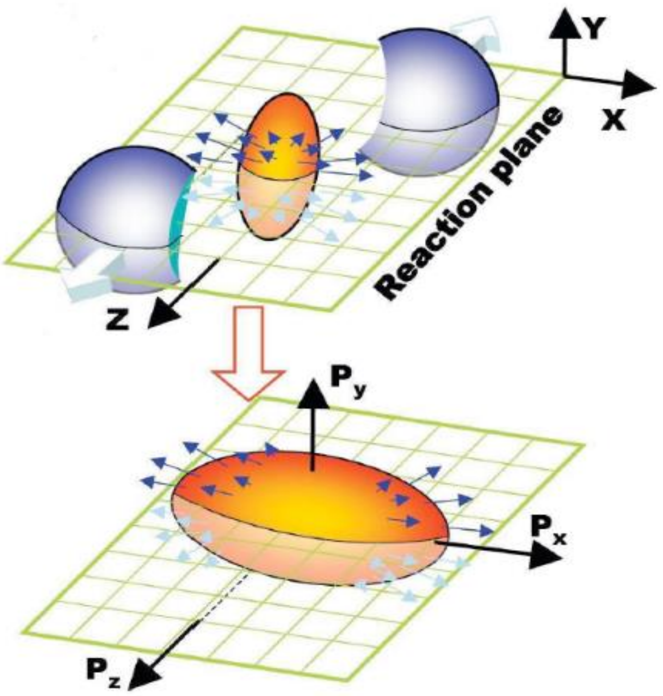
Flow performance in MPD at NICA

Peter Parfenov (MEPhI)
Ilya Svintsov (MEPhI)
Ilya Selyuzhenkov (GSI, MEPhI)
Arkadiy Taranenko (MEPhI)

ICPPA Moscow
11.10.2016

Anisotropic transverse flow



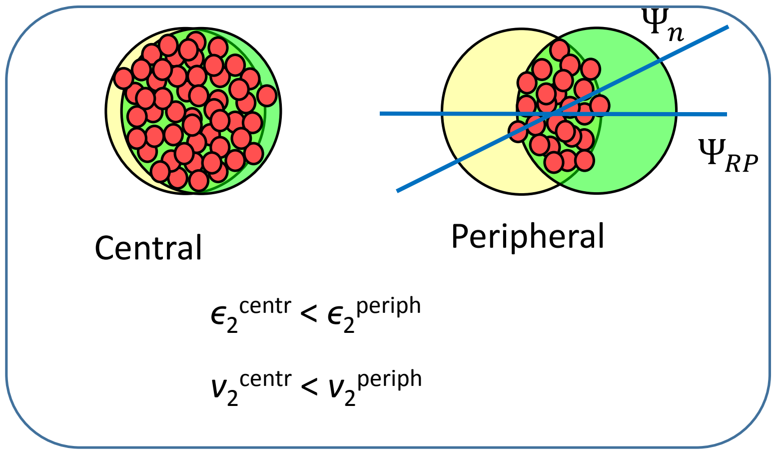
Space anisotropy

Momenta anisotropy

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

$$v_n = \langle cos[n(\varphi - \Psi_{RP})]\rangle$$

Anisotropic transverse flow



Reaction plane Ψ_{RP} is an abstract value. In reality we talk about symmetry plane Ψ_n

$$v_n = \langle cos[n(\varphi - \Psi_n)]\rangle$$

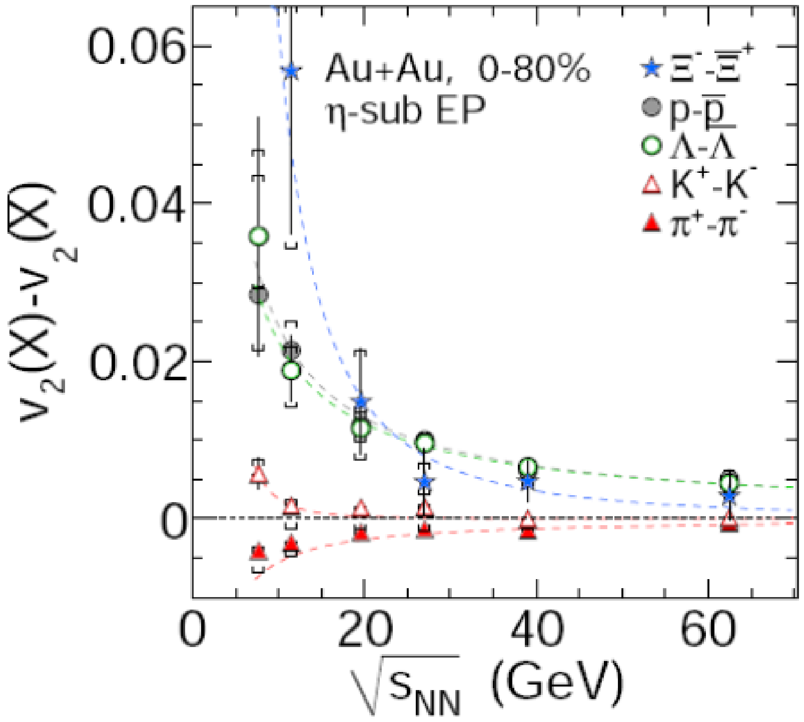
$$\epsilon_n = \frac{\sqrt{\langle r^2 \cos(n\phi_{part})\rangle^2 + \langle r^2 \sin(n\phi_{part})\rangle^2}}{\langle r^2\rangle}$$

$n - th$ flow harmonic with respect to $n - th$ order symmetry plane.

v_1 is called directed flow
v_2 is called elliptic flow

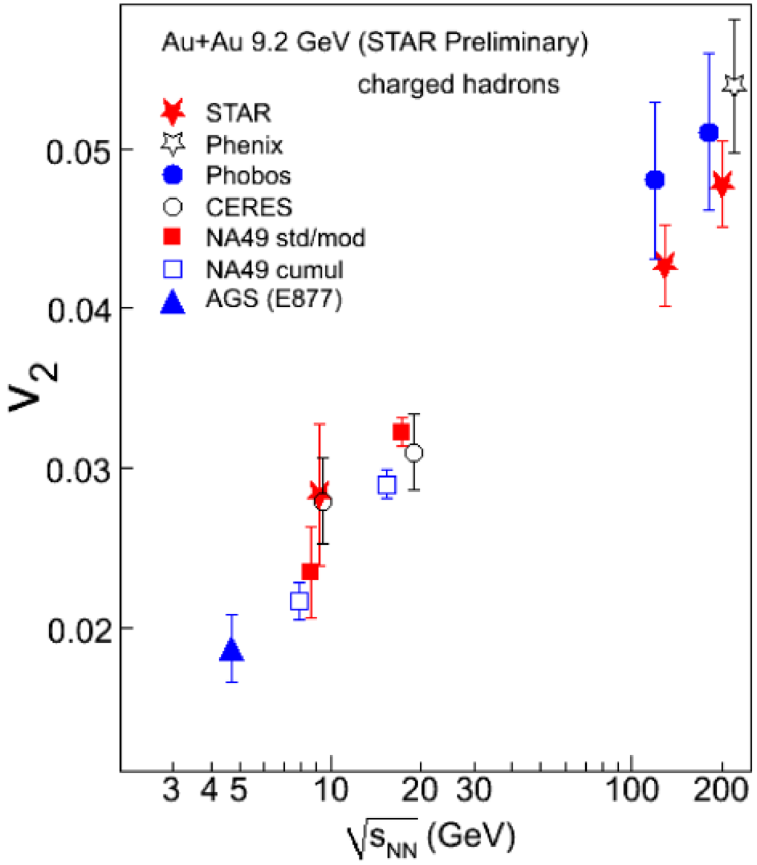
Flow physics at NICA

NICA beam energy range $4 < \sqrt{s_{NN}} < 11\ GeV$



The difference between flow of particles and antiparticles increases with energy decreasing. That causes the number of quark scaling violation at low energies.

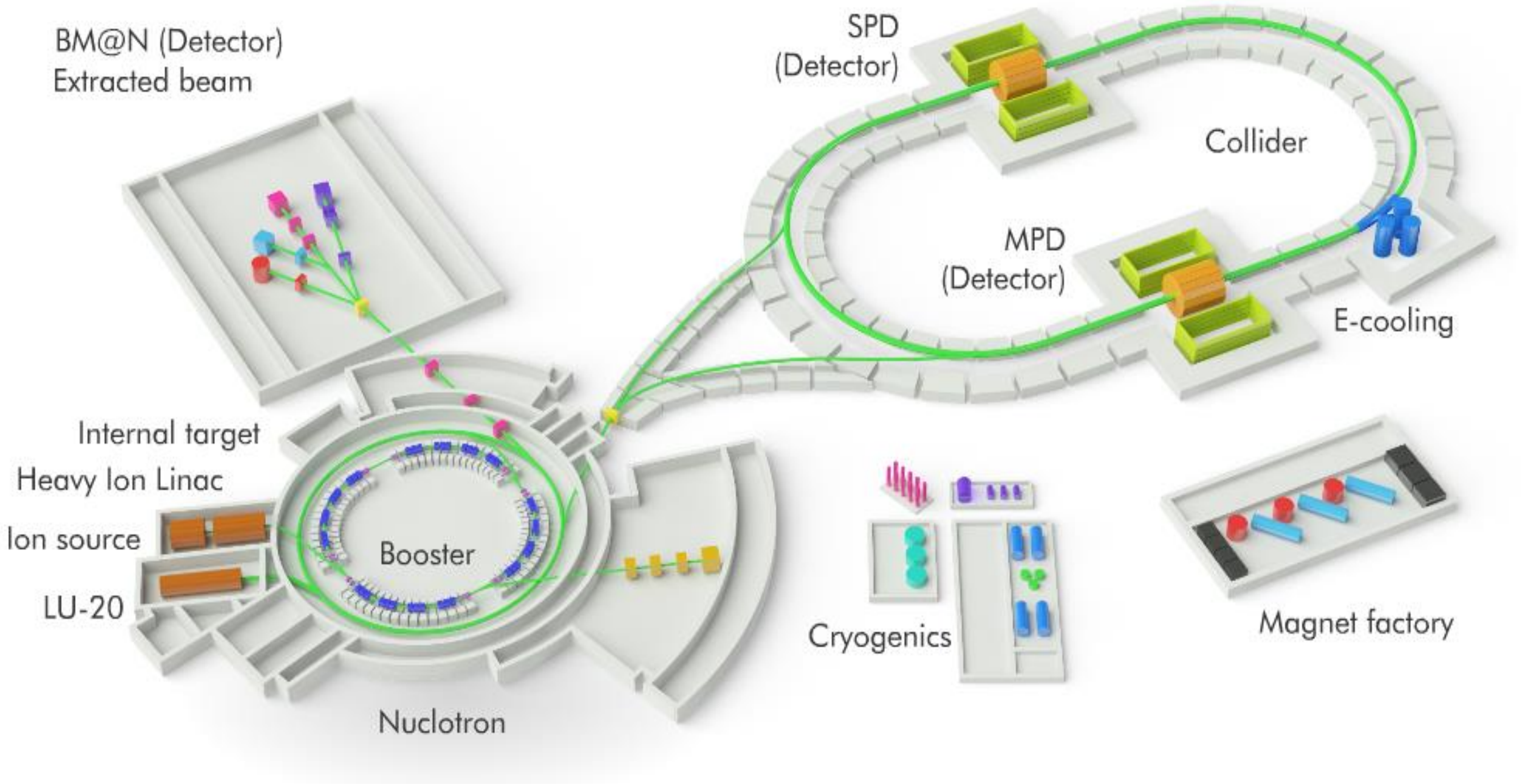
arXiv:1509.08397(2015)



