Double injection scan results for the RD53A

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

Presented by Simon K. Huiberts

ATLAS EXPERIMENT

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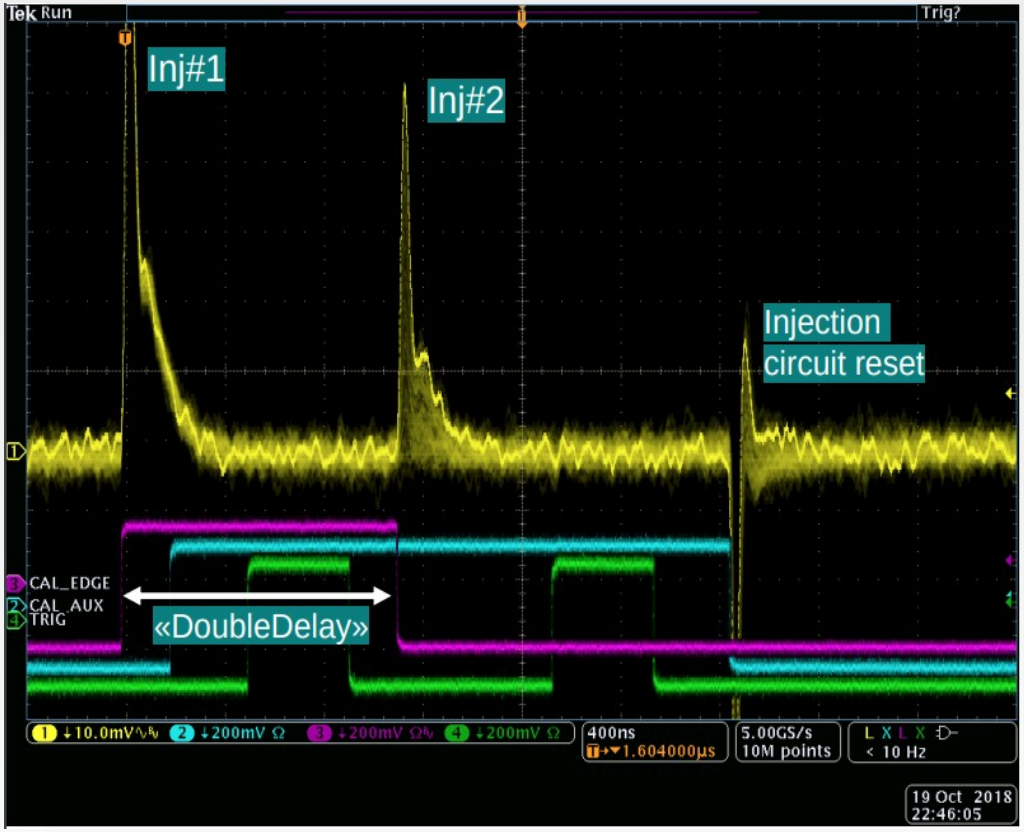
Introduction

- 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

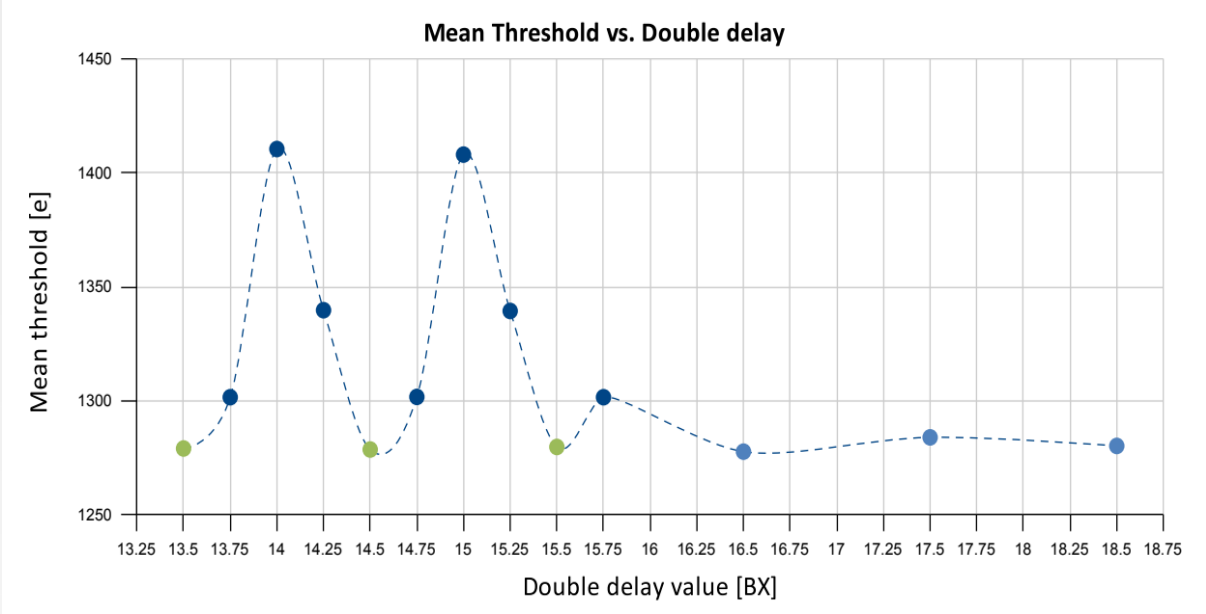
1) Purple line is the CAL_EDGE signal

2) Light blue line is the CAL_AUX signal

3) Green line is the trigger signal

Last presentation (04.09.2020)

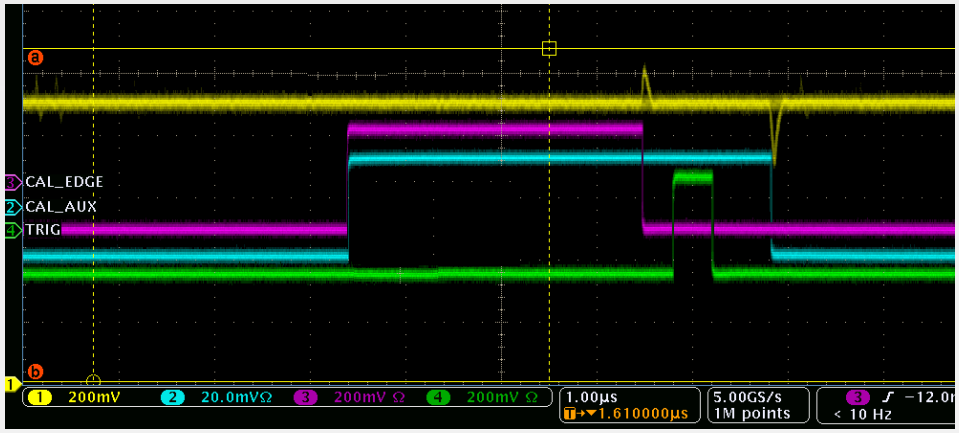
- Observed an issue where the injections were sent out of phase w.r.t the clock edge resulting in an artificially high measured threshold
- This was fixed by selecting half values for the double delay parameter such that the injections happen in the same phase (green points)
- **After fix:** Study the linear and the differential FE with the correct double delay values



