Hyperon production in 158 and 40 A GeV/c Pb-Pb and p-Be collisions from the NA57 experiment

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The NA57 experiment at the CERN SPS has measured strange baryon and antibaryon production in Pb-Pb collisions with 158 and 40 A GeV/c beam momenta. Recent results

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on Λ, Ξ and Ω hyperon enhancements and from the transverse mass spectra analysis for the 158 A GeV/c data sample are presented. The energy dependence of hyperon production at mid-rapidity is discussed.

1. INTRODUCTION

The NA57 experiment [1] has been designed to study the onset of the strange baryon and antibaryon enhancements in Pb-Pb collisions with respect to proton-induced reactions, first observed by WA97 at 158 A GeV/c beam momentum [2]: NA57 has extended the WA97 measurements over a wider centrality range and to lower beam momentum. The apparatus [1] detects strange and multi-strange hyperons by reconstructing their weak decays into final states containing charged particles only. Tracks are measured in the silicon telescope, a 30 cm length array of pixel detector planes with 5×5 cm^2 cross section. Additional pixel planes and double-sided silicon microstrip detectors, placed behind the telescope, are used as a lever arm to improve the momentum resolution for fast tracks. The centrality trigger, based on a scintillator petal system placed 10 cm downstream of the target, selects the most central 60% of the inelastic cross section for Pb-Pb collisions. The centrality of the collision is measured using the charged particle multiplicity sampled at central rapidity by two stations of silicon strip detectors. The apparatus is placed inside the 1.4 Tesla field of the GOLIATH magnet.

2. DATA ANALYSIS AND RESULTS

The particle selection procedure, based on geometrical and kinematical cuts, allows the extraction of signals with negligible background [3]. The collision centrality is expressed as number of wounded nucleons computed from the measured trigger cross section via the Glauber model [4]. The double-differential distribution in rapidity y and transverse mass m_T for each particle type has been fitted, using the maximum likelihood method, according to the following parametrization:

$$\frac{d^2N}{dm_T dy} = f(y)\, m_T \exp\left(-\frac{m_T}{T}\right) \tag{1}$$

We assume a flat rapidity distribution within our acceptance region around central rapidity and leave the inverse slope T as a free parameter. Yields have been calculated as number of particles per event extrapolated to a common phase space window, covering full p_T and one unit of rapidity around midrapidity, by using the fitted slopes:

$$Y = \int_m^\infty dm_T \int_{y_{cm}-0.5}^{y_{cm}+0.5} dy \frac{d^2N}{dm_T dy} \tag{2}$$

2.1. Strangeness enhancements at 158 A GeV/c

The hyperon yields per wounded nucleon in Pb-Pb and p-Pb collisions at 158 A GeV/c, normalized to p-Be values, are shown in Fig.1. The NA57 results for Pb-Pb collisions confirm the pattern already observed in the WA97 data, the enhancements increasing with the strangeness content of the particle up to a factor 20 for the Ω hyperons.

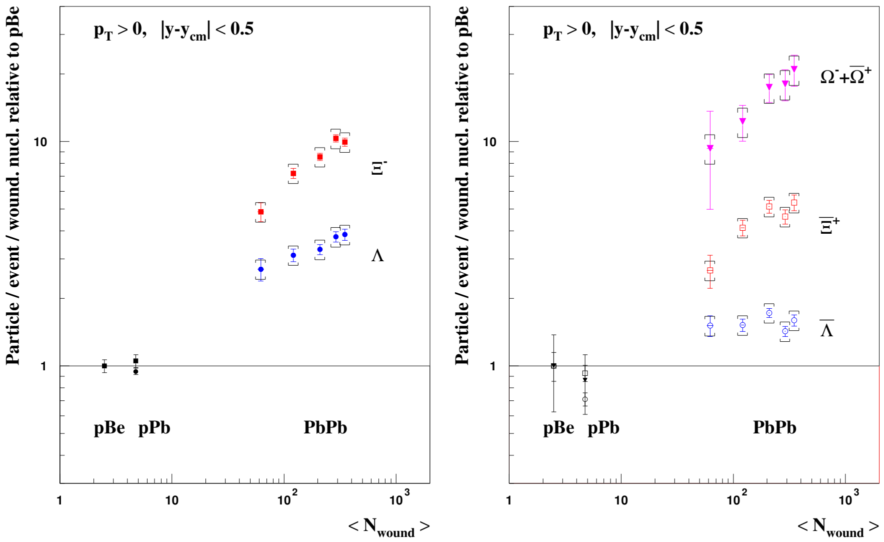

Figure 1. Hyperon yields per wounded nucleons relative to p-Be, as a function of collisions centrality. Horizonthal bracket symbols represent systematical errors.

