The Search for the H Dibaryon with the BNL 2.0 GeV/c Kaon Beam

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ABSTRACT

The status is given for two experiments being carried out to search for evidence of the H dibaryon. BNL experiments E813 and E836 will use the new 2 GeV/c kaon beam line. The former has recently begun data taking. They cover complementary regions of mass-sensitivity and promise to provide sensitive tests of the existence of the H.

INTRODUCTION

The H dibaryon is a hypothetical six-quark (uuddss) flavor-singlet object with $J^\pi = 0^+$. The significance of this particular quark combination was first recognized by Jaffe¹ who pointed out that the color-magnetic interaction due to one gluon exchange within the MIT bag model:

$$\Delta E = - \sum_{i < j} \sigma_i \cdot \sigma_j \lambda_i \cdot \lambda_j \quad M(m_i R, m_j R)$$

is maximal for symmetric spin-color combinations. Because of this interaction, which is strong enough to cause the 300 MeV N- Δ mass splitting, the flavor-singlet state (unique to the H, among all SU₃ dibaryons candidates) was predicted to be bound relative to all strong-decay channels. Jaffe's original mass estimate of 2150 MeV/c² was followed by several other bag-model predictions² as well as quark cluster³, and Skyrme model⁴ predictions, most of which were closer to the $\Lambda\Lambda$ mass of 2230 MeV/c². The first lattice-QCD prediction⁵ had the mass of the H above the $\Lambda\Lambda$ decay threshold, but suffered from severe finite-volume effects. A subsequent lattice-gauge calculation⁶ on a larger lattice gave an H which was bound even relative to the lightest known two-baryon system, the deuteron.

The experimental status of the H remains unclear. An early search⁷ for the pp $\rightarrow$ H K⁺ K⁺ reaction set an upper limit of 30 nb near the $\Lambda\Lambda$ mass. This is not a very sensitive limit because of the large momentum transfer. Two bubble-chamber events have been reported⁸ which fit a neutral dibaryon hypothesis (at 2174 MeV/c² and 2218 MeV/c²) but each could be explained by an alternate reaction at a few per cent confidence level. Two double- Λ hypernuclear candidates⁹ have long been known. A third has recently been reported¹⁰. If these events have been correctly interpreted, they would appear to set a lower limit on the H's mass to be within about 10 MeV/c² of the

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$\Lambda\Lambda$ mass. (The possibility of suppression of the decay to a very tightly bound H is controversial.)

EXPERIMENTS 813 AND 836

The existing uncertainties clearly call for a set of sensitive measurement which are applicable over a wide mass range. E813 is designed to detect production of the H by a two-stage process. The (K^-, K^+) reaction on a LH_2 target is used to produce Ξ^- 's. The paths of the kaons are measured as they enter and leave the target, allowing reconstruction of the production vertex. Also, both Kaons are momentum-analyzed to allow clear tagging of Ξ^- production. The Ξ^- 's emerging from the LH_2 vessel encounter one of 20 tungsten degraders designed to almost range them out. They then pass through silicon detectors (operating at LH_2 temperature) which tag those Ξ^- 's which have very low velocity and a resulting energy loss roughly forty times that of a minimum-ionizing particle. The Ξ^- 's then enter a LD_2 vessel within the same cryostat. Those Ξ^- 's tagged by the Si detectors have a good chance ($\approx 25\%$) of ranging out in the LD_2 , capturing to form Ξ^-d atoms, and reaching an $L=0$ state by Stark mixing. Aerts and Dover¹¹ have shown that there is a relatively high probability (about .3 to .9, depending of choice of interaction models), if the H is not too tightly bound, that the Ξ^- and p will fuse into the H, leaving the spectator neutron to carry away the energy released. This fusion probability, R, falls off for a very bound H because the neutron is not likely to be found with a sufficiently high momentum. Detecting the mono-energetic neutrons from the fusion would provide the evidence of H formation, while the energy of the neutron would imply the mass of the H.

