Strange and multistrange baryon production in sulphur-tungsten interactions at 200 GeV/c per nucleon

The WA85 Collaboration

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Abstract

Multi-strange baryon and anti-baryon production is expected to be a useful probe in the search for Quark-Gluon Plasma formation. We present the transverse mass distributions of negative particles, Λs and Ξ^-s produced in sulphur-tungsten interactions at 200 GeV per nucleon and give the fully corrected ratios $\overline{\Lambda}/\Lambda$, Ξ^-/Λ and $\overline{\Xi}^-/\overline{\Lambda}$. We compare our results with published results of $\overline{\Xi}^-/\overline{\Lambda}$ for p p and p $\overline{\text{p}}$ interactions and note that our ratio $\overline{\Xi}^-/\overline{\Lambda}$ appears large in comparison to that from normal hadronic interactions.

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Hyperon production is expected to be a useful probe for the dynamics of hadronic matter under the extreme conditions realised in central heavy ion collisions [1]. If a Quark-Gluon Plasma (QGP) is produced during the collisions the hyperon and, in particular, antihyperon yields are expected to be enhanced with respect to normal hadronic interactions and give rise to an anomalously large $\overline{\Xi^-}\ /\overline{\Lambda}$ ratio [2]. WA85 is the only experiment which has obtained results on the production of cascades in heavy ion interactions. In this paper the m_T distributions for negative particles (mostly pions), Λs and Ξ^-s produced in S W interactions at 200 GeV/c per nucleon are presented. The $\overline{\Lambda}/\Lambda$, Ξ^-/Λ and $\overline{\Xi^-}/\overline{\Lambda}$ ratios, corrected for contamination from Ξ decays are also given.

The WA85 experiment [3] was performed using the CERN Omega Spectrometer with a 200 GeV/c per nucleon beam of ^{32}S ions incident on a tungsten target. The aim is to study strangeness production at $p_T \geq 1$ GeV/c and central rapidity. The Omega multiwire proportional chambers were modified to select only high p_T tracks so that several tracks are recorded out of the several hundred produced in a central collision, making reconstruction of both strange and multi-strange baryons possible in this kinematic region. Figure 1 shows a fully reconstructed event with a cascade candidate where it can be seen that the number of background hits is not excessive. The apparatus and trigger, which select central collisions, have been discussed in a previous publication [4].

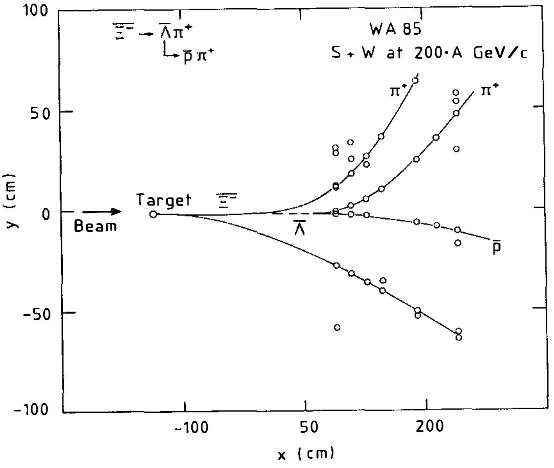

Figure 1: Example of a fully reconstructed event with a cascade candidate

The method of reconstructing Λ[†] [4] and Ξ^- [5] decays has already been explained in previous publications. From the full statistics of our 1987 S W data (10 million triggers) we have 13,307 Λ and 3,407 $\overline{\Lambda}$ candidates and 108 Ξ^- and 44 $\overline{\Xi^-}$ andidates. The phase space window used for Λs and $\overline{\Lambda}$s is $2.3 < \mathrm{y_{lab}} < 3.0$ and $0.9 < \mathrm{p}_T < 2.8$ GeV/c; for Ξ^-s and $\overline{\Xi^-}$s it is $2.3 < \mathrm{y_{lab}} < 3.0$ and $1.1 < \mathrm{p}_T < 3.3$GeV/c.

