# Effects of Nucleon Potential on the Cumulants of Net-Proton and Net-Baryon Multiplicity Distributions in Au+Au Collisions at $\sqrt{s_{NN}}$=5 GeV

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arXiv:1607.06376

# Outline

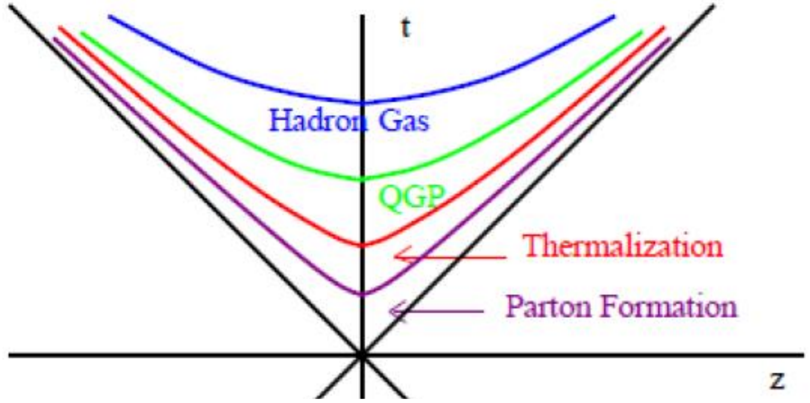
- Fluctuation and QCD Phase Diagram
- Transport model in the study of potential effect
- Analysis Results

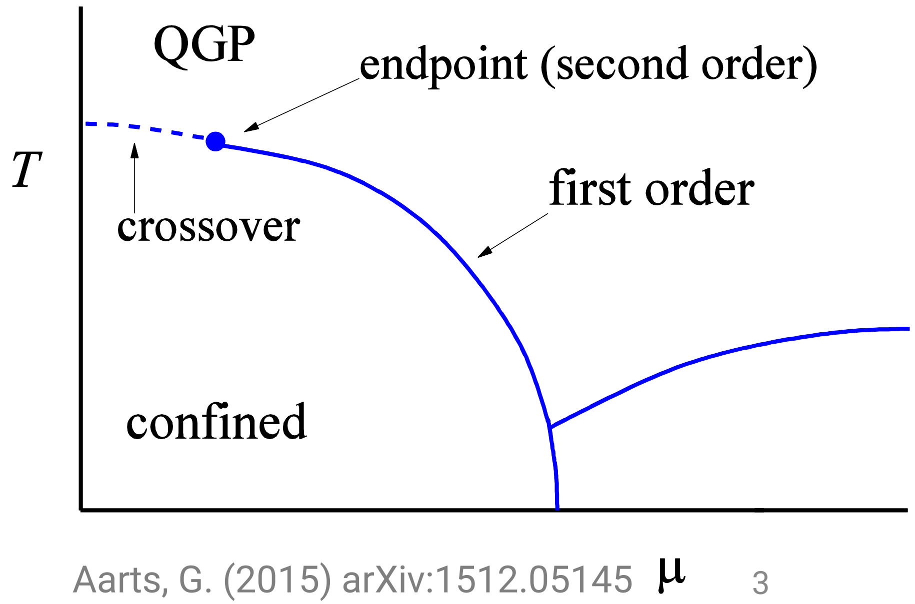
# Why Study the Fluctuation of Conserved Charge

Fluctuation reveals the properties of primordial thermodynamics of the medium

Fluctuation of conserved charge are sensitive to correlation length of the medium

