15^{th} RD50 Workshop

Charge Collection Annealing Study of p-in-n Silicon Microstrip Detectors

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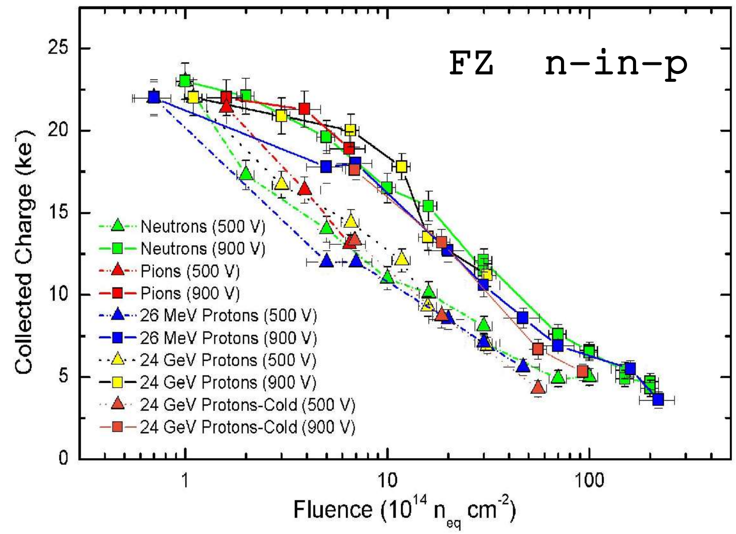
17^{th} November 2009

Introduction

In Liverpool the focus has been on charge collection efficiency (CCE).

So far mostly for n-side readout sensors.

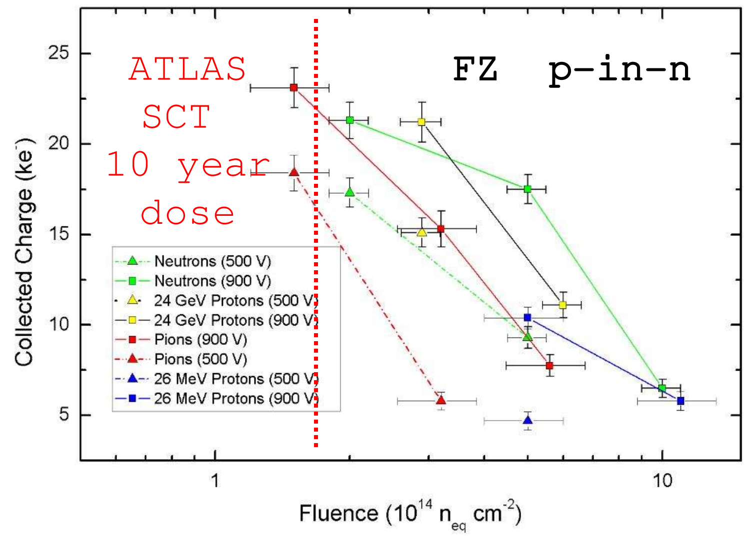
Less detailed data is available for p-in-n sensors.



Clear that p-in-n fails at lower doses than n-in-p.

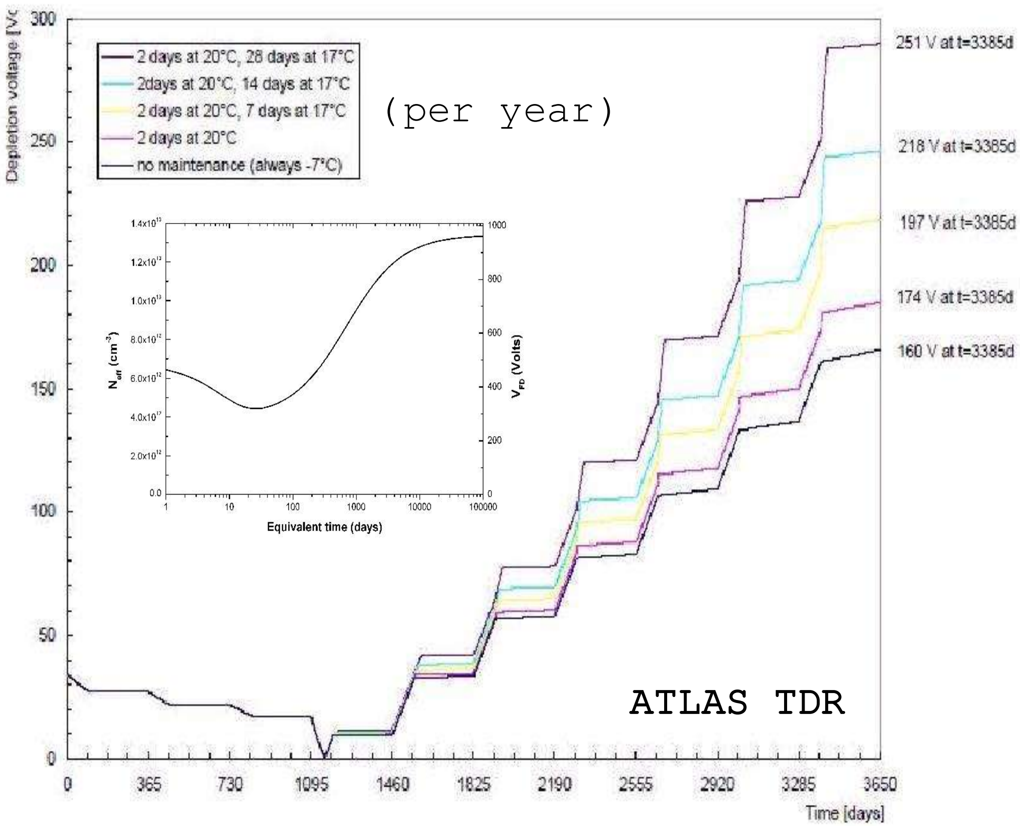
Significant scattering of the different results.
BUT… differences in annealing not accounted for.
(Some irradiations done warm).

