Wafer Probing Update

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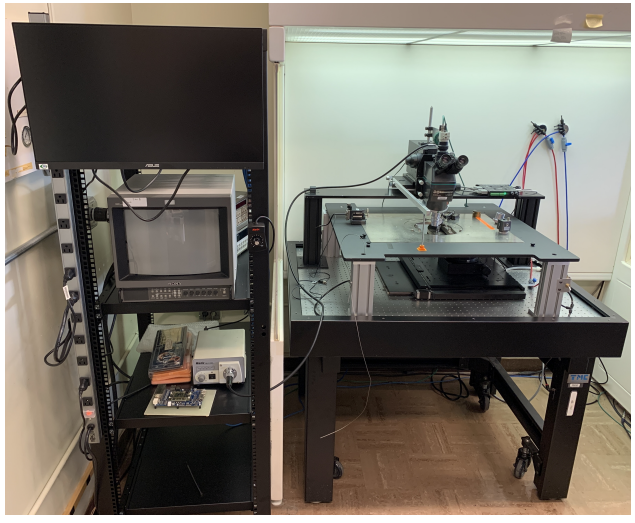
LBNL Instrumentation Meeting, 17th March 2023

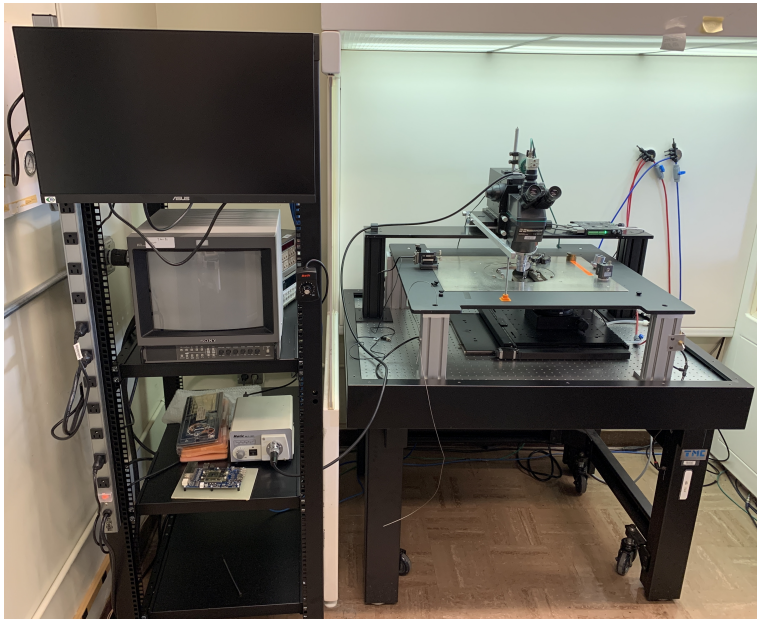


BERKELEY LAB

ATLAS EXPERIMENT

Reminder: Overview

- Preparing to qualify as a backup site for ITk pixel wafer probing
- "Custom" probe station assembled: vibration isolation table, laminar flow hood, vacuum chuck, microscope, Zaber X-Y and Z stages
- We have an RD53a wafer, an ITkPixV1 wafer, and single chip, and the necessary relevant probe cards, and well as the KX1 and KX2 BDAQ boards



Reminder: Horizontal Movement Accuracy

11	-	-	-	B	C	C	B	-	-	-
10	-	B	B	**A**	C	B	**A**	C	-	-
9	-	C	C	B	B	A	A	A	A	-
8	B	C	B	B	A	A	B	C	A	-
7	C	A	C	B	B	B	C	A	C	A
6	B	A	B	B	A	A	B	A	B	C
5	**A**	A	A	**A**	A	A	**A**	A	A	**A**
4	A	B	A	A	B	C	B	X	X	B
3	B	A	A	A	B	B	B	C	C	-
2	B	B	A	A	B	B	B	B	A	-
1	-	C	A	A	A	B	B	A	-	-
0	-	-	B	**A**	A	B	**A**	-	-	-
	0	1	2	3	4	5	6	7	8	9

Reminder: Horizontal Movement Accuracy

11	-	-	-	B	C	C	B	-	-	-
10	-	B	B	**A**	C	B	**A**	C	-	-
9	-	C	C	B	B	A	A	A	A	-
8	B	C	B	B	A	A	B	C	A	-
7	C	A	C	B	B	B	C	A	C	A
6	B	A	B	B	A	A	B	A	B	C
5	**A**	A	A	**A**	A	A	**A**	A	A	**A**
4	A	B	A	A	B	C	B	A	A	B
3	B	A	A	A	B	B	B	C	C	-
2	B	B	A	A	B	B	B	B	A	-
1	-	C	A	A	A	B	B	A	-	-
0	-	-	B	**A**	A	B	**A**	-	-	-
	0	1	2	3	4	5	6	7	8	9

With chip-by-chip corrections. Only re-measured manually changed chips and previously X chips

BDAQ Board and Scans

- Updated to KX2 board and latest BDAQ software/firmware version 1.7
- Working on single chip to get scans running
- Attempted various scans, with mostly default parameters (and a little hacking), and resulting in differing success so far...

Summary of Scans

Scan/test	Running (even with errors)
Register scan	✓
Digital scan	✓
Analog scan	✓
Threshold scan	✓
Noise occupancy scan	✓
External trigger scan	✗
Source scan (random trigger)	✓
Tune TLU	✗
Injection delay scan	✗
In time threshold scan	✗
Crosstalk scan	✓
Hitor calibration	✓

Path Forwards

1. Implement remaining scans/tests, and check parameters on these scans/tests
   - Should this be left for later?
2. Implement contact sensing and height map to control vertical movement
3. **Test movement+electrical tests working on ITkPix v1.1 wafer**
4. Deep-clean of probe station, and procure nano structures for probe card cleaning and heat sink for BDAQ board
   - Currently uncertain due to my ankle

Preliminary Scan Results

Register Scan

- Writes random data into the specified registers, then reads back the data and compares read and written data

This is a bdaq53 pixel_register_scan for chip 0x162BC.
Run 20230317_022047_pixel_register_scan was started 2023-03-17 02:20:47.

Scan config	Value
test_pattern	170
trigger_pattern	0xffffffff

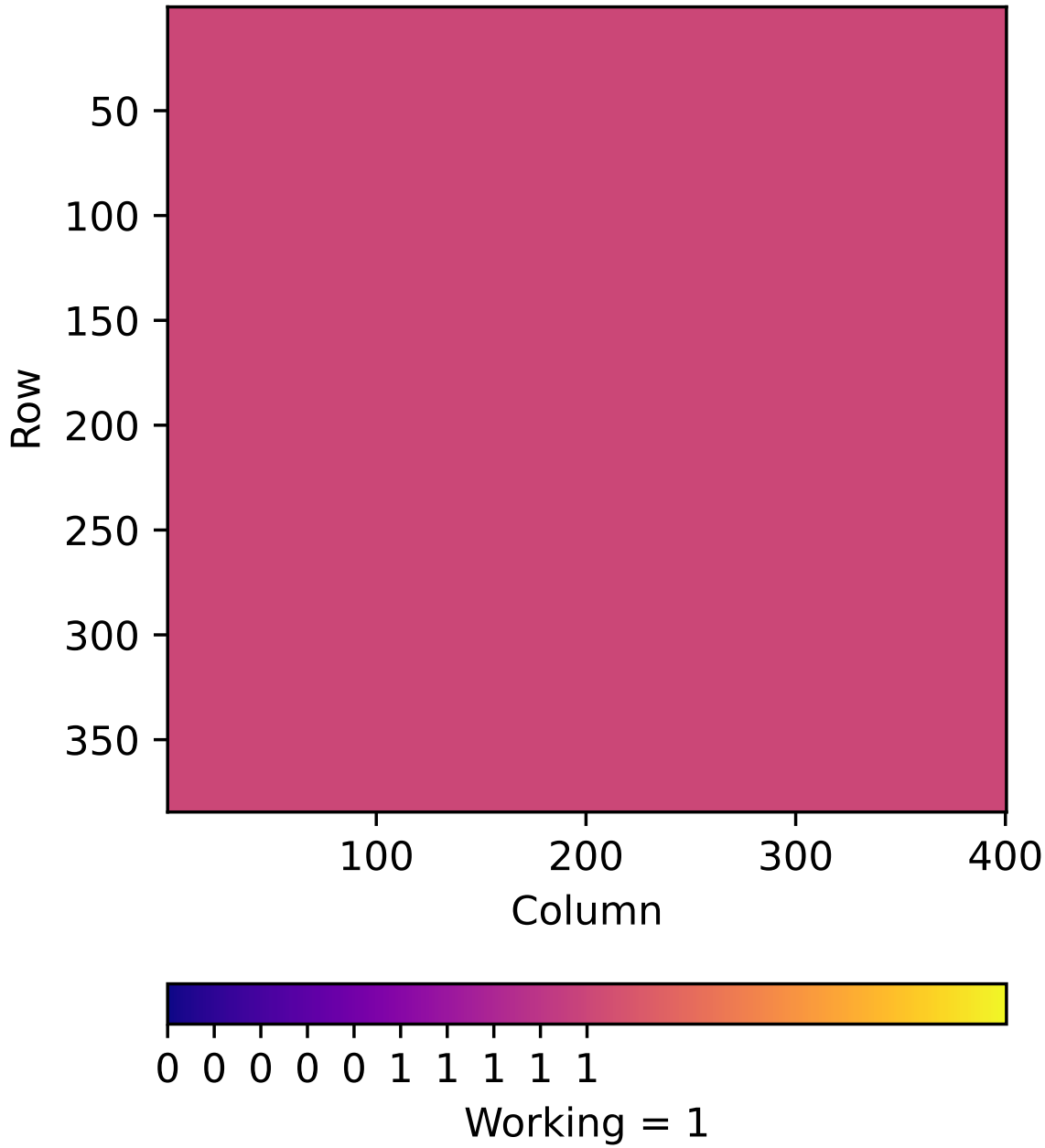
ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

Software version: Tag: v1.7
Changed files: bdaq53/scans/scan_in_time_threshold.py, bdaq53/scans/scan_injection_delay.py, bdaq53/system/bdaq53.py

ITKPixV1 preliminary

Chip S/N: 0x162BC

Map of Working Pixel Registers (Σ = 153600.0)



Digital Scan

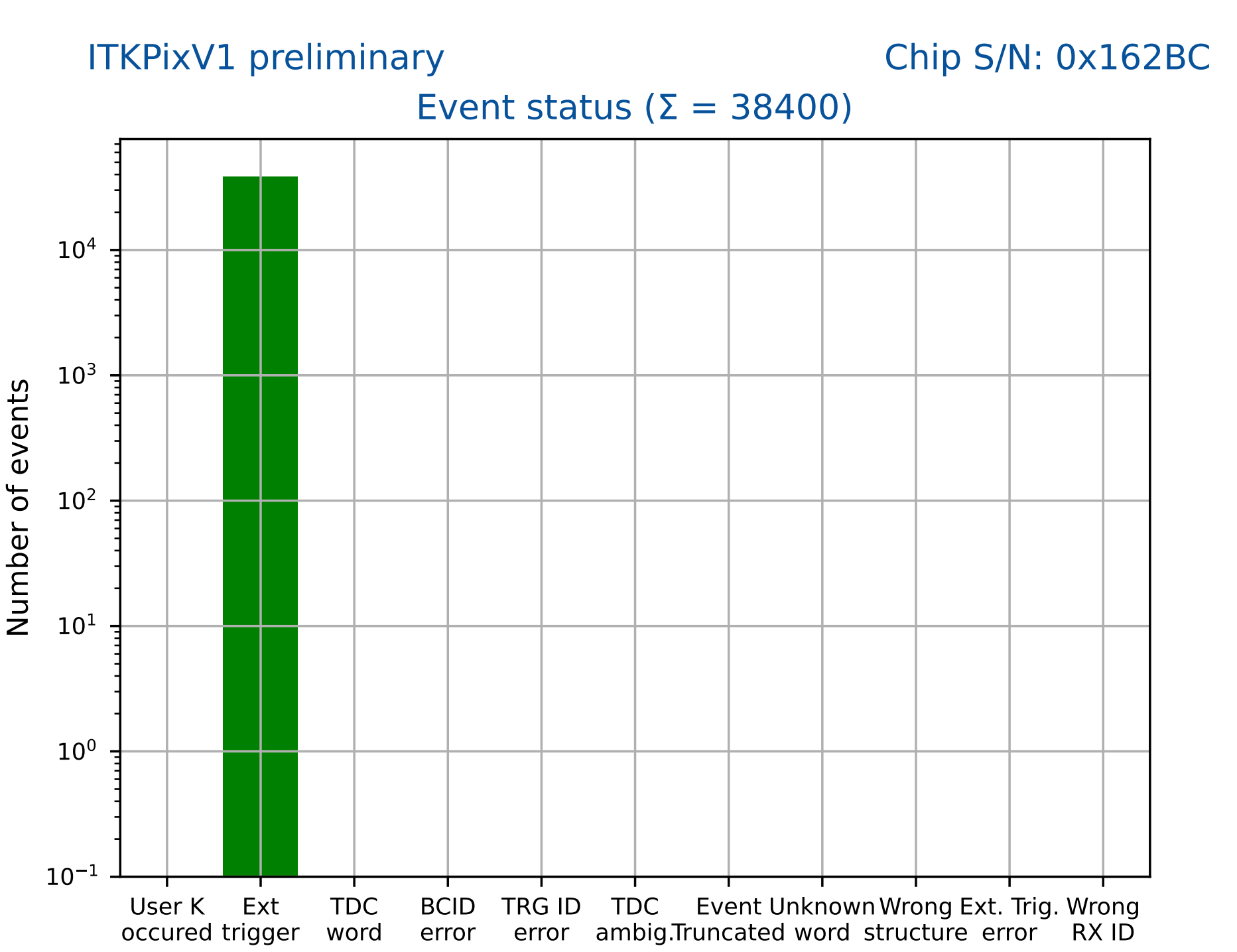
- Digital signal injected into every enabled pixel
- Only a few pixels are injected at once and the injection mask is shifted until all enabled pixels have been injected

This is a bdaq53 digital_scan for chip 0x162BC.
Run 20230208_145656_digital_scan was started 2023-02-08 14:56:56.

Scan config	Value
n_injections	100
start_column	0
start_row	0
stop_column	400
stop_row	192
trigger_pattern	0xffffffff

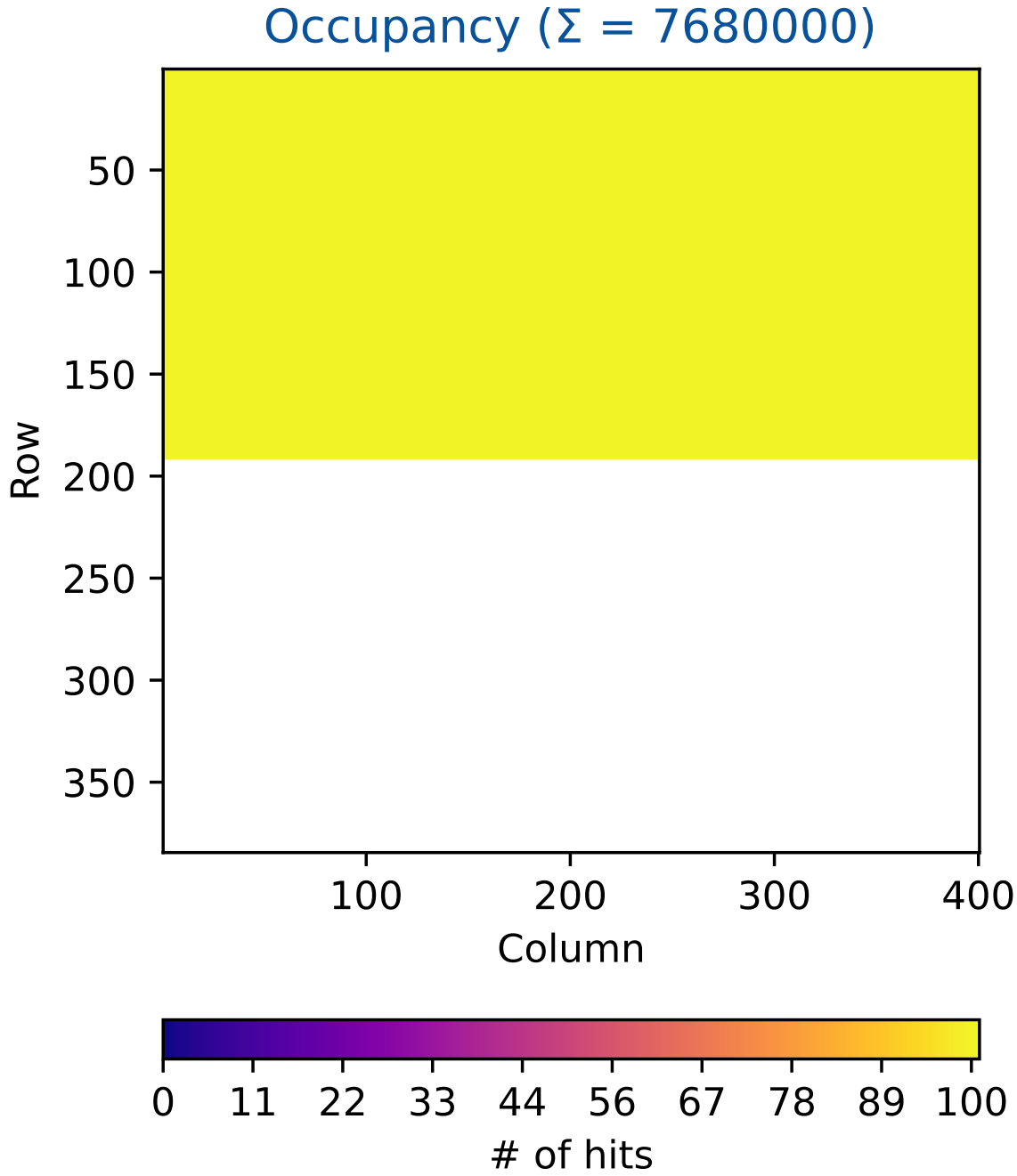
ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

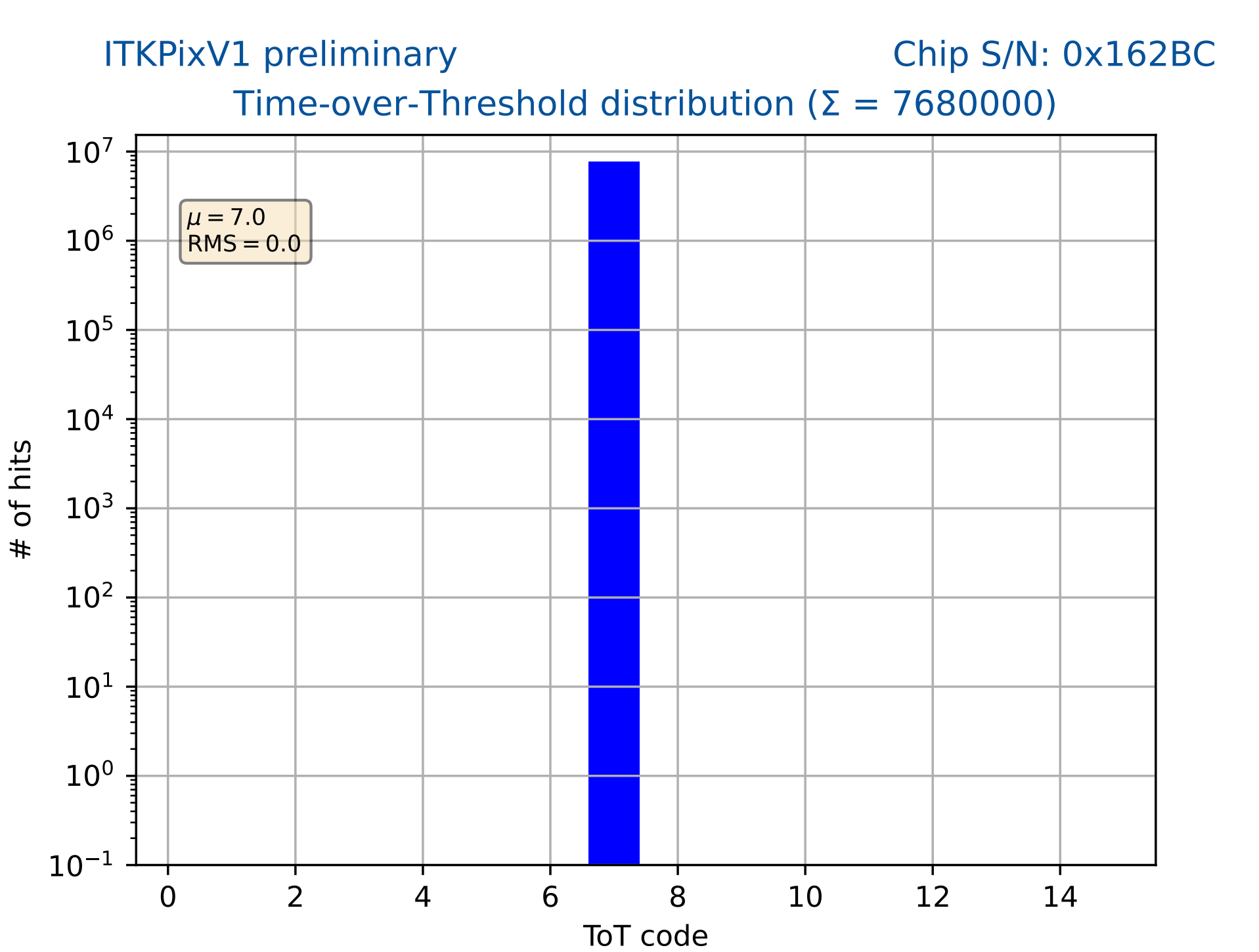
Software version: Tag: v1.7
Changed files: bdaq53/system/bdaq53.py


ITKPixV1 preliminary
Chip S/N: 0x162BC
Event status (Σ = 38400)
Number of events
10^4
10^3
10^2
10^1
10^0
10^{-1}
User K occured
Ext trigger
TDC word
BCID error
TRG ID error
TDC ambig.
Event Truncated
Unknown word
Wrong structure
Ext. Trig. error
Wrong RX ID

ITKPixV1 preliminary

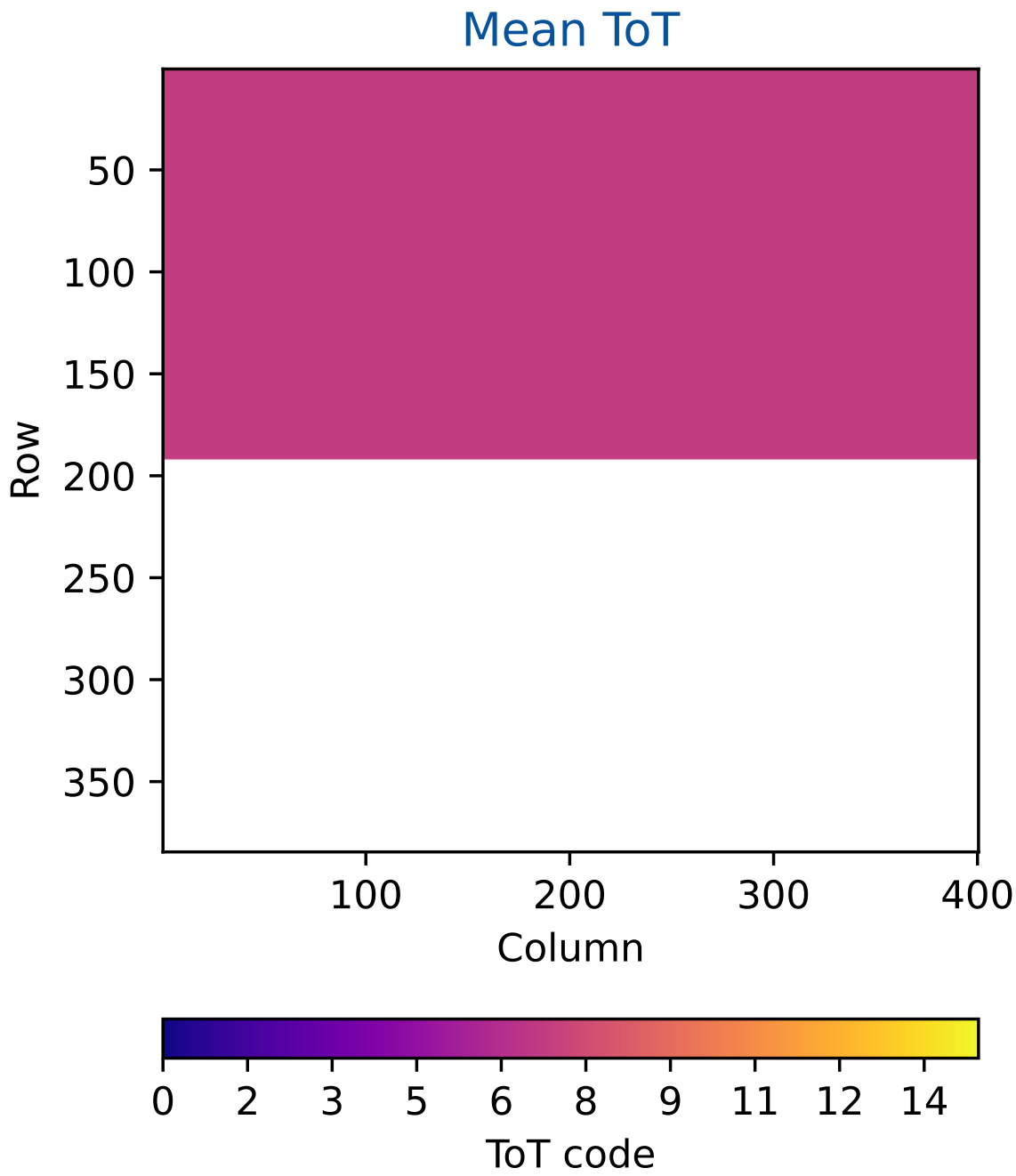
Chip S/N: 0x162BC

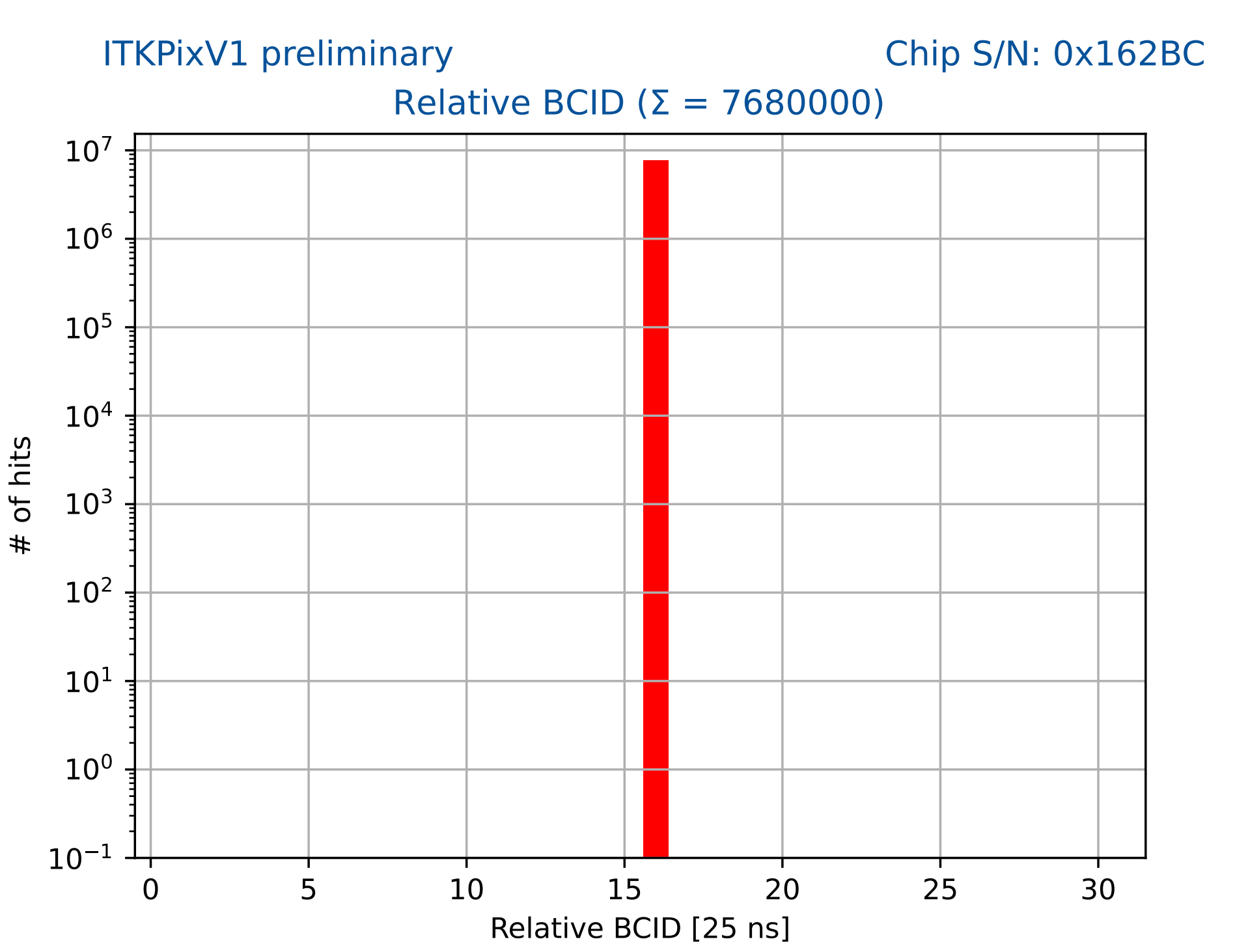



ITKPixV1 preliminary
Chip S/N: 0x162BC
Time-over-Threshold distribution (Σ = 7680000)
μ = 7.0
RMS = 0.0
# of hits
ToT code
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^−1
0
2
4
6
8
10
12
14

ITKPixV1 preliminary

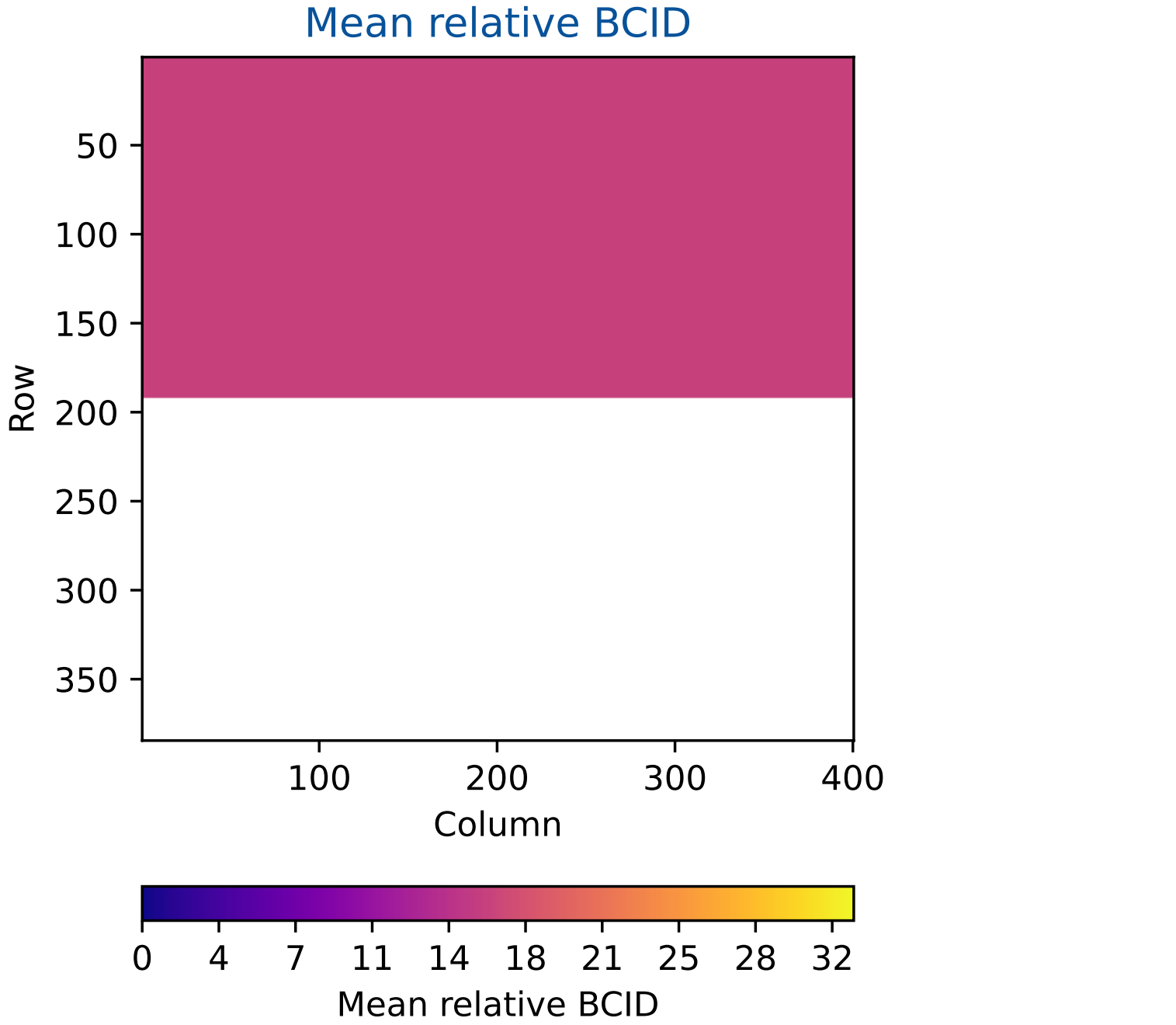
Chip S/N: 0x162BC

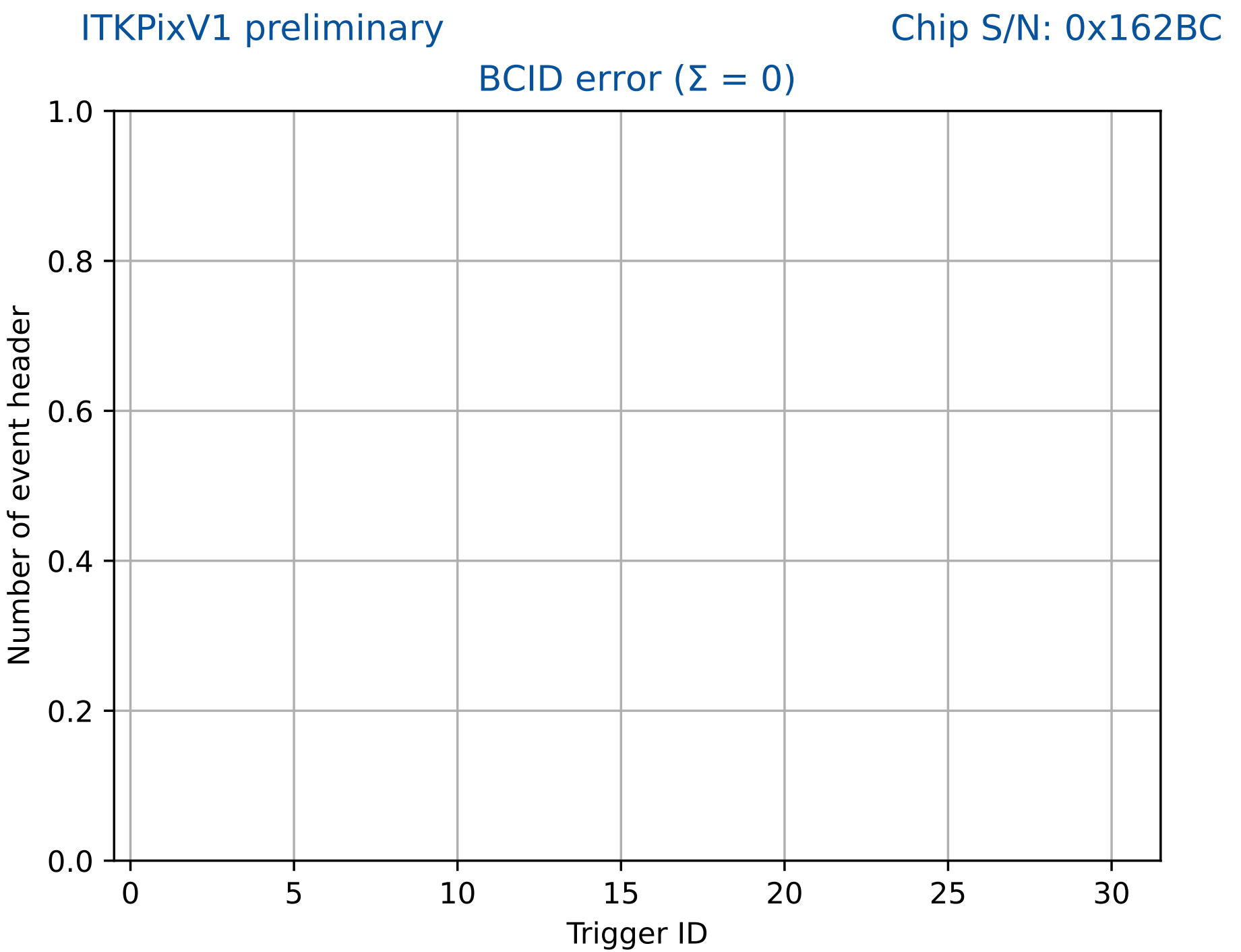



ITKPixV1 preliminary
Chip S/N: 0x162BC
Relative BCID (Σ = 7680000)
# of hits
Relative BCID [25 ns]
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
0
5
10
15
20
25
30

ITKPixV1 preliminary

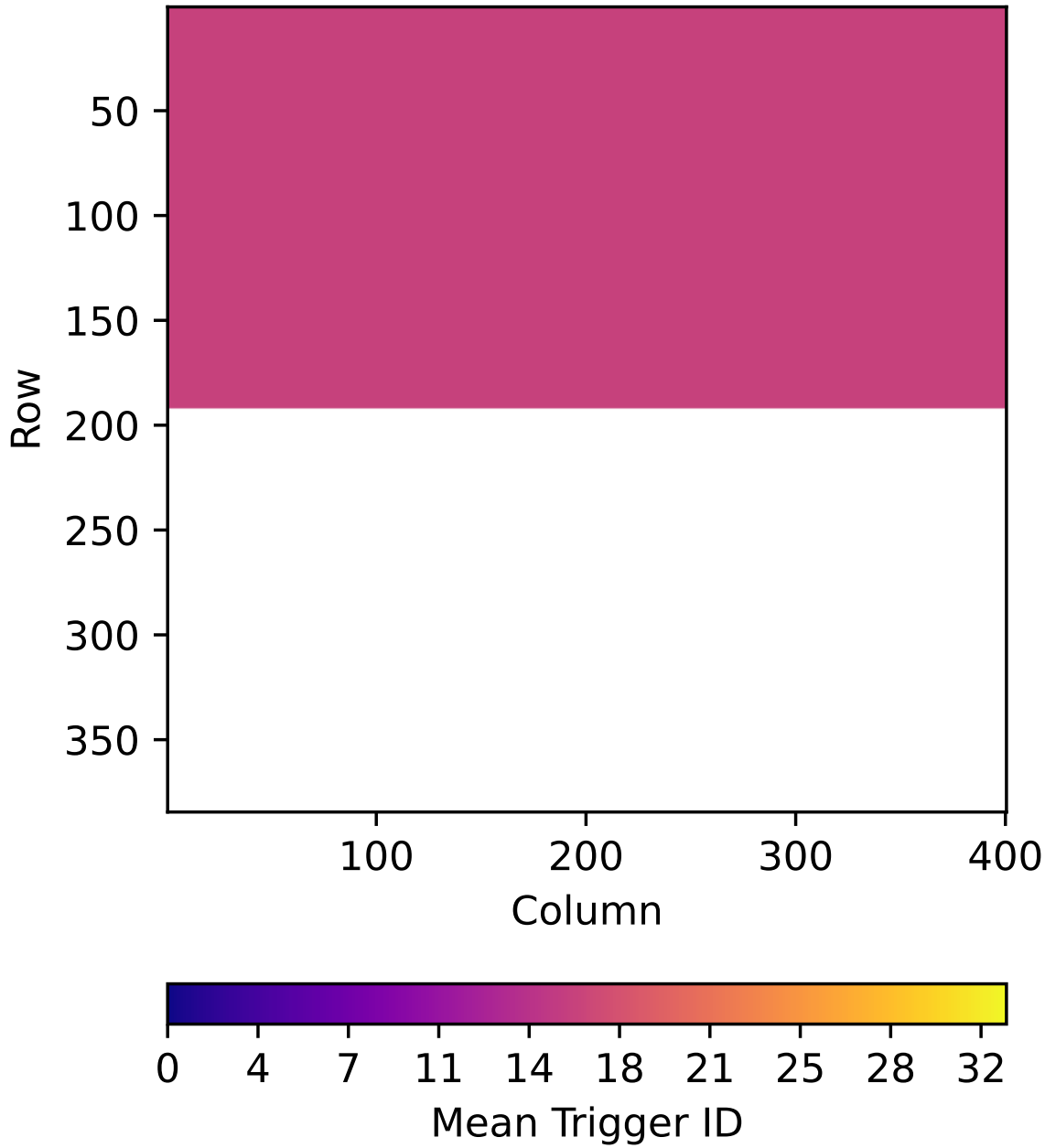
Chip S/N: 0x162BC




ITKPixV1 preliminary
Chip S/N: 0x162BC
BCID error (Σ = 0)
Number of event header
Trigger ID
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30

ITKPixV1 preliminary Chip S/N: 0x162BC

Trigger ID Histogram without Error correction



Analog Scan

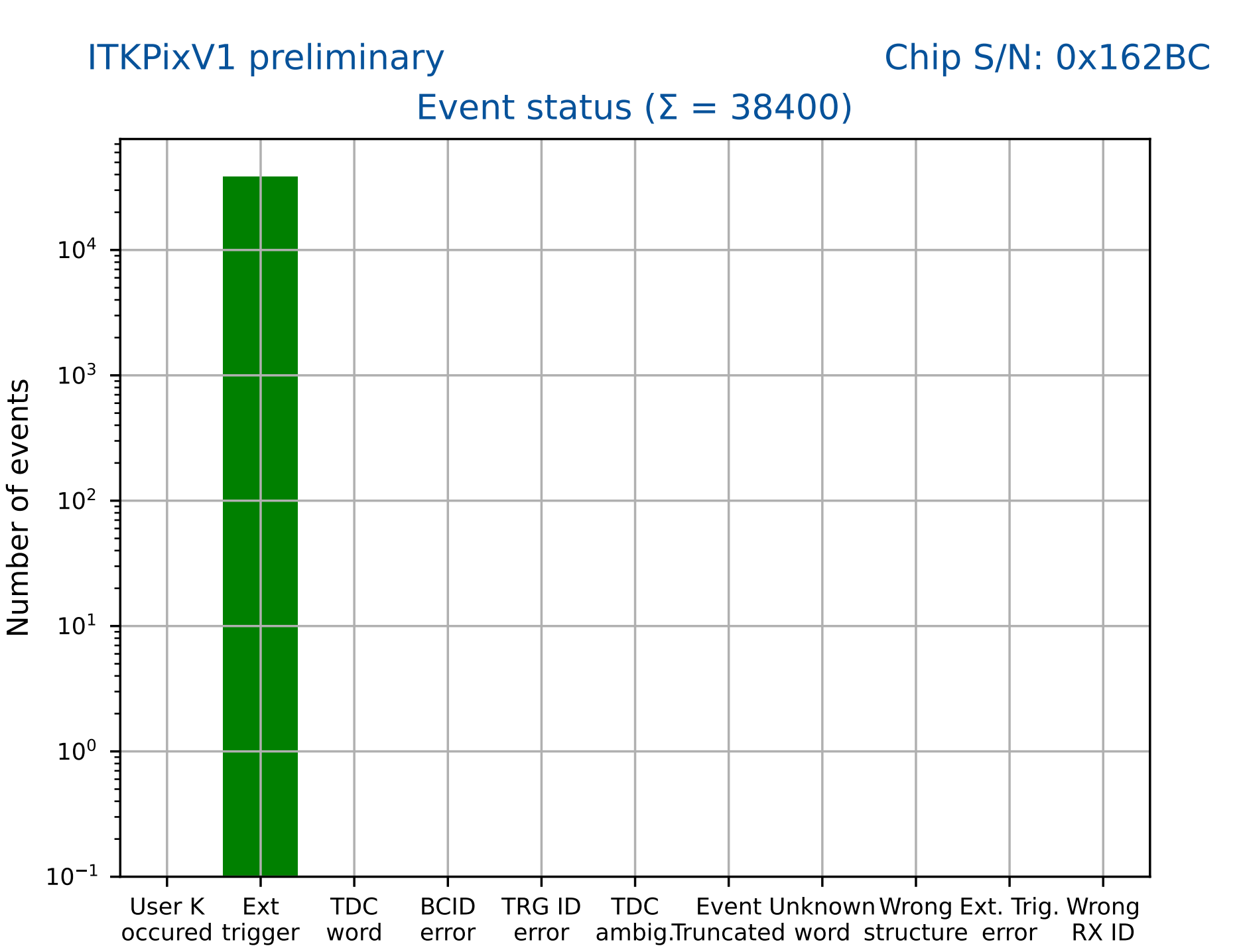
- Analog pulse injected into every enabled pixel
- Only a few pixels are injected at once and the injection mask is shifted until all enabled pixels have been injected

This is a bdaq53 analog_scan for chip 0x162BC.
Run 20230317_013841_analog_scan was started 2023-03-17 01:38:41.

