Two-particle transverse momentum correlations in Pb–Pb collisions at ALICE

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Two-particle transverse momentum correlations

Enable measurements of collision dynamics features sensitive to momentum currents

- System life time increases with collision centrality
- The longer the system lives the wider the reach of the momentum transfer
- The changes in the shape of the rapidity dependence of the correlation function (1) with collision centrality provides information about the evolution of the system
- It has been proposed
  - Kinematic viscosity $\nu = \eta/(Ts)$ contributes to the longitudinal diffusion of momentum currents
  - η/s can be estimated [1] based on the longitudinal broadening of the correlation function (2)
  - Systematic changes in the shape of the longitudinal dependence of the correlation function with collision centrality make it possible to distinguish between diffusive propagation and wave propagation and to extract τ_π, the system relaxation time [2]

Observable definition

$$G_2(\Delta\eta, \Delta\varphi) = \frac{\langle \sum_i^{n_{1,1}} \sum_{j\neq i}^{n_{1,2}} p_{\mathrm{T},i}\, p_{\mathrm{T},j} \rangle}{\langle n_{1,1}\rangle \langle n_{1,2}\rangle} - \langle p_{\mathrm{T},1}\rangle \langle p_{\mathrm{T},2}\rangle \quad (1)$$

$n_{1,j}$, single particle multiplicity – $n_{1,1}$, $n_{1,2}$ particle one, two, multiplicity
$p_{\mathrm{T},1}$, $p_{\mathrm{T},2}$ particle one, two, transverse momentum

Measured as

Charge independent (CI) driven by collective behavior

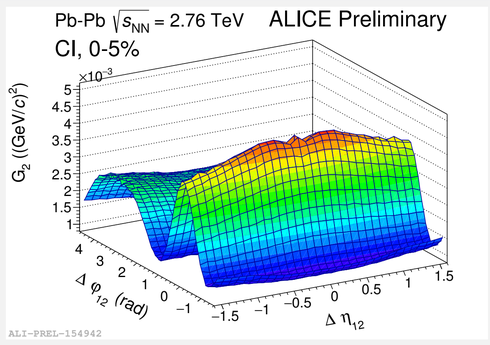
$$\mathrm{CI} = \frac{1}{4}((+-) + (-+) + (++) + (--))$$

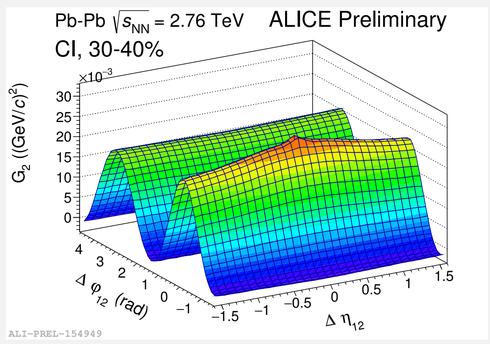
Charge dependent (CD) influenced by charge conservation

$$\mathrm{CD} = \frac{1}{4}((+-) + (-+) - (++) - (--))$$

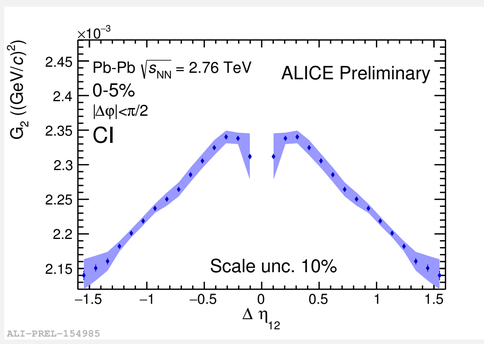
G_2 near-side fitted to characterize its shape evolution
– Background (flow) + 2D Generalized Gaussian
– Width extracted as the variance of generalized Gaussian

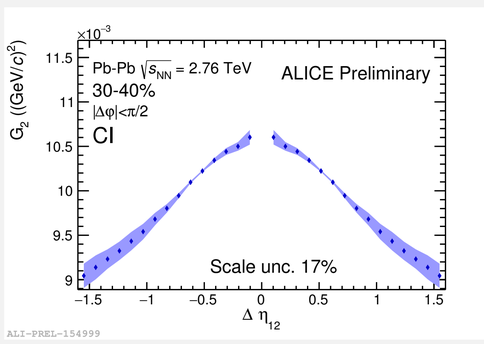
Measured two-particle transverse momentum correlations



