The R&D Progress of the Jinping Neutrino Experiment

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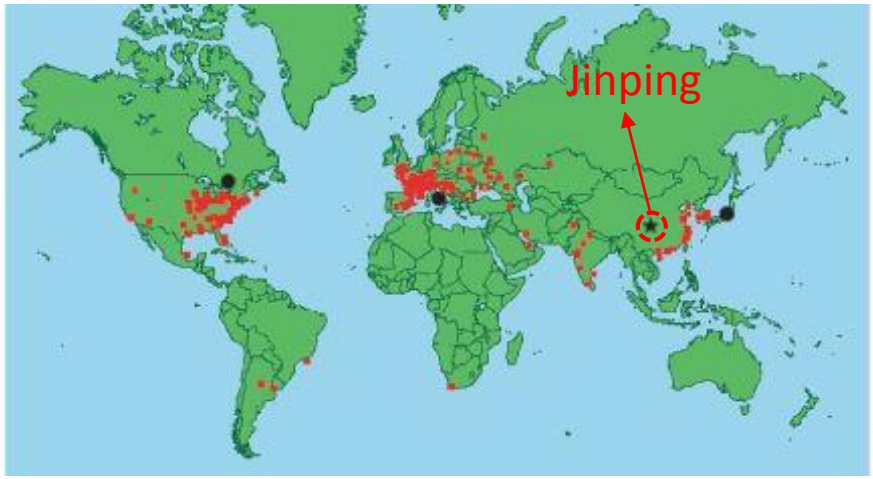
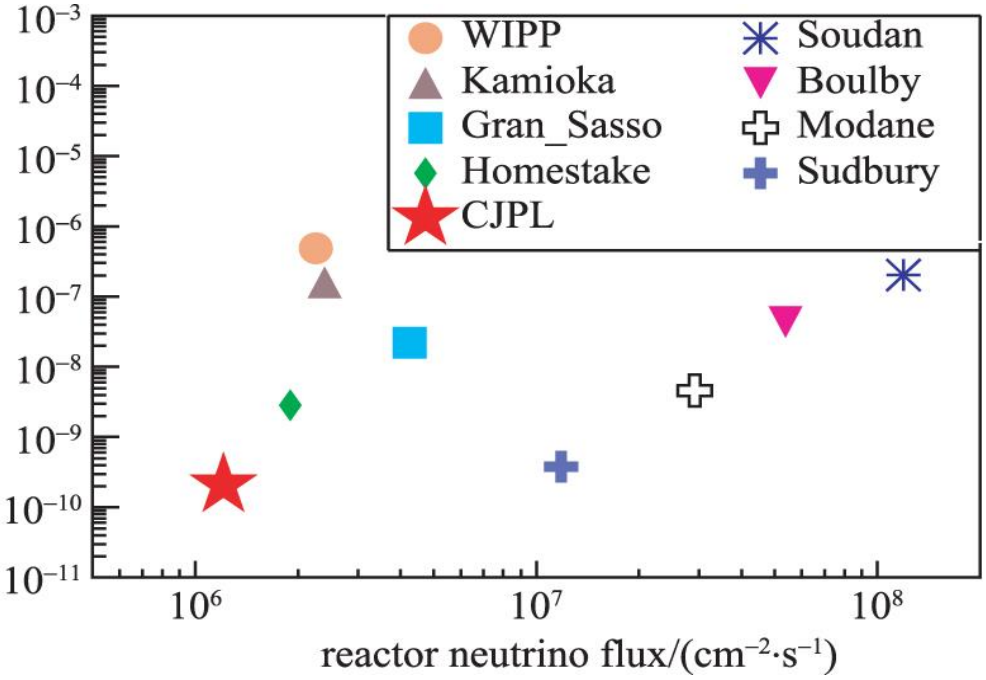
May.23.2017

(for Jinping neutrino experiment research group)

Ideal low Bkg. Laboratory

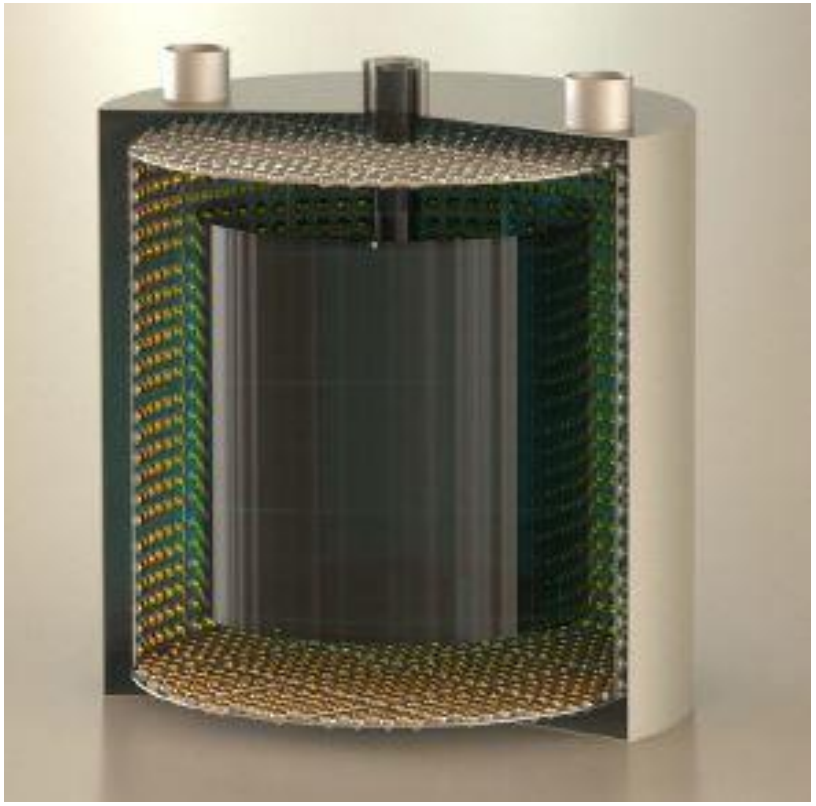


Red pot: Nuclear power plants



- ✓ Jinping Underground laboratory is located in Sichuan province in china
- ✓ Coverage 2400 m rock, muon flux is as low as $2 \times 10^{-10}/(\mathrm{cm}^{-2} \cdot \mathrm{s})$.
- ✓ Jinping is far away from all nuclear power plants. Rector neutrino flux is as low as $\sim 10^{6}/(\mathrm{cm}^{-2} \cdot \mathrm{s})$

