Measurement of cosmic muon flux and cosmogenic neutron yield at CJPL-I

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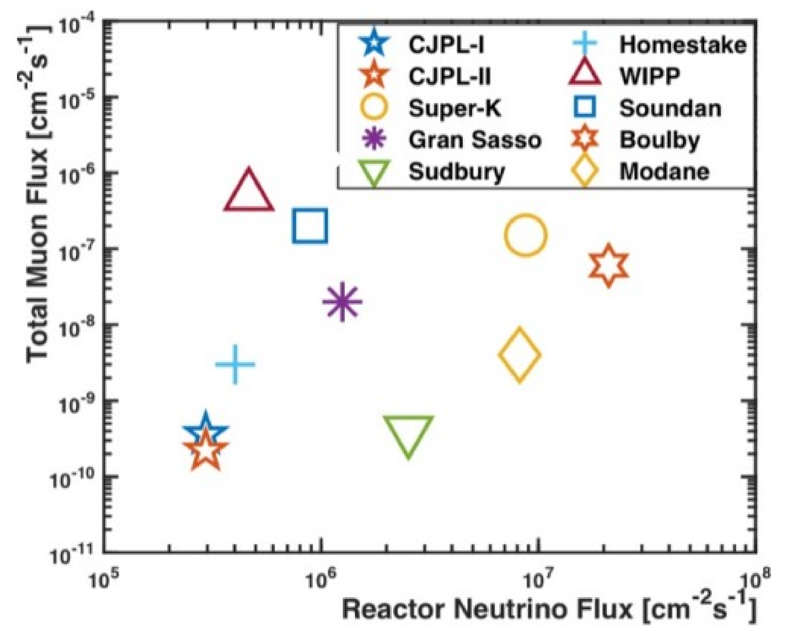
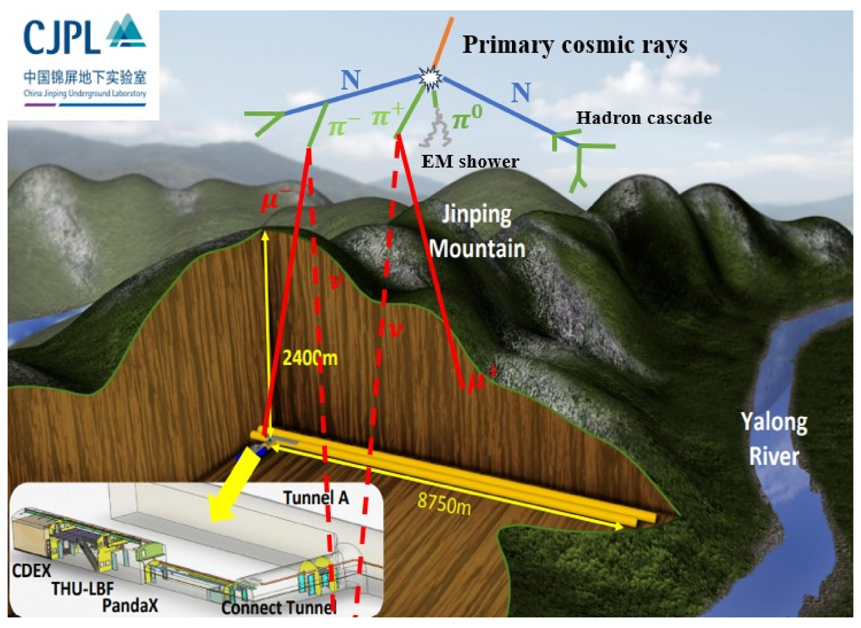
ICHEP 2024

