Performance of FFD detector for anisotropic flow analysis with the MPD experiment

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Outline

- Anisotropic transverse flow;
- MPD introduction and FHCal-FFD overview;
- Scalar product method for flow analysis;
- Event plane Resolution comparison between FHCal and FFD;
- Comparison between FHCal and FFD for directed and elliptic flow of charged hadrons measurements;
- Summary

Anisotropic transverse flow

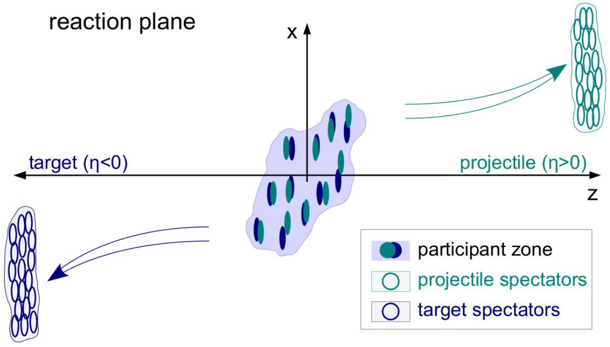
Spatial asymmetry of energy distribution at the initial state is transformed, through the strong interaction, into momentum anisotropy of the produced particles.

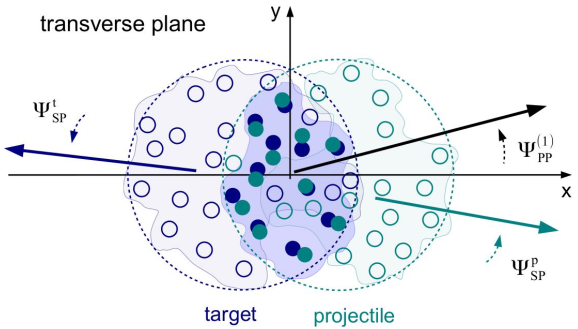
$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_{RP}))\right)$$

$$\Downarrow$$

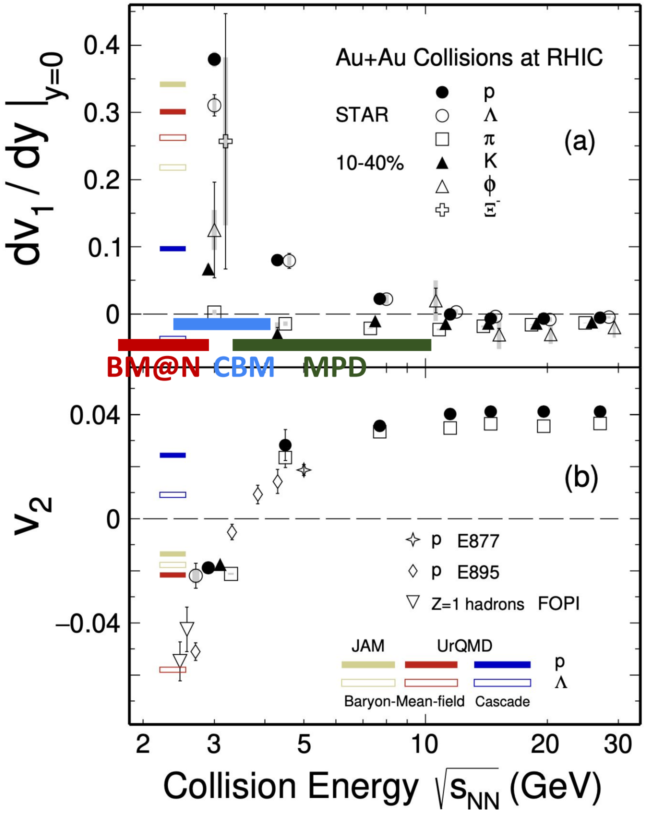
$$v_n = \langle \cos(n(\phi - \Psi_{RP}))\rangle$$

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





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



Strong energy dependence of dv_1/dy and v_2 at $\sqrt{s_{NN}}$ =4-11 GeV.

