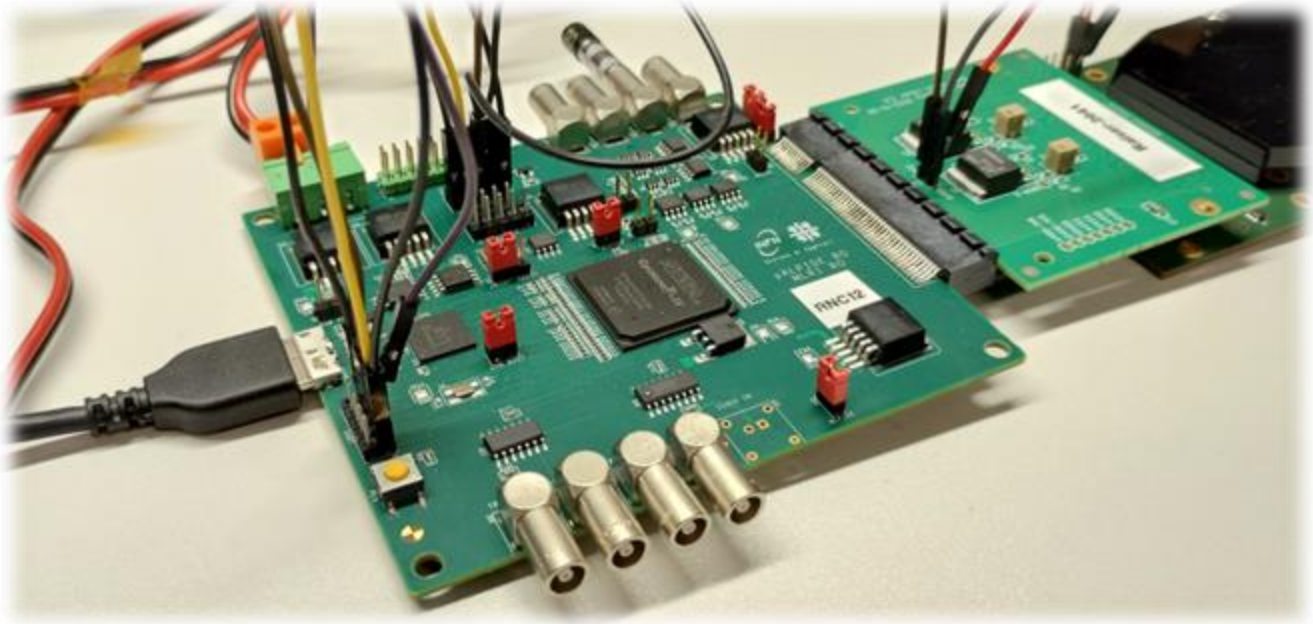
babyMOSS Test Set-up and Scans at Bari



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for the babyMOSS Testing Team @Bari

04 April 2025

INFN BARI
Istituto Nazionale di Fisica Nucleare
Sezione di Bari

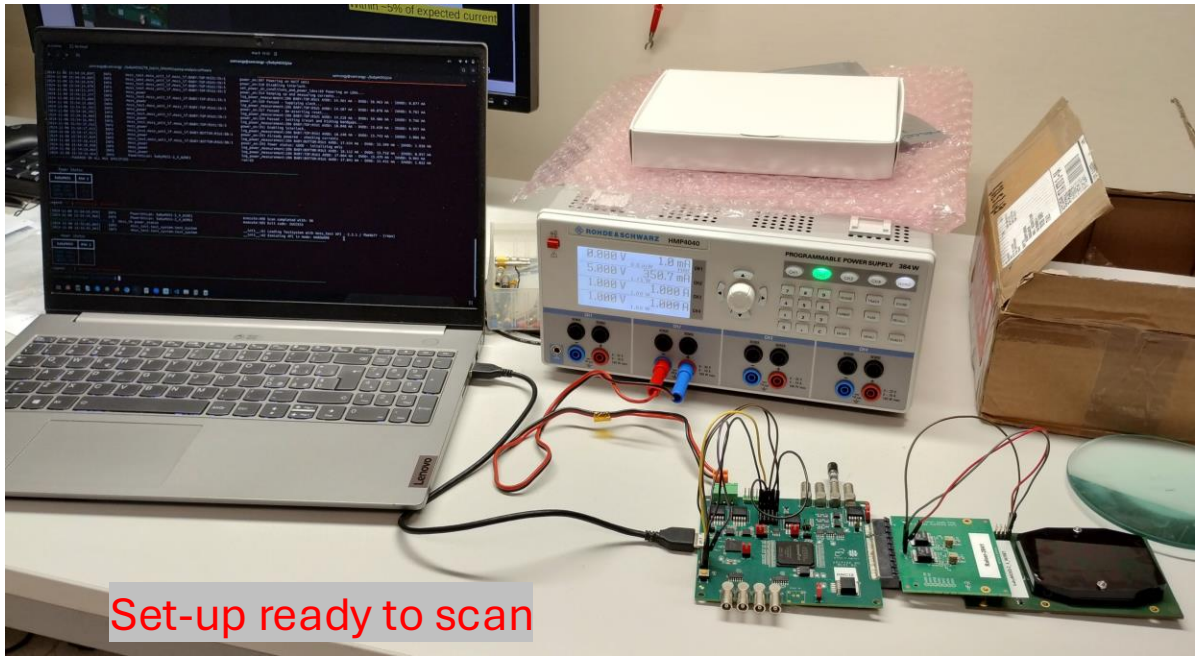
ALICE

Set-up configuration

- DAQ board ID: `DAQ-0009012905D1273D`, Raiser board ID: Raiser-`2041`, Chip ID: `babyMOSS-2_4_W20E1`
- Zero-ohm shunt resistor in SUB at VBB = 0 V
- No Temperature control

Results to be Presented

- Fe^{55} X-ray spectra analysis using Time-over-Threshold (ToT) method.
  1. Changing Vbb = 0 V, -1.2 V
  2. Cluster analysis
  3. Targeted pixel's ToT



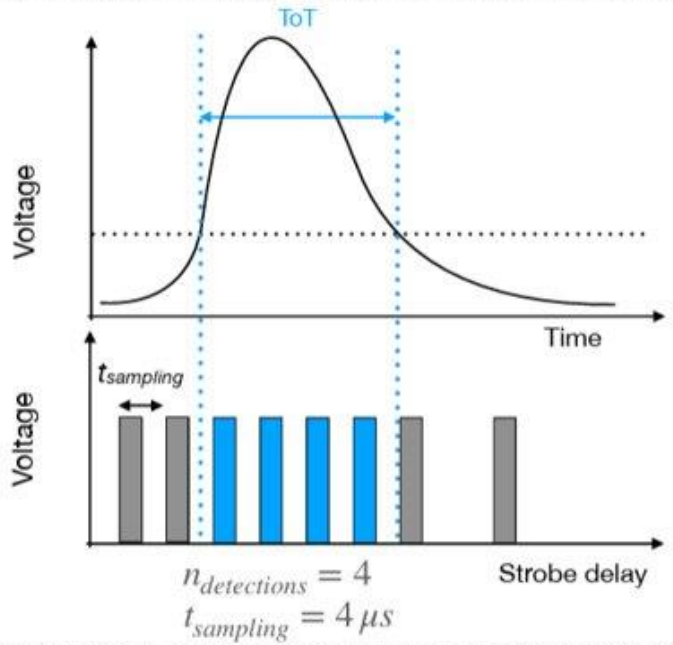
MOSS ToT measurement: Source Scan

Source-scan:

- **Provides method to assess ToT event-by-event**
- Send a consecutive train of $n_{strobes}$ strobes
- Count number of strobes leading to a hit
- ToT estimated by:

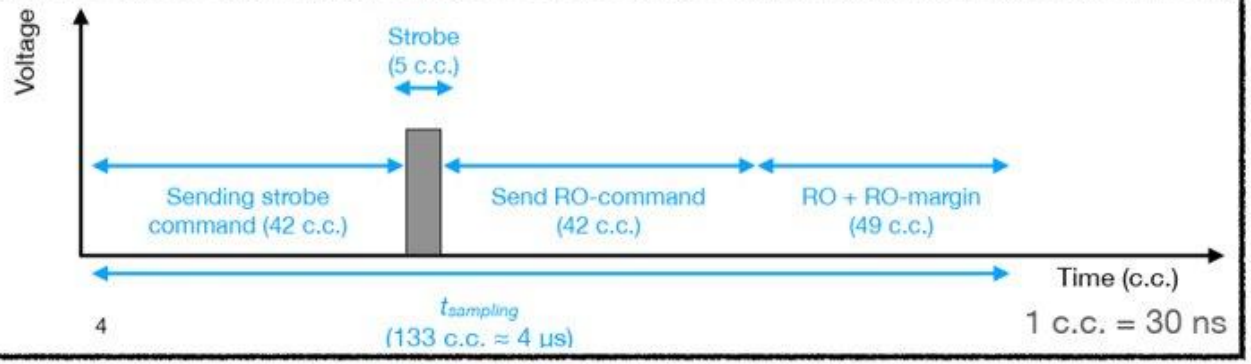
$$ToT = n_{detections} \cdot t_{sampling}$$

- $t_{sampling}$: distance between two strobes



Resolution limitation:

- Command transaction for strobe/ RO takes 42 c.c.
- RO-time depends on hit multiplicity -> need to account for margin
- Minimum $t_{sampling}$ of ~ 4 µs
- **Limits measurement resolution of the ToT in source scan**

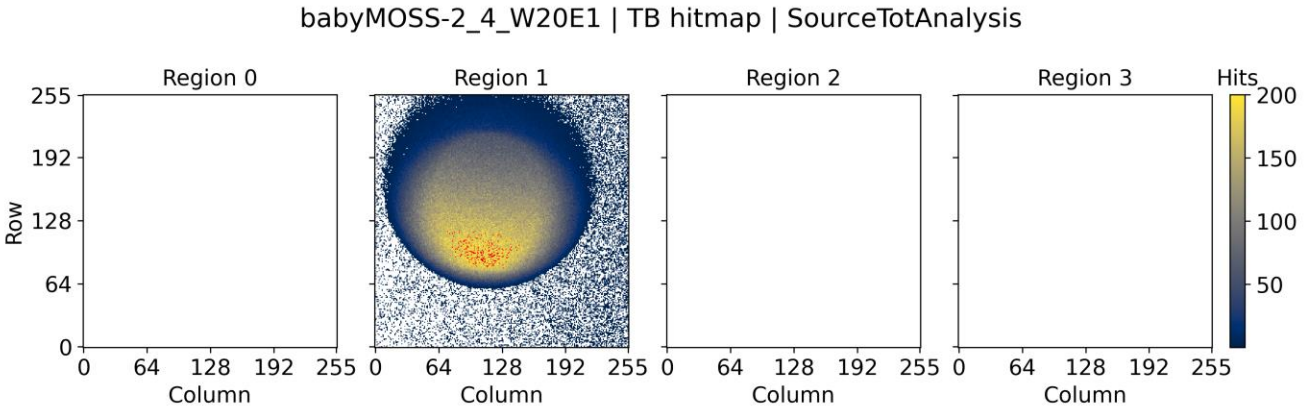


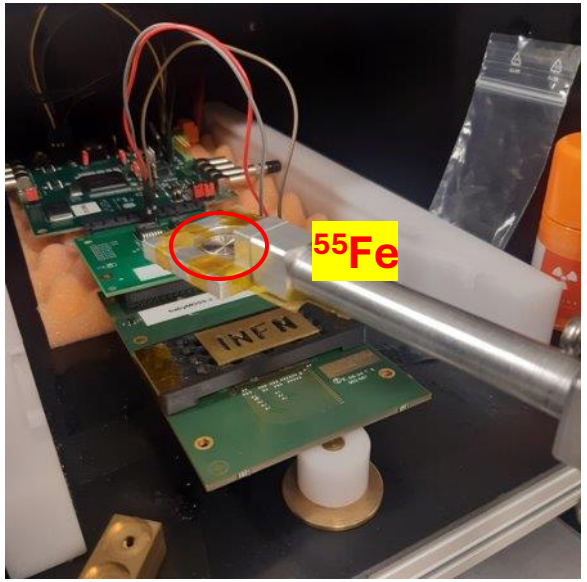
Marius Wilm Menzel, WP3, 21/10/2024

[ToT study, M. Menzel]

Setup for ToT measurement using ^{55}Fe X-ray

- ^{55}Fe X-ray energy spectrum measurement using Time-over-Threshold (ToT) method.
- n_events: 50M (max)
- I_{RESET}: variable
- V_{CASB}: 10
- All other DAC parameters: DEFAULT
- V_{SUB}: 0 V , -1.2 V



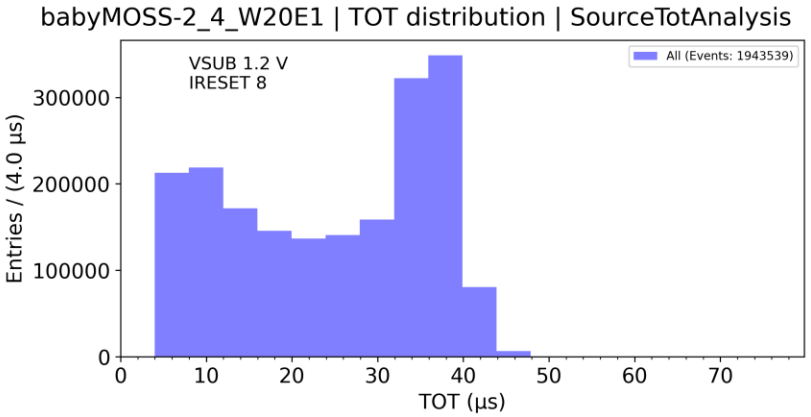


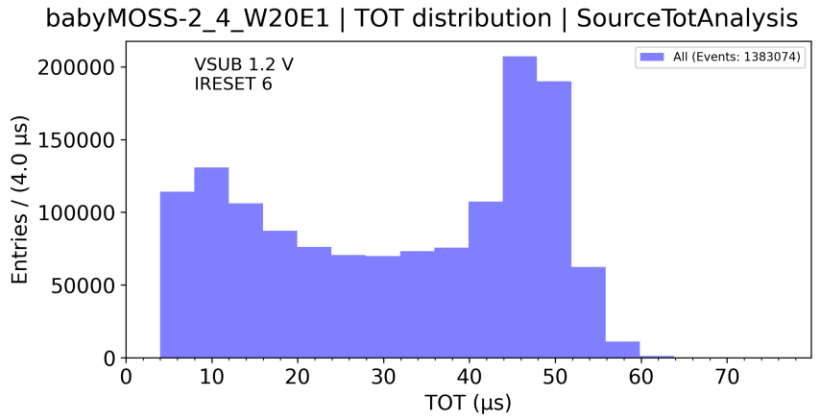
- With decreasing I_{RESET}, pulse length increases, i.e. spectrum resolution increases
- Is it possible to resolve Si_{esc}-peak or K_{β}-peak low I_{RESET}?