Scan config	Value
VCAL_HIGH	1300
VCAL_MED	500
n_injections	100
start_column	0
start_row	0
stop_column	400
stop_row	192
trigger_pattern	0xffffffff

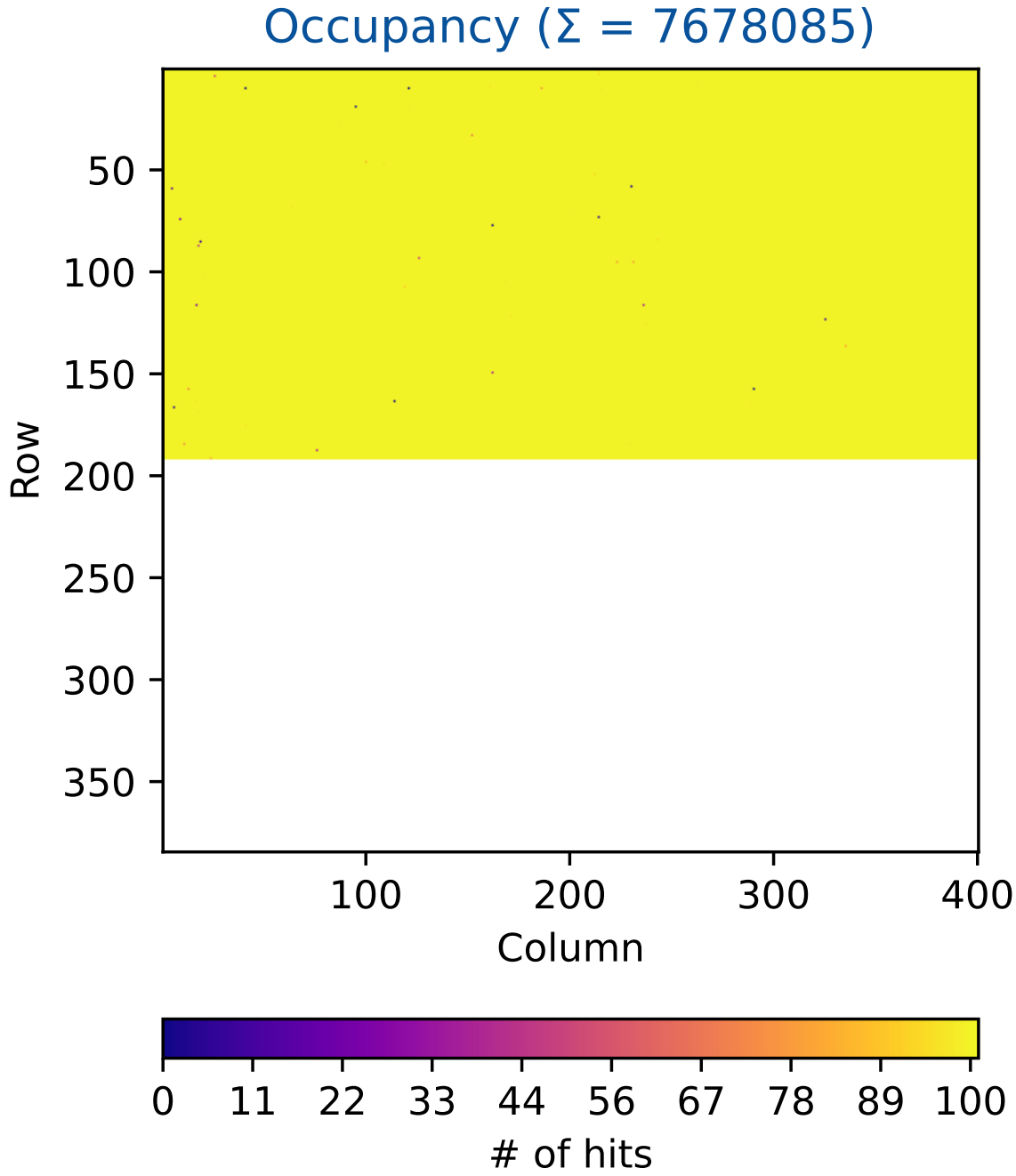
ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

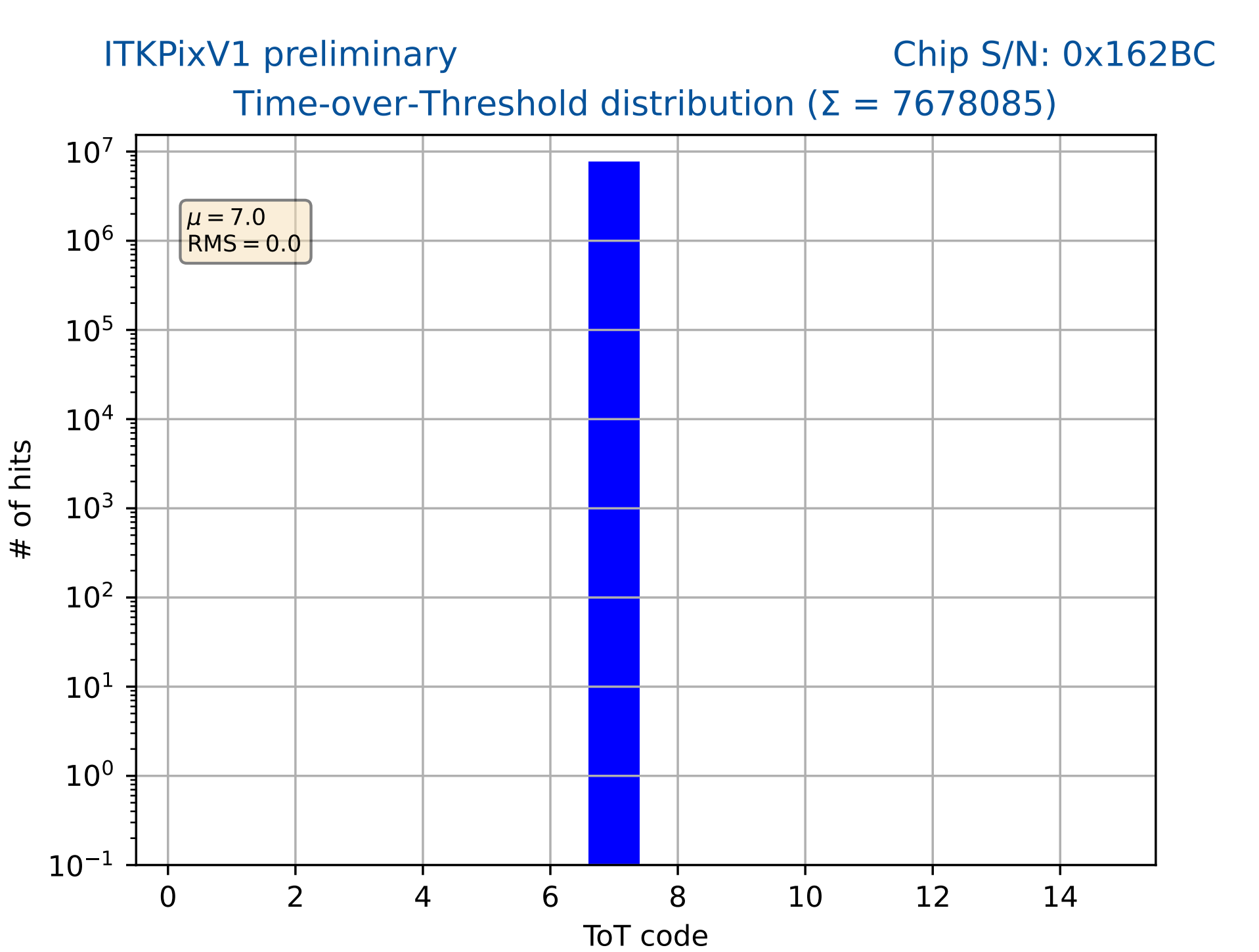
Software version: Tag: v1.7
Changed files: bdaq53/system/bdaq53.py


ITKPixV1 preliminary
Chip S/N: 0x162BC
Event status (Σ = 38400)
Number of events
10^4
10^3
10^2
10^1
10^0
10^{-1}
User K occured
Ext trigger
TDC word
BCID error
TRG ID error
TDC ambig.
Event Truncated
Unknown word
Wrong structure
Ext. Trig. error
Wrong RX ID

ITKPixV1 preliminary

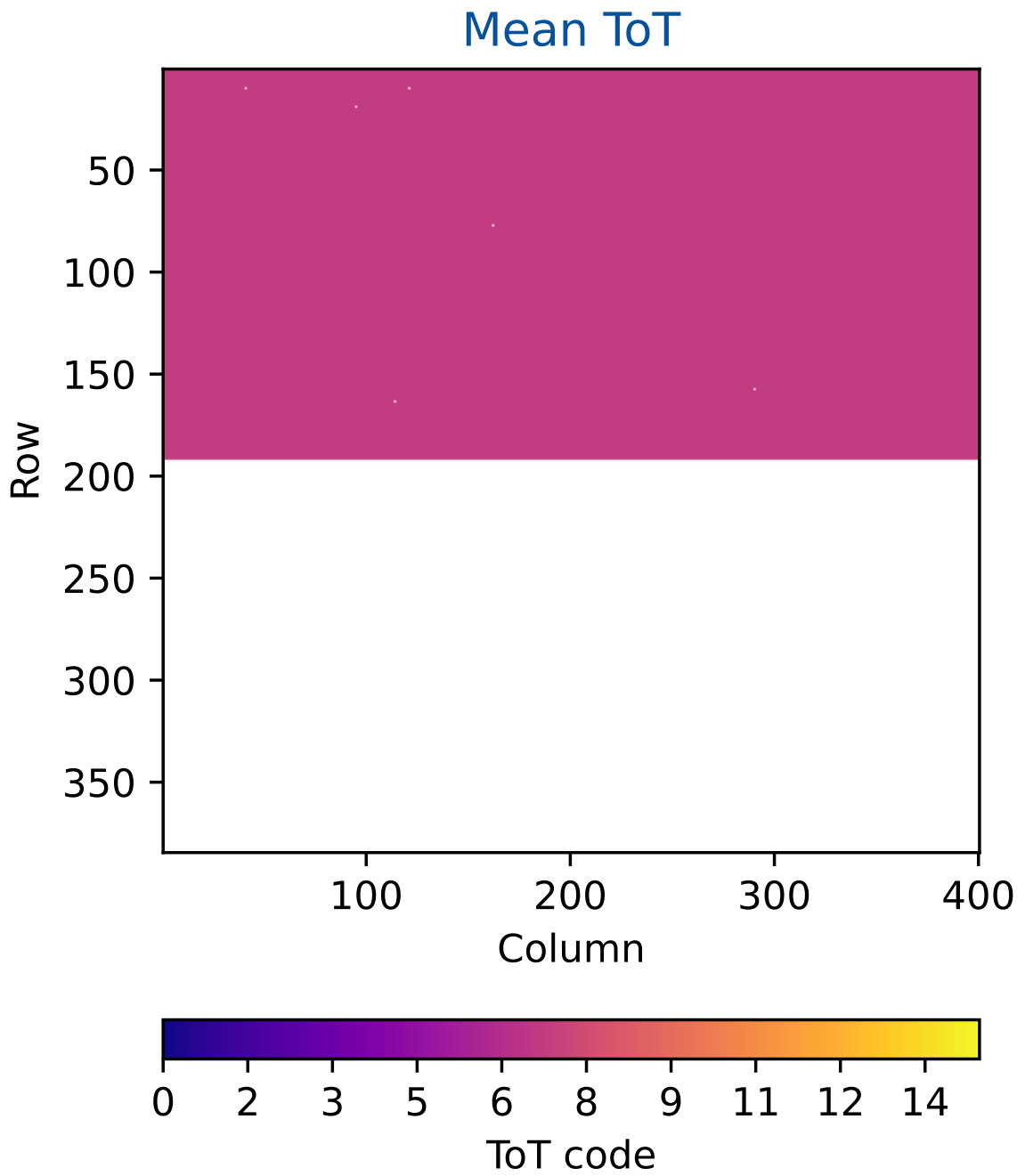
Chip S/N: 0x162BC

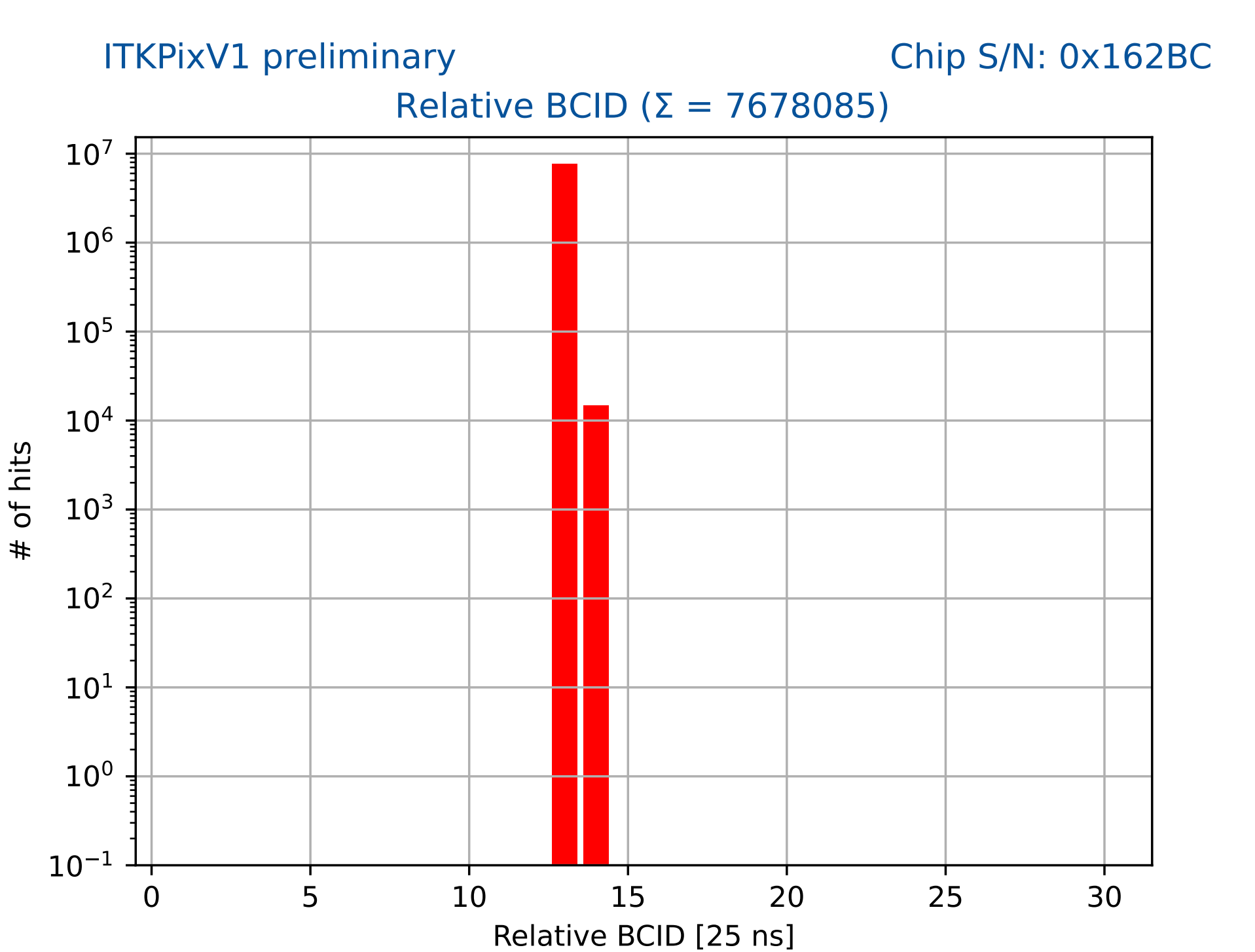



ITKPixV1 preliminary
Chip S/N: 0x162BC
Time-over-Threshold distribution (Σ = 7678085)
μ = 7.0
RMS = 0.0
# of hits
ToT code
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^−1
0
2
4
6
8
10
12
14

ITKPixV1 preliminary

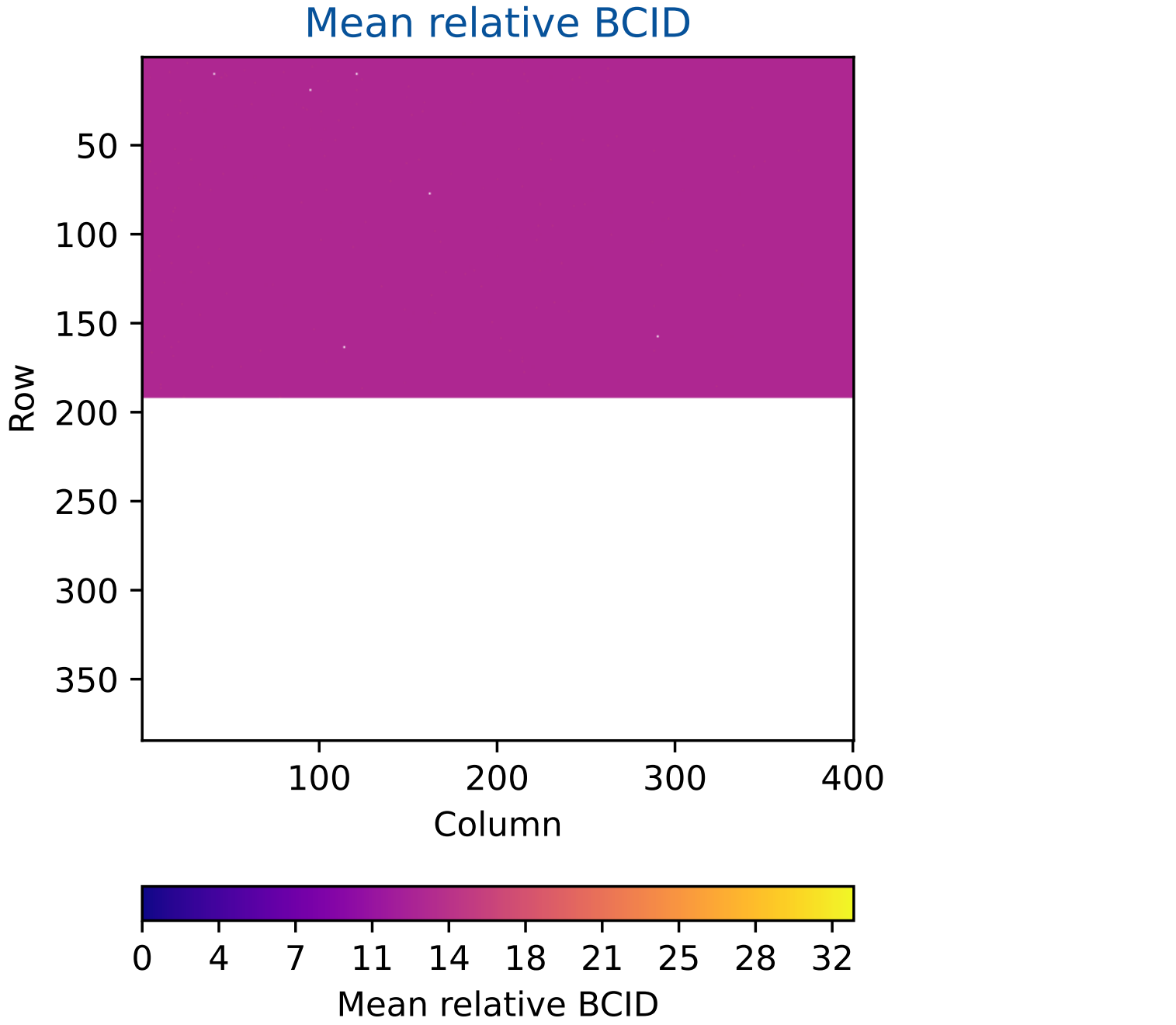
Chip S/N: 0x162BC

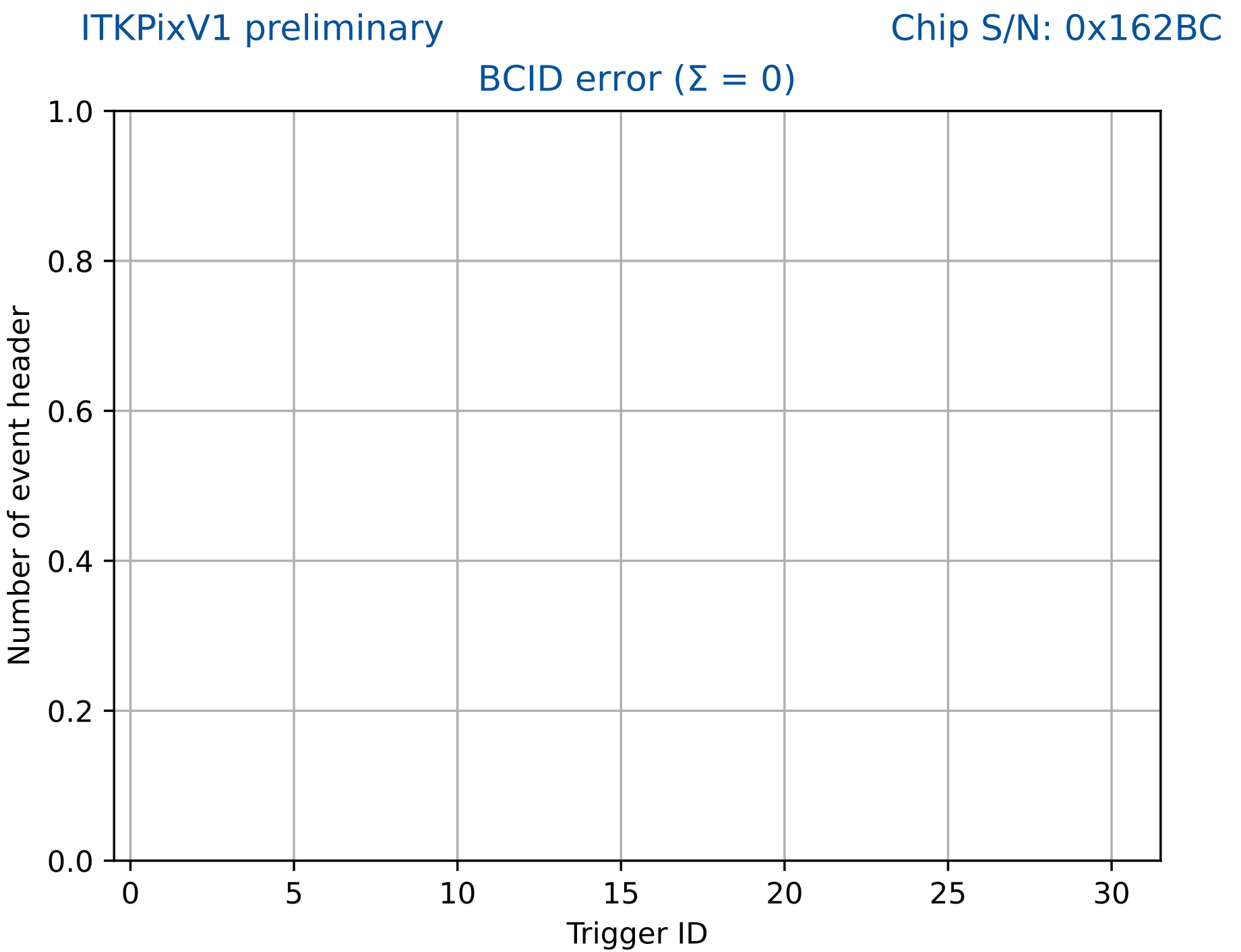



ITKPixV1 preliminary
Chip S/N: 0x162BC
Relative BCID (Σ = 7678085)
# of hits
Relative BCID [25 ns]
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
0
5
10
15
20
25
30

ITKPixV1 preliminary

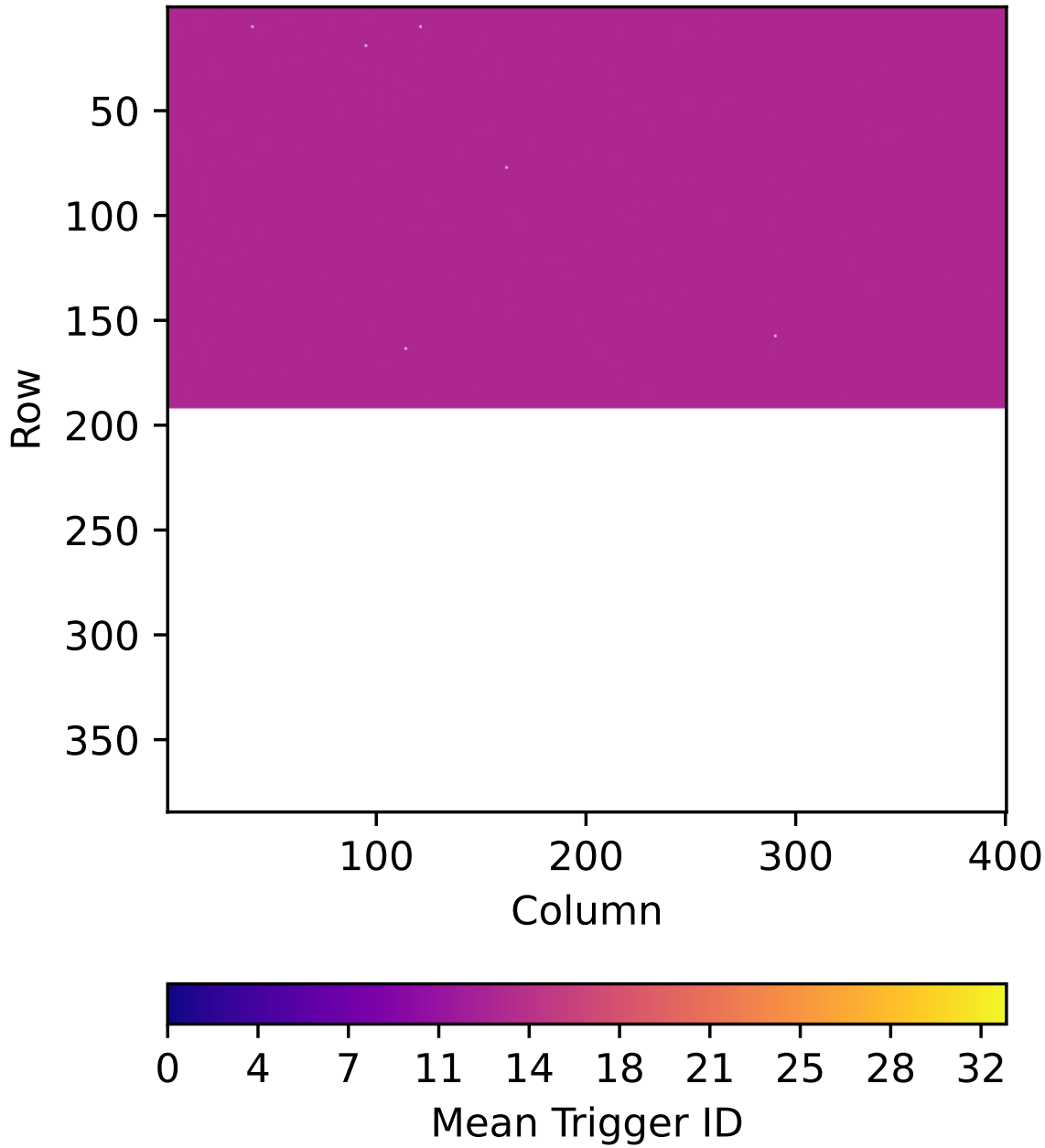
Chip S/N: 0x162BC

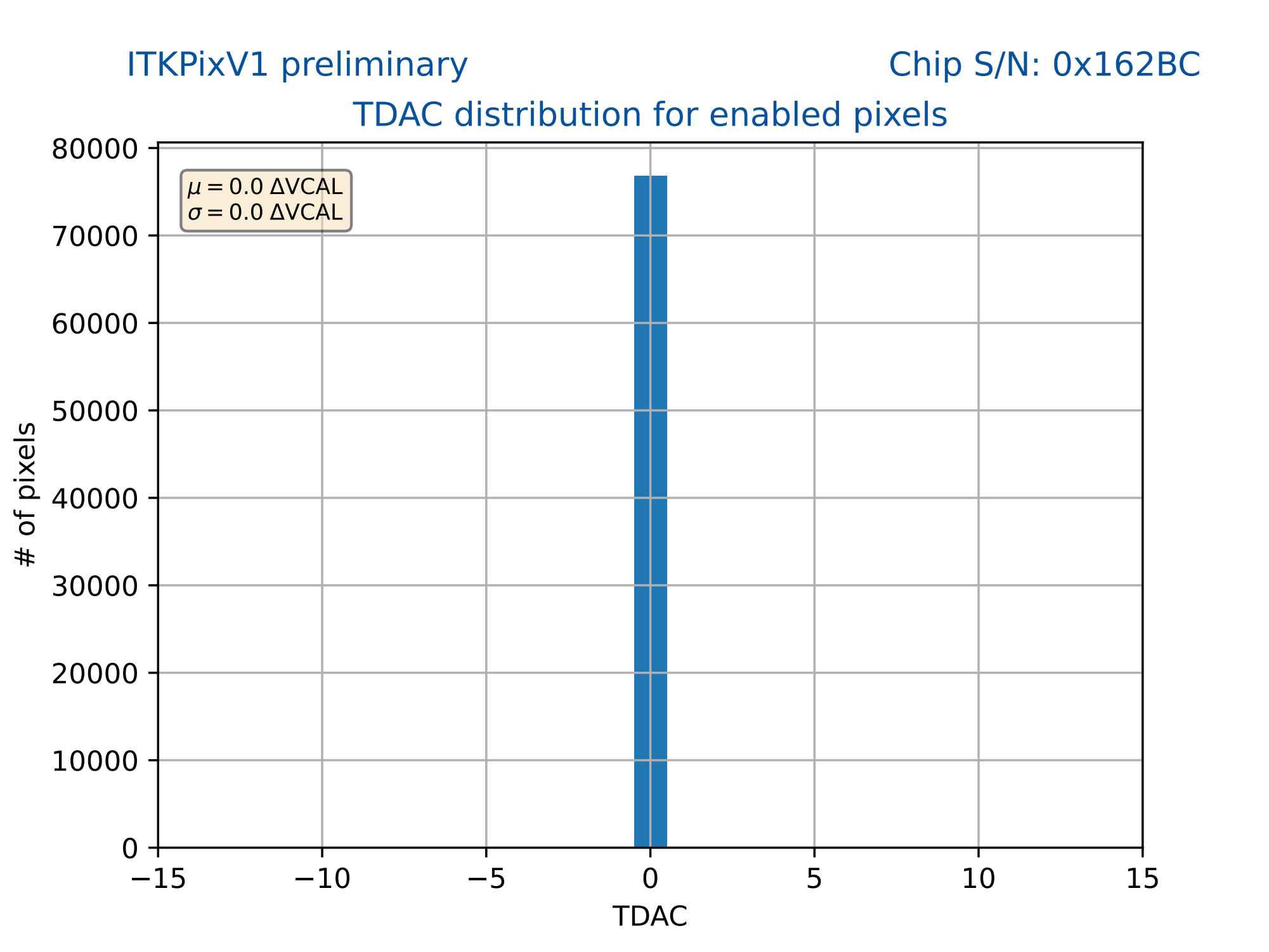


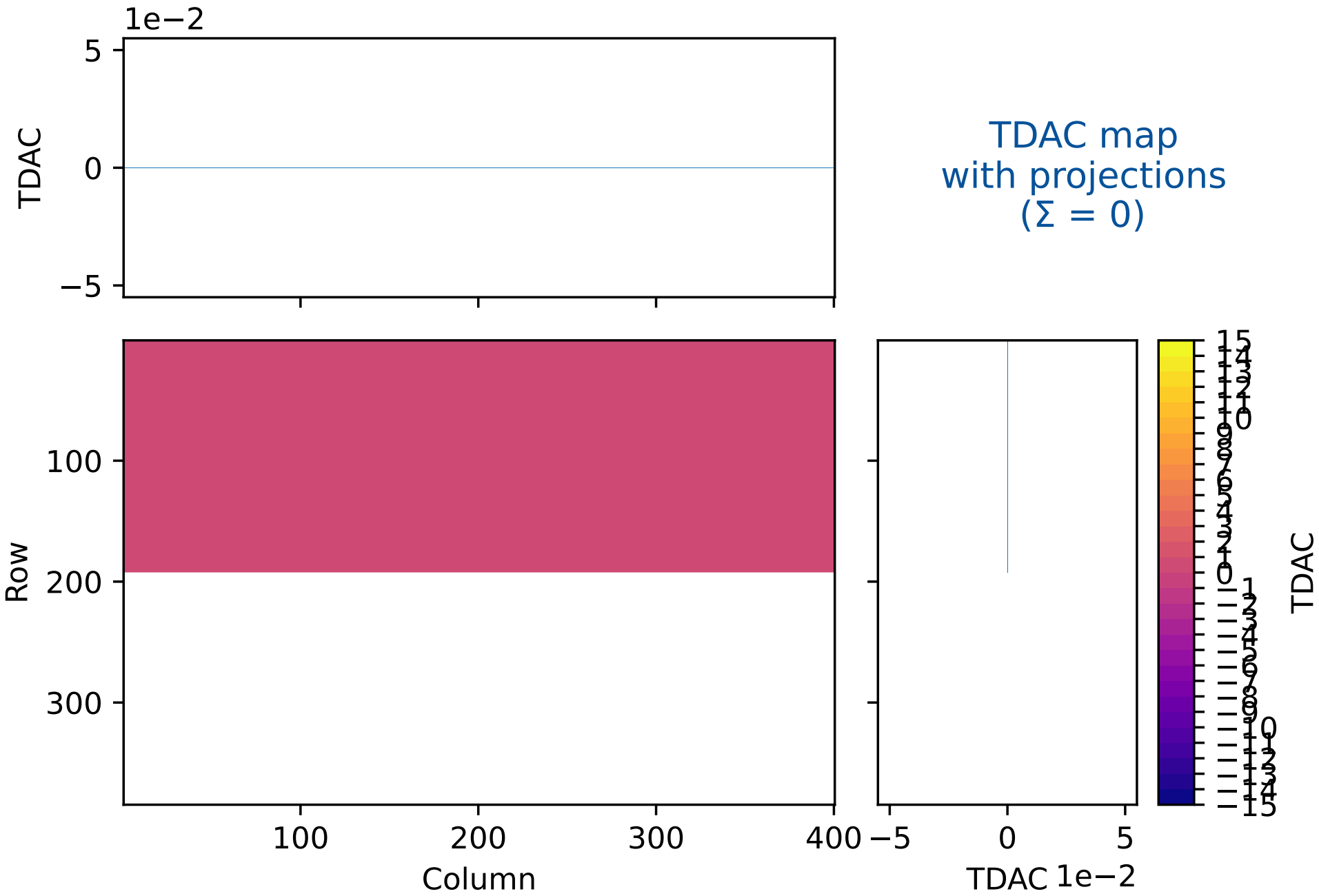

ITKPixV1 preliminary
Chip S/N: 0x162BC
BCID error (Σ = 0)
Number of event header
Trigger ID
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30

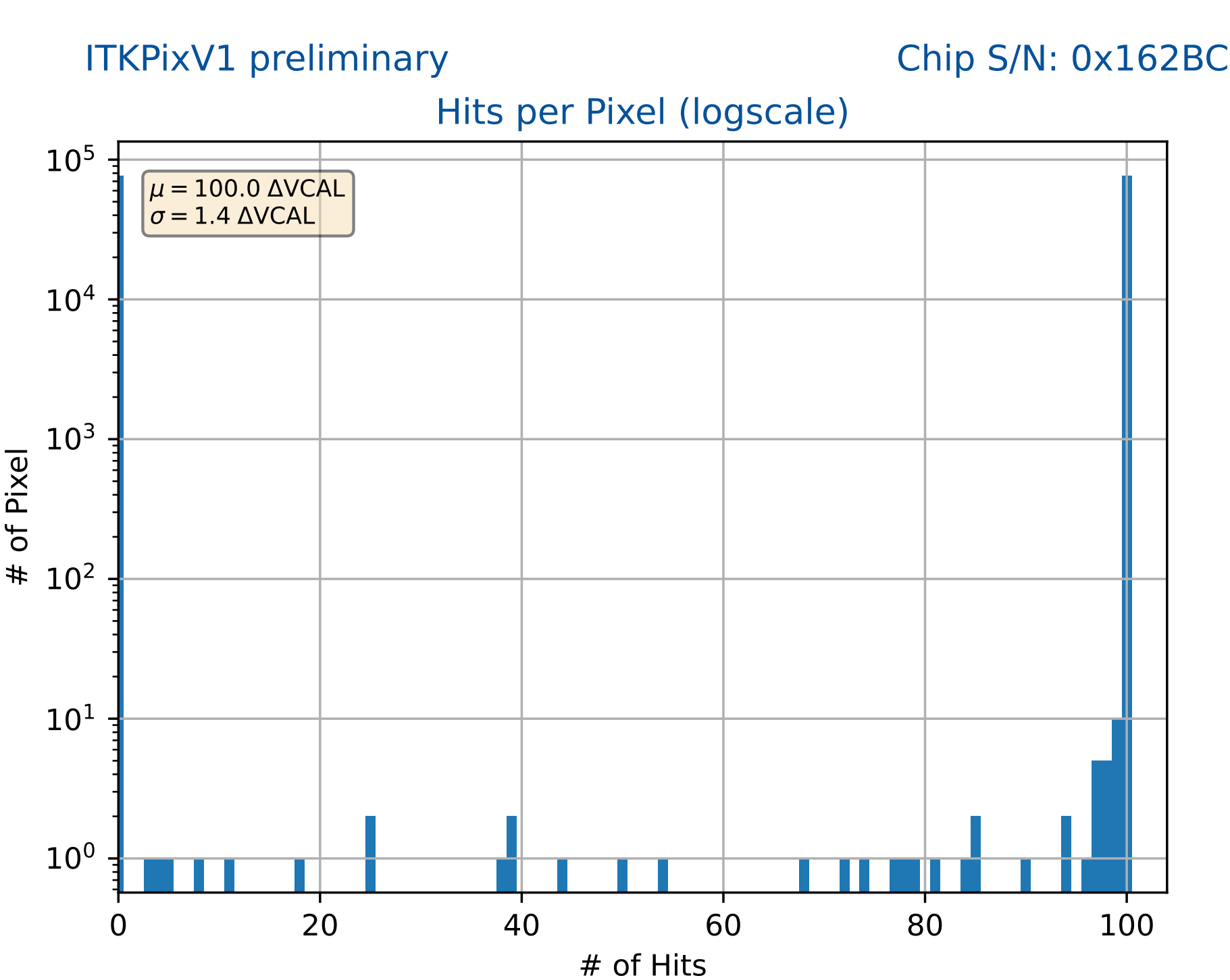
ITKPixV1 preliminary Chip S/N: 0x162BC

Trigger ID Histogram without Error correction




ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC distribution for enabled pixels
$\mu = 0.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
# of pixels
TDAC
80000
70000
60000
50000
40000
30000
20000
10000
0
−15
−10
−5
0
5
10
15


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC map
with projections
(Σ = 0)
1e−2
5
0
−5
TDAC
Row
100
200
300
Column
100
200
300
400
−5
0
5
TDAC
1e−2
TDAC
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0


ITKPixV1 preliminary
Chip S/N: 0x162BC
Hits per Pixel (logscale)
$\mu = 100.0$ ΔVCAL
$\sigma = 1.4$ ΔVCAL
# of Pixel
# of Hits
10^0
10^1
10^2
10^3
10^4
10^5
0
20
40
60
80
100

Threshold Scan

- Lower value of differential injection DAC is set to a fixed value, while the higher value is scanned over a defined range
- This yields the S-curves for every enabled pixel, which show the the amount of hits in a pixel at a given injection value
- From a fit to this curve, the threshold and noise of every pixel is determined

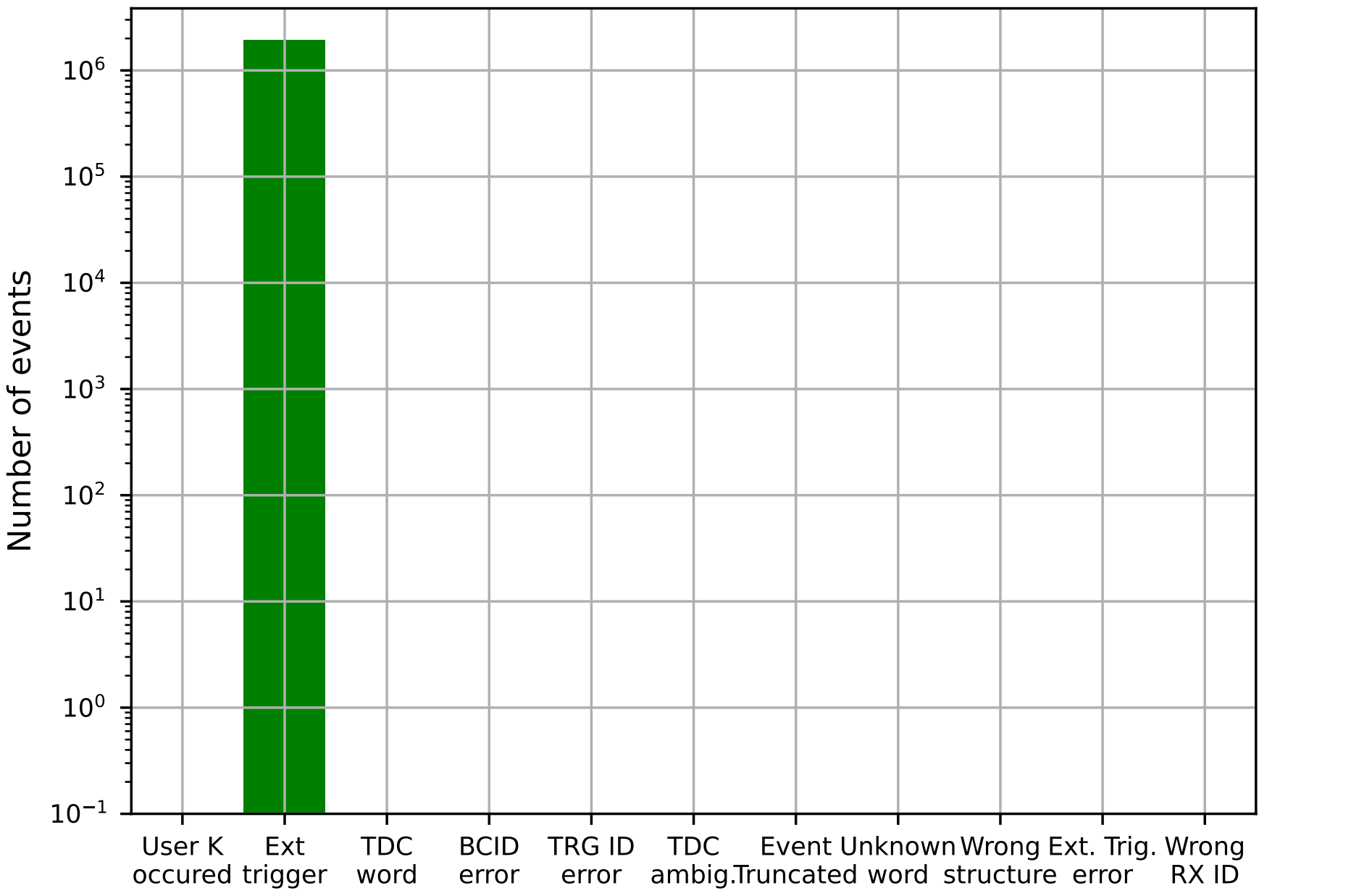
This is a bdaq53 threshold_scan for chip 0x162BC.
Run 20230317_024402_threshold_scan was started 2023-03-17 02:44:02.

Scan config	Value
VCAL_HIGH_start	700
VCAL_HIGH_step	10
VCAL_HIGH_stop	1200
VCAL_MED	500
n_injections	100
start_column	128
start_row	0
stop_column	264
stop_row	192
trigger_pattern	0xffffffff

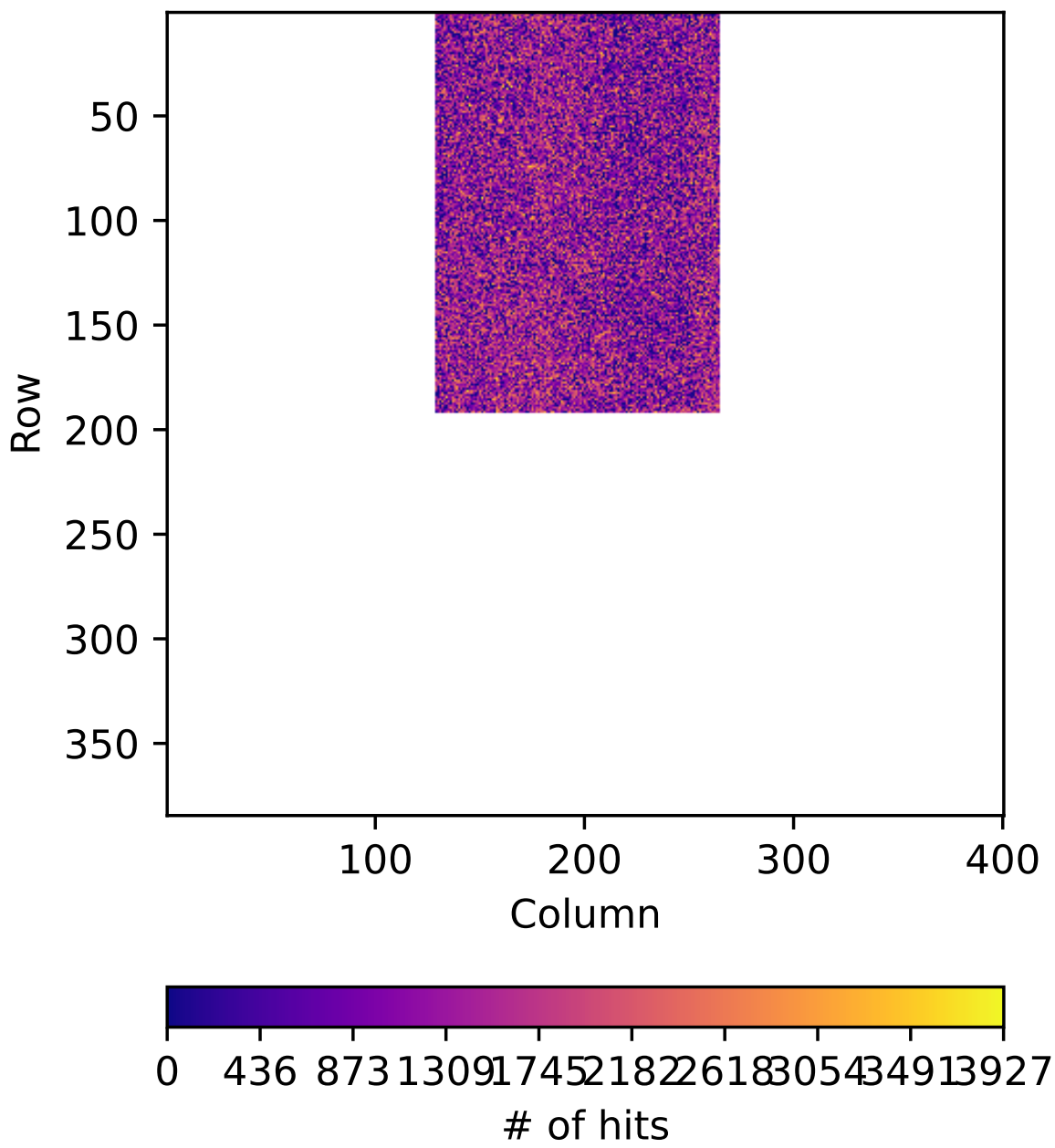
ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

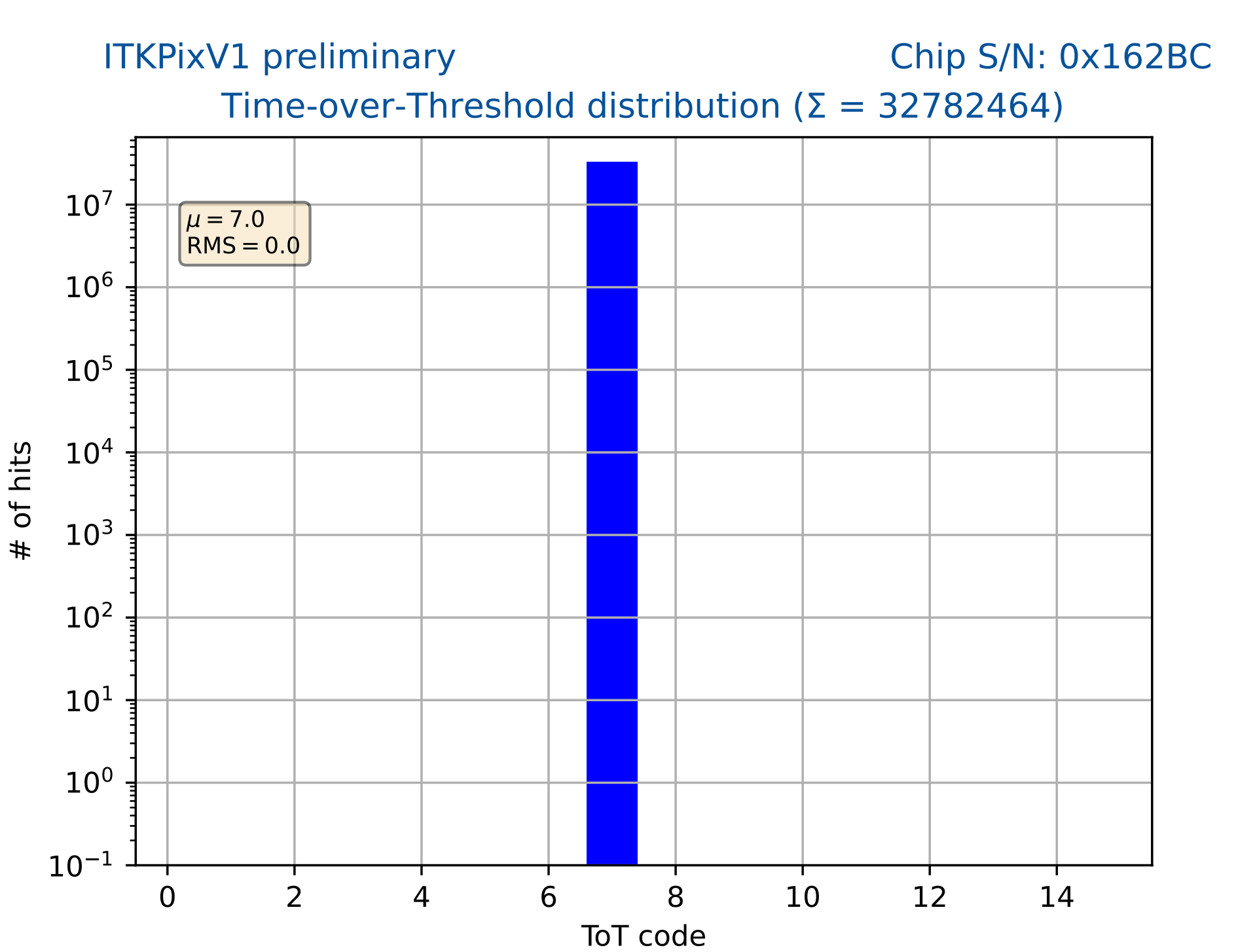
Charge calibration: $y\,[e^-] = x\,[\Delta VCAL] \cdot (4.65 \pm 0.40)\,[\frac{e^-}{\Delta VCAL}] + (0 \pm 60.00)\,[e^-]$

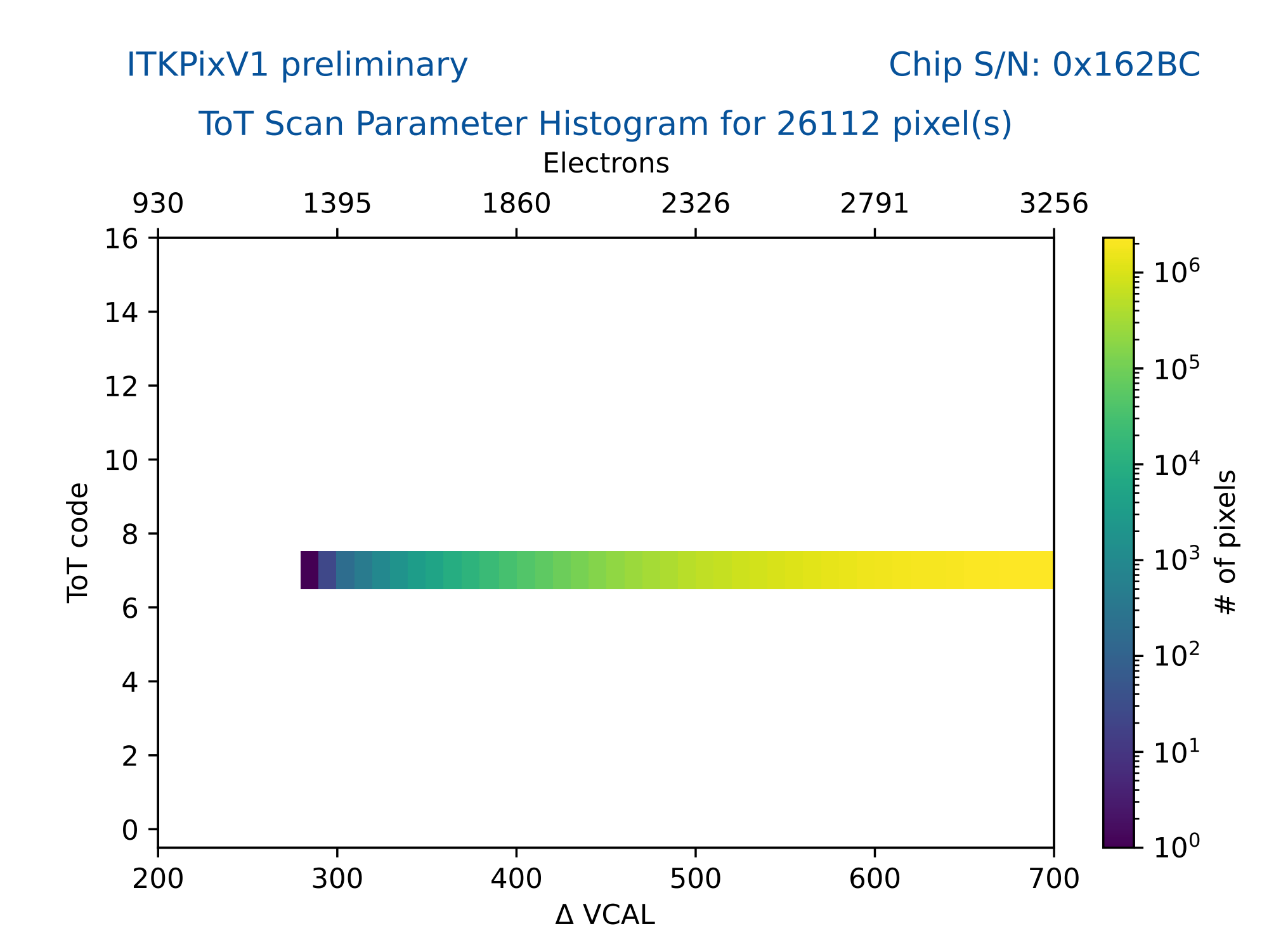
Software version: Tag: v1.7
Changed files: bdaq53/scans/scan_in_time_threshold.py, bdaq53/scans/scan_injection_delay.py, bdaq53/system/bdaq53.py


ITKPixV1 preliminary
Chip S/N: 0x162BC
Event status (Σ = 1920000)
Number of events
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
User K occured
Ext trigger
TDC word
BCID error
TRG ID error
TDC ambig.
Event Truncated
Unknown word
Wrong structure
Ext. Trig. error
Wrong RX ID

ITKPixV1 preliminary Chip S/N: 0x162BC

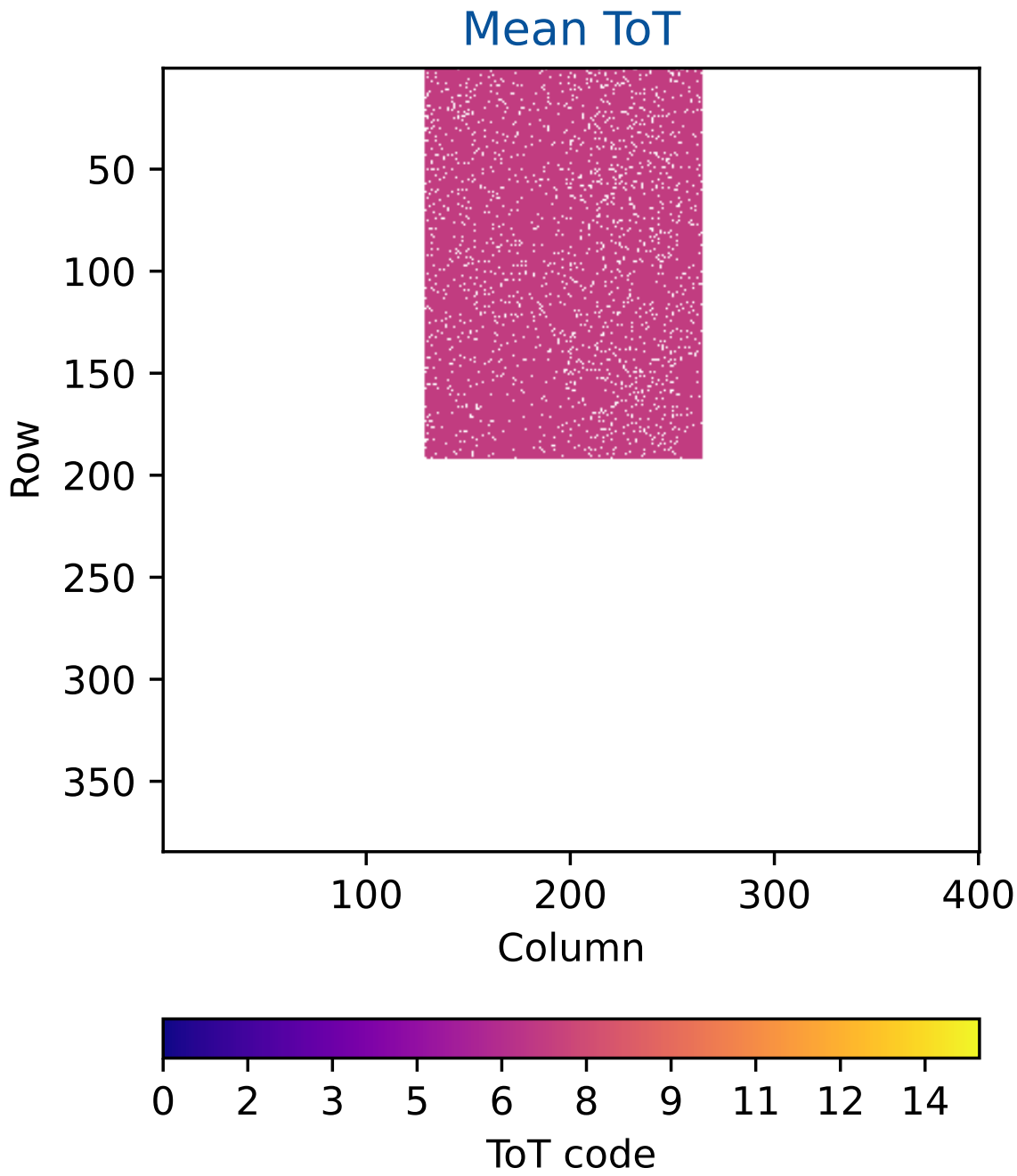


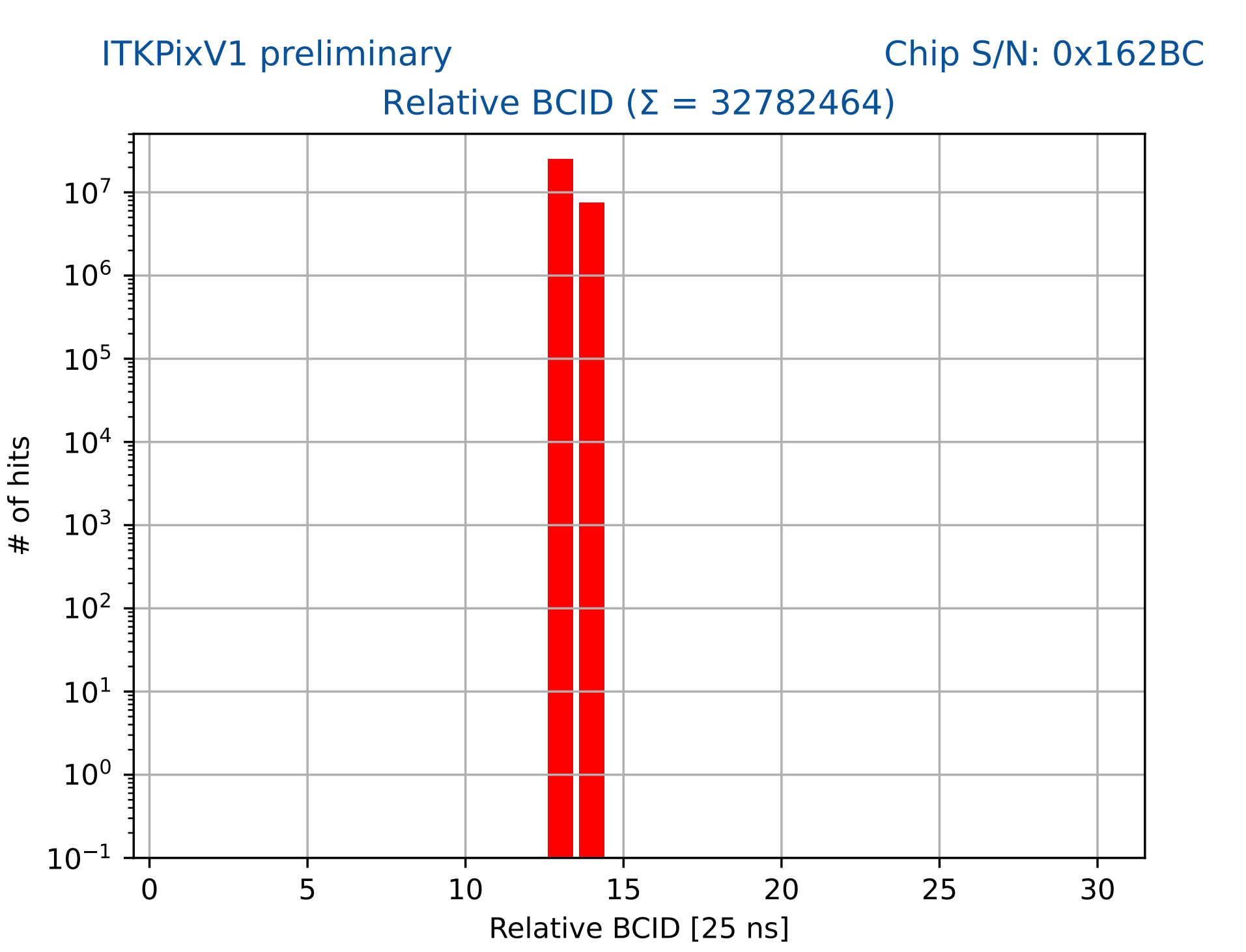

ITKPixV1 preliminary
Chip S/N: 0x162BC
Time-over-Threshold distribution (Σ = 32782464)
μ = 7.0
RMS = 0.0
# of hits
ToT code
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^−1
0
2
4
6
8
10
12
14


