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

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We are studying non-mesonic weak decay(NMWD) of Λ hypernuclei(Λ+N $\rightarrow$ N+N). This NMWD is the very unique strangeness-changing baryon-baryon weak interaction process, which can occur only in nuclei. Concerning the ratio of two possible NMWD modes, $\Gamma n/\Gamma p \equiv \Gamma(\Lambda+n\rightarrow n+n)/\Gamma(\Lambda+p\rightarrow n+p)$, theoretical calculation based on one-pion exchange model predicts $\Gamma n << \Gamma p$, whereas recent experiments for A=5,12 suggests large ratios close to unity [1,2]. However these reported results have large errors of 30$\sim$100%. Up to now, most of the experiments concerning this ratio 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 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 this 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 $\Lambda+p\rightarrow n+p$ or $\Lambda+n\rightarrow n+n$ NMWD process. When we select two-nucleon pairs which has back-to-back angular correlation and applied energy sum cut (Q-value for NMWD for $^{5}_{\Lambda}$He is 152MeV) for them, we can measure $\Gamma n/\Gamma p$ ratio directly only from the ratio of 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. We took ^{6}Li(π^{+},K^{+}) data during year 2000-2001 with SKS.

Fig. 1 shows the neutron and proton spectra from the NMWD of $^{5}_{\Lambda}$He. Energy loss of proton inside the target is corrected. Whereas the theoretical calculation predicts the observation of the broad peak at Q-value/2 [3] especially in the neutron spectrum, the observed neutron spectrum shows no peaking. This suggests large contribution of FSI effect and/or $\Lambda NN\rightarrow NNN$ decay process in the NMWD even at A=5. The number of neutron above 50-60MeV is only 2.1 times larger than that of proton. This ratio is significantly lower than the naïve expectation of $\Gamma n/\Gamma p$=1 (initial number ratio=3), indicating the dominance of $\Lambda+p\rightarrow n+p$ decay process.

We also established the way to identify back–to-back n+p- and n+n-pairs. Fig. 2 shows the angular correlation of the n+p- and n+n-pairs from the NMWD of $^{5}_{\Lambda}$He (double coincidence acceptance is corrected). In both of n+p/n+n, we observed clear back-to-back correlation. Also the sum energy distributions of two nucleons show peak at the Q-value of NMWD.

From the back-to-back coincidence ratio, we obtained the $\Gamma n/\Gamma p$ ratio as

$$\Gamma n/\Gamma p = 0.42\text{+-}0.10 \text{ (}\textbf{\textit{preliminary}}\text{)}.$$

Recent theoretical calculation considering heavier meson predicts the $\Gamma n/\Gamma p$ ratio close to this value[4]. Although the result is still preliminary, both of the dominance of $\Lambda+p\rightarrow n+p$ decay process and the significant contribution of $\Lambda+n\rightarrow n+n$ process are established for the first time.

As by-products of the experiment, we are also analyzing the asymmetry of proton emission from the NMWD of polarized $^{5}_{\Lambda}$He. Concerning the proton decay asymmetry parameter, we obtained small $\alpha_{NM}=0.09\pm0.08$ (***preliminary***) and confirmed the result of previous SKS experiment [5] (E278: 0.24 ± 0.22) with improved error.

From the theoretical point of view, it is very hard to simultaneously explain the observed $\Gamma n/\Gamma p$ ratio and small decay asymmetry parameter α_{NM}. This requires reconsideration of the decay mechanism of NMWD.

