Vol. 29 (1998) *ACTA PHYSICA POLONICA B* No 11

K-Λ PRODUCTION IN p+Bi INTERACTION*

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(Received September 2, 1998)

The production of Λ hypernuclei was studied in p+Bi reaction. The lifetime of the produced heavy hypernuclei was measured by observation of delayed fission using the recoil shadow method. The measurements were performed at 1.9 GeV proton energy whereas the background was determined at 1.0 GeV. Upper limit for cross section for reported elsewhere component of a lifetime 2700 ps was estimated.

PACS numbers: 21.80.+a, 14.20.Jn, 25.80.Pw

1. Introduction

The understanding of nonmesonic weak decay mechanism (NMWD) is far from being complete. There have been several model calculations for NMWD processes, but none of them gives the branching ratios satisfactory yet. The essential difficulties arise from fact that experimental uncertainties of the data have to be small in order to use them as stringent tests for

* Presented at the Meson'98 and Conference on the Structure of Meson, Baryon and Nuclei, Cracow, Poland, May 26–June 2, 1998.

theoretical models. Especially the lifetime of hyperons, the inverse of total decay rate is needed as the cleanest experimental observable.

In free space hyperon Λ decays in 99.7 % in the following way:

$$\Lambda \rightarrow p + \pi^- + 38 \text{ MeV},$$

$$\Lambda \rightarrow n + \pi^0 + 41 \text{ MeV}.$$

The total decay width of a hypernucleus is defined in terms of the mesonic and nonmesonic decay modes:

$$\Gamma_{\text{total}} = \Gamma_{\text{mesonic}} + \Gamma_{\text{nonmesonic}},$$

$$\Gamma_{\text{mesonic}} = \Gamma_{\pi^-} + \Gamma_{\pi^0}, \quad \Gamma_{\text{nonmesonic}} = \Gamma_p + \Gamma_n,$$

Γ_p and Γ_n are decay widths due to processes

$$\Lambda + p \rightarrow n + p + 177 \text{ MeV},$$

$$\Lambda + n \rightarrow n + n + 176 \text{ MeV}.$$

In the heavy hypernuclei the leading mechanism of their decay that defines their lifetime is NMWD. It is so because Pauli blocking reduces the partial width for mesonic decay drastically; the damping factor reaches $\sim$100 for hypernuclei (HY) with mass already 100. The NMWD $\Lambda N \rightarrow NN$ is a strangeness changing process which is very important for understanding the baryon–baryon weak interactions. It is practically impossible to investigate it in the scattering state. However, through the decay of heavy hypernuclei, one can study this weak interaction process.

We would like to report on measurement of $\sigma_{_\Lambda A}$ and $\tau_{_\Lambda A}$ *i.e.* the cross section for the production of heavy hypernuclei and the lifetime of hypernuclei.

Λ-hyperons are produced with rather high rates (cross section in the order of few hundred microbarns [1]) in proton induced reactions on heavy targets like Bi already at energies slightly below the threshold for ΛK^+ production in nucleon–nucleon collisions. The hyperons are produced with some distribution in kinetic energy relative to the target at rest (Ref. [2]), however, only a small fraction of them can be bound by the attractive nuclear field when excluding final state interactions. Thus the process of hyperon–nucleon rescattering is essential in decreasing the hyperon momentum with respect to the target frame of reference. Such a slower hyperon can be easier bound to residual nucleus.

$$\boxed{p + A \rightarrow K^+ + \Lambda + A \xrightarrow[\text{rescattering}]{} {}_\Lambda A'}$$

$$\begin{aligned} \sigma_{K^+} &\approx \sigma_\Lambda, \\ \sigma_{_\Lambda A} &\approx \sigma_\Lambda \times \text{SP}, \end{aligned}$$

(SP–sticking probability). Here are the theoretical estimates for the Λ sticking probability (from [2]) for Bi target, with and without taking into account this rescattering effect:

TABLE I

T_p / GeV	σ_Λ	$SP_{without\_resc.}$	$SP_{with\_resc.}$	$\sigma_{\Lambda A}$
1.0	0.72 μb	0.10	0.41	0.30 μb
1.9	1730. μb	0.007	0.19	330. μb

It follows from the above Table I that the Λ-nucleon rescattering should intensify by factor ~ 25 the production of hypernuclei.

The experimental data were taken using internal proton beam of COSY accelerator, Jülich. An internal proton beam hits the target. If hypernucleus is formed, it flies downstream with some distribution of velocity. After time $\tau_{\Lambda A}$ the Λ hyperon decays inside the nucleus, exciting the former hypernucleus which consequently breaks into fragments. As described in [3], by means of shadow method of detection one of the fragments can be registered by two multi-wire proportional chambers operating in coincidence. It

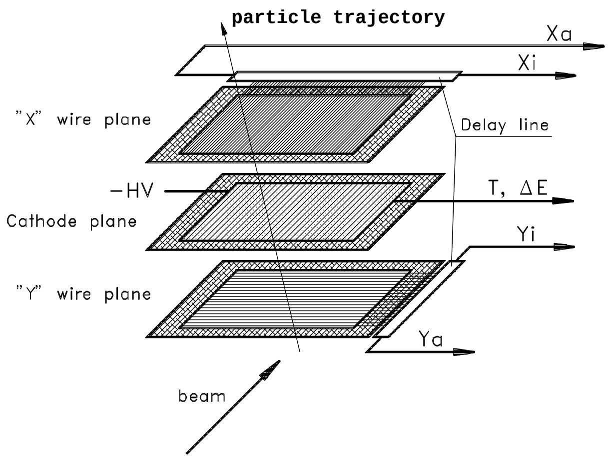

Fig. 1. Construction and operation principle of multiwire proportional chambers used in the COSY-13 experiment.

should be mentioned that counting efficiency for fission fragments is $\simeq$100 % while being less then 10^{-11} for electrons and protons. Further background suppresion was achieved in off-line data analysis by means of track reconstruction and appropriate gate set on two-dimensional TOF-ΔE spectrum (see Fig. 2).

