Search for the QCD Critical Point

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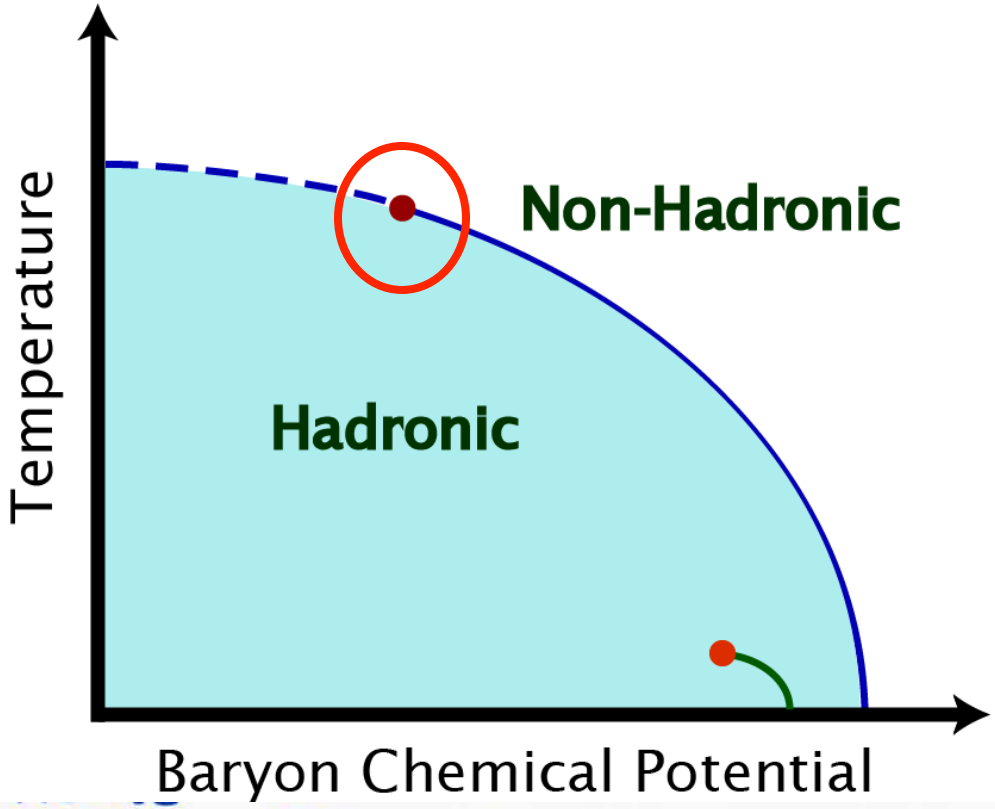
LBNL

For the STAR Collaboration

QCD Critical Point



Critical Point:

Solid State Phys

- Susceptibilities diverge
- Correlation Length diverges

HI Reactions

- Becomes Critical Region
- Correlation Length ξ = System size

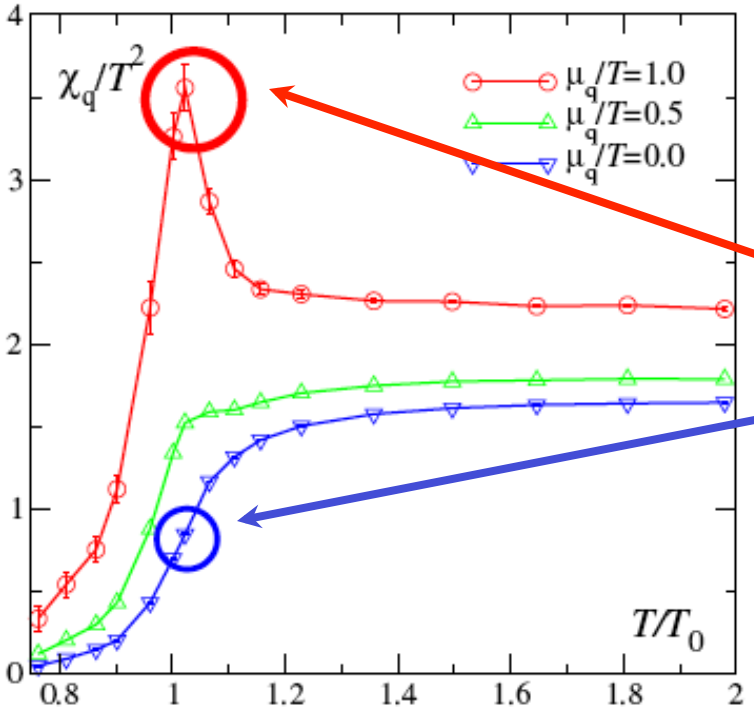
$\langle (dN)^2 \rangle \sim \xi^2$

Mapping the phase diagram. Finding the landmark that would go in any future book on QCD. Can RHIC do this

