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

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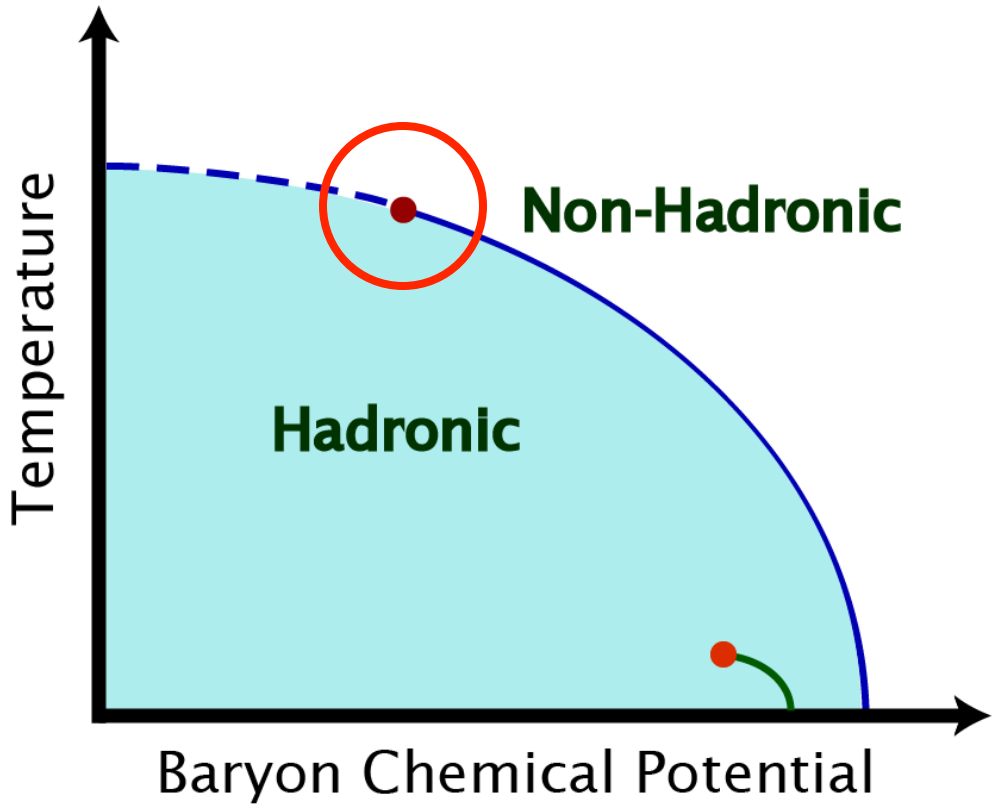
LBNL

For the STAR Collaboration

QCD Critical Point



Critical Point:

Solid State Phys

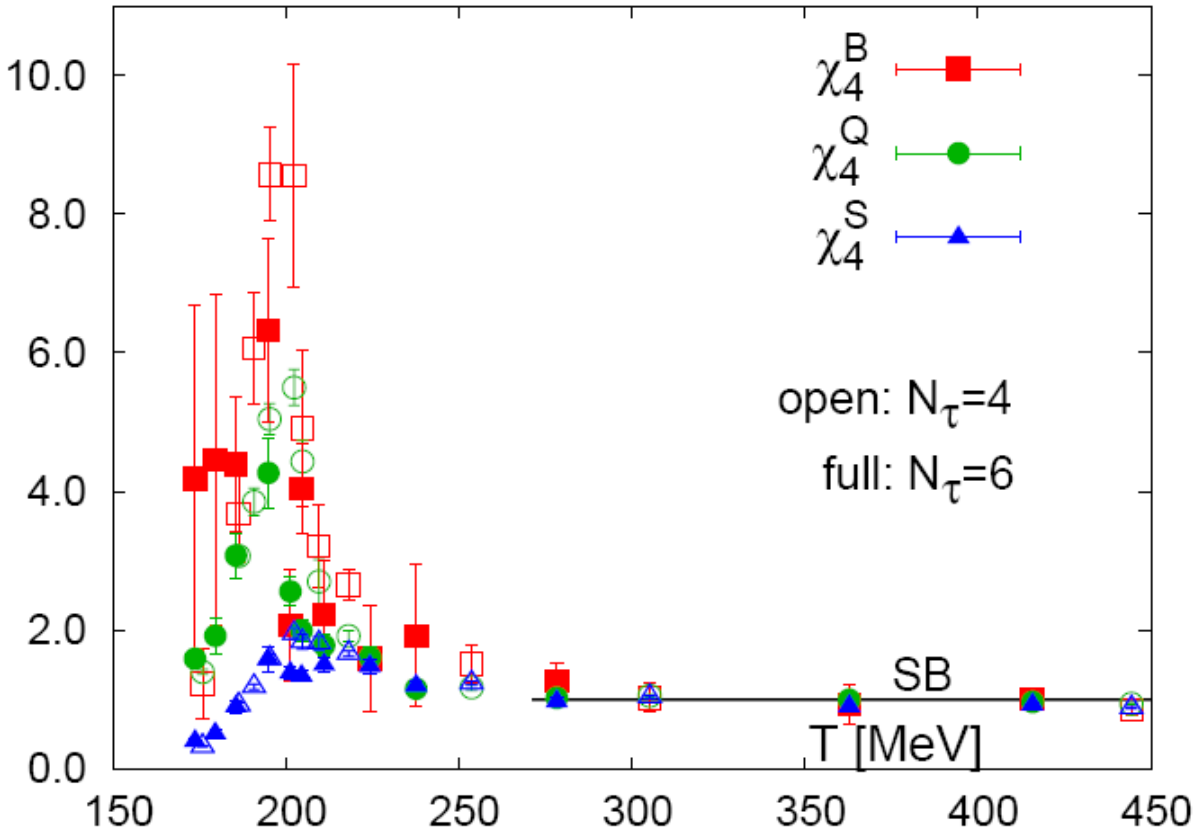
- Susceptibilities diverge
- Correlation Length diverges