I. Introduction

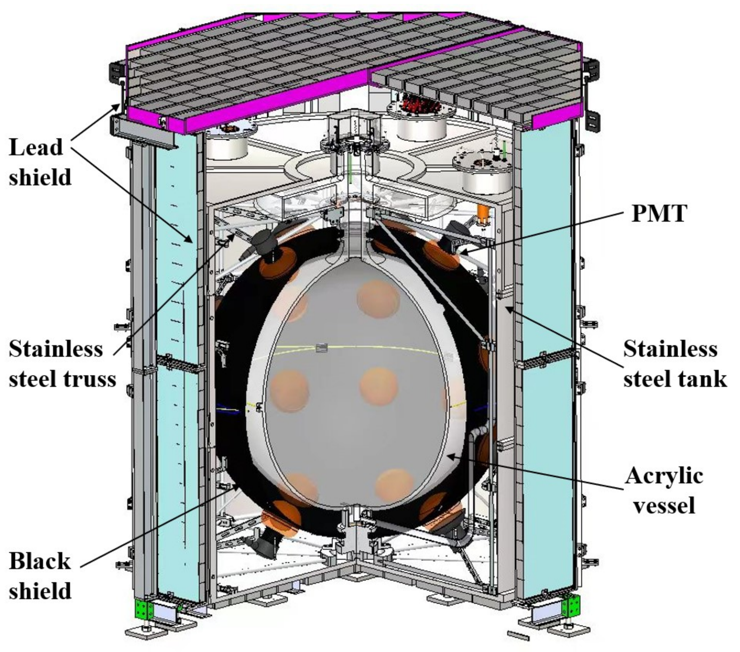
- Located under 2400 m rock overburden, China Jinping Underground Laboratory (CJPL) [1] is an ideal site for low energy neutrino experiment with extremely low background [2].
- Cosmogenic backgrounds such as neutrons induced by muon are irreducible in rare events research such as solar neutrino studies and $0\nu\beta\beta$ search, so quantitative evaluation of these backgrounds is significant in analysis. This study gives the measurement of cosmic muon flux and cosmogenic neutron yield with the highest average muon energy in the world.





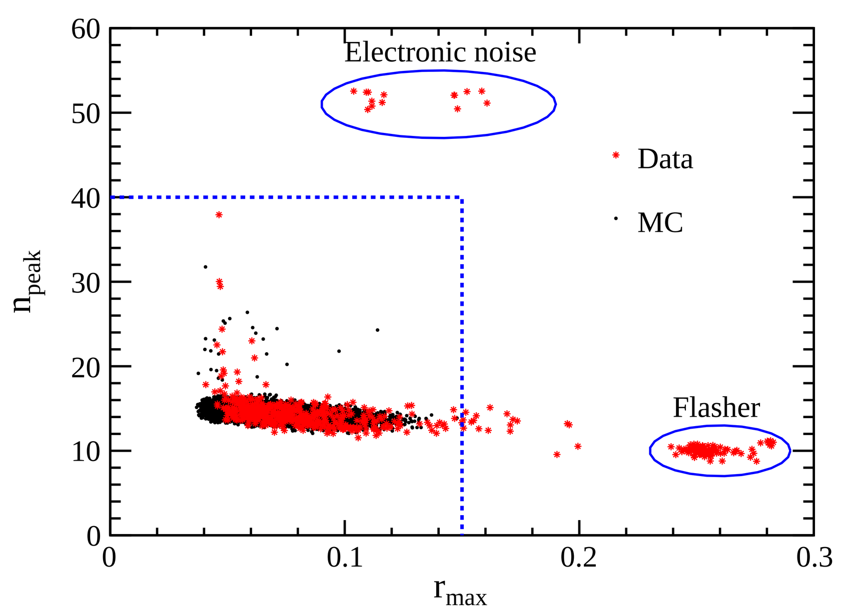
II. One-ton liquid scintillator detector

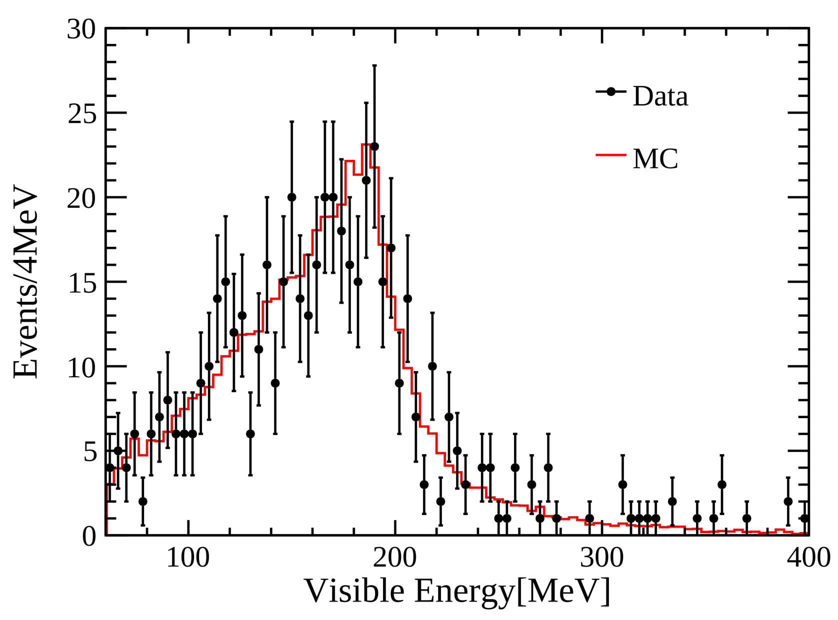
- One-ton detector, built as a prototype for Jinping Neutrino Experiment (JNE), is a liquid scintillator detector in CJPL-I. This detector is constructed for systematical test of detector technologies.
- Using this detetcor, the radioactivities are measured in previous study [3].
- In this analysis, all data collected from 31th, July, 2017 to 2nd, September, 2023 is used.



