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Search for Strangelets and Other Rare Objects in $Au + Pt$ Collisions at the AGS Using a Fixed-Angle Focusing Spectrometer

A. Rusek[g], B. Bassalleck[g], A. Berdoz[c], T. Bürger[d], M. Burger[d], R.E. Chrien[b], G.E. Diebold[i], H. En'yo[e], H. Fischer[g], G.B. Franklin[c], J. Franz[d], T. Iijima[e], K. Imai[e], J. Lowe[g], R. Magahiz[c], A. Masaike[e], F. Merrill[c], C.A. Meyer[c], S. Mihara[e], J.M. Nelson[a], K. Okada[f], P. Pile[b], B. Quinn[c], E. Rössle[d], N. Saito[e], R. Sawafta[b], H. Schmitt[d], R.A Schumacher[c], R. Stearns[h], R. Stotzer[g], R. Sukaton[c], R. Sutter[b], F. Takeutchi[f], D.M. Wolfe[g], K. Yamamoto[e], S. Yamashita[e], S. Yokkaichi[e], V. Zeps[c], R. Zybert[a]

[a]Department of Physics, University of Birmingham, Birmingham B15 2TT, UK

[b]Brookhaven National Laboratory, Upton, New York 11973

[c]Department of Physics, Carnegie Mellon University, Pittsburgh, Pensylvania 15213

[d]Fakultät für Physik, University of Freiburg, D-79104 Freiburg, Germany

[e]Department of Physics, Kyoto University, Sakyo-Ku, Kyoto 606, Japan

[f]Faculty of Science, Kyoto Sangyo University, Kyoto 603, Japan

[g]Department of Physics and Astronomy, University of New Mexico, Albuquerque, New Mexico 87131

[h]Department of Physics and Astronomy, Vassar College, Poughkeepsie, New York 12601

[i]Physics Department, Yale University, New Haven, Connecticut 06511

During the 1993 AGS heavy ion run, experiment E886 conducted a strangelet search in Au + Pt reactions, with beam momentum of 10.8 GeV/c per nucleon. Presented here are the upper limit for strangelet production, invariant cross sections for p, t, d ^{3}He, ^{4}He, ^{6}He, ^{8}He, ^{6}Li, ^{7}Li, ^{8}Li and ^{7}Be, along with a demonstration of their agreement with a coalescence model fit to data collected by E886 during the 1992 engineering run, and upper limits for production cross sections for other rare objects, such as (H dibaryon)-nucleus systems. All results reported here are preliminary.

1. INTRODUCTION

Heavy ion collisions at the AGS energies create dense hadronic systems with several units of strangeness per collision and therefore constitute a favorable environment for the production of exotic forms of matter such as strangelets [1]. This is the case whether strangelet production is described by the quark-gluon plasma picture or the nuclear coalescence model. The signature of such particles would be an unusual mass to charge ratio (M/Z). Experiment E886 measured M/Z with high sensitivity at the price of small acceptance and restriction to long lifetimes. While the main objective of this experiment was the search for strangelets, the background for this search, consisting of several known ions, was analyzed and invariant cross section values were determined.

2. THE EXPERIMENT

Experiment E886 utilized the AGS D6 separated beamline [2], originaly constructed for the H-particle experiment E813 [3], as a focusing spectrometer, which along with the associated downstream open geometry dipole spectrometer provided two independent momentum per charge (P/Z) measurements. The time of flight (TOF) across each one of the spectrometers was recorded as well, combining with the P/Z to yield two independent mass measurements. The charge was determined by pulse height mesurement in four plastic scintillator counters, placed in the region between the two spectrometers.
Having two independent mass measurements has proven to be a powerful method for obtaining clean M/Z spectra. Particle identification was greatly improved over that achieved by the focusing spectrometer alone. However, using the beam line as a spectrometer limits the acceptance; the beam is extracted into the D6 line at a fixed angle of 5.7^0, and at a rigidity of 1.8 GV the acceptance is $\frac{dp}{p}d\Omega \approx 9$ msr% for $0 < M/Z < 14\ GeV/c^2$. In addition, the length of the beam line, 30 m, limits the search to objects with lifetime on the order of 10^{-8} s or longer.

During the 1993 heavy ion run, E886 collected both positive and negative charge data. Only the results from the positive data are reported here. The total number of Au ions on the production target was 7.34×10^{12}, yielding an estimated 4.32×10^{12} interactions. Fully characterized and identified were π, K, p, d, t, ^{3}He, ^{4}He, ^{6}He, ^{8}He, ^{6}Li, ^{7}Li, ^{8}Li and ^{7}Be. No other signal is seen (see Figure 1).

