Performance of the MPD experiment for the azimuthal flow measurement

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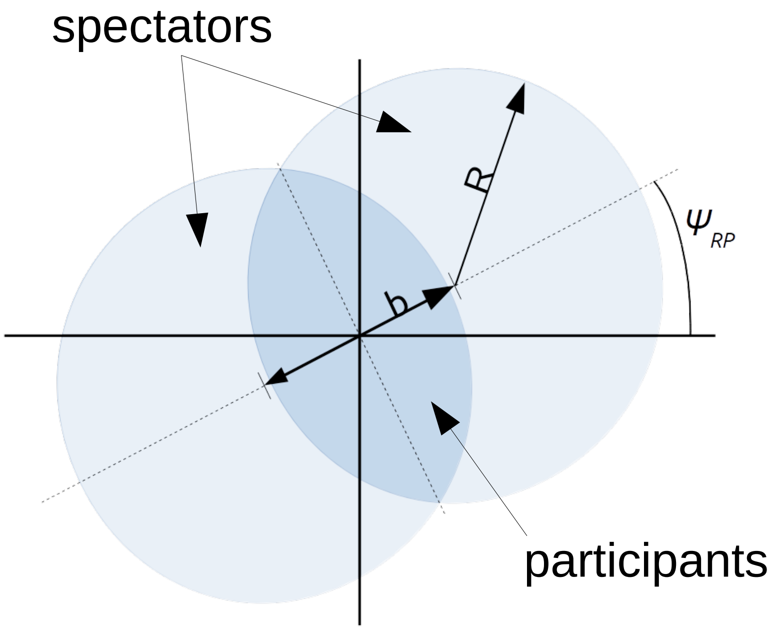
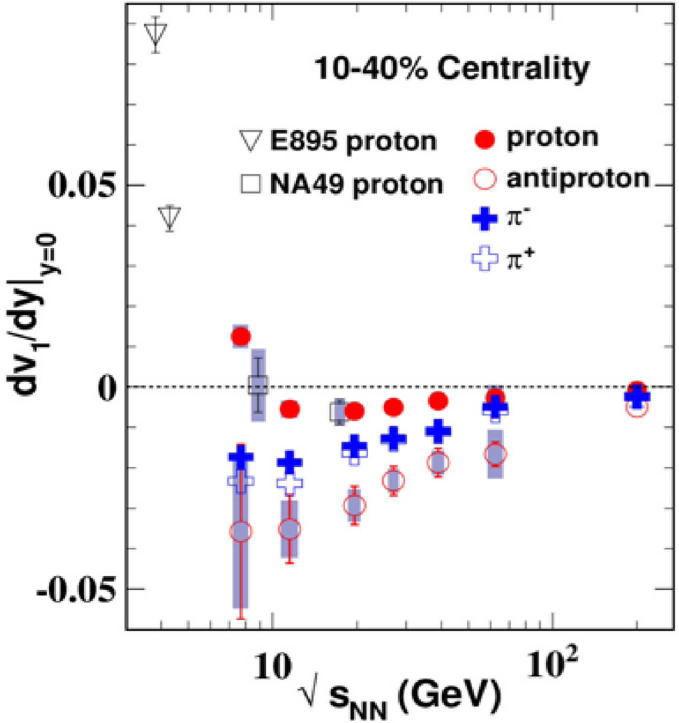
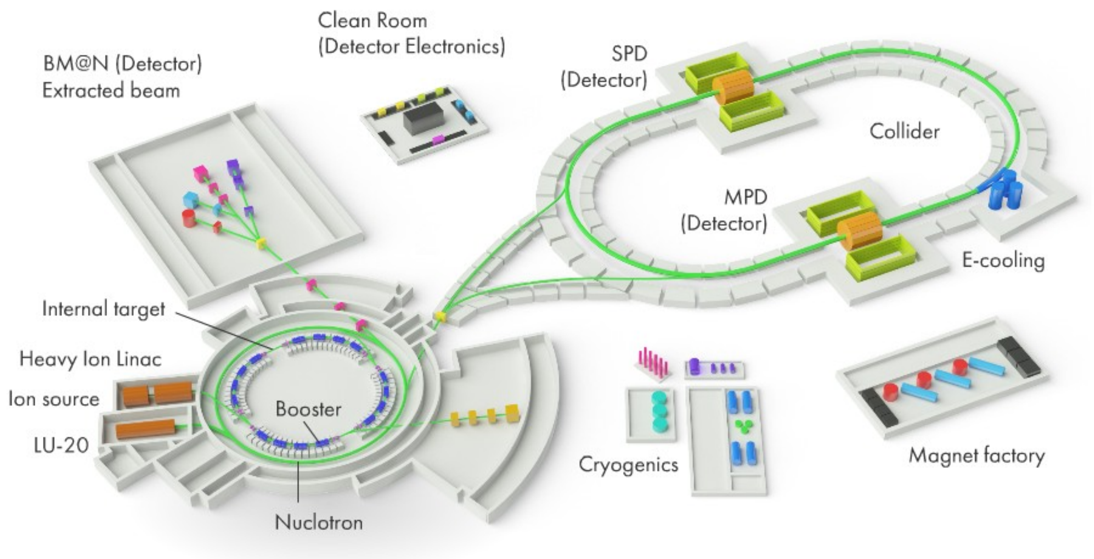
Collision energy dependence of the anisotropic flow





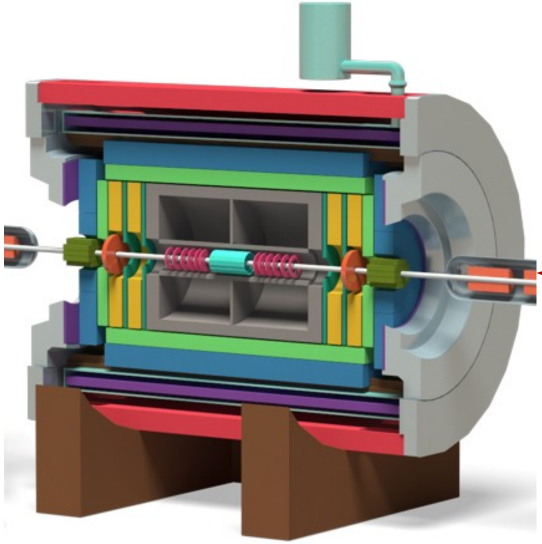
Directed flow is sensetive to the EoS, type of the phase transition and the reaction dynamic of the collision

MPD experiment at NICA

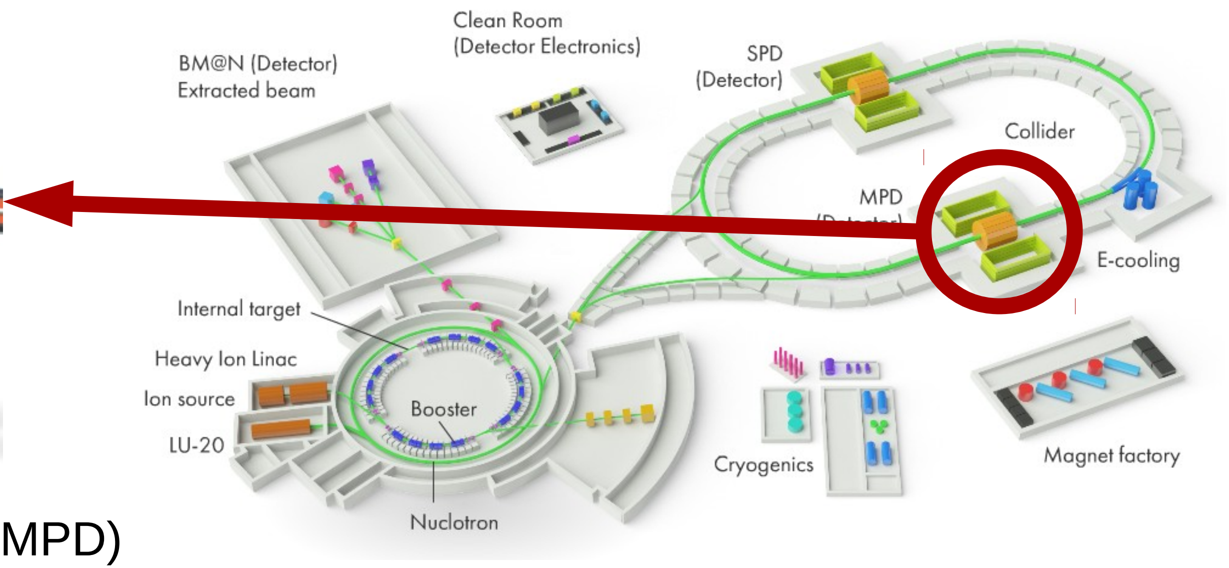


NICA complex

MPD experiment at NICA

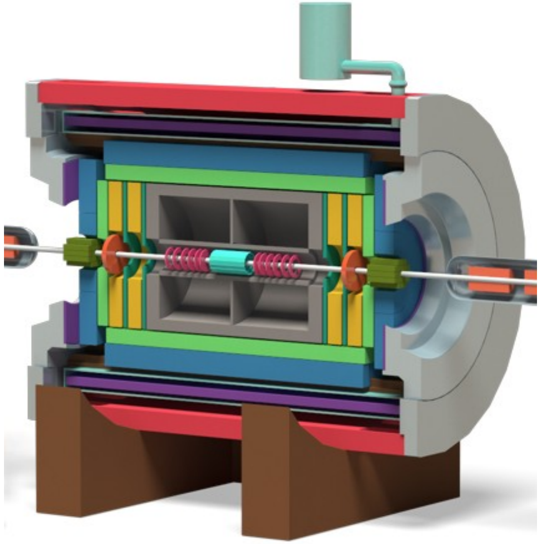


Multi Purpose Detector (MPD)



