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Latest Results on High-p_t Data and Baryon Production from NA49

C. Blume* **for the NA49 Collaboration**
Institut für Kernphysik, J.W. Goethe Universität, Frankfurt am Main, Germany
E-mail: blume@ikf.uni-frankfurt.de

Latest results from the NA49 experiment at the CERN-SPS are discussed. These include new data on proton and antiproton production in minimum bias Pb+Pb collisions at 158*A* GeV. This recent data allow to study the system size dependence of stopping. Also, results on high-p_t nuclear suppression factors, as well as two particle azimuthal correlations are presented.

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*Speaker.

1. Introduction

The NA49 experiment is a fixed target experiment at the CERN-SPS. Details on the experimental setup can be found in [1]. In recent years NA49 has collected data on nucleus nucleus collisions at several beam energies between 20*A* and 158*A* GeV with the objective to cover the critical region of energy densities where the expected phase transition from a deconfined phase might occur in the early stage of the reactions. Also, the system size dependence of various hadronic observables have been studied by investigating minimum bias Pb+Pb collisions at 158*A* GeV.

2. System Size Dependence of Stopping

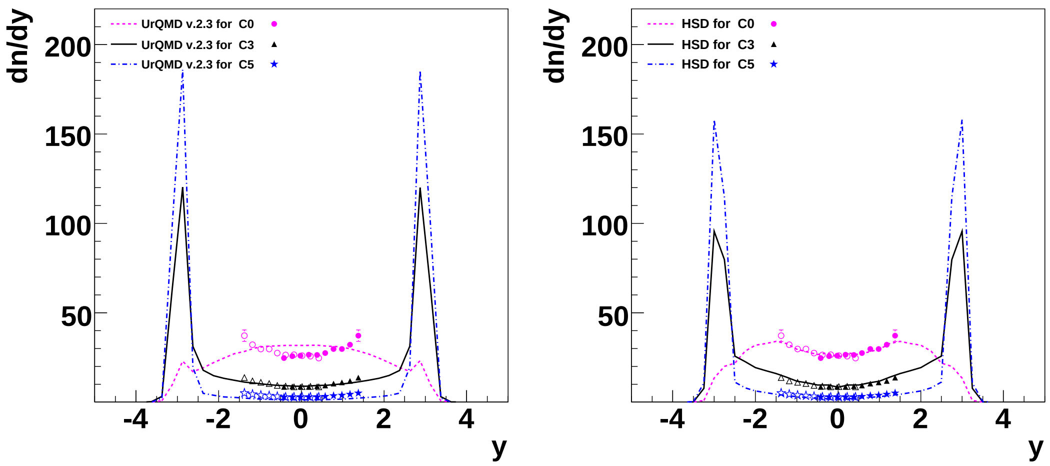

Figure 1: The rapidity distributions of net-protons for minimum bias Pb+Pb reactions at 158*A* GeV. Shown are three different centrality classes: very central (C0), intermediate (C3), and peripheral (C5). The data are compared to UrQMD2.3 [2, 3] (left panel) and HSD [4] (right panel).

New data on proton and antiproton production in minimum bias Pb+Pb reactions allow to study the system size dependence of stopping. Figure 1 shows the net-proton rapidity distributions for three exemplary centrality classes, selected from minimum bias Pb+Pb interactions at 158*A* GeV. A remarkable feature of this data is that there is no change with centrality of the shapes of the distributions inside the measured region. This is at variance with the UrQMD2.3 model [2, 3], which predicts a clear centrality dependence of the shapes for $|y| < 1.7$. HSD [4], which allows a nucleon to re-interact only after the local energy density falls below a threshold instead of using just a formation time, is on the other hand able to reproduce the measurements quite well at all centralities.

3. High p_t Spectra

In order to establish whether any kind of modification in the high p_t region is present in A+A collisions at SPS energies, reference data from p+p and/or p+A collisions are of high importance.

