Hybrid 5 tests: Lab characterization and Irradiations

20th international workshop on DEPFET detectors and applications
11th – 14th May 2016, Seeon

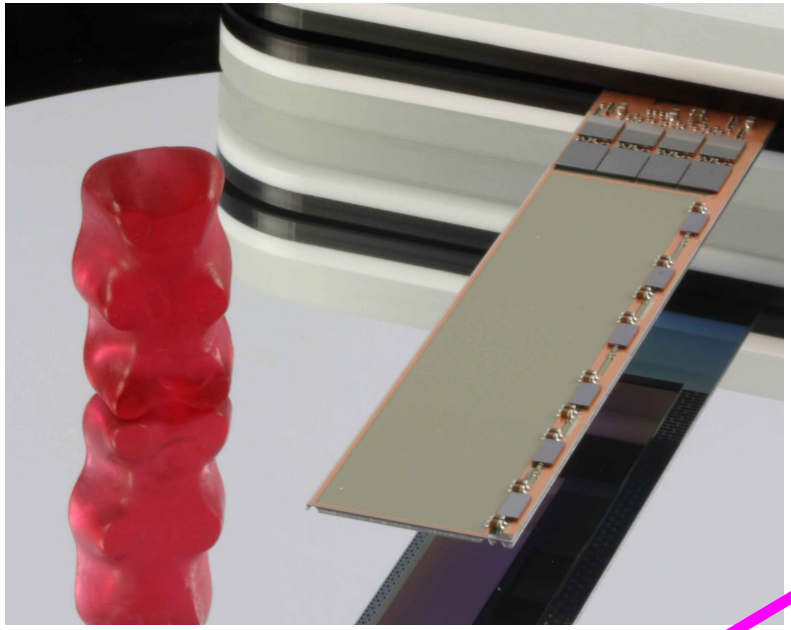
J. Dingfelder, L. Germic, T. Hemperek,
C. Hönig, H Krüger, F. Lütticke, C. Marinas,
B. Paschen, N. Wermes

University of Bonn

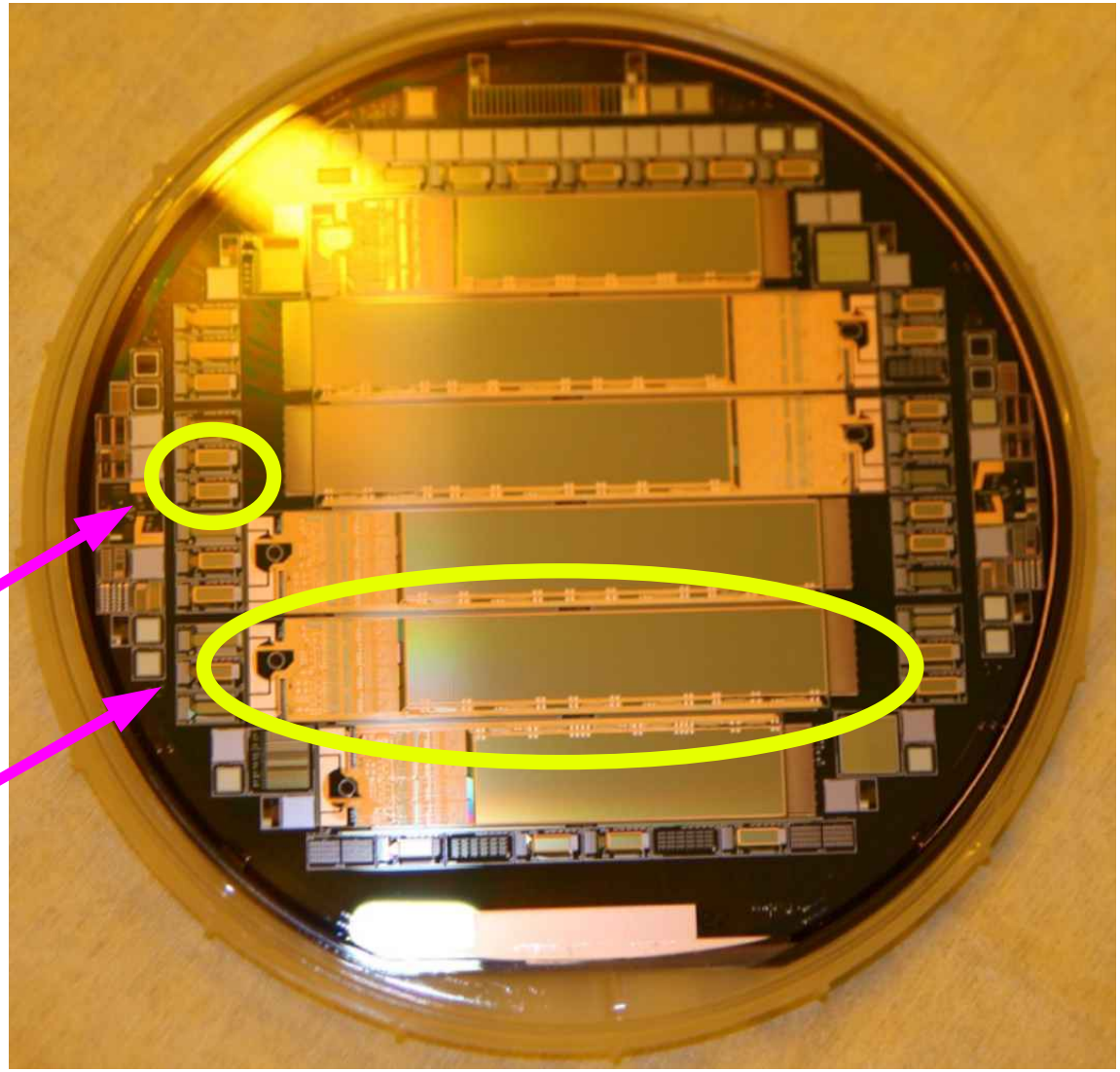
paschen@physik.uni-bonn.de

PXD 9 Production (Pilot Run)

Pilot module: 4 + 4 + 6 ASICs
and large matrix



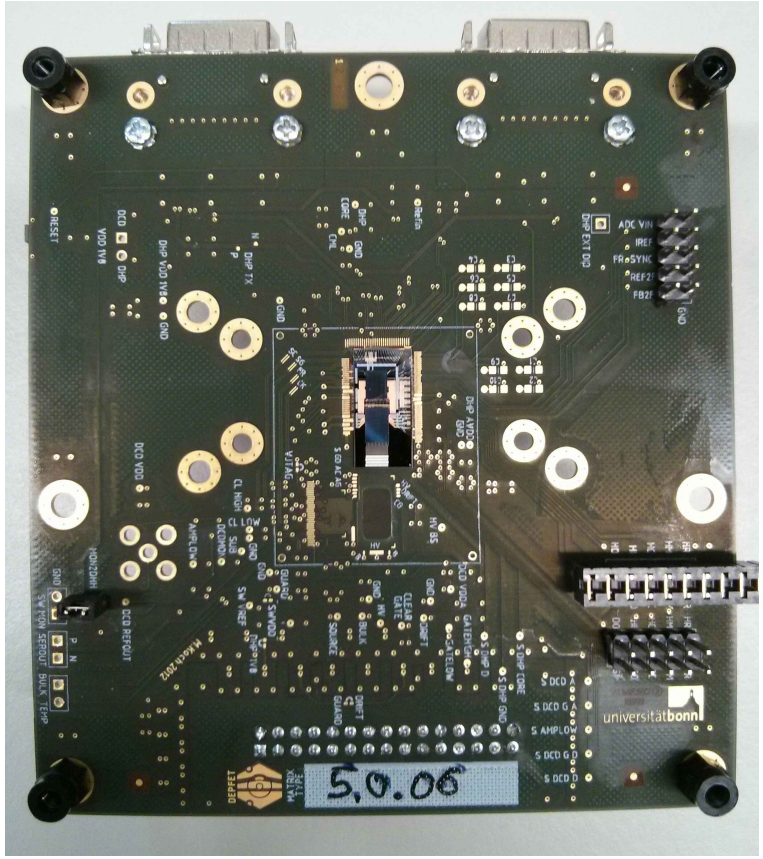
PXD 9 wafer with modules and test structures



Small matrices
(80 x 32 pixels /
20 gates, 128 drainlines)

Full module with
large matrix
(768 x 250 pixels /
191 gates, 1000 drainlines)

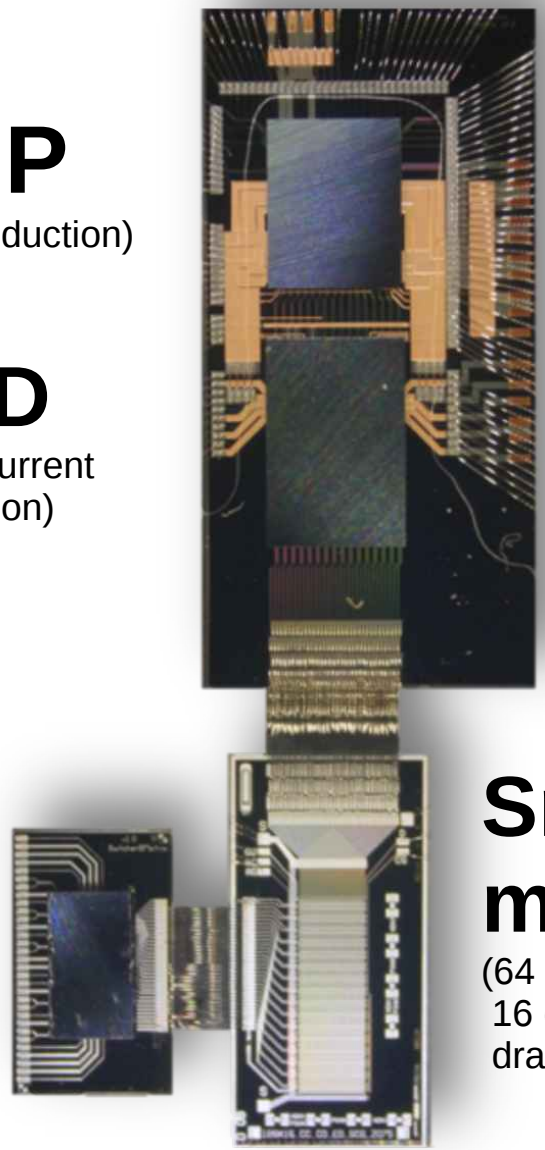
The Hyrid 5 Test System



- PCB with minial number of ASICs for a full test system
- Many test points and configuration possibilities
- Well suited for testing of new components

DHP
(Data reduction)

DCD
(Drain current digitization)

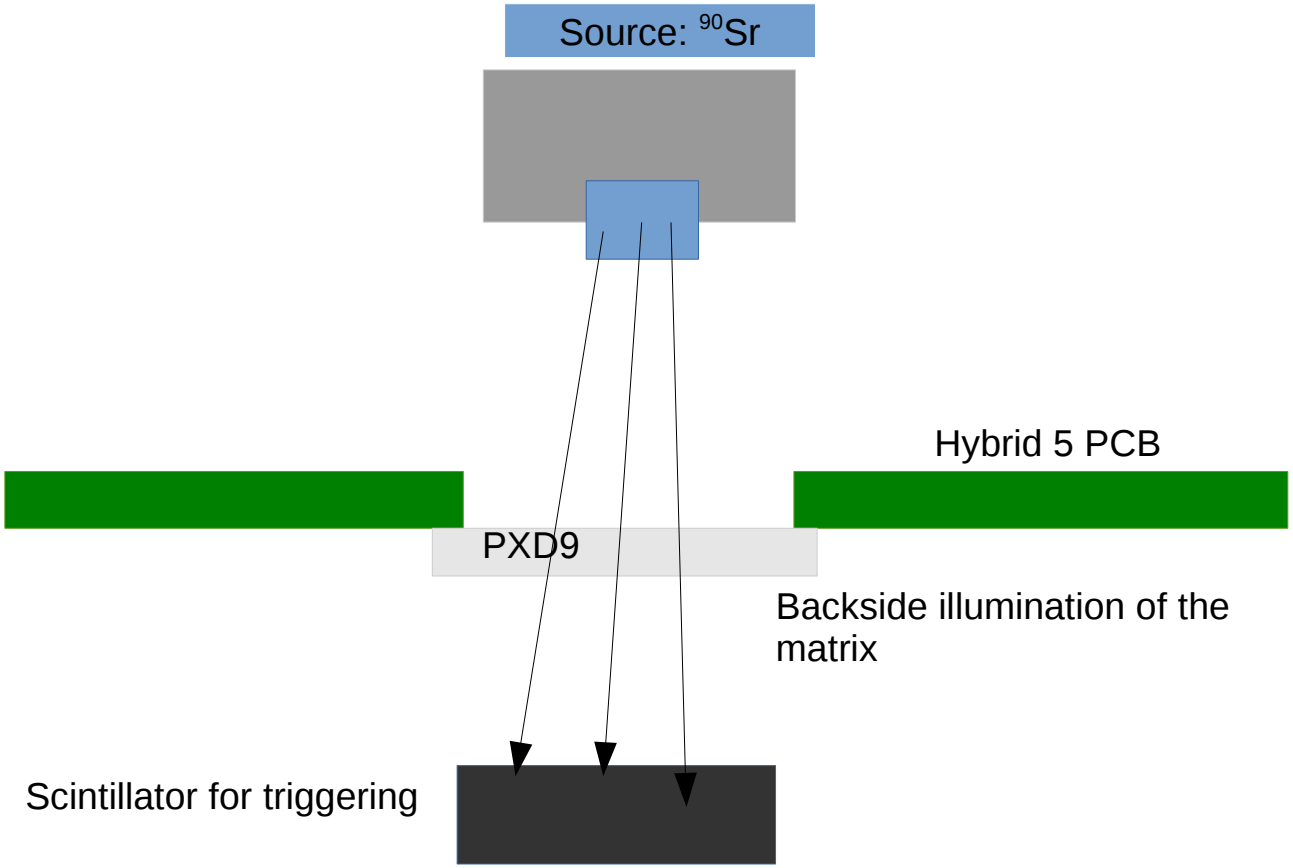


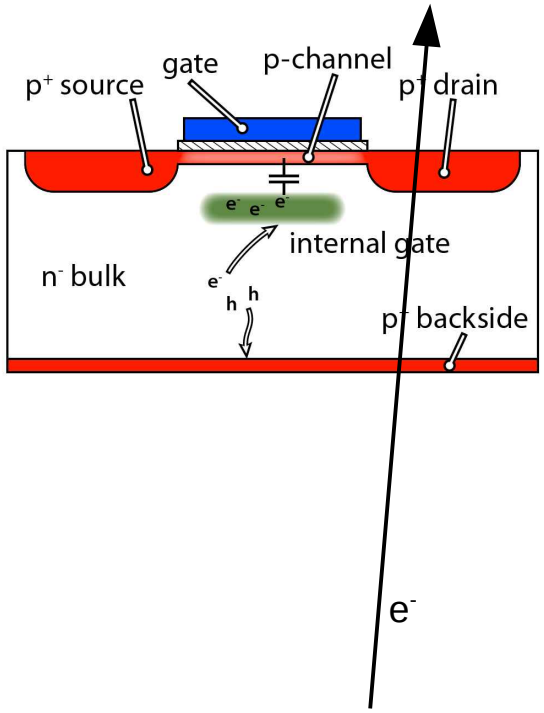
Switcher
(Matrix steering)

Small matrix
(64 x 32 pixels / 16 gates, 128 drainlines)

Laboratory measurements with radioactive sources

Setup:



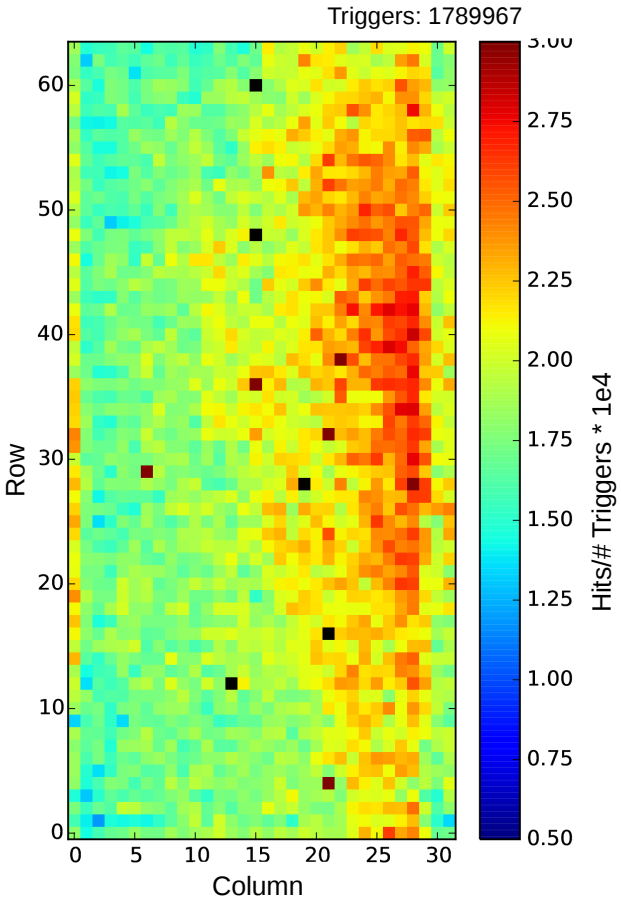


- Electrons from Strontium act as MIPs

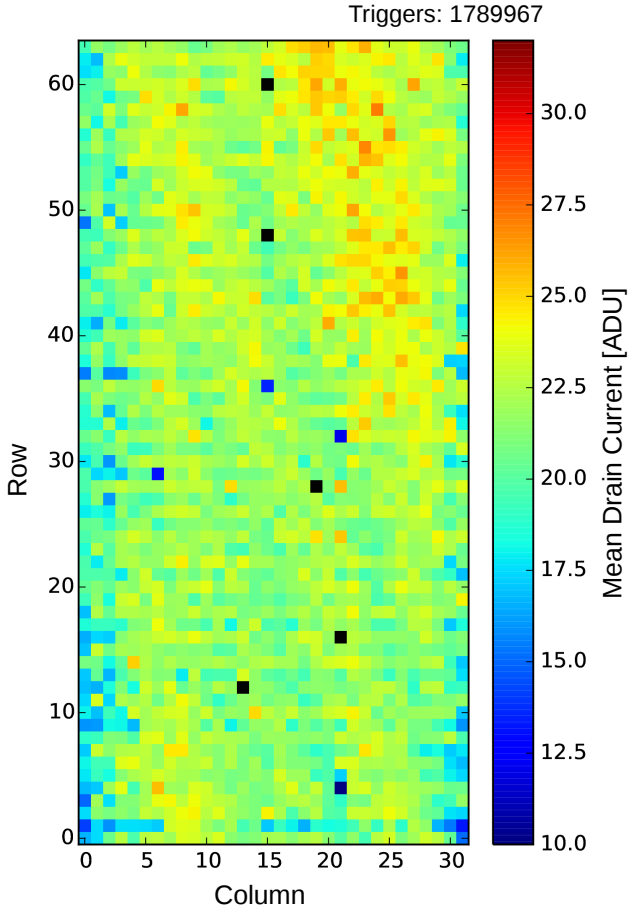
Strontium Measurement

Example measurement at good working point
- Source spot clearly visible
- Drain currents relatively homogeneous

Hit rate

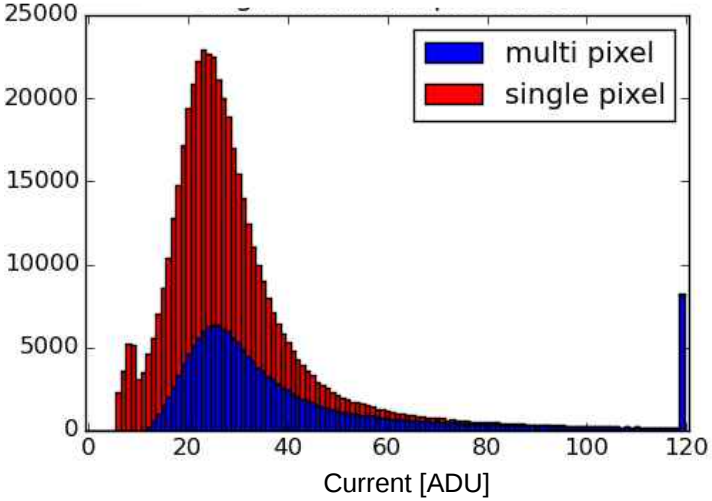


Mean drain current

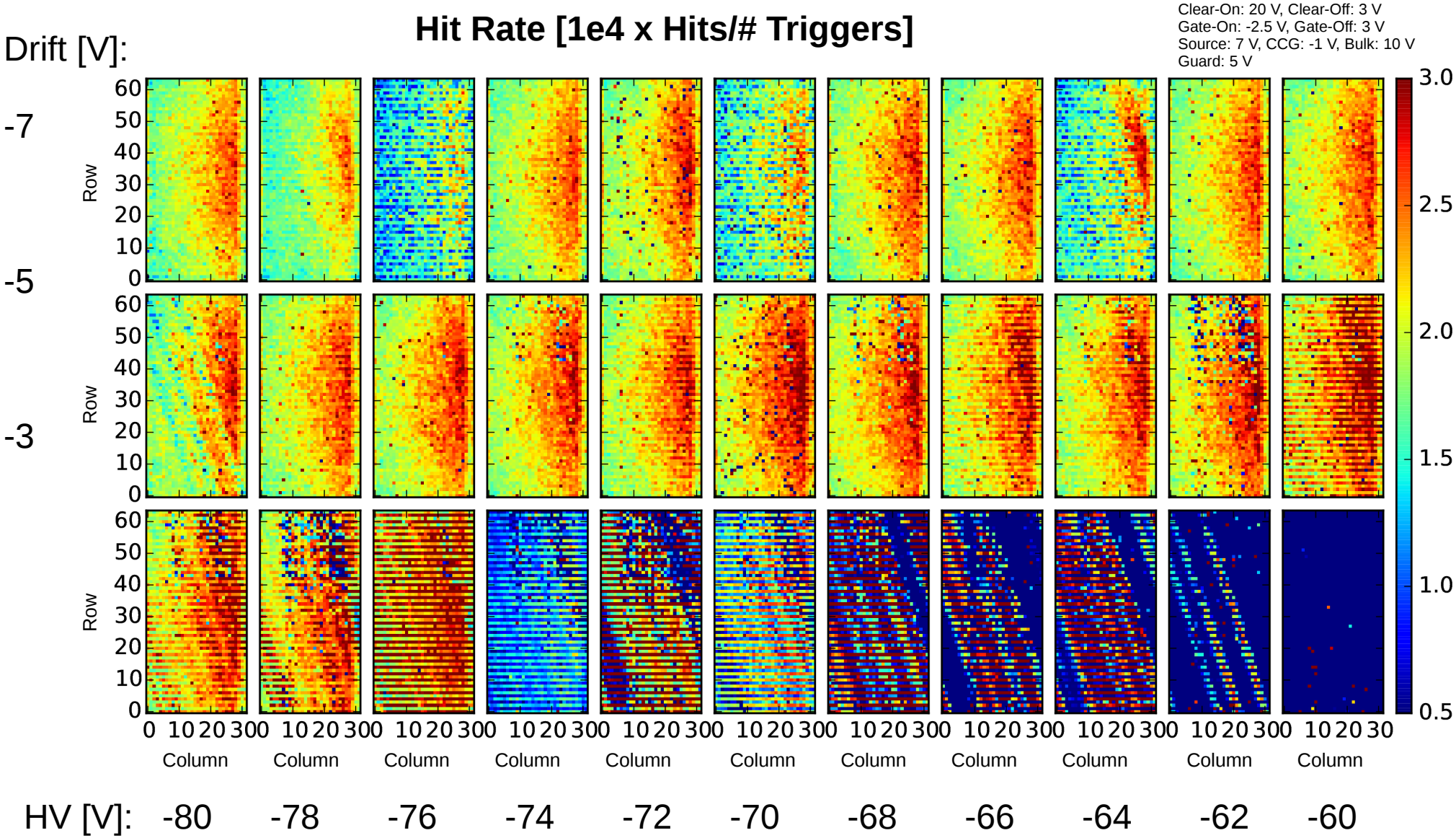


HV: -70 V, Drift: -5 V
Clear-On: 20 V, Clear-Off: 5 V
Gate-On: -2.5 V, Gate-Off: 3 V
Source: 7 V, CCG: -1 V,
Bulk: 10 V, Guard: 5 V

