

First measurement of the yield of ^8He isotopes produced in liquid scintillator by cosmic-ray muons at Daya Bay



Paper

arXiv:2402.05383



Resume

<https://drive.google.com/drive/folders/1Qym5u2oD3xbLvRgPFBCEQZc2QEUKy4>

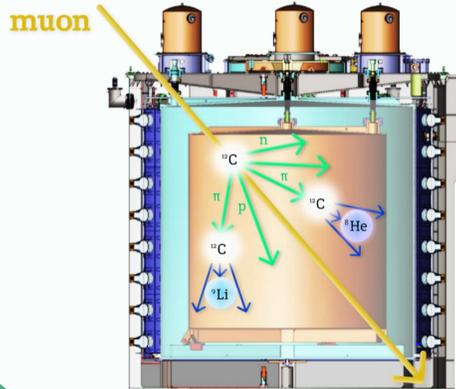
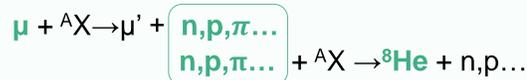
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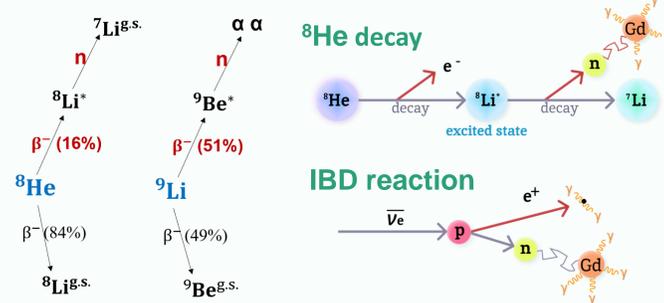
Introduction

Production of cosmogenic ^8He



$^8\text{He}/^9\text{Li}$: critical backgrounds for IBD ($\bar{\nu}_e$)

1. Mimic IBD events: β -neutron decay branch
2. Long lifetime: $^8\text{He} \sim 172\text{ms}$, $^9\text{Li} \sim 257\text{ms}$
3. Similar energies: IBD $\sim 8\text{MeV}$, $^8\text{He}/^9\text{Li} \sim 10\text{MeV}$



Previous measurement

Yield (Y), a quantity characterizing the probability of isotope production, is similar to production cross section

Measured yields:

(generally using the β -n decay branch)

- ^8He consistent with zero within 2σ level
- ^9Li with precision of about 10%

Simulation:

- ^8He yield is at least 10 times lower than other cosmogenic isotopes

An Innovative Method for ^8He Selection

Identifying cascade decay of ^8He and child ^8Li (ground state)

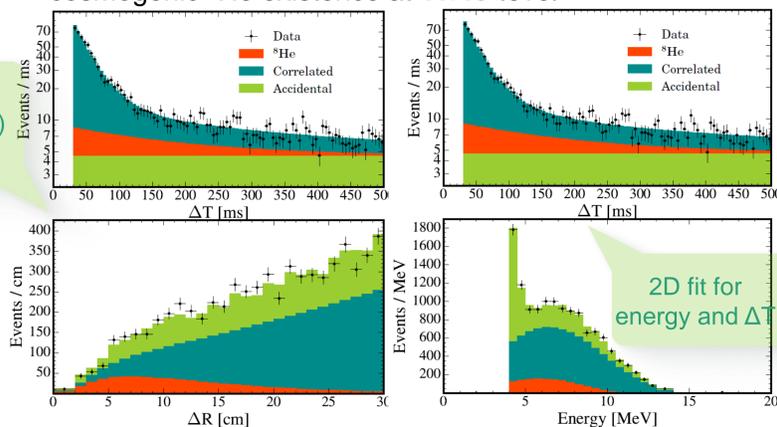
β - β cascade decay: $^8\text{He}-^8\text{Li}^{\text{g.s.}}$

- **β - β temporal and spatial coincidence**
 - time interval of ^8He and $^8\text{Li}^{\text{g.s.}}$ $\sim 1\text{s}$
 - highly localized
- Higher branching ratio $\sim 84\%$

