

Jinping Neutrino Experiment and development of LiCl aqueous solution for neutrino detection

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(for the research group)

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实验融合发展研讨会

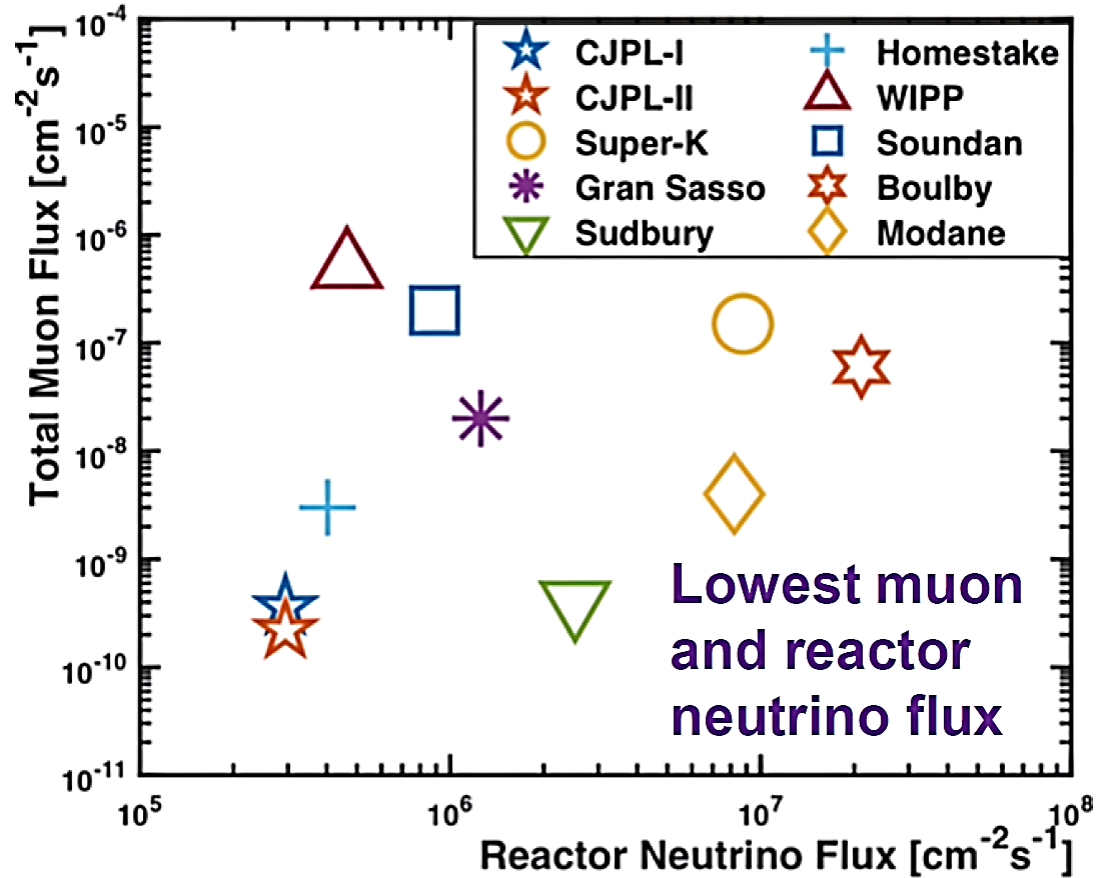
Contents

1. Jinping Neutrino Experiment (JNE) in plan
Target volume, 500 m³, 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) ----