Our Λ and $\overline{\Lambda}$ candidates include K^0_S contamination which is around 7% for Λs and 27% for $\overline{\Lambda}$s. For this study we select only unambiguous decays ($\cos\theta^* < -0.5$)[‡] leaving us with 5,856 Λs and 1,138 $\overline{\Lambda}$s. These are then corrected for geometrical acceptance, decays outside the fiducial region, unseen decay modes and reconstruction efficiencies, giving the ratios $\overline{\Xi^-}$ $/\Xi^- = 0.39 \pm 0.07$ and $\overline{\Lambda}$ $/\Lambda = 0.19 \pm 0.01$.

Particles from a thermal source, in a narrow rapidity window, are expected to have a transverse mass distribution given by [6],

$$\frac{1}{\mathrm{m}_T}\frac{\mathrm{dN}}{\mathrm{dm}_T} \sim e^{-\beta \mathrm{m}_T} \tag{1}$$

where β is the inverse temperature of the source and m_T the transverse mass ($\mathrm{m}_T = \sqrt{\mathrm{p}_T^2 + \mathrm{m}^2}$). For our study of m_T distributions we choose the rapidity interval $2.4 < \mathrm{y_{lab}} < 2.6$ where both Λ and Ξ^- acceptances are good.

The Λ sample need to be corrected for contamination from Ξ^- and Ξ^0 decays because the decay region is far from the target for our experiment [4,5]. This contamination is estimated by Monte-Carlo to be about 8% from Ξ^- decays and about 14% from Ξ^0 decays giving a total contamination $\mathrm{C}_\Lambda = 22 \pm 4$ % in our Λ sample.

Figure 2 shows $\frac{1}{\mathrm{m}_T}\frac{\mathrm{dN}}{\mathrm{dm}_T}$ versus m_T for fully corrected negative particles (mostly pions), Λs (corrected for contamination from Ξ decays) and Ξ^-s . Their inverse slopes ($1/\beta$) are given in table 1. These inverse slopes also have a systematic error estimated by simulation to be about ± 13 MeV.

We note from figure 2 that all the slopes are similar and that the number of Λs at a given m_T is greater than the number of negative particles. From figure 2 we can also deduce the ratio Ξ^- $/\Lambda$ at a given m_T ; at $\mathrm{m}_T = 2$ GeV the ratio Ξ^- $/\Lambda = 0.20 \pm 0.04$.

Although our statistics for $\overline{\Xi^-}$s in this narrow $\mathrm{y_{lab}}$ window are too small to plot their m_T distribution we can estimate the $\overline{\Xi^-}$ $/\overline{\Lambda}$ ratio. Using the contamination of Λs from Ξ decays

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[†] We use the notation Λ for $\Lambda + \Sigma^0$.

[‡] where θ^* is defined as the angle between the flight of the V^0 and the positive decay particle in the V^0 rest frame.

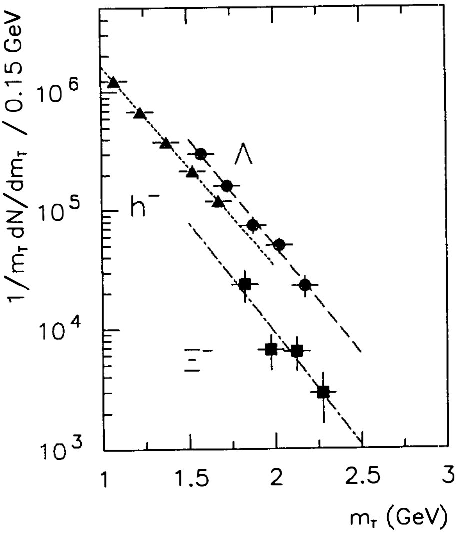

Figure 2: $\frac{1}{m_T}\frac{dN}{dm_T}$ vs m_T for negative particles (h^-), mostly π^-s, Λs and Ξ^-s