Jinping Neutrino Detector



Or spherical inner vessel

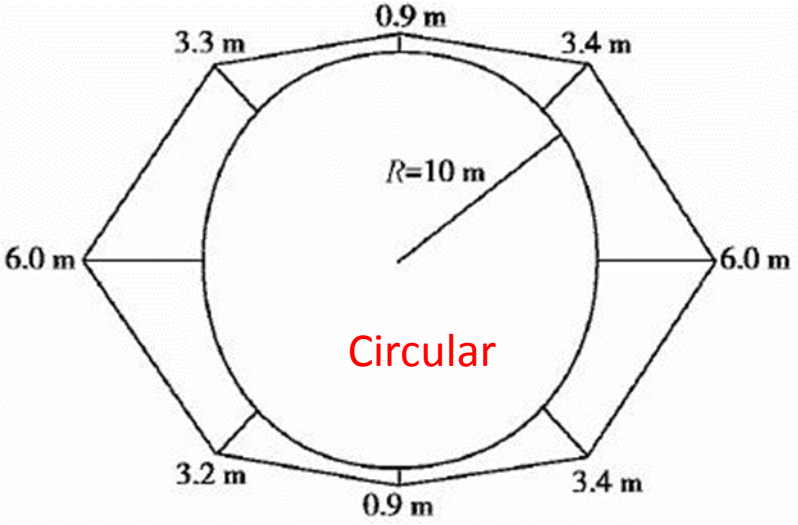
- ✓ Conceptual design for cylindrical
- ✓ Liquid scintillator or slow liquid scintillator
- ✓ Slow LS light yield:
  >500 PE/MeV
- ✓ Total fiducial mass: 2000 tons (solar), equivalent, 3000 tons (geo, supernova)
- ✓ Steel tank filled with pure water

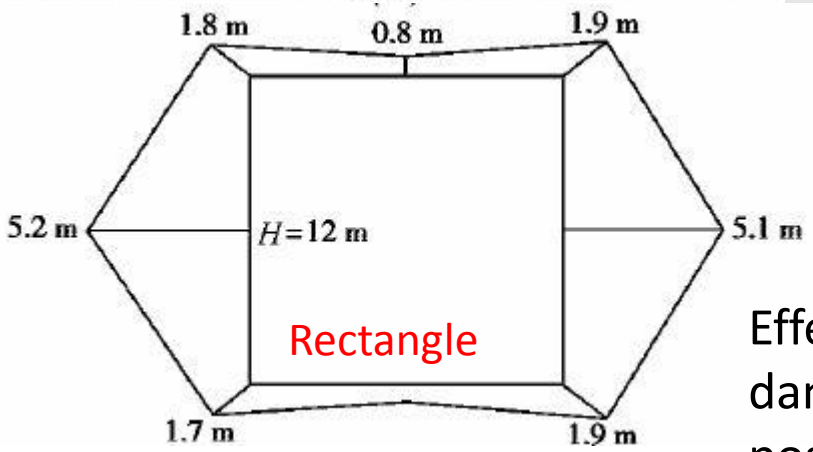
Main Physical Goal

- ✓ Solar neutrino
  - ➢ Improve measurement of the pp, ^{7}Be, and pep neutrino fluxes
  - ➢ Discovery of CNO neutrinos
  - ➢ Distinguish the high and low metallicity hypotheses
  - ➢ Stronger constraint on the vacuum-matter transition to the MSW effect
- ✓ Geo-neutrino
  - ➢ Distinguish U and Th Spectrum
  - ➢ Measure ratio of U/Th
  - ➢ Determine geo-neutrino model
- ✓ Supernova relic neutrino
  - ➢ Slow LS, ten years data -> golden SRN candidate

Rock Damage Zone Study

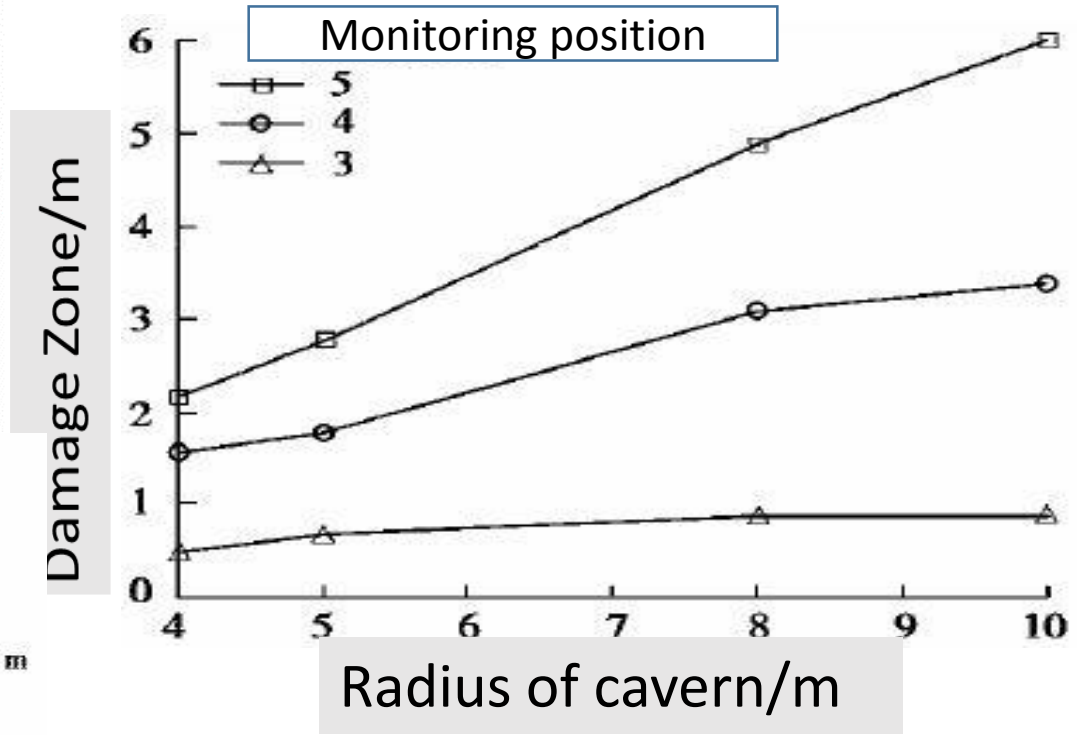
Damage zone shape





Overburden 2400 m rock:

- ✓ High stress ~70 Mpa



Effects of cavern diameter on excavation damage zone of surrounding rock at different positions

Chinese Journal of Geotechnical Engineering, Vol.38 Supp.2, 67 (2016)

Low Background Stainless Steel

- ✓ Test Raw materials: Fe, C, Cr, Ni, Si, Mn, Mo, and MgO
- ✓ Test stage samples: Test radioactive brought by the smelting procedure and remove high radioactive and harmful elements (C, Si, P, S and Mn)
- ✓ Test commercial SST sample: two commercial SST samples 304L and 316L

Three methods to test materials

- ➢ Glow discharge mass spectrometer (GDMS) method: Precision of GDMS can reach ppt level
- ➢ HPGe-Jinping: A low bkg. High-purity germanium gamma ray spectrometer is installed at CJPL and has high sensitivity
- ➢ HPGe-Ground: Another detector is installed at the ground level and has low sensitivity

Compare with other Exp.

