RCNP E398 experiment $^{16}O,^{12}C(p,p')$ to measure γ-ray emission probability from the giant resonances in relation to the γ-ray emission in $^{16}O,^{12}C(\nu,\nu')$

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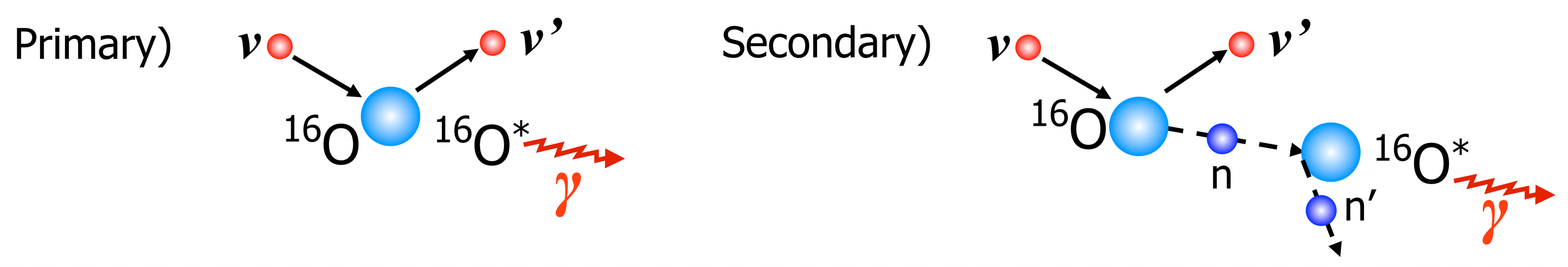
Introduction

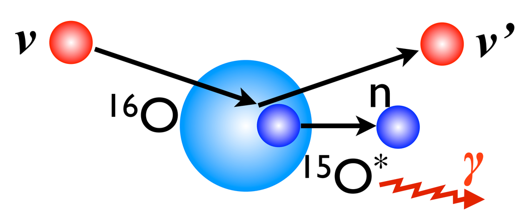
The significant fraction of NC ν-^{16}O and ν-^{12}C reactions contain observable γ-rays.
γ-rays are also produced in secondary n-^{16}O and n-^{12}C interactions.

- Applicable to **Supernova neutrinos** and **neutrino experiments** at E_ν<100MeV.
- These γ-rays can be background also.



Overview

A)E_ν>100MeV:
Quasi-elastic (1N Knock-out) dominates.



B)E_ν<100MeV:
Elastic and Inelastic dominate.

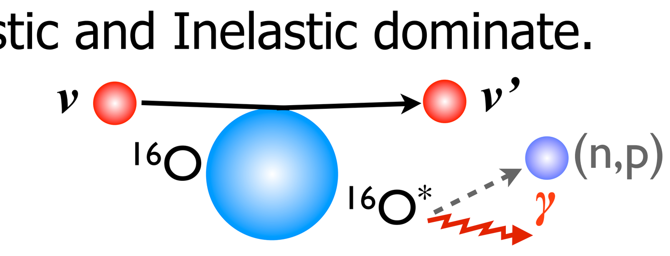
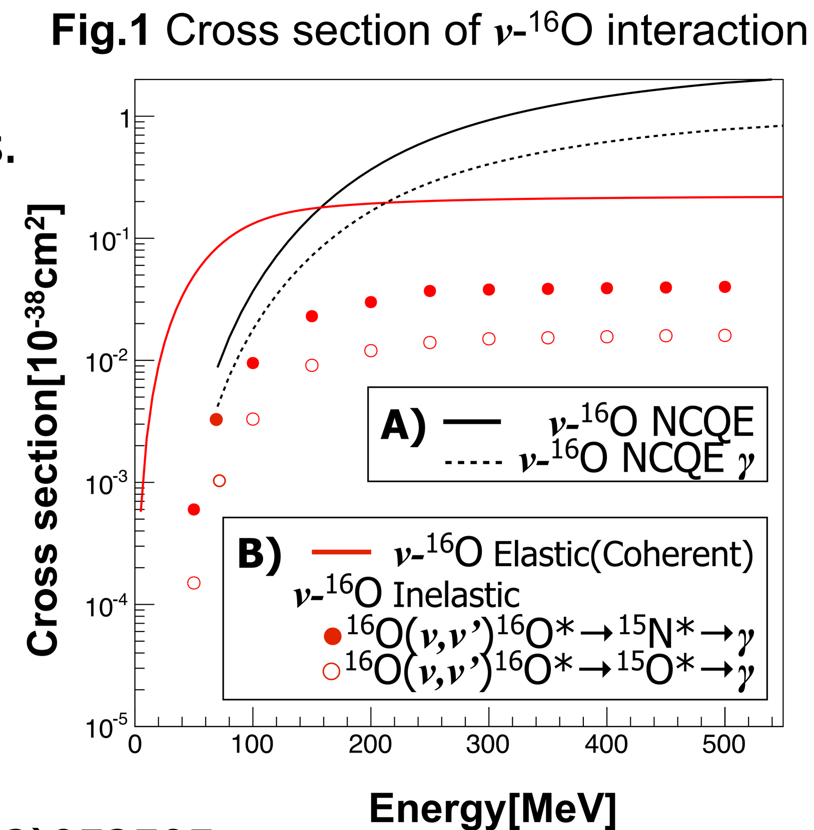