Fit for $^8\text{He}-^8\text{Li}^{\text{g.s.}}$ enriched samples

- **Two fit with consistent results**
 - 2D fit for distance of $^8\text{He}-^8\text{Li}^{\text{g.s.}}$ and ΔT of ^8He and muon
 - 2D fit for energy of ^8He and ΔT of ^8He and muon

cosmogenic ^8He existence at 11.4σ level



2D fit for distance (ΔR) and ΔT

2D fit for energy and ΔT

Measurement for ^9Li

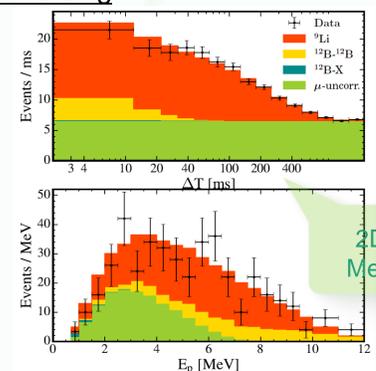
Utilizing β -n decay branch

Method 1:

- 2D fit for energy (^9Li) and ΔT (^9Li -muon)
- ^9Li in low S/B samples limited by dR (^9Li β -n)

Method 2:

- 3D fit for ΔT (^9Li -muon), vertical position, and reactor power
- ^9Li in low S/B samples obtained by unfolding



2D fit of Method 1

Results

1. First measurement of cosmogenic ^8He in liquid scintillator

- ^8He yields with precision of about 14%
- ^8He yield is more than an order of magnitude lower than any other measurement of cosmogenic isotope

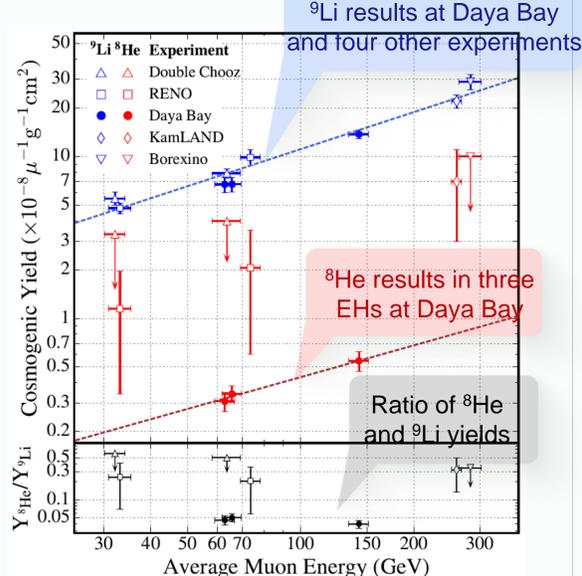
2. Ratio of ^8He and ^9Li yields in three underground experimental halls (EHs) at Daya Bay

- $R_{\text{EH1}} = 4.56 \pm 0.80\%$
- $R_{\text{EH2}} = 5.05 \pm 0.79\%$
- $R_{\text{EH3}} = 3.97 \pm 0.60\%$

3. Isotopic yield with respect to muon energy

$$Y = Y_0 * (E_{\text{avg}}^\mu / 1\text{GeV})^\alpha, \quad Y_0 \text{ in unit of } 10^{-9} \mu^{-1} \text{g}^{-1} \text{cm}^2$$

- ^8He at Daya Bay: $Y_0 = 0.21^{+0.34}_{-0.13}$, $\alpha = 0.65 \pm 0.22$
- ^9Li at five experiments: $Y_0 = 3.3 \pm 0.7$, $\alpha = 0.76 \pm 0.05$



^9Li results at Daya Bay and four other experiments

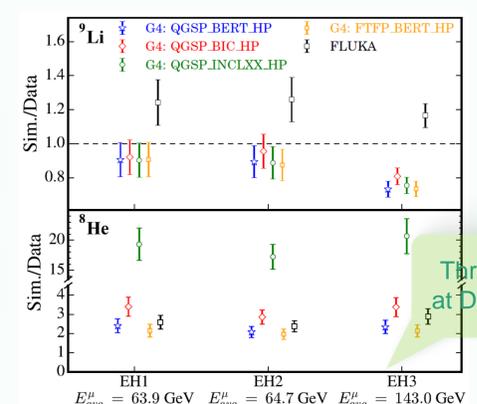
^8He results in three EHs at Daya Bay

Ratio of ^8He and ^9Li yields

Simulation

FLUKA and four models of GEANT4

- ^8He : simulated yields are more than twice larger than measurements
- ^9Li : simulated yields differed from measurements by 10-30%



Three EHs at Daya Bay



Neutrino 2024

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References

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