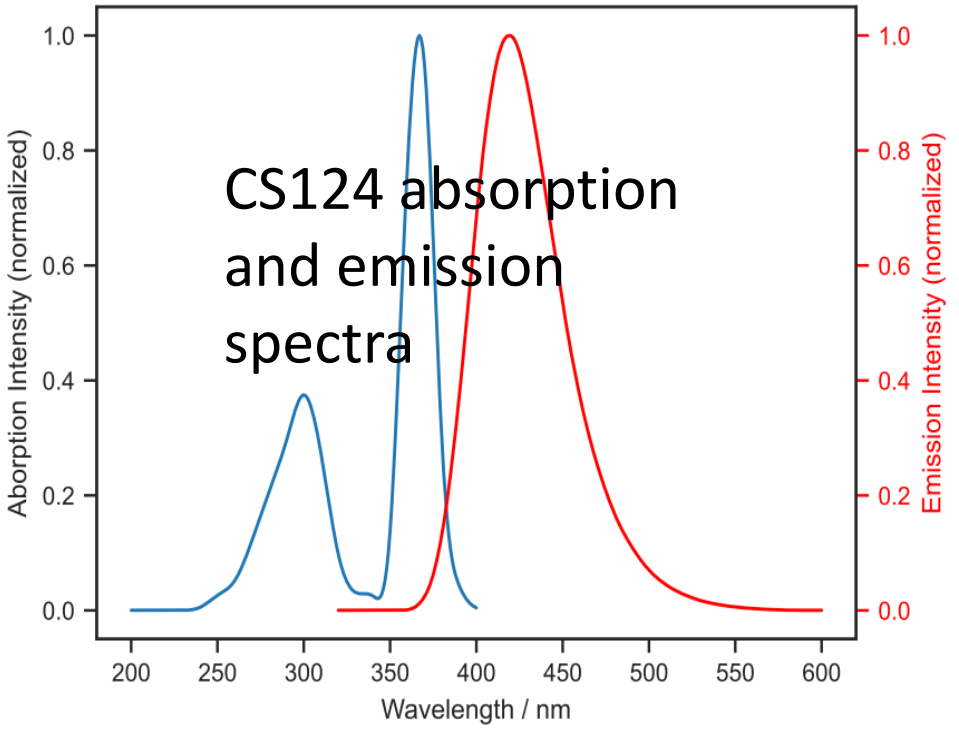


LiCl aqueous solution with carbostyril 124

Adding 1 ppm CS124 to LiCl aqueous solution

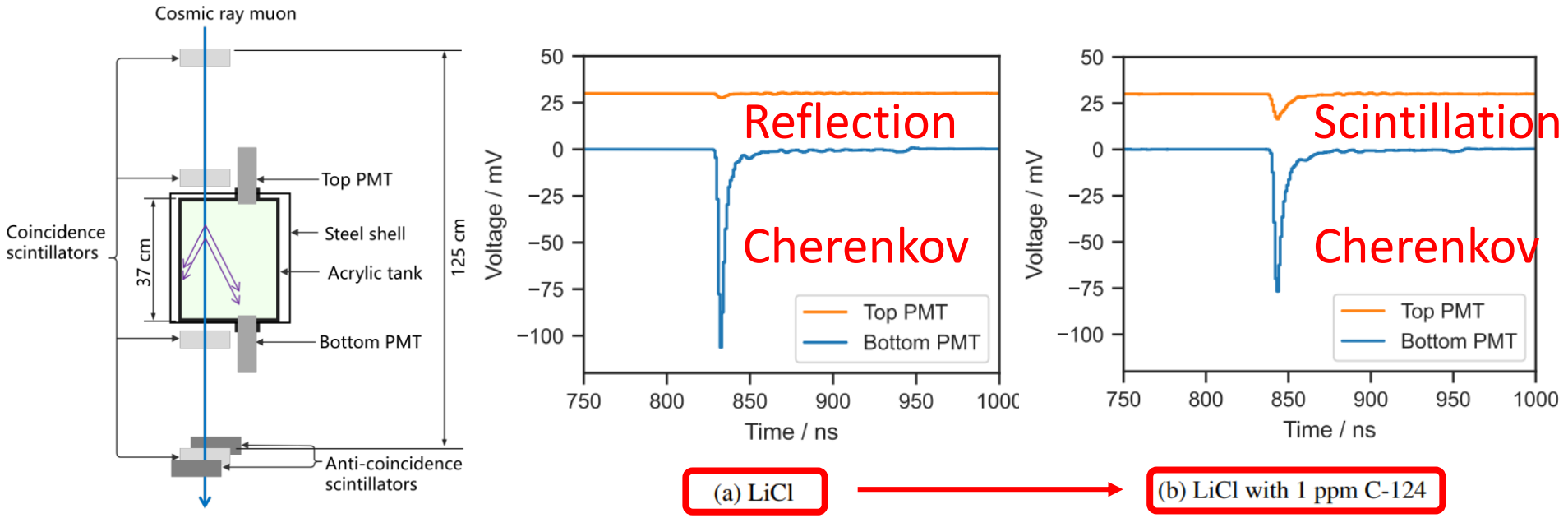
1. Convert short wavelength UV to longer wavelength
2. Convert short attenuation length UV to long attenuation length visible light
3. Minor scintillation light yield





