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Event-by-Event Hadron Ratio Fluctuations from Au+Au Collisions at STAR

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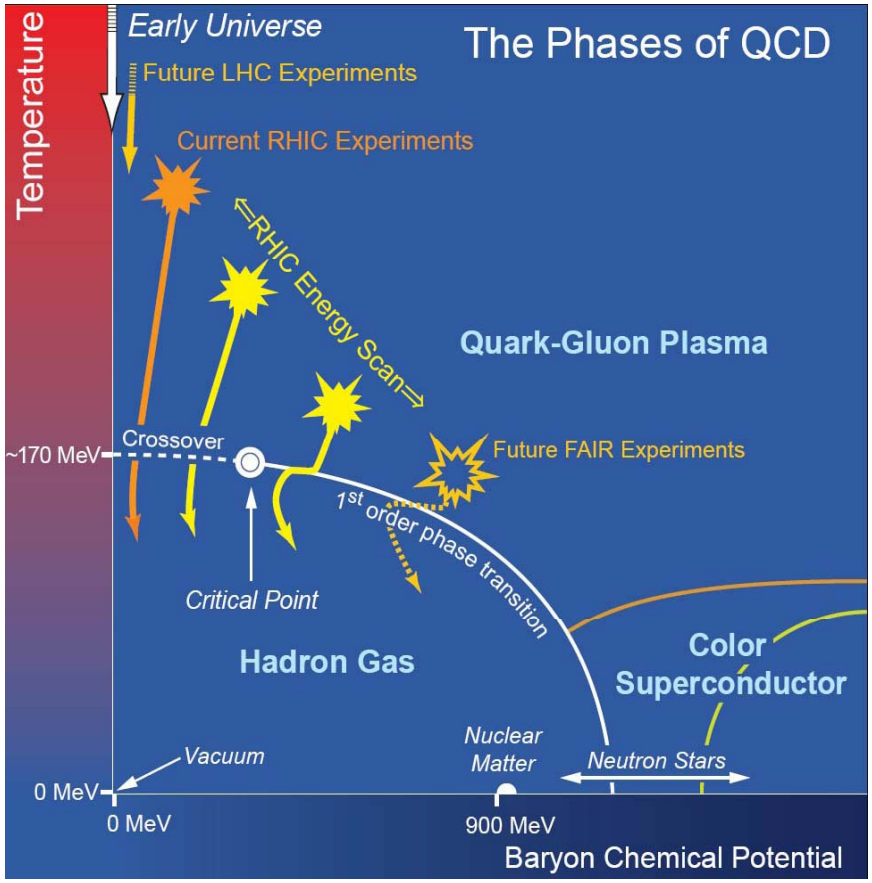
Critical Point and Onset of Deconfinement (CPOD)
7 - 11 November 2011 at Institute of Particle Physics (CCNU)

Outline

- Motivation and Introduction
- STAR Detector and Particle Identification
- Preliminary Results and Discussions
- Summary

