The shapes of the multiplicity distributions in 7.7-200 GeV Au+Au collisions at STAR

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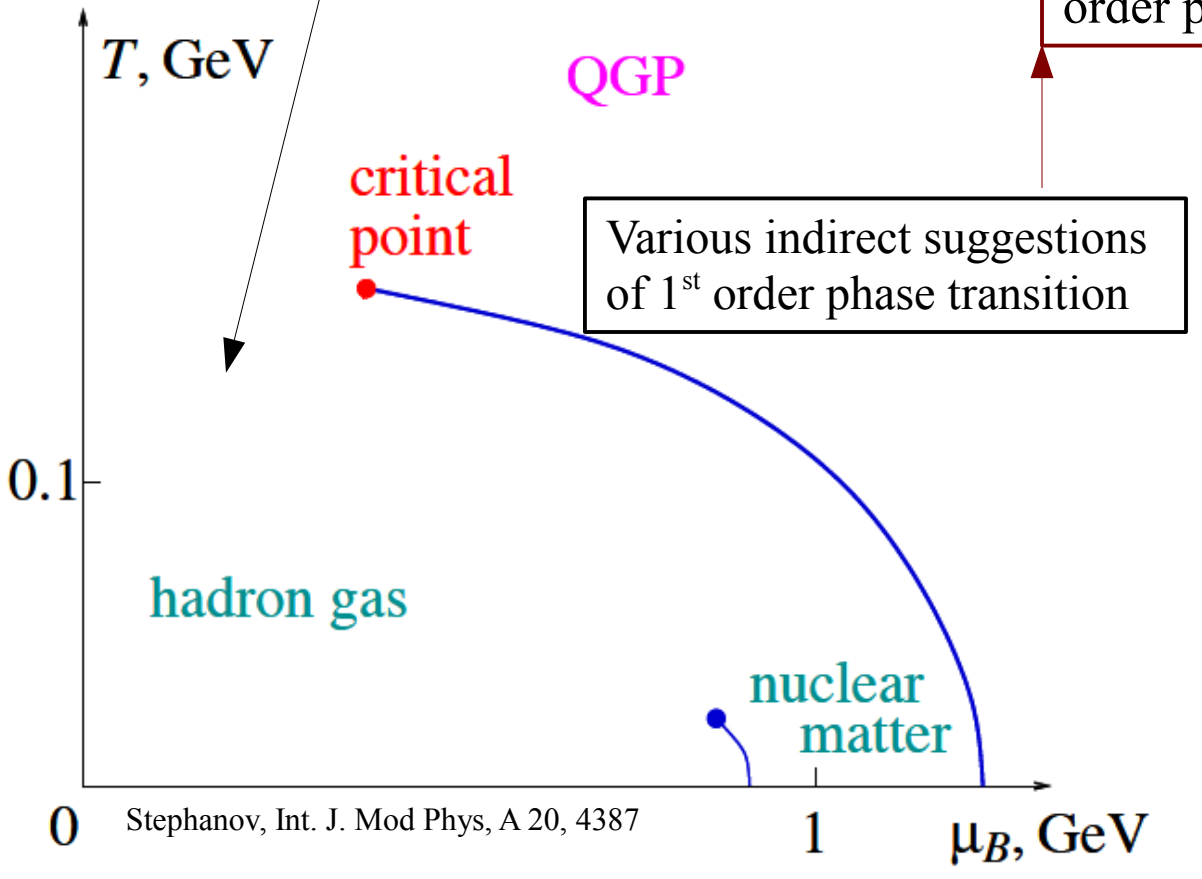
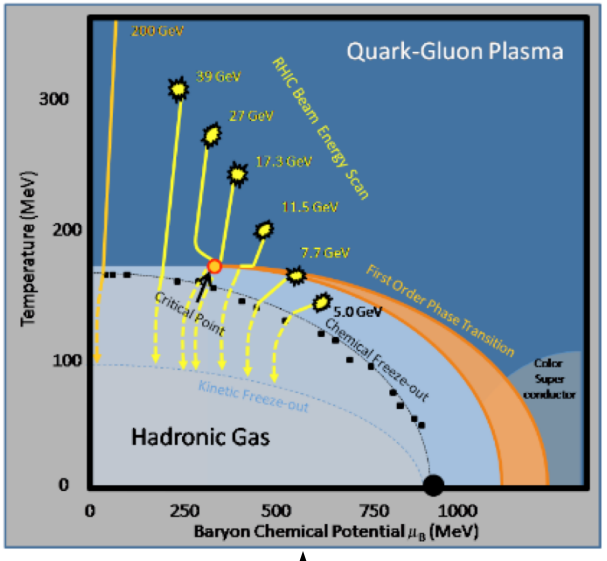
- Top RHIC energies
- baryochemical potential is small
- crossover transition

Thus, a CP might exist somewhere in between these extremes at the end of the 1st order phase transition…





STAR, arXiv:1007.2613 [nucl-ex]

- Varying the beam energy results in different trajectories through this space.
  Decreasing the beam energy results in larger μ_b values.
- I will be describing data collected by the STAR experiment at:
  $\sqrt{s_{NN}}$ = 200, 62.4, 39, 19.6, 11.5, and 7.7 GeV

At the critical point, the correlation length, ξ, should diverge.