Uniform light output from LiCl solution+CS124

Light yield verification with a muon telescope



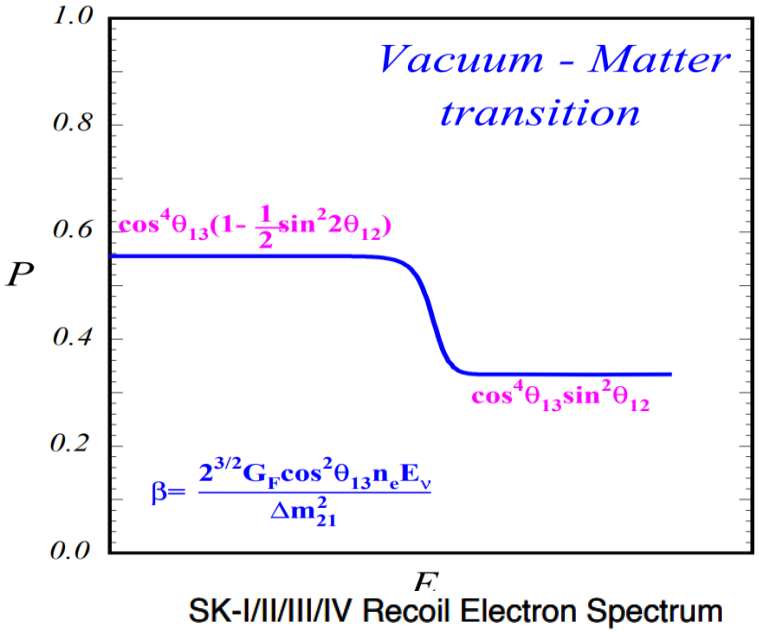
3.7 PE detected from isotropic scintillation (uniform)

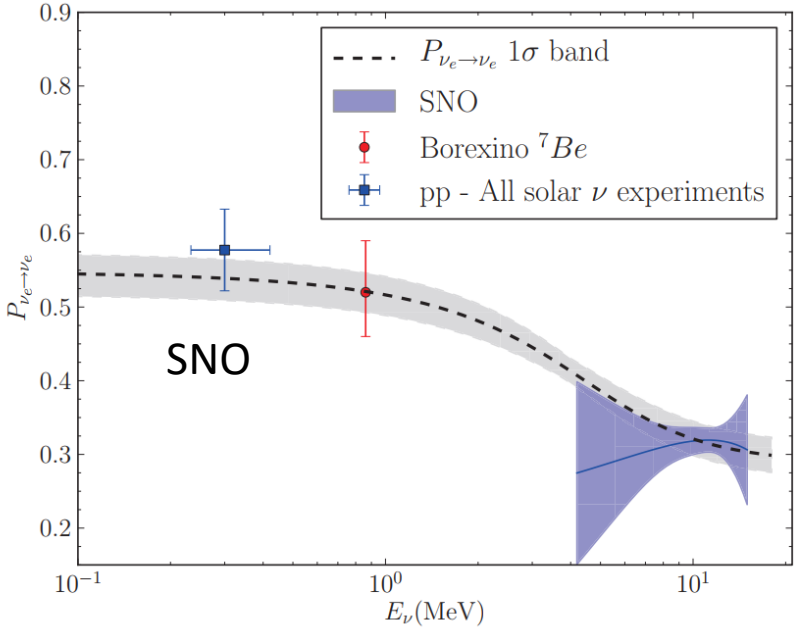
12.3 PE for Cherenkov (forward)

