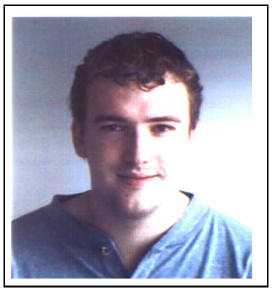
MULTI-STRANGE PARTICLE PRODUCTION IN p-Be, p-Pb, AND Pb-Pb COLLISIONS AT 158 A GeV/c

Presented by P.I. NORMAN for the WA97 Collaboration:



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Abstract

Ξ and Ω particle yields and transverse mass spectra have been measured at central rapidity in p-Be, p-Pb, and Pb-Pb collisions at 158 A GeV/c. Yields are studied as a function of the number of nucleons participating in the collision, N_{part}, which is estimated using the Glauber model. From the proton data to the Pb-Pb data, the yields per participant increase substantially. The enhancement is more pronounced with the strangeness content of the particle, and exceeds an order of magnitude for the Ω. In the ranges N_{part} less than 10, and N_{part} greater than 100, the yields appear to be constant - despite the strong increase that occurs between the two regions.

1 Introduction

Under extreme conditions of temperature and/or energy density, QCD predicts that normal hadronic matter will undergo a phase transition to a new form of matter, known as the Quark-Gluon Plasma (QGP). Although several possible signatures for this phase transition have been proposed, one of the most promising is predicted to be an enhanced yield of strange particles in nucleus-nucleus interactions (in which the QGP is expected to be formed) with respect to normal hadronic interactions [1,2]. In particular, the enhancement should become more pronounced with the strangeness content of the particle (i.e. the enhancement of Ωs should be greater than the enhancement of Ξs, which should be greater than the enhancement of Λs).

A set of three heavy ion experiments were performed at the Omega spectrometer at CERN: WA85 [3], WA94 [4], and WA97 [5]. The aim of these experiments was to provide a comprehensive study of strangeness enhancement at mid-rapidity. The WA85 and WA94 experiments both used the CERN 200 A GeV/c SPS sulphur beam, with WA85 studying S-W and p-W collisions, and WA94 studying S-S and p-S interactions. Both collaborations have reported an enhancement in the singly-strange Λ, and the doubly-strange Ξ in nucleus-nucleus interactions with respect to proton-nucleus interactions [6,7]. The WA97 collaboration has studied Pb-Pb, p-Pb and p-Be collisions, and has added measurements of the triply-strange Ω to these signals.

2 The WA97 experiment

2.1 Experimental set-up

The WA97 set-up is described in detail in ref. 5. For the Pb-Pb runs, the 158 A GeV/c lead beam from the CERN SPS was incident on a lead target corresponding to 1% of an interaction length. Scintillator petal detectors behind the target provided an interaction trigger selecting approximately 40% of the most central Pb-Pb collisions. Two planes of microstrip multiplicity detectors were then used to cover the pseudorapidity regions $2 \leq \eta \leq 3$, and $3 \leq \eta \leq 4$ respectively.

For the p-Pb and p-Be runs, both targets corresponded to 8% of an interaction length, and a trigger was applied to select events with at least two tracks in the silicon telescope. The telescope itself consisted of 7 planes of silicon pixel detectors, with a pixel size of $75 \times 500\ \mu\text{m}^2$, and of 10 planes of silicon microstrips with 50 μm pitch. The telescope had a $5 \times 5\ \text{cm}^2$ cross section, and contained approximately 5×10^5 channels. The telescope was placed 60 cm downstream of the target for the Pb-Pb runs, and 90 cm downstream for the proton reference runs. It was positioned slightly above the beamline, and inclined so that it pointed to the target. This enabled the telescope to accept particles at central rapidity and medium transverse momentum. Both the target and the silicon telescope were placed inside the homogeneous 1.8 T magnetic field of the CERN Omega magnet. The momentum resolution of fast tracks was improved by three MWPCs with cathode pad readout that were placed just outside the magnet.

