Λ, Ξ AND Ω PRODUCTION IN Pb-Pb AND p-Pb INTERACTIONS AT 158 A GeV/c

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Abstract

The WA85, WA94 and WA97 experiments at the CERN OMEGA spectrometer have studied the production of strange and multistrange particles in both nucleus-nucleus and proton-nucleus reactions as a possible signature of a quark-gluon plasma phase. Recent results from WA97 on Λ, Ξ and Ω production in Pb-Pb and p-Pb collisions at 158 A GeV/c are presented. The enhancement of strange baryon production, observed when going from proton to nucleus initiated reactions, will be discussed.

1 Introduction

In collisions of heavy nuclei at relativistic energy the nuclear matter is compressed and significantly excited. In such extreme conditions novel physical phenomena can arise and it is believed that the quarks confined in hadrons can dissolve forming a macroscopic space time region filled with free quarks and gluons: the quark gluon plasma state of matter (QGP).

One of the sensitive signatures for the phase transition to a QGP state is the enhanced yield of strange particles in nucleus-nucleus reactions with respect to hadronic interactions [1]. It is expected, in particular, that the enhancement should be more pronounced for multi-strange baryons and expecially anti-baryons, since hadronic production of such particles is strongly suppressed due to high mass thresholds [2].

Three heavy ion experiments dedicated to the study of strangeness production were performed at the CERN Omega spectrometer: WA85, WA94 and WA97. The WA85 and WA94 experiments utilised the 200 A GeV/c SPS sulphur beam. WA85 investigated strangeness production in S-W and p-W collisions, whereas WA94 studied S-S and p-S interactions. Both experiments showed evidence for enhanced production of Λ ($|S| = 1$) and Ξ ($|S| = 2$) in nucleus-nucleus with respect to proton-nucleus collisions [3,4]. The WA97 experiment has extended this study to the heavier Pb-Pb system and has allowed the measurement of the Ω ($|S| = 3$) signal.

2 The WA97 experiment

2.1 Experimental set-up

The WA97 set-up is described in detail in ref. 5. The 158 A GeV/c lead beam from the CERN SPS was incident on a 1% interaction length lead target. Scintillator petal detectors behind the target provided an interaction trigger selecting roughly 40% of the most central Pb-Pb collisions. Two planes of microstrip multiplicity detectors covered the pseudorapidity region $2 \lesssim \eta \lesssim 3$ (station 1) and $3 \lesssim \eta \lesssim 4$ (station 2) respectively. In the proton reference run an 8% interaction length lead target was used and a trigger was applied to select events with at least two tracks in the telescope.

The tracking was performed by a silicon telescope consisting of 7 planes of silicon pixel detectors with pixel size $75 \times 500\ \mu\mathrm{m}^2$, and of 10 planes of silicon microstrips with 50 μm pitch. The telescope had $5{\times}5$ cm^2 cross section and contained $\approx 0.5{\times}10^6$ channels. It was placed 60 cm downstream of the target (90 cm for the p-Pb reference run) slightly above the beam line and inclined (pointing to the target) in order to accept particles at central rapidity and medium transverse momentum. The target and the silicon telescope were placed inside the homogeneous 1.8 T magnetic field of the CERN Omega magnet. Three MWPC's with a cathode pad readout, placed outside the magnet, improved the momentum resolution of fast tracks.

2.2 Analysis of the signals

The results presented here are based on the analysis of two data samples taken with lead (110 million events) and proton (120 million events) beams at 158 A GeV/c, respectively.

Strange hyperons were identified by reconstructing the following charged particle decays:

$$
\begin{array}{lll}
\Lambda & \rightarrow & \mathrm{p} + \pi^- \\
\Xi^- & \rightarrow & \Lambda + \pi^- \\
 & & \hookrightarrow \mathrm{p} + \pi^- \qquad\qquad + \ c.\ c. \\
\Omega^- & \rightarrow & \Lambda + \mathrm{K}^- \\
 & & \hookrightarrow \mathrm{p} + \pi^-
\end{array}
$$

