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Recent Results and Directions in Hypernuclear and Kaon Physics*

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ABSTRACT

This paper presents recent data and future plans for experiments at Brookhaven National Laboratory on hypernuclei and related topics. It will discuss experiments which put a single strange quark in the nucleus and an experiment to produce nuclei containing two strange quarks ($\Lambda\Lambda$ hypernuclei).

In the conventional picture, strange matter takes the form of hypernuclei. Increased knowledge of hypernuclei will be a cornerstone for understanding proposals for more exotic forms of strange matter[1] as well as for better understanding the structure of nuclei.

Single strangeness experiments are performed in the Low Energy Separated Beam at the Brookhaven Alternate Gradient Synchrotron. The beam has a flux of 5×10^5 K^+ or 1.5×10^5 K^- at 720 Mev/c per 5×10^{12} primary protons. The proton intensity at the AGS has recently set a record of more than 2×10^{13} per pulse and is expected to rise to 6×10^{13} per pulse in a few years. Thus available flux will steadily increase.

The single strangeness experiments include studies of lambda hypernuclei,[2] sigma hypernuclei[3] and K^+- nucleus total[4] and quasielastic[5] cross sections. Because the mean free path of the K^+ in the nucleus is very long, the influence of the nuclear medium on the K^+-nucleus interaction can be isolated from other effects.

The hypernucleus ${}^{13}_{\Lambda}C$ which consists of a Λ bound to ${}^{12}C$ has been studied[2] through its production reaction $K^- + {}^{13}C \rightarrow {}^{13}_{\Lambda}C + \pi^-$ and through its gamma ray deexcitation. A gamma ray identified as the $p_{1/2\Lambda} \rightarrow s_{1/2\Lambda}$ transition has been observed in coincidence with the appropriate region of excitation energy. Its energy, which is approximately 11 Mev, measures this level spacing. Future experiments to observe the $p_{3/2\Lambda} \rightarrow s_{1/2\Lambda}$ gamma ray could determine the lambda spin-orbit interaction in a direct way. It is interesting to note that the corresponding transition in $\Lambda\Lambda$ hypernuclei, $p_\Lambda s_\Lambda \rightarrow s_\Lambda s_\Lambda$, is expected to occur in ${}^{14}_{\Lambda\Lambda}C$.

Hypernuclear experiments using the (K^-, π^0) reaction are under discussion. This reaction can form hypernuclei which are not accessible to (K^-, π^-). The LAMPF eta spectrometer has been moved to BNL for studies of eta meson production.[6] It

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DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED could be used for such hypernuclear studies. Also under discussion is the possibility of moving the LAMPF Neutral Meson Spectrometer to BNL. With this spectrometer[7] a resolution of 500 Kev could be obtained opening up a new window on hypernuclear studies.

Because the sigma particle can convert to a lambda particle in the nucleus, sigma hypernuclei will have strong interaction widths. It was thus surprising when relatively narrow sigma hypernuclear states were discovered at CERN more than a decade ago. An experiment[3] is scheduled for the next running period to clarify under what conditions narrow sigma states exist.

In light of proposed new particles and states of matter containing multiple strange quarks, hypernuclei containing two lambda particles are of special interest and an experiment[8] is planned to observe and study them. Does matter containing u, d and s quarks exist as hypernuclei or as H particles and strangelets?

There are three reported observations[9] of $\Lambda\Lambda$ hypernuclei in which the event is well characterized. These events were observed in photographic emulsion experiments (one recent and two 30 years ago). Though the flux has increased by several orders of magnitude, each experiment has yielded only a single event. Clearly the present data is insufficient to answer most important questions. The planned experiment at the AGS will have flux of two orders of magnitude higher than the most recent experiment.

By using a K^- beam incident on a polyethylene (CH_2) target, several experiments can be performed at once. $\Lambda\Lambda$ and Ξ hypernuclei will be produced directly through interaction with carbon nuclei; free Ξ^- particles will be produced through interactions with free and bound protons

$$K^- + {}^{12}C \rightarrow {}^{12}_{\Lambda\Lambda}Be + K^+ \tag{1}$$

$$K^- + {}^{12}C \rightarrow {}^{12}_{\Xi}Be + K^+ \tag{2}$$

$$K^- + p \rightarrow \Xi^- + K^+. \tag{3}$$

The experiment will utilize the 2 Gev Kaon Beam at the AGS. The beam can be run with 10^6 K^- per pulse and a purity of 80% K^- -a remarkable achievement. The momentum is 1.8 Gev/c, ideal for forming Ξ^-. The spectrometer used to identify and momentum analyze the K^- and K^+ is described elsewhere in these proceedings.[10] Better momentum resolution may be needed to pick out individual hypernuclear states. However, since 15 Mev is required to remove a Λ from ${}^{12}_{\Lambda\Lambda}$Be, the bound $\Lambda\Lambda$ hypernuclear region can be easily resolved.

$\Lambda\Lambda$ hypernuclei will also be formed by the capture of Ξ^- particles by nuclei. A tungsten degrader slows the free Ξ^- and it is brought to rest in a secondary target. The Ξ^- interacts with the nucleus from an atomic orbit.

$$\Xi^- + {}^{6}Li \rightarrow {}^{6}_{\Lambda\Lambda}He + n \tag{4}$$

$$\Xi^- + {}^{12}C \rightarrow {}^{12}_{\Lambda\Lambda}B + n \tag{5}$$

The branching ratio for the reaction on ${}^6Li$ has been calculated to be 5%.[11] Detection of the monoenergetic neutron in a time of flight array signals the formation of the double hypernucleus. In the first stage of the experiment it is planned to stop Ξ^- in a block of scintillating fibers. This can give detailed information on the decay of the system. However, because of the multiplicity of possible final states, the branching ratio for the reaction on ^{12}C is much more difficult to calculate.

The decays of $\Lambda\Lambda$ hypernuclei are of great interest. Just as for single hypernuclei, the free decay modes are suppressed due to Pauli blocking and new decay modes due to the weak interaction of the lambda with nucleons occur. In $\Lambda\Lambda$ hypernuclei the weak interaction between two Λ particles will occur, for example through the decay mode[12] $\Lambda\Lambda \rightarrow \Sigma^- + p$. The emission of a Σ^- would be a striking signature of this novel process.

Thus we have a full program of hypernuclear studies at BNL and expect some interesting results over the next few years.

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