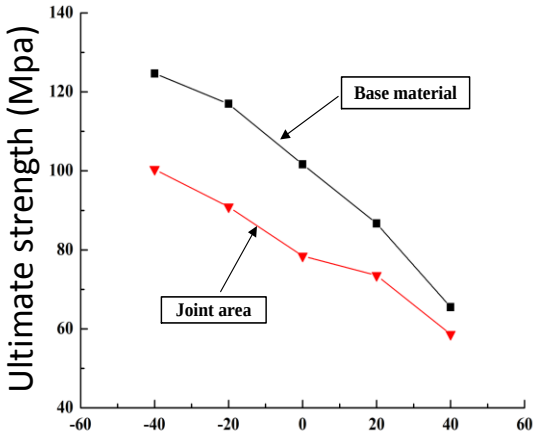
Radioisotopes	Jinping mBq/Kg	Borexino[1] mBq/kg	Next[2] mBq/kg
^{238}U	< 5.4	4.569 ± 0.864	32 ± 9
^{232}Th	< 2.0	11.36 ± 1.218	1.9 ± 0.2
^{40}K	< 12.9	< 14	3.2 ± 0.7
^{60}Co	1.4 ± 0.4	6 ± 1	1.8 ± 0.1

[1]:Astroparticle Physics 18 (2002) 1–25
[2]:AIP Conference Proceedings 1672, 060002 (2015)

- Test all the stage sample and commercial sample and select one stage sample with the lowest U, Th concentration
- Comparable with Borexino and NEXT double beta decay experiment

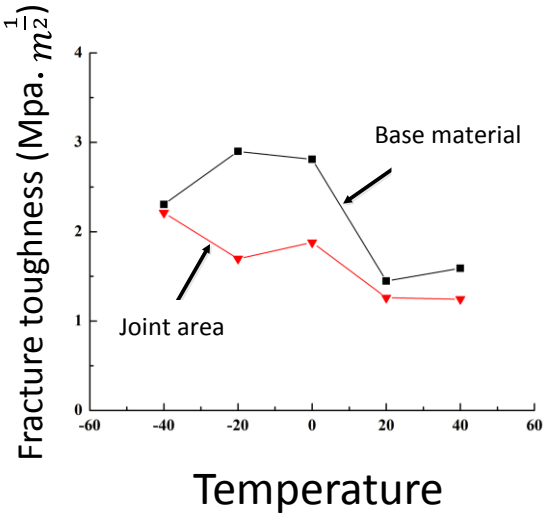
Mechanical Property of Acrylic

Tensile-strength



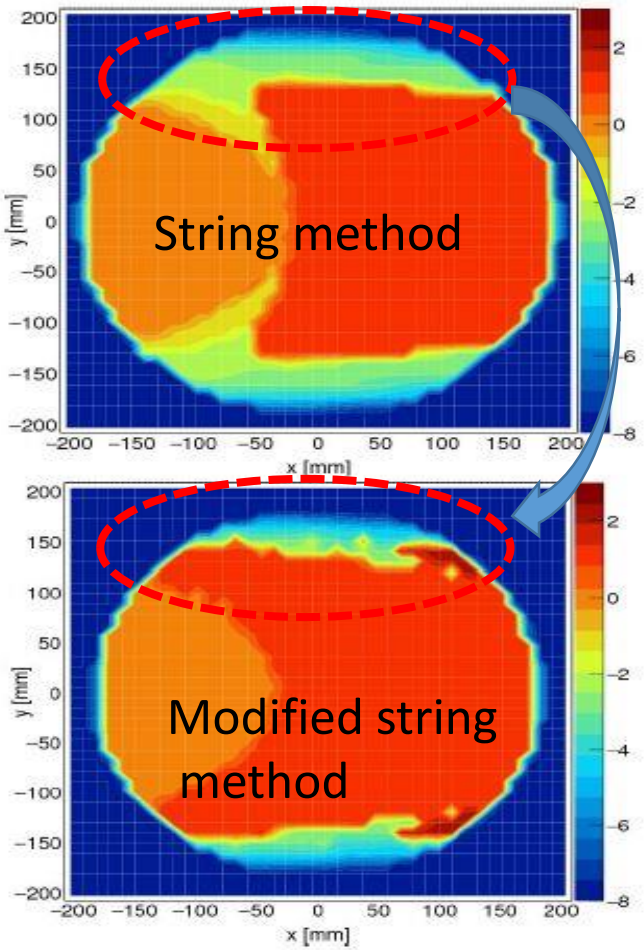
- ✓ Relationship between ultimate strength and temperature
- ✓ Base material always better than joint area material
- ✓ Better than most of acrylic material in market

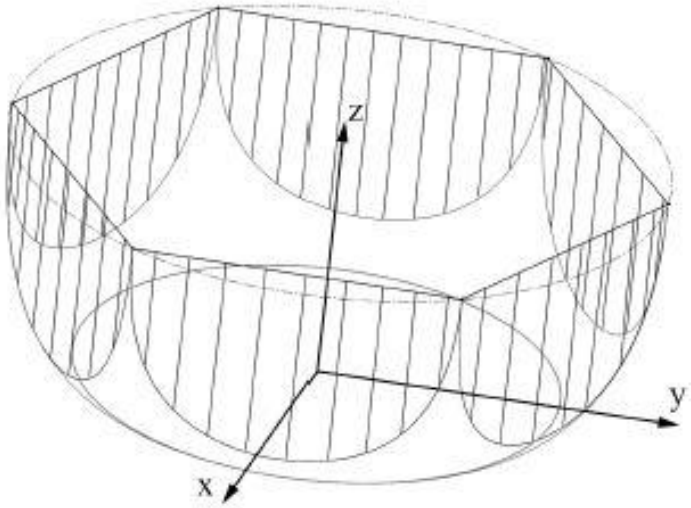
Fracture toughness



- ☐ Relationship between fracture toughness of acrylic and temperature
- ☐ In general, low temperature fracture toughness better than high temperature

