Minimum Bias at LHCb
Proceedings

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Abstract
The LHCb detector covers a rapidity region complementary to the ATLAS and CMS central detectors. Through its measurements on Minimum Bias events LHCb can contribute to determine the effects of the Multi Partonic Interactions in proton-proton collisions at the LHC centre of mass energy.

1 The LHCb experiment

LHCb is a dedicated beauty physics experiment at the LHC accelerator [1]. Advantages of performing a beauty experiment at the LHC proton collider are related to the high value of the quark beauty production cross sections available,which is expected to be of the order of $500\mu\mathrm{b}$ at the 14 TeV energy of the colliding beams. Moreover, running at the LHC accelerator LHCb will have the opportunity to access all the b-hadrons as B_d, B_s and B_c being produced.
Due to the expected tracks multiplicity the challenge of the LHCb experiment is of performing the exclusive reconstruction of the interesting B signals and the tagging of the B flavour in the forward region. In fact, since the differential beauty production cross section peaks at small θ angles with respect to the beam line, with small relative opening angles between the b quarks pairs, the LHCb detector has been instrumented to cover the forward region between 15 mrad $< \theta <$ 300 mrad, covering a rapidity region complementary to the ATLAS and CMS central detectors as shown in Figure 1.
The LHCb detector has been built as single arm spectrometer, equipped with a vertex detector (VELO) [2] and a tracking system [3], [4] for good mass resolution and very precise proper time measurements of the B secondary vertexes. Excellent particle identification capabilities are provided instead by the two RICH detectors [5], by the calorimeter system [6] and by the muons detector [7].
Due to the high rate of background events (the inelastic cross section is estimated to be of the order of 80 mb), the LHCb detector has been equipped with a selective and efficient trigger system, structured in two levels [8]. The first level, called the Level Zero Trigger (L0), implemented on custom electronics, aims selecting those events presenting high p_T momentum particles in the final state. The L0 trigger will have to sustain an input rate of 40 MHz to select events at the maximum output rate of about 1 MHz. The High Level Trigger (HLT) is a software trigger, running at the input rate of about 1 MHz, with event size of the order of 50 kB/evt, and a max output rate set to about 2 kHz. The HLT is implemented by means of selection algorithms running on the on-line PC cluster [9], [10].

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LHCb will run at a reduced instantaneous luminosity with respect to the max LHC capabilities, in the range $2 \div 5 \times 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, which will allow to maximise the probability of single interaction per bunch crossing, easing the reconstruction of the B secondary vertexes.

1.1 Multi Partonic Interactions tuning in Pythia and minimum bias events

Pythia is the main event generator used by the LHCb collaboration to simulate primary proton-proton collisions at the LHC energy. The composite nature of the two colliding protons implies the possibility, modelled in Pythia, that several pairs of partons can enter into separate and simultaneous scatterings, such that Multiple Partonic Interactions (MPI in the following) can take place (in particular at low transverse momentum) contributing to the overall event.
Tuning of the Pythia MPI parameters has been carried out in LHCb since Pythia version 6.1 up to version 6.3, although LHCb is currently using for its simulations the new Pythia version 6.4. Amongst the MPI models provided by Pythia LHCb selected the so called Pythia "model 3", which simulates the proton-proton collisions by varying the impact parameter, assuming hadron matter overlap consistent with a Gaussian matter distribution and assuming a continuous turn-off of the cross-section as a function of the transverse momentum, down to the minimum value of transverse momentum cut-off $p_{\perp\mathrm{min}}$.
The transverse momentum cut-off plays a very important role in the model since it affects the average number of interactions per collision, according to the relation:

$$n_{\mathrm{mean}}(s) = \frac{\sigma_{hard}(p_{\perp\mathrm{min}})}{\sigma_{nd}(s)} \tag{1}$$