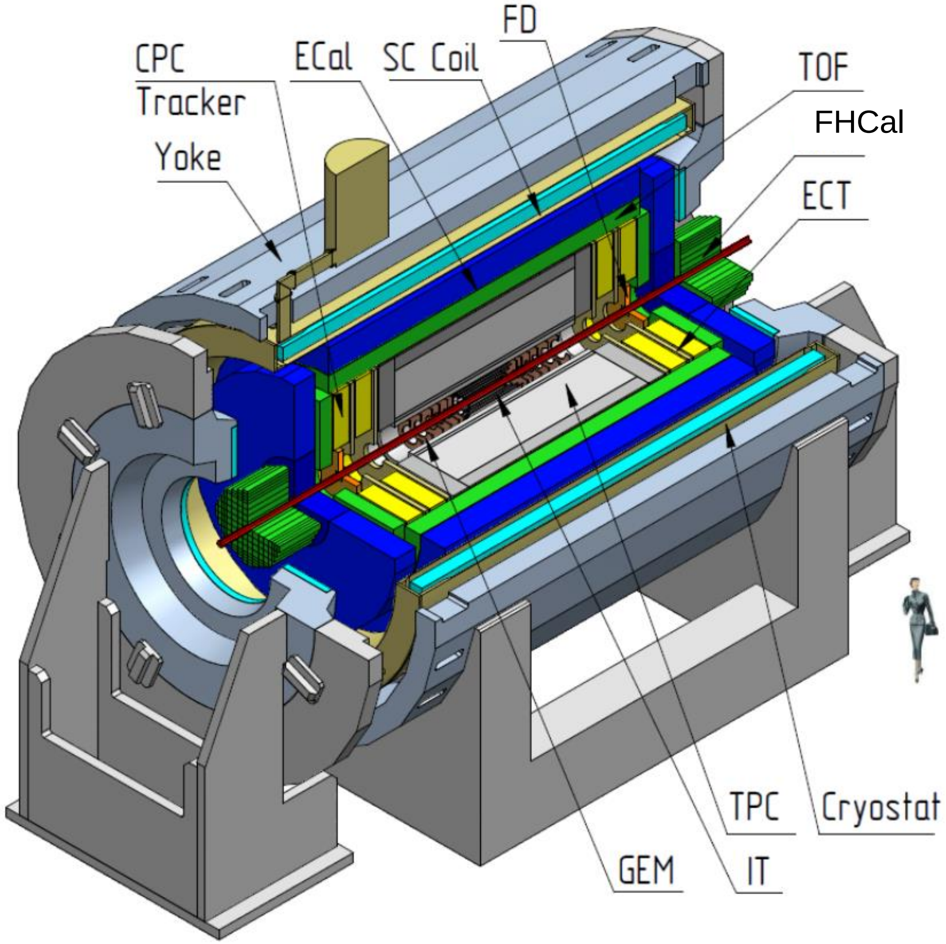
At SPS energies v_2 energy dependence for baryons is not yet established. More detailed measurements are needed.

W. Zajc, "Quark matter 2009"

NICA complex



Multi-Purpose Detector (MPD) at NICA

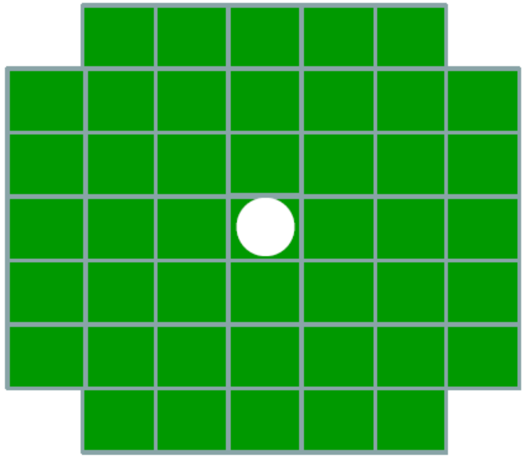


Used detectors:

- TPC for tracking (p_t, η, ϕ) and particle identification $(\frac{dE}{dx})$
- FHCal for event plane reconstruction
- TOF – for m^2 particle identification for higher p_t

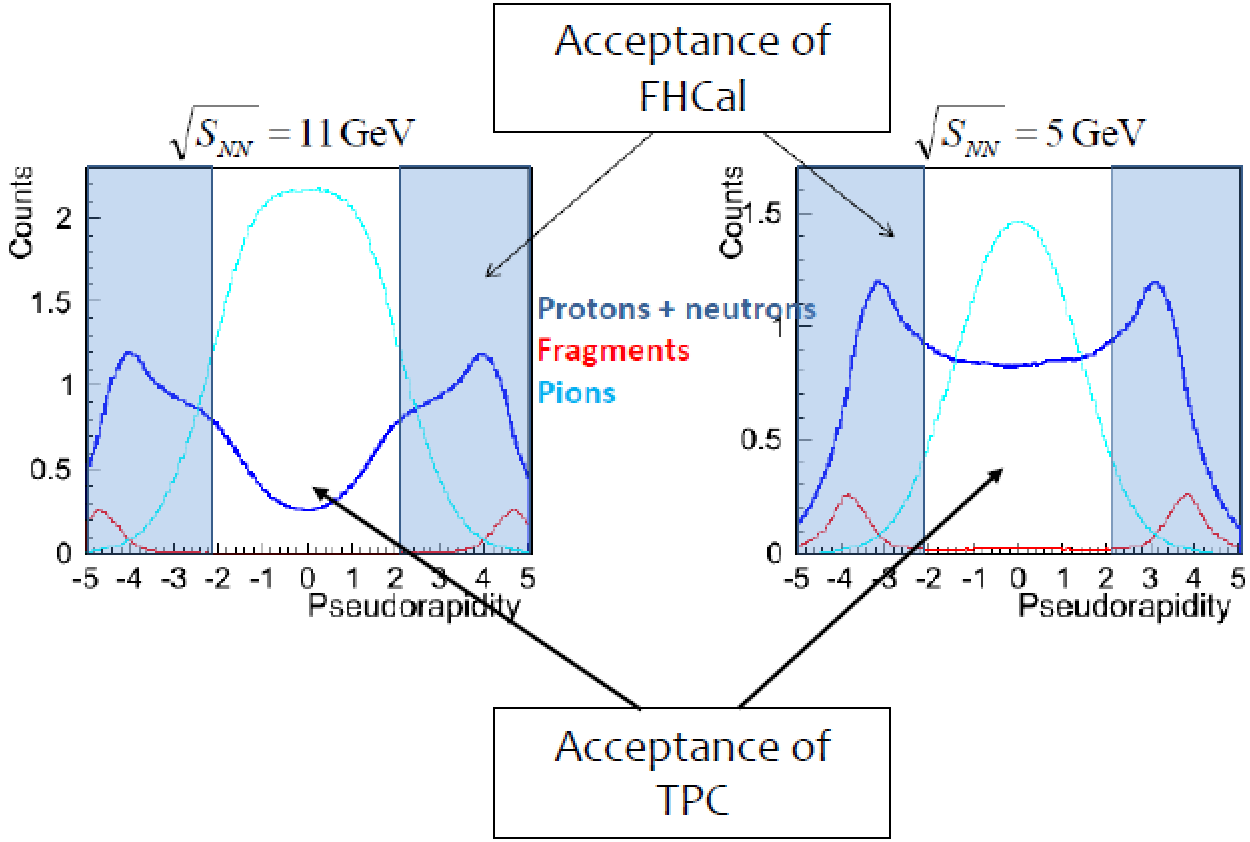
TPC and FHCal acceptance and transverse layout

FHCal detector geometry



45 modules 15 × 15 cm each.

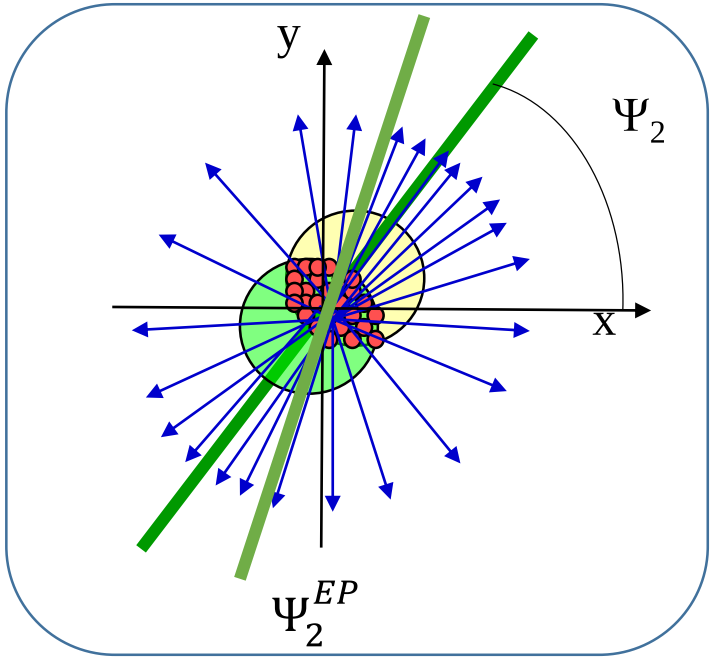
This level of granularity is found to be optimal for experimental needs.



Event plane method

Event plane angle is an estimation of reaction plane.
Q-vector is used for calculation of event plane angle:

$$\vec{Q} = \left\{\sum_i \omega_i \cos(n\phi_i), \sum_i \omega_i \sin(n\phi_i),\right\}$$



Where the sum goes over given set of particles. Then event plane angle calculated as

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

In order to exclude detector acceptance effects and get v_n one should calculate EP resolution factor

$$Res_n\{\Psi_m^{EP}\} = \langle\cos(n(\Psi_m^{EP} - \Psi_m))\rangle$$

$$v_n = \frac{\langle\cos(n(\phi - \Psi_n^{EP}))\rangle}{Res\{\Psi_n^{EP}\}}$$

We get $Res_n\{\Psi_m^{EP}\}$ using 2-subevent method

EP method implementation

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

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

$$\Psi_m^{EP} = \frac{1}{m} Atan2(Q_y^m, Q_x^m)$$

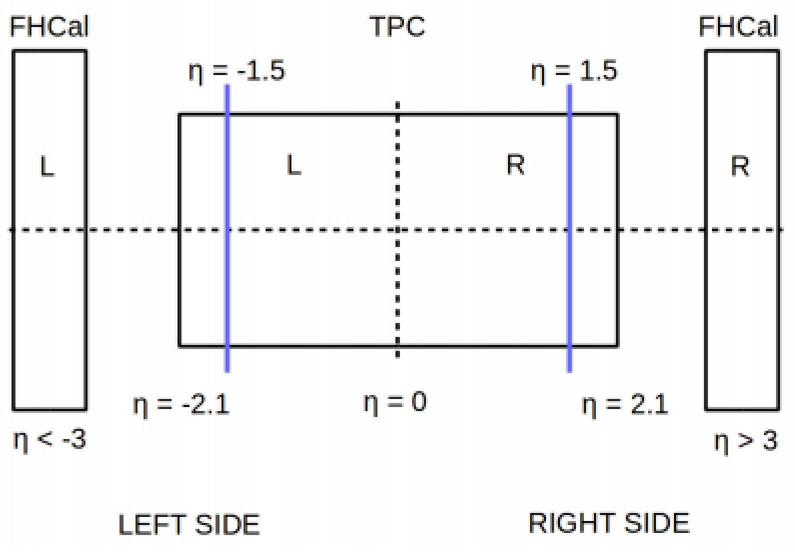
m=1 was used

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.