Signal histogram



Strontium Measurement: Drift vs. High Voltage



~ 1.8 M Triggers per measurement point

Strontium Measurement

CCG [V]:

-2.0

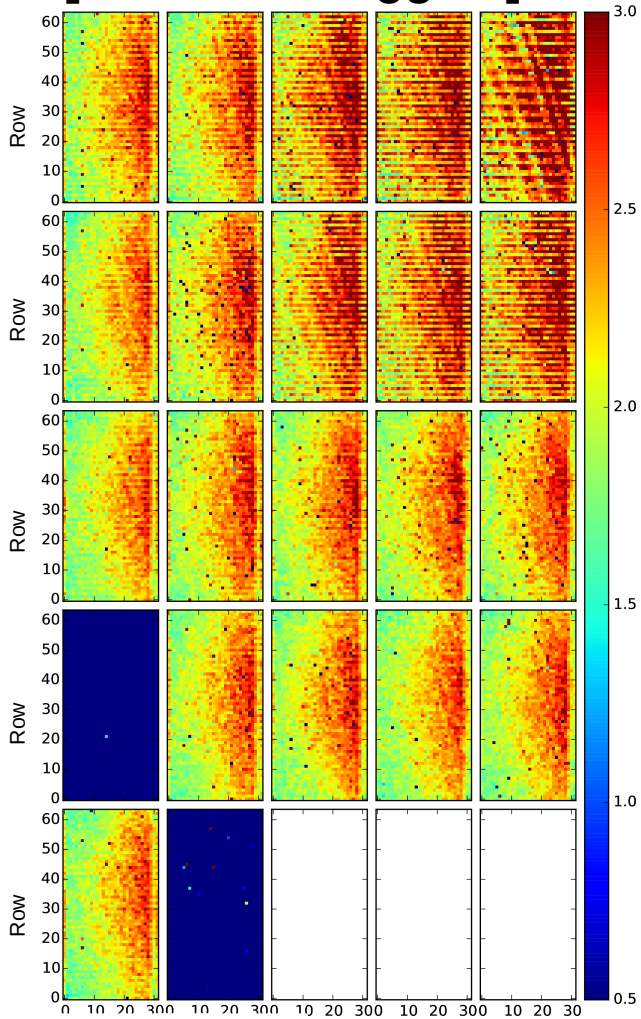
-1.5

-1.0

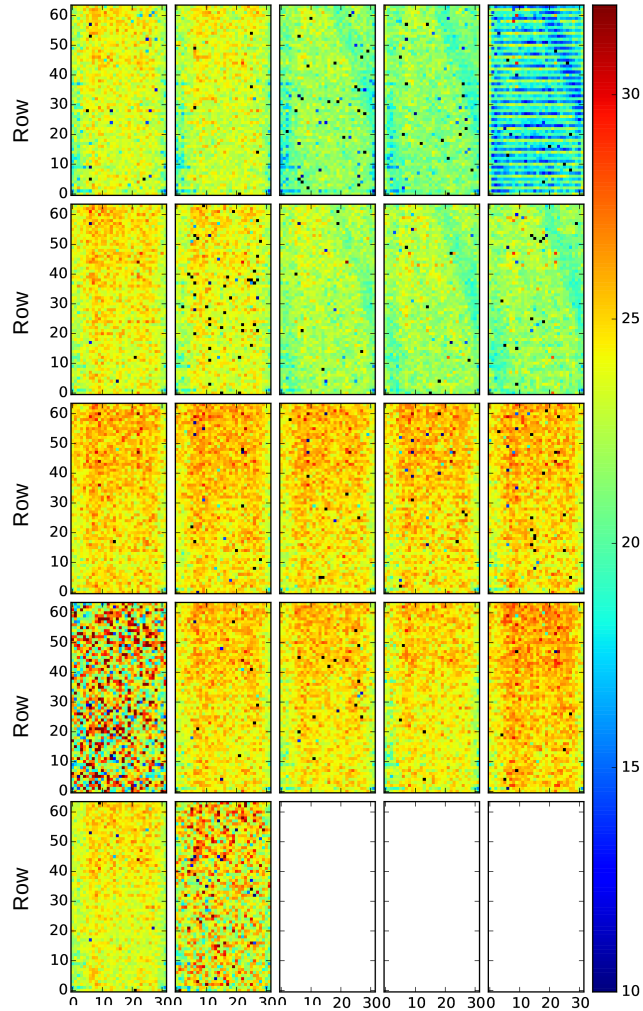
-0.5

0.0

Hit Rate [1e4 Hits/# Triggers]



Mean Signal in ADU



Clear-On: 20 V,
Gate-On: -2.5 V, Gate-Off: 3 V
Source: 7 V, Bulk: 10 V, Guard: 5 V
HV: -70 V, Drift: -5 V

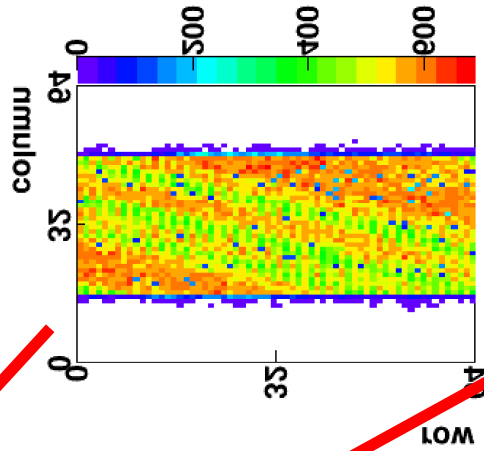
Clear-Off [V]: 5 4 3 2 1 5 4 3 2 1

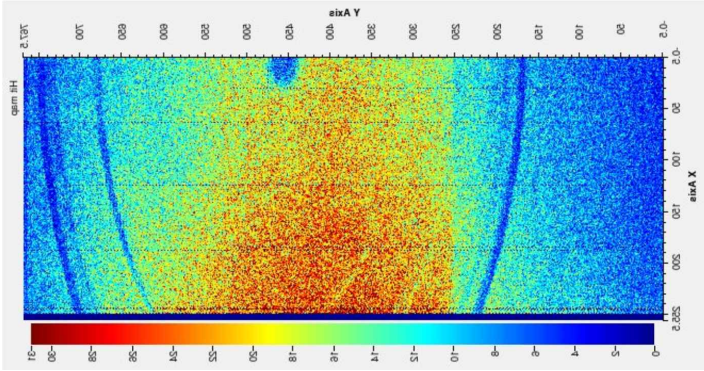
~ 1.8 M Triggers per measurement point

Rings in the matrix

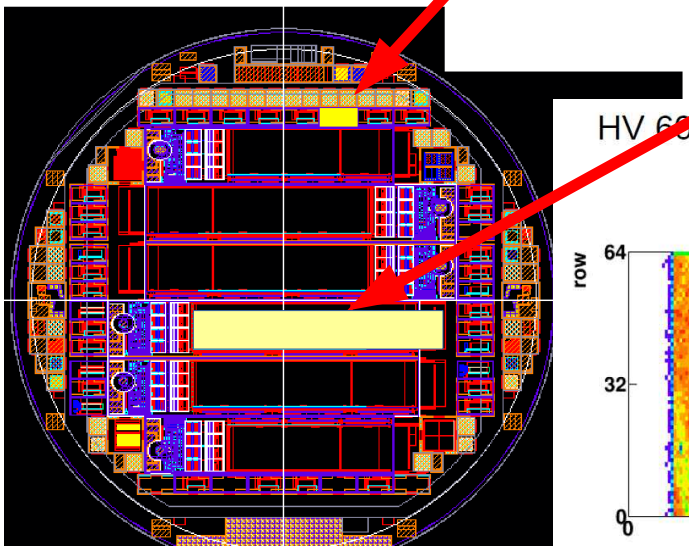
Rings of different hit efficiency are visible for certain working points

- Seem t o be concentric with the wafer
- Current explanation: Doping variation inside the wafer introduced during crystal growth



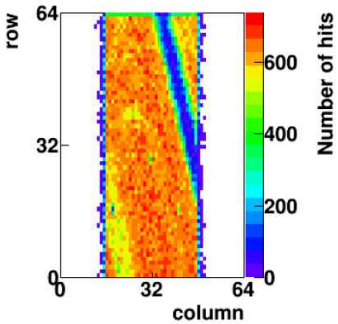


W35_OB1
at DESY



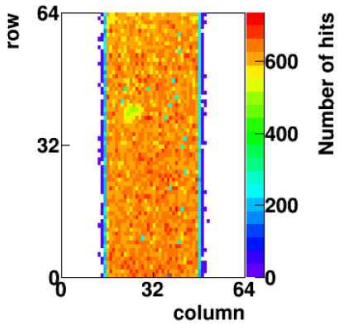
"Hit efficiency measurement" with 4 GeV electrons at DESY:

HV 69V / Drift 5V

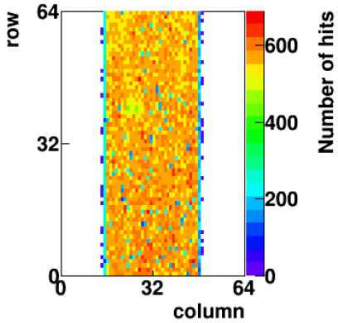


HV 70V / Drift 5V

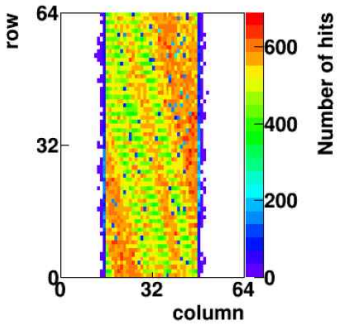
(best)



HV 75V / Drift -5V



HV 80V / Drift 5V

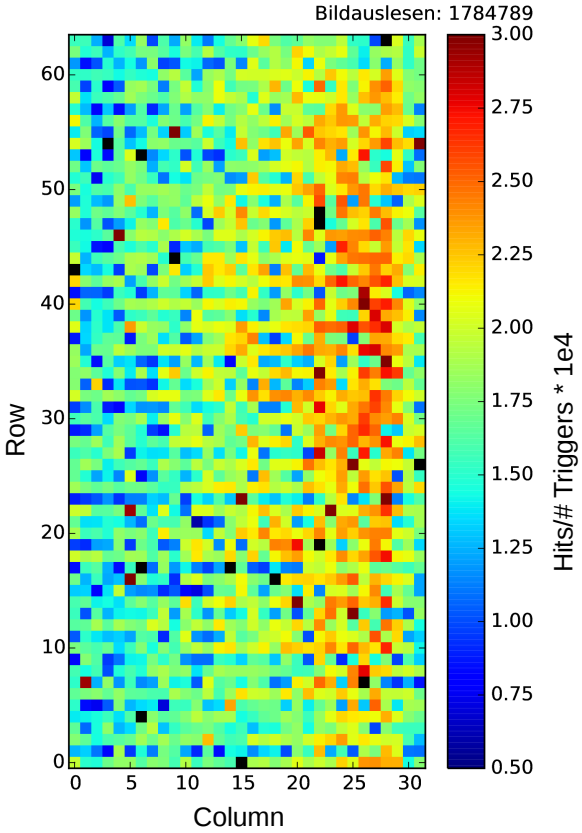


Even/Odd Effect

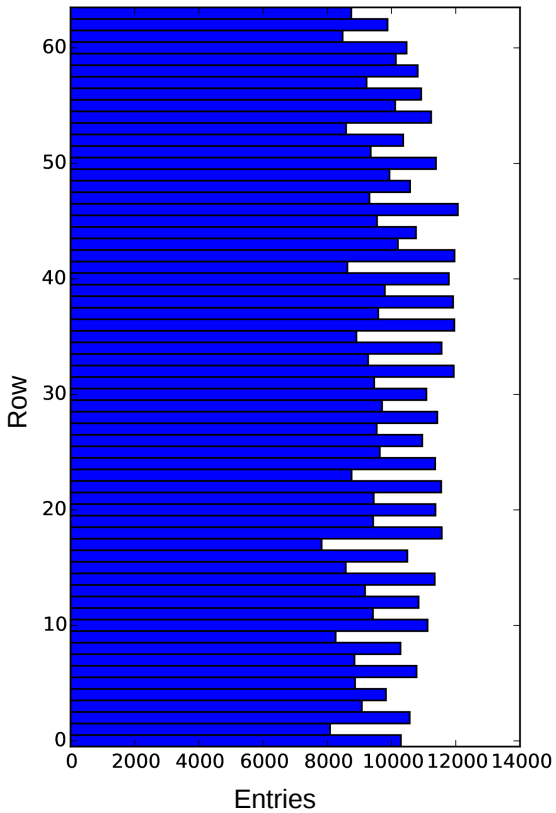
For certain working points even and odd rows show differences in hit rates and drain currents

- Not understood yet
- Drain current histogram does not look homogeneous anymore

Hit rate

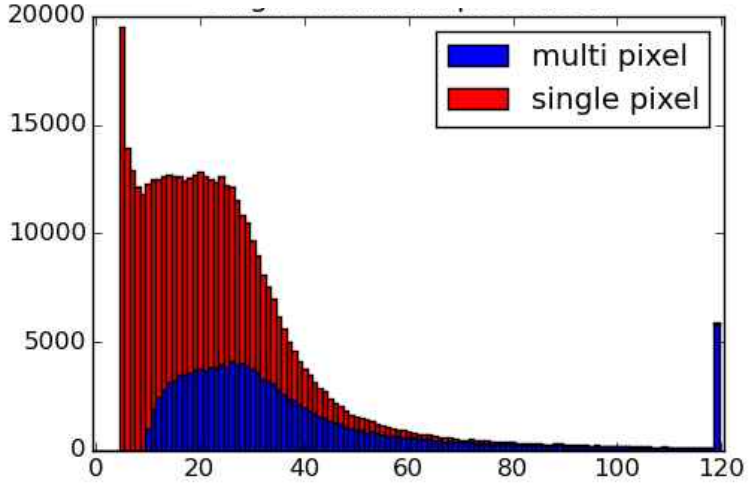


Row projection of hit rate

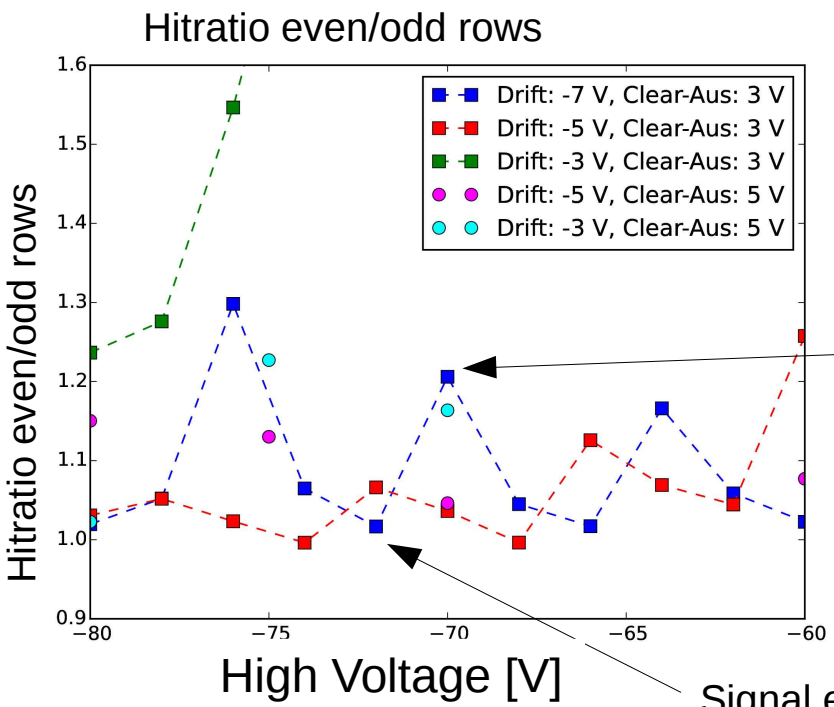


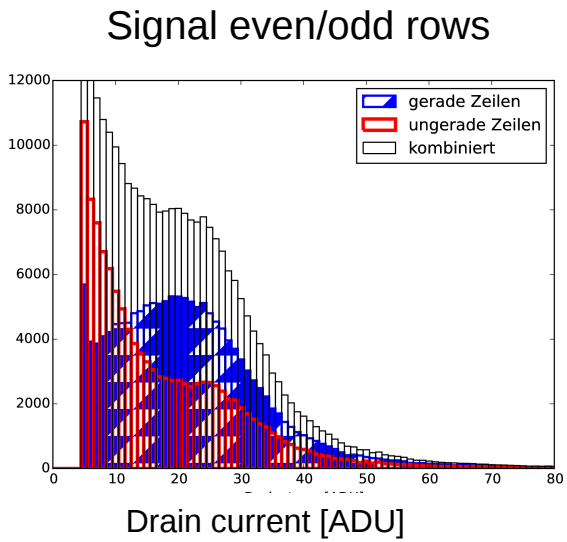
HV: -70 V, Drift: -7 V
Clear-On: 20 V, Clear-Off: 3 V
Gate-On: -2.5 V, Gate-Off: 3 V
Source: 7 V, CCG: -1 V,
Bulk: 10 V, Guard: 5 V

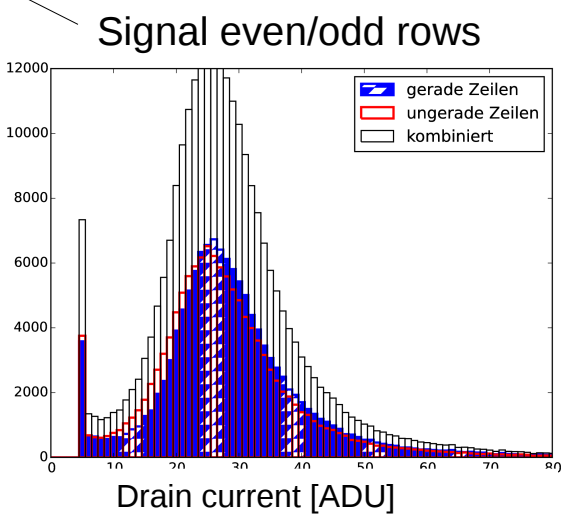
Signal histogram



Even/odd effect



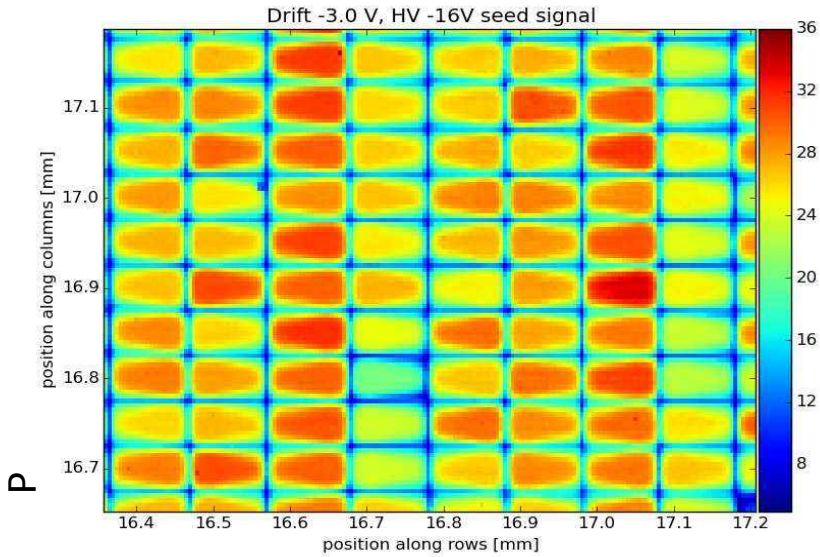


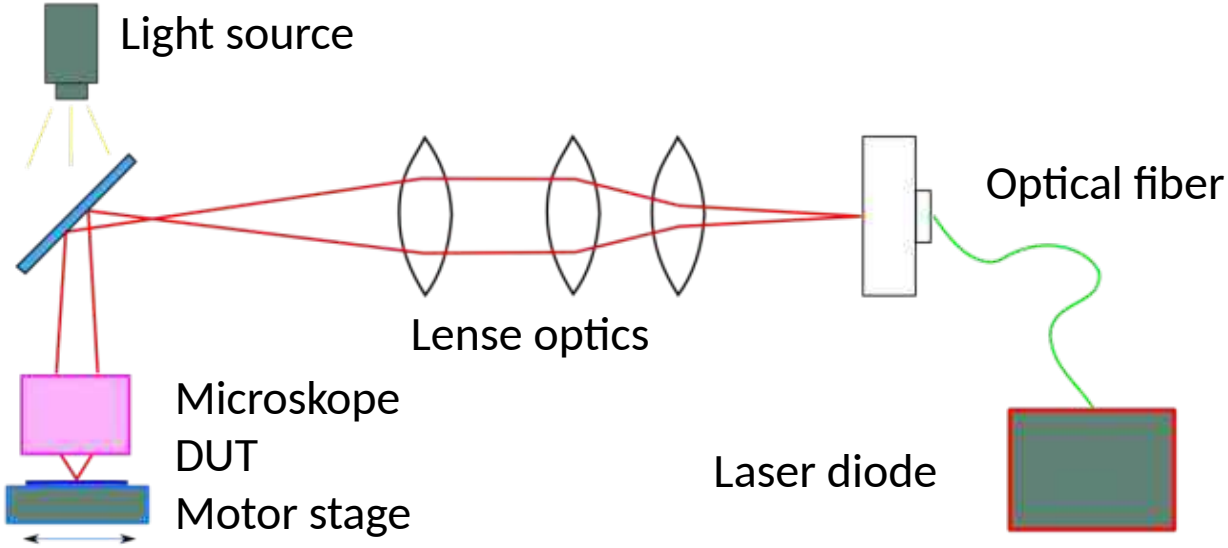


- Behavior changes quickly within steps of 2 V of high voltage
- Magnitude of change depends on drift voltage

Laser measurements

- Red laser with DUT on motor stage
- 3 µm laser spot
- Spacially resolved measurement





