Double injection studies on the RD53B-ATLAS chip

Charge injection scans performing two rapid injections on the RD53B chip measuring the hit ratio and time over threshold (pToT) on the effected subsequent injection.

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ABSTRACT

Operation at the High Luminosity LHC (HL-LHC) requires the pixel detectors of ATLAS and CMS to separate collisions occurring at an extremely high rate. The RD53 collaboration has been working on the design of a dedicated readout chip to meet these goals, the RD53 chip. This poster presents charge injection studies performed on the RD53B-ATLAS chip, specifically looking at its response when a pixel is exposed to injections happening close in time. Results show that the measured charge of an injection is changed by a preceding injection. The results can be explained by the behaviour of the comparator.

Introduction

A dedicated scan procedure called the double injection scan was developed to study the behavior of the Front-end (FE). The double injection scan performs two injections in rapid succession by utilizing the specialized charge injection circuit attached to each pixel input. In this way, we were able to inject two consecutive injections with a time gap as small as 5 bunch crossings (BX) = 125 ns.

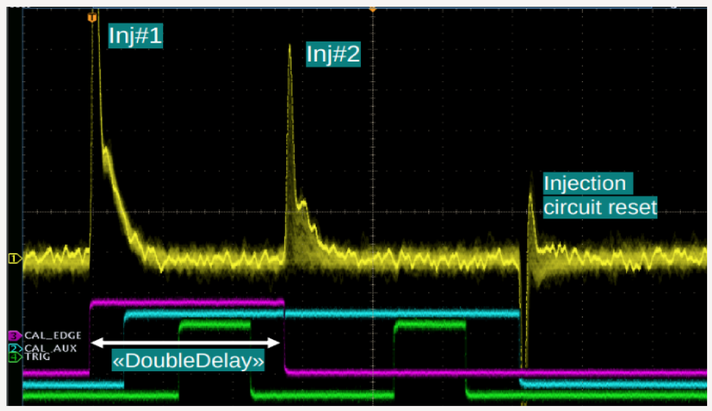
Procedure

1) Inject a constant charge into a selected pixel (Inj#1)

2) Wait a set period of time (Time after injection [BX])

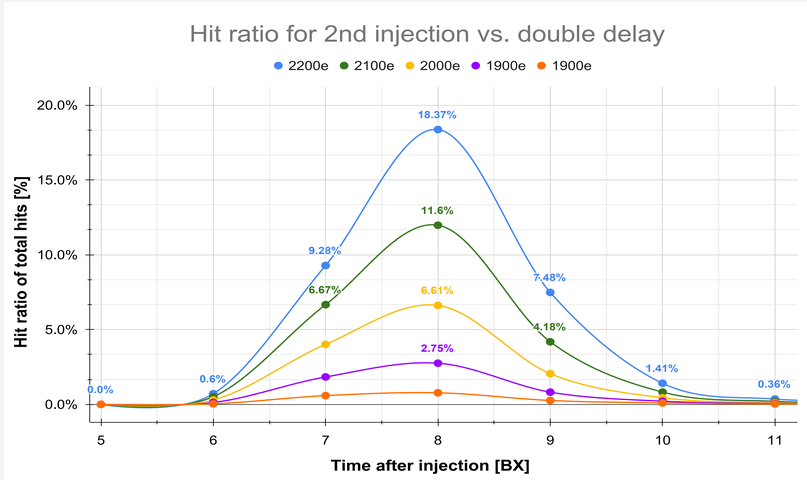
3) Inject a second charge of varying magnitude (Inj#2)

4) Measure the hit rate and time over threshold (pToT) of the second injection.



Hit ratio for 2nd injection

The hit ratio is the number of injections read out (hits) dived by the number of injections inserted. This was measured for the 2nd injection at time separations 5-11 BX from the primary injection. The primary injection charge was set to 15 000e. The threshold was set at 2300e and the 2nd injection was varied in the low magnitude scale between 2200e (blue) to 1900e (orange), keeping it always below the threshold region.