Space-time diagram




Aarts, G. (2015) arXiv:1512.05145

# Observable: Cumulants of Net Baryon

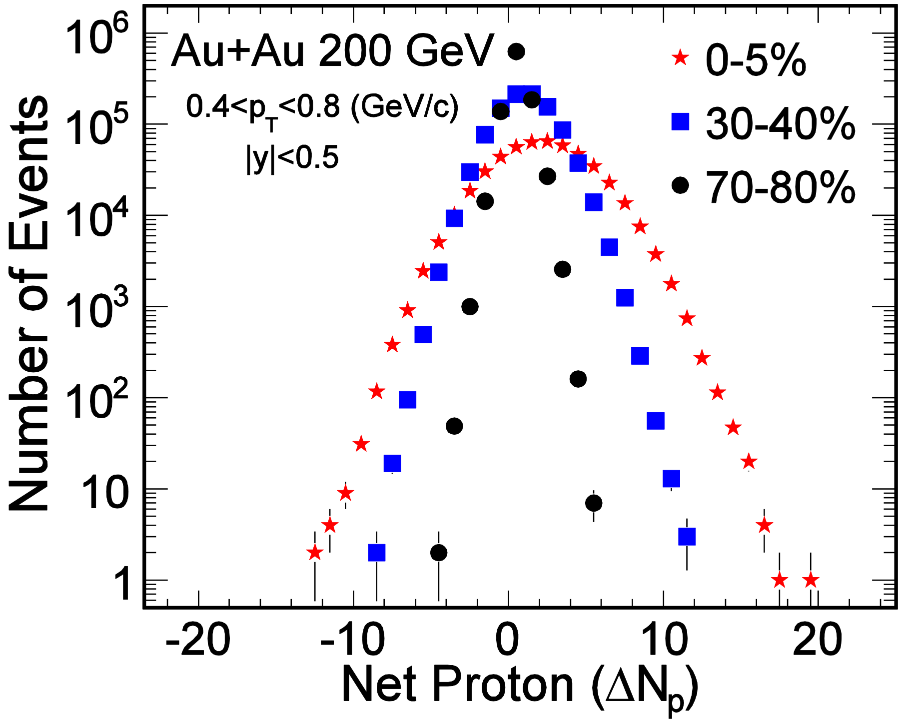
- Moments and cumulants

$$C_1 = \langle N \rangle,$$
$$C_2 = \langle (\delta N)^2 \rangle,$$
$$C_3 = \langle (\delta N)^3 \rangle,$$
$$C_4 = \langle (\delta N)^4 \rangle - 3\langle (\delta N)^2 \rangle^2.$$

Where $\delta N = N - \langle N \rangle$. Using net proton as a proxy of net baryon number.

- Net proton fluctuation are measured event by event.
- Susceptibility and cumulants ratios

$$\frac{\chi_B^4}{\chi_B^2} \rightarrow \frac{C_4}{C_2} = \kappa\sigma^2, \frac{\chi_B^3}{\chi_B^2} \rightarrow \frac{C_3}{C_2} = S\sigma$$

