PRODUCTION OF Ξ^- AND Ω^- IN HEAVY-ION COLLISIONS AT THE CERN SPS

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Abstract

A series of experiments at the CERN OMEGA Spectrometer (WA85, WA94, WA97) have studied the production of strange particles (kaons, Λ, Ξ^-, Ω^- and their antiparticles) in both nucleus–nucleus and proton–nucleus reactions. Strange (anti-)baryon enhancements at central rapidity have been reported by WA85 and WA94 in S–W and S–S with respect to p–A reactions. Recently WA97 has presented a study of Ξ and Ω produced in Pb–Pb and in p–Pb collisions at 160 A GeV/c. The first results suggest a significant enhancement of Ω over Ξ production when going from p–Pb to Pb–Pb. This contribution aims to summarize the results obtained up to now and to present the latest results from the analysis of the Pb–Pb data.

1 Introduction

The study of the strange particle production in high-energy nucleus-nucleus collisions provides important information on the behaviour of hot and dense hadronic matter. The enhanced relative yield of strange and, particularly, multi-strange particles and anti-particles in nucleus-nucleus with respect to hadronic reactions has been suggested as a signature of the phase transition to a quark-gluon plasma (QGP) state [1, 2].

In the QGP scenario such an enhancement could be created in a time interval comparable with the interaction time of the high-energy heavy-ion collision (a few fm/c). On the other hand, in a purely hadronic scenario the establishment of a similar system would require a much longer time. It is expected [3] that the enhancement should be more pronounced for multi-strange than for singly-strange particles because of the high density of $s\bar{s}$ - pairs in the plasma and, on the other hand, the suppression of strange particle production in the hadronic processes which increases with growing strangeness content.

Such behaviour has been observed for particles with strangeness $|s| = 1$ and 2 in sulphur initiated reactions by the WA85 and WA94 experiments [4,5]. In Fig. 1 the comparison of WA85 and WA94 data on Ξ^-/Λ and $\overline{\Xi}^+/\overline{\Lambda}$ ratios with available pp data from the AFS experiment [6] is presented. Strange particle production processes exhibit a similar behaviour in S–S and S–W reactions. The WA85 data showing the enhanced strange particles production in S–W with respect to p–W collisions, normalized to yields of negatively charged hadrons, are presented in Fig. 2 as a function of the strangeness content. The observed enhancement is, in agreement with the above mentioned predictions, significantly higher for double-strange Ξ hyperons than for singly-strange kaons and Λ's.

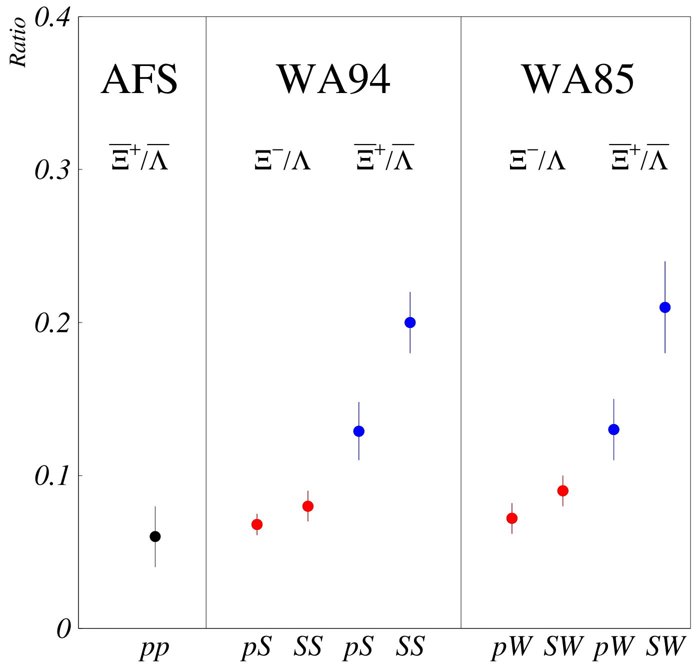

Fig. 1. Compilation of AFS, WA94 and WA85 data on Ξ/Λ ratios.