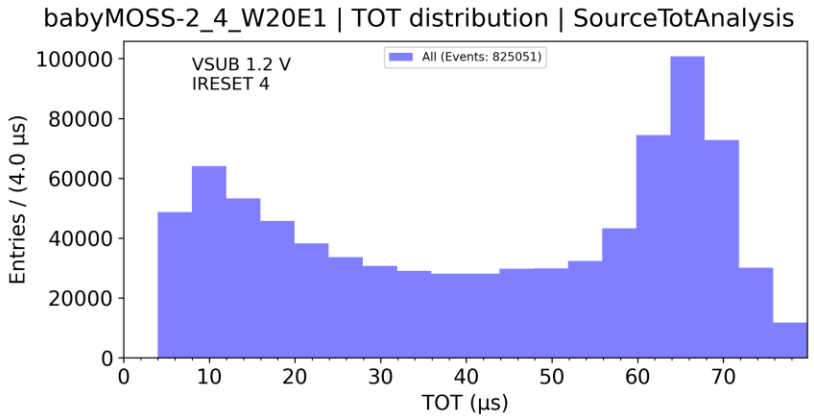
Explored methods

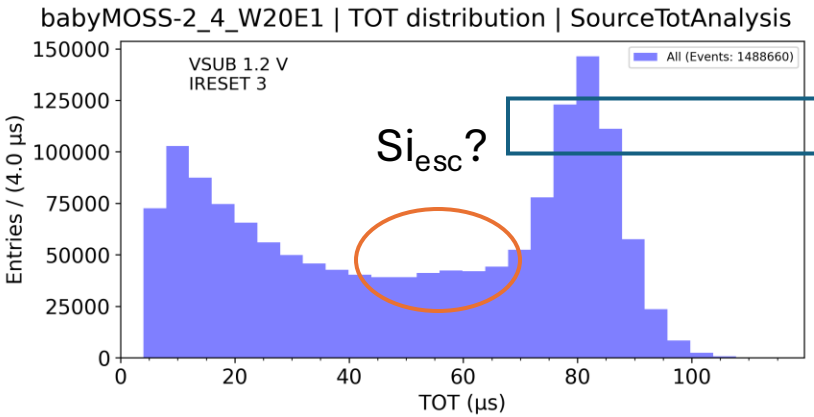
1. Variable V_{SUB} to 0 V and -1.2 V
2. ToT of Clusters analysis
3. Single pixel ToT measurement to avoid the gain calibration of the matrix

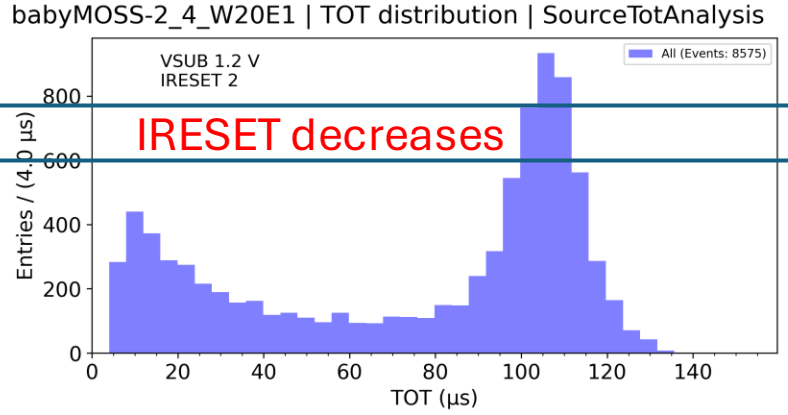
ToT measurement with I_{RESET} changing

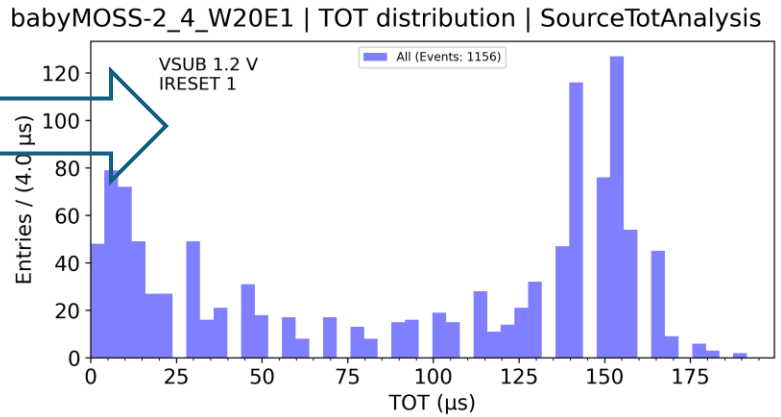








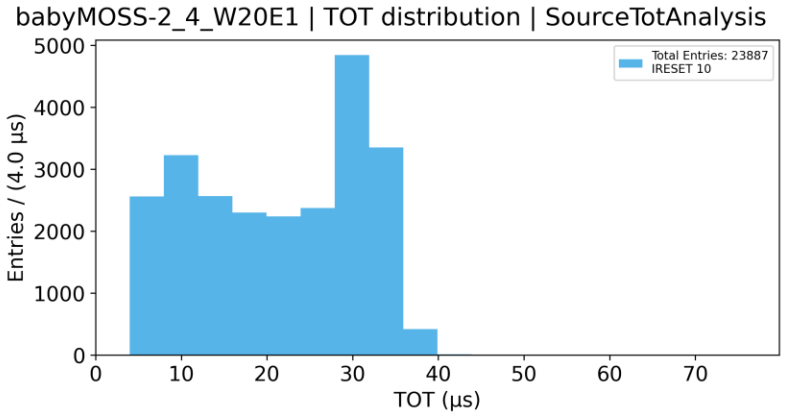


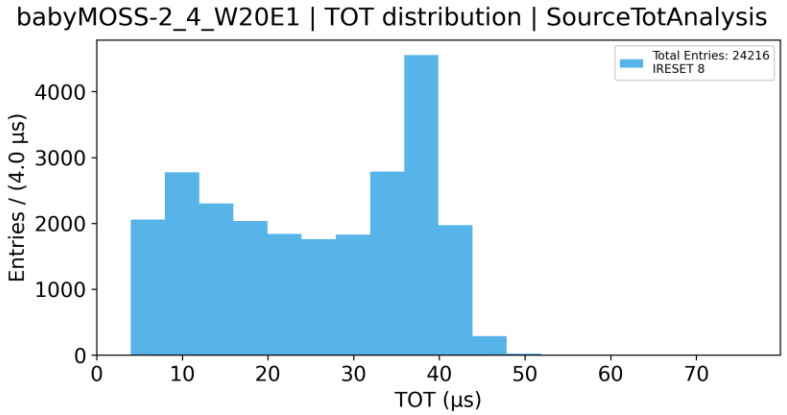


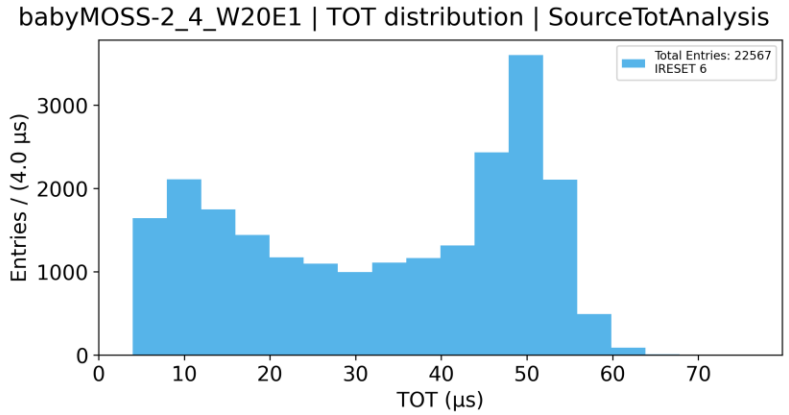
- This time we explored with VSUB = -1.2 V, and ToT measurement is possible to down to IRESET = 1
- With decreasing IRESET, ToT value of 5.9 keV K_α is increasing

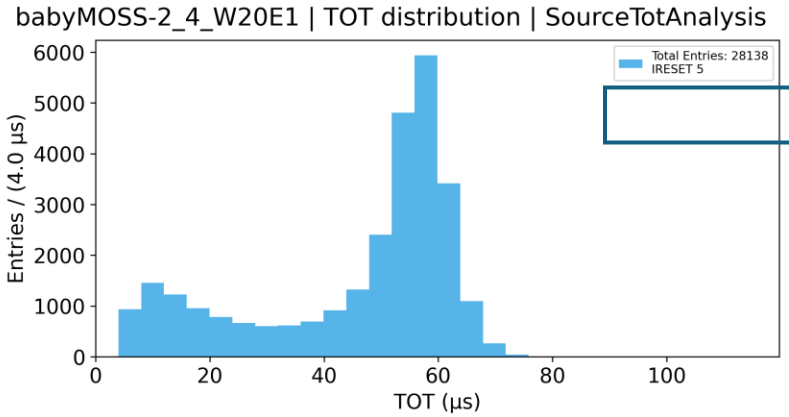
VSUB = - 1.2 V

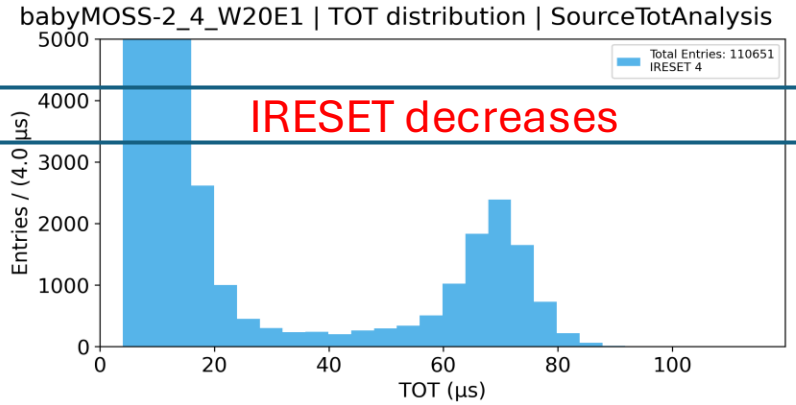
ToT measurement with I_{RESET} changing

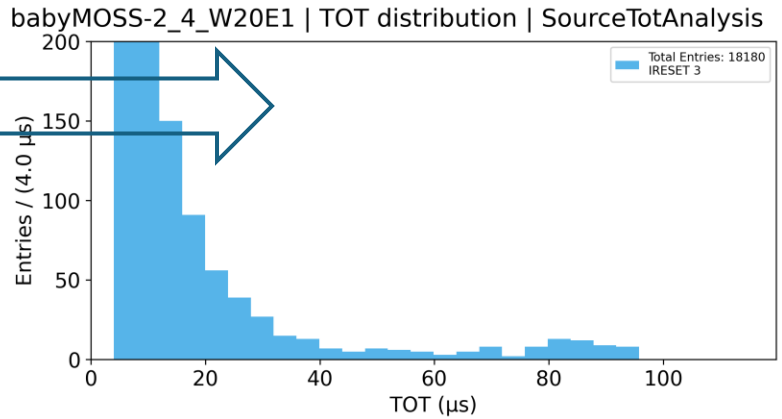












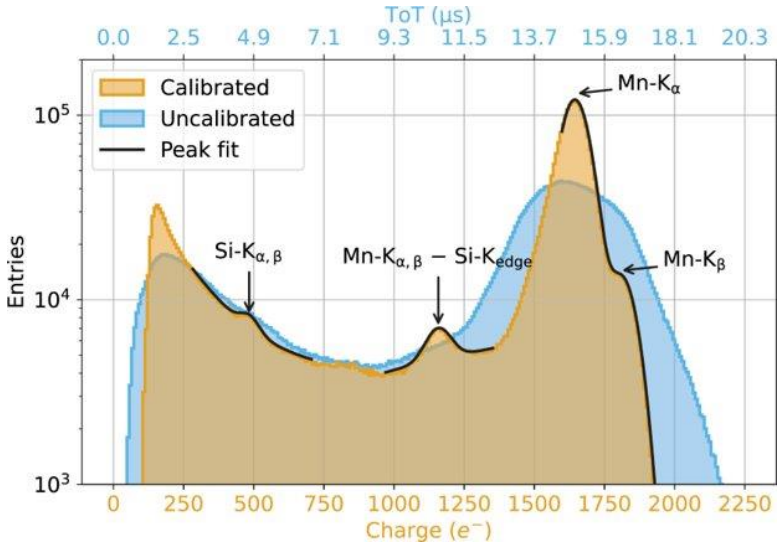
IRESET decreases

- With decreasing IRESET, ToT value of 5.9 keV K_α is increasing
- In this set up of VBB = 0 V, ToT scan performed down to IRESET = 3

VSUB = 0 V

Last presentation

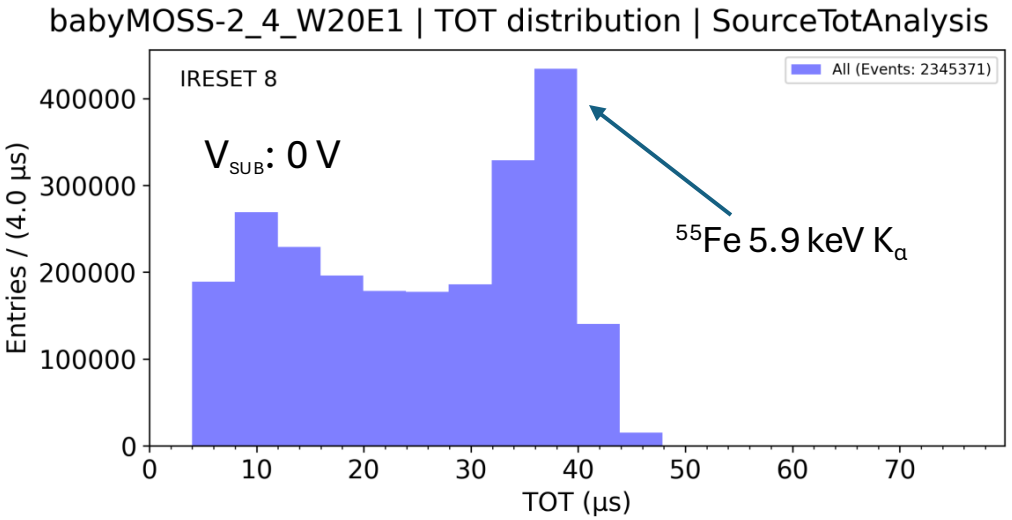
ToT measurement with I_{RESET} changing



DPTS paper

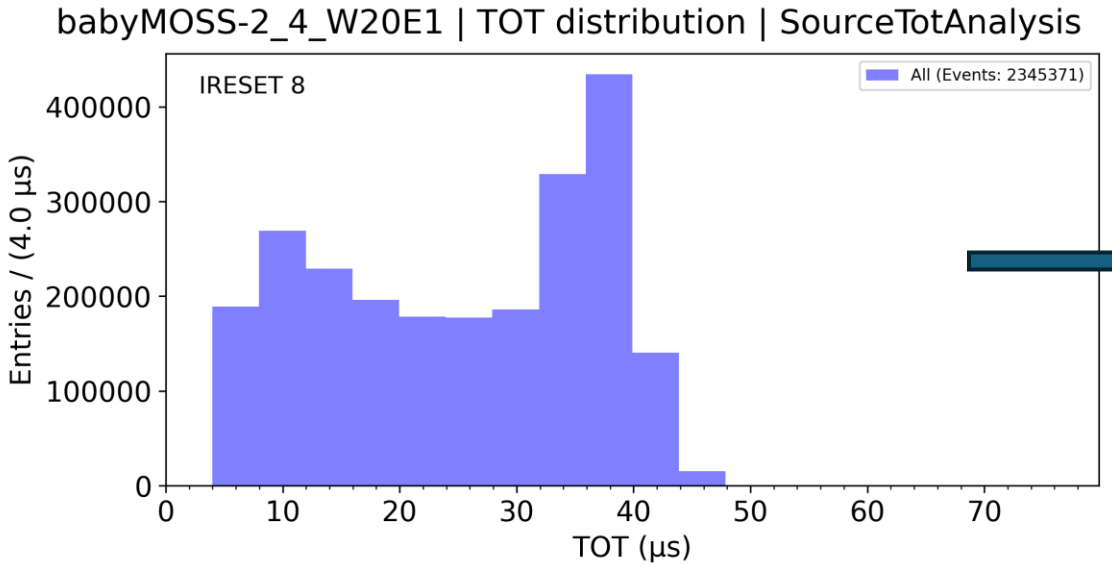
Peak	$Mn\text{-}K_\alpha$	$Mn\text{-}K_\beta$	Si_{esc}	Si_{fl}
Energy (keV)	5.90	6.51	4.16	1.74

