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Strange Particle and Antiproton Production in S+Nucleus Collisions at 200 GeV/nucleon

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ABSTRACT

Central S+S, S+Ag and S+Au collisions at 200 GeV/nucleon were studied in experiment NA35 at the CERN SPS. Recent results on strange particle production as well as preliminary results on antiproton production are presented and discussed. Enhanced strangeness production relative to the pion and antiproton yields is observed in nucleus-nucleus collisions relative to p–p and p–A. Microscopic string models fail to consistently describe the available set of data.

1. Introduction

Collisions between heavy nuclei at relativistic energies and small impact parameters are a unique probe of the properties of a large volume of hot and dense hadronic matter. Phenomenological models, as well as QCD lattice calculations, predict a phase transition in nuclear matter leading to a state in which quarks and gluons are free to move over an extended region, the Quark Gluon Plasma (QGP). A series of experiments were built to study this high energy density system and to search for possible signals of QGP creation. Enhanced strange particle production has been proposed as a signature of a deconfined state.[1] This is based on the following considerations. The energy threshold in elementary free-parton interactions, e.g. $gg(q\bar{q}) \rightarrow s\bar{s}$, producing strangeness is lower than in the corresponding interactions between nucleons, e.g. $p + p \rightarrow p + K^+ + \Lambda$. At the same time, the $u\bar{u}$ and $d\bar{d}$ production will be suppressed due to Pauli blocking. Also, the fast equilibration time of the gg interactions, relative to the life–time of the system, might allow for a stronger enhancement.

The NA35 experiment at the CERN SPS measures the final state of charged hadrons ($h^{\pm}$) in reactions of ^{32}S projectiles at 200 GeV/nucleon on various targets.[2] It consists of two large tracking devices which provide the momentum measurement of charged particles over the full rapidity range, a 2 m long streamer chamber (SC) which is placed inside a 1.5 T vertex magnet, and a 2.5x1.5x1.0 m^3 Time Projection Chamber (TPC).[5] A calorimeter placed in the beam path selected near head-on collisions, i.e. events where only a small amount of energy (mostly spectator nucleon energy) was detected in an angular acceptance of less than 0.3 degrees around the beam axis.[3] The data sample consists of three systems: S+S, S+Ag and S+Au with respective trigger selection of the most central 3, 3.2 and 6 % of the total inelastic cross section.

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No particle identification information was obtained on a track-by-track basis. Charged kaons ($K^{\pm}$) were identified by their characteristic decays in the SC[7] and the TPC.[8] K^0_s, Λ and $\overline{\Lambda}$ were identified by their V_0 decay topology in the SC. $K^{\pm}$, pion and antiproton ensemble yields were obtained by dE/dx measurements in the TPC.[4]

2. Strangeness and Antiproton Production

Figure 1 shows Λ, K^0_s, $\overline{\Lambda}$ and K^+ rapidity distributions for the three collision systems studied.[11] In order to make comparisons, the measured yields are extrapolated over the full phase space.[10] Table 1 shows the 4π yields for each species and for the different systems. The degree to which flavor equilibrium is achieved at the quark level in the final state is usually characterized by the *strangeness suppression* factor λ_s,

$$\lambda_s = \frac{<\mathrm{s}+\overline{\mathrm{s}}>}{0.5\cdot(<\mathrm{u}+\overline{\mathrm{u}}> + <\mathrm{d}+\overline{\mathrm{d}}>)} \approx \frac{<\Lambda> +4\cdot <K^0_s>}{3\cdot <\pi>}$$

where the quantity λ_s can be calculated according to ref. [9,13] from the numbers in Table 1. The above equation also makes apparent why we always normalize to the pion yields when we compare data from different systems. The curves in the Λ and K^0_s distributions show p+S data multiplied by a factor of 29. We found that we could reproduce the negative hadron distributions in S+Ag reactions by multiplying those of p+S by the factor 29 (see also Table 1). This allows a model independent

