Test beam 2003
Third short status of data analysis

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Abstract

This document contains an updated[1] analysis of the data collected during the 2003 test beam. Selection of the single muon sample was refined and finalized. New efficiency calculations were therefore performed, although minor differences were found. Data collected in the various tested configurations were analyzed and the incidence of the parameters modification on the trigger performance in terms of efficiency and noise was evaluated.

1. Previous reports are available as http://cms.pd.infn.it/testbeam/TB2003_report1.pdf and http://cms.pd.infn.it/testbeam/TB2003_report2.pdf

1. Introduction

The 2003 test beam data were collected in order to test the performance of the trigger in different configurations. The most important parameters of BTI, TRACO and TS were varied with respect to their default values in order to verify that the default choice was indeed giving a reasonable compromise between efficiency and noise requests. The effect of any single modified parameter on trigger efficiency, on-time noise (spatial ghosts identified as second tracks) and out of time noise (temporal noise due to false hits alignments) will be reported for the single muon sample. Whereas the full collected sample was used for the analysis of the default configuration, a limited amount of data (50000 events per run) was used in the alternative configurations studies.

2. Data selection

Data selection was modified to reject multiple muons that were still present in the previous selection. The variable chosen to select a safe single muon sample was the number of hits recorded in the TDCs: all the hits falling inside the time window -400 ns $\leq t_d \leq$ 800 ns were counted to avoid a bias in the efficiency calculations connected to a too tight selection window.

After checking few possibilities we chose to select on the number of hits independently on each Superlayer: we asked that there were at most six hits in at least one of the φ SLs (in order to keep possible electromagnetic showers generated inside any of them and absorbed in the aluminium honeycomb) and at most six hits in the θ SL (this cut allows rejection of double muons that are hitting the same φ tube). The results of the selection on the normal incidence sample is shown in Figure 1: the left plots show the number of hits in any SL for accepted events, while the right plots show the number of hits in the rejected sample. The multimuon background in the selected sample is clearly negligible and the other one is a mixture of multimuons: the apparent single muons peak in the φ SL plots is due to multimuons identified from the cut on the θ SL and classified as muons traversing the same tube in the φ-view. Evident peaks corresponding to dimuons and trimuons (and even four muons) are visible. Similar results hold at any angle of incidence.

The final cuts identifying the single muons selection sample were therefore set as follows:

a) scintillator trigger with ±2 ns tolerance on average time
b) > 2 cells with recorded hits in the beam region in the φ projection
c) < 3 hits recorded outside the time interval -400ns $\leq t_0 \leq$ 800 ns in the φ projection
d) < 7 hits in at least one φ SL
e) < 7 hits in θ SL

Further cuts were applied to the events falling in the rejected sample in order to select a sample of simultaneous dimuons.

3. Configurations

Data were collected in several configurations changing one by one the default value of the most important parameters of the devices constituting the trigger system. These parameters should modify the trigger response changing its efficiency and its rate. Unfortunately the tests done to check the trigger behaviour on modification of the BTI alignment tolerance were wrongly performed and those data cannot be used. Data were collected in the following configurations (apart from the default one):

1. Single LTRGs filtered asking for a HTRG in θ view (TS parameter acting on TRACO)
2. Single LTRGs always rejected (TRACO parameter)
3. BTI LTS algorithm disabled in both views
4. BTI LTS algorithm disabled only in θ view
5. TRACO LTS algorithm enabled
6. TRACO correlation tolerance set to minimum
7. TRACO correlation tolerance set to maximum
8. Carry mechanism disabled on TS system
9. TSM recovery of H_i triggers enabled
10. TS ghost type 2 rejection disabled
11. TS ghost type 1 and 2 rejection disabled

In every configuration only the listed parameter was changed, while all the others had their default value.

4. Results

Most of the parameters (cases 1,2,3,4,5,10,11) were introduced in order to provide handles that could be used to control and reduce the background of false triggers. Some of them are instead more directly related to trigger efficiency (cases 6 and7) and correct muon selection (cases 8 and 9). We will find the influence of each parameter on the suppression of bad triggers (either in space or in time) and on the efficiency.

4.1 Default configuration

4.1.1Trigger efficiency

We will start discussing the results on the default configuration trying to explain and define the variables used to describe the efficiency and noise figures. We introduced two ways to define the trigger efficiency. The first one is the so called bunch crossing efficiency that informs that a muon chamber trigger was recorded independently from the actual value of the output parameters. The second one instead is a muon identification efficiency and requires that the absolute difference between the radial angle measured from a fit to the TDC data and the one output from the trigger is less than 5 units[1]. These efficiencies are compared in Figure 2 as a function of the angle of incidence. The bunch crossing efficiency was also plotted as a function of the fitted position (intercept at SL center). The plots of Figure 3 shows that the inefficiency at normal incidence is concentrated in the I-beam region, while it is scattered around in the other cases, but at 45° incident angle where a complicated structure is found.

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1. We didn't try to cut also on the incident angle because of the large difference in resolution among trigger types that we addressed in the previous report.

4.1.2Trigger noise

The drift tubes local trigger produces false trigger (hereafter called ghosts) due to the intrinsic behaviour of the algorithm (temporal ghosts) and to the superposition between adjacent devices (spatial ghosts).

A temporal ghost is generated at wrong bunch crossings and is related either to the allowed alignment tolerances causing hits alignment around the right bunch crossing, or to alignments including hits reflections associated to the left-right ambiguities typical of drift chambers. More than one temporal ghost can be created from the same true muon hits. The fraction of events with more than a trigger is shown in Figure 4: the average fraction of wrong triggers is increasing with the angle consistently with the availability of more BTI patterns for alignment.

A spatial ghost is either a copy of the good trigger associated to the superposition between TRACOs or a lower quality trigger due to the superposition between BTIs. These ghosts are output as second tracks in the same bunch crossing of the good trigger. The output of two trigger candidates per chamber per bunch crossing is a mandatory choice needed to allow dimuon detection within the same chamber. In our selection we expect all second tracks to be noise triggers.

There are two ways to quote the fraction of noise triggers: quoting the number of ghost triggers over the total number of triggers or quoting the fraction of events with at least a ghost trigger. The first way is probably more relevant, since it reflects the rise of the trigger rate, while the second way shows only how frequently the problem happens.

In the default configuration, the probability of more than one bunch crossing with two tracks is negligible an so we show in Figure 5 only the first quantity in the case of the spatial noise. The fraction of second triggers at the same bunch crossings is rather small and is again a function of the angle. As already explained in the previous report, the positive angles must be ignored, since there is an error in the redundant patterns table in the default BTI configuration. The solution and its effects were already discussed in the previous report. A comparison with the plot shown in that report shows also that most of the second tracks that were found at a first rough sight were connected to close multimuons. Restricting to the negative angles, we verified that almost all the second tracks are of single L trigger type.

In the case of the temporal noise we show in Figure 6 both ways of quoting the trigger noise. The difference of course reflects the fact that more than one ghost trigger can be found in an event. The most relevant way is the first one, since the DTTF will treat each ghost trigger as an independent one and it will try to build a trigger primitive connecting ghost tracks in different chambers. In the CMS detector the distribution of the incident angle is basically flat below 20° with tails extending to higher angles. The design request was at most a 100% rate of ghost triggers (i.e. the ghost rate equals the true muon rate) and is clearly met from the trigger results.

