Energy dependence of moments of net-charge multiplicity distributions in Au+Au collisions at RHIC

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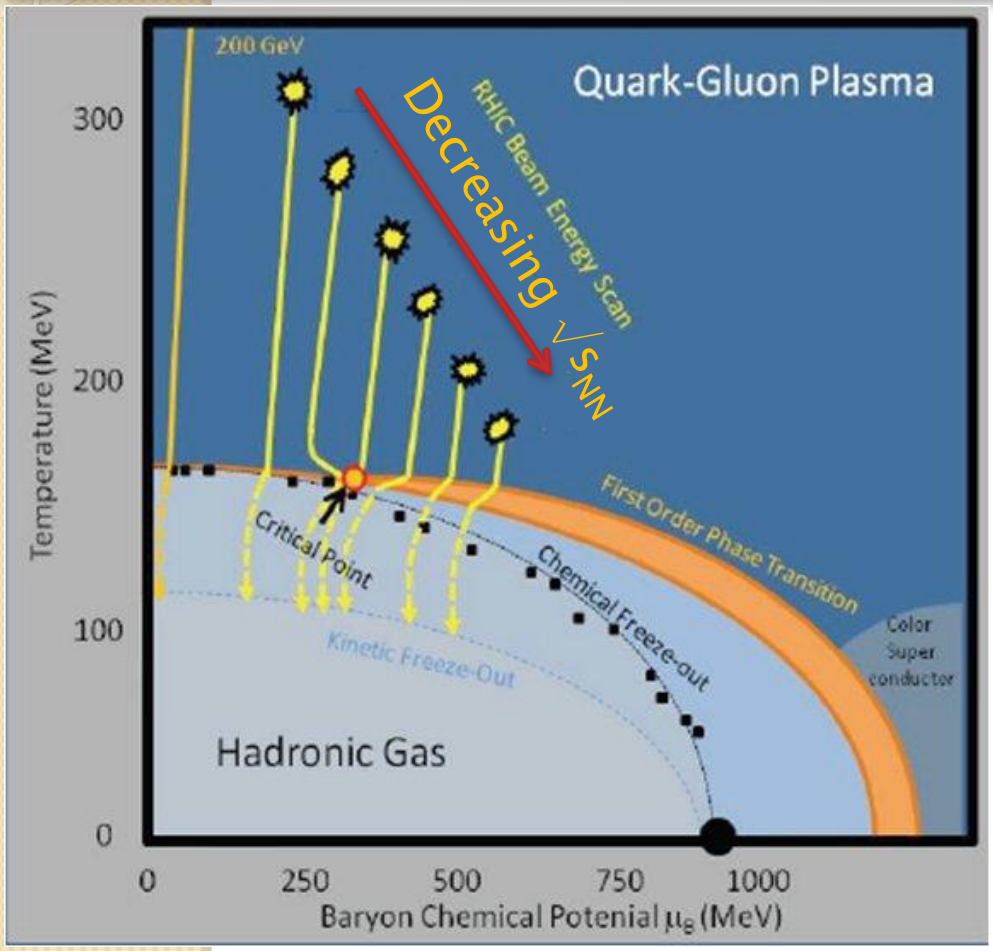
Outline

- Introduction
- PHENIX experiment
- Results for moments of net-charge distributions
- Summary/Outlook

Introduction



- At large μ_B
  → Ist order phase transition
- At μ_B ~ 0
  → crossover from QGP to HG
- The end point of the Ist order phase Transition
  → Critical end point

Lattice QCD predicts the existence and location of the Critical End Point in the phase diagram.

Introduction …

As $T \rightarrow T_c$: approaching critical point

- Susceptibility diverges
- Correlation length (ξ) diverges
  - ξ ~ system size

- Heavy ion collisions that pass close to a QCD critical point might demonstrate observable with large fluctuations in correlation lengths (ξ) of particular global variables like: total charge, net-charge.

Relation to experimentally measured quantity

- The correlation length (ξ) is related to the various moments of conserved quantities: *net-baryon, net-charge, net-strangeness*

Variance : $\sigma^2 = \langle(\Delta N)^2\rangle \sim \xi^2$ *where* $\Delta N = N - \langle N\rangle$

Skewness: $S = \langle(\Delta N)^3\rangle/\sigma^3 \sim \xi^{4.5}$ $\langle N\rangle$ = Mean

Kurtosis: $\kappa = \langle(\Delta N)^4\rangle/\sigma^4 - 3 \sim \xi^7$

- Higher moments are sensitive to non-Gaussian nature → amplify the signal.

