Strangeness production at SPS energies

Michael K. Mitrovski for the NA49 Collaboration†

Institut für Kernphysik, J.W. Goethe-Universität, 60438 Frankfurt, Germany

E-mail: `Michael.Mitrovski@cern.ch`

C. Alt[9], T. Anticic[23], B. Baatar[8],D. Barna[4], J. Bartke[6], L. Betev[10], H. Białkowska[20], C. Blume[9], B. Boimska[20], M. Botje[1], J. Bracinik[3], R. Bramm[9], P. Bunčić[10], V. Cerny[3], P. Christakoglou[2], P. Chung[19], O. Chvala[14], J.G. Cramer[16], P. Csató[4], P. Dinkelaker[9], V. Eckardt[13], D. Flierl[9], Z. Fodor[4], P. Foka[7], V. Friese[7], J. Gál[4], M. Gaździcki[9,11], V. Genchev[18], G. Georgopoulos[2], E. Gładysz[6], K. Grebieszkow[22], S. Hegyi[4], C. Höhne[7], K. Kadija[23], A. Karev[13], D. Kikola[22], M. Kliemant[9], S. Kniege[9], V.I. Kolesnikov[8], E. Kornas[6], R. Korus[11], M. Kowalski[6], I. Kraus[7], M. Kreps[3], A. Laszlo[4], R. Lacey[19], M. van Leeuwen[1], P. Lévai[4], L. Litov[17], B. Lungwitz[9], M. Makariev[17], A.I. Malakhov[8], M. Mateev[17], G.L. Melkumov[8], C. Meurer[9], A. Mischke[1], M. Mitrovski[9], J. Molnár[4], St. Mrówczyński[11], V. Nicolic[23], G. Pálla[4], A.D. Panagiotou[2], D. Panayotov[17], A. Petridis[2], W. Peryt[22], M. Pikna[3], J. Pluta[22], D. Prindle[16], F. Pühlhofer[12], R. Renfordt[9], C. Roland[5], G. Roland[5], M. Rybczyński[11], A. Rybicki[6,10], A. Sandoval[7], N. Schmitz[13], T. Schuster[9], P. Seyboth[13], F. Siklér[4], B. Sitar[3], E. Skrzypczak[21], M. Slodkowski[22], G. Stefanek[11], R. Stock[9], C. Strabel[9], H. Ströbele[9], T. Susa[23], I. Szentpétery[4], J. Sziklai[4], M. Szuba[22], P. Szymanski[10,20], V. Trubnikov[20], D. Varga[4,10], M. Vassiliou[2], G.I. Veres[4,5], G. Vesztergombi[4], D. Vranić[7], A. Wetzler[9], Z. Włodarczyk[11] I.K. Yoo[15], J. Zimányi[4]

[1]NIKHEF, Amsterdam, Netherlands.
[2]Department of Physics, University of Athens, Athens, Greece.
[3]Comenius University, Bratislava, Slovakia.
[4]KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.
[5]MIT, Cambridge, USA.
[6]Institute of Nuclear Physics, Cracow, Poland.
[7]Gesellschaft für Schwerionenforschung (GSI), Darmstadt, Germany.
[8]Joint Institute for Nuclear Research, Dubna, Russia.
[9]Fachbereich Physik der Universität, Frankfurt, Germany.
[10]CERN, Geneva, Switzerland.
[11]Institute of Physics Świ etokrzyska Academy, Kielce, Poland.
[12]Fachbereich Physik der Universität, Marburg, Germany.
[13]Max-Planck-Institut für Physik, Munich, Germany.

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[14]Institute of Particle and Nuclear Physics, Charles University, Prague, Czech Republic.
[15]Department of Physics, Pusan National University, Pusan, Republic of Korea.
[16]Nuclear Physics Laboratory, University of Washington, Seattle, WA, USA.
[17]Atomic Physics Department, Sofia University St. Kliment Ohridski, Sofia, Bulgaria.
[18]Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria.
[19]Chemistry Department, Stony Brook University, SUNY, Stony Brook, USA.
[20]Institute for Nuclear Studies, Warsaw, Poland.
[21]Institute for Experimental Physics, University of Warsaw, Warsaw, Poland.
[22]Faculty of Physics, Warsaw University of Technology, Warsaw, Poland.
[23]Rudjer Boskovic Institute, Zagreb, Croatia.