First measurements

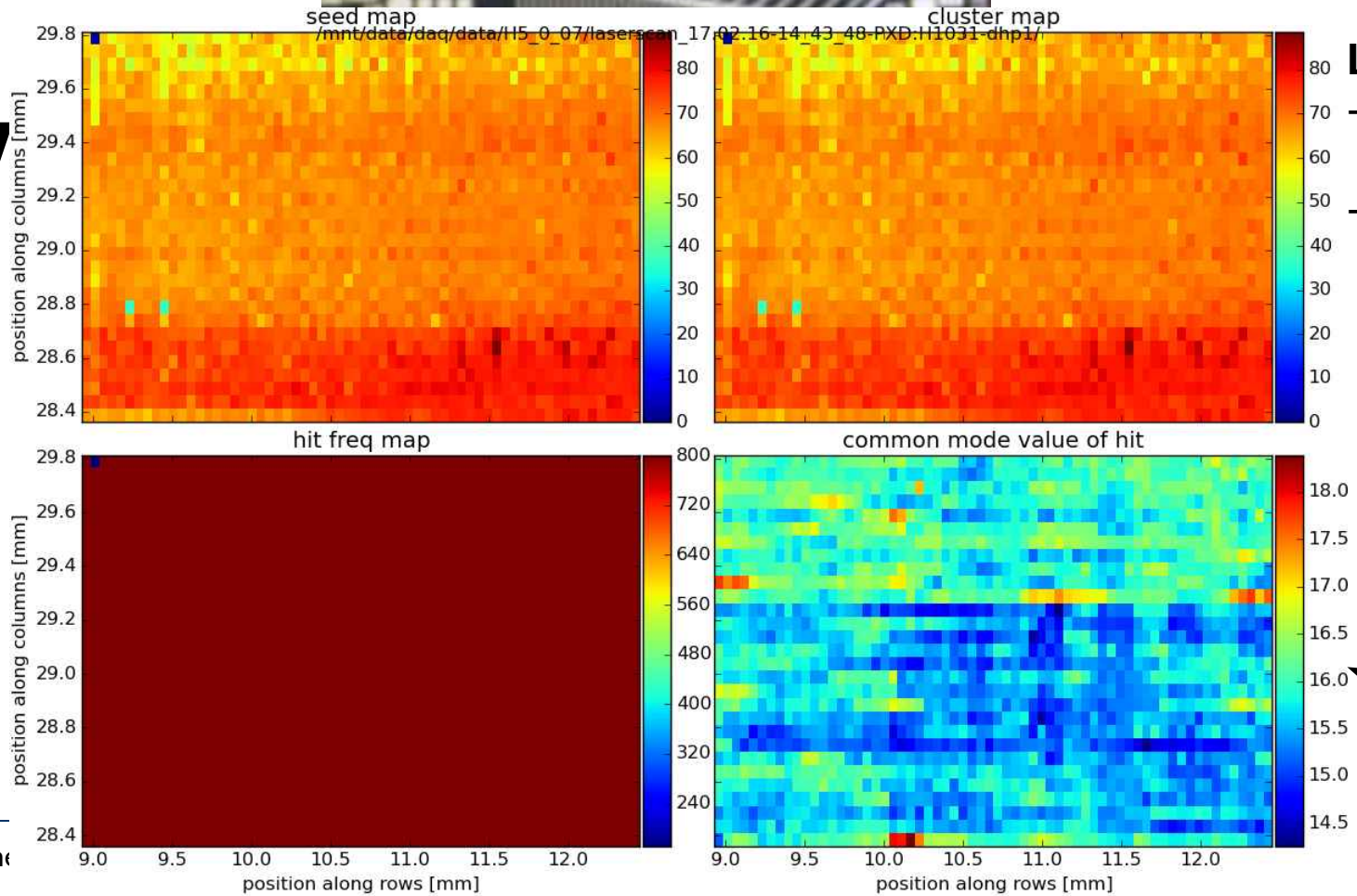
Rows (vertical)

Columns

HV = -70 V
Drift = -5 V

50x55 μm^2 steps

Matrix readout time: **2.05 μs**



Laser:
- from backside
- ~20 injections per frame
- **800 frames** per point of measurement

(almost) full matrix
One bin per pixel

First measurements

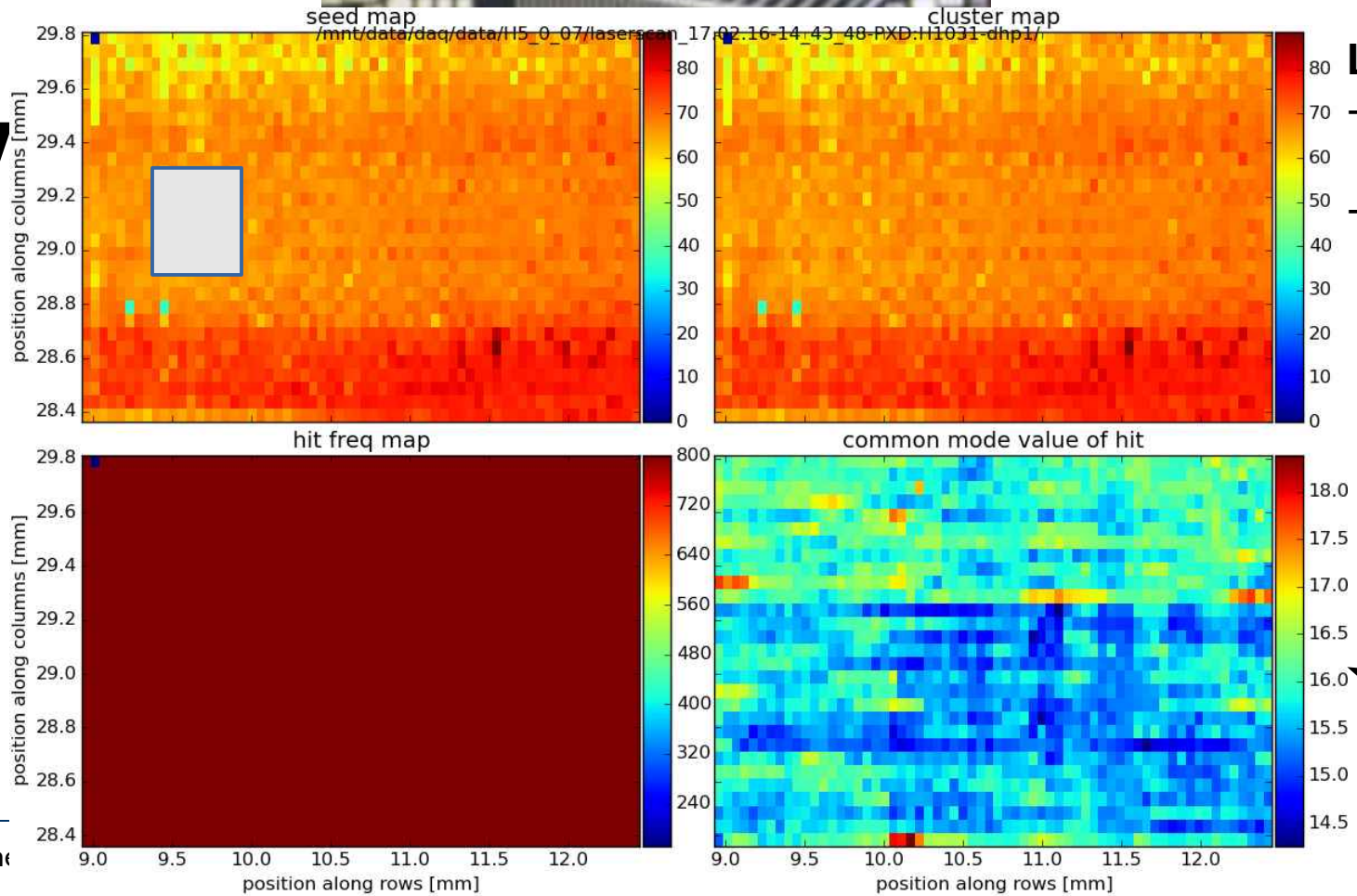
Rows (vertical)

Columns

HV = -70 V
Drift = -5 V

50x55 μm^2 steps

Matrix readout time: **2.05 μs**



Laser:
- from backside
- ~20 injections per frame
- **800 frames** per point of measurement

(almost) full matrix
One bin per pixel

First measurements

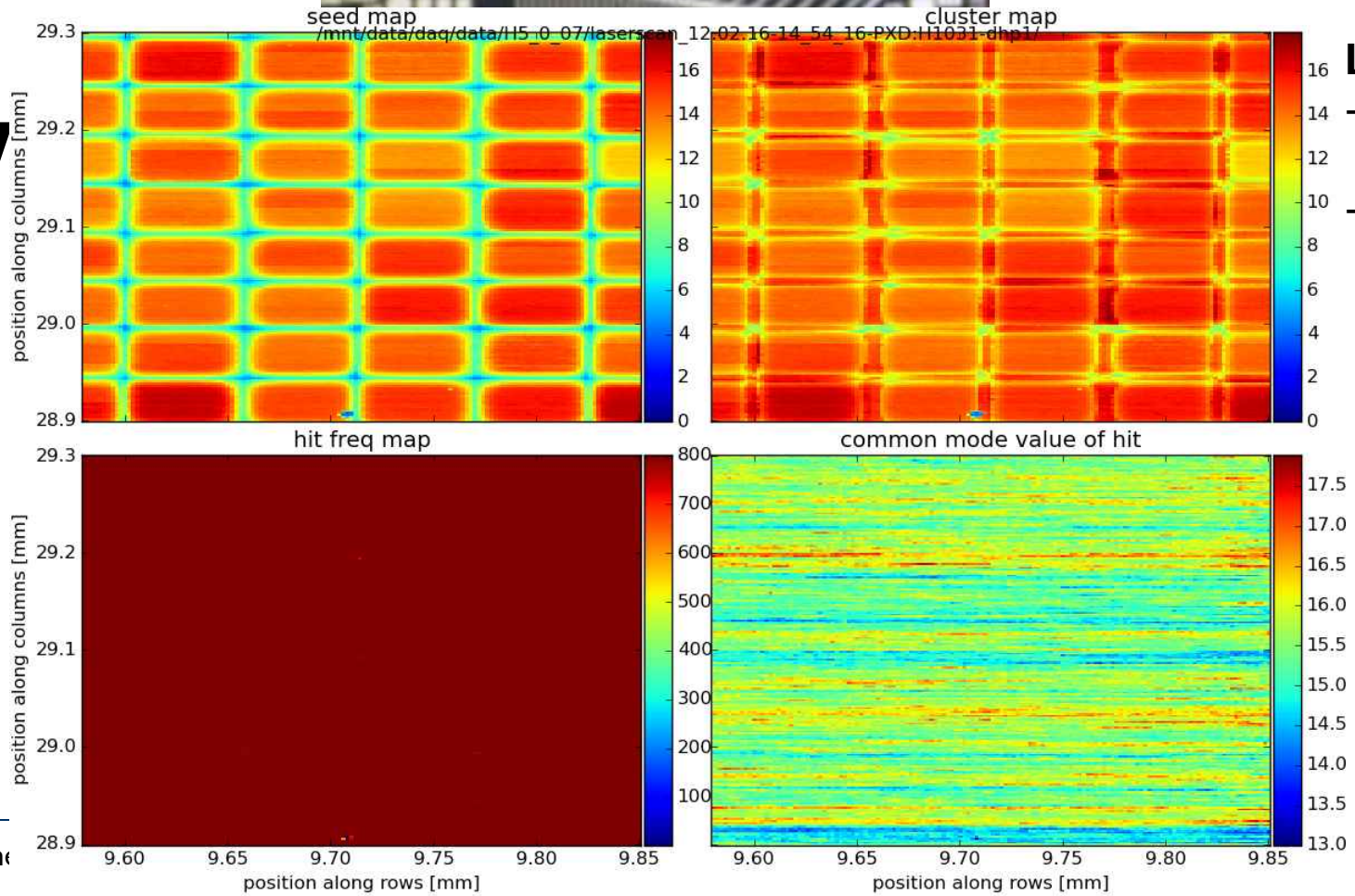
Rows (vertical)

Columns

HV = -70 V
Drift = -5 V

4x4 μm²
steps

Matrix readout time: **2.05 μs**



Laser:
- from backside
- ~20 injections per frame
- **800 frames** per point of measurement

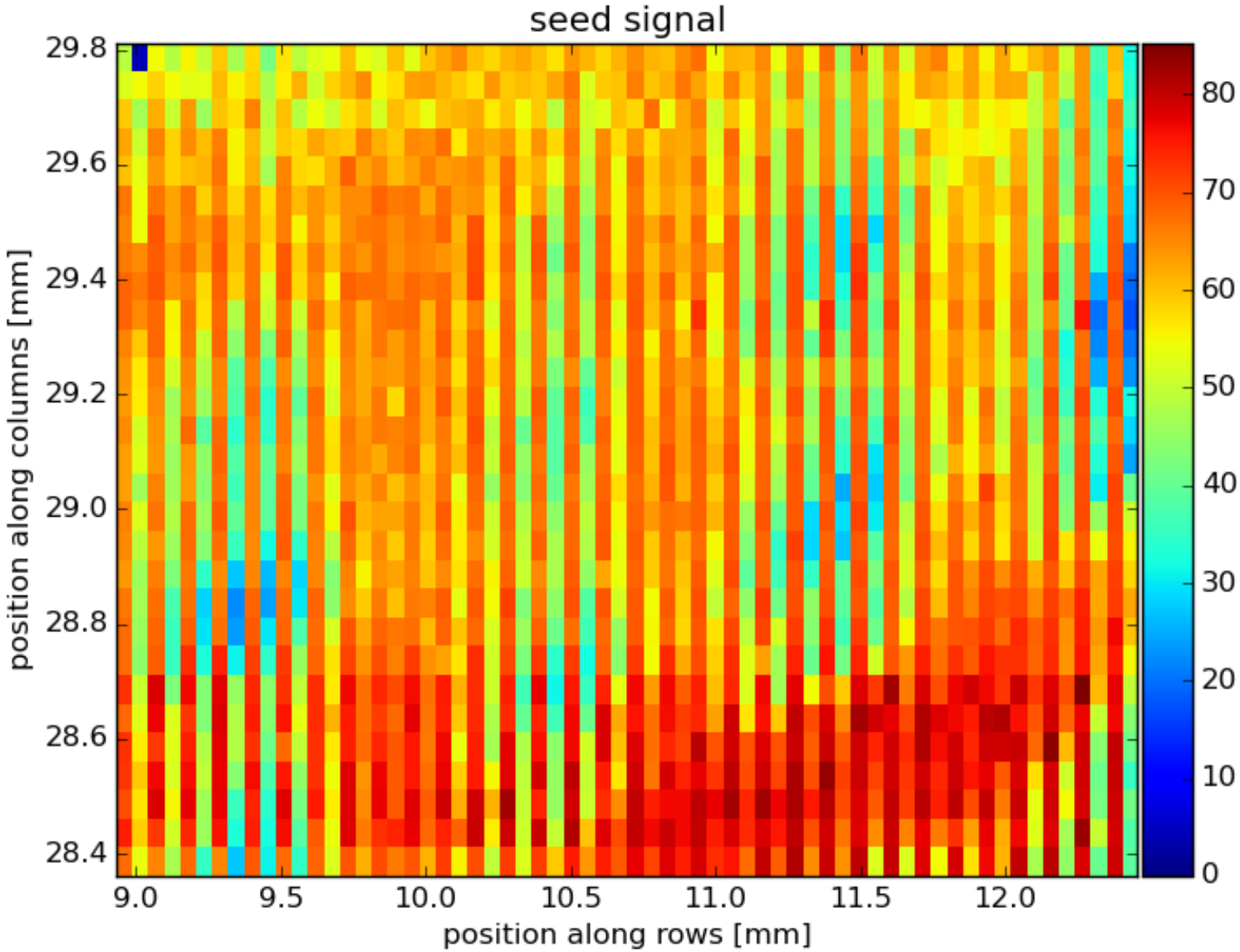
(almost) full matrix
One bin per pixel

Rings

HV = -80 V
Drift = -5 V

Rows (vertical shutter direction)