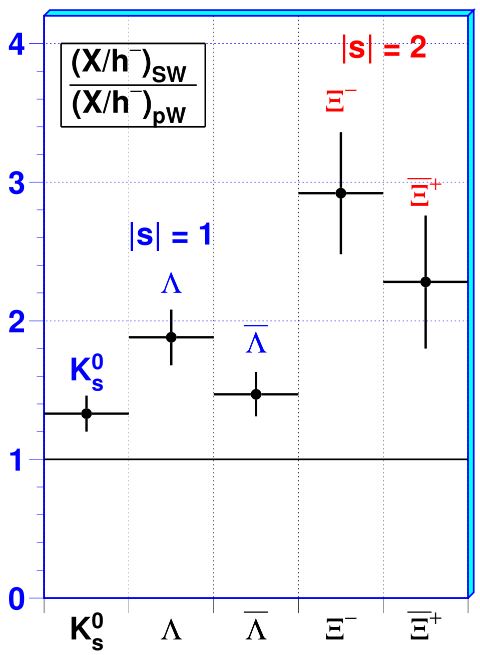

Fig. 2. WA85 data on enhancement of strange particles in S–W with respect to p–W collisions normalized to the yield of negative particles.

It is therefore of considerable interest to extend this study to the really heavy-ion (Pb–Pb) collisions and to the Ω hyperons with $|s| = 3$. The WA97 experiment performed at the CERN SPS aims to cope with this task exploiting its capability to perform an efficient pattern recognition and precise measurements of particles in a high multiplicity environment and to reconstruct reliably the cascade decays of Ξ and Ω hyperons.

The recent study of Pb–Pb and p–Pb collisions performed on part of the WA97 data has suggested [7] that the Ω/Ξ ratio is significantly higher in Pb–Pb compared to p–Pb reactions.

2 Experimental set-up

The experimental set-up, shown schematically in Fig. 3, is described in detail in ref. 8.

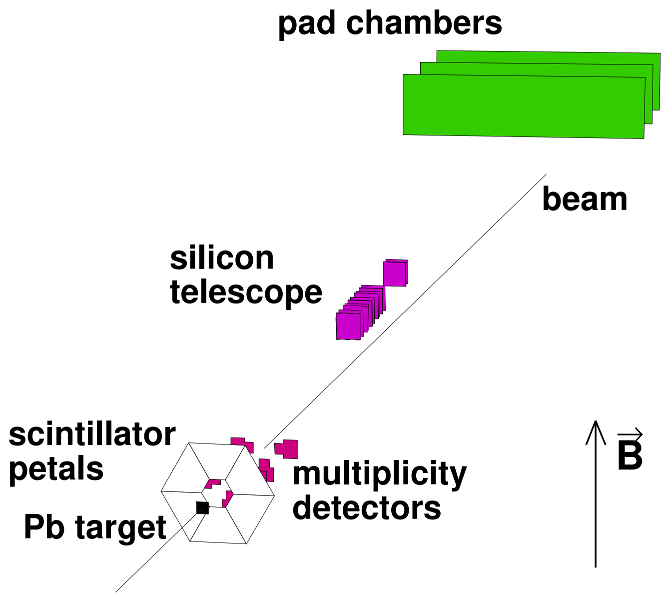

Fig. 3. WA97 set-up in the Omega magnet.

Multiplicity detectors located near the lead target provide a centrality trigger selecting about 30% of the Pb–Pb cross section. In addition, they provide detailed information allowing off line study of multiplicity dependences.

The core of the WA97 set-up is a silicon telescope consisting of the novel pixel detectors [9] with a pixel size of $75 \times 500\ \mu\text{m}^2$ and of silicon microstrip planes with a $50\ \mu$m pitch. The telescope, which acts as a pixel tracking chamber (PTC), is placed inside the 1.8 T magnetic field of the CERN Omega spectrometer. The PTC provides $\simeq 0.5 \times 10^6$ detecting elements for precise coordinate measurements.

The reconstruction of tracks is done in the compact part of the PTC where silicon planes with surface of 5×5 cm^2 are closely packed over a distance of 30 cm. The momentum resolution of fast tracks is improved using the lever arm detectors which consist of additional pixel and microstrip planes and of three MWPC's with a pad cathode readout.

Figure 4 shows an event from the 1995 lead run. This no-field event contains 153 reconstructed tracks, corresponding to an occupancy of about 0.2 % of the 72K channels provided by each pixel detector plane.

