

Results on Λ and Ξ production in Pb-Pb collisions at 160 GeV/ c per nucleon from the NA57 experiment

Presented by G.E. Bruno for the NA57 Collaboration:

F. Antinori^l, A. Badalà^g, R. Barbera^g, A. Belogianni^a, A. Bhasin^e, I.J. Bloodworth^e, G.E. Bruno^b, S.A. Bull^e, R. Caliandro^b, M. Campbell^h, W. Carena^h, N. Carrer^h, R.F. Clarke^e, A. Dainese^l, A.P. de Haas^s, P.C. de Rijke^s, D. Di Bari^b, S. Di Liberto^o, R. Divia^h, D. Elia^b, D. Evans^e, K. Fanebust^c, F. Fayazzadeh^k, J. Fedorisin^j, G.A. Feofilov^q, R.A. Fini^b, J. Ftáčnik^f, B. Ghidini^b, G. Grella^p, H. Helstrup^d, M. Henriquez^k, A.K. Holme^k, A. Jacholkowski^b, G.T. Jones^e, P. Jovanovic^e, A. Juskoⁱ, R. Kamermans^s, J.B. Kinson^e, K. Knudson^h, A.A. Kolojvari^q, V. Kondratiev^q, I. Králikⁱ, A. Kravcakova^j, P. Kuijter^s, V. Lenti^b, R. Lietava^f, G. Løvholden^k, M. Luptákⁱ, V. Manzari^b, G. Martinska^j, M.A. Mazzoni^o, F. Meddi^o, A. Michalon^r, M. Morando^l, D. Muigg^s, E. Nappi^b, F. Navach^b, P.I. Norman^e, A. Palmeri^g, G.S. Pappalardo^g, B. Pastircákⁱ, J. Pisut^f, N. Pisutova^f, F. Posa^b, E. Quercigh^l, F. Riggi^g, D. Röhrich^c, G. Romano^p, K. Šafařík^h, L. Šándorⁱ, E. Schillings^s, G. Segato^l, M. Senè^m, R. Senè^m, W. Snoeys^h, F. Soramel^l, M. Spyropoulou-Stassinaki^a, P. Starobaⁿ, T.A. Toulina^q, R. Turrisi^l, T.S. Tveter^k, J. Urbán^j, F.F. Valiev^q, A. van den Brink^s, P. van de Ven^s, P. Vande Vyvre^h, N. van Eijndhoven^s, J. van Hunen^h, A. Vascotto^h, T. Vik^k, O. Villalobos Baillie^e, L. Vinogradov^q, T. Virgili^p, M.F. Votruba^e, J. Vrláková^j and P. Závadaⁿ

^a *Physics Department, University of Athens, Athens, Greece*

^b *Dipartimento IA di Fisica dell'Università e del Politecnico di Bari and INFN, Bari, Italy*

^c *Fysisk Institutt, Universitetet i Bergen, Bergen, Norway*

^d *Høgskolen i Bergen, Bergen, Norway*

^e *University of Birmingham, Birmingham, UK*

^f *Comenius University, Bratislava, Slovakia*

^g *University of Catania and INFN, Catania, Italy*

^h *CERN, European Laboratory for Particle Physics, Geneva, Switzerland*

ⁱ *Institute of Experimental Physics, Slovak Academy of Science, Košice, Slovakia*

^j *P.J. Šafařík University, Košice, Slovakia*

^k *Fysisk Institutt, Universitetet i Oslo, Oslo, Norway*

^l *University of Padua and INFN, Padua, Italy*

^m *Collège de France, Paris, France*

ⁿ *Institute of Physics, Prague, Czech Republic*

^o *University "La Sapienza" and INFN, Rome, Italy*

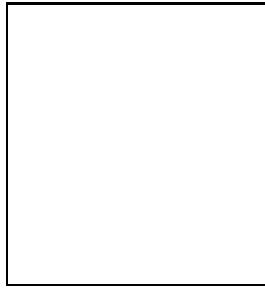
^p *Dipartimento di Scienze Fisiche "E.R. Caianiello" dell'Università and INFN, Salerno, Italy*

^q *State University of St. Petersburg, St. Petersburg, Russia*

^r *Institut de Recherches Subatomique, IN2P3/ULP, Strasbourg, France*

^s *Utrecht University and NIKHEF, Utrecht, The Netherlands*

The NA57 experiment has been designed to study the onset of enhanced production of strange baryons and anti-baryons in Pb-Pb collisions with respect to p-Be collisions. This enhancement is considered a sensitive signature for a phase transition to a new state of matter – the Quark Gluon Plasma (QGP). In this paper, we report results on Λ and Ξ hyperon production in central Pb-Pb collisions at 160 GeV/ c per nucleon beam momentum.