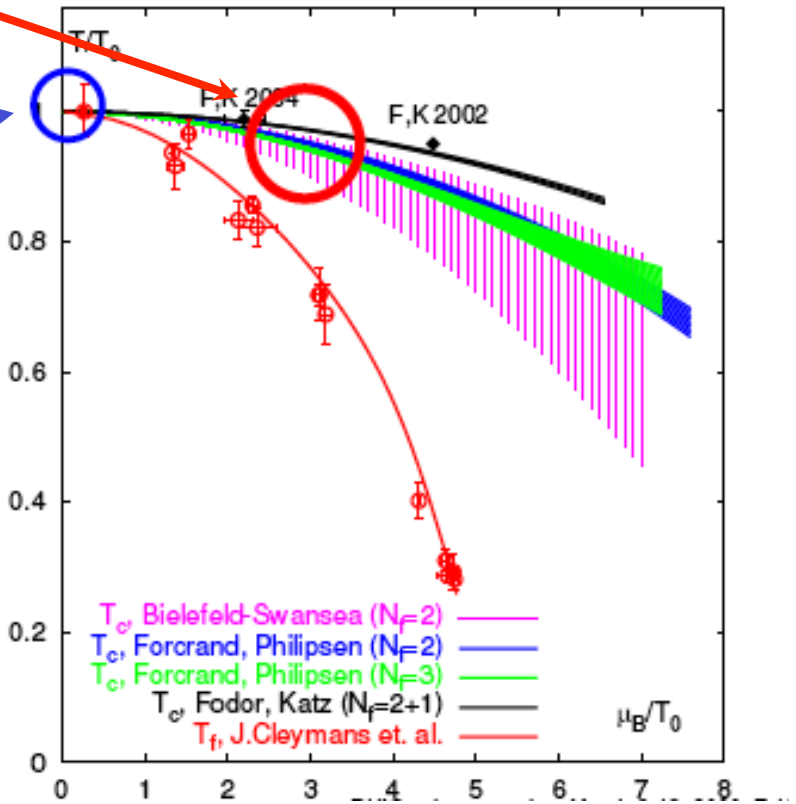
K. Rajagopal

Critical Point in LQCD

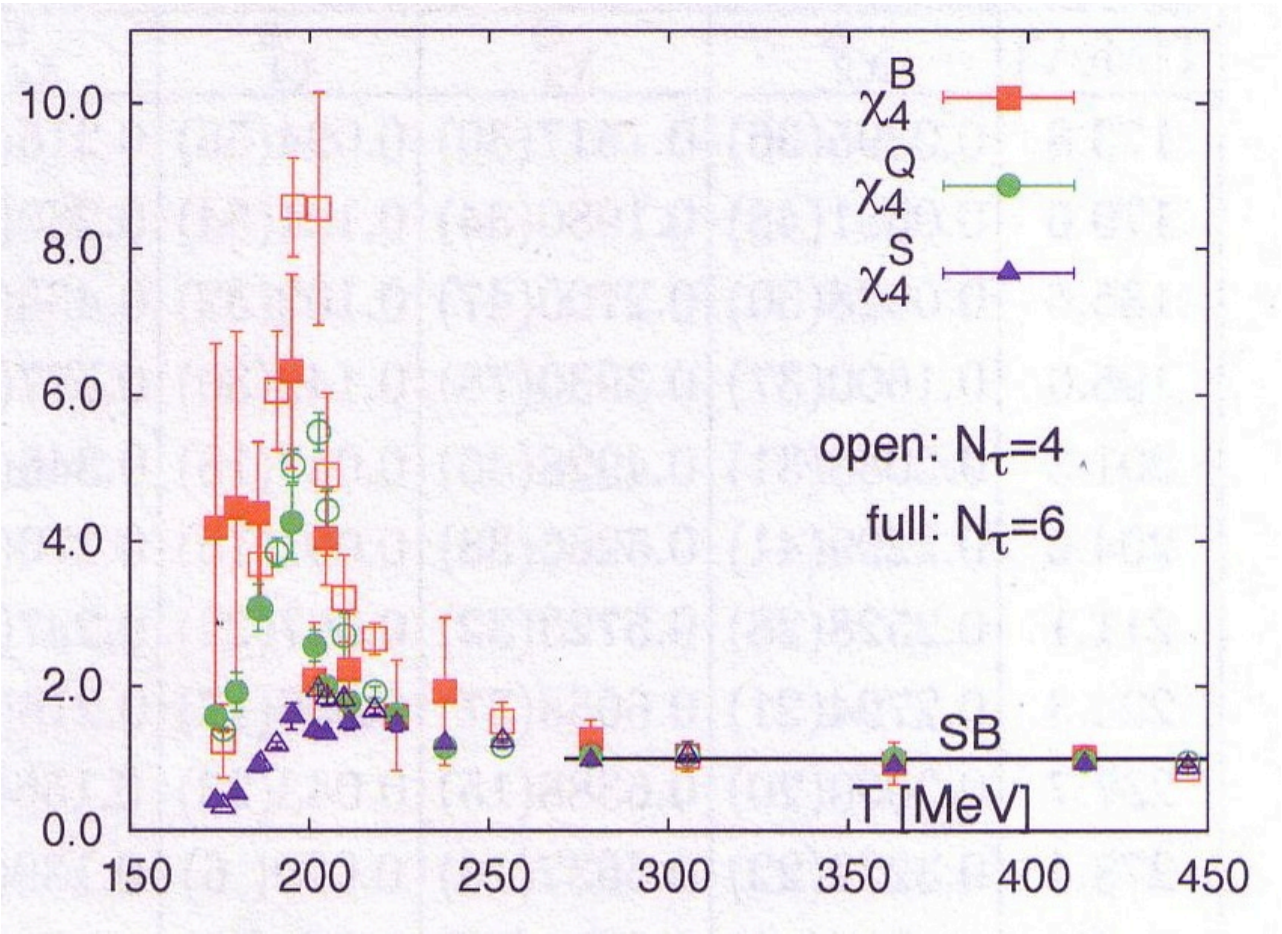
Sudden changes in susceptibility taken as evidence for critical point