Solar Neutrino

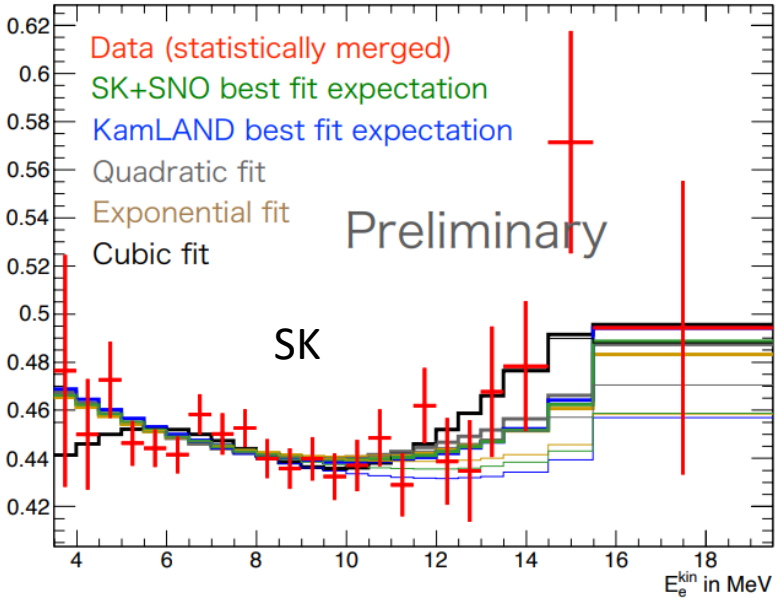
Upturn effect

Solar neutrino survival probability vs energy





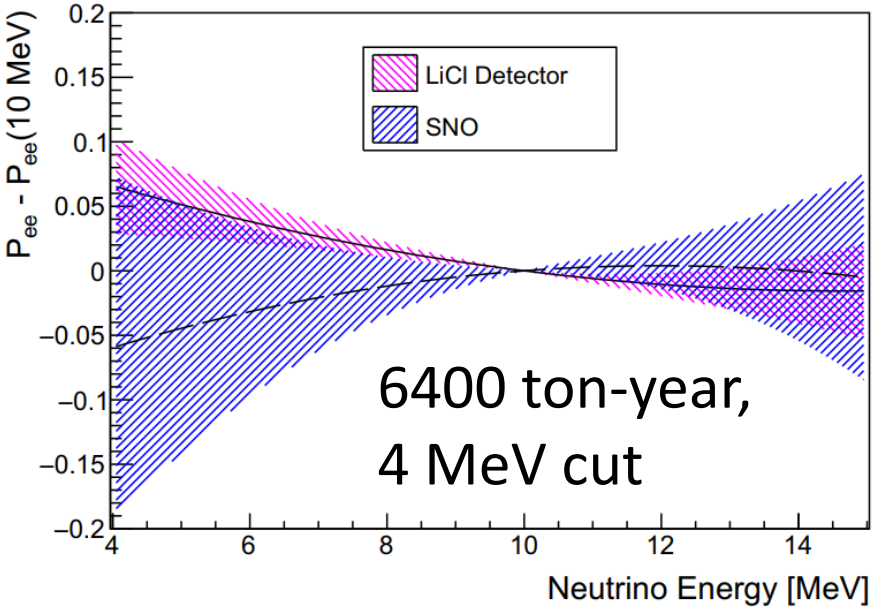
SK-I/II/III/IV Recoil Electron Spectrum



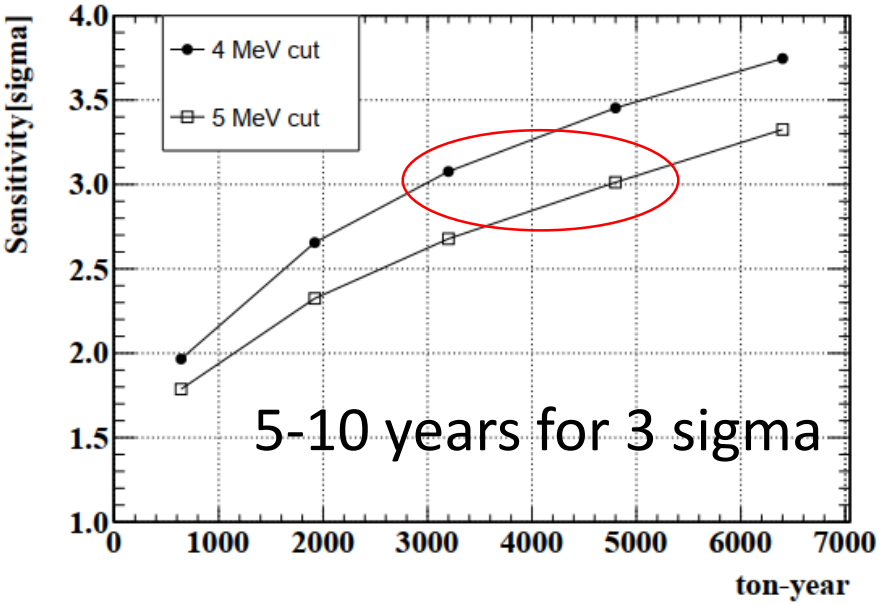
Slightly favors up-turn, though need more data

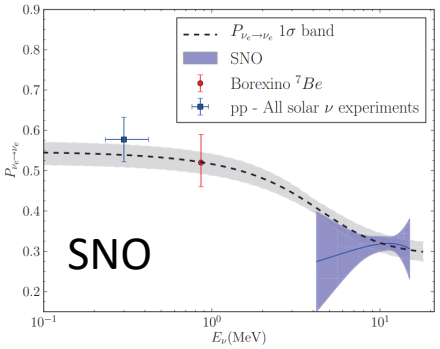
Upturn effect sensitivity with LiCl Solution