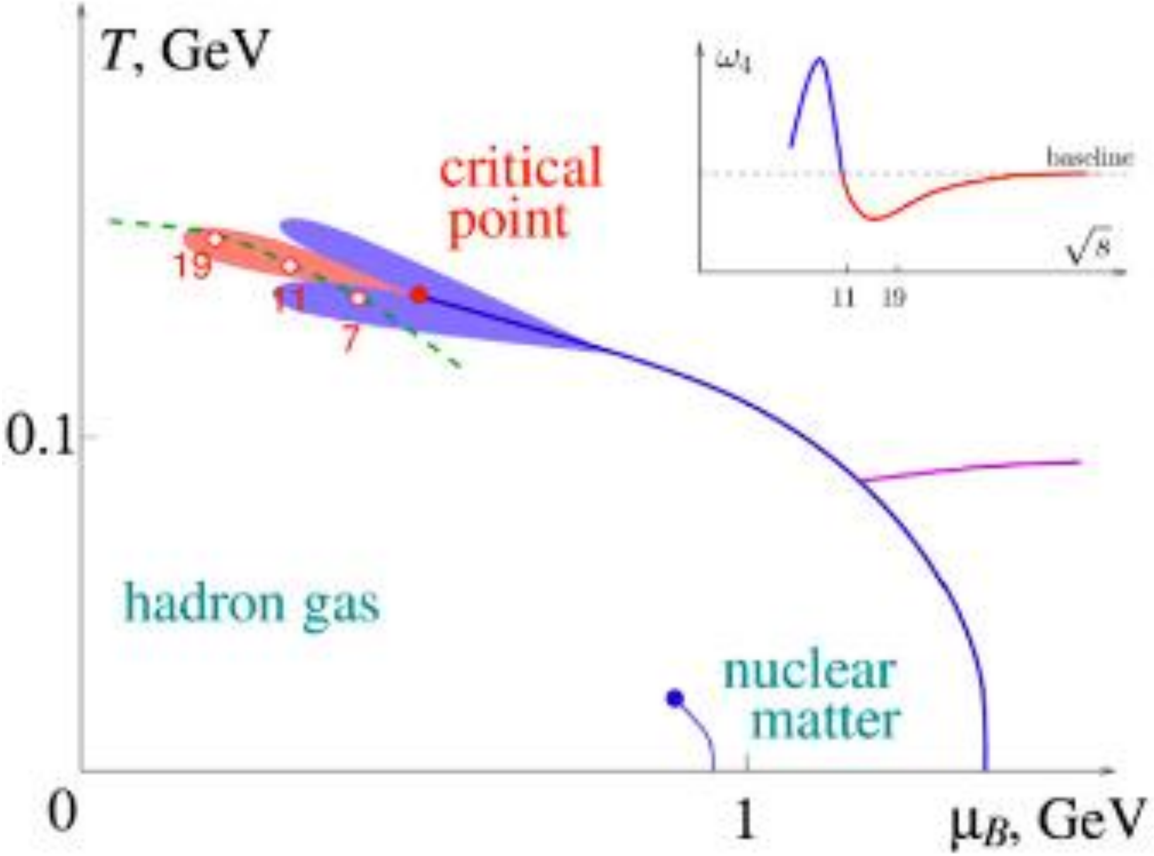


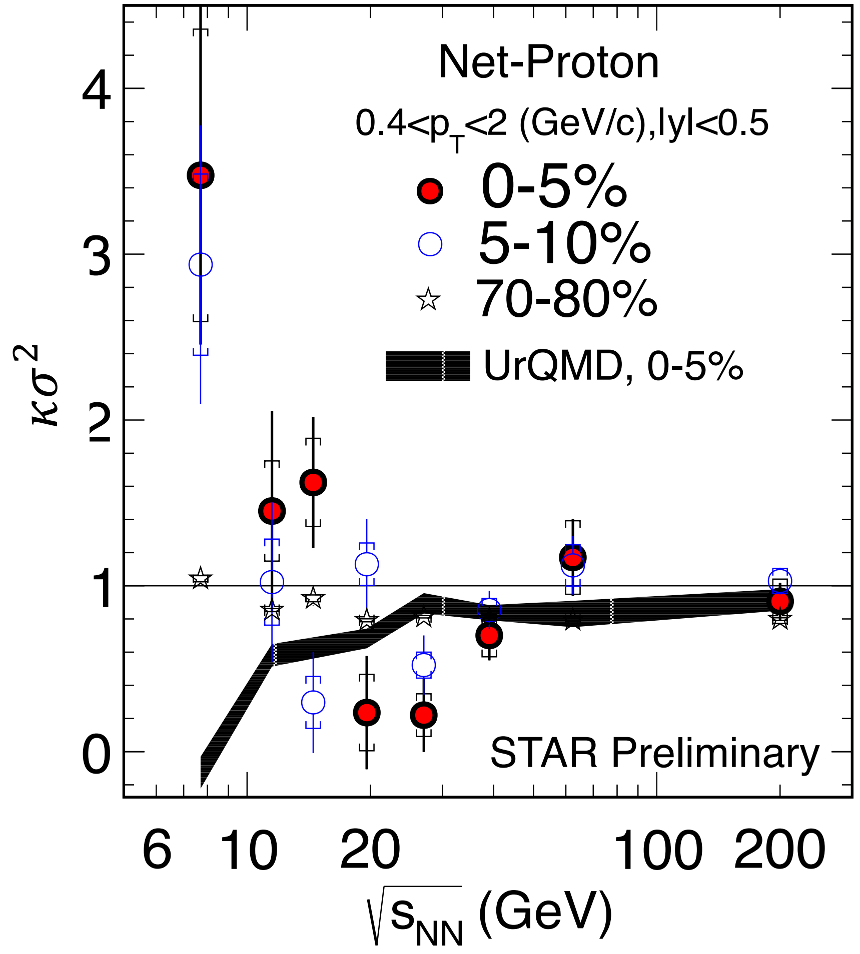

Event by event net proton multiplicity distribution

STAR: PRL 105, 022302 (2010)

# Motivation: What Is Responsible to the Enhancement of Forth Order Cumulants

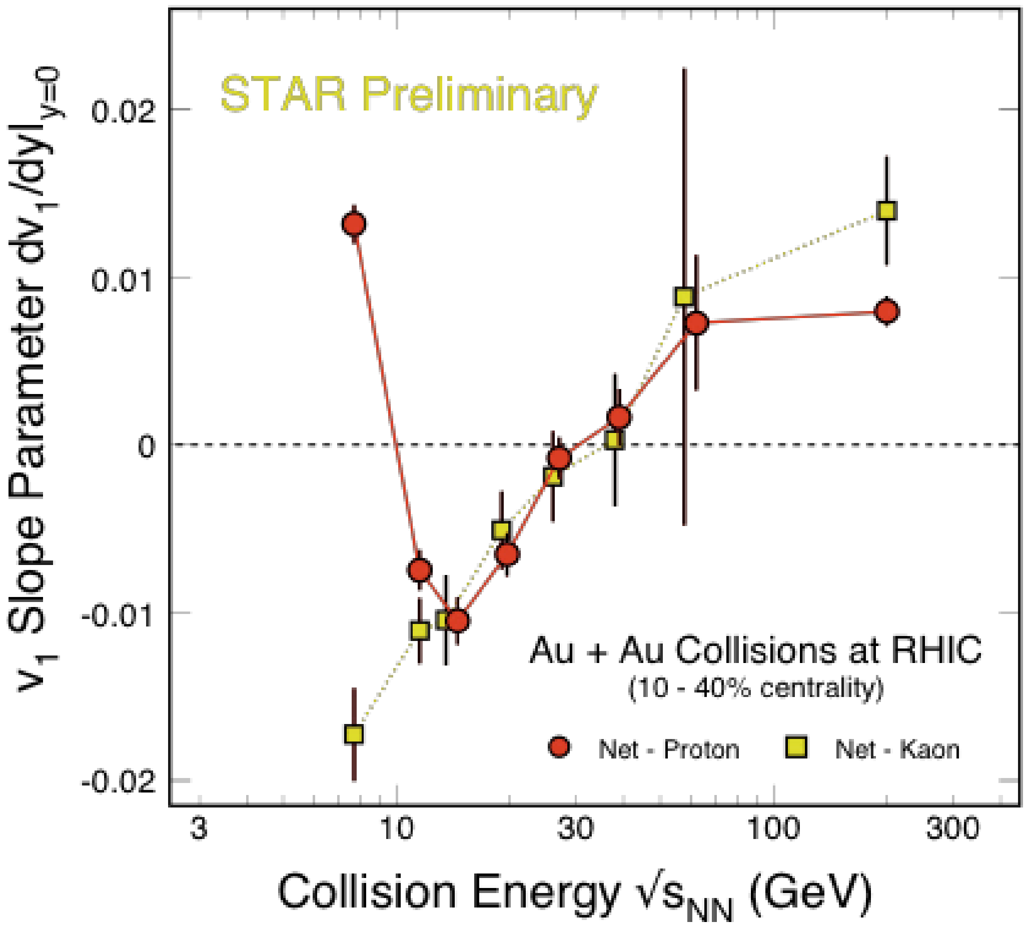
- *Enhancement of $\kappa\sigma^2$ observed in STAR experimental data of net proton.*