QCD Phase Diagram



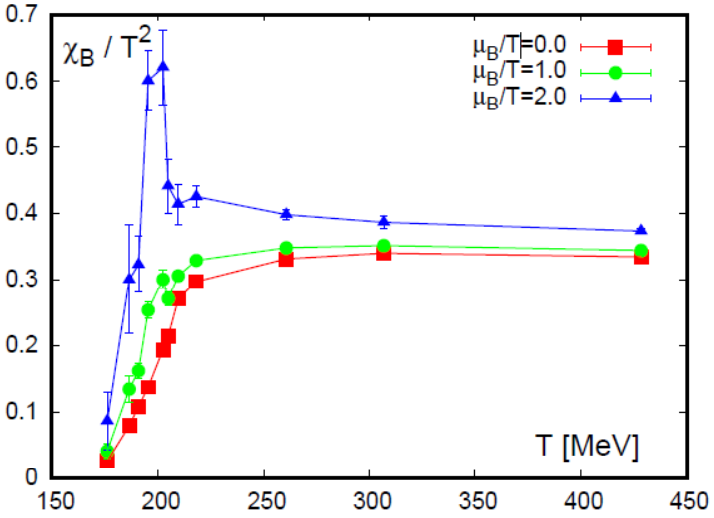
STAR BES, arXiv:1007.2613v1

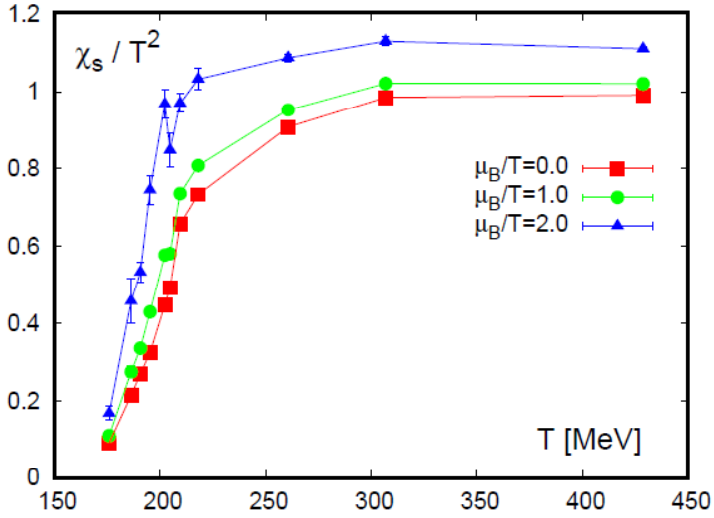
- In a phase transition near critical point, an increase in dynamical fluctuations is expected.
- RHIC "Energy Scan", to look for non-monotonic behaviors as a function of collision energy.
  - — Run10, Au+Au collisions at $\sqrt{s_{NN}}$ = 200, 62.4, 39, 11.5, and 7.7 GeV;
  - — Run11, Au+Au collisions at $\sqrt{s_{NN}}$ = 19.6 and 27 GeV.

Hadron Ratio Fluctuations

- Hadron ratios characterize the chemical composition of the fireball,
  → fluctuations may be sensitive to the phase transition.
- In the picture of quark coalescence for hadronization,
  baryon/meson → local parton densities

  fluctuations → critical point
- Lattice QCD calculations show changes in strangeness and baryon number susceptibilities(χ).





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

Ratio Fluctuation Observables

- The excitation function from NA49 experiment,

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

Mixed event

- Random selection of one track from each different event;
- No internal correlations.

S.V. Afanasiev et al. , Phys. Rev. Lett. 86, 1965 (2001).

- The deviation from Poisson statistical limit,

$$\nu_{dyn,AB} = \frac{\langle N_A(N_A-1)\rangle}{\langle N_A\rangle^2} + \frac{\langle N_B(N_B-1)\rangle}{\langle N_B\rangle^2} - 2\frac{\langle N_A N_B\rangle}{\langle N_A\rangle\langle N_B\rangle} \quad (A,B = \pi, K, p)$$