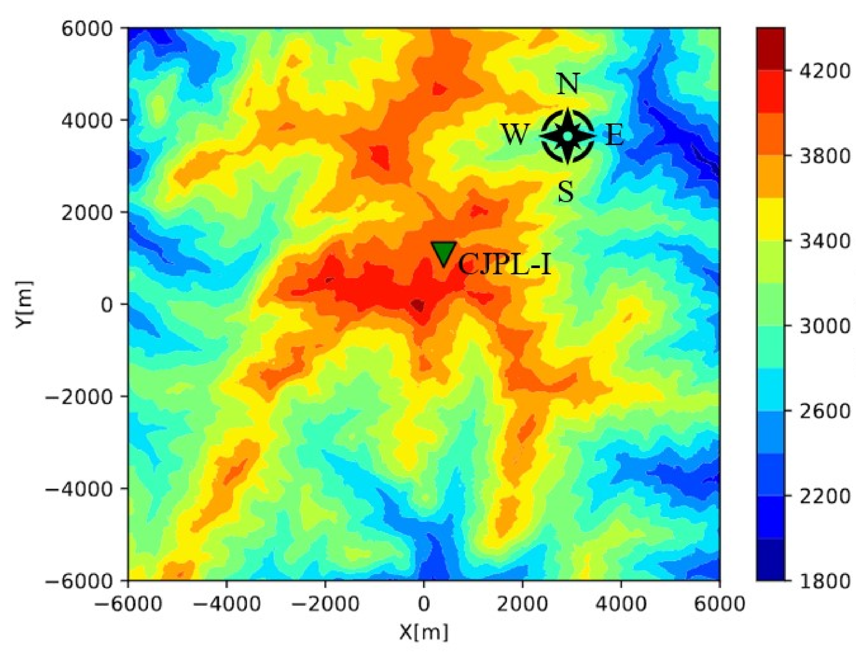
III. Muon event signature

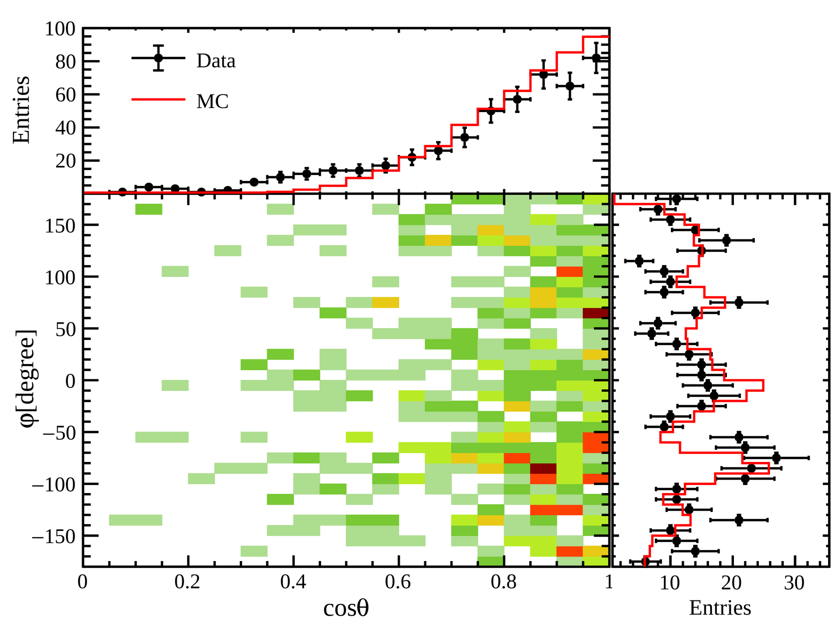
- The average energy of muons reaching CJPL can be up to 340 GeV and the average energy deposited in one-ton prototype is $\sim$100 MeV.
- At this energy level, instrumental signals are dominant backgrounds for muon events, which can be identified by characteristic parameters in data.