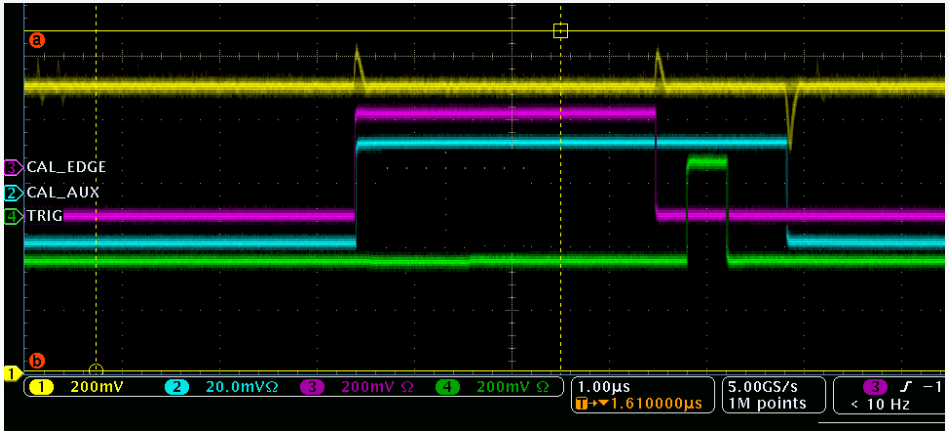
First method

- 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
  - A double injection scan with **#Inj1 = 2000e** (Bottom figure)
    - **#Inj1** crosses the pixel threshold
- **Probe** the effect that the #Inj1 = 2000e has on the measured pixel threshold obtain by **#Inj2**

Baseline (Only have the second charge of varying magnitude)

