Baryon Stopping contribution in net-proton fluctuations measured by STAR experiment

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Introduction

The main goal of Beam Energy Scan program by RHIC is to scan the QCD phase diagram i.e temperature (T) versus baryon chemical potential (μ_B) diagram for strong interaction. At large μ_B existence of QCD critical point (CP) and a first order phase boundary between QGP and hadronic phase is expected. The non-monotonous behavior of higher moment of the distributions of conserved quantity like net-baryon number with $\sqrt{s_{NN}}$ are believed to be a good signature of phase transition and CP. A non-monotonous behavior of $\kappa\sigma^2$ is found around $\sqrt{s_{NN}}$ = 19.6 GeV by STAR experiment [2], which hints for the possible existence of critical point around $\sqrt{s_{NN}}$ = 19.6 GeV. The proton distributions measured by STAR experiment have the contribution from both production as well as stopping. There may be a significant contribution of stopped protons at RHIC and lower energies which also relate to the softening of the equation of state. n the present work we have estimated the contribution of stopped protons in the protons multiplicity distributions measured by STAR experiment to calculate the higher order fluctuations.

Method

As the net-baryon number is conserved and rapidity distribution is changed due to the rescattering of the final state particles, so net-baryon rapidity distribution is a major tool to quantify the baryon stopping. Experiment can't measure neutrons, that's why net-proton rapidity distributions are used instead of net-baryon distribution. The net-proton rapidity distributions are best described by the function as follows[1]:

$$dN/dy = a(exp(-(1/w_s)cosh(y - y_{cm} - y_s)) \\ +exp(-(1/w_s)cosh(y - y_{cm} + y_s)))(1)$$

where a, y_s and w_s are parameters of the function. y_{cm} is the center of mass rapidity. This function is used to analyse net-proton rapidity distribution and to estimate the baryon stopping. Incoming beam of baryons have the maximum rapidity given by $y_b = \log(\sqrt{s_{NN}/m_p})$. So after the collision, the particles can have maximum rapidity of y_b. Thus the rapidity loss by the particle is defined as $y_{loss} = y_b - y$. Here y is the rapidity with which the particles are emitted. For the case of full transparency $y_{loss} = 0$, so $y = y_b$. For full stopping $y_{loss} = y_b$, so $y = 0$. Hence, baryon stopping can be quantify as the number of baryon in the mid rapidity .

The net-proton multiplicity analysed by the STAR experiment uses the most central Au+Au collisions $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27, 39, 62.4, 200 GeV data. So, we have collected the data of net-proton rapidity distribution from AGS (2,4,8 AGeV) and BRAHMS at RHIC (62.4, 200 GeV) for Au+Au collisions. Then, using Eq. 1, we have estimated the fraction of baryons that come from baryon stopping. With the proper parametrization, we estimate at STAR energies. With the help of AMPT model we have estimated the number of protons in the mid-rapidity($|y| < 0.5$) within $0.4 < p_T$(GeV/c) < 0.8 i.e for STAR acceptance.

Results

Using Eq. 1, we fit the experimental data and extract the fit parameter at a particular

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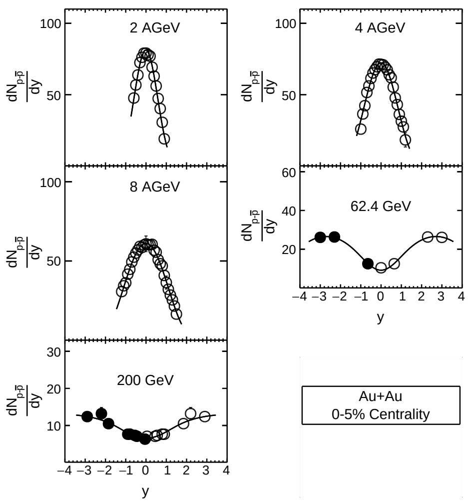

FIG. 1: The rapidity densities of protons at 2, 4, 8A GeV (AGS) and net-proton $(p-\bar{p})$ (for RHIC energies) from central collision of Au+Au (AGS and RHIC) in center-of-mass system. Experimental data are from collaboration E802, E877, E917, E866, RHIC experiments. The open circles are experimentally measured data points and the filled circles are the mirror reflections, assuming a symmetry in particle production. Solid lines represent the two source fit function given by Eq.1

energy. Thus, we use the extracted parameter to calculate the rapidity density at a particular energy. The results are shown in the FIG. 1. With the help of this rapidity distribution, we estimate the fraction of baryon that undergo stopping as:

$$f^{proton}_{stopped} = \int_{-0.5}^{0.5} \frac{dN}{dy} / \int_{-y_b}^{y_b} \frac{dN}{dy}\, dy$$

Hence the percentage of baryon stopping is $\%\ N^{proton}_{stopped} = f^{proton}_{stopped} \times 100$. We parametrize the percentage of baryon stopping in terms of $\sqrt{s_{NN}}$(GeV) with exponential function. Now, after interpolating it, we calculate percentage of baryon stopping for STAR energies. We estimate the fraction of stopped proton in the STAR acceptance using AMPT model. Finally we find, that out of 158 protons(for Au + Au collisions) how many is contribute to baryon stopping in the STAR acceptance. It is seen that there is a substantial contribution of stopping to the existing result. It is shown in the table I.

TABLE I: Column wise (a) $\sqrt{s_{\rm NN}}$ at which the analysis is performed (b) Mean number of protons obtained from baryon stopping in STAR acceptance $[N^{proton}_{stopped}(STAR)]$ (c) Mean number of protons measured by STAR experiment $[N^{proton}_{STAR}]$ (d) N^{proton}_{STAR} - $N^{proton}_{stopped}(STAR)$

(a)	(b)	(c)	(d)
$\sqrt{s_{\rm NN}}$	$N^{proton}_{stopped}(STAR)$	N^{proton}_{STAR}	diff.
7.7	18.79	18.92	0.13
11.5	14.02	15.00	0.99
19.6	9.73	11.37	1.64
27.0	7.61	9.39	1.78
39.0	5.78	8.22	2.44
62.4	3.78	7.25	3.47
200	1.54	5.66	4.11

The details of this work can be found in [3].

References

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