Elliptic and triangular flow for identified hadrons from the vHLLE+UrQMD for BiBi@9.2 GeV (Request 32)

Alexander Demanov, Petr Parfenov, Arkadiy Taranenko,
Dim Idrisov, Valerii Troshin
NRNU MEPhI

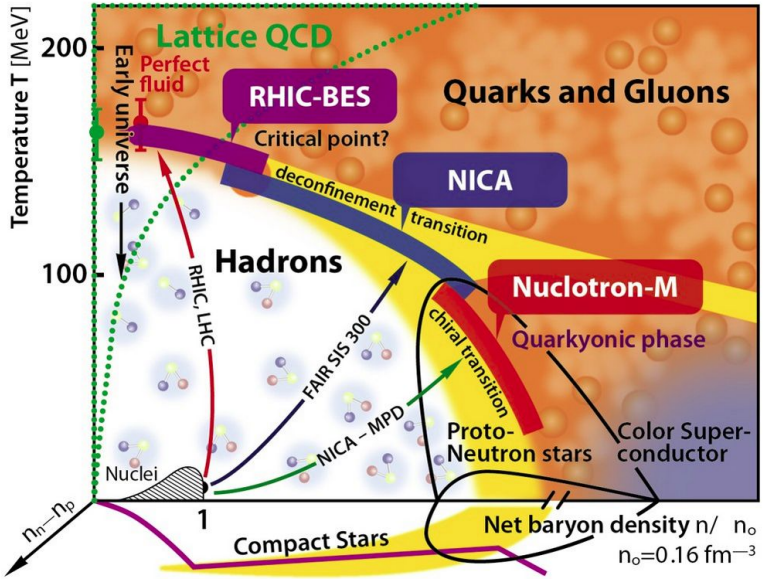
Cross-PWG meeting in MPD

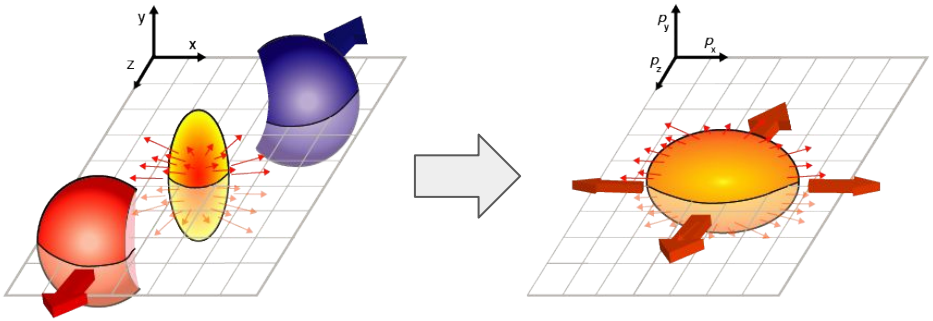
11.07.2023

Outline

- Anisotropic flow
- Review request 32
  - General distributions
  - Centrality determination
- Description of methods for elliptic flow measurements
- Results

Anisotropic flow





$$\epsilon_n = \sqrt{\frac{\langle r^n \cos n\phi\rangle + \langle r^n \sin n\phi\rangle}{\langle r^n\rangle}} \qquad \frac{dN}{d\phi} \propto 1 + 2\sum_{n=1} v_n \cos\left[n\left(\phi - \Psi_{RP}\right)\right]$$

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

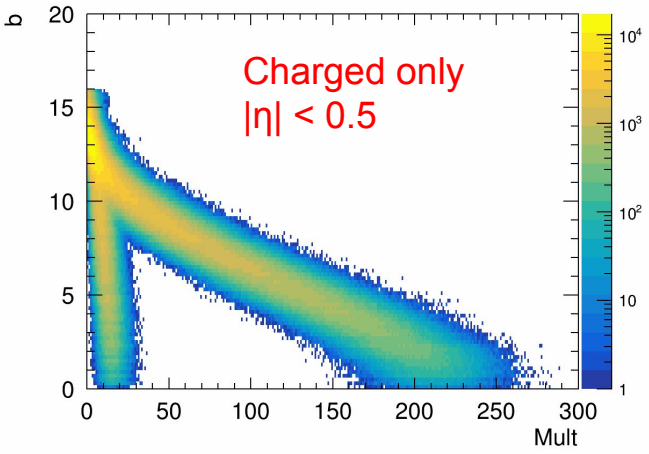
- LHC/top RHIC: cross-over transition leading to the sQGP
- Beam-energy scan programs (RHIC/SPS/NICA/FAIR): search for 1st order phase transition, critical end point

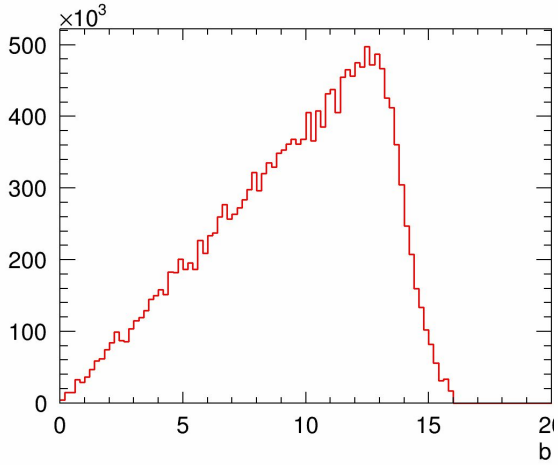
- Transfer of anisotropy from the initial coordinate space into the final momentum space via the thermalized medium
- Anisotropic flow is a sensitive probe of the sQGP properties (η/s, ζ/s, EoS)

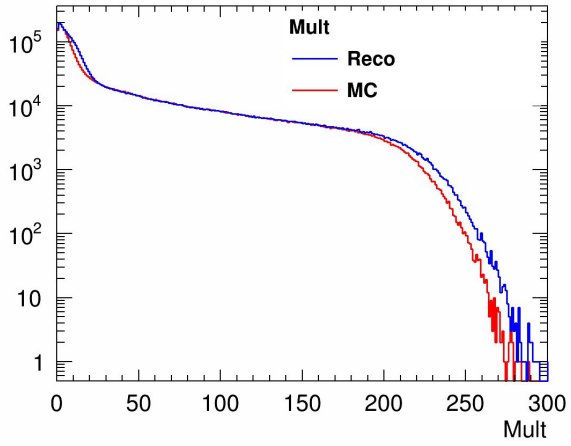
Request 32

- Request 32: Flow - vHLLE+UrQMD, 23M BiBi @ 9.2 GeV
- Event generator: vHLLE+UrQMD
- Detector response simulation: GEANT4
- Input root DST files at /scratch2/taranen/BiBi_ecm9.2GeV_hydro/part1 (/part2, /part3)

General distributions: Event



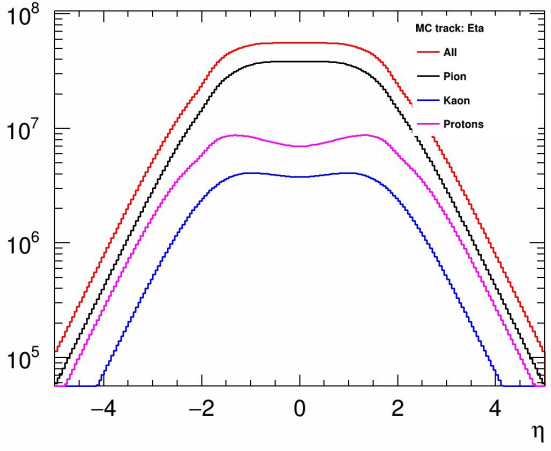


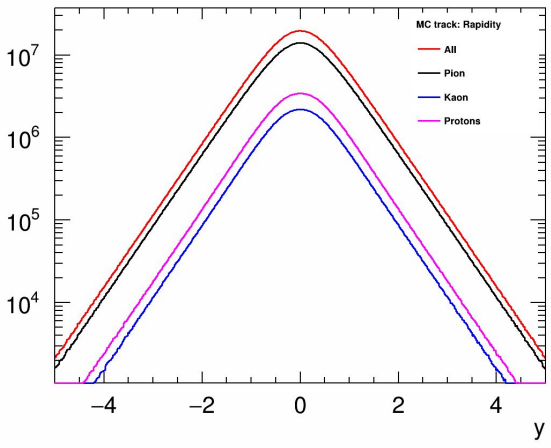


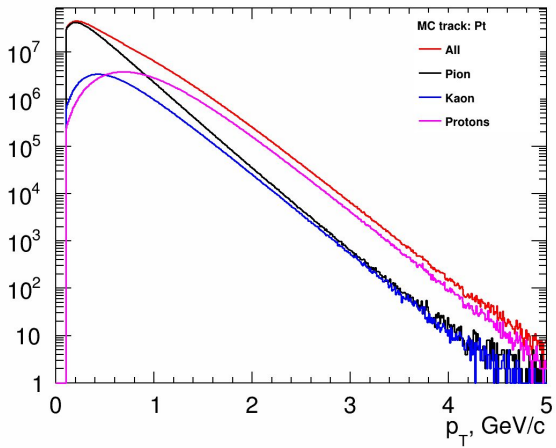
Observed a non-physical tail in the distribution Mult vs b

