First results on strange baryon production from the na57 experiment

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1. Introduction

The NA57 experiment has been designed to study the onset of the strange baryon and anti-baryon enhancements in Pb-Pb with respect to p-Be collisions, first observed by the WA97 experiment at 160 $A\,\mathrm{GeV}/c$ beam momentum [1] (see Fig. 1). The effect is larger for particles of larger strangeness content, up to a factor ~ 15 for $\Omega^- + \overline{\Omega}^+$. Such a behaviour was predicted as a consequence of the QGP phase transition and is not reproduced by microscopic hadronic collision models.

The aim is to look for the dependence of these enhancements on:

- the collision energy per incoming nucleon: NA57 has collected data both at 160 and at 40 $A\,\mathrm{GeV}/c$ while WA97 collected data only at the top SPS beam momentum of 160 $A\,\mathrm{GeV}/c$;

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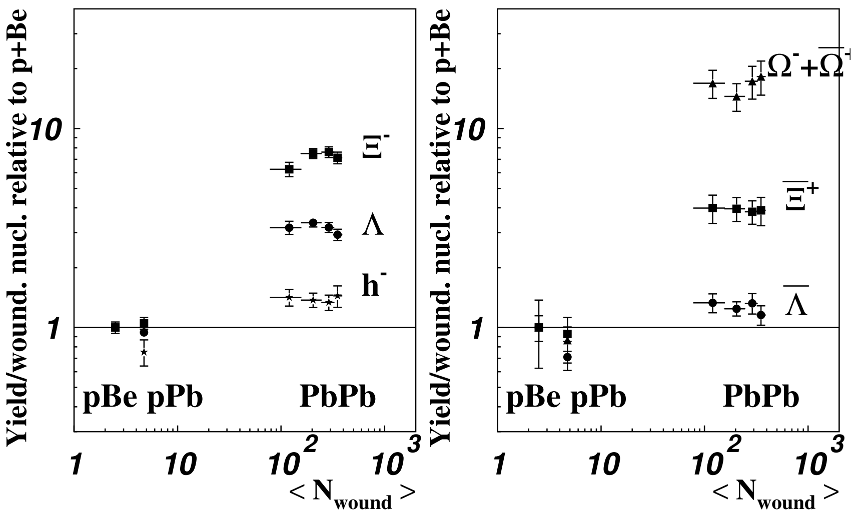

Figure 1. Yields per wounded nucleon relative to the p-Be yields as a function of the number of wounded nucleons for negative particles, Λ and Ξ^- (left) and for $\overline{\Lambda}$, $\overline{\Xi}^+$, $\Omega^- + \overline{\Omega}^+$ (right). The two groups are kept separate (particles with at least one valence quark in common with the nucleon on the left, particles with no valence quarks in common with the nucleon on the right) since it is empirically known that they may exhibit different production features (e.g.: rapidity spectra). While the yields per participant have similar values in p-Be and p-Pb, all the yields per participant measured in Pb-Pb are clearly above the p-A values.

- the interaction volume, as measured by the number of wounded nucleons ($N_{\rm wound}$)i.e. those nucleon which undergo at least one primary inelastic collision with another nucleon [2]: the NA57 centrality range extends down to a lower limit of about 50 wounded nucleons, while the corresponding limit in WA97 was about 100.

In what follows, we briefly describe the experiment, the status of the data taking, of the event reconstruction and of the physics analysis. For the physics results, we shall keep separate the study of the 40 A GeV/c Pb-Pb data (for which the bulk of reference p-Be data are still to be collected in 2001) from the study of the enhancements as a function of the number of wounded nucleons at 160 A GeV/c.