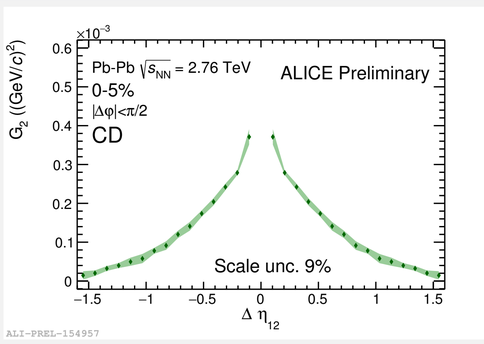


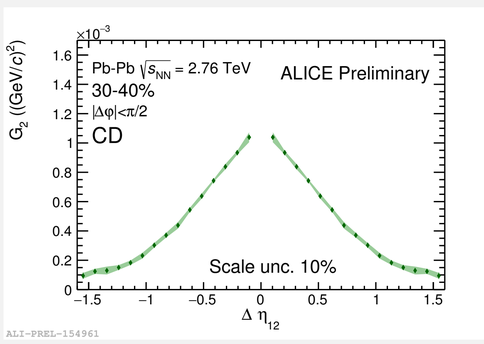
G_2 CI for most central (top) and mid central (bottom) events





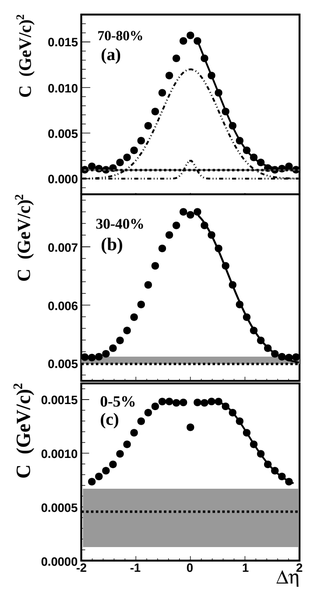
G_2 CI $\Delta\eta$ projection for most central (top) and mid central (bottom) events



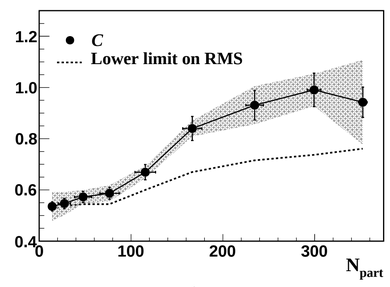


G_2 CD $\Delta\eta$ projection for most central (top) and mid central (bottom) events

Previous results: STAR at RHIC [3]



Au-Au at $\sqrt{s_{NN}} = 200$ GeV

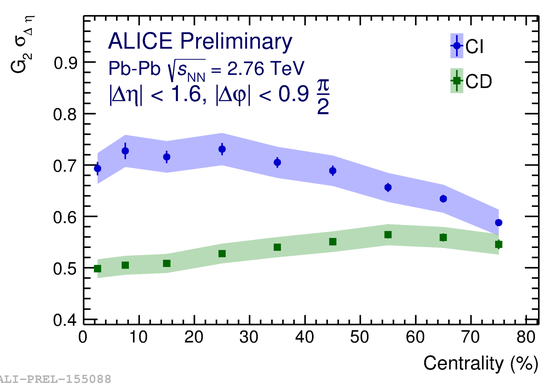


$$\sigma_c^2 - \sigma_0^2 = \frac{4}{T_c}\frac{\eta}{s}\left(\tau_0^{-1} - \tau_{c,f}^{-1}\right) \quad (2)$$

σ_c: width in central collisions ($0.94 \pm 0.06 \pm 0.17$)
σ_0: width at formation time ($0.54 \pm 0.02 \pm 0.06$)
τ_0: formation time (1 fm/c)
$\tau_{c,f}$: kinetic freeze-out time (20 fm/c)
T_c: critical temperature (170 MeV)

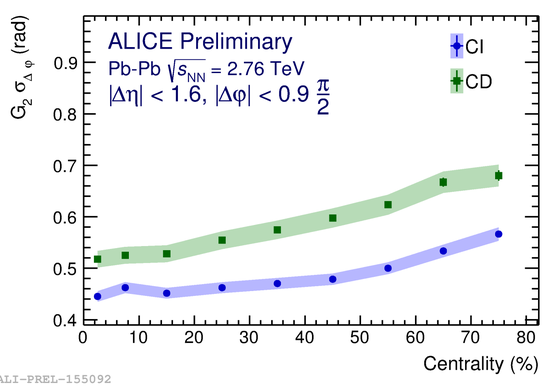
$$0.06 < \frac{\eta}{s} < 0.21$$

Widths evolution



Longitudinal G_2 $\sigma_{\Delta\eta}$ evolution

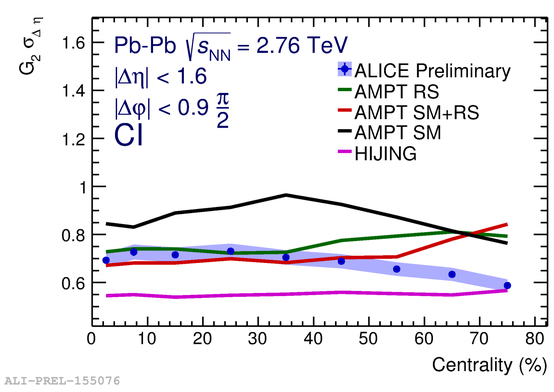
- CI longitudinal broadening
- CD almost flat with centrality



