Leakage Current Measurements from LHCb

Vinícius Franco Lima

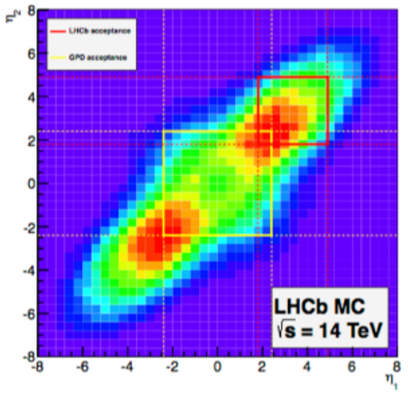
23/04/18

Silicon Detectors in LHCb

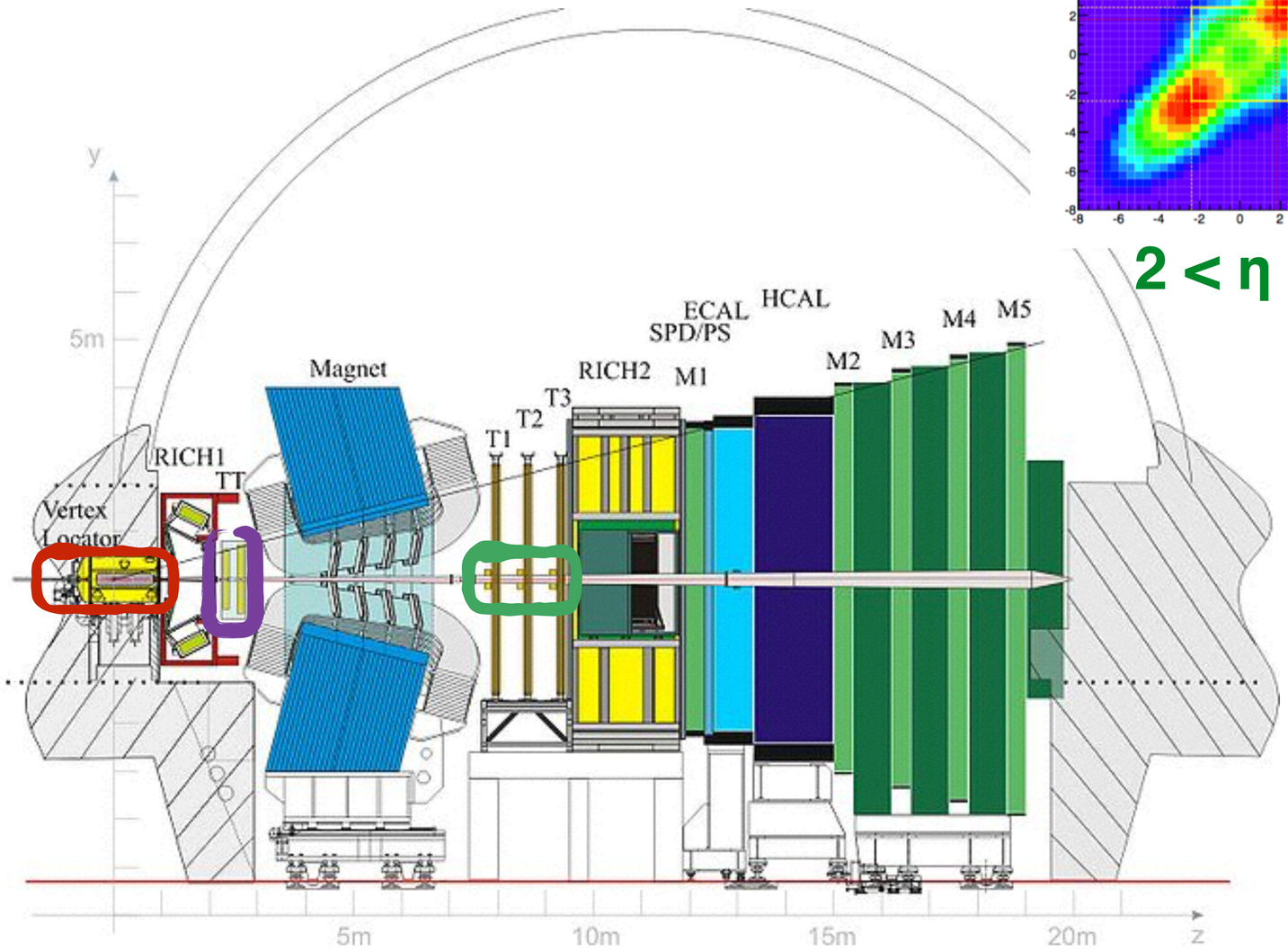
Vertex Locator (VELO)

Tracker Turicensis (TT)

Inner Tracker (IT)



$2 < \eta < 5$



Int. J. Mod. Phys. A **30**, 1530022 (2015)

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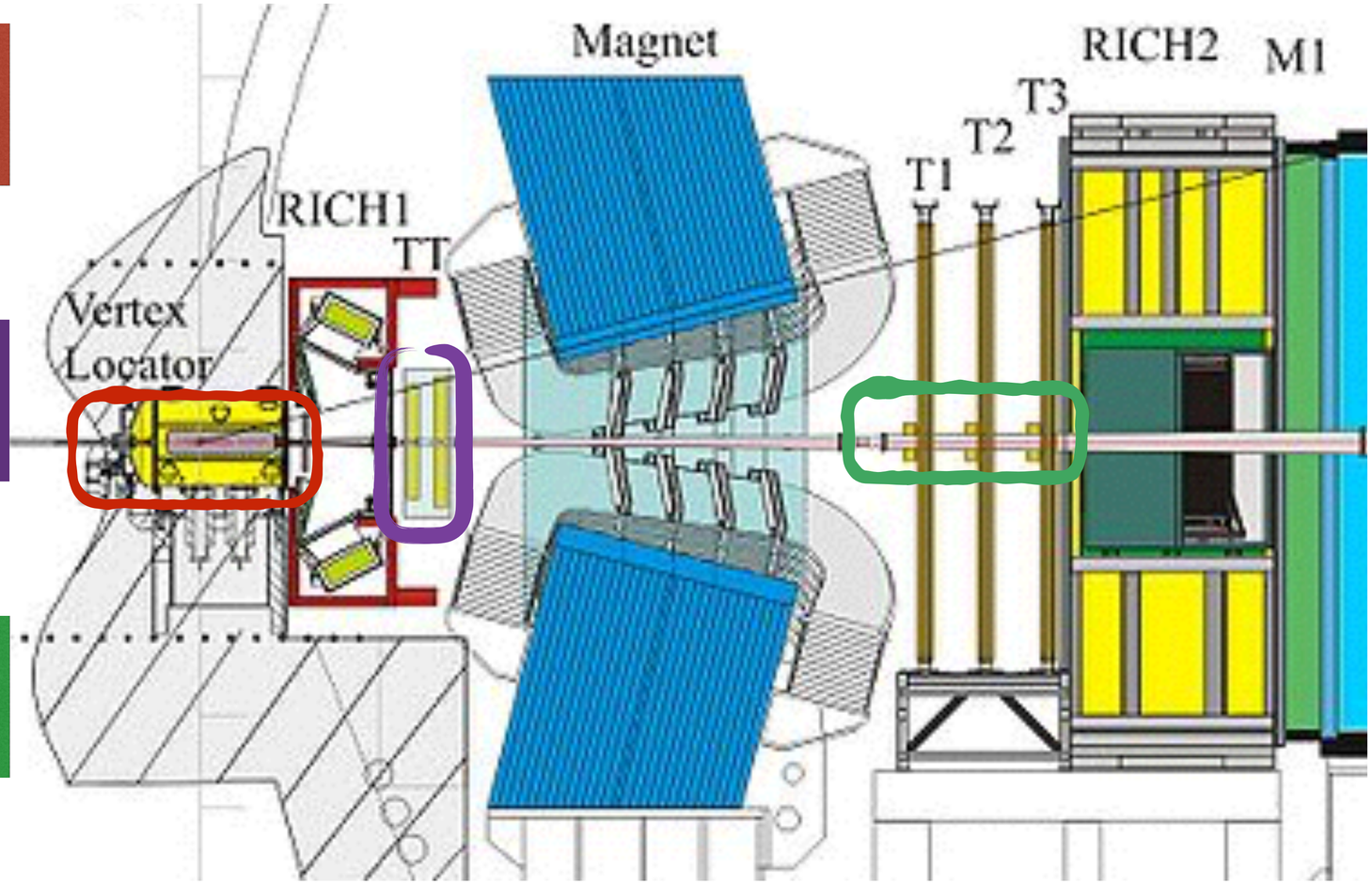

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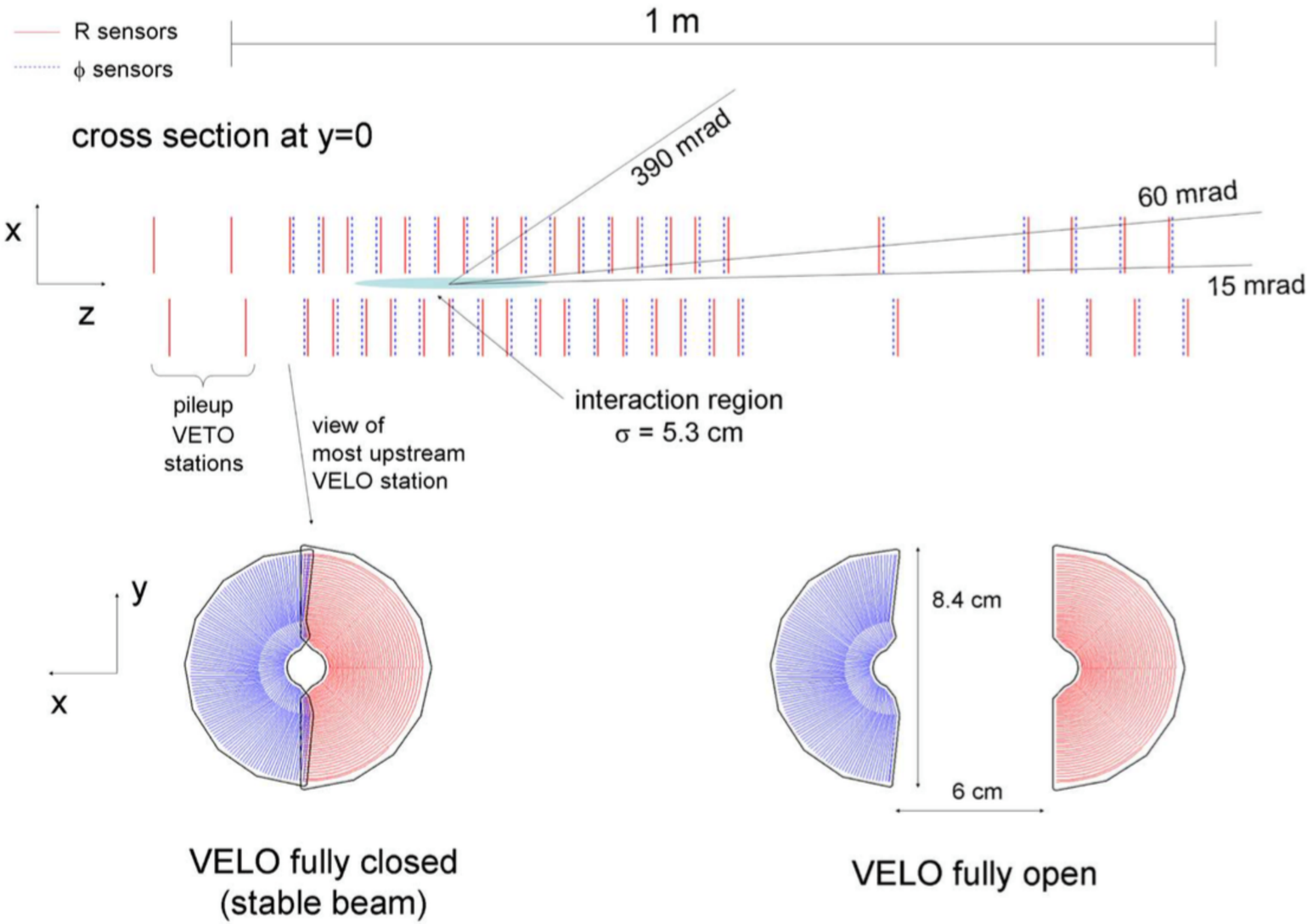
VELO

42 modules with R and ϕ sensors.

Evaporative CO_2 cooling.

Proximity to interaction region: 8.2mm

Intense, non-uniform radiation flux.

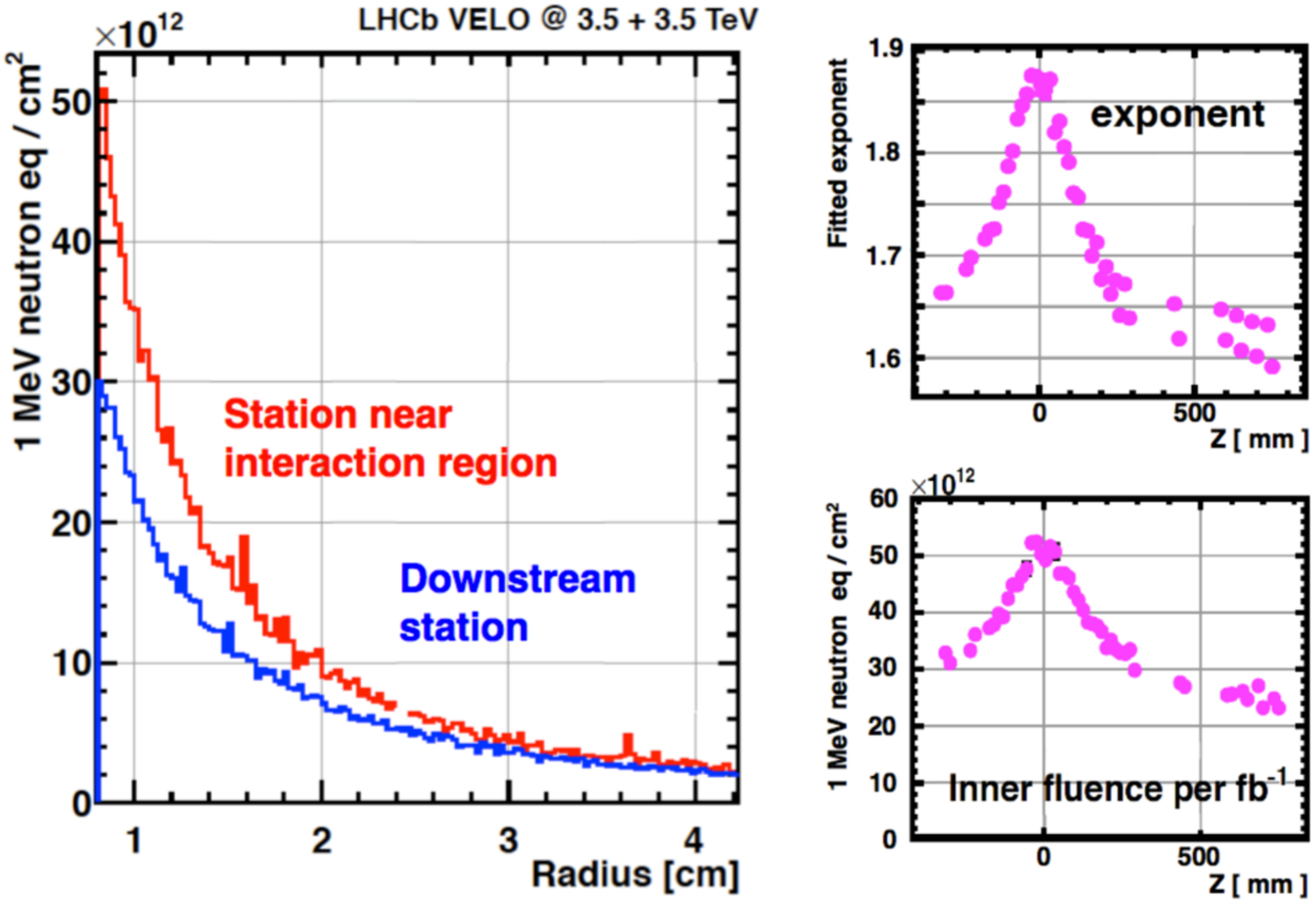


VELO

Expected fluence in the most irradiated regions up to $5x10^{13}$ 1MeV n_{eq}/cm^2

Radiation flux follows $r^{-1.9}$ shape.