F.Karsch



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

➔ Critical fluctuations are Non-gaussian

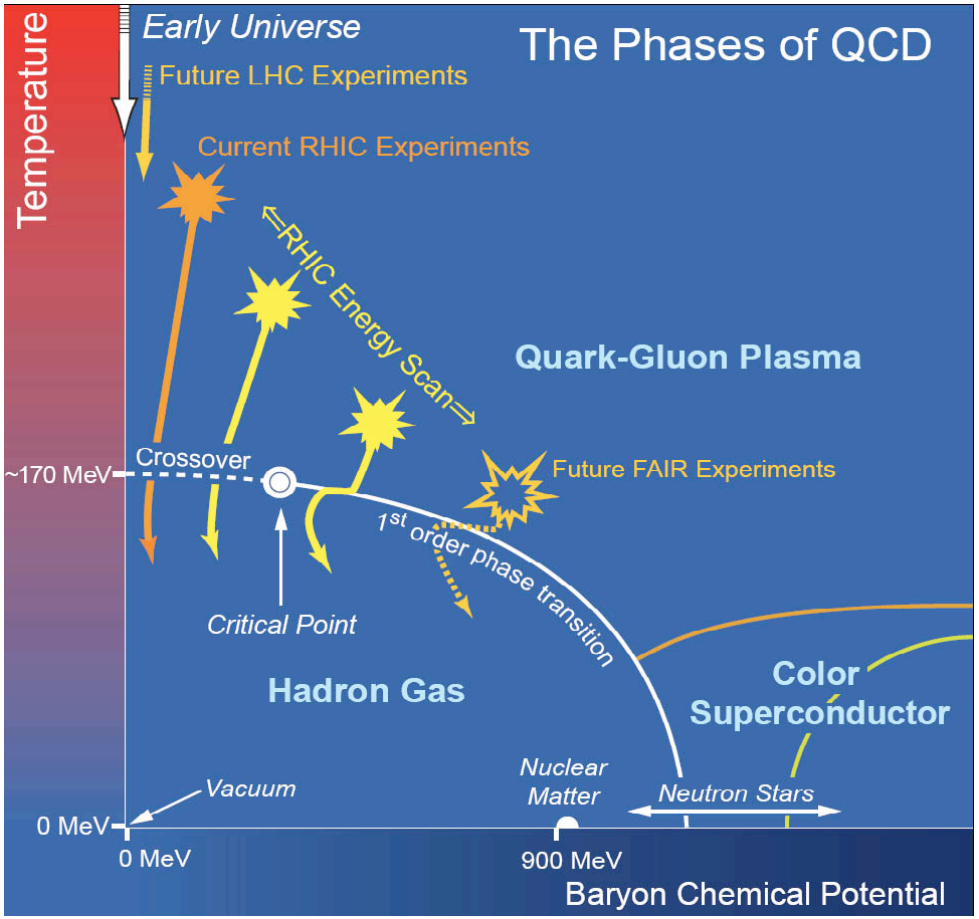
Experimentally:

Net-proton distributions

What to measure

- Non-gaussian multiplicity fluctuations
- In particular, higher moments sensitive to non-gaussian behavior
  - Kurtosis
  - Skewness
- Higher moments amplify signal

Energy Scan at RHIC



μ_B up to ~ 550 MeV
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)

