Double injection scan results for the RD53A

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

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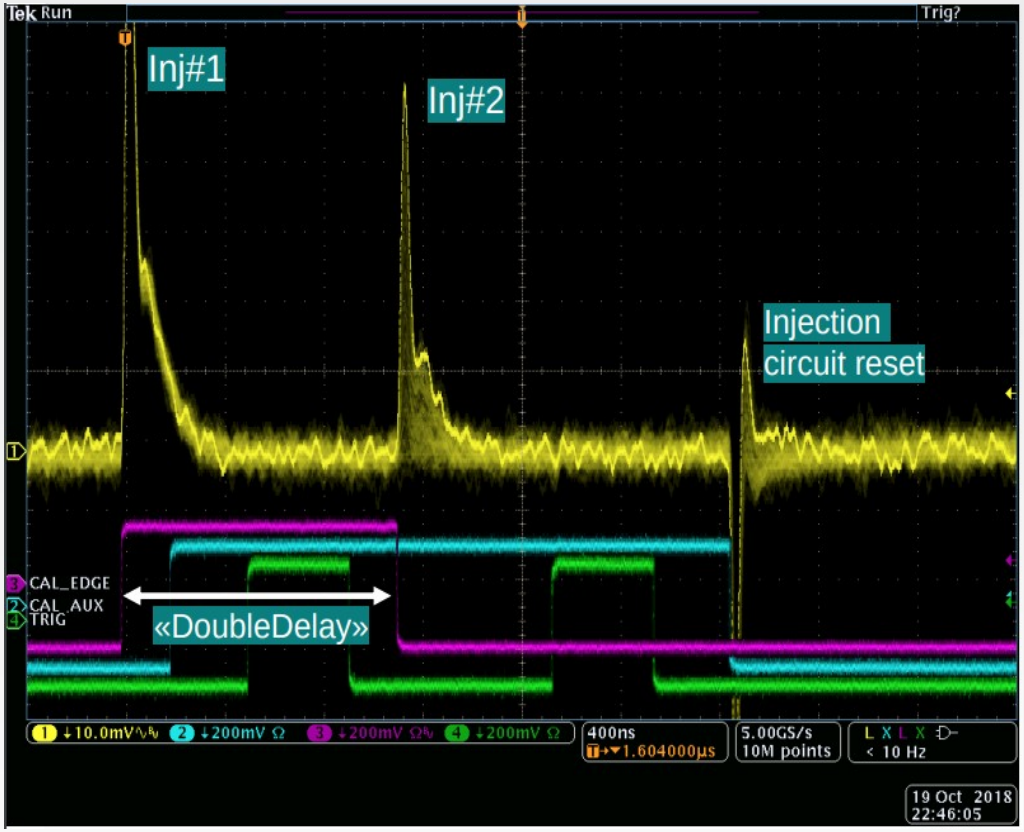
ATLAS EXPERIMENT

UNIVERSITY OF BERGEN

Introduction

- The purpose of the **double injection scan** is to study the behavior of the Front-end (FE) during charge injections and data readout
- E.g. study how the measured pixel threshold 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)
  - 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

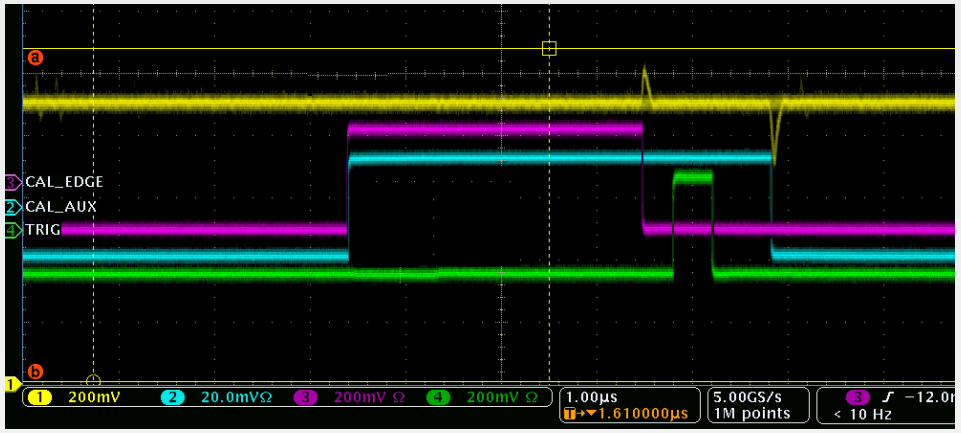
2) Light blue line is the CAL_AUX signal

