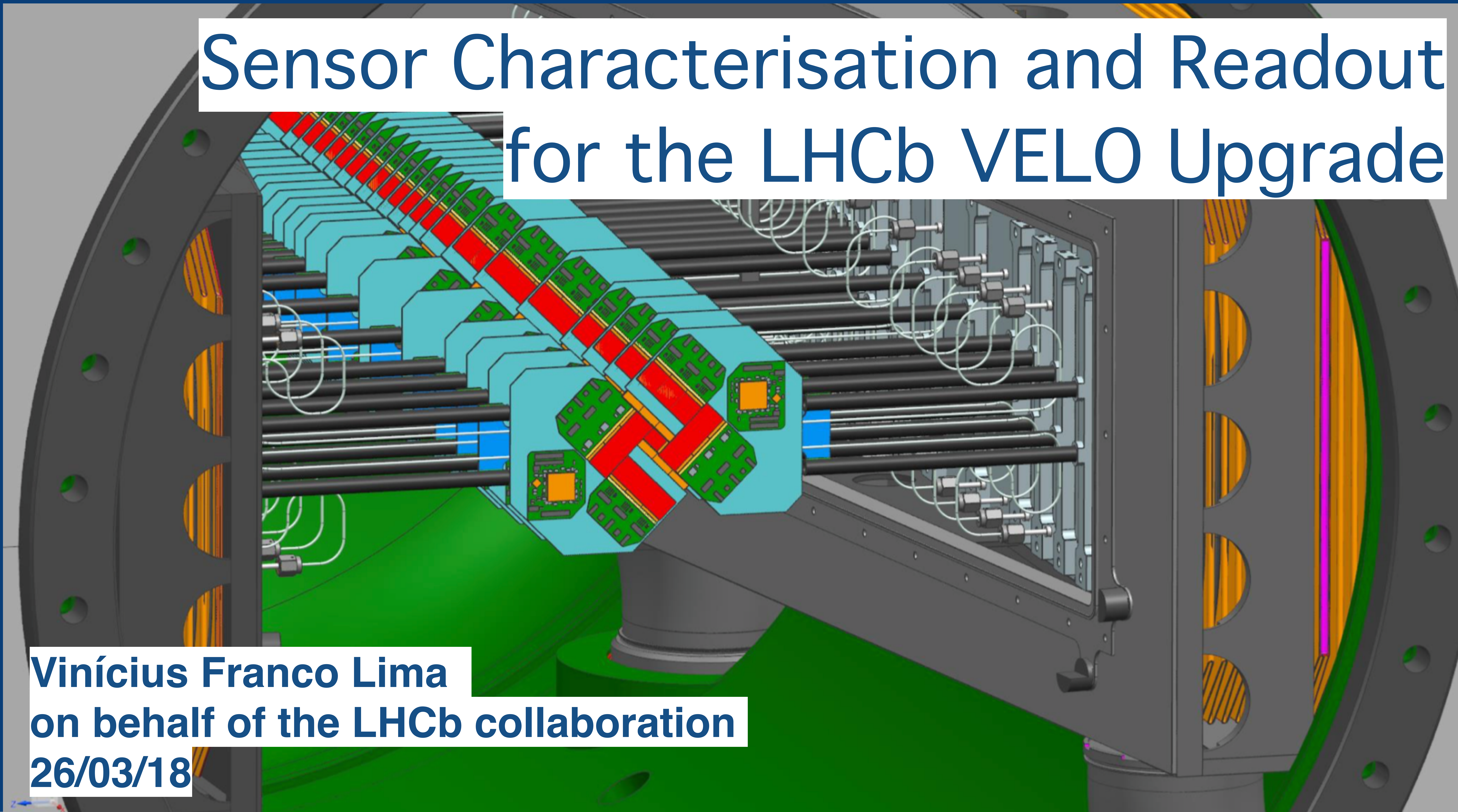
Sensor Characterisation and Readout for the LHCb VELO Upgrade



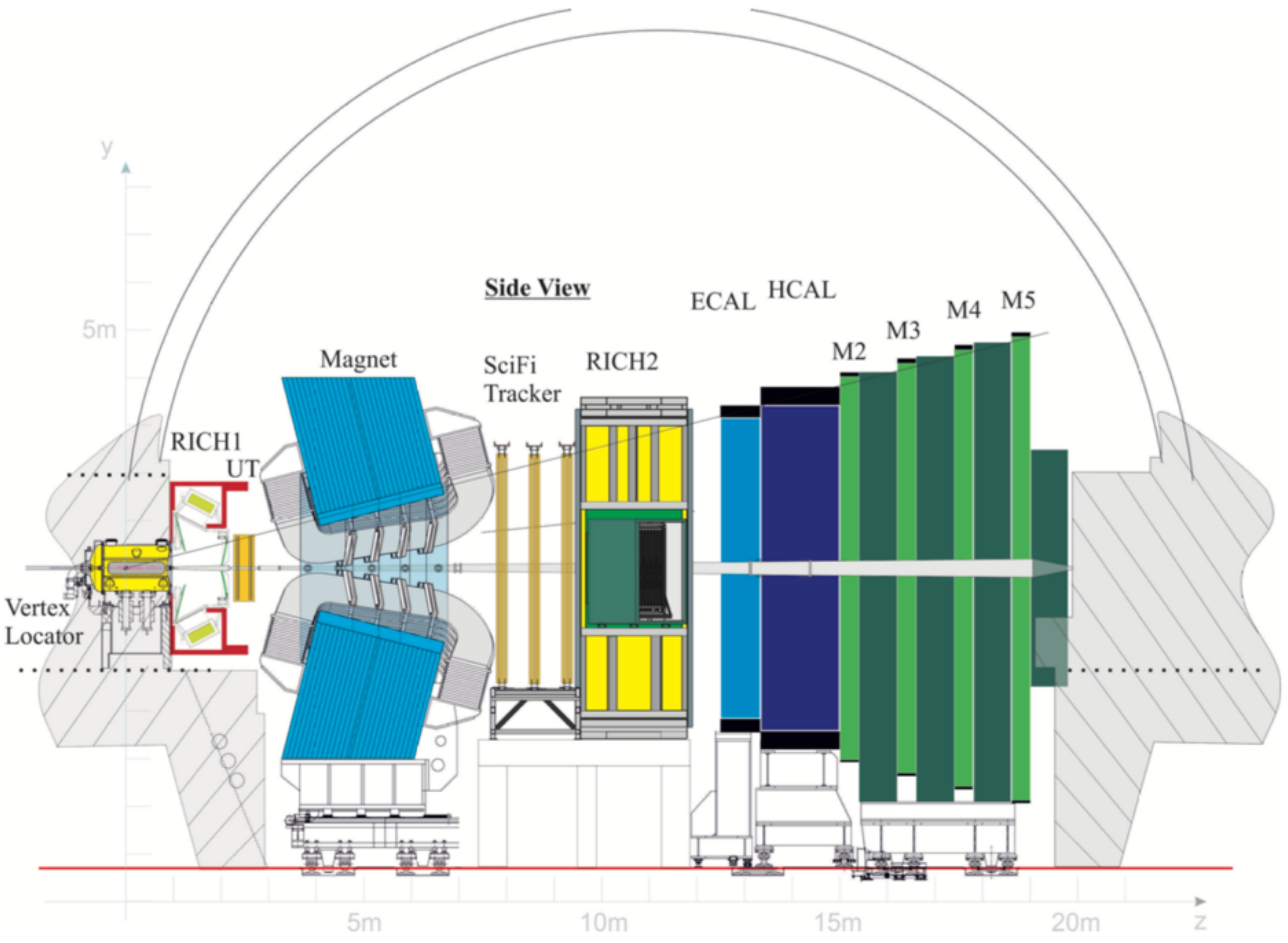
Vinícius Franco Lima
on behalf of the LHCb collaboration
26/03/18

The LHCb Upgrade

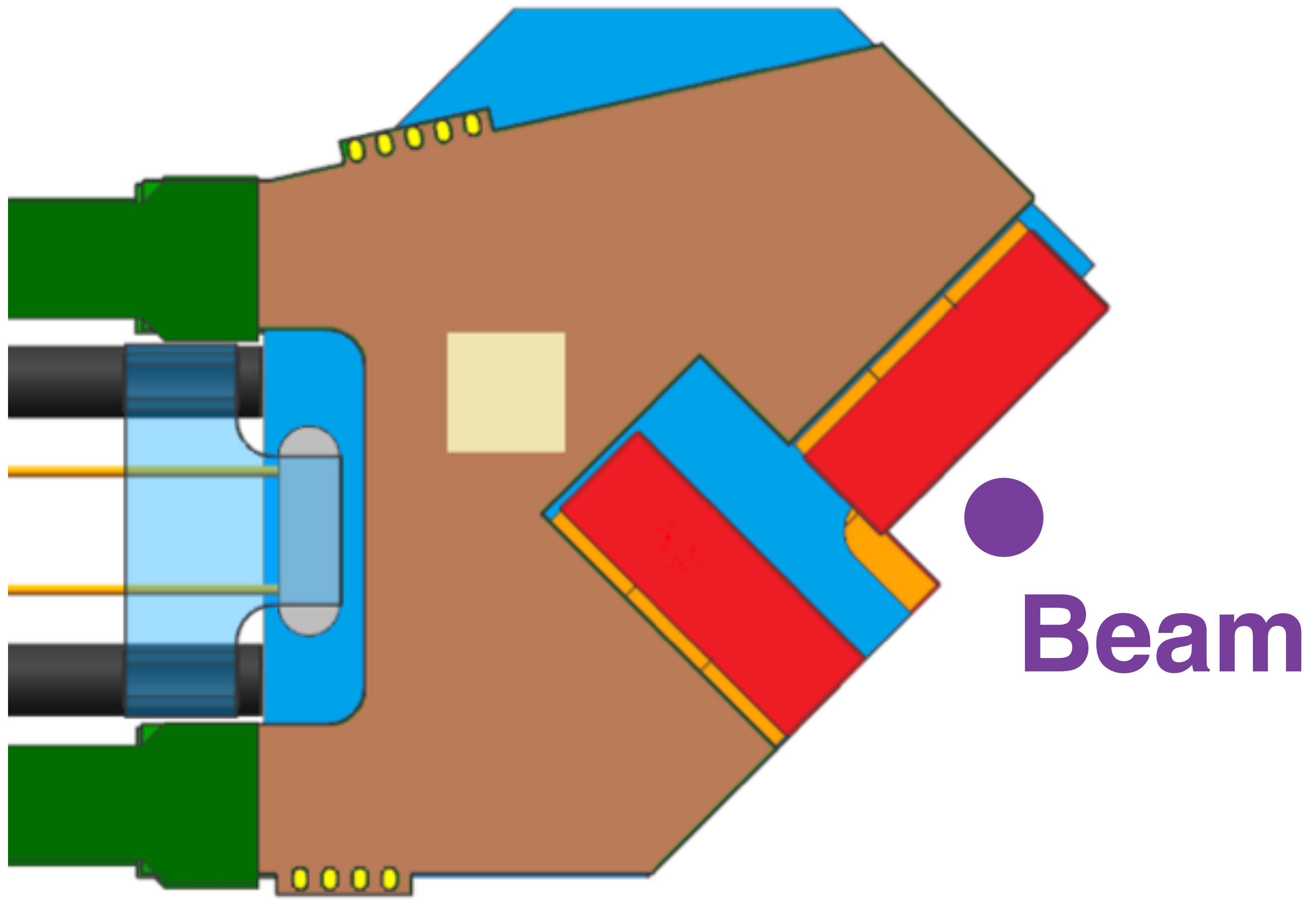
Full 40 MHz readout, Luminosity 5x Higher.

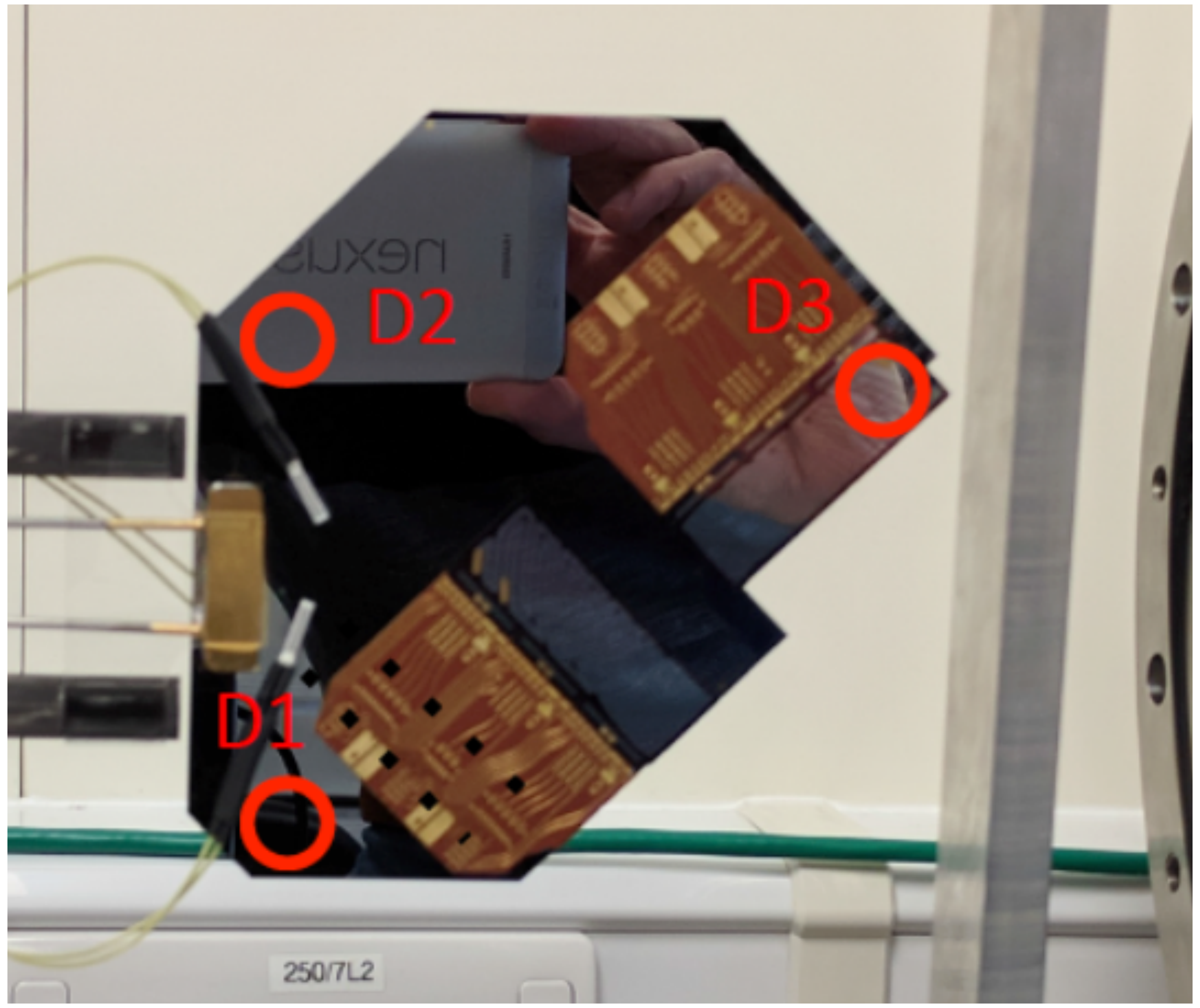
Remove hardware trigger completely, use software trigger for all events.

Change several subdetctors for new readout scheme, including VELO



VELO Moves to Production





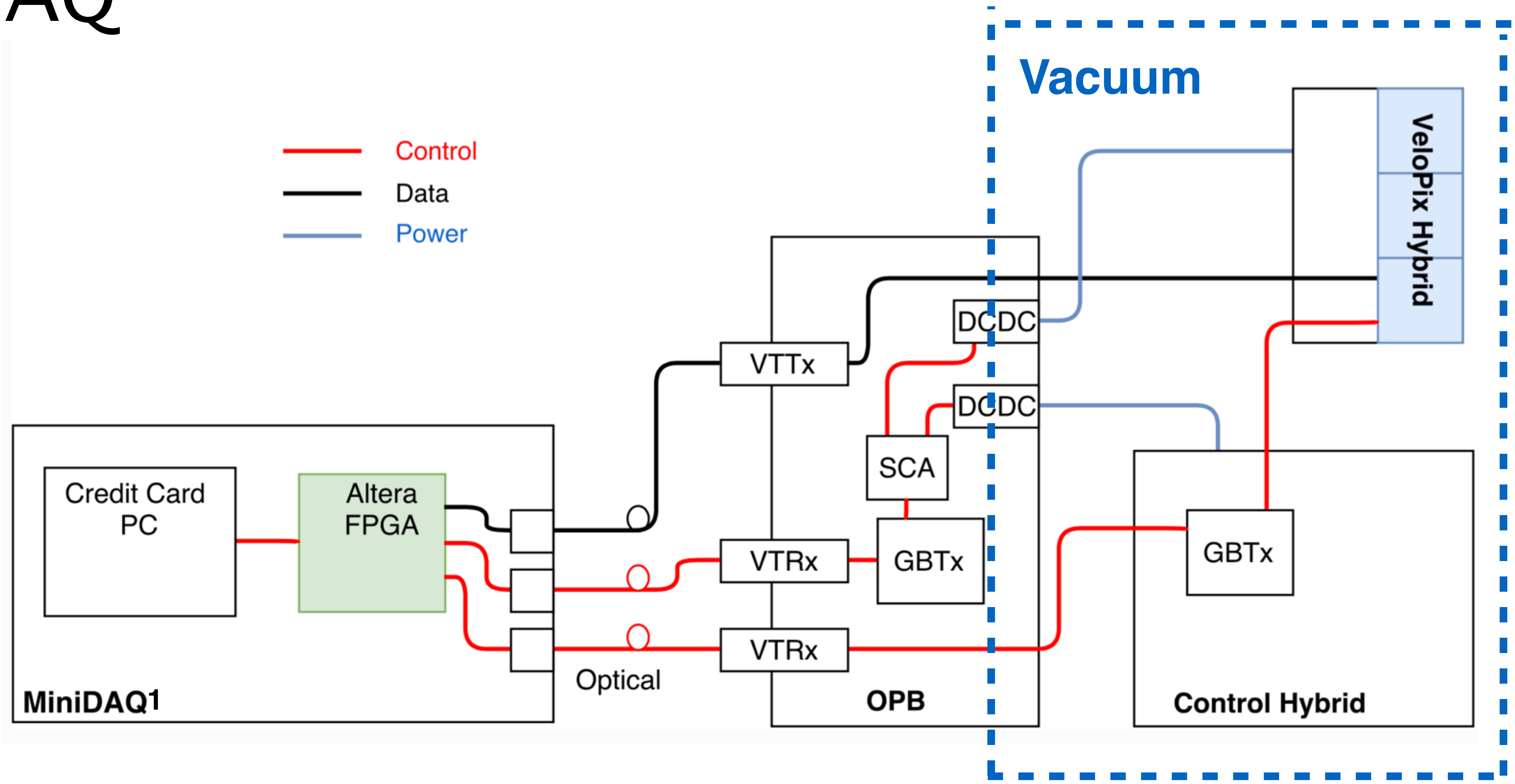
Data Bandwidth of 20 Gbit/s for central ASICS.

Microchannel CO_2 cooling, sensor temperature <-20°C

Develop assembly and tests for production environment.