Abstract. We present a summary of measurements of strange particles performed by the experiment NA49 in central and minimum bias Pb+Pb collisions in the beam energy range 20A - 158A GeV. New results on Ξ production in central Pb+Pb collisions and on Λ, Ξ production in minimum bias collisions are shown. Transverse mass spectra and rapidity distributions of strange particles at different energies are compared. The energy dependence of the particle yields and ratios is discussed. NA49 measurements of the Λ and Ξ enhancement factors are shown for the first time.

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1. Introduction

The NA49 experiment has collected data on Pb+Pb collisions at beam energies between 20A - 158A GeV with the objective to search for phase transition to a deconfined phase which is expected occur in the early stage of the reactions.
In this report we show new NA49 results on strange particle production in central and minimum bias Pb+Pb collisions at all available SPS energies and compare them to previously shown data [1] $-$ [8] at other energies, as well as to model predictions.

2. The NA49 experiment

The NA49 detector [9] is a large acceptance hadron spectrometer at the CERN SPS, featuring four large volume TPCs as tracking detectors. Two of them are inside a magnetic field. The ionisation energy loss (dE/dx) measurements in the TPCs are used for particle identification. Central collisions were selected on the basis of the energy of the projectile spectator nucleons measured by a downstream calorimeter.

3. Energy Dependence of Transverse Mass Spectra

Transverse mass spectra in central Pb+Pb collisions at midrapidity are shown in Fig. 1. On the left side preliminary results at 20A GeV are plotted, on the right side spectra at 158A GeV are shown. Assuming a common transverse flow velocity profile and a common thermal freeze-out temperature for all different particle types, a blast wave parametrization [10] was fitted to the data. It describes the data reasonably well. A freeze-out temperature of $T_f \approx 100$ - 120 MeV and a mean transverse velocity of $\langle \beta_T \rangle \approx 0.5$ is extracted.

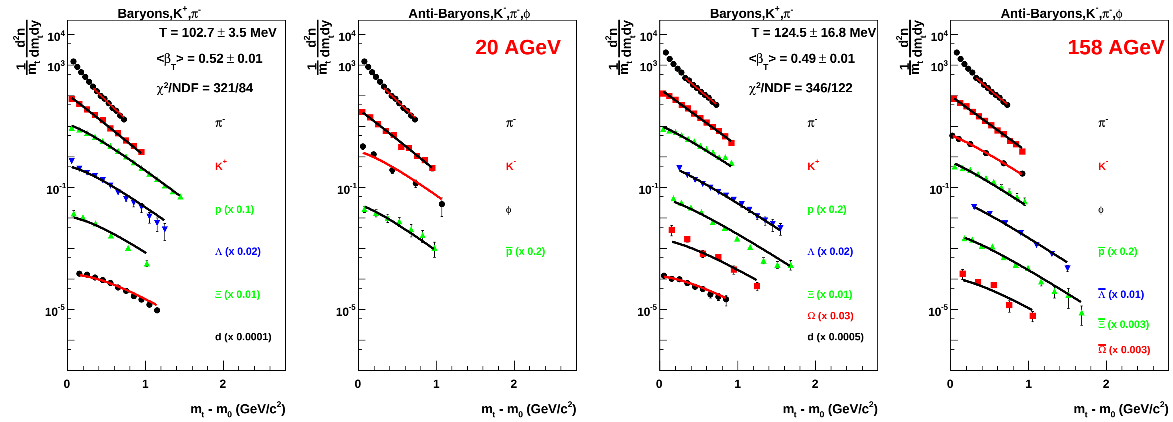

Figure 1. Transverse mass spectra at midrapidity for central Pb+Pb collisions at 20A (left) and 158A GeV (right). The lines indicate the fit range and represent results of a blast wave fit [10]. The corresponding parameter T_f and $\langle \beta_T \rangle$ are displayed in the figures. The errors shown are statistical only.

Fig. 2 shows transverse mass spectra of Ξ^- (left) and $\bar{\Xi}^+$ (right) integrated over the the rapidity range -0.5 < y < +0.5 in central Pb+Pb collisions at different beam energies.

