Research and Development of Jinping Neutrino Experiment

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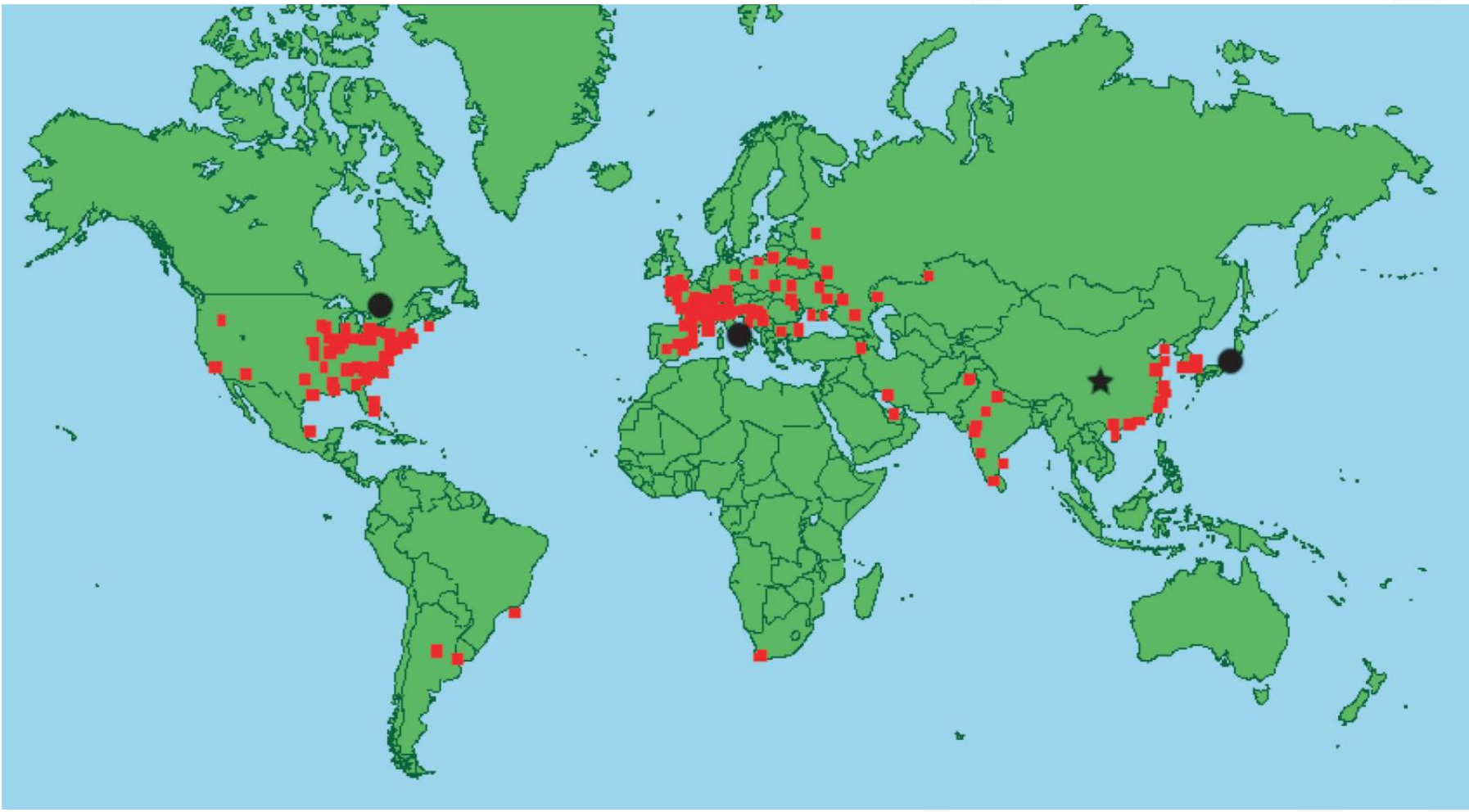
Contents

