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Phenomenological Study of Impact Parameter Dependence in PYTHIA 8

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Abstract. PYTHIA8 predictions are used to study impact parameter dependence in different matter overlap approaches implemented in the PYTHIA8.2 Monte Carlo event generator. It is regulated by some free parameters that need to be tuned to compare their behaviour. The first approach shows no impact parameter dependence, Second option is a simple Gaussian matter distribution with no free parameter. Whereas the other three options have free parameters which were tuned and results were compared with the first two options. It is shown that it is impossible to describe the data without matter overlap consideration. It is observed that double Gaussian gives a better description of minimum bias data among all the five approaches. These types of model/approach studies are important to see their impact on data description which in returns help to improve the implemented physics model.

1 Introduction

PYTHIA is a general purpose event generator [1] for high energy particle collisions, based on the phenomenological concepts used to simulate soft and hard processes, where hard/soft refers to interactions with high/low pT transfer between the scattering particles. These interactions require description of parton showers, multiparton interactions, and string fragmentation processes as well. To simulate these processes PYTHIA8 employed different model options for each physics process to describe data well. In this paper we present a study of different model options of impact parameter dependence provided by PYTHIA 8.3.

Protons, like all hadrons, are not pointlike particles. They have a substructure and their constituent particles, quarks and gluons, are collectively called partons. Events are distributed in impact parameter b.There is an overlap of hadrons during collision, overlap function describe to what extent two hadrons can overlap with each other spatially, in order to determine how it affects the number of multiparton interactions. When protons interact with each other at high energy in a particle accelerator there is enough energy to have the individual partons (quarks and gluons) interact and produce new particles. In these interactions it

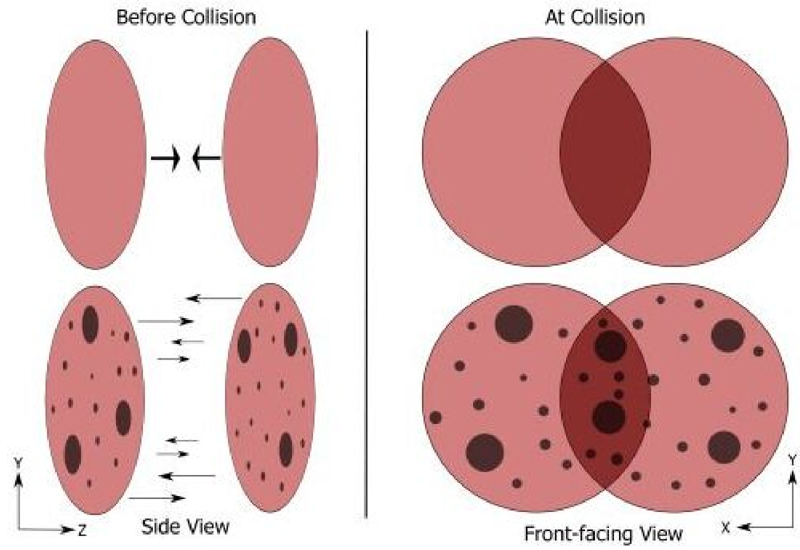

Figure 1. Schematic image of two protons colliding. Left side: side view of the protons approaching each other. The protons are represented as ovals due to lorentz contractions. Right side: the view along the beam pipe of an accelerator at the time of collision. The top row: the interaction between two protons without an internal structure. The bottom row: interaction with substructure. The dark circles represent partons, with smaller circles being sea quarks and gluons, while larger circles represent the valence quarks of the proton [3].

is possible to have more than one pair of partons interacting in the same proton-proton collision, known as multiparton interactions [2]. An example of this can be seen in Figure 1, where two protons are collided and their overlapping area represents the area where multiparton interactions can take place. As the number of interactions is directly related to the size of the overlap, that is why the overlap is extremely important in regards to multiparton interactions clearly seen from Figure 1, MPI is simply a representation of how many partons are available to interact with each other. Given all of this, it might be a surprise that native PYTHIA8 does not use an explicit geometrical picture to describe the collision [2]. It uses an implicit geometrical image of this scenario to derive the overlap function, which in turn is used to randomly pick the average number of interactions in any given event [3].

2 Impact Parameter Dependence

We considered five models provided by PYTHIA 8 [4] for the matter overlap in this study:

mode MultipartonInteractions:bProfile (default = 3)

Option 0: no impact parameter dependence at all.

Option 1: a simple Gaussian matter distribution; no free parameters.

Option 2: a double Gaussian matter distribution, with the two free parameters.