3. RESULTS

In Figure 1 the mean pulse height in the four scintillator counters is plotted against M/Z as measured in the focusing spectrometer. The cuts used to produce this spectrum include an agreement between the two mass measurements to within 2.6σ. The region to the right of the triton and the ^{8}He signals is where the strangelet search was focused and a quick glance will suffice to confirm that no signal is found there. The limits on strangelet production per interaction are shown in Figure 2. For these limits a kinematic production model was assumed [4], and the theoretical distribution integrated over the experiment's transverse momentum and rapidity acceptance to yield a weighted acceptance. To obtain the 90% confidence level sensitivity, we divided 2.3 by the product of the weighted acceptance and the total number of interactions.

As a by-product of the strangelet search the production cross sections for several light nuclei were extracted. The production target used was one interaction length thick, rendering the direct measurement of these cross sections impossible. The effects of secondary interactions contributing to particle production are non-negligible, and a model was put together to try to assess their magnitude. For each produced nucleus a two parameter expression for the invariant cross section was produced, the two parameters being the ratio of invariant cross section for p+Pt $\rightarrow$ nucleus to that for Au+Pt $\rightarrow$ nucleus, and the average number of secondary nucleons produced in each primary collision. For some reasonable choices of these parameters a range of possible values for each cross section

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is obtained. The results of this effort are summarized in Figure 3. The ranges for the invariant cross sections are shown as two horizontal lines about each value in the plot. Symbols are used to indicate the values obtained from an extension of a coalescence fit to data collected by this experiment during 1992 [5,6].

Recently, Baltz *et al.* [7] have calculated the production rates of loosely bound di-lambda states $(\Lambda\Lambda)_b$ by coalescence following Au + Au collisions at AGS energies. We suppose that the two lambdas do form the H particle [8], that there exist (H particle)-nucleus bound states, and that their lifetime is not significantly altered from that of the free H. Under these conditions we can set a limit on the H particle lifetime, and use that result to set a limit on the H particle mass [9]. Two composite systems were considered: the ${}^{5}_{\Lambda\Lambda}$He and the ${}^{4}_{\Lambda\Lambda}$H with estimated M/Z of 2.51 GeV/c^2 and 4.09 GeV/c^2, respectively. The binding energy for these objects is estimated in reference [7]. Viewed as "doorway states" to the formation of an (H particle)-nucleus state, these objects can be searched for in the gap between the ^{4}He and ^{6}He (${}^{5}_{\Lambda\Lambda}$He), and to the right of the triton (${}^{4}_{\Lambda\Lambda}$H) (see Figure 1). For stable systems E886 is 10^4 times more sensitive than necessary for the