3) Green line is the trigger signal

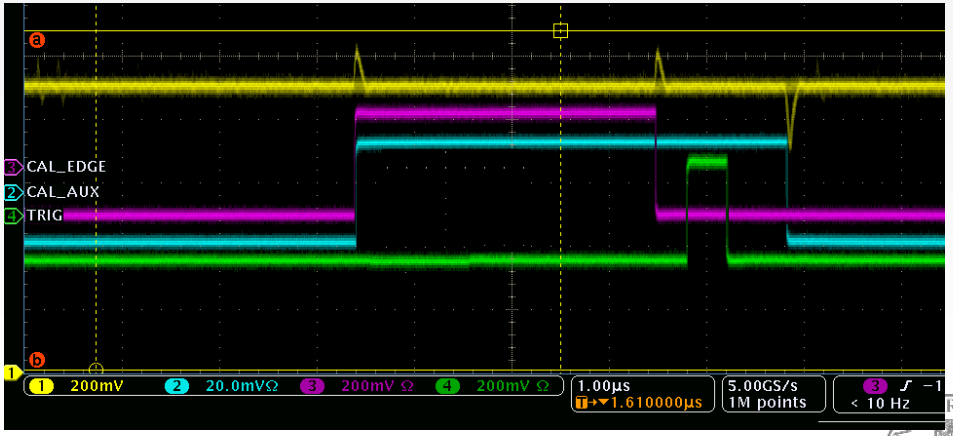
Method

- Test the effect that a preceding charge injection has on the measured pixel threshold
- For each value of the double delay, perform:
  - A double injection scan with **#Inj1 set to 0e** (Upper figure)
    - Gives a **baseline** used for comparison
  - Double injection scans with **#Inj1** set to a higher charge
    - Tested with three different magnitudes: **2000e, 4000e and 6000e**
- **Probe** the effect that the **#Inj1** has on the measured pixel threshold obtain by **#Inj2**

Baseline (Only have the second charge of varying magnitude)