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

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

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

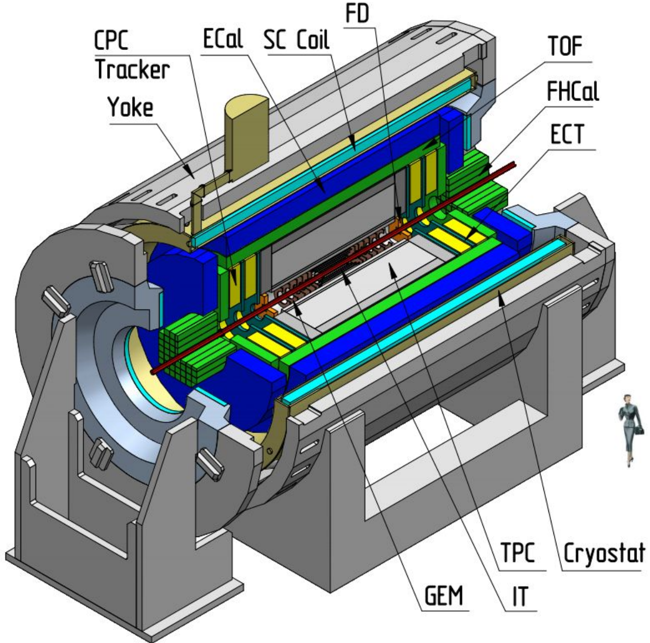
- effects of collective (radial) expansion on anisotropic flow
- interaction between collision spectators and produced matter
- baryon number transport

Several experiments (MPD, BM@N, STAR FXT, CBM, HADES, NA61/SHINE) aim to study properties of the strongly-interacted matter in this energy region.

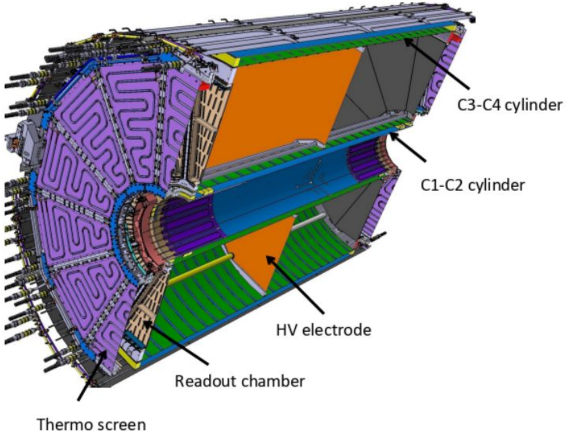
M. Abdallah et al. [STAR Collaboration] 2108.00908 [nucl-ex]

MPD introduction

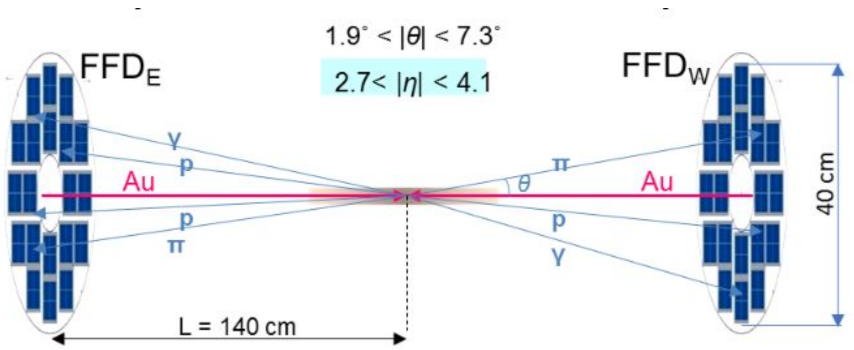
- 4π spectrometer designed to work at high luminosity in the energy range of the NICA collider (4-11 GeV)
- Capable of detecting of charged hadrons, electrons and photons.
- Precise 3-D tracking system and a high-performance particle identification system based on the time-of-flight measurements and calorimetry.
- Forward Hadron Calorimeter (FHCal) allow to reconstruct projectile and target spectator symmetry planes
- Cherenkov Fast Forward Detector (FFD) is a part of trigger system.

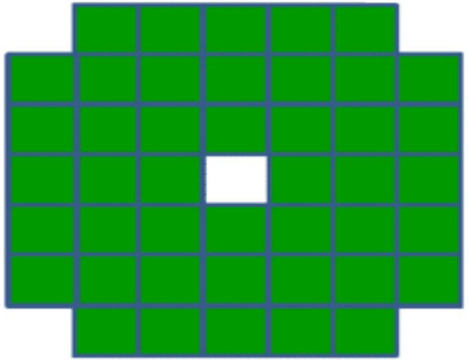


Time Projection Chamber (TPC) is a main tracking detector, overlapping pseudorapidity region |η| <1.5 with high particle reconstruction efficiency for p_T > 0.1 GeV/c



FHCal and FFD detectors





The FFD consists of two sets of Cherenkov counters located at ±140 cm from the nominal interaction point. Each set has 20 physical detectors with 4 read-out channels each. As a result, the total number of read-out channels is 2 sides 80 channels = 160 channels.

