Proposal: Low Energy Neutrino Search at Jinping

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Representing **Jinping Group**

2016/10/27

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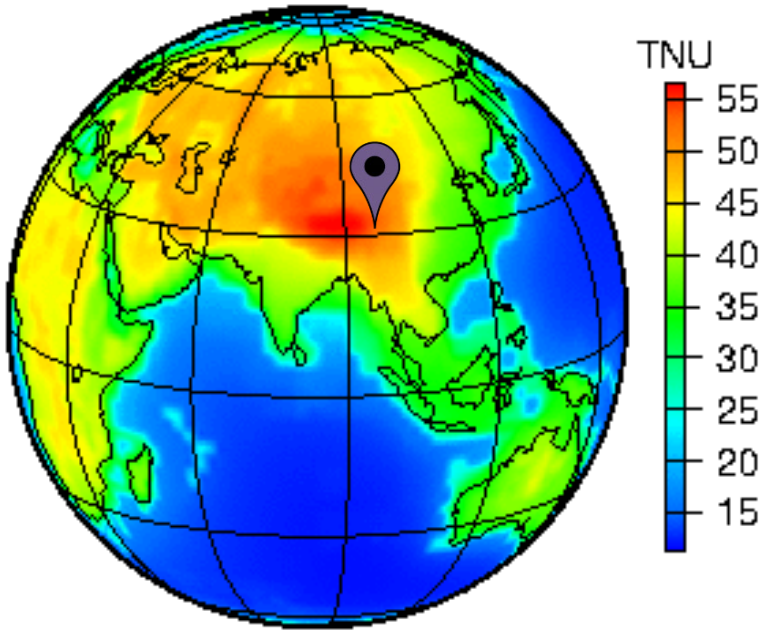
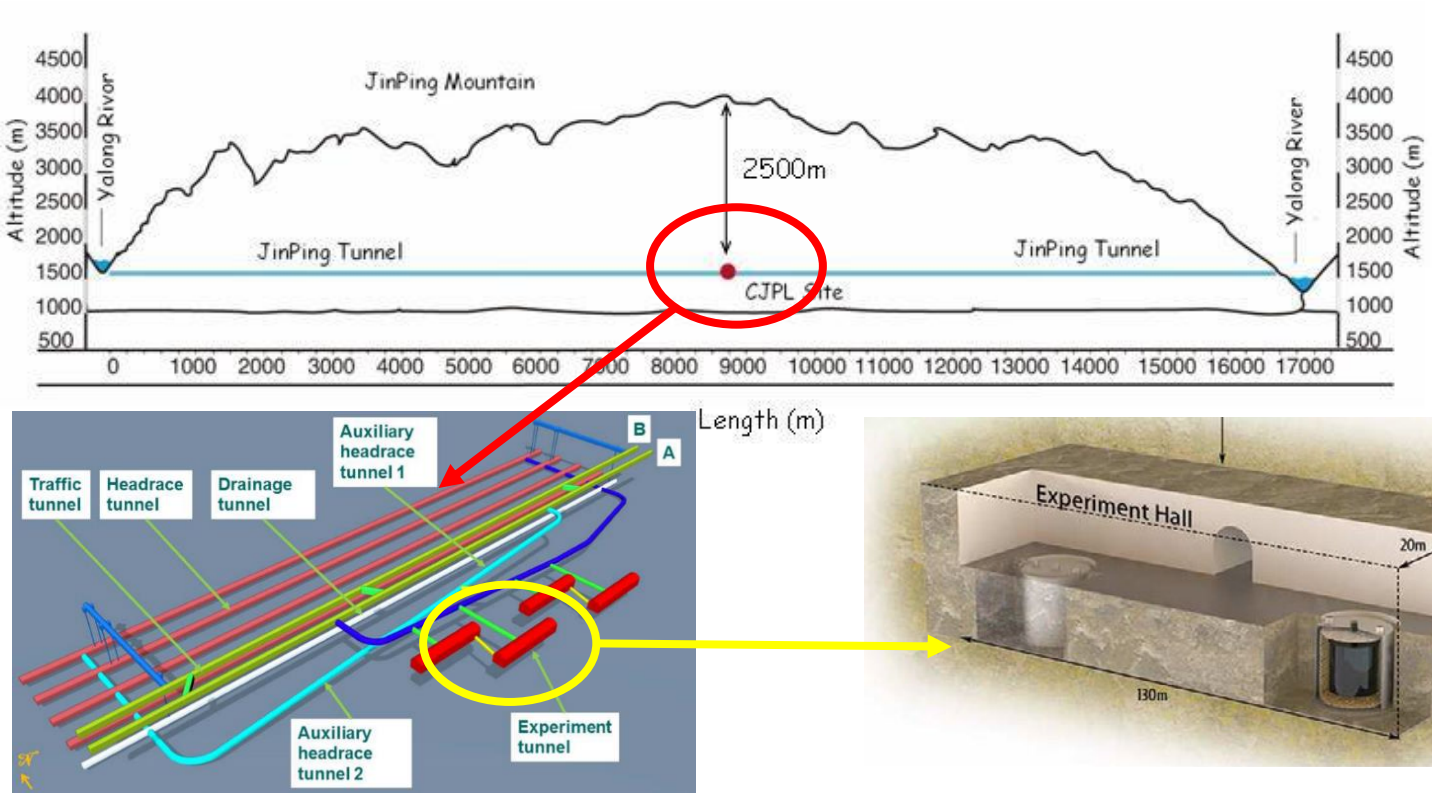
CJPL: Location



- Near Himalaya mountains.

- Located in Sichuan, China. 2 hours drive from Xichang airport.

CJPL: Tunnel View



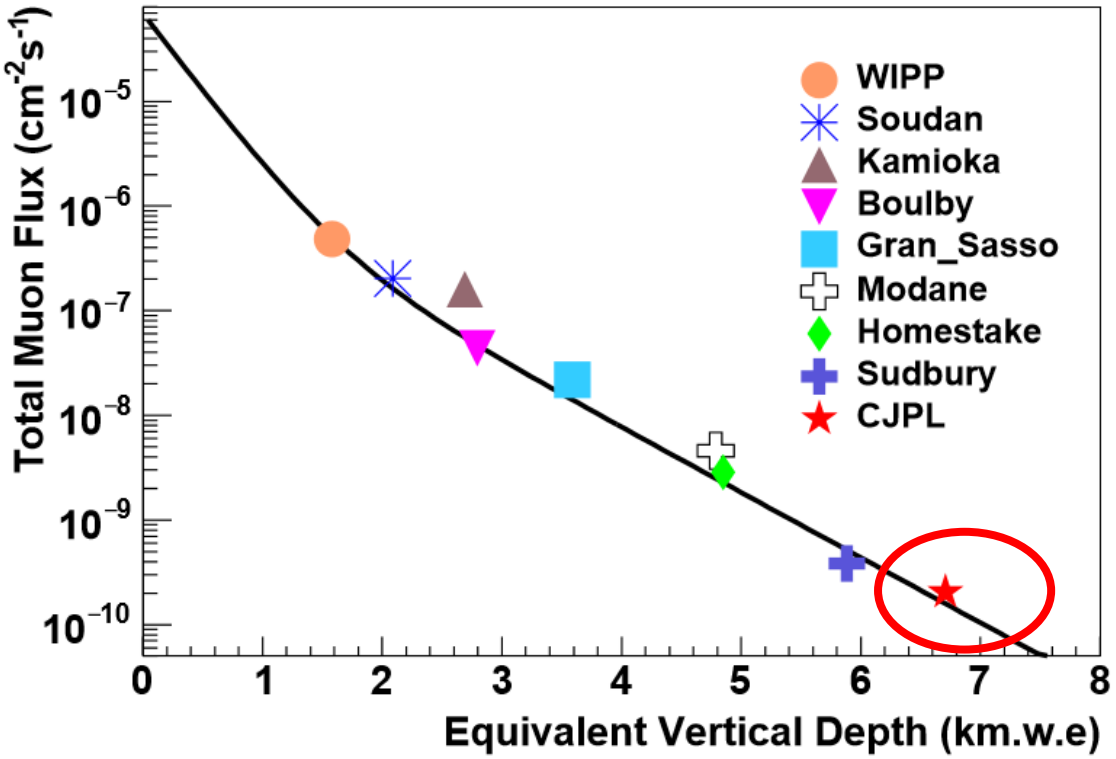
- Tunnel construction nearly finished.
  岩土工程学报, Vol. 38 Supp. 2, 67
- On average **2,400 m** rock shielding;
- 20 m * 100 m experiment hall;