X. Luo, QM 2015 arXiv:1512.09215

# Contributions from Nucleon Potential?




- The repulsive force is important for the strong increasing of proton $dv_1/dy$ at high baryon density region.
- Is the repulsive force or other kind EOS responsible to the enhancement of net-proton high moment?
- Utilize a Monte Carlo model with those effect
- The same model has been used in the study of non-monotonic behavior of $v_1$. The negative slope of rapidity dependence is successfully reproduced

Nara, Ohnishi, arXiv:1512.06299; M. Isse, A. Onishi et al, PRC72, 064908(05)

# Mean Field and Soft EOS from JAM Model

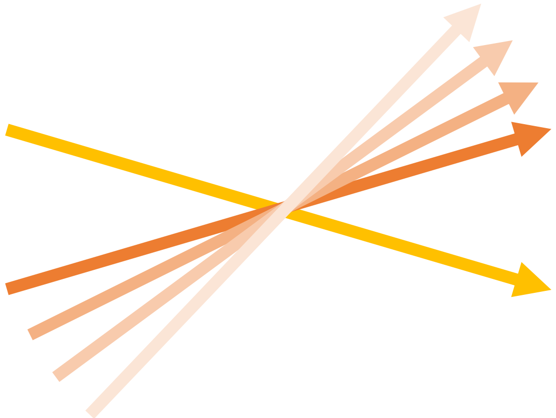
## Hadronic transport model: JAM

(Jet AA Microscopic Transportation Model)

Resonance production at low energies. String exciting at higher energies.

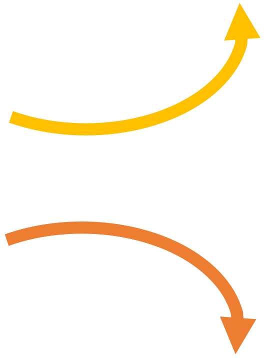
Three modes of running:

Cascade | Cascade + Mean Field (RQMD Framework) | Cascade + Attractive Scattering



In the cascade, scattering angles are chosen randomly.

We utilized a Skyrme-type density and Lorentzian-type momentum dependent mean field potential



Higher density $\rho$ → Repulsive Scattering

Nara, Ohnishi. (2015). arXiv:1512.06299

## Softening of EOS

In calculation, softening of EOS is simulated by data with attractive orbit scattering.

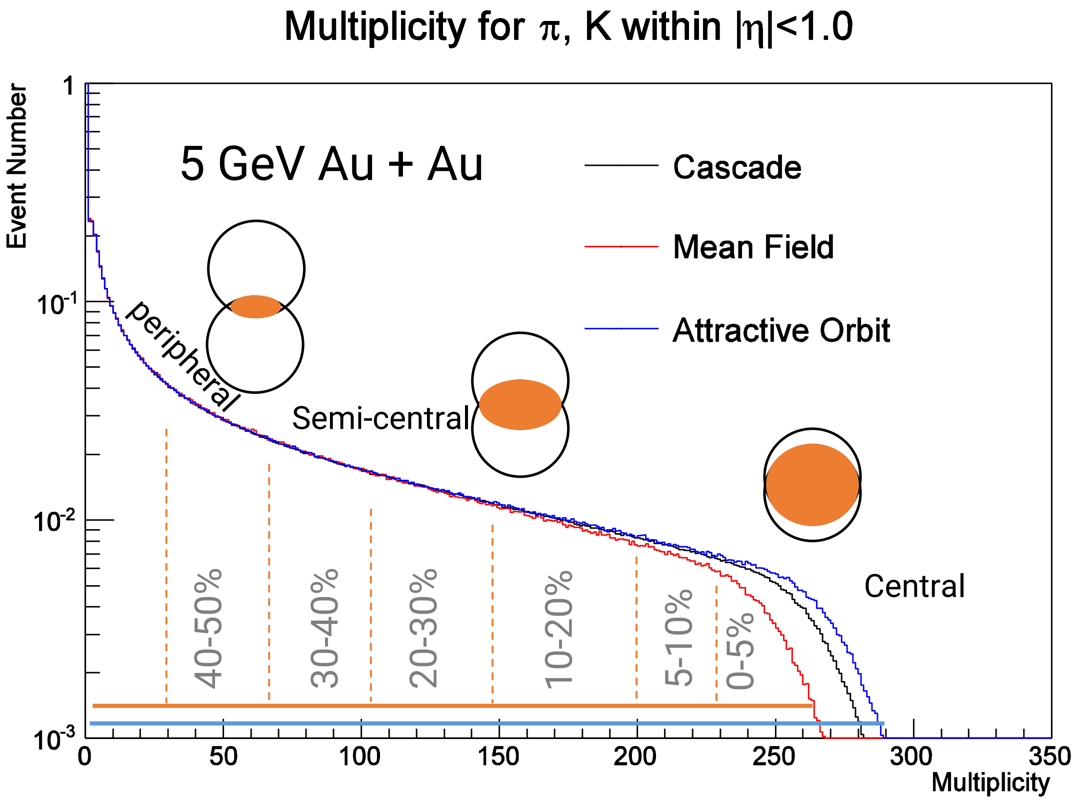
1$^{st}$ phase transition → Decreasing of pressure → Attractive scattering

Alter all the repulsive scattering into attractive scattering in cascade model.

