SATELLITE POPULATION MEASUREMENTS IN PB–PB COLLISIONS WITH THE ALICE ZDC

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Abstract

The ALICE experiment is equipped with a set of Zero Degree Calorimeters: two for spectator neutrons (ZN) and two for spectator protons (ZP), located on both sides of the interaction point. Due to their location and to their timing performance, the neutron calorimeters are an ideal device for measuring the longitudinal structure of colliding beams.

In this contribution, we present a measurement of the satellite charge of the LHC Pb beams in a fill (1533) where luminosity calibration experiments (vdM scans) were performed. The collisions of satellites located in the various RF buckets around the nominal one are separated via the signal arrival time in the two ZNs.

The ZDC results are compared to the results obtained by the LHC Longitudinal Density Monitors (LDM).

INTRODUCTION

The ALICE [1] Zero Degree Calorimeter system (ZDC) is used to measure the centrality in heavy ion collisions, by measuring the energy of spectator nucleons [2, 3]. It is composed by two neutron (ZN) and two protons (ZP) calorimeters and by two small electromagnetic calorimeters (ZEM). The ZNs are also used as a luminometer for heavy ion collisions [4], due to their large sensitivity for electromagnetic dissociation interactions [5].

The two ZNs (ZNA and ZNC) are located 114 m away from the Interaction Point (IP) at the so-called A and C sides of the ALICE detector, defined in such a way that the direction of Beam 1 is from A- to C-side. Each ZN is placed at zero degree with respect to the LHC beam axis and is used to detect neutral particles at pseudo-rapidities $|\eta| > 8.7$.

In fill 1533 (November 2010) vdM scans with Pb beams were perfomed [4, 6]. Satellite charge measurements were provided for Beam 2 by the LHC Longitudinal Density Monitor (LDM) [7]. LDM was not available for Beam 1. In the following, we present a measurement of satellite charge with the ALICE ZNs, performed in order to cross check and complement the LDM measurement.

DATA ANALYSIS

The arrival time distributions in the two calorimeters (Fig. 1) show that the ZN resolution is good enough to separate collisions in different RF buckets. Since the direction of Beam 1 is from ZNA to ZNC, the ZNA arrival time distribution is sensitive to collisions of Beam 1 with satellites of Beam 2. Similarly, the ZNC arrival time distribution is sensitive to collisions of Beam 2 with the satellites of Beam 1.

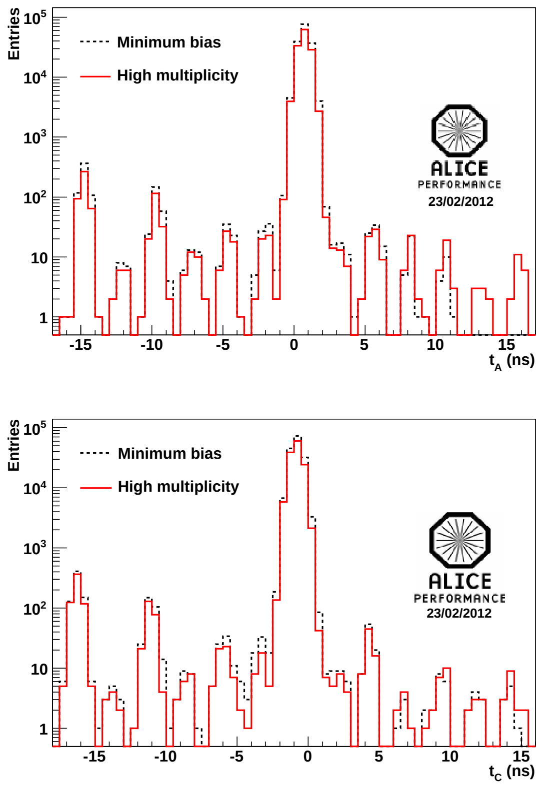

Figure 1: Signal arrival time distribution in ZNA (top) and ZNC (bottom) in fill 1533, for a minimum bias-triggered and a high multiplicity-triggered data sample.

The ZN calorimeters detect neutrons emitted in electromagnetic and hadronic interactions, which travel undeflected along the beam pipe. Due to the large distance between the ZNs and the collision region, it can be assumend that the ZN acceptance for such neutrons is independent of the z-position of the collision. However, no ZN-triggered data are available for fill 1533; instead, our analysis is based on data taken with two different triggers: a minimum bias trigger, requiring the coincidence of at least one hit in each of the two V0 [1] scintillator arrays and at least two hits in the Silicon Pixel Detector (SPD [1]); a high multiplicity trigger, requiring at least 100 hits in the SPD. The efficiency of such triggers is not expected to be fully flat as a function of the z-position of the collisions, so it might introduce a bias in the evaluation of the satellite populations. Statistics-limited observations made in fills where a ZN trigger was available show discrepancies up to 30% of

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the satellite fractions measured with minimum bias or high multiplicity triggers with respect to those measured from ZN-triggered data. We then assume a 30% uncertainty of the satellite populations arising from the not fully known z-dependence of the trigger efficiency.

In this analysis, we focus on the satellites located at a distance of two to six buckets around the main one, which collide with the main bunches at distances from the interaction point ranging from 75 cm to 225 cm, in steps of 37.5 cm. We sum up data from all ALICE colliding bunches (114 slots in fill 1533). For the minimum bias trigger, we limit the analysis to satellites preceding the main bunch or following it by at most three buckets, since later buckets are too close to the edge of the mimimum bias trigger window, as particularly evident in Fig. 1 (top).

