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Results from CERN Experiment NA36 on Strangeness Production

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Abstract

Measurements of the production of strange particles in the reactions S + Pb and S + S at beam momentum 200GeV/c per nucleon are presented. A short description of CERN experiment NA36 and the methods of raw data analysis, is followed by physics results concentrating on the dependence of strange particle production on multiplicity. Transverse momentum distributions are also presented.

1. Experimental Configuration, data statistics.

A simplified schematic layout of NA36 apparatus is shown in figure 1.

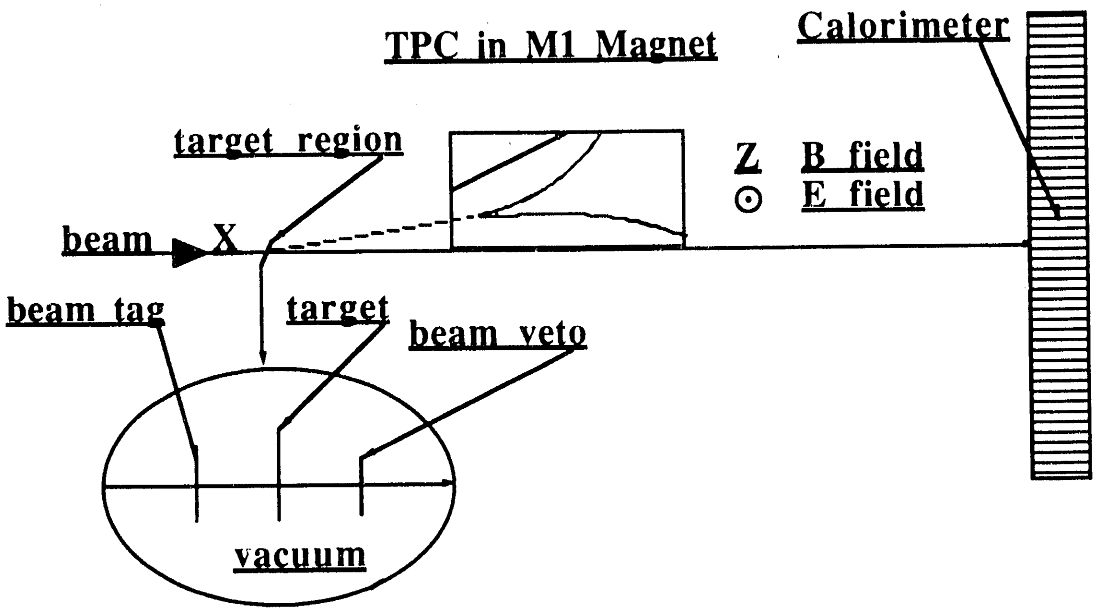

Figure 1. NA36 trigger and detection apparatus.

The TPC was placed about 1 cm above the beam and about 60 cm downstream from the target. A magnetic field of 2.7 tesla, provided by the M1 magnet, was aligned roughly parallel to the drift field of the TPC[1].This configuration was chosen to allow detection of the neutral decays of strange particles at rapidities around mid-rapidity for the beams used. The geometrical acceptance for Λ, $\bar{\Lambda}$ and K^{o} are shown in figure 2.

