Directed end elliptic flow of protons in Xe+CsI at 3.8A GeV

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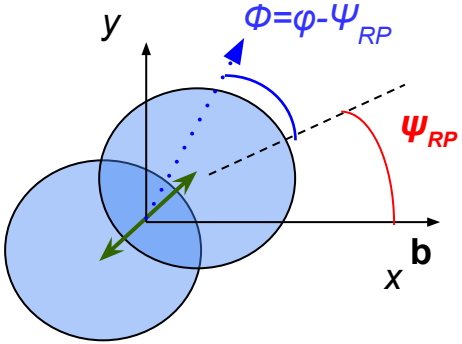
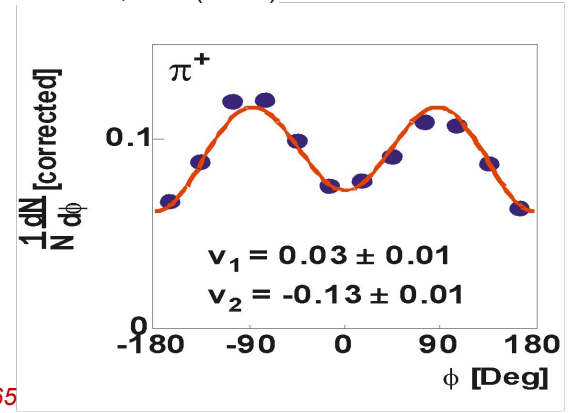
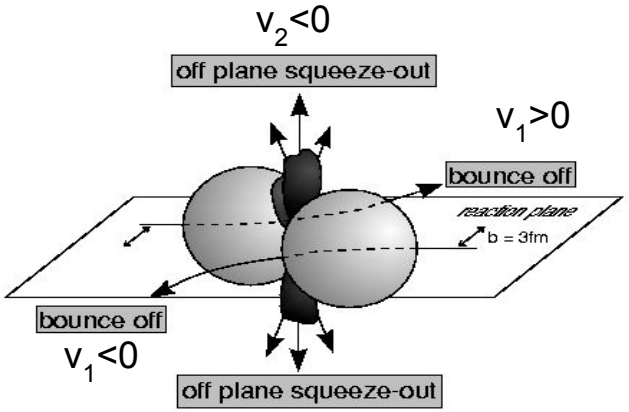
BM@N Collaboration Meeting
13/05/2026

Azimuthal anisotropic flow 1989-2000

Diogene, M. Demoulins et al., Phys. Lett. B241, 476 (1990)
Plastic Ball, H.H. Gutbrod et al., Phys. Lett. B216, 267 (1989)







S Voloshin, Y. Zhang, Z. Phys. C70,(1996), 665

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

The anisotropy is quantified by decomposing the azimuthal distribution in a Fourier series

$$v_n = \langle \cos n(\phi - \Psi_{RP}) \rangle$$

v_1 is directed flow, v_2 — elliptics and v_3 — triangular

Preliminary results for proton v_1

Analysis Note

Directed flow v_1 of protons in the Xe+Cs(I) collisions at 3.8 AGeV (BM@N run8)

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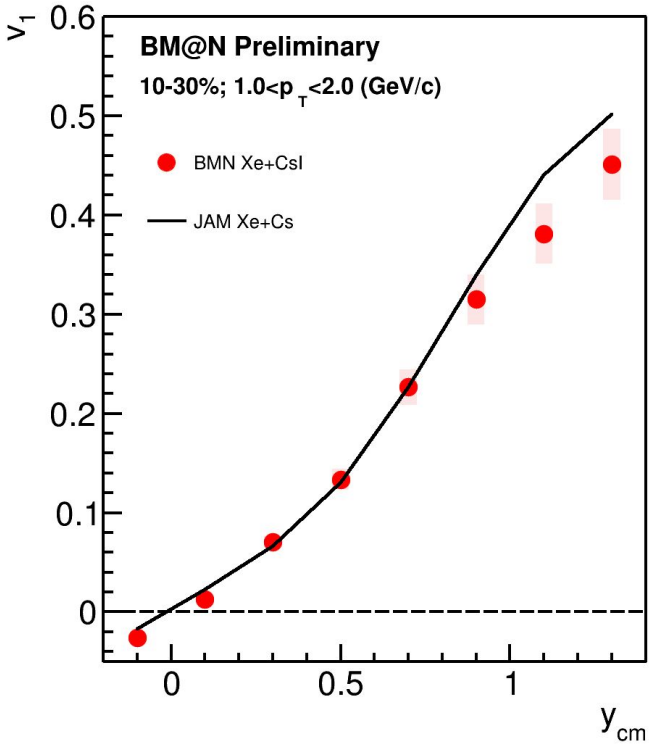
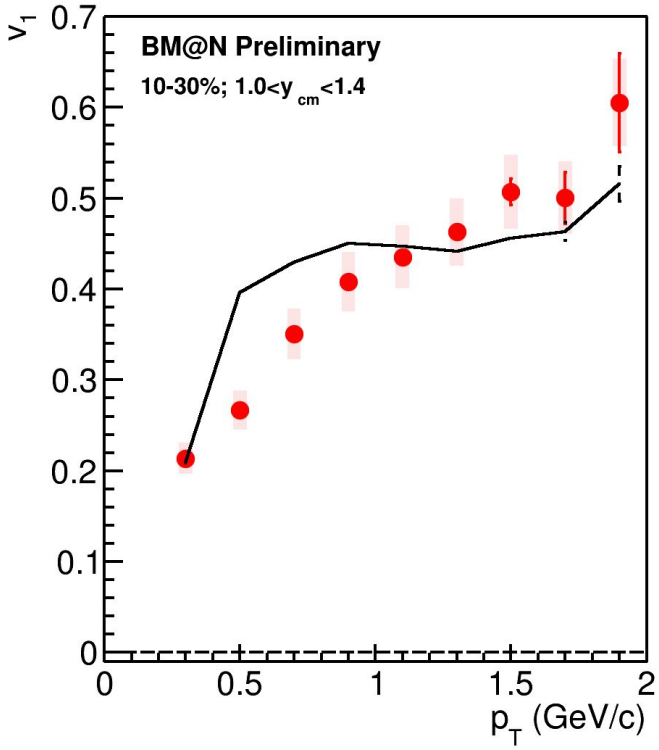
In this note, we present the directed flow v_1 measurements of protons from Xe+Cs(I) collisions at 3.8 AGeV (BM@N run8). We show the datasets, event and track selection cuts, centrality definition, event plane reconstruction and resolution. The v_1 results are presented as function of transverse momentum (p_T) and rapidity (y_{cm}) for 10-30% central Xe+Cs(I) collisions. The systematic uncertainty study will also be presented and discussed. The v_1 measurements are compared with results of JAM transport model calculations and published data from other experiments.

Analysis note: https://indico.jinr.ru/event/4750/attachments/19780/34163/ANoteFlowRun8.pdf

Proton v_1 vs rapidity and transverse momentum

Mamaev M. Int. J. Mod. Phys. E. — 2024. — T. 33, №11. — C. 2441009.

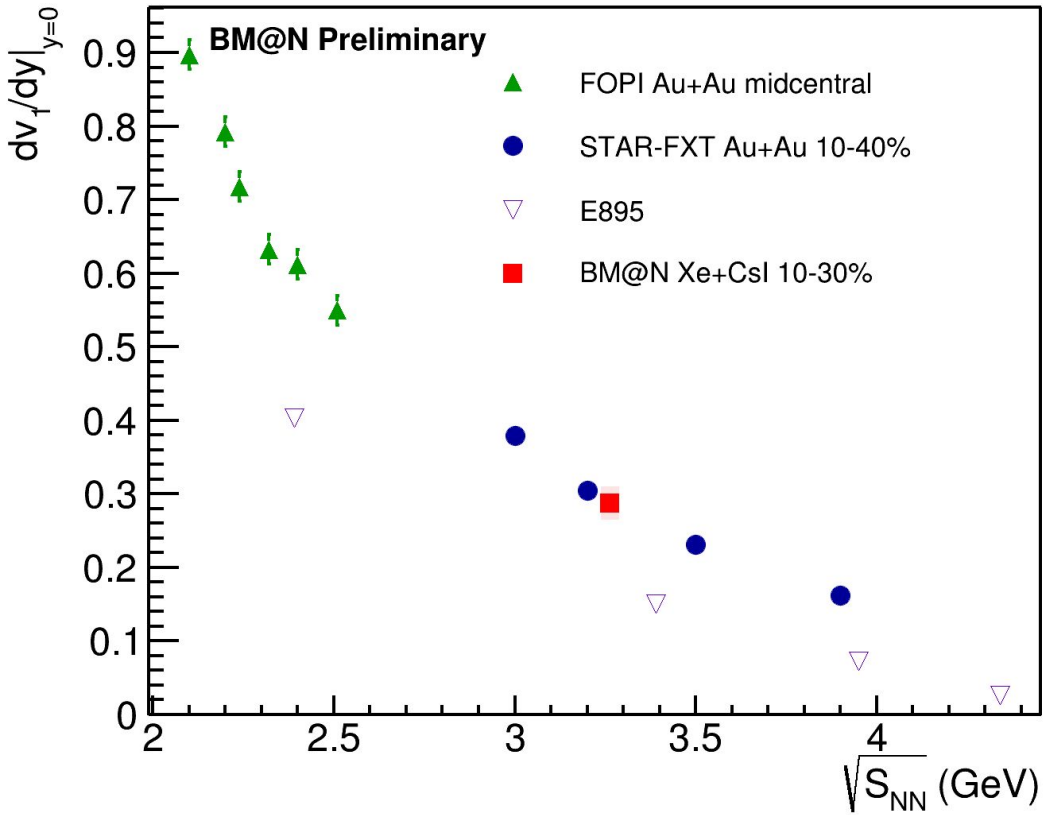




JAM agrees with experimental data within 8% at rapidities $y_{cm}<1$

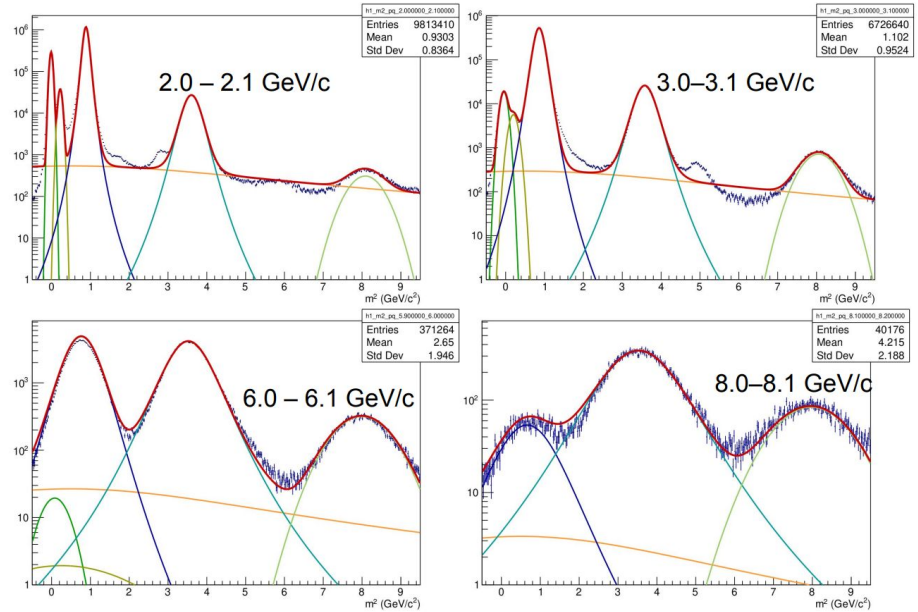
$dv_1/dy|_{ycm=0}$ vs collision energy

FOPI: Nucl.Phys.A 876 (2012)
STAR: Phys.Lett.B 827 (2022)
E895: Phys.Rev.Lett. 84 (2000)

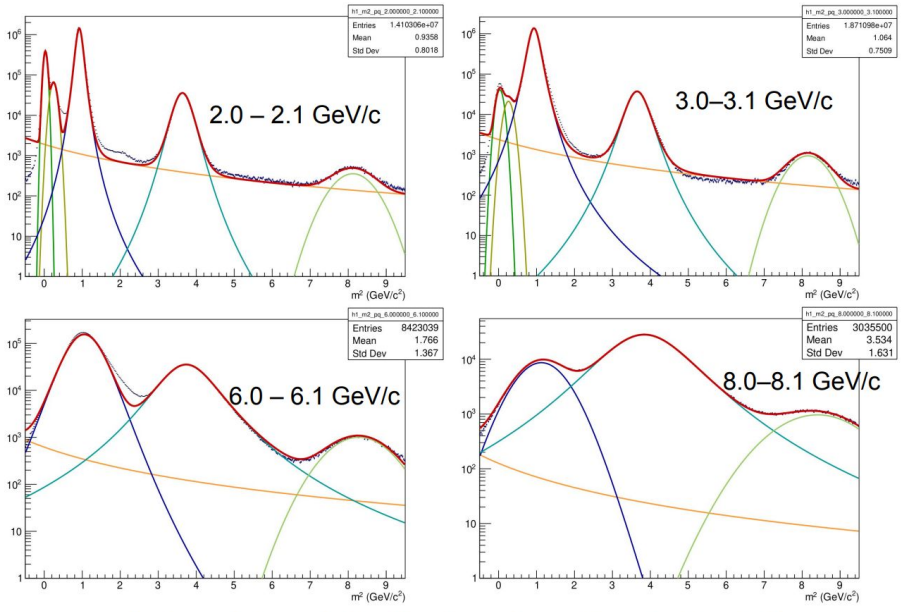


- Proton data from BM@N agree with STAR measurements
- Higher directed flow of proton in BM@N and STAR data suggests more hard equation of state