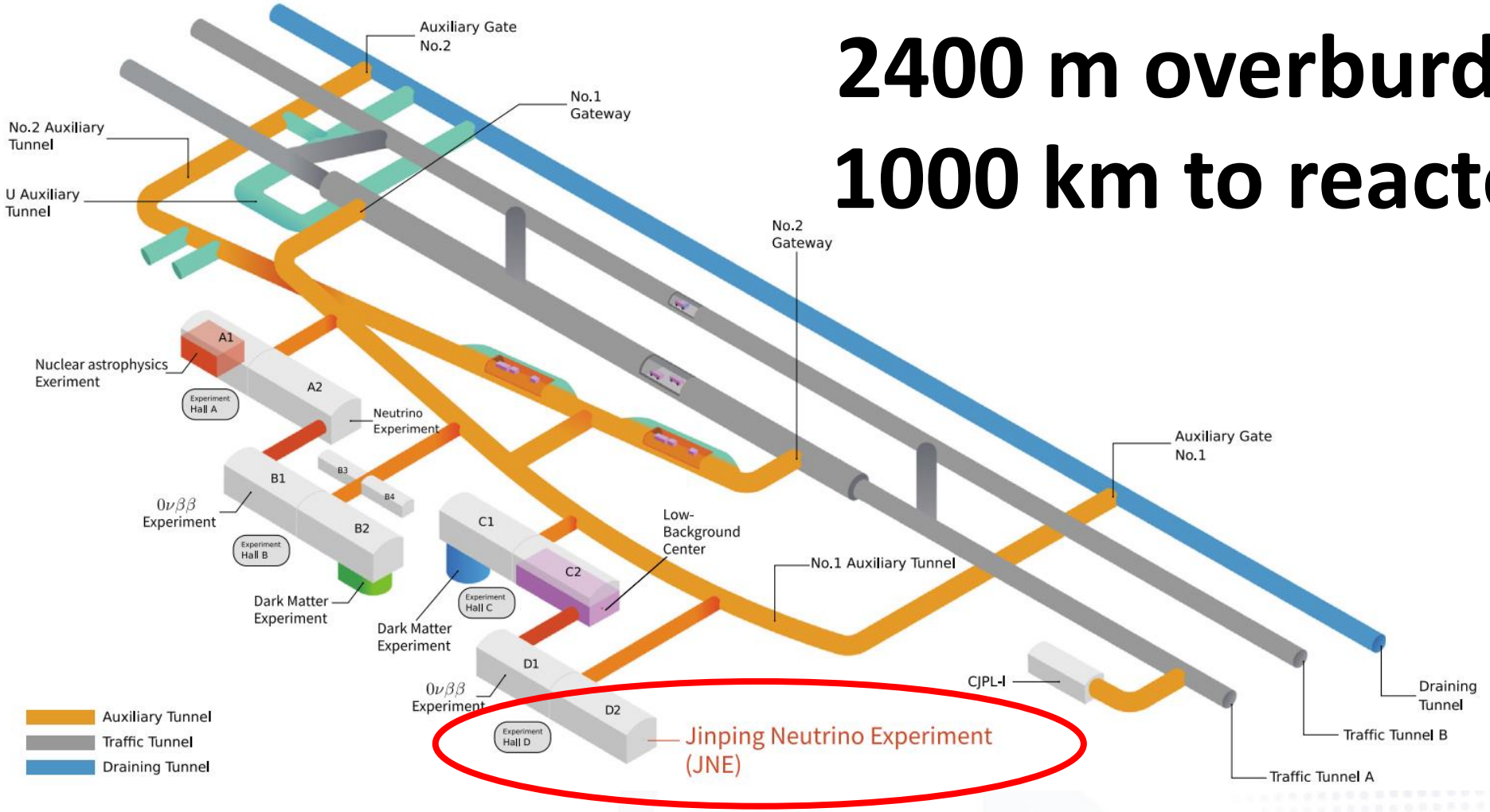
1. Near term goal of the project

Experimental site at CJPL

Solar neutrino observatory at China Jinping underground laboratory



D2 hall of CJPL phase II



2400 m overburden

1000 km to reactors

D2 hall of CJPL-II

Concept of the detector

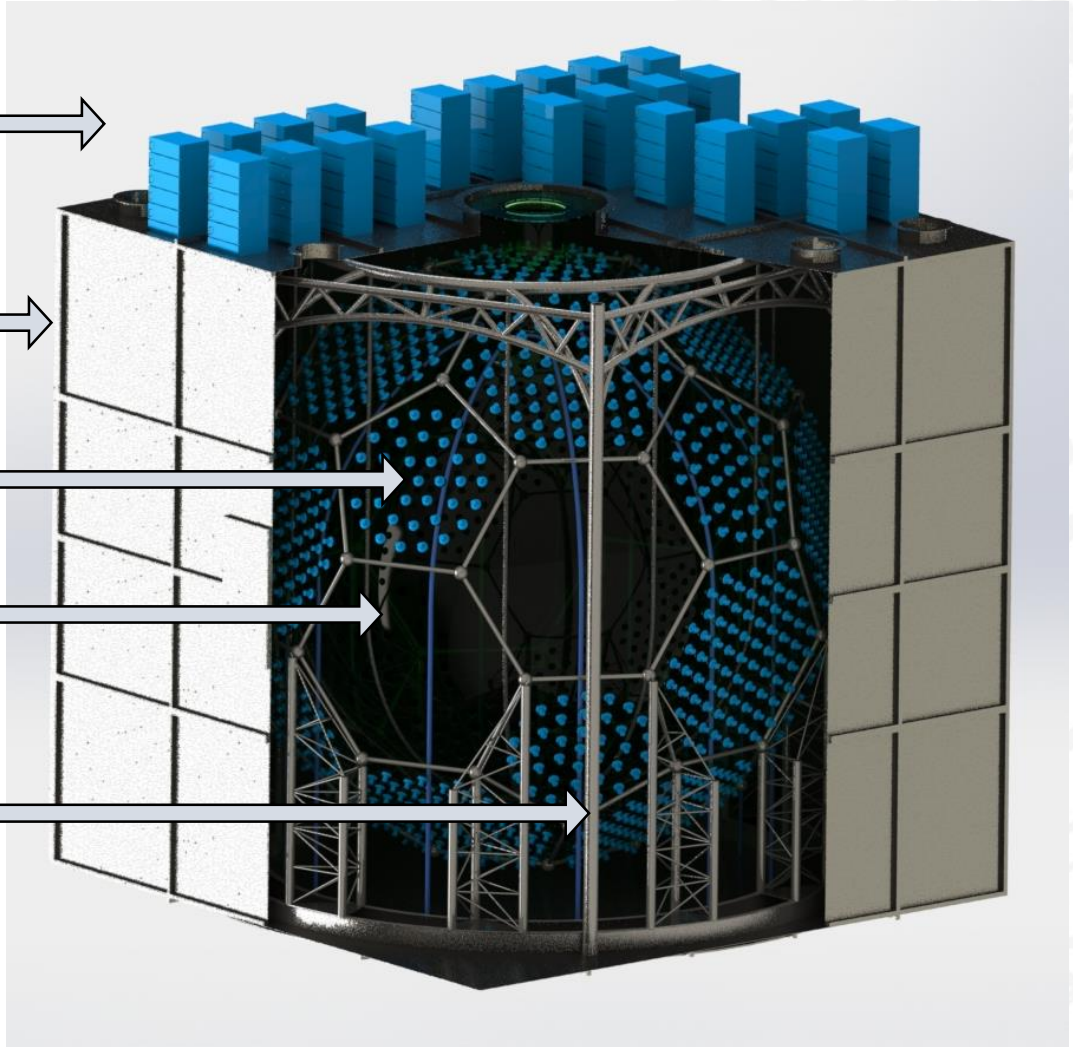
Data acquisition and other system

Stainless steel tank

PMT array

Acrylic sphere （hold detection media）

SST structure
SST sphere for PMT

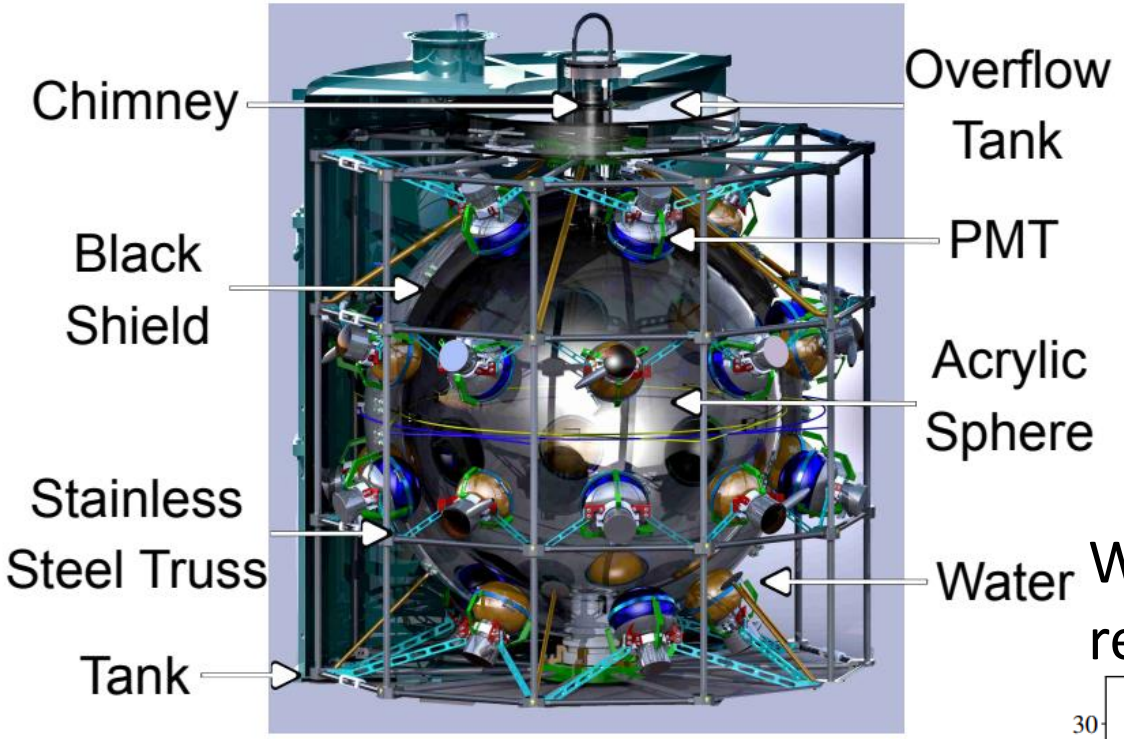


Short term goal

1. **Hundred-ton solar neutrino observatory**
   a. Detector construction
   b. Replaceable detection media, allowed density range ± 20% wrt water, oil- or water- based liquid scintillator
2. **Low background PMT, U, Th<1 Bq/kg, K<2.4 Bq/kg**
3. **ADC chips and waveform readout electronics**
   a. AD chips, 12 bit, 1 GSPS, 350mW
   b. waveform readout, 400 MHz, 40Gbps
4. **Solar B-8 neutrino detection with water**

2. Detector and technology development

One-ton prototype

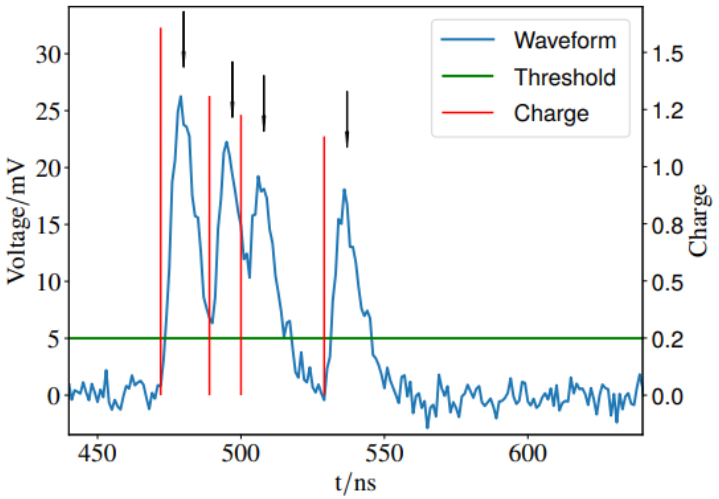


Background measurement

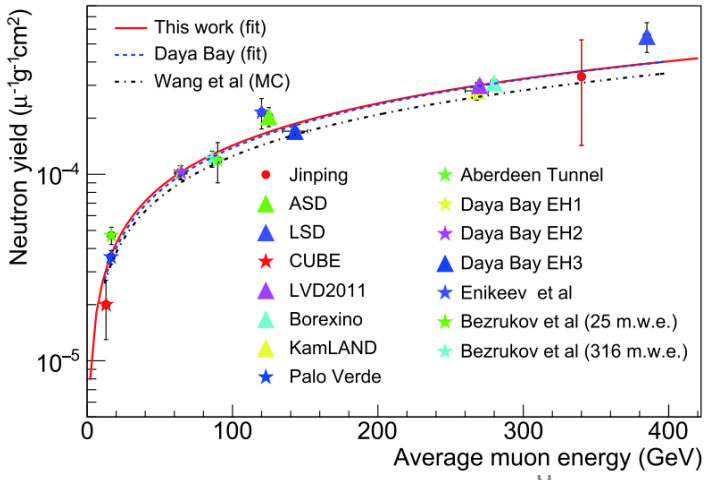
		PMT	LS
Decay rate [Bq/g]	^{214}Bi	-	$(1.59 \pm 0.20) \times 10^{-8}$
	^{208}Tl	$(1.64 \pm 0.47) \times 10^{-3}$	-
	^{212}Bi	-	$<(1.01 \pm 0.20) \times 10^{-9}$
	^{40}K	$(1.24 \pm 0.35) \times 10^{-2}$	-
Contamination level [g/g]	^{238}U	-	$(1.28 \pm 0.16) \times 10^{-12}$
	^{232}Th	$(1.12 \pm 0.32) \times 10^{-6}$	$<(2.49 \pm 0.50) \times 10^{-13}$
	^{40}K	$(4.67 \pm 1.35) \times 10^{-8}$	-

1-ton prototype at CJPL-I
Running for ~5 years

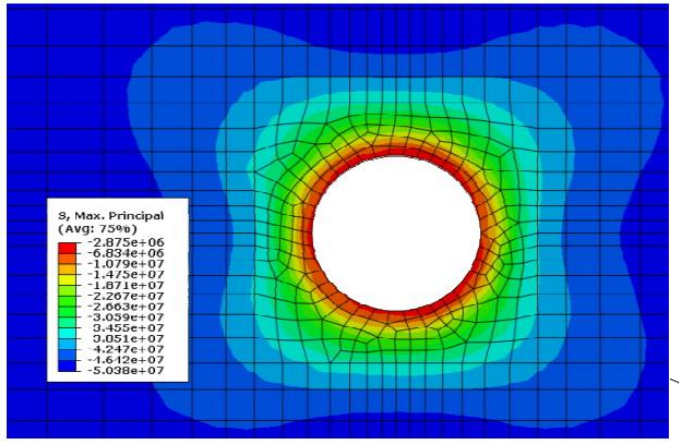
Waveform analysis, total reflection reconstruction



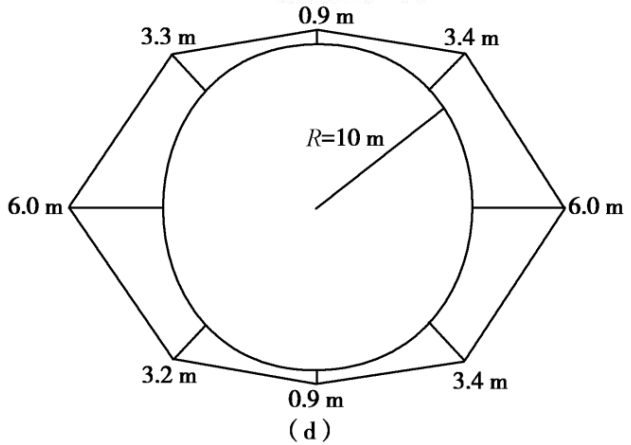
Muon flux and muon-induced neutron yield



