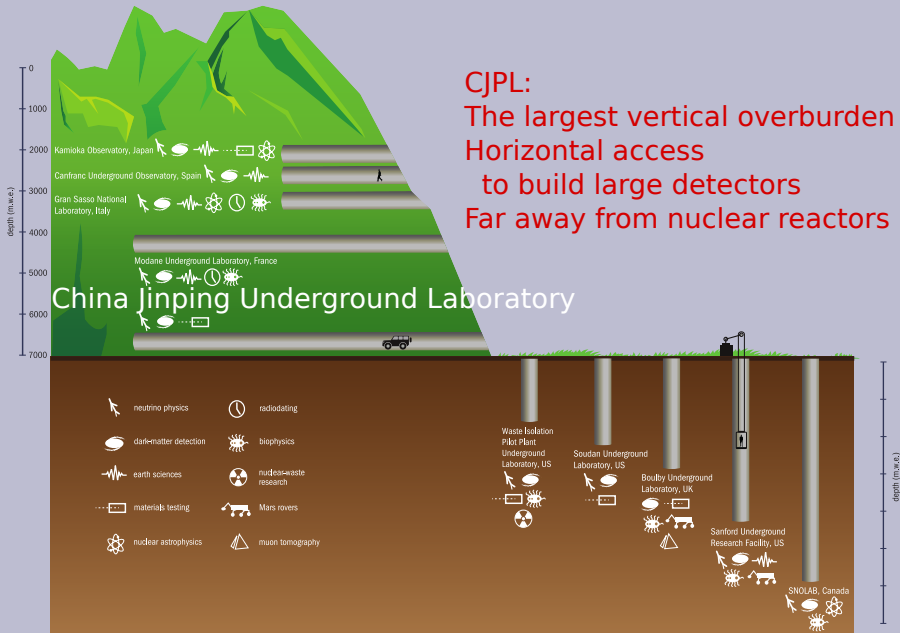


# Progress of Jinping Neutrino Experiment Program

Benda Xu(续本达) on Behalf of Jinping Pre-collaboration

Tsinghua University

2019-10-22 NGS 2019@Praha



Adopted from Physics Today

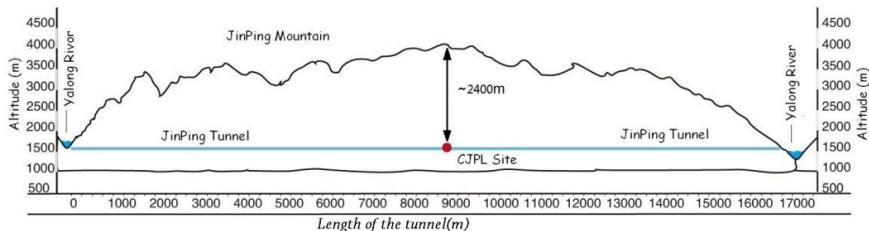
# China JinPing underground Laboratory

Yalong River Hydropower Development Company started to develop the hydro-energy for the entire river since 1990s.



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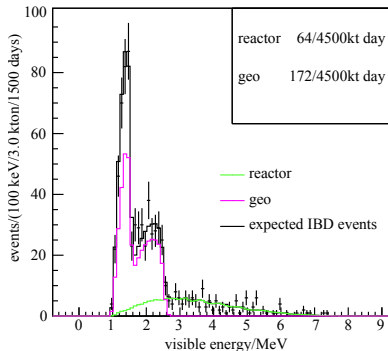
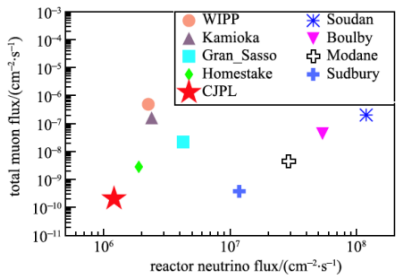


- 8 km long entrance tunnel, possible alternative sites.
- Abundant electricity and water supply.
- In July 2019, China Jinping Laboratory started as "national magnificent scientific and technological infrastructure"