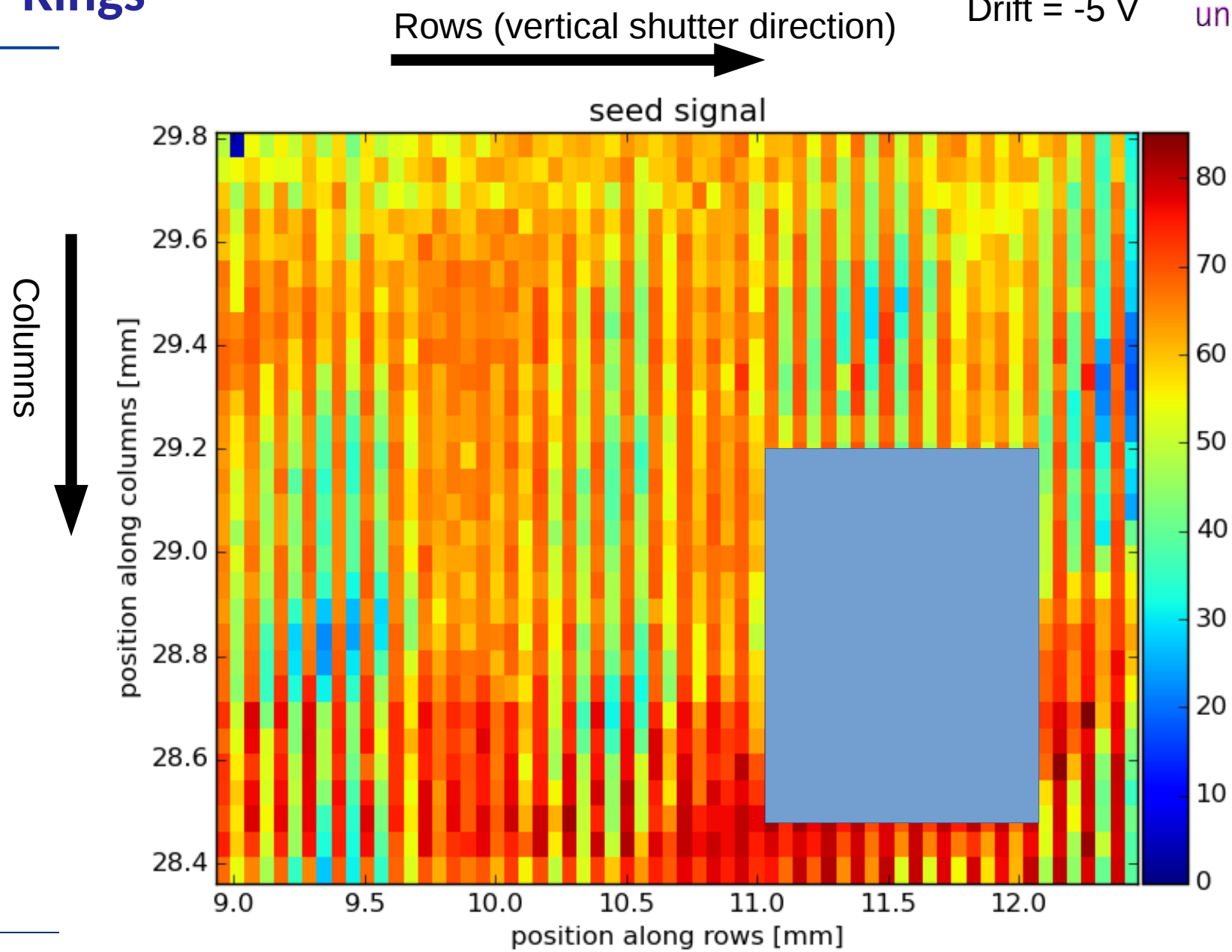
Columns



Full matrix
50x55 **µm²**
steps

Rings

HV = -80 V
Drift = -5 V

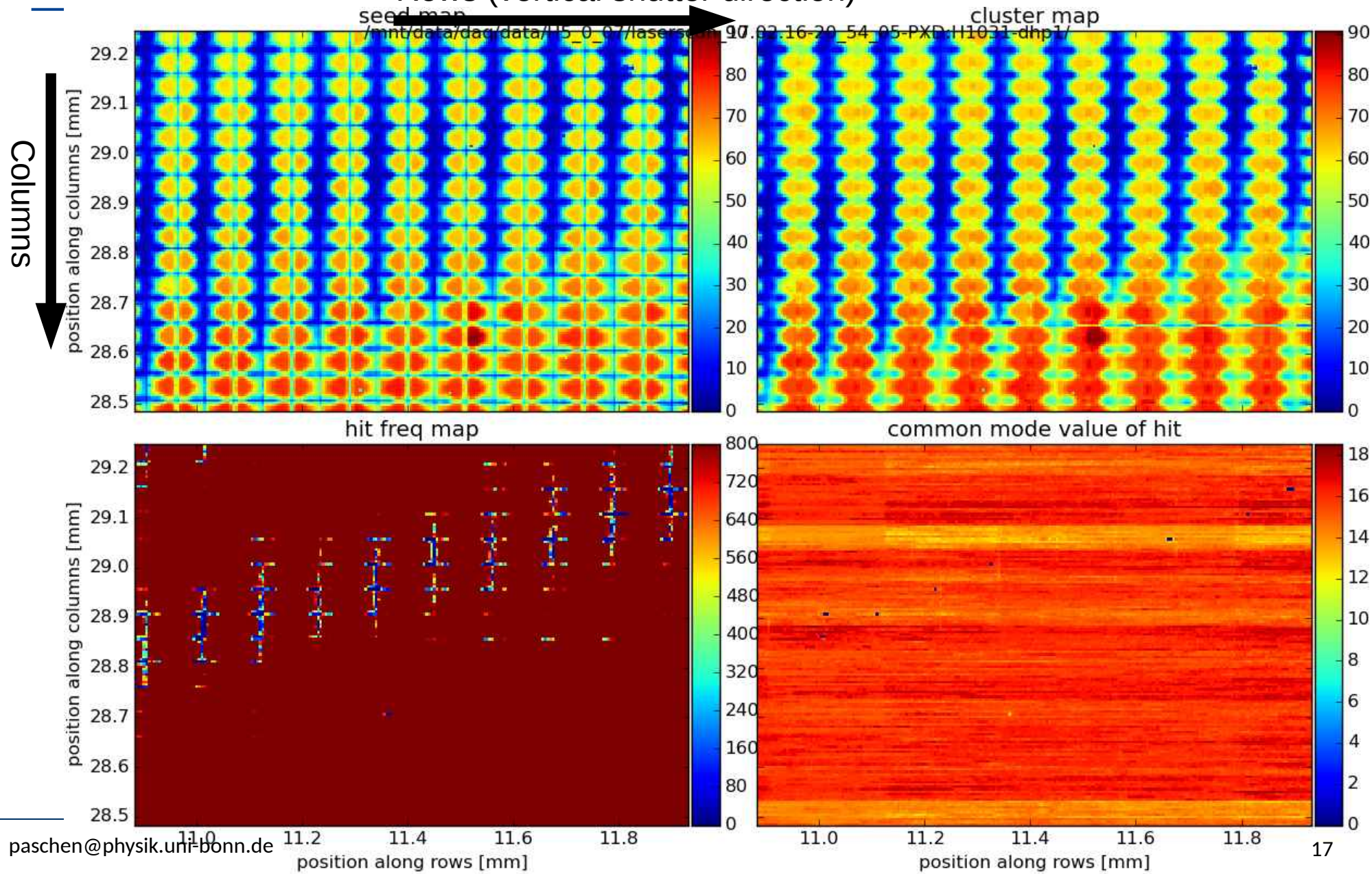


Full matrix
50x55 µm²
steps

Rings

10x10 μm² steps

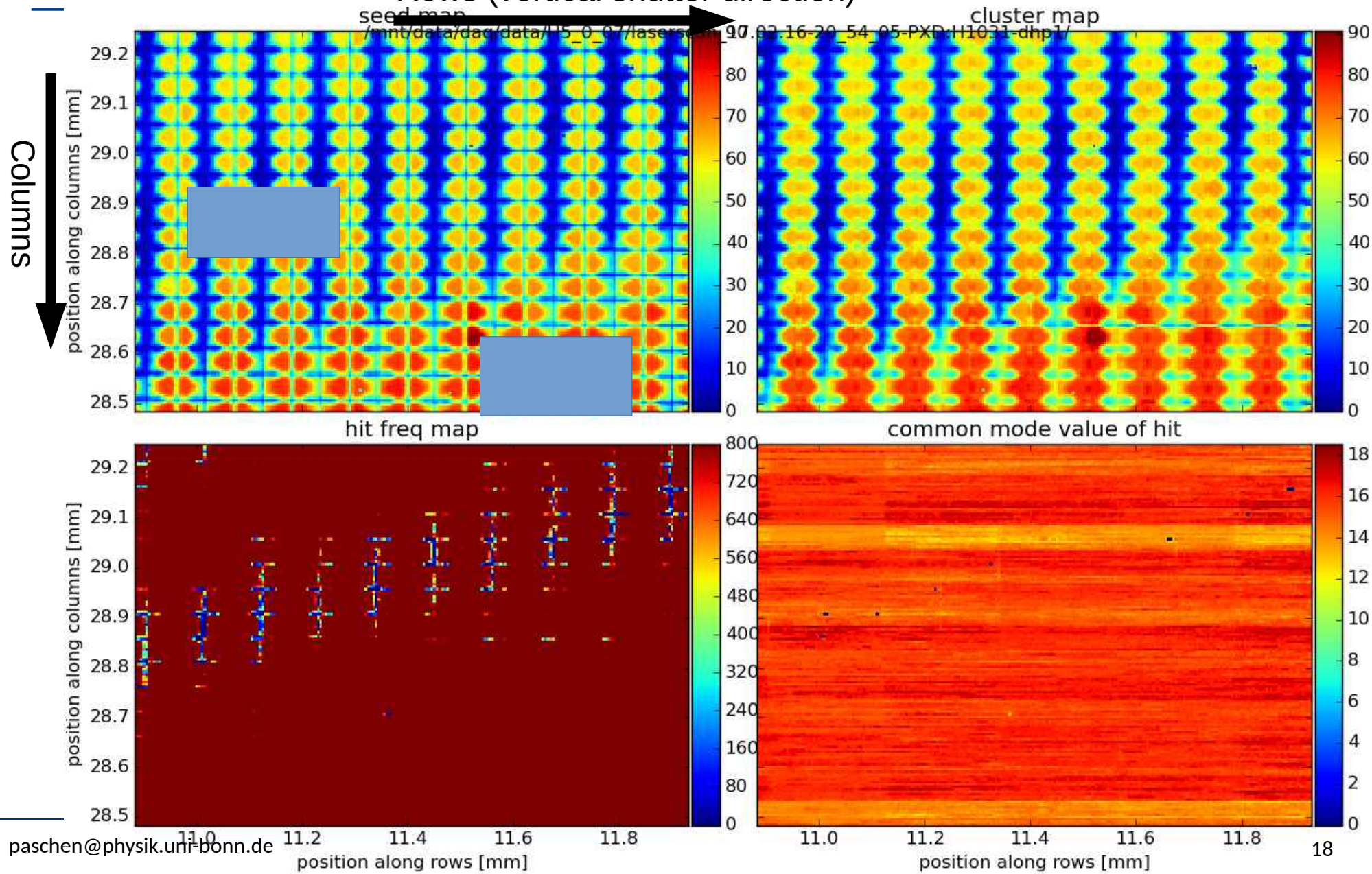
HV = -80 V
Drift = -5 V



Rings

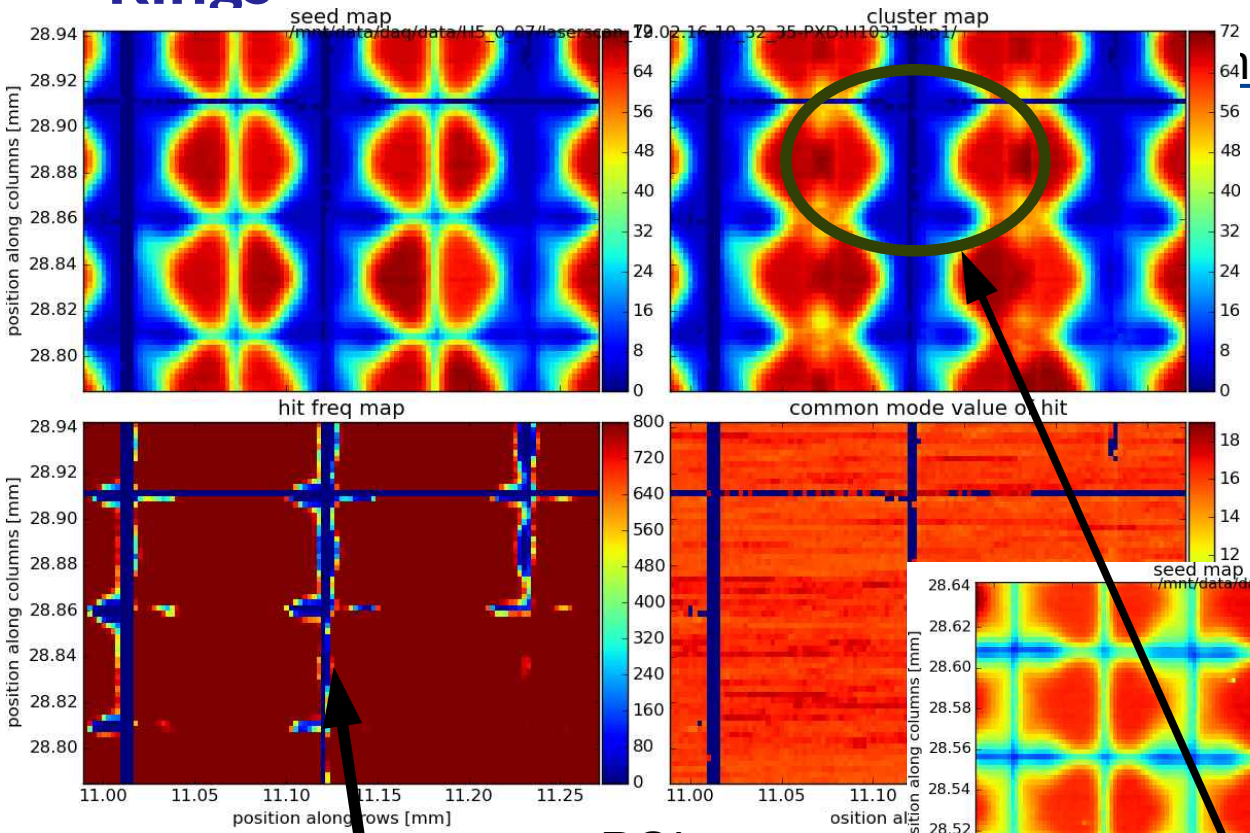
10x10 μm² steps

HV = -80 V
Drift = -5 V



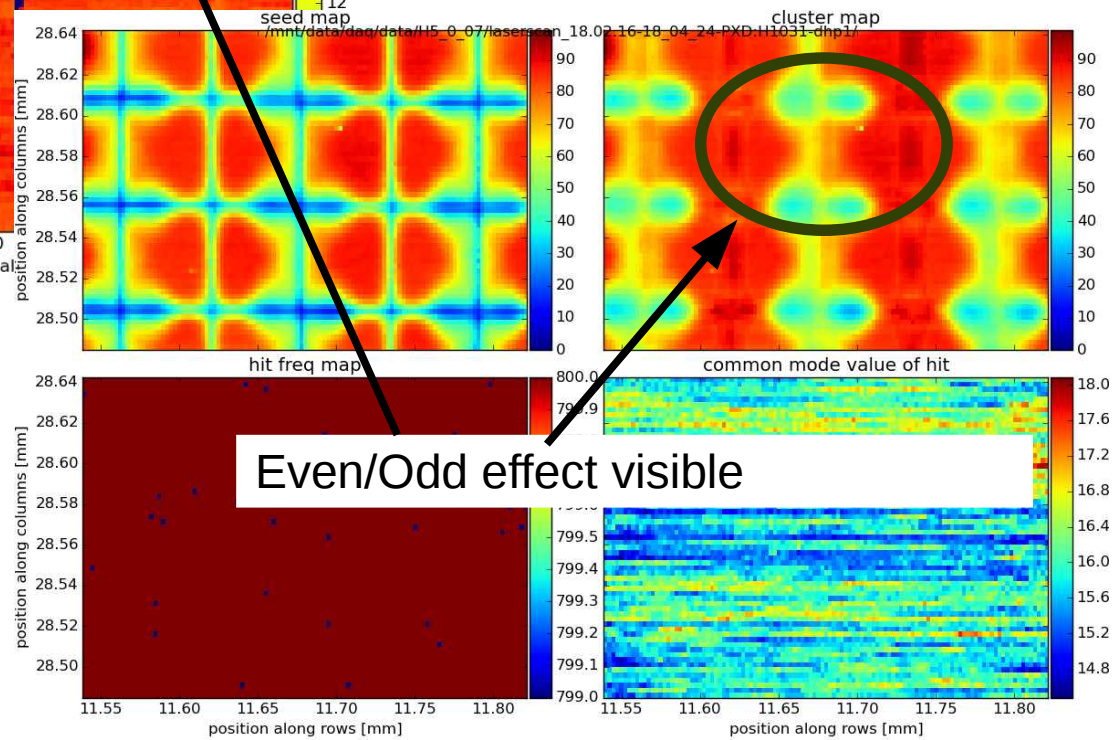
Rings

HV = -80 V
Drift = -5 V



ROIs
5x5 µm²
steps

inefficiencies!



Even/Odd effect visible

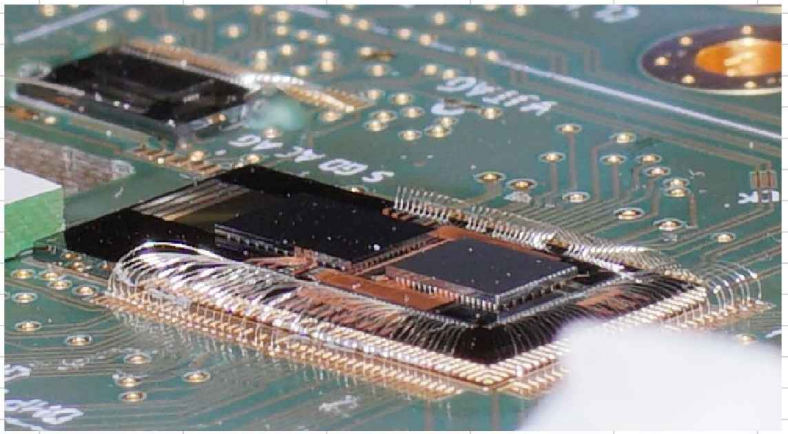
Irradiation of DHPT1.1 and DCDB4pp at KIT

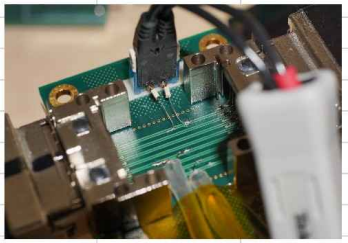
Hybrid 5 laboratory tests

DUT:	**Hybrid5.0.05 with DHPT1.1, DCDpp and SwitcherBG**

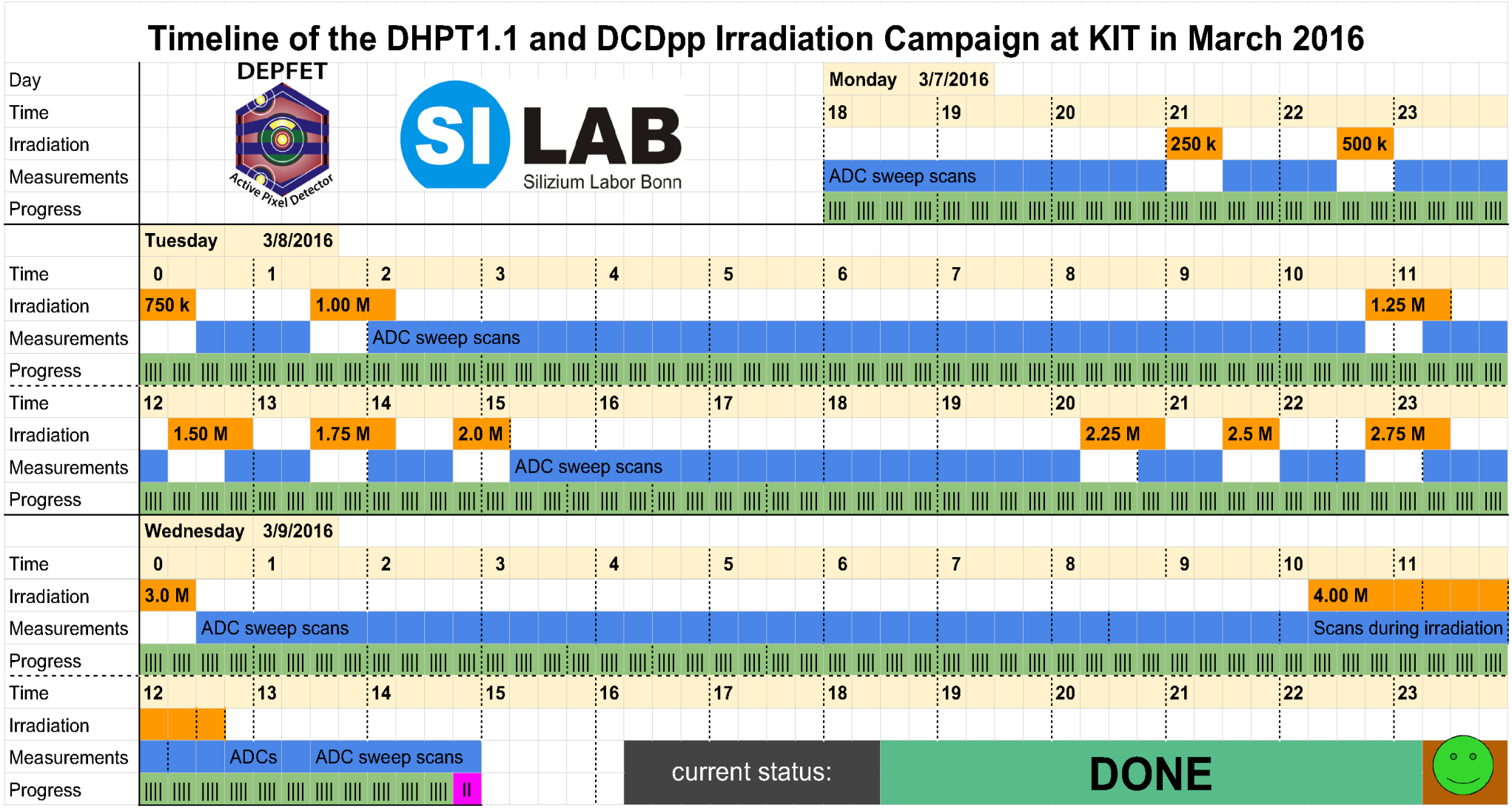
signal pathes:	
HS link	**JTAG link**
DHE	
1m Infiniband	RJ45 cable
JTBB	
1m Infiniband	
Probeadapter	5m Infiniband
5m Infiniband	
Hybrid 5	

wirebonds:	
material	Al with 1% Si
max current for 10 mm	400 mA
max current for 1 mm	1 A
specific resistivity	0.03 Ohm mm2/m

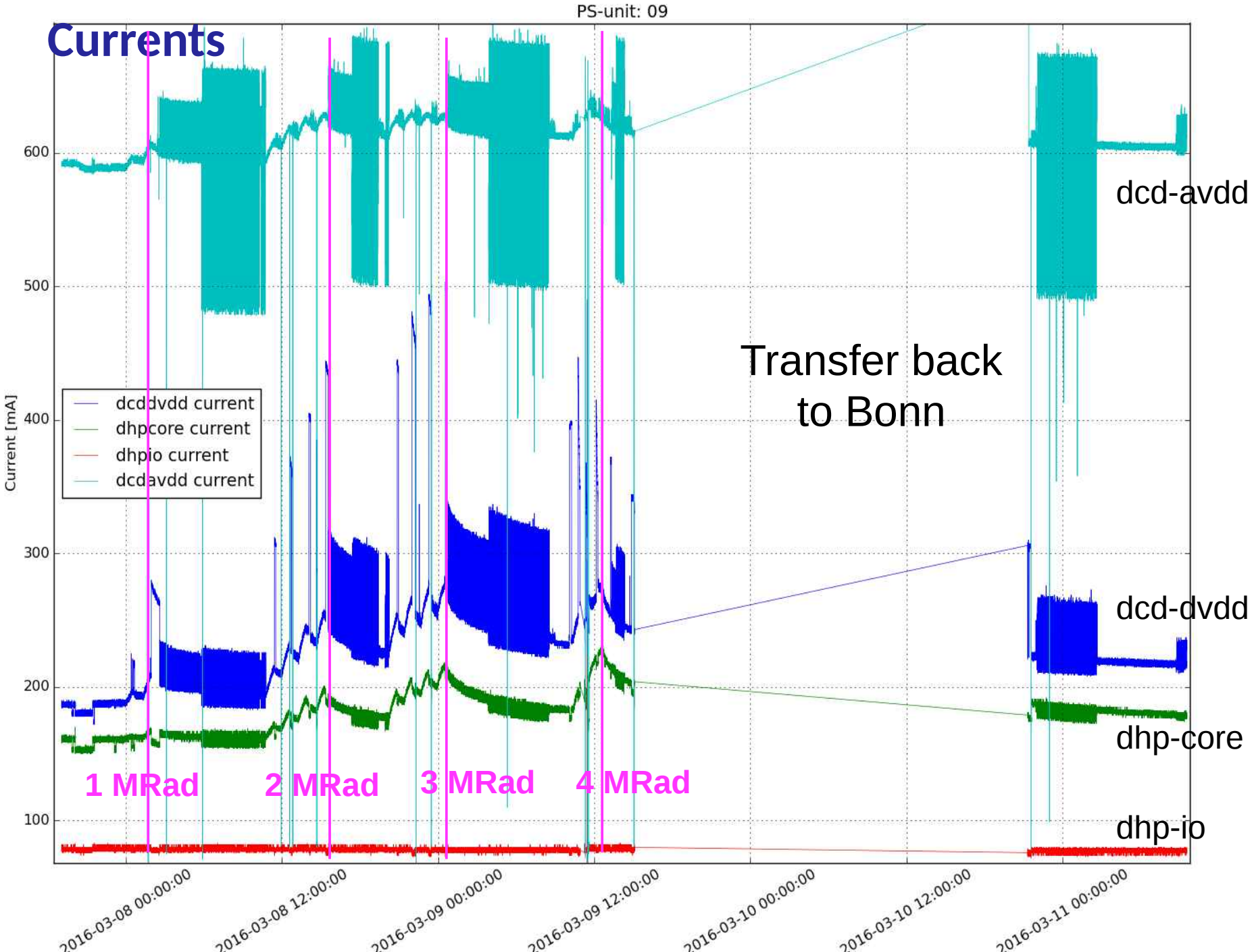




Hybrid 5 laboratory tests

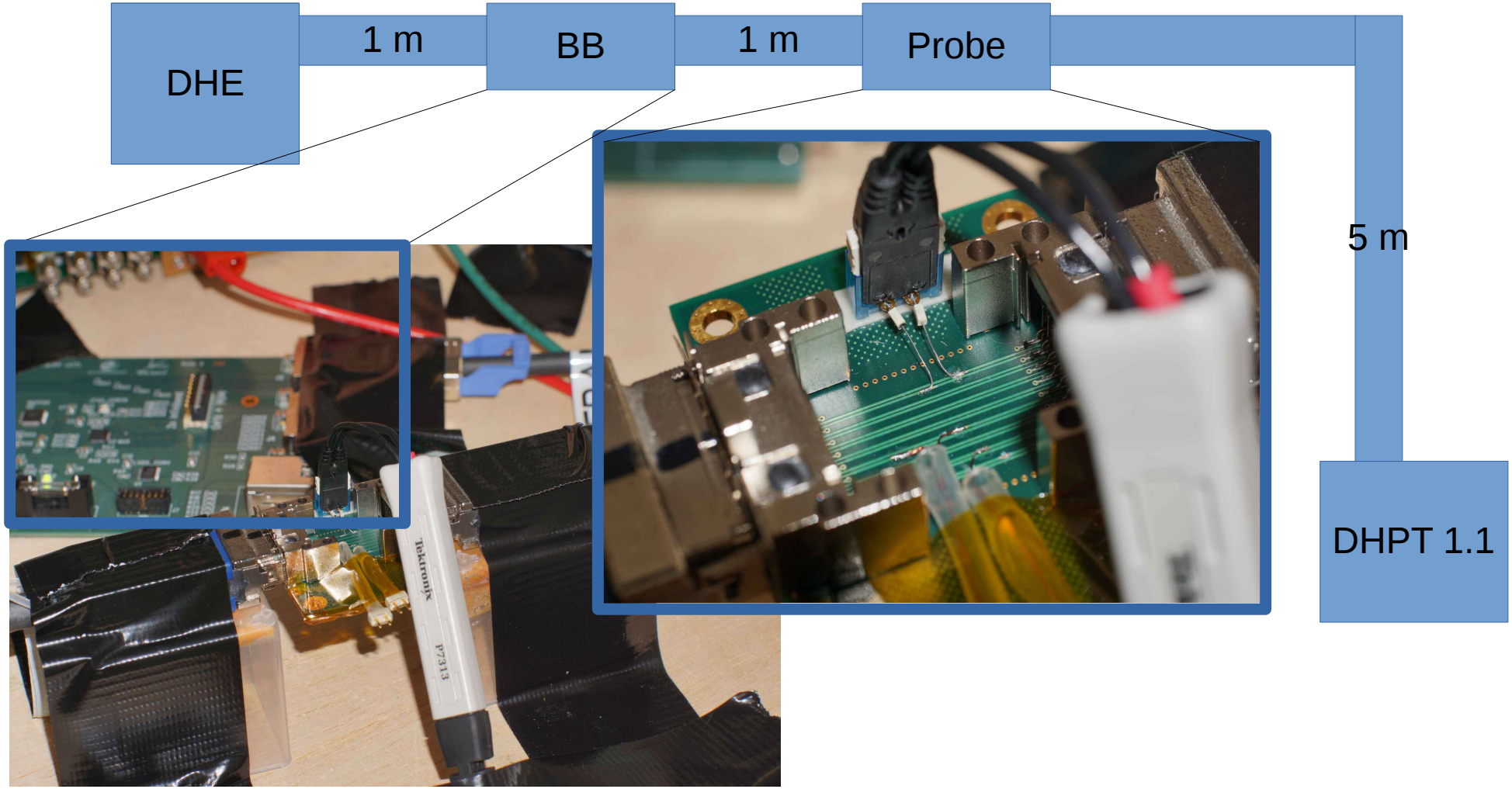


Currents

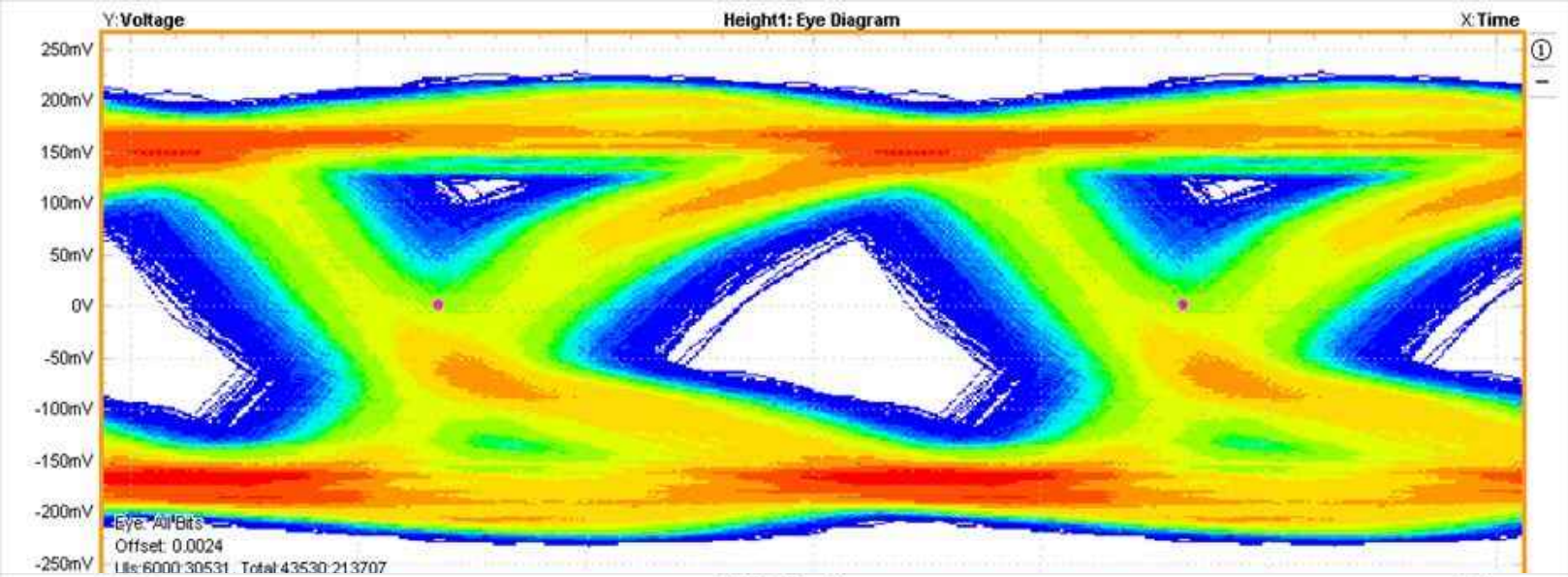

PS-unit: 09
Current [mA]
600
500
400
300
200
100
dcddvdd current
dhpcore current
dhpio current
dcdavdd current
Transfer back
to Bonn
dcd-avdd
dcd-dvdd
dhp-core
dhp-io
1 MRad
2 MRad
3 MRad
4 MRad
2016-03-08 00:00:00
2016-03-08 12:00:00
2016-03-09 00:00:00
2016-03-09 12:00:00
2016-03-10 00:00:00
2016-03-10 12:00:00
2016-03-11 00:00:00

