Search for $\Lambda\Lambda$ hupernuclei in E885 at BNL

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In analysis of the quasi-free cascade production on carbon an upper limit on the decay channel $(\Xi^-,^{12}C)_{atom} \rightarrow^{12}_{\Lambda\Lambda} B + n$ was set. Detecting a neutron peak would be a strong evidence of double-Λ hypernuclei existence. An 90% C.L. upper limit of 7% over a range of neutron kinetic energy 5–55 MeV was obtained.

1. Introduction

The high intensity D6 beam line at AGS made new generation of high statistics experiments in S=-2 domain possible. E885 ran for almost 4 months in 1996, recording about 300 000 cascade production events. A typical AGS spill produced a million K^-'s hitting a 5 cm thick target made of synthetic diamond with average density ρ=3.3 g/cm^3. The incident K^- and outgoing K^+ were tracked and identified using an array of in-beam detectors. The momentum of the incident particle was measured using hit information in the beam line scintillator hodoscope and a stack of drift chambers, located right after the beam exit window. The outgoing K^+ momentum was measured by the large acceptance open geometry spectrometer. The K/π separation for both incident and outgoing particles was achieved by using Cerenkov counters and TOF information. A partial suppression of proton knock-out events was done at the trigger level with the help of a high refraction index aerogel Cerenkov counter and fast logic secondary level trigger.

A fraction of cascades, produced in the reaction $K^- +^{12} C \rightarrow K^+ + \Xi^- + X$, would stop in the dense target before their decay and form $(\Xi^-,^{12}C)$ atoms posessing 2 units of strangeness. The cascade production cross-section, much higher than direct cascade hypernucleus production cross-section, combined with the enhanced stopping rate in the dense diamond target allowed us to create S=-2 objects with 3 orders of magnitude higher rate, as compared to direct cascade hypernucleus production. Monte Carlo simulation indicates more than 20 000 stops for our data sample.

2. Motivation and Goals

Theoretical predictions for the reactions $(\Xi,^6 Li)_{atom} \rightarrow^6_{\Lambda\Lambda} He + n$ [1] and $^{12}_{\Xi}Be \rightarrow^{11}_{\Lambda\Lambda} Be + n$ [3] give the branching ratios of 5% and 20% respectively. Considerably lower value for the former reaction is given in ref. [2].

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The emitted neutron is monoenergetic, which facilitates experimental detection. Provided sufficient signal to backgroud ratio, the peak can be reliably identified and measured. In E885 setup, plenty of cascades should stop and form $(\Xi^-,{}^{12}C)$ atoms. If a peak in the neutron spectrum in coinsidence with cascade production is found, number of events in the peak and its location (neutron energy) can be used to find both the branching ratio for the decay through monoenergetic neutron emission and information on binding energy of the Λ's in the core nucleus. High neutron detection efficiency and high statistics are critical to be able to detect a peak on top of background.

3. Neutron Detection

Neutron detector provides high detection efficiency ($\approx$10%) and high timing resolution in a wide range of neutron energies. This is achieved by arranging 100 scintillator logs with dimensions 182.9cm$\times$15.24cm$\times$5.08cm in 2 stacks on both sides of the target, as shown in Figure 1. A layer of veto counters om each side were used for charged particle identification. Neutrons usually appear as isolated hits in the bulk of the detector. If a veto counter in the line of flight fired, the hit was declared to be caused by a charged particle and dismissed. A clustering algorithm was used to correctly identify adjacent hits with a single particle.

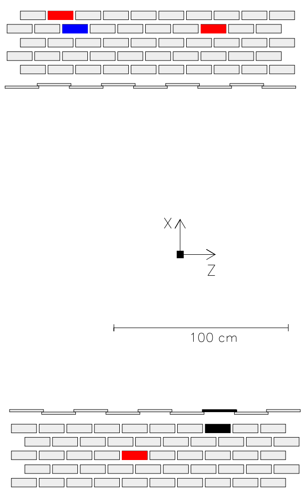

Figure 1. Neutron Detector event (Top view). Z-axis shows direction of flight of the incident particle. Target is shown as a solid rectangle at the origin.

A relatively busy events was chosen to demonstrate different kinds of hits: isolated neutron hits with a single scintillator log fired, a neutron causing a cluster of 2 adjacent logs to fire and a charged hit. The neutron energy is determined by its TOF and distance between the target and the center of the log that fired.

4. Analysis

Most neutrons come from π^- capture and other background processes and give a smooth background spectrum (Figure 2). Missing mass cut can be used to select slower cascades, which are more likely to stop before decaying. Optimal missing mass cut (Figure 3) was calculated based on cascade stopping probability as function of the missing mass and missing mass spectrum. For this particular cut, about 30% of the cascades would stop before decaying, as predicted by Monte Carlo simulation [4].

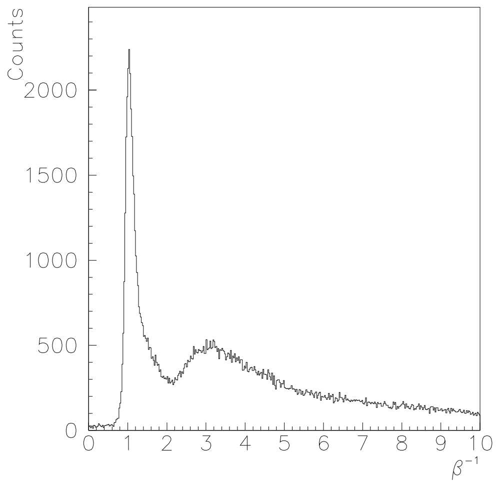

Figure 2. Neutron spectrum as a function of β^{-1}. Prominent peak at $\beta^{-1} = 1$ comes from photons. The neutrons form a smooth spectrum with slower neutrons corresponding to higher values of β^{-1}.