Distance to the interaction region : 5.1 mm

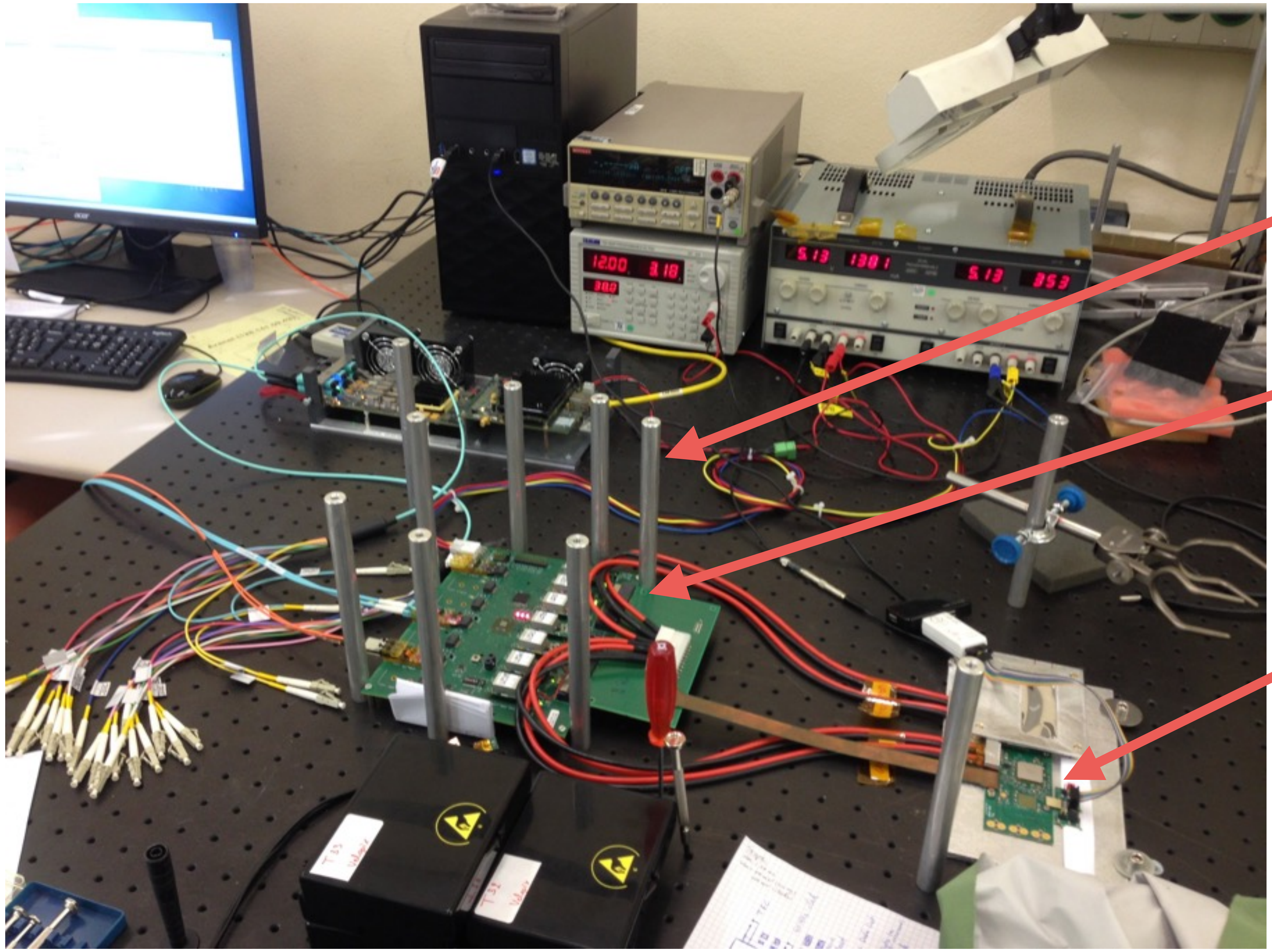
DAQ

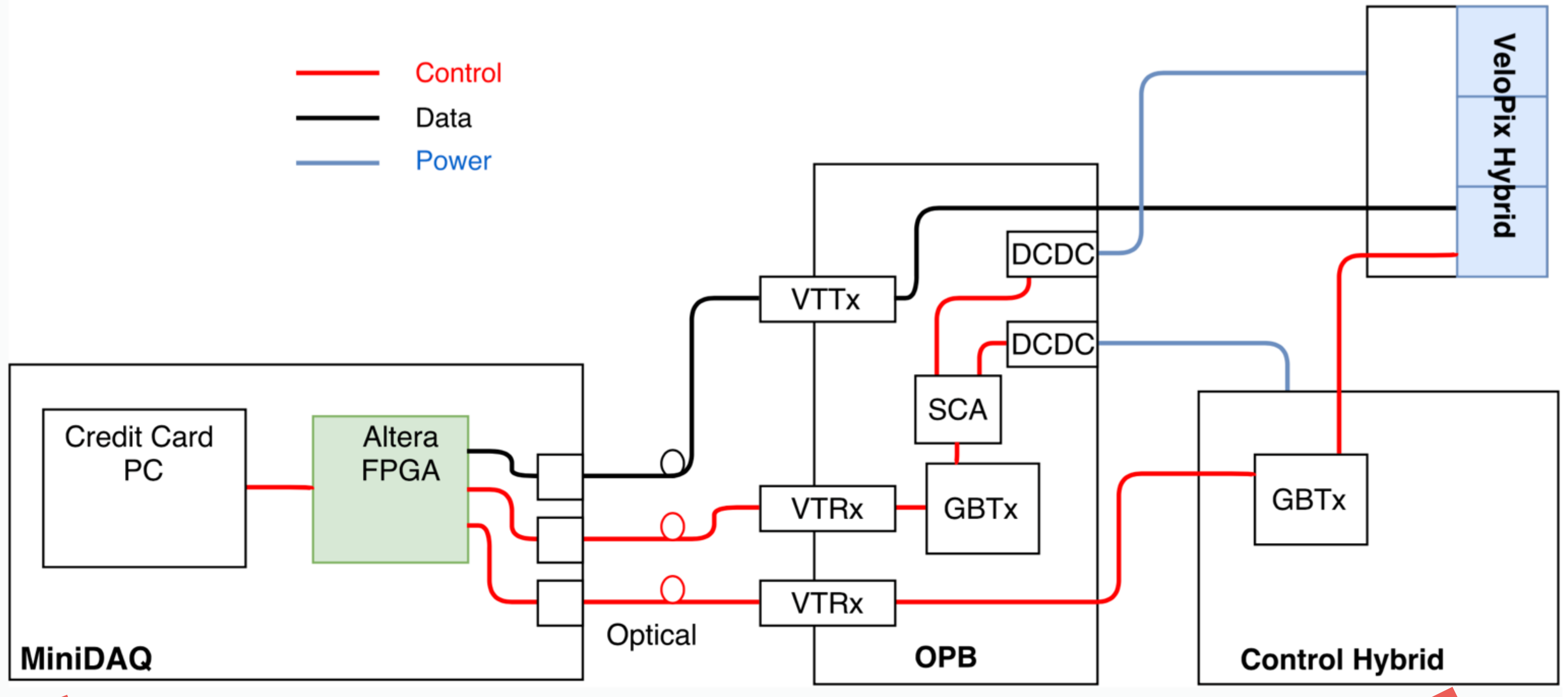


Vacuum
Control
Data
Power
VeloPix Hybrid
DCDC
DCDC
VTTx
SCA
Credit Card PC
Altera FPGA
VTRx
GBTx
VTRx
GBTx
Optical
MiniDAQ1
OPB
Control Hybrid

DAQ

VeloPix hybrids being tested using MiniDAQ.



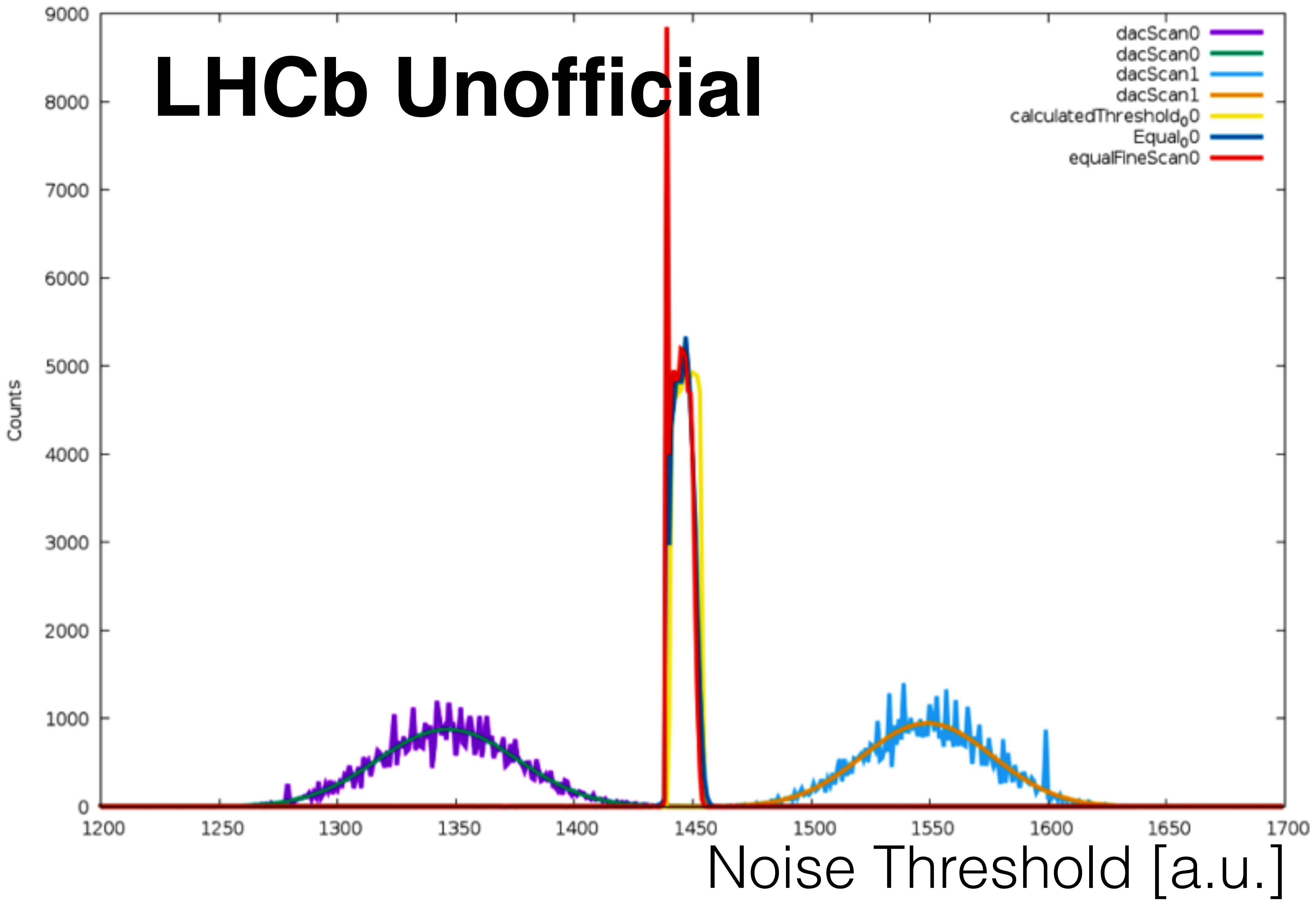


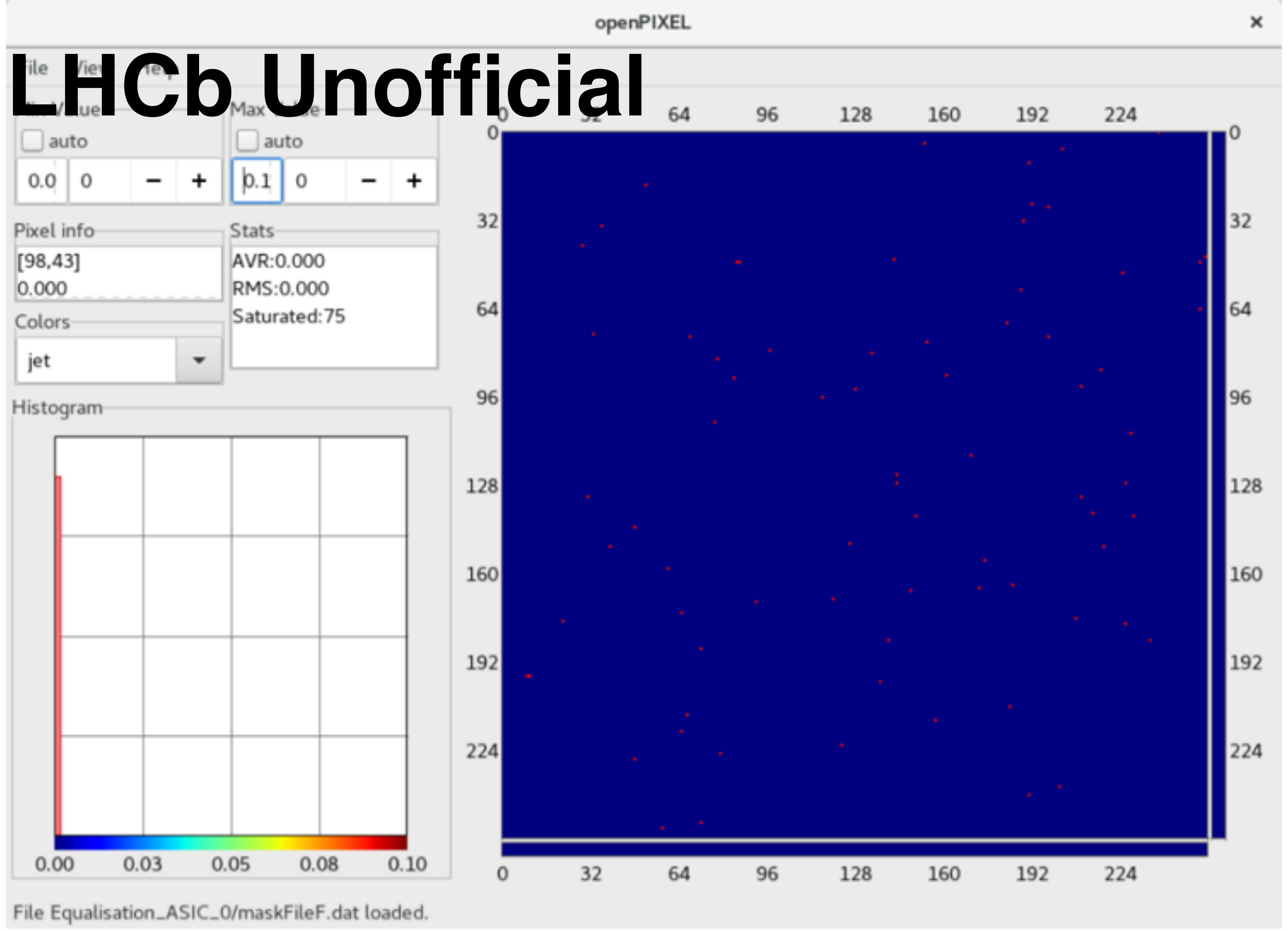
Firmware integrated pre-existing software, most necessary procedures already in place.

Test scripts and communication with VeloPix will be migrated to WinCC

VeloPix Hybrid

Equalisation Example using one of pre-production modules.



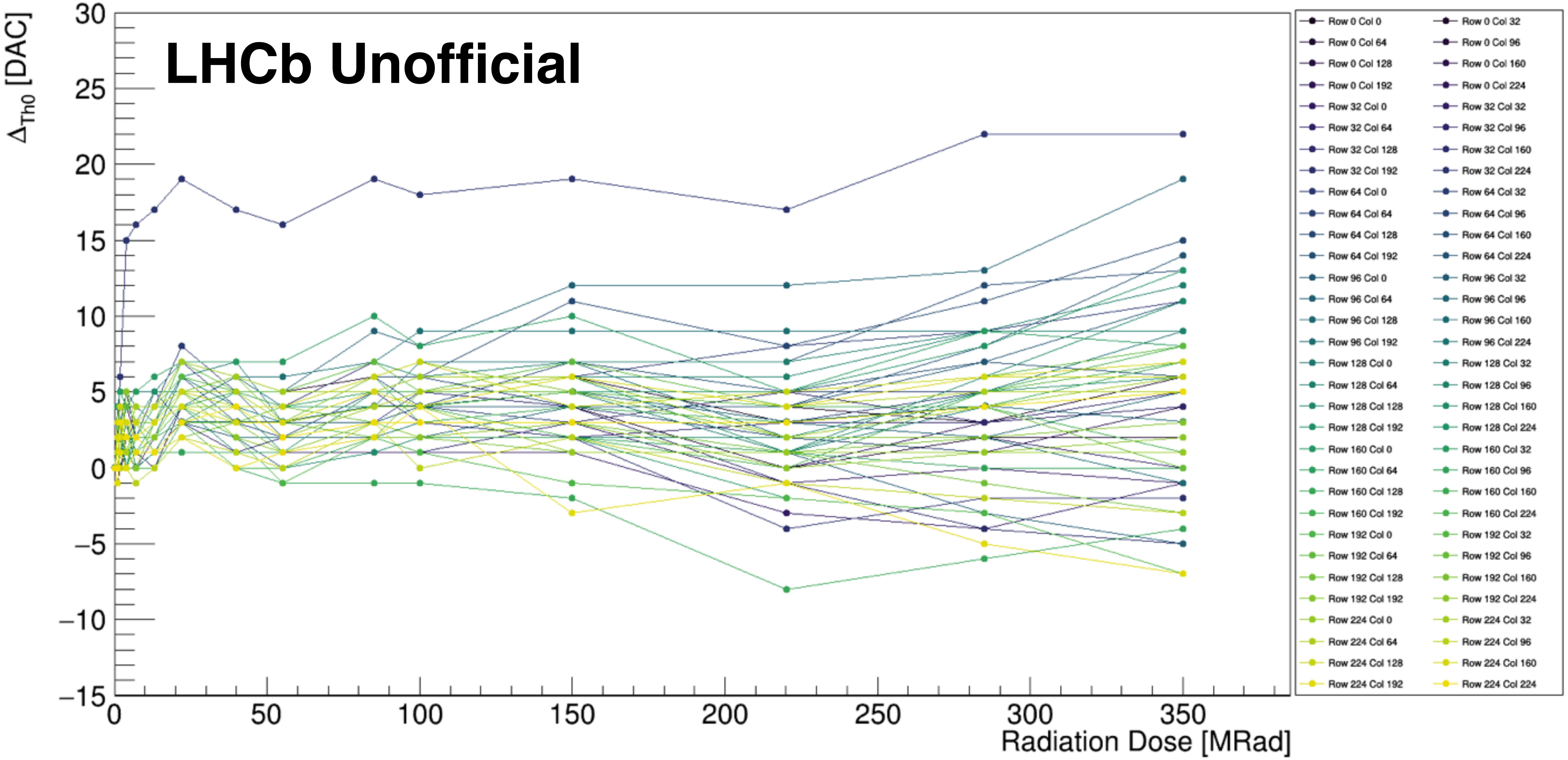


Equalisation procedure works well!
1000e- Threshold gets rid of noise

Pixels that are masked by equalisation still under study.

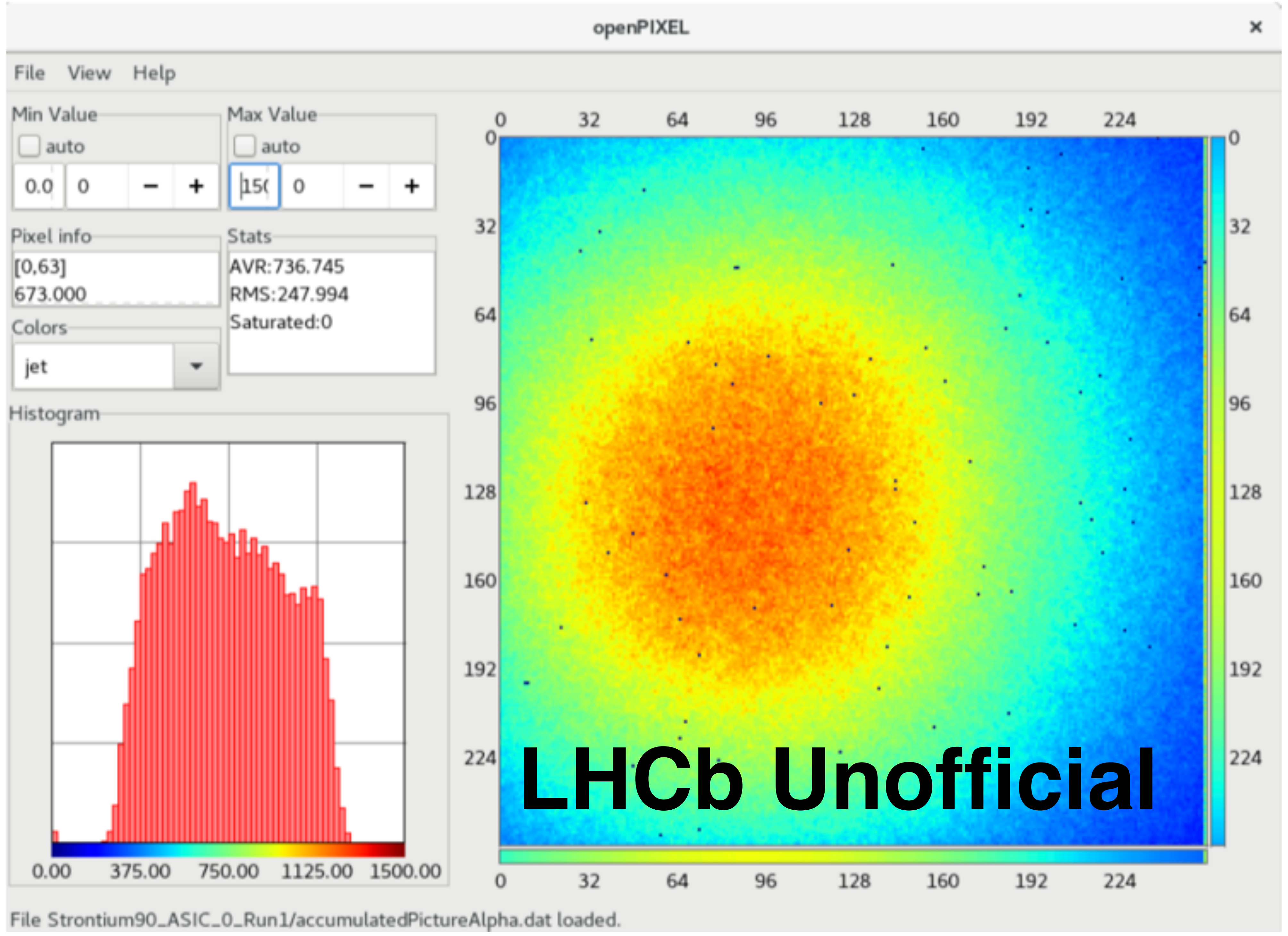
VeloPix Threshold x Dose

Does The VeloPix becomes more noisy with radiation dose?



