PROCEEDINGS OF SCIENCE

Latest results from NA57

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NA57 at the CERN SPS has studied the production of strange particles in Pb–Pb and p–Be collisions. Hyperon enhancements at 40 A GeV/c are presented and compared to results at 160 GeV/c beam momenta. The momentum spectra are analysed based on hydrodynamical models and freeze-out temperature, transverse and longitudinal flow velocities are extracted. Central-to-peripheral nuclear modification factors at 160 A GeV/c are calculated.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

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PoS(HEP2005)126

1. Strangeness Enhancement

An enhanced production of strange particles in nucleus–nucleus collisions with respect to proton–induced reactions was suggested long ago as a possible signature of the phase transition from colour-confined hadronic matter to a Quark-Gluon-Plasma (QGP) [1]. NA57 has measured the production of Λ, Ξ^-, Ω^-, their antiparticles and K^0_S in Pb–Pb and in reference collisions (p-Be and p–Pb) at 40 and 160 A GeV/c in the central unit of rapidity and at medium transverse momentum ($p_T \gtrsim 0.5$ GeV/c) [2, 3]. The Enhancement E is defined as the yield per participant ($Y/ < N_{wound} >$, $Y = \int_{y_{cm}-0.5}^{y_{cm}+0.5} \mathrm{d}y \int_0^\infty \frac{\mathrm{d}N^2}{\mathrm{d}p_T \mathrm{d}y} \mathrm{d}p_T$) relative to p-Be collisions. The hyperon enhancements at 40 and 160 A GeV/c are shown as a function of centrality in fig. 1. The arrow in the 2^{nd} panel of fig. 1 indicates the lower limit to the $\overline{\Xi}^+$ enhancement in the four most central classes at 95% confidence level. At 40 A GeV/c the enhancement pattern follows the same hierarchy with the strangeness content predicted in a QGP scenario: $E(\Lambda) < E(\Xi^-)$ and $E(\overline{\Lambda}) < E(\overline{\Xi}^+)$, as already observed at 160 A GeV/c where further $E(\Xi) < E(\Omega)$ [3]. The rational behind these predictions is that the s and $\bar{s}$ quarks, abundantly produced in the deconfined phase would recombine to form strange and multi-strange particles in a time much shorter than that required to produce them by successive rescattering interactions in a hadronic gas. Comparing the measurements at the two

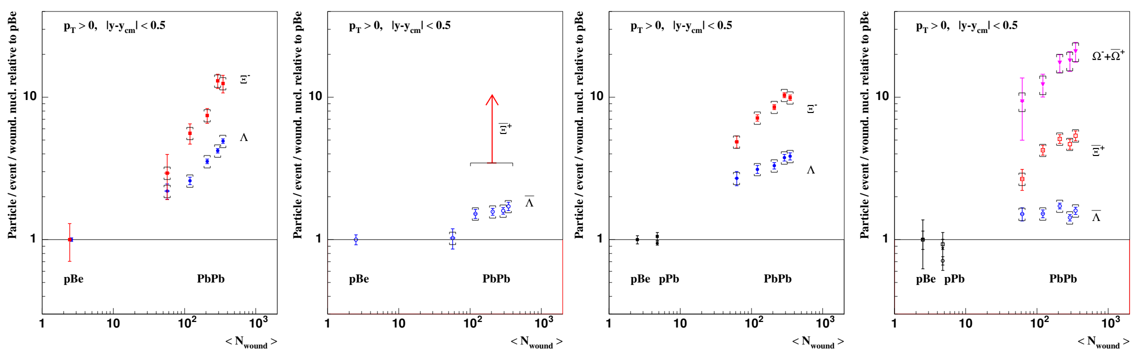

Figure 1: Hyperon enhancements as a function of the number of participants (N_{wound}) at 40 (1^{st} and 2^{nd} panels) and 160 (3^{rd} and 4^{th} panels) A GeV/c. The symbol ⌷ shows the systematic error.

beam momenta: for the most central collisions the enhancements are slightly larger at 40 than at 160 GeV/c, the increase with N_{wound} is steeper at 40 than at 160 GeV/c.