Improved light concentrator



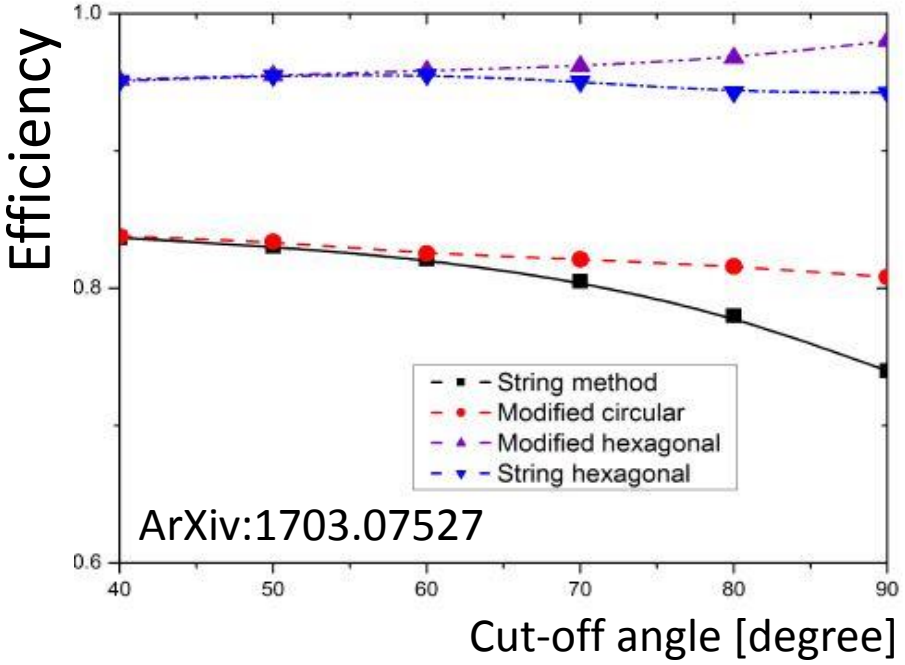


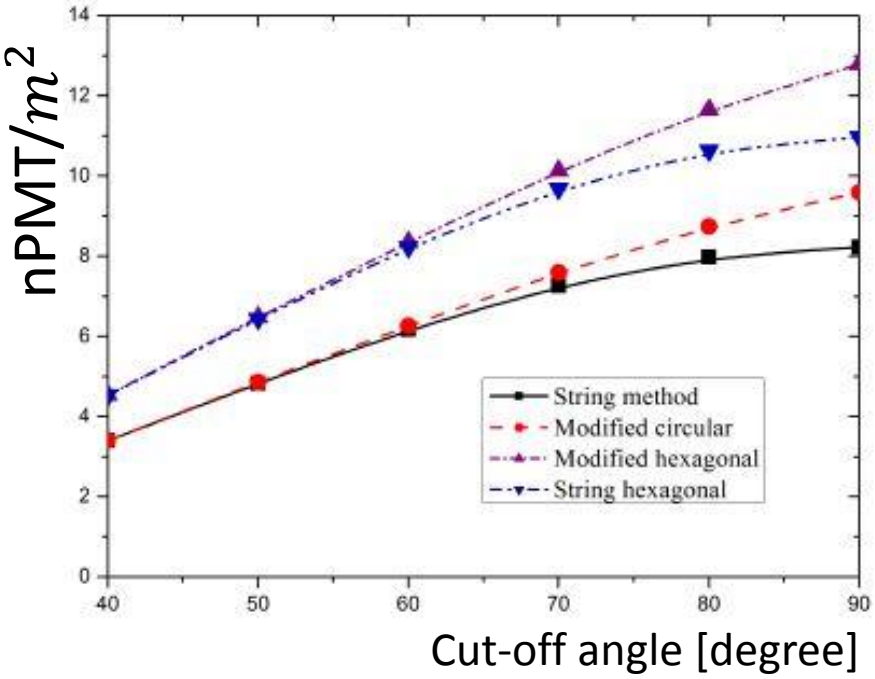
Replacement of a circular opening concentrator with a hexagonal opening one. The hexagonal opening concentrator is achieved by using the inscribed hexagon of the entry aperture to cut along the z axis.

The color code indicates the number of reflections, and non-negative values indicate that the photon arrives at the photo cathode.

ArXiv:1703.07527

Wide field of view and high-efficiency Light Concentrator

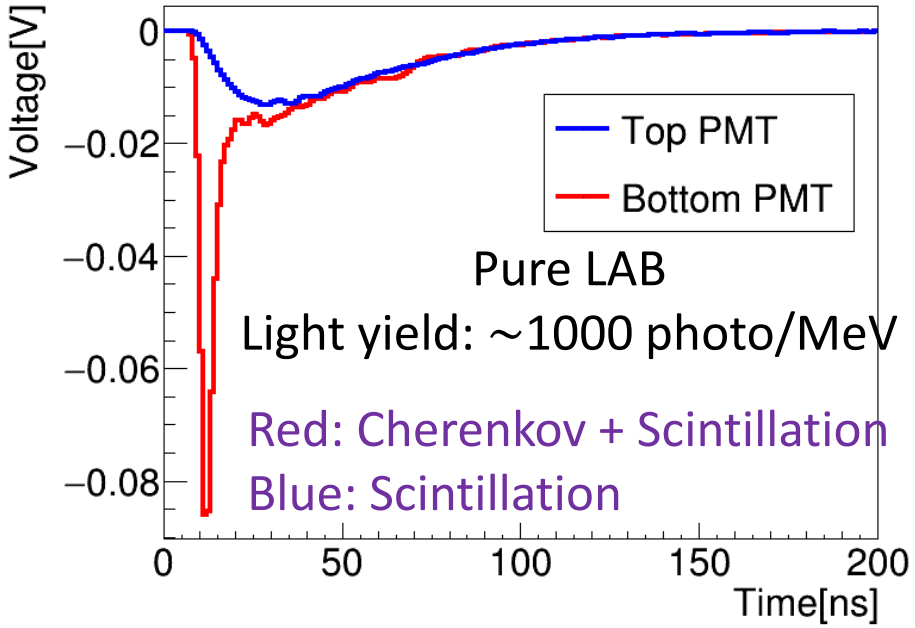


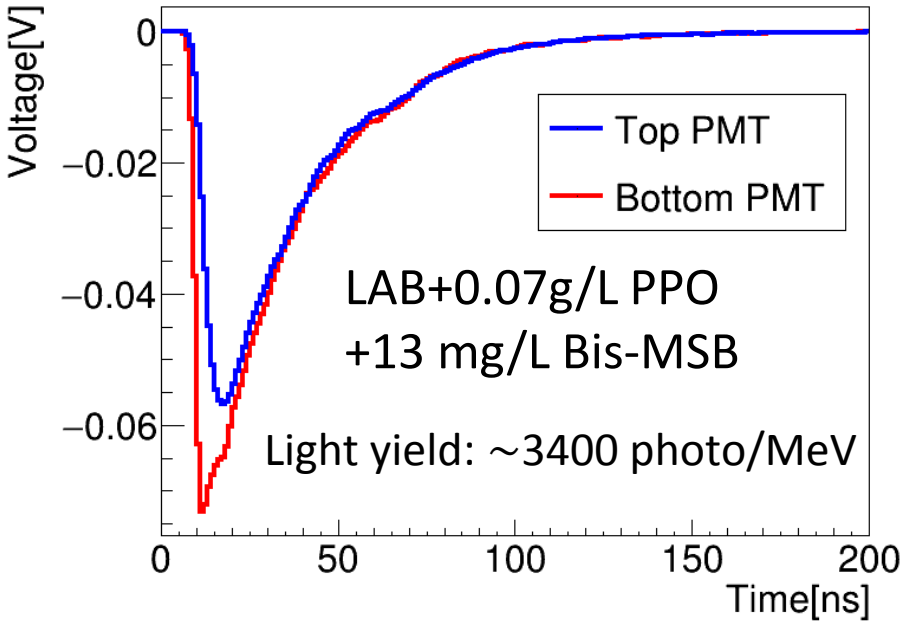


- ✓ Compare 2-Dimensional string method, modified and improved in 3D condition
- ✓ Hexagonal aperture not only have higher efficiency but also could reach 100% coverage compare with circular aperture
- ✓ higher efficiency, smaller light concentrator and more PMTs
- ✓ Attain a wide field view of 90° and a high efficiency of above 98%

Research for slow LS

Slow LS for scintillation and Cherenkov light separation !!!