FHCal consists of two sets of hadron calorimeters in pseudorapidity region 2<|η|<5 Each set has 44 modules form azimuthal symmetry. Total number of modules 88.

u_n, Q_n vectors formalism for flow measurements

- Unit vector of a particle $u_n(\text{centrality}, \text{pid}, p_T, y)$:

$$u_n = e^{in\varphi} = \begin{cases} u_{n,x} \equiv x_n = \cos n\varphi \\ u_{n,y} \equiv y_n = \sin n\varphi \end{cases}$$

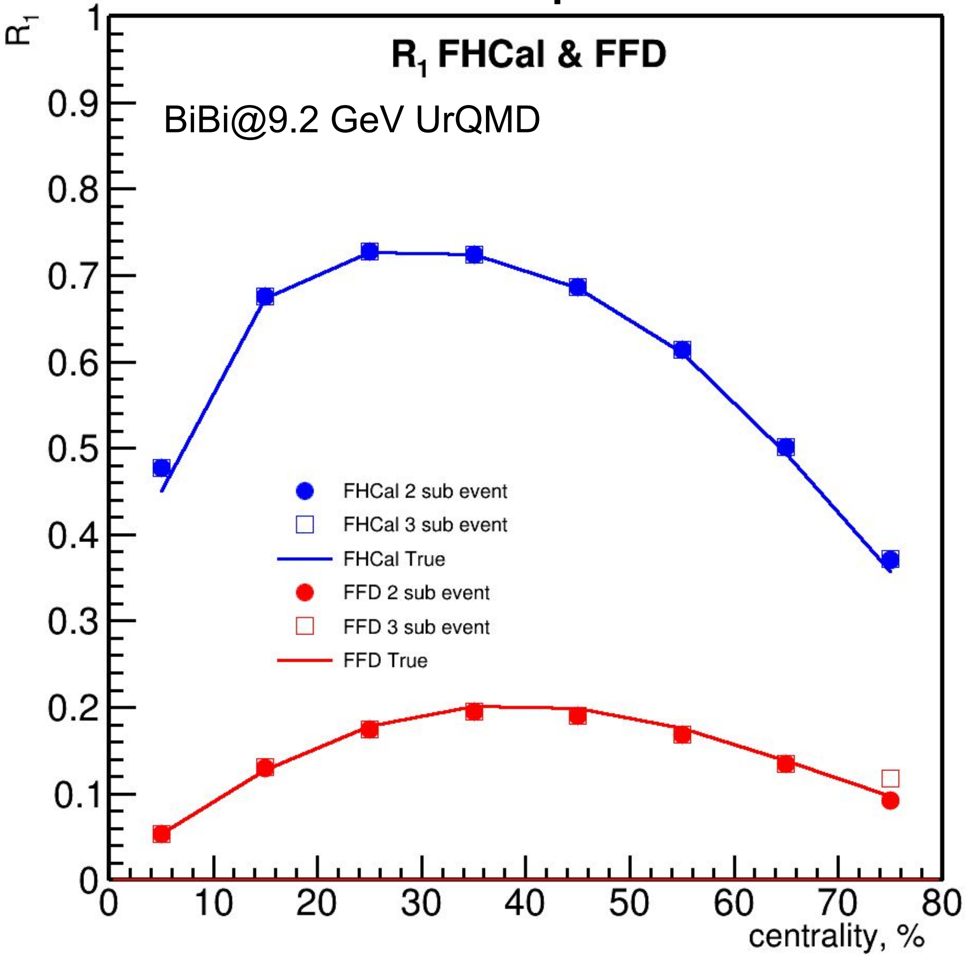
- Event flow vector $Q_n(\text{centrality})$:

$$Q_n = \sum_{k=1}^{M} \omega_n^k u_n^k \equiv |Q_n| e^{in\Psi_n} = \begin{cases} Q_{n,x} \equiv X_n = |Q_n| \cos n\Psi_n \\ Q_{n,y} \equiv Y_n = |Q_n| \sin n\Psi_n \end{cases}$$