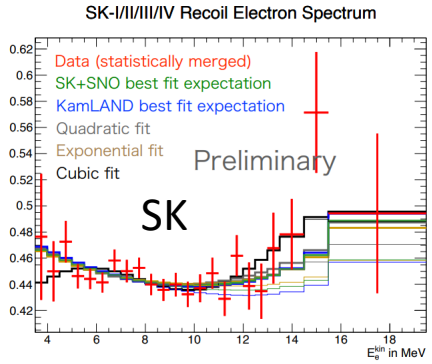
Solar neutrino survival probability-average vs energy



Upturn discovery sensitivity versus exposure





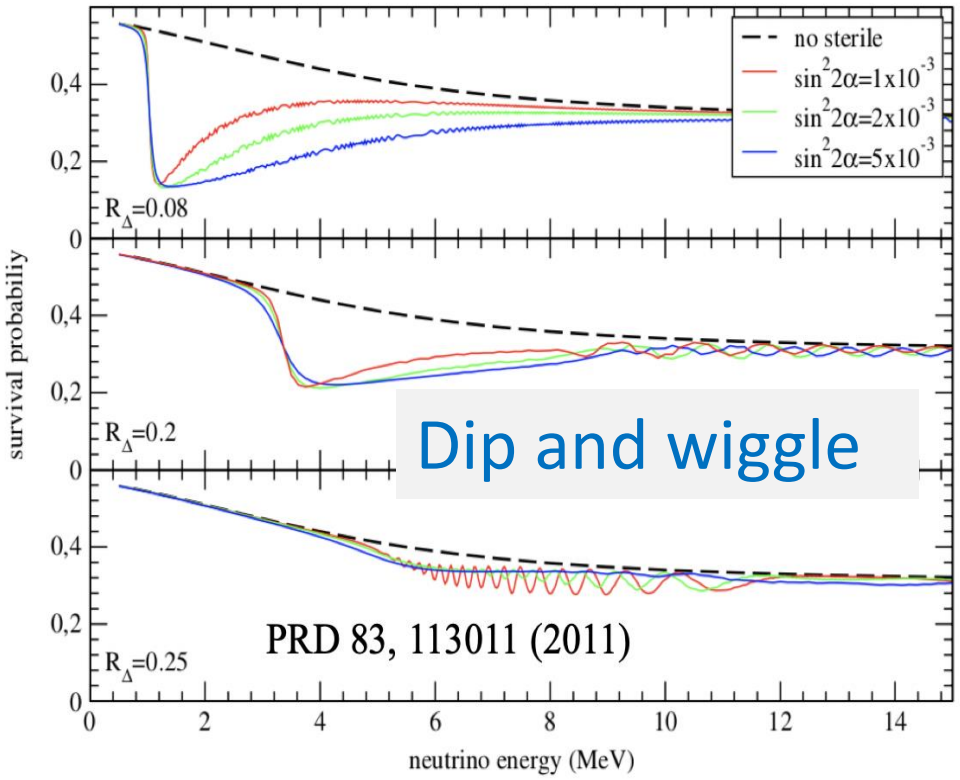


Slightly favors up-turn, though need more data

CC on Li7 has an advantage than ν-e ES in measuring solar neutrino upturn effect.

JNE – A compact detector!

