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Ξ^-, $\overline{\Xi}^-$, Λ and $\overline{\Lambda}$ 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, $\overline{\Lambda}$s and Ξ^-s produced in sulphur-tungsten interactions at 200 GeV/c per nucleon and give the corrected ratios $\overline{\Lambda}/\Lambda$, Ξ^-/Λ and $\overline{\Xi}^-/\overline{\Lambda}$. Our ratio $\overline{\Xi}^-/\overline{\Lambda}$ appears to be larger than that from p p interactions.

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Hyperon production is expected to be a useful probe of the dynamics of hadronic matter under the extreme conditions realised in central heavy ion collisions [1]. In particular, the onset of a Quark-Gluon Plasma (QGP) phase during the collisions is expected to enhance the antihyperon yield with respect to normal hadronic interactions and to give rise to a 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 letter we present the transverse mass distributions for negative particles (mostly pions), Λs, $\overline{\Lambda}$s and Ξ^-s produced in S W interactions at 200 GeV/c per nucleon*. We give the $\overline{\Lambda}/\Lambda$, Ξ^-/Λ and $\overline{\Xi^-}/\overline{\Lambda}$ ratios, where the Λs ($\overline{\Lambda}$s) are corrected for contamination from Ξ ($\overline{\Xi}$) decays.

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 only a few 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, which select central collisions, have been discussed in a previous publication [4].

The method of reconstructing Λ [4] and Ξ^- [5] decays has already been given in previous publications. Figure 1 shows the mass distributions for Λ, $\overline{\Lambda}$, Ξ^- and $\overline{\Xi^-}$ candidates from the full statistics of our 1987 S W data (10 million triggers). We see clear peaks with little background at both Λ and Ξ^- masses and select Λ candidates in a 50 MeV mass interval centred on the Λ mass, giving 13,307 Λ and 3,407 $\overline{\Lambda}$ candidates, and Ξ^- candidates in a 100 MeV mass interval centred on the Ξ^- mass, giving 108 Ξ^- and 44 $\overline{\Xi^-}$ candidates. The full phase space window used for Λs and $\overline{\Lambda}$s is $2.3 < y_{lab} < 3.0$ and $0.9 < p_T < 2.8$ GeV/c; for Ξ^-s and $\overline{\Xi^-}$s it is $2.3 < y_{lab} < 3.0$ and $1.1 < p_T < 3.3$ GeV/c.

The Λ and $\overline{\Lambda}$ candidates include K^0_S contamination which is around 7% for Λs and

*Our Λ sample includes Λs from Σ^0 decays.

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. V^0s and cascades 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],

$$\frac{1}{m_T}\frac{dN}{dm_T} \sim e^{-\beta m_T} \tag{1}$$

where β is the inverse temperature of the source and m_T the transverse mass ($m_T = \sqrt{p_T^2 + m^2}$). In order to study m_T distributions we choose the narrow rapidity interval $2.4 < y_{lab} < 2.6$. The acceptance, integrated over p_T, varies little in this interval.

The negative particle, Λ , $\overline{\Lambda}$ [7] and Ξ^- data are well described by equation (1). The Λ ($\overline{\Lambda}$) samples contain a significant contribution from Ξ^- ($\overline{\Xi^-}$) and Ξ^0 ($\overline{\Xi^0}$) decays because the decay region is far from the target in our experiment [4,5]. The extent of this contamination is estimated by generating Monte Carlo Ξ^-s with a m_T distribution given by equation (1) with β fixed by the real Ξ^- data (see later) and a flat y_{lab} distribution. The number of Ξ^-s produced at the target in the window $2.4 < y_{lab} < 2.6$ and $1.1 < p_T < 3.3$ GeV/c is known from our corrected Ξ^- sample, and so the number of Monte Carlo Ξ^- decays generated can be normalised by this number. The Λs from these Monte Carlo Ξ^- decays are then passed through the full detector simulation, reconstructed and subjected to all the cuts performed on our real Λs . These Monte Carlo Λs are then corrected as if they were real Λs from the target and subtracted from our experimental sample. Contamination from Ξ^0s is calculated in the same way assuming that the number of Ξ^0s produced at the target is the same as for Ξ^-s . The result is that about 8% of our Λs come from Ξ^- decays and about 14% come from Ξ^0 decays giving a total contamination $C_\Lambda = 22 \pm 4$ % in our Λ sample.

