Measurement of the sixth order cumulant of net-proton multiplicity distribution at $\sqrt{s_{NN}}$ = 200GeV from the STAR experiment

JPS fall meeting @Miyazaki
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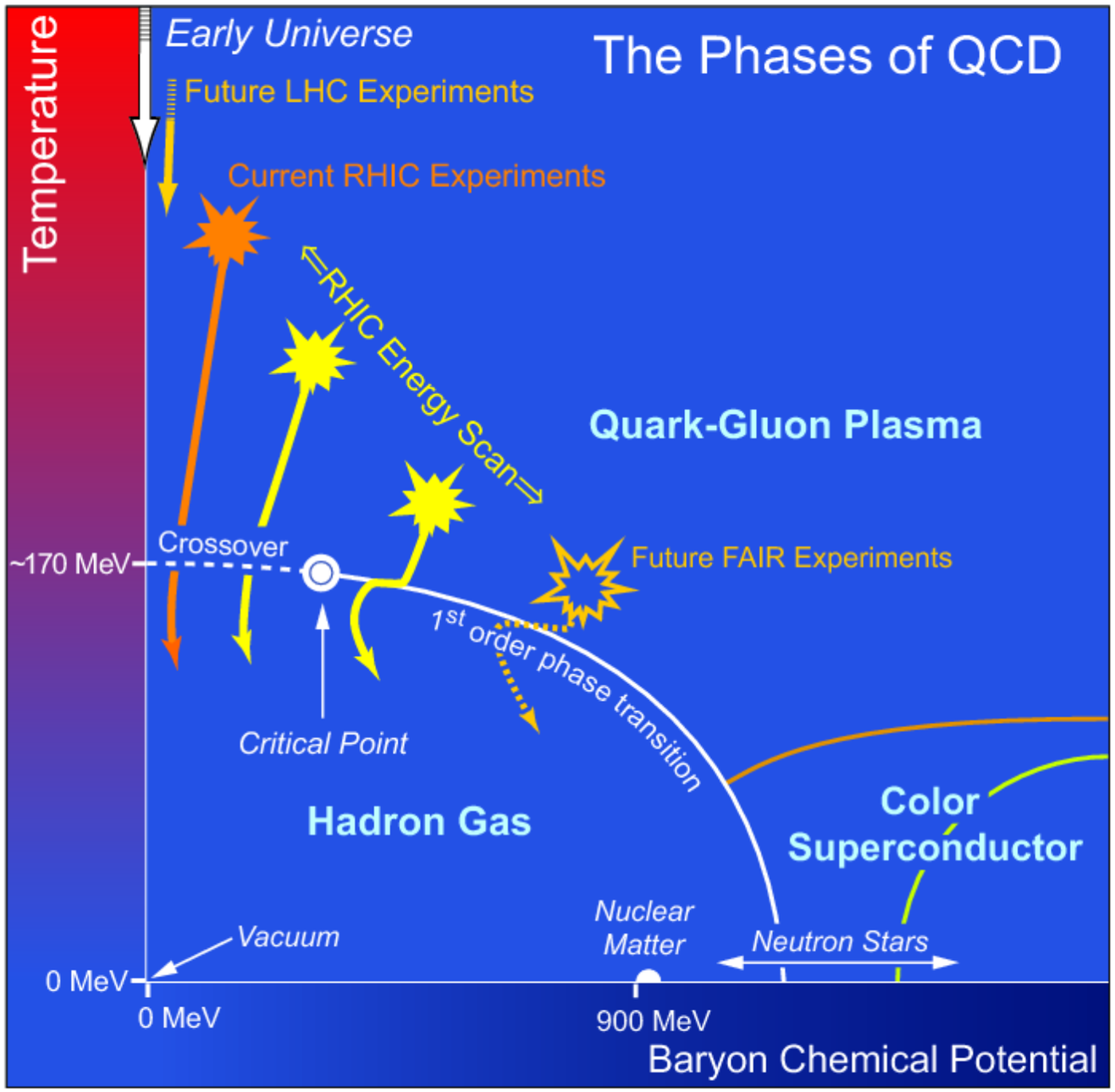
Outline

- ✓ QCD phase diagram
- ✓ Search for CP with Higher Moments
- ✓ STAR detector and Proton Identifications
- ✓ Results and Summary

QCD phase diagram



- ✓ Crossover at μ_B=0
- ✓ 1st order phase transition at large μ_B?
- ✓ Critical point?
- ✓ Beam Energy Scan Phase I at RHIC, $\sqrt{s_{NN}}$=7.7, 11.5, 14.5, 19.6, 27, 39, 62.4 and 200 GeV in 2010, 2011 and 2014.