Light Sterile Neutrino in Solar Neutrino Physics



Dip and wiggle

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

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

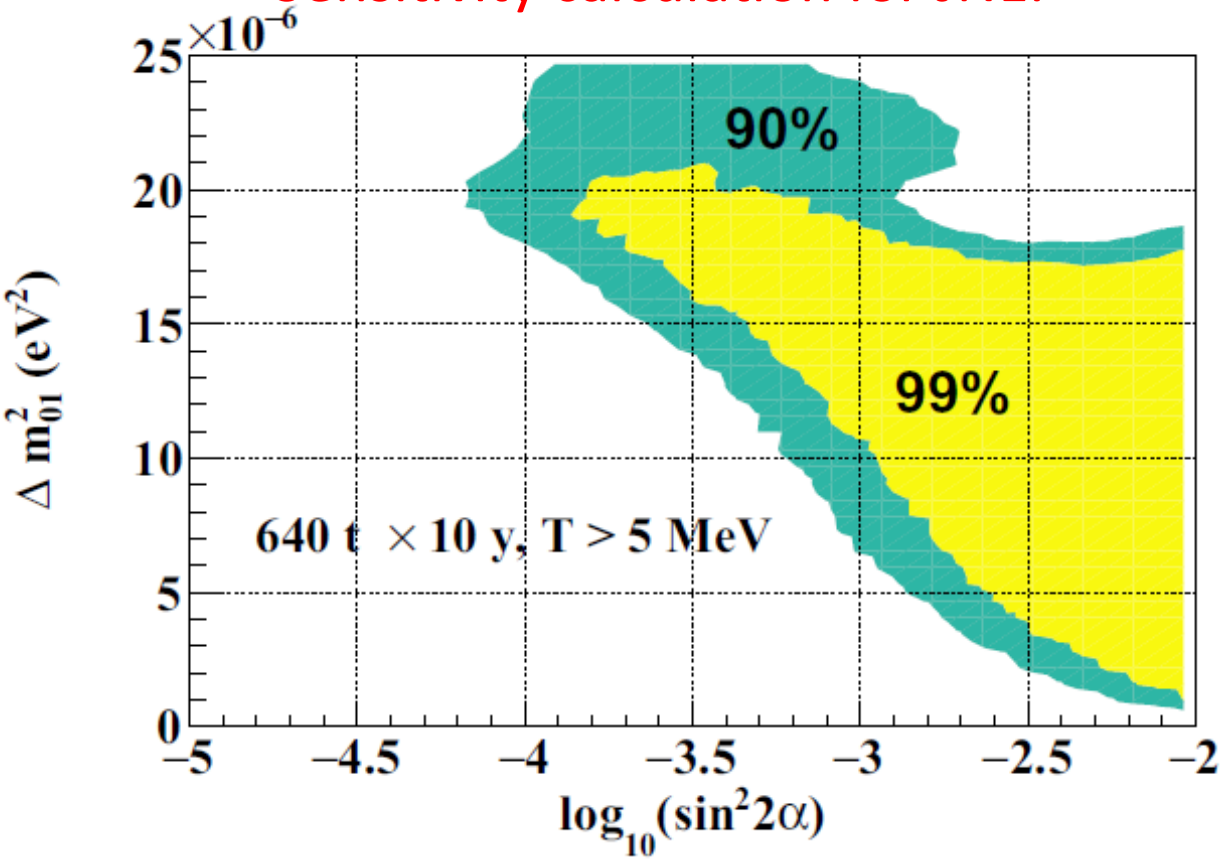
Light sterile neutrino

- Delta mass squared ~ **10^{-5} eV²**
- Not the same as reactor neutrino anomaly and LSND results (Δm^2 ~ **1 eV²**)

Structures: need a CC-Li7 detector

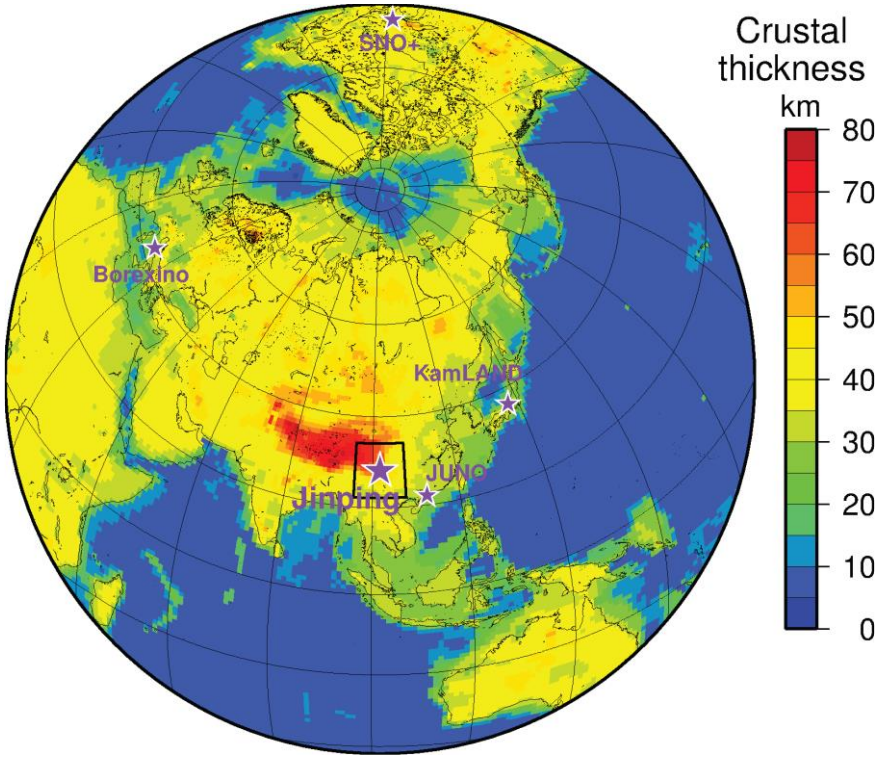
CC-Li7 for Light Sterile Neutrino Rejection

