清華大學
Tsinghua University

Prospects and Progress of the Jinping Neutrino Experiment （锦屏中微子实验）

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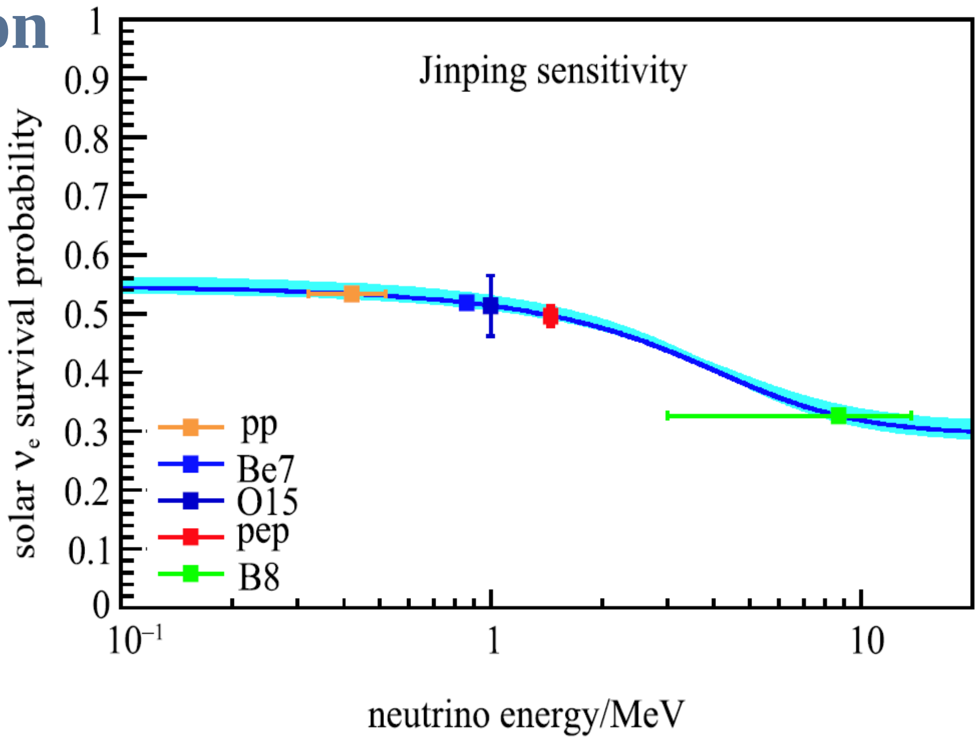
@ CCEPP-2017

Interests in solar, supernova, and geo neutrinos

Solar Neutrino Physics

1. **Precise solar neutrino flux and spectrum measurement of almost all components**

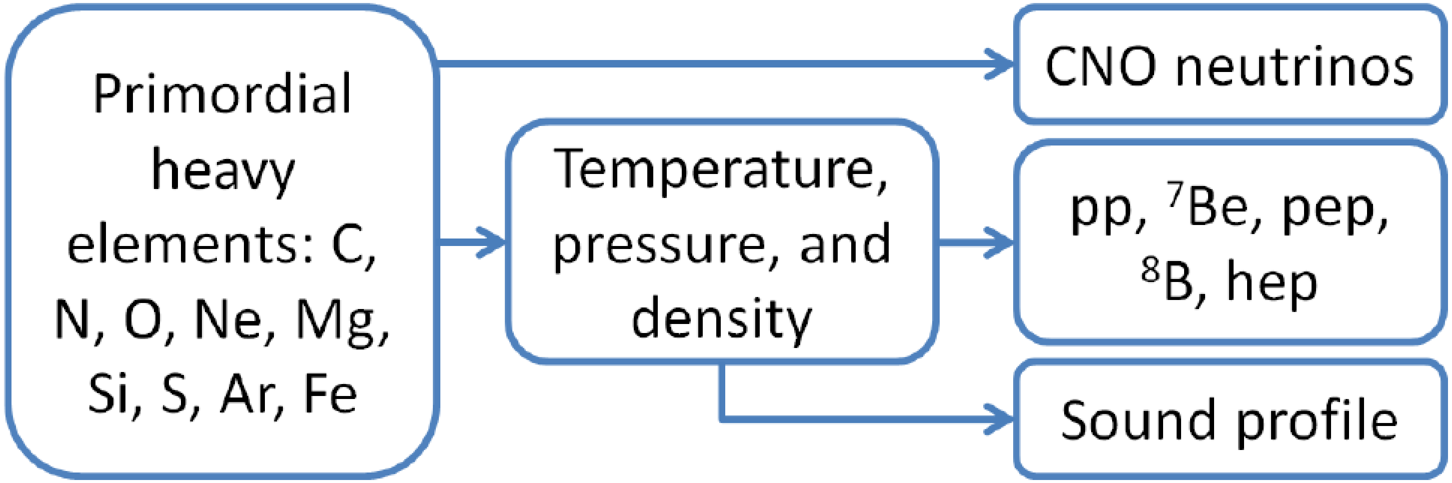
- Solar neutrino oscillation
  * mixing parameters
  * oscillation upturn
- Test standard solar model
- New physics
  * sterile
  * NSI



Solar Neutrino Physics

2. Discover CNO neutrinos

- Missing CNO fusion evidence from the SUN
- CNO cycle – main fusion process of other massive stars
- A direct probe of solar core metallicity
  * Attack solar high/low metallicity problem, resolve degeneracy, use for standard calibration
  * Test homogeneous assumption of primordial star



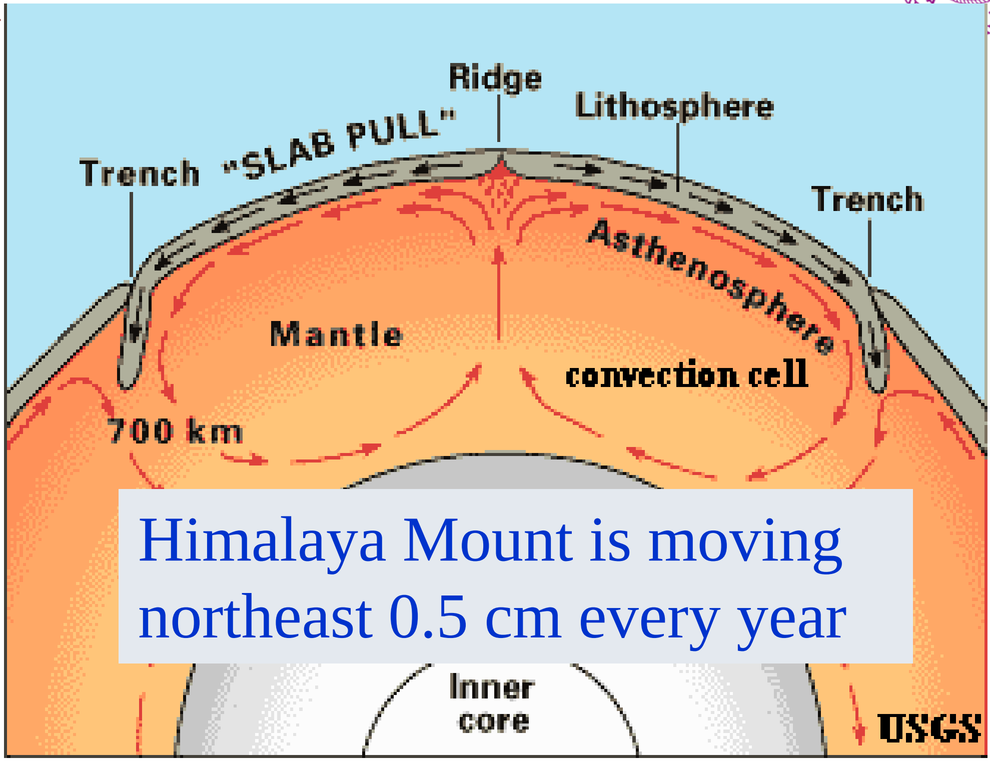
Geoneutrinos

Diving power

- Initial gravity
- Nuclear power, U, Th, K decay

Knowledge:

- Global heat measurement 47±3 TW
- Theoretical predictions：
  - Low range 10 TW
  - Middle range15-30 TW
  - High range 20 TW
- Geoneutrinos from U, Th: 10-30 TW



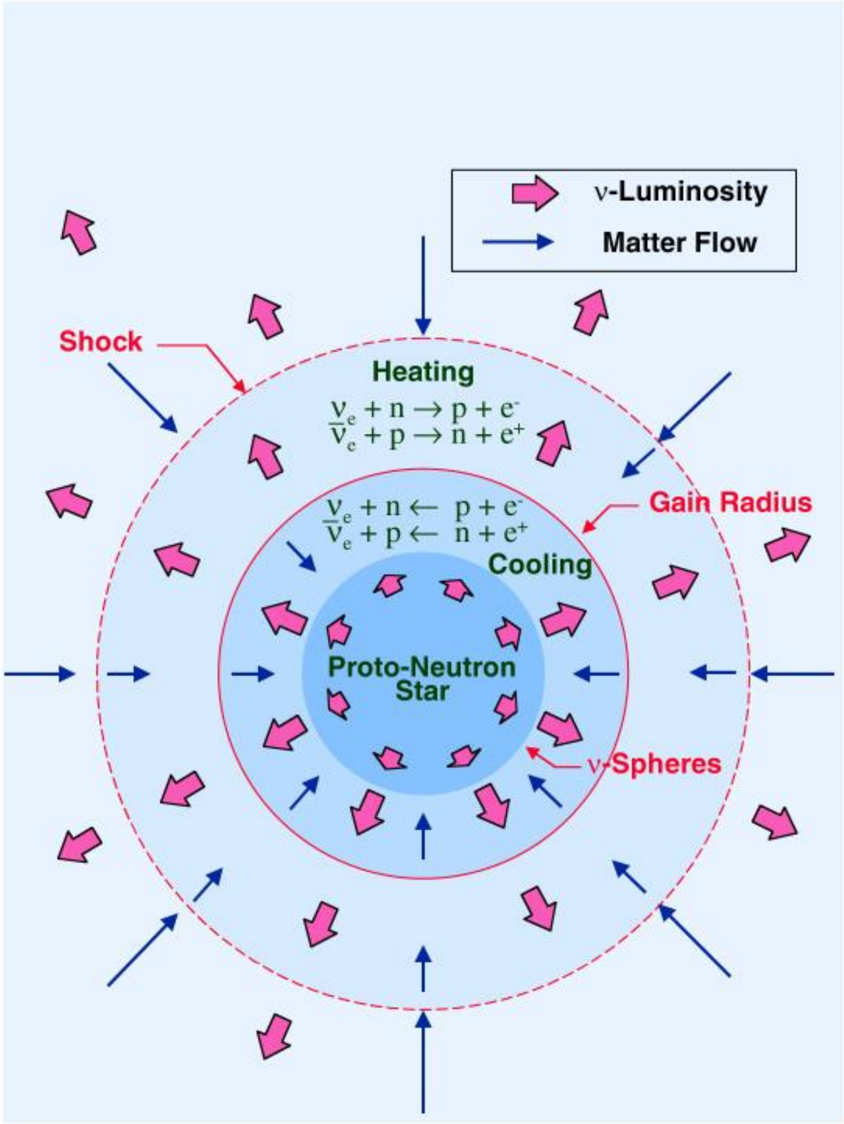
Himalaya Mount is moving northeast 0.5 cm every year

- Still consuming initial gravitational power
- Need more measurement of mantle neutrinos

Supernova relic neutrinos

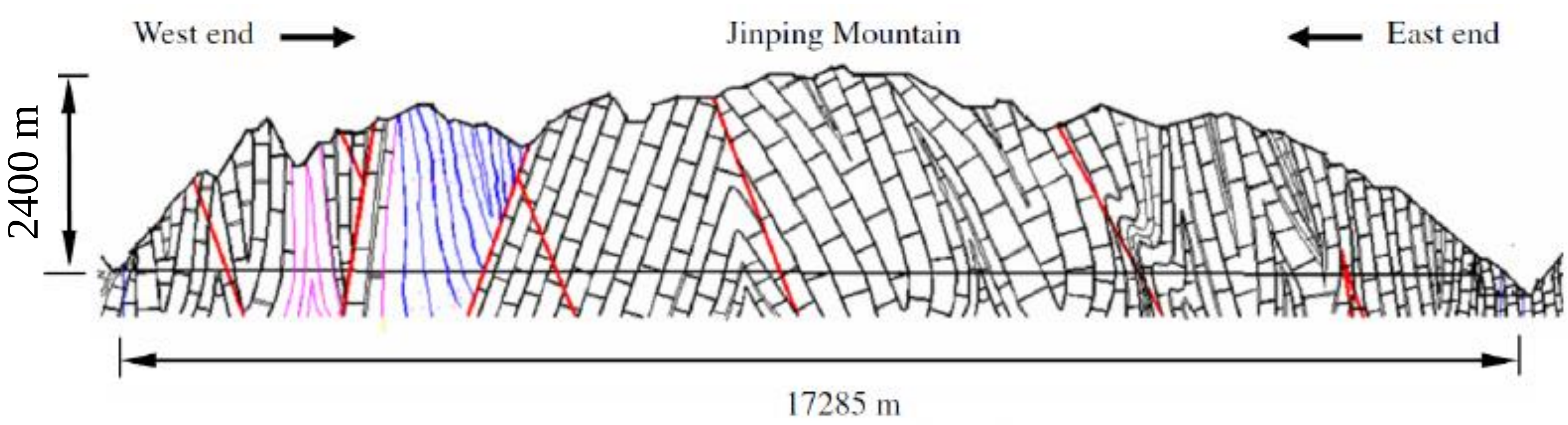
1. Supernova burst neutrino:
   1987a supernova neutrinos were observed
   Rate ~a few/century
2. Diffused supernova neutrino background
   Accumulated background from far distance and time

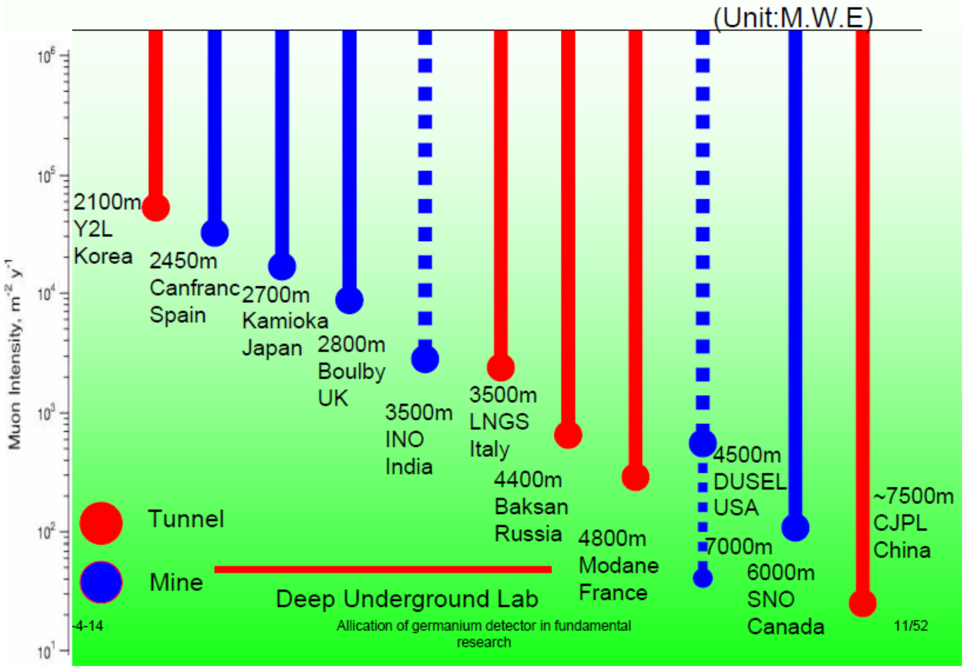
- <u>SRN: A finger print (rate and spectrum) of star formation rate and star evolution mechanism.</u>