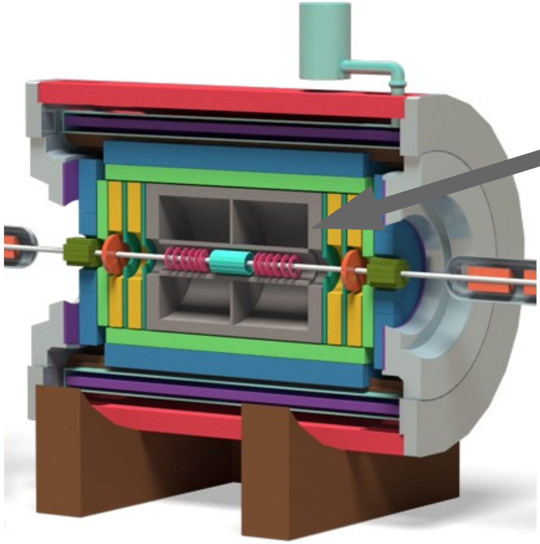
NICA complex

MPD experiment at NICA

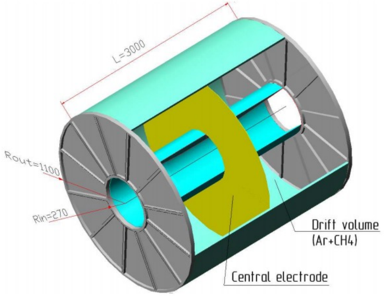


Multi Purpose Detector (MPD)

MPD experiment at NICA



Time projection chamber (TPC)



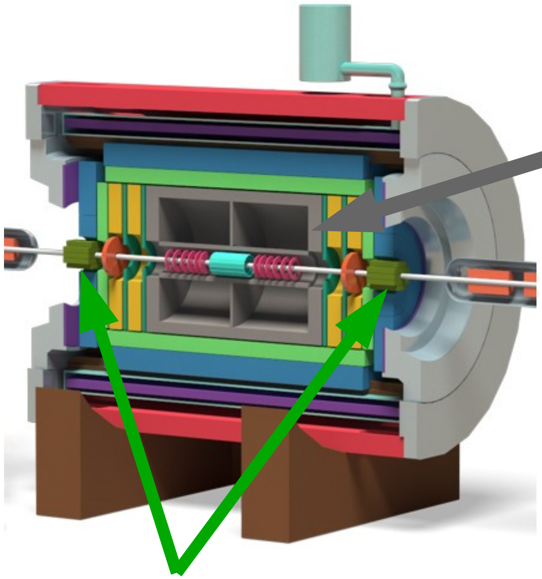
- TPC (l = 340 cm, r_{in} = 54 cm): Charged particles at midrapidity

$-1.5<\eta<1.5$

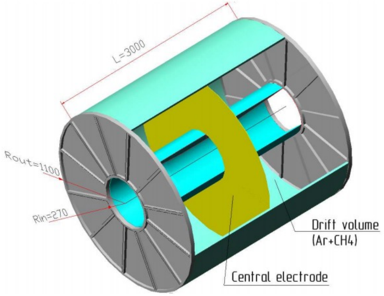
TPC

$0.2<p_T<3$

MPD experiment at NICA

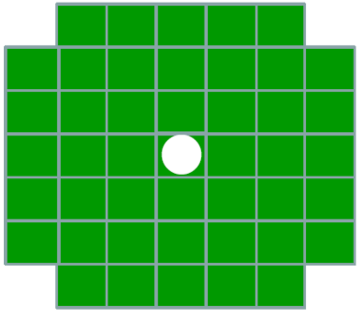


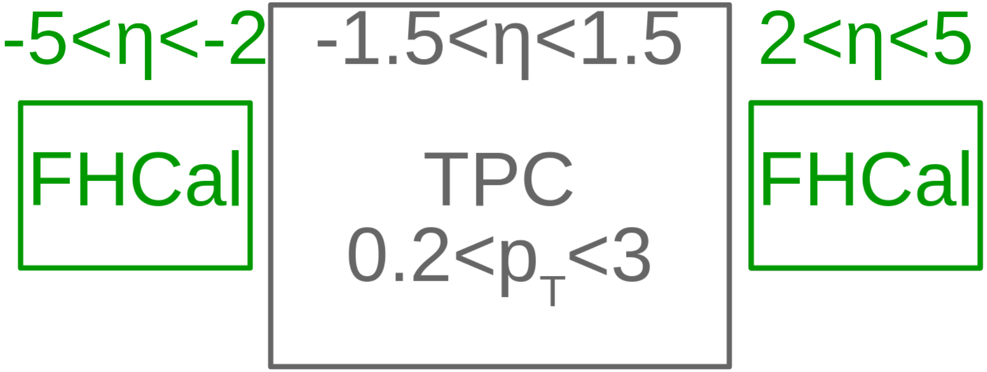
Time projection chamber (TPC)



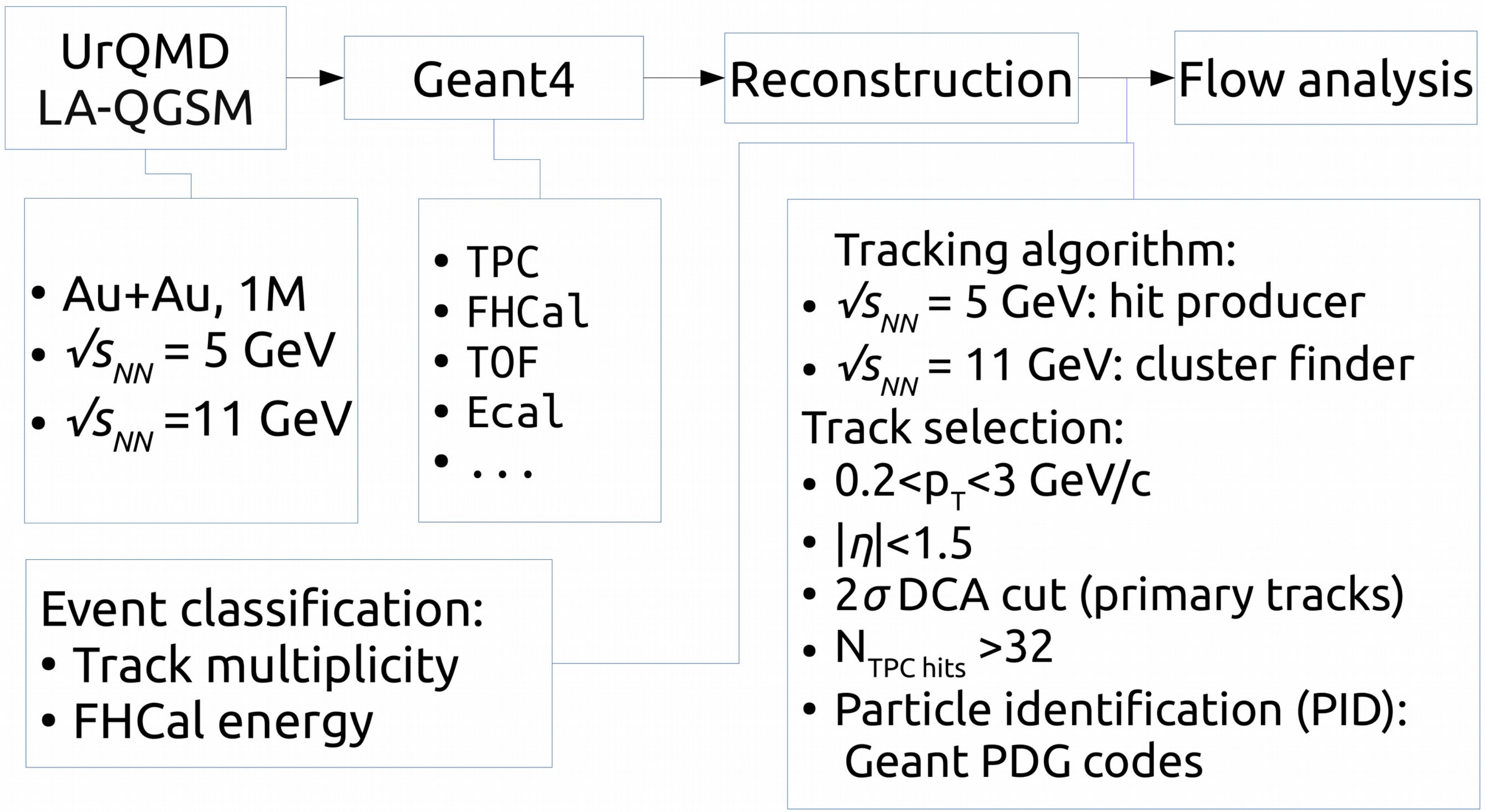
- TPC (l = 340 cm, r_{in} = 54 cm): Charged particles at midrapidity
- FHCal (45 15×15 cm modules): Hadrons at forward rapidity

Forward Hadron Calorimeter (FHCal)