VeloPix Hybrid Source Measurements

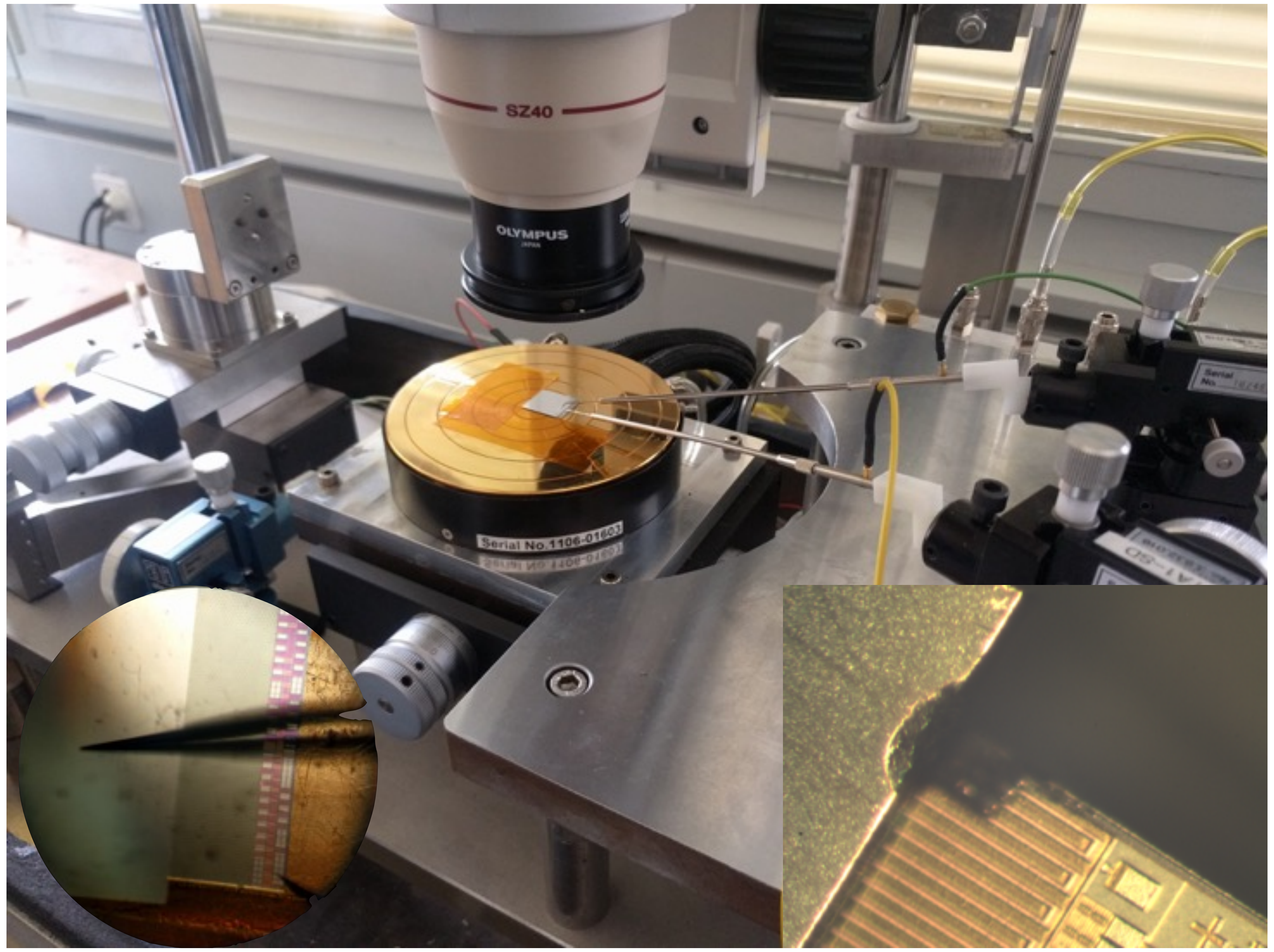
PPH = Pre-Production Hybrids

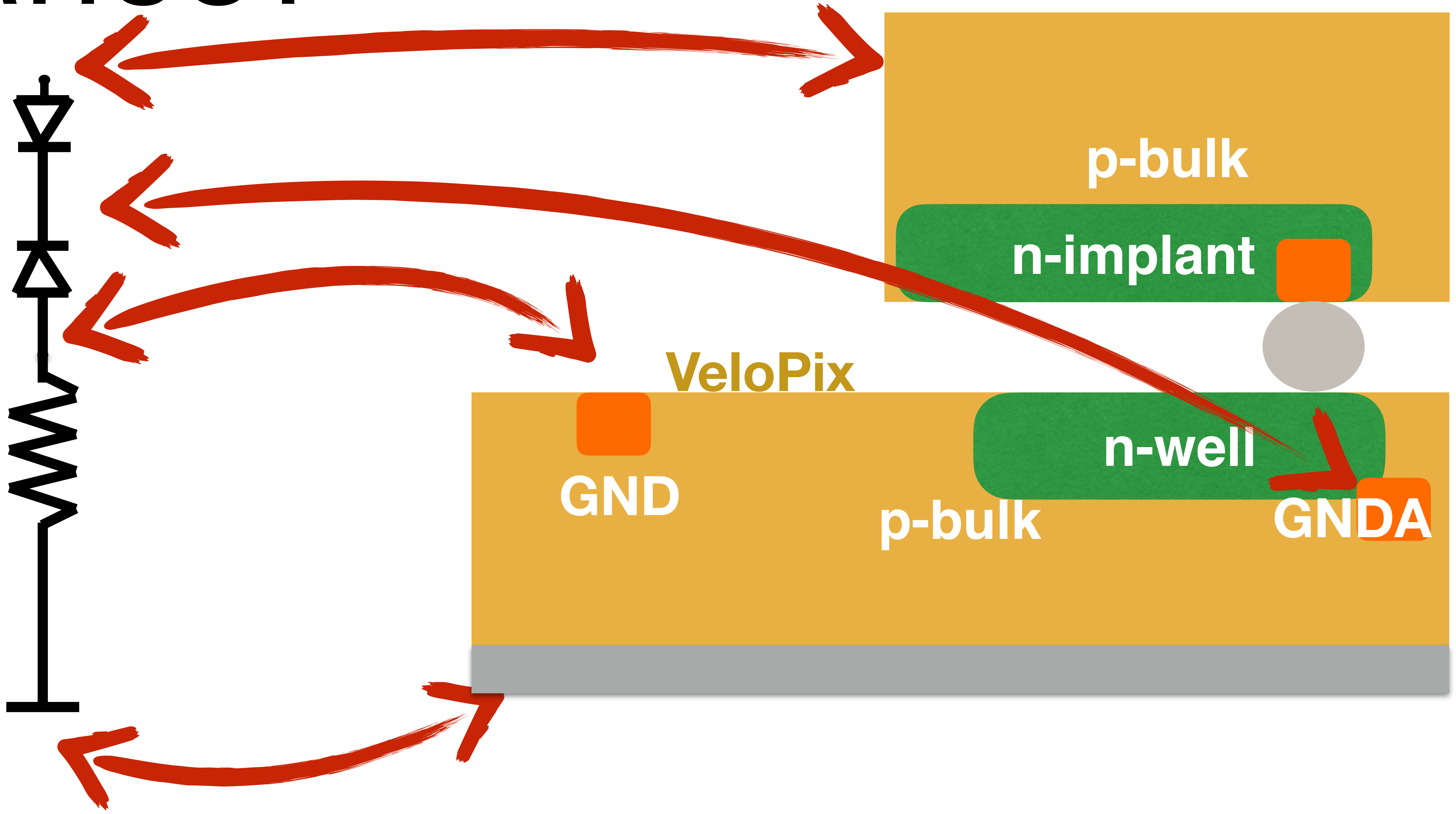


	Number of no response pixels on each ASIC		
PPH 31	47	177	355
PPH 32	44	52	285
PPH 33	54	57	52
PPH 34	75	49	53
PPH 35	72	78	79

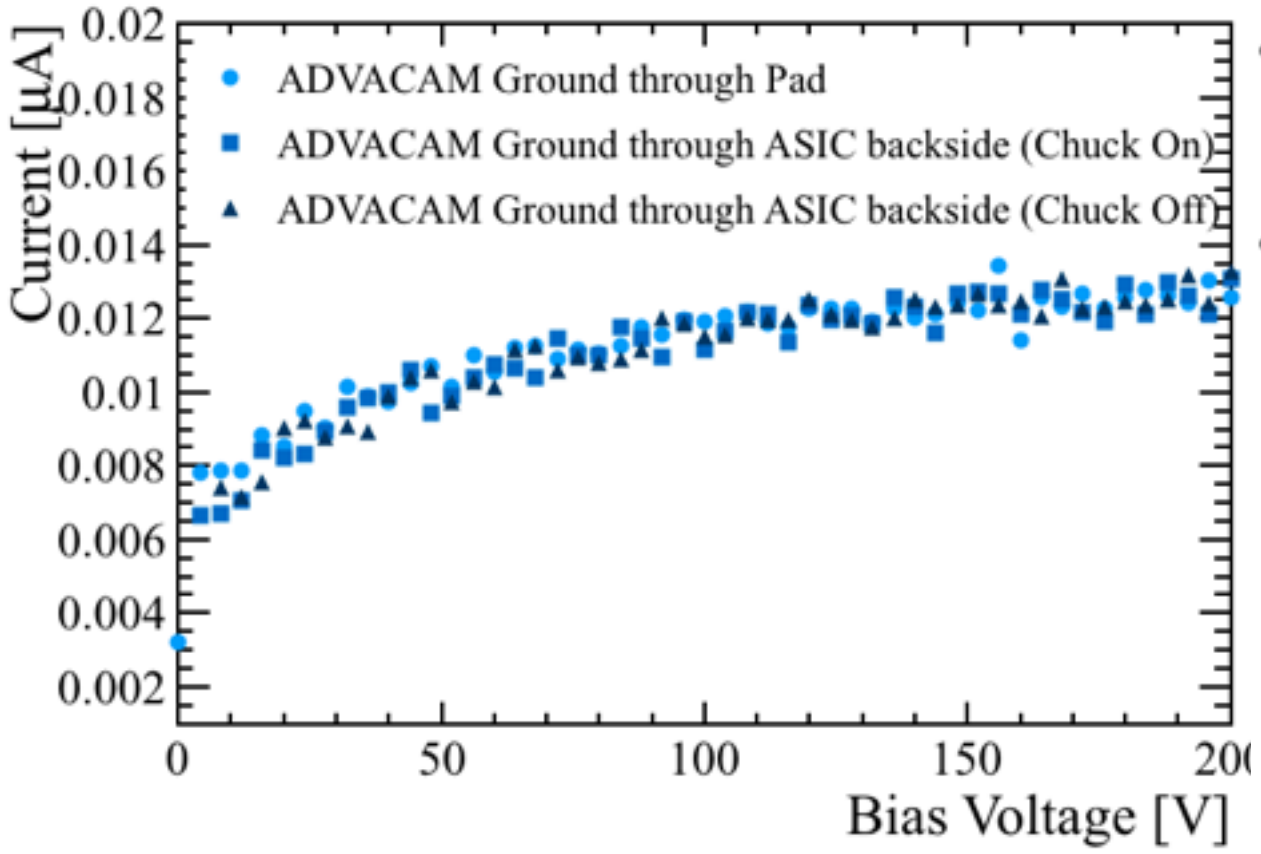
Using Sr^{90} source measurements to probe the bump quality of hybrids.

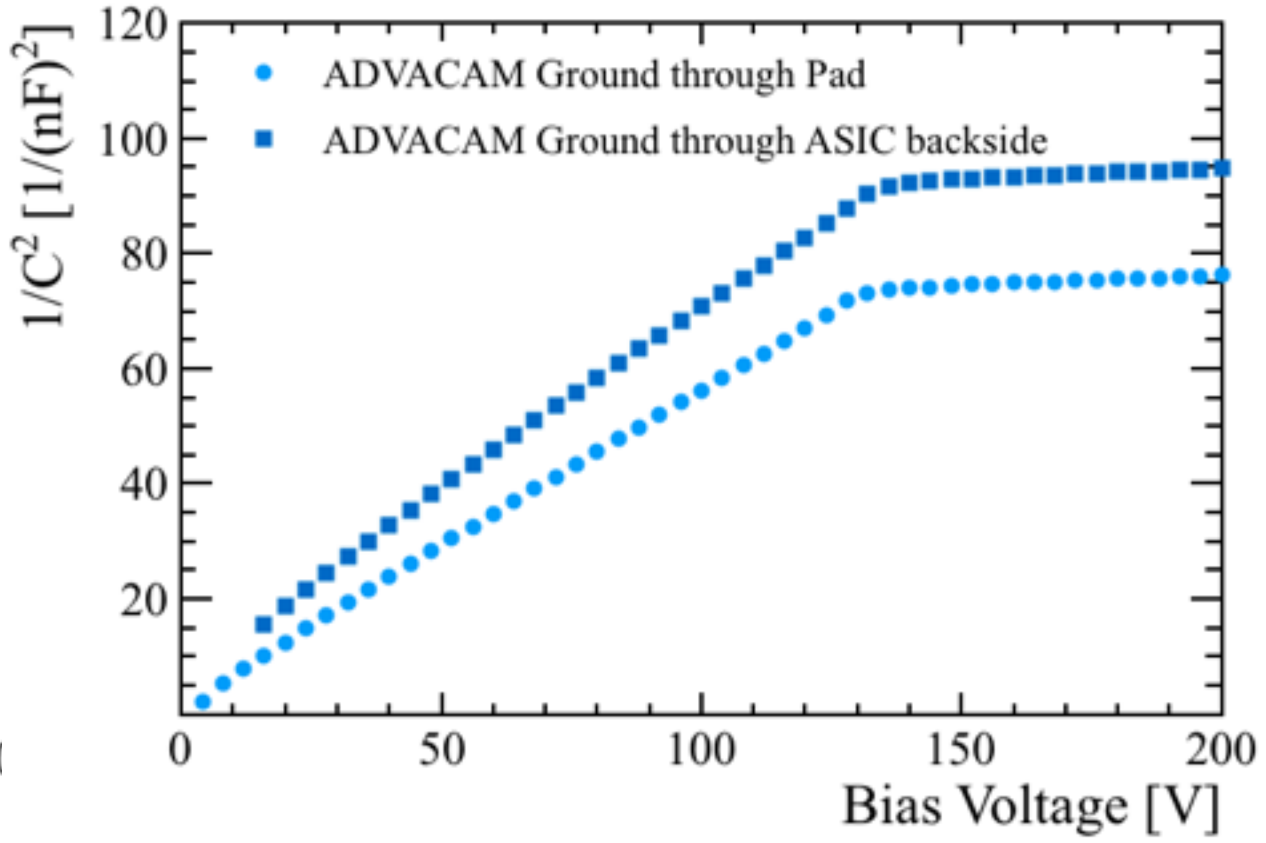
What about HV Tolerance?



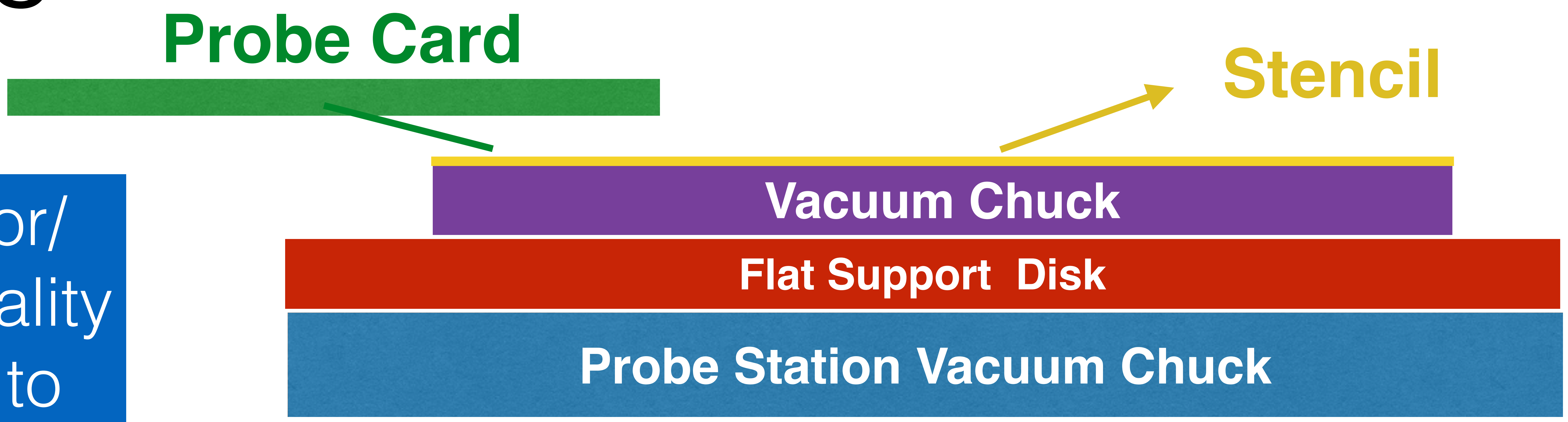


Maybe we can ground the sensor through the ASIC!

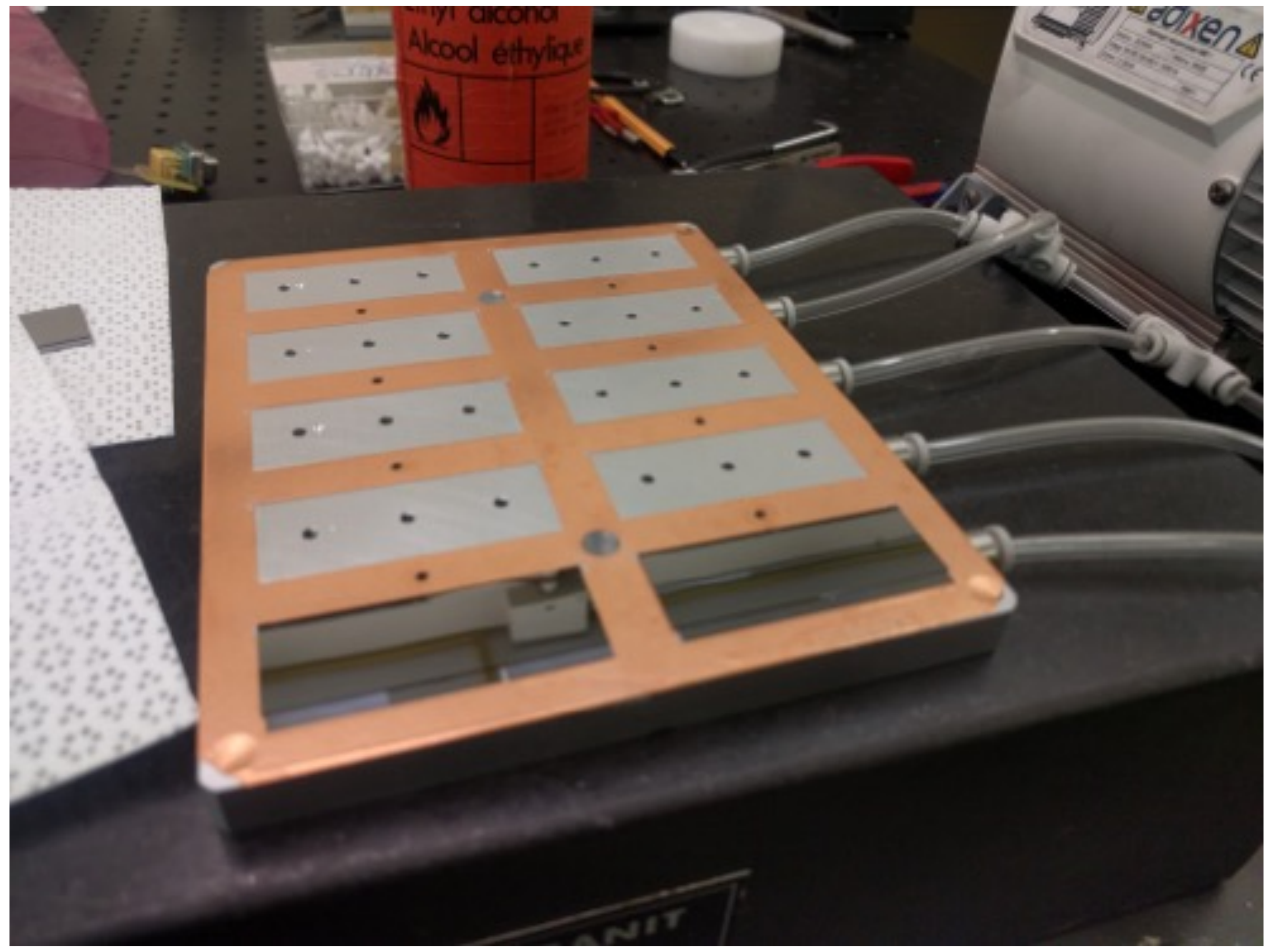


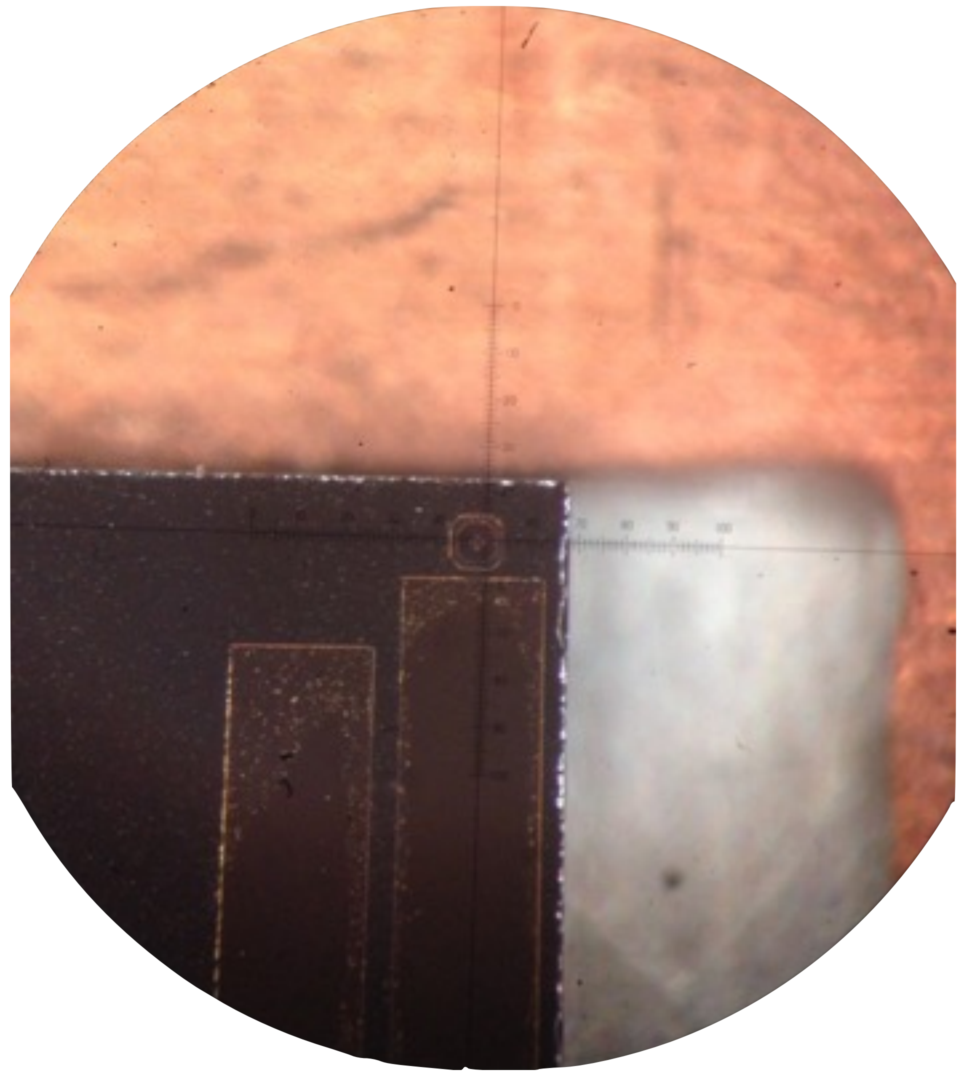


Probe Card Jig



How to test each sensor/ ASIC for bump bond quality before mounting them to modules ?

