The first results for directed flow of deuterons in 3.8A GeV Xe+CsI collisions at the BM@N experiment

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Anisotropic flow

Spatial asymmetry of the initial state matter transforms into momentum anisotropy of the produced particles

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

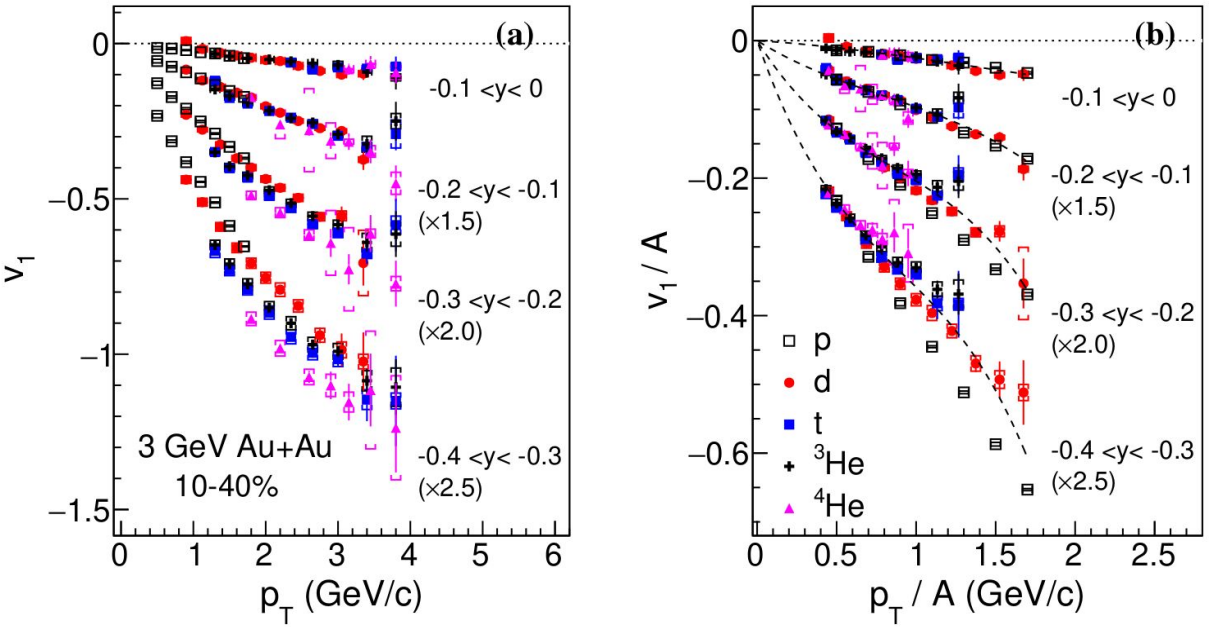
Coalescence mechanism: assuming $v_n^p \approx v_n^n$

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

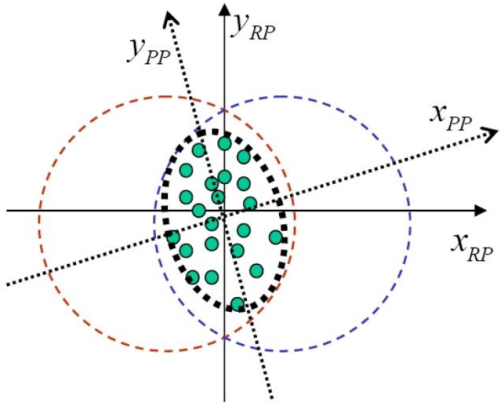
$$v_n = \langle \cos(n(\phi - \Psi_R)) \rangle$$

