Directed flow of Λ hyperons in Xe+Cs(I) collisions at 3.8 AGeV in the BM@N experiment

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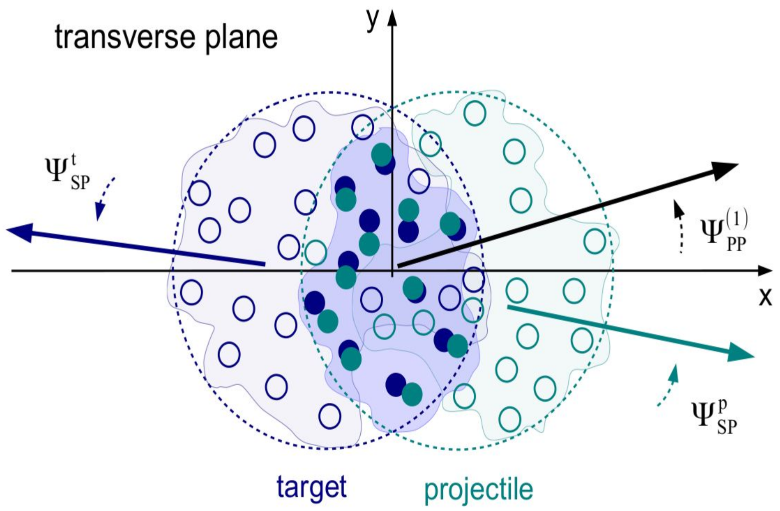
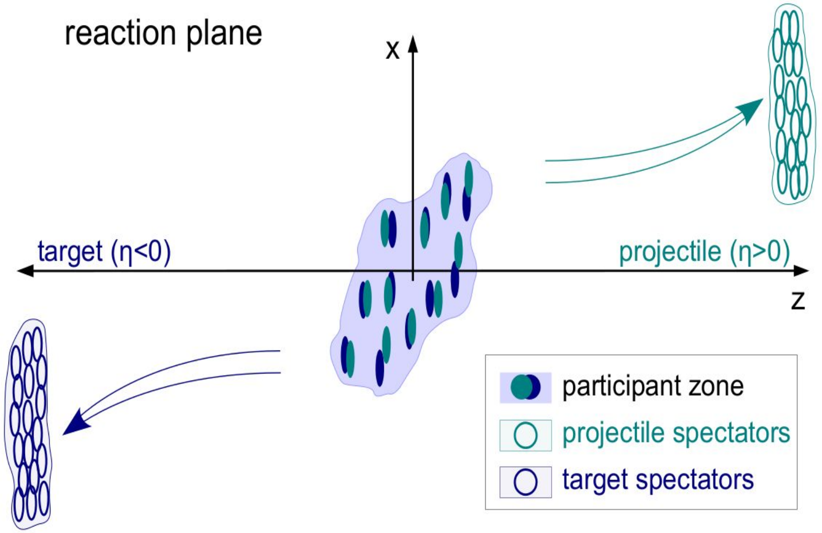
Outline

- Motivation
- BM@N setup and analysis methods
- Performance study with JAM model
- Results
- Summary and Outlook