General distributions: Tracks

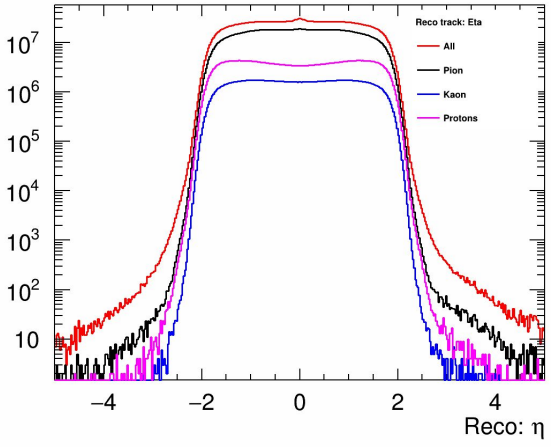
MC

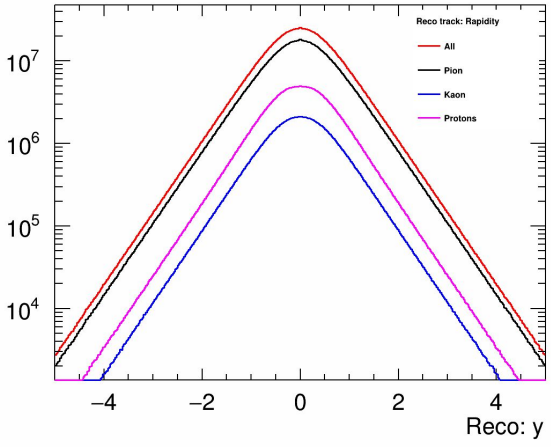


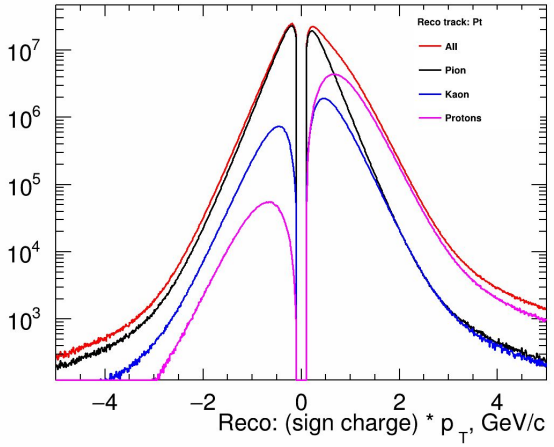




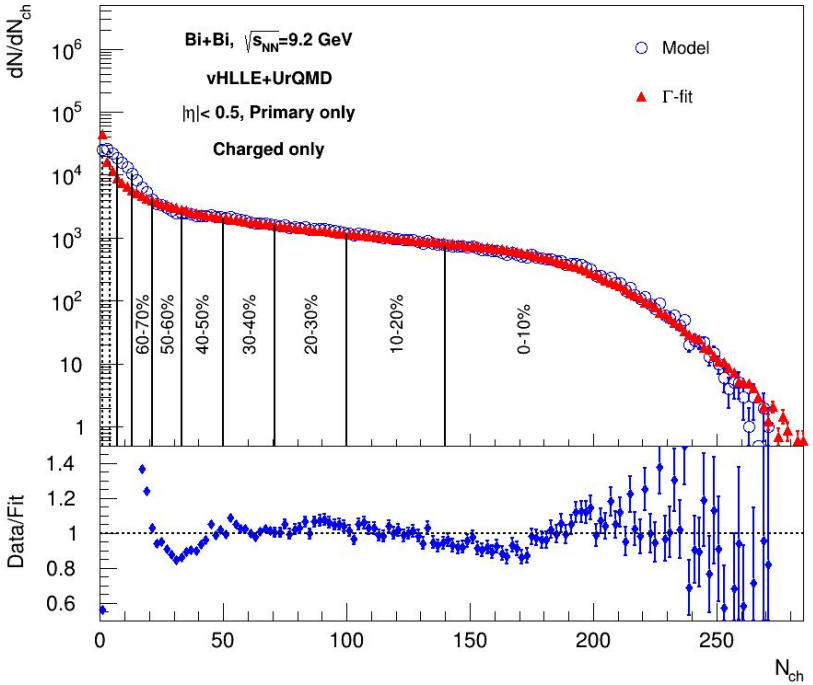
Reco

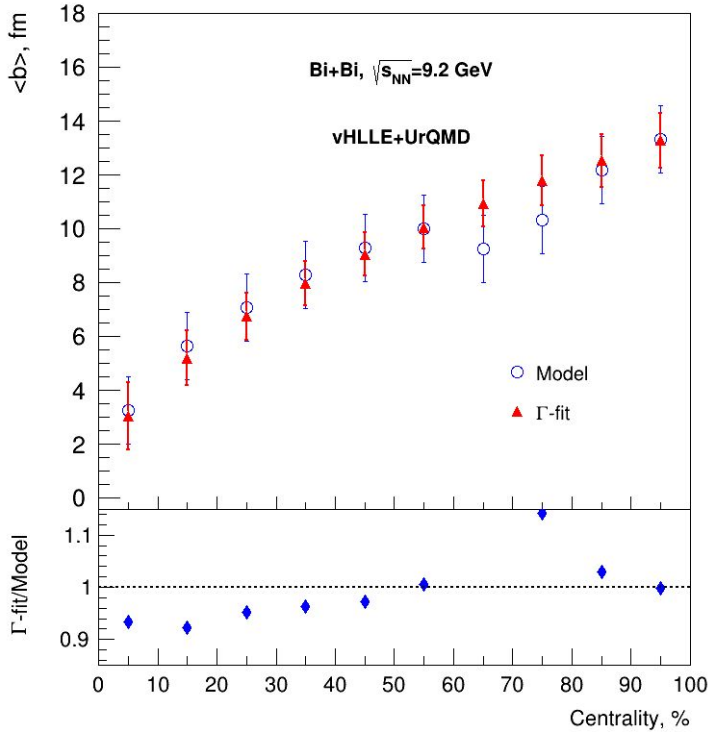






Centrality determination



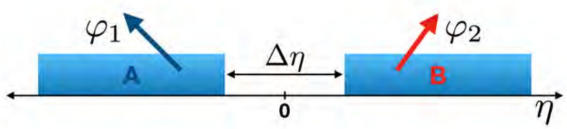


The reasonable fit quality and good agreement of the impact parameter distribution with the model data for 0-60% centrality classes.

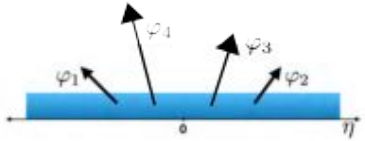
Methods for v_n measurements

- **Sub-event 2-particle Q-cumulants v2{2}:** Δη=0.1 is applied between 2 sub-events A, B to suppress non-flow

$$Q_n = \sum_{i=1}^{M} e^{in\phi} \qquad \langle 2 \rangle_{a|b} = \frac{Q_{n_a} Q^*_{n,b}}{M_a M_b} \qquad v_2\{2\} = \sqrt{\langle\langle 2 \rangle\rangle_{a|b}}$$



- **4-particle Q-cumulants v2{4}**



$$\langle 2 \rangle = \frac{|Q_n|^2 - M}{M(M-1)}$$

$$\langle 4 \rangle = \frac{|Q_n|^4 + |Q_{2n}|^2 - 2\Re[Q_{2n} Q^*_n Q^*_n] - 4(M-2)|Q_n|^2 - 2M(M-3)}{M(M-1)(M-2)(M-3)}$$

$$v_2\{4\} = \sqrt[4]{2\langle\langle 2 \rangle\rangle^2 - \langle\langle 4 \rangle\rangle}$$

- **Event plane method:** Δη=0.1

$$Q_{n,x} = \sum_i w_i \cos(n\phi_i) \qquad Q_{n,y} = \sum_i w_i \sin(n\phi_i)$$

$$\Psi_n^{EP} = \frac{1}{n}\tan^{-1}\left(\frac{Q_{n,y}}{Q_{n,x}}\right) \qquad v_n = \frac{\langle \cos[n(\phi - \Psi_n^{EP})] \rangle}{\sqrt{\langle \cos[n(\Psi_{n,a} - \Psi_{n,b})] \rangle}}$$

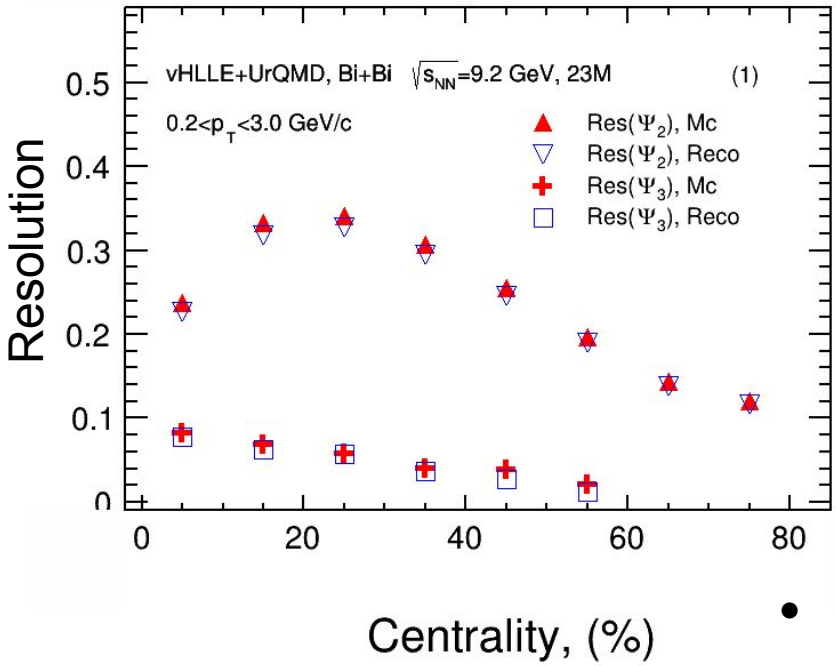
Here: ω_i - $p_{T,i}$ transverse momentum of the i-th track in the TPC

φ_i - azimuthal angle of the i-th track in the TPC

Ψ_n - event plane angles

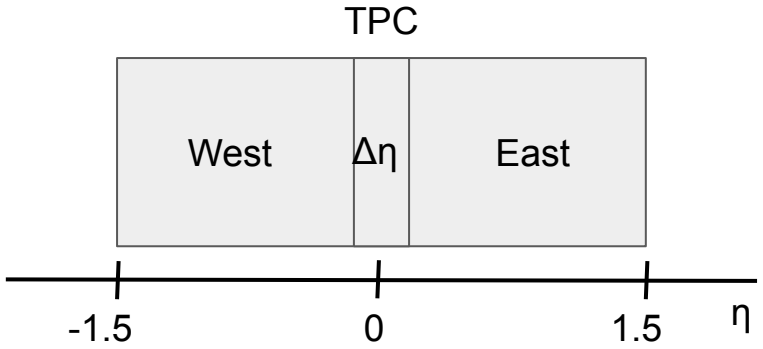
Method's details described in PRC 83 (2011), 044913 , EP method: Phys.Rev.C 77 (2008) 034904