DHPT1.1 Highspeed Link

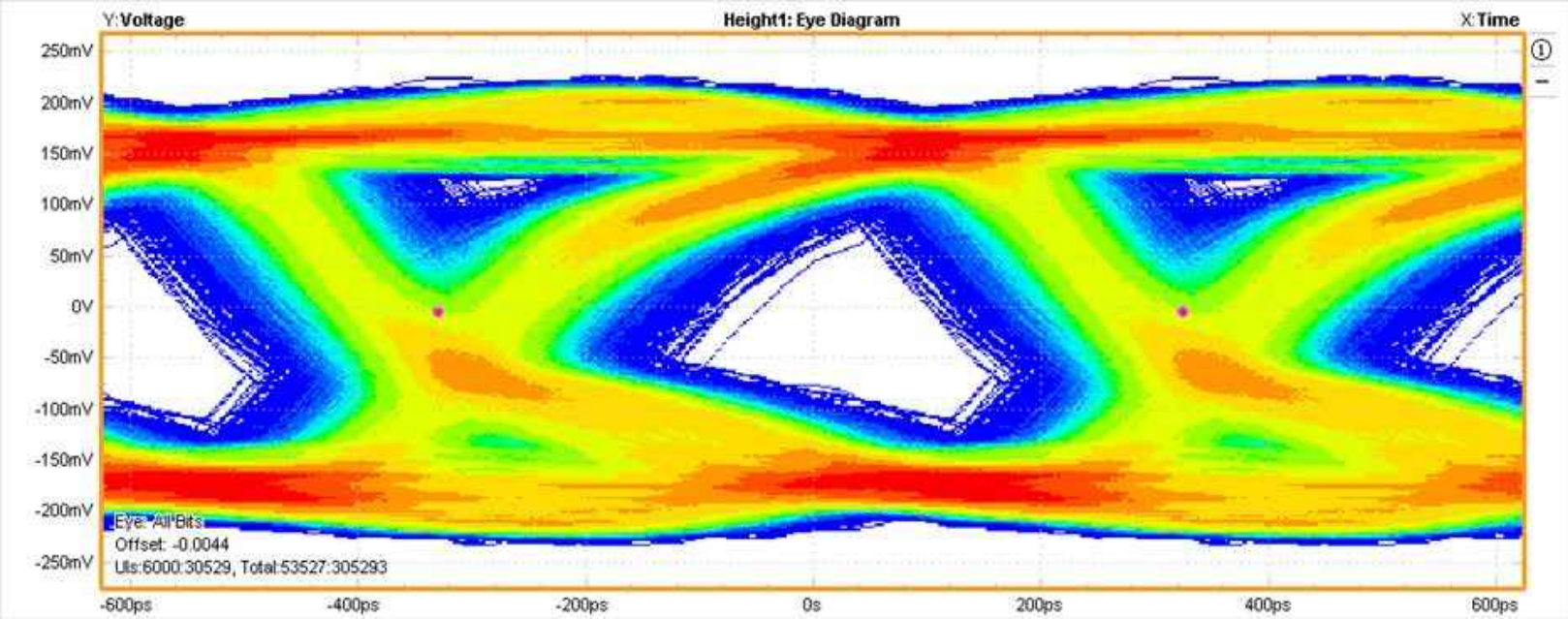
DHPT1.1 Highspeed Link



DHPT1.1 Highspeed Link

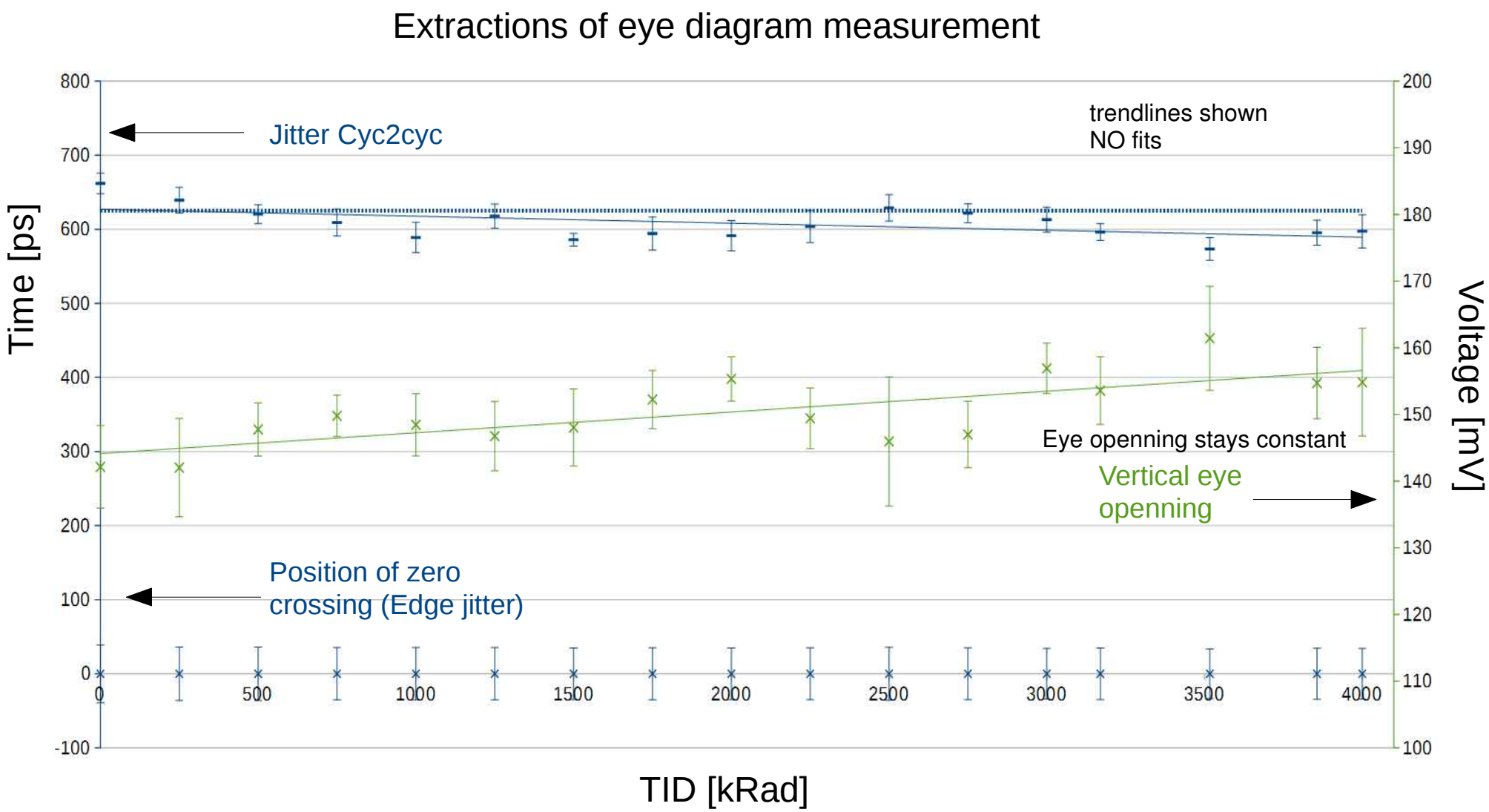


0 MRad



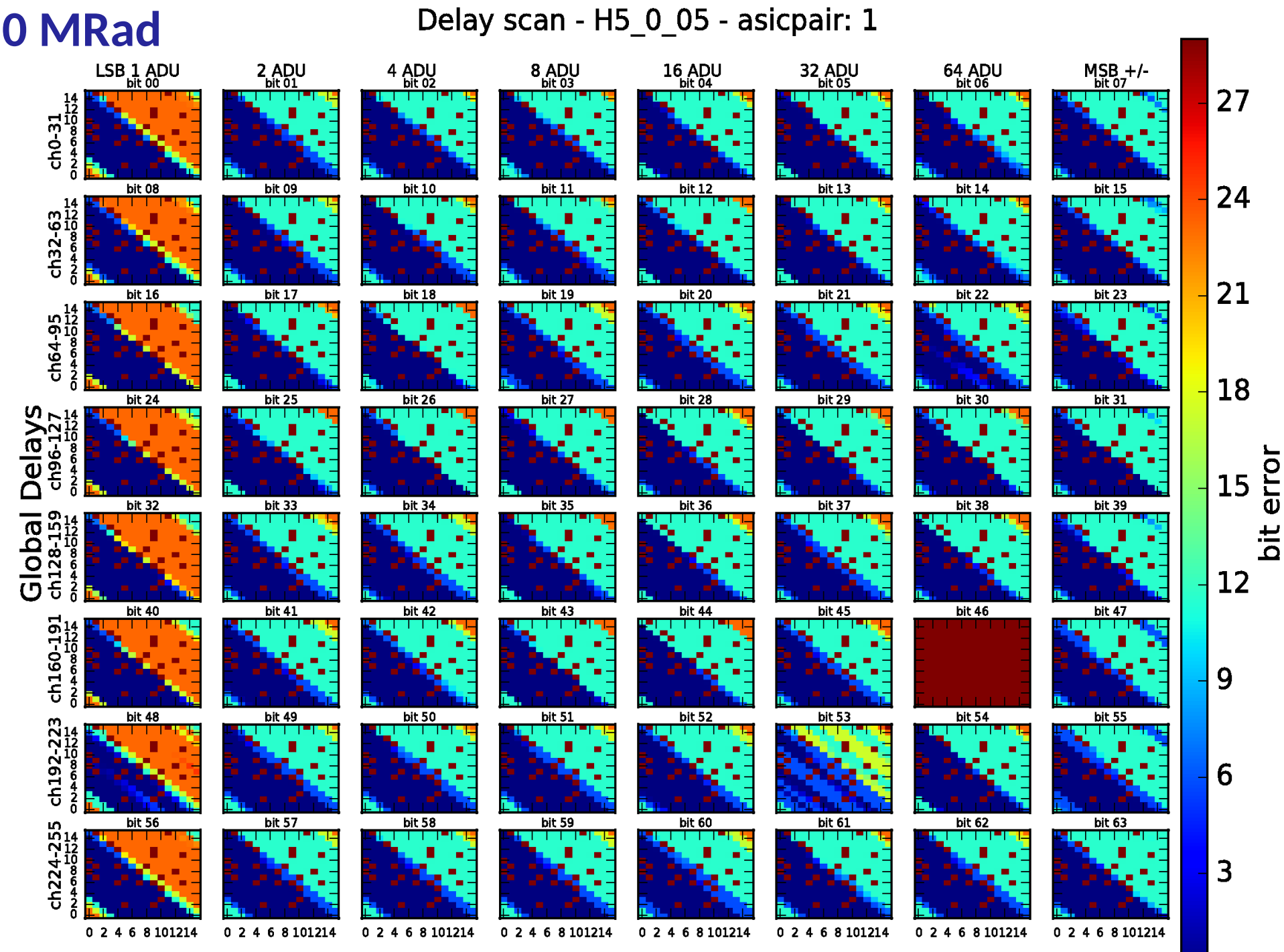
4 MRad

DHPT1.1 Highspeed Link

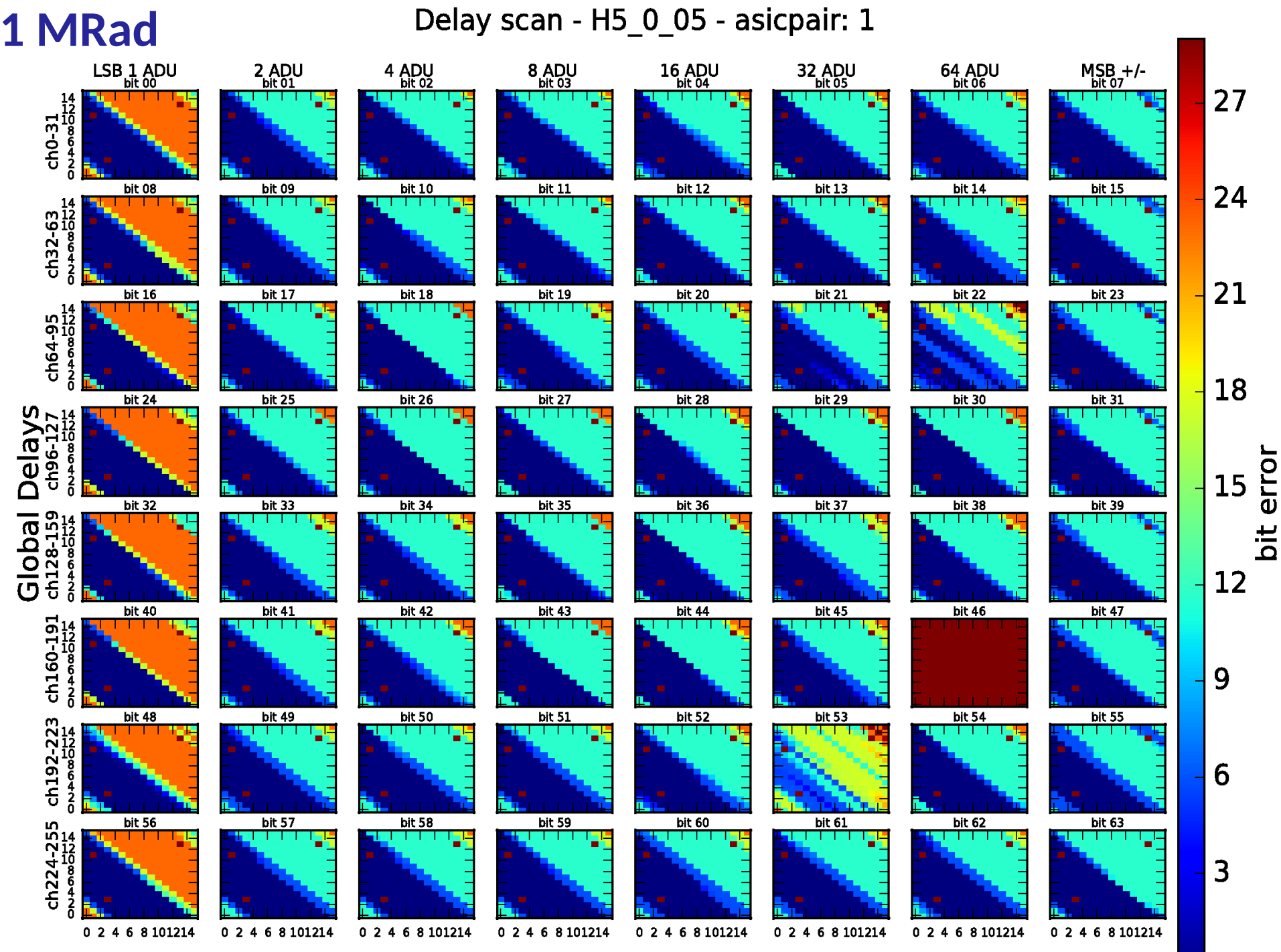


DCD ↔ DHP communication

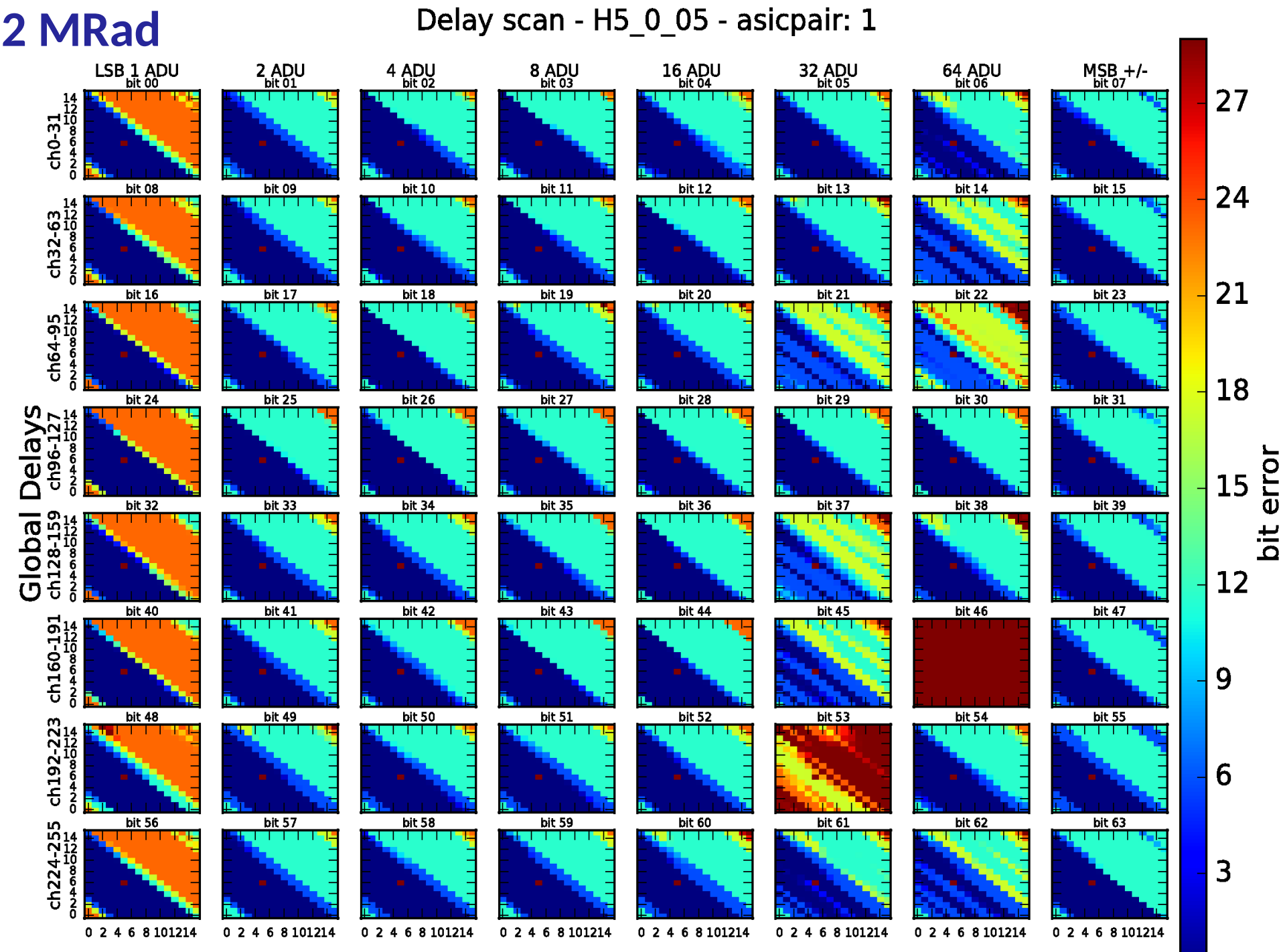
0 MRad


Delay scan - H5_0_05 - asicpair: 1
LSB 1 ADU
2 ADU
4 ADU
8 ADU
16 ADU
32 ADU
64 ADU
MSB +/-
Global Delays
ch0-31
ch32-63
ch64-95
ch96-127
ch128-159
ch160-191
ch192-223
ch224-255
bit 00
bit 01
bit 02
bit 03
bit 04
bit 05
bit 06
bit 07
bit 08
bit 09
bit 10
bit 11
bit 12
bit 13
bit 14
bit 15
bit 16
bit 17
bit 18
bit 19
bit 20
bit 21
bit 22
bit 23
bit 24
bit 25
bit 26
bit 27
bit 28
bit 29
bit 30
bit 31
bit 32
bit 33
bit 34
bit 35
bit 36
bit 37
bit 38
bit 39
bit 40
bit 41
bit 42
bit 43
bit 44
bit 45
bit 46
bit 47
bit 48
bit 49
bit 50
bit 51
bit 52
bit 53
bit 54
bit 55
bit 56
bit 57
bit 58
bit 59
bit 60
bit 61
bit 62
bit 63
0 2 4 6 8 10 12 14
bit error
27
24
21
18
15
12
9
6
3