Proximity to interaction region: 8.2mm



2010 + 2011 Data

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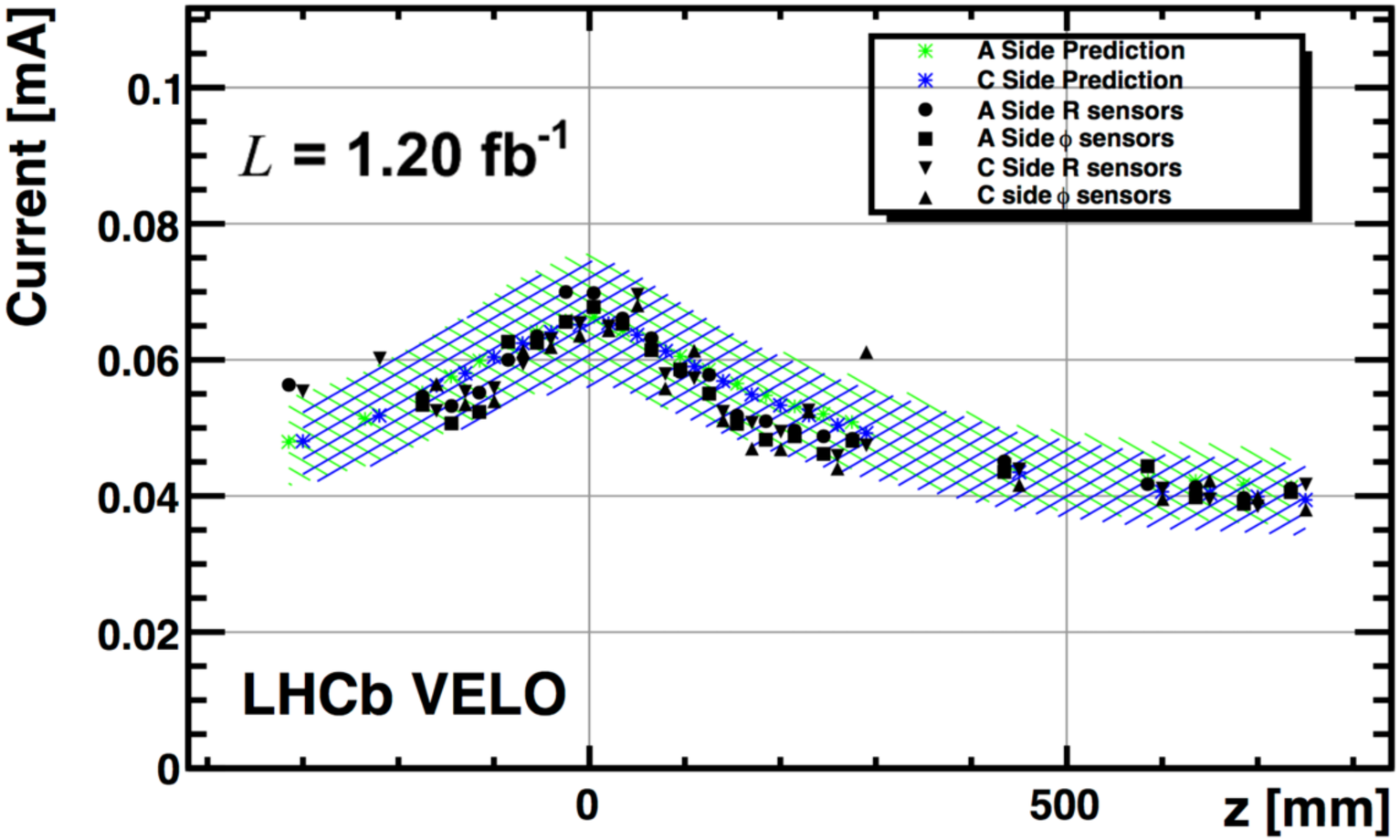
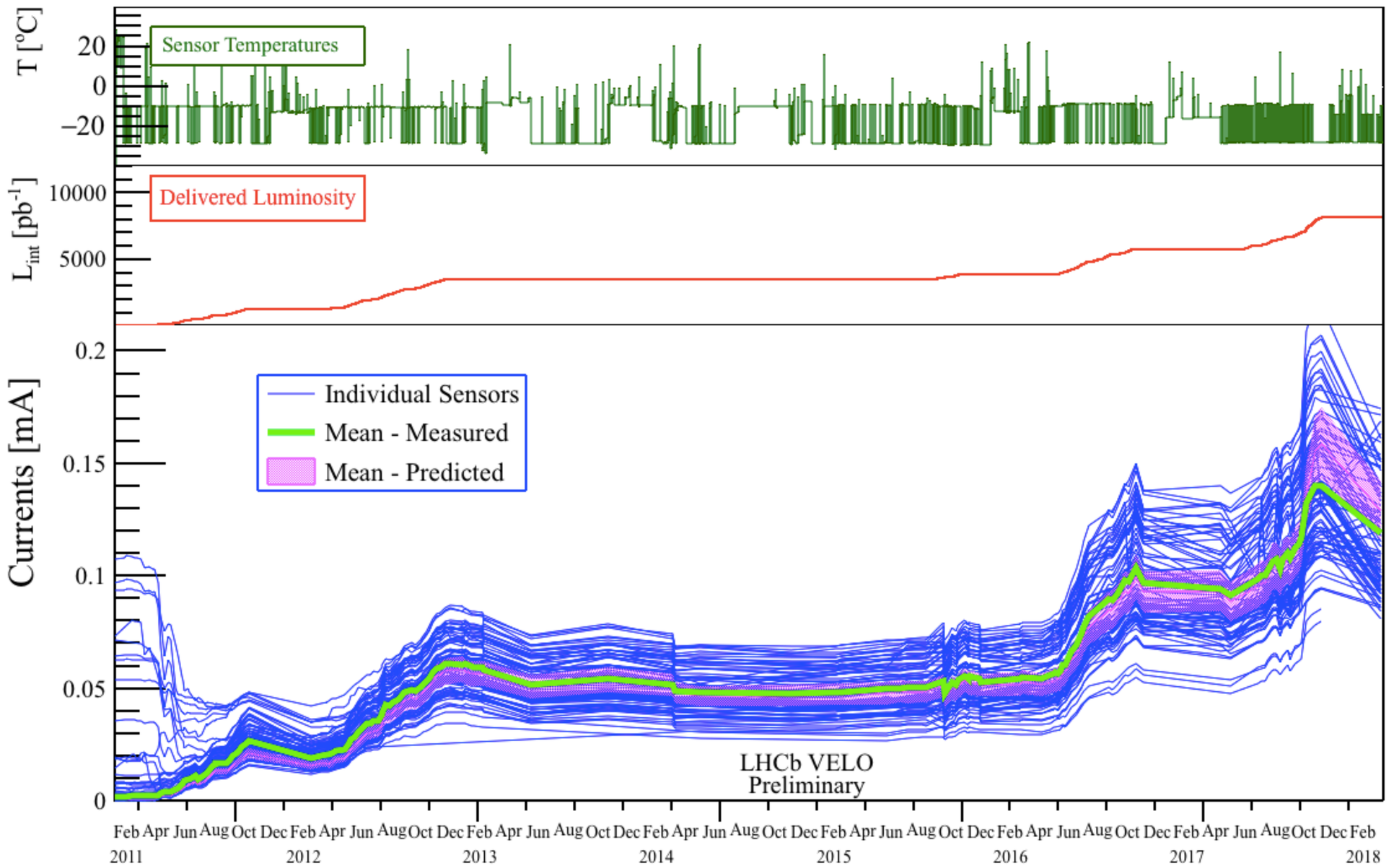
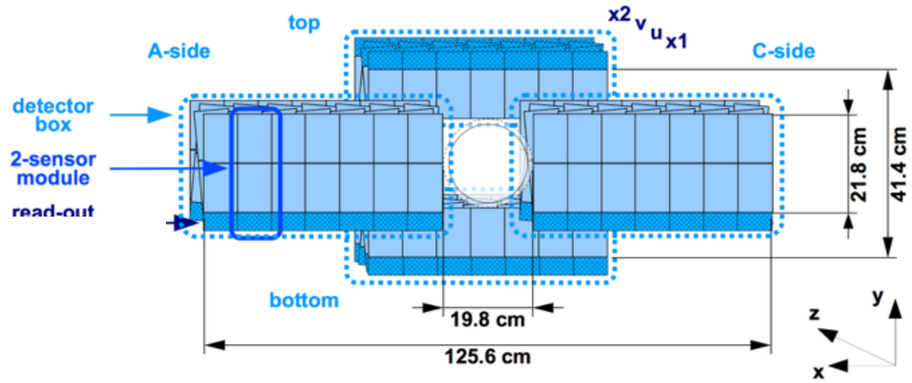


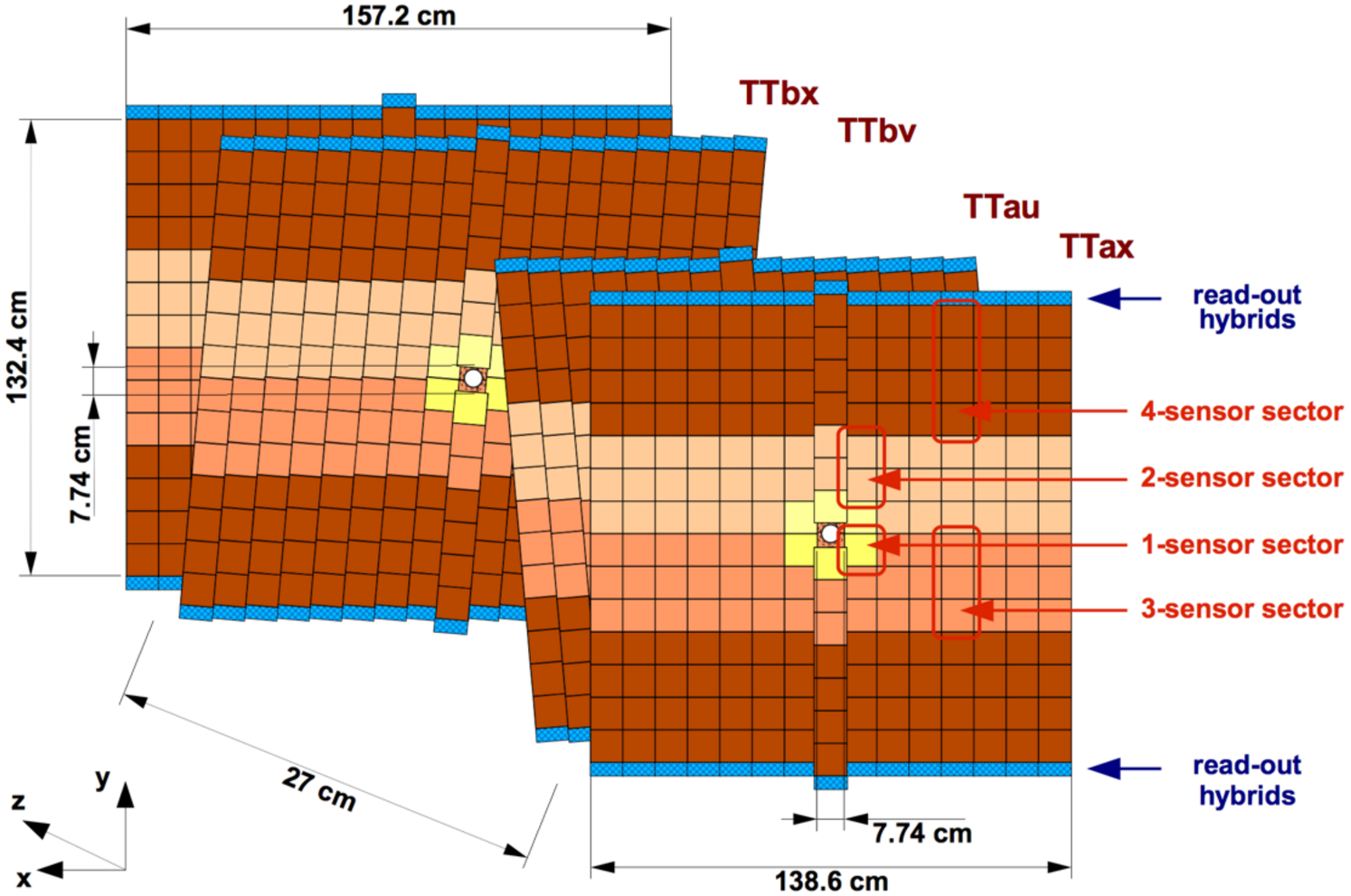
2010 + 2011 Data

VELO


T [°C]
20
0
−20
Sensor Temperatures
L_{int} [pb^{-1}]
10000
5000
Delivered Luminosity
Currents [mA]
0.2
0.15
0.1
0.05
0
Individual Sensors
Mean - Measured
Mean - Predicted
LHCb VELO
Preliminary
Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb Apr Jun Aug Oct Dec Feb
2011
2012
2013
2014
2015
2016
2017
2018