ITKPixV1 preliminary
Chip S/N: 0x162BC
ToT Scan Parameter Histogram for 26112 pixel(s)
Electrons
930
1395
1860
2326
2791
3256
ToT code
16
14
12
10
8
6
4
2
0
200
300
400
500
600
700
Δ VCAL
# of pixels
10^6
10^5
10^4
10^3
10^2
10^1
10^0

ITKPixV1 preliminary

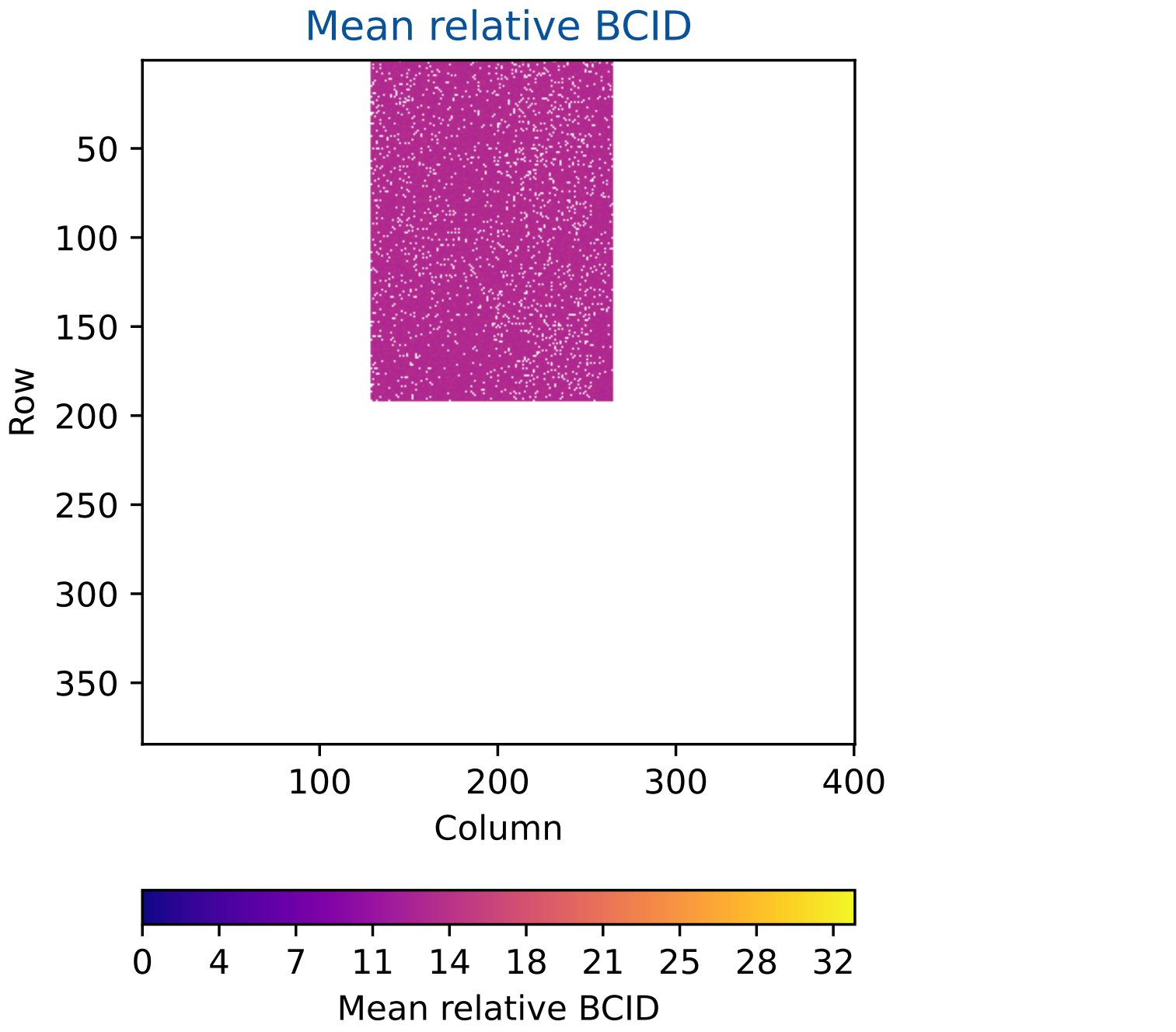
Chip S/N: 0x162BC

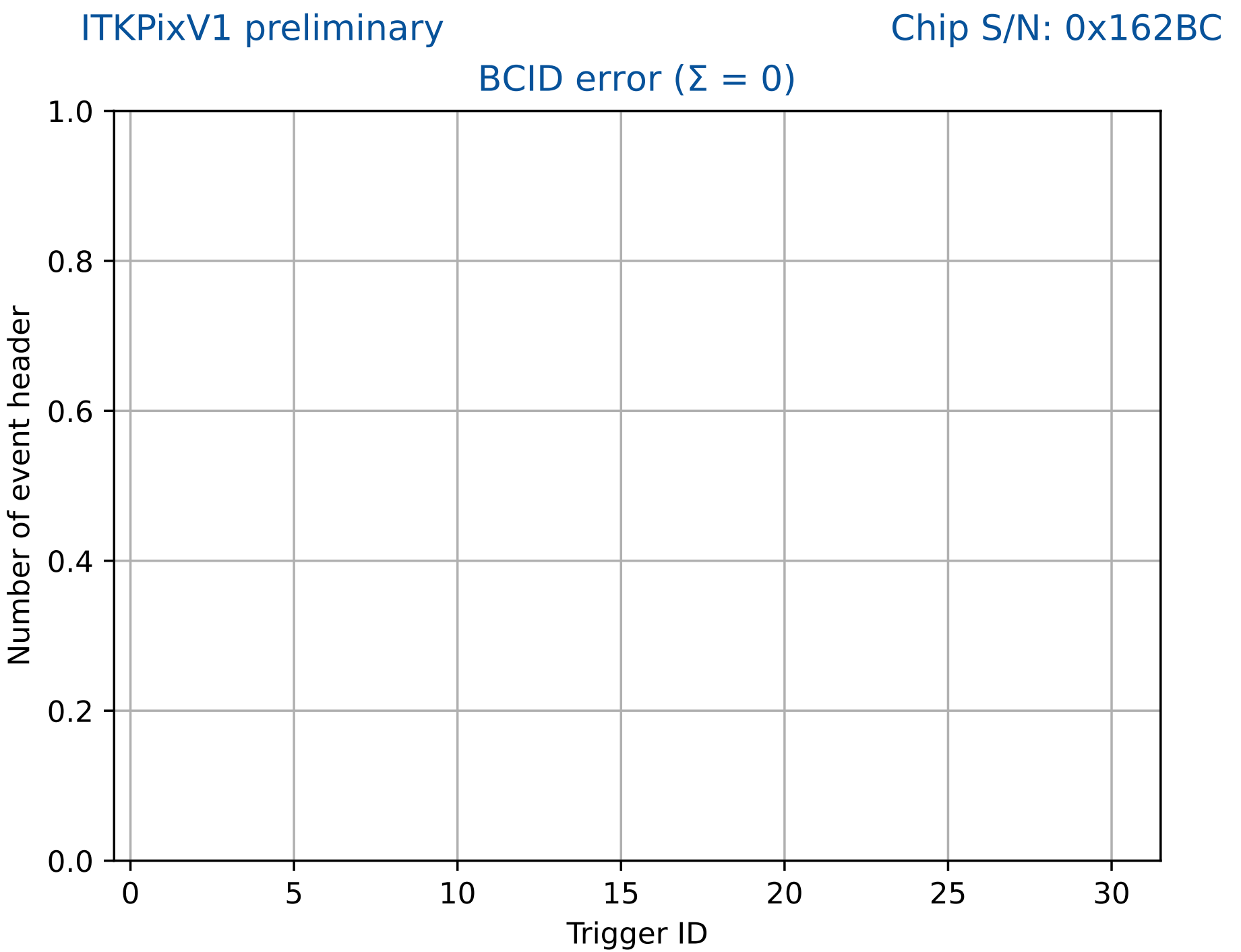



ITKPixV1 preliminary
Chip S/N: 0x162BC
Relative BCID (Σ = 32782464)
# of hits
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
0
5
10
15
20
25
30
Relative BCID [25 ns]

ITKPixV1 preliminary

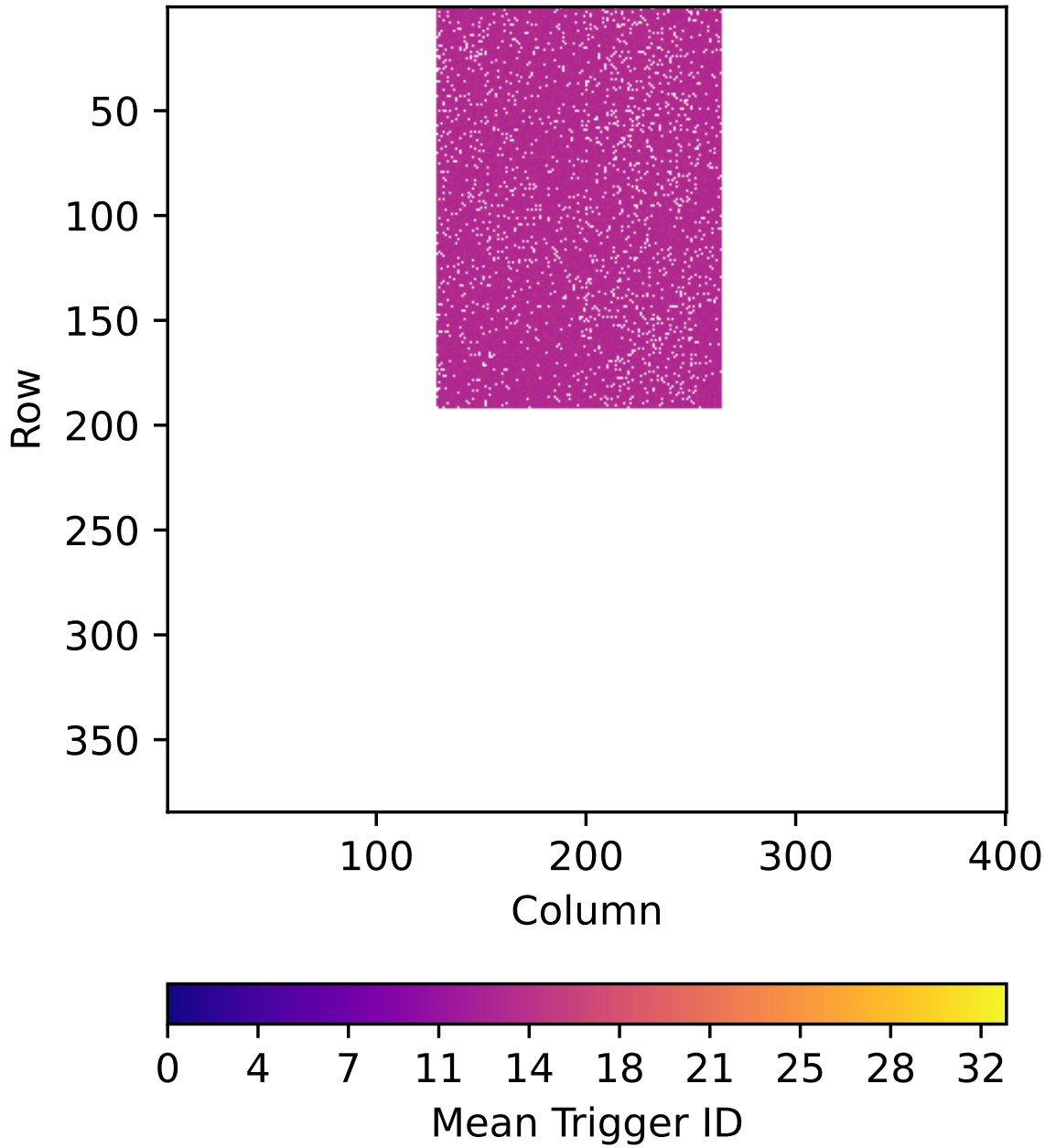
Chip S/N: 0x162BC

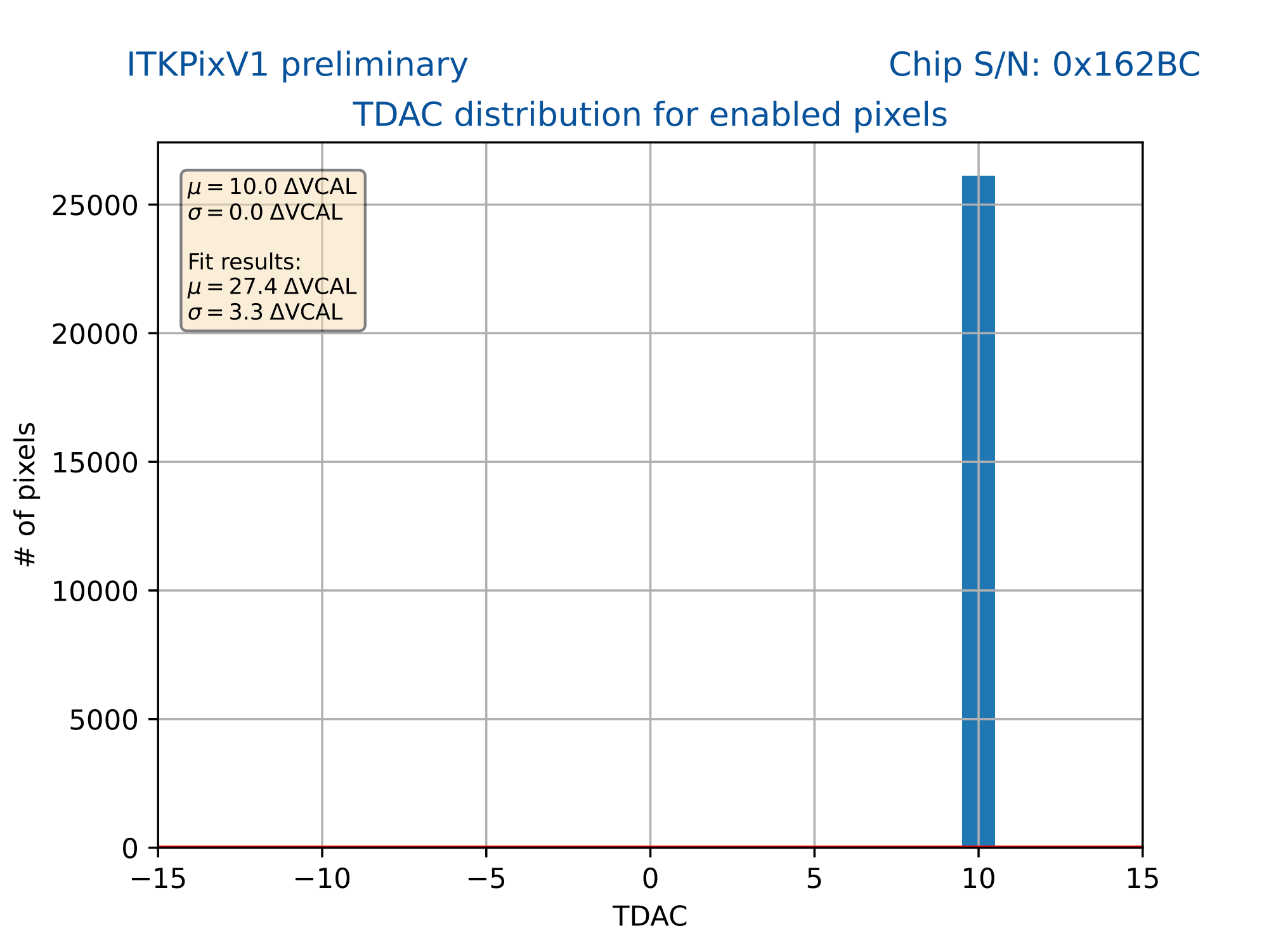


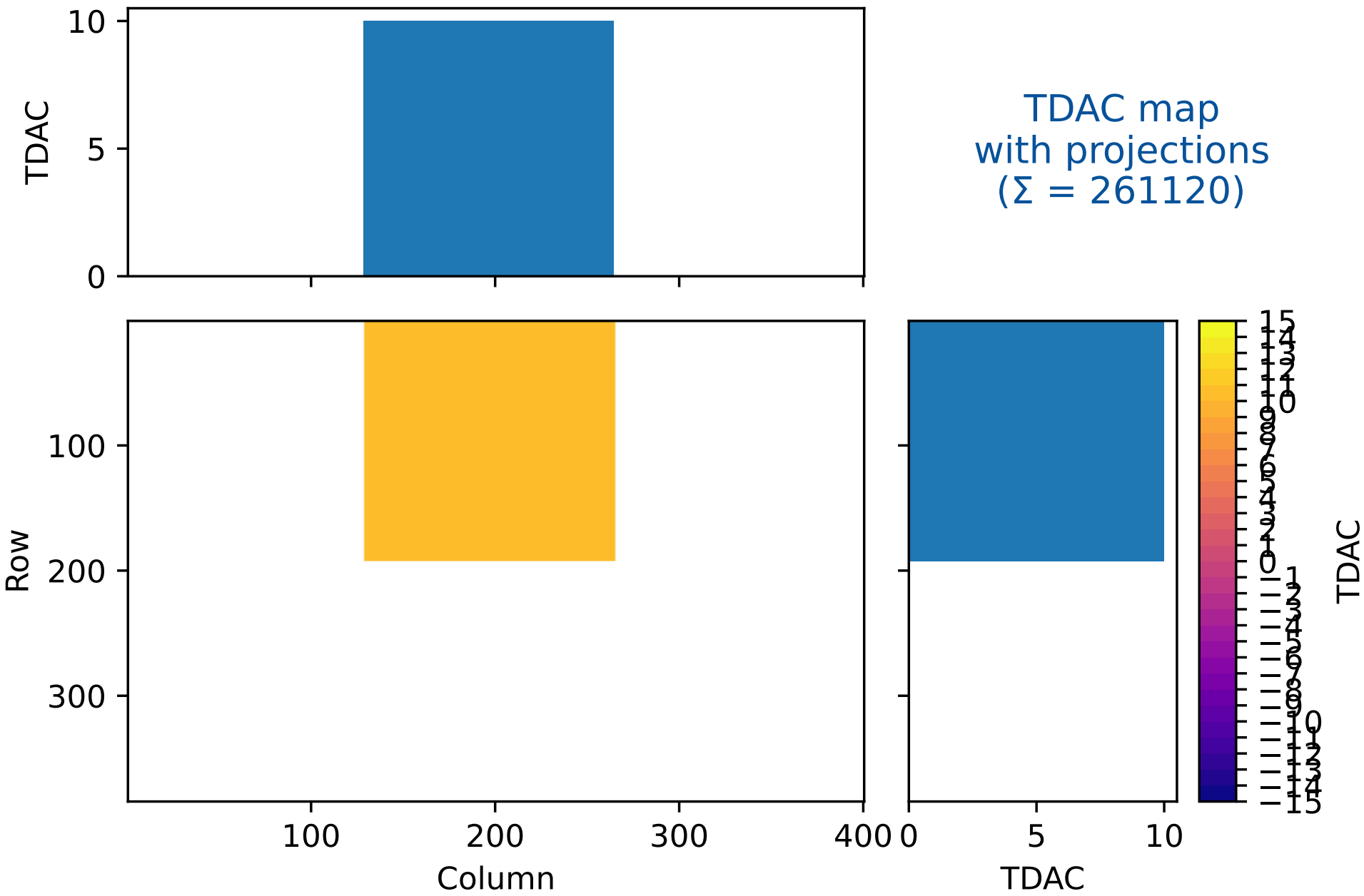

ITKPixV1 preliminary
Chip S/N: 0x162BC
BCID error (Σ = 0)
Number of event header
Trigger ID
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30

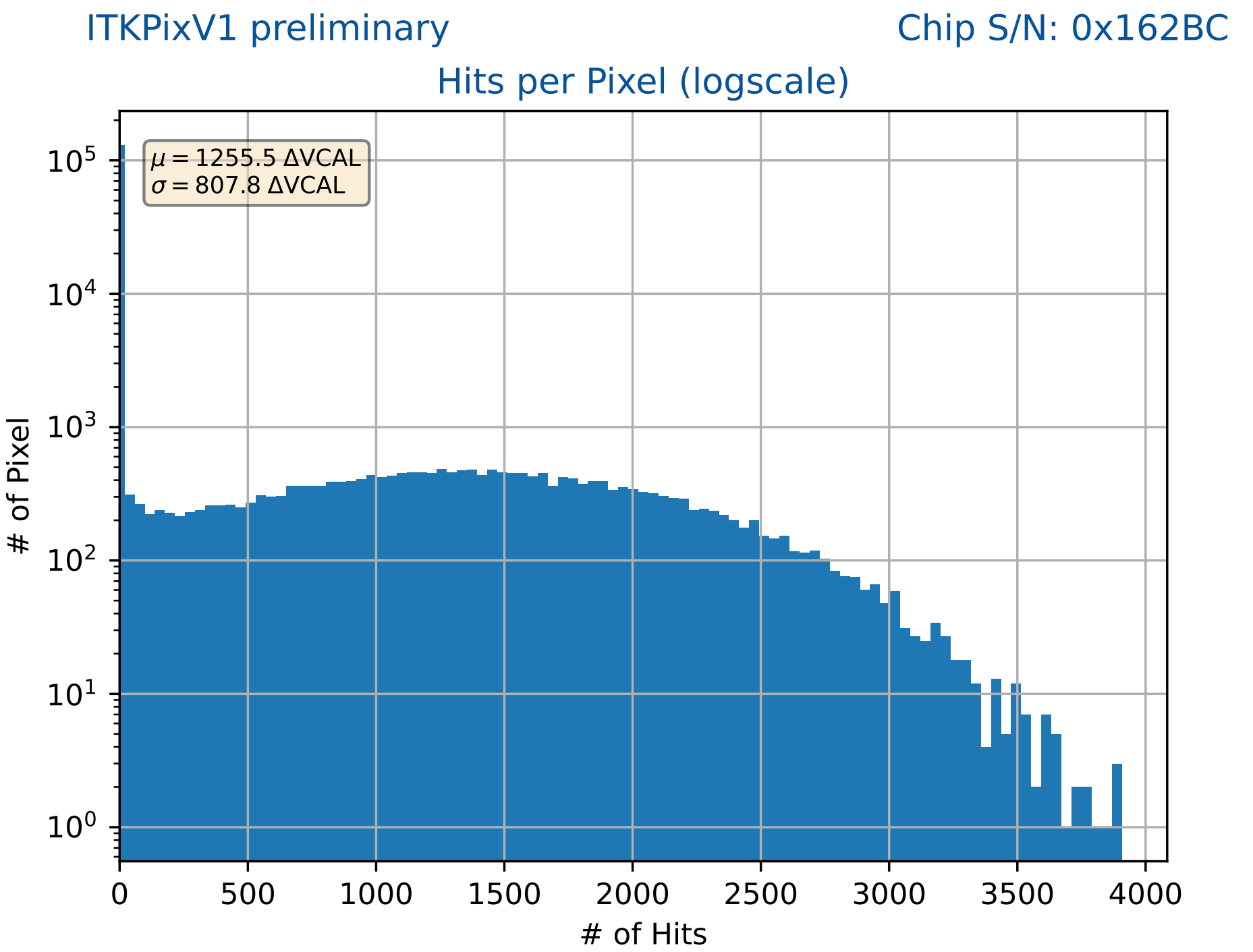
ITKPixV1 preliminary Chip S/N: 0x162BC

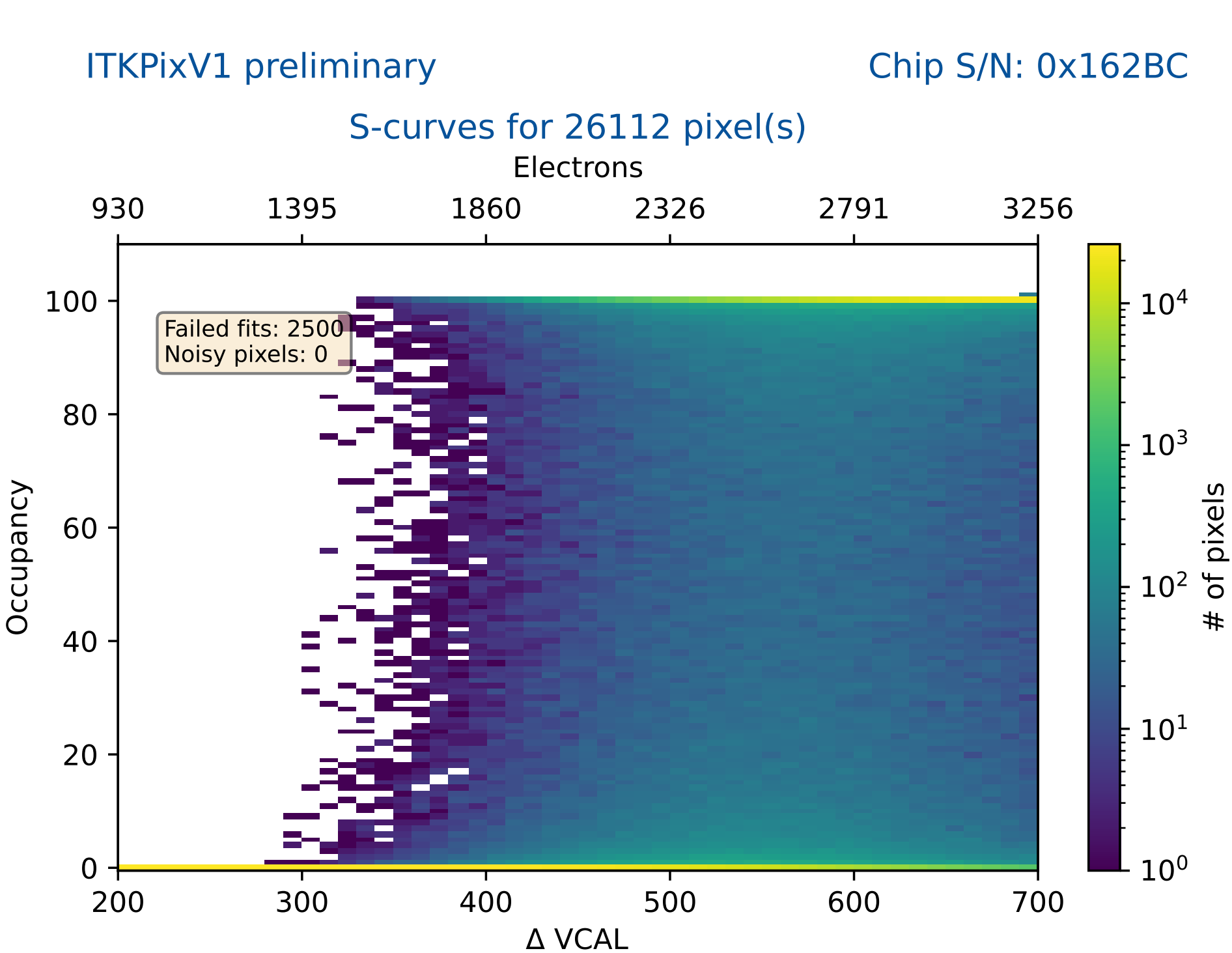
Trigger ID Histogram without Error correction

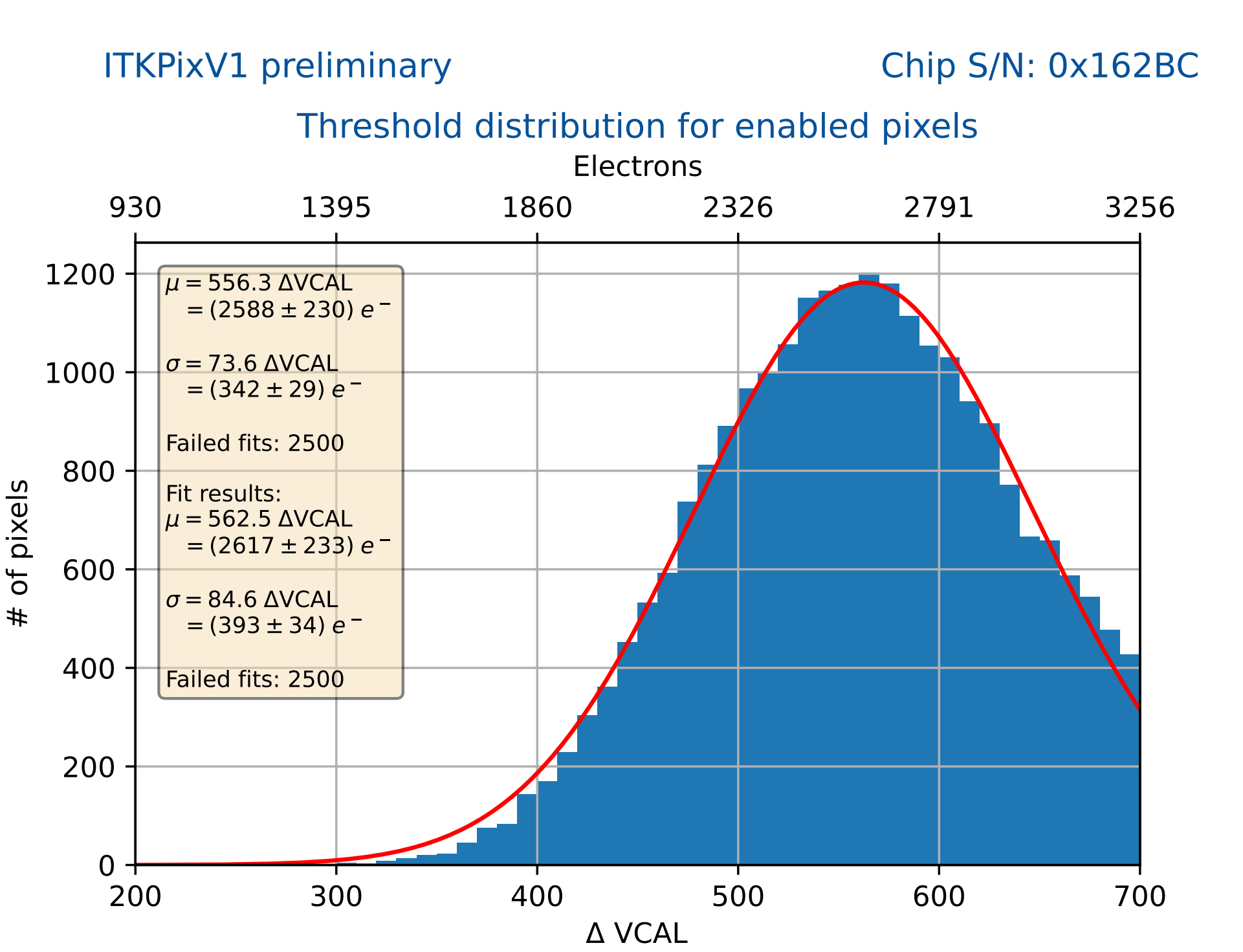


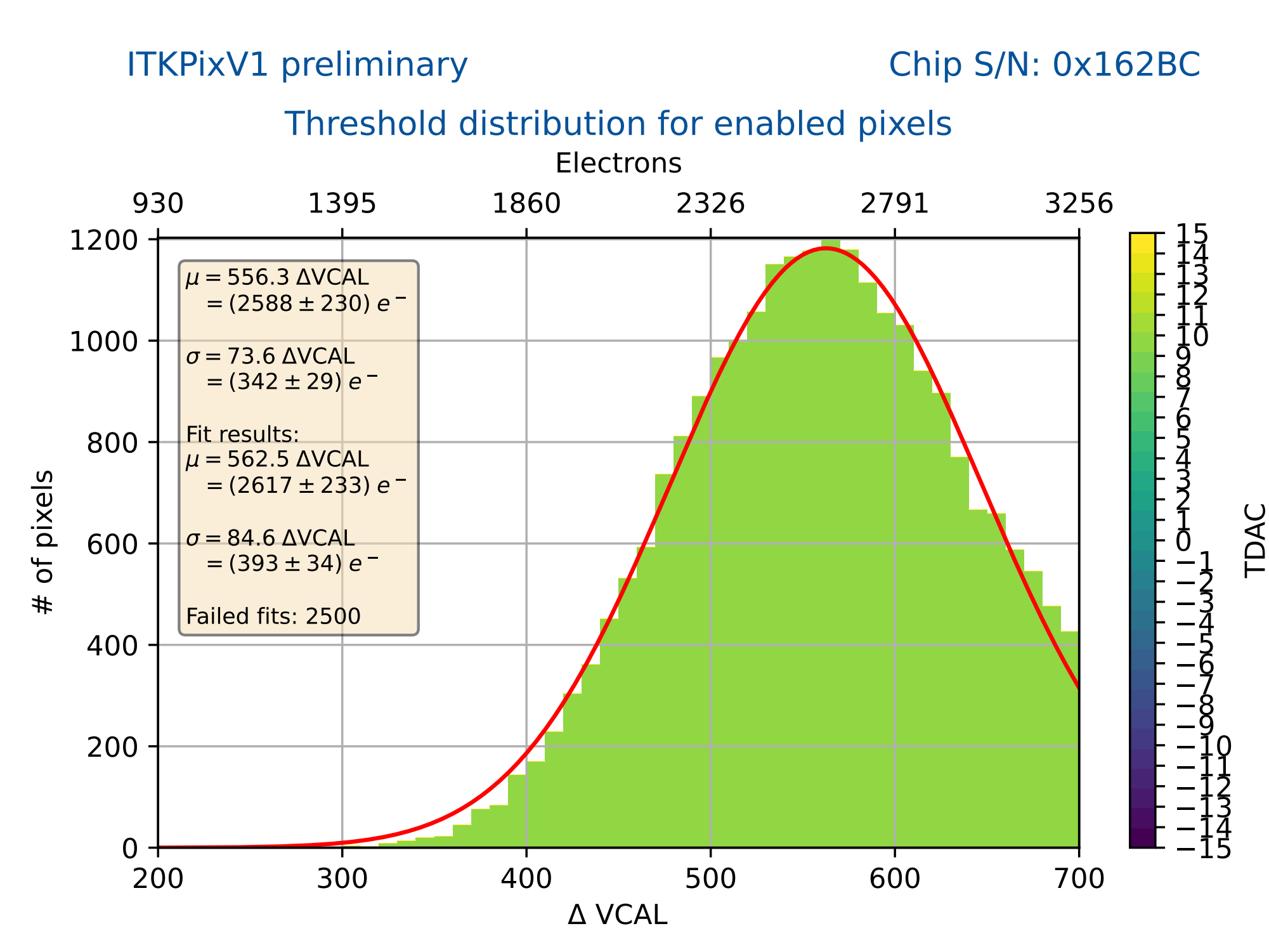

ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC distribution for enabled pixels
$\mu = 10.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
Fit results:
$\mu = 27.4$ ΔVCAL
$\sigma = 3.3$ ΔVCAL
# of pixels
0
5000
10000
15000
20000
25000
−15
−10
−5
0
5
10
15
TDAC


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC map
with projections
(Σ = 261120)
TDAC
Row
Column
TDAC
TDAC


ITKPixV1 preliminary
Chip S/N: 0x162BC
Hits per Pixel (logscale)
$\mu = 1255.5$ ΔVCAL
$\sigma = 807.8$ ΔVCAL
# of Pixel
10^5
10^4
10^3
10^2
10^1
10^0
0
500
1000
1500
2000
2500
3000
3500
4000
# of Hits

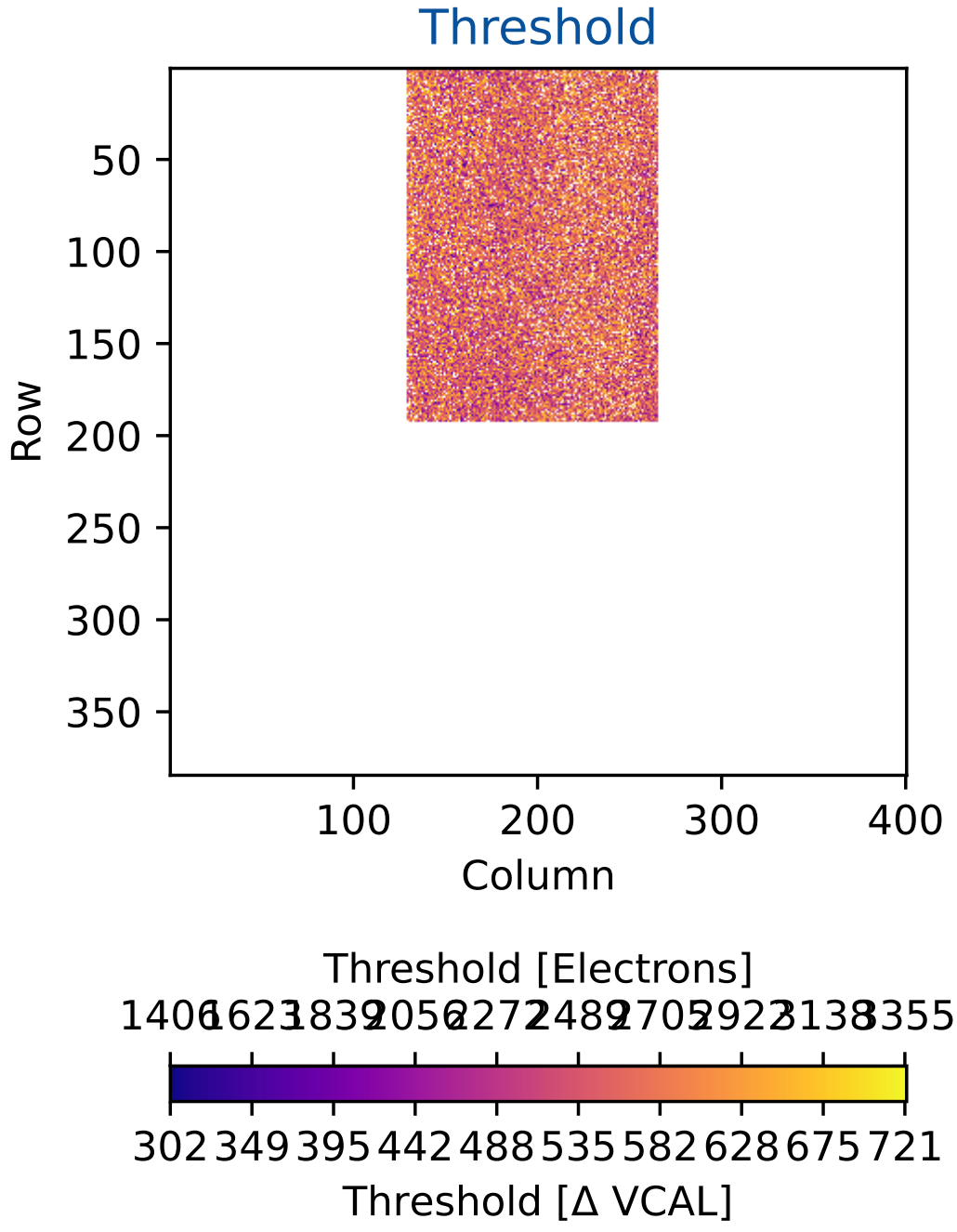

ITKPixV1 preliminary
Chip S/N: 0x162BC
S-curves for 26112 pixel(s)
Electrons
930
1395
1860
2326
2791
3256
Failed fits: 2500
Noisy pixels: 0
Occupancy
0
20
40
60
80
100
200
300
400
500
600
700
Δ VCAL
# of pixels
10^0
10^1
10^2
10^3
10^4

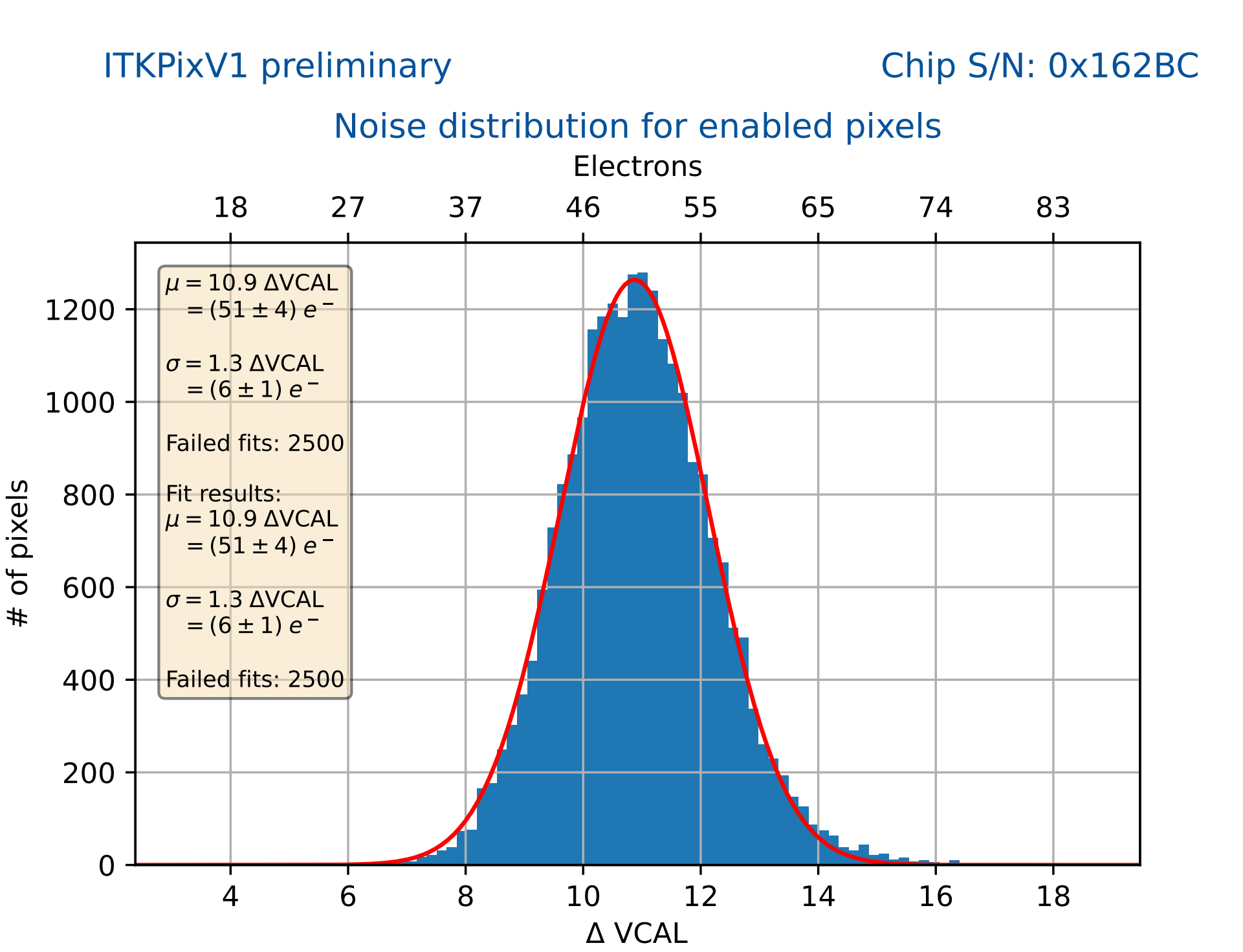

ITKPixV1 preliminary
Chip S/N: 0x162BC
Threshold distribution for enabled pixels
Electrons
930
1395
1860
2326
2791
3256
$\mu = 556.3$ ΔVCAL
$= (2588 \pm 230)\ e^-$
$\sigma = 73.6$ ΔVCAL
$= (342 \pm 29)\ e^-$
Failed fits: 2500
Fit results:
$\mu = 562.5$ ΔVCAL
$= (2617 \pm 233)\ e^-$
$\sigma = 84.6$ ΔVCAL
$= (393 \pm 34)\ e^-$
Failed fits: 2500
# of pixels
0
200
400
600
800
1000
1200
200
300
400
500
600
700
Δ VCAL


ITKPixV1 preliminary
Chip S/N: 0x162BC
Threshold distribution for enabled pixels
Electrons
930
1395
1860
2326
2791
3256
$\mu = 556.3$ ΔVCAL
$= (2588 \pm 230)\ e^-$
$\sigma = 73.6$ ΔVCAL
$= (342 \pm 29)\ e^-$
Fit results:
$\mu = 562.5$ ΔVCAL
$= (2617 \pm 233)\ e^-$
$\sigma = 84.6$ ΔVCAL
$= (393 \pm 34)\ e^-$
Failed fits: 2500
# of pixels
0
200
400
600
800
1000
1200
Δ VCAL
200
300
400
500
600
700
TDAC
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
−13
−14
−15

ITKPixV1 preliminary

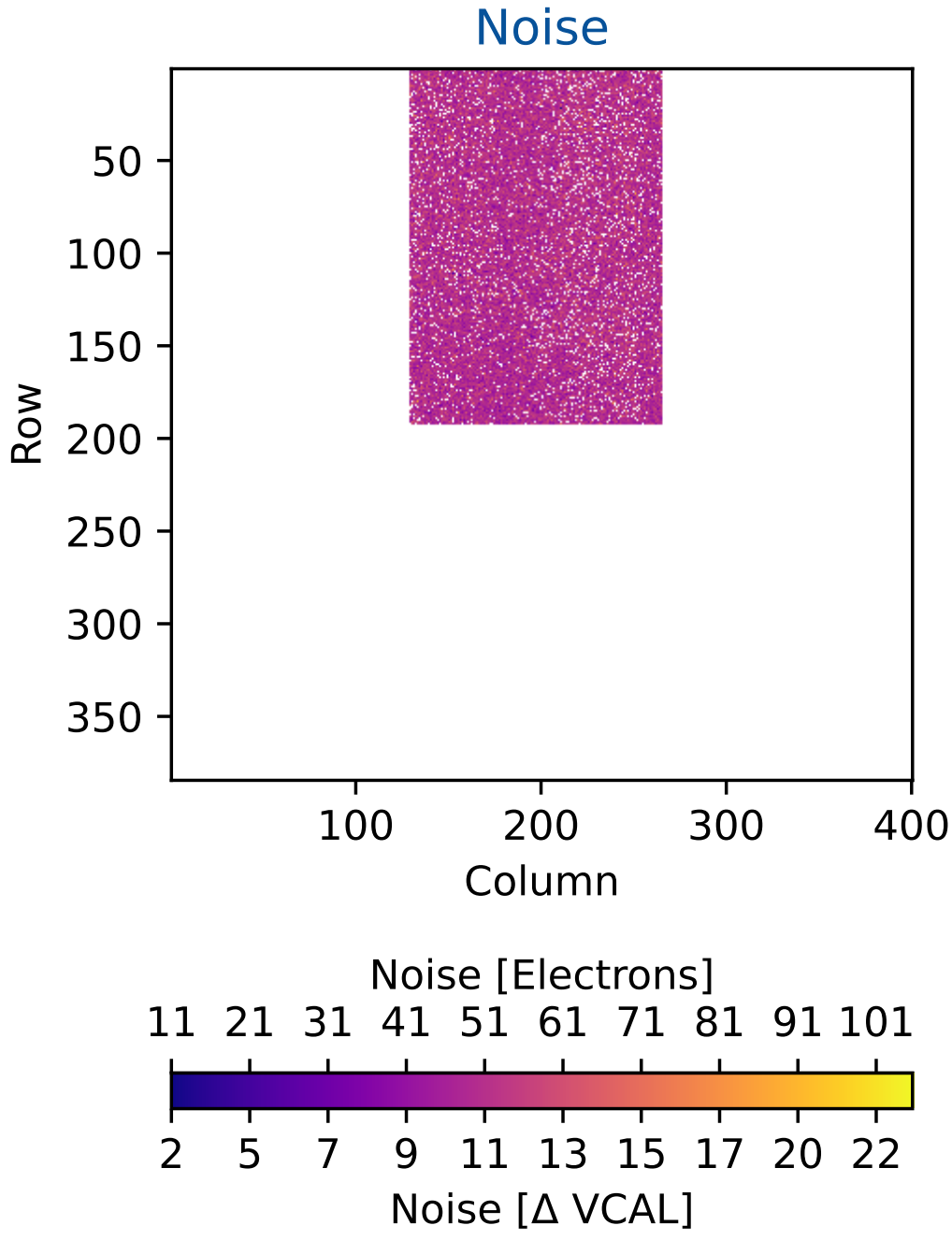
Chip S/N: 0x162BC




ITKPixV1 preliminary
Chip S/N: 0x162BC
Noise distribution for enabled pixels
Electrons
18
27
37
46
55
65
74
83
$\mu = 10.9$ ΔVCAL
$= (51 \pm 4)\ e^-$
$\sigma = 1.3$ ΔVCAL
$= (6 \pm 1)\ e^-$
Failed fits: 2500
Fit results:
$\mu = 10.9$ ΔVCAL
$= (51 \pm 4)\ e^-$
$\sigma = 1.3$ ΔVCAL
$= (6 \pm 1)\ e^-$
Failed fits: 2500
# of pixels
0
200
400
600
800
1000
1200
4
6
8
10
12
14
16
18
Δ VCAL

