Energy Dependence of High-Moments of Net-proton Distributions at RHIC

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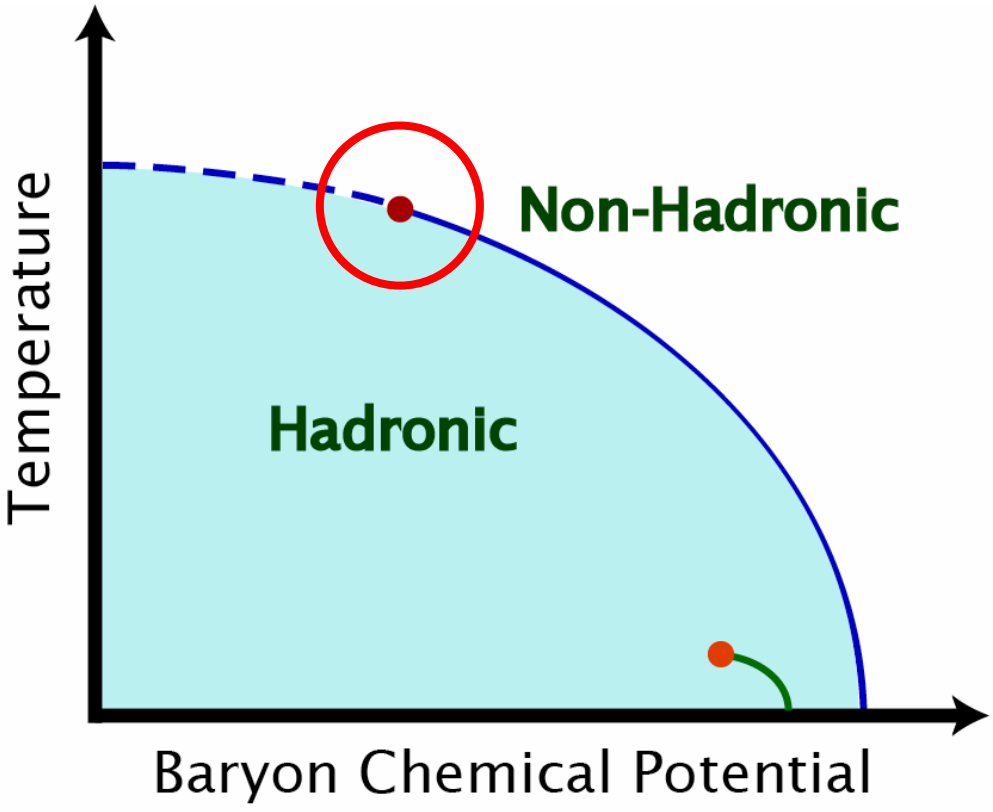
QCD Critical Point



Critical Point:

Solid State Phys

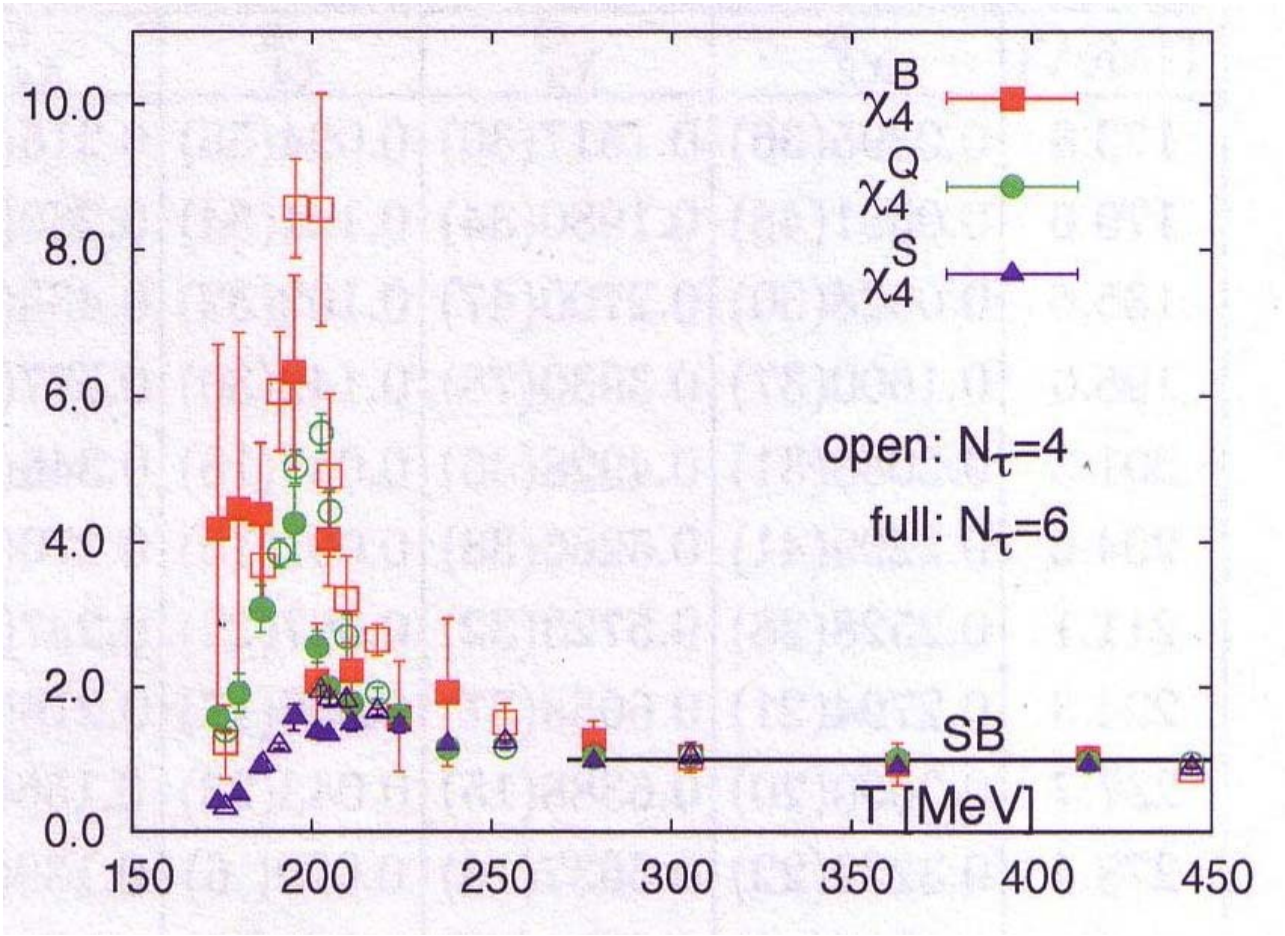
- Susceptibilities diverge
- Correlation Length diverges

