# First look at net charge and particle ratio event-by-event dynamical fluctuations with MPD

Bi+Bi collisions at $\sqrt{s_{NN}}$= 9.2 GeV, UrQMD model

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# Motivation, physic interest

- Fluctuations of conserved quantities (**B,S,Q**) in a limited phase space probe the QGP phase.

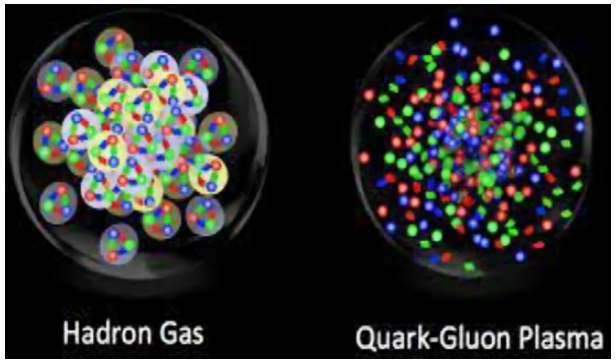
➔ Differentiate partonic vs hadronic state.

D-measure: $4\frac{\langle \delta Q^2 \rangle}{\langle N_{ch} \rangle}$

$$D = \begin{cases} 4\text{ , HG} \\ 3\text{ , HRG} \\ 1\text{ - }1.5\text{ , QGP} \end{cases}$$

S. Jeon, V. Koch, Phys. Rev. Lett. **85**, 2076
S. Jeon, V. Koch, arXiv:hep-ph/0304012

Fluctuations of total charge Q ~ $q^2$ of sources




$q^2$=1 $q^2$=1/9, 4/9

- Non-monotonic behavior in fluctuations as a function of beam energy are proposed as signatures of the QCD critical point.
  J.Phys.G34:S437,2007; Phys. Rev. Lett. 81, 4816 (1998)

- At NICA it is possible to investigate fluctuations via collision energy.

# Dynamical net charge fluctuations

- Net-charge, net-proton, net-strangness fluctuations are analysied in terms of moments of distributions (**M**, standard deviation **σ**, skewness **S**, kurtosis **κ**), higher moments (cumulants).

- Dynamical fluctuation variable **ν** was introduced (to get rid from statistical fluctuations) which measures deviation from Poisson behavior:

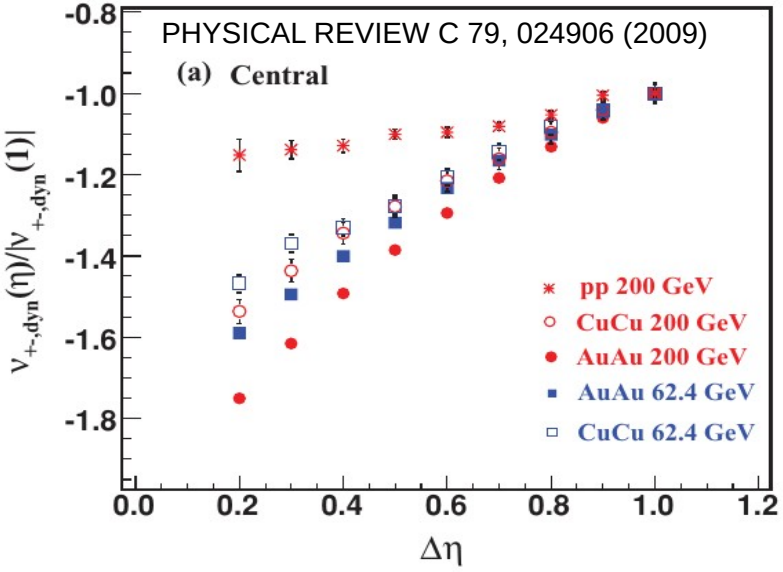
$$\nu_{dyn}[+,-] = \frac{\langle N_+(N_+-1)\rangle}{\langle N_+\rangle^2} + \frac{\langle N_-(N_--1)\rangle}{\langle N_-\rangle^2} - 2\frac{\langle N_+N_-\rangle}{\langle N_+\rangle\langle N_-\rangle}$$