Looking in the out of time triggers, there is a particular sample of events in which the trigger is output only at the wrong bx. Indeed almost all the inefficiency shown in Figure 2 is identified as muons triggering only out of time as it can easily be seen looking at Figure 7. The possible reasons for this behaviour are: a penetrating δ-ray very close to the real muon position; a local distortion of the electric field or of the space-time relationship; an unusual fluctuation of the primary electron generation. Except for the highest incident angle, where probably the major contribution came from the non-linearity of the space-time relationship, a mixture of these problems is the actual cause. This conclusion is supported also if we look at the distribution of out of time triggers divided per trigger type shown in Figure 8: apart from observing that the bulk of wrong triggers is of single L type, we see that the higher quality wrong triggers fraction increases with the incident angle as expected from the deviations from linearity of the space-time relationship[2]. The single L are a less dangerous background, since the DTTF uses this kind of triggers only as target and not as track origin when connecting the different stations.

4.2 Alternative configurations

The test of the alternative algorithm flows was intended in order to validate the design choices and to see the extent of noise suppression still available using non-default algorithm. In all the cases the important quantities to check are efficiency and noise (both spatial and temporal).

We grouped the alternative flows depending on their action. Configuration # 8 changes the way the selection of the second track is done from the server disabling the Carry mechanism. Configuration # 9 recovers H_i triggers marked as second tracks if the first track of the current event is a single L. These features were introduced in order to make a correct selection of the dimuons and have no effect on single muons (apart from modifying the actual parameters of the ghost track), but in the case of important electromagnetic background. Since in this test we were missing the iron in front of the chamber this kind of background is very small and no effect should be seen. We therefore ignored them after having checked that changing the default values was indeed having no effect.

The first group we consider is the possible ways of validating the single L triggers. The default choice is the validation of these triggers if any type of BTI trigger (LTRG or HTRG) is found in any BTI of the θ view. Although accepting any L trigger could be possible correctly configuring BTI and TRACO, it is clearly unacceptable and we didn't check this possibility. We tested instead configurations that could reduce the background, namely the possibility of accepting single L only if there was a HTRG in any BTI of the θ view and the rejection of any single L trigger.

The relevant plots are shown in Figure 9. The first alternative choice reduces a lot the background almost preserving the efficiency, while the second one does not actually have a large impact on ghosts rate, but reduces the efficiency. The impact on second tracks is marginal.

The second group considers different application of the available LTS algorithms. Results are plotted in Figure 10. It is clear that the BTI LTS algorithm must be applied since otherwise the ghost rate would be unacceptable. If needed the TRACO LTS could be applied, since a tiny efficiency reduction is associated to a good noise suppression.

The third group uses different TRACO tolerances for correlations. No important effect is seen on any relevant quantity as shown in Figure 11. We checked also that the correlation probability remained roughly the same, although a marginal reduction could be observed using the minimal tolerance. This is not a surprise, since the quality of the BTI triggers parameter was seen in the 1999 test to be really good.

The last group modifies TS ghost suppression algorithm: the trigger server is the only part of the trigger system that can apply configurable spatial noise suppressions. Figure 12 reports the effect of the available options. Disabling spatial ghost suppression should modify the second track ghost fraction. This is indeed the case: a lot of false dimuons is appearing in the relative plots.

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2. This is not true at normal incidence where the bump is of course correlated with the smaller probability of four hits due to the presence of consecutive I-beams

5. Conclusions

The analysis of the single muon sample is completed. Final results on efficiencies and noise were reported. The effect of the most important options available were studied. The results obtained fully validates the design choices and shows that we met indeed the trigger requirement. Space is available for further noise reductions at the price of acceptable efficiency reduction if the CMS environment will be worse than expected.

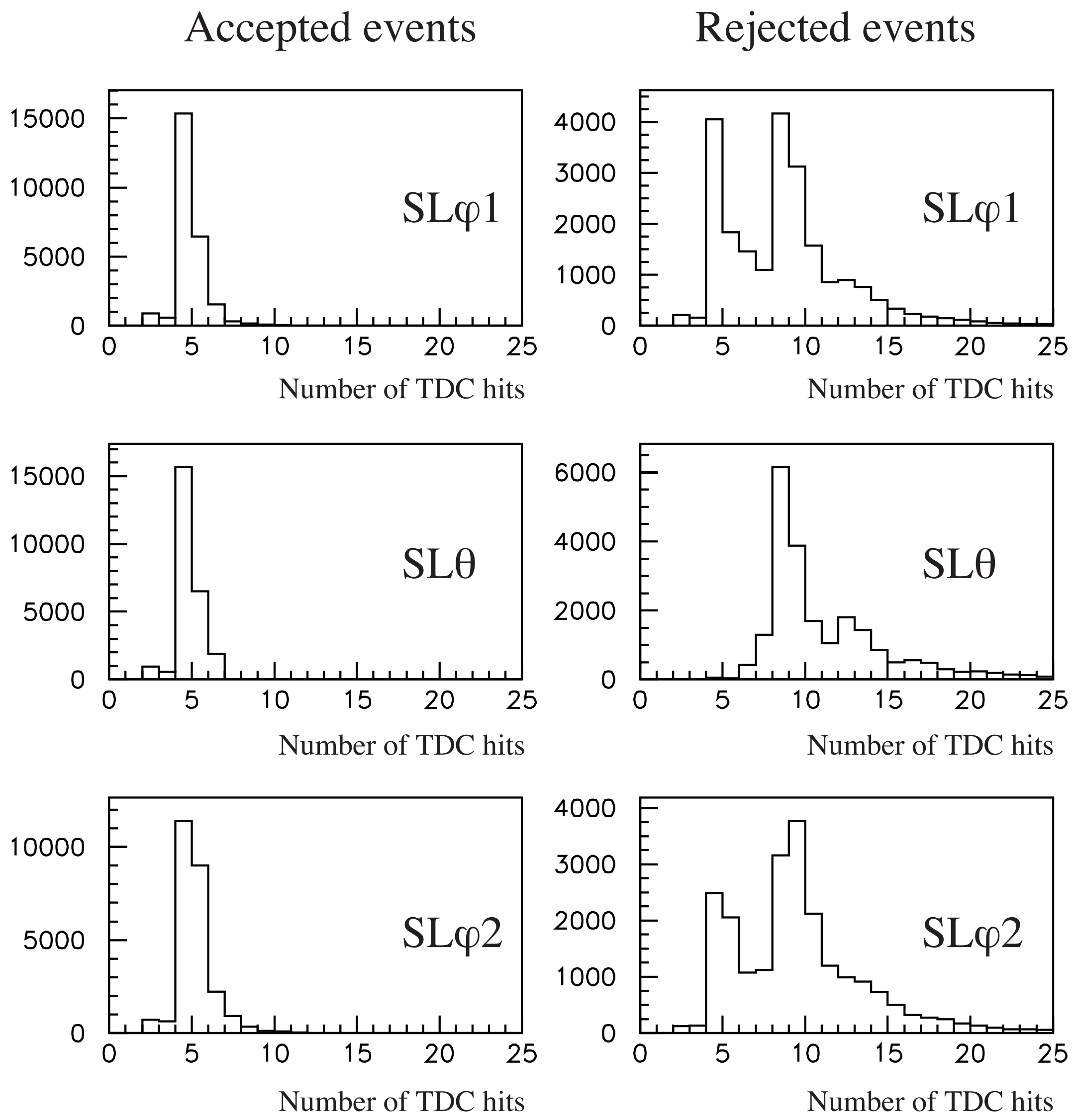

Figure 1- Number of hits recorded from TDC inside the selection window for normal incidence muons (-400ns $\leq t_0 \leq$ 800ns). The plots on the left show this quantity for data in the single muon selection independently for each superlayer. The plots on the right report the same information for the events rejected from the applied cut on number of hits. The different peaks on these plots correspond to multimuon events. Data at other incident angles show the same behaviour.