Stephanov et al, PRL **81**, 4816 (1998)
P. Braun-Munzinger arXiv: 0801.4256v2

The statistical moments of the multiplicities of identified particles that are proxies of conserved quantities should be very sensitive to the value of ξ.

$$\delta x \equiv x - \langle x \rangle$$
$$\kappa_{2x} \equiv \langle\langle x^2 \rangle\rangle \equiv \langle (\delta x)^2 \rangle$$
$$\kappa_{3x} \equiv \langle\langle x^3 \rangle\rangle \equiv \langle (\delta x)^3 \rangle$$
$$\kappa_{4x} \equiv \langle\langle x^4 \rangle\rangle \equiv \langle (\delta x)^4 \rangle - 3 \langle (\delta x)^2 \rangle^2$$

$$\omega_{ip} \equiv \frac{\kappa_{ip}}{\langle N_p \rangle}$$

Athanasiou et al.
arXiv:1006.4636v2 [hep-ph]

Volume normalization is the average number of particles

$$\kappa_2 = \langle \sigma_0^2 \rangle \simeq \xi^2 ; \qquad \kappa_3 = \langle \sigma_0^3 \rangle \simeq \xi^6 ;$$
$$\kappa_4 = \langle \sigma_0^4 \rangle_c \equiv \langle \sigma_0^4 \rangle - \langle \sigma_0^2 \rangle^2 \simeq \xi^8$$

Stephanov PRL **102**, 032301 (2009)

Higher moments go with ξ to higher powers

The cumulants for measured particles that are proxies for conserved quantities might diverge if the system has passed close to the critical point.

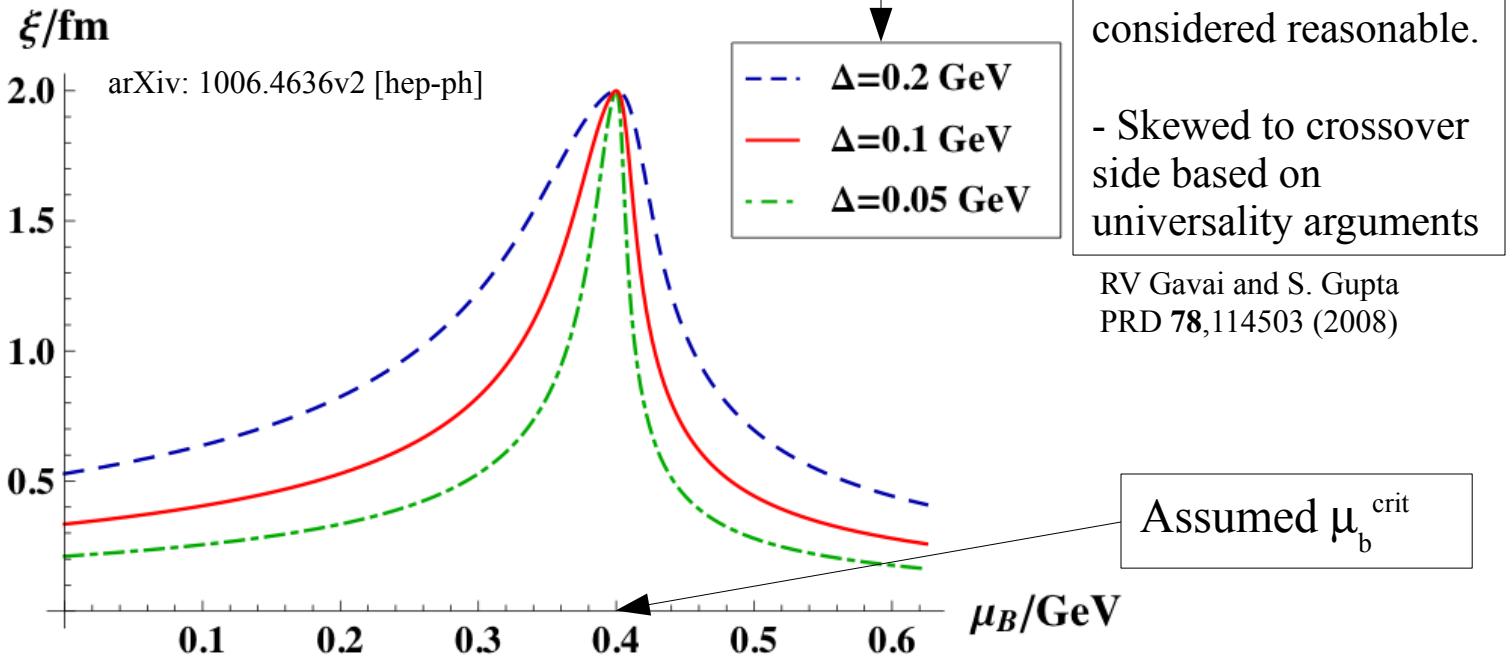
Experimentally, we can measure the following proxies of conserved quantities:

Baryon number	→ Net-protons	[p-$\bar{p}$]	(B)
Strangeness	→ Net-Kaons	[K^+-K^-]	(S)
Charge	→ Net-hadrons	[h^+-h^-]	(Q)

→ more studies on the viability of these particle proxy assumptions is needed

This presentation will concentrate only on ω_3 and ω_4

An *ansatz* reproducing the expected trends:



- Delta is unknown, but 100 MeV is considered reasonable.

