Strange Baryon Production in Pb–Pb Collisions at 158 A GeV/c

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Abstract

The first results on fully corrected Λ, Ξ, and Ω particle production obtained by the WA97 experiment in Pb–Pb and p–Pb collisions are presented.

1 Introduction

An enhanced production of strange particles has been suggested long ago as a useful diagnostic tool in heavy ion reactions since flavour equilibration times are expected to be much shorter in a Quark–Gluon Plasma(QGP) than in a Hadron Gas [1, 2, 3, 4]. In particular, multi-strange (anti-)baryons can be expected to probe the early phase of the collision [5], since hadronic production of such particles is suppressed due to high mass thresholds while in a QGP scenario they can be easily created due to a copious production of strange quark pairs from gluons.

An enhanced production of multistrange (anti-)baryons has already been observed in sulphur initiated reactions by the WA85 and WA94 collaborations [6, 7] and the WA97 experiment has extended this study to a Pb–Pb system.

We shall present a comparison of the Pb–Pb results on Ξ and Ω with those from the p–Pb run. For Pb–Pb we shall present the $m_{\rm t}$ distributions for Λ and Ξ, and the Ξ^-/Λ particle ratio as a function of the number of participants in the collision.

2 The experimental setup

The WA97 set-up, shown schematically in figure 1, is described in detail in ref. [9]. The target and most of the detectors are placed inside the homogeneous region of the 1.8 T field of the CERN Omega spectrometer.

The tracks are detected using the silicon telescope as a Pixel Tracking Chamber (PTC). This makes use of planes of the novel pixel detectors [10] with pixel dimensions of 75×500 μm^2 (about 0.5×10^6 detecting elements) and of silicon micro-strip planes with a pitch of 50 μm. The area of each plane is about 5×5 cm^2.

The reconstruction of tracks is done in the compact part of the PTC where 6 pixel planes and 5 micro-strip planes are closely packed over a distance of 30 cm. The momentum resolution of fast tracks is improved using lever arm detectors which consist of additional pixel and micro-strip planes as well as three MWPCs with pad cathode readout.

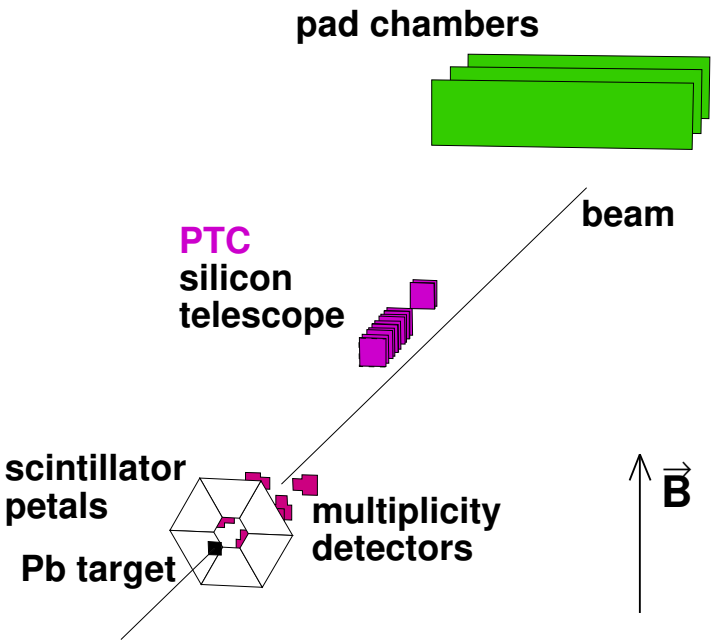

Figure 1: The WA97 set-up in the Omega magnet.

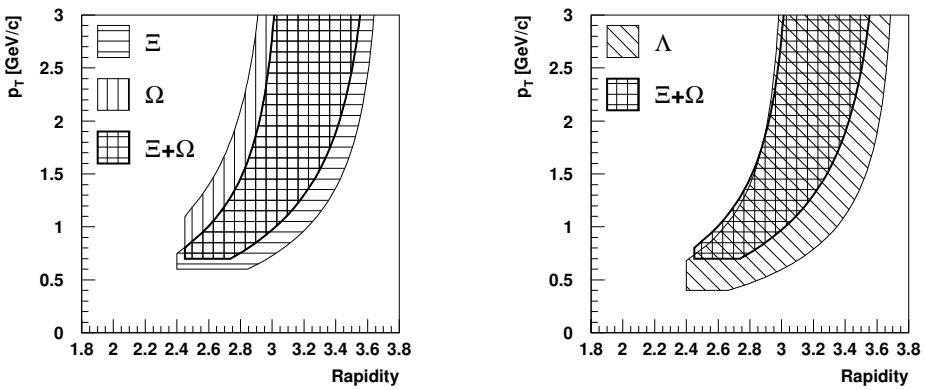

Figure 2: The acceptance in transverse momentum and rapidity for Λ, Ξ and Ω and the overlap region for Pb–Pb collisions.

