Energy dependence of Cumulants of Net-Proton, Net-Kaon and Net-Charge Multiplicity Distributions in Au+Au collisions within JAM model

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Outline

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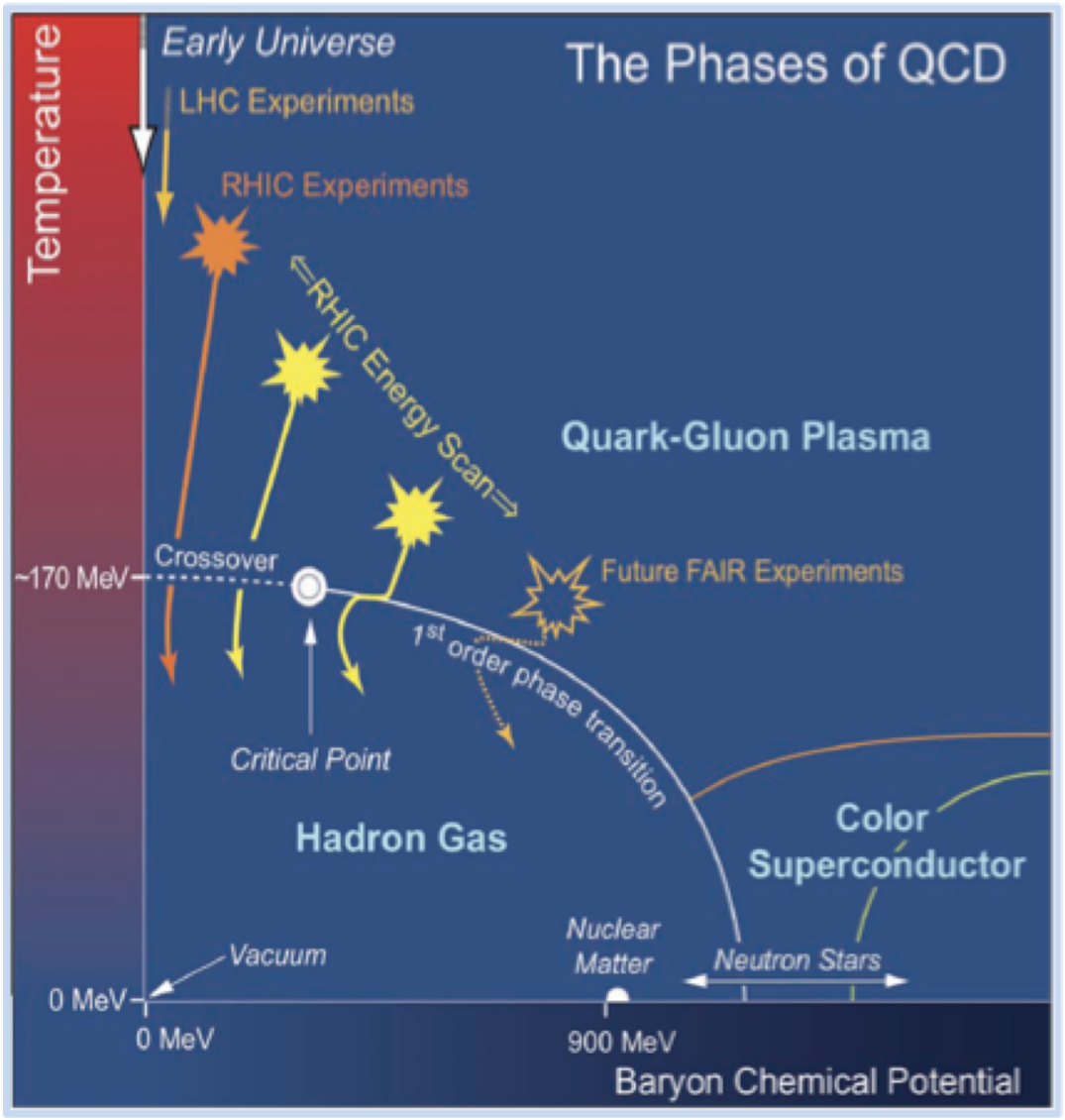
- JAM model
- Calculation result
- Summary

Motivation



- Crossover at $\mu_B = 0$
- First order phase transition at non-zero μ_B ?
- An critical end point at the end of 1st order transition line?