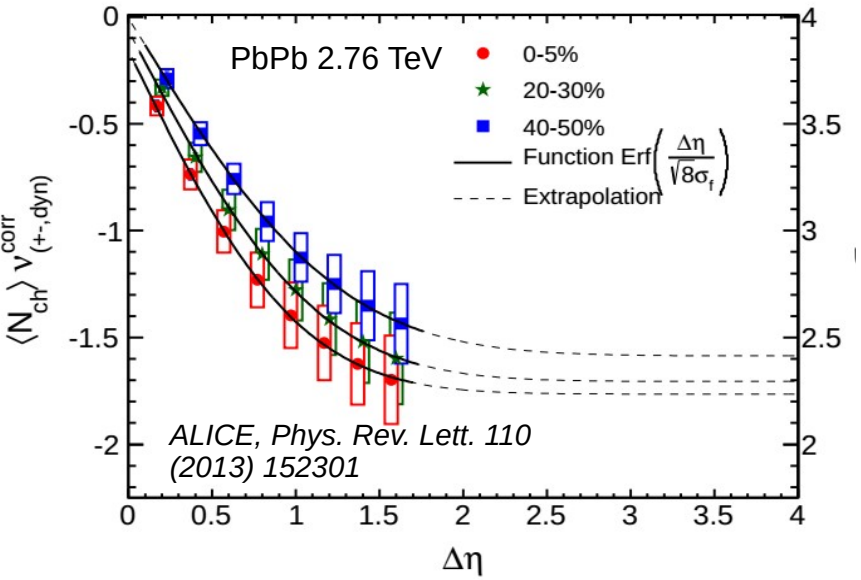
  - $\nu_{dyn} < 0$ → (opposite charge) correlations dominate
  - $\nu_{dyn} > 0$ → (same charge) fluctuations dominate
  - $\nu_{dyn} = 0$ → independent particle production

For $\langle N_+\rangle \approx \langle N_-\rangle$: $$D = 4\frac{\langle \delta Q^2\rangle}{\langle N_{ch}\rangle} \approx \langle N_{ch}\rangle\langle \nu_{dyn}\rangle + 4$$

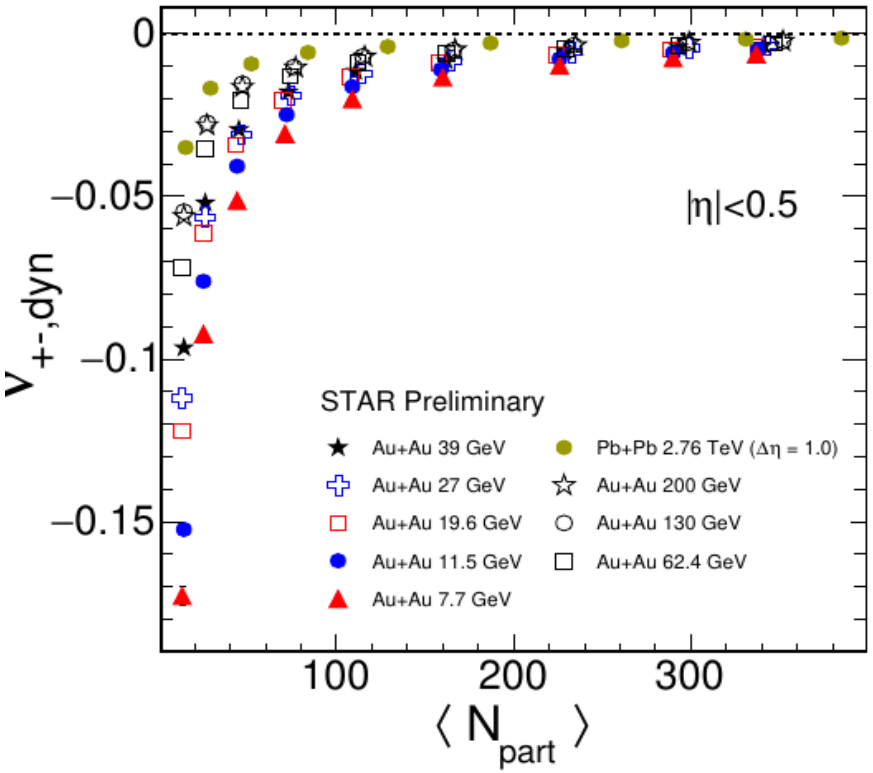
# Experimental data on net-charge fluctuations