Figure 2 a) shows $\frac{1}{m_T}\frac{dN}{dm_T}$ versus m_T for 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 to be

† where θ^* is defined as the angle between the line of flight of the V^0 and the decay (anti)proton in the V^0 rest frame.

about ± 15 MeV by simulation. We note from table 1 that all the slopes are compatible. The ratio Ξ^-/Λ in the overlapping m_T region $m_T > 1.72$ GeV is calculated to be $\Xi^-/\Lambda = 0.20 \pm 0.04$ where the error is dominated by statistics.

Our $\overline{\Xi}$ statistics does not allow us to estimate the $\overline{\Xi}$ contamination in the $\overline{\Lambda}$ sample and to compute the corrected $\overline{\Xi^-}/\overline{\Lambda}$ ratio by the method described above. Nevertheless, we can obtain such an estimate by using the Ξ contamination in the Λ sample, C_Λ, and the $\overline{\Lambda}/\Lambda$ ratio, R_Λ, evaluated in the interval $2.4 < y_{lab} < 2.6$. For this we assume

(i) the $\overline{\Xi^-}/\Xi^-$ ratio R_Ξ in this interval is 0.39 as determined in our full rapidity window ($2.3 < y_{lab} < 3.0$) and

(ii) the slopes of the m_T distributions for Ξ^- and $\overline{\Xi^-}$ are equal.

We then find

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

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

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

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

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

Figure 2 b) shows $\frac{1}{m_T}\frac{dN}{dm_T}$ versus m_T for $\overline{\Lambda}$s (corrected for contamination from $\overline{\Xi}$ decays by the method outlined above), negative particles (mostly pions) and Λs . The $\overline{\Lambda}$ distribution has an inverse slope of $1/\beta = 201 \pm 24 \pm 15$ MeV.

The ratios Ξ^-/Λ and $\overline{\Xi^-}/\overline{\Lambda}$ have been measured by other experiments [8,9,10] in p p, $\overline{\text{p}}$ p, and $e^+ e^-$ interactions. These results are for Ξ^- and Λ production selected by p_T, so in order to compare our results directly we must consider our ratios for a given p_T range. Table 2 shows our results, integrated over the p_T range $1 < p_T < 2$ GeV/c, together with those from p p collisions at $\sqrt{s} = 63$ GeV [8], $\overline{\text{p}}$ p collisions at $\sqrt{s} = 900$ GeV [9], and from $e^+ e^-$ collisions [10]. Contamination from Ξ decays in these experiments is expected to be negligible because their decay regions are close to the interaction point. These results are also shown in figure 3.

As can be seen from figure 3, our ratio Ξ^-/Λ is compatible with those from other interactions. However, the ratio $\overline{\Xi^-}/\overline{\Lambda}$ is about five times greater than that quoted by the AFS collaboration; this corresponds to a two standard deviation effect with the current statistics.

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

In table 3 we give the relative hyperon production ratios obtained in this paper and in previous publications [5]. The results indicate that our $\overline{\Xi^-}$ production rate, relative to $\overline{\Lambda}$, is enhanced with respect to p p interactions; this result is difficult to explain in terms of non-QGP models [11] or QGP models with complete hadronisation dynamics [12]. We note, however, that sudden hadronisation from QGP near equilibrium could reproduce this enhancement [2].

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

Particle	inverse slope (MeV)	statistical error (MeV)	systematic error (MeV)
negative	256	$\pm$ 3	$\pm$ 15
Λ	238	$\pm$ 9	$\pm$ 15
Ξ^-	233	$\pm$ 54	$\pm$ 15

Table 2: The ratios Ξ^- / Λ and $\overline{\Xi^-} / \overline{\Lambda}$ in the region $2.4 < y_{lab} < 2.6$ and $1 < p_T < 2$ GeV/c for central S W interactions. Also given are p p data at 63 GeV [8], $\overline{p}$ p data at 900 GeV [9], and data from $e^+ e^-$ experiments [10].

Exp.	int.	$\sqrt{s}$ (GeV)	p_T (GeV/c)	Ξ^- / Λ	$\overline{\Xi^-} / \overline{\Lambda}$
WA85	S W	19	1-2	0.11 $\pm$ 0.02	0.33 $\pm$ 0.11
AFS	p p	63	1-2		0.06 $\pm$ 0.02
UA5	$\overline{p}$ p	900	> 1	$0.07^{+0.08}_{-0.04}$	
TASSO	$e^+ e^-$	34.4	all p_T	0.09 $\pm$ 0.04	
MARK II		29.0		0.08 $\pm$ 0.03	
HRS		29.0		0.07 $\pm$ 0.03	
TPC		29.0		0.10 $\pm$ 0.05	
CLEO		10.38-10.64		0.07 $\pm$ 0.01	