Fluctuation of conserved quantities

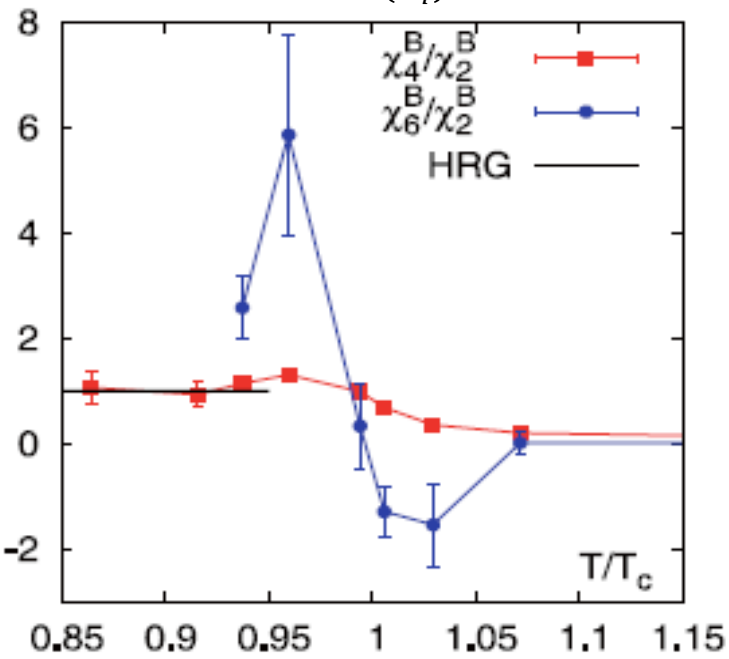
- sensitive to correlation length(ξ).

$\langle(\delta N)^2\rangle \sim \xi^2, \langle(\delta N)^3\rangle \sim \xi^{4.5}, \langle(\delta N)^4\rangle - 3\langle(\delta N)^2\rangle^2 \sim \xi^7$

M. A. Stephanov, Phys. Rev. Lett. 102, 032301 (2009).
M. A. Stephanov, Phys. Rev. Lett. 107, 052301 (2011).
M.Asakawa, S. Ejiri and M. Kitazawa, Phys. Rev. Lett. 103, 262301 (2009).

- directly connected to susceptibility of the system

$$\chi_q^{(n)} = \frac{1}{VT^3} * C_{n,q} = \frac{\partial^n \left(\frac{p}{T^4}\right)}{\partial(\mu_q)}, q = B, Q, S$$



S. Ejiri et al,Phys.Lett. B 633 (2006) 275.
Cheng et al, PRD (2009) 074505. B. Friman et al., EPJC 71 (2011)
S. Gupta, et al., Science, 332, 1525(2011).
A. Bazavov et al., PRL109, 192302(12)

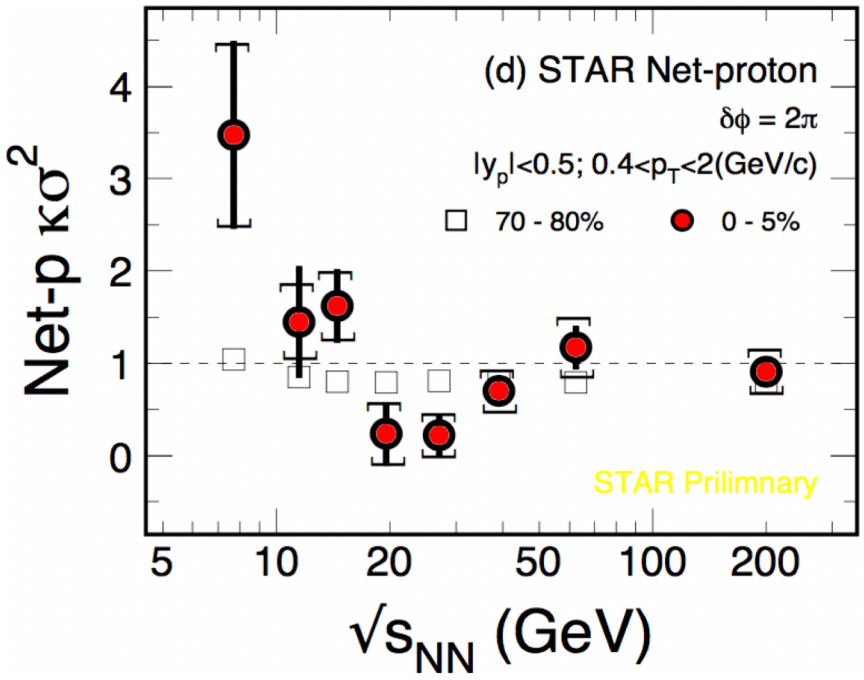
- net-baryon → net-proton
  net-strangeness → net-kaon
  net-charge