Cumulants of conserved quantities

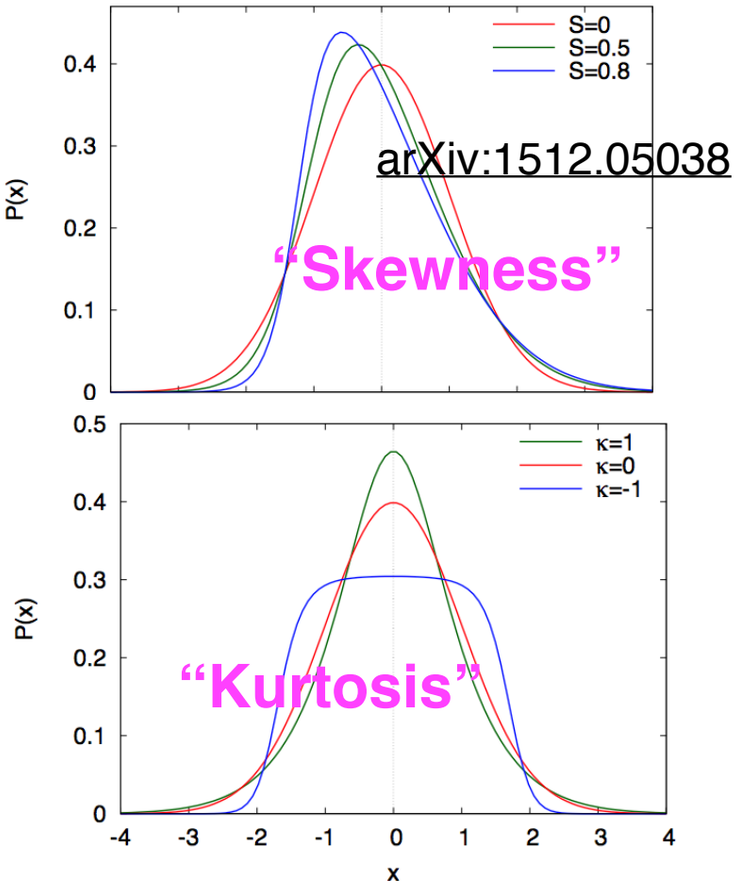
✓ **Net-baryon, net-charge and net-strangeness**

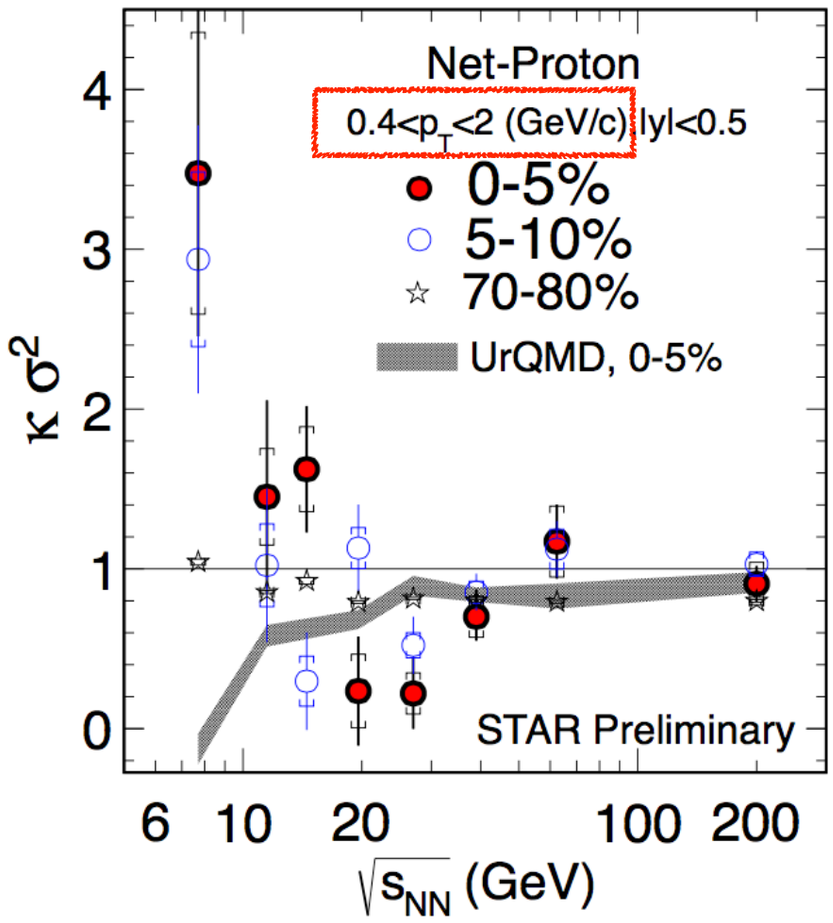
- **Sensitive to the correlation length**

$$< \delta N >= N - < N >$$
$$C_1 = M =< N >$$
$$C_2 = \sigma^2 =< (\delta N)^2 > \approx \xi^2$$
$$C_3 = S\sigma^3 =< (\delta N)^3 > \approx \xi^{4.5}$$
$$C_4 = \kappa\sigma^4 =< (\delta N)^4 > -3 < (\delta N)^2 >^2 \approx \xi^7$$

- **Direct comparison with susceptibility**

$$S\sigma = \frac{C_3}{C_2} = \frac{\chi_3}{\chi_2}$$
$$\kappa\sigma^2 = \frac{C_4}{C_2} = \frac{\chi_4}{\chi_2}$$





✓ **Recent net-proton results show the non-monotonic behaviour with extended p_T region.**