2. Collective Dynamics

The expansion dynamics of the Pb–Pb collisions has been studied in the transverse and longitudinal directions by measuring, respectively, the m_T $(= \sqrt{p_T^2 + m^2})$ spectra (details in ref. [5, 6]) and the rapidity distributions (details in ref. [7]) of strange particles, based on a hydro-dynamics inspired model [8]. A simultaneous description of all the measured particle spectra, both for rapidity and p_T can be achieved with the following set of parameters (for the most central 53% of the inelastic Pb–Pb cross section at 160 A GeV/c): freeze-out temperature $T = 144 \pm 7$ MeV, average flow velocities $< \beta_\perp > = 0.38 \pm 0.02$ and $< \beta_\parallel > = 0.42 \pm 0.03$, as shown in fig. 2. With increasing centrality, the freeze-out temperature decreases and the transverse flow velocity increases. In the

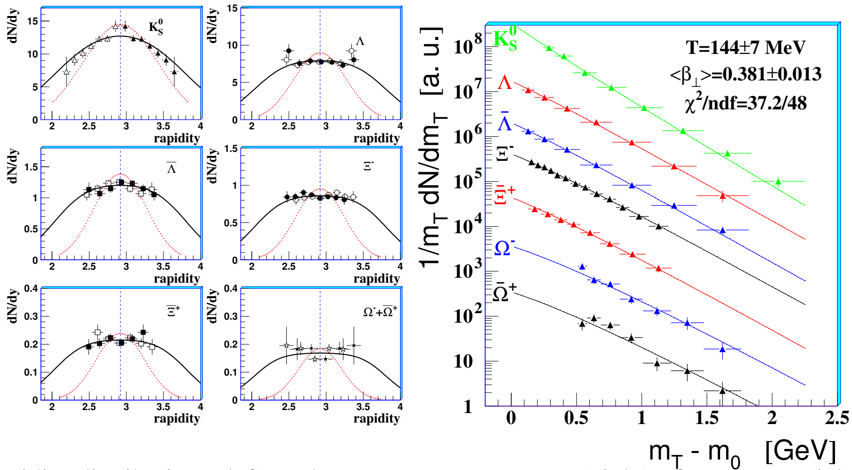

Figure 2: Rapidity distributions (left) and transverse mass spectra (right) of strange particles for the most central 53% of the inelastic Pb–Pb cross-section. Blast-wave fits are superimposed to the data point (full lines). The dotted lines in the left panel show the distribution expected for a thermal source without any longitudinal flow.

longitudinal direction, instead, we do not observe a centrality dependence. The freeze-out temperature is lower at 40 ($T = 118 \pm 5$ MeV) than at 160 A GeV/c, but the transverse velocity is compatible at the two energies.

3. Nuclear Modification Factors

At the Relativistic Heavy Ion Collider (RHIC), the central-to-peripheral nuclear modification factor

$$R_{\rm CP}(p_{\rm T}) = \frac{\langle N_{\rm coll}\rangle_{\rm P}}{\langle N_{\rm coll}\rangle_{\rm C}} \times \frac{{\rm d}^2N^{\rm C}_{\rm AA}/{\rm d}p_{\rm T}{\rm d}y}{{\rm d}^2N^{\rm P}_{\rm AA}/{\rm d}p_{\rm T}{\rm d}y}$$

measured for a large variety of particles has proven to be a powerful tool for the study of parton propagation in the dense QCD medium expected to be formed in nucleus–nucleus collisions (see, e.g., [9]). At SPS energy, so far, only π^0 $R_{\rm CP}$ measurements were available [10]; the first results on the particle-species dependence (unidentified negatively charged hadrons, $\rm K^0_S$, Λ, and $\overline{\Lambda}$) were reported recently by the NA57 Collaboration in [11]. Figure 3 (left panel) shows the results for 0–5%/40–55% $R_{\rm CP}$ nuclear modification factors. At low-$p_{\rm T}$ $R_{\rm CP}$ scales with the number of participants for all particles except the $\overline{\Lambda}$. With increasing $p_{\rm T}$, $\rm K^0_S$ mesons reach values of $R_{\rm CP} \approx 1$: we do not observe the enhancement above unity that was measured in proton–nucleus relative to pp collisions (Cronin effect [12]). An enhancement is, instead, observed for strange baryons, Λ and $\overline{\Lambda}$, that reach $R_{\rm CP} \simeq 1.5$ at $p_{\rm T} \simeq 3$ GeV$/c$. In fig. 3 (middle panel) we compare our $\rm K^0_S$ data to predictions (X.N. Wang) obtained from a perturbative-QCD-based calculation [13], including (thick line) or excluding (thin line) in-medium parton energy loss. The initial gluon rapidity density of the medium was scaled down, from that needed to describe RHIC data, according to the decrease by about a factor 2 in the charged particle multiplicity. The data are better described by the curve that does include energy loss. The prediction of a second model of parton energy loss (PQM) that describes several energy-loss-related observables at RHIC energies [14] is also in agreement with the value reached at high-$p_{\rm T}$ by the data. Figure 3 (right panel) shows the ratio of