Event plane Resolution



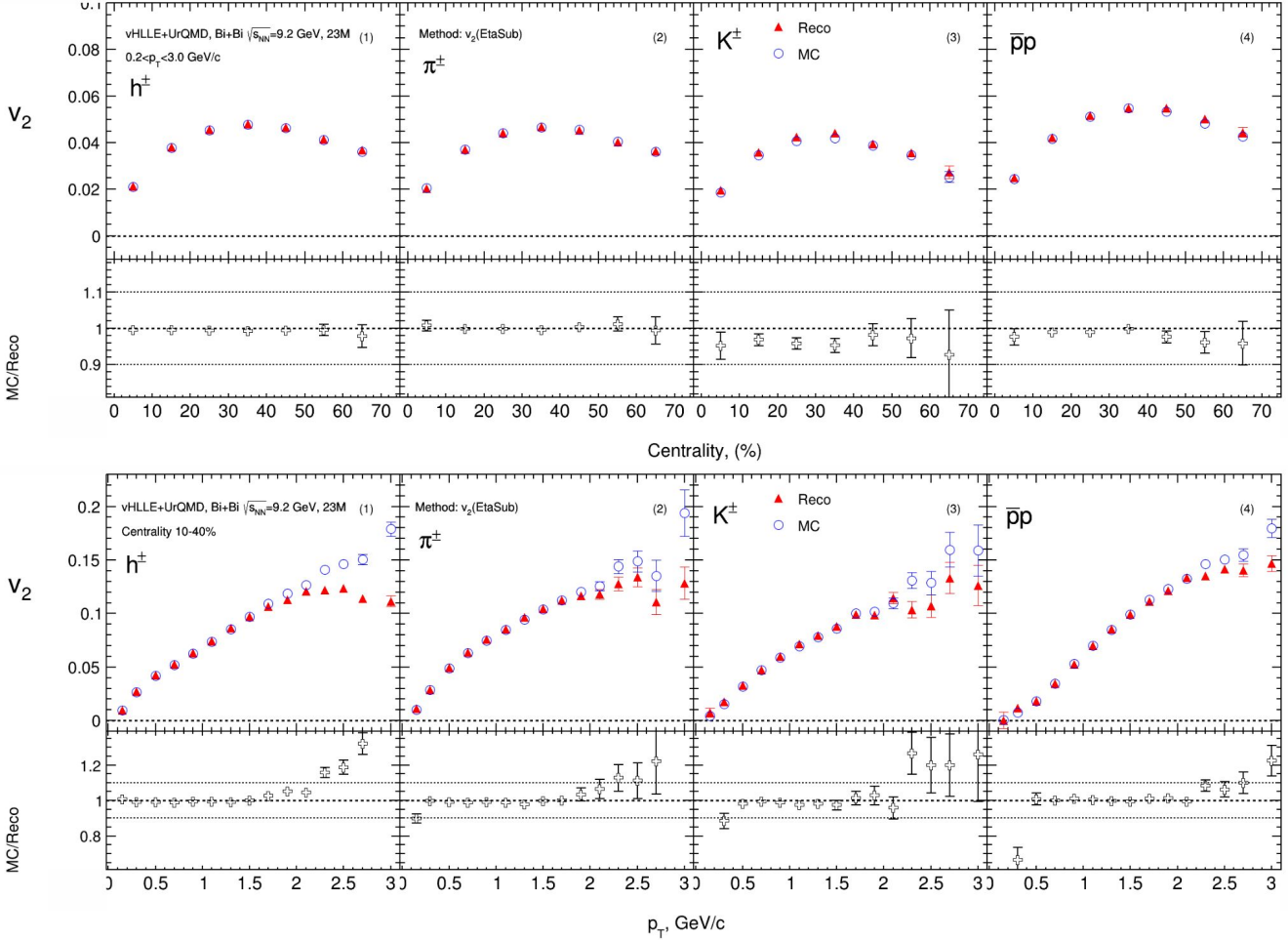
2 sub event: Δη=0.1

$$Res\{\Psi_n^{E(W)}\} = \sqrt{\langle \cos\left[n(\Psi_n^E - \Psi_n^W)\right]\rangle}$$



- We do not measure the Ψ_3 resolution after to 60% centrality
- Ψ_3 resolution are smaller than Ψ_2
- Good agreement between $R_{MC}(\Psi_n)$ and $R_{reco}(\Psi_n)$

Comparison of Reco and MC: v_2 eta-sub EP

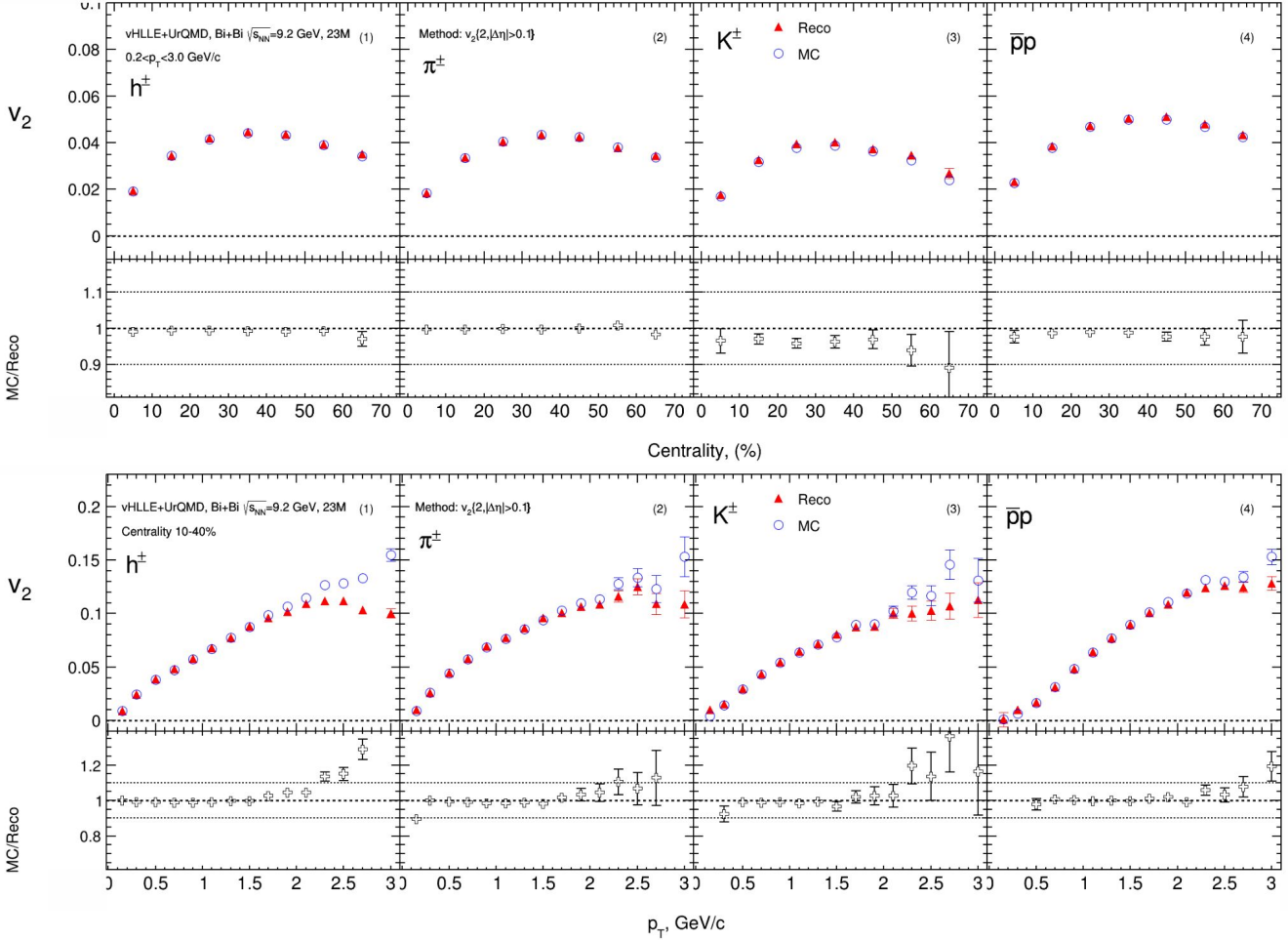


Cuts:

- Charged particles only
- Primary
- $|\eta|<1.5$
- $\Delta\eta = 0{,}1$
- $p_T > 0.2$ GeV/c
- $|DCA|<3\sigma$
- nTPC hits ≥ 16
- PID: PDG code

- good agreement of the $v_{2,mc}$ with $v_{2,reco}$ data
- The difference at large p_T between $v_{2,mc}$ and $v_{2,reco}$ (non-flow?)