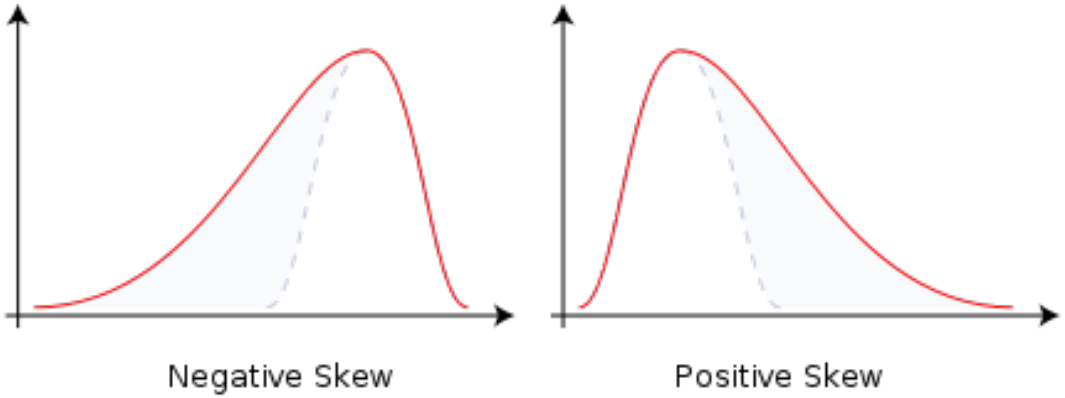
Skewness and Kurtosis

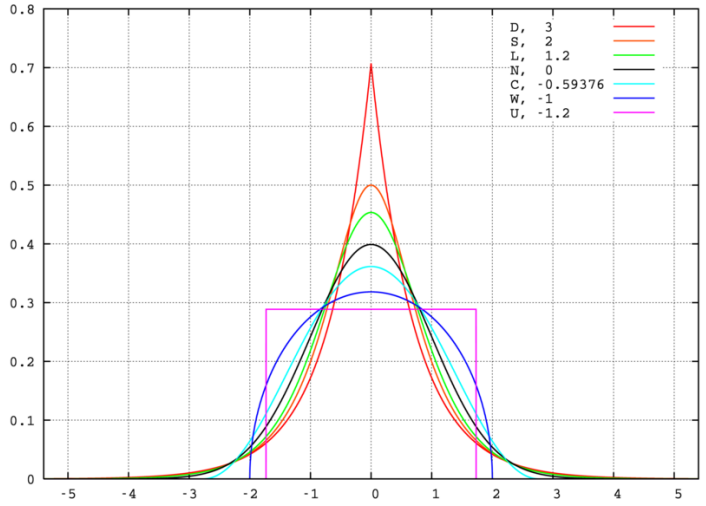
Mean: $Y = < N >$

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

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

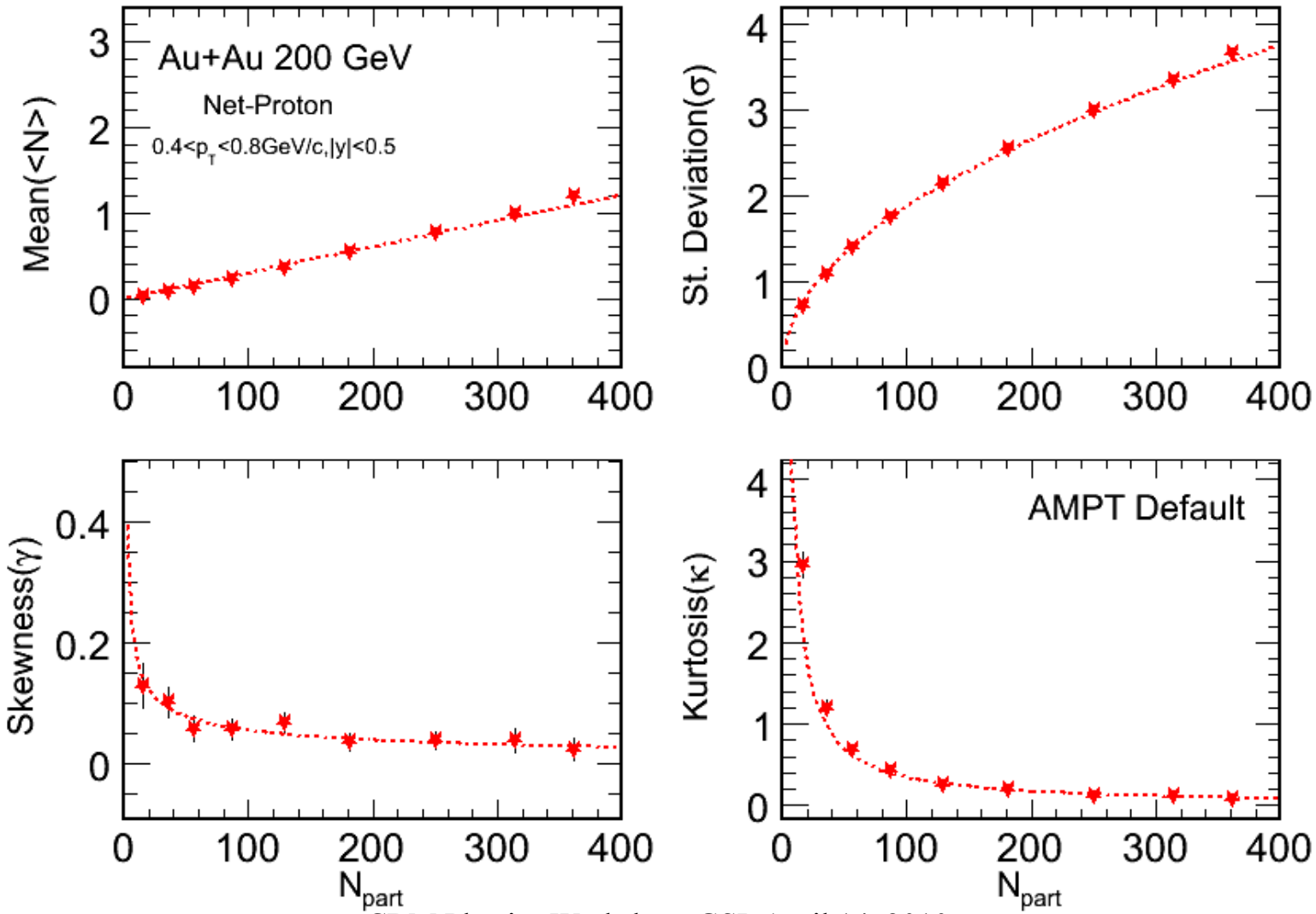
Kurtosis: $\kappa = \dfrac{< (N - < N >)^4 >}{\sigma^4} - 3$