✓ Separation of Cherenkov and scintillation lights

✗ Lower light yield

✓ Higher light yield

✗ Faster rise time

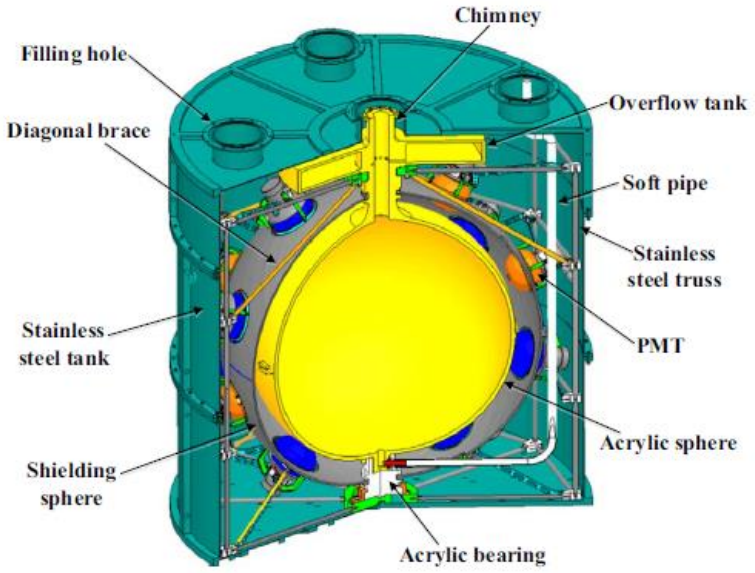
✗ Shorter attenuation length

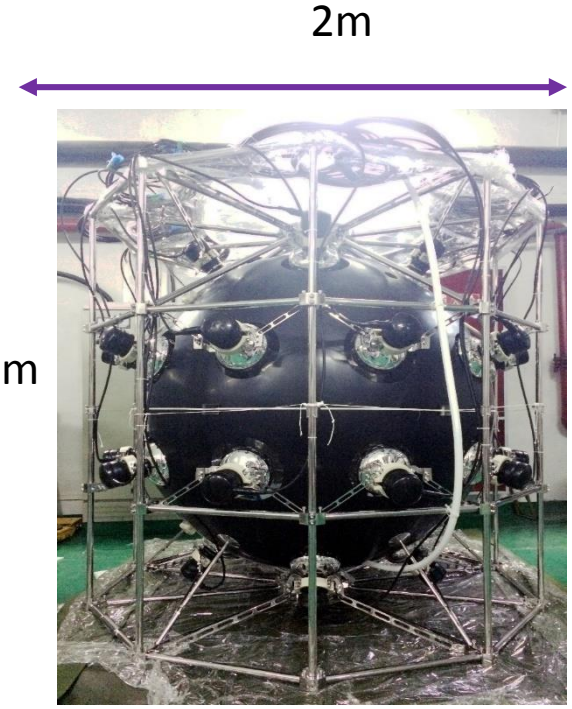
Talked By Ziyi Guo, This Morning

Nucl. Instrum. Methods Phys. Res. A 830 (2016) 303-308

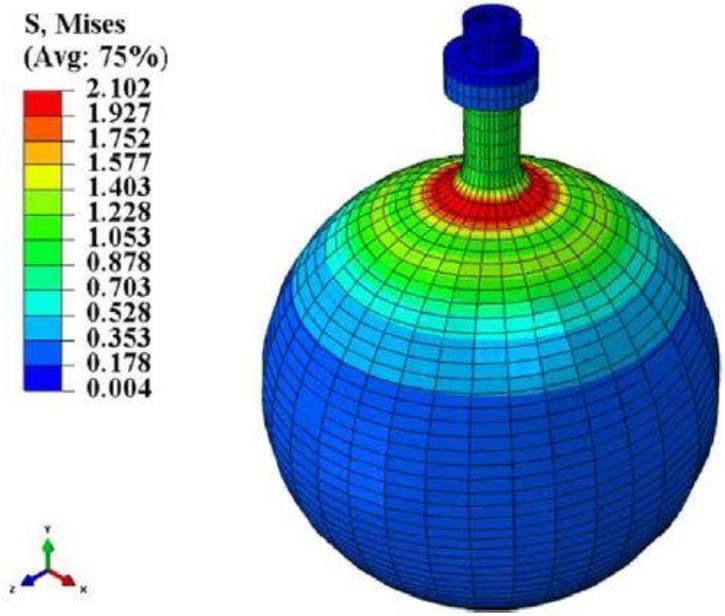
1-ton Prototype

- ✓Detector design and fabrication
- ✓Pure water operation
- ✓Test target material: Pure water, LS, and slow LS
- ✓Measure underground lab background level, for example fast neutron, gamma etc
- ✓As a low background detector





1-ton Prototype Acyclic Test



- ✓ The worst work condition (Acrylic vessel is filled with water and no water outside the vessel) Mises stress is only ~2.1 Mpa lower than safety Mises stress ~5 Mpa