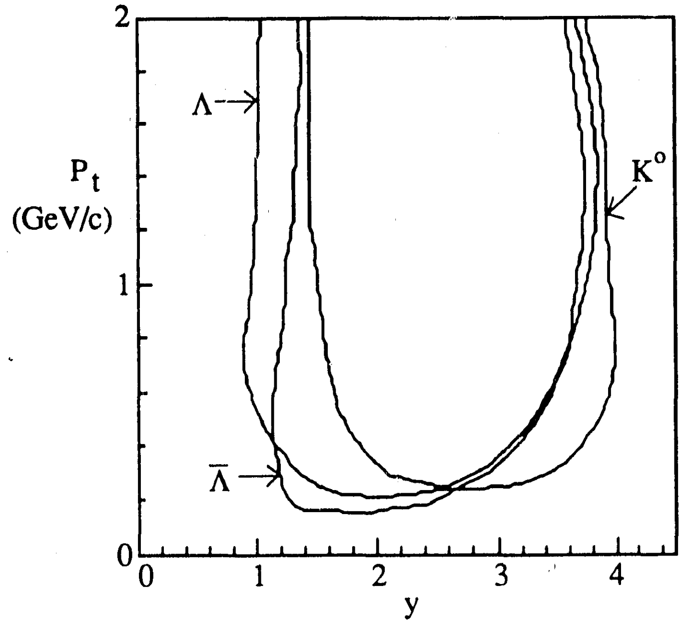

Figure 2. Geometrical acceptance for Λ, $\bar{\Lambda}$ and K°

The magnet was run in two polarities: M1 positive, favoring Λ's, and M1 negative, favoring $\bar{\Lambda}$'s. Targets of Pb and S, each with a 5% interaction length, were used. Three triggers were mixed to allow full impact parameter coverage and normalization. They were:

BEAM (10%)	incoming charge Z=16 at beam tag with no other beam particles seen for 10 microseconds before or after the beam particle chosen.
MIN-BIAS (40%)	BEAM + charge $\leq$ 16 in beam veto
CENTRAL (50%)	MIN-BIAS + Zero degree energy below a threshold corresponding to a 6 fm impact parameter.

Data from the detectors were stored during the spill in FASTBUS memories. At the end of the spill, the data were transferred to a two-processor VME system for event building and subsequent transfer to IBM 3480 cartridge drives[2]. Data rates of 100-300 events per spill generated an average of 15 MBytes/spill. The rate streamed to cartridges during the inter-spill gap was 1MB/s.
All data reported here was taken during August 1990. The amount of data taken was as follows:

S + Pb	1,375,000 events with M1 positive
	2,200,000 events with M1 negative
S + S	600,000 events with M1 positive

All tapes were processed to a Data Summary Tape level which included track finding, track fitting, V° finding and V° fitting. About 80% of the tapes were processed on the Parallel Processing Computer System (PPCS), stage 2 in the DD division at CERN. After V° selection criteria are applied we are left with a data sample containing;

K^{o}=24000
Λ=30000
$\bar{\Lambda}$=10000

2. Analysis methods, signal, mass resolution.

The NA36 pattern recognition software is based on the ALEPH algorithm[3]. This algorithm has been extensively modified to deal with the NA36 configuration and the extremely high multiplicities encountered in ion reactions. Monte Carlo tests indicate that an average of 80% of tracks are properly reconstructed in events averaging 100 tracks in the TPC.

The V° candidates are then found by searching for track pairs of opposite charge originating away from the target position. The raw signal is quite clear as can be seen in Figure 3.