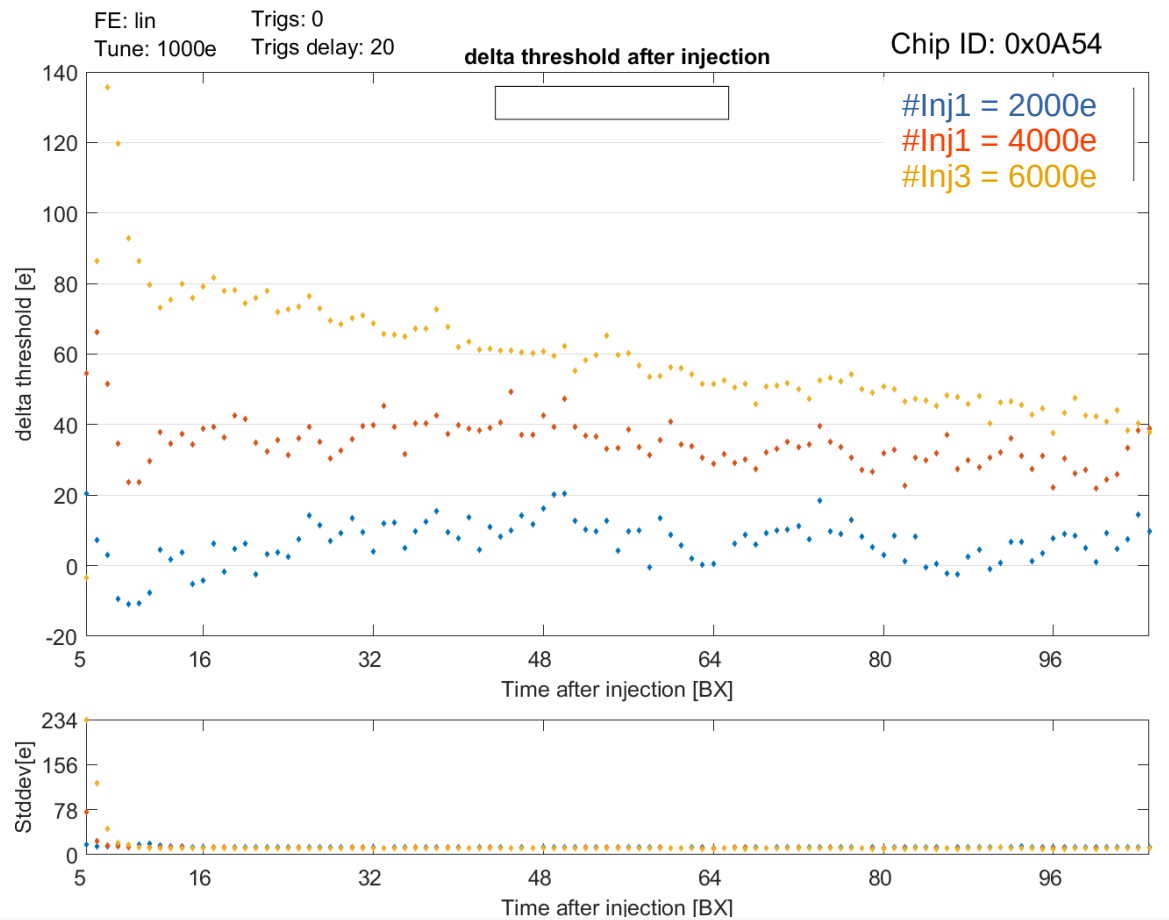


#Inj1 with charge and then inject a second charge of varying magnitude



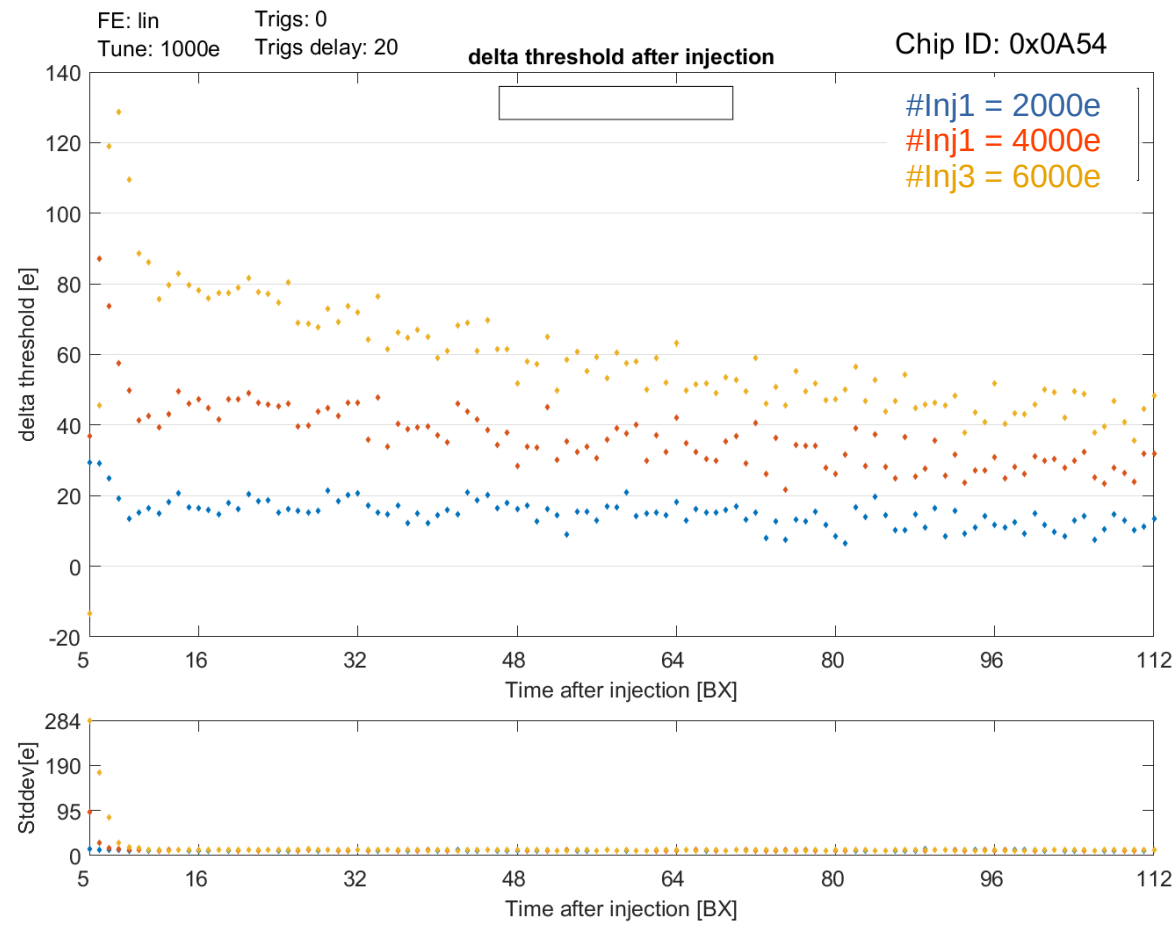
Results LIN FE: Mean of pixel threshold differences vs. double delay

- Linear FE tuned to 1000e
- Plot show: The mean of the pixel threshold difference for the 2000e, 4000e, and 6000e injections with the baseline scan
- Configured for fast discharge: LinKrumCurr: 36
  - Sets the Krummenacher feedback bias current - > Controls the discharge rate and therefore the effect off the #Inj1
- Difference increases for lager magnitude of #Inj1
- Make sens that a larger injection will have a greater effect on the second injection
- The measured difference in the pixel threshold decreases linearly as the double delay increases
- Make sense that the effect of the #Inj1 decreases as the separation of the two injections becomes larger



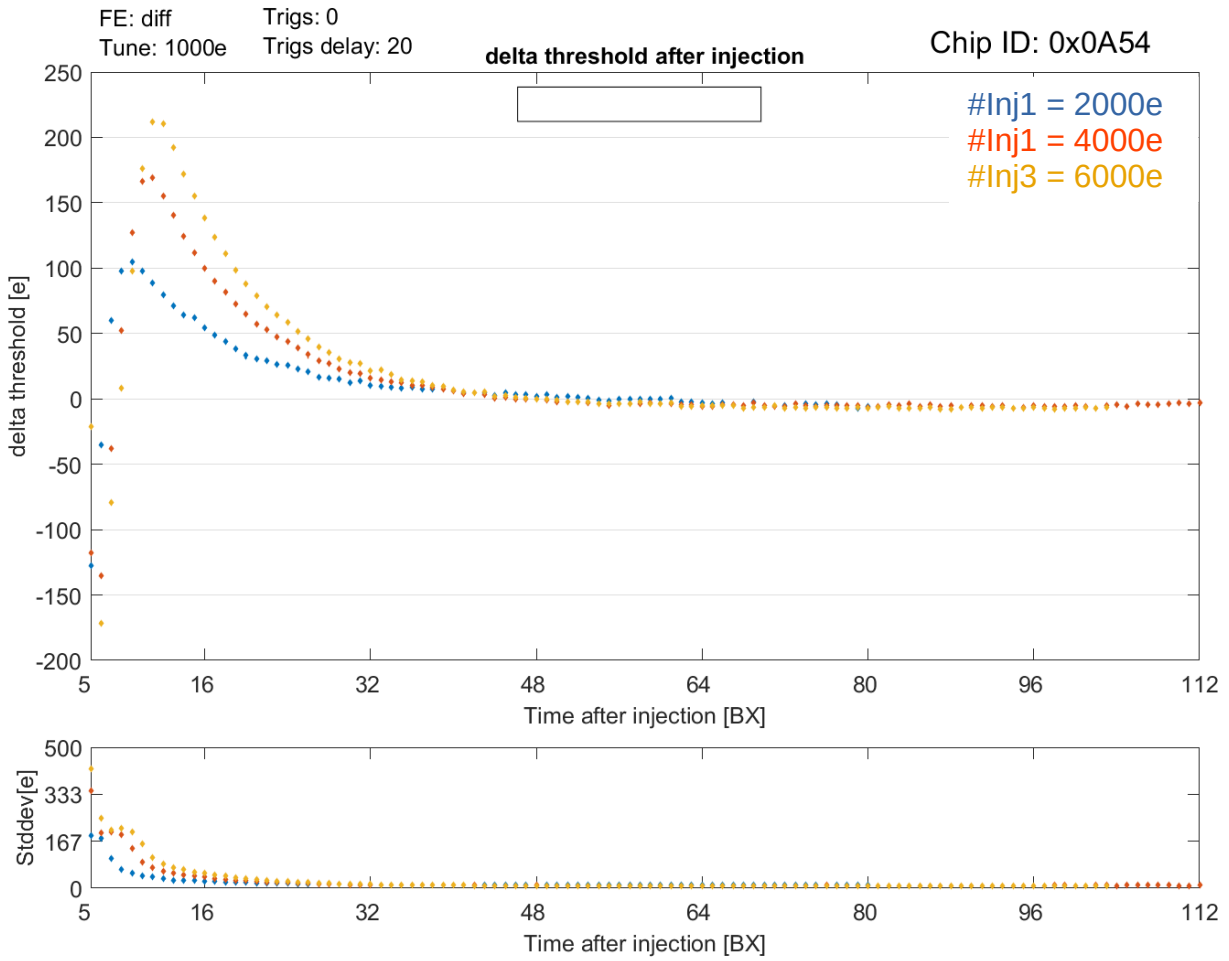
Results LIN FE: Mean of pixel threshold differences vs. double delay

