Ξ^- PRODUCTION IN HEAVY ION COLLISIONS AT THE AGS *

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ABSTRACT

We report the first observation of Ξ^- in heavy ion collisions at the AGS. The lifetime of Ξ^- measured agrees very well with the particle data group value. We present the observed Ξ^- effective mass spectrum and the rapidity distribution after acceptance correction using different models. In the measured rapidity region(1.4-2.9) for 14.6 GeV/c *Si* on *Pb*, we obtained a yield of 0.25 ± 0.04 Ξ^- per central event and a ratio of $N(\Xi^-)/N(\Lambda)=0.12 \pm 0.02$ using a fireball model for acceptance correction(statistical error only). This result is greater than any cascade model prediction so far.

1. Introduction

In searching for Quark Gluon Plasma(QGP) in Heavy Ion collisions, strangeness enhancement has long been regarded as one of the most promising signatures[1]. A number of the BNL and CERN experiments reported significantly enhanced production of single strangeness particles over that of a naive superposition of NN collisions.[2-5] However, newly emerged cascade models like RQMD and ARC have reproduced these results very well at AGS energies by involving rescatterings of resonant states such as Δ and N^* etc, without introducing the QGP scenario at all[7-11]. AGSHIJET+N^* reproduced both Λ and K^0_s rea-

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sonably well for $Si+Pb$, although it failed by almost a factor of 2 for $Si+Si$.[6,7] As pointed out in Ref.12, the enhancement of particles with single strangeness can not serve as a clean signature of the QGP formation, since it carries too much background information of the hadronized state. However, the theory of strangeness enhancement as a signature of QGP still may be important; the question is how to observe it! In a hadron gas, producing multi-strange hyperons requires rescattering among strange hadrons or multiple rescattering of resonant states. This makes their enhancement difficult for the conventional models to account for. During the QGP (Quark Gluon Plasma) phase transition into a HG (Hadron Gas) phase, Ref. 13 demonstrates that a large antistrangeness content will build up in the HG phase while a large strangeness excess will be left in the QGP phase. This excess during hadronization could favor multi-strange hyperon production as well as strangelet formation. With strangelet searches still not successful, we consider hyperons of multiple strangeness a much better probe for QGP than single strangeness searches. To push the strangeness enhancement study to a new stage of QGP search, we have searched for a Ξ^- signal in our data.

2. Experimental Method

E810 was designed to cover a large rapidity range and record as much information as possible on an event by event basis. The detailed experimental method of E810 has been described in previous publications[5,9]. Briefly, we measured charged tracks in three TPC (Time Projection Chamber) modules in a magnetic field. The detector covered the forward hemisphere in the center-of-mass of the nucleon-nucleon system. The trigger, as decribed in Ref. 5, selected centrally enriched events for data recording. For the final data sample we selected the most central events using a cut on the highest multiplicity of the negatively charged tracks within our good acceptance. We selected the most central events from the Pb target corresponding to a cross section of approximately 300 mb. These cuts correspond to approximately 10% of the geometric cross section. The effective masses for Λ's were calculated by kinematic hypothesis by assigning a proton or a pion mass to the positively

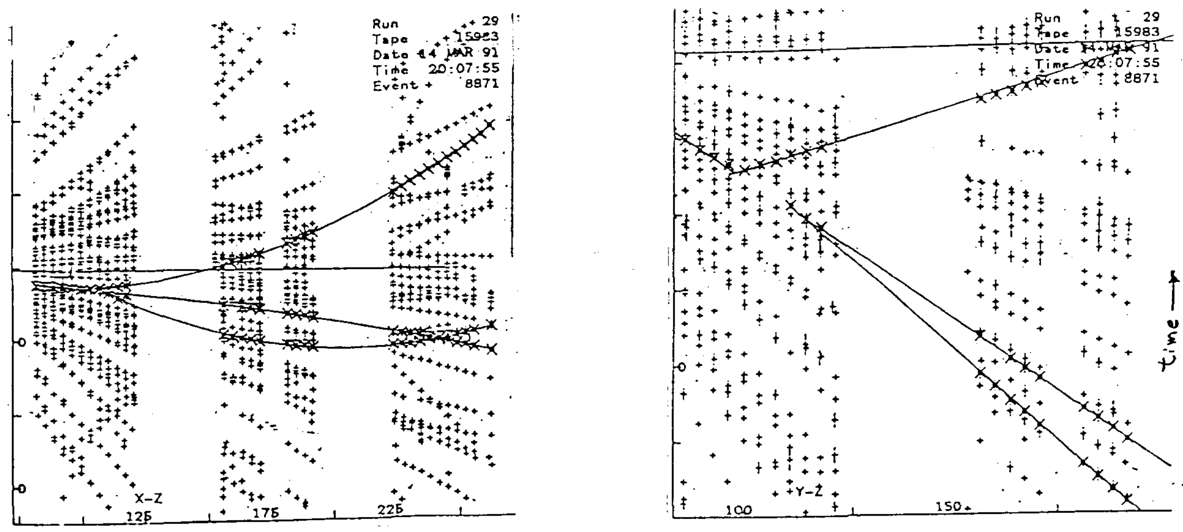

Fig.1 a): The X-Z view of a Ξ^- decaying in TPC module b): Enlarged Y-Z view of the same decaying Ξ^-

or negatively charged tracks which form a vertex. For more details on Λ reconstruction and its rapidity distribution, please refer to Ref. 7.