Nucl. Instrum. Methods Phys. Res. A 855, (2017) 81

Status of 1-ton Prototype

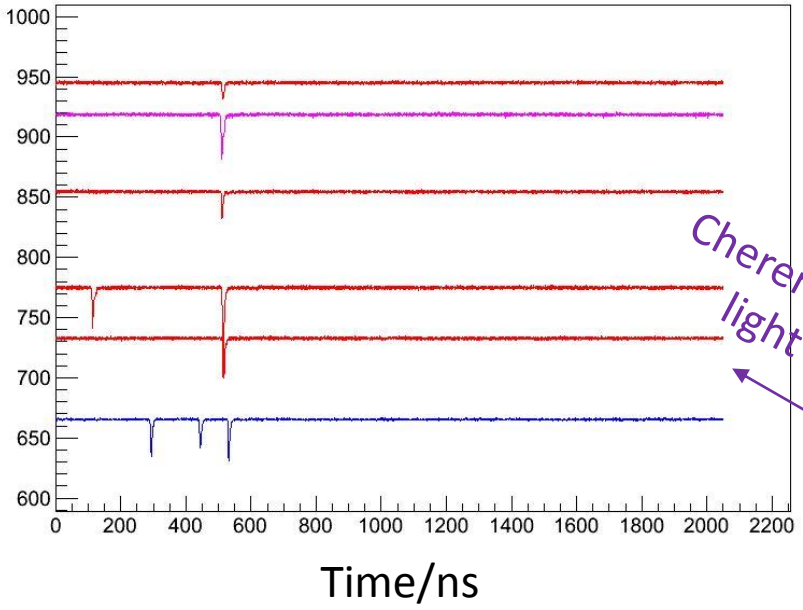
Lead Wall

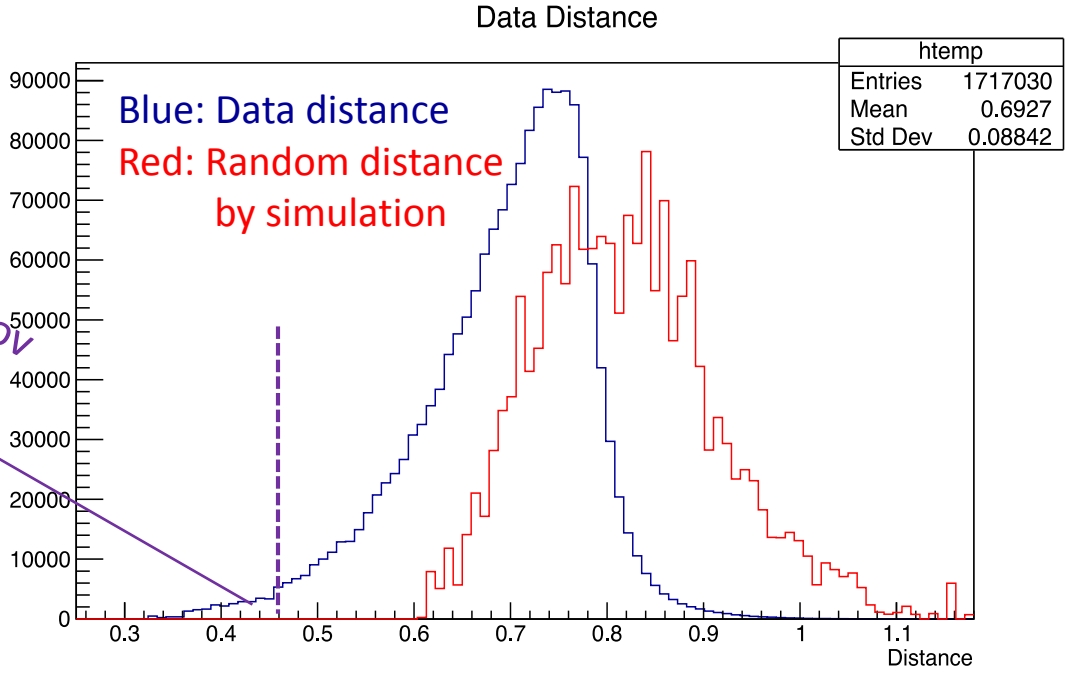
Assembly May. 2017

Assembly Feb. 2017

Taking Data Now

1-ton Prototype Data Analysis

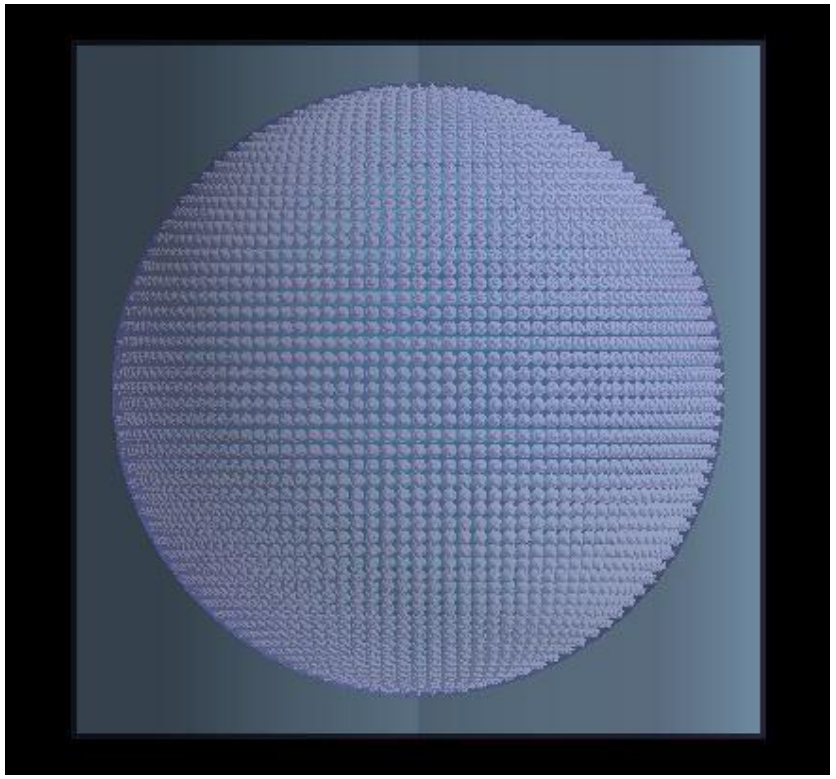




Preliminary analysis result

- ✓ Average data PMT-to-Barycenter distance and randomly generated PMT-to-Barycenter distance
- ✓ For one ton prototype detector, Cherenkov light could be observed
- ✓ PMTs in one ton prototype could work very well

Jinping Simulation & Analysis Package (JSAP)



- **JSAP**
  - Kilos ton geometry
  - Handle different geometry setup, for example, target material mass, PMT coverage
  - Understand more about detector, like efficiency
  - Simulate nature radioactive elements and fast neutron background

Calorimeter Function, more physical Replacing Crystal Ball

Fit range	Calorimeter Best fit	Crystal ball Same range	Crystal ball Best fit
Liquid scintillator			
Peak accu.	−0.042%	−0.80%	−0.53%
Resolution accu.	0.044%	4.8%	1.9%
Peak area accu.	−0.59%	22%	19%
χ^2/NDF	119/118	9027/120	115/47
Calibration source			
Peak accu.	0.0054%	−0.40%	−0.25%
Resolution accu.	0.22%	5.8%	2.6%
Peak area accu.	−0.095%	18%	14%
χ^2/NDF	59/35	5197/35	81/15
CsI crystal array			
Peak accu.	−0.18%	−1.2%	−1.1%
Resolution accu.	0.15%	7.3%	5.5%
Peak area accu.	17%	128%	124%
χ^2/NDF	378/395	8383/395	1411/176

Nucl. Instrum. Methods Phys. Res. A 827 (2016) 165-170

- ✓ $f_{cal} = f_{DE} \otimes f_{resolution}$

DE: deposited energy

- ✓ Peak energy and resolution, and peak area was improved by an order of magnitude compare with Crystal Ball function

