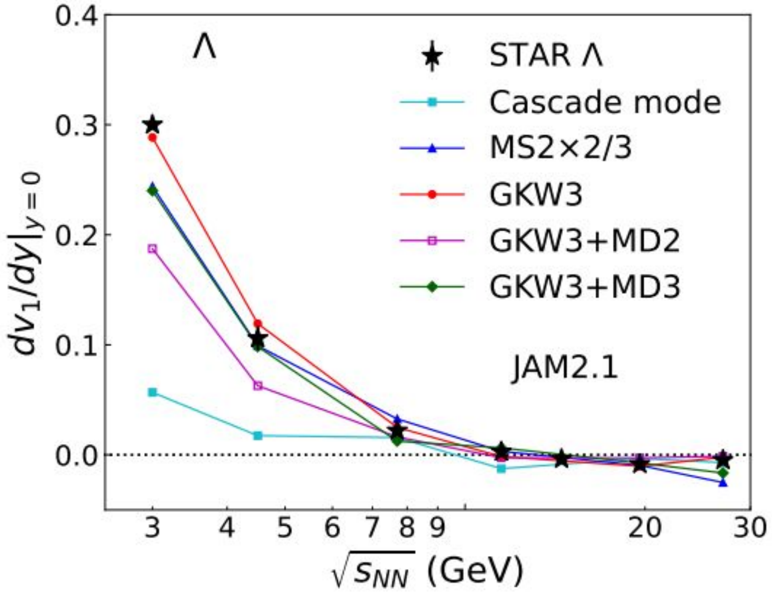
Λ reconstruction and directed flow measurements for BM@N Run8

V. Troshin, M. Mamaev, P. Parfenov, A. Taranenko

Motivation



Yasushi Nara et al. *EPJ Web Conf.* 276 (2023) 01021
Yasushi Nara et al. *EPJ Web Conf.* 271 (2022) 08006
Yasushi Nara et al. *Phys.Rev.C* 106 (2022) 4, 044902

Strong repulsive Λ potential U_Λ that is predicted by Λ chiral effective field theory(**χ**EFT) may explain the existence of two-solar-mass neutron stars by suppressing Λ in dense nuclear matter by Λ-N-N three-body interactions, and directed flow of Λ is expected to constrain U_Λ.

The picture shows the dv_1/dy slope of Λ for different potentials and comparison with STAR data. MD2 and MD3 is a different momentum dependences for U_Λ, GKW3 denotes a three-body interactions of Λ. It is shown that three-body interactions in JAM model with mean-field mode gives the best agreement with STAR data, especially for lower energy.

Anisotropic transverse flow

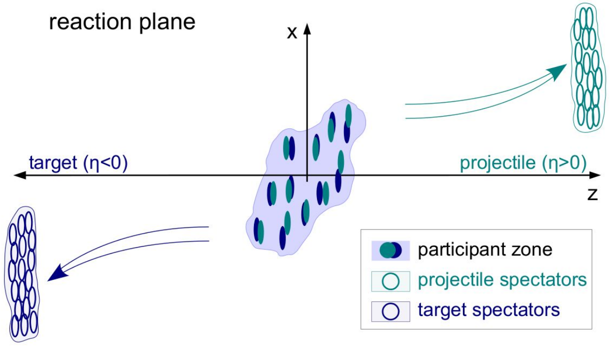
Spatial asymmetry of energy distribution at the initial state is transformed, through the strong interaction, into momentum anisotropy of the produced particles.

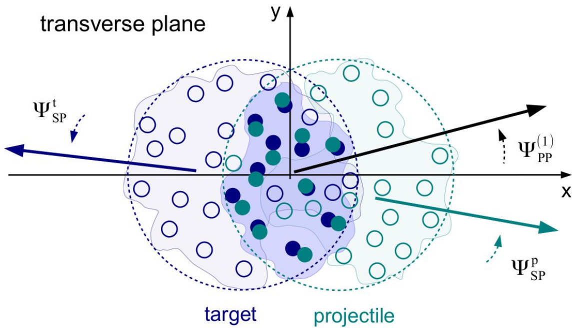
$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_{RP}))\right)$$

$$\Downarrow$$

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

In the experiment reaction plane angle Ψ_{RP} can be approximated by participant Ψ_{PP} or spectator Ψ_{SP} symmetry planes.