Anisotropic transverse flow



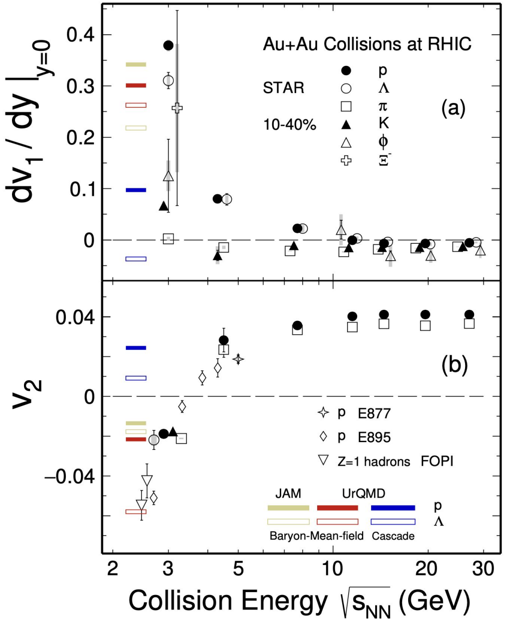


$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_{RP}))\right)$$

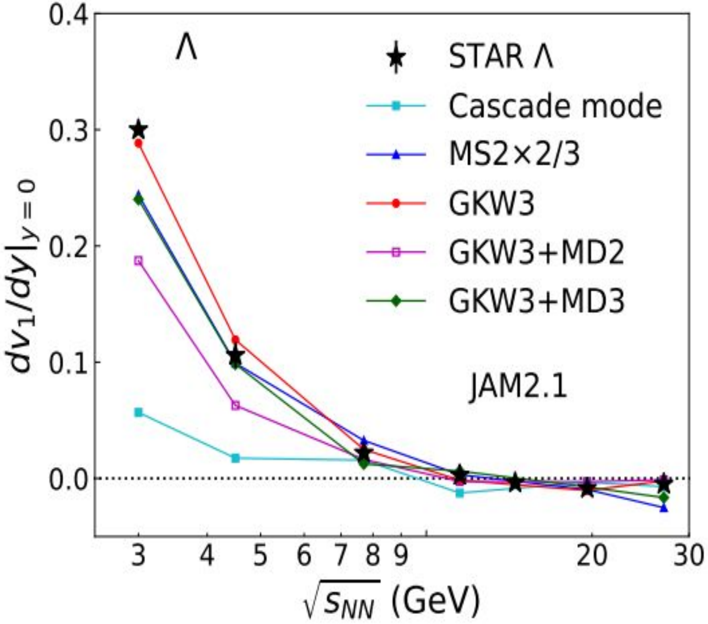
$$v_n = \langle \cos(n(\phi - \Psi_{RP})) \rangle$$

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

Study at Nuclotron-NICA energies



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



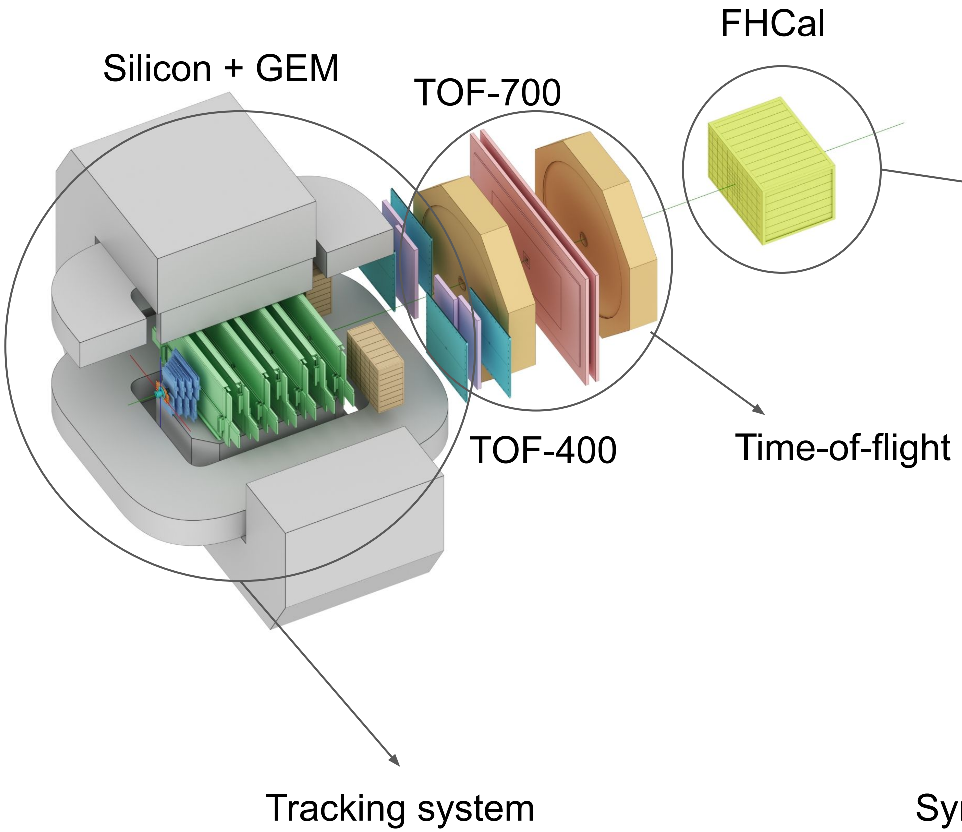
Yasushi Nara et al. *Phys.Rev.C* 106 (2022) 4, 044902

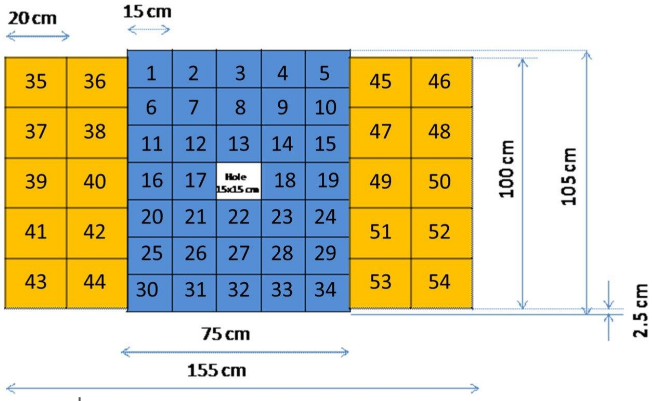
Strong energy dependence of dv_1/dy and v_2 at SN$\sqrt{s_{NN}}$-11 GeV.
Anisotropic flow at FAIR/NICA energies is a delicate balance between:

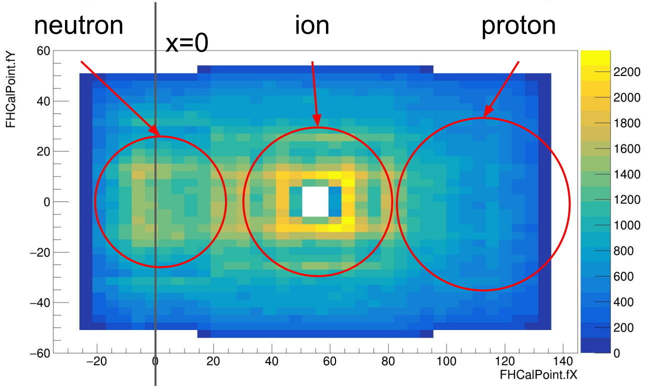
- The ability of pressure developed early in the reaction zone
- Long passage time (strong shadowing by spectators)

- Λ potential is important to explanation of existence
- of two-solar-mass neutron stars
- Constrained by v_1
- Best agreement with model includes interactions with hyperons

The BM@N experiment: recent Xe+Cs(I) 3.8 AGeV run





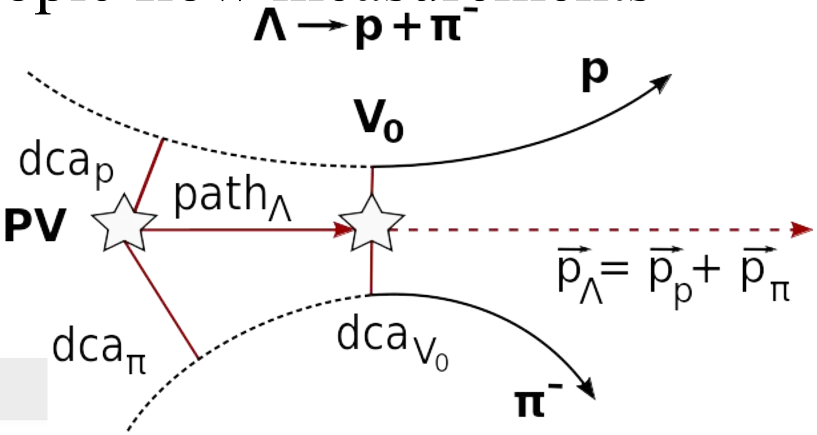


Symmetry plane estimation with the azimuthal asymmetry of projectile spector energy

Λ hyperon reconstruction and anisotropic flow measurements

1. Centrality determination and track selection
2. Building Λ with p π^- pairs
3. Applying topological selection cuts
4. Fitting the m_{inv} distributions and $v_n(m_{inv})$

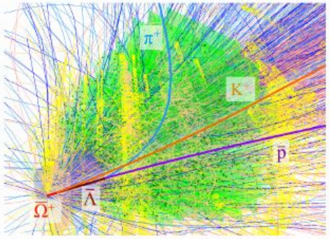
$$v_n^{SB}(m_{inv}, p_T) = v_n^S(p_T)\frac{N^S(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_n^B(m_{inv}, p_T)\frac{N^B(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$



KFParticle formalism

Particles in heavy-ion collision:

STAR ALICE CBM



KFParticle:

- developed for complete reconstruction of short-lived particles with their P, E, m, $c\tau$, L, Y

Main benefits:

- based on the Kalman filter mathematics
- idependent in sense of experimental setup (collider, fixed target)
- allows one reconstruction of decay chains (cascades)
- daughter and mother particles are described and considered the same way
- daughter particles are added to the mother particle independently

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

Scalar product method for v_n calculation

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

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

Scalar product (SP) method:

$$v_1 = \frac{\langle u_1 Q_1^{F1} \rangle}{R_1^{F1}}$$

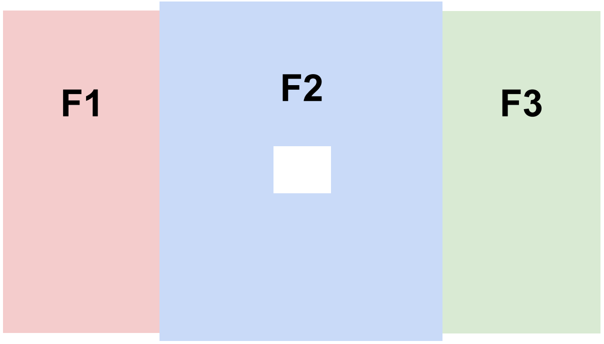
Where R_1 is the resolution correction factor

