Results on Hyperon Production from CERN NA57 Experiment

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Abstract. NA57 has been specifically designed to study the onset of strange baryon and antibaryon enhancements in Pb-Pb with respect to p-Be collisions, first observed by the WA97 experiment at 160 A GeV/*c* beam momentum. The aim is to look for the dependence of these enhancements on the interaction volume, as measured by the number of wounded nucleons, and the energy per incoming nucleon. In NA57 the centrality range goes down to a lower limit of about 50 wounded nucleons, compared with about 100 in WA97. Data have been collected both at 160 and at 40 A GeV/*c*, while WA97 collected data only at the top SPS beam momentum of 160 A GeV/*c*. In this contribution we recall the main features of the NA57 experiment and we present the first results on Ξ^- and $\overline{\Xi}^+$ hyperon production in Pb-Pb collisions at 160 A GeV/c.

INTRODUCTION

The WA97 experiment at CERN SPS has measured an enhancement of strange and multi-strange baryon and anti-baryon yields at midrapidity when going from p-Be to central Pb-Pb collisions at 160 A GeV/*c* [1].

Fig. 1 shows the WA97 yields per wounded nucleon per unit of rapidity at mid rapidity relative to p-Be for negative particles, Λ, Ξ^-, Ω^- and their antiparticles, as functions of the average number of wounded nucleons for p-Be, p-Pb and Pb-Pb collisions. The Pb-Pb data are divided in four centrality classes according to the number of wounded nucleon. Wounded nucleons are those nucleons both from projectile and target which undergo at least one primary inelastic scattering with another nucleon. All yields are extrapolated to a common phase space window, covering full p_T and one unit of rapidity centred at midrapidity.

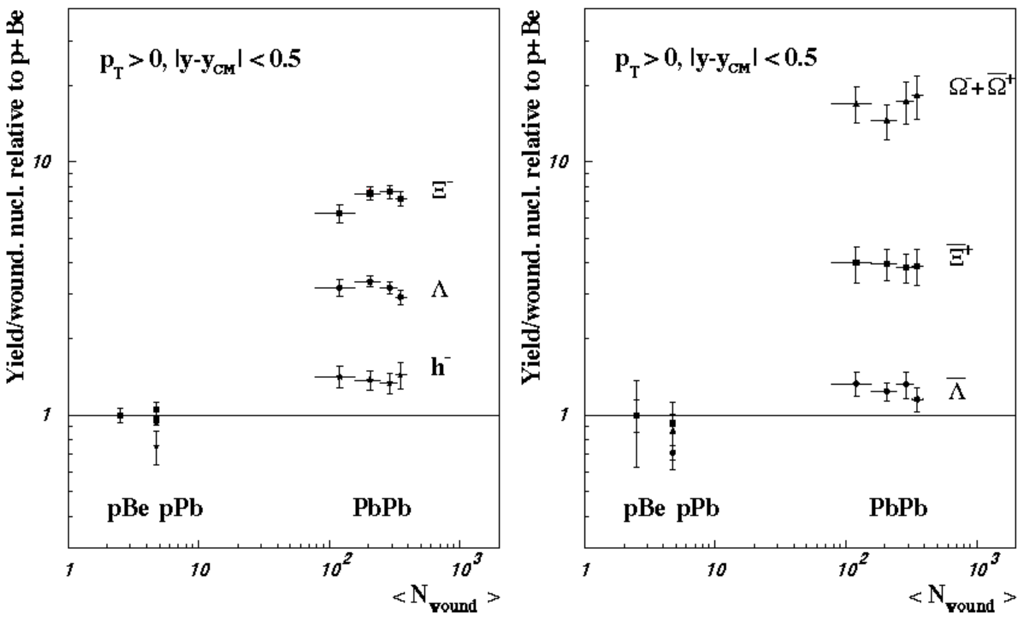

FIGURE 1. WA97 particle yields per unit of rapidity at central rapidity per wounded nucleon relative to p-Be yields, as functions of the number of wounded nucleons. The line refers to a yield proportional to the number of participants crossing the p-Be common point.

The horizontal bars of Pb-Pb points (yields) represent the FWHM of the distribution of the number of nucleons taking part to the collision in the four multiplicity classes.

