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Effect of Pulse Overspill on the Level 1 Trigger

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Abstract
This short note is an addendum to note 2001-043 [1]. We briefly report on the results of VeLo Level 1 Trigger PreProcessor Interface simulation in presence of pulse overspill.

1 Introduction

In previous notes [2, 1] we have shown that the Level 1 trigger algorithm is very robust against noise and that its efficiency is hardly affected by noise.

This may be different in the presence of noise hits due to overspill. Pulse overspill is the remaining signal from the previous interaction due to the tail of the pulse shape. The remaining fraction of the peaking signal F_{PO} can be positive, producing highly correlated fake hits, or negative, which may cause the loss of true hits. The latter is not an issue in the VeLo as the occupancy is very low. A positive overspill fraction may produce aligned noise hits that mimic high impact parameter tracks and spoil the topological trigger efficiency.

Figure 1 shows the pulse shape of the SCTA128A chip measured during beam tests. Although there is an undershoot starting at 45 ns after the peaking time, one measures still $F_{\mathrm{PO}} = 34\%$ of the peak signal after 25 ns.

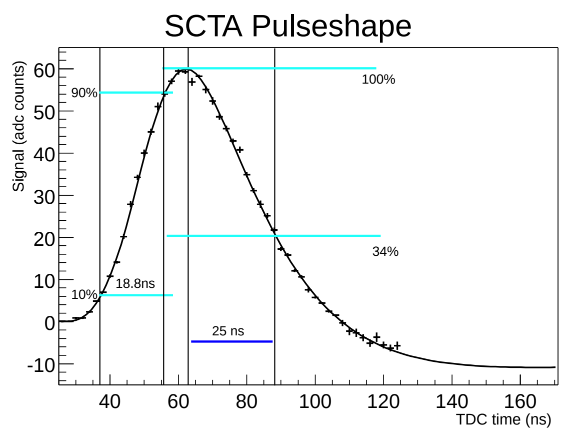

Figure 1: *Measured pulse shape of the SCTA128A readout chip. Figure taken from the* VeLo *TDR [3].*

In Ref. [2] we already presented the effect of overspill on the L1 trigger efficiency using the L1 algorithm described in the Technical Proposal [4]. An overspill of 30% was found to be acceptable while higher values degrade the trigger efficiency dramatically. Since then a multiple interaction veto was added to the L1 trigger algorithm. This veto rejects events where several primary vertices are found using a histogramming method [5]. We show here that this modification also allows a better rejection of events affected by overspill.

2 Probability of overspill

At the luminosity $\mathcal{L} = 2 \cdot 10^{32}$ cm^{-2}s^{-1} the beams cross in average at 29.8 MHz at IP8 and interact at 12.3 MHz. The probability of an interaction in a non-empty bunch crossing is hence 41.3%. Only 80% of these events produce tracks in the VELO. According to the LHC bunch structure [6] when there is a non-empty bunch crossing at time $t = 0$, the probability for a bunch-crossing at time $t = -25$ ns is 98.7%. The overall probability that there was an interaction producing tracks in the VELO at $t = -25$ ns is thus

$$\mathcal{P}_{\mathrm{PO}} = (41.3\%) \cdot (80\%) \cdot (98.7\%) = 32.6\%.$$

3 Results

The same simulation as described in Ref. [1] is used. To simulate overspill we read in simulated raw VELO hits from minimum bias events. All charges are multiplied by the overspill fraction F_{PO} before digitization.

Events with and without pulse overspill are weighted by $\mathcal{P}_{\mathrm{PO}}$ and $1 - \mathcal{P}_{\mathrm{PO}}$ respectively before the trigger is applied.

The signal to noise ratio is set to 10, which is about where the trigger efficiency begins to drop because of noise. We compare the effect of overspill fractions $F_{\mathrm{PO}} =$ 30%, 40%, 50% and 70% with the situation without overspill. The trigger efficiency for $\mathrm{B} \to \pi\pi$ events versus F_{PO} is shown in Figure 2. In every situation one looks for a *best* set of parameters (which describe the common-mode correction and zero suppression cuts) that optimizes the trigger efficiency and an *economic* set that minimizes the event size. The procedure is described in [1].

The L1 efficiency is stable for $F_{\mathrm{PO}} \leq$ 30%. Even at 70% overspill the loss of signal is only 20%. The number of clusters sent to the level 1 trigger processor farm is found to be increased by less than 3% for overspill fractions below 50% and by 15% at 70% overspill.

