STRANGE BARYON PRODUCTION IN Pb–Pb INTERACTIONS AT CERN SPS

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Recent results on strange baryon and antibaryon production in Pb–Pb collisions at 160 GeV per nucleon from the NA57 experiment are reported. Strangeness enhancements and the transverse mass spectra properties are described.

PACS numbers: 25.75.Dw, 25.75.Ld

1. The NA57 experiment

The NA57 experiment at the CERN SPS is devoted to the study of the production of strange and multi-strange baryons and antibaryons in Pb–Pb collisions. It extends the measurements of the WA97 experiment [1, 2] to a wider centrality range and a lower beam energy, triggering on $\simeq 60\%$ of most central Pb–Pb events and collecting data at beam momenta of 158 and 40 A GeV/c.

The NA57 set-up and experimental procedure are described elsewhere [3, 4, 5]. A telescope of compactly packed high granularity silicon pixel detectors, located in a 1.4 T magnetic field, is used as a main tracking device. Its configuration and geometry enables to measure the particle yields and spectra in a half unit of rapidity centered at mid-rapidity. Two stations of silicon microstrip detectors provide data for the charged particle multiplicity measurement and, subsequently, for the offline collision centrality determination. As a measure of the centrality we use the number of wounded nucleons computed from the measured trigger cross sections via the Glauber model [6].

The $\mathrm{K^0_S}$ mesons, the Λ, Ξ^- and Ω^- hyperons and their antiparticles are identified by reconstructing their weak decays into final states containing charged particles only. The selection procedure allows us to extract strange particle signals with a negligible level of background. The results presented in this paper are based on the data sample consisting of 460 M events of Pb–Pb collisions at 158 A GeV/c. Data are corrected for geometrical acceptance and for detector and reconstruction inefficiencies. We are analyzing all the reconstructed multi-strange particles, while for the much more abundant $\mathrm{K^0_S}$, Λ and $\overline{\Lambda}$ particles we only corrected a fraction of the total data samples in order to reach a statistical accuracy better than the limits imposed by the systematics. The systematic errors, both for particle yields and spectra, are estimated to be about 10% for Λ, Ξ and $\simeq 15\%$ for Ω hyperons.

The double differential cross sections for each particle under study were fitted using the expression

$$\frac{\mathrm{d}^2N}{\mathrm{d}m_\mathrm{T}\,\mathrm{d}y} = f(y)\,m_\mathrm{T}\,\exp\left(-\frac{m_\mathrm{T}}{T_{app}}\right)\,, \tag{1}$$

where $m_\mathrm{T} = \sqrt{m^2 + p_\mathrm{T}^2}$ is the transverse mass, assuming the rapidity distribution to be flat in our limited acceptance region ($f(y) = const.$).

2. Strangeness enhancements

Using the parametrization given by equation (1), with the inverse slope T_{app} value extracted from from the maximum likelihood fit to the data, one can determine the yield (rapidity density at mid-rapidity y_0) of each particle under study:

$$Y = \left.\frac{\mathrm{d}N}{\mathrm{d}y}\right|_{y=y_0} = \int_m^{\infty} \mathrm{d}m_{\mathrm{T}} \int_{y_0-0.5}^{y_0+0.5} \frac{\mathrm{d}^2N}{\mathrm{d}m_{\mathrm{T}}\,\mathrm{d}y}\,\mathrm{d}y\ . \tag{2}$$

The data have been divided into five centrality classes (0–4) [1] and rapidity densities Y were calculated for each centrality class. Then, using the yields of strange baryons for 158 GeV/c p–Be interactions measured by the WA97 experiment, one can determine the strangeness enhancement

$$E = \left(\frac{Y}{\langle N_{\mathrm{wound}}\rangle}\right)_{\mathrm{Pb-Pb}} \Big/ \left(\frac{Y}{\langle N_{\mathrm{wound}}\rangle}\right)_{\mathrm{p-Be}}\ . \tag{3}$$

The NA57 results on strangeness enhancements are presented in figure 1. The enhancements are shown separately for particles containing at least