Option 3: an overlap function, the convolution of the matter distributions of the two incoming hadrons

Option 4: a Gaussian matter distribution with a width that varies according to the selected x value of an interaction.

3 Results

The list of selested observables of Minimum Bias events measured at ATLAS experiment are given in Table 1 at 7 TeV. The comparison between data and MC for average pt vs Charged particle multiplicity Nch is given in Figure 3 for four bprofile options. This is a very sensitive observable of Minimum Bias event and almost equally well described all the three different models. First option with no matter distribution is just for the study purpose to see the difference otherwise practically this option can not be used as it not favoured by the experimental data. This effect is clearly seen in Figures 3, 4 and 5. The third option (bProfile=2) which is double Gaussian matter distribution provides better description of data. Charged particle multiplicity can not be described without considering matter overlap (bProfile=0) shown in Figure 5.

Table 1. List of observables of minimum bias event data at 7 TeV [2]

Observable	**ATLAS minimum bias event data**	**ECM**
Nch	Track Pt $>$ 500 MeV, Nch $\geq$ 1	0.9 TeV
Pt	Track Pt $>$ 500 MeV, Nch $\geq$ 1	0.9 TeV
Eta	Track Pt $>$ 500 MeV, Nch $\geq$ 1	0.9 TeV
$\langle$Pt$\rangle$ vs Nch	Track Pt $>$ 500 MeV, Nch $\geq$ 1	0.9 TeV
Nch	Track Pt $>$ 500 MeV, Nch $\geq$ 6 (diffraction suppressed)	0.9 TeV
Pt	Track Pt $>$ 500 MeV, Nch $\geq$ 6 (diffraction suppressed)	0.9 TeV
Eta	Track Pt $>$ 500 MeV, Nch $\geq$ 6 (diffraction suppressed)	0.9 TeV
Nch	Track Pt $>$ 500 MeV, Nch $\geq$ 1	7 TeV
Pt	Track Pt $>$ 500 MeV, Nch $\geq$ 1	7 TeV
Eta	Track Pt $>$ 500 MeV, Nch $\geq$ 1	7 TeV
$\langle$Pt$\rangle$ vs Nch	Track Pt $>$ 500 MeV, Nch $\geq$ 1	7 TeV
Nch	Track Pt $>$ 500 MeV, Nch $\geq$ 6 (diffraction suppressed)	7 TeV
Pt	Track Pt $>$ 500 MeV, Nch $\geq$ 6 (diffraction suppressed)	7 TeV
Eta	Track Pt $>$ 500 MeV, Nch $\geq$ 6 (diffraction suppressed)	7 TeV

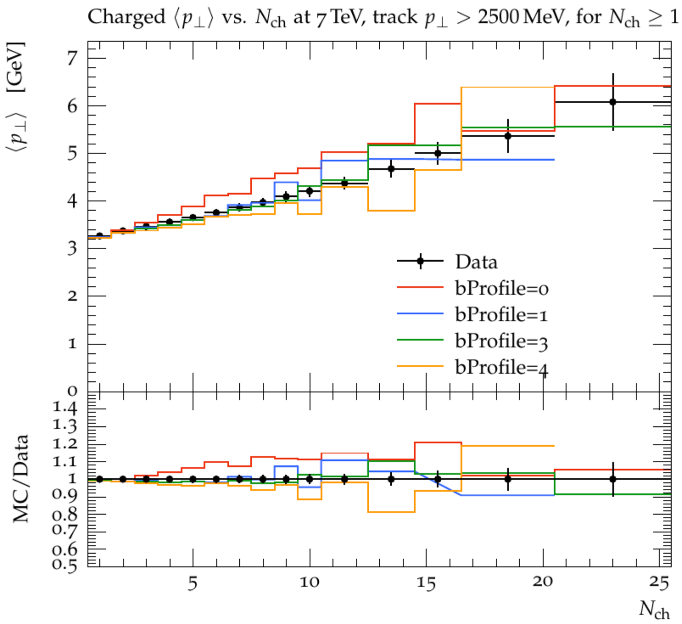

Figure 2. Data / MC comparison of average pt vs Charged particle multiplicity Nch, Minimum bias event at 7 TeV.