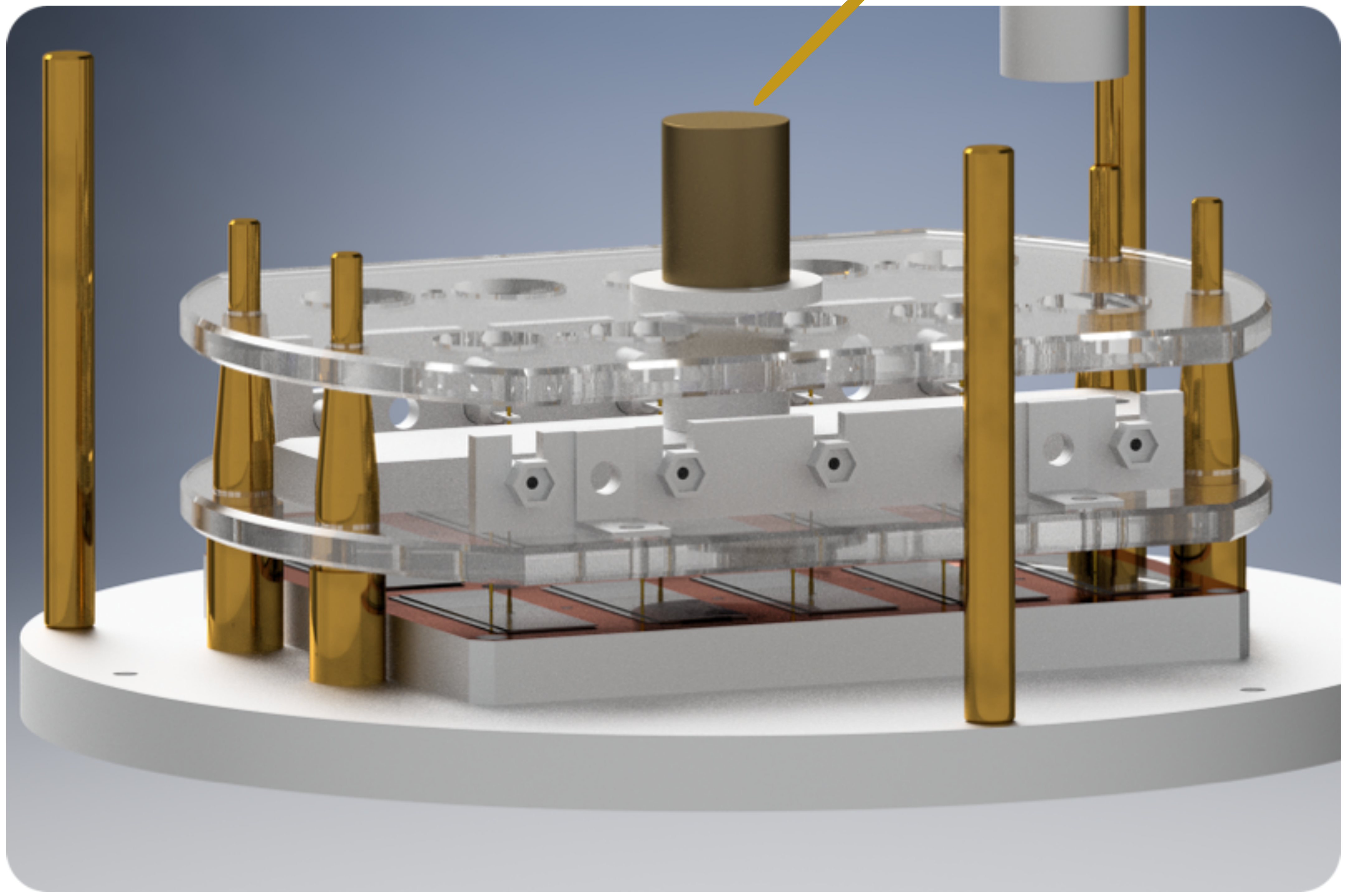


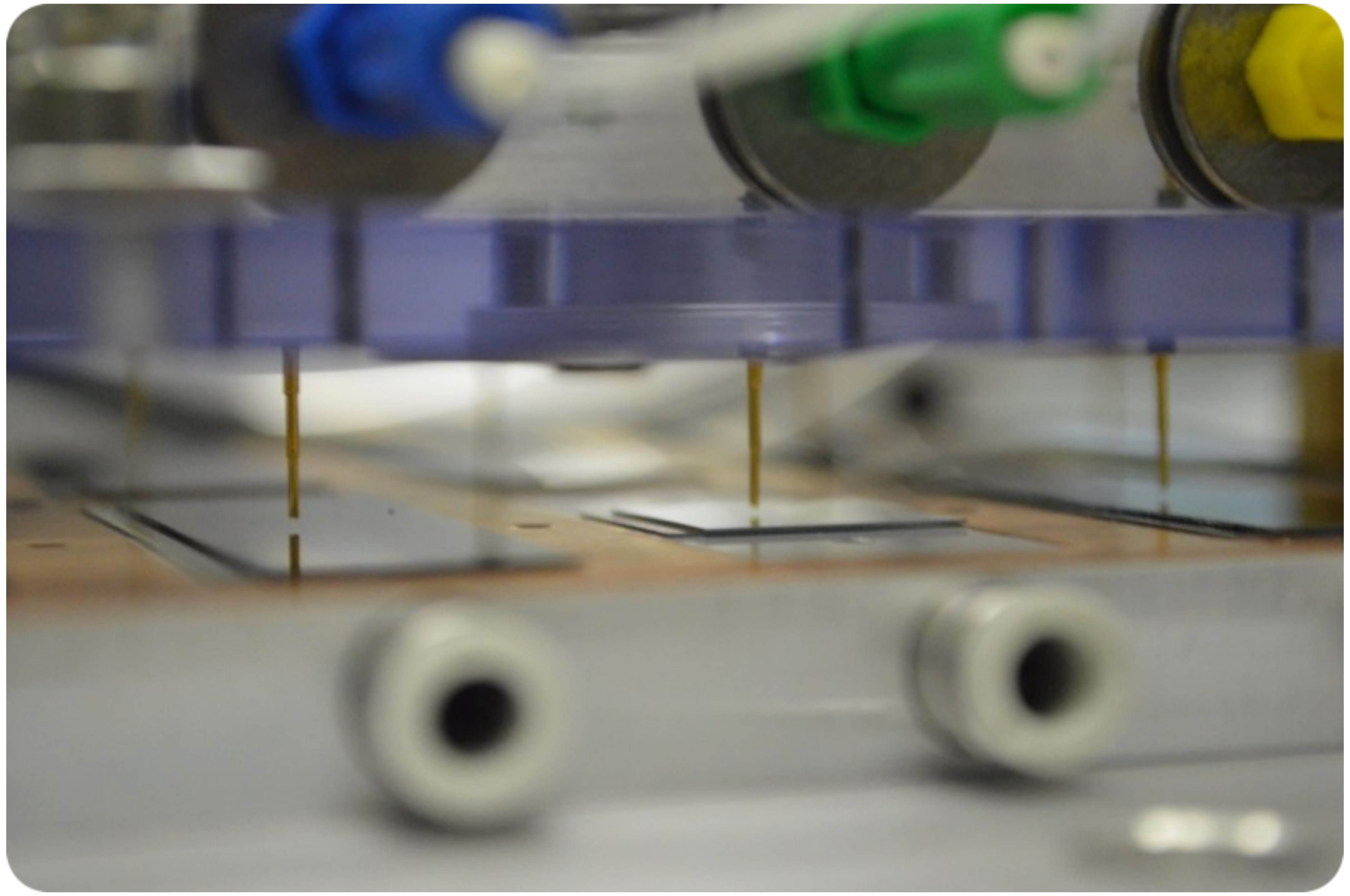


(After some training) Sensors are all within 40um of the average step.

Vacuum Hood

Screw allows for a very controlled touch of the sensors by the needles

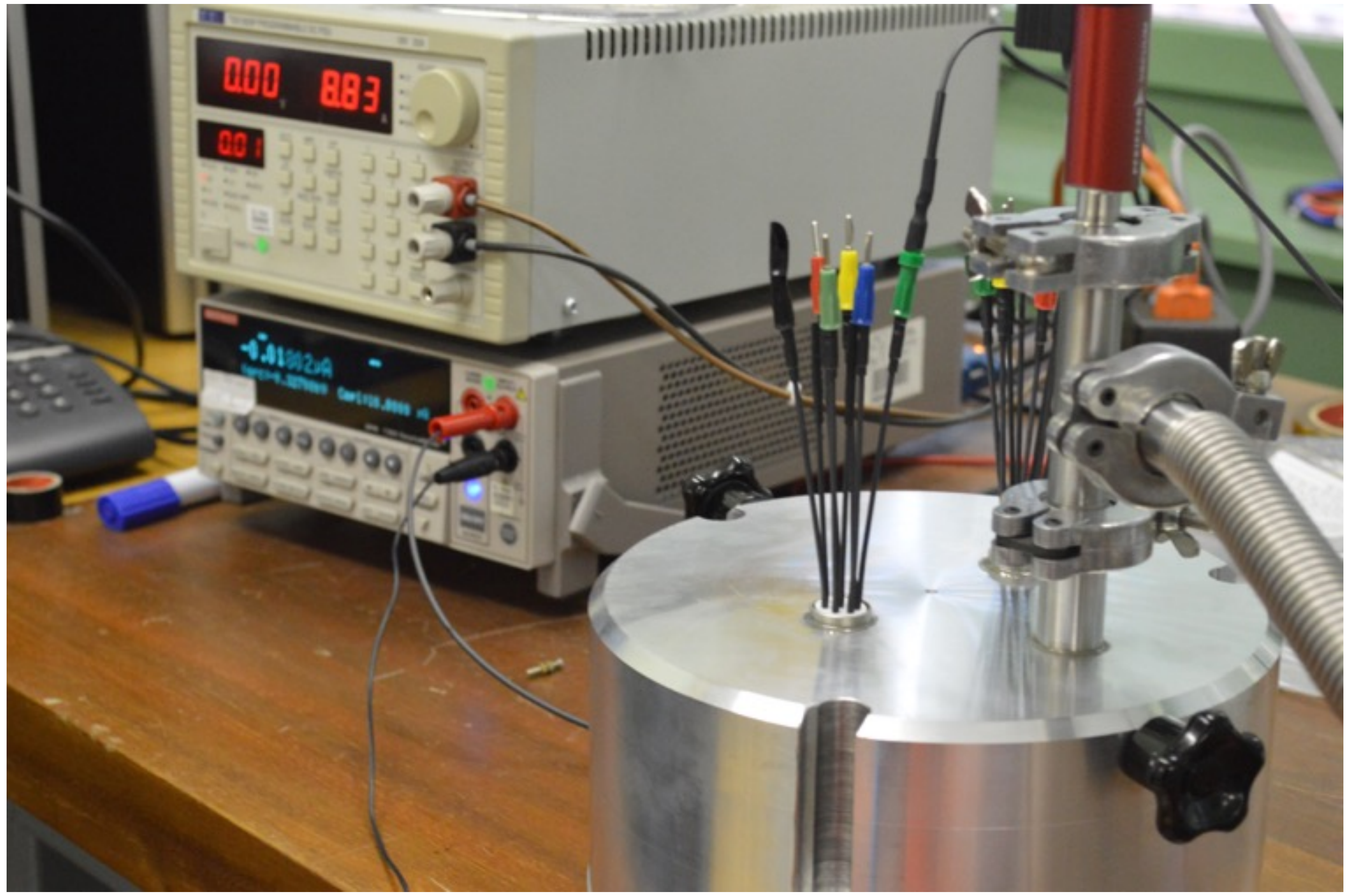


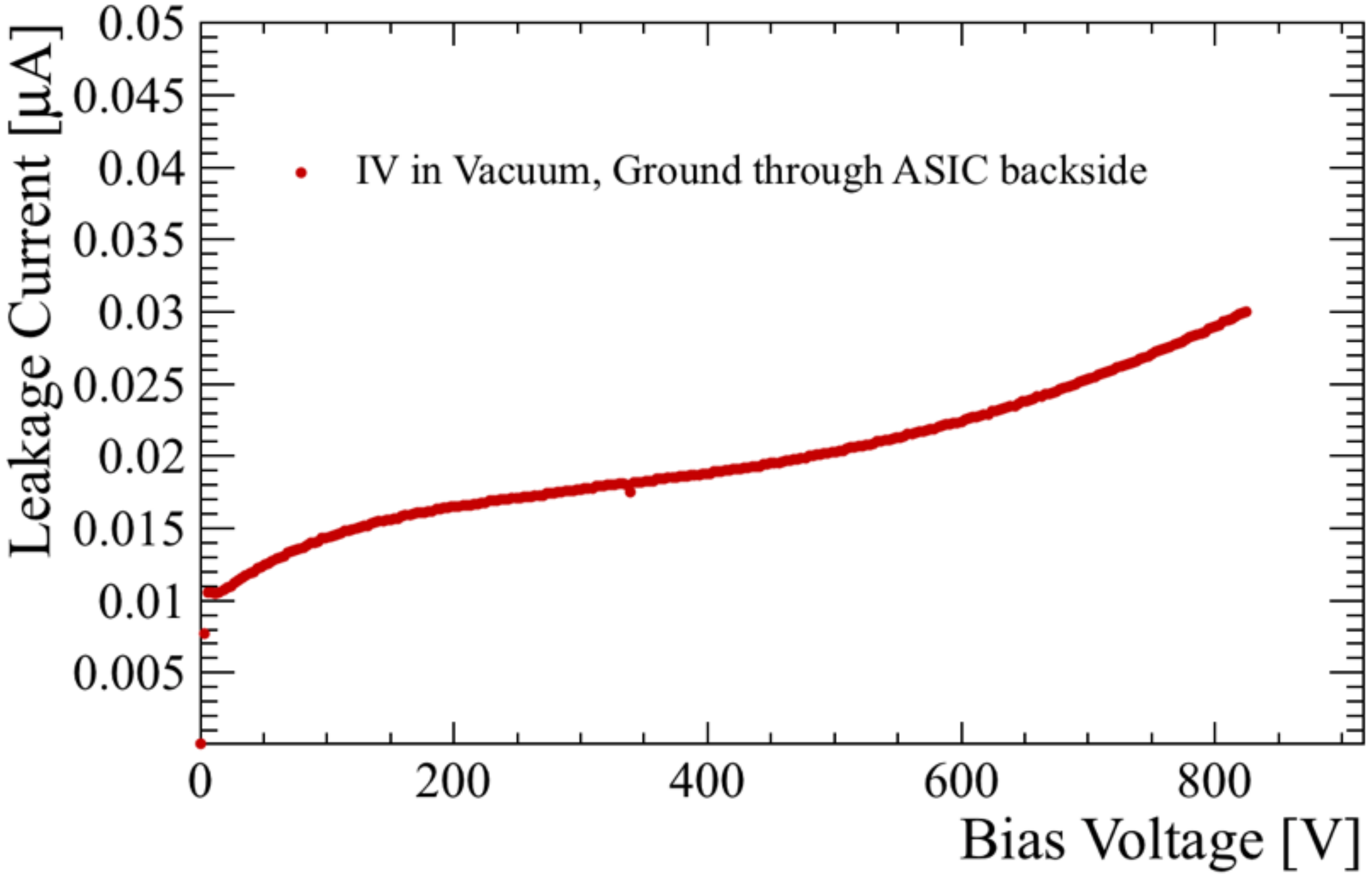


Spring loaded probe needles keep small pressure on sensors.

Dowels stop needles before end of spring compression.

Vacuum Hood





IV performed in available single thinned assembly.

VeloPix Hybrids IV Curves

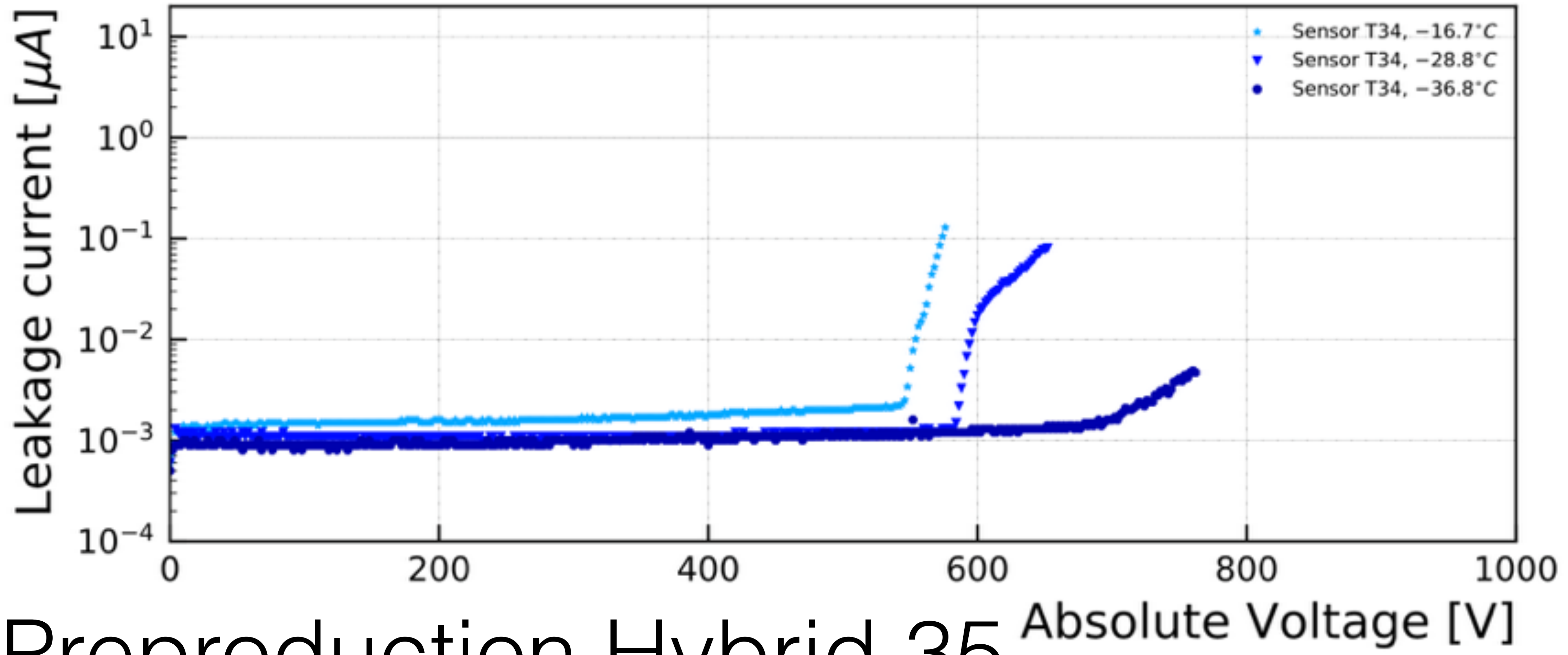
Tested under Vacuum.

3 Temperatures: -20°C, -30°C & -40°C (on the copper plate).

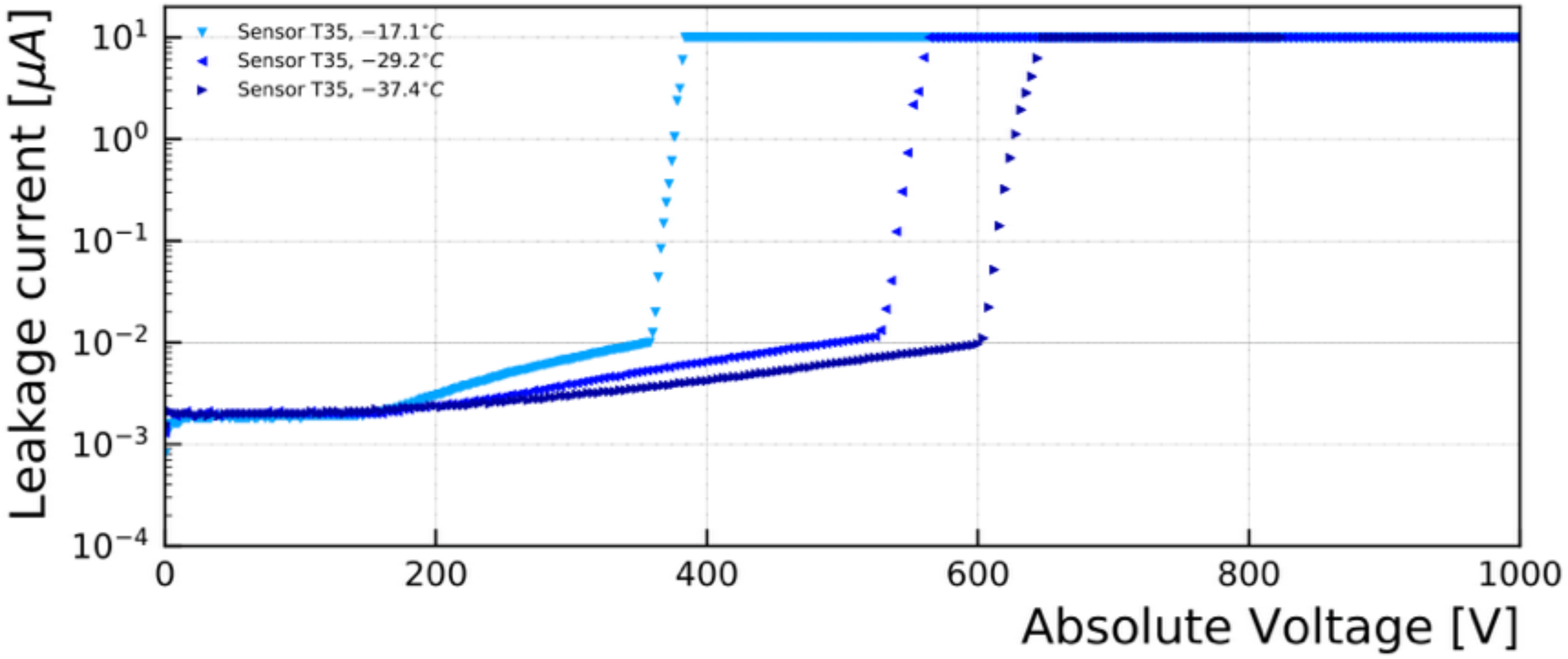
Step of 2V, every 2s from 0 to Breakdown.

Currently performing 300 thermal Cycles from -40°C to 60°C.

Preproduction Hybrid 34



Preproduction Hybrid 35



Summary

MiniDAQ Firmware have been used to characterise a few VeloPix Hybrids.

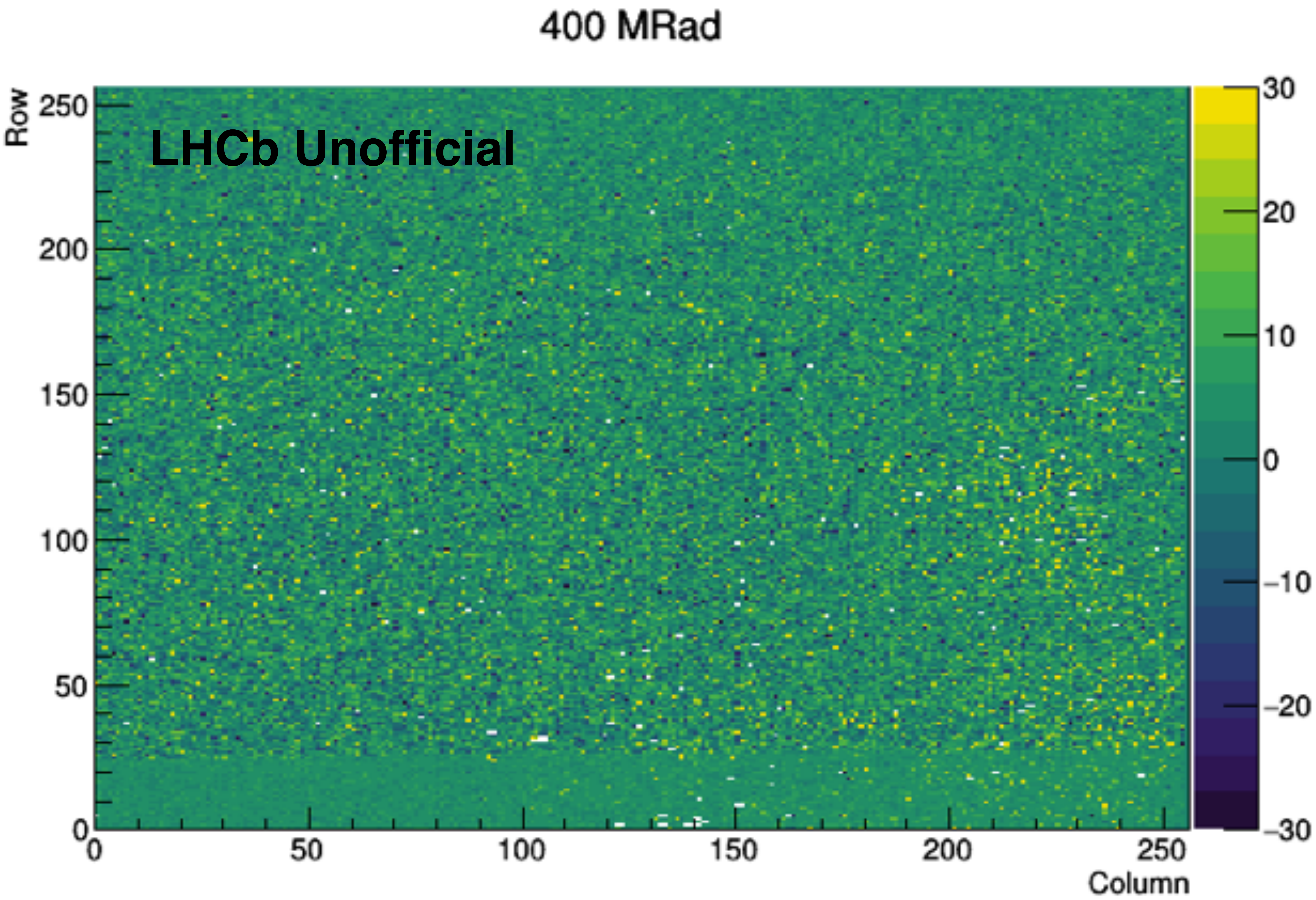
VeloPix resubmission seems to have solved known issues.

Bump Bonding of Sensors to VeloPix ASICS should start soon.