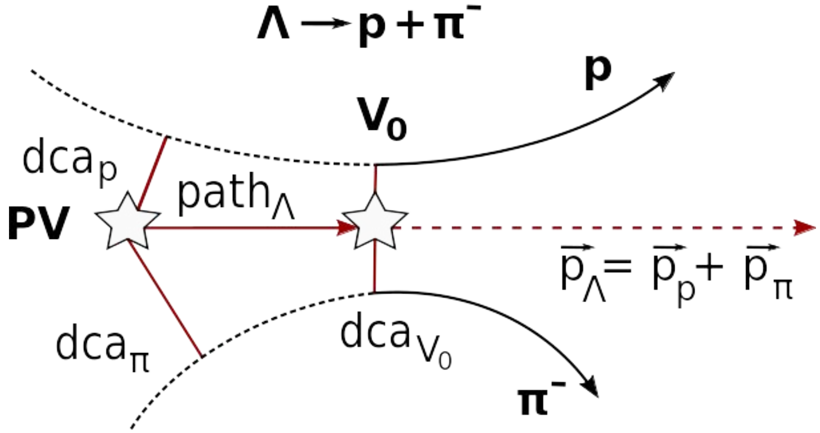




Λ hyperon reconstruction and directed flow measurements

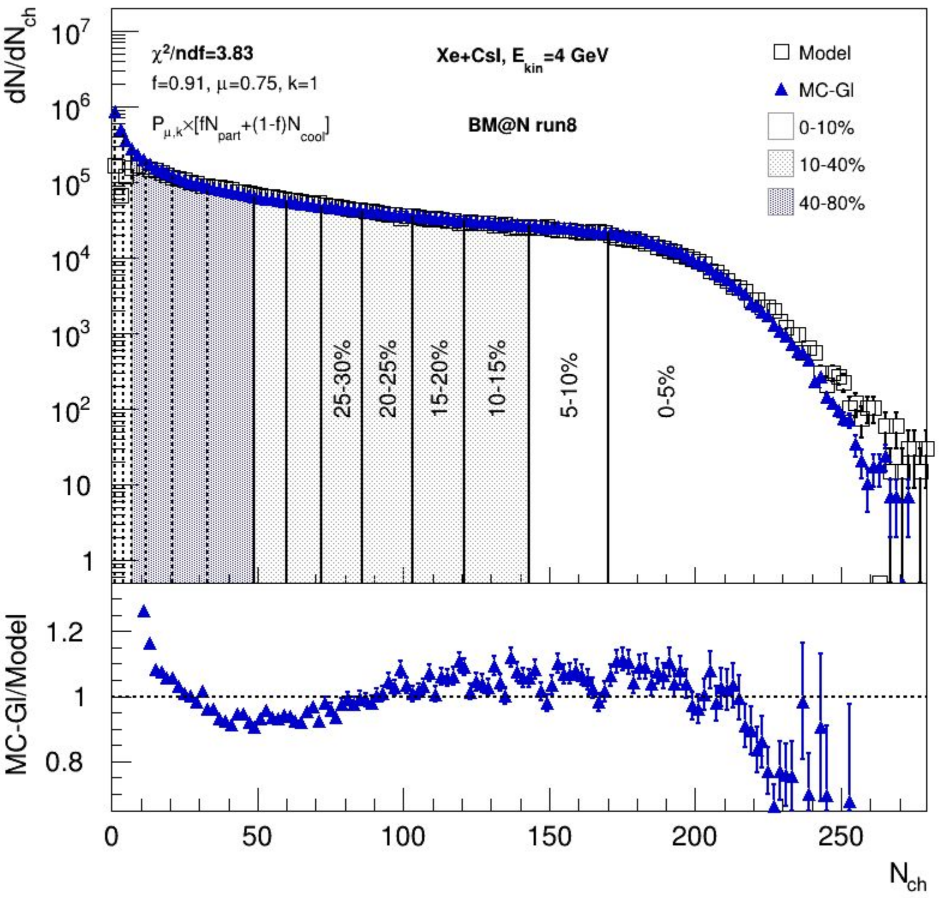
1. Centrality and track selection
2. Build Λ - positive charges as p, negative charges as π^-
3. Selection with Particle Finder software
4. Fitting the m_{inv} distributions
5. Obtain R_1
6. Fitting v_1 as a function of m_{inv}

$$v_1^{SB}(m_{inv}, p_T) = v_1^S(p_T)\frac{N^S(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_1^B(m_{inv}, p_T)\frac{N^B(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$



- PV — primary vertex
- V_0 — vertex of hyperon decay
- dca — distance of closest approach
- path — decay length

Centrality and track selection



- Entire of the recent VF production was analysed
- Event selection criteria:
  - CCT2 trigger
  - Pile-up cut
  - Number tracks for vertex > 1
- Track selection criteria : χ^2/ndf >0.5 ; Nhits > 5

Cut's dictionary

χ^2 prim(1;2)	dca	L	L/dL	χ^2geo	χ^2topo	cos_topo
χ^2 of daughter particle to primary vertex	Distance between daughter tracks in their closest approach	Length of interpolated track from secondary to primary vertex	Distance between primary and secondary vertices divided by error	χ^2 of daughters' tracks in their closest approach	$\chi^2$of the mother's track to the primary vertex	Cosine of the angle between reconstructed mother's momentum and mother's radius vector beginning in the primary vertex
χ^2(p)>10 χ^2(pi)>200	dca<0.7 cm	L>1 cm	L/dL>6	χ^2geo <30	χ^2topo <40	cos_topo>0.999

Flow vectors

From momentum of each measured particle define a u_n-vector in transverse plane:

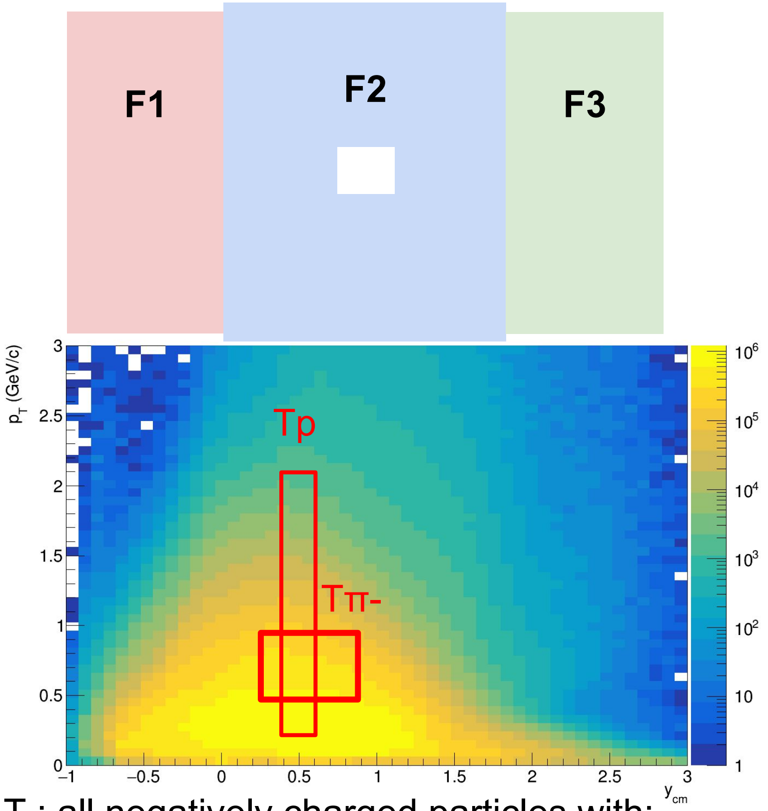
$$u_n = e^{in\phi}$$

where φ is the azimuthal angle

Sum over a group of u_n-vectors in one event forms Q_n-vector:

$$Q_n = \frac{\sum_{k=1}^{N} w_n^k u_n^k}{\sum_{k=1}^{N} w_n^k} = |Q_n| e^{in\Psi_n^{EP}}$$

Ψ_n^{EP} is the event plane angle



T-: all negatively charged particles with:

- $1.5 < \eta < 4$
- $p_T > 0.2$ GeV/c

T+: all positively charged particles with:

- $2.0 < \eta < 3$
- $p_T > 0.2$ GeV/c

Flow methods for v_n calculation

Tested in HADES:

M Mamaev et al 2020 PPNuclei 53, 277–281
M Mamaev et al 2020 J. Phys.: Conf. Ser. 1690 012122

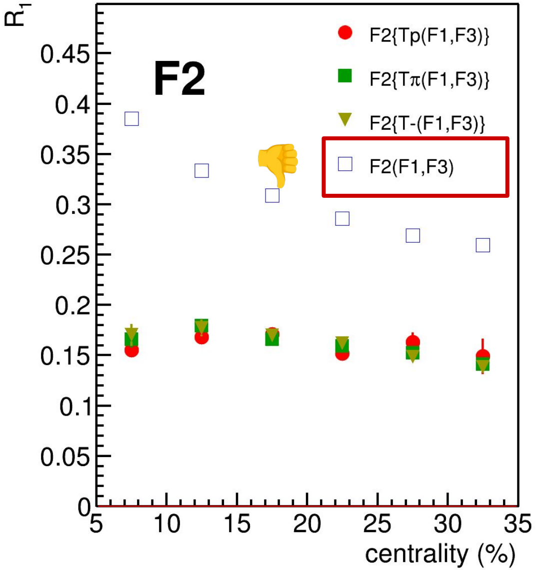
Scalar product (SP) method:

$$v_1 = \frac{\langle u_1 Q_1^{F1} \rangle}{R_1^{F1}} \qquad v_2 = \frac{\langle u_2 Q_1^{F1} Q_1^{F3} \rangle}{R_1^{F1} R_1^{F3}}$$

Where R_1 is the resolution correction factor

$$R_1^{F1} = \langle \cos(\Psi_1^{F1} - \Psi_1^{RP}) \rangle$$

Method helps to eliminate non-flow
Using 2-subevents doesn't



Symbol "F2(F1,F3)" means R_1 calculated via (3S resolution):