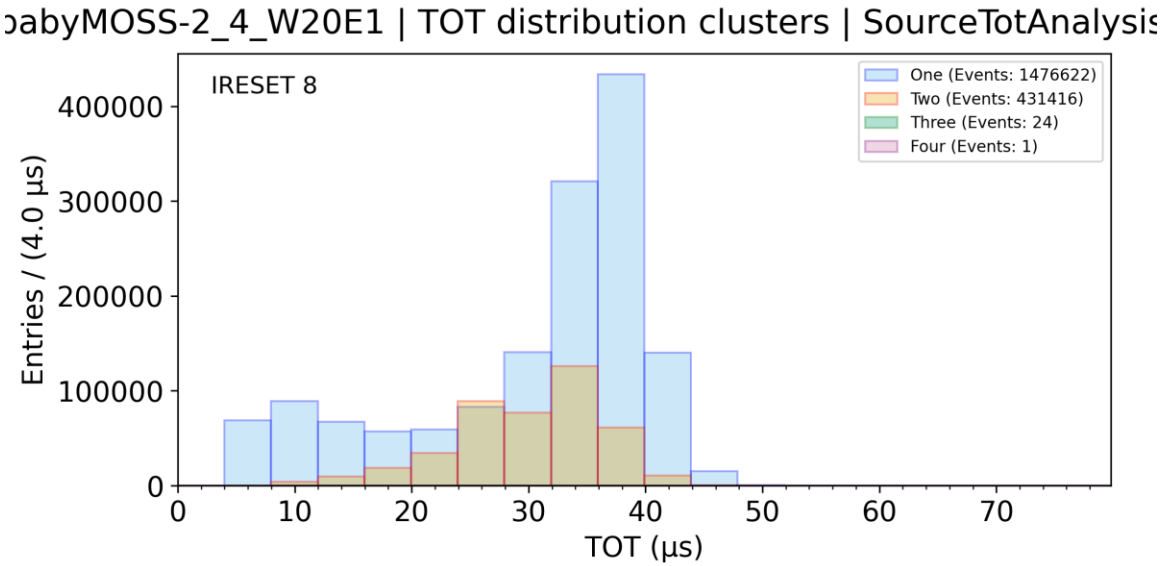
IRESET, VSUB = 0V	ToT(K_α)	Si_{esc}/K_α*ToT(K_α) = 0.7*ToT(K_α)	K_β/K_α*ToT(K_α) =1.1*ToT(K_α)
10	30	21	33
8	38	27	42
6	50	35	55
5	58	41	64
4	70	49	77
3	82	58	90

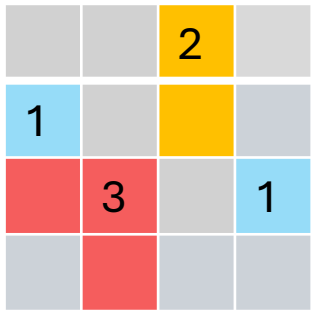


- ToT resolution limited to ≈ 4 µs by Source Scan method
- No corrections applied
- ToT of pixel from all hits cannot resolve Si_{esc}-peak or K_β-peak

ToT measurement of different clusters

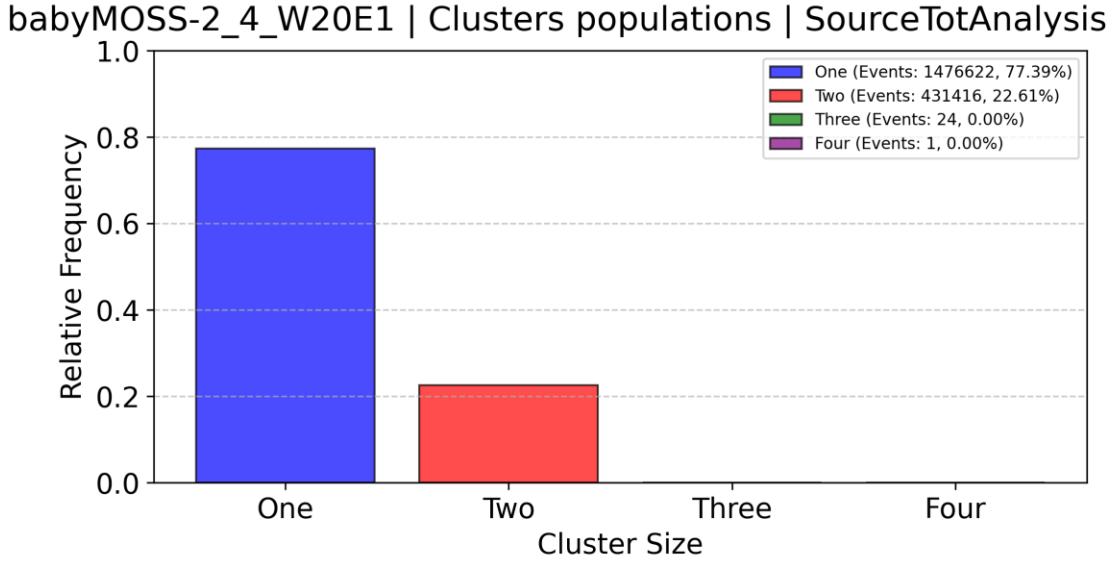






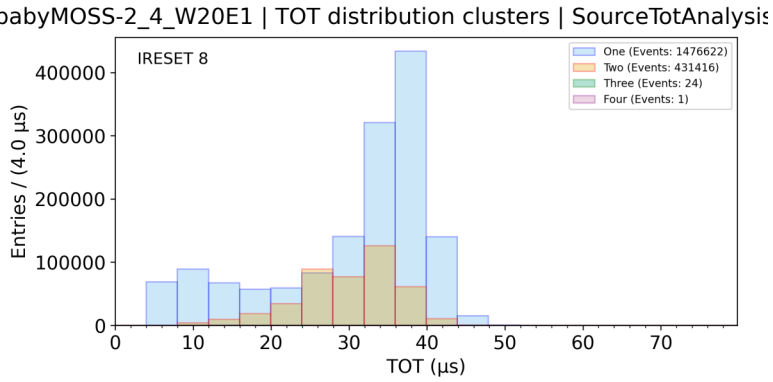
Example of hit clusters

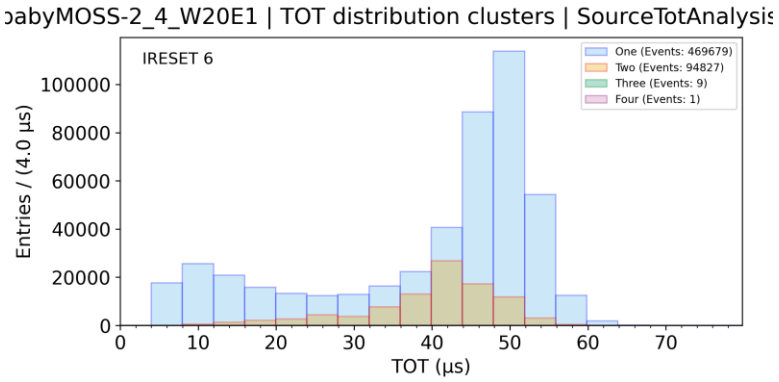
V_{SUB}: 0 V

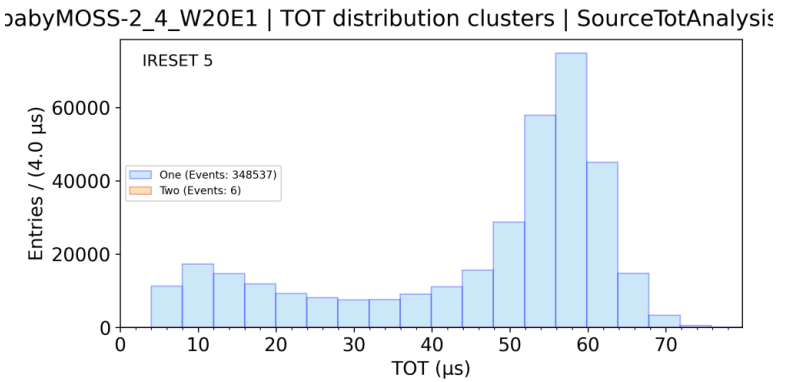


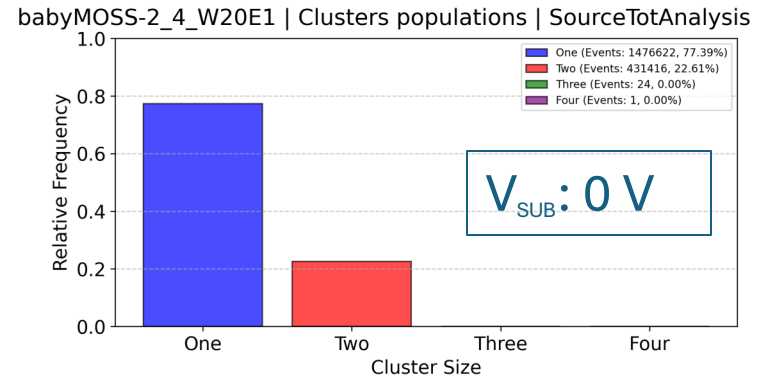
- ToT measurement of the full matrix
- One cluster and two cluster both indicates ToT peak, however a shifting of peak value is there
- 22% of hits having two cluster

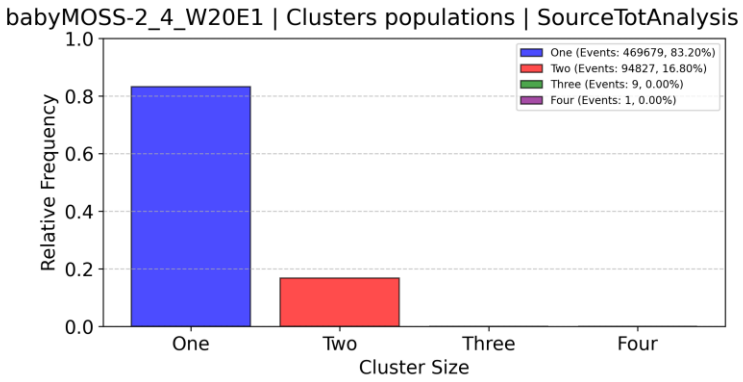
ToT measurement of different clusters with varying I_{RESET}

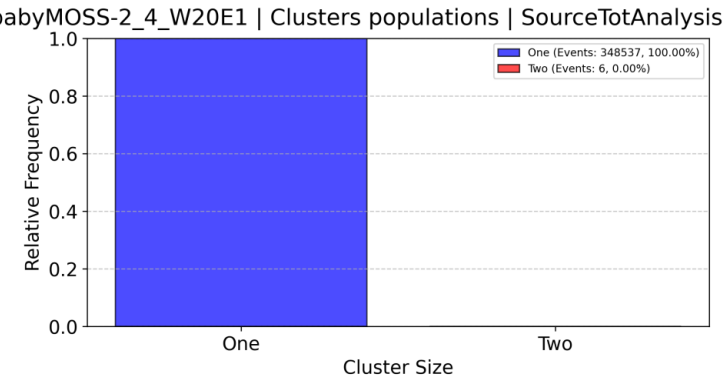


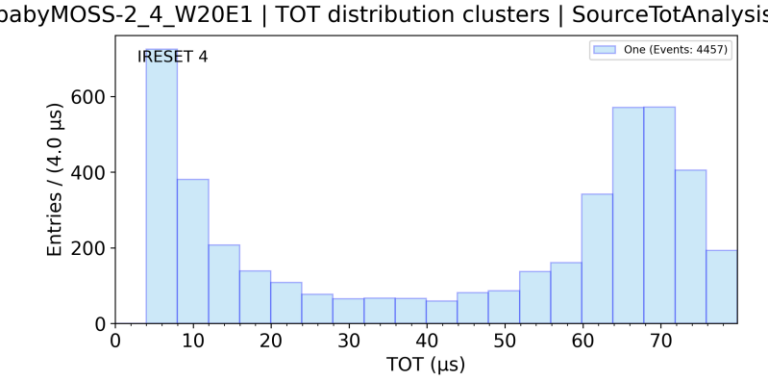


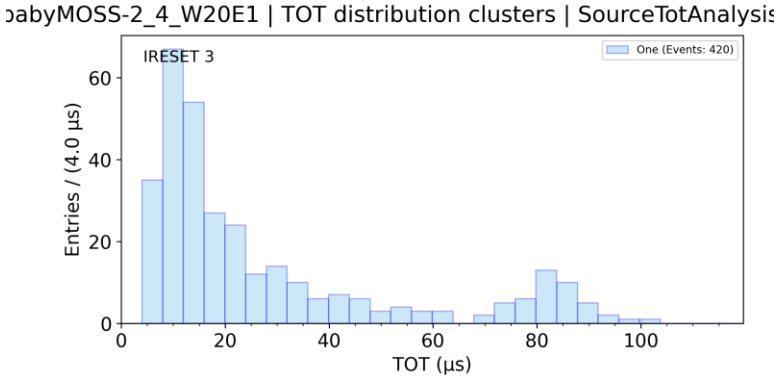






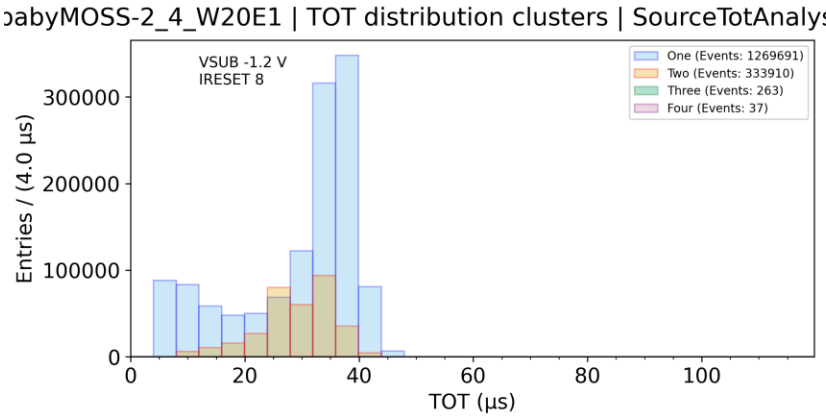


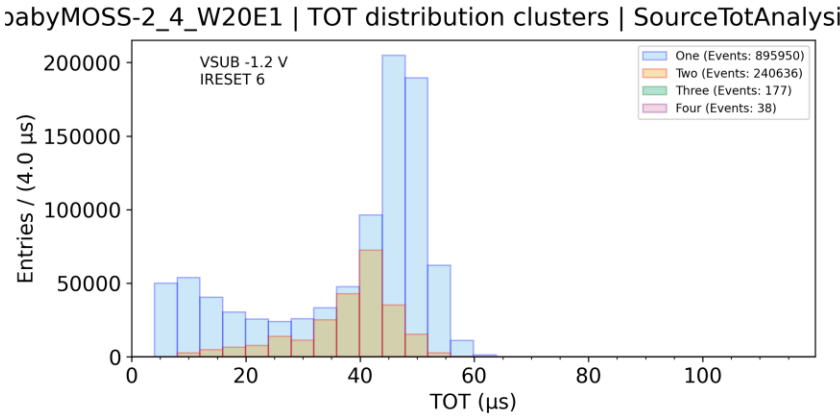


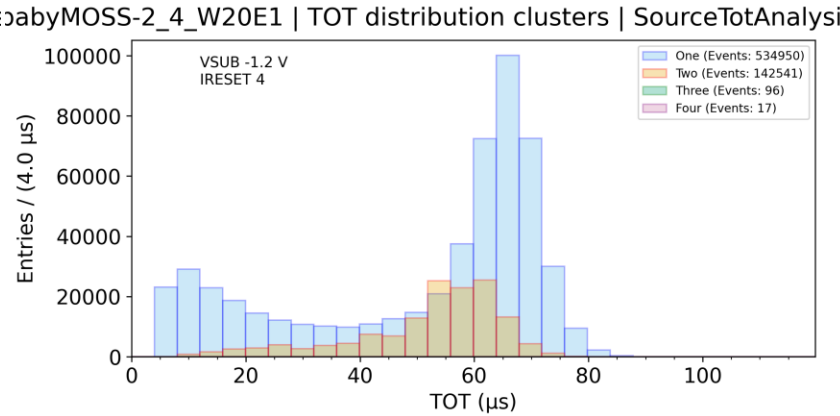


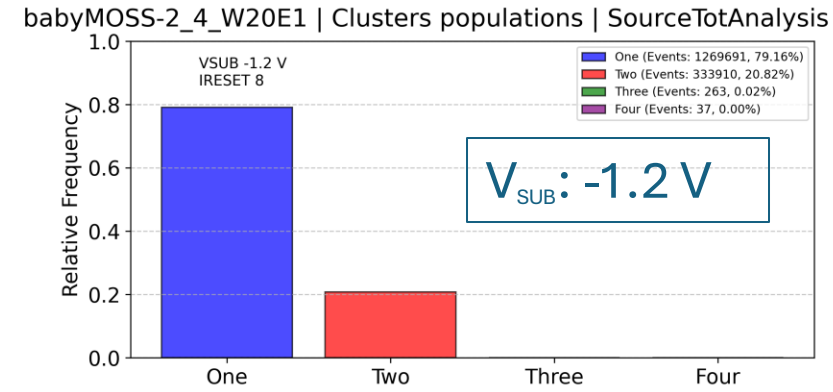
- ToT increases with decreasing I_{RESET} as signal fall time enlarged.
- With decreasing I_{RESET} two-cluster fraction gets down, which is due to signal formation issue at low value of I_{RESET}.
- Below I_{RESET} = 3 is impossible to measure ToT.

