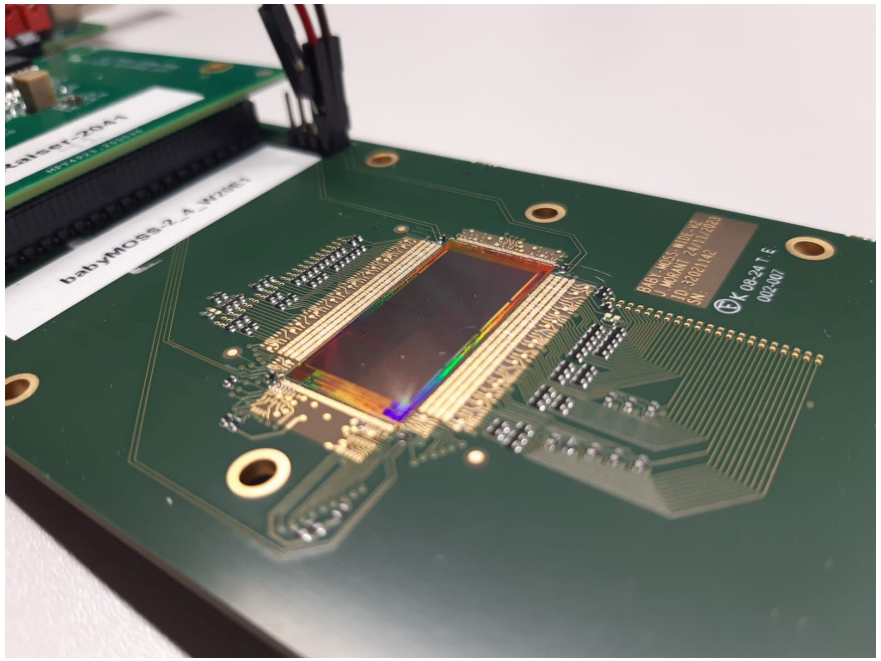
ER1 Activities

babyMOSS characterization and Future Perspectives

Bari

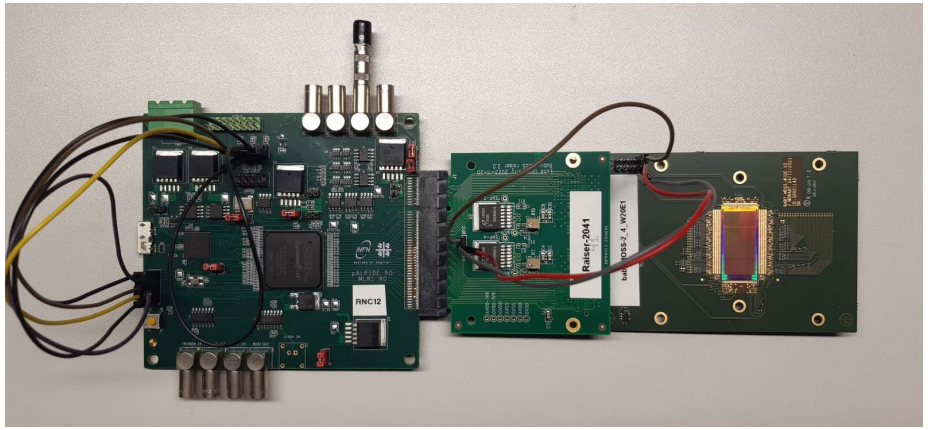


Angelo Colelli, Francesco Barile, Giuseppe Eugenio Bruno, Domenico Colella, Shyam Kumar, Rajendra Patra, Triloki Triloki et Al.

University of Bari and INFN sez. Bari

Setup Configuration

- DAQ board ID: **DAQ-0009012905D1273D**, Raiser board ID: **Raiser-2041**, Chip ID: **babyMOSS-2_4_W20E1**
- Testing at V_{sub} = 0 V (Zero-ohm shunt resistor in SUB)
- No Temperature control

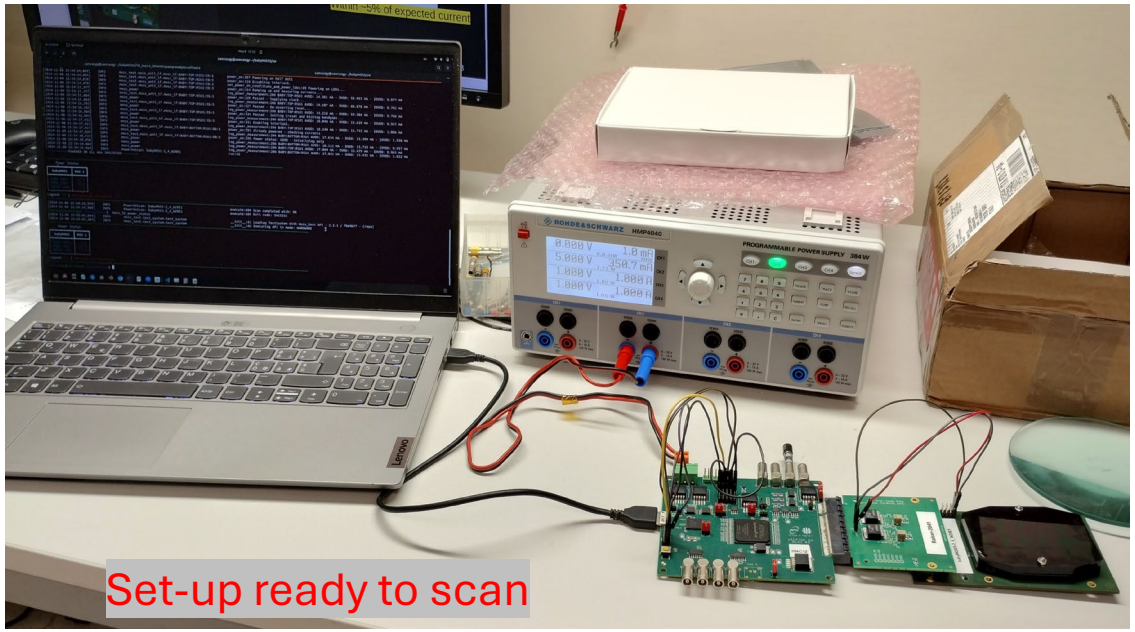


Outline

1. Test-bench setup, functional and pixel matrix tests, along with a comparison of the results with tests conducted at CERN.
2. Detailed study of THR and FHR as a function of V_{casb} scans, cross-talk study of neighbouring regions.
3. ^{55}Fe spectra analysis using Time-over-Threshold (ToT) method.
4. Future Plan

Summary of babyMOSS test scans

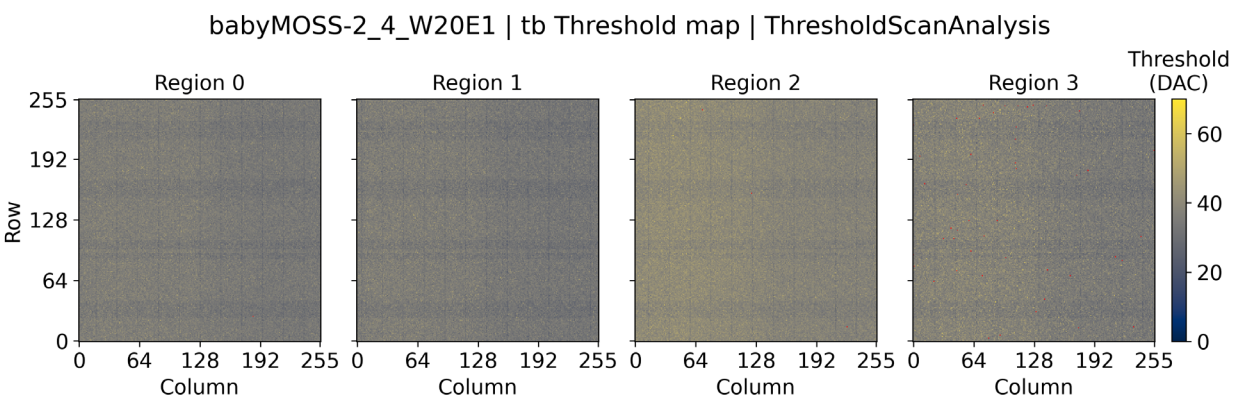
	Scans	babyMOSS-2_4_W20E1
Functional tests	Power on	OK
	Register	OK
	Shift register	OK
	DAC	OK
Readout and pixel matrix tests	Digital	OK
	Analogue	OK
	FHR	OK
	Threshold	OK
^{55}Fe characterization	ToT	Ongoing

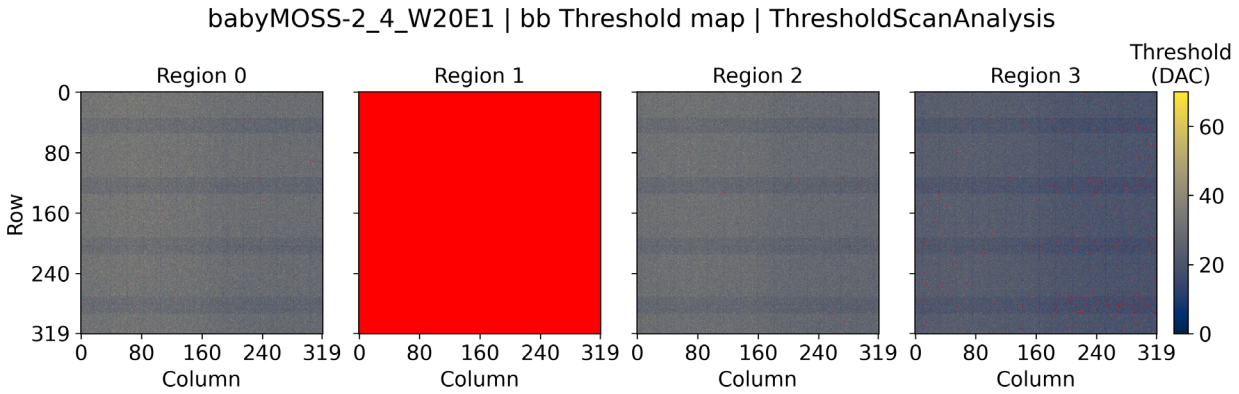


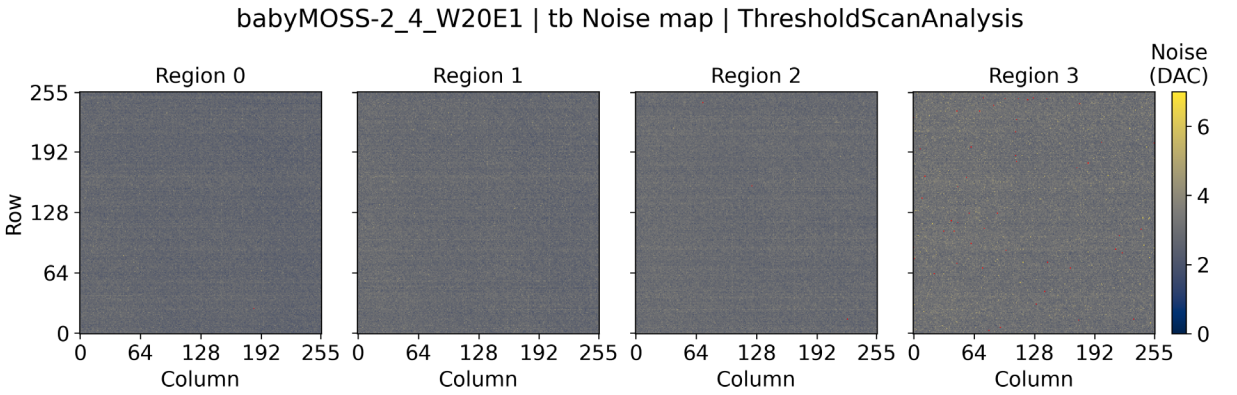
Threshold Scan

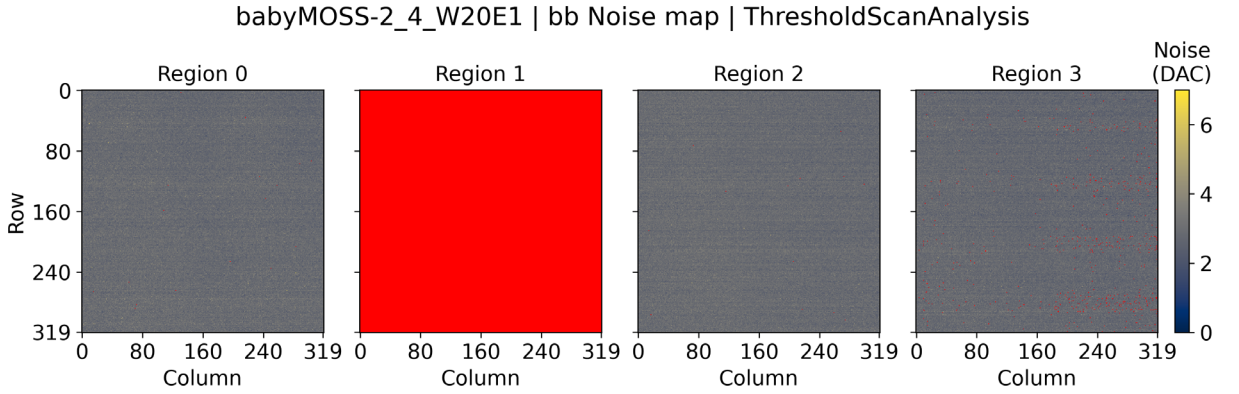
V_{casb} = 15

Bb region 1 masked







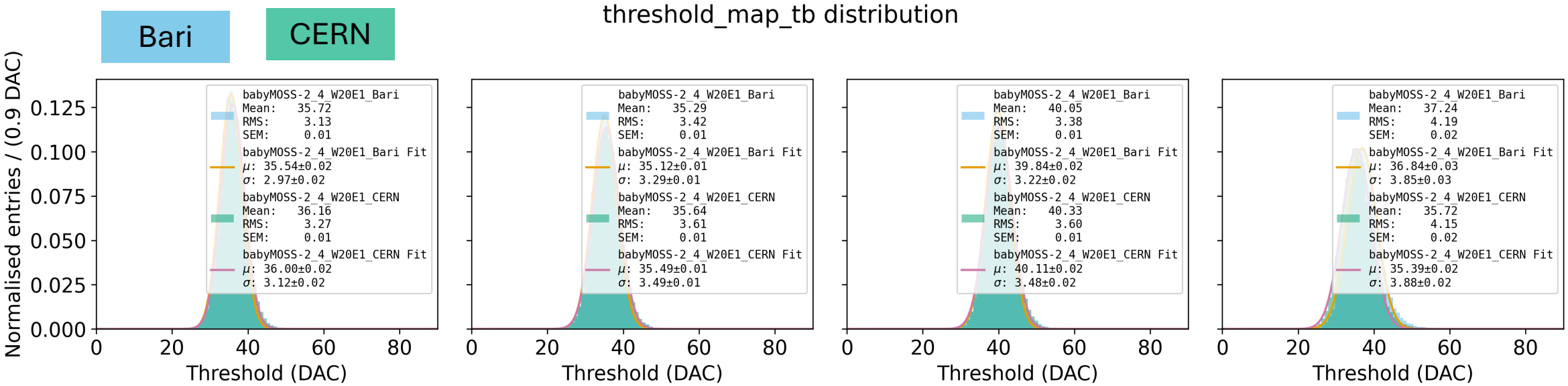


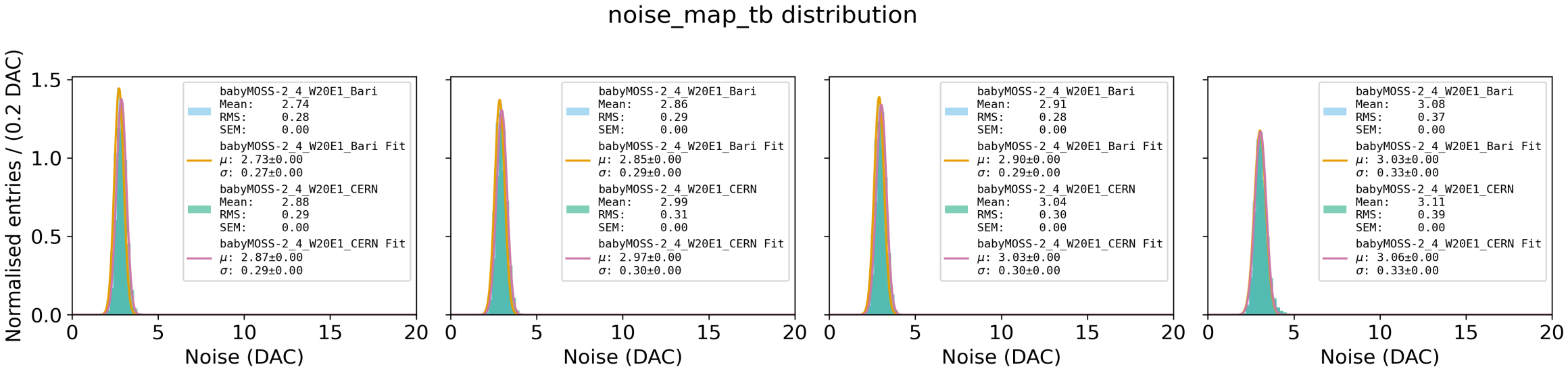
- Region 1 of the bottom half unit is found to be noisy, as also reported by CERN tests.