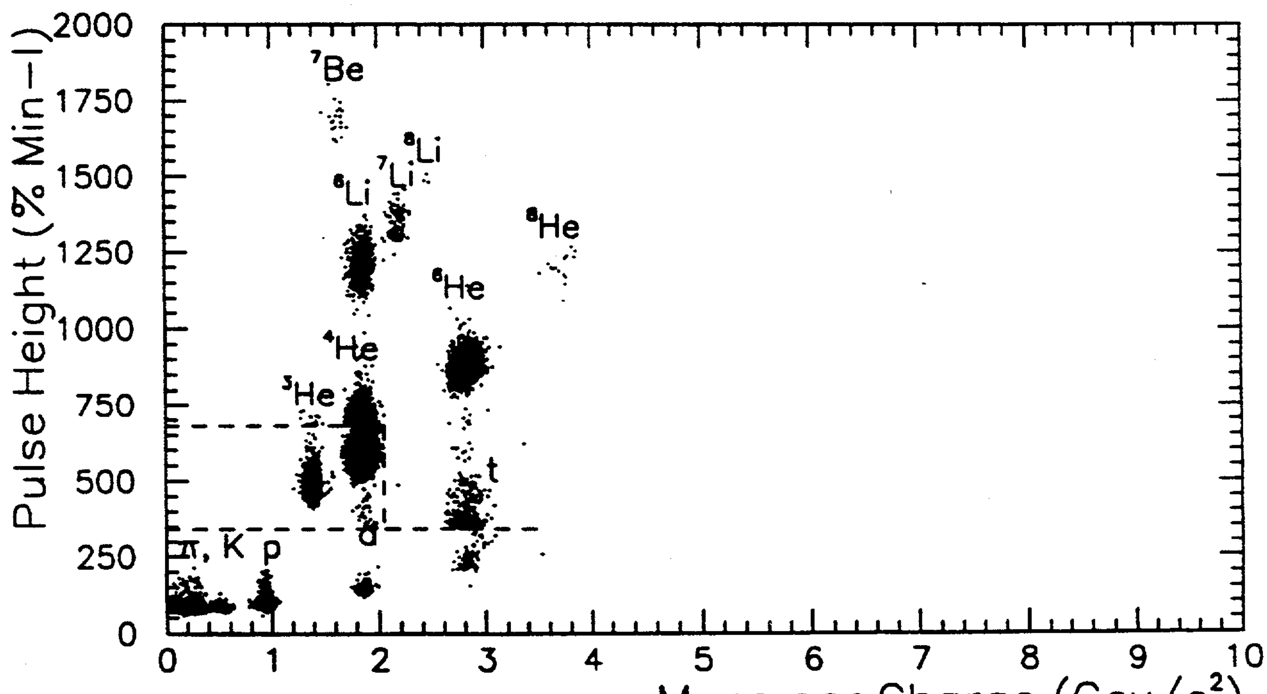

Figure 1. Pulse height vs. M/Z. The dashed lines separate different data sets. This causes the apparent deficiency in the Z=1 nuclei which are represented here by only about 0.0005% of the total number identified by the experiment. The ^{6}He, ^{8}He and the Z=3,4 nuclei in this plot represent the full data set. Note the lack of signal or background in the region to the right and in between identified ions; the redundant M/Z measurement is greatly responsible for the cleanliness of this spectrum.

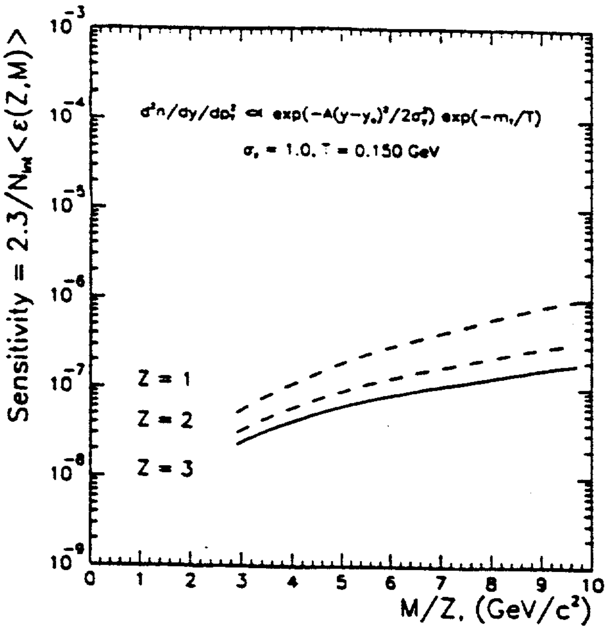

Figure 2. Stable strangelet production limit, assuming a kinematic model in which the production is distributed as a Gaussian in rapidity and an exponential in transverse momentum [4].

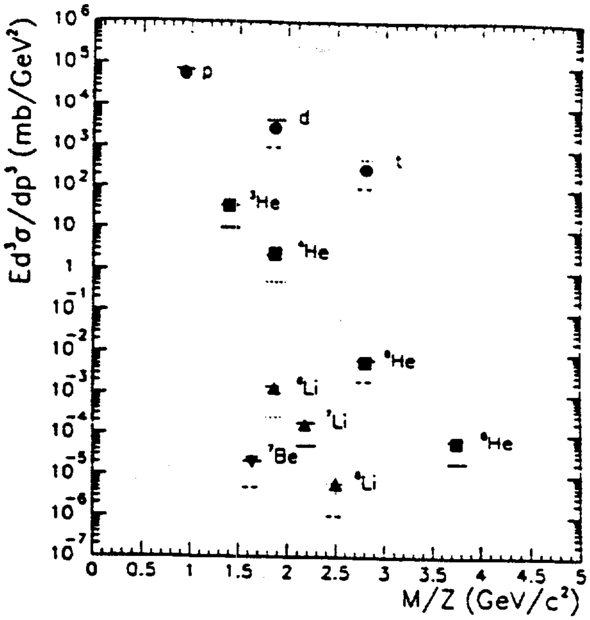

Figure 3. Invariant cross sections for all ions identified vs. M/Z. The horizontal bars indicate the region of possible values for each ion. The symbols indicate the values obtained from an extention to a coalescence fit to 1992 data [5].

predictions of reference [7]. The complete lack of signal in these regions sets a limit on the lifetime of the (H particle)-nucleus system of less than approximately 20 ns. Again, if the lifetime of the system is not very different from that of the free H particle, then using the result of reference [9], the limit on lifetime implies an H mass of no less than 2.13 GeV/c^2 (ΣN threshold).

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