



Double injection scan with precision ToT measurements for the RD53B

Thanks to Maurice Garcia-Sciveres, Timon Heim and Magne Lauritzen

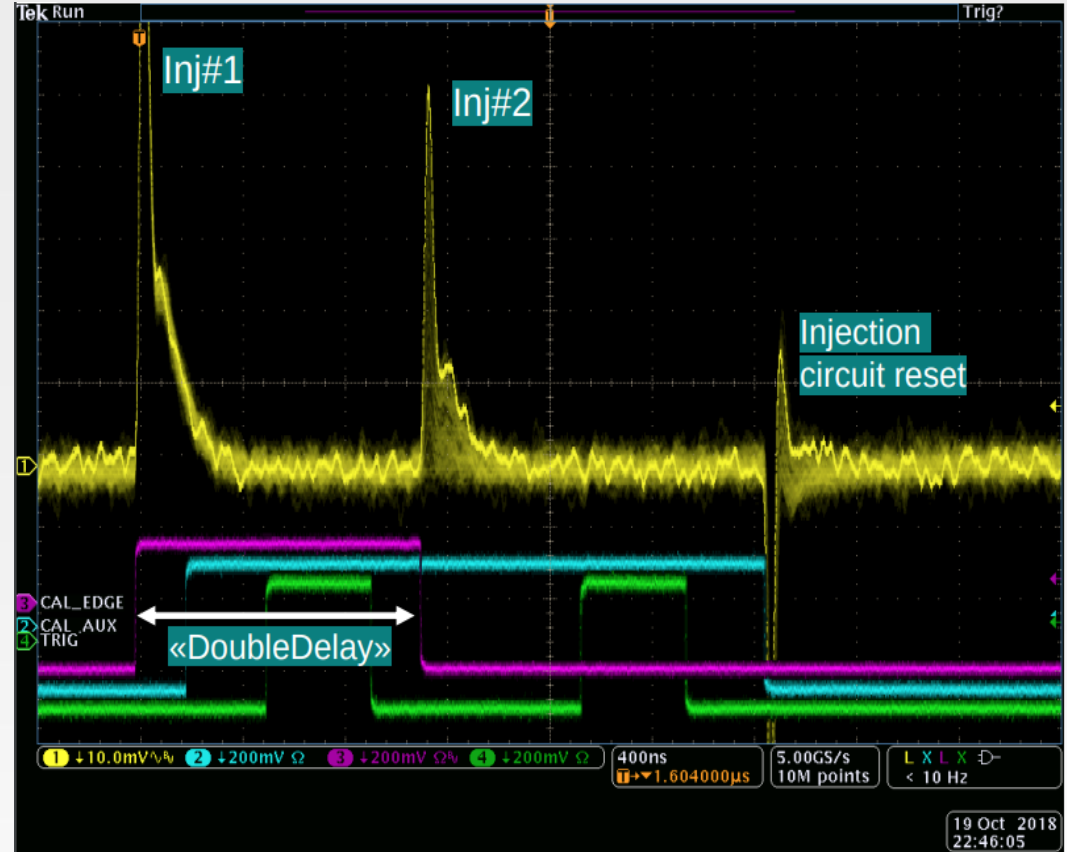
Presented by Simon K. Huiberts





Introduction

- The purpose of the **double injection scan** is to study the behaviour of the Front-end (FE) during charge injections and data readout
- E.g. see how the measured pixel ToT is **affected** by a **preceding injection**
- The double injection scan** can inject **two consecutive charge injections** into each pixel
 - Done via **Cal commands** which control the capacitor injections for a selected pixel
- How it's done:**
 - First injecting a constant charge into the selected pixel (Inj#1)
 - Wait a set period (DoubleDelay [BX]) (1BX value = 25 ns)
 - Injecting a second charge of varying magnitude into the same pixel (Inj#2)
 - Send triggers to read out the data



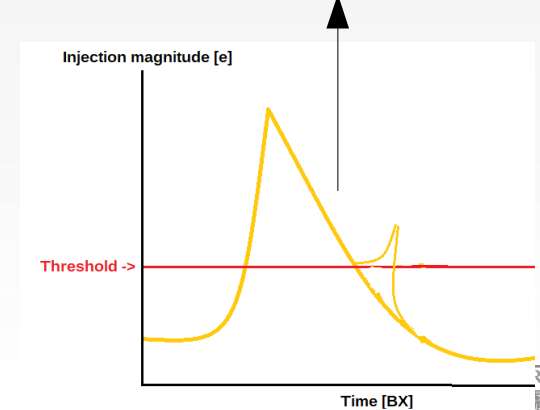
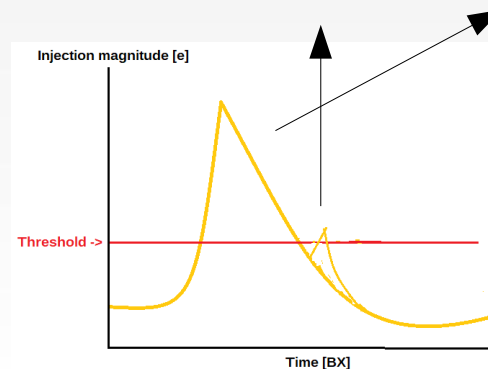
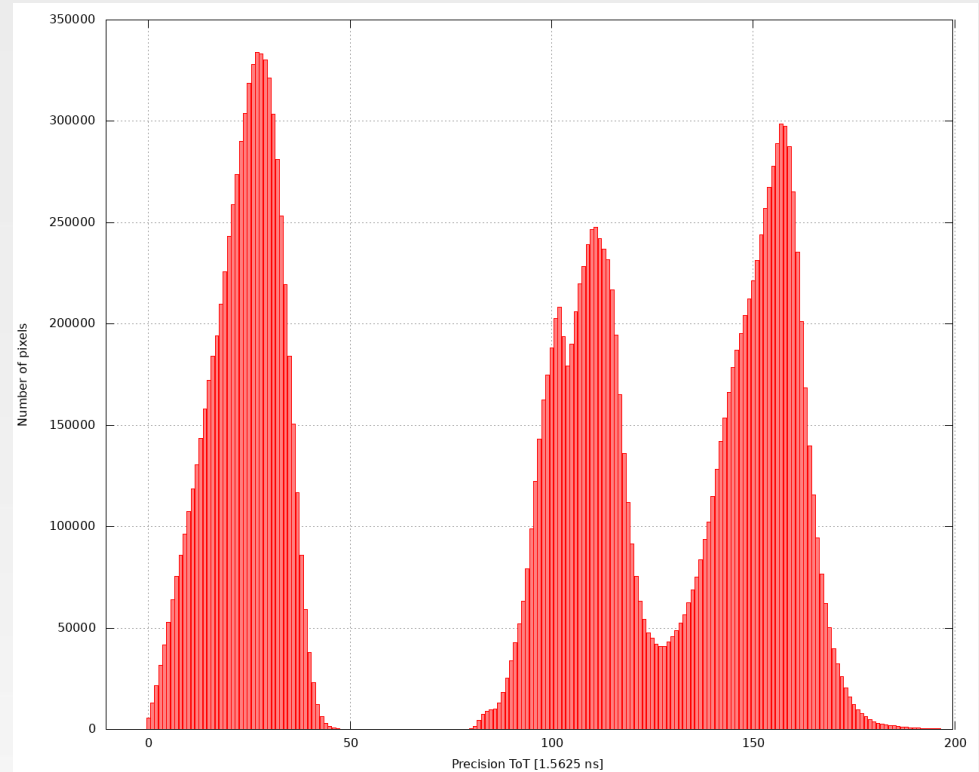
Double injection scan taken by an oscilloscope. Figure by Magne Lauritzen

