Measurement of fast neutrons from spallation reaction by 392MeV proton

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High-intensity fast neutron beams are useful for experimental studies of various processes induced by fast neutrons such as neutron-induced nuclear reactions in stars and the early universe, electro-magnetic properties of the neutron, n-p inelastic scatterings at the intermediate energies, radiation damages of LSI chips by fast neutrons, durability of the materials used in high-radiation environments, and so on. Spallation neutron sources (SNSs) driven by ring cyclotrons are expected to be suitable for such studies, because of its nice features of high averaged neutron flux and extremely low probabilities of the pileup effects of the background neutrons and γ rays, thanks to a high (> 10MHz) repetition rate of the incident proton beam pulse.

To study the properties and the performances of a cyclotron-driven SNS, we performed a test experiment to measure the intensities of the spallation neutrons and the background radiations. The experiment was carried out at the N0 beam course of the RCNP ring cyclotron facility. The spallation reaction was caused by bombarding a target made of 0.1mm thick metallic tungten with the 392MeV proton beam from the ring cyclotron. The average current and the duty factor of the proton beam were 10nA and 1/12, respectively. The produced neutrons were detected using a liquid scintillation counter (8"Φ×3") located 6.73m downstream of the spallation target.

By using the n-γ discrimination technique, the signals of the neutrons and the backgrounds were separated. Fig. 1 and Fig. 2 show the time distributions of the spallation neutrons and the background γ rays, respectively.

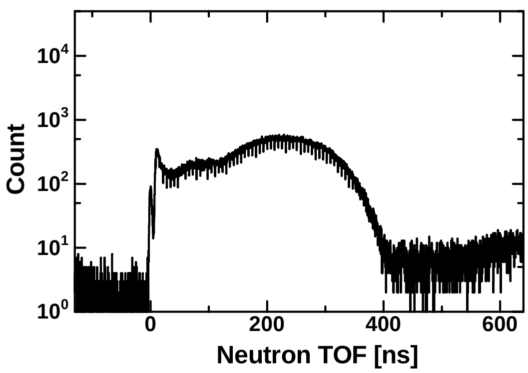

Figure 1. Time distribution of the neutron signals.

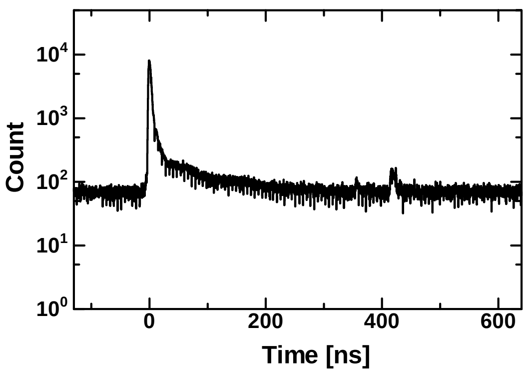

Figure 2. Time distribution of the background.

From the observed spectrum of the neutron flight time, the energy distribution was obtained as shown by Fig. 3. Here the absolute detection efficiency of the liquid scintillation counter for fast neutrons was calculated with the Monte Carlo code CECIL [1]. The peak intensity of the spallation neutrons was determined as $2n \cdot s^{-1} \cdot sr^{-1} \cdot eV^{-1} \cdot nA^{-1}$ at the neutron energy of 2~3MeV for a 1mm thick tungsten target.

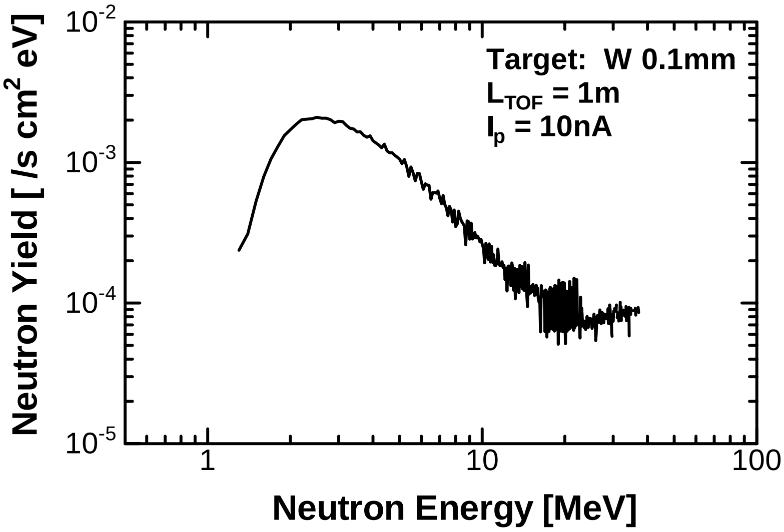

Figure 3. Energy distribution of the spallation neutrons.

From the result one can expect a peak intensity as large as $300 n\cdot s^{-1}\cdot cm^{-2}\cdot eV^{-1}$ at the position of 1m downstream of the target, using a 5cm thick spallation target and a proton beam current of 3μA. Therefore a SNS driven by the RCNP ring cyclotron can be one of the most powerful fast neutron sources in the world (see Table 1.).

Facility (Institute)	Method / Beam power [kW]	Neutron flux at En=40keV (sample position, $n\cdot sec\cdot cm^2\cdot eV$)
Karlsruhe	$^7Li(p,n)^7Be$ / 0.025	14
RLNR (Tokyo Inst. Tech.)	$^7Li(p,n)^7Be$ / 0.024	13
GELINA (IRMM)	(e,e’n) / 7.5	1
LANSCE (LANL)	Spallation / 46	90
KENS (KEK)	Spallation / 2.5	8
n_TOF (CERN)	Spallation / 50	10
JPARC (plan)	Spallation / 600	1000
RCNP (Osaka Univ., plan)	Spallation / 1.2	300

Table 1. Fast neutron sources for researches of nuclear physics and astro-nuclear physics in the world.

References

[1] R. A. Cecil et al., Nucl. Instr. and Meth. 161 (1979) 439-447