Since the correlation length is expected to diverge at the CP, $S\sigma$ and $\kappa\sigma^2$ will show large deviation.

Theoretical model

Fluctuations of conserved quantities related to thermodynamic susceptibilities

- Lattice QCD and Hadron Resonance Gas (HRG) model

$$\chi_Q^{(1)} = \frac{\langle N_Q \rangle}{VT^3} \qquad \chi_Q^{(3)} = \frac{\langle (\delta N_Q)^3 \rangle}{VT^3} \qquad S_Q = \frac{\langle (\delta N_Q)^3 \rangle}{\sigma_Q^3}$$

$$\chi_Q^{(2)} = \frac{\langle (\delta N_Q)^2 \rangle}{VT^3} \qquad \chi_Q^{(4)} = \frac{\langle (\delta N_Q)^4 \rangle - 3\langle (\delta N_Q)^2 \rangle^2}{VT^3} \qquad \kappa_Q = \frac{\langle (\delta N_Q)^4 \rangle}{\sigma_Q^4} - 3$$

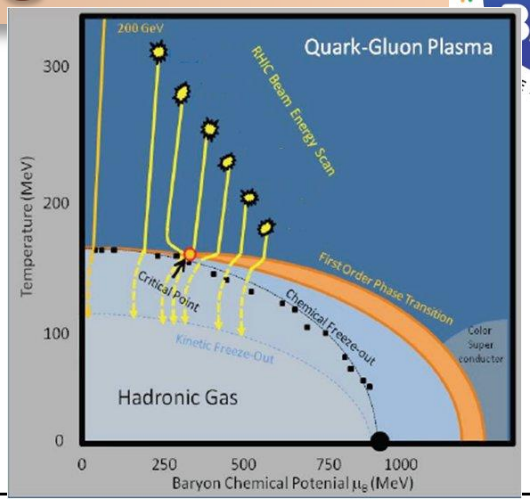
$$\frac{\sigma_Q^2}{M_Q} = \frac{\chi_Q^{(2)}}{\chi_Q^{(1)}}, S_Q\sigma_Q = \frac{\chi_Q^{(3)}}{\chi_Q^{(2)}}, \kappa_Q\sigma_Q^2 = \frac{\chi_Q^{(4)}}{\chi_Q^{(2)}}$$

} Volume cancels out

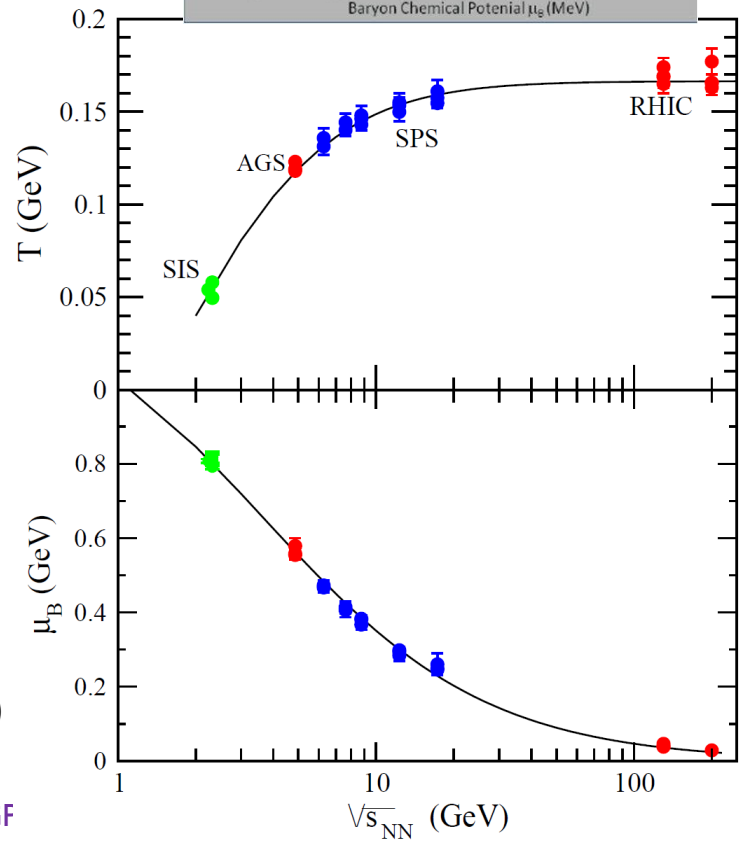
Experimentally measured higher moments can be used to extract freeze-out parameters. PRL 109 (2012) 192302

How to probe

By systematically varying the beam energy in heavy ion collisions will be able to probe different regions of the QCD phase diagram.