Threshold scan tb: comparison with CERN tests

Bari

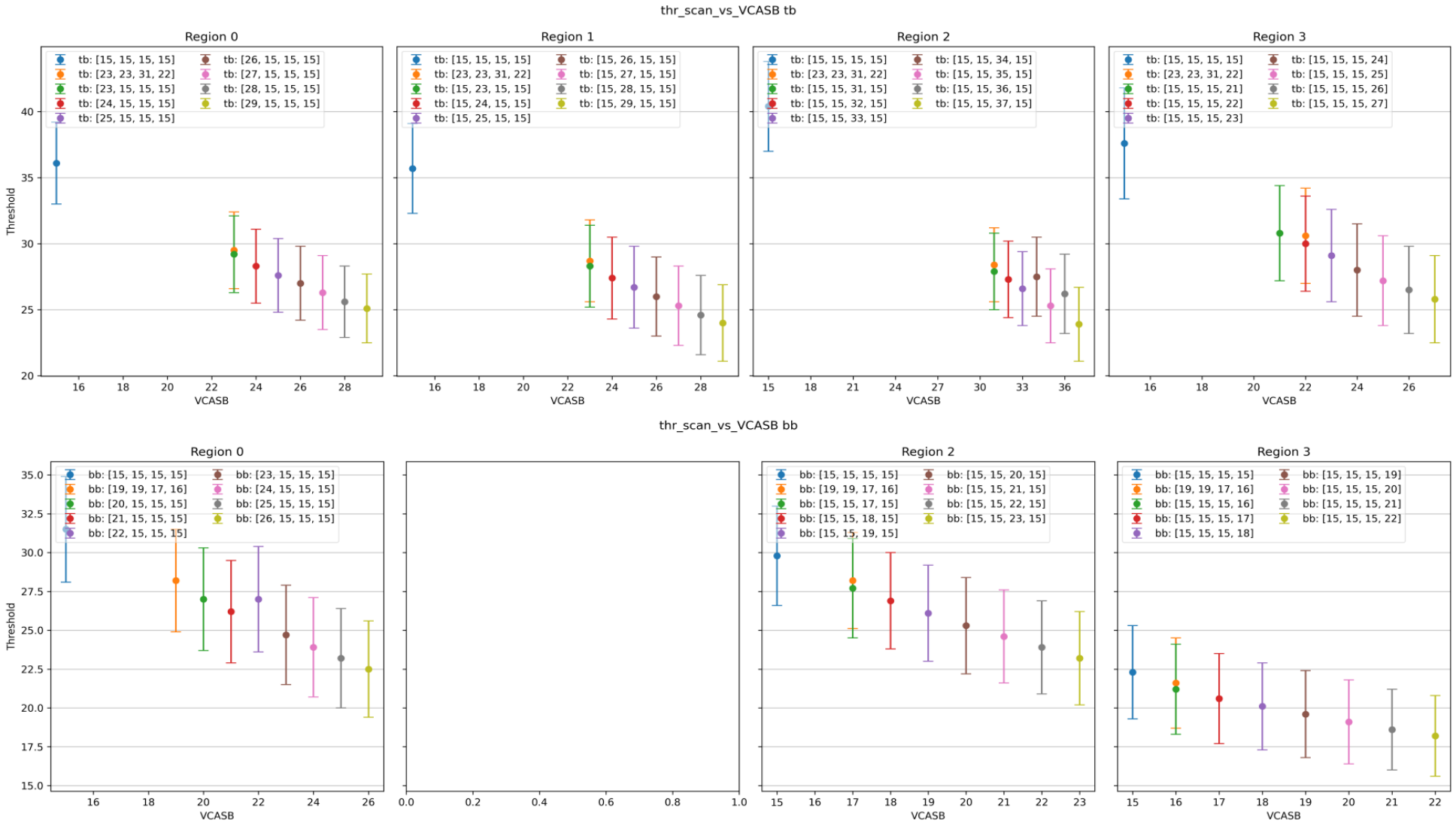
CERN





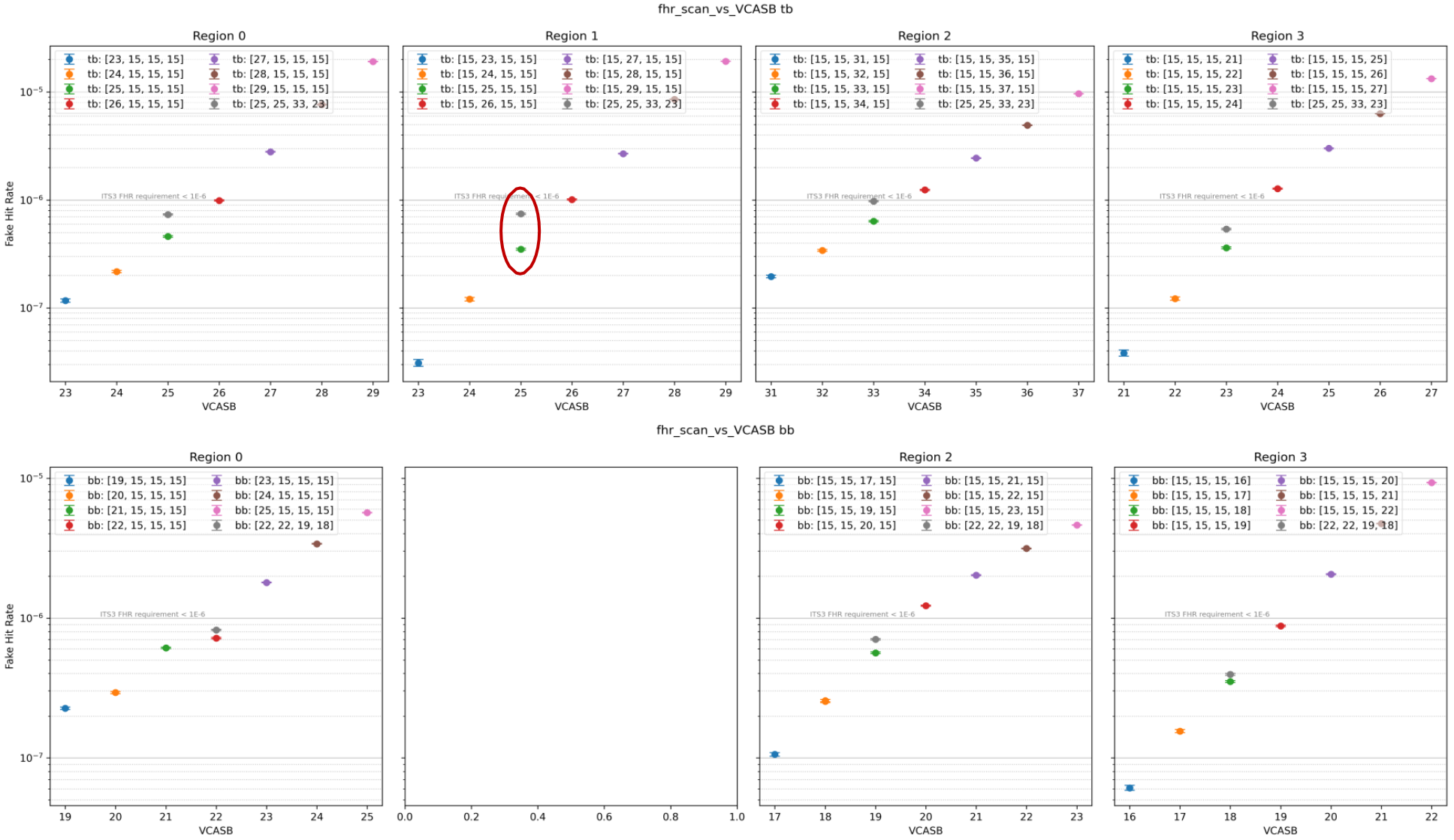
- Threshold values are matching with CERN test results. Similar results for the bottom region are reported in backup.

Threshold Scan at different V_{casb} values



- To avoid cross-talk, one region is scanned while others remain inactive during a single scan.
- V_{casb} = 15 (as default).
- The higher the V_{casb} the lower the threshold
- TB region 3 has higher threshold
- BB region 3 has lower threshold

FHR Scan at different V_{casb} values



- To avoid cross-talk, one region is scanned while others remain inactive during a single scan.
- V_{casb} = 15 (as default).
- The higher the V_{casb} the higher the FHR
- Neighbouring region influence (cross-talk) presents in all regions.

Threshold and FHR scans with VCASB

MOSS User Manual

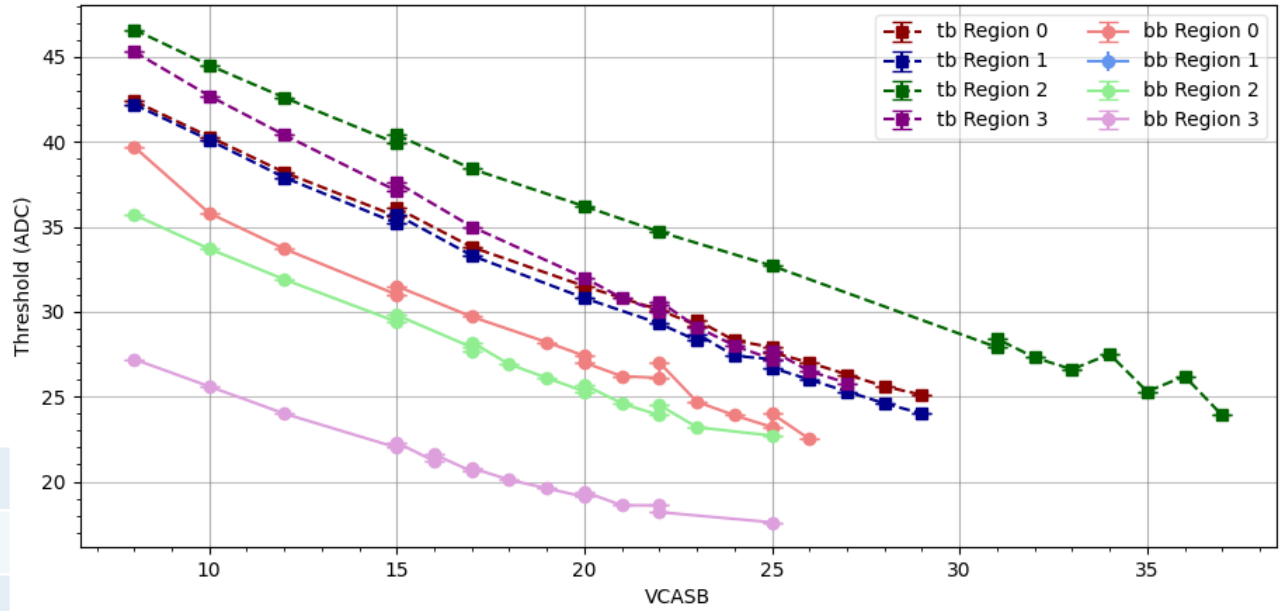
Thresholds	Region 0	Region 1	Region 2	Region 3
TOP	104 e	108 e	130 e	106 e
BOTTOM	104 e	104 e	104 e	85 e

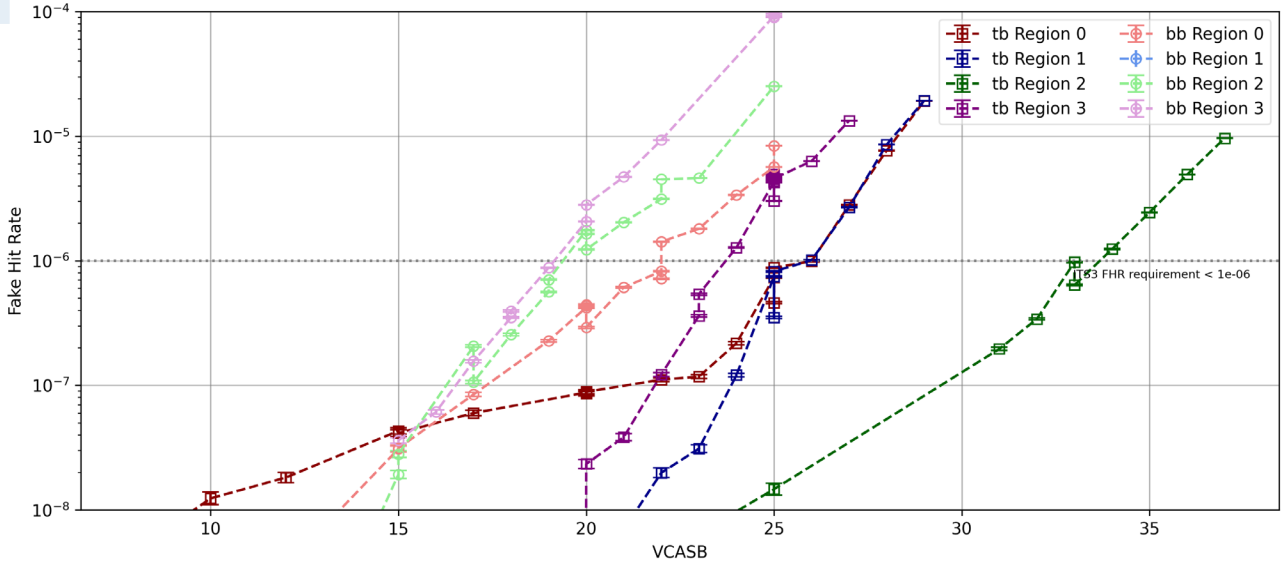
- At V_{casb} > 20:

Thresholds	Observed	Expected
TOP	TH1 ≲ TH0 = TH3 << TH2	TH0<TH3<TH1<TH2
BOTTOM	TH0 ≳ TH2 >> TH3 (reg1 masked)	TH0=TH1=TH2>>TH3

- At V_{casb} = 25:

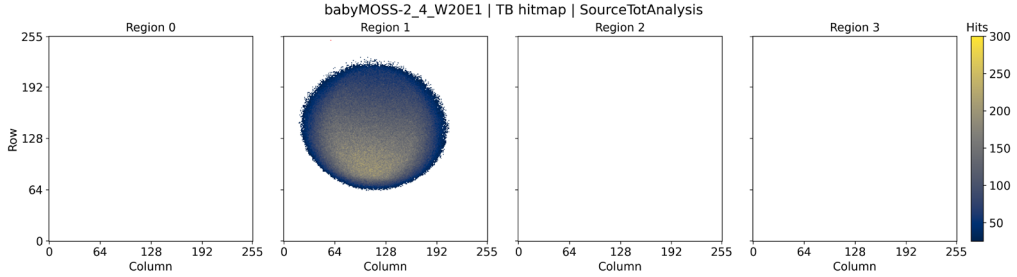
FHR	Observed
TOP	FHR2 << FHR0, FHR1, FHR3
BOTTOM	FHR3 >> FHR2 >> FHR0 (reg1 masked)

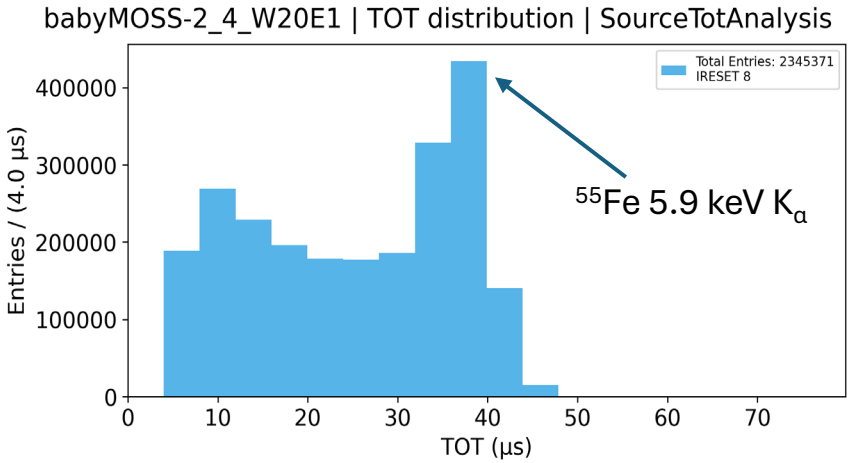




Setup for ^{55}Fe babyMOSS testing

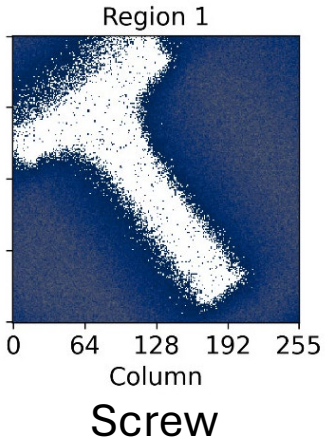
- ^{55}Fe X-ray energy spectrum measurement using **Time-over-Threshold** (ToT) method.
- n_events: 50M
- I_{reset}: variable
- V_{casb}: 10
- All other DAC parameters: DEFAULT
- V_{sub}: 0 V

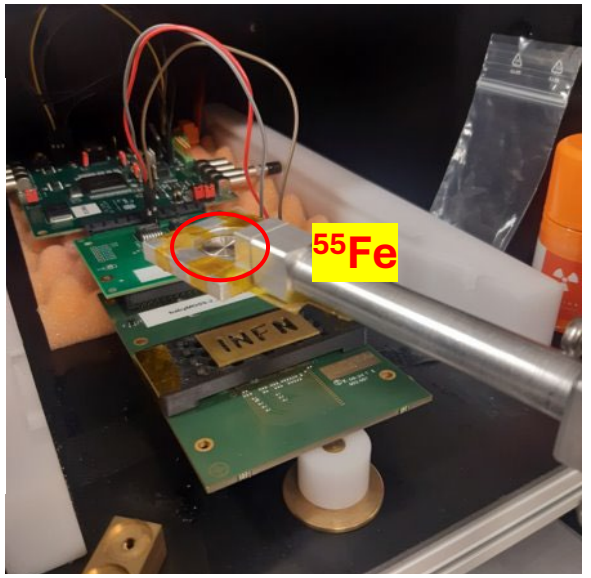




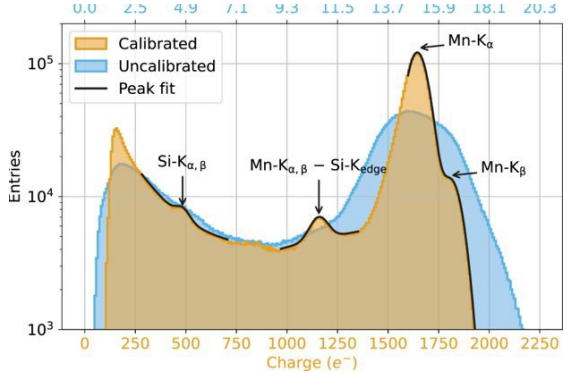
ToT resolution limited to ≈ 4 µs by measurement

- No corrections applied



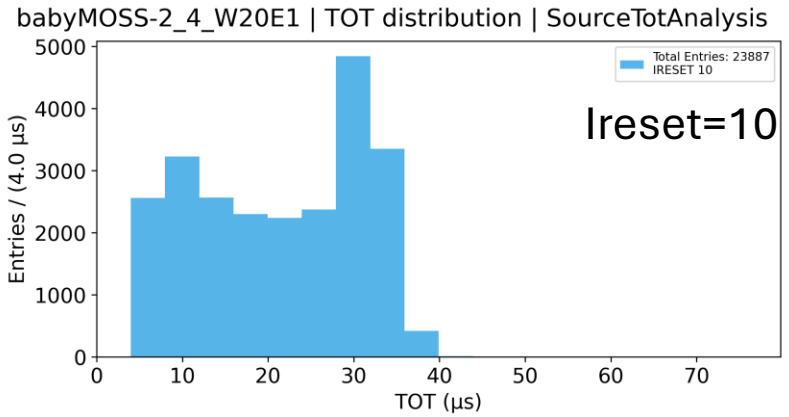


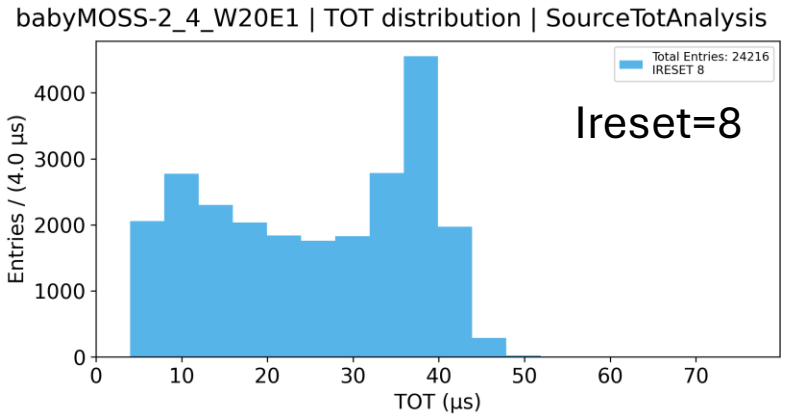
Peak	$Mn\text{-}K_\alpha$	$Mn\text{-}K_\beta$	Si_{esc}	Si_{fl}
Energy (keV)	5.90	6.51	4.16	1.74