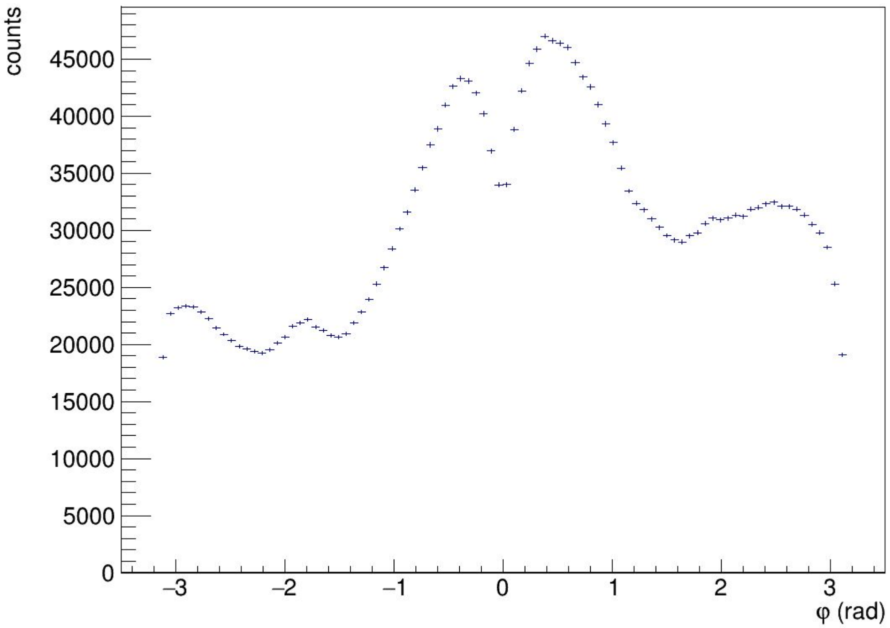
$$R_1^{F2(F1,F3)} = \frac{\sqrt{\langle Q_1^{F2} Q_1^{F1} \rangle \langle Q_1^{F2} Q_1^{F3} \rangle}}{\sqrt{\langle Q_1^{F1} Q_1^{F3} \rangle}}$$

Symbol "F2{Tp}(F1,F3)" means R_1 calculated via (4S resolution):

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

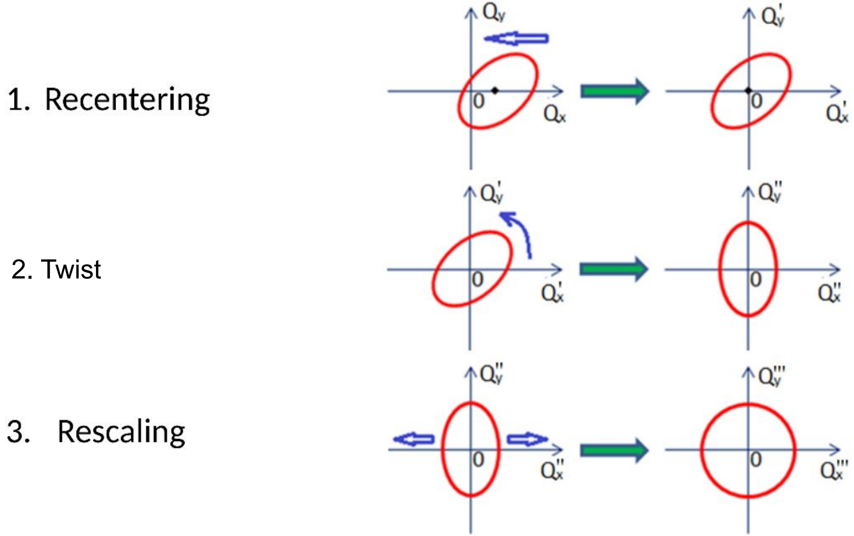
Azimuthal asymmetry of the BM@N acceptance