X. Luo (STAR collaboration) arXiv:1503.02558v2

Sixth order cumulant

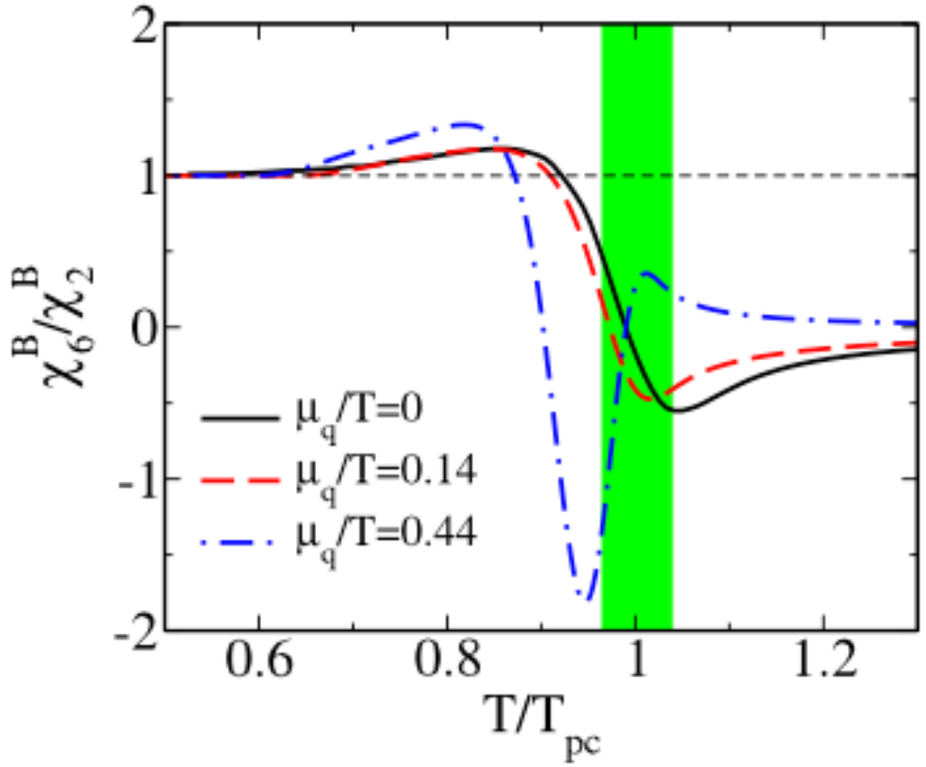
- ✓ **Lattice calculations predict a "smooth crossover" at μ_B=0.**

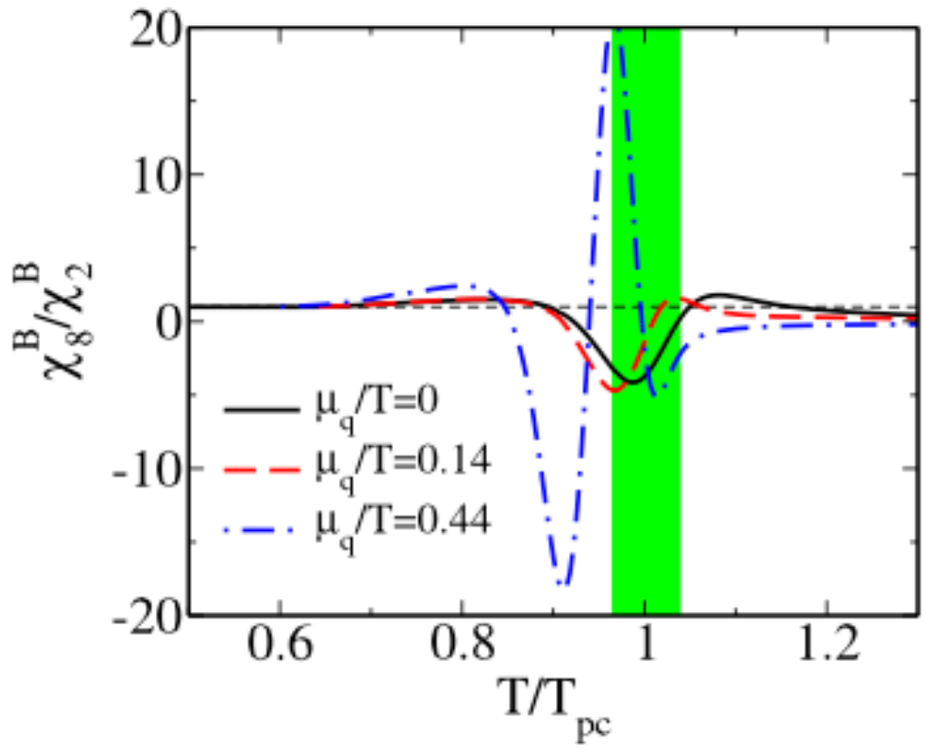
  Y. Aoki, Nature 443, 675(2006)

- ✓ **Theoretically the six order cumulant of net-baryon and net-charge fluctuation change sign near the chiral phase transition.**

  Friman et al, Eur. Phys. J. C (2011) 71:1694

- ✓ **Find a direct evidence for the crossover with measurement of the sixth order cumulant at the STAR experiment.**