Table 3: Summary of relative hyperon production rates from WA85

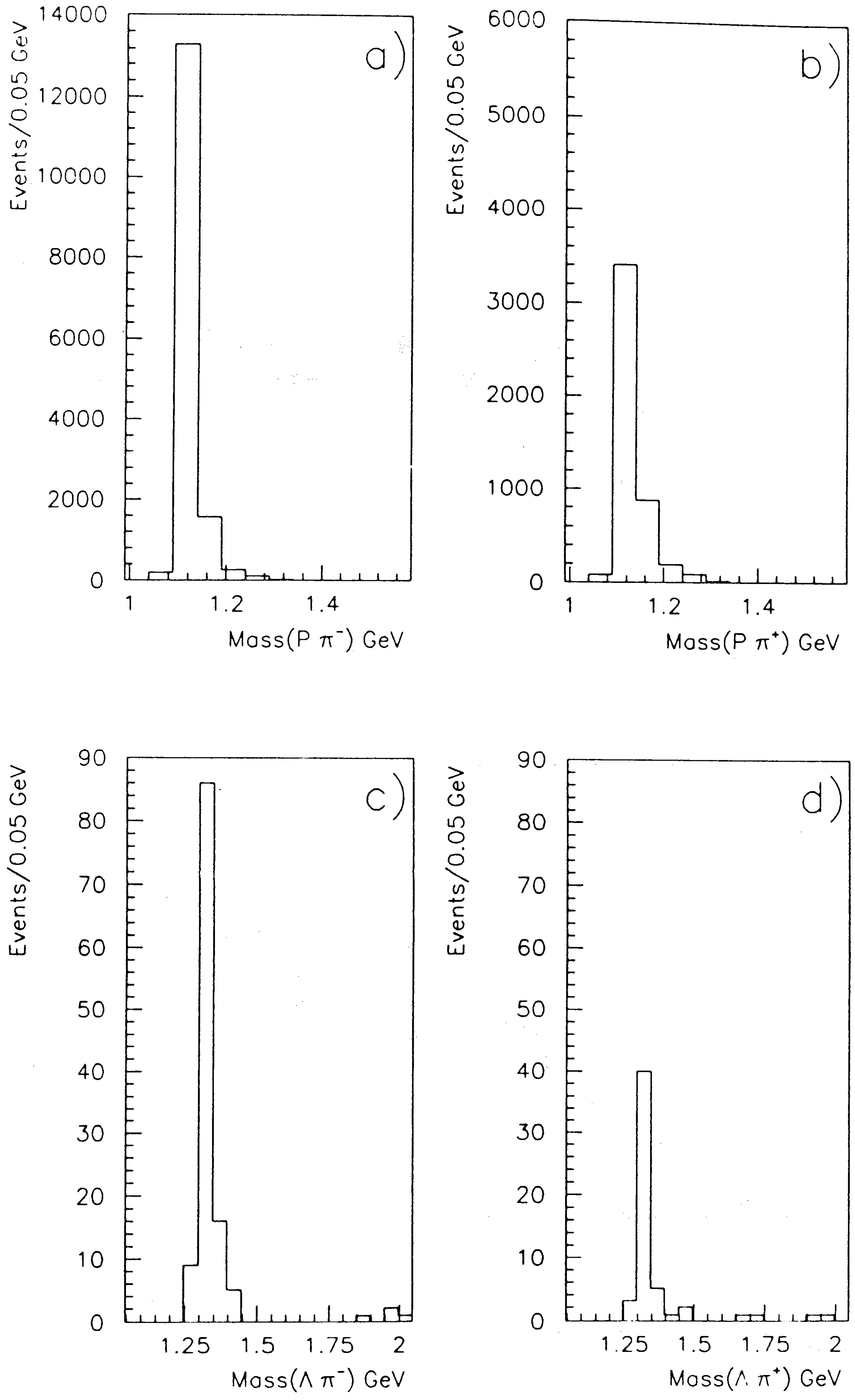
Ratio	$m_T > 1.72$ GeV	$1 < p_T < 2$ GeV/c
$\overline{\Lambda} / \Lambda$	0.13 $\pm$ 0.03	0.13 $\pm$ 0.03
$\overline{\Xi^-} / \Xi^-$	0.39 $\pm$ 0.07	0.39 $\pm$ 0.07
Ξ^- / Λ	0.20 $\pm$ 0.04	0.11 $\pm$ 0.02
$\overline{\Xi^-} / \overline{\Lambda}$	0.60 $\pm$ 0.20	0.33 $\pm$ 0.11