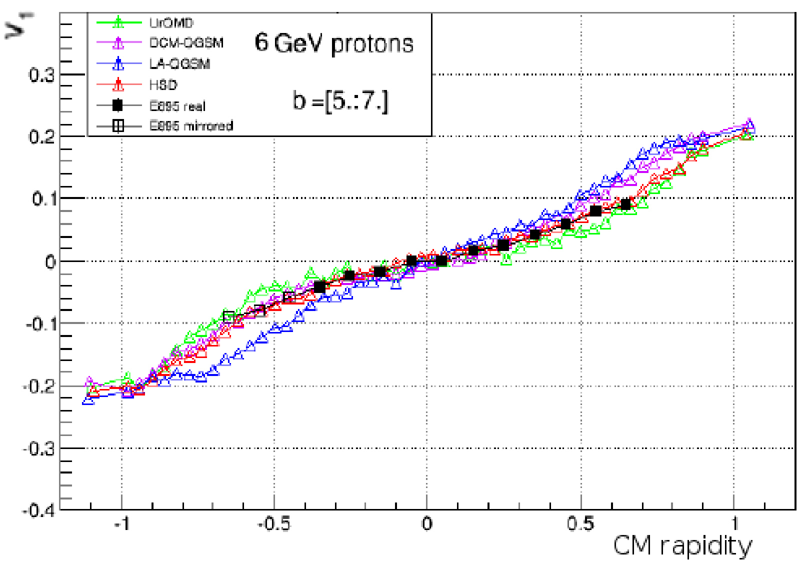


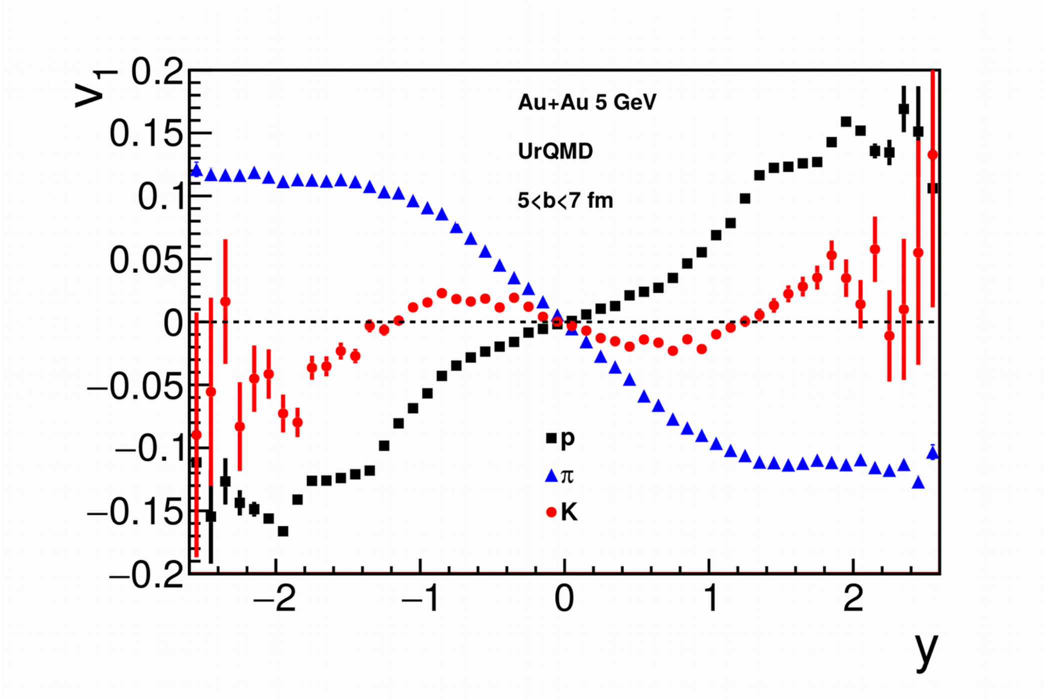


Analysis chain



Modeling directed flow at NICA energies

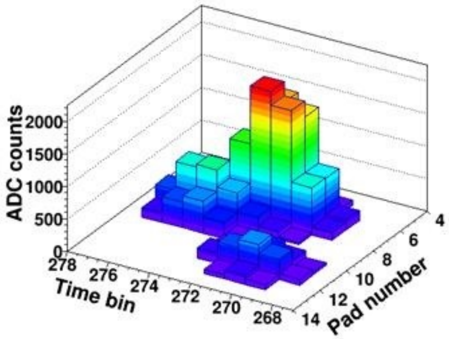


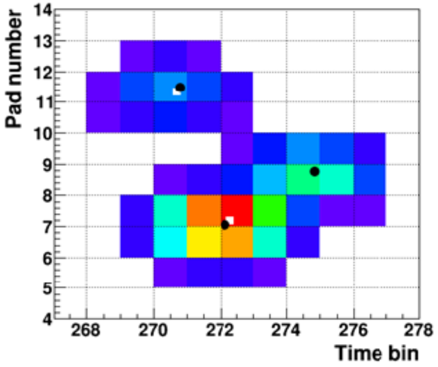


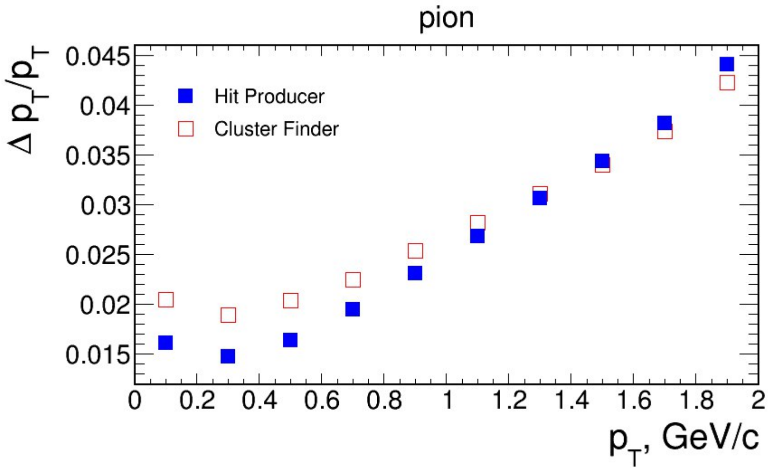
Both UrQMD and LAQGSM are in agreement with experimental measurements
For performance study UrQMD and LAQGSM are used

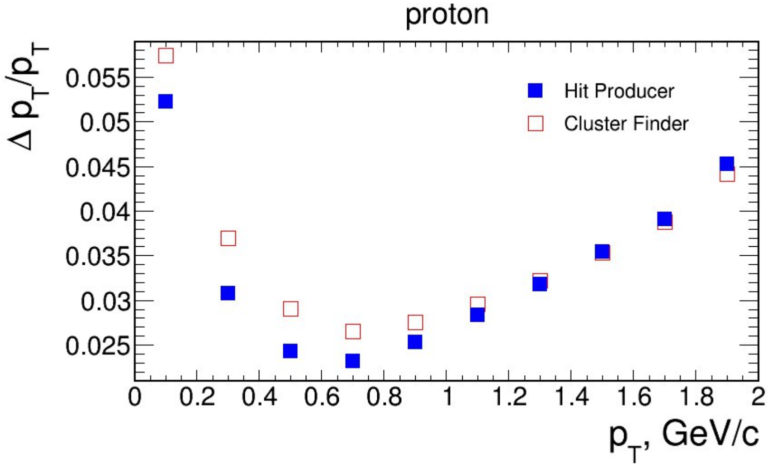
Tracking algorithms

- Hit Producer: forms reconstructed track around local signal maxima via “peak-and valley” algorithm
- Cluster Finder: groups adjacent pixels in pad-time pad space in TPC:

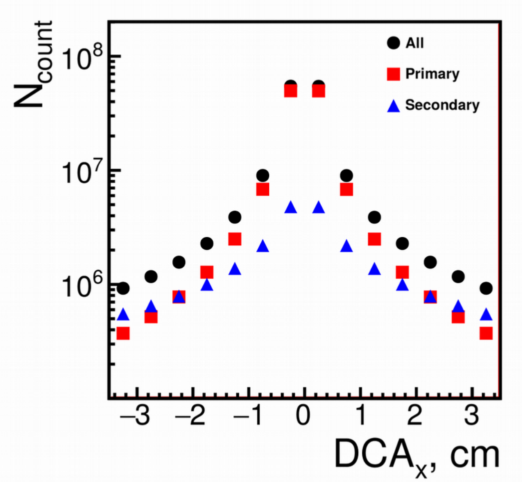




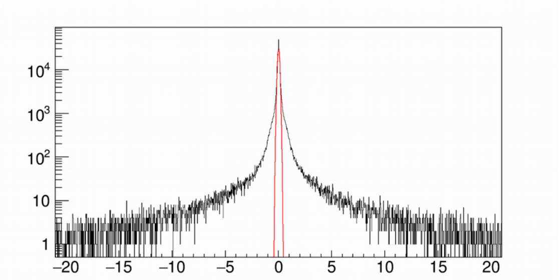




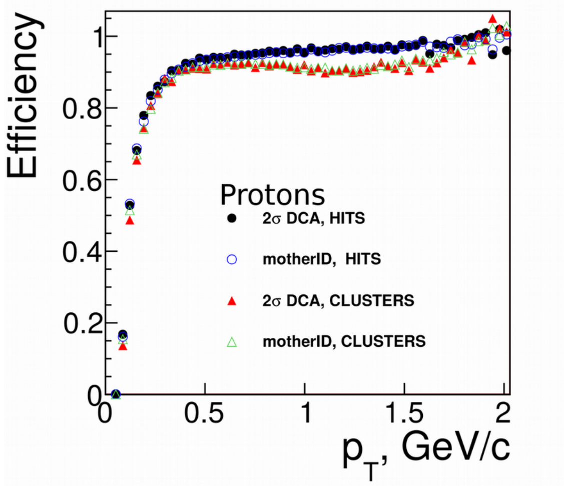
Primary track selection



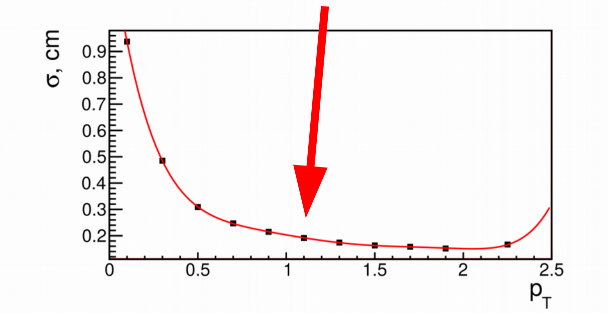
- Distance of the closest approach (DCA) between TPC tracks and primary vertex
- Tracks from secondary particles distort measured signal
- Introduced p_T and η dependent 2σ DCA cut from Gaussian fit with smoothened p_T dependence to reduce secondary contamination