CJPL: Depth & Muon Flux

Deepest:
2,400 m rock overburden

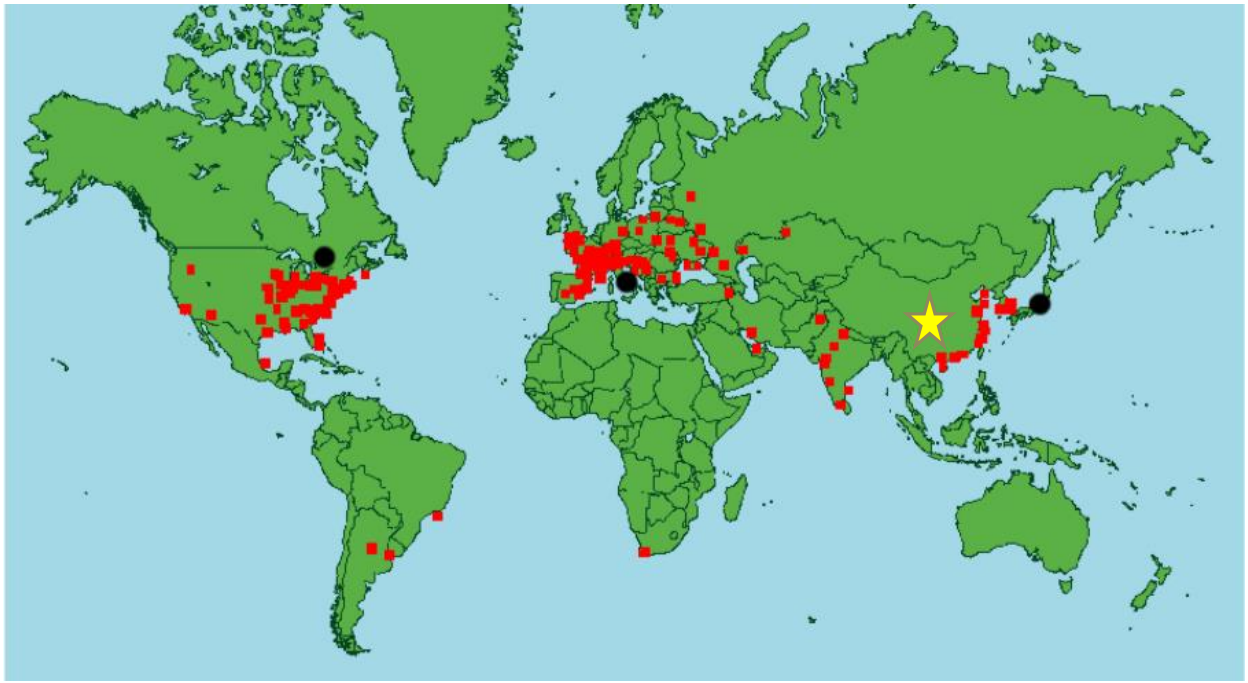
Lowest muon rate:
$(2.0 \pm 0.4) \times 10^{-10}$ / (cm^2·s)

Extremely low spallation background



- Spallation induced radioactive isotopes ^{9}Li & ^{8}He are the main source of non-neutrino background for geo-neutrino detection.

CJPL: Reactor Neutrino Flux



Reactors

Main Neutrino Observatories

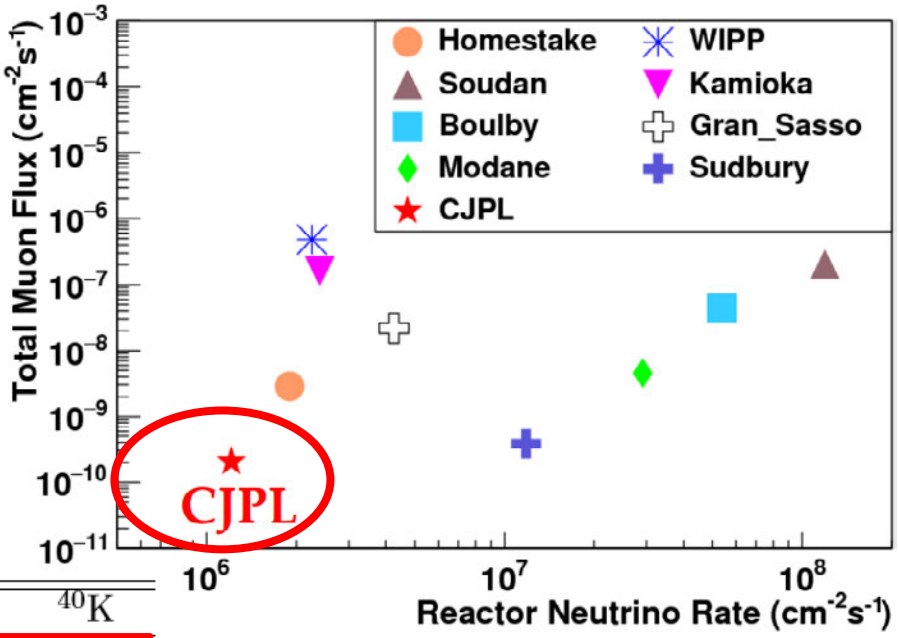
Jinping

Numerical results later in this talk.

- ❑ Reactor neutrinos are the dominant background overlapping with geo-neutrino energy range and signal signature.
- ❑ More than 900 km away from the nearest nuclear plant.

CJPL:
A Low Background Laboratory

- ❑ Lowest muon rate;
- ❑ Lowest reactor neutrino rate.
- ❑ Lowest rock radioactivity contamination.



Site	^{238}U	^{232}Th	^{40}K
Jinping	1.8±0.2 (^{226}Ra)	<0.27	<1.1
Sudbury	13.7±1.6	22.6±2.1	310±40
Gran sasso hall A	116±12	12±0.4	307±8
Gran sasso hall B	7.1±1.6	0.34±0.11	7±1.7
Gran sasso hall C	11±2.3	0.37±0.13	4±1.9
Kaminoka	~12	~10	~520

Ideal place for low background experiments: dark matter search, neutrino observatory, …

CJPL Phase I & Phase II

- CJPL I finished construction in 2010, now hosting 2 dark matter experiments: **CDEX** and **PandaX**.
- CJPL II under construction now, planning to host Jinping Neutrino Experiment as well as several other low background experiments.