国家重大科技基础设施项目

# Probe Into the Earth from Jinping

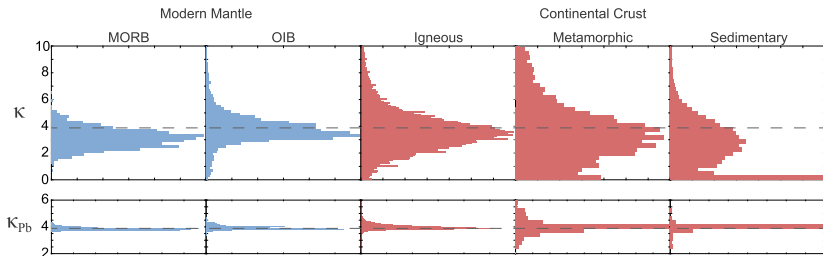
- Low reactor neutrino background.
- Large geoneutrino flux from the tibet plateau.



- Test the geochemical model of U Th concentration in the crust.
- Measure the abundance ratio of U/Th.
- Test georeactor hypothesis.

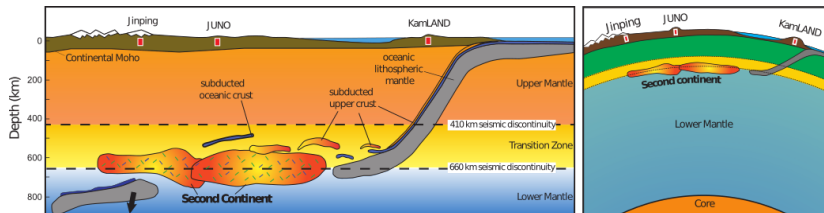
# Measurement of Th/U Ratio

- An undifferentiated Earth Th/U ratio has been established.



- Continental crust is hard to estimate in bulk, because of sampling biases, etc.
- At Jinping, the bulk Th/U ratio of the locals and Tibet Plateau can be tested.
  - ▶ At 4500 kton-day exposure, Th/U to be determined to 27%.

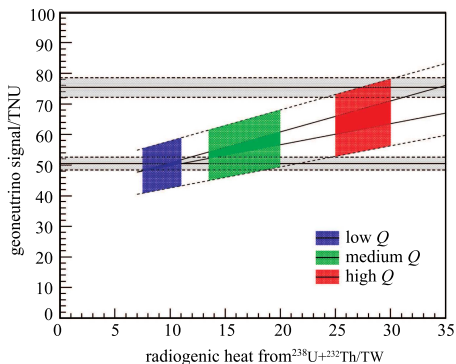
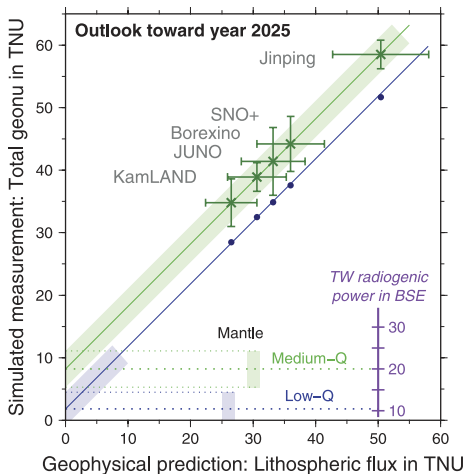
# Subducting Continent



- It is speculated that subducting plates could form gravitationally stable "second continent" at the mantle transition zone.
- A second continent below China is predicted, which will give excesses of geoneutrinos at JUNO and Jinping, but not much to KamLAND.
- Test the hypothesis with 3 experiments.