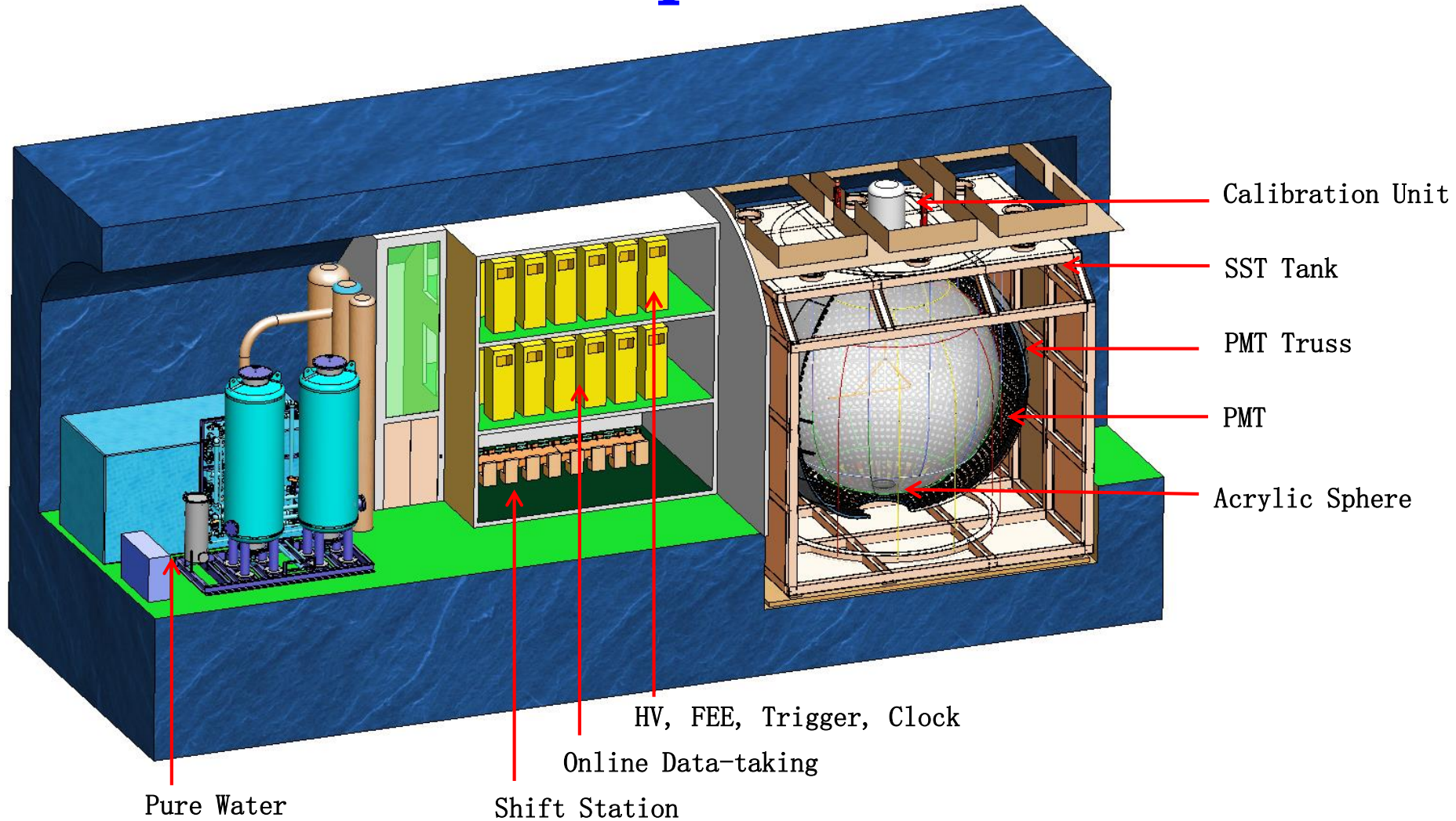
An ideal low background experiment site

2400 m
overburden



1000 km to reactors

A 500 m³ detector is planned at CJPLII



Target volume: 500 cubic meter

Current Status of the D2 hall

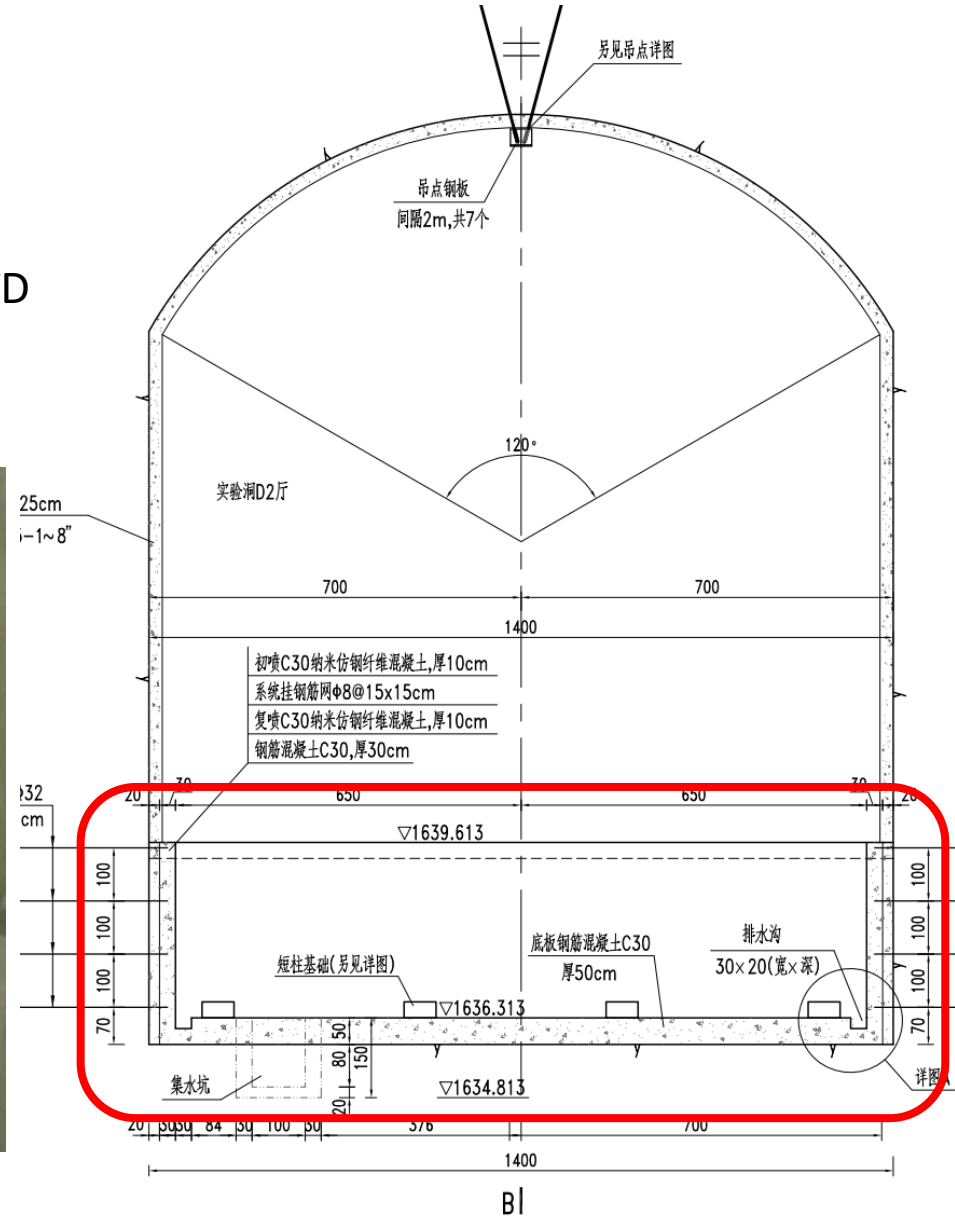


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Pit for Detector

Construction of the pit is finished 2023 summer

1. Designed by Huadong Engineering Corporation Limited
2. Constructed by Sinohydro Bureau 5 Co. LTD
3. Onsite management: Yalong Hydro CJPL Administration Bureau



Detector Design

Stainless steel tank:

14.5 m (L)*12.9 m (W)*13.2 m (H)

SST PMT truss:

12.16 m (Diameter)

Acrylic vessel:

9.96 m (Diameter), 0.05 m (Thickness)

500 cubic meter

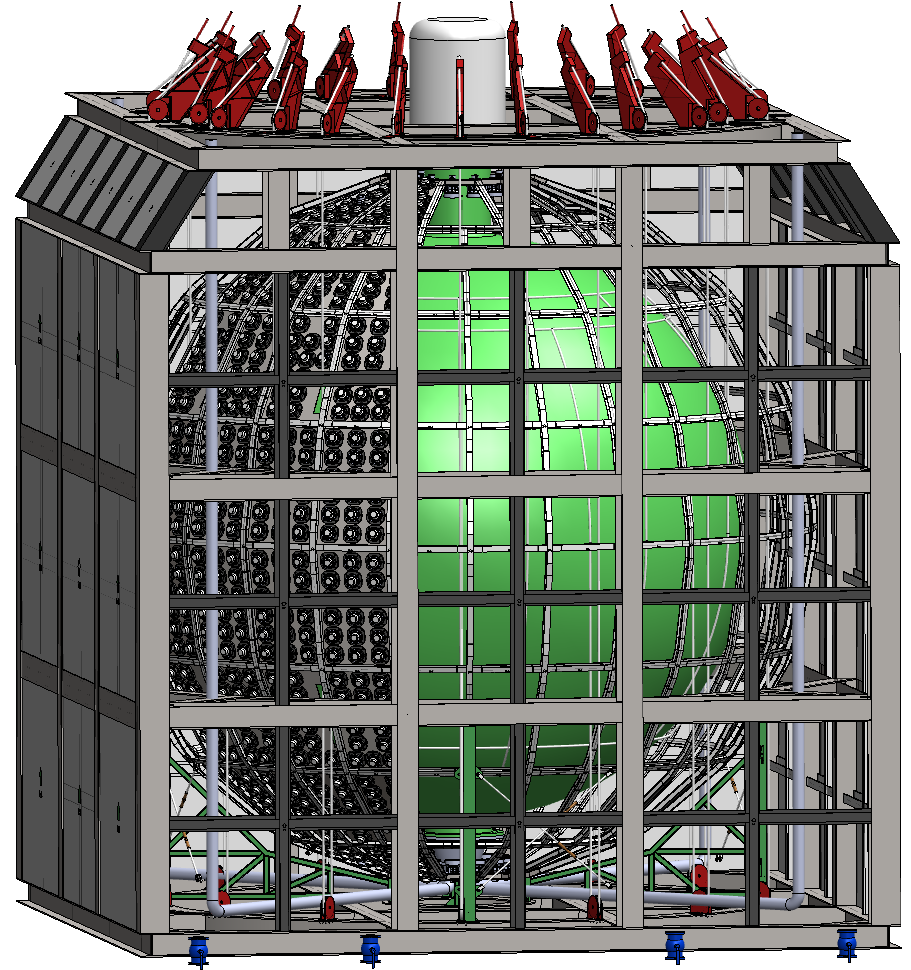
Rope network:

holding-up and holding-down

(Allow a detection material heavier or lighter than water with 20% density difference.)

Shielding material:

Water and SST (or lead)

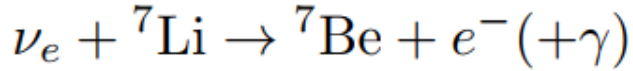


Goal of the Jinping Neutrino Experiment (JNE)

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 :



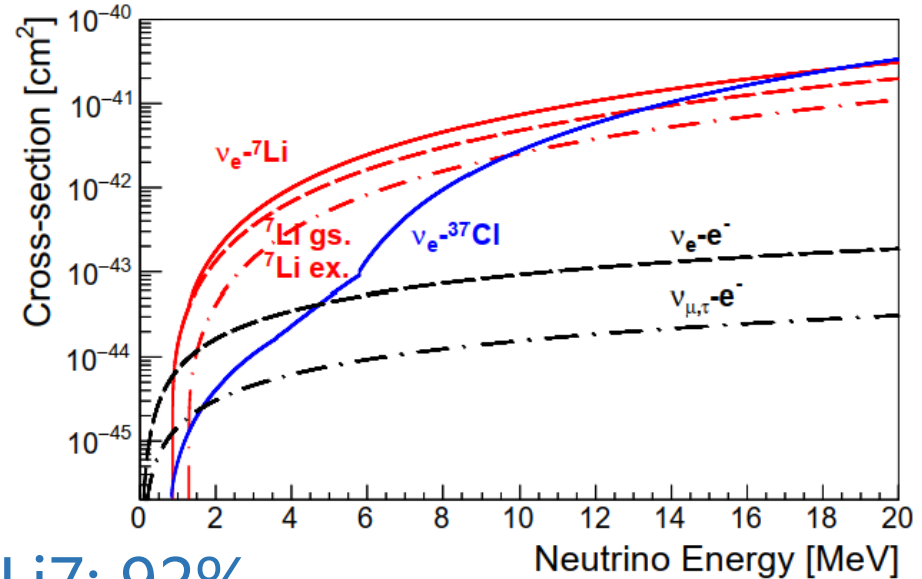
Measure neutrino energy

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

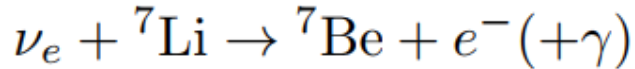


B8 Event rate/100 ton-year solution

	${}^7\text{Li}$	${}^{37}\text{Cl}$	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

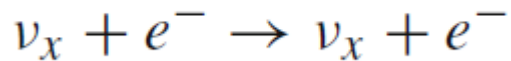
1. CC-Li7 process for ν_e :



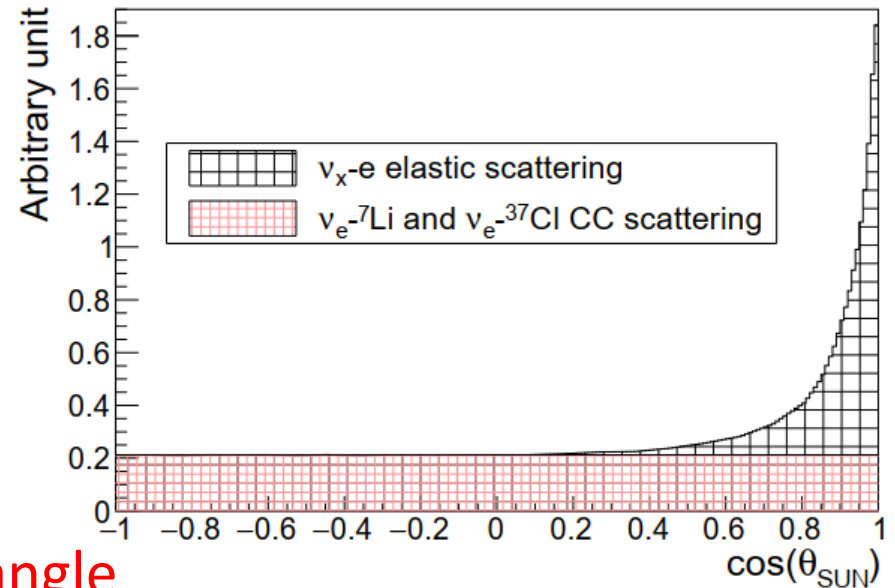
Measure neutrino energy

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

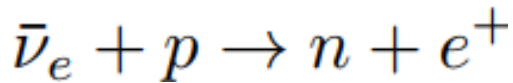
2. Elastic scatter on e^- :