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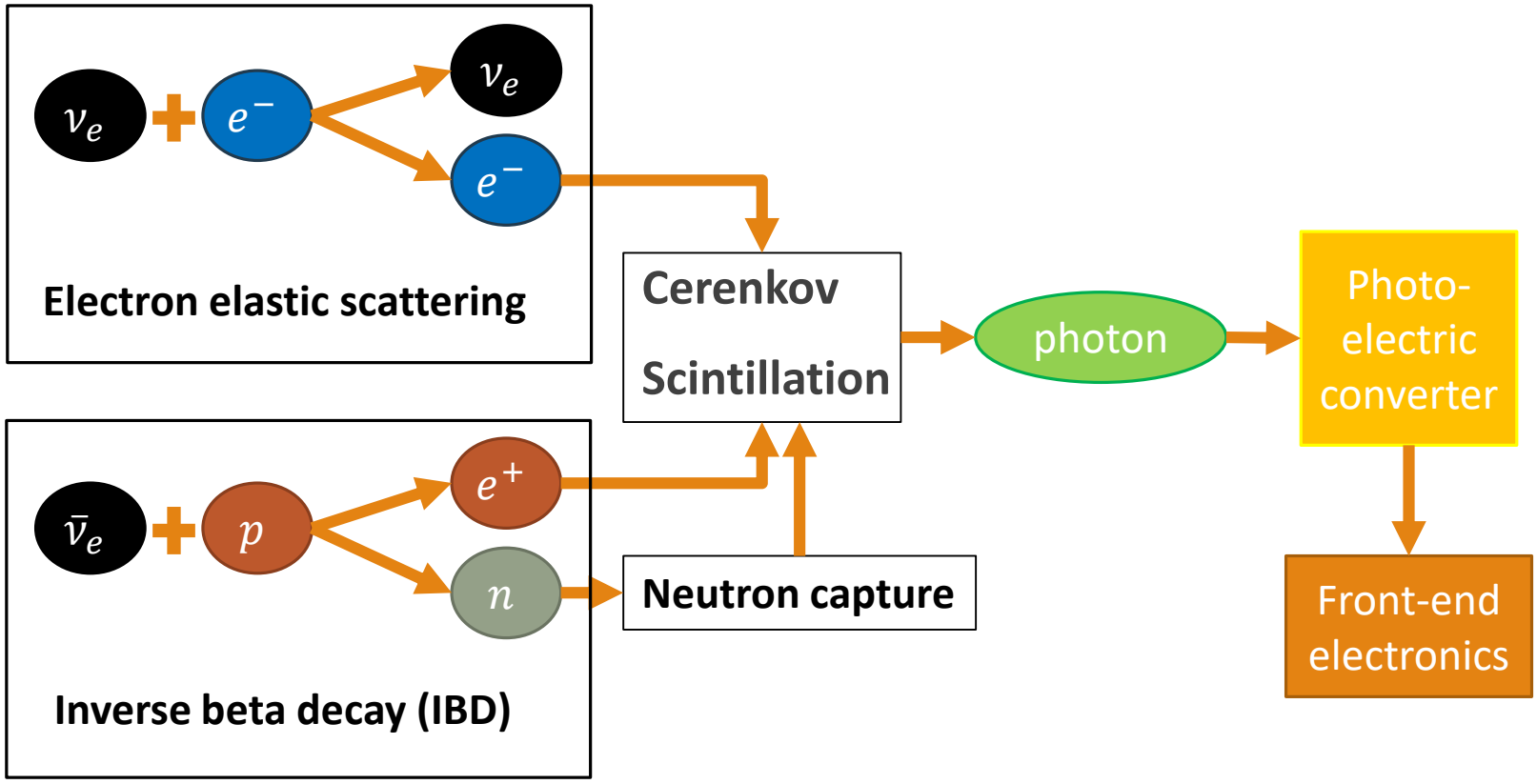
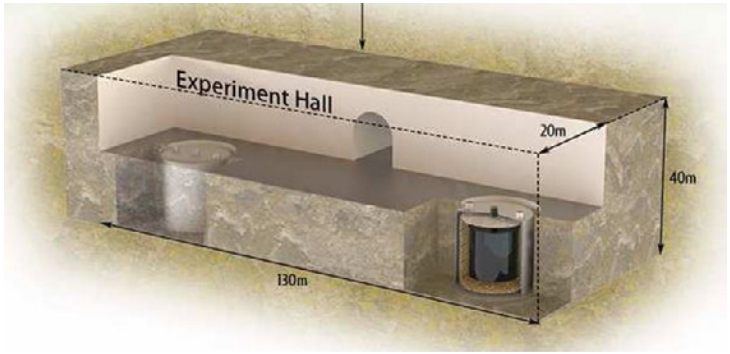
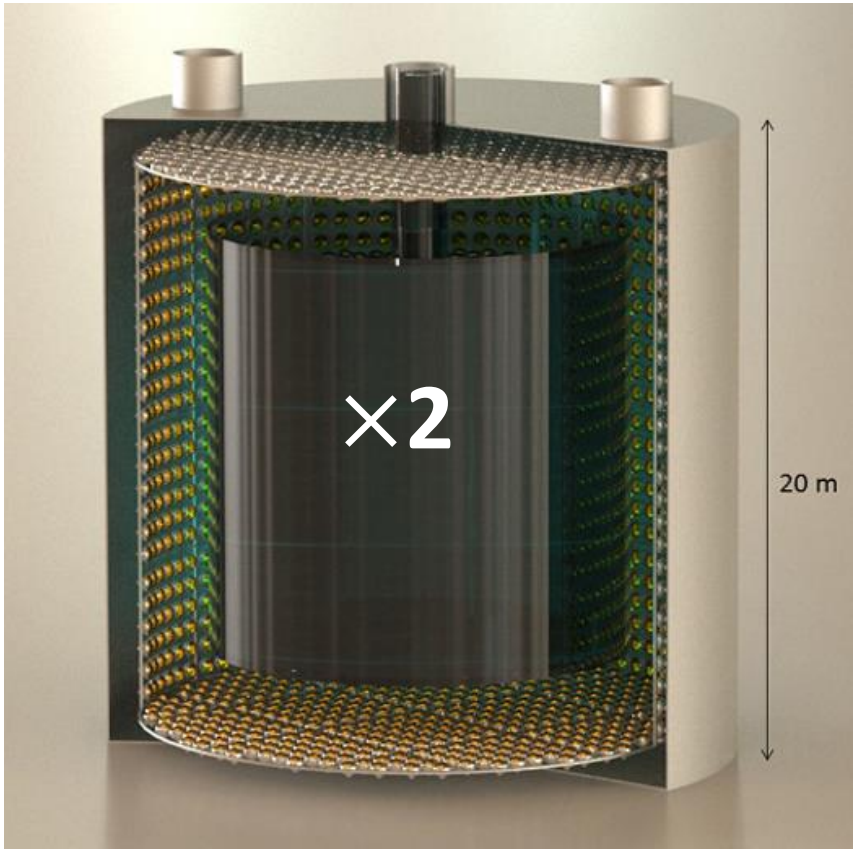
Neutrino Detection Technique



Detector Concept

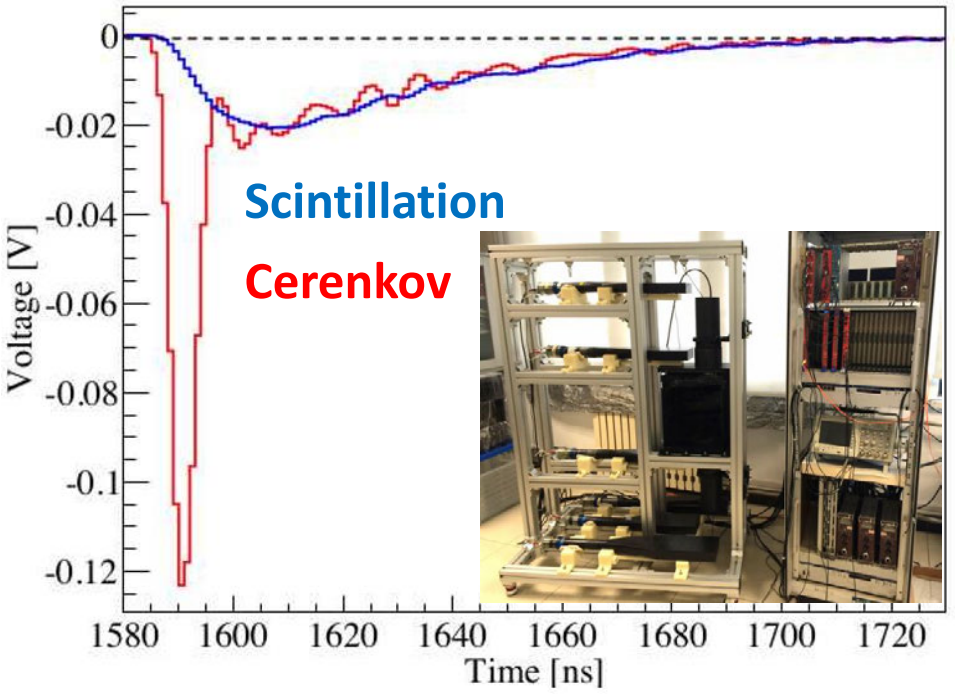
- 1.5 kton×2 Fiducial for IBD
- PMT coverage >70%
  with self-designed light concentrator
- Energy Resolution: 500 p.e.





