Minimum Bias Trigger for pp Physics with ALICE

A. Bhasin, D. Evans, G.T. Jones, P. Jovanović, A. Jusko, R. Kour, M. Krivda, C. Lazzeroni, R. Lietava, Z.L. Matthews, S. Navin*, R.J. Platt, H. Snow, J.D. Tapia Takaki and O. Villalobos Baillie for the ALICE collaboration.

School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom

ALICE will measure the properties of strongly interacting matter created in heavy-ion collisions. In addition, taking advantage of the low p_t acceptance in the central barrel, ALICE will play an important role in understanding pp collisions with minimum bias triggers at LHC energies. The proposed minimum bias trigger is sensitive to about 90% of the total inelastic cross section and 99% of the non-diffractive cross section. A procedure to calculate the trigger efficiency and an estimate of the systematic uncertainty due to the limited acceptance of the detector are presented.

I. INTRODUCTION

A Large Ion Collider Experiment (ALICE) is a general-purpose heavy-ion experiment designed to study the physics of strongly interacting matter and the Quark-Gluon Plasma (QGP) in nucleus-nucleus collisions at the LHC. The first step in the LHC physics program will be to measure and understand pp collisions with minimum bias (MB) triggers. This paper discusses the MB measurements foreseen in the initial period of running, a description of the essential detectors needed for these measurements and a method to estimate trigger bias and efficiency to provide corrections for these measurements. For this study the Physics Data Challenge 2006 (PDC06) pp data at 14 TeV have been used.

II. THE DETECTOR SETUP

The detector consists of two main components: the central barrel and the forward muon spectrometer. The central part is embedded in a large magnet with a field of 0.5 T. The design of the detector has been based on the highest value for the multiplicity of charged particles produced in a central Pb-Pb collision (8000 per unit rapidity for $|\eta| \leq 0.9$). This multiplicity dictates the granularity of the detectors and their optimal distance from the colliding beams [1].

Tracking Detectors

Track finding in heavy-ion collisions at the LHC presents a big challenge, because of the extremely high track density. The tracking detectors foreseen for the first physics measurements are the Inner Tracking System (ITS) and the Time Projection Chamber (TPC).

The ITS is made from six layers of silicon detectors covering the central rapidity region located at radii between 4 and 43 cm. There are two layers each of pixels, drifts and strips. They surround the collision point and are used primarily to determine the positions of primary and secondary vertices. Primary vertices for pp collisions are localised in the plane perpendicular to the beam with a resolution better than 100 μm [2] to enhance the reconstruction of secondary vertices. Low momentum ($p_t < 100$ MeV/c) particles are detected only by the ITS, hence it improves the momentum and angle resolution for particles reconstructed by the TPC and reconstructs particles in the dead regions of the TPC.

* Electronic address: sparsh.navin@cern.ch

Particle tracking continues in a large, gas-filled detector called the TPC. A large cylindrical field cage is filled with 90 m^3 of Ne, CO_2 and N_2. Following ionisation, electrons are transported from either side of the central electrode to the end plates, where there are readout pads. The maximum drift time of electrons is about 90 μs [2]. The TPC is optimised to provide charged-particle momentum measurements with good two-track separation, particle identification and vertex determination. The momentum resolution is 3% for particles of energy up to 60 GeV. For $p_{\rm t} > 0.5$ GeV, efficiency is above 90% [4]. The phase space covered by the TPC in pseudorapidity is $|\eta| < 0.9$ for tracks reaching the outer wall of the TPC and $|\eta| \leq 1.5$ for reduced track length. Except for the dead zones between the readout chambers, the TPC covers the full azimuth with a $p_{\rm t}$ range of about 0.1 GeV/$c \leq p_{\rm t} \leq 100$ GeV/c.

The TPC and ITS detect the path of the original charged particle. The rapidity coverage ($|\eta| \leq 0.9$ for all vertices located within the length of the interaction diamond i.e., $z = \pm 5.3$ cm along the beam direction) and the granularity of the tracking system enable it to detect several thousand particles per heavy-ion collision.

Triggering detectors

In this study we consider two triggering detectors:

The V0 detector is a small angle detector. It consists of two disks (V0A and V0C) of scintillators, one on each side of the interaction point. Each disk has 32 elementary counters arranged in 4 rings and 8 sectors. The V0C disk is 94 cm from the vertex on the same side as the muon spectrometer and the V0A disk is 340 cm from the vertex on the opposite side. The pseudorapidity range of V0A is $2.8 < \eta < 1.5$ and that of V0C is $-3.7 < \eta < -1.7$ [2]. It provides a MB trigger for the central detectors and also trigger background corrections in the form of beam gas (BG) suppression. The V0 trigger uses the fact that particles from pp and BG interactions arrive at the two disks of scintillators at different times. The time difference between the hits on the two disks for a pp interaction is different from the time difference between the hits for a BG interaction [5].