- Skewed to crossover side based on universality arguments

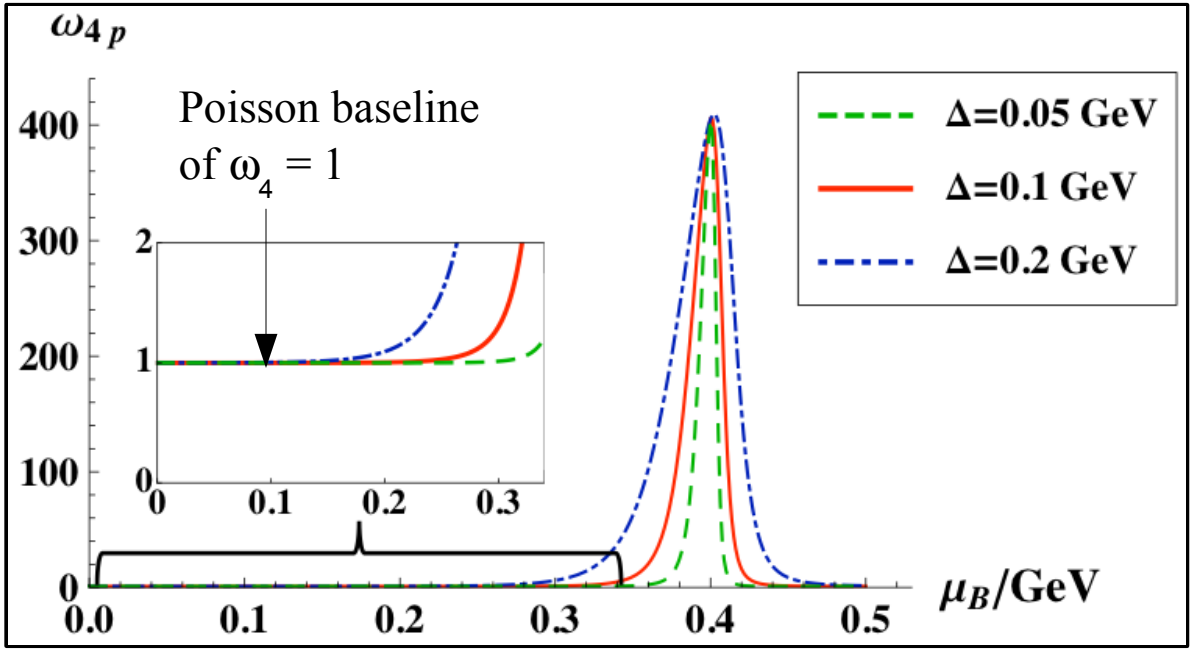
RV Gavai and S. Gupta
PRD **78**,114503 (2008)

Assumed maximum of correlation length based on finite size and lifetime of the system and "critical slowing down effect"

Berdnikov and Rajagopal
hep-ph/0912274v2

Assumed μ_b^{crit}

This model then predicts large enhancements of the 4th cumulant and other cumulants near the critical point.



It is important to remove experimental sources of fluctuations which are not related to critical fluctuations

- requires careful data QA and study of cuts

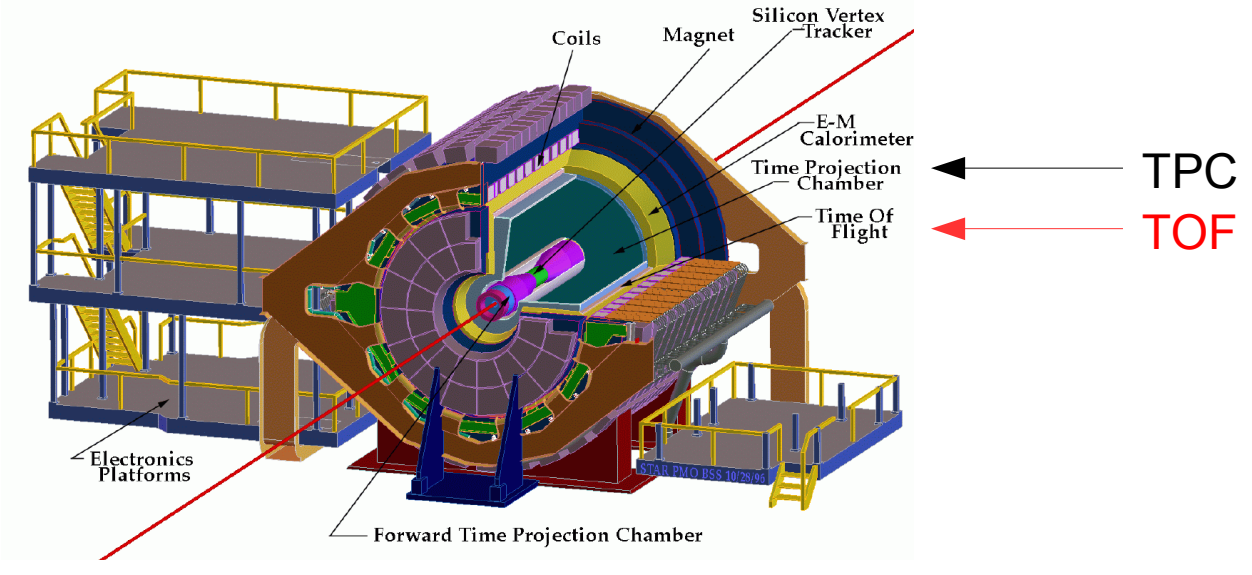
Good event cuts:

- all beam energies: |Zvtx| <30 cm, Rvtx <1.2, TOFmult >= 5 & other cuts on global observables
- careful bad run rejection performed

Good track cuts: Nhitsfit >15, NhitsdE/dx >10, $|\eta|$ <0.5, gldca <1.0, Nhitsratio >0.52

$0.2<p_t<1.0$ for π,K $\quad$ $0.4<p_t<1.0$ for p

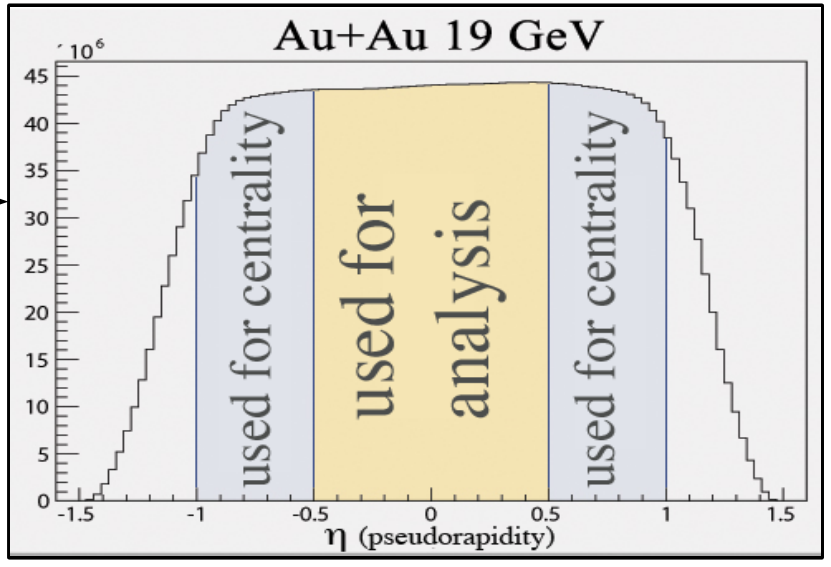
Particle identification (PID) is done using a combination of Time Projection Chamber (TPC) ionization energy loss (dE/dx) and time-of-flight (TOF) information



Centrality Selection

- To remove autocorrelations between centrality cuts and moments, the centrality is determined by the hadron multiplicity outside of analysis range.
- Moments are corrected for centrality bin-width effects.

X. Luo arXiv: 1106.2926 [nucl-ex]



- Only the most central events, 0-5%, are discussed here.

Cumulants

- Will show cumulants for 4 particle groups:

p-$\bar{p}$	net-protons,	proxy of net-baryon number
K^+-K^-	net-Kaons,	proxy of net-strangeness
h^+-h^-	net-hardrons,	proxy of net-charge
p+$\bar{p}$	total-protons,	could be more sensitive than net-protons

Athanasiou et al. arXiv:1006.4636v2 [hep-ph]

Error bars are from an analytical calculation and are statistical only.

Numbers of events surviving cuts (0-80%)

	7.7 GeV	11.5 GeV	19.6 GeV	39 GeV	62.4 GeV	200 GeV
# events	1.74 M	6.12 M	14.3 M	22.6 M	39.5 M	45.0 M

Critical "signal" is a strong enhancement with respect to a Poisson baseline.

Poisson expectation for ω_3 and ω_4 calculated using only the average number of particles, where $\mu_+ = \langle N_+ \rangle$, $\mu_- = \langle N_- \rangle$

-Then, Poisson expectation for cumulants of net-moments given by:

$\kappa_3 = \mu_+ - \mu_-$ $\kappa_4 = \mu_+ + \mu_-$

By definition: $\omega_x = \kappa_x / (\mu_+ + \mu_-)$

so... $\omega_{3,poisson} = \kappa_3/(\mu_+ + \mu_-)$ $\omega_{4,poisson} = \kappa_4/(\mu_+ + \mu_-)$

$\omega_{3,poisson} = (\mu_+ - \mu_-)/(\mu_+ + \mu_-)$ $\omega_{4,poisson} = (\mu_+ + \mu_-)/(\mu_+ + \mu_-) = 1$