$$Efficiency = \frac{\frac{dN}{p_T}(reco)}{\frac{dN}{p_T}(true)}$$

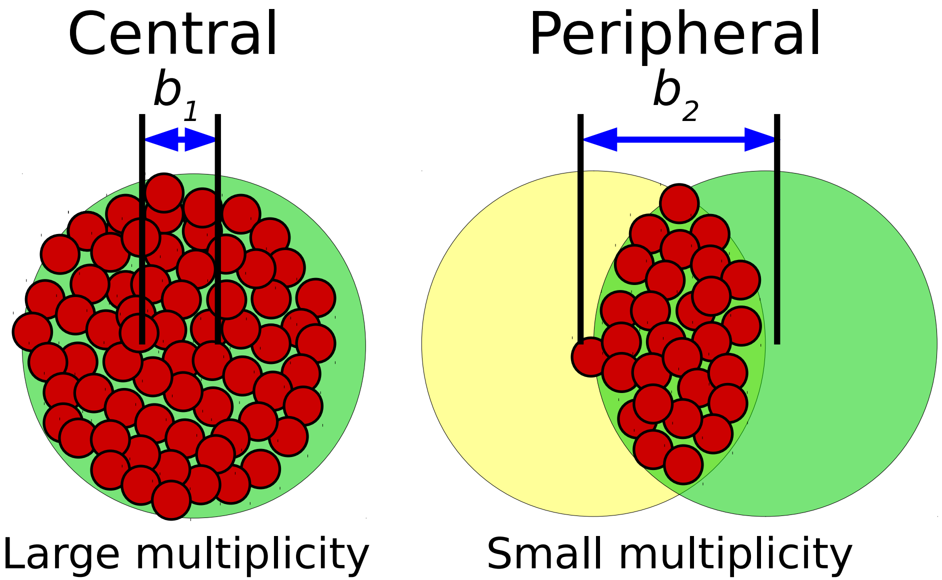


Given track selection suppresses efficiency loss



Centrality determination

Centrality determination



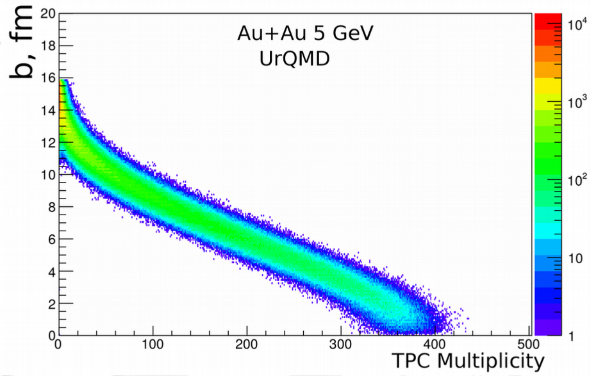
Impact parameter is not known

Experimentally:
Centrality classes determined based on a fraction of a total number of nucleon-nucleon inelastic collisions

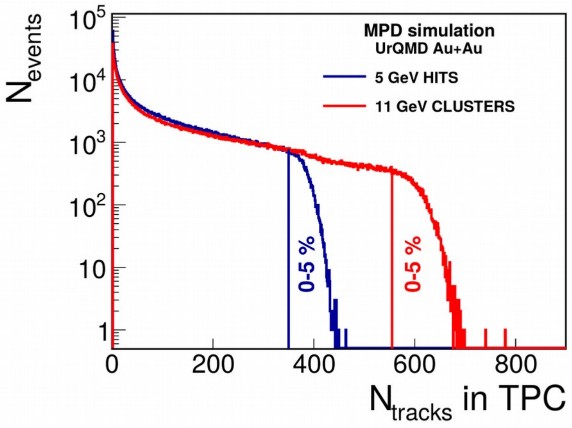
Multiplicity of the produced particles and/or spectator’s energy can be used for centrality determination

Multiplicity from TPC tracks is used to determine centrality

Centrality estimation for multiplicity distributions

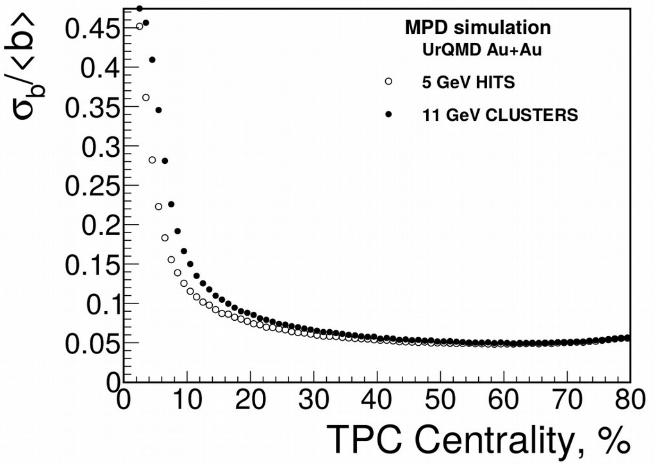


multiplicity in TPC



- Good correlation between *b* and TPC Multiplicity
- Multiplicity distributions of the selected particles were sliced in centrality classes

Centrality resolution

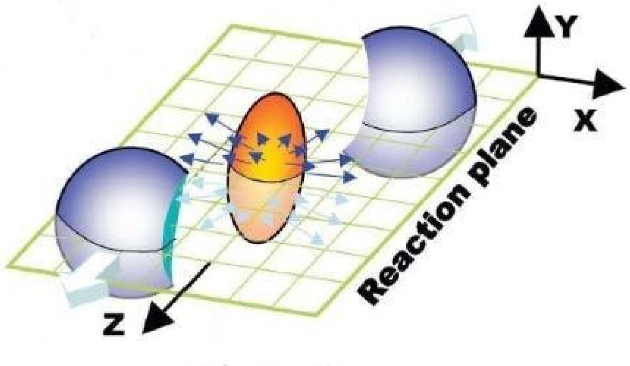


TPC centrality resolution is 5-10% for ~10-80% centrality range

Anisotropic flow performance

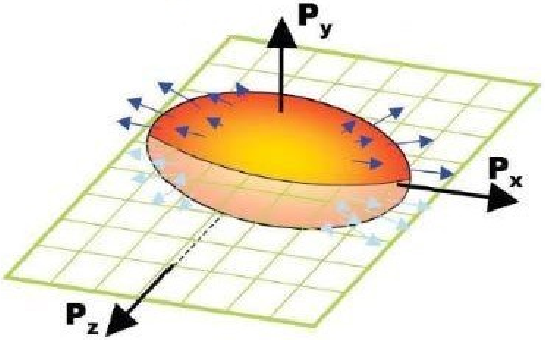
Anisotropic flow in heavy-ion collisions

Spacial anisotropy



Interaction

Momentum anisotropy



$$\frac{dN}{d\varphi} \sim 1 + \sum_{n=1}^{\infty} 2 v_n \cos\left(n\left(\varphi - \Psi_{RP}\right)\right) \qquad v_n \equiv \left\langle \cos\left(n\left(\varphi - \Psi_{RP}\right)\right)\right\rangle$$

v_1/v_2 – directed/elliptic flow

Event plane method

- Reaction plane is not known
- Finite number of detected particles leads to limited resolution of the event plane orientation
- Emitted particles can be measured experimentally