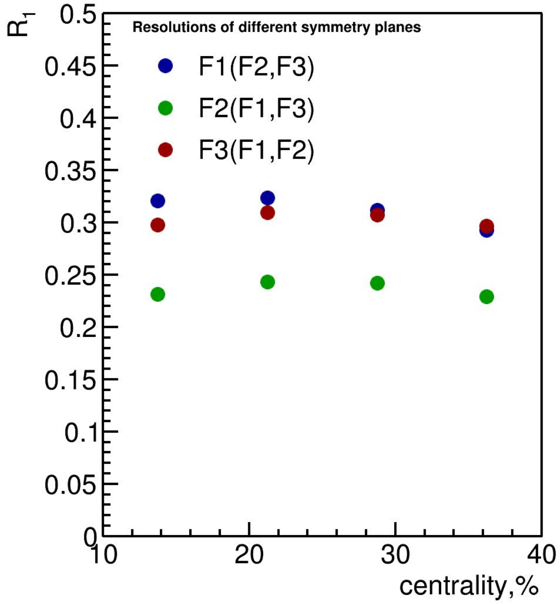
$$R_1^{F1} = \langle \cos(\Psi_1^{F1} - \Psi_1^{RP}) \rangle$$

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

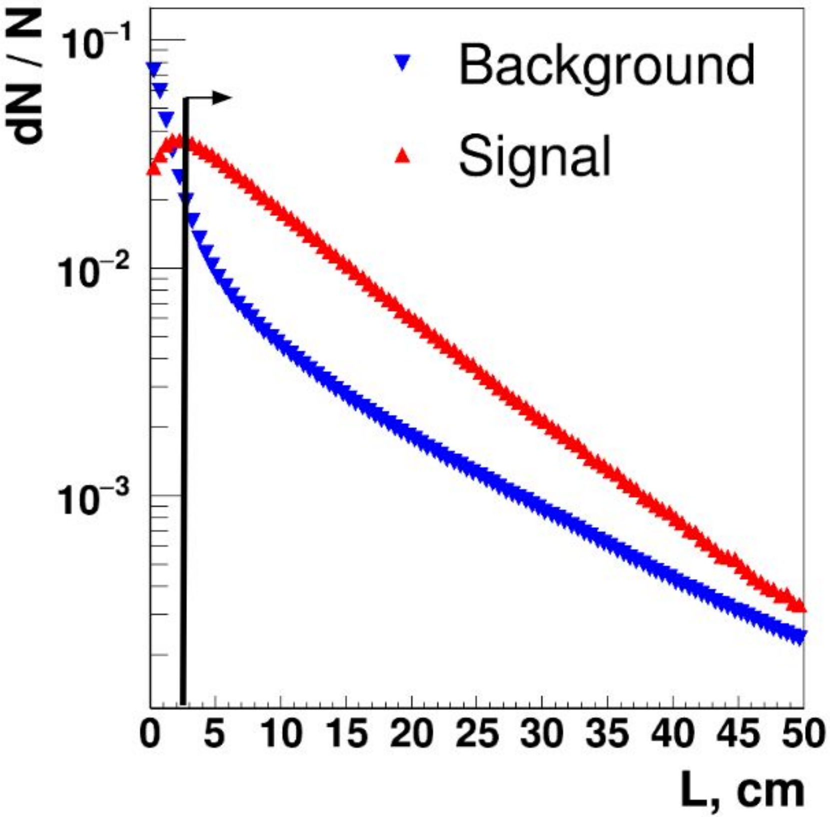
$$R_1^{F2(F1,F3)} = \frac{\sqrt{\langle Q_1^{F2} Q_1^{F1} \rangle \langle Q_1^{F2} Q_1^{F3} \rangle}}{\sqrt{\langle Q_1^{F1} Q_1^{F3} \rangle}}$$