1 Introduction

The WA97 experiment at the CERN SPS has observed strange baryon and antibaryon enhancements in Pb-Pb collisions with respect to p-Be collisions at 160 A GeV/c¹. The enhancement increases with the strangeness content of the hyperon. Such a behaviour has been predicted as a consequence of the QGP phase transition².

The aim of the NA57 experiment, which continues and extends the measurements of WA97, is to study the dependence of the enhancement (*i*) on the interaction volume and (*ii*) on the collision energy per incoming nucleon³. For the first purpose NA57 can extend the centrality range to more peripheral collisions with respect to WA97; for the second one the experiment has collected data using both 160 and 40 A GeV/c beams at the CERN SPS.

2 The NA57 experiment

The NA57 apparatus has been described in details elsewhere⁴. The tracking device consists of a telescope made of 13 planes of silicon pixel detectors, with a sensitive area of about 5 × 5 cm². The telescope is placed inside a uniform 1.4 T magnetic field, 60 cm downstream of the lead target, inclined with respect to the beam line and pointing to the target to accept particles produced at central rapidity.

Strange and multi-strange hyperons are identified by reconstructing their weak decays into final states containing only charged particles, e.g.: $\Xi^- \rightarrow \Lambda\pi^-$, with $\Lambda \rightarrow \pi^-p$.

The centrality of the Pb-Pb collisions is determined by analyzing the charged particle multiplicity measured in the pseudorapidity interval $2 < \eta < 4$ by two stations of silicon strip detectors. An array of scintillator counters, placed 10 cm downstream of the target, provides a signal to trigger on the centrality of the collisions. The most central 60% of the total inelastic cross section has been selected in Pb-Pb interactions at 160 A GeV/c.

To study the strange baryon and anti-baryon production at a lower center of mass energy, the experiment has also collected data at 40 A GeV/c beam momentum on both Pb-Pb and p-Be collisions. Reference data on p-Be and p-Pb at 160 GeV/c are available from the WA97 measurements.

The results on Ξ^- , Ξ^+ , Λ and $\bar{\Lambda}$ particles reported in this paper have been obtained analyzing the Pb-Pb data sample at 160 A GeV/c collected in 1998. A second sample of Pb-Pb data at 160 A GeV/c has been collected in year 2000: the 1998 and 2000 data sets together will allow to study the more rare Ω signal and to double the present statistics for Ξ^- and Ξ^+ .

3 Data analysis and results

The hyperon signals are extracted on the basis of kinematical selections with the same method used in the WA97 experiment⁵. Fig.1 shows the proton-pion and the lambda-pion invariant mass distributions after all the selection cuts and the corresponding kinematic windows (enclosed area) selected in the y - p_T distributions of the reconstructed particles.