2. The NA57 experiment

The NA57 layout [3,4] is shown schematically in Fig. 2. The heart of the apparatus is a telescope tracker made of silicon pixel detectors placed in a 1.4 T vertical magnetic field. The telescope is inclined with respect to the beam line and points back to the target; the inclination angle can be changed to cover different rapidity intervals. Strange and multi-strange particles are identified by reconstructing their weak decays into final states containing only charged particles, e.g.:

$$\begin{array}{lll}\Xi^- \rightarrow & \Lambda & +\pi^- \\ & \hookrightarrow & \mathrm{p}+\pi^-\end{array}$$

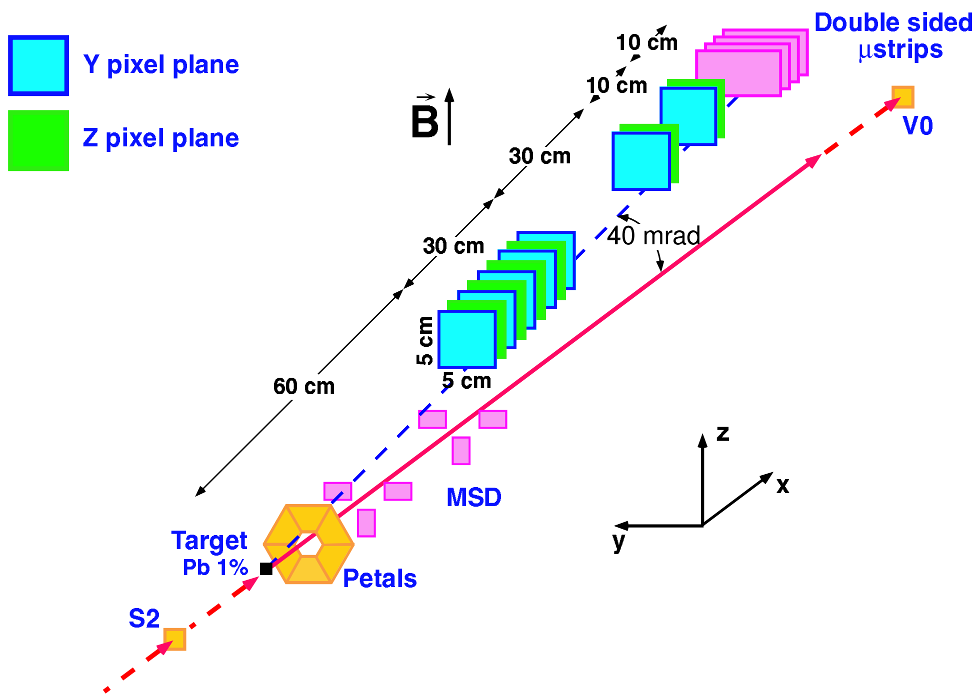

Figure 2. Layout of the NA57 experiment (Pb-Pb setup).

The acceptance windows are similar to those of WA97, covering about one unit of rapidity centred at mid-rapidity, and transverse momenta down to a few hundred MeV/c [4].

The centrality trigger for Pb-Pb, based on a scintillator petal system placed 10 cm downstream of the target, selects the most central 60% of the inelastic cross section. The centrality of the collision is determined from the charged particle multiplicity, sampled at central rapidity by two silicon strip detector stations (MSD). A special effort has been made to extend the centrality coverage towards more peripheral events with respect to WA97, by reducing various background sources.

The main differences between the NA57 and WA97 spectrometers are:

- a new telescope layout, fully based on silicon pixel detectors;
- a new magnet GOLIATH, which provides a slightly weaker, less uniform field than the OMEGA magnet used by WA97 (due to the decommissioning of the OMEGA spectrometer in 1997);
- a new data acquisition system, based on the ALICE oriented development of DATE [5].

Another difference between the two experiments concerns the way in which the interaction vertex is determined. In WA97 it is determined event by event from the reconstructed tracks; such a procedure however becomes inefficient as the event multiplicity decreases, i.e. in the new centrality range covered by NA57. It has become therefore necessary to replace the previous event by event vertex with an average vertex position measured about