- The direction of muon selected is reconstructed and the zenith and azimuth angle distributions are both consistent with simulation [4].
- The uneven distribution of azimuth observed indicates that the different cosmic-ray leakage due to the mountain terrain above CJPL-I





IV. Cosmic muon flux

- The cosmic ray muon flux at underground laboratory can be calculated as

$$\phi_\mu = \frac{N_{total}}{T \times S} = \frac{N_\mu}{\varepsilon \times S \times T},$$

- ϕ_μ: Cosmic muon flux,
- N_μ: The number of selected muons,
- N_{total}: The number of muons reaching laboratory,
- S: Projection area of laboratory,
- T: Effective DAQ time,
- ε: Efficiency of selection.

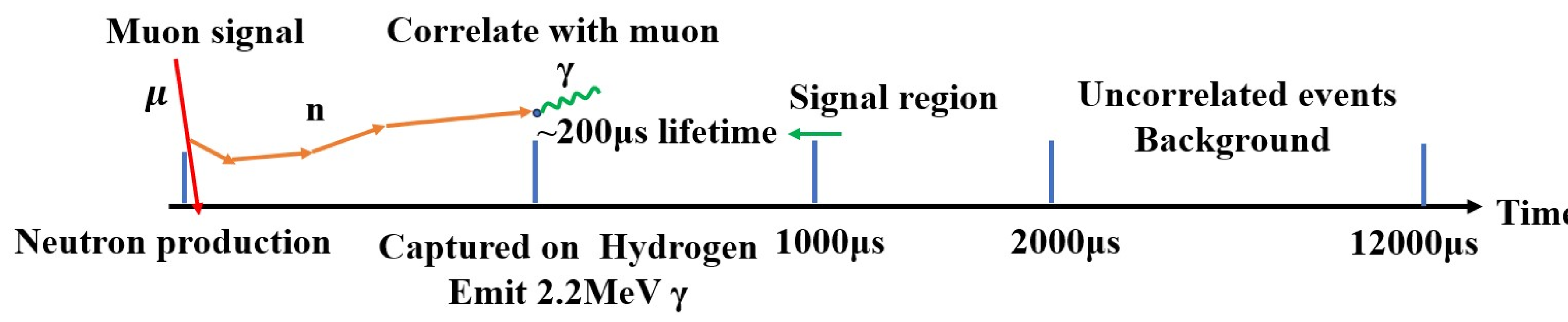
Using 1178.0 days effective DAQ data of this detector, 493 muons are selected and the corresponding cosmic muon flux can be expressed as

$$\phi_\mu = (3.56 \pm 0.16(\mathrm{stat.}) \pm 0.10(\mathrm{sys.})) \times 10^{-10}\ \mathrm{cm^{-2}s^{-1}}.$$

- This measurement indicates that CJPL is one of the laboratories with **the lowest cosmic ray flux** in the world.

V. Cosmogenic neutron yield in liquid scintillator

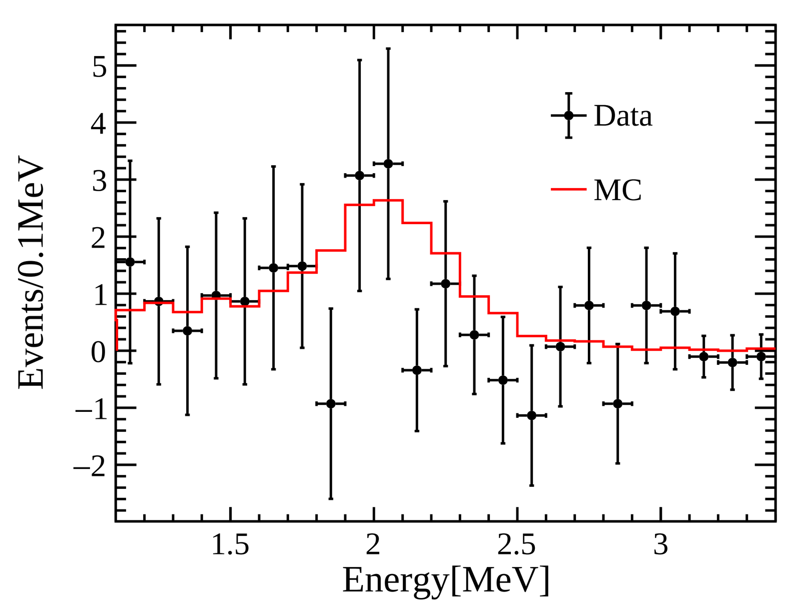
- The cascade between muon and neutron signals is used to select the cosmogenic neutron candidates in data. After the subtraction of uncorrelated background, the number of cosmogenic neutrons induced by muons N_{obs} is obtained.