Jinping Laboratory

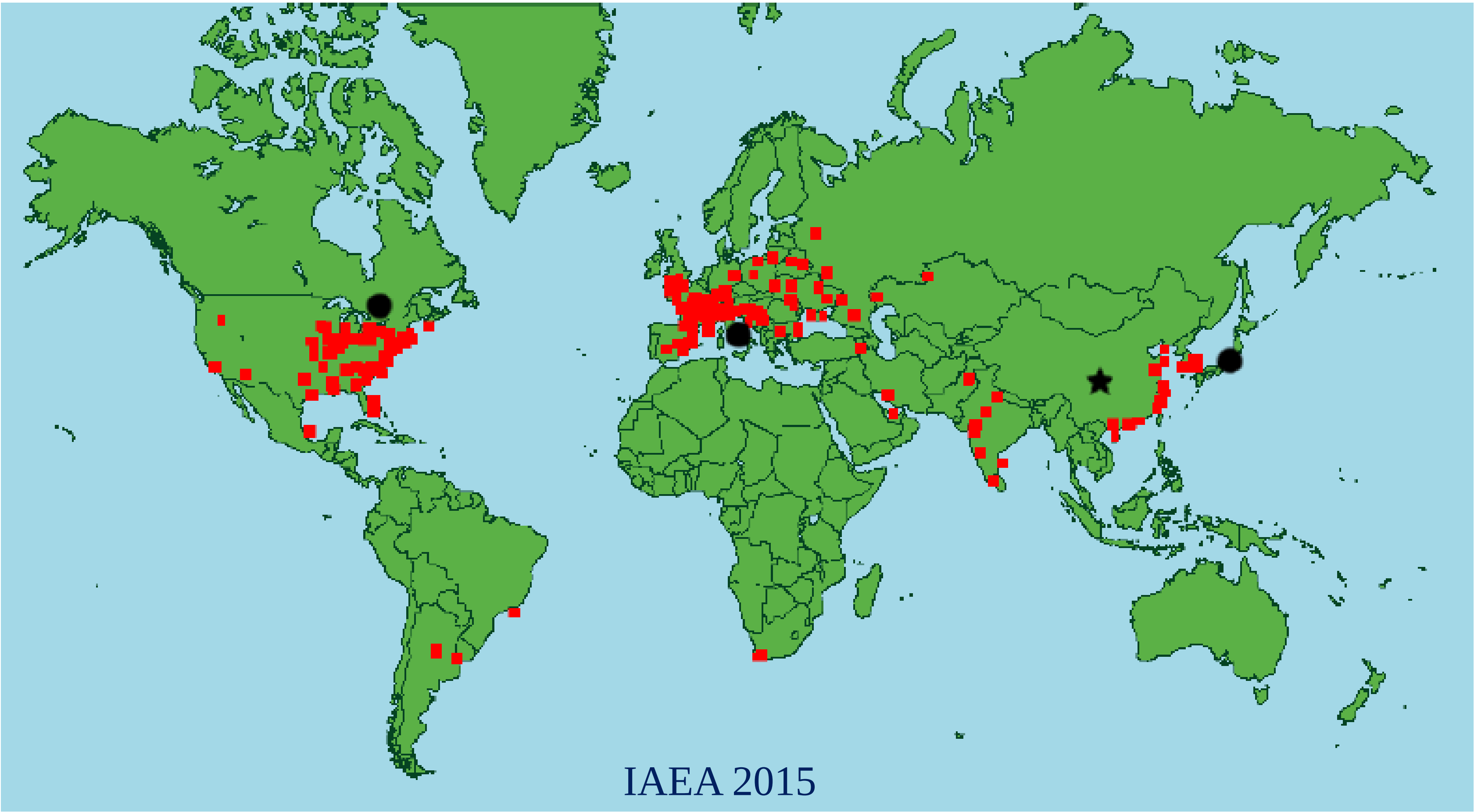
Depth and Muon Flux





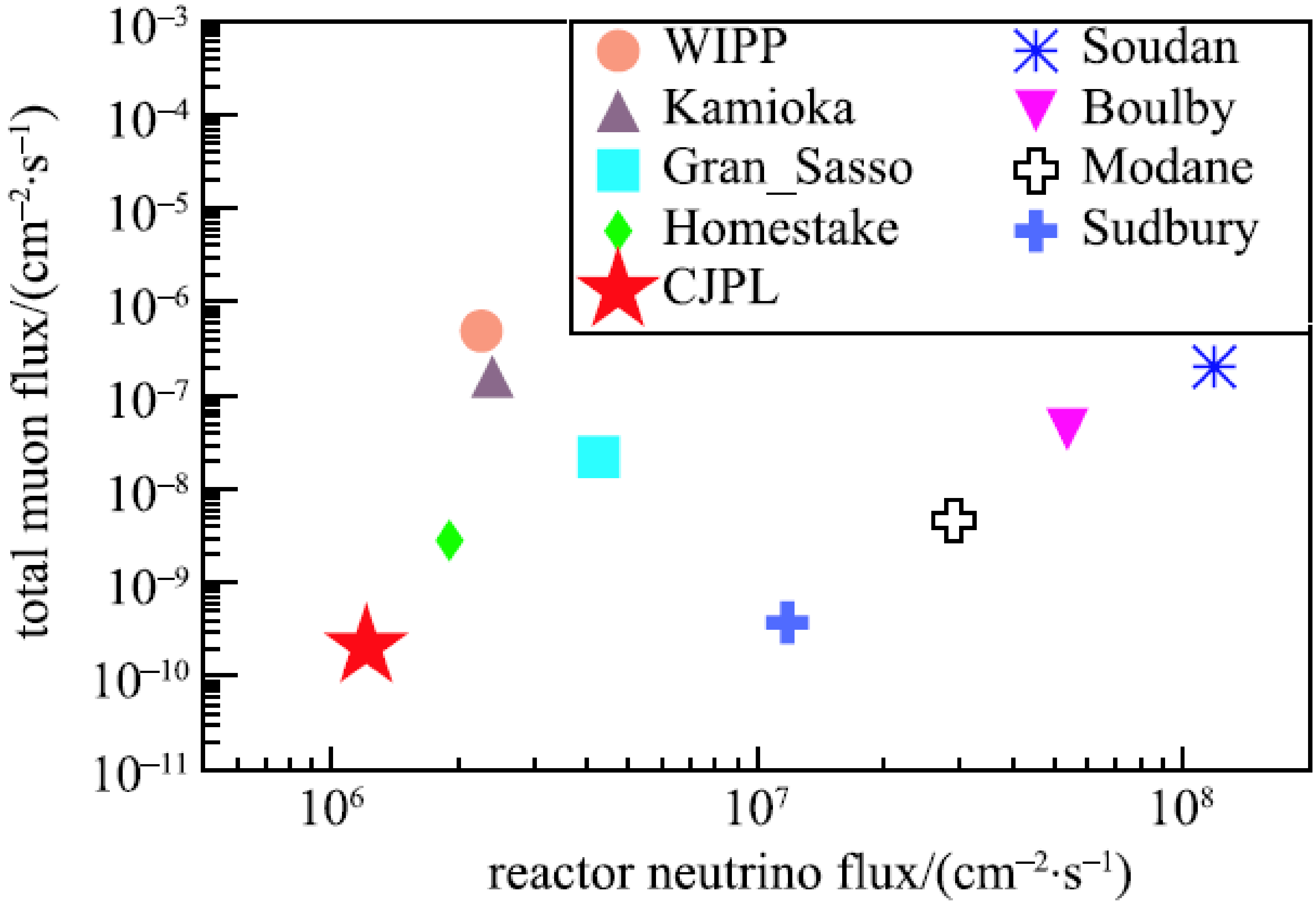
2400 m underground
Muon and related background
- 1/200 of LNGS
- 1/2 of SNOLAB

Reactor Neutrino Background



Closest reactor 1200 km

An ideal site for low background neutrino Exp.



Jinping Neutrino Experiment Proposal

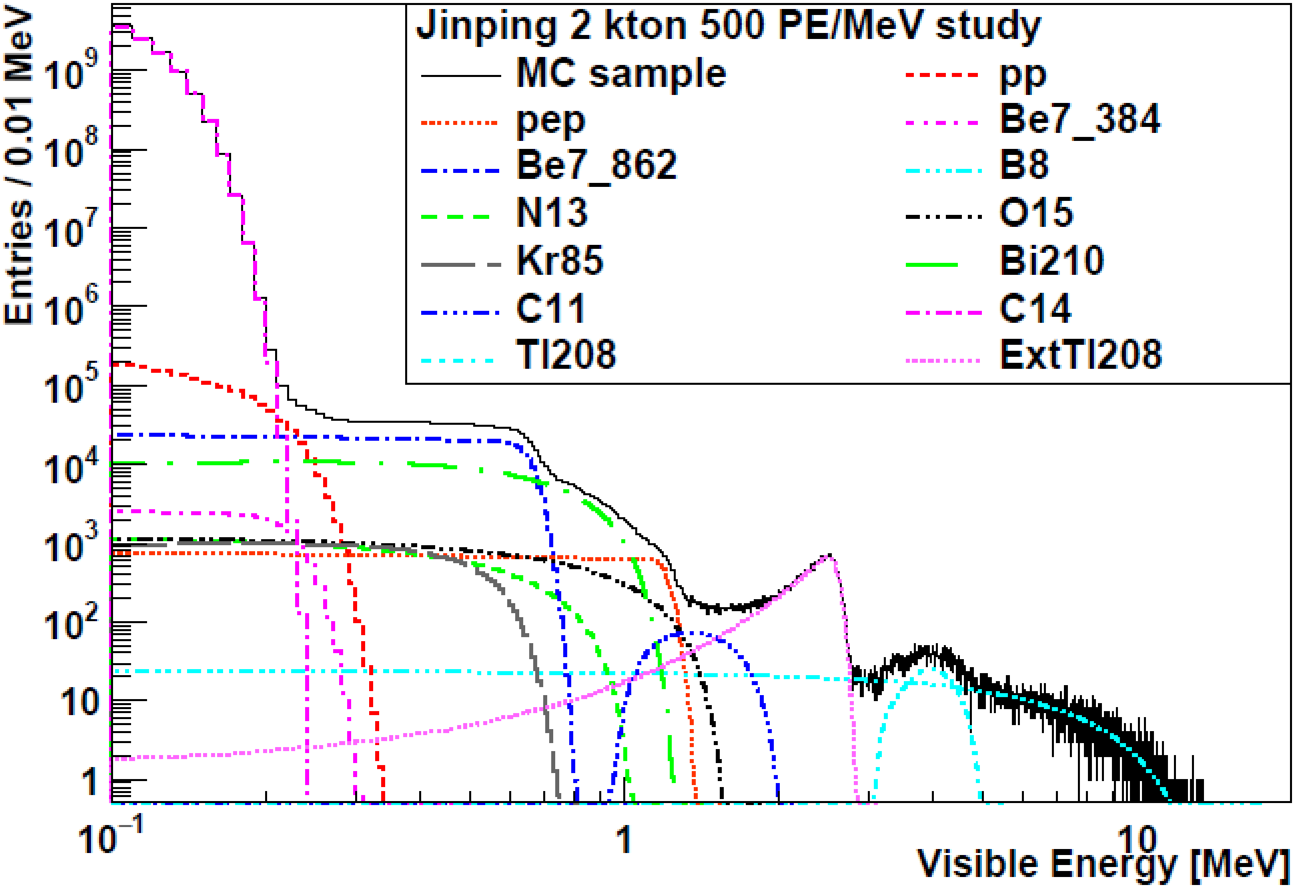
Jinping Neutrino Experiment Proposal

With 2 kton fiducial mass for solar neutrino (equivalently 3 kton for geo and supernova relic neutrinos)

1. Discover CNO neutrinos
2. Solar ν oscillation
3. Precise geoneutrino flux measurement and U/Th ratio
4. Study SRN

Proposal published: Chinese Physics C 41 (2017) 023002, Highlight

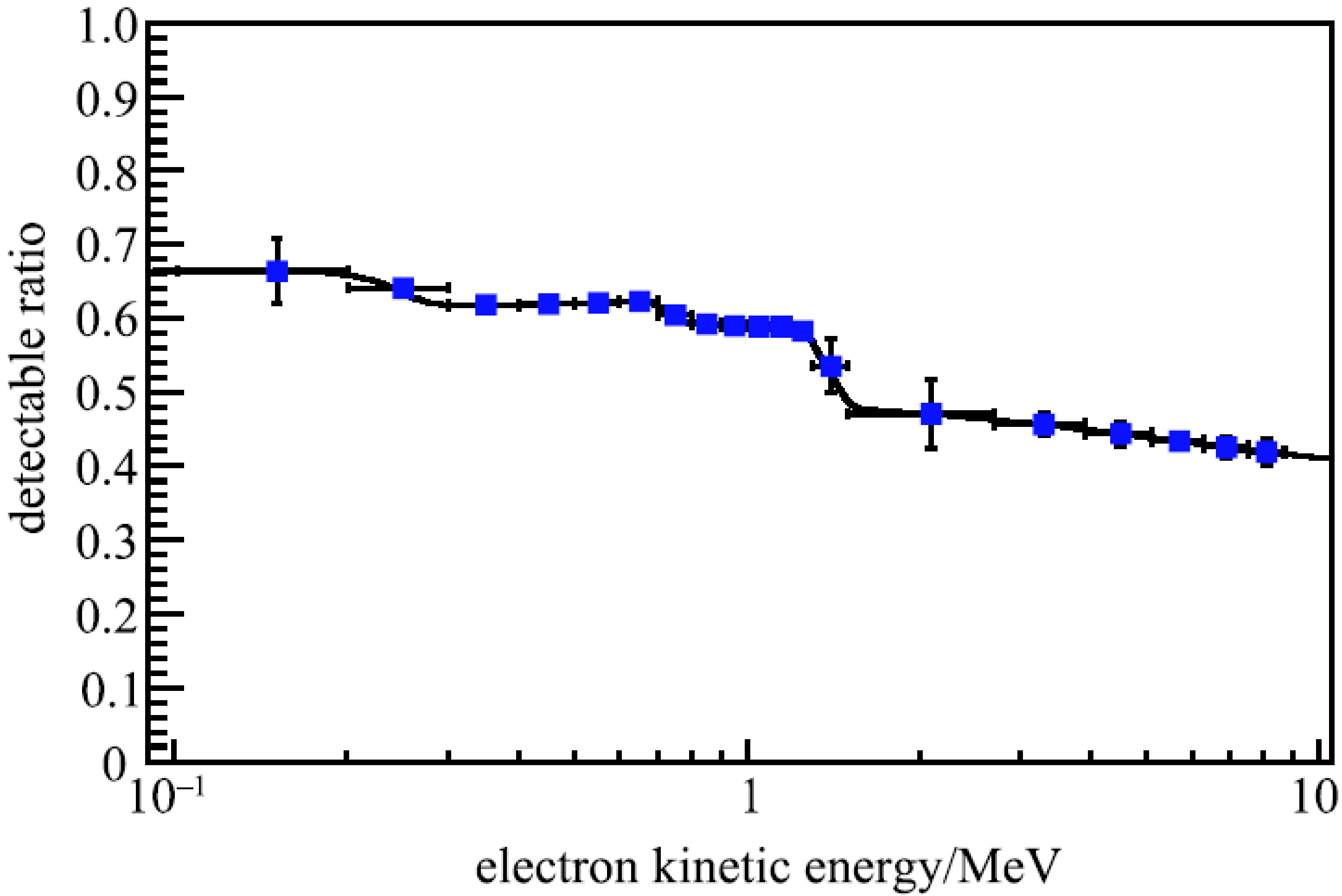
Solar Neutrinos



Simulation study with Borexino and Jinping assumptions.

