Anisotropic flow of identified particles in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV with ALICE

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Abstract

Identified particle anisotropic flow provides valuable information on particle production mechanisms. In this poster we present the elliptic and higher order flow of identified particles in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV recorded by the ALICE detector. The measurements are presented for a wide range of particle transverse momenta within the pseudorapidity region $|\eta| < 0.8$. The results are compared to hydrodynamic models. The scaling properties of v_2 with the number of constituent quarks (n_q) is studied.

Collective behavior

Multiple interactions between medium constituents convert initial geometric anisotropy into a final state momentum anisotropy

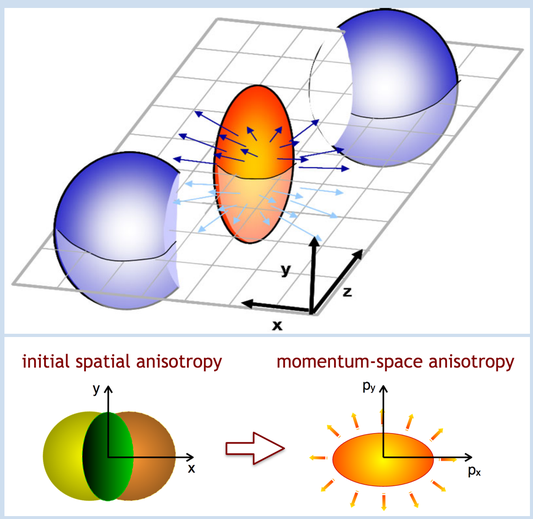

Figure 1. Schematic 3D picture of a non-central collision.

The anisotropy is quantified by a Fourier expansion of momentum distribution:

$$E\frac{d^3N}{d^3p} = \frac{d^2N}{2\pi p_T dp_T dy}\left\{1 + \sum_{n=1}^{\infty} 2v_n \cos\left[n\left(\phi - \Psi_n\right)\right]\right\}$$

where ϕ is the azimuthal angle of each particle and Ψ_n is the reaction plane angle.

Azimuthal correlations:

$$v_n = \langle \cos\left[n\left(\phi - \Psi_n\right)\right]\rangle$$

v_n of charged hadrons is measured using the scalar product method:

$$v_n = \frac{\langle u \cdot Q_{V0C}\rangle}{\sqrt{\frac{\langle Q_{V0C}\cdot Q_{V0A}\rangle\langle Q_{V0C}\cdot Q_{TPC}\rangle}{\langle Q_{V0A}\cdot Q_{TPC}\rangle}}}$$

$$u = \langle e^{in\phi}\rangle$$

$$Q = \sum w_i e^{in\phi}$$

where w_i are weighting factors for the particles. Correlations coming from nonflow effects are suppressed in the scalar product method by the large $\Delta\eta$ separations between Q_{V0C}, Q_{V0A}, Q_{TPC}, and the particles of interest (u).

Improvements over Run I

♢ Larger data sample gathered in Run II compared to Run I.
♢ Kinematic range of measurements is extended.
♢ High-precision measurements of v_2 of ϕ mesons and higher mass hadrons are possible.
♢ Run II provides more stringent constraints for models.

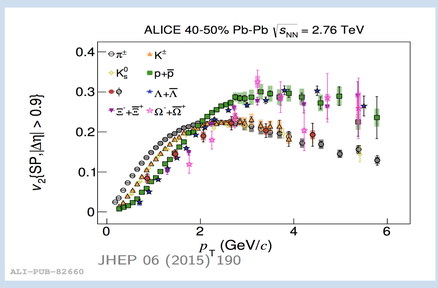

Figure 10. v_2 of identified particles in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV

PID of π, K, p

Particle identification uses the TPC and TOF systems:
$p_{\rm T} < 4$ GeV/c : $n^2_{\sigma PID} = n^2_{\sigma TPC} + n^2_{\sigma TOF}$,