φ yield of Λ candidates

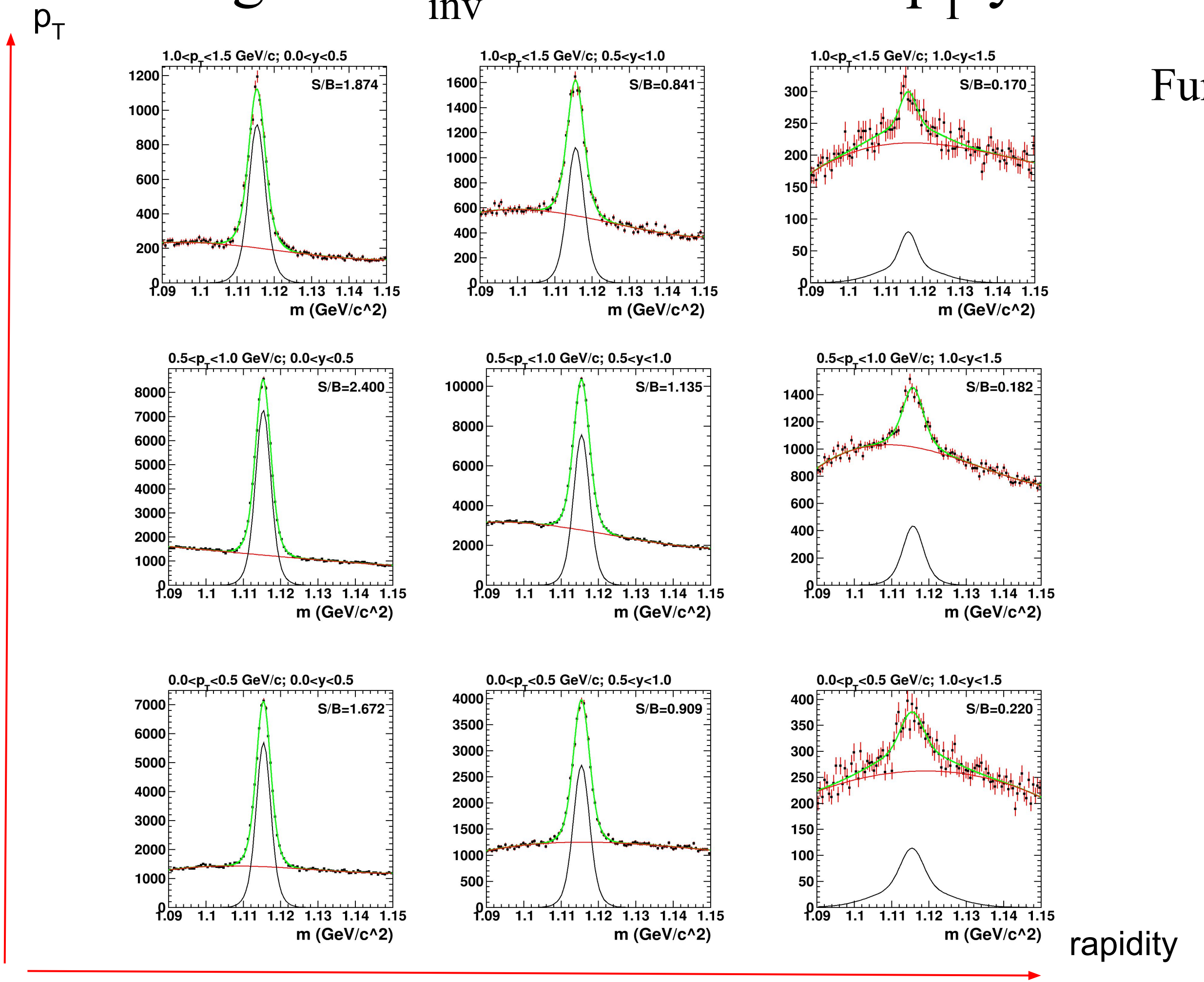


Non-uniform acceptance - corrections are required

Corrections are based on method in:
I. Selyuzhenkov and S. Voloshin PRC77, 034904 (2008)

