Anisotropic flow measurements from the NA61/SHINE and NA49 beam momentum scan programs at CERN SPS

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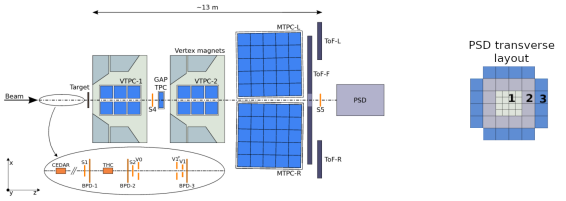
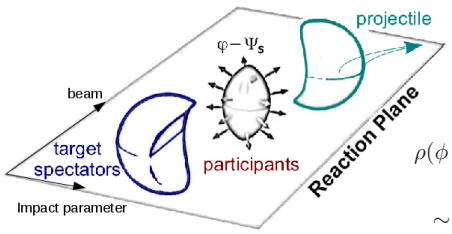
Abstract

We present a continuation of the directed and elliptic flow studies [1, 2] from the NA61/SHINE and NA49 beam momentum scan programs. The results extend the existing world data available from the previous NA49 measurements and ongoing BES-II and fixed-target programs at STAR. The developed analysis techniques are also relevant for measurements at the future CBM experiment at FAIR and the MPD and BM@N experiment at NICA.



Anisotropic Transverse Flow



$$\rho(\phi - \Psi_s) \sim$$

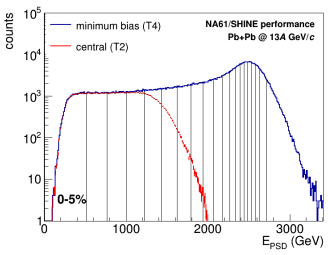
$$\sim 1 + 2\sum_{n=1}^{\infty} v_n \cos n(\phi - \Psi_s)$$

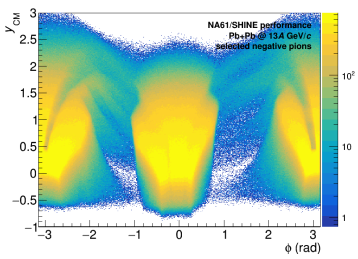
Anisotropic transverse flow is quantified by Fourier coefficients in the decomposition of the particle azimuthal distribution relative to the collision symmetry plane (Ψ_s). Ψ_s can be determined by the projectile (target) spectator deflection Ψ_{proj} (Ψ_{targ}) or the shape of the participant zone Ψ_{pp}.

Data

NA61/SHINE subsystems [3] used for the analysis:

- VTPC-1, VTPC-2, MTPC for tracking and particles identification;
- Projectile Spectator Detector (PSD) for spectator plane estimation and centrality;





Corrections for detector azimuthal anisotropy in flow analysis are applied p_T-y differentially using an extension of the Qn-Corrections Framework [4, 5].

Flow Observable

$$v_n^A(p_T, y) = \frac{2\langle u_{i,n}(p_T,y) Q^A_{i,n}\rangle}{R^A_{i,n}},$$

where flow vectors u_n and Q_n:

$$u_n = u_{x,n} + i u_{y,n} = \cos n\phi + i \sin n\phi$$
$$Q_n = Q_{x,n} + i Q_{y,n} = \sum_k w_k u_{n,k}$$

k-th PSD module energy is taken as weight w_k. Event plane resolution R_n is calculated using 3+1-subevents method. For $A = PSD1, PSD3$:

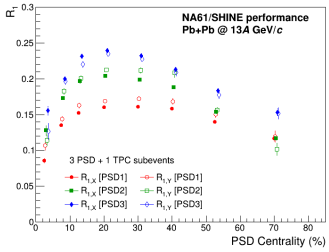
$$R^A_{i,n} = \sqrt{2\frac{\langle Q^A_{i,n} Q^T_{i,n}\rangle \langle Q^A_{i,n} Q^C_{i,n}\rangle}{\langle Q^T_{i,n} Q^C_{i,n}\rangle}},$$

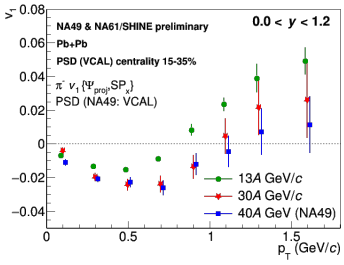
$$R^{PSD2}_{i,n} = \frac{\langle Q^{PSD2}_{i,n} Q^T_{i,n}\rangle}{R^T_{i,n}}$$

where $Q^T_{i,n}$ is formed from protons $0.8 < y < 1.2$ and

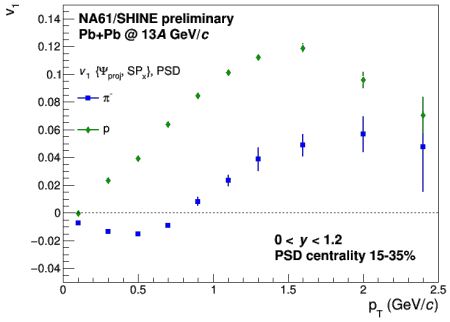
$$R^T_{i,n} = \sqrt{2\frac{\langle Q^A_{i,n} Q^T_{i,n}\rangle \langle Q^T_{i,n} Q^C_{i,n}\rangle}{\langle Q^A_{i,n} Q^C_{i,n}\rangle}};$$

$i = x, y$.

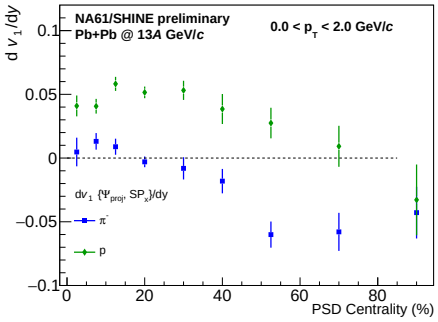




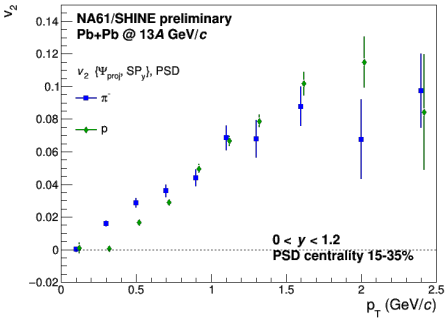
Results



Clear mass dependence of $v_1(p_T)$



Changing sign at different collision centrality



Clear mass dependence $v_2(p_T)$

Summary

Directed and elliptic flow were measured relative to the spectator plane in Pb+Pb at 13, 30, and 40A GeV. Clear mass dependence is observed for v_1 and its slope dv_1/dy, and v_2. The directed flow shows strong energy dependence, with the slope of protons and negatively charged pions changing sign at different collision centralities.

References

[1] E. Kashirin, O. Golosov, V. Klochkov, and I. Selyuzhenkov. *Acta Physica Polonica B*, 12:419, 01 2019.

[2] Viktor Klochkov and Ilya Selyuzhenkov. *Nucl. Phys.*, A982:439–442, 2019.

[3] N. Abgrall et al. *JINST*, 9:P06005, 2014.

[4] Ilya Selyuzhenkov and Sergei Voloshin. *Phys. Rev.*, C77:034904, 2008.

[5] Victor Gonzalez, Jaap Onderwaater, and Ilya Selyuzhenkov. https://github.com/flowcorrections/flowvectorcorrections.