where $\sigma_{hard}(p_{\perp\mathrm{min}})$ represents the hard interaction cross-section, while $\sigma_{nd}(s)$ is the non-diffractive cross-section.
The charged multiplicities produced per collision also have a strong dependence on $p_{\perp\mathrm{min}}$: lowering the $p_{\perp\mathrm{min}}$ increases the average number of multiple interactions in an event and therefore increases the average charged multiplicity.
The energy dependence of $p_{\perp\mathrm{min}}$ is assumed to increase, in the same way as the total cross section, to some power low as:

$$p_{\perp\mathrm{min}}(s) = PARP(82)\left(\frac{\sqrt{s}}{PARP(89)}\right)^{2PARP(90)} \tag{2}$$

where the $p_{\perp\mathrm{min}}$ dependence on $\sqrt{s}$ has been expressed in terms of the PARP Pythia parameters. On the other end we also know that the energy dependence of the mean charged multiplicity of minimum bias events at hadron collider phenomenologically is well described by a quadratic logarithmic form:

$$\left.\frac{dN_{ch}(s)}{d\eta}\right|_{|\eta|\leq 0.25} = A\ln^2(s) + B\ln(s) + C \tag{3}$$

In order to estimate the average multiplicity of minimum bias events at the LHC energy we tune the value of $p_{\perp\mathrm{min}}$ to reproduce charged multiplicity data from established hadron collider experiments to then extrapolate $p_{\perp\mathrm{min}}$ to 14 TeV. We can rely on the measured values of the charged particle densities $\rho_{\rm exp}$ in the central region of pseudo-rapidity, measured in proton-antiproton collisions performed at energies up to 1.8 TeV, available from the UA5 and CDF experiments:

$$\rho_{\rm exp}(s) = \frac{dN_{ch}(s)}{d\eta}|_{\eta=0} \tag{4}$$

Table 1 shows the values of the charged multiplicities measured in the central pseudo-rapidity region, corresponding to the range of $|\eta| \leq 0.25$.

It is worth to mention that to properly set the value of the relevant Pythia parameters in LHCb we also take into account the need of reproducing the production of B-mesons through orbital exited states. According to the measurements performed at LEP and Tevatron many of the B-mesons that will be produced in primary collisions at LHC are expected to be orbital exited states. Inclusion of the B-meson exited states is important for LHCb in order for studying and optimising the tagging algorithms.

The parameters affecting the production of B-mesons exited states affect the average multiplicity of minimum bias events, since some settings are shared between the heavy and light flavoured mesons in the hadronization model. The addition of orbital excited meson states increases the multiplicity produced by Pythia at all the energies at each the primary collisions would take place. The parameters affecting the the production of B-mesons have been set to reproduce the measured B-meson fraction and LEP B^{**} spin counting, measured in the produced B-hadrons.

Pythia is then used to generate non-single-diffractive events at the various centre of mass energies, corresponding to the centre mass energy values of the available measurements of the UA5 and CDF collaborations listed in Table 1. At a given centre of mass energy the value of $p_{\perp \rm min}$ parameter is varied over suitable ranges, such that the simulated charged multiplicities spreads over two standard deviations around the measured value. The linear fit of the charged multiplicity vs the $p_{\perp \rm min}$ to determine the best value of $p_{\perp \rm min}$ is performed using MINUIT.

An example of the best fit of the charged average track multiplicity estimated with Pythia as a function of $p_{\perp \rm min}$ at the centre of mass energies of 546 Gev is shown in Figure 2. The value of $p_{\perp \rm min}$ is obtained by inverting the fitted line. Sufficient events were generated such that the uncertainty on the fitted values is unaffected by the Monte Carlo statistical errors.