Improvements of the PID procedure



Fitting of the m2 distributions in pq slices (TOF400)

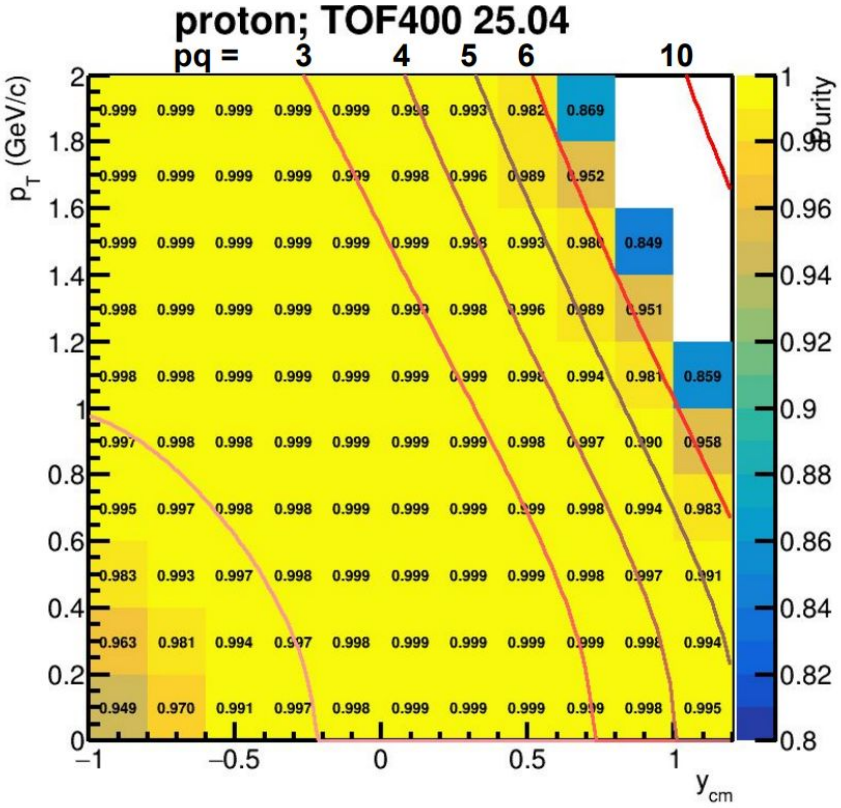


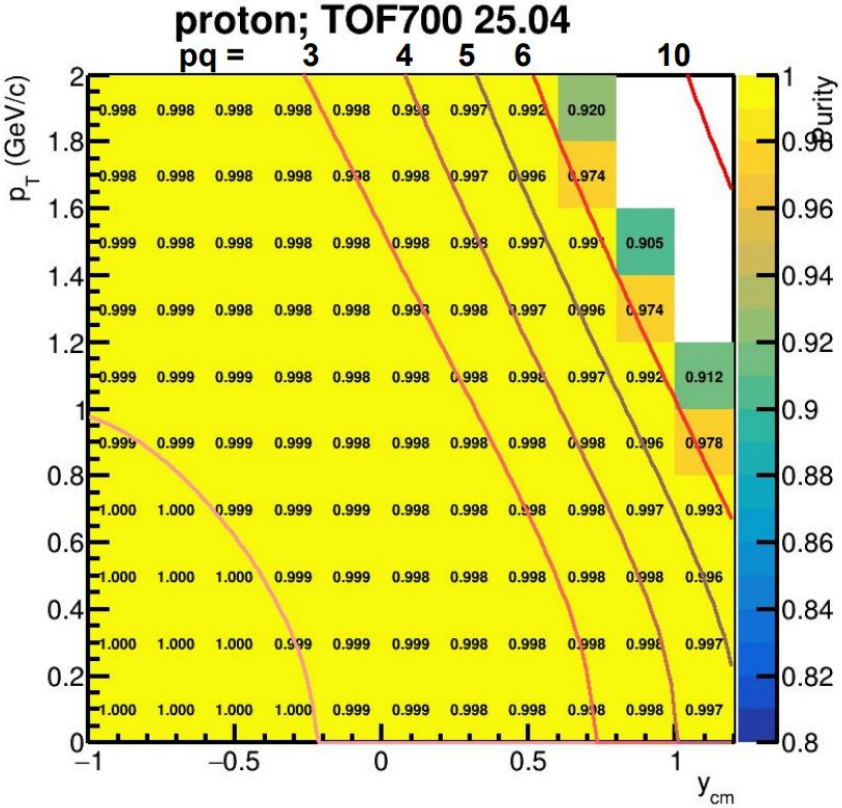
Fitting of the m2 distributions in pq slices (TOF700)

See the talk of I.Zhavoronkova on AM-14 for more details

Purity of proton selection

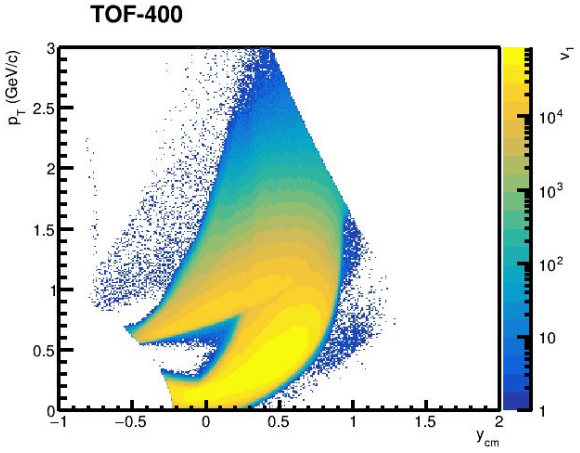
By I.Zhavoronkova

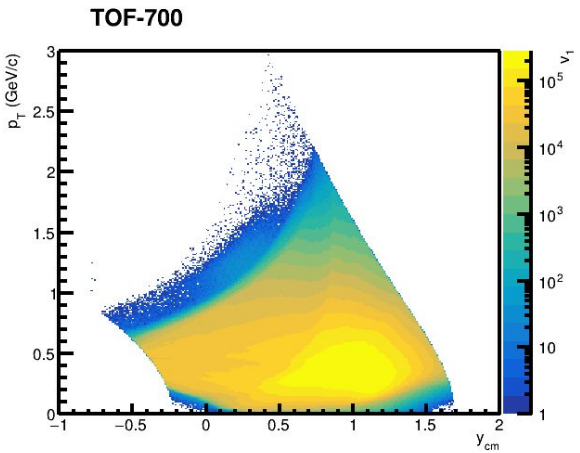


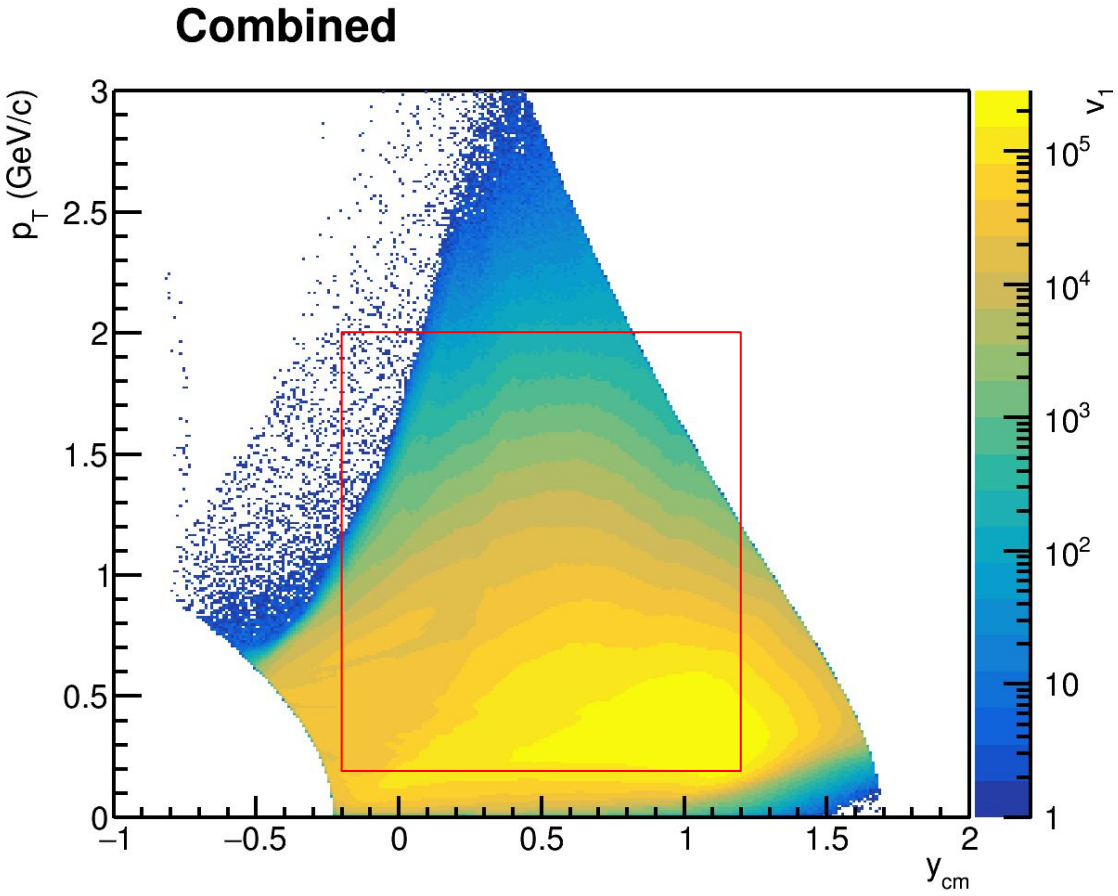


The ratio of proton to all particles (purity) in $[\langle m^2\rangle - 3\sigma; \langle m^2\rangle + 3\sigma]$ is around 99%