ITKPixV1 preliminary

Chip S/N: 0x162BC



Noise Occupancy Scan

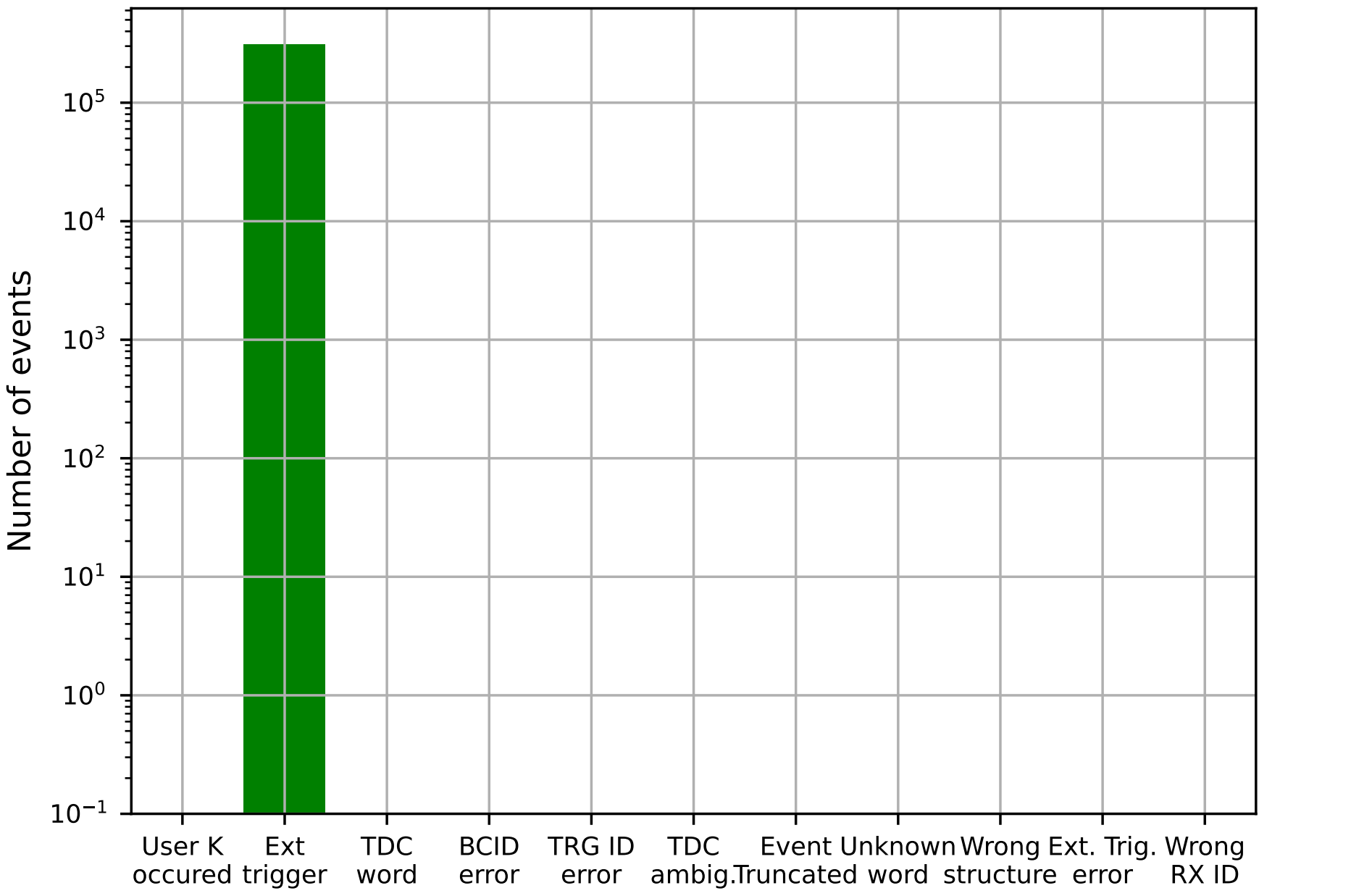
- Sends triggers without injection into enabled pixels to identify noisy pixels

This is a bdaq53 noise_occupancy_scan for chip 0x162BC.
Run 20230317_021905_noise_occupancy_scan was started 2023-03-17 02:19:0

Scan config	Value
min_occupancy	10
n_triggers	10000000.0
start_column	0
start_row	0
stop_column	400
stop_row	192
trigger_pattern	0xffffffff
wait_cycles	400

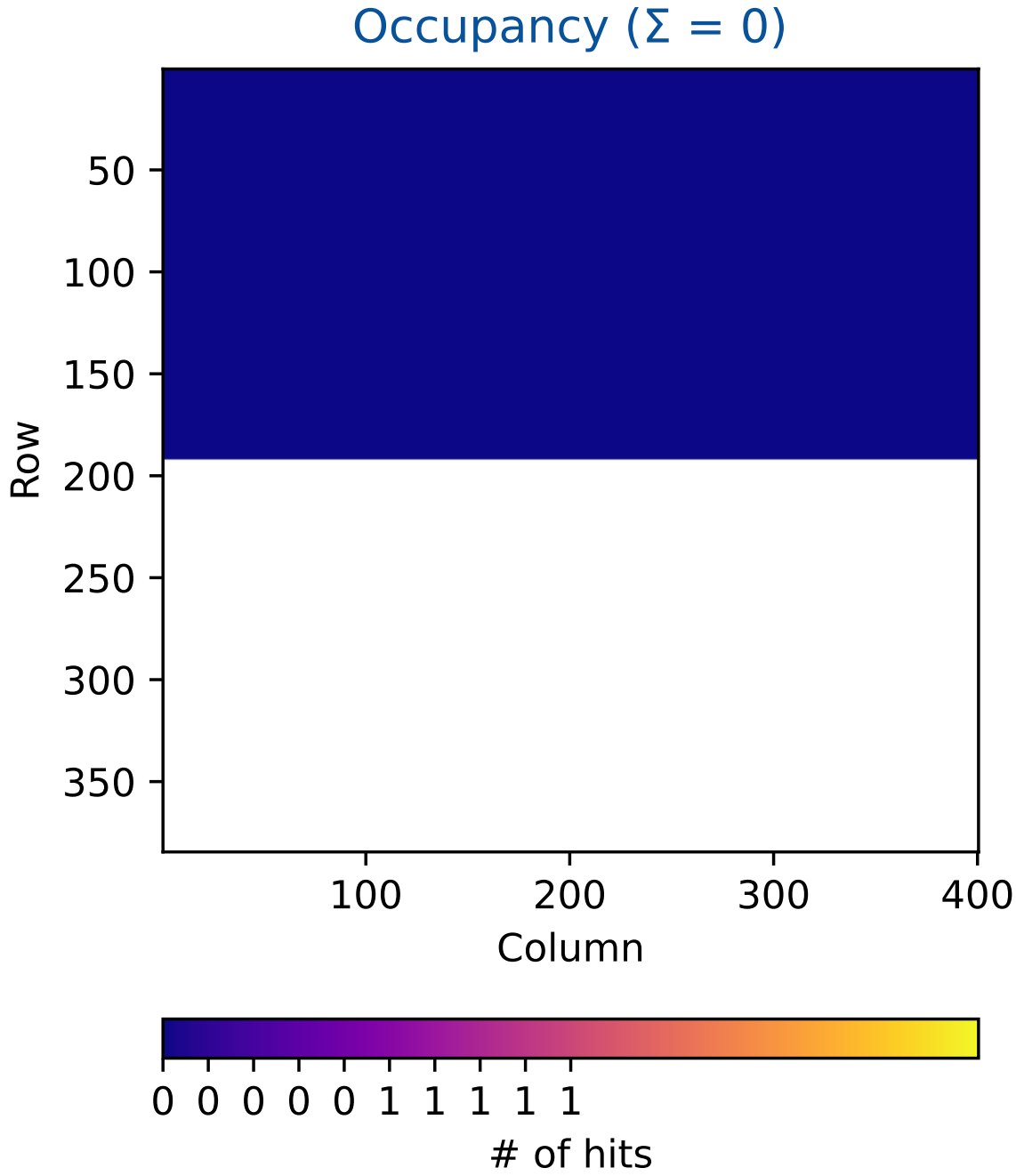
ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

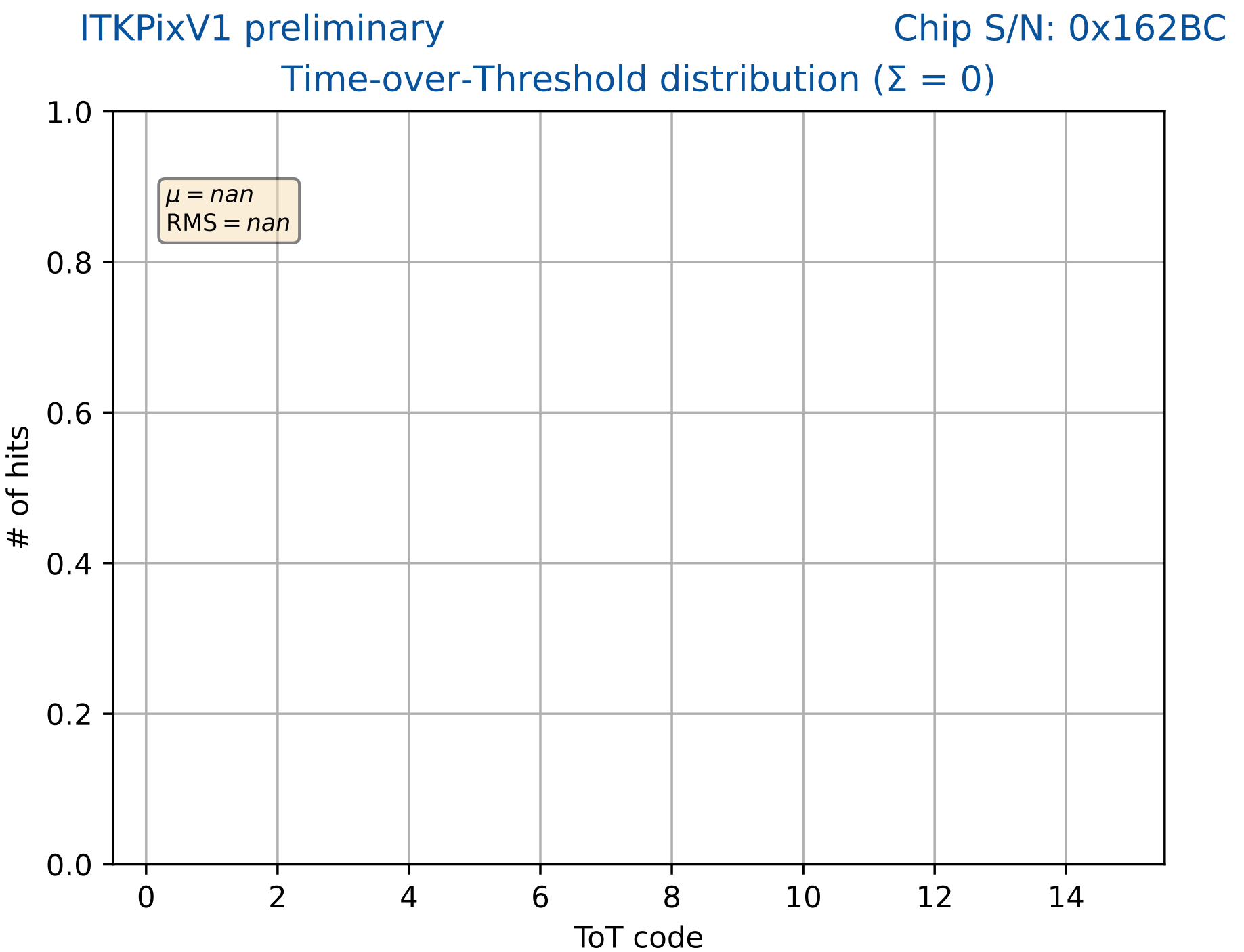
Software version: Tag: v1.7
Changed files: bdaq53/scans/scan_in_time_threshold.py, bdaq53/scans/scan_injection_delay.py, bdaq53/system/bdaq53.py


ITKPixV1 preliminary
Chip S/N: 0x162BC
Event status (Σ = 312500)
Number of events
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
User K occured
Ext trigger
TDC word
BCID error
TRG ID error
TDC ambig.
Event Truncated
Unknown word
Wrong structure
Ext. Trig. error
Wrong RX ID

ITKPixV1 preliminary

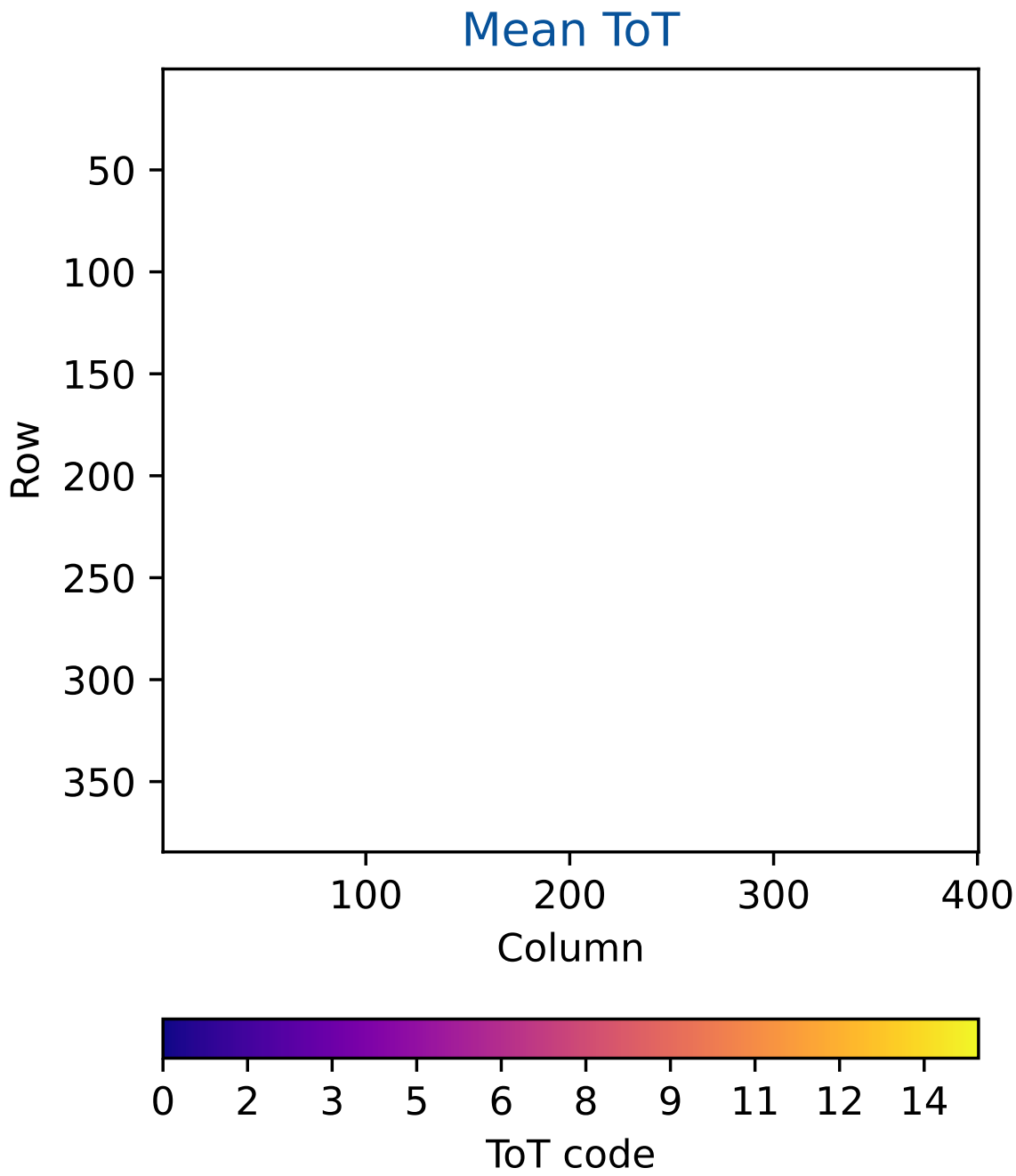
Chip S/N: 0x162BC

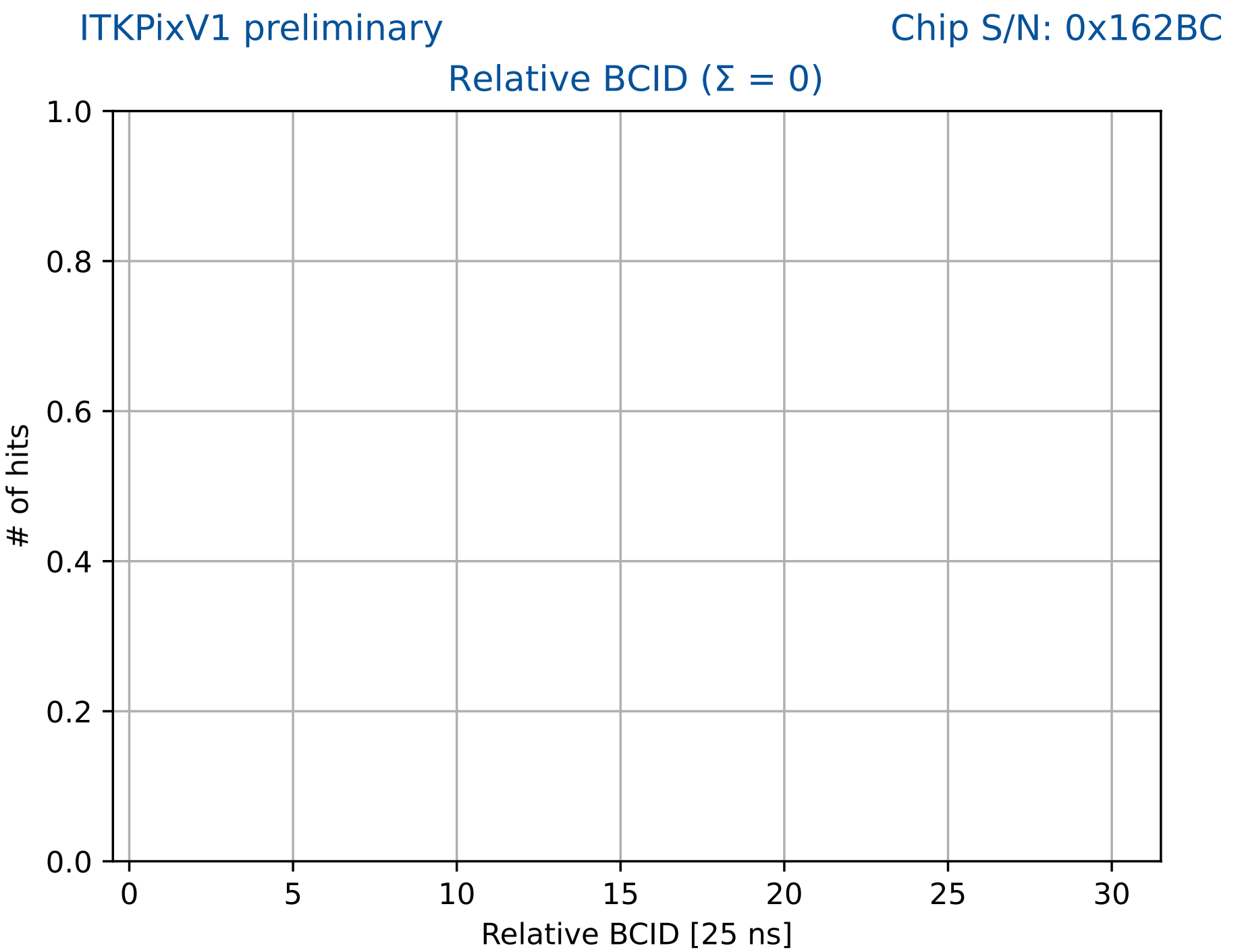



ITKPixV1 preliminary
Chip S/N: 0x162BC
Time-over-Threshold distribution (Σ = 0)
μ = nan
RMS = nan
# of hits
ToT code
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
14

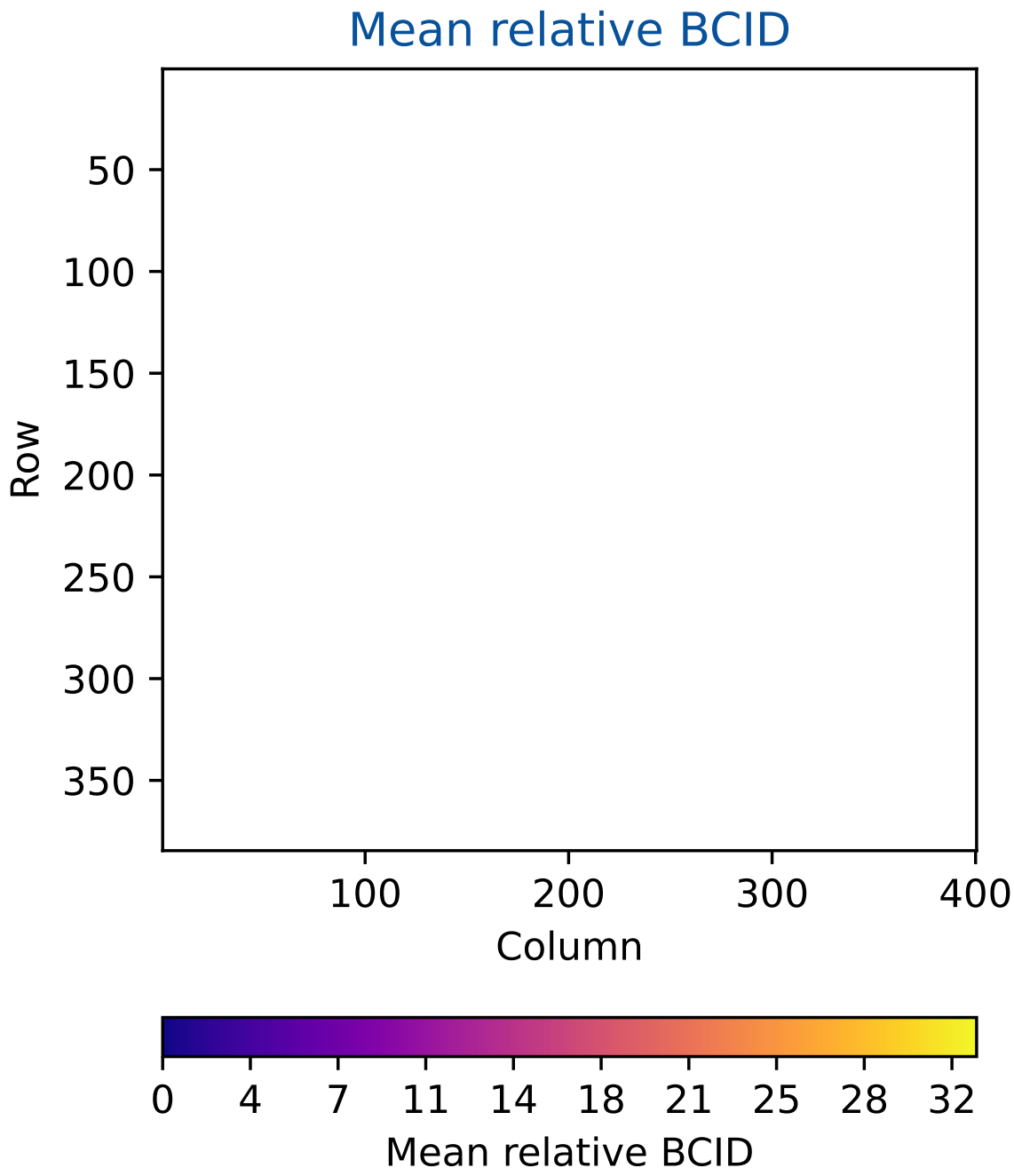
ITKPixV1 preliminary

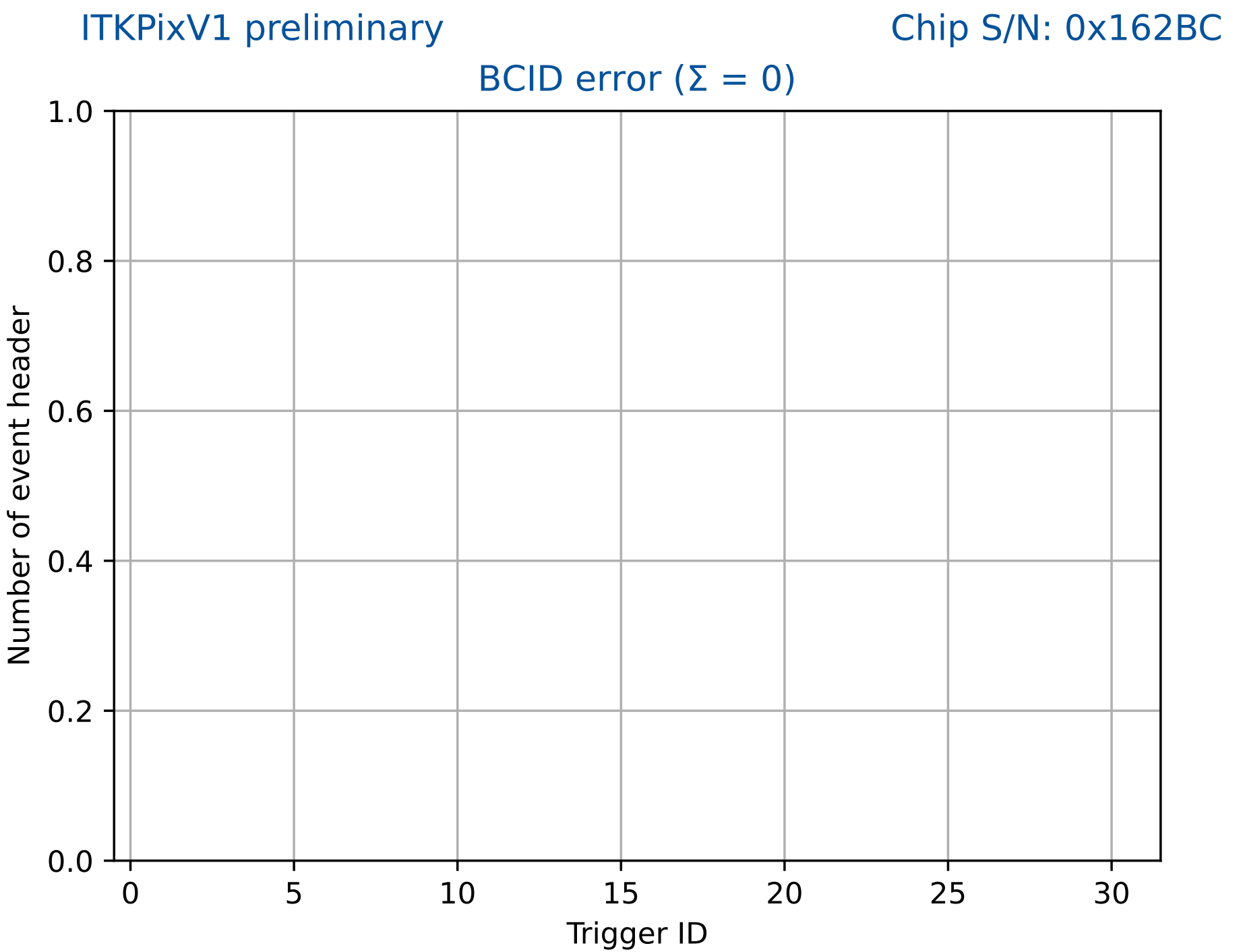
Chip S/N: 0x162BC




ITKPixV1 preliminary
Chip S/N: 0x162BC
Relative BCID (Σ = 0)
# of hits
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Relative BCID [25 ns]

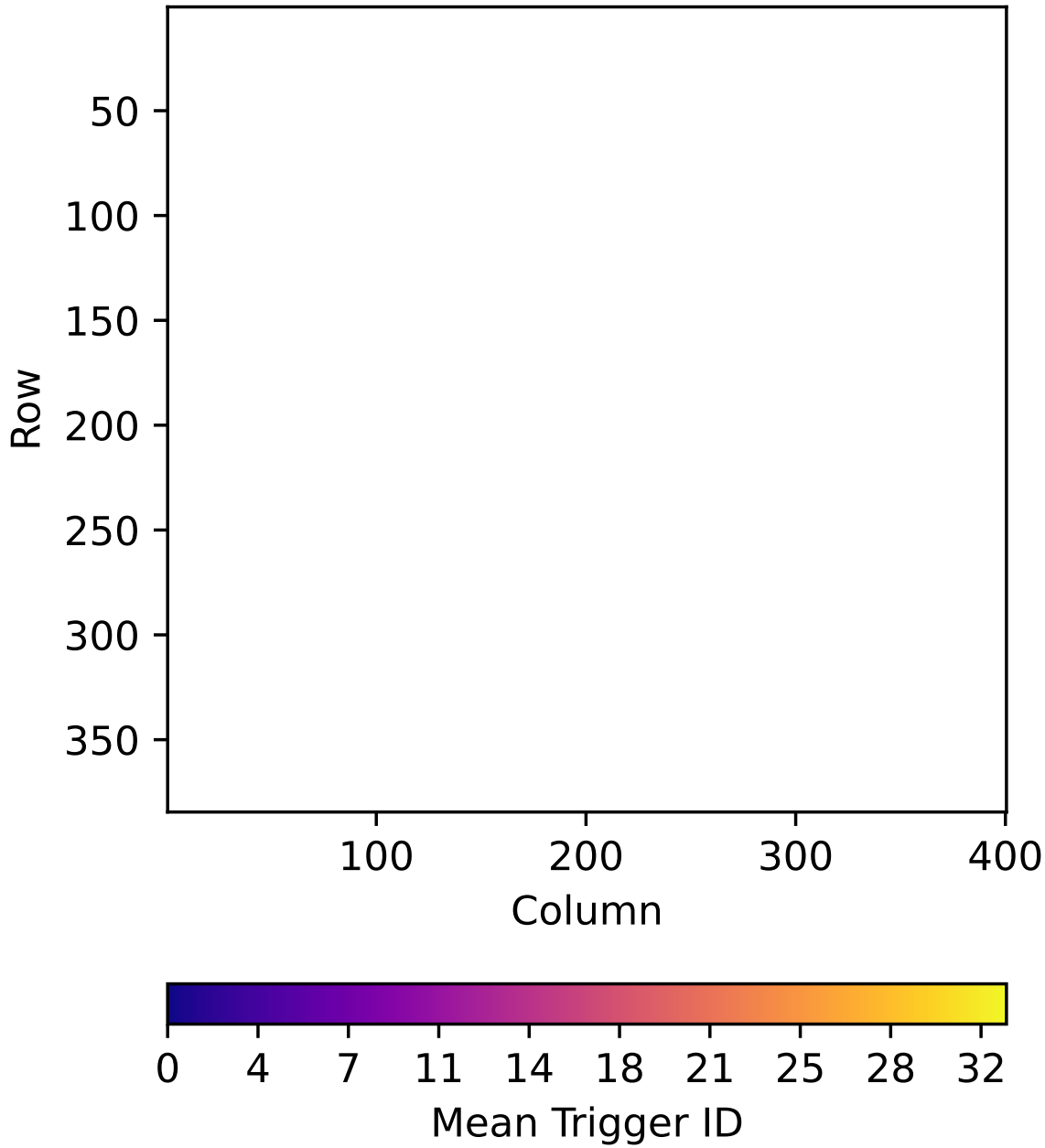
ITKPixV1 preliminary Chip S/N: 0x162BC

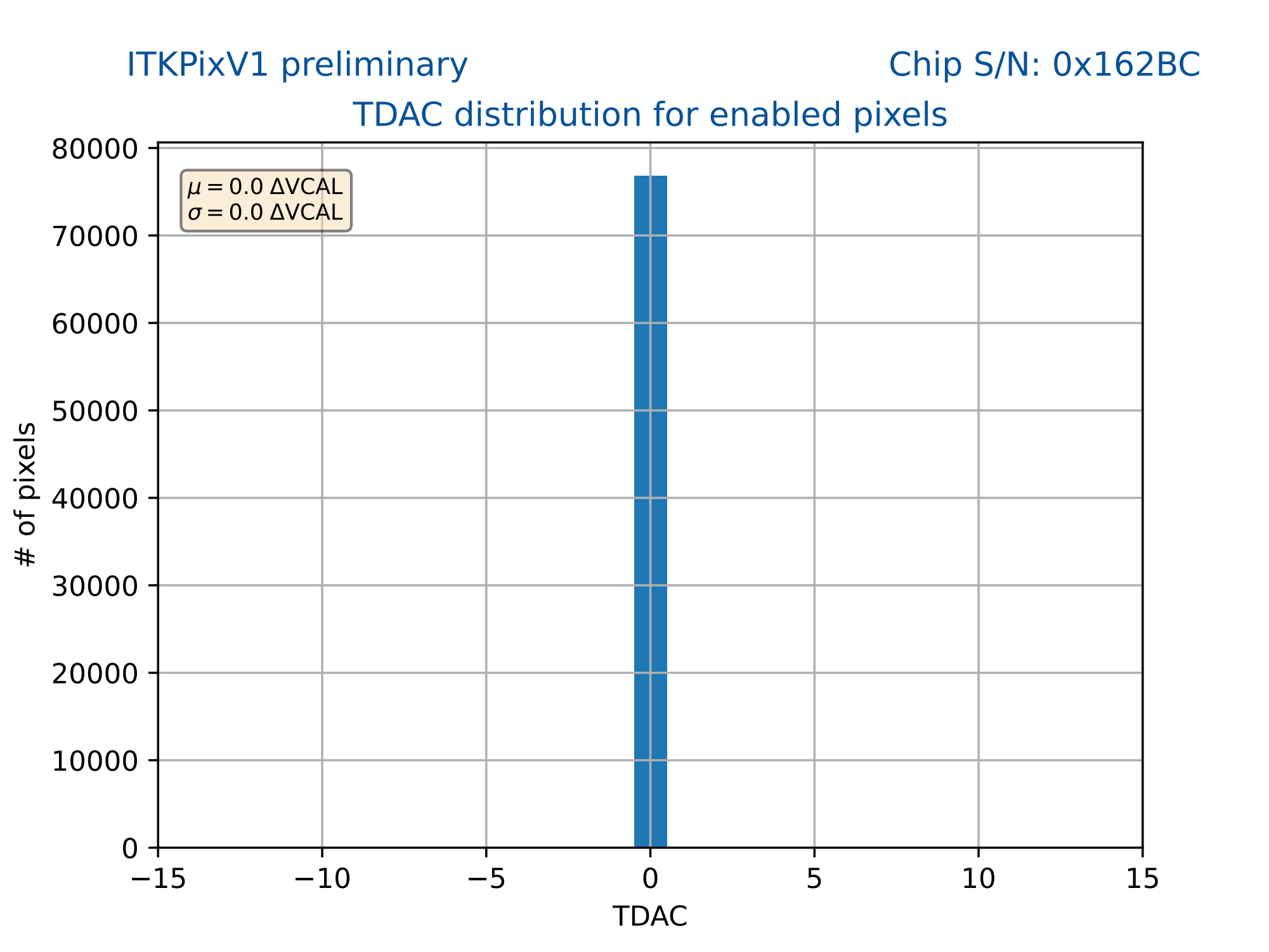


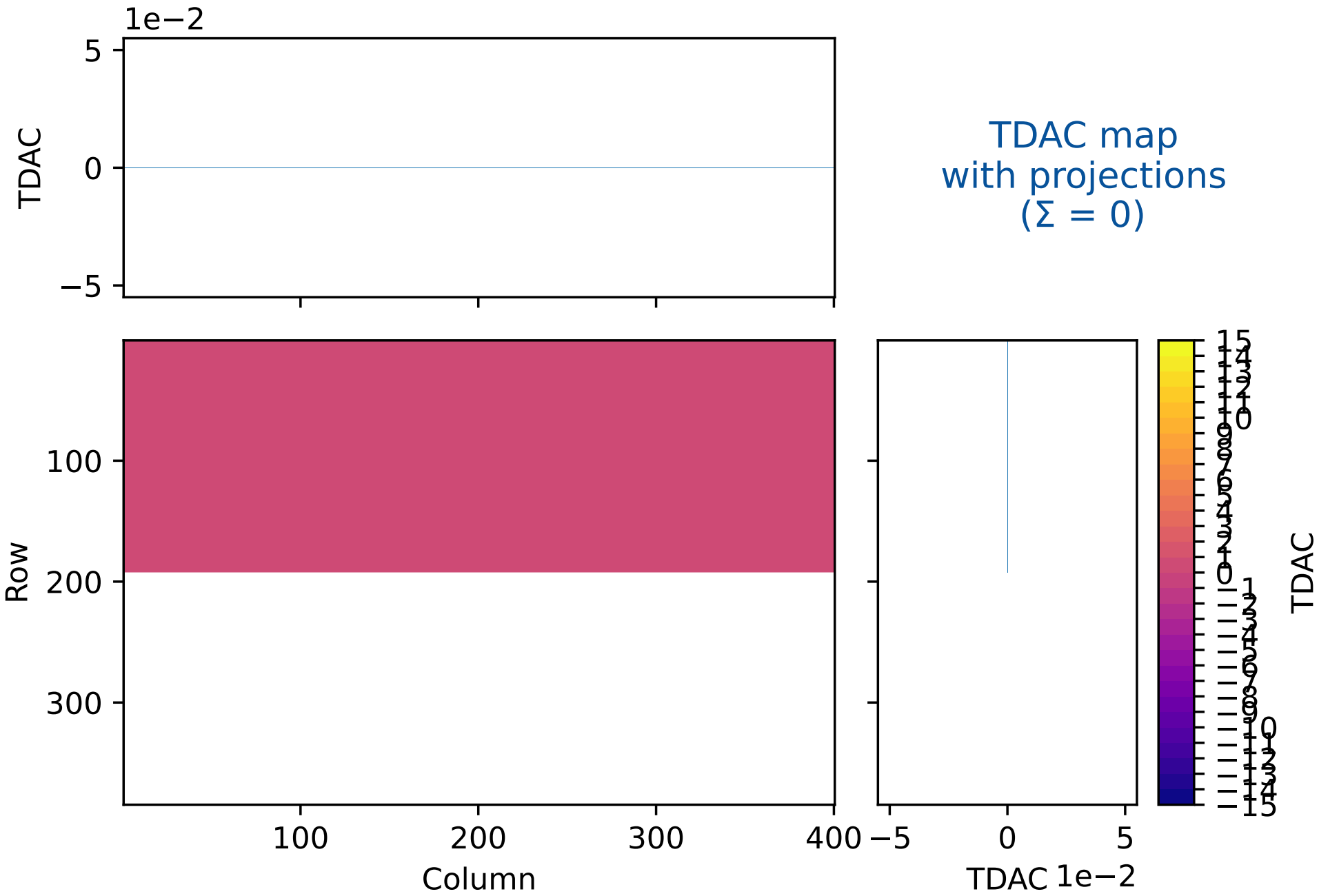

ITKPixV1 preliminary
Chip S/N: 0x162BC
BCID error (Σ = 0)
Number of event header
Trigger ID
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30

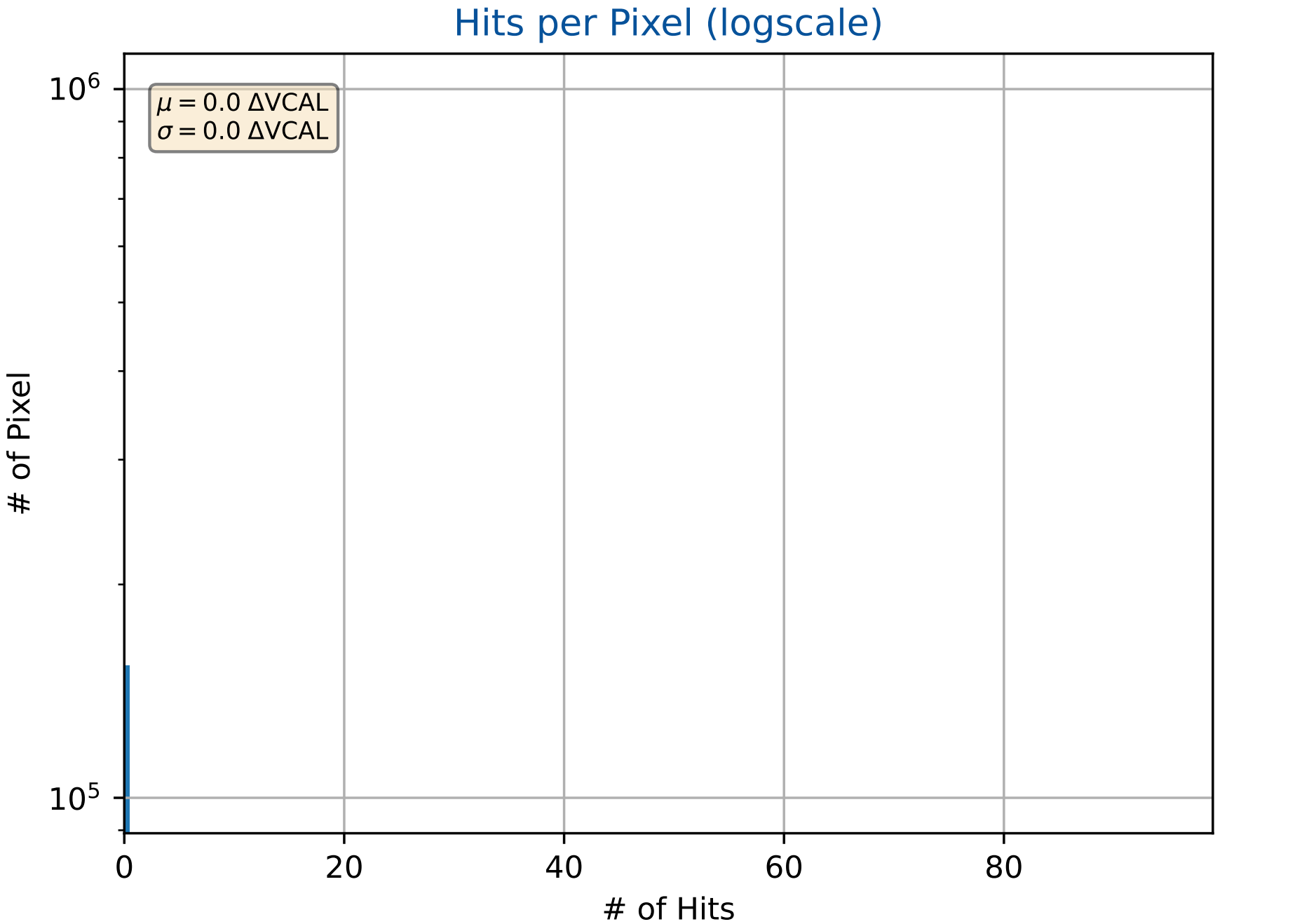
ITKPixV1 preliminary Chip S/N: 0x162BC

Trigger ID Histogram without Error correction




ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC distribution for enabled pixels
$\mu = 0.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
# of pixels
TDAC
80000
70000
60000
50000
40000
30000
20000
10000
0
−15
−10
−5
0
5
10
15


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC map
with projections
(Σ = 0)
1e−2
5
0
−5
TDAC
Row
100
200
300
Column
100
200
300
400
−5
0
5
TDAC
1e−2
TDAC
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0


ITKPixV1 preliminary
Chip S/N: 0x162BC
Hits per Pixel (logscale)
$\mu = 0.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
10^6
10^5
# of Pixel
0
20
40
60
80
# of Hits

Source Scan (Random Trigger)

- A BDAQ self-trigger (external trigger) scan, using the HitOr as the trigger input

This is a bdaq53 source_scan_random_trigger for chip 0x162BC.
Run 20230317_024142_source_scan_random_trigger was started 2023-03-17 0

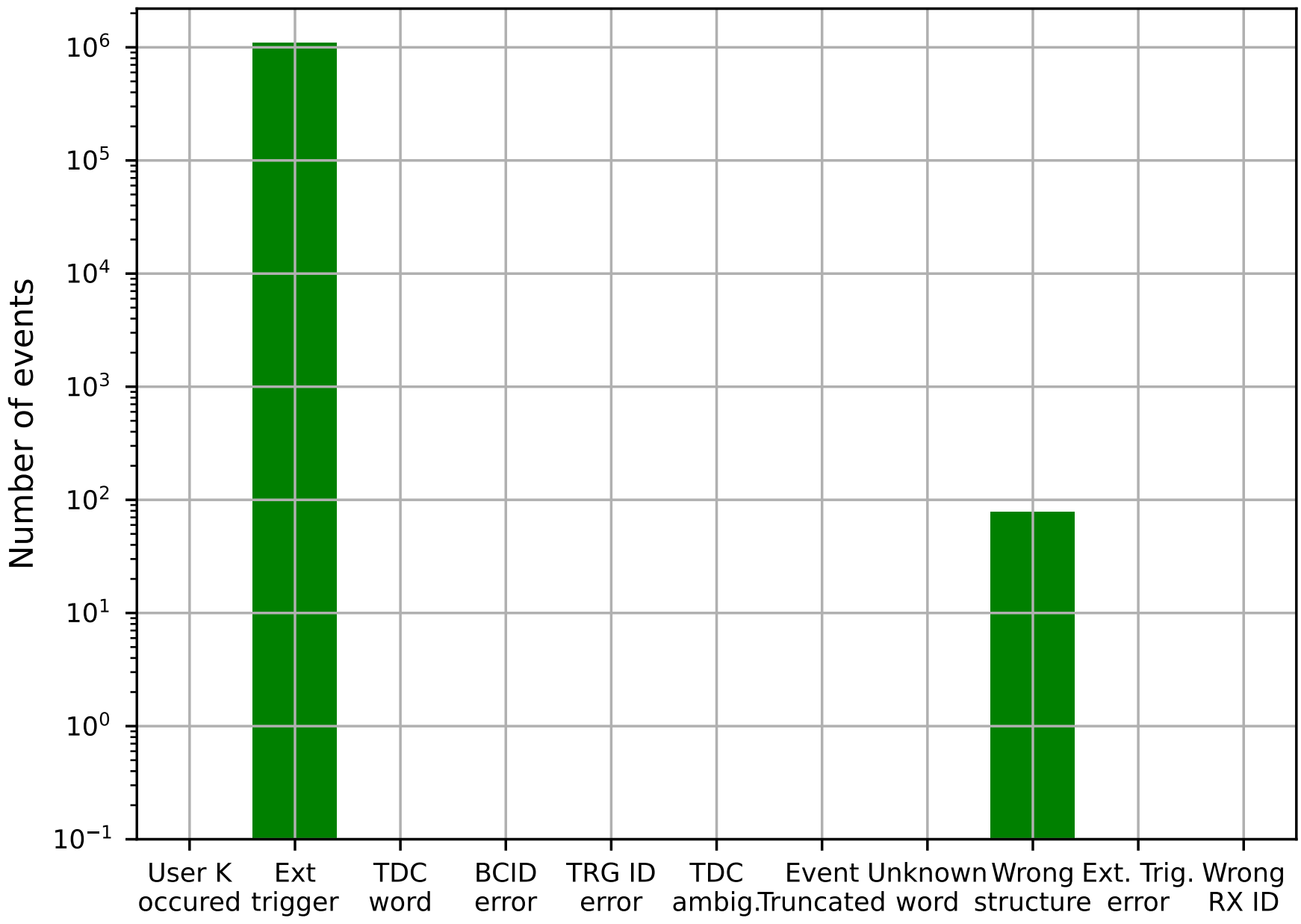
Scan config	Value
bench	{'TLU': {'TRIG
n_triggers	
scan_timeout	30
start_column	0
start_row	0
stop_column	400
stop_row	192
trigger_delay	65
trigger_latency	100
trigger_length	32
trigger_pattern	0xffffffff
use_tdc	False
veto_length	500
wait_cycles	40

ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

Software version: Tag: v1.7
Changed files: bdaq53/scans/scan_in_time_threshold.py, bdaq53/scans/scan_injection_delay.py, bdaq53/system/bdaq53.py