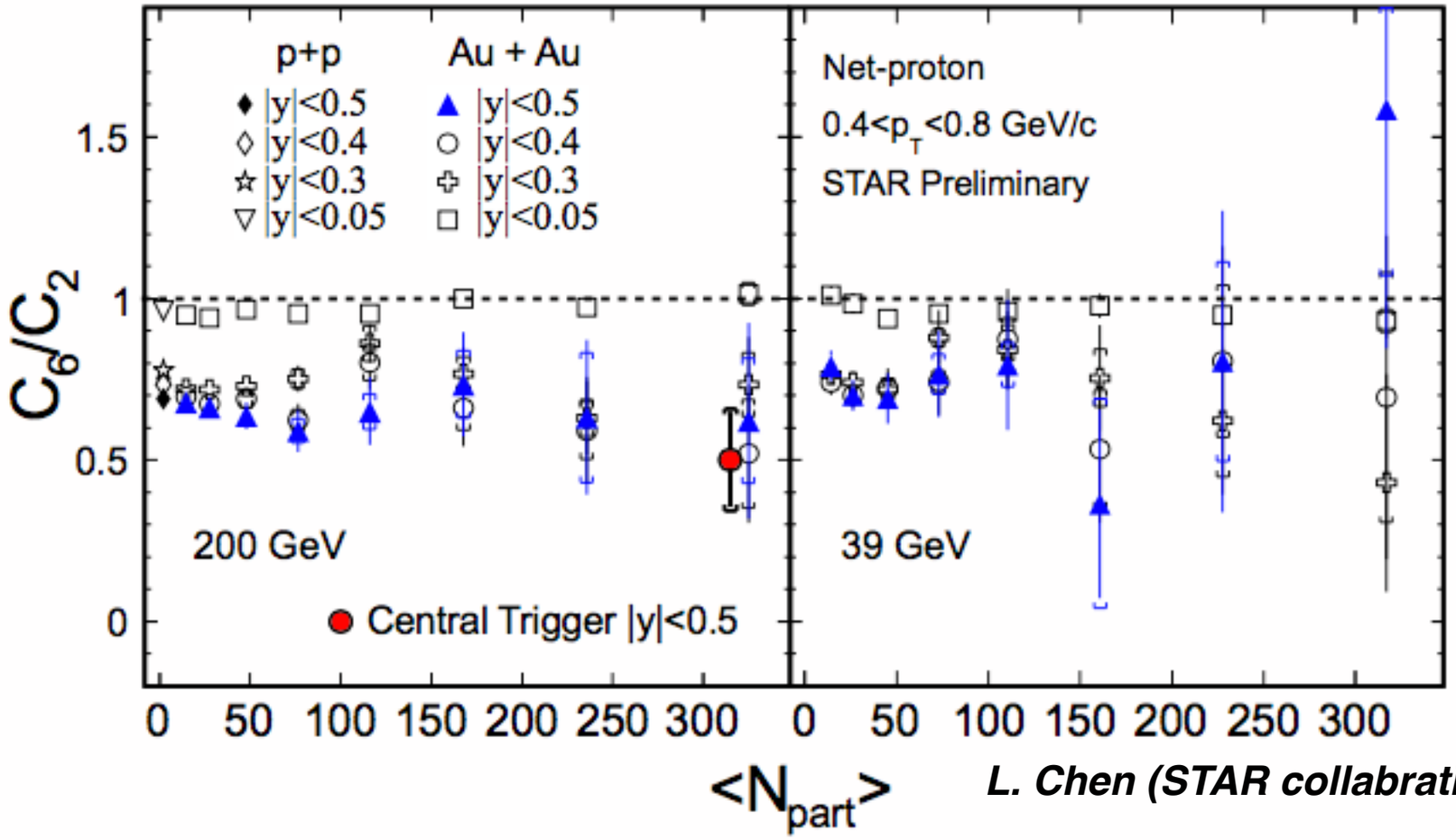
Friman et al, Eur. Phys. J. C (2011) 71:1694

STAR results

- ✓ The STAR experiment measured C_6/C_2 at low p_T region at $\sqrt{s_{NN}}$=200GeV of Run10 datasets (~250M events).

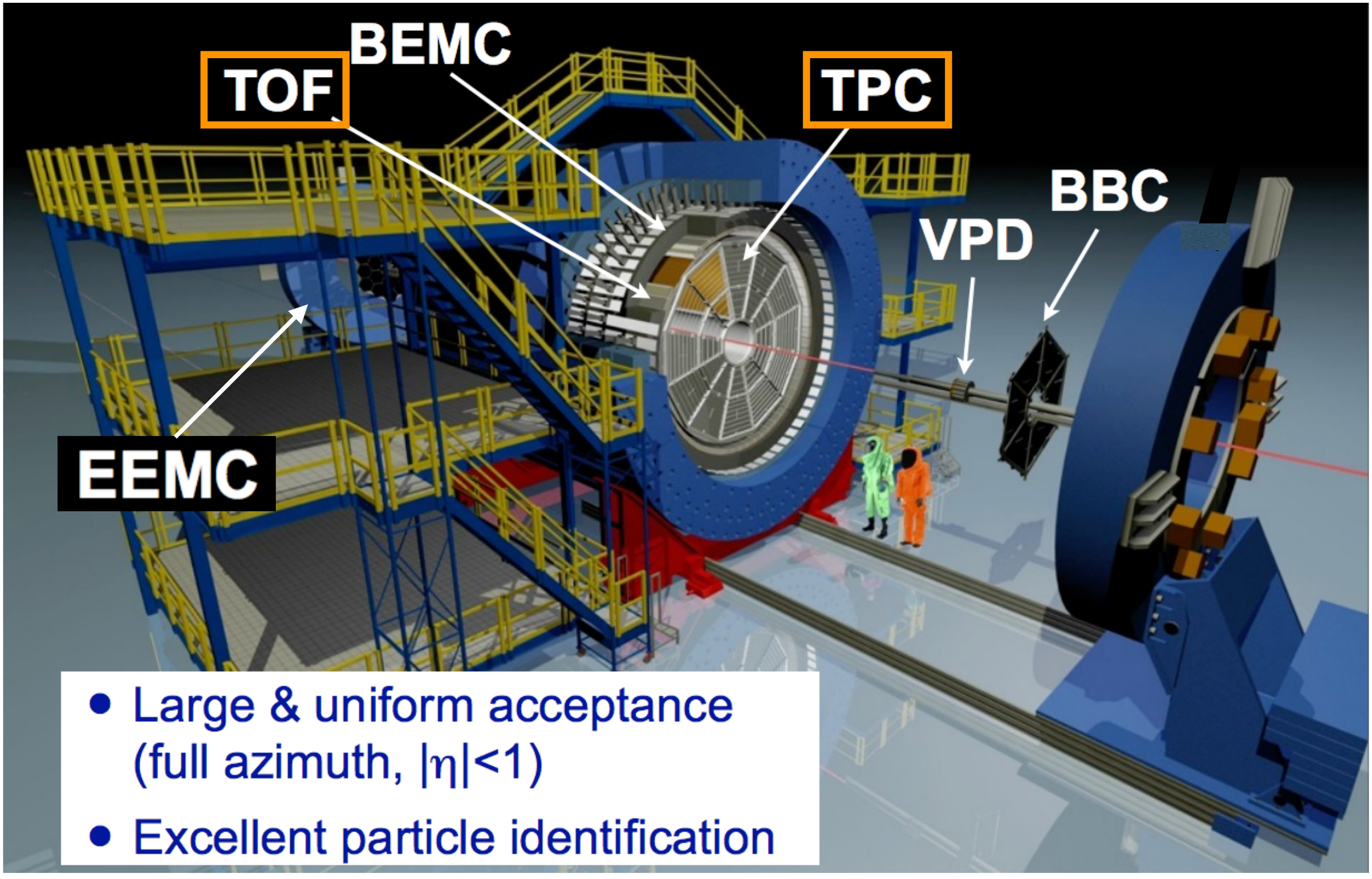
  L. Chen (STAR collabration), NPA 904-905(2013)