Setup in place for readout of ASICs after Bump Bonding.

New Setup to test IV of sensor with ground through the ASIC built and tested.

Backup



400 MRad
LHCb Unofficial
Row
250
200
150
100
50
0
0
50
100
150
200
250
Column
30
20
10
0
−10
−20
−30

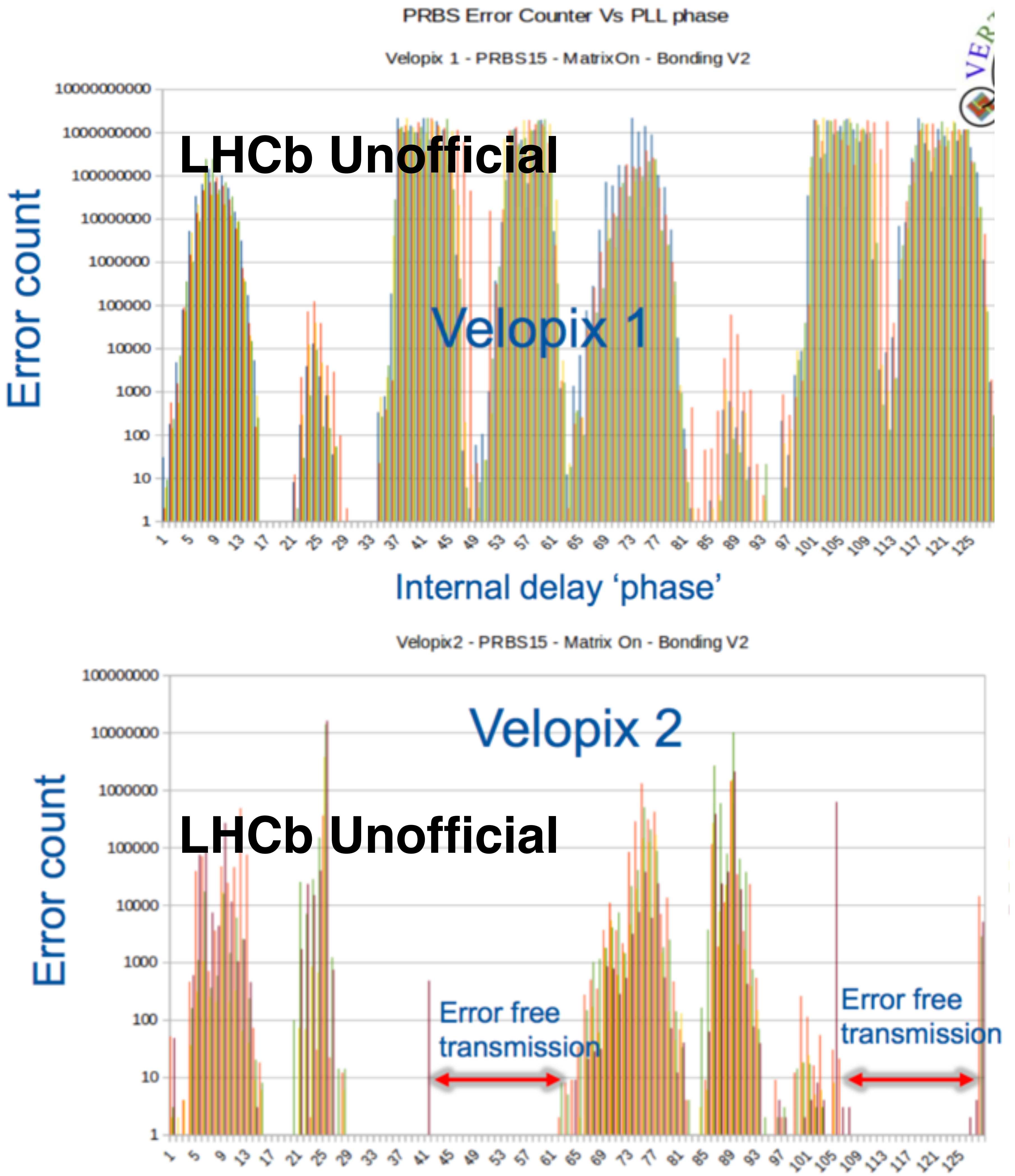
VeloPix2

VeloPix was resubmitted to fix a few features observed in VeloPix 1st Run.

Single Event Latch-up	**Fixed**
Single Event Upset Spurious Reset	**Fixed**
Single Event Upset FIFO	**Fixed**

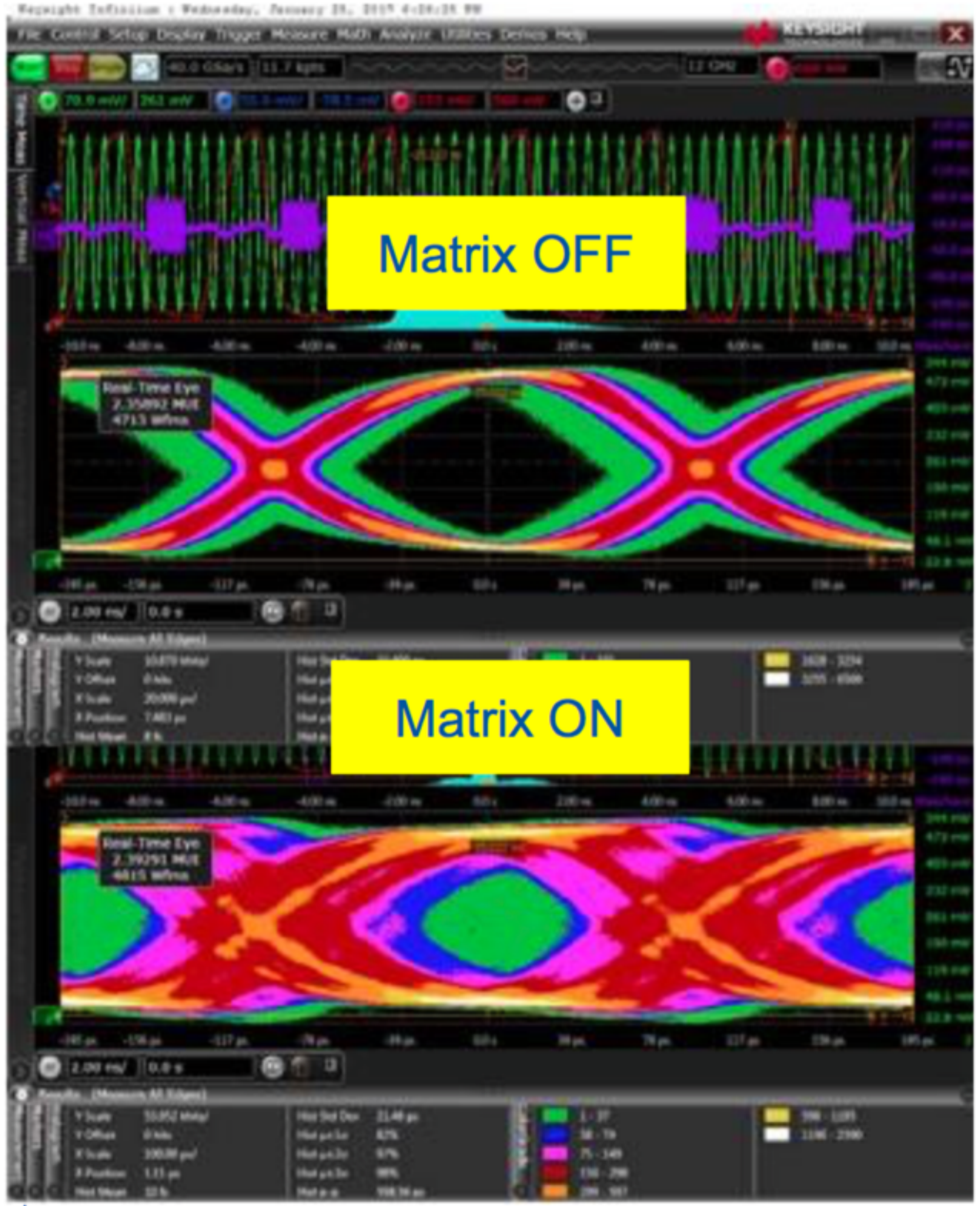
ASICs tested at Louvain with ion beams.

VeloPix GWT PRBS Data Stream

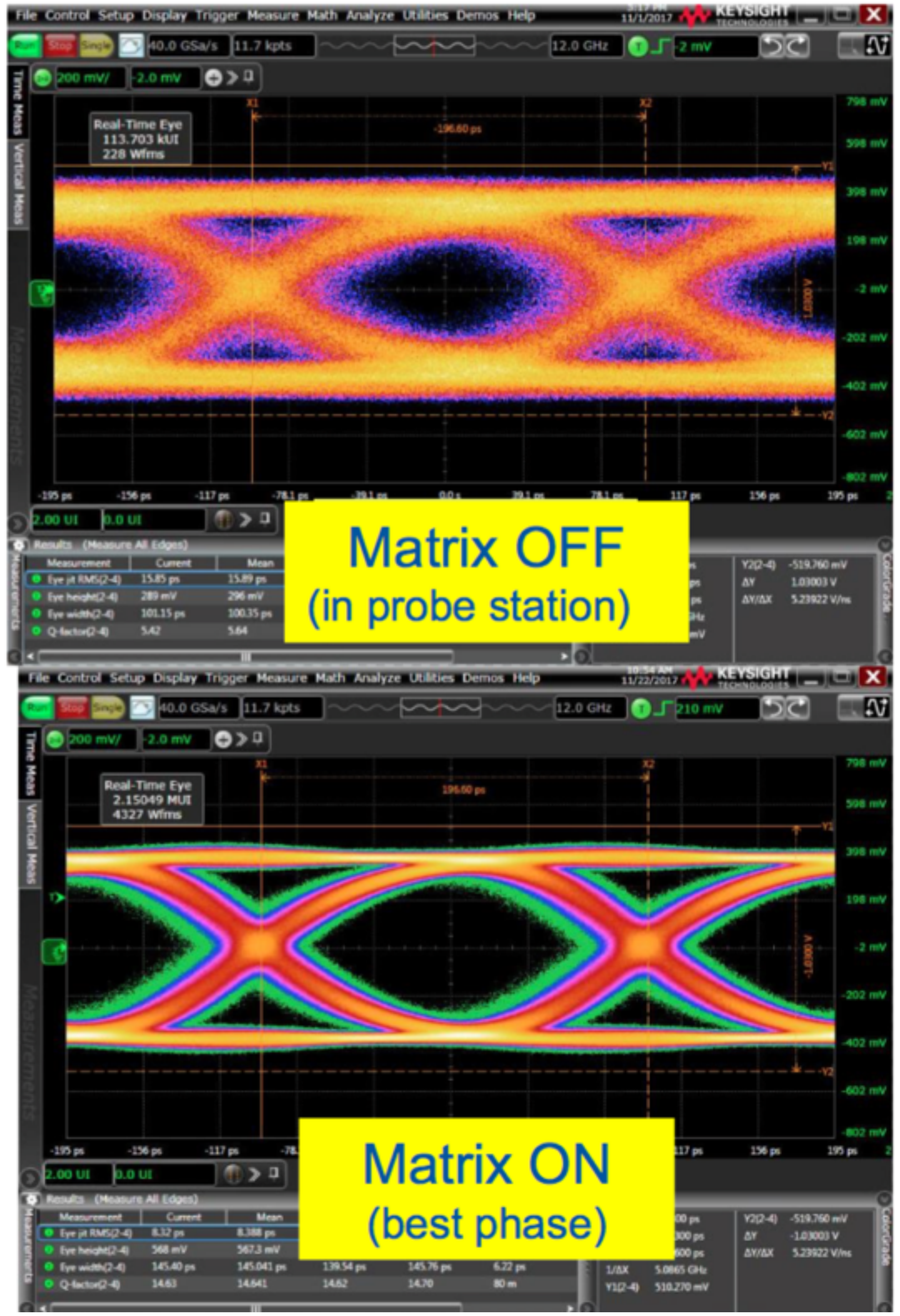


Eye Diagram

Velopix 1



Velopix 2

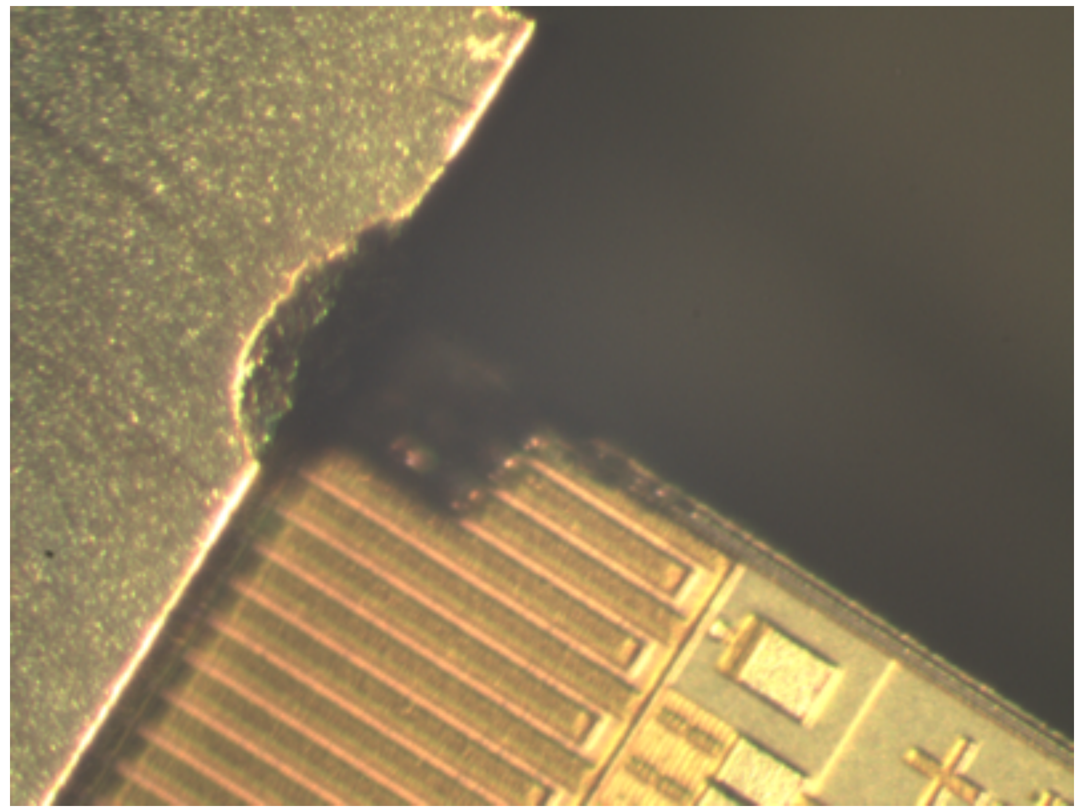


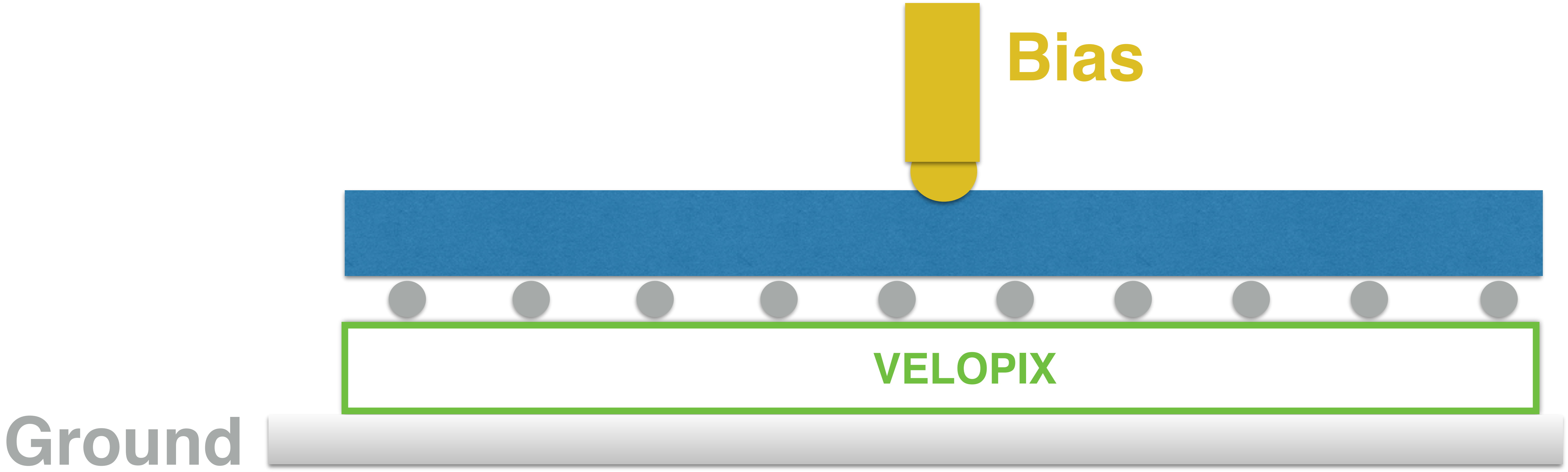
What about HV Tolerance?

Only possible to properly bias the sensors after bump bonding.

Probing BD Voltage of sensors must be done in vacuum.

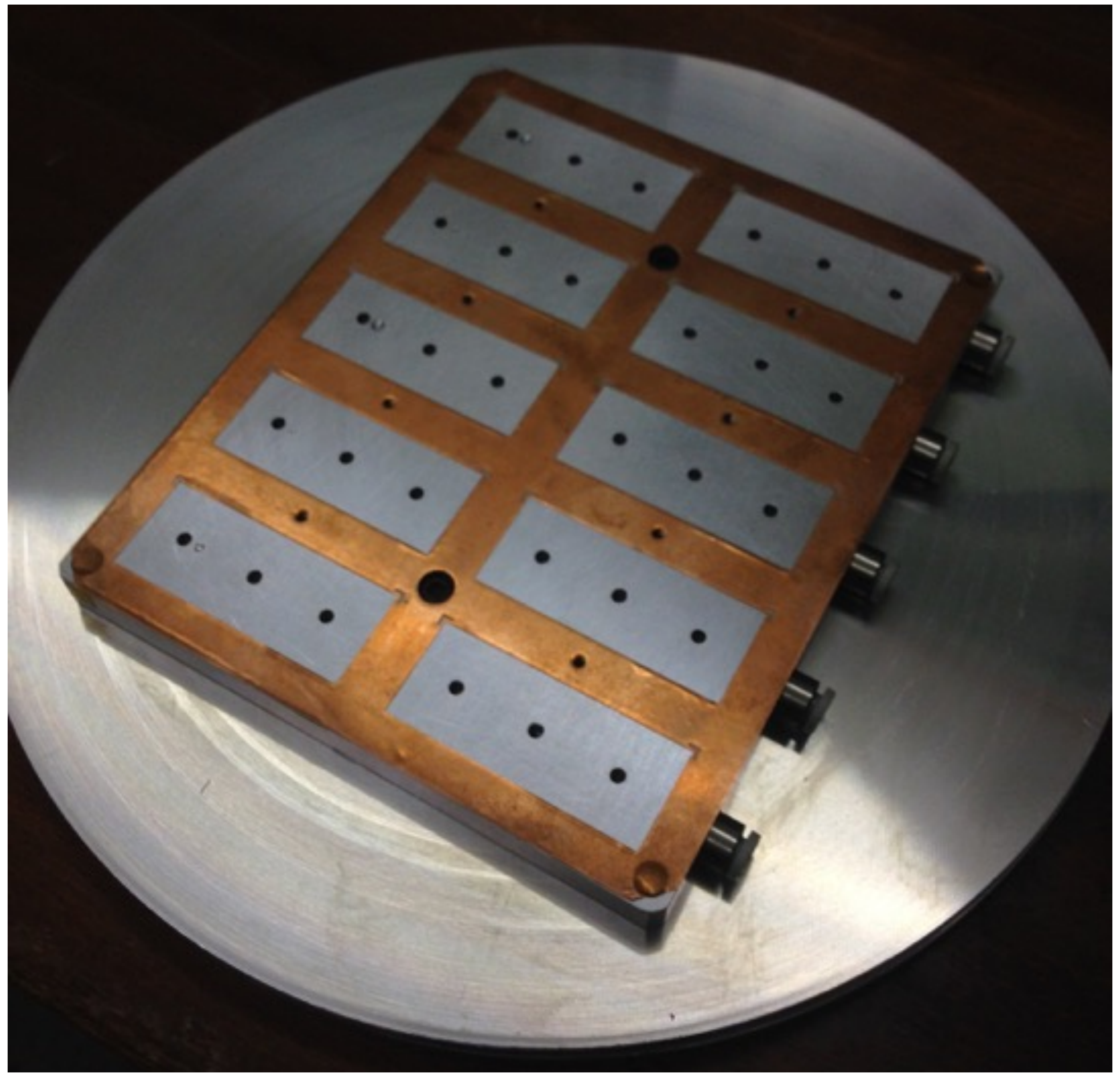
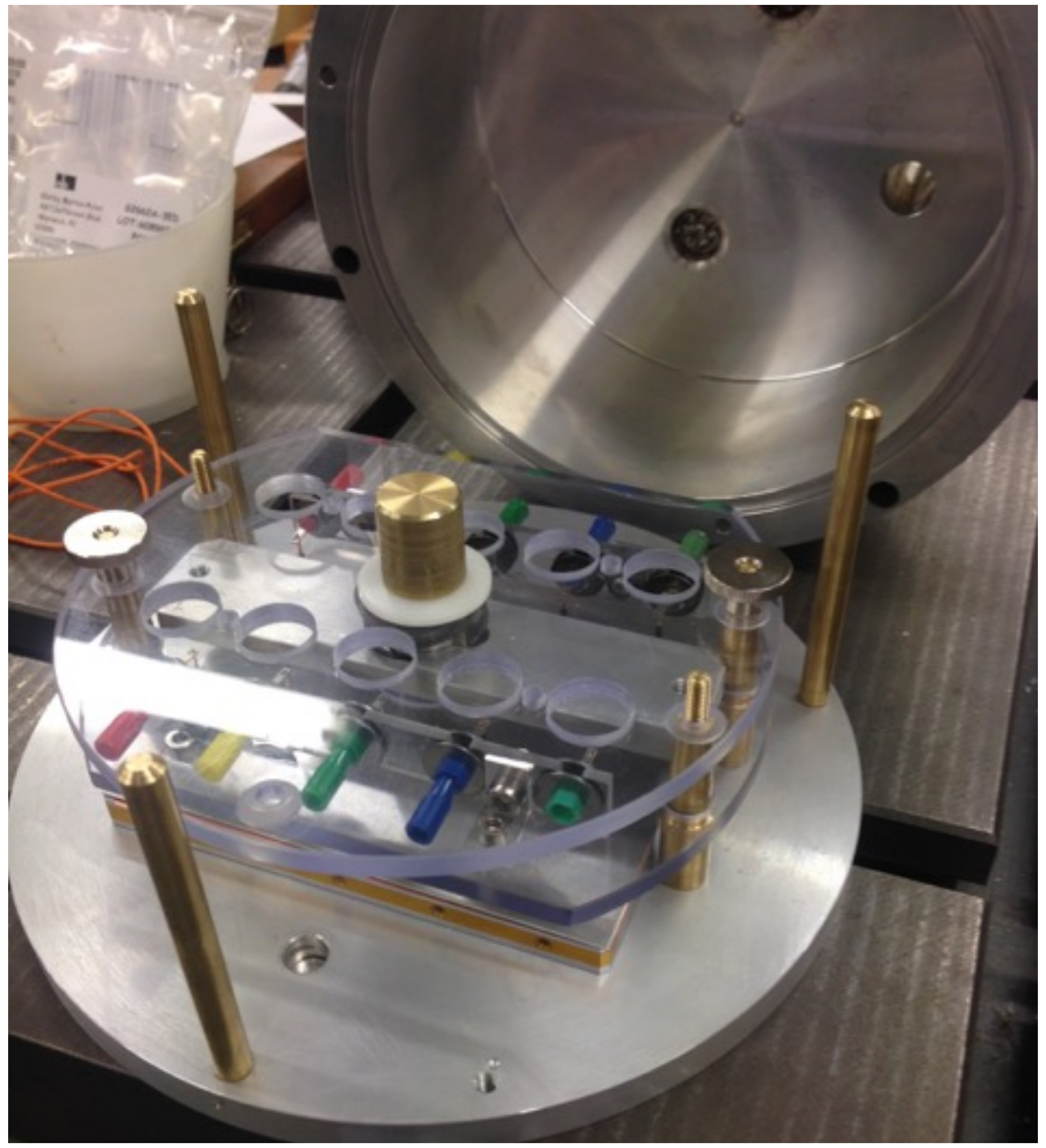
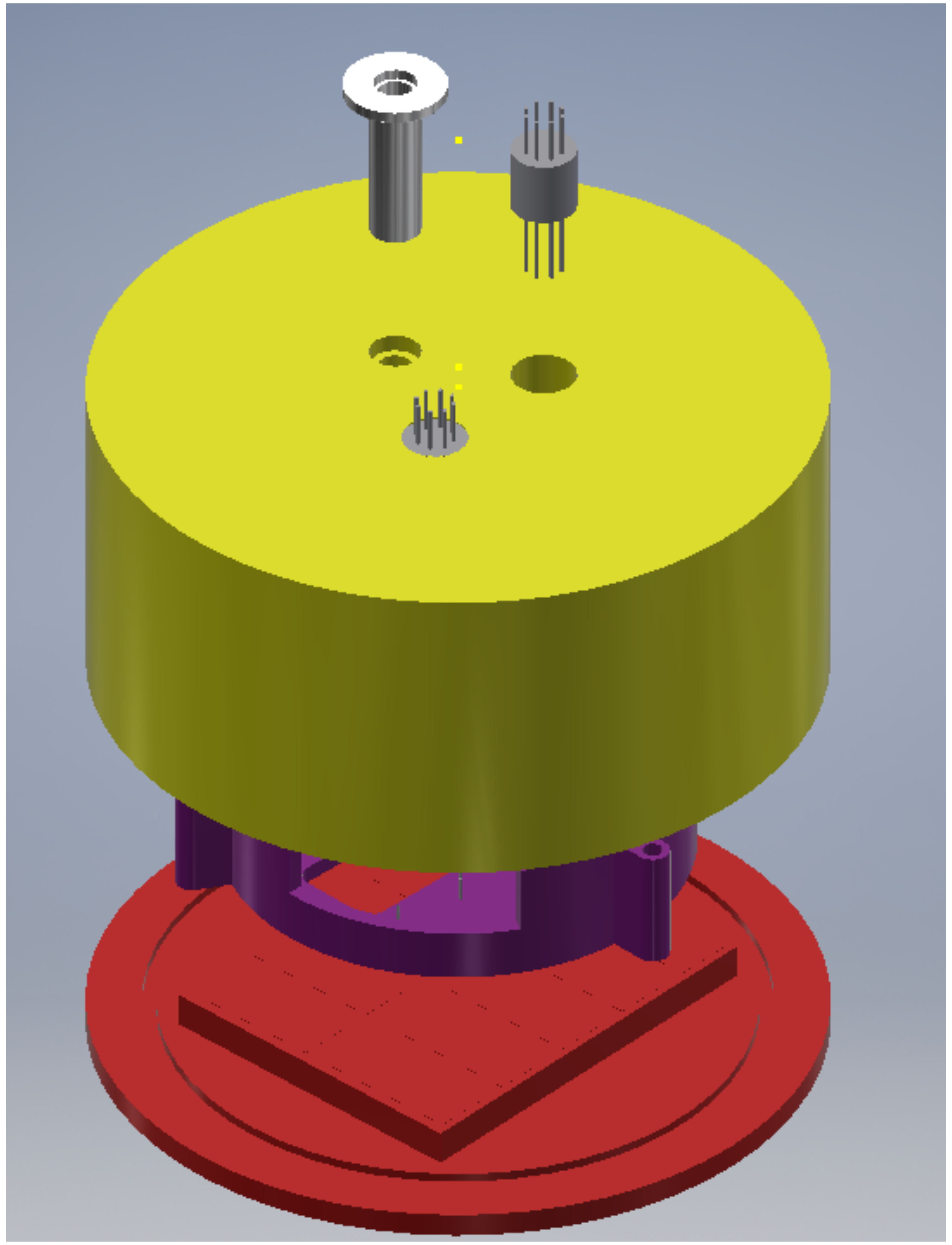
Maybe we can ground the sensor through the ASIC?