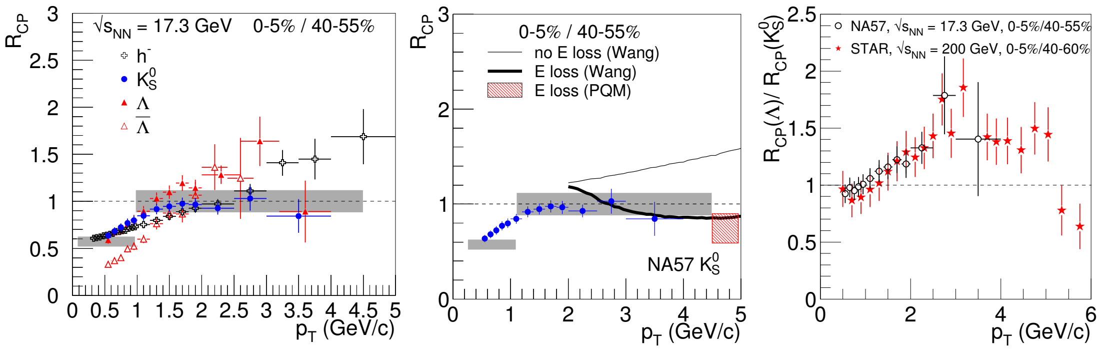

Figure 3: Left: R_{CP} ratios for negatively charged particles (h^-) and singly-strange particles in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 17.3$ GeV [11]. The width of the shaded band centered at $R_{\mathrm{CP}} = 1$ indicates the systematic error due to the uncertainty on the values of $\langle N_{\mathrm{coll}}\rangle$ in each class; the band at low p_{T} show the value expected for scaling with the number of participants. Middle: $\mathrm{K}^0_{\mathrm{S}}$ $R_{\mathrm{CP}}(p_{\mathrm{T}})$ compared to predictions [13, 14] with and without energy loss Right ratio of Λ R_{CP} to $\mathrm{K}^0_{\mathrm{S}}$ R_{CP}, as a function of p_{T}, at the SPS (NA57 at $\sqrt{s_{\mathrm{NN}}} = 17.3$ GeV) and at RHIC (STAR at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV [9, 15]).

Λ R_{CP} to $\mathrm{K}^0_{\mathrm{S}}$ R_{CP}, as measured from our data and by STAR at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV [9, 15] (note that $\Lambda + \bar{\Lambda}$ are considered by STAR and that the centrality range used for the peripheral class is slightly different in the two experiments). The similarity of the Λ–K pattern to that observed at RHIC may be taken as an indication for coalescence effects [16] at SPS energy.

References

[1] Rafelski J and Müller B 1982 *Phys. Rev. Lett.* **48** 1066, ibidem 1986 **56** 2334

[2] Antinori F *et al.* 2004 *Phis. Lett.* B **595** 68-74

[3] Bruno G E *et al.* 2004 *J. Phys. G: Nucl. Part. Phys.* **30** S717-S724

[4] Tounsi A, Mischke A and Redlich K 2003 *Nucl. Phys.* A **715** 565c

[5] Antinori F *et al.* 2004 *J. Phys. G: Nucl. Part. Phys.* **30** 823-840

[6] Bruno G E *et. al.* 2005 *J. Phys. G: Nucl. Part. Phys.* **31** S127-S133

[7] Antinori F *et al.* 2005 *J. Phys. G: Nucl. Part. Phys.* **31** 1345-1357

[8] Schnedermann E, Sollfrank J and Heinz U 1993 *Phys. Rev.* C **48** 2462-2475

[9] Adams J *et al.* 2004 *Phys. Rev. Lett.* **92** 052302

[10] Aggarwal M M *et al.* 2002 *Eur. Phys. J.* C **23** 225; d'Enterria D 2004 *Phys. Lett.* B **596** 32.

[11] Antinori F *et al.* 2005 *Phys. Lett.* B **623** 17

[12] Cronin J *et al.* 1975 *Phys. Rev.* D **11** 3105.

[13] Wang X N 2000 *Phys. Rev.* C **C61** 064910; private communication.

[14] A. Dainese *et al.*, *Eur. Phys. J.* **C38** (2005) 461; private communication.

[15] M.A.C. Lamont, poster presentation at QM2005, *Acta Phys. Slov. in print*.

[16] Hwa R C and Yang C B 2003 *Phys. Rev.* C **67** 064902; Fries R J *et al.* 2003 *Phys. Rev.* C **68** 044902; Greco V *et al. Phys. Rev.* C **68** 034904.