p_T dependence of the correlation between initial state spatial anisotropy and final state momentum anisotropy in relativistic heavy ion collisions

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Abstract

The particle momentum anisotropy v_n produced in relativistic nuclear collisions is considered to be a response of the initial spatial anisotropy ε_n of the system formed in these collisions. The linear correlation between ε_n and v_n quantifies the efficiency at which the initial spatial eccentricity is converted to final momentum anisotropy in heavy ion collisions. The correlation is stronger for central collisions and also for n=2 than n=3 as expected. However, the p_T dependent correlation coefficient shows interesting features which strongly depends on the mass as well as p_T of the emitted particle.

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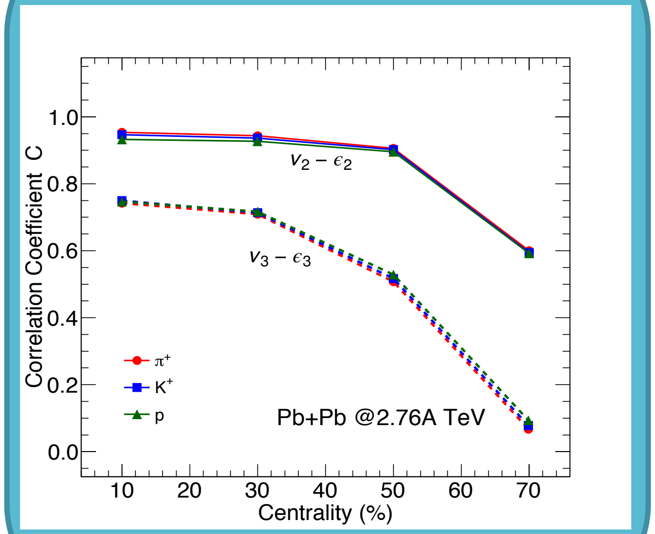
Introduction:

- (2+1) D longitudinally boost invariant hydrodynamical model framework MUSIC
- Initial spatial asymmetry (ε_n) ⟹ Final momentum anisotropy (v_n)
- The strength of the linear correlation between two variables ⟹ Correlation coefficient

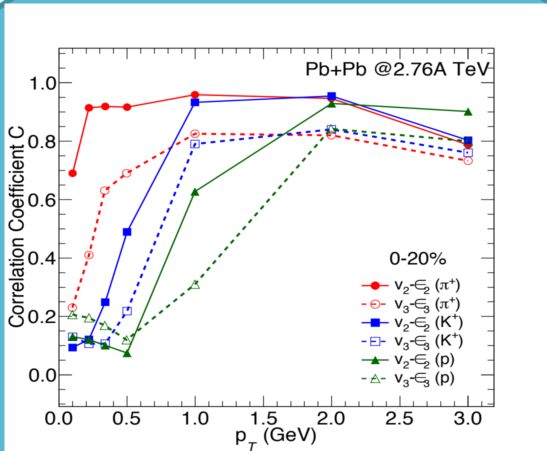
$$C(\epsilon_n, v_n) = \left\langle \frac{(\epsilon_n - \langle \epsilon_n \rangle_{\rm av})(v_n - \langle v_n \rangle_{\rm av})}{\sigma_{\epsilon_n} \sigma_{v_n}} \right\rangle_{\rm av}$$

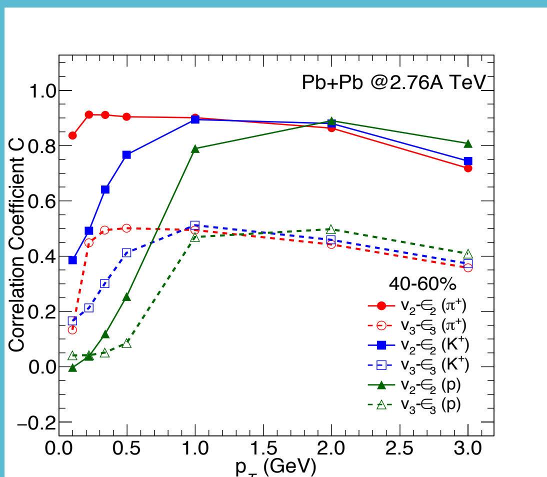
- The ε_2 increases significantly from central to peripheral collisions and consequently the magnitude of the elliptic flow coefficient increases. The rise in ε_3 with collision centrality is relatively slower
- The conversion efficiency of the ε_n to the v_n depends on the initial state as well as on the evolution