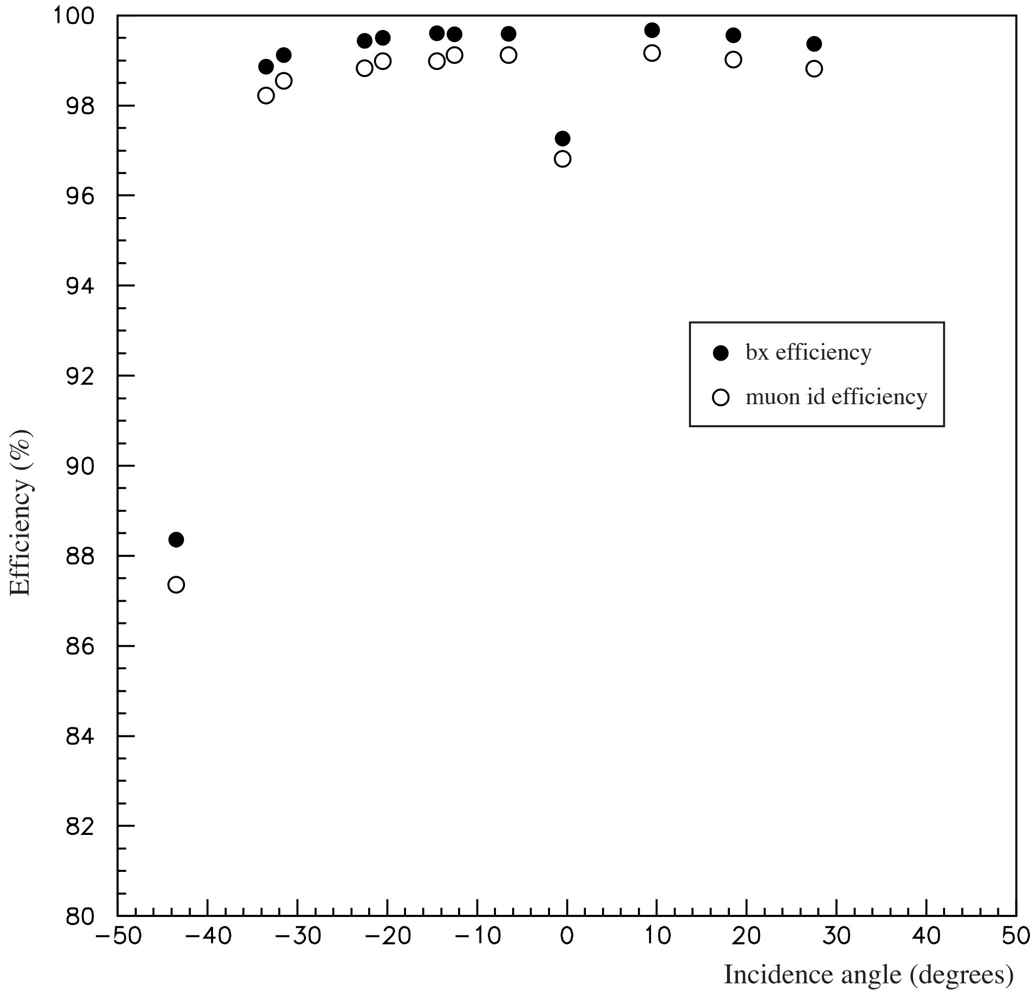

Figure 2- Bunch crossing efficiency compared to muon identification efficiency as a function of incident angle. See text for definitions.

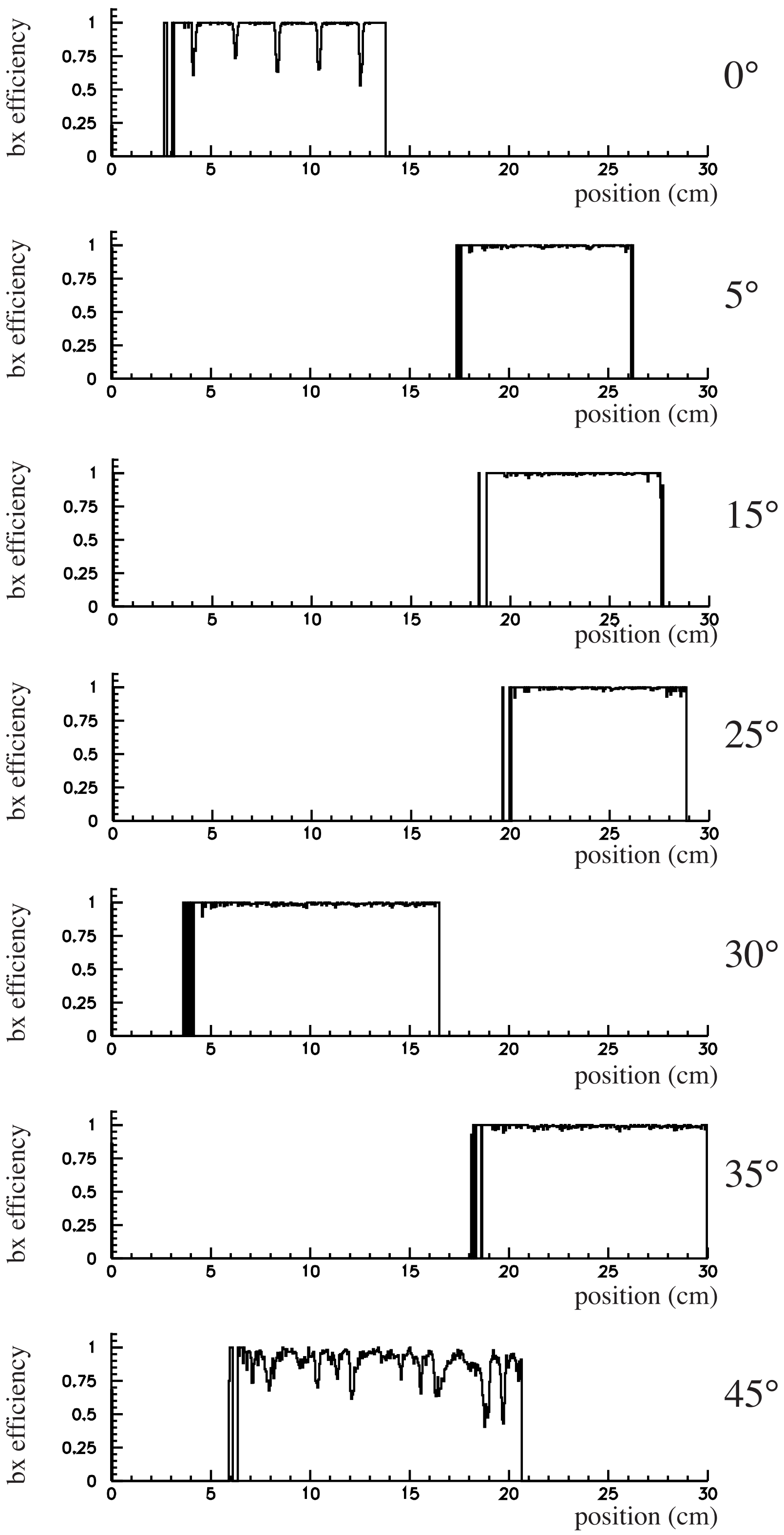

Figure 3- Bunch crossing efficiency as a function of position at different incident angles.

