Elliptic flow (v_2) in pp collisions at LHC : A hydrodynamical approach

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Introduction

The elliptic flow, v_2 has been suggested as a signature of collective expansion in ultrarelativistic nuclear collisions. In heavy ion collisions the v_2 is used to determine the collective properties of the system, e.g. thermalization, EOS, viscosity[1]. The ideal hydrodynamics is applied to the system formed in heavy ion collisions at RHIC assuming the local thermilization which is achieved as the mean free path of the system is much shorter than the system size. At Large Hadron Collider (LHC) enrergies, in pp collisions the achieved energy density might be comparable to the energy density in Au+Au collisons at RHIC and the theoretical treatment based on hydrodynamical expansion can be applicable. We have applied the hydrodynamic evolution to the system formed in pp collisions at $\sqrt{s}$= 14 TeV.

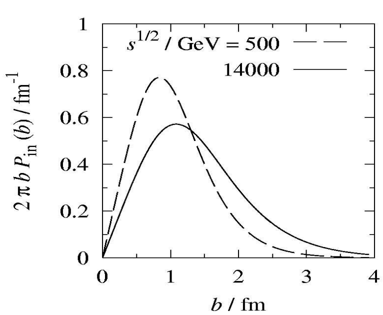

FIG. 1: The normalized impact parameter distribution for generic inelastic collisions, $P_{in}(s,b)$, obtained with the parametrization of the elastic pp amplitude of Islam et al. [3]

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The hydrodynamical model and the simulation

The publicly available AZYHYDRO code[2] has been used for this study. The initial transverse energy profiles parametrized geometrically by using an Optical Glauber model calculation in such a way that the experimentally observed p_t spectra of charged pions in pp collisions at $\sqrt{s}$ = 200 GeV is reproduced. For the Glauber calculation the density distribution of the colliding protons are described by the Wood-Saxon profiles,

$$\rho(r) = \frac{\rho_0}{1 + e^{(r-R)/\xi}} \quad (1)$$

with the proton radius R and the surface diffuseness parameter ξ. The parton-proton thickness function is,

$$t_1(x,y) = \int dz \rho(x,y,z) \quad (2)$$

For a non-central collision of impact parameter B, the energy density profile is calculated as,

$$\epsilon_i(x,y) = \epsilon_0 t_1(x+\frac{B}{2}) t_2(x-\frac{B}{2}) \quad (3)$$

The values of R and ξ, are determined from the fit values of the normalized impact parameter distribution for generic pp inelastic collisions, P_{in}(s,b), as shown in Fig. 1[3]. Where,

$$P_{in}(b) = \frac{(1-e^{-\sigma_0 t_{1,2}(\vec{b})})}{\int d^2\vec{b}(1-e^{-\sigma_0 t_{1,2}(\vec{b})})} \quad (4)$$

σ_0 is the parton-medium cross-section,
$t_{1,2}$ is the proton-proton thickness function.

$$t_{1,2}(B) = \int dxdy t_1(x+\frac{B}{2},y) t_2(x-\frac{B}{2},y) \quad (5)$$

B is the impact parameter, $t_1(b) = t_2(b)$ is the parton-proton thickness function. We have used R = 1.05 fm. The two different values of surface diffuseness parameters viz. $\xi_1 = 0.25$ fm and $\xi_2 = 0.105$ fm, have been used in this study.

We have used the equation of states (EOS) provided in the code AZYHYDRO named “EOS Q” incorporating a first order phase transition at critical temperature, T_c=164 MeV. We apply the Cooper-Frye formalism[4] to calculate the particle spectra at the freeze-out hypersurface. We have taken the initial time, $\tau_i = 0.6$ fm/c and the freeze-out temperature $T_{dec} = 150$ MeV.

For estimating the initial energy density,ϵ_i, we fit the the particle spectra for pp collisions at 200 GeV (RHIC data), calculate the $\frac{dN}{dy}$, extrapolate this $\frac{dN}{dy}$ for $\sqrt{s}$ = 14 TeV assuming the logarithmic dependence on $\sqrt{s}$. and then increase the initial energy density to get the extrapolated $\frac{dN}{dy}$. The energy density ϵ_i=20 GeV/fm^3 and ϵ_i=25 GeV/fm^3 produces the required $\frac{dN}{dy}$ with ξ=0.25 and ξ=0.105 respectively.

Results

We compute the final spectrum of particles from the standard Cooper-Frye formalism The mean p_t and the $\frac{dN}{dy}$ are computed from the particle spectra. For non-zero impact parameter, the azimuthal distribution of the particles in the reaction plane is not symmetric in ϕ. We can decompose the distribution in terms of Fourier expansion as,

$$E\frac{d^3N}{d^3p} = \frac{d^2N}{2\pi p_t dp_t dy} \times (\sum(1 + 2v_n cos(n\phi'))) \quad (6)$$

where, ϕ' is the angle of azimuth of the outgoing particle w.r.t. reaction plane. The coefficient of the second term in the Fourier expansion is known as elliptic flow, v_2. Fig.2 shows the impact parameter dependence of the p_t integrated elliptic flow. The elliptic flow, as a function of p_t for integrated impact parameter is shown in Fig.3. The value of elliptic flow, v_2, is different for different diffuseness parameters. One value of ξ gives

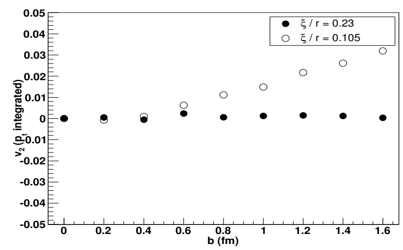

FIG. 2: The integrated elliptic flow, v_2 of π^- as a function of impact parameter for pp colisions for ξ = 0.25 (filled circle) and for ξ = 0.105 (hollow circle).

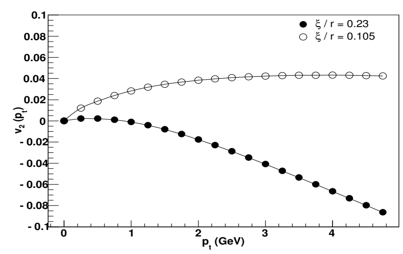

FIG. 3: The elliptic flow, v_2 (p_t) of π^- for pp colisions averaged over all the impact parameter for ξ=0.25 (filled circle) and ξ=0.105 (hollow circle).

negative v_2 whereas the other value gives a finite positive v_2 for pp collisions at $\sqrt{s}$ = 14 TeV. The finite v_2 indicates the collective behavior of the system. The details of the simulation and the results will be presented.

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