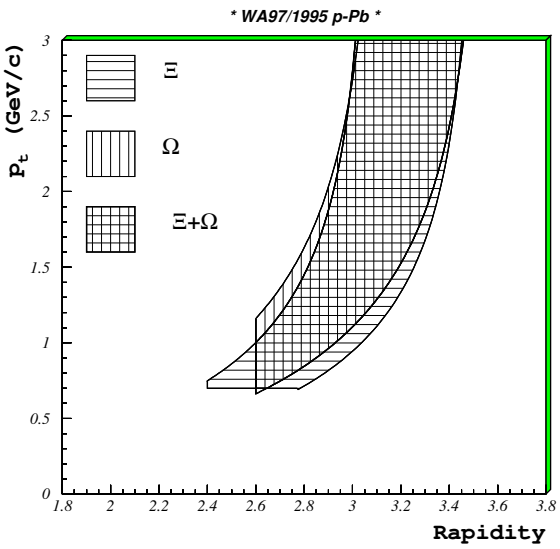

Figure 3: The acceptance in transverse momentum and rapidity for Ξ and Ω and the overlap region for p–Pb collisions.

The telescope is placed slightly above the beam line and inclined (pointing to the target) in order to accept particles at central rapidity and medium transverse momentum. Figure 2 shows the acceptance windows for Λ, Ξ and Ω [1] and the region where the two acceptance windows overlap, for the Pb–Pb collisions.

The acceptance windows (and their overlap) for Ω and Ξ coming from the p–Pb data are shown in figure 3. The geometrical acceptance is the same for particles and antiparticles, since our apparatus is symmetric with respect to the magnetic field.

A set of scintillator petals provides a centrality trigger that selects about 30% of the geometric inelastic cross section. Two planes of silicon microstrip detectors sample the charged particle multiplicity in the pseudorapidity interval $2 < \eta < 4$ and allow for more detailed off-line analysis of centrality dependences.

[1] In the following, Λ, Ξ and Ω will refer both to hyperons and corresponding antihyperons

3 Data sample and selection criteria

The results presented here are based on the analysis of two data samples taken during the 1995 run:

- 42 M Pb–Pb events[2] taken with the PTC placed at a distance of 60 cm from the target. The trigger selected central events corresponding to a cross section of about 2.3 barns,
- 120 M p–Pb events taken with the PTC 90 cm from the target with a trigger that required at least two tracks to pass through the compact part of the PTC.

Both Pb and p beams had a momentum of 158 GeV/c per nucleon. The Λ's are detected via their charged particle decay products in the decay $\Lambda \to \mathrm{p} + \pi^-$. The Ξ^- and Ω^- hyperons are identified by reconstructing their two-step decays:

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

For the Pb–Pb sample the Λ decay vertex is required to fall within a fiducial region starting at 30 cm from the target and ending just before the first plane of the PTC. The fiducial region for the cascade (Ξ, Ω) decay vertex instead starts at 20 cm from the target. For the p–Pb sample all decays have to fall in the region starting at 40 cm from the target. All decay tracks are required to pass through the planes of the compact part of the PTC. The Λ candidates are required to be kinematically unambigous with the decay of a K^0_s and the Ω candidates with the decay of a Ξ. The Λ, Ξ and Ω candidates are required to trace back to the position of the primary vertex.

To illustrate the quality of the data, figure 4 shows the uncorrected $\Xi^- + \overline{\Xi}^+$ and $\Omega^- + \overline{\Omega}^+$ signals for the p–Pb and Pb–Pb data samples.

4 Corrections for acceptance and efficiency

A subsample of the Pb–Pb and all of the p–Pb data have been corrected for acceptance, detector and reconstruction efficiency. The correction procedure of the remaining data is under way.

