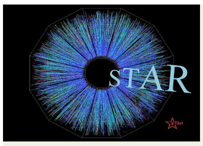

Higher Moments of Net Kaon Multiplicity Distributions at RHIC Energies for the Search of QCD Critical Point

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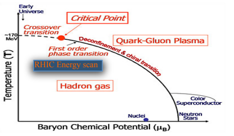
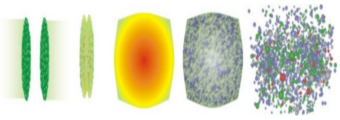
(for the STAR collaboration)

The critical point (CP) is the end point of the first order phase transition line in the QCD phase diagram, where hadronic degrees of freedom changes to color degrees of freedom. At the critical point the hadronic and the quark –gluon QCD phase, coexist along the first order line, mixed into one phase. At the critical point the first order transition becomes continuous, resulting in long range correlation and fluctuation at all length scale. Such properties of state open possibilities for distinct experimental signatures which can be used to discover the critical point[1][2][3][7].





The Relativistic Heavy-Ion Collider (RHIC), at BNL, has started its beam energy scan program to locate the QCD critical point which is also one of the main aims of the STAR experiment. M. Stephnov's sigma model predict that the higher moments of the multiplicity distribution of conserved quantities like the net-charge, net-baryon and net-strangeness are related to the corresponding susceptibilities and the correlation length of the system. These moments show deviation from monotonic behavior at critical point[1][2][5][6].

Lattice prediction

1. Lattice QCD finds a smooth crossover at large T and μ_B~0.
2. Various models find a strong 1st order transition at large μ_B.
3. From lattice calculation shows: CP range ~ $160 < \mu_B < 500$MeV.

Beam Energy Scan Program at RHIC cover this range

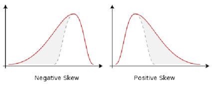
Higher moments: Non-Gaussian Fluctuation Measure

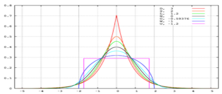
Mean (M) = $\langle N \rangle$

Standard Deviation (σ) = $\sqrt{\langle (N - \langle N \rangle)^2 \rangle}$

Skewness (S) = $\langle (N - \langle N \rangle)^3 \rangle / \sigma^3$

Kurtosis (k) = $\langle (N - \langle N \rangle)^4 \rangle / \sigma^4 - 3$





Skewness represent the asymmetry of the distribution and kurtosis represent the sharpness of the distribution. For Gaussian distribution, the Skewness and Kurtosis values are equal to zero. Higher moments are ideal probe to measure non-Gaussion fluctuation.

In a static, infinite medium, the correlation length (ξ) diverges at the CP. ξ is related to various moments of the distributions of conserved quantities such as net baryons, net charge, and net-strangeness[1][7][9].

At Critical point $\langle (\delta N)^2 \rangle \sim \xi^2$

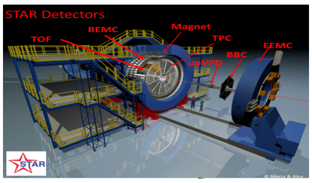
ξ = Correlation length

$\langle (\delta N)^3 \rangle \sim \xi^{4.5}$

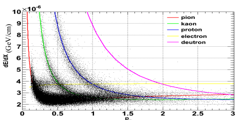
$\langle (\delta N)^4 \rangle - 3 \langle (\delta N)^2 \rangle^2 \sim \xi^7$

STAR Experiment at RHIC & Data Analysis

Ionization energy loss (dE/dx) of charged particles in the STAR TPC was used to identify the inclusive particles by comparing it to the theoretical (parameterized) expectation[5][6].