$p_{\rm T} > 4$ GeV/c : $\triangle_\pi = dE/dx_\pi + \langle dE/dx\rangle_\pi$

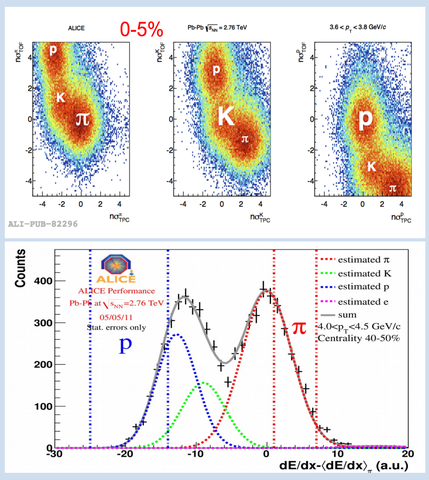

Figure 2. Top side, PID based on TPC and TOF combined. Bottom side, PID based on the ionization energy loss in the TPC.

Extract v_n of ϕ mesons

v_n extraction method: Because the ϕ meson ($\phi \longrightarrow K^+ + K^-$) cannot directly be observed, v_n is measured using the invariant mass fit method.

$$v_n^{Tot}\left(m_{inv}\right) = v_n^{Sig}\frac{N_{Sig}\left(m_{inv}\right)}{N_{Tot}\left(m_{inv}\right)} + v_n^{Bg}\left(m_{inv}\right)\frac{N_{Bg}\left(m_{inv}\right)}{N_{Tot}\left(m_{inv}\right)}$$

Yields N_{Sig} and N_{Bg} are extracted from fits of the invariant mass distributions. v_n^{Sig} is extracted from fits of v_n distribution.
♢ The ϕ meson candidates are reconstructed in bins of p_T and invariant mass. Azimuthal correlations are calculated for candidates in each bin.
♢ The subtraction of background is done by a simultanous fit to the invariant mass distribution and the v_2(mass).

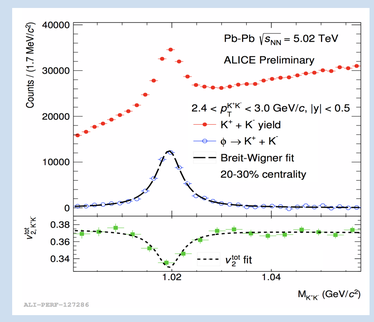

Figure 3. Invariant mass and $v_n^{Tot}(m_{inv})$ distributions of kaon pairs.

Comparison with the hydrodynamic models

Viscous hydrodynamic models have succesfully explained the interplay between the anisotropic expansion coefficients.

♢ v_3 and v_4 have clear mass ordering at low $p_{\rm T}$ ($p_{\rm T} < 1$ GeV/c) similar to v_2
♢ Hydrodynamic models are in good agreement with data for $p_{\rm T} < 2$ GeV/c .
♢ General features described in central collisions for $p_{\rm T} < 2$ GeV/c

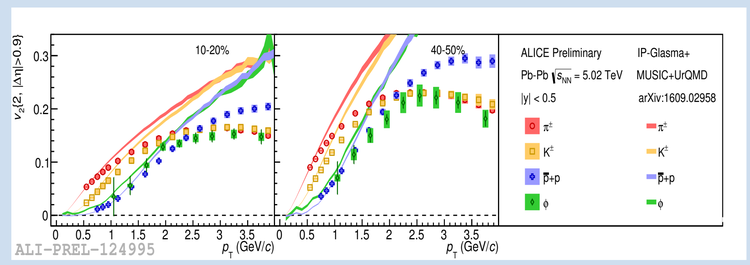

Figure 4. v_2 of identified pions, protons, kaons and the phi-meson, comparison to hydrodynamics

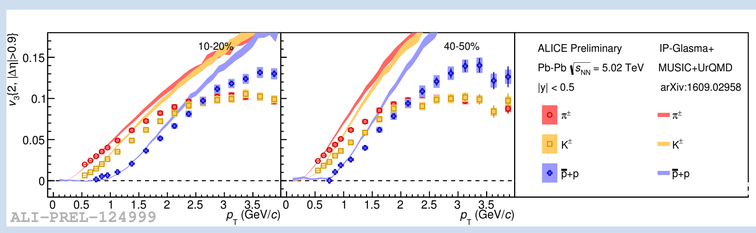

Figure 5. v_3 of identified pions, protons, kaons and the phi-meson, comparison to hydrodynamics

