Neutron-rich Λ-Hypernuclei study with the FINUDA experiment

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Λ-hypernuclei are long lived systems in which the Λ hyperon acts as constituent nucleon. The strangeness degree of freedom of the hyperon makes the Pauli exclusion principle ineffective on it and allows the Λ to populate sharp single particle shell model states down to the Λ(1s) ground state.

In Λ-hypernuclei, then, a strong contribution to the total binding energy is added by the Λ, with the possibility of producing bound systems containing unstable core nuclei (glue-like rôle of the Λ). Λ-hypernuclei are thus suitable tools for investigating neutron-rich (proton-rich) systems, even beyond the neutron (proton) drip line.

The study of neutron-rich Λ-hypernuclei is one the main topics of the scientific program of the FINUDA experiment which has completed its operation at DAΦNE, the INFN-LNF (e^+, e^-) collider working at the Φ(1020) center of mass energy. FINUDA has performed an extensive search for bound neutron-rich Λ-hypernuclear states. In the first data taking (2003-2004), ${}^{6}_{\Lambda}$H, ${}^{7}_{\Lambda}$H and ${}^{12}_{\Lambda}$Be have been investigated by looking at the π^+ from the double charge exchange (K^-_{stop}, π^+) production reaction; upper limits for the production rates have been reported [1]: $R_{\pi^+}({}^{6}_{\Lambda}\mathrm{H}) < (2.5 \pm 0.4_{\mathrm{stat}}{}^{+0.4}_{-0.1\mathrm{syst}}) \cdot 10^{-5}/K^-_{\mathrm{stop}}$, $R_{\pi^+}({}^{7}_{\Lambda}\mathrm{H}) < (4.5 \pm 0.9_{\mathrm{stat}}{}^{+0.4}_{-0.1\mathrm{syst}}) \cdot 10^{-5}/K^-_{\mathrm{stop}}$ and $R_{\pi^+}({}^{12}_{\Lambda}\mathrm{Be}) < (2.0 \pm 0.4_{\mathrm{stat}}{}^{+0.3}_{-0.1\mathrm{syst}}) \cdot 10^{-5}/K^-_{\mathrm{stop}}$.

In the second data taking (2006-2007) a ∼5 times larger statistics has been collected and a new analysis technique has been applied for the search of bound ${}^{6}_{\Lambda}$H and ${}^{9}_{\Lambda}$He, based on the coincidence between a π^+ from the (K^-_{stop}, π^+) production reaction and a π^- from the two body mesonic weak decay of the hypernucleus to $\pi^- + {}^{6}He_{g.s.}$. With this method the existence of ${}^{6}_{\Lambda}$H as a bound state has been assessed, based on 3 clearly identified events, with a binding energy B_Λ=(4.0±1.1) MeV, with respect to ^{5}H+Λ; and a production rate $R_{\pi^+}({}^{6}_{\Lambda}\mathrm{H})$= (5.9±4.0)·$10^{-6}/K^-_{stop}$ [2,3] has been evaluated. Indications on the structure of the ${}^{6}_{\Lambda}$H energy levels have been obtained from a systematic difference among the ${}^{6}_{\Lambda}$H mass evaluated from production and decay reactions.

The same method has been applied to the search for bound ${}^{9}_{\Lambda}$He, which is interesting since it could be a neutron-halo Hypernucleus. No event was found and an upper limit for its production, $R_{\pi^+}({}^{9}_{\Lambda}\mathrm{He})$¡(5.0±4.1) ·$10^{-6}/K^-_{stop}$, was deduced [4].

In the presentation a review of all observed neutron-rich Λ-hypernuclei will be given, with particular emphasis on the FINUDA results and on their discussion.

[1] M. Agnello, et al., Physics Letters B 640 (2006) 145.

[2] M. Agnello et al., Physical Review Letters 108 (2012) 042501.

[3] M. Agnello et al., Nuclear Physics A 881 (2012) 269.

[4] M. Agnello et al., Physical Review C 86 (2012) 057301.