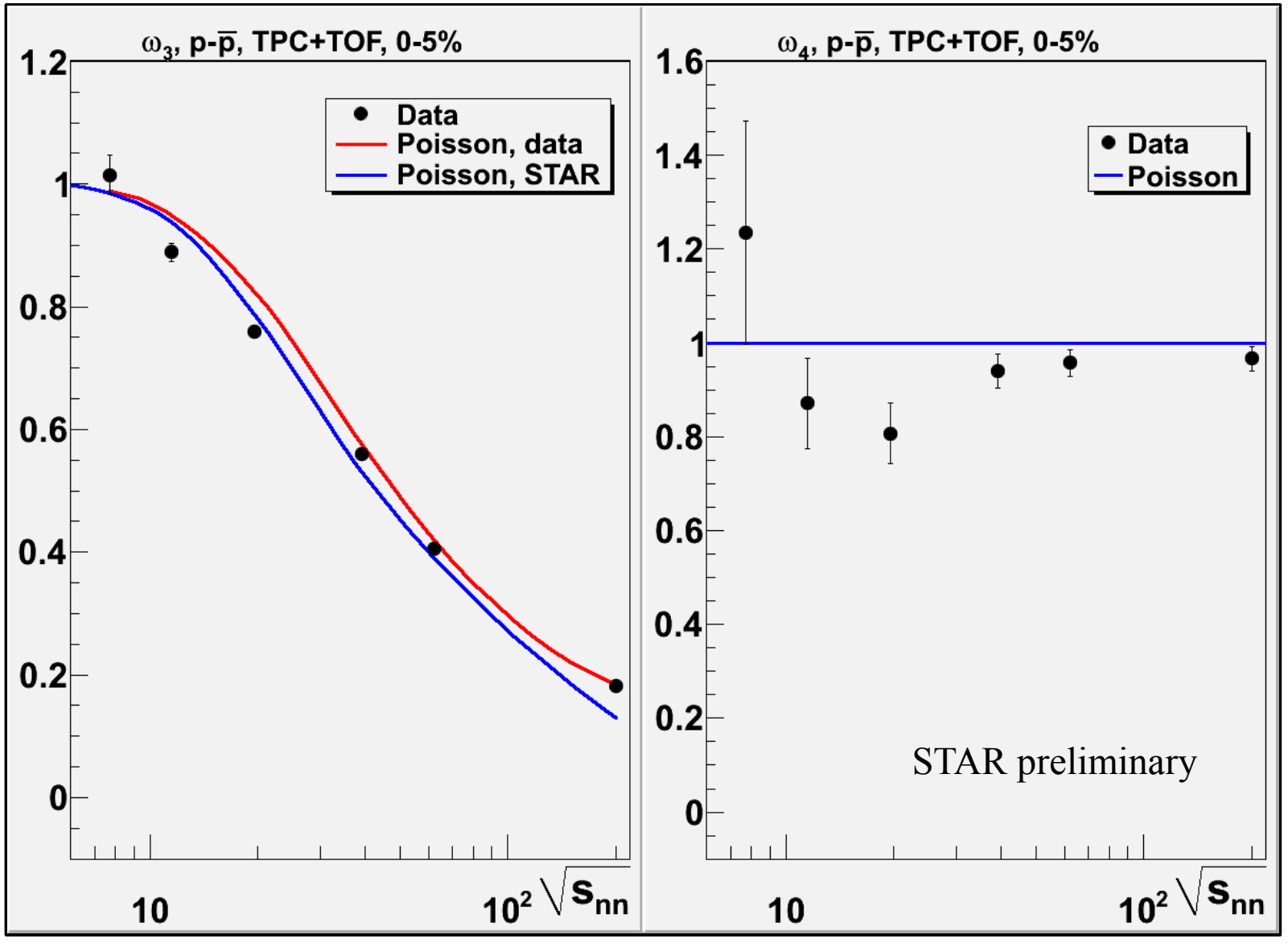
We have two different choices for the values of μ_+ and μ_-

1) efficiency-corrected multiplicities from: L. Kumar arXiv:1106.6071v1 [nucl-ex] STAR, PRC **79**, 034909 (2009)

Labeled as Poisson, STAR

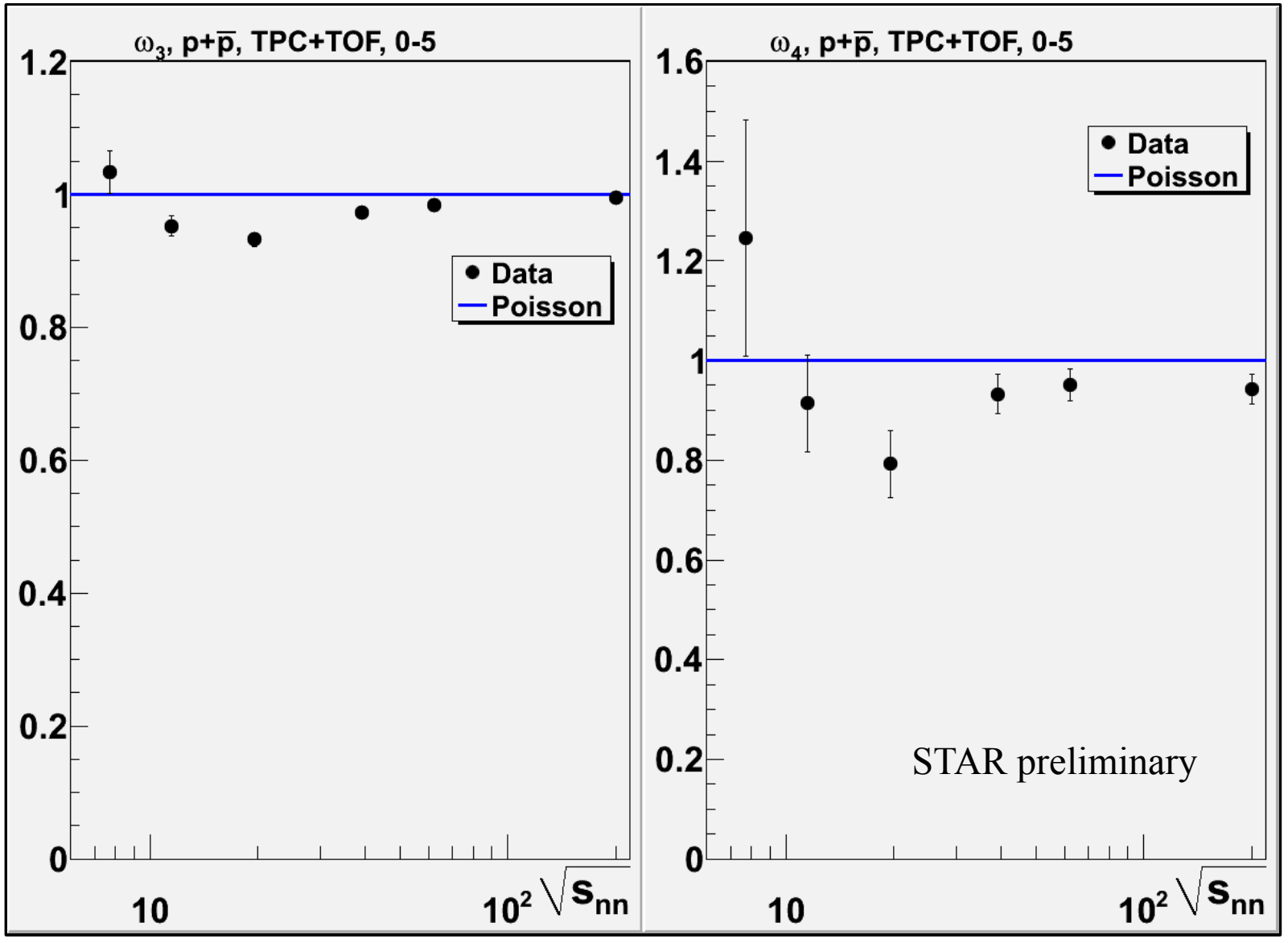
2) multiplicities from present analysis (no efficiency correction)