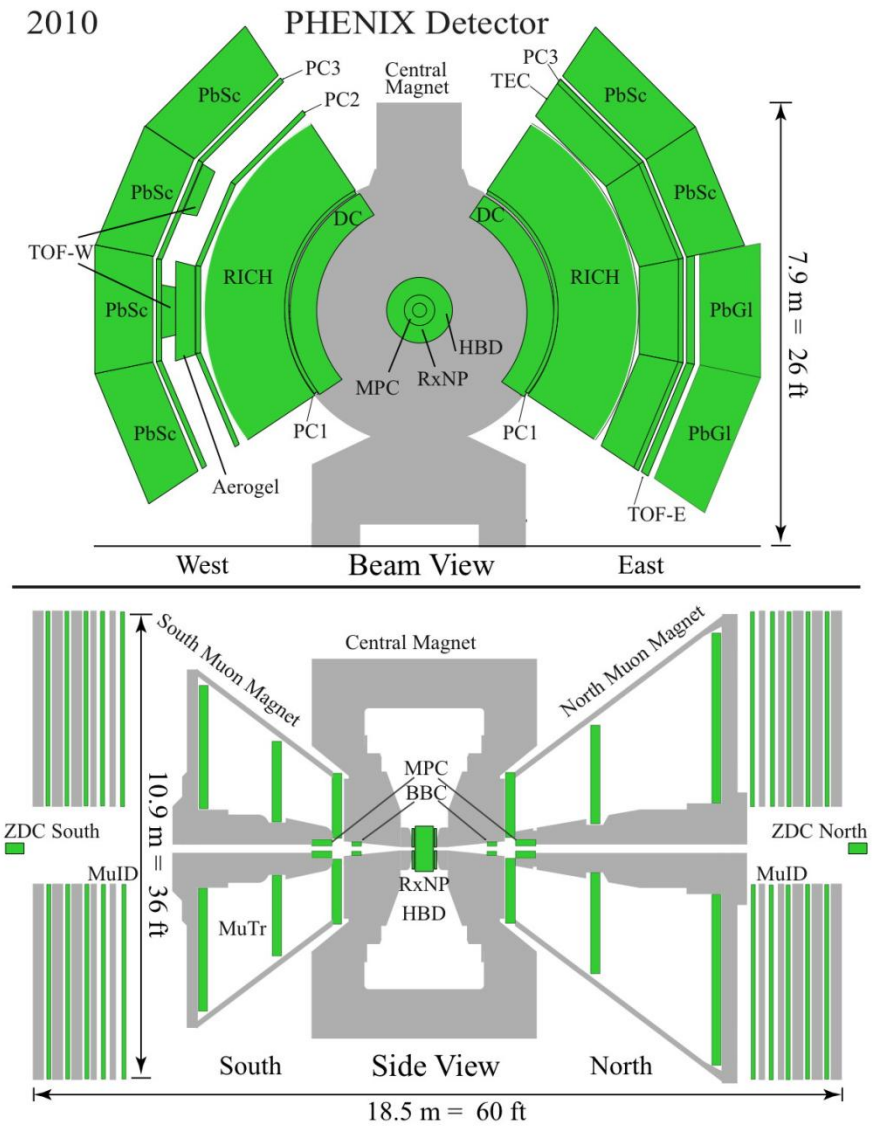


Look for the non-monotonic variations of higher moments of conserved quantity distributions as a function of energy



PRC 73, 034905 (2006)

PHENIX detector at RHIC



Global Detectors:

- BBC (3.0 < |η| < 3.9)
- ZDC (|η| > 6)
- RXNP (1.0<|η|<1.5 [inner]
  (1.5<|η|<2.8 [outer])

Central Arm Detectors :

