Characterization of 30 MeV Proton Cyclotron-Based Neutron Source by Utilizing Bonner Sphere Spectrometer

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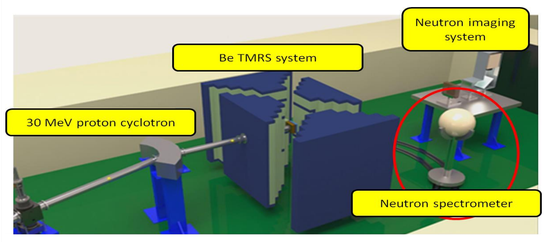
Introduction

❖ **At Advanced Radiation Technology Institutes (ARTI), Jeongeup,**

➔ **Recently developed accelerator-based neutron source**

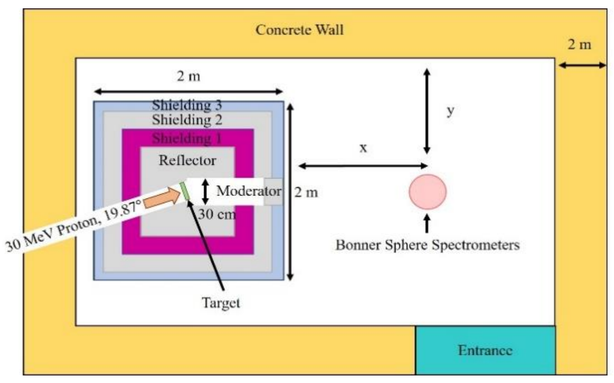
- **Neutron generation by TMRS (target-moderator-reflector-shield)** at RFT-30 cyclotron (30 MeV proton cyclotron) [1]
  - Target : Generating neutrons
  - Moderator : Cooling down neutrons
  - Reflector : Reducing deviated neutrons
  - Shield : Removing unintended radiations
- **Neutron spectrum acquisition by BSS and spectrum unfolding [2, 3]**
  - BSS (Bonner sphere spectrometer) : Set of neutron detectors with different sizes of HDPE (high density polyethylene) for moderation

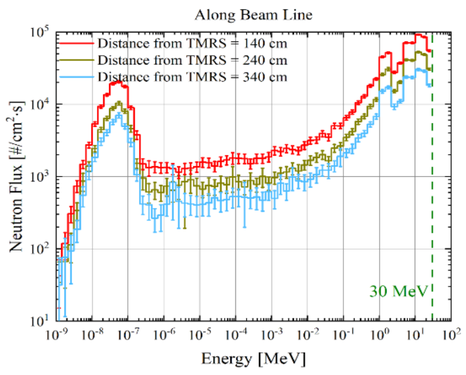


❖ **In this paper are included :**

- **MCNP6.2 simulation results**
- **Neutron detection results** from the BSS
- **Neutron spectrum unfolding results** for the characterization of the TMRS

MCNP6.2 results for TMRS experiment





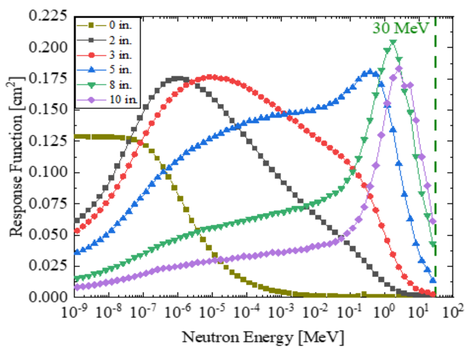
❖ **Neutron spectrum by MCNP6.2 simulation**

- Fast (above 1 MeV) : No or negligible moderation
- Thermal (below 1 eV) : Fully thermalized by moderation
- Others : Not gone through full thermalization

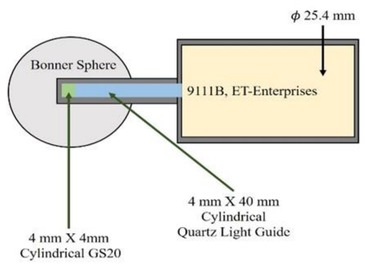
❖ **Experimental setup for TMRS neutron detection**

- Target : 4 T Be
- BSS : Measurements : x = 240 cm, y = 190 cm (Along the beam line) for 60 s
  : Sizes : 0 in. (Bare), 2, 3, 5, 8 & 10 in.