CC-Li7, ES separated by solar angle



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



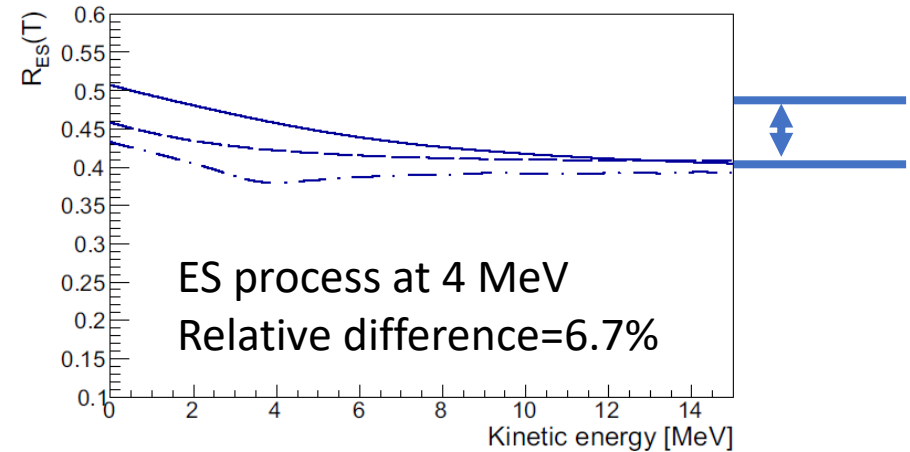
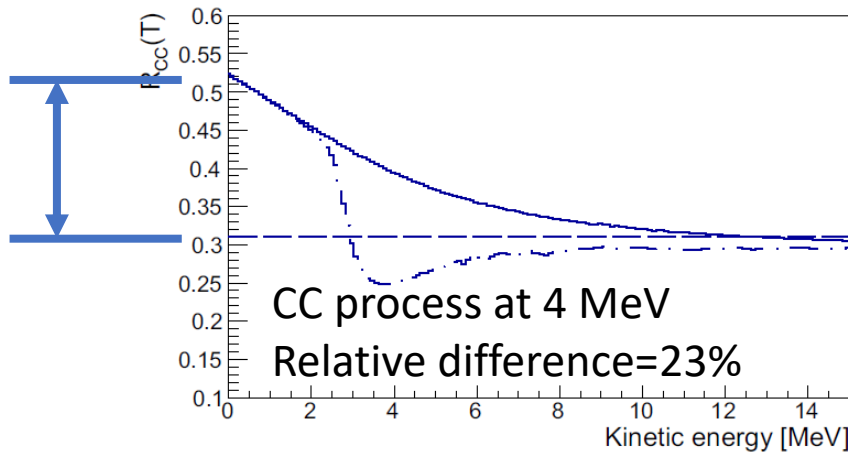
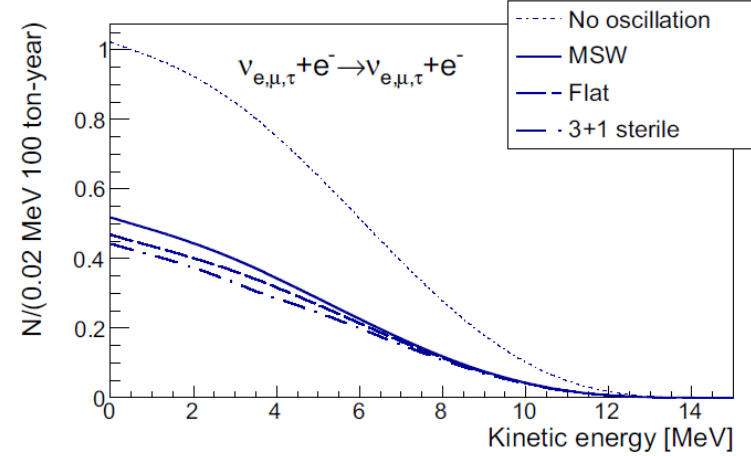
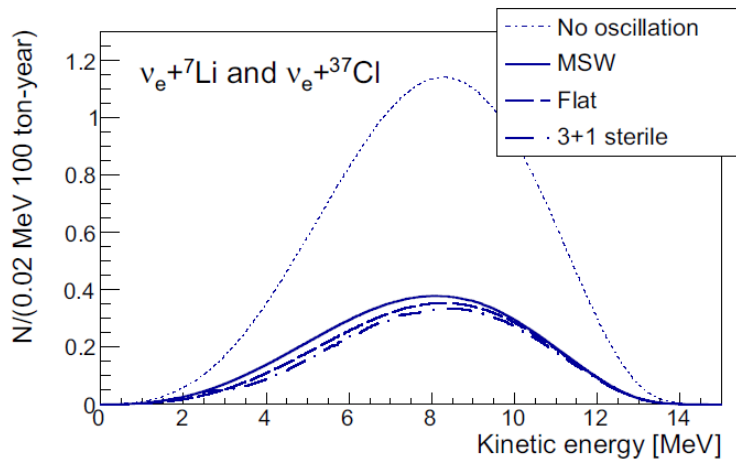
with neutron capture on

H, Li6, and Cl35

measure $\bar{\nu}_e$ energy

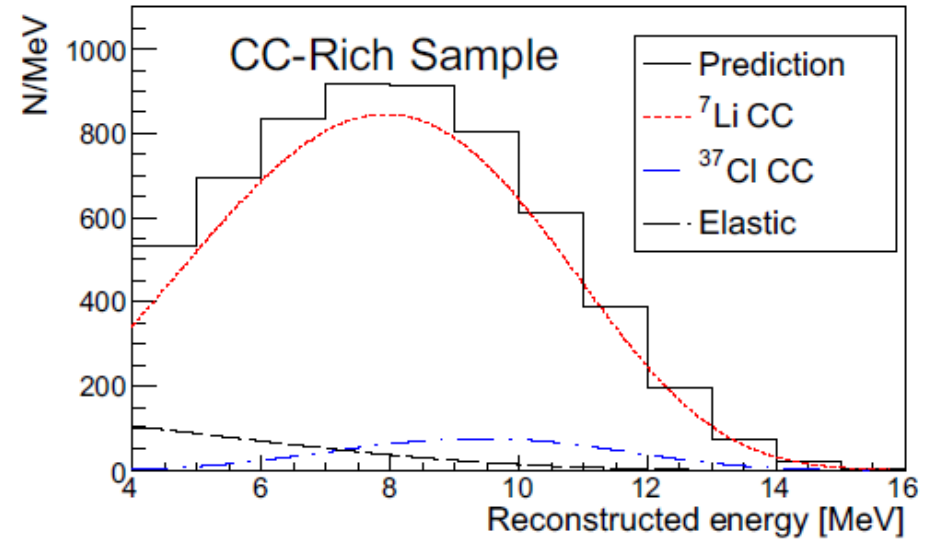
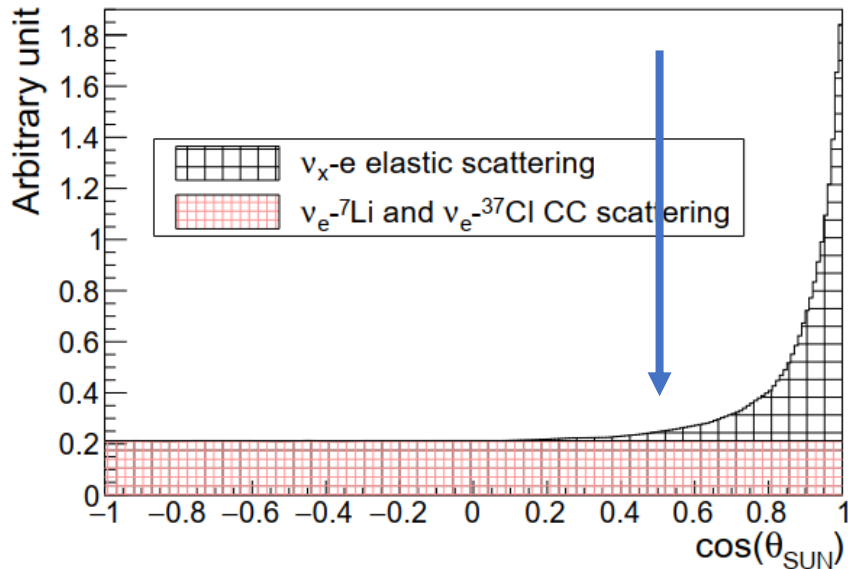
Spectrometer for ν_e and $\bar{\nu}_e$.
Good chance for solar, geo,
and supernova neutrinos.