- DC, PC1, PC2, PC3
- RICH
- ToF
- EmCal

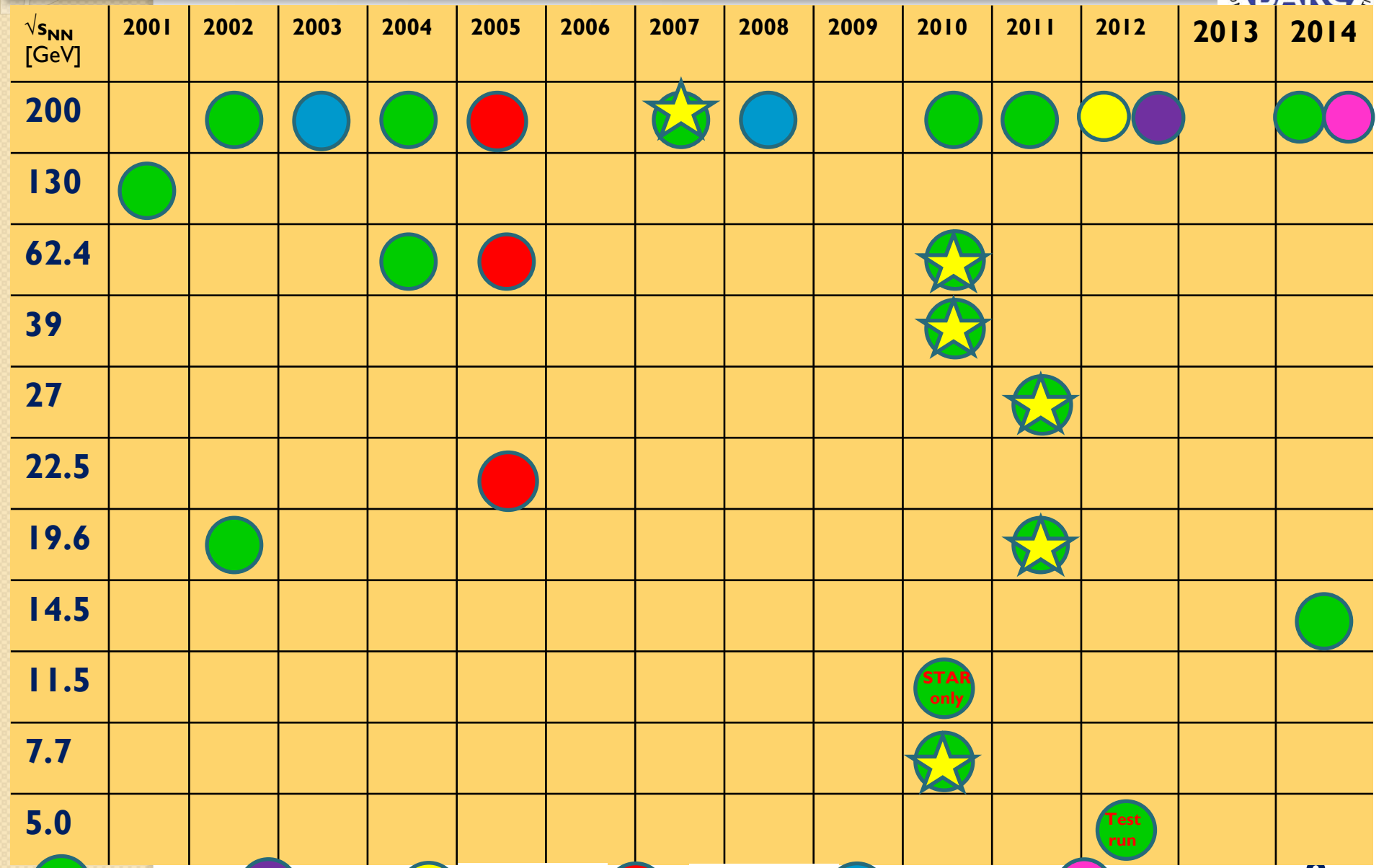
Hadrons, photons,electrons

- |η| < 0.35
- Pe > 0.2 GeV/c
- Δφ = π (2 arms x π/2)

