MULTI-STRANGE PARTICLE ENHANCEMENTS IN PB-PB INTERACTIONS AT 158 GEV/C PER NUCLEON

PRESENTED BY DAVID EVANS FOR THE WA97 COLLABORATION

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Strange and multi-strange baryon and anti-baryon production is expected to be enhanced in heavy ion interactions if a phase transition from hadronic matter to a Quark-Gluon Plasma takes place. The production yields and transverse mass spectra of strange and multi-strange baryons and anti-baryons are presented for lead-lead interactions at 158 GeV/c per nucleon. Yields and transverse mass spectra from proton-lead and proton-beryllium interactions, where no phase transition is expected, are also presented and compared to those from lead-lead interactions.

The results show a significant enhancement of strange and multi-strange baryons in Pb-Pb interactions. The enhancement increases with strangeness content as predicted in QGP models and exceeds one order of magnitude in the case of the Ω particle. These results represent some of the best evidence, to date, for a new phase of matter being formed in these collisions.

1 Introduction

QCD predicts that, under extreme conditions of temperature and density, hadronic matter will undergo a phase transition into a deconfined plasma of quarks and gluons known as a Quark-Gluon Plamsa (QGP). It is believed that the energy densities produced in ultra-relativistic heavy ion collisions may be high enough for such a phase transition to take place. The enhancement of strange particle production in such collisions is considered to be one of the most promising signatures for QGP formation to date [1]. In particular, it is expected that the enhancement of multi-strange particles would be more pronounced than that for singly strange particles [2].

The WA97 experiment was designed to study strange and multi-strange baryon production in Pb-Pb interactions and compare the strangeness yields to those from proton induced reactions.

2 Experimental Setup

The WA97 setup, shown in figure 1, is described in detail elsewhere[3,4]. Particle tracks were reconstructed using a silicon telescope containing seven pixel planes with 75 × 500μm pixel size and ten microstrip planes with a 50 μm pitch. The telescope had a cross-section of 5 × 5 cm^2 and contained about 0.5 $\times 10^6$ channels. The first plane of the telescope was placed 60 cm downstream of the target (90 cm for the proton bean reference runs), above the beam line and inclined at an angle (pointing to the target) in order to accept particles at central rapidity and medium transverse momentum. Pad chambers were used as a leverarm for high momentum particles.

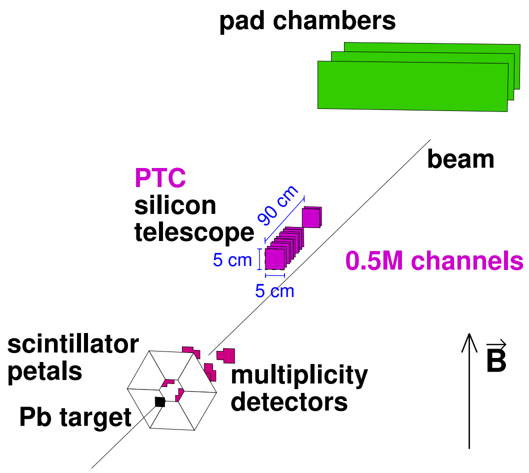

Figure 1. The WA97 experimental layout.

Scintillator ("petals") detectors were used by the trigger to select the most central $\sim$ 40% Pb-Pb interactions. Two planes of microstrip multiplicity detectors (MSD) sampled the overall charged multiplicity in the pseudorapidity region $2 \leq \eta \leq 4$ which was used in the off-line analysis. The whole setup was placed inside the 1.8 T magnetic field of the CERN Omega magnet.

In the proton reference runs, Be and Pb targets were used, both with a thickness corresponding to 8% of the interaction length. In these runs a trigger was applied demanding at least two tracks in the telescope. Data were also collected requiring at least one track in the telescope in order to study negative particle production.

$\mathrm{K}^0_{\mathrm{s}}$ mesons, Λ, Ξ^- and Ω^- hyperons and their anti-particles were identified by reconstructing their weak decays into final states containing only charged particles:

$$\begin{aligned}
\mathrm{K}^0_S &\to \pi^+ + \pi^- \\
\Lambda &\to p + \pi^- \\
\Xi^- &\to \Lambda + \pi^- \\
&\qquad \hookrightarrow p + \pi^- \\
\Omega^- &\to \Lambda + \mathrm{K}^- \\
&\qquad \hookrightarrow p + \pi^-
\end{aligned}$$

A reference sample of negatively charged particles (h^-) have also been analysed. Details of the reconstruction and weighting procedures are described in[4,5]. The acceptance windows for the particles under study are shown in reference[4].

3 Centraility Measurement

The centrality measurements are based on the charged particle multiplicity measured by the MSD. The Pb-Pb data sample is divided into four multiplicity classes. The average number of wounded nucleons in each multiplicity class is determined by a Wounded Nucleon Model[6] fit. The fit procedure has been described in detail elsewhere[7]. Figure 2 shows the results of this fit. The four multiplicity classes are indicated in the figure by dashed lines. The bin widths were chosen so as to contain similar numbers of multi-strange hyperons in each bin before weighting. The data in the first multiplicity bin are corrected for the effect of the centrality trigger. The number of wounded nucleons in proton-induced reactions have been determined as an average value for inelastic collisions in the framework of the Glauber model[8].