Comparison of Reco and MC: $v_2\{2,|\Delta\eta|>0.2\}$

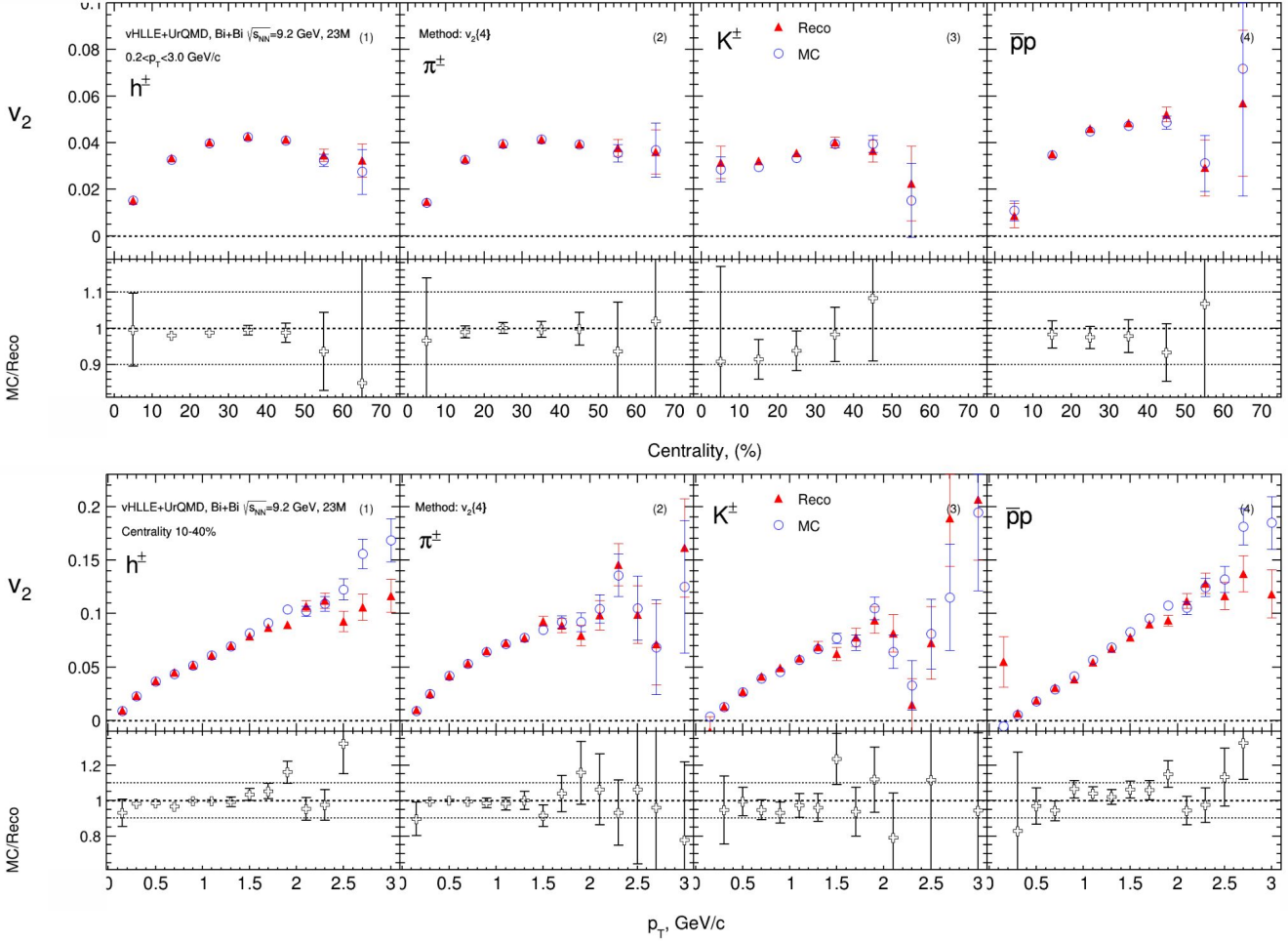


Cuts:

- Charged particles only
- Primary
- $|\Delta\eta| = 0,1$
- $\Delta\eta = 0,1$
- $p_T > 0.2$ GeV/c
- $|DCA| < 3\sigma$
- nTPC hits ≥ 16
- PID: PDG code

- good agreement of the $v_{2,mc}$ with $v_{2,reco}$ data
- The difference at large p_T betwin $v_{2,mc}$ and $v_{2,reco}$ (non-flow ?)

Comparison of Reco and MC: $v_2\{4\}$

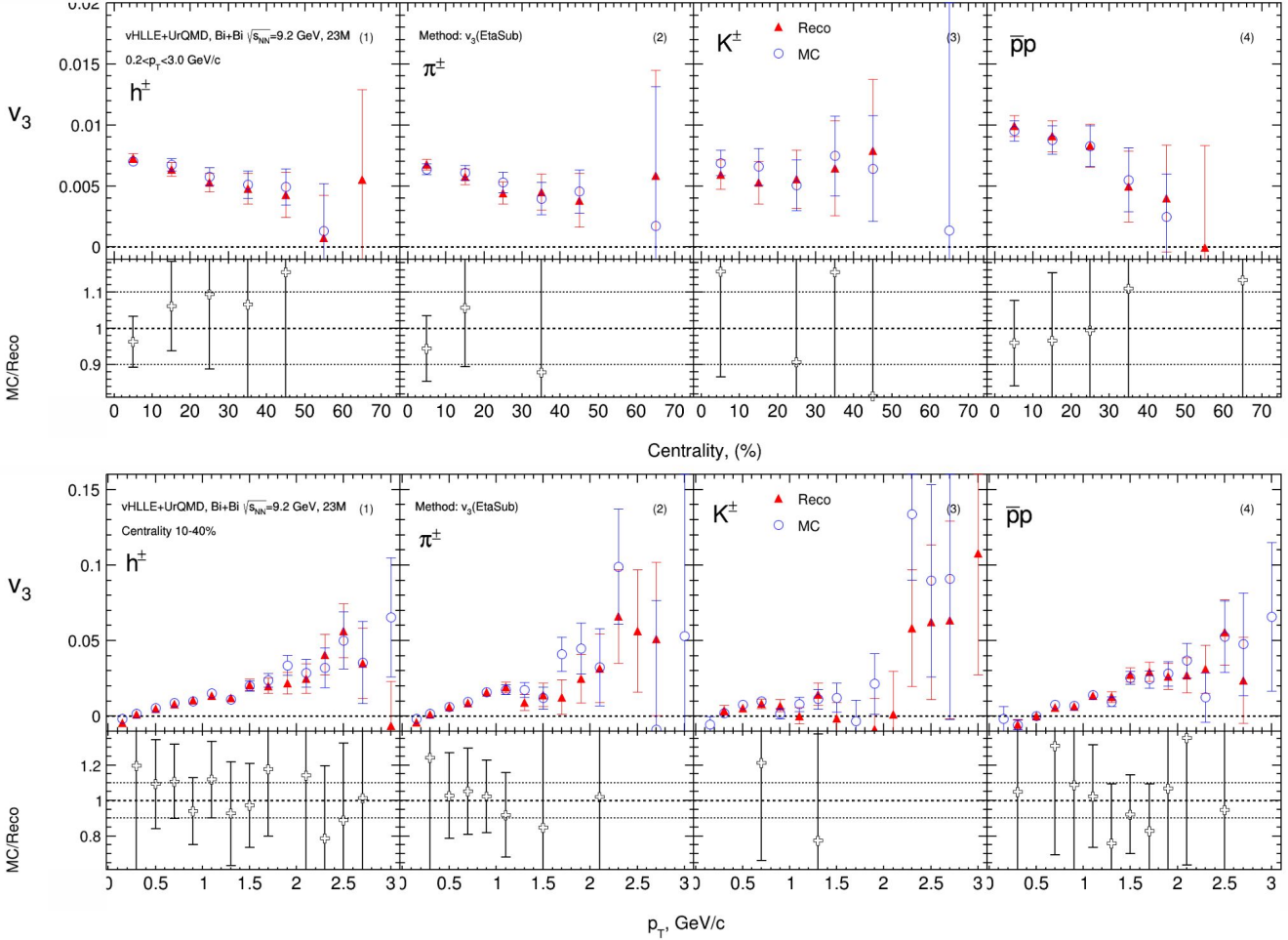


Cuts:

- Charged particles only
- Primary
- $|\eta|<1.5$
- $\Delta\eta = 0,1$
- $p_T > 0.2$ GeV/c
- $|DCA|<3\sigma$
- nTPC hits ≥ 16
- PID: PDG code

- ❑ good agreement of the $v_{2,mc}$ with $v_{2,reco}$ data
- ❑ The difference at large p_T betwin $v_{2,mc}$ and $v_{2,reco}$ is less than for other methods -> Not affected by the non-flow effects

Comparison of Reco and MC: v_3 eta-sub EP



Cuts:

- Charged particles only
- Primary
- $|\eta|<1.5$
- $\Delta\eta = 0,1$
- $p_T > 0.2$ GeV/c
- $|DCA|<3\sigma$
- nTPC hits ≥ 16
- PID: PDG code

❑ Further research is required (need more statistics)

Conclusions

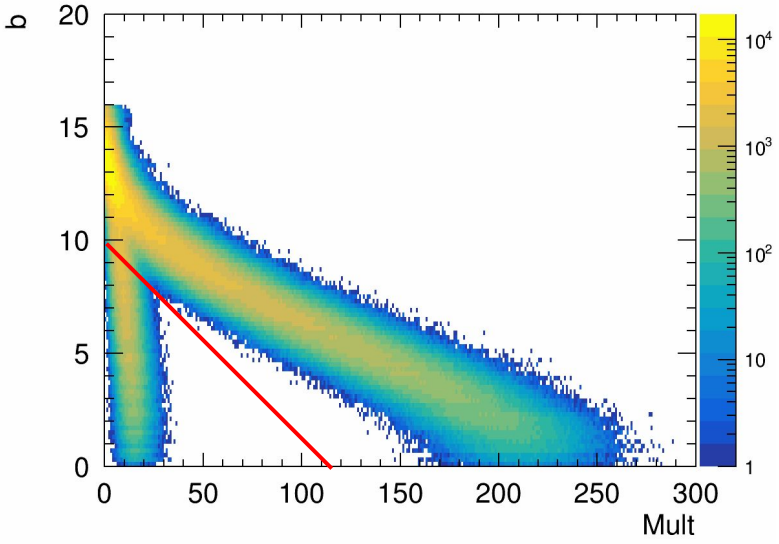
- Observed outlier events in the distribution Mult vs b - typical for this model
- Centrality classes have been determined using the Inverse Bayes method. For this model, flow measurements (without cut on Mult vs b) are possible up to 50-60%
- There is a good agreement between $v_{2,mc}$ and $v_{2,reco}$. But there are differences at large p_T region - contribution from non-flow.
- Current statistics are not enough for v_3 measurements.

Thank you for your attention !