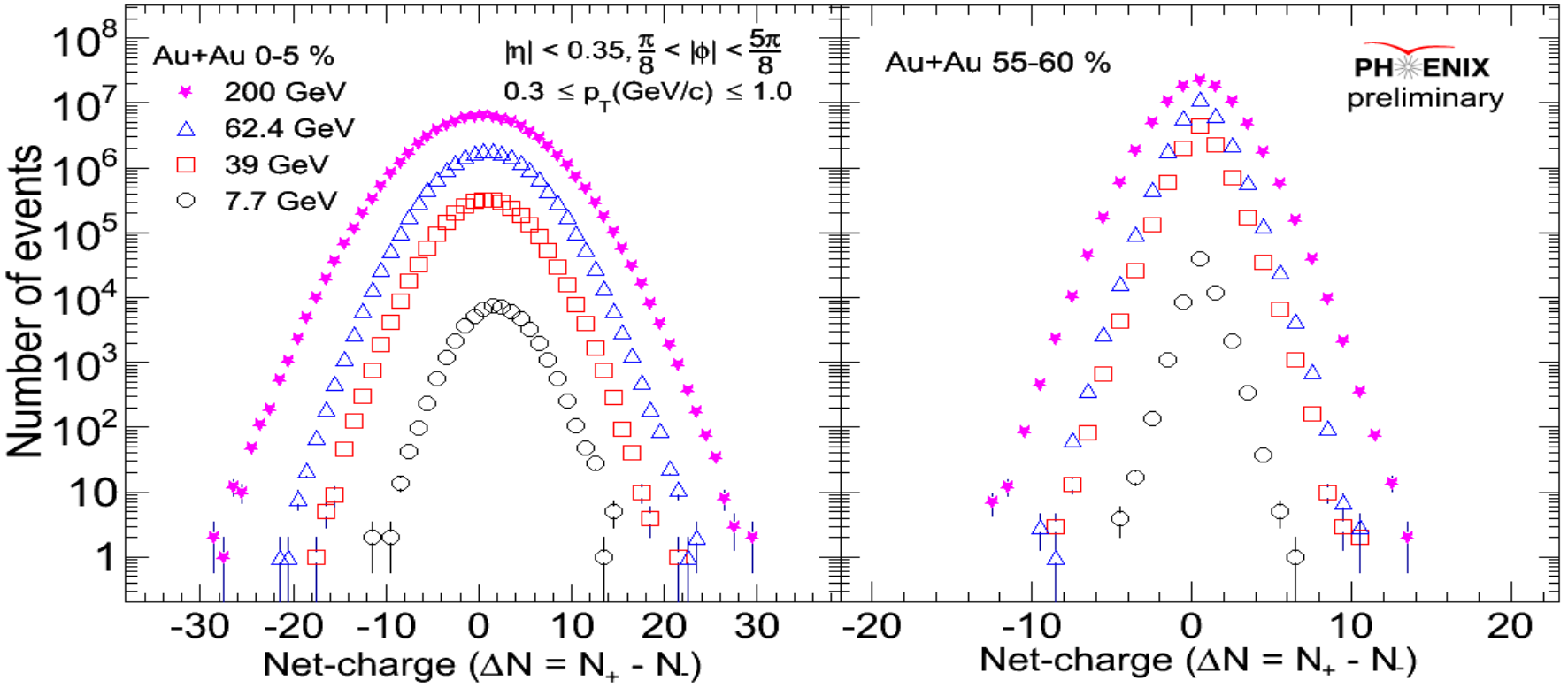
Forward rapidity arms:
Muons

- $1.2 < |\eta| < 2.2$
- $p\mu > 1$ GeV/c
- $\Delta\varphi = 2\pi$

RHIC Beam energy scan program



Net-charge distribution

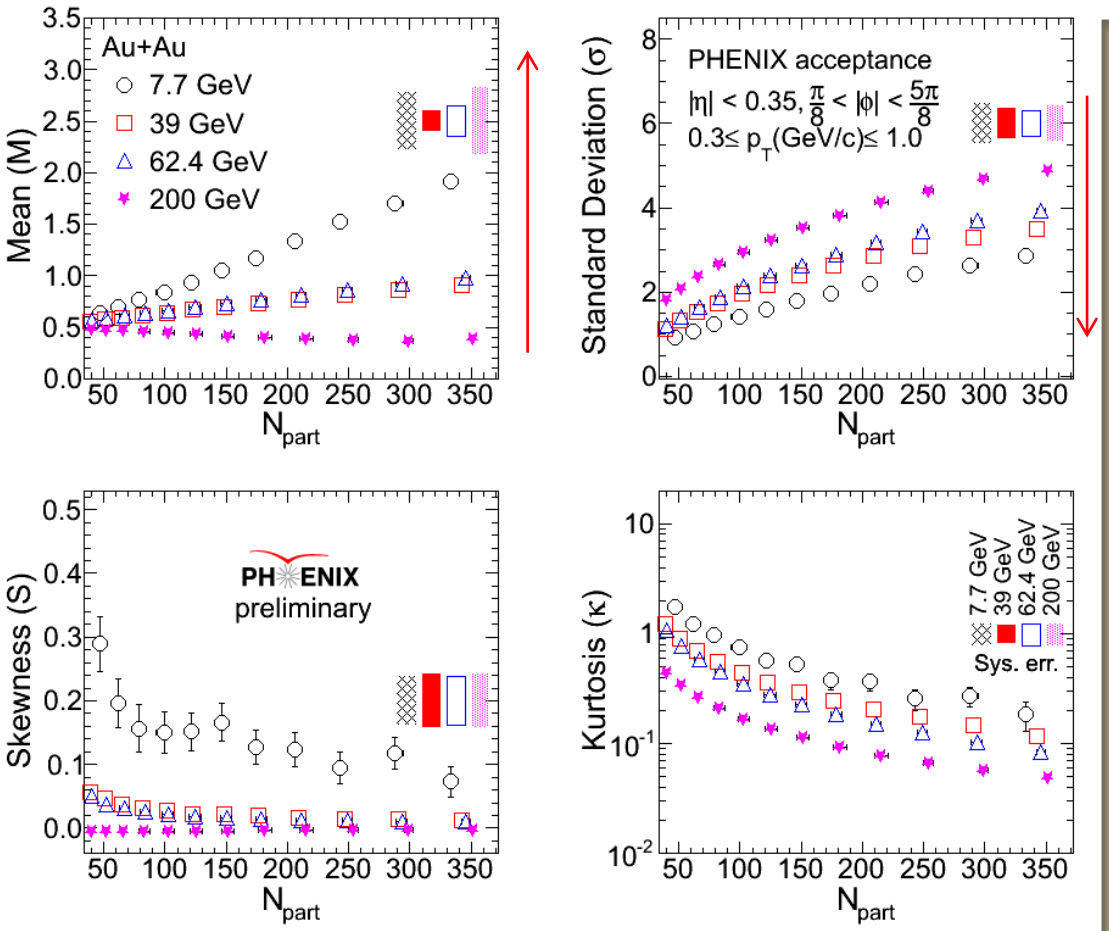