See Hui Wang's talk on Thursday

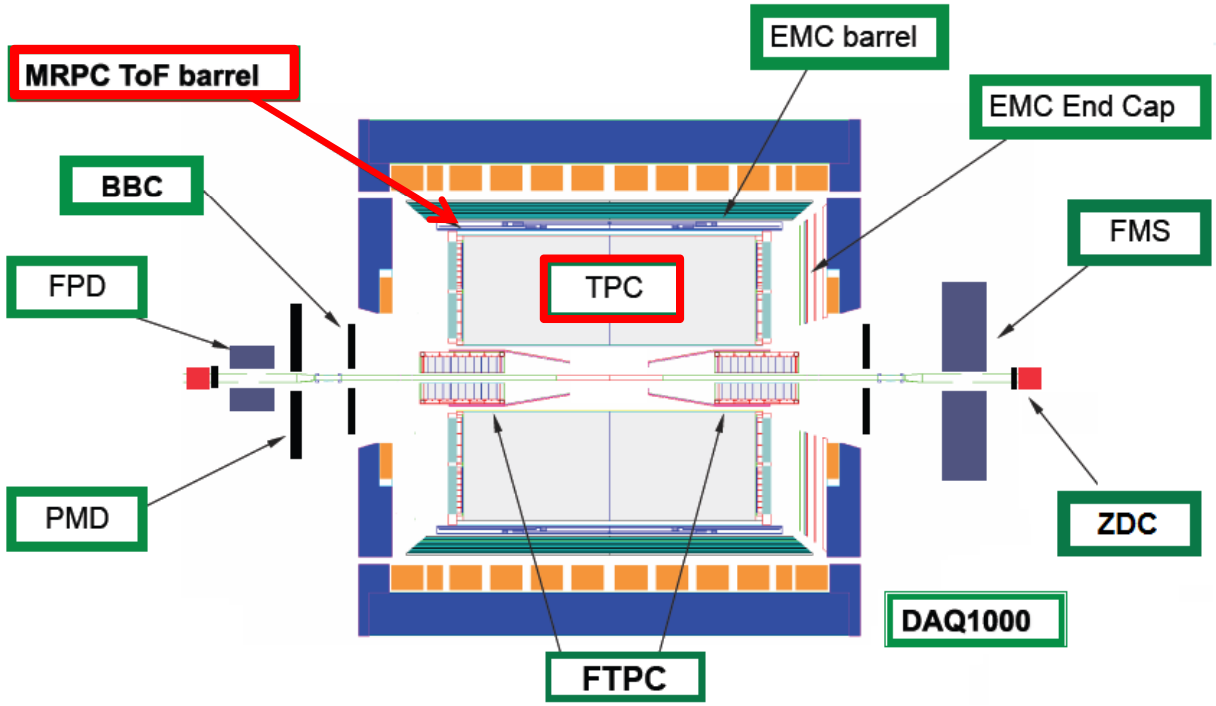
Approximate equality: $\sigma^2_{dyn} = \nu_{dyn}$

— Depends on the number of denominator not being too small (e.g. π).

C. Pruneau, S. Gavin, and S. Voloshin, Phys. Rev. C 66, 044904 (2002).

STAR Experiments

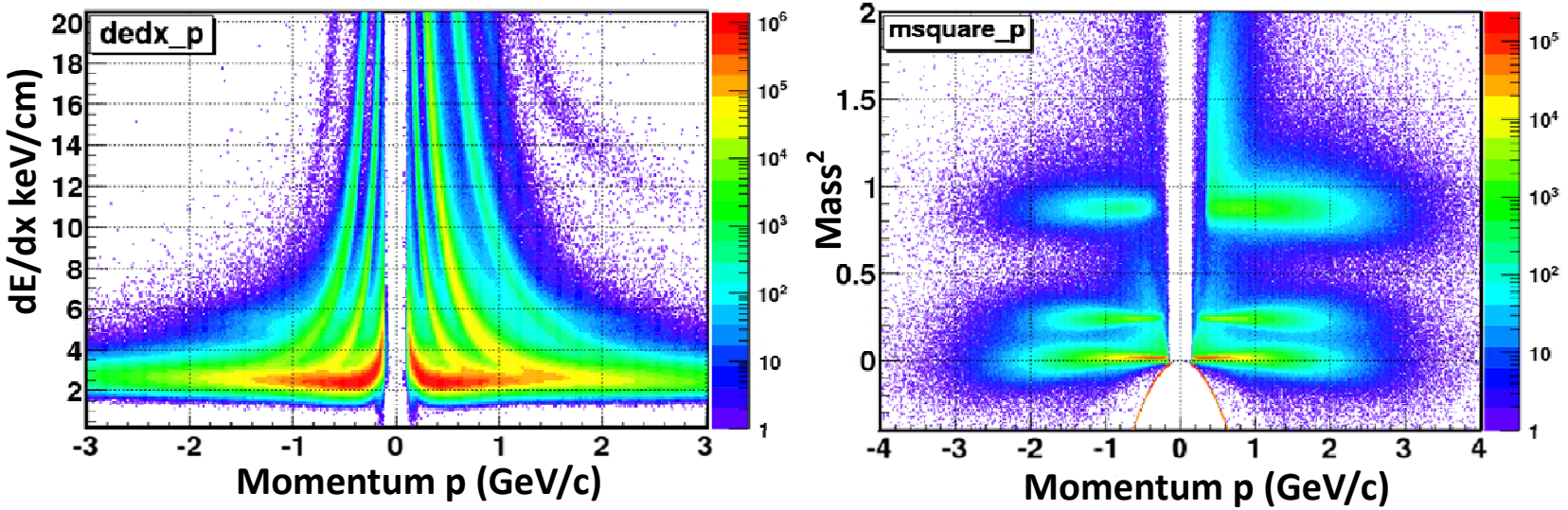
STAR: a complex set of various detectors, with wide range of measurements.



