Production of multistrange baryons and antibaryons in sulphur-tungsten interactions at 200 GeV/c per nucleon

The WA85 Collaboration

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Abstract

Production of Ξ^- and $\bar{\Xi}^-$ has been observed for the first time in heavy ion interactions by the WA85 Experiment. Multi-strange baryon and anti-baryon production is expected to be a useful probe in the search for Quark-Gluon Plasma formation. We describe the procedure used to select these cascade candidates and show that Ξ^- and $\bar{\Xi}^-$ decays can be identified. The ratio of $\bar{\Xi}/\Xi$ production, corrected for geometrical acceptances and reconstruction efficiencies, is 0.39 ± 0.07 for sulphur-tungsten interactions in the central rapidity interval $2.3 < Y_{lab} < 3.0$ and $p_T > 1.1$ GeV/c.

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Strange particle and in particular strange antibaryon production is expected to be a useful probe for the dynamics of hadron matter in heavy ion collisions [1,2,3,4]. If a Quark Gluon Plasma (QGP) is produced there are several reasons to suppose that it would give an enhancement in strange particle production [2]. Gluons would be produced abundantly in a QGP and the gluon-gluon collisions would then give rise to $q\bar{q}$ pairs, strange $q\bar{q}$ pairs having the same coupling to gluons as non-strange pairs. At thermal equilibrium and high temperature the higher mass of the s quark would not significantly inhibit $s\bar{s}$ pair production relative to light quark pairs as this is no longer large compared to the available energy. Moreover, $s\bar{s}$ production is expected to be favoured since, in a baryon-rich environment such as that produced in heavy ion collisions at SPS energies, the abundance of u and d quarks will suppress further production of $u\bar{u}$ and $d\bar{d}$ pairs through Pauli blocking. It is thus expected that strange particle abundances will be enhanced in a QGP relative to those observed in normal hadronic collisions [2].

In addition, it has been proposed [5] that strange particles with medium transverse momenta ($p_T \geq 1$ GeV/c) should originate from the early stages of the QGP, allowing a more direct observation of the QGP than via the large number of particles produced at low p_T during hadronisation.

It has also been suggested that multi-strange baryon and anti-baryon production are of particular interest in the search for the QGP since these particles are more difficult to produce in purely hadronic matter [2]. WA85 is the only experiment which has obtained results on the production of these particles in heavy ion interactions. In this letter we show that Ξ^- and $\bar{\Xi}^-$ decays can be reconstructed in the high multiplicity heavy ion environment and present the corrected $\bar{\Xi}^-$ to Ξ^- production ratio in sulphur-tungsten interactions. Preliminary uncorrected data have already been presented [6].

Results on Ξ^- and $\bar{\Xi}^-$ production from $p - Be$ interactions at 240 GeV/c [7] and 400 GeV/c [8] exist for the fragmentation region, yielding $\bar{\Xi}/\Xi$ production ratios of

about 0.04 for cascades at $x_F \simeq 0.5$. Although these data are for forward cascade production, and therefore cannot easily be compared with our results in the central region ($x_F \sim 0$), it is worthwhile to note that the Ξ/Ξ ratio was shown to increase strongly as x_F decreases [8].

The WA85 experiment [9] was performed using the CERN Omega Spectrometer with a 200 A GeV/c 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. The apparatus and trigger have been discussed in a previous publication [10].

Figure 1 shows a fully reconstructed event with a cascade candidate. As can be seen, the number of background hits is not excessive.

The signature used for a cascade decay is the intersection of the line of flight of a Λ or $\bar{\Lambda}$ candidate with a charged track, at a point well separated from the target region. We consider any pair of oppositely charged tracks as a V^0 candidate if

- (a) the distance of closest approach between the two oppositely charged tracks is < 1.6 cm,
- (b) each track traces through at least the first four multiwire proportional chambers,
- (c) the distance of the decay vertex from the target is > 125 cm, and
- (d) the V^0 momentum is > 6.5 GeV/c.

