Production of multi-strange particles in Pb–Pb interactions at 158 A GeV/c

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Abstract

The first results on fully corrected ratios and production cross sections of Ω^-, $\overline{\Omega}^+$, Ξ^- and $\overline{\Xi}^+$ detected by the WA97 experiment in Pb–Pb collisions are presented.

1 Introduction

An enhanced production of strange particles has long been suggested as a tool to identify the establishment of a flavour equilibrated system in particle reactions [1, 2]. The equilibration times are expected to be much shorter in a Quark–Gluon Plasma than in a Hadron Gas [3, 4]. In particular, multi-strange (anti-)baryons have been suggested as a useful probe of the early phases of the collision [5], since hadronic production of such particles is strongly suppressed due to high mass thresholds.

An enhanced production of multistrange (anti-)baryons has already been observed in sulphur initiated reactions by the WA85 and WA94 collaborations [6, 7].

2 The experimental setup

The WA97 set-up, shown schematically in figure 1, is described in detail in ref. [8]. 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 found using our silicon telescope as a Pixel Tracking Chamber (PTC). The telscope consists of novel pixel detectors [9] with pixel dimensions of 75×500 μm^2 and of silicon micro-strip planes with a pitch of 50 μm. Altogether this provides about 0.5×10^6 detecting elements in the PTC. The planes have a sensitive area of 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.

The telescope is configured to give acceptance in the region of central rapidity and medium transverse momentum. Figure 2 shows the acceptance windows for Ξ and Ω and the region where the two acceptance windows overlap. The geometrical acceptance is the same for particles and antiparticles, since our apparatus is symmetric in the magnetic bend direction.

A set of scintillator petals provide a centrality trigger that selects about 30% of the total interaction cross section. Two planes of silicon micro-strip

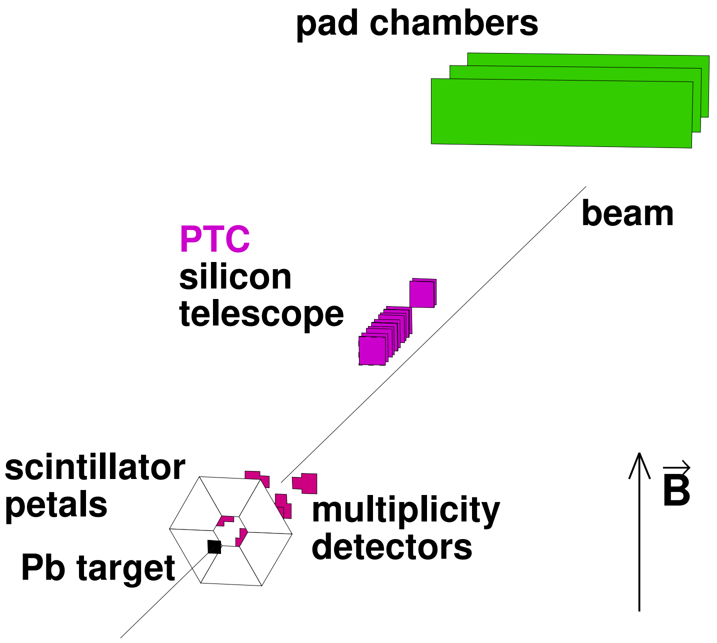

Figure 1: The WA97 set-up in the Omega magnet.

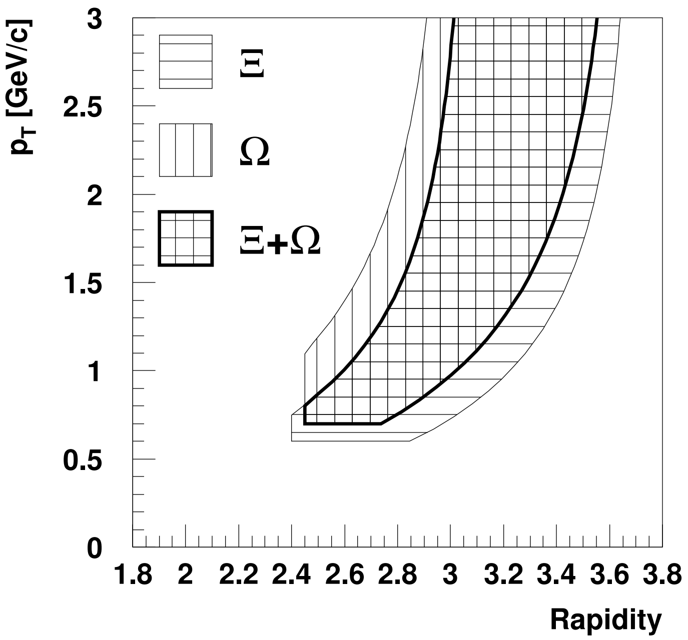

Figure 2: The acceptance windows for Ξ and Ω and the overlap region.

multiplicity detectors sample the charged particle multiplicity in the pseudorapidity interval $2 < \eta < 4$ and allow for more detailed off-line analysis of centrality dependences.

