p/K Fluctuations from Au+Au Collisions at RHIC

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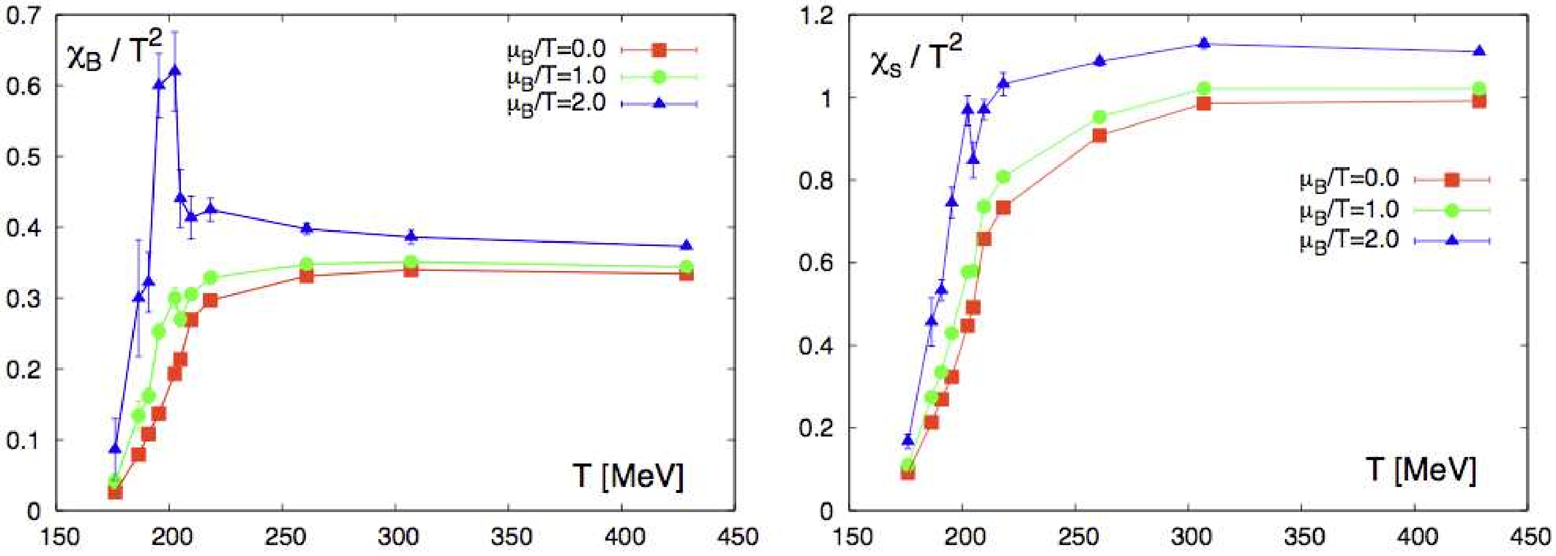
Outline

- **Motivation and Introduction**
  - **Baryon number and strangeness fluctuation**
  - **p/K ratio fluctuation**
- **Fluctuation Observables**
  - σ_{dyn} **and** ν_{dyn}
- **Preliminary Results and Discussions**
  - **Fluctuations as a function of incident energy and collision centrality**
  - **Pair production effect**
- **Summary and Outlook**

Baryon Number and Strangeness Fluctuations

Lattice calculations show changes in baryon number and strangeness susceptibilities.



F. Karsch, PoS (CPOD07) 026 and PoS (Lattice 2007) 015

- Susceptibilities are directly related to number fluctuations $\chi \sim \langle N^2 \rangle$
- Smooth phase transition at $\mu_B = 0$
- The susceptibility may diverge at the critical point.