Azimuthal G_2 $\sigma_{\Delta\varphi}$ evolution

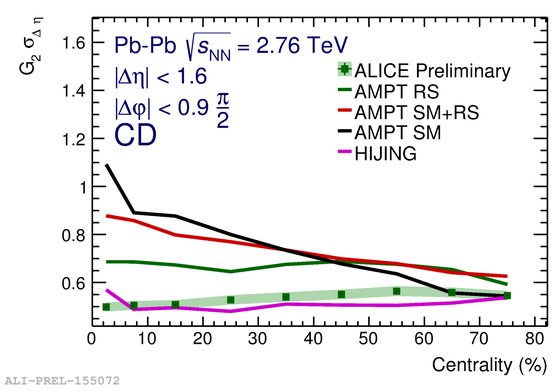
- CI and CD azimuthal narrowing
- CD azimuthally wider than CI

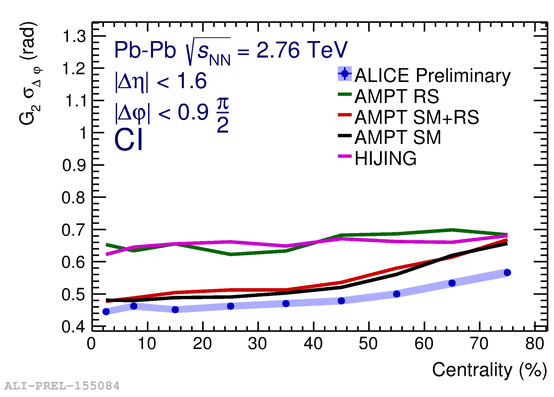
Comparison to models



Longitudinal G_2 $\sigma_{\Delta\eta}$ evolution

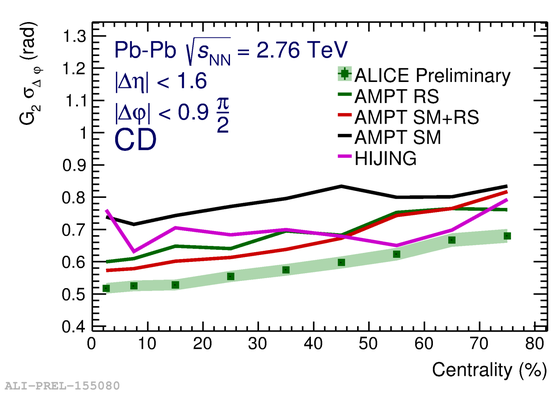
- CI
  - None of the models describe the trend
- CD
  - HIJING describes centrality evolution
  - All settings of AMPT have opposite trend



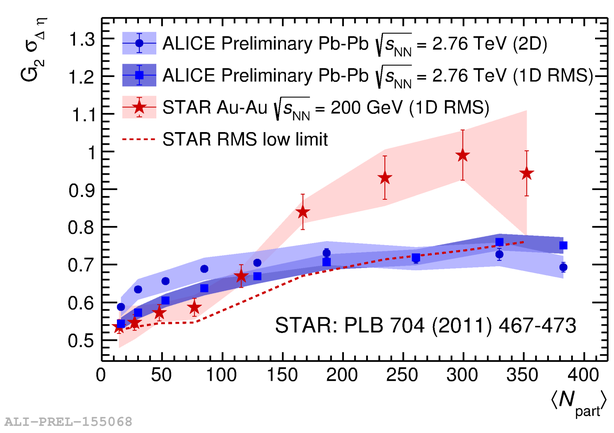


Azimuthal G_2 $\sigma_{\Delta\varphi}$ evolution

- CI
  - AMPT with string melting (SM) mimics centrality behavior
- CD
  - None of the models describe the width values, but
  - all AMPT settings describe the trend



Comparison to RHIC results



G_2 CI longitudinal $\sigma_{\Delta\eta}$ evolution

- With the same method (1D RMS), agreement within systematics for central and mid-central collisions, and within the RMS low limit for peripheral collisions

Conclusions and outlook

- Observed G_2 CI longitudinal broadening with collision centrality in agreement with results from STAR at RHIC
- Measured constant G_2 CD longitudinal width with collision centrality only described by HIJING
- Observed G_2 CI azimuthal narrowing with collision centrality described by AMPT with string melting
- Models do not explain richness of behaviors in both $\Delta\eta$ and $\Delta\varphi$ dimensions
- In the near future
  - Shear viscosity and relaxation time extraction
  - Extract results for other collision energies and collision systems at the LHC

Bibliography

[1] Sean Gavin and Mohamed Abdel-Aziz. Measuring Shear Viscosity Using Transverse Momentum Correlations in Relativistic Nuclear Collisions. *Phys. Rev. Lett.*, 97:162302, 2006.

[2] Sean Gavin, George Moschelli, and Christopher Zin. Rapidity Correlation Structure in Nuclear Collisions. *Phys. Rev.*, C94(2):024921, 2016.

[3] H. Agakishiev et al. Evolution of the differential transverse momentum correlation function with centrality in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. *Phys. Lett.*, B704:467–473, 2011.