- STAR: a perfect tool for measuring ratio fluctuations,
  - ✓ Particle identification: TPC and TOF;
  - ✓ Large acceptance: $0 \le \phi < 2\pi$, $|\eta| < 1$(TPC), $|\eta| < 0.9$(TOF).

Particle Identification (TPC+TOF)

Run11 Au+Au at $\sqrt{s_{NN}}$ = 19.6 GeV



Track with $|\eta|<1$

TOF Match?

No

TPC PID (dE/dx method)

π: p_T>0.2GeV/c, p<0.6GeV/c

K: p_T>0.2GeV/c, p<0.5GeV/c

p: p_T>0.4GeV/c, p<1.0GeV/c

Yes

TOF PID (m^2 method)

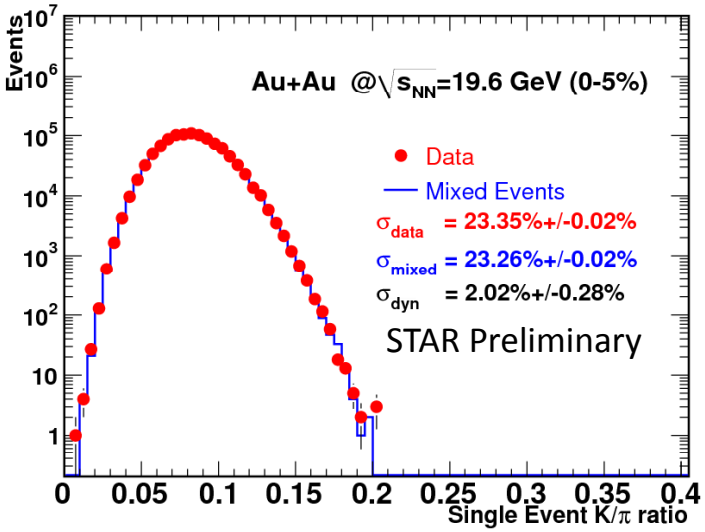
π: p_T>0.2GeV/c, p<1.6GeV/c

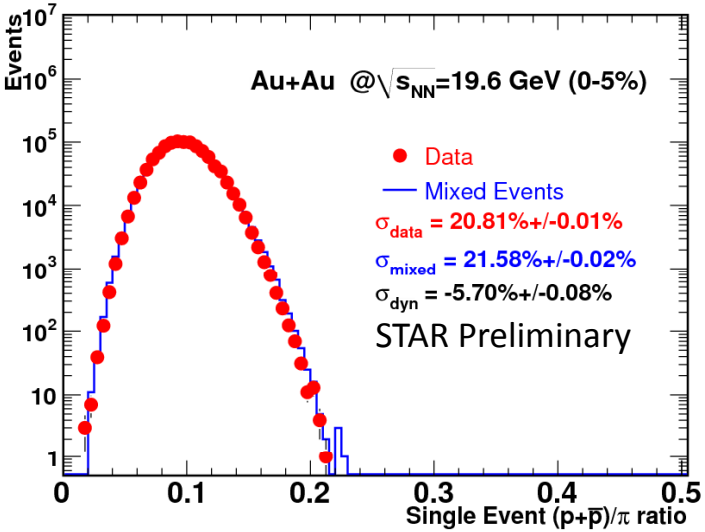
K: p_T>0.2GeV/c, p<1.6GeV/c

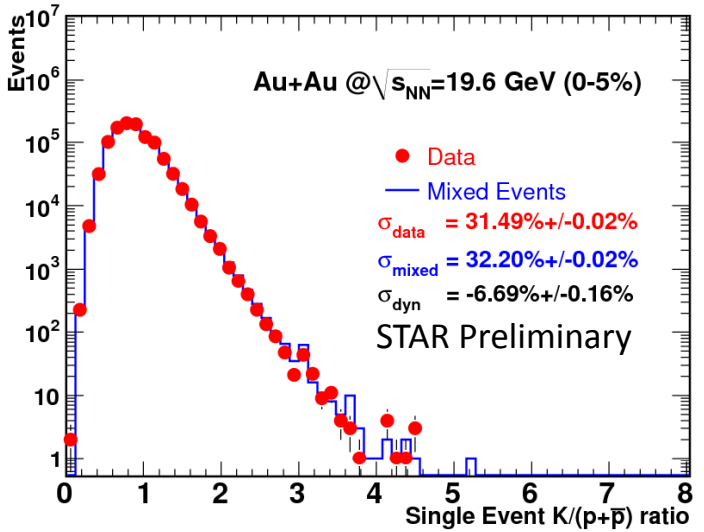
p: p_T>0.4GeV/c, p<3.0GeV/c

Distributions of Hadron Ratios

Run11 Au+Au at $\sqrt{s_{NN}}$ = 19.6 GeV

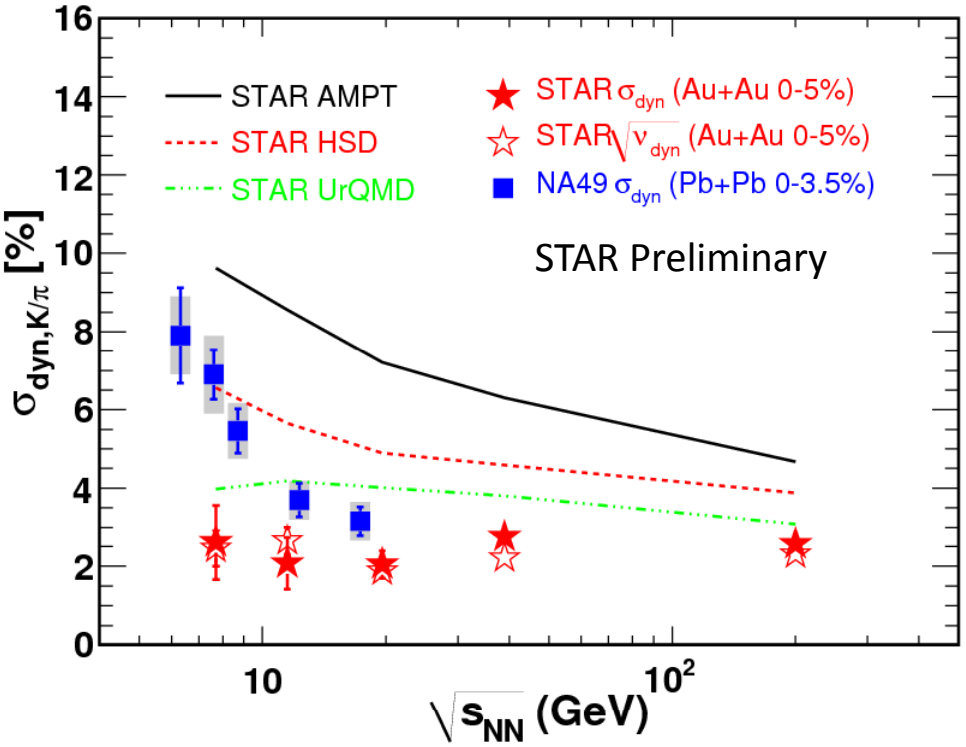






- Data and mixed events have on average the same particle ratios;
- Non-dynamical fluctuations dominate the fluctuations.