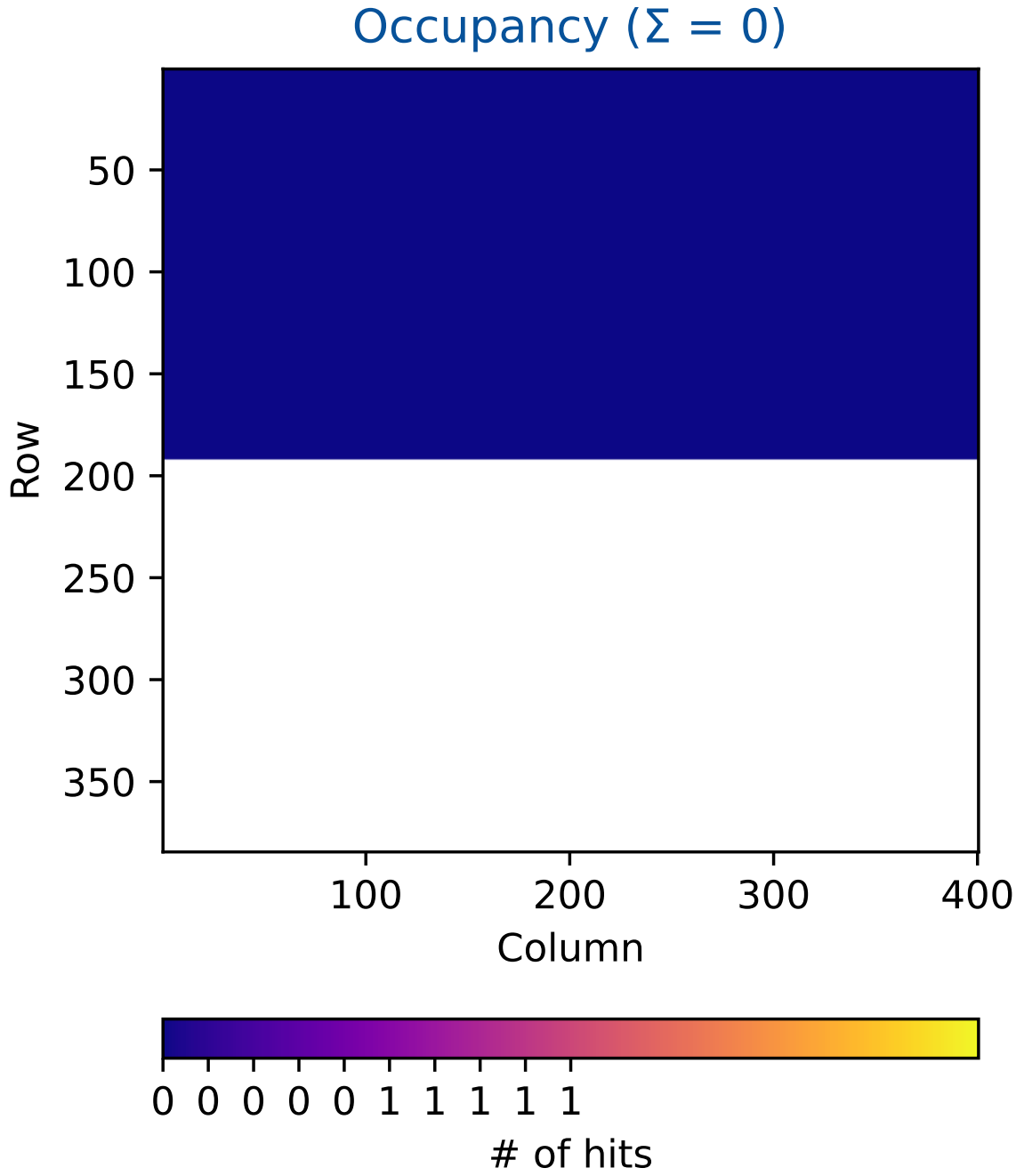
ITKPixV1 preliminary

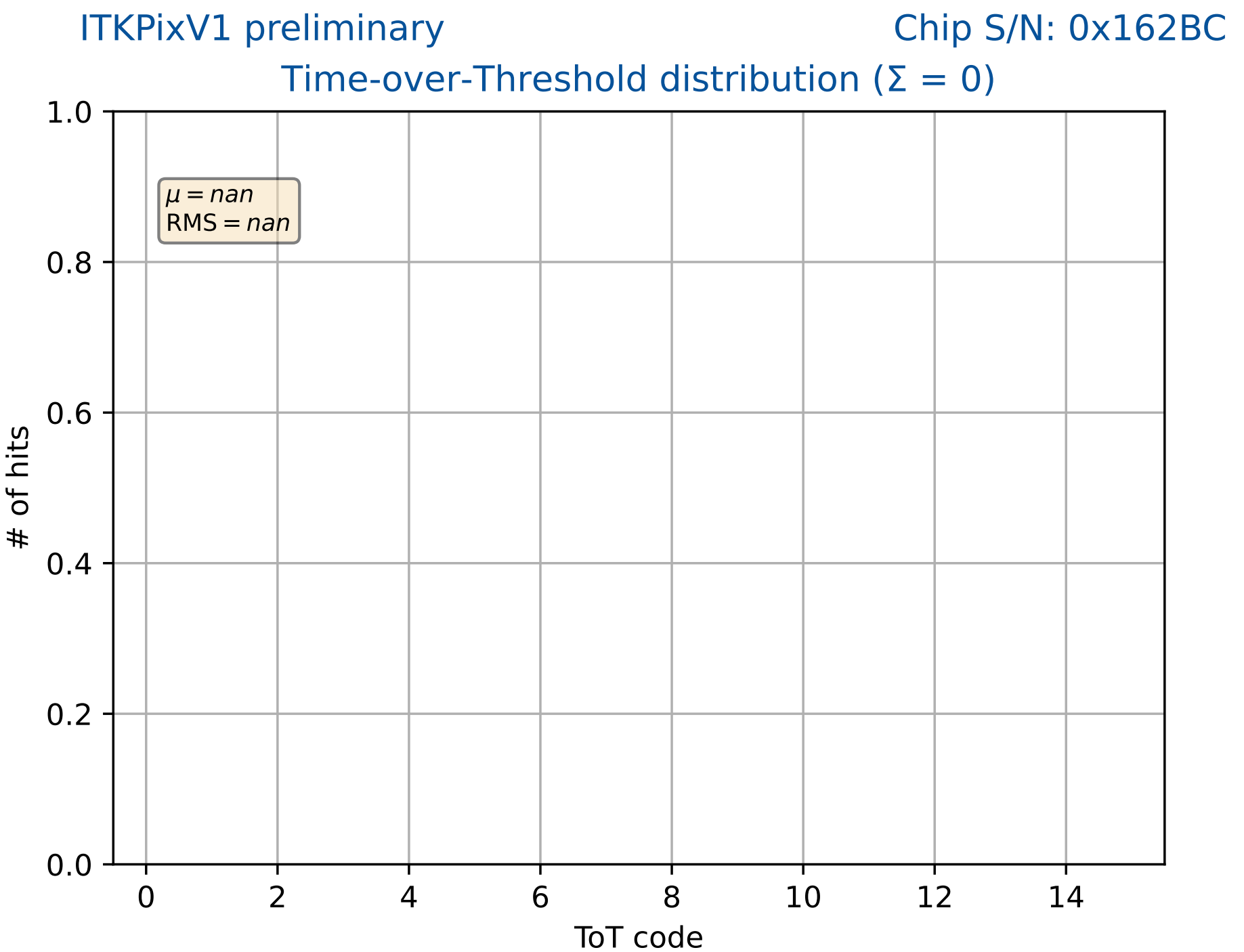
Chip S/N: 0x162BC



ITKPixV1 preliminary

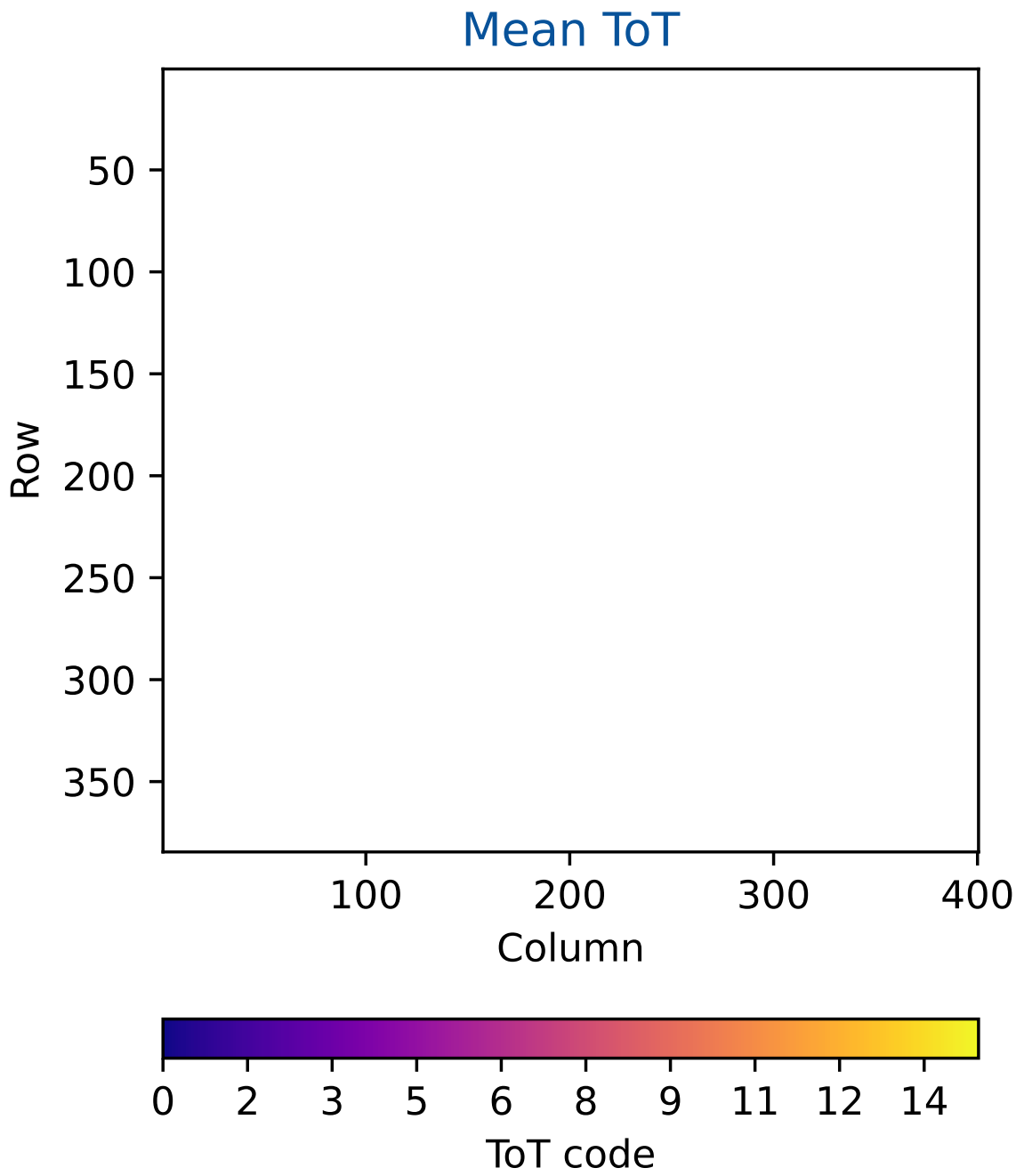
Chip S/N: 0x162BC

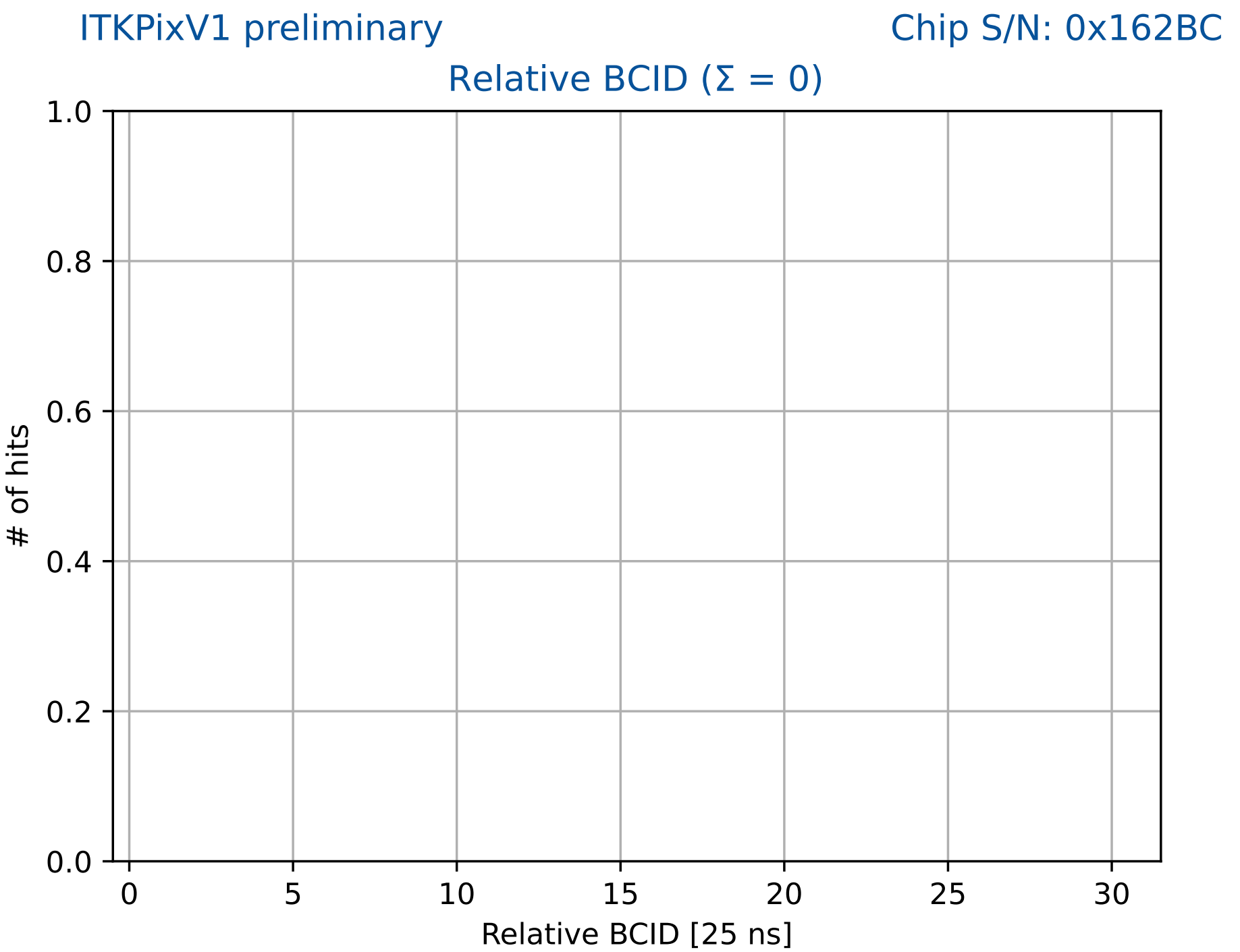



ITKPixV1 preliminary
Chip S/N: 0x162BC
Time-over-Threshold distribution (Σ = 0)
μ = nan
RMS = nan
# of hits
ToT code
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
14

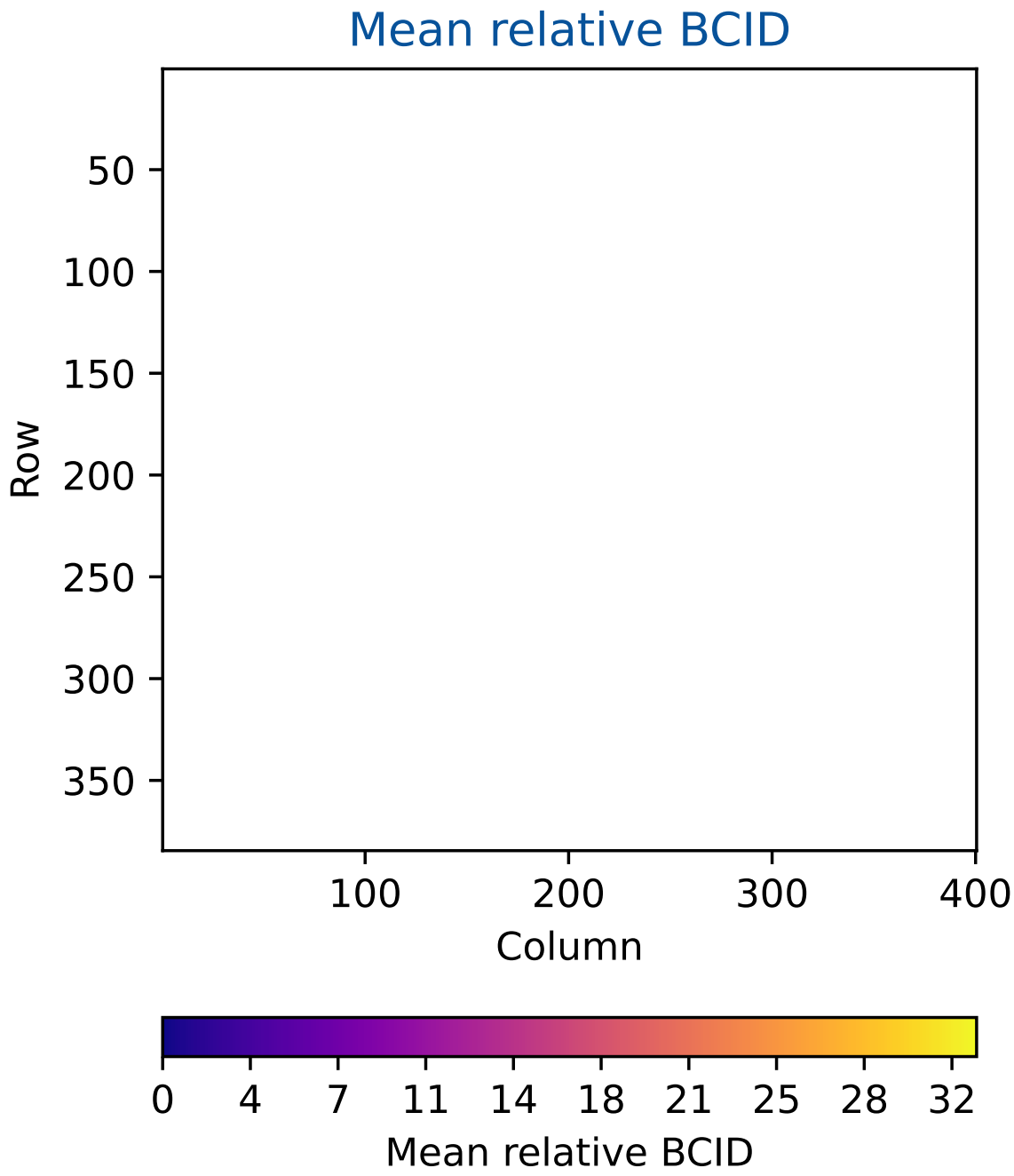
ITKPixV1 preliminary

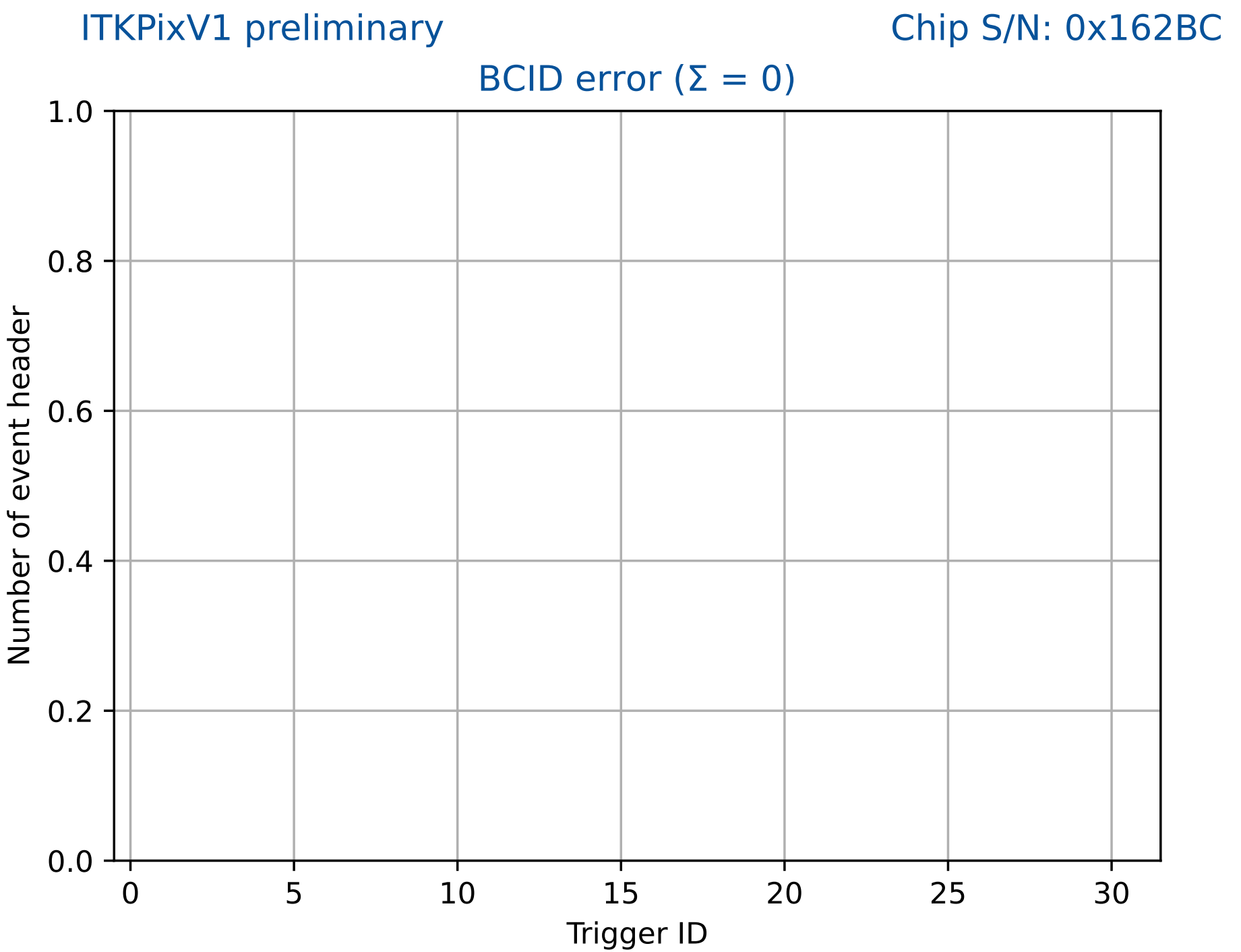
Chip S/N: 0x162BC




ITKPixV1 preliminary
Chip S/N: 0x162BC
Relative BCID (Σ = 0)
# of hits
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Relative BCID [25 ns]

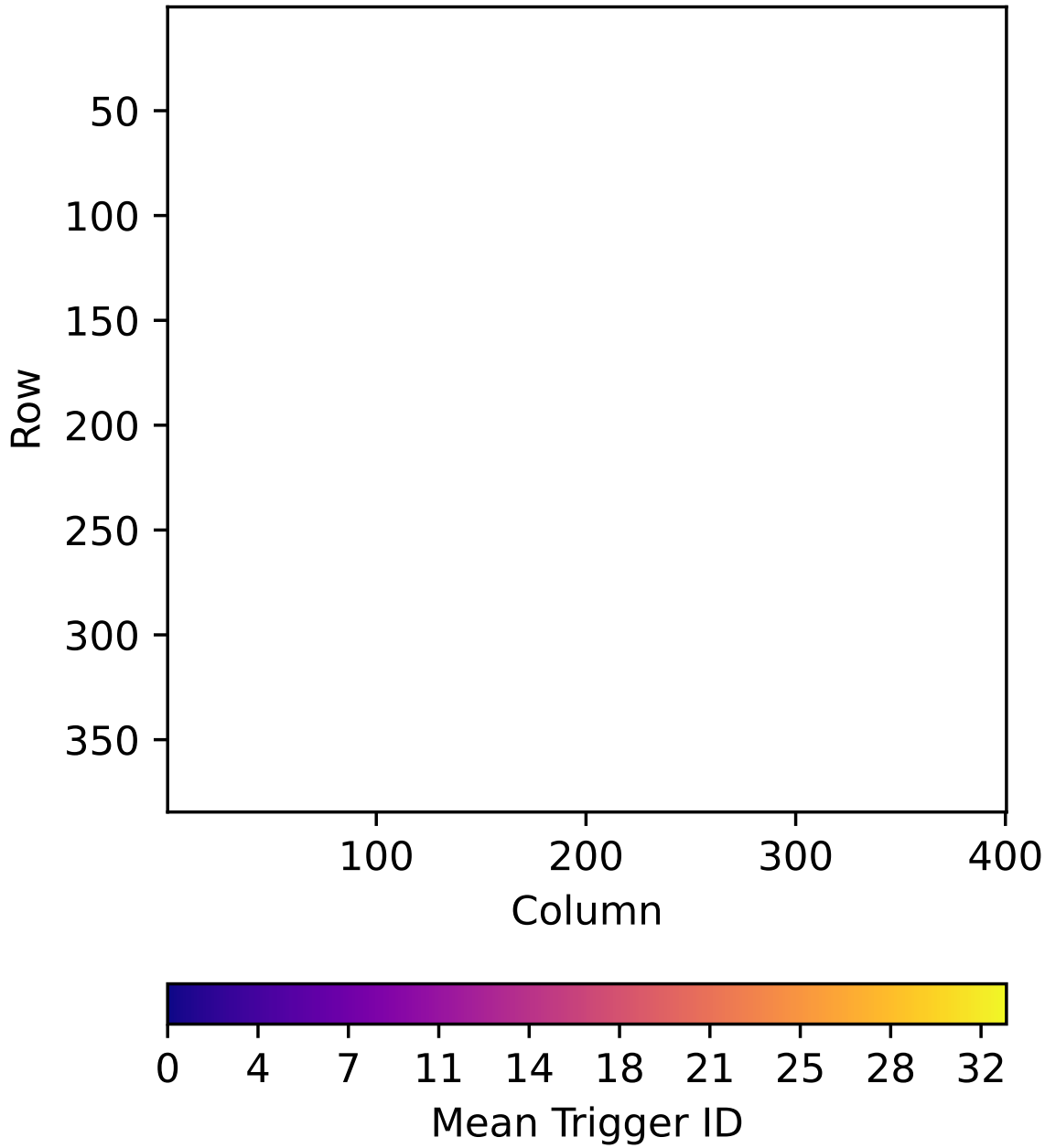
ITKPixV1 preliminary Chip S/N: 0x162BC

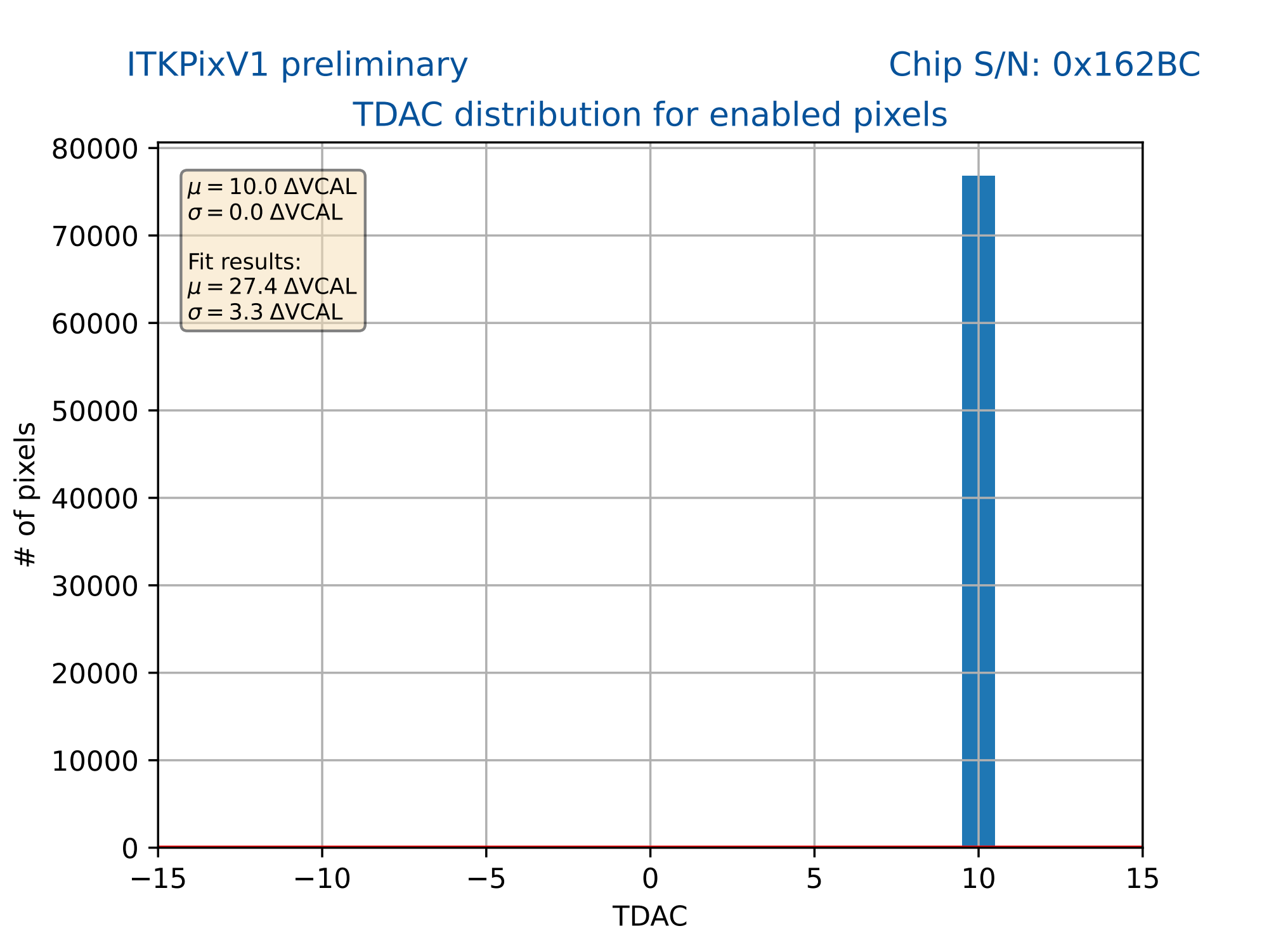


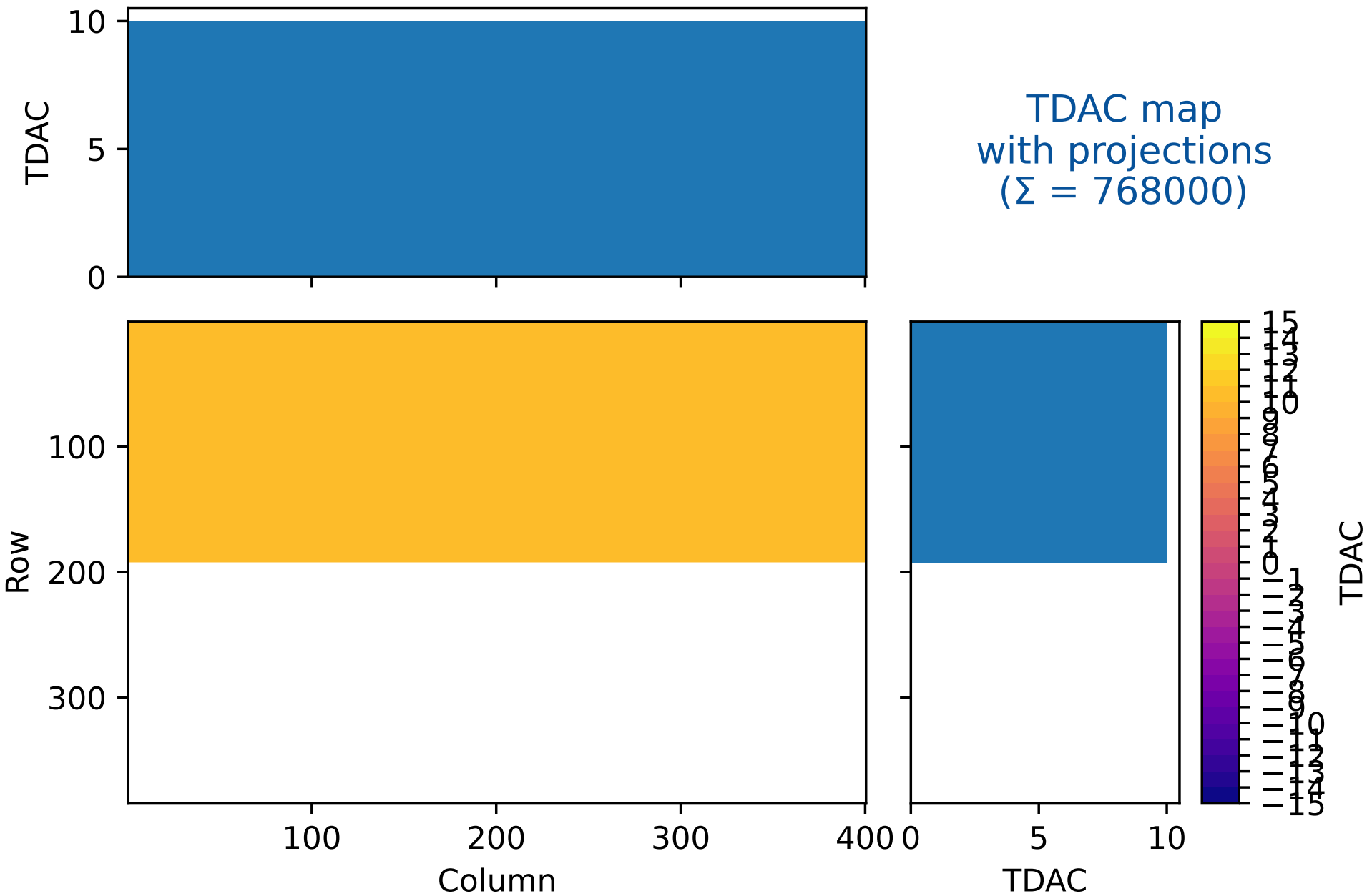

ITKPixV1 preliminary
Chip S/N: 0x162BC
BCID error (Σ = 0)
Number of event header
Trigger ID
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30

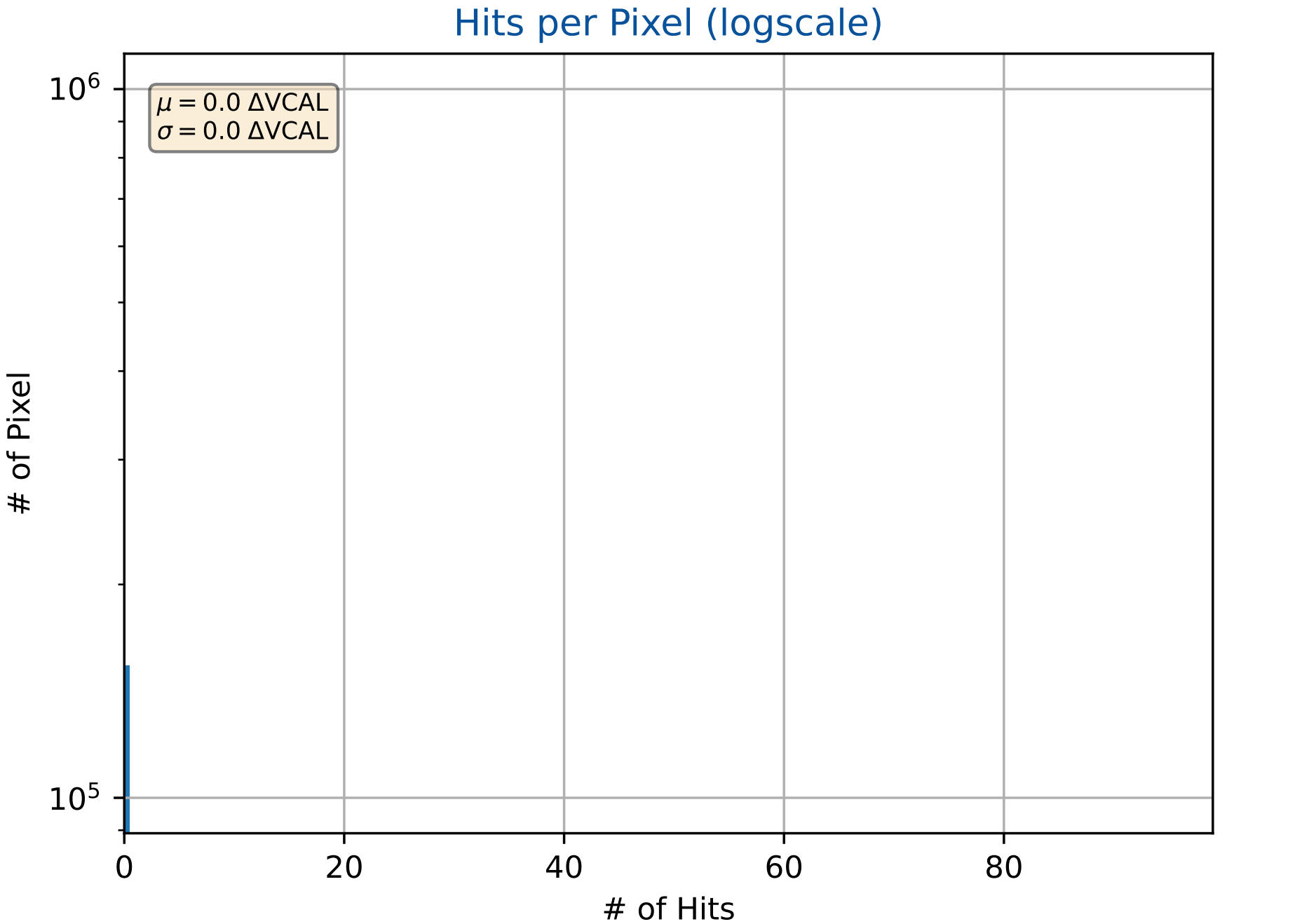
ITKPixV1 preliminary Chip S/N: 0x162BC

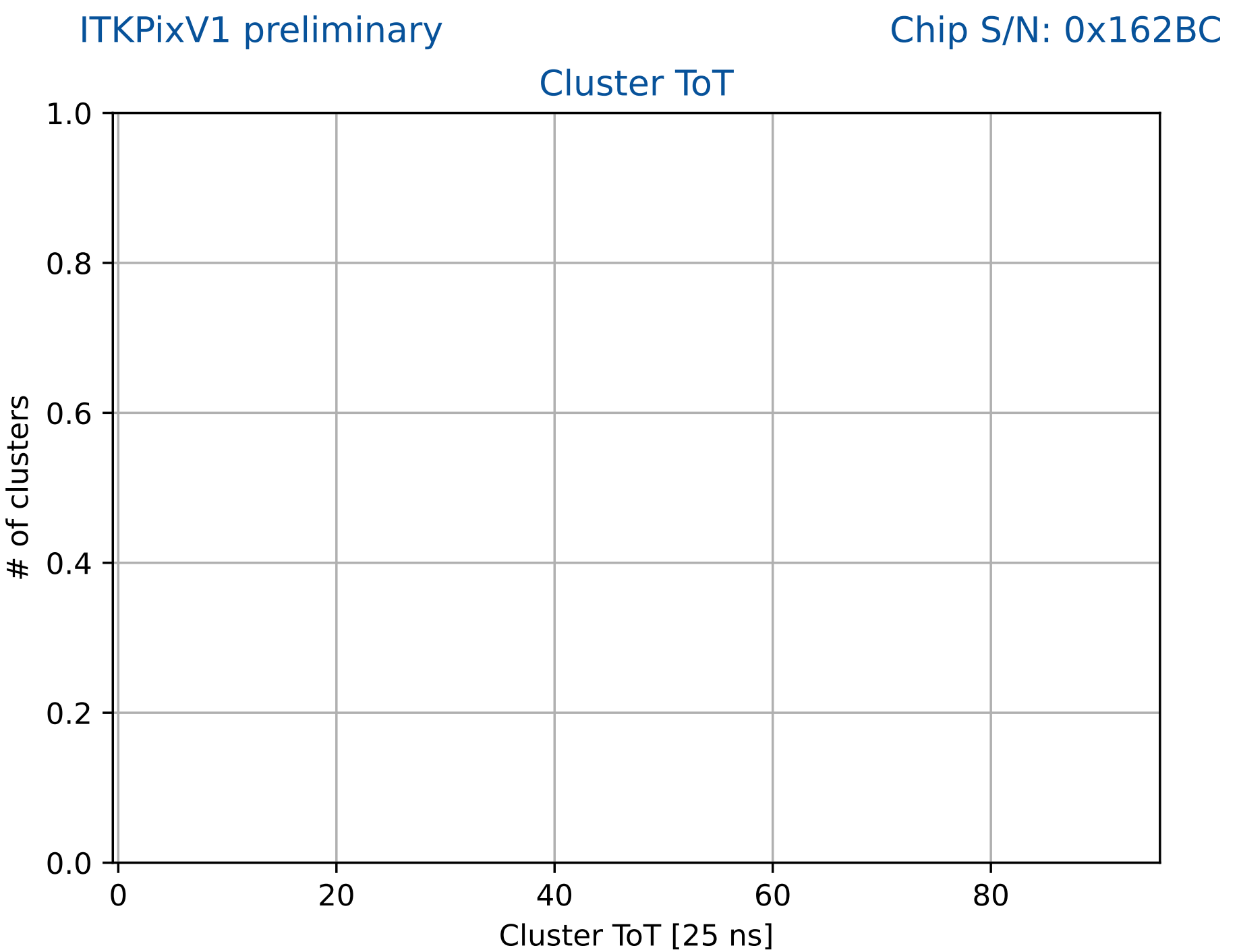
Trigger ID Histogram without Error correction

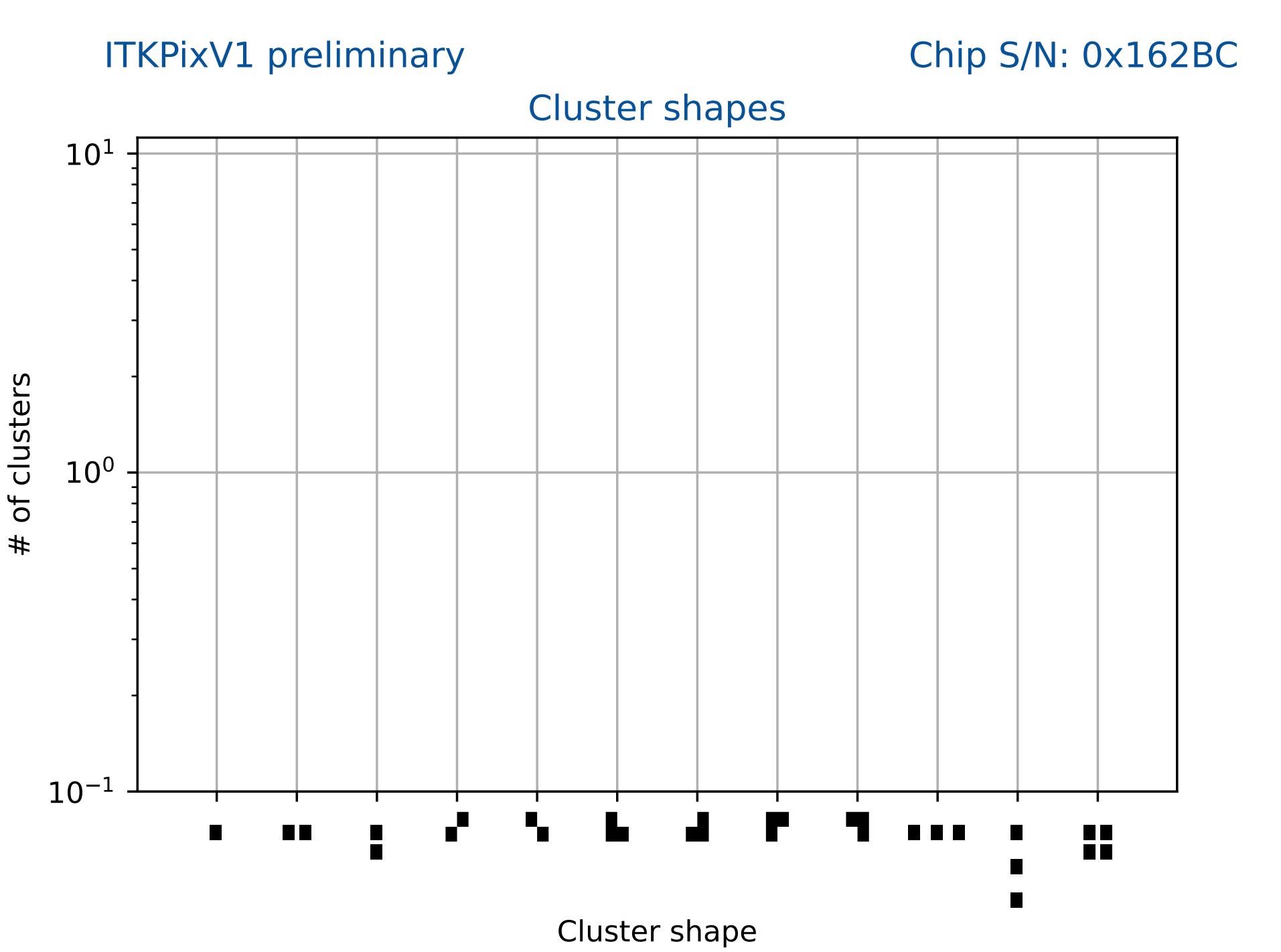


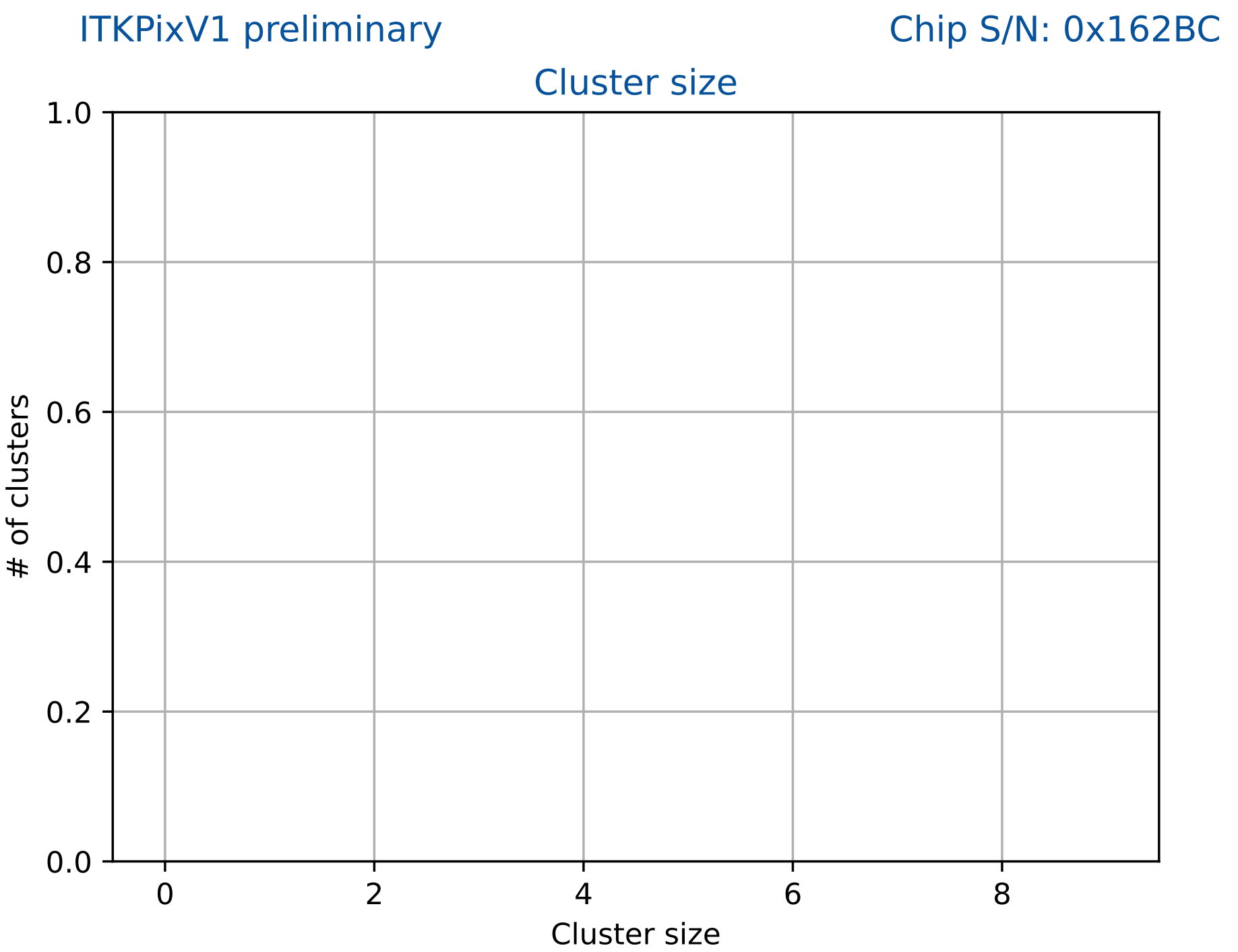

ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC distribution for enabled pixels
$\mu = 10.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
Fit results:
$\mu = 27.4$ ΔVCAL
$\sigma = 3.3$ ΔVCAL
# of pixels
TDAC
80000
70000
60000
50000
40000
30000
20000
10000
0
−15
−10
−5
0
5
10
15

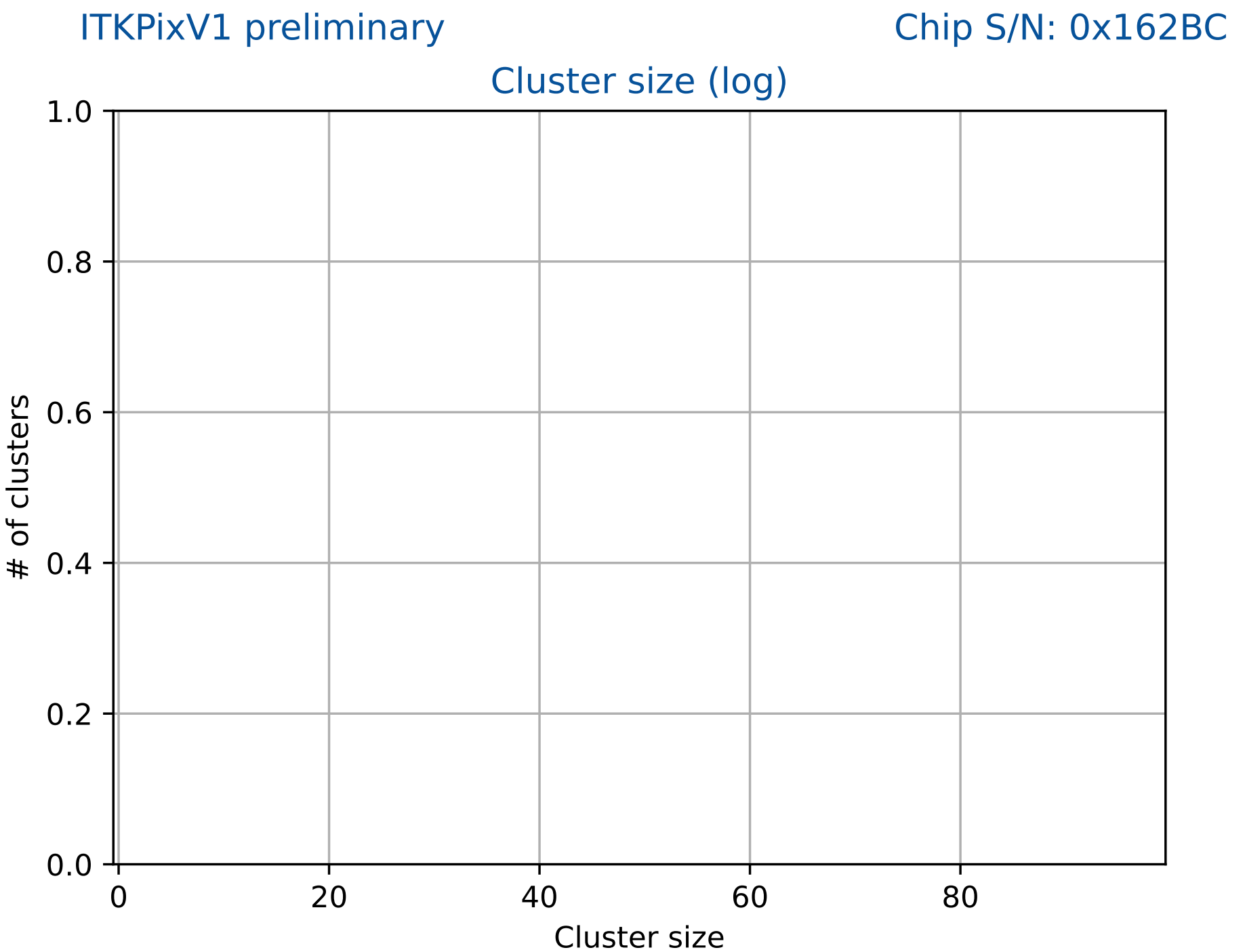

ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC map
with projections
(Σ = 768000)
TDAC
Row
Column
TDAC
TDAC


ITKPixV1 preliminary
Chip S/N: 0x162BC
Hits per Pixel (logscale)
$\mu = 0.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
10^6
10^5
# of Pixel
0
20
40
60
80
# of Hits


ITKPixV1 preliminary
Chip S/N: 0x162BC
Cluster ToT
# of clusters
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
Cluster ToT [25 ns]


ITKPixV1 preliminary
Chip S/N: 0x162BC
Cluster shapes
10^1
10^0
10^{-1}
# of clusters
Cluster shape


ITKPixV1 preliminary
Chip S/N: 0x162BC
Cluster size
1.0
0.8
0.6
0.4
0.2
0.0
# of clusters
0
2
4
6
8
Cluster size


ITKPixV1 preliminary
Chip S/N: 0x162BC
Cluster size (log)
# of clusters
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
Cluster size

Crosstalk Scan

- This reads out one pixel while injecting neighbouring pixels using different injection mask patterns to check for crosstalk
- The principle is the same as in a threshold scan

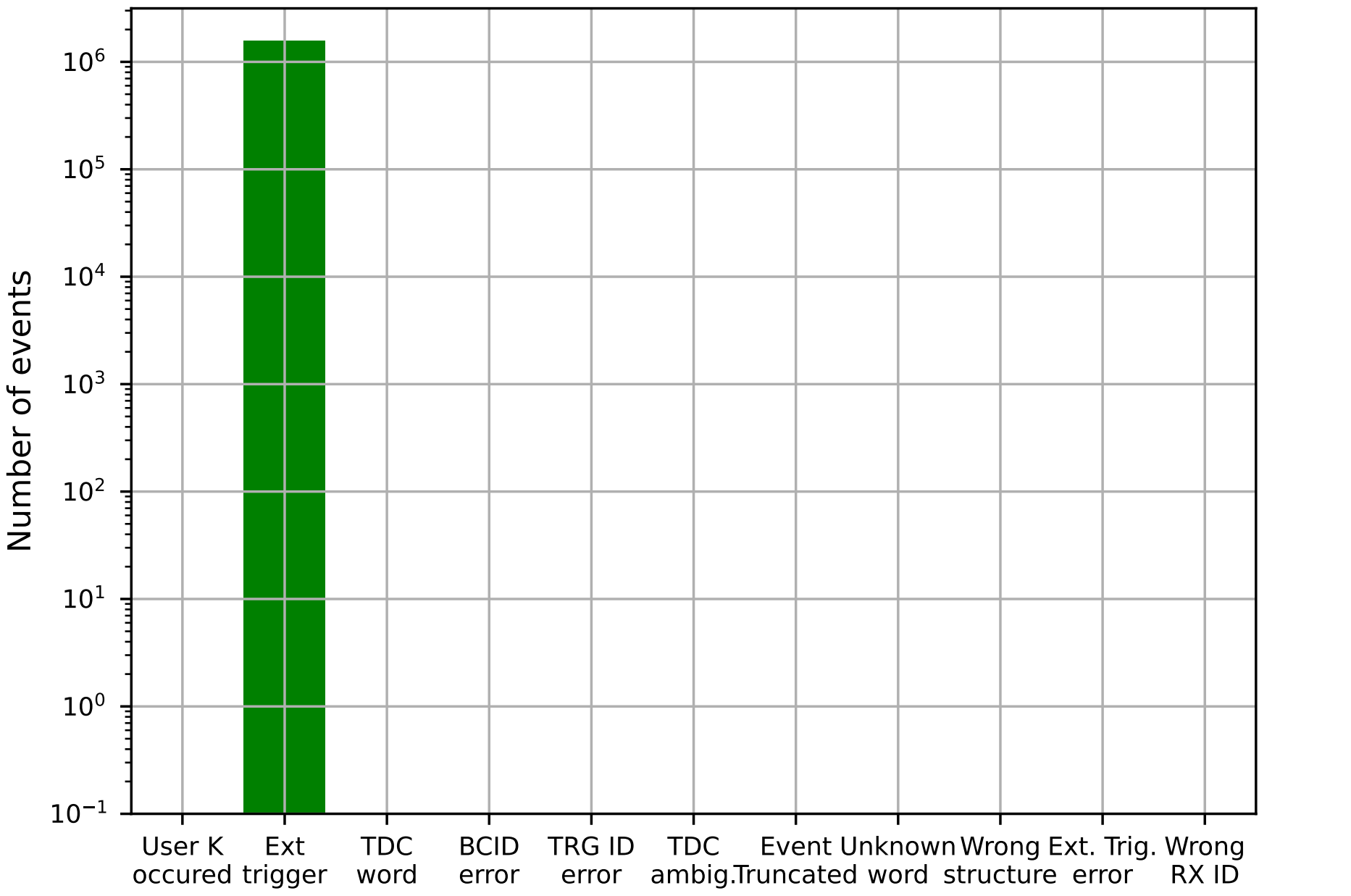
This is a bdaq53 crosstalk_scan for chip 0x162BC.
Run 20230317_014028_crosstalk_scan was started 2023-03-17 01:40:28.

