中国科学院上海应用物理研究所
Shanghai Institute of Applied Physics, Chinese Academy of Sciences

Energy Dependence of Event-by-Event Hadron Ratio Fluctuations from Au+Au Collisions at RHIC

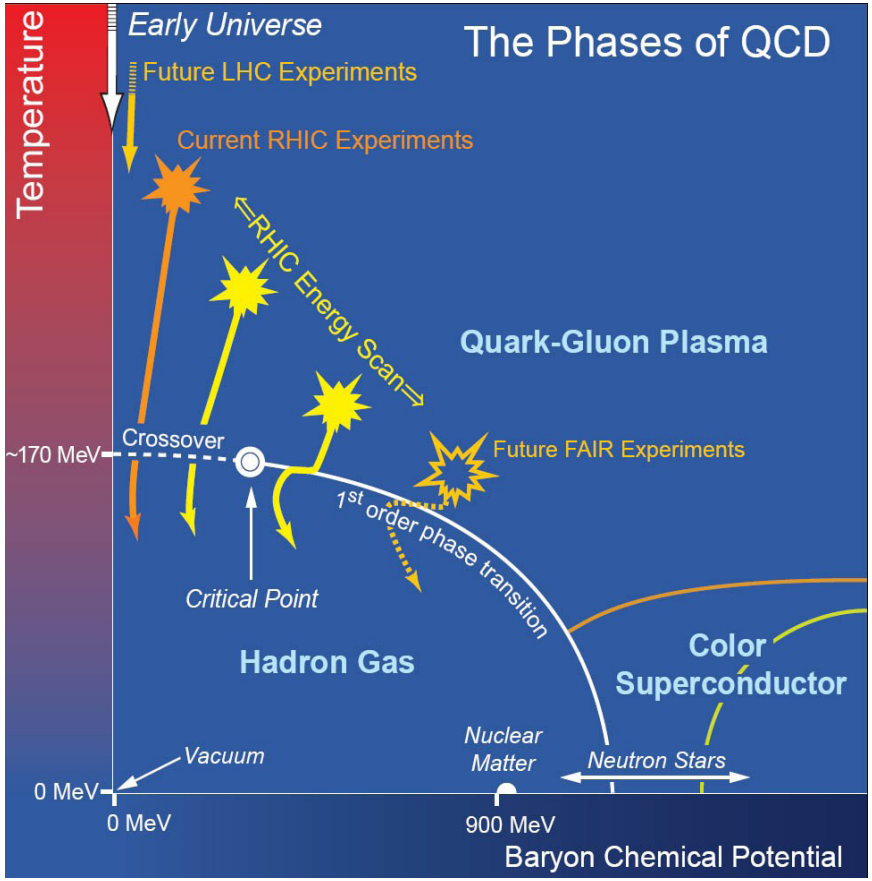
Jian Tian for the STAR Collaboration

Shanghai Institute of Applied Physics, CAS
and University of California, Los Angeles

Outline

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

QCD Phase Diagram



STAR BES, arXiv:1007.2613v1

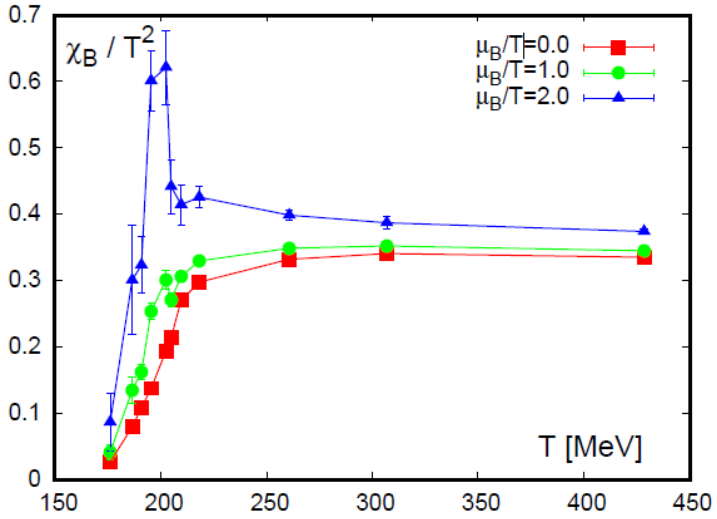
- In a phase transition near critical point, an increase in dynamical fluctuations is expected.
- RHIC "Energy Scan", to look for non-monotonic behaviors as a function of collision energy.
  - — Run10, Au+Au collisions at $\sqrt{s_{NN}}$ = 200, 62.4, 39, 11.5, and 7.7 GeV;
  - — Run11, Au+Au collisions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