Silicon Tracker



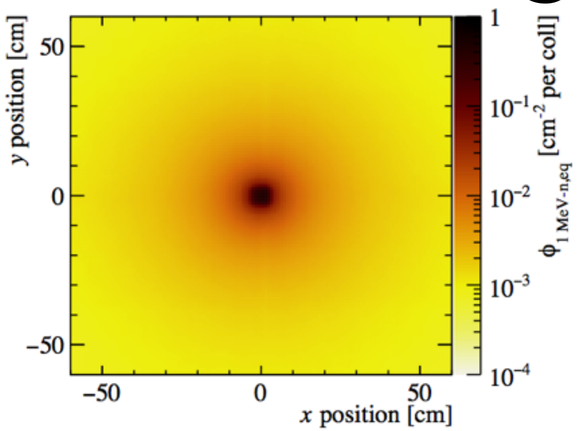


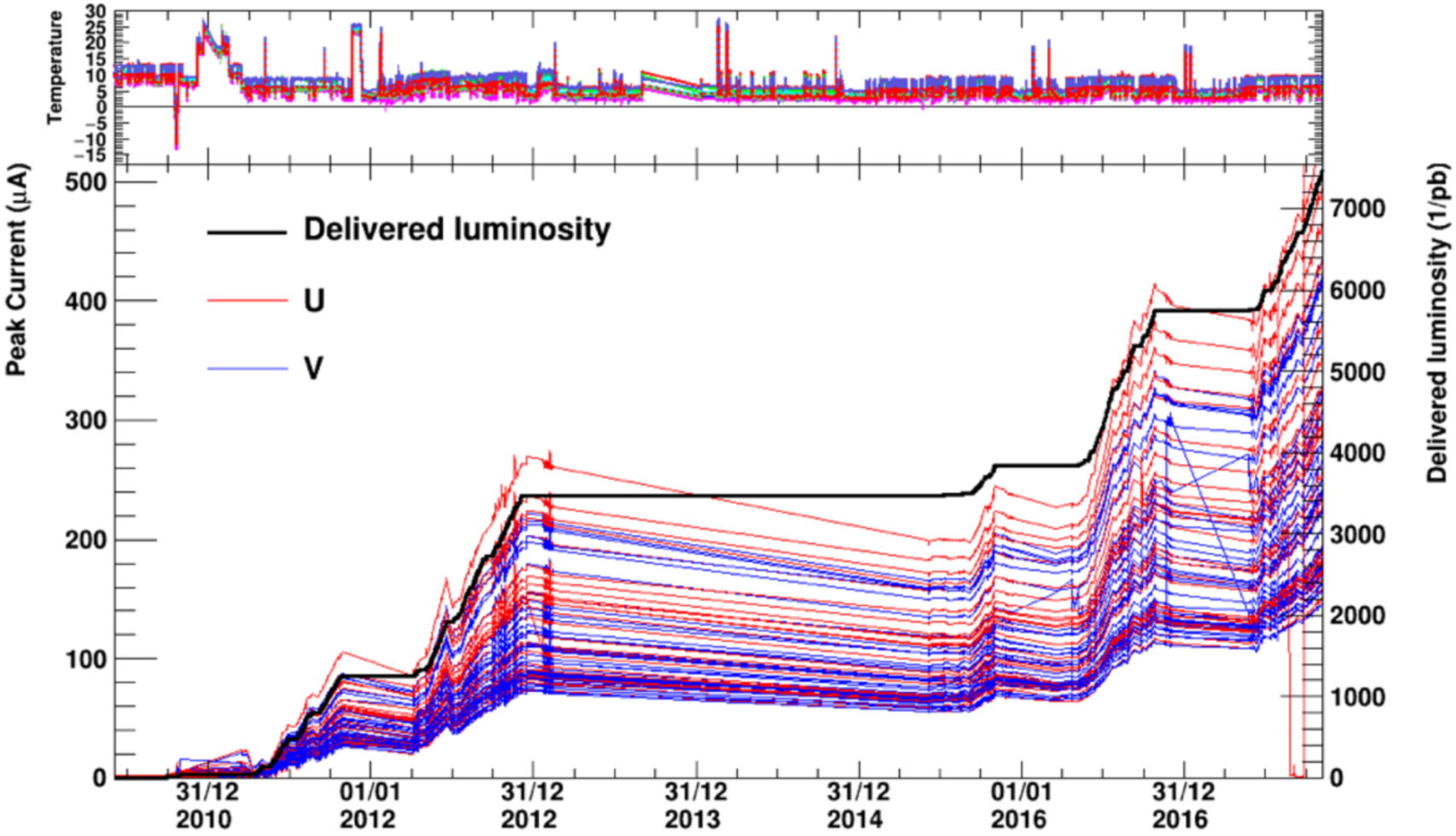
320 to 500 μm thick sensors.

Silicon modules installed both in TT and IT stations.

Proximity to interaction region: 8.2mm

TT Leakage Current

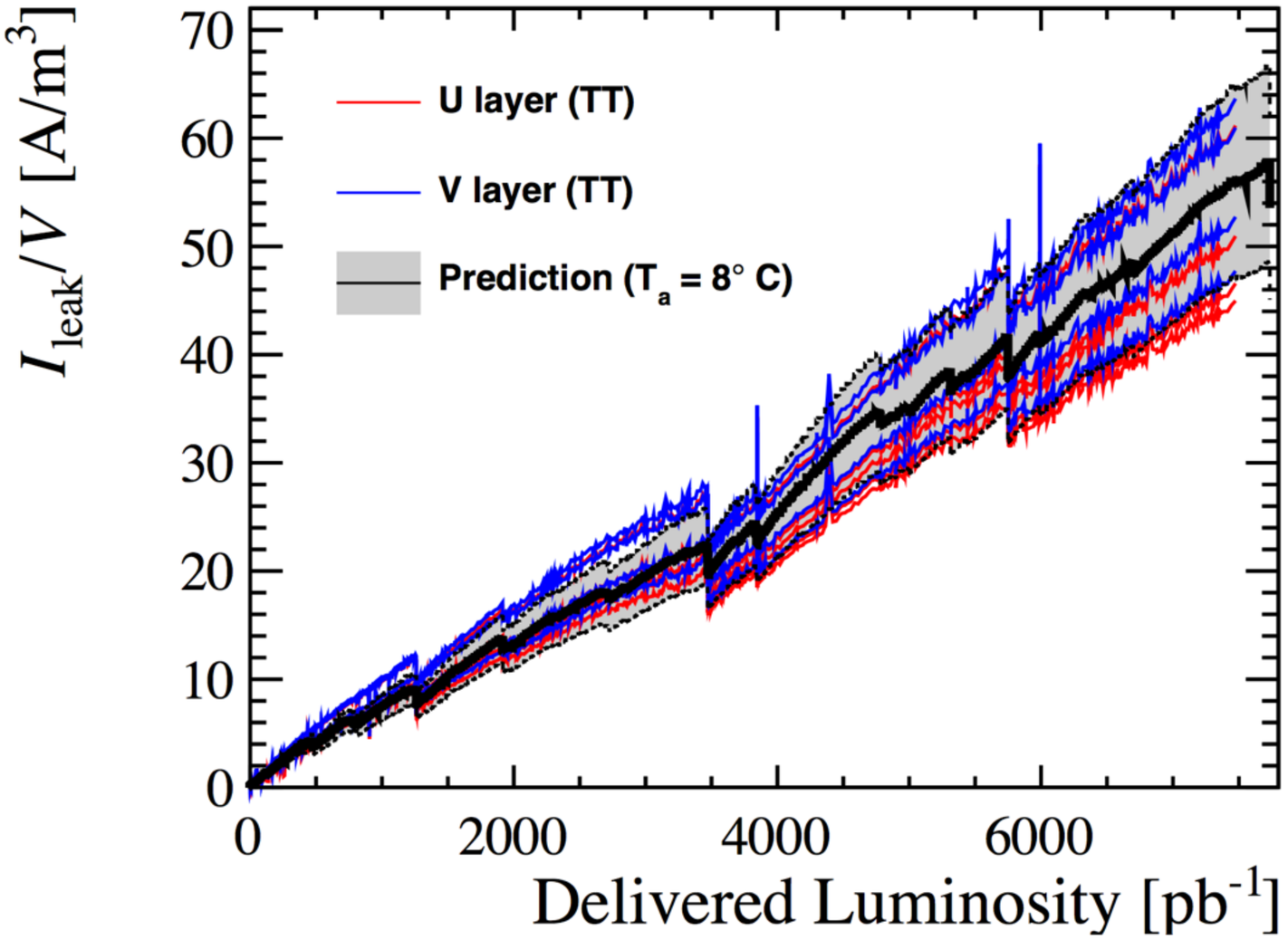




ST Leakage Current

Current is defined as peak current per sensor per fill.

Shown here is the prediction based on the expected does and annealing periods.



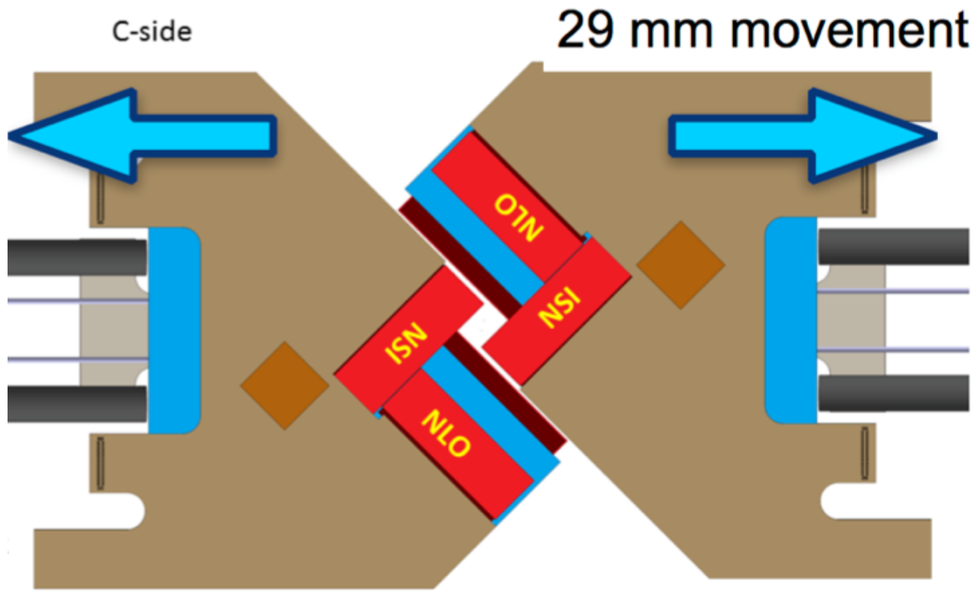
The VELO Upgrade

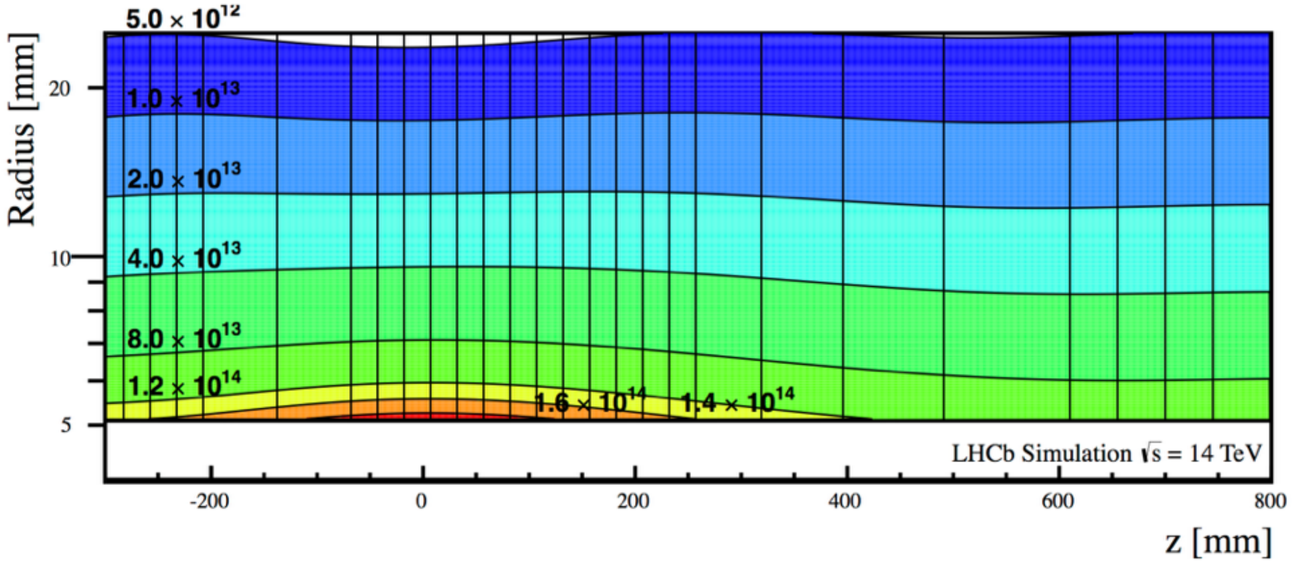
Full 40 MHz readout.

Closest detector to interaction point (5.1mm). Non-Uniform radiation flux.

Data Bandwidth of 20 Gbit/s for central ASICS.

