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High p_T spectra of identified particles produced in Pb+Pb collisions at 158 A GeV beam energy

Tim Schuster[1] **and András László**[2] **(for the NA49 Collaboration**[3]**)**

[1] Institut für Kernphysik, J W Goethe-Universität, 60438 Frankfurt, Germany
[2] MTA-KFKI Research Institute of Particle and Nuclear Physics, Budapest, Hungary

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Abstract
Results of the NA49 collaboration on the production of hadrons with large transverse momentum in Pb+Pb collisions at 158 A GeV beam energy are presented. A range of up to $p_T = 4$ GeV/c is covered. The nuclear modification factor R_{CP} is extracted for $\pi^{\pm}$, $K^{\pm}$ and p, and the baryon to meson ratios p/π^+, $\bar{p}/\pi^-$ and Λ/K^0_s are studied. All results are compared to other measurements at SPS and RHIC and to theoretical calculations.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

The features of high p_T hadron production at RHIC suggest the creation of a new state of matter [1–4]. While nuclear modification factors smaller than 1 at high p_T are interpreted as a sign for energy loss of high momentum partons in a strongly interacting dense medium, the measured high values in baryon/meson ratios can be explained by hadron production via quark coalescence. Studying these effects at the SPS can help to enhance the understanding of the underlying mechanisms. The presented results at the highest SPS beam energy of 158 A GeV ($\sqrt{s_{NN}} = 17.2$ GeV) exhibit similar trends as previously seen in RHIC data. They thus complement the picture obtained from numerous other observables (like e.g. the new results on Λ flow [5]) indicating that at the top SPS energy a state of matter resembling that at RHIC is created.

2. Analysis

The main tracking device of NA49 are four large volume time projection chambers (TPCs). A calorimetric measurement of the projectile spectator energy provides an independent control of the collision centrality. For a detailed description of the detector, see [6].

[3] A list of members of the NA49 Collaboration is given at the end of this issue.

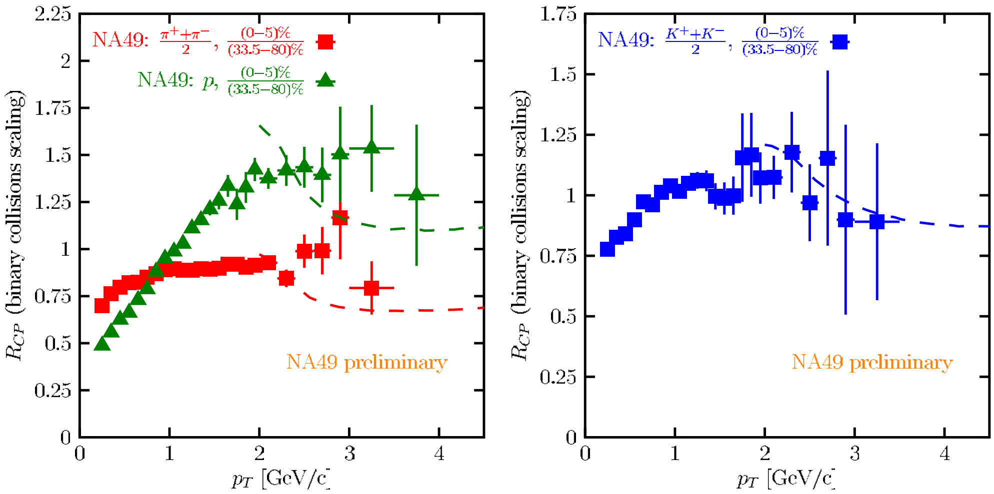

Figure 1. The nuclear modification factor R_{CP} for pions, kaons and protons measured by NA49 in Pb+Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 17.2$ GeV, compared to pQCD model calculations taking into account partonic energy loss (dashed line, [7]). The compared centrality ranges are indicated as a fraction of the total inelastic cross section $\sigma/\sigma_{\mathrm{tot.}}^{\mathrm{inel.}}$.

$\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ are identified via their specific energy loss in the TPCs ($\mathrm{d}E/\mathrm{d}x$). The resolution of this measurement is 3–6% and the tracking efficiency is above 95%. In this analysis of charged hadrons, the collision centrality ranges 0–5%, 12.5–23.5% and 33.5–80% of the total inelastic cross section were used. The presented results refer to the rapidity interval $-0.3 < y_{\mathrm{CM}} < 0.7$. Neutral strange hadrons are identified by a reconstruction of the decay topologies $K_s^0 \to \pi^+\pi^-$ (BR = 68.95%) and $\Lambda \to p\pi^-$ (63.9%). Candidates for these decays are selected by geometrical and kinematical criteria and their invariant mass is calculated to extract yields in $y - p_{\mathrm{T}}$-bins. Here, the centrality interval 0–23.5% and the range $-0.5 < y_{\mathrm{CM}} < 0.5$ around mid-rapidity were used.

All results are corrected for acceptance and reconstruction inefficiency. The Λ, proton and pion yields have not yet been corrected for feed-down from the decay of heavier particles, but the bias has been estimated to be below 10%.

3. Results

The nuclear modification factor R_{CP} is defined as the yield ratio in central over peripheral collisions, scaled by the mean number of binary nucleon–nucleon collisions $\langle N_{\mathrm{coll}}\rangle$:

$$R_{\mathrm{CP}} := \frac{\langle N_{\mathrm{coll}}\rangle^{\mathrm{Per.}}}{\langle N_{\mathrm{coll}}\rangle^{\mathrm{Cen.}}} \frac{(\mathrm{d}^2 N/(\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}y))^{\mathrm{Cen.}}}{(\mathrm{d}^2 N/(\mathrm{d}p_{\mathrm{T}}\,\mathrm{d}y))^{\mathrm{Per.}}}.$$

$\langle N_{\mathrm{coll}}\rangle$ was calculated for each centrality interval using the VENUS model. The scaling may be model dependent and the corresponding systematic error in R_{CP} is assumed to be of the order of $\pm 20\%$. A shaded band indicates this error in figure 2.