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

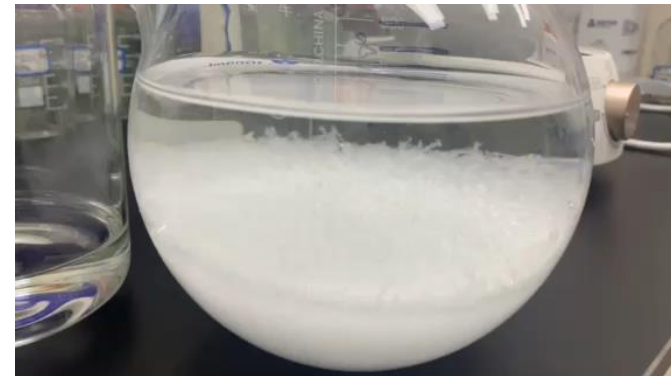
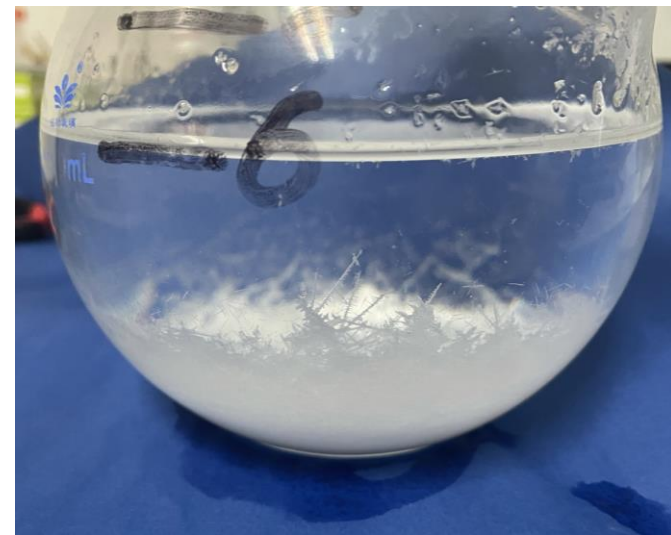


1. With a solar angle cut, CC-Li7 process signals can be clearly extracted.
2. JNE can serve as a solar neutrino spectrometer.

LiCl Water Solution Attenuation Length

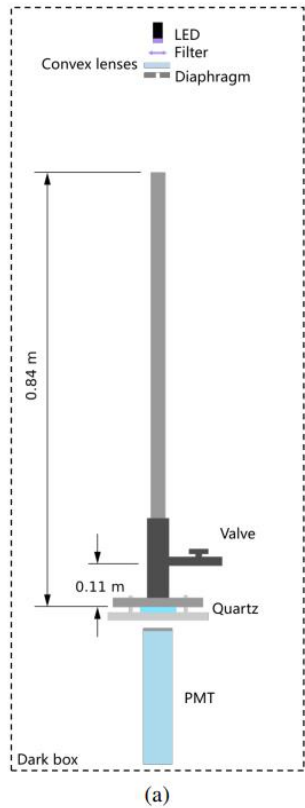
LiCl water solution attenuation length improvement

1. Absorption with powered activated charcoal
2. Thermal recrystallization



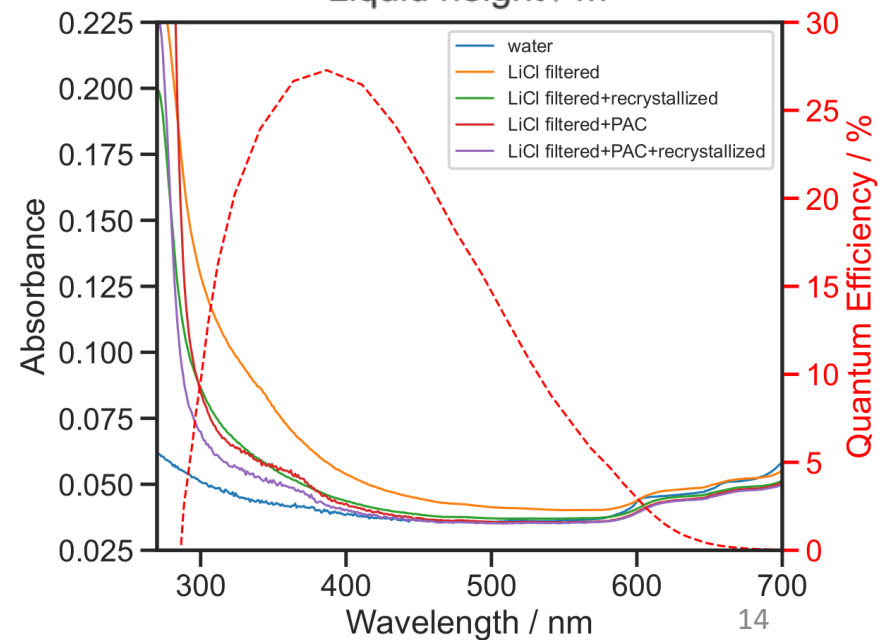
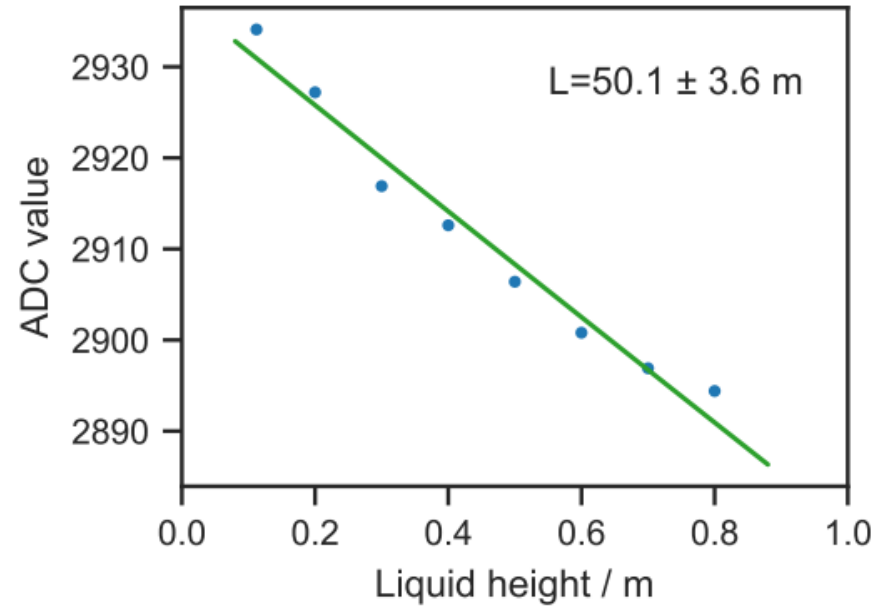
LiCl Water Solution Attenuation Length

50 m attenuation length achieved.



Device at Nanjing University

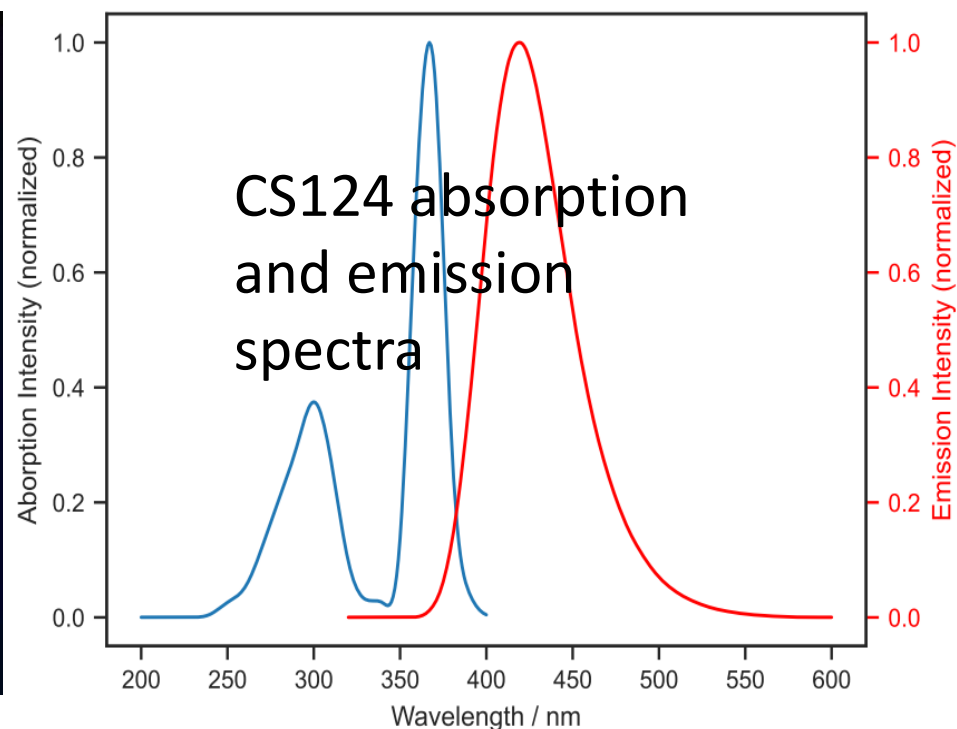
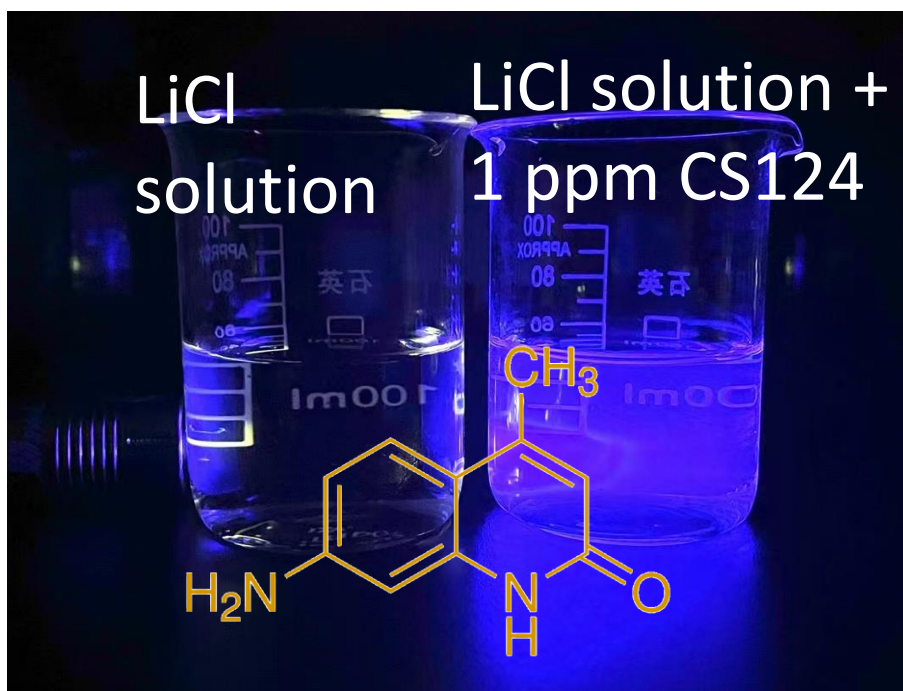
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LiCl aqueous solution with carbostyryl 124