Roskovec et al. 2018 arXiv:1810.10914

# Determination of Mantle Heat Production



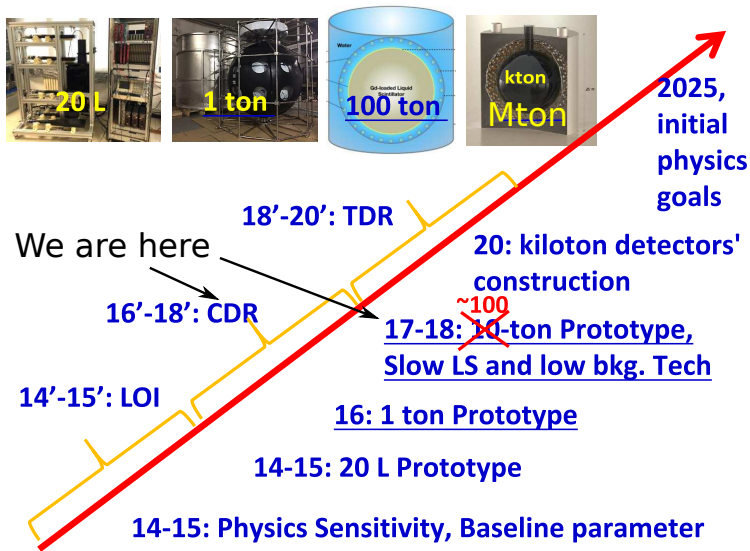
- Jinping will contribute an "outlier" to the global fit of mantle heat production.

Šrámek et al. 2016 Sci.Report

Wan et al. 2017 Phys.Rev.D



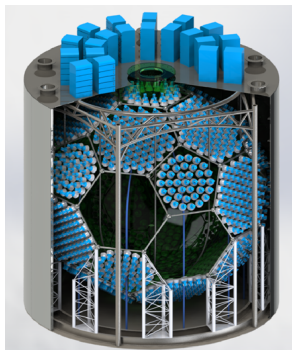
# Jinping Neutrino Roadmap and Milestones



Years to be scaled by  $\times \pi$

# ~100 t prototype

- One of the experimental halls of CJPL 2nd Phase will hold a neutrino experiment, suitable for the next ~100 t detector.



- Sensitivity to geoneutrinos from the Himalaya.
- Measure and control backgrounds.
- Test-bed for novel detection techniques.
  - ▶ Towards detection of  $^{40}\text{K}$  neutrino.

- Major parts are being purchased and delivered.
- Potential significant in-kind contribution to boost photo-coverage.

## 2019 Workshop of Jinping Neutrino Program

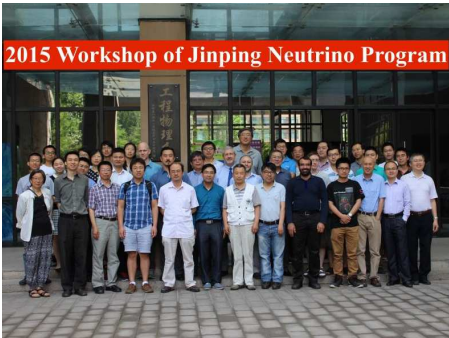
27-28 July, 2019, Beijing



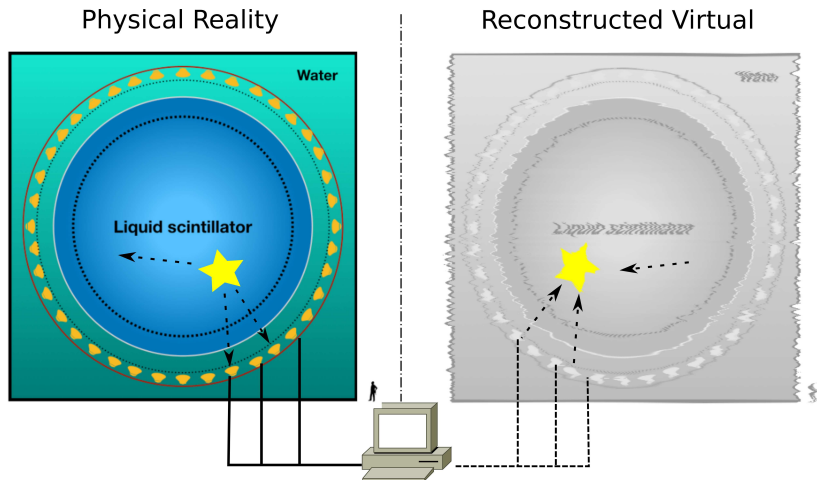
- Ever growing interest from the community.
- Active working group.
- Starting CDR draft: Welcome to join!