2.2 Signal selection

The data sample used for the analysis consisted of approximately 110 million triggers for the Pb-Pb data, 120 million triggers for the p-Pb data, and a further 160 million triggers for the p-Be data. Multi-strange hyperons were reconstructed from the following charged particle decays, and the corresponding charge conjugate decays:

$$\Xi^- \rightarrow \Lambda + \pi^-$$
$$\hookrightarrow p + \pi^-$$

$$\Omega^- \rightarrow \Lambda + K^-$$
$$\hookrightarrow p + \pi^-$$

The selection criteria used to select the signals are summarised briefly below:

- all decay tracks are required to pass through each plane of the compact part of the pixel tracking chamber (PTC);
- all decay vertices are required to fall inside a decay region located before the first plane of the PTC, and downstream of the target;
- the reconstructed Λ vertex must follow the reconstructed cascade vertex;
- a cut is applied on the distance of closest approach of the extrapolated tracks at the decay vertex;
- a cut on the impact parameters is applied, to require that the Ξs and Ωs come from the interaction vertex, but that their decay products do not;
- Ωs are required to be kinematically unambiguous from Ξs.

The data have not been corrected for feed-down decays, but for the WA97 geometry such corrections are expected to be of minor importance, with feed-down for both Ξ^- and $\overline{\Xi}^+$ from Ω decays estimated to be less than 2%. The acceptance regions for Ξs and Ωs in p-Be are shown in fig. 1.

To obtain the particle yields in a well defined kinematic region, the following procedure was used:

- each identified hyperon was corrected for geometrical acceptance and reconstruction efficiency, using a GEANT based simulation of the apparatus;
- $d^2N/dm_T dy$ of hyperons were fitted in the corresponding acceptance windows using the method of maximum likelihood;
- the particle yields were extrapolated to a region $\mid y - y_{cm} \mid < 0.5$ and $p_T > 0$ GeV/c, where y_{cm} is the centre-of-mass rapidity for the nucleon-nucleon system.

A flat rapidity distribution for $\mid y - y_{cm} \mid < 0.5$ has been assumed for this analysis.

3 Results

3.1 Transverse mass distributions

The transverse mass spectra for Ξ and Ω were parametised by

$$\frac{dN}{dm_T} \propto m_T^{\alpha} exp(-\frac{m_T}{T}) \tag{1}$$

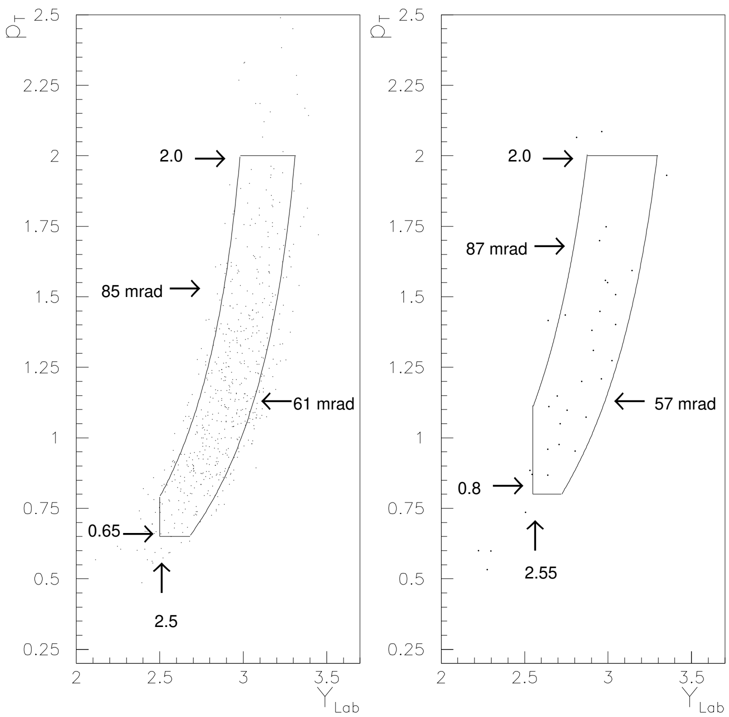

Figure 1: Regions of good acceptance for Ξs (left), and Ωs (right).

where the transverse mass, m_T, is given by $m_T = \sqrt{p_T^2 + m^2}$, and the value $\alpha = 1$ is used for the results presented in this paper. The inverse slope parameters for Ξ^-, $\overline{\Xi}^+$, and $\Omega + \overline{\Omega}^+$ in the p-Be, p-Pb, and Pb-Pb data are shown in Table 1.