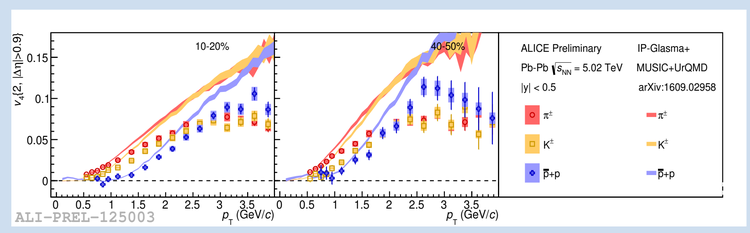

Figure 6. v_4 of identified pions, protons, kaons and the phi-meson, comparison to hydrodynamics

NCQ scaling test

NCQ scaling: scale axes by number of constituent quarks n_q

♢Transition from mass ordering to baryon/meson ordering happens around $p_{\rm T} = 1$ GeV/c.
♢Scaling above $p_{\rm T} = 1$ GeV/c holds better for v_3 (Fig.8) and v_4 (Fig.9).
♢Exhibits deviations from the number of constituent quark (NCQ) scaling for $p_{\rm T} > 2.5$ GeV/c.

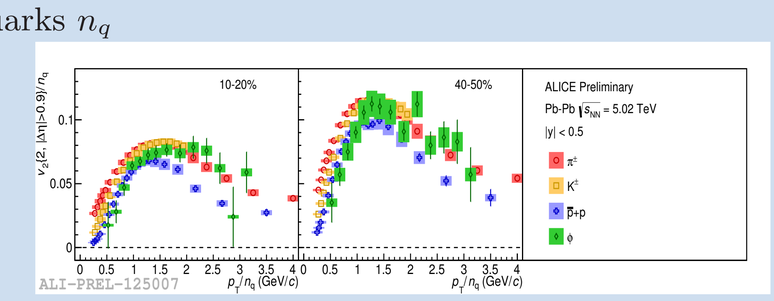

Figure 7. v_2 of pions, protons, kaons and phi mesons for various centrality classes, n_q scaling

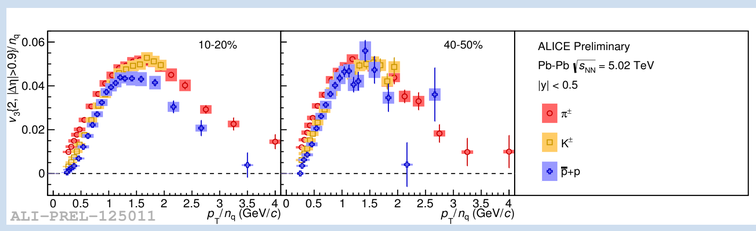

Figure 8. v_3 of pions, protons, kaons and phi mesons for various centrality classes, n_q scaling

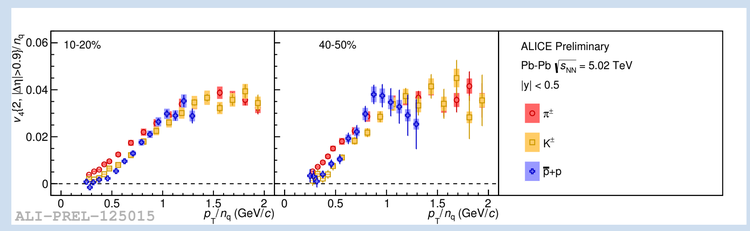

Figure 9. v_4 of pions, protons, kaons and phi mesons for various centrality classes, n_q scaling

Conclusion

♦ Elliptic flow constrains the initial conditions of the system and the dynamical properties of its early thermalized phase .
♦ From this analysis mass ordering of v_2 is observed for $p_{\rm T} < 2$ GeV/c.
♦ Quark degrees of freedom dominate in the early stages of heavy-ion collisions (from NCQ scaling).
♦ Due to higher statistics, Run II has a smaller statistical error.
♦ Viscous hydrodynamics gives a reasonable description of results at low $p_{\rm T}$
♦ More analysis of other particles (Λ, Ξ, Ω) are underway.