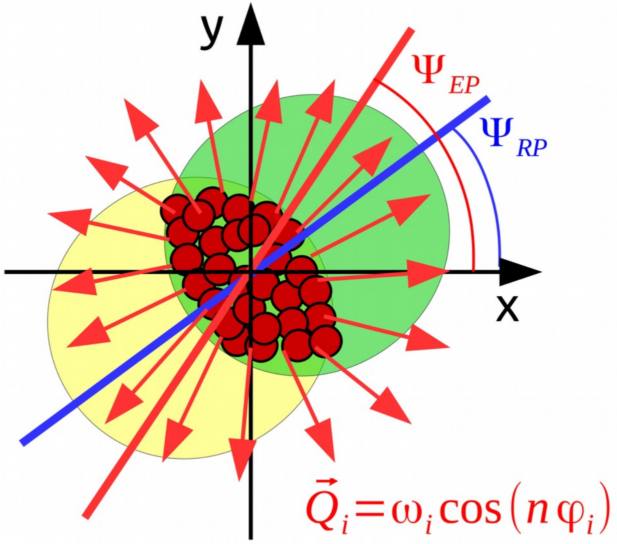
$$\vec{Q} = \{Q_x, Q_y\}$$

$$Q_{n,X} = \sum_i \omega_i \cos(n\varphi_i) = |\vec{Q}| \cos(n\Psi_n^{EP})$$

$$Q_{n,Y} = \sum_i \omega_i \sin(n\varphi_i) = |\vec{Q}| \sin(n\Psi_n^{EP})$$

$$i = 0 \ldots N_{particles}$$

$$\Psi_n^{EP} = \frac{1}{n} \tan^{-1}\left(\frac{Q_{n,Y}}{Q_{n,X}}\right)$$



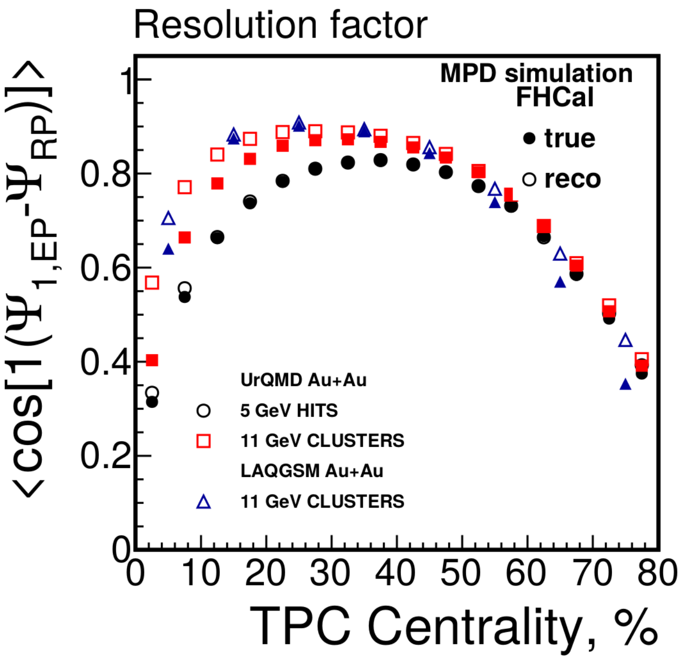
$$v_n = \frac{\langle \cos(n(\varphi - \Psi_{n,EP})) \rangle}{R_{n,EP}}$$

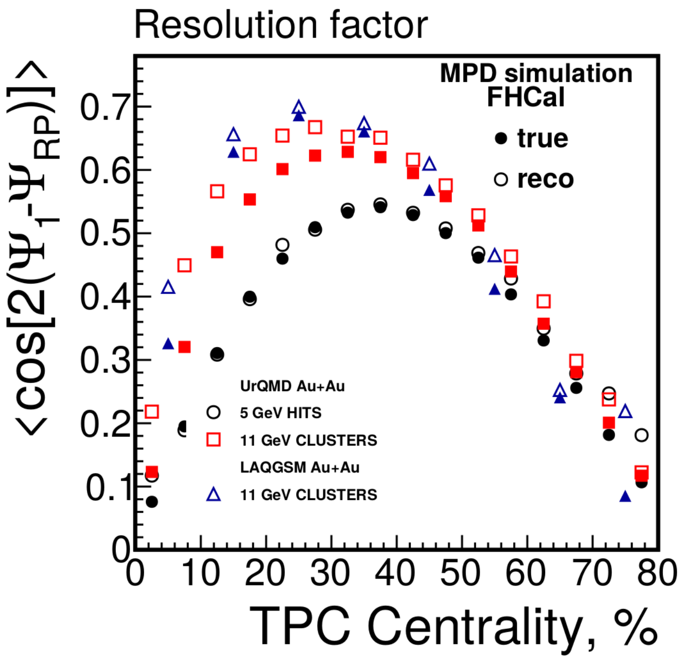
$$R_{n,EP} = \langle \cos(n(\Psi_{n,EP} - \Psi_{RP})) \rangle$$

$R_{n,EP}$ – Resolution correctioin factor

Event plane resolution factor

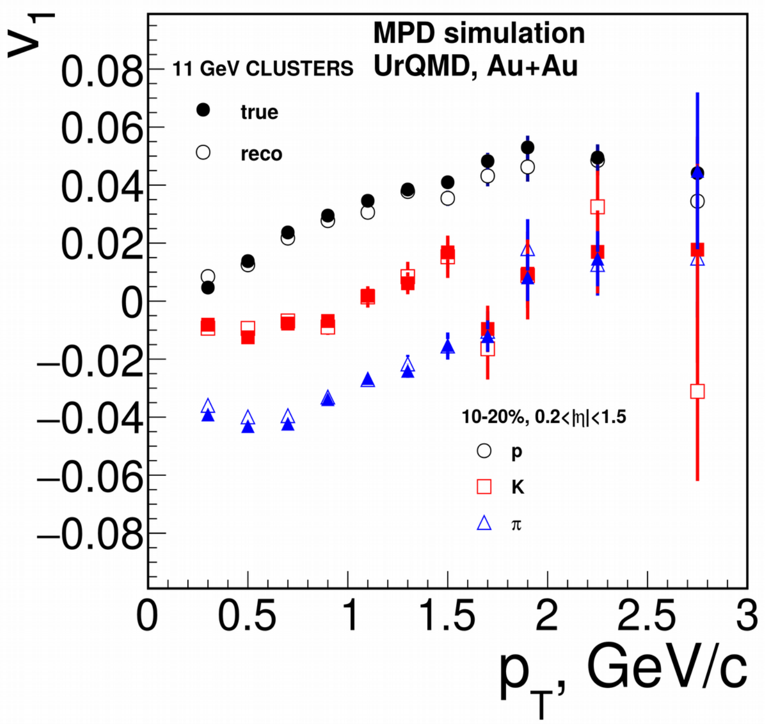
$R_{n,EP}$ appears due to limited accuracy of estimated event plane orientation

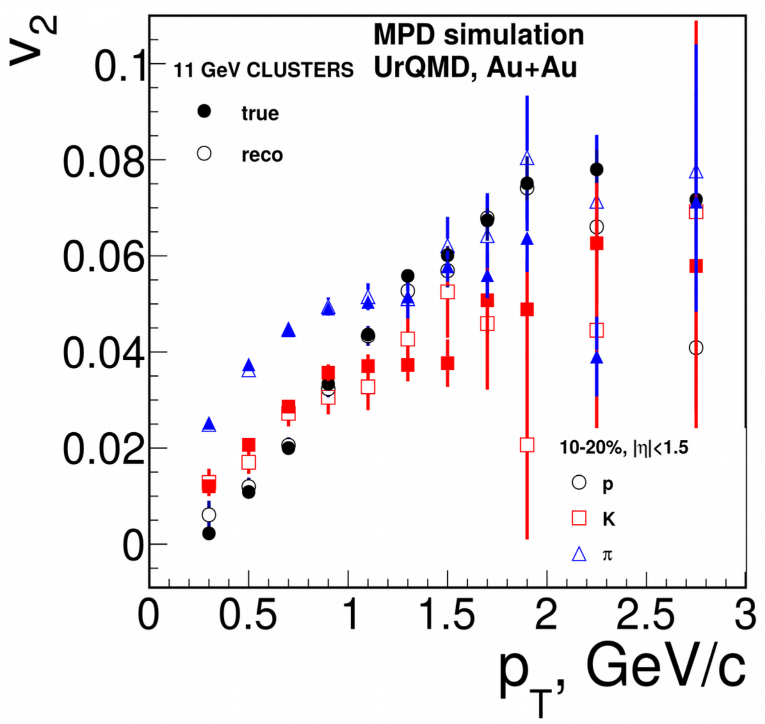




Good performance in the centrality range 0-80%

Directed and elliptic flow as a function of p_T





Both directed and elliptic flow results after reconstruction and resolution correction are comparable to that of MC simulation

Summary

Centrality:

- Track multiplicity in TPC can be used for centrality determination with resolution 5-10%

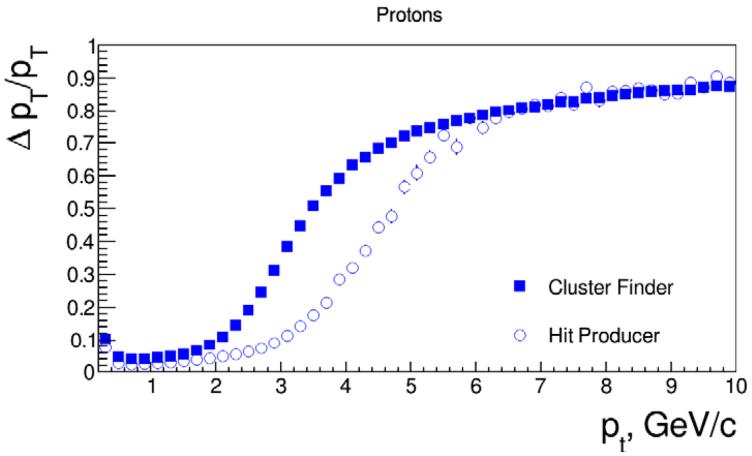
Anisotropic flow:

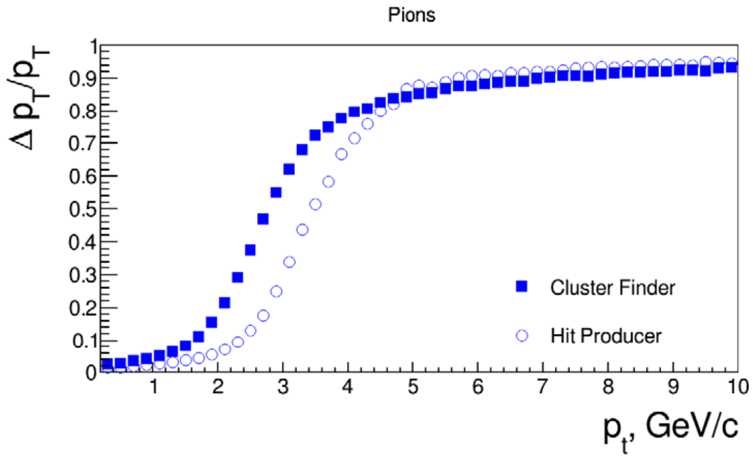
- Event plane orientation can be estimated using energy deposition in FHCal with high resolution factor ($R_{n,EP}\sim 0.9$ for centrality 20-40%)
- Directed and elliptic flow are recovered using event plane method and give correct values