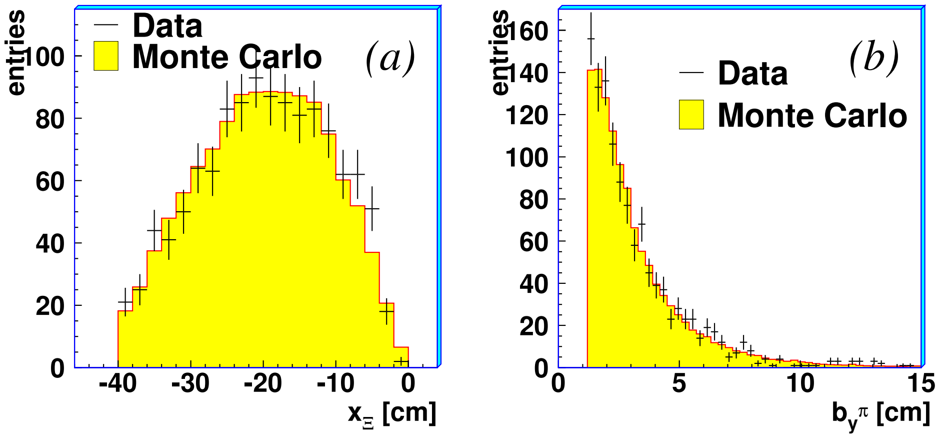

Figure 3. Comparison between data and Monte Carlo for (a) the decay lenght of the Ξ and (b) the impact parameter of the π.

each 1/2 hour during the run. This has been possible thanks to the good spot definition ($350 \times 650\,\mu\mathrm{m}^2$ in the transverse direction) of the NA57 beam and to its stability.

NA57 has taken Pb-Pb data both at 160 and at 40 $A\,\mathrm{GeV}/c$ beam momentum together with a sample of p-Be reference data at 40 GeV/c. More p-Be data at 40 $A\,\mathrm{GeV}/c$ will be collected in 2001 [6]. For proton reference data at 160 $A\,\mathrm{GeV}/c$, we intend to use the WA97 p-Be and p-Pb data samples.

In order to ascertain how well we understand the new NA57 spectrometer, a detailed comparison between simulated and real data is ongoing. As an example Figs. 3a,b show such a comparison for two quantities related to the decays of the Ξ into a Λ and a π^-: the decay length of the Ξ^- and the the impact parameters of the π^- trajectories when extrapolated to the collision vertex. The agreement between data and simulation is satisfactory in both cases.

3. Strange baryons: 40 $A\,\mathrm{GeV}/c$ versus 160 $A\,\mathrm{GeV}/c$

The observation of significantly lower enhancements at 40 $A\,\mathrm{GeV}/c$ than at 160 $A\,\mathrm{GeV}/c$ for the same particle species would suggest the onset of deconfinement to be in between the two energies. However, we are not yet able to make such a comparison since only about 25% of the p-Be reference data needed to determine the various enhancements have been collected; the collection of the remaining data is scheduled for summer 2001.

Fig. 4 shows the Λ, $\overline{\Lambda}$, Ξ^- and $\overline{\Xi}^+$ signals for the existing sample of 290 million Pb-Pb central events (the most central $\sim$ 20% of the total cross section). Λ and $\overline{\Lambda}$ signals are also available from the small existing sample of p-Be events.

In Table 3, the $\overline{\Lambda}/\Lambda$ and $\overline{\Xi}^+/\Xi^-$ ratios measured in Pb-Pb collisions at 40 $A\,\mathrm{GeV}/c$ are compared to the published values [7] at 160 $A\,\mathrm{GeV}/c$. Also shown are the $\overline{\Lambda}/\Lambda$ ratios for p-Be collisions at both energies. The present p-Be statistics does not allow any estimate