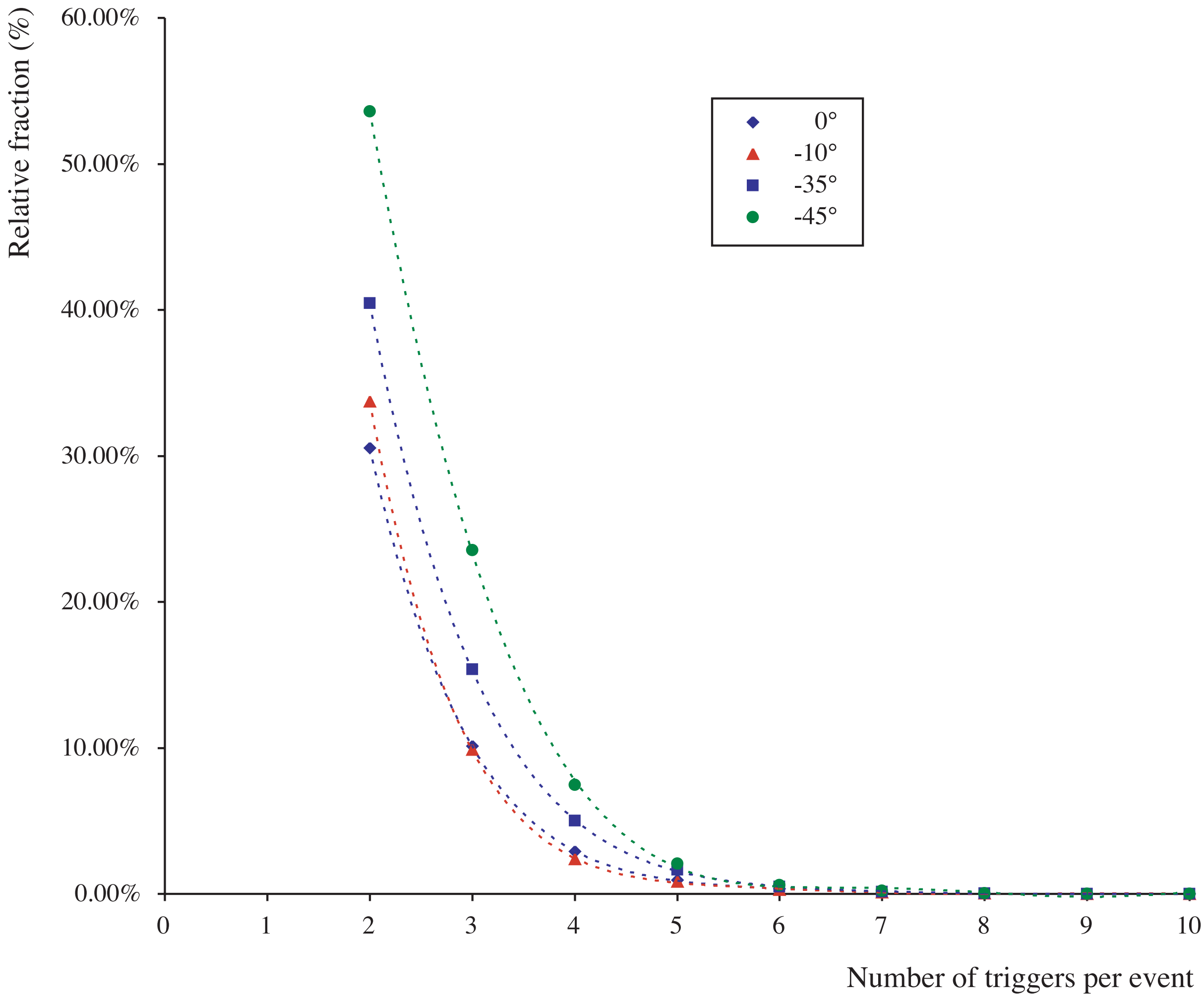

Figure 4- Relative fraction of event with at least a ghost triggers for some angles of incidence. The result is symmetric in angle. The events without wrong triggers were not included for sake of clarity.

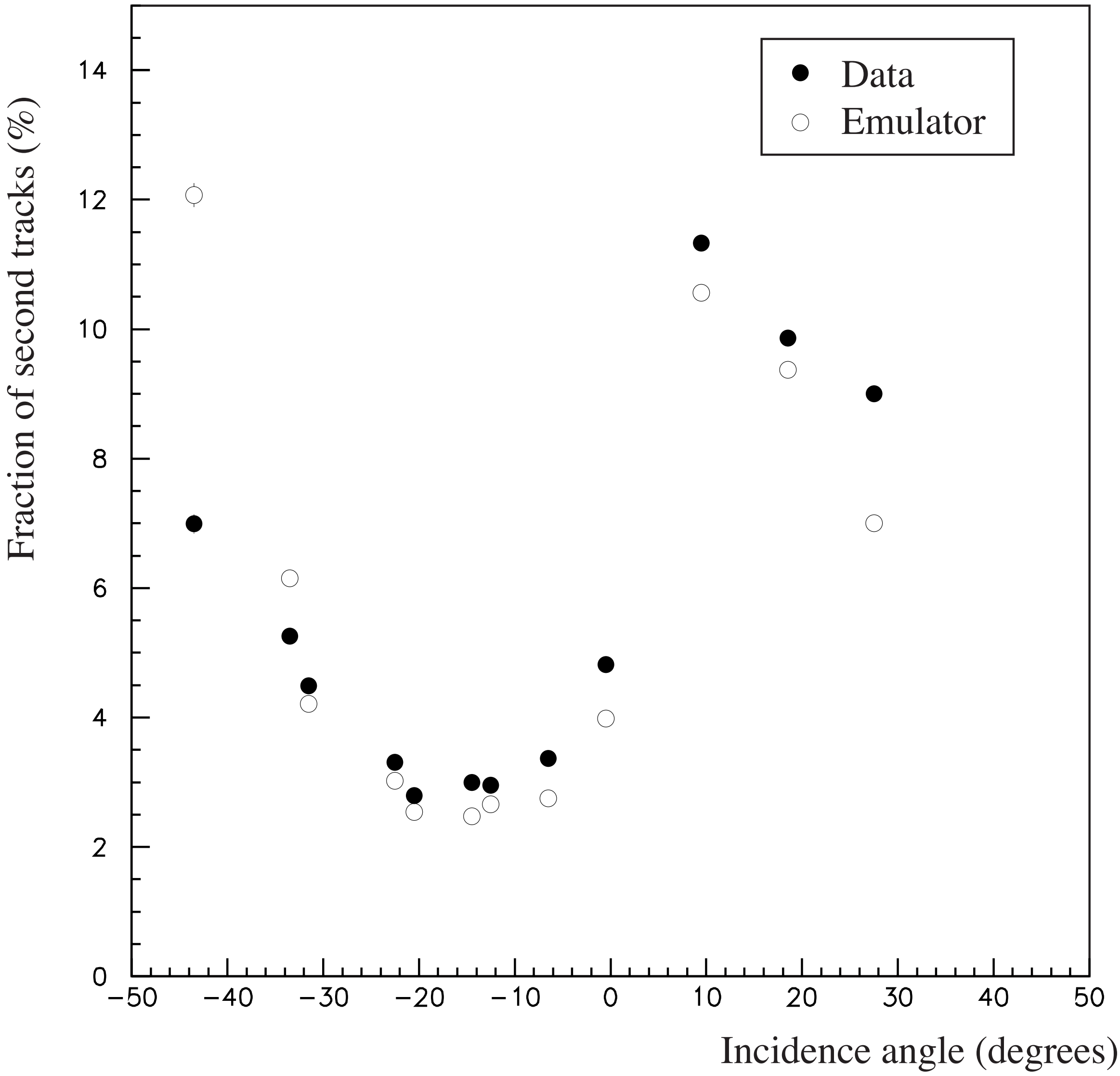

Figure 5- Fraction of second tracks recorded in the trigger data compared to the emulator response. The positive angle fraction is different from the negative angle fraction because of a hardware bug in the BTI and should be ignored (see previous report for explanation and solution).