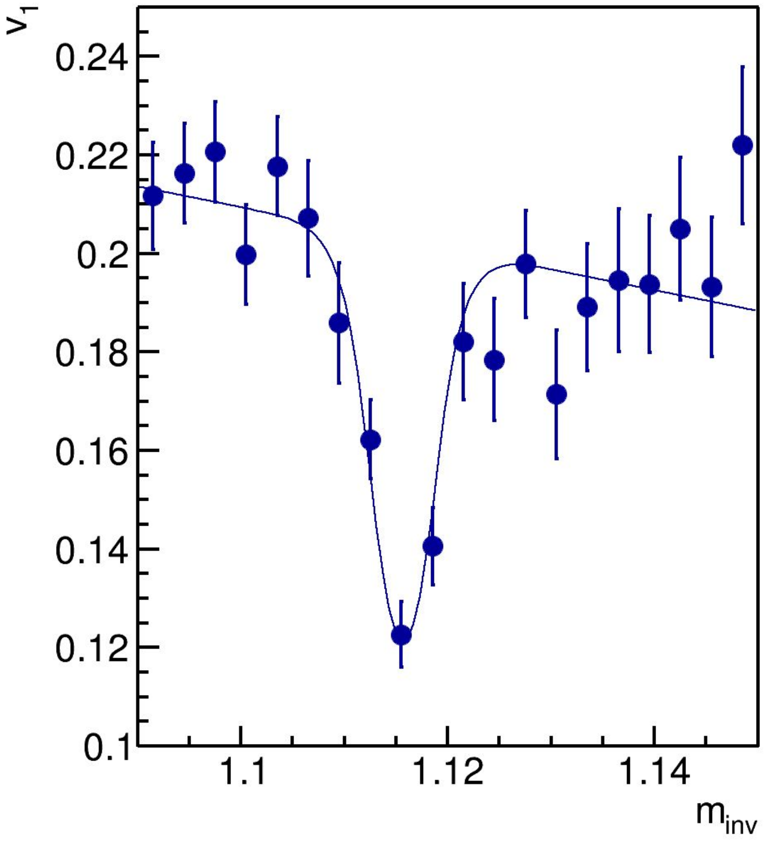


Fitting the m_{inv} distributions in p_T-y bins



Func: 2 gauss + pol5

Fitting the m_{inv} distributions of v_1

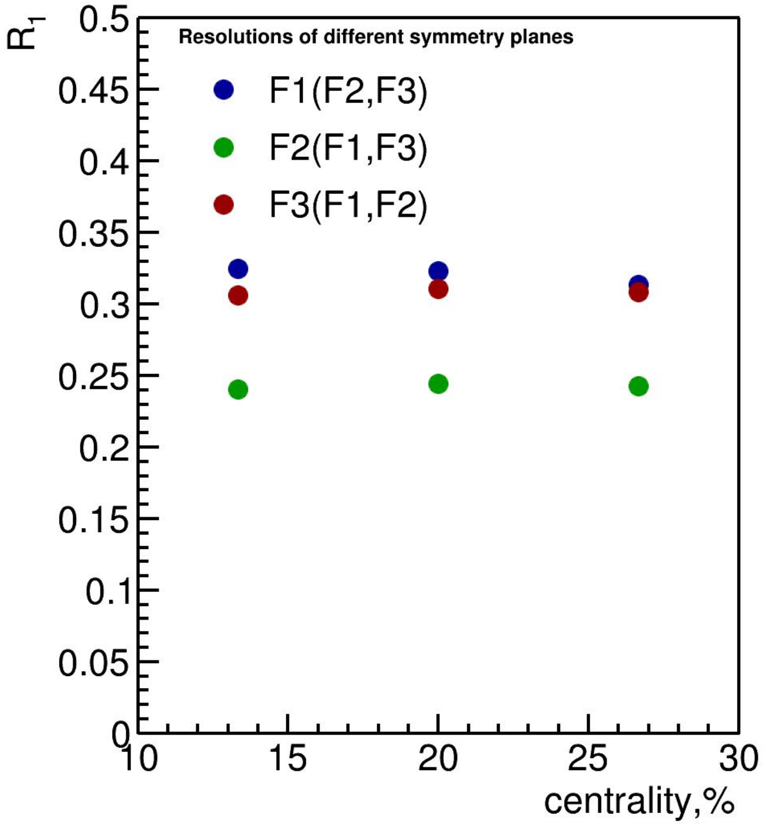


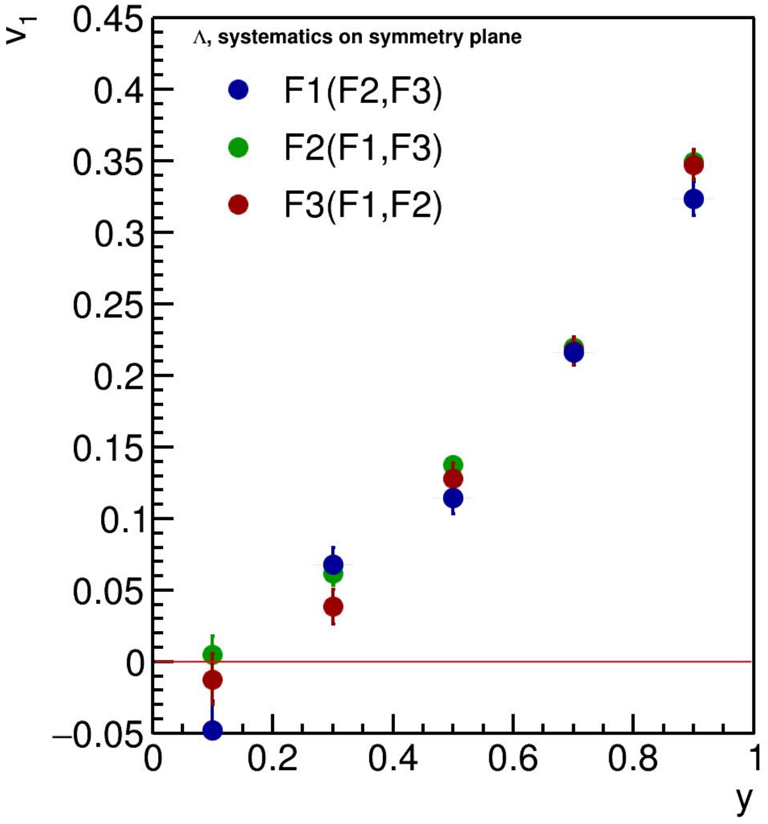
$$v_1^{SB}(m_{inv},p_T) = v_1^S(p_T)\frac{N^S(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_1^B(m_{inv},p_T)\frac{N^B(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$

v_1^S - have to find
v_1^B - pol1

centrality: 10-30%
p_T 0.5-1 GeV/c
y_{CM} 0.4-0.6

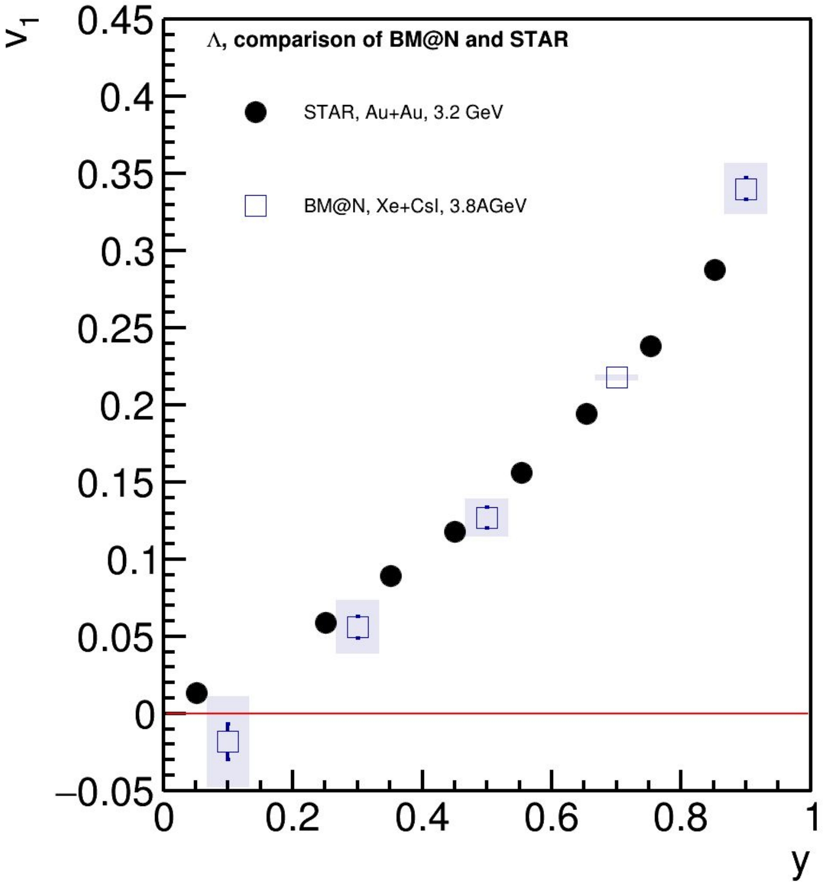
Symmetry plane resolution and systematics