$n -$ harmonic number

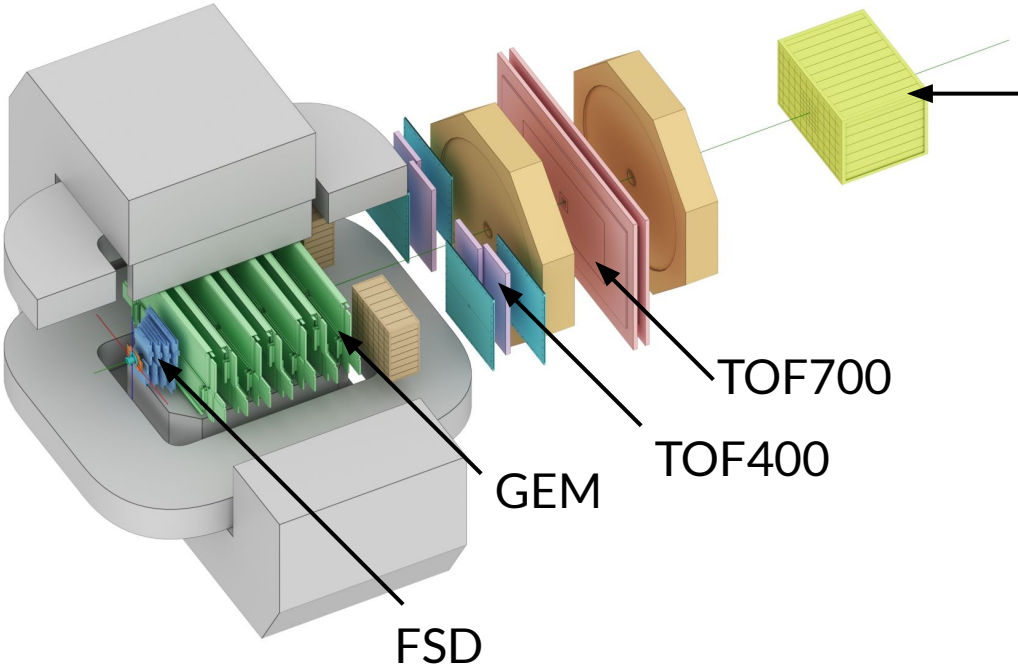
Ψ_{RP} – reaction plane angle

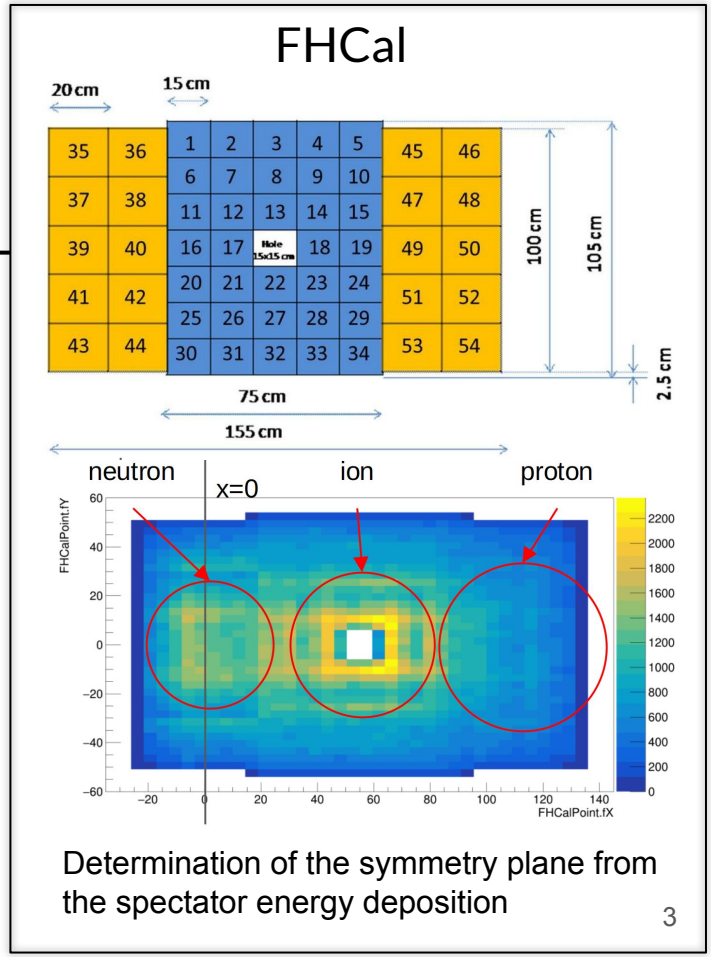


M. S. Abdallah, et al., STAR Collaboration, Phys. Lett. B 827, 136941 (2022).



The BM@N Setup: Xe+CsI 3.8A Gev

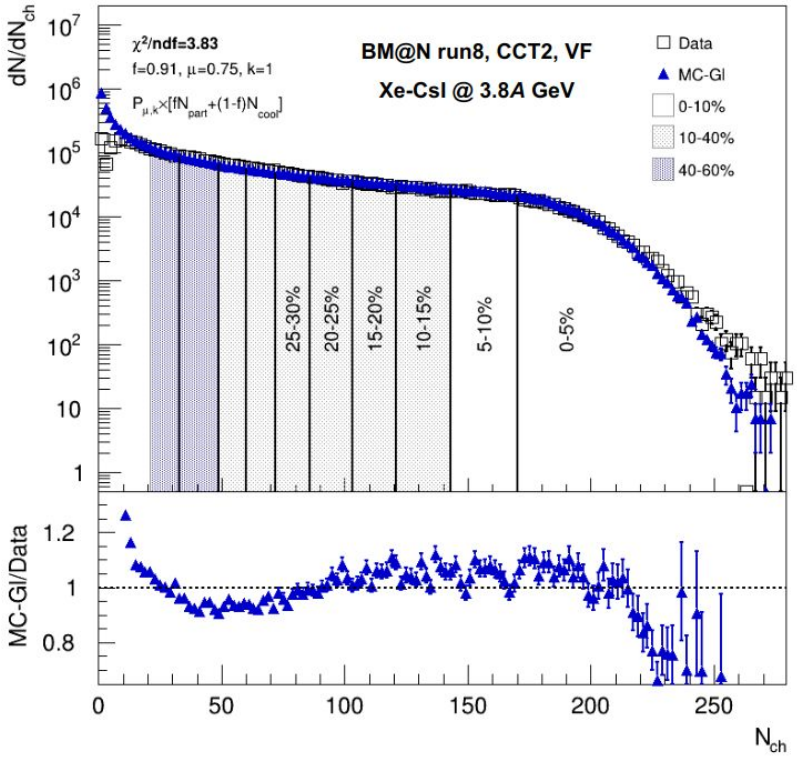


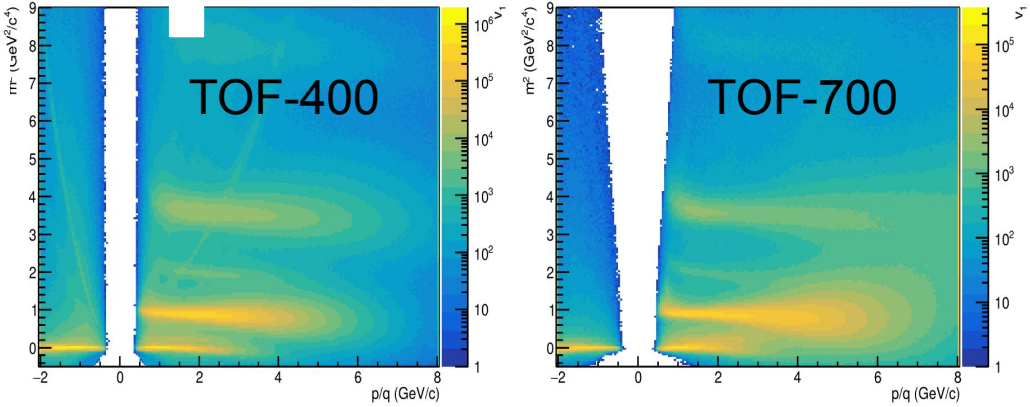


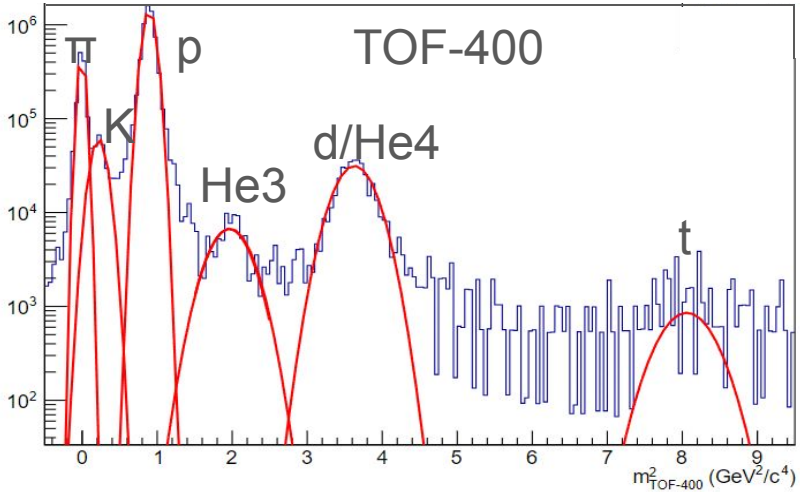
Determination of the symmetry plane from the spectator energy deposition