The fraction of main-satellite to main-main collisions for each beam can be extracted from the time distributions in Fig. 1, just by counting the number of events in the satellite and in the main peaks.

The satellite collision fractions must be converted into satellite population fractions by correcting for the z dependence of the luminosity due to the hour-glass effect. Moreover, a non-zero residual crossing angle in the Y plane was measured by the two ZNs using the centroid of the spot of spectator nucleons, and estimated to be ϕ=20±4 μrad (full angle). Due to the crossing angle, satellites collide with the main bunch with separation zϕ. The overall dependence of luminosity on the z position of the collisions is then:

$$L(z) = L(0)\frac{e^{-\frac{(z\phi)^2}{2\Sigma_y^2(z)}}}{1+z^2/\beta^{*2}} \qquad (1)$$

where $\Sigma_y(z) = \Sigma_{y,0}\sqrt{1+z^2/\beta^{*2}}$ and $\Sigma_{y,0}$ is the effective width of the overlap region in the Y direction, as measured in the vdM scan [4].

The satellite population fractions are obtained by dividing the collision fractions by the z-dependent luminosity drop factors L(z)/L(0).

RESULTS

The obtained satellite fractions for Beam 2 are reported in Tab. 1, while those for Beam 1 are reported in Tab. 2. The reported uncertainties are the convolution of the statistical uncertainties with the systematic uncertainty obtained by varying the crossing angle within its error, and with the above mentioned 30% uncertainty from trigger efficiency. In Tab. 1 the ALICE results for Beam 2 are compared to the LDM results for satellites in the same buckets. The comparison is also shown in Fig. 2. We note that there is generally good agreement between the populations measured by the ALICE ZN and by the LDM, with the exception of buckets 3 and -3, for which the LDM result is lower by a factor of three to four. We also note that, in spite of the very different trigger conditions, the satellite populations measured by ALICE with the minimum bias and with the high multiplicity trigger are in very good agreement with each other. The satellite populations of Beam 1 are slightly higher than those measured for Beam 2.

Table 1: Beam 2 satellite fractions in fill 1533 as measured by the ALICE neutron calorimeters from a minimum bias (MB) and a high multiplicity (HM) data sample, compared to the LDM results

Bucket	**z (cm)**	**Satellite fraction (%)**		
		ALICE (MB)	ALICE (HM)	LDM
-6	225	0.562±0.171	0.495±0.151	$0.481^{+0.168}_{-0.120}$
-5	187.5	0.014±0.006	0.015±0.006	$0.010^{+0.003}_{-0.002}$
-4	150	0.179±0.055	0.159±0.049	$0.161^{+0.057}_{-0.040}$
-3	112.5	0.023±0.008	0.025±0.009	$0.007^{+0.002}_{-0.002}$
-2	75	0.043±0.014	0.042±0.014	$0.024^{+0.008}_{-0.006}$
2	-75	0.051±0.016	0.050±0.016	$0.038^{+0.013}_{-0.009}$
3	-112.5	0.020±0.007	0.028±0.010	$0.007^{+0.002}_{-0.002}$
4	-150	-	0.026±0.009	$0.018^{+0.006}_{-0.004}$
5	-187.5	-	0.008±0.004	$0.005^{+0.002}_{-0.001}$
6	-225	-	0.022±0.008	$0.019^{+0.007}_{-0.005}$

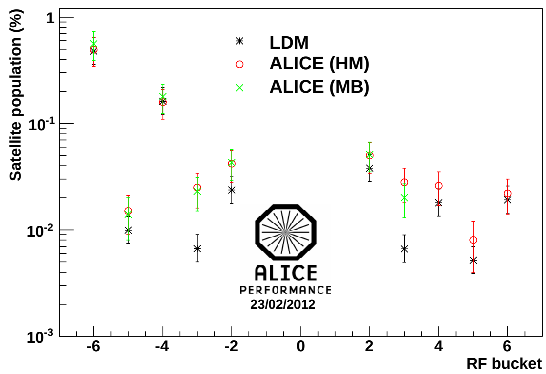

Figure 2: Beam 2 satellite populations for a few RF buckets around the colliding one, measured by the ALICE neutron calorimeters from a minimum bias (MB) and a high multiplicity (HM) data sample. The LDM results are also shown.

Table 2: Beam 1 satellite fractions in fill 1533 as measured by the ALICE neutron calorimeters from a minimum bias (MB) and a high multiplicity (HM) data sample.

Bucket	**z (cm)**	**Satellite fraction (%)**	
		ALICE (MB)	ALICE (HM)
-6	-225	0.666±0.203	0.719±0.219
-5	-187.5	0.010±0.004	0.009±0.004
-4	-150	0.225±0.069	0.220±0.068
-3	-112.5	0.015±0.006	0.015±0.006
-2	-75	0.055±0.018	0.047±0.016
2	75	0.054±0.017	0.056±0.018
3	112.5	0.004±0.002	0.006±0.003
4	150	-	0.019±0.007
5	187.5	-	0.008±0.004
6	225	-	0.019±0.007

CONCLUSIONS

The ALICE ZDCs have measured satellite populations for the LHC Pb beams in fill 1533. The total satellite population is on the order of 1%, slightly higher for Beam 1 than for Beam 2. The ZDC results for Beam 2 are compatible with those obtained by the LHC Longitudinal Density Monitor.

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