We consider two trigger conditions: V0OR only requires a hit in one of the V0 disks, and V0AND needs a hit recorded in both the V0 disks.

The Silicon Pixel Detector (SPD) comprises the two innermost layers of the ITS. Its fundamental purpose is to determine the position of the primary vertex. It operates in a region where the track density could be as high as 50 tracks/cm^2, hence its spatial resolution (in the plane perpendicular to the beam) of 12 μm. The SPD consists of a two-dimensional matrix of reverse-biased silicon detector diodes bump-bonded to readout chips. Chips are arranged on ladders. In total there are 240 ladders with 1200 chips for a total of 9.8×10^6 cells [2]. It complements the V0 detector in providing the MB trigger because its geometrical acceptance is in the central rapidity region.

The Global Fast Or (GFO) is the trigger signal we obtain from the SPD. This is the "OR" of hits from each of the pixel chips in the detector (hence global) available at the first level of the ALICE trigger (hence fast) [3].

III. FIRST MEASUREMENTS

The first measurements that ALICE will be able to perform in pp collisions are the pseudorapidity density of primary charged particles, the multiplicity distribution [6, 7] (i.e., the frequency distribution for the number of primary charged tracks) and the transverse momentum spectrum of charged particles. These measurements are essential in understanding MB interactions at the LHC energy and provide data for tuning of the Monte Carlo models [8].

For these measurements MB triggers will be used.

IV. MINIMUM BIAS TRIGGER

The MB trigger should combine high efficiencies for low multiplicity and diffractive events with a good BG rejection. Four different trigger combinations (MB1 to MB4) have been defined as possible minimum bias triggers for this study. The description of these is given below.

$$\begin{aligned}\mathrm{MB1} &= (\mathrm{GFO\ or\ V0OR})\ \mathrm{and}\ \overline{\mathrm{BG}}\\ \mathrm{MB2} &= (\mathrm{GFO\ and\ V0OR})\ \mathrm{and}\ \overline{\mathrm{BG}}\\ \mathrm{MB3} &= (\mathrm{GFO\ and\ V0AND})\ \mathrm{and}\ \overline{\mathrm{BG}}\\ \mathrm{MB4} &= (\mathrm{GFO\ or\ V0AND})\ \mathrm{and}\ \overline{\mathrm{BG}}\end{aligned}$$

Since the triggering detectors do not provide full phase space coverage, the MB triggers do not detect all interactions. The trigger efficiencies are different for different physics processes. Hence, a correction has to be applied and the systematic error due to limited knowledge of the physics processes is to be studied.

Collisions can be of two types: elastic or inelastic. For this study we only consider inelastic collisions as elastic collisions have negligible acceptance. Inelastic collisions can either be diffractive (single (SD) or double (DD)) or non-diffractive (ND).

The inelastic cross section (σ_{INEL}) is the sum of all the individual cross sections, where $\sigma_{\mathrm{INEL}} = \sigma_{\mathrm{SD}} + \sigma_{\mathrm{DD}} + \sigma_{\mathrm{ND}}$.

The event generator used for this study is PYTHIA 6.214 [9] with ATLAS tuning [10]. Our default contributions for the three different physics processes are $\frac{\mathrm{SD}}{\mathrm{INEL}} = 0.158$ $\frac{\mathrm{DD}}{\mathrm{INEL}} = 0.106$ $\frac{\mathrm{ND}}{\mathrm{INEL}} = 0.736$. Table I shows the efficiencies for different triggers for each process taken separately where INEL=SD+DD+ND. These percentages correspond to the trigger efficiencies at our default PYTHIA cross sections.

TABLE I: Efficiencies for various trigger configurations

%	**MB1**	**MB2**	**MB3**	**MB4**
INEL	93.9	88.8	83.0	90.0
ND	99.8	99.1	98.0	99.5
SD	71.6	56.9	39.8	58.1
DD	86.3	65.2	43.8	70.8

Systematics:

The exact cross sections of SD, DD and ND events are not known, but the trigger efficiency and mean multiplicity for the different types of processes are known to be different. To implement trigger corrections properly, we study the variation of mean multiplicity with the proportion of SD and DD events. This is done by weighting the fraction of SD events (σ_{SD}) by a factor f. We assume that σ_{SD} and σ_{DD} are not independent of each other. So, if σ_{SD} is scaled by f, σ_{DD} is scaled by f^2. σ_{ND} also changes so that σ_{INEL} is kept constant.

