

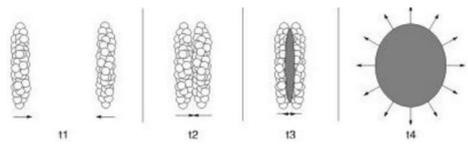
Coulomb influence on charged pion production in Au+Au collisions at relativistic energies

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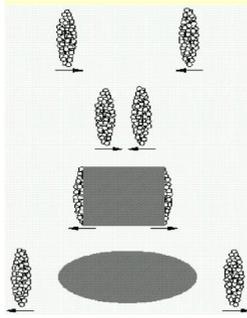
Introduction

In heavy-ion collisions, the differences in shape between the positive and negative pion transverse momentum spectra at low p_T can be used to study the Coulomb final-state interaction [1].

The produced charged particles are moving in a Coulomb field generated by the positive net-charge of the stopped participant protons. The charged pions, as the most abundantly produced and lightest species, are the particles most strongly influenced by this Coulomb field. Therefore, they are accelerated or decelerated and their final momentum is changed.



The strength of the Coulomb field depends on the degree of baryon stopping produced in the collision.



Transparency – higher energies

Stopping – lower energies

The STAR-BES data were analyzed using an analytic model developed in Ref [2]. The model considers the longitudinal Bjorken expansion of the fireball and assumes that on average, a charged pion will receive a momentum change due to the Coulomb interaction or “Coulomb kick”, p_c

$$p_c \equiv |p_T - p_{T,0}| \cong 2e^2 \frac{dN^{ch}}{dy} \frac{1}{R_f} \quad (1)$$

where $p_{T,0}$ is the transverse momentum at freeze-out, p_T is the final transverse momentum, dN^{ch}/dy is the net-charge distribution and R_f is the kinetic freeze-out radius. The charged pion ratio is

$$\frac{\pi^-}{\pi^+} = \left\langle \frac{\pi^-}{\pi^+} \right\rangle \frac{p_T + p_c}{p_T - p_c} \exp\left(\frac{m_T^- - m_T^+}{T}\right) \quad (2)$$

Where: $m_T^\pm = \sqrt{m^2 + (p_T \pm p_c)^2}$

$\left\langle \frac{\pi^-}{\pi^+} \right\rangle$ is the initial pion ratio and T is the thermal freeze-out temperature.

Results – energy and centrality dependence

Figure 1, 2 and 3 show the π^-/π^+ ratios produced in Au+Au collisions at 7.7, 11.5 and 19.6 GeV as a function of transverse momentum. The data are from [3]. The red lines are the fits to the ratio data using Eq. 2.

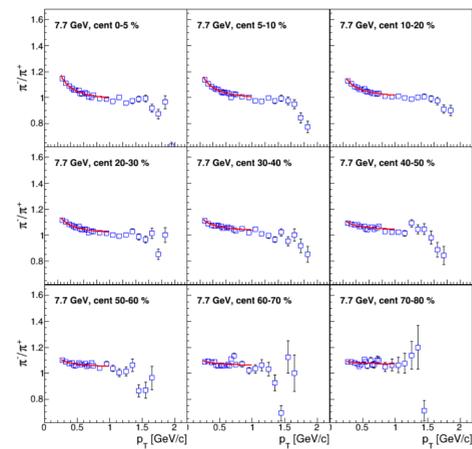


Figure 1

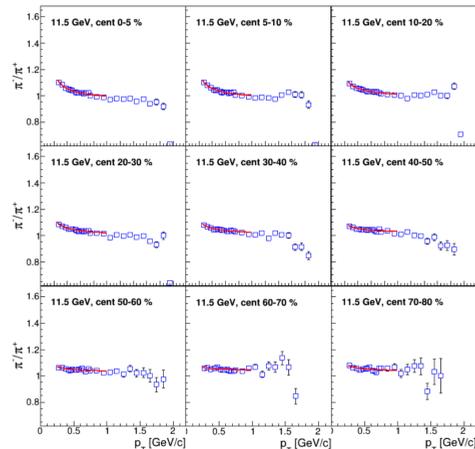


Figure 2

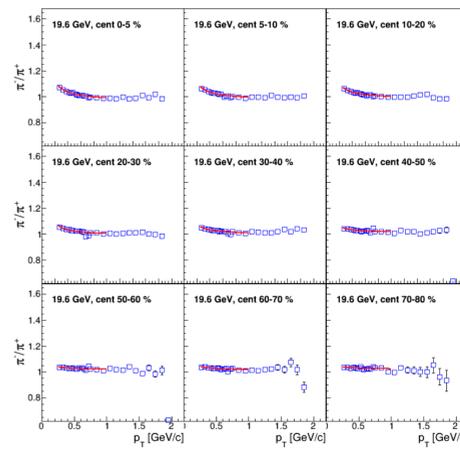
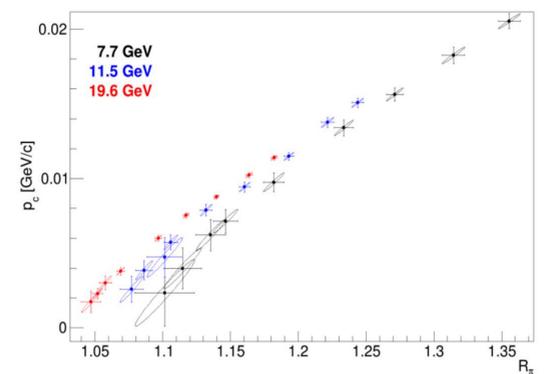
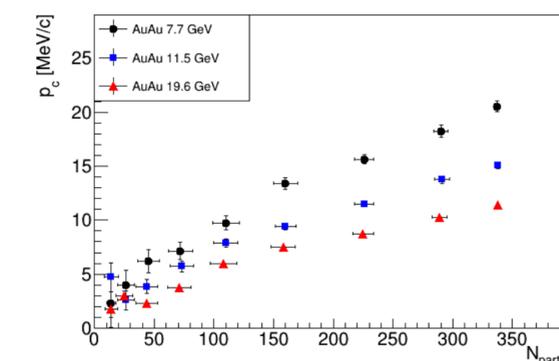