Slow Liquid Scintillator

- Distinguish between scintillation & Cerenkov light in time spectrum.
- Enable particle identification which suppresses fake electron background.
- Now work to improve the scintillation light yield w/o changing the timing structure.



N. I. M Phys. Res. A 827 (2016) 165-170

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China JinPing underground Laboratory

Detector Concept

Geo-Neutrino

Other Physics

Status

Geo Neutrinos:

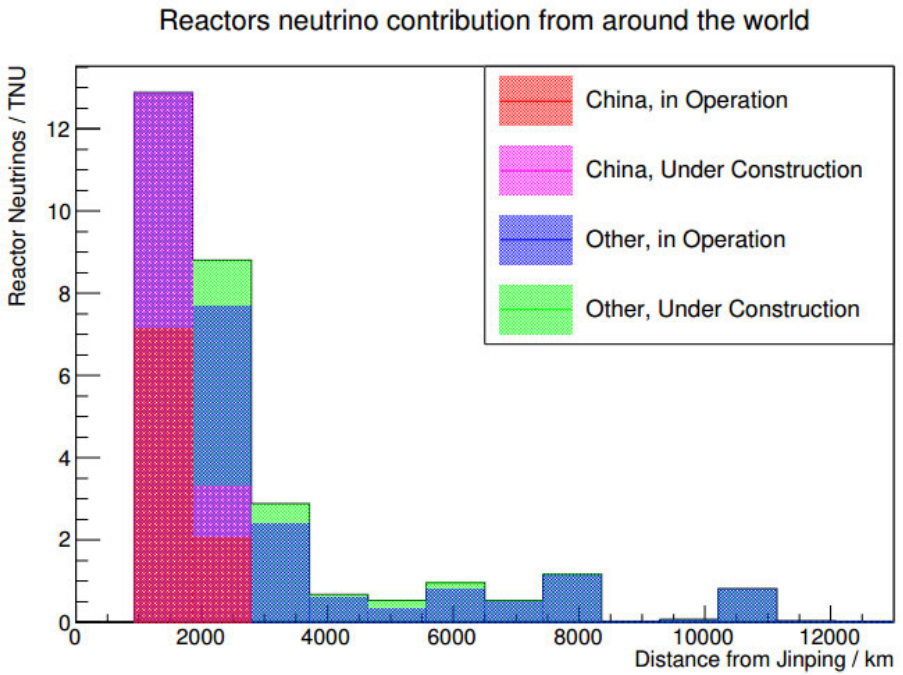
- Are low energy (< 3.5 MeV) $\bar{\nu}_e$'s from natural radioactivity emitted by U/Th/K heat producing elements.
- Provide constrain on Earth's thermal budget with geo neutrino measured radiogenic earth heat.
- Can be detected via IBD reaction.

TNU:
To get avoid of the redundant conversion of target mass / live time etc..
1 TNU = 1 event / 10^{32} protons / 365 days.

Reactor Neutrino Background

- SER: Signal Energy Region overlapping with geo neutrino (1.8 ~ 3.3 MeV)
- Reactor neutrino background in Jinping mainly come from reactors in coastal China.

IAEA 2016



Event Rate (TNU)	Constructed China	Constructed Others	Under Construction China	Under Construction Others	Total
FER	9.2	11.1	6.6	2.1	29.0
SER	2.4	2.4	1.7	0.6	7.1

Non-Neutrino Background

❑ ^{9}Li & ^{8}He

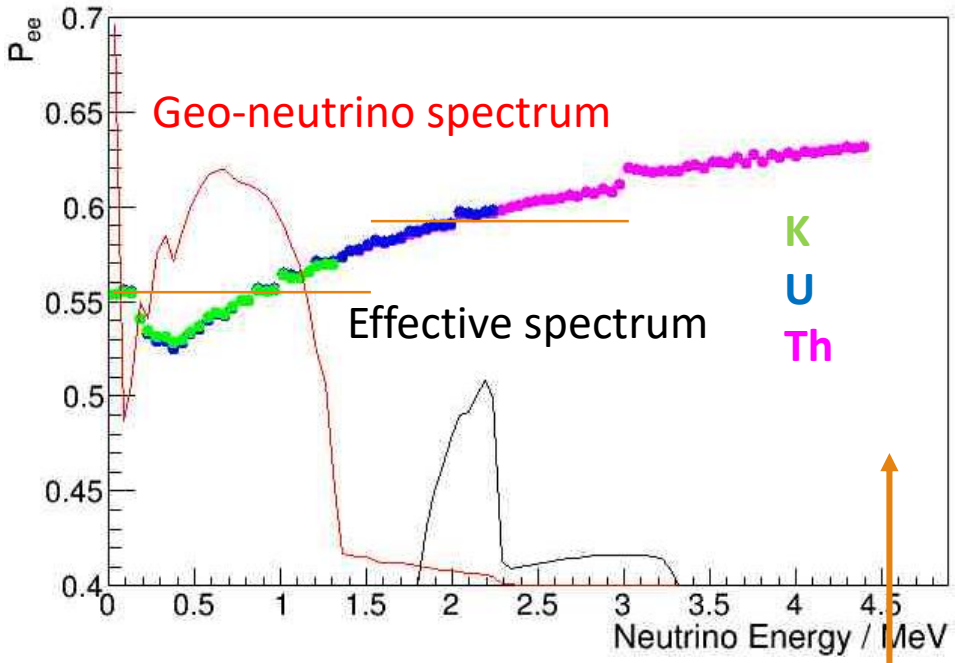
The extremely low muon rate $(2.0 \pm 0.4) \times 10^{-10}$ / (cm^2·s) gives much lower spallation background compared to other experiments. This background is estimated to be $<$ **0.1 event / 3 kton / 1,500 days** in Jinping.

❑ (α, n) reaction

This background is closely related to the level of 210Po contamination inside the tank. Assuming same level purity as Borexino, we estimate this background to be **1.7 event / 3 kton / 1,500 days** in Jinping.

Comparing with the dominant reactor neutrino background (**61.3 events / 3 kton / 1,500 days**), the above non-neutrino background are not taken into consideration in following analysis.

Geo-Neutrino Oscillation



$$\phi(i) = \frac{X\lambda N_A}{\mu} n_\nu \int\int\int \frac{A(\vec{r}')\rho(\vec{r}')}{4\pi|\vec{r}' - \vec{r}|^2} P_{ee} d\vec{r}'.$$

- In the present estimation of geo-neutrino flux at Jinping, P_{ee} is employed as an overall parameter 0.553.
  Sci. Rep. 6, 33034 (2016)
- This overall parameter simplification is corrected by oscillation analysis in prediction, giving a 7% difference.