Table 1: Inverse slopes with $\alpha = 1$

	p-Be	p-Pb	Pb-Pb
Ξ^-	202 ± 13	235 ± 14	286 ± 9
$\overline{\Xi}^+$	182 ± 17	224 ± 21	284 ± 17
$\Omega^- + \overline{\Omega}^+$	169 ± 40	334 ± 99	251 ± 19

There appears to be a clear increase in the inverse slope parameters as one moves from proton on light nucleus, to proton on heavy nucleus, and then to heavy nucleus on heavy nucleus.

3.2 Hyperon yields

The yield per interaction for the various hyperon species was calculated as a function of the number of nucleons participating in the collision. For the Pb-Pb data, the number of participants is calculated using a Glauber model fit to our multiplicity spectrum. This fit assumes that the number of participants is proportional to the multiplicity. For the proton beam data, the number of participants is calculated by averaging over all possible impact parameters. Figure 2 shows the yields of Λs, Ξs and Ωs for the p-Be, p-Pb and Pb-Pb data. The yields normalised to the p-Be value are shown in the second part of this figure. The solid line has a gradient of one, and therefore shows where data would be expected to lie if the yields simply scaled with the number of participants. Although this appears to be the case for the p-Be and p-Pb data, the

Pb-Pb data shows a significant enhancement of all hyperon species, and in particular, that the enhancement follows a distinct hierarchy, such that it increases with the strangeness content of the particle.

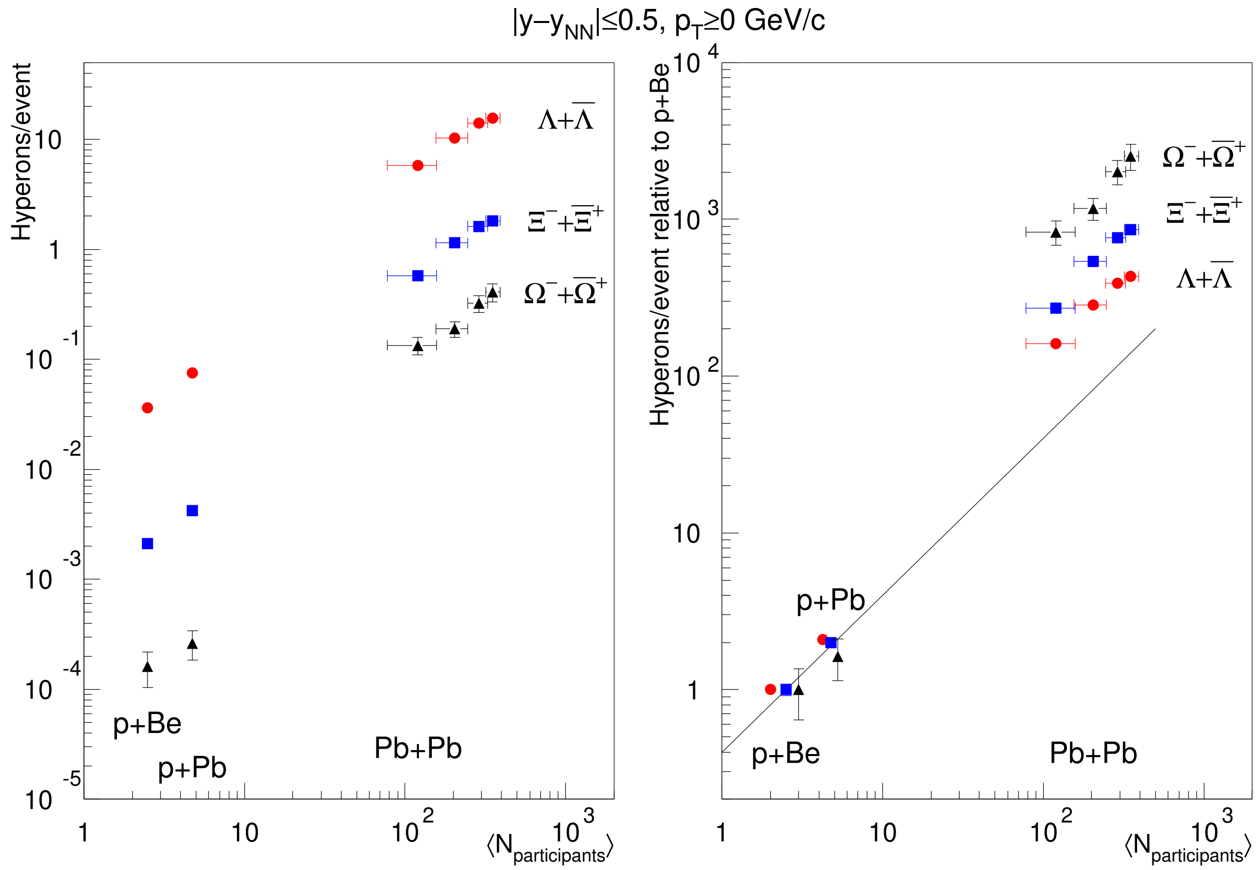

Figure 2: Hyperon yields per interaction (left), and hyperon yields per interaction normalised to p-Be (right).