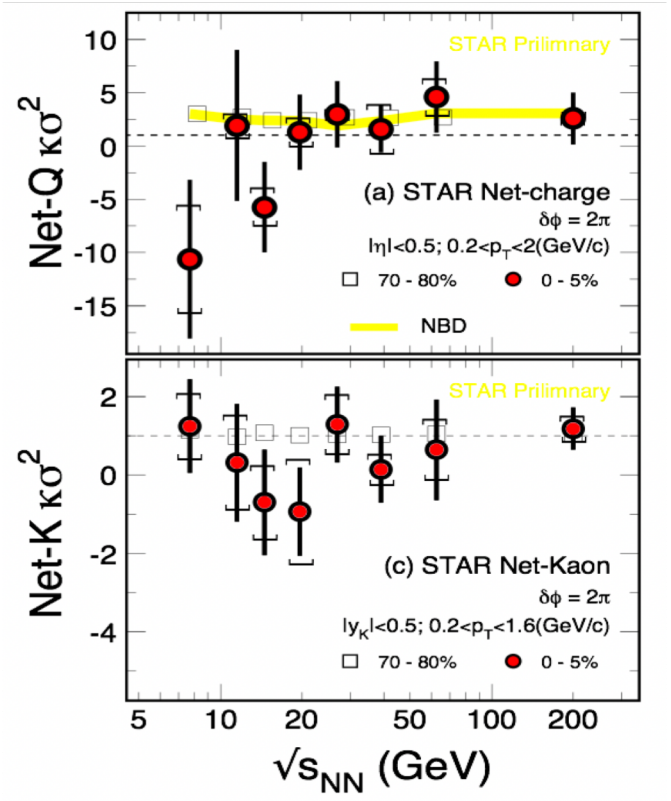
Higher Moments

- definition $N = N_{particle} - N_{anti-particle}$
  - $C_1 = \langle N \rangle$ $\delta N = N - \langle N \rangle$
  - $C_2 = \langle(\delta N)^2\rangle$
  - $C_3 = \langle(\delta N)^3\rangle$
  - $C_4 = \langle(\delta N)^3\rangle - 3\langle(\delta N)^2\rangle^2$
- reflect the shape of certain distribution
- reflect non-gaussian distribution
  gaussian distribution is zero at higher order(>2)
- cumulant ratios :

$$S\sigma = \frac{C_3}{C_2}, \kappa\sigma^2 = \frac{C_4}{C_2}$$

In Experiment

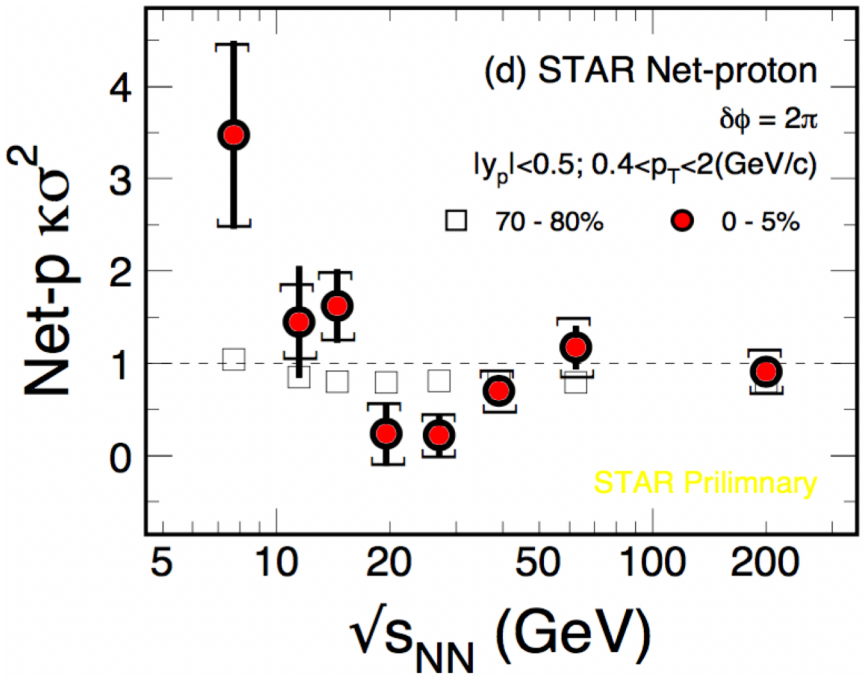


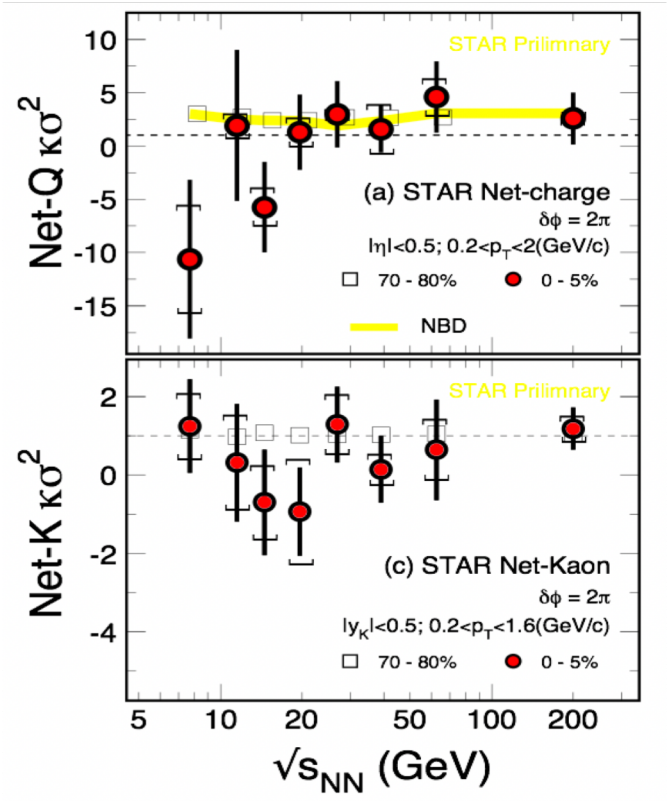


- Non-monotonic energy dependence of Net-Proton's $\kappa\sigma^2$ observed.
- Weak energy dependence in net-charge and net-kaon results within errors

STAR, PRL105,022302;; PRL112,032302 (2014).
X. Luo (for STAR Coll.), PoS CPOD2014 (2015) 019
Phys. Rev. Lett. 113 092301 (2014). Phys. Lett. B 785,)551)(2018).