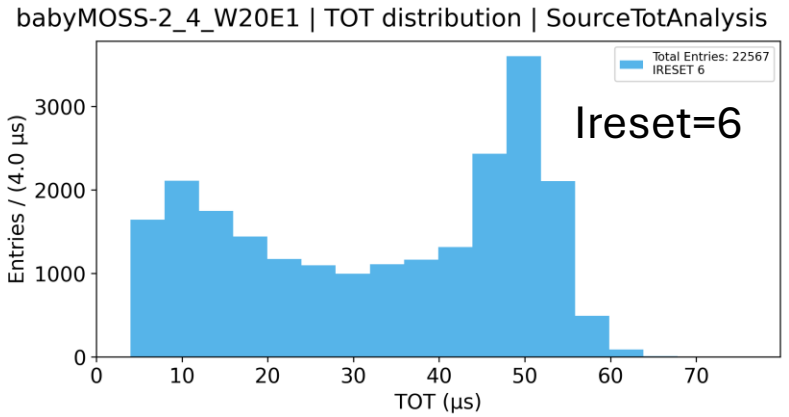


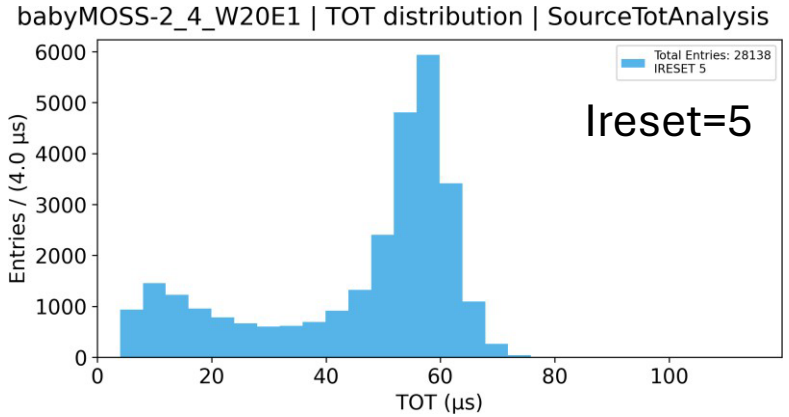
DPTS paper

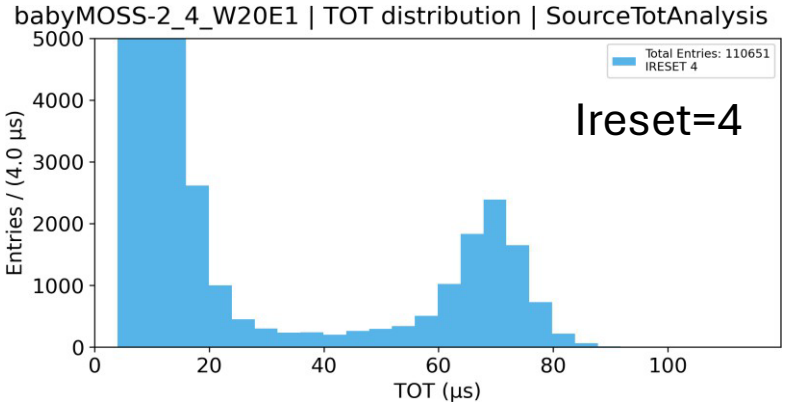
^{55}Fe ToT Scan at different I_{reset} values

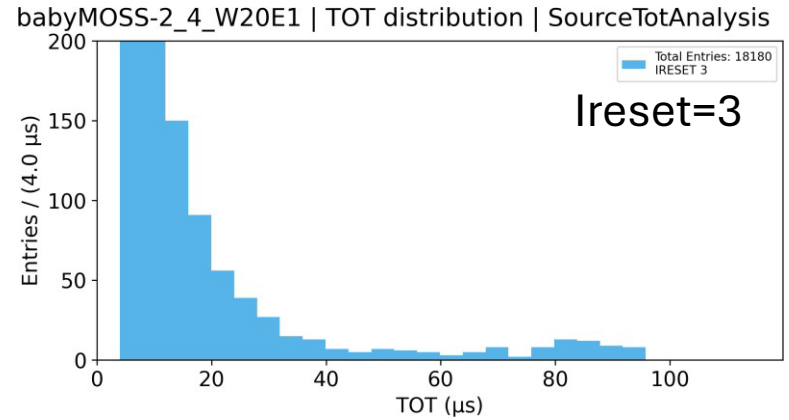








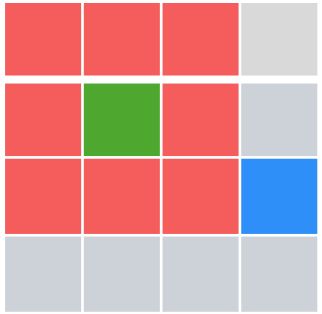


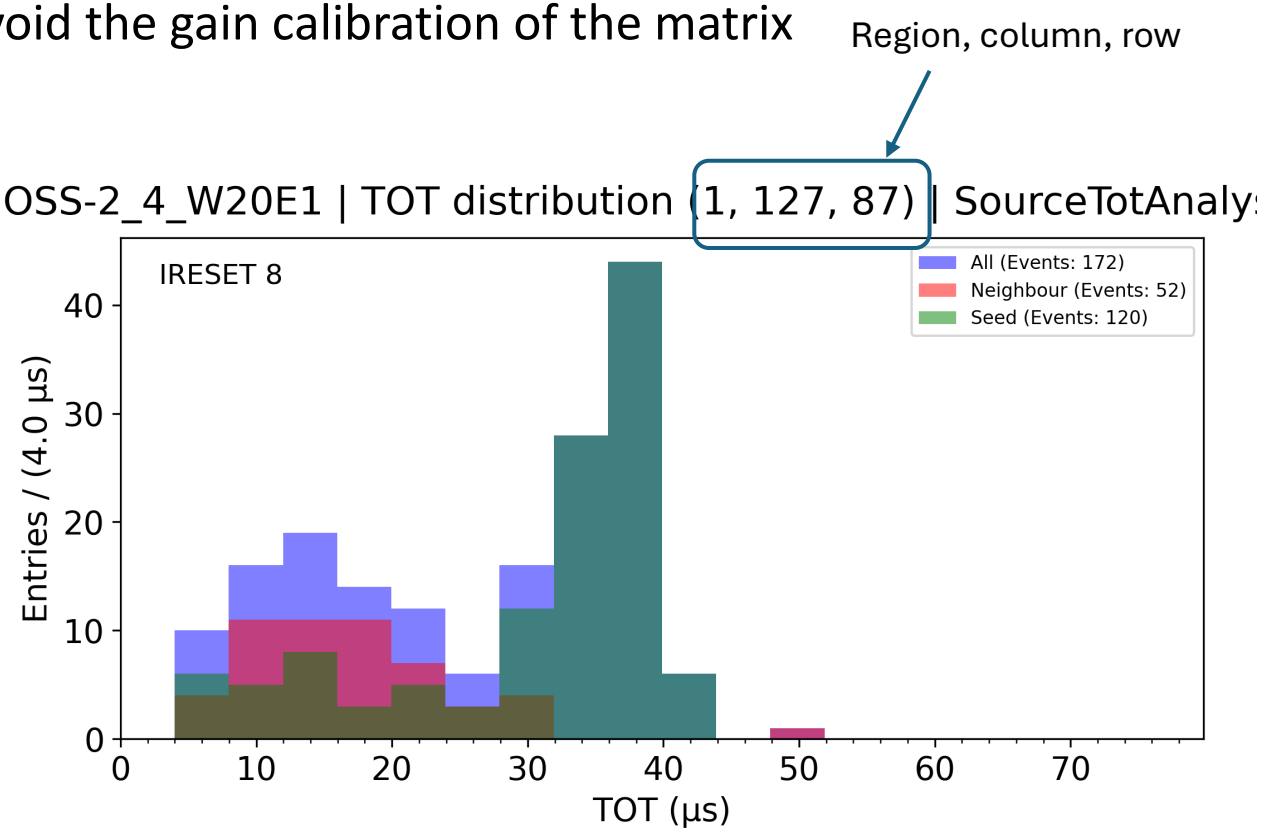


- As the I_{reset} decreases, the main peak distribution shifts to high ToT values.

ToT measurement of single pixels

- Is it possible to resolve Si_{esc}-peak or K_{β}-peak low I_{reset}?
- Single pixel ToT measurement can be useful to avoid the gain calibration of the matrix
- Separating the clusters of charge sharing

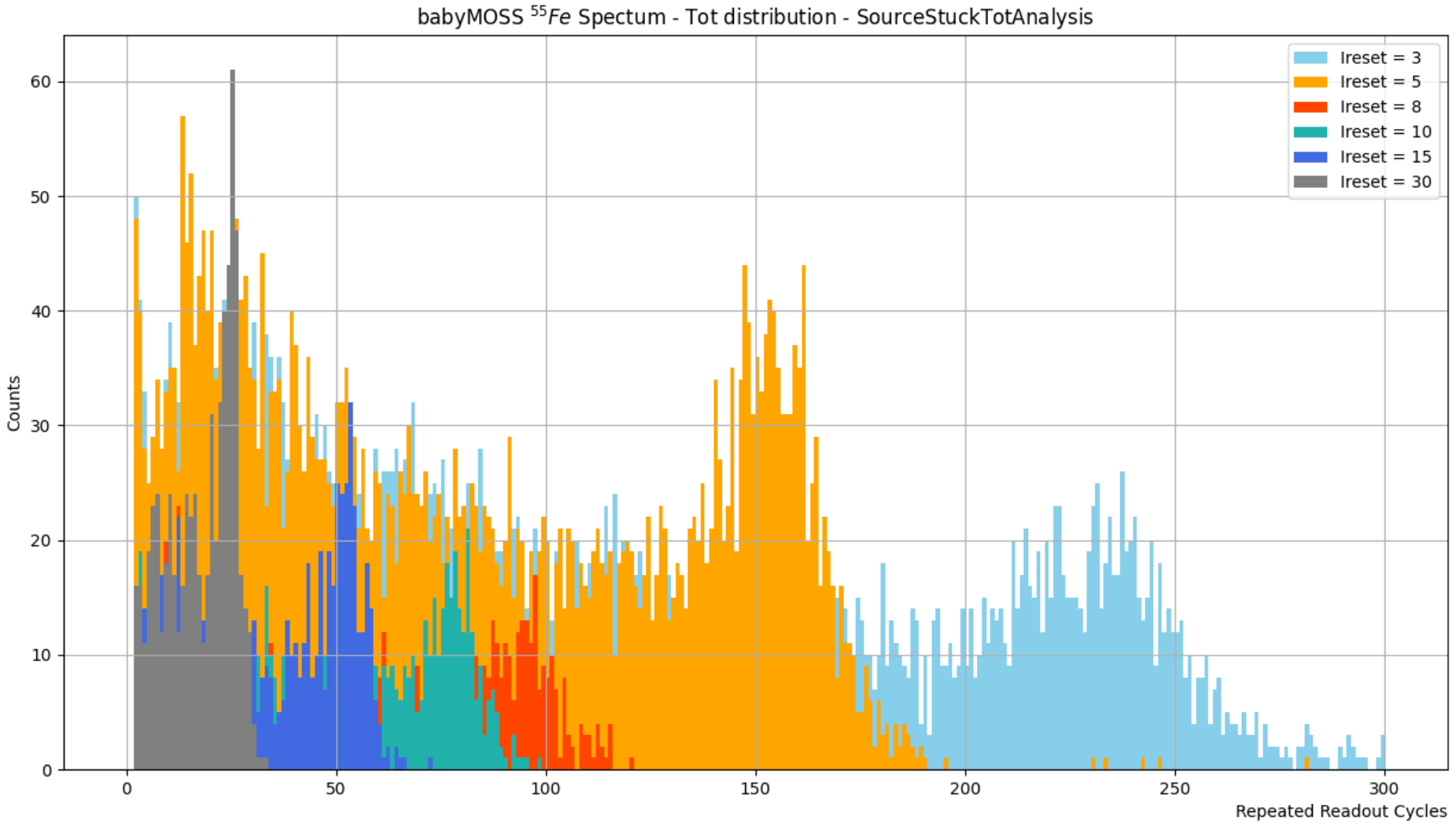




For example:

- Neighbouring pixels: [TotHit(region=1, column=127, row=87, tot=23.93), TotHit(region=1, column=127, row=88, tot=11.96)]
- Single pixel: [TotHit(region=1, column=127, row=87, tot=35.91)]
- Away pixels: [TotHit(region=1, column=167, row=144, tot=27.93), TotHit(region=1, column=127, row=87, tot=35.91)]

^{55}Fe ToT Source Stuck Readout Scan



- 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

Summary

- BabyMOSS test set-up has been assembled in Bari and different scans have been performed at V_{sub} = 0 V
- Threshold scan, FHR scan with varying V_{casb} are performed
  - Operating range of V_{casb} can be found
- Characterization with ^{55}Fe source:
  - ToT peak value increases with higher I_{reset}
- Talk at WP3:
  - https://indico.cern.ch/event/1513821/contributions/6369949/attachments/3012365/5311585/babyMOSS_testing_Bari_110225_its3_wp3.pdf

Future Plans

- Perform babyMOSS testing and ^{55}Fe measurements at Vsub = -1.2V
- Avaiability to test the babyMOSAIX chip of ER2 in Bari.

- Possible activity in the development and characterization of babyMOSS chip bent in synergy with other INFN sites.

Back-up

TOT measurement: Source Scan

MOSS ToT measurement: Source Scan

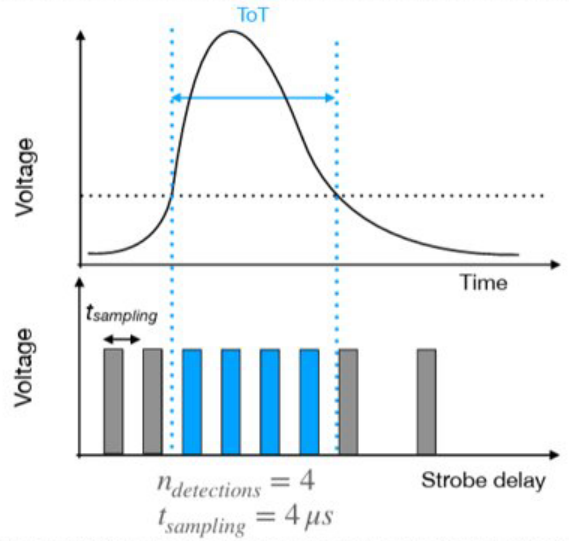
Marius Wilm Menzel, WP3, 21/10/2024

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:

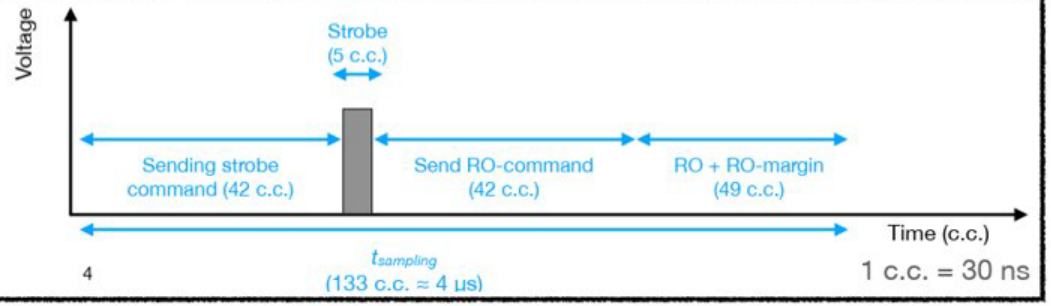
$$ToT = n_{detections} \cdot t_{sampling}$$

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

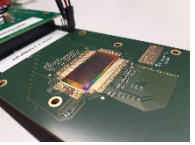


Resolution limitation:

- 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**



[ToT study, M. Menzel]

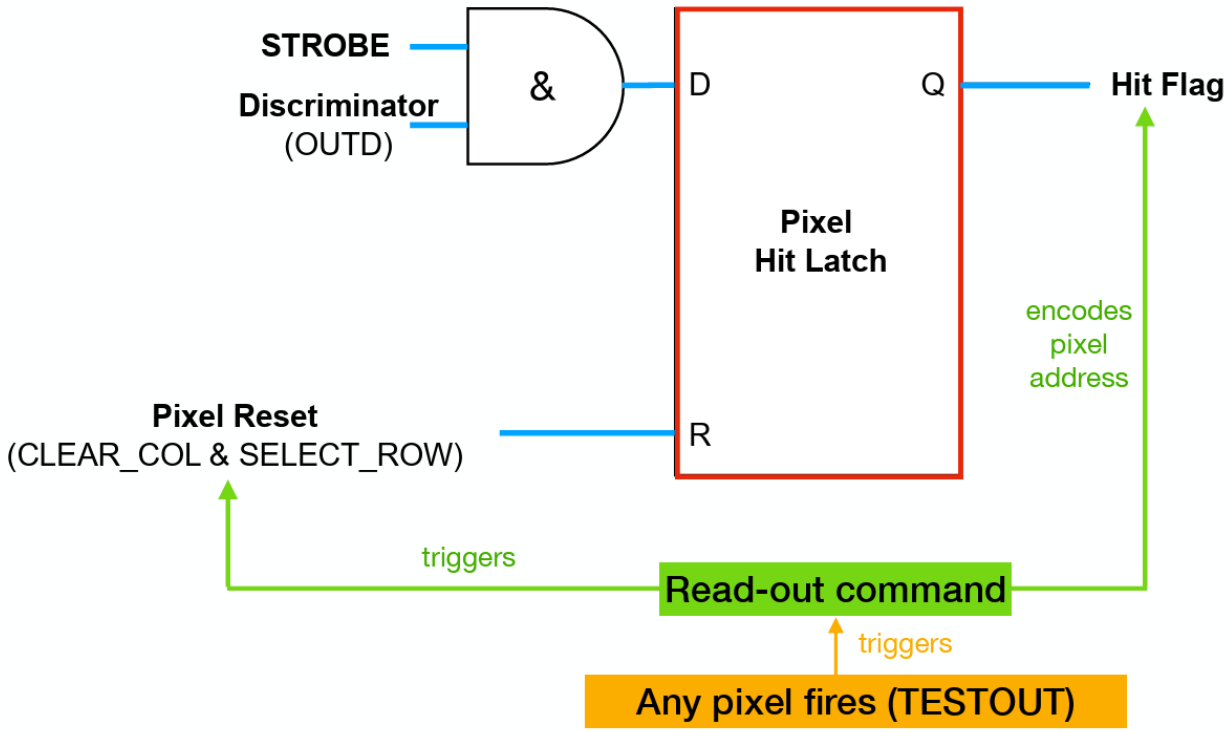


TOT measurement: Source Stuck Readout Scan

MOSS pixel read-out

How can we make the RO get stuck intentionally?