To extrapolate the value of $p_{\perp \rm min}$ to the LHC energy a fit of the $p_{\perp \rm min}$ dependence on the centre of mass energy is performed using the form suggested by Pythia:

$$p_{\perp \rm min}(s) = p_{\perp \rm min}^{\rm LHC} \left(\frac{\sqrt{s}}{14\ TeV} \right)^{2\epsilon} \tag{5}$$

The best fit of the $p_{\perp \rm min}$ as a function of the centre mass energy is shown in Figure 3. The value of $p_{\perp \rm min}$ we got using Pythia version 6.4 is of $p_{\perp \rm min}^{\rm LHC} = (4.28 \pm 0.25)\ GeV/c^2$, with $\epsilon = (0.119 \pm 0.009)$. By means of the extrapolated value of $p_{\perp \rm min}^{\rm LHC}$ it is then possible to use Pythia to predict the distribution of the charged multiplicity, the rapidity and momentum distribution of the particles produced in the interactions at the LHC energy.

The LHCb collaboration plans to collect large samples of untriggered events, running at the maximum rate of 2 kHz, sustainable by the data acquisition system.

Minimum Bias data-sets will be used to measure inclusive charged particles distributions, as for instance:

$$\frac{dN}{d\eta}, \frac{dN}{dp_\perp}, \frac{dN}{d\phi}, \frac{dN}{d\eta dp_\perp} \tag{6}$$

The distributions of the charged multiplicity as a function of the pseudo-rapidity, of the transverse momentum and of the azimuthal angle, for both the charge signs, can be achieved in the early measurements, even with small integrated luminosity samples. As an example the expected charged multiplicity as a function of the pseudo-rapidity is shown in Figure 4. These results are very important by themselves for the understanding of MPI allowing checking the prediction of the Monte Carlo generator used to describe high energy collisions at the LHC collider.
The synoptic table of the possible physics reach of LHCb versus the integrated luminosity is shown in Figure 5.

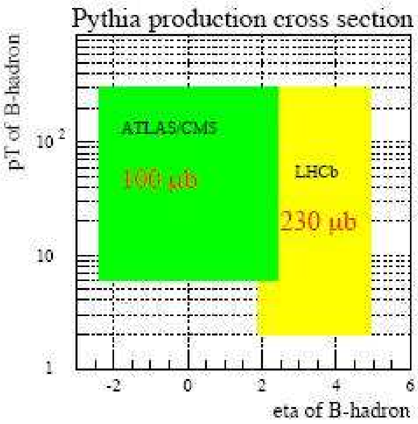

Fig. 1: Rapidity vs momentum region phase space covered by the LHC detectors. LHCb covers the rapidity region between 2 and 4.5, complementary to the ATLAS and CMS central detectors.

$\sqrt{s}$(GeV)	ρ_{EXP}
53[UA5]	1.96±0.10
200[UA5]	2.48±0.06
546[UA5]	3.05±0.03
630[CDF]	3.18±0.12
900[UA5]	3.46±0.06
1800[CDF]	3.95±0.13

Table 1: Measured values of the density of charged particles in the central region as a function of the energy in the centre of mass reference frame $\sqrt{s}$.

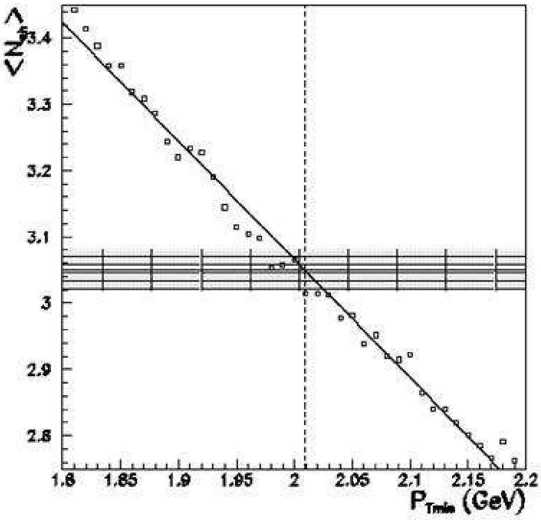

Fig. 2: Determination of the $p_{\perp\min}$ value at the energy of $\sqrt{s} = 546$ GeV by fitting the average charged multiplicity linear dependence on $p_{\perp\min}$ according to Pythia. The shadowed area represents the 2 σ region of the measured value. Dots represent the average charged multiplicity evaluated with Pythia, without error bars due to the high statistics of the data-sets generated at various $p_{\perp\min}$.