- 1) Purple line is the CAL_EDGE signal
- 2) Light blue line is the CAL_AUX signal
- 3) Green line is the trigger signal

Raw precision ToT measurements



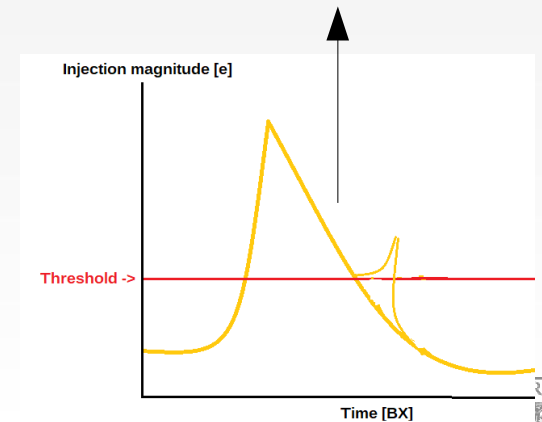
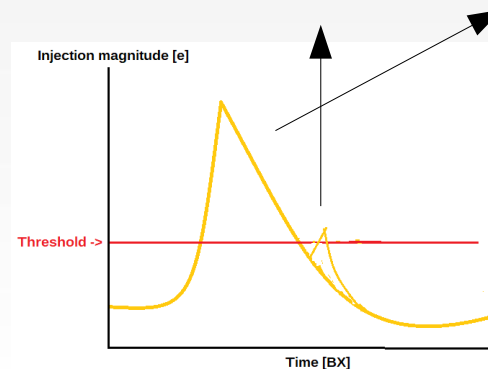
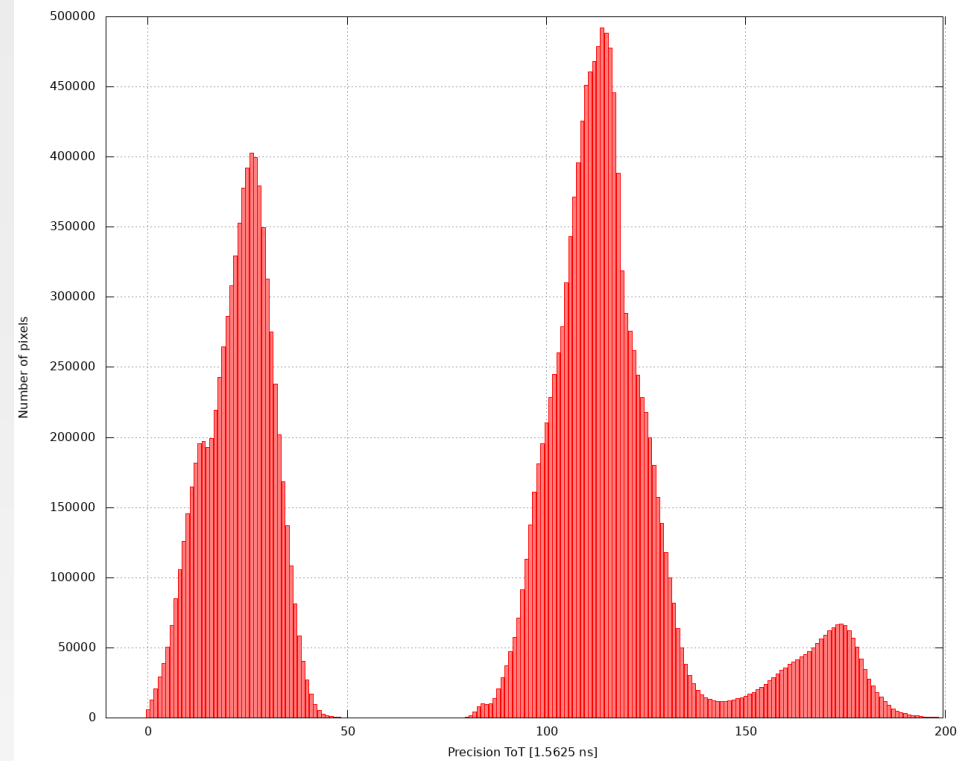
- Raw precision ToT from a double injection with:
 - First injection = 15 000e
 - Second injection is the threshold scan from: 1300e to 3200e
 - Tuned to ~2300e
 - Double delay value = 8 BX
- First peak shows the pToT values of the threshold injection
- Second peak shows the pToT of the first injection
- Third peak is the pToT when the two injections overlap
- If increases the time separation between the two peaks -> third peak should get smaller