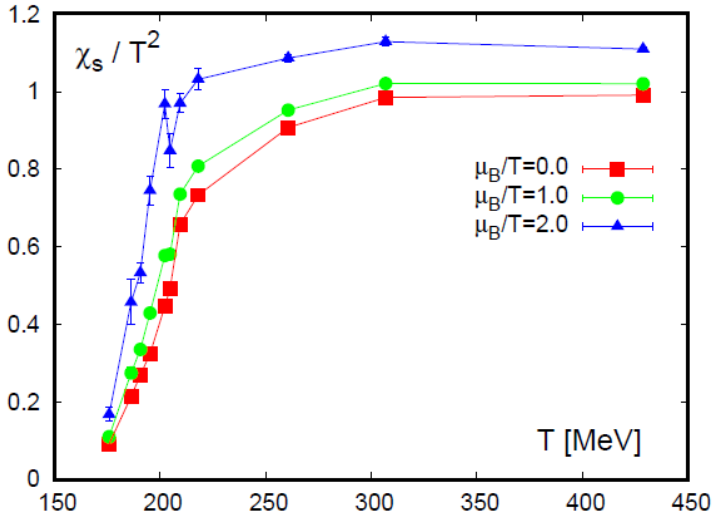
Hadron Ratio Fluctuations

- 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 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 event;
- No internal correlations.

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

- The deviation from Poisson statistical limit,

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

See Terry Tarnowsky's talk

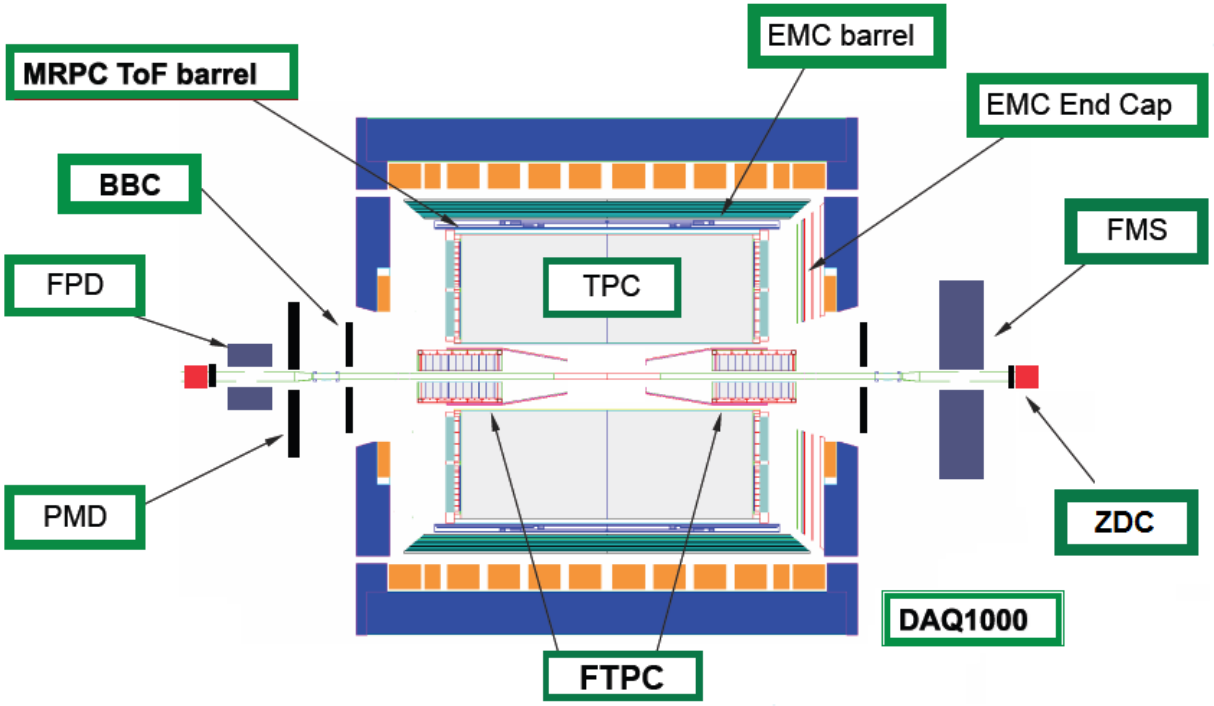
Approximate equality: $\sigma^2_{dyn} = \nu_{dyn}$