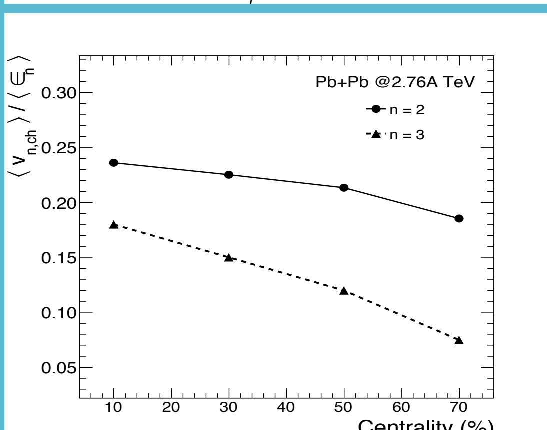


Results I:

- The p_T integrated C values for π^+, K^+, and p are close to each other, **no mass dependence is observed**, although the anisotropic flow is different for them
- C(ε_3 , v_3) shows a stronger sensitivity to the collision centrality as it decreases faster for peripheral collisions compared to C(ε_2,v_2) as expected
- The correlation strength deceases towards peripheral







Results II:

- Mass ordering of v_n (p_T) is a signature of the collective behaviour of the medium – known! **Does there also exist any mass dependence in the p_T dependent correlation coefficients ?**

- A clear mass dependence in the correlation coefficient C(ε_n , v_n (p_T)) can be seen for all the centrality bins!!!

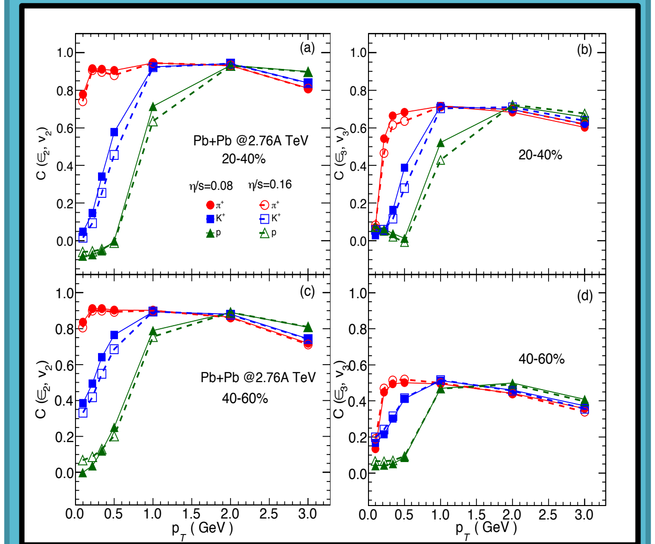
- C(ε_2 , v_2 (p_T)) is found to be larger for lighter particles in the p_T region 0.1 to 2 GeV

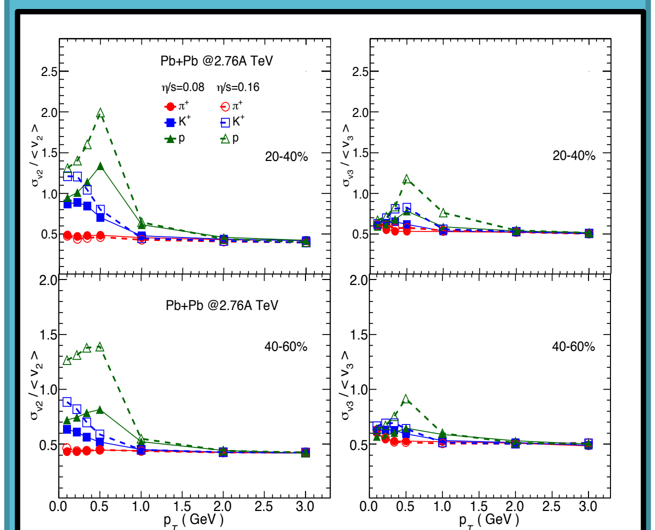
- A relatively stronger p_T dependent correlation for K^+ and p compared to π^+ $\Longrightarrow$ C falls sharply below p_T 1 GeV.