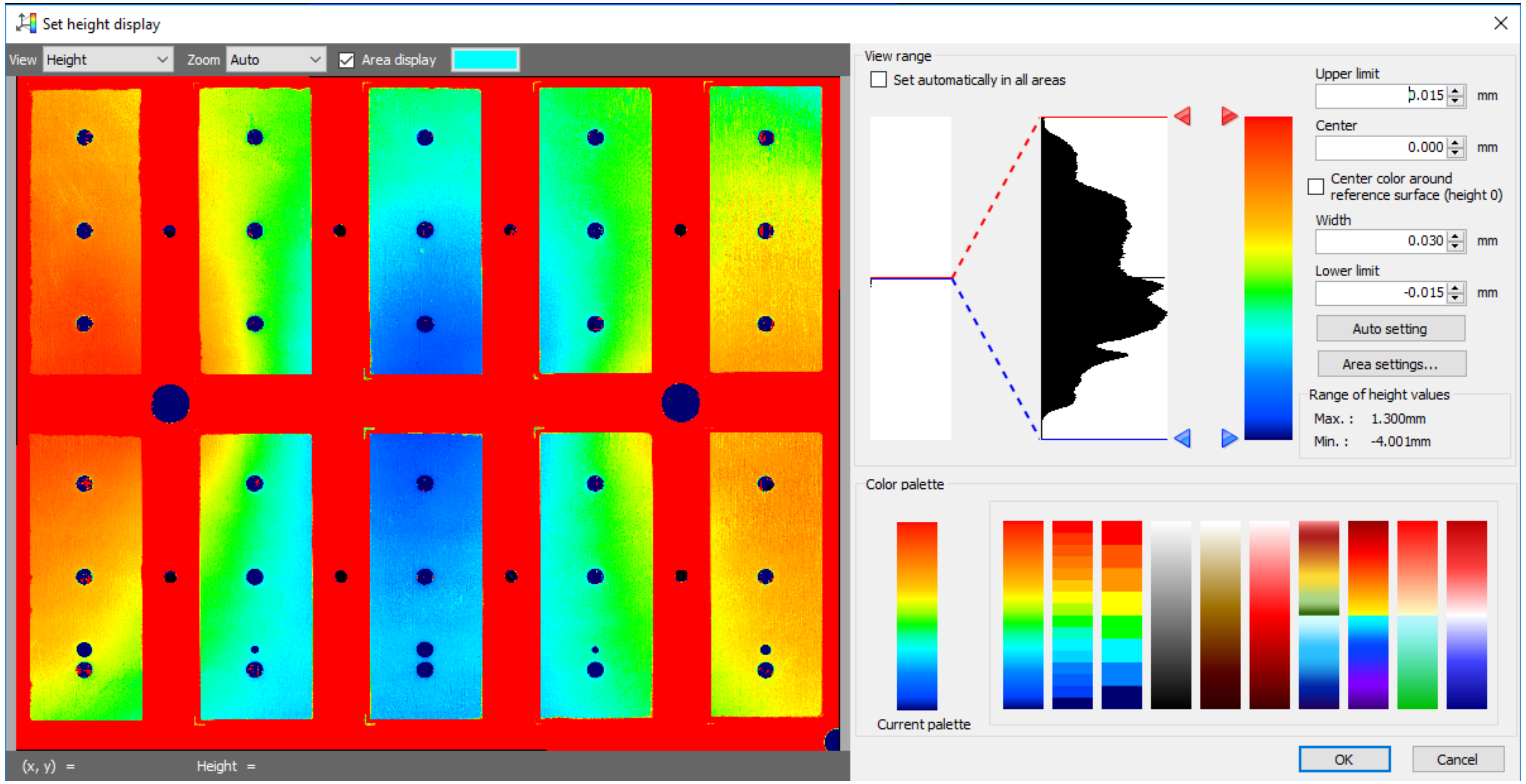
HV Jig

Use Probe Card Jig to hold sensors.
Vacuum Chamber is a lid.

QA

- Check the flatness of the surface using the white light interferometer.



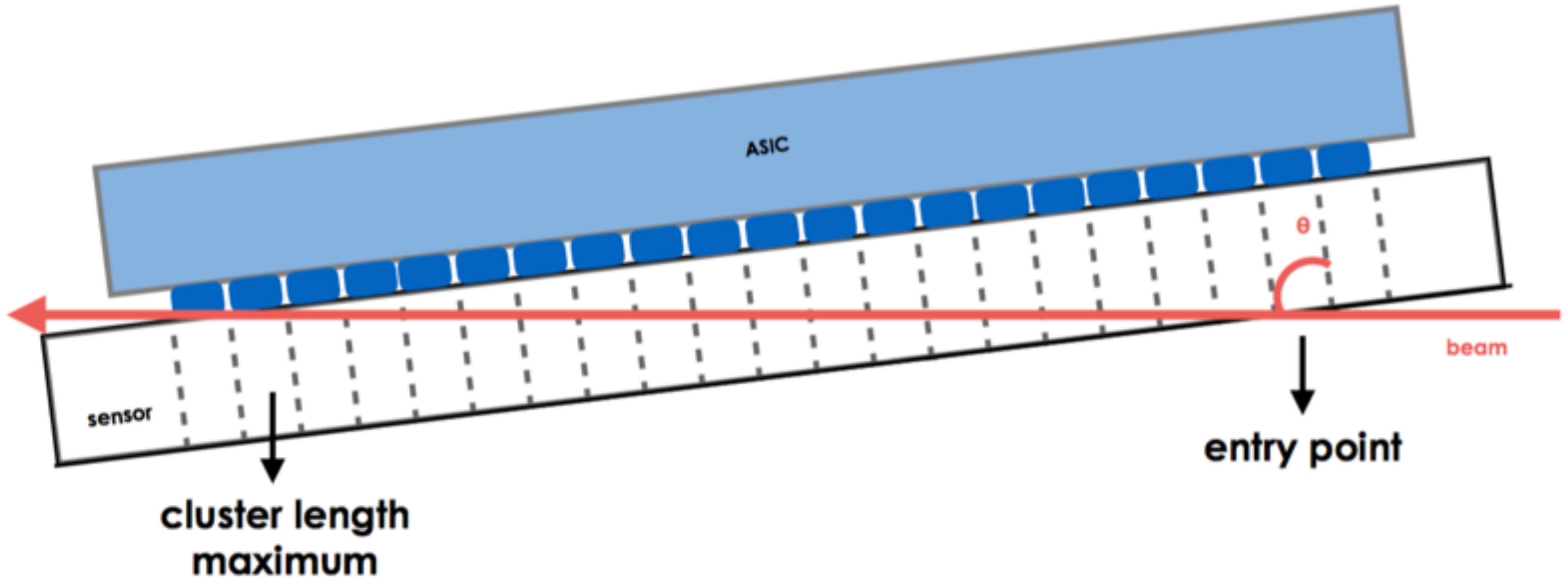
Overall height variation of 30 um over the whole surface.

Charge Collection and Depletion Depth

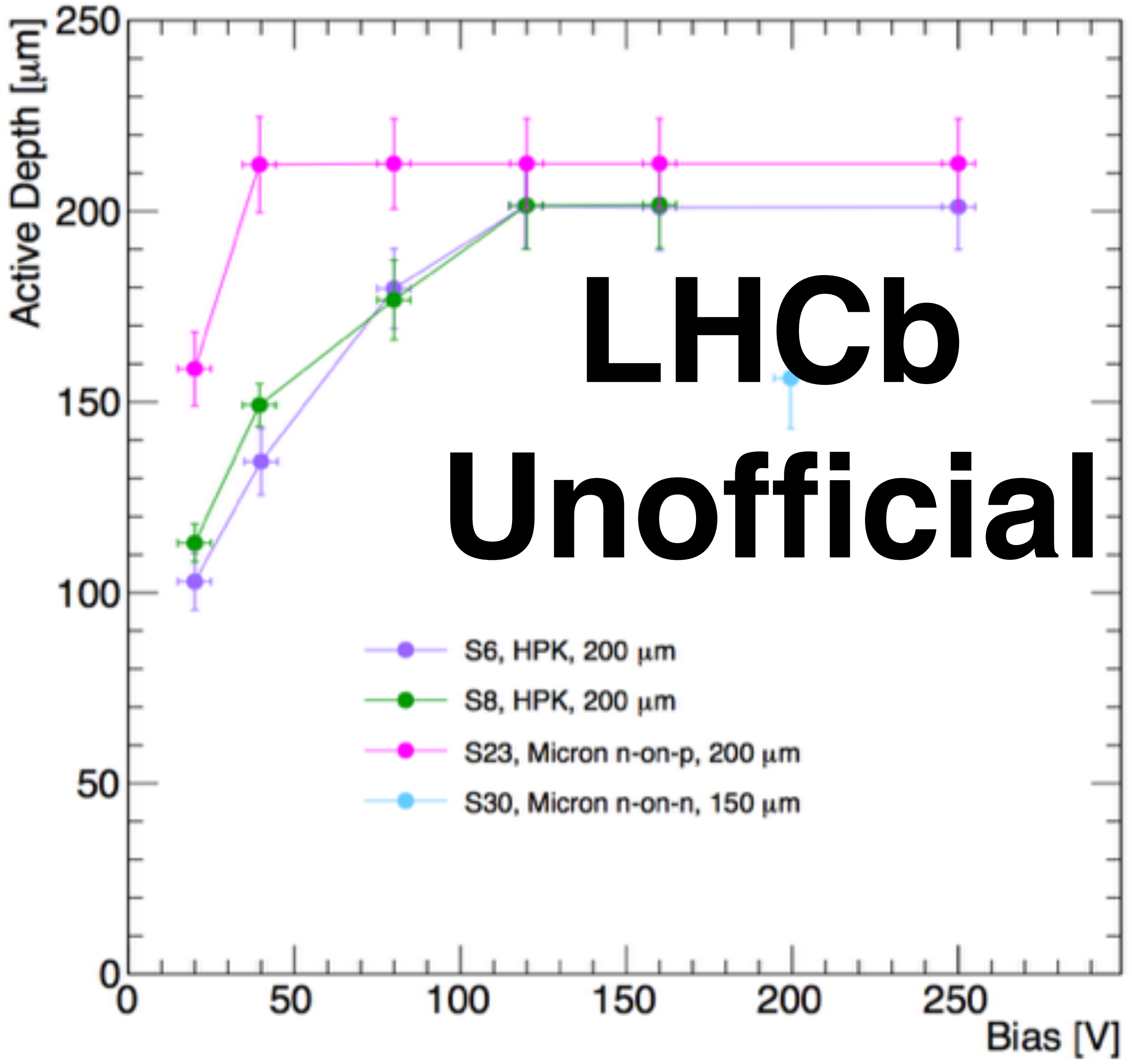
Determined using Grazing Angle Technique.

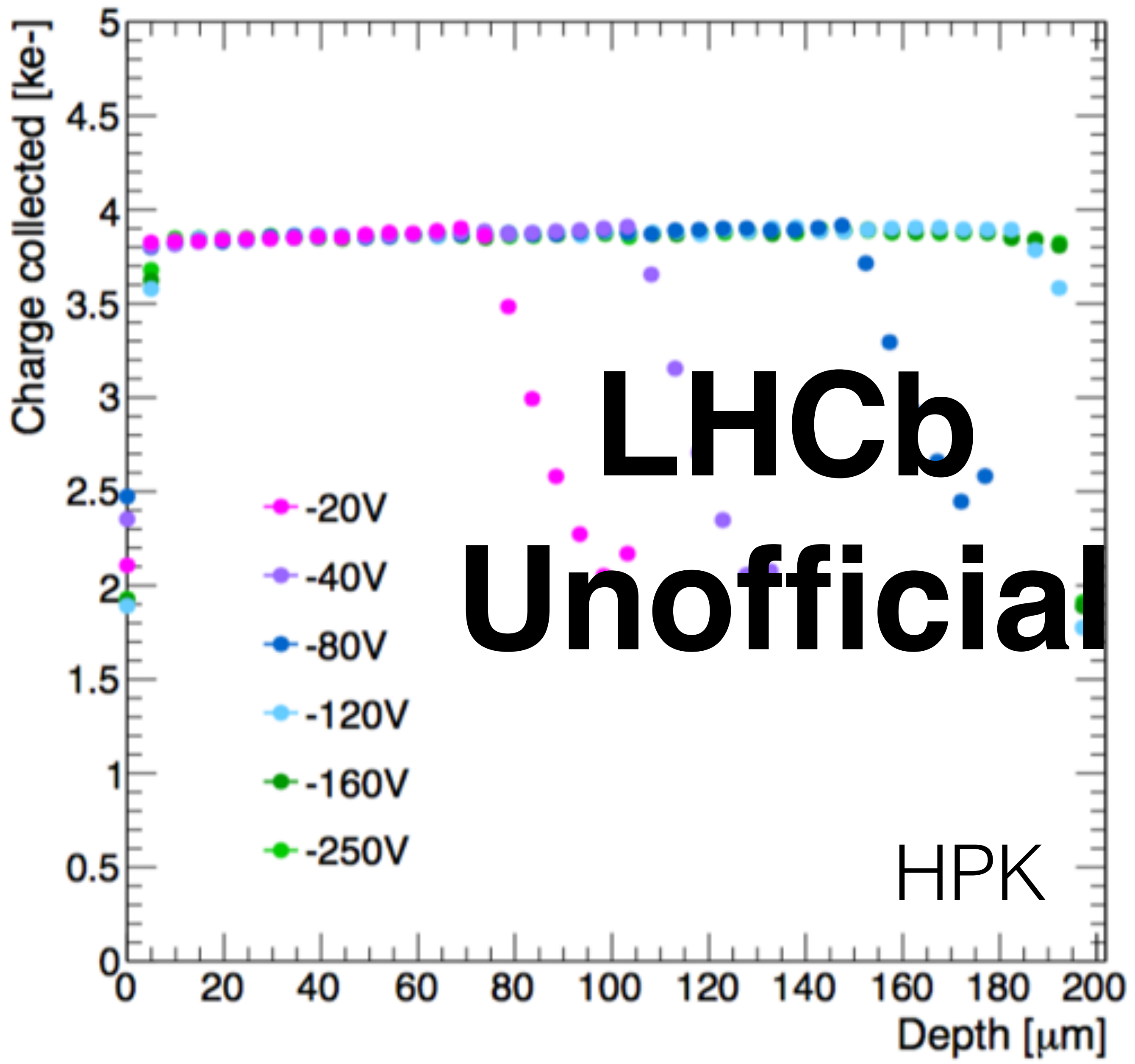
DUT clusters associated with a track if within a 10 ns window.

Correction for Timewalk effect is applied using charge collection time of tracks passing wishing 20µm of implants