500 hundred ton detector foundation pit

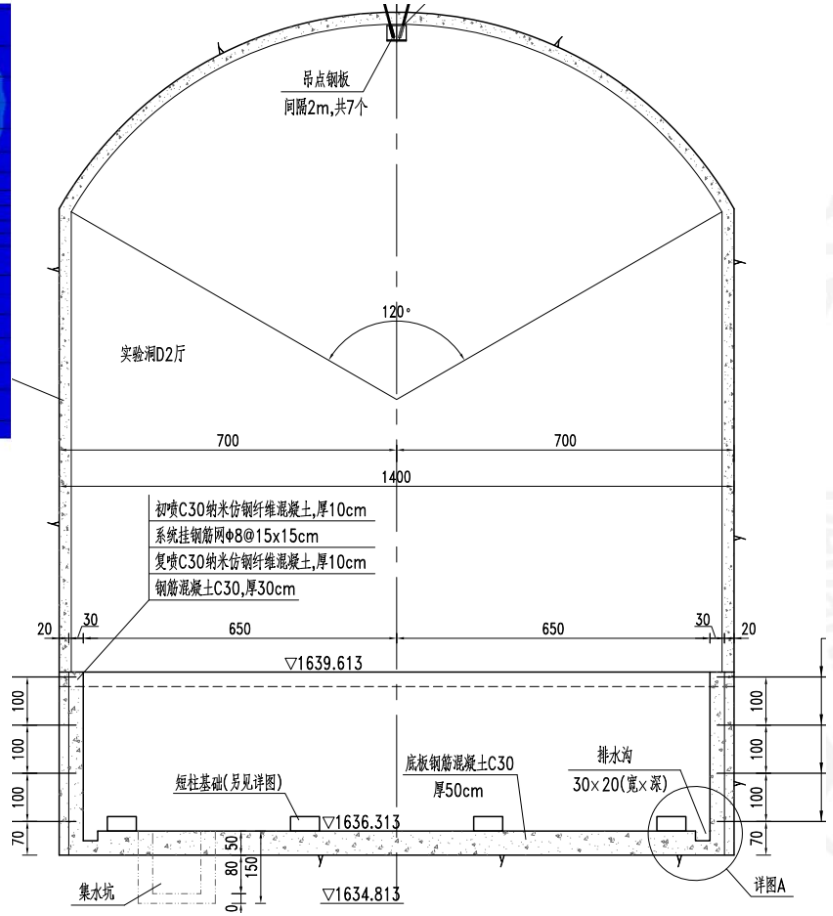


（a）最大主应力



（d）

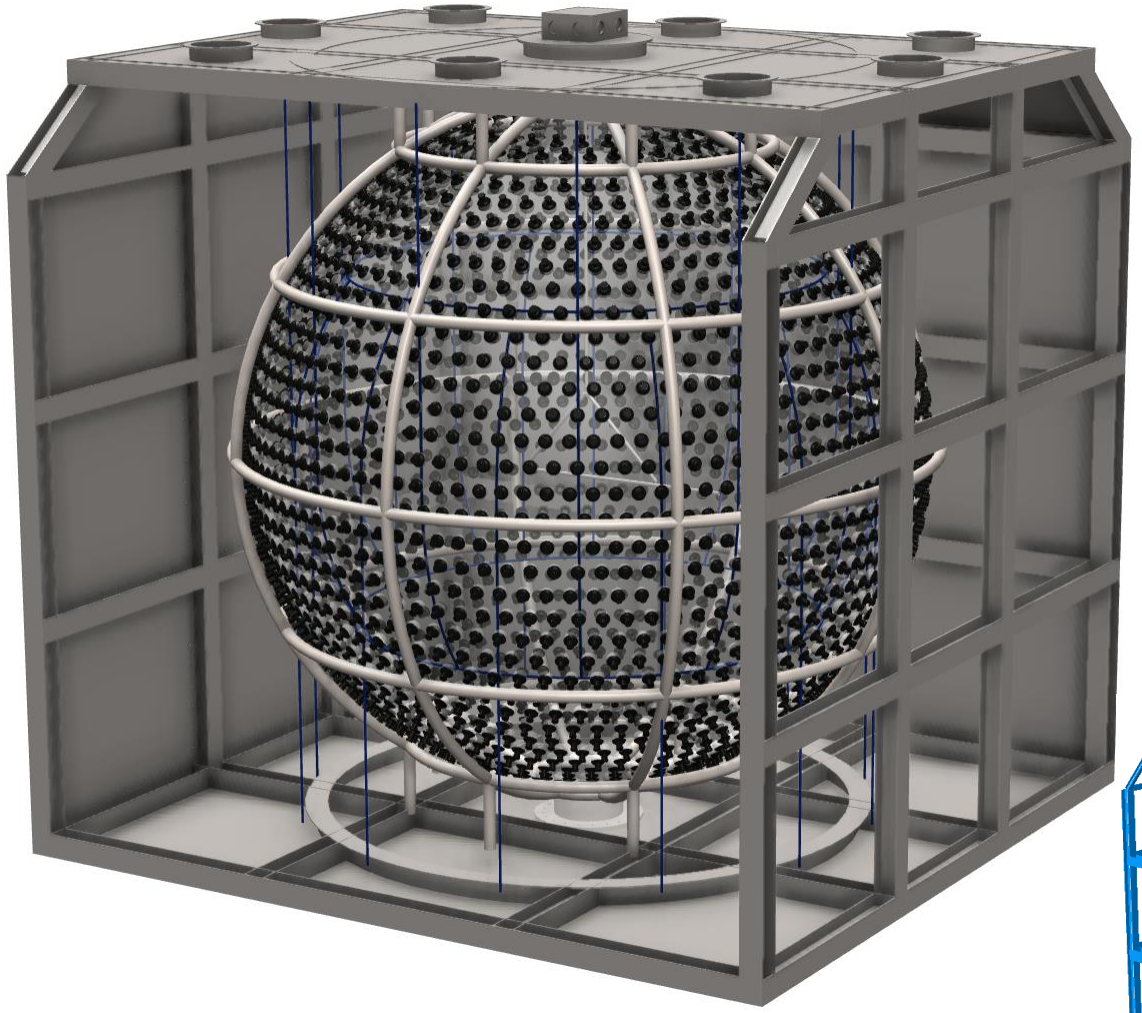
Damage zone study



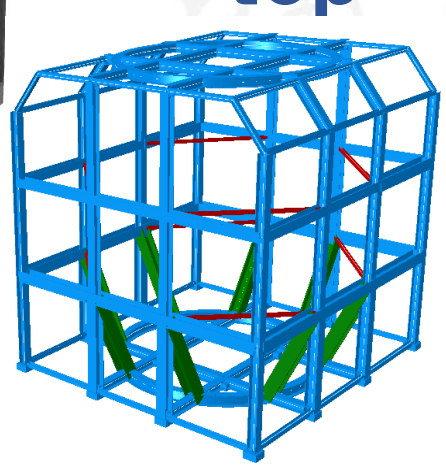
Detector foundation pit design

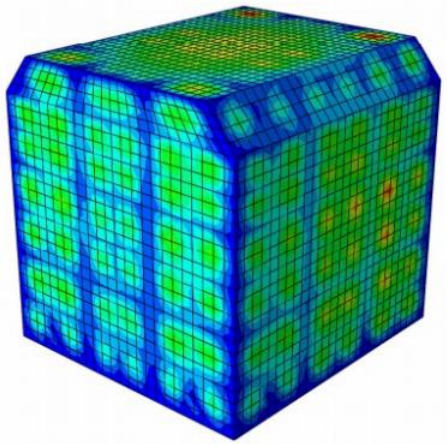
Last month: First stage finished,
15.3*13m*3m
Will be water- and radon- proofed

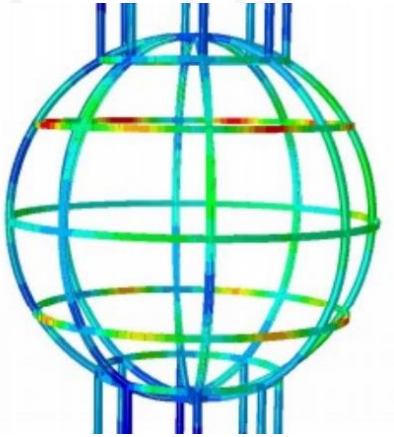
Detector tank and main structure



1. Contain veto water
2. Hold PMTs’ SST sphere
3. Hold central acrylic vessel
    a. gravity, and
    b. buoyancy
4. Support instruments on top

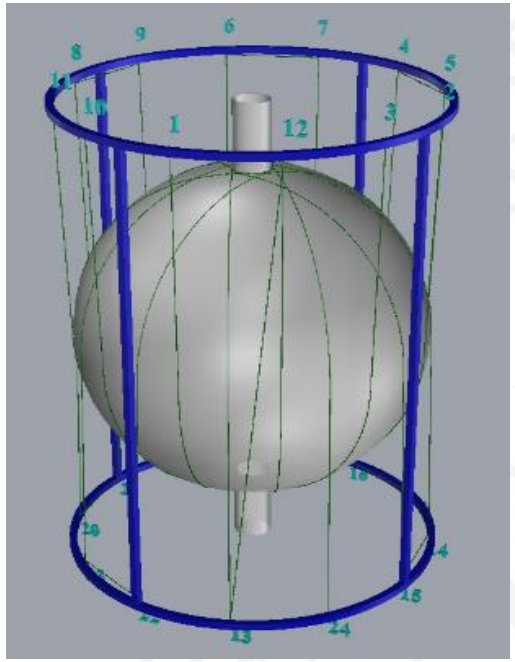


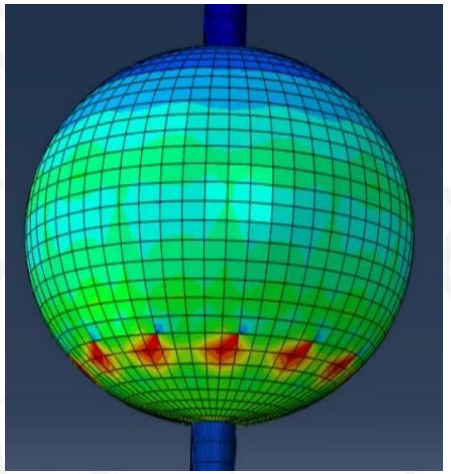


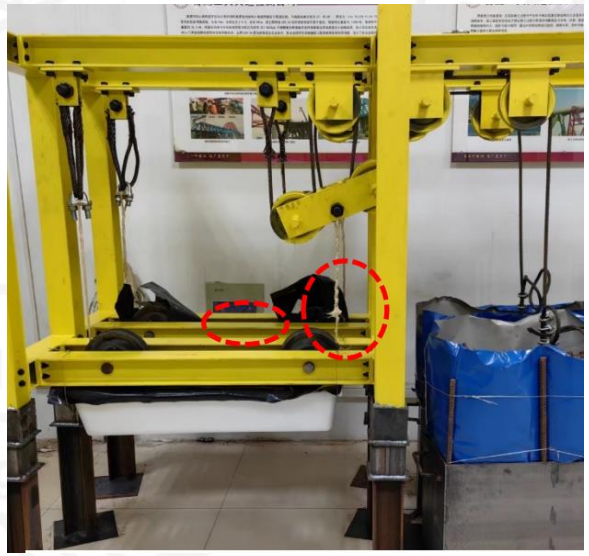


Rope to hold the central acrylic vessel

1. **Acrylic vessel and rope**
   a. 500 cubic meter
   b. Rope for low background
2. **Rope net**
   a. Gravity
   b. Buoyancy
3. **Rope tension test**
4. **Creeping test**
   a. in water
   b. in white oil





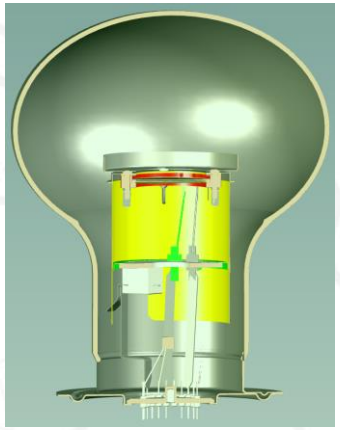


Replaceable detection media, allowed density range ± 20% wrt water, oil- or water- based liquid scintillator

