Exclusive measurement of the Non-Mesonic Weak Decay of ${}^{5}_{\Lambda}$He

E462 collaboration

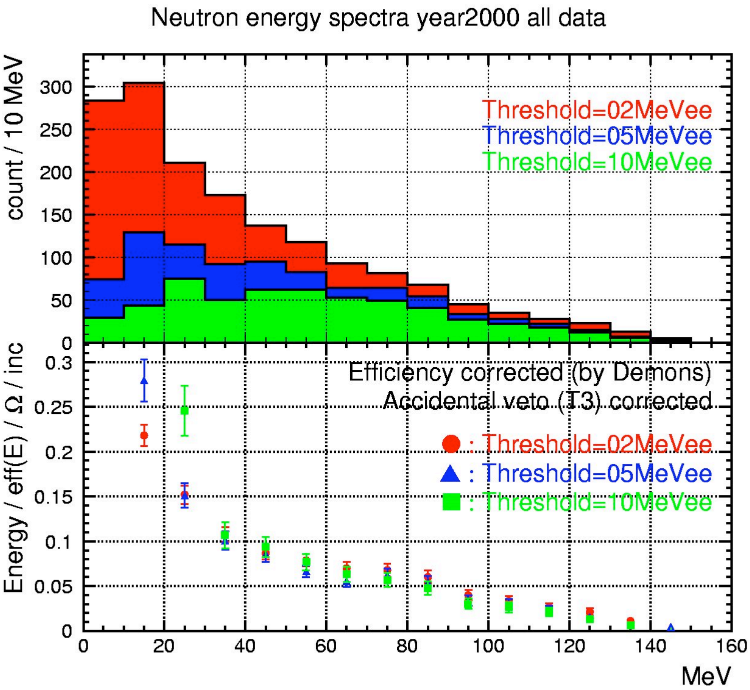
It is known that the dominant weak decay mode of Λ particle bound in nuclei is Λ+N $\rightarrow$ N+N. This non-mesonic decay is the very unique strangeness-changing baryon-baryon weak interaction process, which can occur only in nuclei. Concerning the ratio of two non-mesonic decay modes, $\Gamma n/\Gamma p \equiv \Gamma(\Lambda+n\rightarrow n+n)/\Gamma(\Lambda+p\rightarrow n+p)$, recent experiments for $A=5,12$ suggests large ratios [1,2]. However these reported results have large errors of 30～100% so the large $\Gamma n/\Gamma p$ ratio is not yet experimentally established. So far, several theoretical calculations are carried out based on one-pion or one-boson exchange models or the hybrid quark model, but none of them could simultaneously explain the non-mesonic weak decay(NMWD) rate and $\Gamma n/\Gamma p$ ratio.

Up to now, most of the experiments concerning this ratio of NMWD measured only protons from $\Lambda p \rightarrow n p$ process and Γn was determined by the subtraction of all the other decay processes. Thus the obtained results must be much affected by the small change of the assumption on the rescattering process (final state interaction(FSI) effect) and by the possible existence of the two-nucleon induced NMWD process, $\Lambda NN\rightarrow NNN$.

In order to measure the ratio unambiguously, we choose light s-shell Λ hypernuclei, ${}^{5}_{\Lambda}$He, so as to minimize the FSI effect. In addition, we measured both of n+p- or n+n-pairs emitted from Λ+p$\rightarrow$n+p or Λ+n$\rightarrow$n+n NMWD process. When we select two-nucleon pairs which has back-to-back angular correlation and applied energy sum cut (Q-value for $\Lambda N\rightarrow NN$ decay process for ${}^{5}_{\Lambda}$He is about 152MeV) for them, we can measure $\Gamma n/\Gamma p$ ratio directly only from the n+p- to n+n-double coincidence pair numbers. The result of this measurement is free from the strength of FSI effect and also from the possible $\Lambda NN\rightarrow NNN$ contribution.

With Superconducting Kaon Spectrometer(SKS) at k6, we took ^{6}Li(π^{+},K^{+}) data during year 2000-2001. In the inclusive hypernuclear formation spectrum, we identified more than 50,000 ${}^{5}_{\Lambda}$He formation events.

The left figure shows the preliminary neutron spectra from the NMWD of ${}^{5}_{\Lambda}$He(about 30% of total). Numbers of detected neutrons changes with detection energy threshold(top), but after the correction by the simulated energy- dependent neutron detection efficiency (bottom), all the data points agrees well.

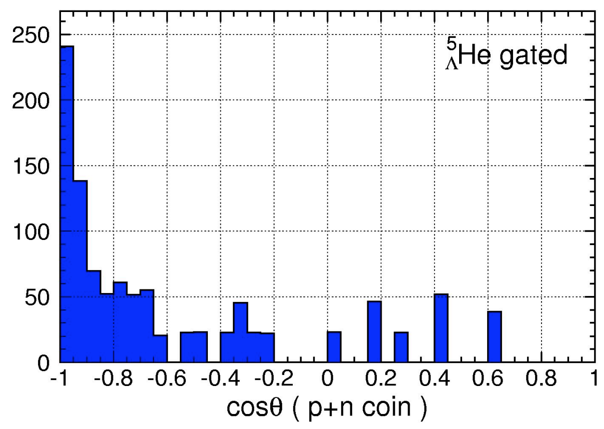


The neutron spectrum (bottom) shows no peaking at Q-value/2～76MeV, which strongly suggests large contribution of FSI effect and/or $\Lambda NN\rightarrow NNN$ decay process in the NMWD of hypernuclei even at A=5.