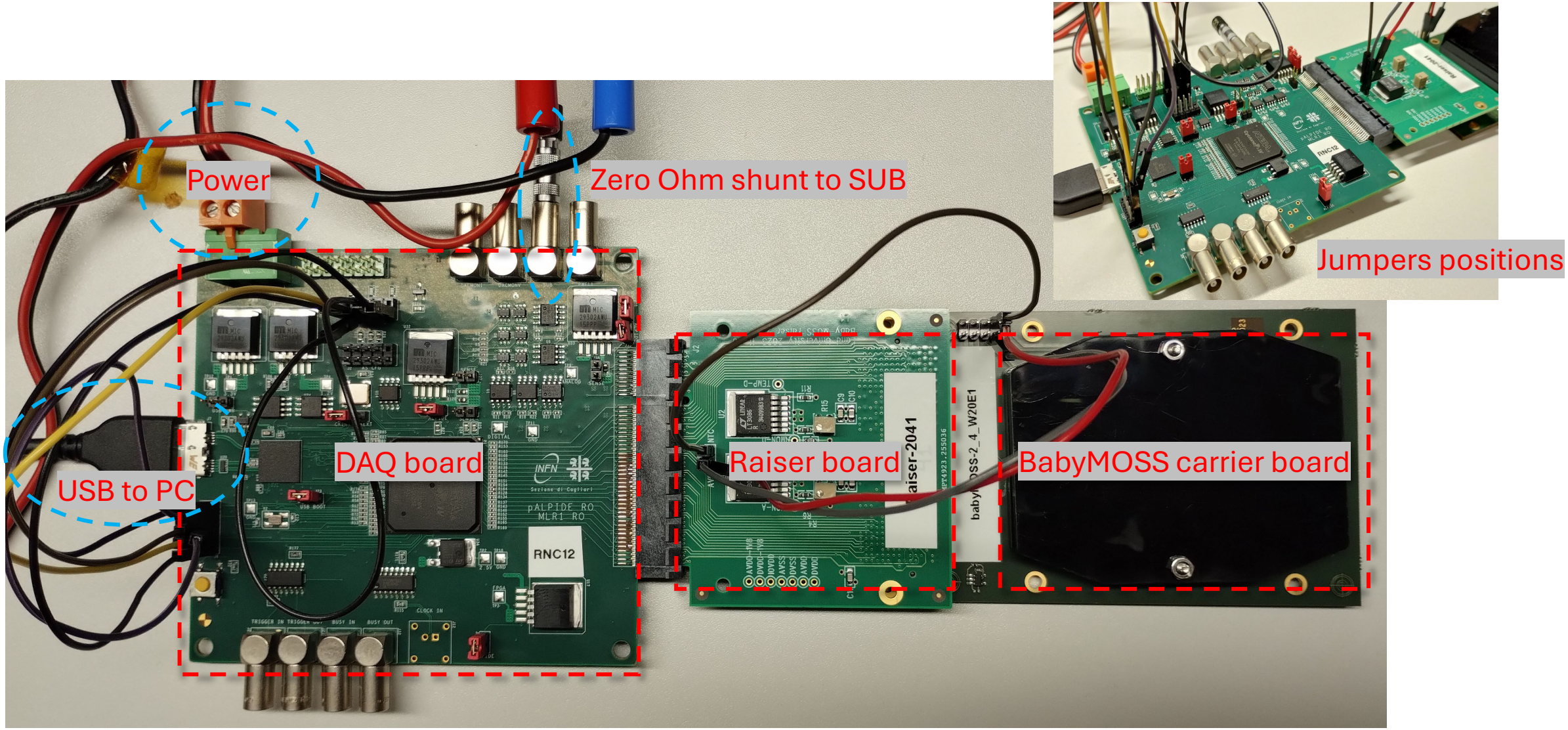
- Assert long STROBE ~ 400 µs
- When OUTD activates, hit gets stored in latch
- TESTOUT configured such that it asserts if any pixel fired
- RO-command on TESTOUT, will read hit, reset latch
- **As STROBE & OUTD still active, latch will store same hit again**
- Priority-encoder will read out same pixel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



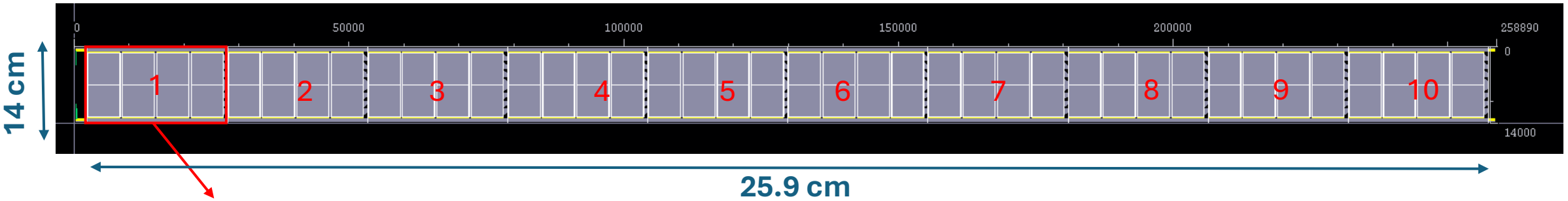
Simplified principle of the MOSS pixel readout

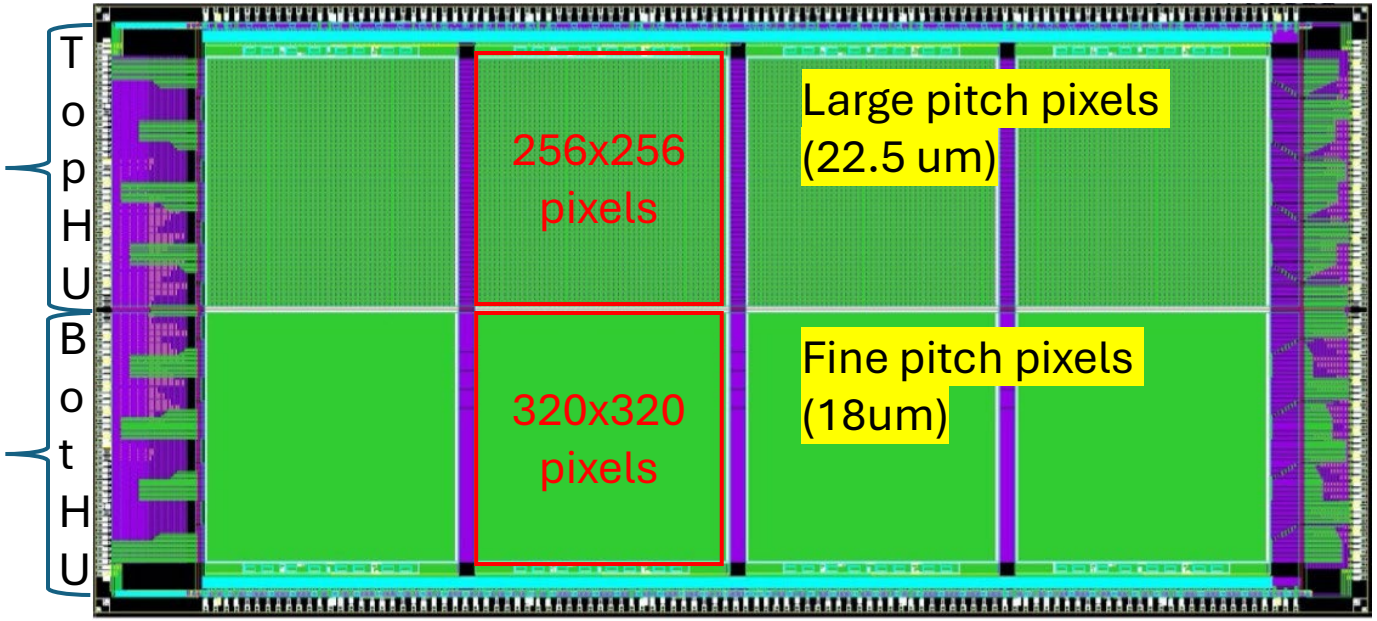
* assuming STROBE still active

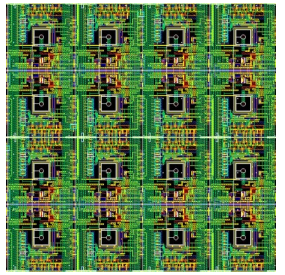
Lab. set up of babyMOSS testing



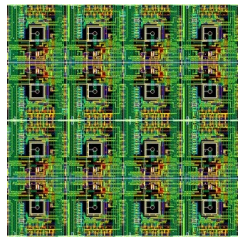
babyMOSS prototype summary







Pitch 22.5 µm Conservative layout
7 mW/cm2 (analog FE)
1us peaking time



Pitch 18 µm
Compact layout
11mW/cm2 (analog FE)
1us peaking time

- MOnolithic Stiched Sensor (MOSS) is made of ten **repeated sensor units** (**RSUs**).
  babyMOSS is equivalent to pixel matrix of the One RSU.
- Each RSU is composed of two **half-units (HUs)**, labeled **top** and **bottom**.
  Each half-unit contains four **matrices**, also referred to as **regions.**

babyMOSS pixel structure

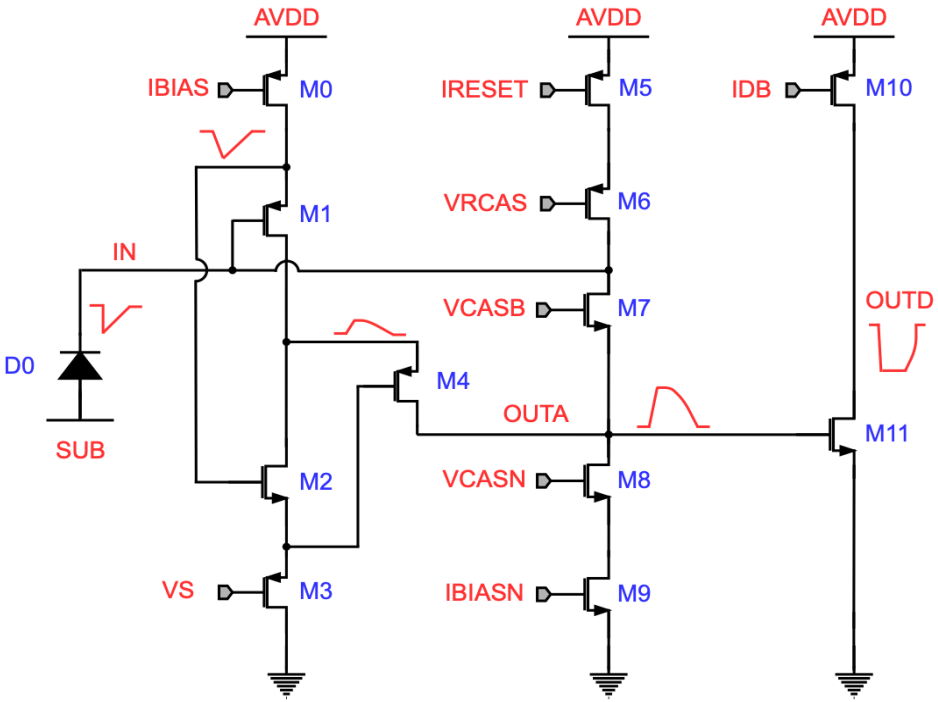
- There are different front-end variants within a HU:

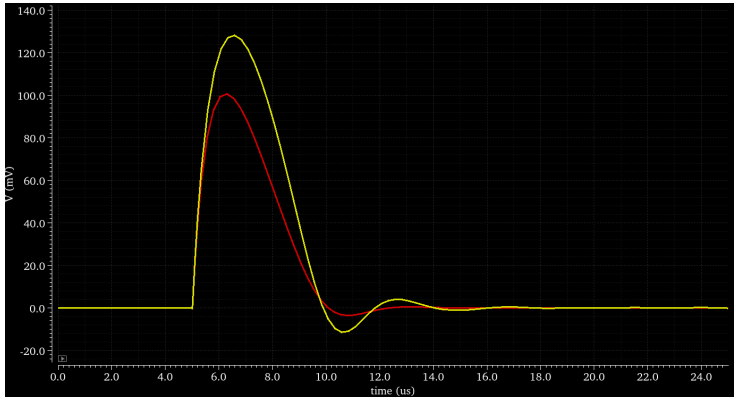
	Region 0	Region 1	Region 2	Region 3
TOP	Standard	Larger input transistor (M1)	Larger discriminator input transistor (M11)	Larger common-source transistor (M2)
BOTTOM	Standard	Standard	Standard	Slightly different layout

- 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

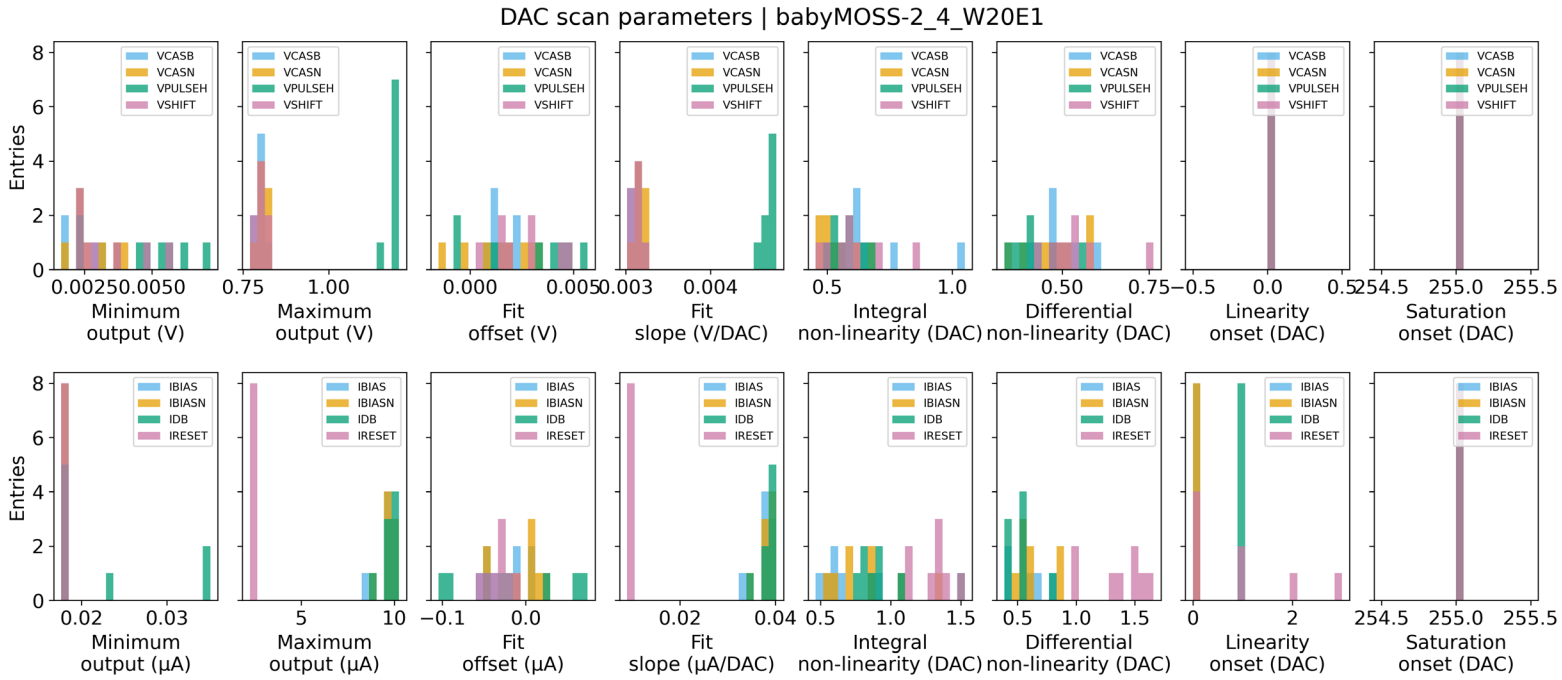
  - In "**standard layout**" a parasitic capacitance added to improves the stability of the circuit. This capacitance, however, also reduces the front-end gain (red curve).
  - In "**slightly different layout**" parasitic capacitance was slightly reduced, so front-end gain increases (yellow curve).

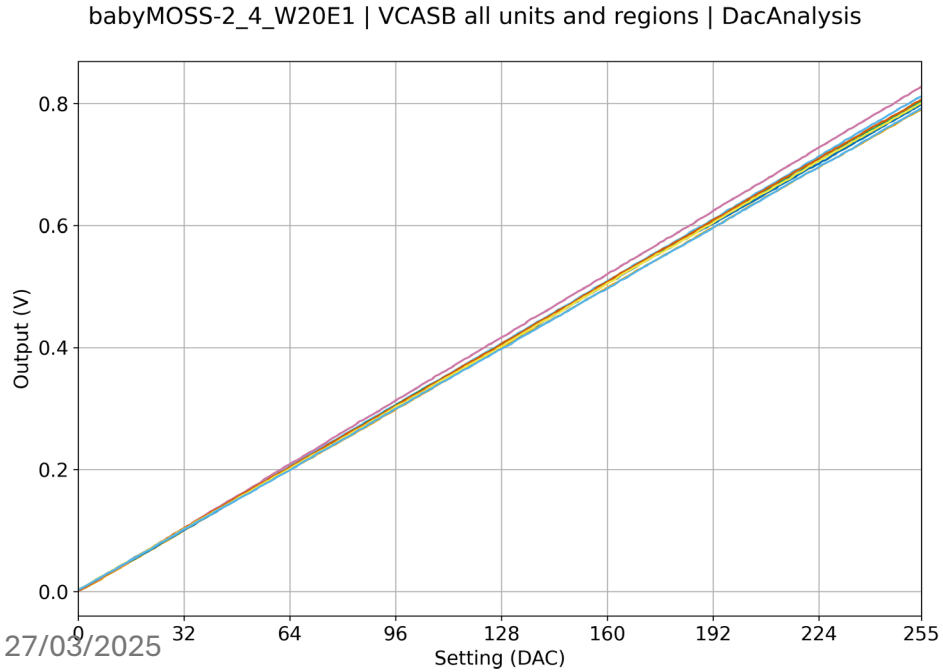


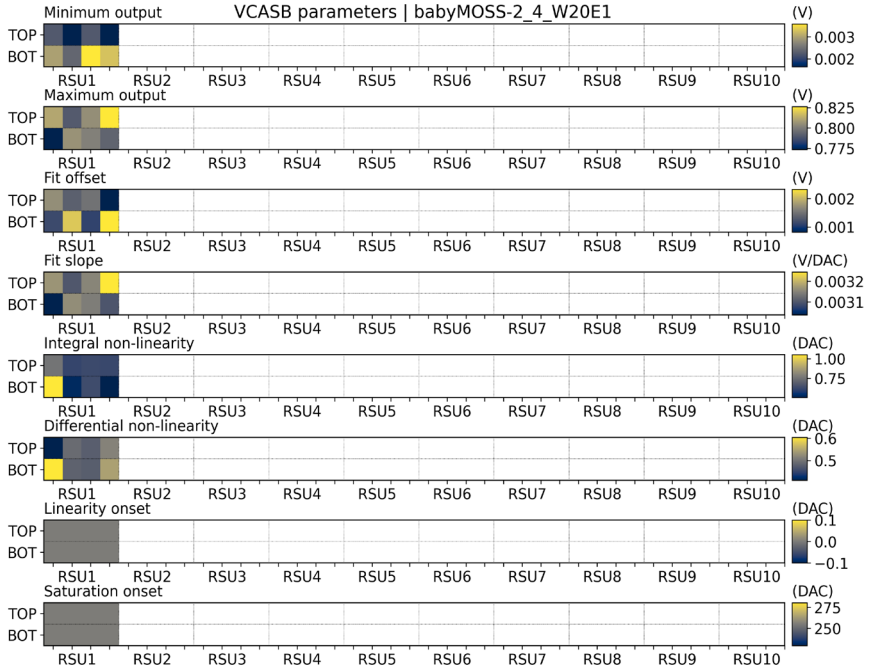


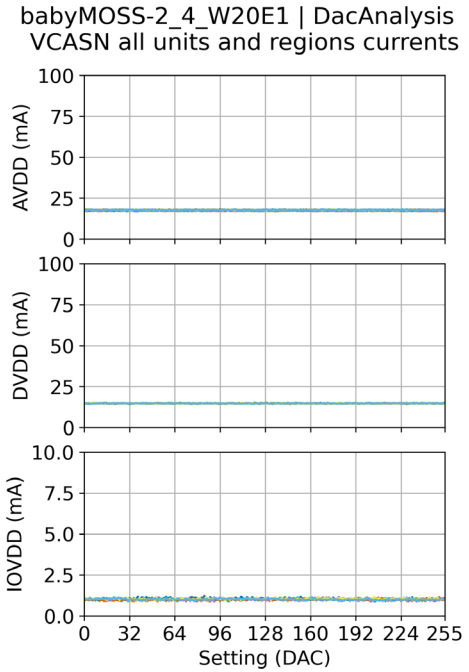
DAC scans

- Each parameter is scanned with changing DAC values 0 - 255
- DAC Scan produces 20 plots of different combination of the dac parameters
- Few of the DAC scan results are shown