p/K Fluctuation

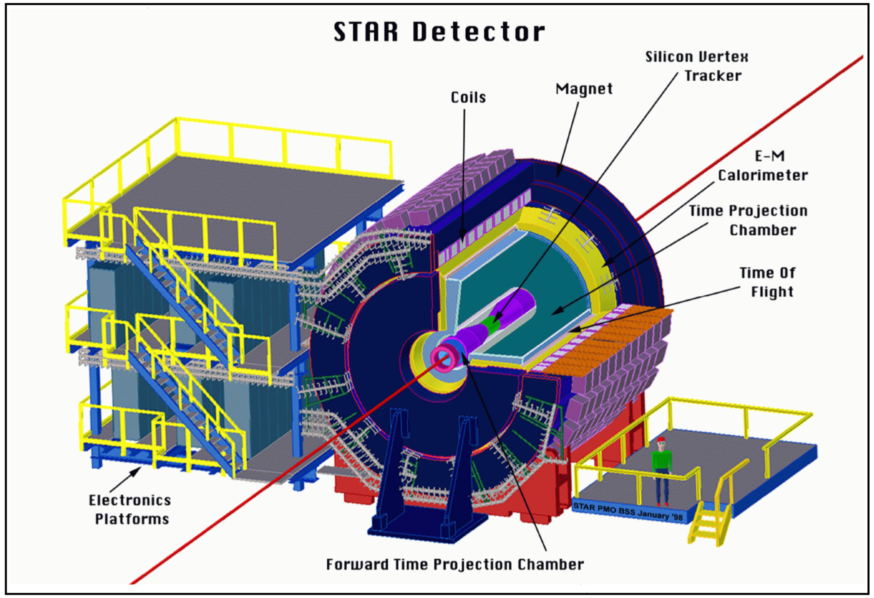
- Proton and kaon are good proxies for baryon and strangeness
  → fluctuations of this ratio may be sensitive to the QGP phase change.
- In the picture of quark coalescence for hadronization in nucleus-nucleus collisions,

  proton/kaon ~ baryon/meson

  → local parton densities

  → critical point
- Kaons and protons can be identified in the same y_T range.

STAR Experiments and Dataset



STAR: a complex set of various detectors, with wide range of measurements .

TPC: measure momentum and dE/dx, identify particles of certain momentum.

Run04 Au+Au 200, 62.4 GeV

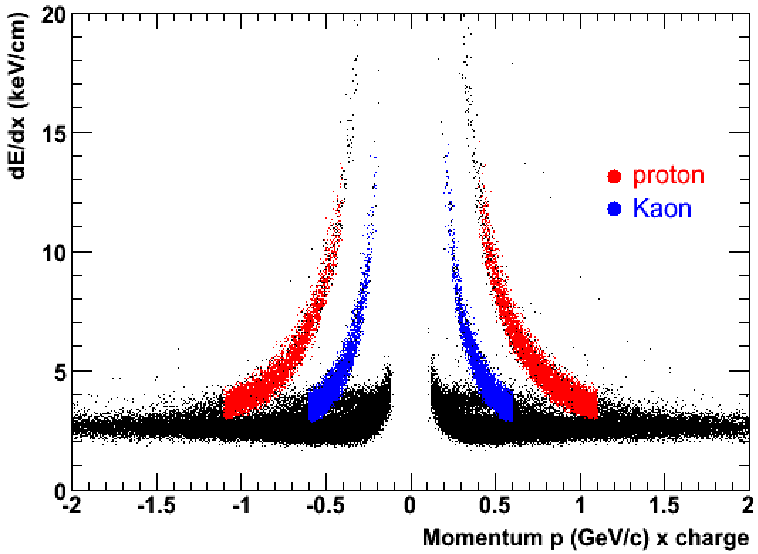
|Vz| < 15cm

proton momentum :

$p_T > 0.4$GeV/c, p <1.1GeV/c

kaon momentum:

$p_T > 0.2$GeV/c, p <0.6GeV/c

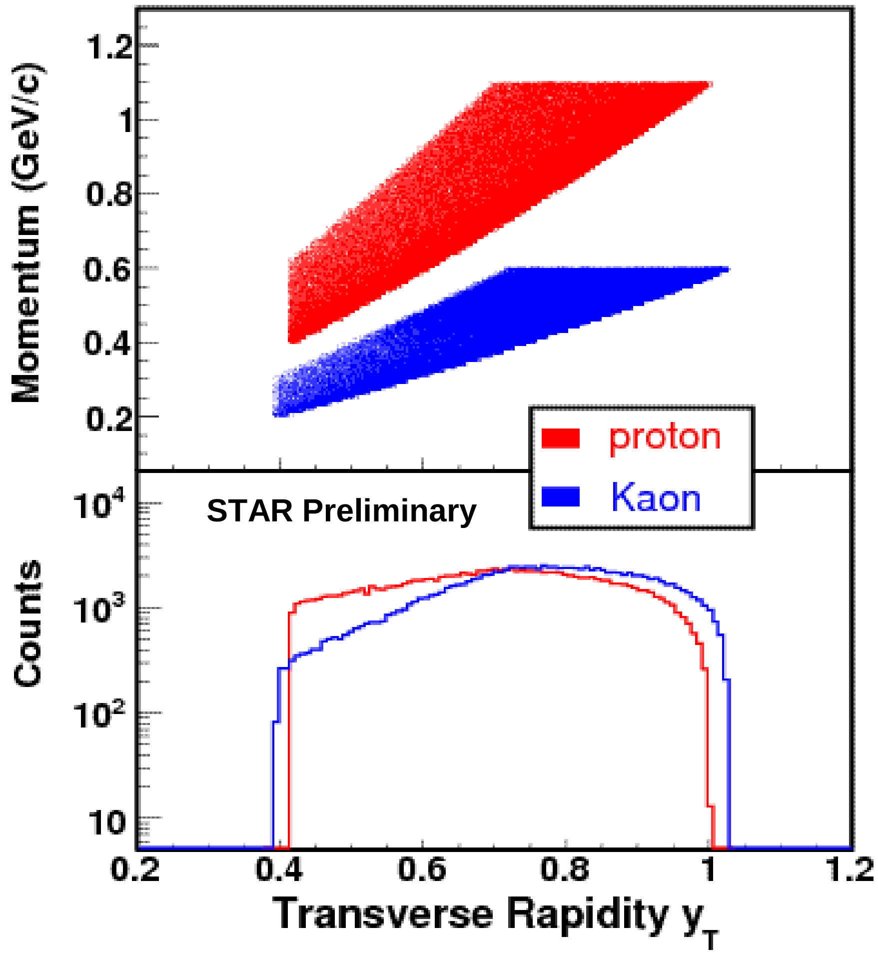


Transverse Rapidity Distribution

Using the definition of transverse rapidity:

$$y_T = \ln\left(\frac{m_T + p_T}{m_0}\right)$$

- No overlap for proton and kaon;
- Identified proton and kaon are in the same y_T range, i.e. have the same transverse velocity.



Fluctuation Observables

- **The dynamical fluctuations σ_{dyn} [1] are estimated by,**

$$\sigma_{dyn} = \mathrm{sign}(\sigma^2_{data} - \sigma^2_{mixed})\sqrt{\left|\sigma^2_{data} - \sigma^2_{mixed}\right|}$$

Mixed events — random selection of tracks max one track from each event — Multi-event mixing.

- **The deviation from Poisson statistical limit $\nu_{dyn,pK}$ [2],**

$$\nu_{dyn,pK} = \frac{\langle N_p(N_p - 1)\rangle}{\langle N_p\rangle^2} + \frac{\langle N_K(N_K - 1)\rangle}{\langle N_K\rangle^2} - 2\frac{\langle N_p N_K\rangle}{\langle N_p\rangle\langle N_K\rangle}$$

Approximate equality: $\sigma^2_{dyn} = \nu_{dyn}$

- Depends on the number of denominator (p/K or K/p) not being too small [2];