Nucl. Instrum. Meth. A 1065 (2024) 169532

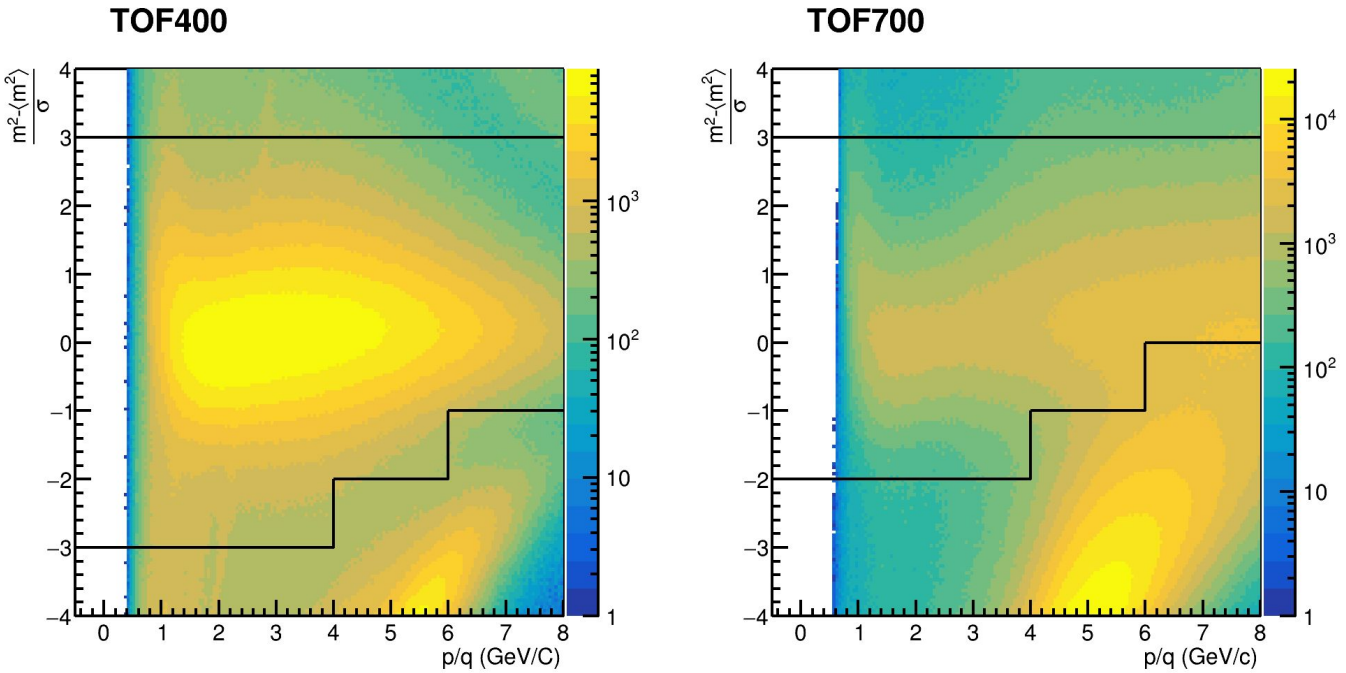
Centrality. Particle identification





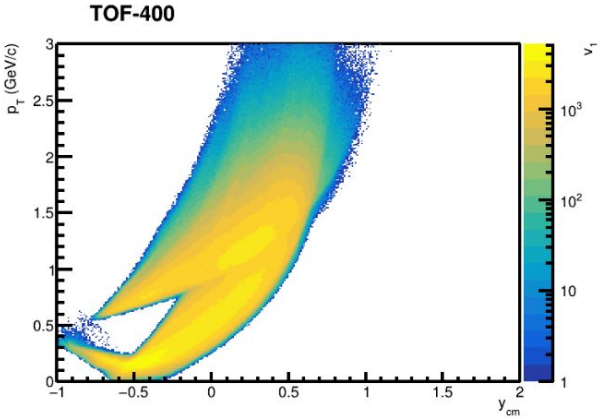


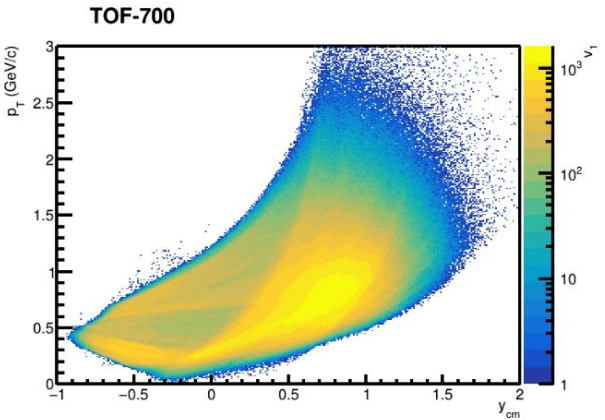
Deuteron identification criteria

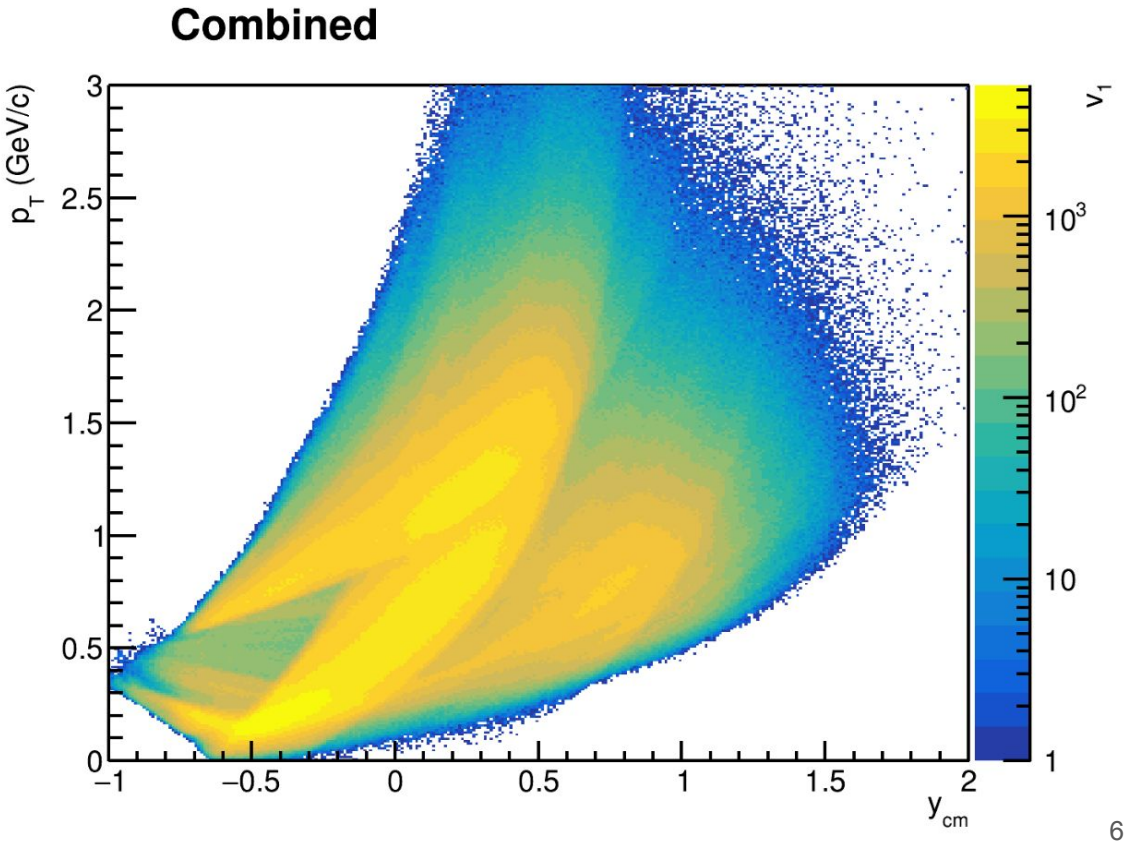


N-σ distributions for deuteron candidates
Solid lines represent the selection criteria for different p/q ranges.

Deuteron p_T-y acceptance







Flow vectors and SP method

A unit vector is defined in the transverse plane for each particle k:

$$u_{n,k} = e^{in\phi_k}$$

Event flow vector Q_n - an estimate of the reaction plane:

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

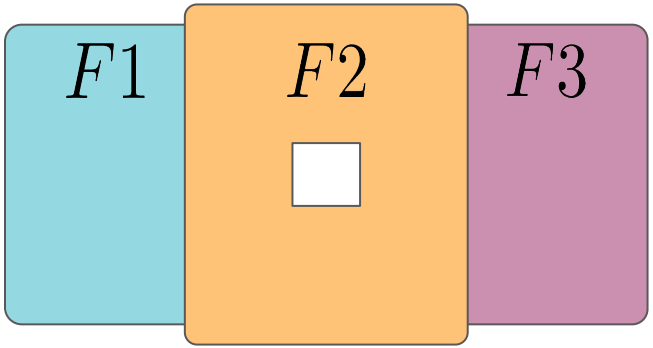
Scalar product method and the resolution correction factor R:

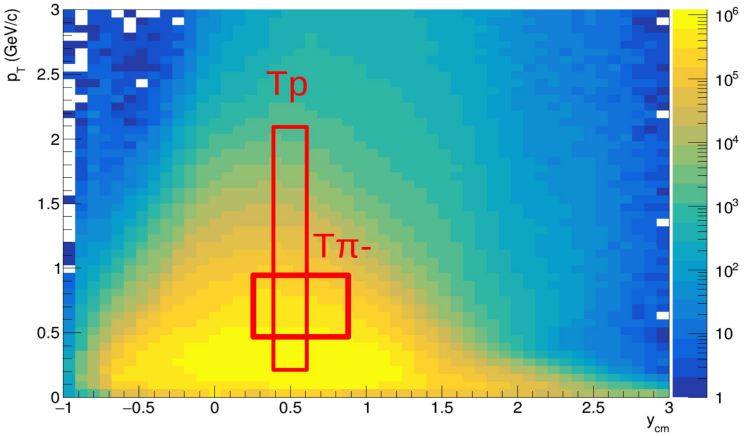
$$v_1 = \frac{\langle u_1 Q_1^{F1} \rangle}{R_1^{F1}} \qquad R_1^{F1} = \langle \cos(\Psi_1^{F1} - \Psi_1^{RP}) \rangle$$

Using three groups of particles and the pairwise correlations of Q_1, R_1 reads

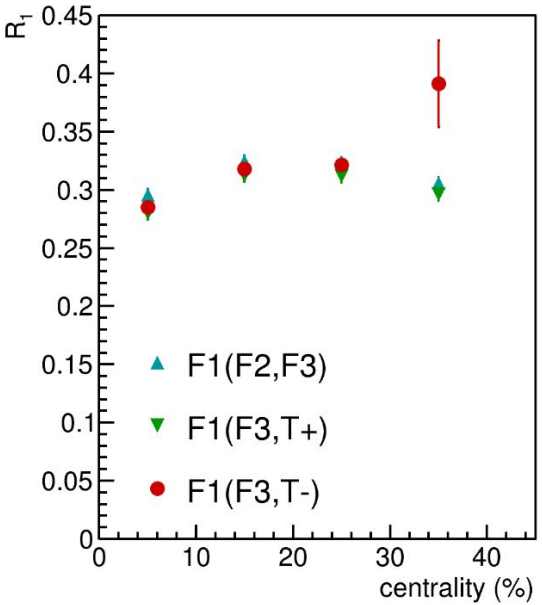
$$R_1^{F2(F1,F3)} = \frac{\sqrt{\langle Q_1^{F2} Q_1^{F1} \rangle \langle Q_1^{F2} Q_1^{F3} \rangle}}{\sqrt{\langle Q_1^{F1} Q_1^{F3} \rangle}}$$

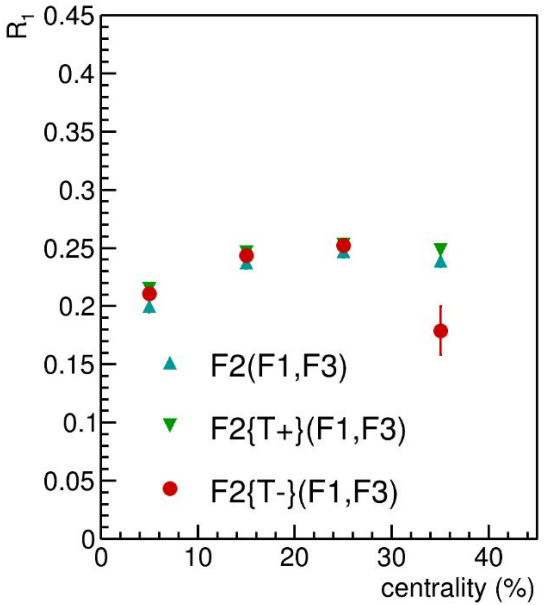
$$R_1^{F2\{Tp\}(F1,F3)} = \langle Q_1^{F2} Q_1^{Tp} \rangle \frac{\sqrt{\langle Q_1^{F1} Q_1^{F3} \rangle}}{\sqrt{\langle Q_1^{Tp} Q_1^{F1} \rangle \langle Q_1^{Tp} Q_1^{F3} \rangle}}$$