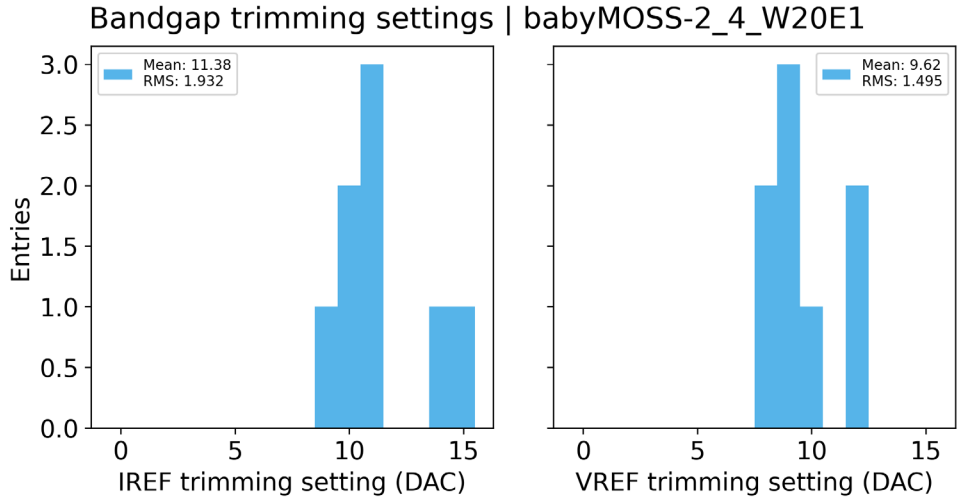


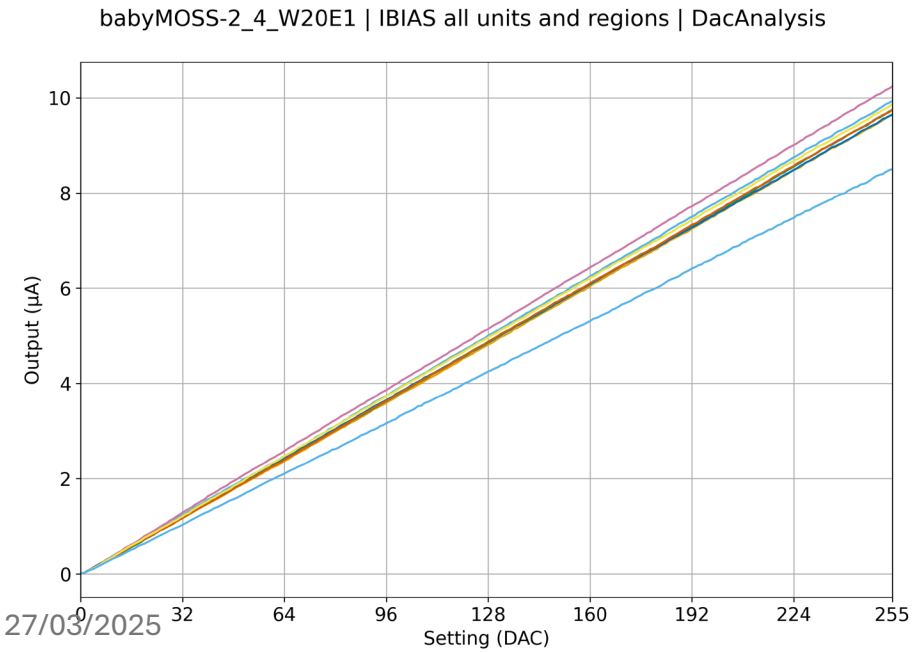


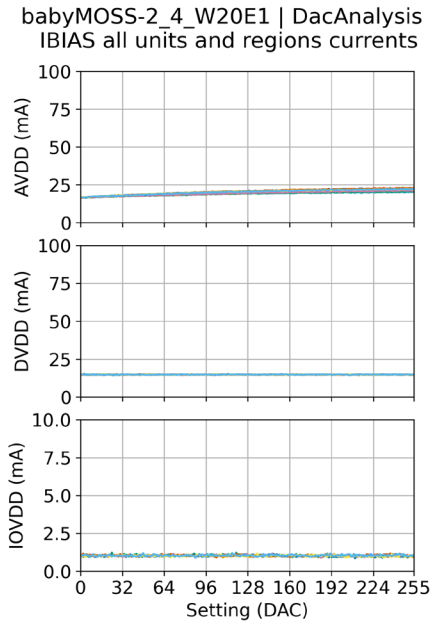


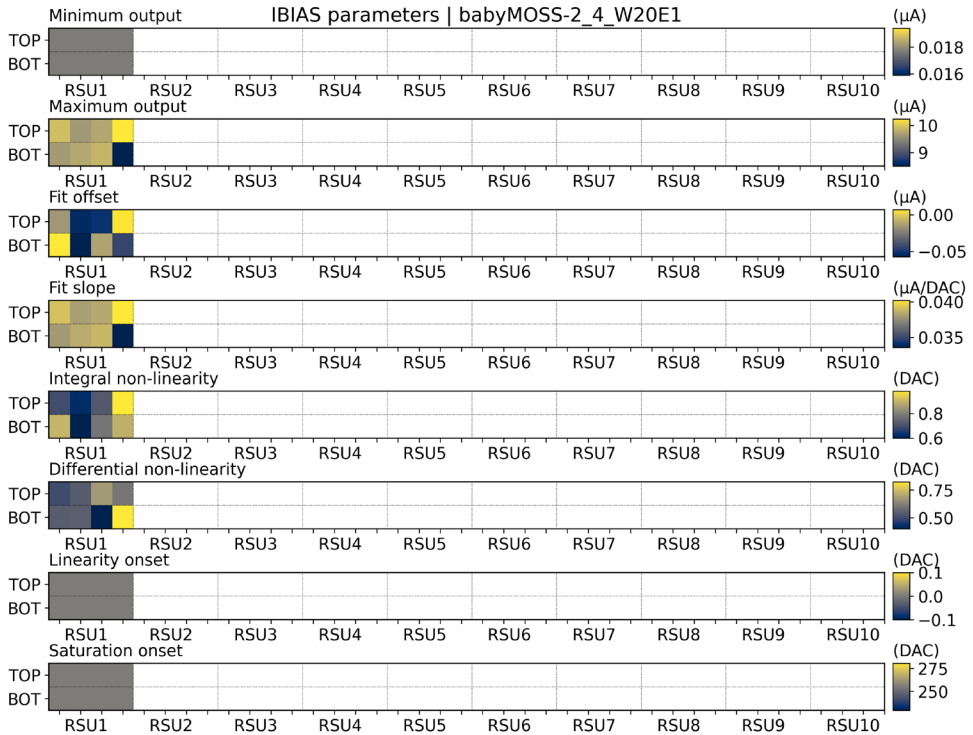


DAC Scan

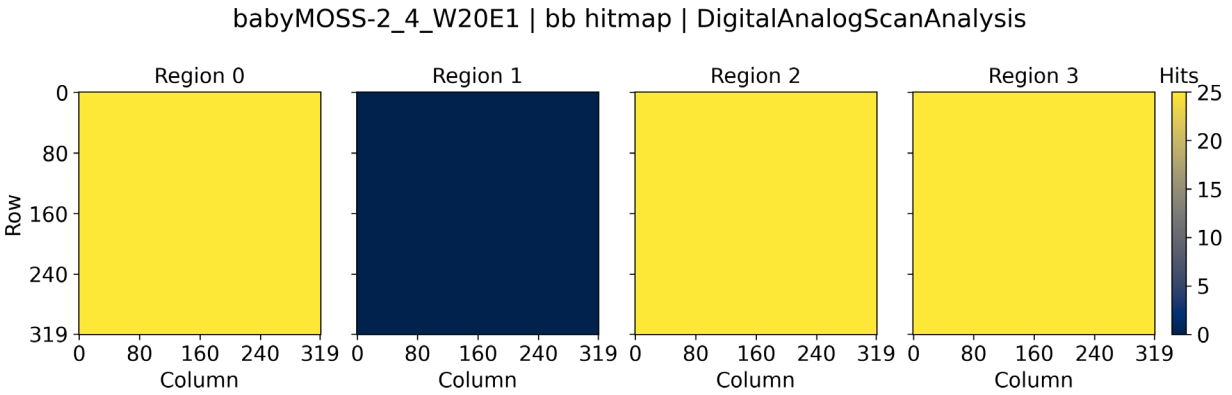

Bandgap trimming settings | babyMOSS-2_4_W20E1
Mean: 11.38
RMS: 1.932
Mean: 9.62
RMS: 1.495
Entries
IREF trimming setting (DAC)
VREF trimming setting (DAC)

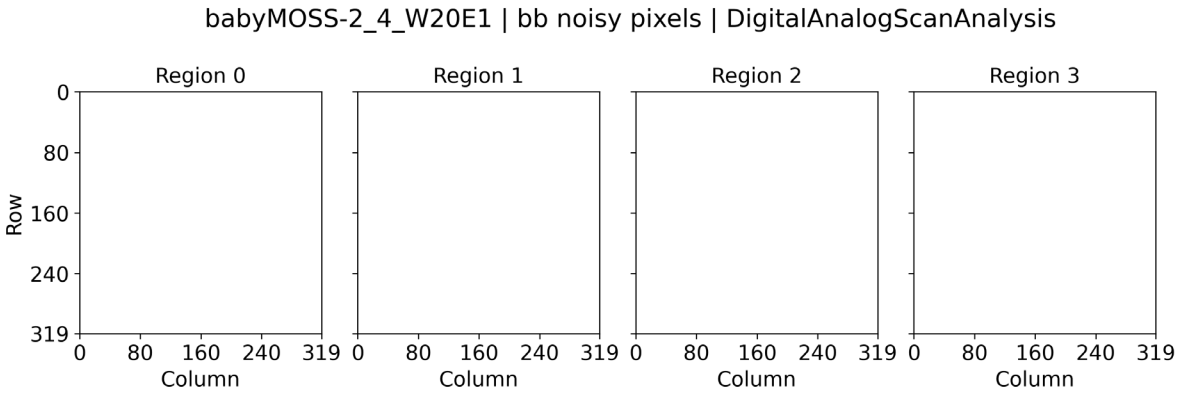

babyMOSS-2_4_W20E1 | IBIAS all units and regions | DacAnalysis
Output (µA)
Setting (DAC)

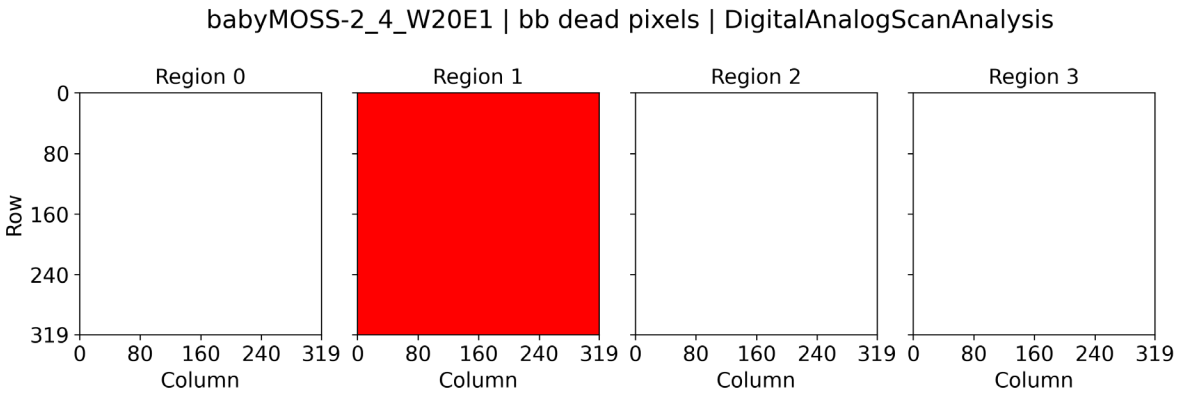

babyMOSS-2_4_W20E1 | DacAnalysis
IBIAS all units and regions currents
AVDD (mA)
DVDD (mA)
IOVDD (mA)
Setting (DAC)

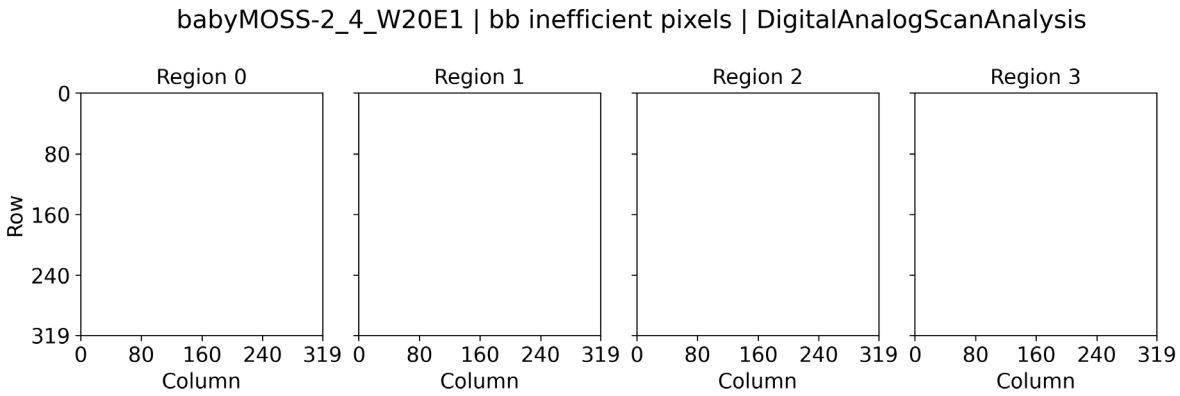

IBIAS parameters | babyMOSS-2_4_W20E1
Minimum output
Maximum output
Fit offset
Fit slope
Integral non-linearity
Differential non-linearity
Linearity onset
Saturation onset
TOP
BOT
RSU1
RSU2
RSU3
RSU4
RSU5
RSU6
RSU7
RSU8
RSU9
RSU10
(µA)
(µA/DAC)
(DAC)

Digital scan: bb



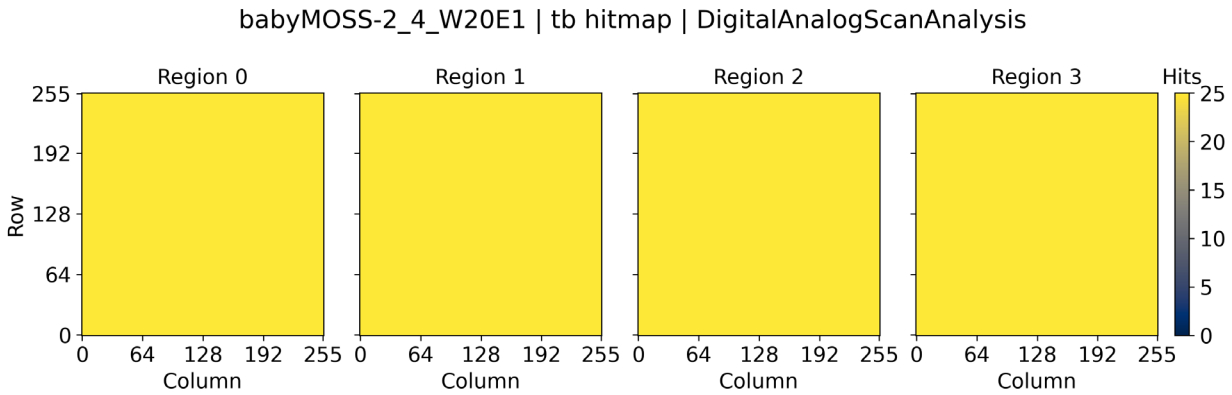


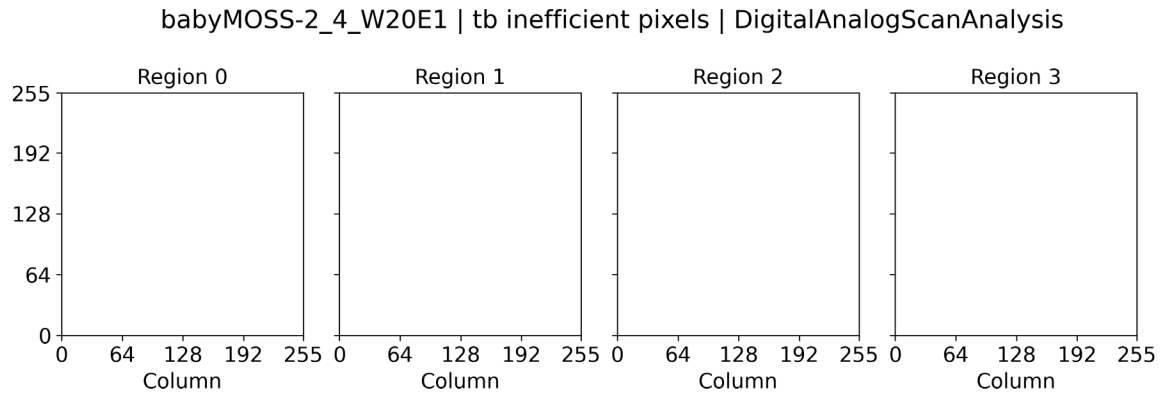


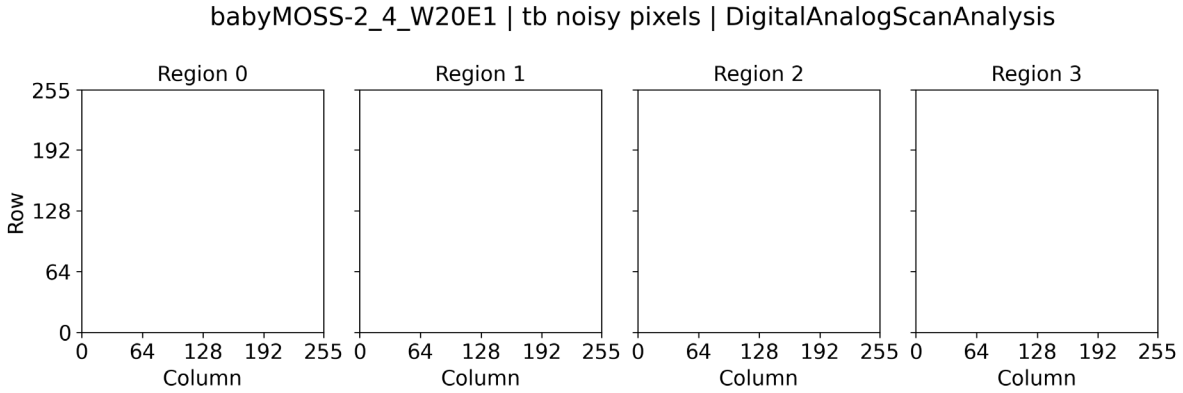


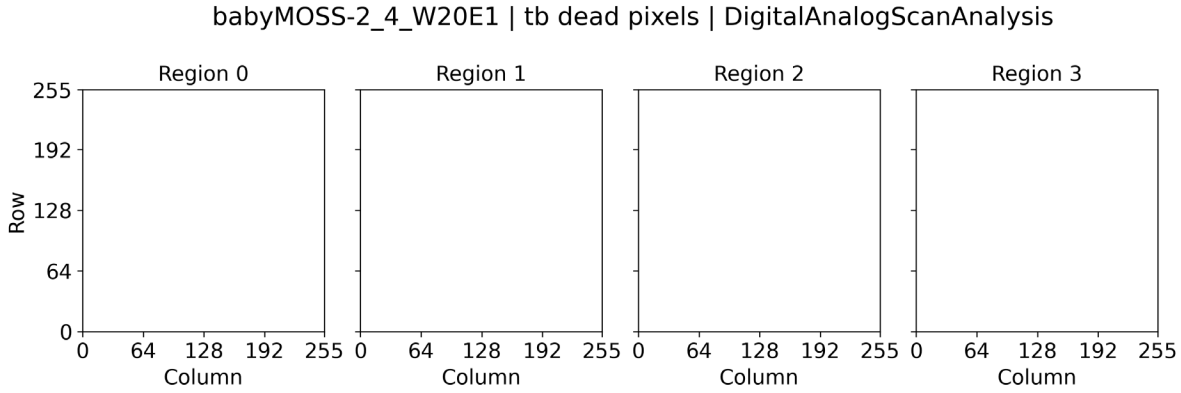
- Digital Scan test performed after masking the noisy region.