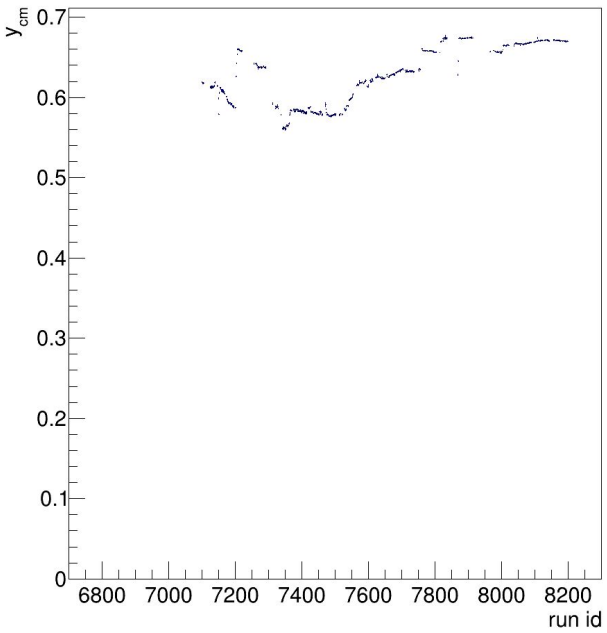
Proton p_T-y acceptance

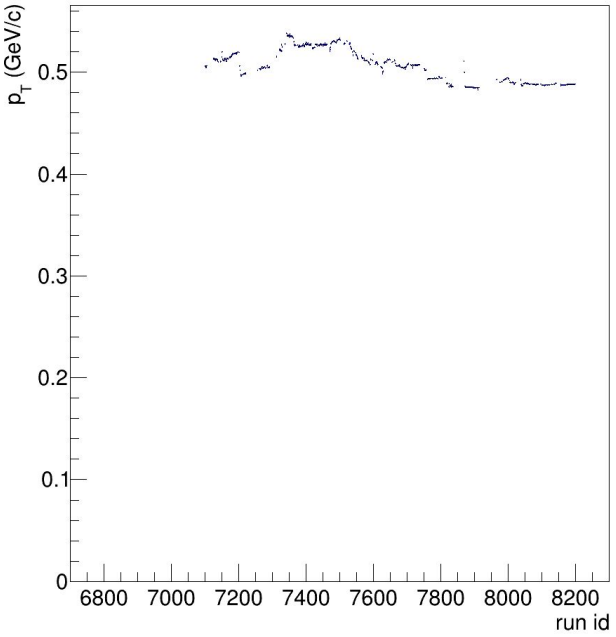


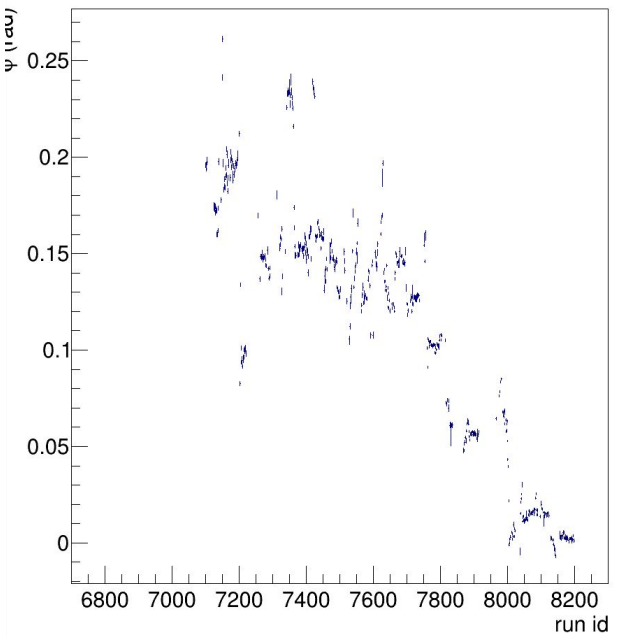




Run-by-run fluctuations in detector performance

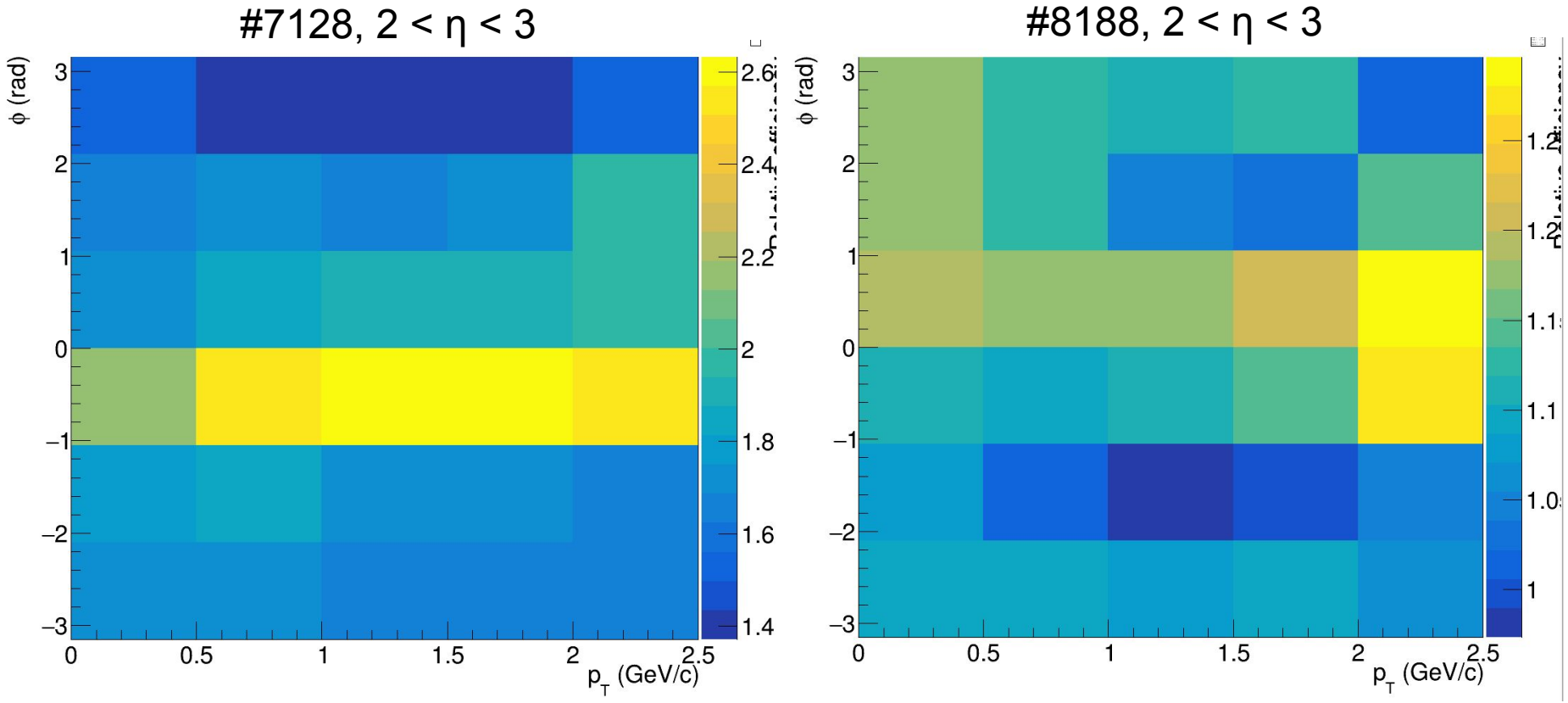






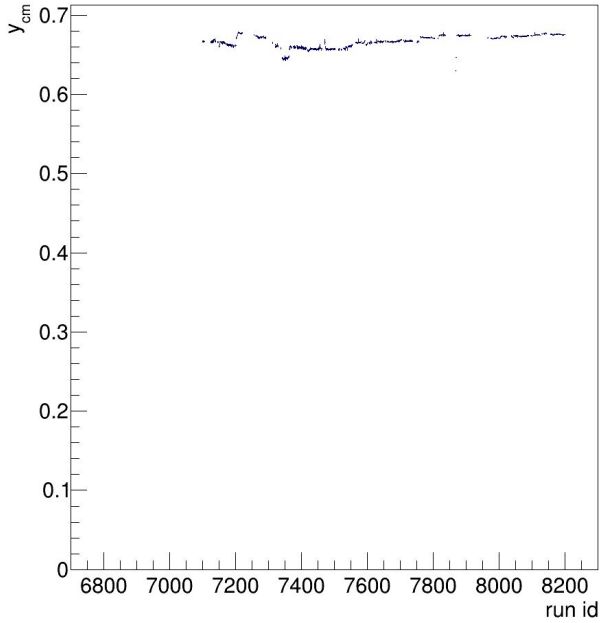
We observe significant fluctuation in effective acceptance during data taking (run-id)

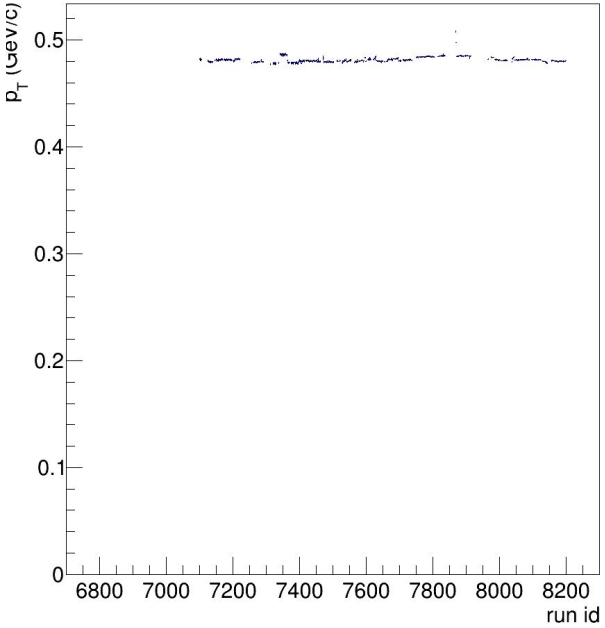
Relative run-by-run efficiency (target run 7500)

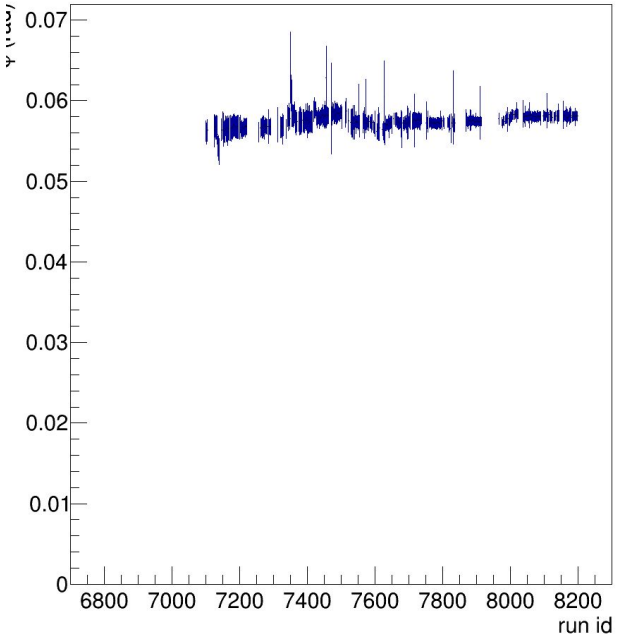


4D-efficiency was built: η, p_T, ϕ, run-id. E = $N_{curr}/N_{target\ run\text{-}id}$

Run-id-corrected averages vs run-id

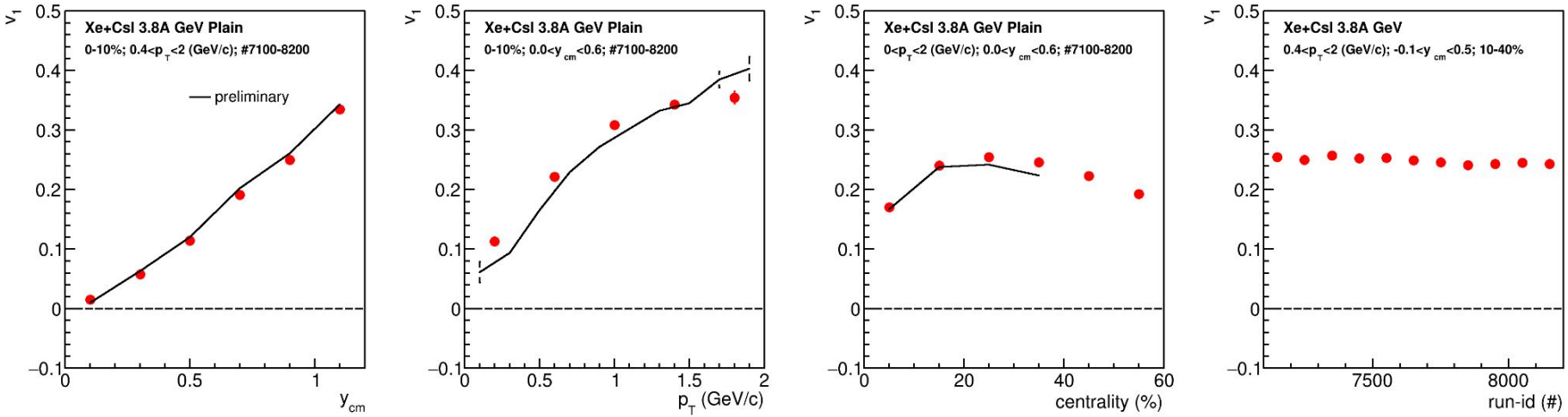






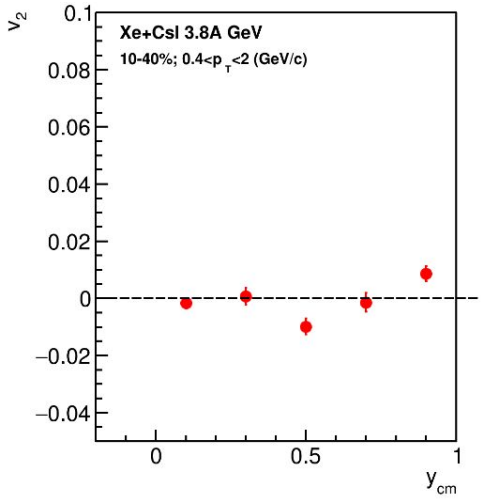
After reweighting the acceptance is stable