A significant increase of the yields per wounded nucleon with the number of wounded nucleons is observed for all the particles except $\overline{\Lambda}$, while saturation, if any, is possible only for the two most central classes (corresponding to about 10% most central collisions).

2.2. Blast wave analysis of transverse mass spectra at 158 A GeV/c

The transverse mass spectra of all the measured hyperons (and K^0_S mesons) have been described in the framework of a simplified hydro-dynamical model (assuming a constant velocity profile) derived from [5]. All the measured spectra have been fitted using two parameters, T (temperature) and β_T (transverse flow velocity), yielding the following values with the corresponding statistical errors:

$$T = 161 \pm 7 \text{ MeV}, \qquad \beta_T = 0.395 \pm 0.015 \qquad\qquad (\chi^2/\text{ndf} = 26/39)$$

Compatible freeze-out parameters have been found analyzing particles and antiparticles separately, that might indicate similar production mechanism and negligible final state interactions. Preliminary results from the centrality dependence study suggest rise of β_T and decrease of T going towards more central collisions. Fitted values in the most central class ($T = 131 \pm 10$ MeV, $\beta_T = 0.47 \pm 0.02$) show good agreement with NA49 results obtained with a similar approach [6]. Further studies, including a more realistic transverse flow velocity profile, are currently under way.

2.3. Energy dependence of hyperon yields

Hyperon yields per unit rapidity at 40 and 158 A GeV/c have been compared within a centrality range corresponding to 40% most central collisions. Going from 40 to 158 A GeV/c, the Λ and Ξ^- yields are similar while the corresponding antiparticle yields increase by a factor 5. The Ω hyperon production shows a larger increase, with about a factor 3 rise for the particle and more than a factor 7 for the antiparticle. In Fig.2 the NA57 hyperon yields per unit rapidity at both energies are compared with those from the STAR experiment at RHIC for $\sqrt{s_{NN}} = 130$ GeV Au-Au collisions [7–9]. For this comparison we restricted our data to the same centrality range used for STAR results (5%, 10% and 11% most central collisions for Λ, Ξ and Ω respectively).

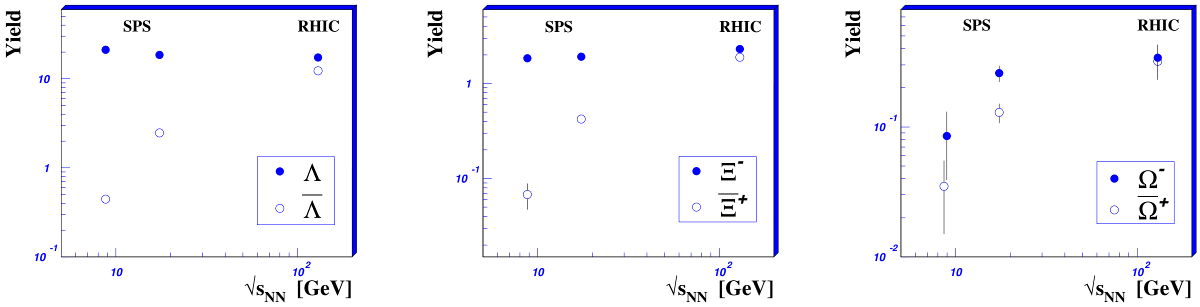

Figure 2. Hyperon yields per unit rapidity at central rapidity for SPS and RHIC energies. Errors shown are statistical only. Restricted NA57 samples have been used to allow comparison with STAR data.

As already seen in the SPS range, the Λ and Ξ^- yields do not vary much with energy up to RHIC collisions, while for Ω^- there is some increase. A stronger energy dependence is seen for the three antihyperon yields. These results can be understood as a consequence of a smaller baryon density in the central region at higher energy.

3. CONCLUSIONS

Results from NA57 on hyperon production in Pb-Pb collisions at 158 and 40 A GeV/c beam momentum have been presented. Normalized hyperon yields at 158 A GeV/c confirm the pattern of increasing strangeness enhancement with increasing strangeness content of the particles. A significant centrality dependence of the enhancements has been observed. The measured transverse mass spectra at 158 A GeV/c can be described in the framework of a simplified hydro-dynamical model with common thermal freeze-out parameters: temperature and transverse flow velocity.
The Λ and Ξ^- yields per unit rapidity stay roughly constant while those of Ω^-, $\overline{\Lambda}$, $\overline{\Xi}^+$ and $\overline{\Omega}^+$ increase when going from lower to top SPS energy. Comparison with higher energy data results from the STAR experiment at RHIC confirms the same trend, with hyperons showing a weaker energy dependence than antihyperons. The global pattern is consistent with a decrease of the baryon density in the central region as energy is increased.

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