Digital scan: tb



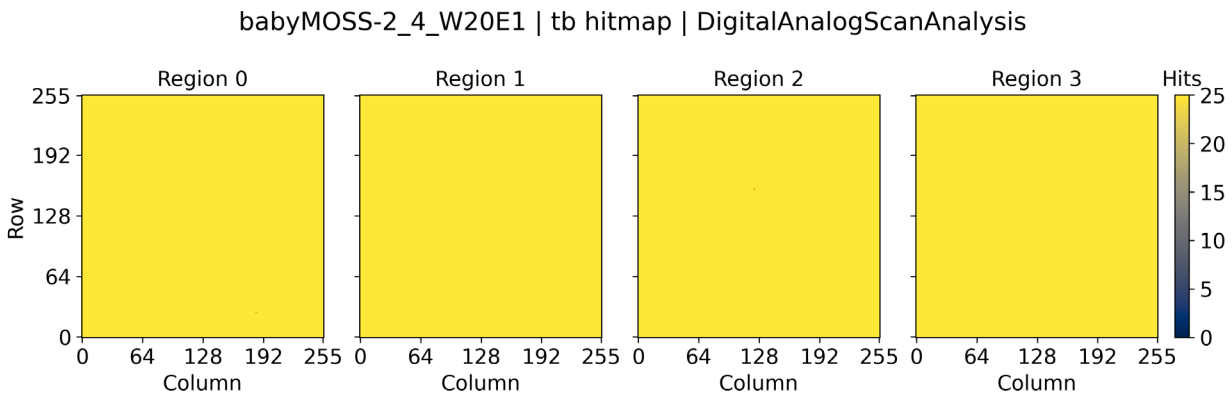


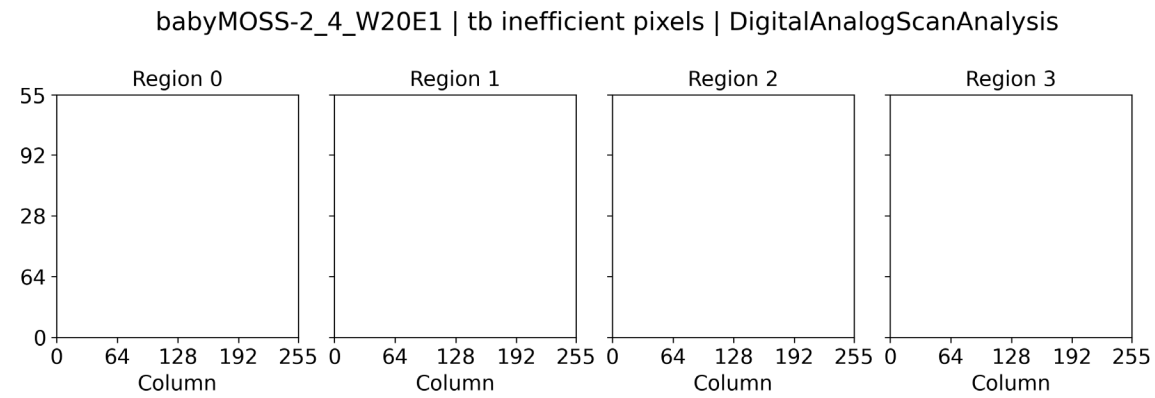


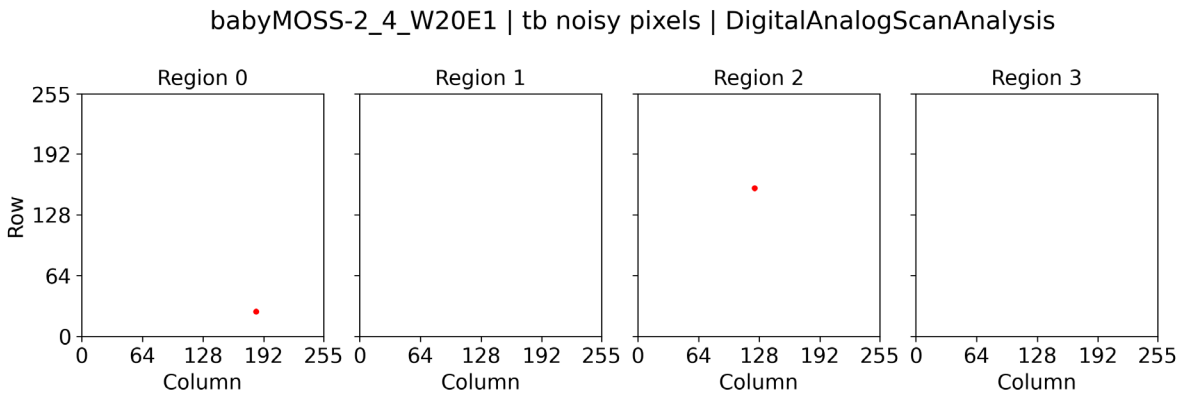


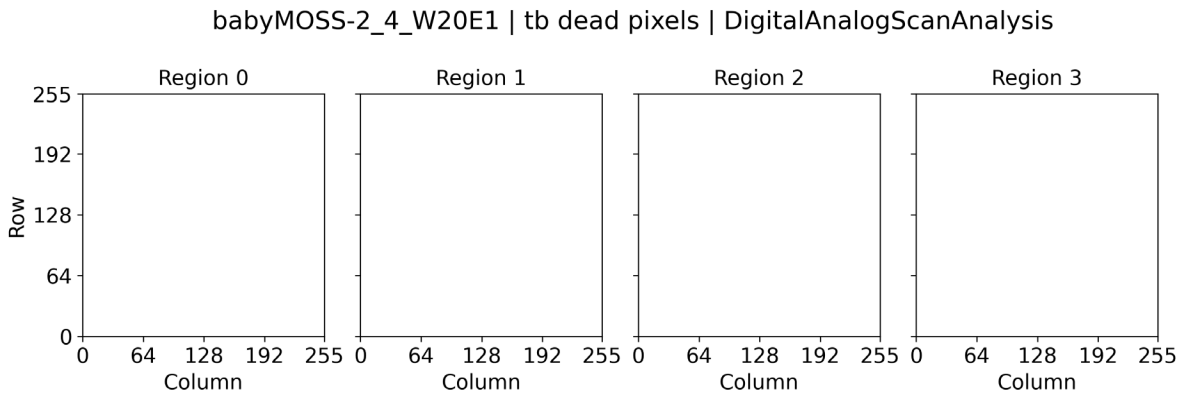
- Digital scan is found to be okay. Bottom region scan is in back-up.