- ✓ Event statistics is very important for higher orders.
- ✓ We focus on $\sqrt{s_{NN}}$=200GeV of Run11 datasets which have ~500M events.



L. Chen (STAR collabration), NPA 904-905(2013)

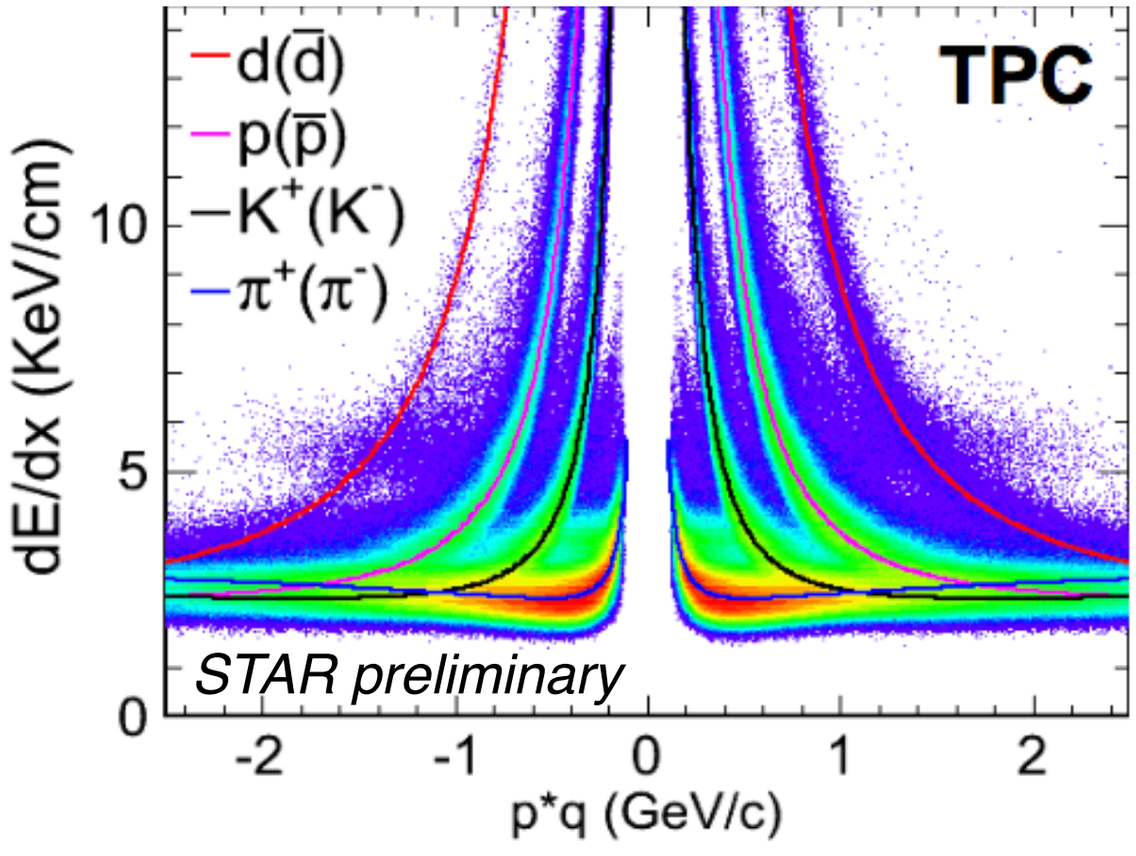
Solenoidal Tracker At RHIC

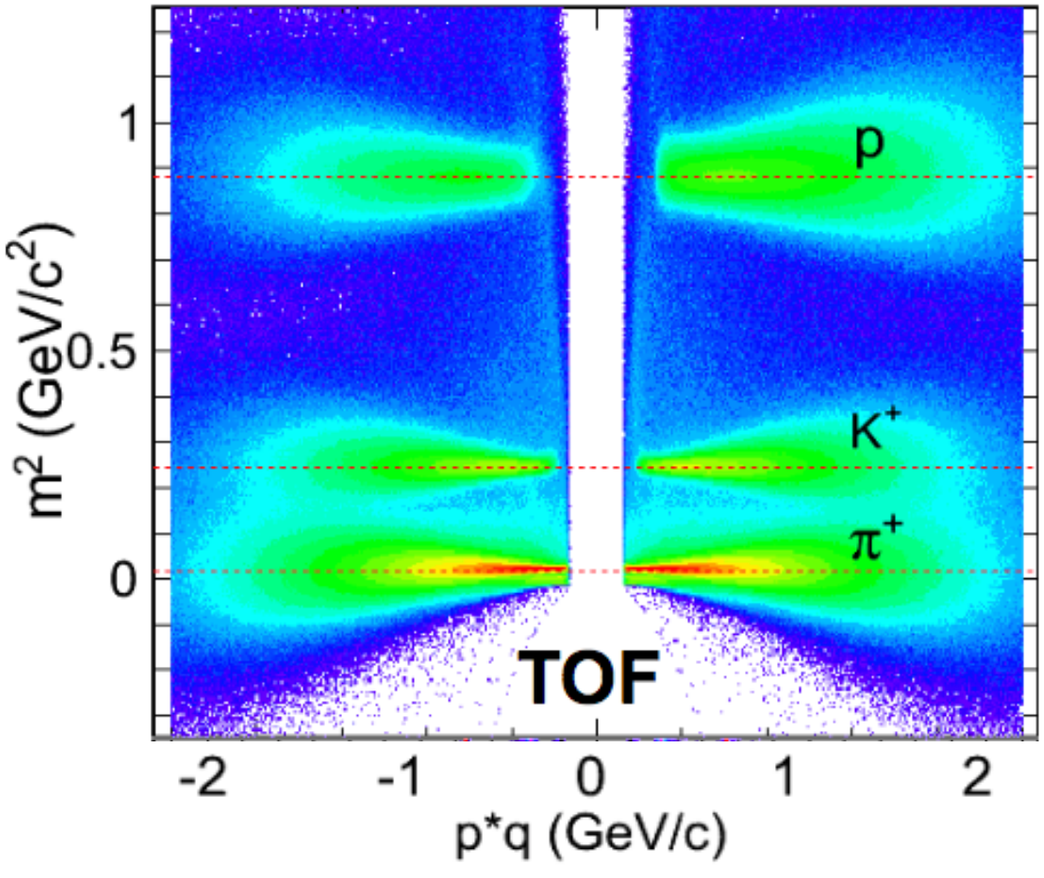


- Large & uniform acceptance (full azimuth, $|\eta|<1$)