Adding 1 ppm CS124 to LiCl aqueous solution

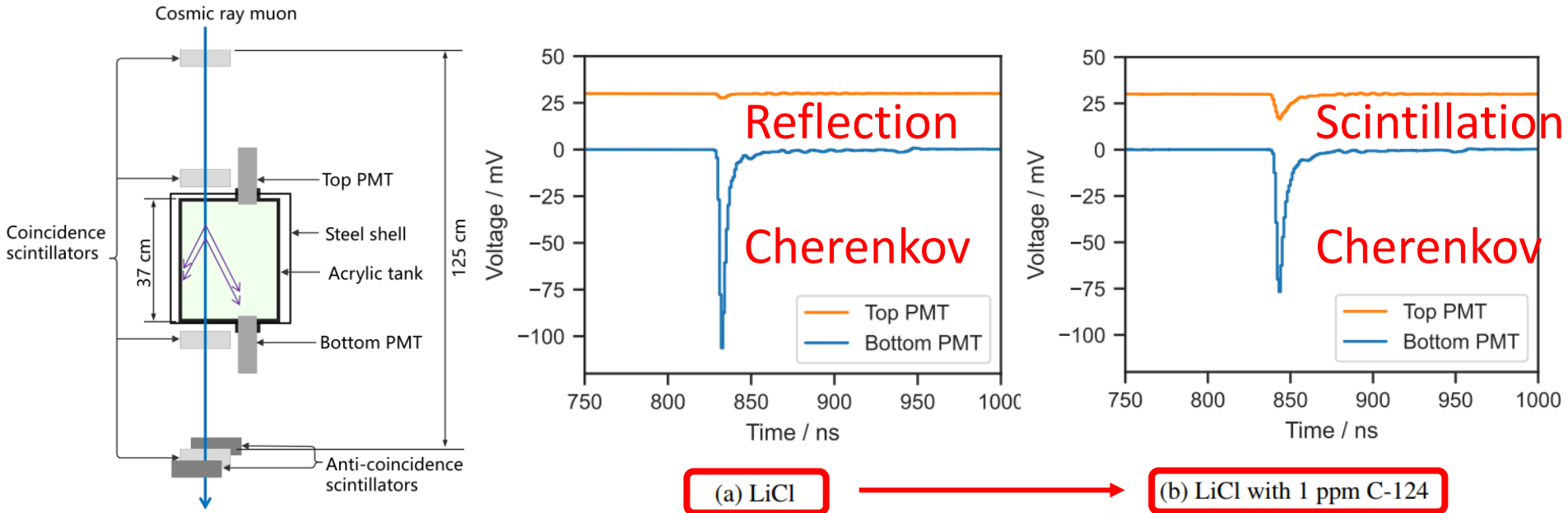
1. Convert short wavelength UV to longer wavelength
Convert short attenuation length UV to long attenuation length
visible light
2. Minor scintillation light yield



(Lithium salt fluorescent water)

Uniform light output from LiCl solution+CS124

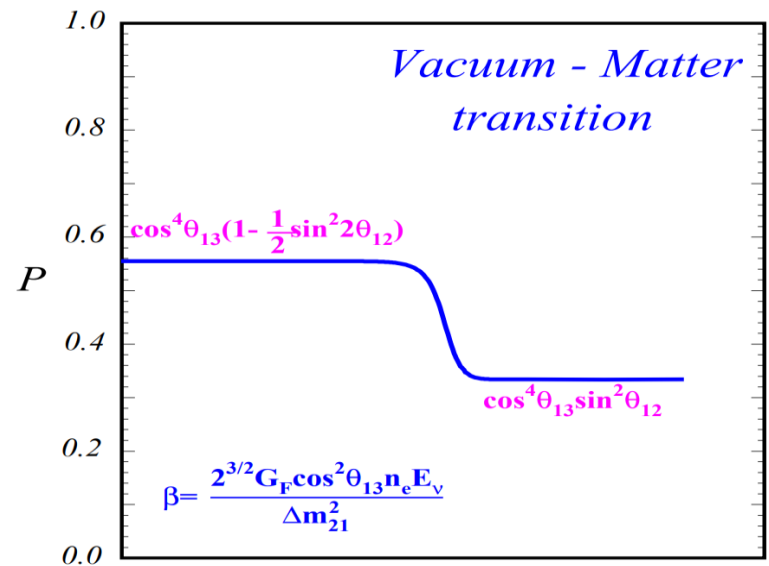
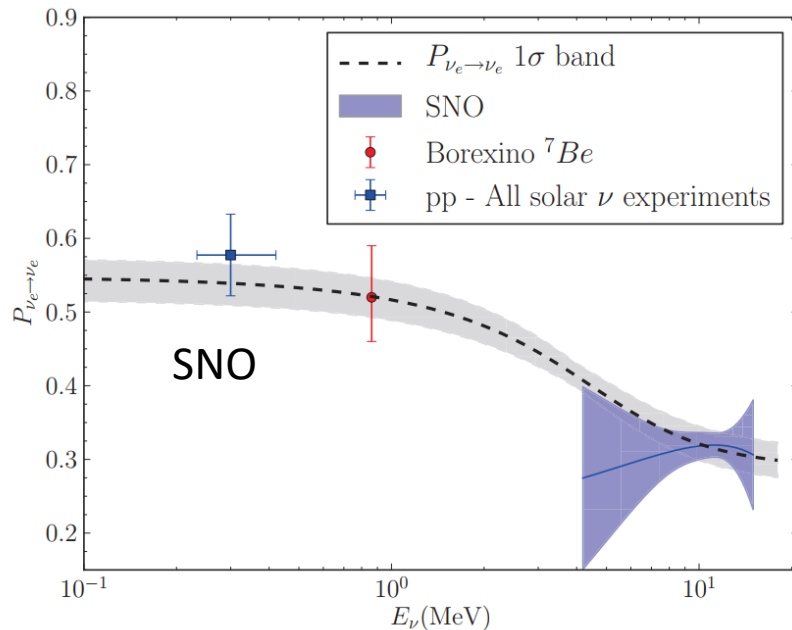
Light yield verification with a muon telescope



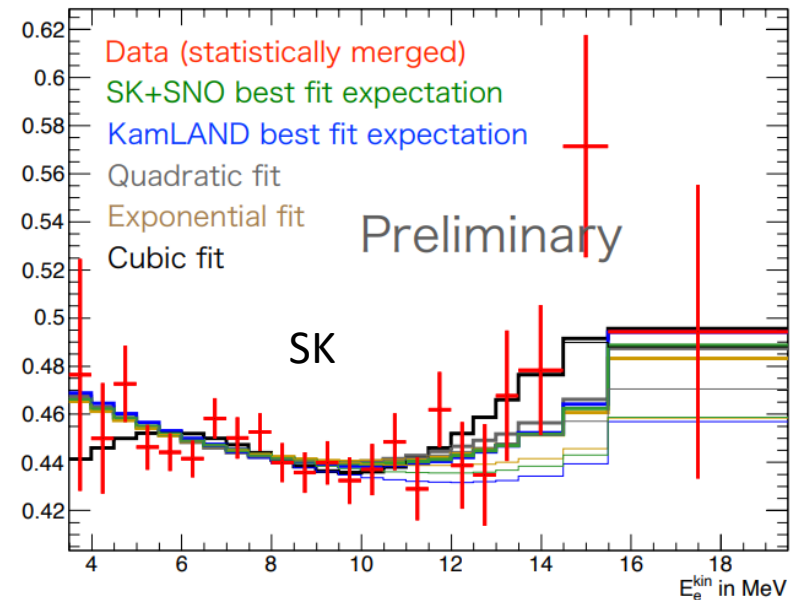
3.7 PE detected from isotropic scintillation (uniform)
12.3 PE for Cherenkov (forward)