Heavy Ions

- 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:0811.1006

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

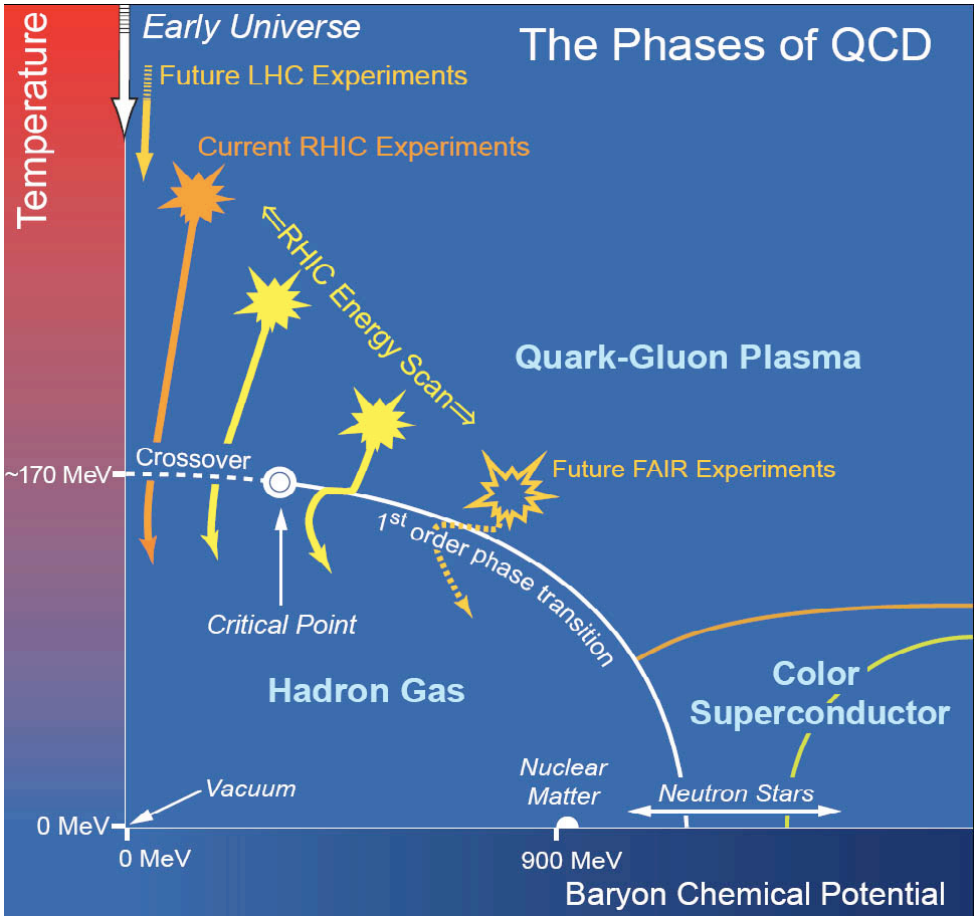
Lattice QCD (LQCD) predictions

➔ 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)