In Experiment





- How will non-critical effects influence net-p, net-k and net-q fluctuation in model ?

  Resonance weak decay

  Hadronic scattering

JAM Model

- Microscopic transport model
- From initial stage to final state of interaction
- Particles have explicit space-time trajectories

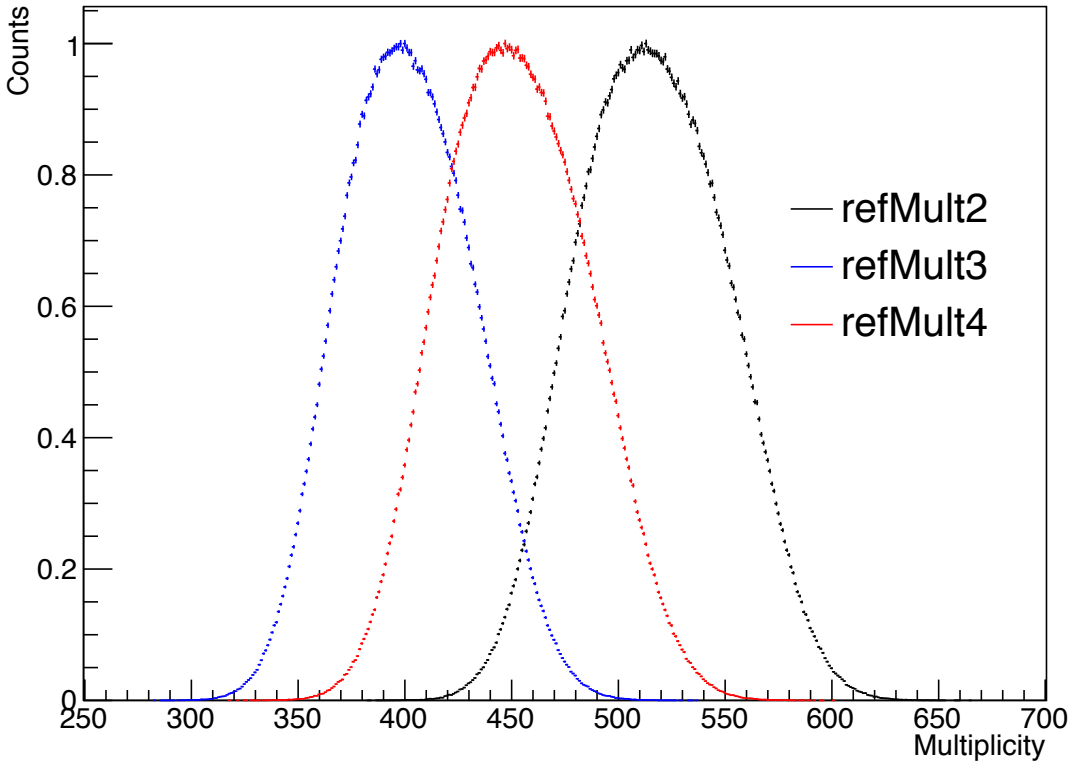
PHYSICAL REVIEW C, VOLUME 61, 024901
http://www.aiu.ac.jp/~ynara/jam/

Data Production Detail								
Au+Au								
$\sqrt{S}$/GeV	7.7	11.5	14.5	19.6	27	39	62.4	200
Events/10^6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	1
Impact parameter : 0<b<3 fm (roughly corresponds to 0-5%)								
Default configurtion			Resonance weak decay off			Elastic scattering off (keep inelastic scattering)		