Electron neutrino survival probability

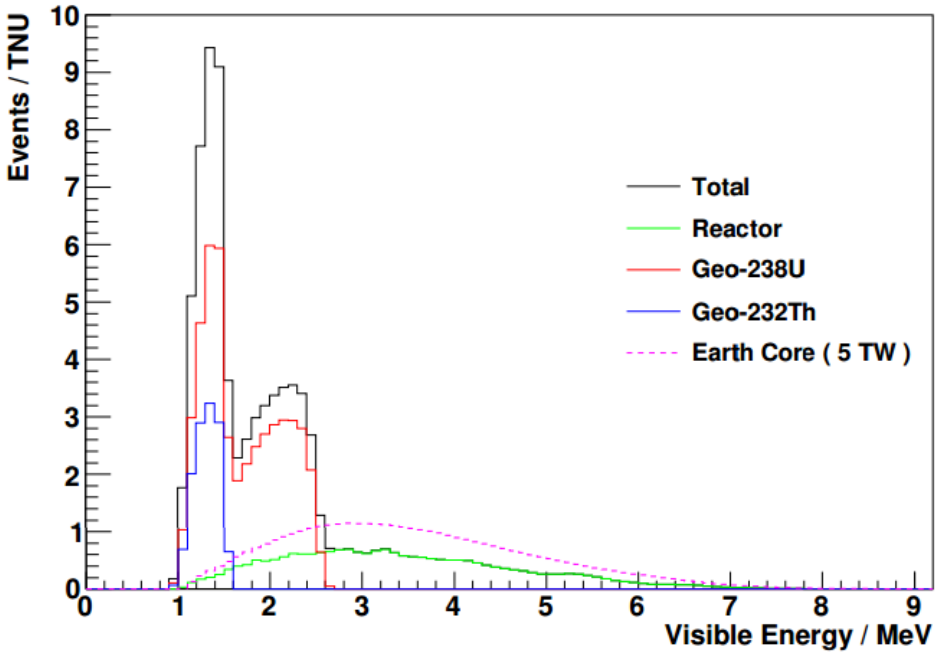
Uncertainty Estimation in Geo-Neutrino Flux Prediction

Source		Uncertainty
Crustal HPE Modeling		*12%
Oscillation	Vacuum parameter	<1%
	MSW oscillation	<1%
Predicted detection precision in Jinping		8%

* Sci. Rep. 6, 33034 (2016)

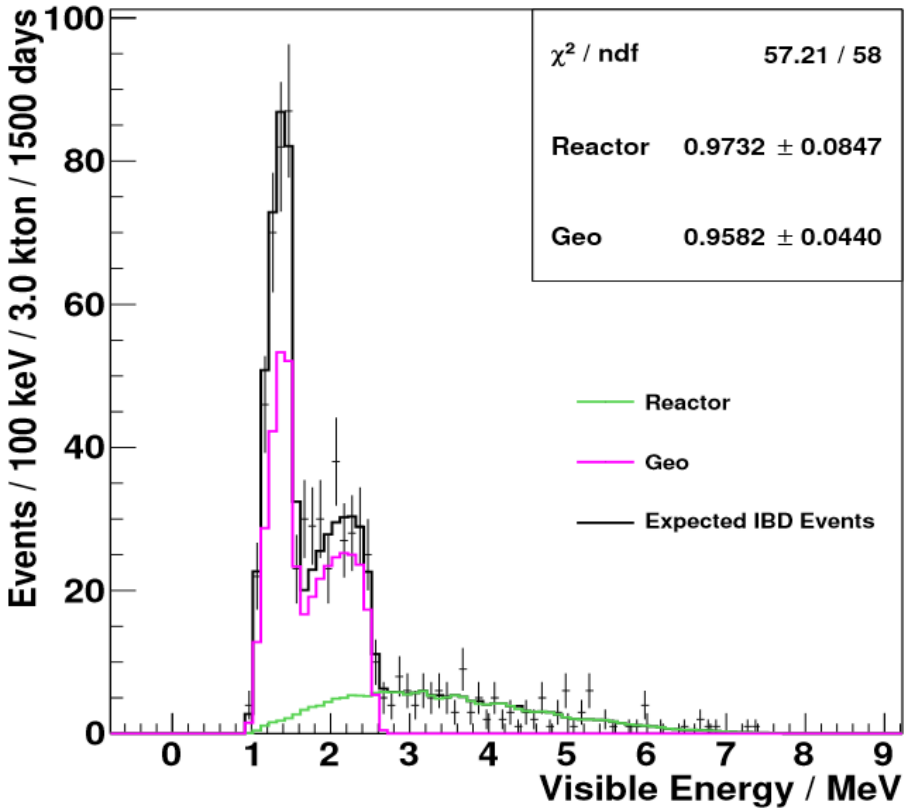
Prediction: IBD Events at Jinping

- 500 p.e. energy resolution
- The calculation of geo neutrino signal will be covered in Sramek's talk.
- Signal/Background ratio > 8 in SER.



	Geo-neutrino			Reactor	
	^{238}U	^{232}Th	Total	FER	SER
Rate / TNU	47.0	11.5	58.5	29.0	7.1

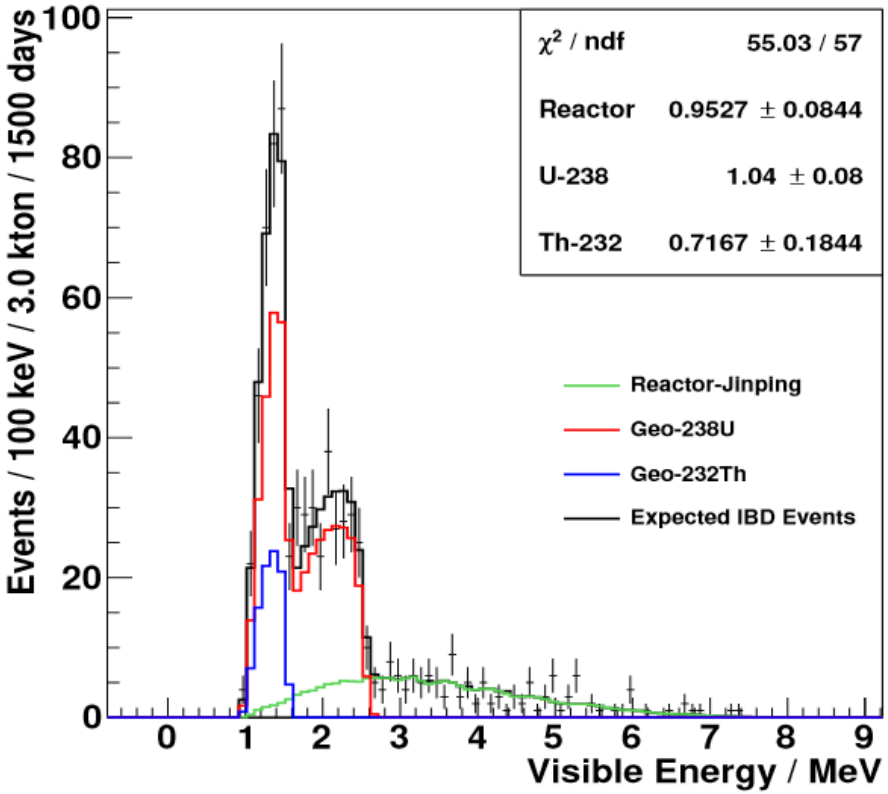
Predicted Sensitivity: With Fixed Th/U Ratio



- With a **fixed Th/U ratio** in accordance with theoretical assumption (3.9),
- And a **free reactor flux** parameter,
- sensitivity for geo-neutrinos reaches **4%**. (statistical, 1σ)

Live time: 3.0 kton, 1,500 days
Energy resolution: 500 p.e.

Predicted Sensitivity: With Free Th/U Ratio



- With **free Th/U ratio**,
- sensitivity for geo neutrino reaches **8%**. (statistical, 1σ)
- Precision of U/Th ratio measurement reaches **25%**. (statistical, 1σ)

Live time: 3.0 kton, 1,500 days
Energy resolution: 500 p.e.

