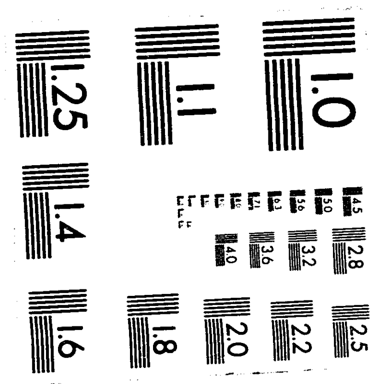

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STRANGE CLUSTER FORMATION IN RELATIVISTIC HEAVY ION COLLISIONS

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ABSTRACT

Using the cascade code ARC to simulate relativistic heavy ion collisions at Brookhaven AGS energies (11.7 - 14.6 GeV/c), we have estimated the production rate of strange clusters ranging from a hypothetical doubly strange (S=-2) bound $(\Lambda\Lambda)_b$ dibaryon to the hypernuclei ${}^{6}_{\Lambda\Lambda}$He and ${}^{7}_{\Xi^0\Lambda\Lambda}$He.

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STRANGE CLUSTER FORMATION IN RELATIVISTIC HEAVY ION COLLISIONS*

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Using the cascade code ARC to simulate relativistic heavy ion collisions at Brookhaven AGS energies (11.7 - 14.6 GeV/c), we have estimated the production rate of strange clusters ranging from a hypothetical doubly strange (S=-2) bound $(\Lambda\Lambda)_b$ dibaryon to the hypernuclei ${}^{6}_{\Lambda\Lambda}$He and ${}^{7}_{\Xi^0\Lambda\Lambda}$He.

For the formation of multi–strange bound systems, high energy heavy ion collisions offer the only feasible method, since one can take advantage of the hyperons which are copiously produced in such collisions (typically 20 Λ's in a Au+Au central collision at the AGS) to form the composite object by coalescence. We have estimated[1] the production rates of strange clusters with $2 \leq A \leq 7$ in a simple coalescence model, using Si+Au and Au+Au collision events generated by the cascade code ARC.[2,3] From ARC, we obtain phase space densities of protons (p), neutrons (n) and Λ hyperons. The single particle rapidity distributions dN/dy from ARC are in excellent agreement with Brookhaven AGS data for p and Λ. An ARC event gives us the momentum and spatial location of each (n,p) or other produced particle at the time of last interaction with other hadrons. From this information, we compute the relative two–body c.m. momentum $\Delta p = \frac{1}{2}|\vec{p}_1 - \vec{p}_2|$ of an (n,p) pair and their relative spatial separation $\Delta r = |\vec{r}_1 - \vec{r}_2|$ at the later time of last interaction of the neutron or proton. If Δp and Δr satisfy the conditions

$$\Delta p \leq (\Delta p)_{\max}, \qquad \Delta r \leq (\Delta r)_{\max}, \tag{1}$$

at this local "freezeout" time, then we count a deuteron as having been formed. We use phenomenological values for $(\Delta p)_{\max}$ and $(\Delta r)_{\max}$ adjusted to reproduce the AGS data on d, ^{3}He, ^{3}H and ^{4}He production. Heavier clusters are built up by sequential coalescence, taking care to avoid double counting. For instance, to form the hypernucleus ${}^{3}_{\Lambda}$H, we first coalesce an np pair, and then search for a Λ which satisfies Eq. (1), where Δp and Δr are now computed with respect to the

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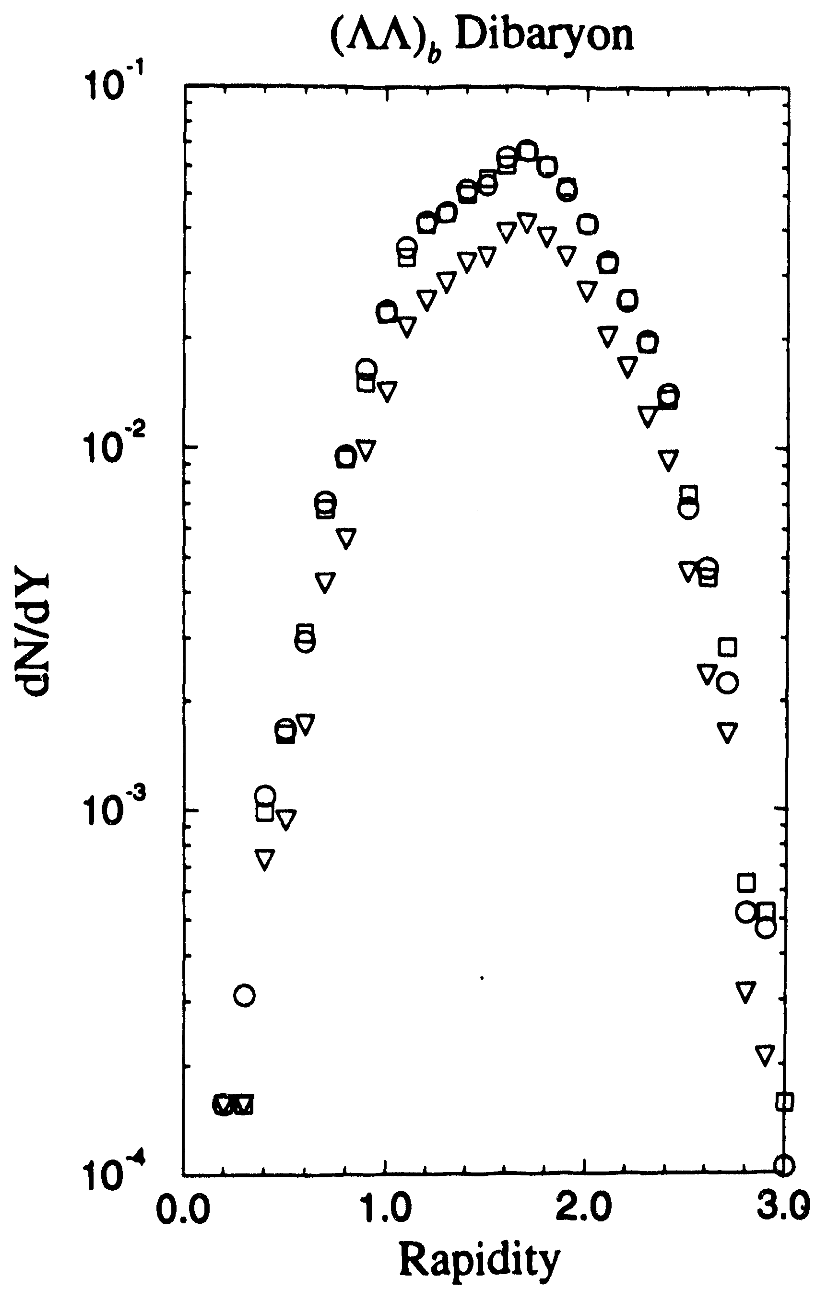