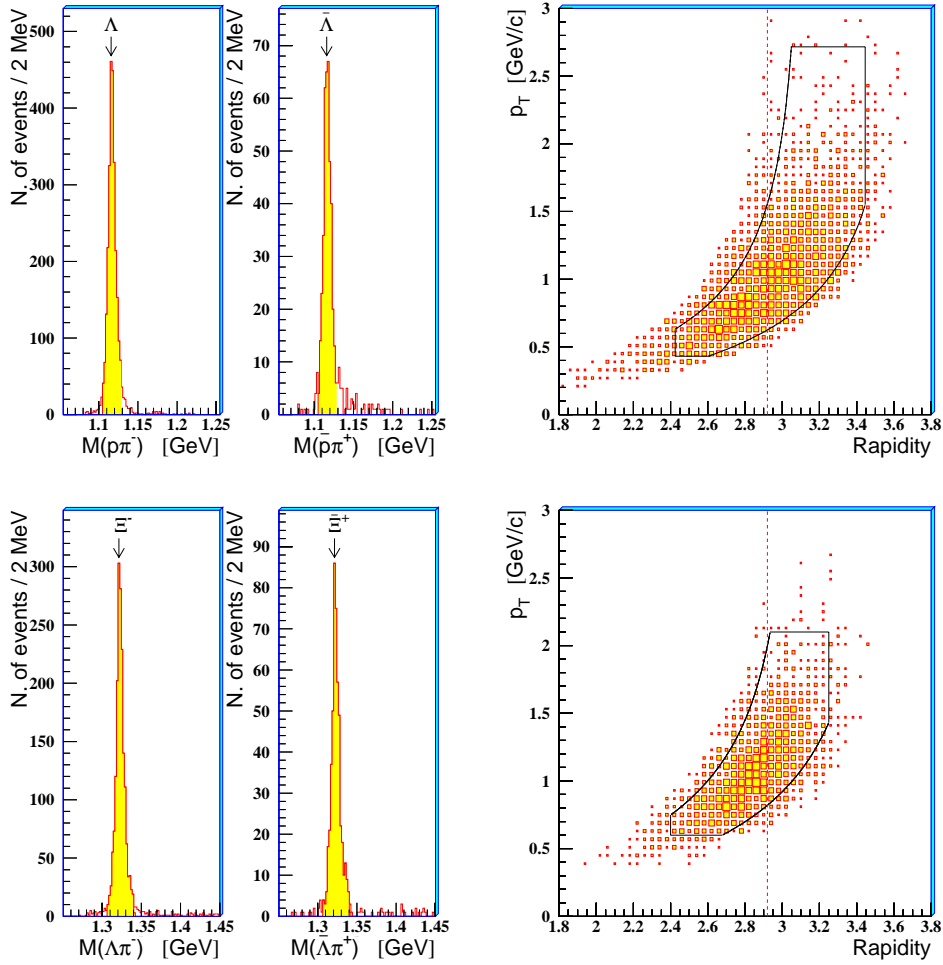


Figure 1: Proton-pion (**top**) and lambda-pion (**bottom**) invariant mass distributions (**left**) and corresponding p_T versus rapidity distributions (**right**). Respectively, the 86% and 79% of the reconstructed Λ s and Ξ s falls within the selected acceptance window (enclosed area).

In the y - p_T distribution the central rapidity is highlighted with a dashed line on the acceptance window. The mass spectra for Λ and Ξ are centered at the nominal value and the FWHM is about 5 MeV and 8 MeV, respectively. Although the mass spectra show very low background, a detailed study of the residual combinatorial background has been performed using the method of *event mixing*. Fake Λ s are built by pairing all the negative charged particles from one event with all the positive ones from a different event, selecting events which are close in multiplicity. Then the fake Λ s from mixed events are processed with the standard NA57 reconstruction program. With this method any signal from a real neutral particle decaying in two oppositely charged particles (e.g. $\Lambda \rightarrow \pi p$, $K_S^0 \rightarrow \pi^- \pi^+$, γ conversion) is removed and what remains is the combinatorial background. The absolute normalization is based on the number of pairs of oppositely charged particles in real and mixed events. The mixed event sample describes very well the residual background in the physical distributions from real events where no signal is expected. As an example, Fig. 2 shows the $p\pi$ invariant mass distribution for real and mixed events *before* (left) and *after* (right) all the analysis cuts have been applied. The agreement in these distributions and in others, not shown here (e.g. the closest distance in space between the extrapolated π and proton tracks coming from the decay, the π and proton impact parameter^a,

^aThe impact parameter is defined as the distance (perpendicular to the beam direction) between the extrapo-

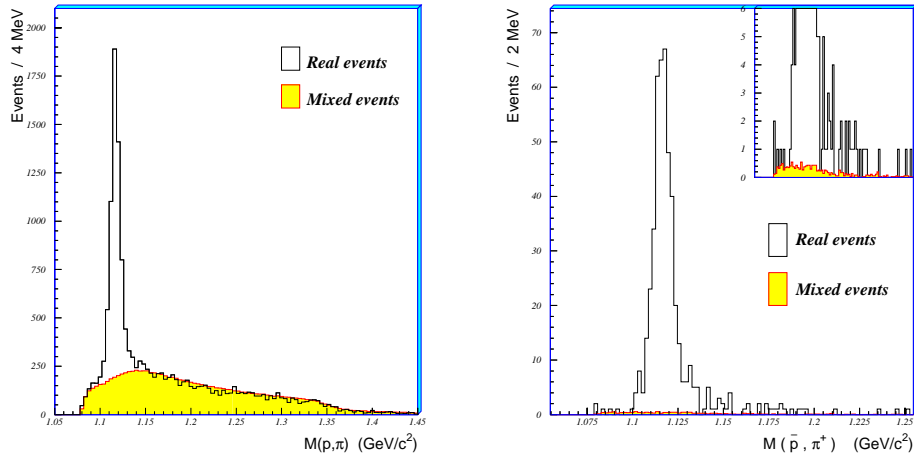


Figure 2: Comparison between real and mixed events for the $p\pi$ invariant mass distribution before analysis cuts (left panel, both Λ and $\bar{\Lambda}$) and after analysis cuts (right panel, $\bar{\Lambda}$ particles only). The insert in the right panel is a zoom on the vertical axis.

etc.), in regions far from any physical signal, gives confidence in the method. The total amount of combinatorial background is estimated to be about 0.3% for Λ and 1.0% for $\bar{\Lambda}$ and therefore can be safely neglected. The estimate of the total Ξ background, evaluated with a similar technique, is less than 4%.