- Excellent particle identification

Proton Identification

- ✓ dE/dx measured with TPC is used for proton identification at $0.4<p_T<0.8$ GeV/c
- ✓ The combined PID with m^2 from TOF is used at $0.8<p_T<2.0$ GeV/c.





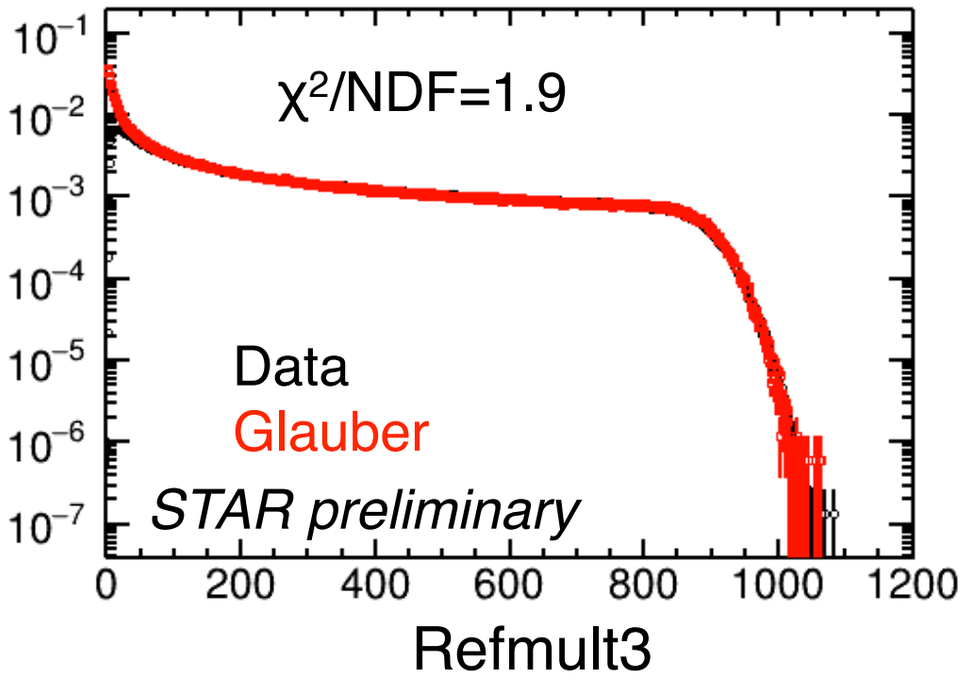
Analysis technique

1. Centrality determination

Use charged particles except protons in order to avoid the auto correlation.