References

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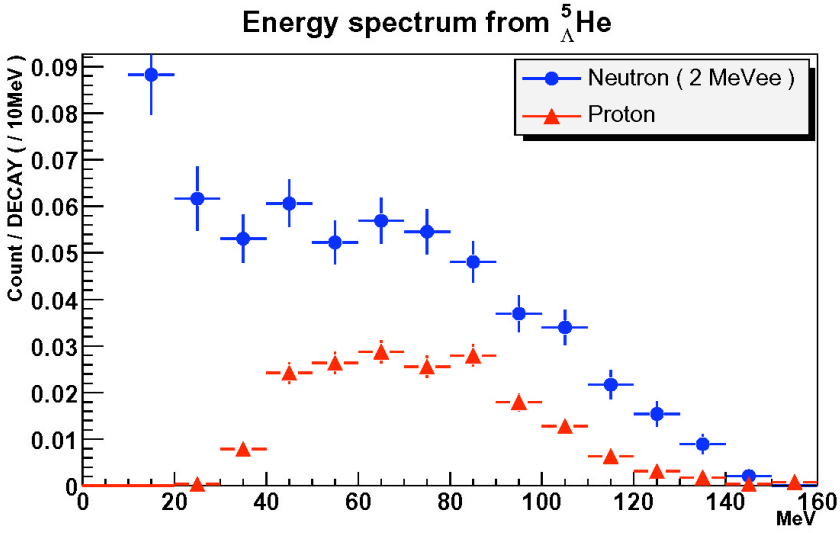

Fig. 1 Neutron and proton spectra from the NMWD of $^{5}_{\Lambda}$He

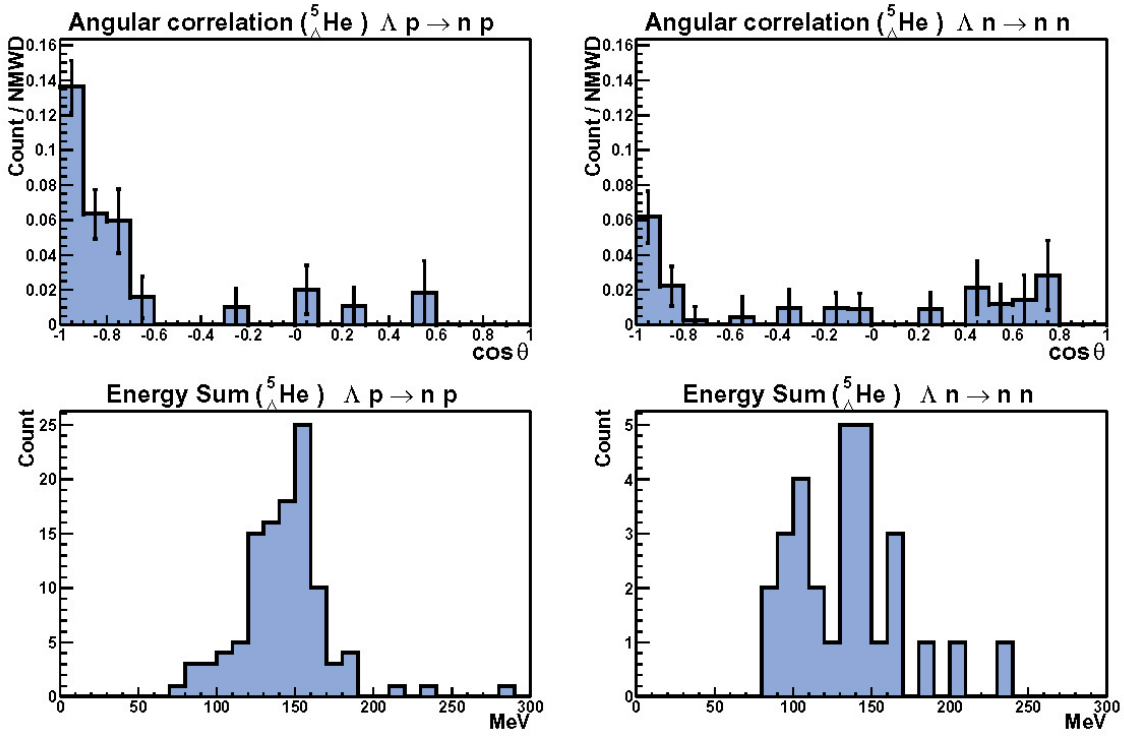

Fig. 2 Two-nucleon angular correlation(top) and energy sum(bottom) from the NWMD of $^{5}_{\Lambda}$He for n+p(left) and n+n(right), showing the dominance of $\Lambda + p \rightarrow n + p$ process.