	$<h^->$	$<\Lambda+\Sigma^0>$	$<\overline{\Lambda}+\overline{\Sigma}^0>$	$<K^0_s>$	$<K^+>$	$<K^->$
S+Ag	160±8	13.0±0.7	2.4±0.4	13.2±1.1	17.4±1.0	9.6±1.0
50 * NN	—	4.8±0.5	0.7±0.2	10.0±1.0	12.0±3.0	8.5±2.5
p+S	5.7±0.2	0.28±0.02	0.043±0.003	0.38±0.04	—	—
S+S	95±5	8.2±0.9	1.5±0.4	10.6±2.0	12.5±0.4	6.9±0.4
30 * NN	—	2.9±0.3	0.4±0.1	6.0±0.6	7.2±1.9	5.1±1.6

Table 1. Mean total particle multiplicities (4π) in p+S, S+Ag and S+S collisions.

comparison. We observe that the S+Ag strange particle data are systematically higher than the scaled p+S data. It was also observed that the difference is larger for the Λ and K^+ particles which is qualitatively expected in a baryon rich environment, where 'associated production'–type of interactions are favored by the quark content of the initial nucleons.[10] It has also been found[11] that λ_s is half as strong in the S+S and S+Ag systems (~ 0.35) as compared to nucleon–nucleon[12] and nucleon–nucleus[13] systems ($0.15-0.2$). This means that strange particle production, relative to pions, in nucleus–nucleus collisions is enhanced by a factor of about two.

We finally compare the $\overline{\Lambda}$ to $\overline{p}$ production. The quark content of these particles ($\overline{\Lambda} \equiv \overline{u}\overline{d}\overline{s}$ and $\overline{p} \equiv \overline{u}\overline{d}\overline{d}$) makes them an invaluable tool since they do not contain any valence quarks, which are abundant in the incoming nucleons. The only drawback is the large annihilation cross-section[15] for the $\overline{p}$ given the fact that the environment contains about 8–20 baryons[6] near mid-rapidity, depending on the collision system.

Figure 2a shows the ratio of $\overline{\Lambda}/\overline{p}$ in p-p, p-A (min. bias and 'central') and S+S, Ag, Au near mid-rapidity, as a function of the rapidity density at mid-rapidity of negatively charged hadrons. We observe that the ratio increases from around 0.25–0.40 for nucleon–induced reactions to about 0.75–1.5 for central S–nucleus collisions. This enhancement of the ratio can be studied in more detail for the S+S system. Scaling the rapidity densities at mid-rapidity in p-p interactions with the ratio of the negative hadron multiplicities (≈ 30) in 4π, as shown in Fig. 2b, we observe that the pion and antiproton yield remain relatively constant and that the $\overline{\Lambda}$ yield (at mid-rapidity) is greatly enhanced. We should take into account the fact that according to RQMD calculations,[15] there is a reduction of the primordial $\overline{p}$ yield by a factor of about two (the $\overline{\Lambda}$ yield remains unaffected) due to rescattering, This makes the difference less pronounced. Nevertheless, we may conclude that the enhancement in the $\overline{\Lambda}/\overline{p}$ ratio is due to the $\overline{s}$ quark. This is compatible with the rest of the strangeness data.

Microscopic string models, have great difficulties in consistently reproducing the observed enhancement[11] i.e. of reproducing the strange particle yields both in nucleon–nucleon and nucleus–nucleus collisions. New collective mechanisms at the parton level have being explored such as color rope[15] (RQMD[14]) or double string formation (VENUS[16]).

3. Summary

- New data on strange particle production show a two-fold strangeness enhancement (relative to pions) when comparing nucleus–nucleus to p-p and p-A.
- It appears that part of the enhancement, namely the excess of Λ over $\overline{\Lambda}$, and K^+ over K^-, can be explained by an 'associated production'-like process.
- The $\overline{\Lambda}/\overline{p}$ ratio suggests that the observed enhancement is specific to particles carrying strangeness.
- Thus far no model calculation can consistently reproduce the observed enhancement, although the onset of collective processes (not just rescattering) appears to be compatible with a subset of the data.