Microchannel CO2 cooling, sensor temperature <-20°C





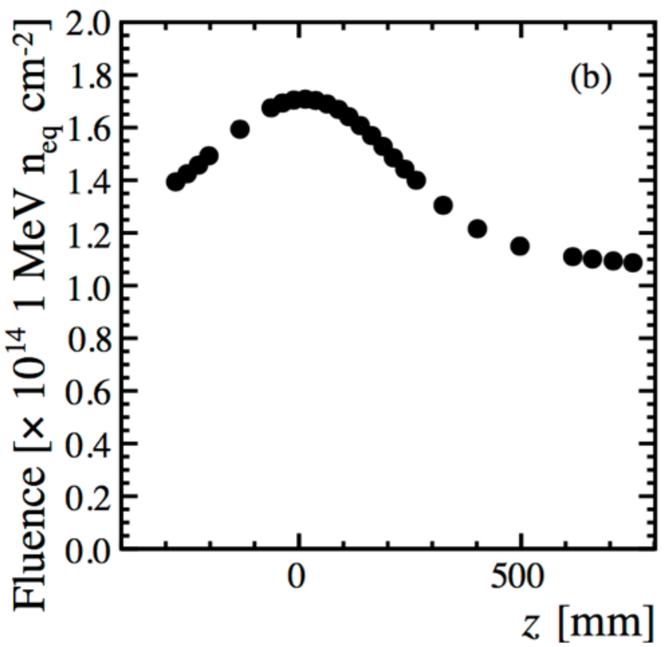
VELO Upgrade

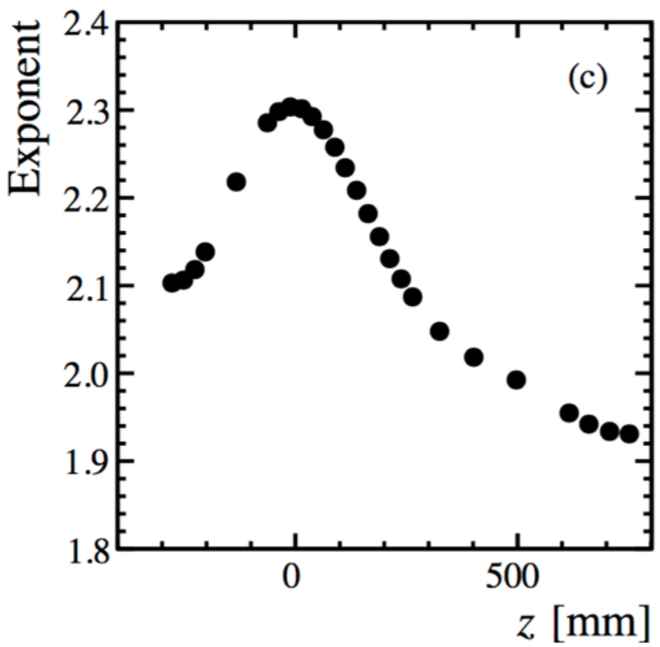
Expected fluence in the most irradiated regions up to 1.5×10^{14} 1MeV n_{eq}/ cm^2 per fb^{-1}

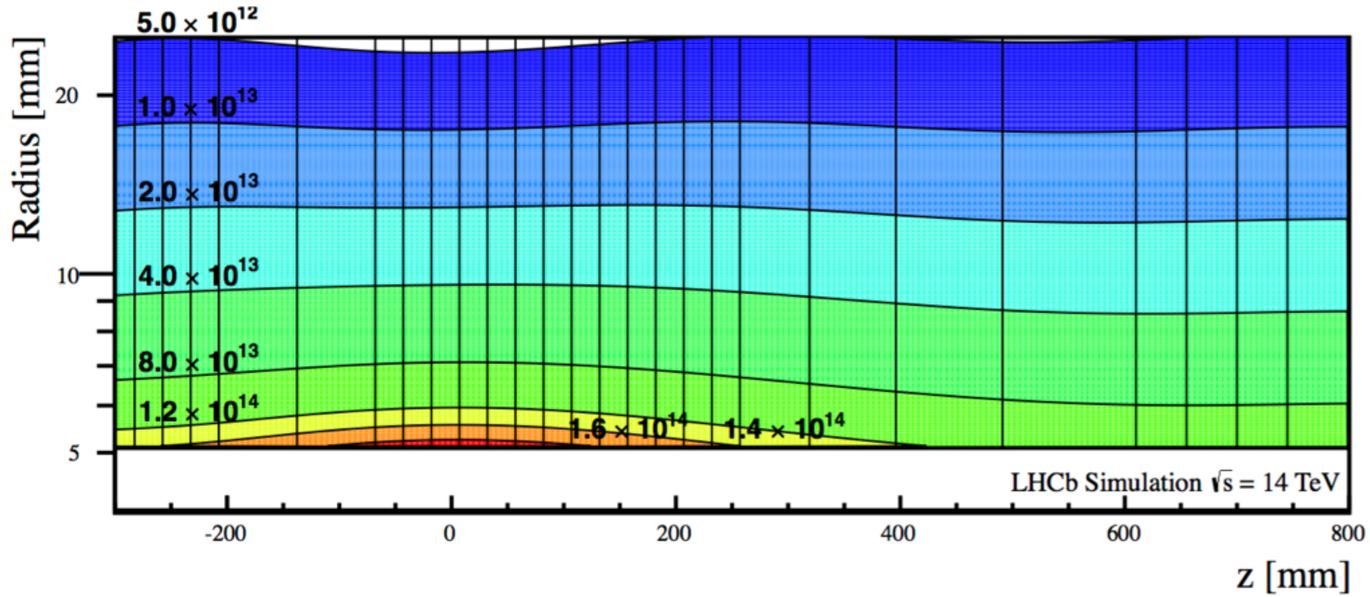
Radiation flux follows $r^{-2.3}$ shape.

Proximity to interaction region: 5.1mm

Total Integrated Luminosity: 50fb^{-1} !





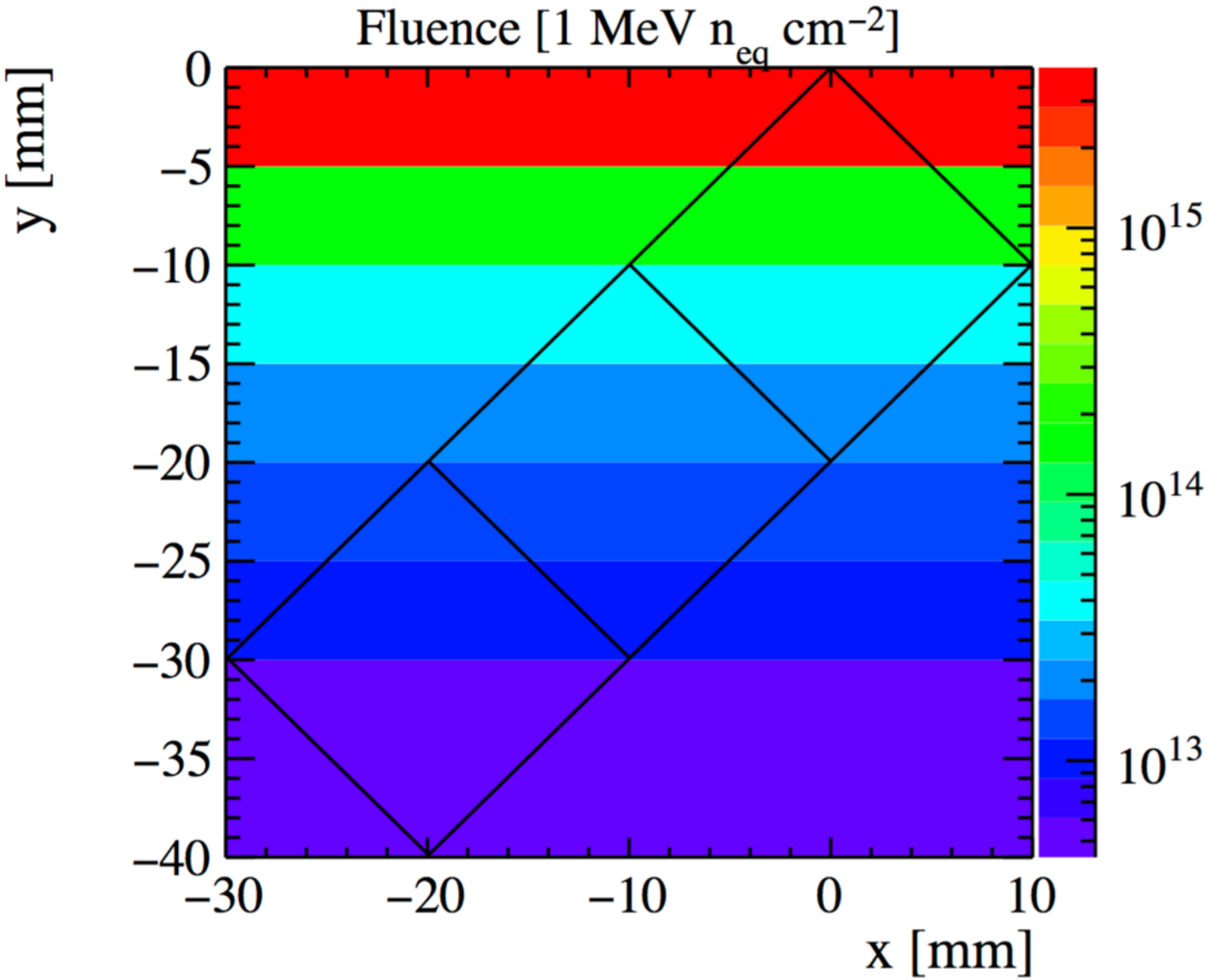


Irradiation

Different Irradiation campaigns were performed.

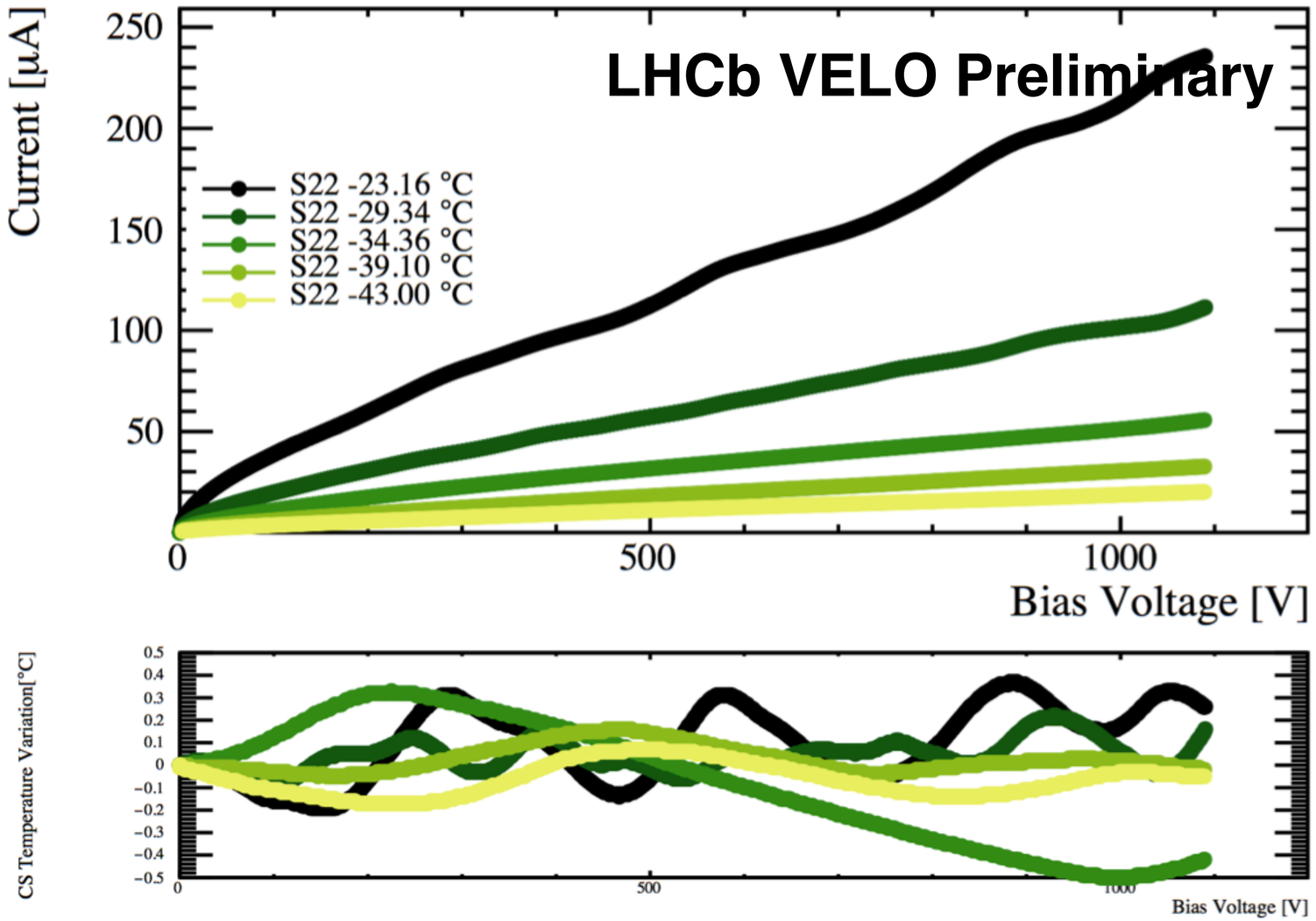
Goal was to confirm the radiation hardness up to 8×10^{15} 1MeV n_{eq}/cm^2

Protons and neutrons uniformly and non-uniformly.



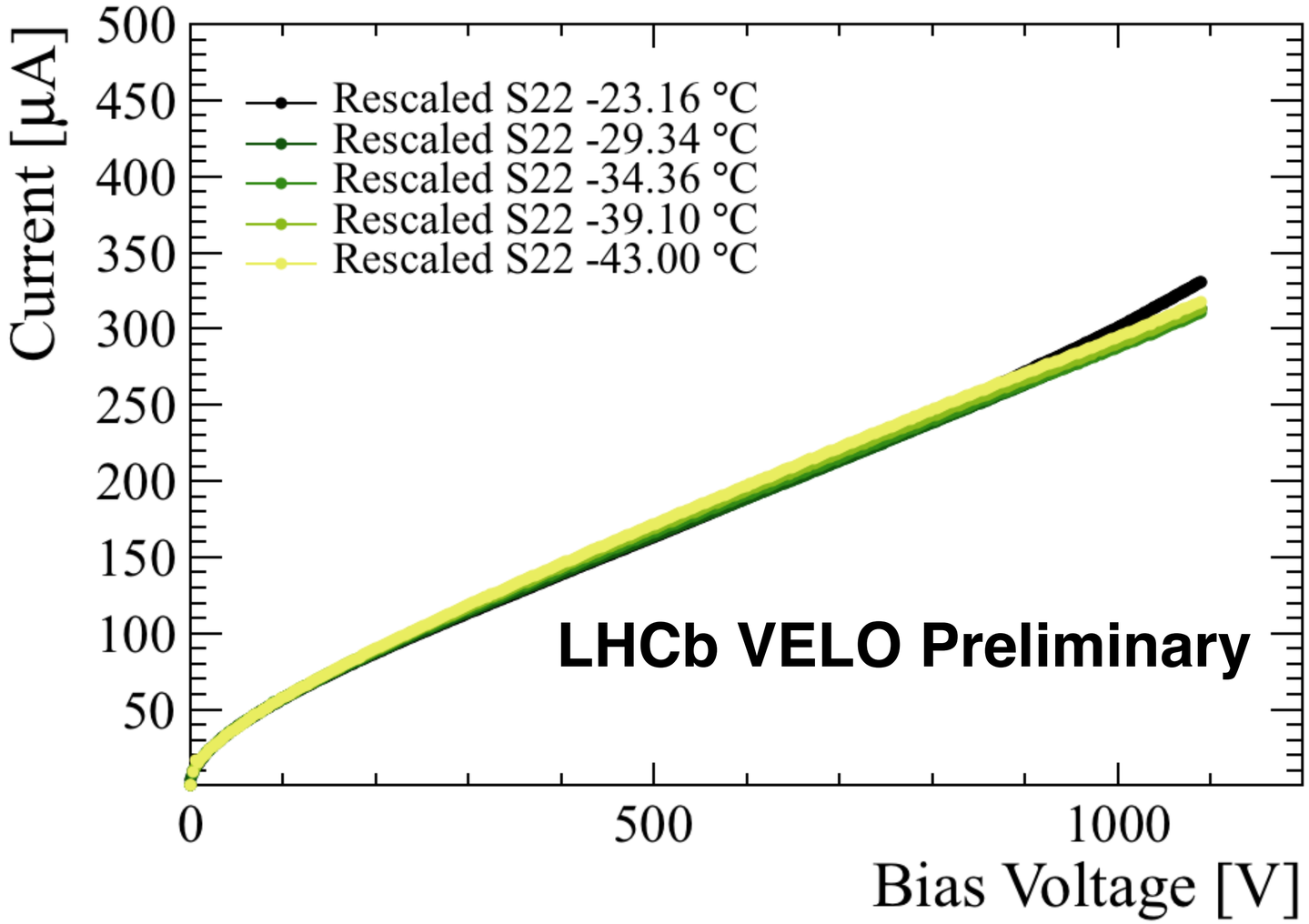
KIT Non-Uniform Profile

Temperature Control



Looking at correlation between the small temperature oscillations in Temperature explains the weird kinks in the IV curves.