  - φ – azimuthal angle of the produced particle
  - ω – weight of the Q_n vector (for example, $\omega = 1$ for participant plane and $\omega = E$ for spectator plane)
  - Ψ_n – event plane angle

More information:
https://inspirehep.net/literature/757158

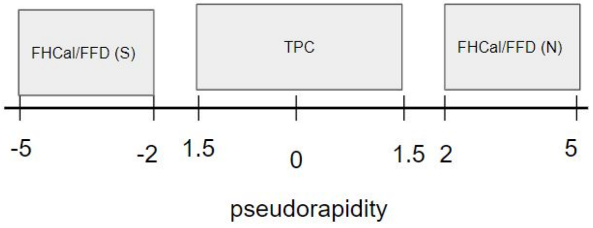
FHCal & FFD event plane Resolution for v_1



2 sub event

$$R_{1,i} = \sqrt{\langle Q^N_{1,i} Q^S_{1,i} \rangle}, i = x, y$$

$$R^{True}_{1,i} = \langle Q_{1,i} \Psi_{RP} \rangle$$

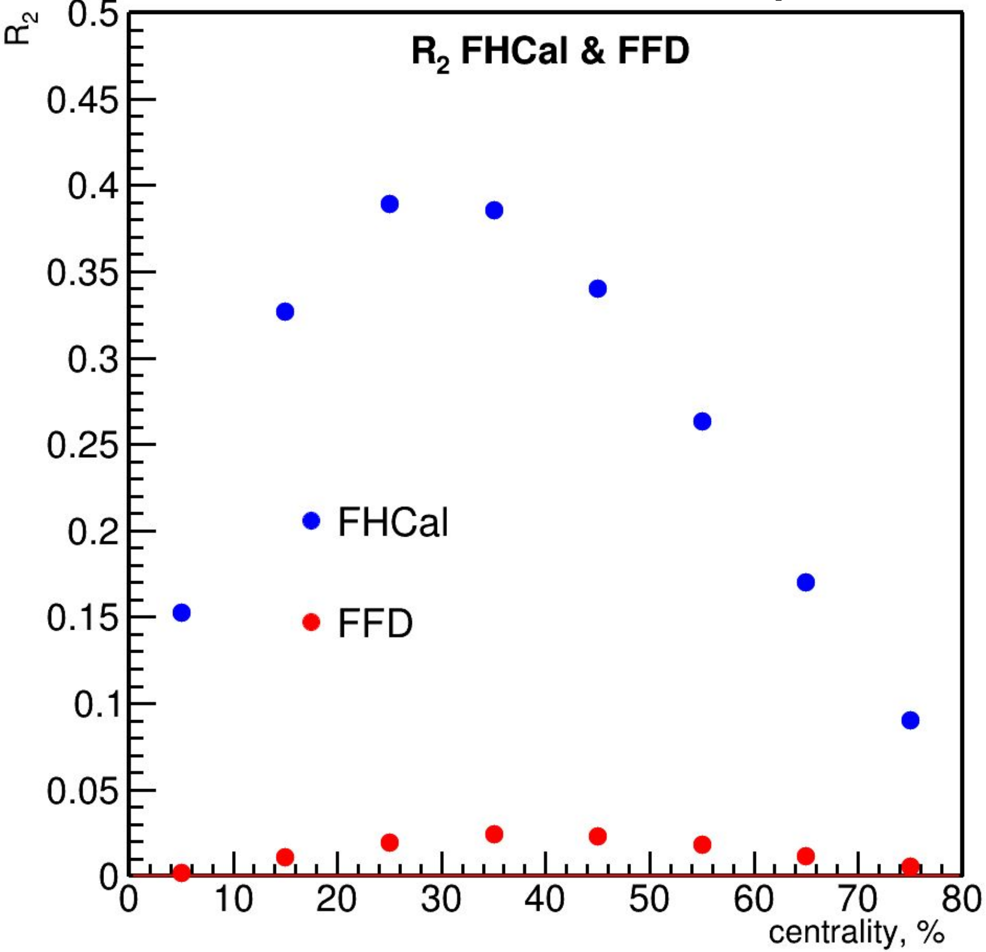


3 sub event

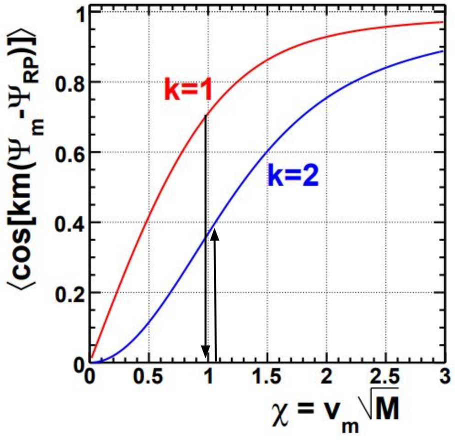
$$R^N_{1,i} = \sqrt{\frac{2\langle Q^N_{1,i} Q^S_{1,i} \rangle \langle Q^S_{1,i} Q^{TPC}_{1,i} \rangle}{\langle Q^N_{1,i} Q^{TPC}_{1,i} \rangle}}$$

- FFD resolution are smaller than FHCal
- 2 and 3 sub event has good agreement with True Resolution