— 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

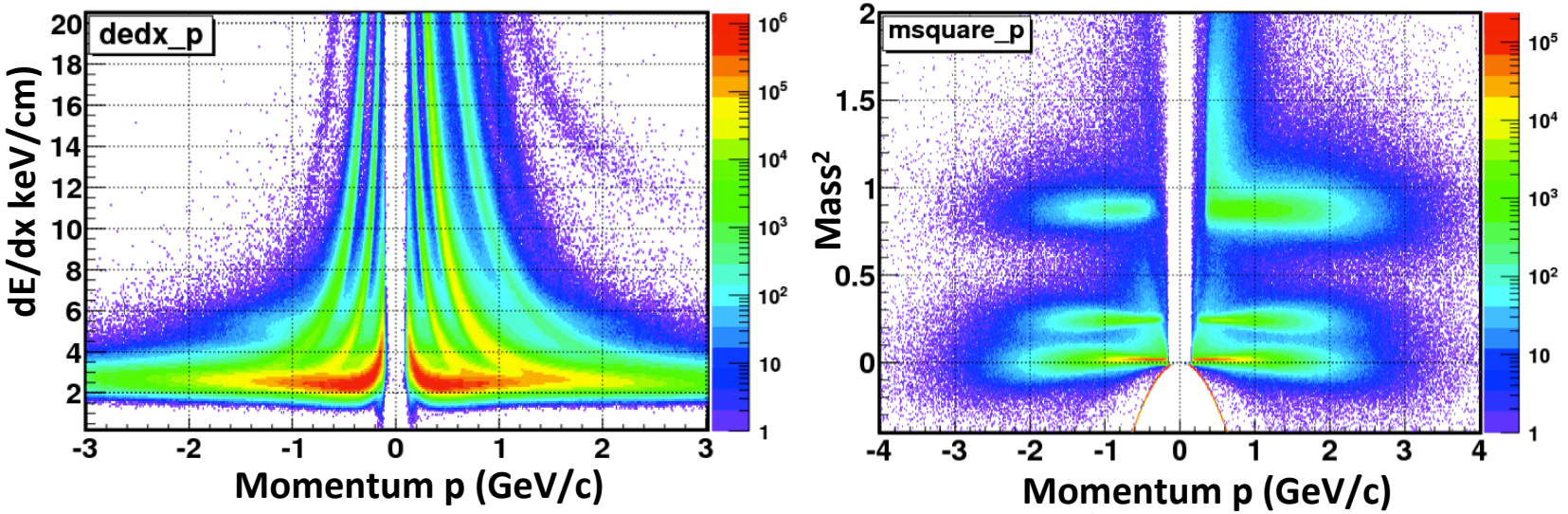
STAR: a complex set of various detectors, with wide range of measurements.