Scan config	Value
VCAL_HIGH_start	0
VCAL_HIGH_step	102
VCAL_HIGH_stop	4096
VCAL_MED	0
injection_type	cross_injection
n_injections	100
start_column	128
start_row	0
stop_column	264
stop_row	192
trigger_pattern	0xffffffff

ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

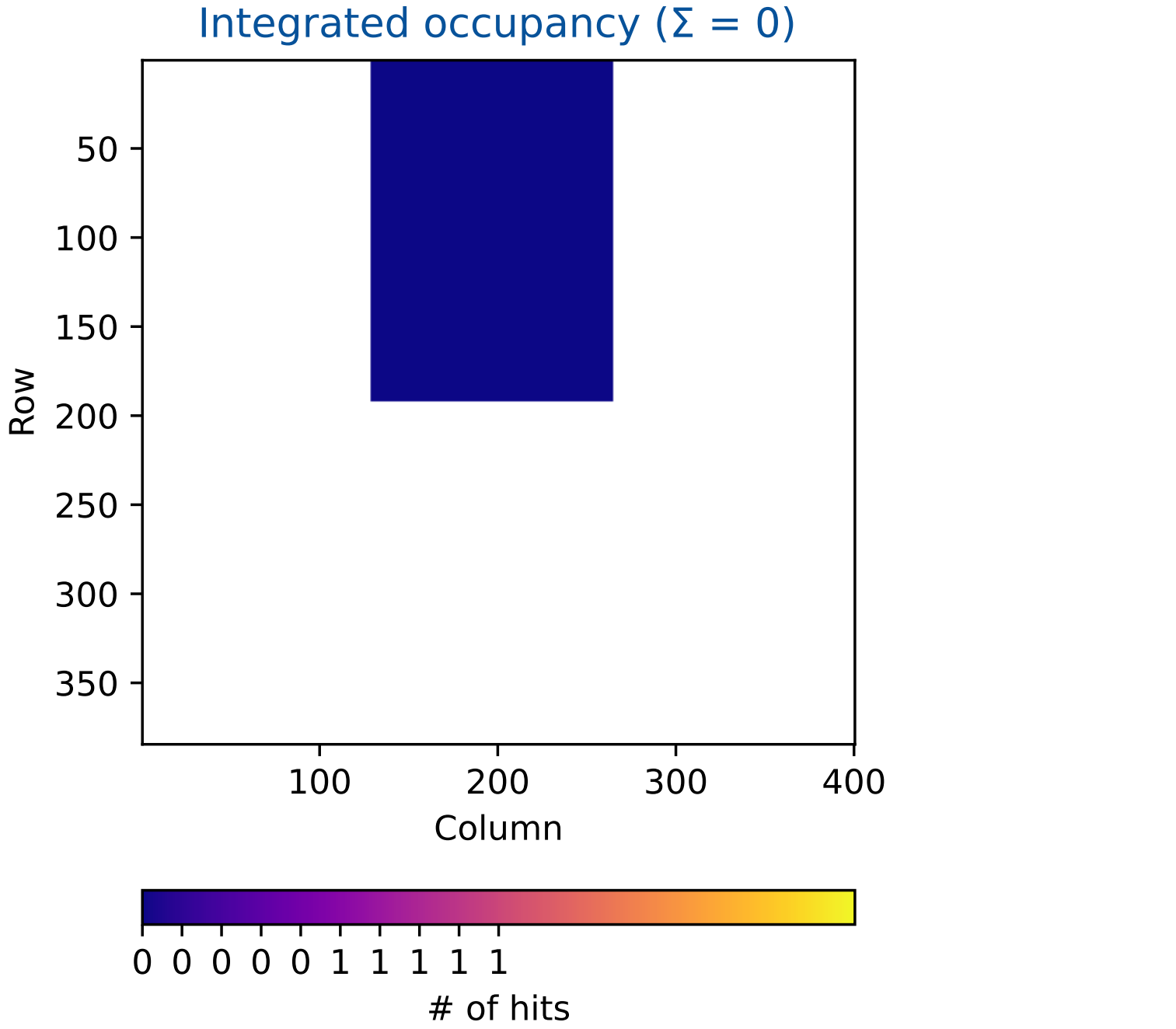
Charge calibration: $y\,[e^-] = x\,[\Delta VCAL] \cdot (4.65 \pm 0.40)\,[\frac{e^-}{\Delta VCAL}] + (0 \pm 60.00)\,[e^-]$

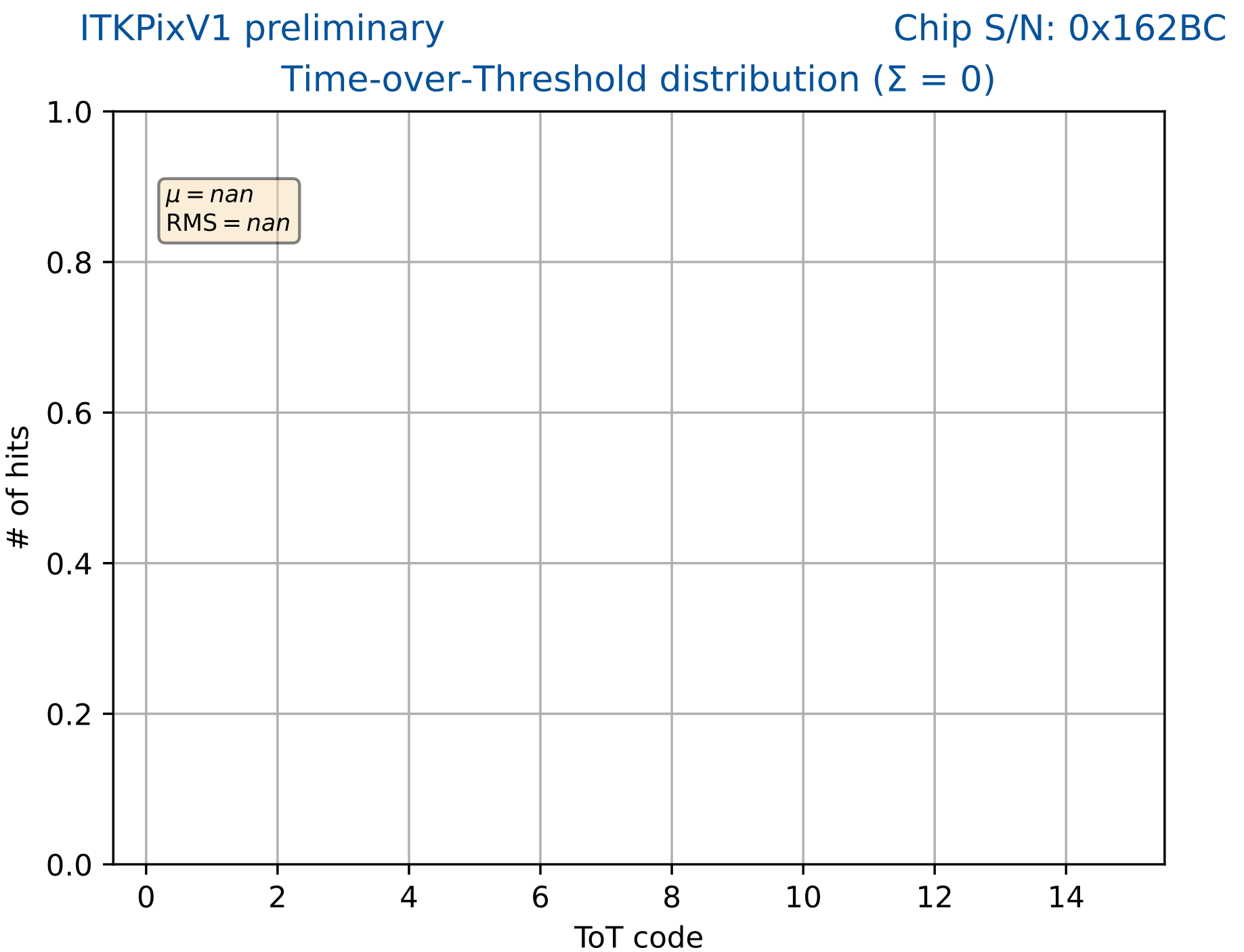
Software version: Tag: v1.7
Changed files: bdaq53/system/bdaq53.py


ITKPixV1 preliminary
Chip S/N: 0x162BC
Event status (Σ = 1574400)
Number of events
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
User K occured
Ext trigger
TDC word
BCID error
TRG ID error
TDC ambig.
Event Truncated
Unknown word
Wrong structure
Ext. Trig. error
Wrong RX ID

ITKPixV1 preliminary

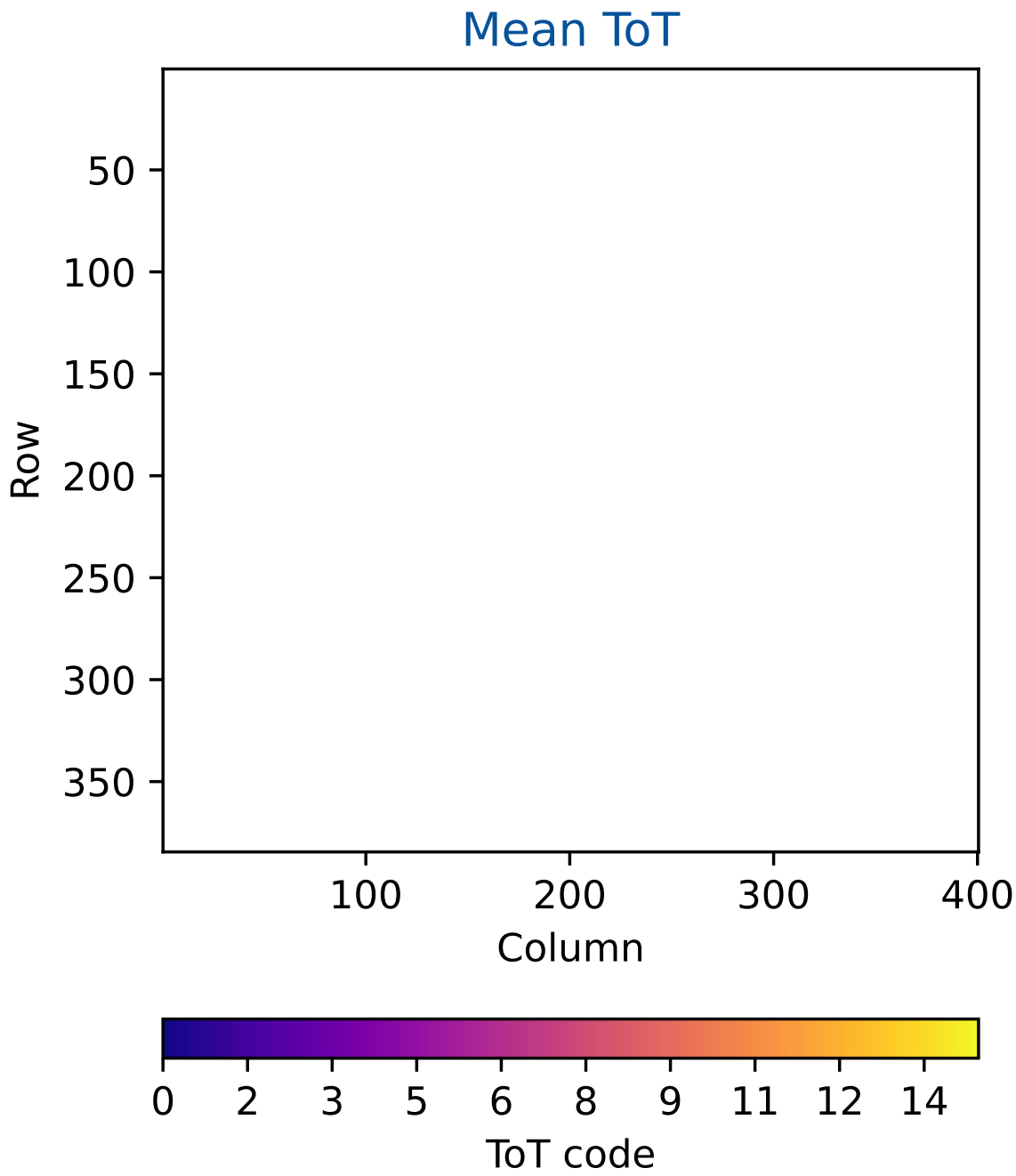
Chip S/N: 0x162BC

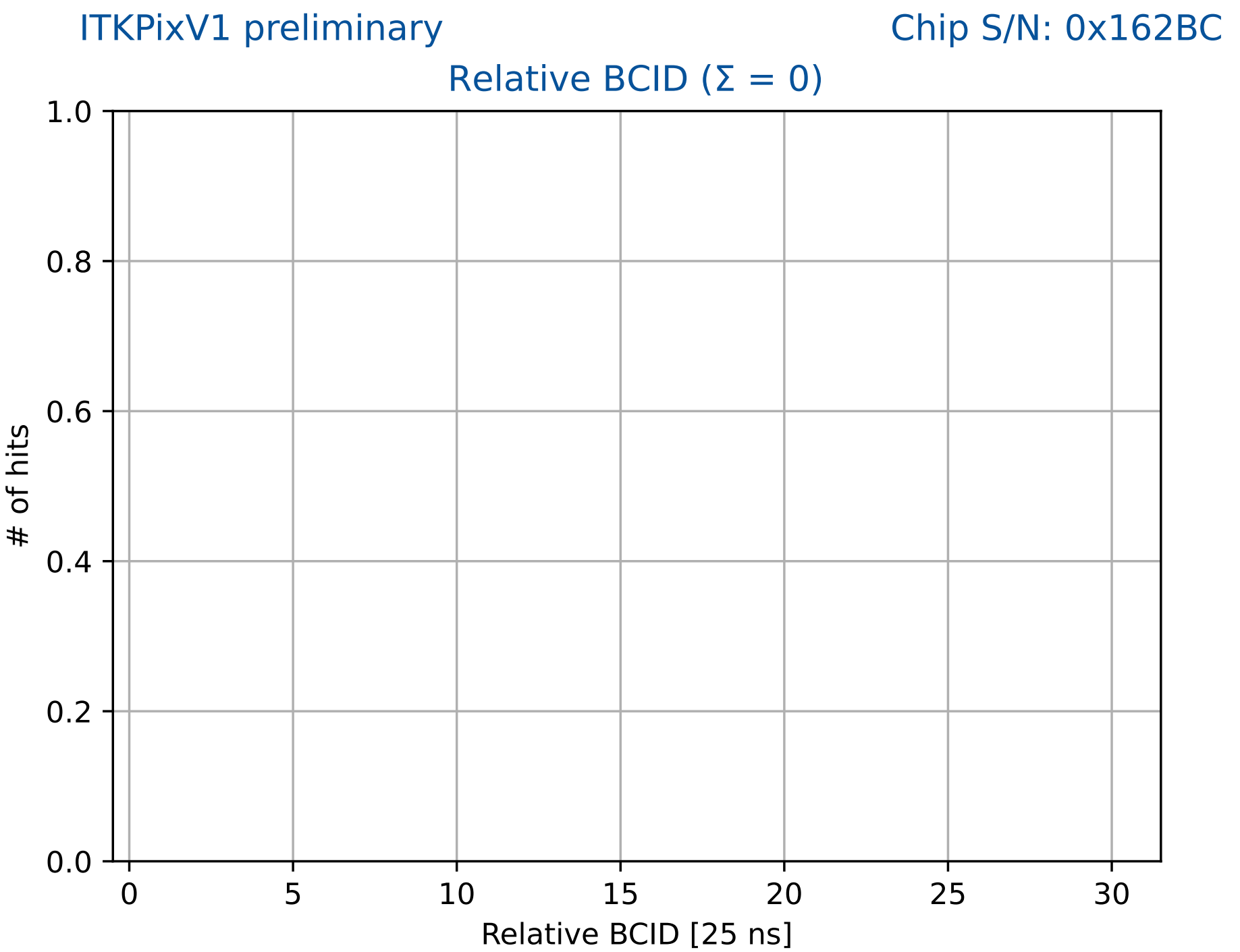



ITKPixV1 preliminary
Chip S/N: 0x162BC
Time-over-Threshold distribution (Σ = 0)
μ = nan
RMS = nan
# of hits
ToT code
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
14

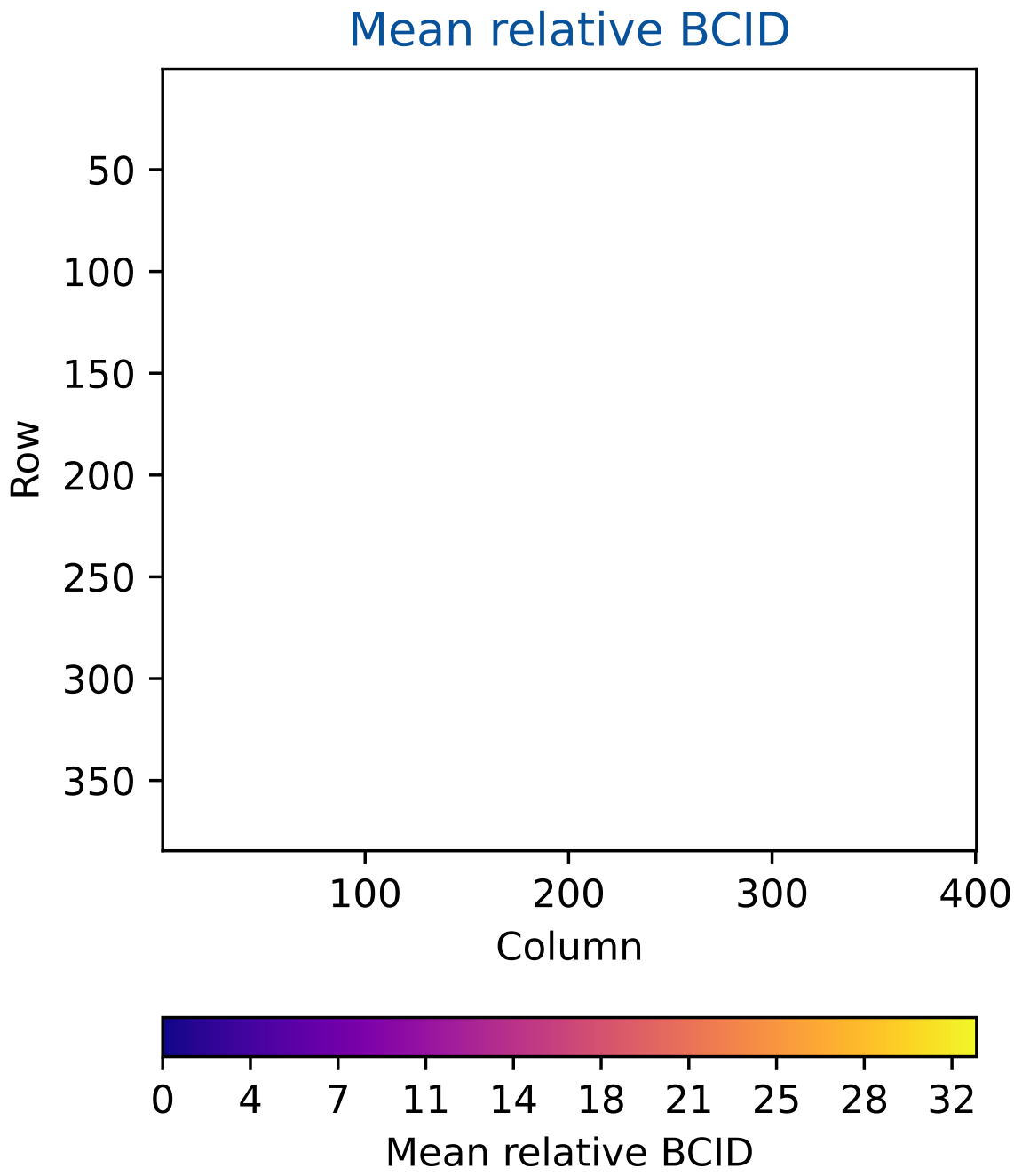
ITKPixV1 preliminary

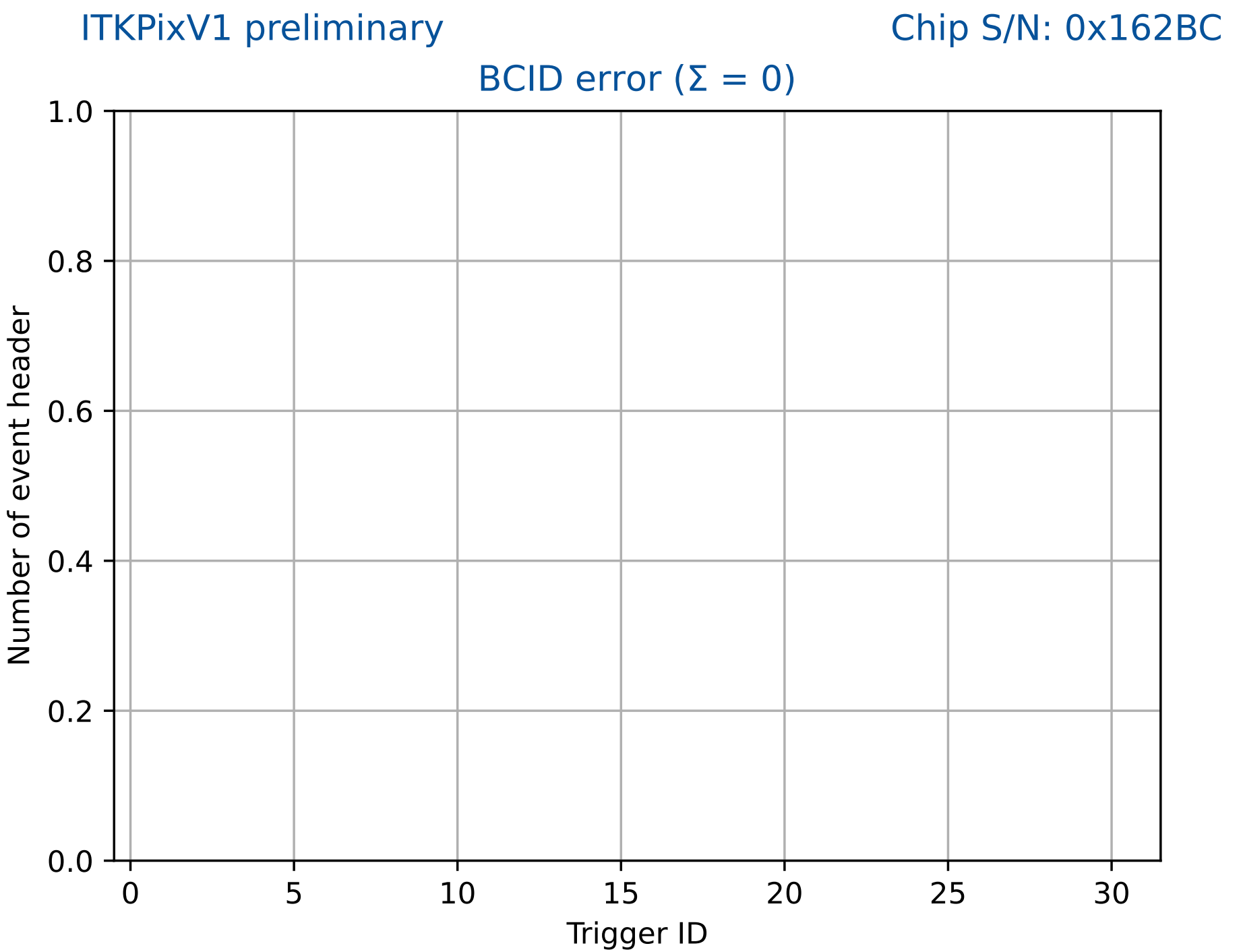
Chip S/N: 0x162BC




ITKPixV1 preliminary
Chip S/N: 0x162BC
Relative BCID (Σ = 0)
# of hits
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Relative BCID [25 ns]

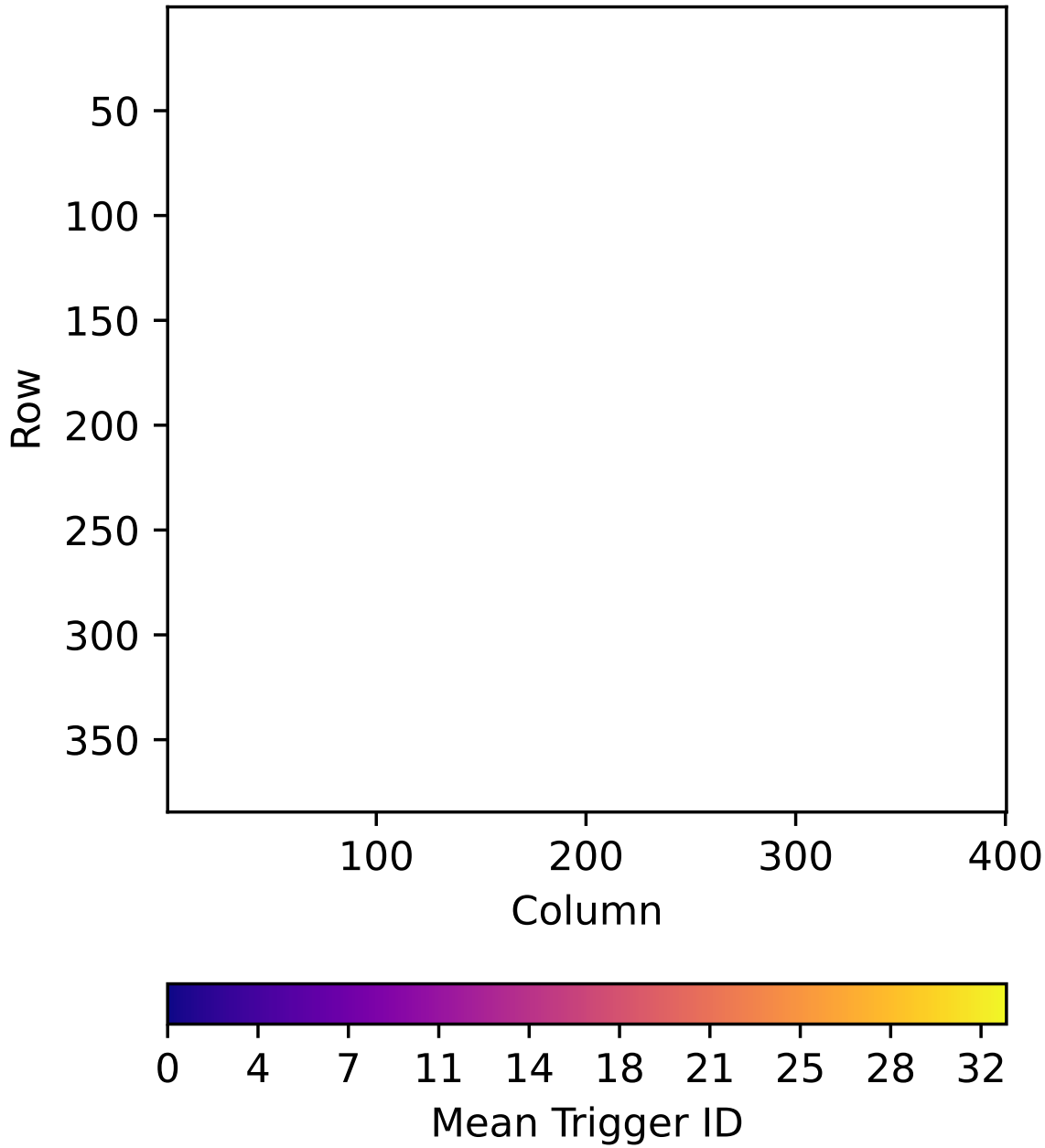
ITKPixV1 preliminary Chip S/N: 0x162BC

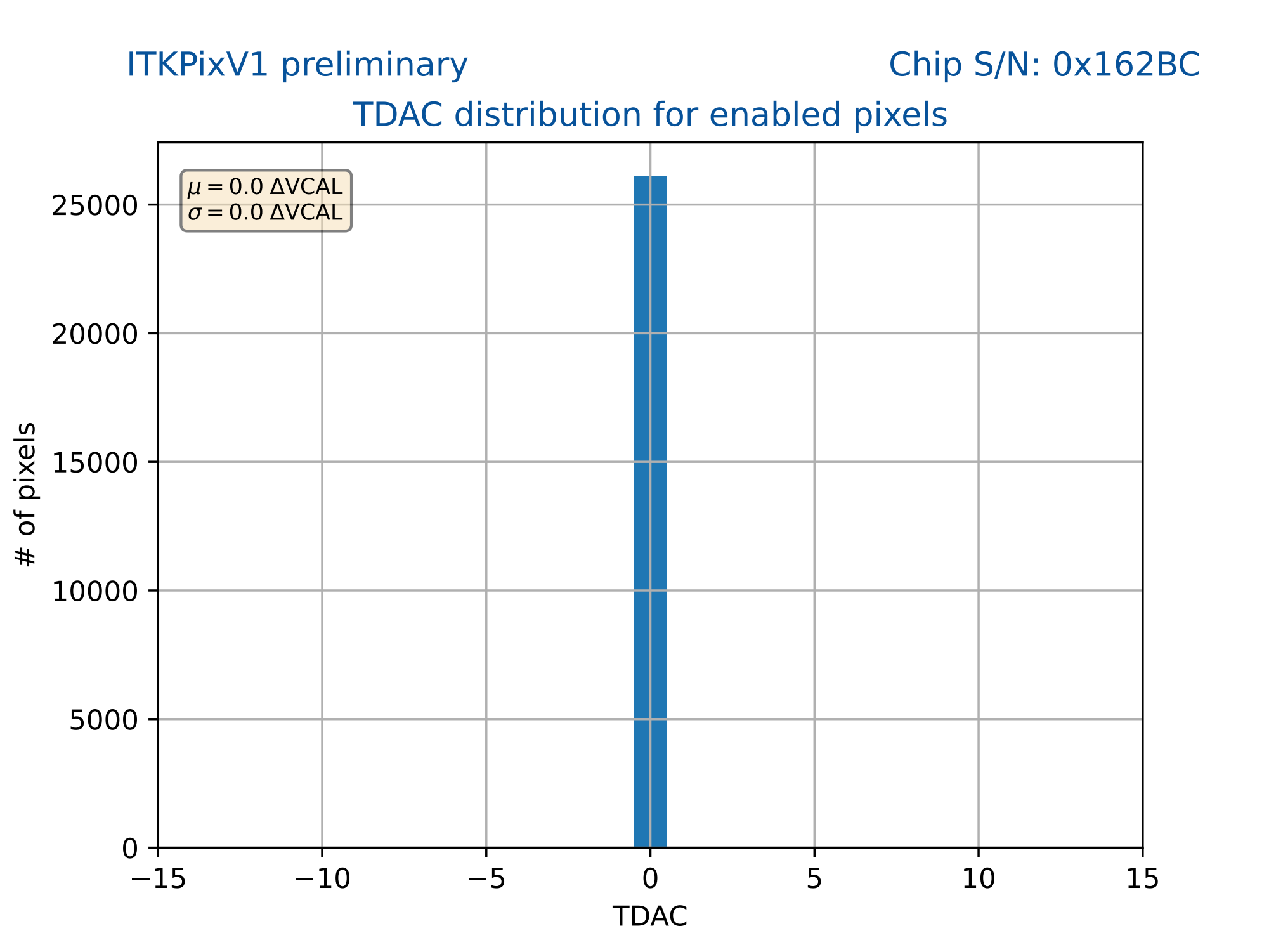


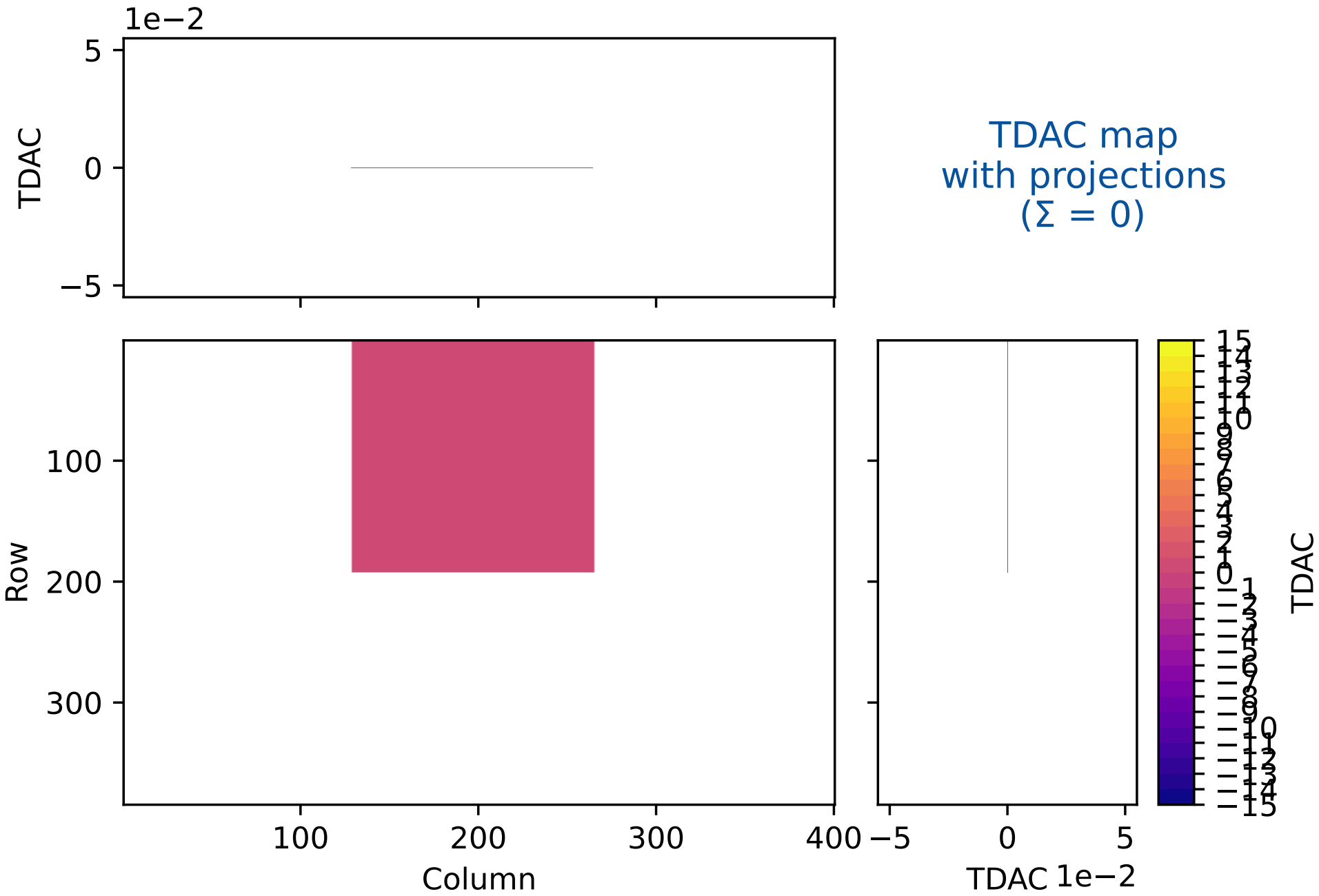

ITKPixV1 preliminary
Chip S/N: 0x162BC
BCID error (Σ = 0)
Number of event header
Trigger ID
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30

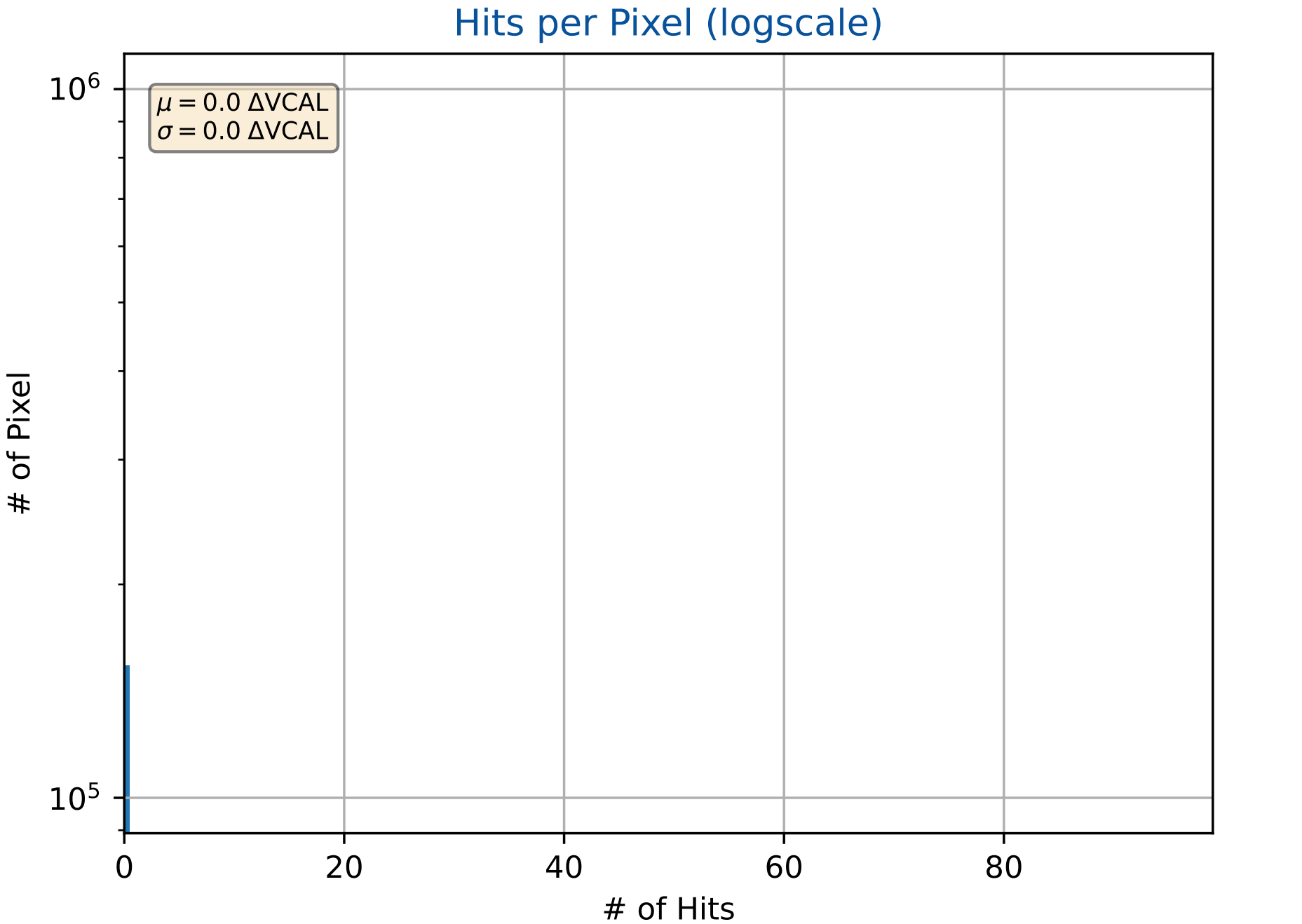
ITKPixV1 preliminary Chip S/N: 0x162BC

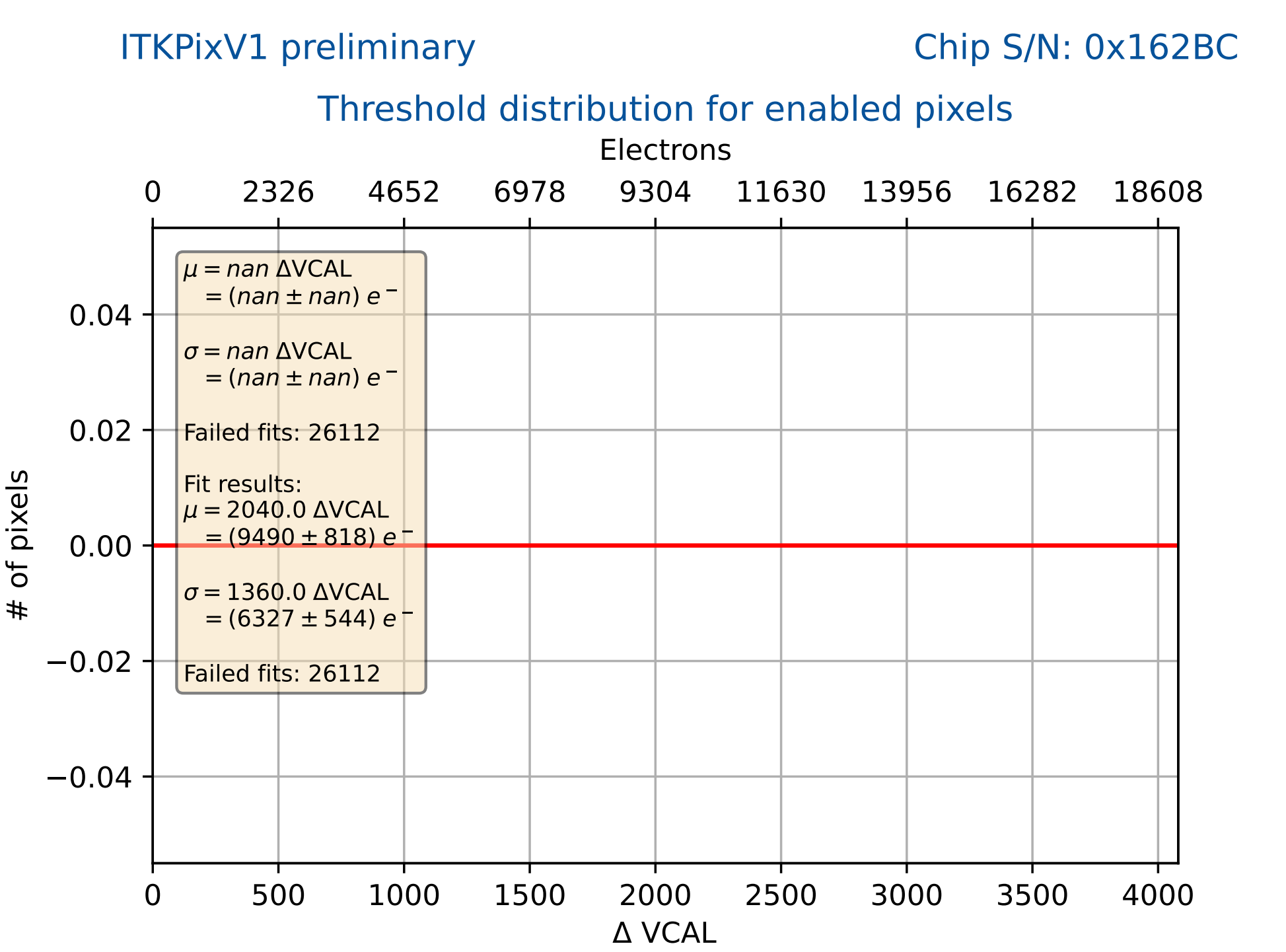
Trigger ID Histogram without Error correction

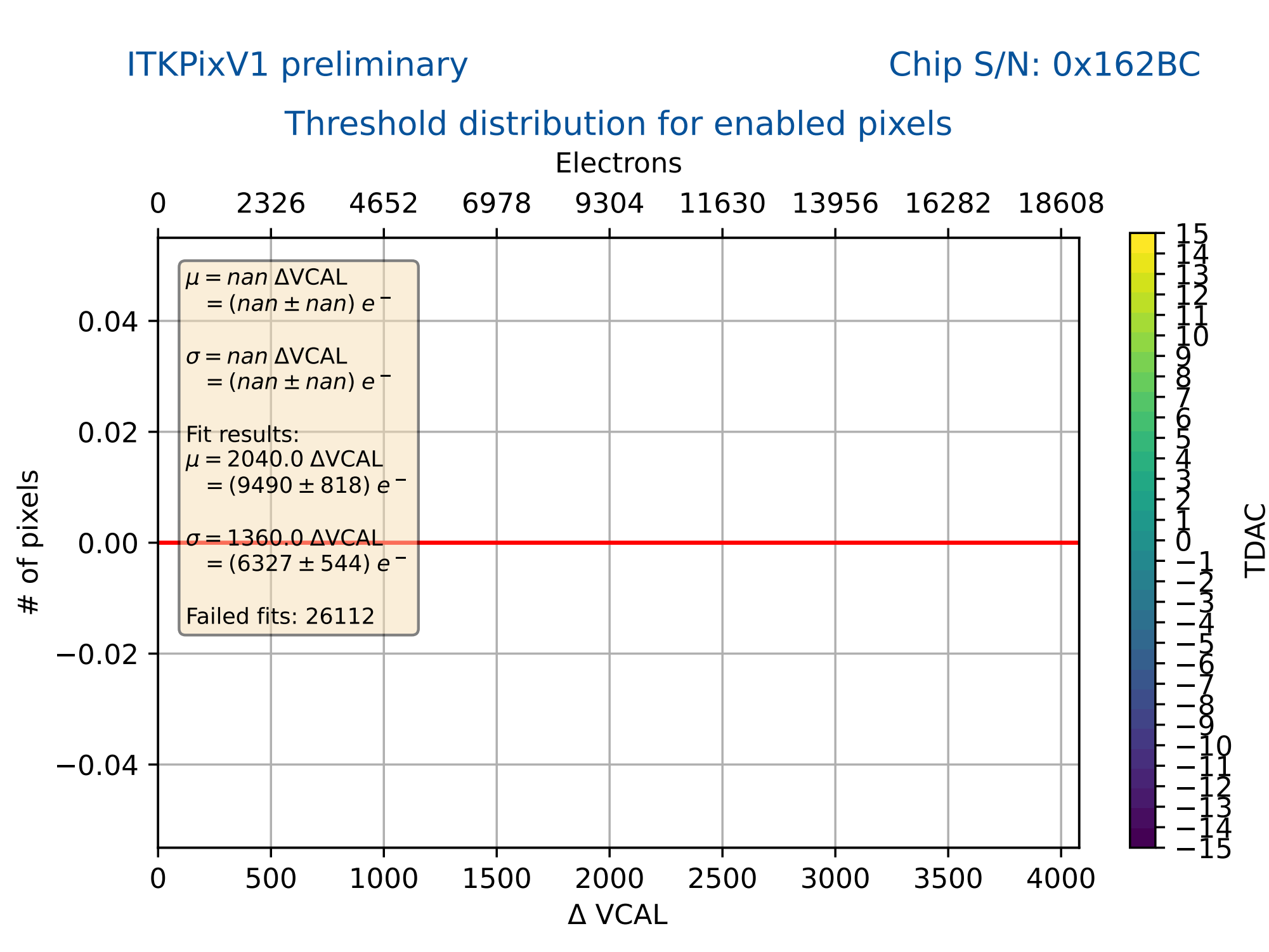



ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC distribution for enabled pixels
$\mu = 0.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
# of pixels
0
5000
10000
15000
20000
25000
−15
−10
−5
0
5
10
15
TDAC


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDAC map
with projections
(Σ = 0)
1e−2
5
0
−5
TDAC
Row
100
200
300
100
200
300
400
Column
−5
0
5
TDAC 1e−2
TDAC

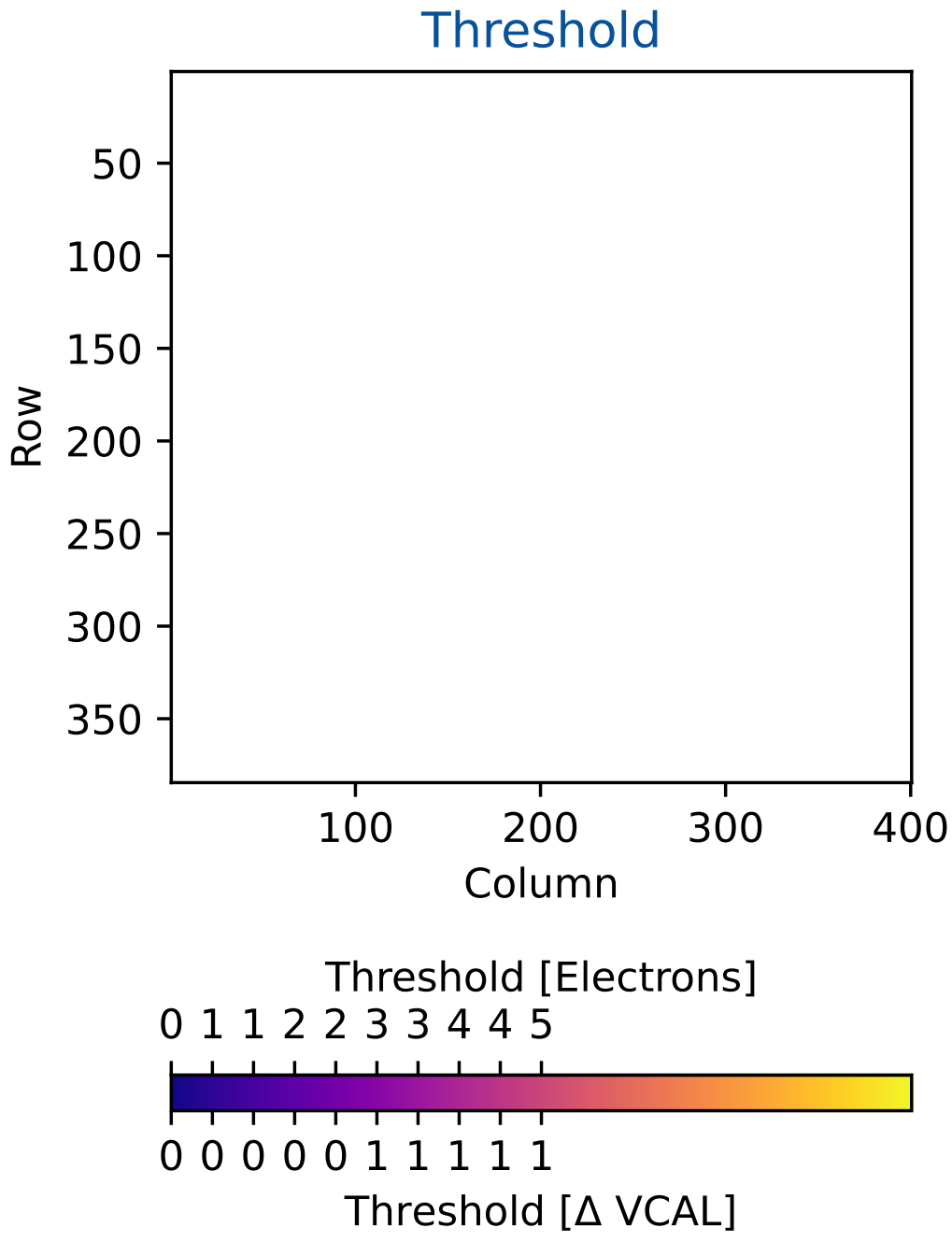

ITKPixV1 preliminary
Chip S/N: 0x162BC
Hits per Pixel (logscale)
$\mu = 0.0$ ΔVCAL
$\sigma = 0.0$ ΔVCAL
10^6
10^5
# of Pixel
0
20
40
60
80
# of Hits


ITKPixV1 preliminary
Chip S/N: 0x162BC
Threshold distribution for enabled pixels
Electrons
0
2326
4652
6978
9304
11630
13956
16282
18608
μ = nan ΔVCAL
= (nan ± nan) e⁻
σ = nan ΔVCAL
= (nan ± nan) e⁻
Failed fits: 26112
Fit results:
μ = 2040.0 ΔVCAL
= (9490 ± 818) e⁻
σ = 1360.0 ΔVCAL
= (6327 ± 544) e⁻
Failed fits: 26112
# of pixels
0.04
0.02
0.00
−0.02
−0.04
0
500
1000
1500
2000
2500
3000
3500
4000
Δ VCAL


ITKPixV1 preliminary
Chip S/N: 0x162BC
Threshold distribution for enabled pixels
Electrons
0
2326
4652
6978
9304
11630
13956
16282
18608
μ = nan ΔVCAL
= (nan ± nan) e⁻
σ = nan ΔVCAL
= (nan ± nan) e⁻
Fit results:
μ = 2040.0 ΔVCAL
= (9490 ± 818) e⁻
σ = 1360.0 ΔVCAL
= (6327 ± 544) e⁻
Failed fits: 26112
# of pixels
0.04
0.02
0.00
−0.02
−0.04
0
500
1000
1500
2000
2500
3000
3500
4000
Δ VCAL
TDAC
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
−13
−14
−15

ITKPixV1 preliminary

Chip S/N: 0x162BC



Hitor Calibration

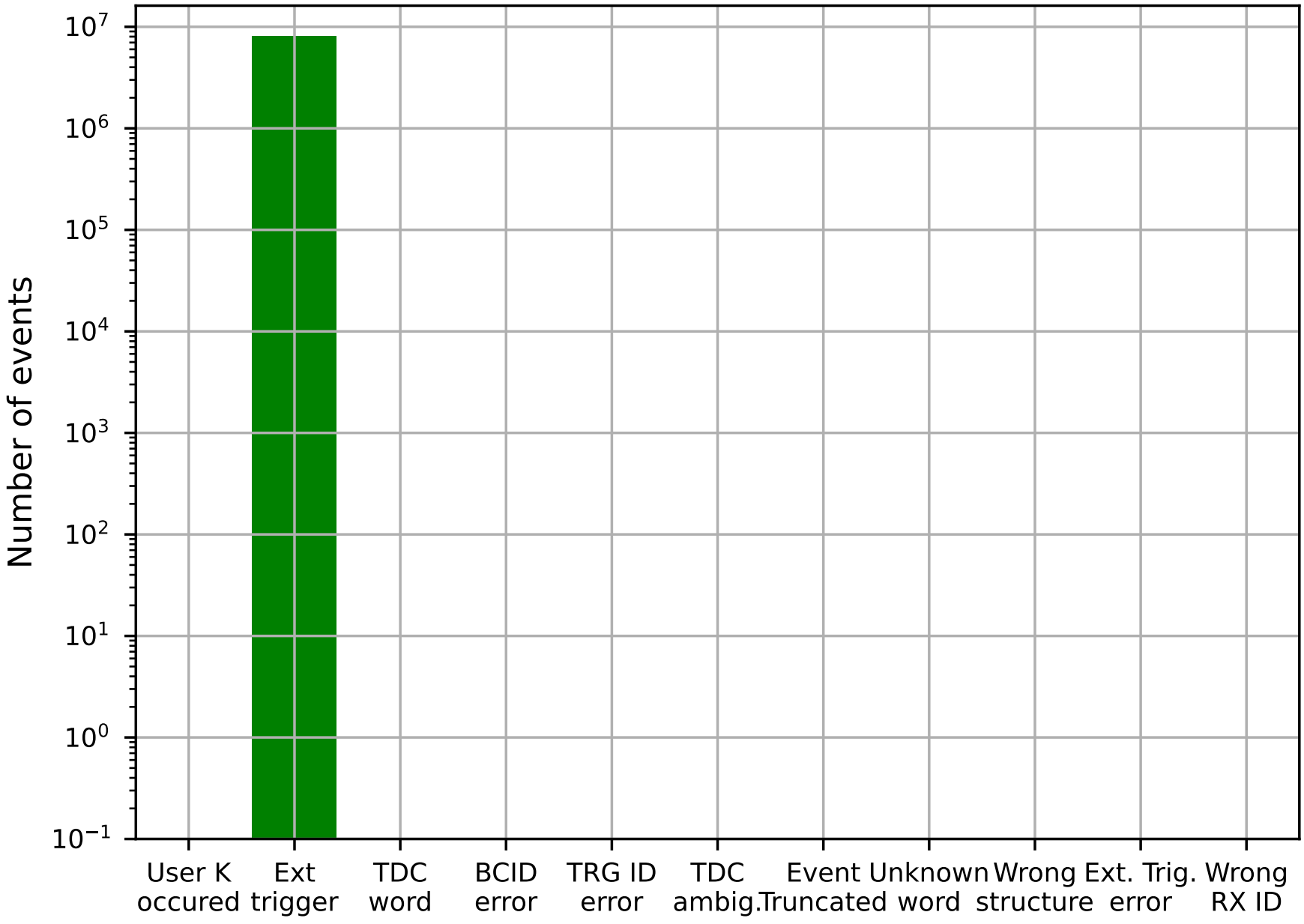
- Calibrates the Hitor for every pixel using the charge injection circuit
- Different charges are injected and the response of the Hitor is measured using the TDC module
- Relationship between Delta VCAL and TDC values is obtained, which is needed for a precise charge measurement

This is a bdaq53 hitor_calibration for chip 0x162BC.
Run 20230317_040923_hitor_calibration was started 2023-03-17 04:09:23.