The quality of the V^0 candidates can be assessed by studying their distribution on the Podolanski-Armenteros plot [11]. The three-momenta of the V^0 decay particles are resolved into components q_L^+, q_L^- parallel to the direction of motion of the V^0 for positive and negative tracks respectively, and q_T transverse to the direction of motion of the V^0 . The variable α is defined as $\alpha = (q_L^+ - q_L^-)/(q_L^+ + q_L^-)$.

The distribution of our V^0 candidates shown in figure 2 where clear accumulations are seen along bands corresponding to the Λ , $\bar{\Lambda}$ and K^0 ellipses. We consider Λ and $\bar{\Lambda}$ candidates over the full kinematically allowed region ($|\alpha| > 0.45$) and with masses greater than 1.086 GeV and less than 1.146 GeV. The quality of the Λ and $\bar{\Lambda}$ signals have been shown in a previous publication [10].

Any combination of a Λ ($\bar{\Lambda}$) and a negatively (positively) charged track is considered as a cascade candidate if both the V^0 and the charged track come from a secondary vertex well separated from the target, i.e.

- (a) the distance of closest approach between the line-of-flight of the Λ ($\bar{\Lambda}$) and the charged track is < 1.6 cm, and
- (b) the cascade decay distance > 100 cm.

In addition we require that:

- (c) The cascade candidate comes from the target (y separation* between the cascade impact and the target centre < 2.0 cm) and
- (d) the decay pion does not come from the target (y separation between the charged track impact and the target centre > 11 cm.)

The effective mass distributions for the candidates, interpreted as $\Lambda\pi^-$ and $\bar{\Lambda}\pi^+$, from our $^{32}\text{S} - W$ data are shown in figs 3 (a) and (b); clear peaks are seen at the Ξ^- and $\bar{\Xi}^-$ positions. The overall charged multiplicity was sampled in the pseudorapidity interval $2.1 < \eta < 3.4$ using two arrays of silicon microstrips [10]. For this letter we consider events in the region $2.3 < Y_{lab} < 3.0$ and $p_T > 1.1$ GeV/c with a microstrip multiplicity greater than 20 (corresponding to $\langle \frac{dN}{dY} \rangle|_{Y \in [2.3, 3.0]} > 40$ [10]). We select candidates with mass greater than 1.27 GeV and less than 1.37 GeV giving 108 Ξ^- and 44 $\bar{\Xi}^-$ candidates.

The data have been corrected for geometrical acceptance, including corrections for decays outside the fiducial region and unseen decay modes, and reconstruction efficiencies. The reconstruction efficiencies are similar for Ξ s and $\bar{\Xi}$ s and vary from

*y is defined as the bend direction in the magnetic field as can be seen in fig. 1.

around 40% down to 10% over our multiplicity range. These efficiencies, which take the electronic efficiencies of the detectors in to account, have been determined to better than 10% relative error by implanting simulated Ξ s and $\bar{\Xi}$ s in real events of varying multiplicity and passing them through the reconstruction programs. The corrected $\bar{\Xi}^-$ to Ξ^- ratio is 0.39 ± 0.07 . It is worthwhile to note that this ratio is larger than usually predicted in complete reaction models (see for example [12]).

In conclusion, it is shown that Ξ^- and $\bar{\Xi}^-$ decays can be successfully reconstructed in the high multiplicity heavy ion environment with little background. In 200 GeV/c per nucleon $^{32}\text{S} - \text{W}$ interactions the corrected $\bar{\Xi}^-$ to Ξ^- ratio is 0.39 ± 0.07 in the rapidity interval $2.3 < Y_{lab} < 3.0$ and with $p_T > 1.1$ GeV/c.

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Figure Captions

Fig. 1 Example of a fully reconstructed event with a cascade candidate.

Fig. 2 Podolanski-Armenteros plot for V^0 candidates.

Fig. 3 Effective mass distributions for cascade candidates as

a) $\Lambda\pi^-$ and b) $\bar{\Lambda}\pi^+$.