This warrants a fresh look.



Evaluation of the Evolution of V_{dep} and I_{leak} in ATLAS SCT

In the ATLAS Inner Detector Technical Design Report (TDR, 1997) V_{dep} and I_{leak} were predicted.



Luminosity

TDR assumed 3 years of low luminosity (10^{33} cm^{-2}s^{-1}) + 7 years of high luminosity (10^{34} cm^{-2}s^{-1}).

One important conclusion:
Avoid warming irradiated detectors above 0°C, as much as possible.

Reason:
V_{dep} undergoes reverse annealing and becomes progressively higher if the detectors are kept above 0°C.

Re-Evaluation of the Evolution of V_{dep} and I_{leak} in ATLAS SCT

V_{dep} and I_{leak} calculations re-done with updated inputs.

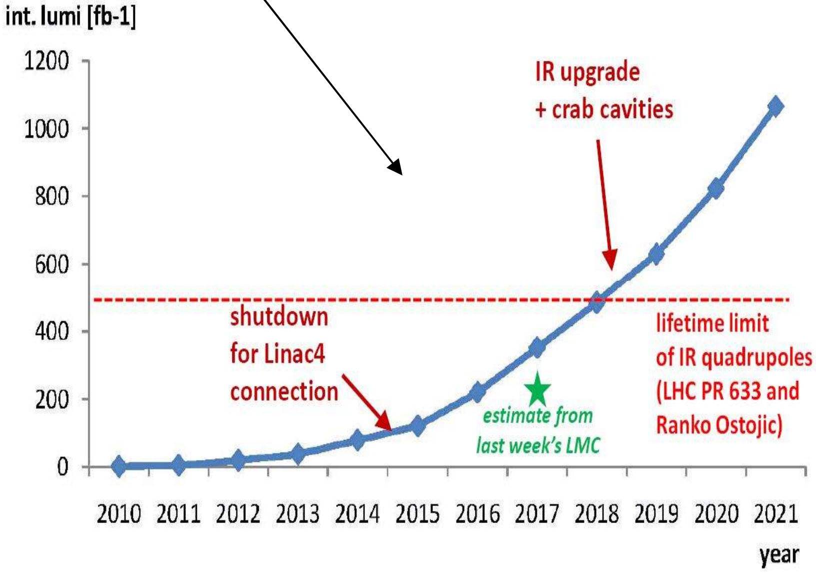
Paul Dervan, Joost Vossebeld, Tim Jones (Liverpool), Taka Kondo (KEK), Graham Beck (QMUL), Georg Viehhauser (Oxford), Steve McMahon (RAL), Koichi Nagai (Brookhaven), Kirill Egorov (Indiana), Richard Bates, Alexander Bitadze (Glasgow)

An updated luminosity profile exists.

