Development of ultra-cold neutron source by means of super-mirror Doppler shifter

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Super-mirror Doppler shifter (SM-DS) is expected to be one of the methods to produce ultra-cold neutrons (UCNs) efficiently from pulsed slow neutrons [1]. To prove the efficiency of SM-DS, we constructed a test type at the C2 beam line of KENS, and made a test experiment using a very-cold neutron (VCN) beam provided at KENS.

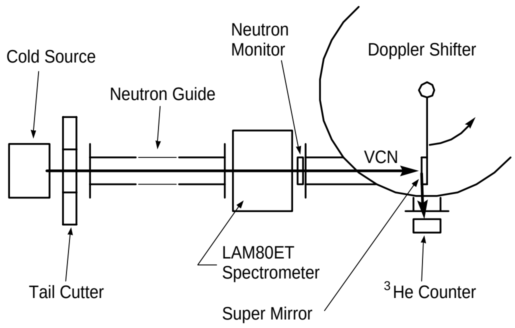

Figure 1. Experimental setup for UCN measurement.

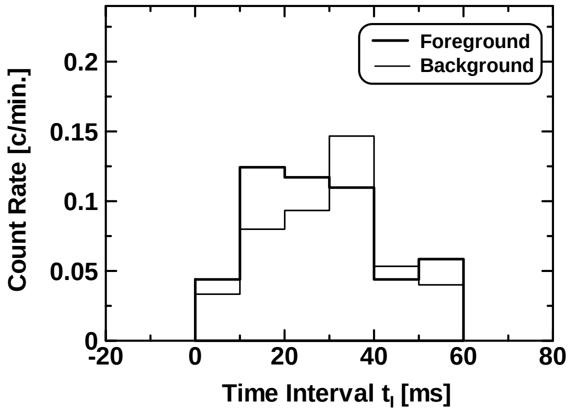

Figure 2. Distributions of t_I obtained for the foreground (thick histogram) and background (thin histogram) measurements.

The experimental setup is shown by Fig. 1. We used a super mirror with peak reflectivity of 50% at the incident neutron velocity of 120m/s. The neutrons scattered by the mirror were detected with a ^{3}He proportional counter, which was placed 50cm distant from the collision point of VCN and the mirror. Fig. 2 shows the spectra of the time interval t_I between the signals of the UCN detector and the mirror position. Here the signal of the mirror position was obtained at the moment when the mirror went across the incident neutron beam in every cycle of the rotation of the SM-DS. To reflect the VCN with the velocity of ~120m/s, the SM-DS was operated with the delay time t_d = 47.2ms, where t_d was the time difference from the timing signal of the KENS pulse to the mirror signal. The background spectrum was also measured by setting t_d to be 33.2ms.

The measured distributions of t_I for the foreground and the background are well reproduced with a Monte Carlo simulation as shown by Fig. 3 and Fig. 4, respectively. From the comparison with the simulations, the excess in the range of t_I from 0ms to 30ms can be attributed to the contribution of the neutron with mean velocity of 6.2m/s. The counting rate R_e of this excess was determined as 0.08±0.06 c/min.

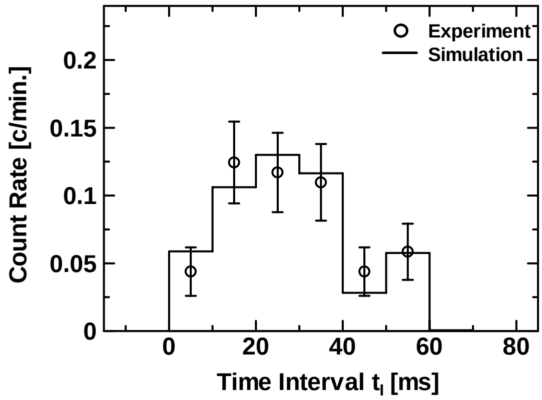

Figure 3. Comparison between the measured (circle) and calculated (histogram) distributions of t_I for the foreground.

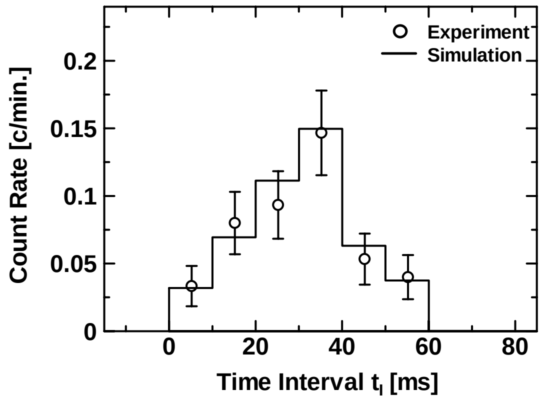

Figure 4. Comparison between the measured (circle) and calculated (histogram) distributions of t_I for the background.

Here, the counting rate R of UCN can be evaluated as follows:

$$R\ [c/s] = \varepsilon \times \Omega \times K \times \Phi_{VCN} \times F_s \times F_d\ , \qquad (Eq.1)$$

where ε and Ω are the detection efficiency and the solid angle of the acceptance of the UCN detector, respectively. K is the reflectance of the super mirror. The absolute flux Φ_{VCN} of the VCN has been known, and is given as

$$\Phi_{VCN}\ [n/cm^2 \cdot \mu eV/s] = 0.007 \times E_{VCN}[\mu eV]\ , \quad (Eq.2)$$

where E_{VCN} is the neutron energy of interest. F_s stands for the synchronization efficiency of the SM-DS to the KENS beam pulse. F_d is the live time ratio of the data acquisition system. The actual values of ε, Ω and K are 0.5, 0.15 and 0.5, respectively. The factor F_s was 0.5, since the rotation frequency of the SM-DS was 15Hz, while the repetition rate of the KENS neutron beam was 20Hz. F_d was 0.33. The acceptable energy range of the super mirror for VCN is calculated from the data of the spectral reflectance, and is 74.6±0.015μeV (total width). Therefore R is expected to be 2.1×10^{-3}c/s or 0.12c/min. This expected value of R is consistent with the above obtained counting rate R_e of the excess, and therefore the excess is possibly due to the contribution of the UCN produced by the operation of the SM-DS. To confirm this, we are planning to perform a measurement with higher statistics by using a new UCN detector which can be installed near the collision point of VCN with the mirror. This will improve the time resolution for t_I, and will make the UCN component clearer in the spectrum of t_I.

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References

[1] T.W. Dombeck et al., Nucl. Instr. Meth. in Phys. Res. 165 (1979) 139.