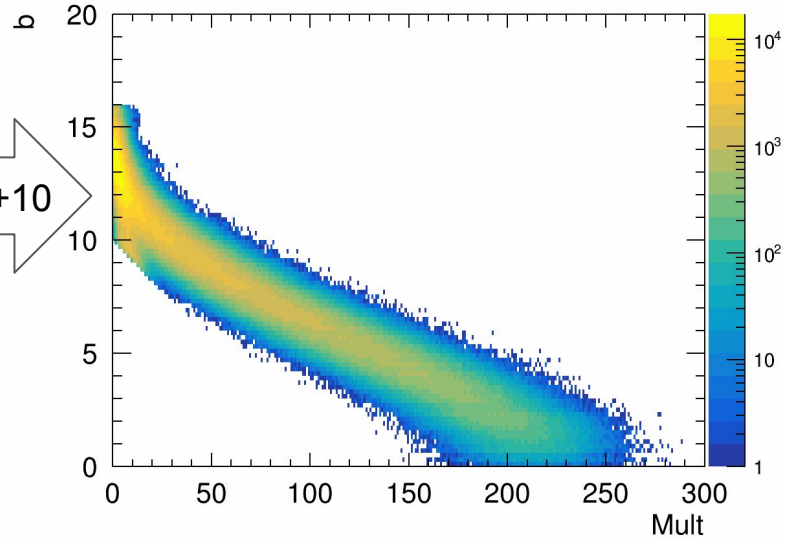
BACKUP

QA test: Event

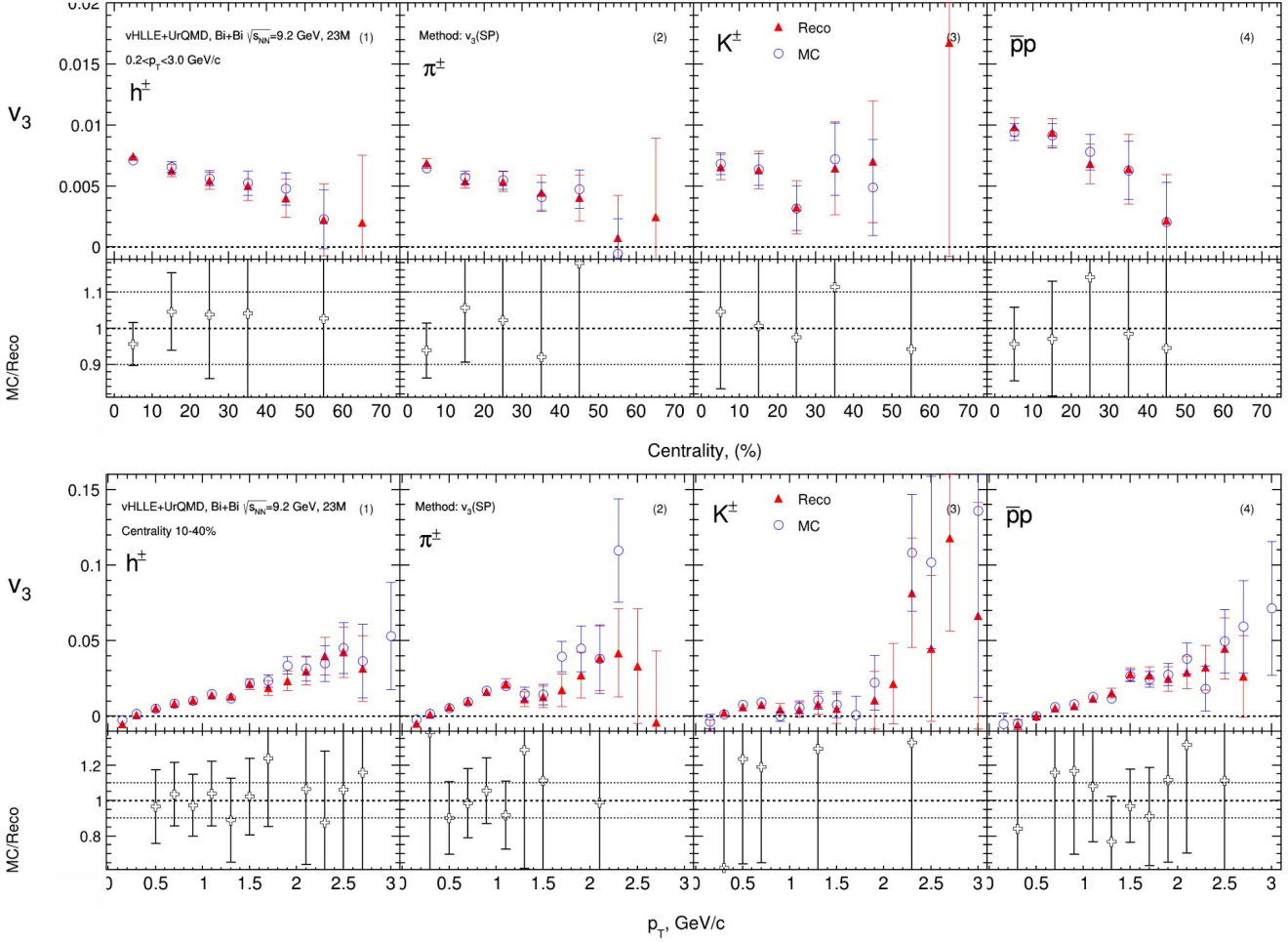
Charged only
$|\eta| < 0.5$



b > -0.09*Mult+10



Comparison of Reco and MC: v_3 SP

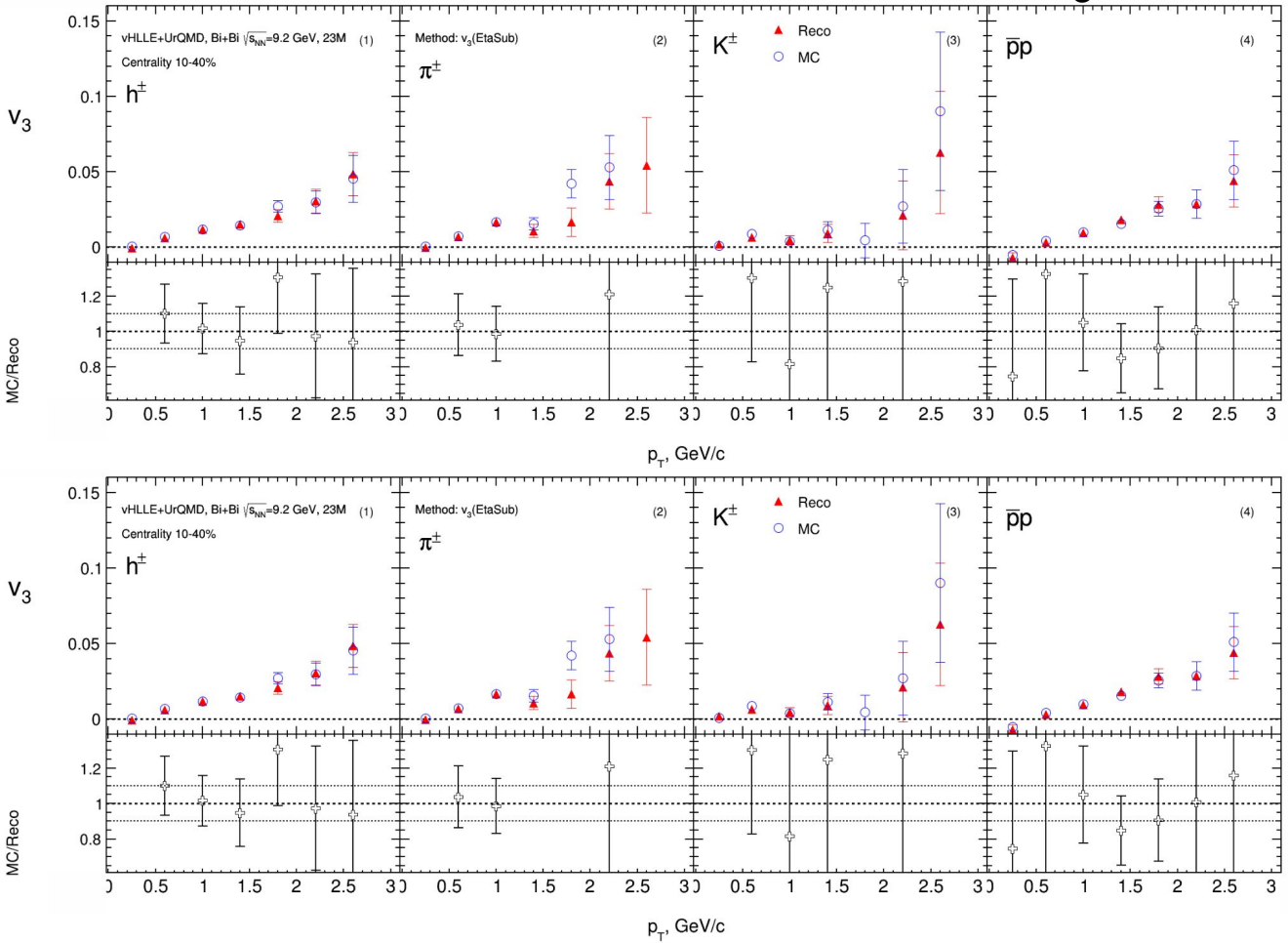


Cuts:

- Charged particles only
- Primary
- $|\eta|<1.5$
- $\Delta\eta = 0,1$
- $p_T > 0.2$ GeV/c
- $|DCA|<3\sigma$
- nTPC hits ≥ 16
- PID: PDG code

❑ Further research is required (need more statistics)

Comparison of Reco and MC: v_3 eta-sub EP



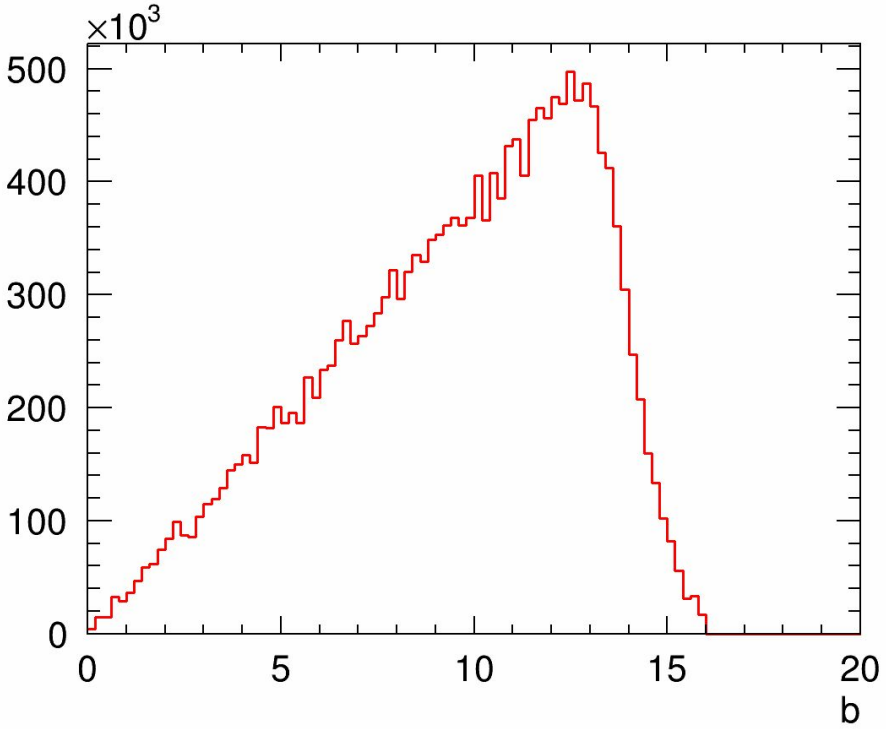
Cuts:

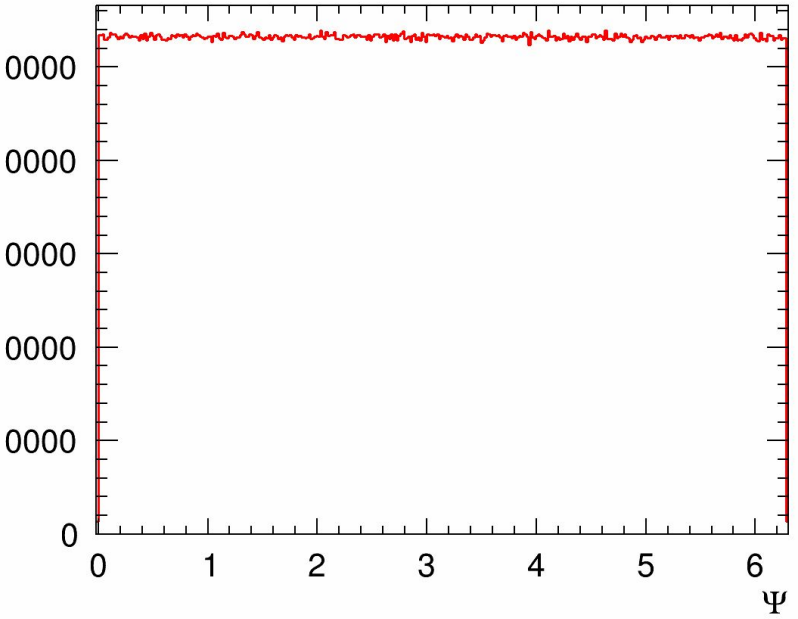
- Charged particles only
- Primary
- $|\eta|<1.5$
- $\Delta\eta = 0,1$
- $p_T > 0.2$ GeV/c
- $|DCA|<3\sigma$
- nTPC hits ≥ 16
- PID: PDG code

❑ Further research is required (need more statistics)

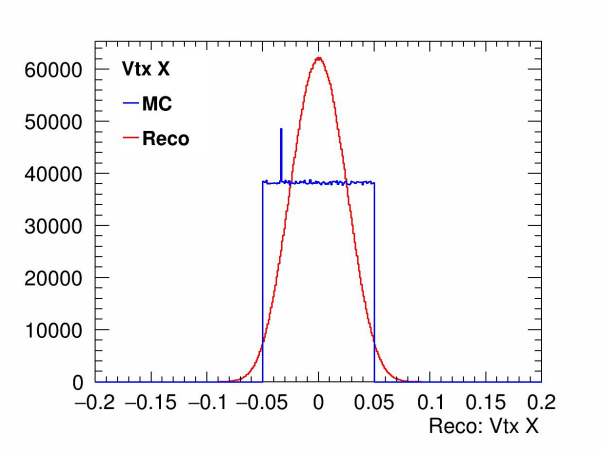
Comparison of Reco and MC: v_2 eta-sub EP (different $\Delta\eta$)

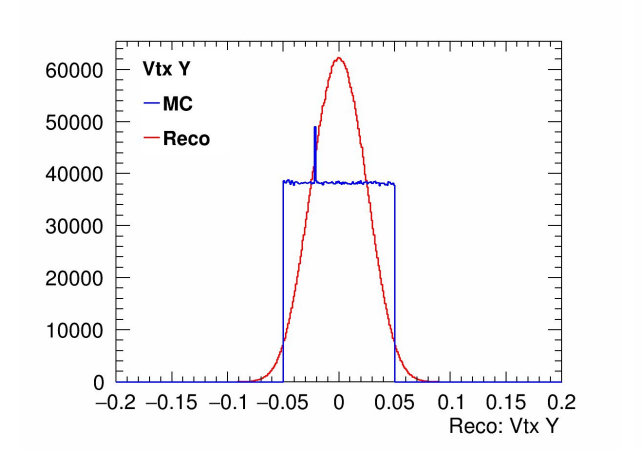
MC events: impact parameter and reaction plane angle