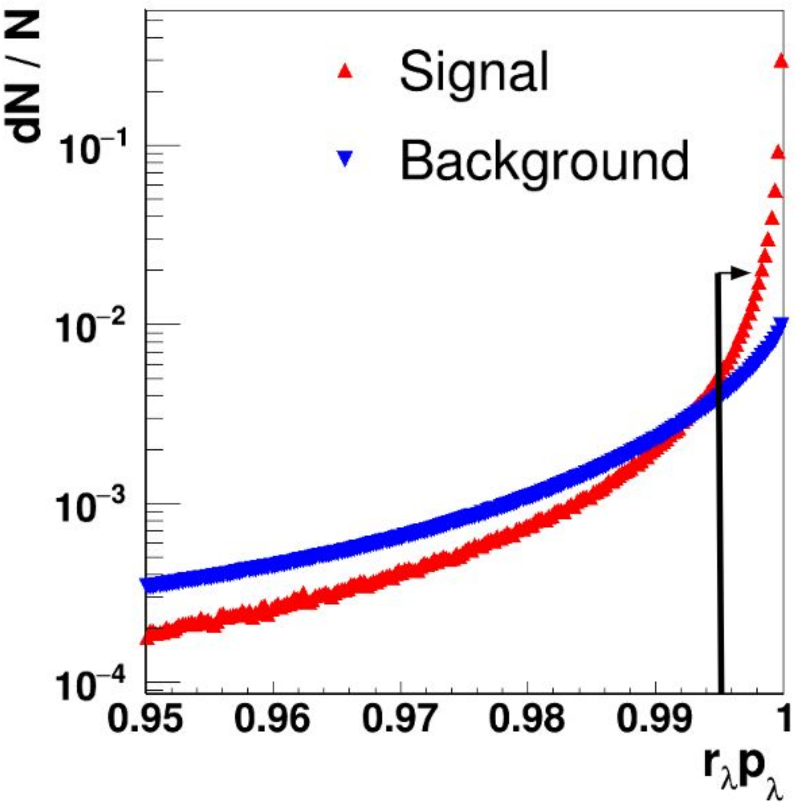
FHCal divided into 3 sub-events





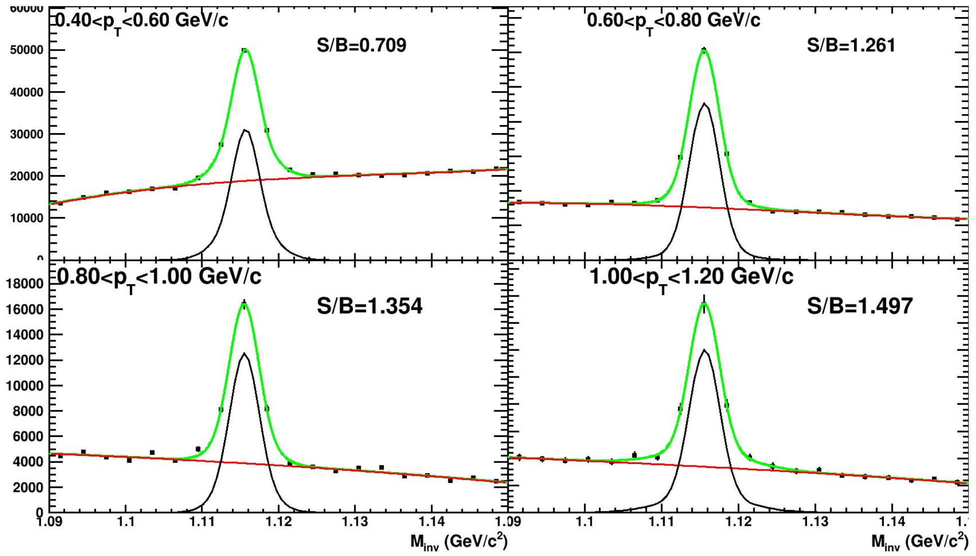
Selection of Λ candidates with KFParticle

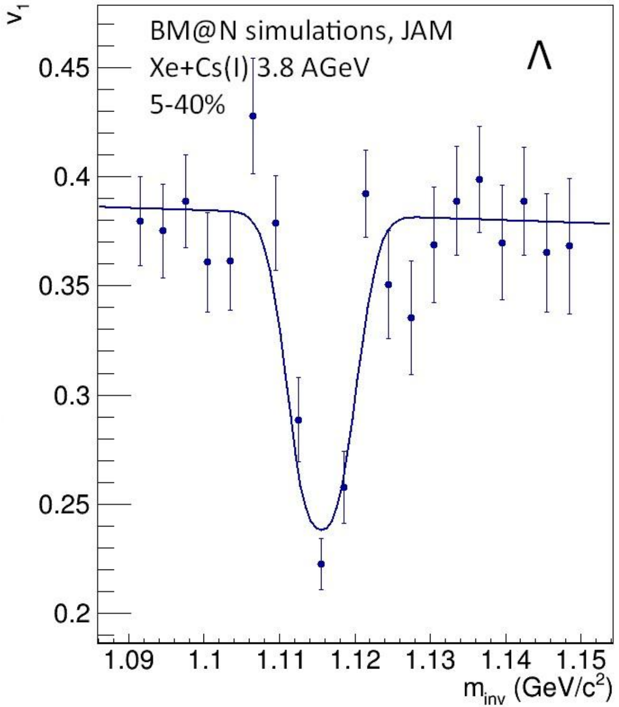




Combinatorial background can be filtered with various topological and quality cuts