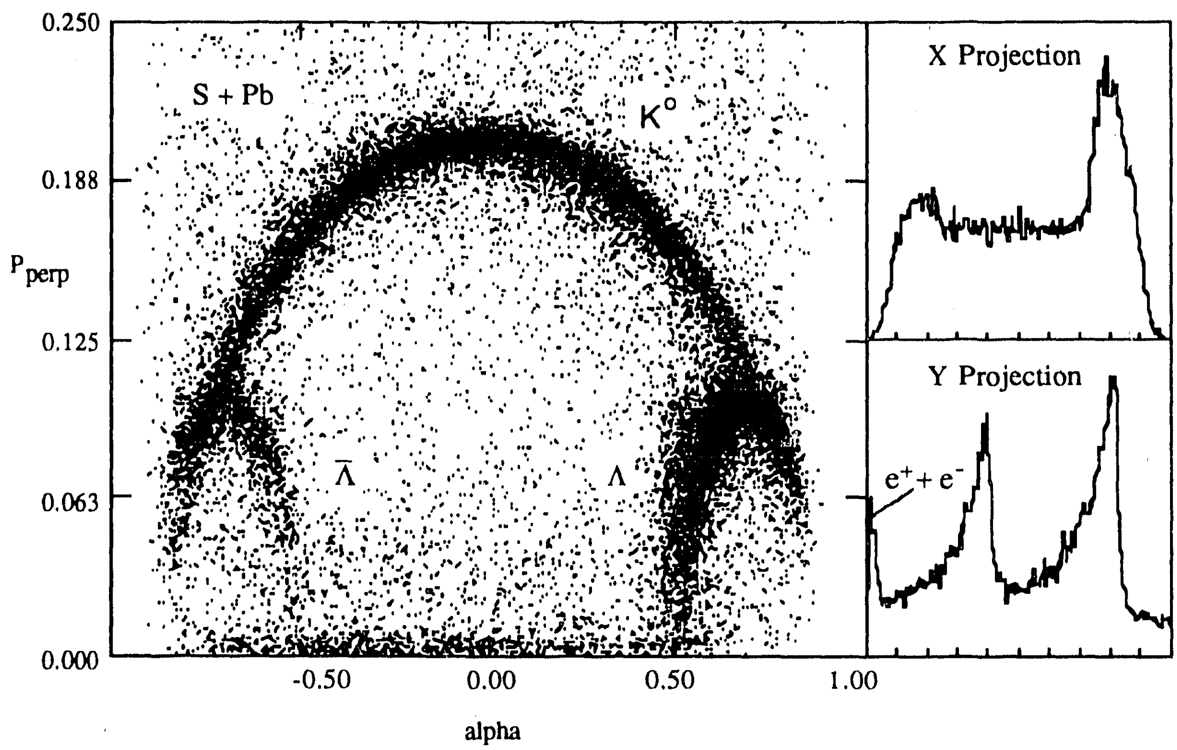

Figure 3. Podolanski-Armenteros plot of raw V0 signal from the positive polarity data sample.

As one would expect from the width of the signal parabolas in Figure 3, the mass resolutions for the V° particles are excellent , agreeing with Monte Carlo estimates of 5-7 mev. Typical spectra are shown in Figure 4.

For a given rapidity or transverse momentum region, the K^{o} background was removed by fitting the mass distribution with a gaussian peak and a polynomial background. This procedure is statistically accurate on account of the large number of events that were available.

A mass plot used for this subtraction for the case of K°s in our second rapidity bin (1.95<y<2.20) is shown in figure 5.

