KamiokaCryolabでの軽い暗黒物質探索に向けた中性子背景事象の評価

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1.Introduction

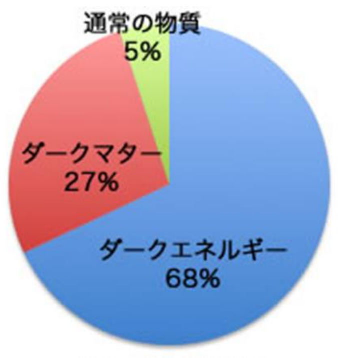
Motivation

Dark matter

Occupies 27% of total mass of universe

No charge and stable

Important to understand the origin of universe



Component of universe

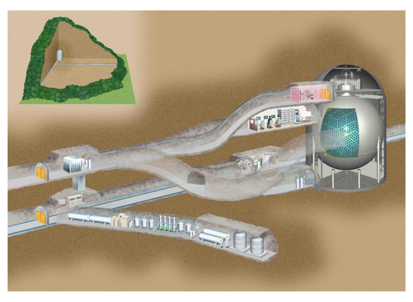
Kamioka Cryolab, located in KamLAND area, is planning a light dark matter(<GeV) search using a superconductor sensor.

In ultra low-background experiment, it is important to evaluate the ambient radioactivity

Kamioka Cryolab aims to accomplish the background less than 10 events/keV/kg/day

Ambient neutron is one of serious backgrounds for a direct dark matter search

- Here I evaluated ambient neutron background
- I also discuss how we can achieve goal (<10events/keV/kg/day)



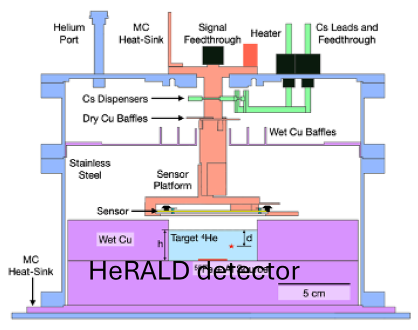
Kamioka Cyolab

2.Principle

Principle

HeRALD module is installed to detect low-energy DM-nuclei recoil.

- Use superfluid He4 as a target
- Sensitive to low energy DM-nuclei recoil



Background

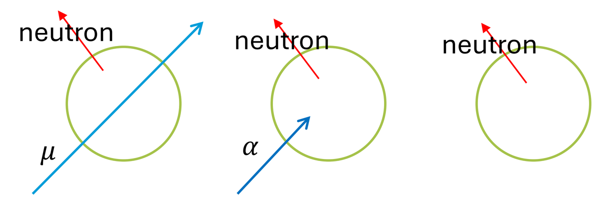
Background candidates

- Muon
- Gamma ray
- Ambient neutron etc.

Among these I focused on ambient neutron background

Types of ambient neutron

- (α,n)reaction generated from U/Th chain
- Spontaneous U fission
- Neutron generated from muon



Shielding material

- Polyethylene(PE): slow down the fast neutron to thermal neutron
- Boron sheet(B_4C):capture thermal neutron