- STAR: a perfect tool for measuring 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 |η|<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)

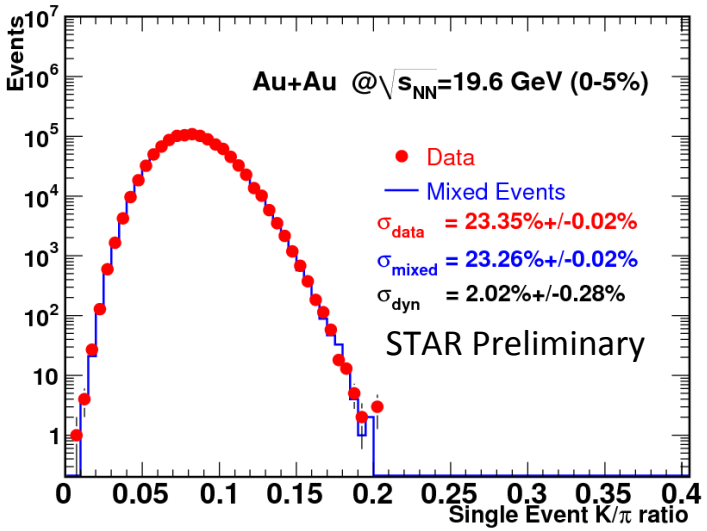
π: p_T>0.2GeV/c, p<1.6GeV/c

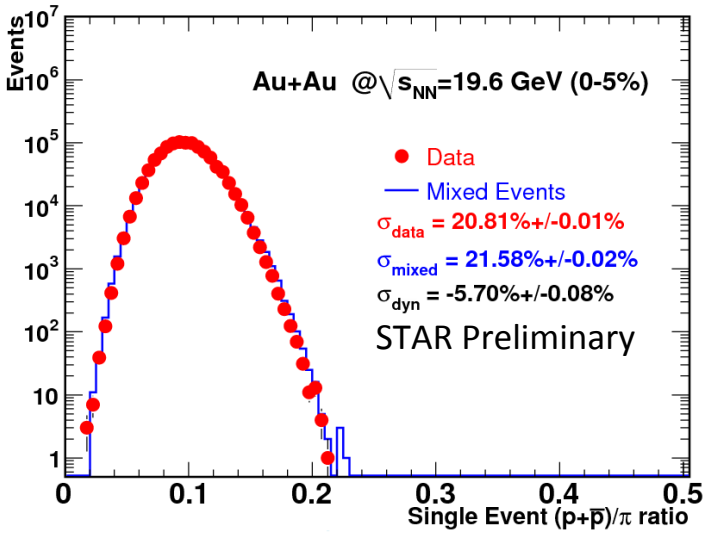
K: p_T>0.2GeV/c, p<1.6GeV/c