Fig.1 Cross section of ν-^{16}O interaction



- Theoretical Calculations **Fig.1**
  - A) E_ν>100MeV: Ankowski et al., PRL108('12)052505
  - B) E_ν<100MeV: Kolbe et al., PRD66('02)013077
- Experiments
  - A) E_ν>100MeV: K2K, T2K, RCNP E148 $^{16}O(p,2p\gamma)$.
  - B) E_ν<100MeV: No experiments for ^{16}O, Karmen for ^{12}C(15.1MeV γ) only.

→ **E398 experiment will measure this by $^{16}O,^{12}C(p,p'\gamma)$.**

Relation of $^{16}O(\nu,\nu')$ and $^{16}O(p,p')$

ν-^{16}O :Calculated cross section(σ) is given by Jachowicz et al. **Fig.2**

- Contribution of J^p = 2^-(T=1) and 1^-(T=1) are large, 0^-(T=1) and 1^+(T=1) are small.
  - J^p=2^-(T=1), 1^-(T=1), 0^-(T=1) : **S**pin-**D**ipole **R**esonances ΔL=1, ΔS=1 and ΔT=1
  - J^p=1^+(T=1) : **G**amov-**T**eller **R**esonance ΔL=0, ΔS=1 and ΔT=1

p-^{16}O :Experimental σ is given by Kawabata et al. **Fig.3**

- SDR (2^-, 1^-) dominate σ of $^{16}O(p,p')$ at scattering angle θ_L=4°. → $^{16}O(\nu,\nu'\gamma)$
- T=0 states and **G**iant **D**ipole **R**esonance (1^-,T=1) dominate at θ_L=0°. → $^{16}O(n,n'\gamma)$

Fig.2 Cross Section of $^{16}O(\nu,\nu')$ at E_ν=50MeV
Jachowicz et al.,PRC59('99)