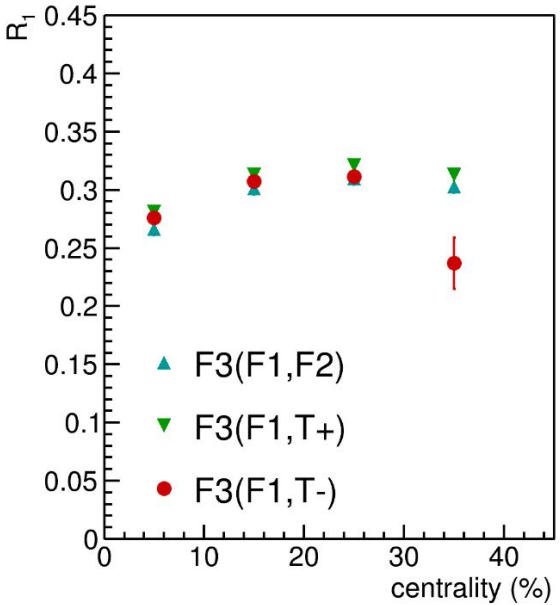




Symmetry plane resolution as a function of centrality

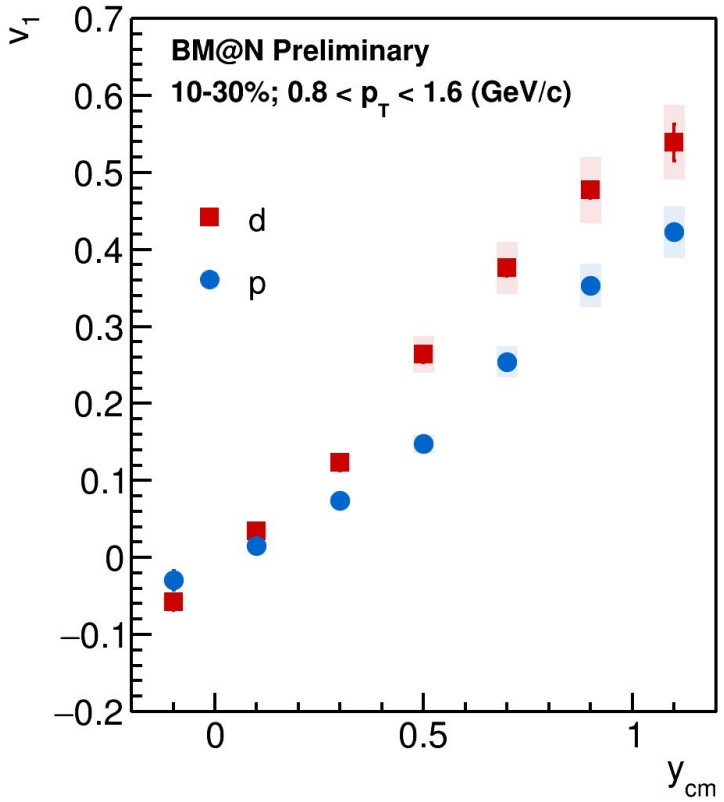


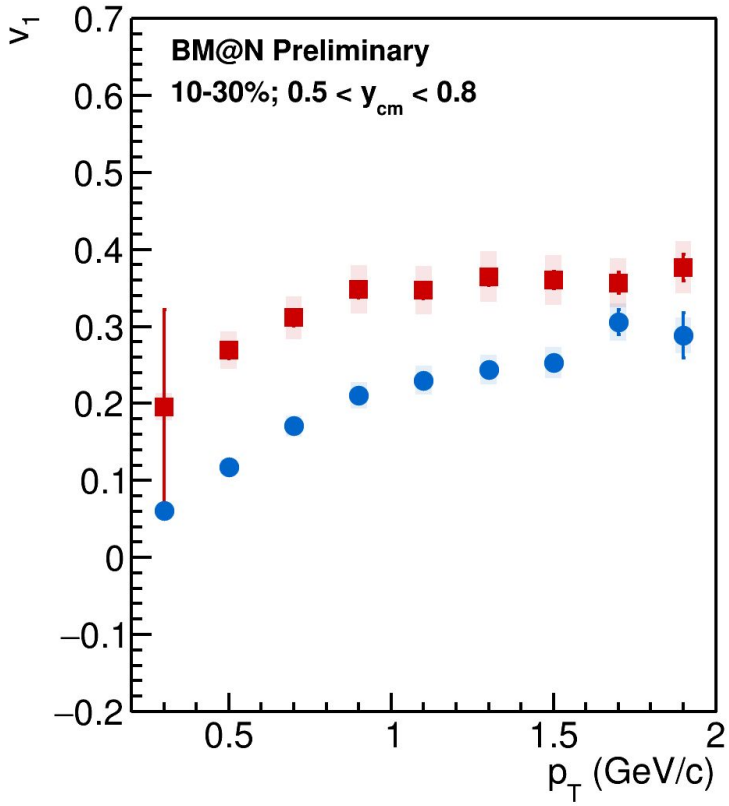




Different estimations of R_1 are in reasonable agreement for all three symmetry planes.

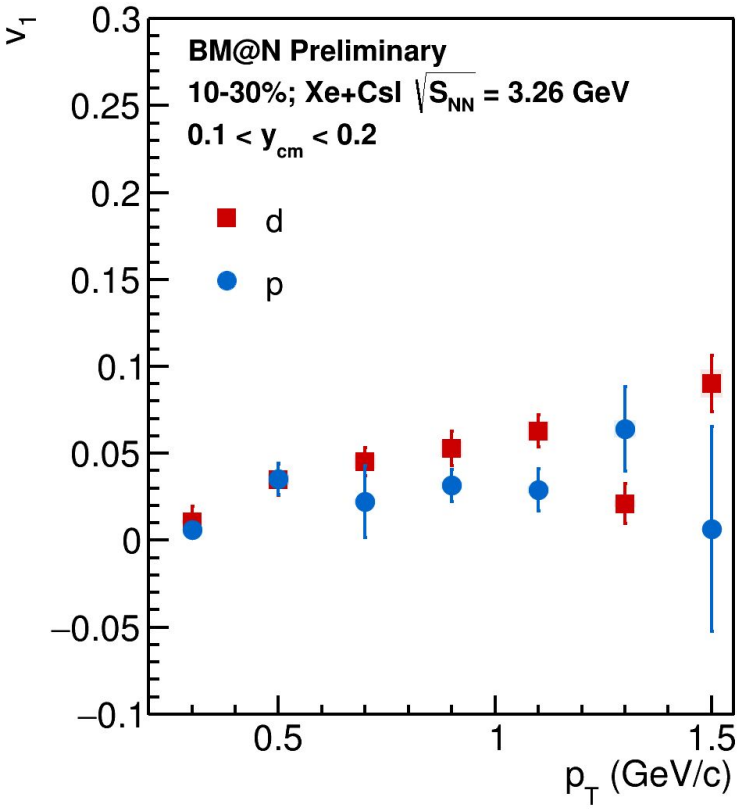
v_1 of protons and deuterons as a function of y and p_T