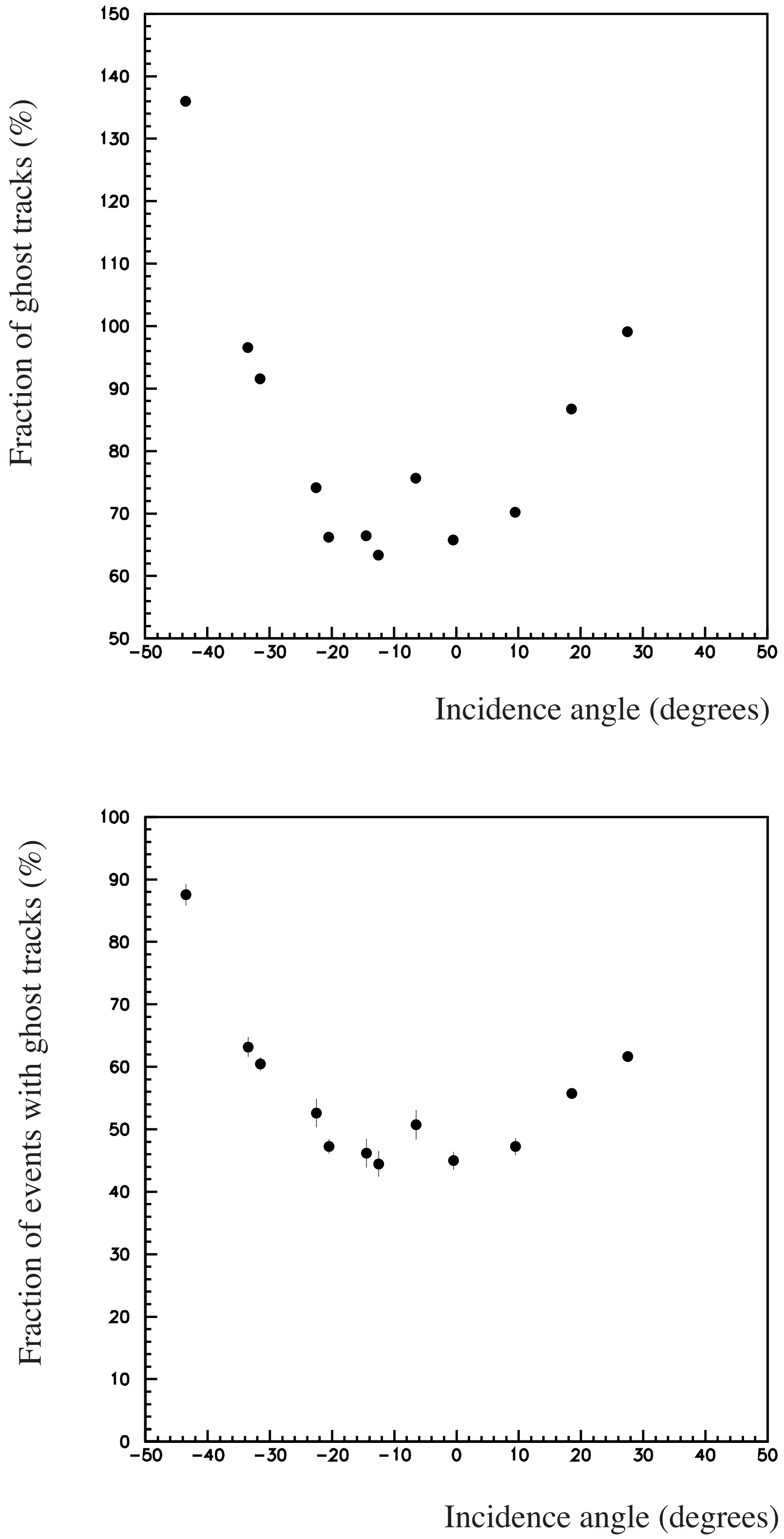

Figure 6- Fraction of out of time ghost tracks as a function of the angle of incidence. The upper plot reports the fraction of ghosts per good trigger, while the lower plot reports the fraction of events with at least a ghost trigger.