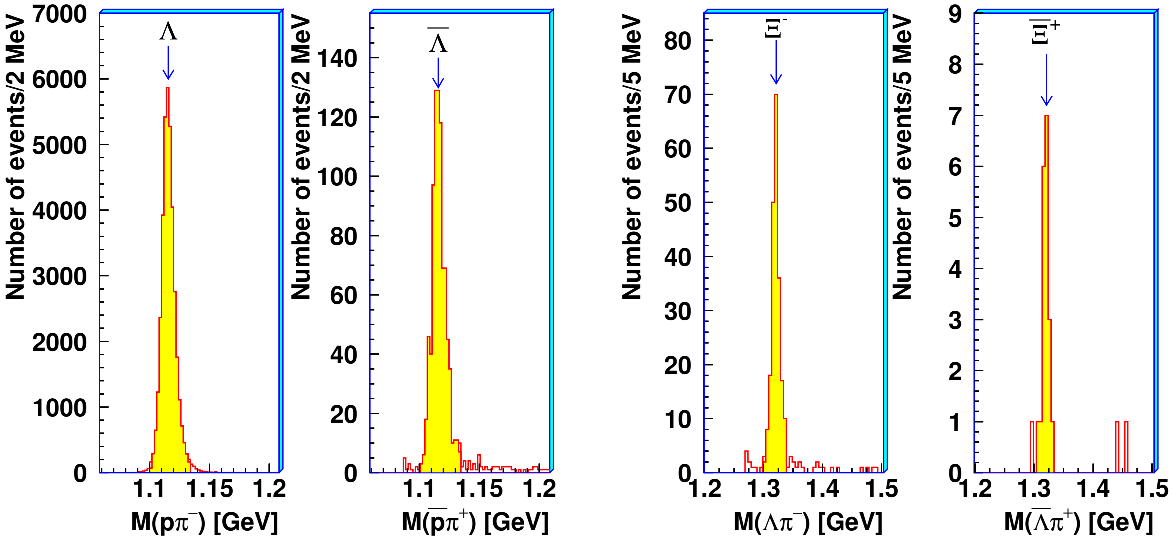

Figure 4. Λ, $\overline{\Lambda}$, Ξ^- and $\overline{\Xi}^+$ signals for the 40 A GeV/c Pb-Pb sample.

for the $\overline{\Xi}^+/\Xi^-$ ratio at 40 A GeV/c.

We note that the $\overline{\Lambda}/\Lambda$ and the $\overline{\Xi}^+/\Xi^-$ ratios in Pb-Pb collisions, decrease by a factor ~ 3 and ~ 6 respectively, when the collision energy in the centre of mass decreases from $\sim 18\,A$ GeV (160 A GeV/c beam momentum) to $\sim 9\,A$ GeV (40 A GeV/c). A reduction of the anti-hyperon over hyperon ratios is expected if the baryon density of the state formed in the collision is higher when going to lower beam momentum. On the other hand a decrease is expected also because the production threshold for anti-hyperons is larger than that for hyperons. A reduction in the $\overline{\Lambda}/\Lambda$ ratio similar to that observed for Pb-Pb collisions is indeed observed already for p-Be collisions.

4. Strange baryons at 160 A GeV/c: enhancements versus centrality

We use for this study only the Pb-Pb data at 160 A GeV/c beam momentum, collected in 1998. About the same statistics will be available from the data collected in 2000.

As a centrality measure, we use the number of wounded nucleons, i.e. the nucleons which

	Pb-Pb		p-Be	
	40 A GeV/c	160 A GeV/c	40 A GeV/c	160 A GeV/c
$\overline{\Lambda}/\Lambda$	**0.023 ± 0.001**	*0.133 ± 0.007*	**0.059 ± 0.007**	*0.332 ± 0.008*
$\overline{\Xi}^+/\Xi^-$	**0.080 ± 0.025**	*0.249 ± 0.019*	—	*0.45 ± 0.07*

Table 1
$\overline{\Lambda}/\Lambda$ and $\overline{\Xi}^+/\Xi^-$ ratios. Values in bold are from NA57, not corrected for acceptance and efficiency. Values in italics are from WA97.