Particles are divided in two groups: those with at least one valence quark in common with the nucleon (left) and those with no valence quark in common with the nucleon (right). We have kept them separate since it is empirically known that they may exhibit different production features, e.g.: Λ and $\overline{\Lambda}$ have different rapidity distributions both in p-S and S-S data [2].

From Fig. 1 one can observe that:

- while the yields per wouded nucleon have similar values in p-Be and p-Pb collisions for all the particles under study, they are found to be enhanced when going from p-A to Pb-Pb collisions. The horizontal line at 1 points out where Pb-Pb yields would have been in case of no enhancement;

- the enhancement is progressively stronger for the hyperons of higher strangeness content ($\Omega > \Xi > \Lambda$), up to a factor about 15 for $\Omega^- + \overline{\Omega}^+$;
- the yields per wounded nucleon appear to be rather constant within the centrality range covered by WA97, i.e. $<N_{wound}> > 100$.

All these features cannot be explained by any current conventional hadronic microscopic model [3], while they nicely fulfil the predictions of a Quark Gluon Plasma phase transition in Pb-Pb collisions[4].

The picture emerging from the above results has led most of the WA97 Collaboration to carry on the study in order to search for an onset of the observed strangeness enhancement effect. In order to address the question of where the deconfinement sets in, a new experiment at the SPS, NA57, has been specifically designed to: a) extend the centrality range of Pb-Pb collisions at 160 A GeV/*c*; b) measure the pattern of multi-strange hyperon production as a function of the beam energy.

THE NA57 EXPERIMENT

The NA57 experiment has been designed for the systematic measurement of strange and multi-strange hyperon and anti-hyperon decays at central rapidity and medium p_T in A-A and p-A collisions. The NA57 layout, very similar to WA97, is outlined in Fig. 2, and has been described in details in[5,6].

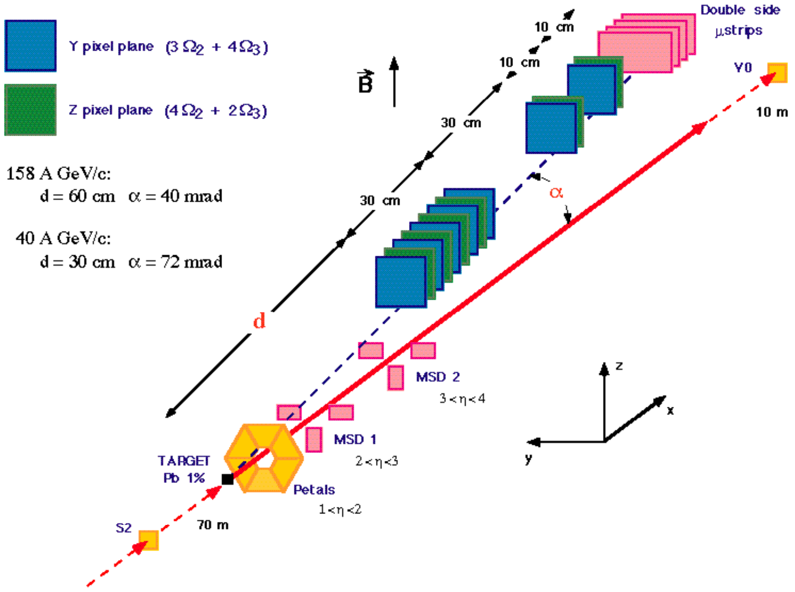

FIGURE 2. A schematicview of the NA57 layout (not to scale).

Tracks are reconstructed in a telescope tracker made of silicon pixel detectors, placed inside a 1.4 T magnetic field. Strange and multi-strange particles are identified by reconstructing their weak decays into final states containing only charged particles, e.g.:

$$\Lambda \rightarrow p + \pi^- \qquad + \text{c.c.}$$

$$\Xi^- \rightarrow \Lambda + \pi^- \qquad + \text{c.c.}$$
$$\hookrightarrow p + \pi^-$$

$$\Omega^- \rightarrow \Lambda + K^- \qquad + \text{c.c.}$$
$$\hookrightarrow p + \pi^-$$

The telescope is inclined above the beam line in order to accept particles produced in the target at central rapidity and medium transverse momentum: the full acceptance coverage is about one unit of rapidity around midrapidity and is the same for particles and anti-particles [3].