Solar Neutrino Upturn effect

Solar neutrino survival probability vs energy



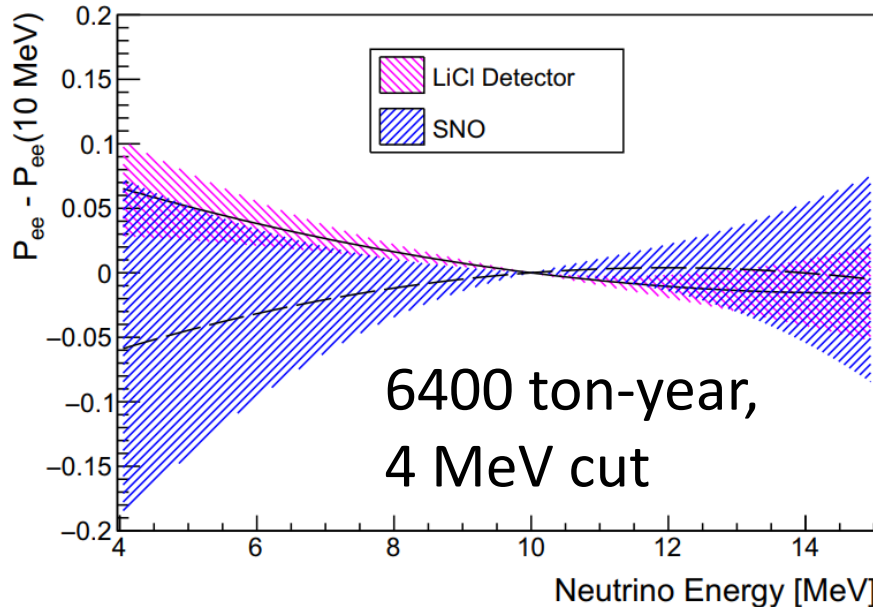
SK-I/II/III/IV Recoil Electron Spectrum



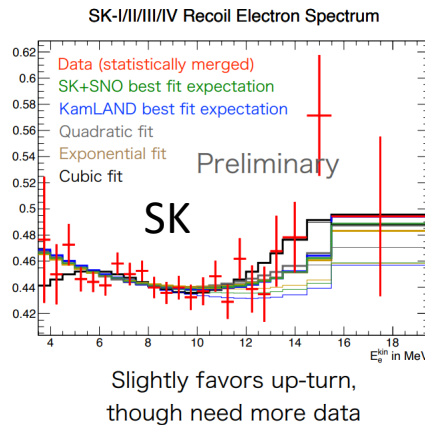
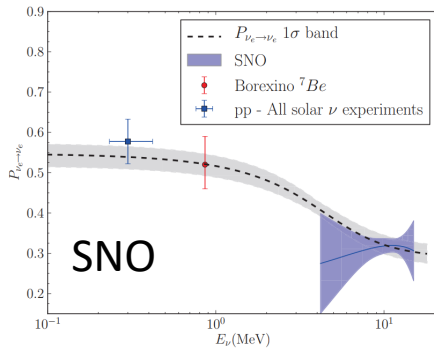
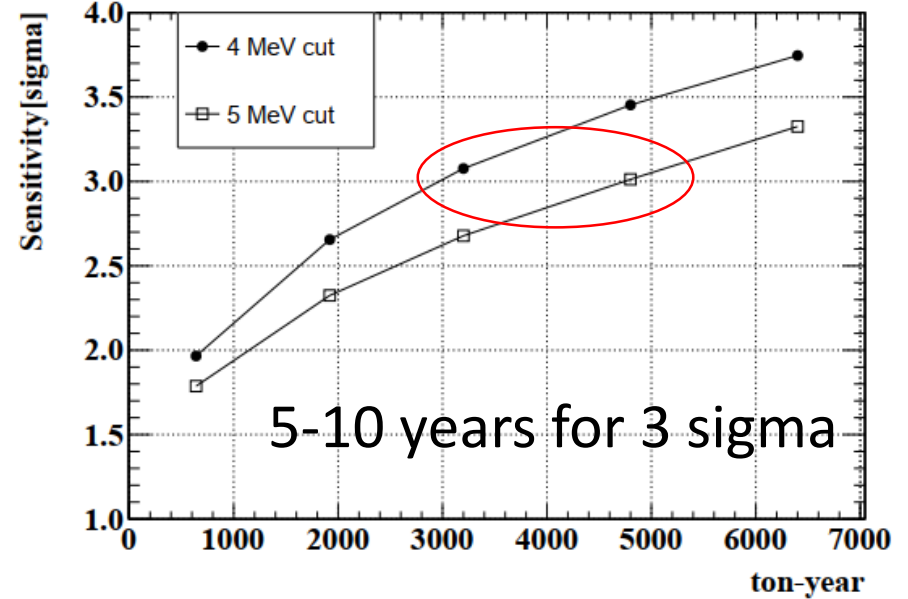
Slightly favors up-turn, though need more data

