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

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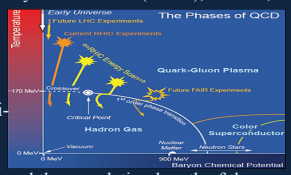
Introduction:

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. Calculations on the lattice 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. 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. For lattice $\mu_B = 0$, not possible, lattice calculation: CP range~ $160 < \mu_B < 500$MeV

Beam Energy Scan Program at RHIC will cover this range

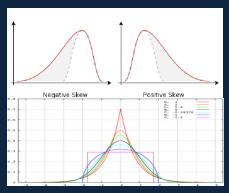
Higher moments: Non-Gaussian Fluctuation Measure

Mean (M) = < N >

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

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

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



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. For non-Gaussian this is a ideal probe to measure the 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.

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

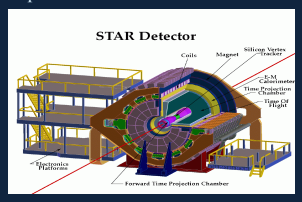
ξ = Correlation length

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

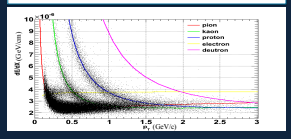
$\langle (\delta N)^4 \rangle - 3 \langle (\delta N)^2 \rangle^2 \sim \xi^7$

STAR Experiment at RHIC & Data Analysis

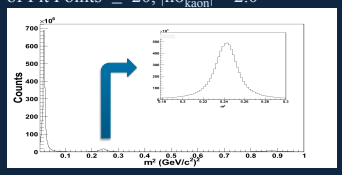
Ionization energy loss (dE/dx) of charged particles in theSTAR TPC was used to identify the inclusive particles by comparing it to the theoretical (parameterized) expectation.



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



Basic cuts used: DCA $\leq$ 1 cm, $|V_Z| \leq 30$ cm, p (Gev/c) < 1.6, $|\eta| \leq 0.5$, Number of Fit Points $\geq$ 20, $|n\sigma_{kaon}| < 2.0$



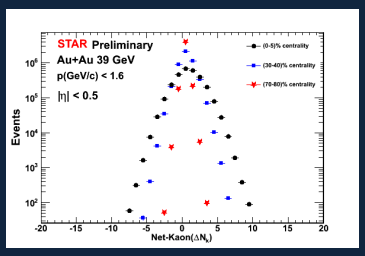
A cut has been applied on the mass square, $0.22 < m^2 < 0.265$, using ToF(Time-of-Flight).

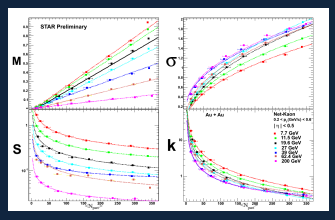
BES data used for the analysis

Energy (in GeV)	Number of Events (in M)	Year
7.7	~ 2.2	2010
11.5	~ 7.4	2010
19.6	~ 13.9	2011
27.0	~ 31.9	2011
39.0	~ 42.2	2010
62.4	~ 43	2010
200	~ 236	2010 & 2011

Results

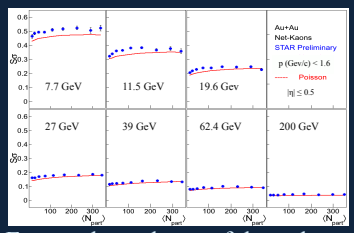
ΔN_K multiplicity distribution in Au+Au collisions at $\sqrt{s_{NN}}$ = 39 GeV for various collision centralities at midrapi-dity ($|\eta|$ <0.5). The net-Kaon distribution showing that, as we are going to more central, the fluctuations are increasing. The centrality selection utilized the un-corrected charged particle multiplicity within the pseudo rapidity 0.5< $|\eta|$<1.0, measured by the TPC.

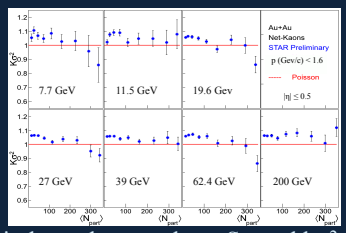




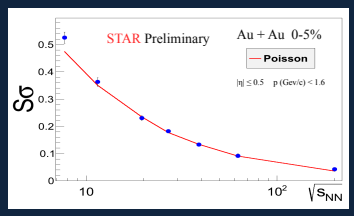
The four moments (M, σ, S, and k) which describe the shape of the ΔN_K distributions at various collision energies are plotted as a function of average number of participants $\langle N_{part} \rangle$ and fitted with it's volume's x, $\sqrt{x}$, $1/\sqrt{x}$ and 1/x respectively (the black lines).

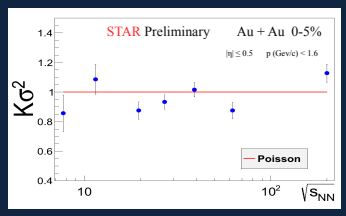
Centrality dependence of the volume independent products σ^2/M, $S\sigma$ and $k\sigma^2$ for ΔN_k in Au+Au collision at $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27, 39, 62.4 and 200 GeV





Energy dependence of the volume independent products $S\sigma$ and $k\sigma^2$





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. Except for top 10% centrality $S\sigma$ value is greater than the Poisson baseline for beam energy below 200GeV. $S\sigma$ is independent of centrality within 15%.
4. Volume independent product $k\sigma^2$ value is independent of centrality except in most central 0-10% collision.
5. In peripheral collision $k\sigma^2$ value is greater than the Poisson expectation.
6. No significant enhancement of moment products was observed compared to the Poisson baseline at presently available energies.

References

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