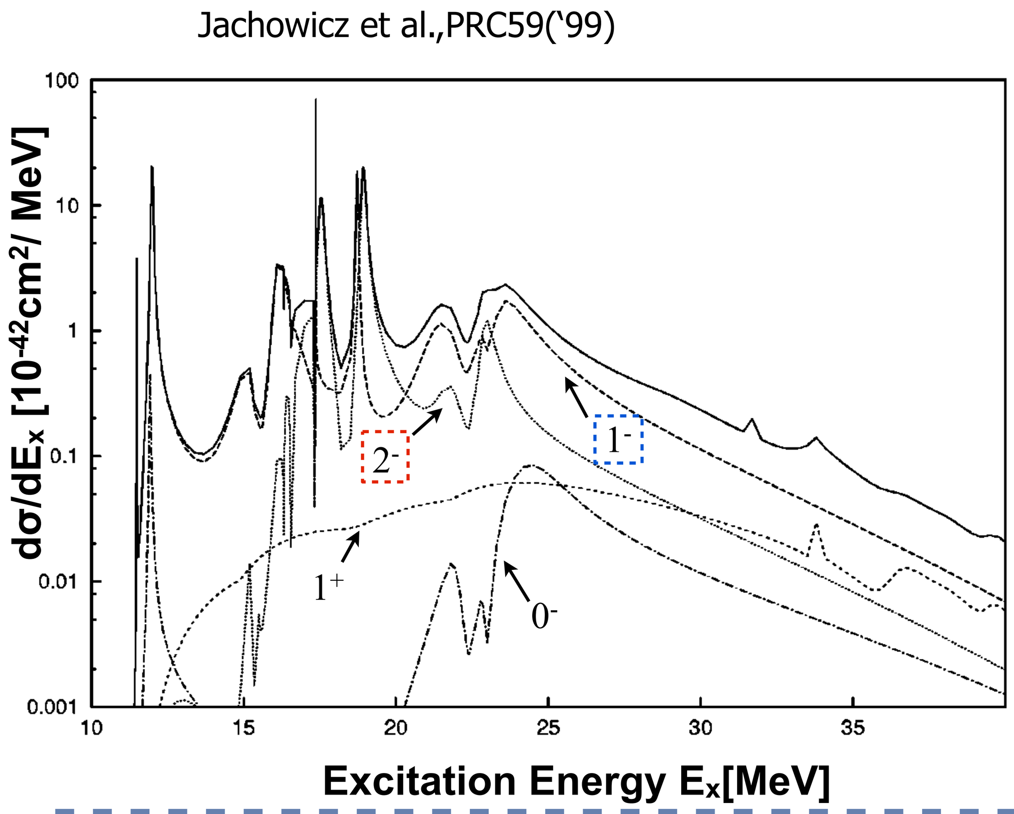
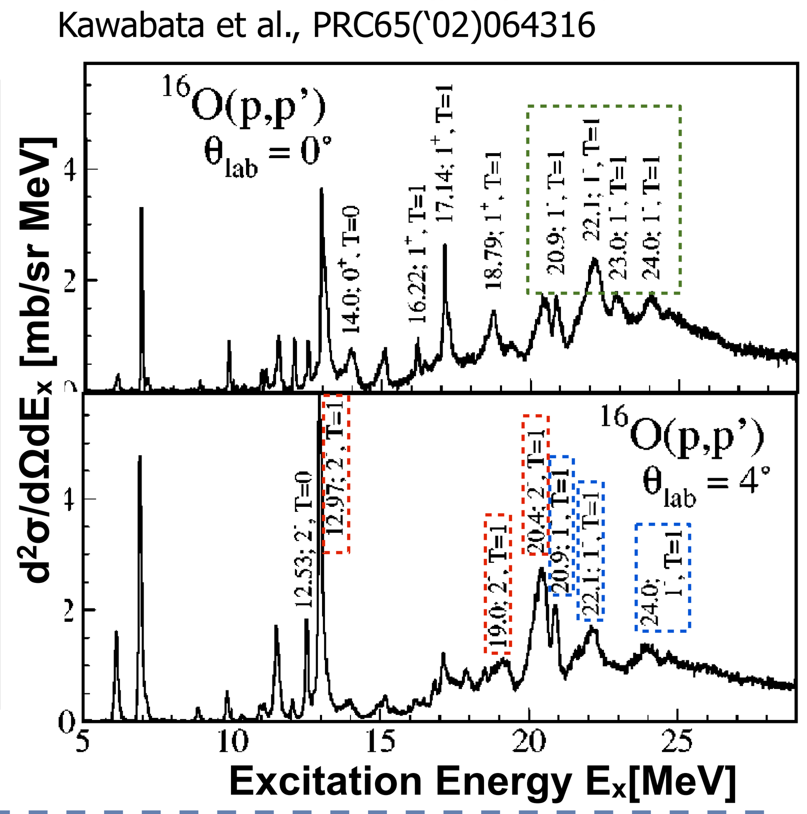