Raw precision ToT measurements



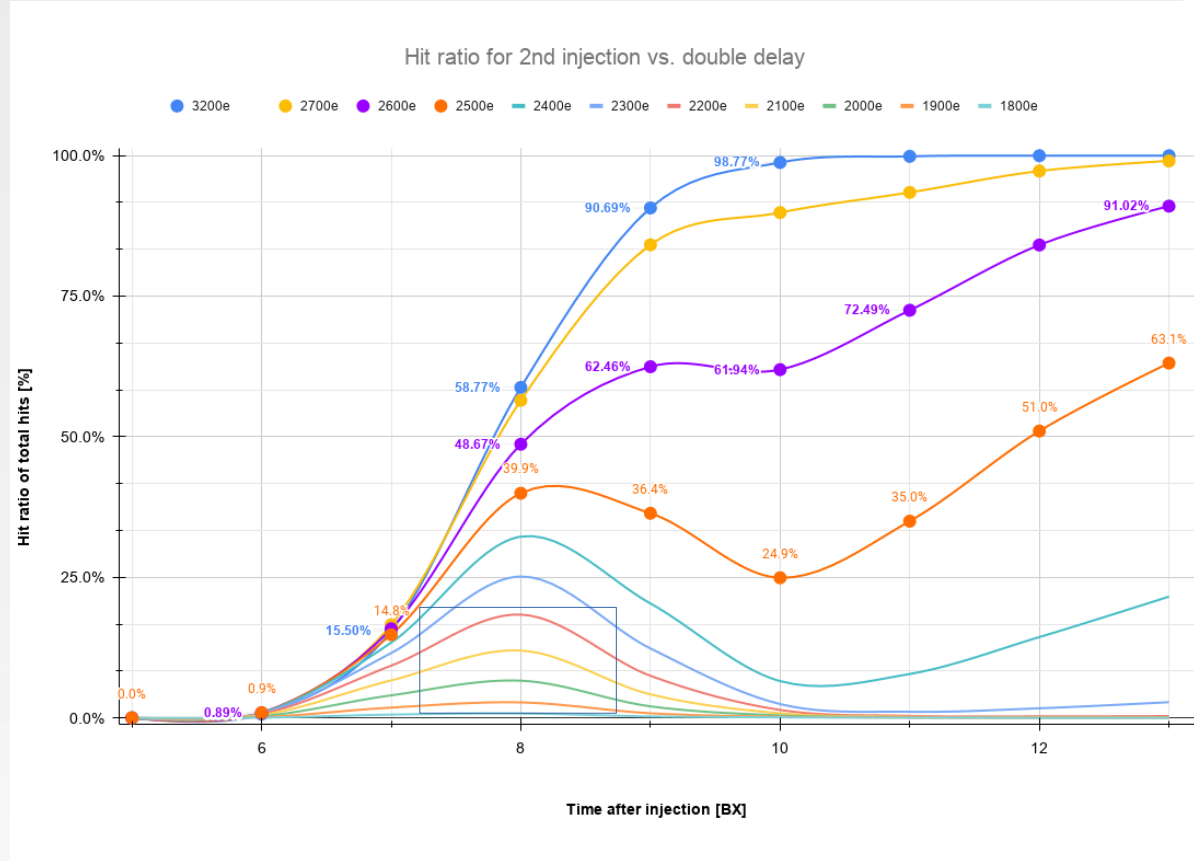
- Raw precision ToT from a double injection with:
 - First injection = 15 000e
 - Second injection is the threshold scan from: 1300e to 3200e
 - Tuned to 2300e (vcal_med to gnd)
 - Double delay value = 9 BX
- First peak shows the pToT values of the threshold injection
- Second peak shows the pToT of the first injection
- Third peak is the pToT when the two injections overlap
- If increases the time separation between the two peaks -> third peak should get smaller
 - Also what we observed!



Hit ratio of the 2nd injection vs double delay



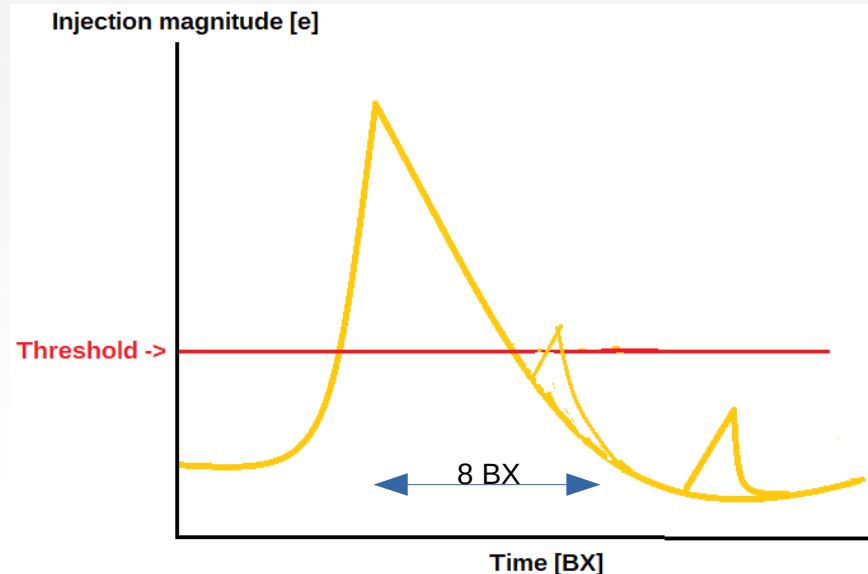
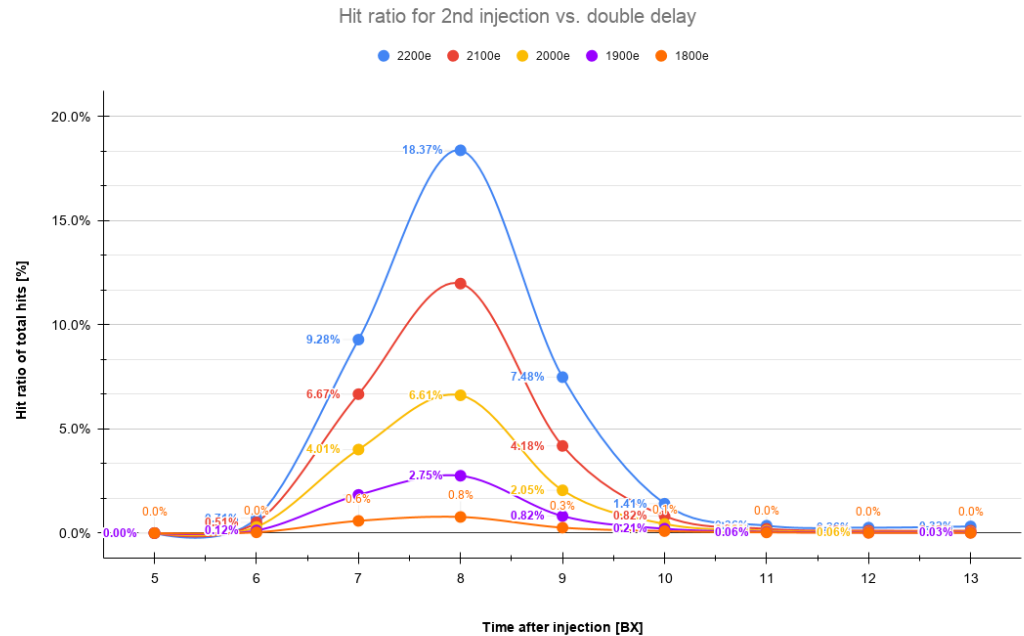
- Plotted the hit ratio of the second injection (threshold injection)
- First injection = 15 000e
- Inject values between 1800e to the maximum injection value 3200e
- Chip tuned to ~2300e
 - 2300e injection hit ratio normally be ~ 50%
- At low double delay values the hit ratio decrease because of the overlap
- Also observed: At certain double delay and injection values the hit ratio increases
 - E.g. the 2500e (orange) at time separation at 8BX
- Effect due to the discharge time of the first injection:
 - Injection below threshold rides the leftover charge and gets above threshold