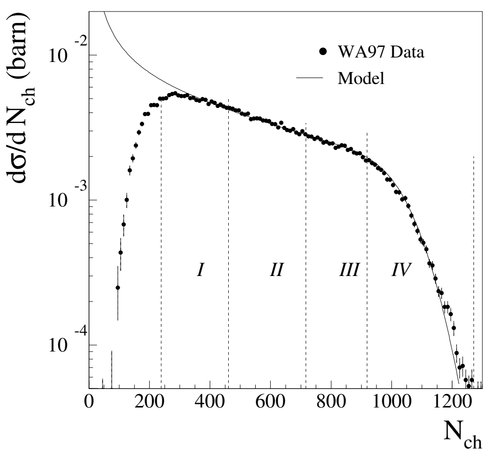

Figure 2. Wounded nucleon model fit to the multiplicity distribution.

4 Transverse Mass Spectra

The distributions of particle yields have been fitted to the expression

$$\frac{\mathrm{d}^2 N}{\mathrm{d}m_{\mathrm{T}}\mathrm{d}y} = f(y) m_{\mathrm{T}} \exp\left(-\frac{m_{\mathrm{T}}}{T}\right) \qquad (1)$$

where m_{T} is the transverse mass and y is the rapidity. The fit was performed using the method of maximum likelihood. The analysis assumed the rapidity distributions to be flat in the region $|y - y_{cm}| < 0.5$ *i.e.* $f(y) =$ constant. Preliminary data on the rapidity distributions of singly-strange particles support this assumption on the flatness of the rapidity distribution near mid-rapidity[9]. Figure 3 shows the inverse slope, T, from expression (1) for different particle species as a function of the number of participants. The squares represent data from p-Be interactions, the triangles represent data from p-Pb interactions, and the circles represent data from Pb-Pb interactions split into four centrality bins. As can be seen from figure 3, the inverse slope as a function of centrality is flat for negative

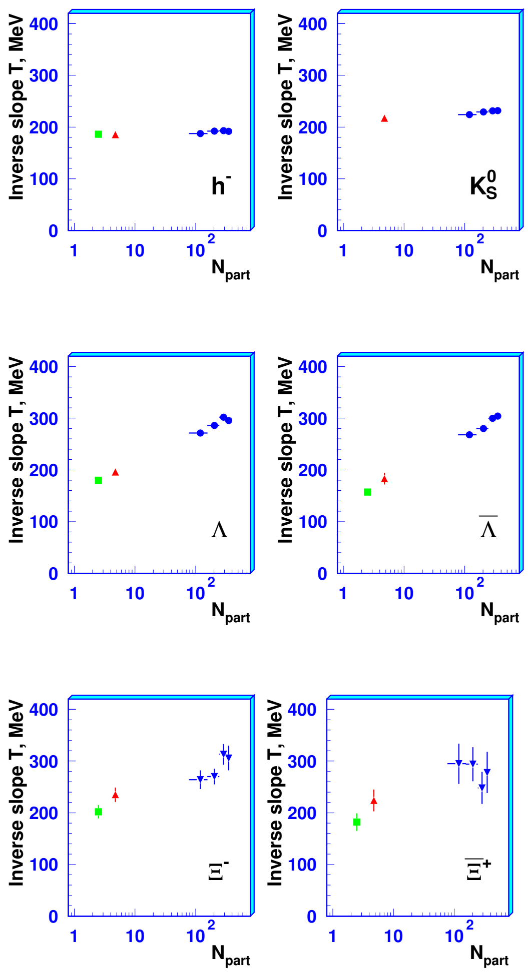

Figure 3. Inverse m_{T} slopes for different particles in different interactions.

particles and almost flat for K^0s while it increases with centrality for Λs and $\overline{\Lambda}$s . There is also an indication that (T) increases with centrality for Ξ^- and $\overline{\Xi}^+$ hyperons although the statistics are lower.

A complilation of inverse slope parameters measured by WA97, WA98, NA44 and NA49 (see ref.[10] and reference therein) is shown in figure 4.

A general trend is observed that the inverse slope increases linearly with particle mass. The Ω, and possible the Ξ, slopes form

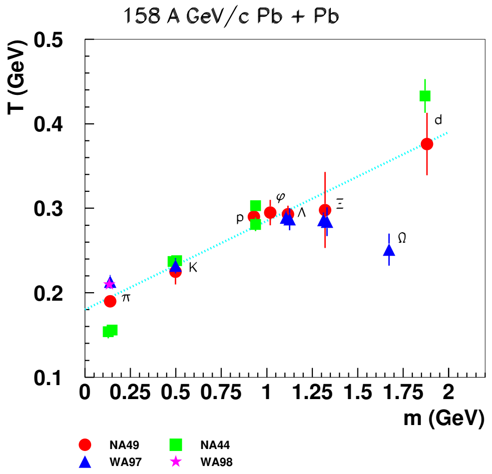

Figure 4. Dependence of the m_T inverse slope patameters, T on the particle rest mass.