## η-phase window dependence

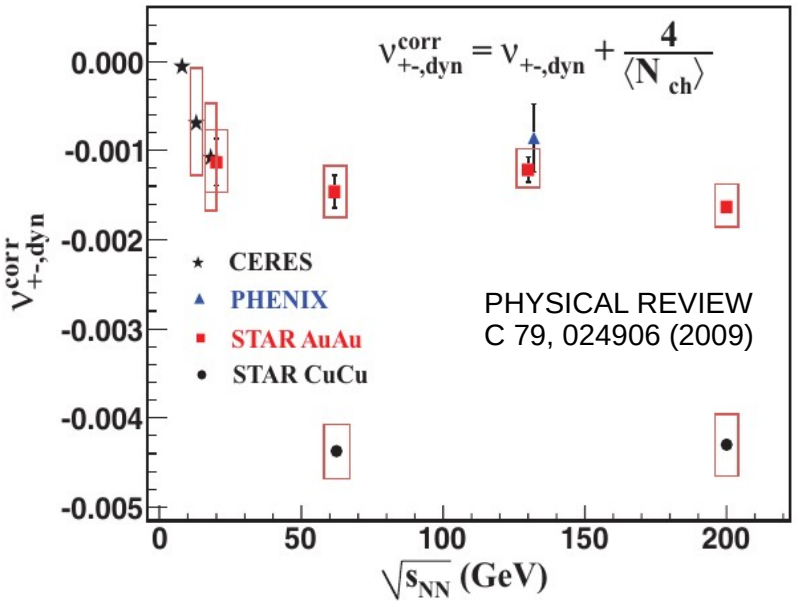


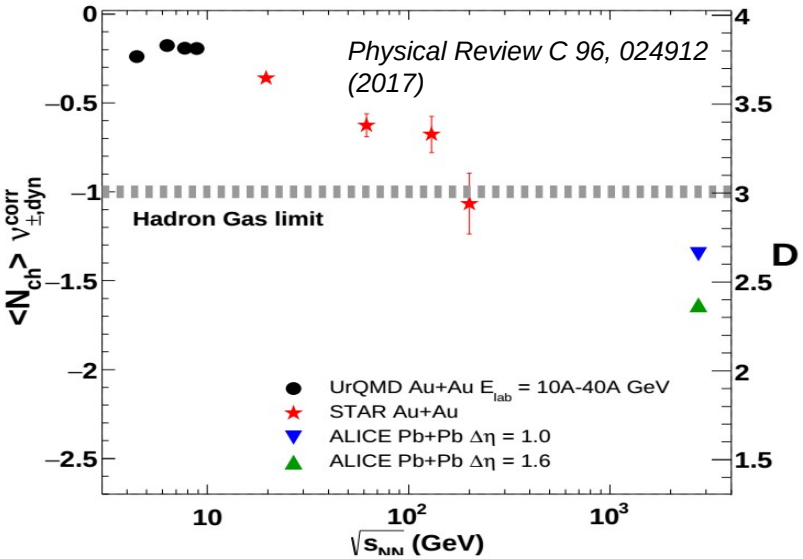




## Centrality dependence




## Collision energy dependence



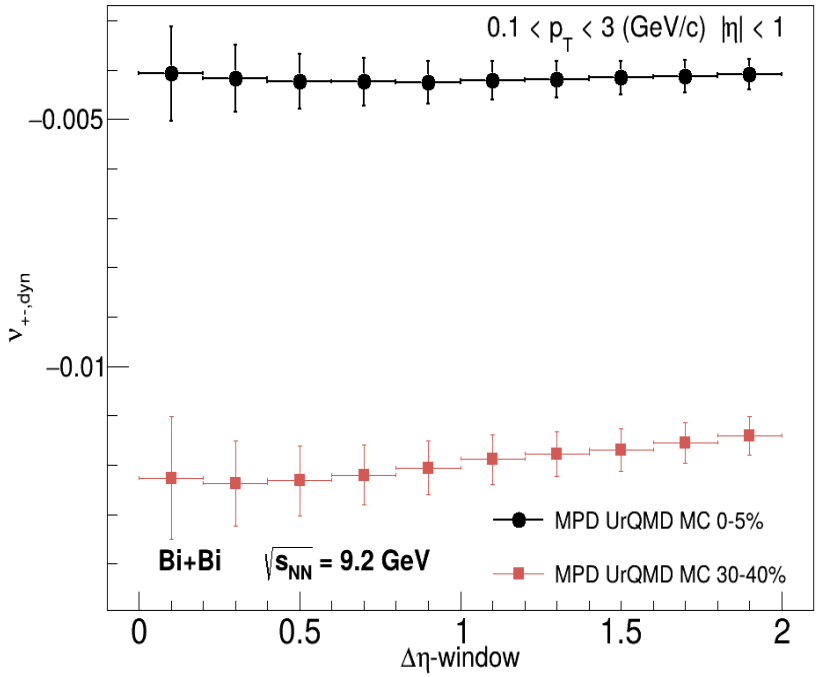



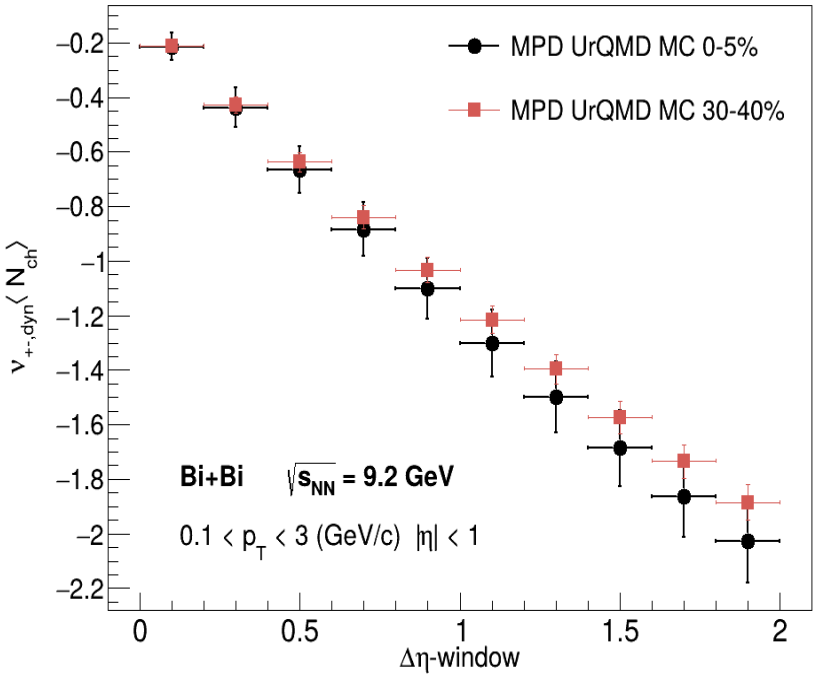
# MPD Results

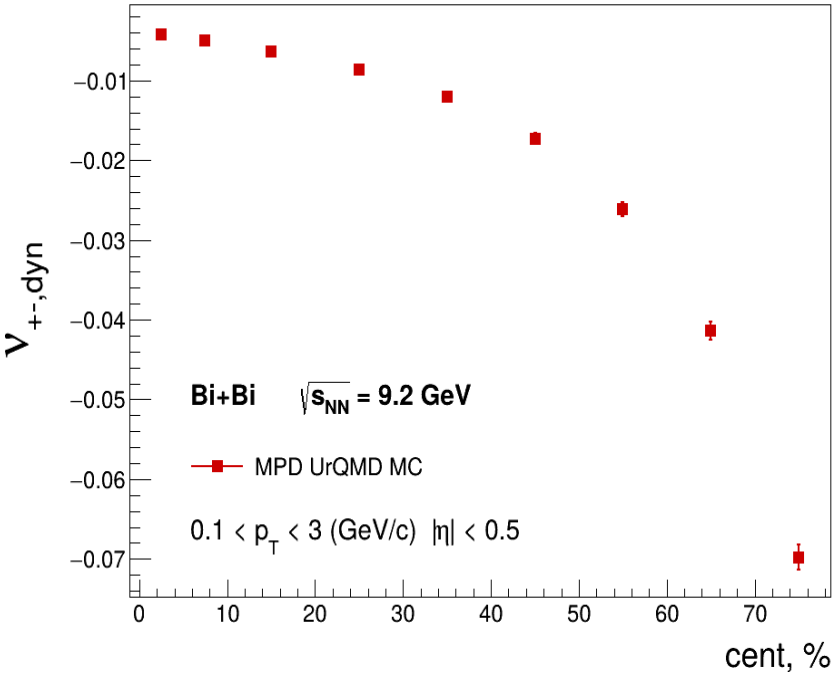
Data set /eos/nica/mpd/sim/data/exp/dst-BiBi-09.2GeV-mp07-22-500ev-req25/BiBi/09.2GeV-mb/urqmd/BiBi-09.2GeV-mp07-22-500ev-req25/0,1,..

Event selection: $|v_z| < 30$ cm, $v_{xy} < 2$ cm, 12 M events

MC tracks: Tracks for final hadrons with $0.1 < p_T < 3$ GeV/c, $|\eta|<1$
Final hadrons = (p,K,π) from primary vertex ($\sqrt{(MCHeader->GetX() - trackMC->GetStartX())^2 + .. } < 1e\text{-}6$)