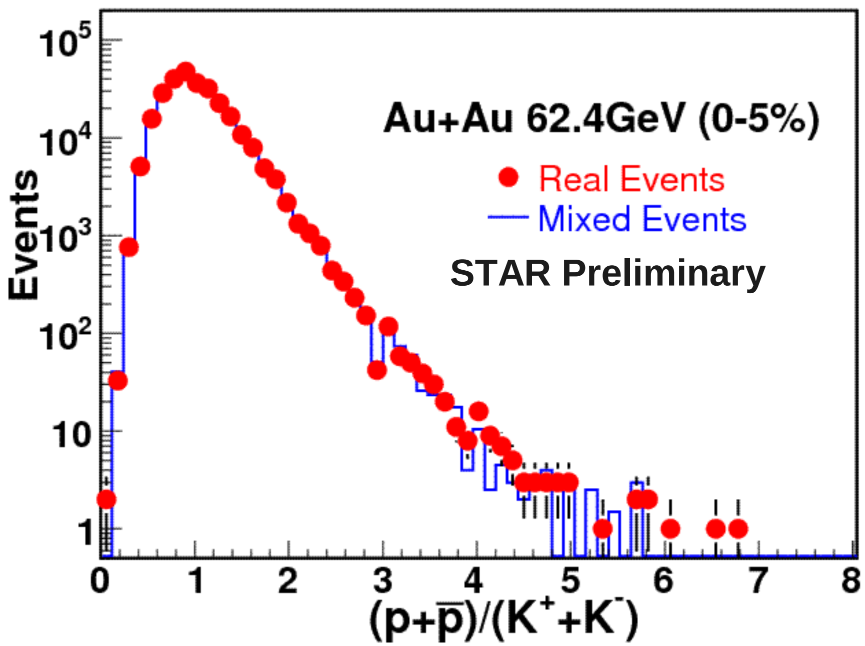
- Confirmed for K/π [3] and p/π fluctuations measurements;

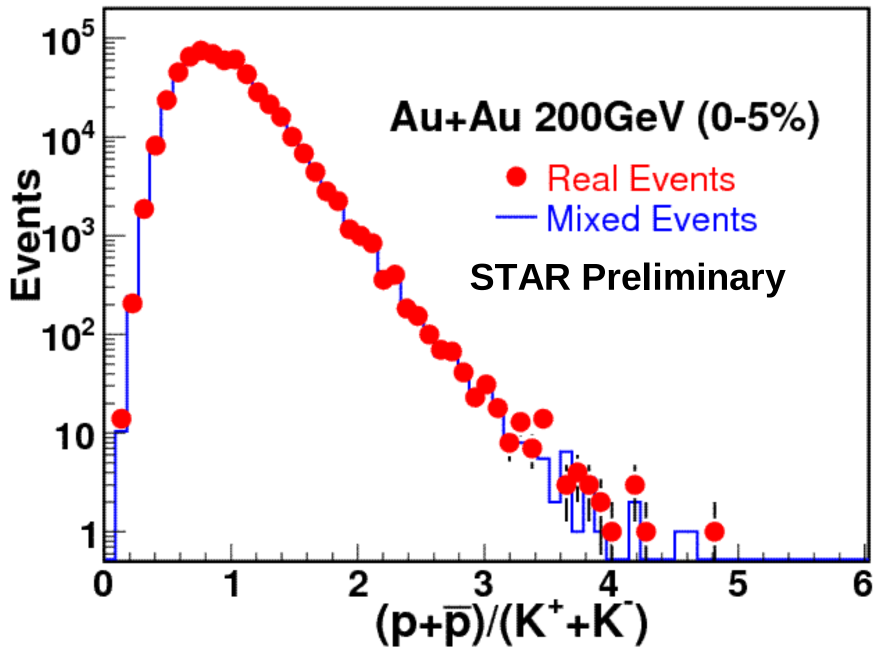
- We will investigate approximation for K/p and p/K.

[1] S.V. Afanasiev et al. , Phys. Rev. Lett. 86, 1965 (2001).
[2] C. Pruneau, S. Gavin, and S. Voloshin, Phys. Rev. C 66, 044904 (2002).
[3] B. I. Abelev et al. Phys. Rev. Lett. 103, 092301 (2009).