A Monte Carlo simulation based on GEANT has been used. For each analysed Λ, Ξ and Ω a weight was calculated by generating hyperons with the

[2]This sample contains about 40% of the Pb–Pb events collected in 1995. Analysis of the remaining data is in progress.

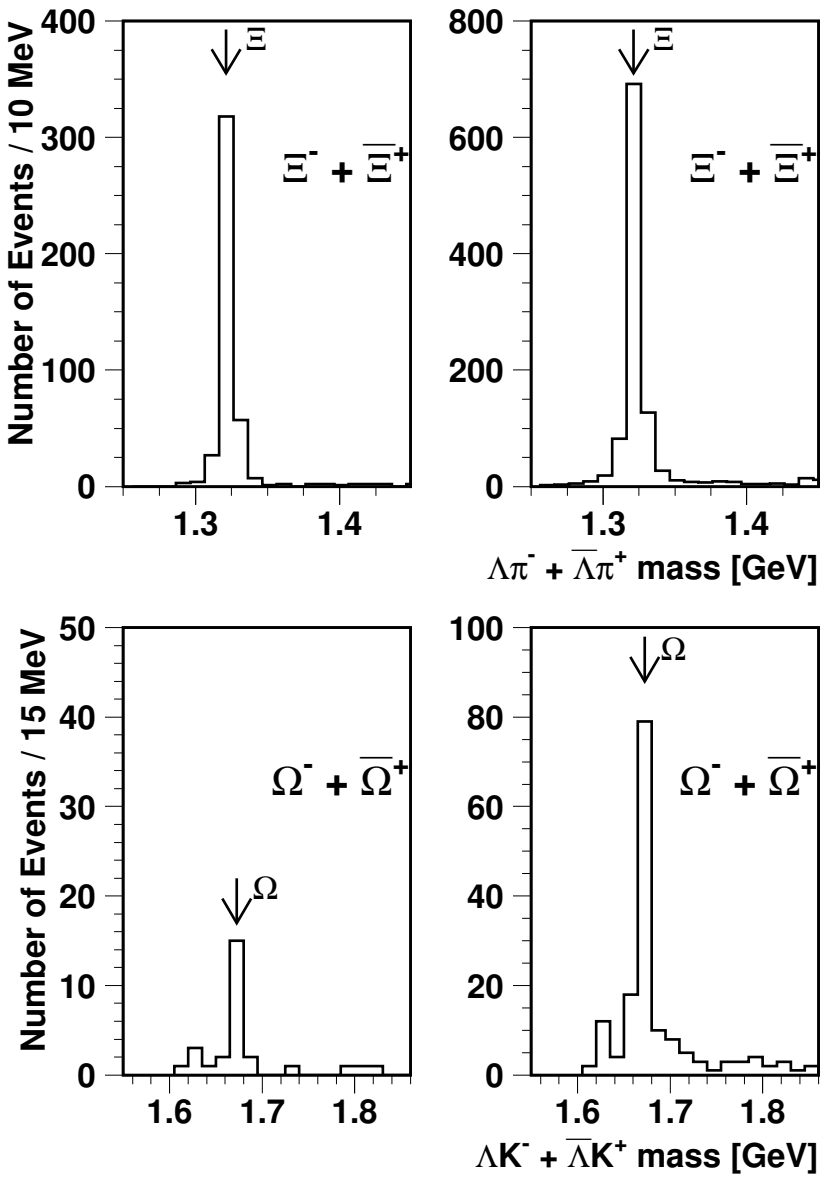

Figure 4: The Ξ and Ω signals in (left) p–Pb and (right) Pb–Pb collisions.

measured transverse momentum, rapidity and position of the primary vertex. The detector efficiencies corresponding to each read-out chip of the pixel planes have been measured and were taken into account. The background tracks and the electronic noise were simulated by embedding the hits of the Monte Carlo tracks into a real event which had a similar hit multiplicity in the PTC as the hyperon event.

These mixed events were processed in the same way as real events for pattern recognition, track fitting and signal selection. The resulting weight is the number of Monte Carlo hyperons generated divided by the number of Monte Carlo hyperons reconstructed.

All 19 Ω and 376 Ξ for the p–Pb and all 107 Ω for the Pb–Pb data were weighted using this procedure, while only subsamples of 253 Ξ and 475 Λ for the Pb–Pb data were corrected.