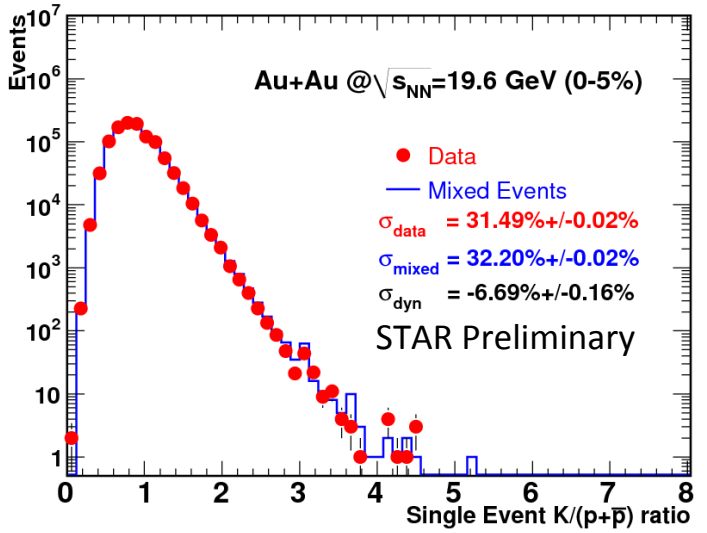
p: p_T>0.4GeV/c, p<3.0GeV/c

Distributions of Hadron Ratios

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

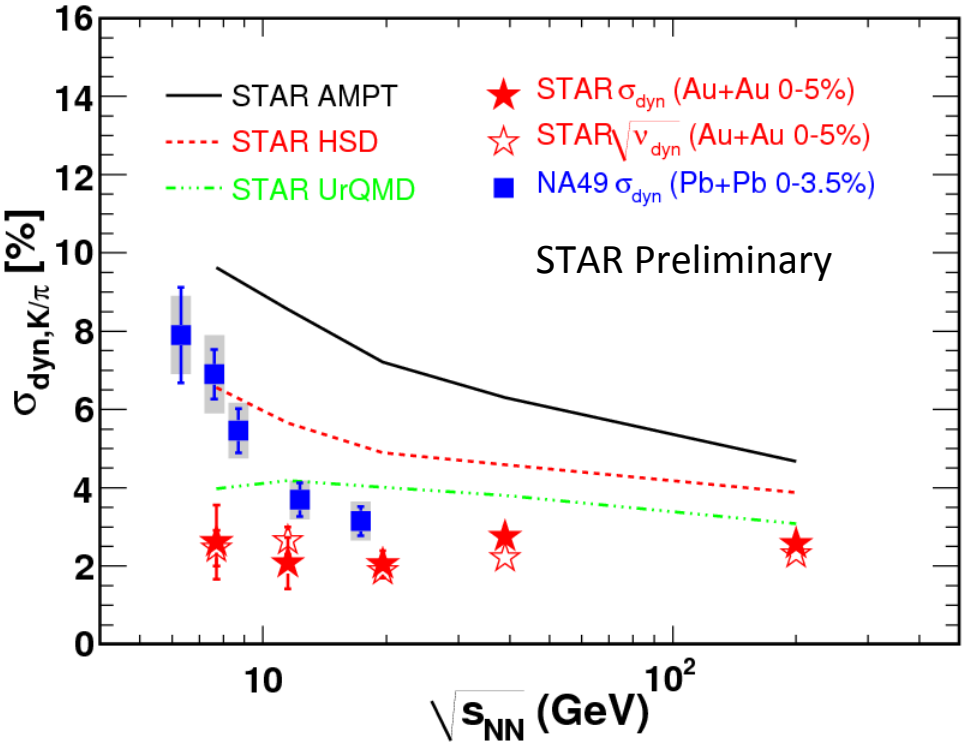






- Data and mixed events have on average the same particle ratios;
- Non-dynamical fluctuations dominate the fluctuations.