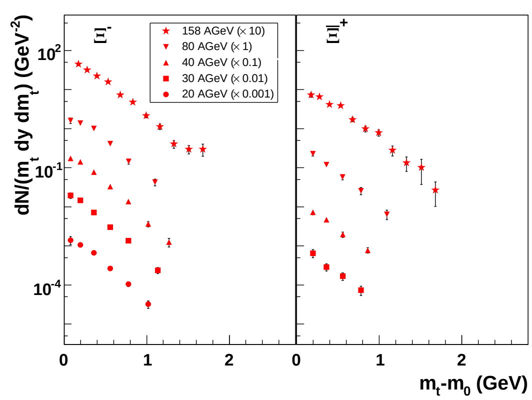

Figure 2. Transverse mass spectra of Ξ^- (left) and $\bar{\Xi}^+$ (right) in central Pb+Pb (7 % most central at 20A − 80A GeV, 10 % most central at 158A GeV) collisions at midrapidity. The errors shown are statistical only.

In Fig. 3 the energy dependence of the mean transverse mass $\langle m_t \rangle - \langle m_0 \rangle$ is shown for Λ, ϕ, Ξ and $\Omega + \bar{\Omega}$. The mean transverse mass was calculated from the measured spectra and using a fitted functions to extrapolate to full $\langle m_t \rangle - \langle m_0 \rangle$ range.

Different methods to extrapolate the $\langle m_t \rangle - \langle m_0 \rangle$ have been done whenever necessary, however the extrapolations are small.

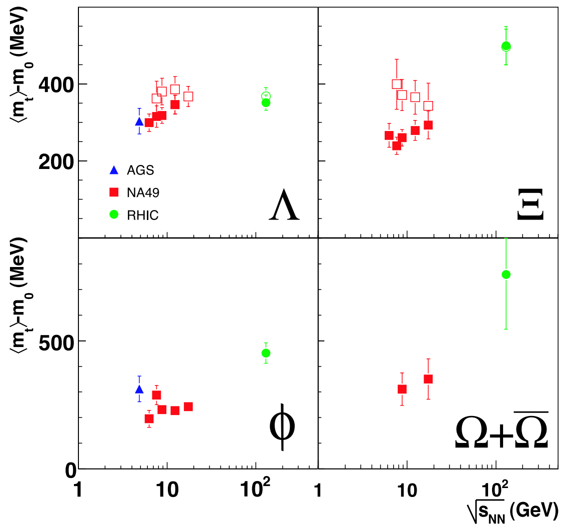

Figure 3. Energy dependence of the mean transverse mass $\langle m_t \rangle - \langle m_0 \rangle$ of Λ, ϕ, Ξ and $\Omega + \bar{\Omega}$ in central Pb+Pb/Au+Au collisions from AGS to RHIC [12] energies. Open symbols indicate the anti-particles.

If energy density and hence pressure increase with beam energy, also an increase of transverse expansion is expected. Assuming that the strength of the transverse expansion is reflected in the mean transverse mass, the variable $\langle m_t \rangle - \langle m_0 \rangle$ should rise with $\sqrt{s_{NN}}$. Previously we have presented results on energy dependence of $\langle m_t \rangle - \langle m_0 \rangle$ for pions, kaons and protons [11]. They show a strong increase of the mean transverse mass at AGS energies. However, at SPS energies this behaviour changes. The energy dependence is weak at SPS energies. Fig. 3 shows new results on $\langle m_t \rangle - \langle m_0 \rangle$ for heavy strange hadrons. Also for these particles no significant energy dependence is observed at SPS energies. Measurements of multiply strange hadrons at AGS energies are needed to fully establish their energy dependence.

4. Energy Dependence of Particle Yields

The NA49 experiment features a large acceptance in the forward hemisphere allowing for measurements of rapidity spectra from midrapidity up to almost beam rapidity. The rapidity spectra for Ξ and Ω in central Pb+Pb collisions are shown in Fig. 4. NA49 results on spectra of π^-, K^+, K^-, ϕ, Λ, and $\bar{\Lambda}$ were presented previously [11].