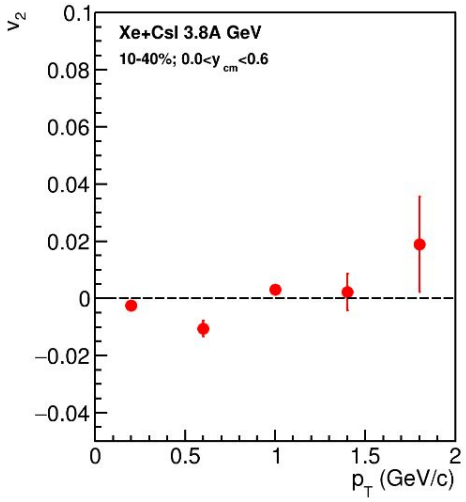
Proton v_1 after track reweighting

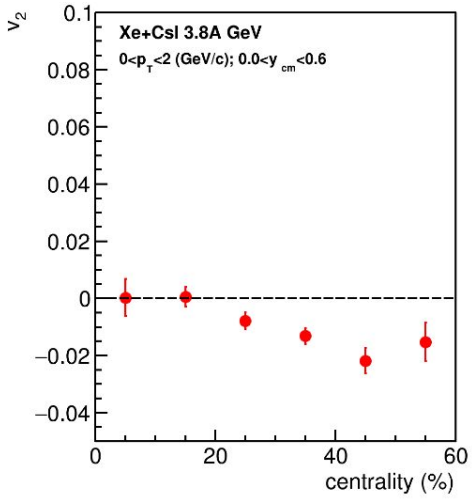


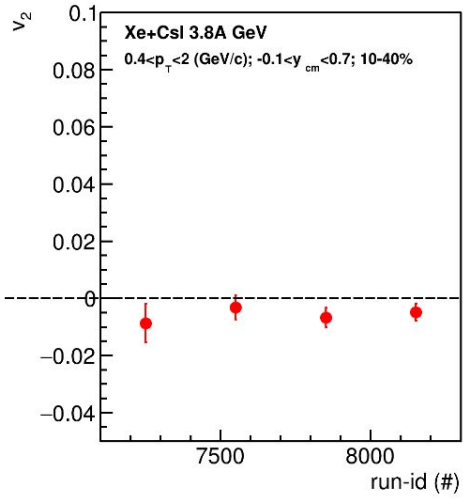
No significant improvement, but stable vs run-id