Labeled as Poisson, Data

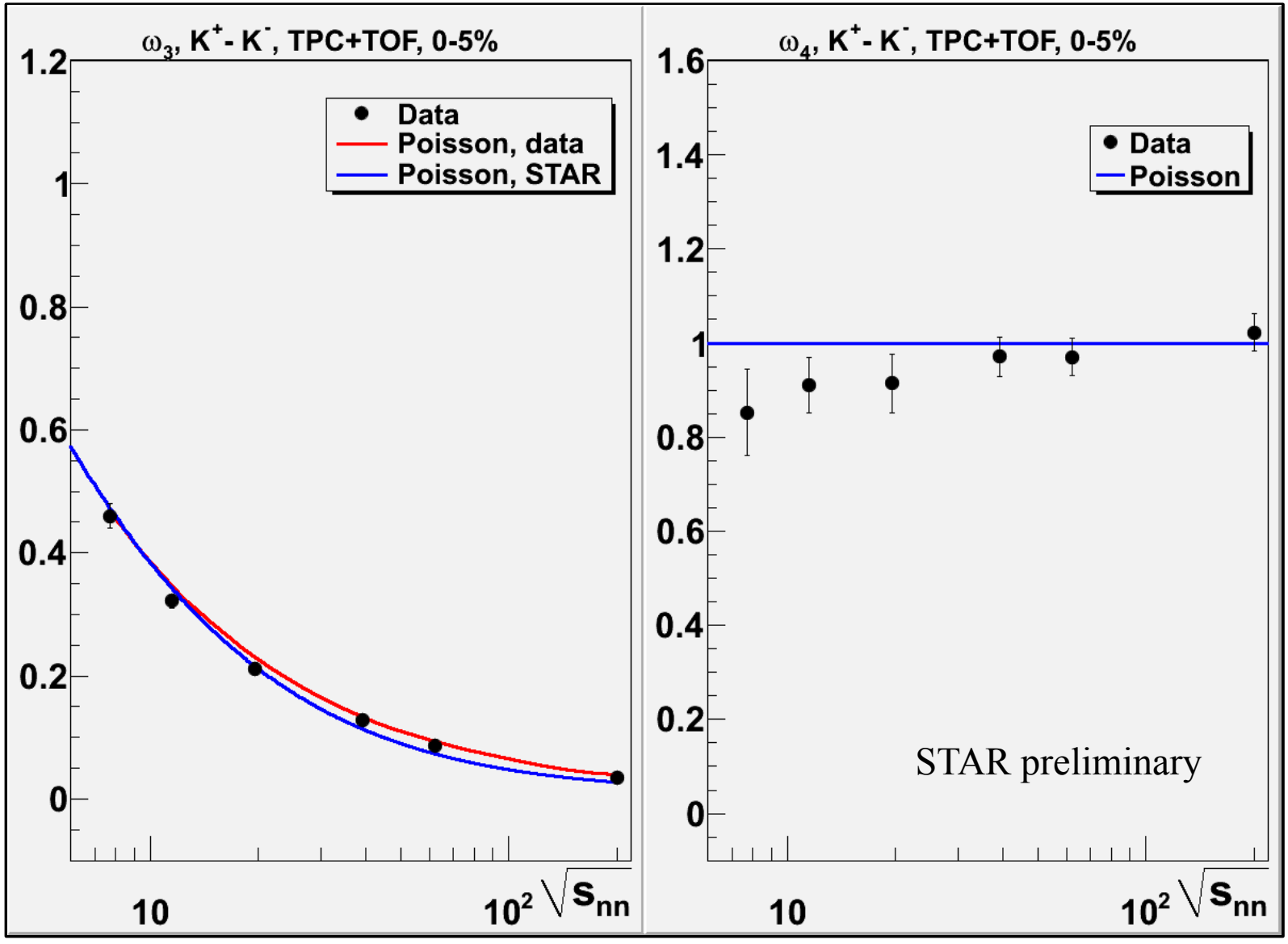


ω_3 and ω_4 for net-protons are generally close to the Poisson baselines.