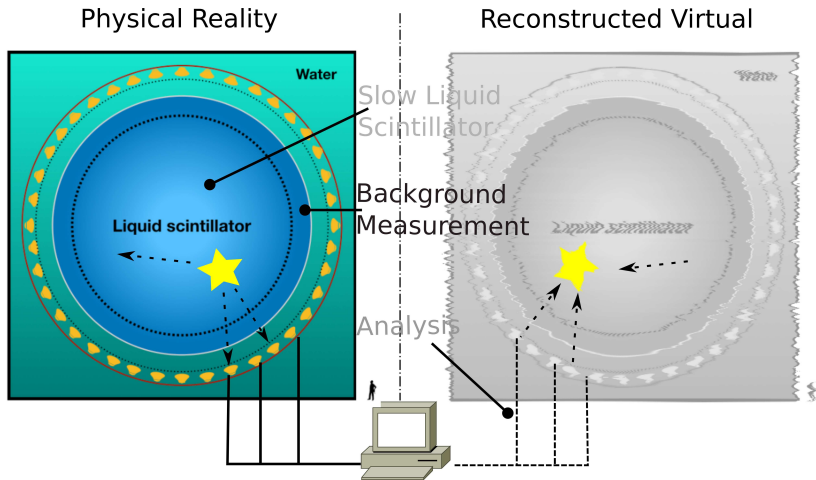
## 2015 Workshop of Jinping Neutrino Program



# Large Liquid Scintillator Detection Principle

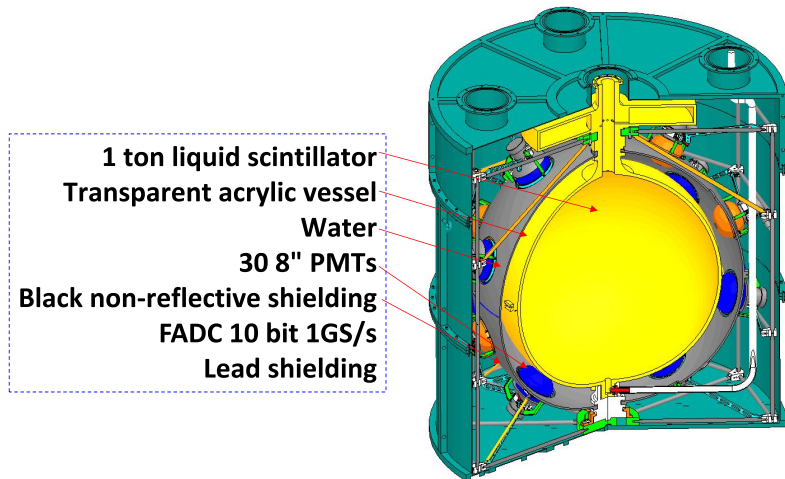


# Large Liquid Scintillator Detection Principle



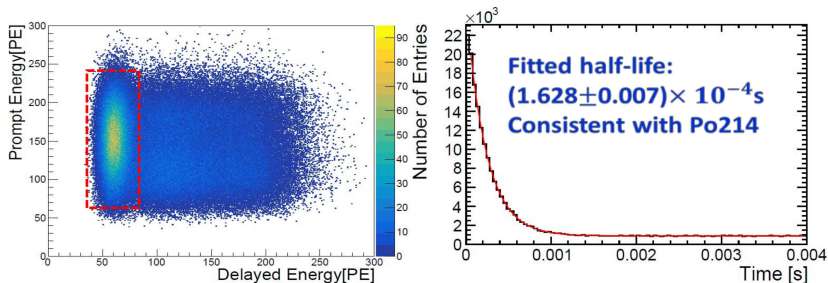
# 1ton Prototype

- In CJPL-I since 2017, besides CDEX and PANDAX experiments.
- Proof of detection principle, background measurement.