NA49 has measured different particle species at midrapidity in 20A, 30A, 40A, 80A, and 158A GeV central Pb+Pb collisions. Results on yields at midrapidity in central Au+Au collisions at $\sqrt{s_{NN}} = 62.4$, 130 and 200 GeV have been published by the STAR

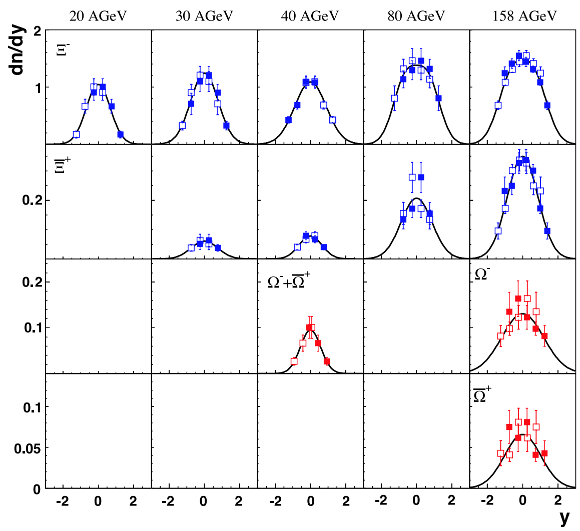

Figure 4. The rapidity spectra of Ξ and Ω produced in central Pb+Pb collisions (7 % most central at $20A - 80A$ GeV, 10 % (Ξ) and 23.5 % (Ω) most central at $158A$ GeV). The closed symbols indicate measured points, open points are reflected with respect to midrapidity. The solid lines represent fits with a single Gaussian. The errors shown are statistical only.

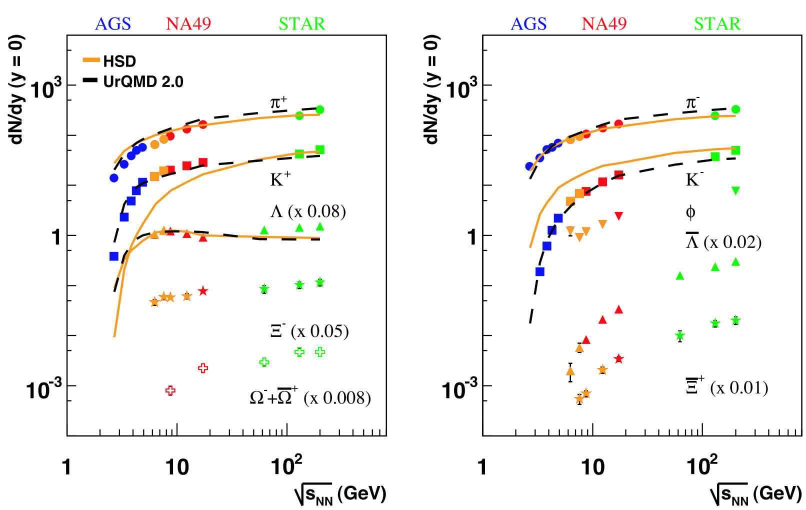

Figure 5. Midrapidity yields from SPS to RHIC energies. The data are compared to string hadronic models [14] (UrQMD 2.0: dashed, HSD: solid). The errors shown are statistical only.

collaboration at RHIC [13]. A compilation of these data is shown in Fig. 5.

One observes a relatively weak energy dependence for hyperons from SPS to RHIC energies, while a strong increase is seen for the anti-hyperons. The data on Λ and kaons yields are compared to string hadronic models [14]. Both models follow the trend of