ToT measurement of different clusters with varying I_{RESET}

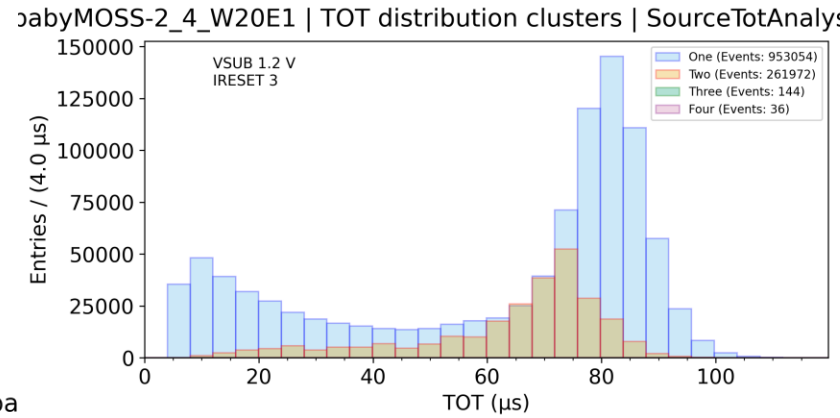


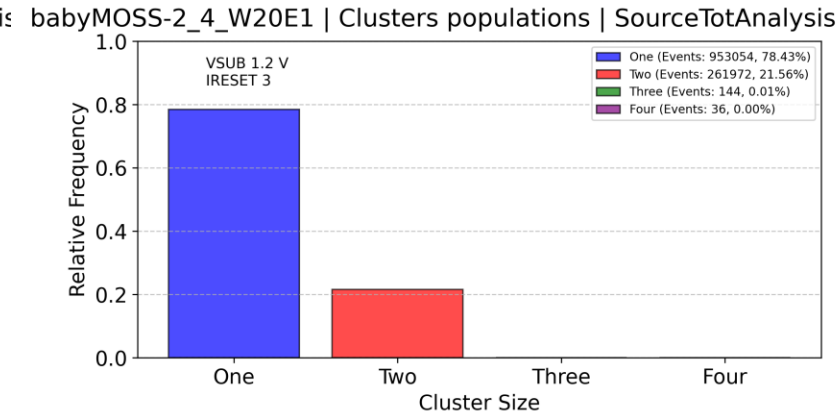


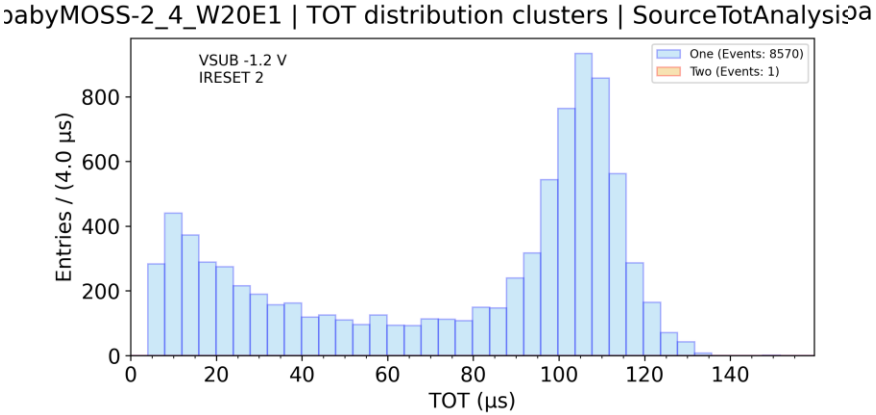


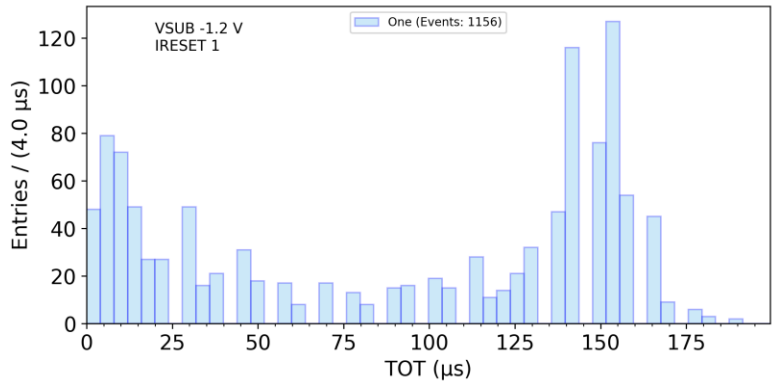


V_{SUB}: -1.2 V



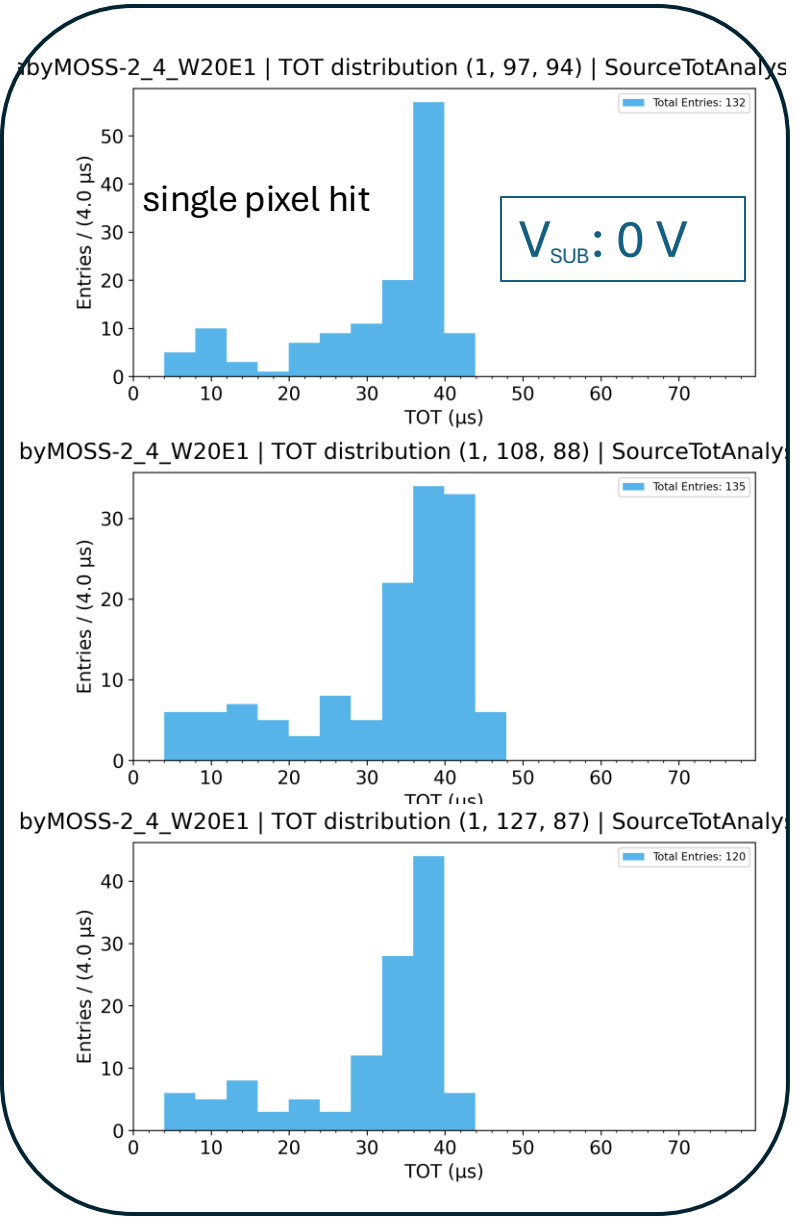


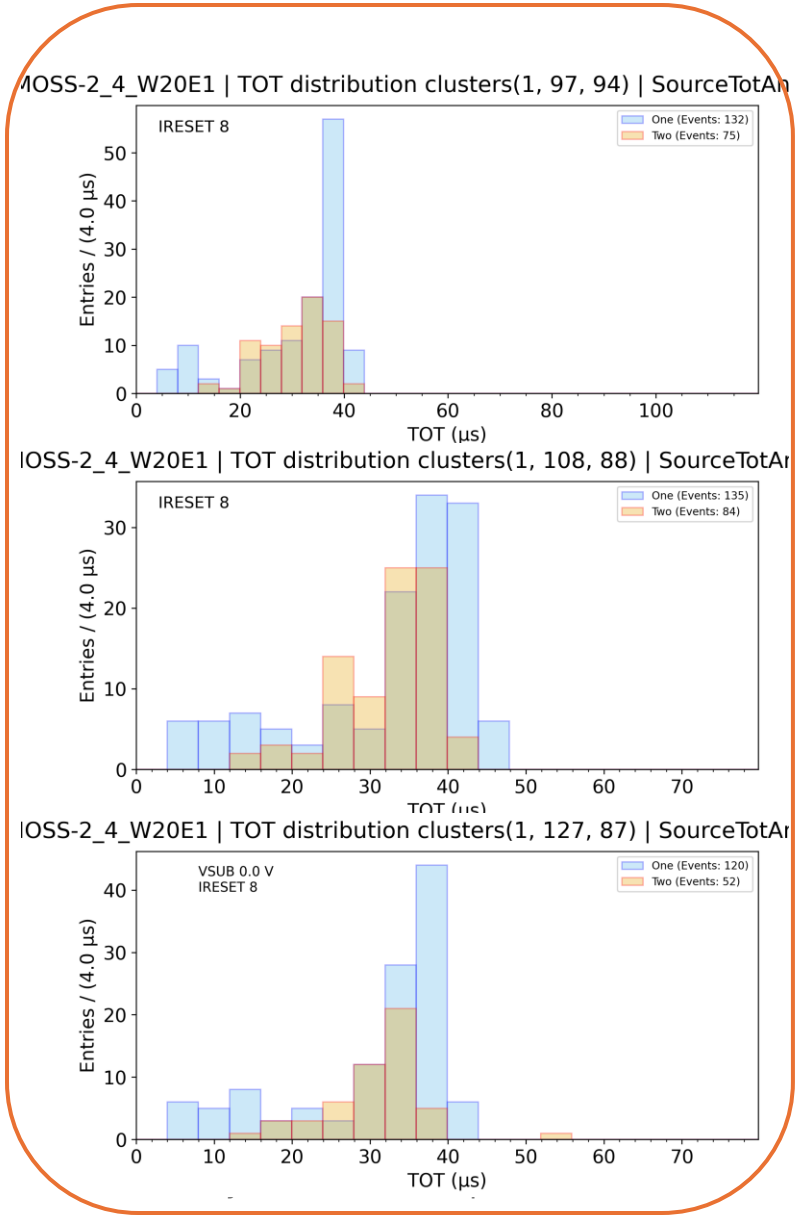




- Two-cluster fraction is remain unchanged upto I_{RESET} = 3
- ToT of VSUB = 0 V and =1.2 V are look similar. The only advantage of VSUB = -1.2 V is we can go down to IRESET = 1.

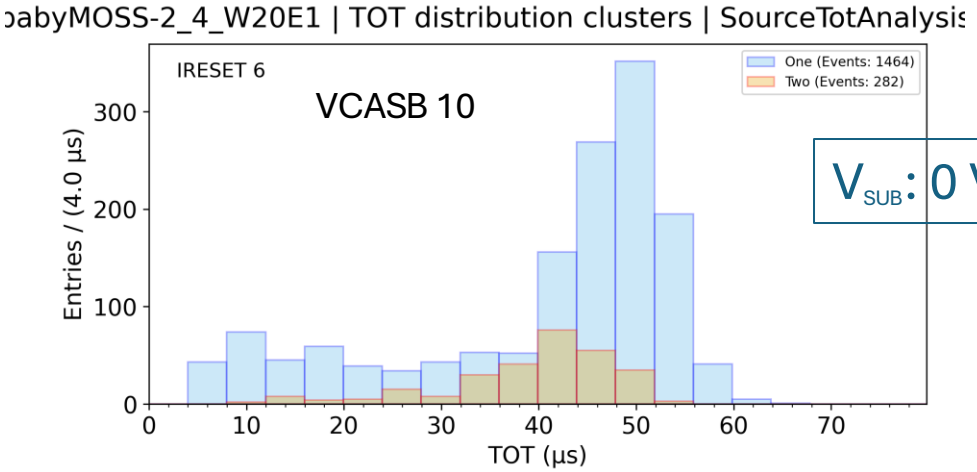
ToT measurement of targeted pixels with IRESET = 8, VSUB = 0 V



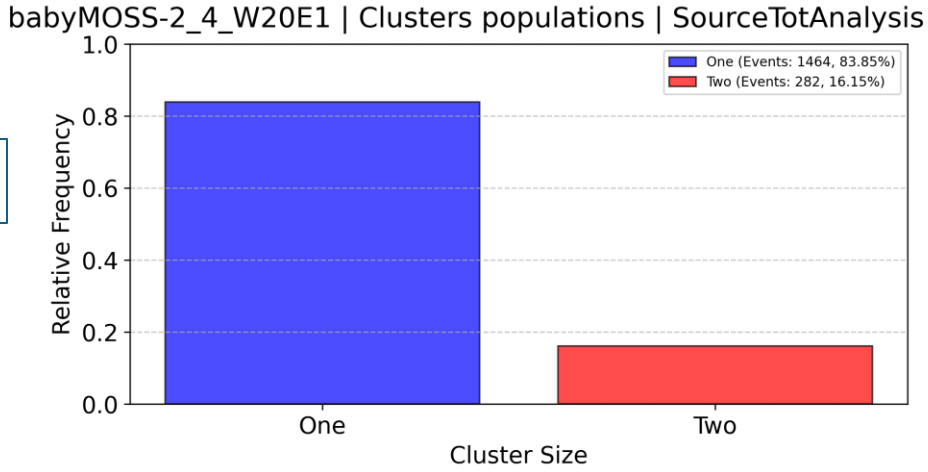


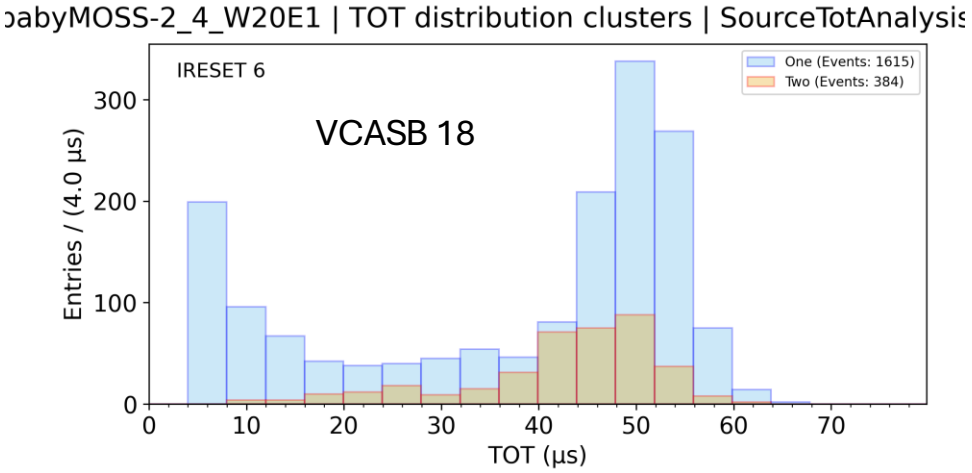
- One cluster distribution is following previously calculated one.
- Two cluster ToT also has a peak, however it looks shifted 1 bin to left.