HI Reactions

- Becomes Critical Region
- Correlation Length ξ = System size

$\langle (dN)^2 \rangle \sim \xi^2$

Critical Point in LQCD



Fluctuations of conserved quantities indicate nearby singularities

M. Cheng, et al., arXiv:1001.3796

What to measure

Baryon number susceptibility:

$X_B \sim \langle(\delta B)^2\rangle$

Similar for other conserved quantities, e.g. charge

➔ Connection between lattice and fluctuations of conserved quantities

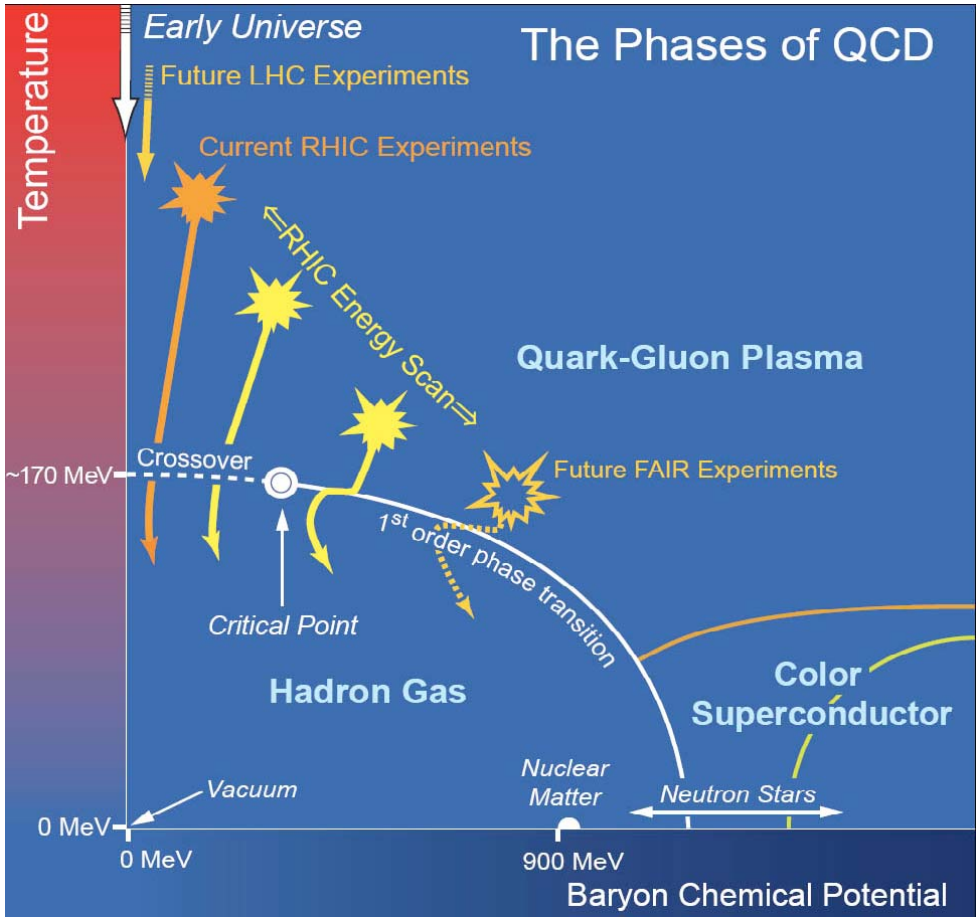
LQCD predictions

➔ Critical fluctuations are Non-gaussian

What to measure

- Non-gaussian fluctuations
- Higher moments sensitive to non-gaussian behavior
  - Kurtosis
  - Skewness
- Higher moments amplify signal

