Measurement of gamma-rays from neutron-oxygen reaction for neutrino-nucleus interaction

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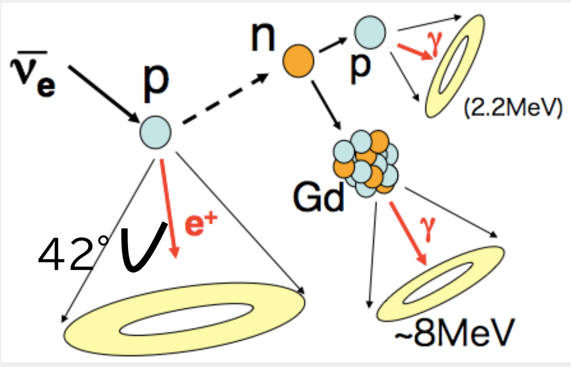
Introduction

Supernova Relic Neutrino : SRN

Superposition of neutrinos emitted by supernova in past.
SRN is important for the **Stellar evolution, Nucleosynthesis**.

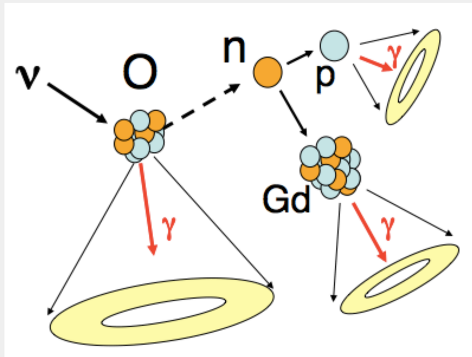


SRN signal

$$\overline{\nu}_e + p \rightarrow \underline{e^+} + \underline{n}$$

$$\nu + {}^{16}O \rightarrow \nu + {}^{15}\underline{O^*} + \underline{n}$$

NCQE signal



Neutral Current Quasi Elastic scattering

NCQE by atmospheric neutrino is one of main background for SRN search in Super-Kamiokande with Gadolinium (SK-Gd).

T2K experiment

Long baseline neutrino experiment shoot from J-PARC to SK. The cherenkov angle distribution has inconsistency between simulation and real data. (Fig.1). It is caused by secondary gamma. (Fig.2)

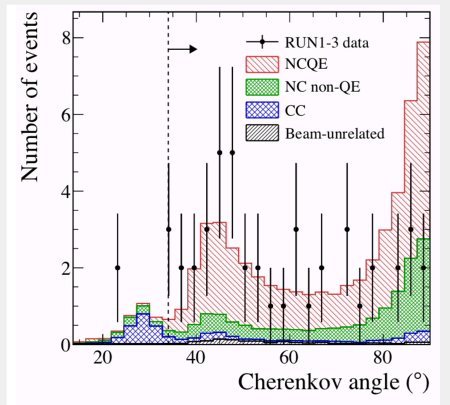


Fig1. cherenkov angledistribution

	Signal	Background		
	NCQE	NC non-QE	CC	Unrel.
Fraction of Sample	68%	26%	4%	2%
Flux	11%	10%	12%	-
Cross sections	-	18%	24%	-
Primary γ production	15%	3%	9%	-
Secondary γ production	13%	13%	7.6%	-
Detector response	2.2%	2.2%	2.2%	-
Oscillation Parameters	-	-	10%	-
Total Systematic Error	23%	25%	31%	0.8%