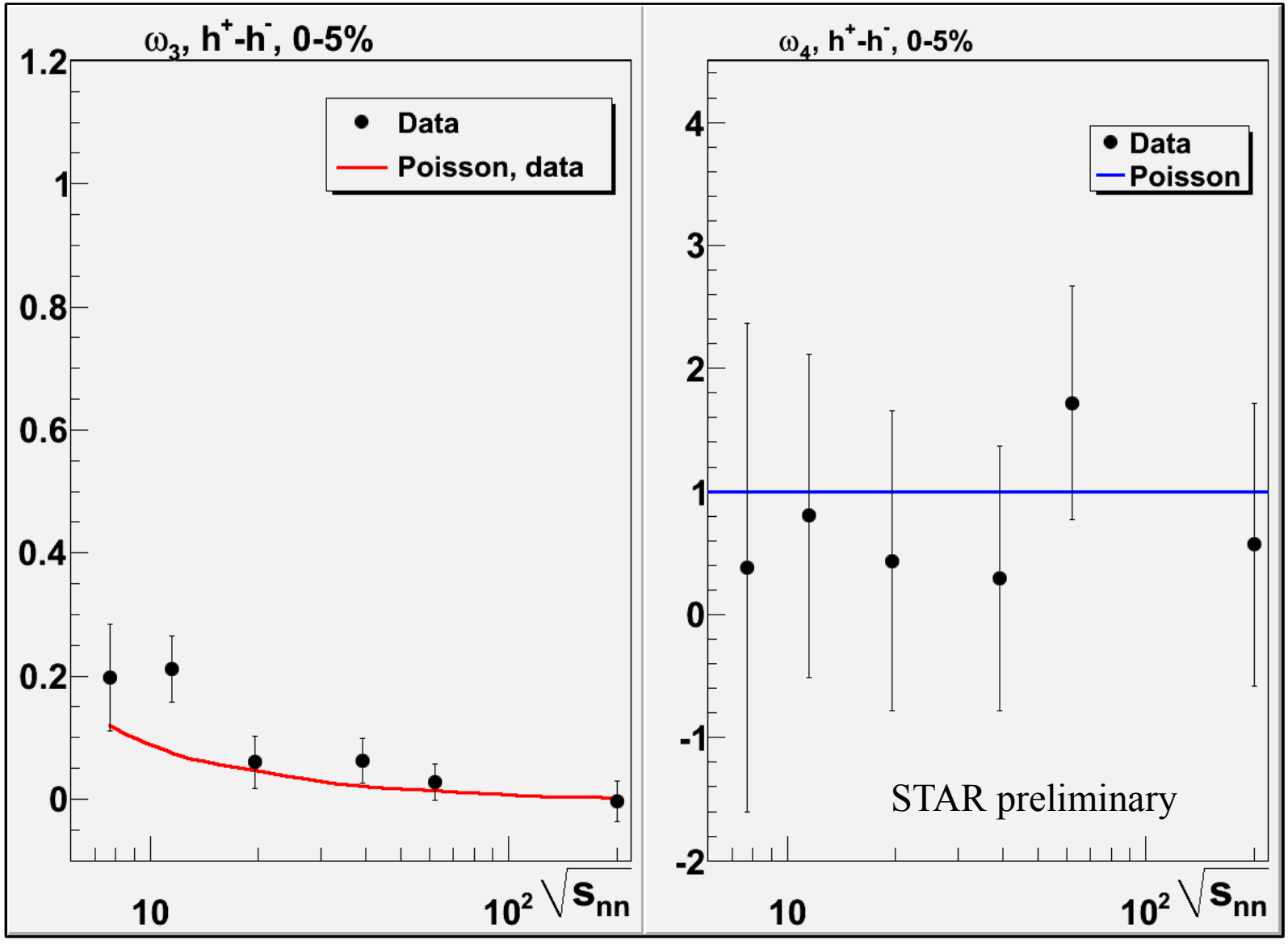
-Efficiency, acceptance and other detector effects are under investigation



Total-proton moments similar to net-proton moments with respect to the Poisson baselines.



Also generally consistent with the Poisson baselines.