JAM Model

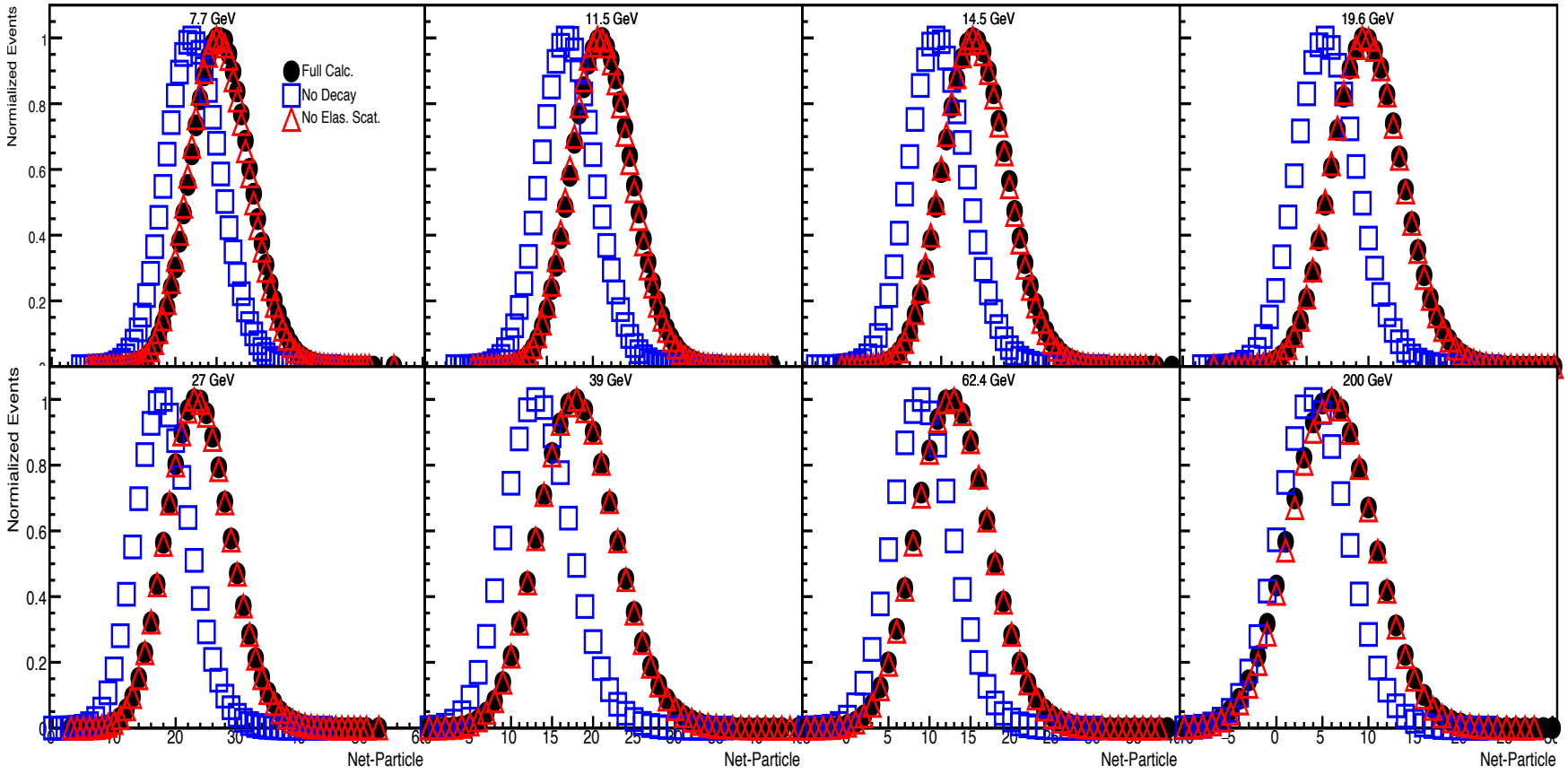
Calculation Detail		
Net-Proton	Net-Kaon	Net-Charge
$\|y\|<0.5$	$\|y\|<0.5$	$\|\eta\|<0.5$
$0.4 < p_T < 2.0$	$0.2 < p_T < 1.6$	$0.2 < p_T < 2.0$
Most central (0-3fm)		
Centrality bin width corrected		
statistical error calculated by Delta theorem (Phys. Rev. C91, 034907)		