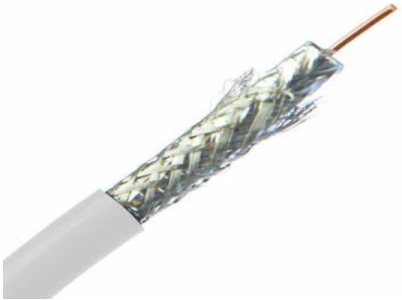
Joint PMT study with NNVT, IHEP

8-inch, MCP-based PMT,
Low U、Th、K background,
Fast, 30% DE

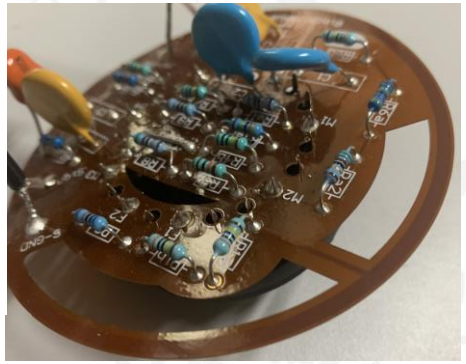
Raw material and production environment



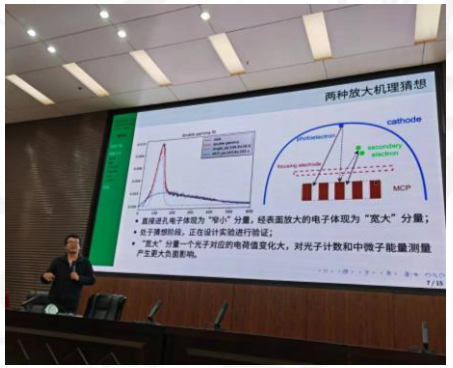
Structure improvement and part selection



Cable



HV divider

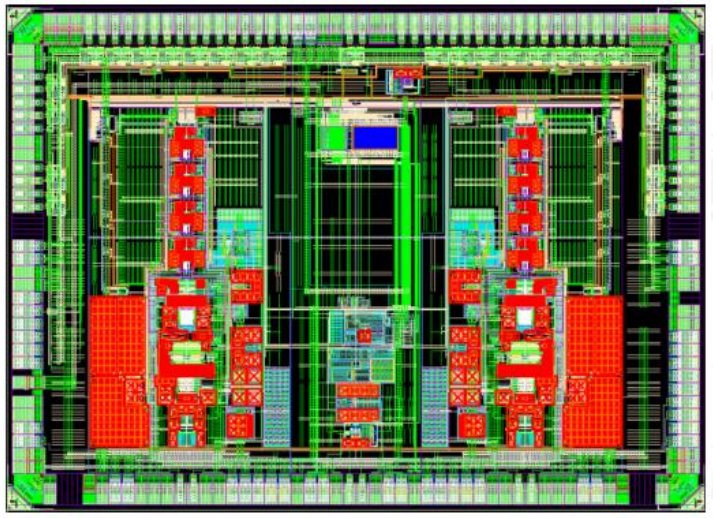


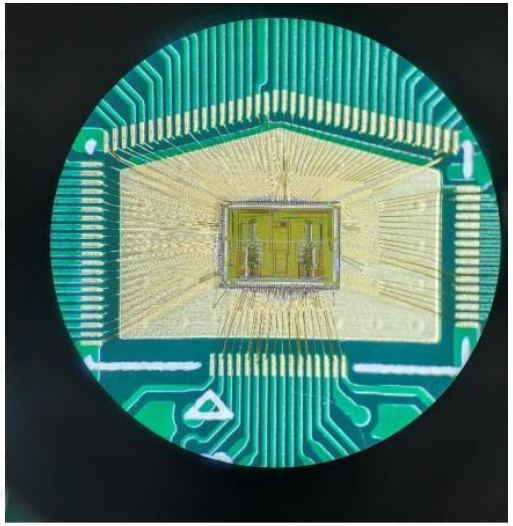
MCP magnifying

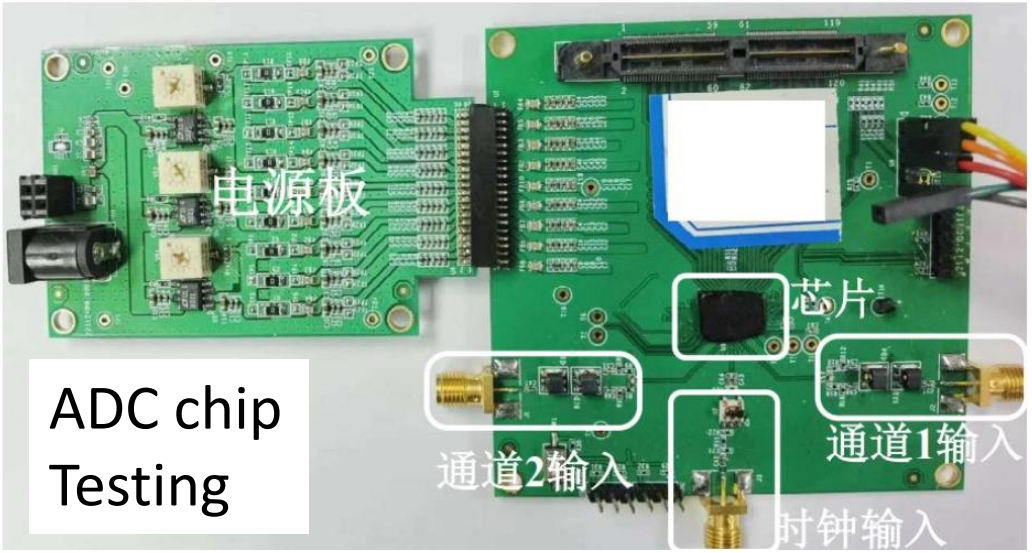
FADC and readout design and testing

Goal:

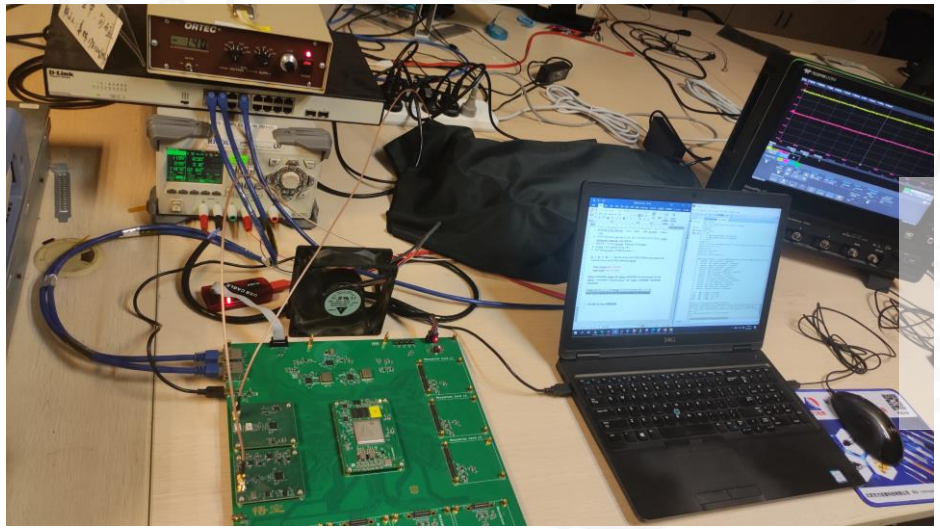
a. AD chips, 12 bit, 1 GSPS, 350mW
b. waveform readout, 400 MHz, 40Gbps







ADC chip Testing



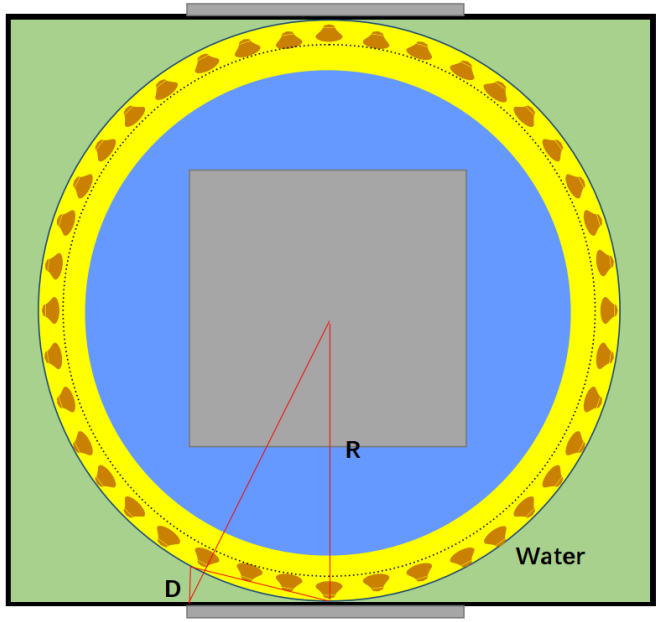
Readout board testing

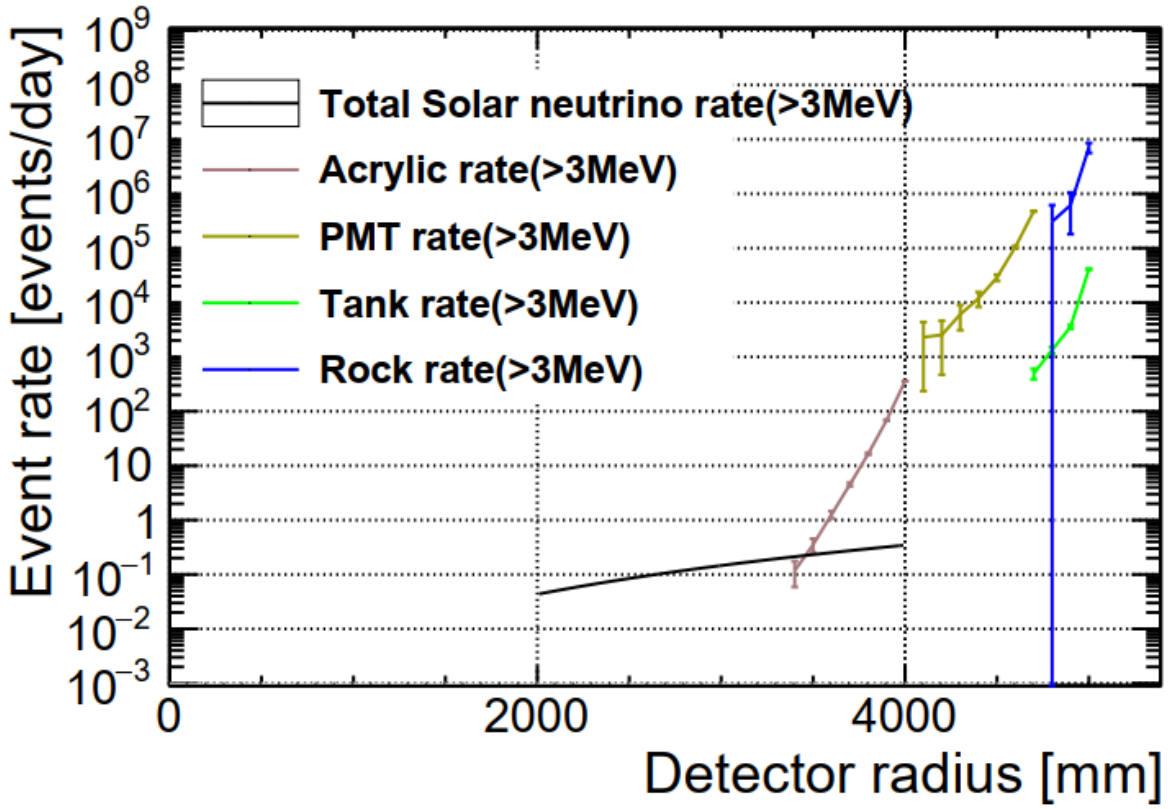
Solar B8 neutrino and background simulation