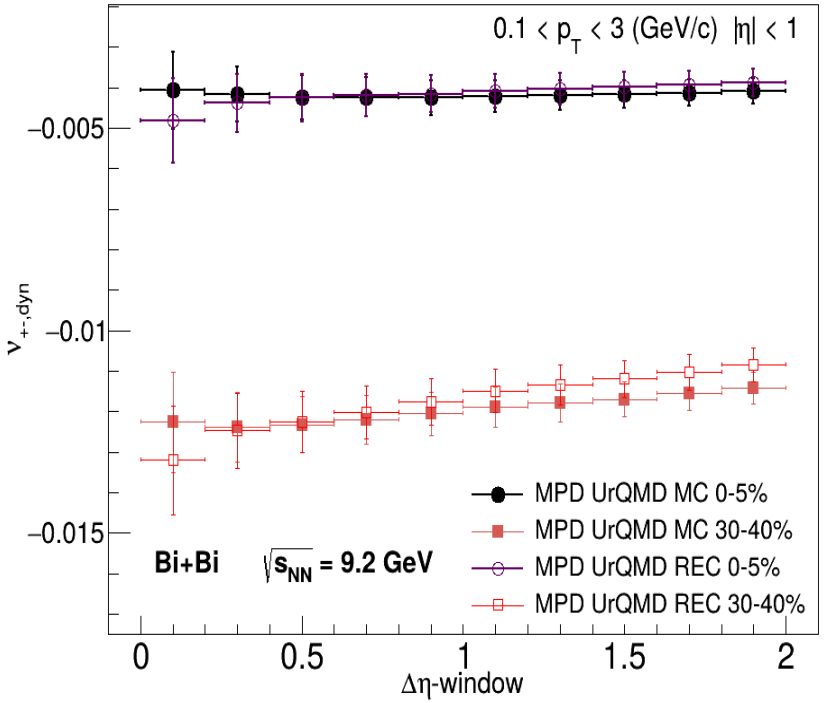



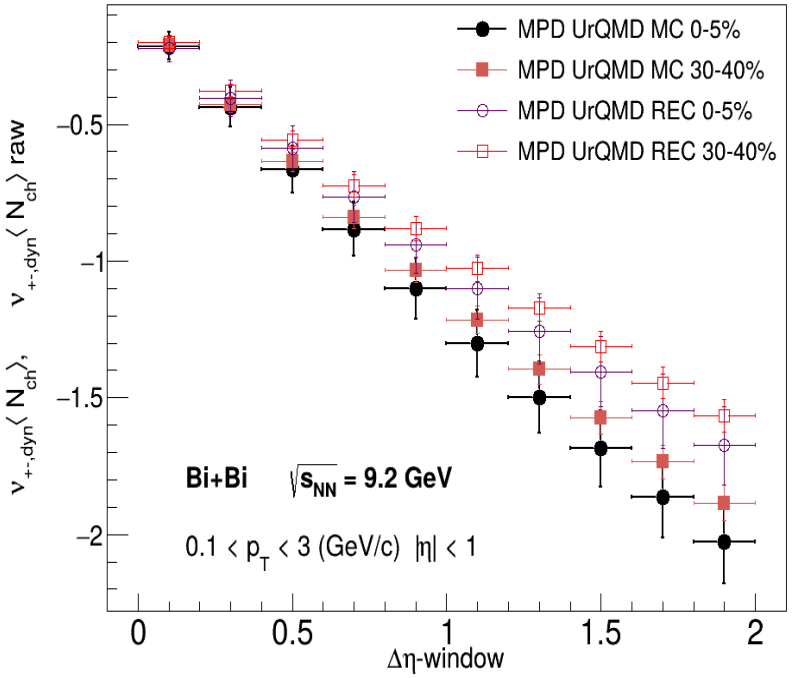



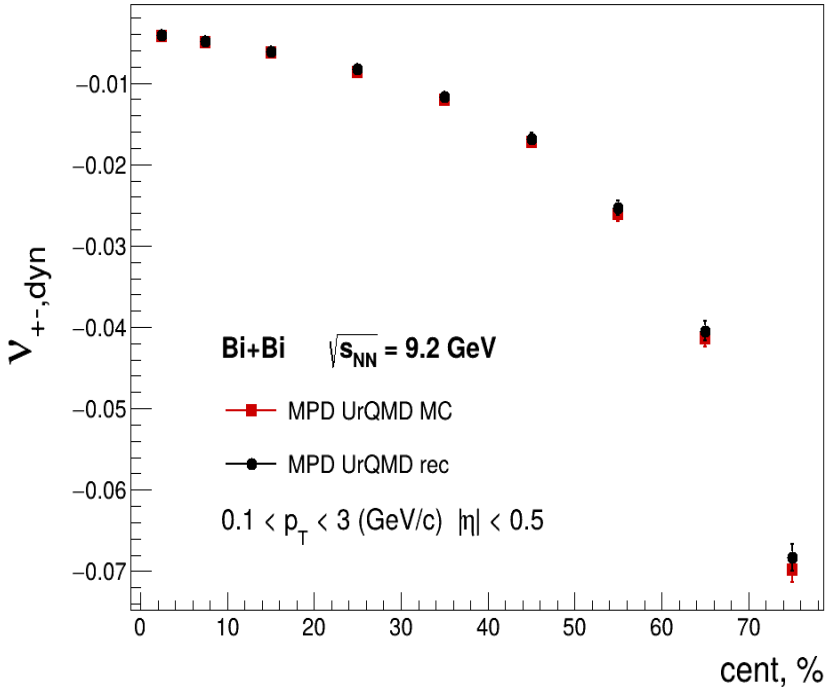

- Generally results have to be corrected for global charge conservation effect.

# UrQMD MC vs reconstructed

Reco tracks: (MpdTrack*)event→GetGlobalTracks(); track→GetNofHits() > 15, dca < 1 cm; $0.1 < p_T < 3$ GeV/c, $|\eta|<1$




- ν observable was found robust against random efficiency losses.
  - Holds only if efficiency is independent on multiplicity

  C. Pruneau, S. Gavin, S. Voloshin, Phys. Rev. C 66, 044904 (2002).
- $\nu\langle N_{ch}\rangle$ observable has to be corrected for the efficiency. *To be done...*

- Fair good MC-rec agreement.
- Track contamination (additional number of uncorrelated particles with random charges), electron elimination … *have to be explored further….*

# Particle Ratio Fluctuations

# Particle Ratio Fluctuations

| p/π | K/π | K/p |
|---|---|---|
| $(p^+ + p^-)/(\pi^+ + \pi^-)$ | $(K^+ + K^-)/(\pi^+ + \pi^-)$ | $(K^+ + K^-)/(p^+ + p^-)$ |

- Non-monotonic behavior of the K/π yield ratio at $\sqrt{s_{NN}} \sim 7.6$ GeV at SPS for central Pb+Pb collisions is observed and is supposed to be a signature of phase transition.
  S. V. Afanasiev et al. (The NA49 Collaboration), Phys. Rev. C 66 054902 (2002)