Hit ratio of the 2nd injection vs double delay



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- Also observed: At certain double delay and injection values the hit ratio increases
 - E.g. the 2200e (blue) at time separation at 8BX
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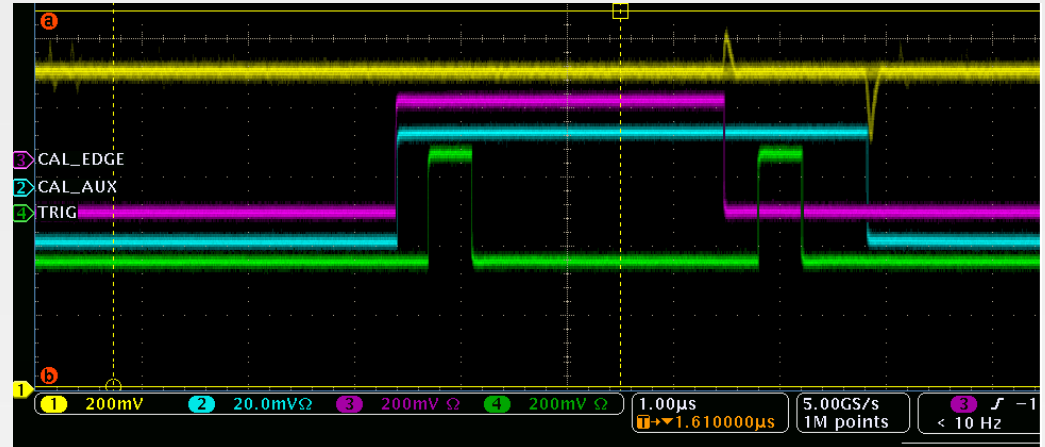


Method

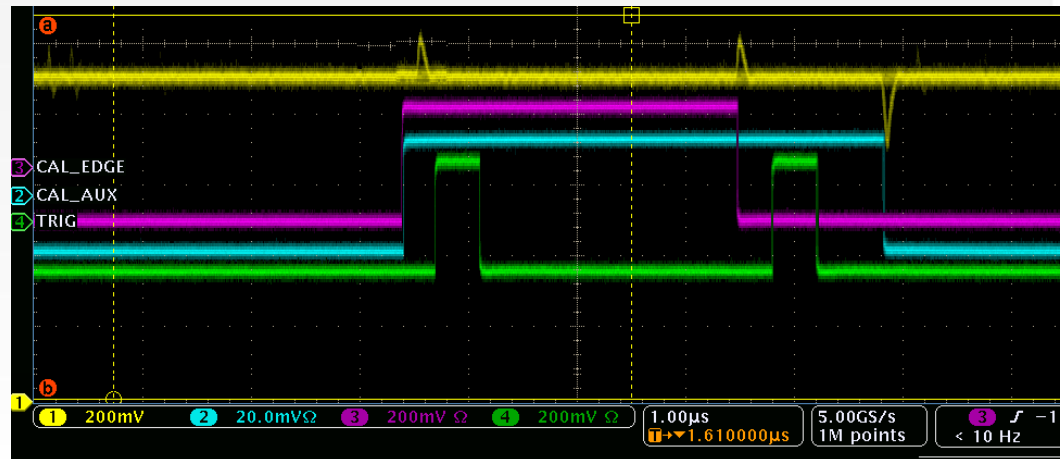
- Test the effect that a preceding charge injection has on the measured pToT
- For each value of the double delay, perform:
 - A scan with **#Inj1 set to 0e** (Upper figure)
 - Gives a **baseline** precision ToT used for comparison
 - A double injection scan with a large **#Inj1** (Bottom figure)
 - **#Inj1** crosses the pixel threshold
- Compare of the mean of the pToT of the threshold injections between the baseline scan and the scans with a **#Inj1**
- **Probe** the effect that the **#Inj1** has on the pToT of our second injection



Baseline (Only have the second charge of varying magnitude)



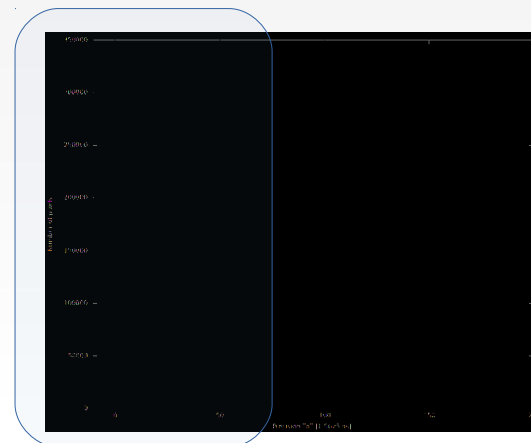
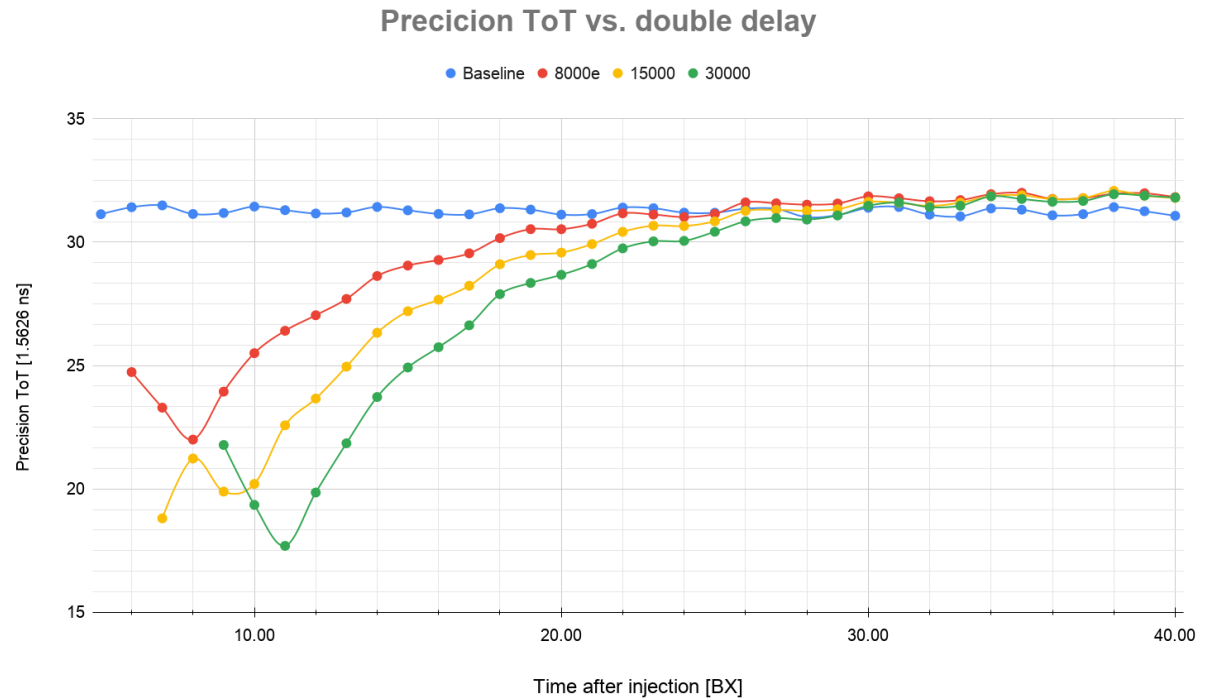
Large #1 injection and then inject a second charge of varying magnitude