- Linear FE tuned to 1000e
- Plot show: The mean of the pixel threshold difference for the 2000e, 4000e, and 6000e injections with the baseline scan
- Configured for slower discharge: **LinKrumCurr: 18**
- For the 2k and 4k injection at smaller double delay values, difference has increased ~20e
- Expected because the effect should increase for slower discharge of #Inj1
- Still very small differences
- Rest of the characteristic are the same as for the previous plot



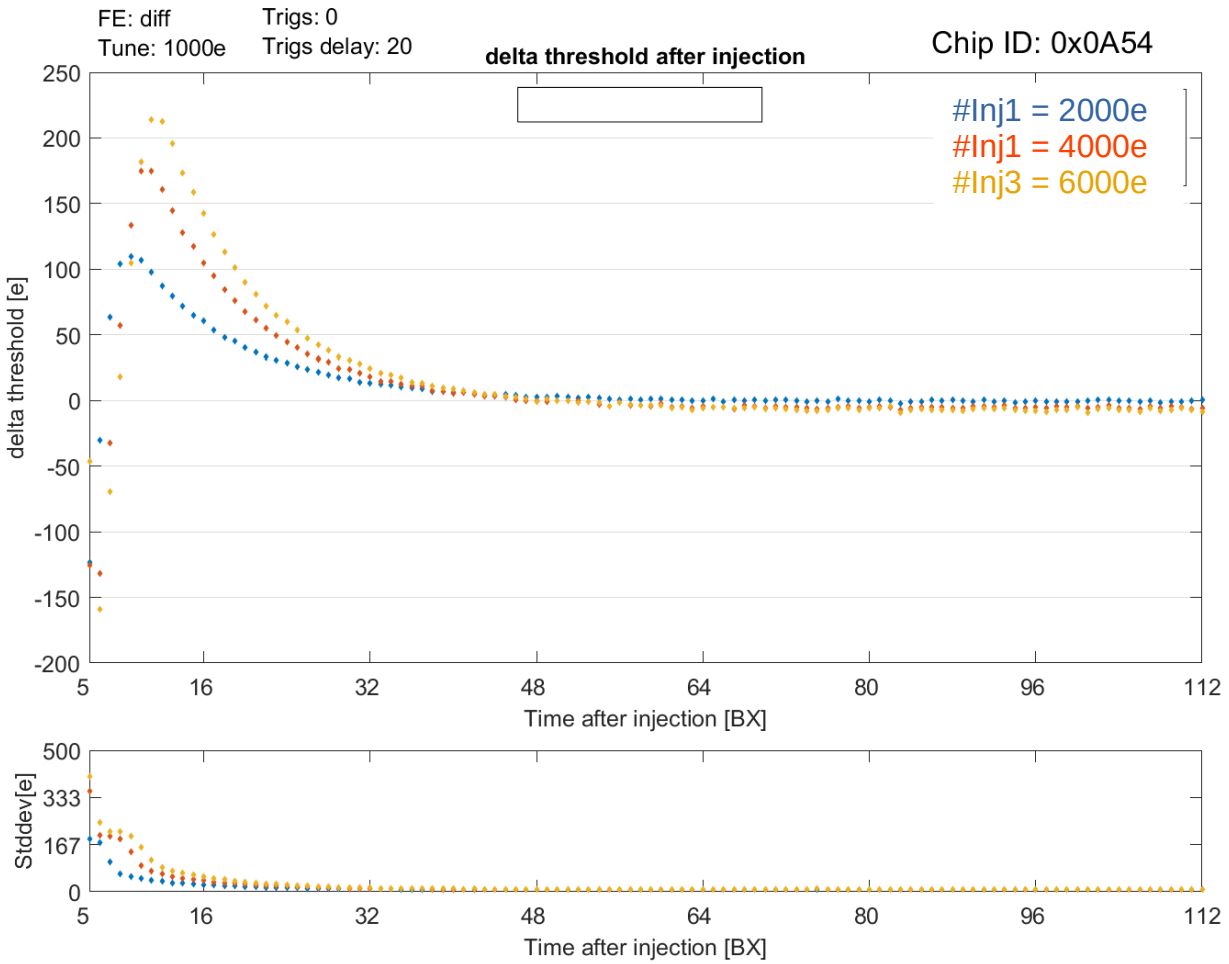
Results: Diff FE: Mean of pixel threshold differences vs. double delay