All the estimations for symmetry plane resolutions are in a good agreement

$v_1(y)$ of Λ, 10-30%, $0.4<p_T<2$ GeV/c



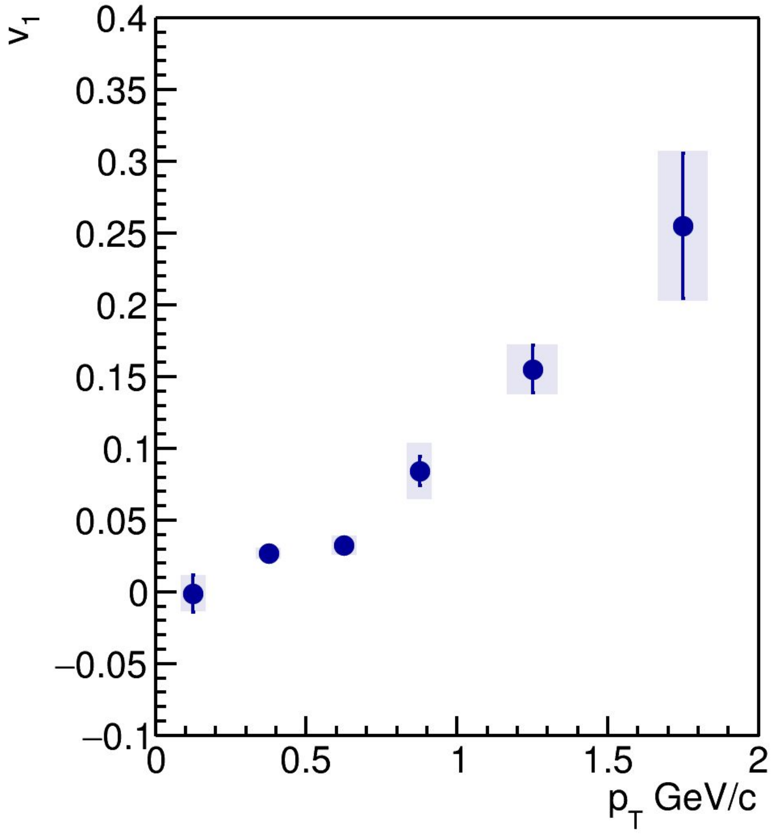
Good agreement for first "raw" results

TO DO:

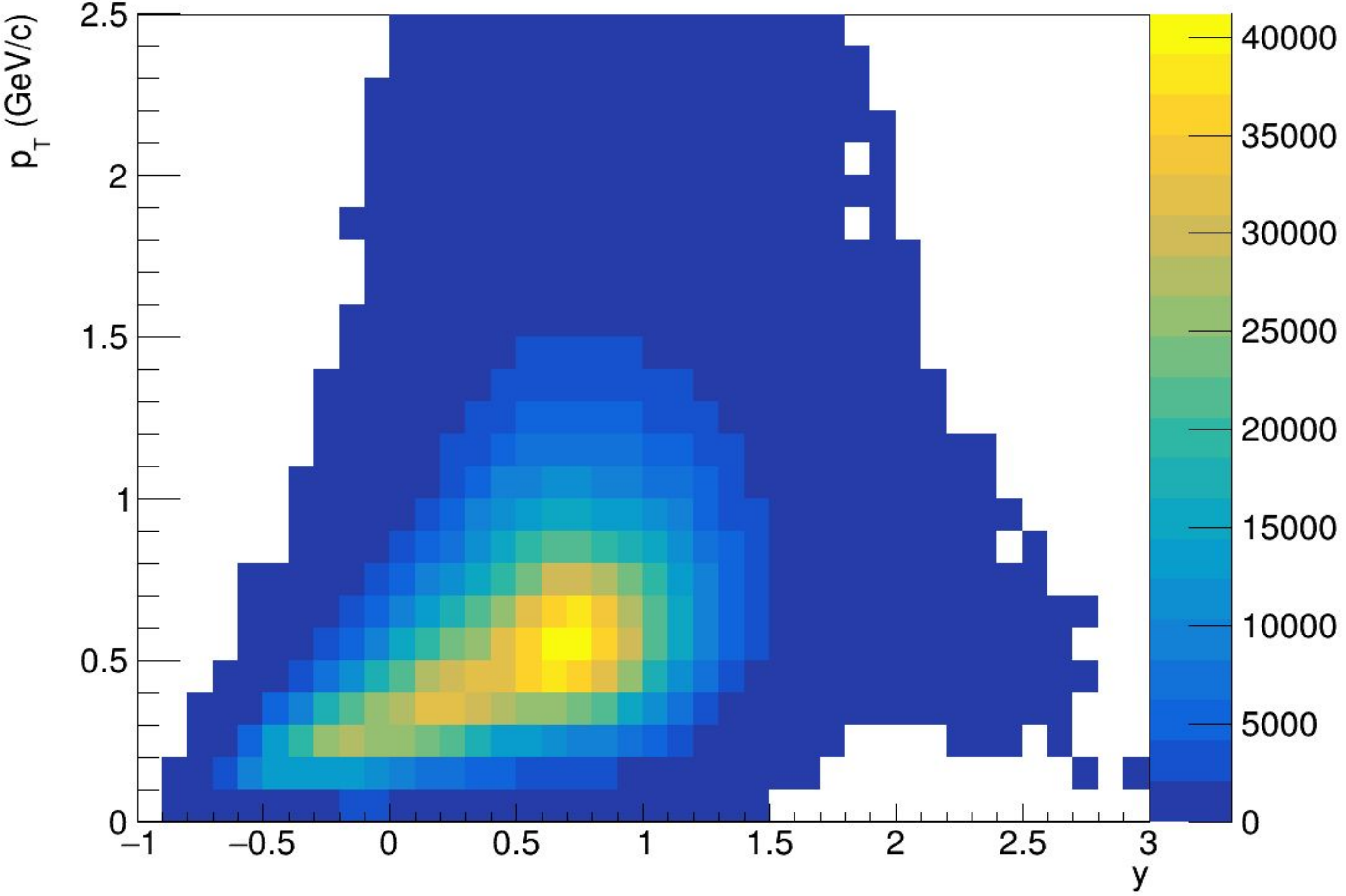
1. An increase of number of bins
2. Calculate the efficiency
3. Study of run-by-run dependences of selection criteria
4. Analysis of systematics
5. ...

BACKUP

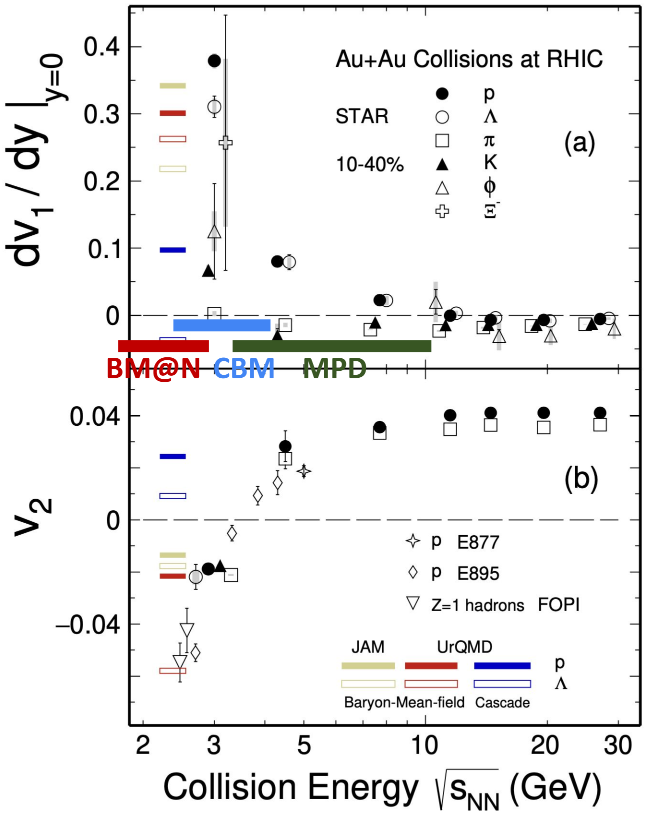
$v_1(p_T)$ of Λ



p_T-y distribution of Λ candidates



Anisotropic transverse flow in heavy-ion collisions at Nuclotron-NICA energies



Strong energy dependence of dv_1/dy and v_2 at $\sqrt{s_{NN}}$ =2-11 GeV.

Anisotropic flow at FAIR/NICA energies is a delicate balance between:

- The ability of pressure developed early in the reaction zone
- Long passage time (strong shadowing by spectators).

Differential flow measurements $v_n(\sqrt{s_{NN}}$, centrality, pid, p_T, y) will help to study:

- effects of collective (radial) expansion on anisotropic flow
- interaction between collision spectators and produced matter
- baryon number transport

M. Abdallah et al. [STAR Collaboration] 2108.00908 [nucl-ex]