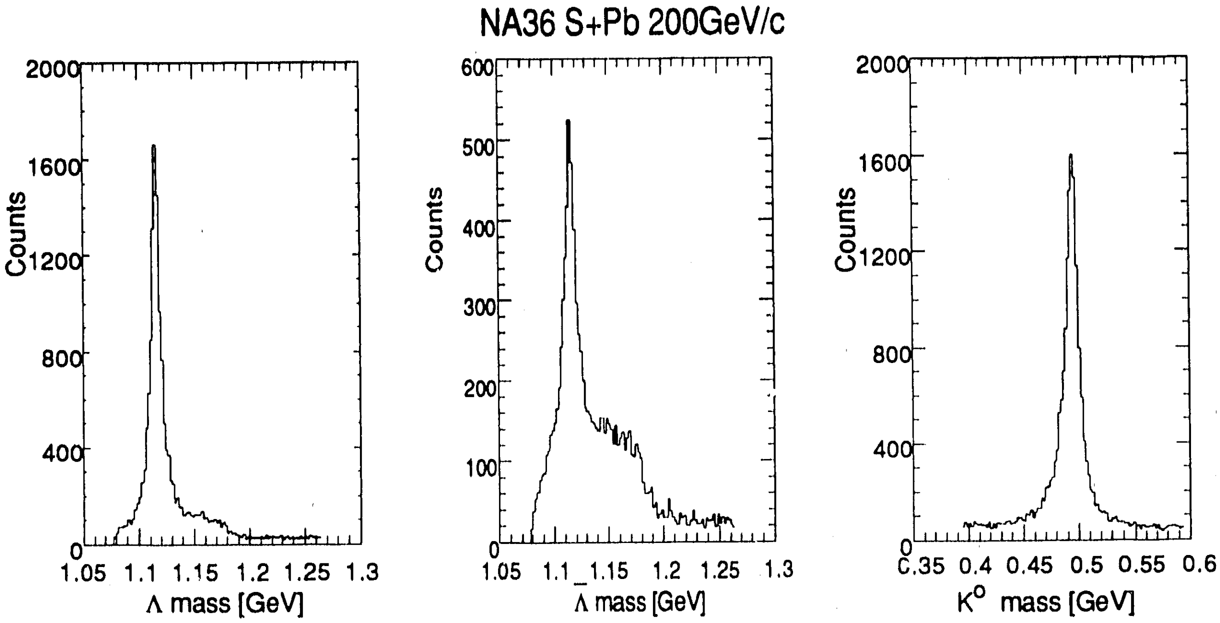

Figure 4. Mass histograms for Λ, $\bar{\Lambda}$ and K°

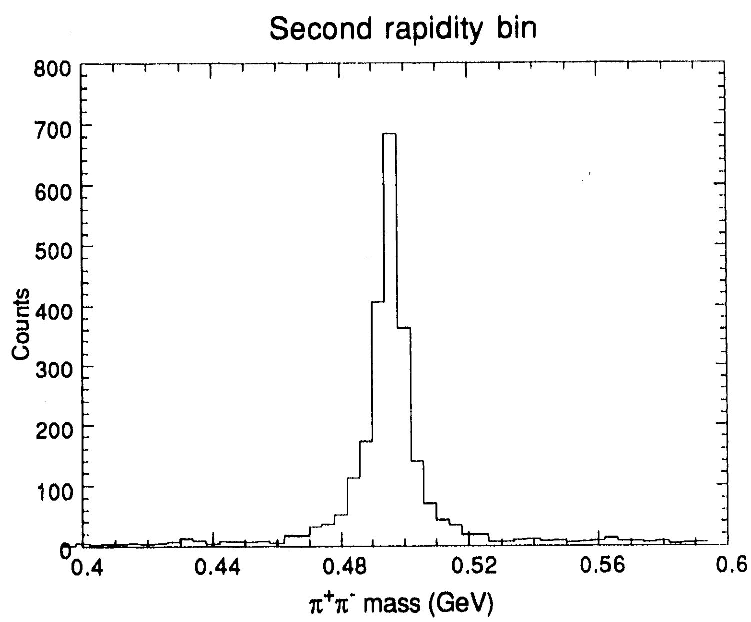

Figure 5. Plot used for background subtraction in 1.95<y<2.2 region of the K° signal.

The efficiency for the signal extraction is calculated by embeding Monte Carlo generated V° signals in the raw data and reanalyzing the events. The efficiency is then combined with the calculated geometrical acceptance to fully correct the data.

3. Multiplicity Determination.

Strangeness production as a function of the violence of the collision can be investigated using parameters such as energy at zero degrees, transverse energy or multiplicity. All of these parameters are correlated in ion reactions. Here we will describe how we extract the total negative particle multiplicity for our events. Multiplicity of negative particles is free of bias from projectile or target fragments and allows convenient comparison with other experiments.[4]

The multiplicity of tracks found in the TPC is subject to many biases. The software classifies each half circle of a spiral as a track thus leading to an over estimate, there is a finite efficiency for reconstructing tracks (about 80%) which leads to an underestimate, finally secondary interactions in the material of the detector and magnet produces tracks not of interest. By defining target tracks as those which track back to the apparent vertex position we can see the effects produced by the spirals and secondary interactions.

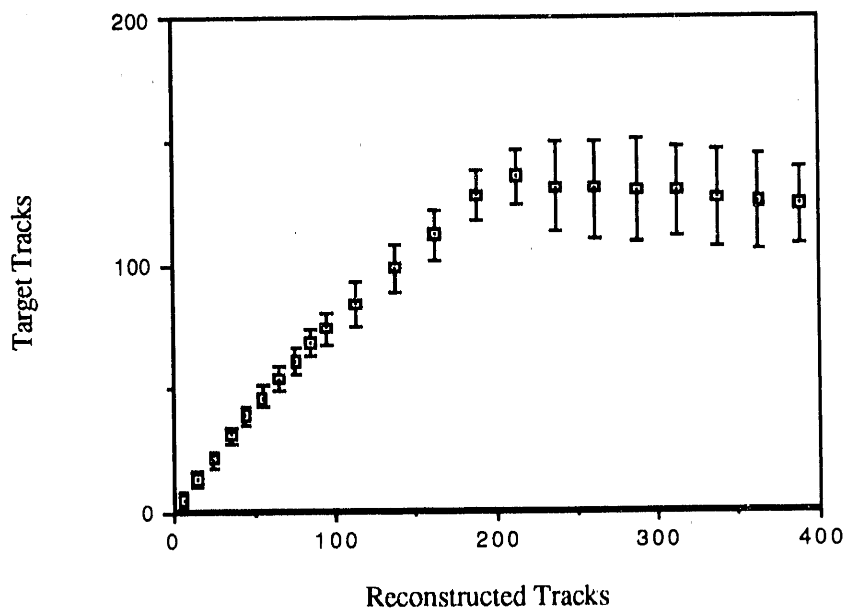

Figure 6. Relationship between tracks from the target and those seen in the TPC.