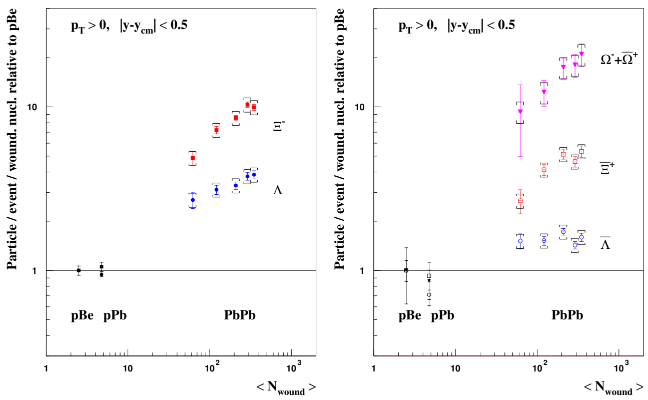

Fig. 1. Hyperon enhancements E as a function of the number of wounded nucleons. The symbol ⌈⌉ indicates the systematic error.

one valence quark in common with the nucleon (left) and for those with no valence quark in common with the nucleon (right). Our results confirm the pattern of strangeness enhancements observed by the WA97 experiment [2]. The enhancement increases with the strangeness content of the hyperon.

[1] The centrality classes (1–4) correspond to the four classes used in the WA97 analysis, while the most peripheral class 0 (with $\langle N_{\mathrm{wound}}\rangle = 62 \pm 4$) is accessible to NA57 only. The most central class 4 corresponds to 5% of most central events.

The Pb–Pb data exhibit a significant centrality dependence of the yields per wounded nucleon for all hyperons except for $\overline{\Lambda}$. However, for the two most central classes 3 and 4 ($\simeq 10\%$ of most central collisions) a saturation of the enhancements is not excluded.

3. Transverse mass spectra

Transverse mass distributions $1/m_{\mathrm{T}}\ \mathrm{d}N/\mathrm{d}m_{\mathrm{T}}$ for hyperons and antihyperons from Pb–Pb collisions at 158 A GeV/c measured in the whole centrality range accessible to the experiment are shown in figure 2. The

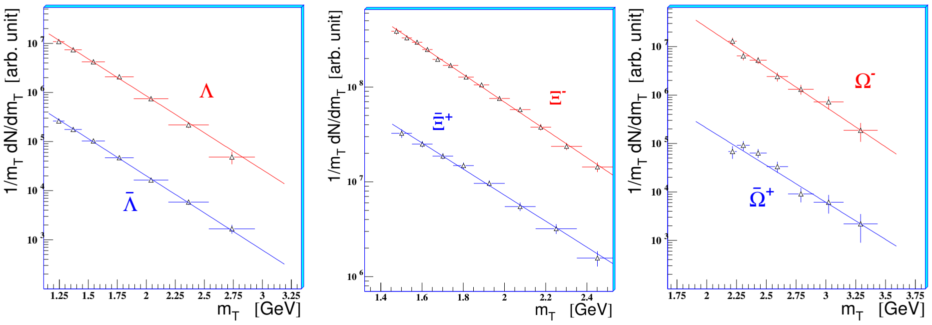

Fig. 2. Transverse mass spectra of hyperons from 158 A GeV/c Pb–Pb collisions.

inverse slopes of superimposed exponential functions correspond to the T_{app} ('apparent temperature') values extracted from the maximum likelihood fit of equation (1) to the data. The shapes of all spectra are close to exponential functions with similar values of T_{app} (~ 300 MeV) for all hyperons and antihyperons [2]. The observed systematics of inverse slopes T_{app} is usually interpreted as a result of simultaneous contributions from a thermal motion in the fireball and from a collective transverse flow.

For a more complex analysis aiming at disentangling the radial flow velocity $\beta_{\perp}(r)$ and the thermal freezout temperature T we have utilized a model based on thermalization and hydro-dynamical transverse flow description [8]. In this approach (the blast-wave model) the m_{T} distribution of the hadron with mass m_i can be approximated as follows:

$$\frac{\mathrm{d}N_i}{m_{\mathrm{T}}\,\mathrm{d}m_{\mathrm{T}}} \propto m_{\mathrm{T}} \int_0^R r\,\mathrm{d}r K_1\left(\frac{m_{\mathrm{T}}\cosh\rho}{T}\right) I_0\left(\frac{p_{\mathrm{T}}\sinh\rho}{T}\right), \qquad (4)$$

where R is the transverse system size, K_1 and I_0 are the modified Bessel functions and $\rho = \mathrm{atanh}\,\beta_{\perp}(r)$ is a transverse boost. The model assumes a

[2] The inverse slope values T_{app} are in agreement within the errors with those measured over a smaller centrality range by the WA97 experiment [7].

kinetic freeze-out of matter at constant temperature T, cylindrically symmetric and longitudinally boost invariant expansion. The transverse velocity field is parametrised according to a power law

$$\beta_{\perp}(r) = \beta_s \left(\frac{r}{R}\right)^n . \quad (5)$$

Assuming a uniform particle density the average transverse velocity is related to the surface velocity β_s by the formula $\langle\beta_{\perp}\rangle = 2/(2+n) \times \beta_s$.