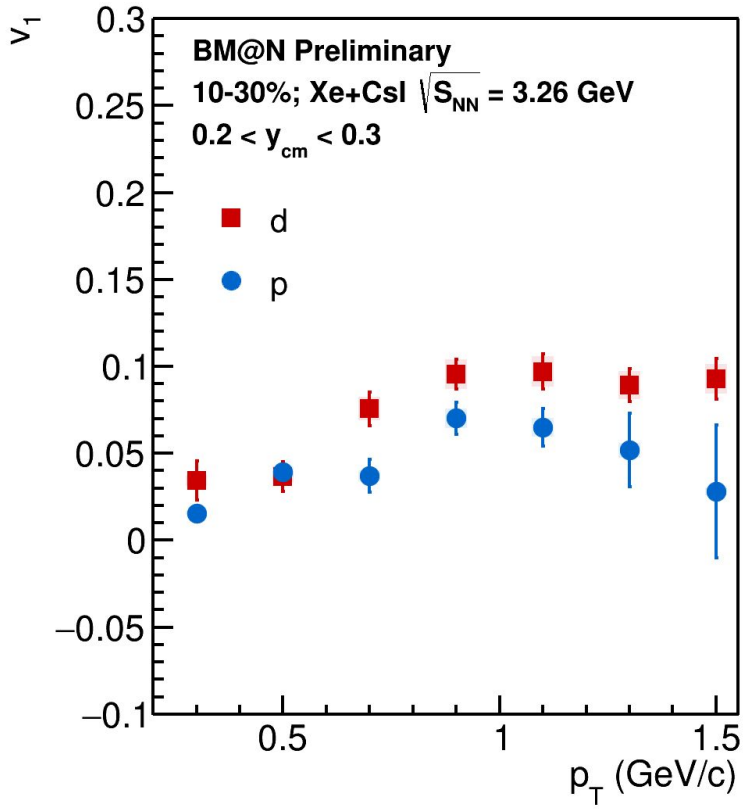




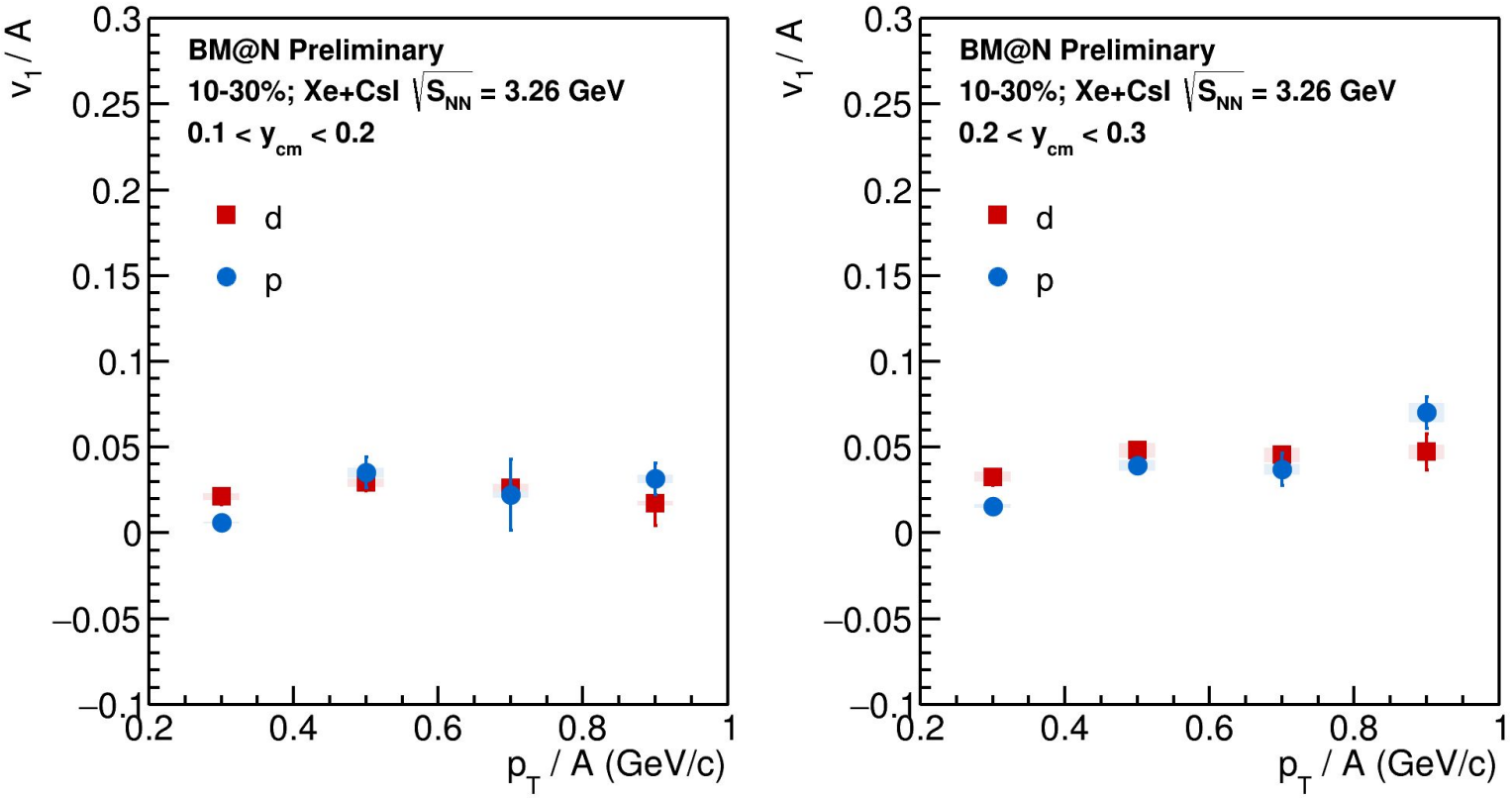
v_1 of deuterons is larger than v_1 of protons as expected.

v_1 of protons and deuterons as a function of p_T



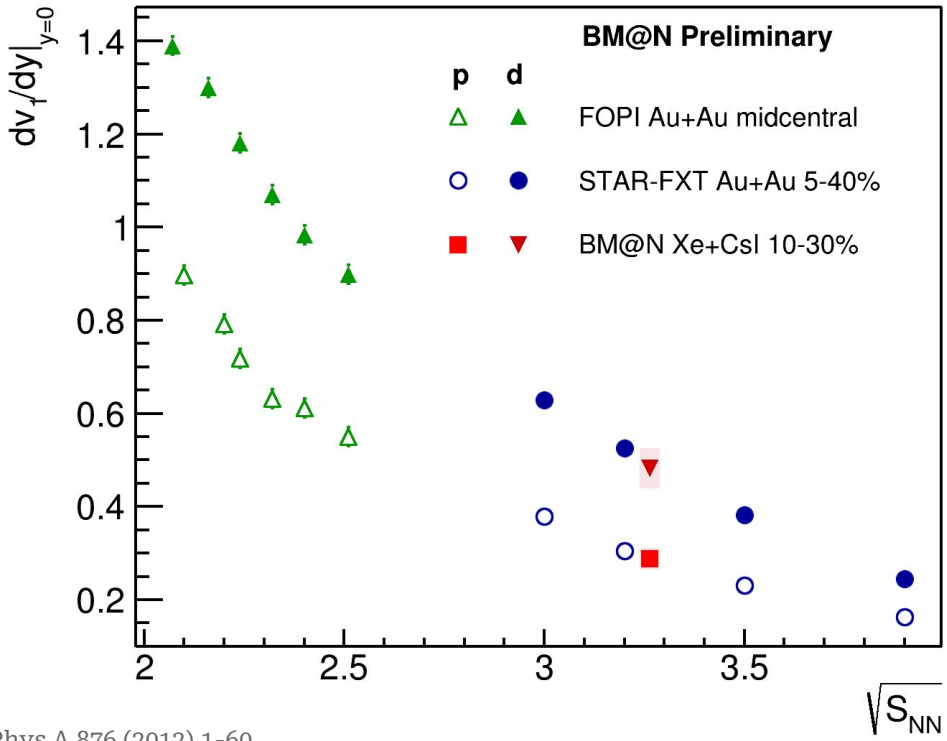


Scaled v_1 of protons and deuterons as a function of scaled p_T/A



v_1 follows approximate scaling with mass number A.

The slope of v_1 of deuterons at midrapidity as a function of collision energy



Directed flow slope of deuterons at midrapidity dv_1/dy is found to be in a good agreement with existing world data.

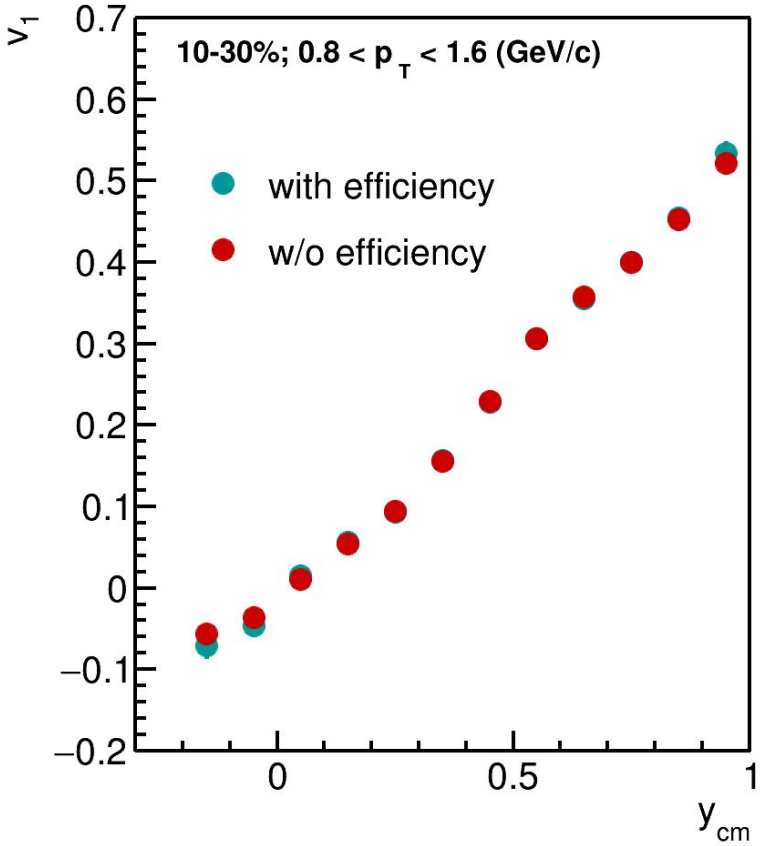
Nucl. Phys A 876 (2012) 1-60
EPJ Web Conf. 296, 05014 (2024)
Phys. Rev. C 103, 034908

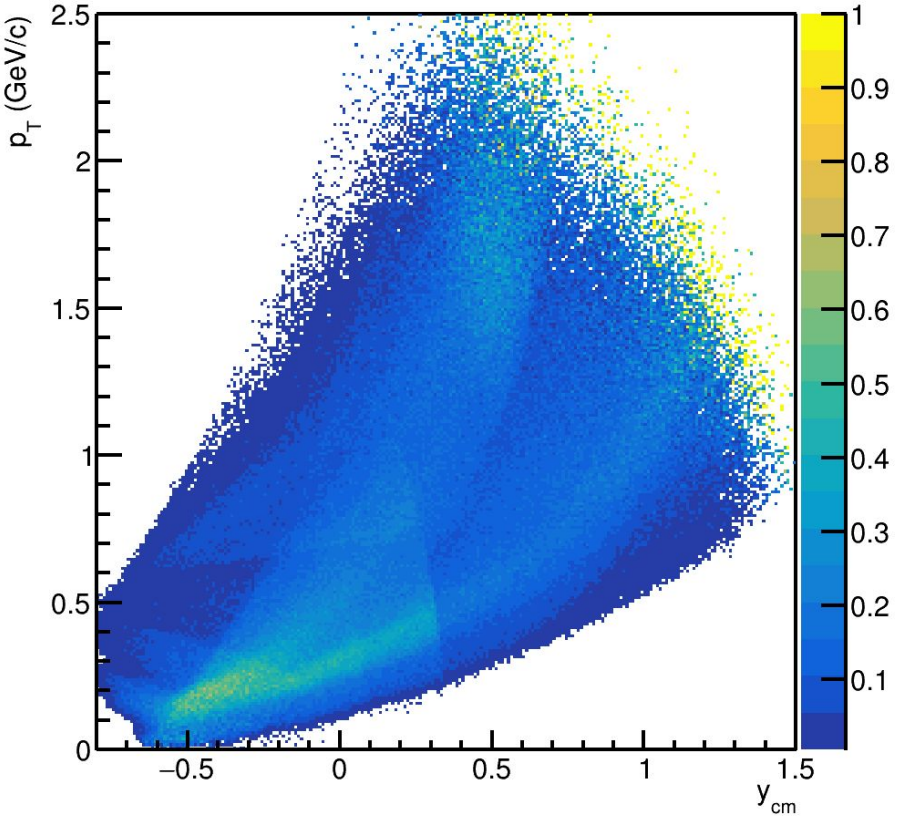
Summary

- v_1 of deuterons was measured differentially as a function of transverse momentum, rapidity and centrality
- The directed flow v_1 of protons and deuterons was studied for mass-number scaling. v_1 for protons and deuterons follow the scaling.
- The directed flow slope at midrapidity $dv_1/dy|_{y=0}$ was extracted. Value for $dv_1/dy|_{y=0}$ is found to be in agreement with the world data