The tracks from the target are well correlated with tracks in the TPC up to a maximum of 200 tracks in the TPC.as can be seen in Figure 6. In the events larger than this the increase of tracks in the TPC is attributed to the production of delta ray spirals and secondaries. The data set we are using for this report contains the multiplicity in the TPC on an event by event basis so that we can use this parameter to measure average multiplicity up to about 200 tracks in the TPC.[5] To calculate the total negative multiplicity for each event we must resort to a Monto Carlo calibration. Using the VENUS 3.11 code we generated events with our mix of impact parameters and analyzed them to determine the relationship between true multiplicity coming from the reaction and the multiplicity seen in the TPC, limiting ourselves to the range where we have found from the data that the correlation is valid. The simulation included secondary interaction in all the material. The resultant relationship is shown in figure 7. There is a clear linear relationship between charged track multiplicity and total negative multiplicity .

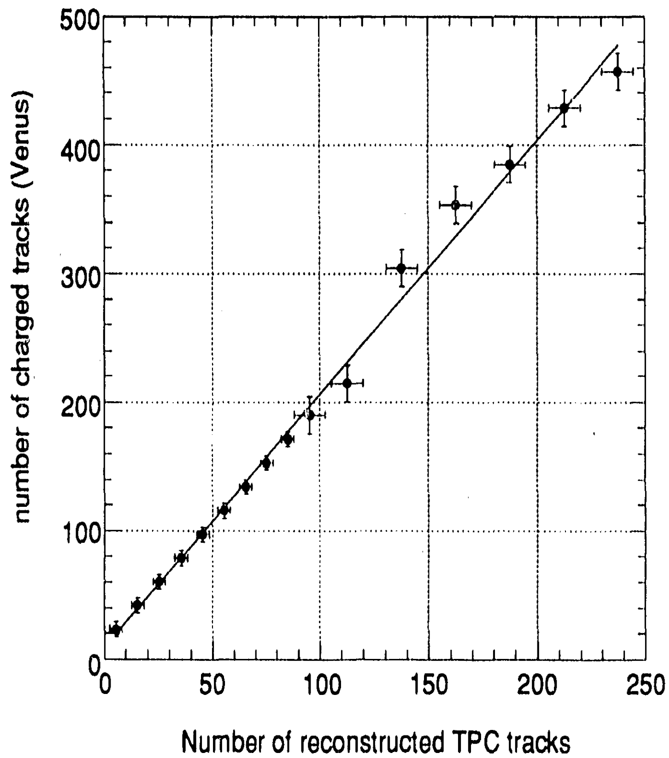

Figure 7. Charged tracks from Venus vs tracks found in the TPC..

4. Strangeness density.

Several experiments have measured the density of strange particles versus multiplicity.[6] We first compare with the measurement of NA35 for lambdas produced in the reaction ^{32}S + ^{32}S in figure 8. Because of the difference in the acceptances of the two experiments we normalize the NA35 data to ours at the lowest multiplicity point.

We see that the rise in the density of Λ per negative track agrees in magnitude. This rise is not predicted by standard models of ion reactions.[7] The reason for this increase is not yet understood. WA85 saw no such increase in the system S + W, however, their measurment was made over a small region of rapidity at high event multiplicity. The NA36 data sample covers the full range of multiplicities and allows us to examine the dependence over a range overlapping with both experiments in an attempt to resolve this apparent disagreement. We plot the dependence in figure 9 for the system S + Pb.