Proton v_2 dependence on y_{cm}, p_T, centrality and run-id

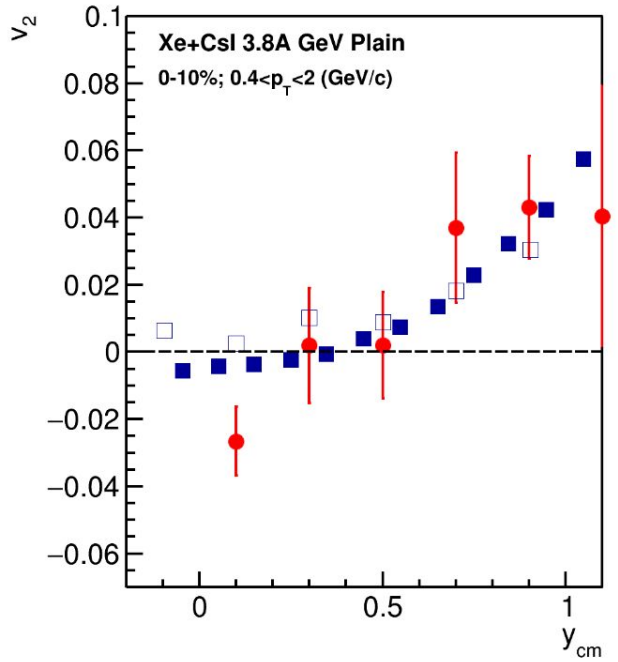


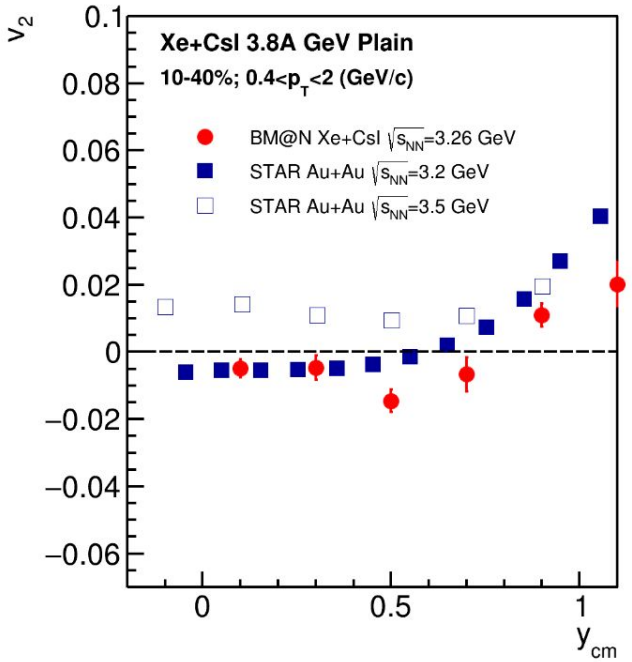


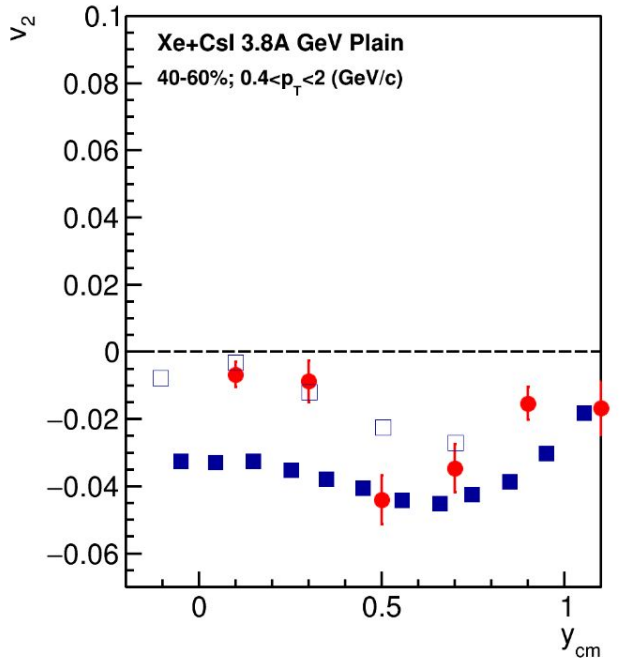




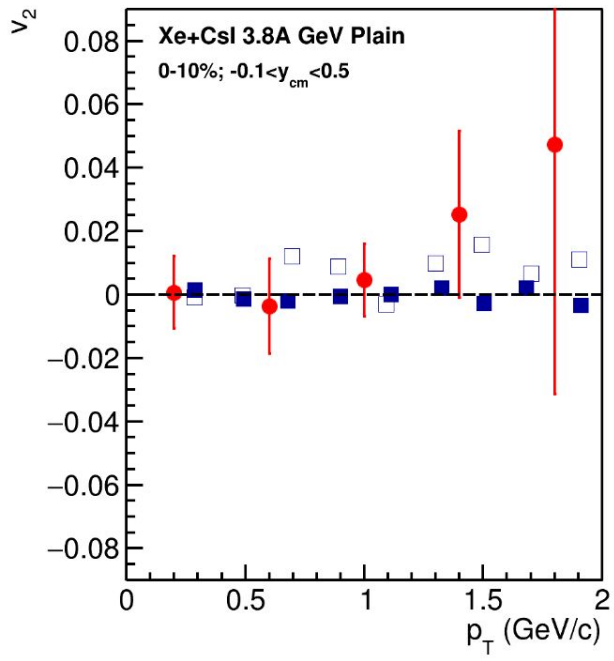
Comparison with STAR: y-dependency

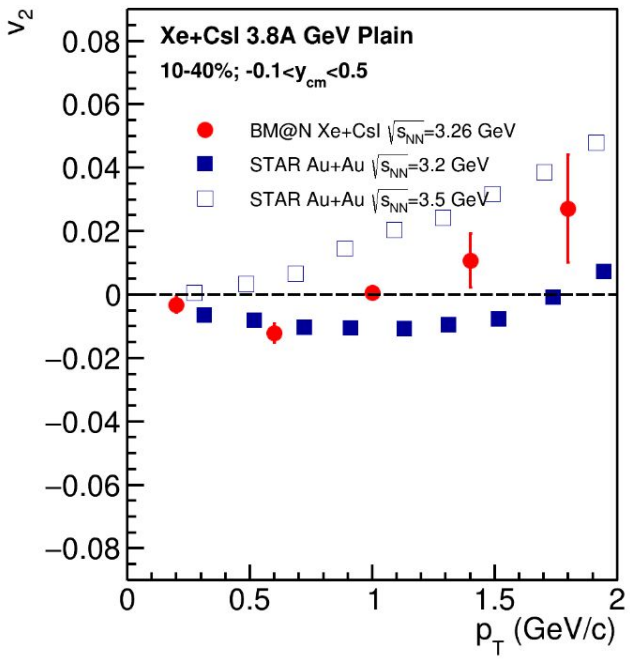


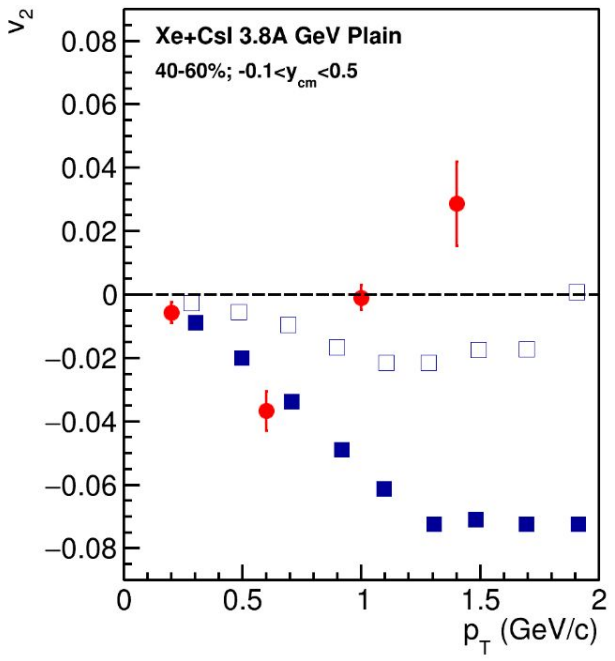




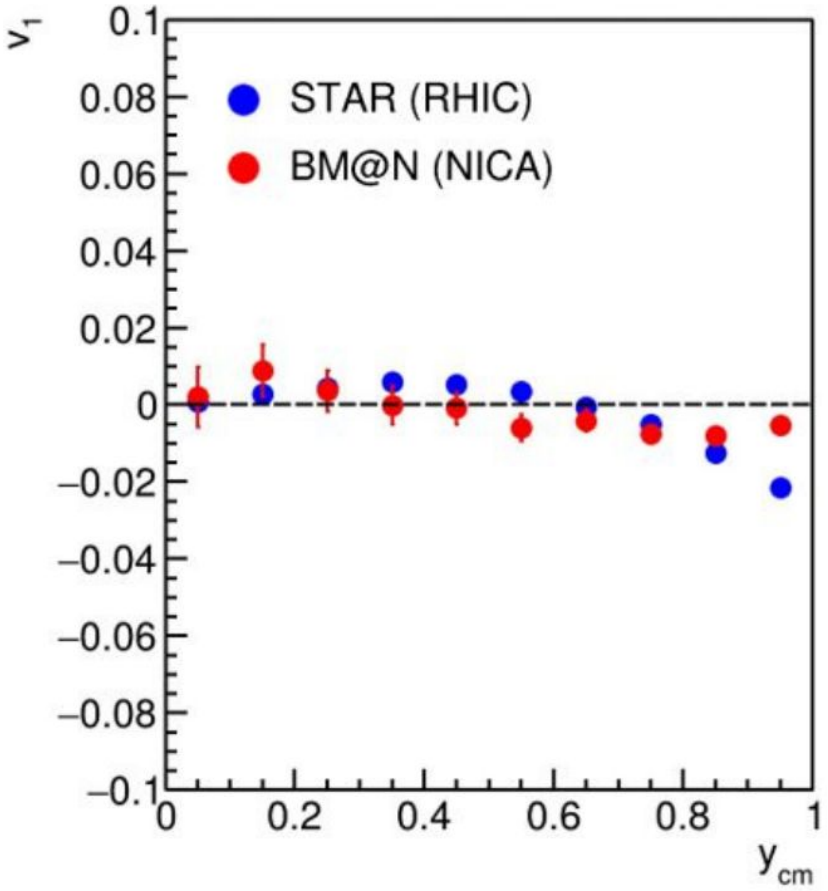
Comparison with STAR: p_T-dependency





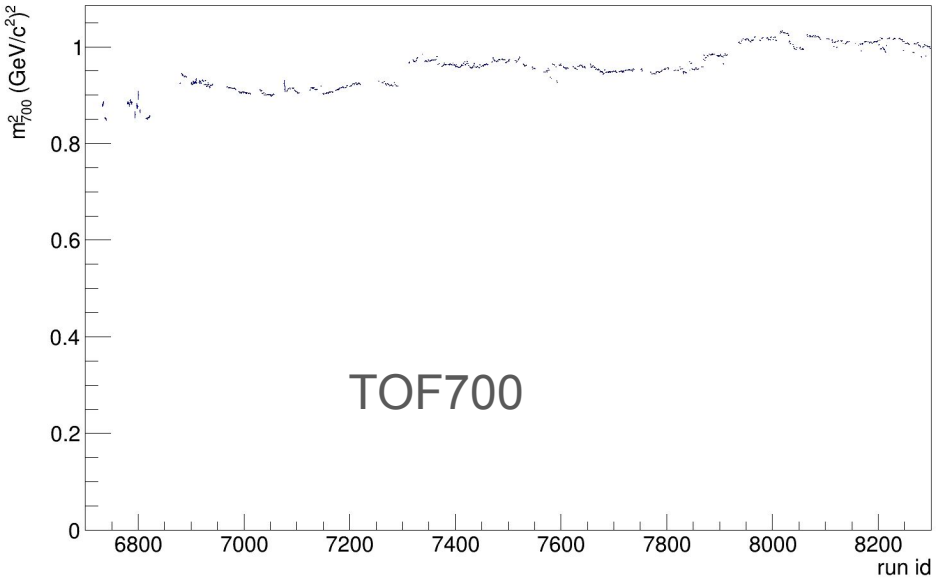


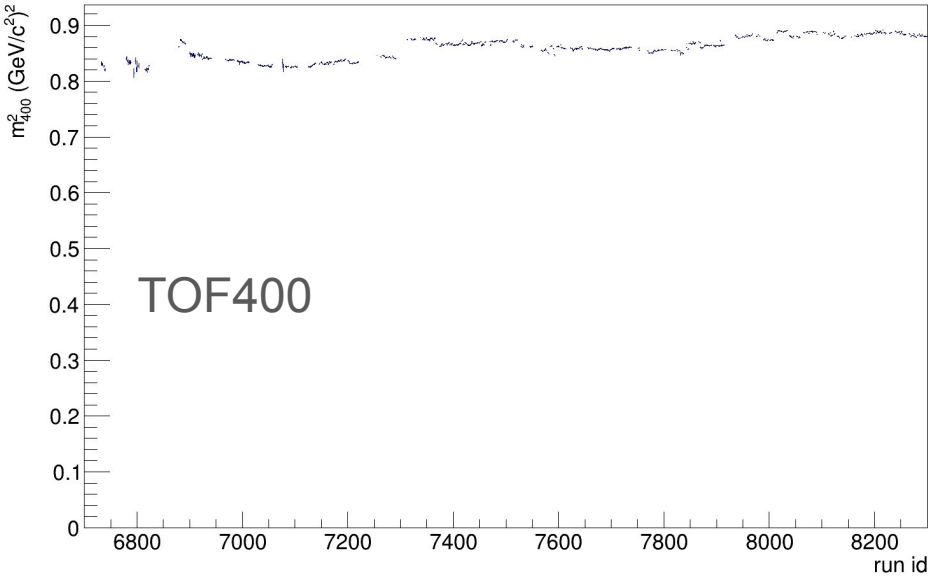
v_1 of negatively charged pions



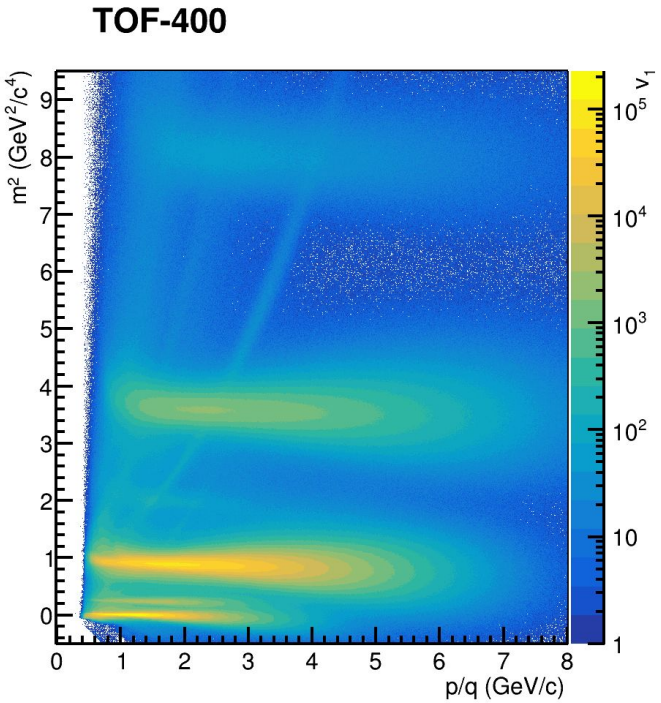
- F.Karpushking measured the directed flow of negatively charged pions
- Rough agreement is observed
- F.Karphushkin includes this result to his bachelor thesis
- Further analysis will be performed

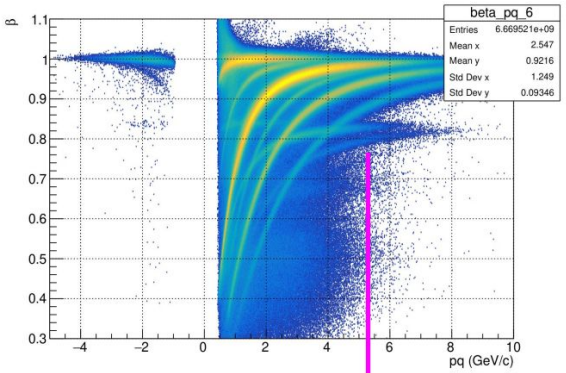
Outlook: checking the systematics run-id variations in PID

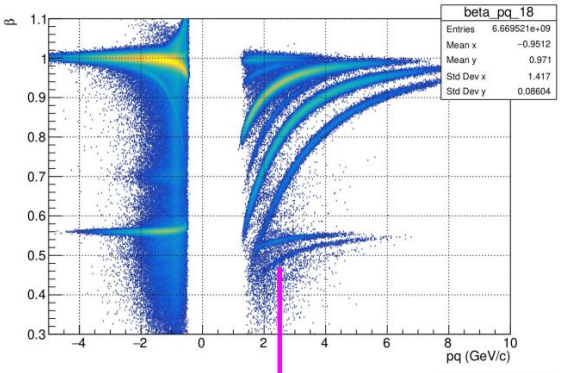


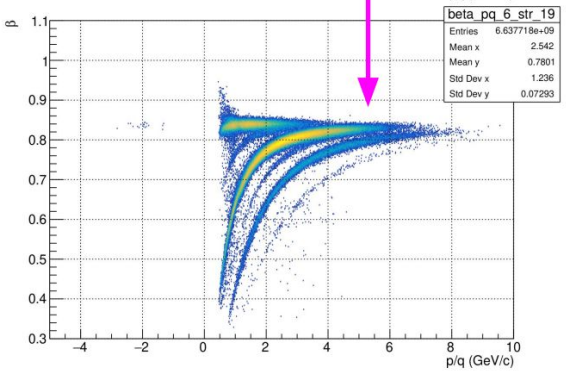


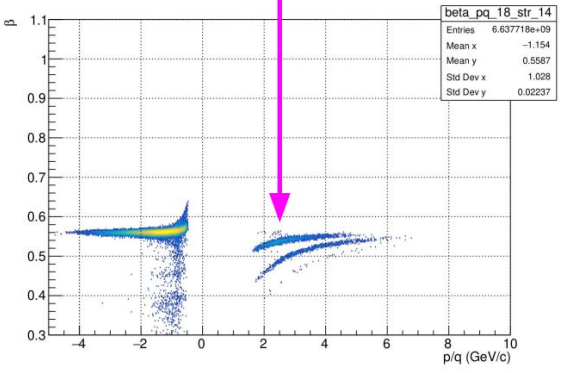
Outlook: Checking for the imperfections in TOF calibration



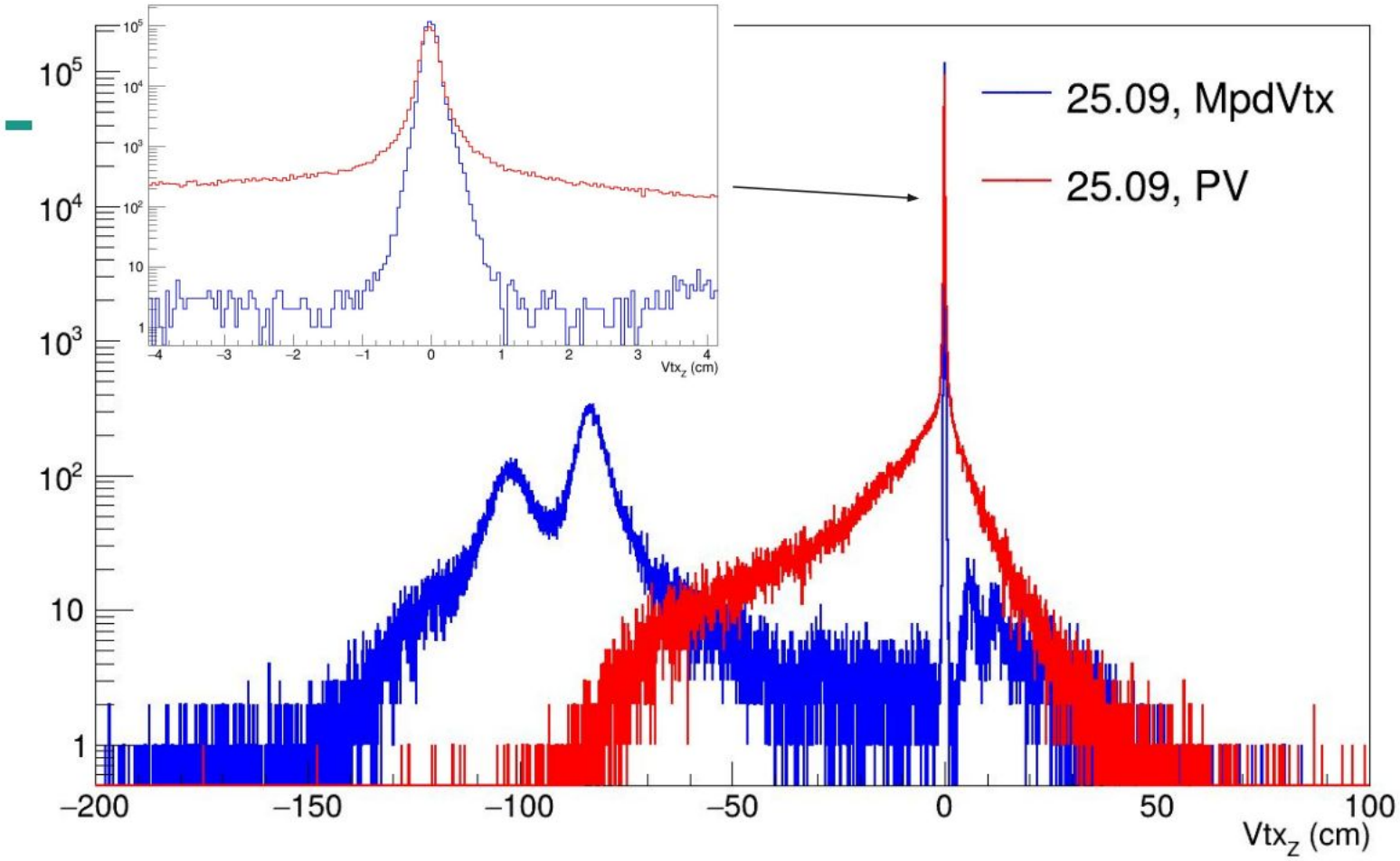






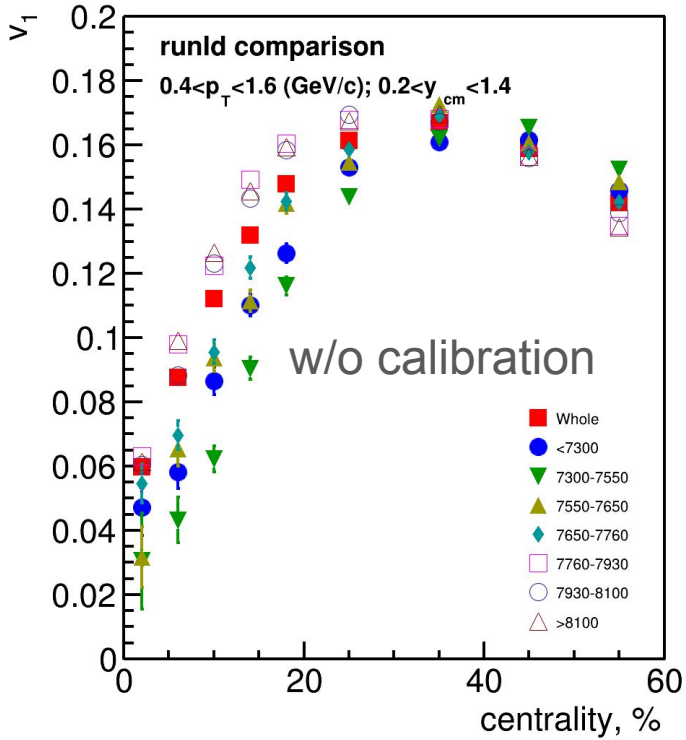


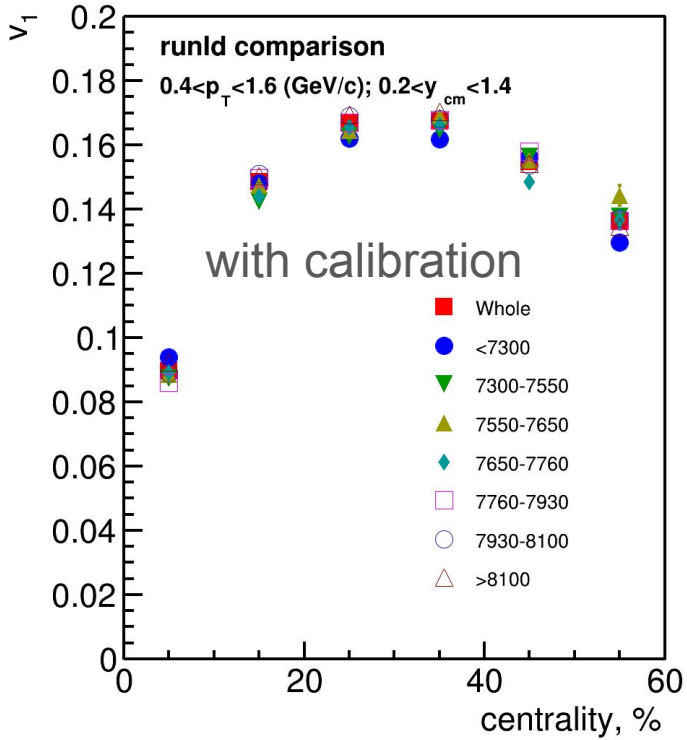
Outlook: Contribution from the off-target events