In the central zone of the detector, B8 neutrinos have a good signal-to-background ratio

a. Gamma, beta, neutron background simulation for PMT, steel structure, rock, water

b. Solar neutrino simulation





3. Liquid scintillator development

The option with Lithium-7 and LiCl aqueous solution

1. CC process for ν_e:

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

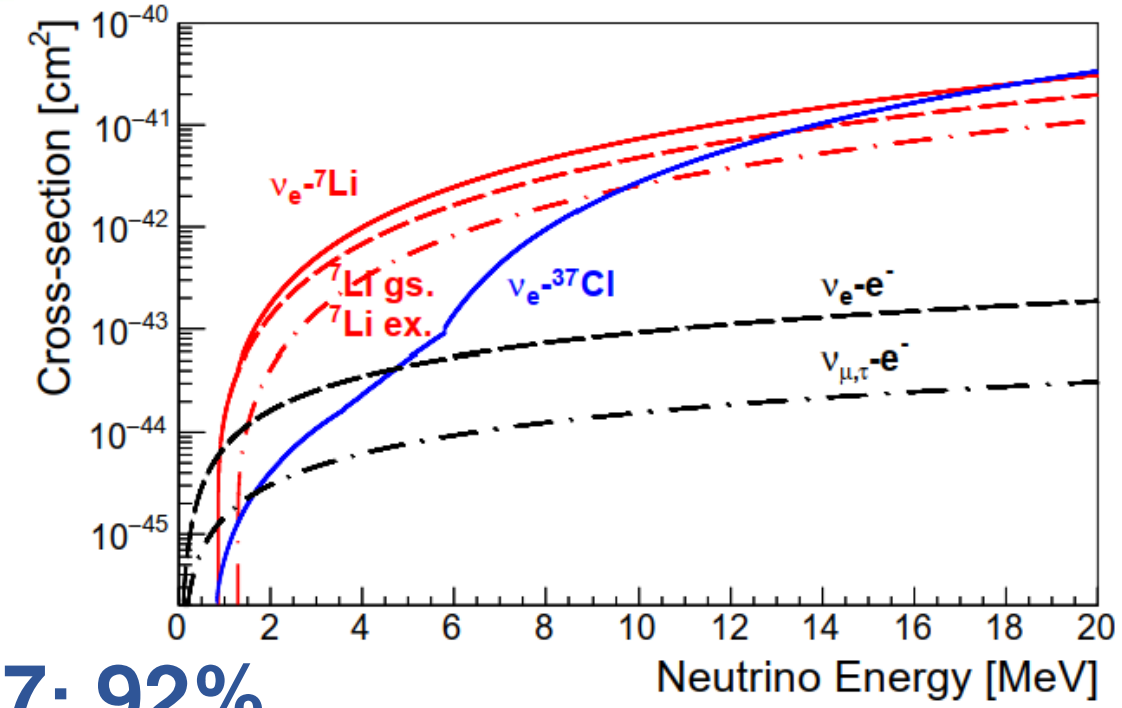
Measure neutrino energy

2. High cross-section:

ν_e-Li7: 60 times of ν_e-e elastic scattering for solar B8 neutrinos

3. High natural abundance of Li7: 92%

4. High solubility: 80 g LiCl in 100 g water



	^{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, ES, and $\bar{\nu}_e$ detections