Combining these two can shield both high/low energy

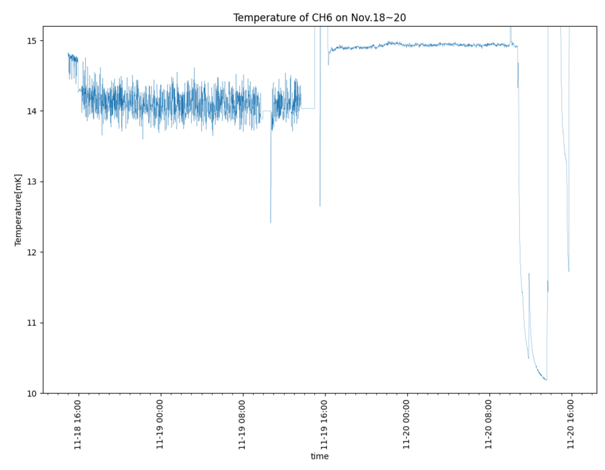
Kamioka Cyolab

Dilution refrigerator

Dilution refrigerator(DR) can cool down to ~10mK

DR was installed to Kamioka Cryolab in last November and test run was conducted

DR accomplished ~10mK at its lowest



3.Setup and Simulation

Setup

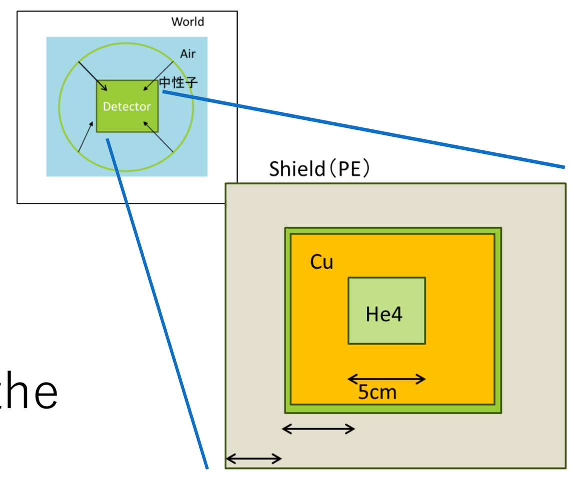
Simulated deposit energy of neutron in He4 on Geant4 (ver:11.0.4,Physics List:QGSP_BIC_HP)

Used a very simplified geometry

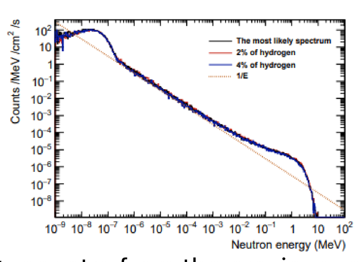
Simulation

Generated 10^8 neutron from a surface to inside the sphere using a cosine-law

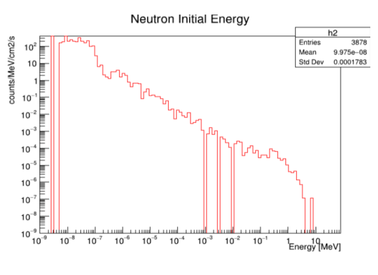
Energy spectra is cited from previous research (Mizukoshi et al., arXiv:1803.09757,2018)



Setup



Energy spectra from the previous research



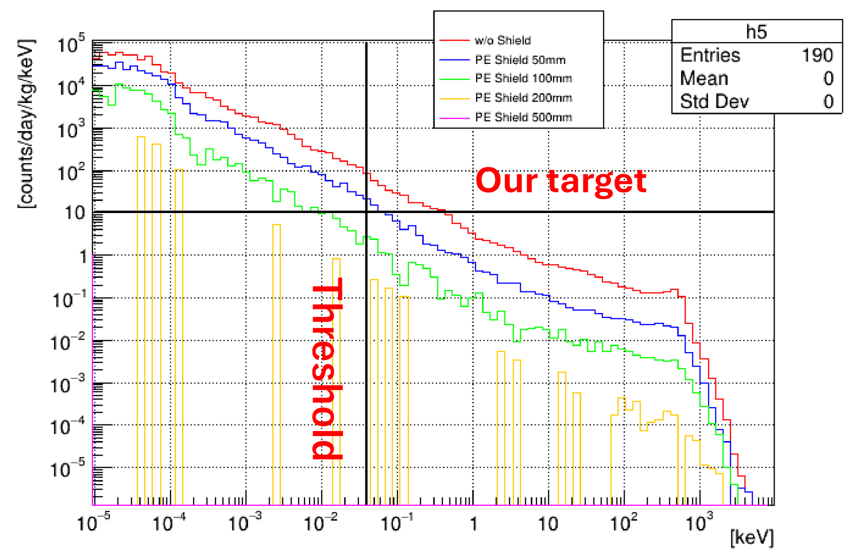
Energy spectra generated on Geant4

4.Result (Comparison of PE Thickness)

PE shield

- I compared the background with and without PE shield
- Integrated from 40 eV to 1keV to obtain the total number of events

→**10+cm thickness of PE is needed** to accomplish the target (<10counts/keV/kg/day)



Comparison of neutron background variation with B thickness

シールドの種類	Counts/kg/day
w/o Shield	11.4±0.1
PE 5cm	2.15±0.05
PE 10cm	0.27±0.02
PE 20cm	$(9.091 \pm 0.525) \cdot 10^{-2}$
PE 50cm	0