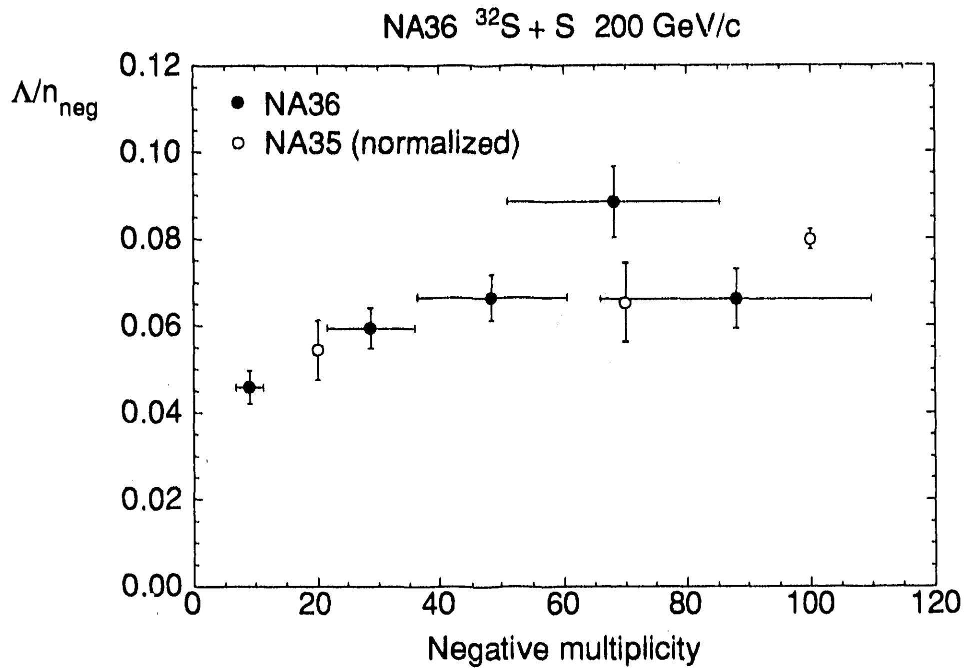

Figure 8. Λ per negative track versus total negative multiplicity for S + S.

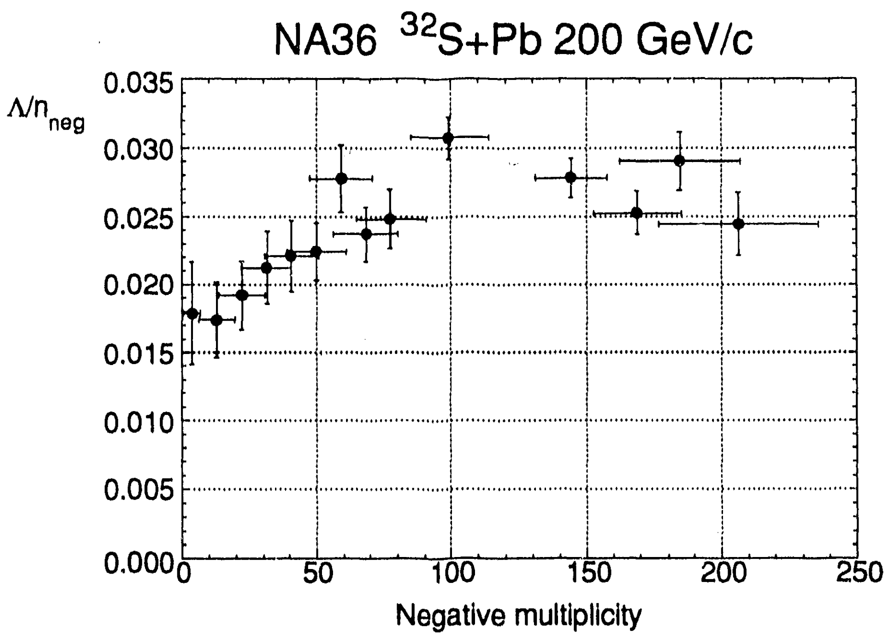

Figure 9. Λ per track as a function of total negative multipliciy for S + Pb.

The density of Λ increases for low multiplicities and then becomes flat. Thus we see that as far as the curve shape is concerned there is no inconsistency between NA35 and WA85. It remains to completely understand this effect. With this large target, complete overlap of projectile and target is possible for impact parameters below 6 fm.. Thus the competition between the possible processes of reinteraction and lambda retention may not vary due to an almost constant number of interactions over the region of complete overlap.[8]

This rise is also seen in our data for production of $\bar{\Lambda}$ as their ratio to Λ remains essentially constant as shown in figure 10.