Table1. systematic uncertainties

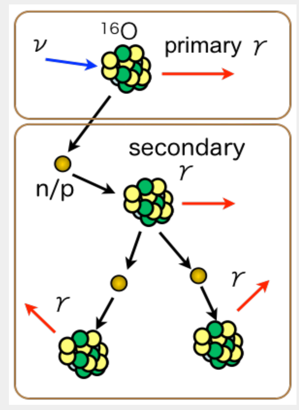


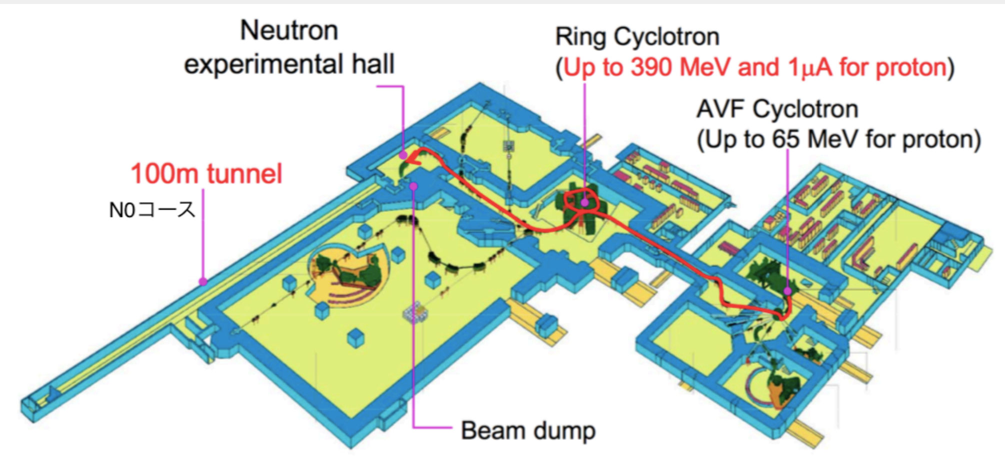
Fig2. Schematic view of secondary gamma production

Motivation

Improve the uncertainty of secondary gamma production. Our goal is that it reduced less than 5%.

Experiment

Research Center for Nuclear Physics (Osaka Univ.)

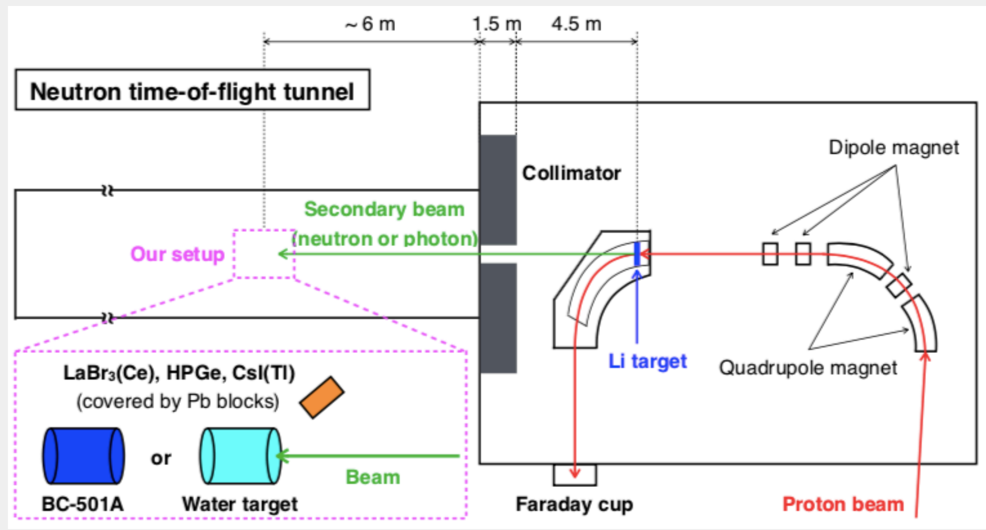


Proton beam was accelerated by two cyclotrons. Almost mono energetic neutron beam was produced through the ^{7}Li(p, n)^{7}Be reaction.