1. **CC process for ν_e:**

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

   Measure neutrino energy

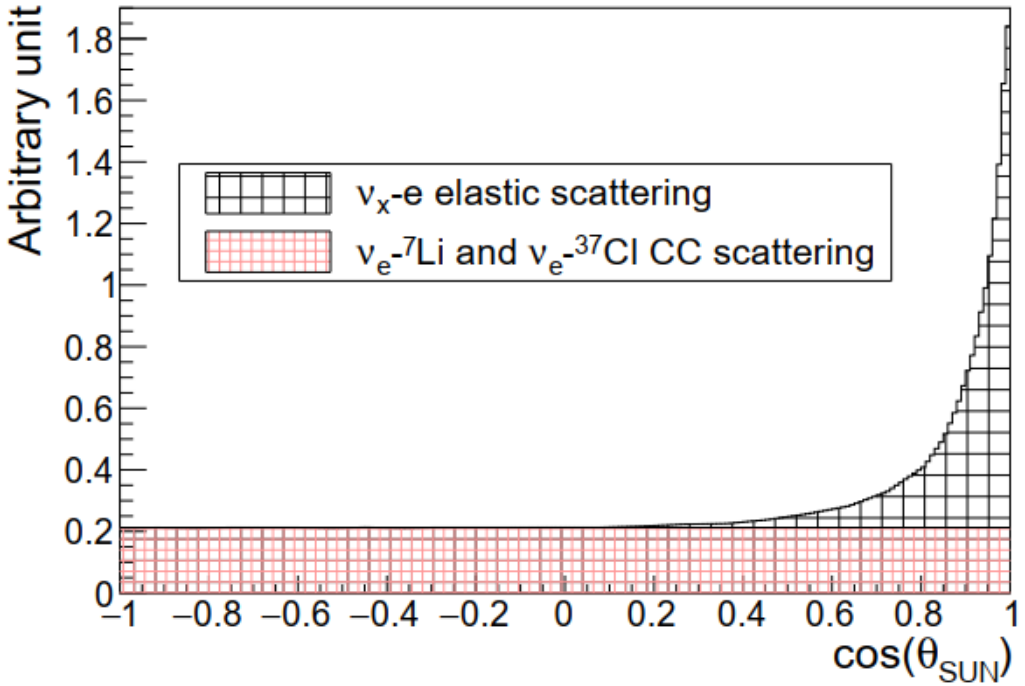
2. **Elastic scatter on e^-:**

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



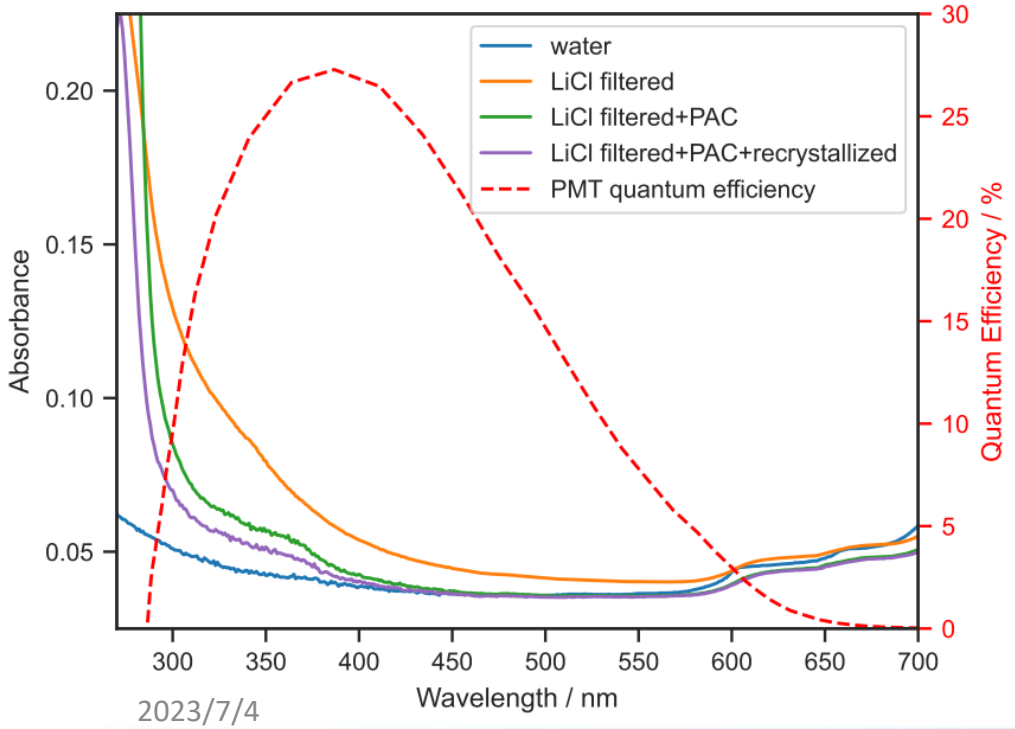
Spectrometer for ν_e and $\bar{\nu}_e$

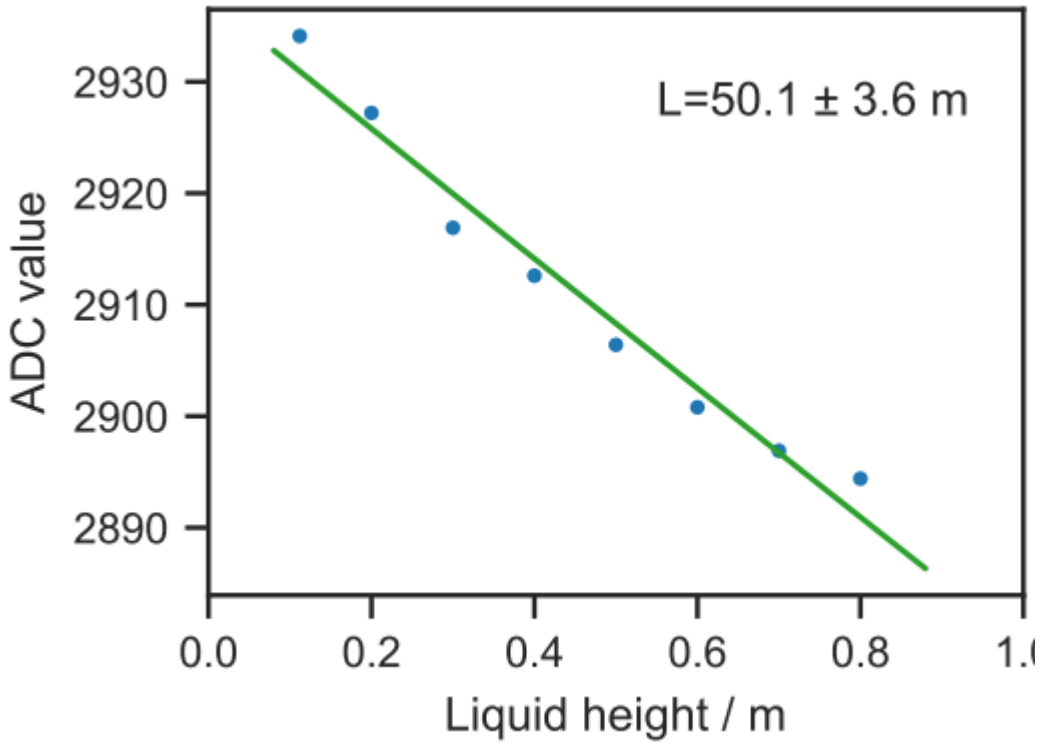
Good chance for solar and geo neutrinos

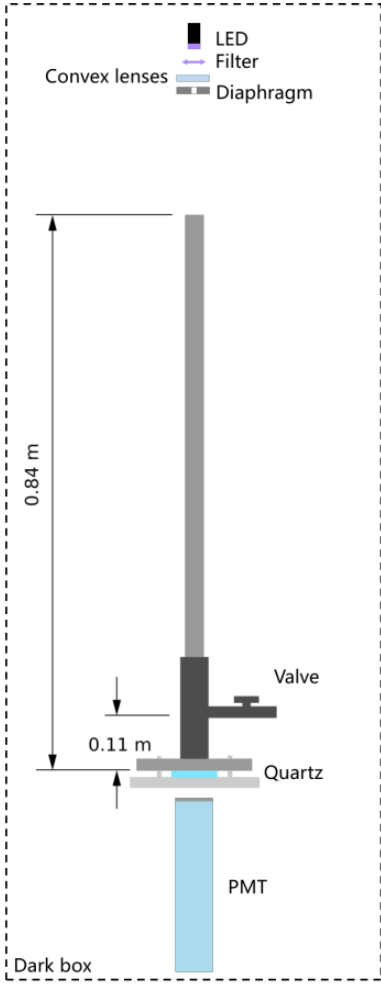
UV spectrum and attenuation length of LiCl solution

Saturated LiCl solution are purified

1. Active carbon absorption and thermal recrystallizaiton
2. Transparency for a wide range
3. Attenuation length: 50 m at 430 nm



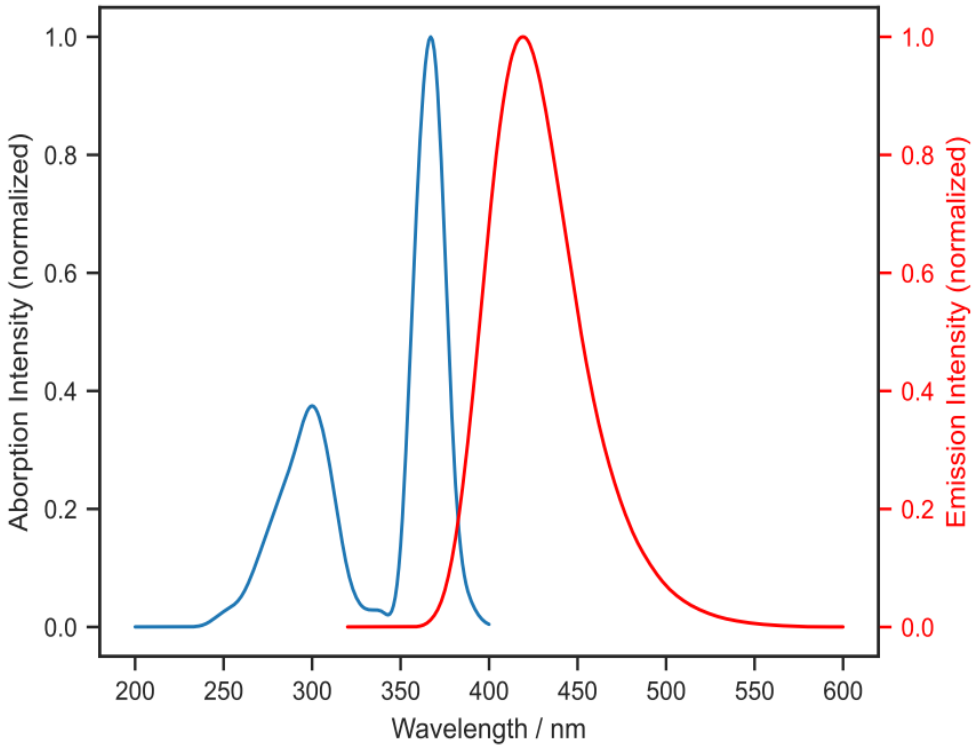




LiCl aqueous solution with carbostyril 124

Adding 1 ppm C124 to LiCl aqueous solution

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

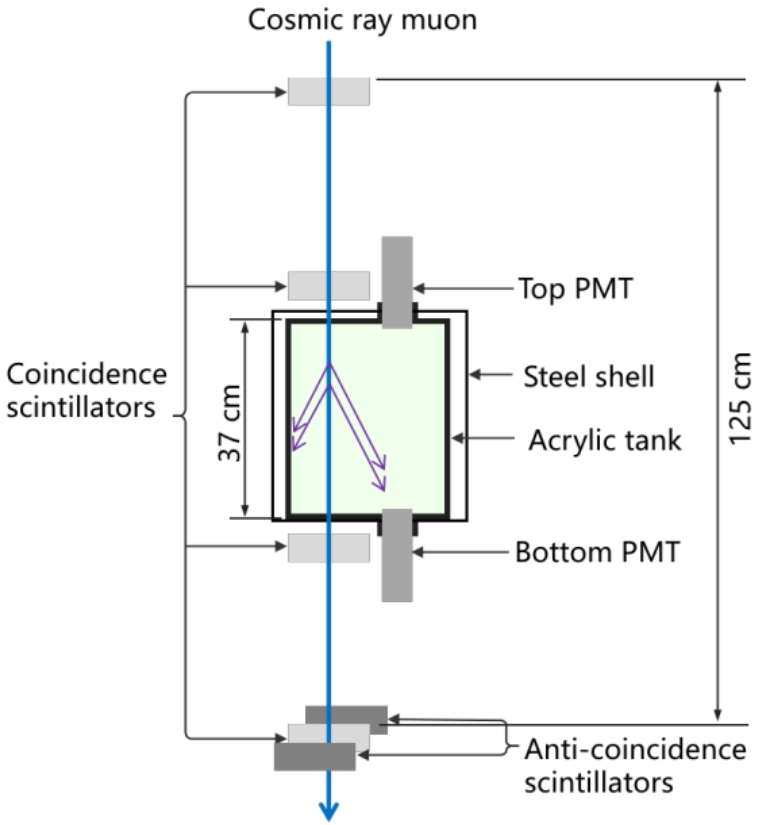


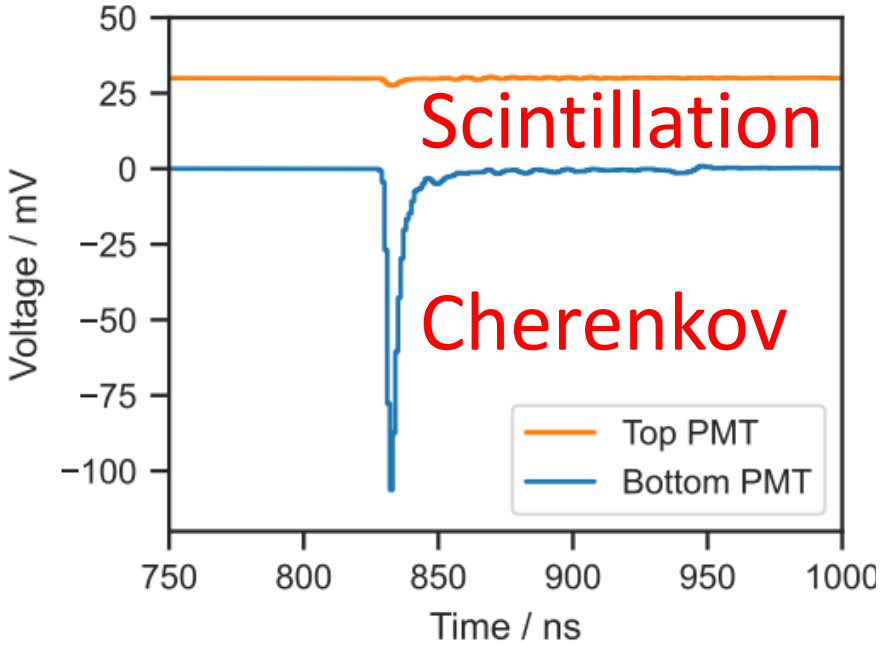
C124 absorption and emission spectra

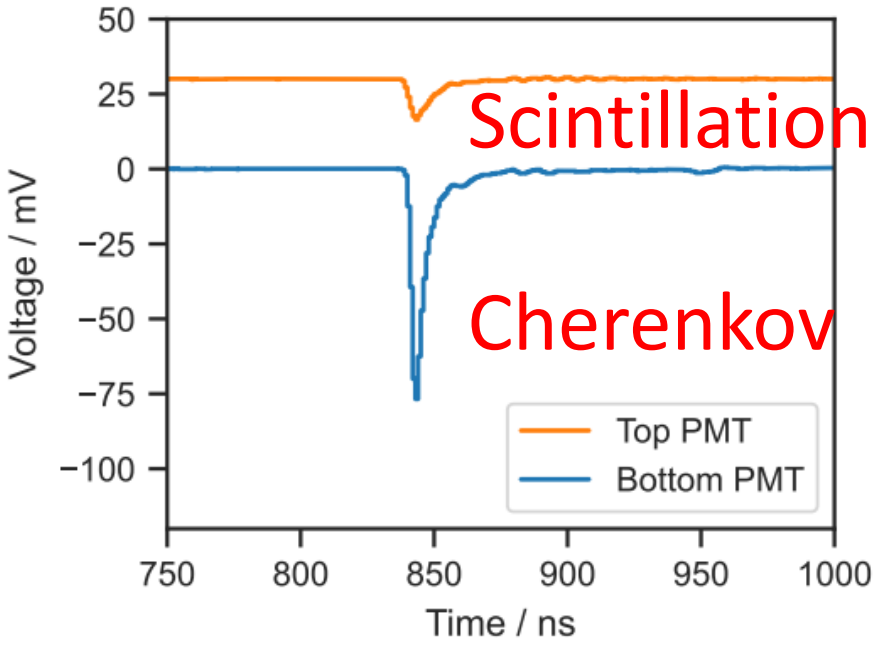
LiCl aqueous solution with carbostyril 124