3 Data sample and selection criteria

The results presented here are based on the analysis of two data samples taken during the 1995 run with beam momentum $158\,A\,\mathrm{GeV}/c$:

- 42 M Pb–Pb events[1] 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 2.3 barn, *ie.* about 30% of the Pb–Pb interaction cross section.
- 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.

The Ξ^- and Ω^- hyperons (and the corresponding antihyperons) are identified by reconstructing their two-step (cascade) decays that contain only charged particles in the final state, *ie.*:

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

All decays are required to fall within a decay region, starting at 20 cm from the target (at 40 cm for p–Pb sample) and ending just before the first plane of the PTC. All decay tracks are required to pass through the planes of the compact part of the PTC. At the decay vertices, the distance of closest approach between the trajectories of the decay particles is required to be less than 1 mm. The Ω^- candidates are required to be kinematically unambiguous with the decay of a Ξ^-. In the lead beam data the cascade is required to trace back to the position of the primary vertex which can be determined event-by-event since the average number of reconstructed tracks in the PTC is about 20.

Figure 3 shows the uncorrected Ξ^-+$\overline{\Xi}^+$ and Ω^-+$\overline{\Omega}^+$ signals for the p–Pb and Pb–Pb data samples. The relative normalization between the two samples has not yet been determined. However a comparison between these uncorrected p–Pb and Pb–Pb data suggests that the ratio Ω/Ξ is about a factor 3 higher in lead induced reactions than in proton induced reactions.

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

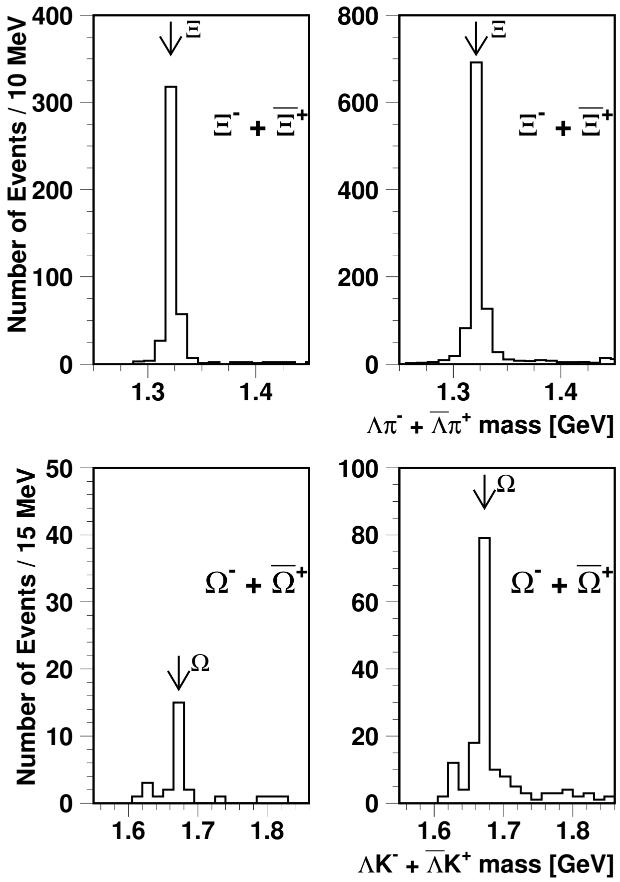

Figure 3: The Ξ and Ω signals in (left) p–Pb and (right) Pb–Pb collisions.

4 Corrections for acceptance and efficiency

The Pb–Pb data have been corrected for geometrical acceptance, detector efficiency and reconstruction efficiency by a Monte Carlo simulation based on GEANT. The correction of the p–Pb data is under way.

For each Ξ and each Ω a weight was calculated by generating cascades with the 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 when the hits for each decay track were generated. The background tracks and the electronics 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 cascade event.

These mixed events were processed in the same way as real events for

Table 1: Ratios of multi-strange baryons in the overlap window for the 30% most central Pb–Pb events.

Ratio	Uncorrected	Corrected
$\frac{\overline{\Xi}^+}{\Xi^-}$	0.27 ± 0.03	0.27 ± 0.05
$\frac{\overline{\Omega}^+}{\Omega^-}$	0.42 ± 0.10	0.42 ± 0.12
$\frac{\Omega^-}{\Xi^-}$	0.18 ± 0.02	0.19 ± 0.04
$\frac{\overline{\Omega}^+}{\overline{\Xi}^+}$	0.27 ± 0.06	0.30 ± 0.09
$\frac{\Omega^-+\overline{\Omega}^+}{\Xi^-+\overline{\Xi}^+}$	0.20 ± 0.02	0.21 ± 0.03

Table 2: Number of multi-strange baryons per event in the overlap window for the 30% most central Pb–Pb events.