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Other Physics Topics: Jinping is Expected to…

Solar Neutrinos:

- ❑ Discover CNO flux (5σ)
- ❑ Measure the transition phase
- ❑ Determine the high/low metallicity hypothesis ($7\sigma \sim 10\sigma$)

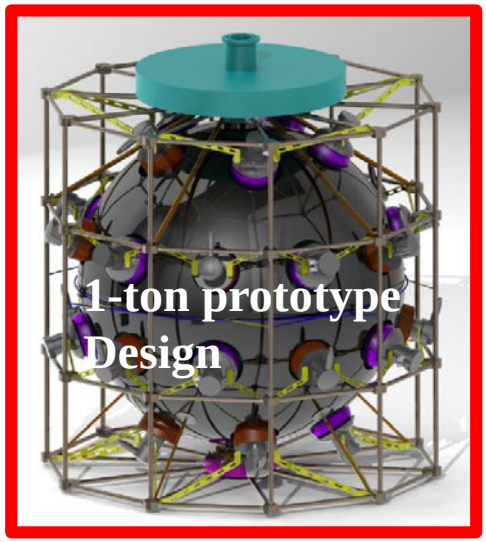
Astro-Neutrinos:

- ❑ Join SNEWS for the supernova burst neutrinos
- ❑ Reach the discover limit for supernova relic neutrinos
- ❑ Constrain on galaxy dark matter

Contents

Timeline

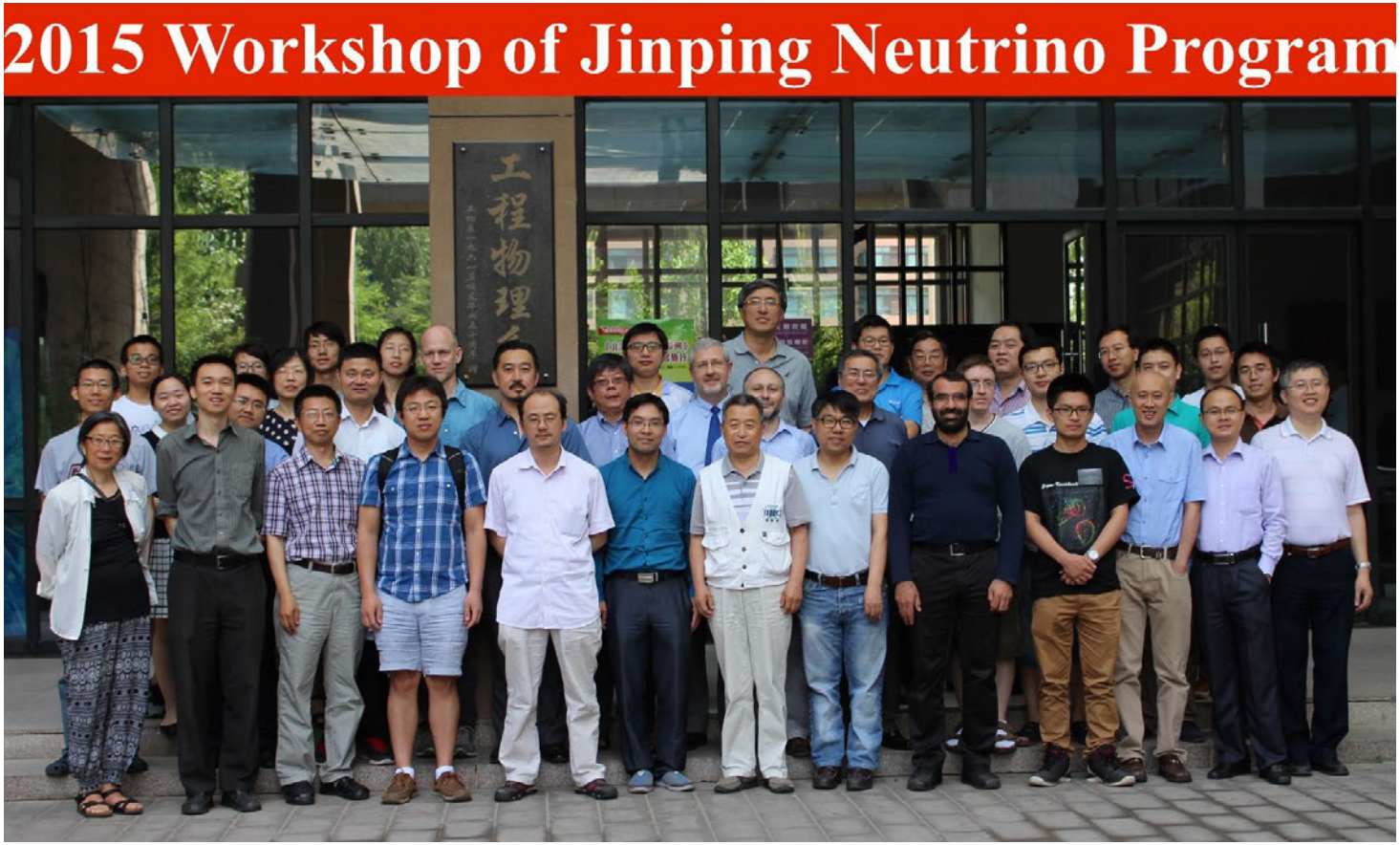
2014: CJPL II started construction
2015: Proposal for Jinping Neutrino Experiment
2016: Letter of Intent: Jinping Neutrino Experiment
1-ton prototype underway **Now here!** ArXiv:1602.01733
2018: 10-ton prototype planned
…



Conclusion

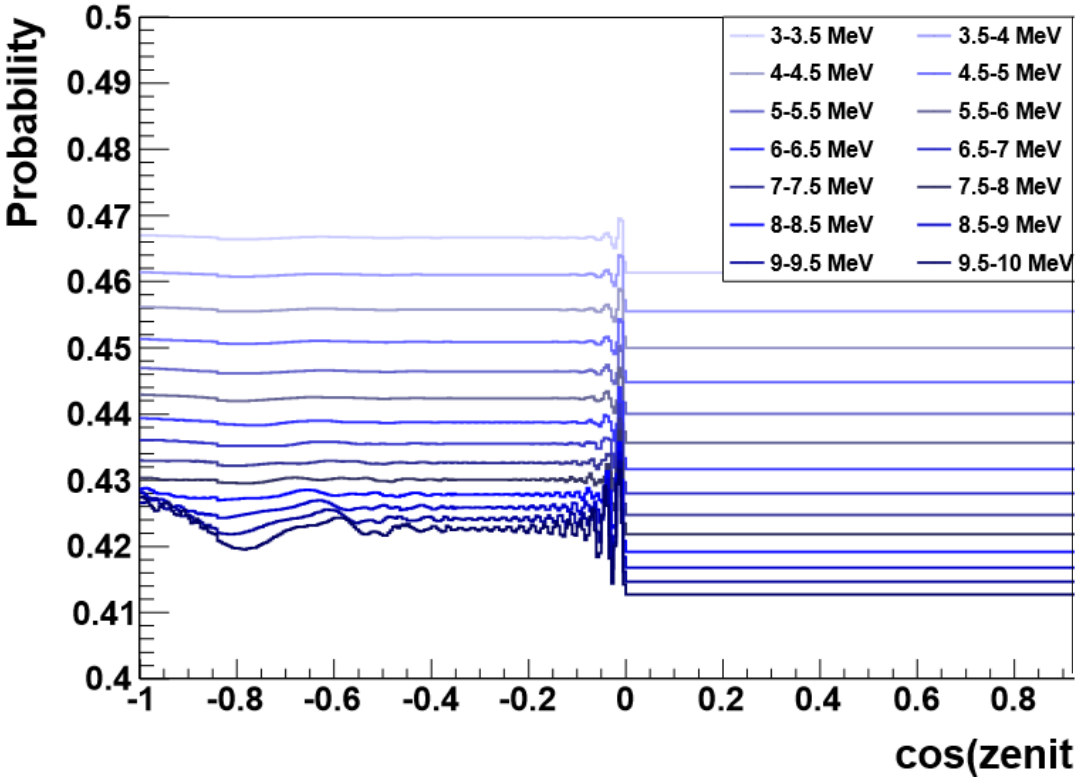
1. **Experiment setup**
   - 2,400 m rock shielding
   - 2 kton * 2 liquid scintillator
   - Lowest reactor neutrino background and muon rate
2. **Geo-Neutrinos**
   - 4% (8%) precise measurement of geo neutrino flux for fixed (free) U/Th ratio
   - 25% sensitivity for U/Th ratio
3. **Status**
   - Now working on 1 ton prototype.
   - Welcoming collaborating!