Energy Scan at RHIC



Look for non-monotonic variations of higher moments of conserved quantity distributions as a function of beam energy

Challenging measurement

Caveats:

Critical slowing down

Dynamical effects

B. Berdnikov & K. Rajagopal, Phys. Rev. D 61, 105017 (2000)
Stephanov, Rajagopal, Shuryak, Phys. Rev. D 60, 114028 (1999)

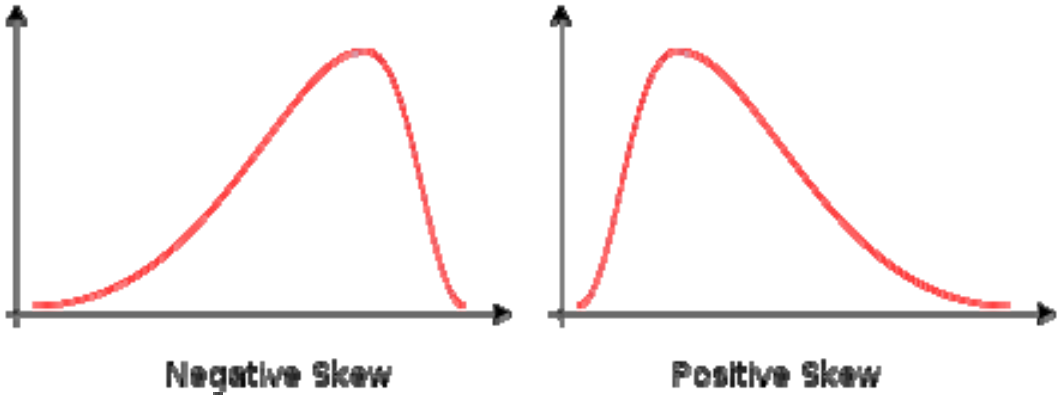
Skewness and Kurtosis

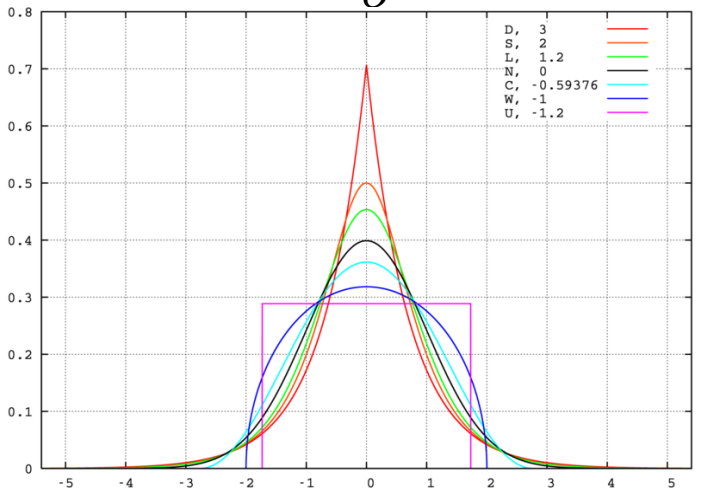
Mean: $Y = < N >$

St. Deviation: $\sigma = \sqrt{< (N - < N >)^2 >}$

Skewness: $s = \frac{< (N - < N >)^3 >}{\sigma^3}$

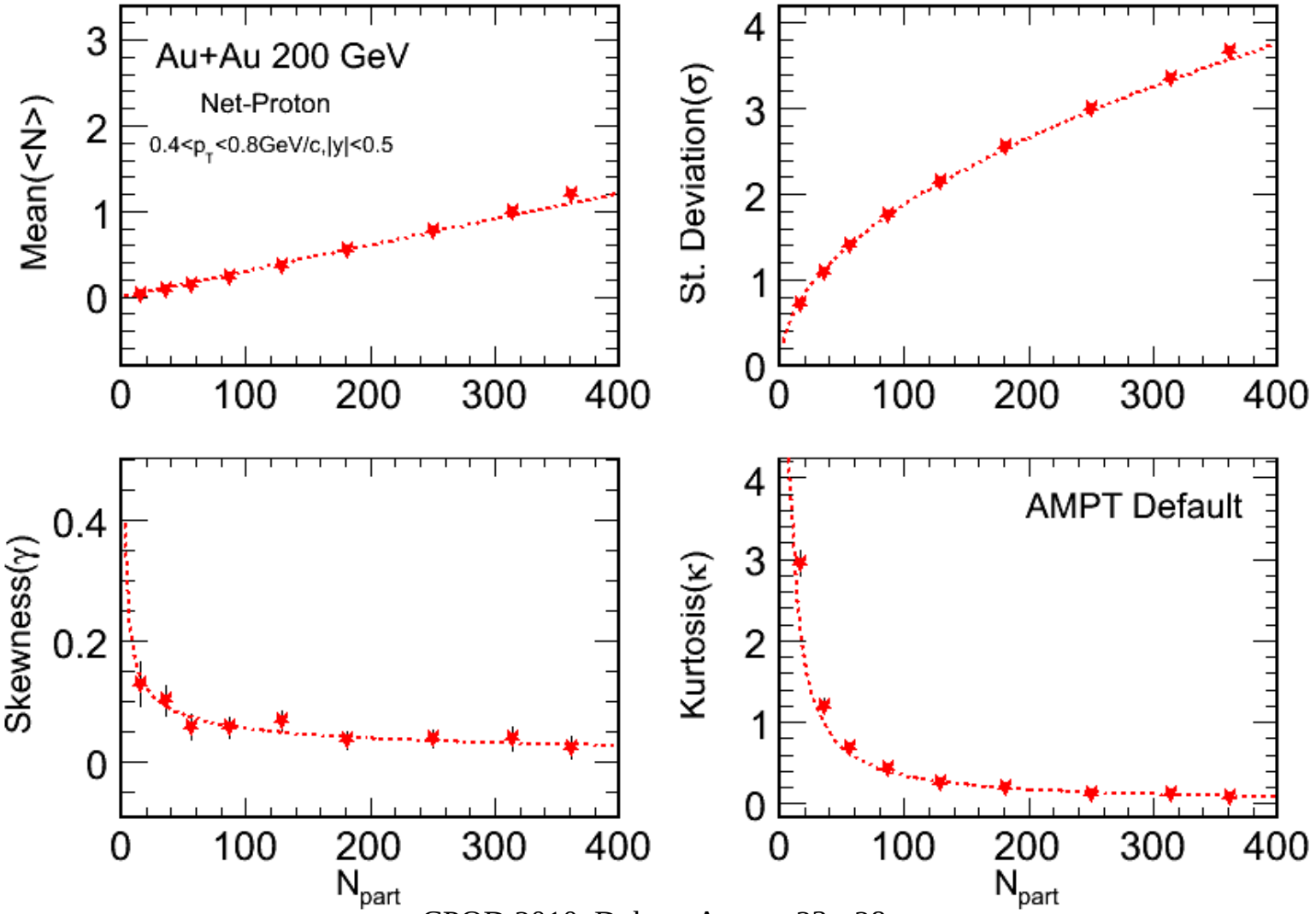
Kurtosis: $\kappa = \frac{< (N - < N >)^4 >}{\sigma^4} - 3$





- Skewness describes the asymmetry of the distribution
- Kurtosis describes the peakness of the distribution
- Equal to zero for Gaussian distribution
- Ideal probes for non-Gaussian fluctuations