Light yield verification with a muon telescope

3.7 PE detected from isotropic scintillation; 12.3 PE for Cherenkov



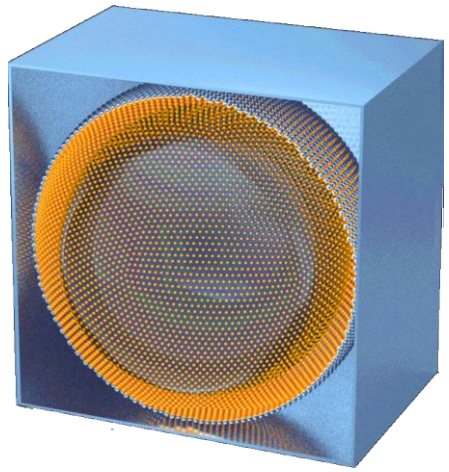




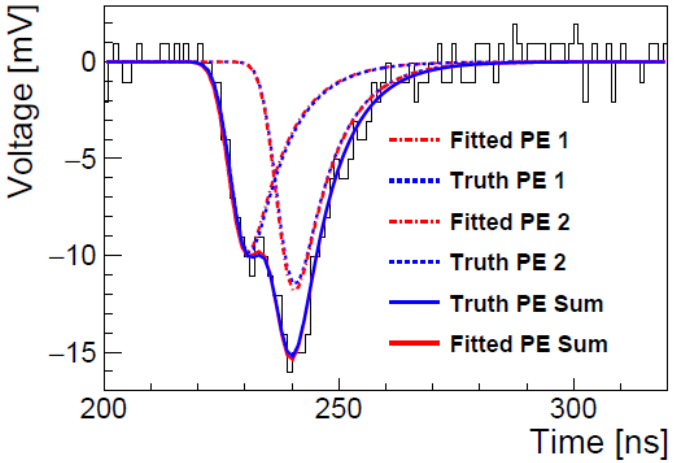
(a) LiCl → (b) LiCl with 1 ppm C-124

Simulation and position, energy, and direction reconstruction

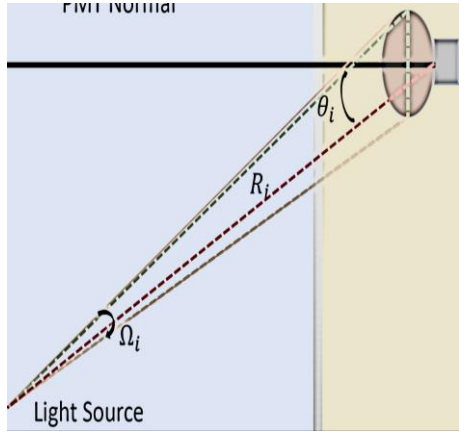
Particle, optics simulation in water, scintillatior, and doped scintillator



Electronics and waveform simulation and reconstruction



Cherenkov and scintillation modelling



Reconstruction based on the hits' charge and time

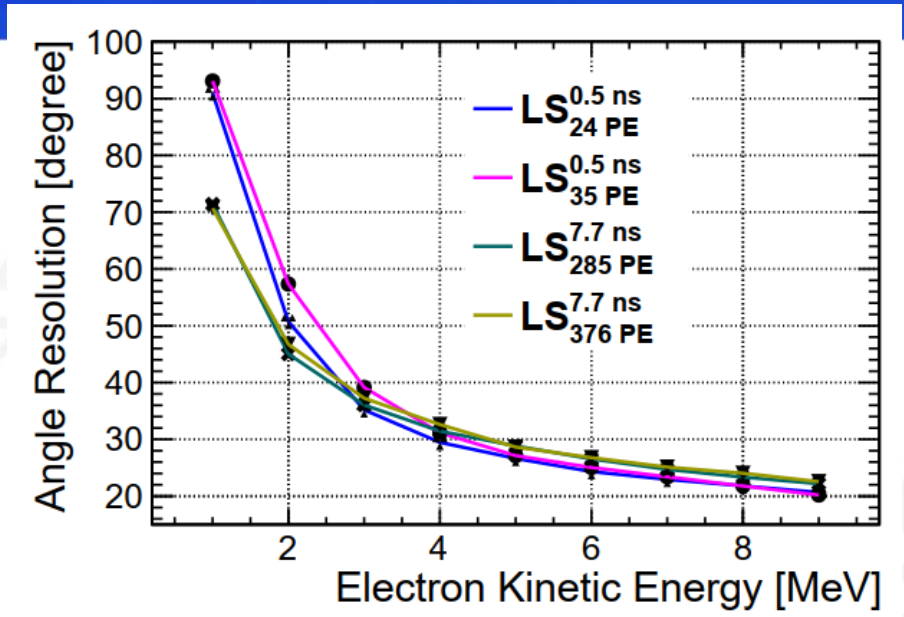
$$\mathcal{L} = \prod_{i}^{N_{\mathrm{PMT}}} P_i^C \prod_{j}^{n_i^{\mathrm{Obs}}} P_{ij}^T$$

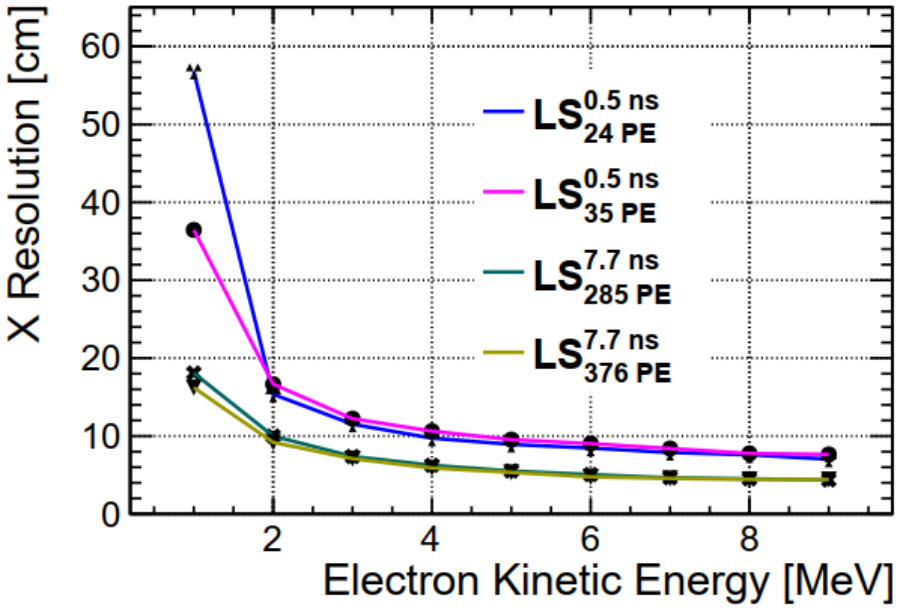
charge time

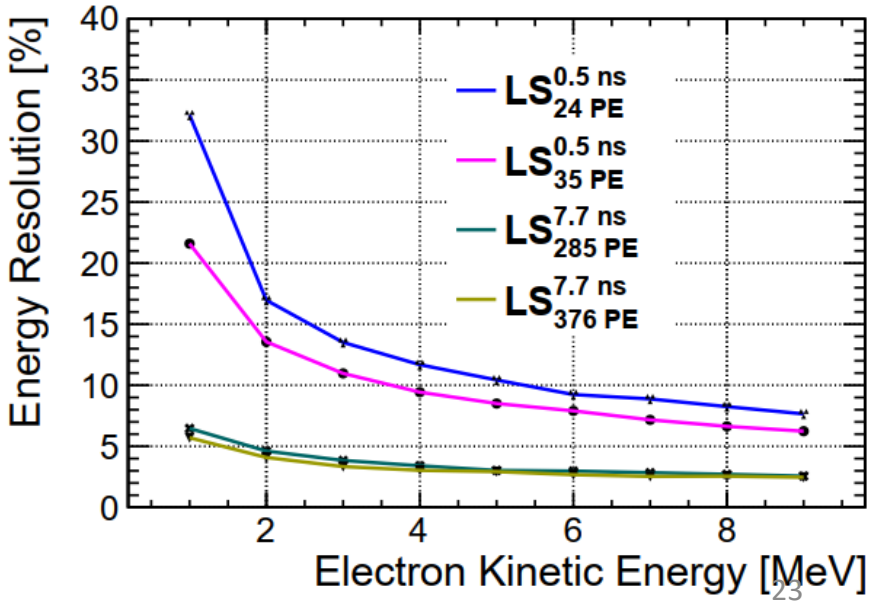
Reconstruction of Cherenkov scintillation detector

Reconstruction performance

1. Good direction precision with a pure Cherenkov detector or with a proper scintillation component (minor or slow)
2. Better position and energy precision