FHCal & FFD event plane Resolution for v_2

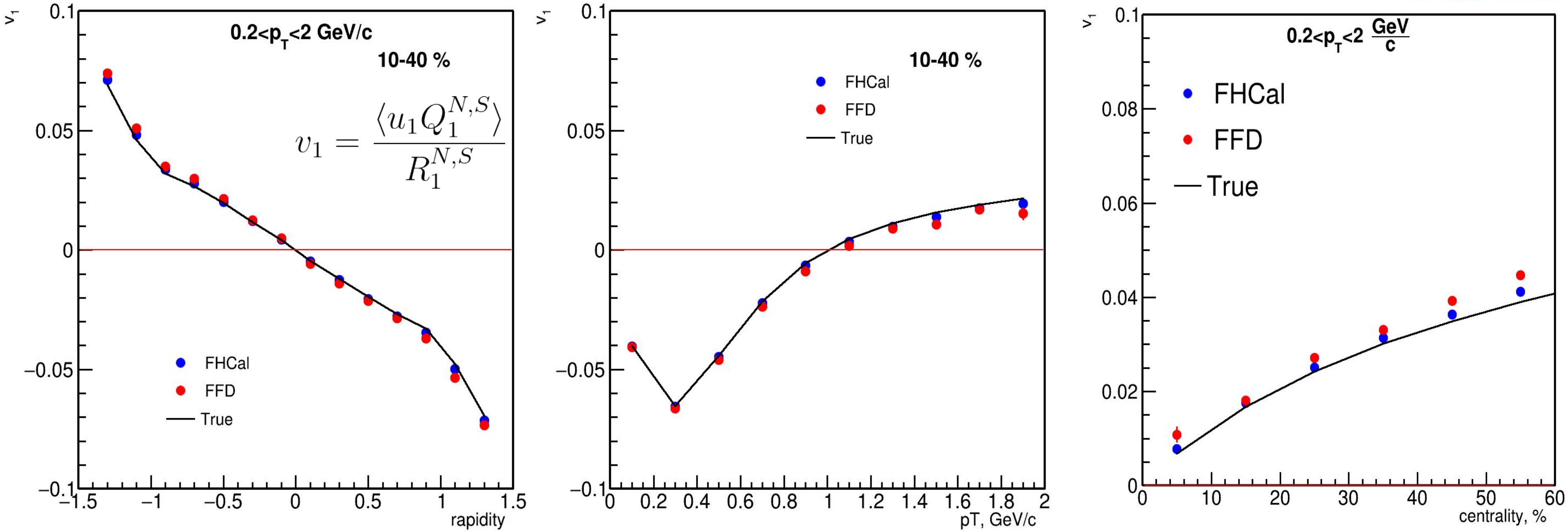


Extrapolation to obtain R_2



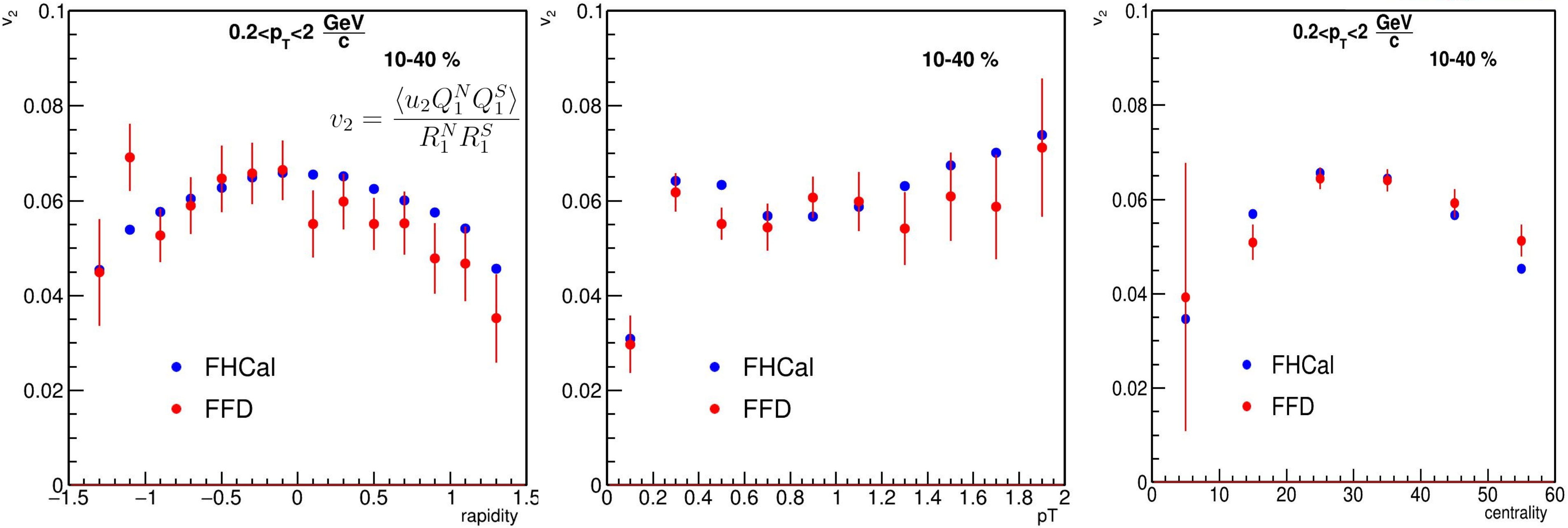
- FFD resolution is extremely small.

Directed flow of charged hadrons with FHCal and FFD



FHCal and FFD have consistent results; both can be used for directed flow measurements.

Elliptic flow of charged hadrons with FHCal and FFD



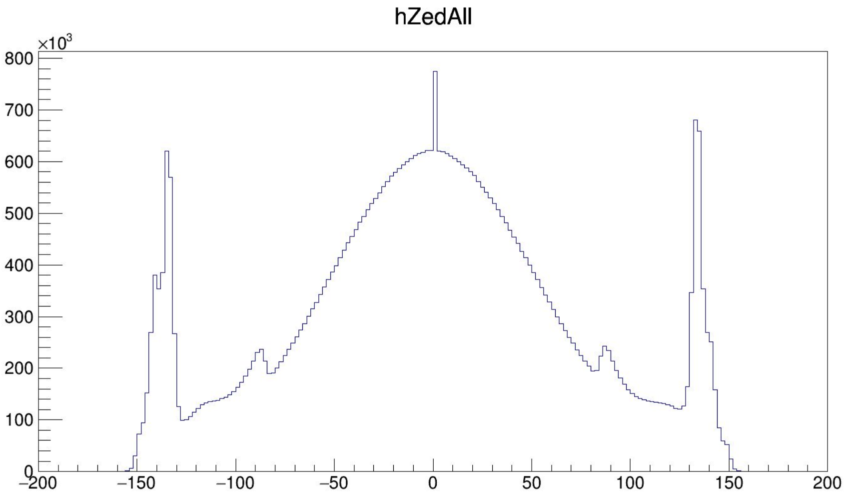
Due to low Resolution FFD need more statistics than FHCal for elliptic flow measurements.