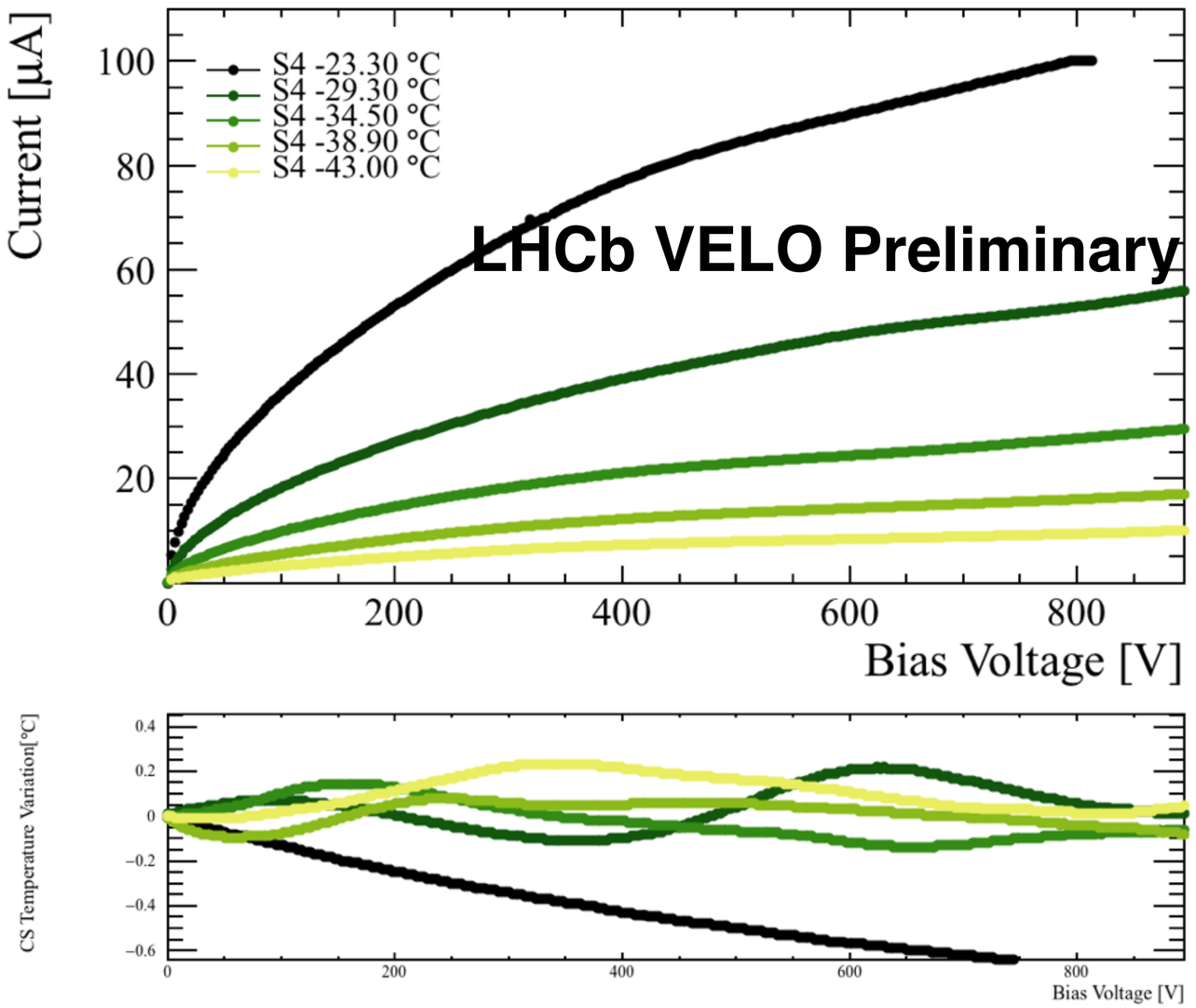
S22



S22 Full Fluence Uniformly irradiated with neutrons at JSI.

Rescaling all IVs to -20°C using the temperature readout removes the kinks and the result seems consistent.

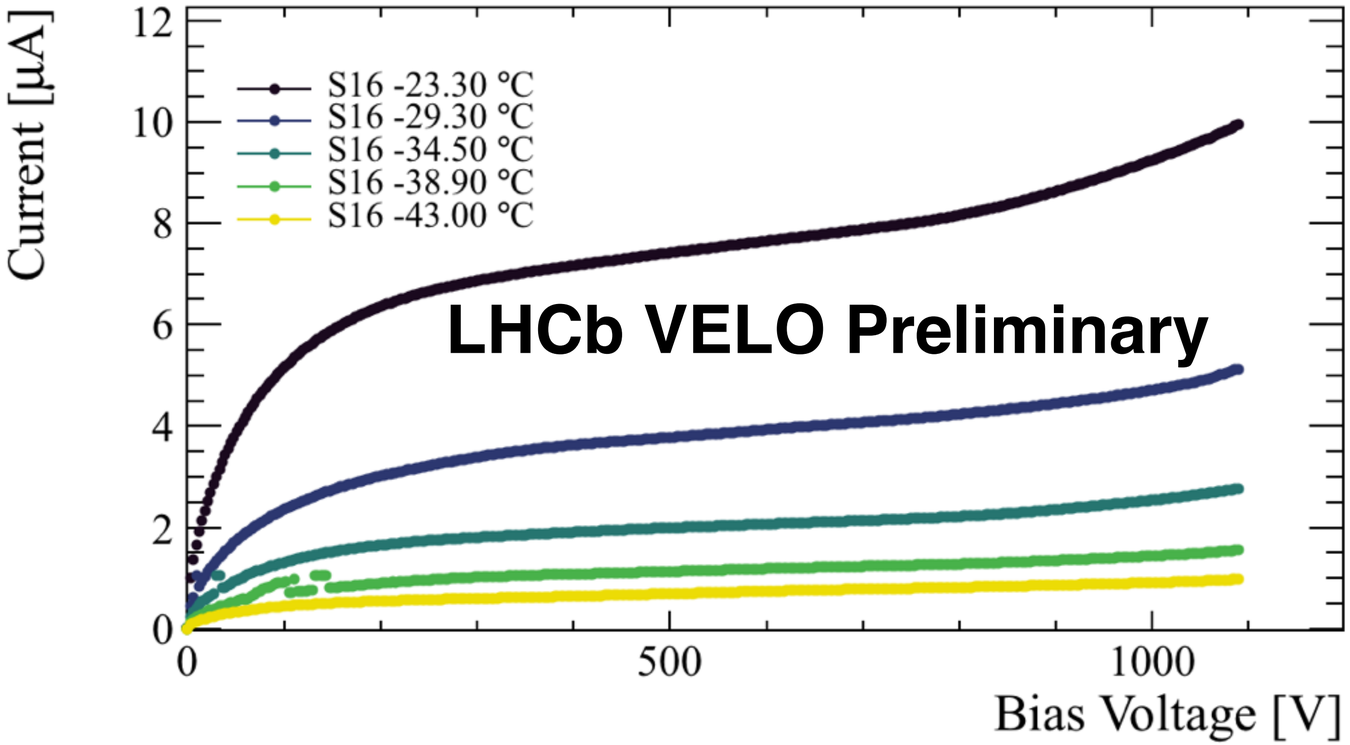
S4

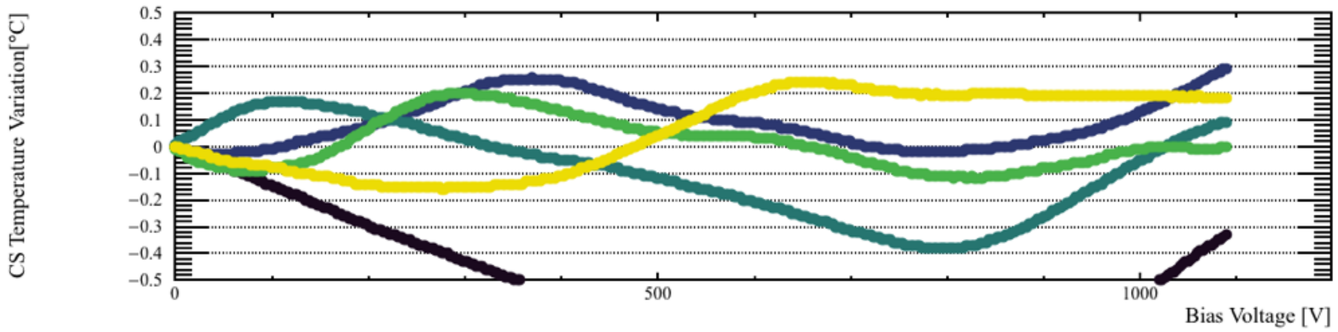


S4 Half Fluence Uniformly irradiated with protons at KIT.

No exponential current behaviour. It doesn't happen for uniformly irradiated.

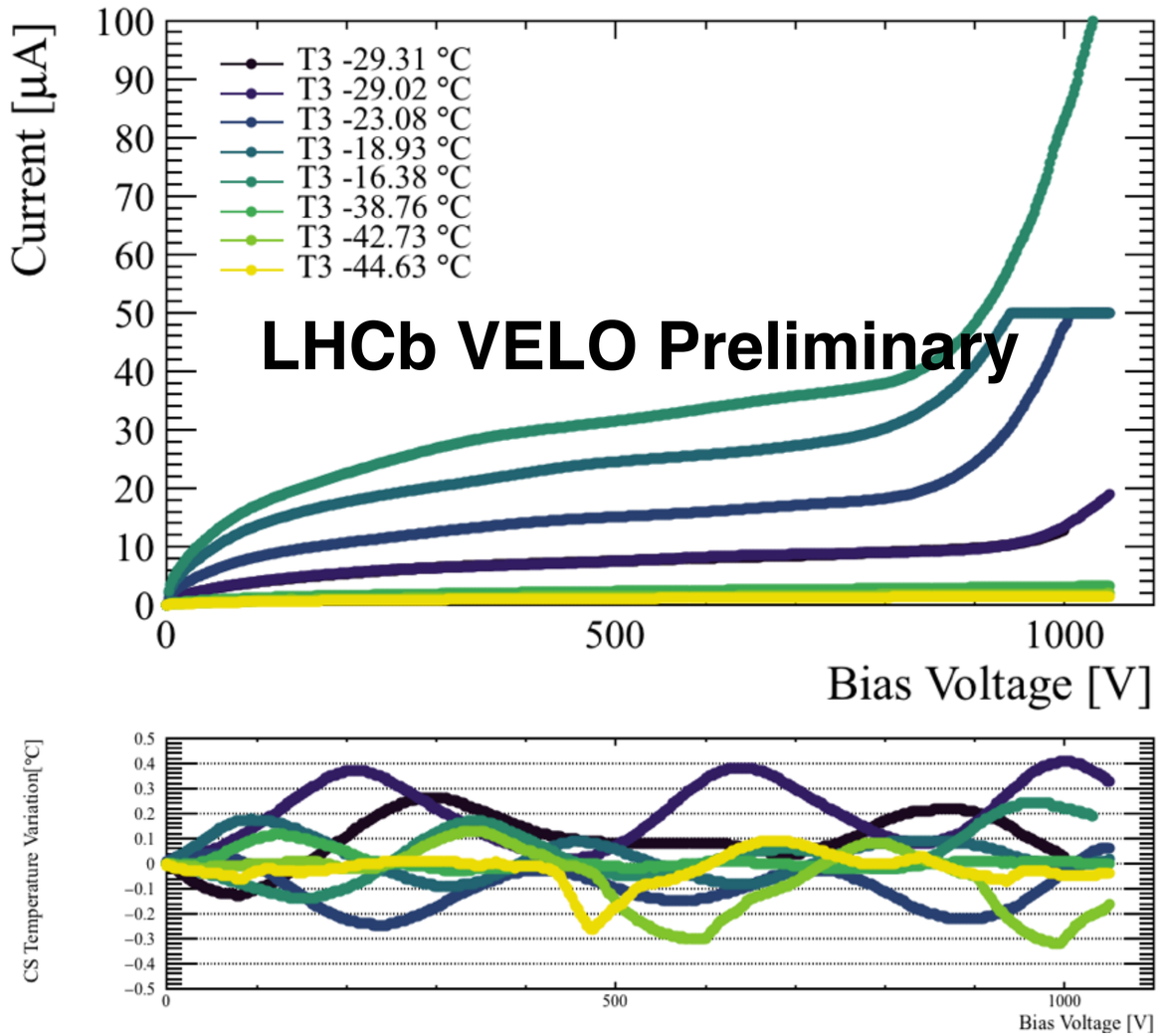
S16





S16 Half Fluence Non Uniformly irradiated with protons at KIT.