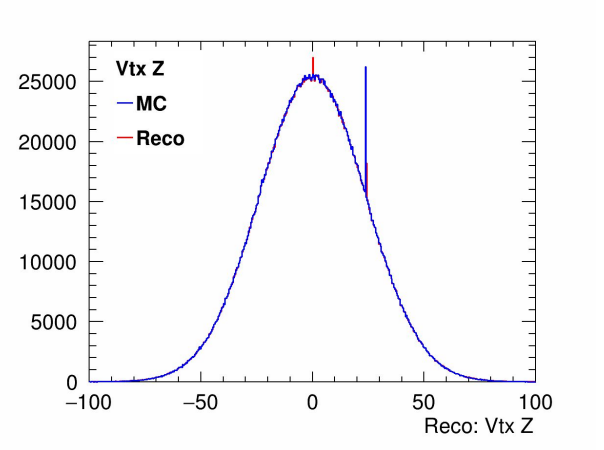




General distributions: Event

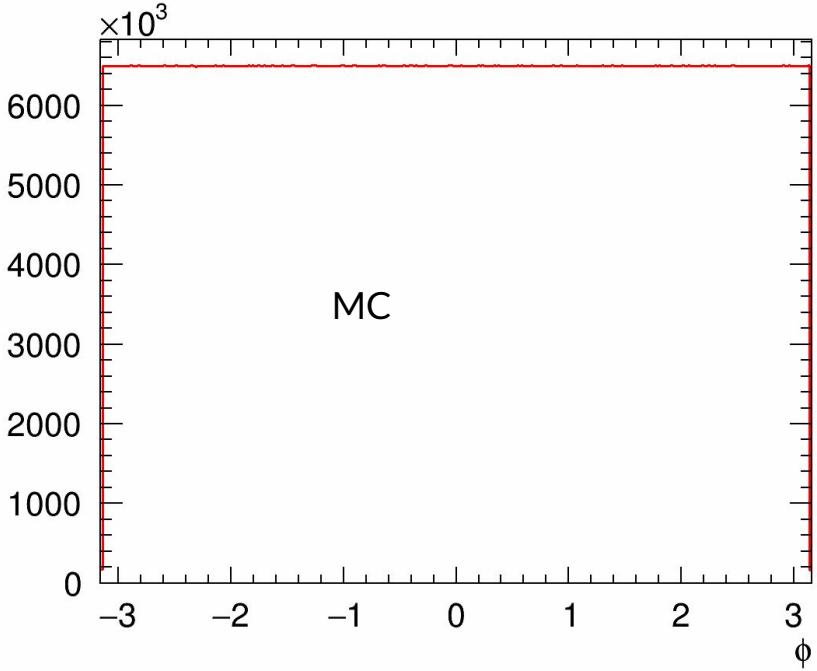


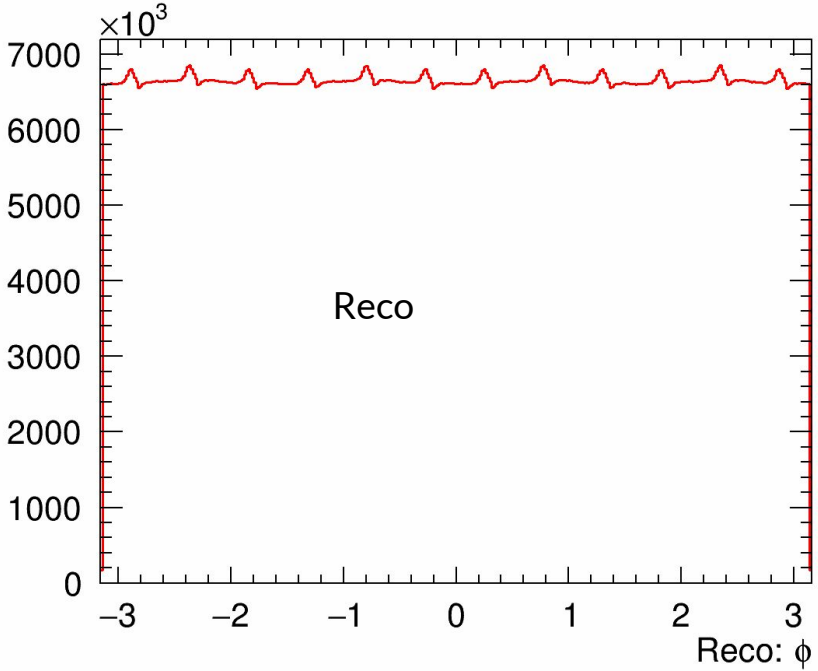




Vtx: Anomalous peaks are visible. Source is unknown

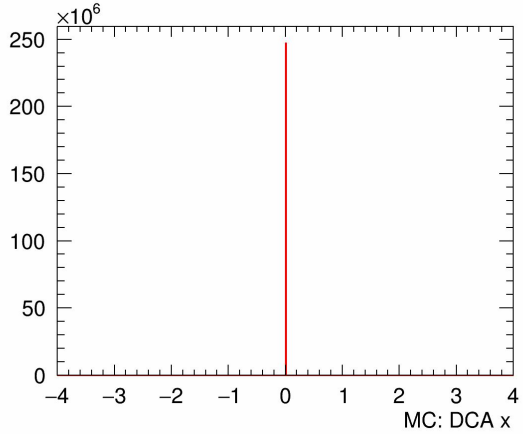
Track: phi

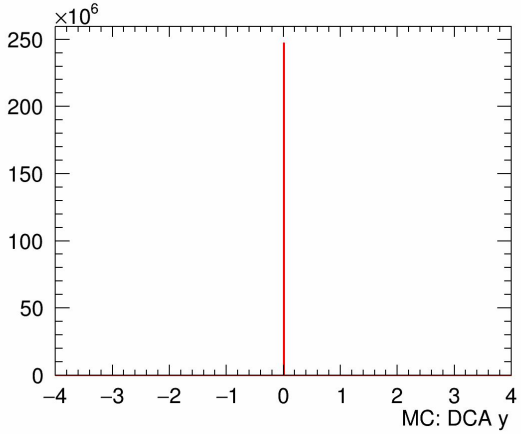

×10^3
6000
5000
4000
3000
2000
1000
0
MC
−3
−2
−1
0
1
2
3
ϕ

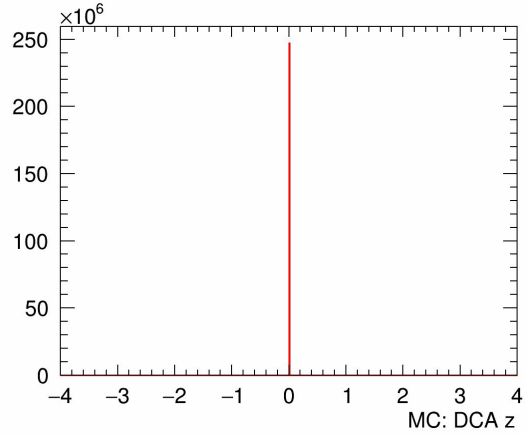

×10^3
7000
6000
5000
4000
3000
2000
1000
0
Reco
−3
−2
−1
0
1
2
3
Reco: ϕ

DCA

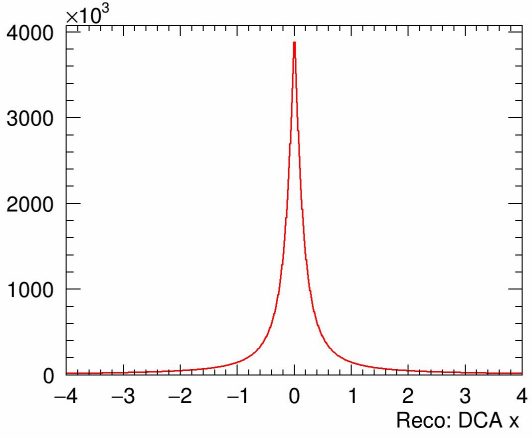
MC

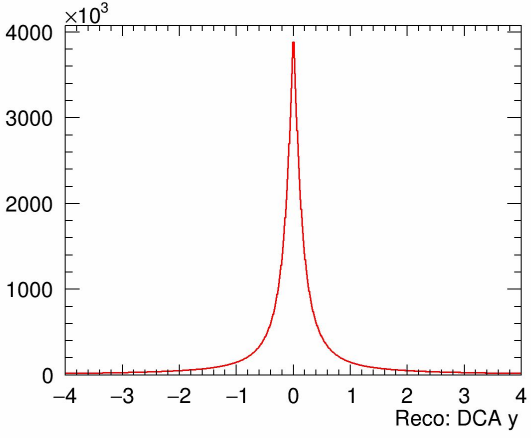

×10^6
MC: DCA x

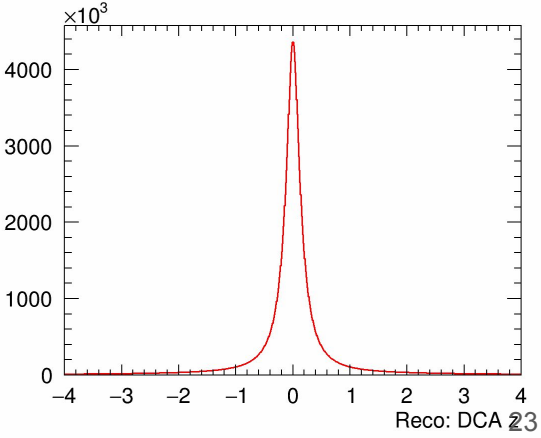

×10^6
MC: DCA y


×10^6
MC: DCA z

Reco

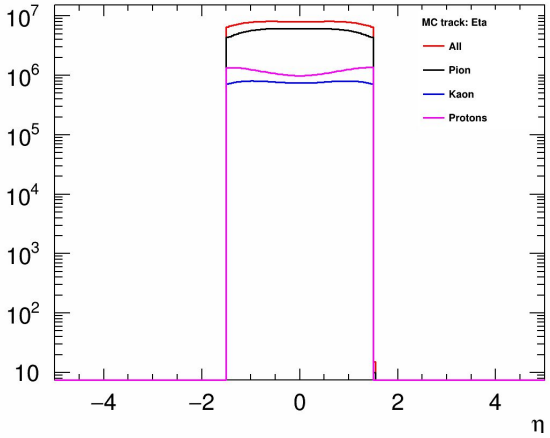

×10^3
Reco: DCA x

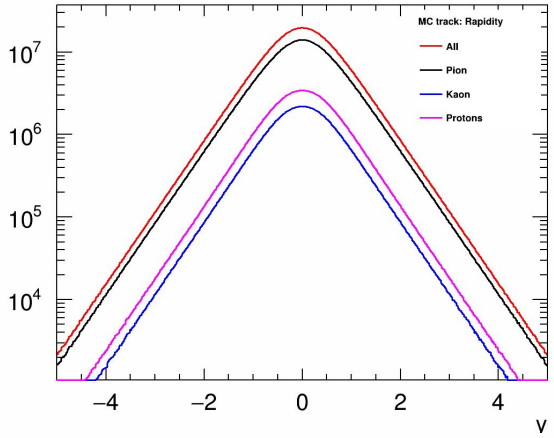

×10^3
Reco: DCA y

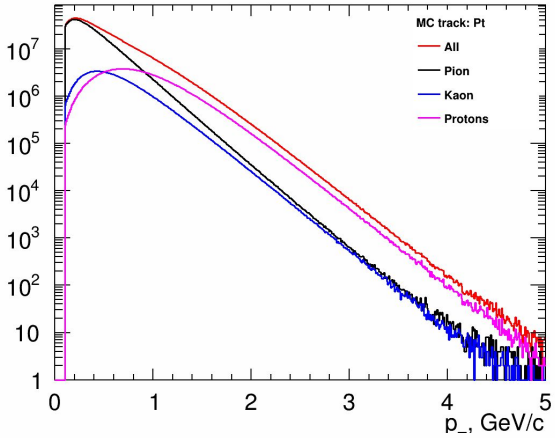

×10^3
Reco: DCA z

QA test: Track (after cuts)