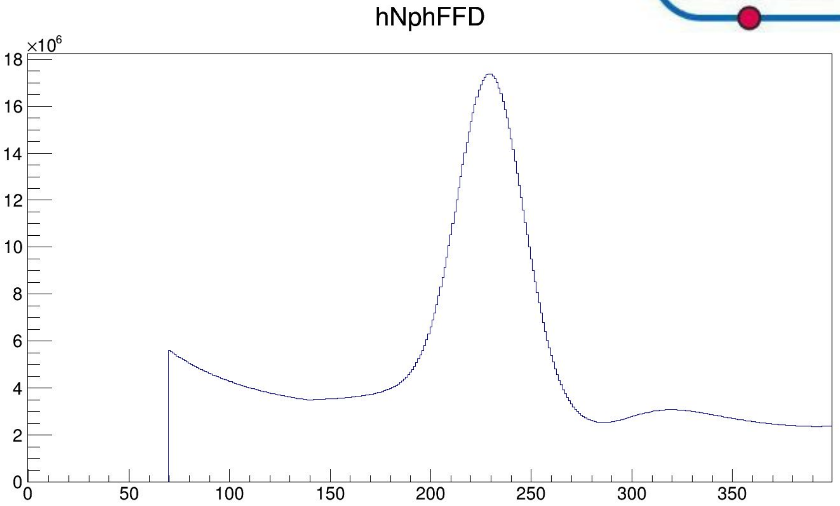
Summary

- Event plane Resolution of FFD is much more smaller than FHCal resolution;
- Good agreement for 2 and 3 sub event methods
- FFD has extremely small Resolution for 2-nd harmonic
- FFD can be used for directed flow measurements
- FFD needs more statistics than FHCal for elliptic flow measurements due to low resolution