4. ACKNOWLEDGMENTS

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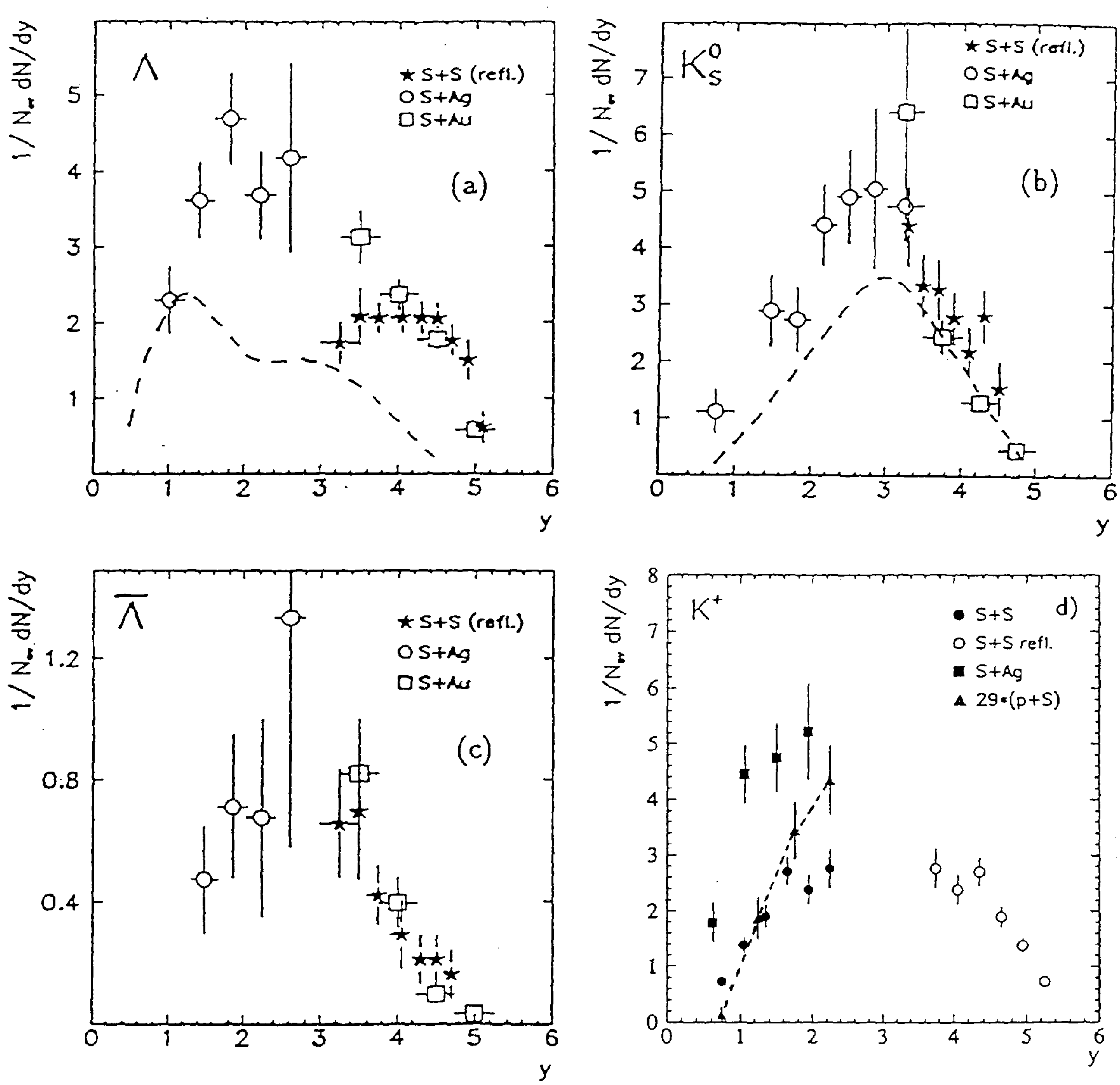

Fig. 1. Rapidity distributions of Λ, K^0_s, $\overline{\Lambda}$ and K^+ in S+nucleus collisions. The dashed curves represent p+S results scaled up by a factor of 29 (see text).

