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Evaluation of the Beam Background Contribution to the pp Minimum Bias Sample Used for First Physics

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Abstract

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1 Introduction

During first data taking with the ALICE detector [1] a minimum bias sample of pp collisions will be collected by reading out the detector upon each bunch crossing (BB). Initially the beam intensity and hence the interaction probability are low. Thus, a fraction of these events will have only detector hits caused by particles from beam background (beam-gas collisions, tertiary halo, ...) or cosmic radiation. Offline trigger cuts will be applied to reduce the contribution of background events to the event sample. In order to quantify this contribution and correct the collision data in the analysis two additional triggers are needed: events with crossing of a bunch and an empty bunch position (EB or BE) and two empty bunches (EE) will be read. These special events will be also used for an optimization of the minimum bias event trigger to be used in future runs.

As will be shown in the next section, the relative contribution of background events to the event sample is expected to be very low. However, at LHC start-up, when the running conditions are not yet stable and optimized one cannot exclude scenarios with much worse beam background condition than expected. Conservative trigger settings have to be planned. We need to collect a sufficiently large sample of (BE, EB, EE)-triggered events without compromising the statistics of the BB-sample. The results of such considerations will be discussed in this note.

In addition, the first sample of events, measured by ALICE on November 23^{rd} 2009 during the LHC commissioning, required a dedicated procedure of background estimation and removal, described in Section 4.

2 Expected beam background condition

Beam backgrounds comprise products of beam-gas collisions (BG) close to the IP within the experimental region $\pm 20\,\mathrm{m}$ and the so called beam halo (BH) which contains particles produced outside the experimental region from beam-gas scattering or from collisions with the tertiary collimators. In ALICE it is expected that the background from the tertiary collimators is relatively small. The reason is that the tertiary collimators only protect the quadrupoles of the inner triplet but do not take part actively in the beam cleaning itself. Nevertheless, a detailed evaluation of this contribution is currently in progress. The main part of the beam halo comes from beam-gas collisions within the inner triplet at a distance of $20 - 40\,\mathrm{m}$ from the IP. The running conditions during first pp physics at $\sqrt{s} = 900\,\mathrm{GeV}$ and $7\,\mathrm{TeV}$ are summarized in table 1.

Table 1: LHC running conditions for planned collisions and background for first pp physics.

	pp $\sqrt{s} = 900\,\mathrm{GeV}$	pp $\sqrt{s} = 7\,\mathrm{TeV}$
Number of bunches	4	12
Particles per bunch	4.0×10^{10}	3.0×10^{10}
Initial Luminosity	6.6×10^{27}	1.7×10^{29}
Interaction Rate [kHz]	0.33	13
Gas density IR [equ. H_2/m^3]	2.0×10^{10}	
Gas density Machine [equ. H_2/m^3]	4.0×10^{12}	
BG Rate [Hz]	0.03	0.07
BH Rate [Hz]	5	12

3 Bunch crossing trigger strategy

One of the most important measurements performed with the first physics data set is the determination of the charged particle pseudo-rapidity density $\mathrm{d}N/\mathrm{d}\eta$. A systematic error on the measurement might be introduced by the presence of beam-halo and beam-gas events. Usually the vertex position of these events cannot be reconstructed, thus these events do not lead to the reconstruction of additional tracks. However, these events may cause a trigger (offline or online) and thus influence the overall normalization of the $\mathrm{d}N/\mathrm{d}\eta$ measurement. Without further correction the fraction of background events can be directly interpreted as a systematic error on the measurement. Depending on the analysis the overall systematic error is in the range of 4% to 8%.

A conservative choice of the number of (BE, EB) events needed can be obtained by the following conservative consideration: the smallest significant fraction of background events is 1% and we want to know this contribution with a relative error of about 10% equivalent to 100 events. According to our assumptions these 100 events are part of a sample of 10000 BB-events. For the $dN/d\eta$ analysis itself 20000 collision events are needed. Thus our goal could be achieved by taking BB/EB/BE triggers with the ratio 4:1:1.

In case the fraction f_B of background events is even smaller, it becomes completely negligible and we are safe. In case the fraction is higher the error on the background contribution is $1/\sqrt{f_B}$ %. For example for a 10% contribution the error would be 3% and correcting the data we can expect to stay with the contribution to the systematic error in the order of per cent.

After a first run with these settings we can use the measured background fraction in order to decide on the further strategy. In particular one might have to consider second order effects that require more statics and different trigger strategies.

- Signal / Background rate variation with time. If there is a strong dependence one should try to equilibrate the number of signal and background events over the course of a run.
- Background rate variation bunch to bunch, i.e. are the triggered BE similar to the BE in the BB sample ? This would require to use different sets of bunches for the BE/EB triggers.