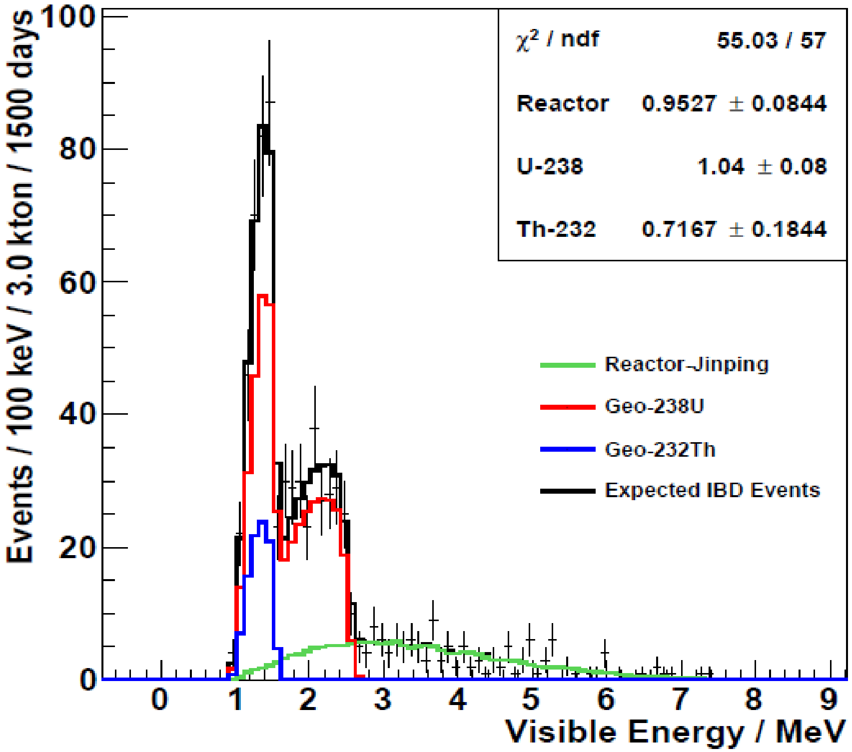
O-15 flux precision 10%

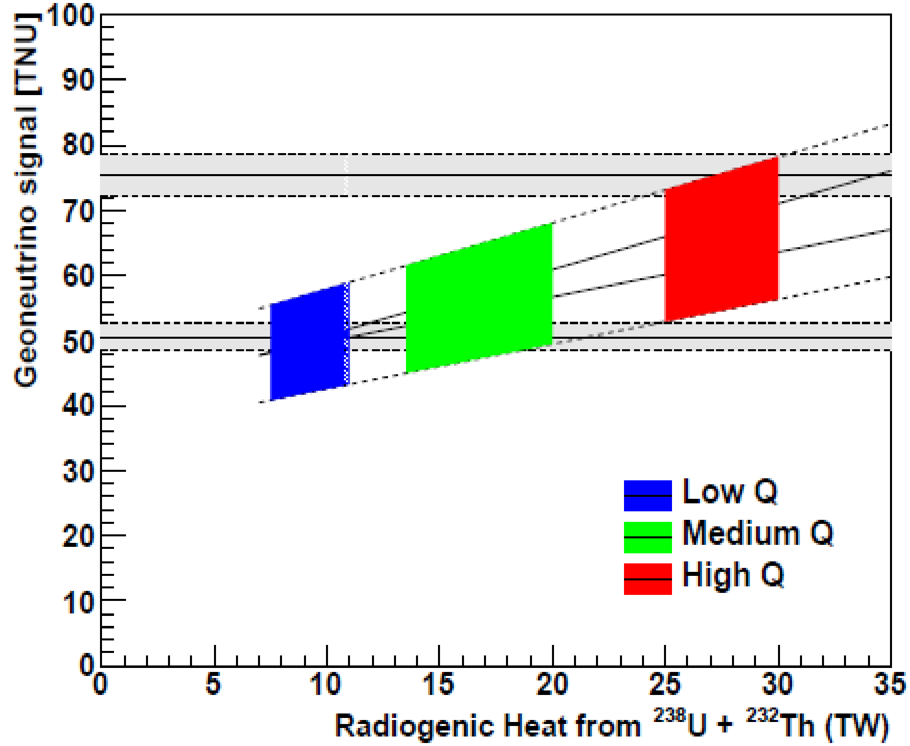
Solar Neutrinos



Constrain oscillation upturn

Geoneutrinos



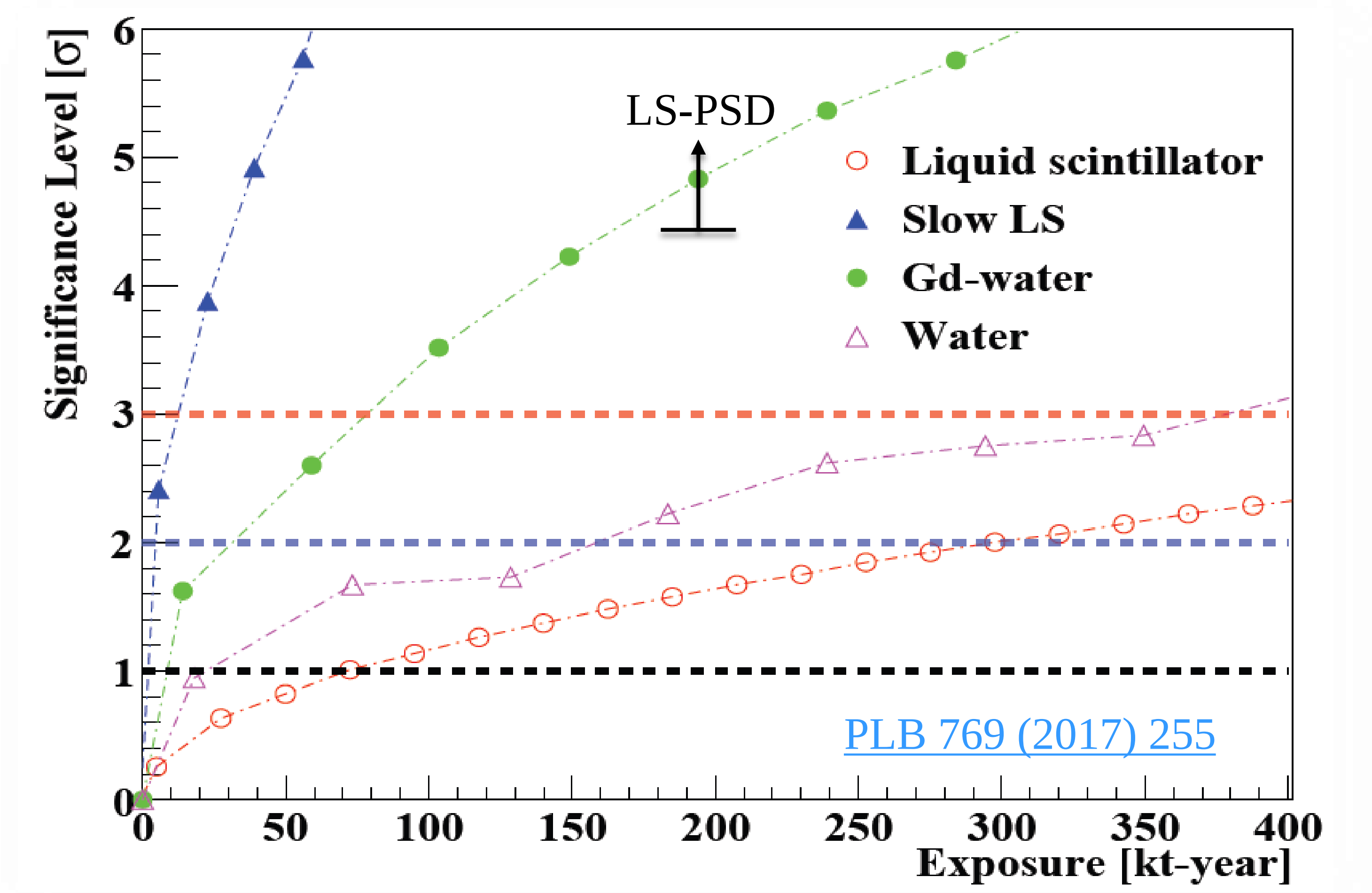


- U geoneutrino spectrum
- Th geoneutrino spectrum
- Th/U ratio ~ 25%
- Geo-reactor

- Address mantel contribution
- Geoneutrino flux prediction at Jinping

Phys. Rev. D 95 (2017), 053001 and Sci. Rep. 6, 33034 (2016)

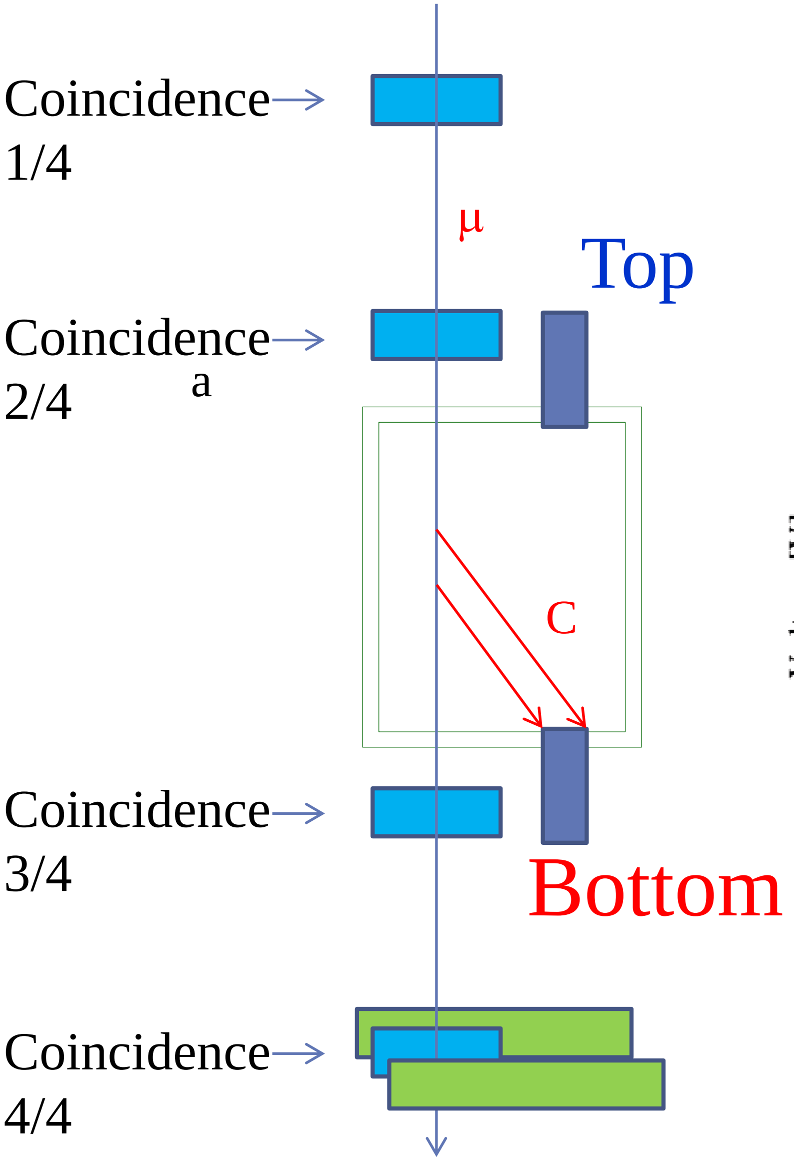
SRN with LS Cherenkov Detector



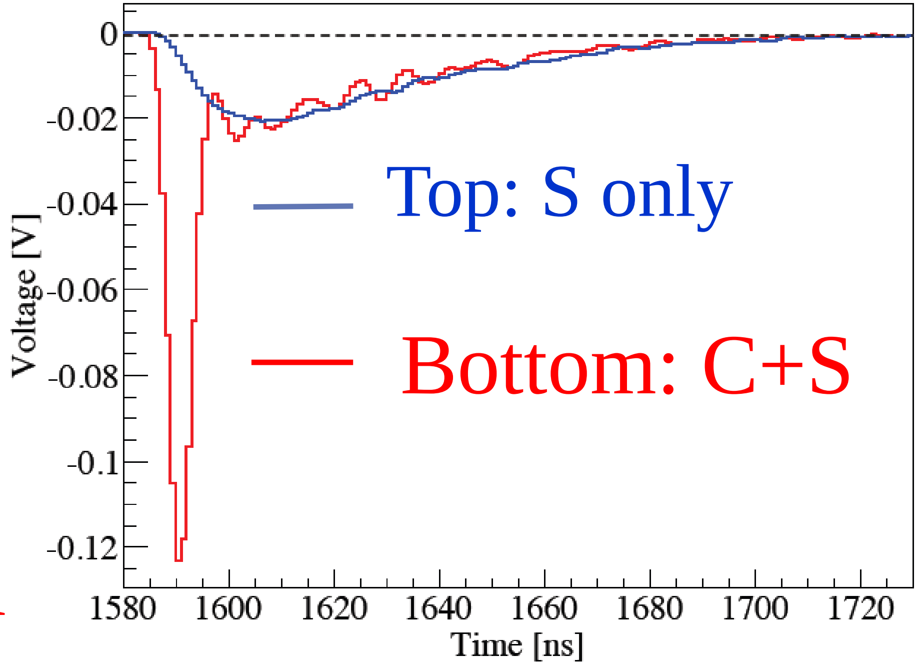
- 15 kton-year for a discovery with Slow LS