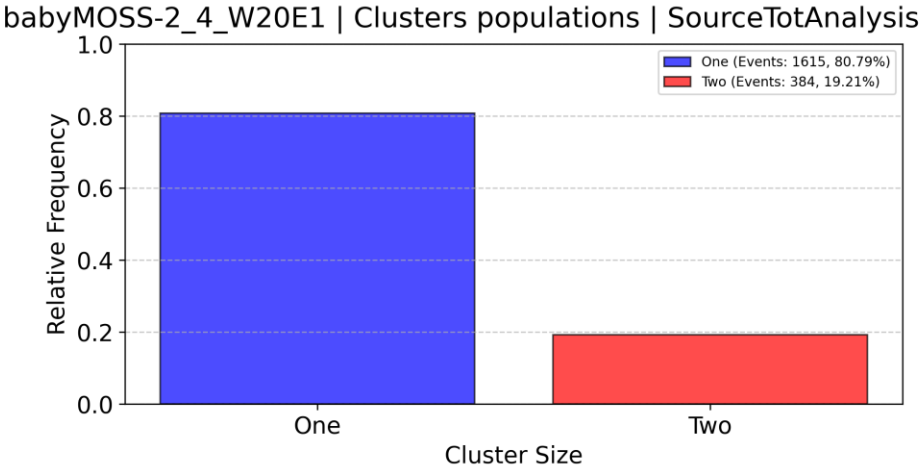
ToT measurement varying the VCASB



V_{SUB}: 0 V

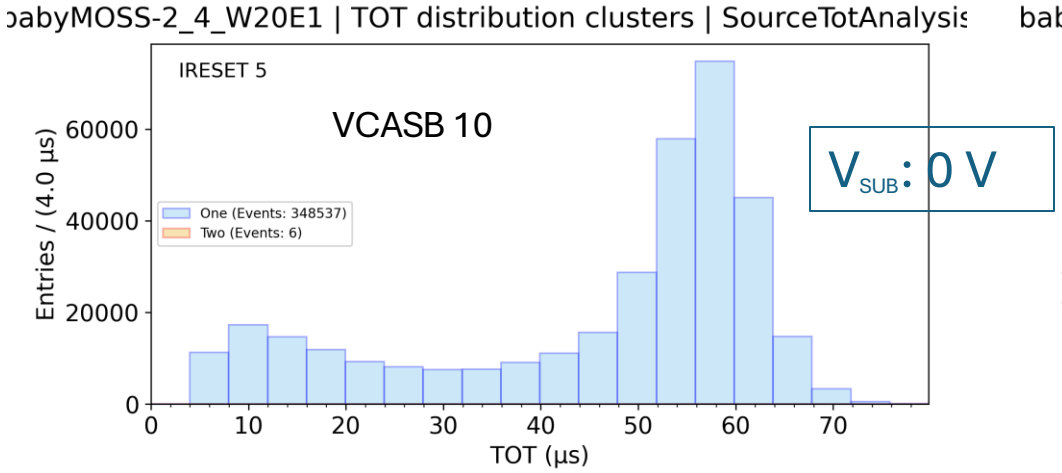




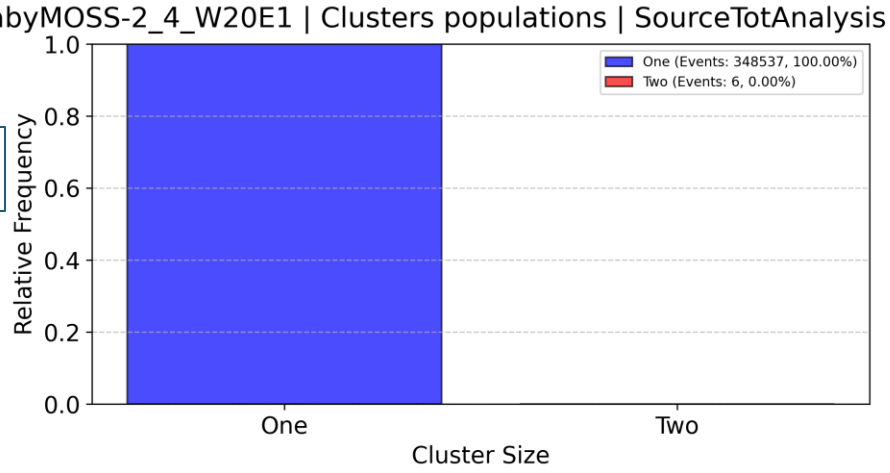


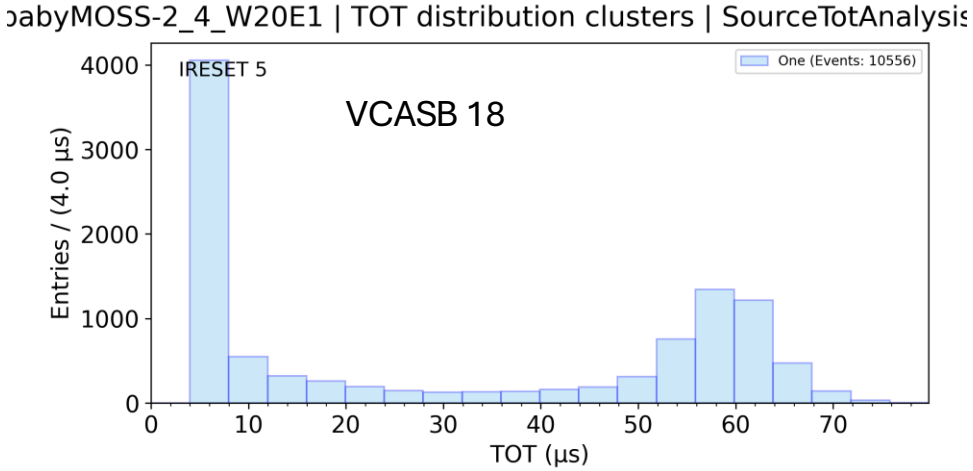
- ToT is not sensitive to VCASB

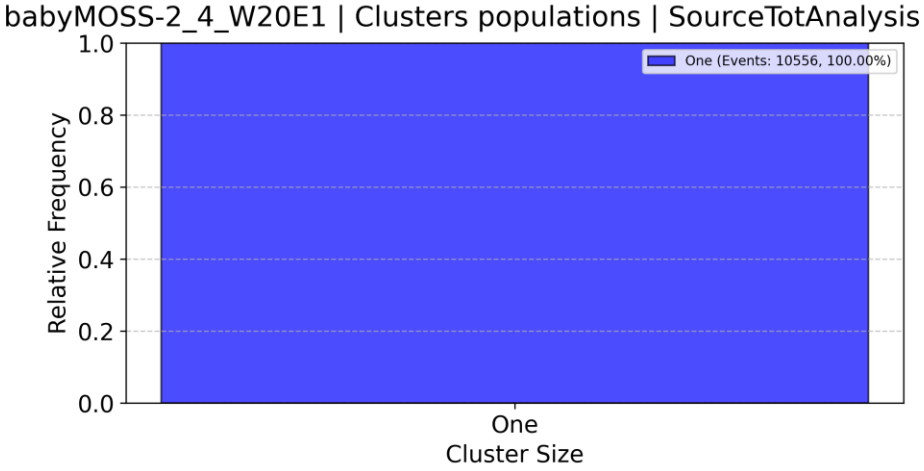
ToT measurement varying the VCASB



V_{SUB}: 0 V







- ToT is not sensitive to VCASB

Summary and Outlooks

- Performed tests of the babyMOSS with V_{SUB} = 0 V, -1.2 V
- Characterization with ^{55}Fe Activities:
  - ToT measurement with varying I_{RESET} for different clustes are studied
  - The ToT response of the targed pixel's for different cluster sizes are similar to the integrated ToT of the matrix.
  - ToT measurement is not sensitive to VCASB.

Plan:

Perform the ToT measurement using *Source Stuck Readout method* at V_{SUB} = 0 V, -1.2 V

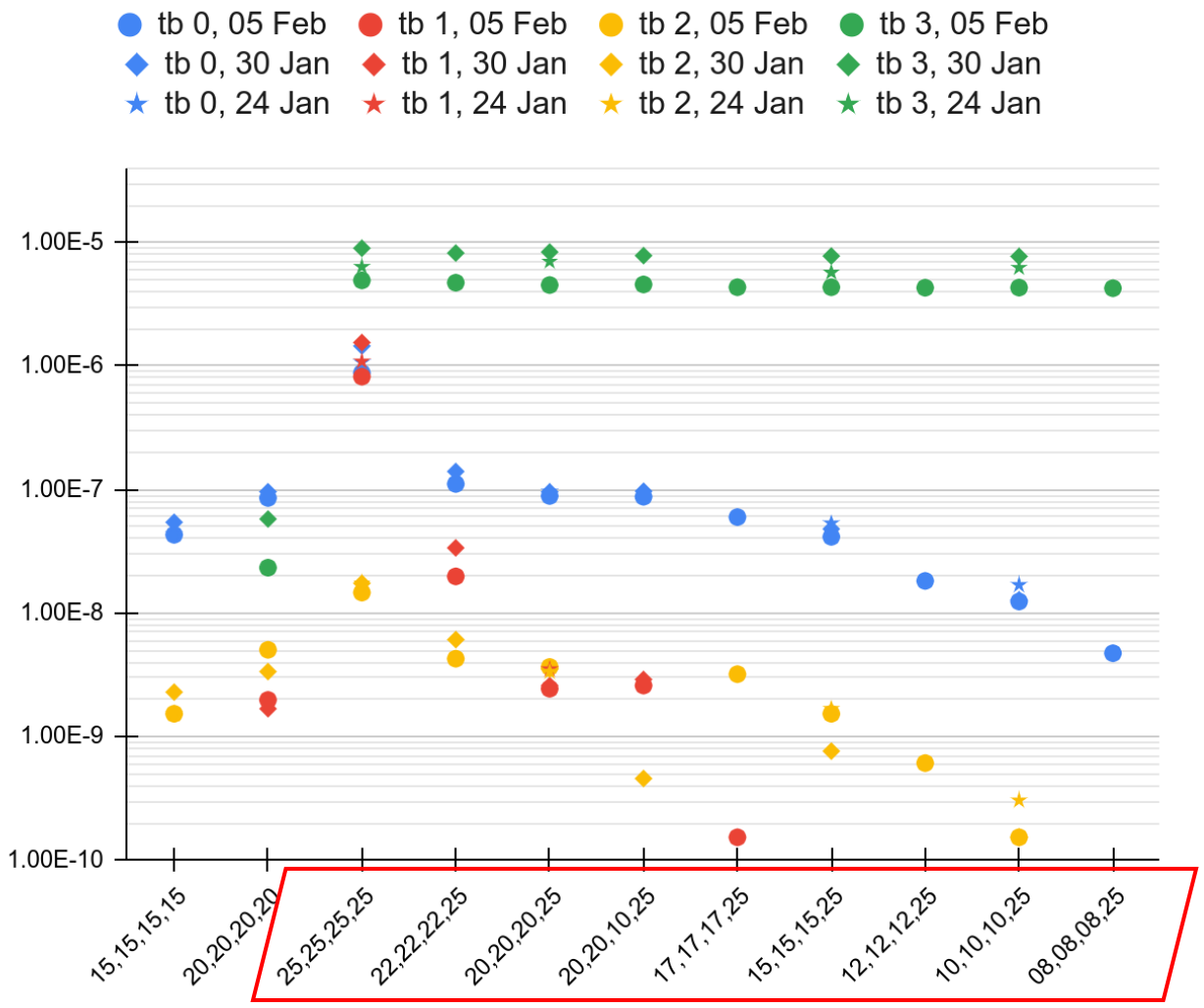
Back-up

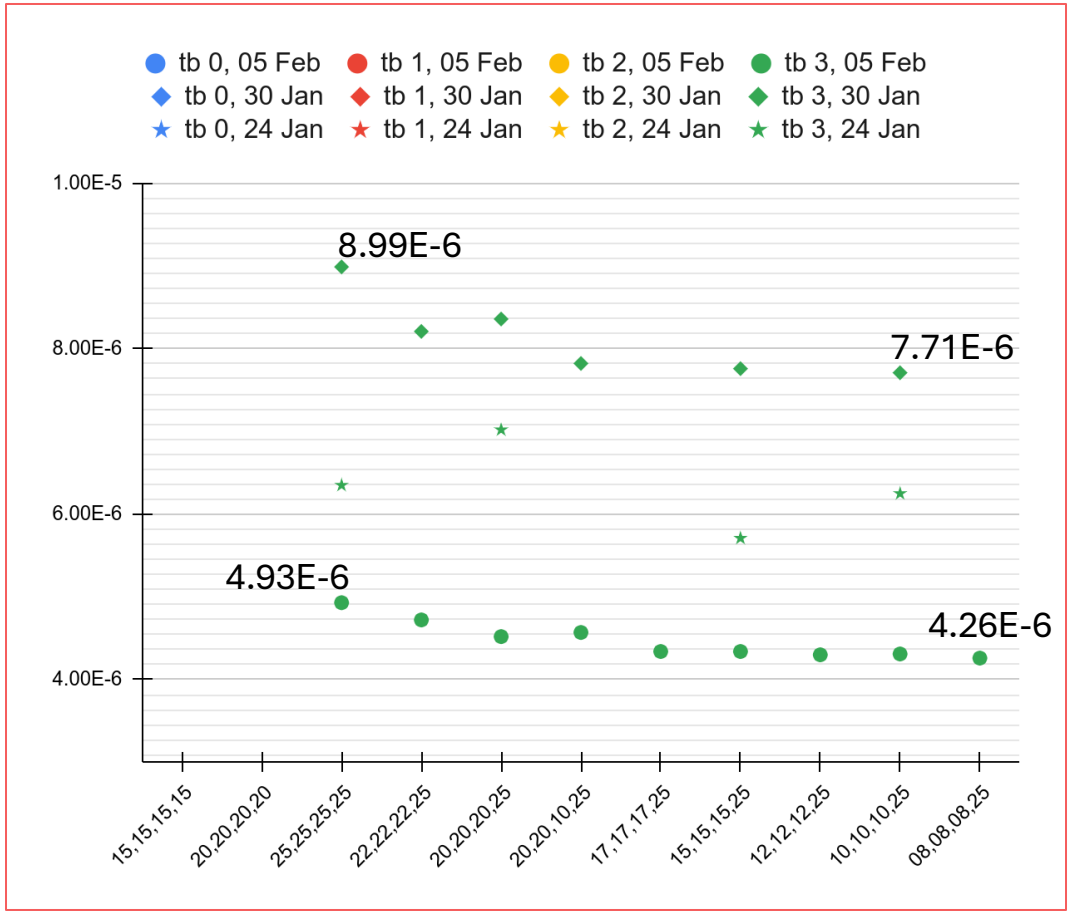
Summary of the different scans performed

	Scans	babyMOSS-2_4_W20E1
Functional tests	Power on	OK
	Register	OK
	Shift register	OK
	DAC	OK
Readout and pixel matrix tests	Digital	OK
	Analogue	OK
	FHR	OK
	Threshold	OK
Energy spectrum	ToT	Ongoing

- Region 1 of the bottom half unit is found to be noisy, as also reported by CERN tests.