Upturn effect sensitivity with LiCl Solution

Solar neutrino survival probability-average vs energy

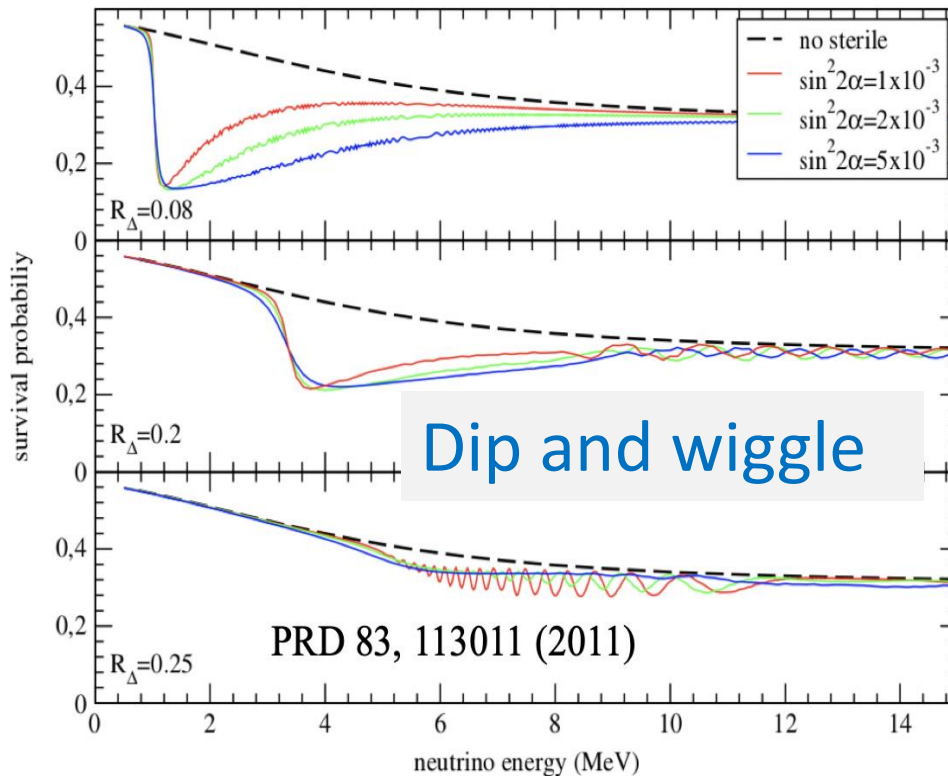


Upturn discovery sensitivity versus exposure



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



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

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

Light sterile neutrino

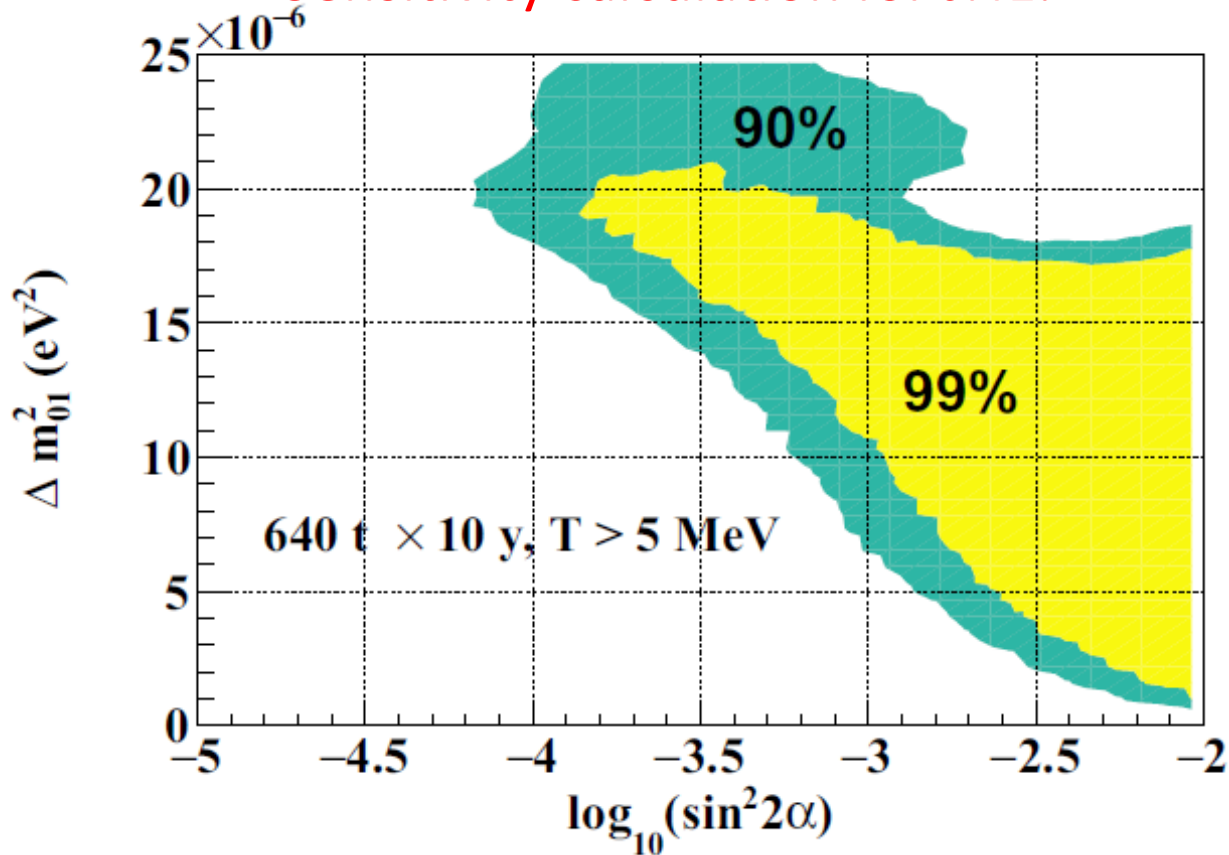
➤ Delta mass squared $\sim 10^{-5} \text{eV}^2$

➤ Not the same as reactor neutrino anomaly and LSND results ($\Delta m^2 \sim 1 \text{eV}^2$)

Structures: need a CC-Li7 detector

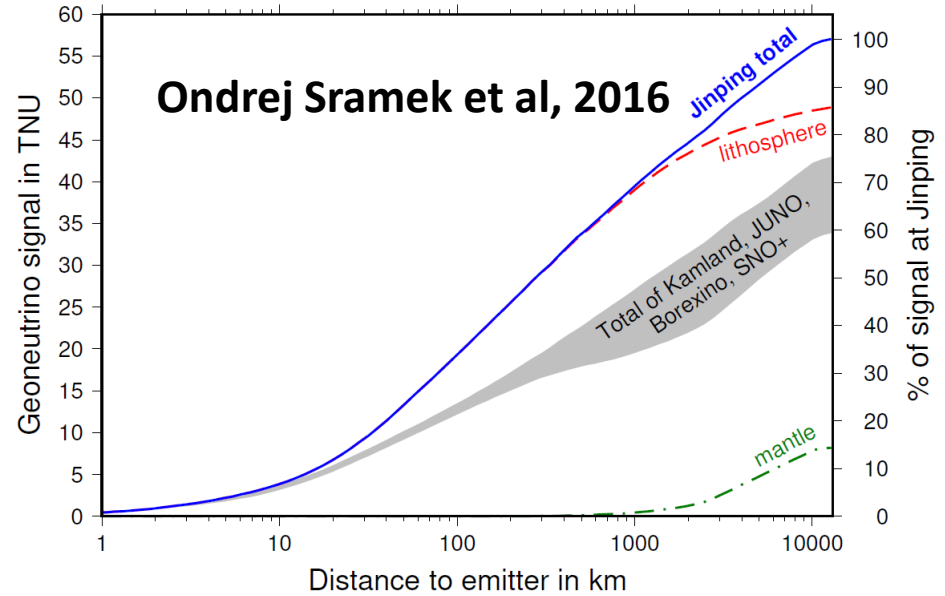
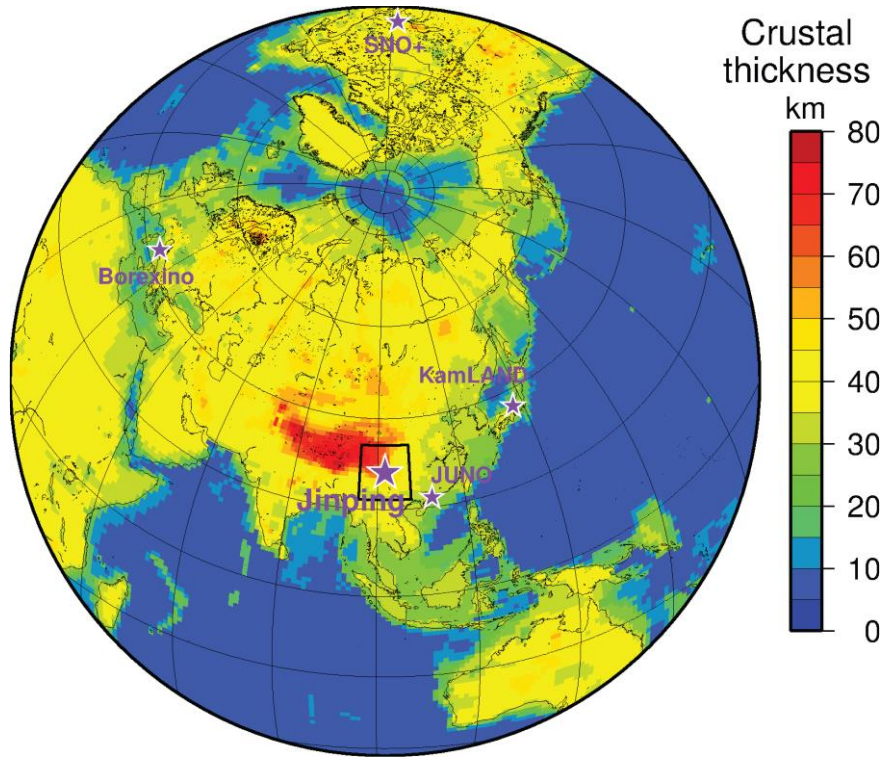
CC-Li7 for Light Sterile Neutrino Rejection

Sensitivity calculation for JNE.

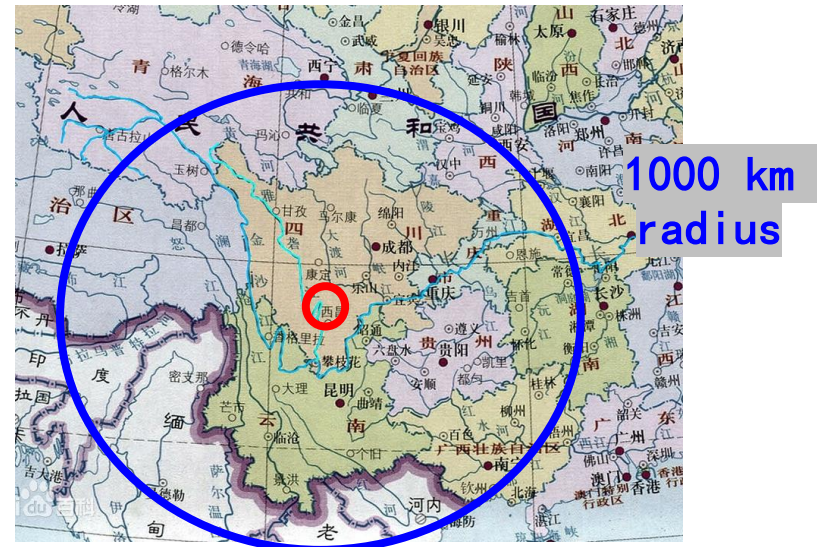


Sensitive to small delta mass squared region of sterile neutrinos, $1\text{e-}5 \text{ eV}^2$

Geo Neutrinos at JNE



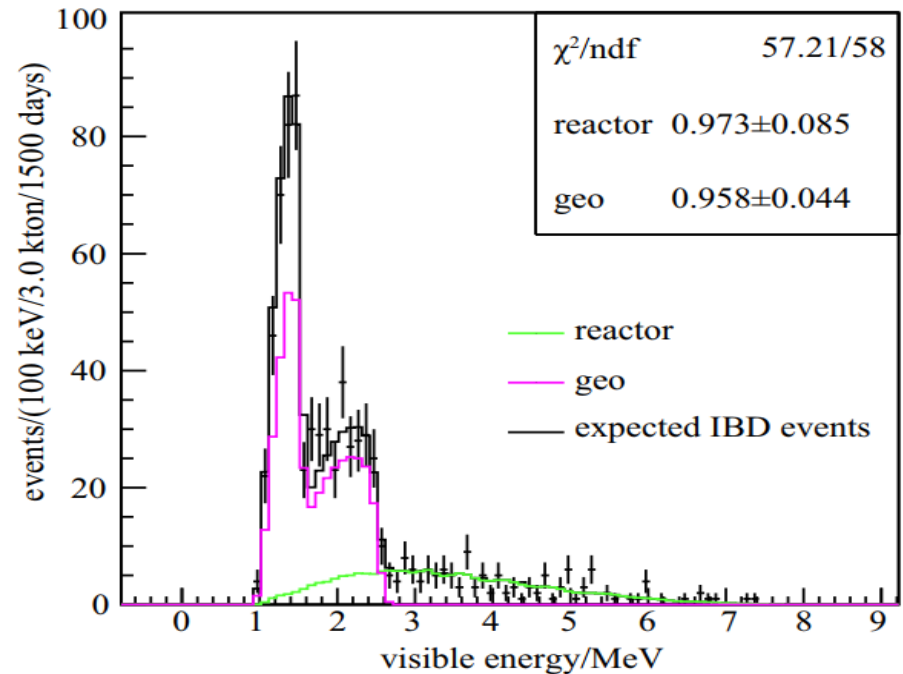
JNE is very sensitive to Qinghai-Tibet plateau crust neutrinos



