Rapidity dependency of coalescence in Au-Au collisions at $\sqrt{s_{NN}}$= 200 GeV

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Abstract. The coalescence of protons and neutrons into deuterons is sensitive to the space-time extent of baryon freeze-out. Several experiments have measured the coalescence parameter B2 at mid-rapidity. BRAHMS can extend these measurements to forward rapidities and so study the longitudinal dependence of the freeze-out volume. At $\sqrt{s_{NN}}$= 200GeV near mid-rapdity the coalescence parameter is the same for baryons and antibaryons and similar in magnitude to lower energy results. We also find that B2 remains constant from y=0 to y=3.2.

1. Introduction

The concept of deuteron coalescence describes the probability of a neutron and a proton (close in momentum space) coalescing into a deuteron. Experimentally this is measured through the coalescence parameter, B_2, which is given by:

$$B_2 = \frac{E_d \cdot \frac{d^3N}{dp_d^3}}{(E_p \cdot \frac{d^3N}{dp_p^3})^2} \tag{1}$$

It is worth noticing that in (1) it is assumed that the proton and neutron distribution functions are the same. For more detailed work their differences should be taken into account. The formed deuteron will have a momentum , p_d, of approximately twice the forming proton momentum, p_p. Since the deuteron is a very loosely bound system (E_{bind} = 2.22 MeV) the coalescence parameter serves as a probe of the collision at the timescale of freeze-out.

Previously B_2 has been measured at numerous experiments at mid-rapidity, showing that for at least pre-RHIC energies B_2 decreases as a function of energy [2]. Furthermore measurements have shown that B_2 increases as a function of p_T, consistent with a transverse flow [4]. It has been proposed by models [1] that the coalescence parameter is inversely connected to the volume of the collision at the time of freeze-out.

All these previous measurements have been conducted in the midrapidity region, whereas the aim for this work is to utilize the unique possibility of the BRAHMS experiment, to measure charged particles at very forward rapidities.