Thank you!

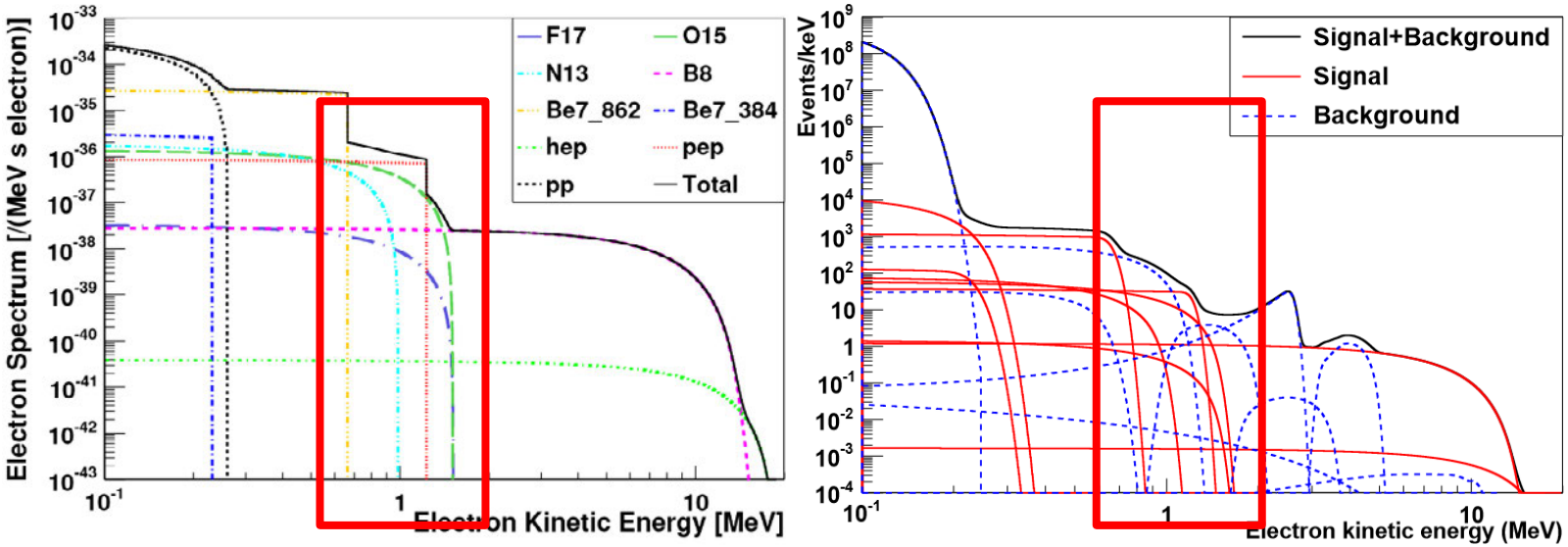


Backup: Discussion of MSW

- With lower energy, the MSW effect become smaller;
- For 3~3.5 MeV, i.e., the maximum of geo-neutrino energy, the MSW oscillation effect is around 1%.



Solar Neutrinos: Signal & Background

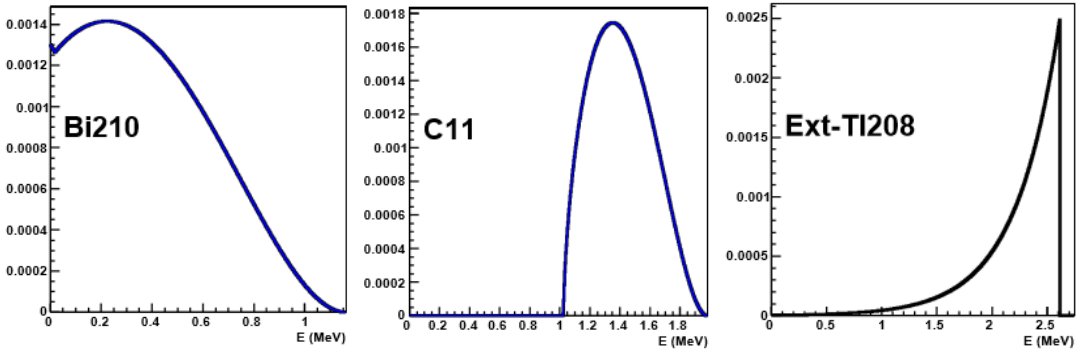


- Main background from radioactivity in scintillator, PMT glass, surrounding environment and muon induced isotopes.
- Backgrounds are estimated using Borexino or SNO result.

Solar Neutrinos: Numerical Result

	Neutrino component	Energy resolution 200 PE/MeV	500 PE/MeV	1000 PE/MeV
Fiducial mass 2,000 ton	*pp*	0.01	0.005	0.004
	^{7}Be	0.005	0.004	0.004
	pep	0.06	0.03	0.03
	^{13}N	0.4	0.3	0.2 (0.3)
	^{15}O	0.2	0.1	0.08 (0.1)
	^{8}B	0.02	0.02	0.02

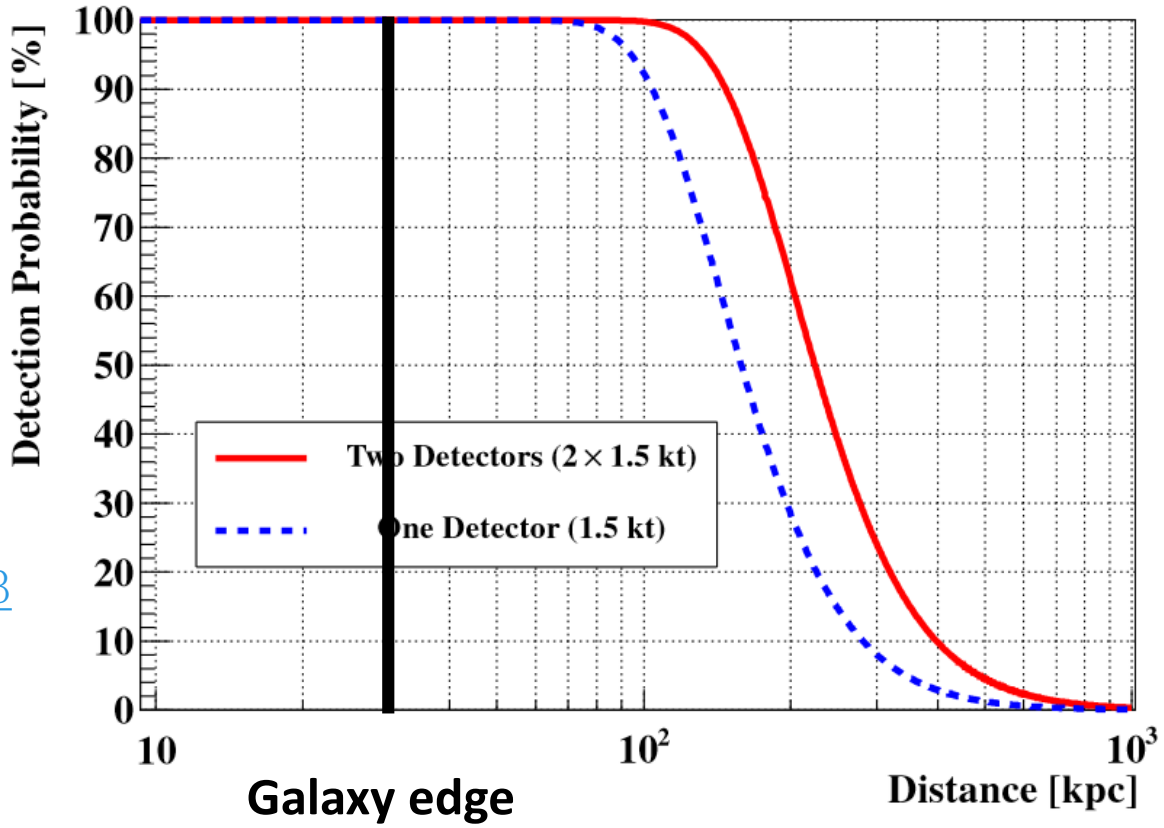
- Mainly influenced by Bi210, C11(muon induced), and External Tl208.