Conclusion and Outlook

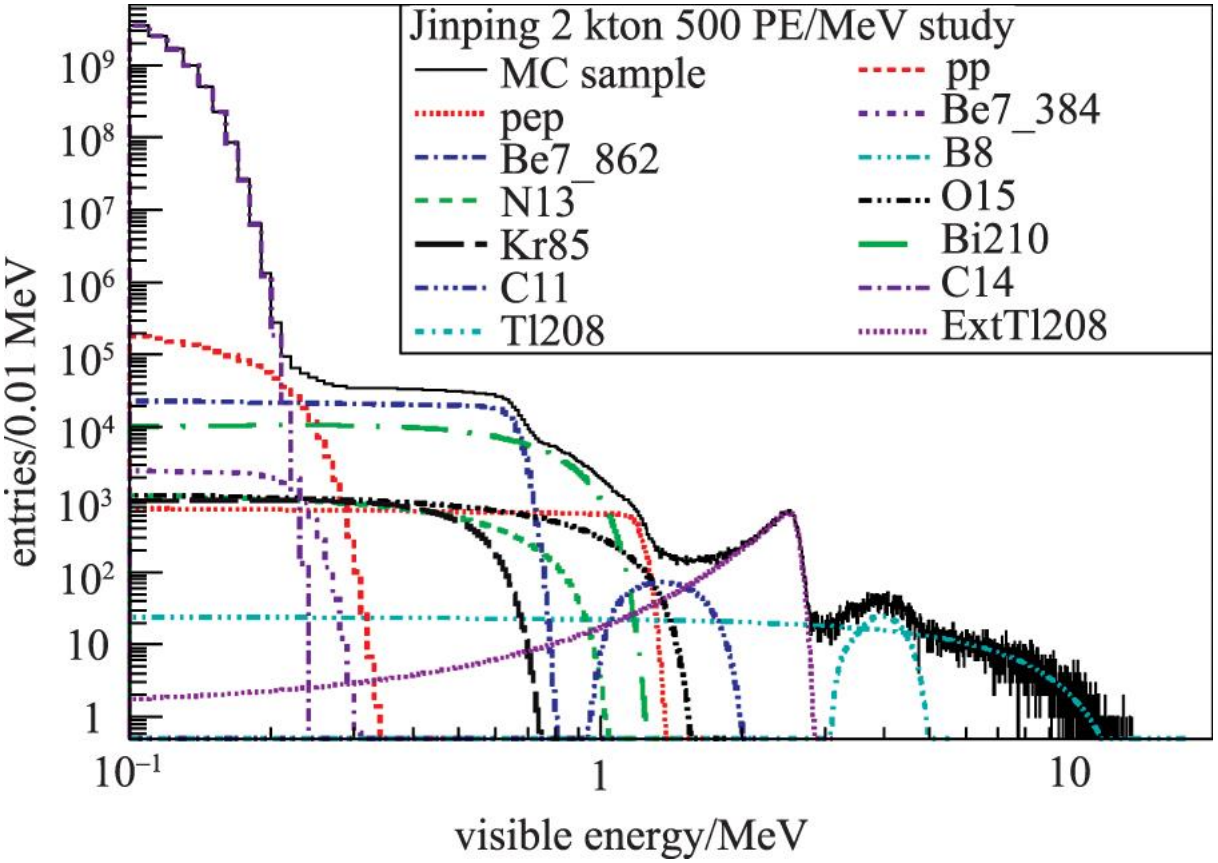
- ✓ CJPL is an ideal low background underground laboratory in the world
- ✓ Jinping neutrino experiment will perform an in-depth research on solar neutrinos, geo-neutrinos, and supernova relic neutrinos
- ✓ Many efforts of research and design about SST, acrylic, target material, and high efficiency light concentrator
- ✓ 1-ton prototype is in use
  - ➢ Understand pure water, LS and slow LS
  - ➢ Measure Jinping underground background level
- ✓ Jinping simulation is in progress
- ✓ 10~100 ton prototype is in plan
  - ➢ Verify detector design, fabrication, and operation
  - ➢ Get ready for a kilos-ton detector

Thank you

More detail of Jinping Neutrino Experiment can be found at
http://jinping.hep.tsinghua.edu.cn

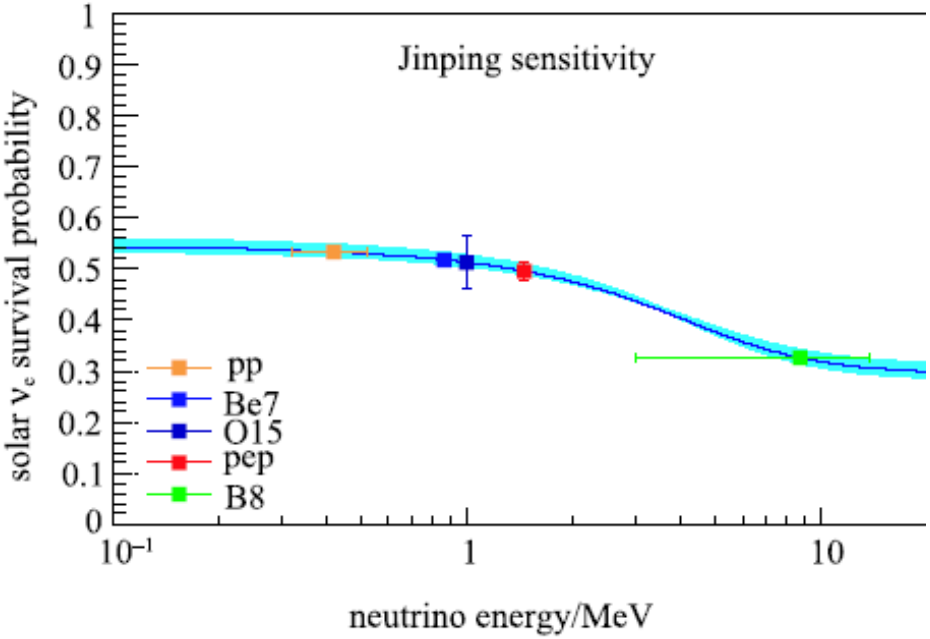
Back Up

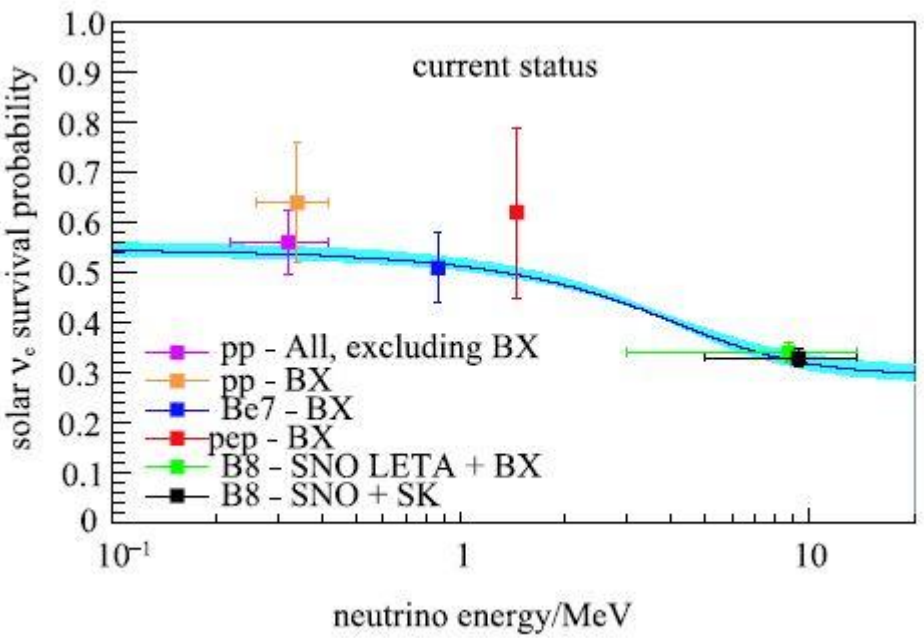
Solar Neutrinos



- ✓ Improved the measurement of known neutrino fluxes
- ✓ discover CNO neutrinos and distinguish high and low metallicity assumptions