T3

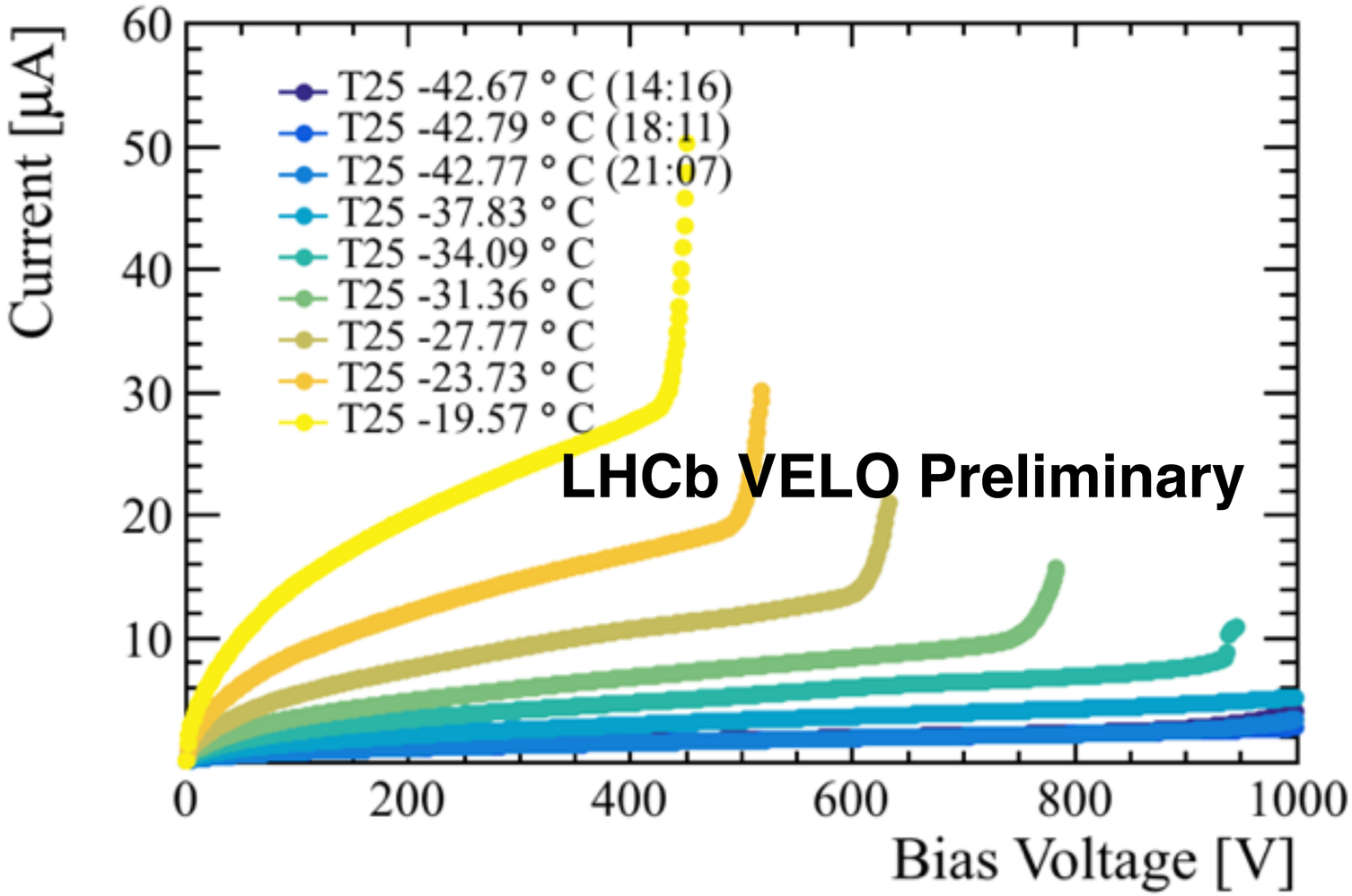


T3 Full Fluence Non Uniformly irradiated with protons at KIT.

Temperature Dependent Breakdown

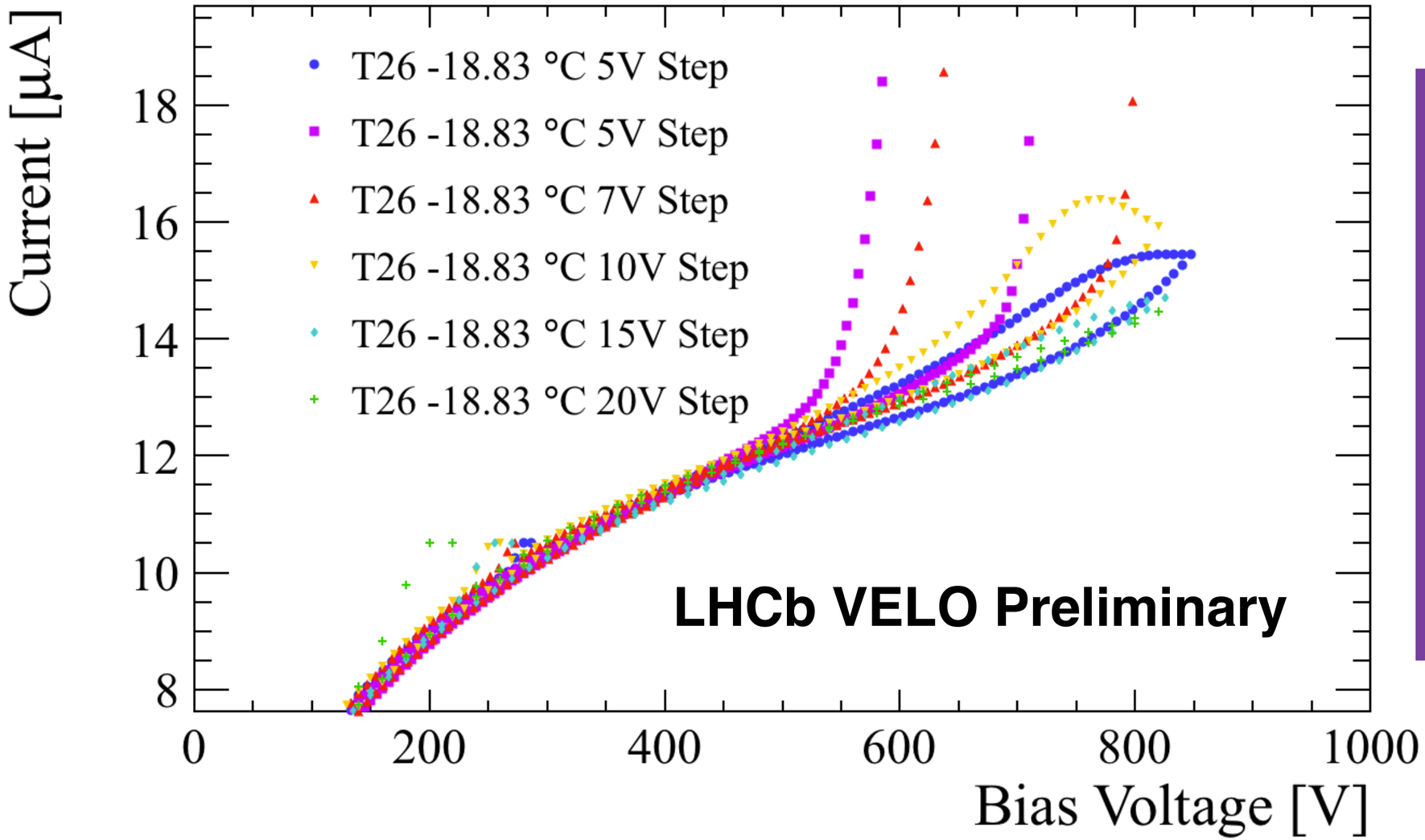
Early breakdown was observed at low voltages.

The temperature scan was done in order to understand the effect.



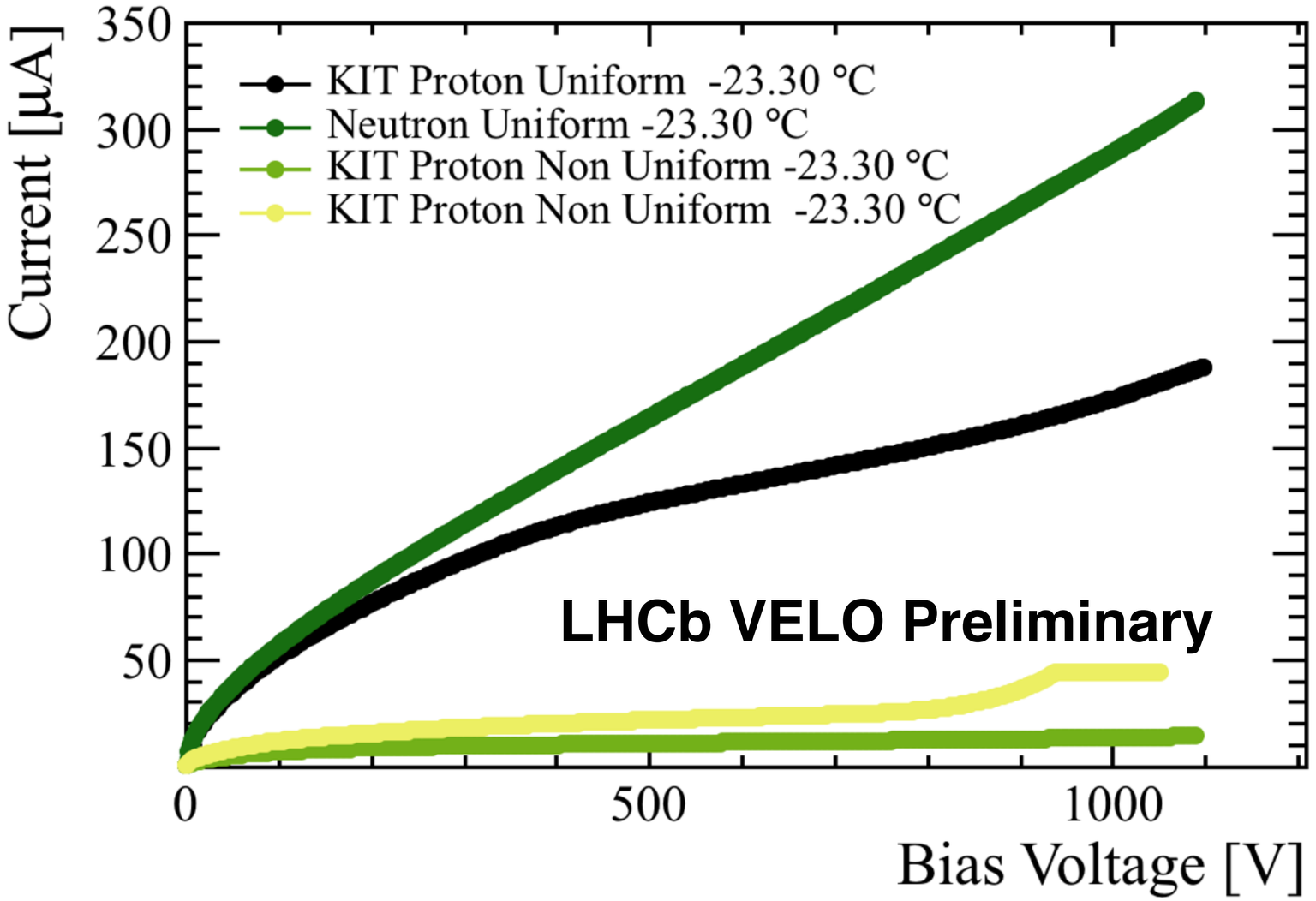
KIT Non-Uniformly Irradiated

Maybe the approach to BD matters?



This hysteresis effect suggests that whatever happens at high voltages, it takes a while to come back to the original state.

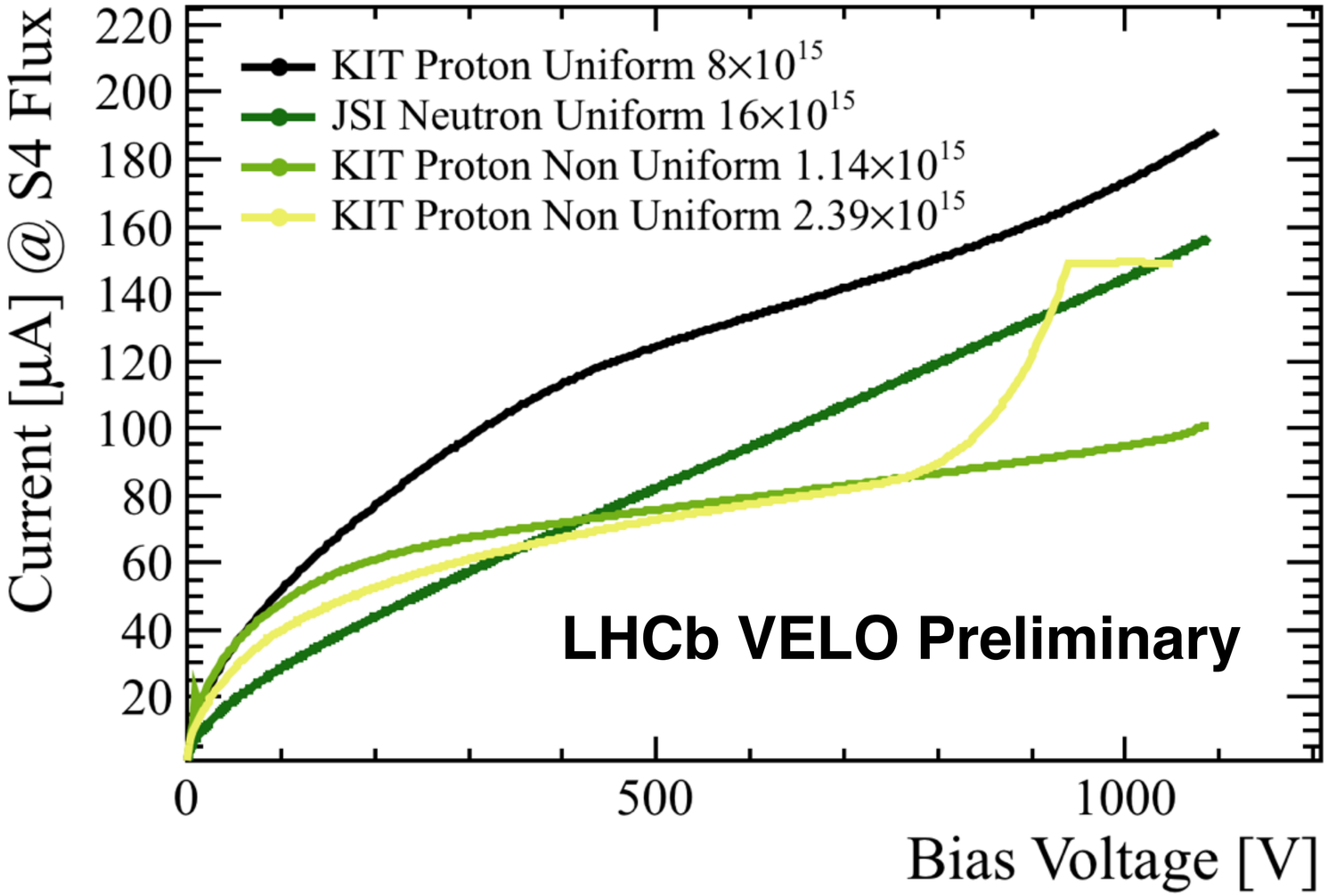
Comparison



All Scaled to -20°C.

Different Radiation dose to each one depending on uniformity / max fluence.

Comparison



All Scaled to -20°C.

Absolute values are very similar, although some features seem slightly different.

Scaling between different irradiations seem to hold well.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168

Conclusion

VELO expected leakage current evolution follow expected behaviour from radiation damage.

