

# Neutron Tagging Technique in Super-Kamiokande

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## 1. Introduction

[Motivation]

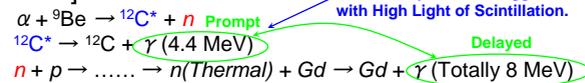
Identification of  $\bar{\nu}_e$  Component of Relic Supernova Neutrinos via Delayed Coincidence in Super-Kamiokande (SK).

- Gadolinium Dissolved in SK Water Proposed & Now Under Discussion.
- ∴ Feasibility Check with Gd Solution for the Study of Neutron Observation Performed Using Am/Be Radioactive Source & BGO Scintillator Crystal.

[Inverse Beta Decay]



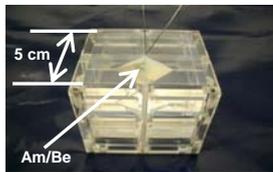
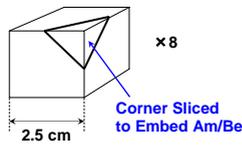
[Am/Be]



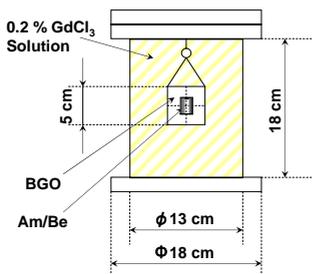
Detected by BGO to Trigger SK with High Light of Scintillation.

## 2. Pictorial Illustration of Apparatus

• Configuration of BGO Crystal



• Cylindrical Vessel for GdCl<sub>3</sub> Solution

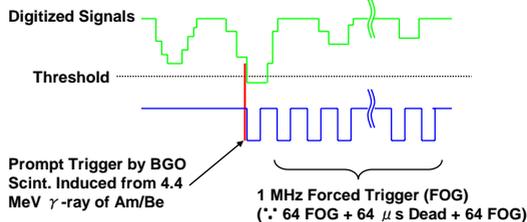


∴ This Apparatus Deployed @ Detector Center in SK for Experiment.

- 0.2 % GdCl<sub>3</sub> Sol. in This Apparatus ⇔ 28 % n Det. Efficiency,
- 0.2 % GdCl<sub>3</sub> Sol. in SK Volume ⇔ 90 % n Det. Efficiency.

## 3. Forced Trigger System

- 1 MHz Forced Trigger Issued after Prompt Trigger with Its Performance of Active 64 μs Succeeding Dead 64 μs and Active 64 μs.
- Prompt Trigger = Global Trigger Originated from Scintillation Light in BGO Induced from 4.4 MeV γ-ray of Am/Be. This Indicates Prompt Signal Candidates in Delayed Coincidence Scheme.



	Data	MC
Octal Case	7.7 ± 0.3 % (Stat. Only)	6.9 ± 0.1 % (Stat. Only)
Single Case	8.8 ± 0.2 % (Stat. Only)	10.2 ± 0.1 % (Stat. Only)

→ Both Data & MC Consistent within ~ 10%.

∴ 90 % of Neutrons Captured with 0.2 % GdCl<sub>3</sub> Solution Filled in SK.

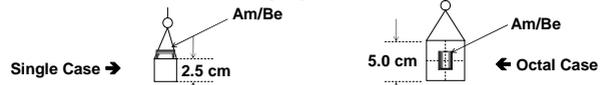
## 5. Summary

- R & D with Apparatus of 0.2 % GdCl<sub>3</sub> Solution, BGO Scintillator and Am/Be Radioactive Source: Spectrum & n Capture Time Consistent in Data & MC.
- Observation Probability of γ-rays with Totally 8 MeV:
- 90 % Evaluated for Real SK Case.

## 4. Data Analysis & Results

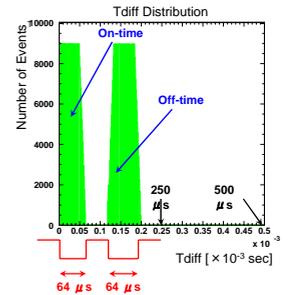
[Experimental Mode]

- Deployment of Both 1 Crystal & 8 Crystals Conducted to Understand the Systematical Difference in γ-ray Spectrum.



[Event Collection with FOG Activation]

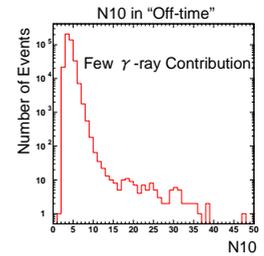
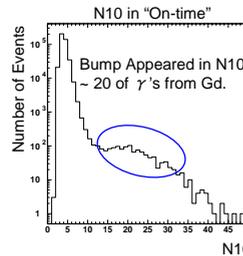
- Tdiff = Time Difference Between Prompt and Delayed Candidates.
- 100 % Detection Efficiency Guaranteed in "On-time" and "Off-time" Region.
- ∴ Only These Two Regions Considered for Analysis.



[Study of N10 for Signal Extract]

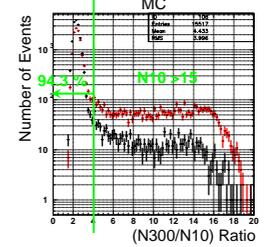
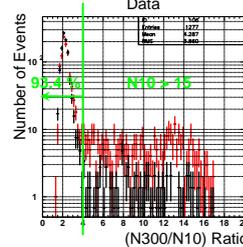
- N10 = Maximum Number of Hit PMTs within Sliding 10 ns Timing Window (The Time of Flight of Photons Subtracted from PMT Timing).

∴ N10 > 15 Applied for Analysis.



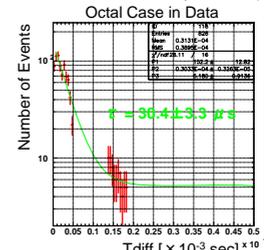
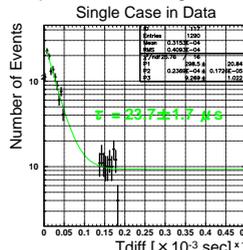
[Ratio of (N300/N10) Cut for Cherenkov Event Retrieval]

- Ratio Used to Discriminate Scintillation Events from Cherenkov Events to Obtain Pure Events of γ's from Gd (∴ 300 ns = BGO Decay Time).
- Scintillation Events = γ's Hitting Deployed BGO Yielding High Light.
- ∴ Ratio < 4 Accounted for Analysis.



[Tdiff Distribution After Data Quality Cuts]

- ∴ Single Exponential Fitting Conducted. Consistent with Expected (~ 20 μs).



[N50 Distribution After Data Quality Cuts]

- ∴ γ Spectrum Consistent with Expected by MC in ~ 2 % in Gaussian Peak.