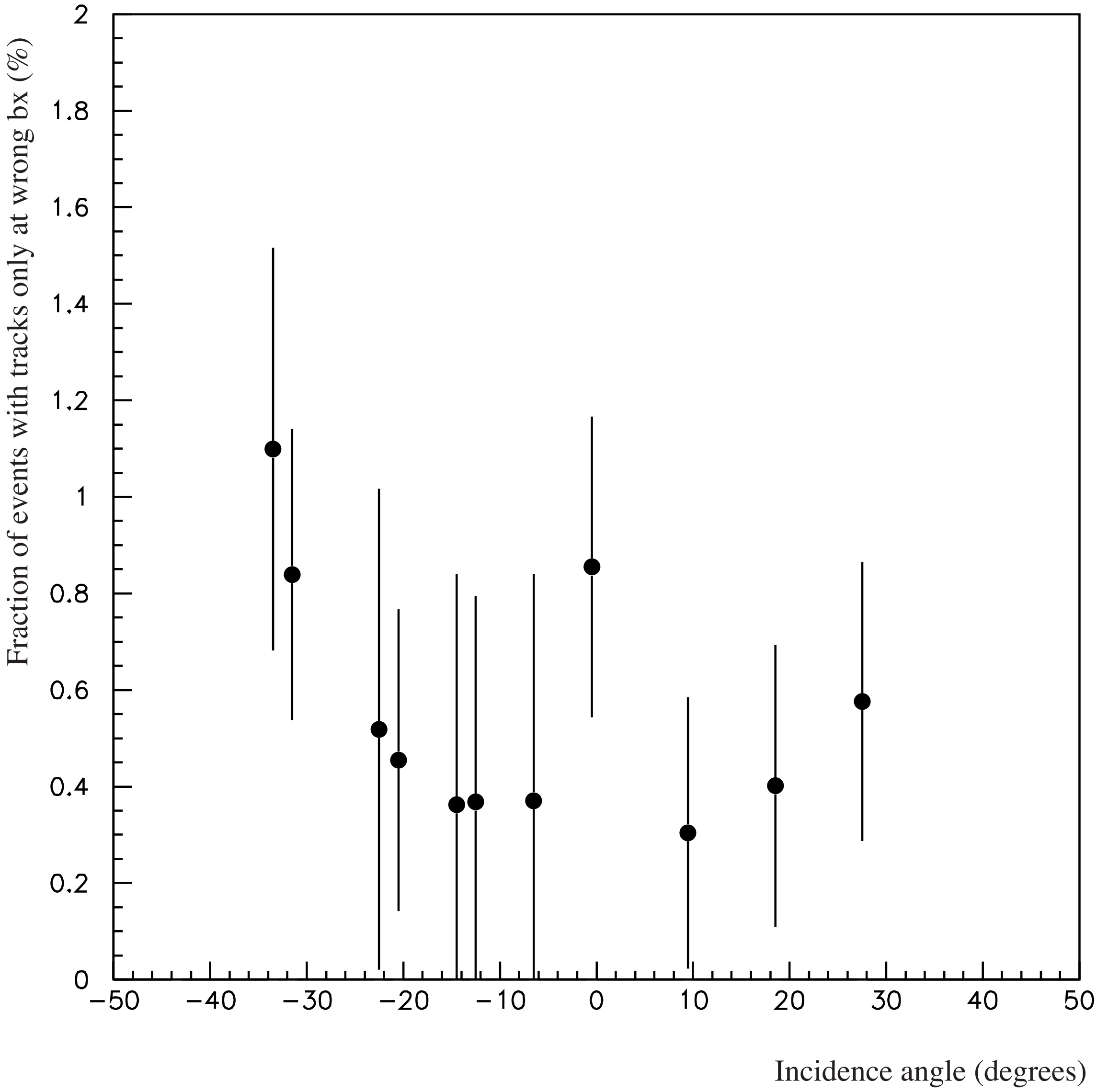

Figure 7- Fraction of events triggering only at wrong bx as a function of incidence angle. The point at 45° (equal to 11.4%) is not shown for sake of clarity.

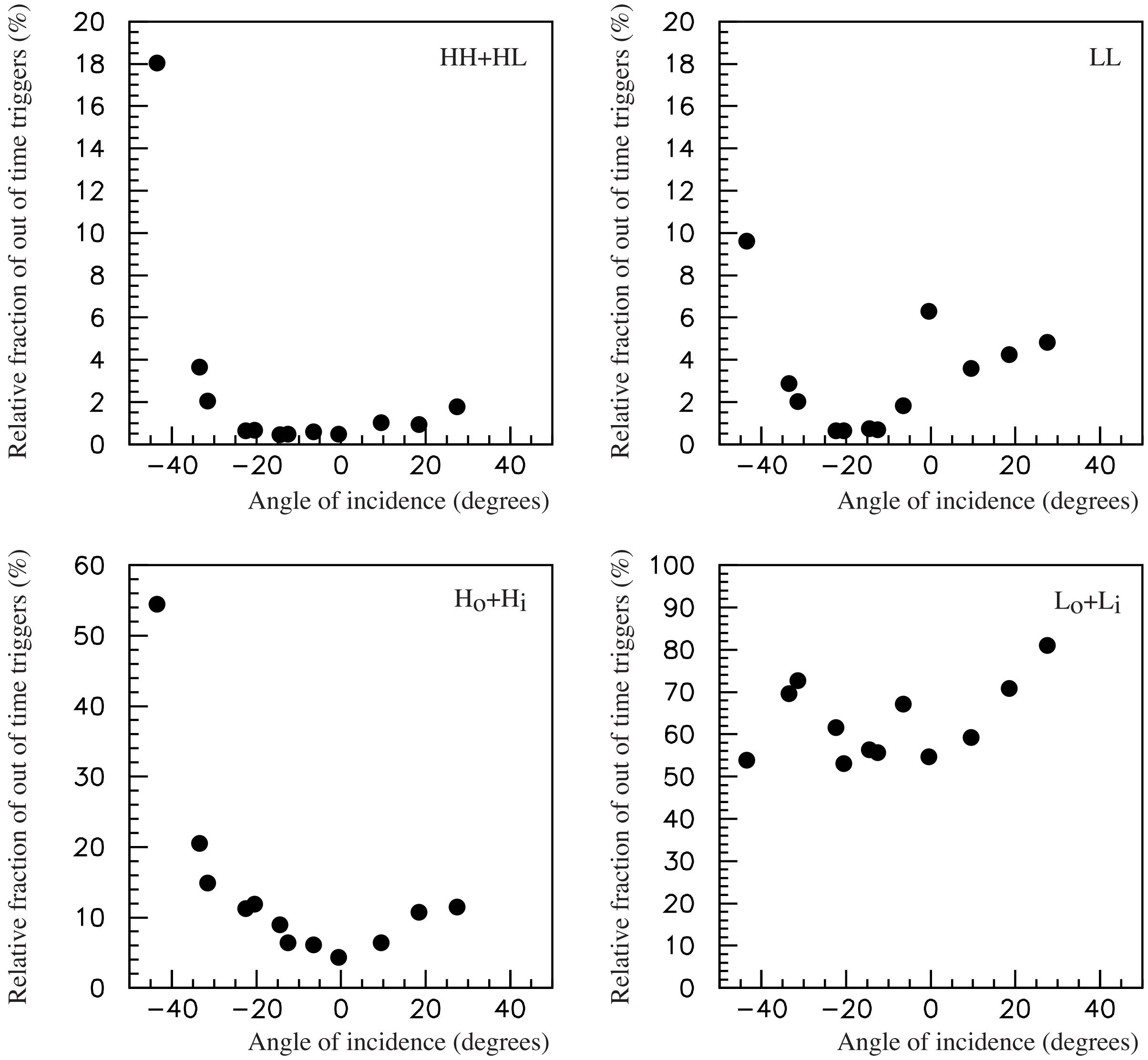

Figure 8- Relative contribution of each trigger type to the out of time ghost rate.