BACKUP

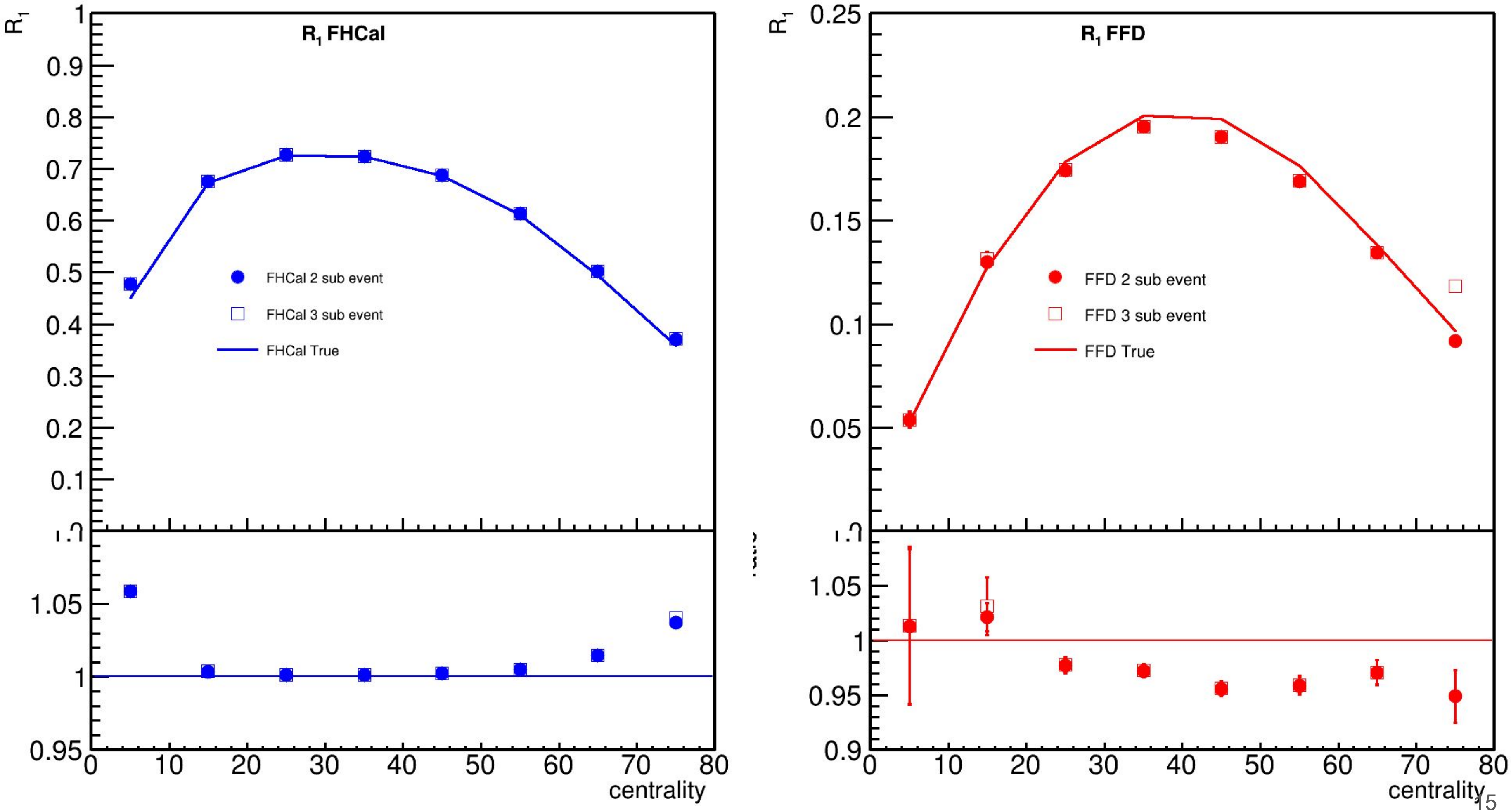
Data set and QA



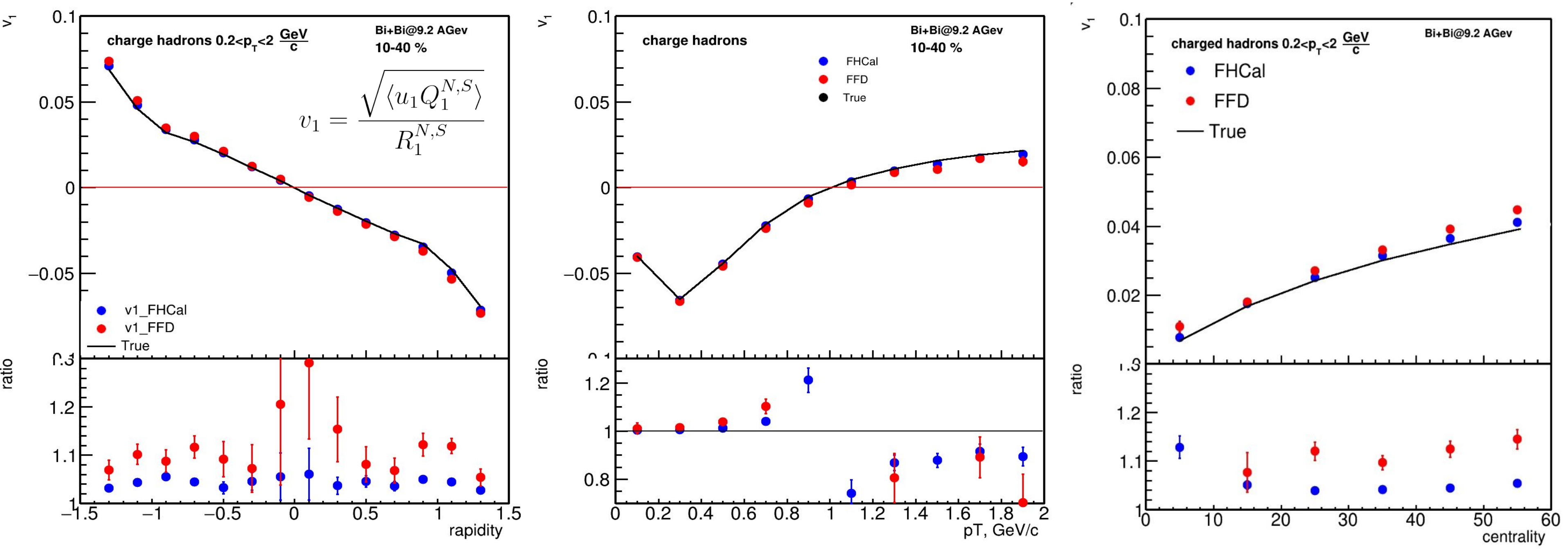


- To reduce impact of vertexZ, set cut |vtxZ|<50 cm and remove peak in vtxZ=0
- Number of photons in FFD is used as the weight

Dataset: BiBi@9.2AGeV UrQMD 50m events


R1 FHCal
FHCal 2 sub event
FHCal 3 sub event
FHCal True
R1
centrality
R1 FFD
FFD 2 sub event
FFD 3 sub event
FFD True
R1
centrality

Directed flow of charged hadrons with FHCal and FFD



FHCal are better than FFD for directed flow measurements

Effects of FFD cut on number of photons [180;290]