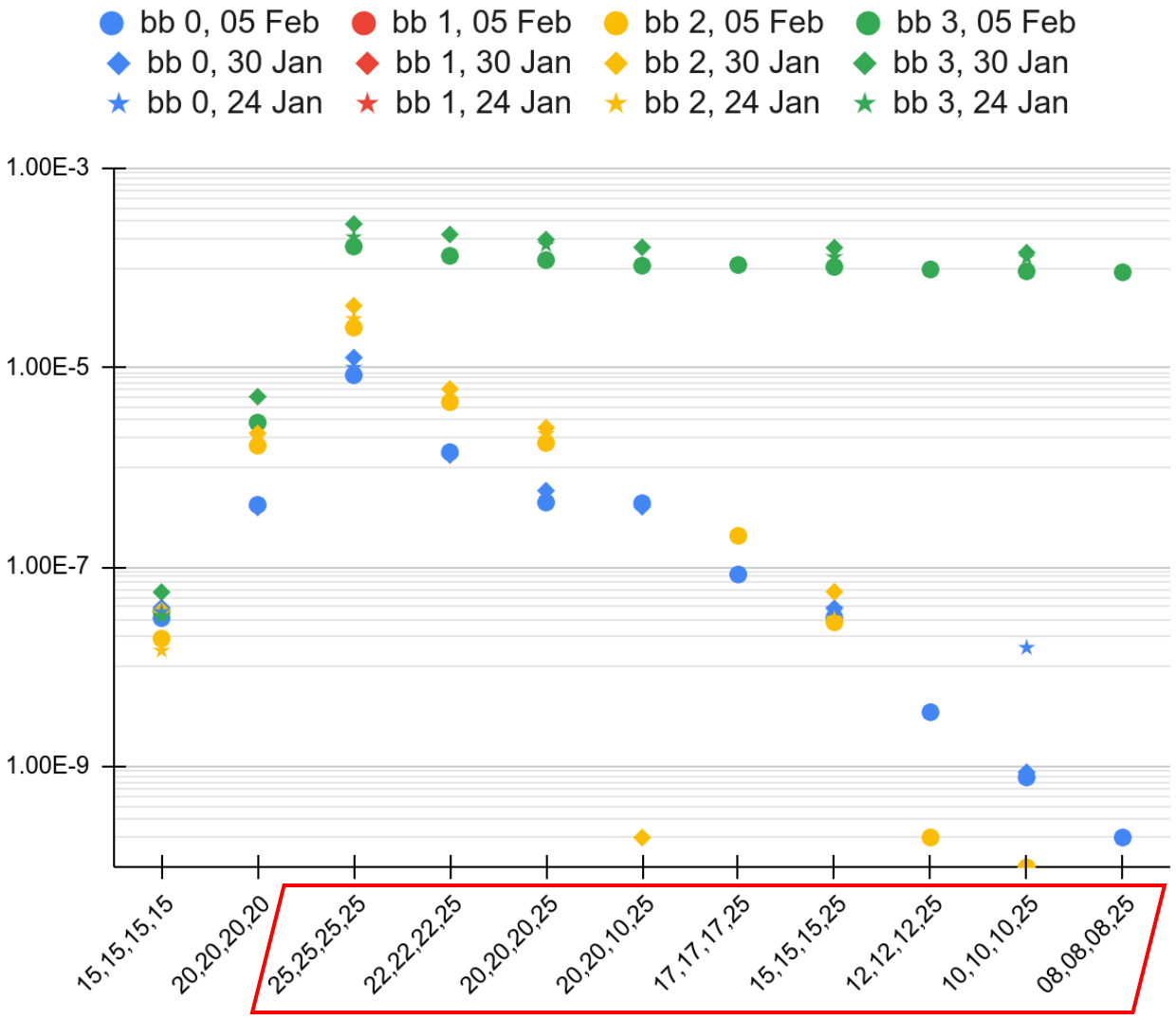
FHR Scan: Different combinations of VCASB

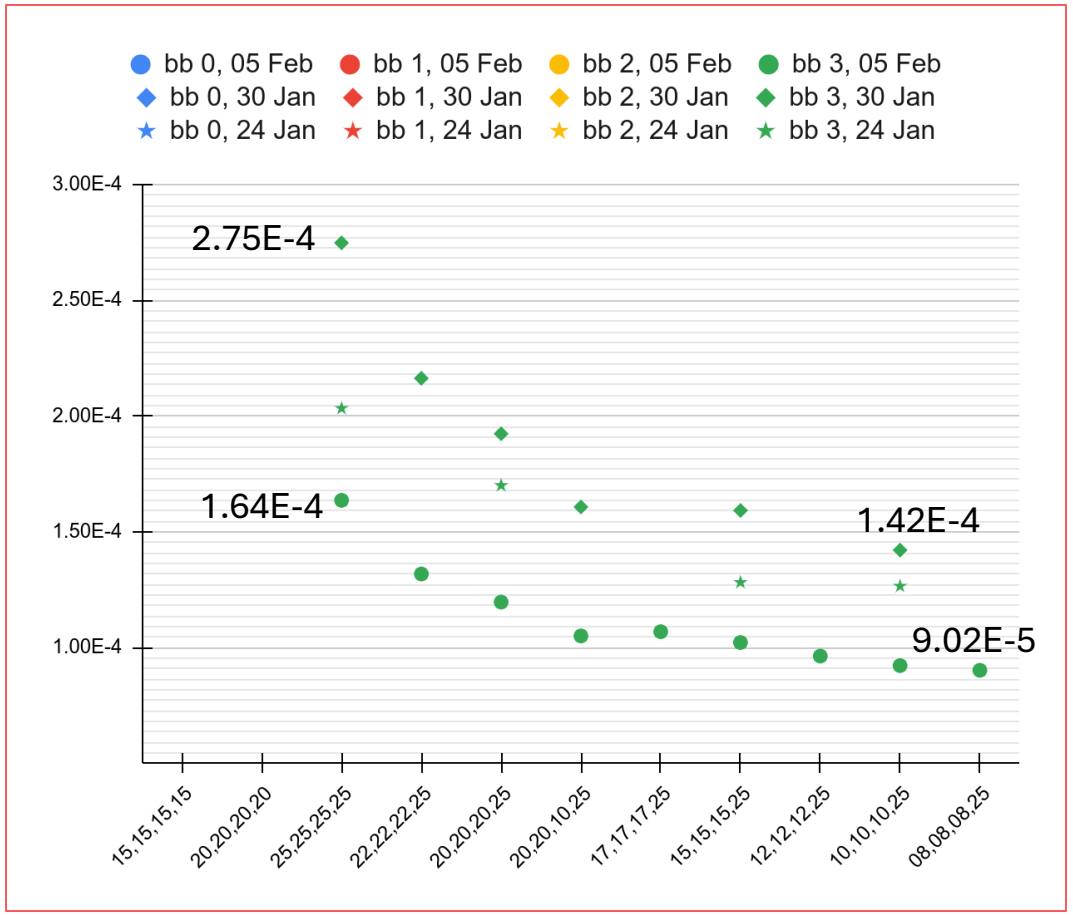




- FHR at tb region 3 measured at VCASB = 25 with varying VCASB for other regions.
- A decreasing trend in FHR due to the influence of neighbouring regions' VCASB was observed.
- The uncertainties of FHR are one order of magnitude lower and are not presented here.

FHR Scan: Different combinations of VCASB on 24.01.2025, 30.01.2025



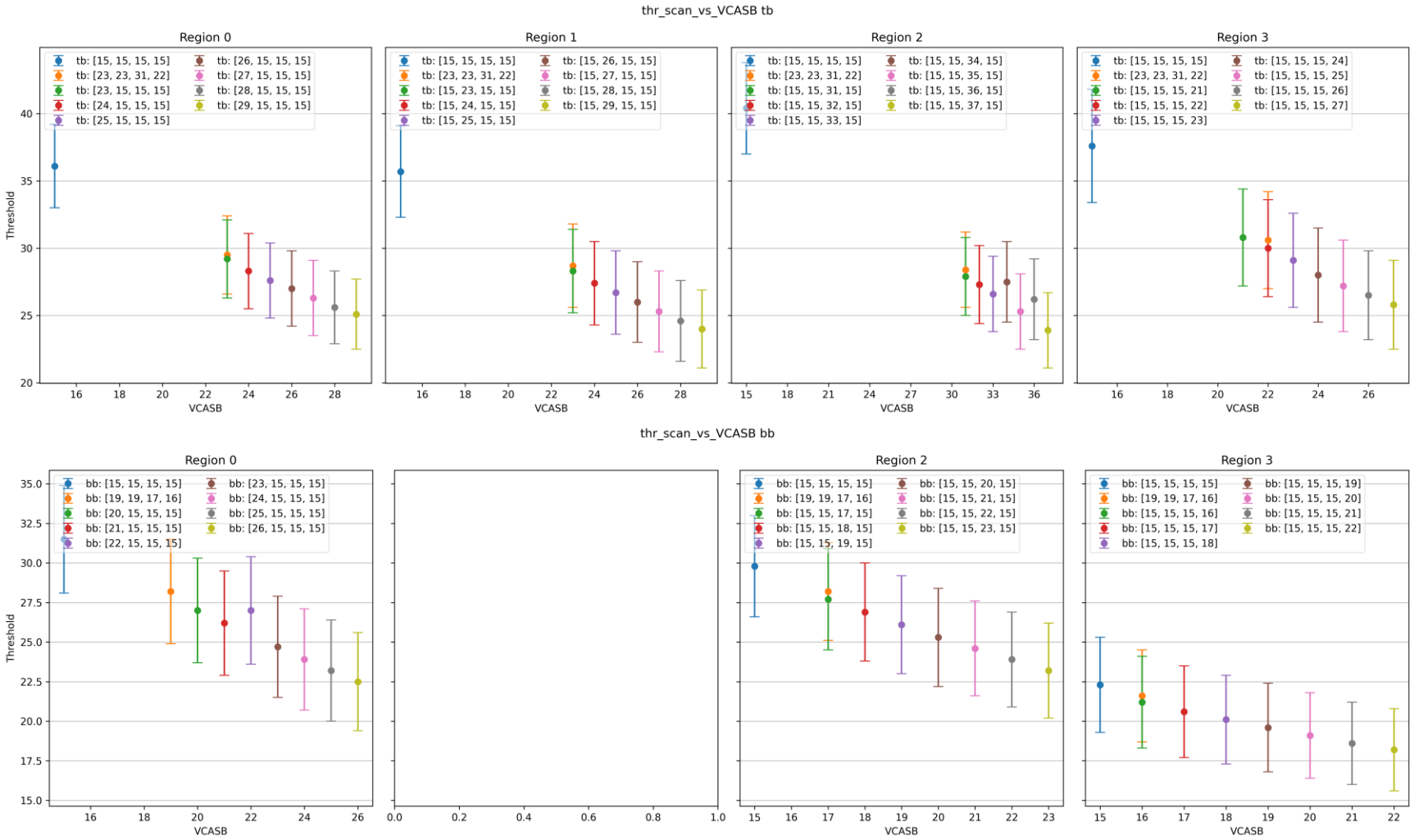


- The influence of neighbouring region is more significant at bottom region 3 which has larger FHR.

Threshold scan with VCASB

Data of 14.02.25

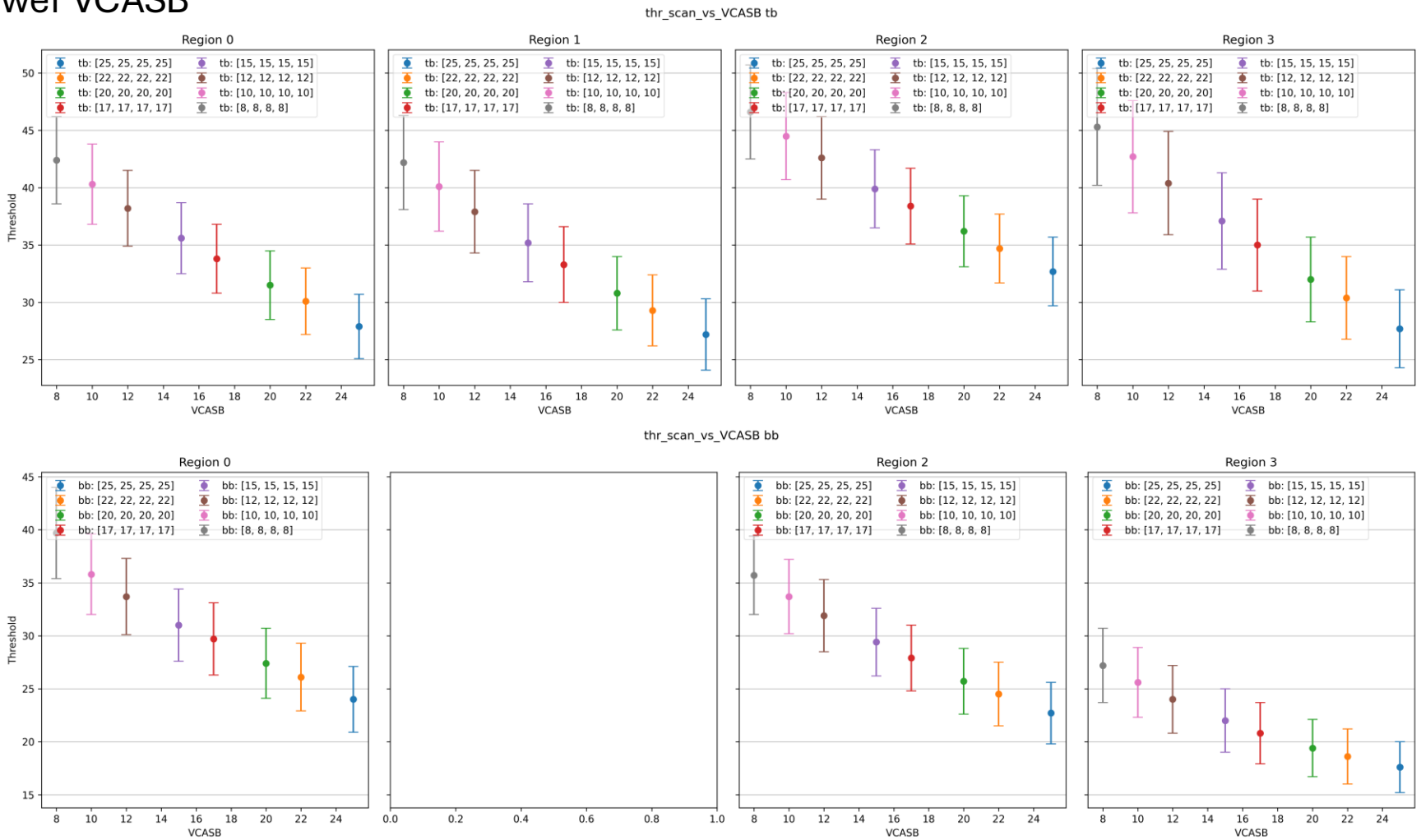
- To avoid cross-talk, one region is scanned while others remain inactive during a single scan, if possible.
- VCASB = 15 is a default one.
- TB region 3 has higher threshold
- BB region 3 has lower threshold



