Evaluation of spallation background for DSNB search in SK-Gd

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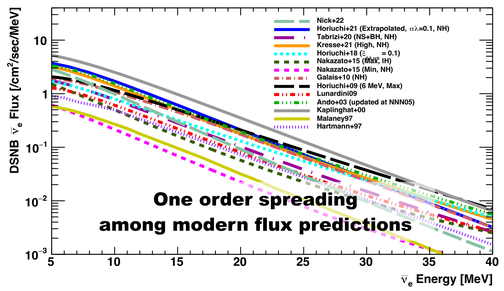
1. Introduction

Diffuse Supernova Neutrino Background: DSNB

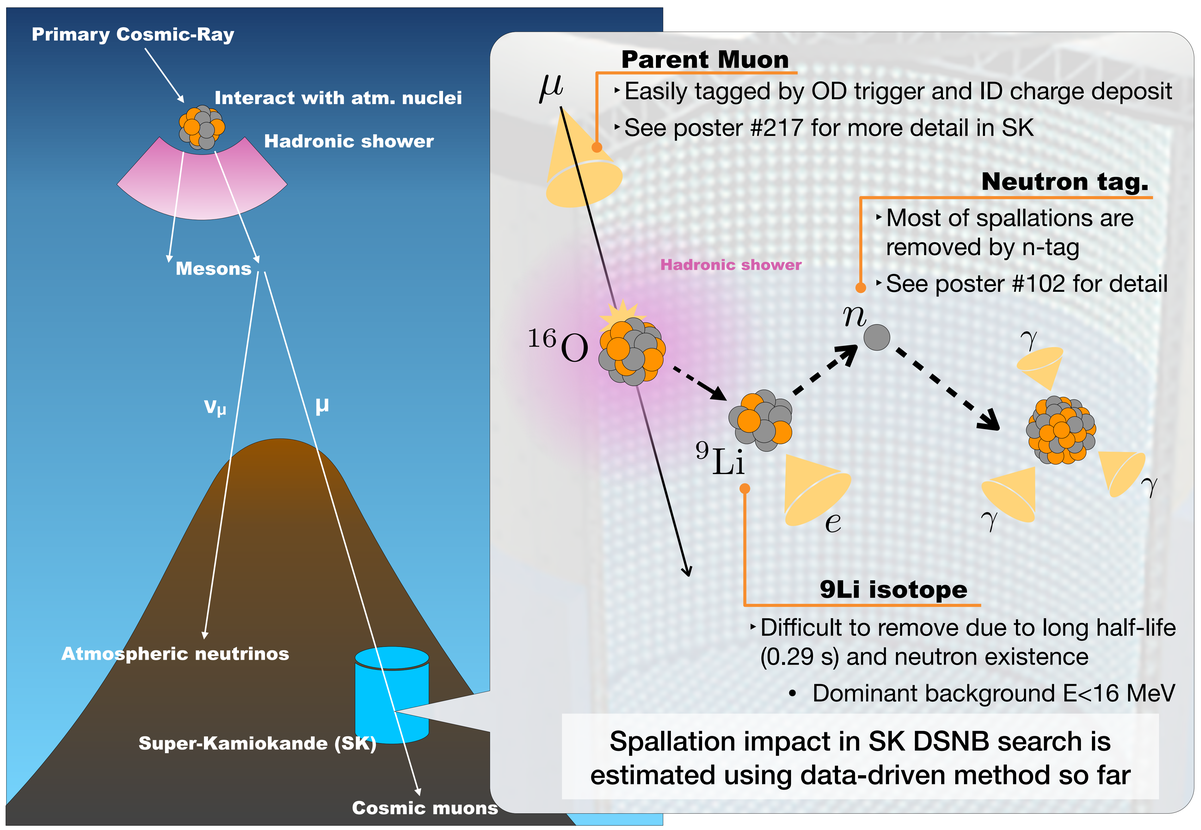
- Integrated flux of neutrinos emitted from past all Supernovae
- SRN flux includes star evolution information
- Perform search in Super-Kamiokande with Gd (SK-Gd)
  - See poster #360 for the latest search

$$\Phi_{\mathrm{SRN}} \propto \int [\text{SN rate}] \otimes \left[\begin{array}{c}\nu \text{ emission} \\ \text{from SN}\end{array}\right] \otimes [\text{Red shift}]$$



Detecting DSNB allows us to investigate **history of star formation and black-hole formation**