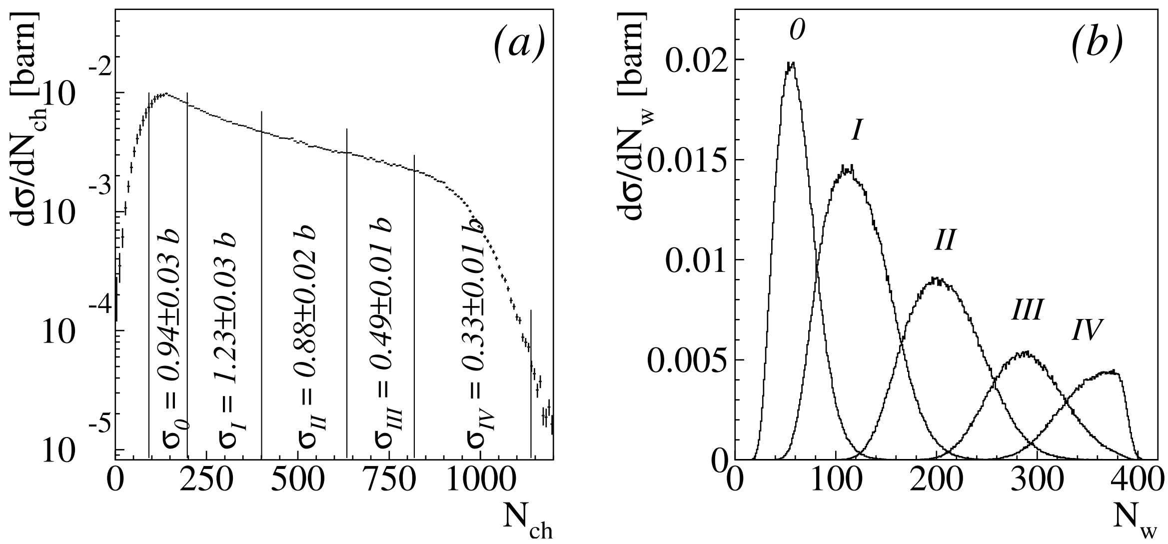

Figure 5. (a) Charged particle multiplicity distribution in the range $2 < \eta < 4$ measured by the NA57 experiment. The 5 classes used in the analysis are shown together with their cross sections. (b) distribution of N_{wound} for the five centrality classes used in NA57.

take part in the initial collision [2]. For the Pb-Pb data, the number of wounded nucleons is computed from the trigger cross section using a Glauber model [8]. For the proton data, the number of wounded nucleons is computed as an average over all inelastic collisions. Since various centrality scales are used by different experiments, some care is needed when comparing experimental results, especially for peripheral collisions. For example, an apparent discrepancy between the centrality dependence of kaon yields measured by the NA49 and the WA97 experiments using different centrality scales, disappears when the data are plotted using the same scale [8,9].

Fig. 5a shows the charged particle multiplicity distribution for Pb-Pb collisions. The data have been binned into five classes. The most central classes (I to IV) correspond to the four centrality classes used in the analysis of WA97, while the more peripheral class 0, corresponding to an average of $N_{\text{wound}} = 62$, is accessible to NA57 only. The drop at very low multiplicities is due to the threshold of our centrality trigger. The distribution of N_{wound} for the five multiplicity classes is shown in Fig. 5b.

To correct for acceptance and efficiency losses, a weight is calculated for each particle [10]. As the enhancements observed by WA97 increase with the strangeness carried by the particle, we chose to calculate corrections first for the strangest particles, namely the Ξ^- and $\overline{\Xi}^+$, for which the available statistics allowed a study of the enhancement dependence on the collision centrality down to ~ 50 wounded nucleons.

The Ξ^- and $\overline{\Xi}^+$ signals, together with their acceptance window are shown in Fig. 6. Fig. 7a shows the corresponding transverse mass (m_T) spectra, corrected both for acceptance and efficiency losses. The superimposed straight lines are the results of the fit with