The standard NA57 method to correct for acceptance and efficiency losses, consists of calculating a weight for each particle using the following procedure⁶:

- Monte Carlo particles are generated and traced through the apparatus by GEANT⁷ with the transverse momentum and rapidity of each observed particle;
- the hits of the Monte Carlo tracks are embedded into real events to account for background tracks and electronic noise;
- these events are reconstructed and processed by the same analysis programs used for real data and the weight is calculated as the ratio of the number of generated Monte Carlo particles to the number of particles selected by the analysis programs.

All the reconstructed Ξ^- s and Ξ^+ s from the 1998 data sample have been corrected with the above method; for the more abundant Λ s and $\bar{\Lambda}$ s only a fraction of the full available statistics, respectively 1/200 and 1/25, has been individually weighted due to the very CPU-time consuming method.

As a measure of centrality we use the number of wounded nucleons, i.e. the nucleons which take part in the initial collisions⁸. The multiplicity distribution is divided into five centrality classes (0, I, II, III, IV), class 0 being the most peripheral ($\langle N_{wound} \rangle = 62$) and class IV the most central ($\langle N_{wound} \rangle = 349$). The method to calculate the number of wounded nucleons is described elsewhere⁹.

The transverse mass distributions have been parametrized as:

$$\frac{d^2N}{dm_T dy} = A m_T \exp\left(-\frac{m_T}{T}\right) \quad (1)$$

and the inverse slopes T have been extracted by means of a maximum likelihood fit method. In Table 1 the inverse slopes for Ξ^- and Ξ^+ and the preliminary results for Λ and $\bar{\Lambda}$ are presented. The values are found to be compatible for particles and their anti-particles, and with the WA97

lated lines of flight of the decay particles and the primary vertex position.

Table 1: Inverse slopes T (MeV) in the full centrality range (**0-IV**) and in different centrality classes.

	0-IV	0	I	II	III	IV
Λ	284 ± 6	258 ± 19	261 ± 11	276 ± 11	313 ± 13	310 ± 15
$\bar{\Lambda}$	287 ± 6	274 ± 18	258 ± 10	279 ± 10	307 ± 13	309 ± 14
Ξ^-	303 ± 11					
Ξ^+	321 ± 23					

ones. We observe a slight increase of Λ and $\bar{\Lambda}$ slopes with centrality, while no significant variation is observed¹⁰ for Ξ^- and Ξ^+ within the present statistics.

By integrating Eq. 1 over one unit of rapidity and extrapolating to $p_T = 0$, the particle yields over the whole p_T range are computed according to the following expression

$$Yields = \int_m^\infty dm_T \int_{y_{cm}-0.5}^{y_{cm}+0.5} dy \frac{d^2 N}{dm_T dy} \quad (2)$$

where m is the mass of the particle.

In Fig.3 the NA57 yields per participant in Pb-Pb at 160 A GeV/c relative to the p-Be ones from WA97 are shown (open symbols) for Ξ^- , Ξ^+ , Λ and $\bar{\Lambda}$ in the five centrality classes, i.e. as a function of the centrality of the collision.