5 Results

a) We have measured the ratio $(\Omega^- + \overline{\Omega}^+)/(\Xi^- + \overline{\Xi}^+)$ both for the p–Pb and Pb–Pb data in the overlap acceptance window. We find that this ratio is enhanced by a factor of 3.2 ± 1.1 when going from p–Pb to Pb–Pb. The statistical error is due mainly to a limited number of Ω in the p–Pb data.

b) The m_{t} distributions have been studied for Pb–Pb collisions for Λ and Ξ (present statistics did not allow us to do this study for Ω). We have used the parametrisation:

$$\frac{1}{m_{\mathrm{t}}}\frac{d\mathrm{N}}{dm_{\mathrm{t}}} = C \cdot \exp(-m_{\mathrm{t}}/T)$$

Because of the complicated shape of the acceptance windows (fig. 2), we have used the maximum likelihood method in order to extract inverse slopes T and test a possible rapidity dependence of the cross sections. The inverse slopes obtained with this method, still very preliminary, can be seen in table 1. Our slopes are systematically higher than those found by the WA94 experiment for S–S collisions [8]. Only a part of this difference ($\sim$ 20 MeV) could be attributed to a slightly different parametrization used by the WA94 Collaboration ($1/m_{\mathrm{t}}^{3/2}$ factor). The remaining difference could result from a higher collective flow present in Pb–Pb collisions [11]. This collective flow is expected to be more pronounced for heavier particles.

Table 1: Inverse slopes (in MeV/c^2) obtained from the maximum likelihood fit for the 30% most central Pb–Pb events and for the S–S collisions (WA94 experiment).

Particle	WA97 (Pb–Pb)	WA94(S–S)
Λ^0	257 ± 13	213 ± 2
Ξ^-	291 ± 22	222 ± 10

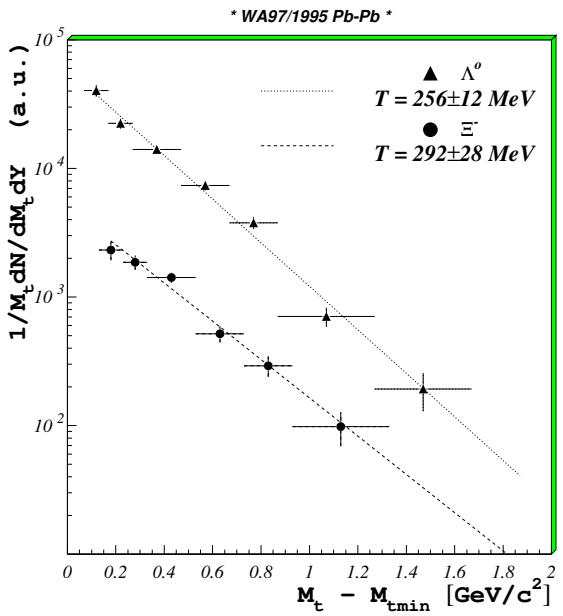

Figure 5: The transverse mass plots for Λ and Ξ^- from Pb–Pb collisions obtained under assumption of flat rapidity distributions.

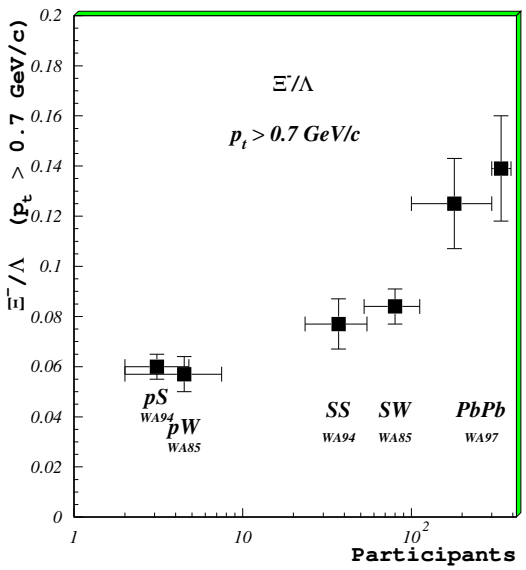

Figure 6: Compilation of the Ξ^-/Λ ratio for the different colliding systems. Horizontal bars indicate approximate range of the number of participants for each experiment.