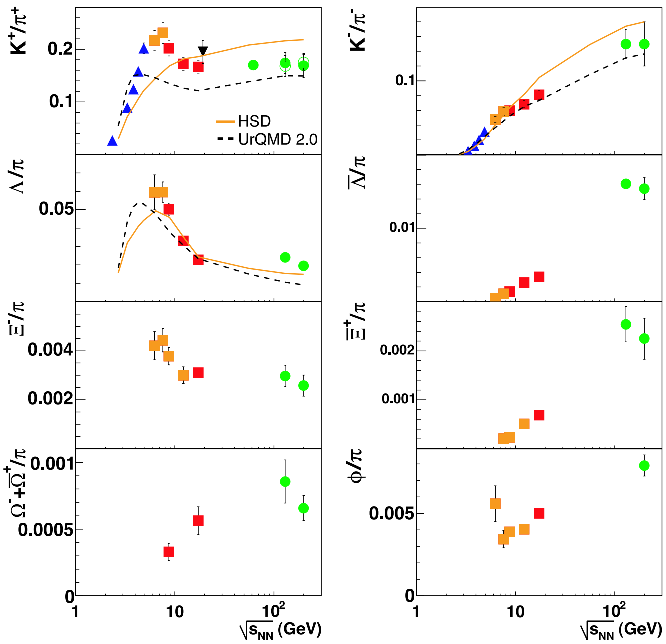

Figure 6. The energy dependence of the midrapidity yields of strange hadrons, normalized to the midrapidity pion yields ($\pi = 1.5\ (\pi^- + \pi^+)$), in central Pb+Pb/Au+Au collisions. The data are compared to string hadronic models [14] (UrQMD 2.0: dashed, HSD: solid).

the measured data, but they fail to reproduce the data quantitaively. Predictions for multi-strange hyperons and ϕ-meson are still not available.

Figs. 6 and 7 show the energy dependence of relative strange particle yields. The ratio of the midrapidity and total yields normalized to the respective pion yields are compared to model calculations. While $\langle K^- \rangle / \langle \pi^- \rangle$, $\langle \bar{\Lambda} \rangle / \langle \pi \rangle$, $\langle \bar{\Xi}^+ \rangle / \langle \pi \rangle$, $\langle \Omega^- + \bar{\Omega}^+ \rangle / \langle \pi \rangle$ and $\langle \phi \rangle / \langle \pi \rangle$ ratios rise continuously with energy, a distinct maximum is visible in the energy dependence of the ratios $\langle K^+ \rangle / \langle \pi^+ \rangle$, $\langle \Lambda \rangle / \langle \pi \rangle$ and $\langle \Xi^- \rangle / \langle \pi \rangle$. The same structure is seen for the midrapidity ratios. Hadron gas [15] (only shown for 4π multiplicity ratios) and microscopic models [14] do not provide a proper description of the structures observed in the data.

The NA49 antibaryon/baryon ratios are shown in Fig. 8 as a function of the beam energy. The ratios increase with increasing strangeness content of the hyperons at a given energy. The energy dependence of the ratio gets weaker with increasing strangeness content. This general trend can be understood as a result of a decrease of the net-baryon density at midrapidity with increasing energy. The open symbols represent measurements from the NA57 Collaboration [16]. While the particle ratios are in good agreement to the NA49 data, the absolute yields, however, tend to be systematically higher by about 30 %, both in central Pb+Pb collisions at 40A and 158A GeV [17].

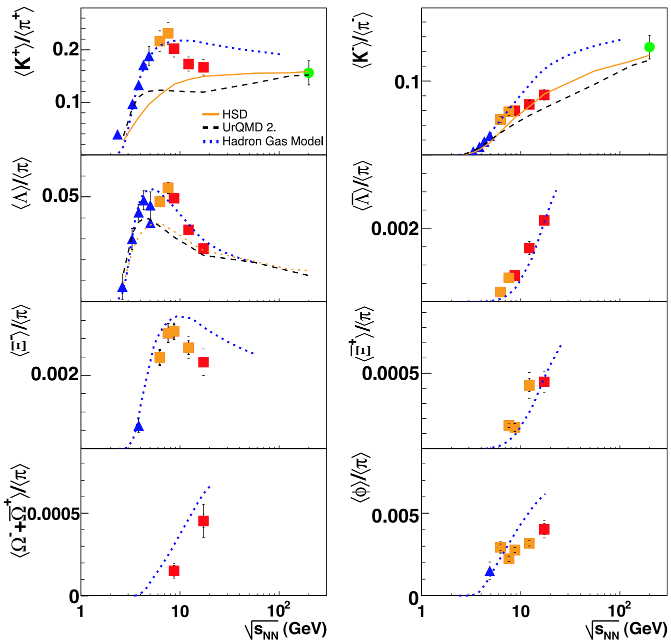

Figure 7. The energy dependence of the total yields of strange hadrons, normalized to the total pion yields ($\langle\pi\rangle = 1.5\ (\langle\pi^-\rangle + \langle\pi^+\rangle)$), in central Pb+Pb/Au+Au collisions. The data are compared to string hadronic models [14] (UrQMD 2.0: dashed, HSD: solid) and statistical hadron gas model [15] (assuming strangeness in full equilibrium: dotted).