Proton beam energy
30, 250 MeV

Detectors
HPGe: Gamma ray energy
LqS : Neutron flux
CsI : Neutron BackGround

Checking source
^{22}Na, ^{60}Co, ^{137}Cs, ^{241}Am/Be



Analysis of 30 MeV run

HPGe energy distribution : water target

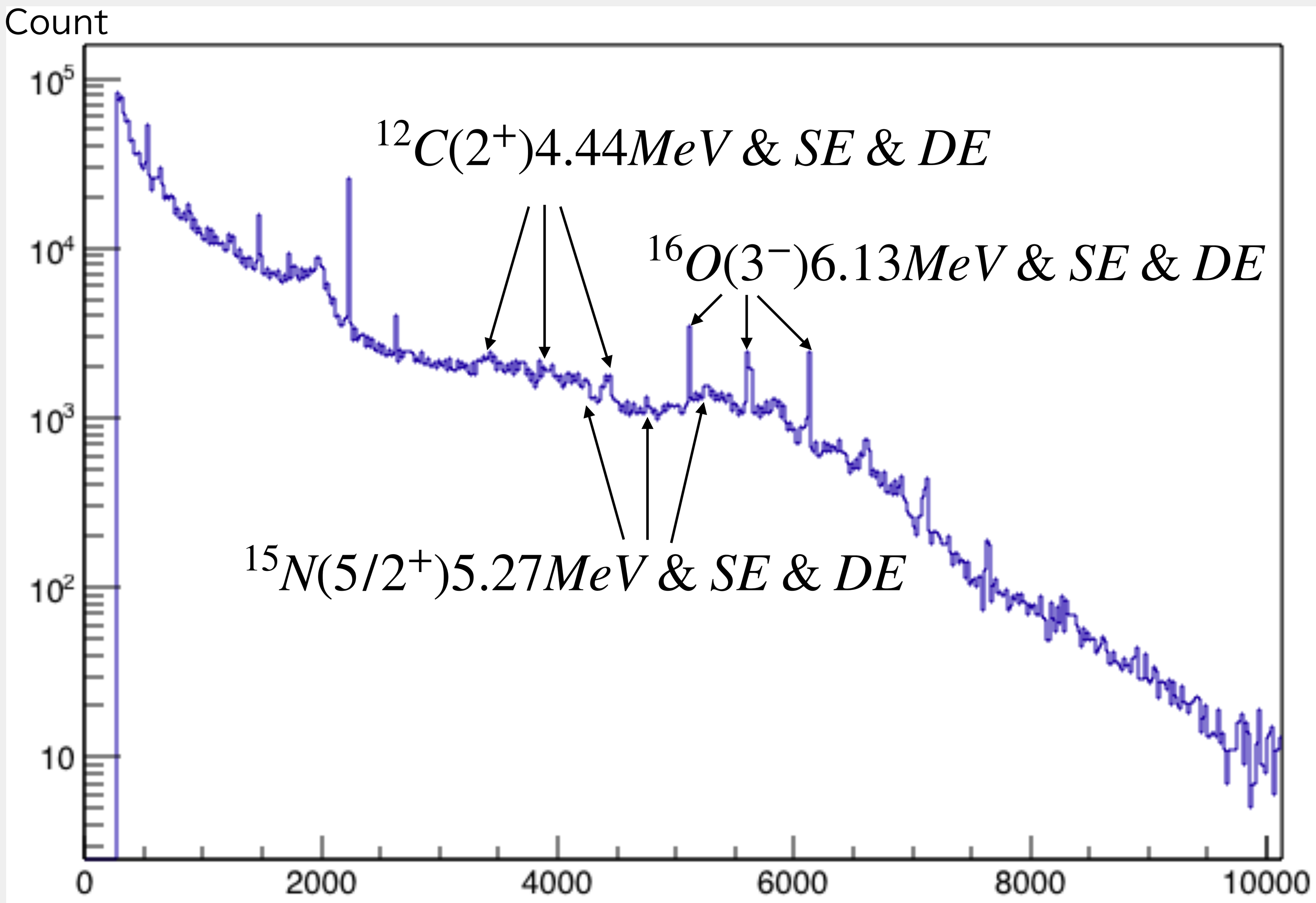


Fig3. HPGe energy distribution

$6.13MeV\ |{}^{16}O(n,n'){}^{16}O^*$

$5.27MeV\ |{}^{16}O(n,n'){}^{16}O^*$ *then* ${}^{16}O^* \rightarrow {}^{15}N^* + p$, *or* ${}^{16}O(n,np){}^{15}N^*$, *or* ${}^{16}O(n,d){}^{15}N^*$

$4.44MeV\ |{}^{16}O(n,n'){}^{16}O^*$ *then* ${}^{16}O^* \rightarrow {}^{12}C^* + \alpha$, *or* ${}^{16}O(n,n\alpha){}^{12}C^*$

We calculate the gamma ray cross section each energy.

$$\sigma_\gamma = \frac{N_{sig} - N_{bkg}}{\phi_n \epsilon_\gamma T}$$

- N_{sig} : Normalized number of signal events —HPG
- N_{bkg} : Normalized number of background —CsI, no water run
- ϕ_n : Normalized neutron flux —LqS
- ϵ_γ : Calculated gamma ray detection efficiency —Simulation, experiment
- T : Number of target oxygen nuclei par area —Calculate
  $= 8.3546 * 10^{23} [/cm^3]$

