Mesonic and Non-Mesonic Weak Decay of Hypernuclei with FINUDA


Abstract

The FINUDA experiment performed a systematic study of both mesonic and non-mesonic weak decay of hypernuclei.
decay of \textit{p-shell} \(\Lambda\)-hypernuclei. Recent results on the mesonic decay rates and the non-mesonic decay ratios are illustrated and briefly discussed.

\textit{Key words:} \(\Lambda\)-hypernuclei, mesonic decay, non-mesonic decay, FINUDA experiment

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FINUDA is a hypernuclear physics experiment \cite{1} operating at \(DA\Phi NE\), the LNF \(\Phi\)-factory. Its scientific program is focussed on the study of spectroscopy and decay of \(\Lambda\)-hypernuclei produced by the reaction \(K_{stop}^– + ^{A}\Lambda \rightarrow \pi^- + ^{A}\Lambda\), by stopping the very low energy \(K\) mesons from \(\Phi\) decay. \(\Lambda\)-hypernuclei decay weakly, as observed by FINUDA, through mesonic weak decay (MWD), \(^A\Lambda \rightarrow ^A(Z + 1) + \pi^-\), and non-mesonic weak decay (NMWD), \(^A\Lambda \rightarrow ^A(Z - 1) + p + n\), charged channels. The apparatus is suited to perform high resolution spectroscopy of the emitted charged particles: \(\pi^-\) mesons of \(\sim 260 - 280\) MeV/c for production of the ground state, \(\pi^-\) mesons of \(\leq 130\) MeV/c in MWD, protons of \(\leq 600\) MeV/c in NMWD.

In this paper preliminary results are presented based on a total integrated luminosity of 1056 \(pb^{-1}\) (the full FINUDA data bank, up to 2007). MWD and NMWD of \(p\)-\textit{shell} \(\Lambda\)-hypernuclei are discussed (\(^6\)Li, \(^7\)Li, \(^9\)Be, \(^12\)C, \(^{13}\)C, and \(^2\)D \(_2\)O targets).

MWD was studied in events in which a high momentum \(\pi^-\) meson, tagging the formation of ground or low lying excited states, was detected in coincidence with a low momentum \(\pi^-\) meson. MWD of \(^5\)\(\Lambda\)Li, \(^8\)\(\Lambda\)Be, \(^{11}\)\(\Lambda\)B (\(^{12}\)C targets) and \(^{15}\)\(\Lambda\)N (\(^{16}\)O targets) was investigated. In the present analysis the \(\pi^-\) momentum resolution is \(\Delta p/p \approx 1\%\) FWHM at 270 MeV/c and \(\approx 6\%\) FWHM at 110 MeV/c. The acceptance function for low momentum \(\pi^-\) mesons was evaluated with simulated tracks. Background from quasi-free \(\Lambda\) production and decay was simulated and subtracted from the \(^{11}\)\(\Lambda\)B and \(^{15}\)\(\Lambda\)N spectra.

Kinetic energy spectra were evaluated and compared with theoretical predictions of decay strength functions \cite{2}. A good agreement was found. Decay rates, \(^b\pi^- = \Gamma_{\pi^-}/\Gamma_{tot}\), and \(^\Gamma_{\pi^-}/\Gamma_{\Lambda} = b_{\pi^-} \cdot \Gamma_{tot}/\Gamma_{\Lambda}\), were calculated, using, for each hypernucleus, known \(\Gamma_{tot}/\Gamma_{\Lambda}\) or a linear fit to the measured values from the available \(A = 4 - 12\) \(\Lambda\)-hypernuclei. Table 1 summarizes the results and shows the comparison with recent existing data \cite{3,4} and with theoretical calculations \cite{2}. Also in this case a good agreement was found. The \(^5\)\(\Lambda\)He \(b_{\pi^-}\) and \(^\Gamma_{\pi^-}/\Gamma_{\Lambda}\) were evaluated (from \(^6\)Li targets) for comparison.

To study NMWD events with a formation \(\pi^-\) meson in coincidence with a proton were selected. Kinetic energy spectra of decay protons were obtained featuring a detection

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threshold as low as 15 MeV, and a resolution \( \Delta T/T \approx 1.5\% \) FWHM at 80 MeV. The background due to the absorption of \( K^- \) mesons on a \((np)\) cluster of the target nucleus was simulated and subtracted, as described in [5]. Acceptance correction was applied.

Table 2

\[ \begin{array}{cccc}
R_p & R_p & R_p & R_p \\
\frac{3}{2}^7Li & 0.37 \pm 0.09 & 11^B & 0.40 \pm 0.05 & 13^C & 0.47 \pm 0.10 & 16^O & 0.32 \pm 0.07 \\
\end{array} \]

All the spectra show a similar shape, with a peak at \( \sim 80 \) MeV as expected for the free \( \Lambda p \rightarrow np \) reaction and a low energy rise that should be due to final state interaction (FSI) and to two nucleon induced processes (\( \Lambda np \)). The decay ratio, \( R_p \), between the number of detected protons and the number of formed hypernuclei was evaluated and is reported in Table 2. To disentangle the contribution due to FSI and to \( \Lambda np \) a systematic study was performed, considering, in each spectrum, as contribution due to the NMWD reaction the total area of the gaussian that describes the spectra from 80 MeV on, and the remaining part as due to both FSI and \( \Lambda np \). A linear fit of the value of the ratio of this remaining area to the total area of the spectrum versus the mass number of the daughter nucleus is shown in Fig. 1 (see caption) and indicates that \( \Lambda np \) gives a contribution as large as 40\% to our spectra, value that can be compared with those in [6].

![Fig. 1](image)

Fig. 1. Fraction of the total spectrum due to FSI and \( \Lambda np \), as evaluated from the spectra (red circles) and as extracted by extrapolating to zero the detection threshold for decay protons energy (blue squares). Linear fits are also indicated.

In conclusion, the FINUDA experiment has performed a systematic study of MWD and NMWD of \( p\)-shell \( \Lambda \)-hypernuclei, performing for the first time a magnetic analysis of the spectra of MWD \( \pi^- \) mesons and NMWD protons for all \( p\)-shell targets. MWD decay rates and \( \Gamma_{\pi^-}/\Gamma_{\Lambda} \) and NMWD \( R_p \) have been evaluated.

References