Scan config	Value
VCAL_HIGH_values	range(900, 20
VCAL_MED	500
n_injections	100
start_column	128
start_row	0
stop_column	264
stop_row	192
trigger_pattern	0xffffffff

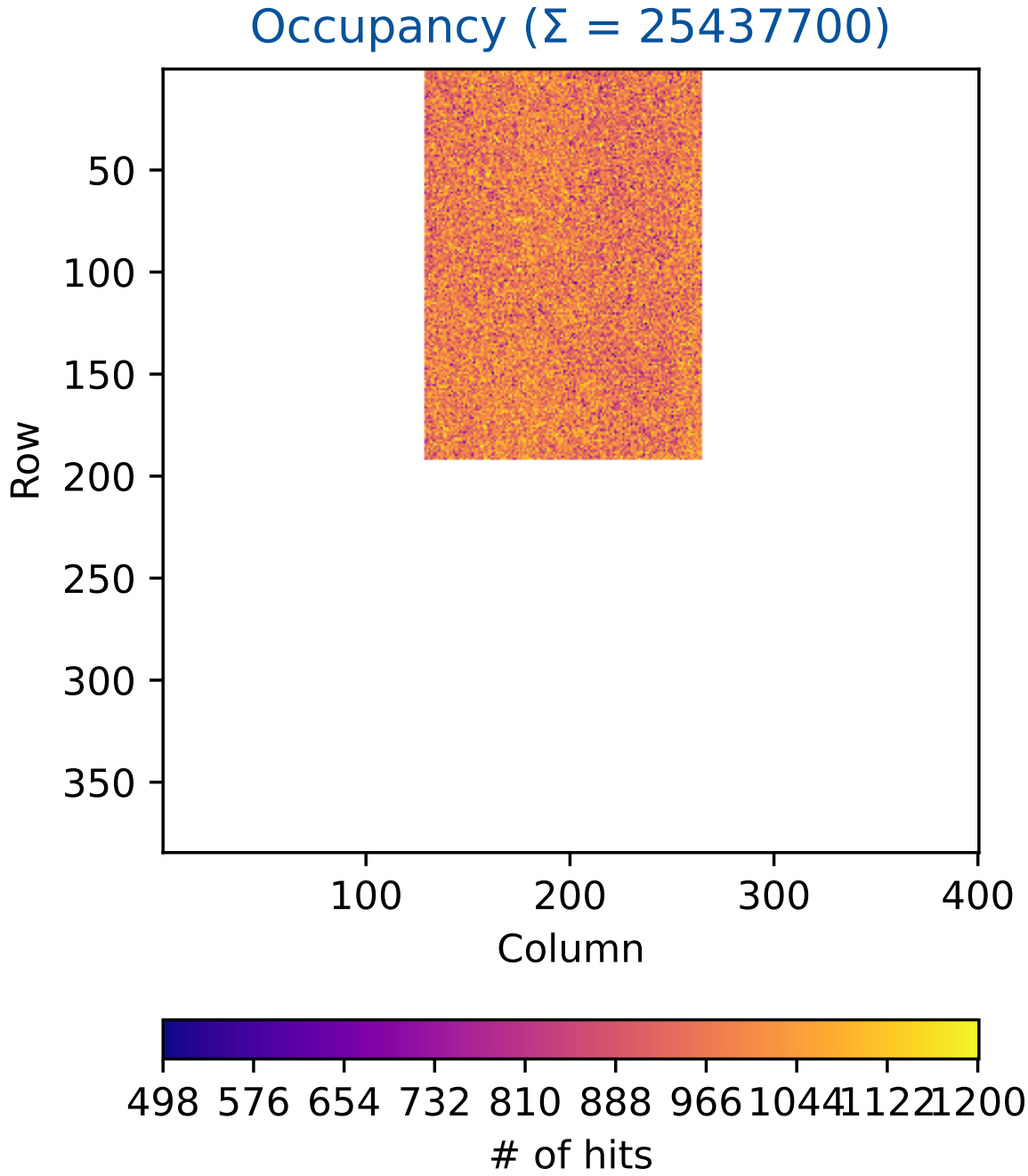
ITkPixV1 config	Value
DAC_PREAMP_L_DIFF	895
DAC_PREAMP_R_DIFF	895
DAC_PREAMP_TL_DIFF	895
DAC_PREAMP_TR_DIFF	895
DAC_PREAMP_T_DIFF	895
DAC_PREAMP_M_DIFF	895
DAC_PRECOMP_DIFF	300
DAC_COMP_DIFF	523
DAC_VFF_DIFF	160
DAC_TH1_L_DIFF	220
DAC_TH1_R_DIFF	220
DAC_TH1_M_DIFF	220
DAC_TH2_DIFF	0
DAC_LCC_DIFF	200
LEACKAGE_FEEDBACK	0

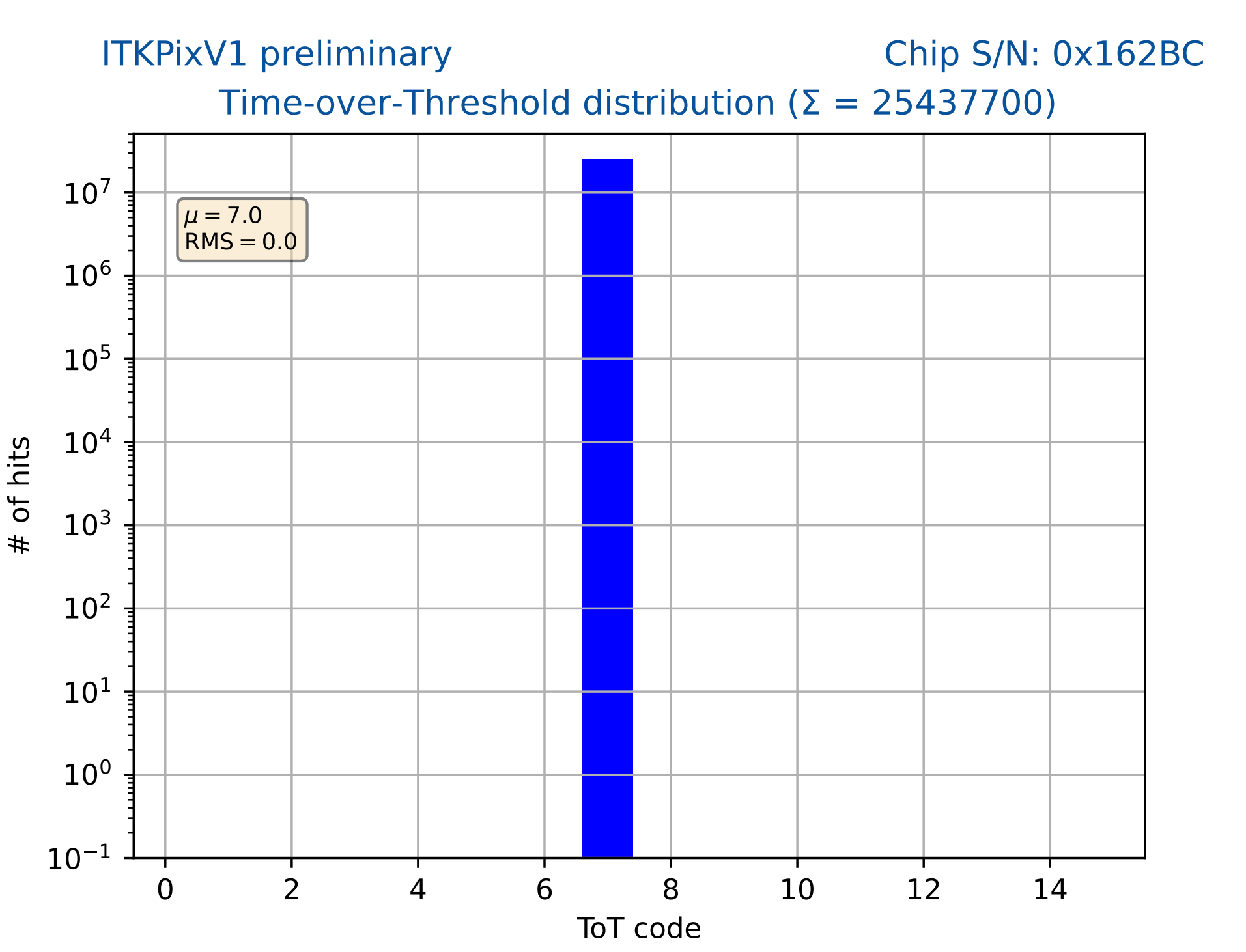
Software version: Tag: v1.7
Changed files: bdaq53/scans/scan_in_time_threshold.py, bdaq53/scans/scan_injection_delay.py, bdaq53/system/bdaq53.py

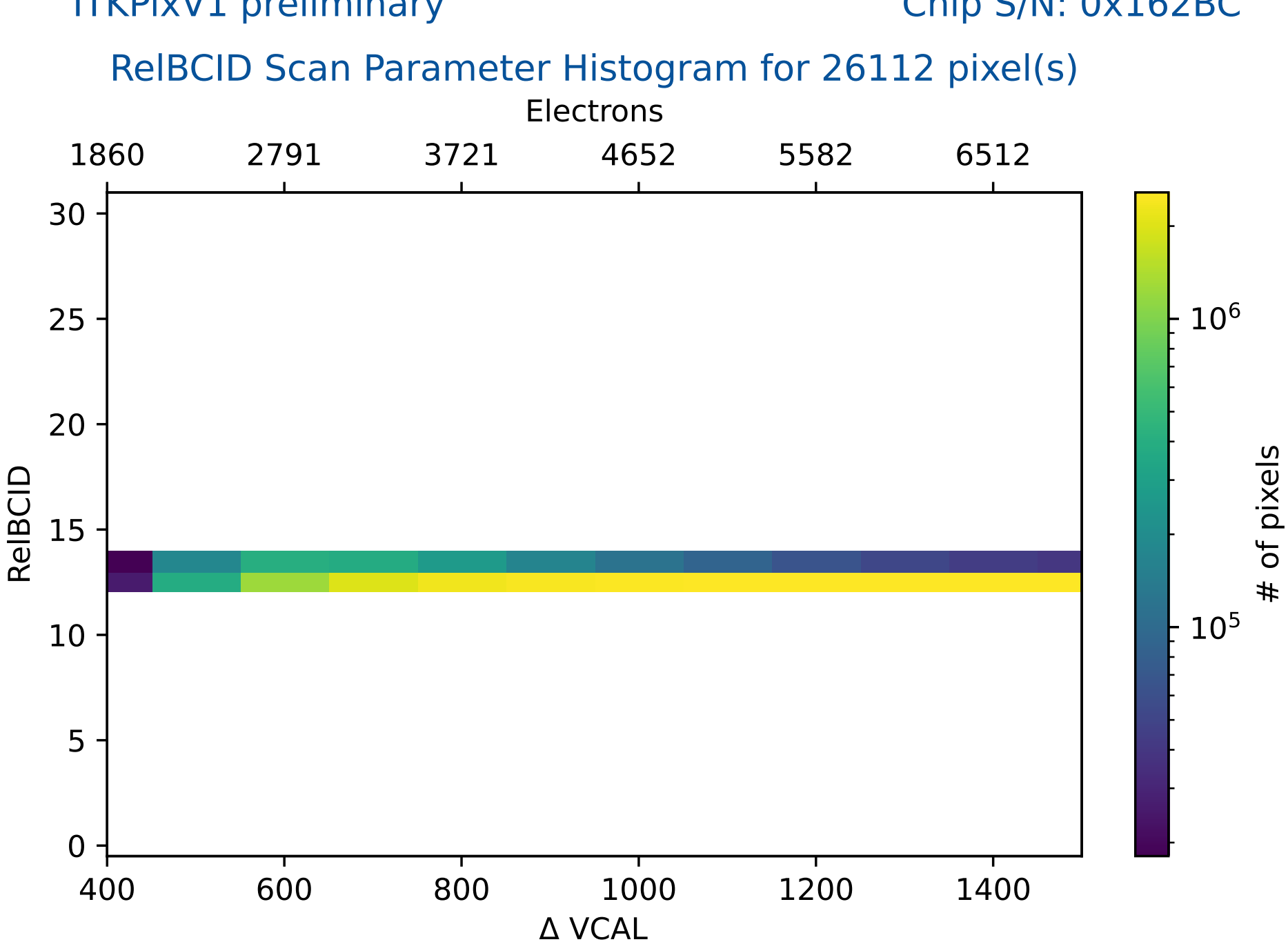

ITKPixV1 preliminary
Chip S/N: 0x162BC
Event status (Σ = 8078400)
Number of events
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
User K occured
Ext trigger
TDC word
BCID error
TRG ID error
TDC ambig.
Event Truncated
Unknown word
Wrong structure
Ext. Trig. error
Wrong RX ID

ITKPixV1 preliminary

Chip S/N: 0x162BC

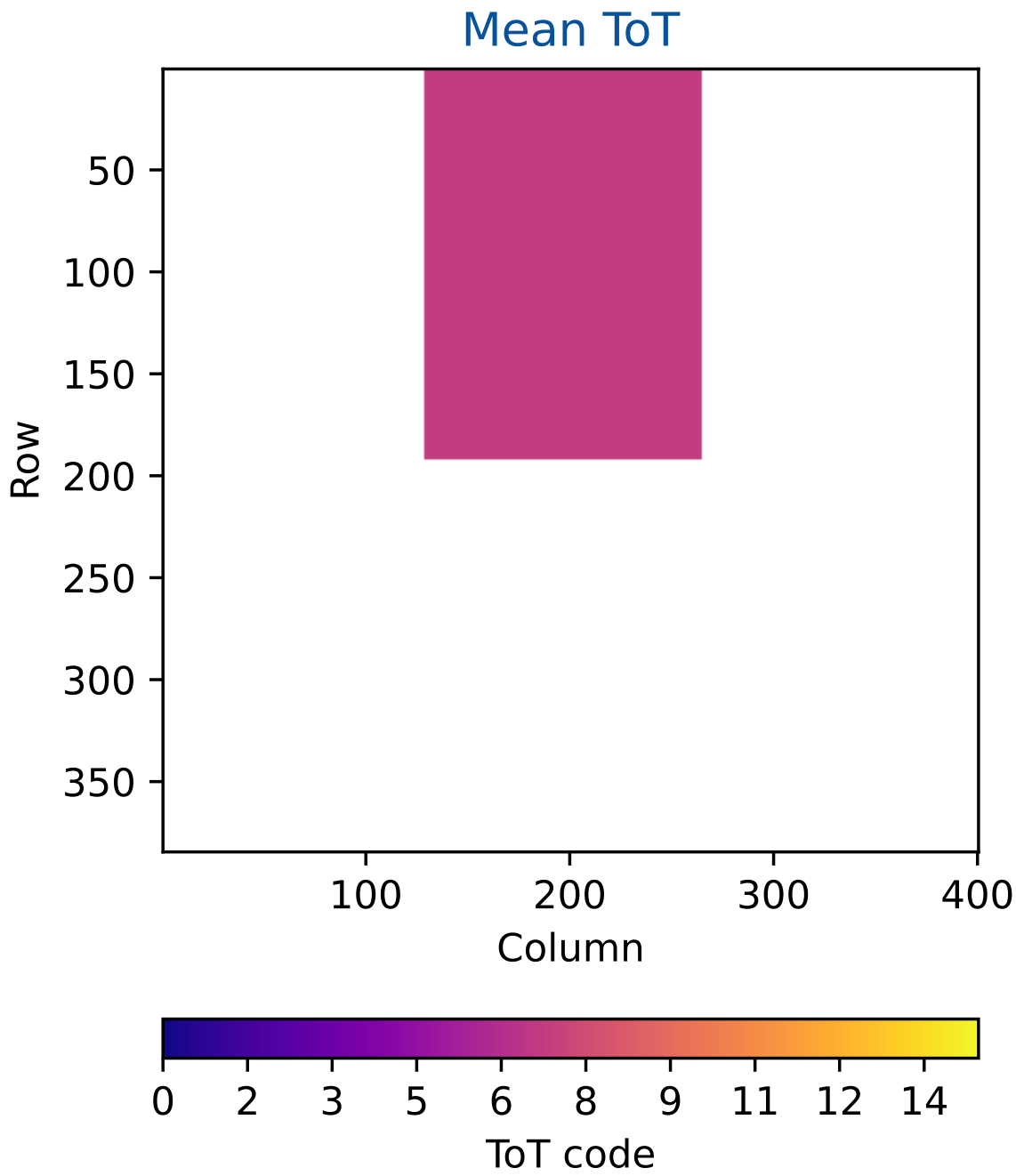


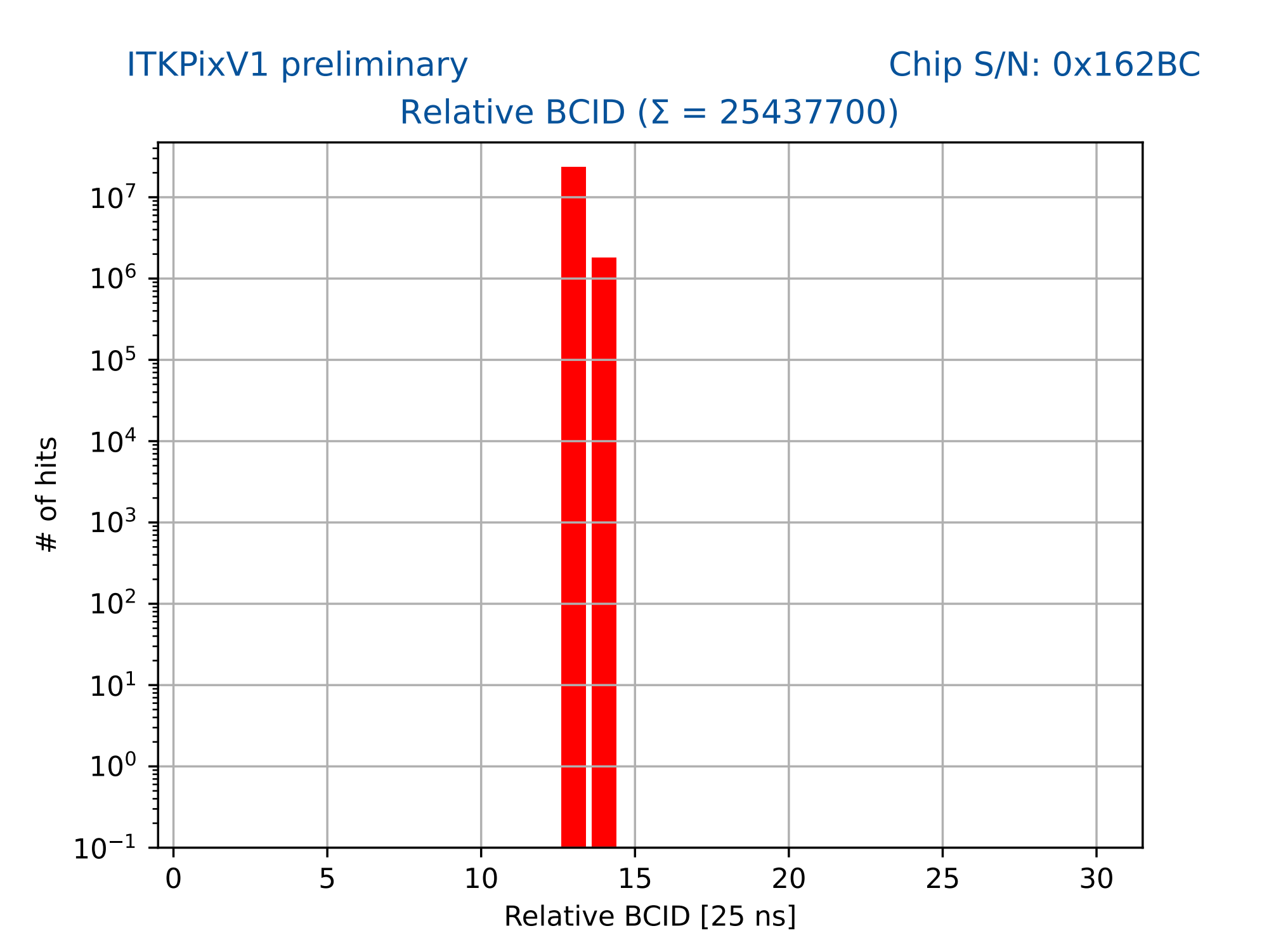

ITKPixV1 preliminary
Chip S/N: 0x162BC
Time-over-Threshold distribution (Σ = 25437700)
μ = 7.0
RMS = 0.0
# of hits
ToT code
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^−1
0
2
4
6
8
10
12
14


ITKPixV1 preliminary
Chip S/N: 0x162BC
RelBCID Scan Parameter Histogram for 26112 pixel(s)
Electrons
1860
2791
3721
4652
5582
6512
RelBCID
30
25
20
15
10
5
0
400
600
800
1000
1200
1400
Δ VCAL
# of pixels
10^6
10^5

ITKPixV1 preliminary

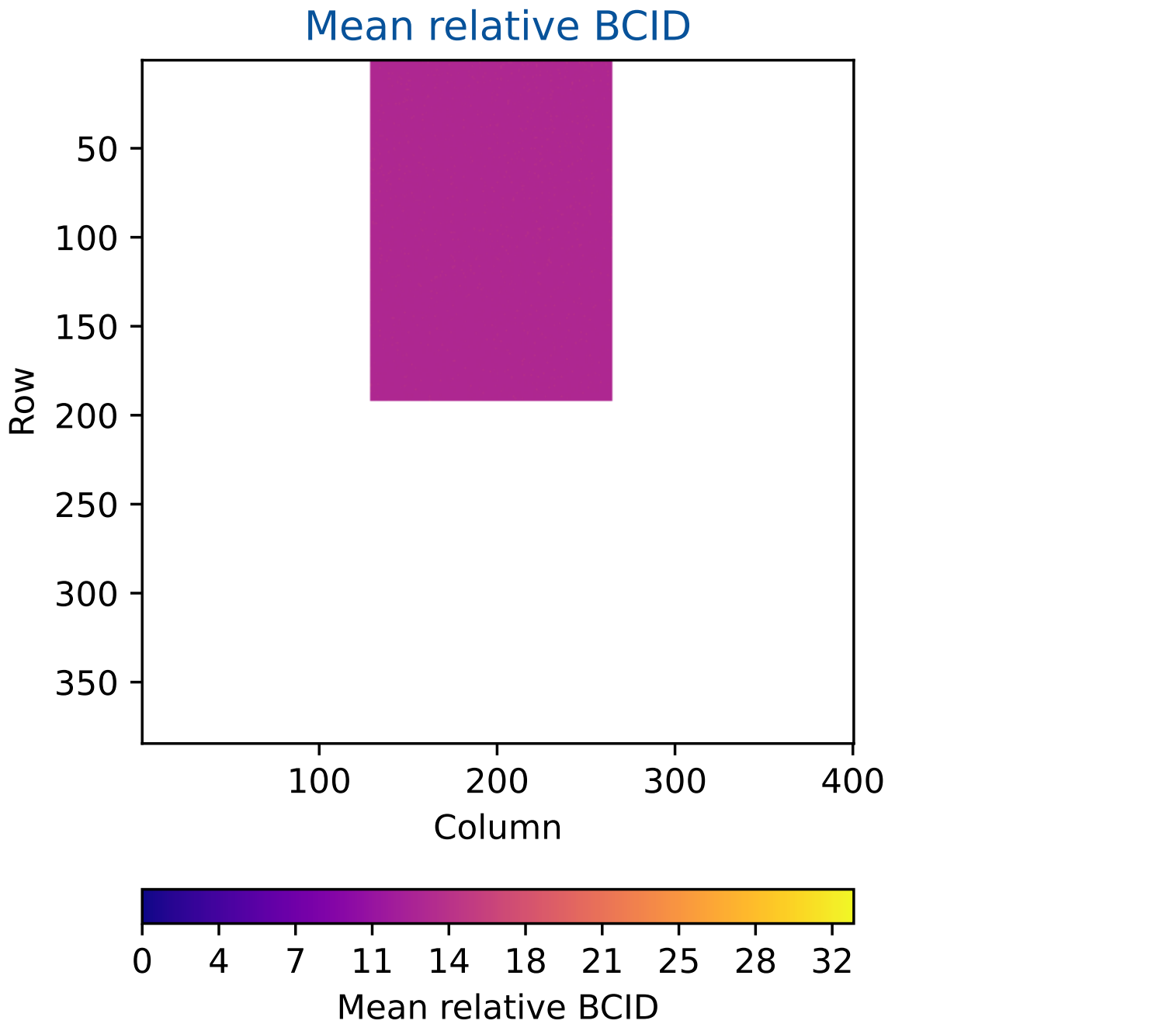
Chip S/N: 0x162BC

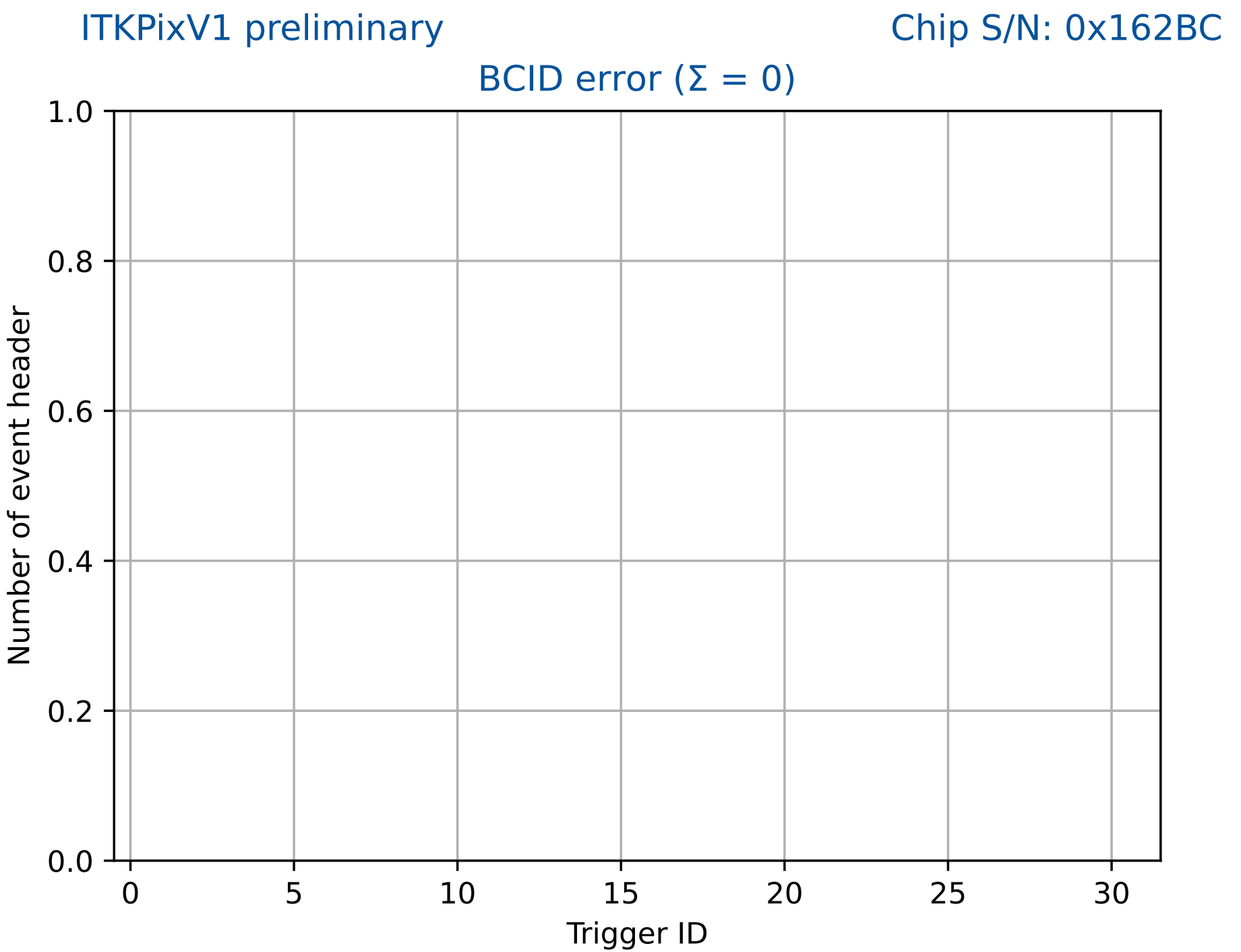



ITKPixV1 preliminary
Chip S/N: 0x162BC
Relative BCID (Σ = 25437700)
# of hits
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
0
5
10
15
20
25
30
Relative BCID [25 ns]

ITKPixV1 preliminary

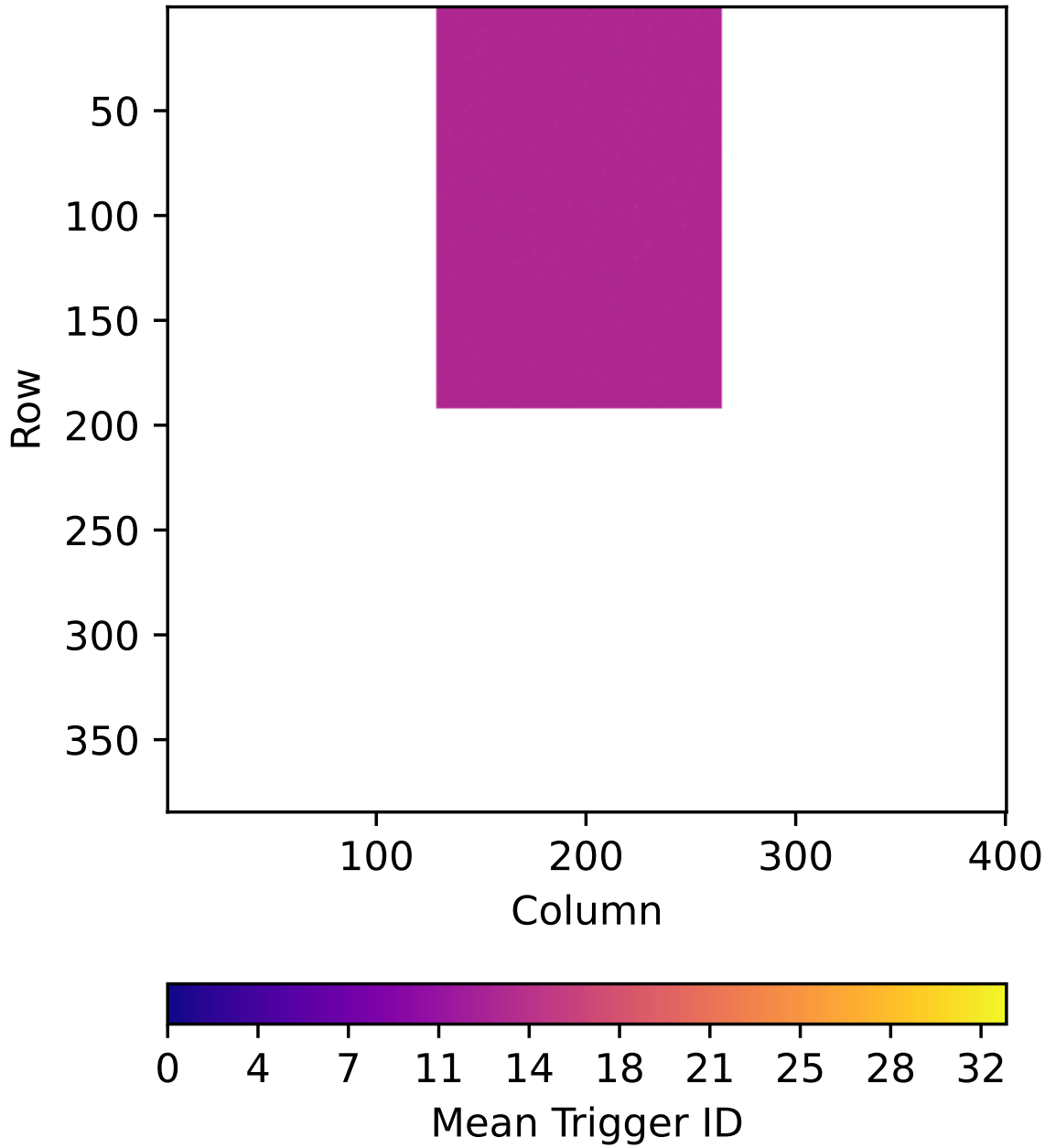
Chip S/N: 0x162BC

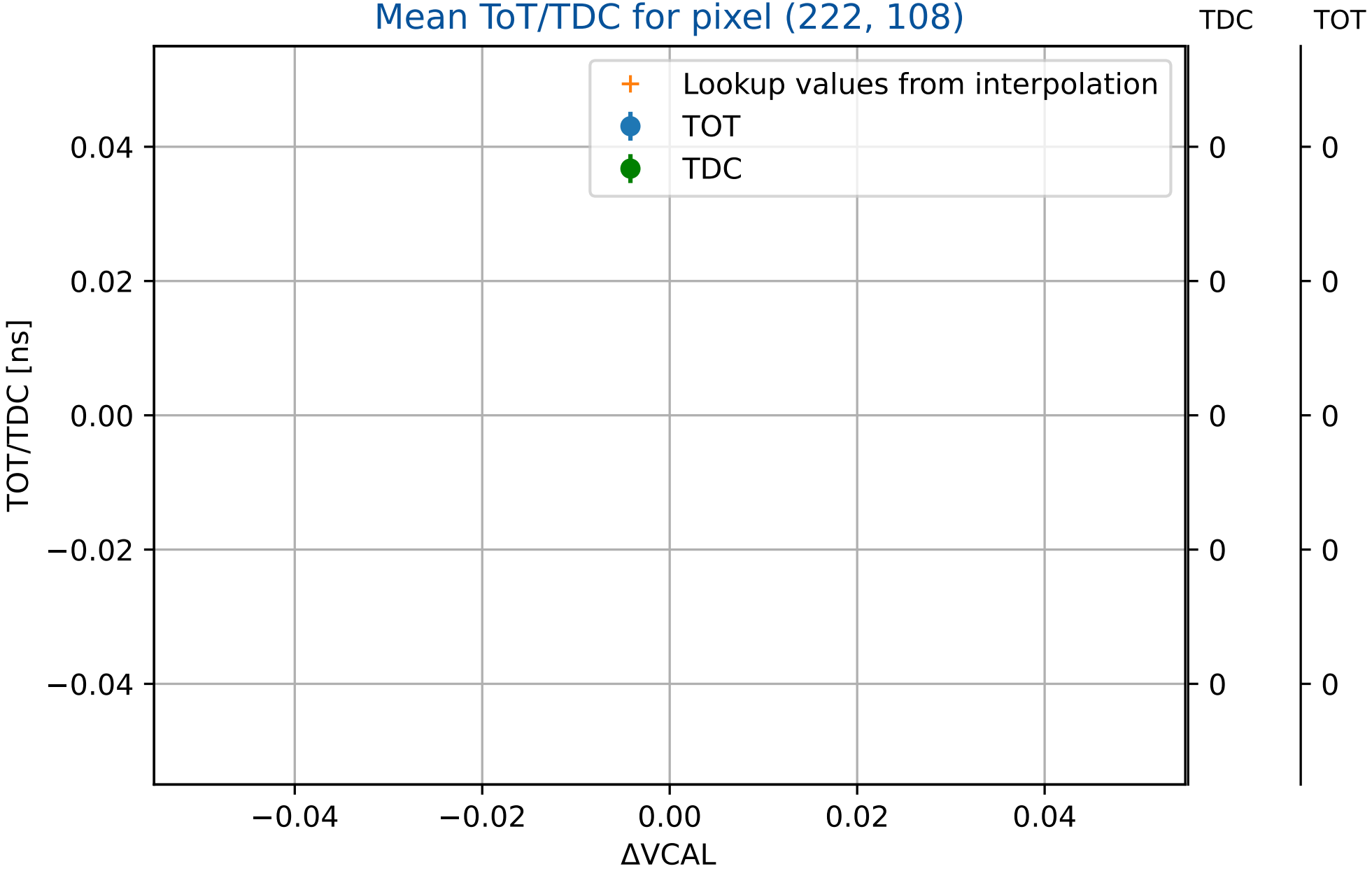


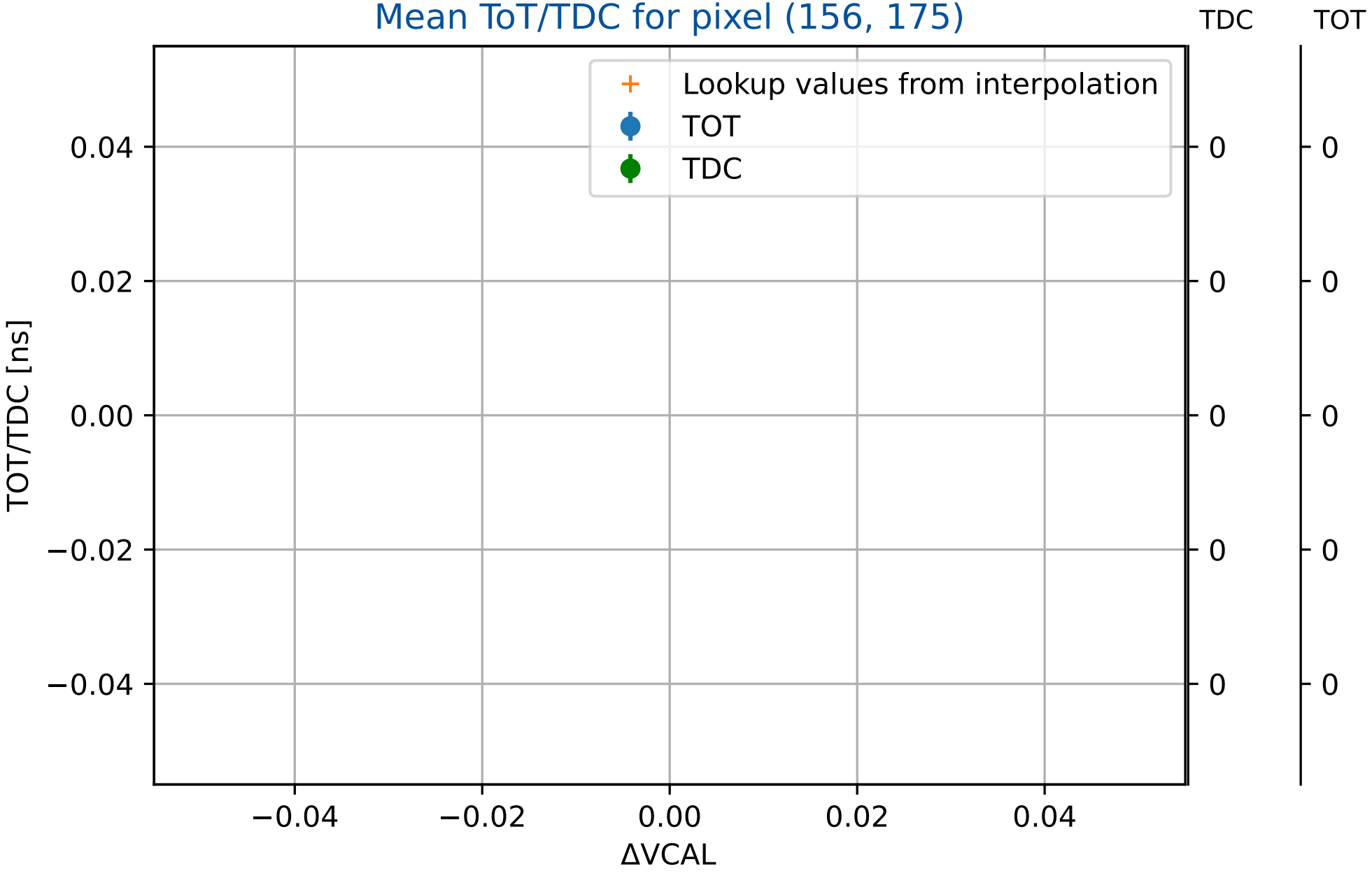

ITKPixV1 preliminary
Chip S/N: 0x162BC
BCID error (Σ = 0)
Number of event header
Trigger ID
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30

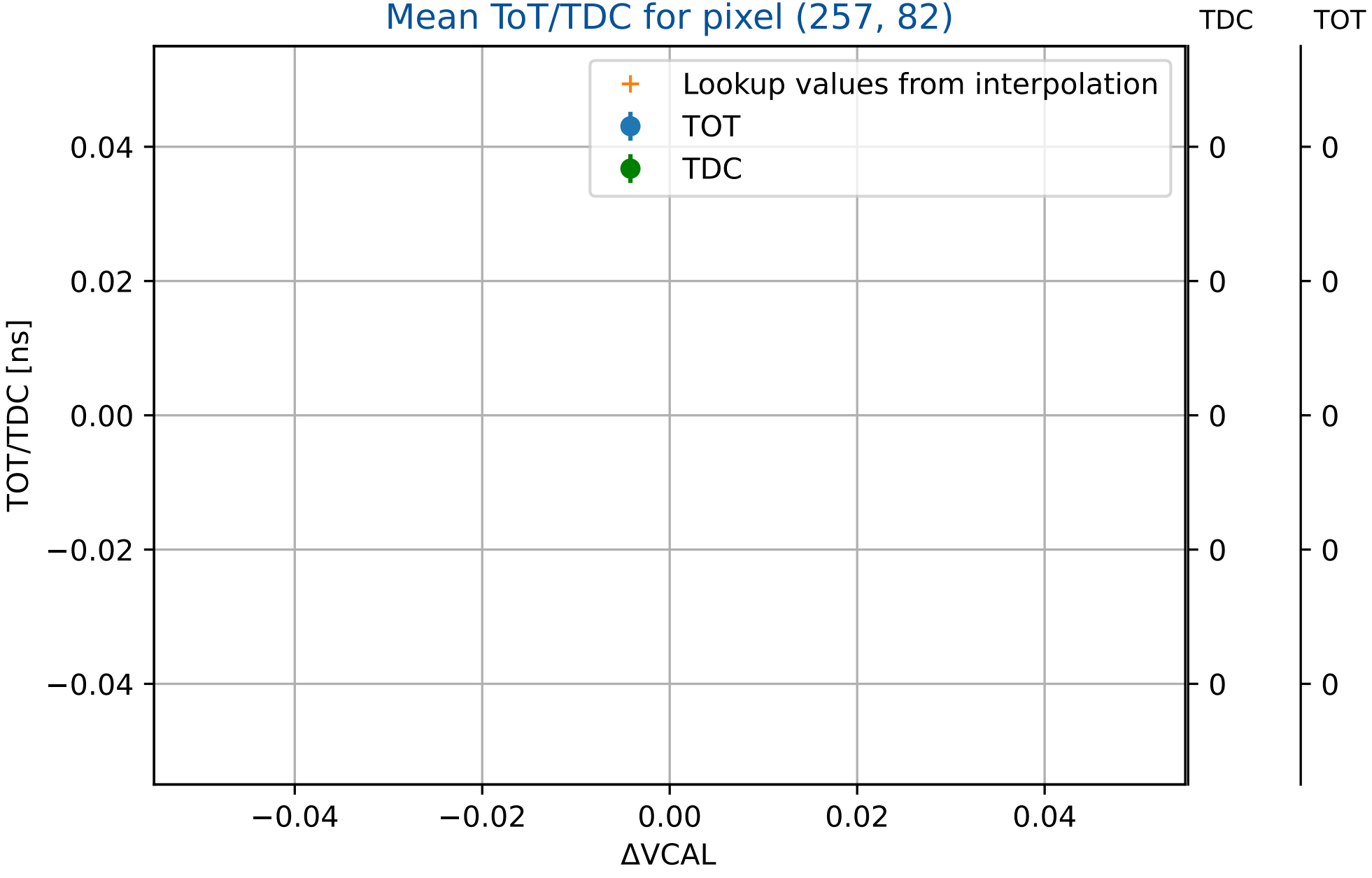
ITKPixV1 preliminary Chip S/N: 0x162BC

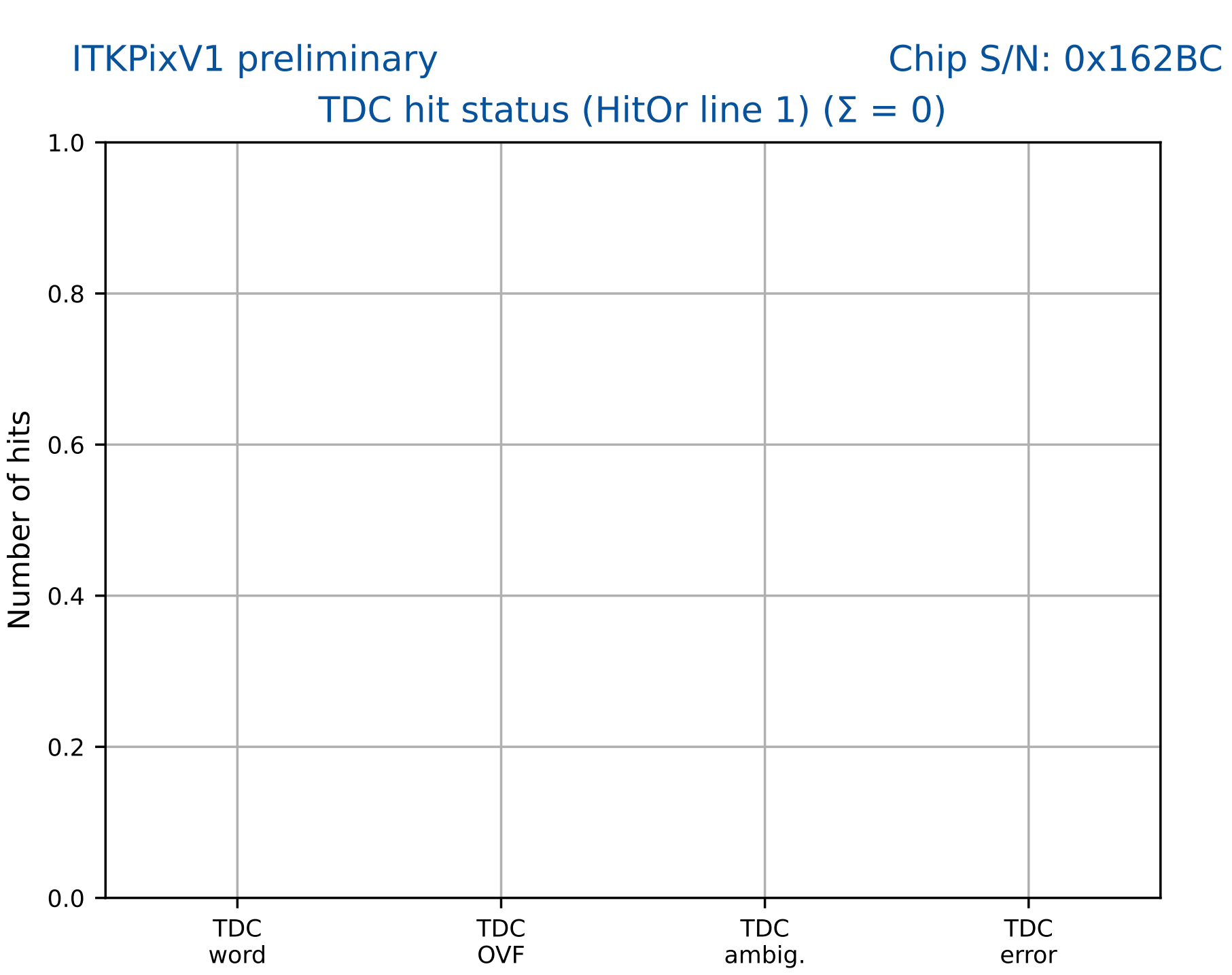
Trigger ID Histogram without Error correction

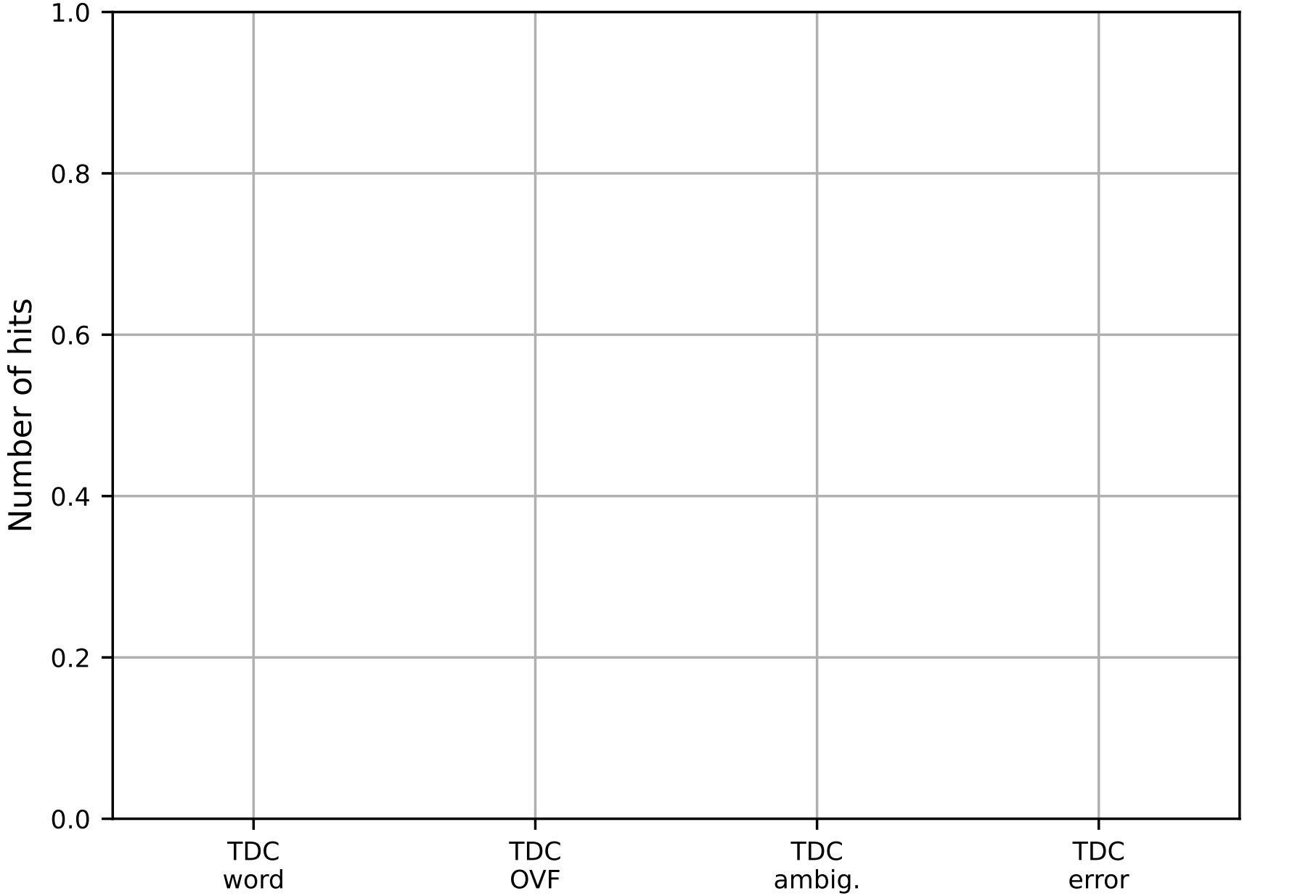



ITKPixV1 preliminary
Chip S/N: 0x162BC
Mean ToT/TDC for pixel (222, 108)
TDC
TOT
Lookup values from interpolation
TOT
TDC
0.04
0.02
0.00
−0.02
−0.04
TOT/TDC [ns]
0
0
0
0
0
0
0
−0.04
−0.02
0.00
0.02
0.04
ΔVCAL