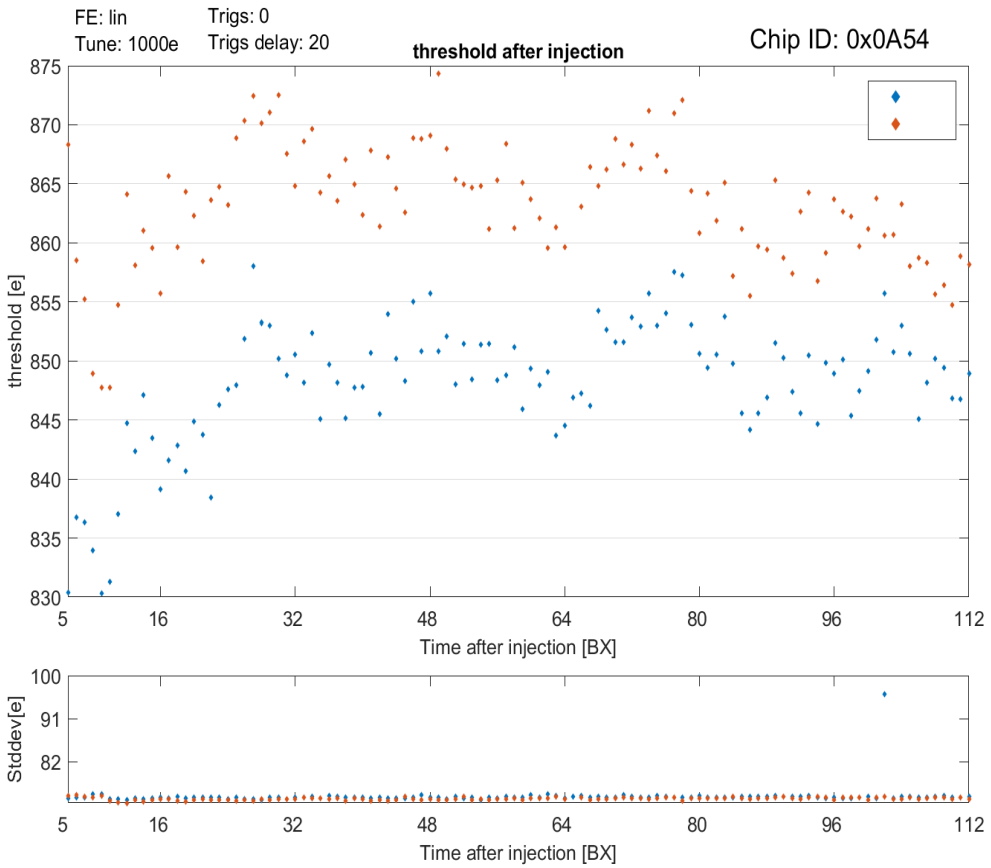


Inject 2000e and then inject a second charge of varying magnitude



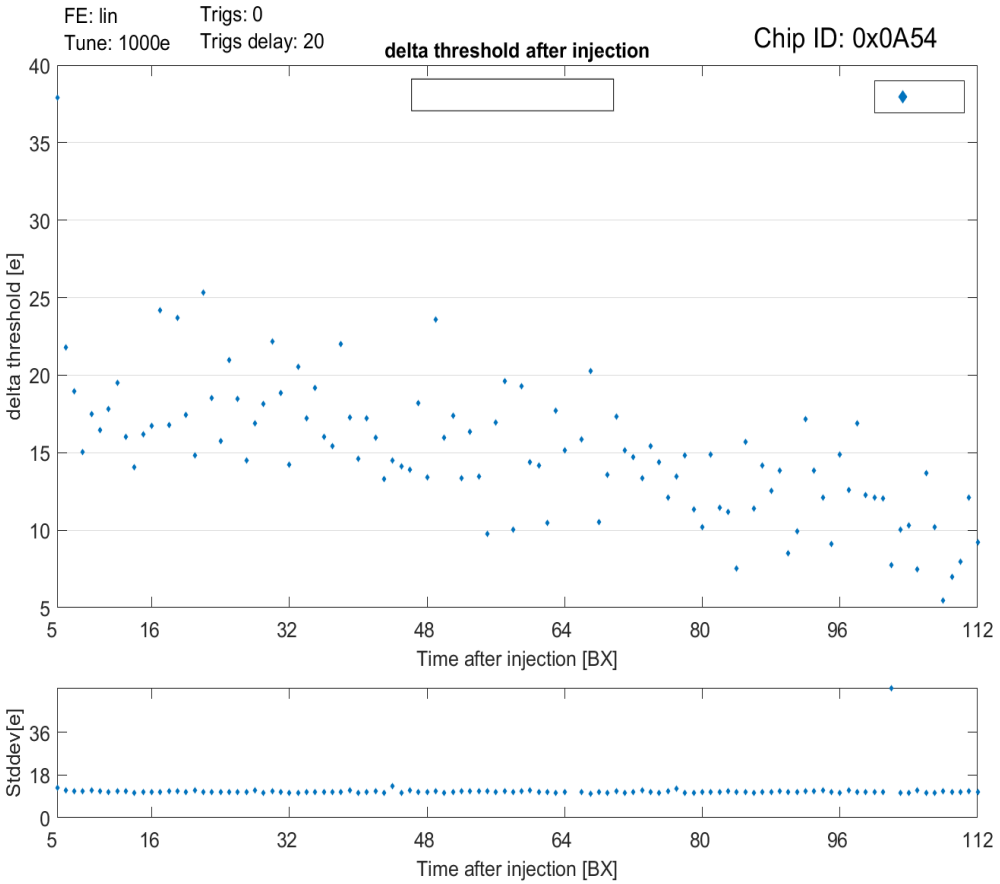
Lin FE: Mean Threshold vs. double delay

- Linear FE tuned to 1000e
- Red points: 2000e injection
- Blue points: Baseline (No injection)
- Configuration LinKrumCurr: 36
  - Sets the Krummenacher feedback bias current - > Controls the discharge rate and therefore the effect on the #Inj1



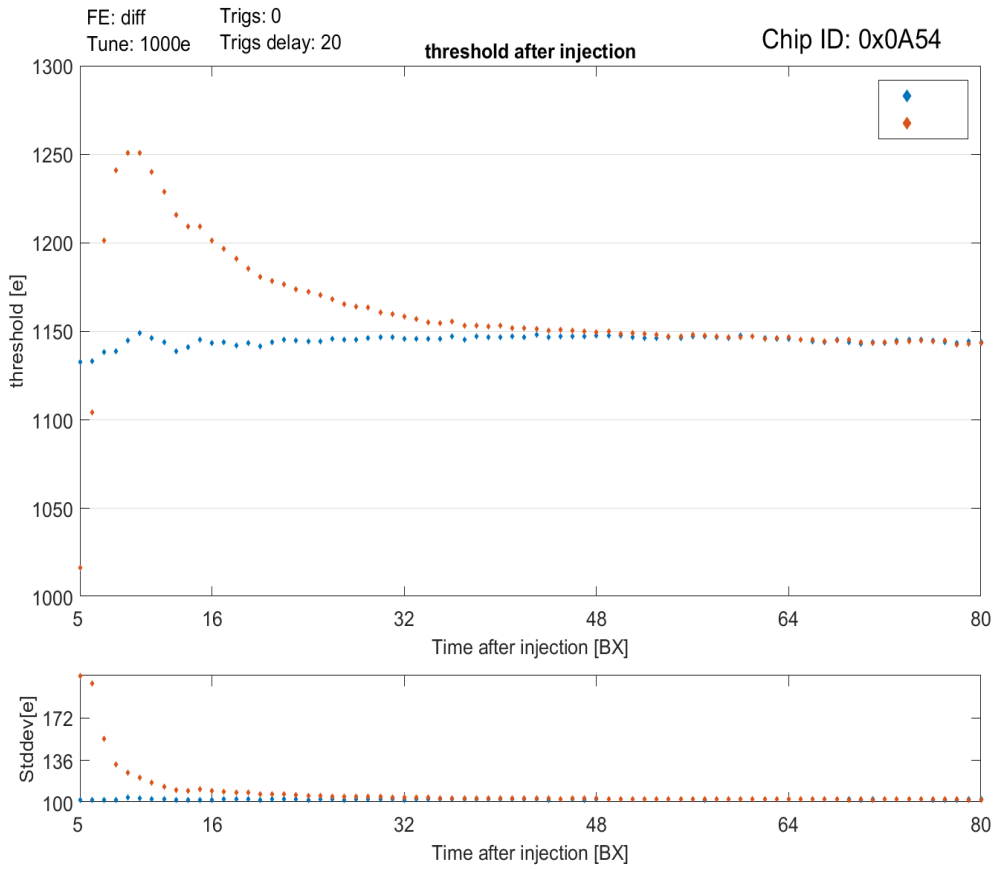
Lin FE: Mean of the pixel threshold differences vs. double delay

- Linear FE Tuned to 1000e
- Blue points: Mean of the pixel threshold difference between the 2000e injection and baseline scan
- Configuration LinKrumCurr: 36
- Small difference ~20e
- The measured difference in the pixel threshold decreases linearly as the double delay increases
- Make sense as the effect of the #Inj1 decreases as the separation of the two injections becomes larger



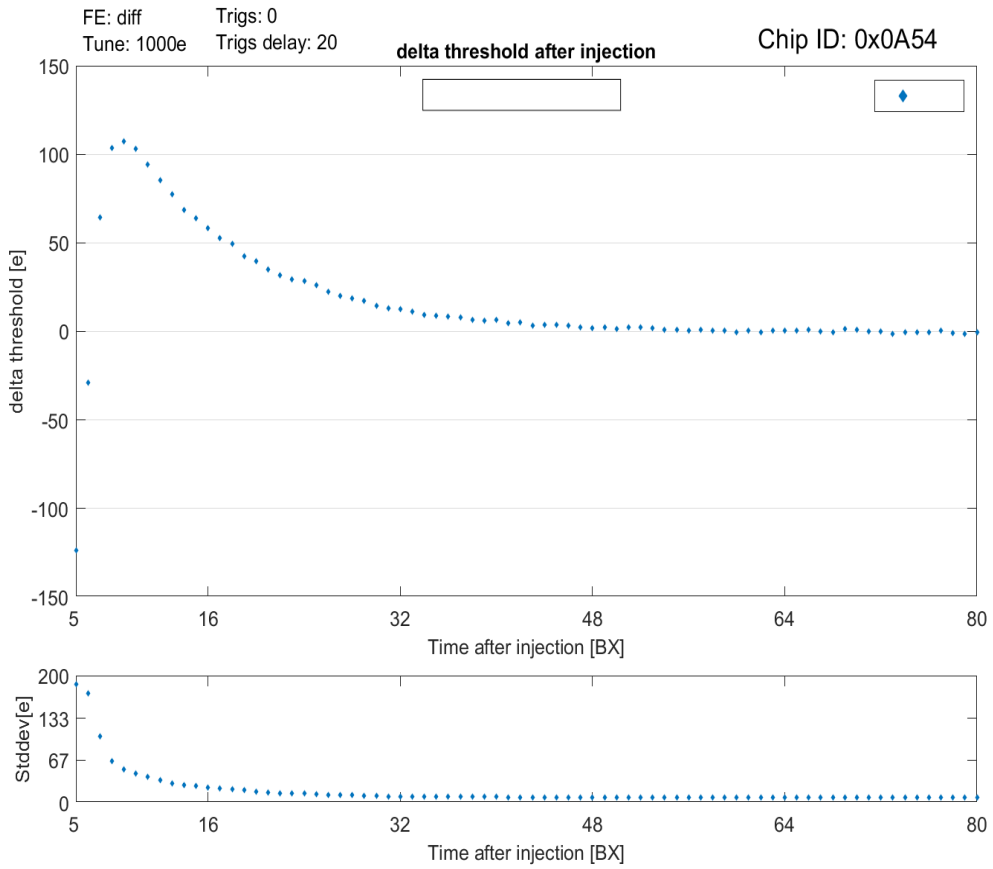
Diff FE: Mean Threshold vs. double delay