The centrality of the Pb-Pb collisions is determined by analyzing the charged particle multiplicity measured by the multiplicity strip detector (MSD) in the pseudorapidity interval $2<\eta<4$. The scintillator petals, placed 10 cm downstream the target, provide a signal to trigger on the centrality of the collision.

The sample of data collected by NA57 are reported in Table 1.

Table 1. Samples of data collected by NA57

System	Beam momentum	Sample size (trigger x 10^6)	Data taking year
Pb-Pb	160 A GeV/*c*	230	1998
		230	2000
Pb-Pb	40 A GeV/*c*	260	1999
p-Be	40 GeV/*c*	60	1999
		110	2001

The 160 A GeV/*c* Pb-Pb data will provide information on the hyperon production at lower centrality with respect to WA97.

The 40 A GeV/*c* Pb-Pb sample of data allows to study the strange baryon and anti-baryon production at lower center of mass energy: for instance, a significantly lower enhancement at 40 A GeV/*c* than at 160 A GeV/*c* would suggest the onset of deconfinement to be in between the two energies. The p-Be reference data at 40 GeV/c have been taken in the same condition for comparison with lead data at the same energy.

DATA ANALYSIS

Pb-Pb events are fully reconstructed and hyperon signals are extracted on the basis of kinematical selections with the same method used in WA97 [7].

Fig. 3 shows Ξ^- and $\overline{\Xi}^+$ signals from the whole Pb-Pb data sample at 40 A GeV/c and the relative y-p_T acceptance window.

Fig. 4 shows the Ξ^- and $\overline{\Xi}^+$ signals from the whole Pb-Pb data sample at 160 A GeV/c from the 1998 run and the relative $y - p_T$ acceptance window.

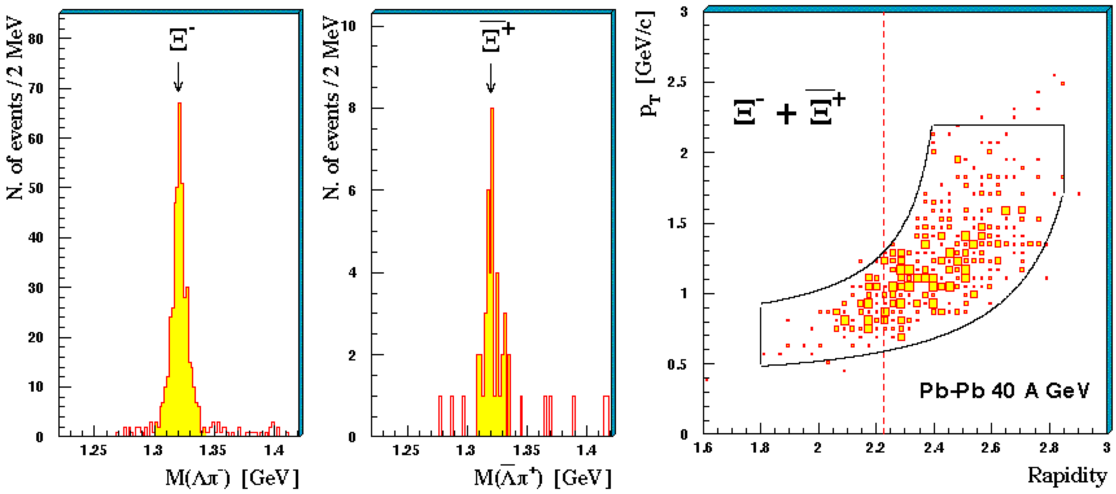

FIGURE 3. Ξ^- and $\overline{\Xi}^+$ signals for Pb-Pb collisions at 40 A GeV/c (left) and the corresponding y-p_T acceptance window.