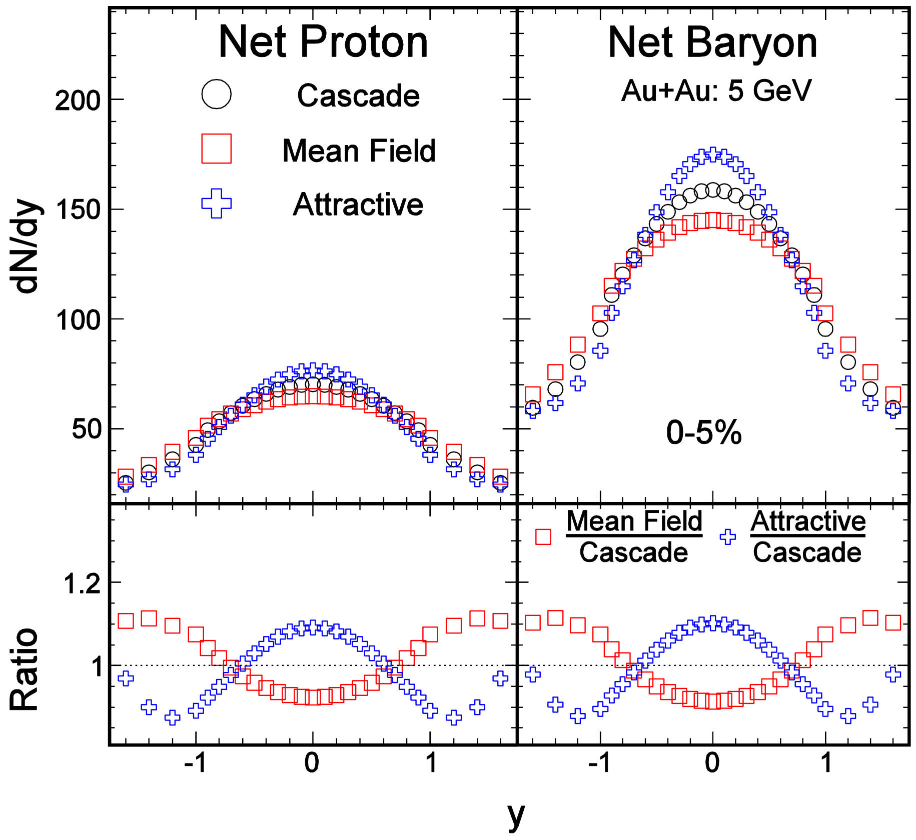

The pressure of system is then reduced

# Analysis Details

| **Data by JAM model with minimum-biased impact parameter (*b*) distribution** |
| --- |
| Simulation Run: Au + Au collision at $\sqrt{s_{\mathrm{NN}}} = 5$ GeV |
| Event Selection: 5% Most Central Events |
| Centrality Reference: Charged pion and kaon within pseudo-rapidity $\|\eta\|$<1.0 in final state |
| $p_{\mathrm{T}}$ dependence analysis: $0.4, \dots, 1.4 < p_{\mathrm{T}} < 2.0$ GeV/c |