- Differential FE tuned to 1000e
- Red points: 2000e injection
- Blue points: Baseline (No injection)
- Configuration DiffVff: 76
- Sets the Preamp feedback (discharge) current - > Also controls the effect of the #Inj1



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

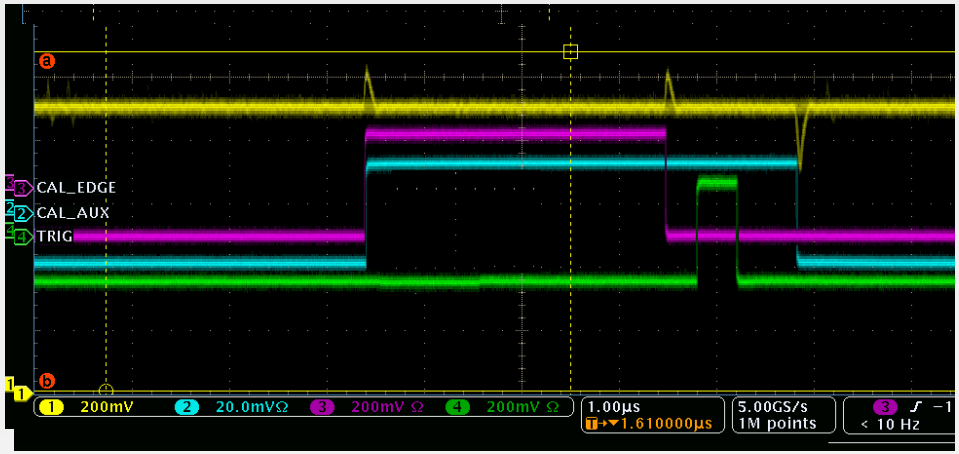
- Differential FE Tuned to 1000e
- Blue points: Mean of the pixel threshold difference between the 2000e injection and baseline scan
- Configuration DiffVff: 76
- The difference reaches right above 100e for double delay = 8-10 [BX]
- The measured difference in the pixel threshold decreases exponentially after
- Make sense as the effect of the #Inj1 decreases as the separation of the two injections becomes larger



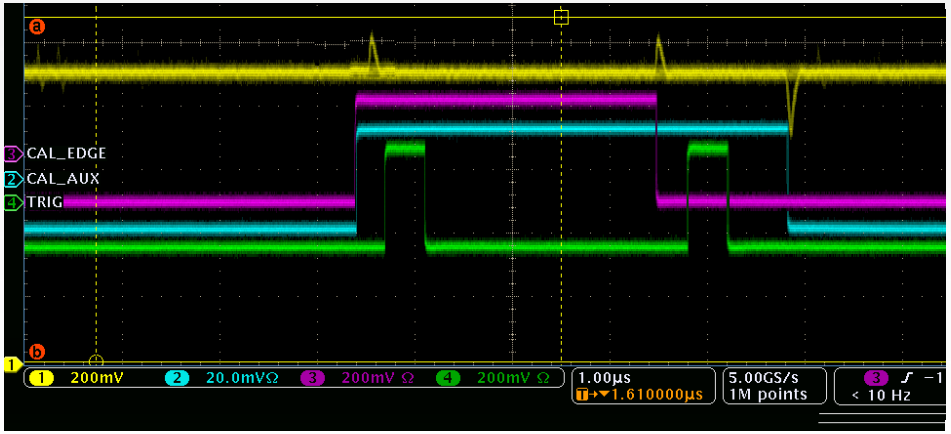
Second method

- Test the effect that the readout has on measured pixel threshold
- For each value of the double delay, perform:
- A double injection scan with two injections but only the **second trigger** (Upper figure)
  - Gives a **baseline** used for comparison
- A double injection scan (two trigger scan) with two injections and **two triggers** (Bottom figure)
  - **#Inj1** crosses the pixel threshold and is read out
- **Probe** the effect that readout of the first injection has on the threshold distribution

Baseline (Only have the second trigger)