Figure Captions

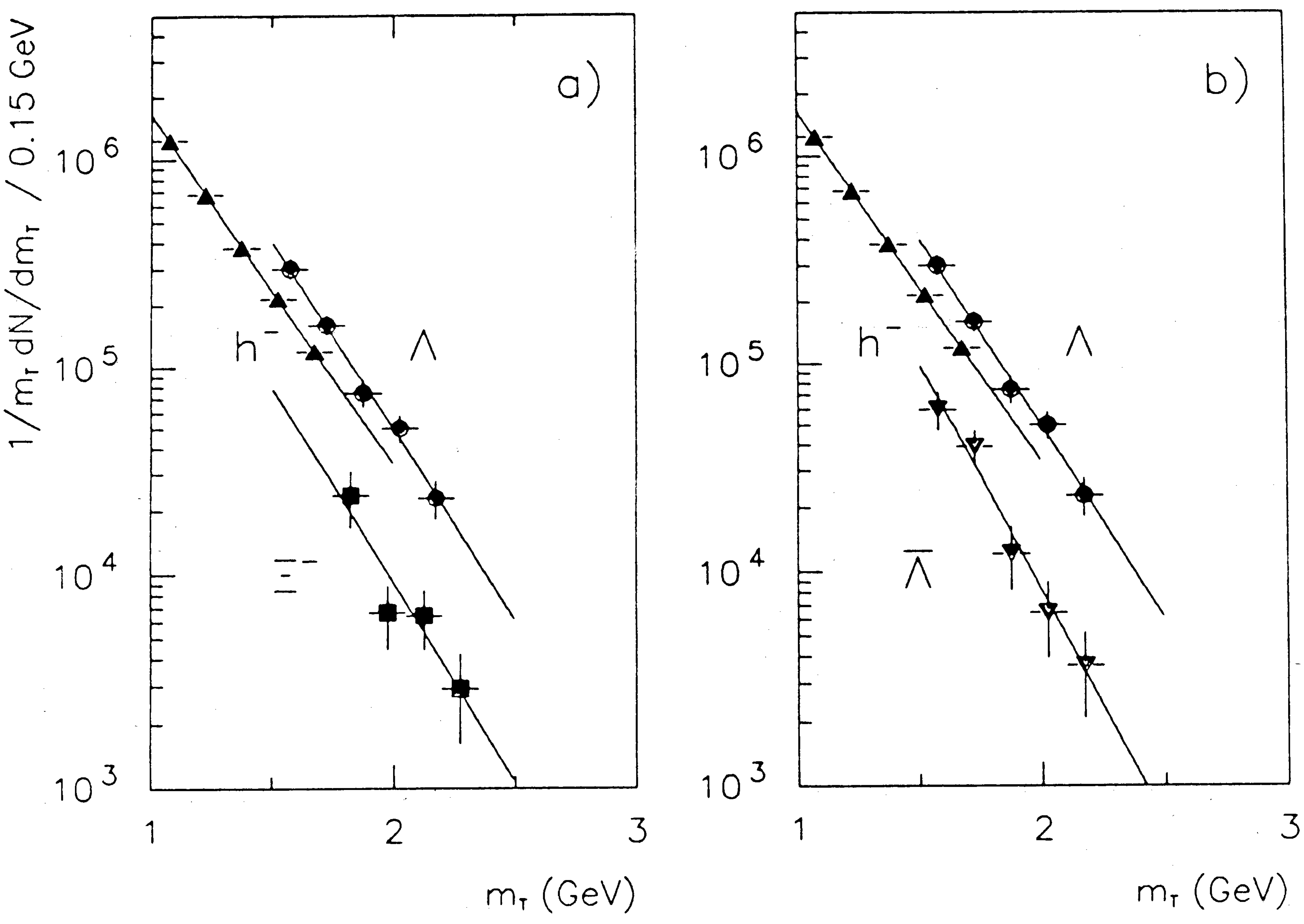
Fig. 1 Effective mass distributions for V^0 candidates as
a) $p\pi^-$ and b) $\overline{p}\pi^+$, and cascade candidates as
c) $\Lambda\pi^-$ and d) $\overline{\Lambda}\pi^+$.

Fig. 2 $\frac{1}{m_T}\frac{dN}{dm_T}$ vs m_T in arbitary units (bin size 0.15 GeV) for
a) negative particles, h^- (mostly π^-s), Λs and Ξ^-s .
b) negative particles, h^- (mostly π^-s), Λs and $\overline{\Lambda}$s .