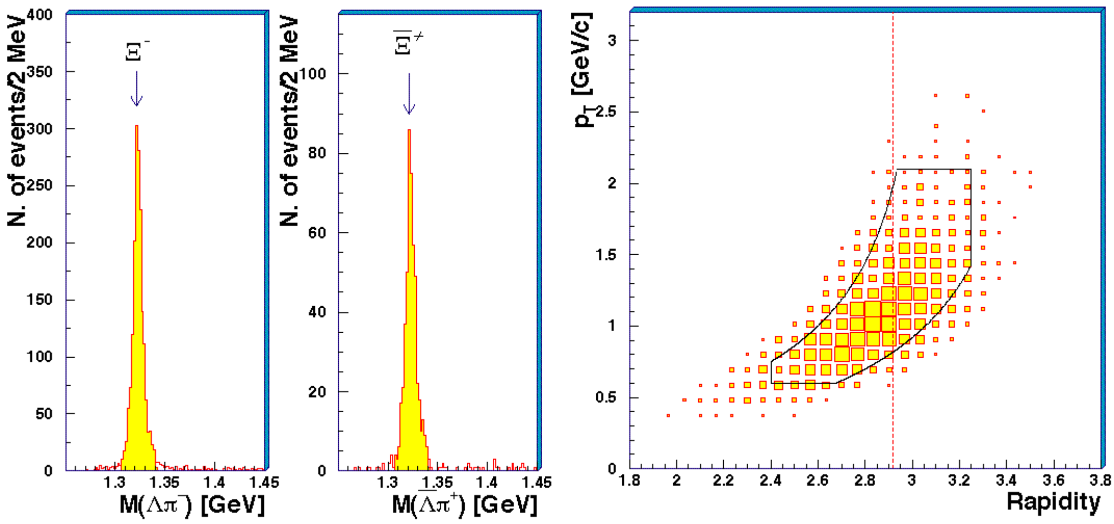

FIGURE 4. Ξ^- and $\overline{\Xi}^+$ signals for Pb-Pb collisions at 160 A GeV/c (left) and the corresponding y-p_T acceptance window.

In both figures the central rapidity is highlighted with a dashed line on the acceptance window. Due to the symmetry of the colliding system data can be reflected around midrapidity. The mass spectra for Ξ^- and $\overline{\Xi}^+$ are centered at the nominal value and show very low background: the FWHM is about 15 MeV at 40 A GeV/c and 10 MeV at 160 A GeV/c. Compared with the 160 A GeV/c data, one can observe that the production cross sections for hyperons and in particular anti-hyperons are significantly lower at 40 A GeV/c.

Since the enhancements observed by WA97 increase with the strangeness content of the particle, we started the analysis from cascades. In Pb-Pb events at 160 A GeV/c clear Ξ and Ω signals are visible in the correlation of the $\Lambda\pi$ and ΛK invariant masses, after preliminary analysis cuts, as shown in Fig. 5.

The Ξ^- and $\overline{\Xi}^+$ yields with the available statistics allows a study of the enhancement dependence on the collision centrality down to $N_{wound} \approx 50$. When the data sample from year 2000 data taking will be available for the analysis, the same kind of study will be feasible for the more rare Ω signal.

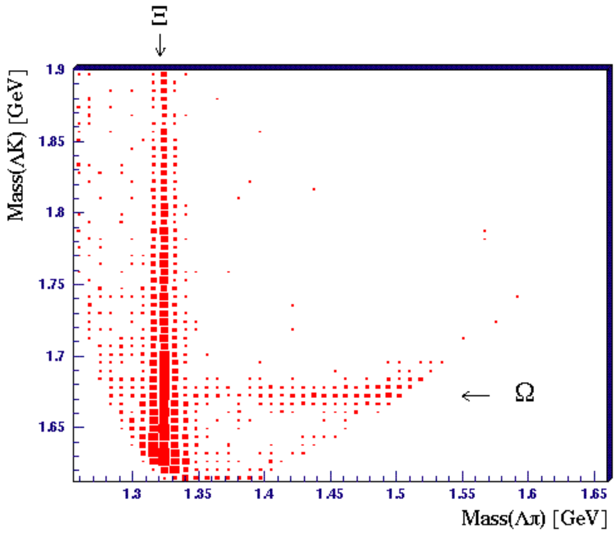

FIGURE 5. Scatter plot of ΛK versus $\Lambda\pi$ invariant mass for Pb-Pb collisions at 160 A GeV/*c*.