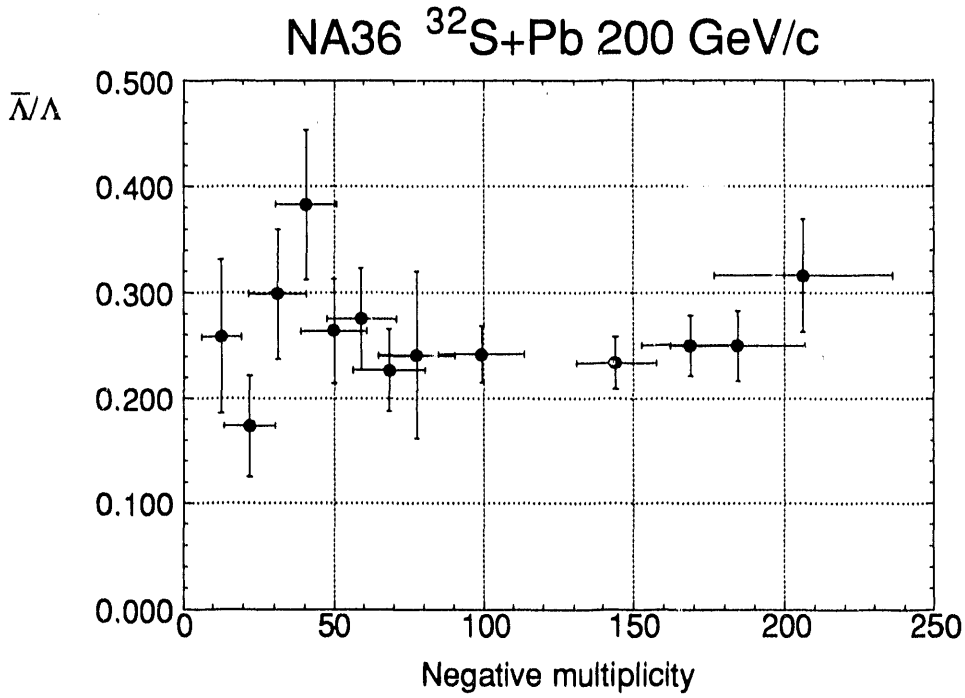

Figure 10. $\bar{\Lambda}/\Lambda$ ratio as a function of total negative multiplicity.

Looking at the K° densities could help to understand the processes responsible as the K° production does not require as large a content of constituent quarks. In figure 11 we show that the dependence for K° is flat. This is in agreement with recent results published for the system p + Xe where the rise for Λ was seen with no corresponding rise for K°.[9] It should be also kept in mind that a flat distribution is seen for both Λ and K° in p + p reactions.[10]

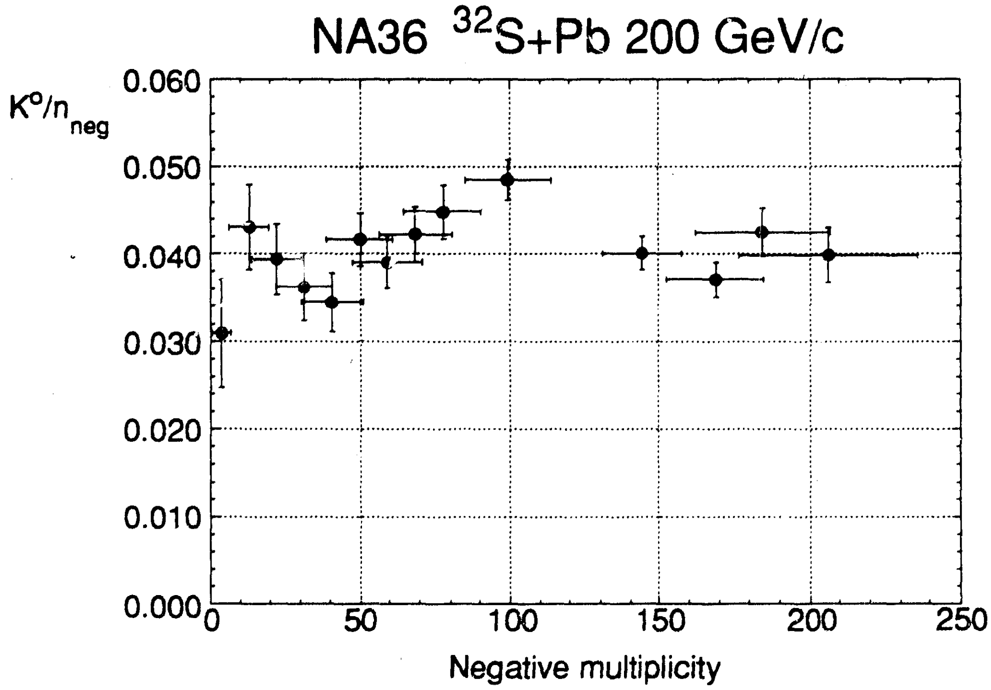

Figure 11. K° density per negative track versus total negative multiplicity.