Precision ToT vs. double delay



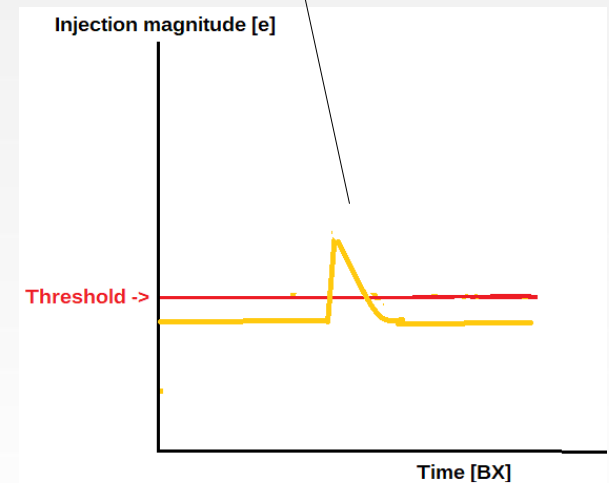
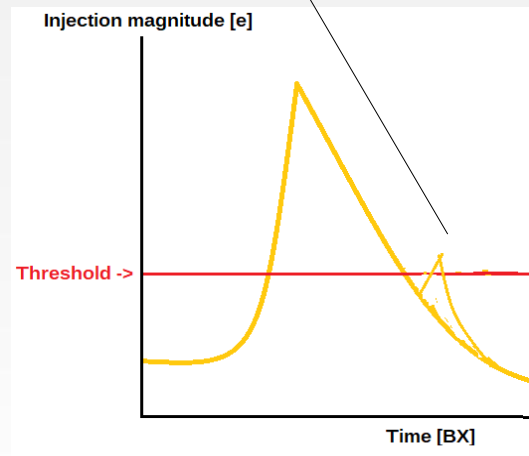
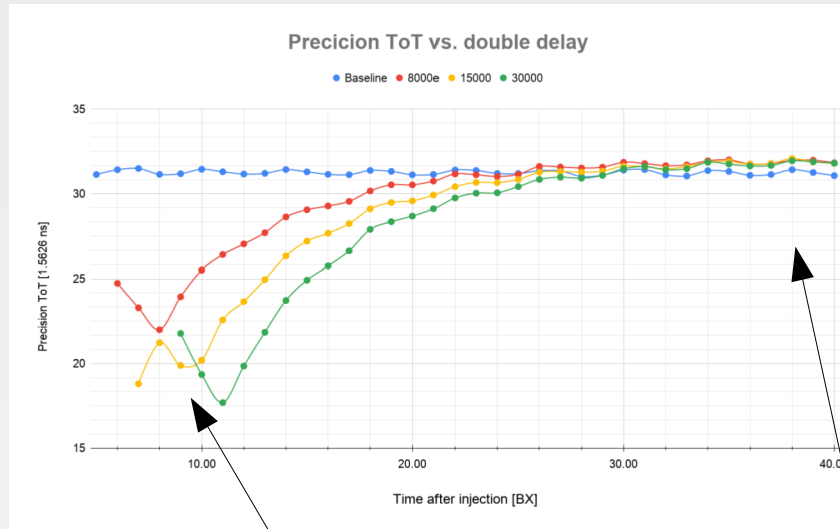
- Plotted the pToT of the second injections (threshold injection)
- Mean pToT value of the threshold injections for 5 pixels
- Baseline scan are the blue points
- Red, yellow and green injection from 8ke to 30ke
- Observed: At low double delay values the pToT decrease
- Effect increases at larger primary injections
- PtoT goes towards baseline when the time gap increases
- Effect due to the discharge of the first injection
 - Second injection will get a lower ToT as its dragged down by the discharge of the primary injection



Precision ToT vs. double delay



- Plotted the pToT of the second injections (threshold injection)
- Mean pToT value of the threshold injections for 5 pixels
- Baseline scan are the blue points
- Red, yellow and green injection from 8ke to 30ke
- Observed: At low double delay values the pToT decrease
- The pToT goes lower when the first injection increases
- PtoT goes towards baseline when the time gap increases
- Effect due to the discharge of the first injection
 - Second injection will get a lower ToT as its dragged down by the discharge from the primary injection



Conclusion



- A double injection scan sends out two consecutive charge injections into a single pixel
- Test the effect that a preceding charge injection has on the pToT of the threshold injections
- **Results:**
- At certain time separations and injection values the hit ratio of the second injection increases more compared to a baseline scan
- The pToT decreases at lower time gaps between the primary and the secondary injection
 - This effect increases at higher primary injections
- pToT value returns to baseline at higher time gap separations
- **Future work:**
- Measure the pToT for a fixed injection value (
- Merge the double injection scan into YARR



Thank you for your attention!