With $\sim$ 3000 well defined Λ's from the Pb target, we successfully found the Ξ^- signal with the following proceedures:

We only used those Λ's and negative tracks(with sagittas $\geq$ 0.375 cm) that did not come from the primary vertex. When a Λ and a negative track formed a vertex, we took this as a possible Ξ^- decay vertex and extrapolated it to the primary vertex as a helix with a momentum vector of $\vec{P}(\Xi^-) = \vec{P}(\Lambda) + \vec{P}(\pi^-)$. A typical, reconstructed Ξ^- decaying in our TPC module is shown in Fig.1.

For all the vertices that survived the above cuts, we calculated their effective mass with the $\pi^-\Lambda$ hypothesis as plotted in Fig.2a. We selected those 97 candidates that lie in the range of 1.306-1.336 GeV/c^2 as our Ξ^- signal. Those 19 which lie in the range of 1.280-1.294 GeV/c^2 and 1.348-1.364 GeV/c^2 are treated as backgrounds.

3. Results and Discussions

Due to the limited statistics, we can only do a model dependent acceptance correction to our Ξ^- data. In order to calculate acceptances, a complete Monte Carlo simulation of events was performed using GEANT. Events were generated using the AGSHIJET+N^* model. The generated TPC's hits included all the known effects of the detectors apertures,efficiencies, resolutions, and distortions. The same code has been used to calculate the acceptance of Λ data and proved successful[7]. The lifetime of the Ξ^- is $c\tau = 4.92$ cm as given by Particle Data Group. We measured the acceptance corrected decay distribution as a function of proper time as shown in Fig.2b, which is in good agreement with the known value. This gives us confidence in our acceptance calculations. The acceptance corrected rapidity spectrum using the AGSHIJET+N* model for the Ξ^- is shown in Fig.3a along with AGSHIJET+N*'s prediction scaled up by a factor of 4. This production is equal to 0.15 Ξ^- per central event

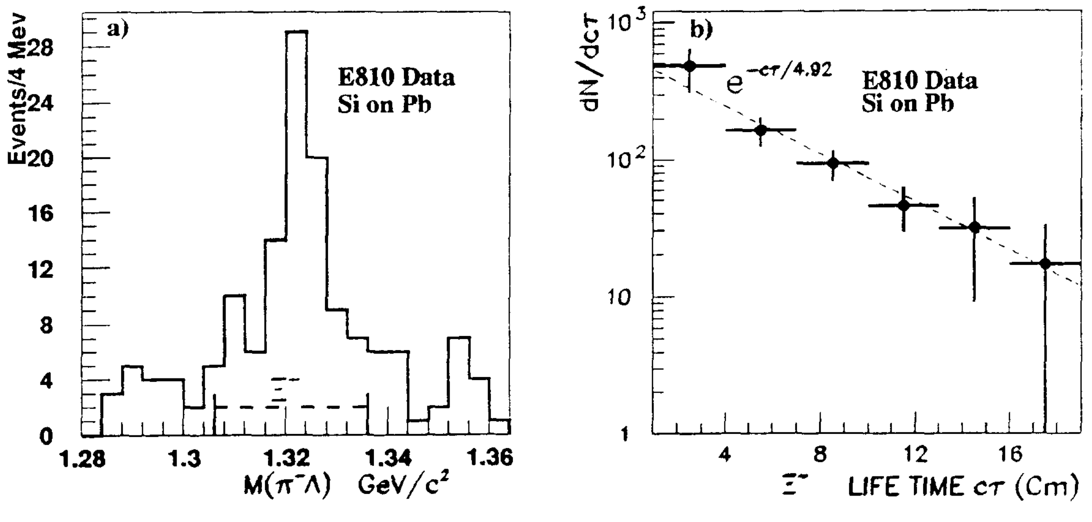

Fig.2 a): Effective mass plot of $\pi^-\Lambda$ hypothesis for the decay vertices. b): The Ξ^- decay distribution from central events. The dashed curve is not a fit, but the known value $e^{-c\tau/4.92}$.

in the measured rapidity region(1.4-2.9). For $Si+Si$ HIJET underestimated the observed production of single strange particles by a factor of (almost)2. HIJET's factor of 4 underestimation of Ξ^- for $Si+Pb$ leads us to suspect that for some reason, HIJET might have a factor of 2 underestimation for each strange quark.