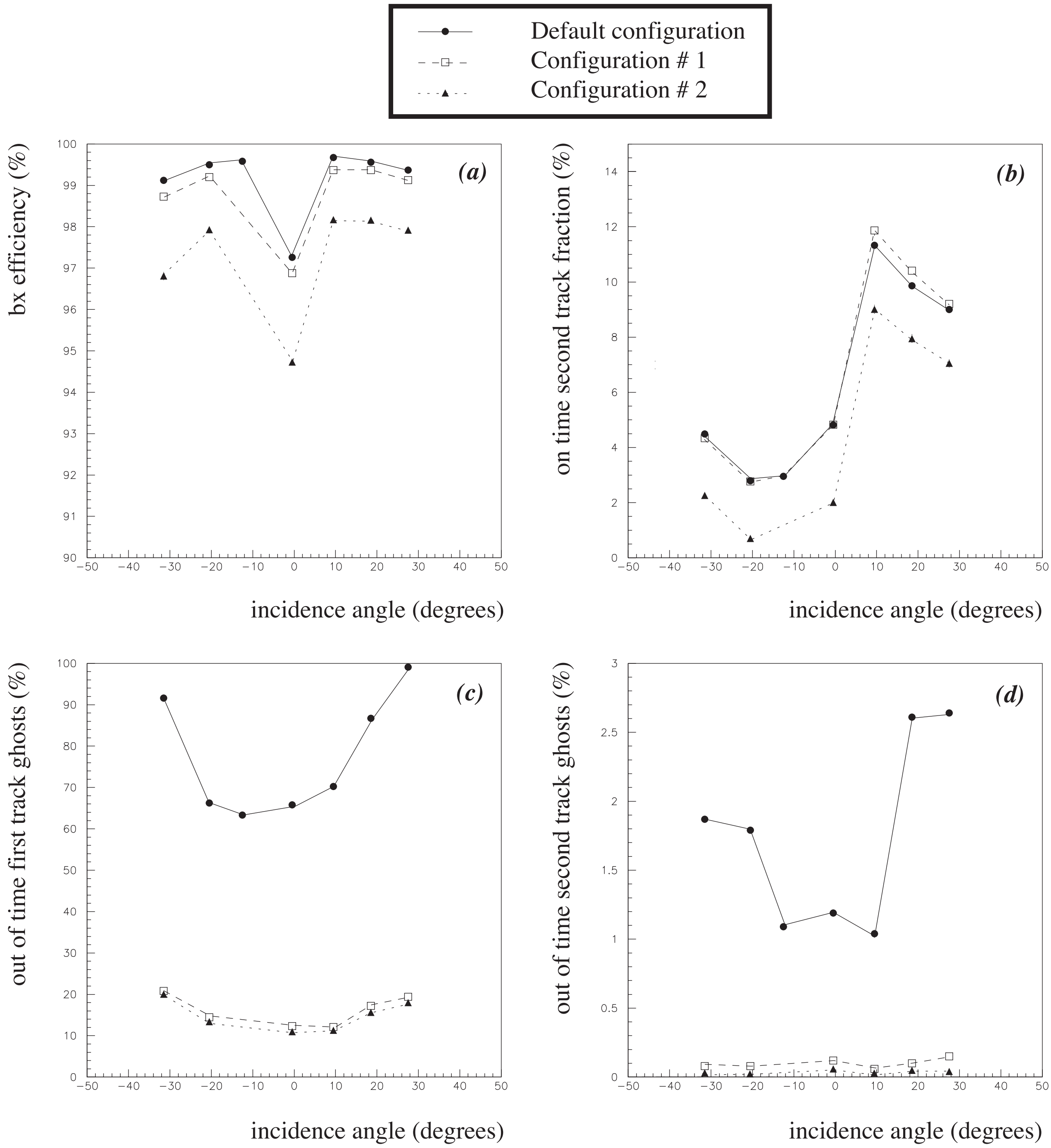

Figure 9- Performance of the trigger for different selections of the single L triggers: default configuration means that L triggers are accepted if validated from any kind of trigger in θ view; configuration # 1 means that L triggers are accepted if validated from a H trigger in θ view; configuration # 2 means that L triggers are rejected. The plots show the effect on (a) bunch crossing efficiency, (b) second track ghosts at correct bx (c) first track out of time noise, (d) out of time second track ghosts versus the incident track angle. The point at -10° for the alternative configuration is not reported due to bad data collected (no scintillator signals available).

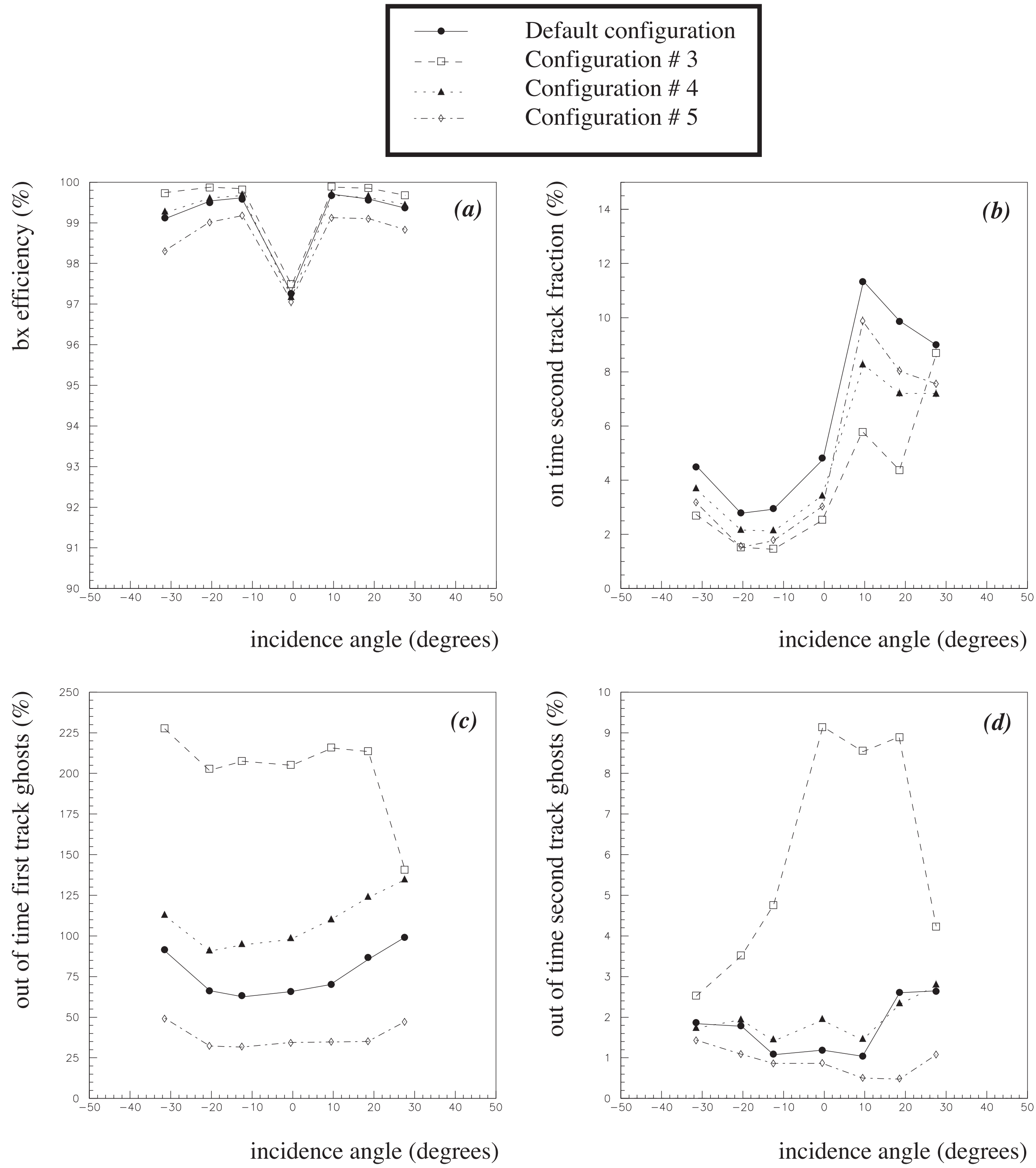

Figure 10- Performance of the trigger for different ways of application of the LTS algorithm: default configuration means that BTI LTS is enabled in both views; configuration # 3 means that BTI LTS is disabled in both views; configuration # 4 means that BTI LTS is disabled only in θ view; configuration # 5 means that TRACO LTS is enabled. The plots show the effect on (a) bunch crossing efficiency, (b) second track ghosts at correct bx (c) first track out of time noise, (d) out of time second track ghosts versus the incident track angle.