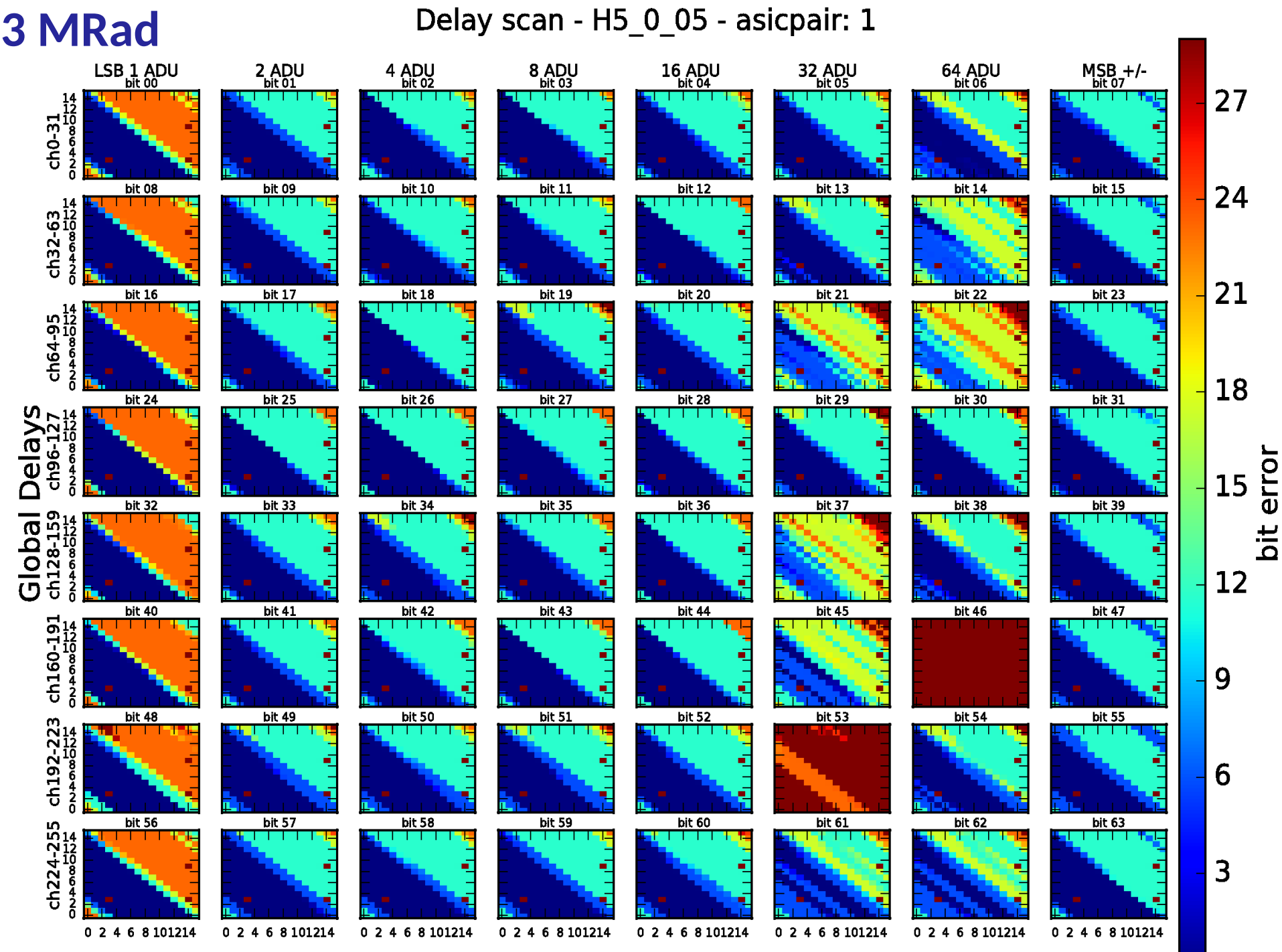
1 MRad


Delay scan - H5_0_05 - asicpair: 1
LSB 1 ADU
2 ADU
4 ADU
8 ADU
16 ADU
32 ADU
64 ADU
MSB +/-
Global Delays
ch0-31
ch32-63
ch64-95
ch96-127
ch128-159
ch160-191
ch192-223
ch224-255
bit 00
bit 01
bit 02
bit 03
bit 04
bit 05
bit 06
bit 07
bit 08
bit 09
bit 10
bit 11
bit 12
bit 13
bit 14
bit 15
bit 16
bit 17
bit 18
bit 19
bit 20
bit 21
bit 22
bit 23
bit 24
bit 25
bit 26
bit 27
bit 28
bit 29
bit 30
bit 31
bit 32
bit 33
bit 34
bit 35
bit 36
bit 37
bit 38
bit 39
bit 40
bit 41
bit 42
bit 43
bit 44
bit 45
bit 46
bit 47
bit 48
bit 49
bit 50
bit 51
bit 52
bit 53
bit 54
bit 55
bit 56
bit 57
bit 58
bit 59
bit 60
bit 61
bit 62
bit 63
0 2 4 6 8 10 12 14
bit error
27
24
21
18
15
12
9
6
3

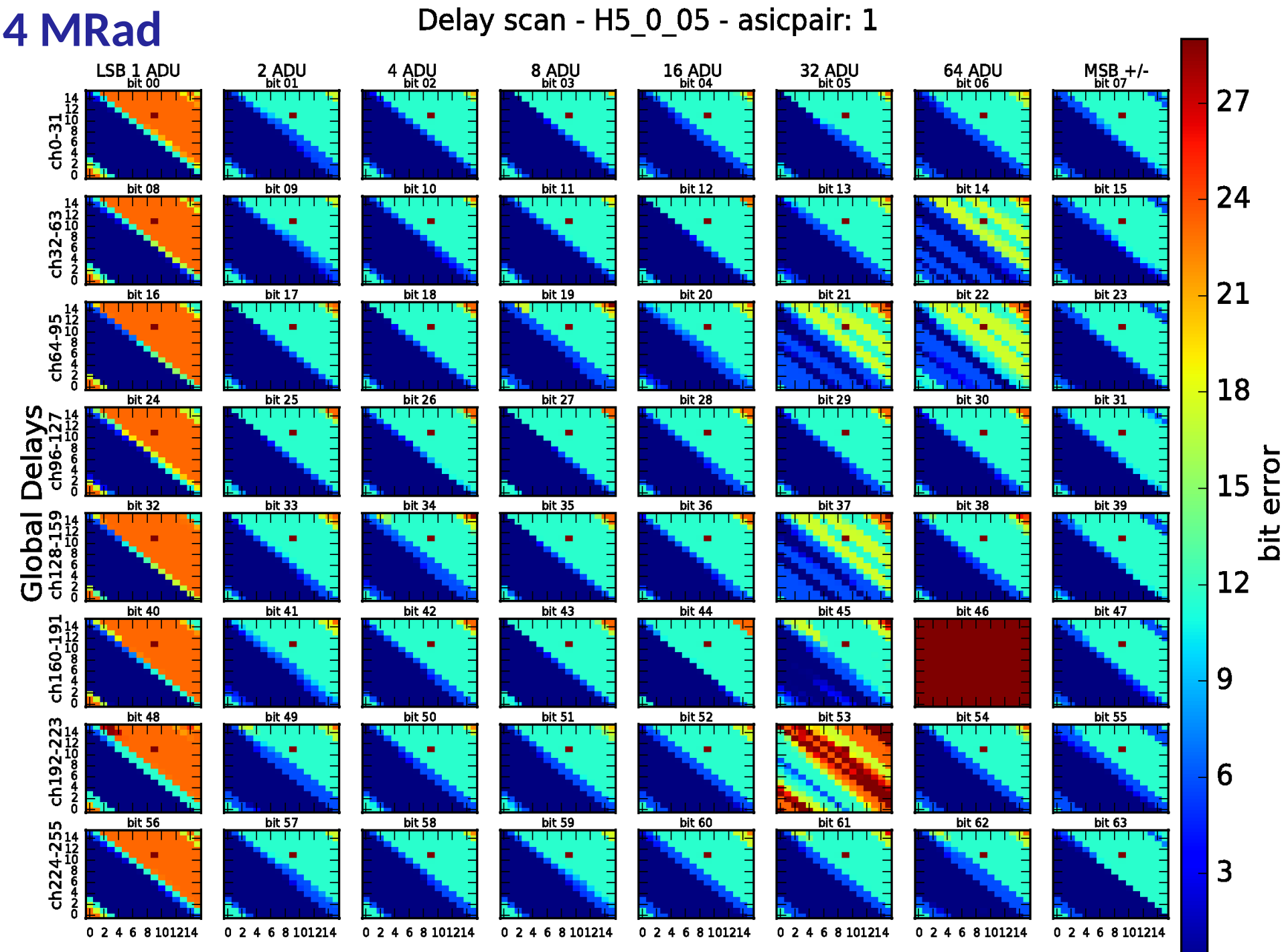
2 MRad


Delay scan - H5_0_05 - asicpair: 1
LSB 1 ADU
2 ADU
4 ADU
8 ADU
16 ADU
32 ADU
64 ADU
MSB +/-
Global Delays
ch0-31
ch32-63
ch64-95
ch96-127
ch128-159
ch160-191
ch192-223
ch224-255
bit 00
bit 01
bit 02
bit 03
bit 04
bit 05
bit 06
bit 07
bit 08
bit 09
bit 10
bit 11
bit 12
bit 13
bit 14
bit 15
bit 16
bit 17
bit 18
bit 19
bit 20
bit 21
bit 22
bit 23
bit 24
bit 25
bit 26
bit 27
bit 28
bit 29
bit 30
bit 31
bit 32
bit 33
bit 34
bit 35
bit 36
bit 37
bit 38
bit 39
bit 40
bit 41
bit 42
bit 43
bit 44
bit 45
bit 46
bit 47
bit 48
bit 49
bit 50
bit 51
bit 52
bit 53
bit 54
bit 55
bit 56
bit 57
bit 58
bit 59
bit 60
bit 61
bit 62
bit 63
0 2 4 6 8 10 12 14
bit error
27
24
21
18
15
12
9
6
3

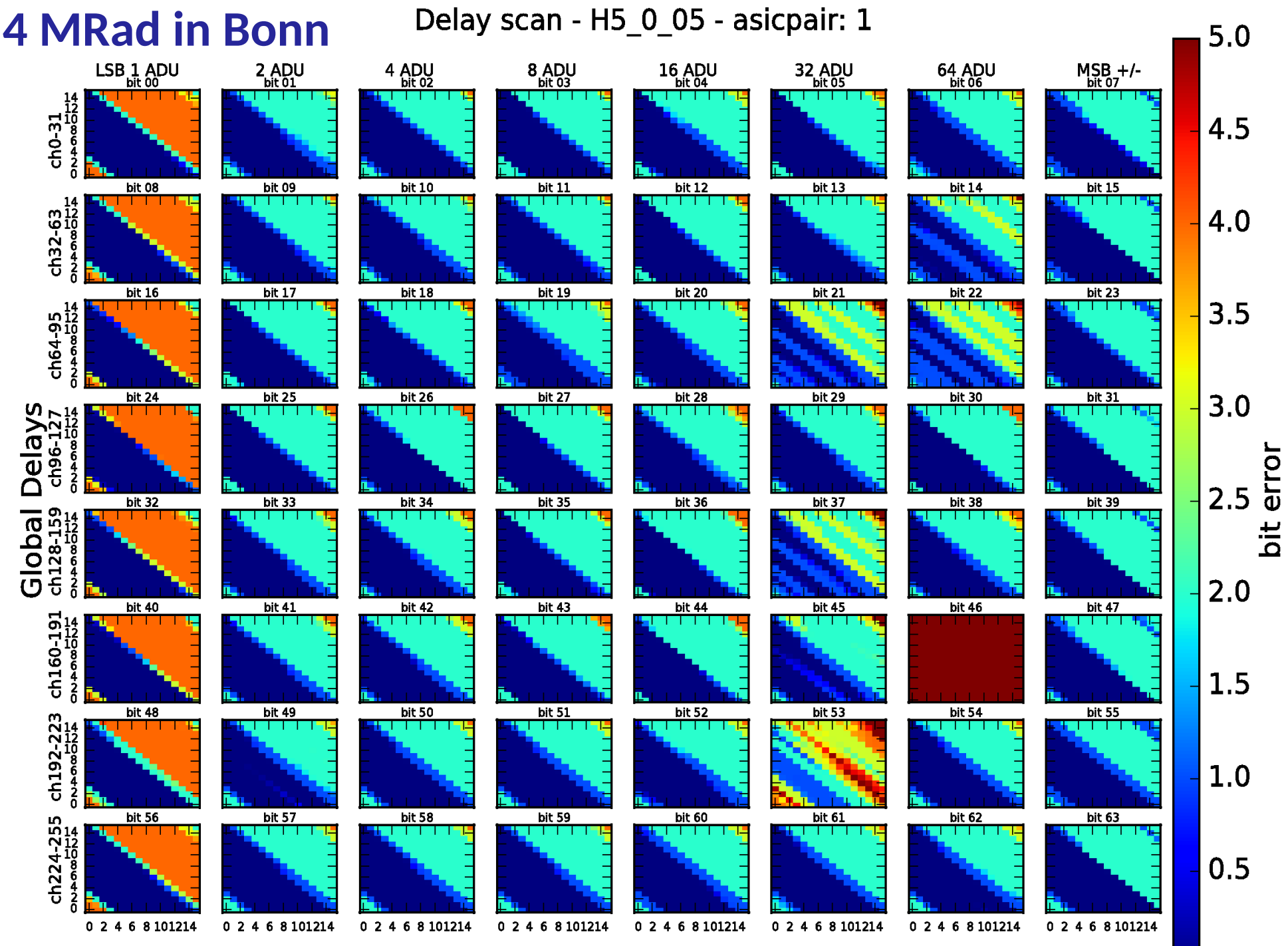
3 MRad


Delay scan - H5_0_05 - asicpair: 1
LSB 1 ADU
2 ADU
4 ADU
8 ADU
16 ADU
32 ADU
64 ADU
MSB +/-
Global Delays
ch0-31
ch32-63
ch64-95
ch96-127
ch128-159
ch160-191
ch192-223
ch224-255
bit 00
bit 01
bit 02
bit 03
bit 04
bit 05
bit 06
bit 07
bit 08
bit 09
bit 10
bit 11
bit 12
bit 13
bit 14
bit 15
bit 16
bit 17
bit 18
bit 19
bit 20
bit 21
bit 22
bit 23
bit 24
bit 25
bit 26
bit 27
bit 28
bit 29
bit 30
bit 31
bit 32
bit 33
bit 34
bit 35
bit 36
bit 37
bit 38
bit 39
bit 40
bit 41
bit 42
bit 43
bit 44
bit 45
bit 46
bit 47
bit 48
bit 49
bit 50
bit 51
bit 52
bit 53
bit 54
bit 55
bit 56
bit 57
bit 58
bit 59
bit 60
bit 61
bit 62
bit 63
0 2 4 6 8 10 12 14
bit error
27
24
21
18
15
12
9
6
3

4 MRad


Delay scan - H5_0_05 - asicpair: 1
LSB 1 ADU
2 ADU
4 ADU
8 ADU
16 ADU
32 ADU
64 ADU
MSB +/-
Global Delays
ch0-31
ch32-63
ch64-95
ch96-127
ch128-159
ch160-191
ch192-223
ch224-255
bit 00
bit 01
bit 02
bit 03
bit 04
bit 05
bit 06
bit 07
bit 08
bit 09
bit 10
bit 11
bit 12
bit 13
bit 14
bit 15
bit 16
bit 17
bit 18
bit 19
bit 20
bit 21
bit 22
bit 23
bit 24
bit 25
bit 26
bit 27
bit 28
bit 29
bit 30
bit 31
bit 32
bit 33
bit 34
bit 35
bit 36
bit 37
bit 38
bit 39
bit 40
bit 41
bit 42
bit 43
bit 44
bit 45
bit 46
bit 47
bit 48
bit 49
bit 50
bit 51
bit 52
bit 53
bit 54
bit 55
bit 56
bit 57
bit 58
bit 59
bit 60
bit 61
bit 62
bit 63
0 2 4 6 8 10 12 14
bit error
27
24
21
18
15
12
9
6
3

4 MRad in Bonn



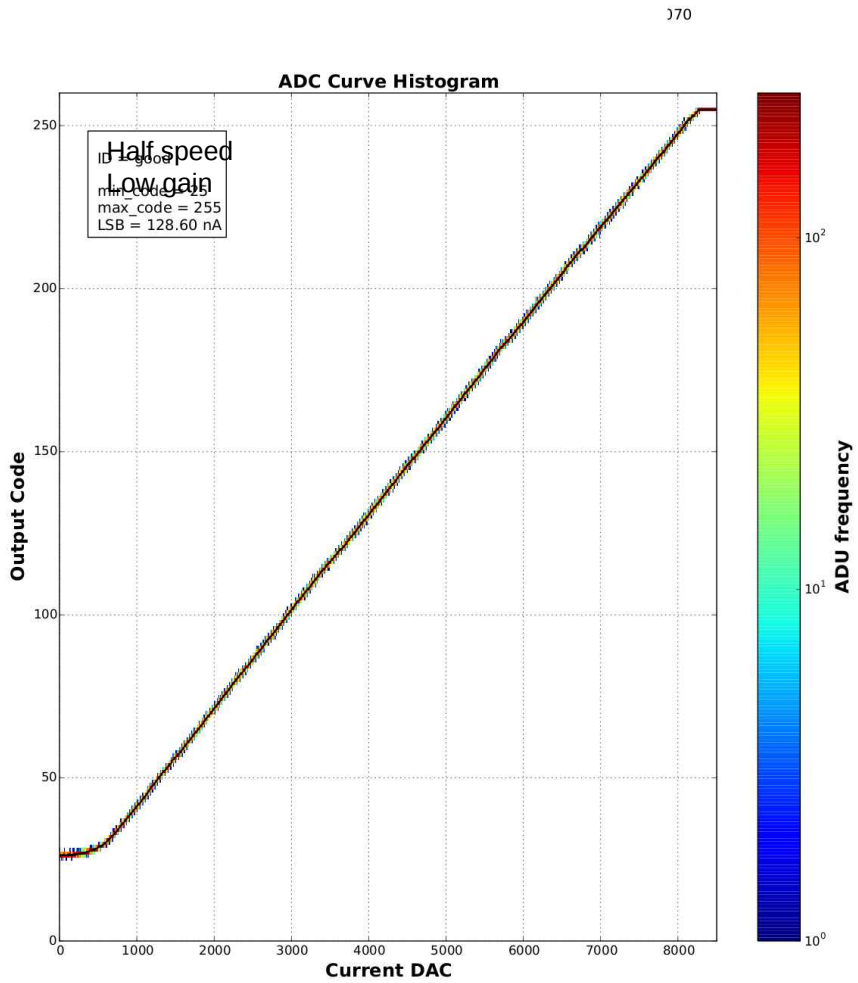
DCD optimization

DCD optimization

DCD is the part of the electronics directly connected to the matrix.
It is responsible for digitizing the signal current generated in the matrix.

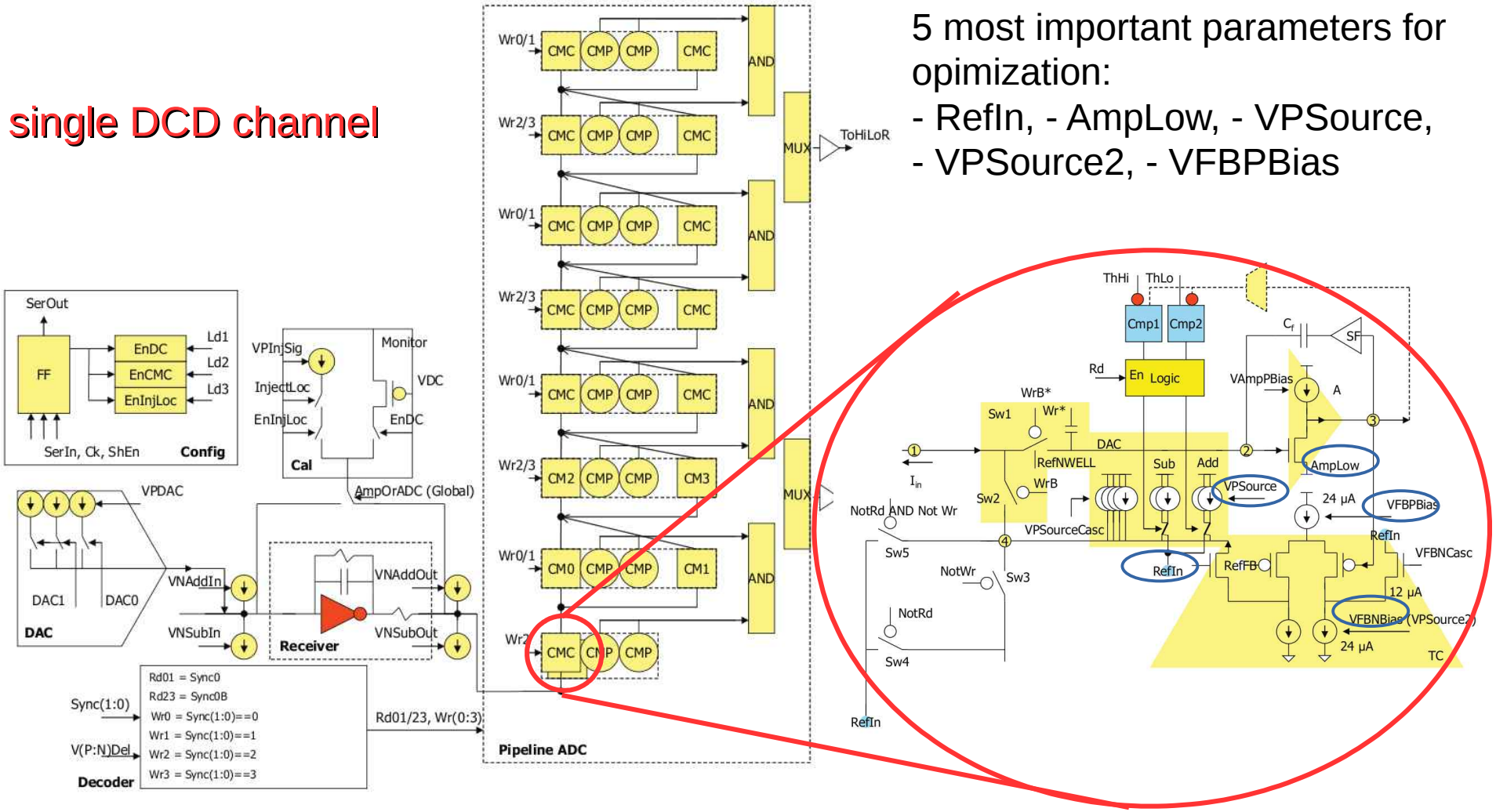
Optimize DCD for:

- range of curve
- linearity
- missing codes/bit errors
- noise



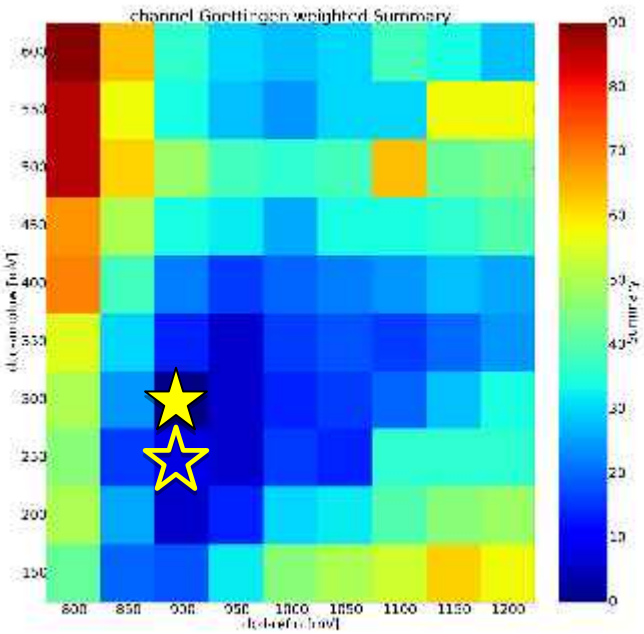
DCD and its parameters

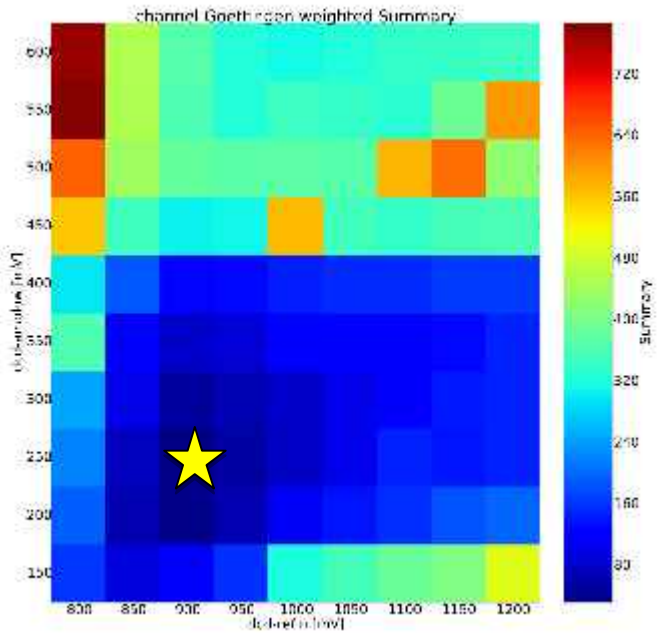
single DCD channel

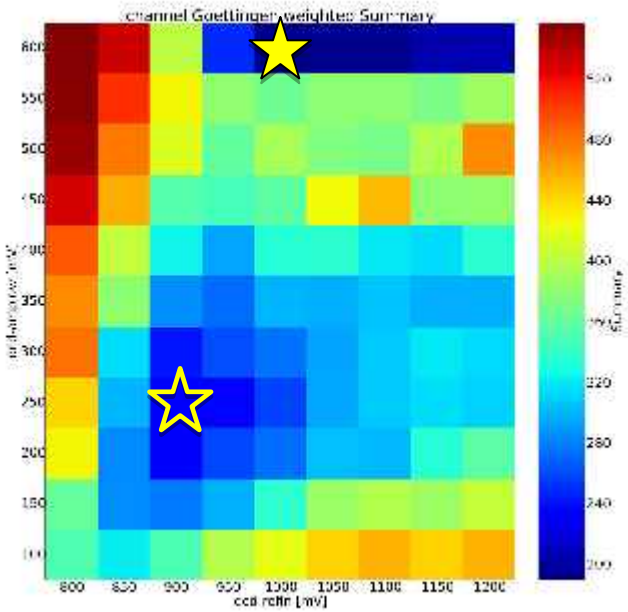


5 most important parameters for opimization:
- RefIn, - AmpLow, - VPSource,
- VPSource2, - VFBPBias

DCD optimal working point







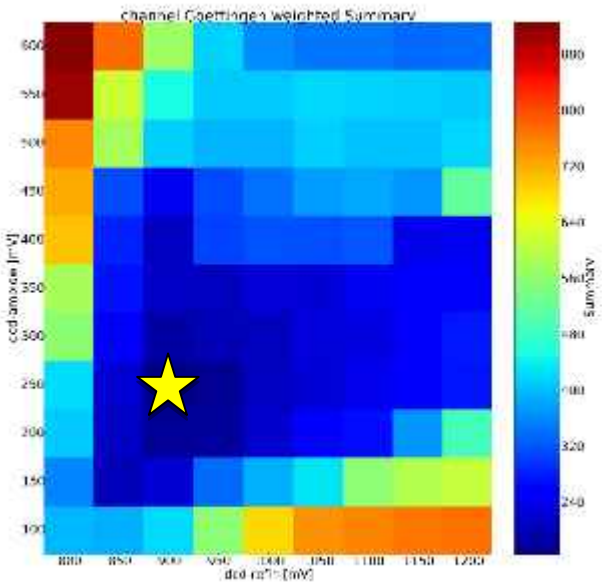
Unirradiated
Optimal:
AmpLow = 300 mV
RefIn = 900 mV

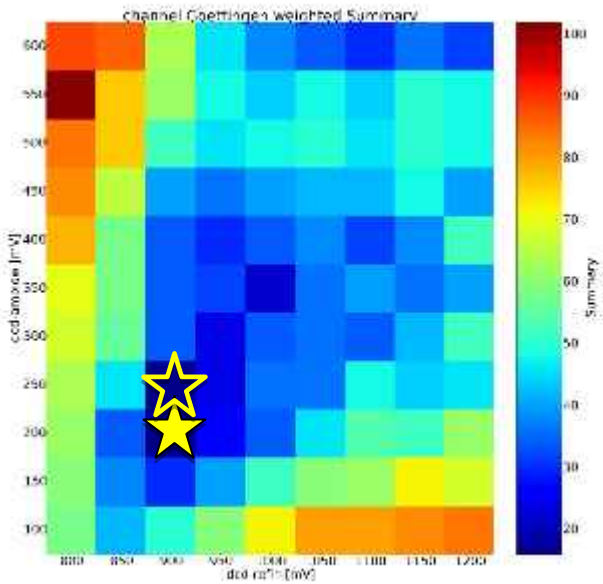
1000 kRad
Optimal:
AmpLow = 250 mV
RefIn = 900 mV

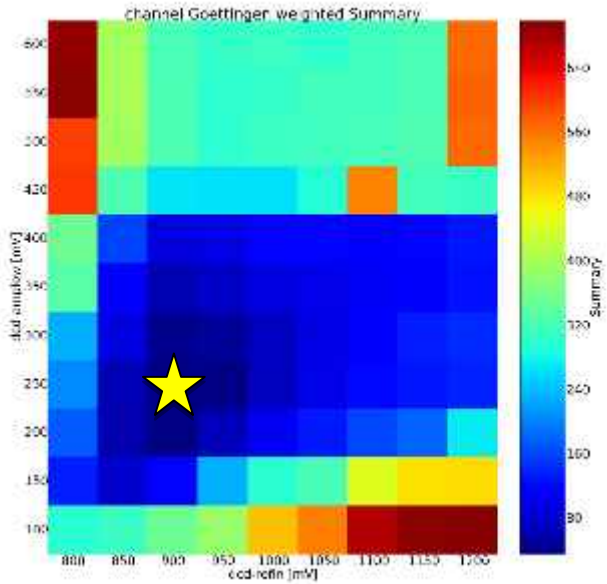
2000 kRad
Optimal:
AmpLow = 600 mV
RefIn = 1000 mV
(determined by program)

AmpLow – RefIn scan

DCD optimal working point







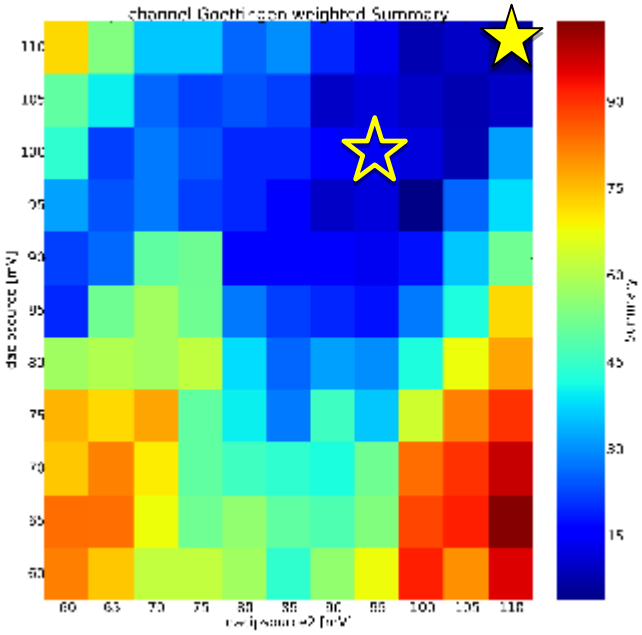
3000 kRad
Optimal:
AmpLow = 250 mV
RefIn = 900 mV

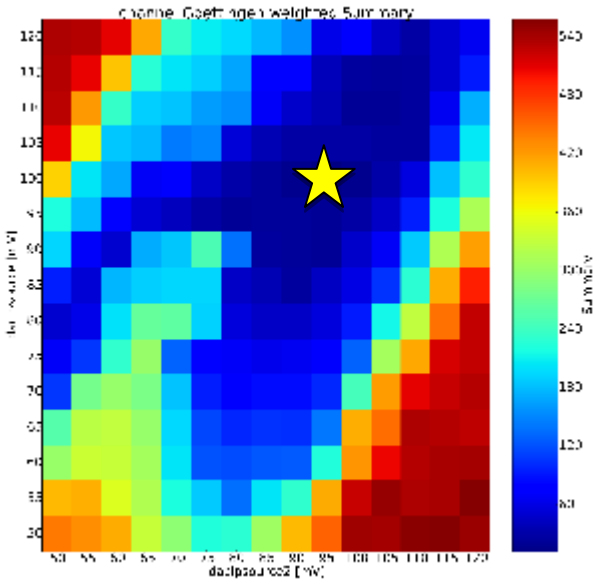
4000 kRad
Optimal:
AmpLow = 200 mV
RefIn = 900 mV

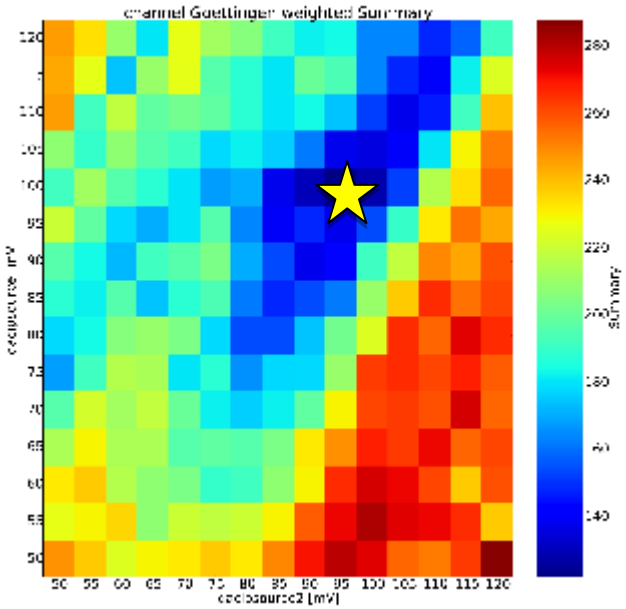
After irradiation back in Bonn
Optimal:
AmpLow = 250 mV
RefIn = 900 mV
(determined by program)

AmpLow – RefIn scan

DCD optimal working point







Unirradiated
Optimal:
Ipsource = 110 mV
Ipsource 2 = 110 mV

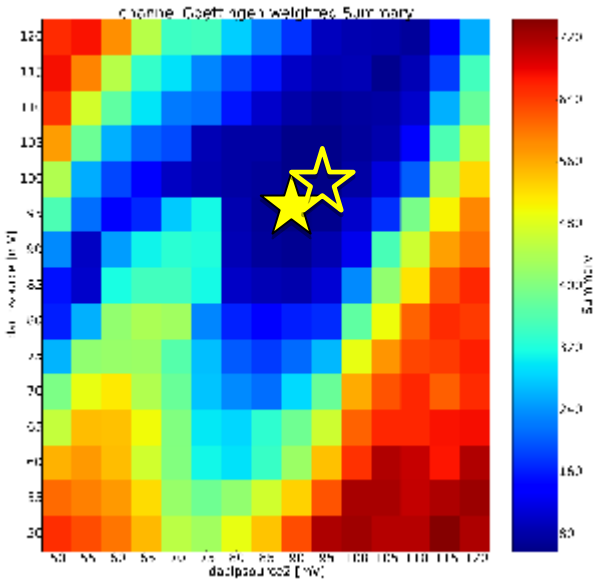
1000 kRad
Optimal:
Ipsource = 100 mV
Ipsource 2 = 95 mV

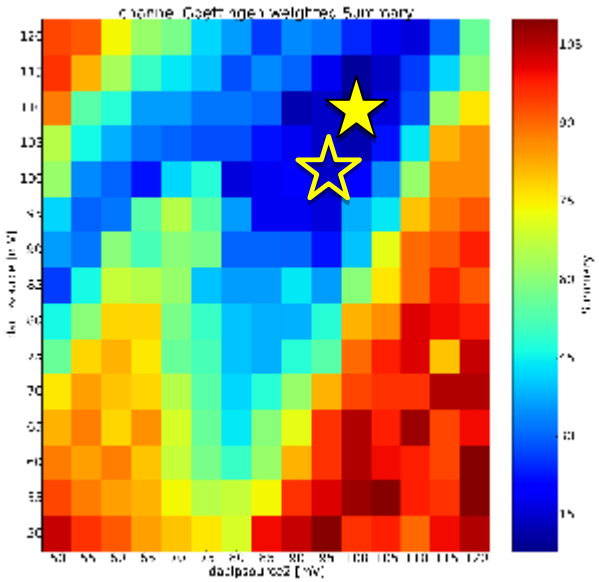
2000 kRad
Optimal:
Ipsource = 100 mV
Ipsource 2 = 95 mV

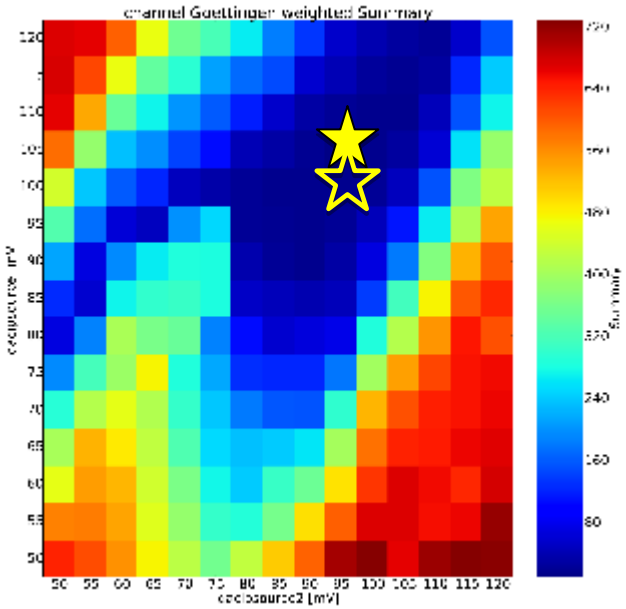
Ipsources scan

Scans done with different number of channels some use 12 channels some use 87.

DCD optimal working point







3000 kRad
Optimal:
Ipsource = 95 mV
Ipsource 2 = 90 mV

4000 kRad
Optimal:
Ipsource = 110 mV
Ipsource 2 = 100 mV

After irradiation
Optimal:
Ipsource = 105 mV
Ipsource 2 = 95 mV

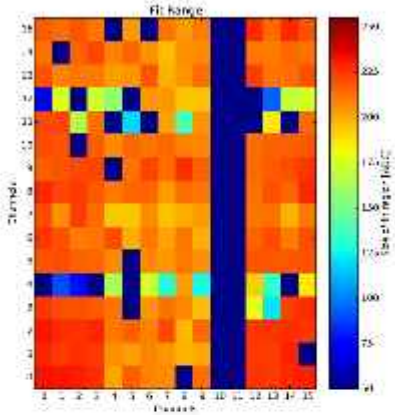
Ipsources scan

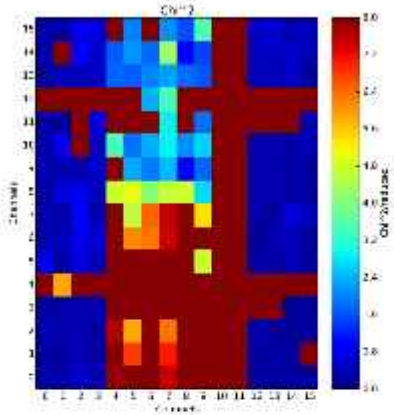
Scans done with different number of channels some use 12 channels some use 87.