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

$$v_n = \frac{\langle \cos(n(\phi - \Psi_n^{EP}))\rangle}{Res\{\Psi_n^{EP}\}}$$

ϕ is taken from TPC



Setup and analysis cuts

UrQMD
LAQGSM

Particles →

Geant4 → Reconstruction → Flow analysis

- Au+Au
- $\sqrt{s_{NN}} = 11\ GeV(2M)$,

- TPC
- FHCal
- TOF
- ECal
- …

Track cuts:
- $|p_t| < 3$
- $|\eta| < 1.5$
- $N_{TPC\ hits} > 15$
- $\text{MotherID} = -1$
- PID: PDG codes from Geant

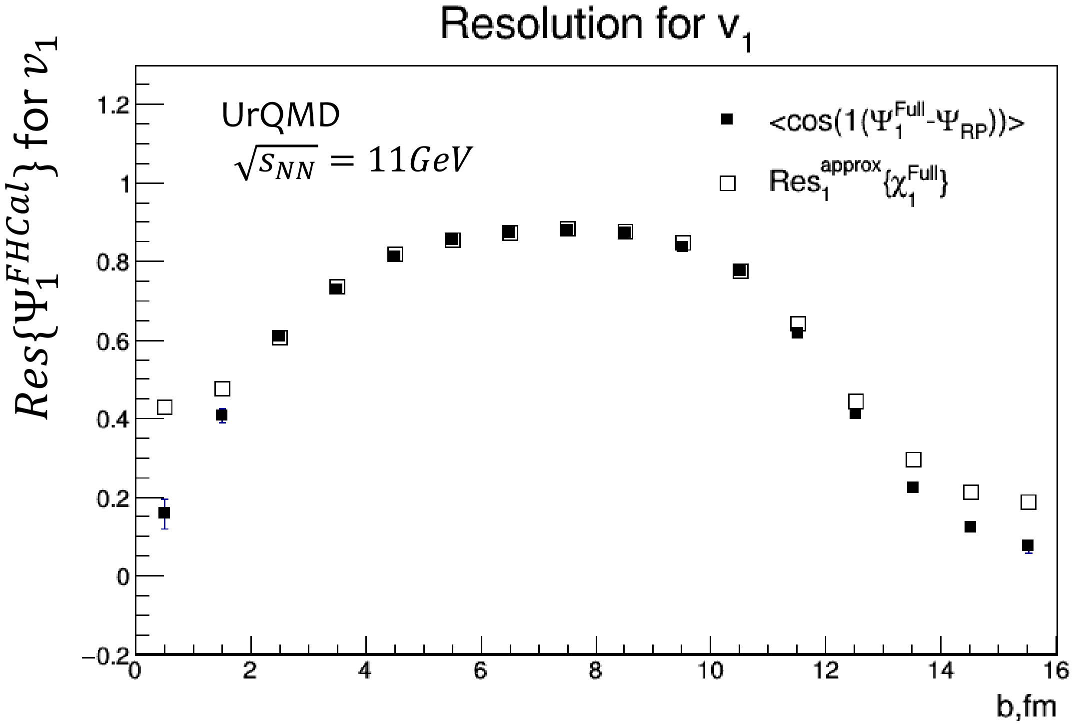
Event selection:
- Impact parameter (b)

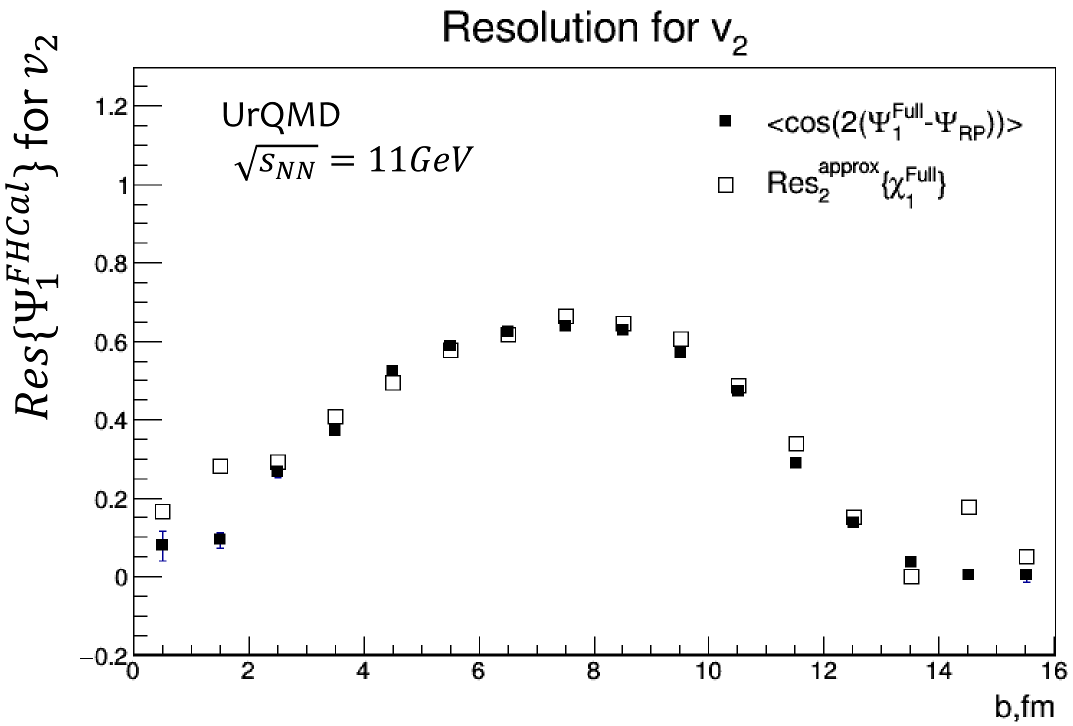
- Old tracking: hit producer
- New tracking: cluster finder

MPDRoot, July 2016

Event plane resolutions

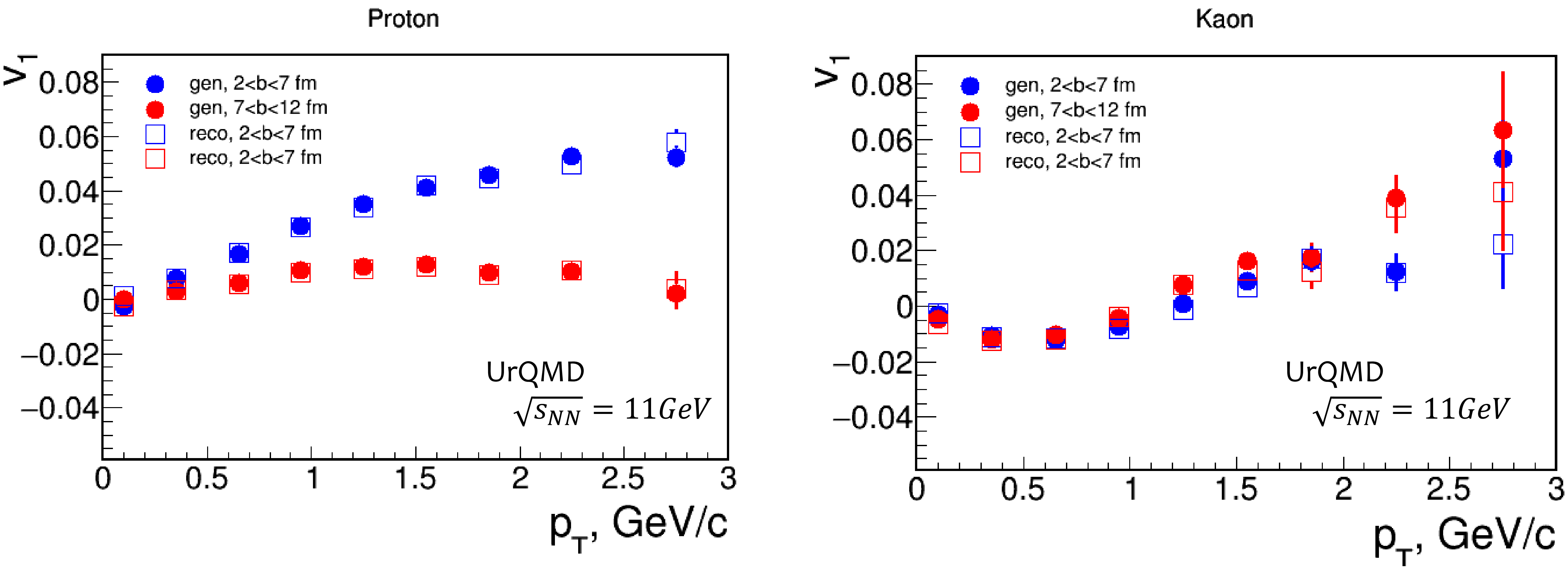
Obtained using 2-subevent method.





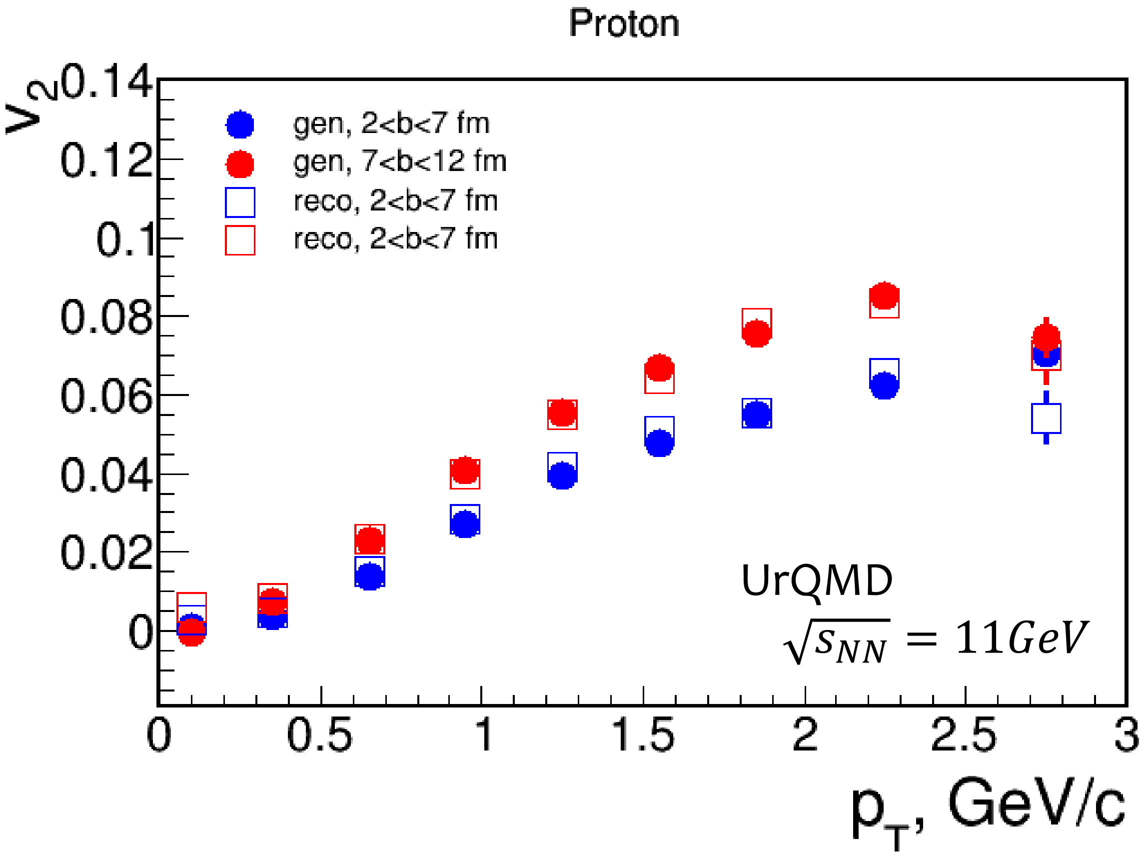
Statistical errors aren't shown.
There's the difference for central and peripheral collisions which we're trying to explain.