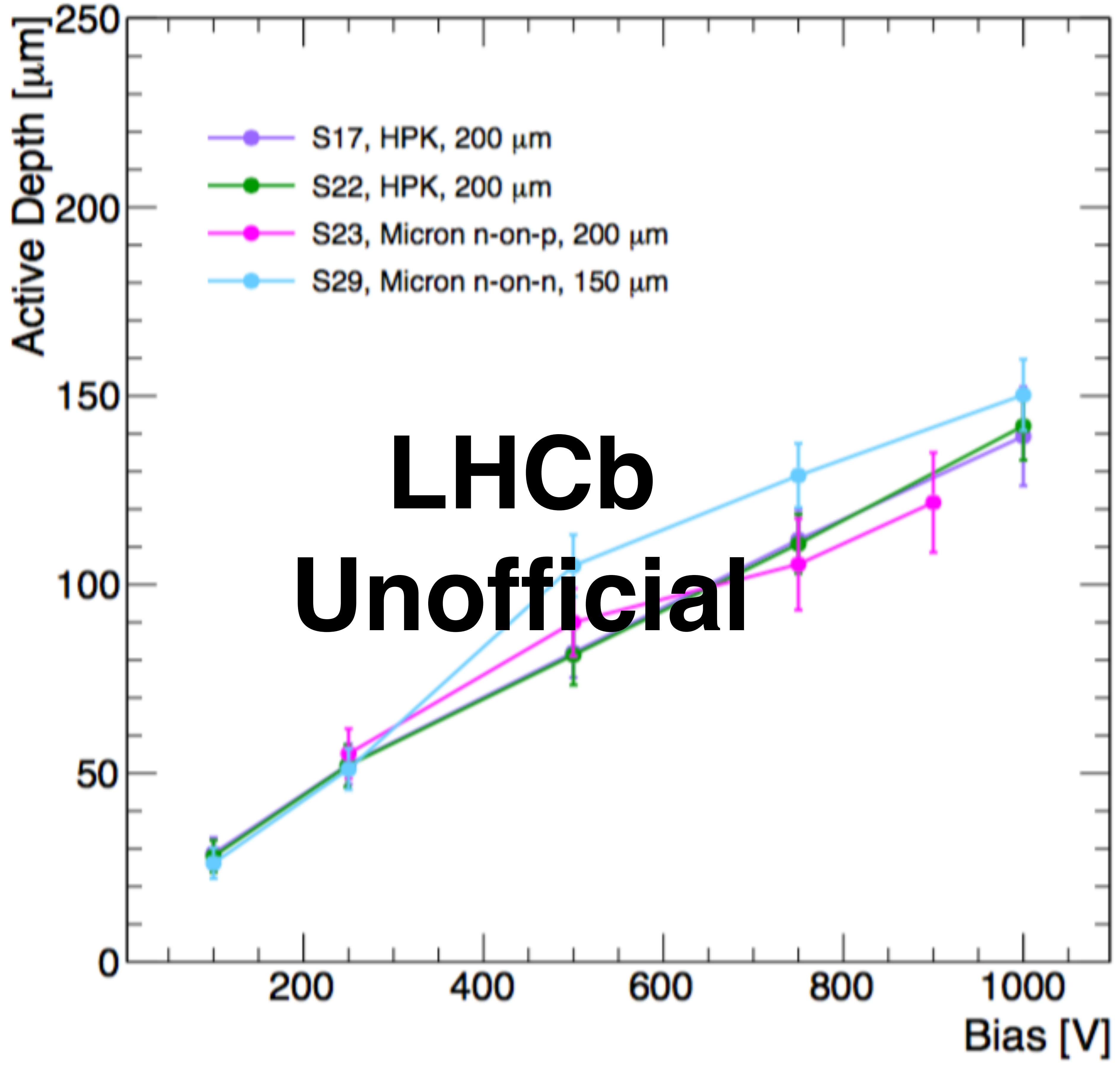
Non irradiated sensors

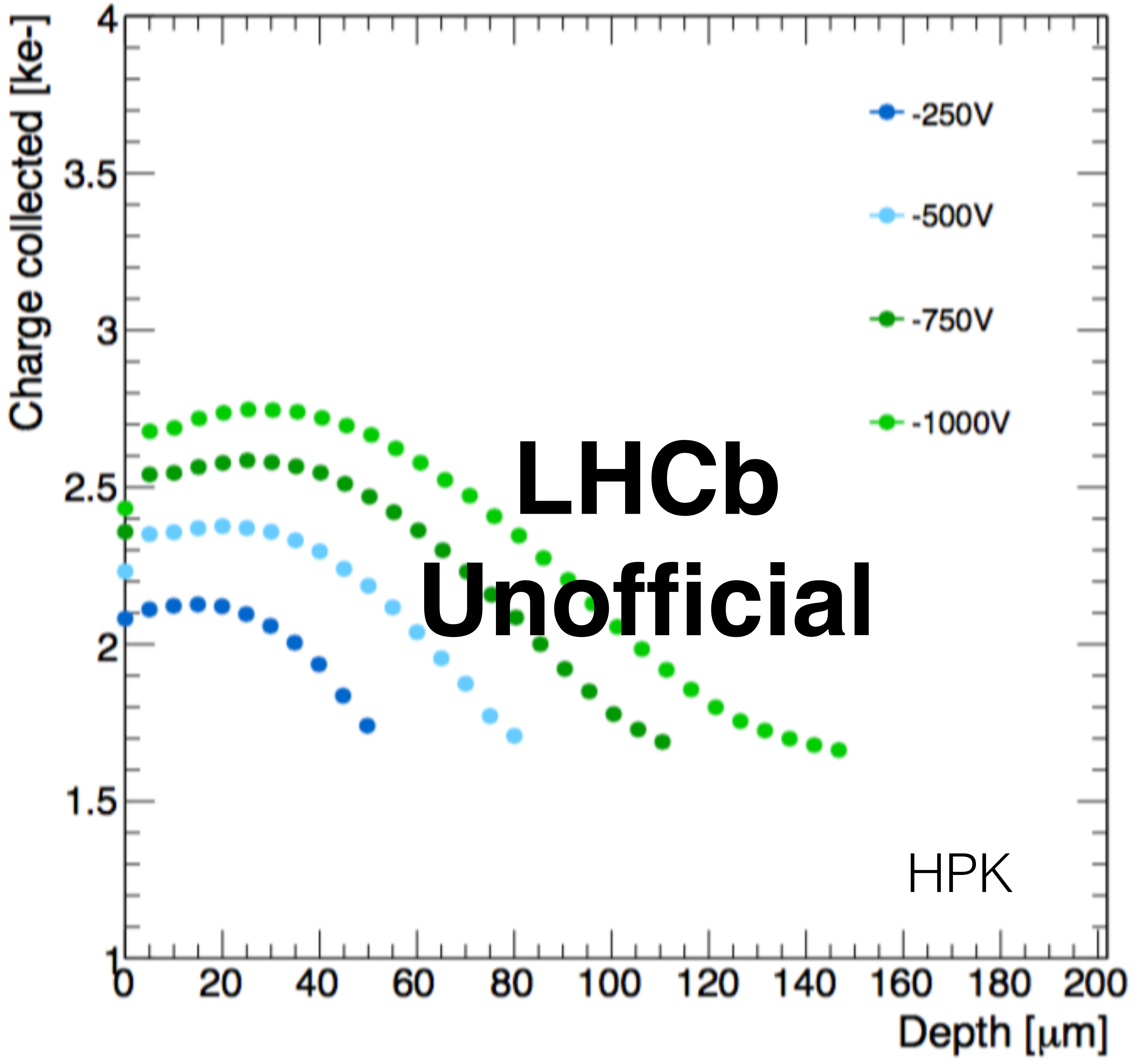




Charge Collection and Depletion Depth

Neutron Uniformly Irradiated to Full Fluence



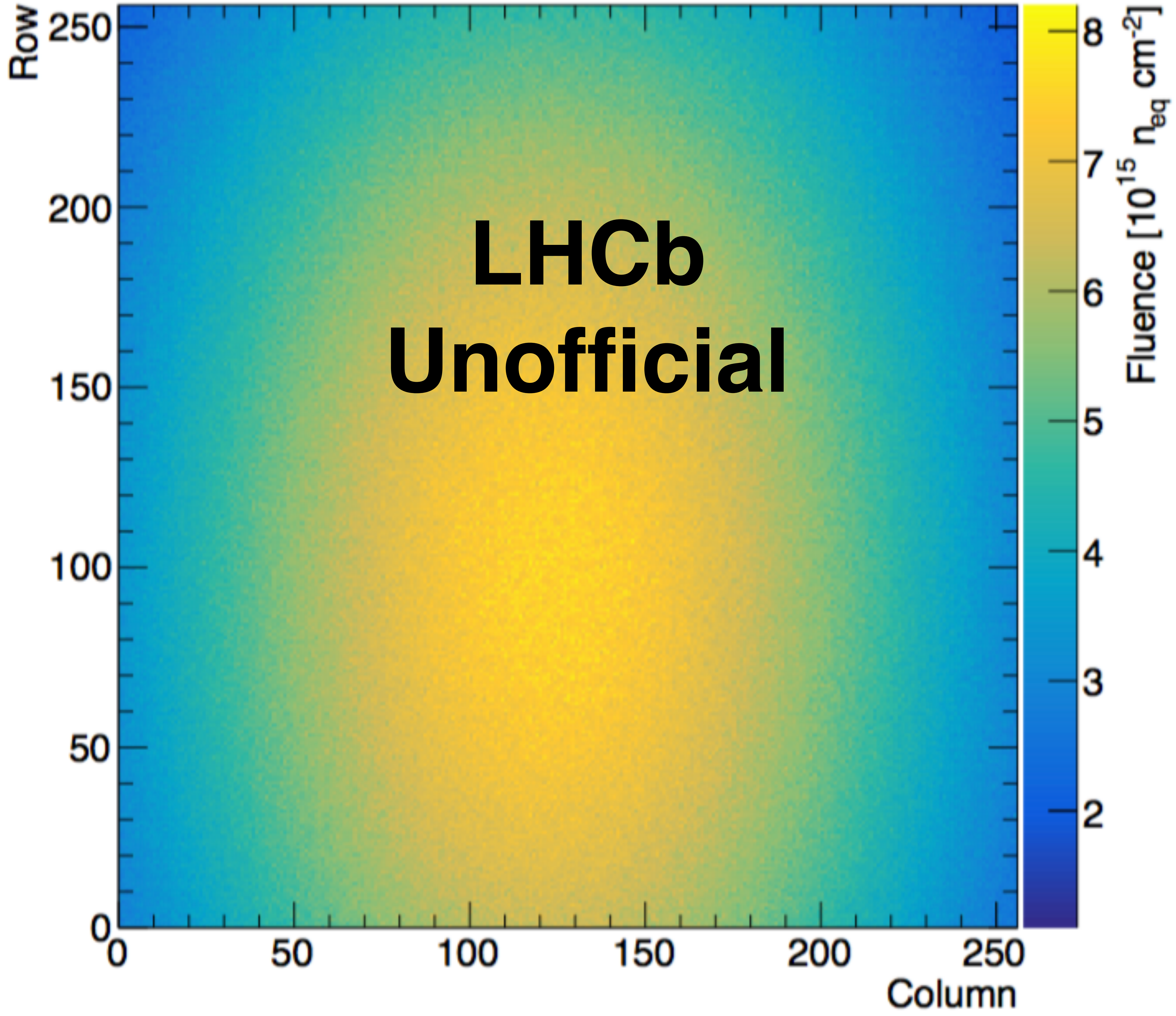


Charge Collection and Depletion Depth

Non-Uniform proton Irradiated sensors at IRRAD.

Combining dosimetry measurements to activation of the sensors.

Non-uniform profile allows study of charge collection as a function of fluence.

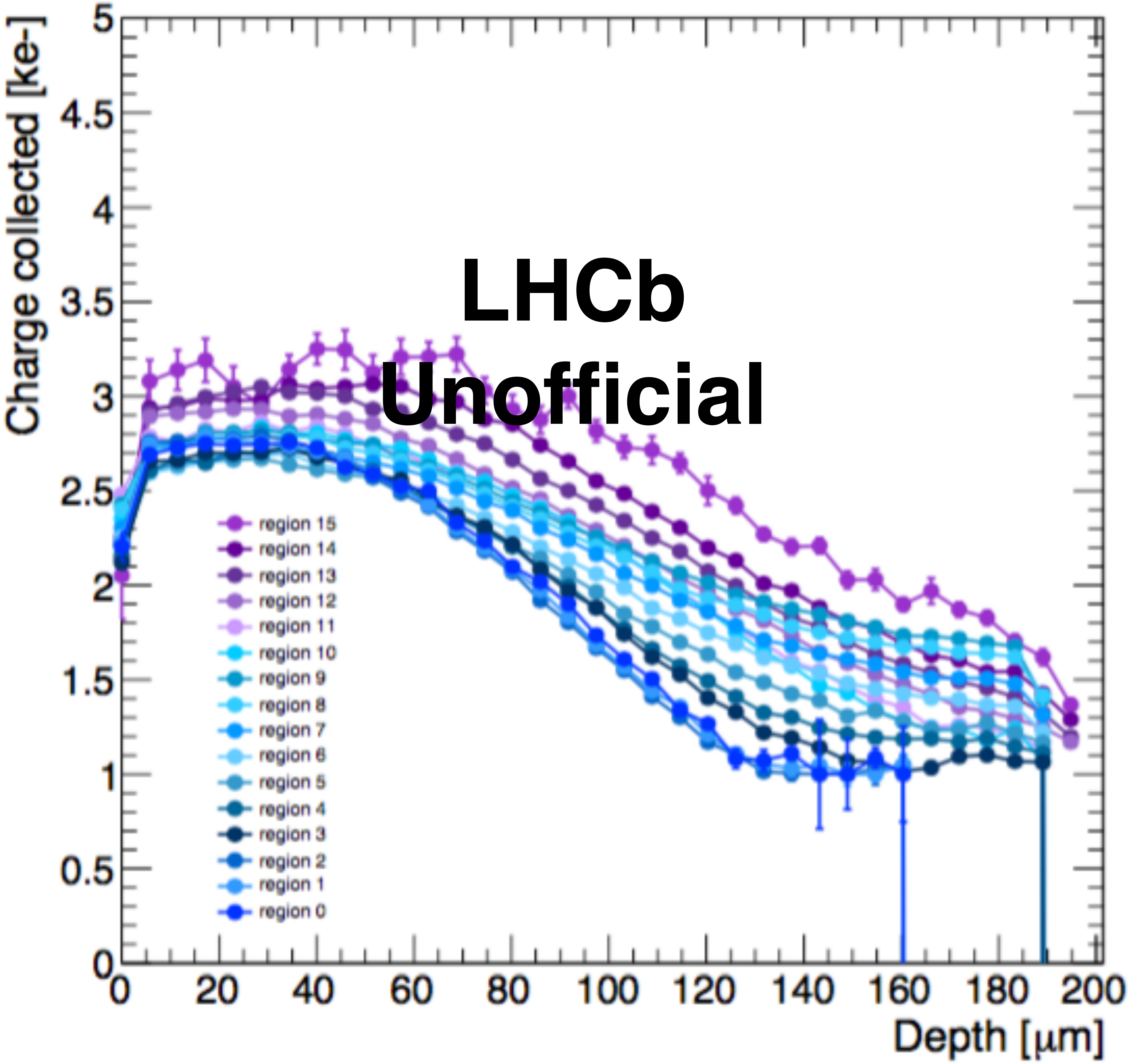


Charge Collection and Depletion Depth

Non-Uniform proton Irradiated sensors at IRRAD.

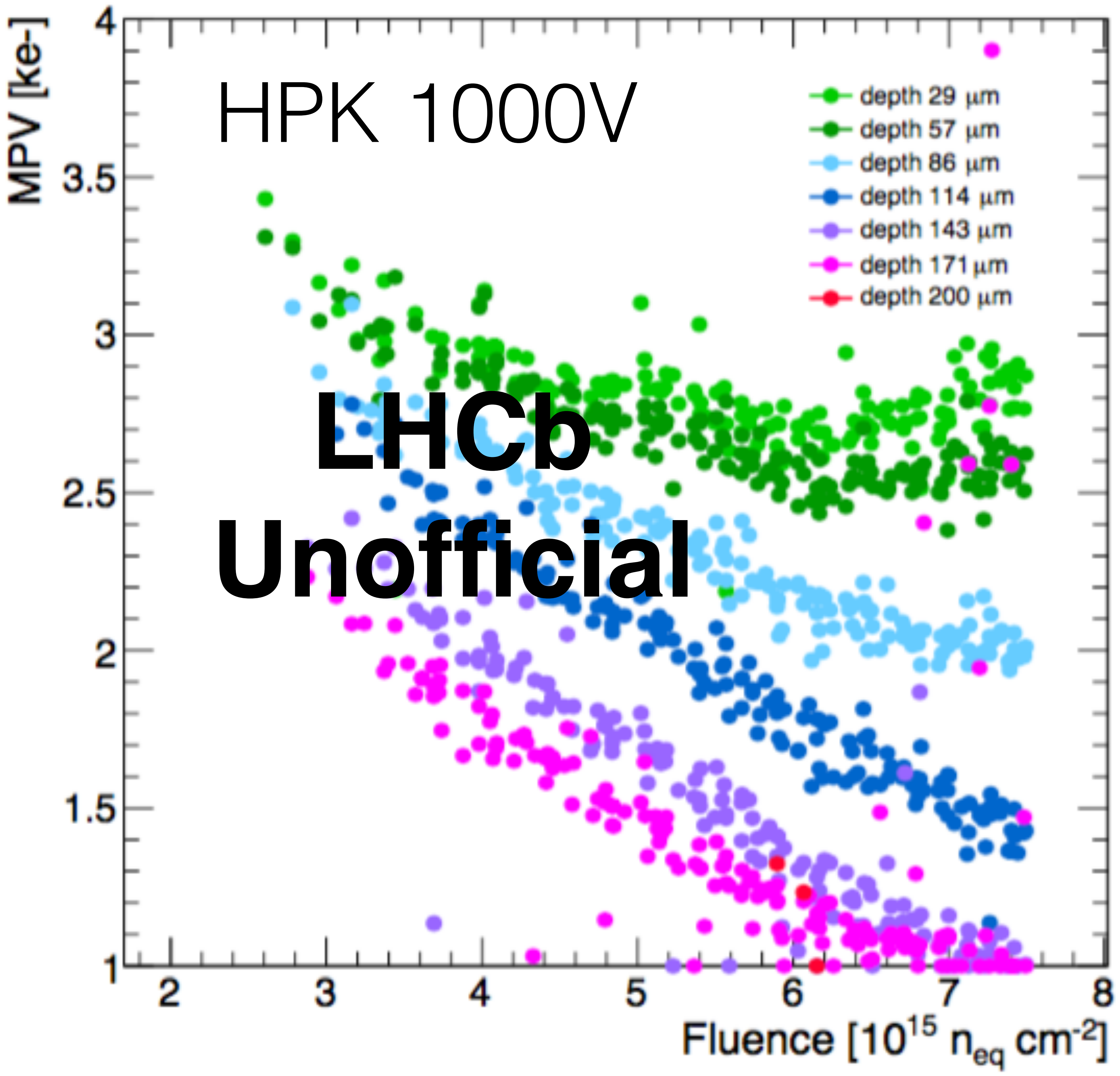
Non-uniform profile allows study of charge collection as a function of dose.

Correlate dosimetry measurements to activation on the sensors.

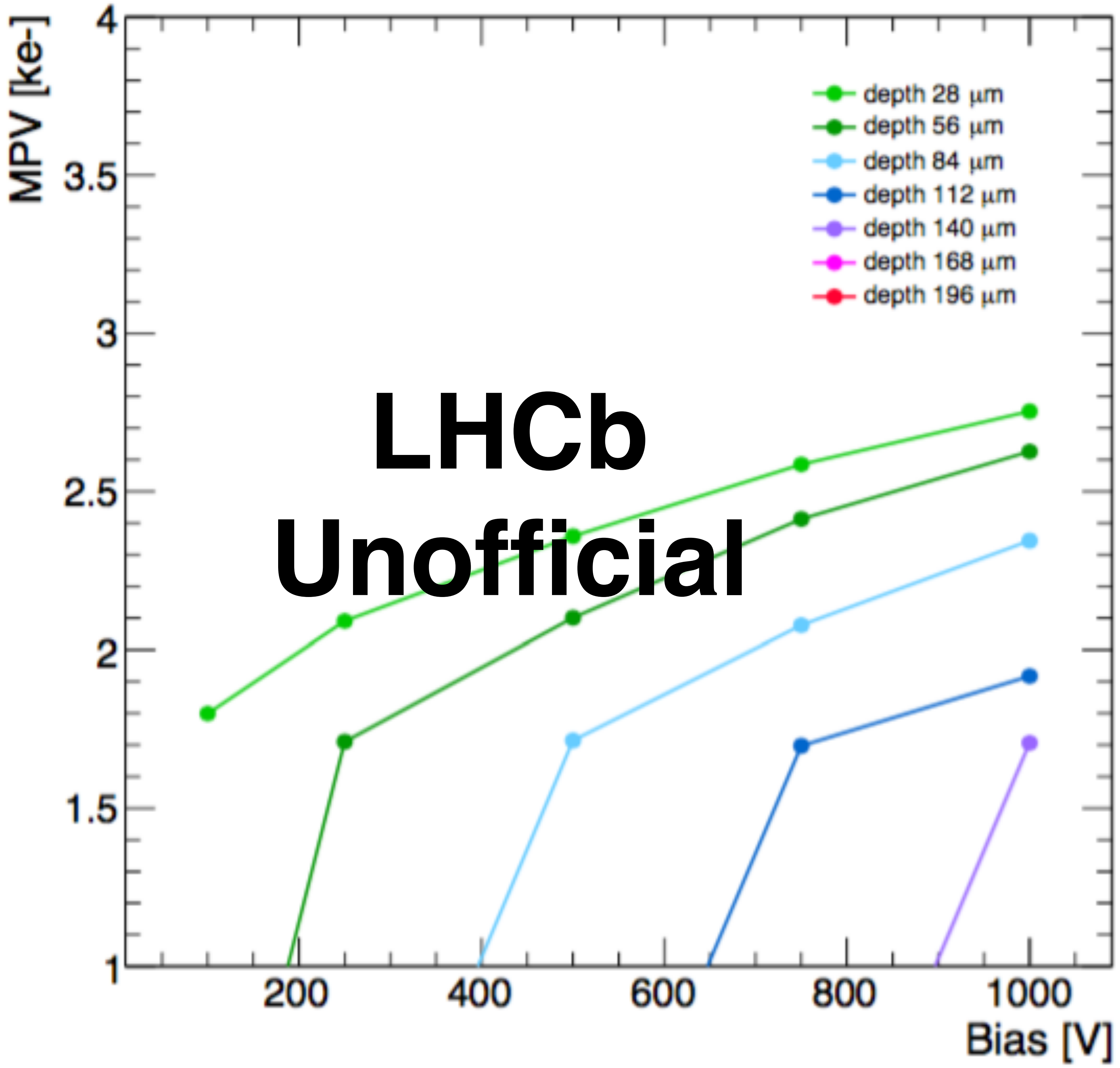


Charge Collection and Depletion Depth

Non-Uniform proton Irradiated sensors at IRRAD.

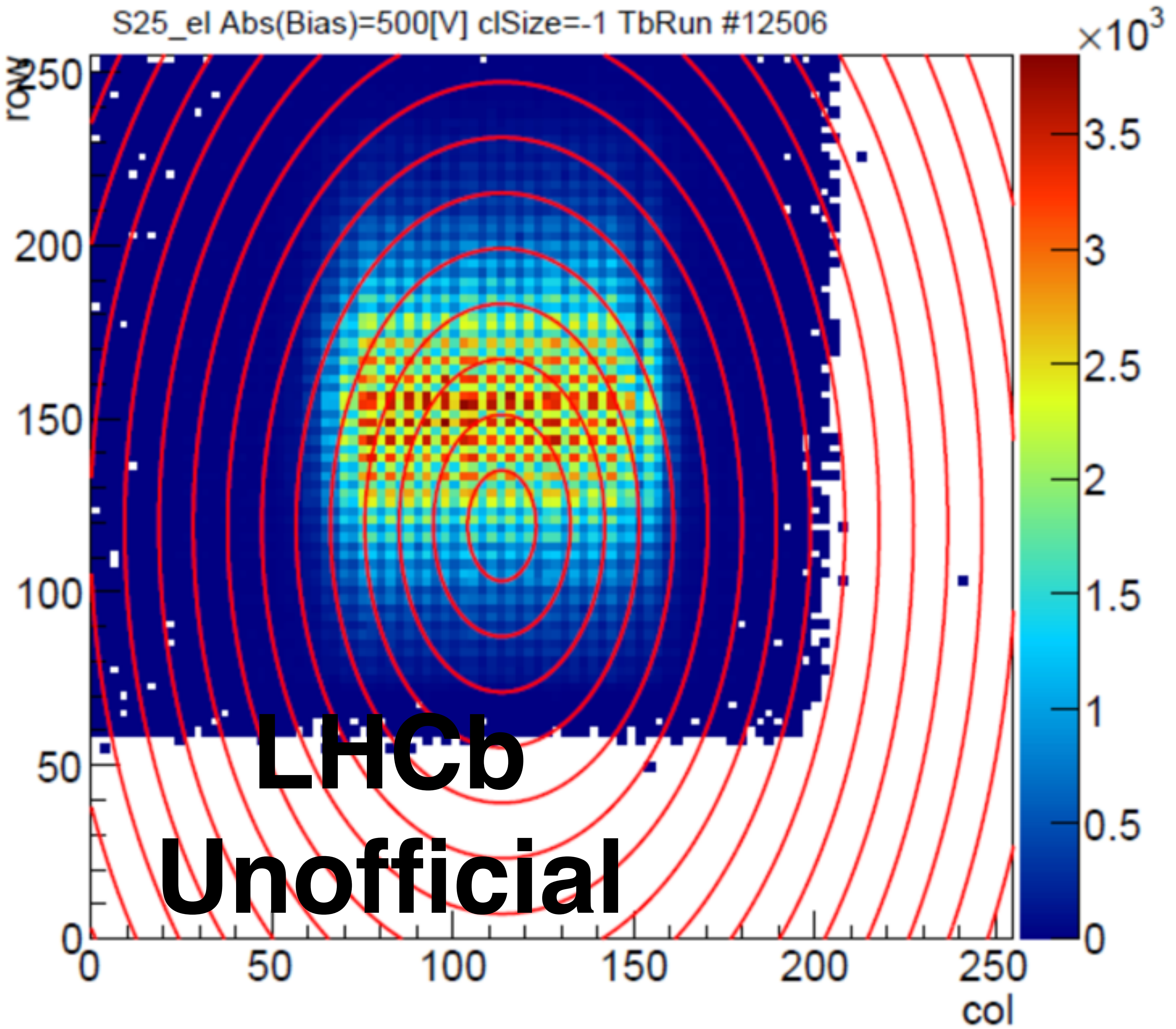


Uniform neutron Irradiated sensors at JSI.