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Backup



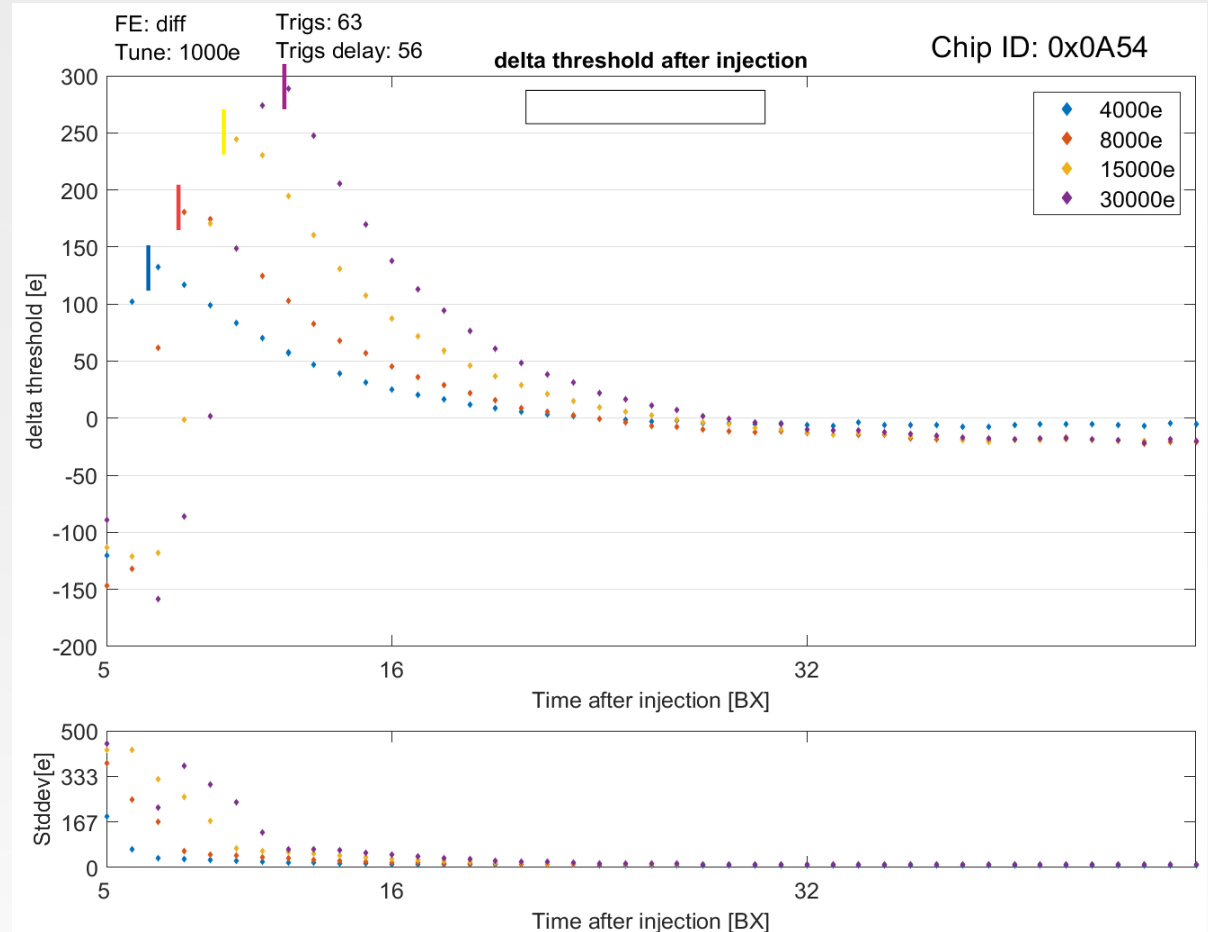
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Re-visit: Mean of the pixel threshold differences vs. double delay



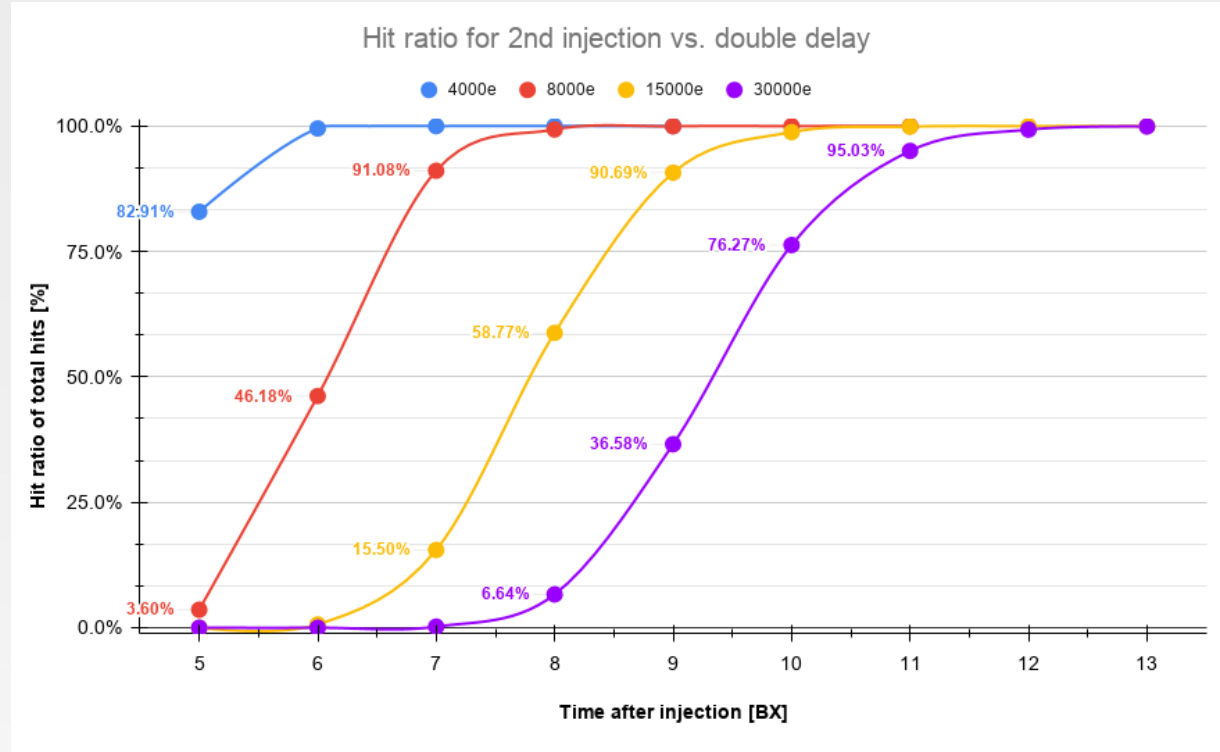
- Tuned with $V_{cal_Med} = 230$
- Colour code represents scans with different injection magnitude
- The maximum Δ threshold value increases with larger injections
- Threshold deviation goes up to:
 - ~ 140e (4k), 190e (8ke), 250e (15k), 290e (30k) injections
- Maximum deviation point on each curve moves to higher double delay values for larger injections
- Δ threshold decreases exponentially after the maximum point
- 8-30ke injection gets a undershoot after 24 BX
- Values below the maximum point on each curve is artificially low due to the overlapping of the first injection (see marker)