Ratio Distribution

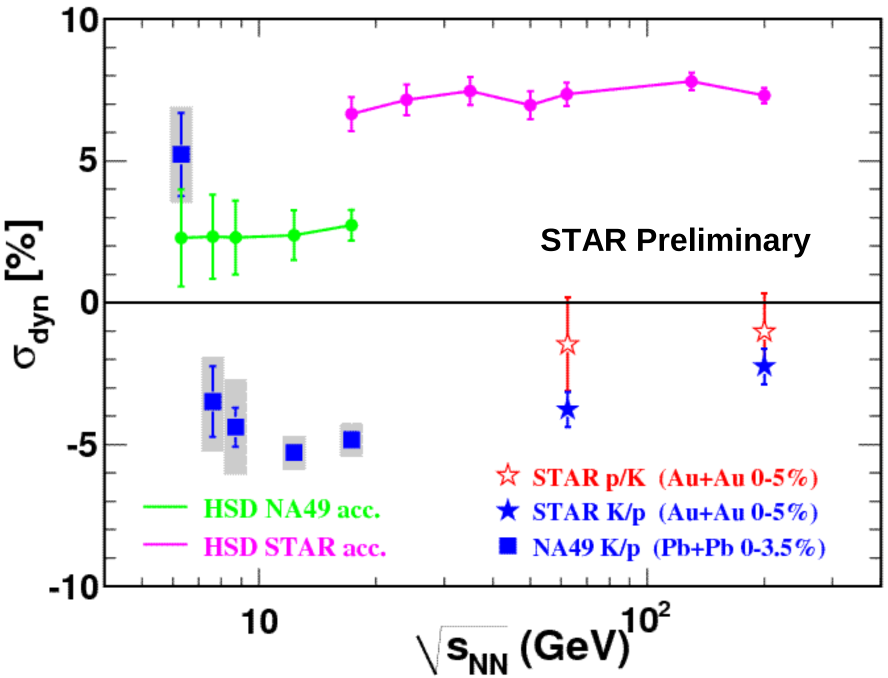
p/K ratio distribution from real events and mixed events.





- Have on average the same particle ratios;
- Non-dynamical fluctuations dominate the fluctuations.

Ratio Fluctuations in Central Collisions



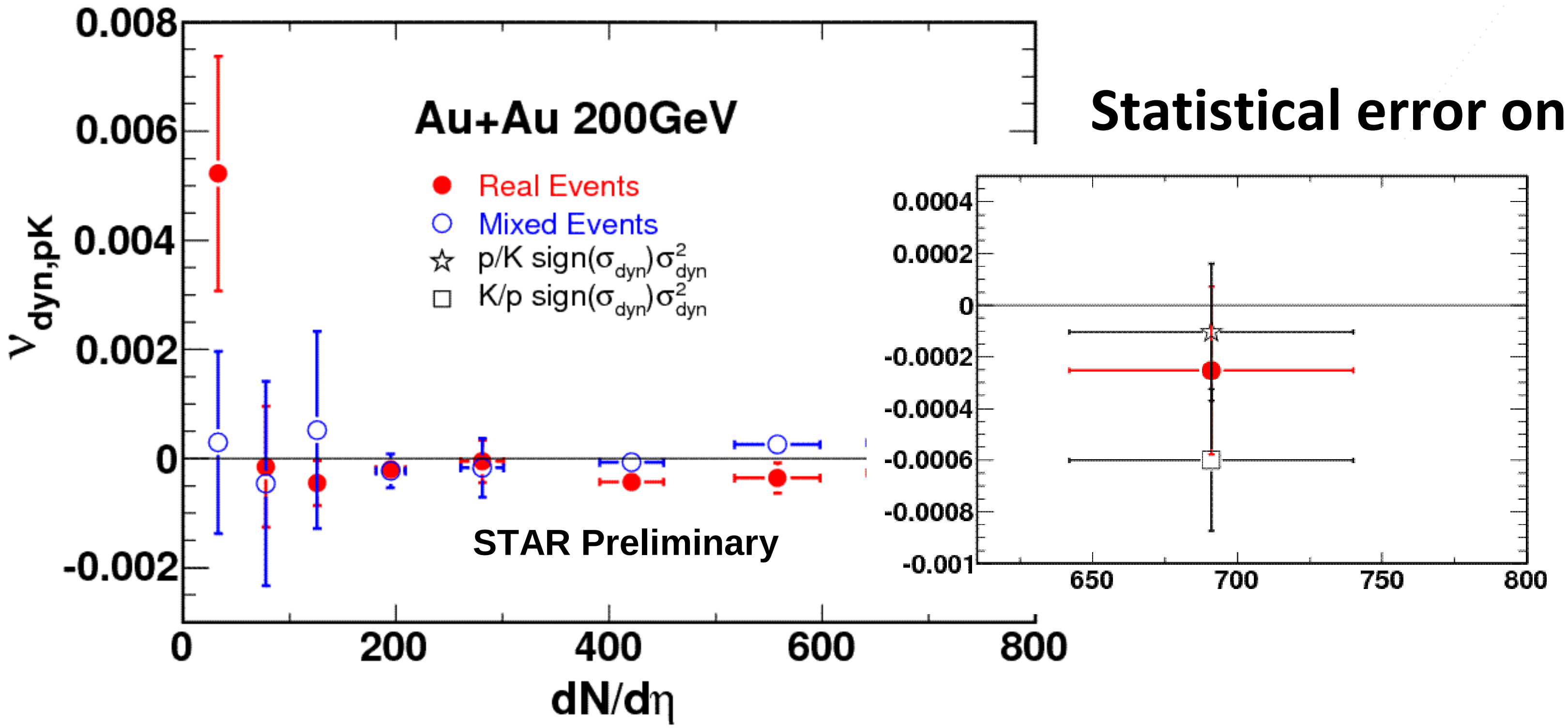
Statistical errors only for STAR results.