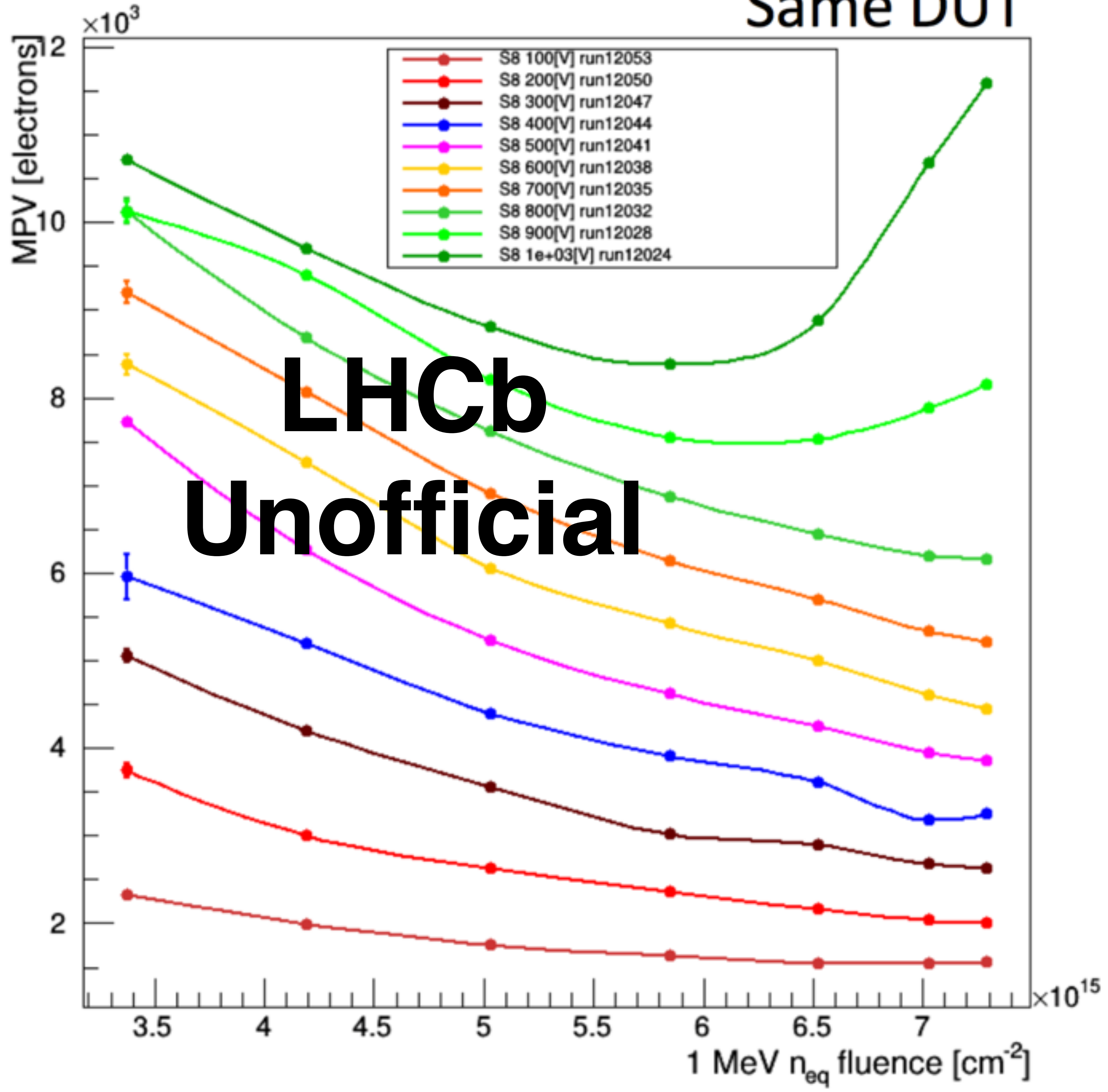
Charge Collection

Non-Uniform proton Irradiated sensors at IRRAD, Binned in fluence.



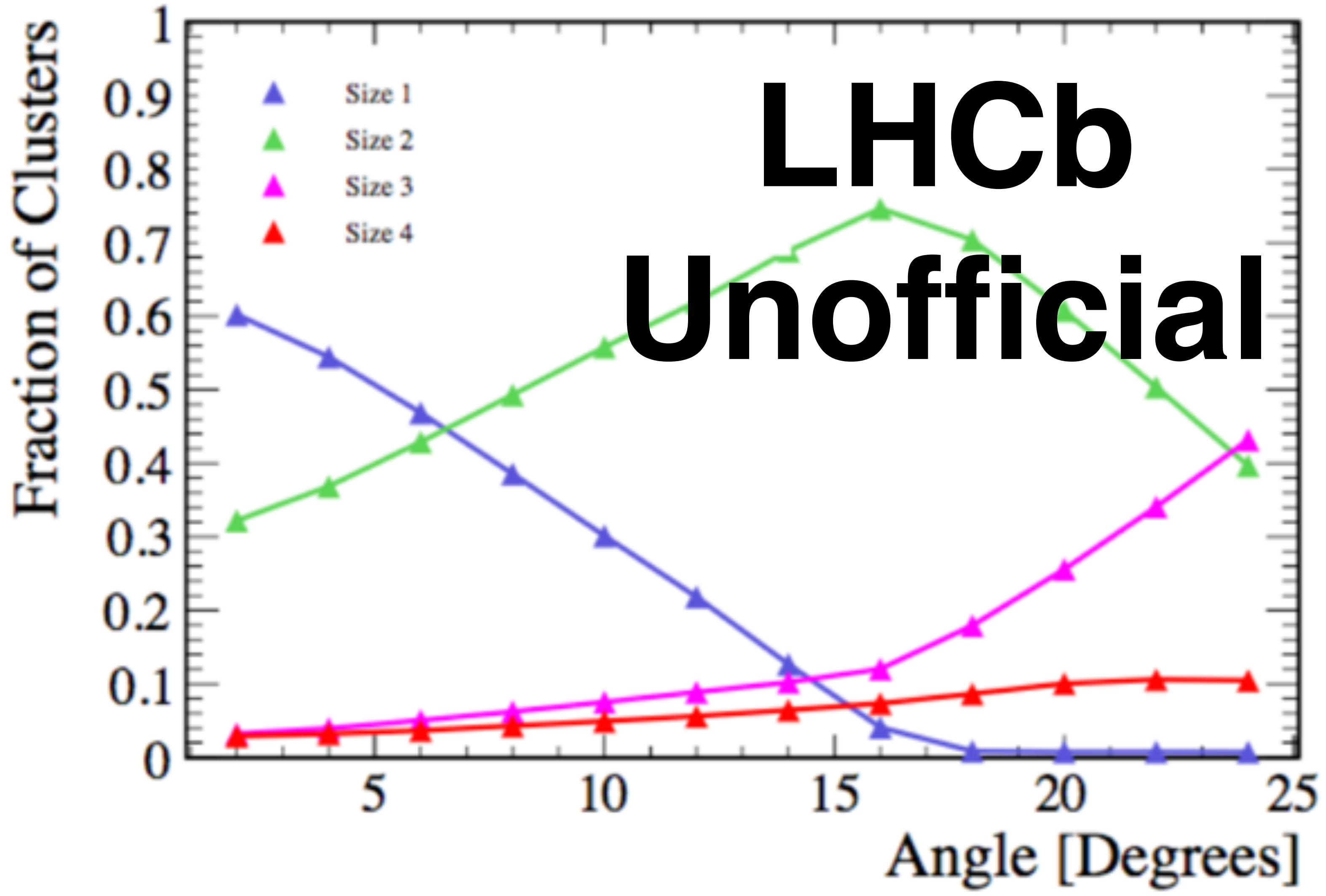
Similar effect observed using a completely different method.

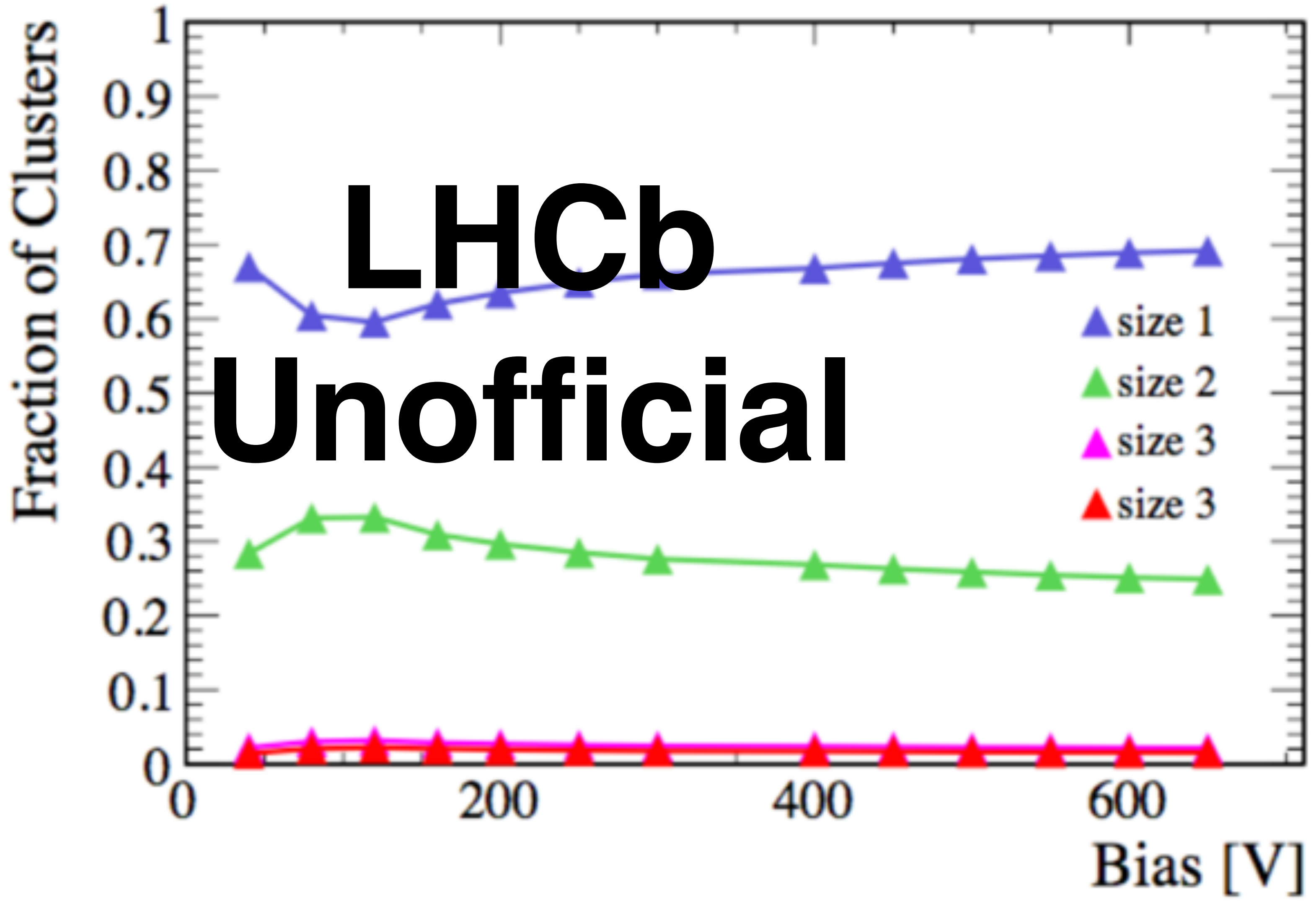
Same DUT



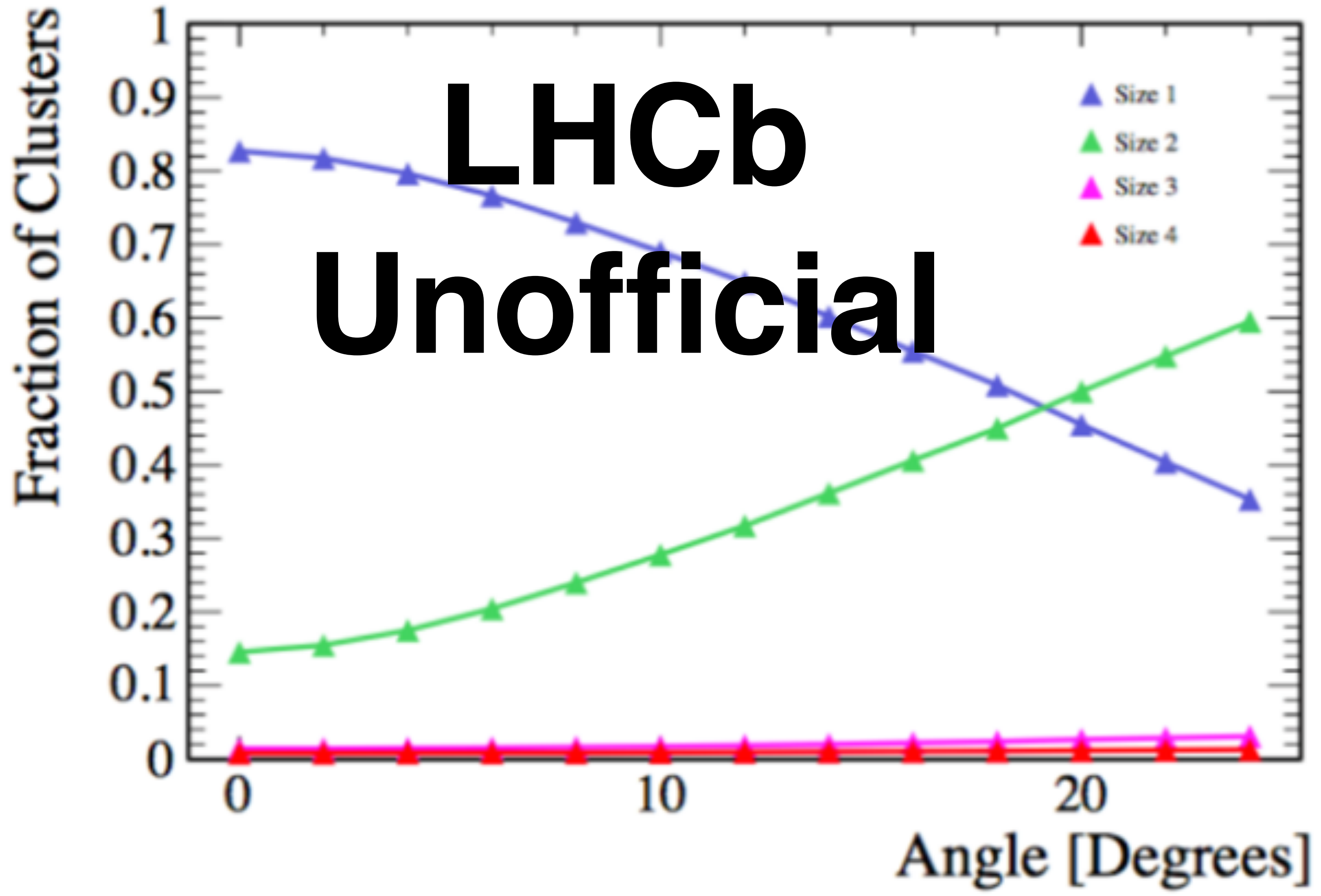
Cluster Sizes Distributions

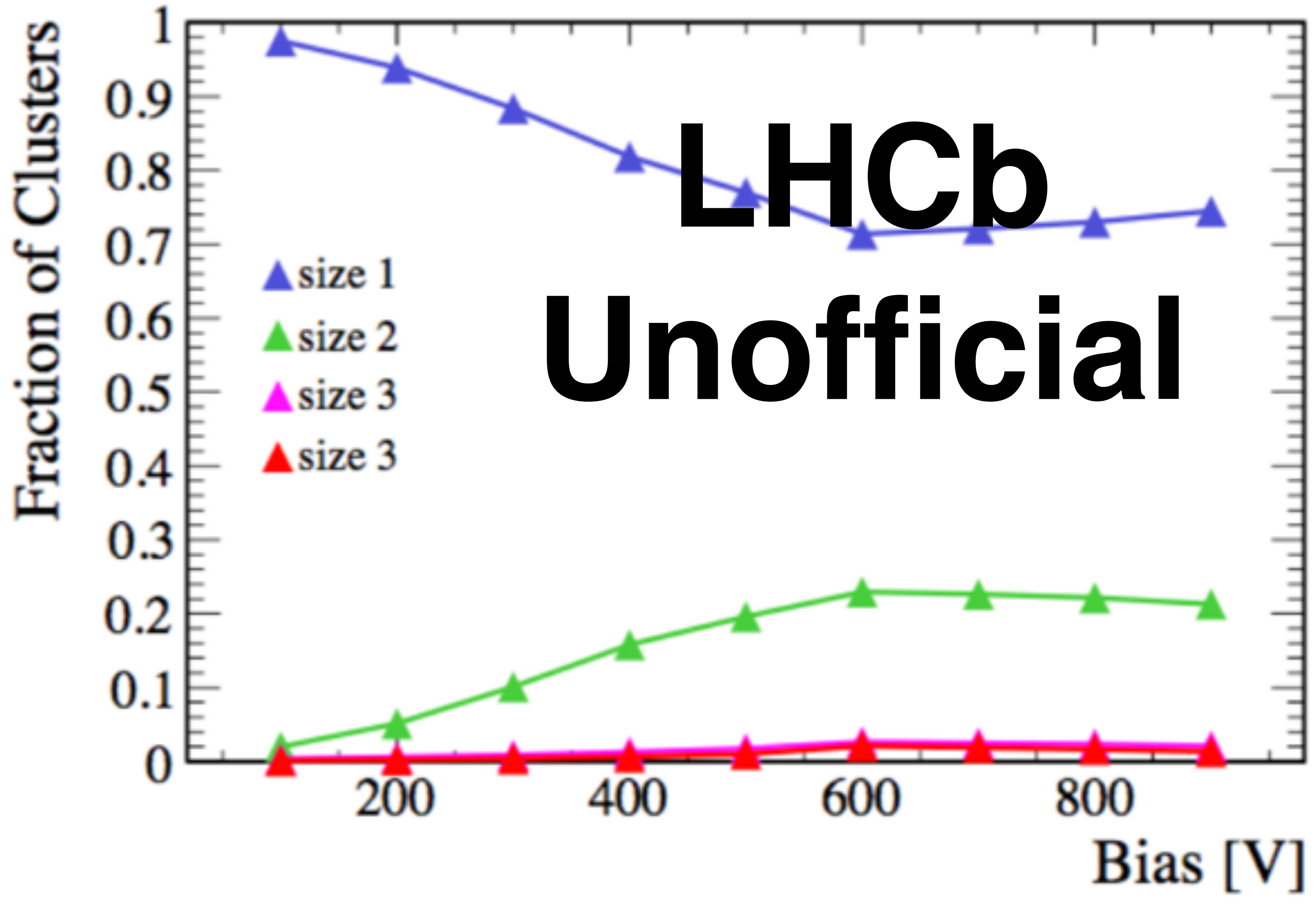
Non-Irradiated
Micron n-on-p





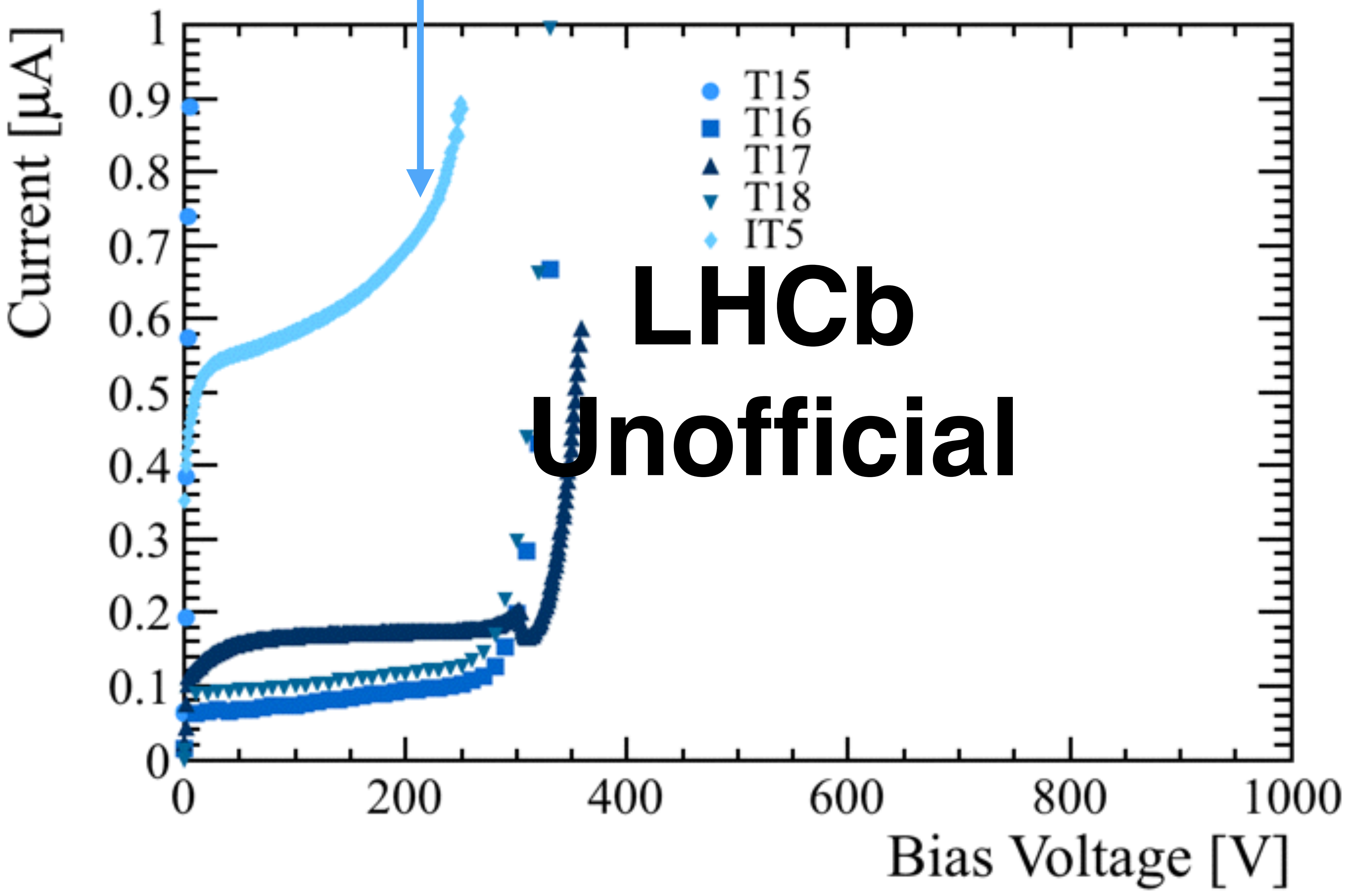
Post Irradiation
Micron n-on-p





IV Analysis

Thinned chip micron n-on-p assembly from IZM (for later).



Scaling of leakage current per area.