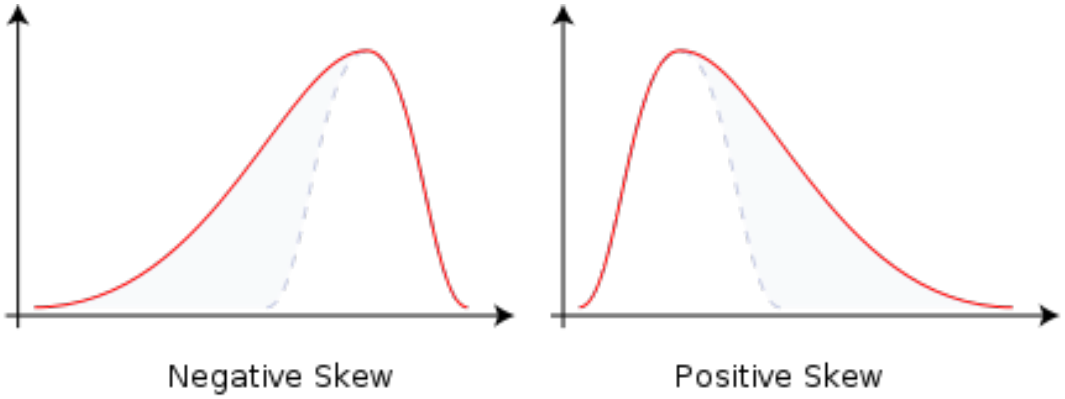
Skewness and Kurtosis

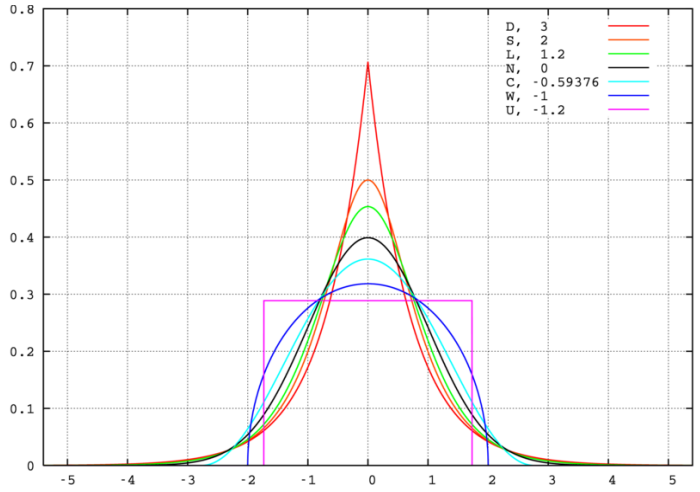
Mean: $Y = < N >$

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

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

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





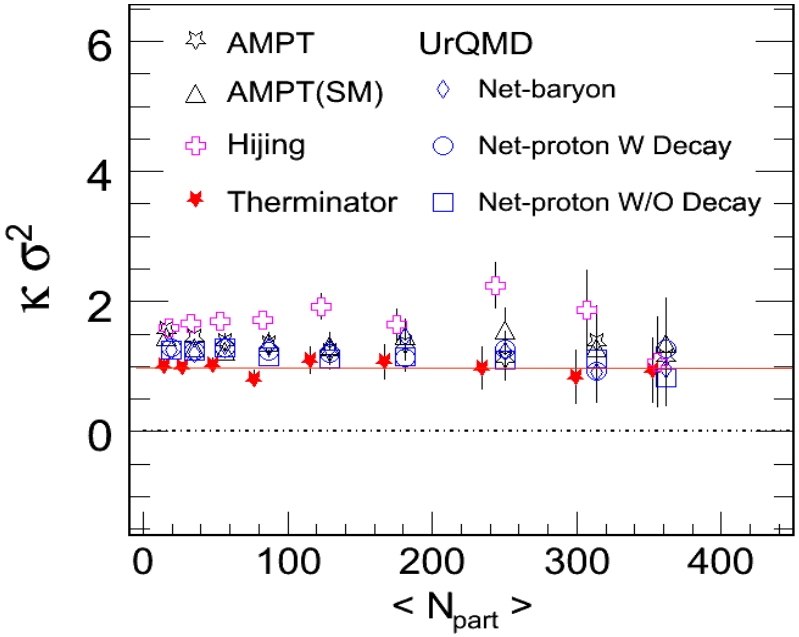
- Skewness describes the asymmetry of the distribution
- Kurtosis describes the peakness of the distribution
- Equal to zero for Gaussian distribution
- Ideal probes for non-Gaussian fluctuations

Central Limit Theorem

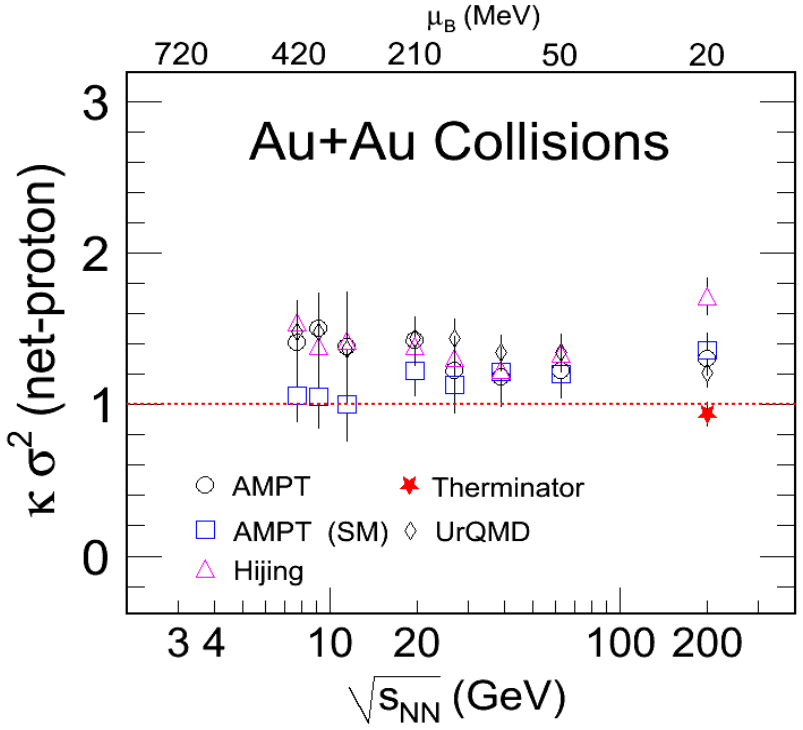
- Multiplicity dependence can be taken out and results plotted as a function of Npart
- Possible observables:
  - Kurtosis x Variance
  - Skewness x St. Deviation
- Ratio of Susceptibilities, Volume drops out:
  - $K*\sigma^2 \sim X^4/X^2$
  - $S*\sigma \sim X^3/X^2$