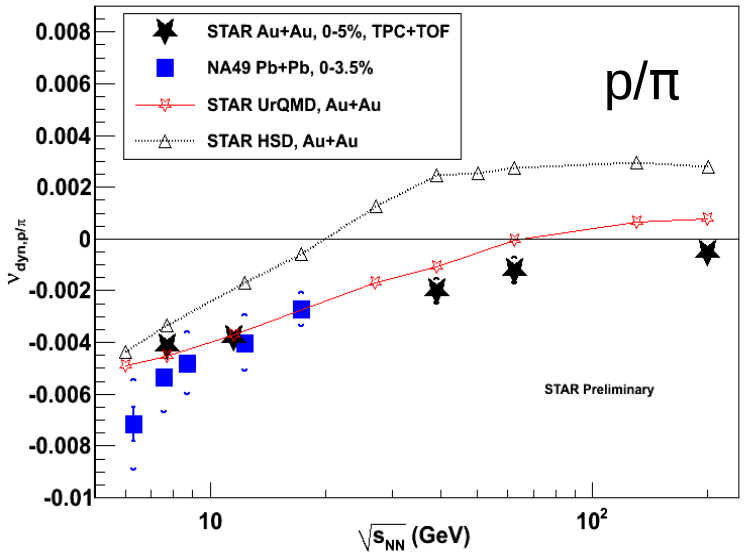
- At SPS $\sigma_{dyn}$ observable was used.
- STAR uses $\nu_{dyn}$

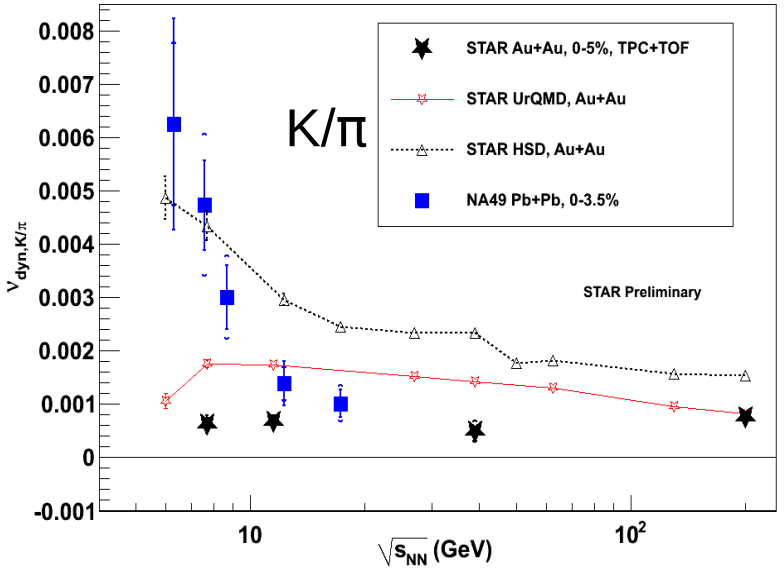
$$\nu_{\mathrm{dyn},K\pi} = \frac{\langle N_K(N_K - 1)\rangle}{\langle N_K\rangle^2} + \frac{\langle N_\pi(N_\pi - 1)\rangle}{\langle N_\pi\rangle^2} - 2\frac{\langle N_K N_\pi\rangle}{\langle N_K\rangle\langle N_\pi\rangle}$$

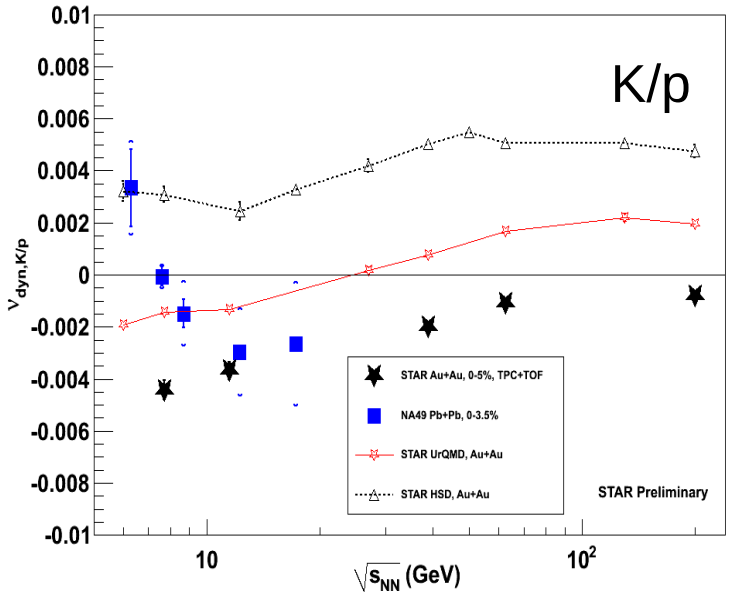
  - $\nu_{dyn} < 0 \rightarrow$ (Kπ) correlations dominate
  - $\nu_{dyn} > 0 \rightarrow$ (KK), (ππ) fluctuations dominate or anticorrelation (Kπ)

# Particle ratio fluctuations $\nu_{dyn,x/y}$

NA49 $\sigma_{dyn}$, converted to $\nu_{dyn}$, with $\sigma^2_{dyn} \equiv \nu_{dyn}$.