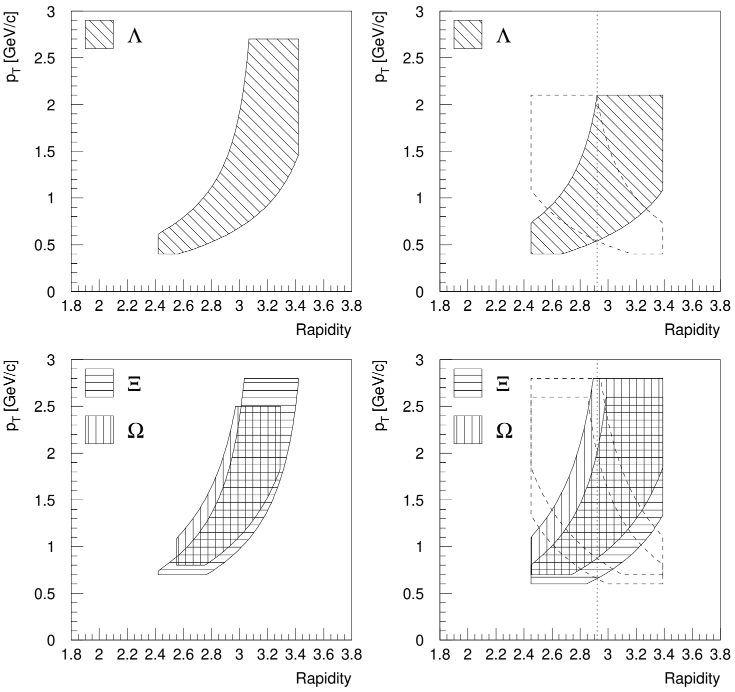

Figure 1: Acceptance windows for Λ, Ξ and Ω hyperons for p-Pb (left) and Pb-Pb (right) interactions. For Pb-Pb collisions, the symmetry of the system allows to symmetrize the acceptance windows by reflection around y_{cm}. The reflected windows are drawn with dashed lines.

In the particle spectra the mass resolution of the peaks was better than 6 MeV (FWHM). The data have not been corrected for feed-down from Ξ to Λ. It is estimated to be less than 5% for Λ and less than 10% for $\overline{\Lambda}$.

The acceptance windows for Λ, Ξ and Ω from Pb-Pb and p-Pb collisions are shown in Fig. 1. To obtain the particle yields in a well defined kinematic region the following procedure was applied:

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

At the moment, only a part of the hyperons observed in Pb-Pb has been used and, for the present analysis, a flat rapidity distributions for $|y - y_{cm}| < 0.5$ was assumed.

3 Results

3.1 Transverse mass distributions

The transverse mass spectra for Λ, Ξ and Ω were parametrised by

$$\frac{dN}{dm_{\mathrm{T}}} \propto {m_{\mathrm{T}}}^{\alpha} \exp(-\frac{m_{\mathrm{T}}}{T}) \tag{1}$$

where $m_{\mathrm{T}} = \sqrt{p_{\mathrm{T}}^2 + m^2}$ and the values $\alpha = \frac{3}{2}$ and $\alpha = 1$ where used, in order to facilitate a comparison with other experiments. The two values correspond to different longitudinal flow

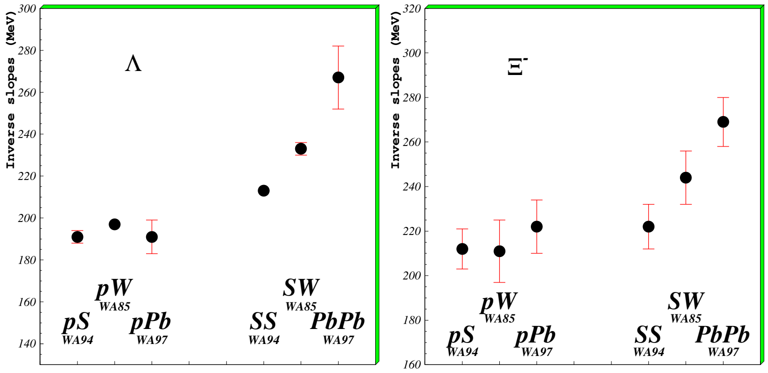

Figure 2: Inverse slopes of Λ and Ξ for different colliding systems. The $\alpha = \frac{3}{2}$ value has been used.