R&D Effort

Slow liquid scintillator

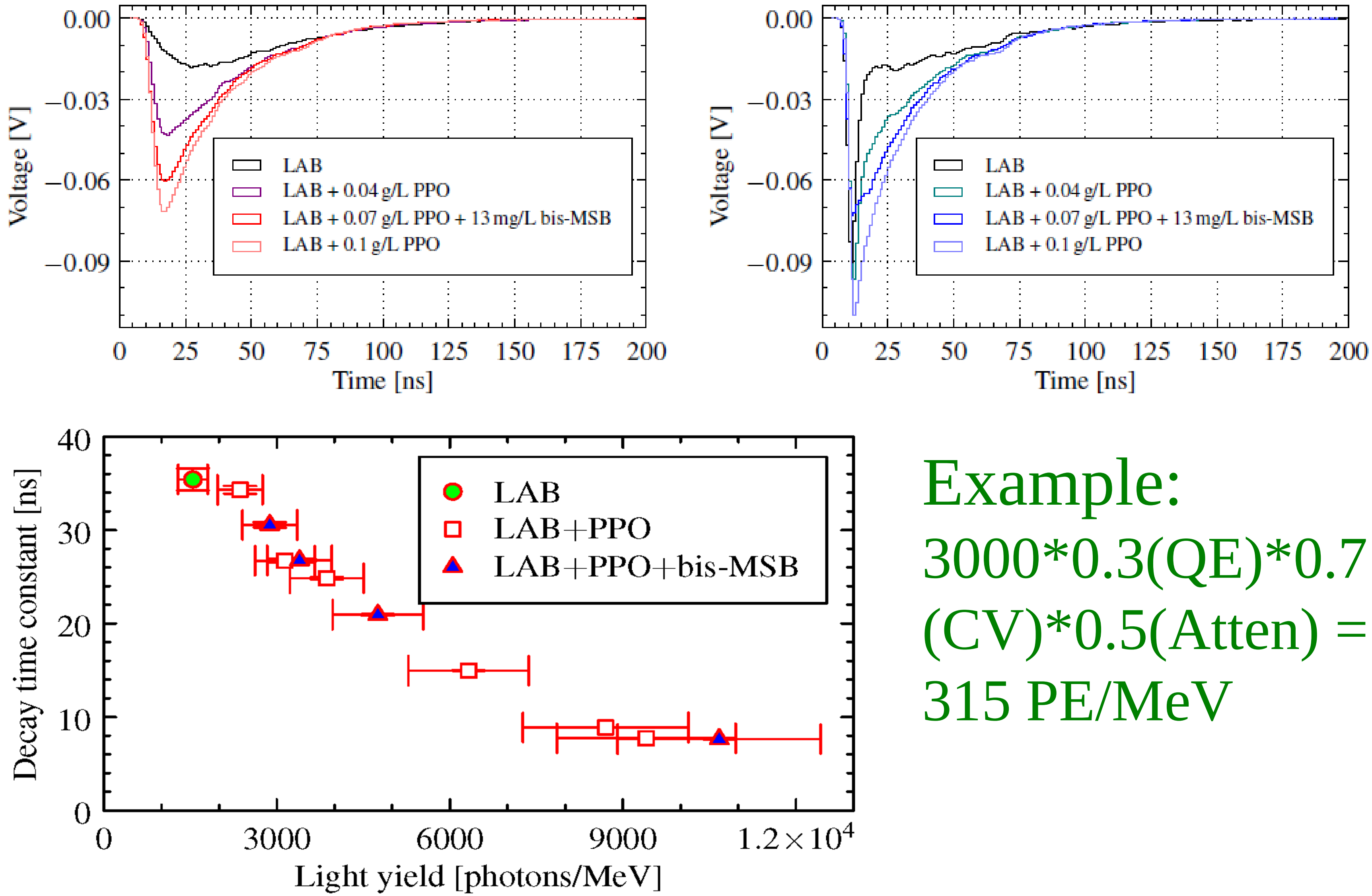


Waveforms of top and bottom PMTs in LAB



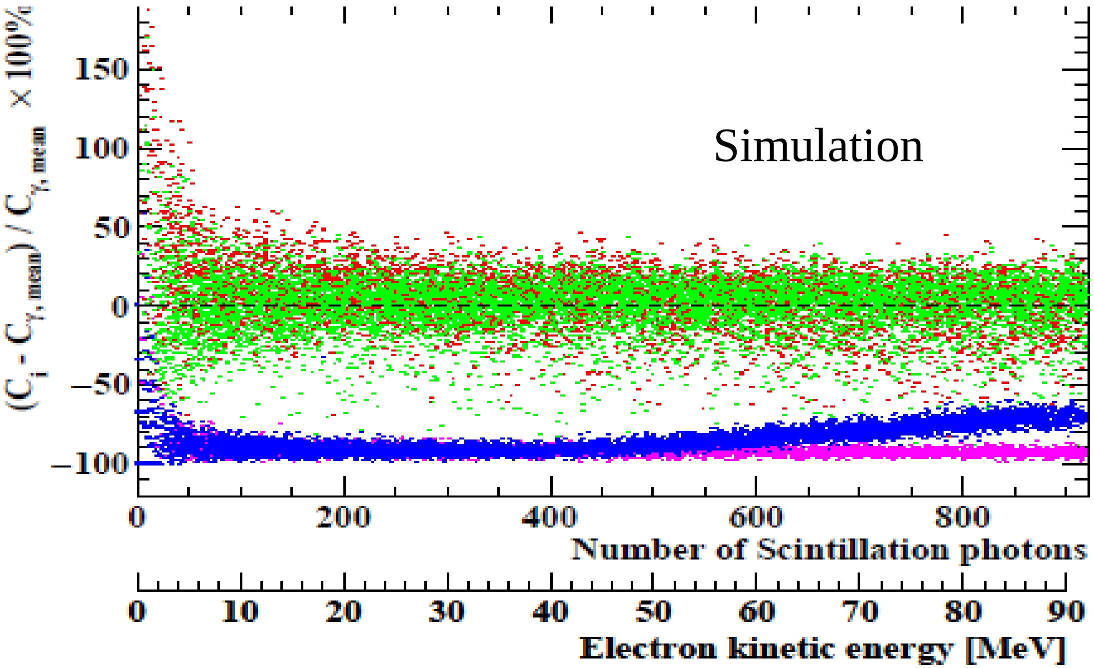
NIM A 830 (2016) 303
and arXiv:1708.07781

High light yield and Cherenkov separation



Example:
3000*0.3(QE)*0.7 (CV)*0.5(Atten) = 315 PE/MeV

Liquid Scintillator Cherenkov Detector

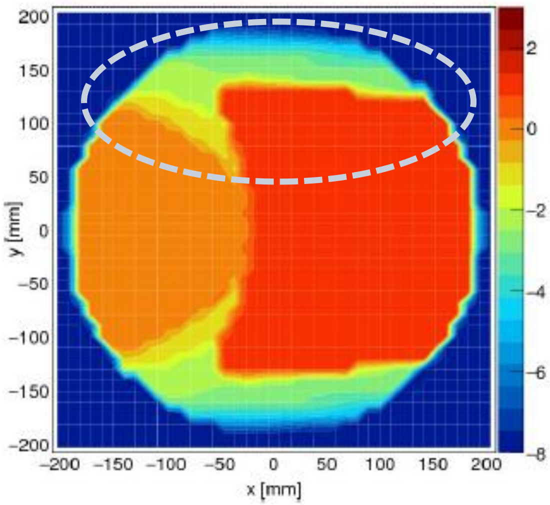


- Distinguish Cherenkov and scintillation light
- Reasonable light yield 3000 photons/MeV
- Directionality (> 5MeV)
- Particle identification (mainly for electron, muon, proton, minor effect for gamma and positron)

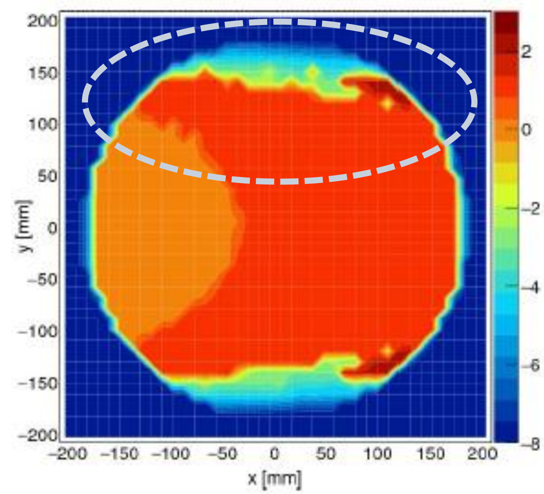
Improve PMT coverage to 100% and improve efficiency

- We add two more ideas to the String Method [ArXiv:1703.07527]

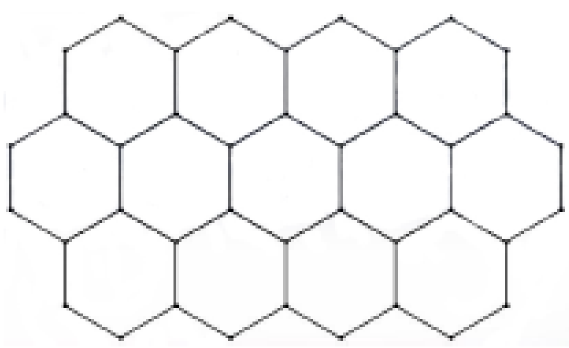
1. Consider the 3D geometry profile of PMT

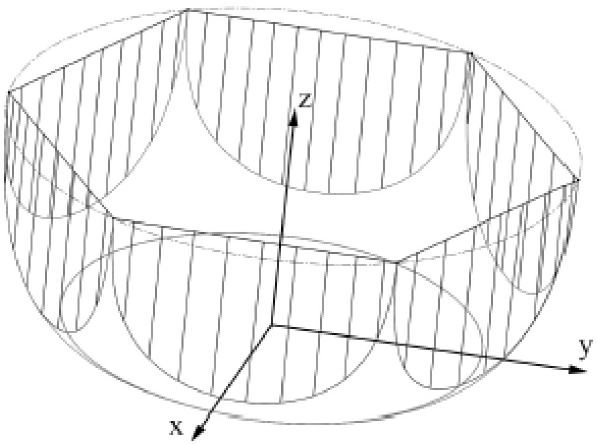


More light accepted

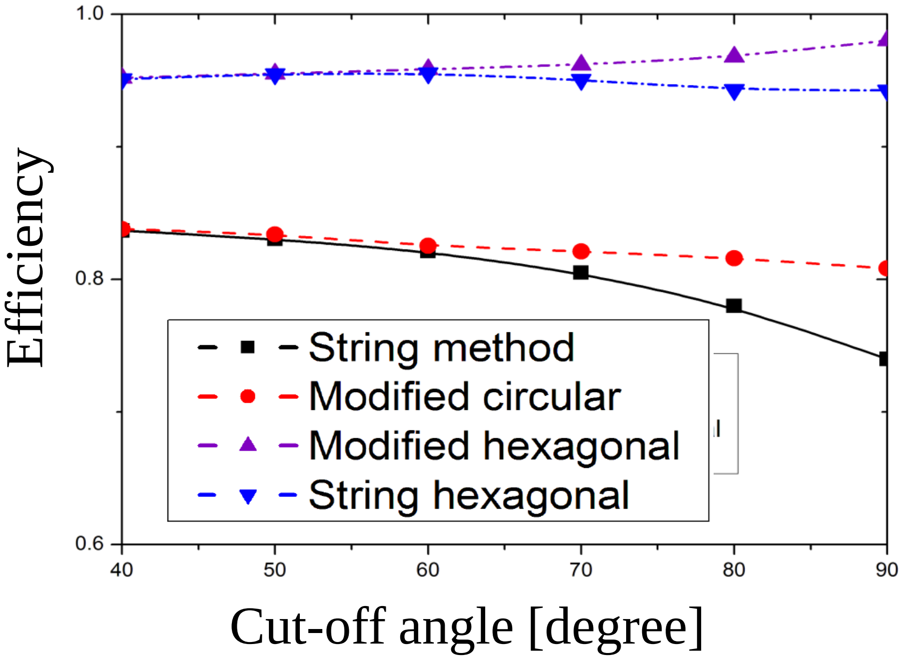


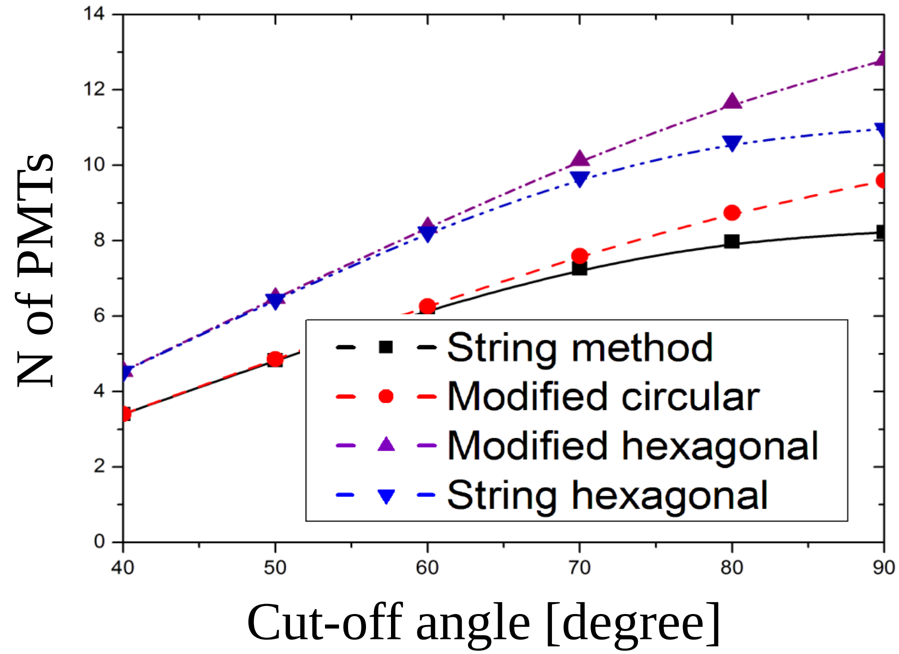
2. Use hexagonal opening





Geometry acceptance and numbers





90º Cut-off	Photo cathode Coverage	Collection efficiency	N of PMT (m^{-2})
No reflector	91%	100%	14.73
Modified hexagonal	100%	97%	11.65

Low background SST by smelting process

Analyzed by GDMS (1E-9 g/g), HPGe-groud (Bq/Kg), HPGe-Jinping (mBq/Kg)

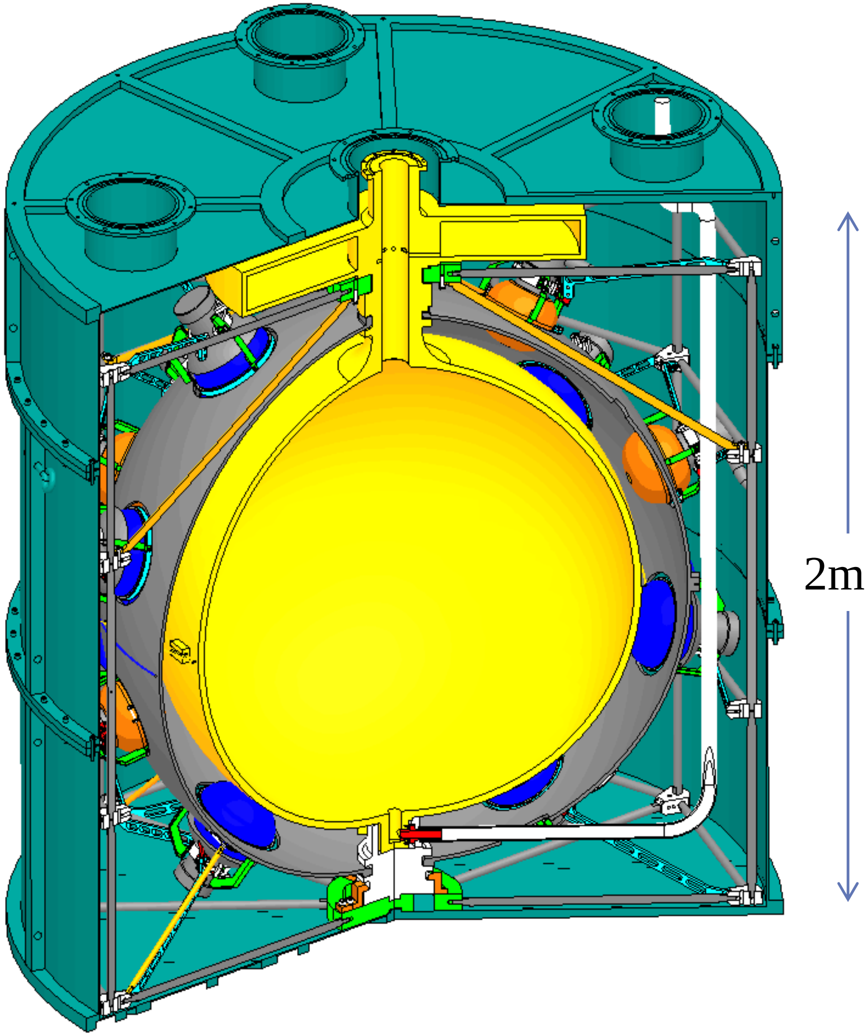
1. C, Si, MgO sand: have a significant radioactivity
2. S, P: harmful to SST
3. Mn is not 100% necessary
4. Settle down on Fe, Cr, Ni (304L), Mo (316L)
5. Small impact from MgO crucible

Our sample has reached a comparable level of Borexino.