In order to view this enhancement more clearly, the normalised yields can be divided by the number of participants - in which case the solid line in figure 2 maps onto a flat line at yield per participant = 1. This plot is shown in figure 3. It can be seen that while the p-Be points are quite consistent with a yield per participant of 1, the enhancement of Ξs in Pb-Pb is by a factor of 5, and for Ωs it exceeds an order of magnitude.

4 Conclusions and Outlook

While multi-strange particle yields in p-Be and p-Pb data appear to follow simple scaling with the number of participants, the yields found in central Pb-Pb collisions increase much faster than expected from direct proportionality with N_{part}. Moreover, the enhancement increases with the strangeness content of the particle, and is greater than an order of magnitude for the Ω.

Work is currently under way to add K_s^0 and negative hadron signals to the other p-Be points. Greater statistics are also expected from the Pb-Pb data taken in the 1996 run.

Finally, our successor, experiment NA57 [8], is working to answer the question of when this effect of strangeness enhancement switches on - both as a function of the number of participants (by looking at less central Pb-Pb events), and also with respect to the centre of mass energy of the collision system (by running with a 40 A GeV/c lead beam from the CERN SPS).

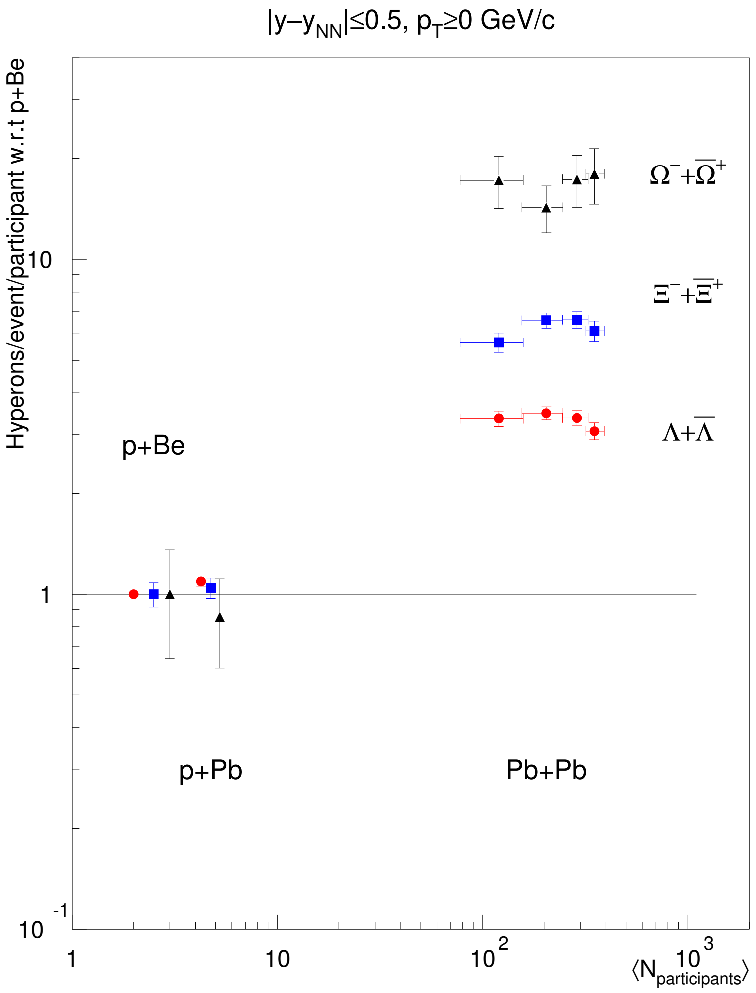

Figure 3: Hyperon yields per interaction, normalised to the p-Be values and divided by the number of participants.

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