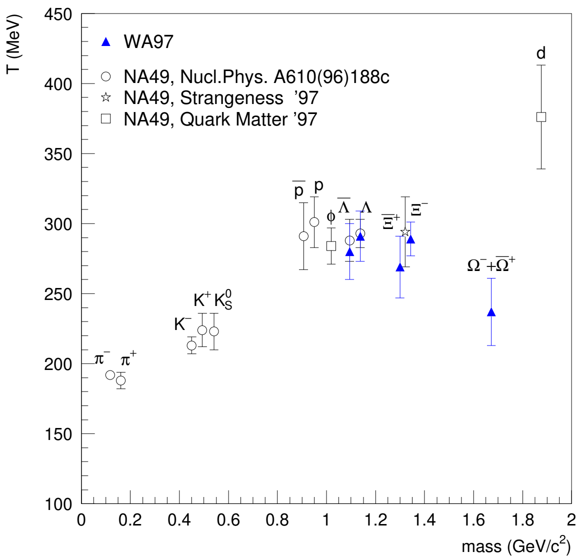

Figure 3: Inverse slope parameter dependence on the particle mass. The $\alpha = 1$ value has been used.

contributions [6]. The inverse slope parameters T for Λ, Ξ and Ω resulting from the fitting procedure applied to Pb-Pb and p-Pb collisions are summarised in Table 1. Due to the limited statistics, the combined data on Ω^- and $\overline{\Omega}^+$were put together.

In fig. 2 the inverse slope parameters for Λ and Ξ are compared with previous WA85 [7] and WA94 [8] results. It can be noted a clear increase of the parameter T with the size of the collision system for nucleus-nucleus reactions, while their values for proton induced reactions are compatible with each other. The same trend has been observed for $\overline{\Lambda}$ and $\overline{\Xi}^+$.

Furthermore, in fig. 3, the inverse slope parameters for different hadrons in the Pb-Pb system are shown as a function of their mass. The present results on Λ, Ξ and Ω are superimposed on recent results from the NA49 experiment [9]. It can be noted that strange and multi-strange baryons deviate from the steadly increase of the parameter T with the particle mass.

3.2 Hyperon yields

The yields for the various hyperon species were calculated as a function of centrality of the collision. As a measure of the centrality we used the number of participant nucleons. From the multiplicity detector measurements we estimated the number of participants in the collision using a Glauber model for Pb-Pb interactions, together with the assumption of proportionality between the number of participants and the multiplicity. The two multiplicity detector stations

Table 1: Inverse m_{T} slope parameters T in MeV for Pb-Pb and p-Pb interactions.

	Pb-Pb		p-Pb	
Particles	$\alpha = 3/2$	$\alpha = 1$	$\alpha = 3/2$	$\alpha = 1$
Λ	267± 15	291±18	191± 8	203± 9
$\overline{\Lambda}$	257± 17	280±20	170± 14	180±15
Ξ^-	269± 11	289±12	222± 12	235±14
$\overline{\Xi}^+$	251± 19	269±22	211± 19	224±21
$\Omega^-+\overline{\Omega}^+$	225± 22	237±24	312± 86	334±99

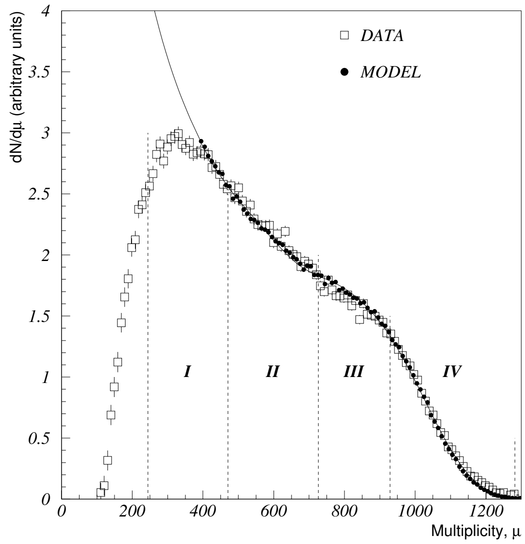

Figure 4: Charged particle multiplicity spectrum (squares) compared with a Glauber model calculation (points).

provide independent measurements of the number of participants which allows to estimate the detector resolution. In fig. 4 the model calculation, modified to account for the multiplicity detector resolution, is compared to the measured multiplicity spectrum.