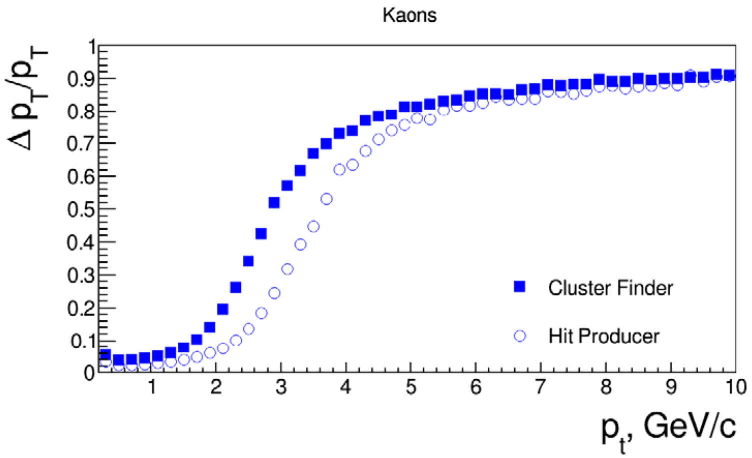
Thank you for your attention

Backup slides

Momentum resolution: simple approach



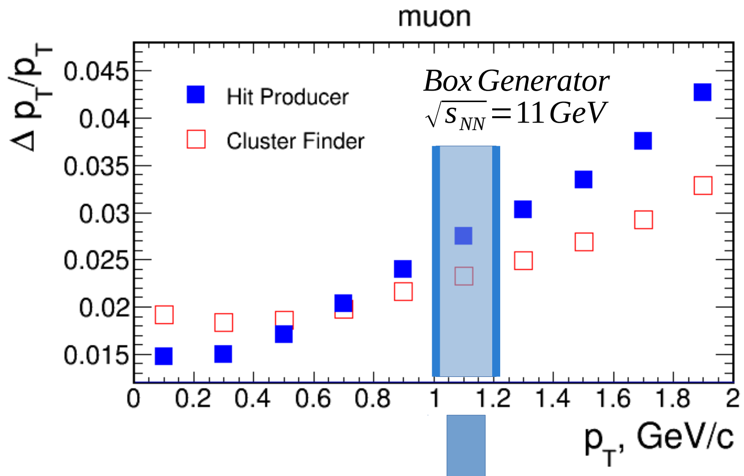




$$\frac{\Delta p_T}{p_T}=\frac{p_T(Monte-Carlo)-p_T(Reconstructed)}{p_T(Monte-Carlo)}$$

Cluster finder gives higher difference between reconstructed and generated p_T

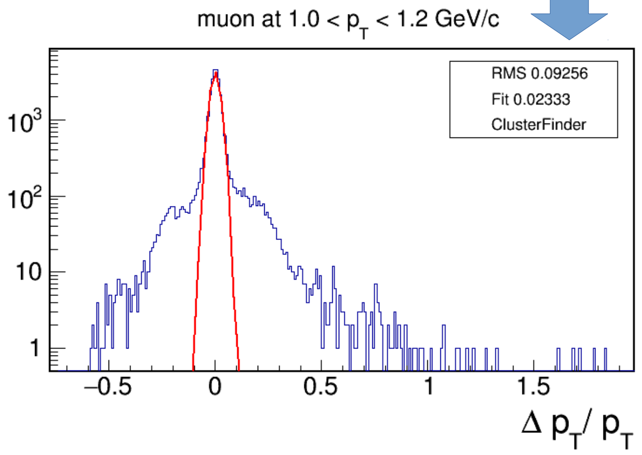
Momentum resolution: fit method

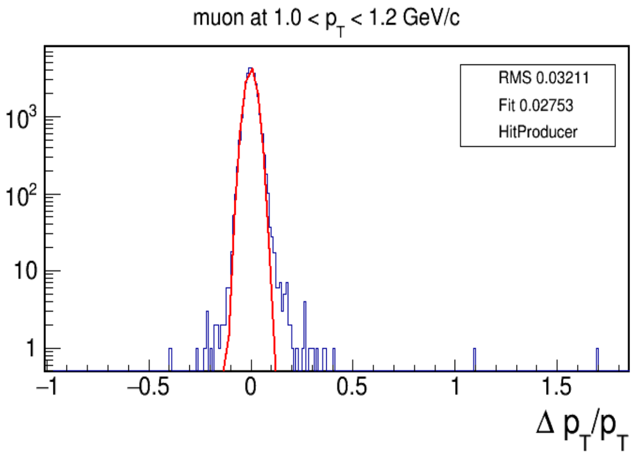


$$\frac{\Delta p_T}{p_T} = \frac{p_T(Monte-Carlo) - p_T(Reconstructed)}{p_T(Monte-Carlo)}$$

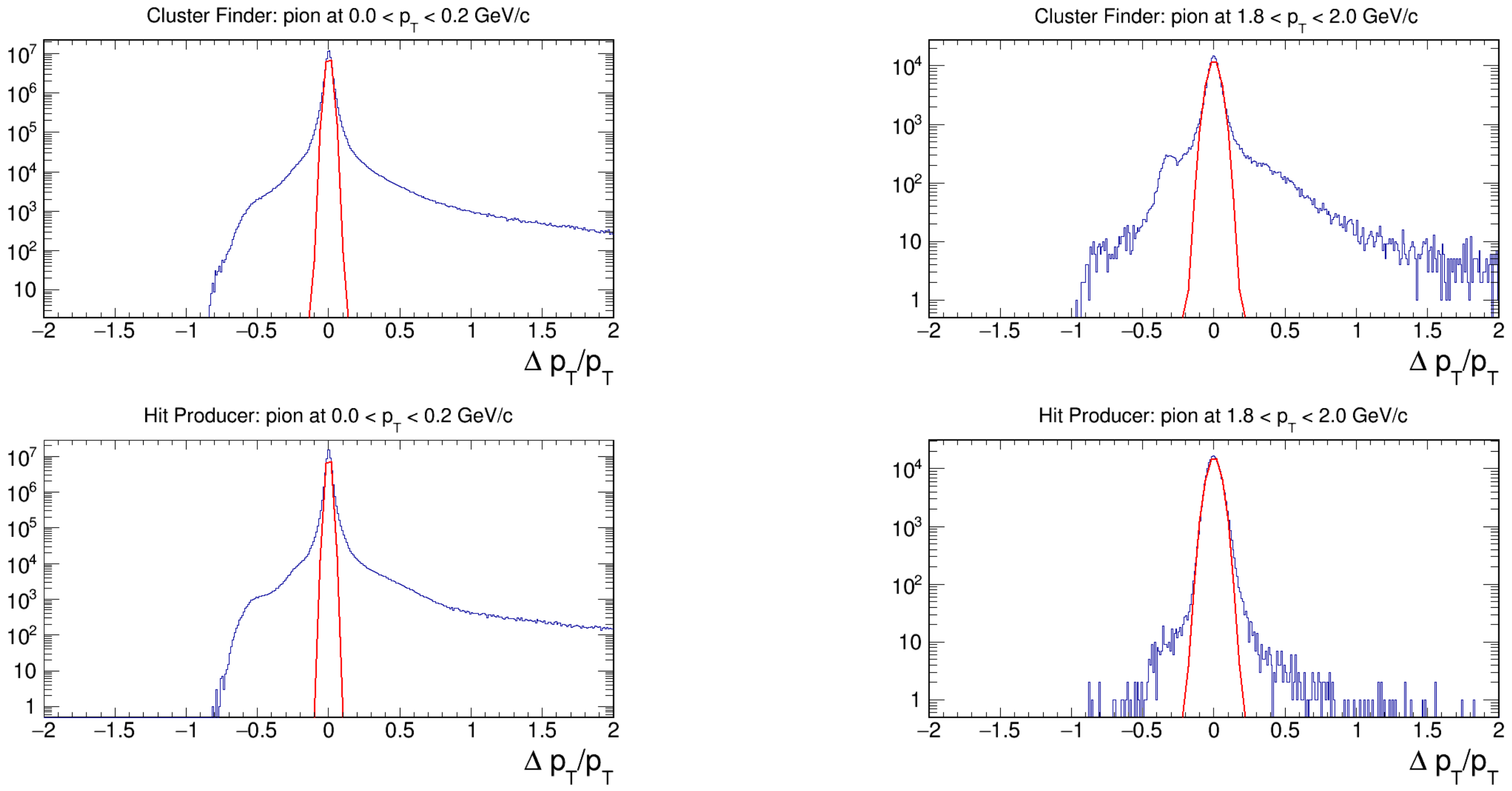
- Profile in each p_T bin has been fitted via gaus
- σ of the fit – is the momentum resolution