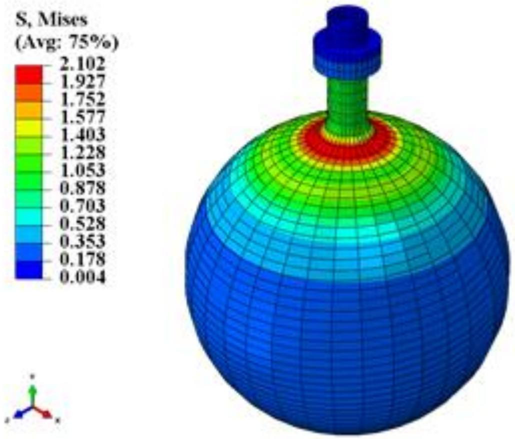
A 1-ton prototype at Jinping

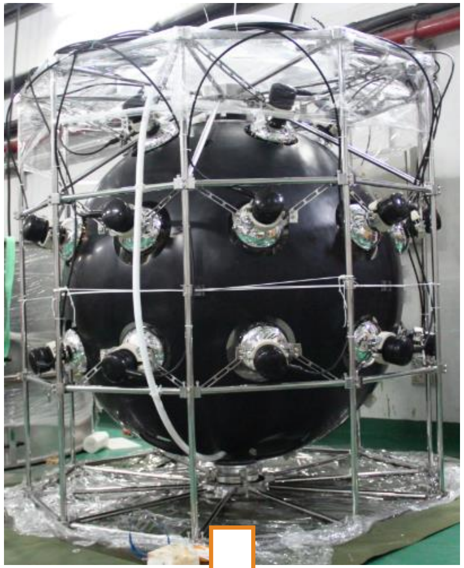
1. **Measure fast neutron background**
2. **Test detection material: water, LS, and slow LS**
3. **A low bkg. facility**
4. **Reconstruction**

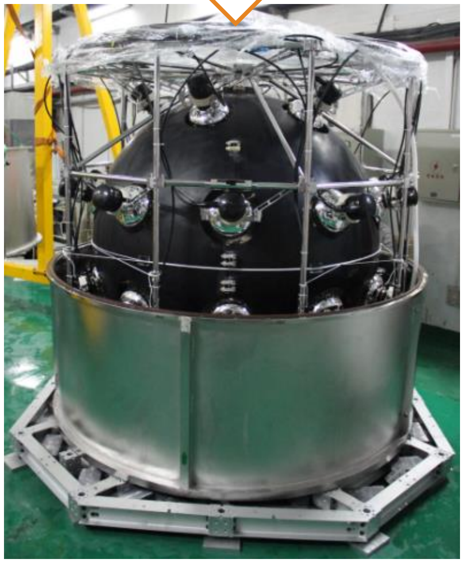
Thirty 8" PMTs
FADC 10 bit 1GS/s
Transparent acrylic vessel
=> Inside: 1ton for LS
=> Water outside
Whole detector: lead shielding



Design and installation





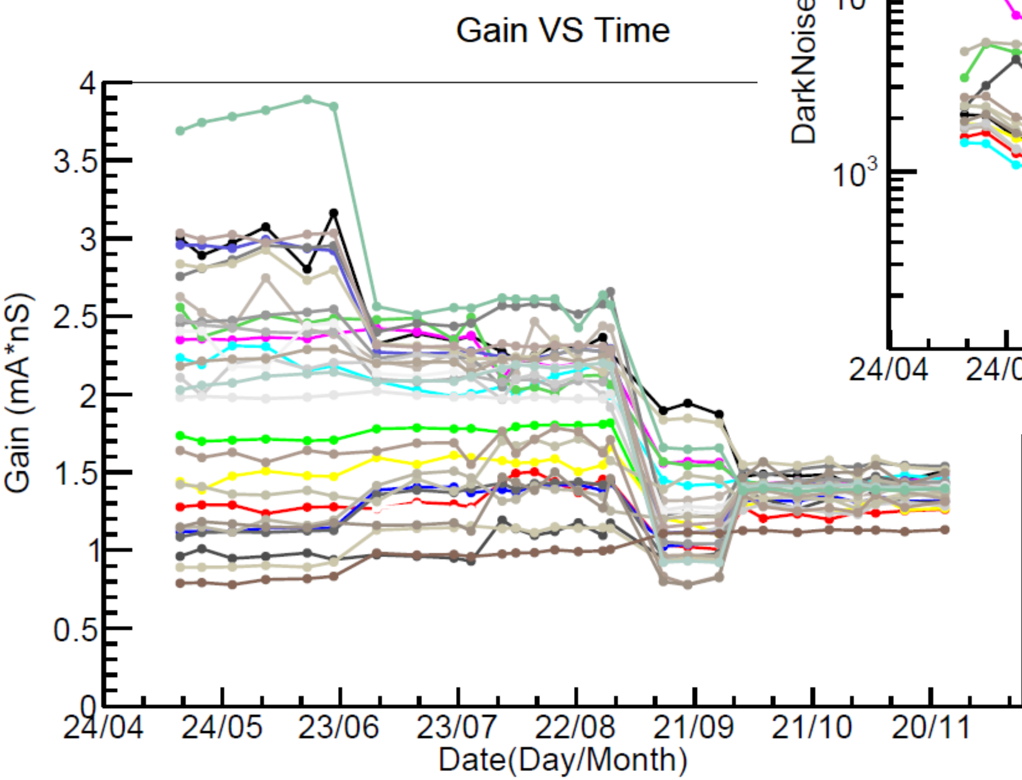


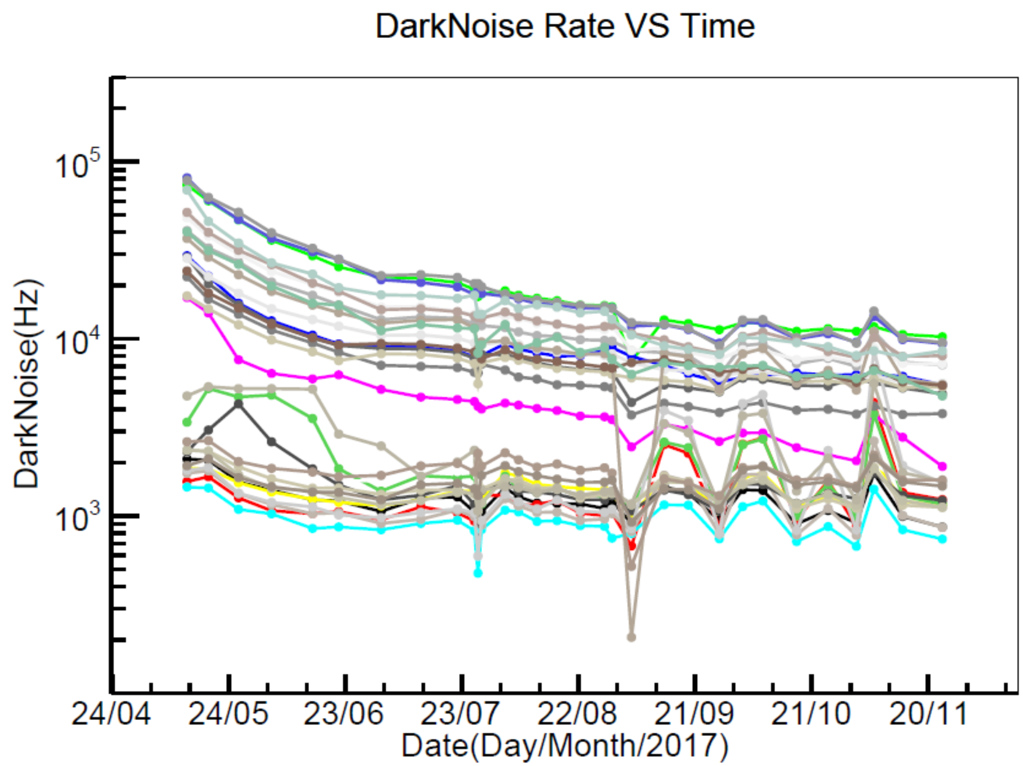
A 1-ton prototype at Jinping

Since May 10, 2017, taking data with pure water inside.
Now taking data with a liquid scintillator sample.

One-ton prototype at CJPL-I

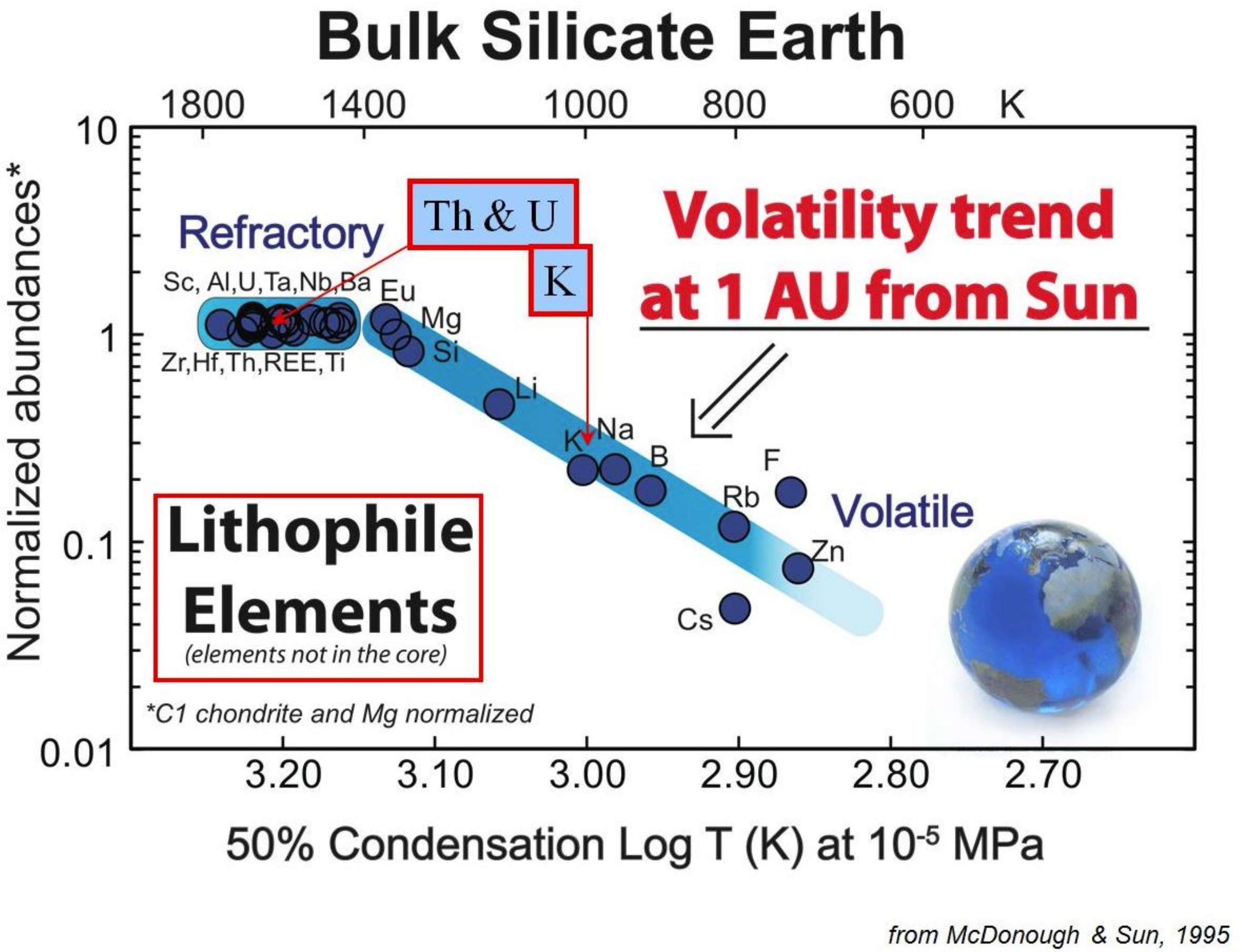
1. **Understand the detector**
2. **More results are coming**





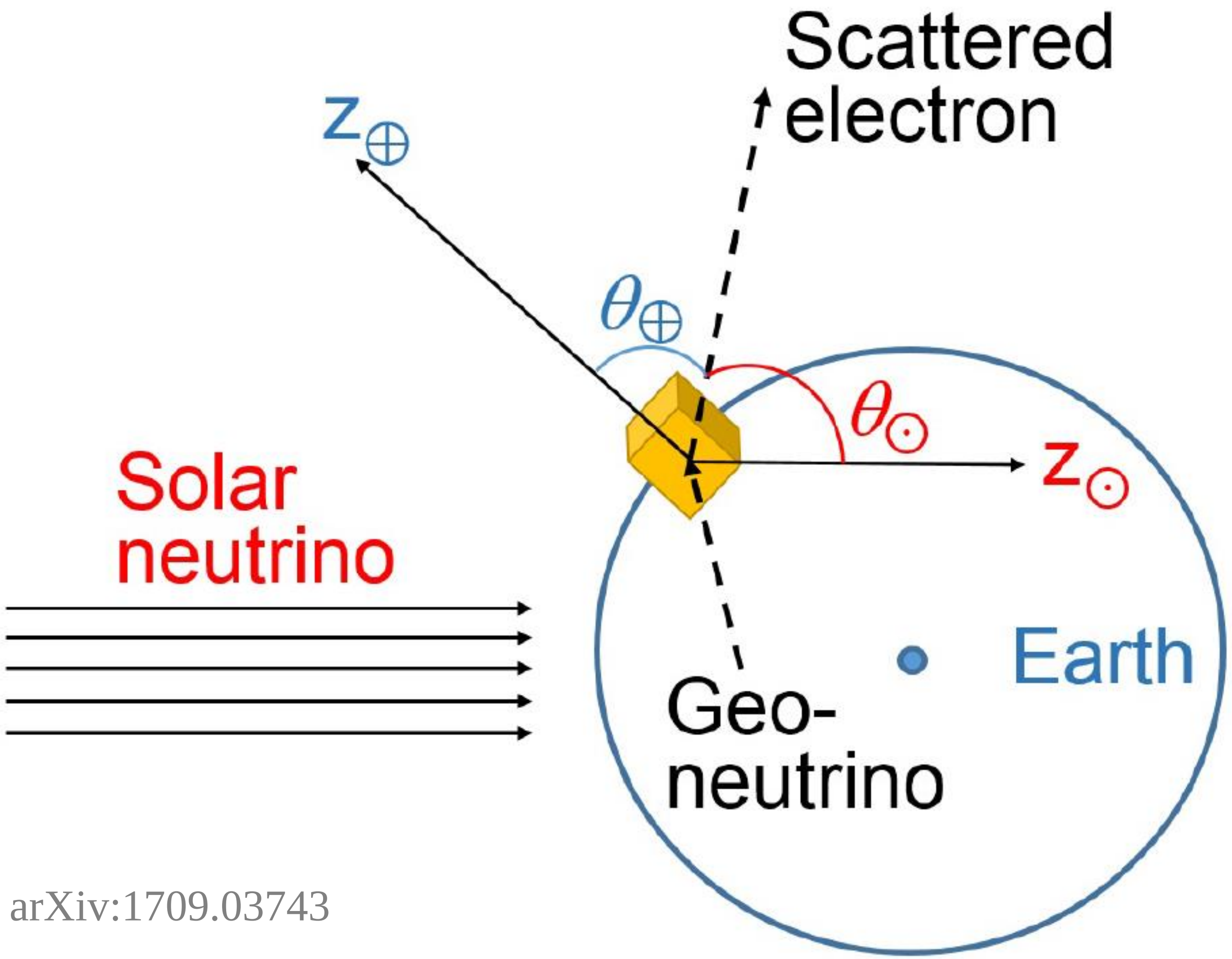
More wild idea about geo neutrino detection