- C is found to be slightly higher for heavier particles above 2 GeV

- C(ε_3 , v_3 (p_T)) shows a similar behaviour but the magnitude is considerably smaller.

- The slope C_3 for Pb+Pb collisions falls faster than C_2 towards peripheral collisions.



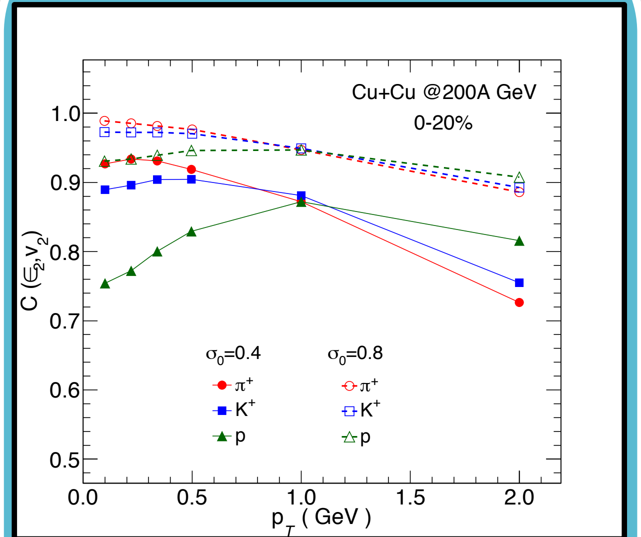


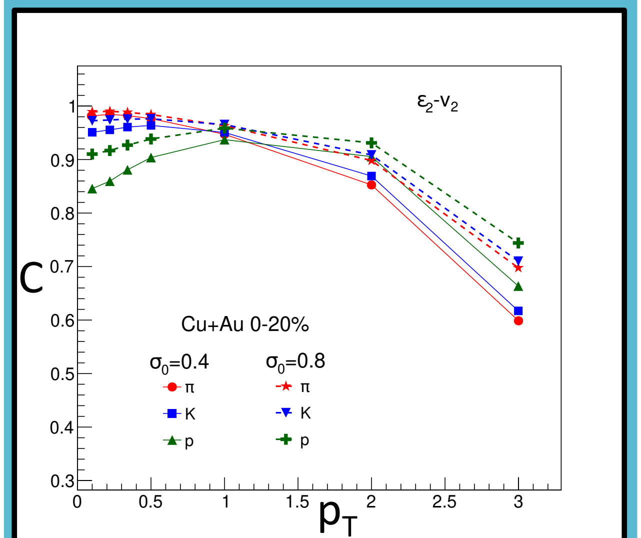
Results III:

- C is found to vary only marginally when η/s is changed from 0.08 to 0.16
- The relative fluctuation in the anisotropic flow parameters $\sigma_{vn} / \langle v_n \rangle$ → a potential observable → reflects the ratio of the first two moments of the initial state eccentricity distribution
- The relative fluctuation as a function of p_T is found to be quite sensitive to the value of η/s
- The sensitivity to η/s is much stronger for protons than for pions and also in the low pT (< 1 GeV) region
- The sensitivity to the value of η/s is much stronger for protons than for pions and also in the low p_T (< 1 GeV) region for Pb+Pb collisions