Distributions are not corrected for efficiency and acceptance

Data covers several orders of magnitude

Distributions are symmetric around zero

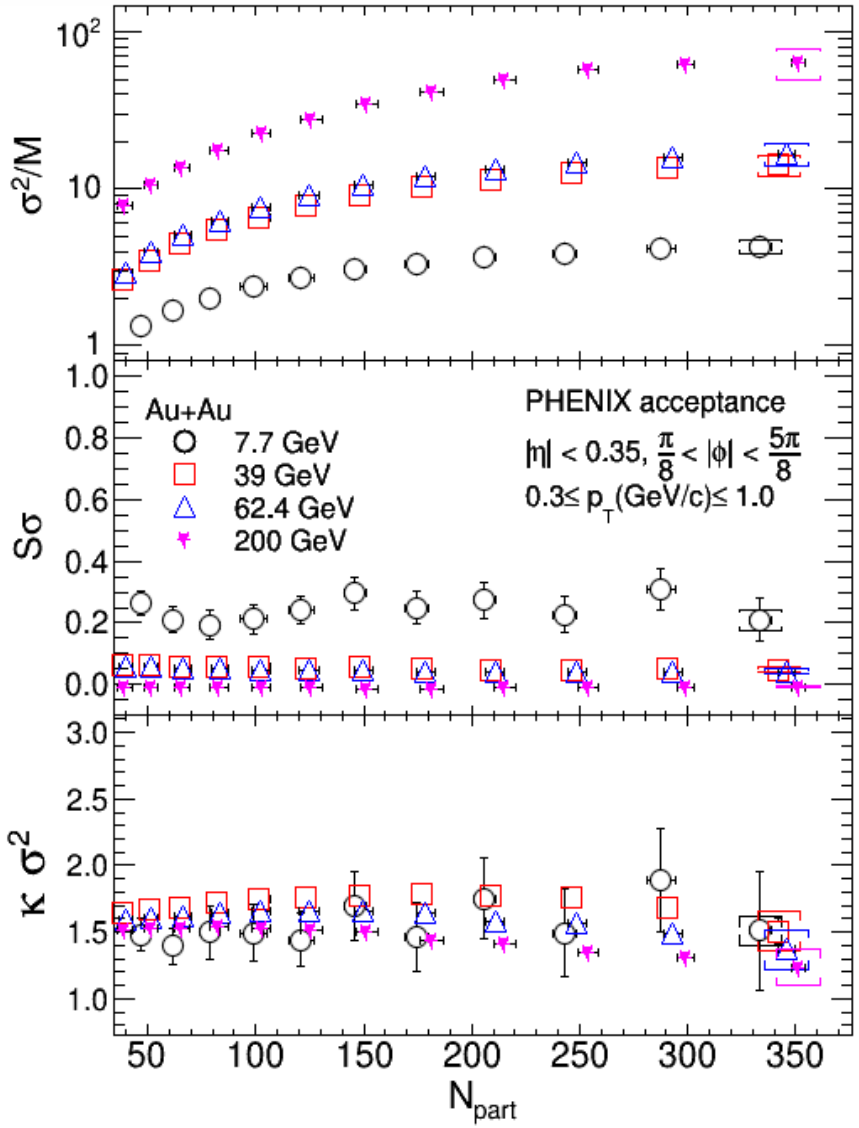
Moments of the distribution



- M increases as we go higher to lower energy