Volatile elements on the Earh



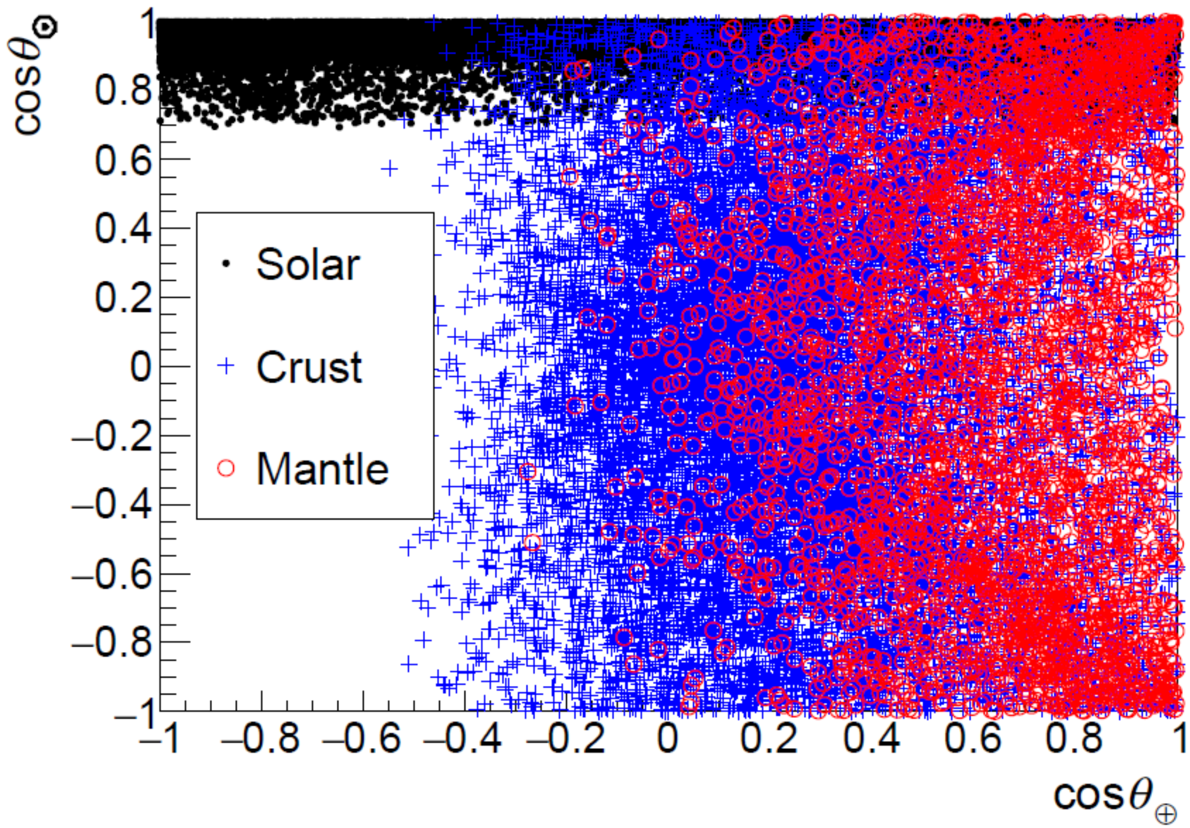
- Need more measurement of K40 geoneutrinos to finish the picture

Reveal K-40 and mantle geo neutrinos



arXiv:1709.03743

Suppression of solar neutrino background

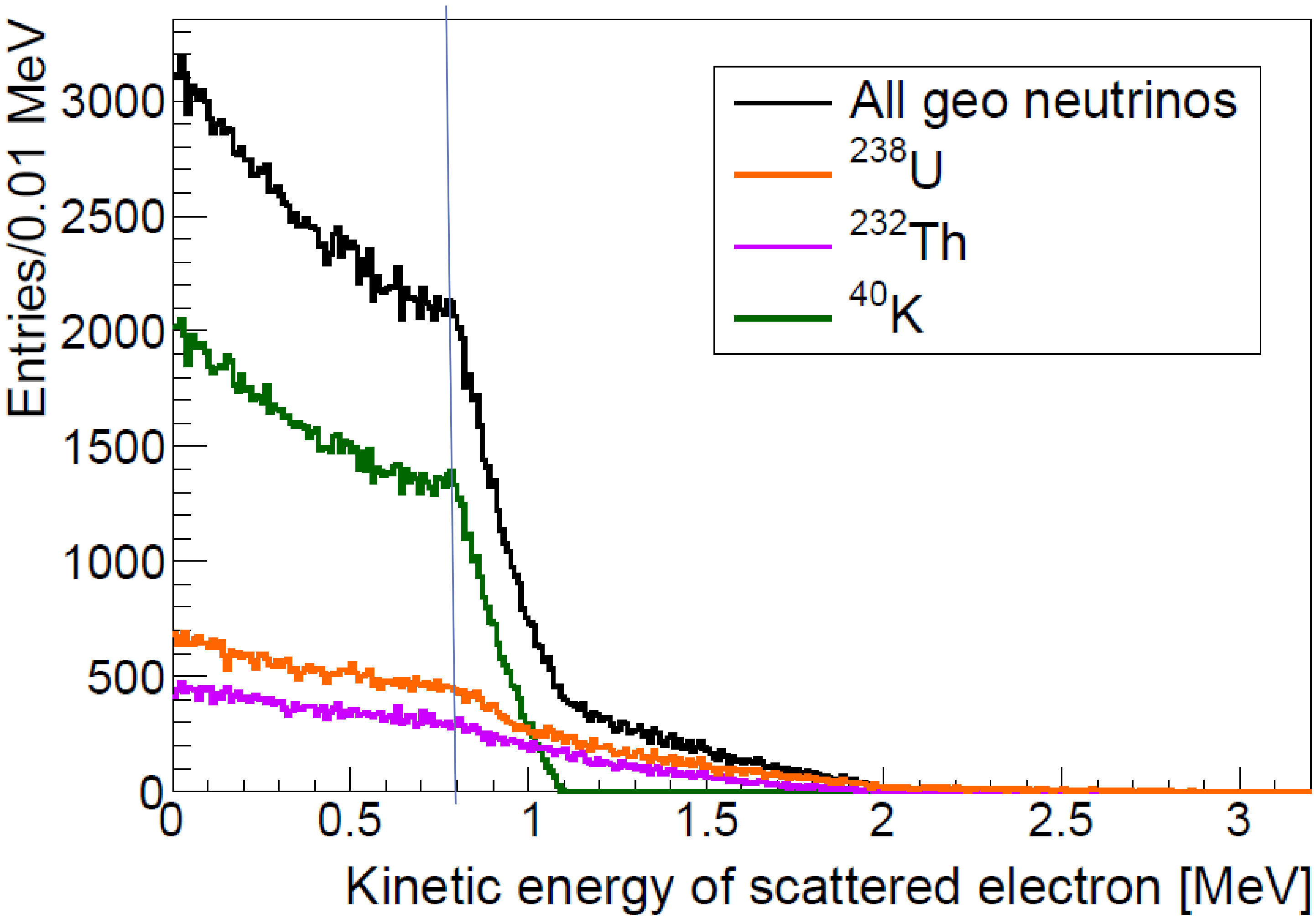


With Te>0.8, solar and geo neutrinos are in different groups.

Liquid Scintillator Cherenkov Detector may play an interesting role

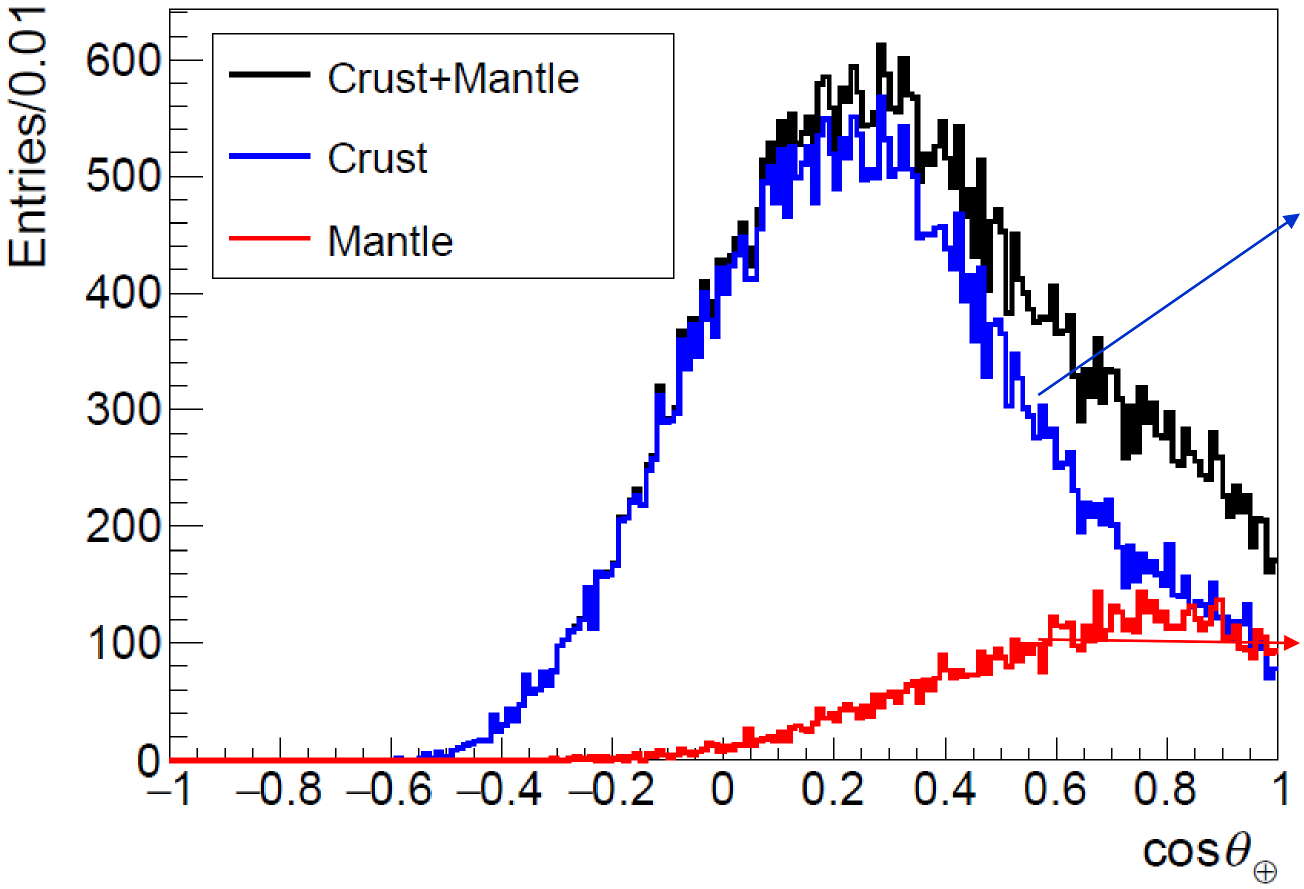
ArXiv:1709.03743

Distinguish K-40 neutrinos



At 0.8 MeV, K-40 dominant, distinguishable structure

Mantle and crust neutrinos



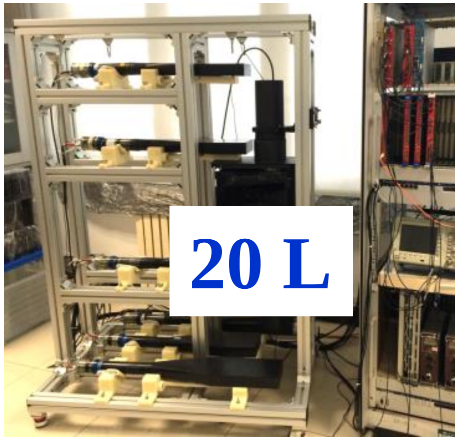
Distribution determined by crust shell structure

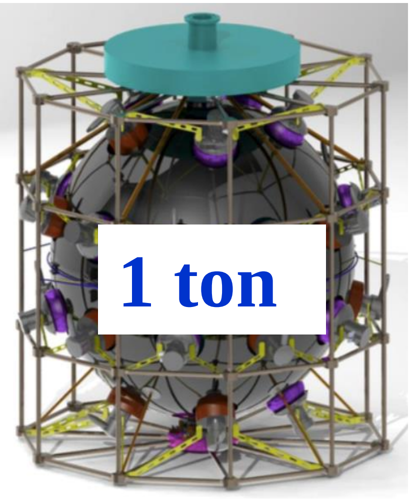
Mantle structure, from underneath

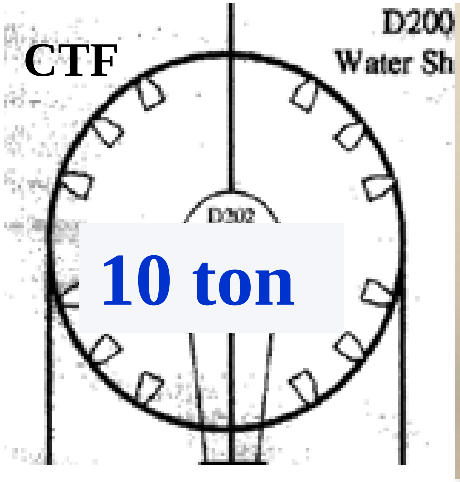
Distinguish mantle from crust components by spectrum fitting.

