Hadron Physics with CERES: Spectra and Collective Flow

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Hadronic spectra from interactions of Pb on Au at 158 AGeV/c have been measured by the CERES experiment at the CERN SPS. We report on preliminary results on transverse mass spectra of identified pions and negative hadrons as well as spectra of the positive charge excess obtained by subtracting the negative particle distribution from that of positive tracks. We have also performed a study of the event azimuthal anisotropies which give evidence for directed and elliptic flow in non-central collisions.

1. INTRODUCTION

The study of hadronic spectra provides additional systematic information on the behavior of the hot fireball formed in heavy-ion collisions at the highest energy now available. The aim is to test whether conditions favorable for the QGP transition are indeed reached.

2. EXPERIMENTAL SETUP AND DATA ANALYSIS

Although CERES (CErenkov Ring Electron Spectrometer) was originally designed as a hadron-blind spectrometer devoted to measure electron pairs [1,2], it incorporates several possibilities to detect hadrons. Two Silicon Drift Detectors (SDD), located 10 cm downstream of the target, permit with their high efficiency, excellent granularity, and good position resolution to measure the charged particle distribution and to analyze the event azimuthal anisotropies. In combination with the information of a Pad Chamber located

behind the magnetic field, we measure, on a statistical basis (without particle identification), the momentum distribution of positive and negative particles in the pseudorapidity range from 2.1 to 2.6. Momenta are calculated via the azimuthal deflection in the magnetic field.
Moreover, using the full spectrometer, pions which exceed the Cherenkov threshold in the two RICH detectors (p > 4.5 GeV/c) are identified individually. In this case, momenta are evaluated more precisely by the Cherenkov ring radius.

3. CHARGED PARTICLE DISTRIBUTION

Using the two SDDs, the charged particle distribution was determined over a wide range in pseudorapidity and impact parameter corresponding to the most central 35% of the geometrical cross section (σ_{geo}). Fig. 1 (left) represents the charged particle pseudorapidity density obtained for seven mutually exclusive centrality bins. On the right hand side we show the variation of the maximum (top) and the width of the Gaussian-fit distribution (bottom) for the some seven centrality bins. One observes an increase of the peak value which corresponds to the increase in the number of participants in the collision and a decrease of the width indicating a higher degree of stopping reached in more central interactions. A comparison with the NA49 result [3] shows that the width of a distribution of negative hadrons is as expected somewhat narrower. The event generators VENUS [4] and RQMD [5] do not reproduce well the shape of the standard deviation (bottom) and overestimate the maximum (top) of the charged particle pseudorapidity distributions.

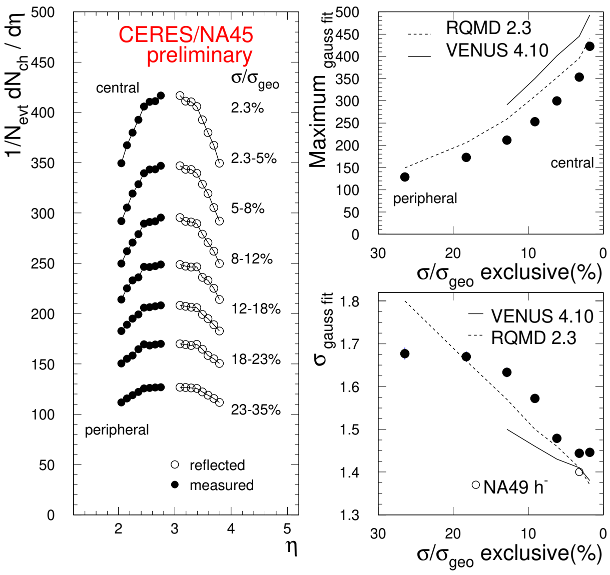

Figure 1. Centrality dependence of the charged particle pseudorapidity distribution compared to models.

4. SINGLE-PARTICLE SPECTRA

Spectra of negative hadrons (h^-), mostly pions with a contribution of K^- and $\bar{p}$ smaller than 10% and a negligible contamination of electrons (< 1%), have been extracted using the SDDs and the Pad Chamber. Combined with data from identified negative pions, they cover a wide range in transverse mass: $0.2 < m_\perp - m_0 < 4$ GeV/c^2. The data, corrected for efficiency as well as for momentum resolution are shown in Fig. 2. It can be seen in the overlap region that the two completely different detection methods are in very good agreement. In Fig. 3 we show the change of the local inverse slope of the spectra (width of fit interval 400 MeV/c^2 for h^- and 1 GeV/c^2 for π^-) with $m_\perp$ for more peripheral and the most central collisions. One observes a continuous change of the local inverse slope which is less pronounced for central collisions.