In a preliminary study [9, 10] we considered a simplified model with a constant velocity profile ($n = 0$ in equation 5). We have now performed a more detailed analysis which will be presented in a forthcoming paper [11]. Here we report main results of the blast-wave model fit to NA57 data with a linear velocity profile ($n = 1$).

As shown in the left portion of figure 3 it is possible to obtain a good fit to all particle spectra with common values of the thermal freeze-out temperature T and average transverse flow velocity $\langle\beta_{\perp}\rangle$. The fitted values of these quantities and their statistical errors are also shown in figure [3].

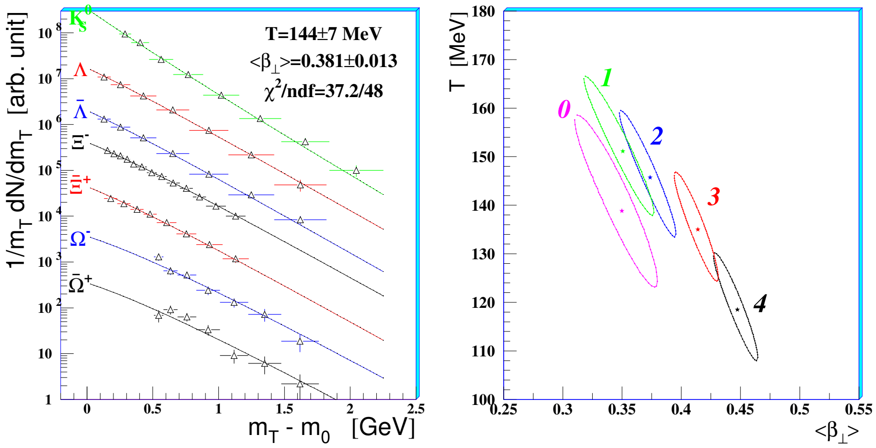

Fig. 3. Result of simultaneous fitting of equation (4) to the hyperon m_{T} spectra measured in the whole NA57 centrality range. Preliminary $\mathrm{K^0_S}$ data are also included (left). The 1σ confidence level contours for blast-wave fits to the spectra corresponding to individual centrality classes (right).

In order to check whether some particle species deviate from the common freeze-out description determined according to this model, we have attempted to fit the m_{T} spectra for each particle separately. For all particle

[3] The systematic errors of quantities T and $\langle\beta_{\perp}\rangle$ are estimated to be ± 14 MeV and ± 0.012 respectively.

species the T and $\langle\beta_\perp\rangle$ values resulting from individual fits do not deviate more than two standard deviations from the values extracted from the global fit.

In order to investigate the centrality dependence of freeze-out parameters we have also performed the global fits of m_{T} spectra for each of the five NA57 centrality classes. The results of these fits are summarized in the right portion of figure 3. Apart from the most peripheral interactions, the centrality dependence of the T and $\langle\beta_\perp\rangle$ parameters show opposite trends: the freeze-out temperature is decreasing and the average flow velocity is increasing with increasing centrality of collision.

4. Conclusions and outlook

The analysis of the transverse mass spectra in the framework of the blast-wave hydrodynamic model shows that the data for all the particles under study are compatible with the common freeze-out scenario. A centrality dependence of the freeze-out parameters T and $\langle\beta_\perp\rangle$ is observed.

The NA57 data on the normalized hyperon yields at 158 A GeV/c confirm the pattern of strangeness enhancements found by WA97: the enhancement increases with the strangeness content of particle reaching a factor $\simeq 20$ for the triply-strange Ω hyperons. A significant centrality dependence of enhancement for all hyperons and antihyperons (except for the $\overline{\Lambda}$) is observed. The ongoing analysis of 40 A GeV/c data will soon allow to measure the energy dependence of strangeness enhancements.

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