Due to HIJET's poor job at representing the transverse mass distribution of the Λ's,as shown in Fig.3b where data are from Ref.14 and Ref.15, we have reason to believe that HIJET also underproduced Ξ^- in the region of high transverse momentum. Comparing different baryons' m_t distribution, we see that the heavier the mass of the particles, the smaller the slope of the m_t spectrum. Since no satisfactory model prediction is available, we assumed that Ξ^-'s obey the same transverse mass distribution as Λ's and used the global fit to our Λ data to do another acceptance study in our measured rapidity region(1.4-2.9). The Ξ^-'s generated using fireball model were embedded in HIJET central events, followed by the same Monte Carlo process as above. This acceptance gives us the yield of 0.25 ± 0.04 Ξ^- per central event and the ratio of $N(\Xi^-)/N(\Lambda)=0.12 \pm 0.02$ in the measured rapidity region(1.4-2.9).

In Fig.4, we show the acceptance corrected rapidity distribution(using the Λ global fit) of Ξ^- along with 1/8 of our Λ data. The global fit for the Λ is[7]:

$$\frac{1}{m_t}\frac{d^2N}{dydm_t} = Ae^{-m_t(a+b\cosh(y-y_0))}. \quad (1)$$

Where A is an arbitrary constant, $m_t = \sqrt{m_0^2 + p_t^2}$, and the cosh term represents a fireball. The constants a, b and y_0 were adjusted to fit E810 data in the measured region ($1.4 \leq Y < 2.9, P_t < 1.0$ GeV/c). They were 2.6712, 1.1071 and 1.2688 respectively. Comparing Fig.3a with Fig.4, we see that our acceptance calculation is sensitive to the model used.

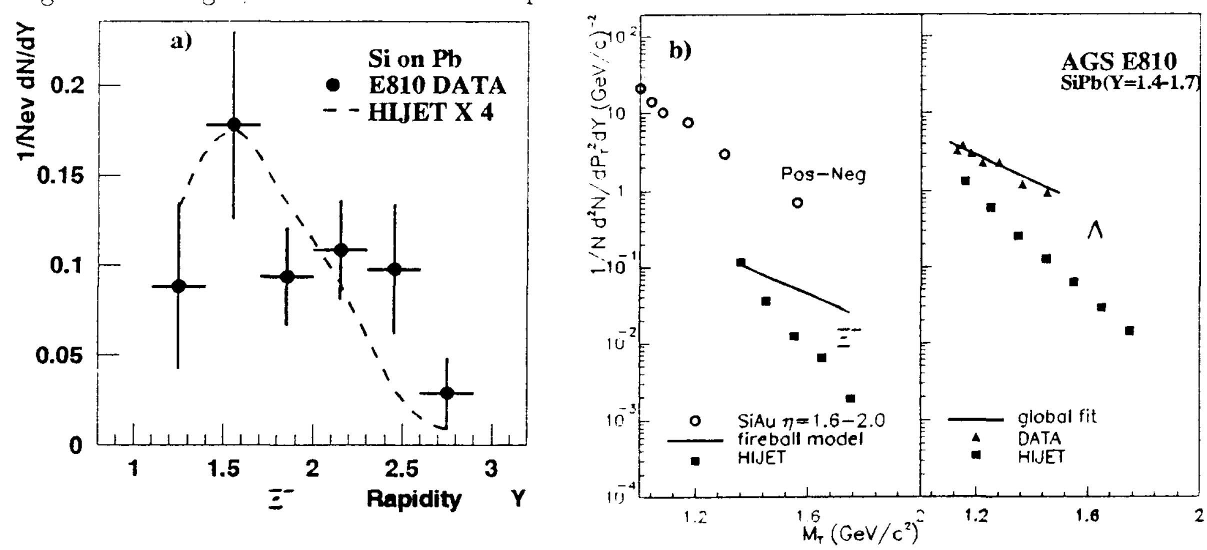

Fig.3 a): Rapidity distribution of Ξ^-'s, acceptance corrected by AGSHIJET+N* model(see text). The dashed curve is four times the prediction of the AGSHIJET+N* model. Errors shown are statistical only. b): Transverse mass distribution of baryons along with Λ's global fit[15]. Pos-Neg approximates proton spectrum[14].