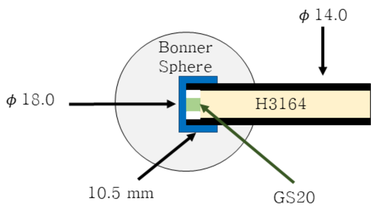
Bonner sphere spectrometer design



※ Structure of BSS



(a) 0, 2, 3 in. case

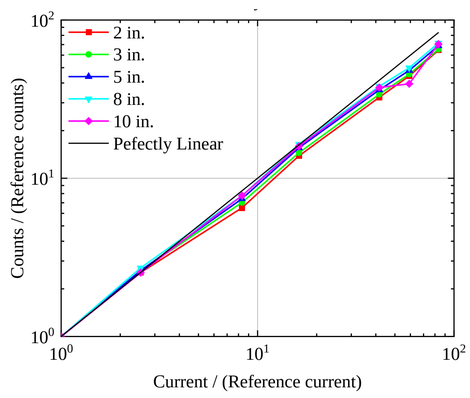


(b) 5, 8, 10 in. case

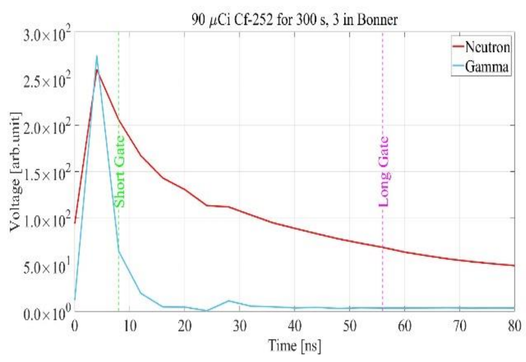
※ Characteristics of BSS

- **BSS with diverse sphere sizes has characteristics to detect widely-ranging neutrons via elastic collision with hydrogen nuclei at HDPE.**

※ Linearity of BSS



※ Pulses from BSS



❖ **BSS design**

- ϕ 4 mm × 4 mm 95 % $^{6}_{3}$Li-enriched GS20
  - Advantages of GS20 : Fast decay constant (~ 18 ns)
    ➔ suitable for high radiation environment
    & capability of neutron-gamma discrimination [4]

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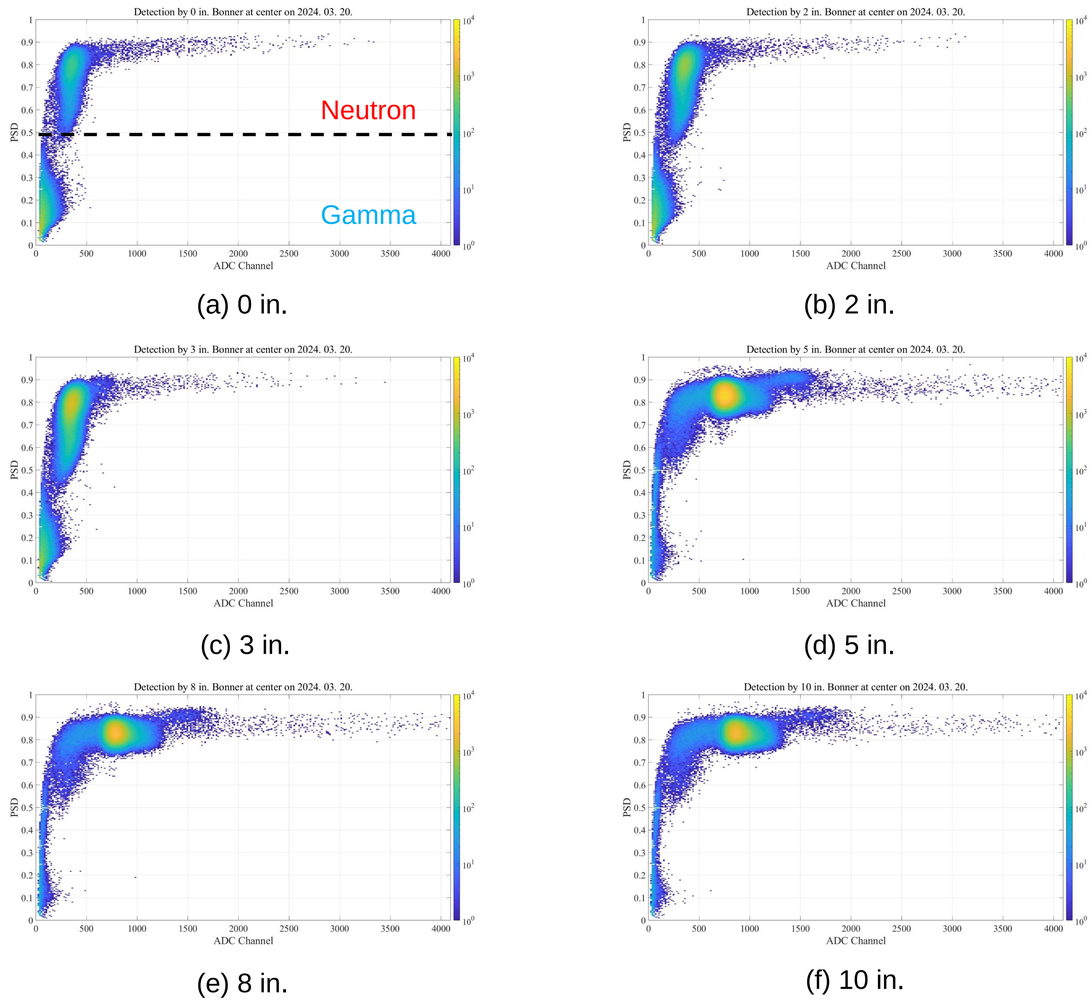
TMRS experiment results