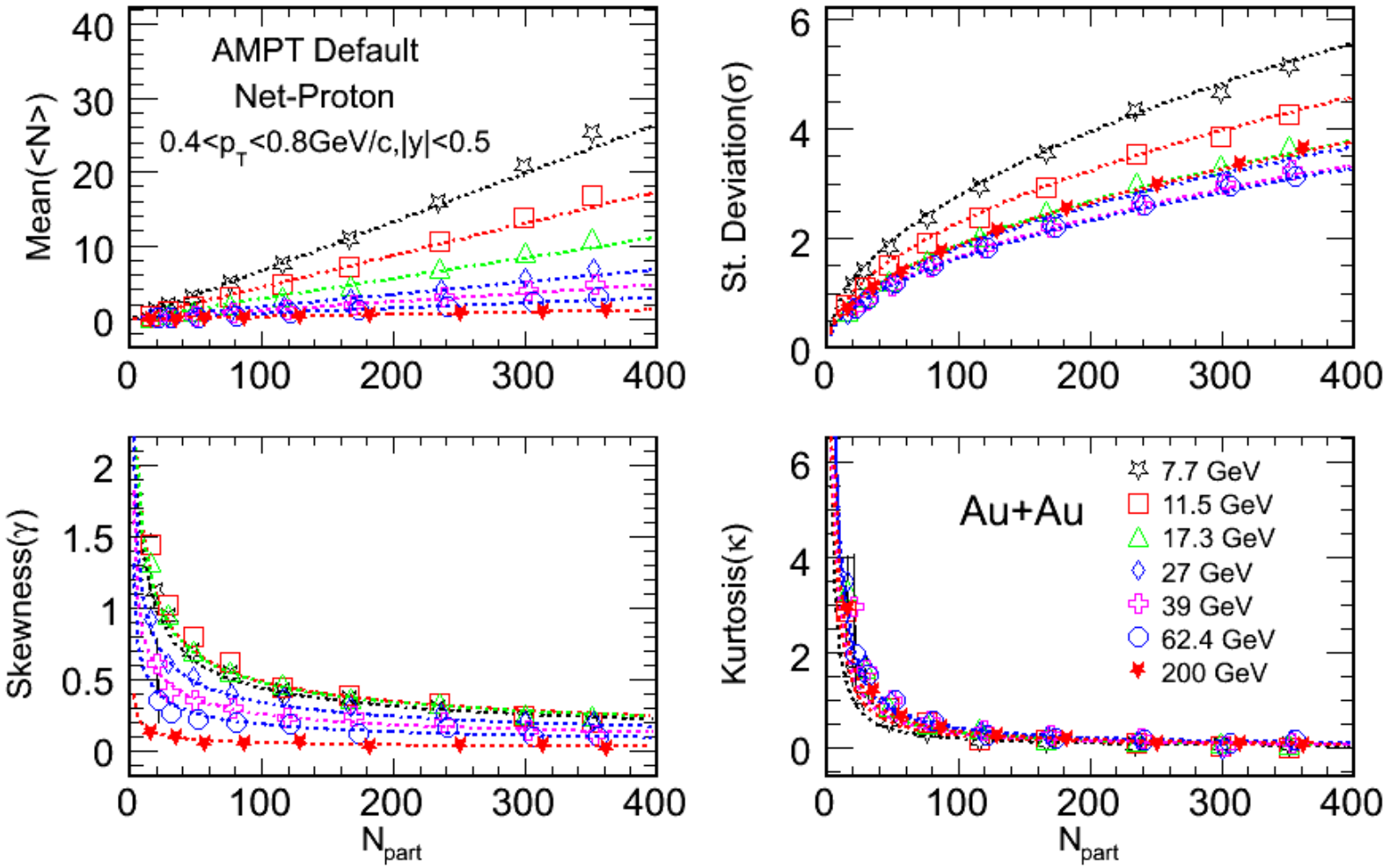


- Skewness describes the **asymmetry** of the distribution.
- Kurtosis describes the **peakness** of the distribution.
- For Gaussian Distribution, the skewness and kurtosis are equal to zero. **Ideal probe for non-Gaussian fluctuations.**