σ_{dyn} for $(K^+ + K^-)/(\pi^+ + \pi^-)$

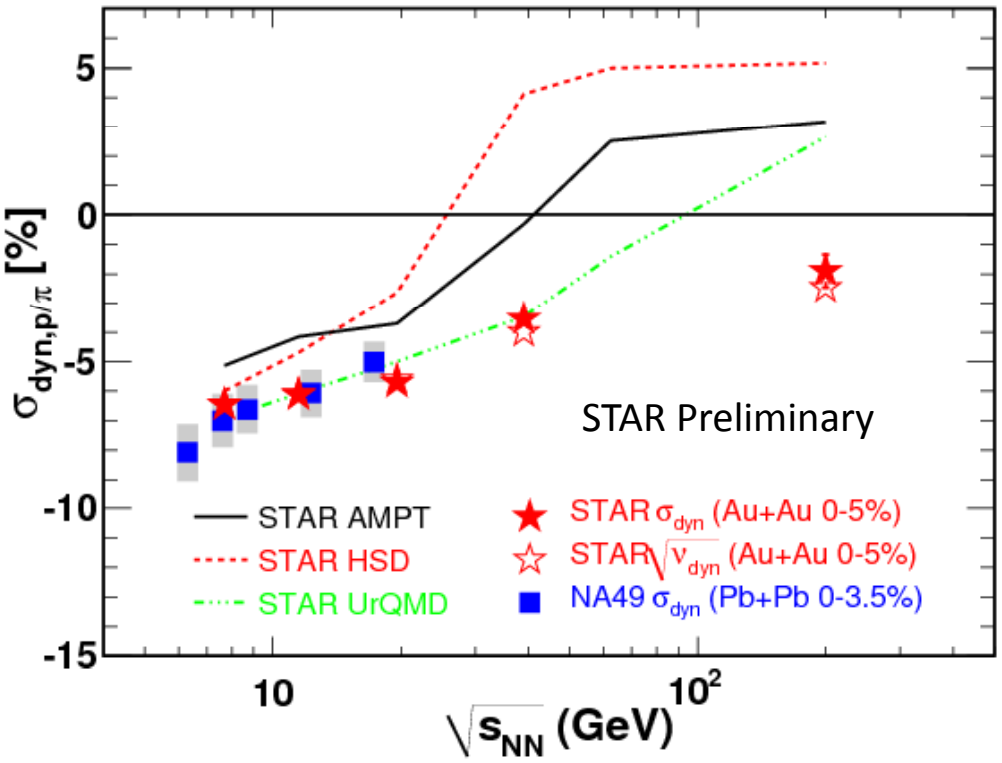


NA49 data are taken from PhysRevC.79.044910(2009)

- ✓ σ_{dyn} and ν_{dyn} are from independent analysis;
- ✓ Statistical error only!

- The σ_{dyn} results and ν_{dyn} results are consistent;
- STAR measurements show little energy dependence;
- Disagreement between STAR and NA49 below 11.5 GeV;
- UrQMD predicts little energy dependence, while HSD and AMPT predict an energy dependence.