A second experiment, E836, uses a similar technique, first suggested by Aerts and Dover¹². A ^3He target is used for both production of the (virtual) Ξ^- and formation of the H. Although the final state is 3-body (K^+, H, n) they predict a sharp peak in the K^+ spectrum at the kinematics which minimizes the momentum carried by the virtual Ξ^- . Observation of this peak (with good momentum resolution) could then indicate production of the H, if it is sufficiently bound to separate this peak from quasi-free Ξ^- production. Good particle identification is essential in this measurement because mis-identification of a pion as a kaon in either the entrance or exit channel can result in a sharp peak in the final momentum as a result of Σ^- production, unless the π rejection is well over 1000 to 1.

These experiments required the construction of a high momentum separated kaon beam line. The 2.0 GeV/c beam line was designed by a member of our collaboration, P. Pile, with optics corrected to third order. The desired multiplicities were achieved by mapping magnet multiplets as a unit and including discrete sextapole and octapole elements. Two separate stages of electrostatic separation are used to eliminate pions originating from a cloud around the production target along with those coming straight from the target. The separators, which must run at 750kV across a 10 cm gap, are based on a KEK design.

The two experiments use essentially identical apparatus apart from the cryogenic target (^3He vs. combined LH_2/LD_2 with tungsten degraders and enclosed Si detectors). Drift chambers track the particles entering and leaving the target. Upstream position and timing hodoscopes give momentum and time-of-flight information on the incident beam. A large aperture spectrometer magnet is used to momentum-analyze outgoing particles with the use of additional large drift chambers in and downstream from the magnet. Particle identification also uses four Aerogel Cherenkov counters (two in the beam and two large ones downstream), a position hodoscope, a time-of-flight hodoscope and a lucite Cherenkov detector. Triggering is assisted by a position hodoscope near the target. Neutrons emerging from the target are detected by two

arrays of 50 large ($72'' \times 6'' \times 2''$) scintillator logs, one array on each side of the target. These logs have 300 pS FWHM timing resolution (for minimum ionizing particles) to allow energy determination by time-of-flight (with the interaction position within the log being determined by time difference).

These two experiments cover largely complimentary regions of H particle mass, with E813 being most sensitive near the $\Lambda\Lambda$ mass where E836 is blinded by quasi-free Ξ^- production. Since the latter experiment requires better particle identification as well as higher resolution, we have started by taking data for the Ξ^- -d atom experiment. Although the optimal incident momentum for the experiment is 1.8 GeV/c, we have decreased the beam momentum to 1.7 GeV/c to compensate for the fact that the electrostatic separators are not yet operating at their design voltage of 750 kV, (but perform well at 600 kV). The reduced separation has also increased the π/k ratio, reducing the kaon flux which can be accepted. While separator problems have delayed achievement of the beam line's goal of $\pi/k = 1/1$ at 10^6 k/spill, it is heartening to note that the beam line's present performance is nearly as predicted for the present operating conditions. A π/k ratio of 1/1 has been achieved, at the cost of kaon flux, and the kaon image has nearly the expected size at the 'cookbook' values of the high order optics.

E813 has been receiving usable beam since early May and will continue until the end of the AGS running period in late June. All detectors are operating well and we are taking production data while also studying rates and backgrounds. Particle identification efficiency is sufficient for the present experiment, although some improvement may be required for E836. The largest trigger rate results from knockout of protons into the K^+ spectrometer. This was anticipated and a lucite Cherenkov counter was constructed for K/p identification. That has very recently been installed and is successfully reducing the trigger rate. Timing cuts are also being determined to allow implementation of a second-level trigger for next year's running at higher kaon flux. Because of low beam flux, this year's running alone may not provide sufficient statistics for any clear results on the question of the H. With improved separation, additional proton flux and improved high-rate capability we expect to greatly increase our accumulated statistics next year, permitting a much stronger statement on the existence of the H.

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