ITKPixV1 preliminary
Chip S/N: 0x162BC
Mean ToT/TDC for pixel (156, 175)
TDC
TOT
Lookup values from interpolation
TOT
TDC
0.04
0.02
0.00
−0.02
−0.04
TOT/TDC [ns]
0
0
0
0
0
0
0
−0.04
−0.02
0.00
0.02
0.04
ΔVCAL


ITKPixV1 preliminary
Chip S/N: 0x162BC
Mean ToT/TDC for pixel (257, 82)
TDC
TOT
Lookup values from interpolation
TOT
TDC
0.04
0.02
0.00
−0.02
−0.04
TOT/TDC [ns]
0
0
0
0
0
0
0
0
−0.04
−0.02
0.00
0.02
0.04
ΔVCAL


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDC hit status (HitOr line 1) (Σ = 0)
Number of hits
1.0
0.8
0.6
0.4
0.2
0.0
TDC word
TDC OVF
TDC ambig.
TDC error


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDC hit status (HitOr line 2) (Σ = 0)
Number of hits
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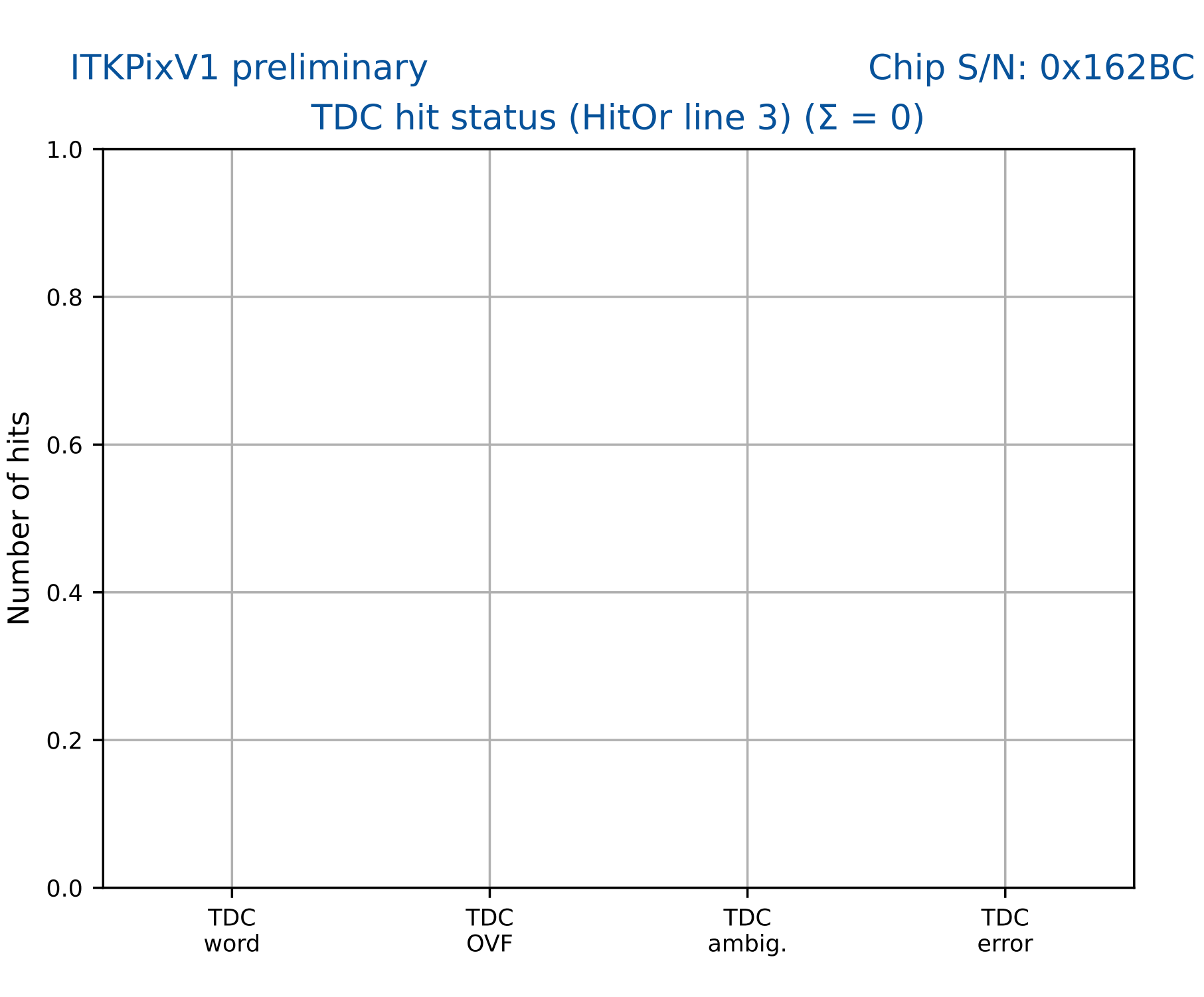
0.6
0.4
0.2
0.0
TDC word
TDC OVF
TDC ambig.
TDC error


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDC hit status (HitOr line 3) (Σ = 0)
Number of hits
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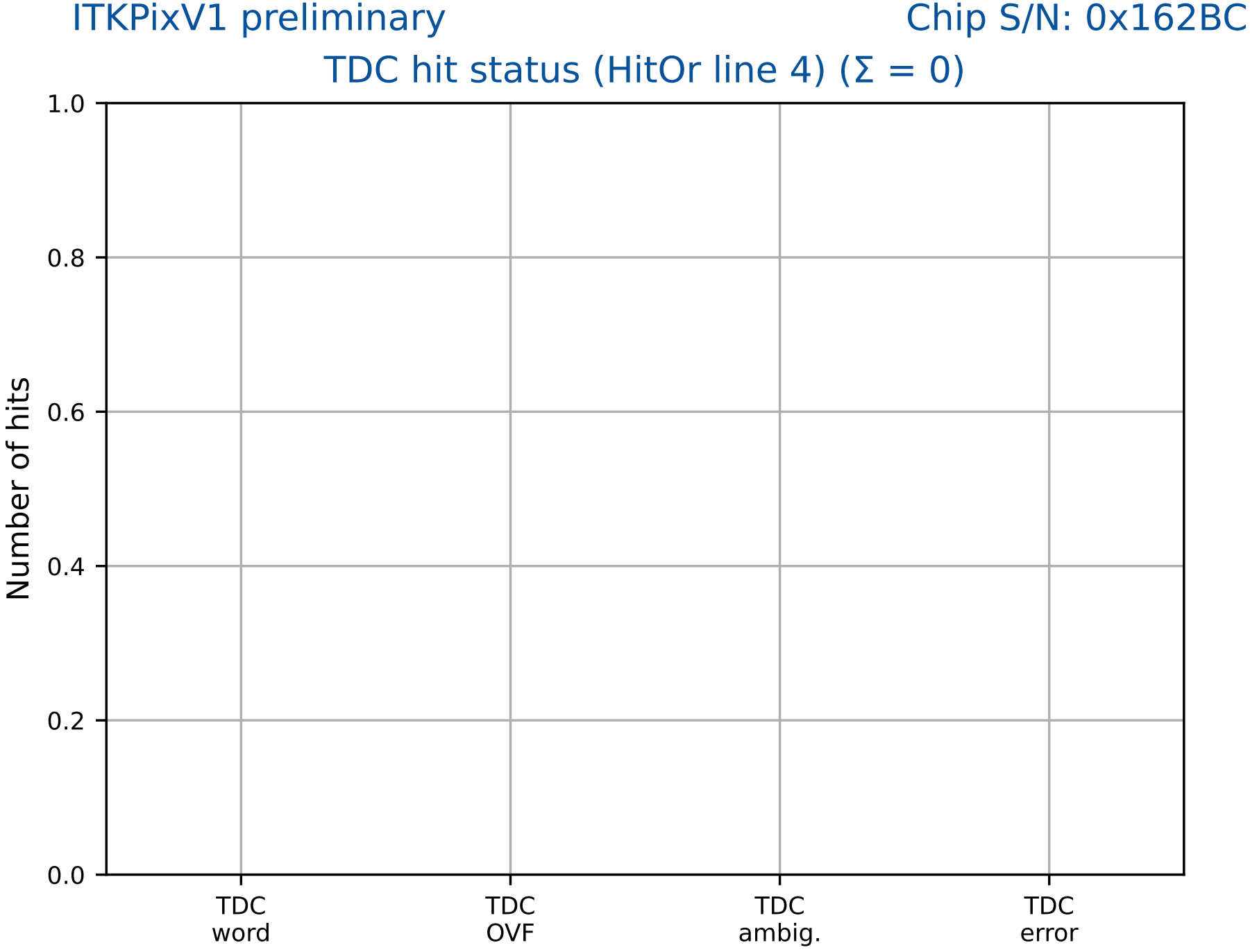
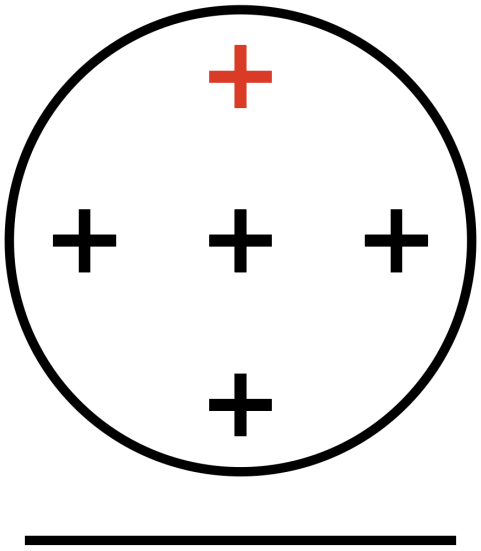
0.6
0.4
0.2
0.0
TDC word
TDC OVF
TDC ambig.
TDC error


ITKPixV1 preliminary
Chip S/N: 0x162BC
TDC hit status (HitOr line 4) (Σ = 0)
Number of hits
1.0
0.8
0.6
0.4
0.2
0.0
TDC word
TDC OVF
TDC ambig.
TDC error

Backup Slides

Chuck Level and Flatness (1/2)



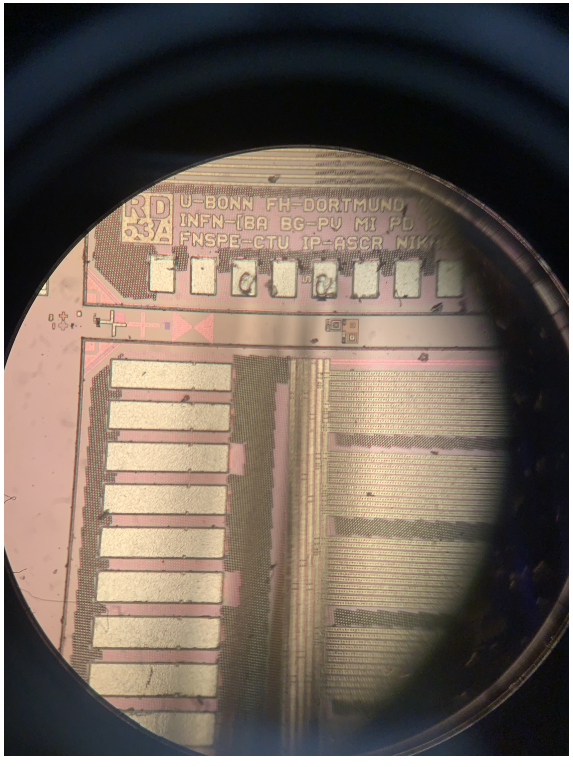
Point	Relative Height / μm	
	No Wafer	Wafer
Middle	290	250
Near	0	0
Far	220	160
Left	110	80
Right	320	320

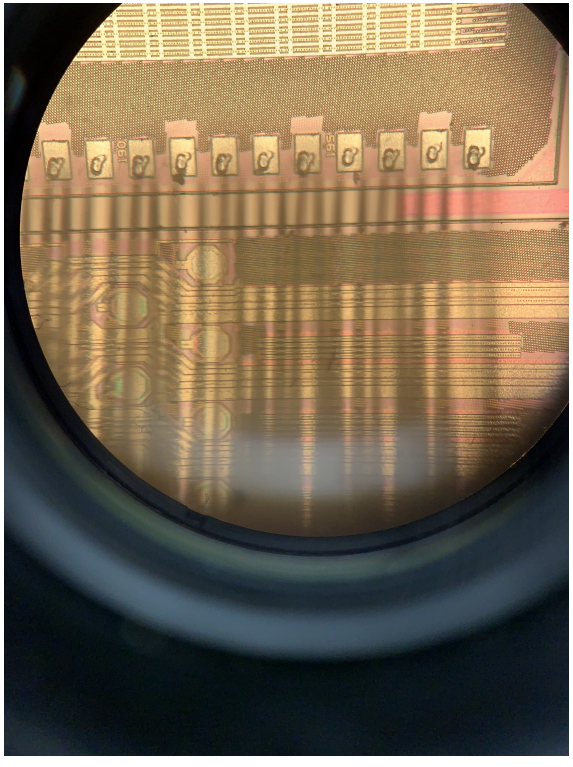
- Measured chuck height at 5 points with and without wafer to determine flatness of chuck and if wafer deforms to shape of chuck
- Dummy wafer conforms to shape of chuck with vacuum turned on
- Wafer levelled, but flatness only consistent within ~ 50 μm, and wafer no longer level after wafer replacement

  $\rightarrow$ **Rely on contact sensing**, with height map for safety

Chuck Level and Flatness (2/2)

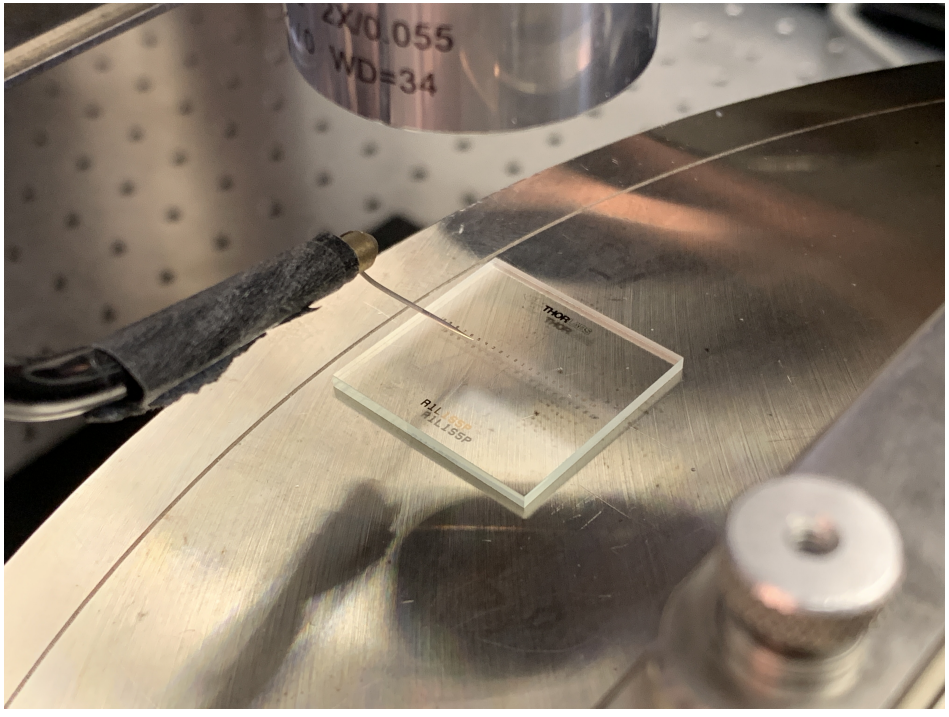
- Brought RD53a wafer into contact with its probe card
- Resulted in **acceptably even contact** marks to pads, despite lack of flatness





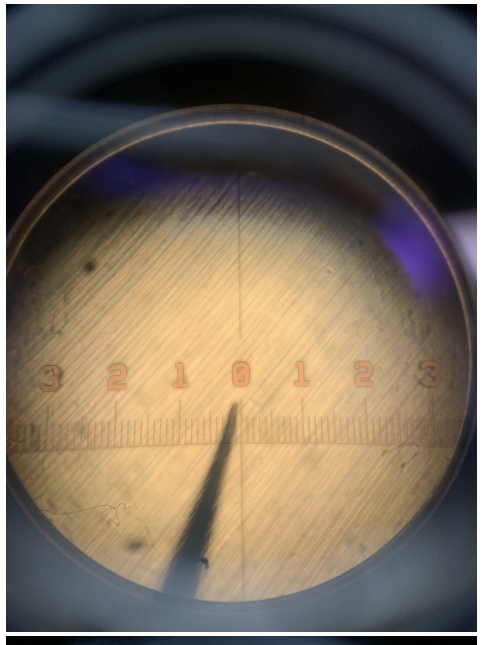
Horizontal Movement Reproducibility (1/2)

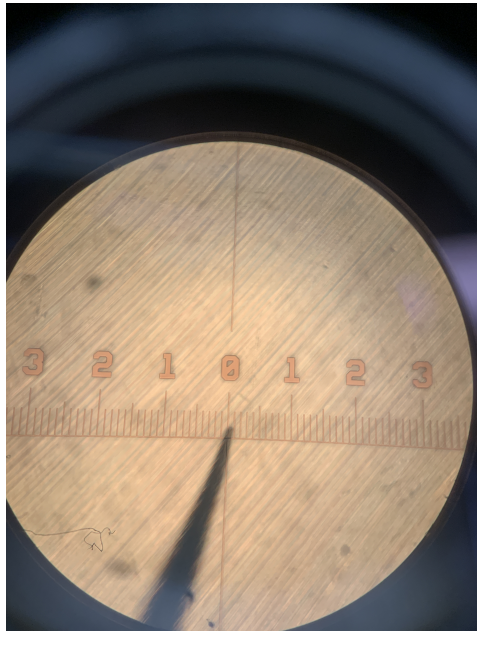
- Used dummy wafer and 2 stage micrometers (100 μm precision) taped to chuck to test accuracy of horizontal stage movements
- Moved towards micrometers multiple times from different directions



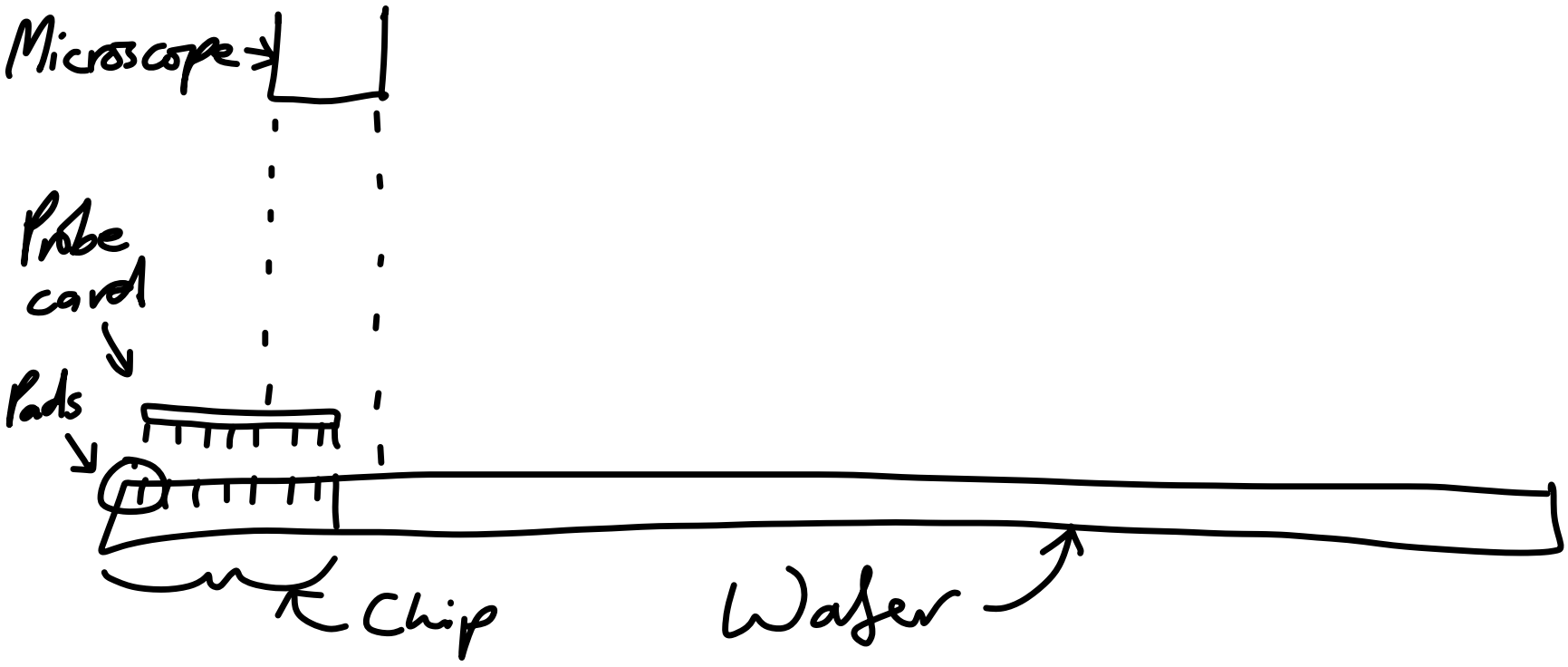
Horizontal Movement Reproducibility (2/2)

- Measurements using left stage micrometer seem roughly consistent with approach path
- Measurements using right stage micrometer differ with approach path by up to ≈ 300 μm (see photos to right)
- **Resolved by moving from consistent direction of approach for both stages**

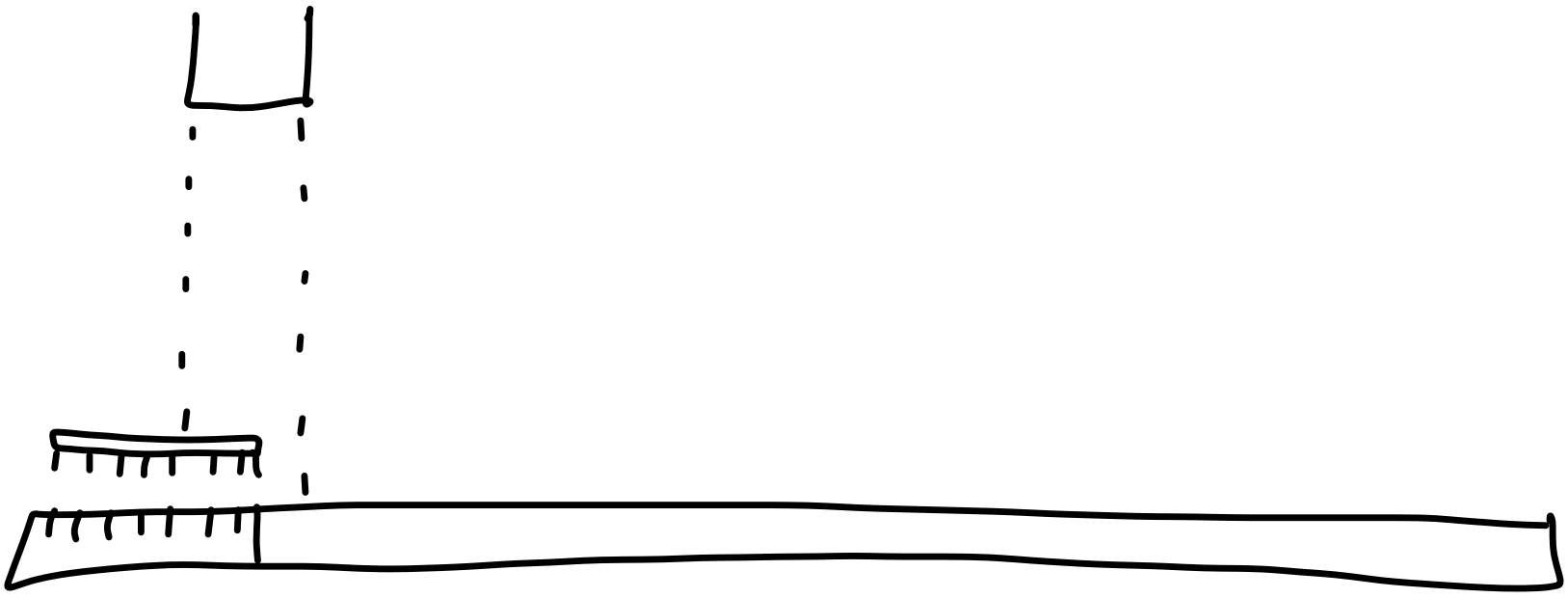




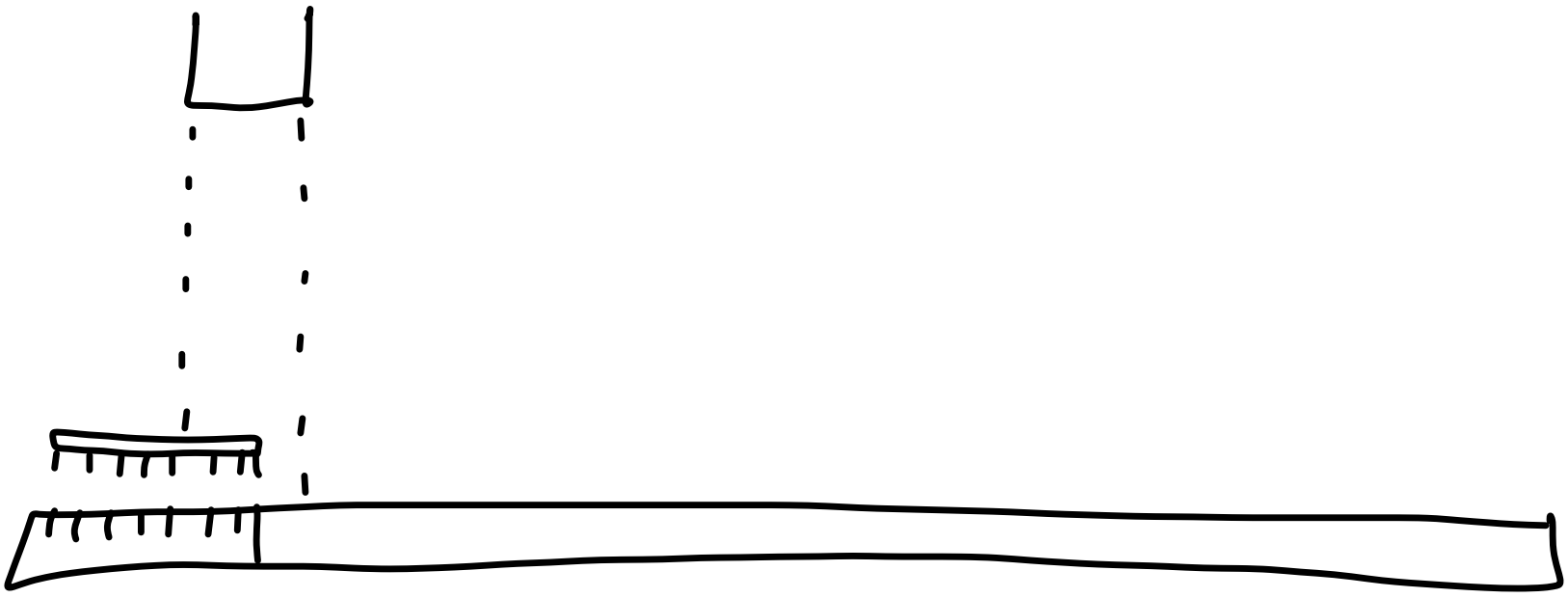
Wafer Alignment Procedure



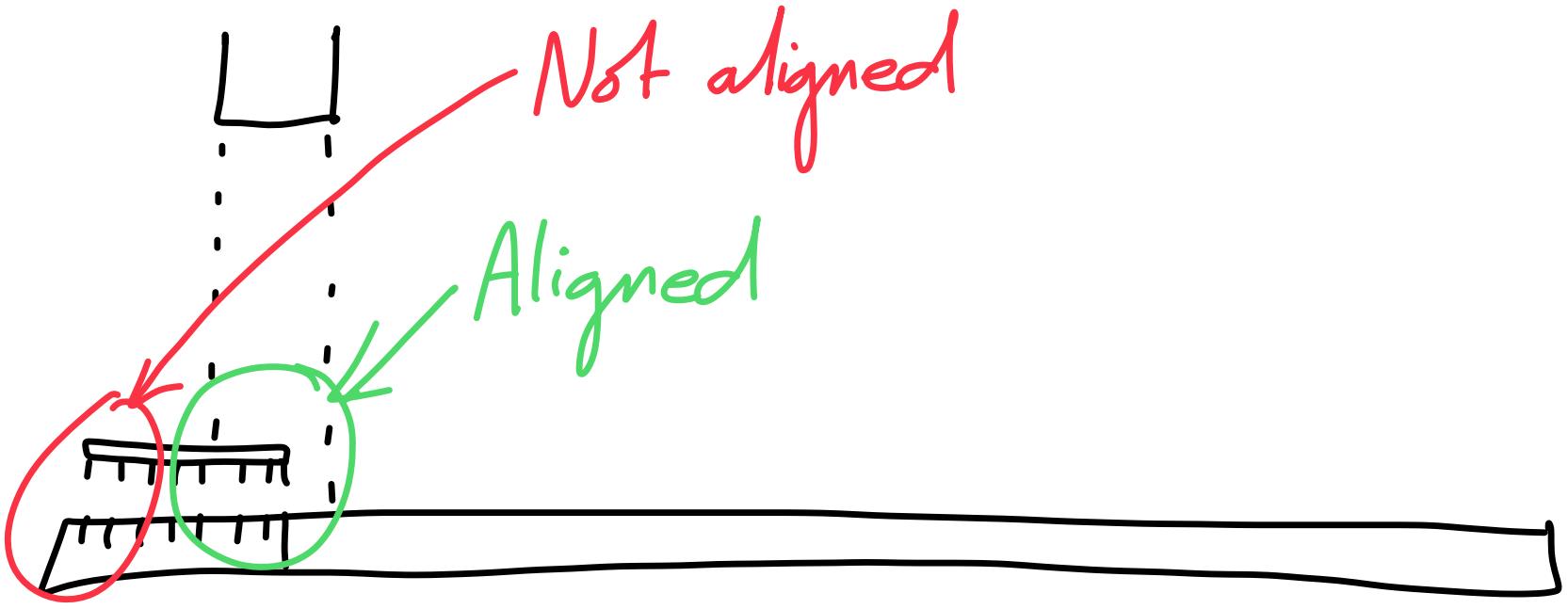
...Place wafer in traced outline...



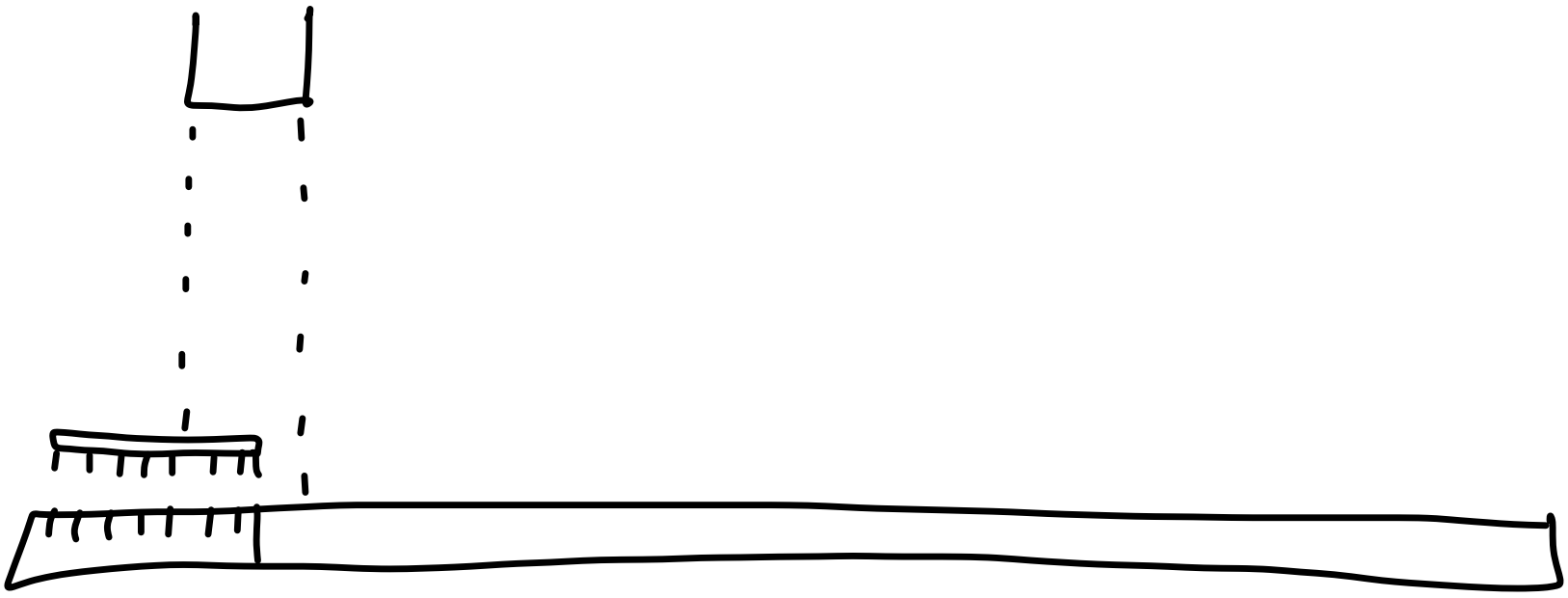
... Translate wafer ...



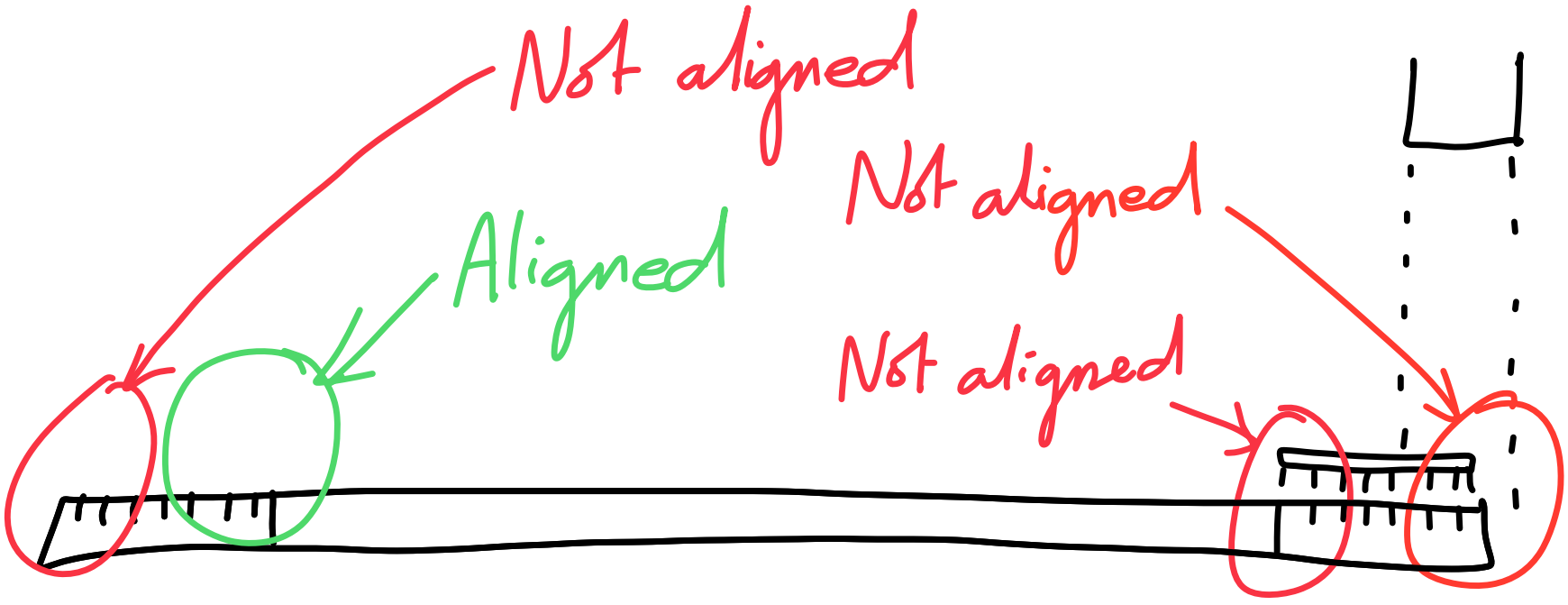
Wafer Alignment Procedure



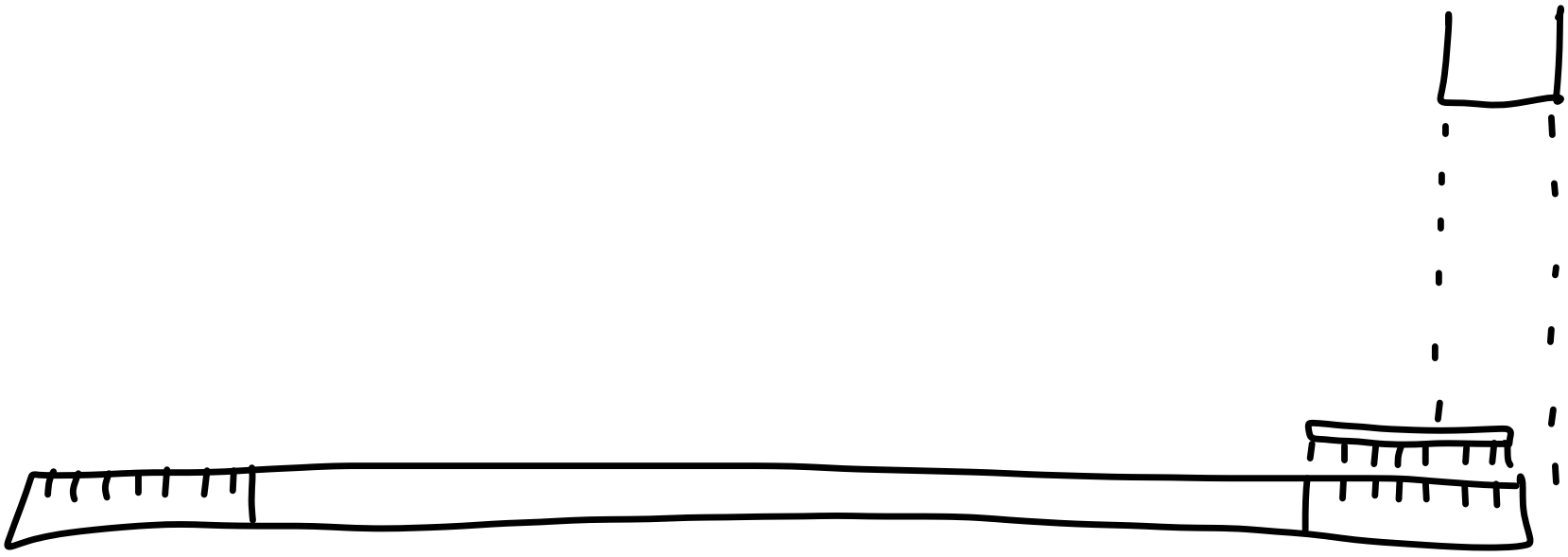
... Translate wafer ...



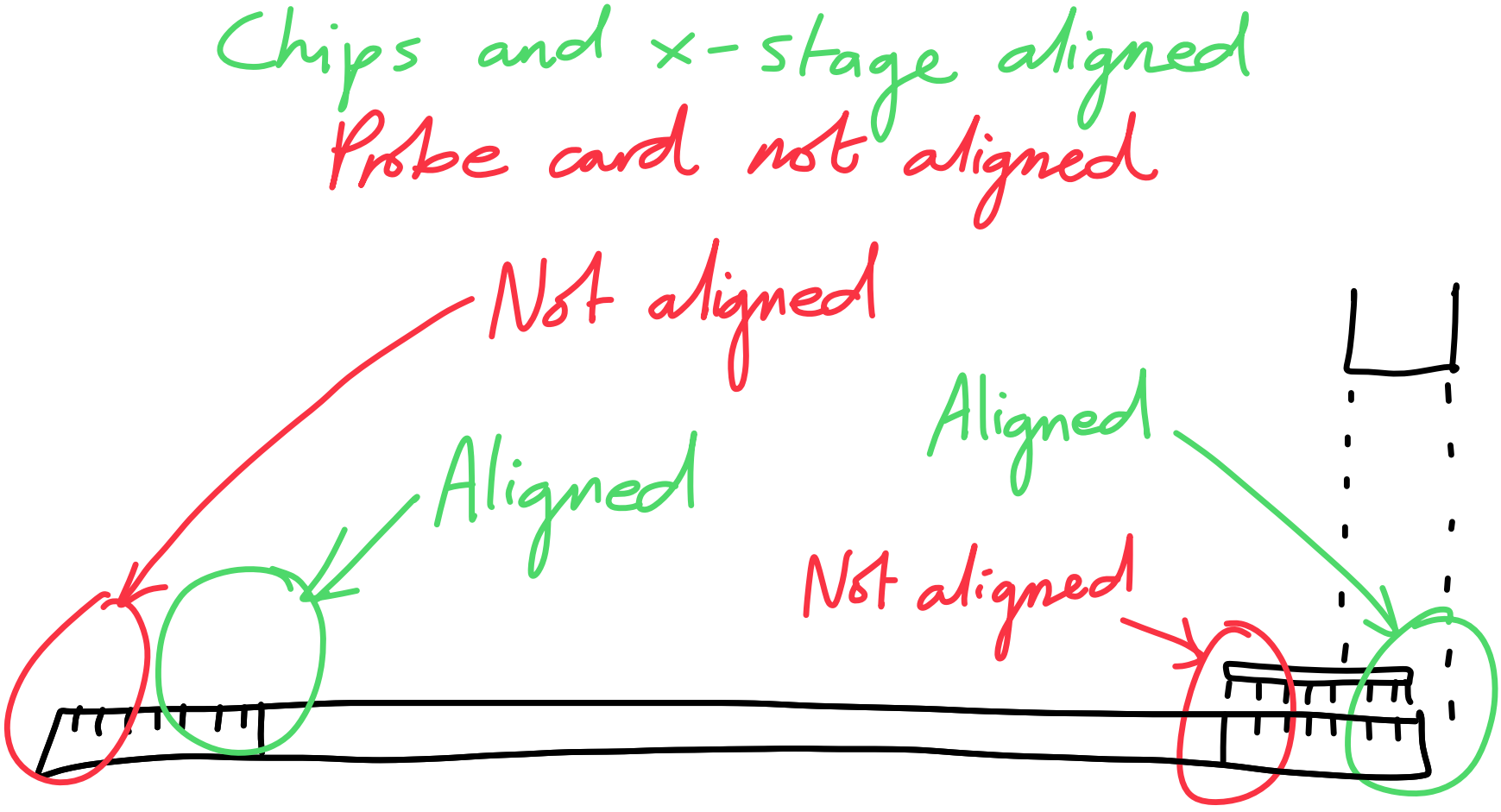
Chips, x-stage and probe card all misaligned



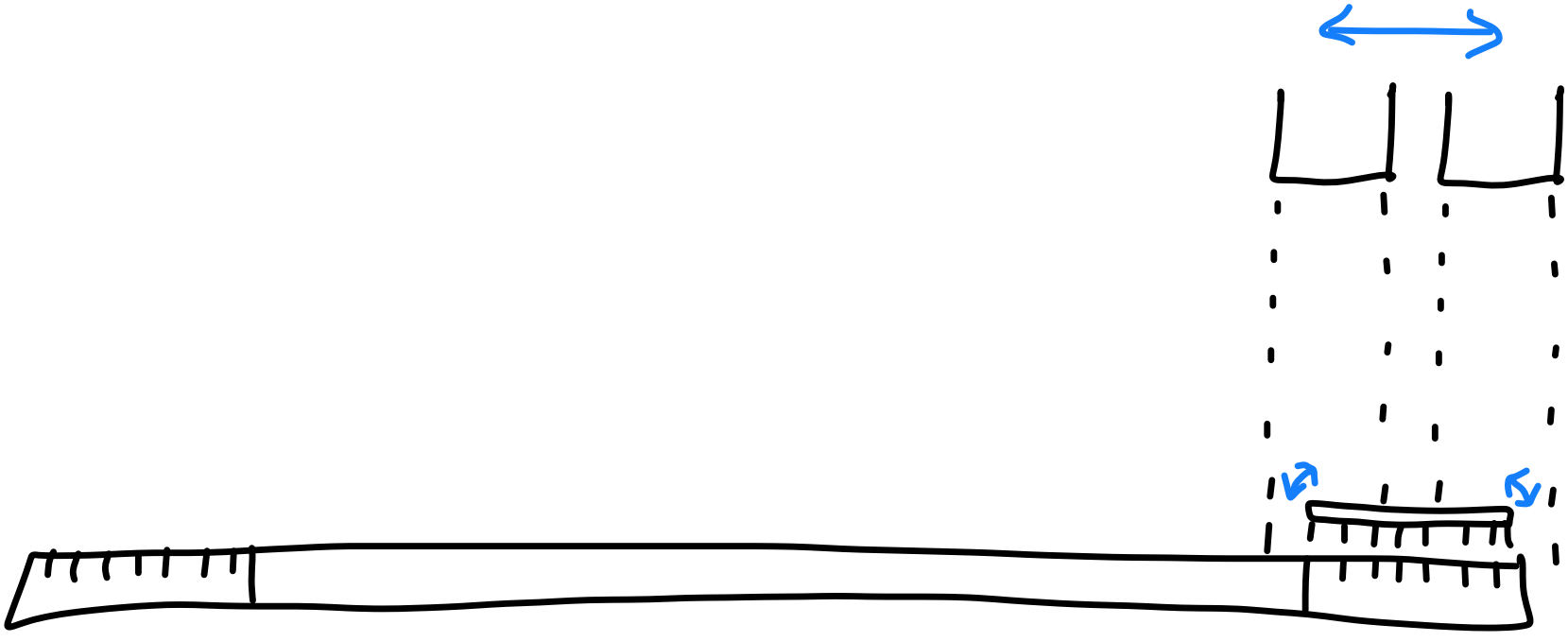
... Rotate and translate wafer ...



Wafer Alignment Procedure

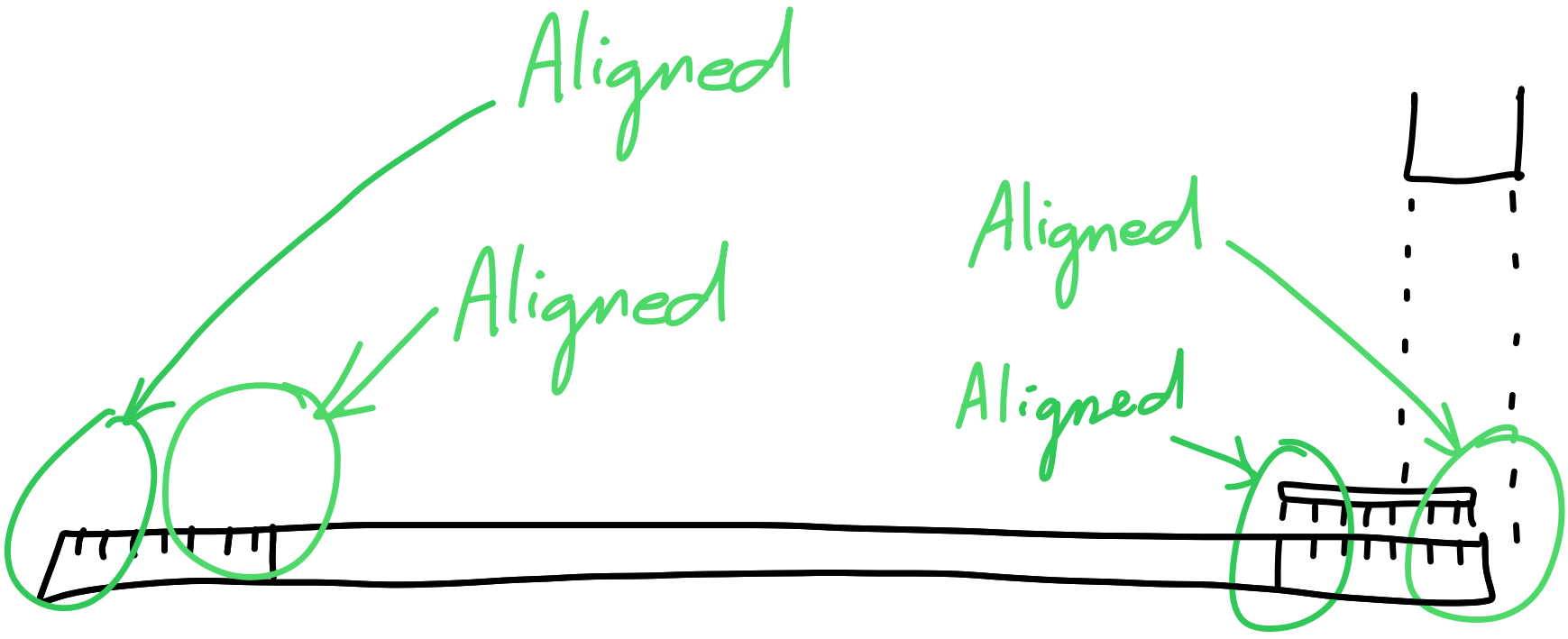


... Adjust probe card fit...



Wafer Alignment Procedure

Chips, x-stage and probe card all aligned



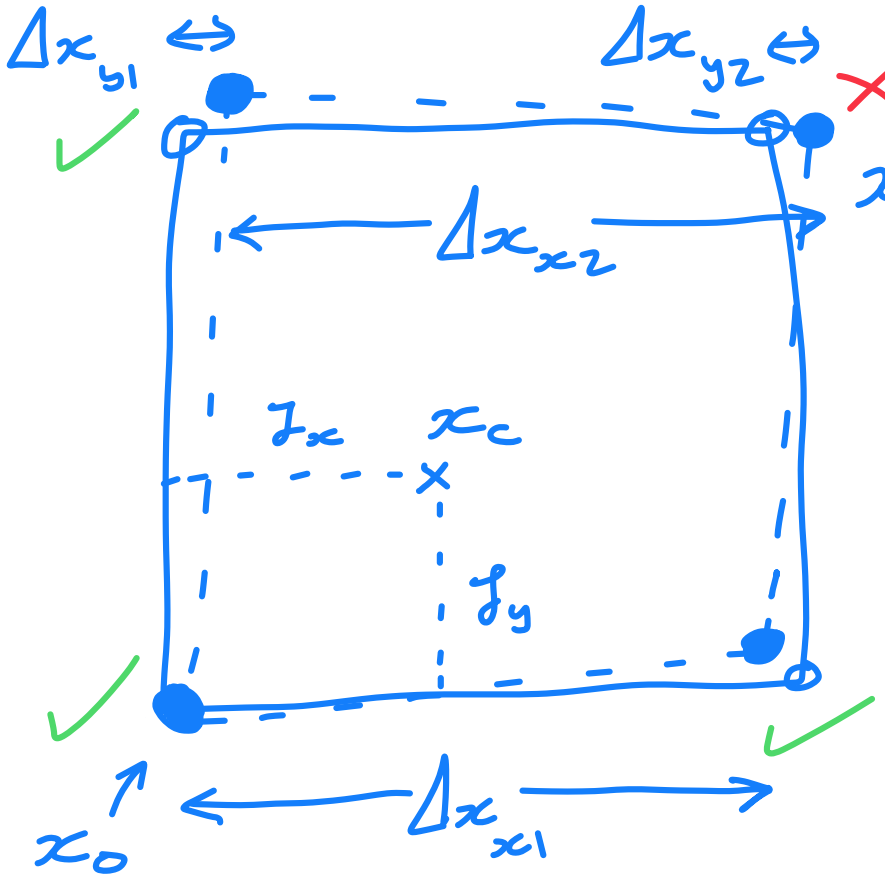
Horizontal Movement Accuracy (1/2)

- **Movement highly non-linear/orthogonal**, e.g. moving x-stage direction causes significant displacement in y-direction

- Designed **calibration**, to map "ideal" x- and y-positions to "true" x-, y- and z-positions
  - Used coordinates of the pads of every 3rd chip in x-direction and every 5th in y-direction
  - Calibrated missing corner chip locations by hand

- Replaced wafer before this test

Horizontal Movement Accuracy (2/2)



$$
\begin{aligned}
x_c = {} & x_0 \\
& + f_x (1 - f_y) \Delta x_{x1} \\
& + f_x f_y \Delta x_{x2} \\
& + (1 - f_x) f_y \Delta x_{y1} \\
& + f_x f_y \Delta x_{y2}
\end{aligned}
$$