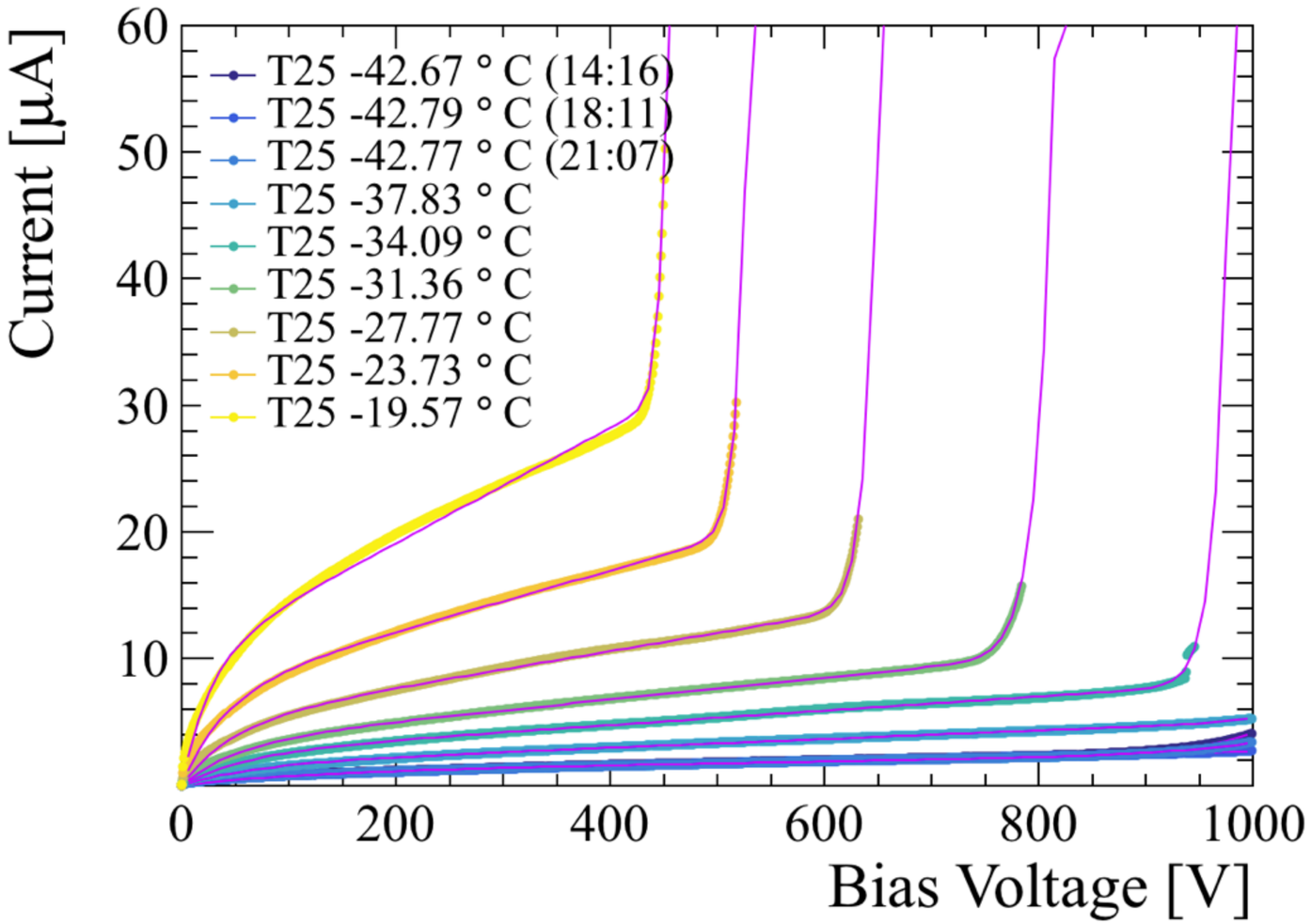
VELO will operate during 2018, entering beyond design integrated luminosity region in great shape.

TT and IT leakage current evolution are also evolving as expected.

Interesting effects observed in some of the irradiated sensors for the VELO Upgrade under investigation. New proton non uniform Irradiation being performed in the MC40 facility at Birmingham.

Backup

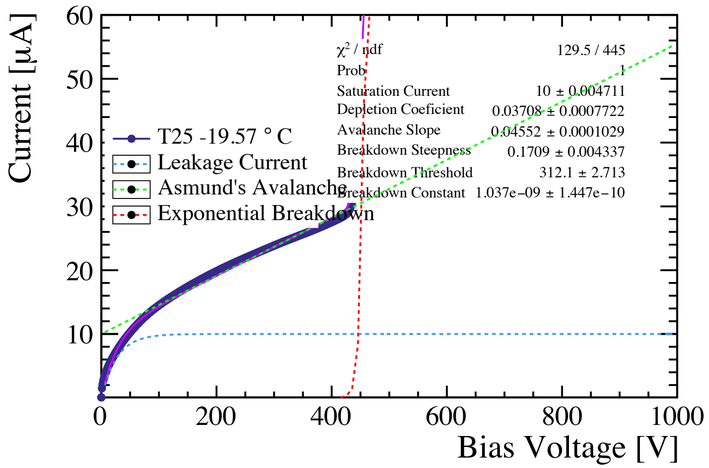
Modelling breakdown

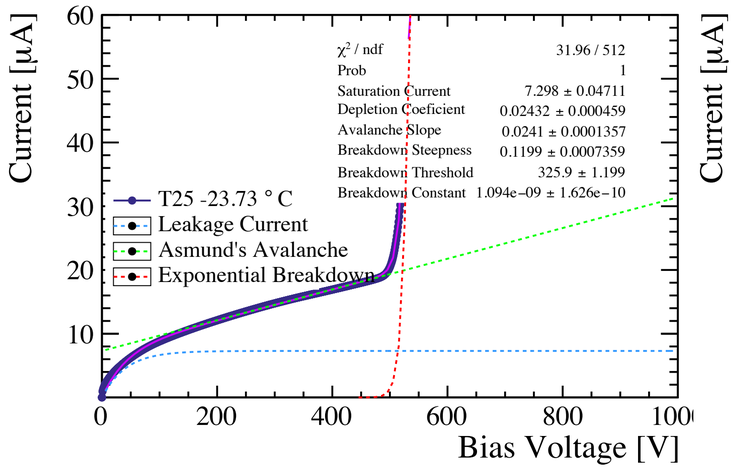


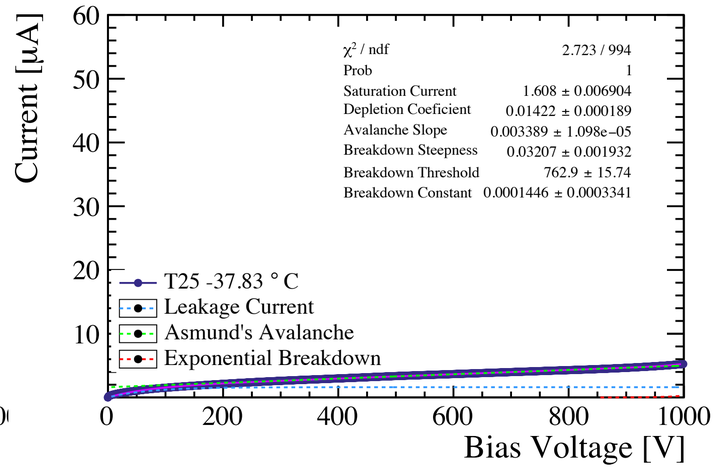
IV curve comprised of three terms

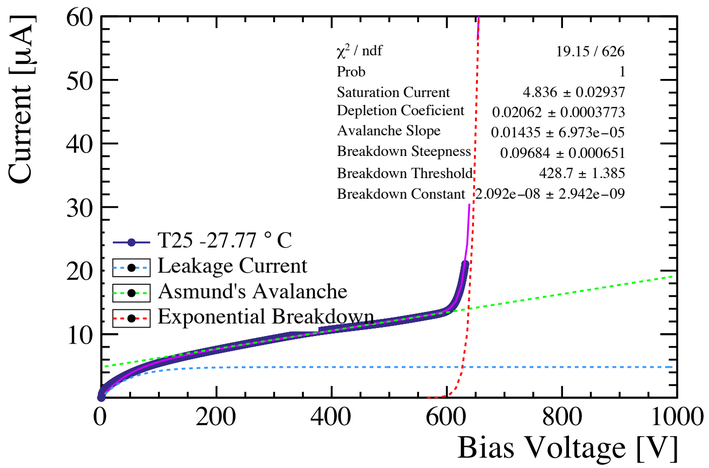
Define breakdown as the point in which the exponential term is 10% of the saturation current.

