Deuteron directed flow in the recent physical data of Xe+Cs(I) collisions at 3.8A GeV from the BM@N experiment

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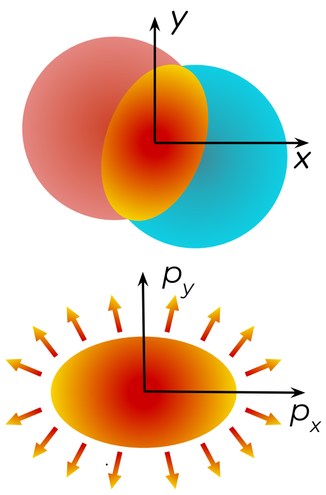
Motivation

The initial spatial asymmetry of the energy distribution transfers to collective anisotropy of the produced particles.



The anisotropy formation is governed by the **transport properties** of the created matter: rapidity-differential anisotropic flows could constrain the **shear viscosity's** temperature dependence.

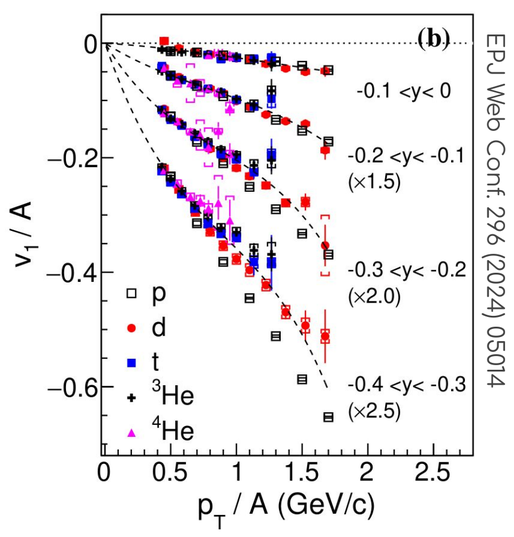
v_1 and v_2 are **sensitive to the EOS**; the flow of **light nuclei** is presumed to be more sensitive than of protons.

Insights into the light nuclei **production mechanism** in HIC - whether coalescence is predominant at energies of a few GeV per nucleon.

The **coalescence** model assumes that light nuclei are formed via the combination of nucleons. Assuming the equity of v_1 of protons and neutrons, coalescence is expected to manifest itself through an approximate **scaling** of collective flow **with mass number A**; in case of v_1 it is:

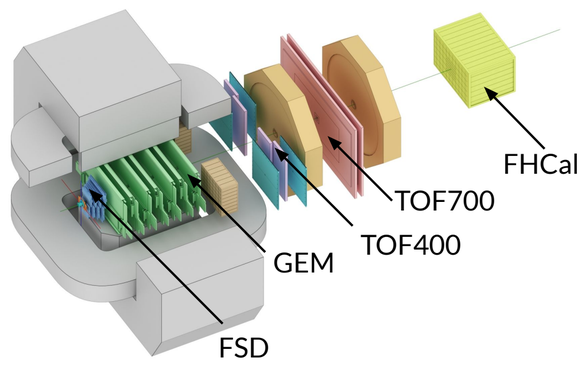
$$v_1^A(p_T, y) \approx v_1^p(p_T/A, y)$$

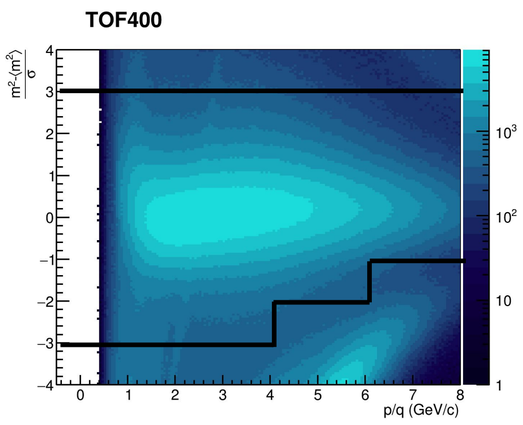
STAR, Au+Au 10-40%, $\sqrt{s_{NN}}$ = 3 GeV