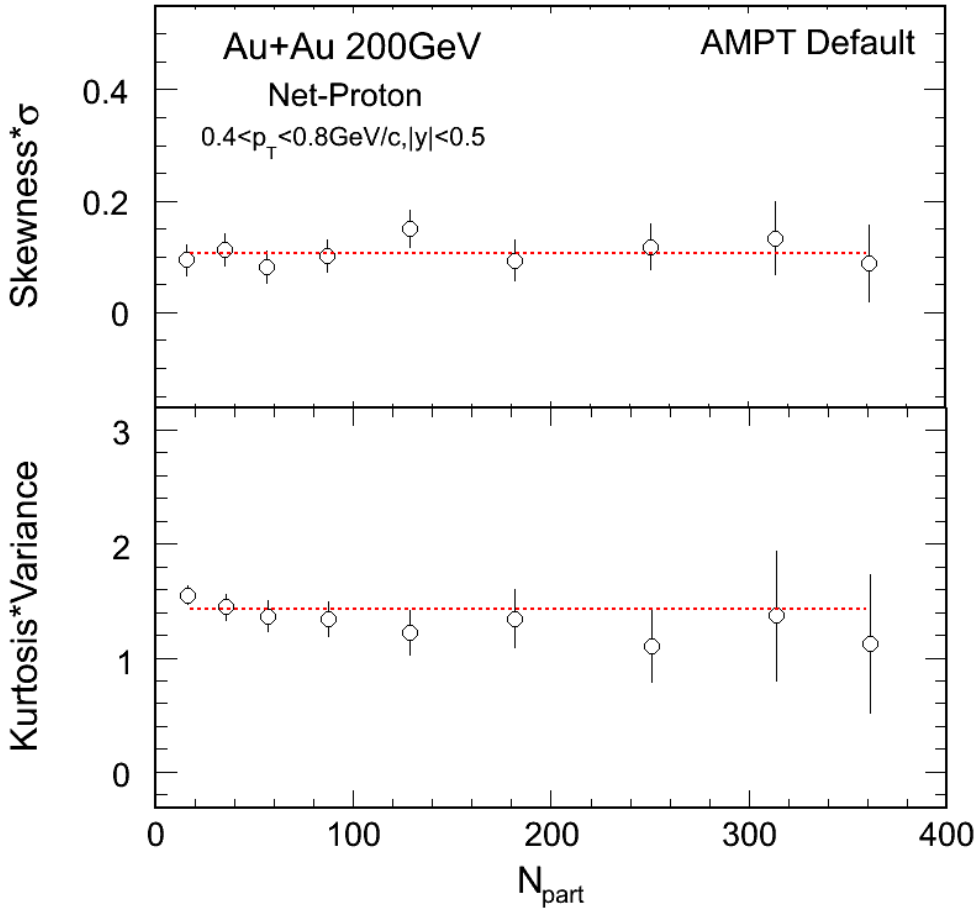
Moments in AMPT



CLT, many sources

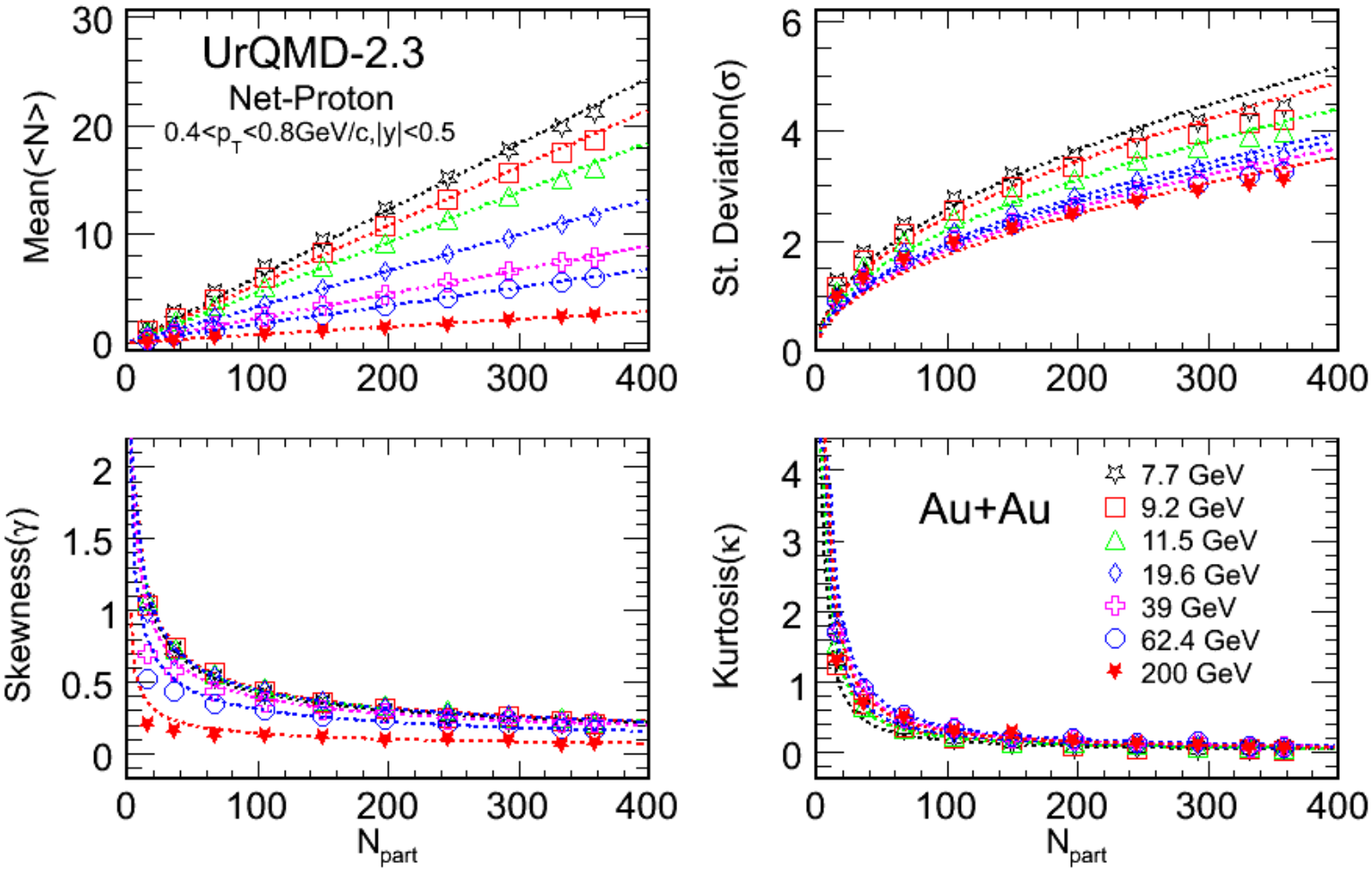
- Multiplicity dependance can be taken out and results plotted as a function of Npart
- Possible observables:
  - Kurtosis x Variance
  - Skewness x St. deviation
- Question: how many sources
- Caveat:
  - Many sources can mask non-gaussian behaviour