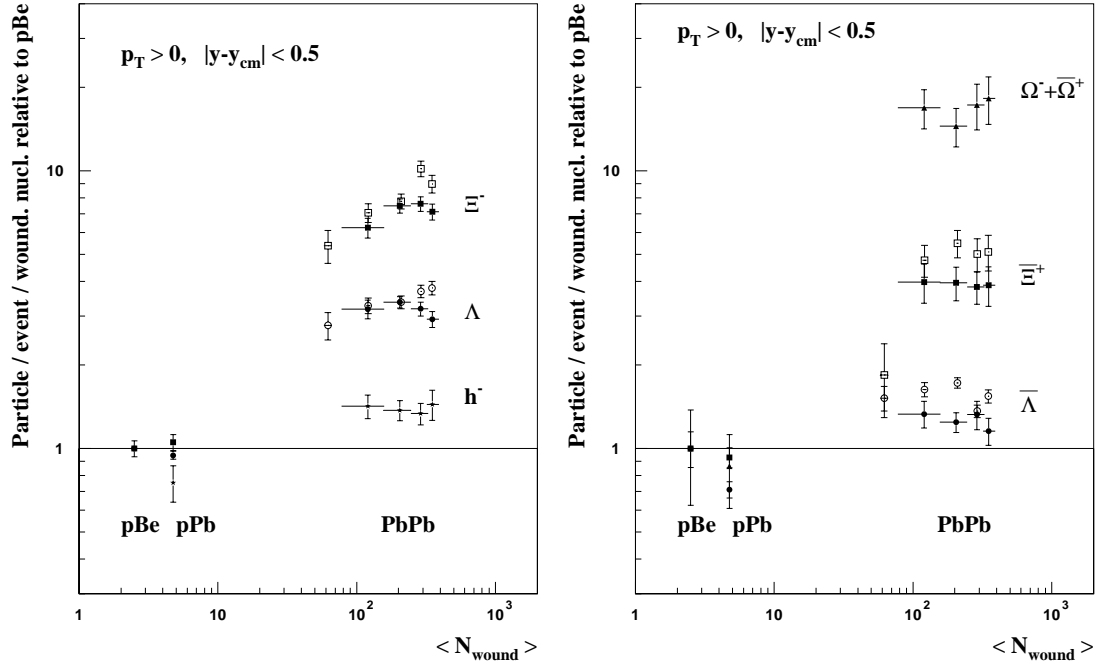


Figure 3: Yields per wounded nucleon relative to p-Be from WA97 for all measured particles (closed symbols) and from NA57 for Ξ^- , Ξ^+ , Λ and $\bar{\Lambda}$ (open symbols). NA57 Λ and $\bar{\Lambda}$ yields are preliminary.

The WA97 results are also reported in Fig.3 using closed symbols. NA57 results confirm that the strange particle yields per participant are enhanced in Pb-Pb collisions with respect to p-A reference collisions. In particular, in the common centrality range the NA57 yields tend to be larger than WA97 by up to 20-30% for Ξ^+ and $\bar{\Lambda}$. To understand these differences extended checks have been carried on for Ξ^{11} : the outcome gives us confidence in the NA57 results. Similar checks are ongoing for the Λ hyperon. Ξ^- , Ξ^+ and Λ yields per wounded nucleon drop when going from $\langle N_{wound} \rangle = 121$ to $\langle N_{wound} \rangle = 62$, i.e. from class I to class 0; the maximum effect is observed for the Ξ^+ particle and it corresponds to a 3.5σ effect.

4 Conclusions and outlook

Results from NA57 on Λ and Ξ production in Pb-Pb collisions at 160 A GeV/c have been reported. The Ξ^- , Ξ^+ and Λ yields per wounded nucleon in the most peripheral bin drop significantly (up to a 3.5 σ effect for Ξ^+) which might indicate the onset of the QGP phase transition. The ongoing data analysis will soon provide results on the rare Ω particle production at 160 A GeV/c and the full pattern of strange particle enhancements at 40 A GeV/c.

References

1. R.A. Fini *et al.*, *J. Phys. G: Nucl. Phys.* **27**, 375 (2001).
F. Antinori *et al.*, *Nucl. Phys. A* **661**, 130c (1999).
2. J. Rafelski and B. Müller, *Phys. Rev. Lett.* **48**, 1066 (1982).
3. R. Caliendo *et al.*, NA57 Proposal, CERN/SPSLP 96-40, SPSLC/P300.
4. T. Virgili *et al.*, *Nuclear Physics A* **681**, 165 (2001).
5. I. Kralik *et al.*, *Nucl. Phys. A* **638**, 5c (1998).
6. F. Antinori *et al.*, *Eur. Phys. J. C* **14**, 633 (2000).
7. R. Brun *et al.*, *GEANT3* CERN program library Q123.
8. C.Y. Wong in *Introduction to High-Energy Heavy-Ion Collisions* (World Scientific, Singapore, 1994) p 251 , and references therein.
9. N. Carrer *et al.*, *J. Part. Phys. G: Nucl. Part. Phys.* **27**, 391 (2001).
10. N. Carrer *et al.*, *Nucl. Phys. A* **698**, 118 (2002).
11. K. Fanebust *et al.*, *J. Part. Phys. G: Nucl. Part. Phys.* **28**, 1607 (2002).