(C_Λ) and our measured ratios $\overline{\Lambda}/\Lambda$ and $\overline{\Xi^-}/\Xi^-$ (R_Λ and R_Ξ respectively), the contamination of $\overline{\Lambda}$s from $\overline{\Xi}$ decays will be

$$C_{\overline{\Lambda}} = \frac{R_\Xi}{R_\Lambda} \times C_\Lambda = \frac{0.39}{0.19} \times 22\% = 45 \pm 12\ \%$$

The true $\overline{\Lambda}/\Lambda$ ratio, $R_{\Lambda\ (\mathrm{true})}$ will therefore be

$$R_{\Lambda\ (\mathrm{true})} = R_\Lambda \times \left(\frac{1 - C_{\overline{\Lambda}}}{1 - C_\Lambda}\right) = 0.13 \pm 0.03$$

Table 1: Inverse slopes ($1/\beta$) for different particles from figure 2.

Particle	inverse slope (MeV)	statistical error
negative	256	± 3
Λ	238	± 9
Ξ^-	233	± 54

and the ratio $\overline{\Xi^-}/\overline{\Lambda}$ is

$$\frac{\overline{\Xi^-}}{\overline{\Lambda}} = \frac{R_{\Xi}}{R_{\Lambda}\ (\text{true})} \times \frac{\Xi^-}{\Lambda} = 0.6 \pm 0.2$$

The ratios Ξ^-/Λ and $\overline{\Xi^-}/\overline{\Lambda}$ have been measured in p p [8] and $\bar{p}$ p [9] interactions. These results are for Ξ^- and Λ production in the same (or similar) p_T range, so in order to compare our results directly we must consider our ratios for a given p_T (not m_T). If we consider our ratios for a p_T of 1.66 GeV/c (corresponding to an m_T of 2 GeV for Λs) we may then compare our results directly to those for other interactions. Table 2 shows our results together with those from p p collisions at 63 GeV [8] and $\bar{p}$ p collisions at 900 GeV [9].

Table 2: The ratios Ξ^-/Λ and $\overline{\Xi^-}/\overline{\Lambda}$ in the region $2.4 < y_{\text{lab}} < 2.6$ and $p_T = 1.66$ GeV/c for central S W interactions. Also given are p p data at 63 GeV [8] and $\bar{p}$ p data at 900 GeV [9].

Exp.	int.	$\sqrt{s}$ (GeV)	p_T (GeV/c)	Ξ^-/Λ	$\overline{\Xi^-}/\overline{\Lambda}$
WA85	S W	19	1.66	0.11 ± 0.02	0.33 ± 0.11
AFS	p p	63	1-2		0.06 ± 0.02
UA5	$\bar{p}$ p	900	> 1	$0.07^{+0.08}_{-0.04}$	

Contamination from Ξ decays in these experiments is negligible because of the short decay distances of their hyperons.

As can be seen from table 2, our ratio Ξ^-/Λ is compatible with that from $\bar{p}$ p interactions. However, the ratio $\overline{\Xi^-}/\overline{\Lambda}$ is 5.5 times greater than that quoted by the AFS collaboration; this corresponds to a two standard deviation effect with the current statistics.

In conclusion, we show that the m_T distributions of negative particles (mostly pions), Λs and Ξ^-s are well described by the function $\frac{1}{m_T}\frac{dN}{dm_T} \sim e^{-\beta m_T}$ and yield a value of $1/\beta$ consistent with 250 MeV as given in table 1.

In table 3 we summarise the ratios obtained in this paper and our previous publications [5]. We note that our ratios are high in comparison to normal hadronic interactions; however, such high ratios have been predicted in sudden hadronisation QGP models [2].

Table 3: Summary of ratios from WA85

Ratio	m_T = 2 GeV	p_T = 1.66 GeV/c
$\overline{\Lambda}/\Lambda$	0.13 ± 0.03	0.13 ± 0.03
$\overline{\Xi^-}/\Xi^-$	0.39 ± 0.07	0.39 ± 0.07
Ξ^-/Λ	0.20 ± 0.04	0.11 ± 0.02
$\overline{\Xi^-}/\overline{\Lambda}$	0.60 ± 0.20	0.33 ± 0.11

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