- Differential FE tuned to 1000e
- Plot show: The mean of the pixel threshold difference for the 2000e, 4000e, and 6000e injections with the baseline scan
- Configured for fast discharge: DiffVff: 76
  - Sets the Preamp feedback (discharge) current
- Difference increases at lager injections and the maximum points shifts to the right
- The maximum difference reaches ~ 100-220e for double delay = 8-11 [BX]
- The measured difference in the pixel threshold decreases exponentially after



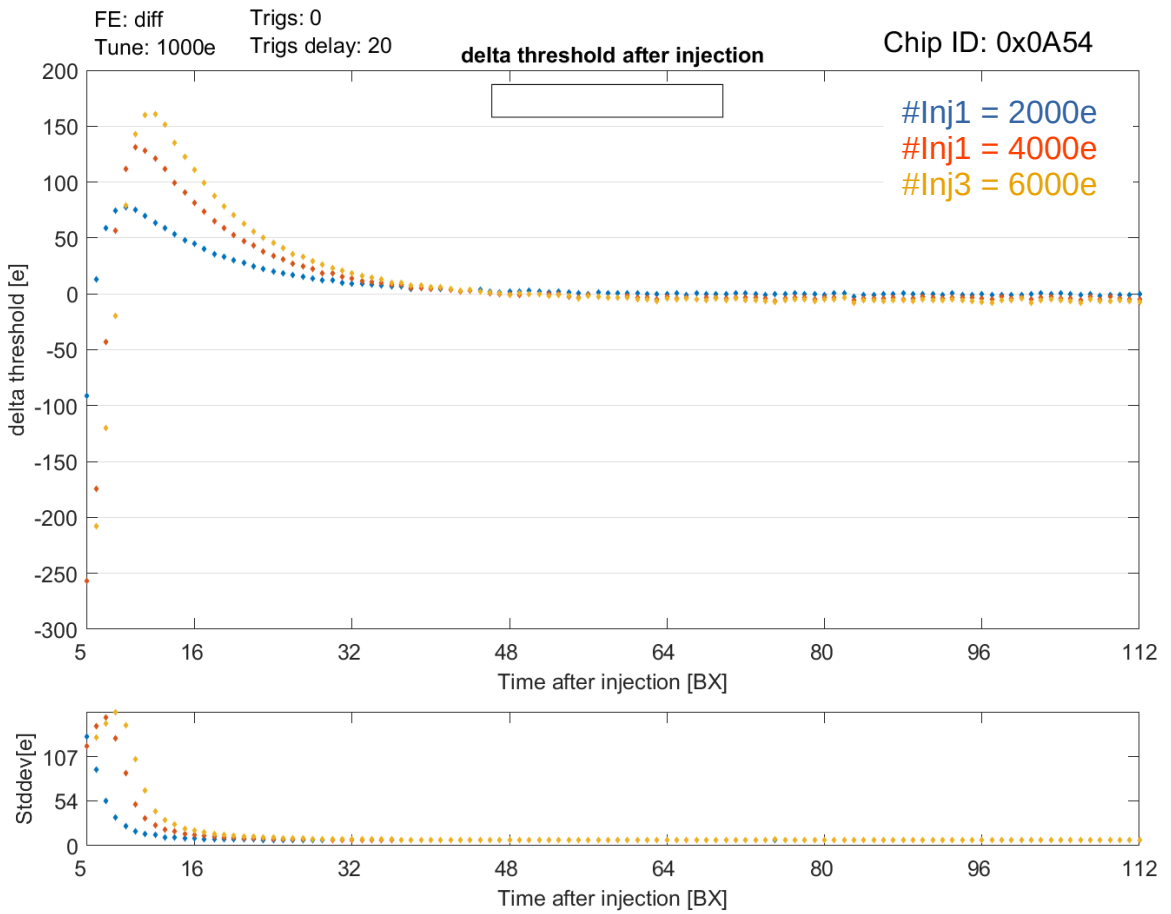
Results: Diff FE: Mean of pixel threshold differences vs. double delay

- Differential FE tuned to 1000e
- Plot show: The mean of the pixel threshold difference for the 2000e, 4000e, and 6000e injections with the baseline scan
- Configured for slower discharge: **DiffVff: 40**
- Can't see any change compared to the fast discharge configuration
- Rest of the characteristic are the same as for the previous plot



Results: Diff FE Good Pixels

- Differential FE tuned to 1000e
- Plot show: The mean of the pixel threshold difference between the 2000e, 4000e, and 6000e injection and baseline scan
- **Only keep good pixels**
- Configured for slower discharge: DiffVff: 40
- The maximum difference decreases with ~50e for each injections sequence when keeping only good pixels
- Rest of the characteristic are the same as for the previous plot



Conclusion

- A double injection scan sends out two consecutive charge injections into a single pixel
- Test the effect that a preceding charge injection with varying magnitude has on the measured pixel threshold
- **Results:**
- **Linear FE** shows a small and linearly decreasing effect as the double delay (separation between the injections) increases
- Difference increases at lager injections and small difference observed between fast and slow discharge
- **Differential FE** shows a mean pixel difference at ~100 - 220e with double delay = 8-11 [BX] and then an exponentially decreasing effect as the delay increases
- Difference increases at lager injections and maximum points shifts to the right. No difference observed between fast and slow discharge

Thank you for your attention!