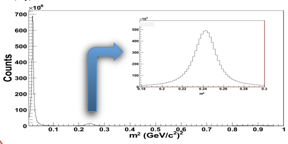


$$z = \ln\left(\frac{dE/dx_{measured}}{dE/dx_{parameterized}}\right)$$



Basic cuts used: DCA ≤ 1 cm, $|V_Z| \leq 30$ cm, $0.2 < p$ (GeV/c) < 1.6, $|\eta| \leq 0.5$, Number of Fit Points $\geq$ 15, $|n\sigma_{kaon}| < 2.0$, where

$$n\sigma_X = \frac{1}{R}\log\frac{\langle dE/dx \rangle|_{measured}}{\langle dE/dx \rangle_X|_{expected}}$$

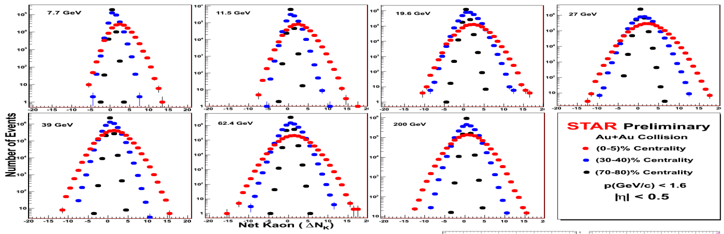


A cut has been applied on the mass square, $0.22 < m^2 < 0.265$, using ToF (Time-of-Flight).

Energy (in GeV)	Number of Events (in M)	Year
7.7	~ 2.3	2010
11.5	~ 7.5	2010
19.6	~ 17	2011
27.0	~ 31.9	2011
39.0	~ 42.2	2010
62.4	~ 43	2010
200	~ 236	2010 & 2011

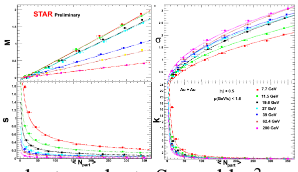
Results

The raw net-Kaon (ΔN_K) multiplicity distribution in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 - 200 GeV for various collision centralities at mid-rapidity ($|\eta|<0.5$), shown in the figure. The net-Kaon (ΔN_K) distribution showing that, as we are going lower to higher energy, the mean shifted towards zero. The centrality selection utilized the uncorrected charged particle multiplicity within the pseudorapidity $0.5 < |\eta| < 1.0$, measured by the TPC.

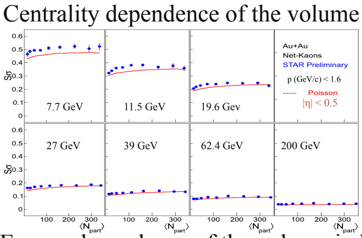


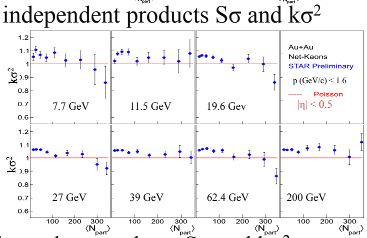
Moments of net-Kaon (ΔN_k) distribution

The four moments (M, σ, S, and k) which describe the shape of the ΔN_K distributions at various collision energies are plotted as a function of average number of participants $\langle N_{part} \rangle$ and fitted with it's predicted dependence function from CLT, goes as volume's x, $\sqrt{x}$, $1/\sqrt{x}$ and 1/x respectively (the dotted lines).

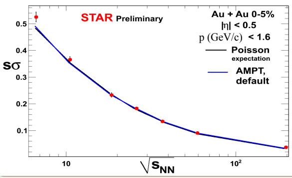


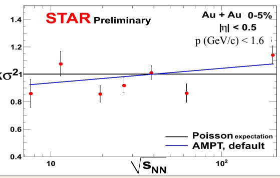
Centrality dependence of the volume independent products Sσ and kσ^2





Energy dependence of the volume independent products Sσ and kσ^2





All errors are statistical and calculated from Delta theorem method [8].

Discussion and Conclusion

1. From net-Kaon multiplicity distribution, it is observed that as the colliding energy increases, the mean of the distribution shifts towards zero.
2. The centrality dependence of moments follows the Central Limit Theorem (CLT) well .
3. Sσ value is independent of centrality within 15%. Sσ value is greater than the Poisson baseline for beam energy below 200 GeV. Sσ increases with decreasing collision energies.
4. Within the statistical uncertainty volume independent product kσ^2 value is independent of centrality within 10%.
5. No significant enhancement of moment products was observed compared to the Poisson baseline at presently available energies.
6. Within the statistical uncertainty AMPT value matches with data.

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