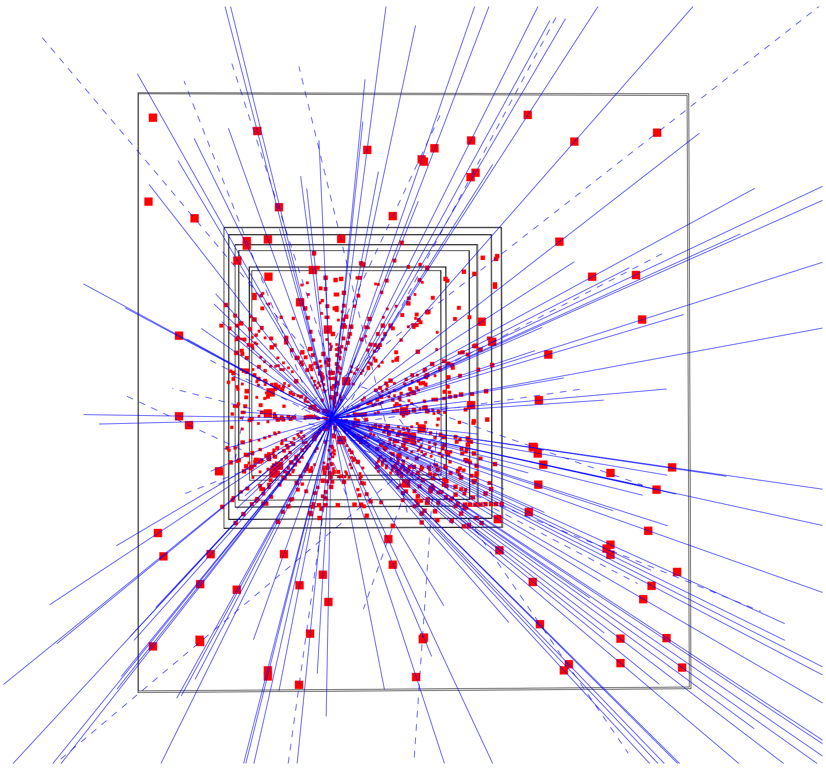

Fig. 4. WA97 no-field event with 153 reconstructed tracks in the pixel tracking chamber.

The geometrical acceptance of the apparatus covers the region of central rapidity ($2.5 < y_{\mathrm{L}} < 3.4$) and medium transverse momentum ($p_\perp > 0.5$ GeV/c) and is the same for particles and antiparticles.

3 Data samples and selection criteria

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

a) 120×10^6 p–Pb events taken with the PTC placed at a distance of 90 cm from the target and under the trigger requirement of having at least two charged particles in the PTC,

b) 20×10^6 Pb–Pb events[1] taken with the PTC 60 cm from the target. The average number of reconstructed tracks in the PTC was $\simeq$ 20.

The Ω^- and Ξ^- hyperons (and the corresponding antihyperons) are identified by reconstructing their two-step decays containing only charged particles in the final state, i.e.

$$\Xi^- \rightarrow \Lambda\pi^- \, , \Omega^- \rightarrow \Lambda \mathrm{K}^- \; (\Lambda \rightarrow \mathrm{p}\pi^-) \; .$$

All decays are required to fall within a decay region, starting at 40 cm from the target (at 20 cm for sample b) and ending just before the first sensitive plane of the PTC. All decay tracks are required to pass through all the planes of the compact part of the PTC. At both vertices of the Ω or Ξ cascade decays, a distance of closest approach between the trajectories of decay particles of less than 1 mm is required. The standard set of cuts, analogous to those described in ref. 5, has been applied to eliminate the background[2]. For the Ω candidates an unambiguity with Ξ was required.

4 Results

Fig. 5 shows the uncorrected $\Xi^-+\overline{\Xi}^+$ and $\Omega^-+\overline{\Omega}^+$ signals for the p–Pb and Pb–Pb data samples.

At the present stage of analysis, the relative normalization between these samples has not yet been determined. Therefore we can only compare the observed Ω/Ξ ratios.

The geometrical arrangement was different at the p–Pb and Pb–Pb data taking, but the integrated acceptance for the Ω/Ξ ratio was only higher by

[1] This sample represents a fraction of the total statistics of about 100×10^6 of triggers. Analysis of the remaining data is in progress.

[2] In the analysis of the Pb–Pb data sample, existence of a sufficient number of reconstructed secondary tracks allowed an improvement of the determination of the interaction vertex position for individual events. Precised knowledge of the primary vertex position was used for efficient background removal from Ξ and Ω mass spectra.