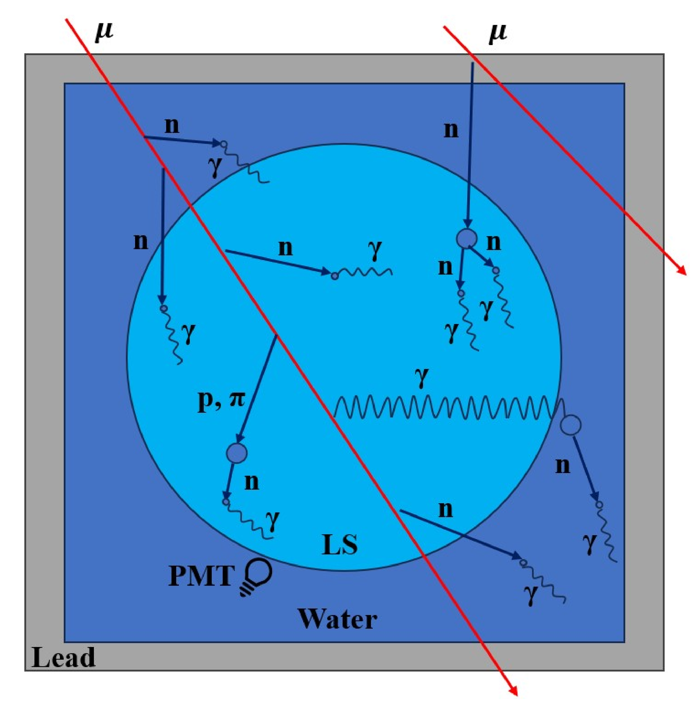


- The neutron yield induced by muons can be expressed as [5]

$$Y_{\mathrm{n}} = \frac{N_{\mathrm{n}}}{(\sum L_\mu) \times \rho} = \frac{N_{\mathrm{obs}} \times \varepsilon}{N_\mu \times L_{\mathrm{avg}} \times \rho},$$

where N_μ is the number of muons selected from data, L_{avg} is the average path length of muon in LS, ε is the overall neutron efficiency, ρ is the density of LS.



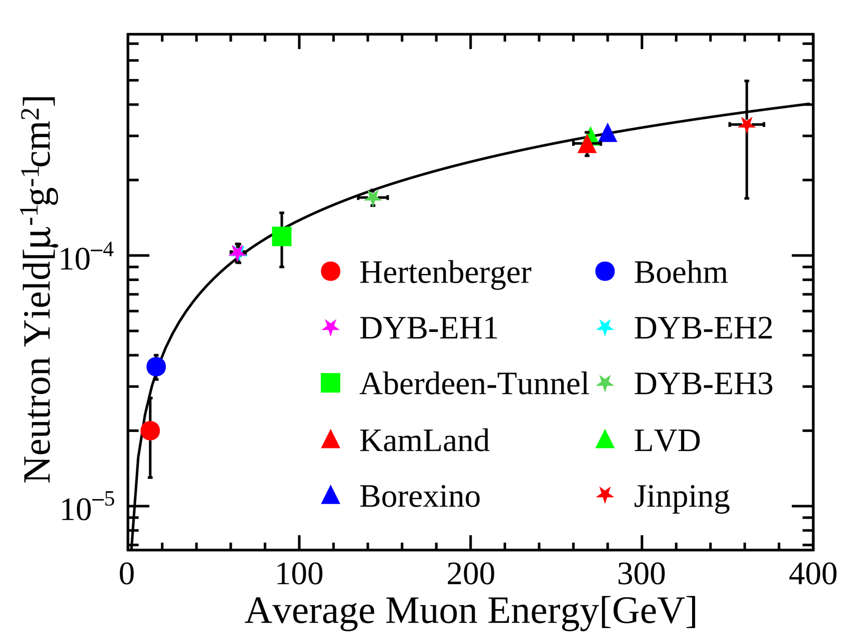


- Due to the finite volume of detector, the spill of neutron and gamma is complex for the measurement of yield. An overall detector simulation is conducted to evaluate these effects.
- Then the cosmogenic neutron yield in LS at CJPL is measured as

$$Y_{\mathrm{n}} = (3.33 \pm 1.56\ (\mathrm{sys.}) \pm 0.90\ (\mathrm{stat.})) \times 10^{-4}\ \mu^{-1}\mathrm{g}^{-1}\mathrm{cm}^2.$$

VI. Conclusion

- Cosmic muon flux is measured at CJPL-I using 1178.0 days of data collected by 1-ton detector.
- This analysis also provides the measurement of cosmogenic neutron yield with **the highest average muon energy** in the world.
- One-ton prototype is under upgrade now, which is introduced in poster 307. Better measurement of cosmogenic background is expected in future.



Reference

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