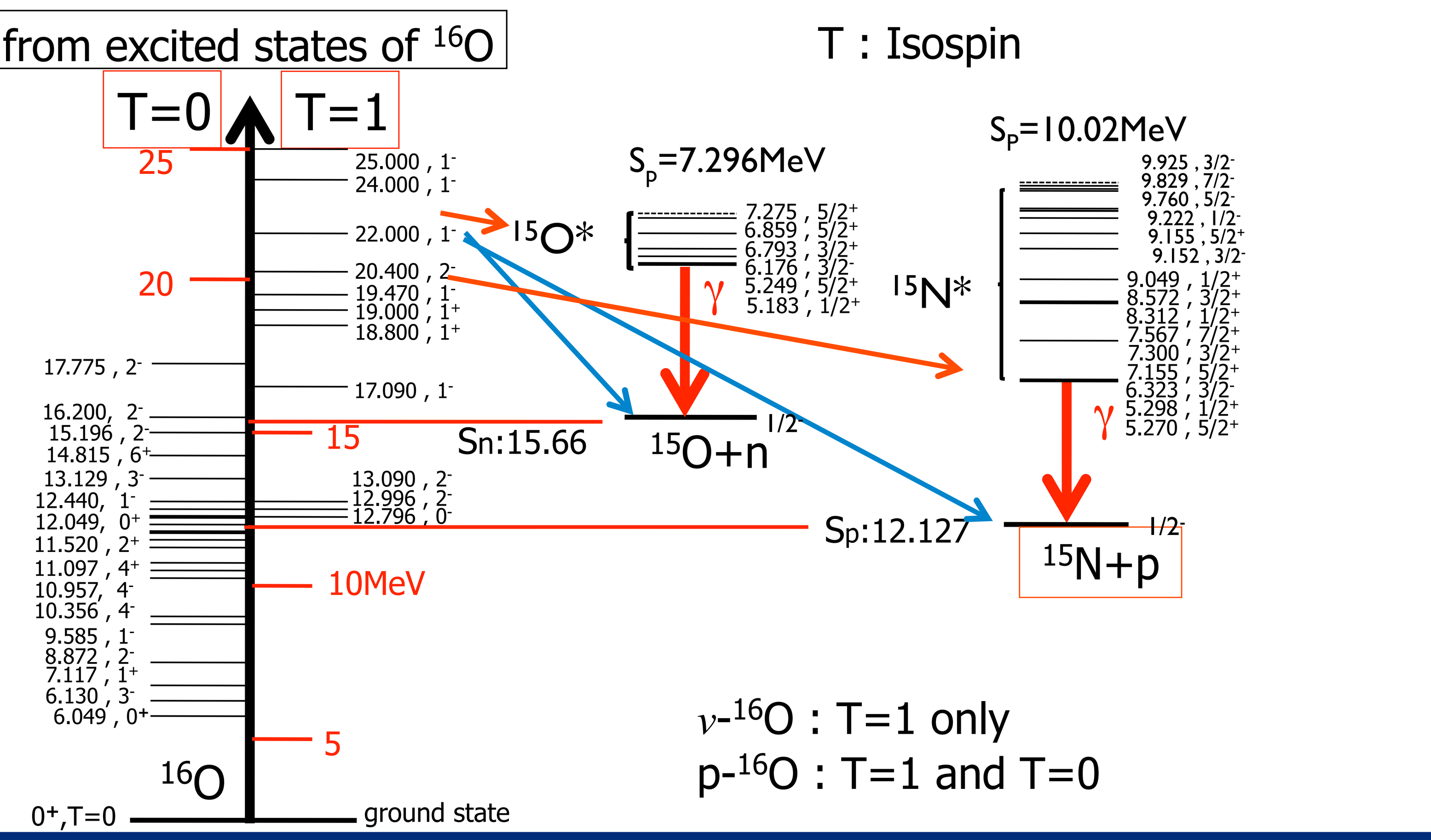


