1 Introduction

The measurement of particle production without a bias of a hard scattering is one of the very first and basic measurements in hadron–hadron colliders at high-energies. Unbiased particle production is of great interest. Minimum Bias events are produced by strong interactions of hadrons and/or partons inside the hadrons. Most of these events are produced in a region where predictions of Quantum Chromodynamics (QCD) cannot be obtained perturbatively and where soft to semi-hard multiple partonic interactions (MPI), soft diffractive and non-diffractive processes are involved. The theoretical description of those components of particle production is extremely difficult and up to now, no unified and consistent description in terms of partonic processes exists, and one has to rely on phenomenological models of these components. However, when a hard scale is involved, predictions obtained from perturbative QCD are in many cases in good agreement with the measurements. An interesting and not yet answered question is to determine the transition region characterized by the interplay between hard processes calculable with perturbative techniques and soft processes described by non-perturbative models. Here are described measurements which could help to better understand this transition region and constrain the modelling of the different components of particle production. Apart from these considerations, the understanding of particle production is crucial when the collider is operated at high intensities since many hadron–hadron collisions are overlaid (pileup) and form a background to all other measurements. The measurements of particle production are often used to adjust (tune) free parameters in the models which simulate hadron–hadron interactions. Since these are used to simulate the pileup contribution, the measurements of particle production are important to achieve precise predictions and search for new physics.

Inclusive measurements of charged-particle pseudorapidity distributions, $dN_{ch}/d\eta$, and transverse momentum distributions, $dN_{ch}/d\not{p_T}$, have previously been performed in $pp$ and $p\bar{p}$ collisions for different centre-of-mass energies and phase space regions [1–10], where $\eta$ is defined as $\eta = - \ln[\tan(\theta/2)]$, with $\theta$ being the polar angle of the particle trajectory with respect to the anticlockwise-beam direction. Here, charged-particle pseudorapidity distribution, also referred to as charged-particle pseudorapidity density, measured with the CMS detector in $pp$ collisions at
a centre-of-mass energy of 13 TeV at 0 Tesla for long-lived charged-hadrons in the range $|\eta| < 1.8$ is discussed [1]. In addition predictions obtained from Monte Carlo (MC) event generators at 3.8 Tesla of pseudorapidity and integrated $p_T$-leading distributions for different event topologies corresponding to an inelastic enhanced event sample (INEL), a sample dominated by non-single diffractive dissociation (NSD) and a sample enriched by single diffractive dissociative events (SD) are discussed. The Monte Carlo (MC) event generators used were tuned to describe the underlying event (UE) properties at $\sqrt{s} = 7 - 8$ TeV [11] and to predictions from an event generator used in high-energy cosmic ray hadronic interactions.

2 Pseudorapidity distribution measurement by CMS detector at $\sqrt{s} = 13$ TeV

The first measurement of $pp$ collisions at $\sqrt{s} = 13$ TeV was the pseudorapidity distribution of long-lived charged hadrons in the range $|\eta| < 1.8$ as shown in Fig. 1 left [1]. This measurement was presented for inelastic events without minimum transverse momentum requirement. A good agreement of the measurement with the MC predictions within the experimental uncertainties is found, with EPOS agreeing slightly better with the measurement.

![Figure 1: Left: Pseudorapidity distribution measured by CMS at $\sqrt{s} = 13$ TeV working at 0T. Right: Average number of hadrons in the central region as function of the center of mass energy.](image)

On the right side of Fig. 1 is shown the average number of long-lived charged hadrons in the region $|\eta| < 0.5$ as a function of the energy of the center of mass compared with two MC predictions. One can notice that both MC predictions give a reasonable description.
3 Particle spectra

3.1 Pseudorapidity in diffractive events

In previous charged particle pseudorapidity measurements done by the CMS experiment a selection of different diffractive events was performed with the help of the TOTEM calorimeters $(5.3 < |\eta| < 6.4)$ [3] according to the activity on the forward regions; an inclusive event sample, a sample dominated by non-single diffractive dissociation (NSD) and a sample enriched by single diffractive dissociative events (SD) by requiring activity or lack of activity on either T2 TOTEM telescopes, activity on both sides simultaneously, and activity in one side only, respectively. In Fig. 2 these distributions for three different event topologies at $\sqrt{s} =$8 TeV are shown. In them it can be noticed a different behaviour between the most inclusive selections (inclusive and NSD-enhanced) and the SD-enhanced selection, being the latest more flat along the full eta range. The measurements are compared with different MC predictions being PYTHIA6 Z2* the only one to described the central $\eta$ region of all of them.

![Figure 2: Pseudorapidity distributions measured by CMS experiment at $\sqrt{s} =$8 TeV for inclusive(left), NonSingle Diffractive(center) and Single Diffractive(right) selections.](image)

3.2 Integrated $p_T$-leading

The total $2 \rightarrow 2$ partonic cross section diverges towards small $p_T$

$$\sigma(p_T) \propto \frac{1}{p_T^2}$$

and eventually becomes bigger than the total inelastic cross section. To deal with it a phenomenological factor $p_{T,0}$ is introduced in order to tame the divergent behaviour at small $p_T$. This turnover region is considered as the transition between perturbative QCD and non perturbative QCD. This region was investigated for minimum bias events (mostly inelastic events) [12], in Fig. 3 is shown the measurement compared to multiple MC predictions. On the left side of Fig. 3 the effect of MPI and the saturation $p_{T,0}$ taming factor are shown. It is immediately noticed...
the importance of the taming factor to describe the data and how MPI has a small effect in this measurement. On the right side of the figure different MC generators are compared.

![Figure 3: Integrated $p_T$-leading distribution measured by CMS experiment at $\sqrt{s}=8$ TeV](image)

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**References**