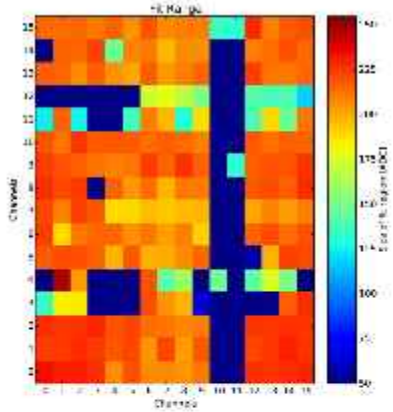
DCD channel map

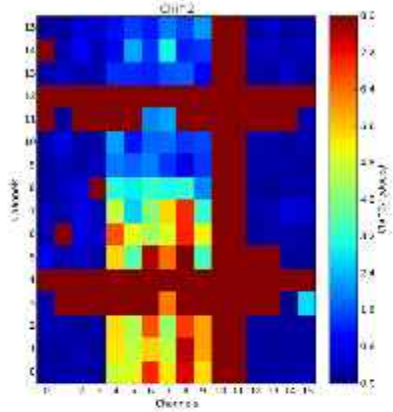
250 kRad

1250 kRad

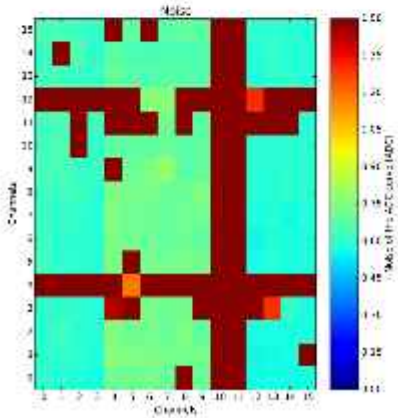


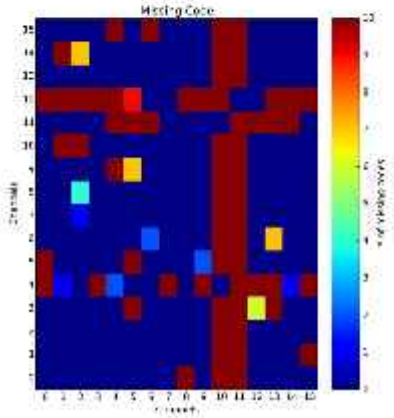


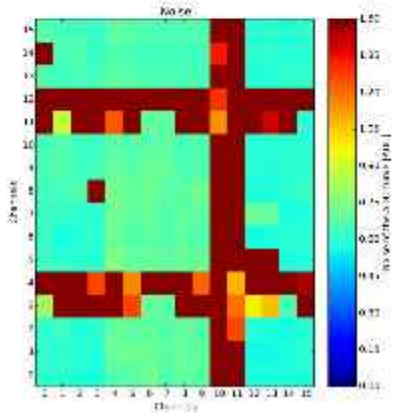


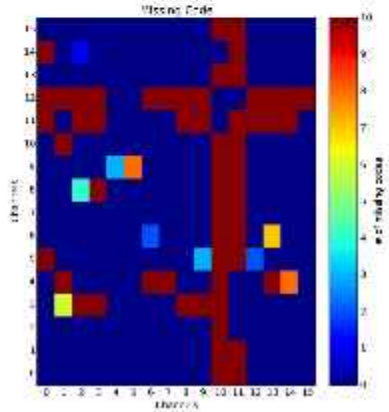


Range









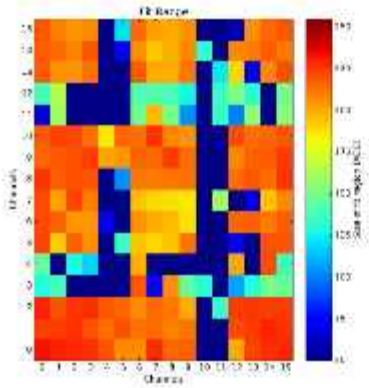
Noise

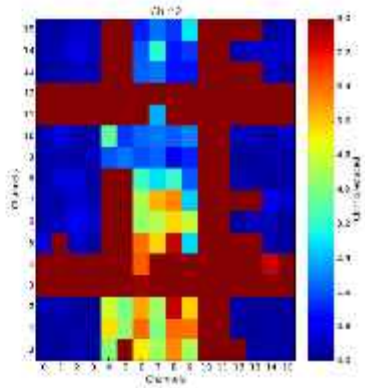
Missing code

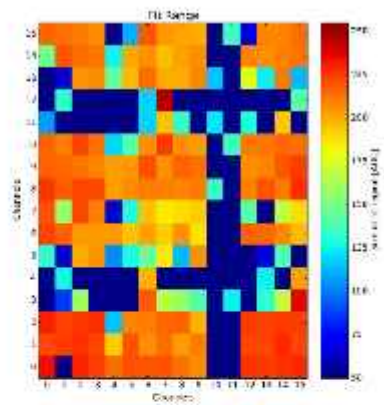
DCD channel map

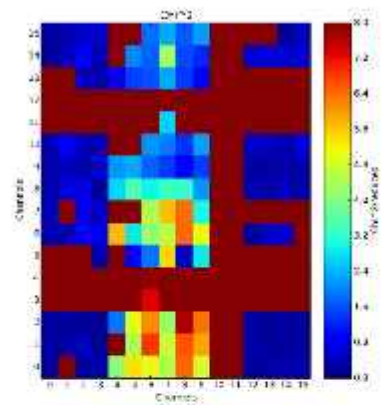
2250 kRad

3000 kRad

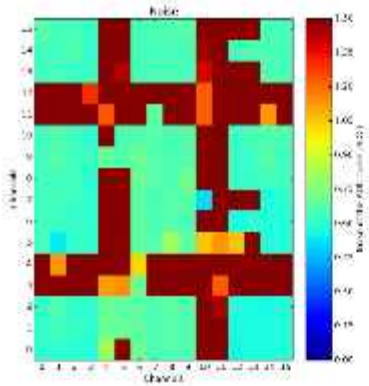


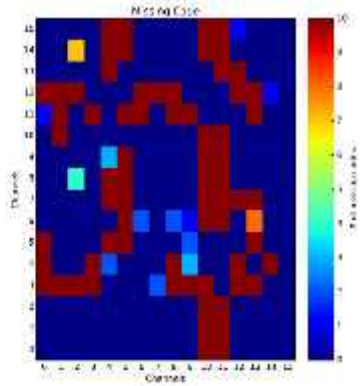


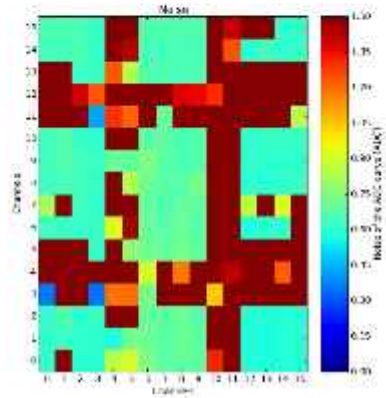


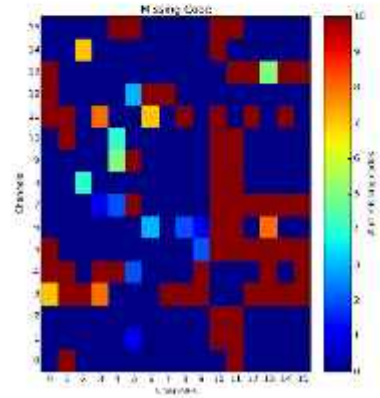


Range







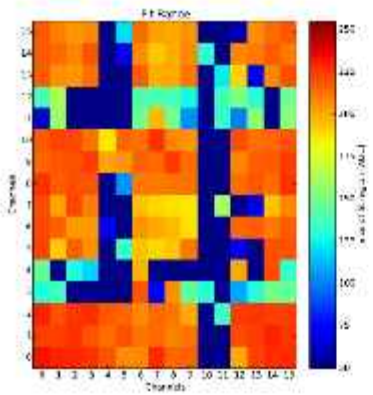


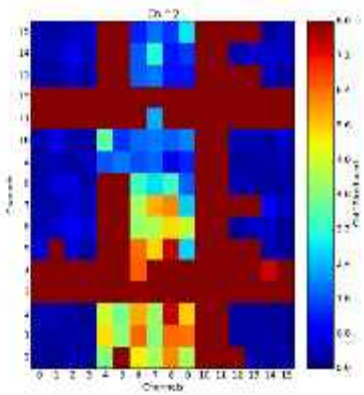
Noise

Missing code

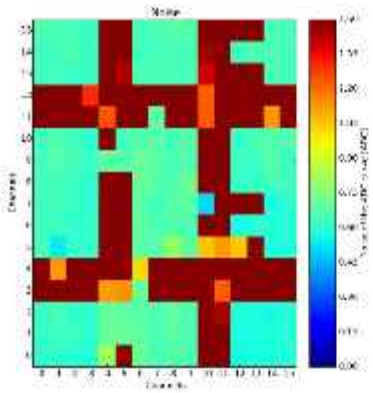
DCD channel map

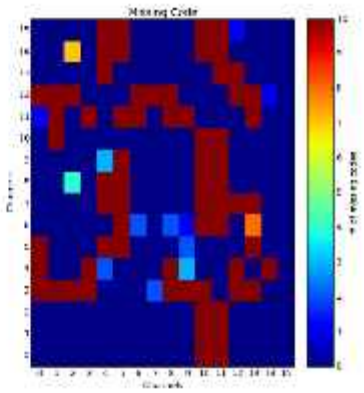
4000 kRad





Range

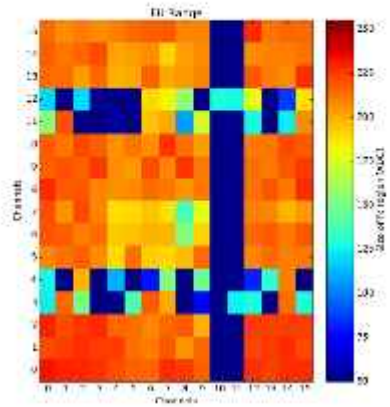


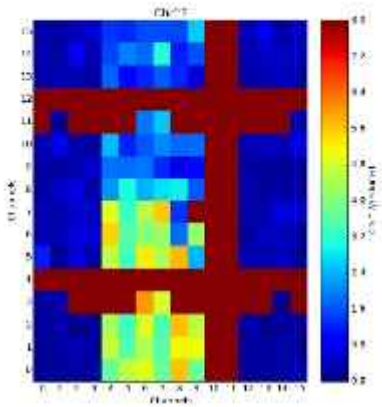


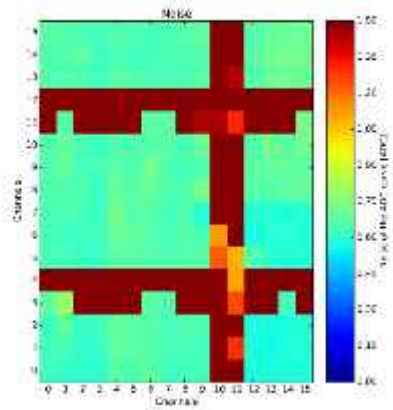
Noise

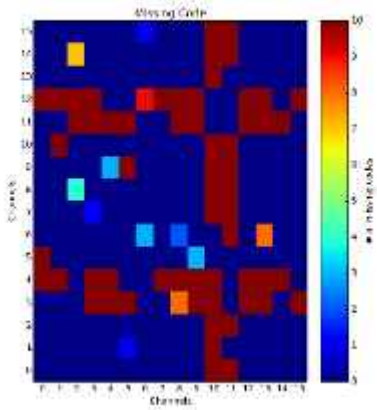
Missing code

Back in Bonn



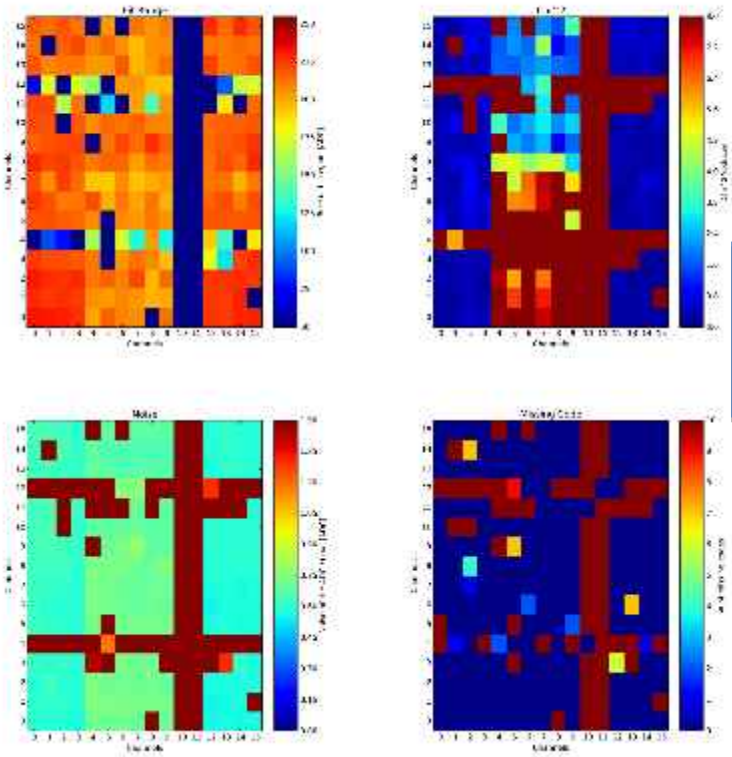






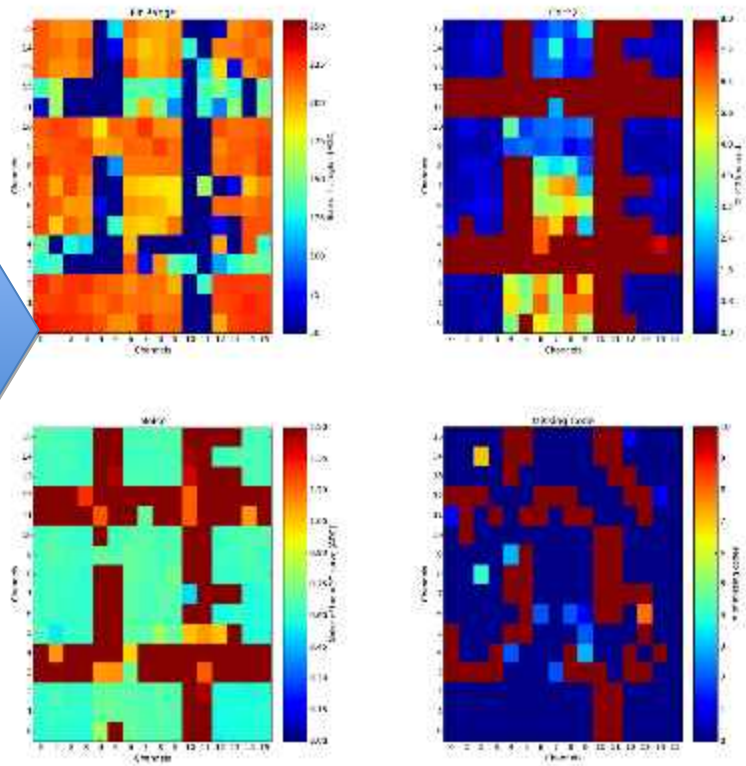
DCD channel map

250 kRad

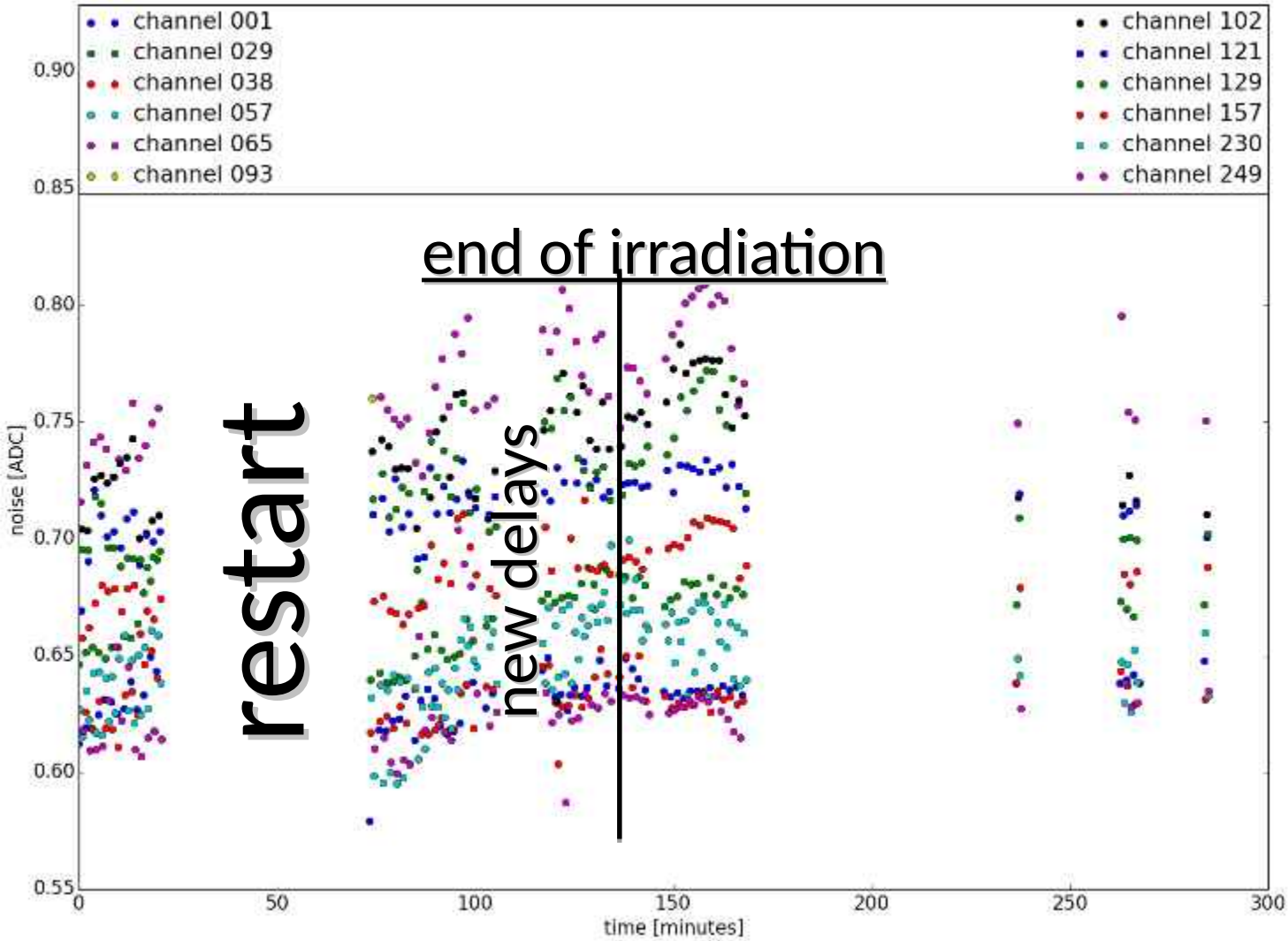


Data transmission of double column stops working

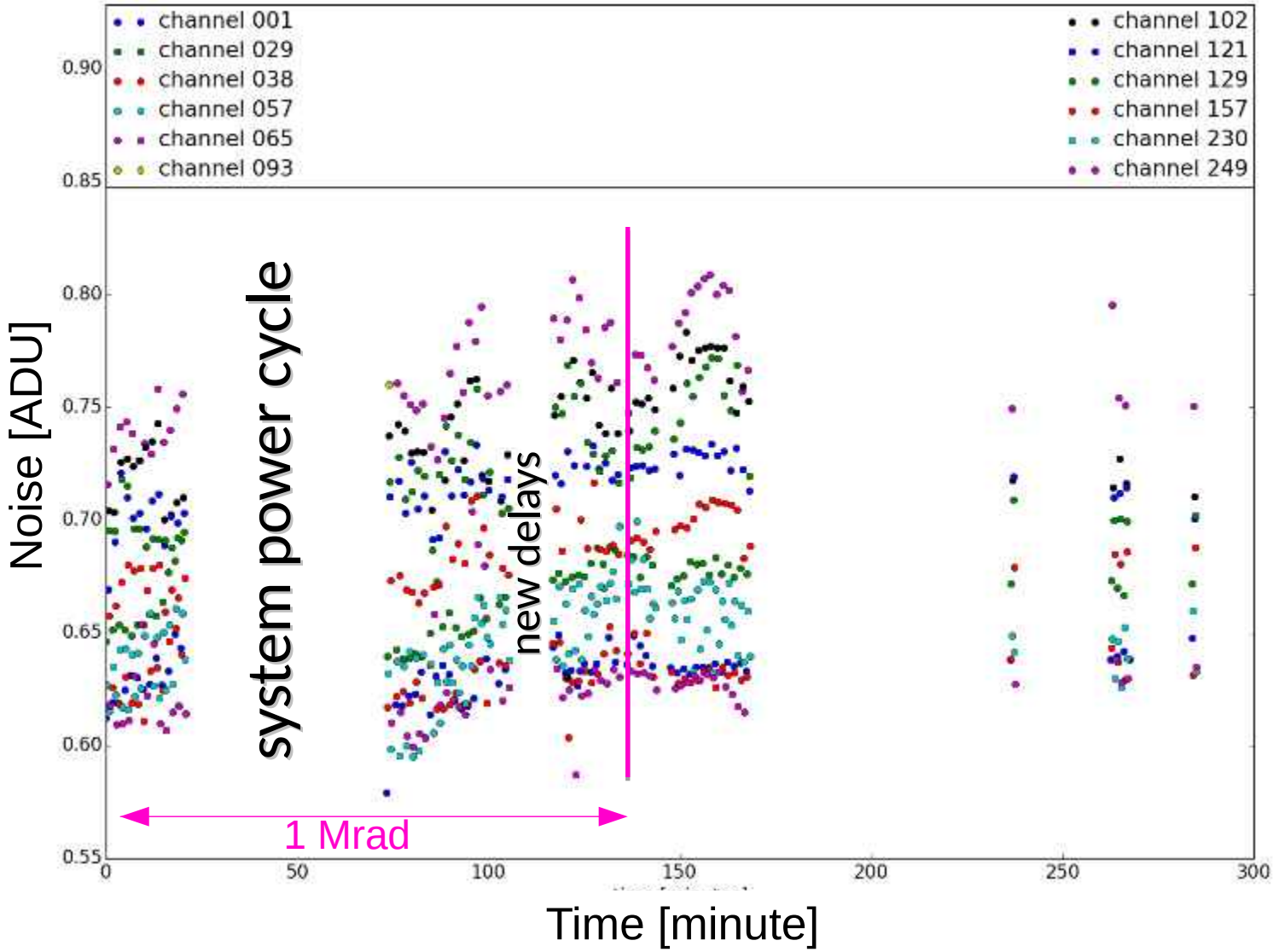
4000 kRad



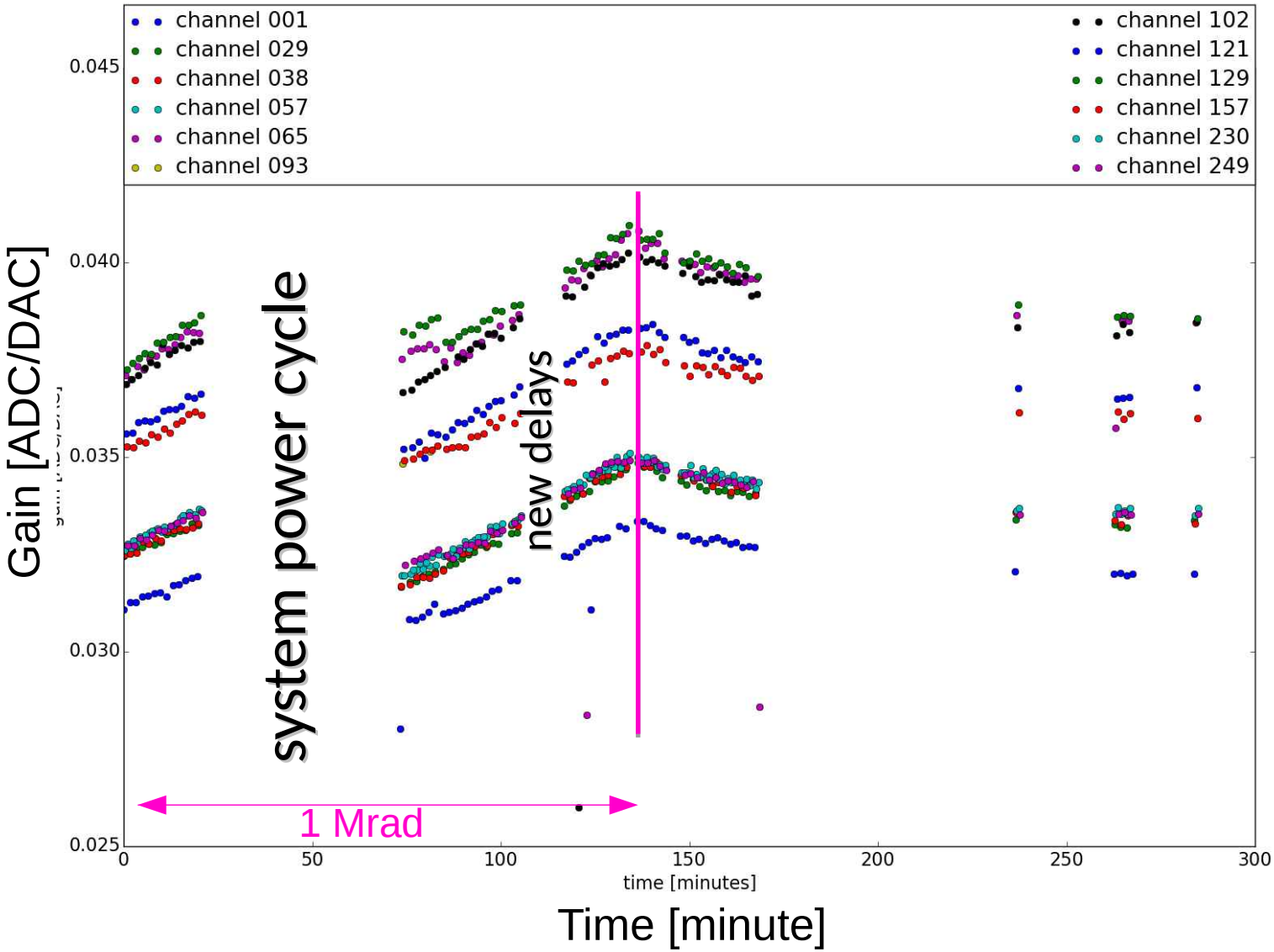
Continuous measurement



Continous measurement during 1 MRad step



Continous measurement during 1 MRad step



Summary

- First characterization of small PXD9 matrix with Strontium source and laser light at laboratory
  - Ring effect likely due to doping vatiations
  - Odd/even effect not understood
    → more detailed measurements necessary
  - Good working point could be found
    → lab tests with full matrix necessary
- Irradiation of DHPT1.1 and DCDB4pp with X-ray source
  - High speed links stable against radiation up to 4 Mrad
  - Optimal working point of DCD stable
  - Degradation of DCD <-> DHP data transmission (maybe bad asicpair)

Next steps

universitätbonn

Hybrid 5 remains major test vehicle for new components

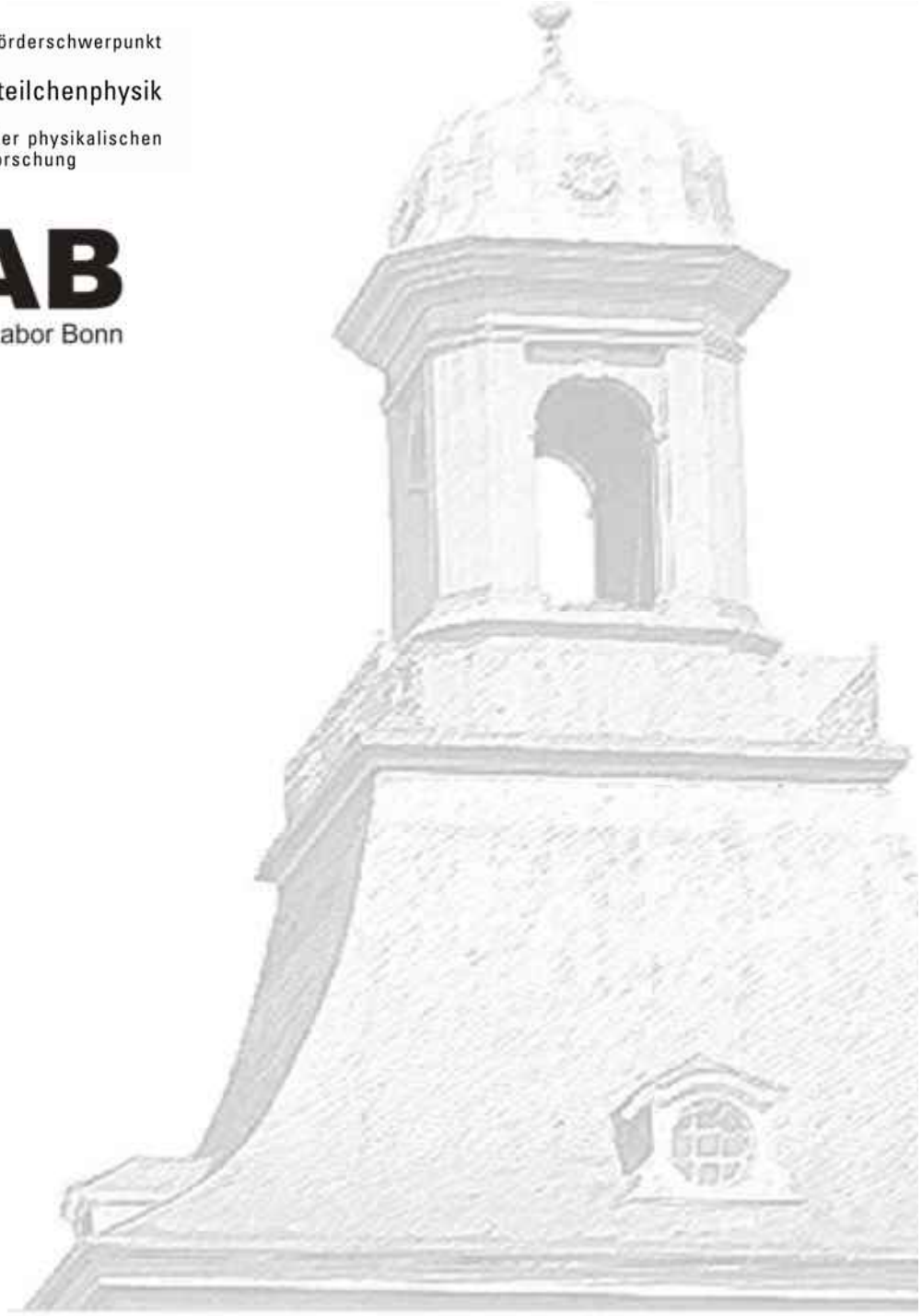
- Received 6 fresh Hybrid 5 boards in Seeon
  - Populated with SMD components at HLL
- Received 7 wirebond adapters with DCD4.1/2 + DHPT1.1 from HLL
  - Assembly onto 7 Hybrid 5 boards in bonn
  - Distributed characterization in Goettingen and Bonn
    - → urgently need new DHE software for new DCD JTAG handling
- As soon as hybrids work and bonded Switchers are available:
  - Add Switchers and small PXD9 matrices to some hybrids for more characterization
- Irradiation campaign? Parasitic test at future PXD exclusive beam test?

universitätbonn

bmb+f - Förderschwerpunkt
Elementarteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

SI LAB
Silizium Labor Bonn

Thank you



paschen@physik.uni-bonn.de