# Analysis Results – Base Distribution

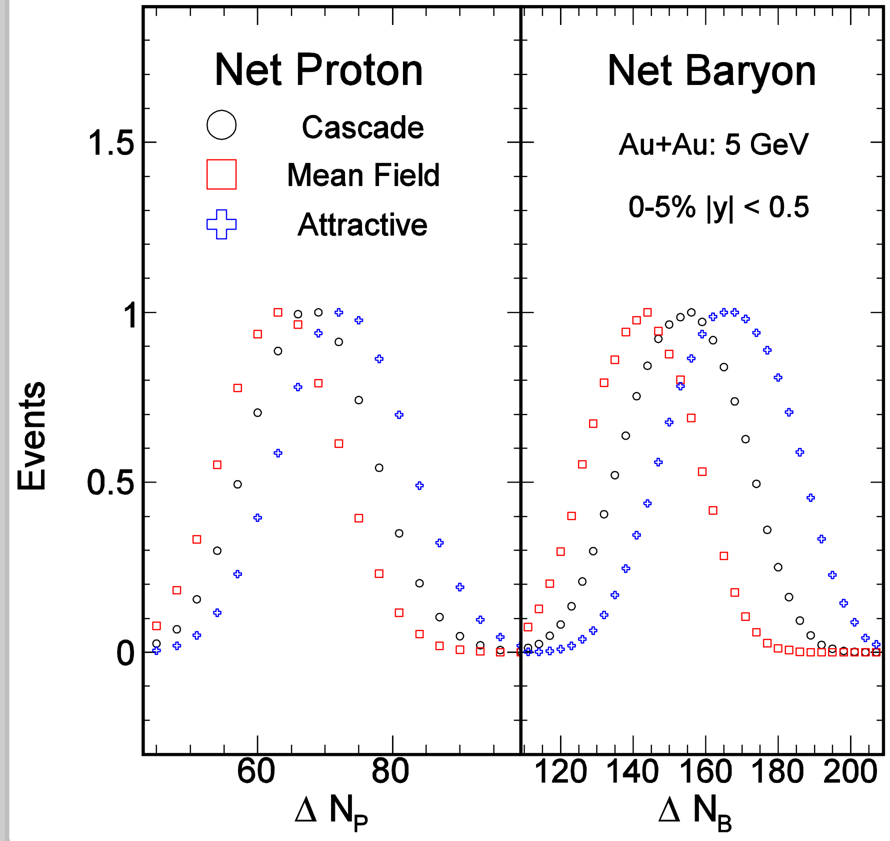



Attractive leads to more Stopping

Repulsive leads to Less stopping

| **Comparing with Cascade model** | |
|---|---|
| Mean Field | Attractive Orbit |
| Wider rapidity distribution | Narrower rapidity distribution |
| Smaller $\Delta N$ | Larger $\Delta N$ |
| Similar results from net baryon and net proton | |

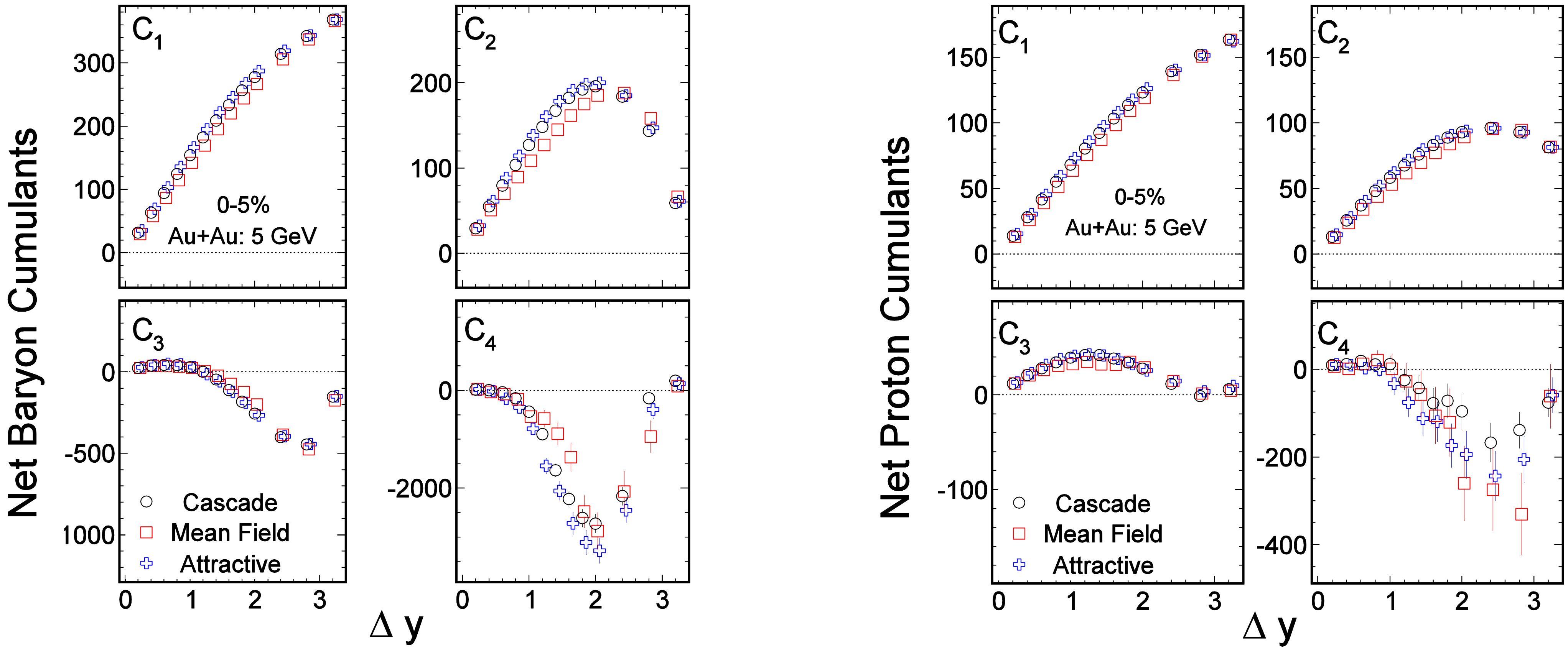
* $\Delta N = N - \bar{N}$
* Height of Events are plotted relative to the maximum (unity).