Moment Products

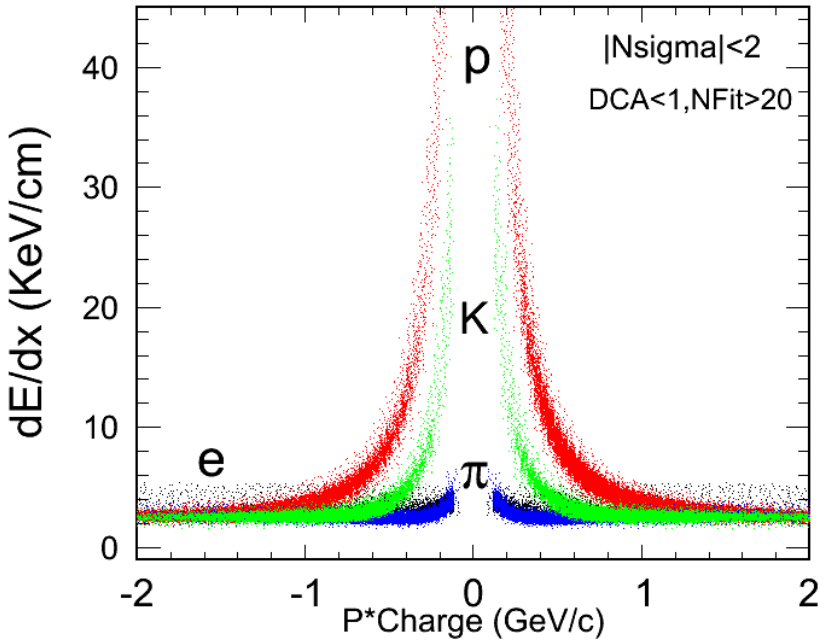
Collision centrality

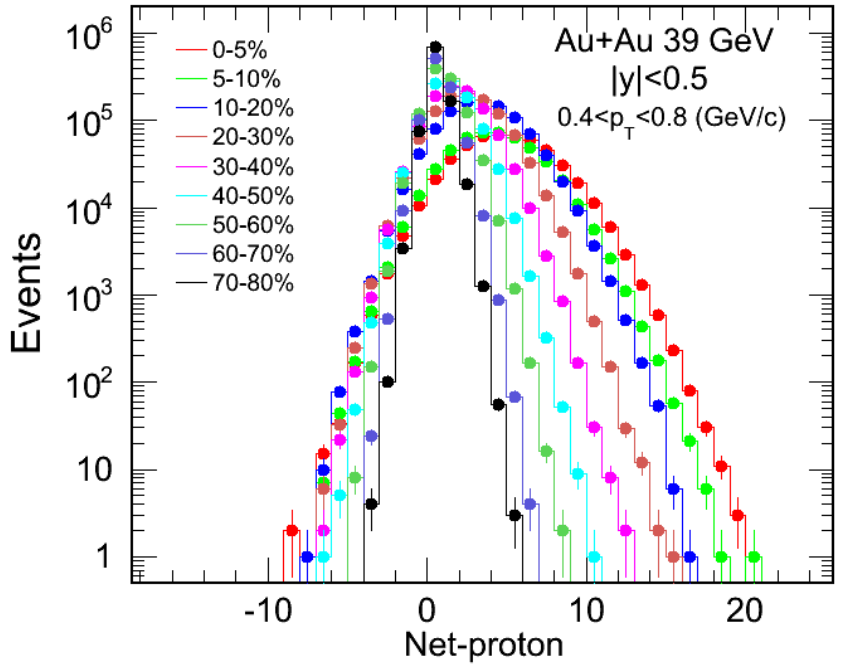


Beam energy