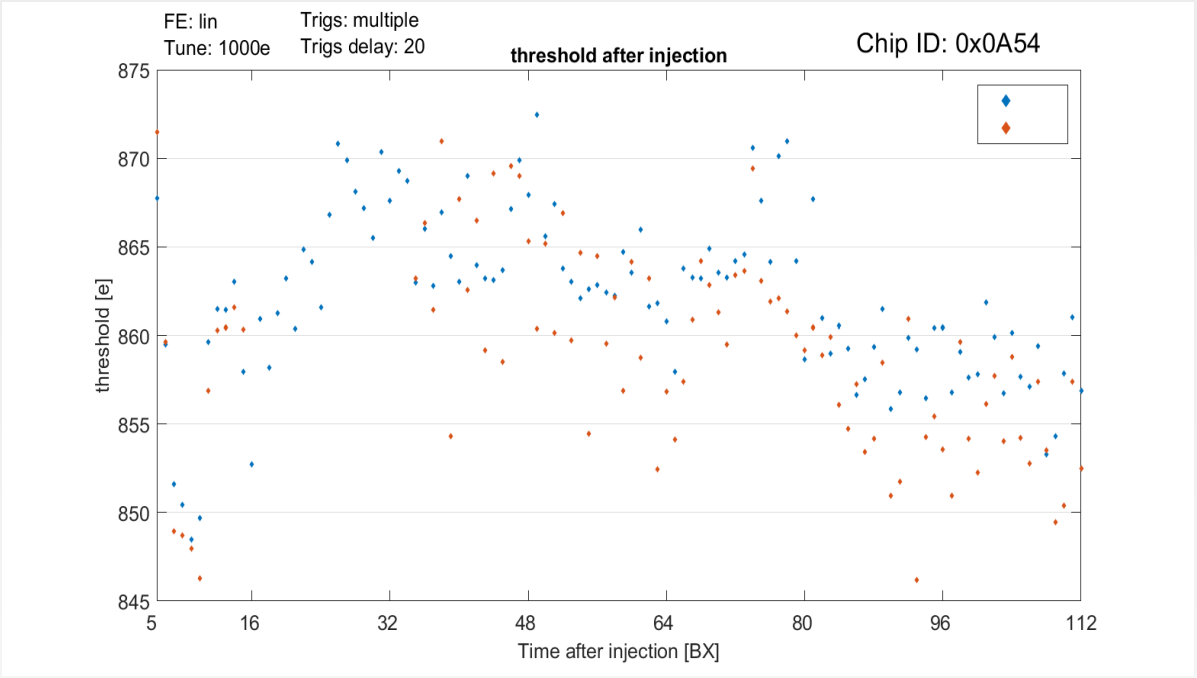


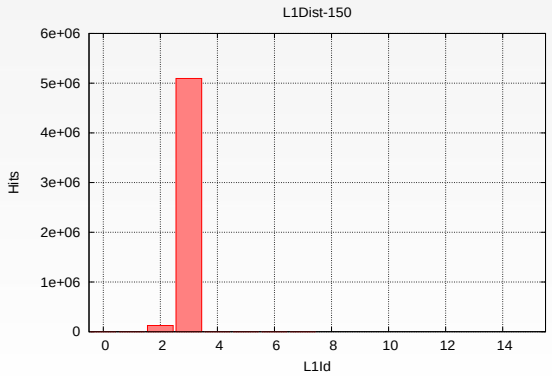
Two Triggers (Have two triggers so both injections are read out)

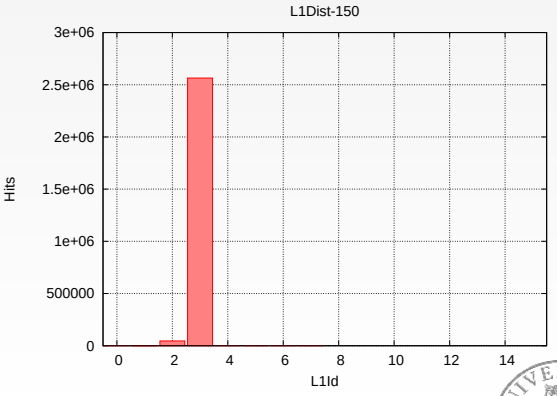


Lin FE: Mean Threshold vs. double delay

- Linear FE tuned to 1000e
- Red points: Two triggers
- Blue points: Baseline (One trigger)
- Level 1 ID (L1ID) distribution at the bottom left is for the two trigger scan showing 5e+6 hits having L1ID = 2 and 3
- L1ID distribution to the bottom right is for the baseline scan and it has half as many hits (2.5e+6) with same L1ID = 2 and 3
- L1ID is a tag each hits receives based on which time the hit is recorded