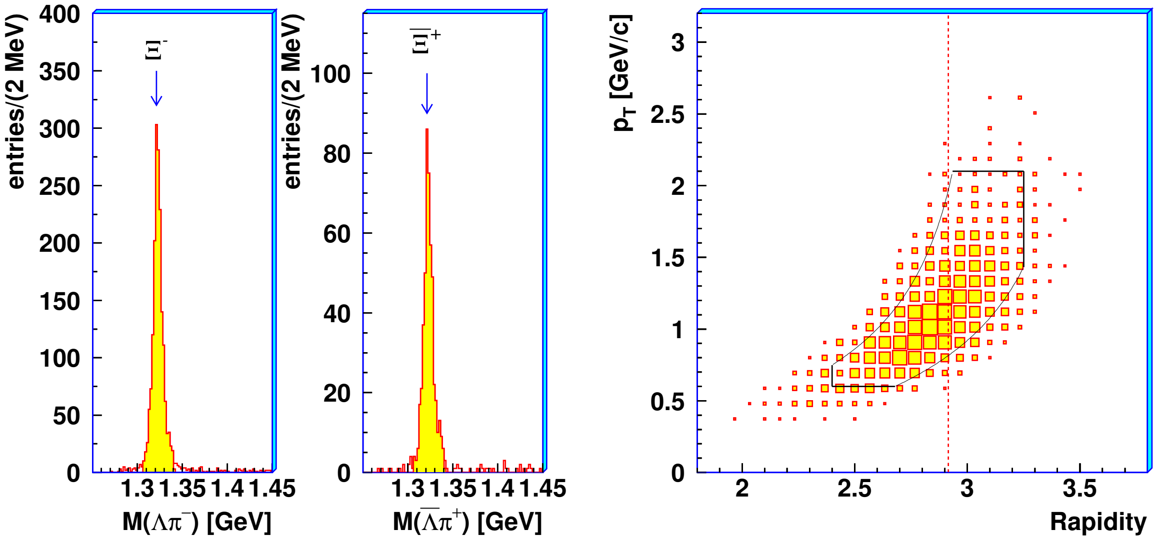

Figure 6. Ξ^- and $\overline{\Xi}^+$ signals for Pb-Pb collisions (left) and the corresponding acceptance window in p_T and rapidity (right).

the function

$$\frac{1}{m_T}\frac{\mathrm{d}N}{\mathrm{d}m_T} = A\ \exp\left(-\frac{m_T}{T}\right). \tag{1}$$

The corresponding inverse slopes T, are compared in Fig 7b with the values obtained by the WA97 experiment. The agreement is good. The statistics, however, is not yet sufficient to study a possible variation of T over the full centrality range covered by the experiment.

Fig. 8 shows the fully corrected yields per participant for the five centrality classes defined as in Fig. 5a. The corresponding WA97 points, available only for the four more central classes, are also shown. We note that in the common centrality range, the yields from NA57 are 20%-30% larger. The reasons for this systematic effect are presently being investigated. In the new low-centrality bin the $\overline{\Xi}^+$ (Ξ^-) yields, as measured by NA57, drop by a factor 2.6 (1.3), corresponding to a 3.5 (1.8) sigma effect. Such a sudden reduction of yields as a function of centrality cannot be an artifact of our acceptance corrections procedure since a similar drop is already present in the uncorrected data (Fig. 9).

It is noteworthy that such a drop is not foreseen by any of the known models. As an example, a recent prediction from a canonical statistical model [11] succeeds in reproducing the enhancements measured by WA97, but predicts that the yields of multi-strange baryons are already close to saturation for $N_{\rm wound} \sim 20$.

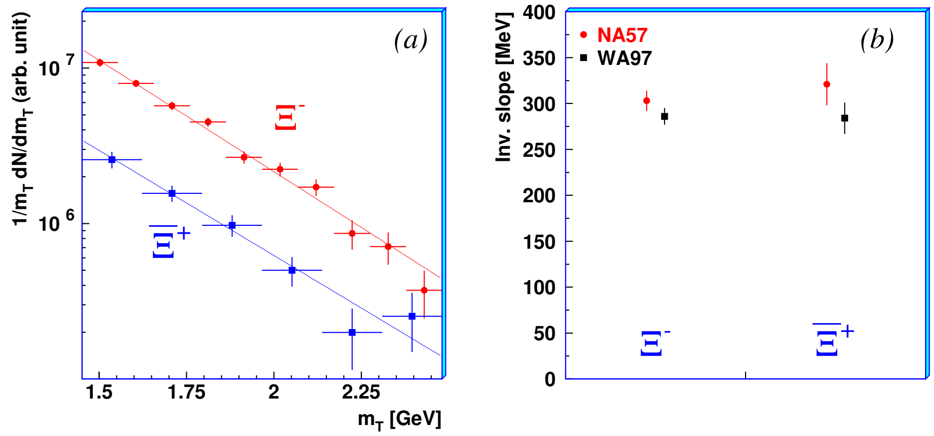

Figure 7. (a) Transverse mass spectra for Ξ^- and $\overline{\Xi}^+$. (b) comparison of the inverse slope T with WA97.