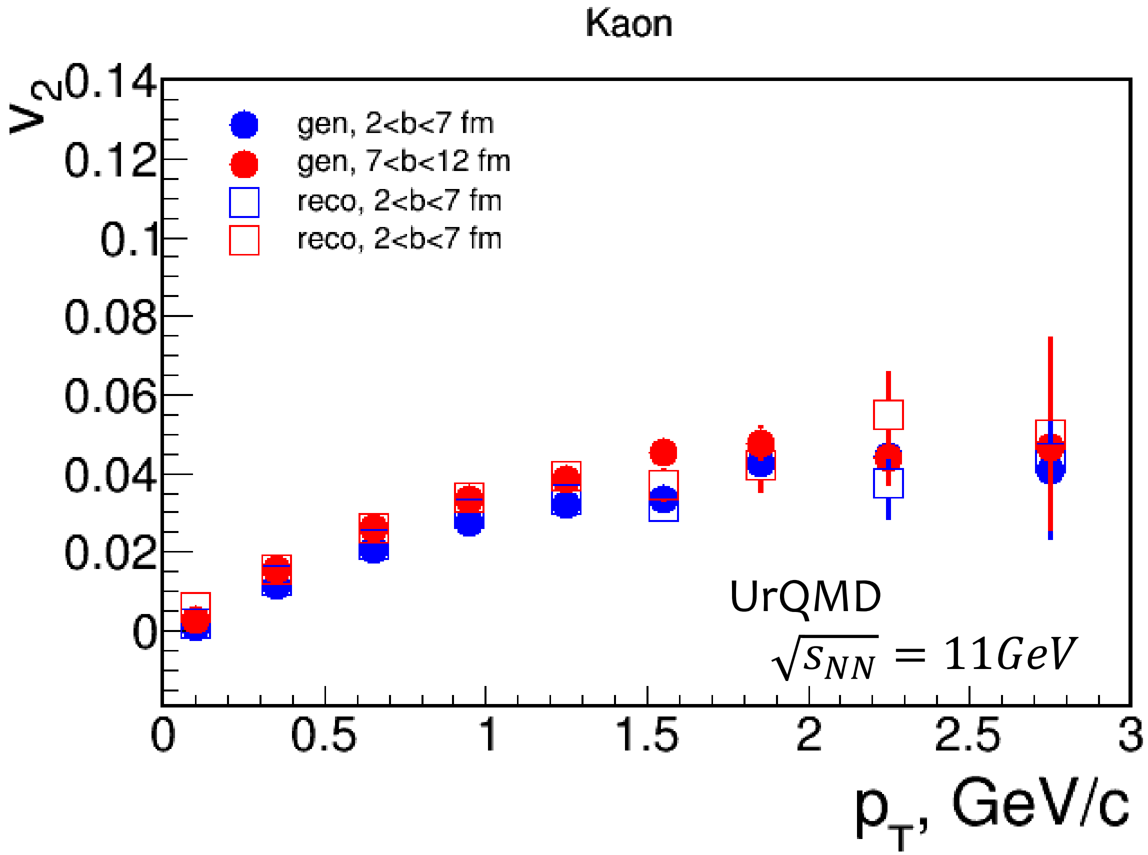
Directed flow for p, K



Agreement between reco/gen values indicates that we can measure v_1 using 2M statistics up to 3 GeV/c for protons and 2.5 GeV/c for kaons in 2 < b < 12 centrality range

Elliptic flow for p, K

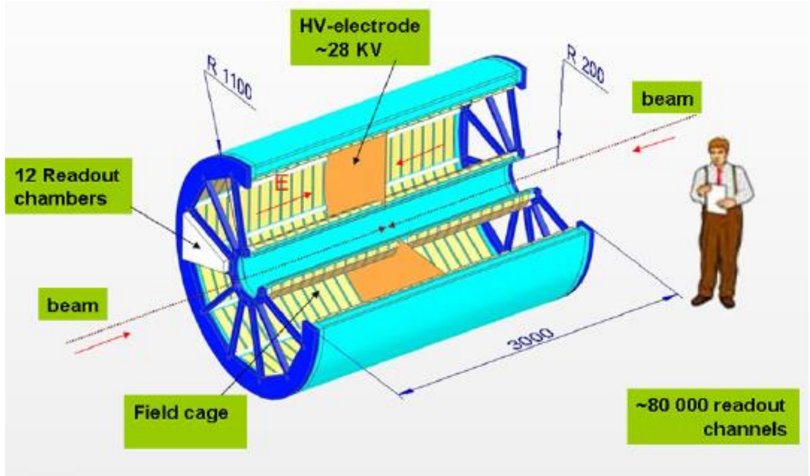




Agreement between reco/gen values indicates that we can measure v_2 using 2M statistics up to 3 GeV/c for protons and kaons in 2 < b < 12 centrality range

Tracking: Cluster Finder and Hit Producer

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



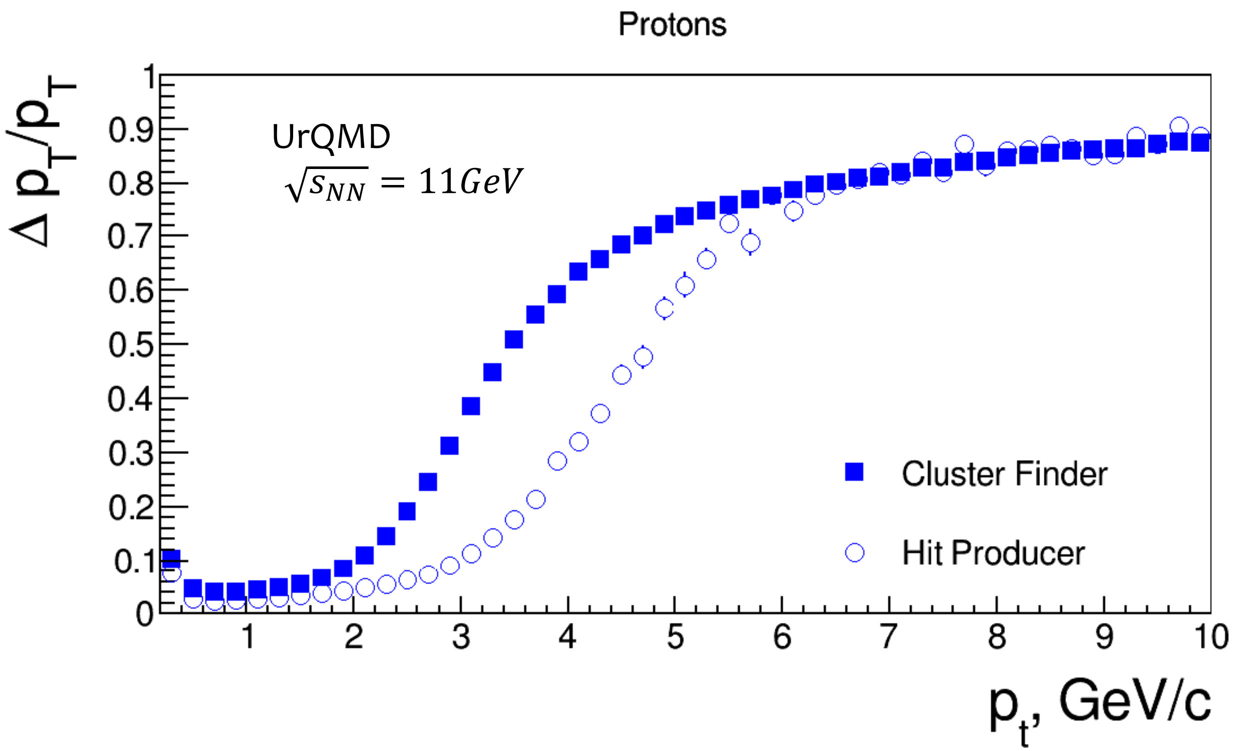
Time Projection Chamber

$$v_n = \frac{\langle \cos(n(\phi - \Psi_n^{EP})) \rangle}{Res\{\Psi_n^{EP}\}}$$

ϕ is taken from TPC

See MPD DAC 15-16 December 2015:http://indico.jinr.ru/materialDisplay.py?contribId=12&materialId=1&confId=1487

Momentum resolution



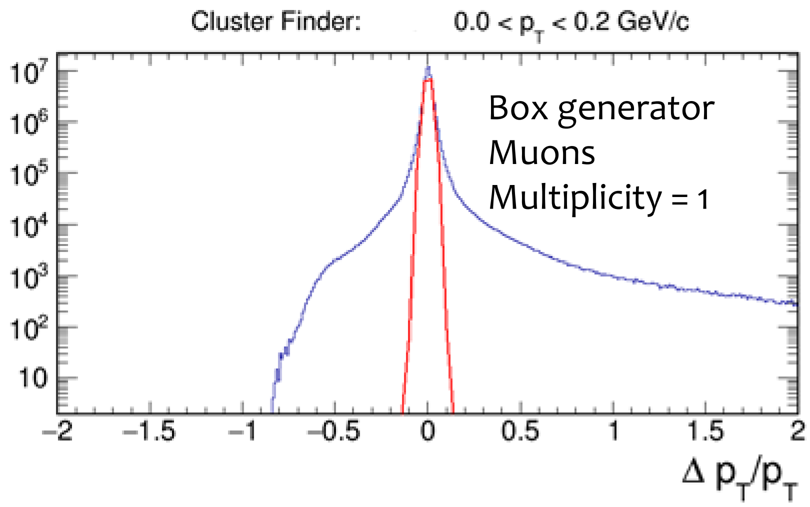
$$\frac{\Delta p_T}{p_T} = \frac{|p_T(Generated) - p_T(Reconstructed)|}{p_T(Generated)}$$

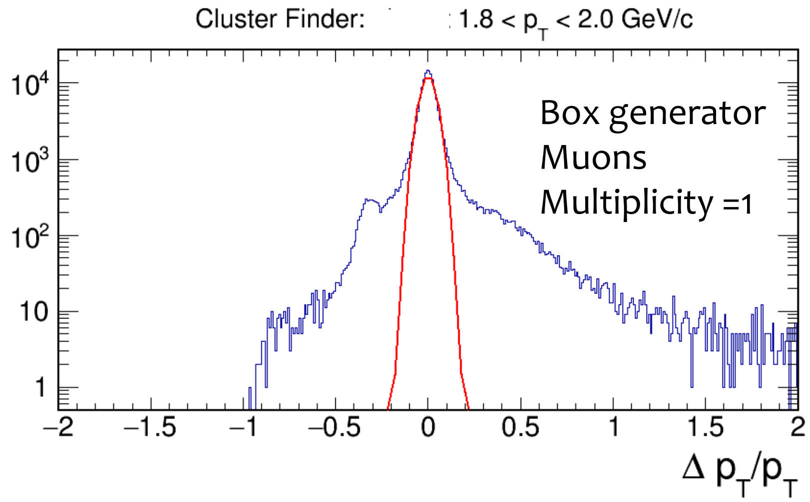
Cluster finder gives higher difference between reconstructed and generated p_T