Moments in AMPT



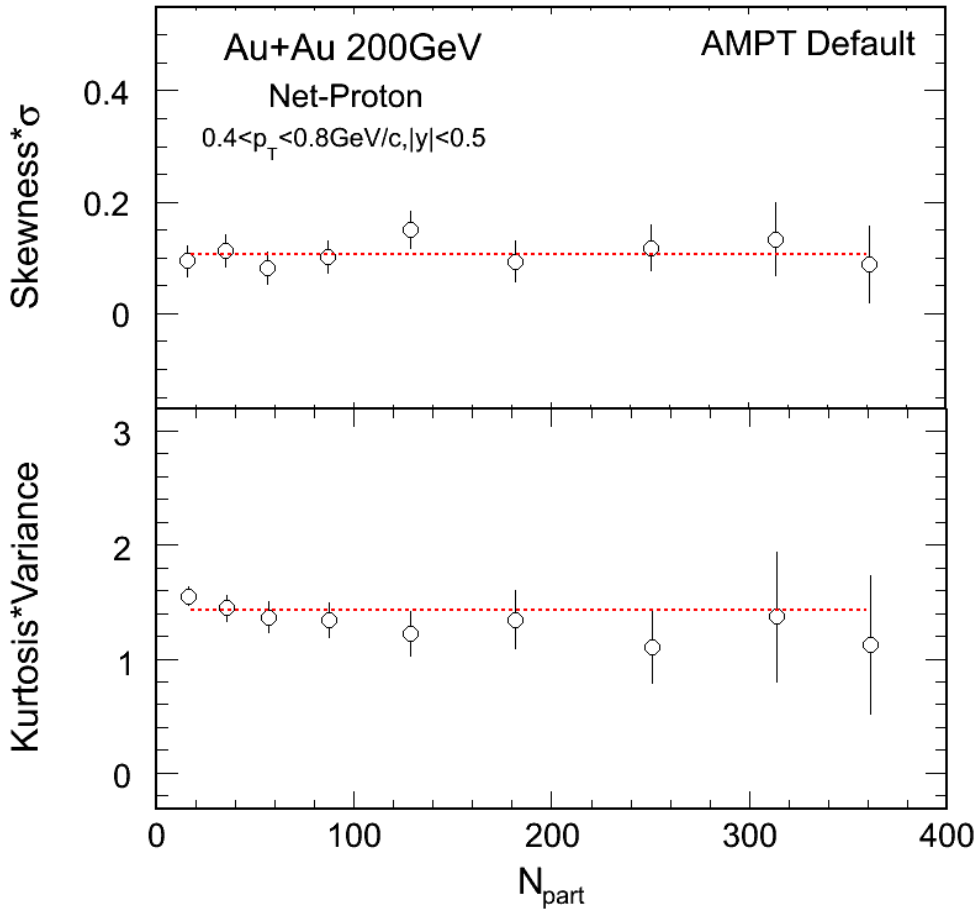
Energy Dependence AMPT



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

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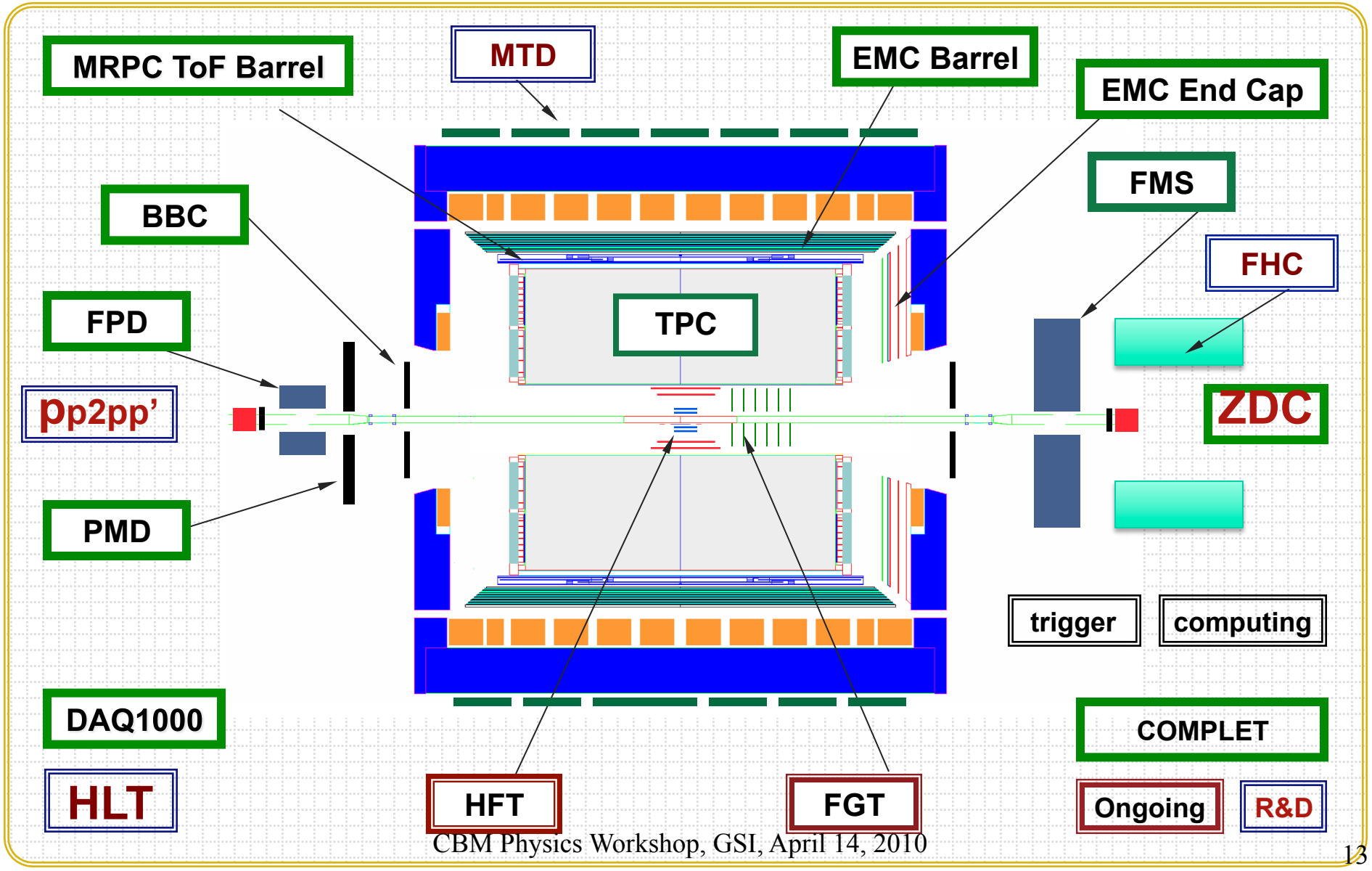

MRPC ToF Barrel
MTD
EMC Barrel
EMC End Cap
BBC
FMS
FHC
FPD
TPC
pp2pp'
ZDC
PMD
trigger
computing
DAQ1000
COMPLET
HLT
HFT
FGT
Ongoing
R&D

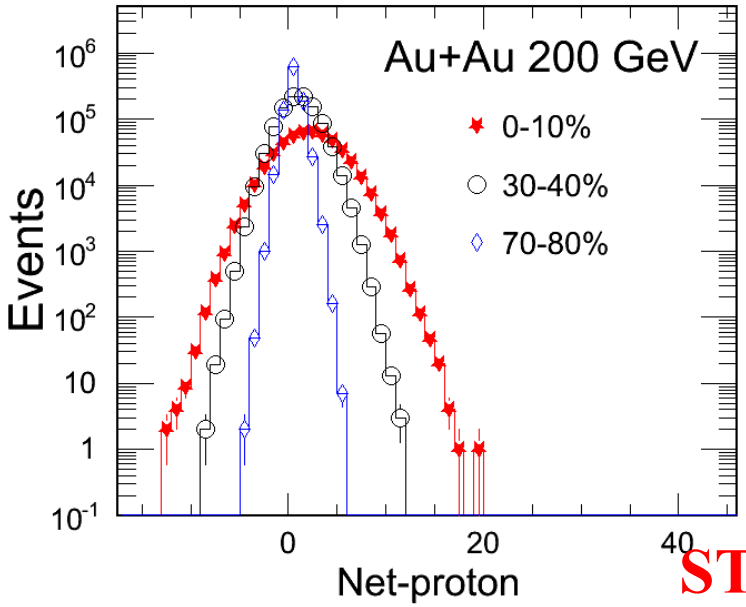
Data Sets

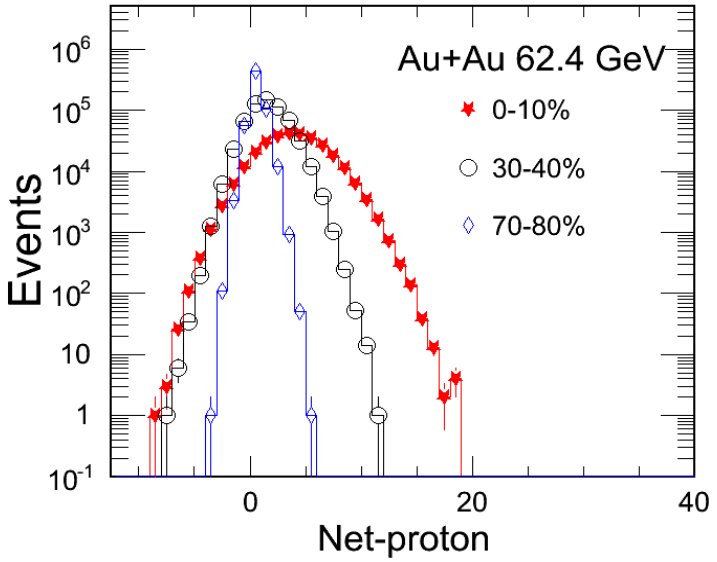
Data Set:

Collision (MB)	Energy	Events (after vtx. cut)	Year
p+p	62.4 GeV	~0.9M	2006
	200 GeV	~140k	
Cu+Cu	22.4 GeV	~0.6M	2005
	62.4 GeV	~10M	
	200 GeV	~3.6M	
Au+Au	9.2 GeV	~3k	2008
	19.6 GeV	~40k	2001
	62.4 GeV	~5M	2004
	130 GeV	~160k	2000
	200 GeV	~8M	2004

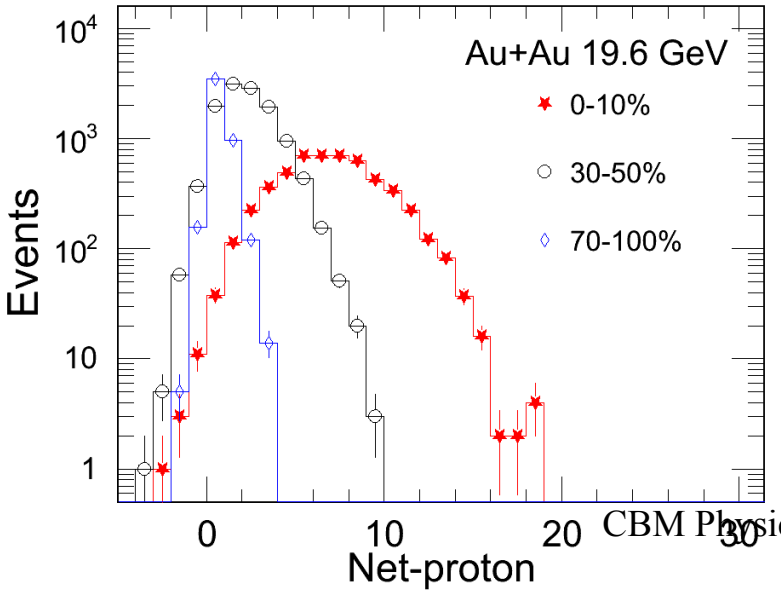
Proton , Anti-proton kinematic cut: $|y|<0.5,\ 0.4<pT<0.8$ (GeV/c)