For multiplicities above 400 the model gives an excellent description of the multiplicity spectrum with only one free parameter, which fixes the scaling factor between the charged particle multiplicity and the number of participants to the value 2.62. To obtain the hyperon yields in Pb-Pb as a function of the number of participants, the multiplicity spectrum is divided into four bins (fig. 4), and in each bin the average number of participants is calculated from the model. In bin I, where the trigger selection introduces a discrepancy with the model, the average number of participants is estimated by weighting the multiplicities with the ratio of the measured multiplicity to the Glauber calculation. The above analysis represents a refinement of that presented in ref. 10. For p-Pb interactions, the estimated number of participants corresponds to minimum bias collisions.

Fig. 5 shows the Λ, Ξ and Ω yields per event for p-Pb and Pb-Pb interactions as a function of the number of participants. All hyperon yields show a steady increase with centrality up to very central events, with no saturation effect. Also presented are the hyperon yields rescaled so that each value for p-Pb is set to one. A line proportional to the number of participants is drawn through the p-Pb common point. It is observed that the Λ, Ξ and Ω yields increase with centrality from p-Pb to Pb-Pb interactions faster than the number of participants. Moreover, this increase in higher for Ω than for Ξ and for Ξ than for Λ.

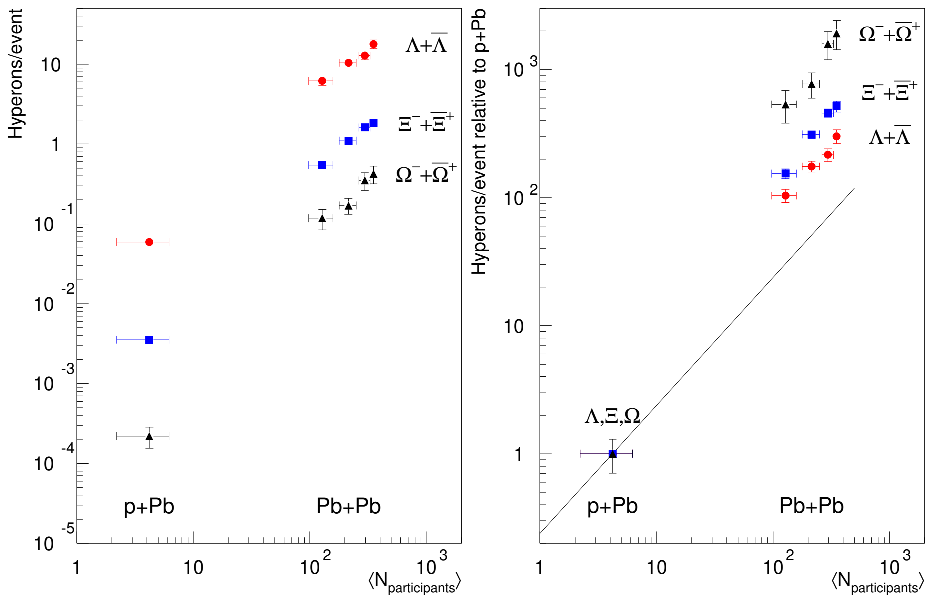

Figure 5: The Λ, Ξ and Ω yields expressed in units of yields per event (left) and in units of yields observed in p-Pb collisions (right). The line refers to a yield proportional to the number of participants.

4 Conclusions and Outlook

Analysis of current results on Λ, Ξ and Ω production in Pb-Pb and p-Pb collisions has shown that inverse slope parameters for $\Lambda(\overline{\Lambda})$ and $\Xi(\overline{\Xi}^{+})$ increase as a function of the size of the collision system. Moreover, multi-strange inverse slopes for the Pb-Pb collision system deviate from the linear increase with the particle mass, discussed in ref. 11 as an evidence of radial flow in nucleus-nucleus collisions.

Strange particle yields increase from p-Pb to central Pb-Pb collisions faster than expected from proportionality with the number of nucleons partecipating to the collisions. This enhancement increases with the strangeness content of the hyperon ($\Omega > \Xi > \Lambda$ hierarchy).

To push further the present work, an analysis based on a larger statistics sample is under way. Also, data on p-Be and the identification of K_s^0 and negatives signals will add extra points to fig. 5. Finally, the future NA57 experiment [12] will extend the centrality coverage in Pb-Pb collisions, allowing to answer to the question whether the increase in the hyperon production is continuous with the number of participants or if any discontinuity is present.

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