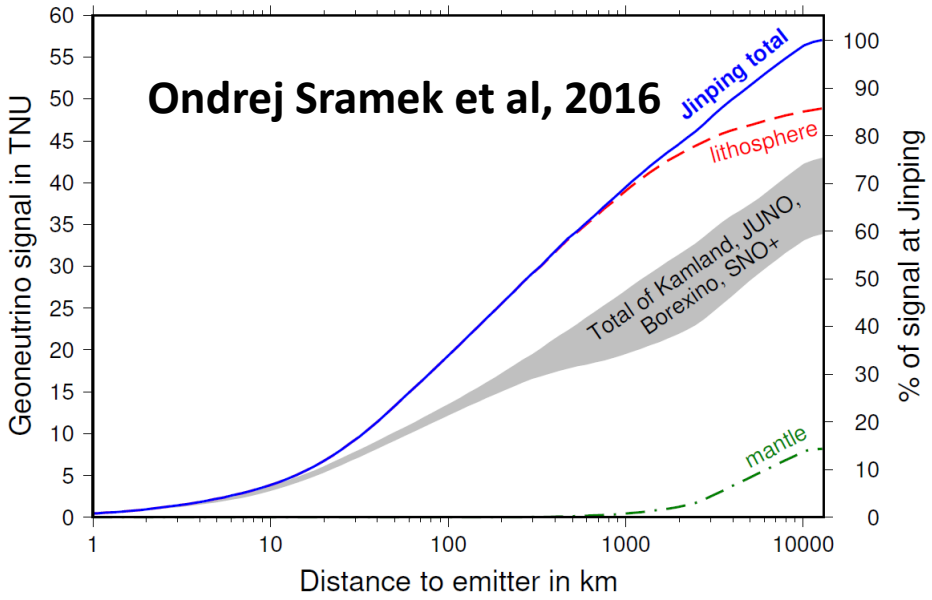
Sensitivity calculation for JNE.