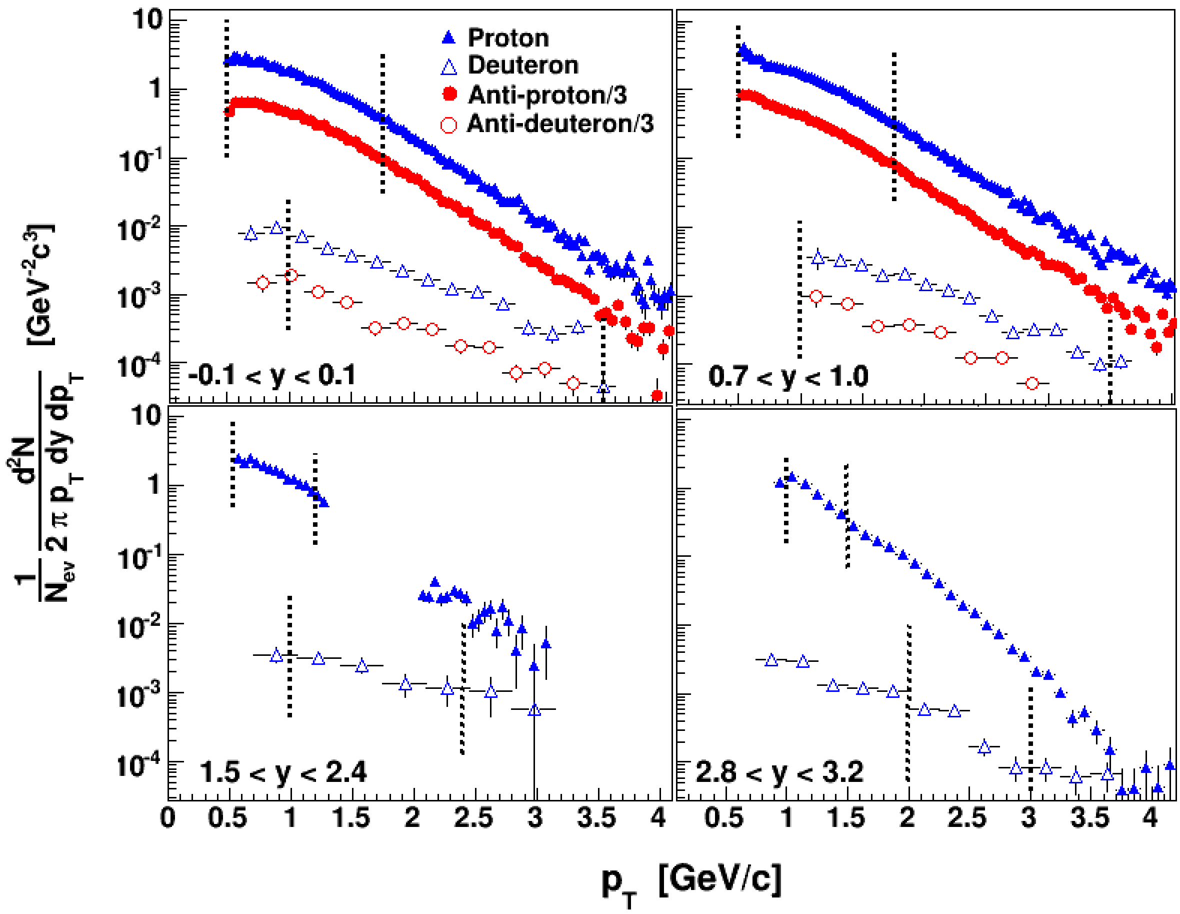

Figure 1. Invariant proton and deuteron spectra at four rapidity bins, and their anti-particle counterpart spectra at rapidity $y \sim 0$ and $y \sim 1$. The vertical dashed lines indicate the interval for each spectrum, used to construct the coalescence parameter. Solid blue triangles denotes Protons, open blue triangles denotes deuterons, solid red circles denotes anti-protons and finally open red circles denotes anti-deuterons .

2. Results

The data presented in this analysis were obtained at the BRAHMS experiment [3] with its two movable magnetic spectrometers, as well as a global detector system for event characterization. In the midrapidity region, particle identification was done using time-of-flight walls. At forward rapidities, paricle identification was done using a ring imaging Cherenkov detector, in conjunction with time-of-flight walls. This work analyzes Au-Au collisions at $\sqrt{s_{NN}}$ = 200 GeV taken at the BRAHMS experiment in 2004. The analysis is constrained to looking at central (0-20%) collisons. Furthermore for this work four rapidity bins were selected for analysis, specifically y=[-0.1;0.1], [0.7;1.0], [1.5,2.4], [2.8,3.2].

In figure 1 the invariant proton and deuteron spectra for all four rapidity slices are presented. For the midrapidity slices also anti-proton and anti-deuteron spectra are presented in figure 1. The (anti-)proton spectra presented have been corrected for

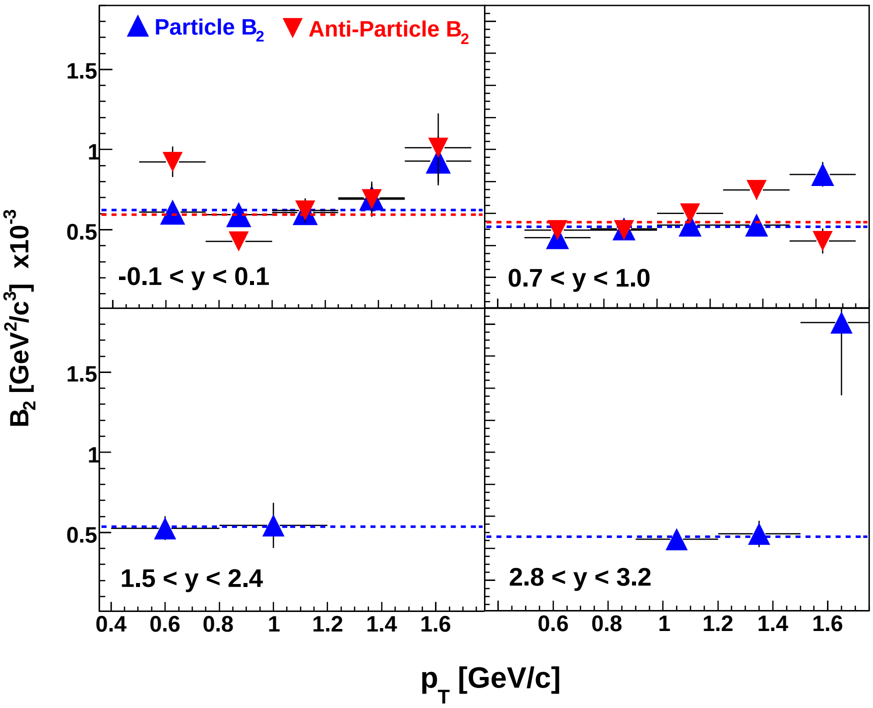

Figure 2. The coalescence parameter, B_2, as a function of transverse momentum, at four rapidity bins. Solid blue triangles denotes particle B_2 and solid red squares denotes anti-particle B_2. The dashed horizontal lines shows the weighted average of each set of points.