- σ increases with energy and centrality
- S and κ increase with decreasing beam energy
- S and κ decrease from peripheral to central collisions

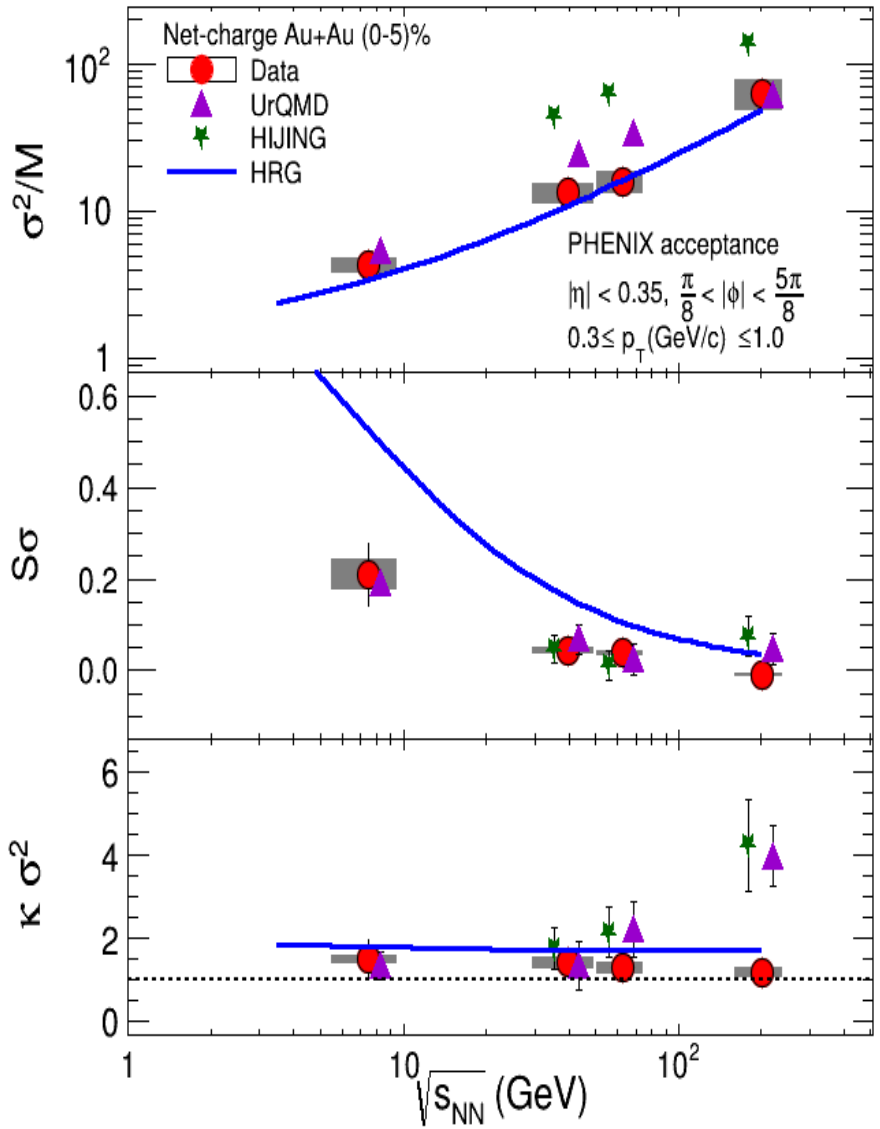
Efficiency uncorrected moments.