Solar Neutrinos Oscillation



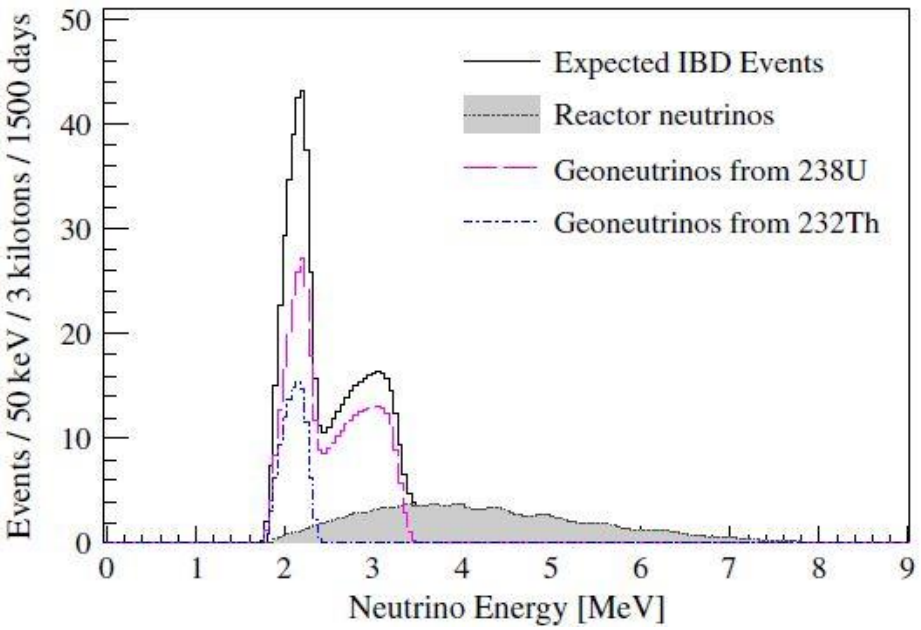


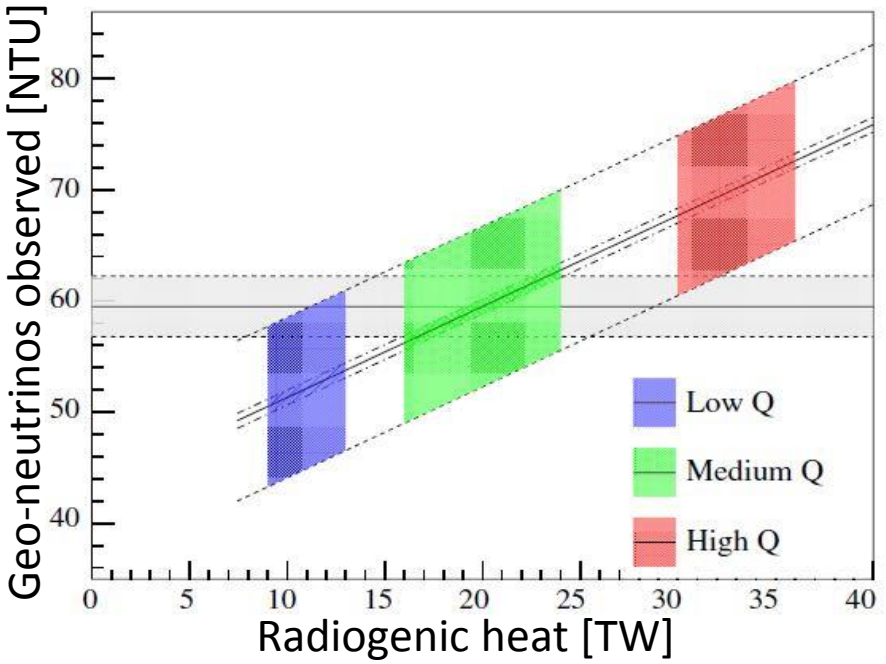
For Jinping simulation:

- ✓ 2000 ton target mass
- ✓ 1500-day exposure
- ✓ 500 PE/MeV
- ✓ Low metallicity assumption

➢ Stronger constraint on the vacuum-matter transition to the MSW effect

Geo-neutrinos



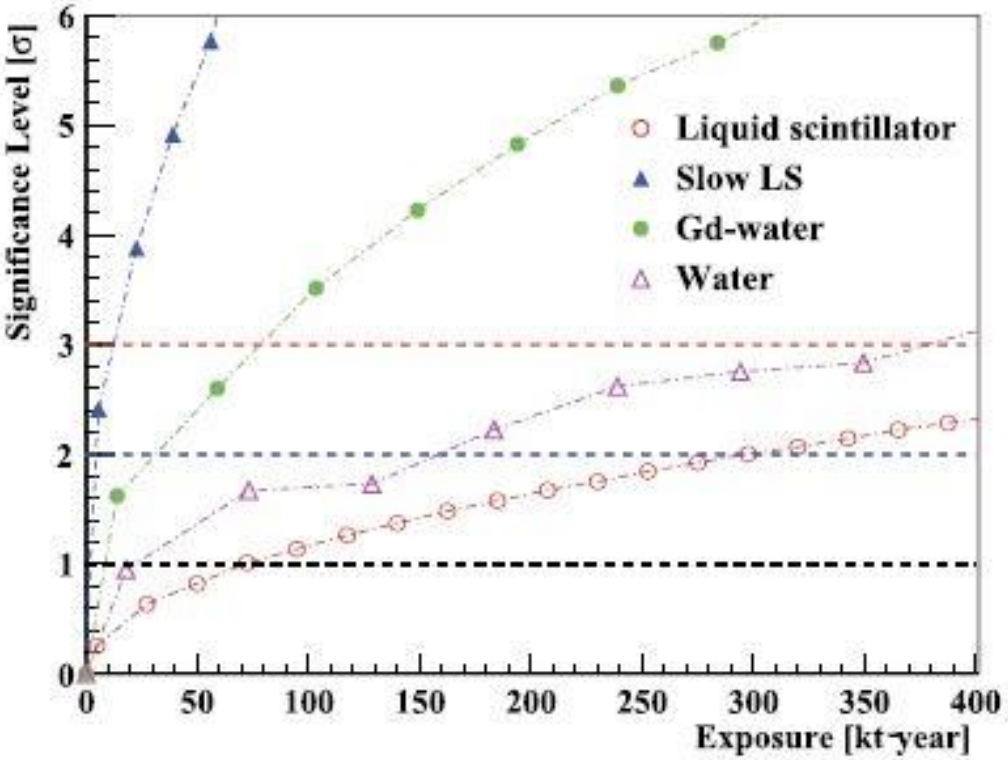


- U geo-neutrino spectrum
- Th geo-neutrino spectrum
- Ratio: $R(U/Th)_{IBD} = 0.26$
- Ratio be measured with 26.3% precision

- Signal to background ratio: 10:1 better than other experiment: 3:1
- Distinguish different BSE model

PHYSICAL REVIEW D 95, 053001 (2017)

Supernova Relic Neutrinos



Phys. Lett. B 769 (2017) 255-261

- Based on the ability of the separation of Cherenkov and scintillation lights in slow LS. Atmospheric neutrino CC and NC could be reduced obviously
- A Kilos-ton scale detector with slow LS has the sensitivity to make a discovery of SRN

10-year Sensitivity	Jinping (2k tons slow LS)	Super-K (20k tons Gd-water)
	3.5σ 10-30 MeV	3σ 15-30 MeV
Ignore cosmogenic muons and reactor neutrinos		4σ 10-30 MeV