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

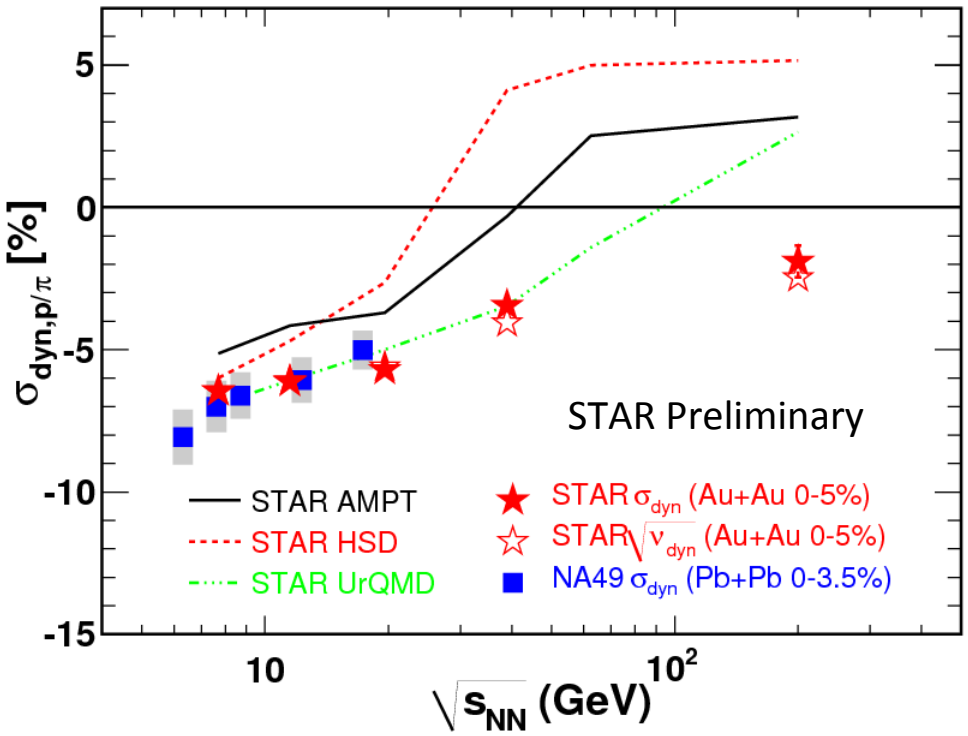


NA49 data are taken from PhysRevC.79.044910(2009)

- ✓ 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 no 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 $(p+\bar{p})/(\pi^+ + \pi^-)$

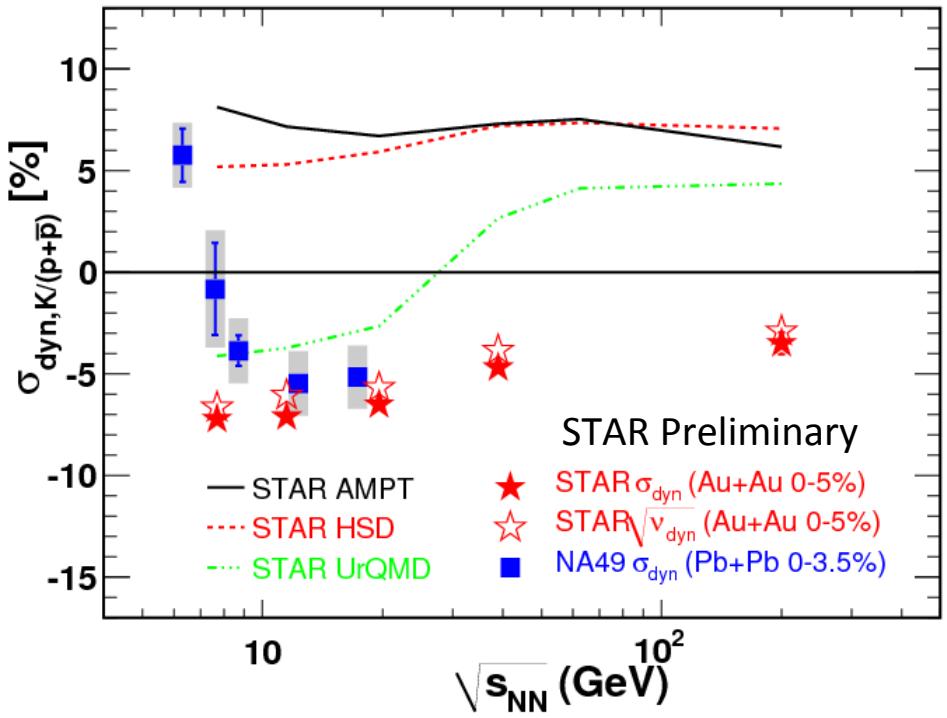


NA49 data are taken from PhysRevC.79.044910(2009)

- ✓ 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 smooth change 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.