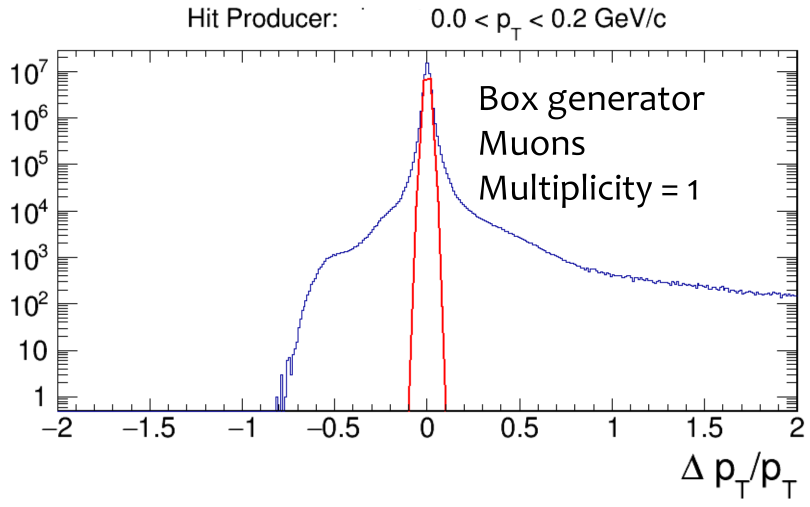
Momentum resolution

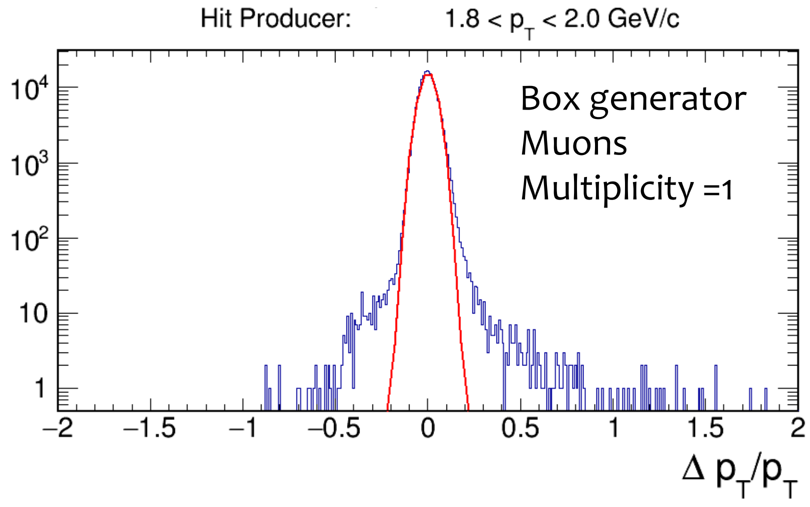
$$\frac{\Delta p_T}{p_T} = \frac{p_T\,(gen) - p_T(reco)}{p_T(gen)}$$

Profiles of momenta resolution slices were fit via Gaussian.
Two trackings have different background at high p_T.