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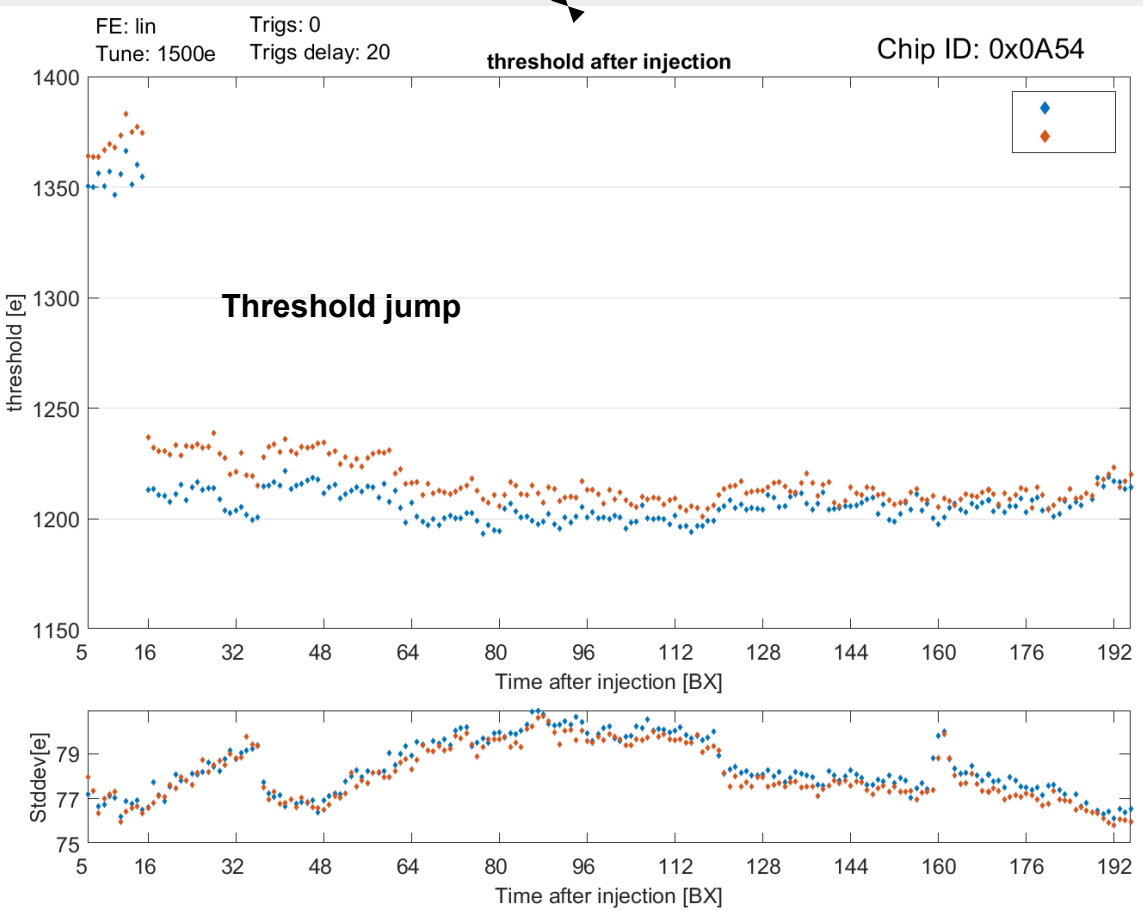
Backup

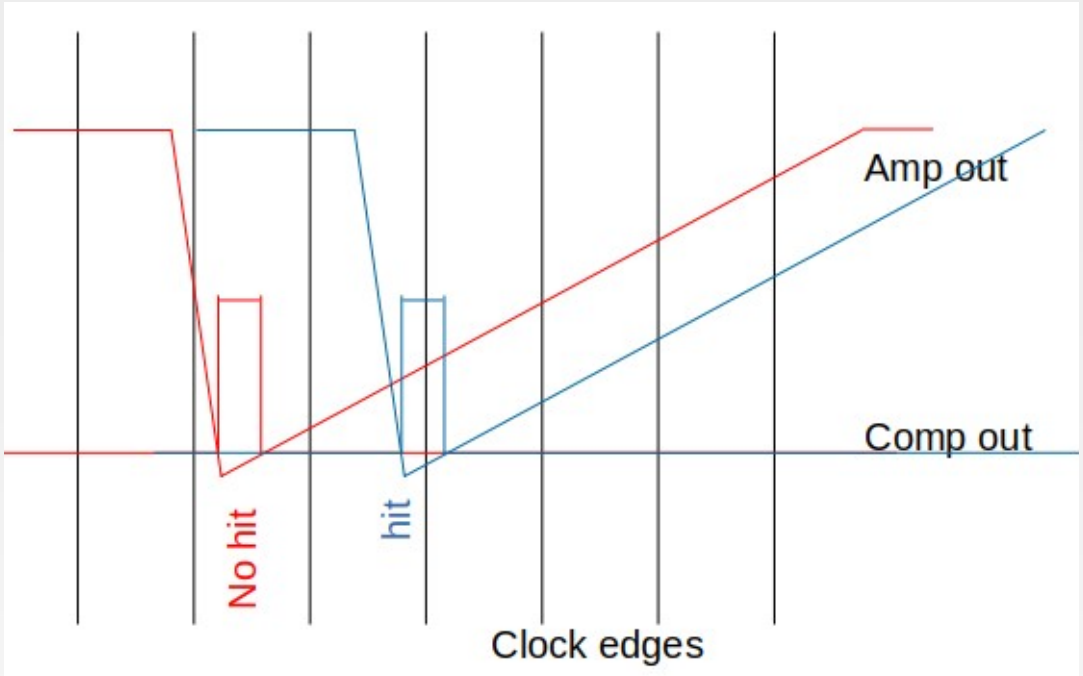
Threshold mean vs. double delay (Linear FE)

