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 $\mu_B$.
2. Various models find a strong 1st order transition at large $\mu_B$.
3. For lattice $\mu_B = 0$, not possible, lattice calculation: CP range $\sim 150 < \mu_B < 500$ MeV.

Beam Energy Scan Program at RHIC will cover this range

Higher moments: Non-Gaussian Fluctuation Measure

\begin{align*}
\text{Mean} & \quad \langle M \rangle = \langle N \rangle \\
\text{Standard Deviation} & \quad \langle \sigma \rangle = \sqrt{\langle N^2 \rangle - \langle N \rangle^2} \\
\text{Skewness} & \quad S = \frac{\langle (N - \langle N \rangle)^3 \rangle}{\langle (N - \langle N \rangle)^2 \rangle^{3/2}} \\
\text{Kurtosis} & \quad K = \frac{\langle (N - \langle N \rangle)^4 \rangle}{\langle (N - \langle N \rangle)^2 \rangle^2} - 3
\end{align*}

SKN, standard deviation of the distribution, expresses the non-Gaussian character of the distribution. In a static, infinite medium, the correlation length is related to various moments of the distributions of conserved quantities such as net baryons, net charge, and net-strangeness.

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.

Basic cuts used: DCA $\leq 1$ cm, $|V_{xy}| \leq 30$ cm, $p$ (GeV/c) $\leq 1.6$, $|\eta| \leq 0.5$, Number of Fit Points $\geq 20$, $|\eta_{ideal}| \leq 2.0$.

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

<table>
<thead>
<tr>
<th>Energy (in GeV)</th>
<th>Number of Events (in M)</th>
<th>Year</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>7.7</td>
<td>$\sim 2.2$</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>11.5</td>
<td>$\sim 7.4$</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>19.6</td>
<td>$\sim 13.9$</td>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>27.0</td>
<td>$\sim 31.9$</td>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>39.0</td>
<td>$\sim 42.2$</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>62.4</td>
<td>$\sim 43$</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>$\sim 236$</td>
<td>2010 &amp; 2011</td>
<td></td>
</tr>
</tbody>
</table>

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, SkN value is greater than the Poisson baseline for beam energy below 200 GeV. SkN is independent of centrality within 15%.
4. Volume independent product $K_{32}$ value is independent of centrality except in most central 0-10% collision.
5. In peripheral collision $K_{32}$ value is greater than the Poisson expectation.

References


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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)

Results

$N_\Delta$ multiplicity distribution in Au+Au collisions at $\sqrt{s_{NN}} = 39$ GeV for various collision centralities at midrapidity ($|\eta| < 0.3$). The net-kaon distribution showing that, as we are going to more central, the fluctuations are increasing. The centrality selection utilized the uncorrected charged particle multiplicity within the pseudo rapidity $0.5 < |\eta| < 1.0$, measured by the TPC.

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

Energy dependence of the volume independent products $S_{32}$ and $K_{32}$

Centrality dependence of the volume independent products $S_{32}$ and $K_{32}$ for $N_\Delta$ in Au+Au collision at $\sqrt{s_{NN}} = 7.7, 11.5, 19.6, 27, 39, 62.4$ and $200$ GeV