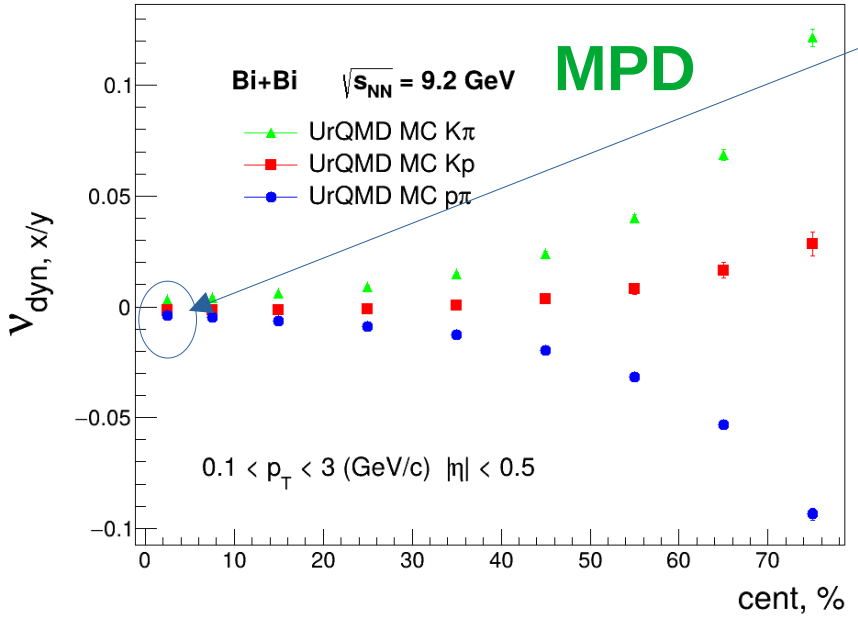




STAR, central collisions

Arxiv.1201.3336, arxiv.1211.0171

Phys.Rev.Lett.103:092301,2009

Central collisions



# Summary and near plans

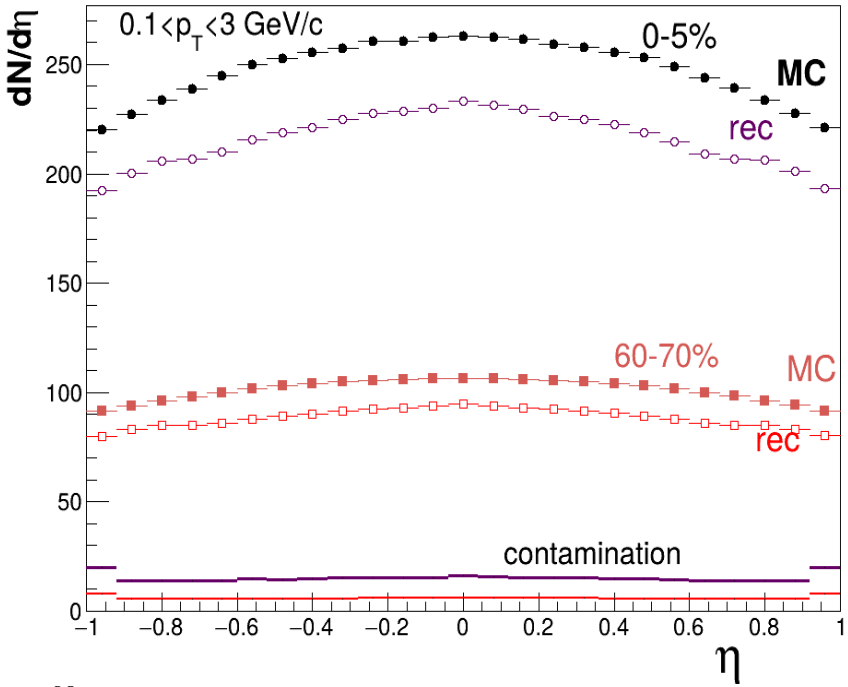
- Net charge fluctuations were calculated using $\nu$ (and $\nu N_{ch}$) observable in BiBi collisions at 9.02 GeV with UrQMD model at MC and Reco levels.
  - Fair good agreement between MC and Reco for $\nu$ observable (may be improved by using PID in reconstruction?)
  - $\nu N_{ch}$ -observable has to be corrected for the tracking efficiency (to be done).
  - Next: study of track contamination and electron elimination by using PID in reconstruction.