It should be noted that the statistics of neutron detection from the NMWD of ${}^{5}_{\Lambda}$He is improved by two-orders of magnitudes compare to the previous measurement[1].

In the preliminary analysis of the 1st year data, we also established the way to identify back –to-back n+p- and n+n-pairs.

Top figure of the next page shows the angular correlation of the neutron and proton which were detected simultaneously from the NMWD of ${}^{5}_{\Lambda}$He (double coincidence acceptance is corrected). We can clearly identify the back-to-back n+p-pair from $\Lambda p\rightarrow np$ NMWD process in this angular distribution plot. The statistics of the n+p events in cos θ <-0.9 region is about 50 counts in year 2000 data.

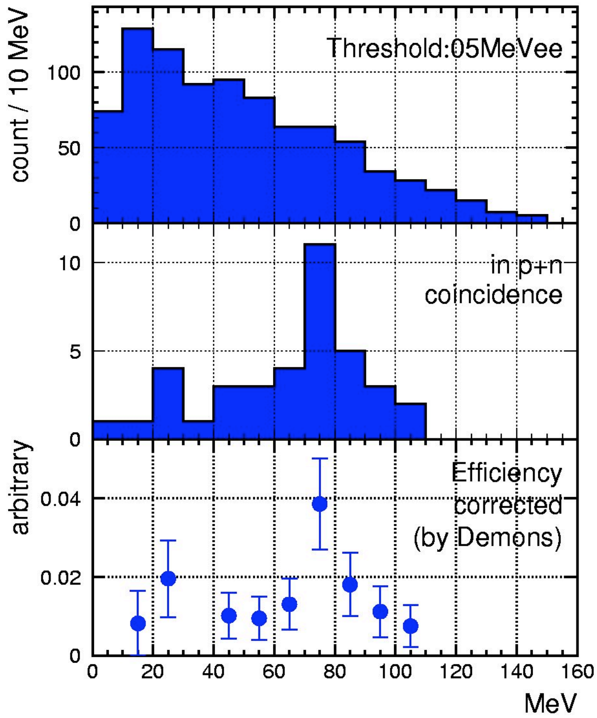


We also analyzed n+n-double coincidence from the $\Lambda n\rightarrow nn$ decay process and found that angular correlation plot of two neutrons has very sharp peaking at cos θ <-0.9 (just 10 counts in year 2000 data). This is the first experimental

evidence for
the existence of the $\Lambda n \rightarrow nn$ NMWD decay process.

When we select the back-to-back component in n+p double coincidence events, the shape of the neutron spectrum changes drastically as given in second figure in this page.

Although single neutron spectrum(top) shows no peaking at Q/2, the spectrum of neutron which have back-to-back proton coincidence pair detection (middle/bottom) gives broad peaking (due to the Fermi motion in the initial state) at about Q/2～76MeV, which shows the clean identification of $\Lambda p \rightarrow np$ NMWD process.



From the n+p to n+n back-to-back coincidence numbers, we can estimate the $\Gamma(\Lambda+n \rightarrow n+n)/\Gamma(\Lambda+p \rightarrow n+p)$ ratios as 0.7±0.2 (***very preliminary***) from year 2000 data, which suggests that the ratio is slightly smaller than one.

Recently, we finished the (π^+,K+) data tracking for year 2001 data. From the yield ratio of the ${}^{5}_{\Lambda}$He peak formation rate, we can expect the improvement of the statistics by 3.5-4 times when we add year 2001 data.
Thus we can achieve $\Delta(\Gamma n/\Gamma p) \sim 0.1$ error level.

Also we finished data taking for ${}^{12}_{\Lambda}$C in this year (E508). We expect same error-level results for both of A=5 and A=12.

As by-products of the experiment, we are also analyzing the lifetime and asymmetry of proton emission from the weak decay of ${}^{5}_{\Lambda}$He.

From year 2000 data, we already obtained the lifetime as 282 ±20 ps (***preliminary***), whose error level is slightly better than the previous measurement[1]. Since the present error is mainly determined by the statistics, we can expect ～10 ps error-level results in the E462 final result.

Concerning the proton decay asymmetry parameter, we obtained α_{NM} =-0.07±0.18 (***very preliminary***) from year 2000 data, which is consistent with the previous SKS experiment [3] (E278: 0.24±0.22).
We will obtain $\Delta\alpha_{NM}$ ～0.1 level results when we analyze all the E462 data.

From the theoretical point of view, it is very hard to simultaneously explain the "large" (close to unity) $\Gamma n/\Gamma p$ ratio and "very small" decay asymmetry parameter α_{NM}. We may need to consider new decay mechanism (e.g. large contribution of the NMWD from p-wave initial ΛN state) when both of them are established experimentally.

The off-line analysis of E462 is in progress now and we will get preliminary results of year 2001 data at around September 2002.

References

[1] J. J. Szymanski *et al.*, Phys. Rev. **C33** (1991) 849.
[2] O. Hashimoto *et al.*, Phys. Rev. Lett. **88** (2002) 042503
[3] S. Ajimura *et al.*, Phys. Rev. Lett. **84** (2000) 4052; Phys. Rev. Lett. **80** (1998) 3471.