- Blue points: Baseline (One have one injection)
- Red points: **Inject 2000e** (Two consecutive injections)
- X-axis shows the time between the two injections (double delay)
- **Observed issue**: High threshold jump going from double delay value of **15 [BX]** to **16 [BX]**
  - Two different injection commands are used here
  - As the **single Cal command** allowed for **quarters bunch crossing delays** to be used
  - Suspected that this threshold jump came from the injected **signals being out of phase** relativity to the clock edge



Phase shift and Comparator output

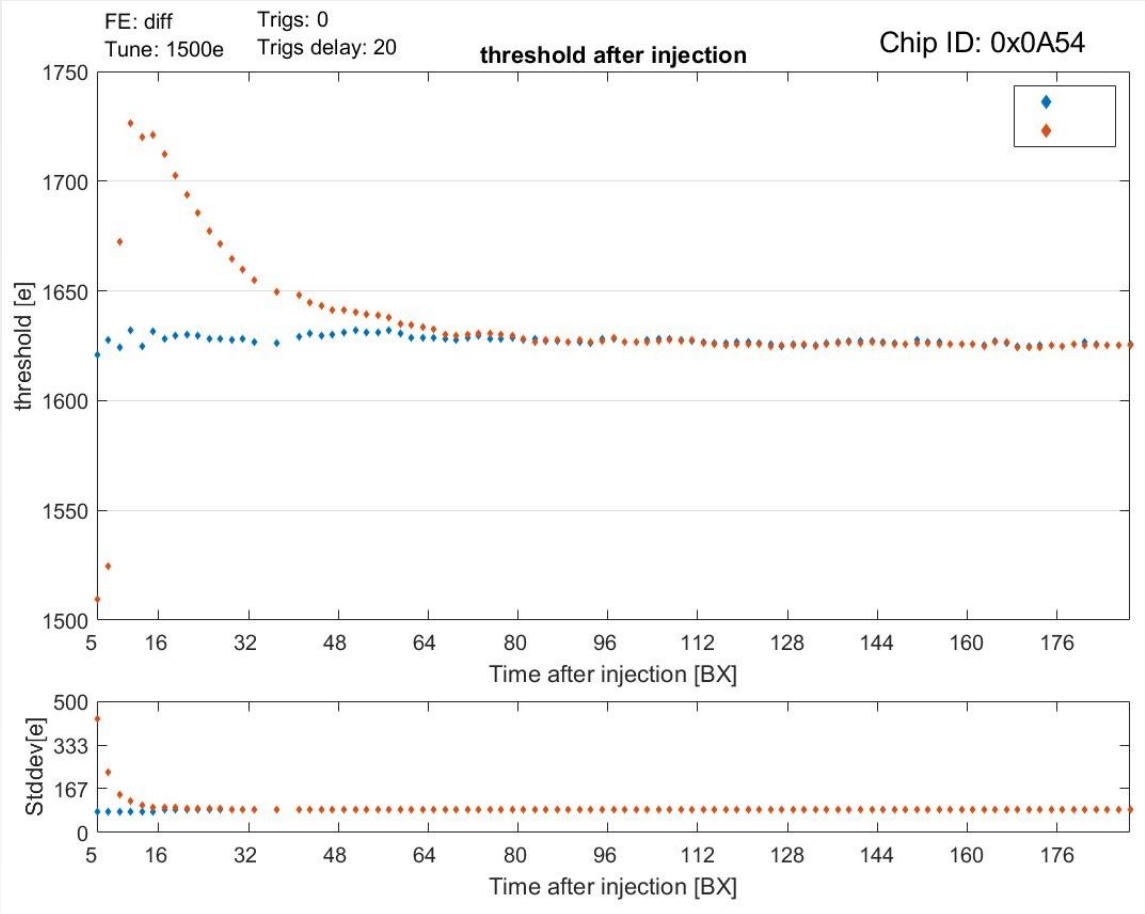
- In RD53A, a signal is only **recorded** as a hit if the **output** of the **comparator** is **high during** a rising **clock edge**
- Comparator is high when the injected signal is above the analogue threshold
- Clock edge has a period of one bunch crossing (BX = 25 ns units)
- This means that depending on the phase of the injection the **output pulse** of the comparator **may or may not** be **recorded**
- E.g. the red line in figure shows an injection that reaches above threshold but as the injection is not in the same phase as the clock edge, the hit is not recorded
- While injecting the same amount of charge in the correct phase (blue) will result in a recorded hit as the comparator output matches the rising clock edge