σ_{dyn} for $(p+\bar{p})/(\pi^+ + \pi^-)$



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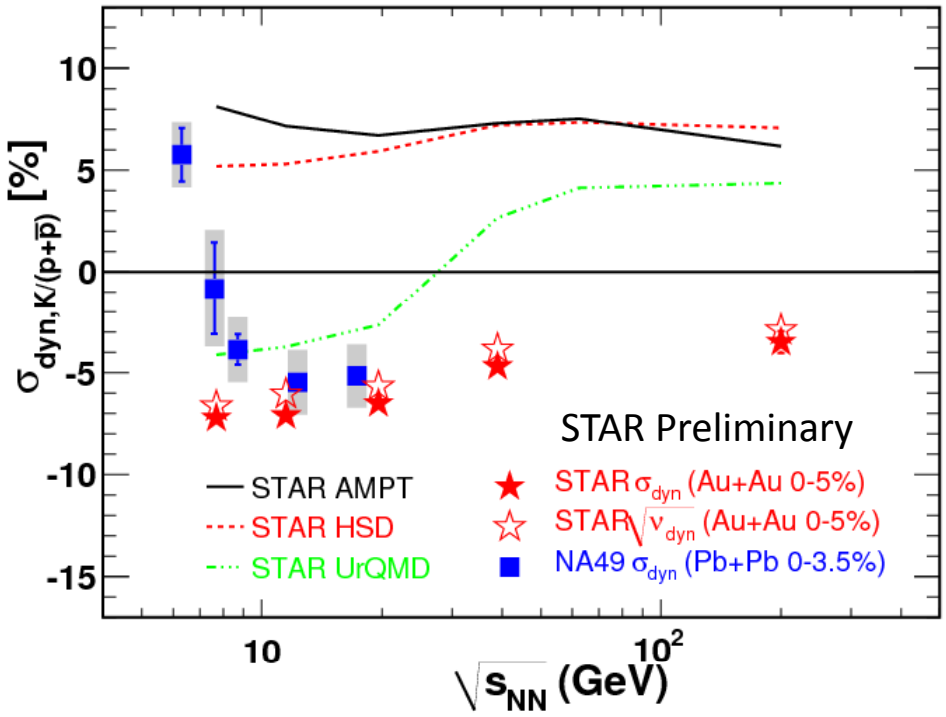
- ✓ σ_{dyn} and ν_{dyn} are from independent analysis;
- ✓ Statistical error only!

- The σ_{dyn} results and ν_{dyn} results are consistent;
- STAR measurements show smooth evolution as energy increases;
- Agreement between STAR and NA49 at low energies;
- Model predictions change signs at high energies.

σ_{dyn} for $(K^+ + K^-)/(p+\bar{p})$



NA49 data are taken from PhysRevC.83.061902(2011)

- ✓ σ_{dyn} and ν_{dyn} are from independent analysis;
- ✓ Statistical error only!

- ➢ Negative fluctuations and smooth evolution at STAR;
- ➢ Disagreement between STAR and NA49 at 7.7 GeV;
- ➢ UrQMD predicts strong energy dependence, while HSD and AMPT show little energy dependence.