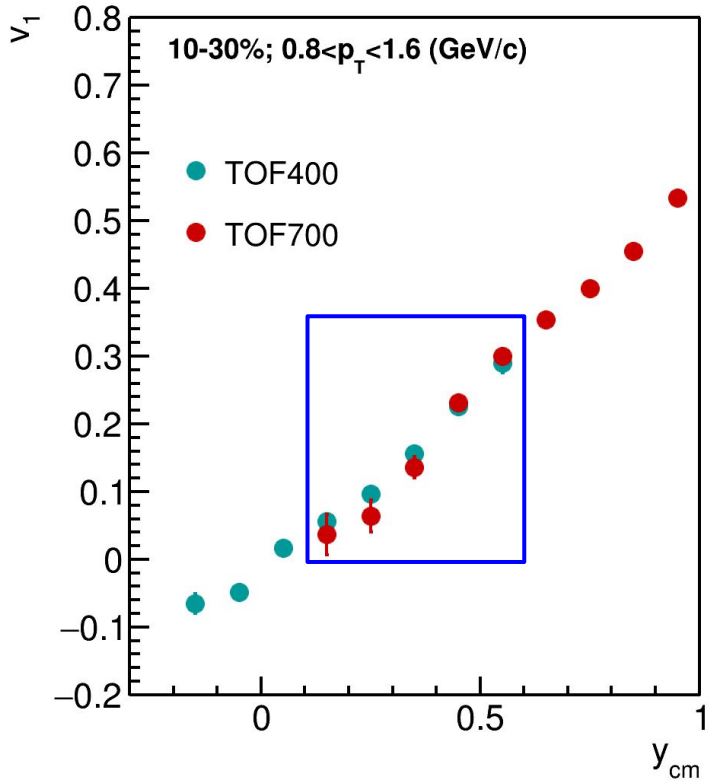
Backup

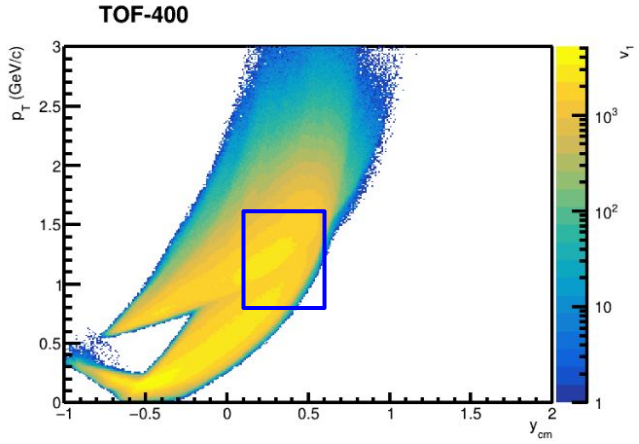
v_1: effect of applying efficiency correction

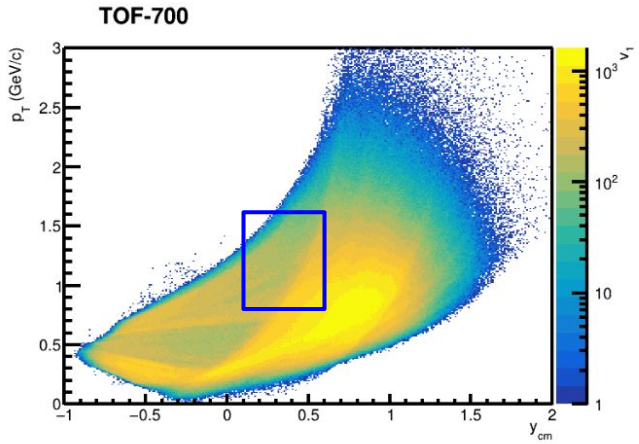




v_1 for deuterons from the TOF400 and TOF700

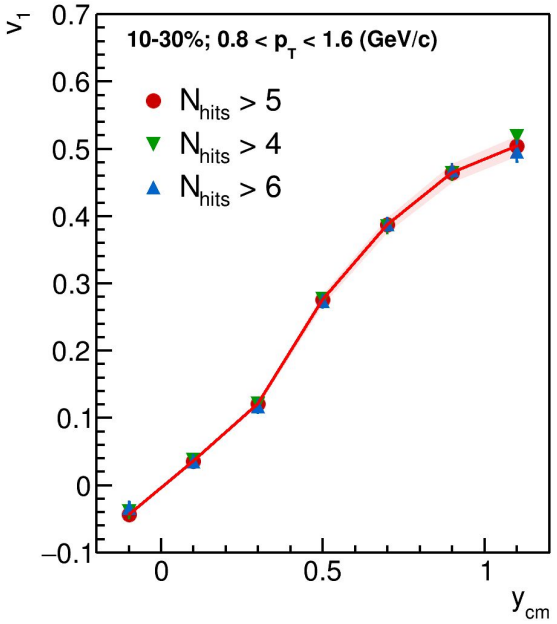




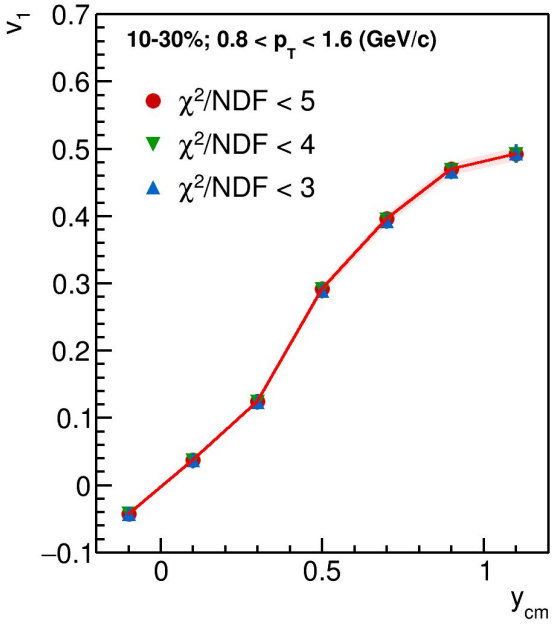


v_1 for deuterons identified separately with TOF400 and TOF700 are in a good agreement

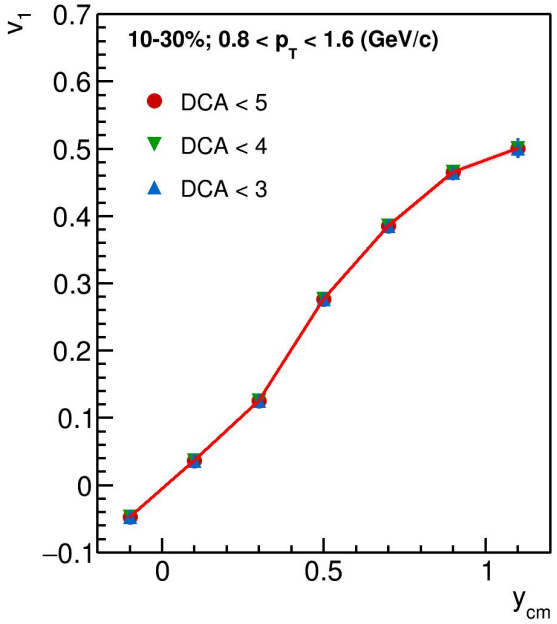
Systematics due to tracking and secondary particles