Particle	Particles per event
Ξ^-	0.180 ± 0.017
$\overline{\Xi}^+$	0.048 ± 0.008
Ω^-	0.034 ± 0.006
$\overline{\Omega}^+$	0.014 ± 0.003

pattern recognition, track fitting and signal selection. The weight is the number of Monte Carlo cascades generated divided by the number of Monte Carlo cascades reconstructed.

5 Results

The particle ratios for Ξ and Ω in the overlap window (fig. 2), for the central events on which we trigger, are given in table 1. The ratios are corrected for the branching fractions into unseen decay modes. The acceptance and reconstruction efficiency for Ξ and Ω are quite similar. Thus the ratios change very little after correction.

We expect that the reconstruction efficiency for Ξ and Ω are similar also in the p–Pb data, since both particles have the same decay topology. There is a small difference in acceptance between the two samples. The integrated acceptance for the ratio Ω/Ξ is about 10% higher in the Pb–Pb sample. Thus the enhancement of about a factor 3 in the ratio $(\Omega^- + \overline{\Omega}^+)/(\Xi^- + \overline{\Xi}^+)$ when going from p–Pb to Pb–Pb should remain after the p–Pb data have been corrected.

Table 3: Production cross section for multi-strange baryons in the overlap window for the 30% most central Pb–Pb events.

Particle	Cross section [mb]
Ξ^-	409 ± 38
$\overline{\Xi}^+$	109 ± 18
Ω^-	78 ± 13
$\overline{\Omega}^+$	33 ± 8

The number of Ξs and Ωs per triggered central event are given in table 2. The corresponding cross sections for production of Ξ^-, $\overline{\Xi}^+$, Ω^- and $\overline{\Omega}^+$ in the kinematic region of the overlap window (fig. 2) are given in table 3. They were calculated by:

$$\sigma = \frac{1}{nL} \frac{1}{\prod \mathrm{BF}} \frac{\sum \mathrm{weights}}{\sum \mathrm{BEAM} \cdot \overline{\mathrm{DT}}},$$

where n is the number of target nuclei per unit volume, L is the thickness of the target, BF are the branching fractions of the detected decay modes, weights are the weights for the detected cascades and $\sum \mathrm{BEAM} \cdot \overline{\mathrm{DT}}$ is the number of beam particles that arrived while the detector was ready to register an event. The errors are statistical only. The systematic error on the normalization is expected to be about 20%.

6 Conclusions and Outlook

The first results on fully corrected ratios and production cross sections of Ω^-, $\overline{\Omega}^+$, Ξ^- and $\overline{\Xi}^+$ detected by the WA97 experiment in Pb–Pb collisions have been presented.

The enhancement of the ratio Ω/Ξ of about a factor 3 when going from p–Pb to Pb–Pb collisions remains after the Pb–Pb data have been corrected for acceptance and reconstruction efficiencies, thus indicating that the production of Ω is significantly enhanced with respect to the production of Ξ when going from p–Pb collisions to Pb–Pb interactions.

The data sample analysed corresponds to about one fourth of the statistics collected by the WA97 experiment in Pb–Pb runs, thus we expect to reduce the errors on the ratios by a factor two.

References

[1] J. Rafelski and B. Müller, Phys. Rev. Lett. **48** (1982) 1066;
J. Rafelski and B. Müller, Phys. Rev. Lett. **56** (1986) 2334.

[2] P. Koch, B. Müller and J. Rafelski, Phys. Rep. **142** (1986) 167.

[3] U. Heinz, Nucl. Phys. **A566** (1994) 206c.

[4] H.C. Eggers and J. Rafelski, Int. Journ. of Mod. Phys. **A6** (1991) 1067.

[5] J. Rafelski, Phys. Lett. **B262** (1991) 333.

[6] WA85 Collaboration: S. Abatzis *et al.*, Nucl. Phys. **A590** (1995) 307c.

[7] WA94 Collaboration: S. Abatzis *et al.*, Nucl. Phys. **A590** (1995) 317c.

[8] WA97 Collaboration: G. Alexeev *et al.*, Nucl. Phys. **A590** (1995) 139c.

[9] E.H.M. Heijne *et al.*, Nucl. Instr. Meth. **A349** (1994) 138;
F. Antinori *et al.*, Nucl. Instr. Meth. **A360** (1995) 91.