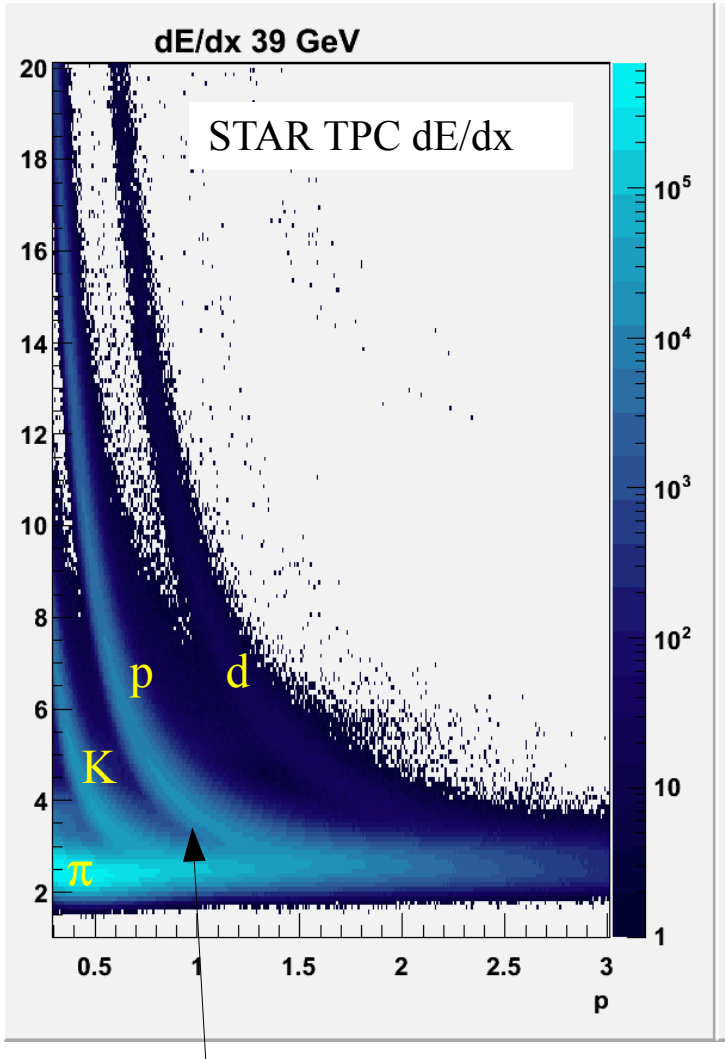
Also generally consistent with the Poisson baselines.

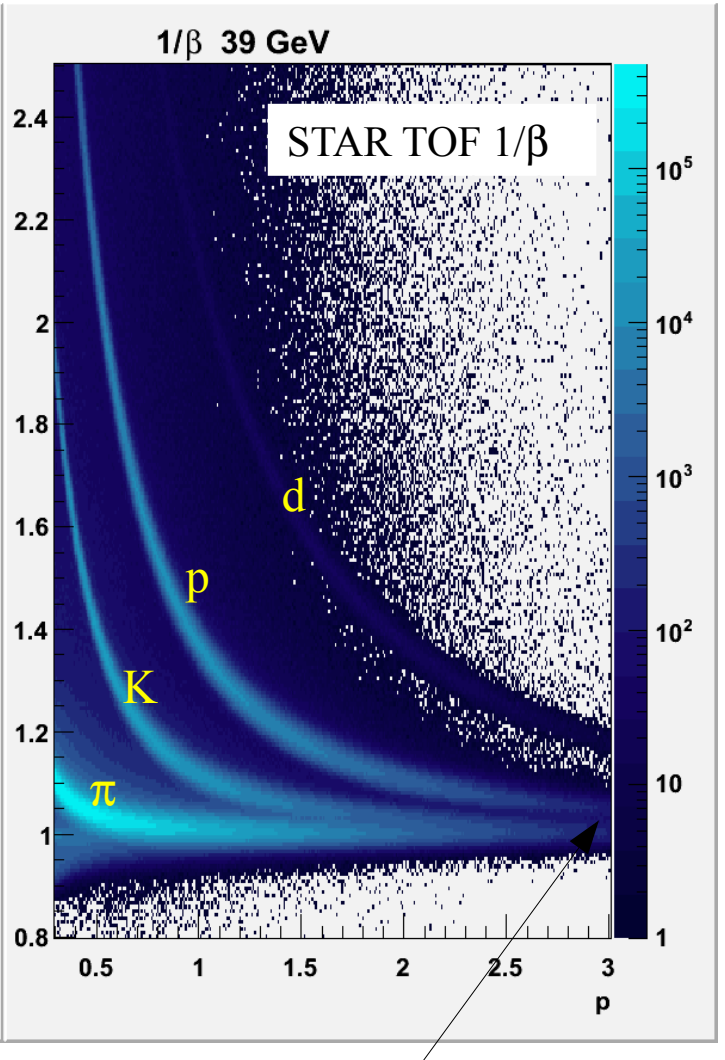
- Reported results from Au+Au collisions over a range of beam energies: 200, 62.4, 39, 19.6, 11.5, 7.7 GeV
- Calculated the intensive-normalized cumulants ω_3 and ω_4 for:
  p-$\bar{p}$, p+$\bar{p}$, K^+-K^-, h^+-h^-
  - Careful cuts done to get clean data samples
  - PID done through combination of TPC and TOF detectors
- Poisson baseline for ω_3 and ω_4 calculated based on average values of the multiplicities and compared to the experiment moments
- At the presently available beam energies, no dramatic enhancement of ω_3 and ω_4 cumulant values with respect to the Poisson baselines was observed.

- Analysis of the $\sqrt{s_{NN}} = 27$ GeV data is underway
- Also exploring the systematic effects on the moments values from the event and track cuts as well as the PID methods
  - Efficiency and acceptance effects are also under investigation

Backup

Different particles appear as different bands below.





Protons merge with π/K at around 1 GeV

Protons merge with π/K at around 3 GeV

PID used here:

-A 2σ cut on $dE/dx_{expected}$ for identified charged particles with a minimum momentum cut

-Then reconstruct $Mass^2$ using $1/\beta$ from TOF detector, and cut on $Mass^2_{expected}$ for identified charged particles with a maximum momentum cut.

-Momentum cuts prevent contamination where particle bands merge