R_{CP} for charged pions, kaons and protons is shown in figure 1. A monotonic rise leads up to a plateau that is reached at $p_{\mathrm{T}} = 1$ GeV/c (for pions and kaons) and $p_{\mathrm{T}} = 2$ GeV/c (for protons). A perturbative QCD calculation taking the radiative energy loss of partons into account [7] is consistent with the data when considering statistical and systematic errors.

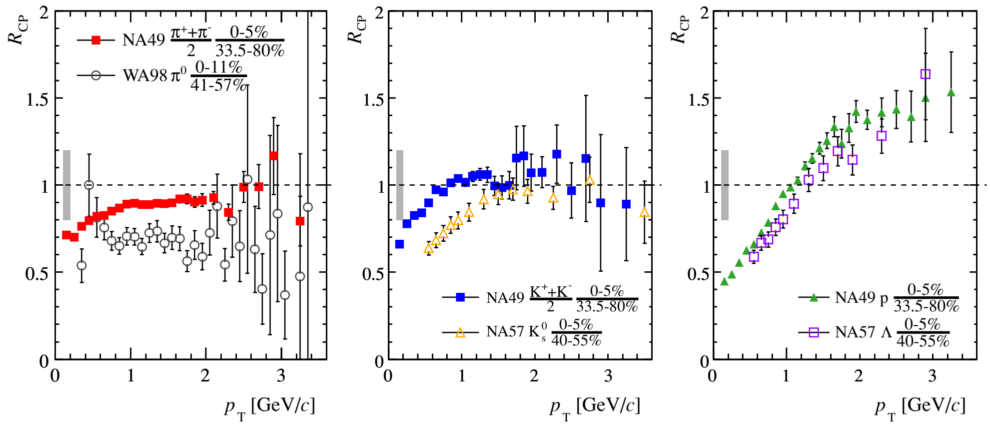

Figure 2. A comparison of R_{CP} measurements in Pb+Pb collisions at the top SPS energy of $\sqrt{s_{NN}} = 17.2$ GeV: π^0 from WA98 (left panel, [8]), K^0_s and Λ from NA57 (middle and right panels, [9]), together with the NA49 results. The shaded bands indicate a systematical error on the NA49 results (see the text).

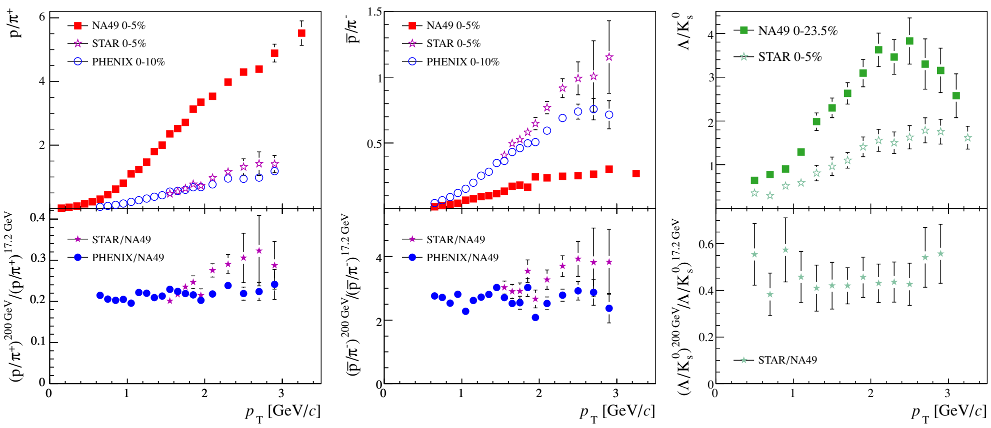

Figure 3. The baryon/meson ratios measured in NA49 at $\sqrt{s_{NN}} = 17.2$ GeV compared to results from RHIC [10, 11] at $\sqrt{s_{NN}} = 200$ GeV. Please note the different scales of the plots.

Figure 2 shows a comparison with other data available at the highest SPS energy of 158 A GeV [8, 9]. When considering all systematic errors introduced by different methods of centrality determination and the calculation of $\langle N_{coll} \rangle$, the results of all three experiments are consistent. R_{CP} tends towards the same values at $p_T > 2$ GeV/c for the compared hadron species.

While at RHIC the high values for baryon/meson ratios at intermediate p_T can be explained by quark coalescence models (see e.g. [10]), no calculations of such models are available for SPS energies yet. The upper panels in figure 3 show the NA49 results for p/π^+, $\bar{p}/\pi^-$ and Λ/K^0_s together with the corresponding results from PHENIX [11] and STAR [10] at the highest RHIC energy of $\sqrt{s_{NN}} = 200$ GeV. The higher net baryon density at SPS energy is manifested in quantitative differences, but the shape of the baryon/meson ratios as a function of p_T is the same for both energies. This can be seen in the lower panels of figure 3, where the double ratios are shown. New results from RHIC Cu+Cu runs at various energies also show no qualitative change with energy in the shape of the baryon/meson ratios [12].

4. Conclusions

The presented results on R_{CP} at the highest SPS energy of $\sqrt{s_{\mathrm{NN}}} = 17.2$ GeV are consistent with a pQCD model that incorporates parton energy loss and is used to explain RHIC results. Although large systematic errors remain, the results of three different SPS experiments are in line with this picture. Baryon/meson ratios as a function of p_{T} have the same shape as at RHIC, but the theoretical interpretation in the SPS energy range is still missing.

Acknowledgments

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