systematics is below 3%

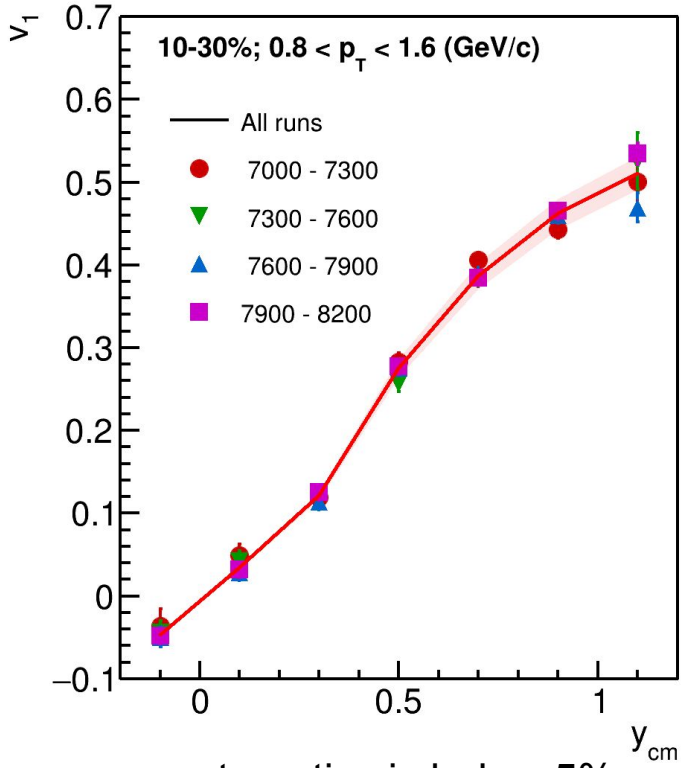


systematics is below 2%



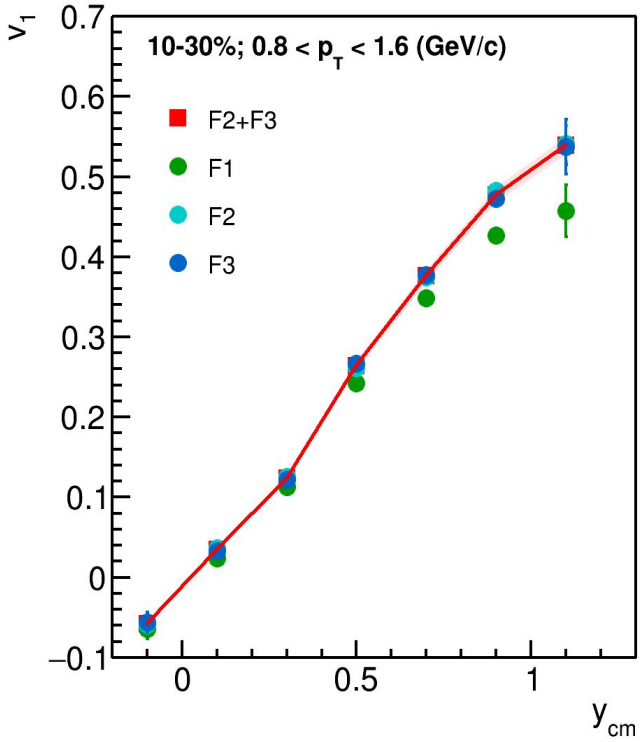
systematics is below 1%

Systematics due to run-by-run variations

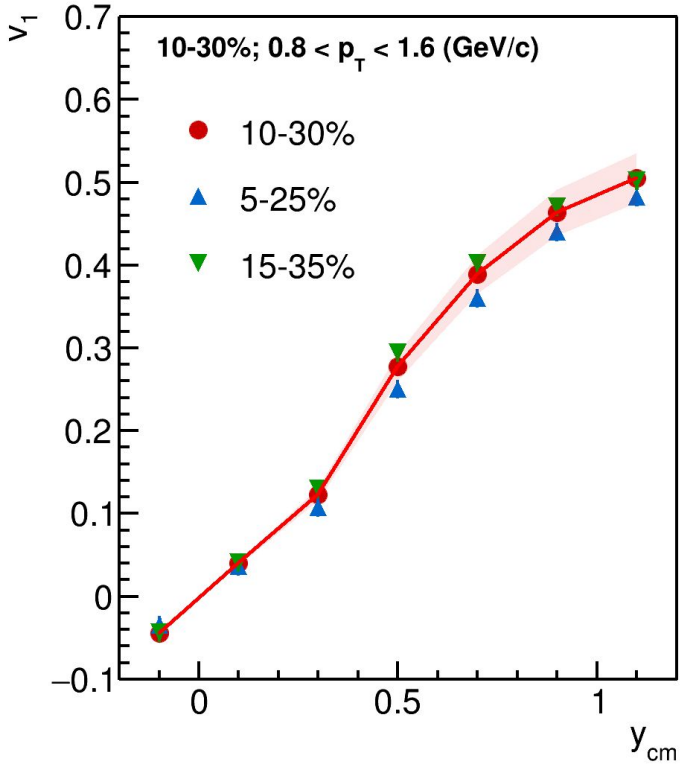


systematics is below 5%

Systematics due to symmetry plane estimation (non-flow)