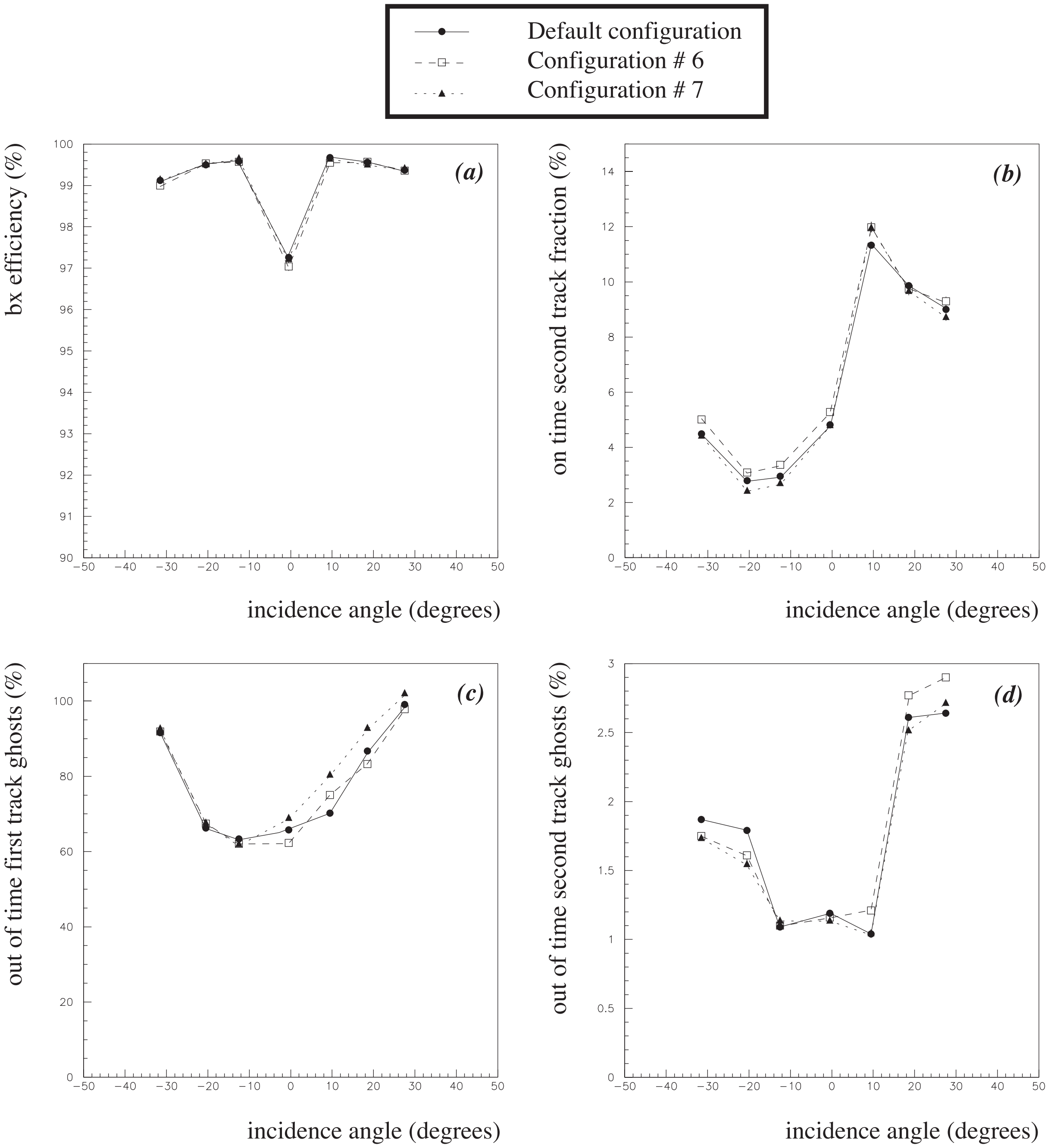

Figure 11- Performance of the trigger for different tolerances of TRACO correlation. Default configuration is standard tolerance; configuration # 6 is minimum tolerance; configuration # 7 is maximum tolerance. The plots show the effect on (a) bunch crossing efficiency, (b) second track ghosts at correct bx (c) first track out of time noise, (d) out of time second track ghosts versus the incident track angle.

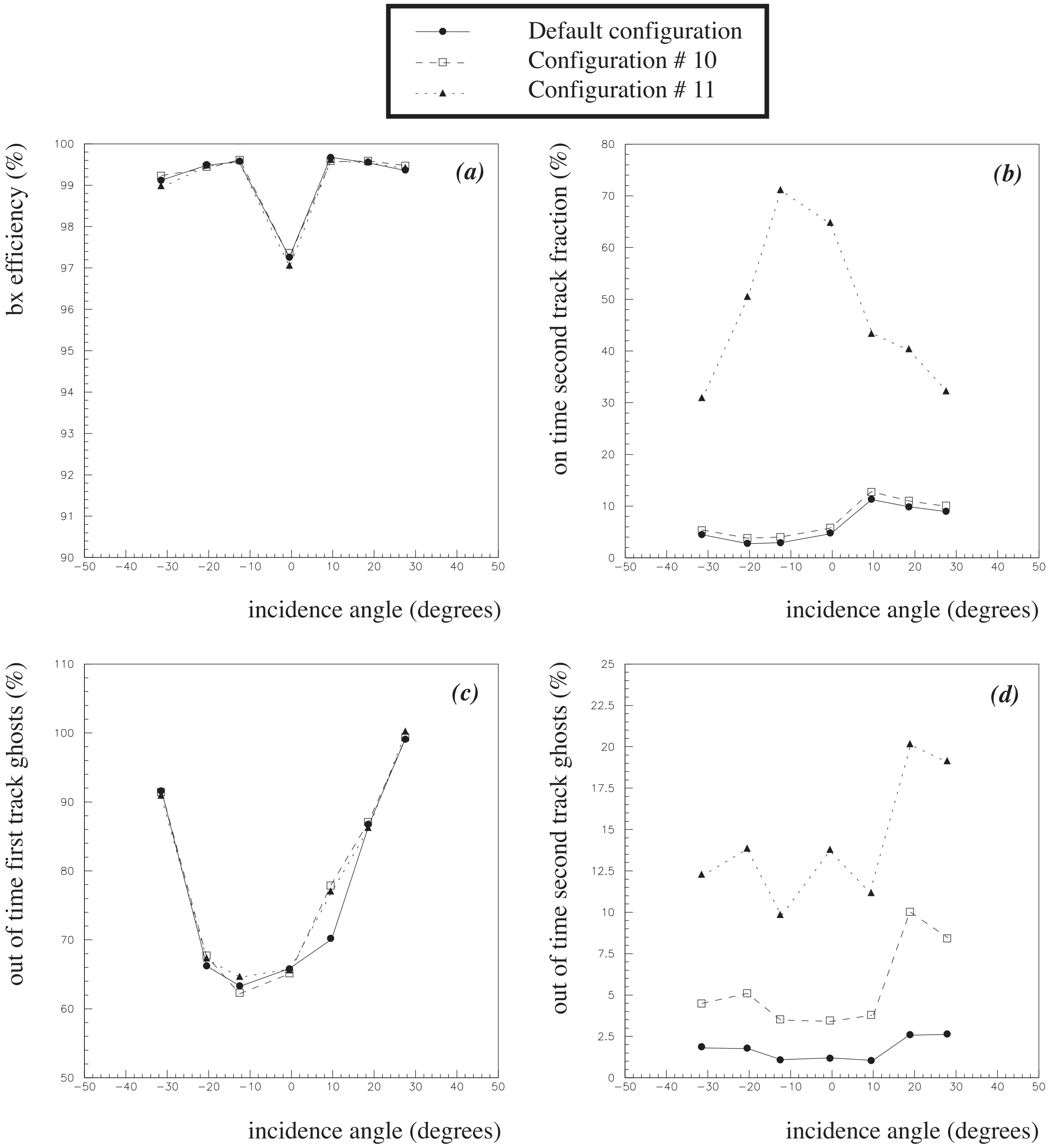

Figure 12- Performance of the trigger for different ghost suppression levels of the TS system: default configuration rejects ghosts of type 1 and 2; configuration # 10 disables rejection of ghosts type 1; configuration # 11 disables rejection of ghosts type 1 and 2. The plots show the effect on (a) bunch crossing efficiency, (b) second track ghosts at correct bx (c) first track out of time noise, (d) out of time second track ghosts versus the incident track angle.