4. Conclusions

We have shown in previous discussions that the dN/dY distribution of the detected Ξ^-'s is dependent on its transverse mass slope(Fig.3a, Fig.4). Since heavier particles have smaller m_t slopes, we believe that using the Λ's m_t slope to calculate the acceptance for Ξ^- is more realistic than using the current cascade models(Fig.3b). We conclude that the Ξ^- production(at 14.6 GeV/c $Si+Pb$) in our data is enhanced with respect to generally known cascade models. In our measured rapidity region(1.4-2.9), the yield of 0.25 ± 0.04 Ξ^- per central event and a ratio of $N(\Xi^-)/N(\Lambda)=0.12 \pm 0.02$ far exceeds all generally known cascade models' predictions at this time. In the table below we compare our data with different cascade models of the ratio of $N(\Xi)/N(\Lambda)$. Note that all presently used cascade models give an $N(\Xi)/N(\Lambda)$ ratio at least a factor of 5 lower than our data. Although they reproduced single strangeness hadron production amazingly well, their predictions of multi-strange hyperon production are still at a very primitive stage or is not available(ARC[16]).

E810 (data)	$N(\Xi^-)/N(\Lambda)=0.12 \pm 0.02$
AGSHIJET+N*	$N(\Xi^-)/N(\Lambda)=0.017$
RQMD[16]	$N(\Xi^0)^{\#}/N(\Lambda)=0.025$

#: $\Xi^- \sim \Xi^0$ from isospin consideration.

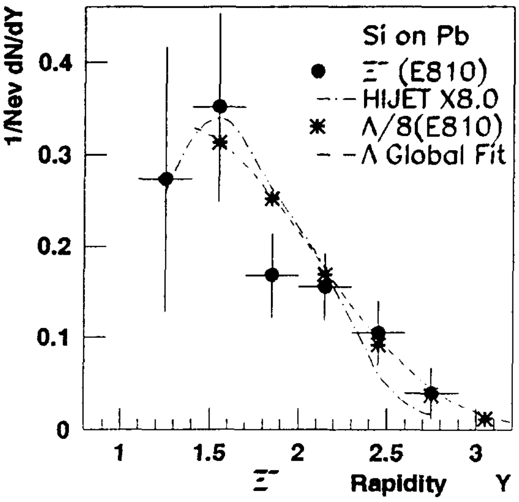

Fig.4: Rapidity distribution of Ξ^-'s, acceptance corrected with the fireball model(see text). The asterisks are 1/8 of the Λ yield. The dashed curve is the global fit, the dotted curve is eight times the prediction of AGSHIJET+N* model. Errors shown are statistical only.

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References

1. P. Koch, B. Müller and J. Rafelski, Physics Reports **142** (1986) 167.
2. T. Abbott *et al.*, Phys. Rev. Lett. **64** (1990) 847; Phys. Rev. Lett. **66** (1991) 1567.
3. J. Barke *et al.*, Z. Phys. **C48** (1990) 191
4. S. Abatzis *et al.*, Phys. Lett. **B244** (1990) 130; S. Abatzis *et al.*, Phys. Lett. **B259** (1991) 508; S. Abatzis *et al.*, Phys. Lett. **B270** (1991) 123.
5. S.E. Eiseman *et al.*, Phys. Lett. **B248** (1990) 254
6. R. Longacre, HIJET with AGS Physics and N*'s, in: Proc. Heavy-Ion Physics at the AGS (Massachusetts Institute of Technology, Jan. 1993) p.304
7. A. Saulys, Neutral Strange Particle Production at the AGS, in: Proc. Heavy-Ion Physics at the AGS (Massachusetts Institute of Technology, Jan. 1993) p.196
8. Y. Pang, T.J. Schlagel and S.H. Kahana, Phys. Rev. Lett. **68** (1992) 2743

9. S.E. Eiseman *et al.*, Phys. Lett. **B297** (1992) 44-48
10. R. Mattiello, H. Sorge, H. Stöcker and W. Greiner, Phys. Rev. Lett. **63** (1989) 1459
11. H. Sorge, R. Mattiello, A. Jahns, H. Stöcker, W. Greiner, Phys. Lett. **B271** (1991) 37
12. K.S. Lee, M.J. Rhoades-Brown and U. Heinz, Phys. Rev. **C37**(1988) 1452,1463
13. C. Greiner, P. Koch and H. stöcker, Phys. Rev. Lett. **58**(1987) 1825.
14. W. Love *et al.*, AGS Silicon Gold Collisions Measured in the E810 TPC, in: Proc. Workshop on Heavy-Ion Physics at the AGS (Brookhaven National Laboratory, March. 1990) p.27
15. A. Saulys *et al.*, Systematics of Hadronic Production from *Si* and *Pb* Targets with 14.6 $\times$ A GeV/c *Si* Beams, in: Proc. PANIC XIII (Italy, 1993), in print
16. C. Dover *et al.*, Production of Strange Clusters in Relativistic Heavy Ion Collisions, in: Proc. Heavy-Ion Physics at the AGS (Massachusetts Institute of Technology, Jan. 1993) p.213