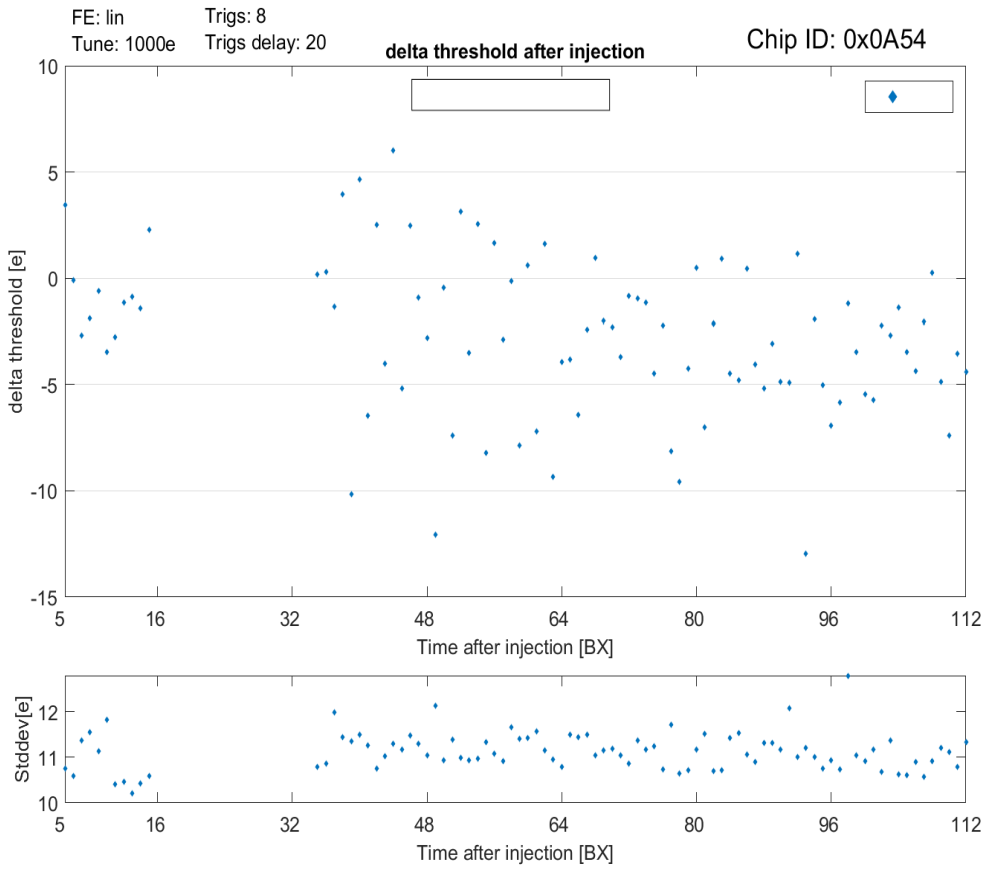






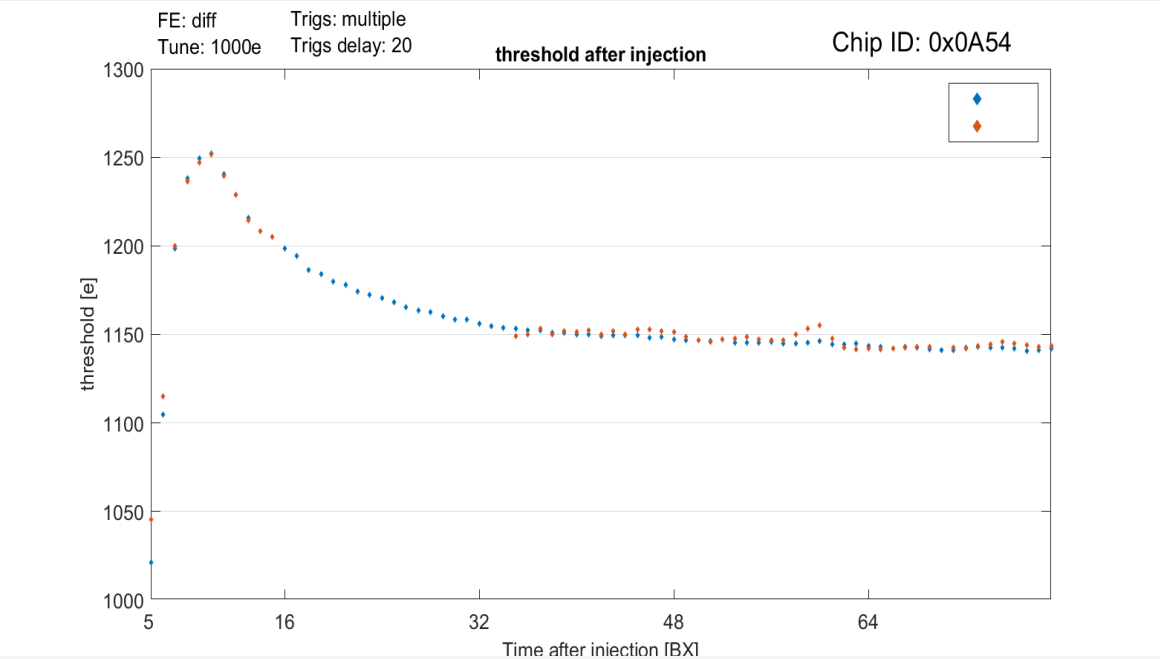
Lin FE: Mean of the pixel threshold differences vs. double delay

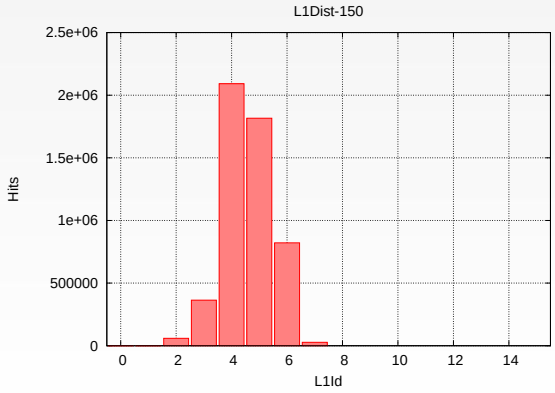
- Linear FE Tuned to 1000e
- Blue points: Mean of the pixel threshold difference between the two trigger scan and baseline scan
- Random small fluctuations around Δ threshold = 0e - > No difference observed

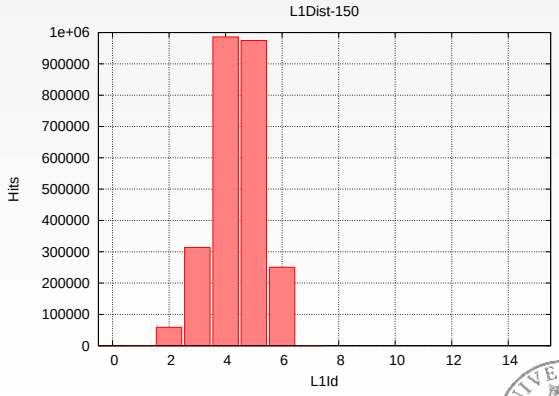


Diff FE: Mean Threshold vs. double delay

- Differential FE tuned to 1000e
- Red points: Two triggers
- Blue points: Baseline (One trigger)
- Level 1 ID (L1ID) distribution at the bottom left is for the two trigger scan showing 2e+6 hits having L1ID between 2 and 7
- L1ID distribution to the bottom right is for the baseline scan and it has half as many hits (1e+6) with L1ID between 2 and 6

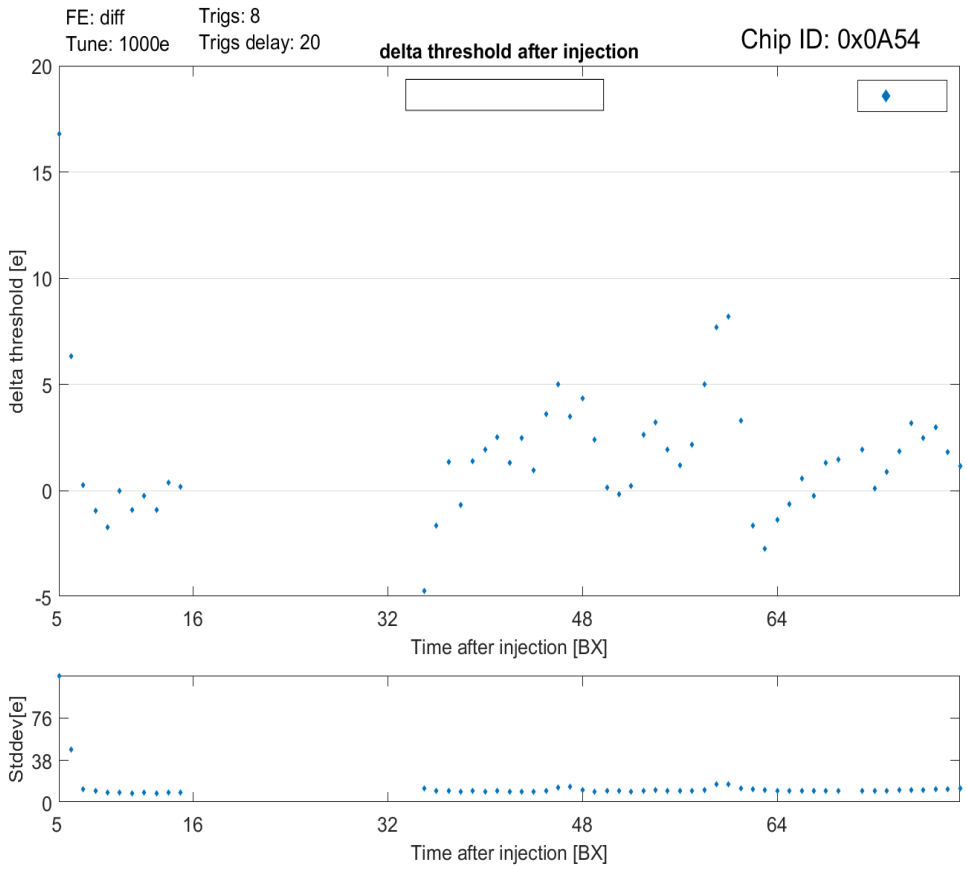






Diff FE: Mean of the pixel threshold differences vs. double delay

- Differential FE Tuned to 1000e
- Blue points: Mean of the pixel threshold difference between the two trigger scan and baseline scan
- Random small fluctuations around Δ trehsold = 0e - > No difference observed
- Good as the digital readout is the same for the linear and differential FE



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 measured pixel threshold and also test the effect of reading out this signal
- **Results:**
- Linear FE shows a small and linearly decreasing effect as the double delay (separation between the injections) increases
- Differential FE shows a mean pixel difference at ~100e with double delay = 8-10 [BX] and then an exponentially decreasing effect as the double delay increases
- None of the two Front Ends shows an effect of a preceding readout of a signal
- **Future work:**
- Test with changing the magnitude of the #Inj1 and with varying LinKrumCurr and DiffVff values
- Merge the double injection scan into YARR

Thank you for your attention!