4 Background estimation for the first data sample

During the first data taking run on November 23^{rd} 2009 we have collected 284 triggers, which were all taken in coincidence with the passage of both LHC beams. Due to security reasons only the ITS detector was participating in the data taking (layer 1 and 2 of the Silicon Pixel Detector SPD, layer 3 and 4 of the Silicon Drift Detector SDD, layer 5 and 6 of the Silicon Strip Detector SSD). For a run of such a limited statistics the statistical methods of background estimation mentioned above were both not possible and not needed. Such a small number of events could be checked one-by-one and background events were identified on an event-by-event basis with the methods described below.

First used method was visual scanning of the events. It was performed using the dedicated ALICE Event Visualization Environment [4] software AliEVE, which is a part of the ALICE offline framework AliRoot [2]. It enables a simultaneous visualization of the detector raw data (with the current alignment applied), reconstructed clusters, the position of the primary vertex, the reconstructed tracklets formed from the primary vertex and clusters in the two layers of the ALICE SPD detector and finally the ITS stand-alone tracks reconstructed from up to six clusters in all the layers of the ALICE ITS.

In order to be able to differentiate between valid and background events, we needed examples of the detector response for the two types of events. For valid pp events we have used the ones generated with the Monte-Carlo generator Pythia [3], then put through the simulation of the ALICE detector response

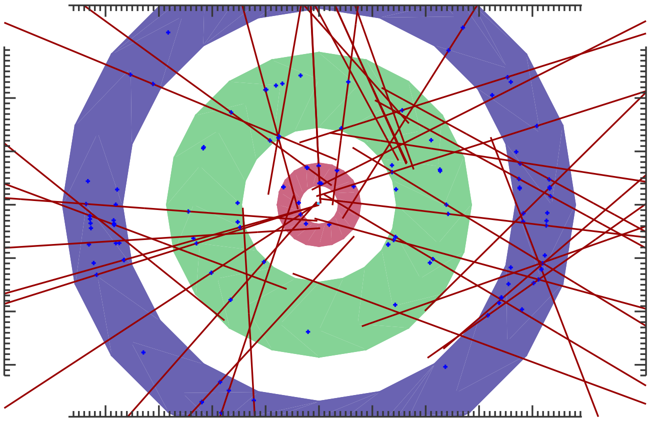

Figure 1: Example background "splash" event, "side" view. The rectangles show the position of the 6 ALICE ITS layers. The blue crosses show ITS clusters, the lines show ITS-only tracks.

and finally reconstructed with the AliRoot software as if they were real data. For the "background" sample we have used real events collected by ALICE with exactly the same experimental conditions as the sample of interest, but with only one LHC beam circulating. We were able to identify specific visual patterns which were unique to the background events and were not seen in the Monte-Carlo simulations, for an example see Fig. 1. In general such events had a number of clusters randomly distributed over all ITS layers, most of them not associated with tracks pointing to the vertex. Most of the events did not have a reconstructed vertex. In a small number of cases they had one, which also meant that there were reconstructed tracklets. However these were not confirmed by hits in the other layers of the ITS, namely the SDD and SSD, while real tracks should have created a signal there. In contrast, for the Monte-Carlo events (for an example see Fig. [**?**]) the majority of the clusters were associated with tracks. Also, the SPD tracklets in the acceptance of the other layers of the ITS were confirmed by ITS-only tracks reconstructed out of up to 6 clusters in all ITS layers.

We scanned visually all 284 events in the sample of interest. We have indeed seen two distinctly different groups of events - one with clear "background" characteristics and another with the features seen in the Monte-Carlo simulation. We have tagged 29 events as "background" or "most probably background" with this method. In addition 2 events were identified as cosmic muons.

For the "background" events we have analyzed the distribution of the position of the reconstructed primary vertex in the z-direction (along the beam). It was found to be wide, approximately flat in the region of -10 to 10 cm used in the analysis. We have also estimated the expected background event rate based on runs with only one LHC beam circulating. In Fig. 3 we show the distribution of the longitudinal position of the reconstructed primary vertex before and after the subtraction of the background.

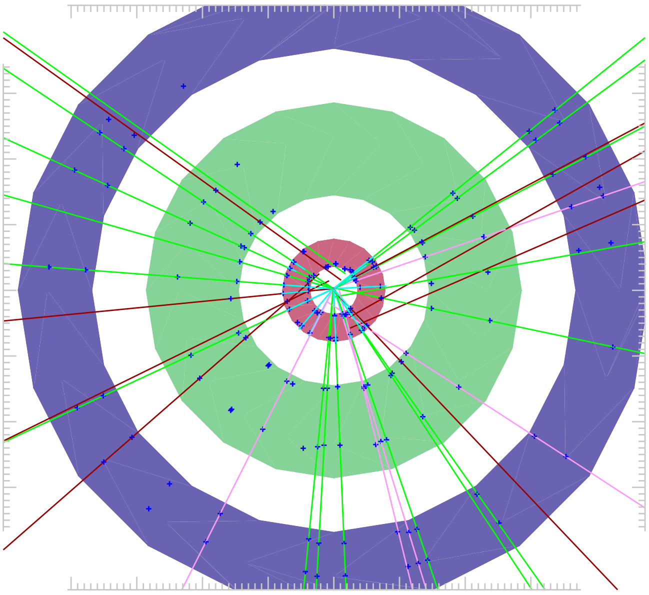

Figure 2: Example of a pp collision from MC, "side" view. The rectangles show the position of the 6 ALICE ITS layers. The blue crosses show ITS clusters, the lines show ITS-only tracks.