Corrected for Multiplicity

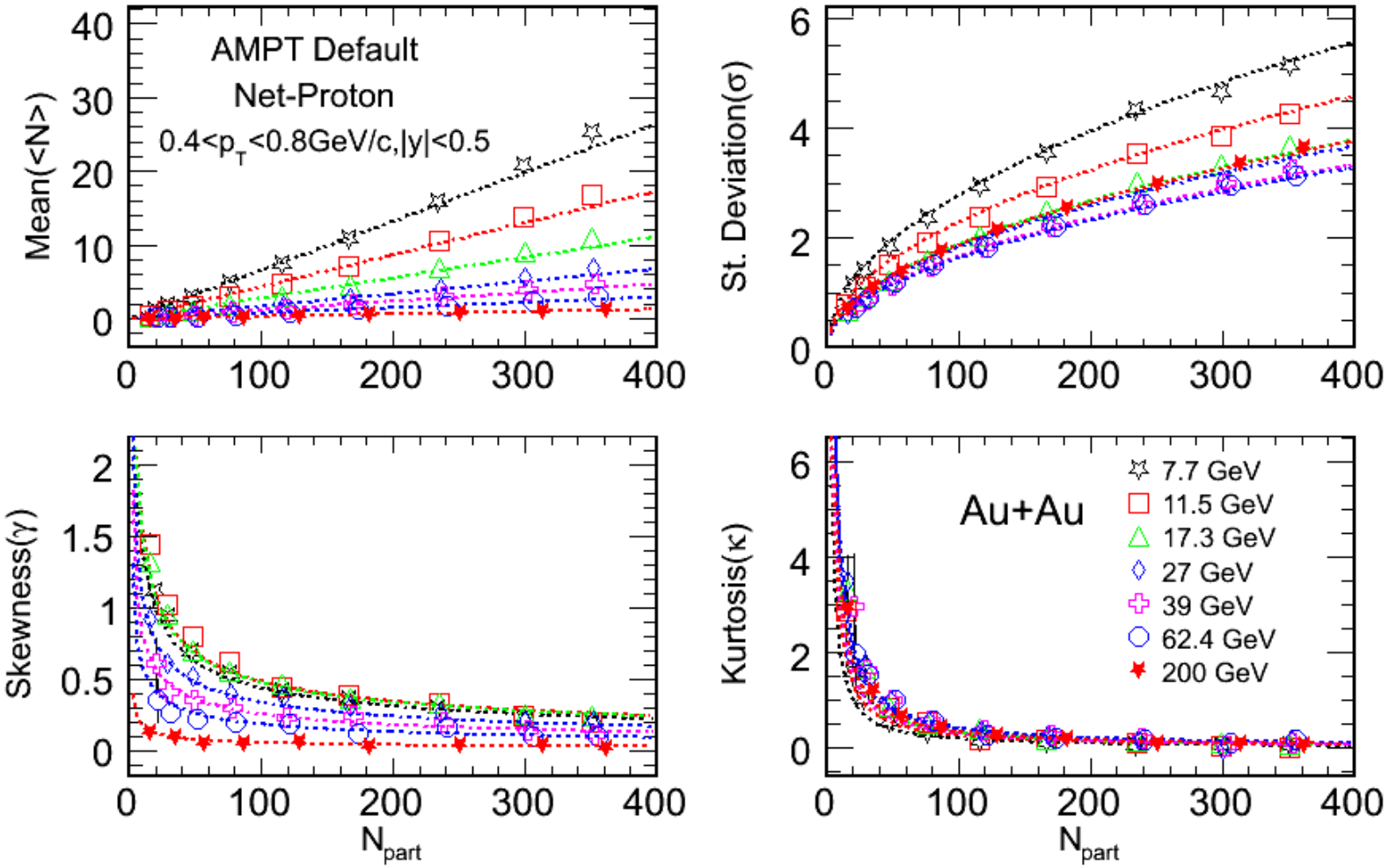


The data will be compared this way

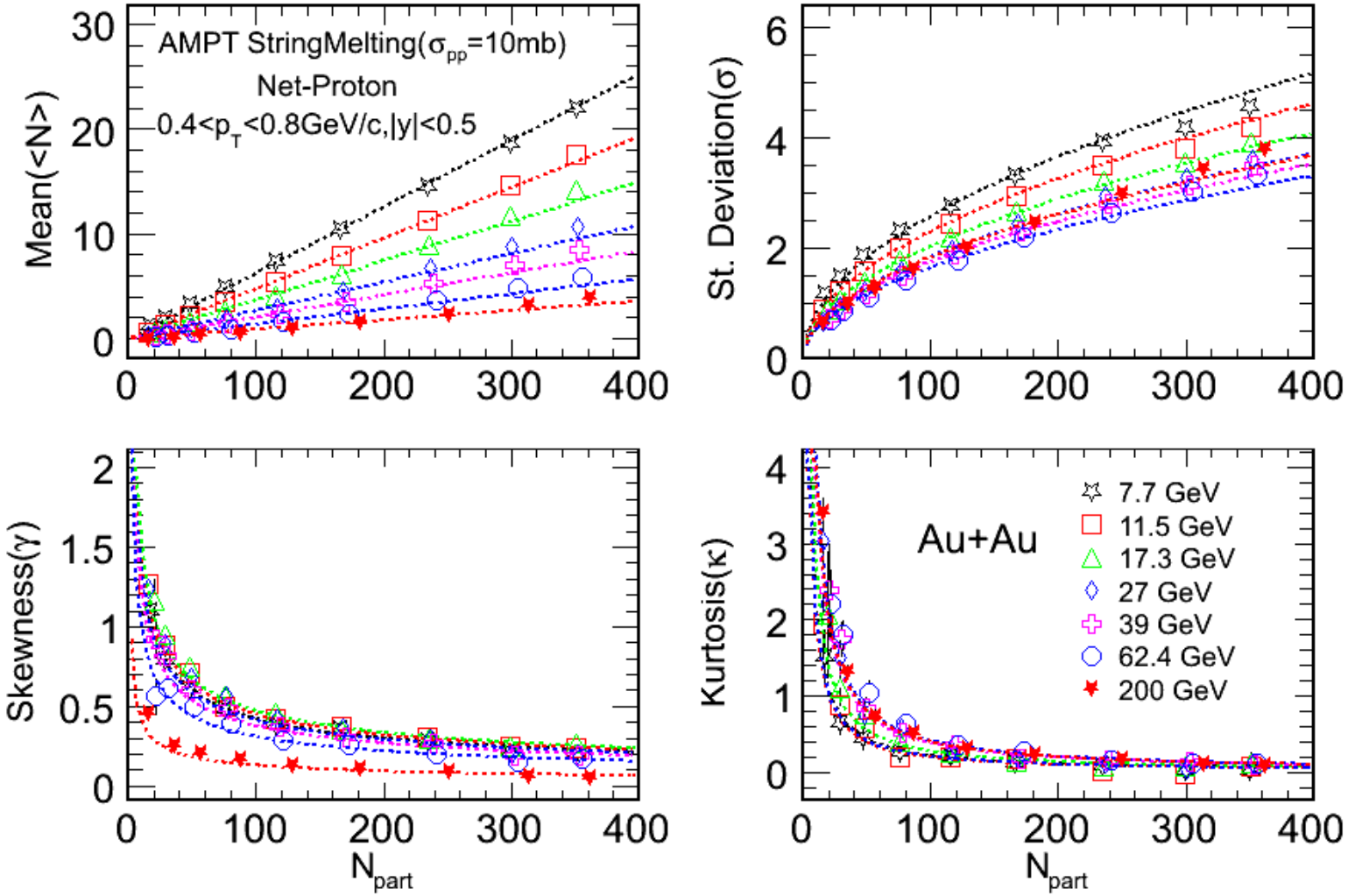
URQMD


UrQMD-2.3
Net-Proton
0.4<p_T<0.8GeV/c,|y|<0.5
Mean(<N>)
St. Deviation(σ)
Skewness(γ)
Kurtosis(κ)
N_part
N_part
Au+Au
7.7 GeV
9.2 GeV
11.5 GeV
19.6 GeV
39 GeV
62.4 GeV
200 GeV