Outlook: centrality determination procedure

A.Demanov
V.Troshin





Large run-by-run variation of multiplicity leads to different ranges for the same centrality -> different v_1

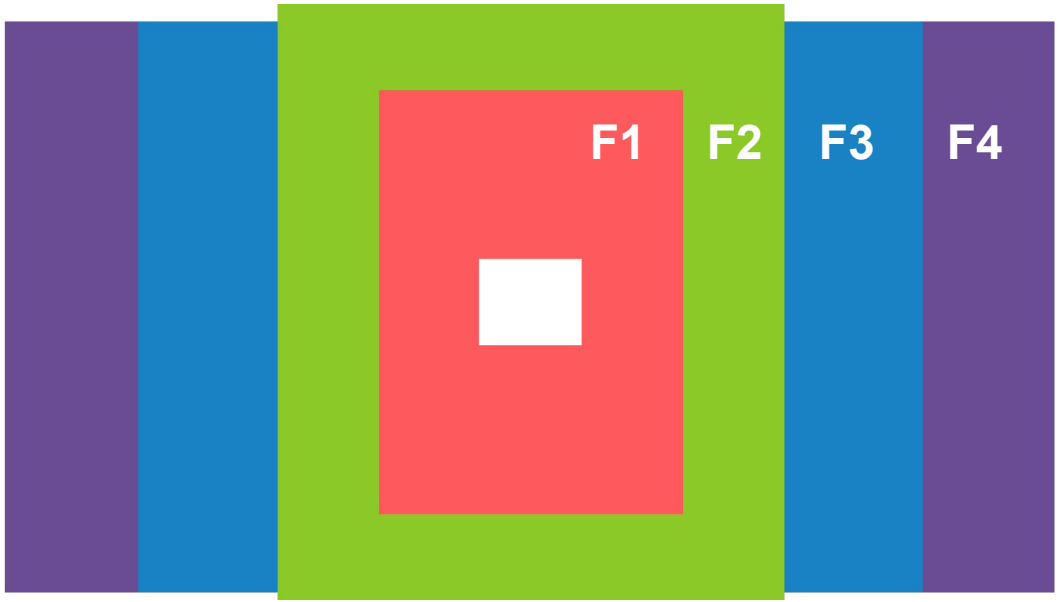
Plan towards the finalization of result on proton v_1

- Correcting the run-by-run effective acceptance variation — Done!
- PID with estimation of occupancy — Done!
- Excluding the imperfectly calibrated TOF strips — Work in progress
- Estimating the systematic uncertainty due to centrality estimation — Work in progress
- Comparison with the prediction of various theoretical models — Work in progress (in collab. with M.Kozhevnikova)
- Evaluating the contamination from off-target collisions — To be done

Thank you for your attention

Backup

Elliptic flow observables

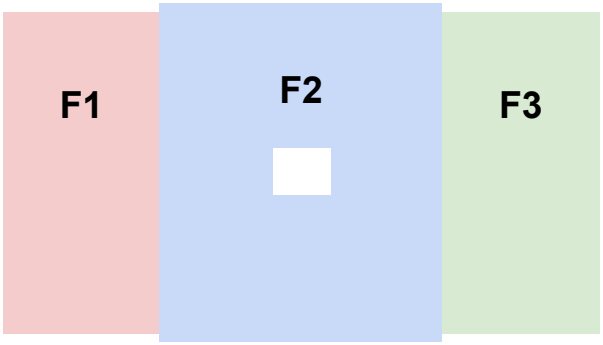


$$v_2 = \frac{\langle u_2 Q_1^a Q_1^b \rangle}{R_1^a R_1^b}$$

$$\langle x_2 X_1^a X_1^b \rangle \quad \langle y_2 X_1^a Y_1^b \rangle$$
$$\langle x_2 Y_1^a Y_1^b \rangle \quad \langle y_2 Y_1^a X_1^b \rangle$$

$$v_2 = 2\frac{\langle x_2 Y_1^a Y_1^b \rangle}{\langle Y_1^a Y_1^b \rangle}$$

Elliptic flow observables



$$v_2 = \frac{\langle u_2 Q_1^a Q_1^b \rangle}{R_1^a R_1^b}$$

$$\langle x_2 X_1^a X_1^b \rangle \quad \langle y_2 X_1^a Y_1^b \rangle$$
$$\langle x_2 Y_1^a Y_1^b \rangle \quad \langle y_2 Y_1^a X_1^b \rangle$$

In the case of azimuthal isotropy of detector acceptance and no magnetic field:

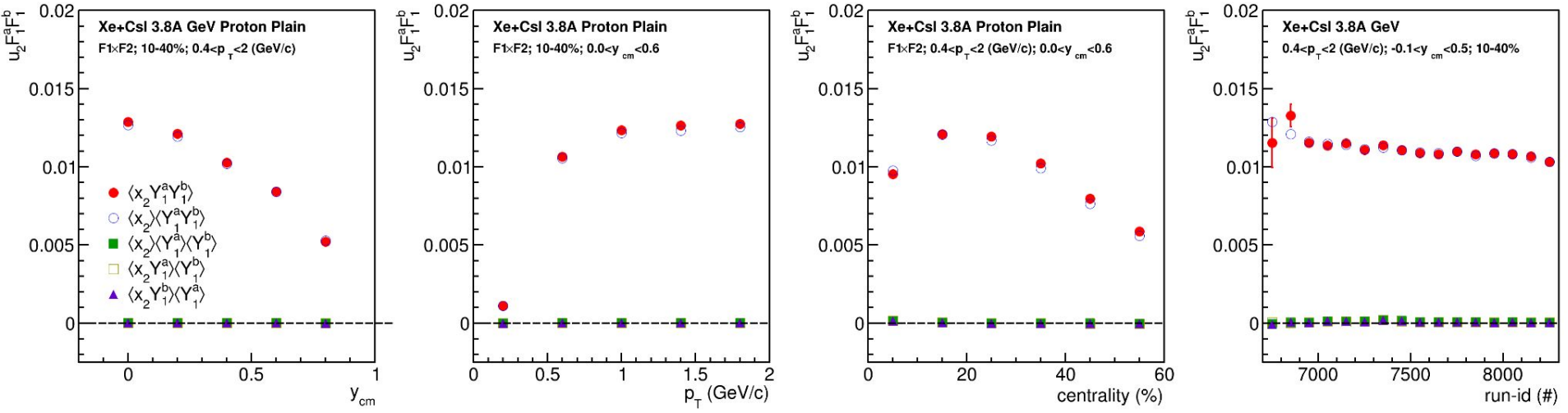
$$\langle x_2 \rangle = 0 \quad \langle Y_1 \rangle = 0$$

$$v_2 = 2\frac{\langle x_2 Y_1^a Y_1^b \rangle}{\langle Y_1^a Y_1^b \rangle}$$

v_2 is the resolution-corrected cumulant of u_2 and two Q_1-vectors

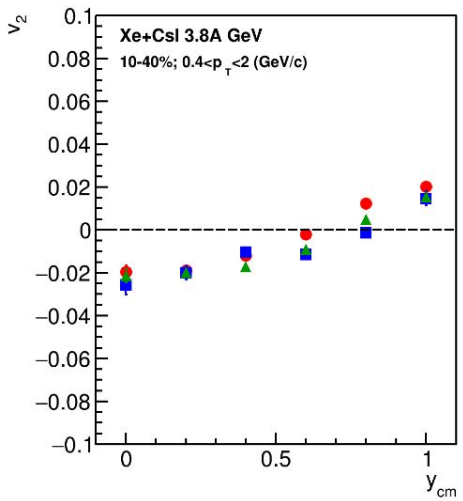
$$v_2 = 2\frac{\langle x_2 Y_1^a Y_1^b \rangle - \langle x_2 \rangle \langle Y_1^a Y_1^b \rangle}{\langle Y_1^a Y_1^b \rangle}$$

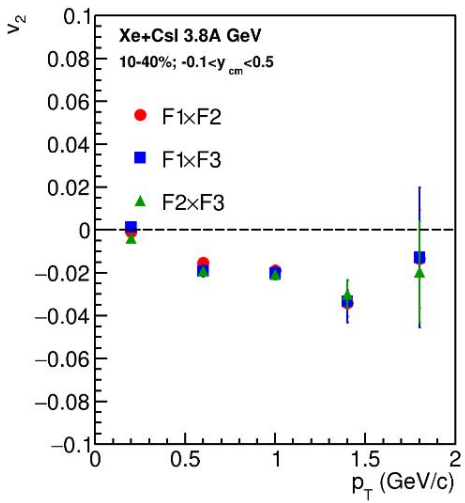
Correlation of proton u_2 with FHCal Q_1

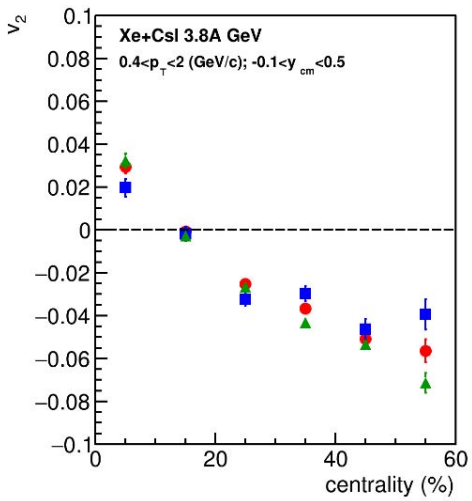


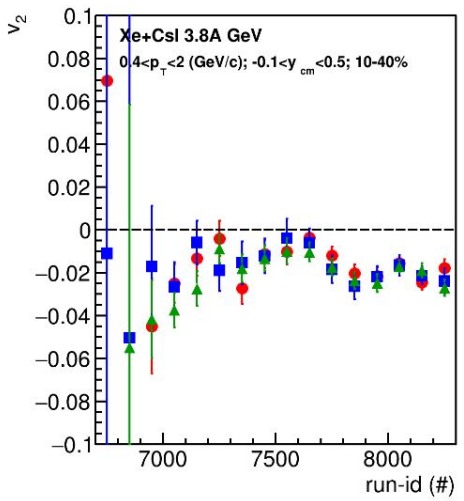
We observe high contribution from detector azimuthal non-uniformity: ellipticity of the acceptance with major axis along x-axis