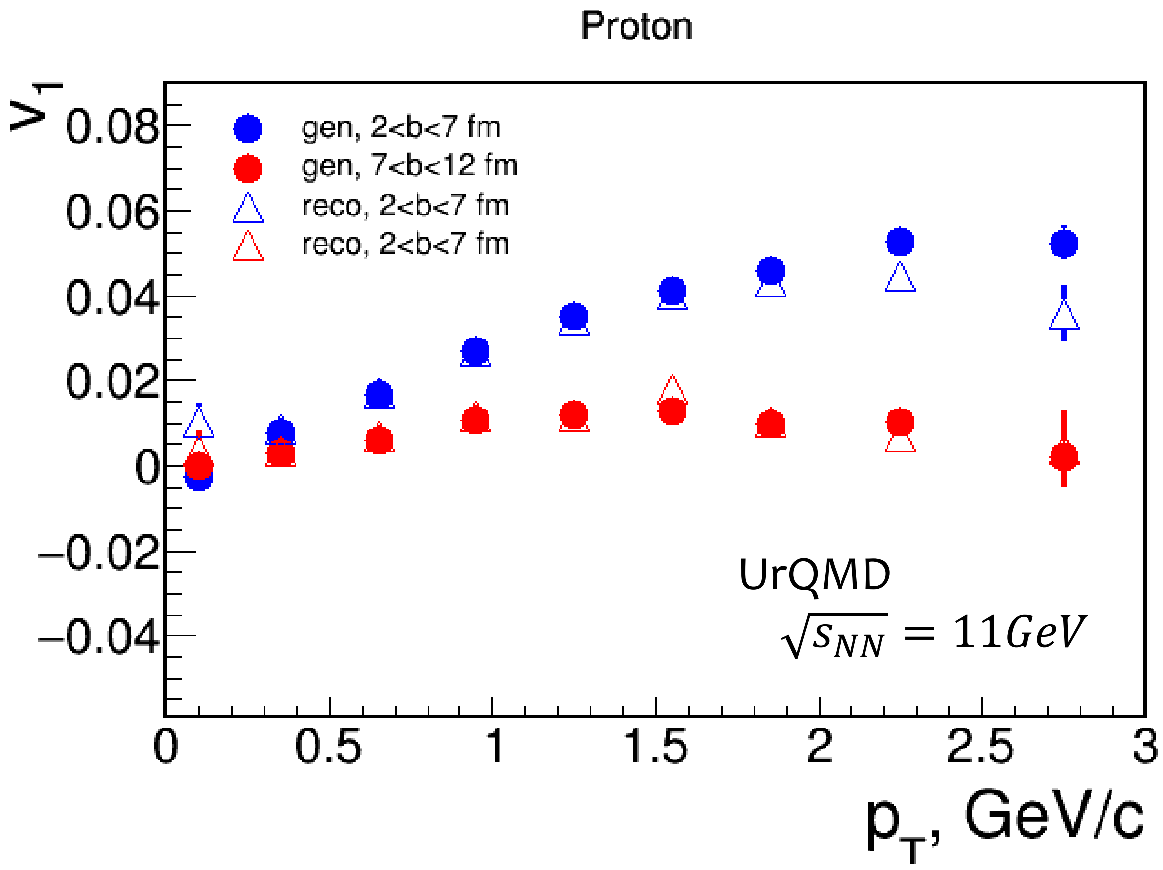


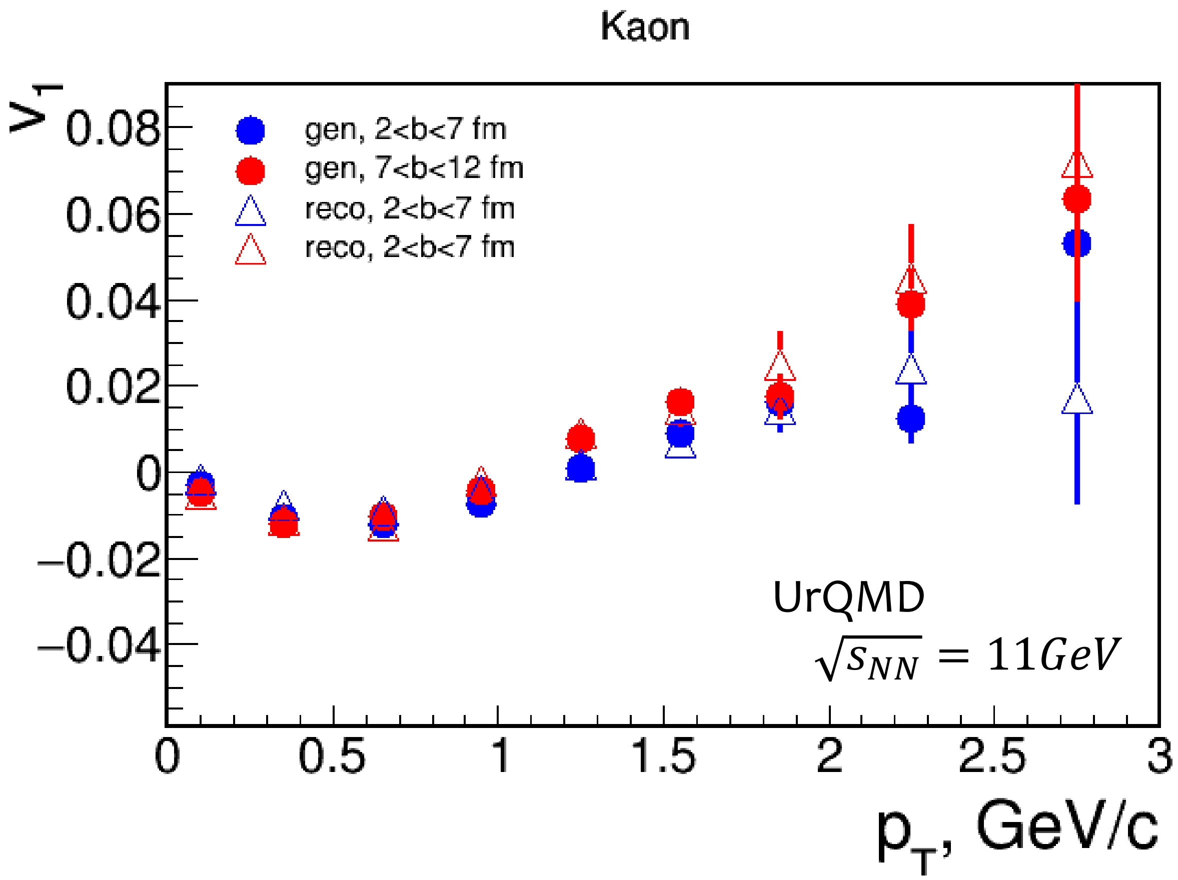




Directed flow for p, K

Cluster finder 2σ cut

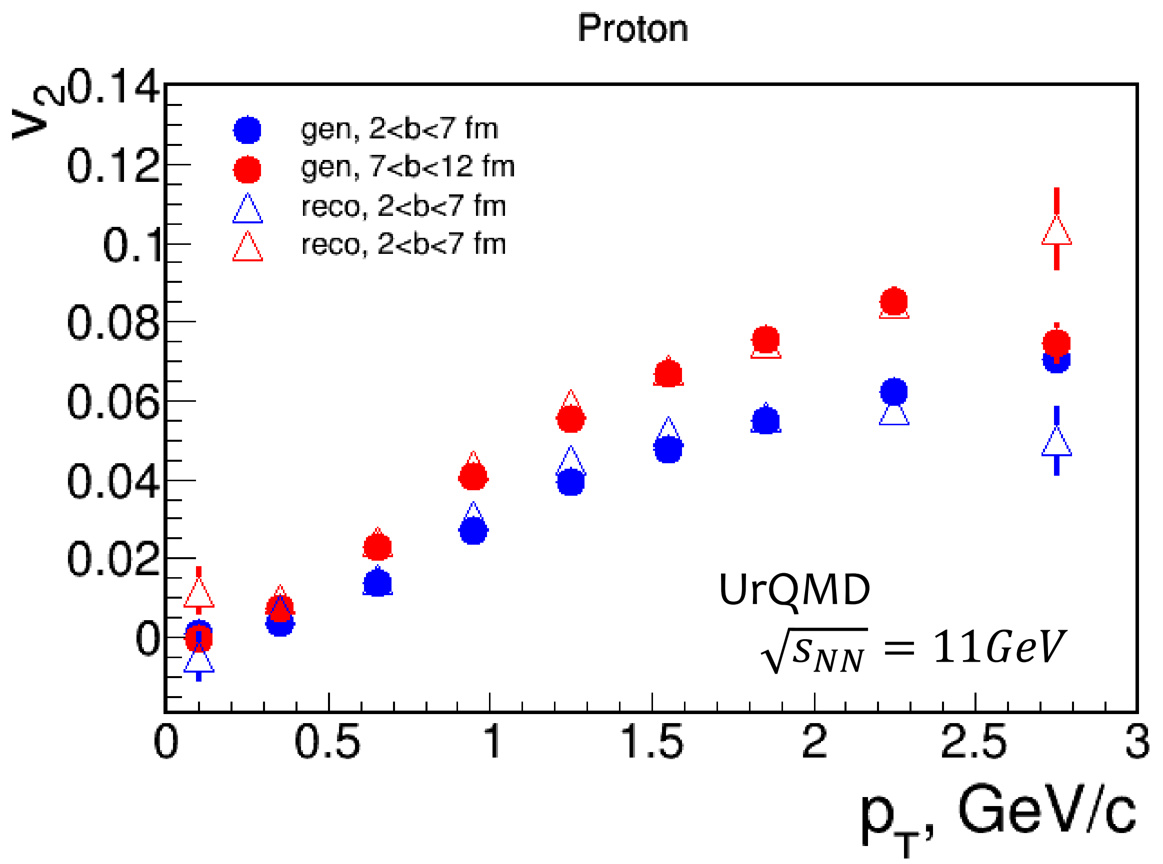


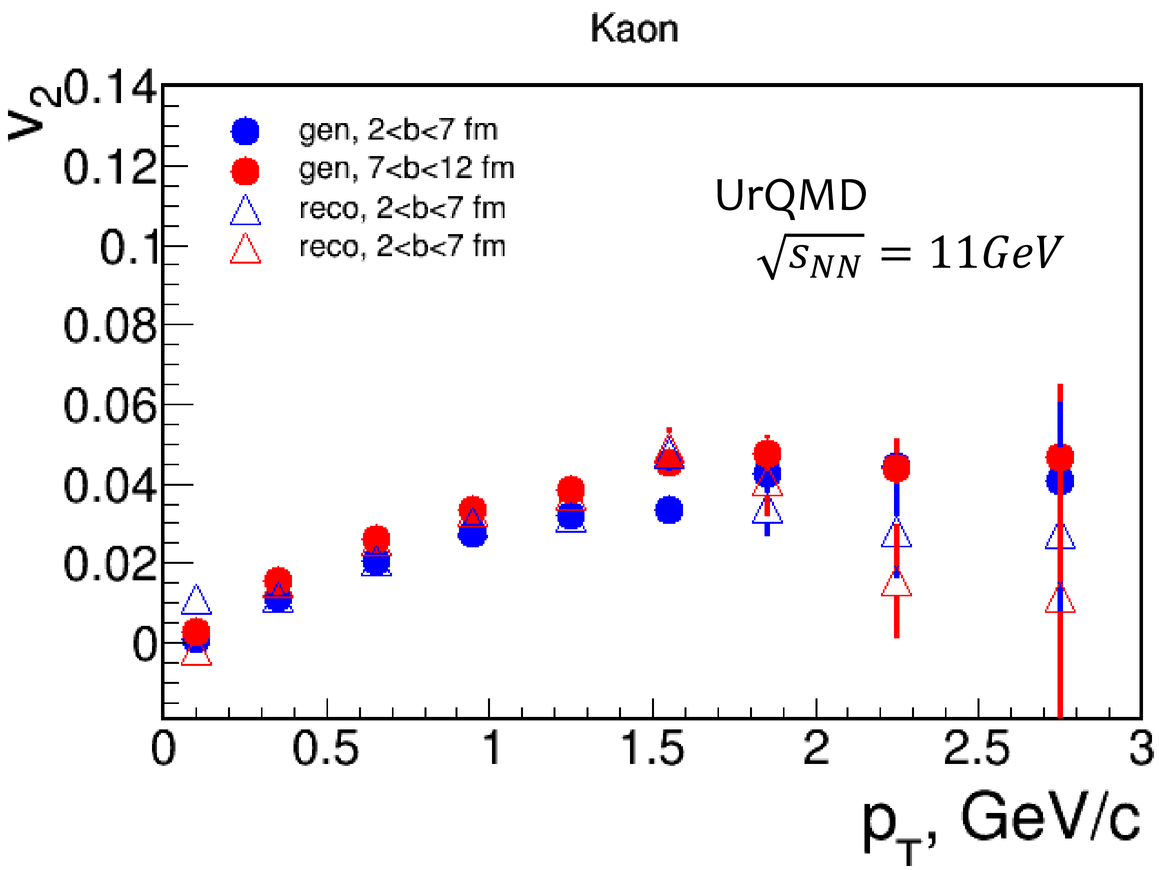


Agreement between reco/gen values indicates that we can measure v_1 using 2M statistics up to 2 GeV/c for protons and 3 GeV/c for kaons in 2 < b < 12 centrality range

Elliptic flow for p, K

Cluster finder 2σ cut





Agreement between reco/gen values indicates that we can measure v_2 using 2M statistics up to 2.5 GeV/c for protons and3 GeV/c for kaons in 2 < b < 12 centrality range

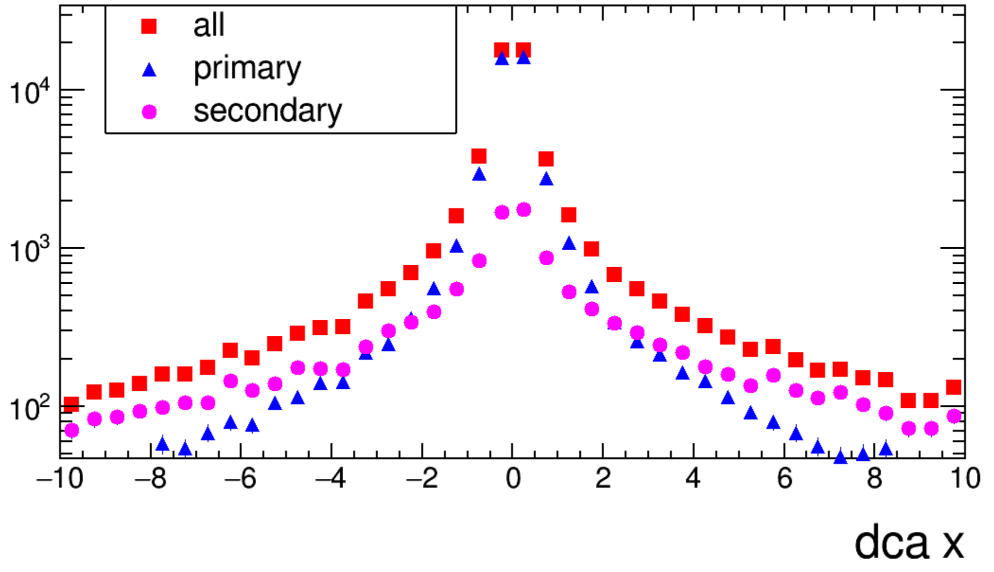
Summary

- Directed and elliptic flow of pions, kaons and protons has been reconstructed for Au+Au collisions at 11 GeV simulated with UrQMD model
- Different tracking configurations have been studied
- Results are obtained with FHCal event plane using reconstructed EP resolution
- True and reconstructed results are consistent for v_1 and v_2

Outlook

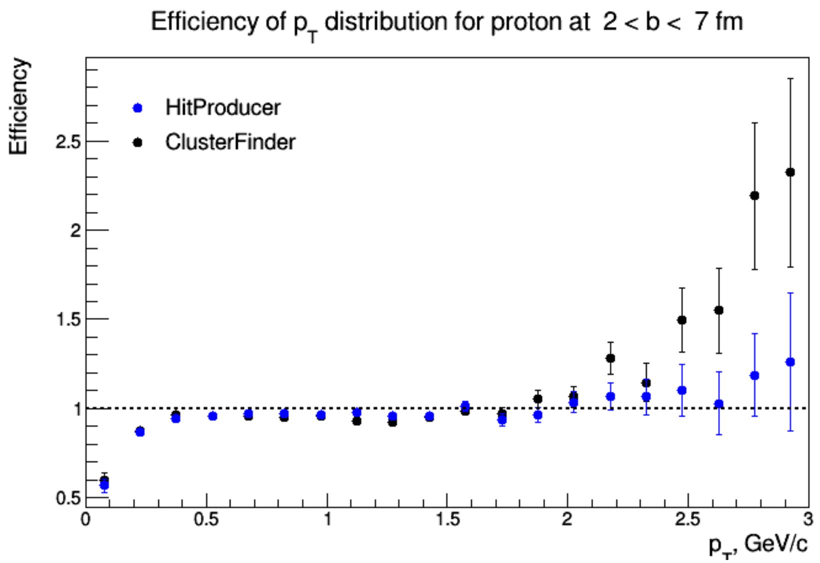
In order to do analysis using reconstructed data only:

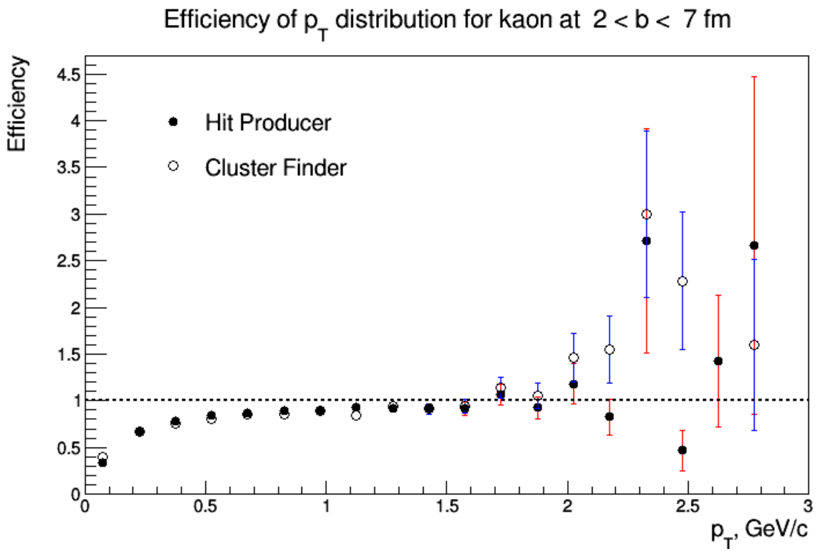
- Use realistic Particle Identification
- Check LA-QGSM model with nuclear fragmentation
- Centrality determination with TPC multiplicity and FHCal energy
- Implement realistic primary track selection using DCA cuts

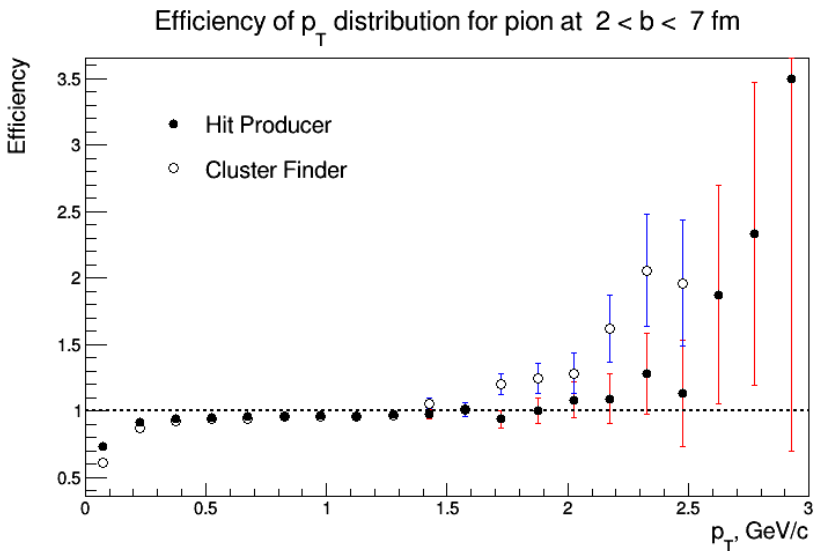


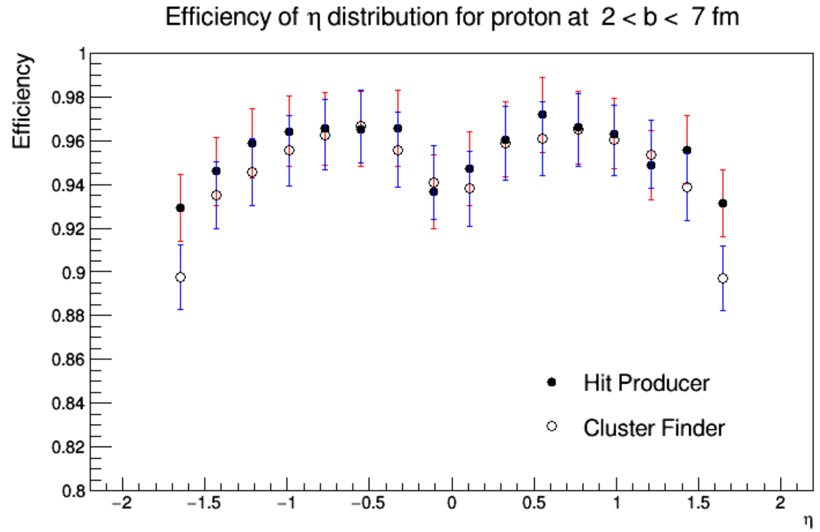
Thank you for your attention!