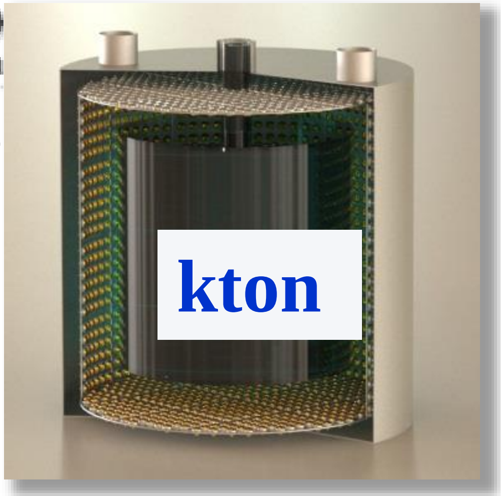
Next step

Plan





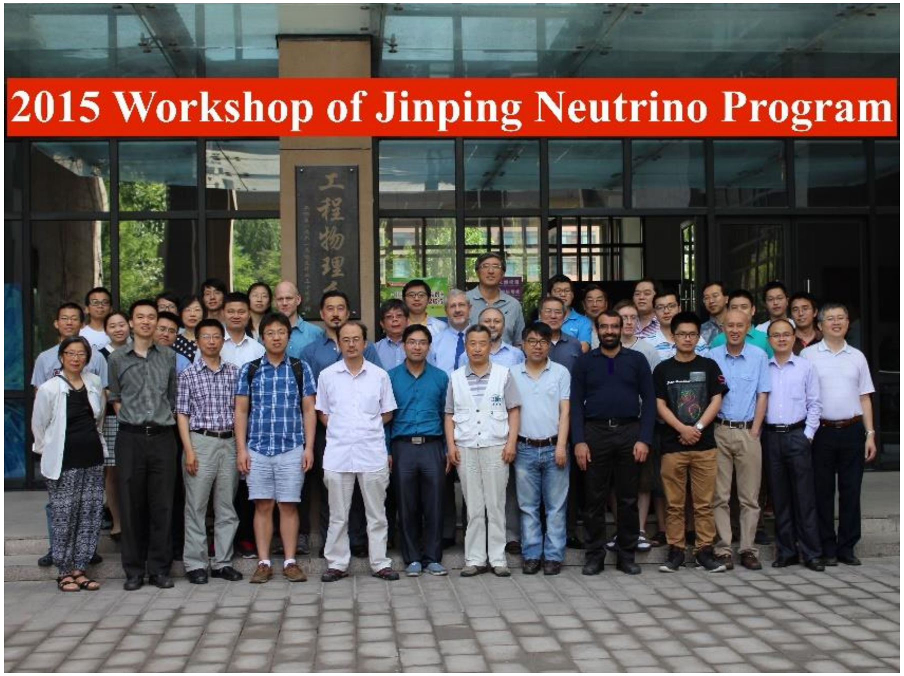




1. A ~10-ton prototype will be build next for testing the final plan for PMT, liquid scintillator, structure etc.
2. More studies on Jinping neutrino physics.
3. kton detector is in the future

Workshop and research group

2015, 2017 two international workshops



Conclusion

- Basic questions for solar, geo, and supernova relic neutrino detections are unsolved.
- CJPL is ideal for these studies. Jinping Neutrino Experiment proposal
- Many R&D efforts: Reflector, low background SST, 1-ton prototype, liquid Cherenkov scintillator (acrylic strength, Electro-magnetic function, etc. not mentioned
- More thoughts on SRN and geo neutrinos
- A 10-ton prototype is in plan

More details can be found at http://jinping.hep.tsinghua.edu.cn/

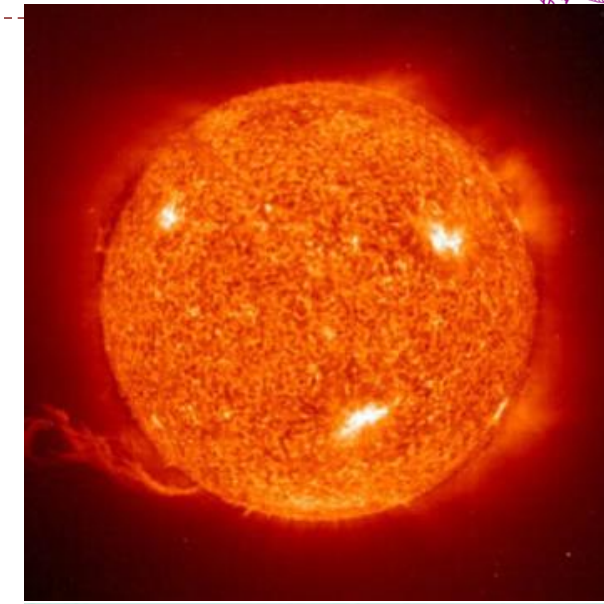
Thank you for your attention.
Thank for the support.

CJPL-IAC “strongly” support this “compelling” project.

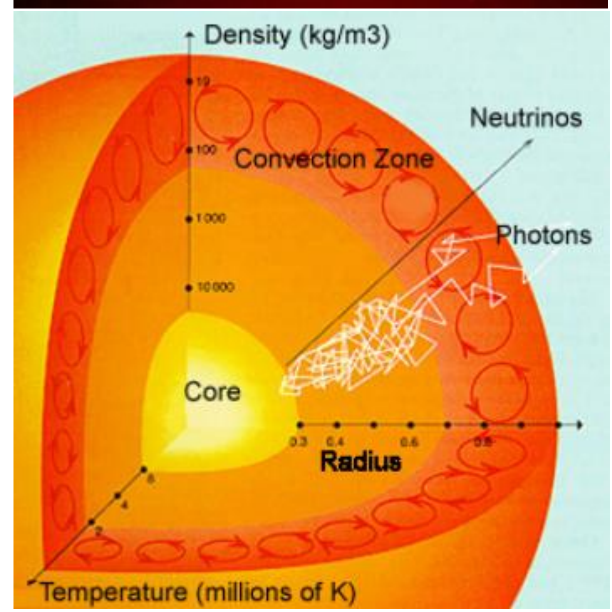
BACKUP

Evolution of the Sun – Solar Model

John Bahcall

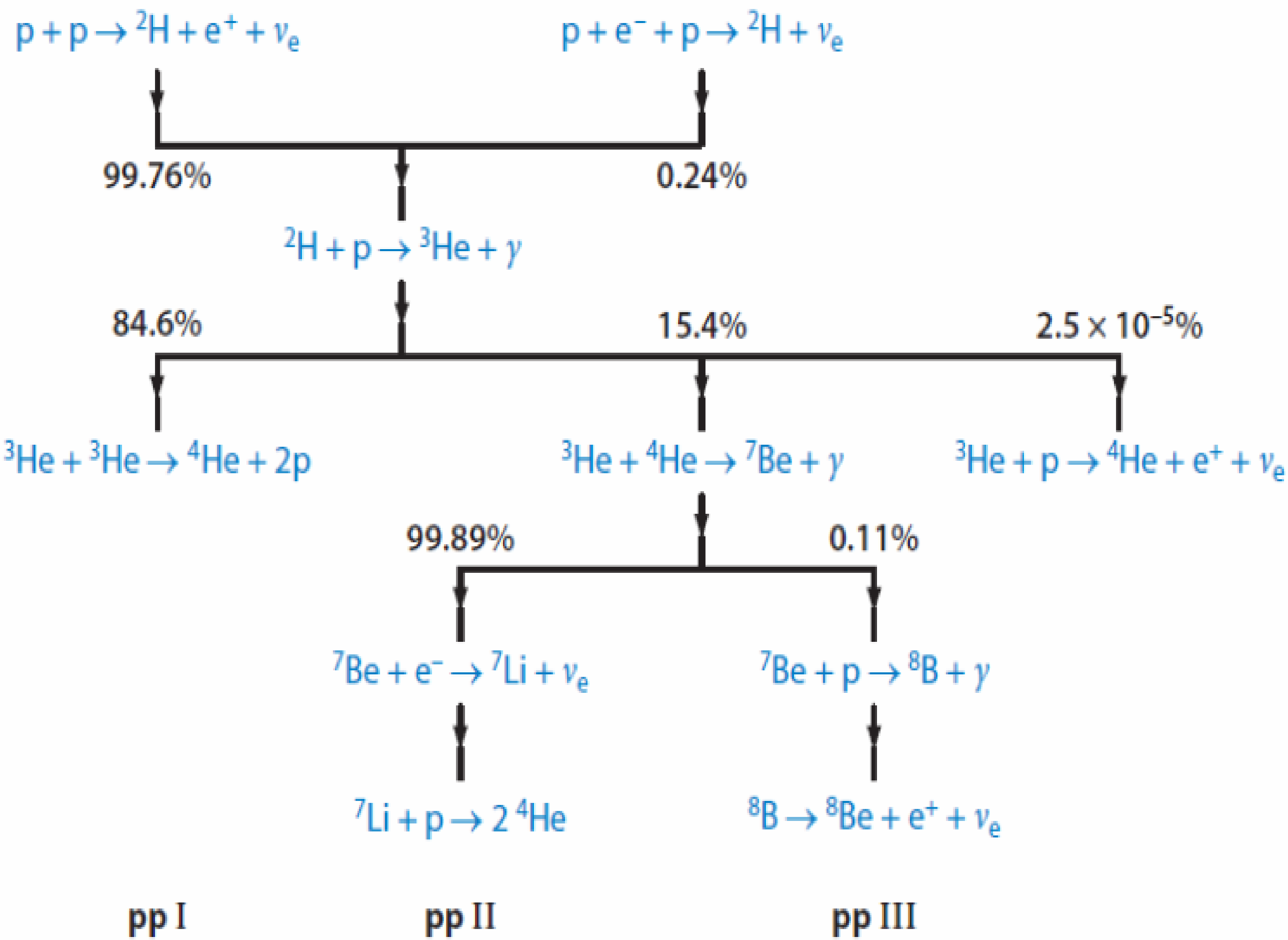


1. **Fueling mechanism:**
   pp chain
   CNO cycle (mainly in high mass stars)
2. **Energy transmission:**
   Radiation (opacity) inner
   convection outer
3. **Equation: Balance of the gravity, radiation, and particle pressure**
4. **Initial conditions**
   Abundance of H, He, metal elements
   Radius, age, mass …
   Assume: Initial metal fraction = surface fraction = core fraction