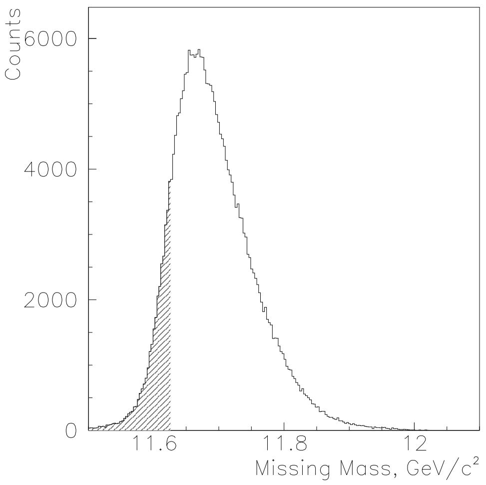

Figure 3. Missing mass for $K^- + ^{12}C \rightarrow K^+ + \Xi^- + X$. Events in hatched area passed the missing mass cut and have high stopping probability

Data sample was broken into 2 classes: a class of events with a relatively high cascade stopping probability and a class with very low cascade stopping probability. Missing mass value was used as a parameter to differentiate the two. The first class of events has both background and signal. The second class of events represents background and is used to find the background shape. The first class is used to set an upper limit on size of the hypothesized neutron peak of known width and position on top of background. Width of the neutron peak was calculated in Monte Carlo simulation code. For neutrons of 20 MeV kinetic energy, width of the peak was calculated to be less than 1 MeV.

Shown in Figure 4 is neutron spectrum for the events of the first class, with a scaled background shape on top. The scaled background fits the spectrum very well and no sign of a monoenergetic peak is present. When the same spectrum is fitted with the scaled background plus a gaussian peak of the known width at a given location, the magnitude of the peak and associated statistical error can be used to set an upper limit on the number of events in the peak. The number of events can be converted to branching ratio, using stopping cascade probability and neutron detection efficiency. In a single fit, the position of the hypothesized neutron peak is fixed at an arbitrary neutron energy and a limit on number of events in the peak is set for that particular energy. Carrying out the fitting procedure for a range of neutron energies, a limit on number of events in a

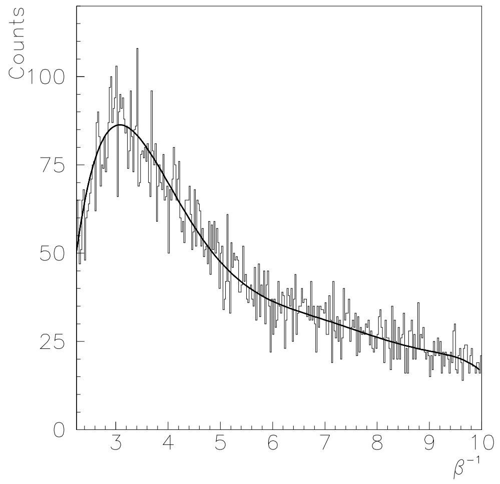

Figure 4. Neutron spectrum for the events with high cascade stopping probability, fitted with scaled background.

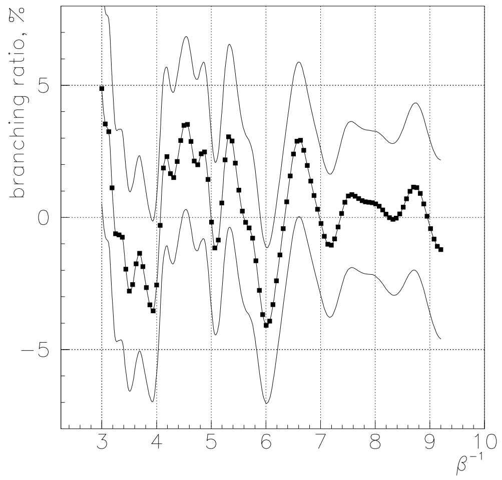

Figure 5. Preliminary branching ratio of the decay $(\Xi^-, {}^{12}C)_{atom} \rightarrow^{12}_{\Lambda\Lambda} B + n$ (center curve) with corresponding 90% C.L. lower and upper limits. Solid rectangles show neutron energies for which fits were carried out.

peak for the whole range is obtained. Central curve in Figure 5 is branching ratio for the reaction $(\Xi^-, {}^{12}C)_{atom} \rightarrow^{12}_{\Lambda\Lambda} B + n$, determined from the series of fits. The values on the curve fluctuate around zero, staying compatible with being zero in the whole range of neutron energies. Lower and upper curves represent 90% C.L. limit on the lower and upper values of the branching ratio respectively. The upper limit is determined by the number of cascade stops, background level and number of events in the hypothesized peak as determined from the fit. An overall upper limit of 7% can be set for the range of kinetic neutron energies 5 MeV–55 MeV.

REFERENCES

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