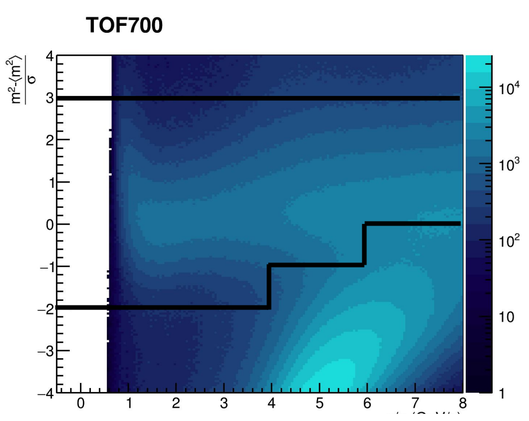


Deuteron identification

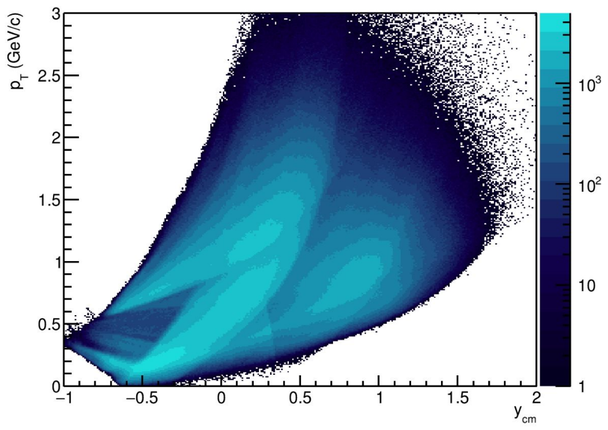
Identification is performed with the information from the tracking system (**FSD+GEM**) and **TOF** systems.
Shown as well is Forward Hadron Calorimeter: used for the event plane reconstruction.







Deuterons are selected as particles with the reconstructed squared mass m^2 lying within n-sigma window from the mean value; mean values $\mu = \mu(p/q)$ are evaluated by fitting the m^2 in narrow windows of p/q;
n = n(p/q) is chosen to suppress possible contamination with protons.



The phase space coverage of identified deuterons as a function of y_{cm} and p_T.

Method

The pattern of the produced particle emission can be described as Fourier decomposition of azimuthal distribution in transverse plane relative to the reaction plane (RP) angle

n – harmonic number
Ψ_{RP} – reaction plane angle

$$\rho(\phi - \Psi_{RP}) = \frac{1}{2\pi}(1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_{RP})))$$

average over all particles and events $v_n = \langle \cos(n(\phi - \Psi_{RP})) \rangle$

Event Plane (EP) - the RP estimate

in experiment:

$$|Q_n|e^{in\Psi_n^{EP}} \rightarrow \frac{\sum_{k=1}^{M} w_k u_{n,k}}{\sum_{k=1}^{M} w_k} = |Q_n|e^{in\Psi_n^{EP}}$$

the unit vector
ϕ – particle azimuthal angle

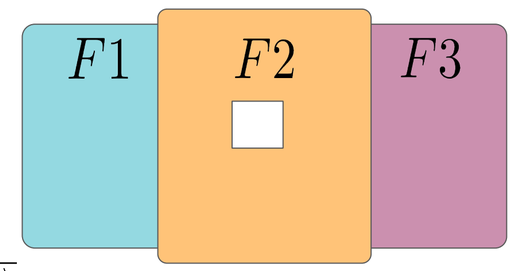
$$v_n = \frac{\langle u_n Q_n^* \rangle}{R_n}, \quad e^{in\phi}$$

Correction for the EP resolution

$$R_n = \langle \cos(n(\Psi_n^{EP} - \Psi_n^{RP}) \rangle$$

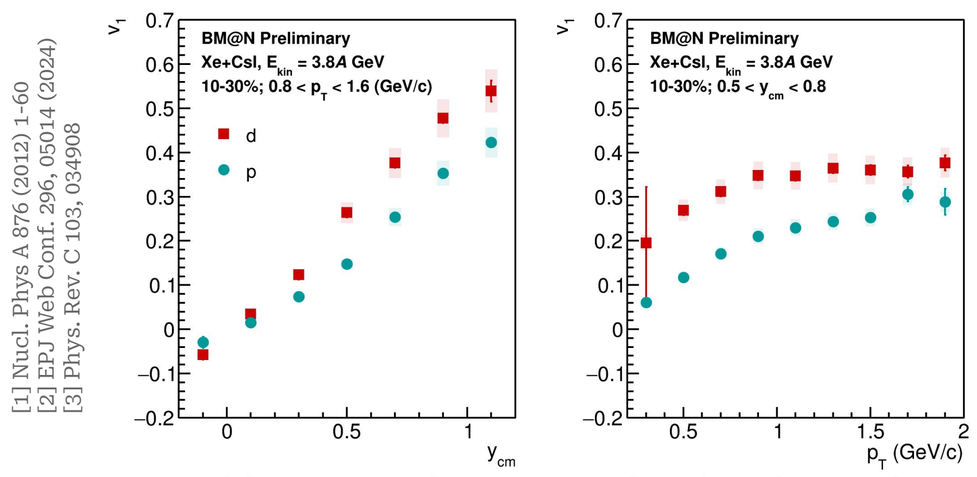
in experiment:

$$R_n\{F1, F2, F2\} = \sqrt{\frac{\langle Q_n^{F1} Q_n^{F2*} \rangle \langle Q_n^{F1} Q_n^{F3*} \rangle}{\langle Q_n^{F2} Q_n^{F3} \rangle}}$$