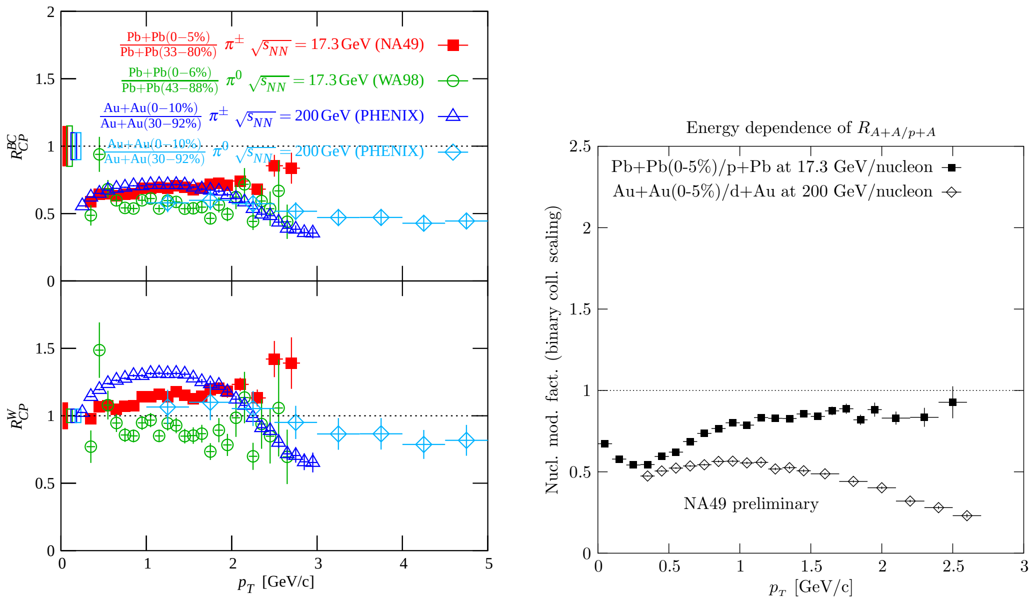

Figure 2: The nuclear modification factors $R_{\rm CP}$ (left panel) and $R'_{\rm AA}$ (right panel) for charged pions at mid-rapidity (-0.3 $< y <$ 0.7) for central Pb+Pb collisions at $\sqrt{s_{\rm NN}}$ = 17.3 GeV as a function of $p_{\rm t}$. Also shown are results on charged and neutral pions by WA98 [5, 11] at the same energy and by PHENIX at $\sqrt{s_{\rm NN}}$ = 200 GeV [9].

Unfortunately, there are no p+p data available at $\sqrt{s} = 17.3$ GeV that cover the interesting $p_{\rm t}$-region above 2 GeV$/c$. Several attempts have been made to replace the missing data by an interpolation from lower and higher beam energies [5, 6, 7]. However, one should keep in mind that at the center-of-mass energies under discussion here, the spectral shape in the higher $p_{\rm t}$ region (i.e. above $p_{\rm t}$ = 2 GeV$/c$) changes drastically with energy since the kinematic limit becomes important here. Therefore, any parametrization introduces a large systematic error. In order to overcome this current limitation, one can either use peripheral nucleus–nucleus data as baseline [5, 8] or employ recent p+A data [10, 11] in order to construct the corresponding nuclear modification factors:

$$R_{\rm CP}(p_{\rm t}) = \frac{\langle N_{\rm coll}(\text{per.})\rangle}{\langle N_{\rm coll}(\text{cen.})\rangle} \frac{{\rm d}N_{\rm AA}^{\rm cen.}/{\rm d}p_{\rm t}}{{\rm d}N_{\rm AA}^{\rm per.}/{\rm d}p_{\rm t}}, \qquad R'_{\rm AA}(p_{\rm t}) = \frac{\langle N_{\rm coll}(\text{p+A})\rangle}{\langle N_{\rm coll}(\text{A+A})\rangle} \frac{{\rm d}N_{\rm AA}/{\rm d}p_{\rm t}}{{\rm d}N_{\rm pA}/{\rm d}p_{\rm t}} \tag{3.1}$$

Both approaches provide a larger $p_{\rm t}$-reach than the presently available p+p data at the SPS and have also the benefit of removing to a certain extent the Cronin effect, which is getting stronger towards lower energies and dominates nuclear modifications here [7]. The upper panel of the left plot in Fig. 2 shows the results for $R_{\rm CP}$ using the number of binary collisions as a scaling parameter. The lower plot uses the number of wounded nucleons instead. Also shown are results from WA98 at the SPS [5] and PHENIX at RHIC [9]. Both SPS experiments measure a $R_{\rm CP}$ that is smaller than unity and would thus suggest that the effect of parton energy loss is also present at SPS energy. A similar conclusion can be drawn from the $R'_{\rm AA}$ values measured at the SPS (right plot of Fig. 2). While the observed $R'_{\rm AA}$ values are clearly not as low at $\sqrt{s_{\rm NN}}$ = 17.3 GeV than at $\sqrt{s_{\rm NN}}$ = 200 GeV [12], there is nevertheless an indication for a small suppression relative to pure binary scaling, in agreement with a recent analysis of π^0 spectra [11].