Figure 1: Predicted rapidity distribution for $(\Lambda\Lambda)_b$ dibaryon production in central Au+Au collisions at AGS energies. The squares correspond to a coalescence calculation with the same values $\{(\Delta r)_{\max} = 3 \text{ fm}, (\Delta p)_{\max} = 110 \text{ MeV/c}\}$ as used for deuterons. For the choices {2.5 fm, 110 MeV/c} and {2.5 fm, 132 MeV/c}, we obtain the diamonds and circles, respectively.

c.m. of the np pair. The coalescence rates have been calculated for the following strange clusters:

$$(\Lambda\Lambda)_b\,(J=0)\,, \quad {}^3_\Lambda\mathrm{H}\,(J=1/2)\,, \quad {}^4_\Lambda\mathrm{He}, {}^4_\Lambda\mathrm{H}\,(J=0,1)\,, \quad {}^5_\Lambda\mathrm{He}\,(J=1/2)\,,$$
$$ {}^4_{\Lambda\Lambda}\mathrm{H}\,(J=1)\,, \quad {}^5_{\Lambda\Lambda}\mathrm{He}, \quad {}^5_{\Lambda\Lambda}\mathrm{H}\,(J=1/2)\,, \quad {}^6_{\Lambda\Lambda}\mathrm{He}\,(J=0) \qquad (2)$$

In Fig. 1, we display our predictions for a hypothetical $(\Lambda\Lambda)_b$ bound state. We envision this object as a loosely bound system, similar to the deuteron in binding energy and size. The various curves in Fig. 1 indicate the degree of sensitivity to the choice of $(\Delta p)_{\mathbf{max}}$ and $(\Delta r)_{\mathbf{max}}$. If $(\Delta r)_{\mathbf{max}}$ is varied within reasonable limits, while the product $(\Delta p)_{\mathbf{max}} \cdot (\Delta r)_{\mathbf{max}}$ is held fixed, the rate for $(\Lambda\Lambda)_b$ production remains almost unchanged.

The total numbers $N_i = \int dy dN_i/dy$ of particles of species i produced in central Au+Au collisions at 11.7 GeV/c are 0.07, 0.15, 0.03, 0.03, 1.4×10^{-3}, 4×10^{-3}, 3×10^{-4}, 4×10^{-4}, 1.6×10^{-5}, respectively, for the species listed in Eq. (2). We note that the N_i values decrease rapidly as A and S increase. The penalty factor associated with the addition of baryons by coalescence limits the size of strange clusters which can be produced with measurable rates in heavy ion collisions. The lightest bound system with a Ξ hyperon,[4] stable against strong conversion $\Xi N \rightarrow \Lambda\Lambda$, is likely to be ${}^{\ 7}_{\Xi^0\Lambda\Lambda}\mathrm{He}$ (${}^4\mathrm{He} + 2\Lambda + \Xi^0$). We estimate a production rate of 10^{-8} for this object per central Au+Au collision.

The strange clusters considered here will decay weakly, with lifetimes $\tau \sim 0.1$ ns, too short to be detected in a time–of–flight experiment. Instead one would have to look for specific weak decay modes, for instance final states involving only charged particles such as

$$(\Lambda\Lambda)_b \rightarrow p\pi^- + \Lambda \rightarrow 2\,(p\pi^-) \quad \left[3 \times 10^{-2}\right] \qquad (3a)$$
$${}^6_{\Lambda\Lambda}\mathrm{He} \rightarrow p\pi^- + {}^5_\Lambda\mathrm{He} \rightarrow 2\,(p\pi^-) + {}^4\mathrm{He} \quad \left[2 \times 10^{-6}\right] \qquad (3b)$$

Our estimates of the product of N_i and the weak decay branching ratio are given in parentheses. Thus an experiment of rather modest sensitivity should suffice to detect $(\Lambda\Lambda)_b$, if it exists.

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