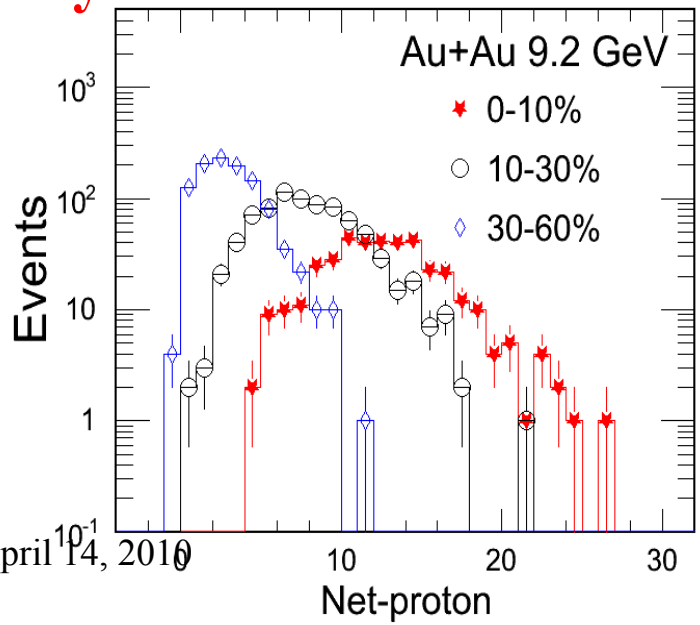
Net-proton Distributions



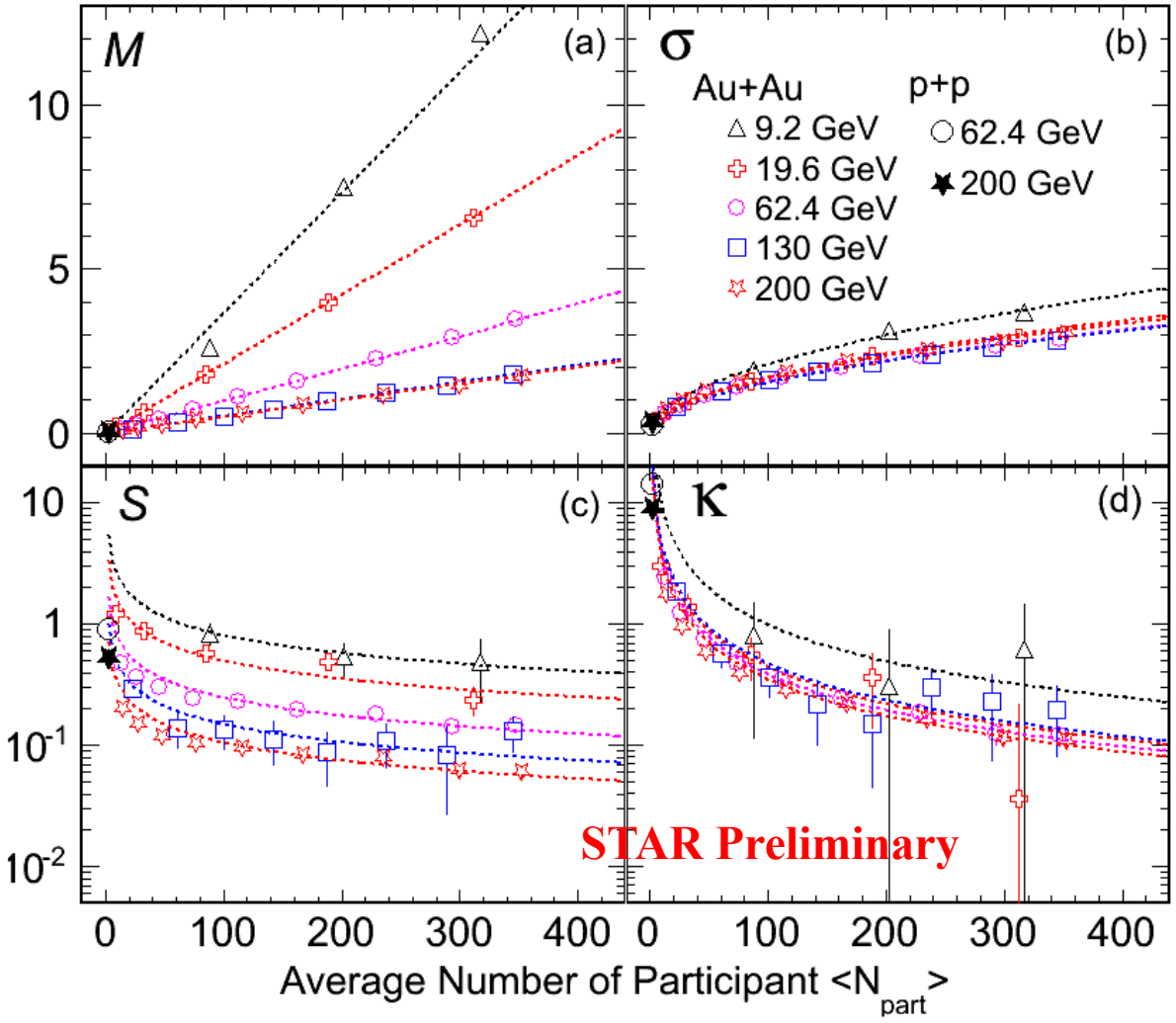


STAR Preliminary

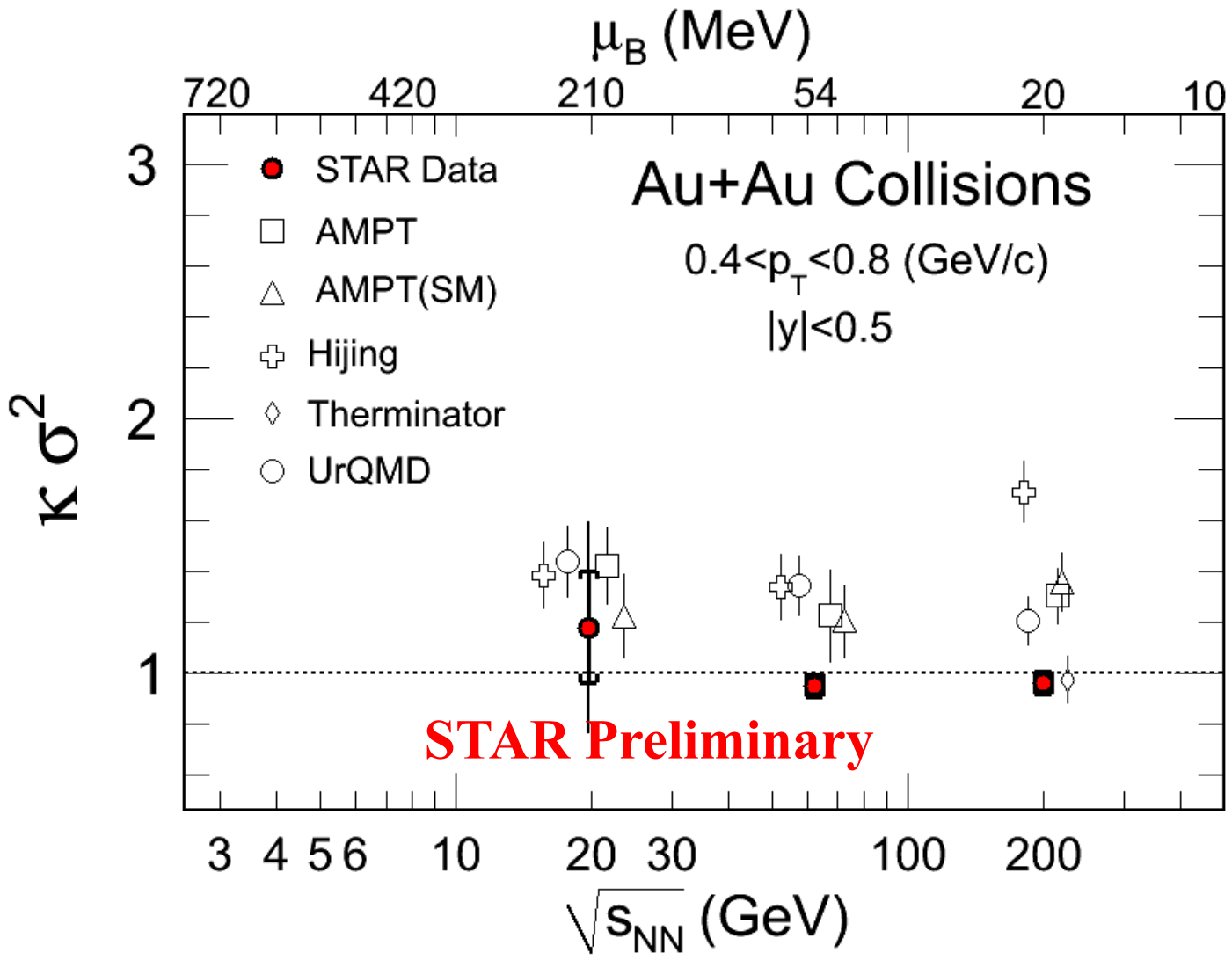




Centrality


M
(a)
σ
(b)
Au+Au
p+p
9.2 GeV
19.6 GeV
62.4 GeV
130 GeV
200 GeV
62.4 GeV
200 GeV
S
(c)
κ
(d)
STAR Preliminary
10
5
0
10
1
10^-1
10^-2
0
100
200
300
400
Average Number of Participant <N_part>

Energy Dependence



Summary

- Direct Search for the QCD Critical Point
- Kurtosis and Skewness appear to be promising observables
- We have established the baseline (null-effect)
- STAR with its large acceptance is ideally suited for such studies
- Beam Energy Scan is underway

The End