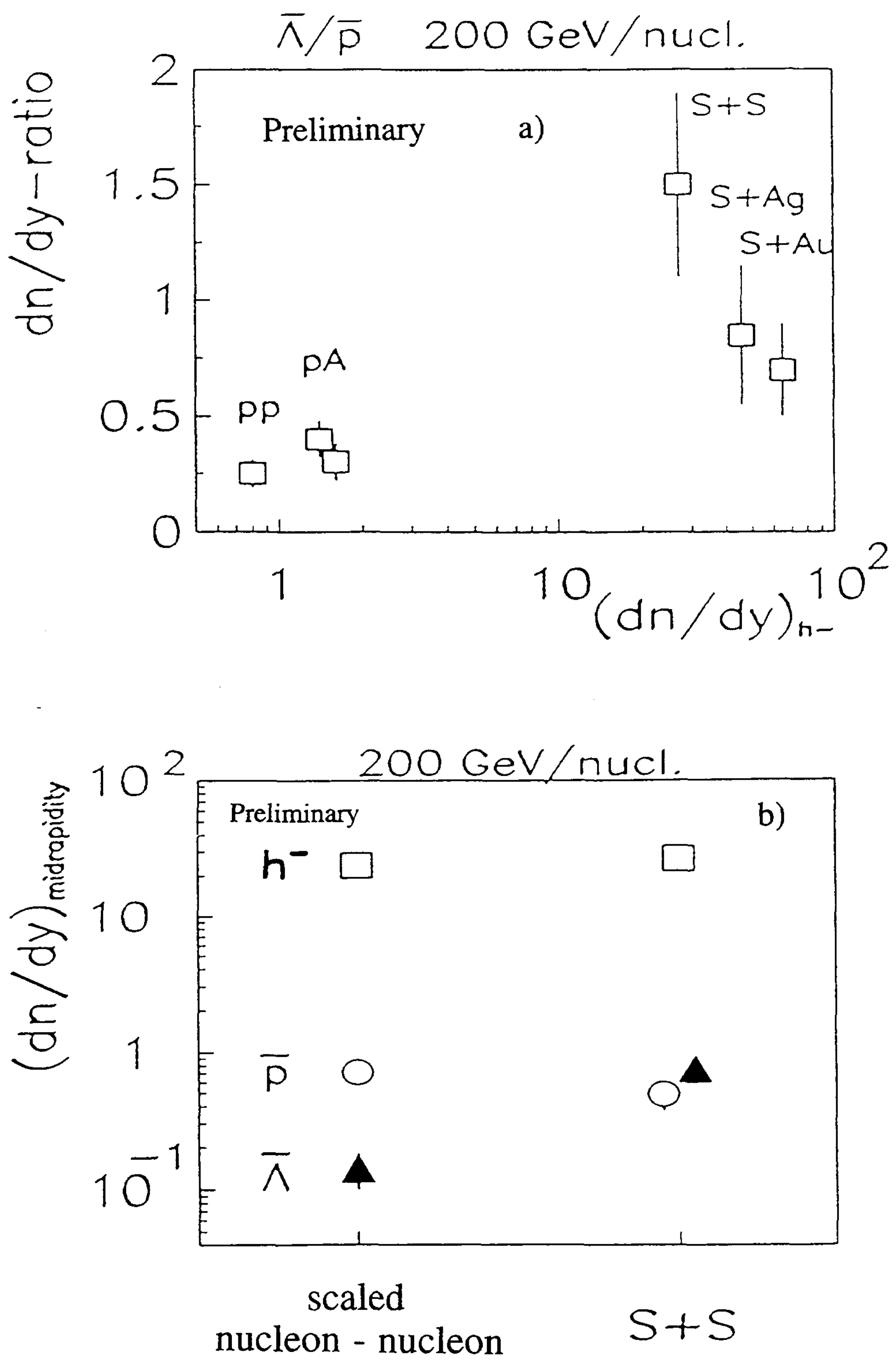

Fig. 2. a) $\overline{\Lambda}/\overline{p}$ ratio near mid rapidity in p-p, p-A and central nucleus–nucleus collisions as a function of the rapidity density at mid-rapidity of negative hadrons. b) $\overline{\Lambda}$ and $\overline{p}$ production near mid-rapidity in central S+S collisions compared to p-p data scaled by the corresponding pion multiplicity ratio in full phase space.