Trackings have different background at high p_T

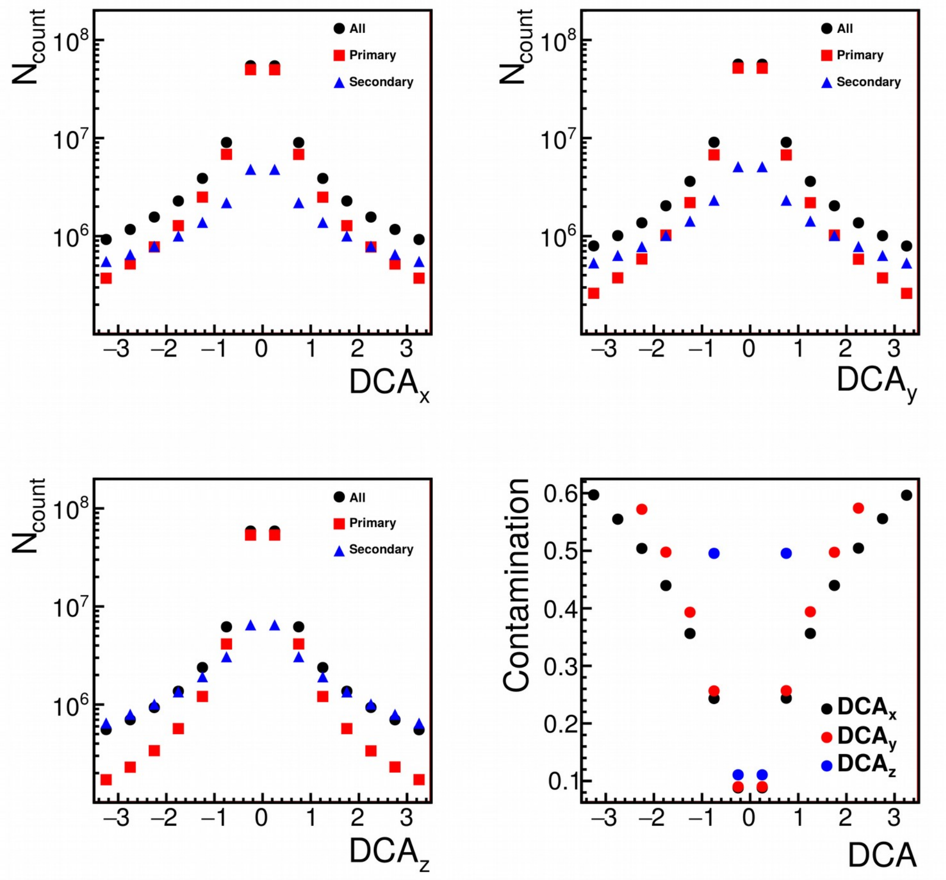




Momentum resolution: profile background



Primary track selection and contamination



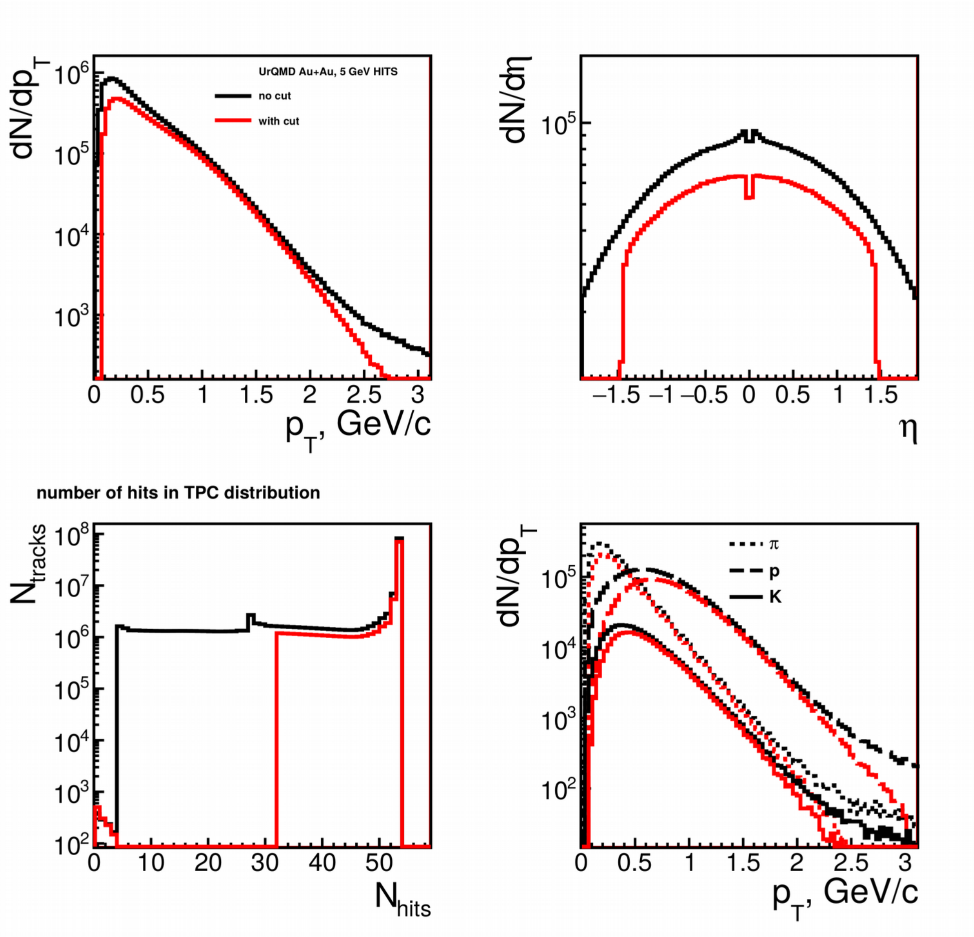
DCA – is the distance of the closest approach between track and primary vertex given from tracking in TPC.

Primary and secondary tracks shown on the figures are given from Monte Carlo **motherID** parameter.

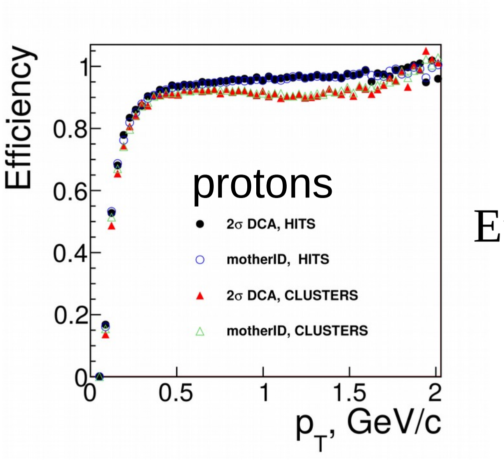
Contamination of the secondary particles (down,right):

$$\text{Contamination} = 1 - \frac{N_{primary}}{N_{all}} \equiv \frac{N_{secondary}}{N_{all}}.$$

Track selection (for v_n)

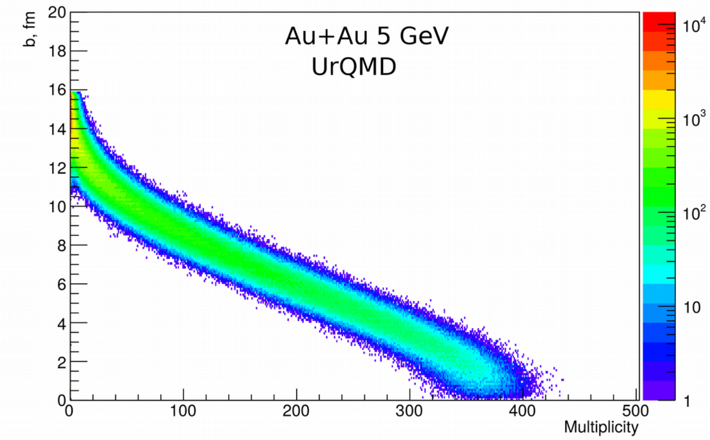


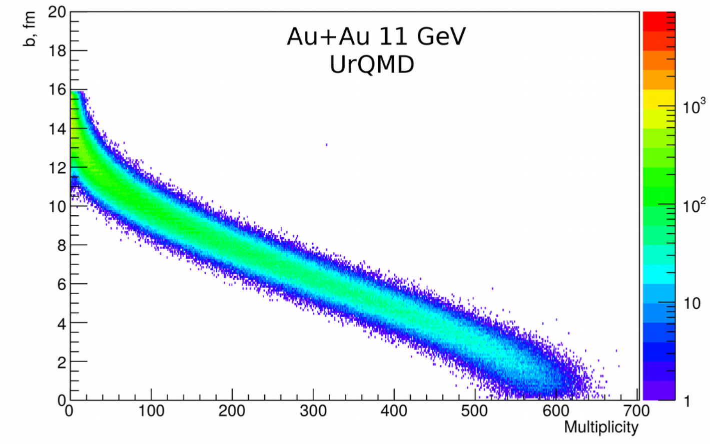
- $N_{TPC\ hits}$ >32
- $|p_T|<3$
- $|\eta|<1.5$
- PID: PDG codes from Geant



$$\text{Efficiency} = \frac{\frac{dN}{dp_T}(reco)}{\frac{dN}{dp_T}(true)}$$

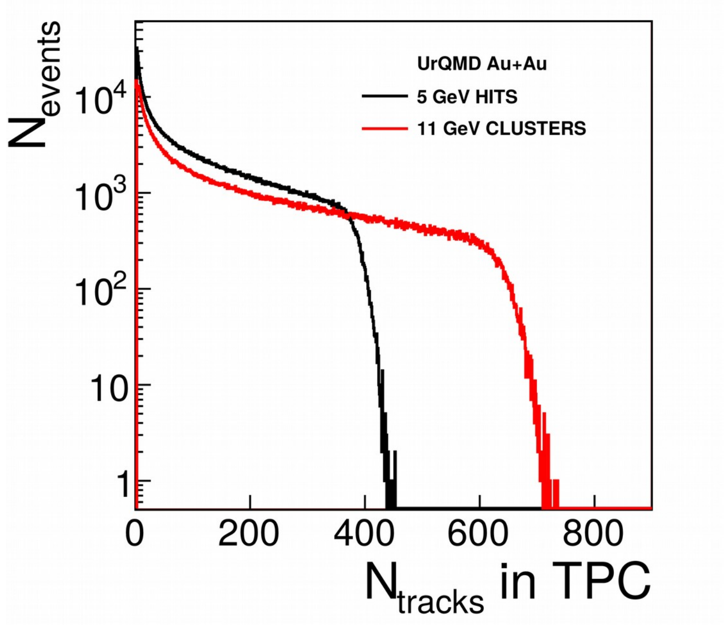
Multiplicity and centrality





Multiplicity distributions of the selected particles were sliced in centrality classes.