Net-proton Multiplicity Distributions



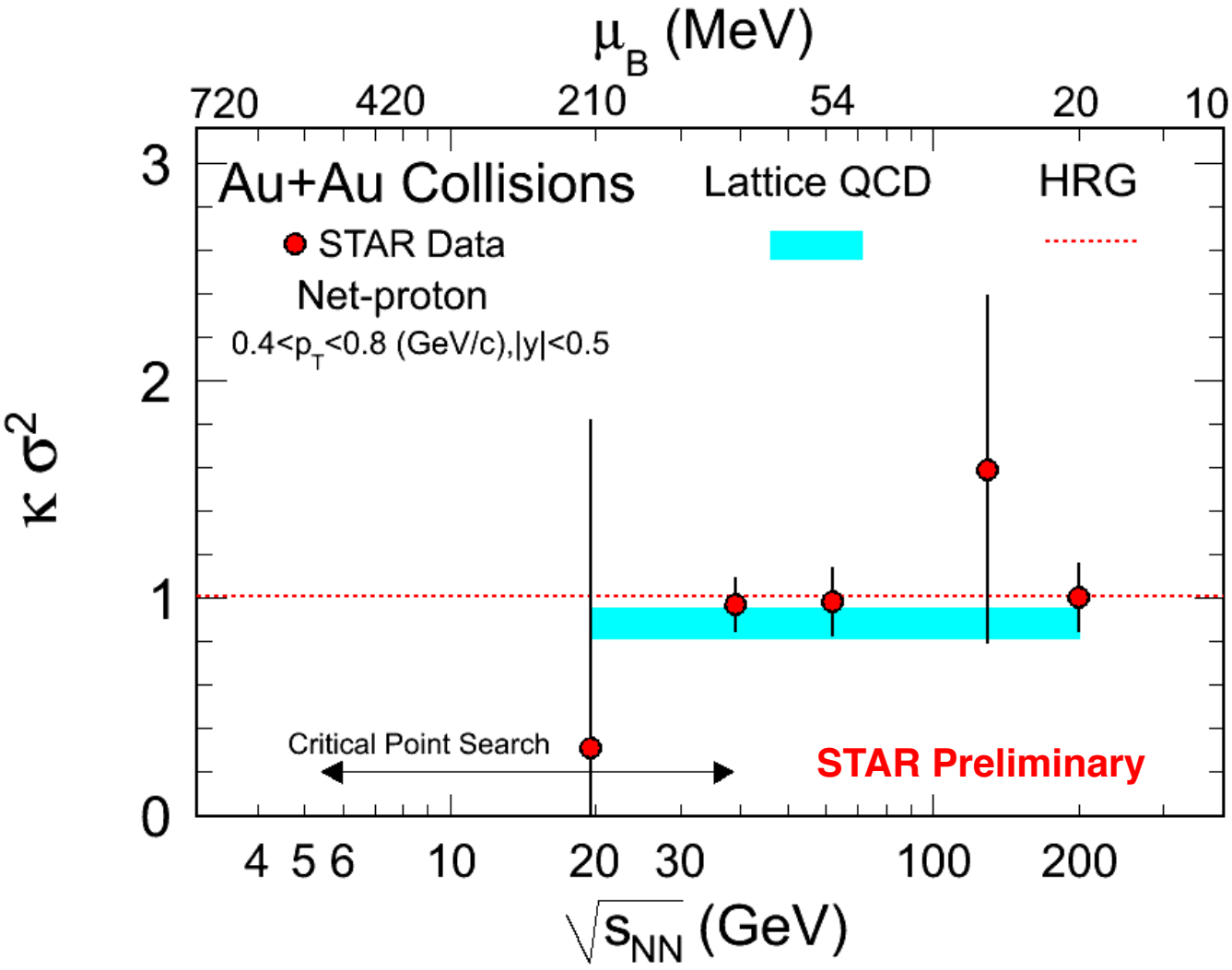


Clean Proton and anti-proton identification:TPC dE/dx with cut:

|NsigmaProton|<2

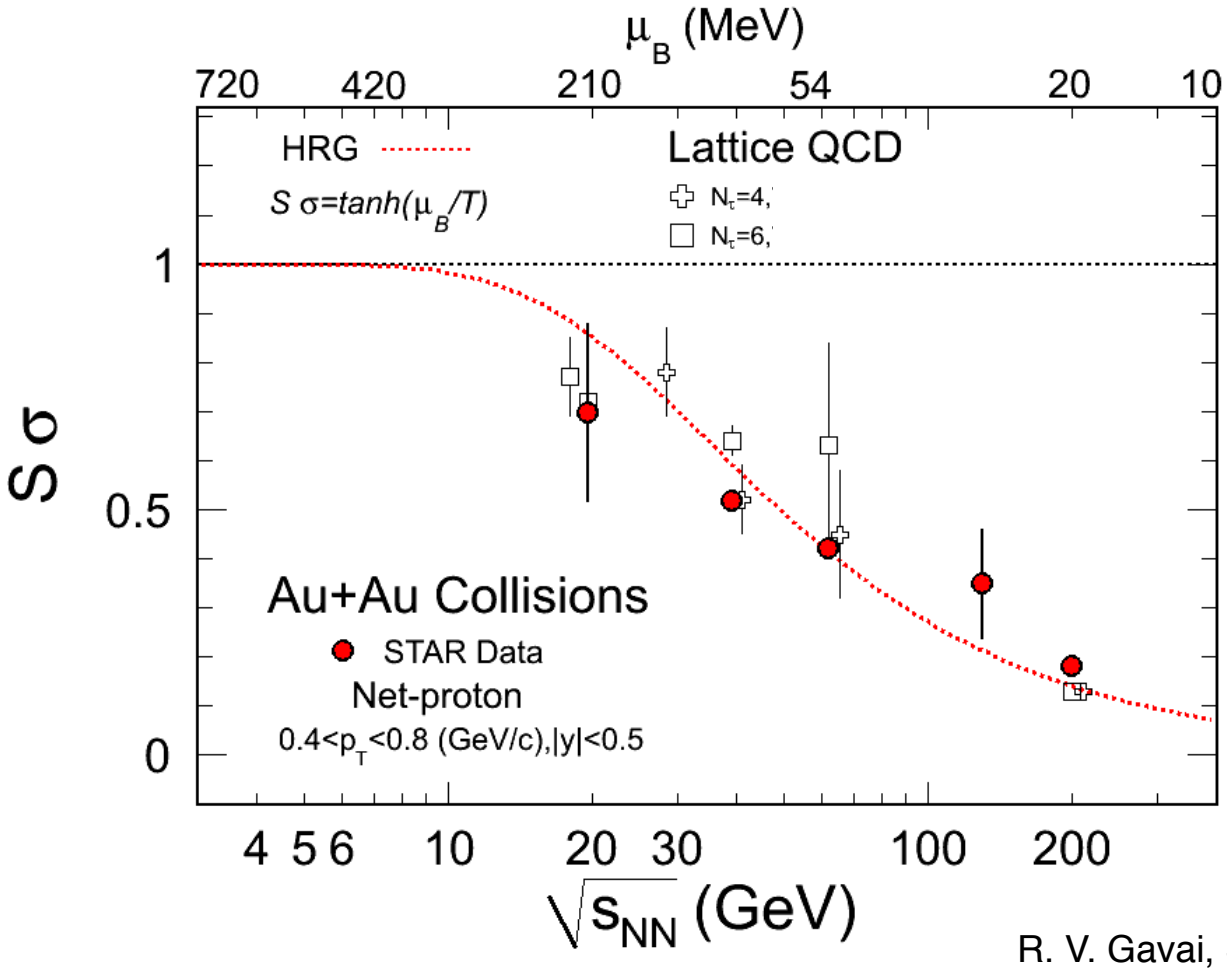
0.4<pT<0.8 (GeV/c),|y|<0.5

Kurtosis



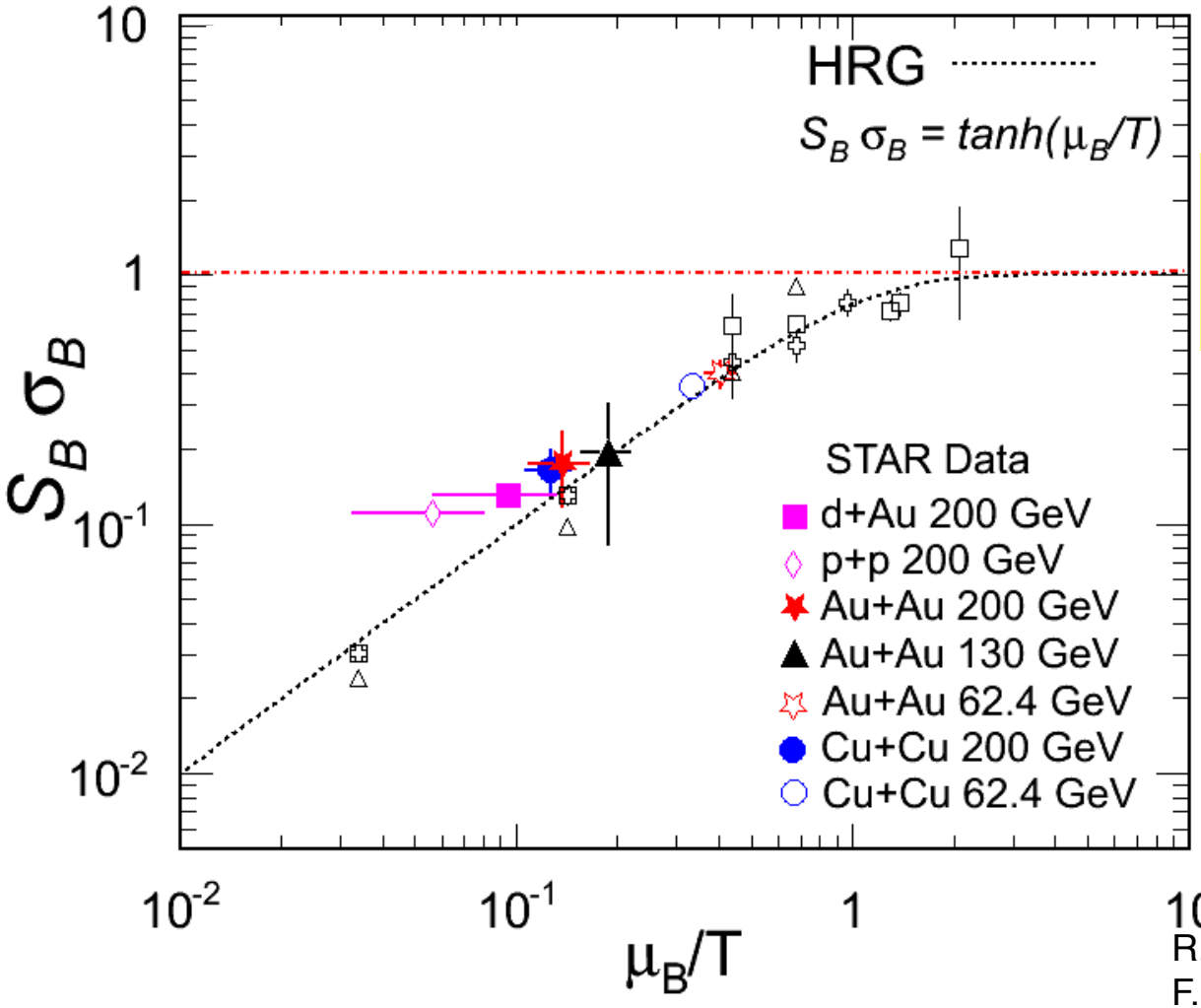
For the first time: Direct connection between data and lattice

Skewness



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

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 shown for the first time
- We are establishing the baseline (null-effect) down to $s^{1/2}$ = 39 GeV

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