Analogue scan: tb

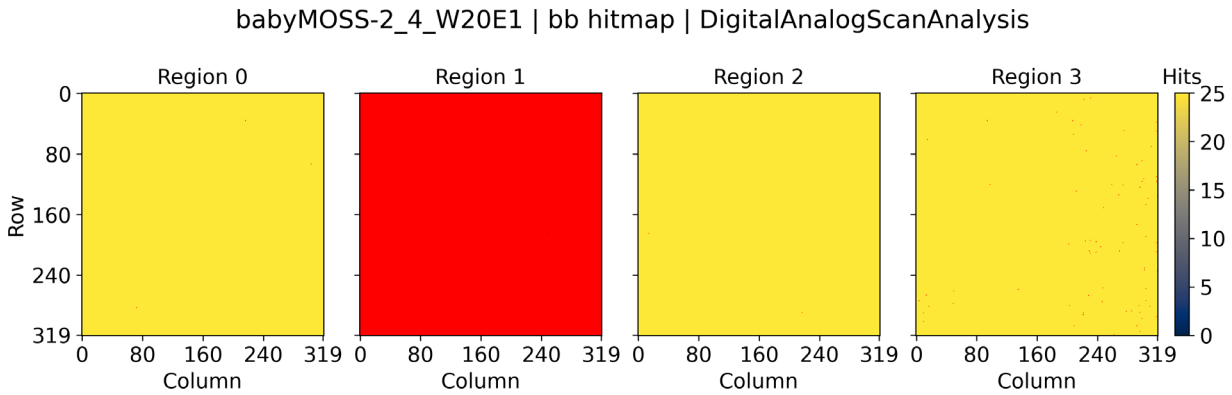


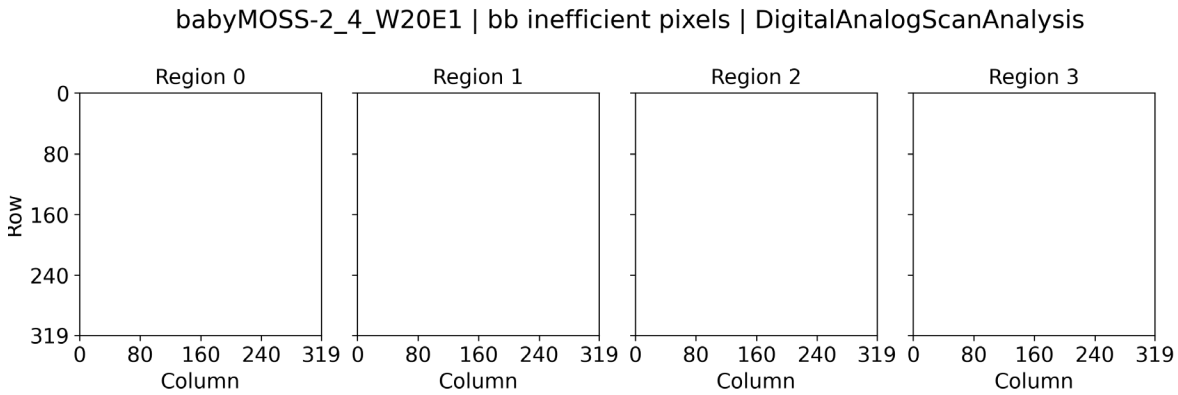


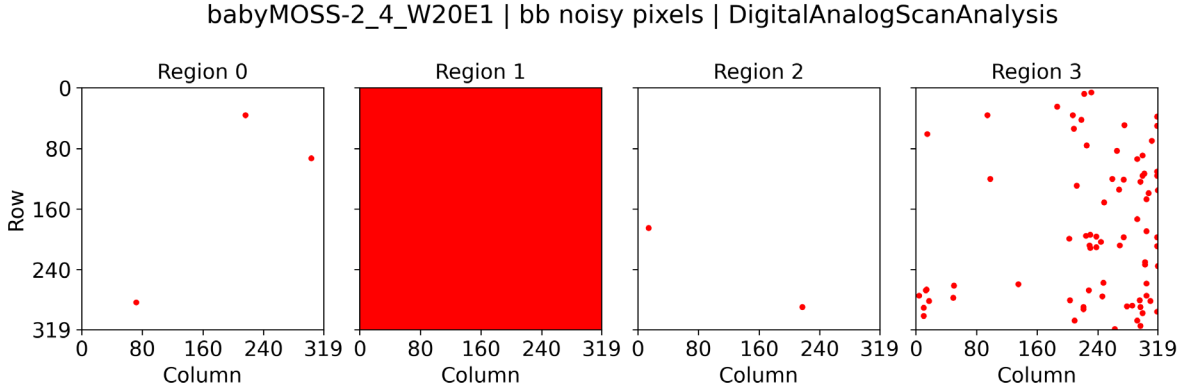


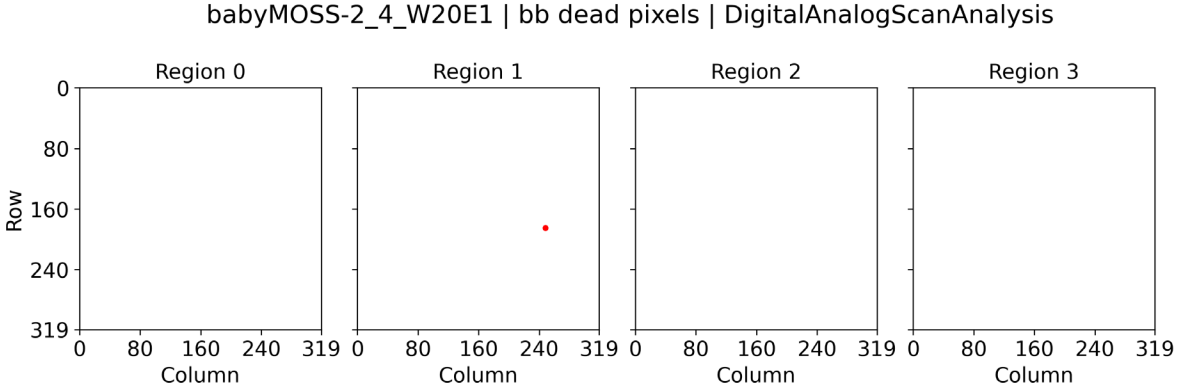


Analogue scan: bb



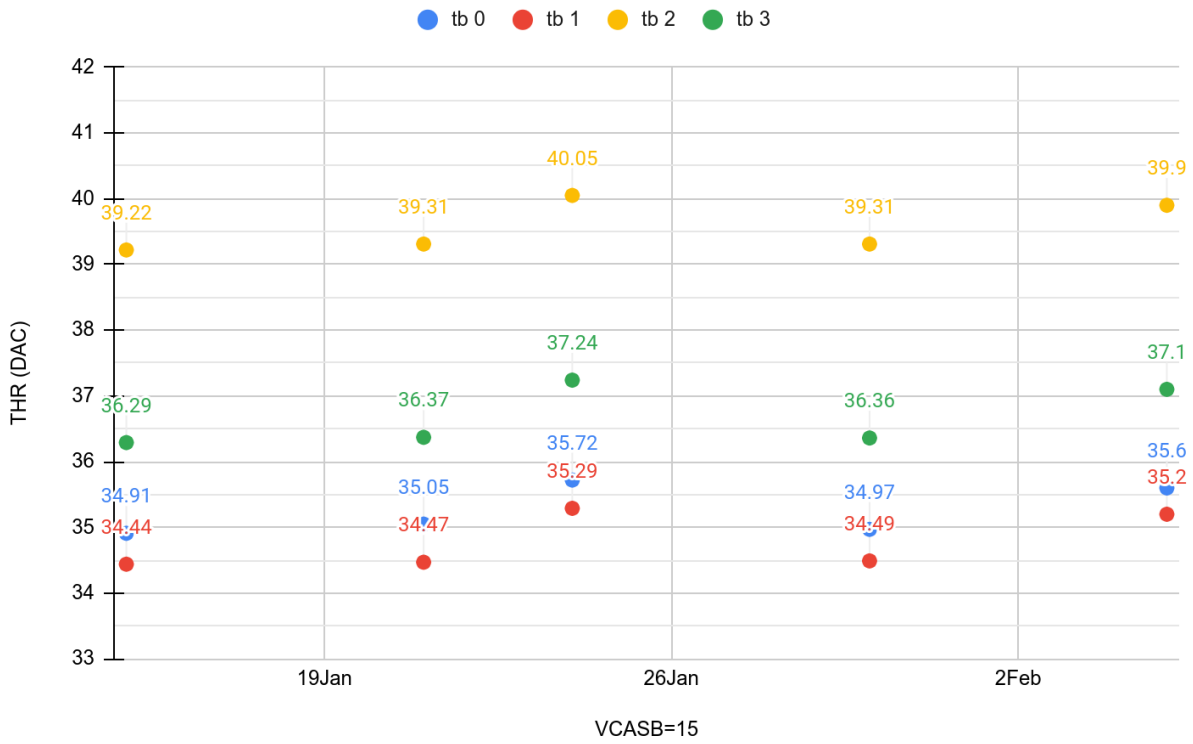


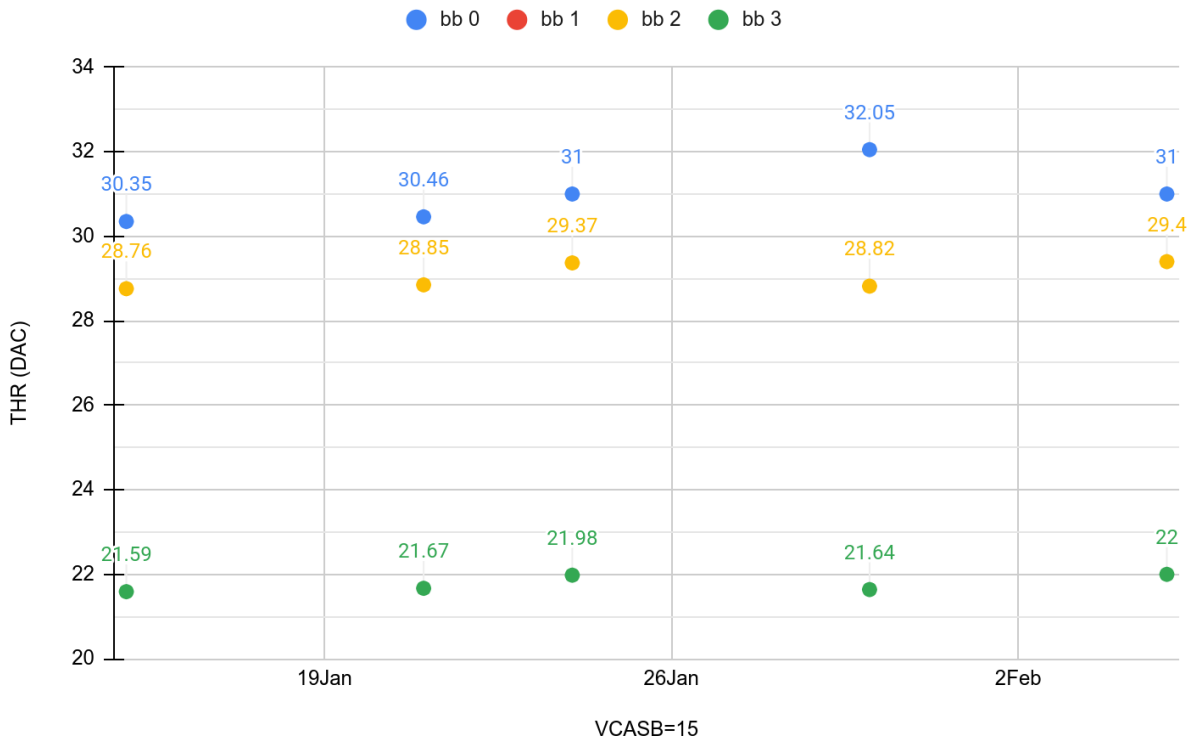




- BB region 1 is noisy

Threshold scan: stability test



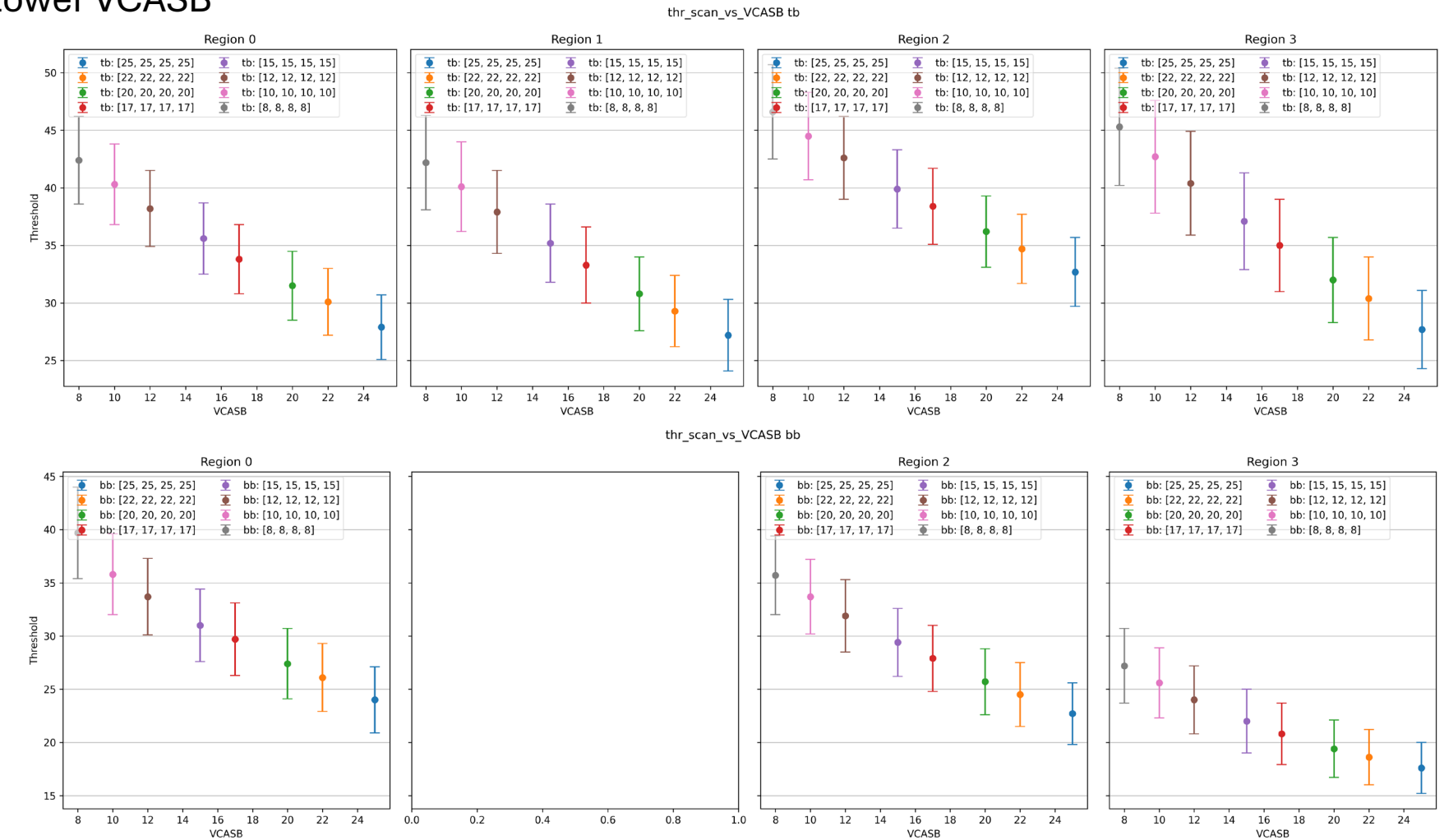


- Thresholds of each regions are consistent across different measurements within 1 ADC.
- The measurements were taken using the default DAC settings, with no temperature control.

Threshold scan with VCASB

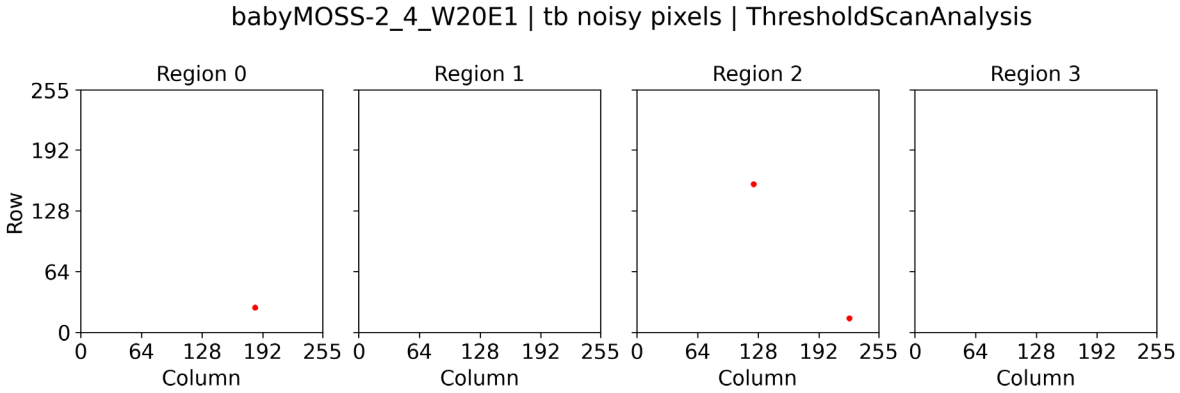
Data of 05.02.25

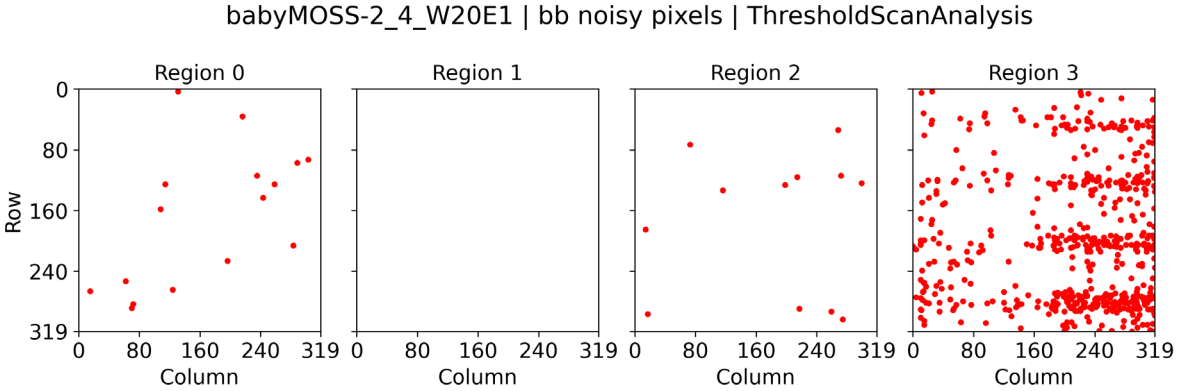
Scans at lower VCASB



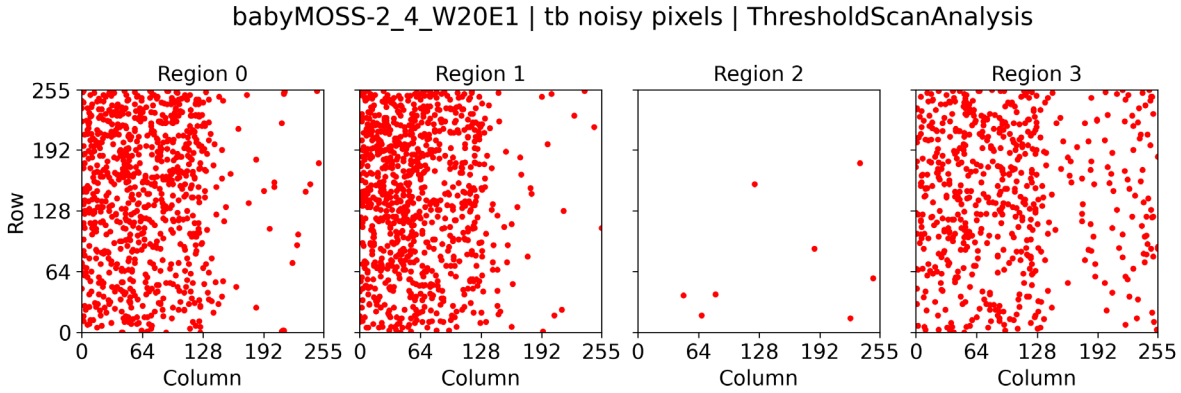
Threshold scan: Scatter plot of noisy pixels

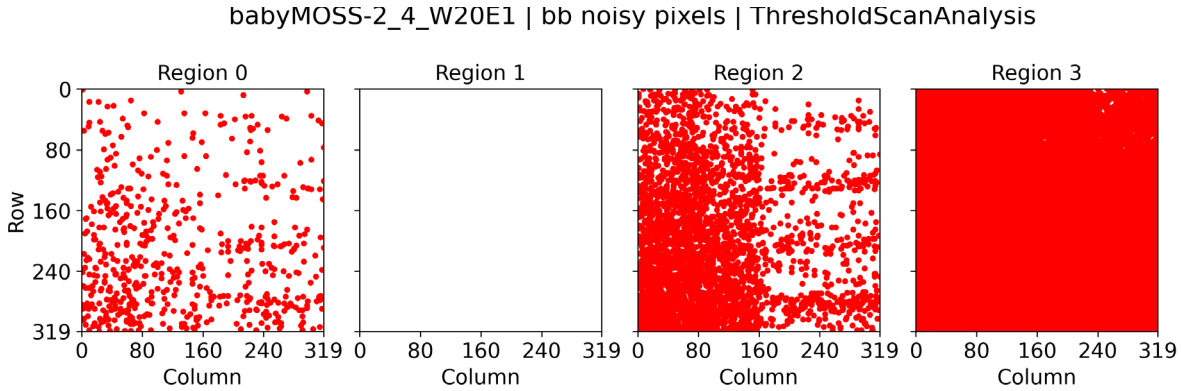
VCASB = 15





VCASB = 25

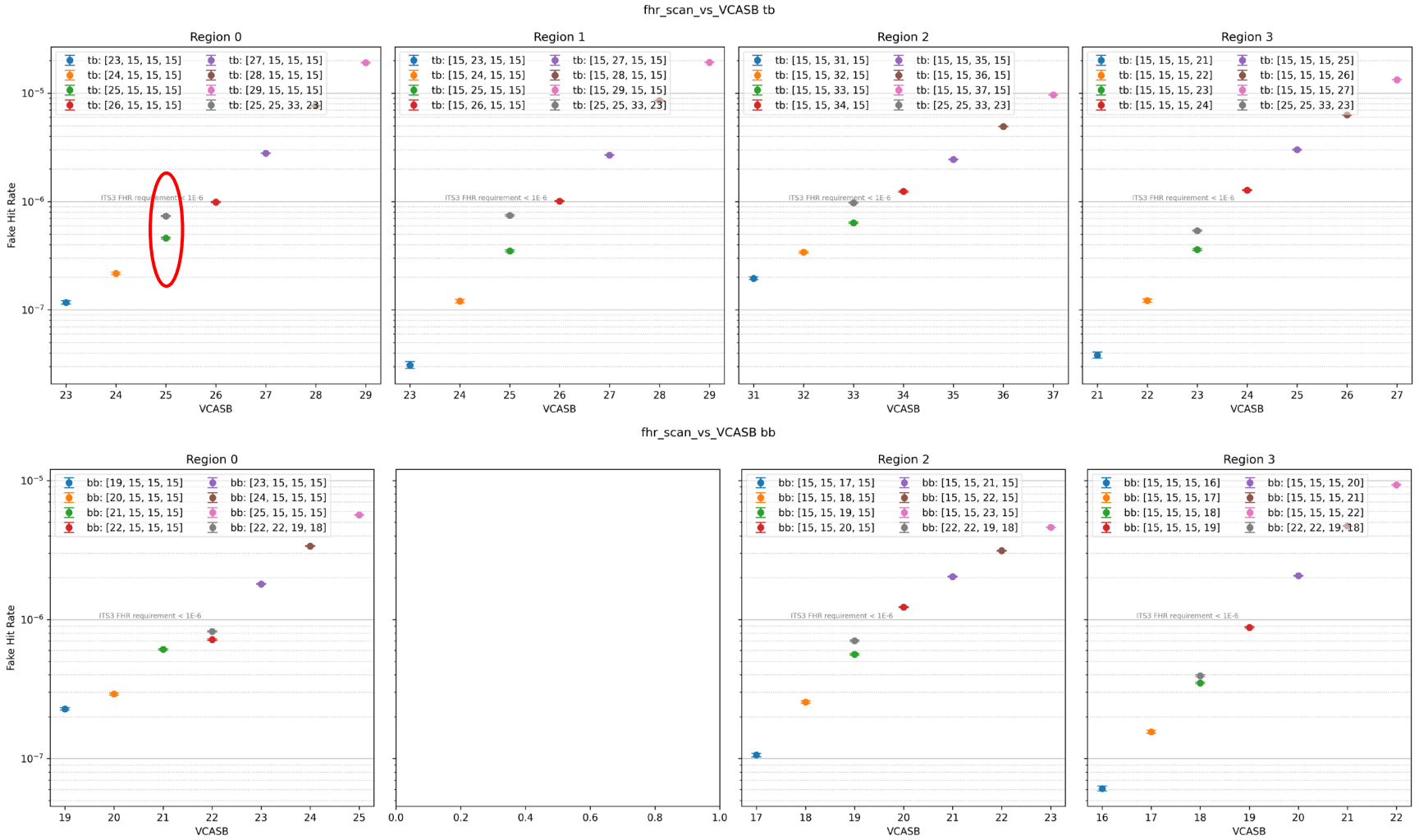




- Noise increases with the higher VCASB, as the THR decreases.
- Noise along the rows are possibly due to the metallic lines on chips.
- Difference in the FHR between the left and right part of the pixel matrix for the columns. Similar observation is reported by Styliani Paniskaki in ITS WP3 meeting.

FakeHitRate scan with VCASB

Data of 13.02.25



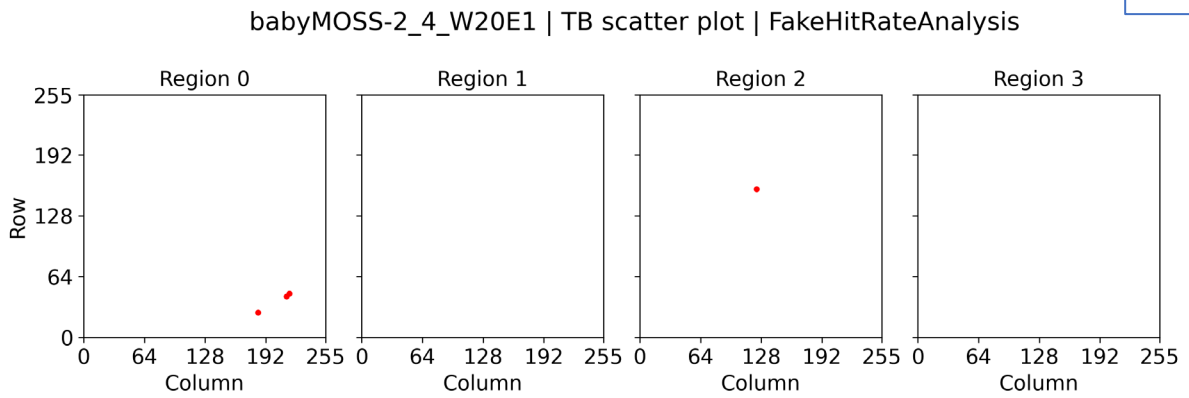
FHR Scan

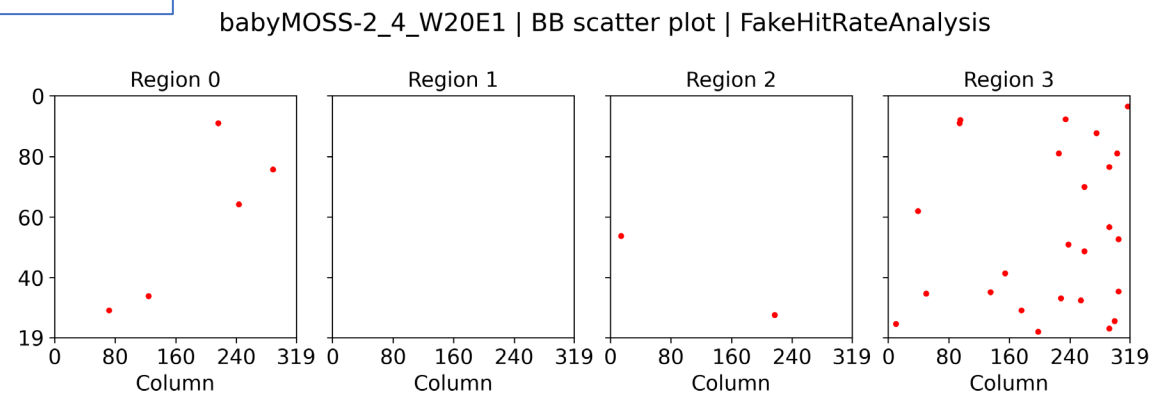
Fake Hit Rate scan

Regions	TB 0	TB 1	TB 2	TB 3	BB 0	BB 1	BB 2	BB3	Test at	Comment
FHR	4.36E-08	0	1.53E-09	0	3.54E-08		1.46E-08	3.23E-08	Bari	
FHR	6.58E-08	1.53E-10	1.07E-09	1.53E-10					CERN	bb: "No MOSS Packets in events",