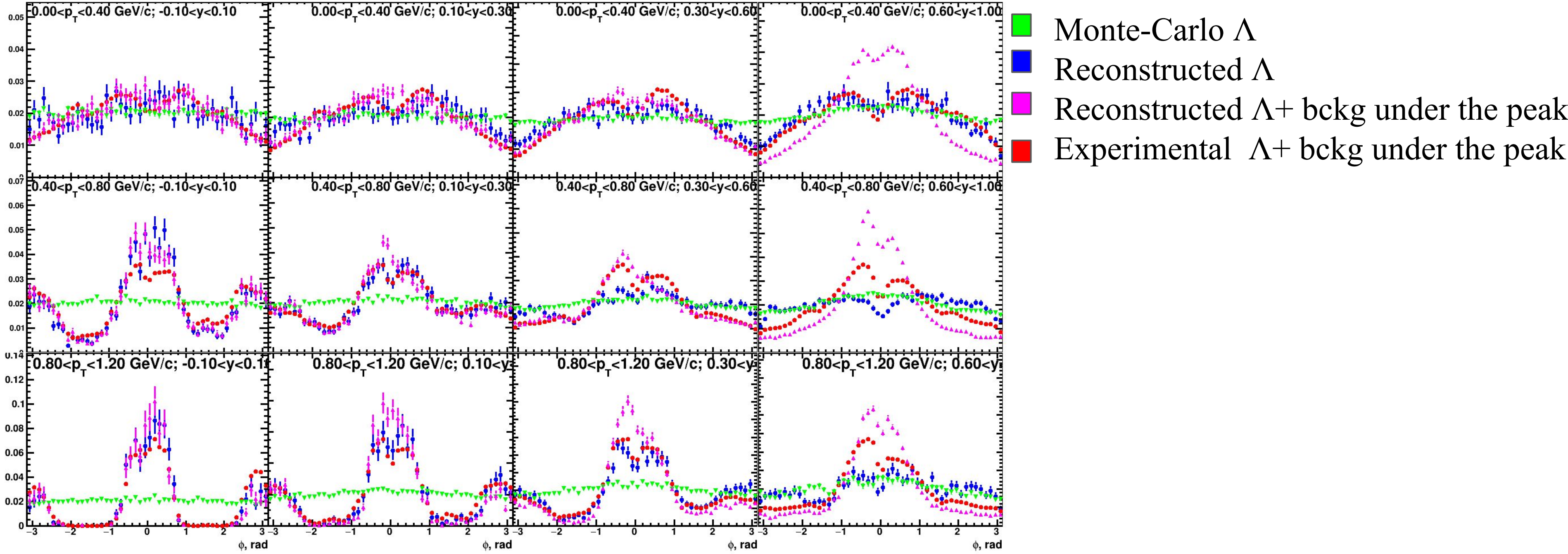
Invariant mass fit method with JAM model





Good fit quality for inv mass distributions in p_T-y bins
An agreement with signal from model

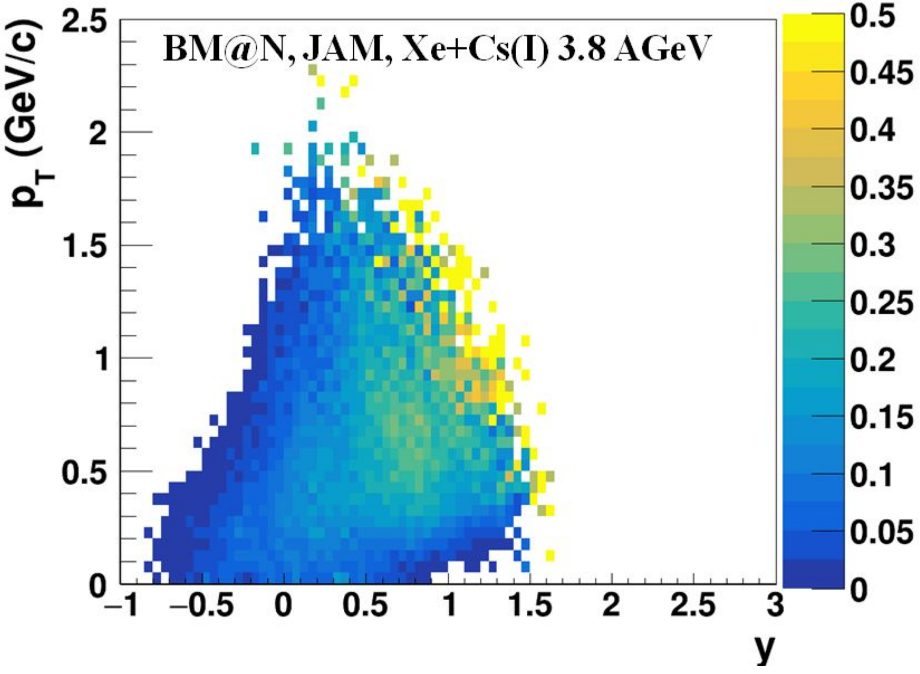
Azimuthal asymmetry of the BM@N acceptance