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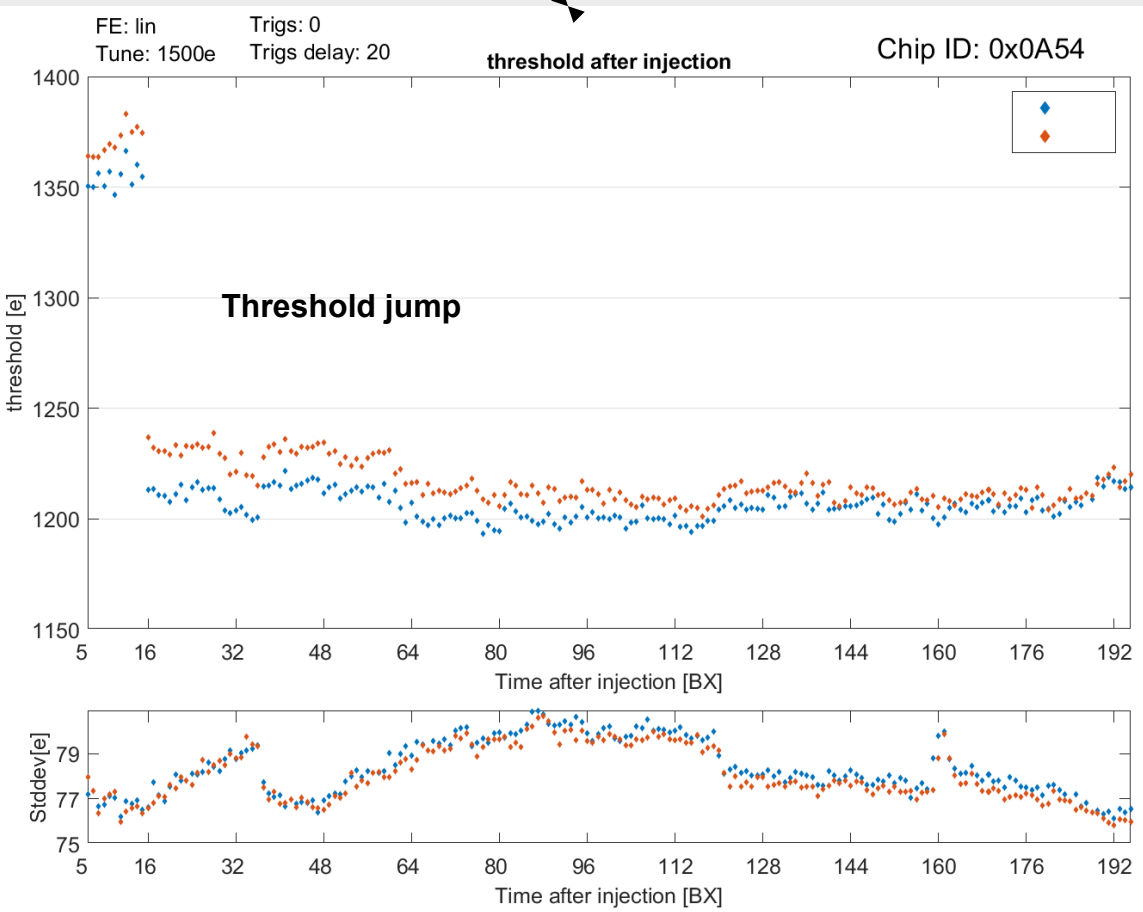
Backup

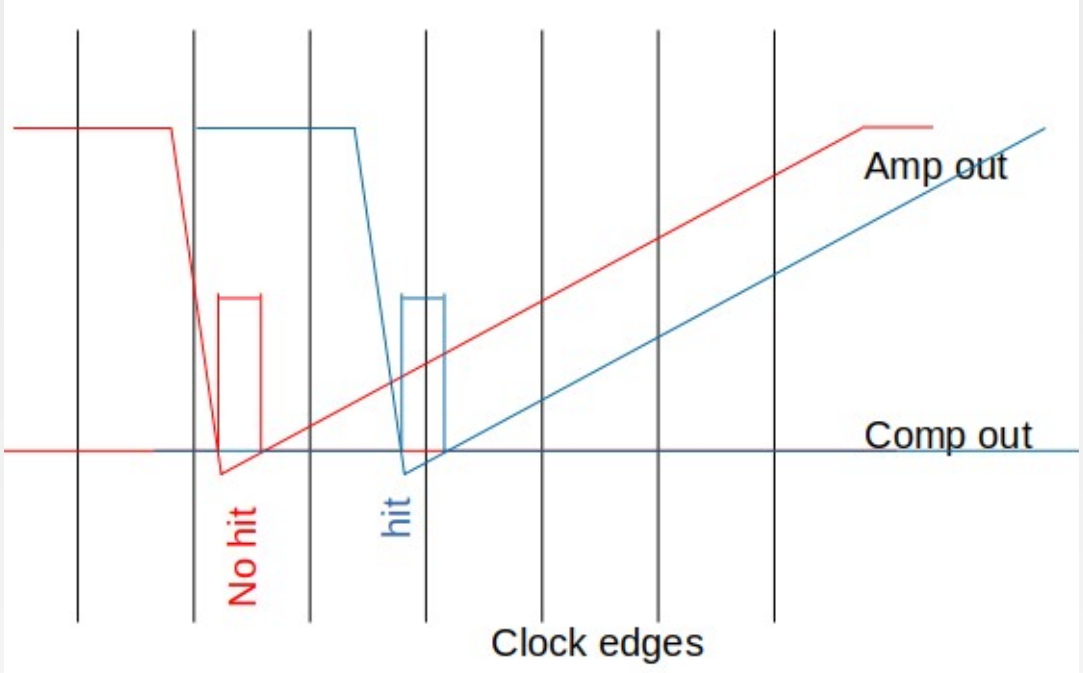
Threshold mean vs. double delay (Linear FE)