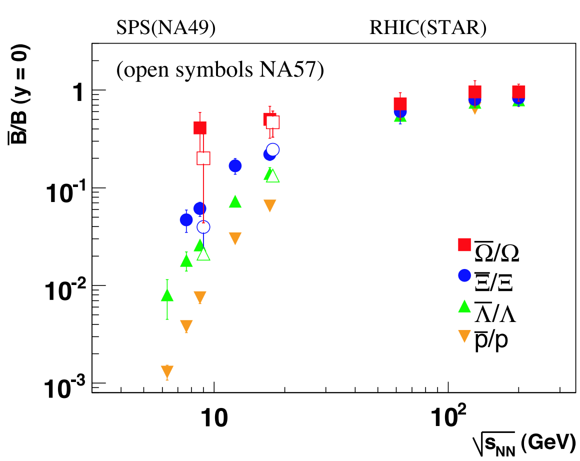

Figure 8. The antibaryon/baryon ratio ($\bar{B}/B$) at midrapidity from SPS to RHIC energies. The errors shown are statistical only.

Fig. 9 shows results on system size and centrality dependence of hyperons at midrapidity at 158A GeV. Having measured particle yields for p+p, C+C, Si+Si and Pb+Pb collisions, one can determine a hyperon enhancement, defined in the follwoing way :

$$E = \left(\frac{Yield}{N_w}\right)_{A+A} / \left(\frac{Yield}{N_w}\right)_{p+p},$$

where N_w is the number of wounded nucleons calculated within the Glauber model [18]. A significant enhancement for the Ξ^- is observed at 158A GeV when going from p+p to Pb+Pb. For the Λ hyperon the enhancement is not as strong as for the Ξ^- hyperon and a slightly weaker centrality dependence is observed.

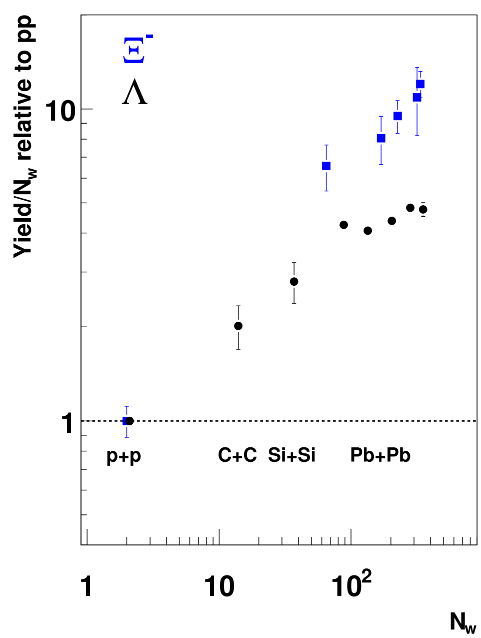

Figure 9. Hyperon enhancement as a function of the number of wounded nucleons at 158A GeV. The errors shown are statistical only.

The NA57 collaboration [16] observes the same trend (not shown) but instead of a p+p they are using a p+Be reference, therefore their enhancement is less than at NA49.

Particle yield ratios at high p_t have been measured in central Pb+Pb collisions. The baryon/meson ratio for $p_t > 2$ GeV/c rises above unity at SPS, similar to what is observed at RHIC energies. As well the nuclear modification factor R_{CP} is extracted and compared to pQCD calculations [19].

The elliptic flow of Λ hyperons has been measured in semi-central Pb+Pb collisions at 158A GeV. The standard method of correlating particles with an event plane has been used. The elliptic flow of Λ particles increases linearly up to 2 GeV/c. The increases of the elliptic flow is weaker at SPS than at RHIC energies, partly due to different centrality selection. A linear increase of v_2 is also observed for all particles as a function of p_t in mid-central collisions at $158A$ GeV [20].

Acknowledgments

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