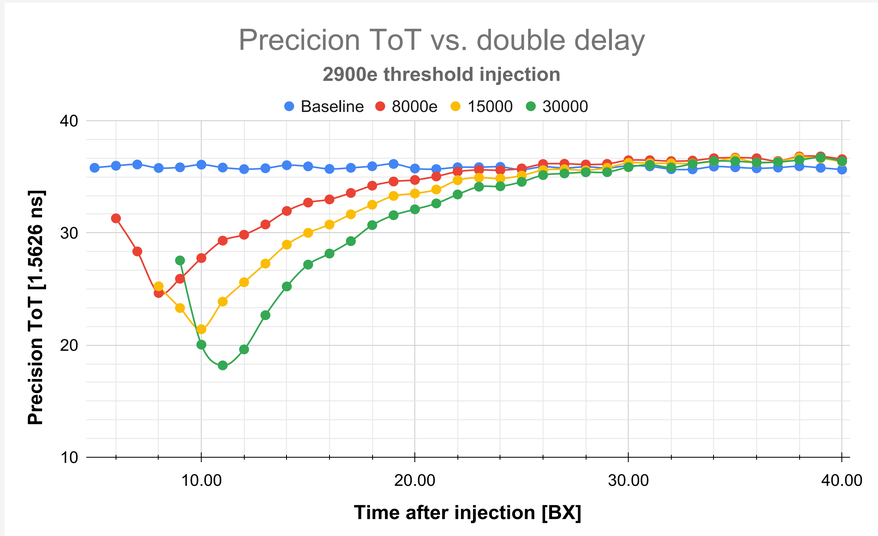
As the injections are always substantially far below threshold, the hit should be close to 0%. However, at certain time separation values (7-9 BX) the charges go above threshold and get read out as a hit. These points at certain time separations are explained by a short threshold reduction after the presence of a hit. As the threshold is effectively reduced, the noise occupancy (NOCC) increases. Thus, real hits will be followed by noise hits in subsequent BX's more frequently than the 10e-6 expectation.

Precision ToT (pToT) vs. double delay

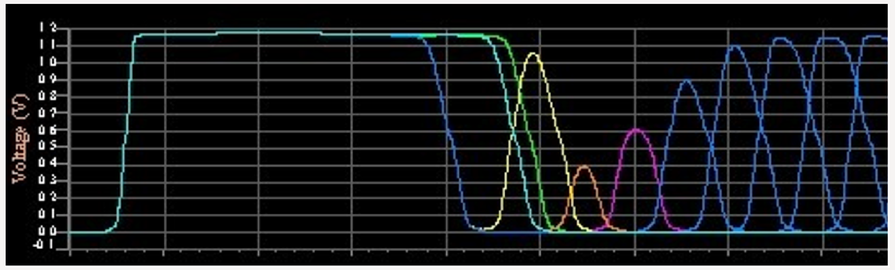
A time over threshold test measured in precision ToT values [1.56 ns] was done to study the effect of a preceding charge injection. This was performed by measuring the pToT of the 2nd injection at different time separations. The primary injection magnitudes were varied from 30ke (green) to 8ke (red).

A baseline scan (blue) was also performed with the primary injection set to 0e such that the unaffected pToT values were obtained. The subsequent injection magnitude was kept constant at 2900e corresponding to a pToT value equal to 33.4 as seen by the blue baseline points.

As seen from the top right figure, at low time separations (7-10 BX) the ToT of the subsequent injection decreases. This effect is greater at larger primary injections.



The ToT then goes towards baseline when the time gap between the injections increases. These effects were shown in design simulations to be explained by the behavior of the pre-amplifier (preamp) and the comparator. As seen in the figure below, the pulse height from the comparator output first decreases and then gradually increases as preamp and comparator recover their bais point. This matches the observations seen in the ToT figure above.



Results

This study shows the effect that a preceding charge injection has on the noise occupancy and pToT of the subsequent injection. The results show that the effect is present only at low time separations.

The NOCC increases between 6-10 BX separations for a subsequent hit due to a short effective threshold reduction by a primary hit.

The ToT of a subsequent hit will also at short time gap separations decrease (6-10 BX). The ToT will then return to baseline as the preamp and comparator regenerate.

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