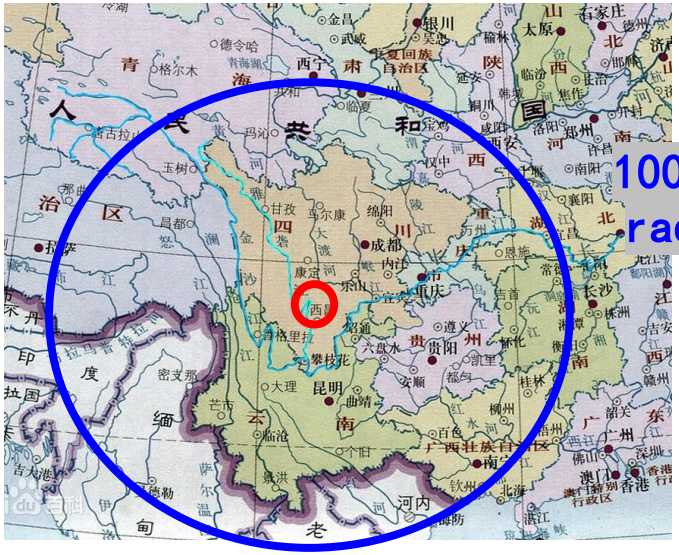


Sensitive to small delta mass squared region of sterile neutrinos, 1e-5 eV^2

Geo Neutrinos at JNE





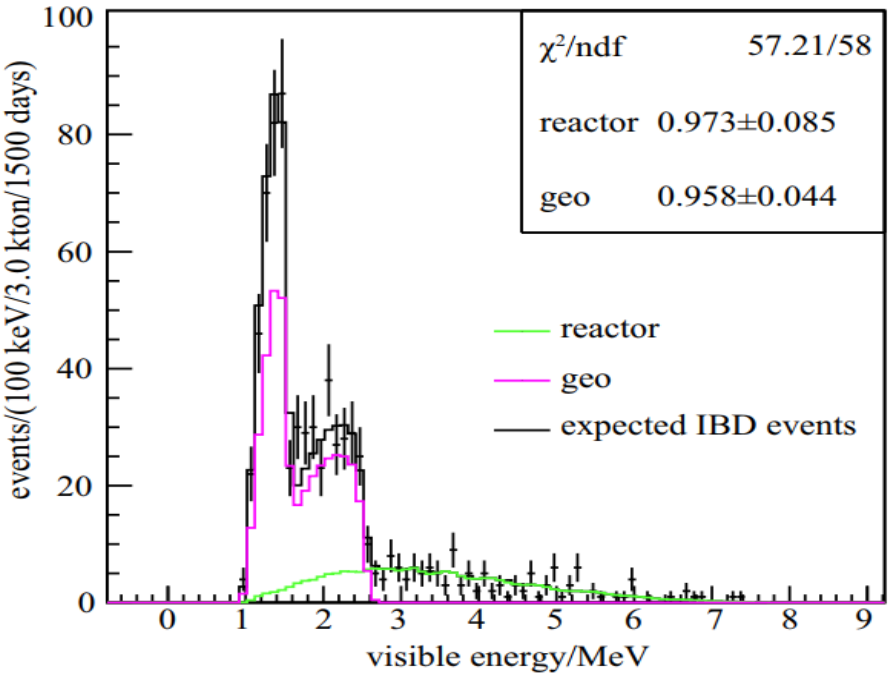


JNE is very sensitive to Qinghai-Tibet plateau crust neutrinos

Geo Neutrino at JNE

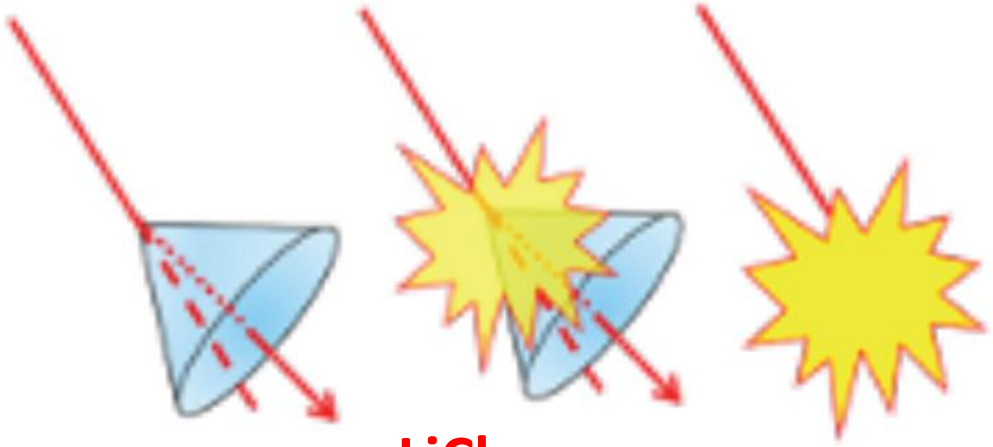
With the prompt-delayed signal detection method in LiCl solution:

- Minor reactor BKG at CJPL
- Expect tens of geoneutrinos in 5-10 years with the 500-ton detector (constrain crust model to 10-20%)
- Initial result on U/Th ratio



Event rate summary for hundred-ton detector		
^{6}Li / 100m^3•yr	^{35}Cl / 100m^3•yr	^{1}H / 100m^3•yr
1.823	0.884	0.055

Adding CS124 indicates that: a high salt (LiCl) Cherenkov liquid scintillator is possible



Direction
Energy
Position
Particle identification

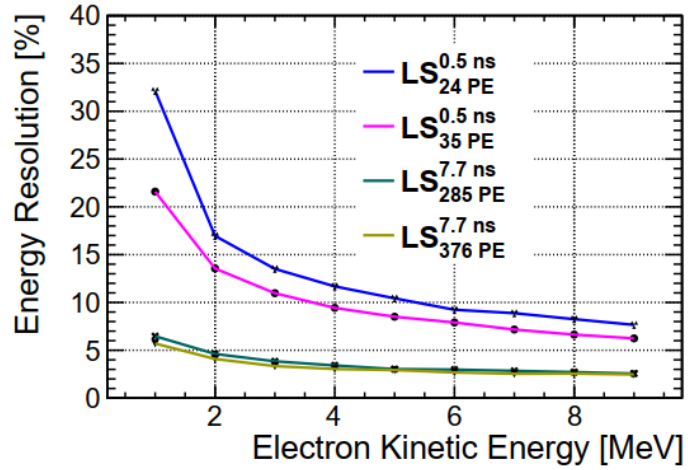
Better than pure water or liquid scintillator

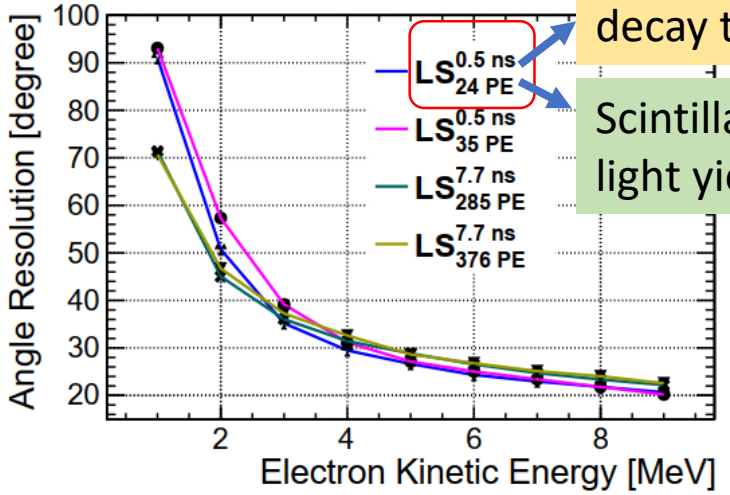
Cherenkov Liquid Scintillator Reconstruction