v_2 as a function of y_{cm}, p_T, centrality and run-id



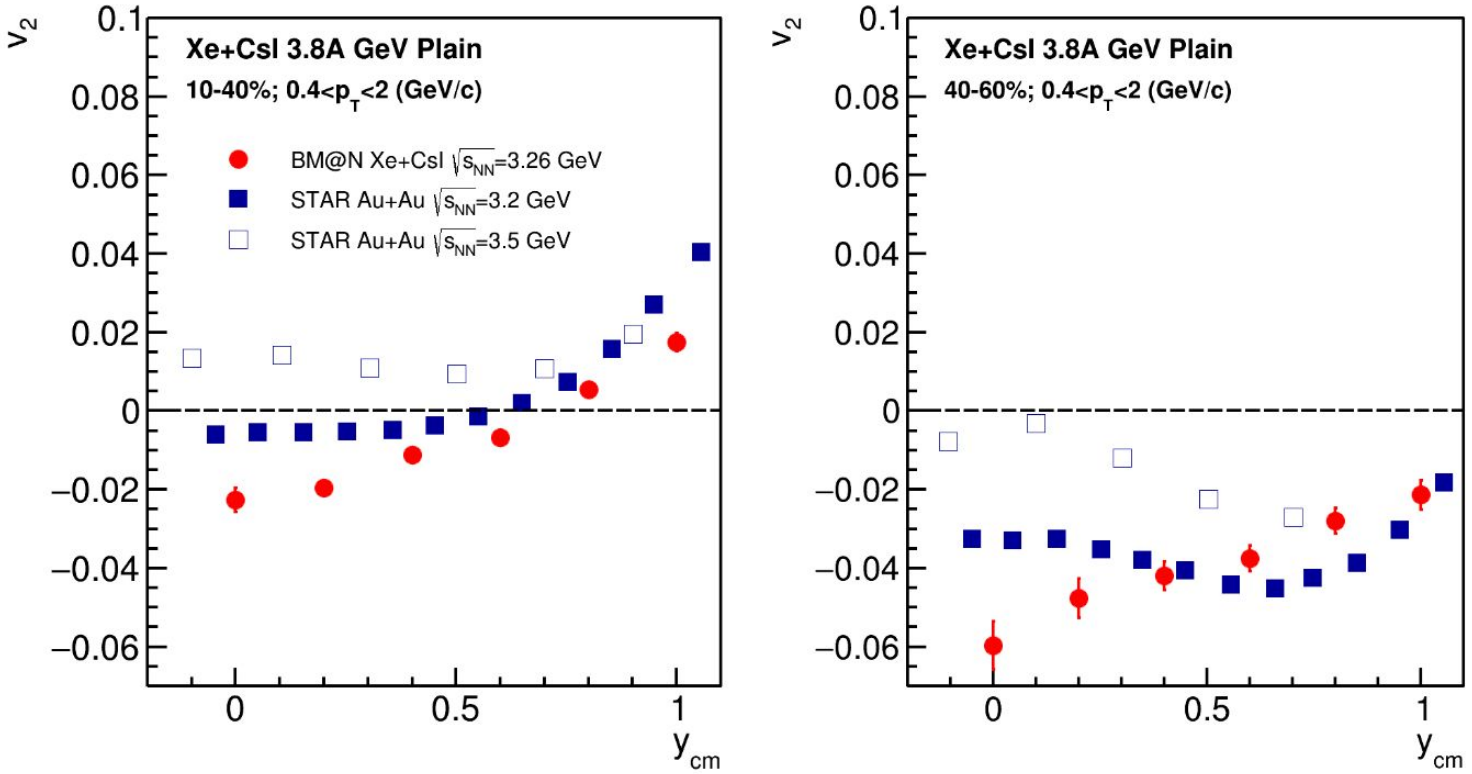






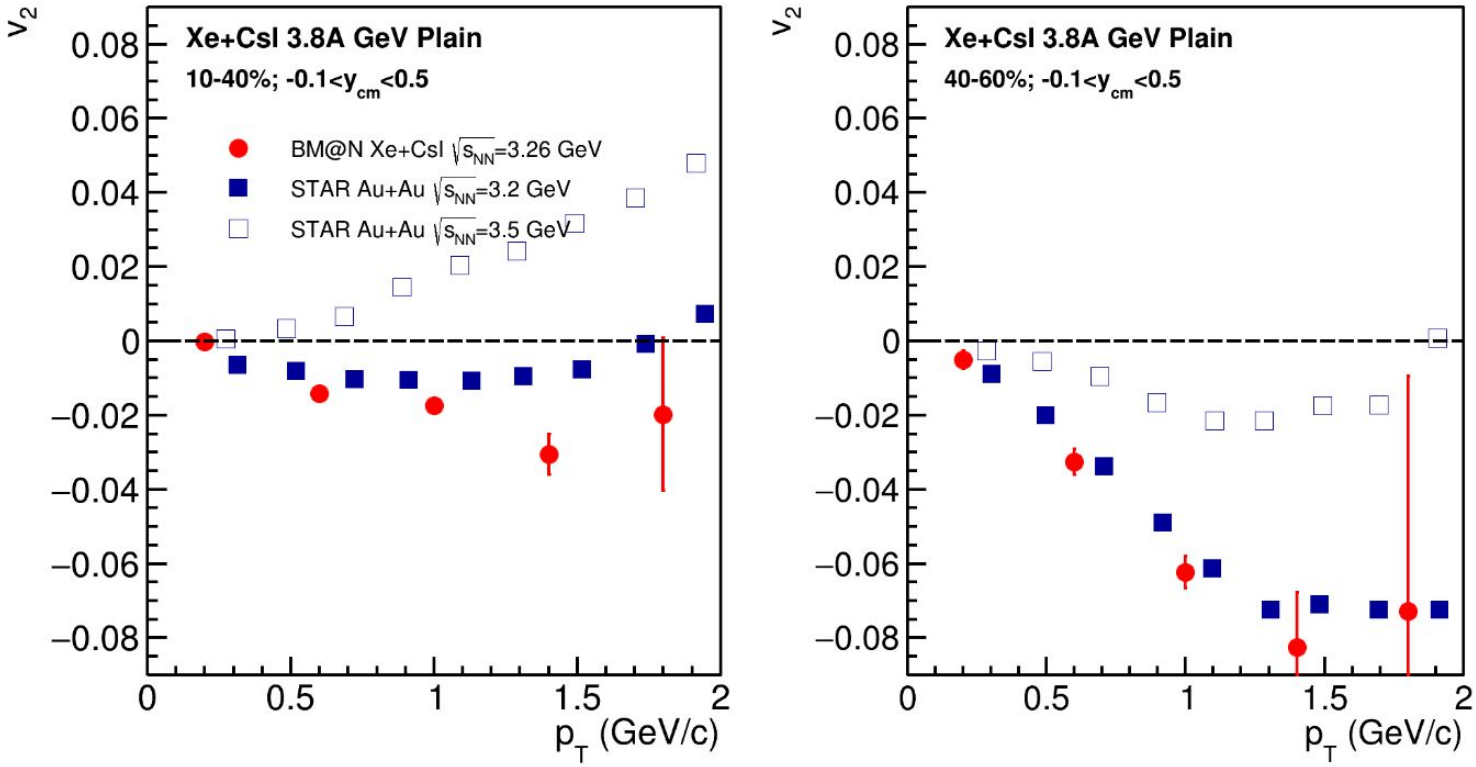
After extracting v_2 we see its dependence on run-id, additional investigations are needed

Comparison with STAR-FXT data: y-dependence



Roughly in agreement with STAR, although additional improvements to the measurement procedure are required

Comparison with STAR-FXT data: p_T-dependence



Roughly in agreement with STAR, although additional improvements to the measurement procedure are required

Preliminary results for proton v_1

Analysis Note

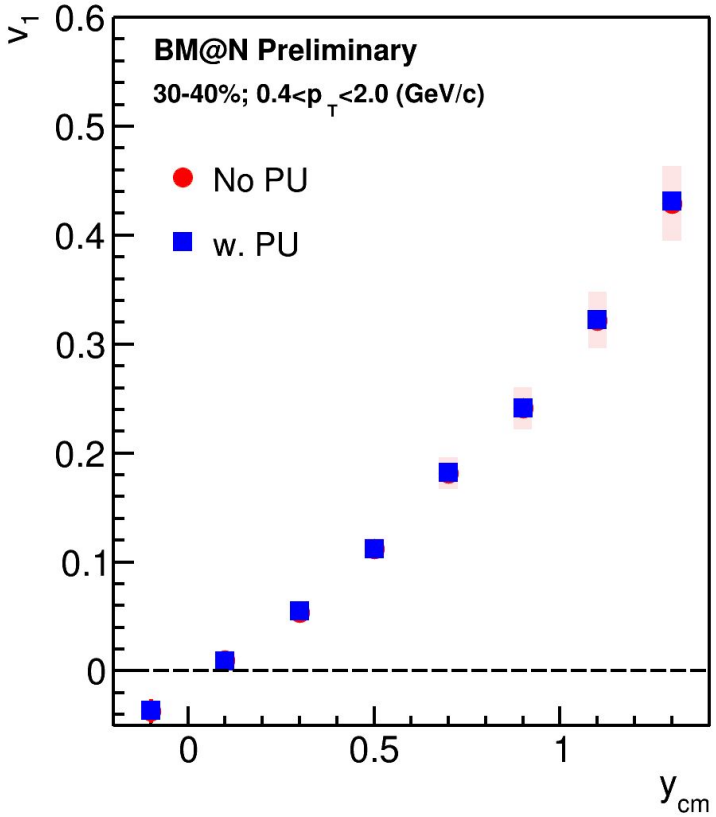
Directed flow v_1 of protons in the Xe+Cs(I) collisions at 3.8 AGeV (BM@N run8)

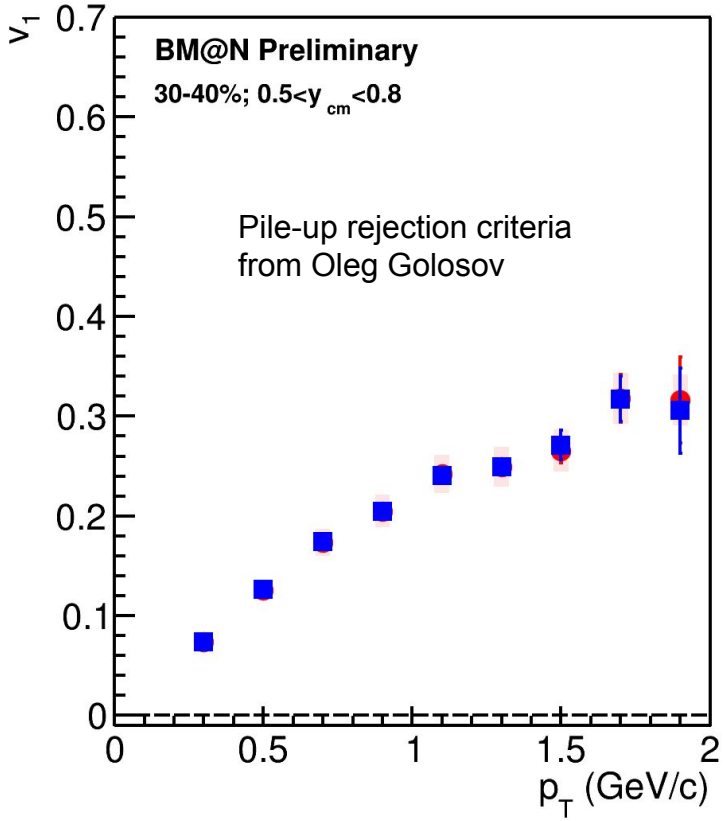
Mikhail Mamamev[1], Arkadiy Taranenko[2], Alexander Demanov, Petr Parfenov, Valery Troshin.
National Research Nuclear University MEPhI, Moscow, Russia
Joint Institute for Nuclear Research, Dubna, Russia
Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia

In this note, we present the directed flow v_1 measurements of protons from Xe+Cs(I) collisions at 3.8 AGeV (BM@N run8). We show the datasets, event and track selection cuts, centrality definition, event plane reconstruction and resolution. The v_1 results are presented as function of transverse momentum (p_T) and rapidity (y_{cm}) for 10-30% central Xe+Cs(I) collisions. The systematic uncertainty study will also be presented and discussed. The v_1 measurements are compared with results of JAM transport model calculations and published data from other experiments.

Analysis note: https://indico.jinr.ru/event/4750/attachments/19780/34163/ANoteFlowRun8.pdf

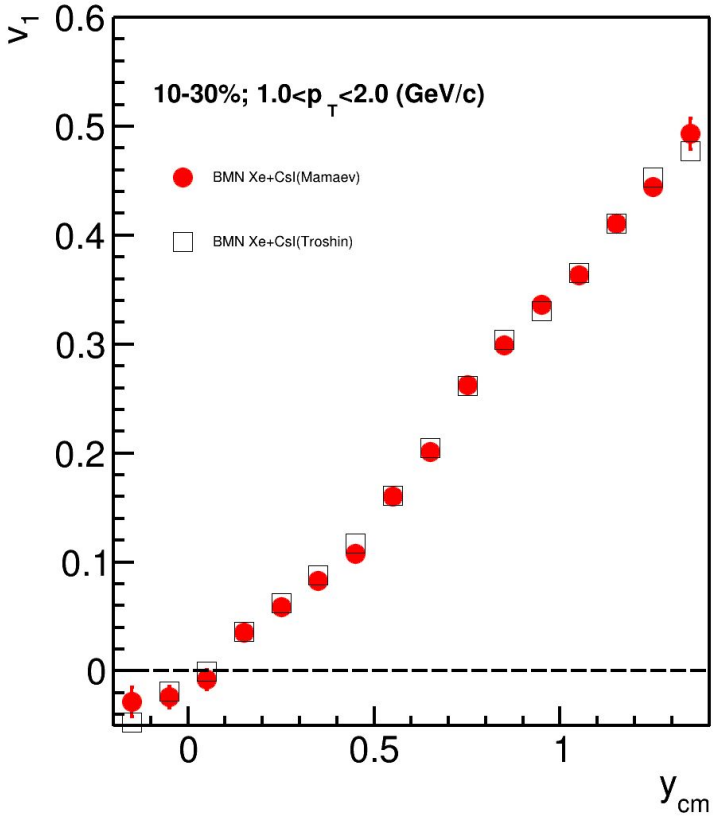
Contribution of the pile-up events to v_1 of protons