Centrality dependence of product of moments



- σ^2/M increase with centrality
- $S\sigma$ and $\kappa\sigma^2$ have very weak centrality dependence

Data vs model comparison



σ^2/M

- increase with increase in colliding energies
- Follows the HRG predictions for all the energies
- Comparable with the model predictions

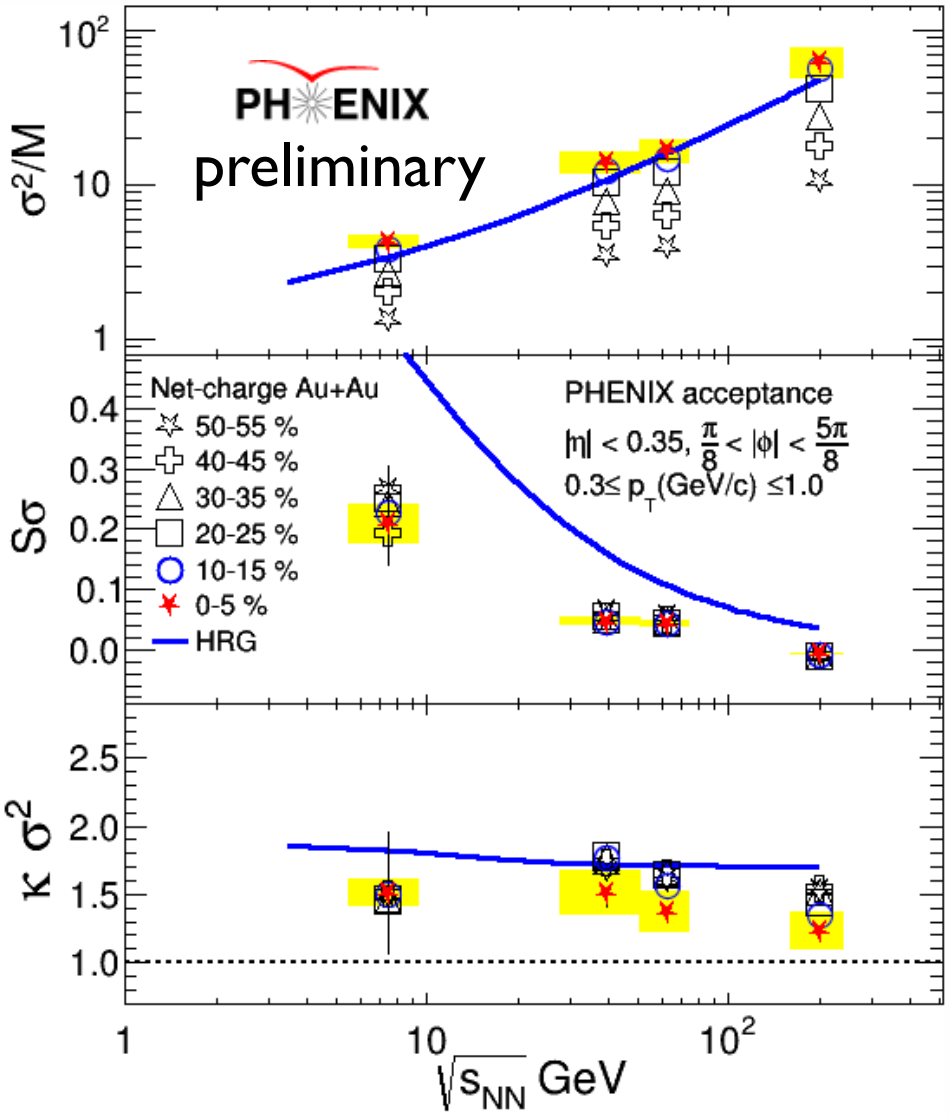
$S\sigma$

- Increase with decreasing colliding energy
- Comparable with the model predictions
- At lower energies experimental values are lower than HRG predictions.

$\kappa\sigma^2$

- No energy dependence and below the HRG predictions
- Comparable with the model predictions
  - except for highest energy point

Centrality and energy dependence



- σ^2/M increase with increase in colliding energies and centrality
- $S\sigma$ and $\kappa\sigma^2$ are independent of centrality

Summary

- Fluctuation of net-charge have been measured at different $\sqrt{s_{NN}}$
- Moments of net-charge
  - σ^2/M increase with colliding energies
  - $S\sigma$ values increase with decreasing energies
  - $\kappa\sigma^2$ is independent of colliding energies
- No significant deviation observed in data.

19.6 and 27 GeV results will be available soon