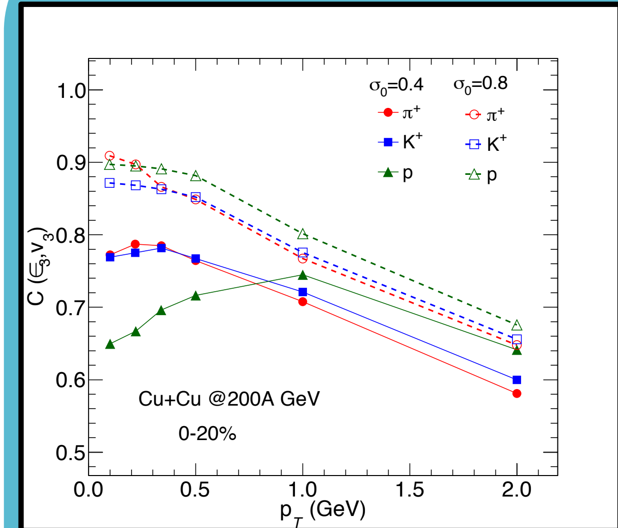
Results IV:

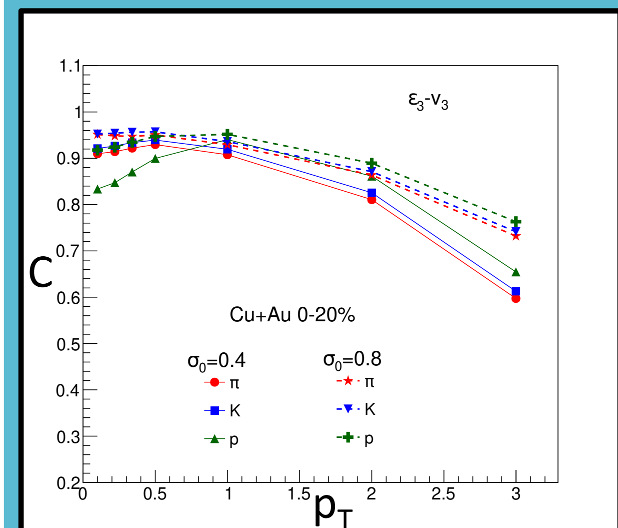
- Cu+Cu at 200A GeV --- a system with relatively smaller temperature and energy density, smaller transverse dimension compared to Pb+Pb collisions at LHC





- The initial state density fluctuations are expected to be higher for Cu+Cu collisions
- A mass ordering of C in a relatively narrower p_T range for Cu+Cu compared to Pb+Pb
- V_n is smaller and the spatial anisotropy is slightly higher for smaller system
- The build up of transverse flow velocity is much weaker for Cu+Cu collisions --- the efficiency at which the spatial anisotropy is converted to momentum anisotropy is also relatively weaker for them compared to Pb+Pb
- The same is studied for Cu+Au collisions at 200A GeV for a system size dependence study
- By smoothing the initial energy distribution (adjusting the fluctuation parameter), the correlation strength is found to increase in both cases, though the increase is more for Cu+Cu
- C is much stronger for Cu+Au than Cu+Cu at same energy specially for ε_3 , v_3 (p_T) correlation





Summary and Conclusions:

- The correlation between v_n (p_T) and ε_n as a function of p_T shows interesting behaviour, the correlation coefficient C depends strongly on the mass of the particles.
- A clear ordering of C is seen in the lower p_T region depending on the particle mass where the correlation strength is larger for lighter particles
- The p_T range for the ordering depends on the collision centrality and also on the beam energy. The p_T dependent C rises with p_T, reach maximum, and then drop slowly beyond 2 GeV p_T value for the Pb+Pb collisions.
- For Cu+Cu, p_T dependent C also shows mass ordering, however the p_T range is much smaller than Pb+Pb --- due to a relatively weaker development of the transverse flow velocity for Cu+Cu at lower beam energy than for Pb+Pb at LHC.
- C is strongest at a much smaller p_T value for Cu+Cu
- C is found to depend only marginally on the value of eta/s. However, the relative fluctuations in the anisotropic flow parameter show strong sensitivity to the value of eta/s.