Supernova Burst Neutrino

Double detector coincidence reduces the wrong alarm rates.

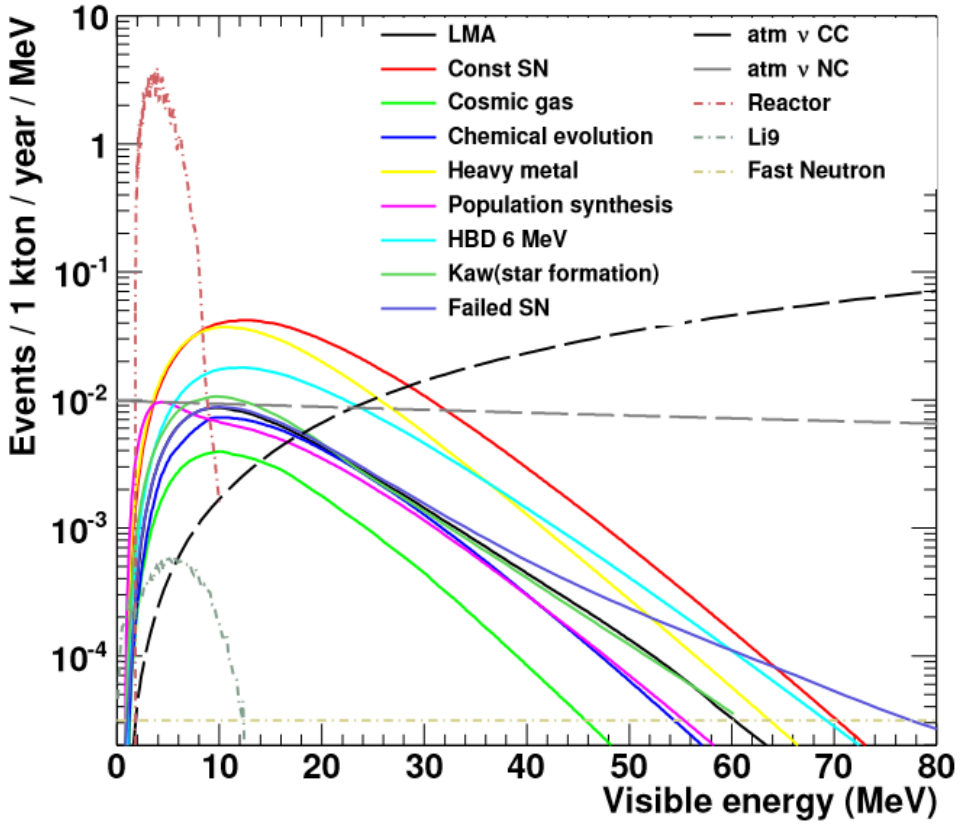
ArXiv:1602.01733



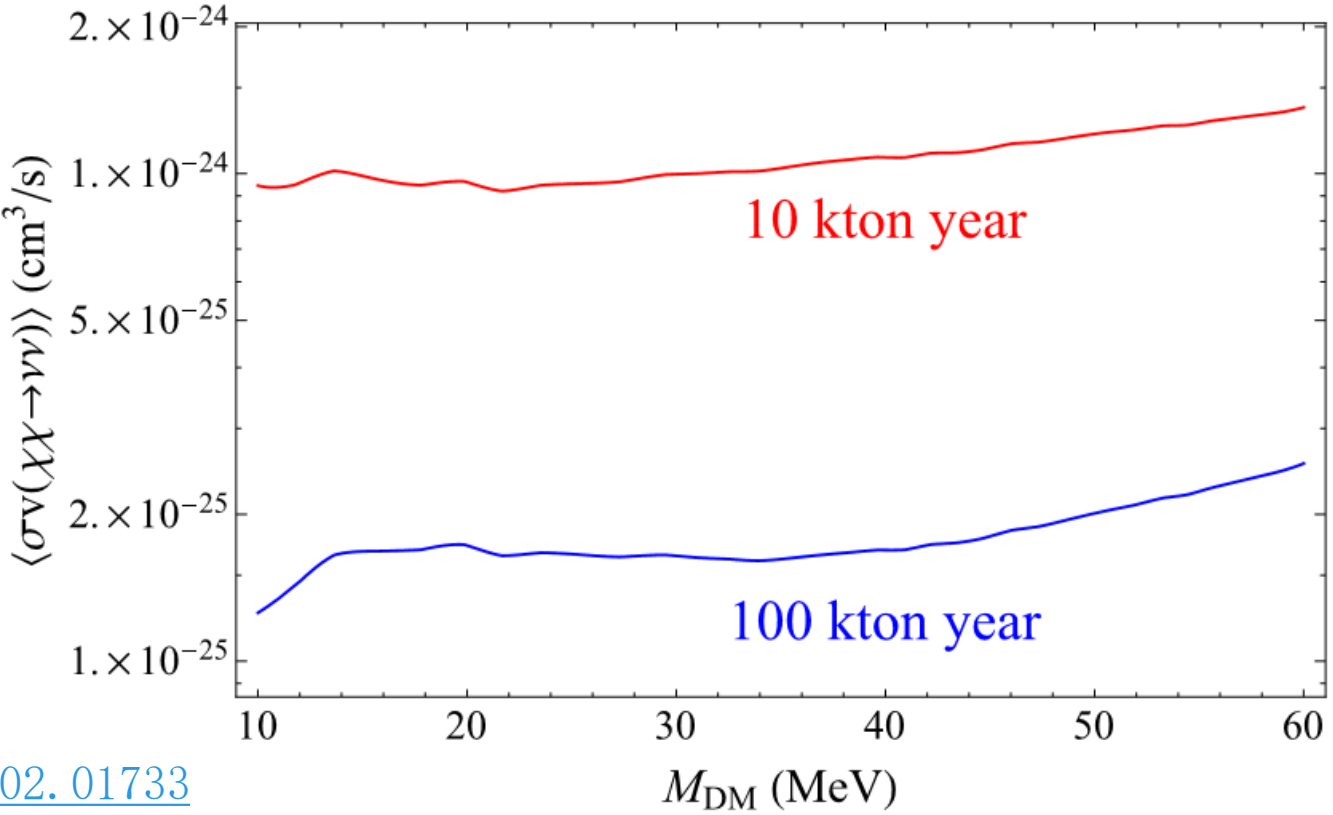
Supernova Relic Neutrino

With scintillation/Cerenkov distinguish technique, backgrounds will be greatly suppressed.

ArXiv:1607.01671



Galaxy Dark Matter



ArXiv:1602.01733