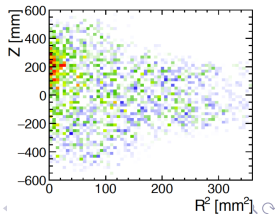


# Background Measurement (Preliminary)

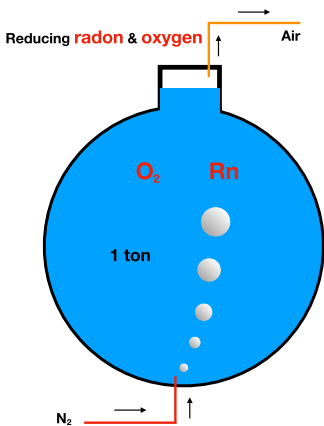
- $^{238}\text{U}$  measurement with  $^{214}\text{Bi}$ - $^{214}\text{Po}$  decay pairs
  - ▶  $\sim 2 \times 10^{-13}$  g/g without any treatment after production.



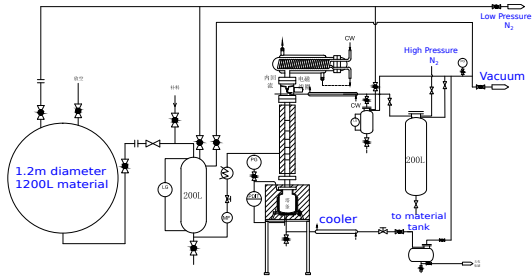
- Vertex distribution indicates leakage from the top.
- $^{232}\text{Th} < 1.3 \times 10^{-14}$  g/g (90% C.L.)



# Background Reduction Efforts



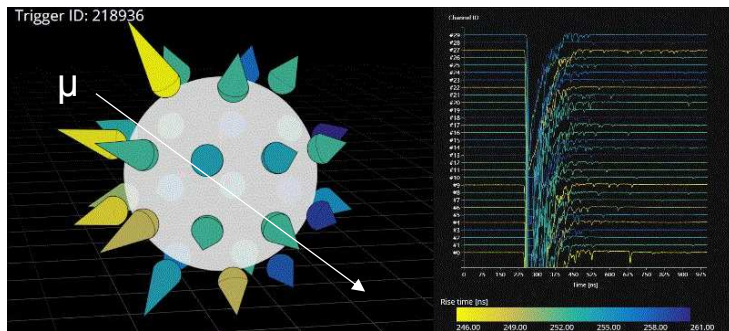
- Positive pressure system by bubbling N<sub>2</sub> has been deployed in August 2019.
- Preliminary result shows that the Rn level has been reduced by factor  $\sim 3$ .
- Distillation tower is designed, test system to be deployed this year.





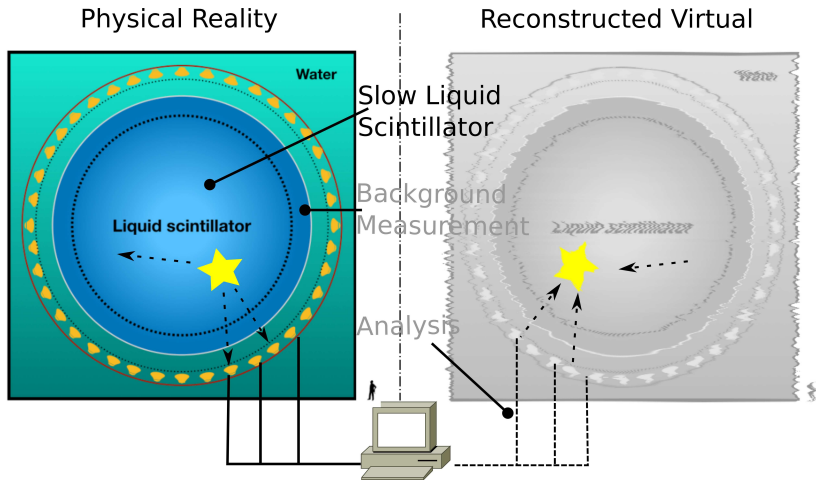
# Cosmic $\mu$ Background Example

- Liquid scintillator, radius  $\sim 0.645$  m.
- Larger detector cross section ( $1.3 \text{ m}^2$ )