Muon Spallation on Oxygen nuclus



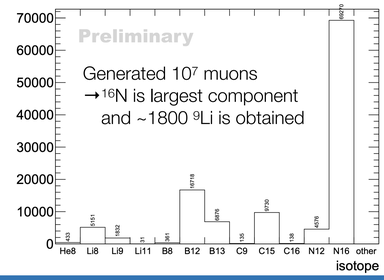
Spallation impact in SK DSNB search is estimated using data-driven method so far

Evaluate removal performance and its uncertainty using Geant4 simulation with detector response with muon/isotope

2. Spallation simulation

Simulation setup

- Use Full Geant4 SK detector simulation (SKG4)[1]
  - FTTP-BERT-HP for hadronic interaction package
- Muon flux by Modified Gaisser Parameterization→MUSIC[3], with measured θ/ϕ direction
- Consider electron and muon event reconstruction



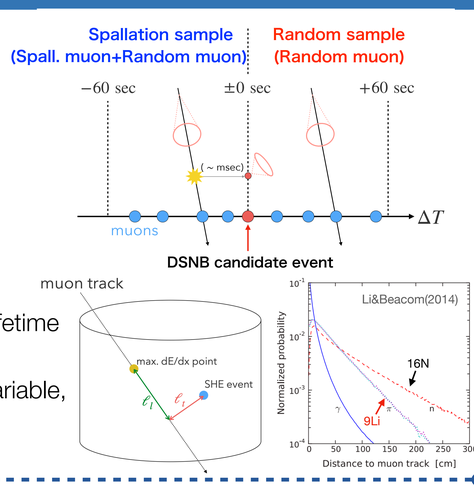
[1] M. Harada, *J. Phys.: Conf. Ser.* **1468** (2020) 012255, [2] A. Tang, *Phys. Rev. D* **74**, (2006) 053007

3. Evaluation

Data-driven ^{9}Li remaining rate evaluation

- Use log-likelihood to remove spallation
- Data driven-method to evaluate performance and creating PDF

$$\mathscr{L} = \log \prod_{i \in vars} \frac{\mathrm{PDF}_i^{\mathrm{spall}}(x)}{\mathrm{PDF}_i^{\mathrm{random}}(x)} \qquad vars = \begin{cases} \text{time diff. from muon } (dt) \\ \text{2 spatial info. } (l_t, l_l) \\ \text{2 charge related var.} \end{cases}$$

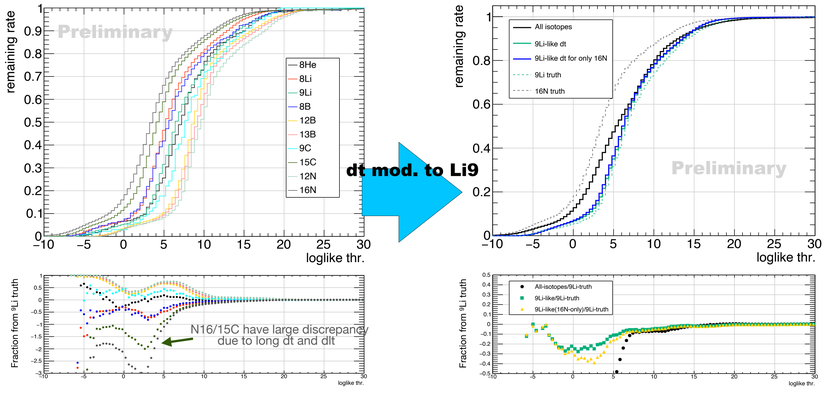


- To estimate ^{9}Li remaining rate, we artificially modify "*only dt*" to ^{9}Li lifetime to obtain ^{9}Li-like likelihood
  - Apparently the there is an isotope dependence for the spatial variable, based on the parent particle.
    - We count *50% uncertainty for ^{9}Li remaining rate* robustly

4. Result

Validation of uncertainty with spallation MC

1. Calculate likelihood with same method and PDF with data
2. Compare the true/recon. eff.



✓Confirm "*dt*" is the largest term for spall. cut, and "*lt*" is subdominant

✓Sys. error for ^{9}Li remaining rate can be reduced to **30%**

Summary

- First time to evaluate spallation background in SK with Geant4 with detector simulation
- Validate spallation cut by reproducing detector response for muon spallation event
- Assign 30% for ^{9}Li remaining rate (previously 50% robustly)