Neutron flux

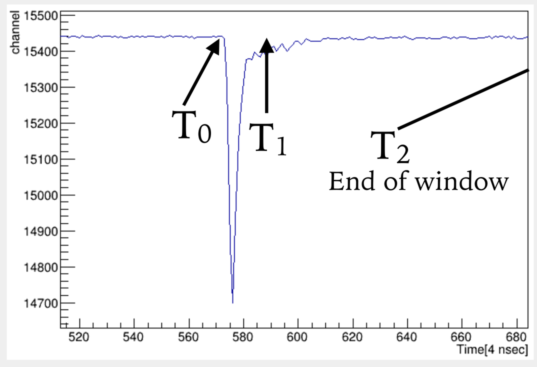
Raw data analysis → TOF distribution (Kinetic energy calculation), PSD distribution (Neutron selection)

Simulation → SCINFUL QMD → Detector efficiency

→ Neutron flux

Neutron selection

Use the Pulse shape discrimination (¦ PSD) method.
Output waveform depends on incident particles.



$$PSD\ par = \frac{Q(T_2) - Q(T_1)}{Q(T_2)}$$

$Q(T_1)$: integration T_0 to T_1
$Q(T_2)$: integration T_0 to T_2

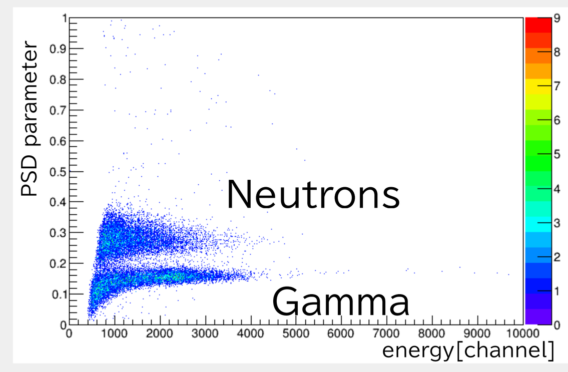
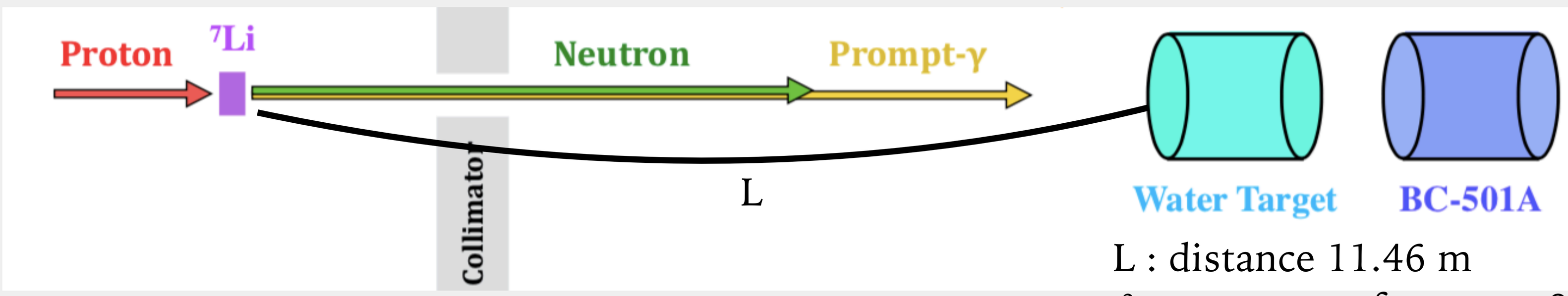


Fig4. neutron selection performance

Neutron beam kinetic energy



L : distance 11.46 m
mc² : rest mass of neutron 939.6 MeV

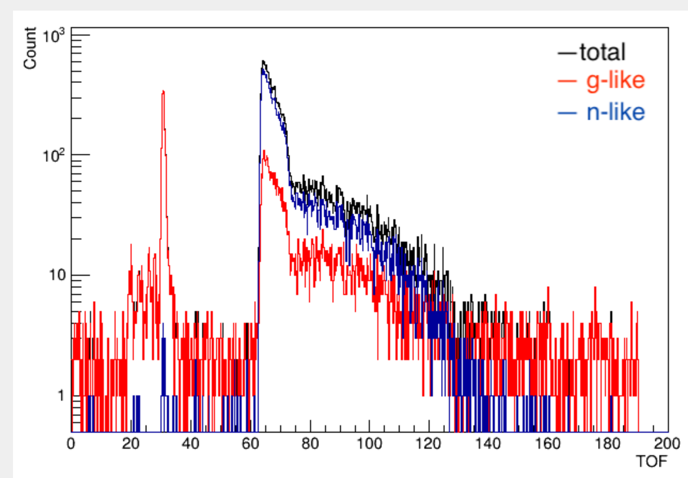


Fig5. TOF distribution

$$TOF_\gamma = \frac{L}{c}, \quad TOF_n = \frac{L}{\beta c} \quad T_{(TOF_n - TOF_\gamma)} = \frac{L}{c}(\frac{1}{\beta} - 1)$$

$$\beta = \frac{1}{1 - \frac{c}{L}(T_{TOF_n - TOF_\gamma})} \qquad E = \frac{mc^2}{\sqrt{1-\beta^2}} - mc^2$$