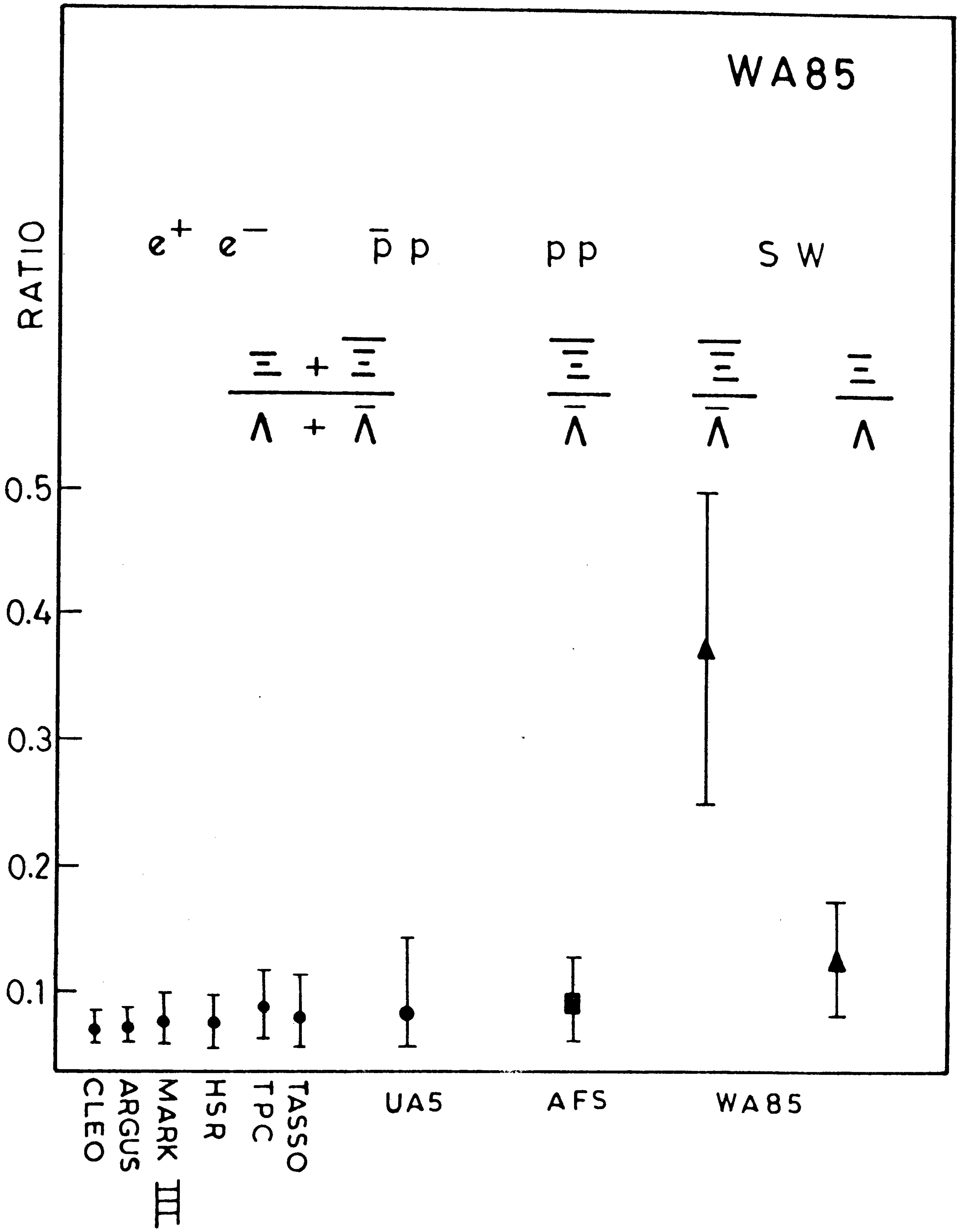
Fig. 3 Ξ^-/Λ and $\overline{\Xi^-}/\overline{\Lambda}$ ratios for different experiments



Events/0.05 GeV
14000
12000
10000
8000
6000
4000
2000
0
a)
1
1.2
1.4
Mass(P π^-) GeV
Events/0.05 GeV
6000
5000
4000
3000
2000
1000
0
b)
1
1.2
1.4
Mass(P π^+) GeV
Events/0.05 GeV
90
80
70
60
50
40
30
20
10
0
c)
1.25
1.5
1.75
2
Mass($\Lambda\,\pi^-$) GeV
Events/0.05 GeV
90
80
70
60
50
40
30
20
10
0
d)
1.25
1.5
1.75
2
Mass($\Lambda\,\pi^+$) GeV



1/m_T dN/dm_T / 0.15 GeV
10^6
10^5
10^4
10^3
a)
b)
h^-
Λ
Ξ^-
Λ̄
1
2
3
m_T (GeV)
m_T (GeV)



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