Analysis on result: Hit ratio of the 2nd injection vs double delay



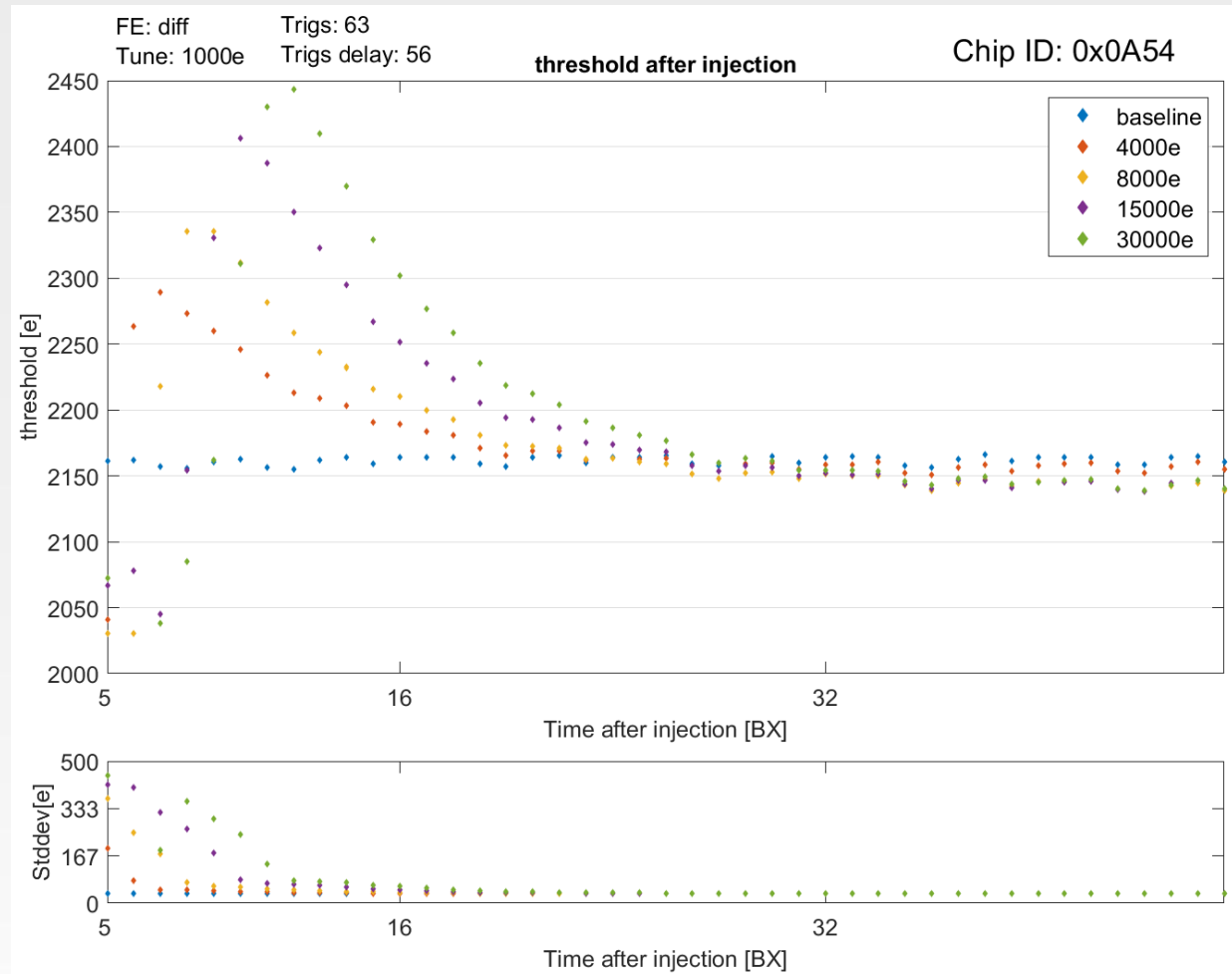
- Plotted the hit ratio of the second injection (threshold injection) at its maximum injection value (3200e)
- Always be above threshold -> ~100%
- Observed: At low double delay values the hit ratio would decrease
- Hit ratio would be lower for larger injections
- 30ke injection stays around 0% after 5-7 BX
- Effect due to the first injection staying above threshold at the second trigger
- Loose hits from the 2nd injection
- Artificially bias the S-curves and lead to lower measured threshold value
- Larger injection has longer ToT and thus this overlapping effect occurs for longer separations



