Investigation of phenomenological models implemented in PYTHIA6

Nameeqa Firdous\textsuperscript{1,a}, Gerald Rudolph\textsuperscript{1}

\textsuperscript{1} Institute of Astro and Particle Physics, University of Innsbruck, Austria

Abstract. Different phenomenological models implemented in PYTHIA6 using best fit to Minimum Bias (MB) data published by ATLAS experiment at two center of mass energies 0.9 TeV and 7 TeV are investigated.

1 Introduction

PYTHIA is highly successful and well established Monte Carlo event generator and developed over the past decades with the experimental discoveries. It can describe most of the features observed in past and present experiments. The core of PYTHIA's model for soft hadronic interactions is based on a phenomenological adaptation of QCD to describe the non perturbative pp processes \cite{1}. In this work we studied different Physics models given by PYTHIA6 to describe their behavior at high energies and to improve our preliminary tunes \cite{6}. PYTHIA6 offers variety of Physics models which can be selected with the so called switches. Each model is defined by certain parameters which are mostly free and need to be tuned. We investigated selected models by tuning their free parameters using ATLAS Minimum Bias (MB) published data \cite{3} at two center of mass energies, 0.9 and 7TeV. The model combination investigated are shown in Figure 1. The choice of models as well as their combinations are totally arbitrary.

2 MPI Model

Since the proton or any other hadron is a composite object, in a head on collision of two hadron there is a probability that more than one pair of partons undergo scatterings, resulting in a higher multiplicity compared to events with only one strong interaction. PYTHIA6 offer this model with the switch MSTP(81).

- For MSTP(81)=0, MPI is switched off.
- For MSTP(81)=21, MPI is switched on with new scenario of multiple parton interactions, interleaved with ISR, and pt as ordering variable

Studies of the average particle transverse momentum $p_T$ as a function of the events charged particle multiplicity $N_{\text{ch}}$, Figure 2, demonstrates that models fail to describe the data if the possibility of multiple parton interactions is neglected. This observable is sensitive to the presence of MPI since a higher multiplicity, which is a result of MPI, result in a lower average $p_T$. In the absence of MPI the average $p_T$ shows harder spectrum. The low activity can also be seen in the multiplicity distribution. If MPI is switched on the model describes the data convincingly well.

3 Lambda Treatment

PYTHIA6 provides possibilities to select the same $\Lambda_{\text{QCD}}$ in the definition of alpha evolution for ISR, ME and FSR as well as three different values. The switch MSTP(3) gives the control over the selection of lambda values.

- For MSTP(3)=2, $\Lambda_{\text{QCD}}$ value is chosen according to the parton distribution function parameterizations. Then...
For MSTP(3) is unable to describe data as shown in Λ values
MSTP(95) Comparison plots showing two option for Multiple
Λ values can be chosen by the user.
MSTP(82) value for all parts of the
Λ Comparison plots showing two options for Matter
80
MSTP(82)
60
Figure 2. Comparison plots showing two option for Multiple
parton interaction model
Figure 3. Comparison plots showing two options for Matter
overlap

same Λ_{QCD} value is used both for the hard scattering and the
initial and final state radiation.
• For MSTP(3)=1, Λ_{QCD} values can be chosen by the user.
Multiplicty and Pt distributions show that model with single
value of Λ_{QCD} is unable to describe data as shown in
Figure 4. This fit is done using CTEQ5L PDF, so the value
passed to the all three lambda is 0.192 GeV. Fit results
show that to describe data well Lambda value for FSR is
quite high around 0.5GeV where as value for ME is lower
than 0.192 GeV. The Lambda for ISR is not sensitive to
the MB data. Because of physics approximations used in
event generator like PYTHIA6, it is not possible to de-
scribe data with the same value of QCD at different parts
of the program.

4 Matter Distribution
The amount of scatterings is described by a matter over-
lap distribution between the two protons, which regulates
how many central hard scatterings and how many less cen-
tral softer scatterings happen. Two options of matter dis-
tribution are investigated with varying impact parameter
approach.
• MSTP(82)=4, hadronic matter overlap consistent with a
double Gaussian matter distribution.
• MSTP(82)=5, hadronic matter overlap consistent with
an interpolation between a Gaussian and an exponential
distribution.
This model effects shape of multiplicity and Pt as well
shown in Figure 3. Double Gaussian describe data well for
central eta values but for higher eta MC is well below the
data opposite effect can be observed for other option. The
approach which interpolates between Gaussian and expo-
nential distribution looks favored by data as compared to
double Gaussian approach.

5 Color Reconnection
The switch MSTP(95) gives control over selection of
method for color reconnection in the final state. Three
choices are studied to see their impact on data.
• MSTP(95)=0, gives no color reconnection
• MSTP(95)=6, gives the total probability for a string
piece to survive the annealing and preserve its original
color connections.
• MSTP(95)=8, calculates the reconnection probability
for each individual string piece by using the average
string density in the region spanned by that string piece
[5].
The pt distribution and average pt vs multiplicity (Nch),
shown in Figure 5 appears to be sensitive to the color struc-
ture of the events, within the framework of the PYTHIA6
modeling. Pt distribution is badly described and average
Pt shows quite soft spectrum when CR is switched off.
It is clear from plots that to describe data CR should be
switched on. The remaining two model choices describe
data equally well except at the higher pt tail where the first
choice MSTP(95)=6 seems better than other choice.

6 Conclusion
Different options of selected physics models offered by
PYTHIA6 are investigated using best fit to ATLAS MB
data at two energies. New scenario for MPI model should
be switched on to get reasonable results for hadron hadron
collision data. The MO option with an interpolation be-
tween a Gaussian and an exponential distribution is fa-
vored by data as compare to the double Gaussian distribu-
tion, though the difference is not much but visible at low
PT and also at low multiplicity. Without the color recon-
nection model the Pt spectrum is too soft. The other two
options for CR model do not show significant differences
in the predictions. Monte Carlo simulations are unable
to describe data with one Λ_{QCD} value for all parts of the
event generation. To describe proton proton collision data
at high energies, the model with adjustable Λ_{QCD} values
should be used. All plots are produced using Rivet toolkit [4].

References

[1] Torbjörn Sjöstrand, Stephen Mrenna, and Peter Z. Skands. PYTHIA 6.4 Physics and Manual. JHEP, 05:026, 2006.

[2] R. Barate et al. Studies of quantum chromodynamics with the ALEPH detector. Phys.Rept., 294:1–165, 1998.

[3] G. Aad et al. Charged-particle multiplicities in pp interactions measured with the ATLAS detector at the LHC. New J.Phys., 13:053033, 2011.

[4] Andy Buckley, Jonathan Butterworth, Leif Lonnblad, Hendrik Hoeth, James Monk, et al. Rivet user manual. 2010.

[5] Peter Zeiler Skands. Tuning Monte Carlo Generators: The Perugia Tunes. Phys.Rev., D82:074018, 2010.

[6] Nameeqa Firdous and Gerald Rudolph. PYTHIA MPI model tuning to hadron collider data: Preliminary results. Nucl.Phys.Proc.Suppl., 207-208:73–76, 2010.