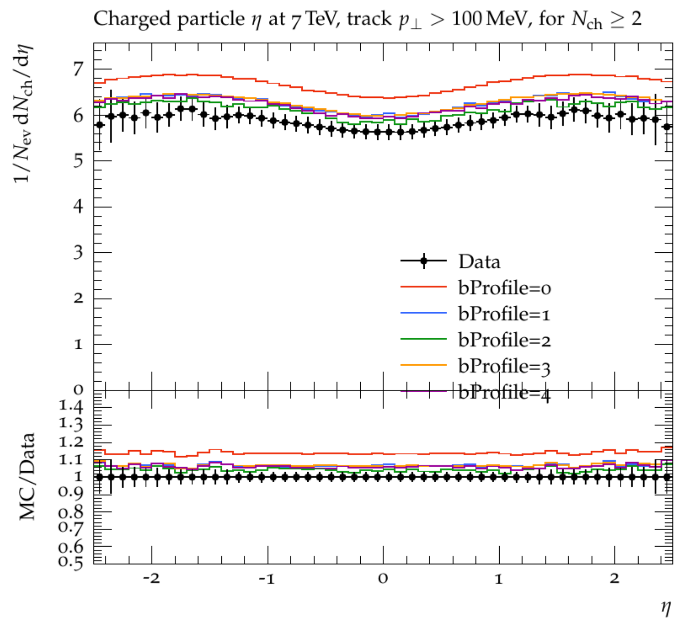

Figure 3. Data / MC comparison of eta distribution, Minimum bias event at 7 TeV.

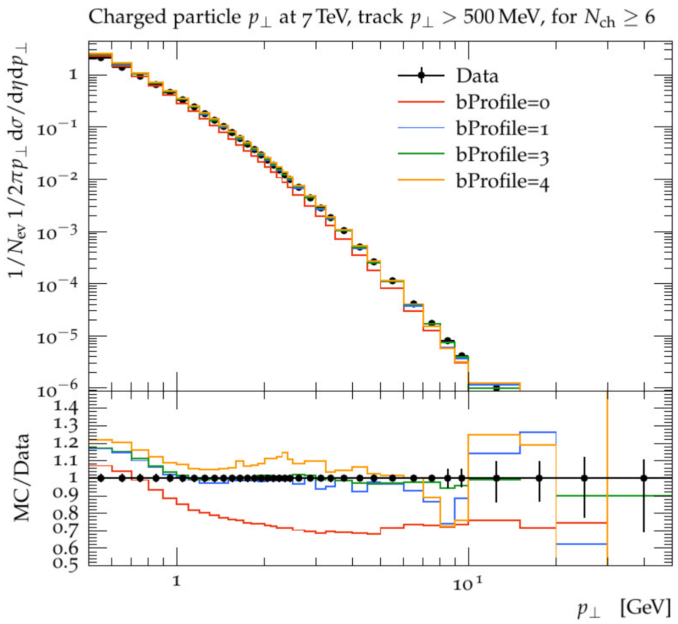

Figure 4. Data / MC comparison of pt distribution, Minimum bias event at 7 TeV.

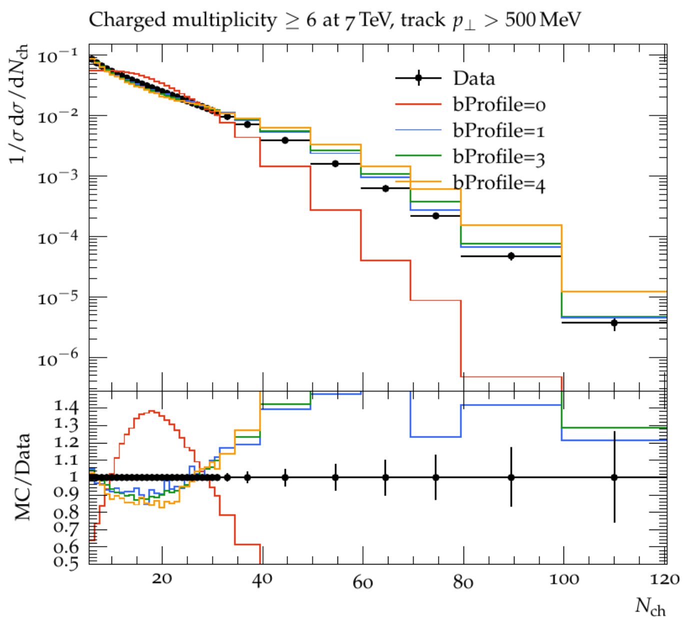

Figure 5. Data / MC comparison of Charged particle multiplicity Nch distribution, Minimum bias event at 7 TeV.

4 Conclusion

We have presented the results of five different model option for matter overlap disribution including no matter overlap option on the sensitive observables of Minimum Bias events, measured by the ATLAS experiment at the 7 TeV. Data / MC comparison shows that double Gaussian matter overlap distrbution provides best results as compared to other model options. This study is done with the default settings [5] and agreement between MC and experimental data can be further improved by tuning the free parameters of the selected models [6,7]. All plots used in this study are generated using Rivet toolkit [8].

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