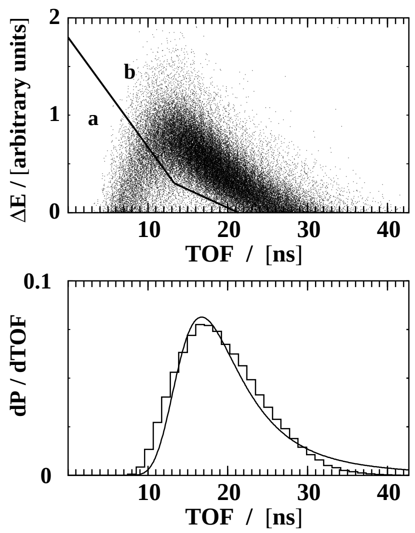

Fig. 2. The upper part shows the scatter plot of experimental events in TOF — energy loss plane. Region "b" corresponds to heavy fragment registration. The lower part shows the histogram obtained by projection of the events from region "b" on the time of flight axis. The full line shows the TOF distribution of fission fragments simulated as described in [3].

The Fig. 3 shows the experimental data after background-suppressing off-line analysis. Contrary to $T_p = 1$ GeV at $T_p = 1.9$ GeV many events

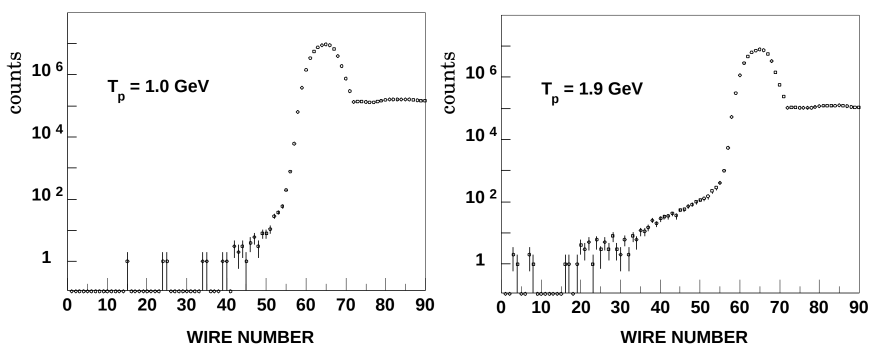

Fig. 3. The abscissa is the distance (in 1mm wide channels) along the lower MWPC, parallel to the beam. Striking similarity of the shape of the distributions at both energies is visible for channels > 54. The shadow region (channels < 54) is significantly more populated in the case of 1.9 GeV; it has to be interpreted as the presence of fragments originating from the delayed fission induced by the hyperon decay.

appear in the shadowed region giving a clear signal of decaying hypernuclei. The actual magnitude of the respective cross section as well as the lifetime $\tau_{\Lambda A}$ was extracted from these data; the details are described in [3].

2. Summary

The following observable values were determined in this experiment:

$$\begin{aligned} \tau_{\Lambda A} &= [161 \pm 7(\text{statist.}) \pm 14(\text{system.})]\ \text{ps}\,, \\ \sigma_{\Lambda A} &= (350 \pm 140)\ \mu\text{b}\,. \end{aligned}$$

The value of the cross section agrees well ith the theoretical prediction 330 μb (see Table I). It confirms that ΛN rescattering dramatically enhances the cross section for production of hypernuclei.

Taking into consideration the statistical accuracy of our background determination as well as that of modelling the delayed fission component, we are able to give upper limit for cross section for production of hypernuclei of a lifetime ~ 2700 ps. It is estimated to be less than 80 nb. (Such a long-lived component was reported in [4]). The Fig. 4 presents the overview of results

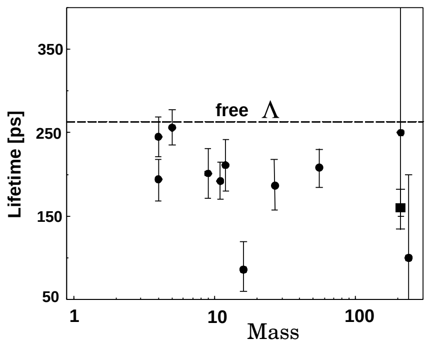

Fig. 4. Filled circles — results of previous lifetime measurements (for overview see [5]); filled square — result of our measurement performed using p+Bi reaction [3].

of hypernuclei lifetime measurement as a function of mass of hypernucleus. It should be stressed that contrary to idea put forward in [5], the lifetime for ^{56}Fe and our measured lifetime do differ significantly.

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