multiplicity in TPC



EP method implementation

Q-vectors and Ψ_n were calculated both left and right FHCal parts in order to obtain EP resolution for half of the detector and then for full detector:

$$Q_x^m = \frac{\sum E_i \cos(m\varphi_i)}{\sum E_i}, Q_y^m = \frac{\sum E_i \sin(m\varphi_i)}{\sum E_i}$$

$$\Psi_m^{EP} = \frac{1}{m} ATan2(Q_y^m, Q_x^m)$$

$$m=1 \text{ was used}$$

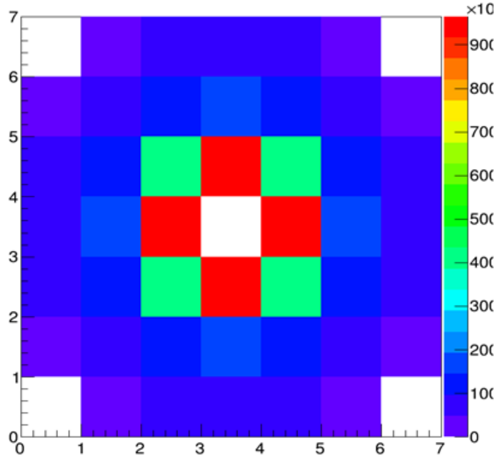
E_i is the energy deposition in *i-th* FHCal module and φ_i is its azimuthal angle. For *m=1* weights had different signs for backward and forward rapidity.

No gain calibration was used.

$$Res^2\{\Psi_n^{EP,L}, \Psi_n^{EP,R}\} = \langle \cos[n(\Psi_n^{EP,L} - \Psi_n^{EP,R})] \rangle$$

$$Res_m\{\Psi_n^{EP,true}\} = \langle \cos[n(\Psi_{RP} - \Psi_n^{EP})] \rangle$$

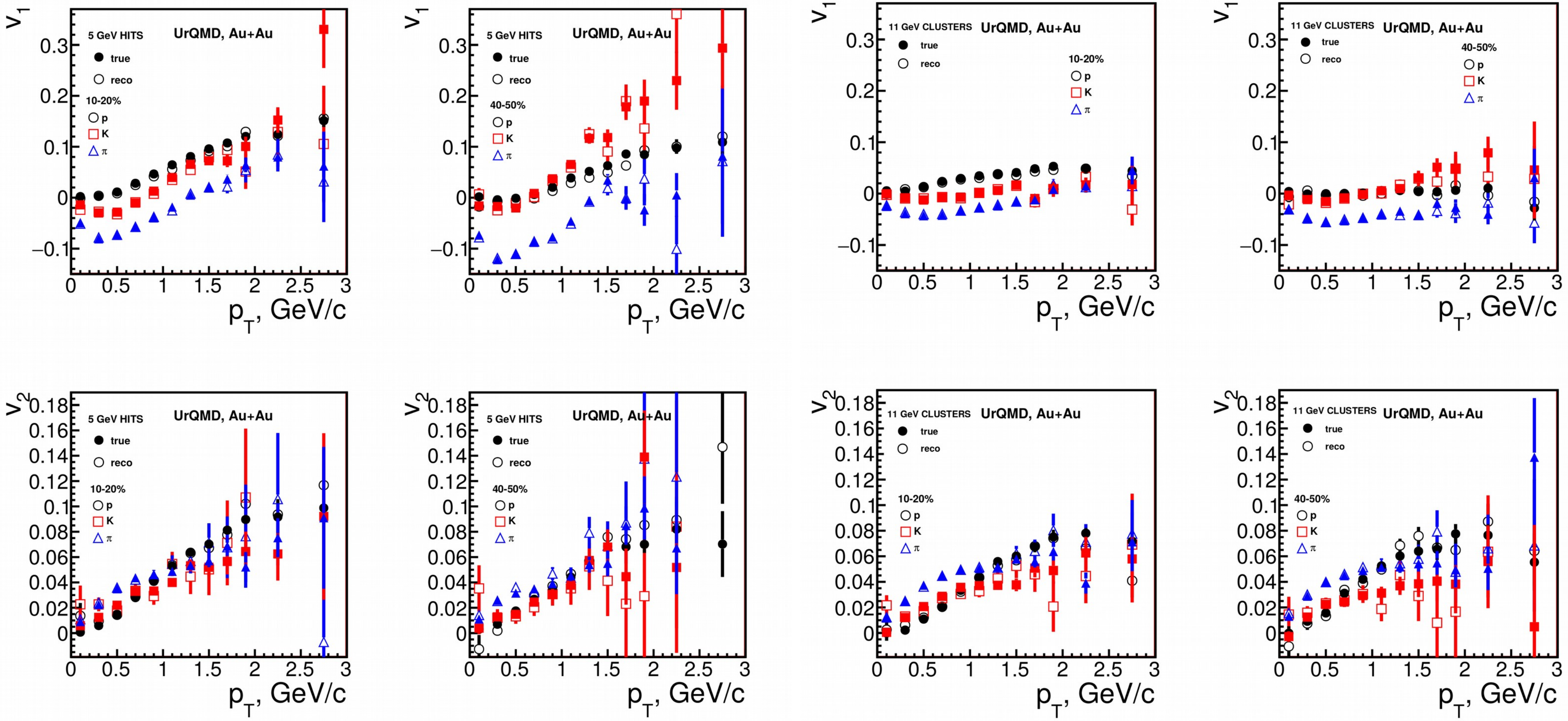
$$v_n = \frac{\langle \cos[n(\Psi_{RP} - \Psi_n^{EP})] \rangle}{Res_m\{\Psi_n^{EP,true}\}}$$



Energy distribution in FHCal

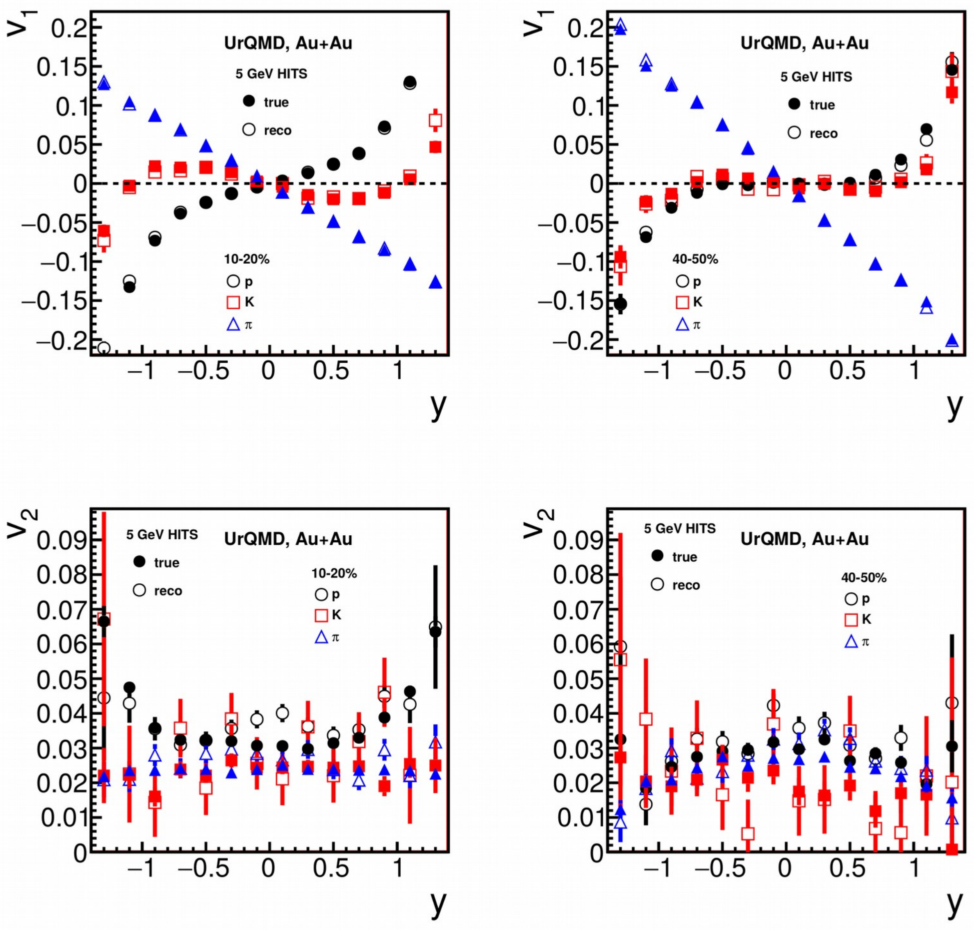
Azimuthal flow as function of p_T

5 GeV 11 GeV



Azimuthal flow as function of *y*

5 GeV



11 GeV