# Modeling initial condition for Proton-Proton collisions at LHC energies

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## 1. Introduction

Results of relativistic proton-proton ($p+p$) collisions are used as reference or base line for interpreting various results of heavy ion collisions at relativistic energies, which are aimed at creation and characterization of phases of strongly interacting matter governed by Quantum Chromodynamics (QCD), e.g., Quark-Gluon Plasma (QGP). For interpretations of experimental results of relativistic heavy ion collisions to characterize QGP, it is assumed that, in $p+p$ collisions, no intermediate partonic medium is formed. However, recent results show that such assumptions may not be correct for high multiplicity $p+p$ collisions. In this regard, for understanding dynamics of QCD medium formed in relativistic heavy ion collisions, it is very crucial to understand results of $p+p$ collisions. For understanding underlying physics, and for characterizing the possibly formed medium in these collisions by using theoretical models, proper estimation of initial condition for such collisions is crucially important. In this work, we present the results of Glauber-like model calculations to obtain charged particle multiplicity distribution in $p+p$ collisions at $\sqrt{s} =$ 7 TeV. Calculated multiplicity distribution is contrasted with ALICE data, a relation of impact parameter with multiplicity is estimated and multiplicity distribution of flow harmonics is estimated for $p+p$ collisions.

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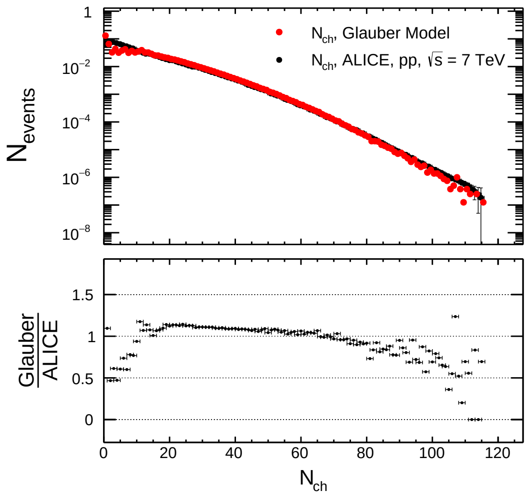


FIG. 1: Color online) Upper panel: Comparison of charged multiplicity distribution obtained from present work and ALICE experiment for $p+p$ collisions at $\sqrt{s} = 7$ TeV. Black dots represents ALICE data and red dots represents the present work. Lower panel: Ratio of this work to the ALICE experimental data [1].

## 2. Formalism

In this study, we have used a model inspired by the shape of deep inelastic scattering structure functions with fluctuating proton orientation and it has three effective quarks and gluonic flux tubes connecting them. The densities of quarks ($\rho_q$) and gluons ($\rho_g$) are taken as Gaussian type assuming spherically symmetric distribution of quark densities from its respective centers and cylindrically symmetric gluon densities about the line joining two

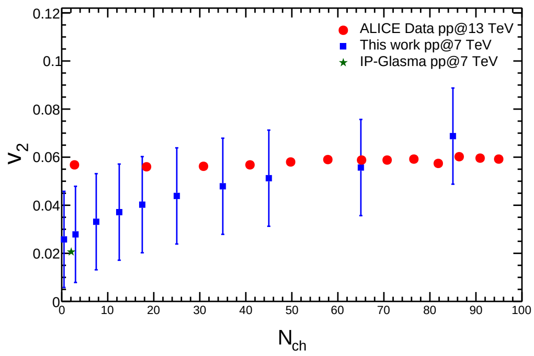


FIG. 2: Elliptic-flow, $v_2$ as a function of final state multiplicity density in $p+p$ collisions at LHC energies [1].

adjacent quarks as [2]

$$\rho_q(\mathbf{r};r_q) = \frac{1}{(2\pi)^{3/2}r_q^3}e^{-\frac{r^2}{2r_q^2}} \quad (1)$$

$$\rho_g(\mathbf{r};r_s,r_l) = \frac{1}{(2\pi)^{3/2}r_s^2 r_l}e^{-\frac{x^2+y^2}{2r_s^2}-\frac{z^2}{2r_l^2}} \quad (2)$$

where, $r_q$ is the radius of the quark, $r_s$ and $r_l$ is the radius and the length of the gluon tube.

The collision plane is taken to be in $x-y$, hence dependence along $z$-axis is integrated out as follows: $T(x,y) = \int \rho(x,y,z)dz$. The overlap function $T_{pp}(b)$ for projectile proton (**A**) and target proton (**B**) is defined as $T_{pp}(b) = \int\int T_A(x-\frac{b}{2},y)T_B(x+\frac{b}{2},y)dxdy$. Here $T_{pp}$ is sum of 4-components, namely quark-quark, quark-gluon, gluon-quark, gluon-gluon. Detailed calculation can be found in our recent paper [1]. We have also calculated eccentricity ($\epsilon$) using the present approach defined as $\epsilon(b) = \frac{\int(y^2-x^2)n_{coll}(x,y,b)dxdy}{\int(y^2+x^2)n_{coll}(x,y,b)dxdy}$, where, $n_{coll}(x,y,b) = \sigma_{gg}T_a(x-\frac{b}{2},y)T_b(x+\frac{b}{2},y)$ represents impact plane binary collision density. Using $\epsilon$, we have obtained elliptic flow ($v_2$) as a function of $n_{ch}$ by considering $v_2$ scaling i.e., $v_2 = \Omega\epsilon$, where $\Omega = 0.3 \pm 0.02$.

## 3. Results and Discussion

It is evident from Fig. 1, that this model well describes the data in the mid multiplicity region ($15 < N_{ch} < 90$), with 5-10 % discrepancy. However, towards the low and high multiplicity it is unable to reproduce the experimental measurement. The inability of the model to explain the extreme low and high multiplicity region might be due to lack of statistics.

In Fig. 2, It is observed that for $N_{ch} \gtrsim 8$, our estimation of $v_2$ with linear response to initial geometry reproduces the value obtained from experiment within the error bars. However, for lower multiplicities, our estimation with linear response to initial eccentricity falls short to that obtained from experimental data. This may be due to effects other than collective linear response or final state effects. We also note that this model gives $v_2$ similar to that of the IP-Glasma model estimation for low multiplicity region ($< 8$). We strongly believe that in view of the final state multiplicity scalings observed at the LHC energies and the importance of high-multiplicity $p+p$ collisions in creating possible QGP-droplets [3], this work bears high level of importance to the community.

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## References

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