The robustness against pulse overspill is due to the L1 multiple interaction veto. Lets consider a typical minimum bias vertex with $N_{\mathrm{t}} \approx 47$ tracks in the VELO producing $N_{\mathrm{h}} \approx$ 320 hits. A typical track has 3 r and 3 ϕ hits. The average probability $\mathcal{P}_{\mathrm{h}}$ that a hit is seen in the next event depends on F_{PO}, the applied zero suppression cuts and slightly on the track's momentum. It is supposed to be much smaller than 1 in the following calculations.

- The multiple interaction veto uses 2D tracks in the r–z projection. The probability that 3 consecutive r hits are found on a track is $\mathcal{P}_{\mathrm{h}}^3$. Thus in average $N_{\mathrm{t}}\mathcal{P}_{\mathrm{h}}^3$ tracks form a fake primary vertex in the following event.
- The probability that 3 consecutive r and φ hits are found in the next event is $\mathcal{P}_{\mathrm{h}}^6$. The probability that at least one such track is found in the next event is $N_{\mathrm{t}}\mathcal{P}_{\mathrm{h}}^6$.

As $\mathcal{P}_{\mathrm{h}}^6 \ll \mathcal{P}_{\mathrm{h}}^3$, it is much more likely that

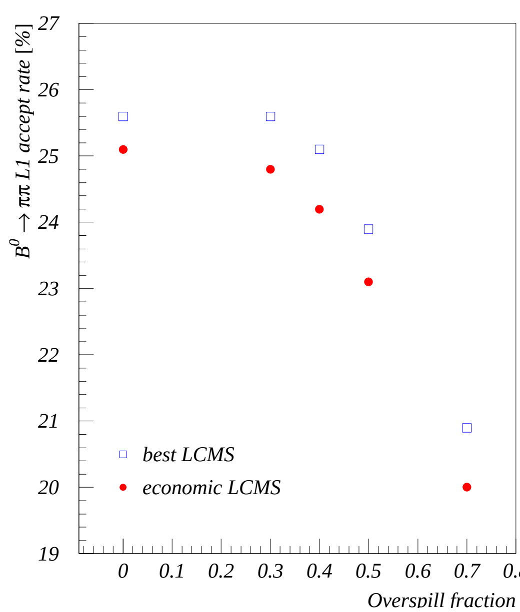

Figure 2: *Trigger efficiency for* $\mathrm{B} \to \pi\pi$ *events versus overspill fraction* F_{PO} *. The Signal to noise ratio is 10. The systematic error on the trigger efficiency is* ± 1.0.

an overspill event mimics a pile-up vertex than high impact parameter tracks. Such events are rejected by the veto, which decreases the number of signal and background events considered for the topological trigger. As the overall minimum bias acceptance is fixed at 4%, the final trigger cut is loosened, which allows to recover signal events.

Without overspill the L1 multiple interaction veto accepts about 80% of the events. This fraction decreases to 75% at $F_{\mathrm{PO}} = 50\%$ and 65% at $F_{\mathrm{PO}} = 70\%$. The trigger efficiency decreases accordingly.

4 Conclusion

Due to the addition of the L1 multiple interaction veto the L1 algorithm has become more robust against overspill. No sizeable effect neither on the L1 trigger efficiency nor on the event size is observed for overspill fractions up to 30%. At higher fractions the trigger efficiency begins slowly to decrease but not as dramatically as with the Technical Proposal trigger algorithm.

References

[1] Guido Haefeli Aurelio Bay and Patrick Koppenburg. LHCb VeLo Off Detector Electronics Preprocessor and Interface to the Level 1 Trigger. LHCb VeLo 2001-043, 2001.

[2] Patrick Koppenburg. Simulation of the vertex trigger preprocessor: Effects of noise on L1 performance. LHCb TRAC 99-003.

[3] LHCb, P.R. Barbosa et al. *LHCb VeLo Technical Design Report.* CERN, Genève, 2001. In preparation.

[4] LHCb, S. Amato et al. *LHCb Technical Proposal.* CERN, Genève, 1998. CERN-LHCC-98-4.

[5] Mike Koratzinos. Multiple Interaction Tagging on the Level 1 Vertex Trigger Algorithm. LHCb VeLo 98-061.

[6] See for instance `http://lhcb-elec.web.cern.ch/lhcb-elec/html/key_parameters.htm`.