multiple scattering, absorbtion and weak decay. For the (anti-)deuteron spectra these corrections are work in progress. The vertical dashed lines in figure 1 illustrates the transverse momentum intervals used to construct B_2 for each spectrum. The difference in range for protons and deuterons stems from the fact that protons(/neutrons) at momentum X coalesce into a deuteron at momentum 2X, i.e. the deuteron range is twice the proton range.

Figure 2 shows the B_2 vs. p_T in each rapidity bin. B_2 is found to be rising as a function of p_T for both particles and anti-particles at the first two rapidity bins (in accordance with previous experiments as stated previously). For forward rapidities this behaviour can not be concluded due to lack of deuteron statistics. The dashed lines in figure 2 corresponds fitting each set of points to find the weighted average. In this work the average of the p_T-dependant coalescence parameter for a certain rapidity bin will be used as the coalescence parameter for that rapidity bin.

Figure 3 shows B_2 at the various rapidity bins. The statistical errors on the BRAHMS points are shown as lines, whereas the error box shows the total error, i.e the statistical error plus an estimated systematic error of 10 %. Included in the figure are results deducted from the PHENIX experiment [5]. These points have been obtained in the same way as the BRAHMS points, i.e. by using their official data and making the

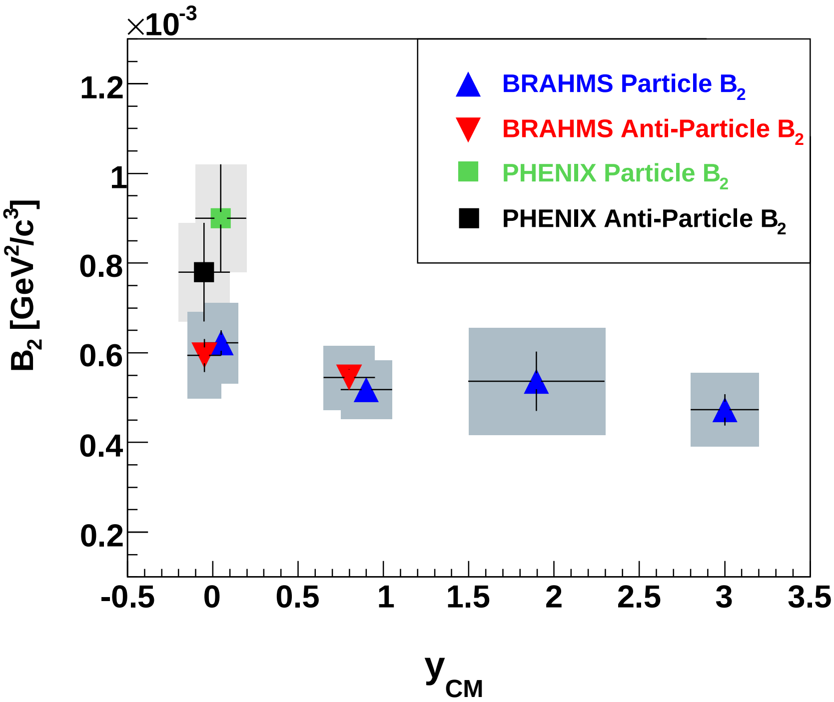

Figure 3. B_2 as a function of rapidity. This work is presented as blue (particle B_2) and red (anti-particle B_2) triangles, whereas the black/magenta square stems from previous PHENIX measurements [5]. Errors on the BRAHMS points are statistical (bars) and the total error (boxes). For the PHENIX points, errors presented are the total error.

weigthed average. Hence the points in figure 3 are not published PHENIX results.

The deuteron coalescence parameter is found to be constant within errors at all four rapidity bins, as seen in figure 3. Furthermore no difference is found between the coalescence parameter for particles and anti-particles. This indicates that in the examined window of rapidity the volume of the collision at freezeout is comparable. Thus deuteron coalescence shows a similar rapidity independency, which is, amongst others, also found for the nuclear modification factor [6], identified particle elliptic flow [7] and Hanbury-Brown-Twiss radii [8].

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