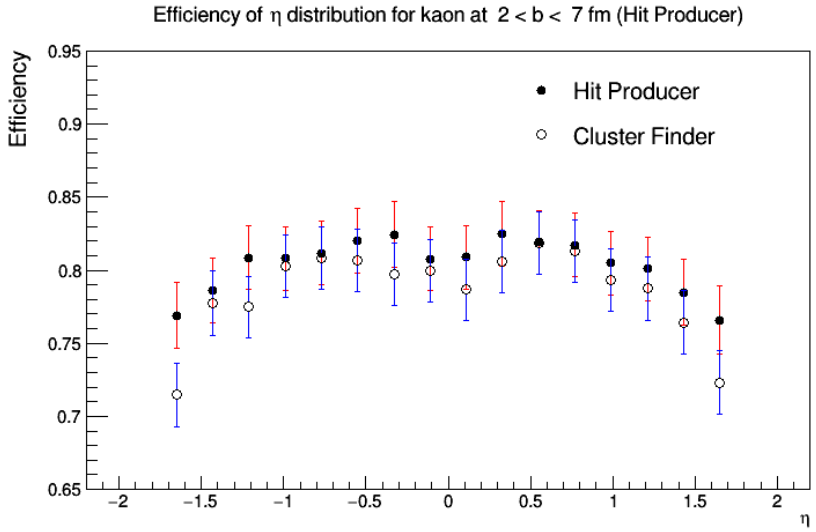
BACKUP SLIDES.

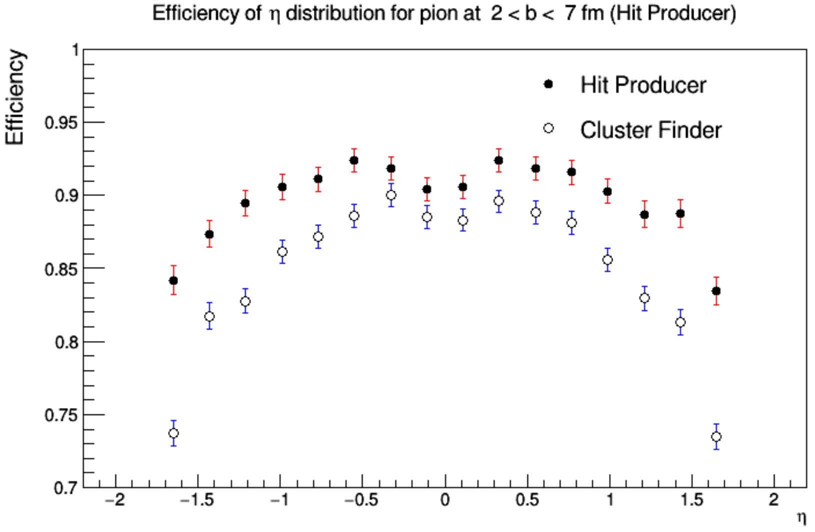

Efficiency of p_T distribution for proton at 2 < b < 7 fm
Efficiency
HitProducer
ClusterFinder
p_T, GeV/c


Efficiency of p_T distribution for kaon at 2 < b < 7 fm
Efficiency
Hit Producer
Cluster Finder
p_T, GeV/c

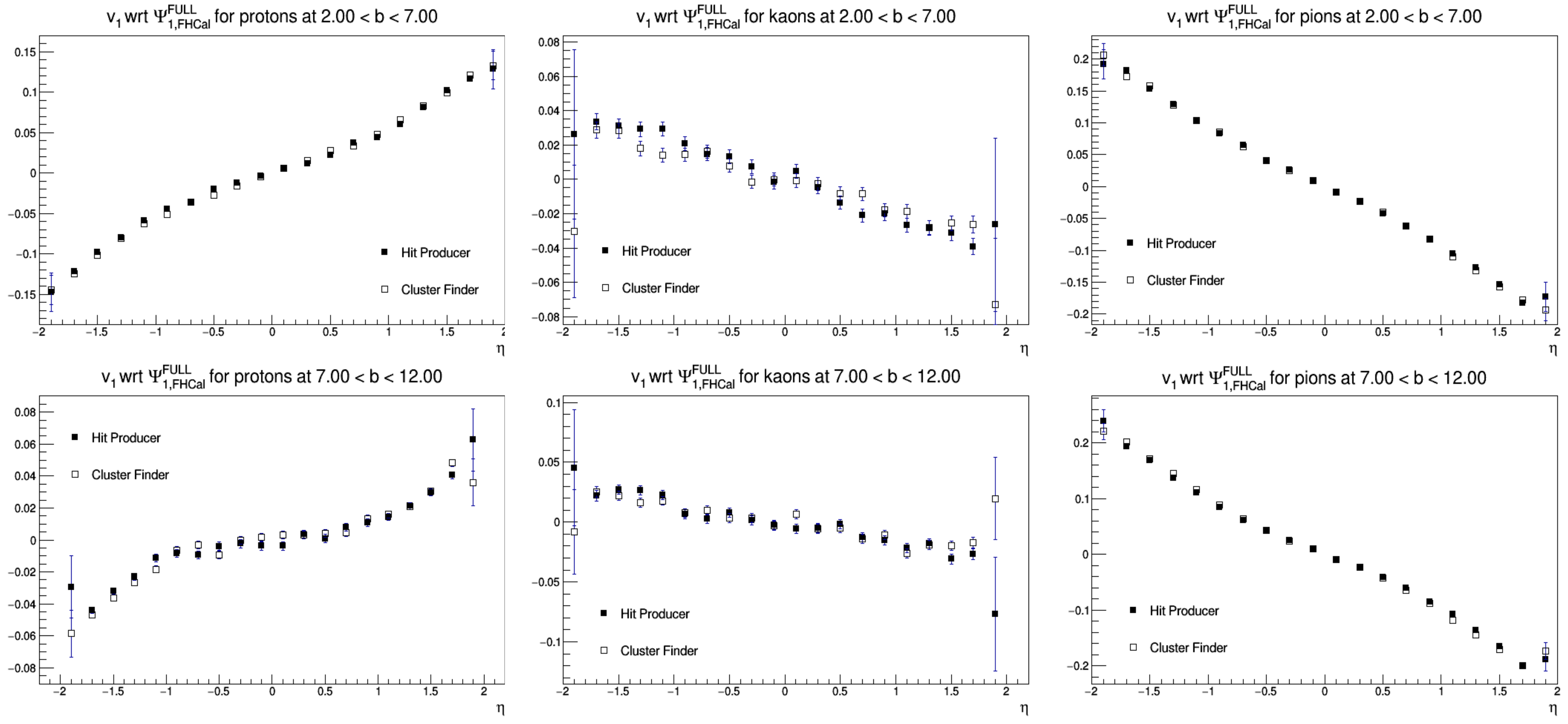

Efficiency of p_T distribution for pion at 2 < b < 7 fm
Efficiency
Hit Producer
Cluster Finder
p_T, GeV/c


Efficiency of η distribution for proton at 2 < b < 7 fm
Efficiency
Hit Producer
Cluster Finder
η

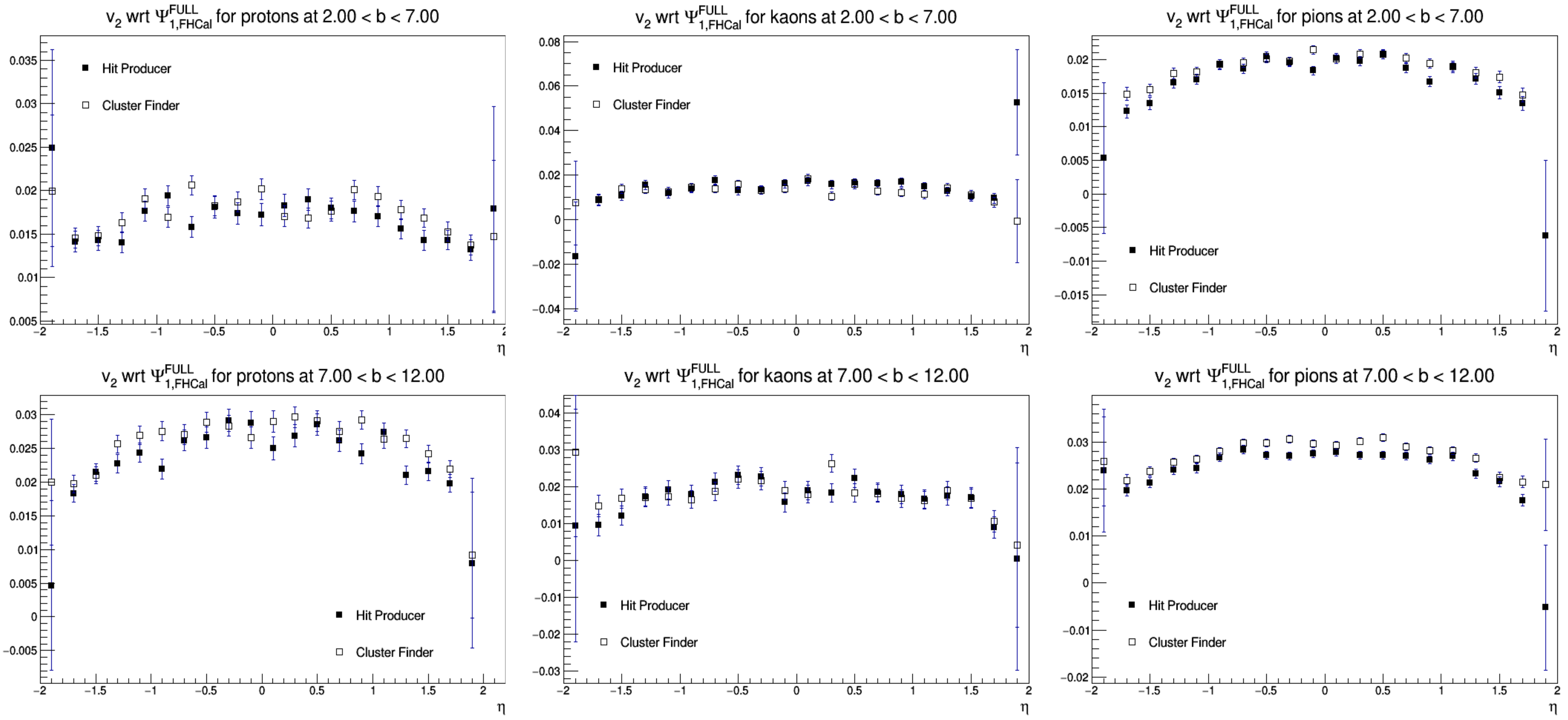

Efficiency of η distribution for kaon at 2 < b < 7 fm (Hit Producer)
Efficiency
Hit Producer
Cluster Finder
η


Efficiency of η distribution for pion at 2 < b < 7 fm (Hit Producer)
Efficiency
Hit Producer
Cluster Finder
η