Data are corrected for geometrical acceptance, detector efficiency and reconstruction efficiency: a weight is calculated for each observed particle by a MonteCarlo simulation based on GEANT, as in WA97 [7].

The particle yields on the whole transverse momentum (p_T) range are calculated by integrating the transverse mass ($m_T = \sqrt{m^2 + p_T^2}$) distribution over one unit of rapidity and extrapolating to $p_T = 0$, according to the following formula:

$$Yield = \int_m^\infty dm_T \int_{y_{cm}-0.5}^{y_{cm}+0.5} dy \frac{d^2N(m_T, y)}{dm_T dy} \tag{1}$$

where the (m_T, y) distributions of identified hyperons are parametrized as

$$\frac{d^2N(m_T, y)}{dm_T dy} = f(y) m_T \exp\left(-\frac{m_T}{T}\right) \tag{2}$$

In equation (2) the rapidity function *f(y)* is assumed to be constant in the acceptance region of the experiment and the inverse slope parameter *T* is evaluated by a maximum likelihood fit [8].

Ξ AND ANTI-Ξ YIELDS AT 160 A GEV/C

As mentioned in the Introduction, NA57 aims to study the enhancement as a function of the interaction volume, as measured by the number of nucleons taking part in the collision, i.e. wounded nucleons.

In order to enlarge the centrality range covered by WA97 to more peripheral collisions, special efforts were made in NA57 to reduce background sources. The NA57 charged particle multiplicity distribution measured in the pseudorapidity range $2<\eta<4$ is shown in Fig. 6. About the most central 60% of the total inelastic cross section was selected in NA57, to be compared with 40% in WA97. The drop in the multiplicity distribution at very low values is the effect of the centrality trigger applied to collect data, which suppresses low multiplicity events.
The multiplicity distribution is described in the framework of the Wounded Nucleon Model (WNM) [9]: the number of wounded nucleons is estimated from the trigger cross section using a Glauber model [10]. The Pb-Pb data sample is divided in 5 classes of multiplicity and the average number of wounded nucleons is determined for each class. The four most central classes (I to IV) are the same used in WA97 analysis, while the extended centrality range of NA57 allows to define one more peripheral class 0. The distribution of wounded nucleons for the five multiplicity classes is also shown in Fig. 6: for the new class 0 the average is 62.

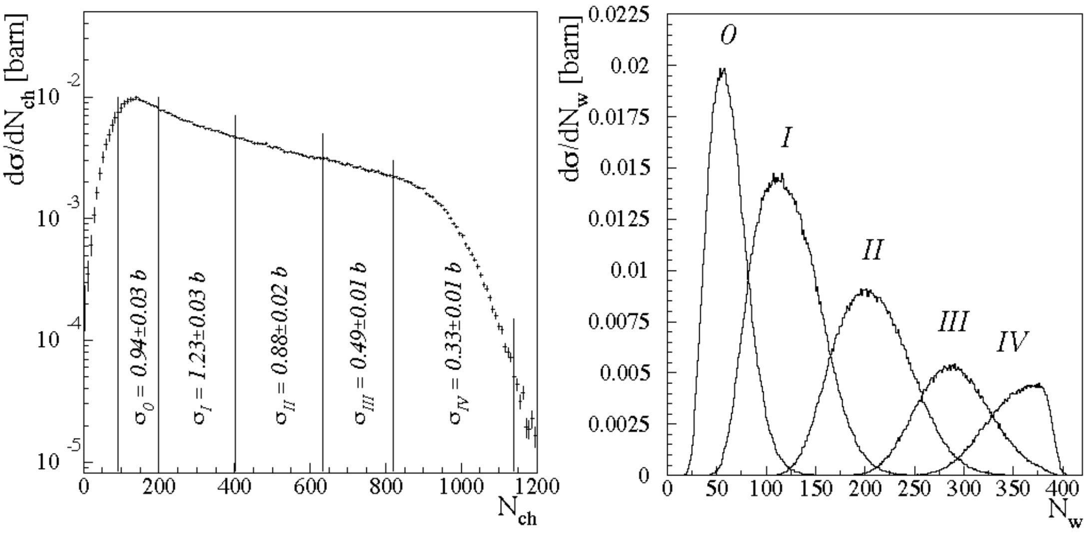

FIGURE 6. NA57 charged particle multiplicity distribution for Pb-Pb collisions at 160 A GeV/*c* (left) and wounded nucleon distribution for the five centrality classes (right). The cross section corresponding to each centrality class is also shown.