Result - Part 1



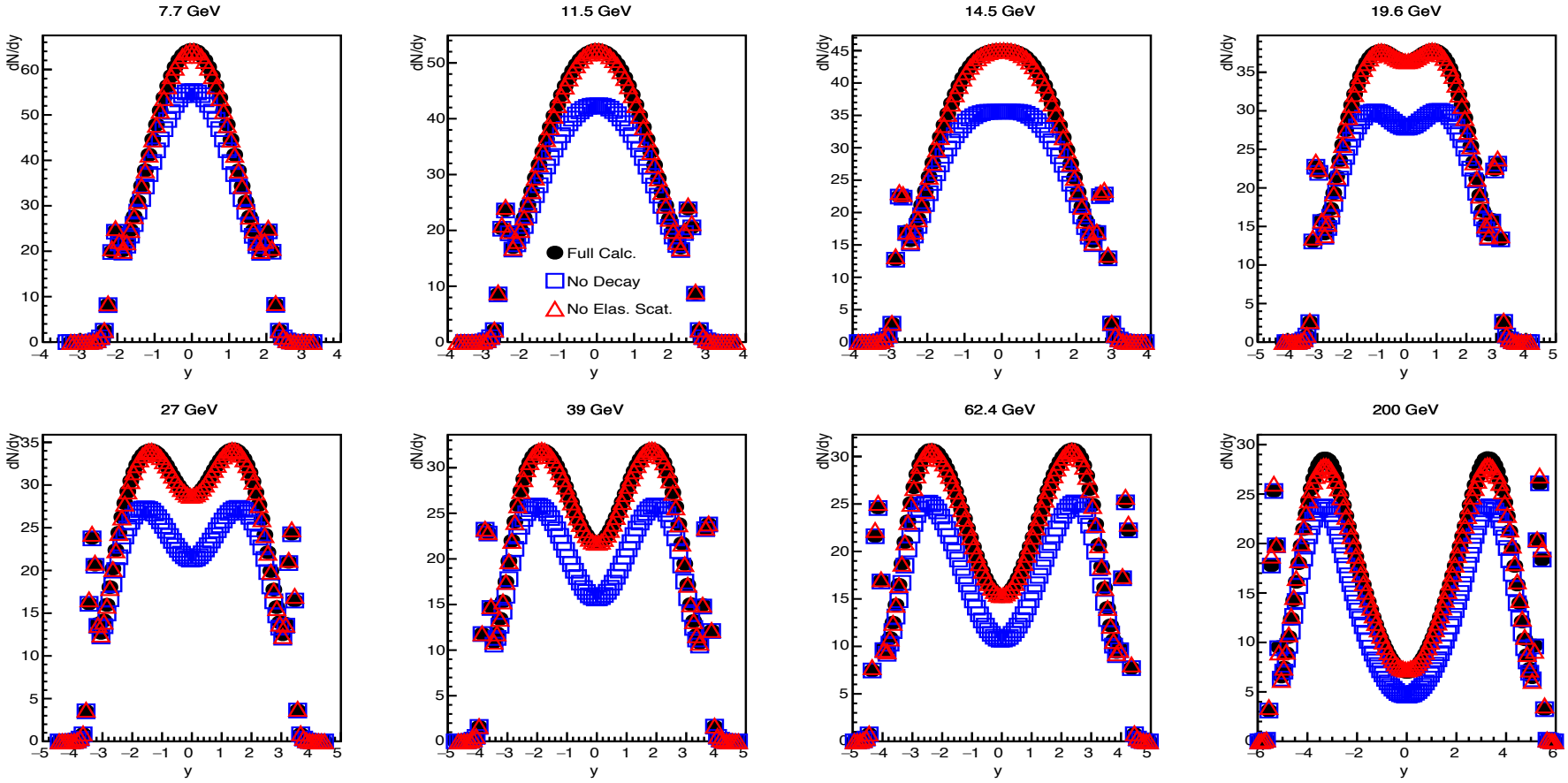
	definition
refMult2	charged particles in $0.5 < \|\eta\| < 1.0$
refMult3	(anti) pion+(anti) kaon in $\|\eta\| < 1.0$
refMult4	(anti) proton+(anti) pion in $\|\eta\| < 1.0$

Event by event distribution of net-proton



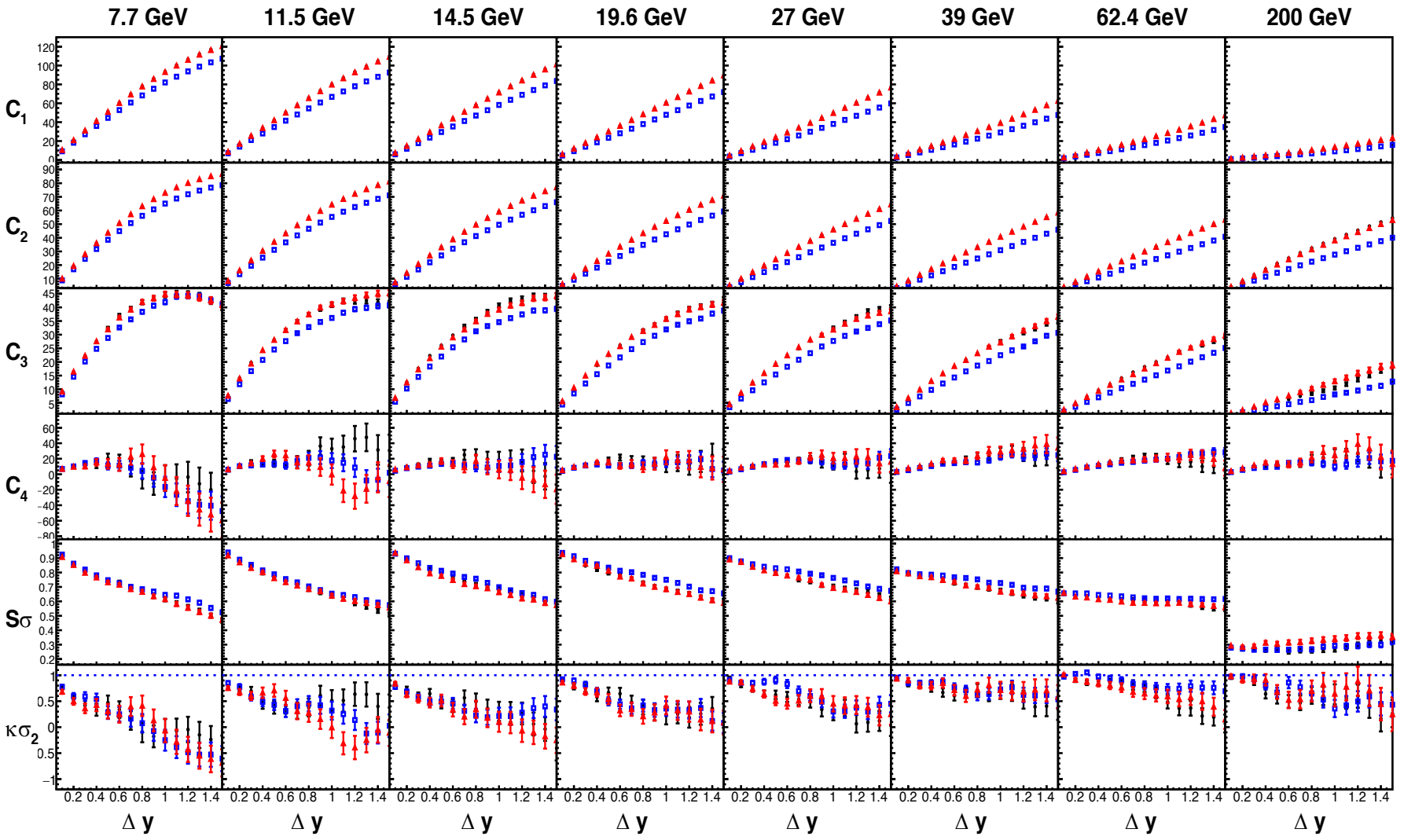
- A broadened particle number distribution under larger energys.
- Turning off weak decay suppresses proton production clearly.
- Left shift of distribution in higher energys.