Fig.3 Cross Section of $^{16}O(p,p')$ at E_p=295MeV
Kawabata et al., PRC65('02)064316



γ-rays from excited states of ^{16}O

T : Isospin



ν-^{16}O : T=1 only
p-^{16}O : T=1 and T=0

E398 experiment

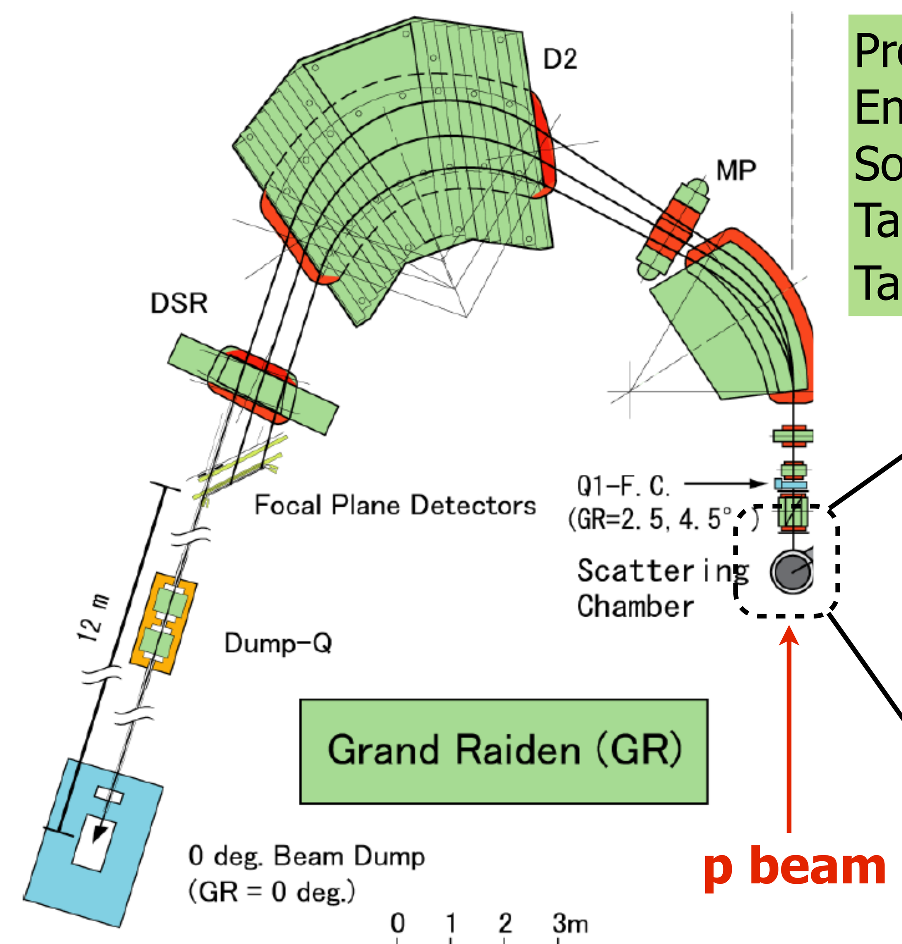
1. Experimental Goal

- We will measure the γ-ray emission probability from giant resonances (E_x=16~30MeV) of ^{16}O & ^{12}C, as the functions of excitation energy (E_x).

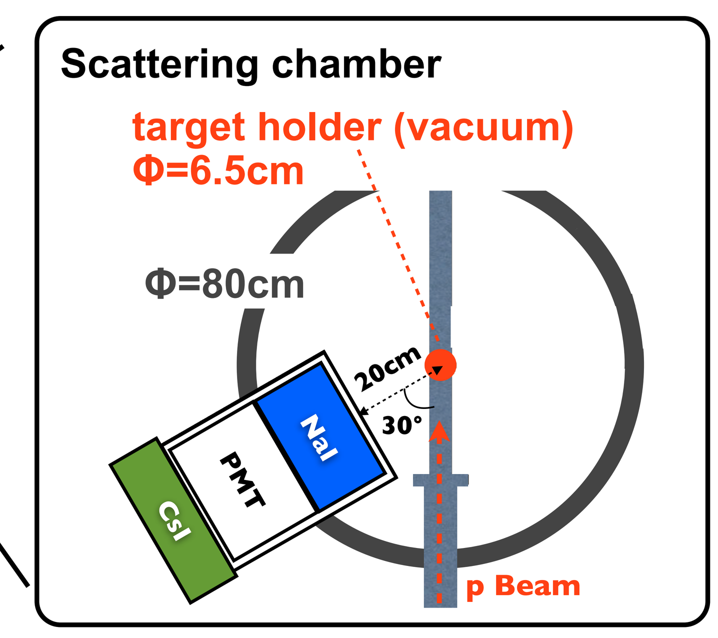
2. Setup

- RCNP proton beam and Magnetic Spectrometer (Grand Raiden) provide precise measurement of the excitation energy (E_x=E_p-E_p', ΔE_x=~20keV). We will implement a **new γ-ray detector**.

RCNP (Research Center for Nuclear Physics) in Osaka, Japan
Hadron beam and Grand Raiden