The NA57 Ξ^- and $\overline{\Xi}^+$ yields per participant in the five centrality classes are shown in Fig. 7, with the corresponding WA97 points for the four most central classes. In the common centrality range, the NA57 yields agree within 20-30% with WA97 yields, the latter being smaller. The reasons for this difference, which appears to be a systematic effect, are currently being investigated. From Fig. 7 a drop of Ξ^- and $\overline{\Xi}^+$ absolute yields, as measured by NA57, is visible in the new most peripheral bin. In particular, $\overline{\Xi}^+$ yield per wounded nucleons drops by a factor 2.6 when going from $N_{wound} = 121$ to $N_{wound} = 62$, i.e. from class I to class 0, corresponding to a 3.5 σ effect. The measured sudden reduction of yields as a function of centrality is not an artifact of our acceptance and efficiency correction procedure, since a similar drop is already shown by uncorrected data.

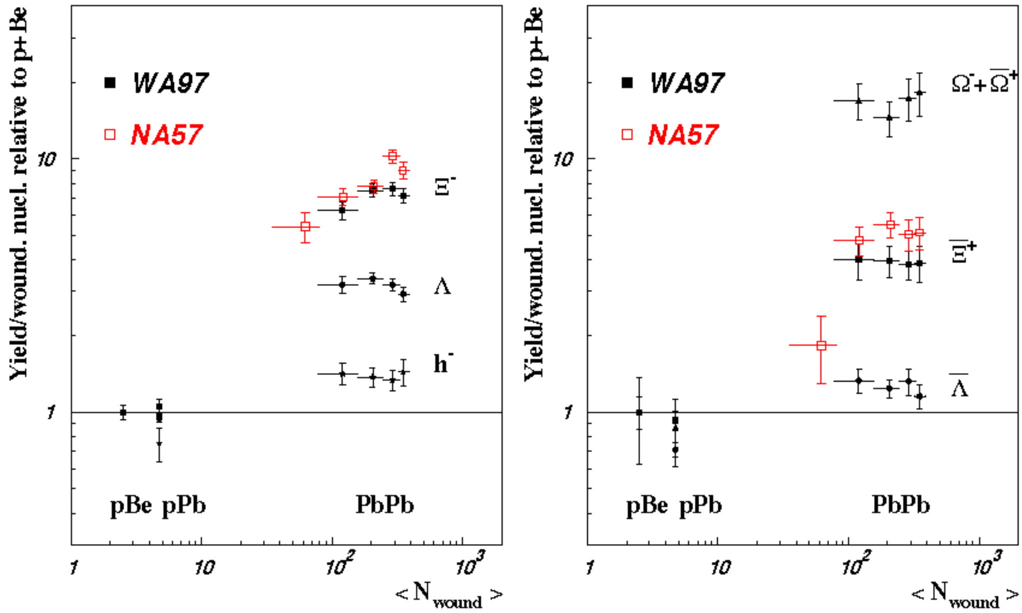

FIGURE 7. Ξ^- and $\overline{\Xi}^+$ yields per wounded nucleon relative to p-Be (same as in Figure 2) from NA57 data (open squares) are superimposed to the WA97 results (closed symbols).

CONCLUSIONS AND OUTLOOK

The NA57 has collected Pb-Pb and p-Be data at 40 A GeV/*c* beam momentum as well as Pb-Pb data at 160 A Gev/*c*. The first results on Ξ^- and $\overline{\Xi}^+$ yields at 160 A GeV/*c* from NA57 provide an indication of an onset of the enhancement between 50 and 100 nucleons taking part in the collision. The ongoing data analysis will provide information on the full pattern of strange baryon and antibaryon enhancements, which might show evidence of the QGP phase transition.

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