Threshold scan with VCASB

Data of 05.02.25

Scans at lower VCASB

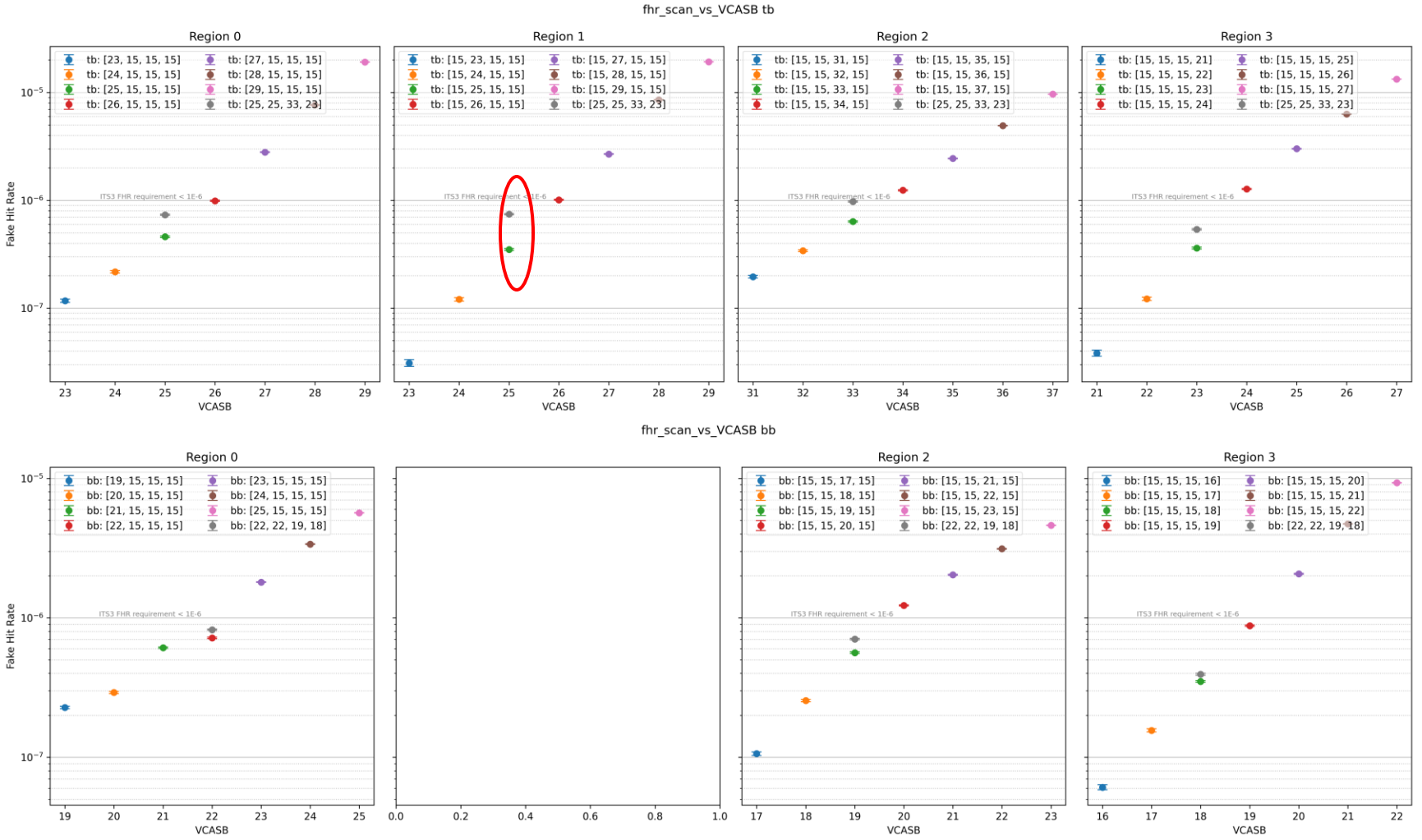


FakeHitRate scan with VCASB

Data of 14.02.25

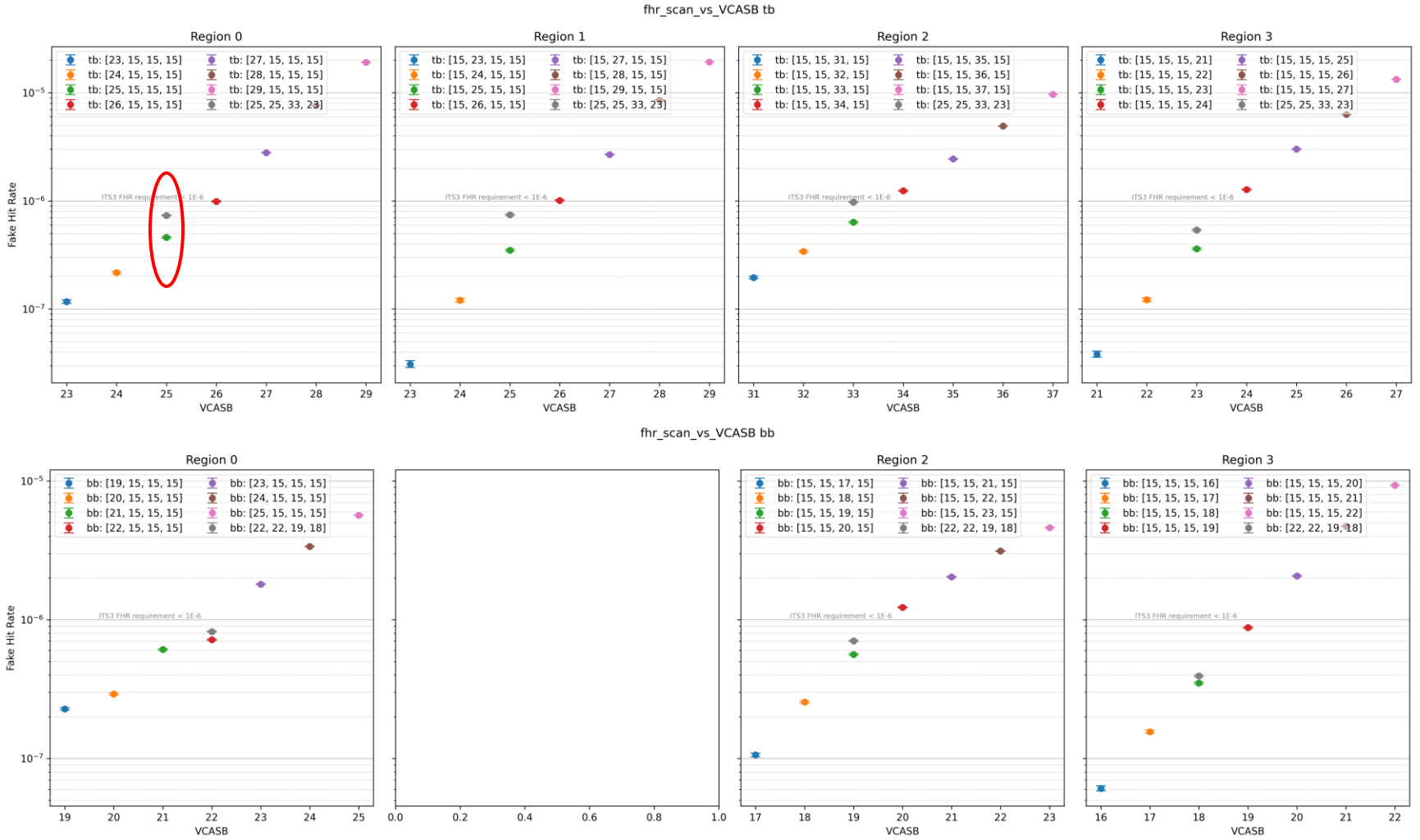
To avoid cross-talk, one region is scanned while others remain inactive during a single scan, if possible.

- The influence of neighbouring regions (or, cross-talk) is found in all regions.



FakeHitRate scan with VCASB

Data of 13.02.25



Threshold and FHR scans with VCASB

Thresholds	Region 0	Region 1	Region 2	Region 3
TOP	104 e	108 e	130 e	106 e
BOTTOM	104 e	104 e	104 e	85 e

MOSS User Manual

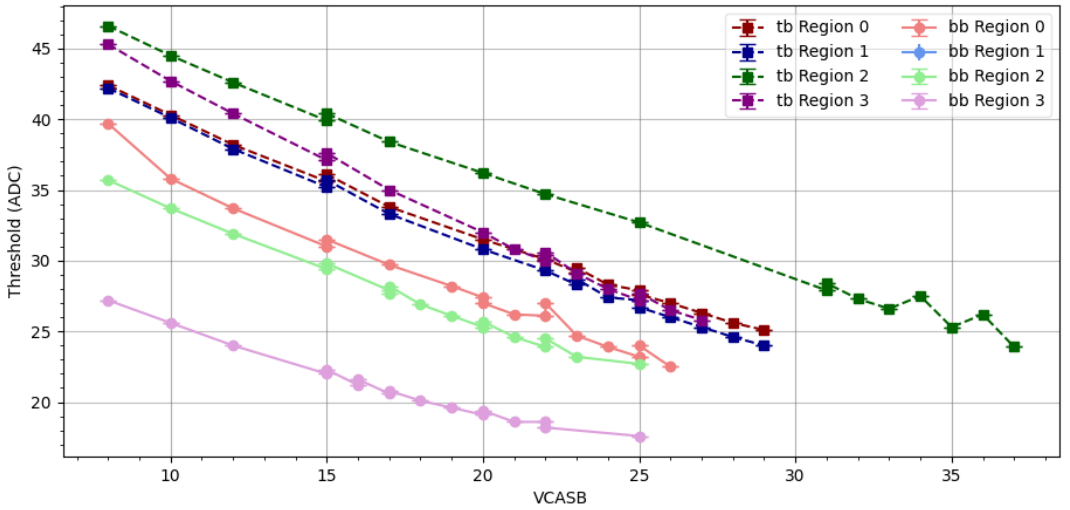
THR scan

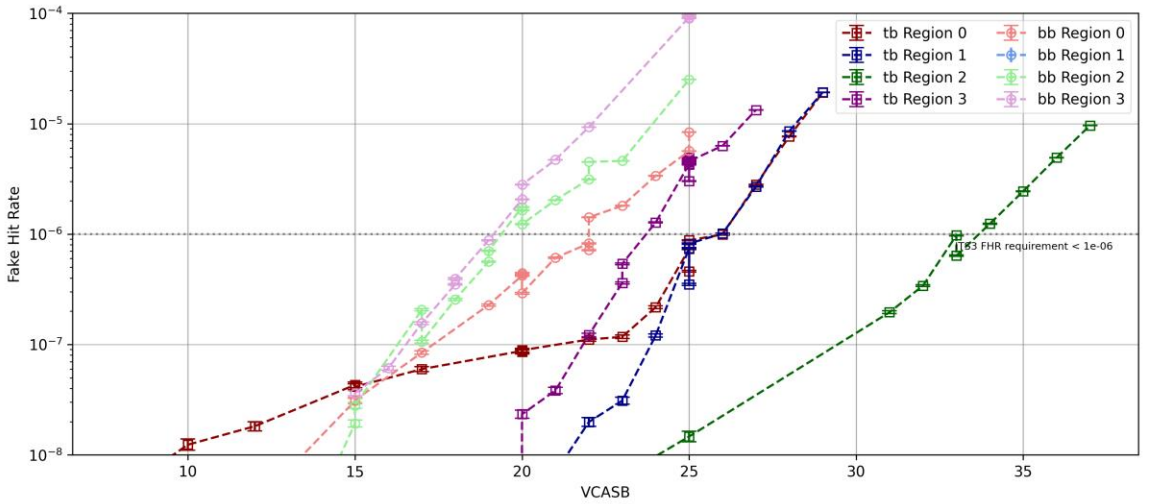
In THR stability scan at VCASB = 15, we observed before

- In TOP - THR expected: TH0 ≲ TH3 ≲ TH1 << TH2 - observed: TH1 ≲ TH0 ≲ TH3 << TH2
  - This scan show that TH1 ≲ TH0 = TH3 << TH2 at VCASB ≳ 20
- In BOTTOM – THR expected: TH0 = TH1 = TH2 >> TH3 - observed: TH0 ≳ TH2 >> TH3 (masked region 1)
  - The results are consistent

FHR scan

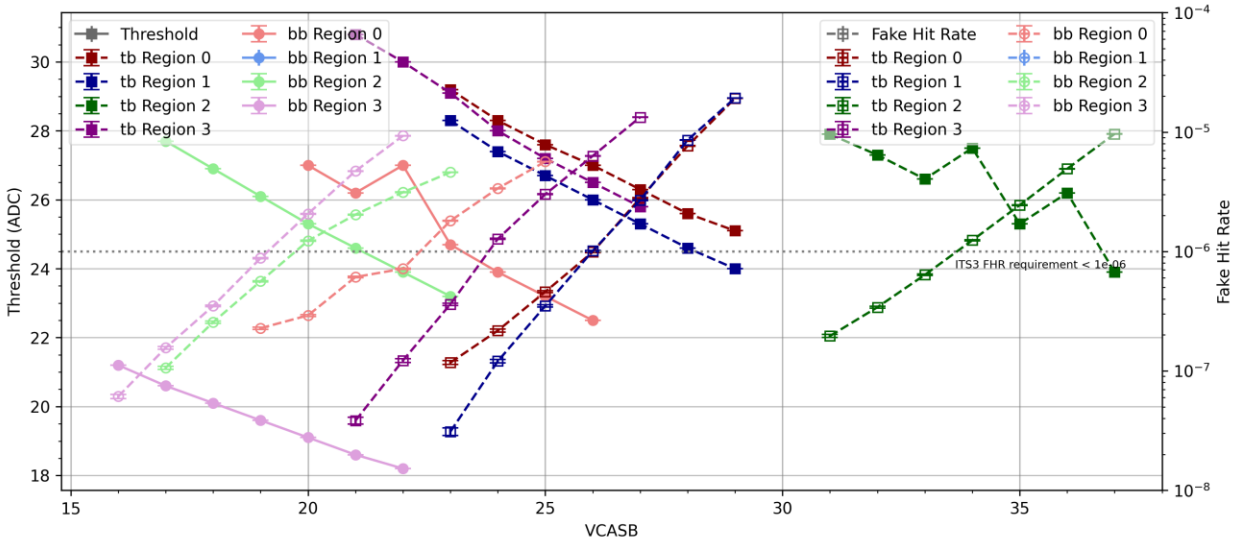
- In TOP - FHR2 << FHR0, FHR1, FHR3
- In BOTTOM – FHR3 >> FHR2 >> FHR0



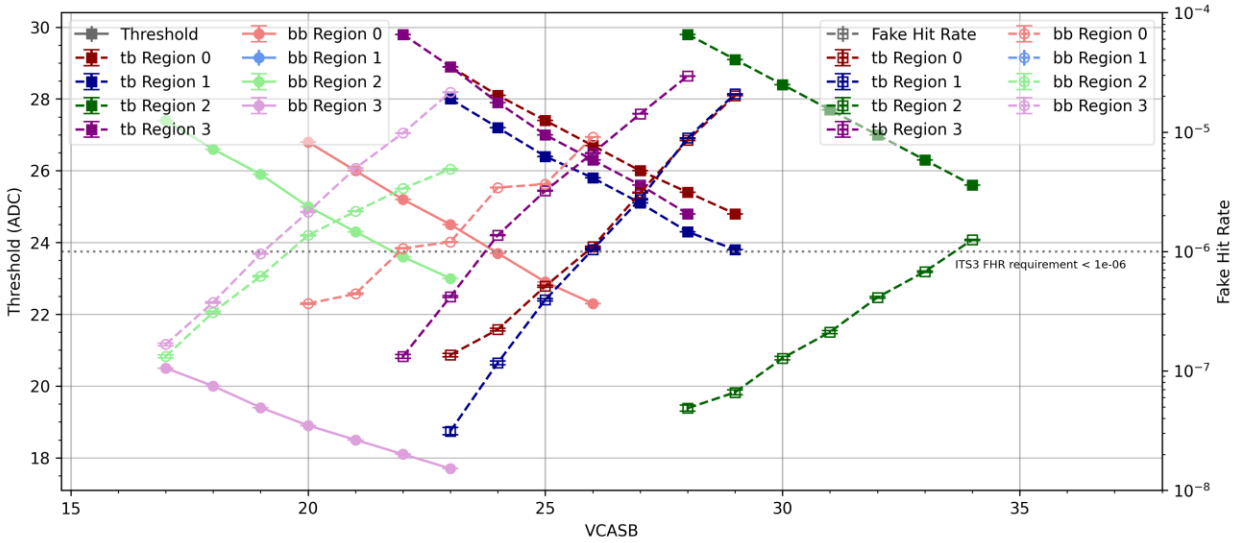


Threshold and FHR scans with VCASB

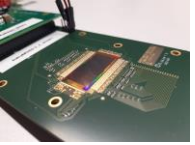
Data of 14.02.25



Data of 13.02.25



- We can find the operating VCASB for each region provided that the FHR of ITS3 limit of <1E-6

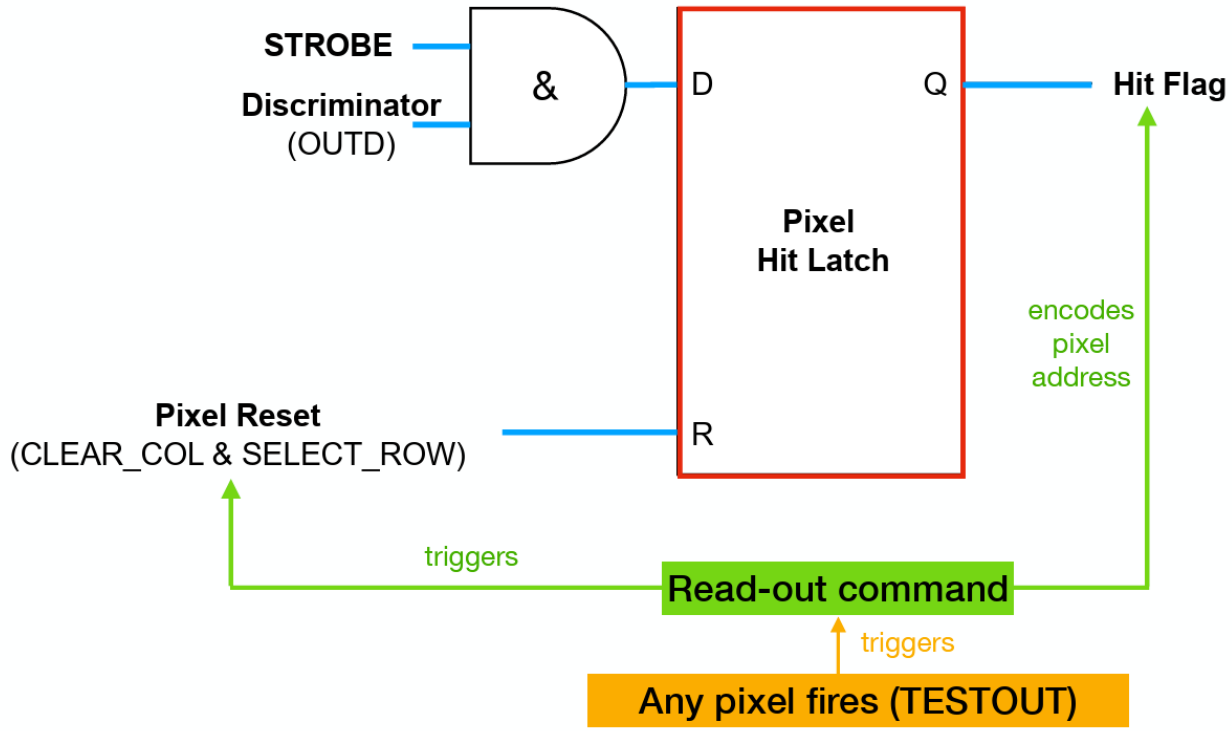


TOT measurement: Source Stuck Readout Scan

MOSS pixel read-out

How can we make the RO get stuck intentionally?