dN/dy distribution of net-proton



- Proton and anti-proton have smaller difference at larger energy in mid-rapidity region.

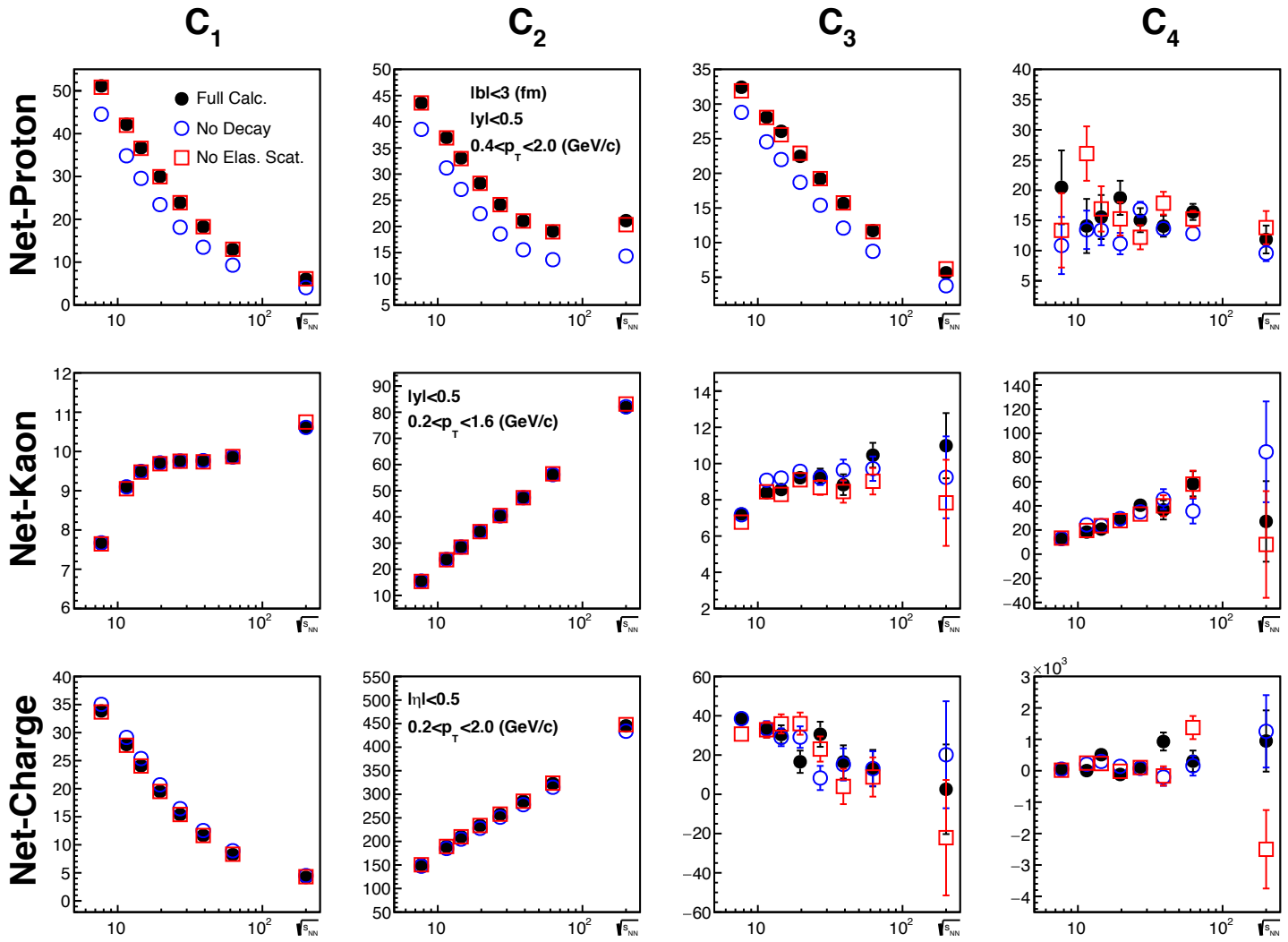
Rapidity dependence of net-proton cumulants