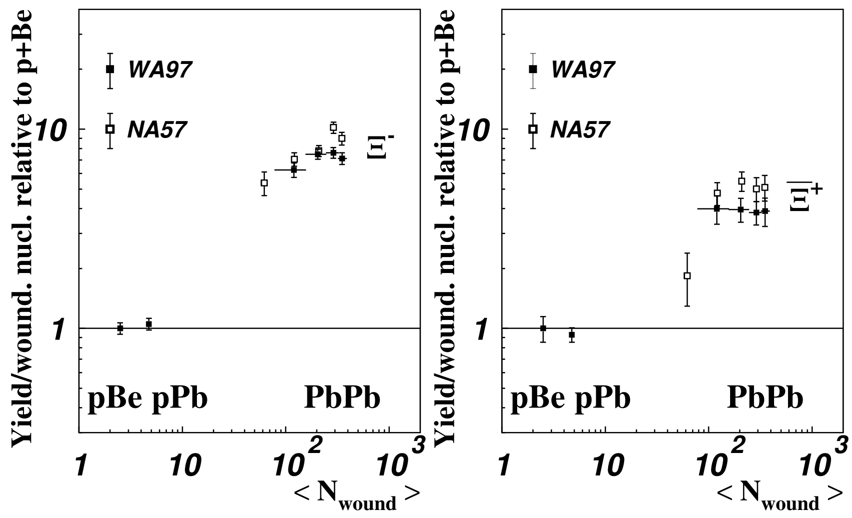

Figure 8. $\overline{\Xi}^+$ and Ξ^- yields per wounded nucleon relative to the p-Be yields. The NA57 data (open symbols) are shown together with the WA97 results (closed symbols).

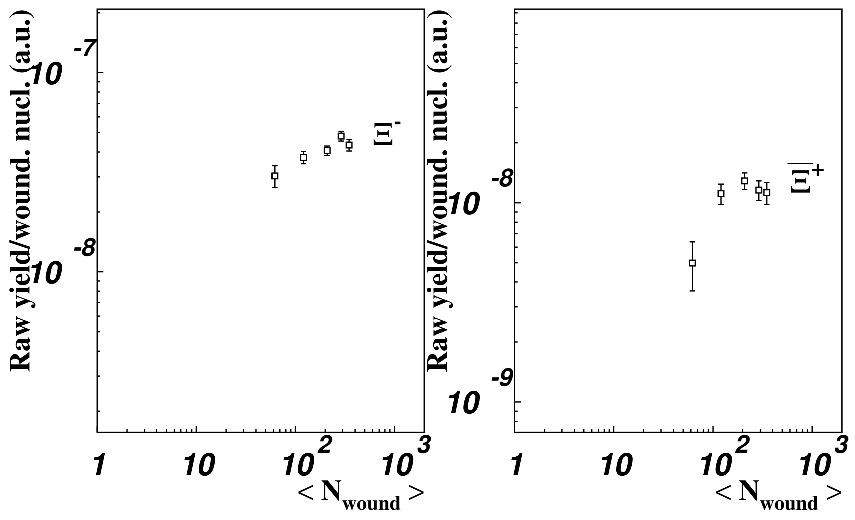

Figure 9. $\overline{\Xi}^+$ and Ξ^- raw yields per wounded nucleon relative from NA57 (arbitrary units).

5. Conclusions and outlook

The indication of an onset for the Ξ^- and $\overline{\Xi}^+$ enhancements when the collision involves between 50 and 100 nucleons, urges us to look at the full set of enhancements, since it could indicate the point of the QGP phase transition. Such a study is under way.

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