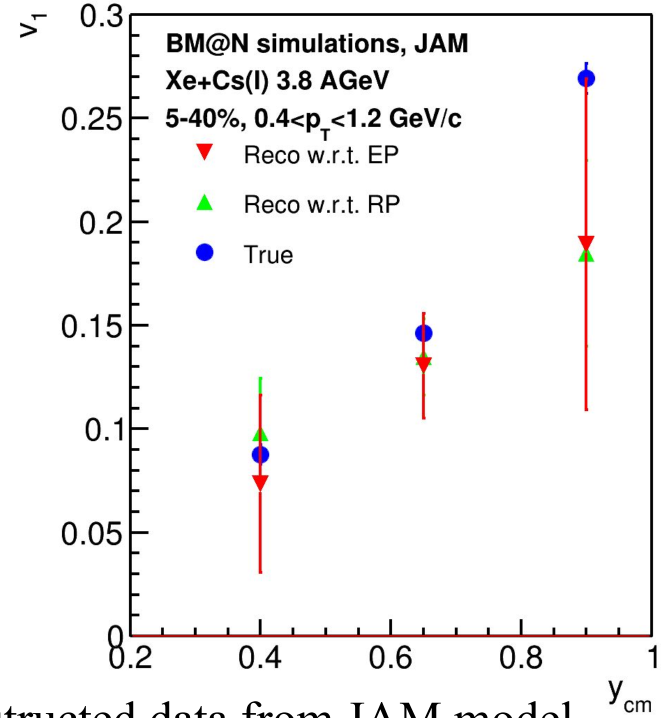


Non-uniform acceptance - corrections are required

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

Performance study with JAM fully reconstructed data



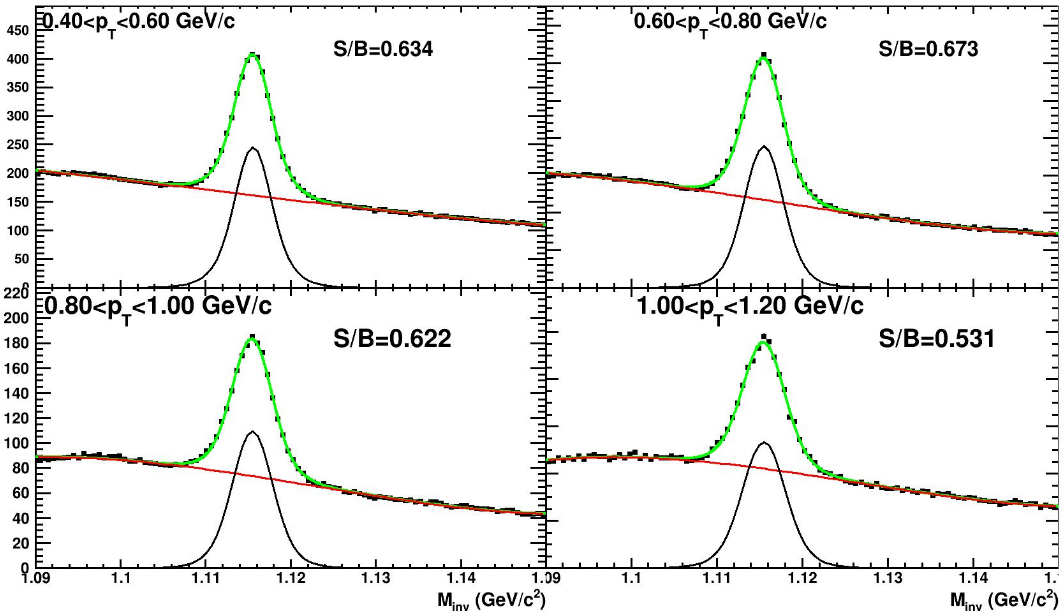


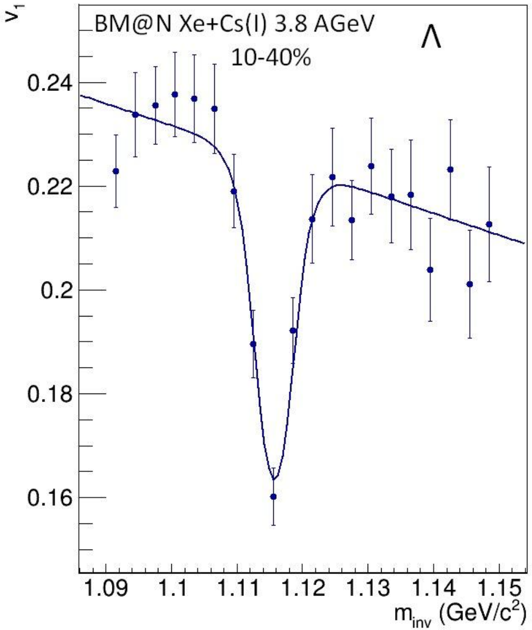
For performance study 15 M events of fully reconstructed data from JAM model are used

Very limited p_T-rapidity coverage

An agreement with signal from model

v_1 of Λ hyperons in the BM@N Xe+Cs(I) at 3.8AGeV exp data

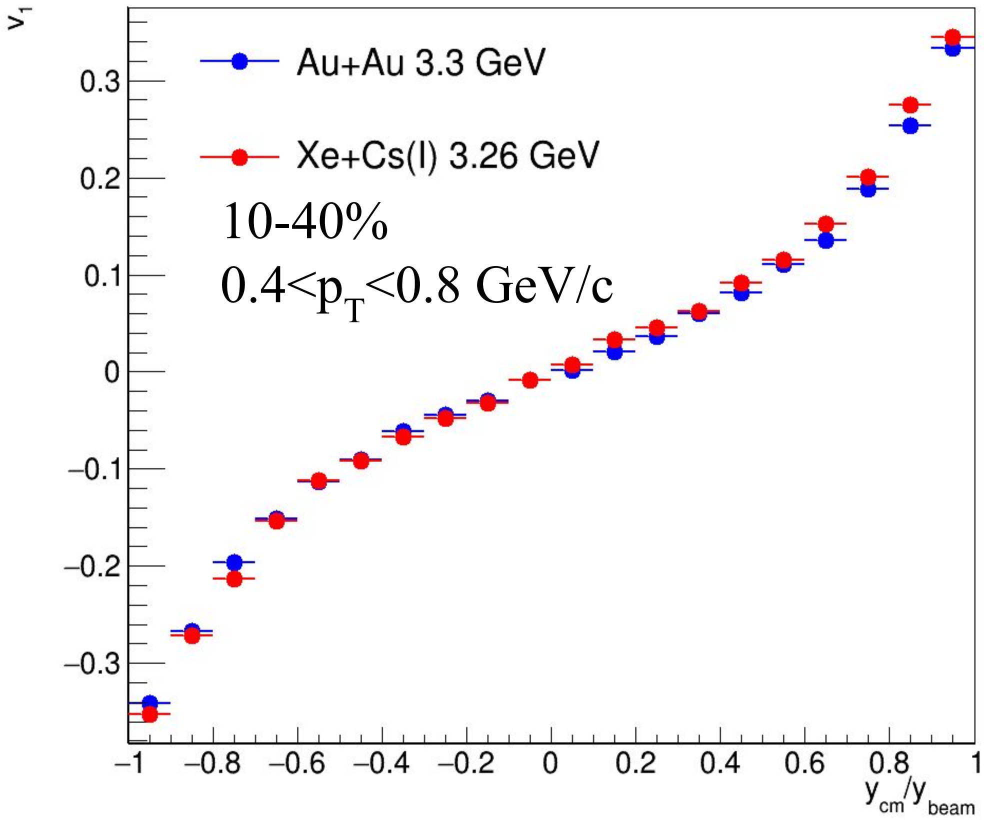




$$v_1^{SB}(m_{inv}, p_T) = v_1^S(p_T)\frac{N^S(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)} + v_1^B(m_{inv}, p_T)\frac{N^B(m_{inv},p_T)}{N^{SB}(m_{inv},p_T)}$$

Good performance of KFParticle and invariant mass fit method, applied to BM@N experimental data

v_1 of Λ hyperons for different systems with JAM model



System-size effect should be checked for future comparison with existing experimental data

No significant difference

Summary

- Performance study for flow measurements of Λ hyperons for Xe+Cs(I) at E_{kin}=3.8 AGeV with JAM at BM@N is presented
  - Invariant mass fit method for reconstructed data show an agreement with simulated data
  - The size of colliding system should not strongly affect the v_1 measurements
- Application of invariant mass fit method for directed flow measurements at recent BM@N Xe+Cs(I) experimental run is shown
  - Further analysis is under work

Outlook

- Further efficiency study and analysis of systematic effects
- Obtain rapidity and transverse momentum dependence of v_1 for experimental data
- Comparing results with existing data