Reconstruct both Cherenkov light and scintillation light

1. Energy; 2. Direction; 3. Position; 4. **Particle identification**

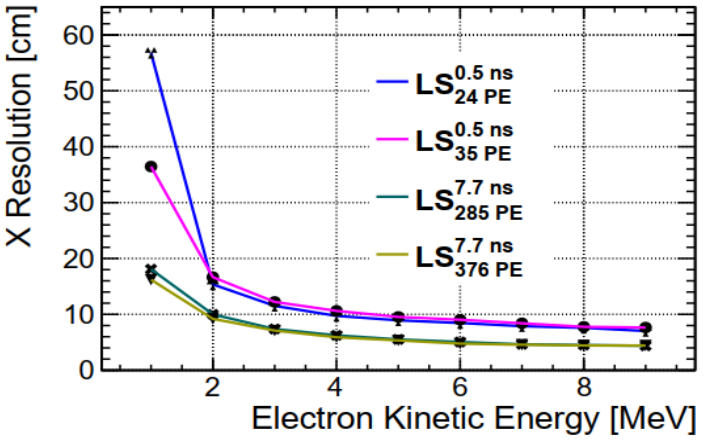
Guide liquid scintillator development

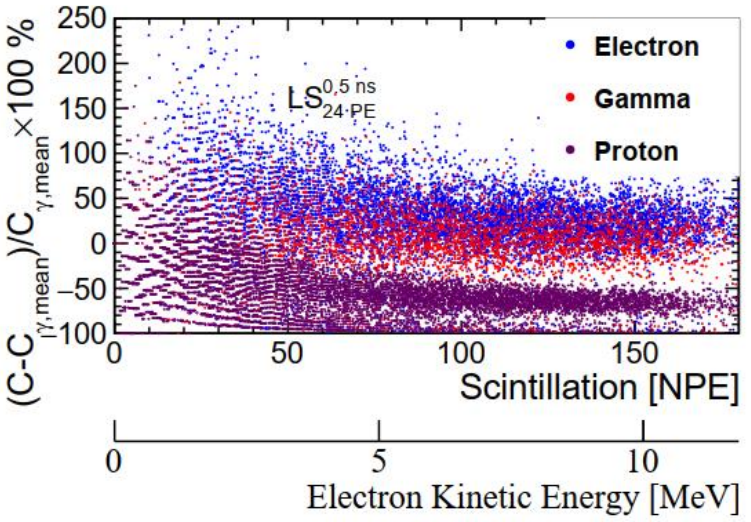




Scintillation decay time

Scintillation light yield



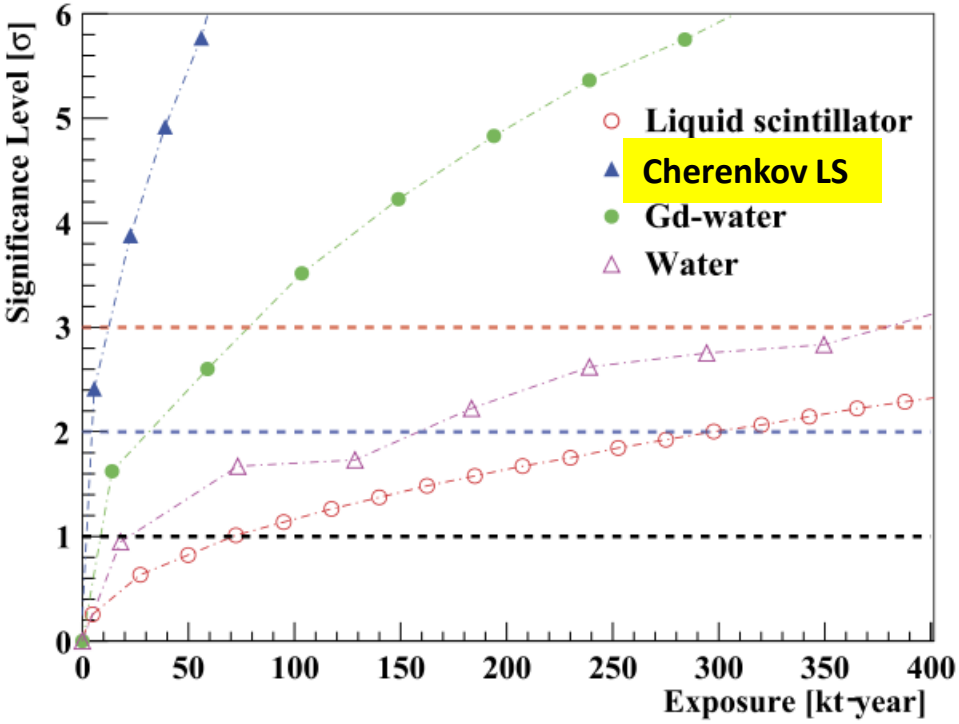


Diffuse supernova neutrino background

With Cherenkov-scintillation liquid scintillator:

1. Have the capability for particle identification to suppress atmospheric neutrino neutral current background

2. Expect a few golden candidate supernova relic neutrinos in 5-10 years with the 500-ton detector



Expect an improvement better than this figure. Work in progress.

Summary

- LiCl aqueous solution
  - Long attenuation length, 50 m at 430 nm
  - Fluor can be added, ex. CS-124 ➔ Cherenkov liquid scintillator
- Compact detector for solar neutrino upturn study
- Sizable geo-neutrino signal strength from Qinghai-Tibet plateau
- Great signal-to-background ratio in DSNB detection

LiCl aqueous solution -- A new neutrino detection medium candidate

Thank you.

All related publications can be found at
http://jinping.hep.tsinghua.edu.cn/Publications.php