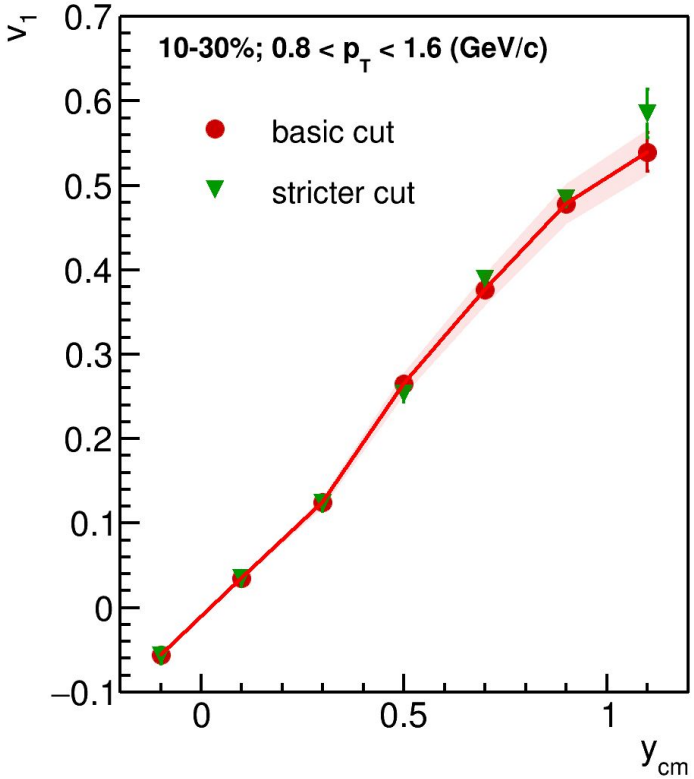


The systematics for combined (F2+F3) planes is below 2%

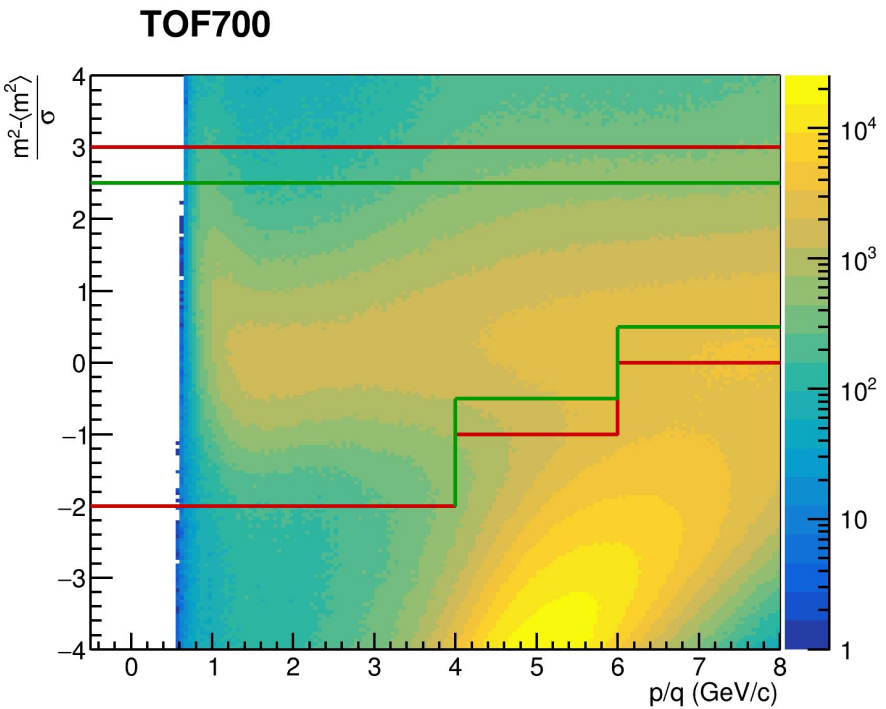


systematics is below 5%

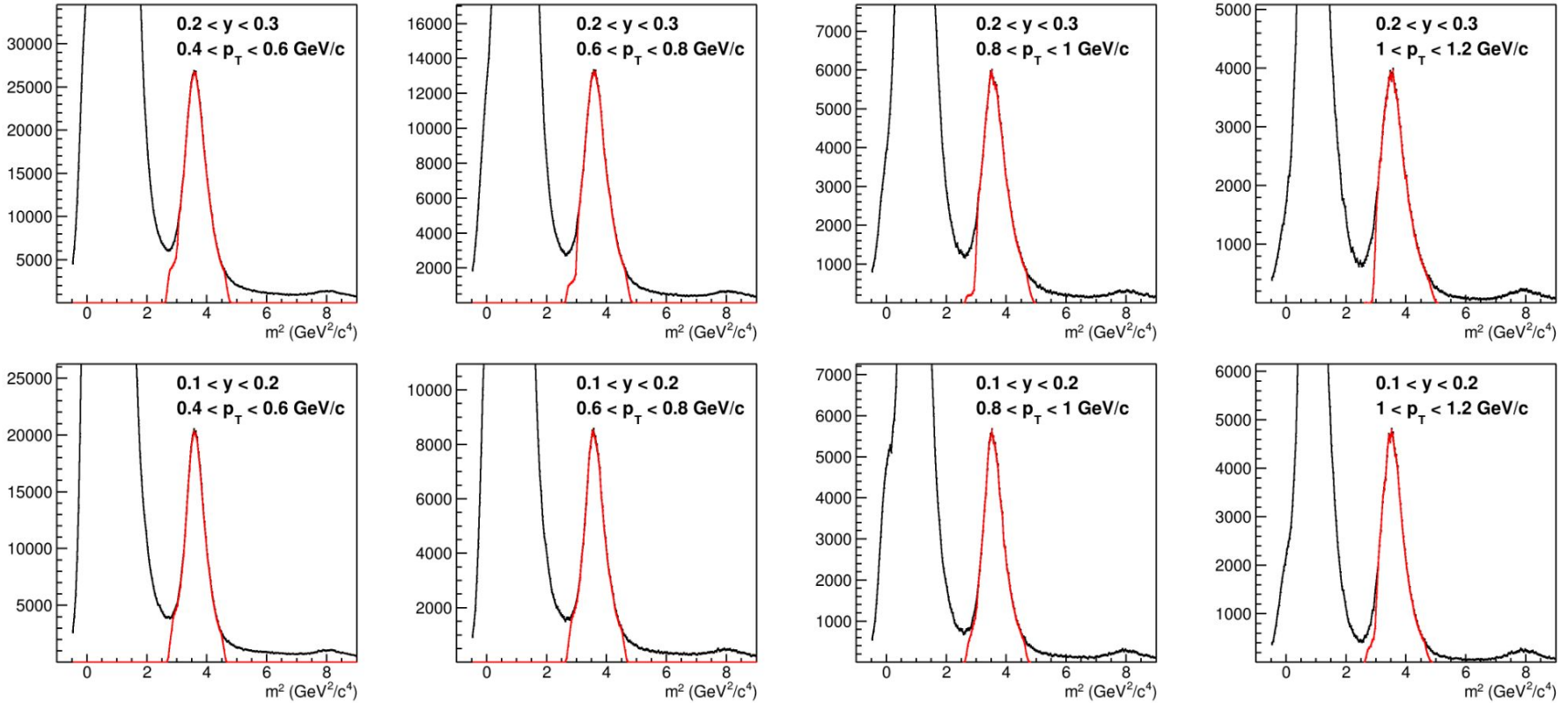
Systematics due to contamination from other particle species



systematics is below 5%

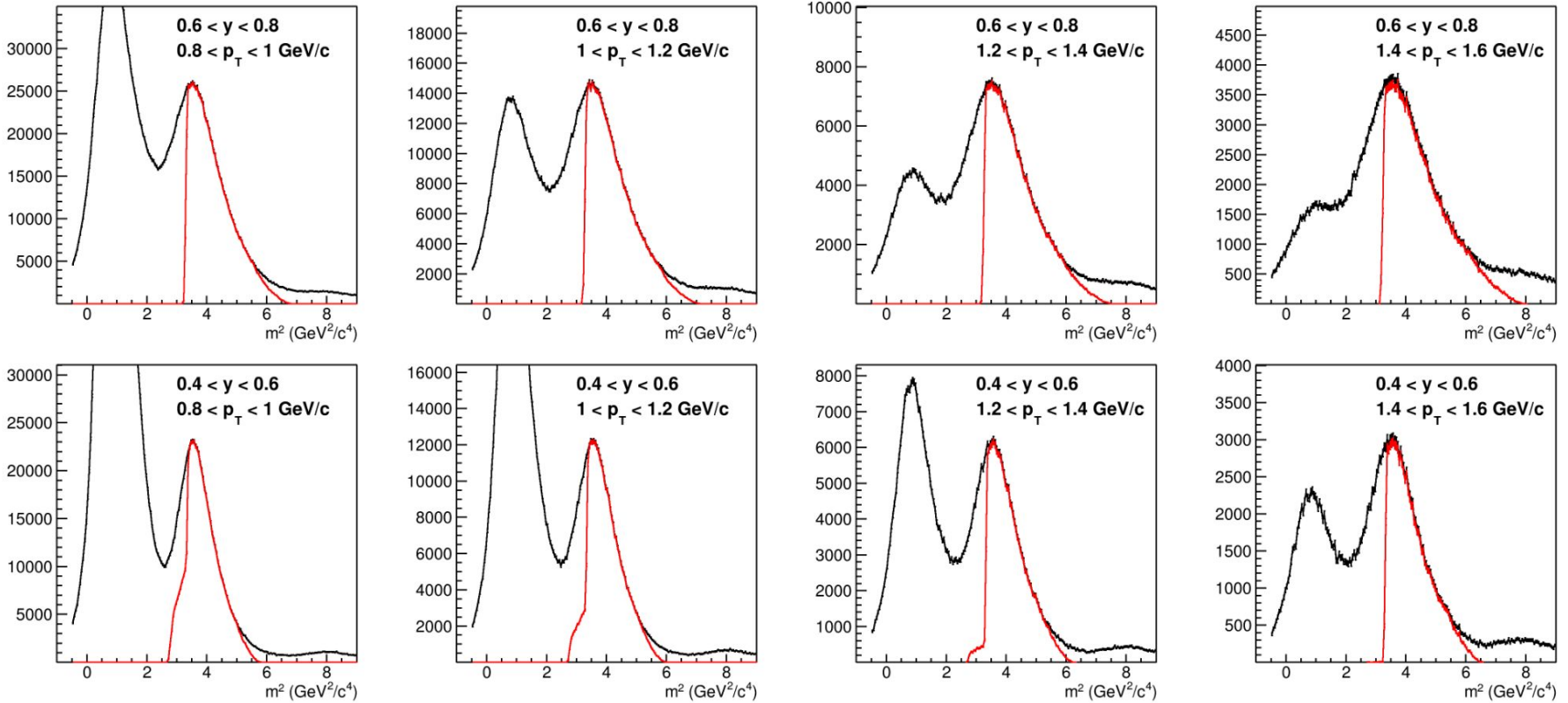


m^2 -distribution in p_T-y windows



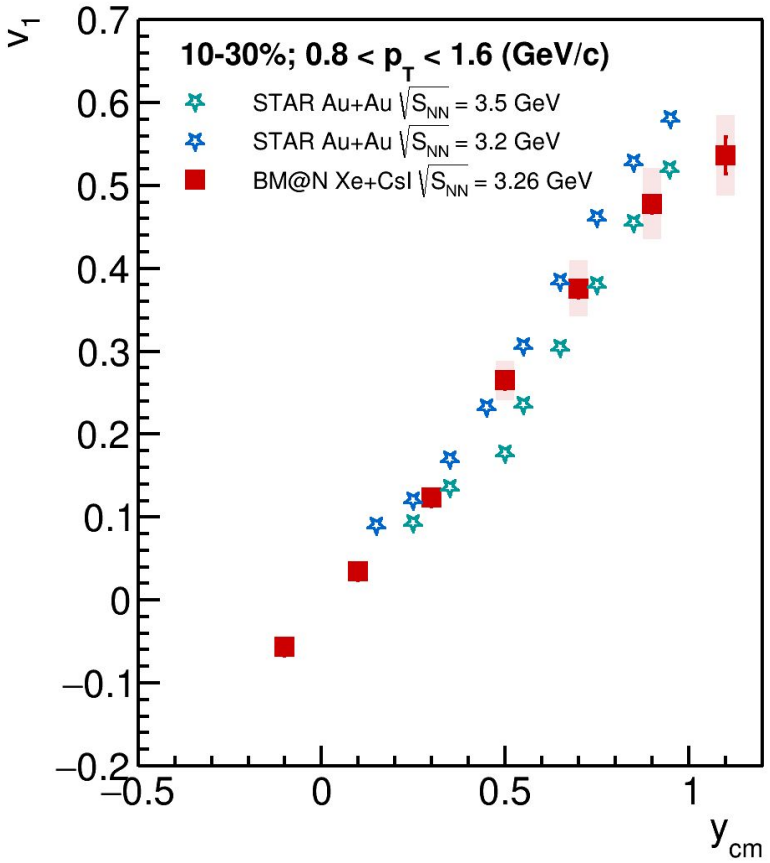
m^2 particle distribution in p_T and y bins in the TOF700

m^2 -distribution in p_T-y windows



m^2 particle distribution in p_T and y bins in the TOF700

v_1 of protons and deuterons as a function of y and p_T



centrality 10-30% - for the BM@N data
centrality 5-40% - for STAR