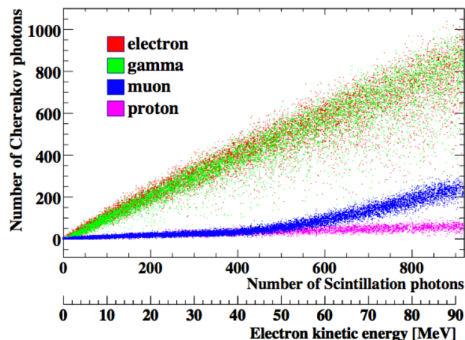
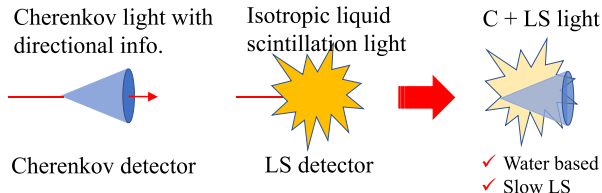


- $\mu$  angular distribution is being measured at CJPL I.

# Large Liquid Scintillator Detection Principle



# Slow Liquid Scintillator



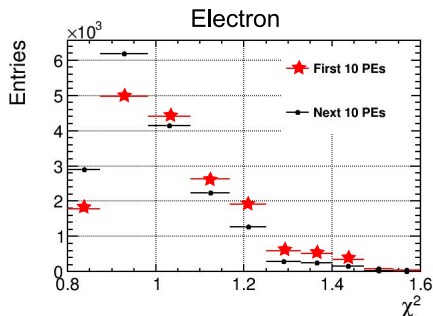
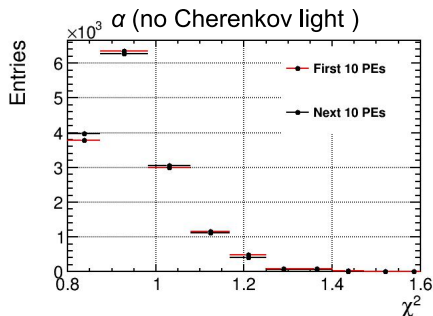
NIMA 830(2016) 303-308, j.astropartphysics.2019.02.001

- Separate atmospheric  $\nu$  NC events from supernova  $\nu$ .
- Direction of solar  $\nu$ .
- Potential to study  $^{40}\text{K}$  Geo- $\nu$ .
- Demonstrated by cosmic ray with a 20L detector.

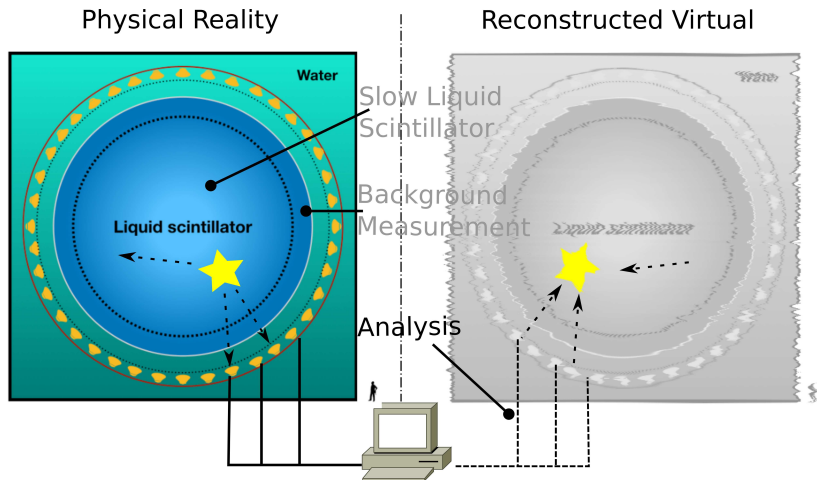
# Demonstration by 1ton Detector

- $^{214}\text{Bi}$ - $^{214}\text{Po}$  decay:
  - ▶ Prompt 2 MeV  $\beta$  emits Cherenkov light;
  - ▶ Delayed 7.7 MeV  $\alpha$  has no Cherenkov light.
- Select signals  $R < 0.2$  m:
  - ▶ Define a test statistic  $\chi^2 = \sum_{i=0}^{29} \frac{(q_i - \bar{q})^2}{\bar{q}}$  to measure sphericity.