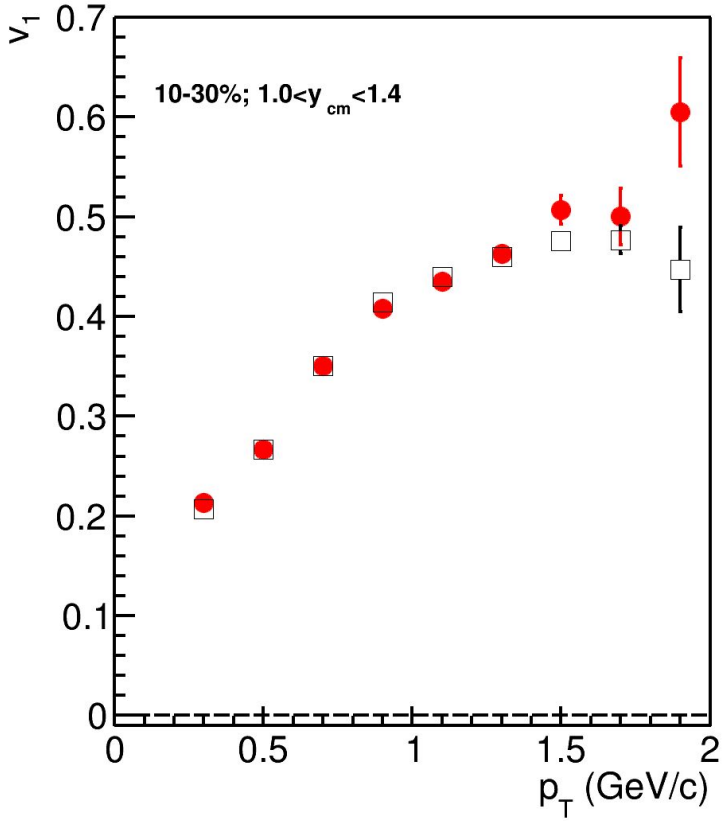




No significant contribution from pile-up was observed

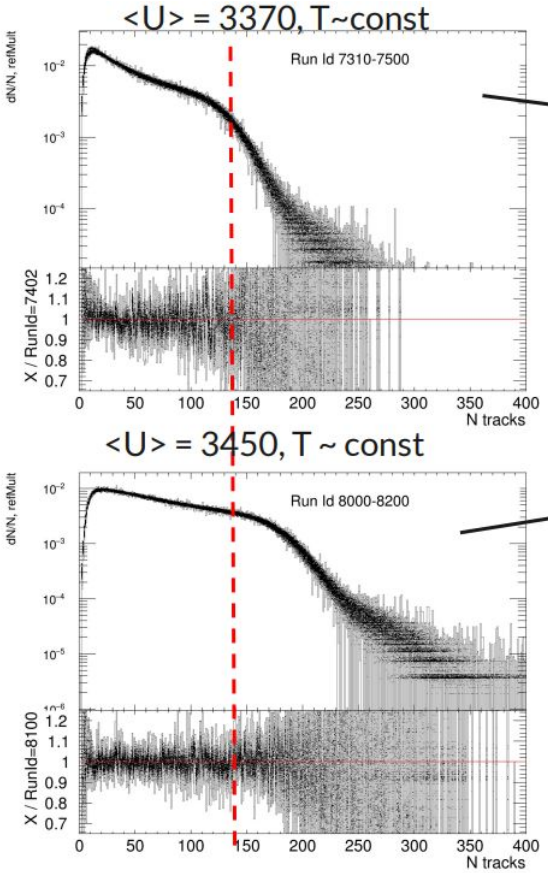
Updates on v_1 of protons



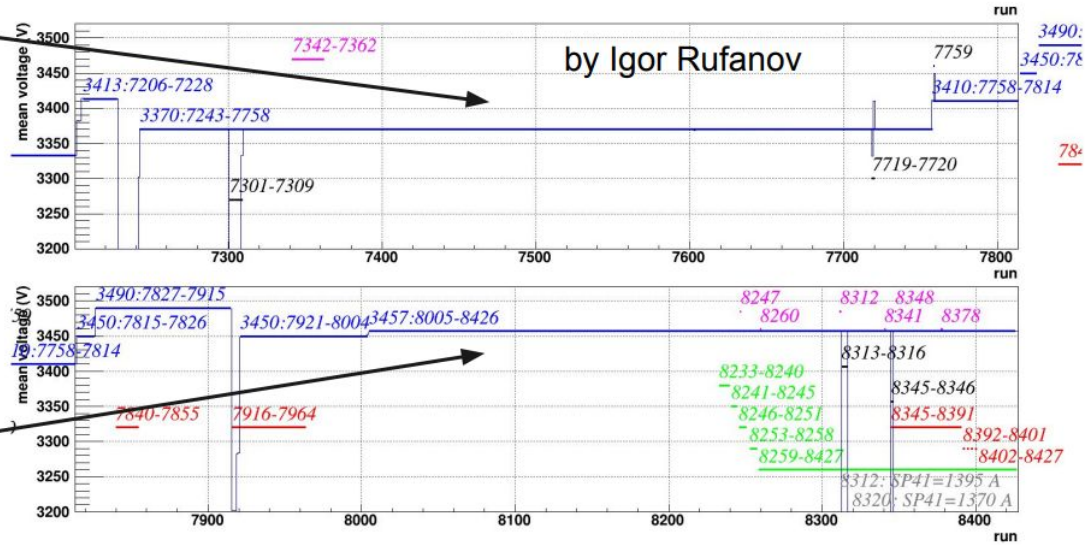


Valery Troshin independently reproduced the preliminary result

Run-ID-dependence of centrality estimation



By A.Demanov



Strong dependence of multiplicity on voltage.
Run-by-run corrections are required!

Run-by-run multiplicity calibration

By A.Demanov

RunId$_{ref}$: 8120-8170

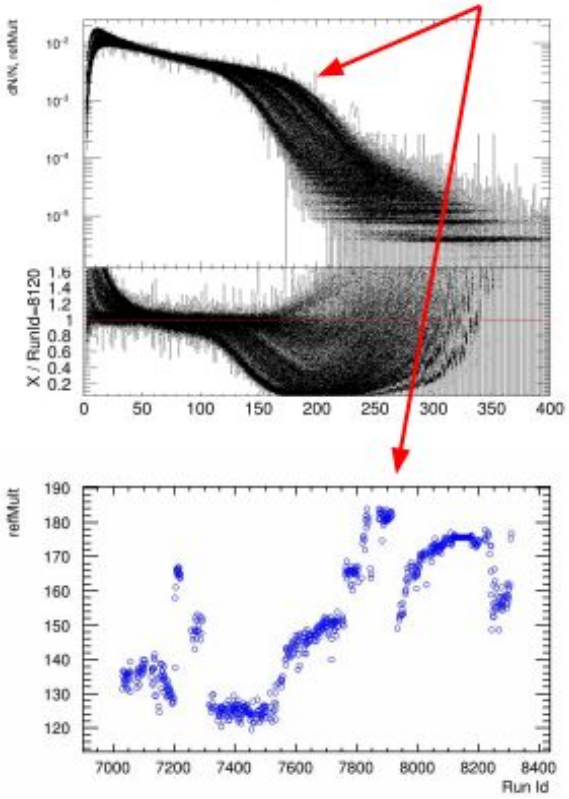
Extract the high-end point of refMult distribution in each RunId via fitting the refMult tail by the function:

f(refMult) = A*Erf(-σ*(refMult-h)) + A

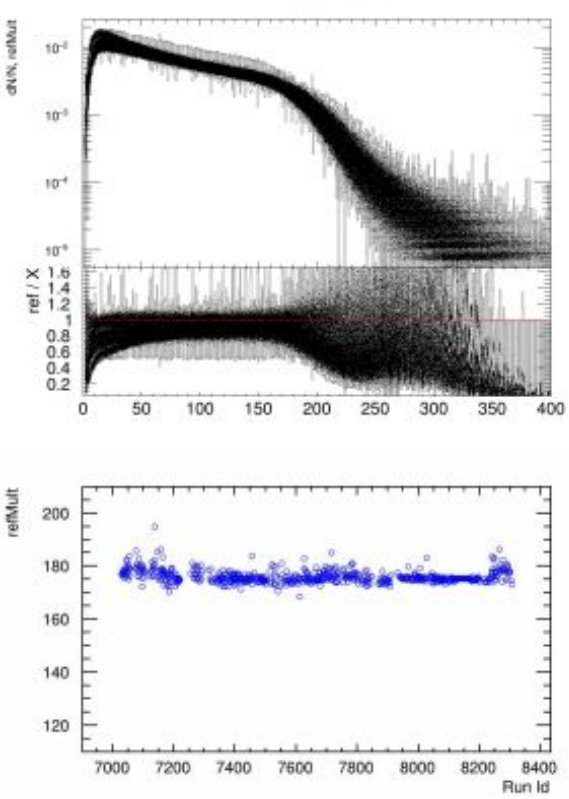
refMult can then be corrected by:

refMultCorr = refMult * h$_{ref}$ / h(RunId)

Def

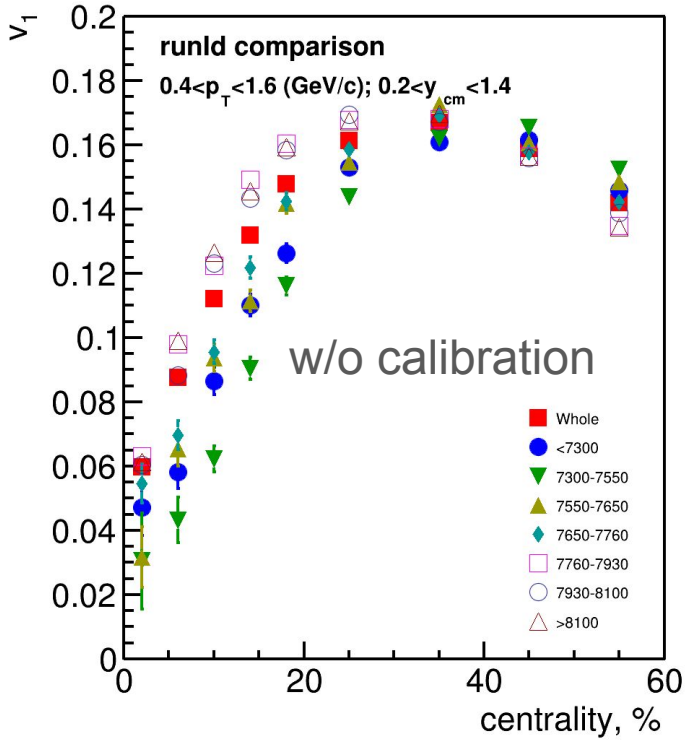


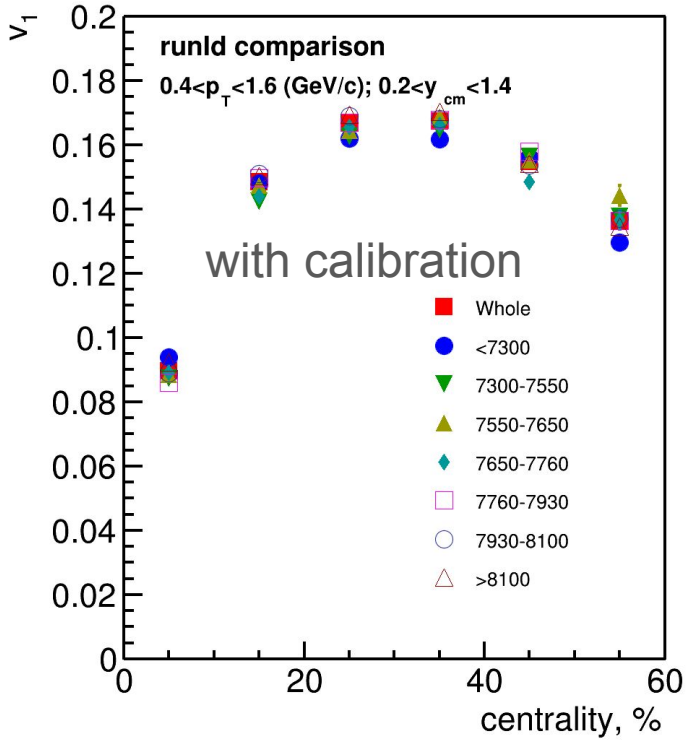
After shift



v_1 vs centrality for different RunId groups: 5 bins

A.Demanov
V.Troshin





Large run-by-run variation of multiplicity leads to different ranges for the same centrality -> different v_1

Outlook and summary

- Elliptic flow is measured in Xe+CsI collisions at 3.8A GeV
- Run-id dependence is observed, additional investigation is needed
- Rough agreement with STAR-FXT data
- No significant difference between preliminary results and new pile-up rejection is observed
- Preliminary result for v_1 of protons is independently reproduced by V.Troshin
- Centrality estimation procedure is being refined.

Backup

Proton v_2 vs deuteron v_2