- 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

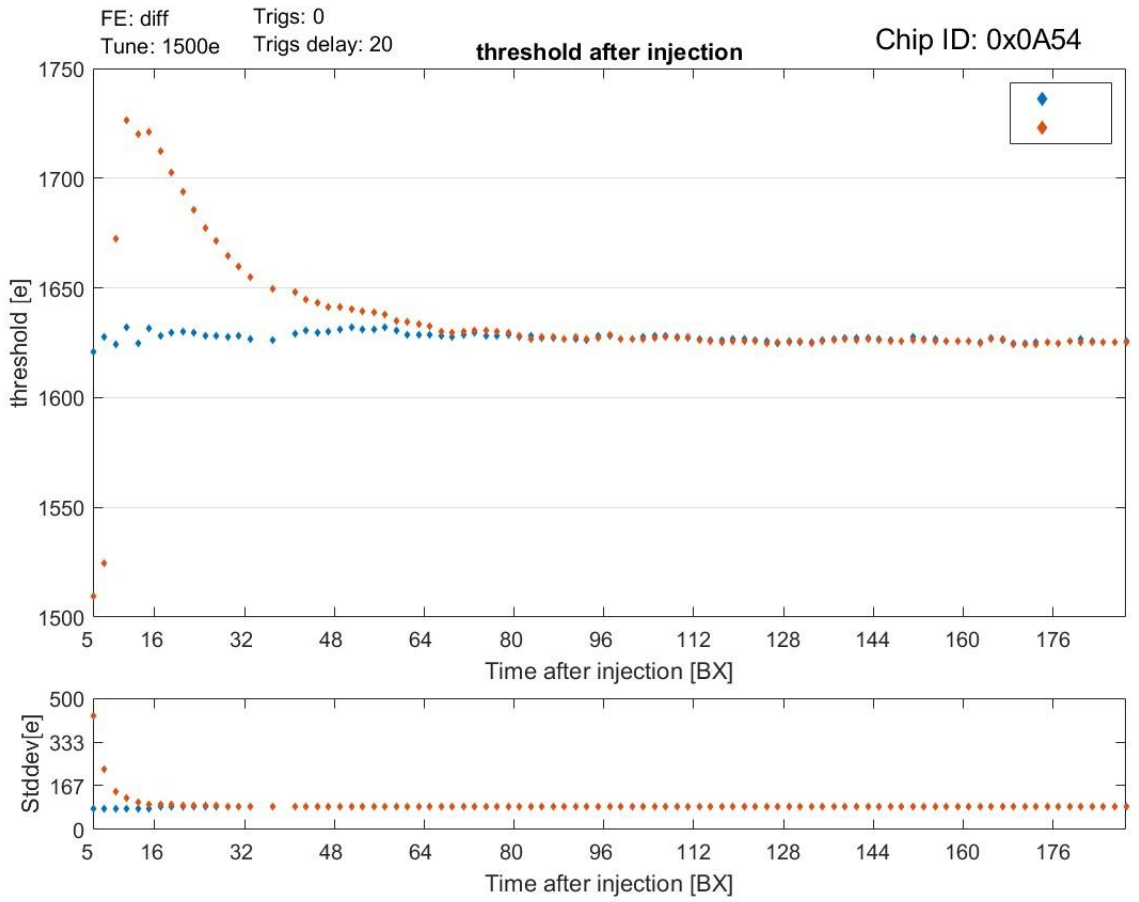
- In RD53A, a signal is only **recorded** as a hit if the **output** of the **comparator** is **high during** a rising **clock edge**
- Comparator is high when the injected signal is above the analogue threshold
- Clock edge has a period of one bunch crossing (BX = 25 ns units)
- This means that depending 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)

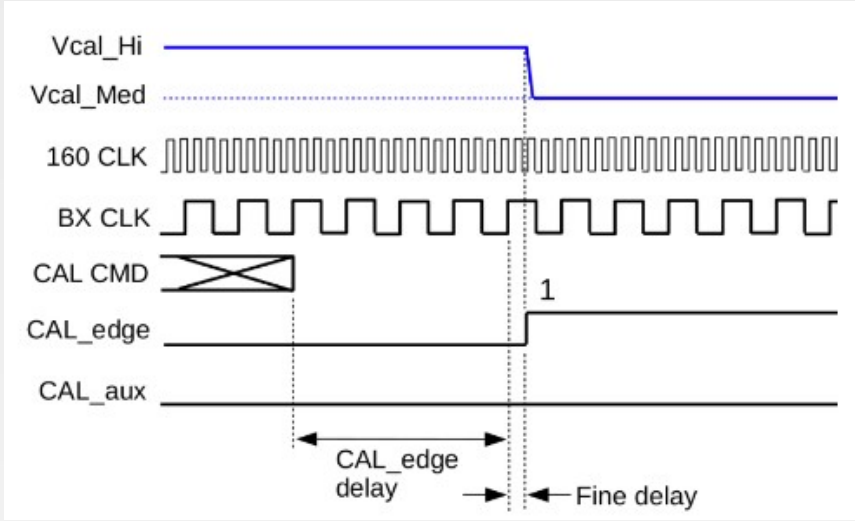
- Diff FE: Tuned to 1500e
- Blue points: **Baseline** (Only have the second charge of varying magnitude)
- Red points: I**nject 2000e** and then inject a second charge of varying magnitude
- X-axis shows the time between the two injections (double delay)
- When the double delay is small - > the mean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



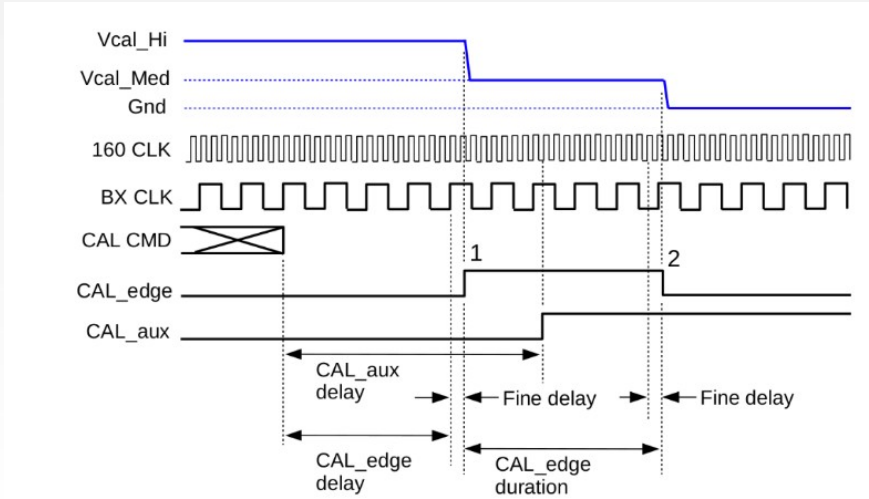
Cal command

- 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



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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