It has been found that the data, within our statistical sensitivity and the investigated rapidity range, are consistent with flat rapidity distributions. This has enabled us to obtain the $m_{\rm T}$ distributions corrected for the rapidity acceptance (fig. 5). The inverse slopes obtained with this method are compatible with those obtained by the maximum likelihood method.

c) Cross sections and particle ratios are being calculated for Λ, Ξ^-, Ω^- and their antiparticles. We present here results on the Ξ^-/Λ ratio in Pb–Pb, which we compare to previous experiments, and on the Ω^-/Ξ^- ratio both from Pb–Pb and p–Pb collisions. The Ξ^-/Λ ratio has been calculated for $p_{\rm t} > 0.7$ GeV/c and one unit of rapidity for two intervals of the collision centrality, whose central values correspond to 180 and 340 participating nucleons respectively. The number of nucleons participating in the collision was estimated by means of the VENUS program from the measured multiplicities. These ratios are numerically the same as in the overlap window. They are shown in fig. 6 together with the values previously obtained by our Collaboration in p–S, p–W, S–S and S–W collisions. For the comparison these values, measured at

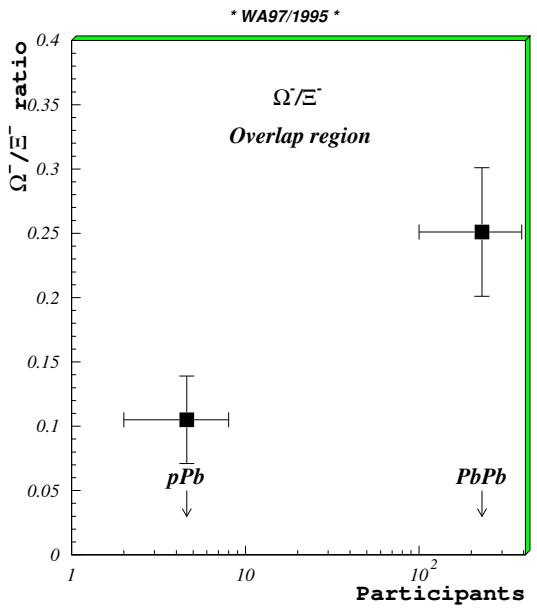

Figure 7: Ω^-/Ξ^- ratio for the p–Pb and Pb–Pb data. Horizontal bars indicate approximate range of the number of participants.

central rapidity unit for $p_{\rm t} > 1.2$ GeV/c, have been extrapolated down to $p_{\rm t} > 0.7$ GeV/c which is the lower $p_{\rm t}$ limit for the Pb–Pb data. Such an extrapolation has been performed using the published slopes [8] of the $m_{\rm t}$ distributions. Forthcoming data from WA97 both in p–Be and p–Pb collisions will allow us to compare directly this ratio in exactly the same $p_{\rm t}$–rapidity window. There is clearly an enhancement of Ξ^- relative to Λ at central rapidity when increasing the volume of colliding nuclei. The expected increase of statistics should allow us ascertain whether this ratio has a sudden increase or not, when going from S–S to Pb–Pb. Fig.7 shows the same for Ω^-/Ξ^- but only for data from our experiment, because no other data exist for this ratio. In this case Ω^- and Ξ^- are compared in the same kinematic window, *i.e.* the overlapping window between Pb–Pb and p–Pb data. Again we can see an increase of a higher strangeness baryon production as compared to a lower strangeness baryon. This points to a pattern of strangeness enhancement increasing with strangeness content of a baryon.

6 Conclusions and outlook

The first results on fully corrected ratios of Ξ^- and Λ, detected by the WA97 experiment in Pb–Pb collisions have been presented. Also first results from the p–Pb run on Ω^- and Ξ^- are given.

The enhancement of the ratio $(\Omega^- + \overline{\Omega}^+)/(\Xi^- + \overline{\Xi}^+)$ is of 3.2 ± 1.1 when going from p–Pb to Pb– Pb collisions (it is 2.4 for the Ω^-/Ξ^- ratio). The Ξ^- hyperon production is in turn enhanced relative to Λ when going from p–S to Pb–Pb collisions by a factor of about 2 (the enhancement with respect to S–S is of 1.7).

The inverse slopes of transverse mass distributions for Λ and Ξ^- have been found larger in Pb–Pb than in S–S interactions, as could be expected.

The Pb–Pb data sample analysed till now corresponds to about one fourth of the statistics, of which all Ω, but only a fraction of Λ and Ξ, have been passed through the correction procedure. For the p–Pb data all Ω and Ξ have been used. Further analysis is in progress which should enable us to complete these results and to improve their statistical precision.

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