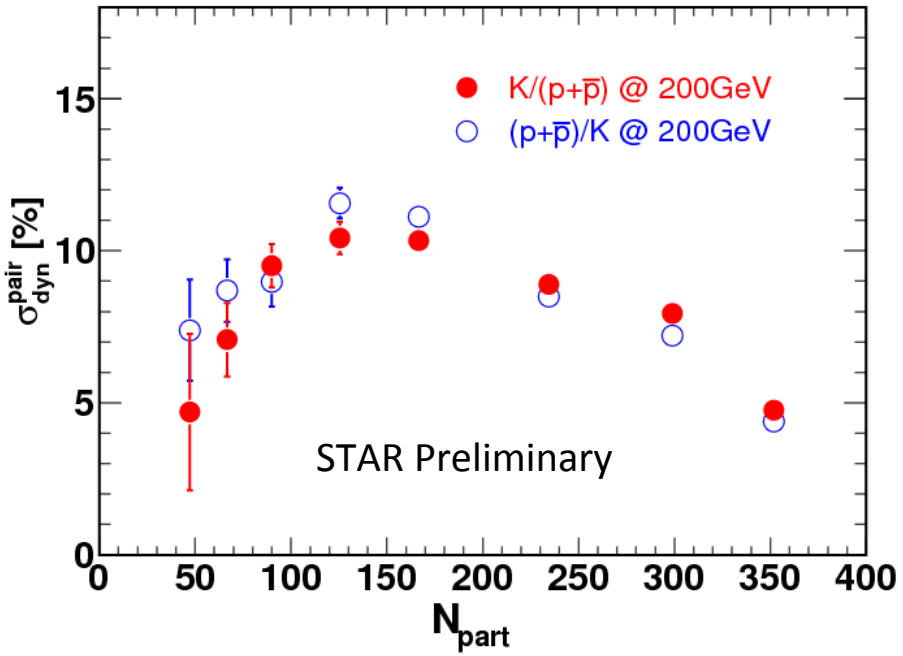
Effect from Pair Production

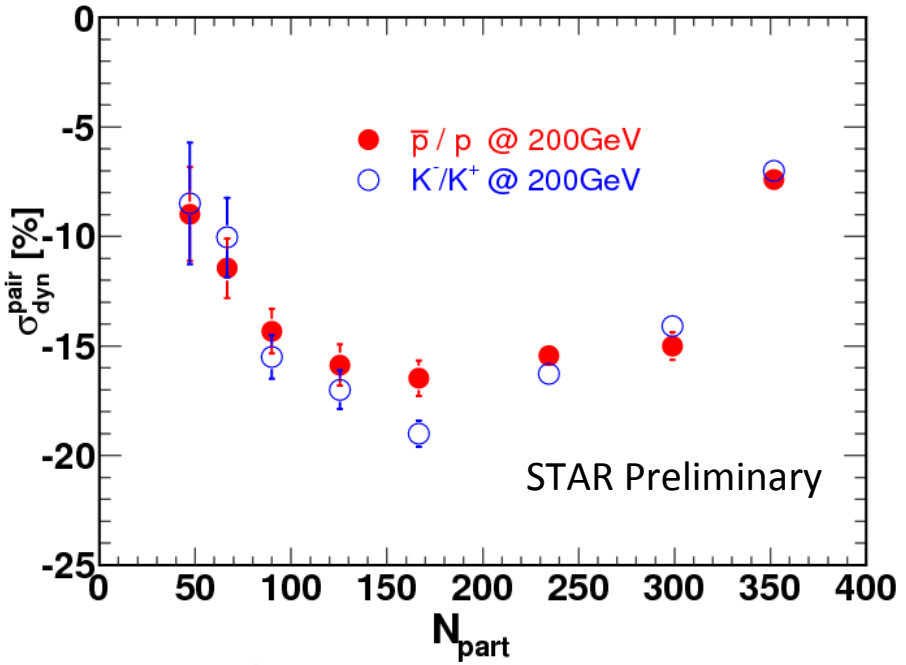
- Baryon numbers (proton) and strangeness quantum numbers (Kaon) are mostly pair-produced in high energy A +A collisions!
- New reference can be constructed to study the effects of these pair production,
  - ✓ Mixed events — Randomly selecting p, $\bar{p}$, K^+ and K^- from four independent events.
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