Results: Mean of the threshold vs. double delay



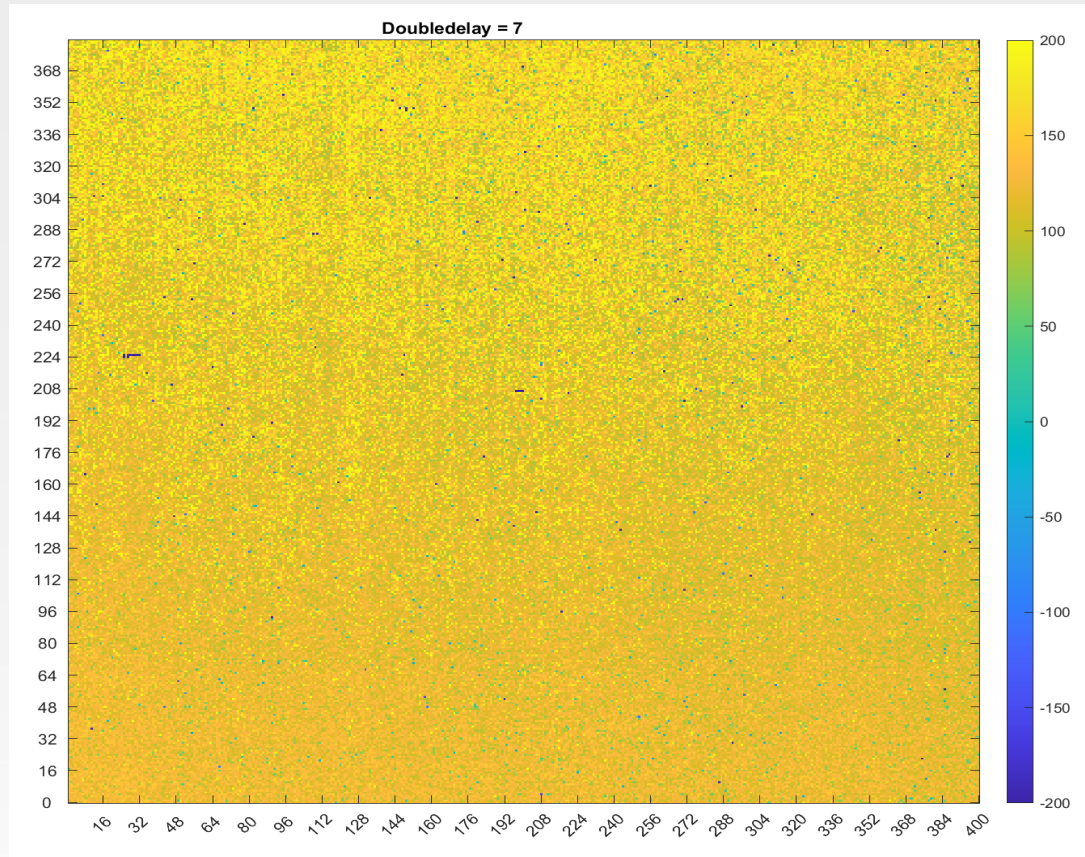
- Tuned with $V_{cal_Med} = 230$
- **Blue points:** Baseline threshold with **#Inj1 set to 0e**
 - Uniform threshold at $\sim 2160e$
- Red & yellow points: First injection is 4ke and 8ke respectively
- The maximum threshold value increases with larger injections:
 - $\sim 2290e$ (4k), $2340e$ (8k), 2410 (15k), 2450 (30k)
- This value moves to larger BX for larger injections:
 - ~ 7 BX (4k), $8-9$ BX (8k), 10 BX (15k), 12 BX (30k)
- Threshold approaches baseline at ~ 23 BX for both injection scans
- Some small fluctuations



Threshold difference on pixel map



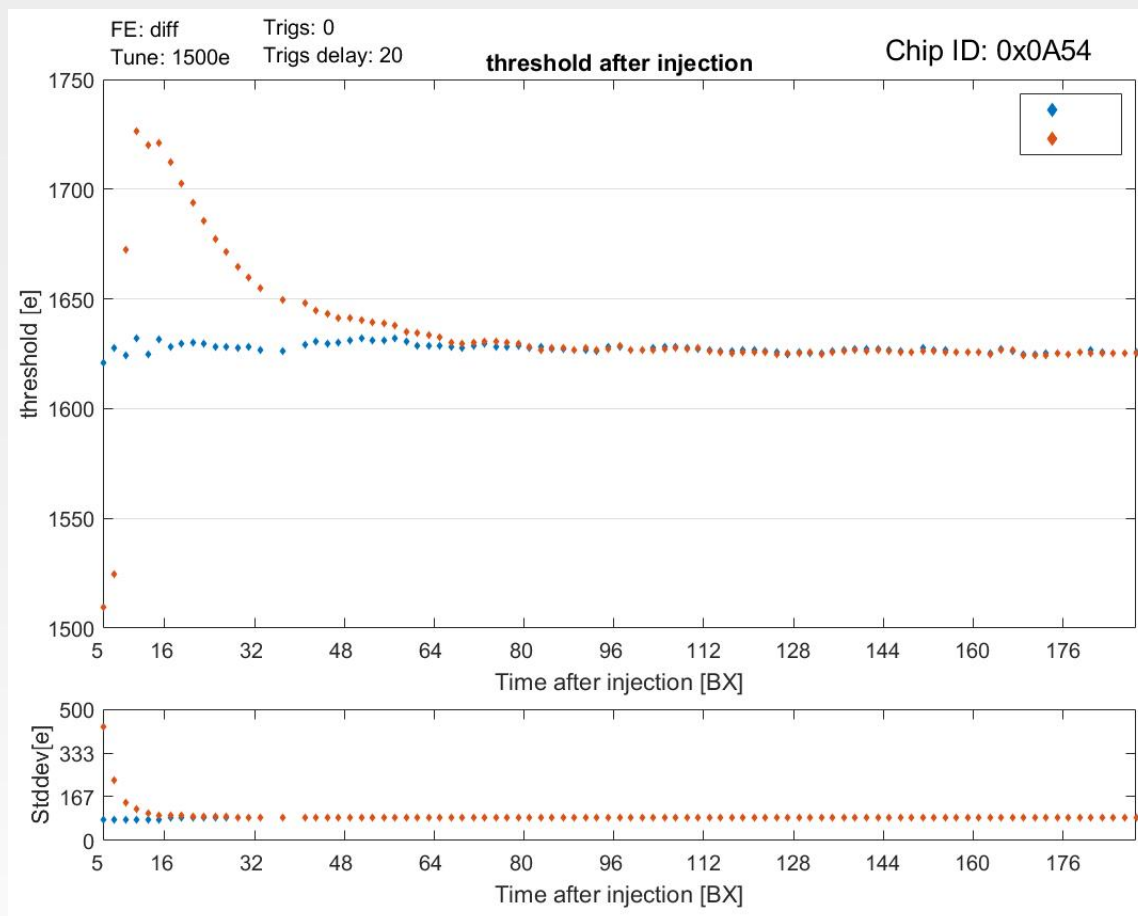
- Tuned with $V_{cal_Med} = 230$
- Pixel threshold difference between the 4000e injection scan and the baseline scan
- Double delay = 7 BX
- Colour axis set to $\pm 200e$
- Think pattern comes from the V_{cal_med} to gnd tuning





RD53A: Threshold mean vs. Double delay (Differential FE)

- Diff FE: Tuned to 1500e
- **Blue points: Baseline** (Only have the second charge of varying magnitude)
- **Red points: Inject 2000e** and then inject a second charge of varying magnitude
- X-axis shows the time between the two injections (double delay)
- When the double delay is small - > the mean of threshold increases when having a first injection of 2000e (**Red points**)
- Most likely caused by the disturbance of the first analog injection or the readout





Double injection on RD53A

- Good news as in the RD53A chip had a bug in the cal command
- The cal edge would go low (if high) right after receiving a CAL CMD.
- Had to change the cal cmd procedure in order to make this work