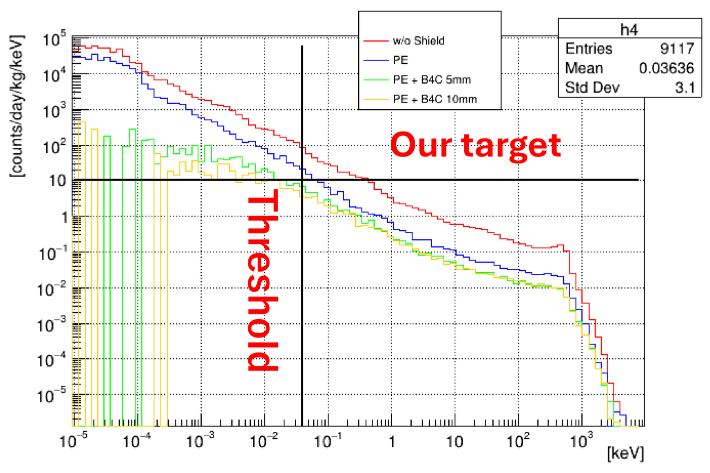
5.Result (Comparison of B Thickness)

B sheet

- I also compared the influence of B sheet thickness
- Integrated from 40 eV to 1 keV to obtain the total number of events

→It actually captures thermal neutron at least single B sheet is needed

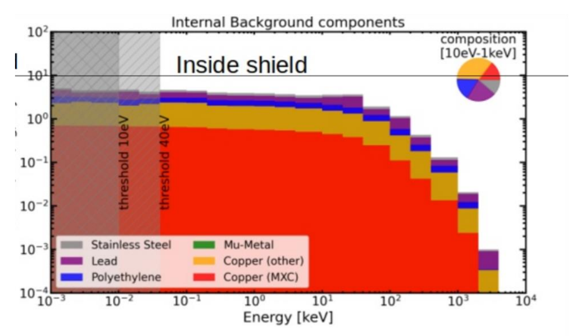
If combined with PE shield, we can accomplish background lower enough than target(<10 events/keV/kg/day)



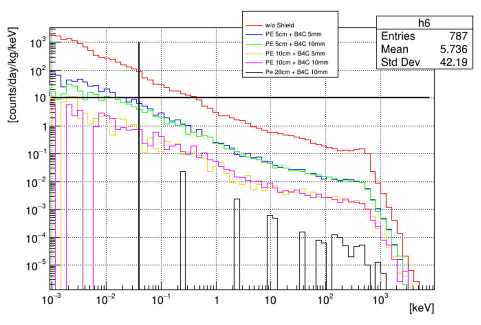
Comparison of neutron background variation with B thickness

Types of shield	Counts/kg/day
w/o Shield	11.4±0.1
PE 5cm	2.15±0.05
PE5cm+B4C5mm	0.936 ± 0.035
PE5cm+B4C10mm	0.74 ± 0.03

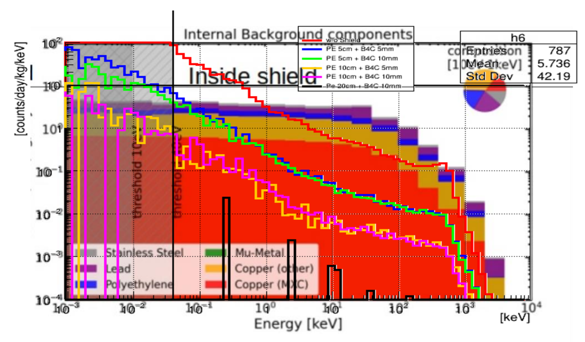
6.Summary & Future Prospect



Previous research about the internal background



Neutron background in this research



Comparison

Summary

To accomplish the targaet(<10events/keV/kg/day), **10cm PE shield and single B sheet** can decrease the ambient neutron background

Future prospect

- Simulation with more precise geometry is needed
- Other background candidates should be taken into account

7.Reference

R. Anthony-Petersen et al., "First Demonstration of the HeRALD Superfluid Helium Detector Concept," arXiv:2307.11877 [physics.ins-det], 2024.

S. A. Hertel et al., "Direct detection of sub-GeV dark matter using a superfluid 4He target," arXiv:1803.09757 [hep-ex], 2019.

K. Mizukoshi et al., "Measurement of ambient neutrons in an underground laboratory at Kamioka Observatory," arXiv:1803.09757,2018