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Experimental overview on flow observables in heavy ion collisions

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Abstract

This paper summarizes the experimental results on flow phenomena that were presented at Quark matter 2015, with a focus on new flow observables and correlations in small systems. The results presented include event-shape selected p_{T} spectra and v_n measurements, correlations between flow harmonics of different orders, study of factorization breakdown in two-particle correlations, and principal component analysis of two-particle correlations. Recent developments in investigation of collective effects in small collisions systems, namely, p+A, d+A and ^{3}He + A as well as in pp collisions are also presented.

Keywords: Heavy Ion Collisions, Quark Gluon Plasma (QGP), Harmonic Flow

1. Introduction

Flow measurements have lead to an understanding of the initial geometry, such as the initial energy density profiles, as well as the dynamical properties, such as the viscosity to entropy density ratio (η/s), of the medium produced in heavy ion collisions. However, sensitivity to both initial geometry and η/s acts as a double edged sword, and it is difficult to tightly constrain either of these using the traditional v_n measurements. To address this issue, several new flow observables have been recently developed, which are sensitive to one but not the other. The first measurements of these observables are discussed in this paper.

A quantum leap in the understanding of heavy ion collision took place a few years back with the realization that there are large event by event fluctuations in the collision geometry. Similarly, it is now realized that the event-plane angles Ψ_n which were previously assumed to be constant for a given event, have explicit dependence on p_{T} and pseudorapidity η. The first observables that measure these longitudinal and p_{T} dependent Ψ_n fluctuations are presented.

Recently, the measurement of flow like correlations in p+A collisions have resulted in intense debate on whether these effects are indeed collective in origin, or arise from initial geometry effects. Identifying the origin of these correlations, as well as determining how small a system size one can go to where such correlations are present, have been some of the most important questions in flow measurements. This has now been further investigated by several measurements of inclusive as well as identified charged hadron v_n measurements in pp, p+A, d+A and ^{3}He + A collisions, which are discussed in this paper.

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2. Measurements

2.1. Event-shape selected v_n measurements

Measurements of event-by-event v_n distributions in heavy ion collisions have shown that even within a narrow centrality class, there is considerable variation in the initial geometry, due to fluctuations in the positions of the colliding nuclei [1]. These fluctuations lead to variations in the v_n within a typical 5% wide centrality class, that are comparable to the variation in the mean v_n across all centralities. Traditionally for flow measurements, the centrality has been used as a proxy for event-geometry, which leads to intermixing of event-shape dependent effects with event-size dependent effects. Recently it was proposed to perform measurements, when selecting both on the centrality as well as the geometry of a given event [2]. Such "Event-shape selected" v_n measurements reveal several hidden correlations between the flow harmonics and improve our understanding of the hydrodynamic response to the initial geometry . Detailed event-shape selected flow measurements were recently performed in Pb+Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV by the ATLAS [3] and ALICE collaborations [4]. In the ATLAS measurements, the selection on the geometry of the event was done by measuring the integrated v_n (called q_n) in the ATLAS Forward calorimeter (3.2< $|\eta|$ <4.9), and categorizing the events into classes of event-ellipticity or triangularity based on the q_2 and q_3 respectively. The v_n were measured using the ATLAS inner detector covering $|\eta|$ <2.5, thus ensuring that the same set of particles are not used to select on the event-shape and to perform the v_n measurements. In the ALICE measurements, a similar strategy was employed.

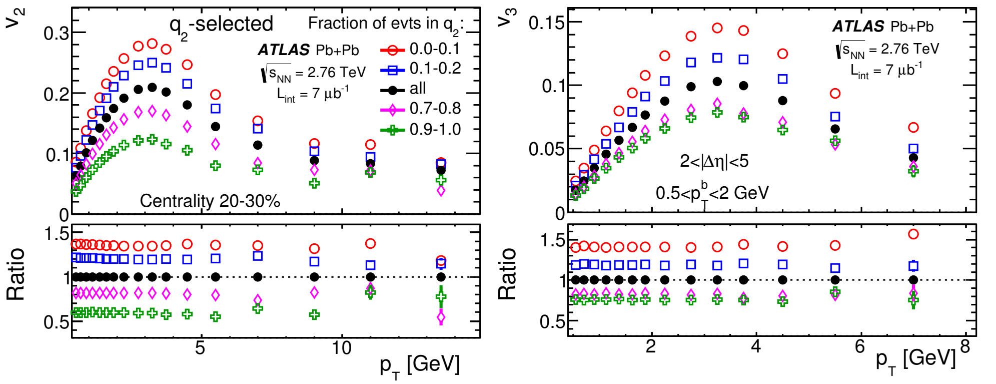

Fig. 1. The v_2 (left panel) and v_3 (right panel) as a function of p_T in the (20-30)% centrality interval. The different graphs correspond to different q_2 (left panel) and q_3 (right panel) classes. The q_n ∈(0.0-0.1) corresponds to the 10% of the events with the largest q_n, while the q_n ∈(0.9-1.0) corresponds to the 10% of the events with the smallest q_n. The solid black points correspond to the inclusive case (*i.e.* when not binning in q_n). The lower sub-panels shows the ratio of the different q_2 (q_3) to the inclusive v_2 (v_3). Figure taken from [3].

Figure 1 shows the $v_2(p_T)$ (left panel) and $v_3(p_T)$ (right panel) when selecting on different q_2 and q_3 classes respectively, within the (20–30)% centrality interval. It is seen, perhaps trivially, that selecting events with a larger $q_2(q_3)$ leads to events with larger $v_2(v_3)$. This simply implies that events with larger v_n at forward rapidity have larger v_n at mid-rapidity. The interesting observation is actually seen in the lower panels which show the ratio of the q_n selected v_n to the inclusive v_n for the (20–30)% centrality class. This ratio is almost independent of p_T up to ~10 GeV for v_2 and up to ~5 GeV for v_3. This shows that for a fixed centrality (or system-size) when one picks events with different collision geometries, the increase or decrease in the v_n is independent of the p_T . This implies that the hydrodynamic response in heavy ion collisions factorizes into an initial geometry dependent part and a p_T dependent part. Further, this also implies that the viscous effects in heavy ion collisions are controlled by only the system-size and not the system-shape. Had viscous effects been larger (or smaller) in events with larger ellipticity or triangularity, then these ratios would not be independent of p_T .