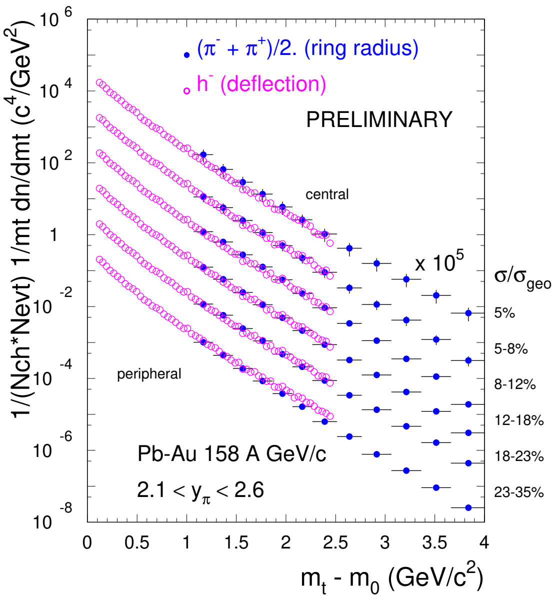

Figure 2. Transverse mass spectra of negative hadrons and identified pions for different centrality selections, successively scaled by factors 10.

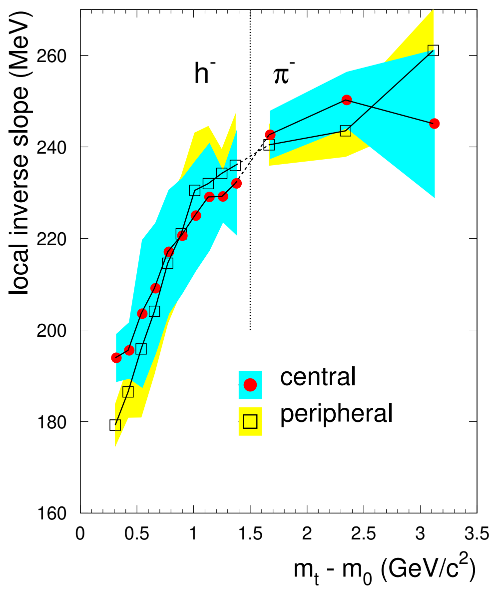

Figure 3. Local inverse slope versus transverse mass for two different exclusive centrality bins ($23-30\%$ and $<5\%$ of σ_{geo}).

Also, 'net proton-like' spectra obtained by subtracting the h^- spectra from those of positive hadrons (h^+) have been studied. The angular acceptance of the CERES spectrometer corresponds for protons to the rapidity interval $1.0 < y_p < 2.6$, with a varying transverse momentum coverage. For the most central collisions ($\sigma/\sigma_{geo} = 2.3\%$), the corrected $h^+ - h^-$ spectra are presented in Fig. 4a. A steepening of the slope with $m_\perp$ can be noticed. For the spectra in the rapidity interval $2.1 < y_p < 2.5$, the inverse slope parameter extracted in the region $0.7 < m_\perp - m_0 < 2$ GeV/c^2, has found to be 250 ± 12(stat) $\pm\, 10$(syst) MeV. The centrality dependence (Fig. 4b) is very weak with a 5% change over the centrality range covered (35% to 2.3% σ_{geo}).