Neutron flux was obtained from kinetic energy distribution after efficiency correction.
Detector efficiency Calculated by SCINFUL-QMD MC (Fig6)

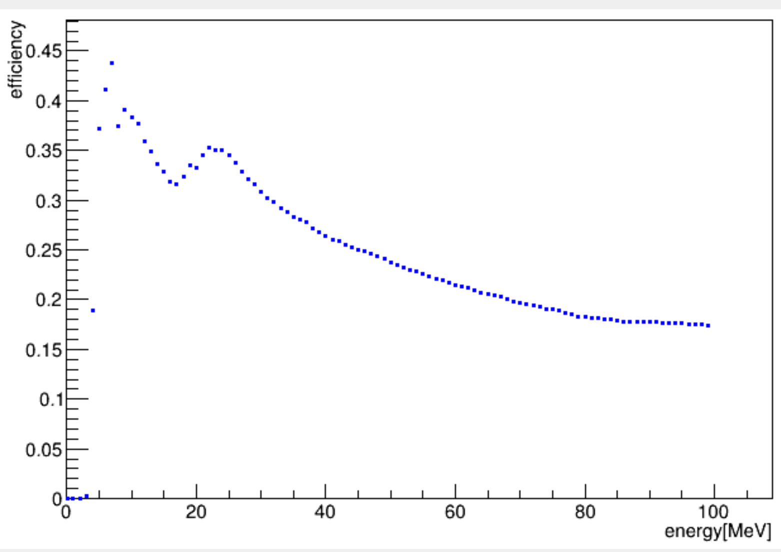


Fig6. Detection efficiency about BC501A

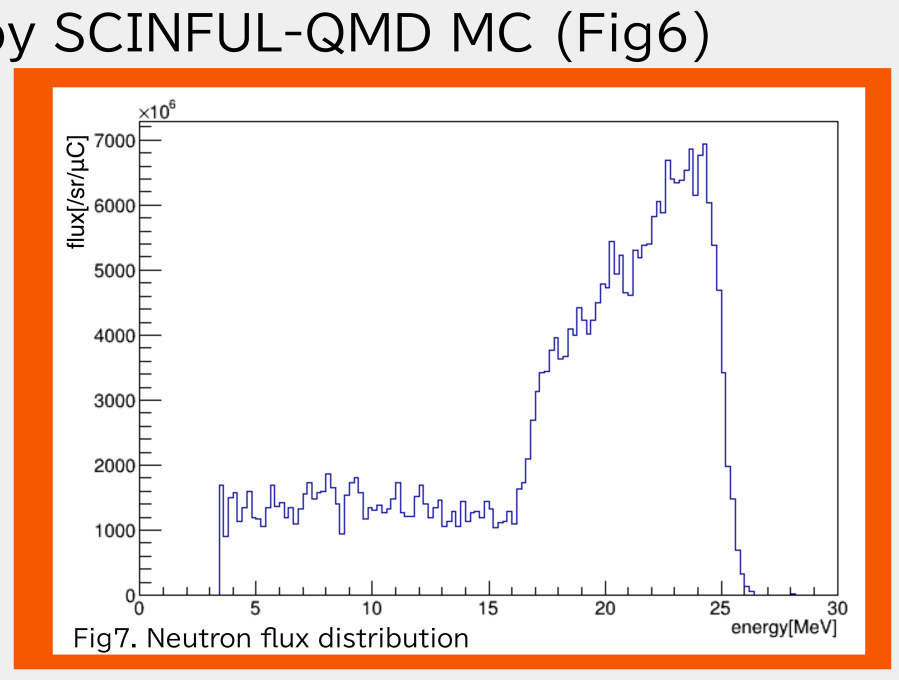


Fig7. Neutron flux distribution

Conclusion & Outlook

We calculated neutron beam flux.
Estimation of the systematic uncertainty of neutron flux, Gamma ray cross section, 250 MeV analysis is in progress.