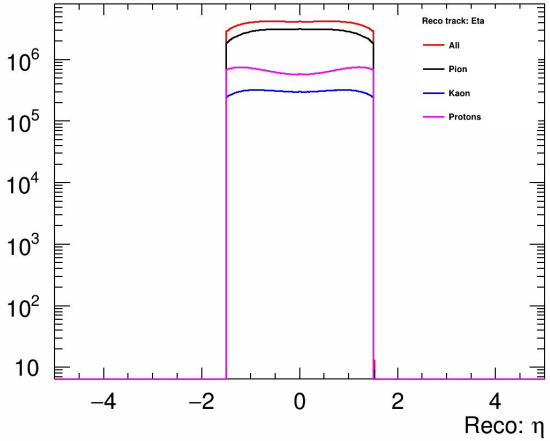
MC

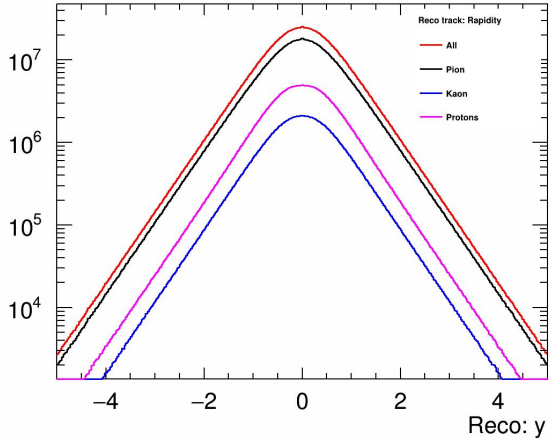


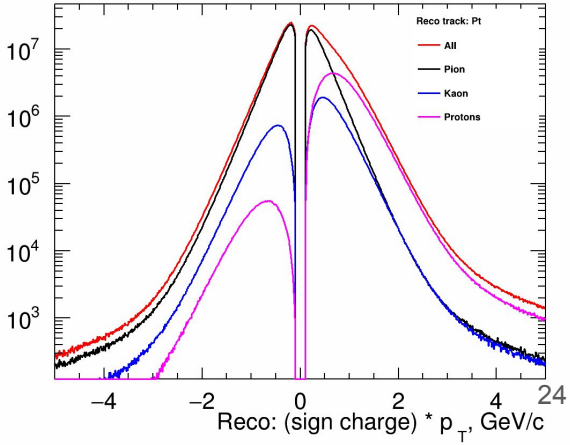




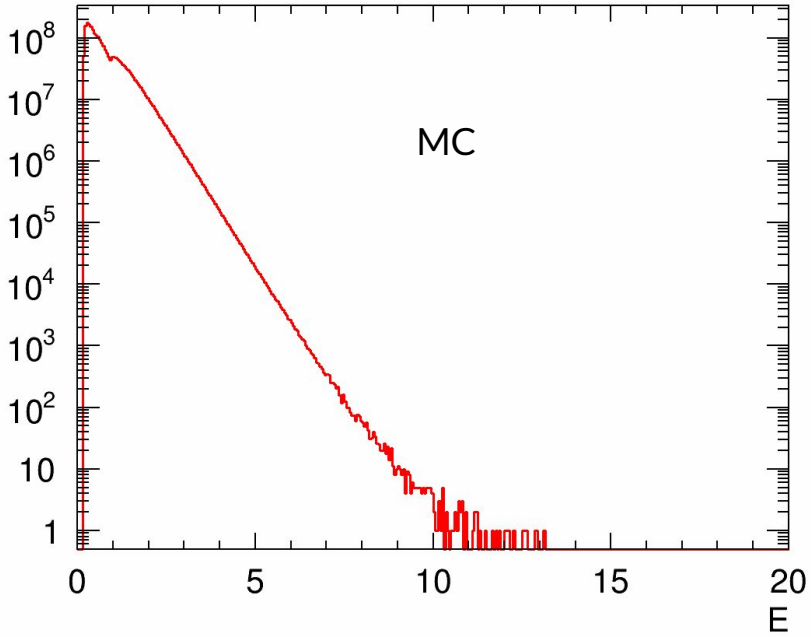
Reco

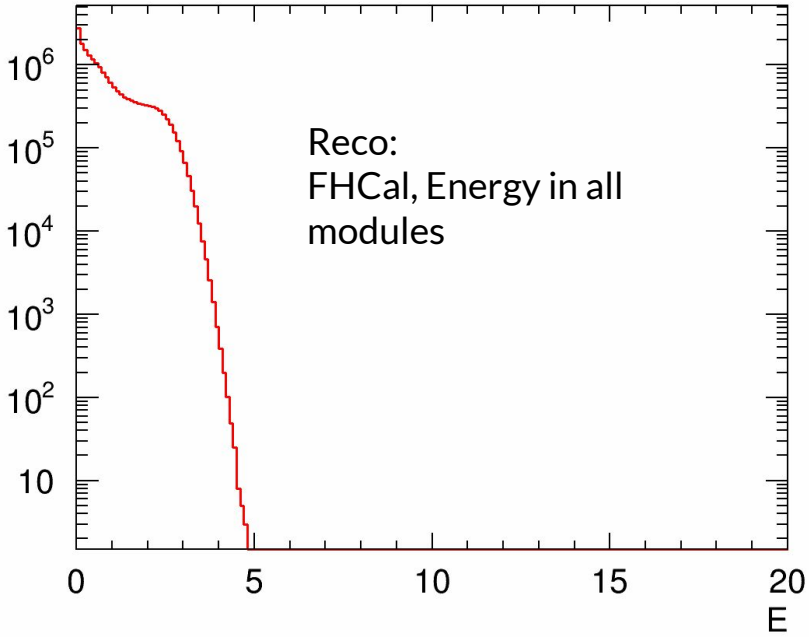






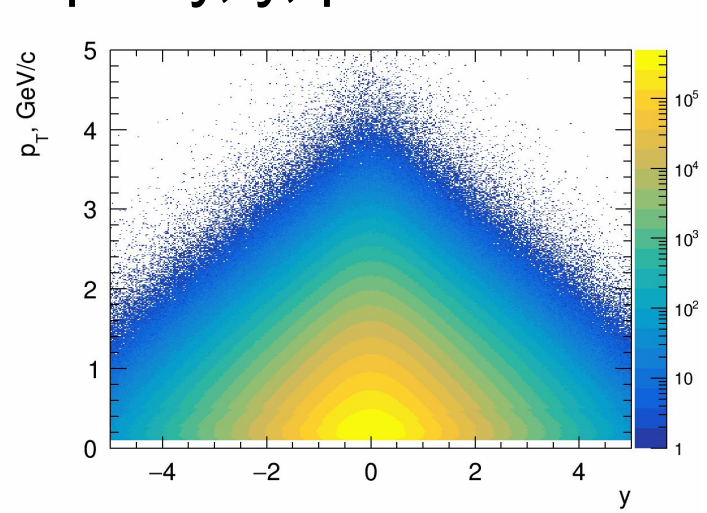
Energy

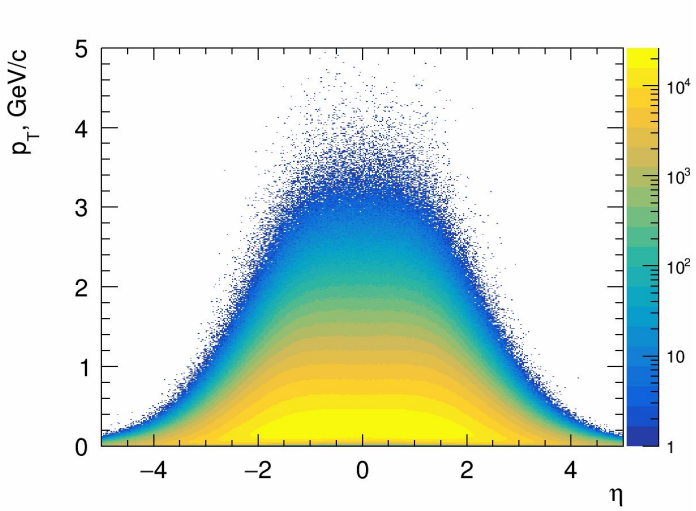

MC
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
0
5
10
15
20
E


Reco:
FHCal, Energy in all modules
10^6
10^5
10^4
10^3
10^2
10
0
5
10
15
20
E

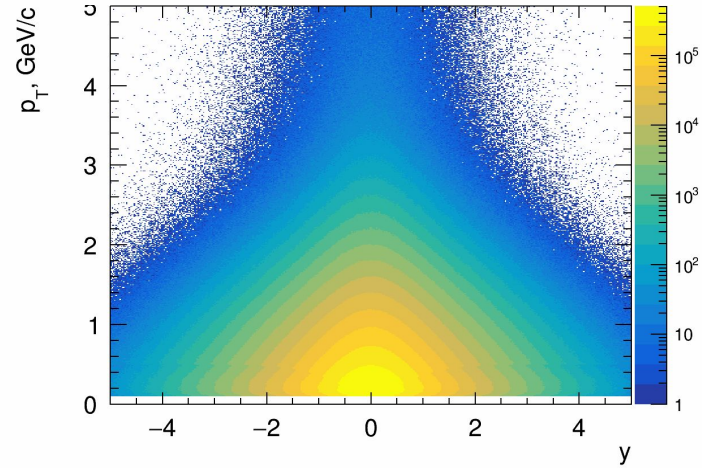
Rapidity, y, pt

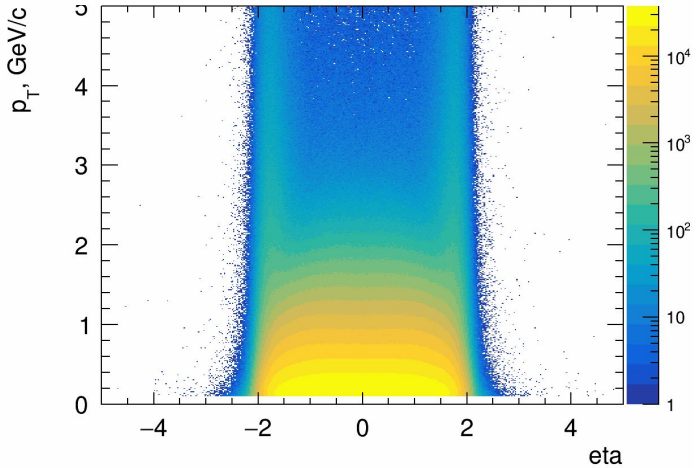
MC





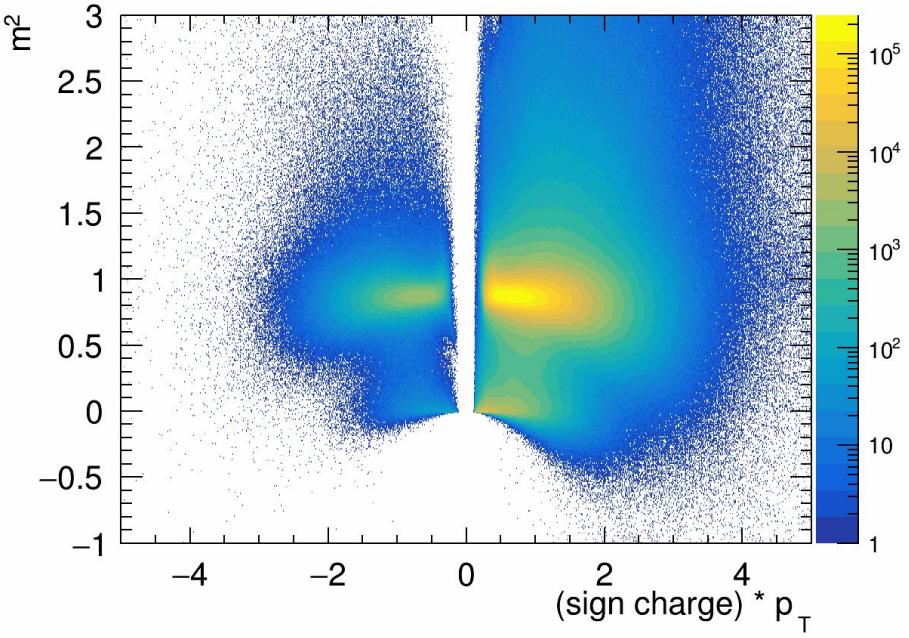
Reco

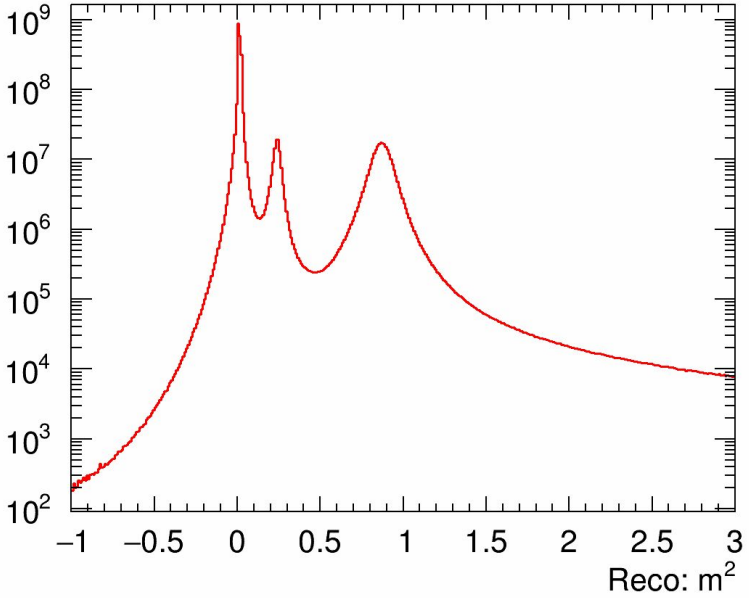




PID

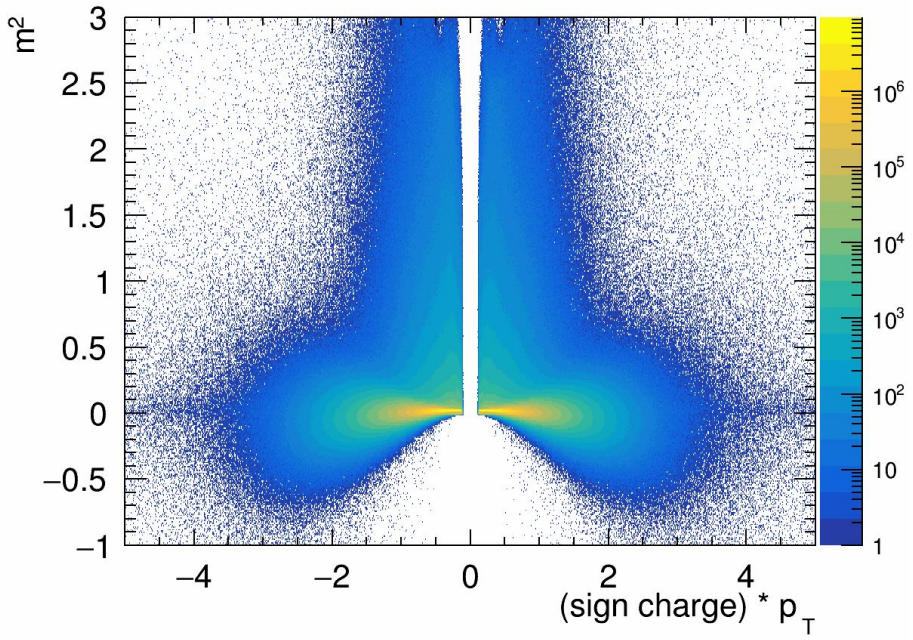
(Anti)Protons





PID

Pions



Kaons