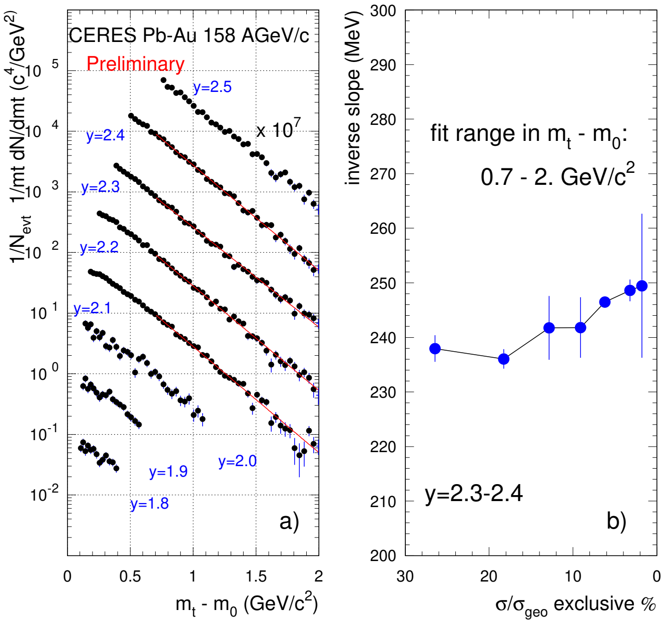

Figure 4. (a) Transverse mass spectra of $h^+ - h^-$ successively multiplied by factors of 10 with increasing rapidity. (b) Centrality dependence of the inverse slope.

5. EVENT SHAPE ANALYSIS

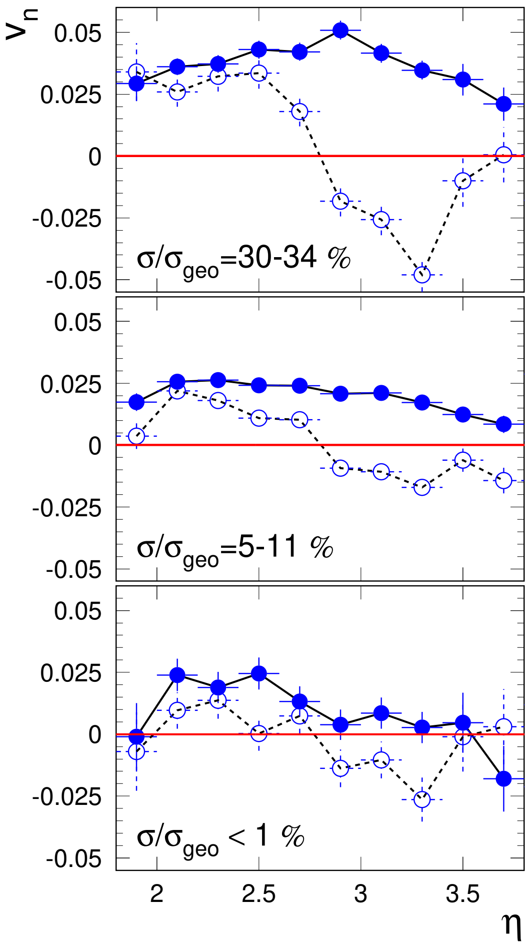

Figure 5. Pseudorapidity dependence of the directed (○) and elliptic flow (●) of all charged particles, v_1 and v_2 respectively.

A Fourier analysis [6–8] of the azimuthal charged particle distribution with respect to the reaction plane was performed making use of the hits of the two SDDs. The amplitude v_1 of the first harmonic is associated with the directed flow. The second harmonic coefficient v_2 is a measure of the elliptic flow. In Fig. 5 the pseudorapidity dependence of both flow parameters, v_1 and v_2, is shown for different centrality selections. We have chosen a negative sign of v_1 in the forward hemisphere, following the usual notation in which the pions are seen to have flow opposite to protons. We notice in this case (open symbols in the figures) the expected change in sign of v_1 at midrapidity ($\eta \sim 3$) and a centrality dependence which ranges from maximum directed flow values v_1 of 3.5% (for $30 - 34\%$ σ_{geo}) to 1% for the most central collisions ($< 1\%$ σ_{geo}). Concerning the elliptic flow the sign of v_2 was determined relative to the directed flow and found to be positive, i.e. the longer axis of the ellipse lies in the reaction plane. The v_2 values are decreasing from 4.5% to again $1 - 2\%$ with decreasing impact parameter. The rapidity dependence of v_2 seems to be rather weak.

REFERENCES

1. Proposal to the SPSLC, CERN SPSLC/94-1/P280
2. CERES/NA45 Report to Cogne 1995, CERN SPSLC/95-20/M542
3. P.G. Jones *et al.* (NA49 Collaboration), Nucl.Phys. **A610** (1996) 188c
4. K. Werner, Phys. Rep. **232** (1995) 87
5. H. Sorge, Phys. Rev. **C52** (1995) 3291
6. S. Voloshin and Y.Zhang, Z. Phys. **C 70** (1996) 665
7. J. Barrette *et al.* (E877 Collaboration), Phys. Rev. **C55** (1997) 1420; Phys. Rev. **C56** (1997) 3254
8. J.-Y. Ollitrault, preprint nucl-ex/9711003 (1997)