Directed flow as η function

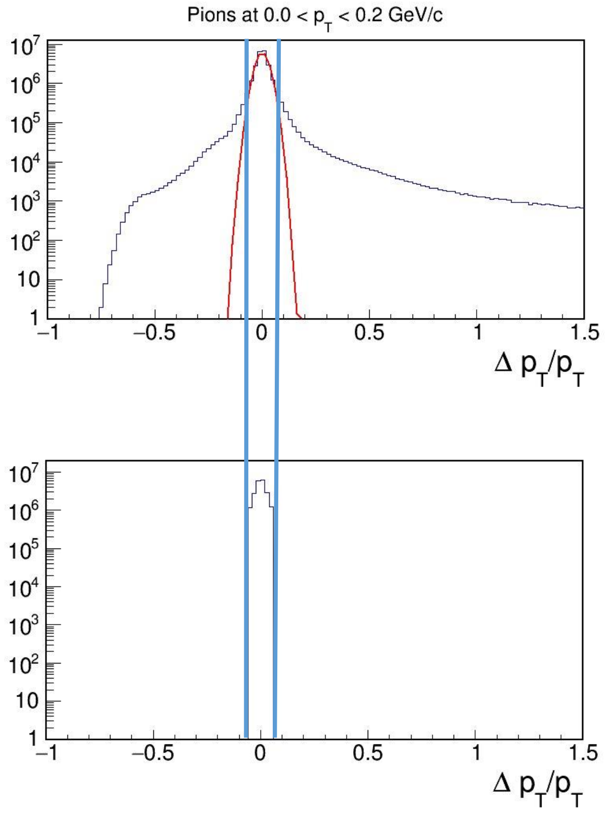


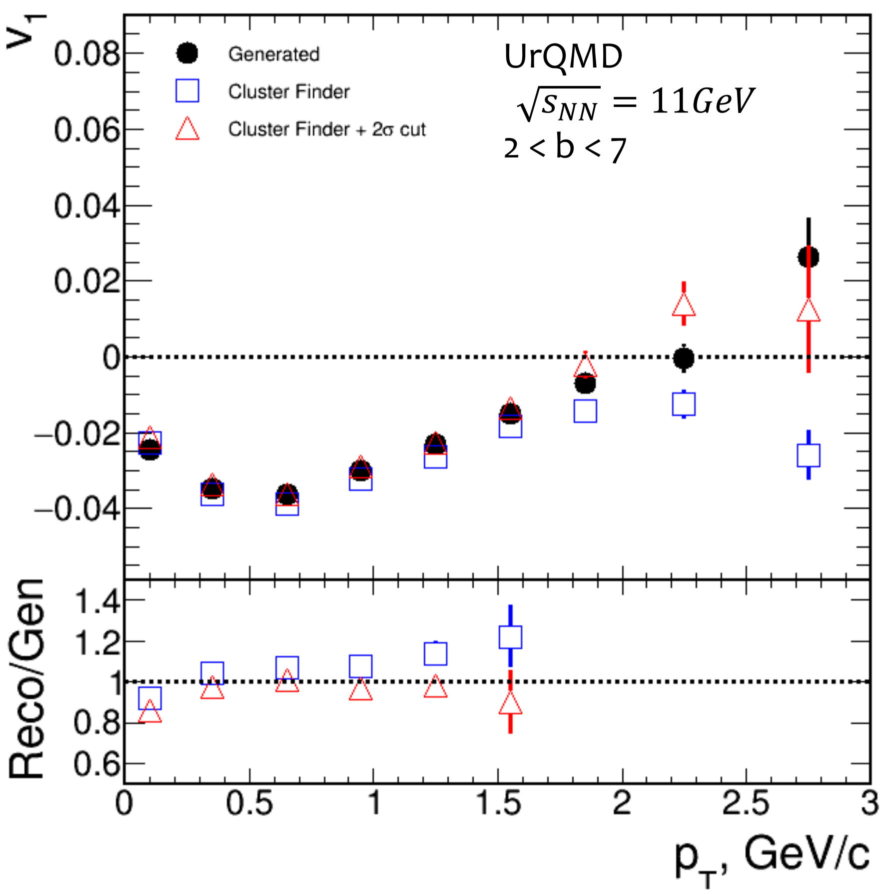
Elliptic flow as η function

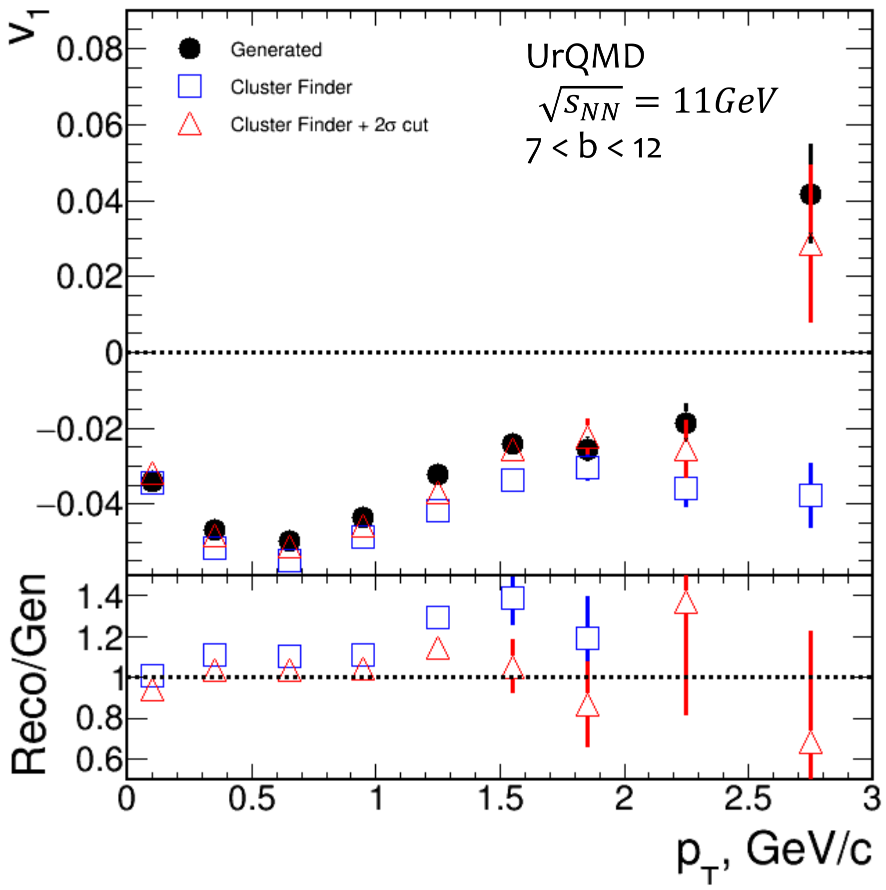


Directed flow: 2σ cut

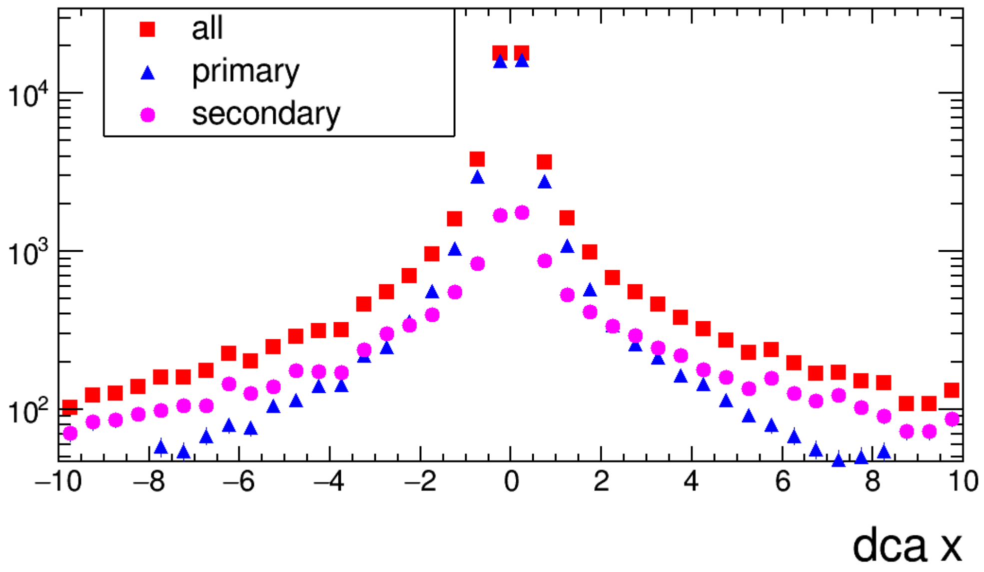
To exclude possible background effects 2σ cut was used

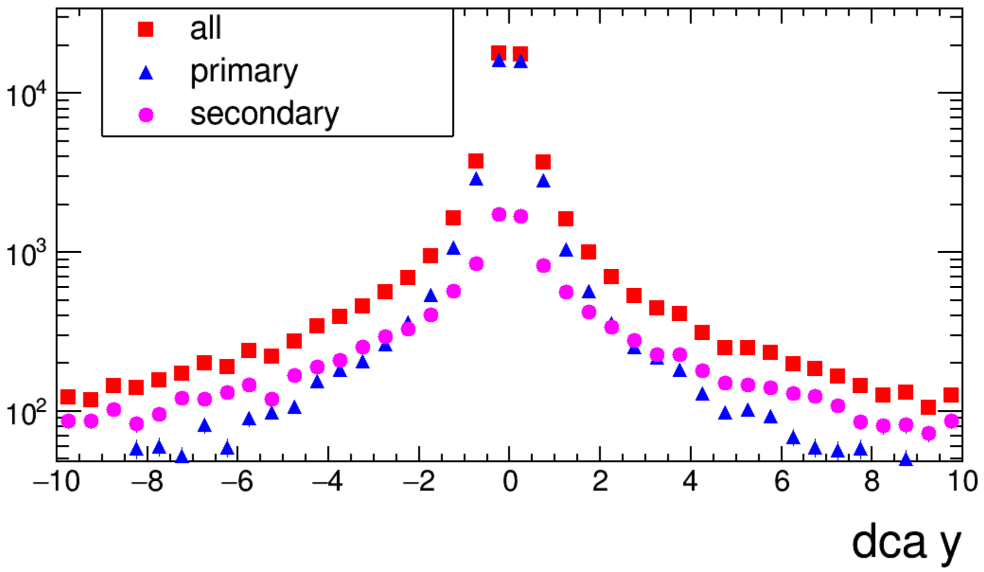


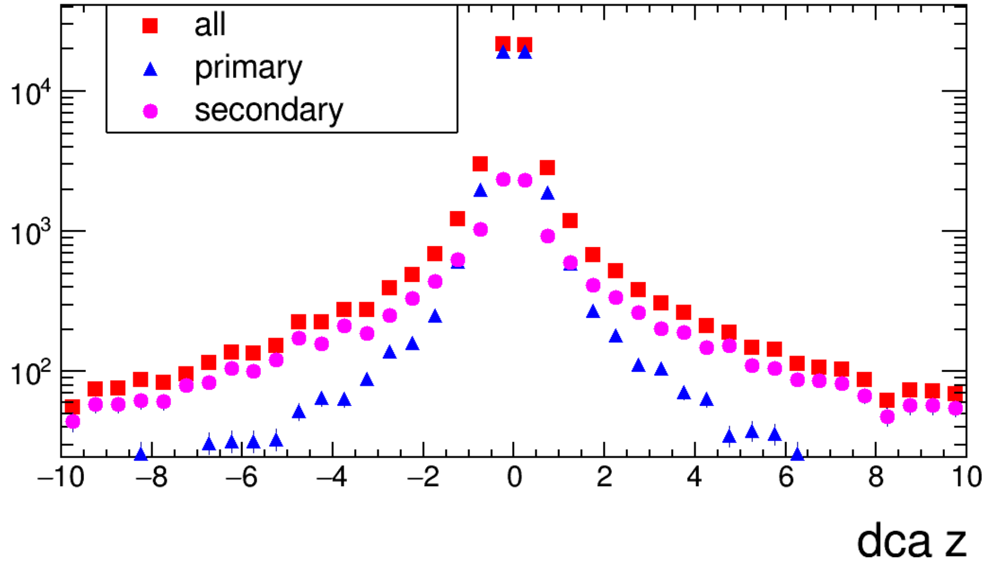




Distance of closest approach.







DCA – is minimal distance between primary vertex and track helicity reconstructed in TPC (Cluster Finder tracking used).

Secondary tracks contribution can be minimized using DCA cuts.