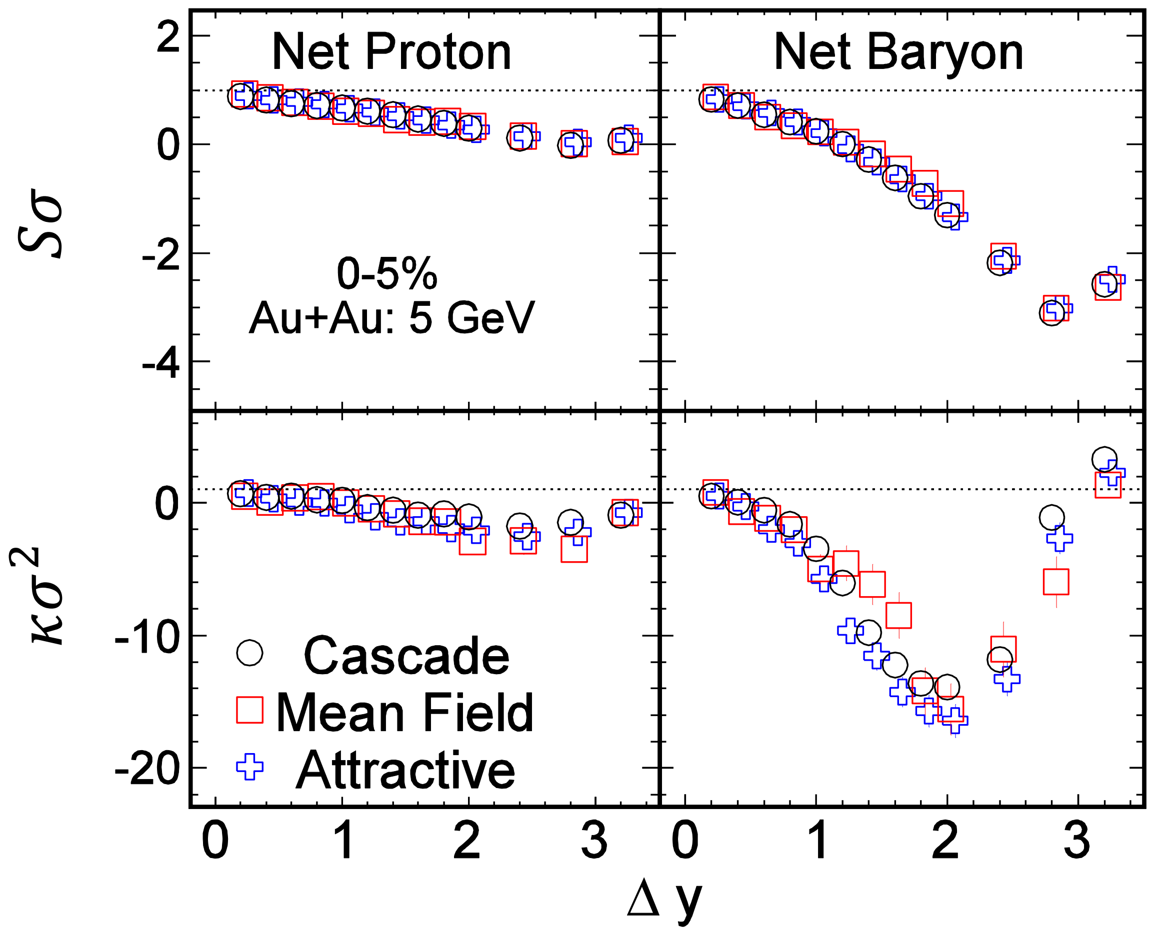

Attractive scattering leads more shift in the proton (baryon) dominant region, i.e. high baryon density region

# Rapidity Acceptance of Cumulants

## Cumulants increase with $\Delta y$ acceptance
## Similar tendency in Cascade, Mean Field and Attractive orbit



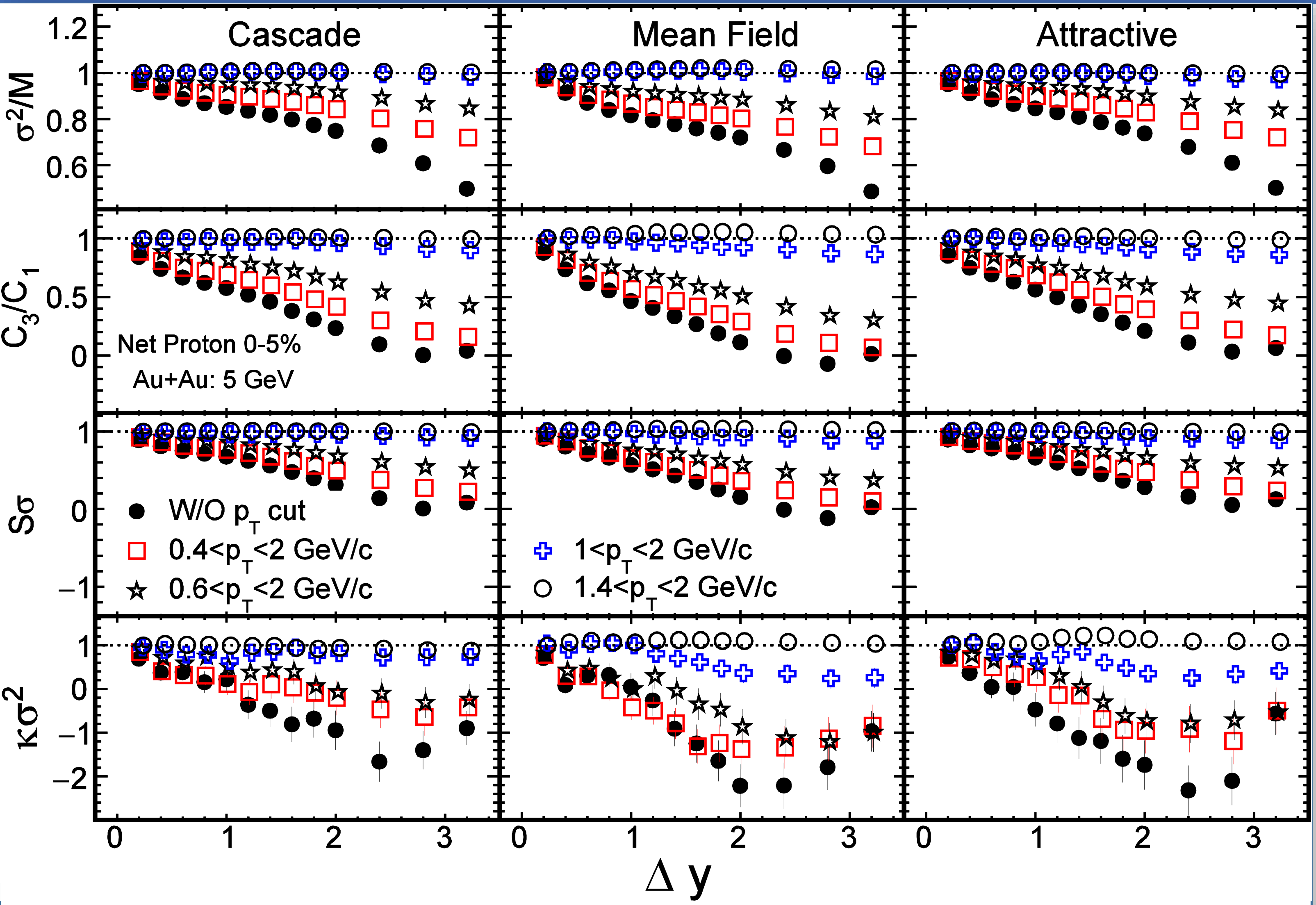
# Rapidity Acceptance of Cumulant Ratios