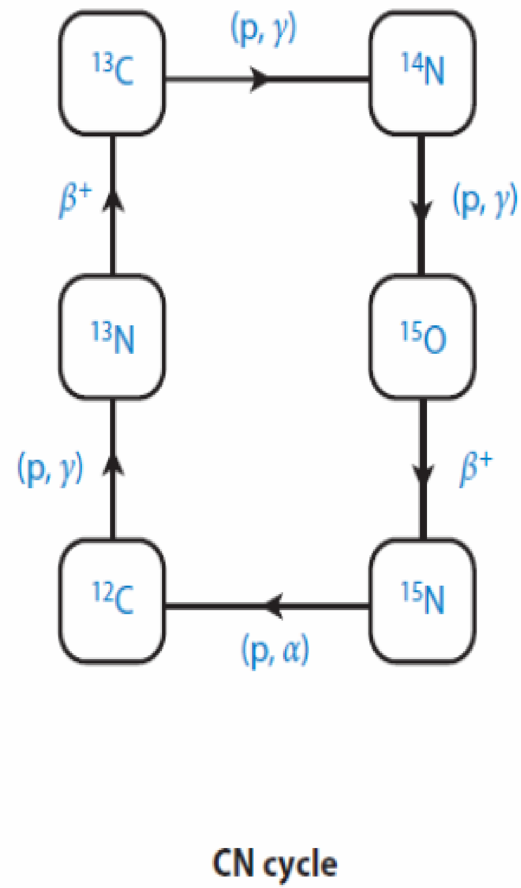


Solar Modal and Neutrino Components

The pp Chain

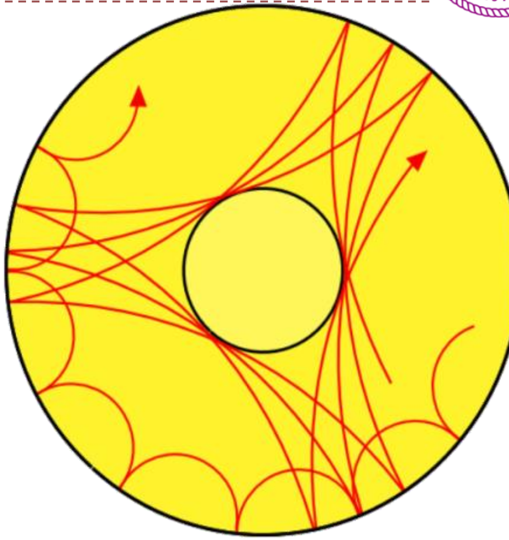


The CNO

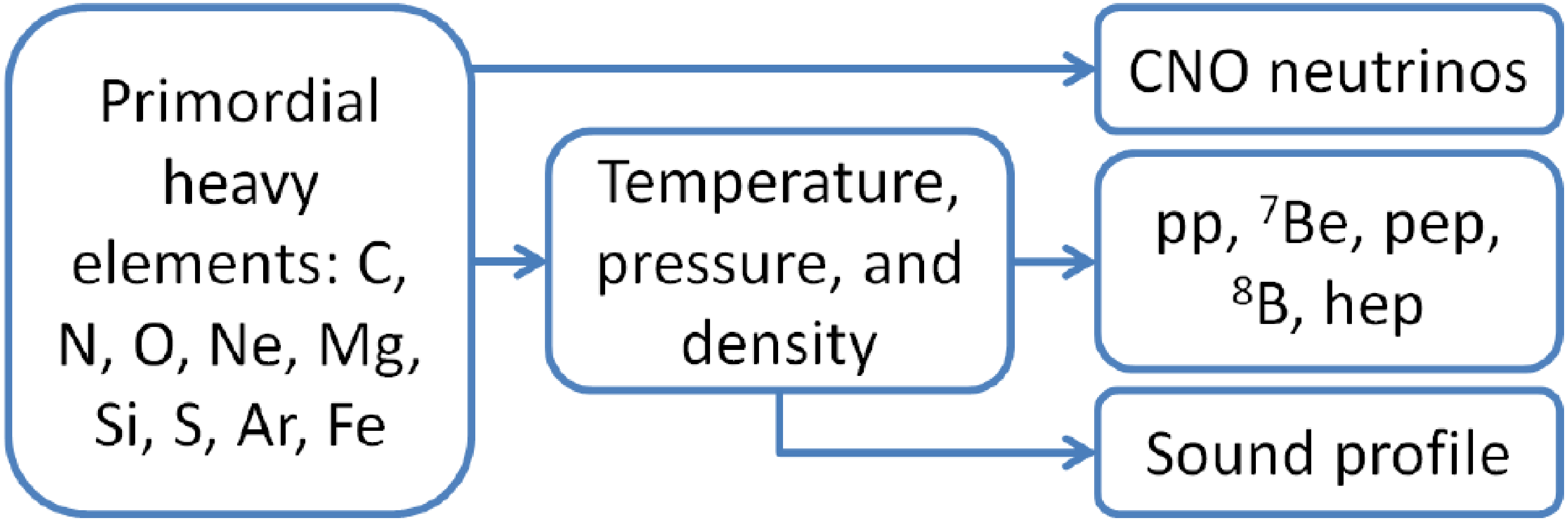


Helioseismology and conflict

Helioseismology: Solar surface vibration with T=~5 min, v=~0.5 km/s, A=~100 km

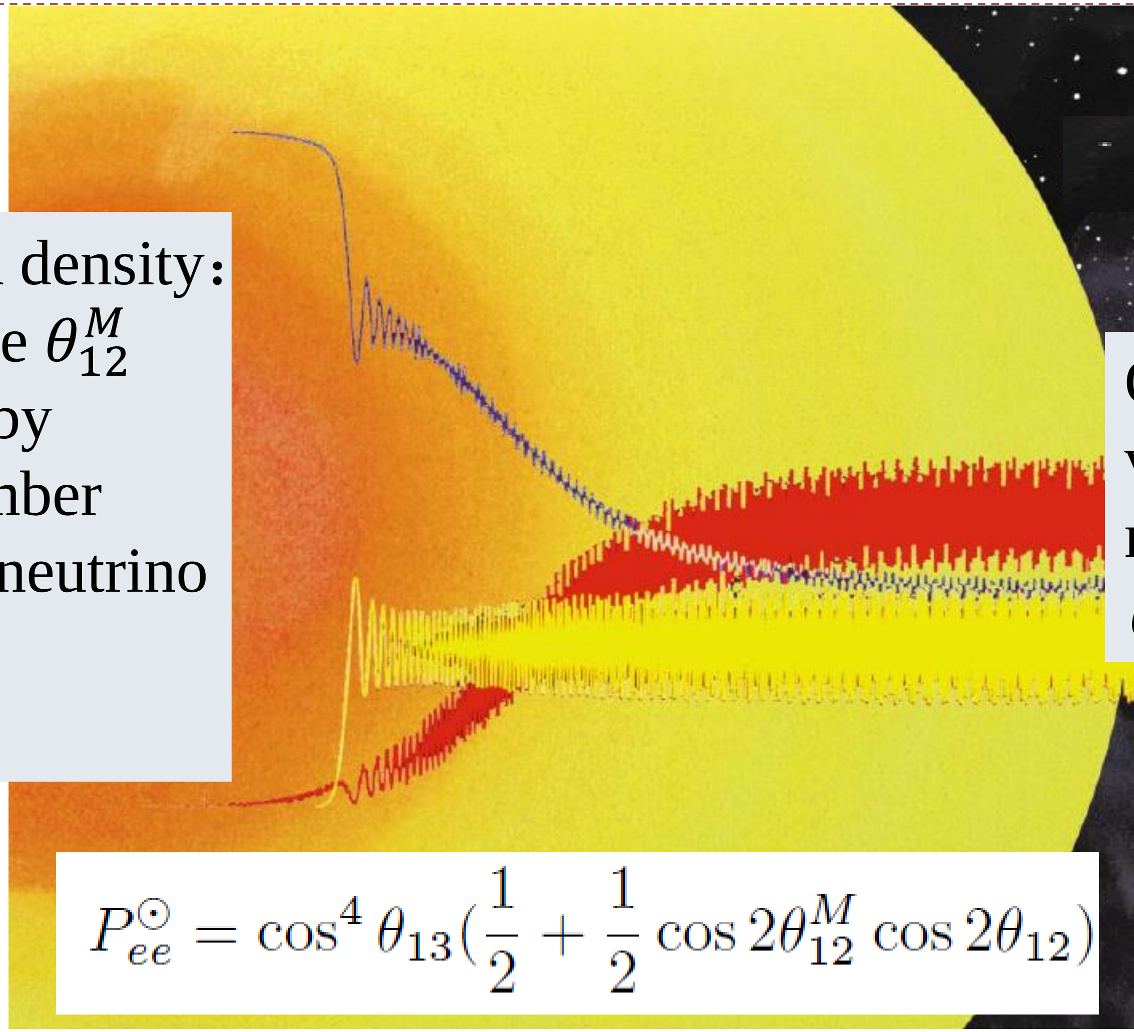


New (better) calculation of
Solar model conflicts with helioseismology measurement: sound speed differ by ~40%



Neutrino oscillation upturn

Center-High density: Mixing angle θ_{12}^{M} determined by electron number density and neutrino energy



$$P_{ee}^{\odot} = \cos^4\theta_{13}\left(\frac{1}{2} + \frac{1}{2}\cos 2\theta_{12}^{M}\cos 2\theta_{12}\right)$$

Outside: vacuum mixing angle θ_{12}

* If going through the Earth, the survival probability will change ~3%

Basic questions of the Sun

The mechanism of solar evolution

- CNO neutrinos not discovered

  1% in the Sun, but major fueling process for high temperature stars

- CNO neutrinos: a direct probe of the core of the Sun

  Study solar metal element fraction, resolve the conflict

- Understand our closest star

Neutrino oscillation

- Solar neutrino oscillation

  Transition from vacuum to matter oscillation

- Precise measurement and new physics

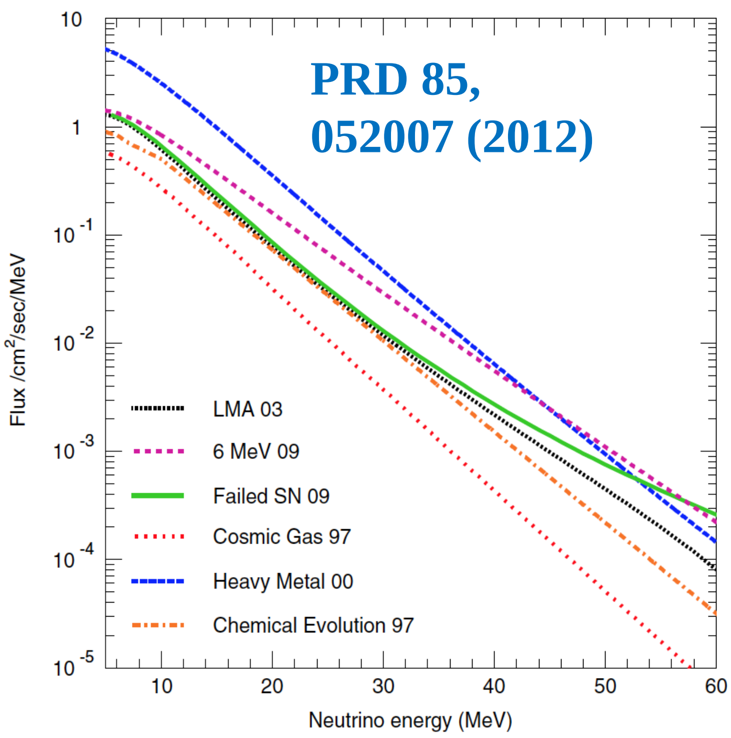
Supernova relic neutrino distribution

$$\frac{d\phi(E)}{dE} = \int R_{ccSN}(z)\frac{dN(E')}{dE'}(1+z)\left|\frac{dt}{dz}\right|dz$$

1. R_{ccSN} – Rate of core collapse supernova (optical observation)

2. dN/dE' – Neutrino energy spectrum (Supernova temperature)

3. Other constants: redshift



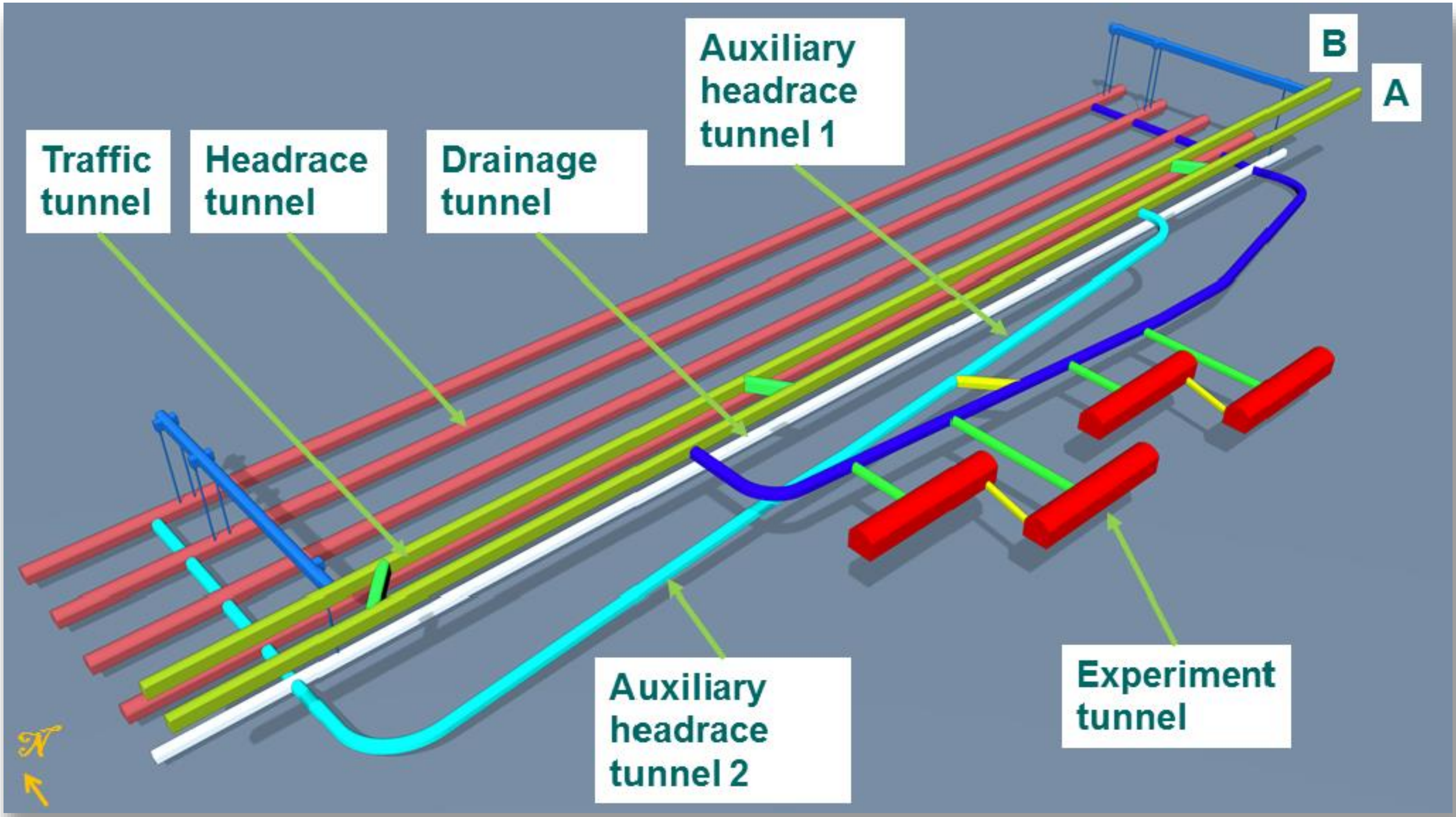
- SRN: A finger print of star formation rate and star evolution mechanism.

China Jinping Underground Laboratory

Flight: Beijing (Shanghai, Guangzhou) - Xichang

Car: Xichang - Jinping (2 hours)

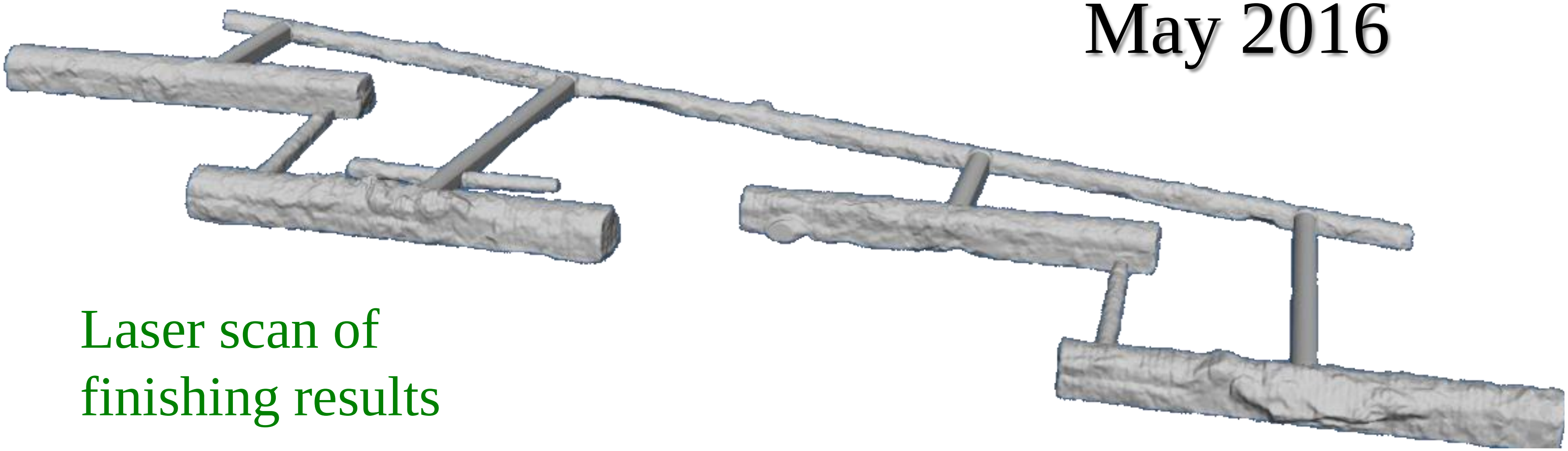
Design of CJPL-II



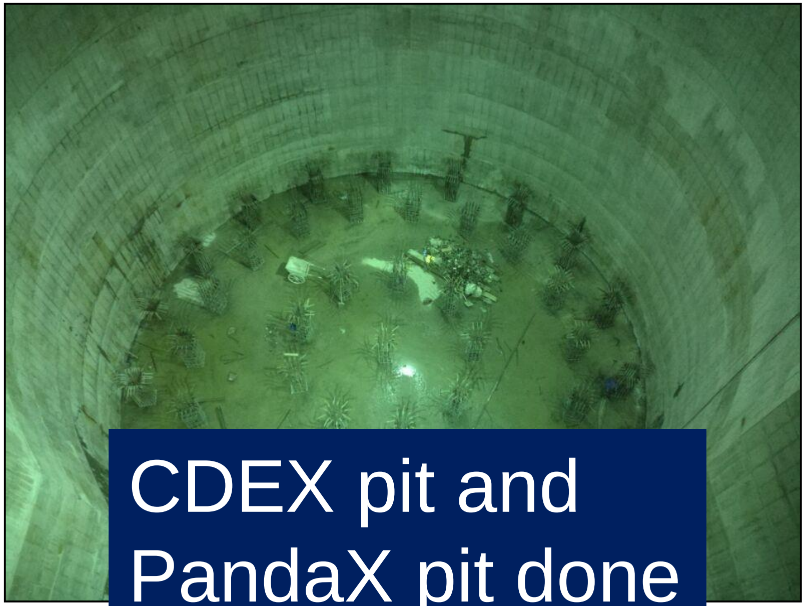
	CJPL-I	CjPL-II
Rock Work	4000 m^3	131000m^3

CJPL Current status

May 2016



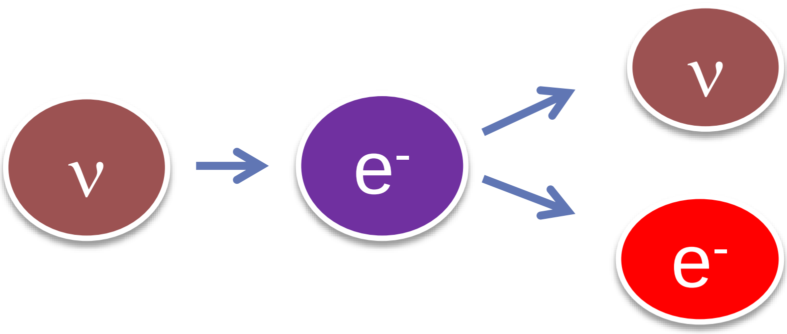
Laser scan of
finishing results



CDEX pit and
PandaX pit done

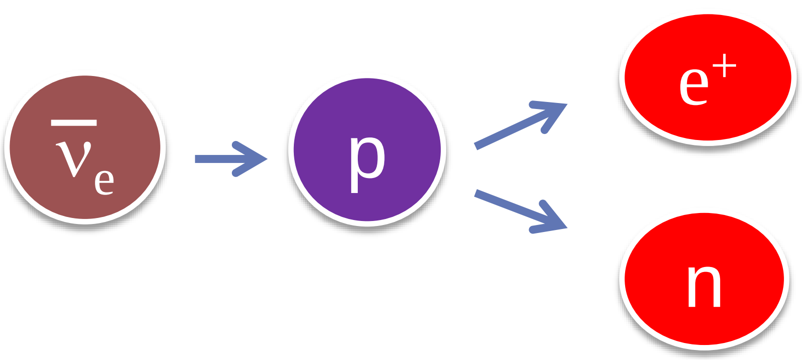
One hall

Solar neutrino detection



The electron is selected and its energy is measured with liquid scintillator and is related to original neutrino

Geo and SRN neutrino detection



The positron and neutron are selected and positron energy is measured with liquid scintillator.