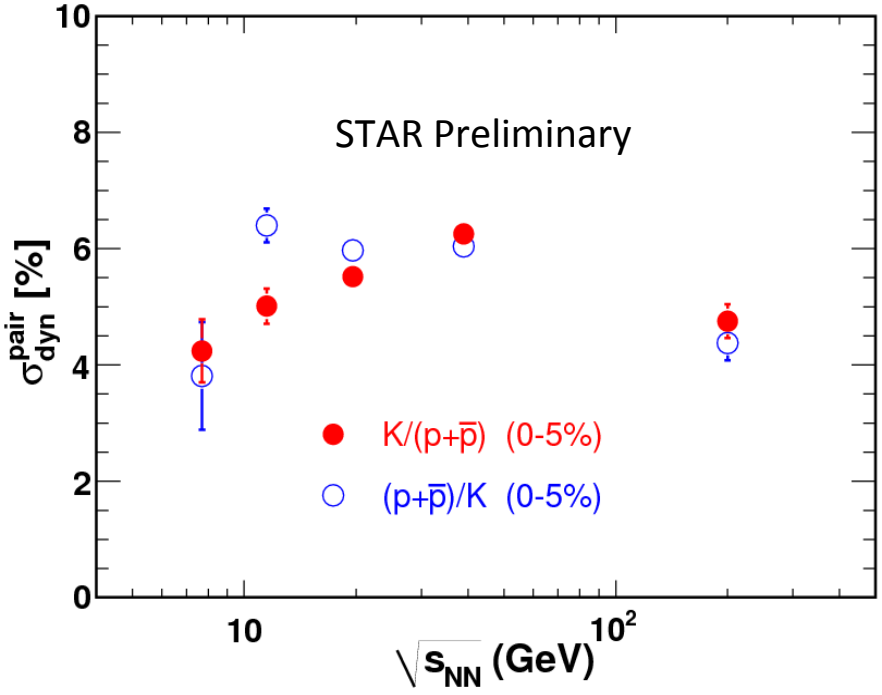


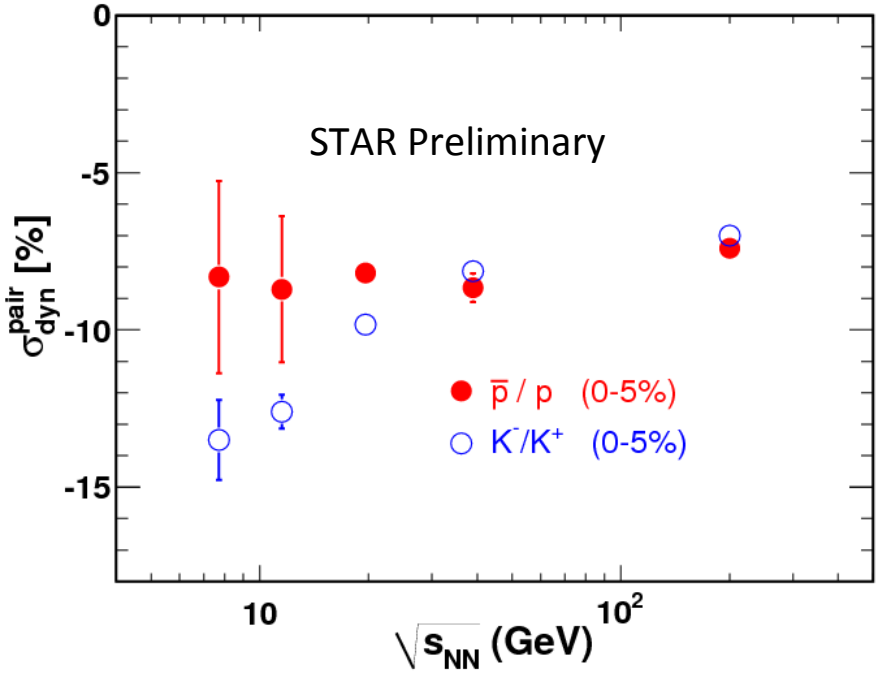


- Positive fluctuations;
- Maximum fluctuations at mid-centralities;
- Statistical error only.

- Negative fluctuations;
- Maximum fluctuations at mid-centralities;
- Statistical error only.

Energy Dependence for σ_{dyn}^{pair}





- Positive fluctuations;
- Slightly energy dependence;
- Statistical error only.

- Negative fluctuations;
- Energy dependence of K^-/K^+ fluctuations;
- Statistical error only.

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.
- Systematic errors are under study.

Thanks!

Backup slides

STAR and NA49 Acceptance