Sub-events defined from the modules of the FHCal

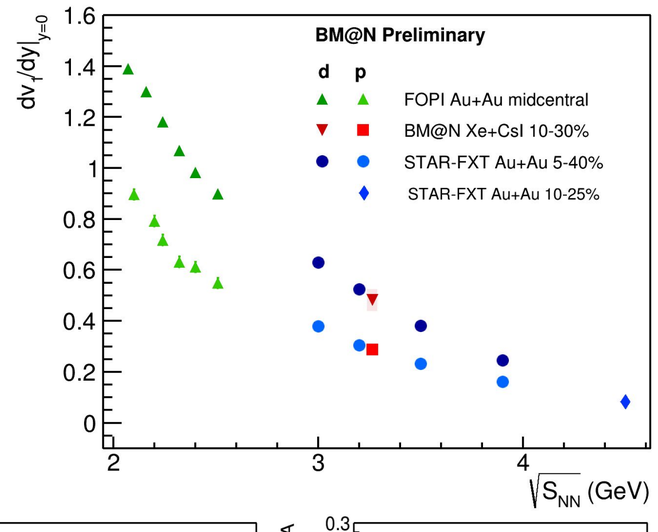
Results



v_1 of deuterons and protons as a function of y_{cm} and p_T

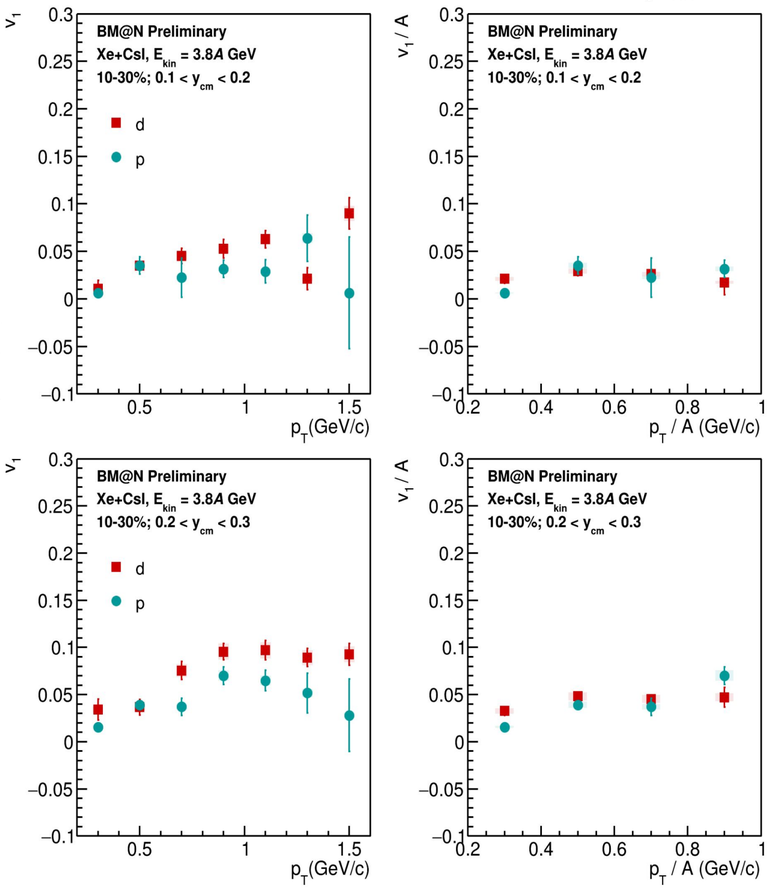
[1] Nucl. Phys A 876 (2012) 1-60
[2] EPJ Web Conf. 296, 05014 (2024)
[3] Phys. Rev. C 103, 034908

Collision energy dependence of the slope at mid-rapidity for deuterons (d) and protons (p).
The BM@N preliminary v_1 results for Xe+Cs(I) are in agreement with the published FOPI[1] and STAR[2, 3] data.



Scaling

Similar to how it was done in STAR (see Motivation section), the scaling properties of v_1 is examined.
Shown are directed flow of protons and deuterons before (left plots) and after (right plots) applying the scaling in different rapidity bins. v_1 of deuteron is observed to follow the scaling in selected rapidity ranges.



Summary

The first result for deuteron v_1 in Xe+Cs(I) collisions at 3.8A GeV is presented. It is compared with the BM@N result for proton v_1 as a function of y_{cm} and p_T; the slope at mid-rapidity for deuterons agrees with the world data. The results for proton and deuteron v_1 are found to follow the scaling with mass number A at this energy.