The four plots in Figure 1 show how changing the fraction of diffractive events relative to PYTHIA's default values (on the x-axis) changes the corrected mean multiplicity density relative to the same quantity calculated at PYTHIA's default cross sections (on the y-axis) for events selected by each of the four trigger configurations MB1 to MB4. This provides an estimate of the systematic uncertainty. The point (1,1) in the plots represents the default PYTHIA parameters. The percentages in TABLE I correspond to this point in the respective plots.

The plot for MB1 shows that varying the fraction of SD and DD events in a range of 2 relative to PYTHIA's default value changes the mean multiplicity by only 7%, while for MB3 it changes by about 35%. The MB1 and MB3 configurations have the least and the most variations in mean multiplicity with varying SD, DD and ND cross sections respectively.

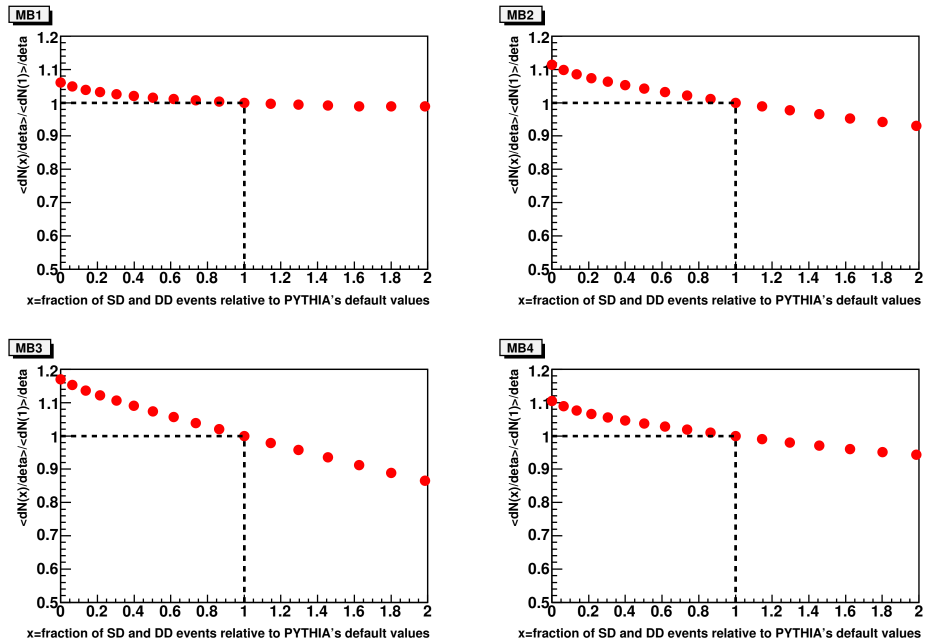

FIG. 1: The figure shows MB1 to MB4 systematics plots. On the x axis is x = $\frac{\mathrm{SD+DD}}{\mathrm{INEL}}$ relative to PYTHIA's default, which is 27% at x=1. At x=0, this fraction is 0% and at x=2 this fraction is 54%.

V. SUMMARY

This paper gives a brief description of the detectors used in MB triggers and the first measurements we expect to make. To correct for the bias the MB triggers introduce, we need to estimate what fraction of the cross sections we take with different MB triggers. This paper covers trigger efficiency and systematics, in particular the dependence of efficiency on proportions of different physical processes (SD, DD and ND) as estimated using PYTHIA 6.214. The same analysis will be carried out using PHOJET as the event generator in order to study the effects of particle kinematical distributions on the trigger efficiencies. Also, a differential method is under review, in which we will consider mean multiplicity bin by bin. Trigger corrections will be incorporated into the analysis framework, within which first physics measurements will be analysed.

References

[1] ALICE Collaboration, ITS-TDR ALICE-DOC-2005-002 v.1
[2] ALICE Collaboration, ALICE Technical Paper I, submitted to J.Inst.
[3] G. Aglieri Rinella, A. Kluge, M. Krivda, CERN-2007-001 361
[4] F. Carminati et. al., PPR Vol. I, J. Phys. G: Nucl. Part. Phys. 30 (2004) 1517
[5] J. Conrad, J.G. contreras and C.E. Jørgensen, ALICE-INT-2005-025, (2005) 5
[6] J.F. Grosse-Oetringhaus, these proceedings; ALICE-INT-2008-002 (2008)
[7] J.F. Grosse-Oetringhaus, C. Jørgensen, ALICE-INT-2007-005
[8] C. Jørgensen, Acta Physica Polonica B, Vol.38 1001-1007 (2007)
[9] T. Sjostrand et. al., Comput. Phys. Commun. 135 (2001) 238
[10] A. Moraes, C. Buttar and I. Dawson, Eur. Phys. J. C 50 (2007) 435