Tim Schuster CPOD 2009

arXiv:0906.3229v1

- **Interesting evolution of K/p fluctuations from lowest SPS energies to RHIC energy;**
- **Data are significantly different from model calculations;**
- **The p/K and K/p fluctuations for σ_{dyn} at RHIC are not identical: perhaps related to small numbers of particle.**

Dynamical Fluctuation ν_{dyn}

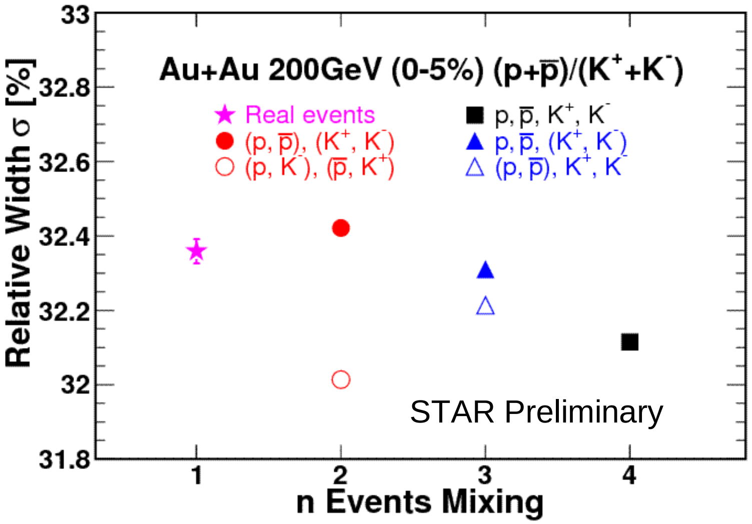


Statistical error only!

- **Fluctuations from all centralities are at small scale;**
- **For the most central collisions, $\nu_{dyn,pK}$ value is close to p/K σ_{dyn} and K/p σ_{dyn} , with large errors!**
- **Results suggest new analyses approaches should be considered.**

Effect from Pair Production

- Baryon numbers and strangeness quantum numbers are pair-produced in nucleus-nucleus collisions!
- Mixed events can be constructed to study the effects of pair production — mixed events stem from independent events, contain different correlations from pair production.



Relative width:
σ = RMS/mean

There are indeed correlations in pairs

- p-pbar and K^+-K^- correlation will enhance the relative fluctuation;
- p-K correlations will reduce the relative fluctuation;
- Correlation of K^+-K^- pair have larger effect than p-pbar pair.