Figure 3

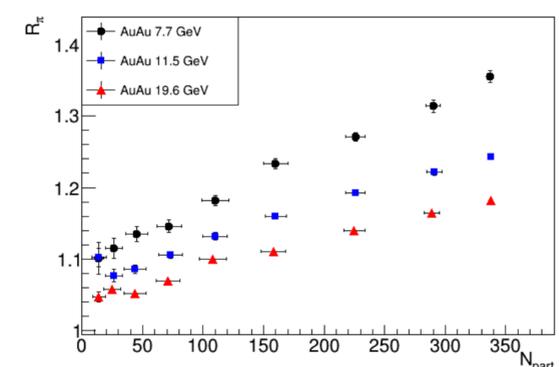


The contours in the $p_c - R_f$ plane showing 1- σ deviation lines from the minimum χ^2 values, as well as the values of the fit parameters p_c and R_f (corresponding to the minimum χ^2) with error bars. The contour lines do not overlap for the studied energies, however, in peripheral collisions there is a wider range of possible values compared to more central collisions. The χ^2 contours indicate that the two parameters are positively correlated, if the Coulomb kick increases, the total pion ratio also increases.

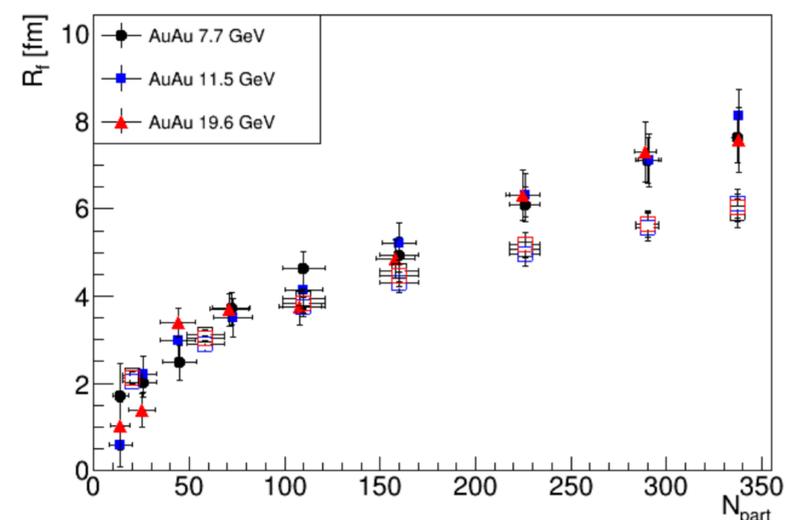
The π^-/π^+ ratio is close to unity for all studied energies at higher p_T . However, at low p_T values an increase of the pion ratio above unity is observed for more central collisions. As the beam energy increases, there is still an asymmetry between π^- and π^+ production as shown by the low- p_T enhancement in ratios, but these effects are much less significant.



- The Coulomb kick increases from peripheral to central collisions for all energies.
- The Coulomb kick values are greater at 7.7 GeV for all centralities than at higher BES energies. This may be due to large baryon stopping at midrapidity at 7.7 GeV.
- The Coulomb kick decreases in more peripheral collisions because the overlap volume is smaller, and therefore, less positive charge generates a smaller Coulomb field in the overlap volume.



- The values of the initial pion ratios, R_{π} , decrease with increasing energy. At lower beam energies the ratios are larger than unity, which is likely due to isospin conservation and significant contributions from resonance decays (such as Δ baryons).
- As the energy is increasing, there is a change in pion production mechanisms and direct pion pair production dominates



- The kinetic freeze-out radius obtained using Eq. 1 as a function of energy and centrality (solid symbols).
- The open symbols represent the chemical freeze-out radius of the system obtained by the STAR collaboration using a thermal model analysis [3].
- The kinetic freeze-out radius decreases from central to peripheral collisions indicating that in a central collision a larger system is formed.

Conclusions:

- ✚ The Coulomb kick decreases with the increase of beam energy, showing that the Coulomb interaction is stronger at lower energies
- ✚ For the same energy, the Coulomb interaction is larger in central collisions because there is strong stopping and an important positive net-charge in the central rapidity region.
- ✚ The Coulomb interaction decreases in peripheral collisions.
- ✚ The kinetic FO radius is not changing with energy for the energy interval considered and shows an increase from peripheral to central collisions → a larger system in more central collisions.
- ✚ The predictions for Coulomb interaction effects in relativistic nuclear collisions using different simulation codes at CBM-FAIR energies will be available soon.

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