1. Similar suppression trends are observed in three different modes for net-proton and net-baryon.
2. The suppression and the restoring of cumulants ratio is a nature consequence of baryon number conservation.

Adam et al, Phys. Rev. C 87, 014901 (2013)

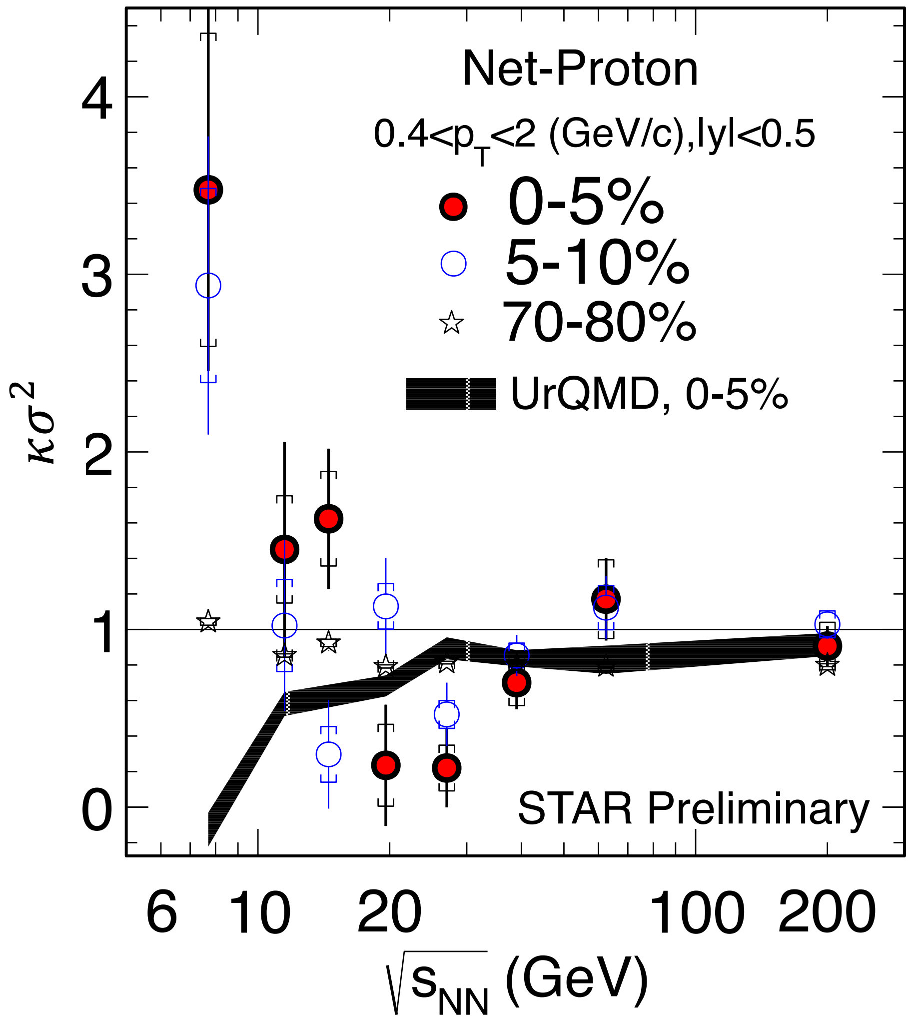
# Momentum Dependences




Deviation from Poisson is larger at higher $p_T$ coverage

Deviation vanished at the coverage of $1.4<p_T<2$ GeV in case of mean field, cascade and attractive.

# Summary




Our test result show that none of the potentials used in the model is responsible to the enhancement of net-proton high moment

# Thanks