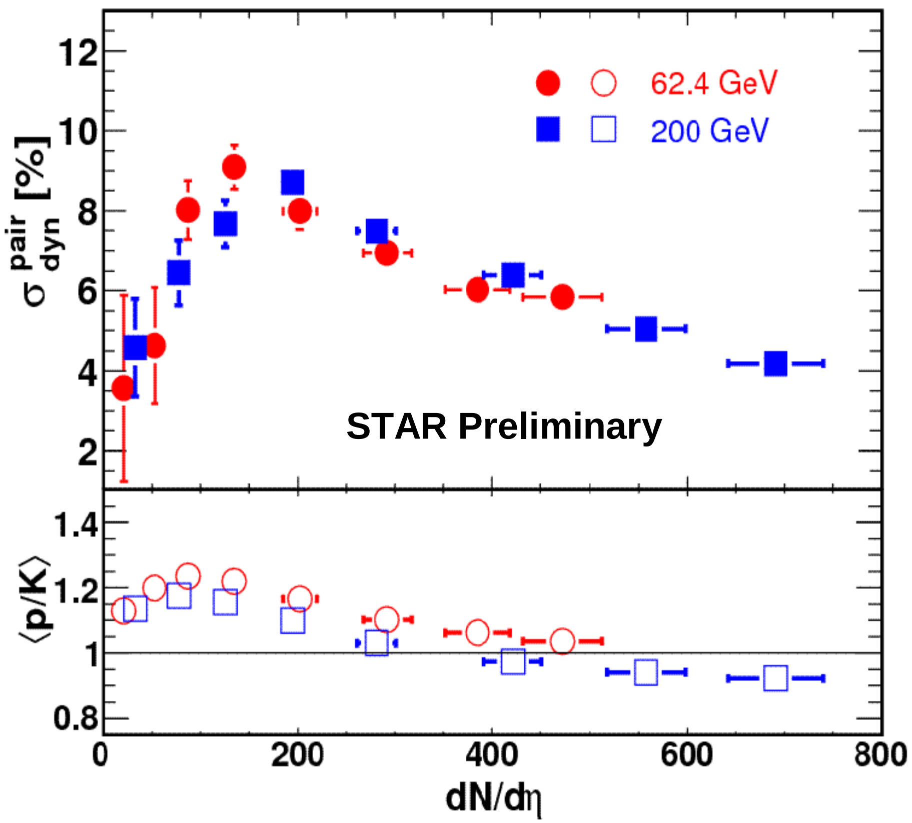
Constrained Reference

- **Choose a mixing sample from 4 independent events with same multiplicity — p, pbar, K^+ and K^- are from these four independent events, respectively — Four-event mixing.**
- **In this sample – individual particle fluctuations unrelated to pair production mechanism are included.**
- **We differentiate from other variables by calling this,**

$$\sigma_{dyn}^{pair} = \mathrm{sign}(\sigma_{data}^2 - \sigma_{4-mixed}^2)\sqrt{|\sigma_{data}^2 - \sigma_{4-mixed}^2|}$$

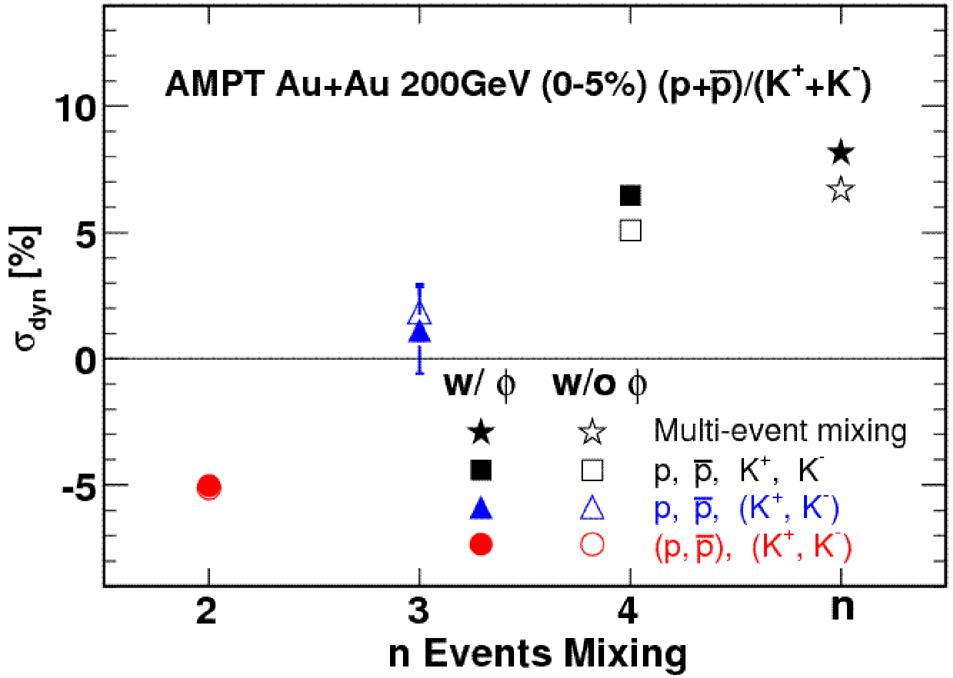
Centrality Dependence

p/K fluctuations using four-event mixing method



- ✓ Two incident energies results are consistent;
- ✓ Maximum fluctuations at mid-centralities, different centrality from maximum <p/k>;
- ✓ For central collisions, 62.4 GeV have larger fluctuation than 200 GeV;
- ✓ Statistical errors only.