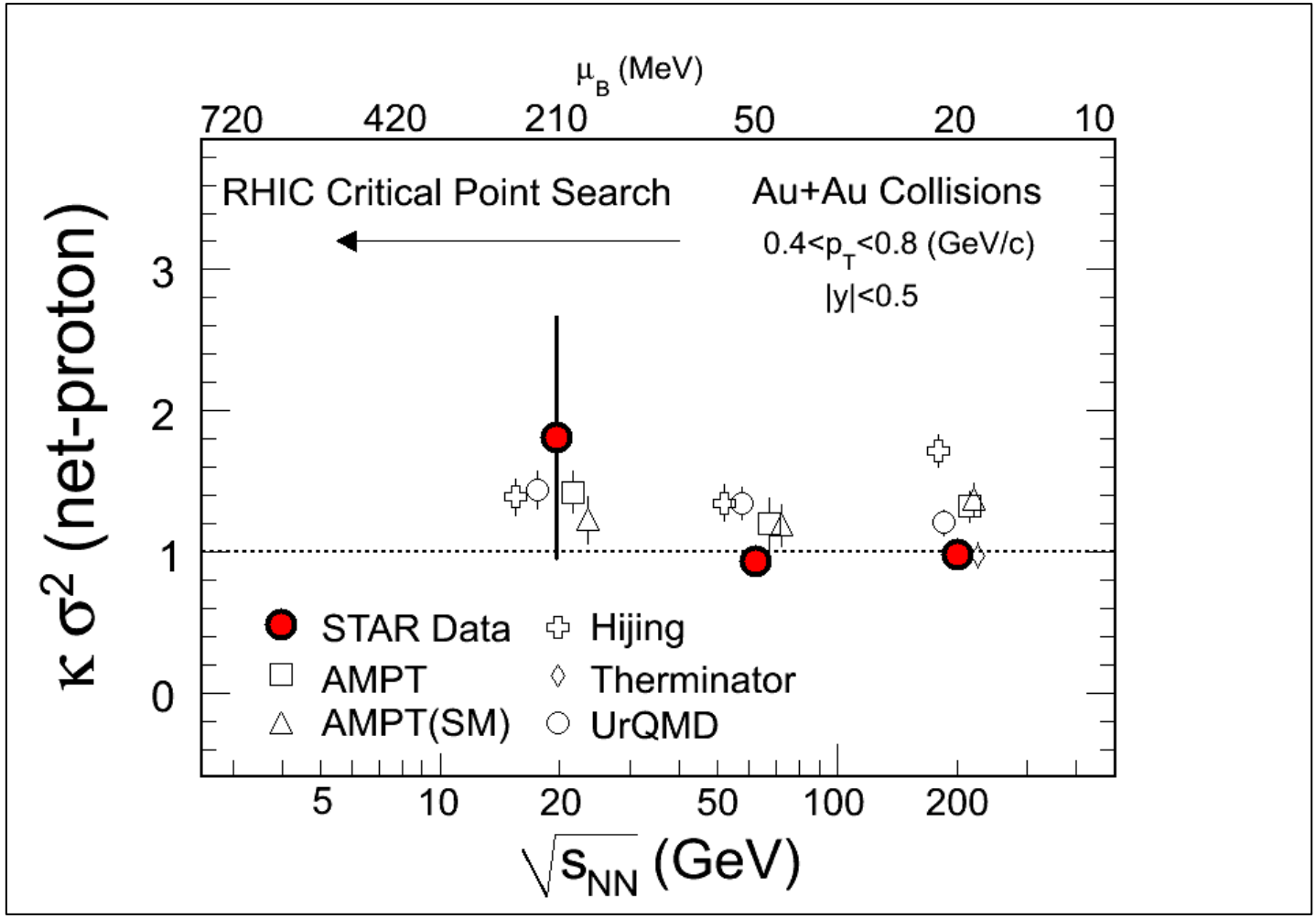
Energy Dependence AMPT



AMPT String Melting

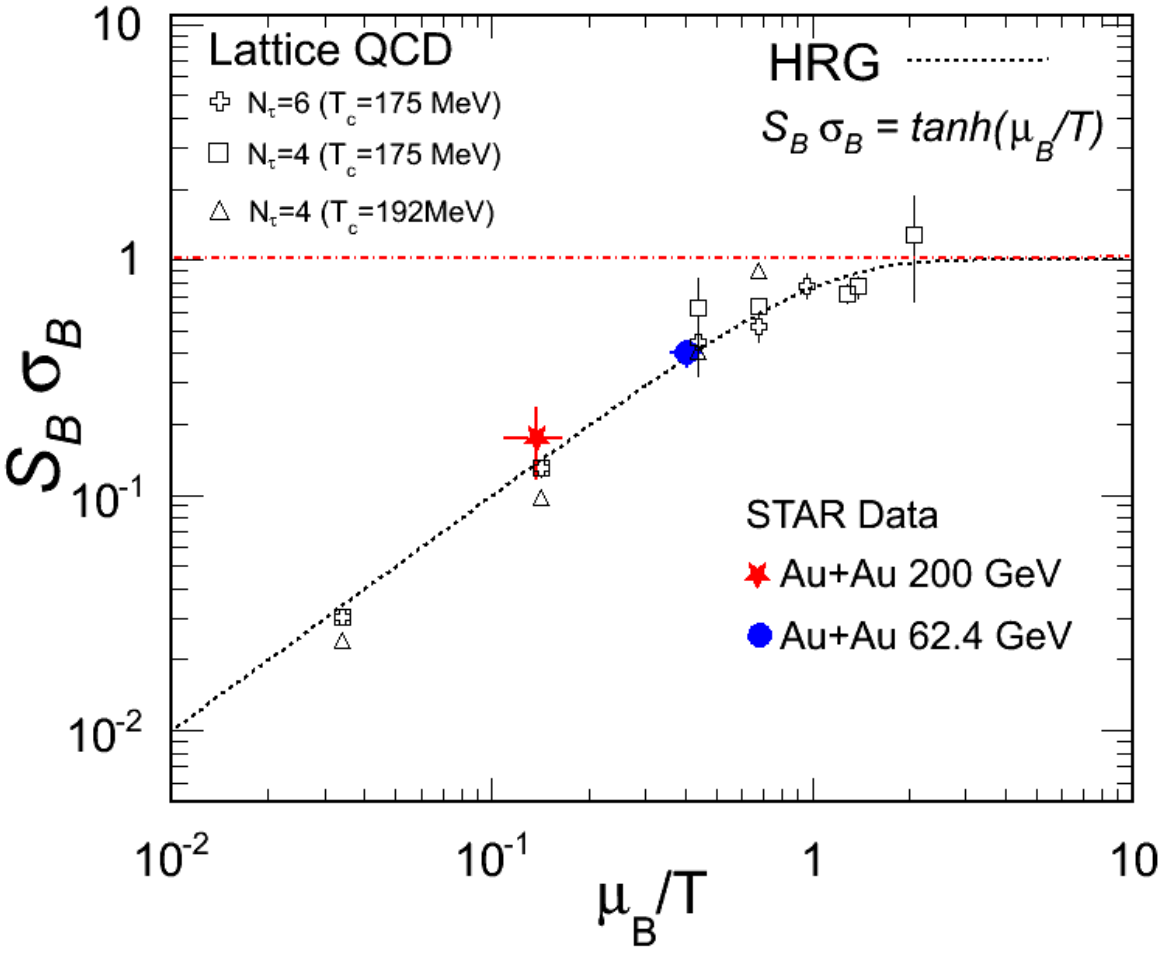


STAR Data



STAR, PRL 105 (2010) 022302

Comparison to LQCD



S*σ predicted by Lattice QCD

R. V. Gavai, S. Gupta, arXiv: 1001. 3796
F. Karsch, K. Redlich, arXiv: 1007.2581

Summary

- Kurtosis and Skewness appear to be promising observables
- Relation to LQCD
- We are establishing the baseline (null-effect)

- STAR with its large acceptance is ideally suited for such studies