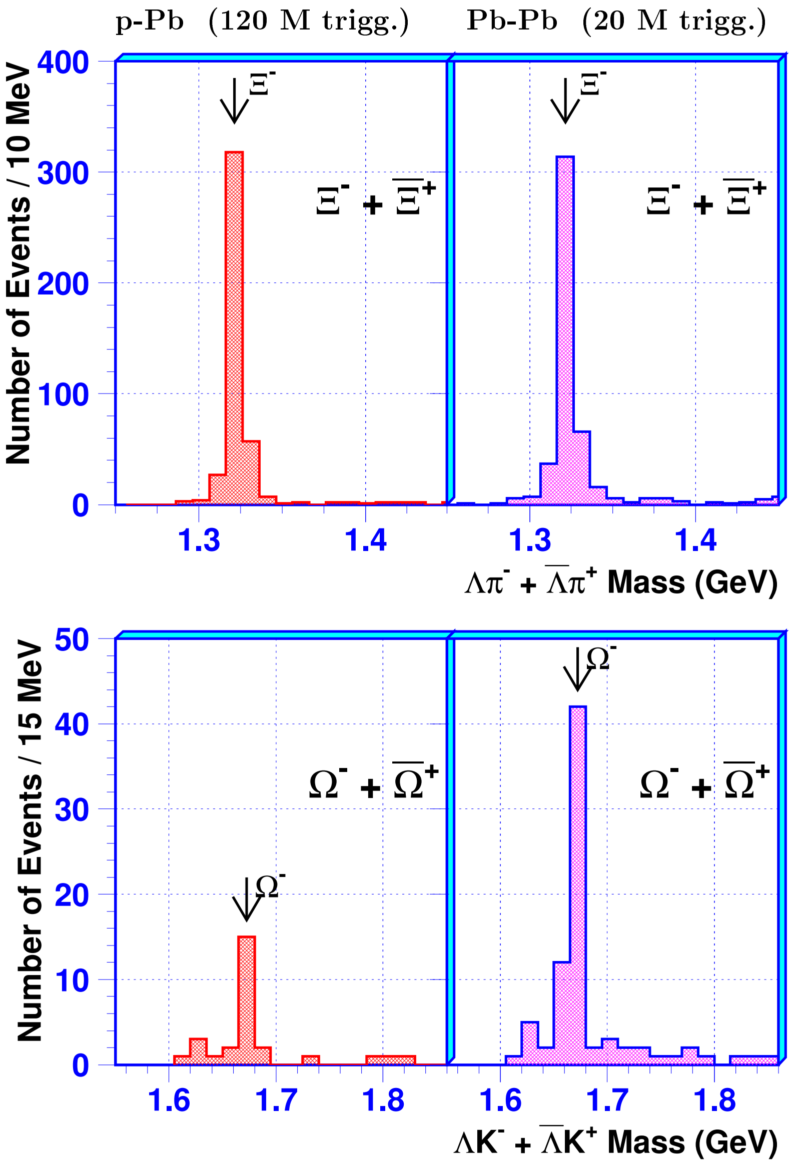

Fig. 5. Uncorrected Ξ and Ω signals in p–Pb and Pb–Pb data.

$\simeq$ 10% for the Pb–Pb sample. We assume the reconstruction efficiencies for Ξ's and Ω's to be the same (for a given data sample) and therefore to cancel in the Ω/Ξ ratio. This assumption is based on the fact that both particles have the same decay topology and the track reconstruction efficiency depends only weakly on its momentum. The preliminary calculations performed for the limited Pb-Pb data sample are consistent with this assumption.

Fig. 5 shows a striking difference between Ω/Ξ ratios in the p–Pb and the Pb–Pb samples. If the Ω/Ξ production ratio were to be the same in p–Pb as in Pb–Pb collisions, one would expect an Ω signal in the p–Pb sample significantly stronger than the one observed. The preliminary estimate of the Ξ^- and Ω^- production cross-sections in p–Pb and Pb–Pb reactions indicates a significantly enhanced Ω^- production in Pb–Pb collisions. Taking into account the knowledge of integrated geometrical acceptance and assuming the same reconstruction efficiency for Ξ and Ω we obtain

$$\frac{(\Omega^- + \overline{\Omega}^+ / \, \Xi^- + \overline{\Xi}^+)_{\mathrm{Pb-Pb}}}{(\Omega^- + \overline{\Omega}^+ / \, \Xi^- + \overline{\Xi}^+)_{\mathrm{p-Pb}}} \simeq 3 \; .$$

An exact estimate of the error on the presented value of enhancement is not easy due to the small number of reconstructed Ω's in the p–Pb sample. Calculations, based on statistical errors only, indicate that the above ratio is bigger than 2 at the 95% confidence level.

5 Conclusions

The new data on the Ω/Ξ ratios in p–Pb and Pb–Pb collisions at 158 GeV/c per nucleon are presented. They are based on statistics significantly higher than those quoted in ref. 7.

The presented result is consistent with the previous one [7], thus strengthening the conclusion that the Ω production is significantly enhanced with respect to Ξ production in Pb–Pb compared to p–Pb reactions.

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