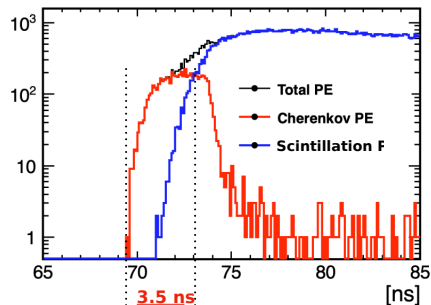
|          | spherical? | First 10 PEs | Next 10 PEs |
|----------|------------|--------------|-------------|
| $\alpha$ | yes        | yes          | yes         |
| $\beta$  | no         | no           | yes         |



# Analysis

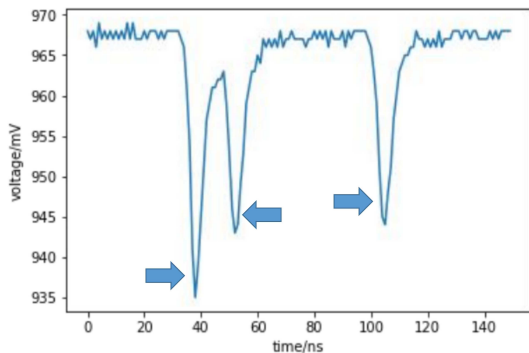


# Slow Liquid Scintillator Reconstruction



- 5kton detector simulation with 2 MeV electron.
  - ▶ Demo <https://youtu.be/G081QiqItTs>
- Slow liquid scintillator gives 3.5 ns window to Cherenkov photons.
- Full likelihood method is developed,
  - ▶ Angular bias is  $\sim 30^\circ$ .
  - ▶ Waveform good-fit ratio is 93%  $\rightarrow$  call for improvements.

# Modern Waveform Analysis



- PMT waveforms made available by fast ADC readouts.
- Challenge at <https://ghost-hunter.net9.org/>.
- 60+ participants compete on an auto-grading platform.
- Deep learning methods begin to dominate the leader board.

# Others Ongoing Studies

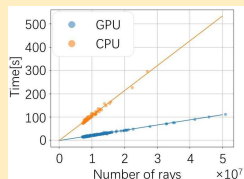
## PMT and Light Concentrator

- PMTs with optimized TTS,  $\sim 1$  ns is desired.  
→ Joint research and development effort with PMT manufacturers.
- PMT light concentrator development, with 3D optimization. Test is ongoing.



## GPU Ray Tracing Simulation

- Light propagation is modeled by GPU ray tracing.
- Acceleration of detector model simulation is proportional to number of photons.





# Conclusion

- 1 Neutrino experiment at Jinping is important for neutrino geoscience.

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  - ▶ Th/U determination by geoneutrinos.
  - ▶ Search for second continent.
  - ▶ Measure mantle heat production.
- ② 1 t prototype detector is running in CJPL.

# Conclusion

- ① Neutrino experiment at Jinping is important for neutrino geoscience.
  - ▶ Th/U determination by geoneutrinos.
  - ▶ Search for second continent.
  - ▶ Measure mantle heat production.
- ② 1 t prototype detector is running in CJPL.
- ③ ~100 t detector is planned to be constructed in the CJPL II.
  - ▶ Targeting geoneutrinos from Himalaya.

## Call for Action

You are warmly welcomed to join our pre-collaboration, to build neutrino detectors at CJPL.

# [100%] Highlights from TAUP2019

- ☒ Newest research from geoscience.
- ☒ Update of background measurement.
- ☒ 100t Plan.
- ☒ Light Concentrator.