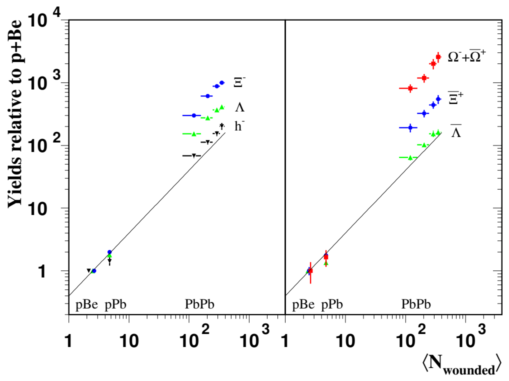

Figure 5. Particle yields relative to p-Be yields.

a notable exception from this trend. This may indicate that the multi-strange particles decouple earlier than other particles.

5 Strangeness Enhancement

Average particle yields per event have been calculated for different particles in p-Be, p-Pb and Pb-Pb interactions. Figure 5 shows the particle yield, as a function of the number of wounded nucleons, relative to that for p-Be interactions (*i.e.* the yields per participant have been rescaled so that the value for the p-Be data is set to one). All the Pb-Pb yields show a steady increase with centrality up to very central events. The particle yields in Pb-Pb interactions have been compared to a yield curve (full line) drawn through the p-Be points and proportional to the number of wounded nucleons. As can been seen from figure 5, the strange particle yields increase from p-Be to Pb-Pb faster than linearly with the number of wounded nucleons. The p-Pb points, however, lie on the line and are compatible with increasing linearly with the number of wounded nucleons.

From the average yield per wounded nucleon

$$\frac{Y}{\langle N_{\mathrm{wound}} \rangle},$$

the strangeness enhancement, E, from p-Be to Pb-Pb interactions, is defined by

$$E = \left(\frac{Y}{\langle N_{\mathrm{wound}} \rangle} \right)_{Pb-Pb} / \left(\frac{Y}{\langle N_{\mathrm{wound}} \rangle} \right)_{p-Be}.$$

The enhancement values, E, for different particles are shown in figure 6. As can be seen from figure 6, there is an enhancement of strange and multi-strange baryons going from proton induced to central Pb-Pb interactions although there is no further increase after $N_{parts} > 100$. The baryon enhancements also increase with strangeness content with the Ω being enhanced by over an order of magnitude.

6 Summary & Conclusions

In conclusion, we find that the inverse m_T slopes, T, in Pb-Pb interactions do not increase with centrality for h^- but do increase with centrality for Λs and $\overline{\Lambda}$s . The inverse m_T slopes, extracted by several experiments, generally show a linear increase with particle mass. Multi-strange hadrons, however, do not follow this trend suggesting that these

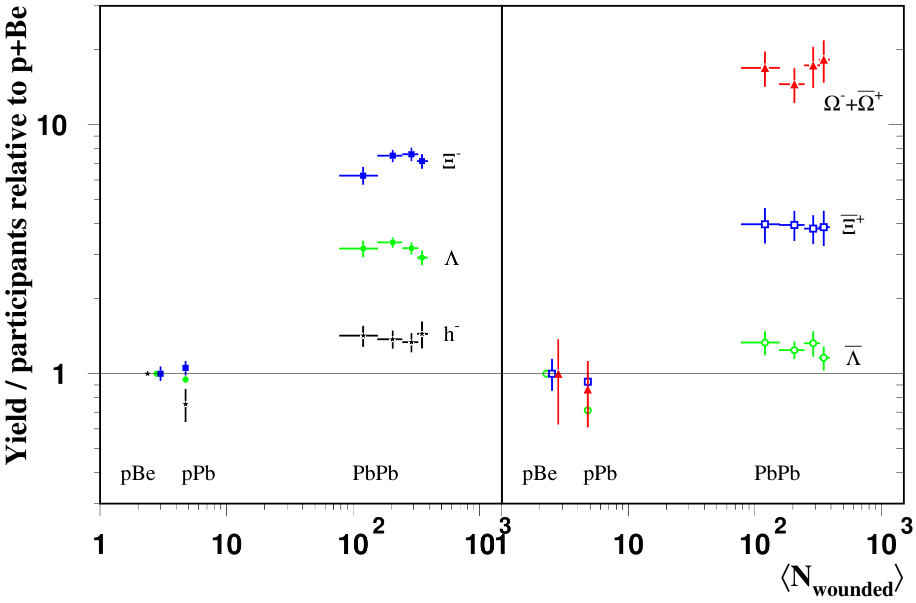

Figure 6. WA97 Particle Enhancements.

particles decouple early from the hadronic phase. There is no increase in strangeness yields per participant from p-Be to p-Pb interactions but there is a significant increase in strangeness from p-Pb to Pb-Pb interactions. The enhancement increases with strangeness content as predicted in QGP models and exceeds one order of magnitude in the case of the Ω particle.

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