Analysis : |y|<0.5, p and pbar

Centrality : |η|<1.0, exclude p and pbar



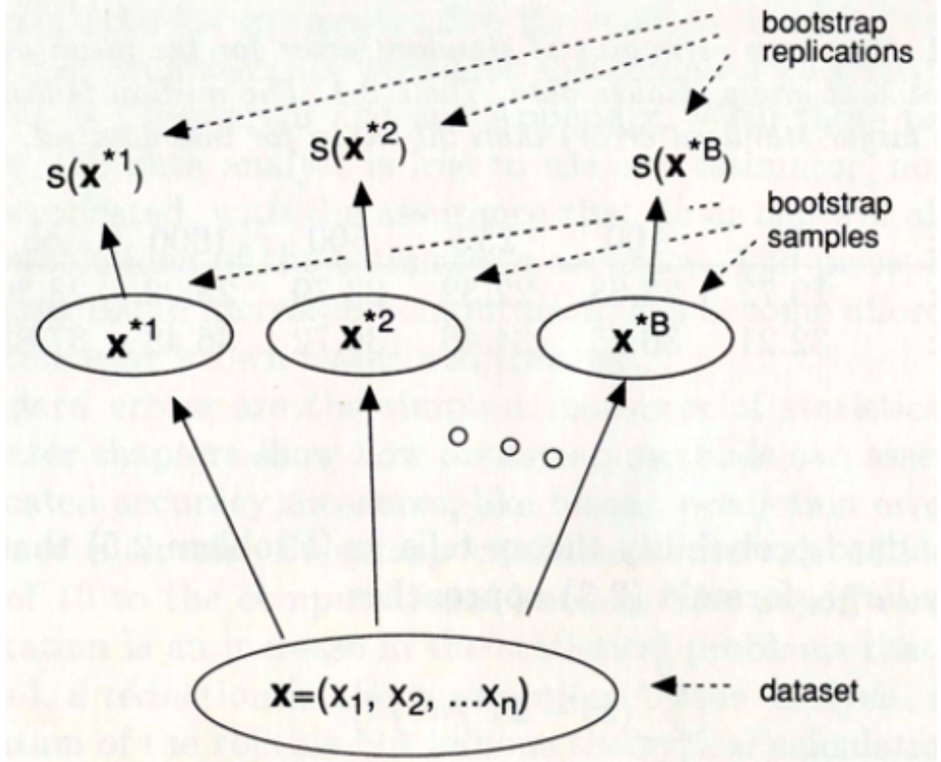
2. Centrality Bin Width Correction

Calculate cumulants at each multiplicity bin in order to suppress the volume fluctuation.

X.Luo et al. J. Phys.G40,105104(2013)

3. Statistical error calculation

- ✓ **Bootstrap**
- ✓ Delta theorem

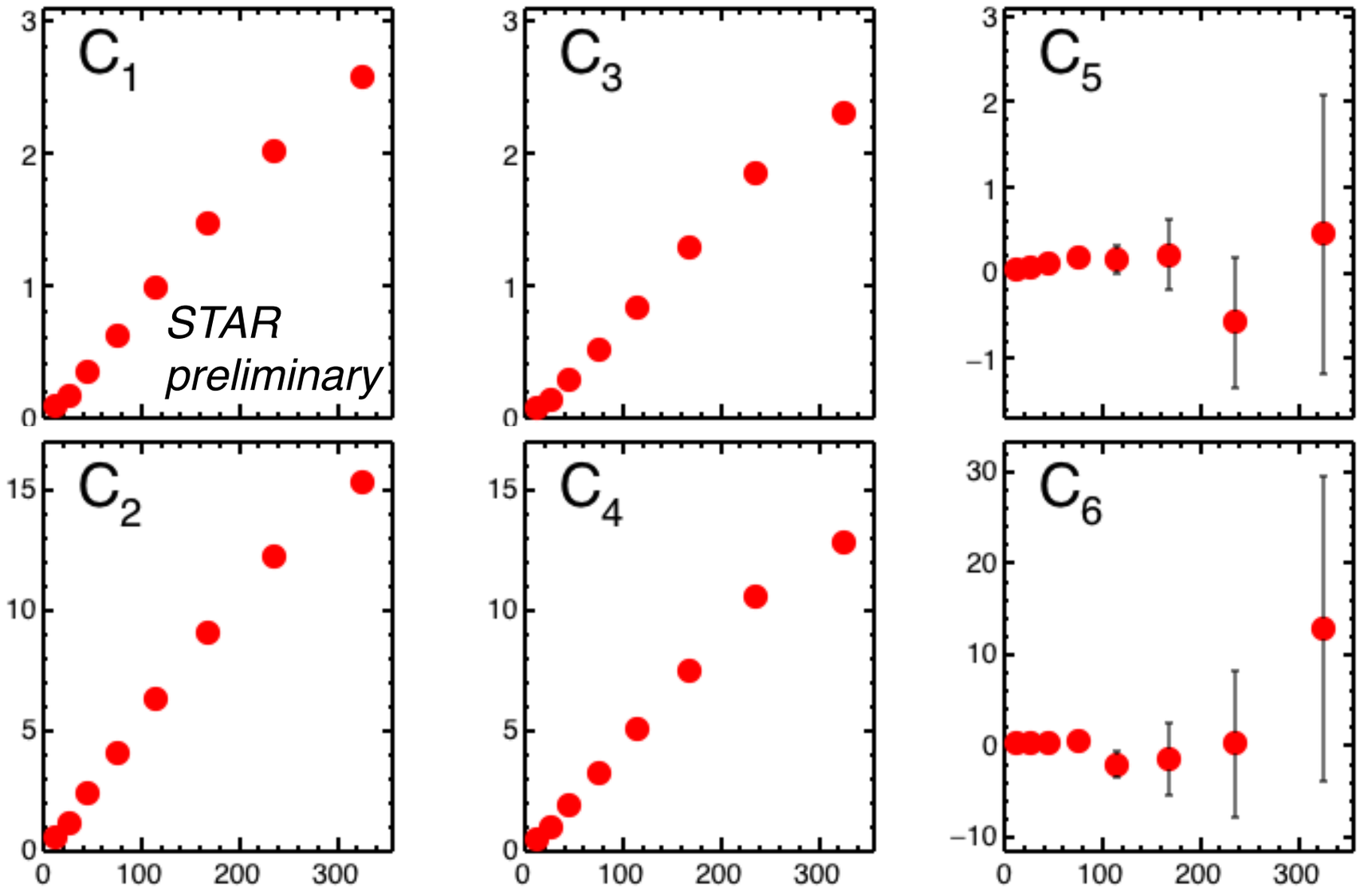


B. Efron,R. Tibshirani, An introduction to the bootstrap, Chapman & Hall (1993).

Cumulants up to sixth order

- ✓ **The 5th and 6th order cumulants deviate from the linear expectation seen for 1st to 4th order.**