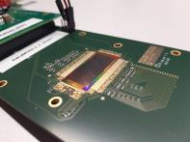
- Assert long STROBE ~ 400 µs
- When OUTD activates, hit gets stored in latch
- TESTOUT configured such that it asserts if any pixel fired
- RO-command on TESTOUT, will read hit, reset latch
- **As STROBE & OUTD still active, latch will store same hit again**
- Priority-encoder will read out same pixel again
- **Pixel will be read-out n times** until OUTD deactivates*



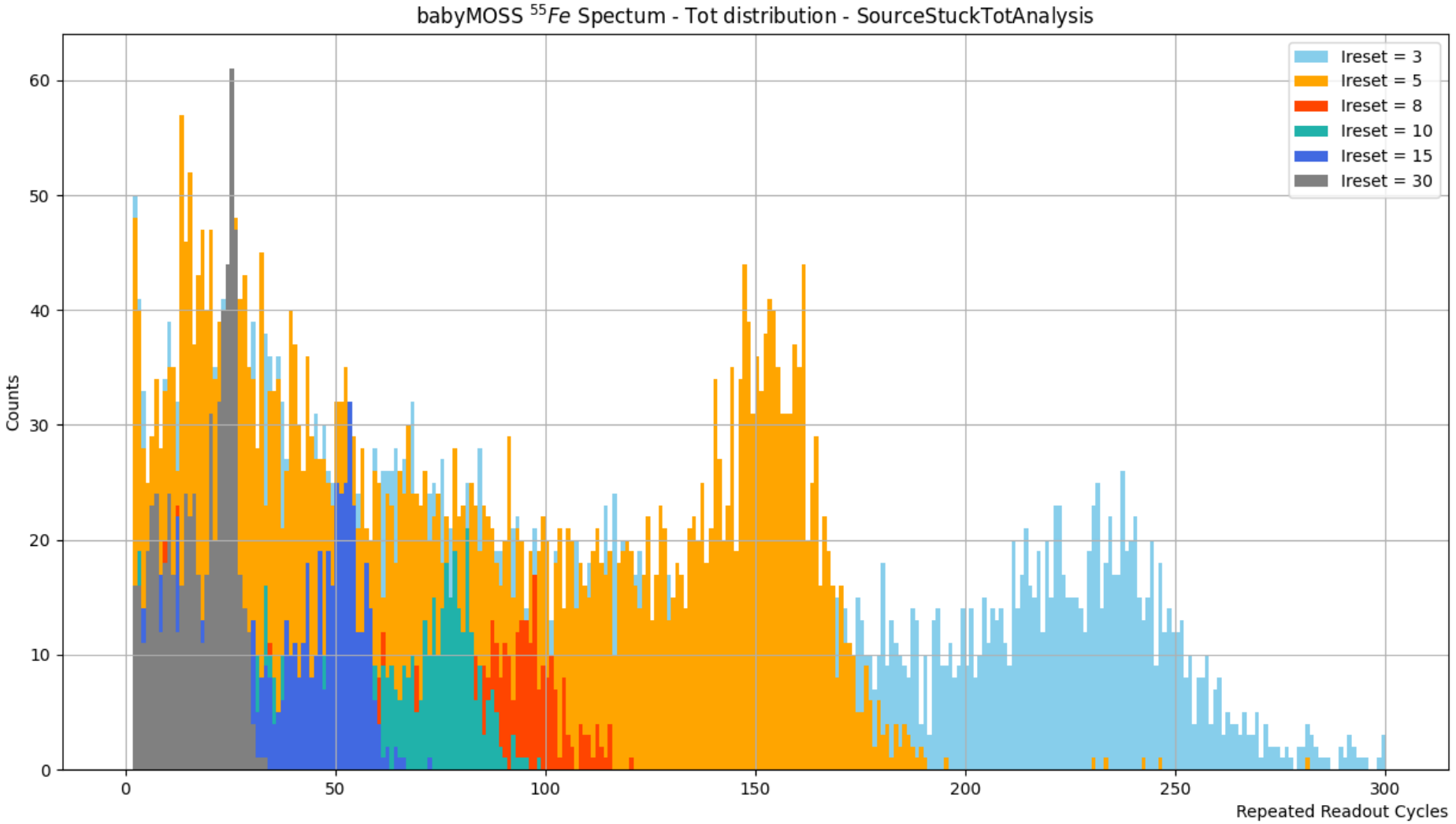
Simplified principle of the MOSS pixel readout

* assuming STROBE still active

https://indico.cern.ch/event/1479059/contributions/6229956/attachments/2983389/5254072/24_12_10_ToT_StuckRO.pdf



Source Stuck Readout Scan - babyMOSS



- Method based on readout of the same pixel when the strobe is activated
- The resolution is higher than the Tot one
- Calibration and correction tecnique under investigation

babyMOSS Prototype summary

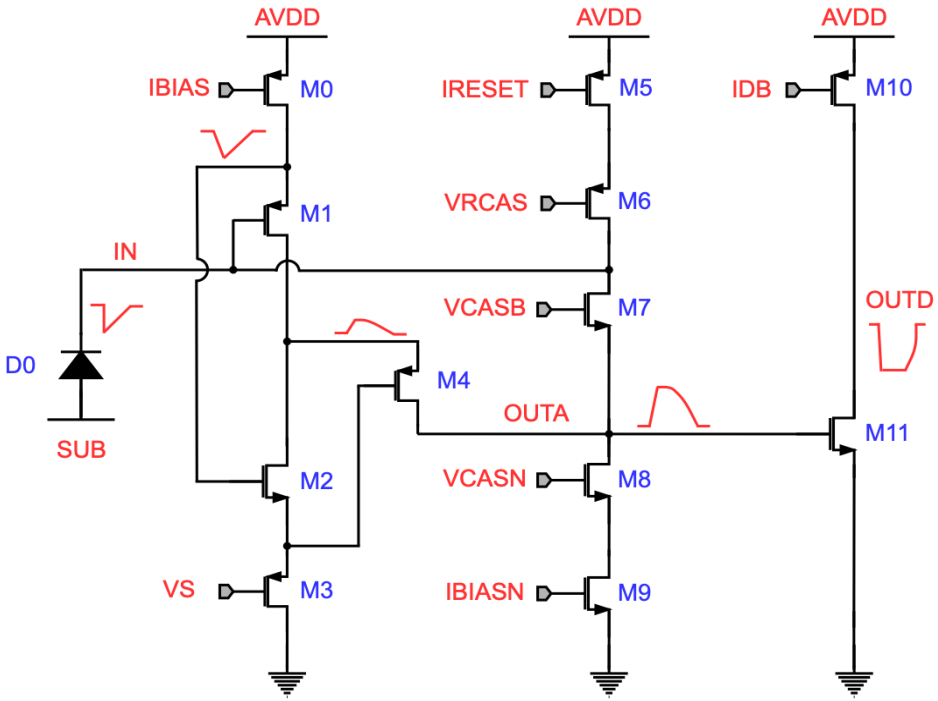
- There are different front-end variants within a HU:

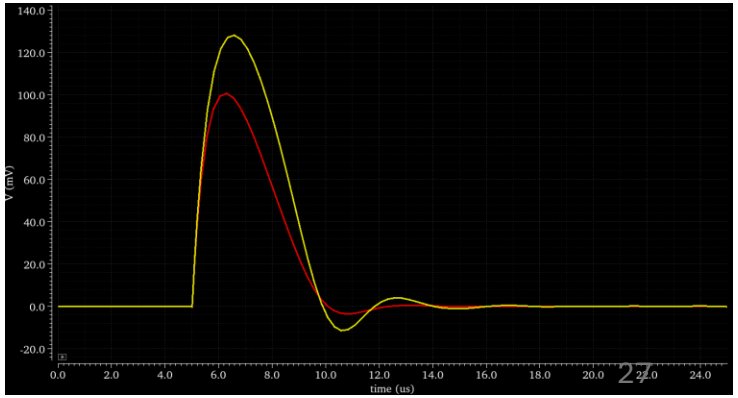
	Region 0	Region 1	Region 2	Region 3
TOP	Standard	Larger input transistor (M1)	Larger discriminator input transistor (M11)	Larger common-source transistor (M2)
BOTTOM	Standard	Standard	Standard	Slightly different layout

- For nominal settings with pwell/psub at 0V and Cin = 5 fF, simulated thresholds are:

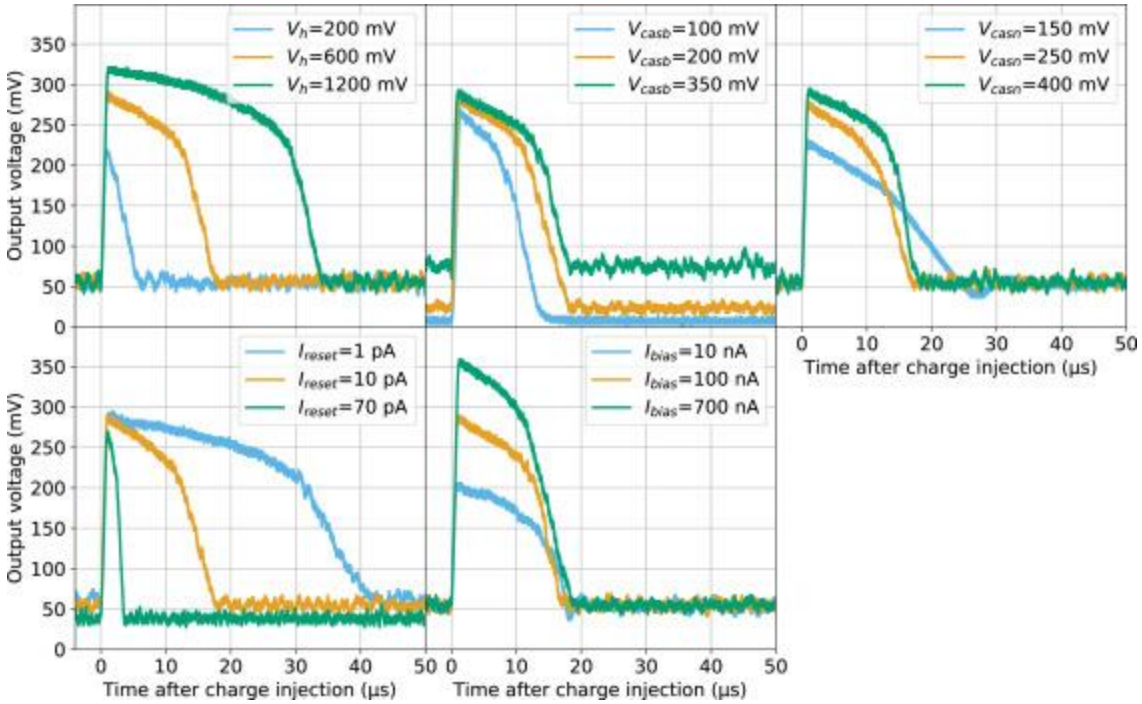
Thresholds	Region 0	Region 1	Region 2	Region 3
TOP	104 e	108 e	130 e	106 e
BOTTOM	104 e	104 e	104 e	85 e

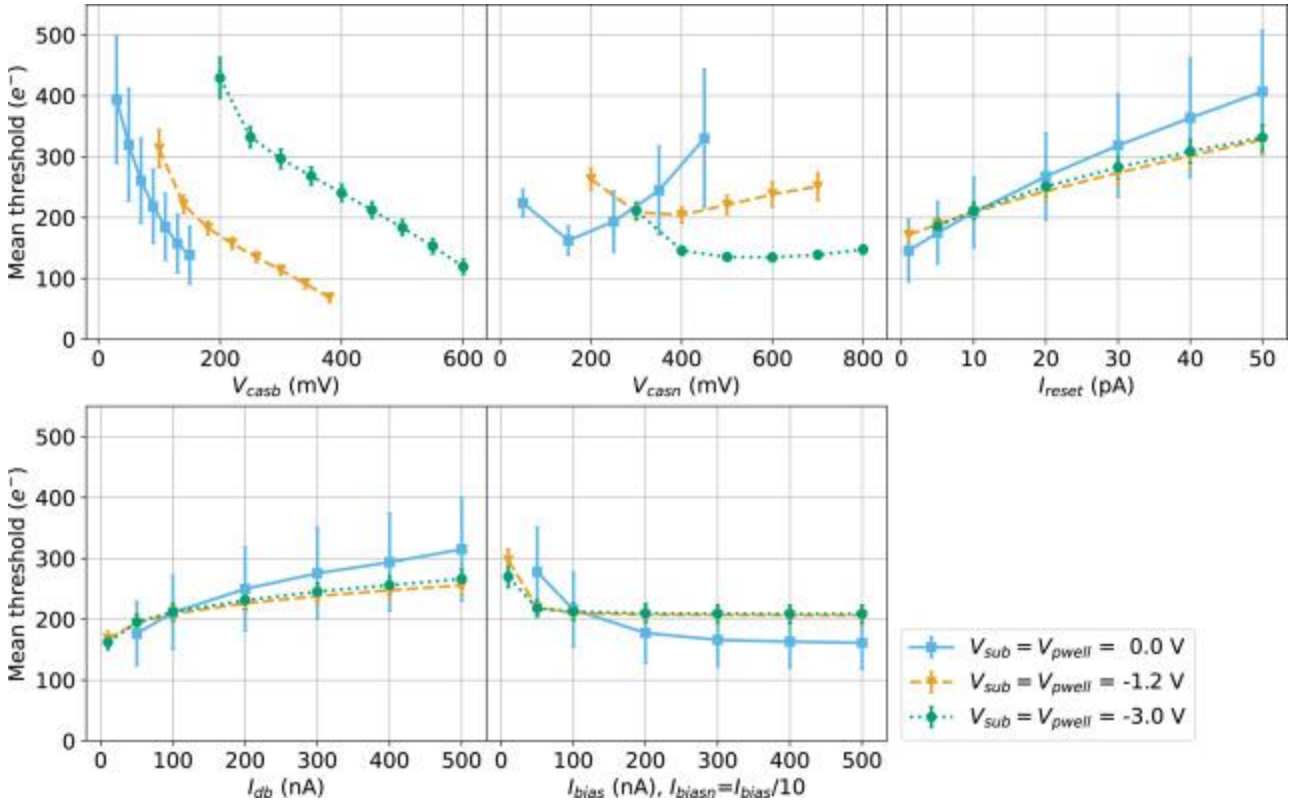
  - In "**standard layout**" a parasitic capacitance added to improves the stability of the circuit. This capacitance, however, also reduces the front-end gain (red curve).
  - In "**slightly different layout**" parasitic capacitance was slightly reduced, so front-end gain increases (yellow curve).





DPTS paper reference plots





DPTS paper