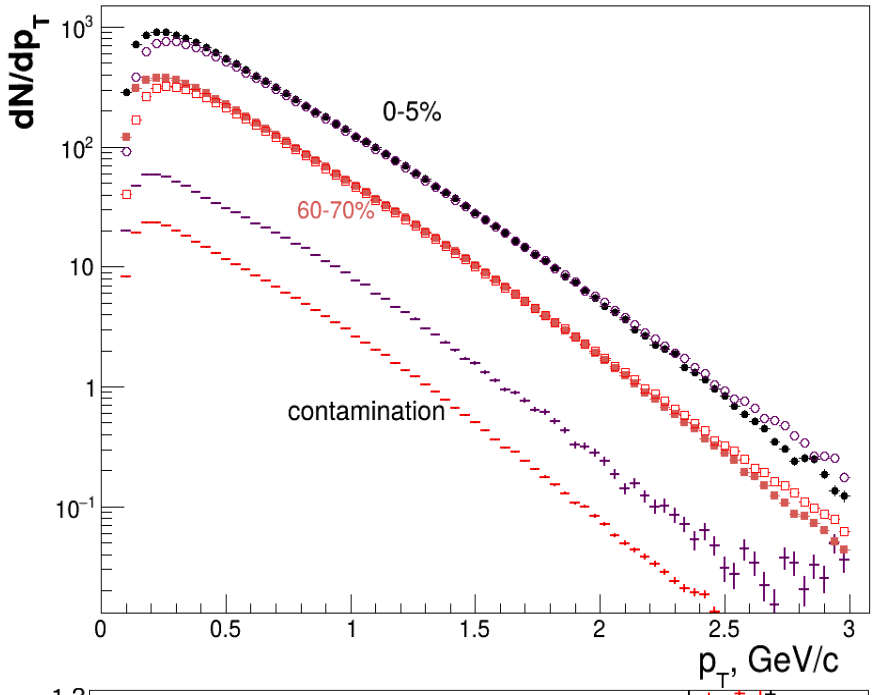
- Particle ratio fluctuations were calculated using $\nu$ observable at MC level.
  - Next: to include PID at Reco level.

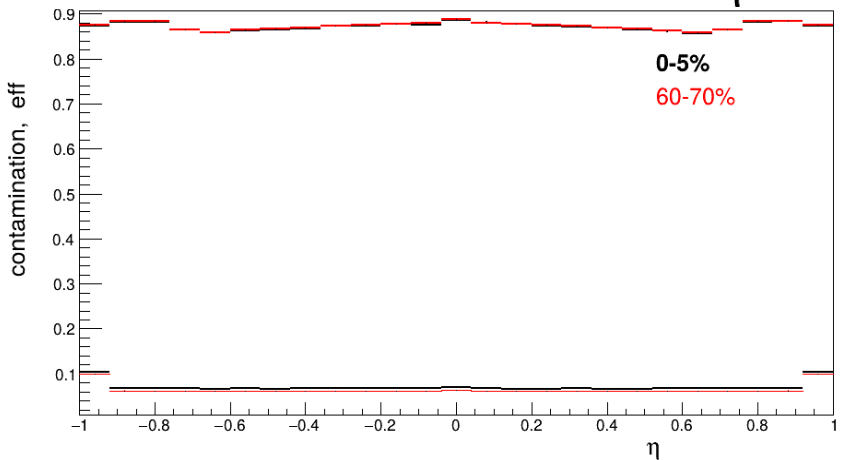
# Backup

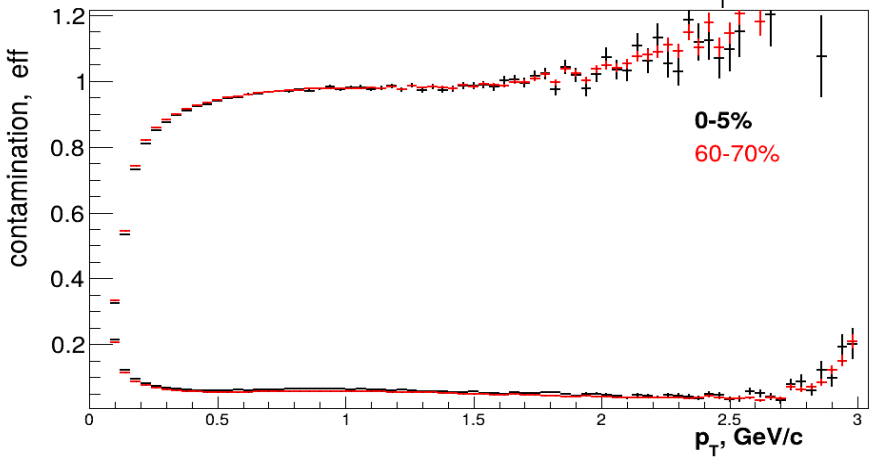
# UrQMD MC vs reconstructed

Reco tracks: (MpdTrack*)event→GetGlobalTracks(); track→GetNofHits() > 15, dca < 1 cm; $0.1 < p_T < 3$ GeV/c, $|\eta|<1$




- Efficiency = $N_{reconstructed}$ / $N_{MC\ track}$ can be improved by varying cuts on rec tracks.
- Contamination: reconstructed tracks which do not match MC tracks of final hadrons (see previous slide).
- Fraction of contamination = $N_{contamination}$ / $N_{reconstructed}$

- ➢ Weak centrality dependence.
- ➢ Large contamination at low $p_T$.