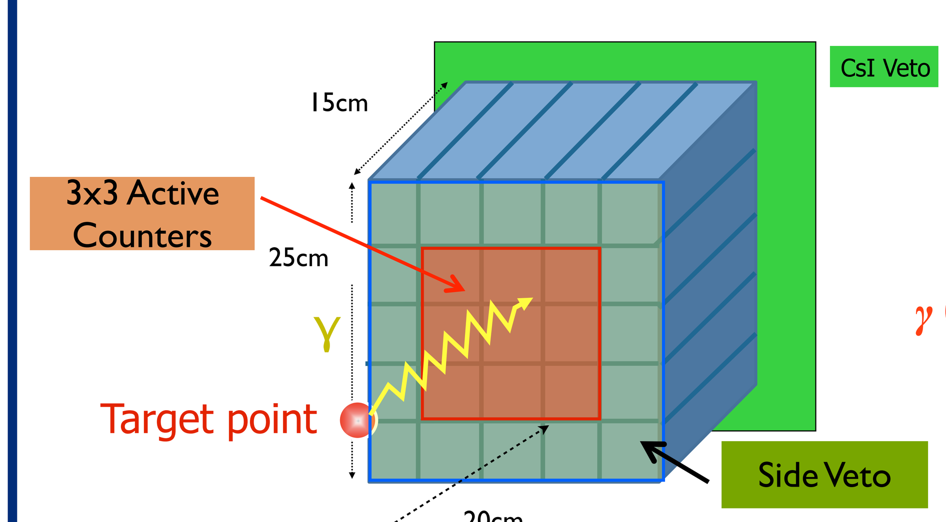


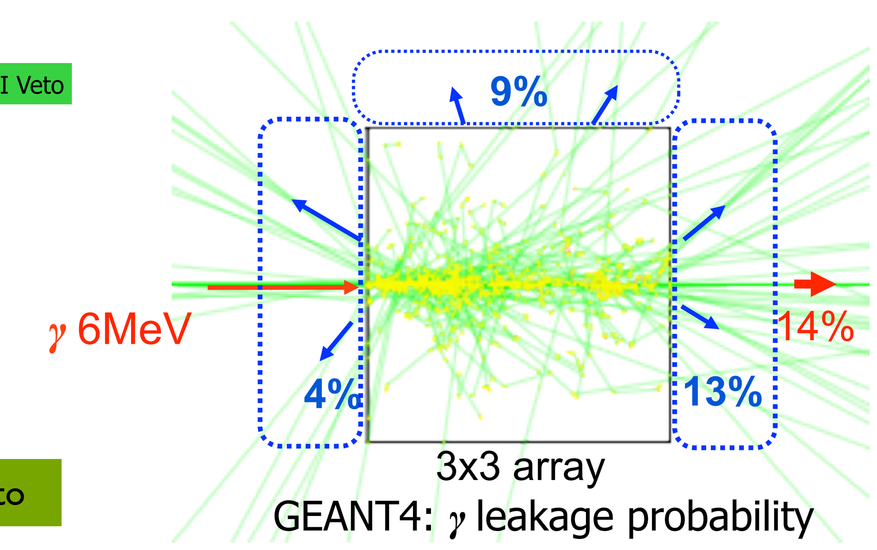
Proton Beam : 295MeV, 10nA
Energy Resolution : 20keV
Solid Angle : 5.6msr
Target : $C_6H_{10}O_5$, ^{12}C
Target thickness : 30mg/cm^2



γ-ray detector

- A 5x5 NaI array (25x25x15cm) will be installed 20cm away from the target.
  - ●Inner 3x3 array → Active counters
  - ●Outer 16 NaI counters & downstream CsI counters → Compton suppressions





3. Calibration

- The γ-rays from the known states will be used to monitor the gain and detection efficiency of the γ-ray detector during the experimental period.

$^{16}O^*$→2^+[6.9MeV, γ:100%],
$^{12}C^*$ →2^+[4.4MeV, γ:100%] & 1^+[15.1MeV, γ:76%]

4. Analysis

- γ-rays emission probability is determined :

$$\Pr[E_x(16\sim30\text{MeV, 1MeV bin})\rightarrow\gamma] = \frac{[\text{Number of }\gamma\text{ event}]}{[\text{Number of excitation}]}\frac{1}{\varepsilon_\gamma}$$

ε_γ : NaI detection efficiency considering solid angle

- Estimation of γ-ray event
  - 3 days of data taking → 12K~18K event in 1 MeV bin (Ex=16~30MeV)

The γ-ray emission probability can be measured with statistic error of **1%**.

Summary

- We presented the goal and the status of RCNP E398 experiment.
- We will measure the γ-ray emission probability for each excitation energy of ^{16}O and ^{12}C, using the RCNP Grand-Raiden Spectrometer and a γ-ray detector.
- If we can measure the γ-ray emission probability for Isospin T=0 and T=1 (2^-,1^-,1^+) states separately by changing scattering angles, we should be able to apply these measurements to the estimation of γ-ray emission probability for low-energy neutrino interactions with those nuclei as well as that for secondary hadronic interactions.
- Data taking will start next year.

NuInt12:Eighth International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region, Oct. 22-27,Rio De Janeiro Brazi