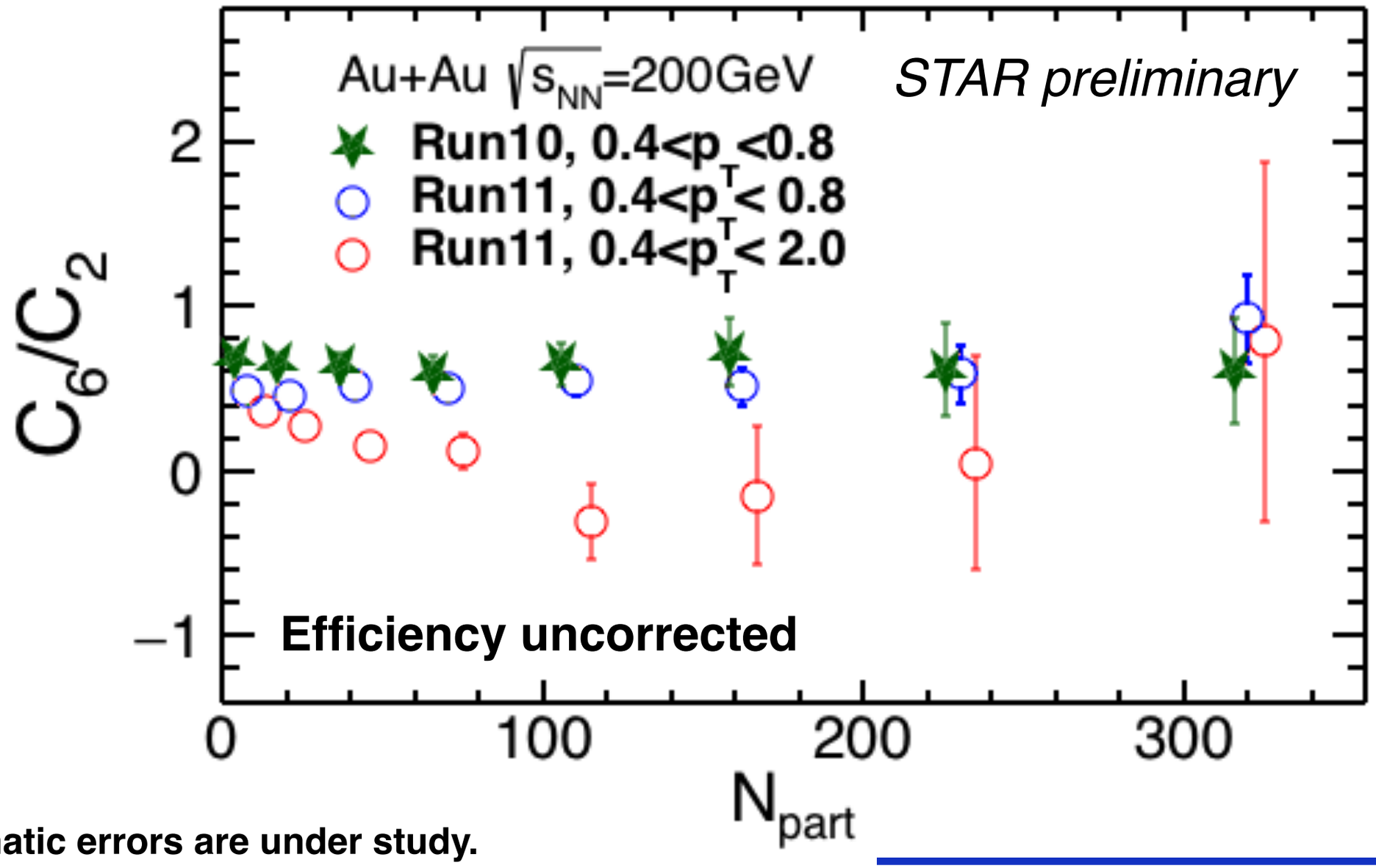
Run11, Au+Au $\sqrt{s_{NN}}$=200GeV
Efficiency uncorrected, $0.4<p_T<2.0$ GeV/c



Systematic errors are under study.

Cumulant ratio

- ✓ **Previous STAR results using Run10 datasets are consistent with Run11 within errors.**
- ✓ **Extended p_T region gives larger signals compared to the low p_T region.**



Systematic errors are under study.

Summary

- ✓ **Cumulants and cumulant ratios up to 6th order of net-proton multiplicity distribution are being measured with $0.4<p_T<2.0$ GeV/c and $|y|<0.5$ in Au+Au collisions at $\sqrt{s_{NN}}$=200GeV.**
- ✓ **Efficiency correction is ongoing.**
- ✓ **Statistical errors are still large. Results from the other datasets will be merged in order to extract physics information.**

Au+Au 200GeV	Run10	Run11	Run14
MB events	~350M	~650M	~1.5B
Remarks	One TPC sector dead	N/A	HFT installed Production ongoing