4. High p_{t} Correlations

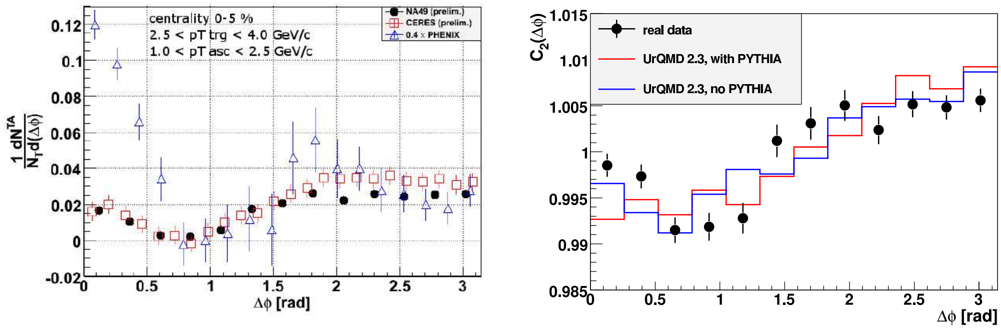

Figure 3: Left: The per trigger conditional yield for 5% most central nucleus–nucleus interactions. The black dots represent the preliminary NA49 results for Pb+Pb collisions at 158*A* GeV. Also shown are CERES results for Pb+Au reactions at the same beam energy [17] (red squares). The blue triangles are data from the PHENIX collaboration for Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV [15], which have been scaled to match the SPS data at the minimum. Right: The two particle azimuthal correlations functions $C_2(\Delta\phi)$ compared to the UrQMD2.3 model [2, 3] with and without the simulation of hard processes using PYTHIA.

Two particle azimuthal correlations have been studied extensively at RHIC in order to learn aboutt the effect of a hot and dense medium on the evolution of dijets. It has been found that the away side structure is strongly broadened, which is usually interpreted as a sign of parton medium interactions. A similar study has now been performed by the NA49 collaboration [13, 14]. Following the procedure as described in [15], the correlation function $C_2(\Delta\phi)$ is defined as the ratio of two distributions in $\Delta\phi = \phi_{\mathrm{asc}} - \phi_{\mathrm{trg}}$, where ϕ is the azimuthal angle. One distribution is calculated from pairs of trigger and associated particles taken from the same event $N_{\mathrm{corr}}(\Delta\phi)$, while the uncorrelated reference distribution $N_{\mathrm{mix}}(\Delta\phi)$ is constructed using an event mixing technique:

$$C_2(\Delta\phi) = \frac{N_{\mathrm{corr}}(\Delta\phi)}{N_{\mathrm{mix}}(\Delta\phi)} \frac{\int N_{\mathrm{mix}}(\Delta\phi')\,\mathrm{d}(\Delta\phi')}{\int N_{\mathrm{corr}}(\Delta\phi')\,\mathrm{d}(\Delta\phi')} \tag{4.1}$$

The trigger particles are selected from the p_{t}-range $2.5\,\mathrm{GeV}/c \leq p_{\mathrm{t}}^{\mathrm{trg}} \leq 4.0\,\mathrm{GeV}/c$ and the associated particles from the interval $1.0\,\mathrm{GeV}/c \leq p_{\mathrm{t}}^{\mathrm{asc}} \leq 2.5\,\mathrm{GeV}/c$. Based on the assumption that the correlation function can be decomposed into contributions from hard scatterings and elliptic flow, the second contribution is subtracted following the Zero Yield At Minimum (ZYAM) method [16]. This allows to derive the per-trigger conditional yield of associate particles:

$$\frac{1}{N_{\mathrm{T}}} \frac{\mathrm{d}N^{\mathrm{TA}}}{\mathrm{d}\Delta\phi} = \frac{C_2^{\mathrm{jet}}(\Delta\phi)}{\int C_2(\Delta\phi')\,\mathrm{d}(\Delta\phi')} \frac{N^{\mathrm{TA}}}{N_{\mathrm{T}}} \tag{4.2}$$

Here N_{T} is the number of trigger particles and N^{TA} the number of trigger–associate pairs in the same event.

The left panel of Fig. 3 shows the conditional yield measured by NA49. A small near side peak and a relatively broad structure at the away side are visible. The comparison with the data from the CERES collaboration [17] demonstrates good agreement of the two measurements. Also shown is a measurement by PHENIX at $\sqrt{s_{NN}}$ = 200 GeV [15]. Here the near side peak is much more pronounced than for the SPS data. However, the distributions on the away side look relatively similar at both energies.

In the right panel of Fig. 3 a comparison of the NA49 data to calculations with the UrQMD2.3 model [2, 3] is shown. Additionally to the soft processes that are the main ingredients of UrQMD, the version 2.3 allows to include hard processes by using the PYTHIA model [18]. The calculation is quite close to the measurement. Especially the broad structure on the away side is also seen in the model, regardless of the inclusion of the hard scattering component. Since there is no parton medium interaction implemented in UrQMD2.3 the shape of the structure in the simulation is most likely caused by momentum conservation effects.

Acknowledgments

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