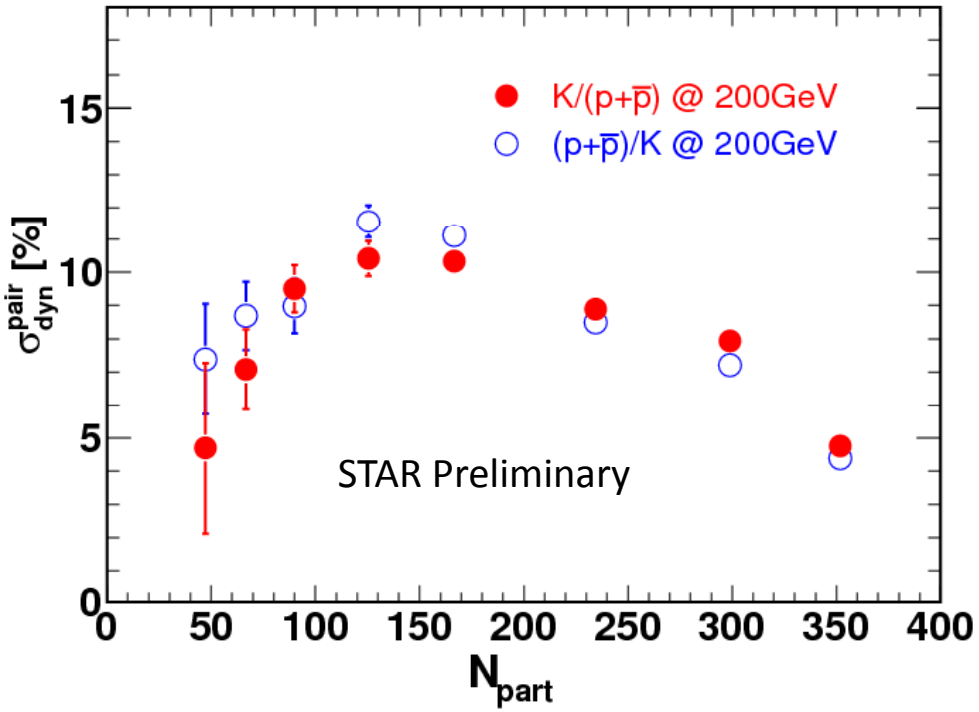
Effect from Pair Production

- Baryon numbers (proton) and strangeness quantum numbers (Kaon) are mostly pair-produced in high energy A+A collisions!
- New reference can be constructed to study the effects of these pair production,
  - ✓ Mixed events — Randomly selecting p, $\bar{p}$, K^+ and K^- from four independent events.
    - ➢ Ratio fluctuations related to pair production,

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

Centrality Dependence for σ_{dyn}^{pair}

Run10 Au+Au at $\sqrt{s_{NN}}$ = 200 GeV

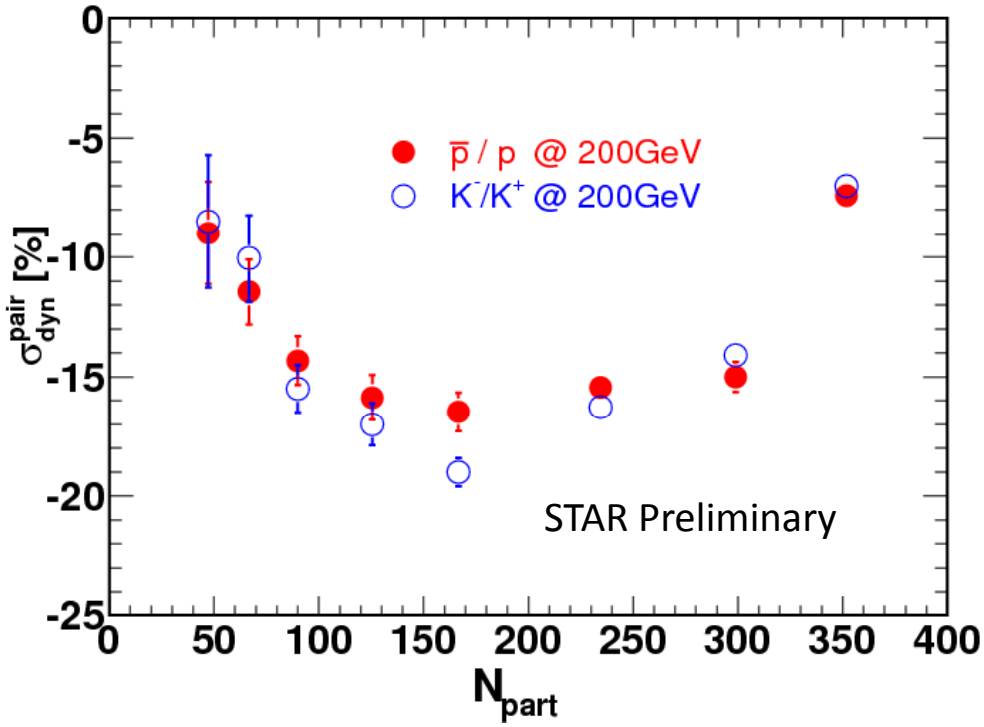


Statistical error only.

- All fluctuations are positive;
- Two fluctuations are consistent within errors;
- Maximum fluctuations at mid-centralities.

Centrality Dependence for σ_{dyn}^{pair}

Run10 Au+Au at $\sqrt{s_{NN}}$ = 200 GeV



Statistical error only.

- All fluctuations are negative;
- Maximum fluctuations at mid-centralities;
- Consistent with the results from K/p(p/K).

Summary

- Dynamical hadron ratio fluctuations from RHIC Energy Scan are present.
  - K/π fluctuations: No strong energy dependence;
  - K/p and p/π fluctuations: Smooth evolution as collision energy increases;
- Studies on ratio fluctuations related to pair production is now being explored.
  - Maximum fluctuations at mid-centralities;
- Systematic errors are under study.

Outlook:

- New results from 27 GeV will come soon.

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Thanks!

Backup slides

STAR and NA49 Acceptance