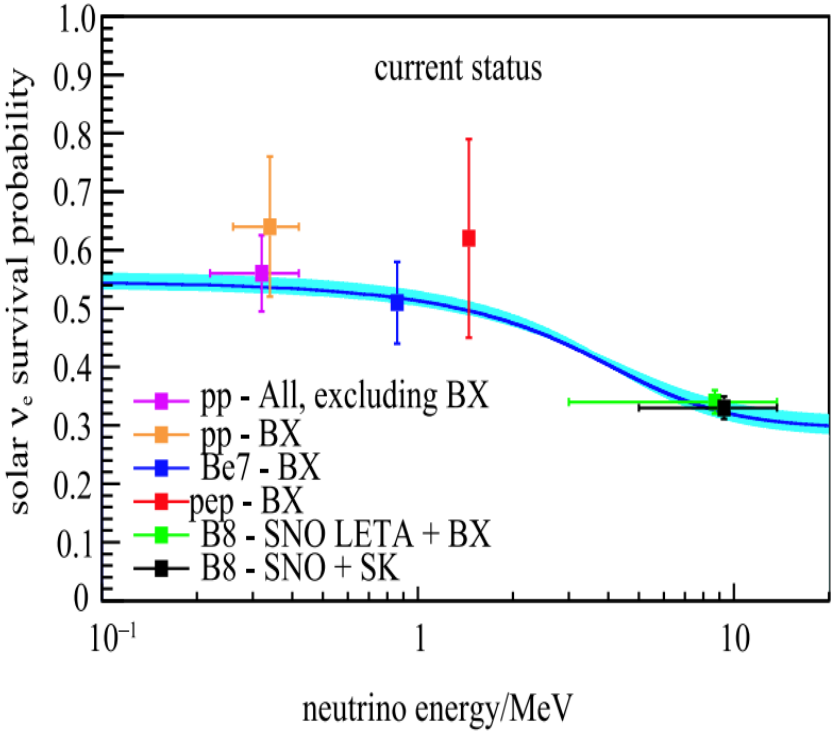


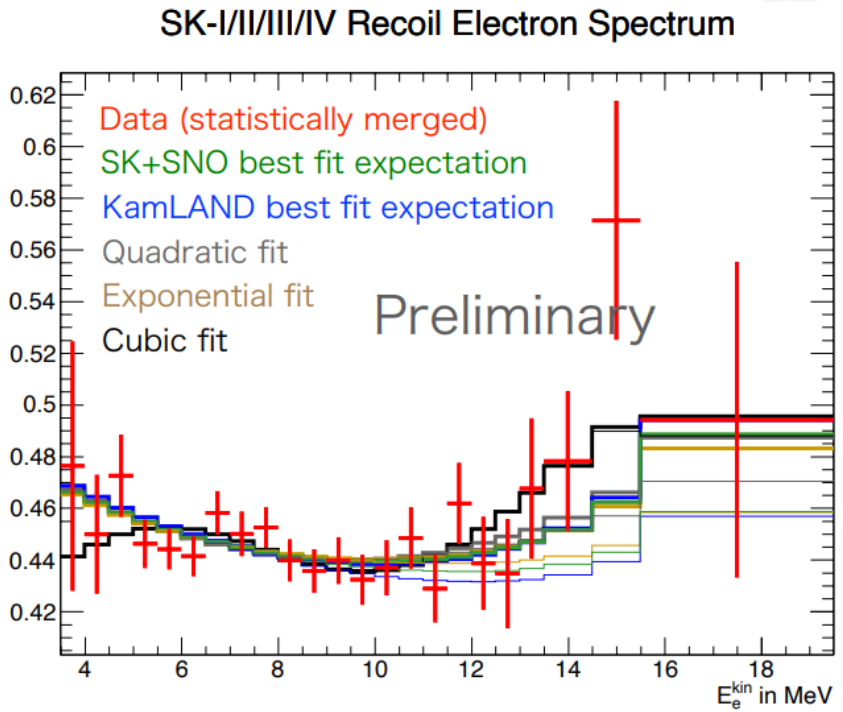




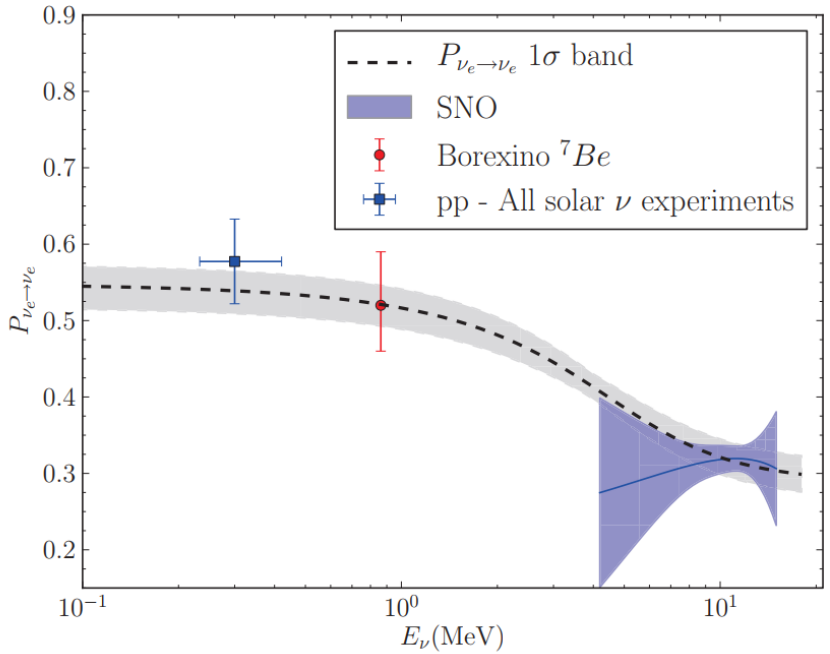
Testing one solar neutrino oscillation

From matter–dominant to vacuum oscillation: upturn





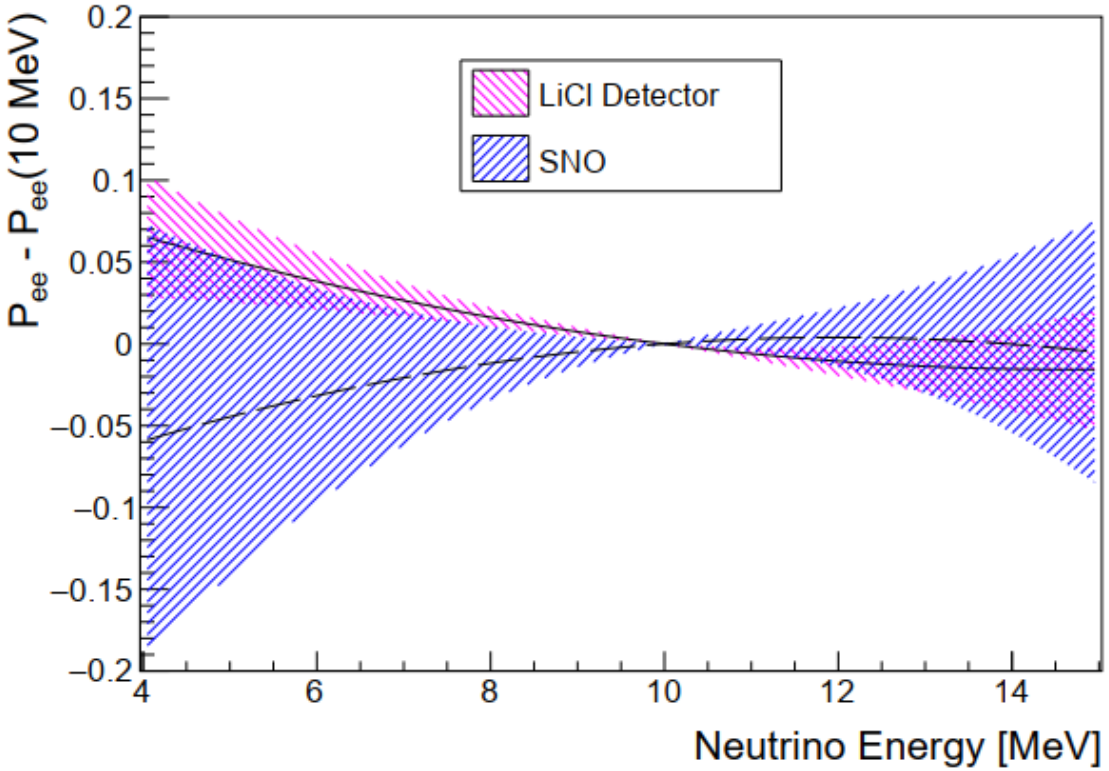
Slightly favors up-turn,
though need more data

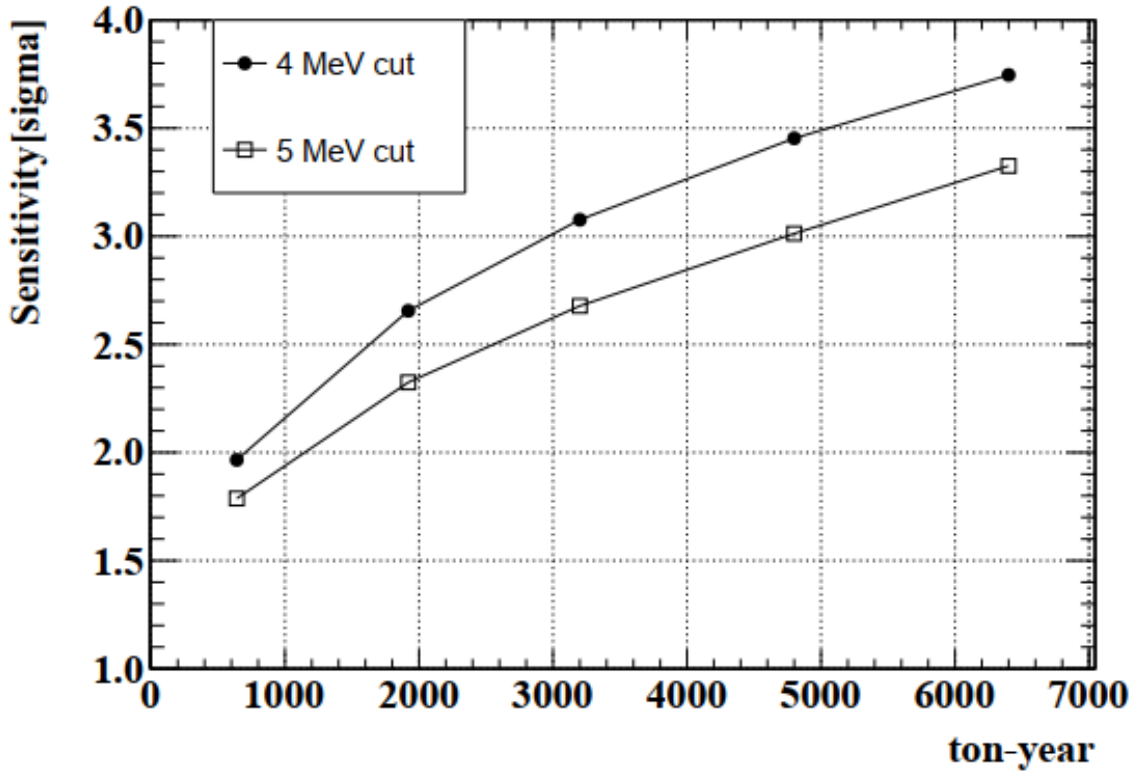


Not clearly observed.

Solar neutrino upturn sensitivity with LiCl solution

A competitive option for solar neutrino oscillation study





6400 ton-year, 4 MeV cut

4. Summary

1. **Hundred-ton solar neutrino observatory at CJPL II**
   a. Detector construction
   b. Replaceable detection media, allowed density range ± 20% wrt water, oil- or water- based liquid scintillator
2. **New MCP-PMT, Low background, fast, high QE**
3. **ADC chips and waveform readout electronics under design and testing**
   a. AD chips， 12 bit, GSPS, 350mW
   b. waveform readout， 400 Mz, 40Gbps
4. **Solar B-8 neutrino detection with water**
5. **Explored the option with LiCl aqueous solution**

Thank you.

http://jinping.hep.tsinghua.edu.cn