$$-\frac{\Delta y}{2} < y < \frac{\Delta y}{2}$$

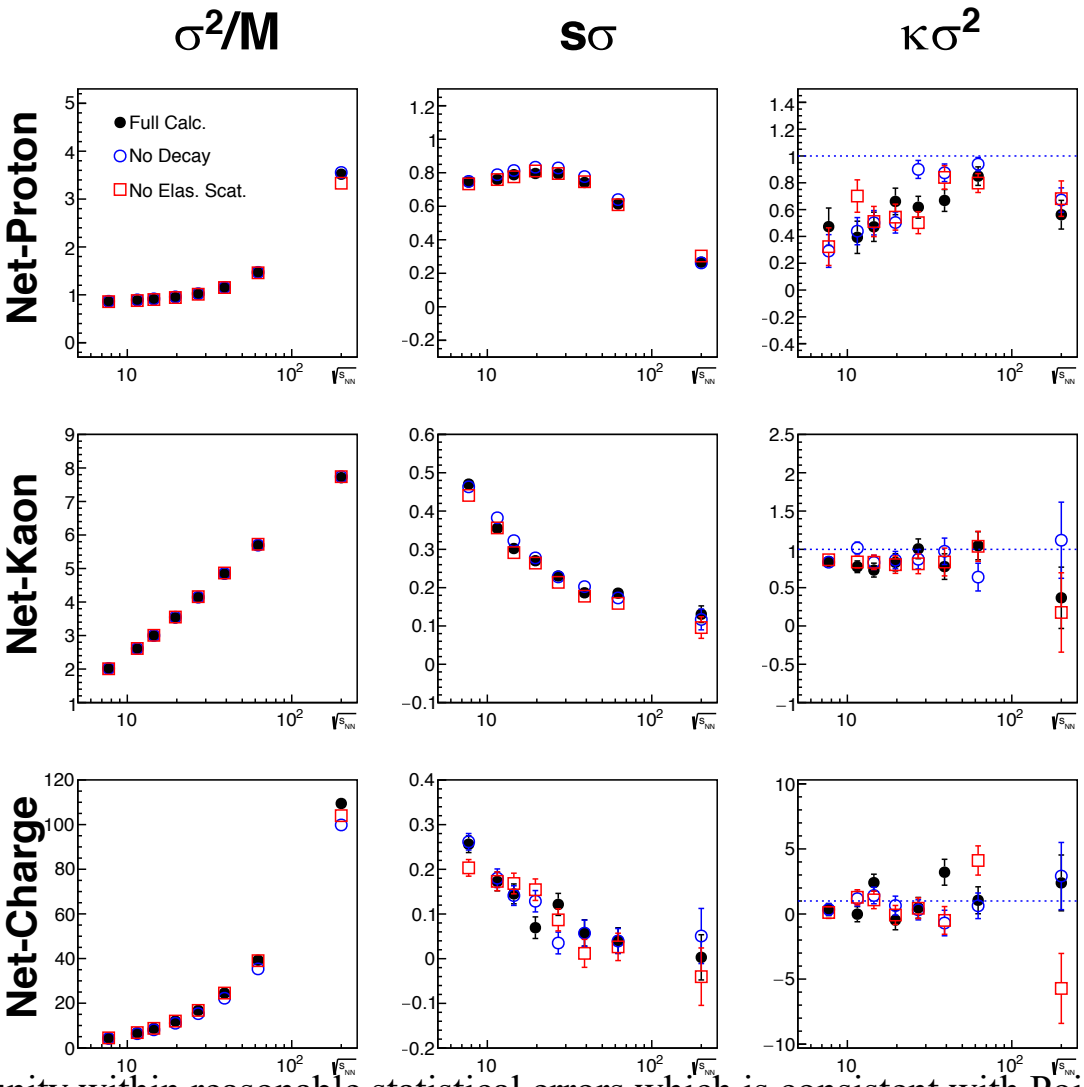
- Higher order cumulants are suppressed

Part 2 – Energy Dependence of Cumulants



- Turning off resonance weak decay suppresses net-proton cumulants in first 3 order cumulants.
- Elastic scattering shows little influence on all 3 net-particle cumulants
- Weak decay and elastic scattering show no big influence on net-kaon and net-charge cumulants.

Energy Dependence of Cumulant Ratio



- $\kappa\sigma^2$ is around unity within reasonable statistical errors which is consistent with Poisson baseline.
- no significant difference found when turning off weak decay and baryon elastic scattering.
- $\kappa\sigma^2$ shows no significant energy dependence.

Summary

- Present calculation of net-proton, net-kaon and net-charge cumulants and cumulant ratios up to 4^{th} order under JAM model
- Turning off Weak decay suppresses proton and anti-proton production, and make little difference to net-kaon and net-charge.
- Net-particle number's $\kappa\sigma^2$ are around unity and shows no remarkable energy dependence.

Thank you!