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

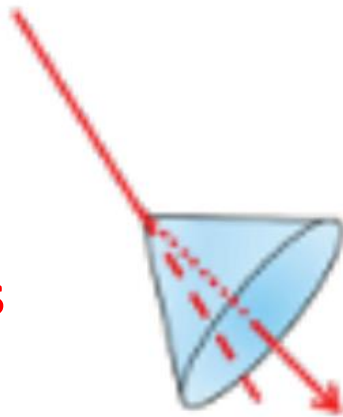


Event rate summary for hundred-ton detector

${}^6\text{Li} / 100\text{m}^3\cdot\text{yr}$	${}^{35}\text{Cl} / 100\text{m}^3\cdot\text{yr}$	${}^1\text{H} / 100\text{m}^3\cdot\text{yr}$
1.823	0.884	0.055

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

Pure
LiCl
aqueous
solution



LiCl
aqueous + fluor
solution



fluor



Direction
Energy
Position
Particle identification



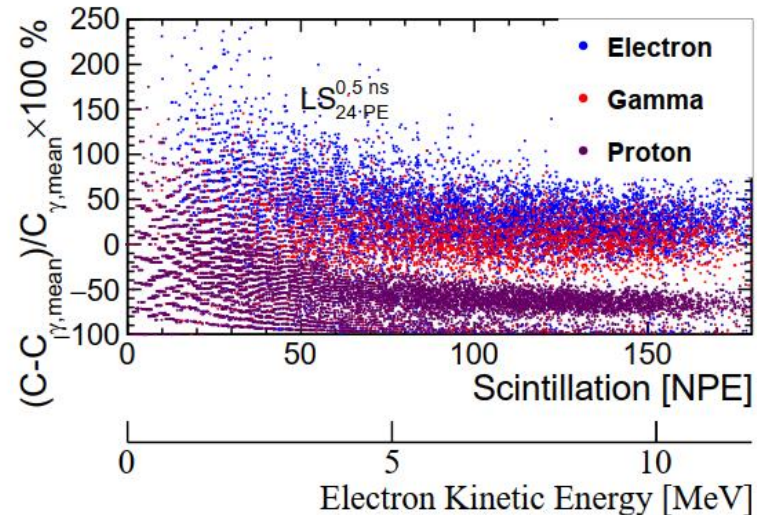
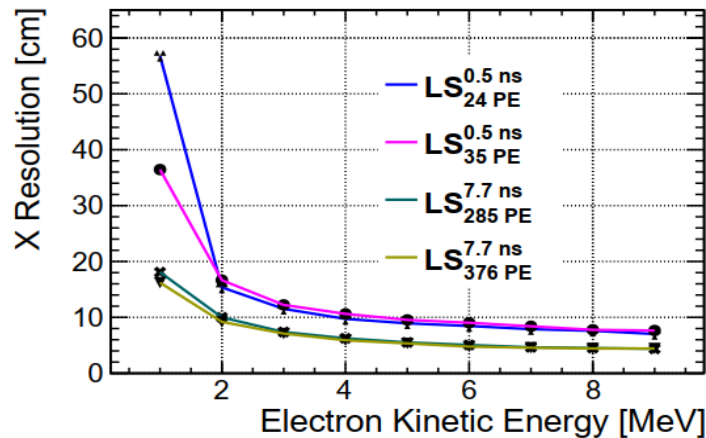
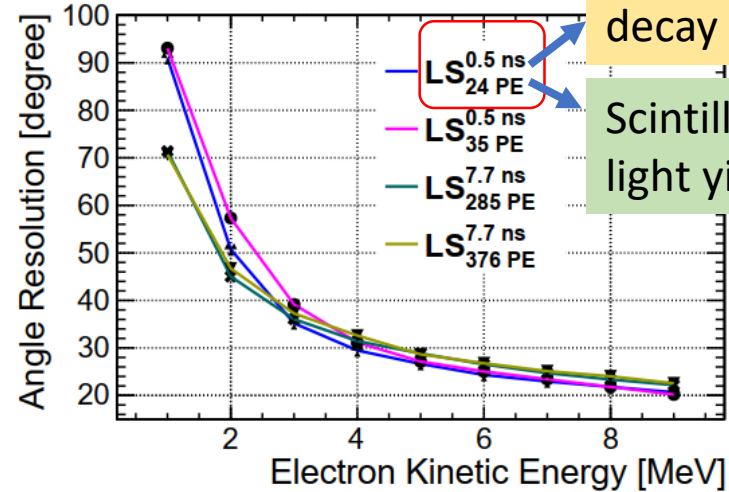
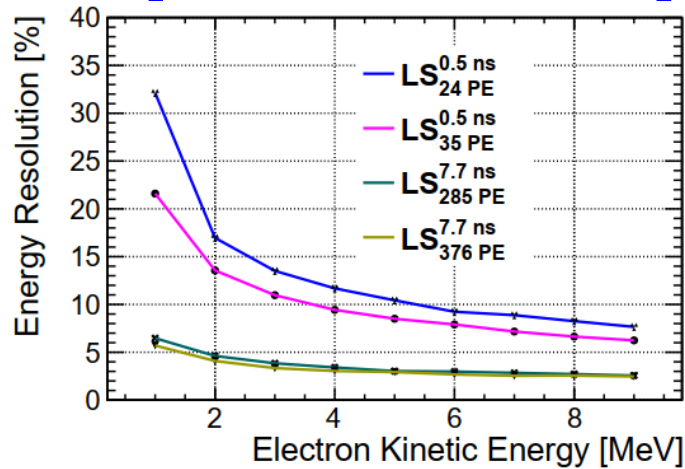
Better than pure water
or liquid scintillator

Cherenkov Liquid Scintillator Reconstruction

Reconstruct both Cherenkov light and scintillation light

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

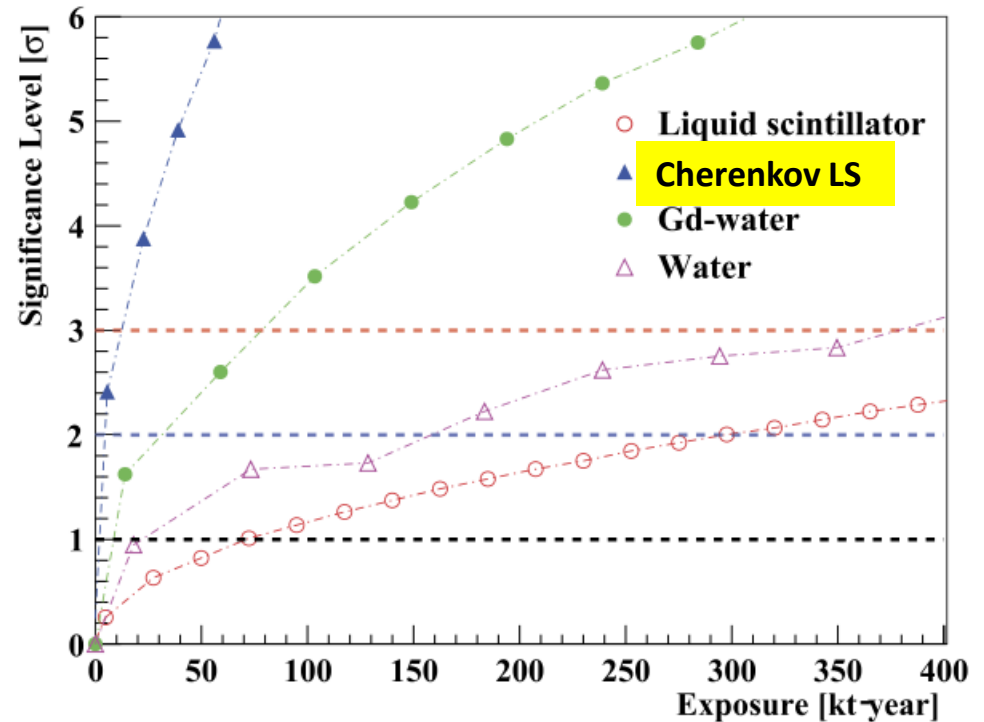
Guide liquid scintillator development



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

(Lithium salt fluorescent water)

-- A new neutrino detection medium candidate

Thank you.

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