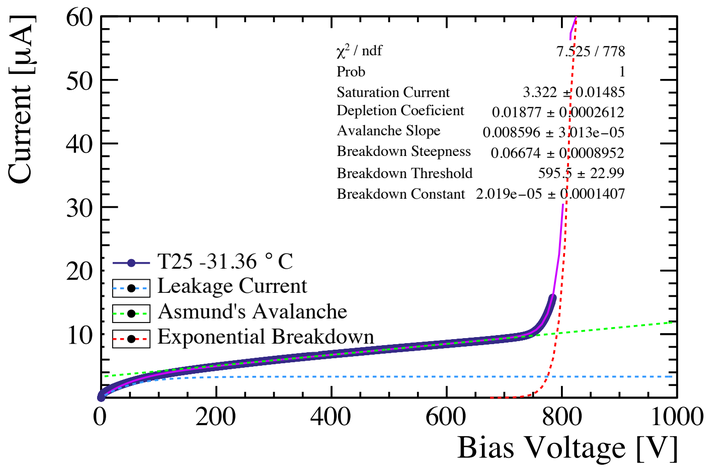
Modelling breakdown

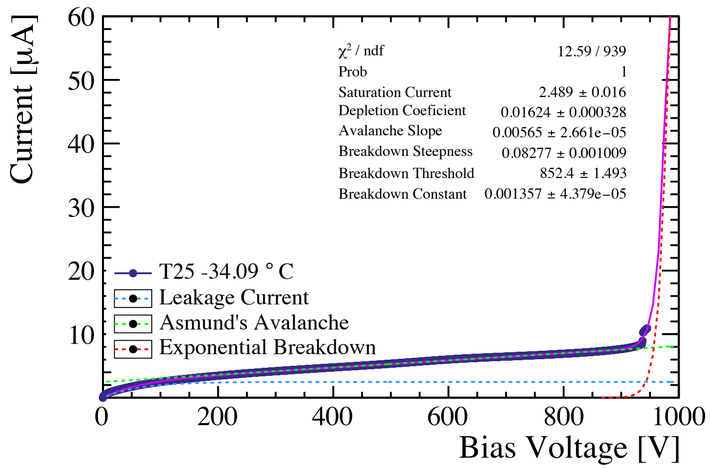




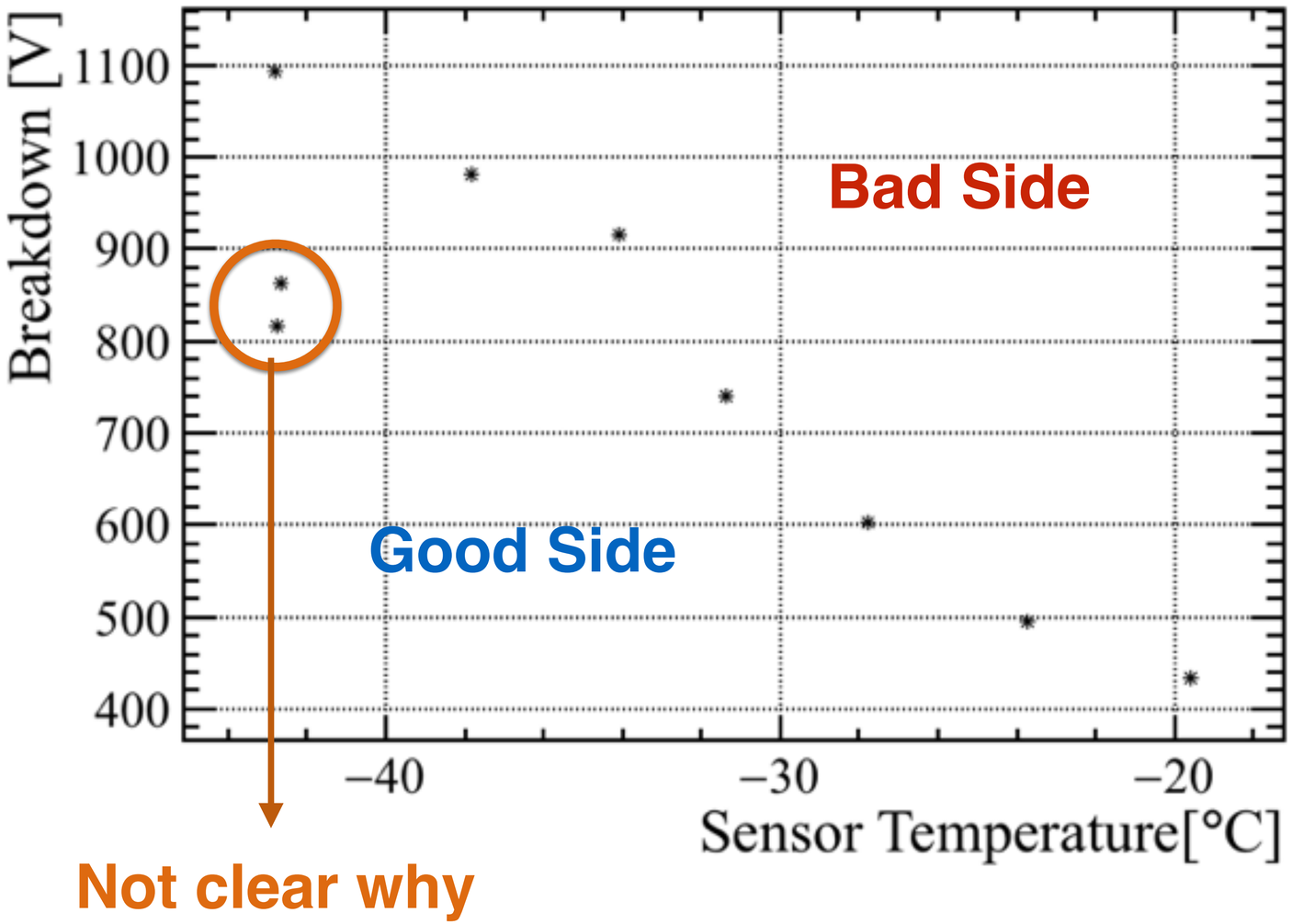








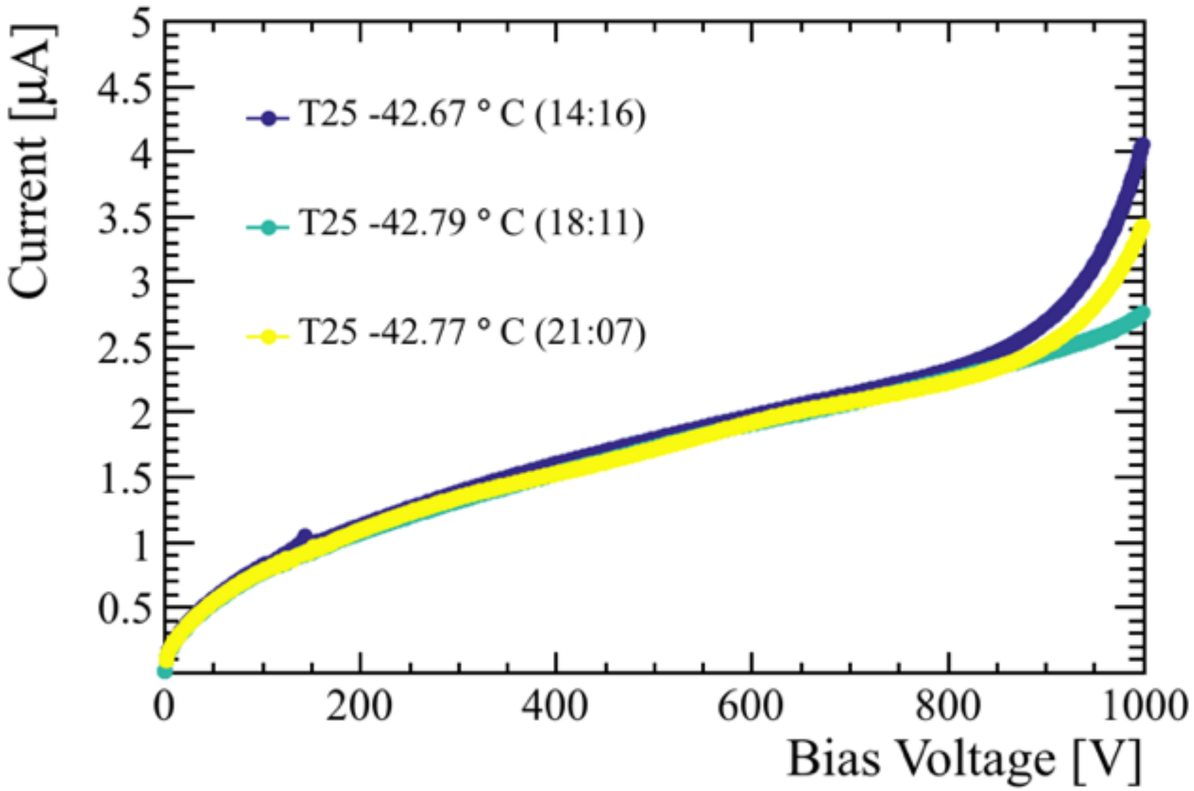
Breakdown x Temperature



BD Voltage definitely depends on temperature.

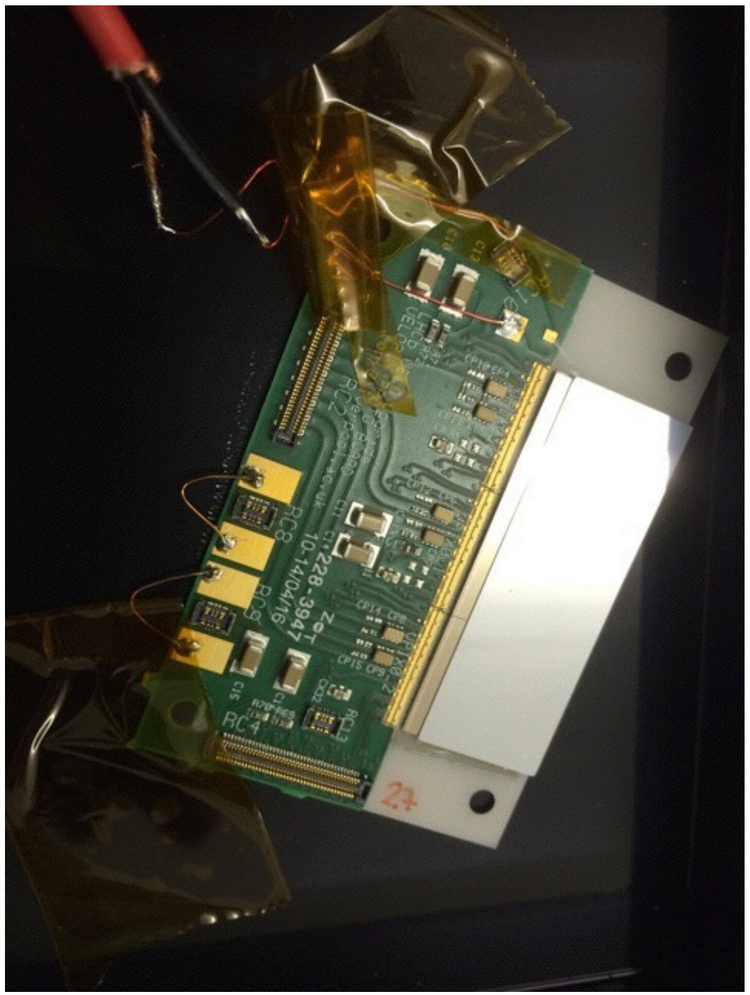
However it seems not very deterministic

Temperature Dependent Breakdown



However, even at same temperature behaviour at very high voltages changes.

HPK n-on-p Respin



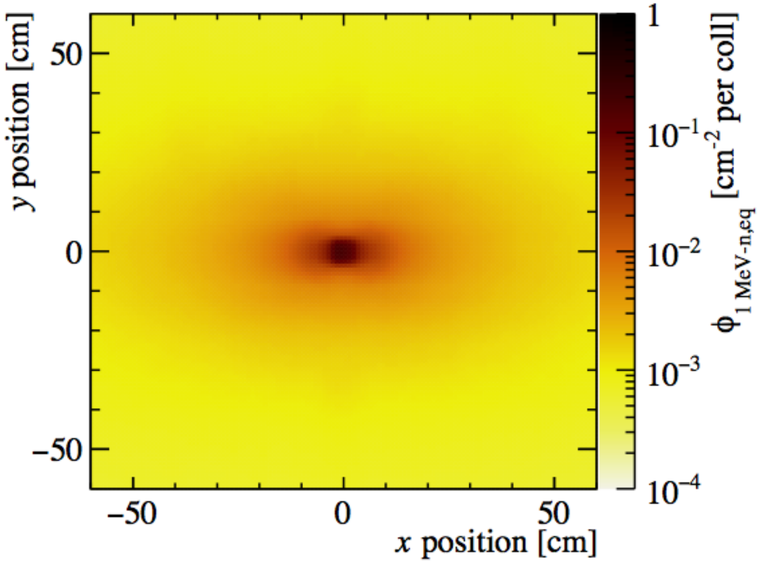
Variation on original n-on-p design

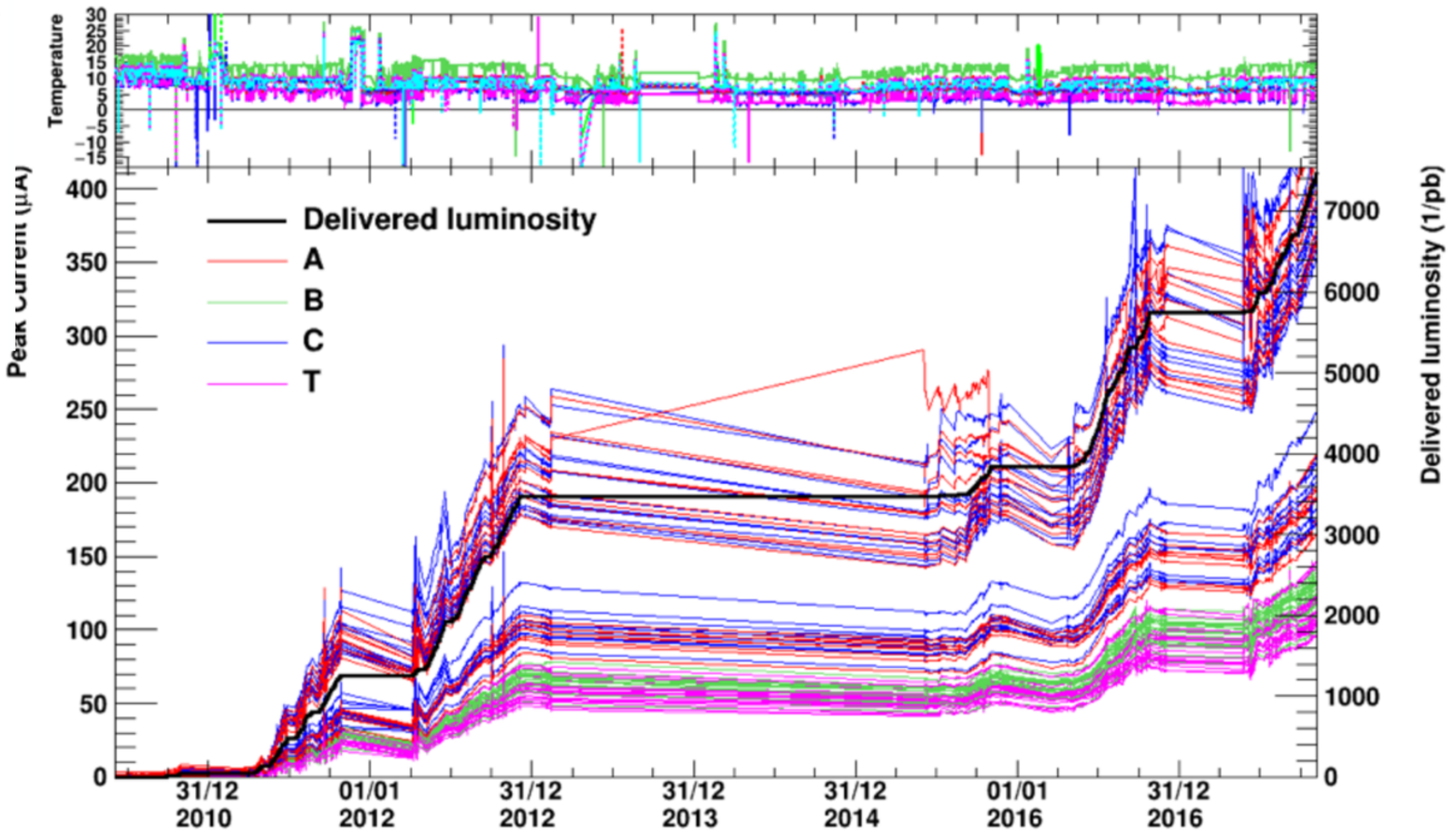
Rounded corners

Longer Interchip distance

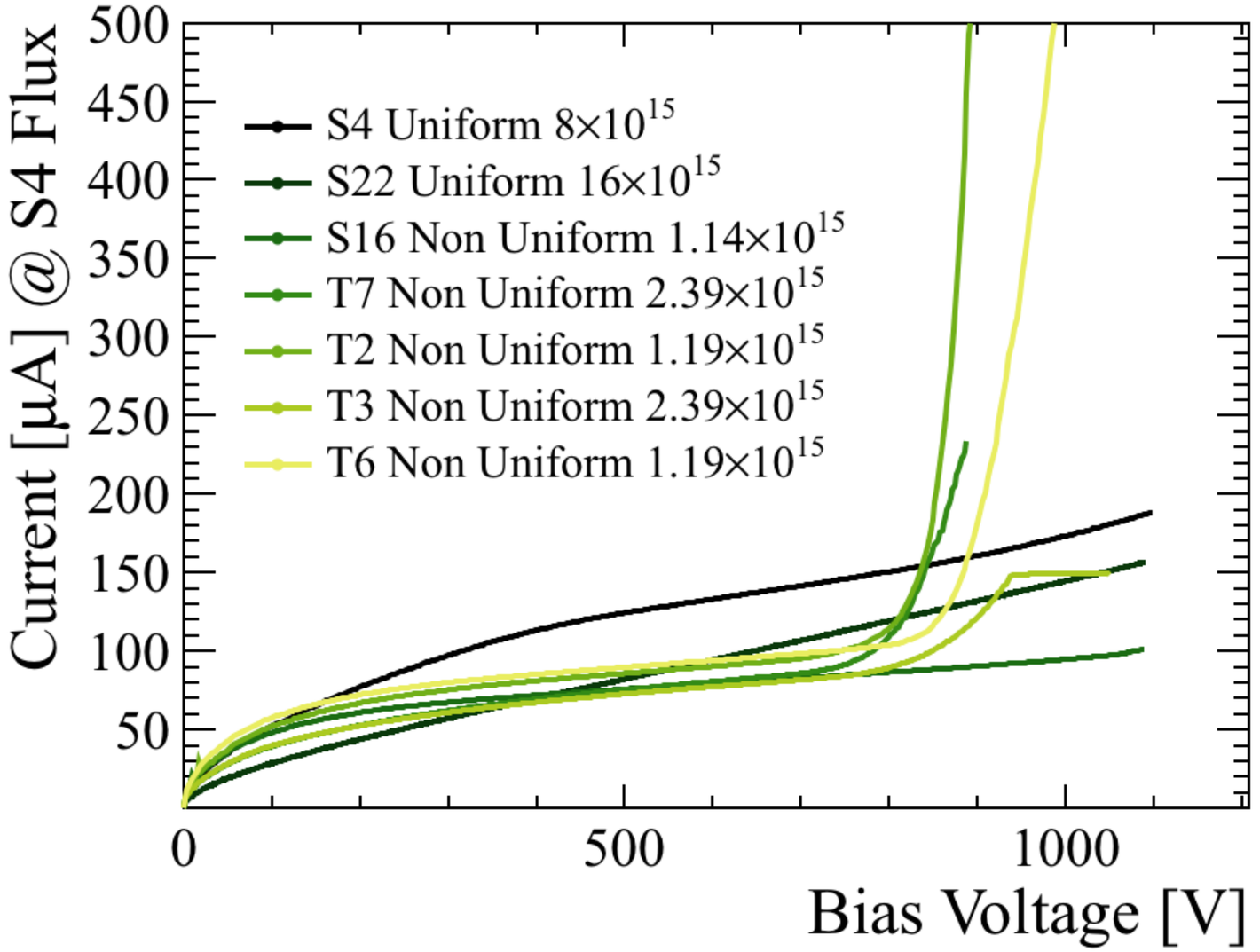
Results very fresh

IT Leakage Current





Comparison



All Scaled to -20°C.

Absolute values are very similar, although some features seem slightly different.

Scaling between different irradiations seem to hold well.

Lab Setup

Sensors readout with Timepix3 chip

Vacuum and Dry Air operation