Several low multiplicity events were classified as "suspicious", but events with similar topology and features were also seen in the MC sample. The 29 events which were unambiguously identified as background correspond to the 10% of the datasample, which is in agreement with the background fraction inferred from the z-vertex distribution of background events and rates measured for single-LHC-beam runs. Therefore we have decided to treat all "suspicious" events as valid pp collisions.

The second method used the information from the ALICE V0 detector to tag background events by looking for ones which produced a hit within the time window expected for the beam-gas interaction. The V0 information was only available for a subset of the 284 events. In this subsample 17 were flagged as beam-gas interactions by the V0. We have correlated this information with the result of the visual scanning and found excellent correlation: 16 of them were flagged as "background" and the remaining one as "most probably background" by scanning. Out of the other 12 events tagged by scanning , 2 did not have any hits in the V0, and for the other 10 the V0 information was not available.

5 Identification with ITS information alone

Studying runs with one or two circulating beams without bunch crossings in ALICE's collisions points shows that background events usually have a high number of clusters but only a few reconstructed tracklets in the SPD. Figure 4

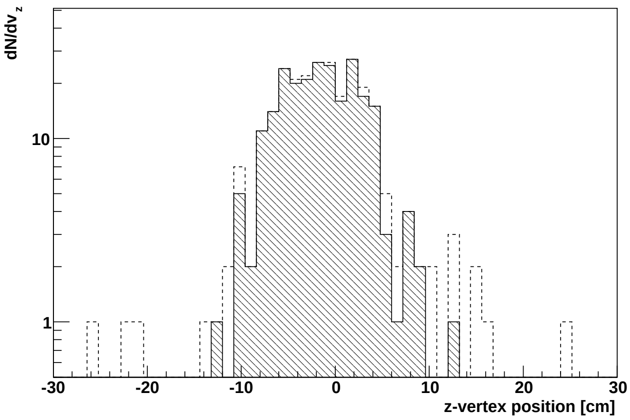

Figure 3: The distribution of the longitudinal position of the primary vertex in the data sample of interest. Dashed histogram shows the final distribution after background removal, dotted line shows the initial distribution.

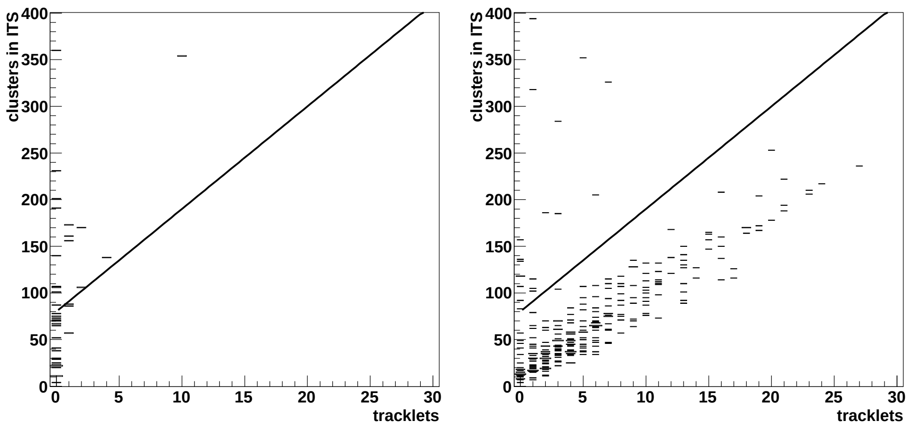

Figure 4: The plots show the total number of found clusters in the ITS vs. the number of found tracklets for a background run (left panel) and for the collision run (right panel). The line illustrates the cut that has been applied (see text).

shows the total number of clusters in the ITS vs. the number of found tracklets for background run (left panel) and the collision run (right panel). In the right panel one can clearly identify the outliers that are confirmed by visual scanning as splash events. Events that fulfill the following condition were rejected:

$$N_{\text{clusters}} > 80 + N_{\text{tracklets}} \cdot 11 \quad (1)$$

This cut, that is also shown in Figure 4, identifies a big fraction of those events that have been flagged by visual scanning.

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