Comparator output for injections at different phases. Figure by Maurice Garcia-Sciveres

Threshold mean vs. Double delay (Differential FE)

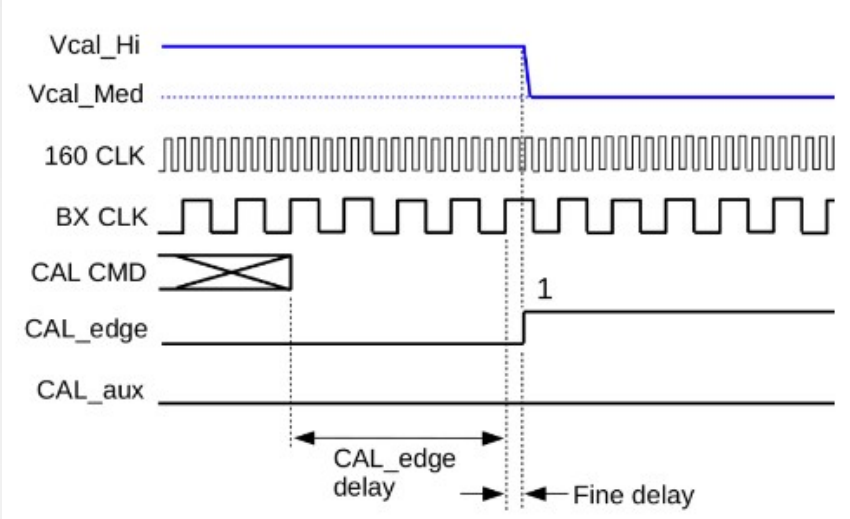
- Diff FE: Tuned to 1500e
- Blue points: **Baseline** (Only have the second charge of varying magnitude)
- Red points: I**nject 2000e** and then inject a second charge of varying magnitude
- X-axis shows the time between the two injections (double delay)
- When the double delay is small - > the mean 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



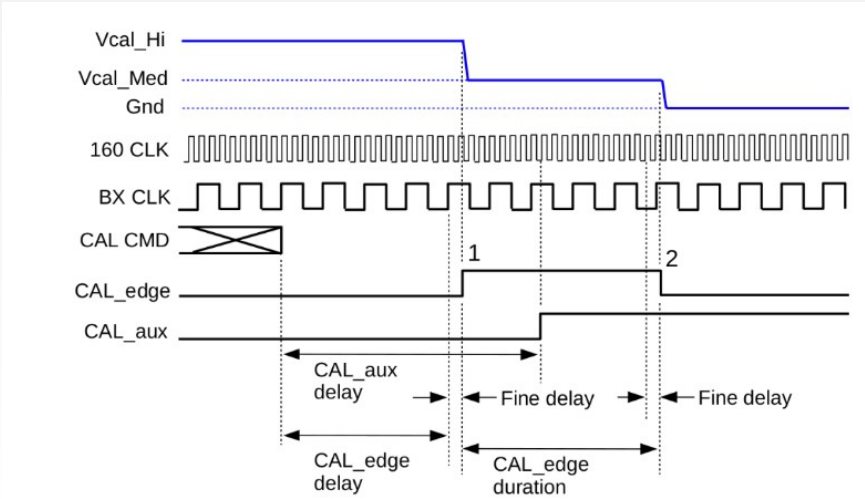
Cal command

- The **Cal command controls** the generation of two internal signals **CAL_edge** and **CAL_aux**
- Injecting charge into the pixel in done when these internal signals are changed
  - Top figure: The CAL command changes CAL_edge from **low to high**
  - Inject charge from **Vcal_Hi to Vcal_Med**
- CAL_edge can either be set to a **single step mode** (top figure) or a **pulse mode** (bottom figure)
  - In **step mode** CAL_edge it will **stay up**
  - In **pulse mode** it will **stay up** only for a given time and **then go low** again
    - Inject **twice** with only one **CAL command**

Step mode with **one** injection



Pulse mode with **two** injections



Tuning routine

std_digitalscan.json (with -m 1 to reset masks)

std_analogscan.json

diff_tune_globalthreshold.json (good starting threshold target is 1000e, resets prev. TDACs)

diff_tune_pixelthreshold.json (1000e target again)

diff_tune_globalpreamp.json (use mid of the range ToT values, e.g. 10000e at 8ToT)

diff_tune_pixelthreshold.json (1000e target again)

diff_tune_finepixelthreshold.json (1000e target again)

lin_tune_globalthreshold.json (good starting threshold target is 2000e, resets prev. TDACs)

lin_tune_pixelthreshold.json (2000e again)

lin_retune_globalthreshold.json (now retuning from 2000e to 1000e target)

lin_retune_pixelthreshold.json (1000e again)

lin_tune_globalpreamp.json (use mid of the range ToT values, e.g. 10000e at 8ToT)

lin_retune_pixelthreshold.json (1000e again)

lin_tune_finepixelthreshold.json (1000e again)

Scan sequence in original code (now fixed)

- Due to a bug in the RD53A chip, the cal edge would go low (if high) after receiving a CAL CMD.
- This would cause a second injection to interfere with the threshold scan injection as show in the figure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