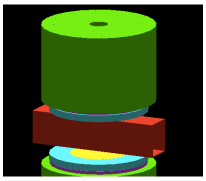
Comparison of gamma production from thermal neutron capture of gadolinium with the Monte Carlo simulation

K.Hagiwara(Okayama Univ.)
P.K.Das, T.Tanaka, I.Ou, Y.Yamada, R.Dhir, T.Mori, T.Kayano, M.Sakuda, Y.Koshio (Okayama Univ.)
T.Yano (Kobe Univ.), A.Kimura, H.Harada, N.Iwamoto, S.Nakamura (Japan Atomic Energy Agency)



1. Introduction

Gadolinium (Gd, Z=64)

The neutron capture reaction on Gd emits γ-rays with total energy of 8MeV. Need more precise experimental data!

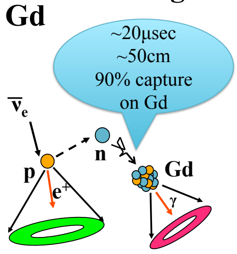
Measuring γ-rays from thermal neutron capture on Gd

Reaction	Cross-section of thermal neutron cpature[barn]
n+p→d+γ	0.3326
$n+^{6}Li \rightarrow \alpha+^{3}He$	940
$n+^{10}B \rightarrow \alpha+^{7}Li$	3837
$n+^{155}Gd \rightarrow ^{156}Gd+\gamma$	60900
$n+^{157}Gd \rightarrow ^{158}Gd+\gamma$	254000

New method of neutrino measurement using neutron capture on Gd

In order to discriminate electron anti-neutrino and neutrino, $Gd_2(SO_4)_3$ will be loaded into Super-Kamiokande. Event tag by positron and delayed γ-rays generated by Gd.
However, the uncertainty of simulation for reaction on Gd is large!

Studying model of reaction for thermal neutron capture on Gd by experiment.



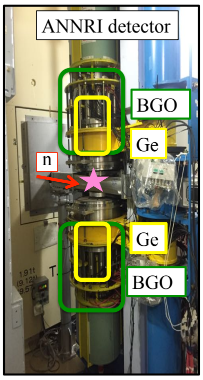
Present and future neutrino experiments using Gd

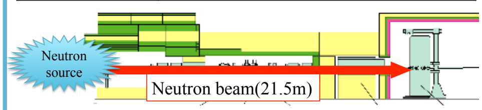
Abbreviation	Detector	Measure
EGADS	Water Cherenkov	R&D detector for SK-Gd
SK-Gd (2018~)	Water Cherenkov	SRN, SN ν, Solar ν, atm ν, p^+ decay
Daya Bay, RENO, Double Chooz	Liquid scintillator	The mixing angle θ_{13}

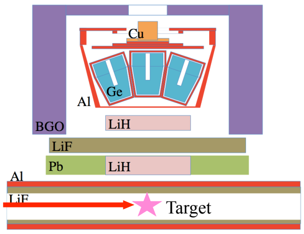
2. J-PARC/ MLF/ ANNRI

ANNRI Detector

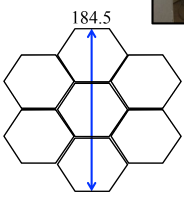
Neutron beam	Pulse type beam(highest intensity) ($\Delta E_n/E_n$~1%, power : 300kW)
Ge detector (14 crystals)	Measurement of γ-rays energy with high accuracy (ΔE_γ=9keV@1.3MeV)
BGO detector	VETO detector



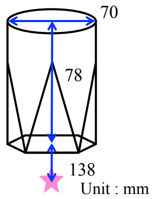




Top half detector



Ge cluster



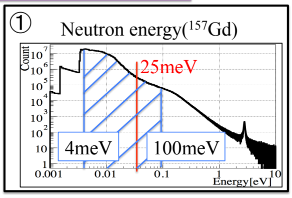
Experimental Information

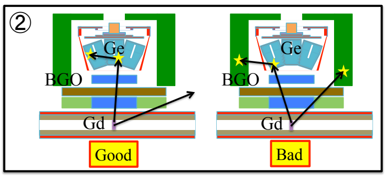
	2012 B0025	2014 B0124
Period	2013/3/14~3/17	2014/12/11~12/16
Target	・Natural Gd(99.99%) 5mm×5mm×10,20μm	・Enriched Gd A=155(91.65%),157(88.4%)
Total events	3×10^9 events	8×10^9 events
Calibration source	^{60}Co, ^{137}Cs	^{22}Na, ^{60}Co, ^{137}Cs, ^{152}Eu, NaCl(n,γ)

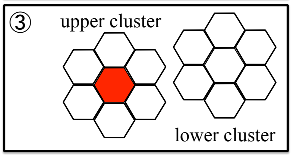
3. Analysis method

Event selection

① Thermal neutron energy(4meV~100meV).
② BGO detectors for veto counter.
③ Single γ-ray was required.







γ-Emission model

The probability(P) of transitioning from level E_a to level E_b emitting γ-ray(E_γ) can be expressed by using "Transmission coefficient T" and "Number of levels $\rho(E_b)\Delta E_b$".

$$P(E_a,E_b)\Delta E_b = \frac{T(E_a,E_b)\left[\rho(E_b)\Delta E_b\right]}{\int_0^{E_a} T(E_a,E_b)\rho(E_b)\mathrm{d}E_b}$$

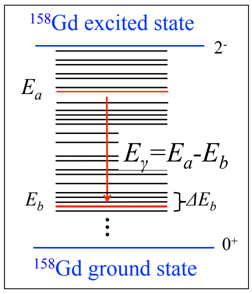
$T(E_a,E_b)$ can be expressed by Photon Strength Function(PSF)

$$T(E_\gamma) = E_\gamma^3 \sum_{i=1}^{2} \frac{\sigma_i E_\gamma \Gamma_i^2}{\left(E_\gamma^2 - E_i^2\right)^2 + E_\gamma^2 \Gamma_i^2}$$

PSF E1 resonance parameters

	Energy (E_i) [MeV]	Strength(σ_i) [mb]	Width(Γ_i) [MeV]
^{158}Gd	11.7	165.0	2.6
	14.9	249.0	3.8

Ref. Kopecky *et al.* PRC 47.312

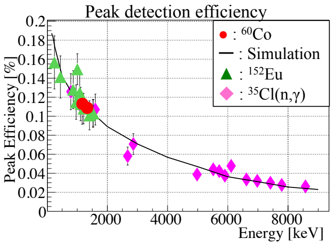


4. Results

Peak detection efficiency by calibration sources

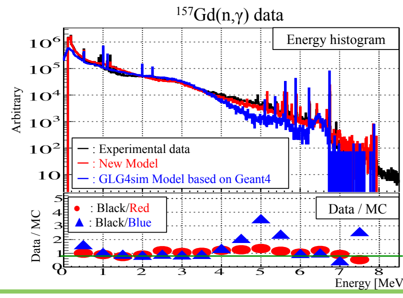
Energy dependence of peak detection efficiency in range of 0.1~8MeV was estimated with uncertainty of ±7%.

Good agreement between data and simulation. Detectors were precisely calibrated.



Comparison of experimental data and simulation

As shown in right figures, the new model was agree with better than GLG4sim. Difference between data and new model was estimated to be about ±30%. (Improvement by order of magnitude)



5. Summary

- Gd will be used in Super-Kamiokande.
- To understand reaction on Gd, two experiments were carried out.
- Detector calibration was well performed within ±7%.
- Good agreement between experimental data and new model.

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