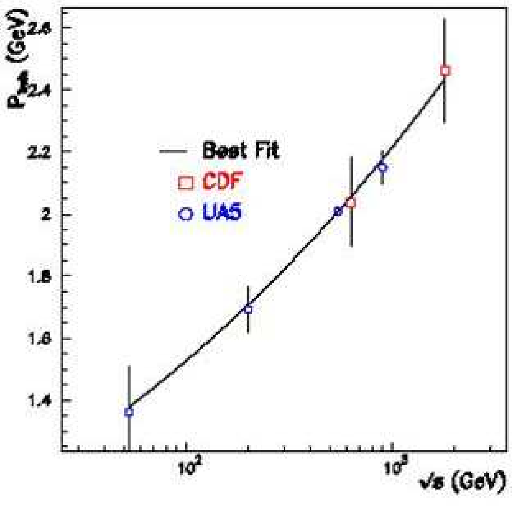

Fig. 3: Best fit of the $p_{\perp\min}$ value to the available experimental data as a function of the centre of mass energy $\sqrt{s}$. The value of $p_{\perp\min}$ of the Pythia model can be extrapolated on this bases to the LHC energy.

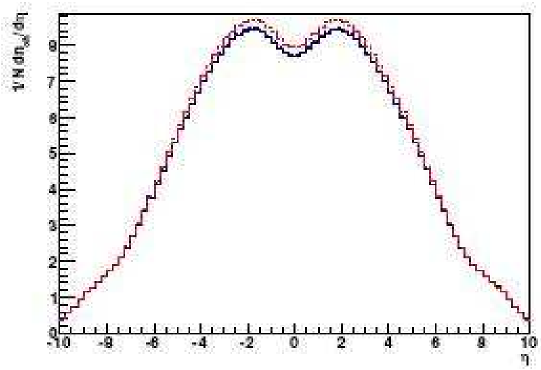

Fig. 4: Pseudo-rapidity distribution according to Pythia by using the $p_{\perp\min}$ extrapolated to the LHC centre of mass energy. Prediction achieved with Pythia version 6.4 are overlapped to those of Pythia version 6.2 and 6.3 for comparison.

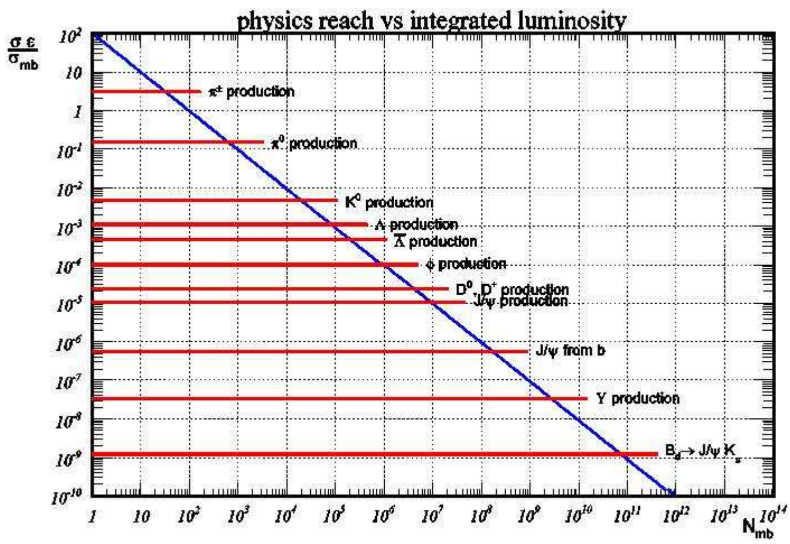

Fig. 5: Synoptic table of the possible physics reach versus the integrated luminosity.

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