STROBE_LENGTH = 200 (default)

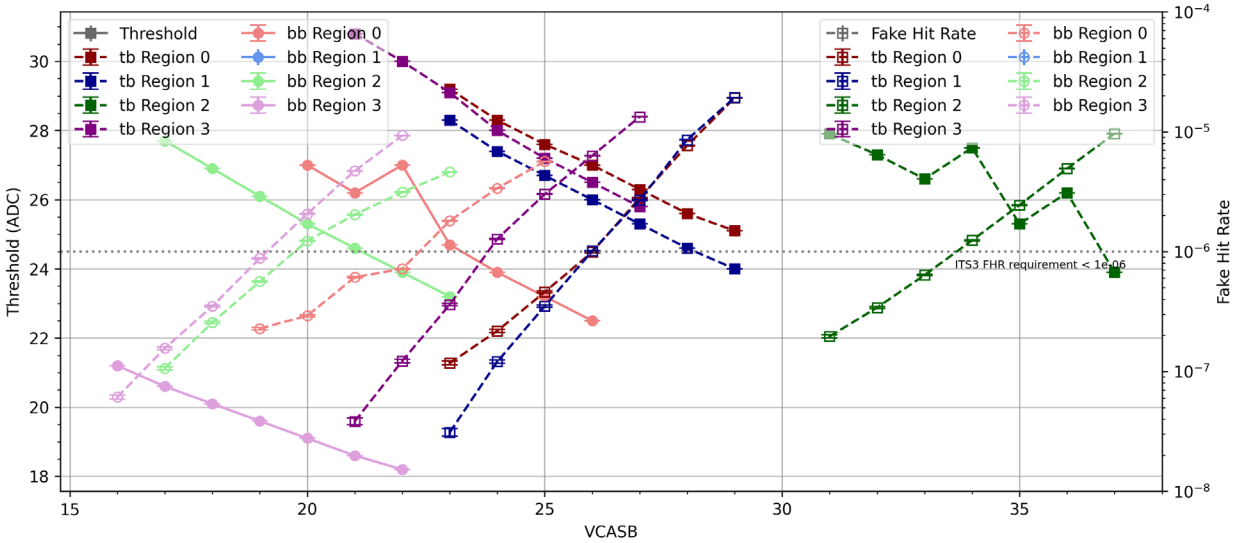
VCASB = 15



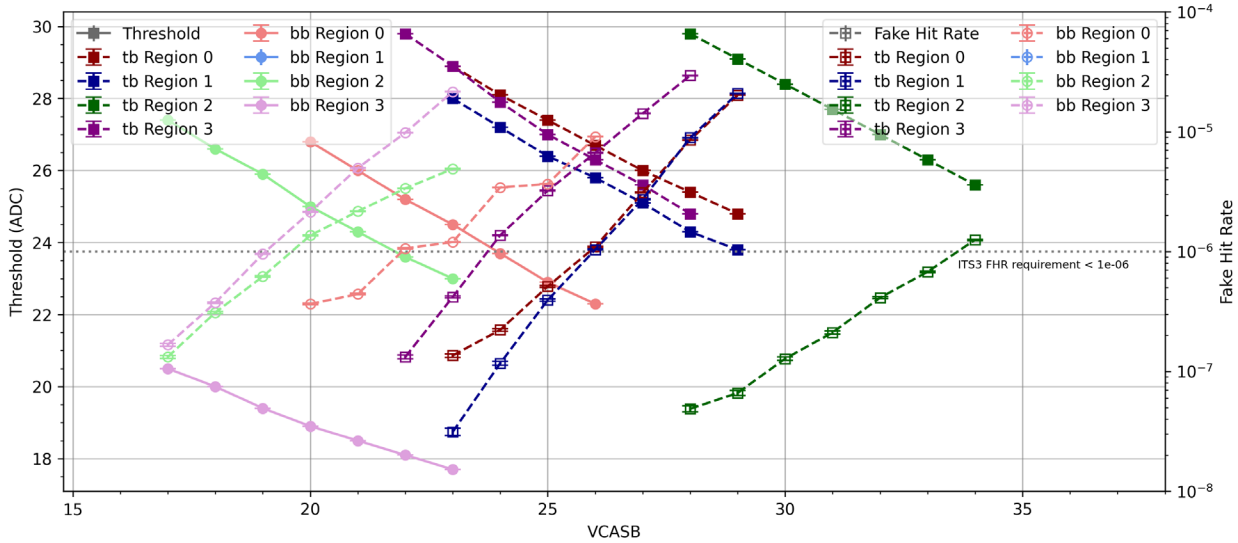


Threshold and FHR scans with VCASB

Data of 14.02.25

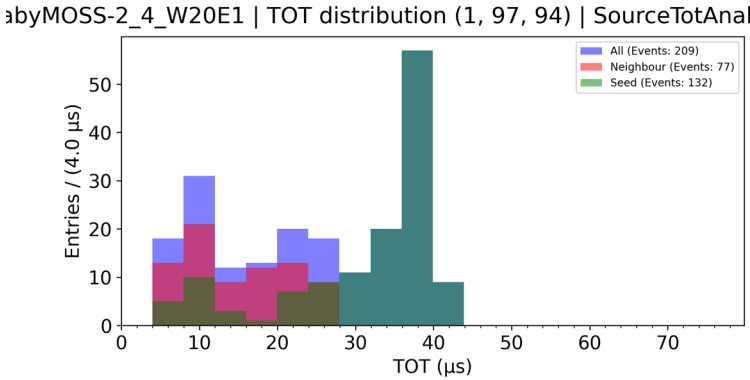


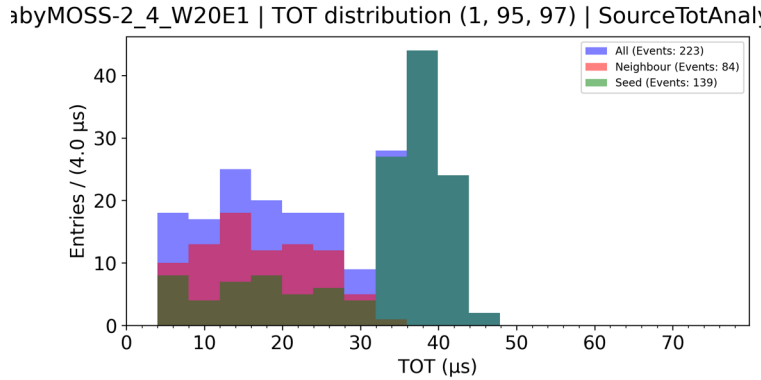
Data of 13.02.25

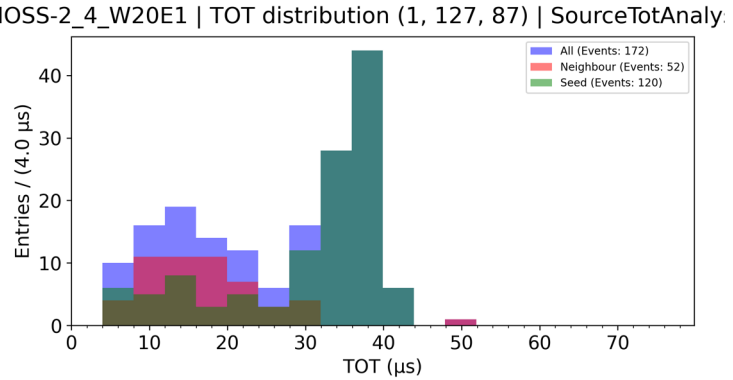


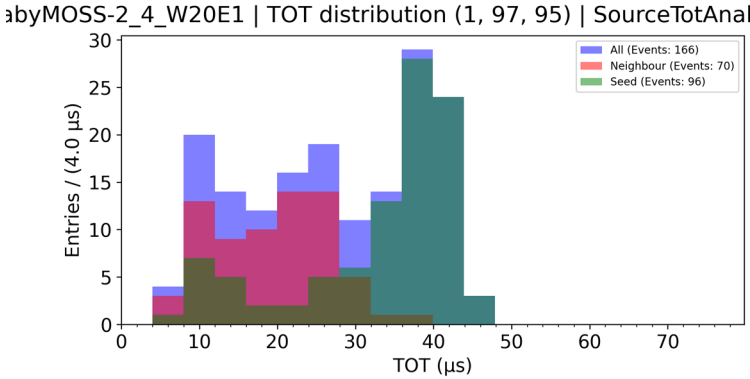
- We can find the operating VCASB for each region provided that the FHR of ITS3 limit of <1E-6

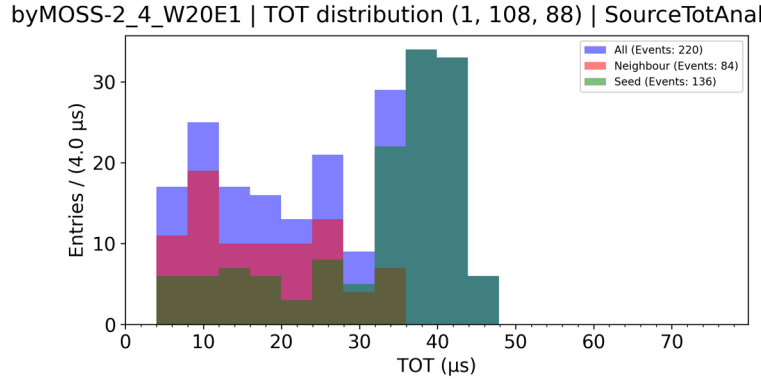
ToT measurement of single pixels with IRESET = 8

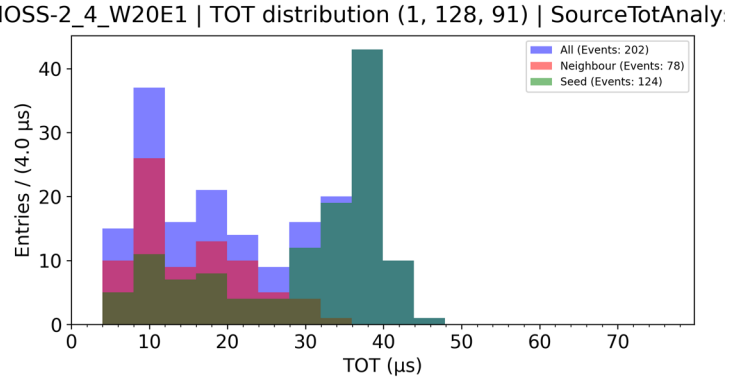


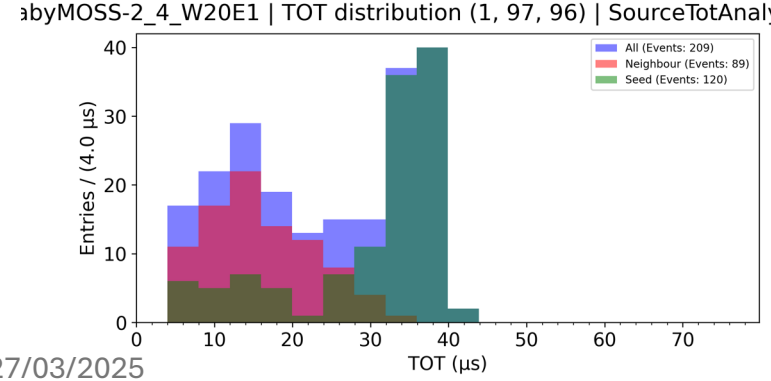


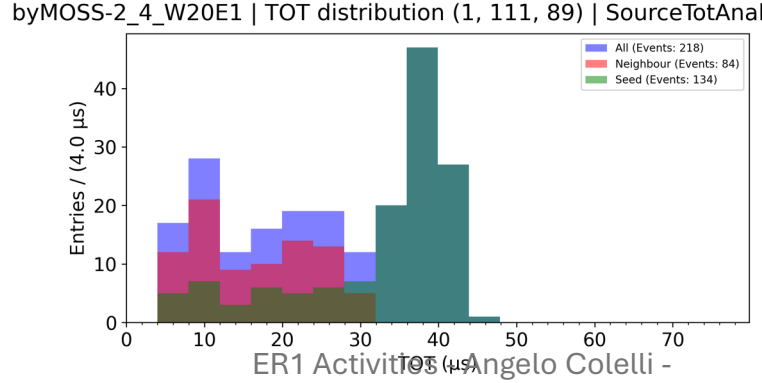


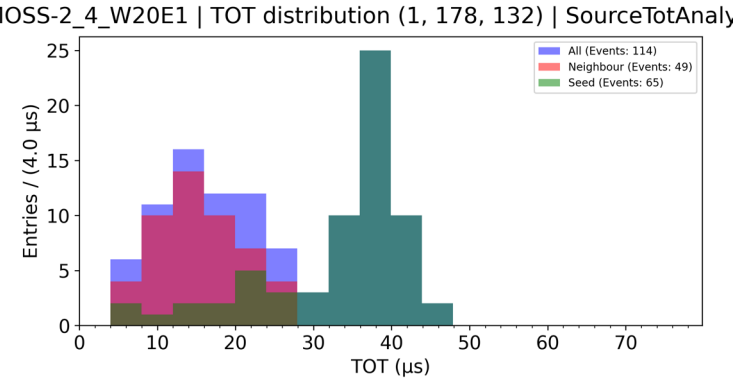






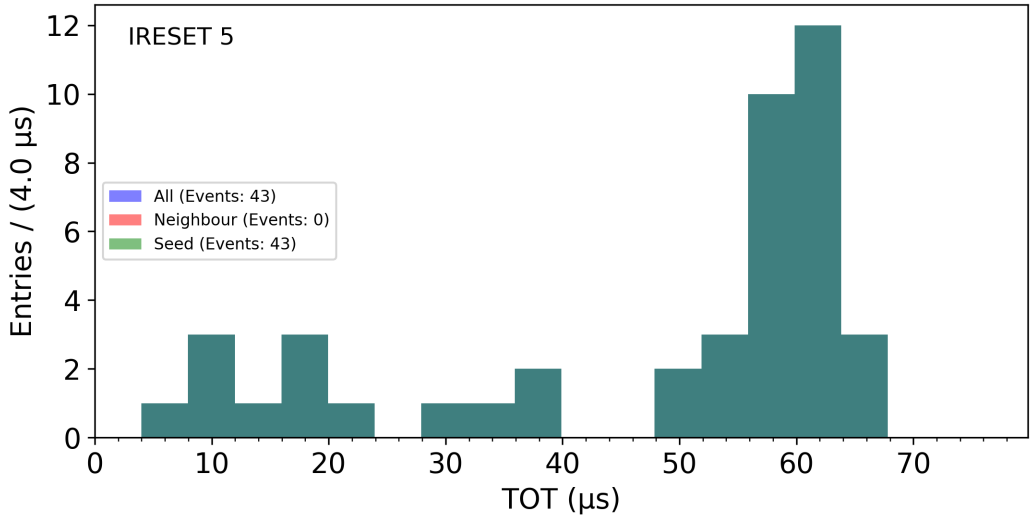




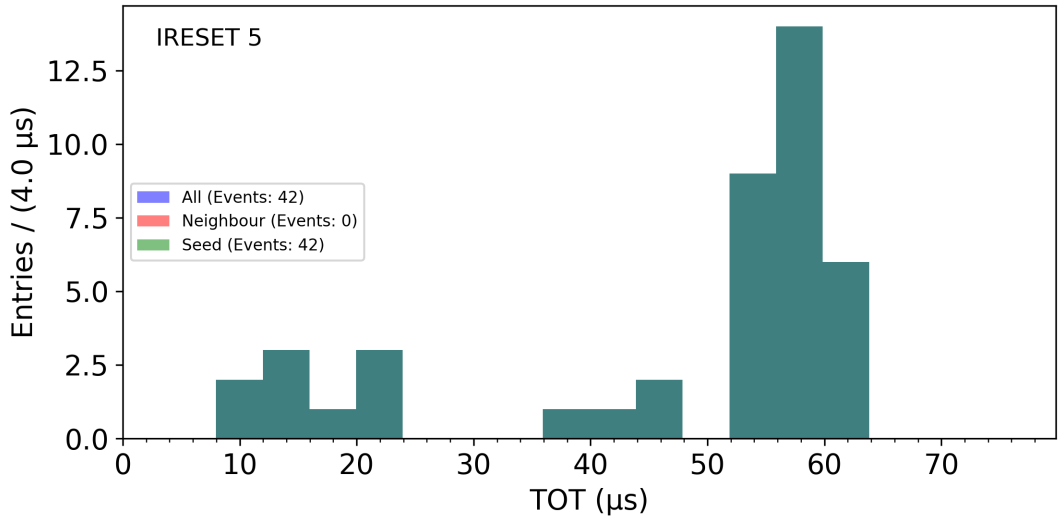


ToT measurement of single pixels with IRESET = 5

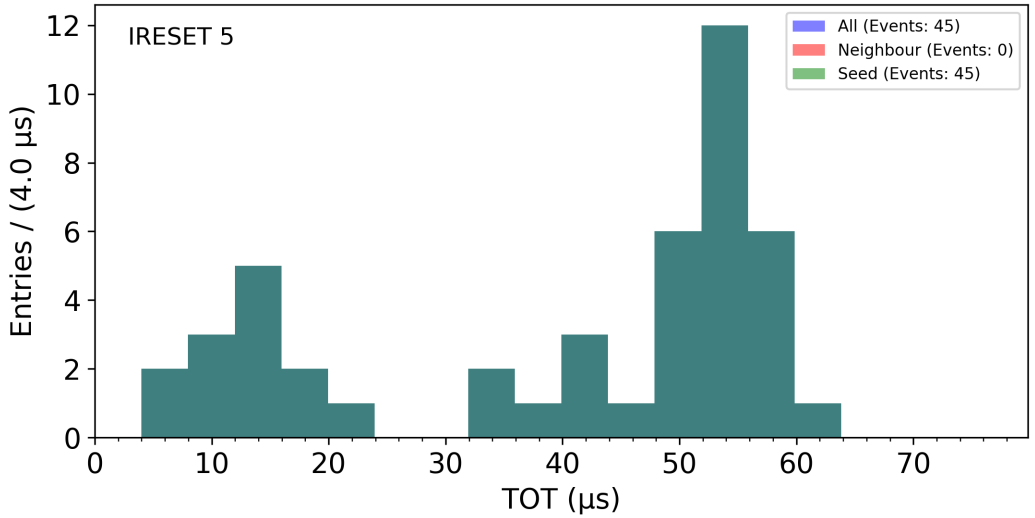
byMOSS-2_4_W20E1 | TOT distribution (1, 75, 194) | SourceTotAnaly



byMOSS-2_4_W20E1 | TOT distribution (1, 52, 169) | SourceTotAnaly



byMOSS-2_4_W20E1 | TOT distribution (1, 107, 194) | SourceTotAnaly



byMOSS-2_4_W20E1 | TOT distribution (2, 62, 194) | SourceTotAnaly