Resonance Decay Effect



- ϕ decay will increase the p/K ratio fluctuation;
- With/without ϕ decays → the difference is small;
- Simulation shows that $\phi \rightarrow K^+K^-$ is not the main source for kaon pair correlations.

Summary

- We have measured p/K fluctuations on an event-by-event basis at RHIC ,
  - σ_{dyn} (NA49 scheme--multi-event mixing) and ν_{dyn} both show small fluctuations for p/K.
  - Possible deviations between p/K and K/p σ_{dyn} are observed, which may possibly related to low multiplicities.
- Baryon number and strangeness fluctuations can be affected significantly by the pair production dynamics,
  - We developed a new method using 4-event mixing,

$$\sigma_{dyn}^{pair} = \mathrm{sign}(\sigma_{data}^{2} - \sigma_{4-mixed}^{2})\sqrt{|\sigma_{data}^{2} - \sigma_{4-mixed}^{2}|}$$

  - σ_{dyn}^{pair} changes as a function of centrality and has the highest amplitude at mid-centrality with $dN/d\eta$ ~150 - 200.
- Our simulation shows that ϕ mesons will increase the fluctuation, but do not contribute significantly.

Outlook

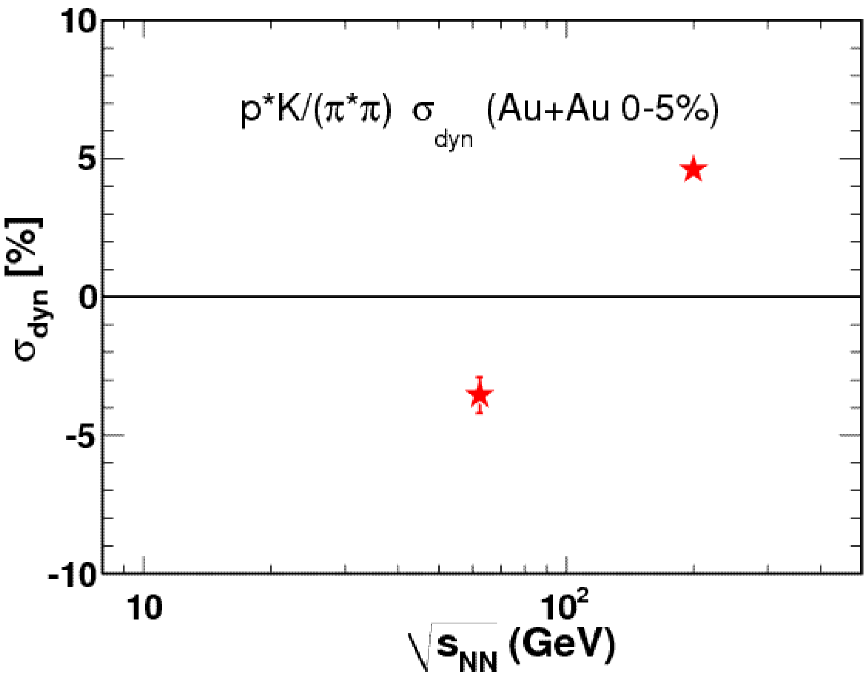
- TOF upgrade will enhance our capability of particle identification, especially for proton and kaon;
- RHIC beam energy scan program provides us a wonderful opportunity to search for the QCD critical point via particle ratio fluctuation;
- p*K may be more sensitive to baryon number and strangeness fluctuations than p/K. We have been investigating this as well.

Thanks for your attention!

Extra slides

p*K/(π*π) Fluctuations

- Correlations between baryon number and strangeness, p*K may be more sensitive to p/K ;
- Try p*K/(π*π) where π is for normalization.



✓ change significantly for two incident energies

✓ Only two points

✓ Statistical errors only

K/p Ratio Distribution