※ PSD plot for TMRS experiments



- Abscissa : Proportional to Q_{total}
- Ordinate : PSD ratio

- **Neutron counts are located at the upper regions in the PSD plots due to the heavy tails of the neutron pulses.**

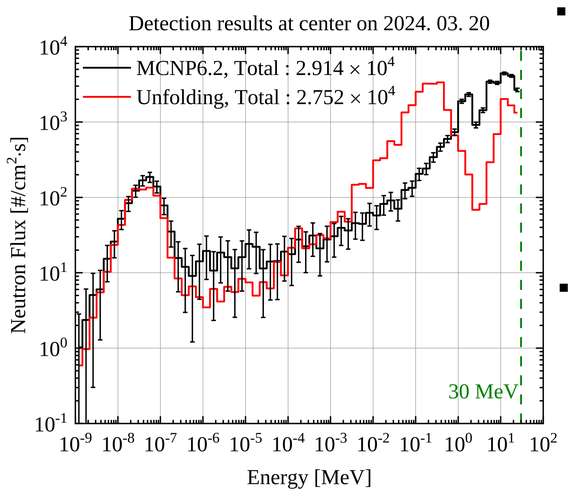
❖ **PSD (Pulse Shape Discrimination) to distinguish neutron and gamma pulse**

- Q_{total} : V-t integral from pulse rise to signal tail (Long gate)
- Q_{tail} : V-t integral from signal head (Short gate) to signal tail

➔ PSD ratio : $\frac{Q_{tail}}{Q_{total}}$

	Sphere size [in.]	0	2	3	5	8	10
Neutron counts	MCNP6.2	4.697×10^4	6.747×10^4	1.497×10^5	4.053×10^5	6.472×10^5	6.671×10^5
	Experiments	6.183×10^4	1.700×10^5	3.423×10^5	7.990×10^5	4.607×10^5	4.383×10^5

❖ **Neutron spectrum unfolding based on GRAVEL [2, 5]**



- Neutron spectrum, ϕ_j, can be obtained through the spectrum unfolding when the neutron counts, N_i, and the response matrix, R_{ij}, are related as:

$$N_i = \sum_j R_{ij}\phi_j$$

- GRAVEL deduces the spectrum by minimizing χ^2 when σ_i is the standard deviation of N_i.

$$\chi^2 = \sum_i \frac{\left(N_i - \sum_j R_{ij}\phi_j\right)^2}{\sigma_i^2}$$

Conclusions & Future Plan

❖ **Accomplishment of the TMRS neutron energy spectrum obtainment through the BSS and the spectrum unfolding**

❖ **Ongoing improvement work in reducing the count discrepancies by adjusting the criterion for the neutron and gamma signal discrimination**

Reference

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