5. Transverse momentum distributions.

Another clue to the physical processes responsible is contained in the transverse momentum distributions of the strange particles. Large inverse slopes are expected, for instance, if the underlying process produces high entropy as in quark-gluon plasma. We present the observed transverse mass distributions for Λ, $\overline{\Lambda}$ and K° integrated over multiplicity in figures 12,13 and 14.

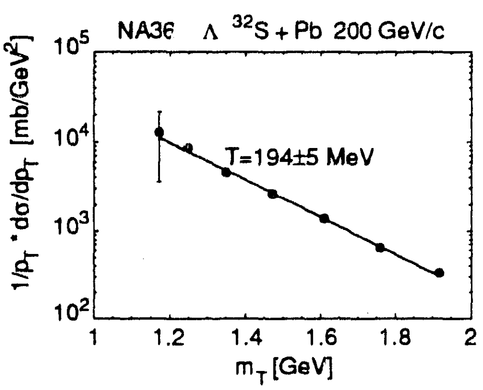

Figure 12. Transverse mass distribution for Λ.

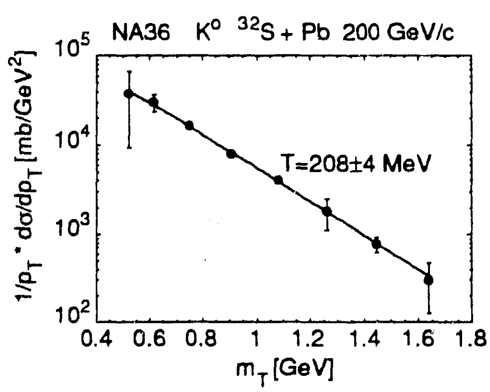

Figure 13 Transverse mass distribution for $\overline{\Lambda}$

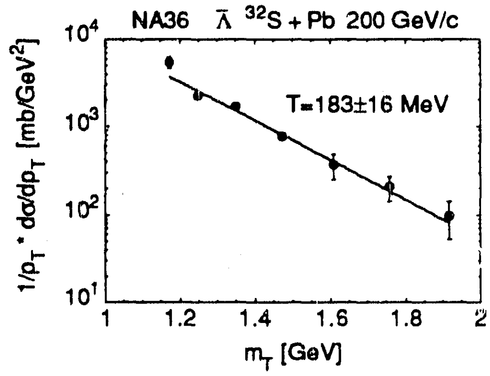

Figure 14. Transverse mass distribution for K°.

These temperatures are similar to those seen by other experiments, they are high when compared to those seen in p+ p and p + Nucleus and are consistent in shape with thermal distributions.

6. Summary.

The density of Λ and $\overline{\Lambda}$ increases with the total negative multiplicity of the event and then saturates at about 100 tracks. This behavior resolves the apparent disagreement in results seen by NA35 and WA85 and is not predicted by the available Monte Carlo models of ion-ion interactions.

K°'s do not exhibit this rise with negative multiplicity. This was seen also in p+Xe interactions which raises the possibility that it is an effect which is related primarily to reinteractions and not quark-gluon plasma production.

The transverse mass distributions are consistent with thermal distributions at temperatures of about 200 MeV.

7. Acknowledgements.

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[1] 'C. Garabatos representing the NA36 collaboration, Nucl. Instr. and Meth. **A283** (1989) 553

[2] E. Andersen et al. Submitted to Nuclear Instruments and Methods

[3] W. B. Atwood, et al. Performance of the Aleph Time projection Chamber - submitted to Nuclear Instruments and Methods A. and ALEPH note 88-6

[4] J. Bartke et al. (NA35) Z. Phys. C - Particles and Fields 48, 191-200 (1990)

[5] Currently a second analysis pass is 50% completed where we will have several new global parameters including counts of the tracks coming from the target on an event-by event basis.

[6] S. Abatizs et al.(WA85) Phys. Lett. B 244,130 (1990)

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7 Werner, K.: Phys. Rev D39 (1989) 780; Nucl. Phys. A498 (1989) 93c
8 Z. Phys. C. - Particles and Fields 44,645-650 (1989)
9 I. Derado et al. (NA5): Z. Phys.C 50, 31-36 (1991)
10 Physics Reports (Section C of Physics Letters) 10; no. 5 273-373(1974)

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