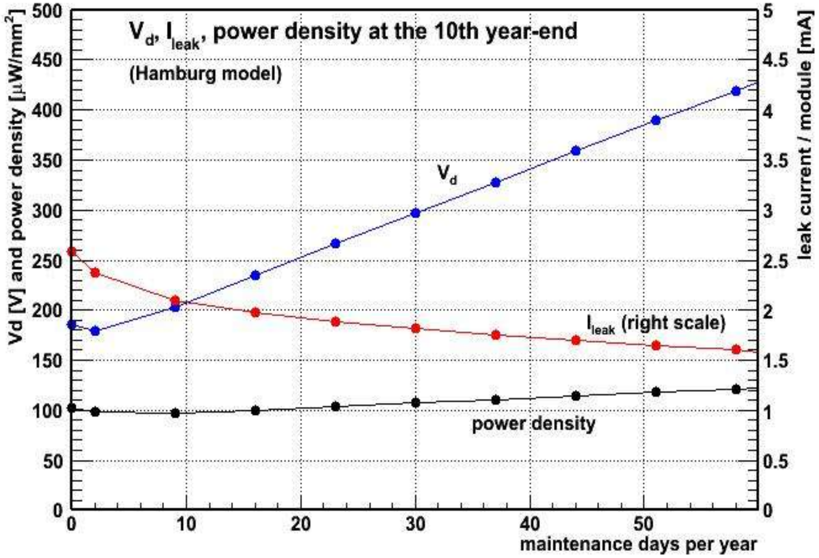
Updated access scenarios

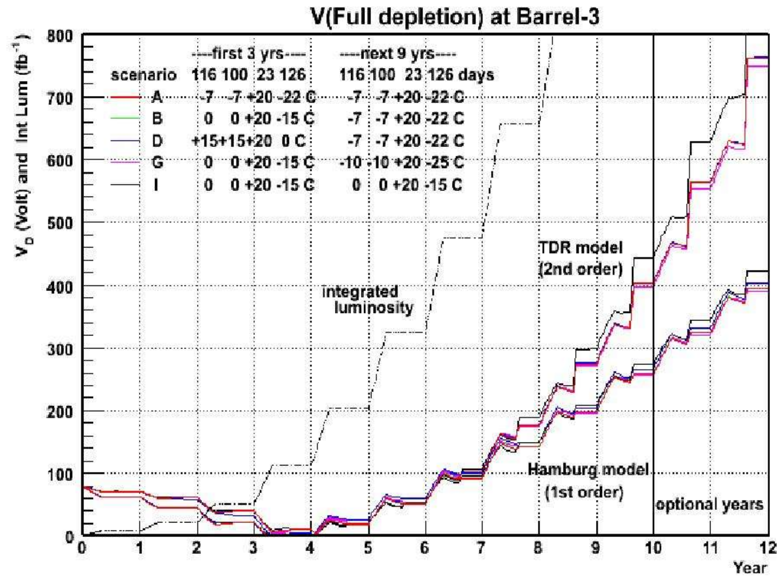
Maintenance/shutdown periods and cooling temperatures being reviewed in line with improved experience.

- achievable coolant temperatures
- IBL (Insertable B-Layer) installation
- possibly longer maintenance periods



Re-Evaluation of the Evolution of V_{dep} and I_{leak} in ATLAS SCT





Length of warm periods have strong detrimental effect on V_{dep} + smaller beneficial effect on I_{leak}.

Note for ATLAS SCT risk of thermal runaway, due to increased power dissipation.

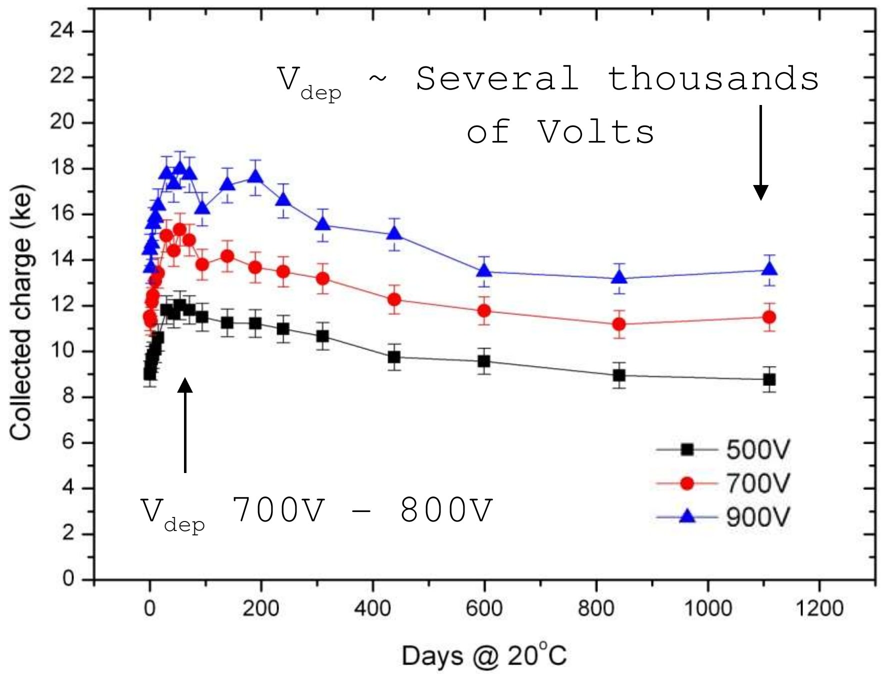
Expected to be the limiting factor (not discussed further here).

V_{dep} predictions suggest 450V (max SCT V_{bias}) sufficient for at least 10 years of operation.

Large differences between TDR model and Hamburg model.

Nice to have some high dose, long annealing data to confirm Hamburg model is the better one.

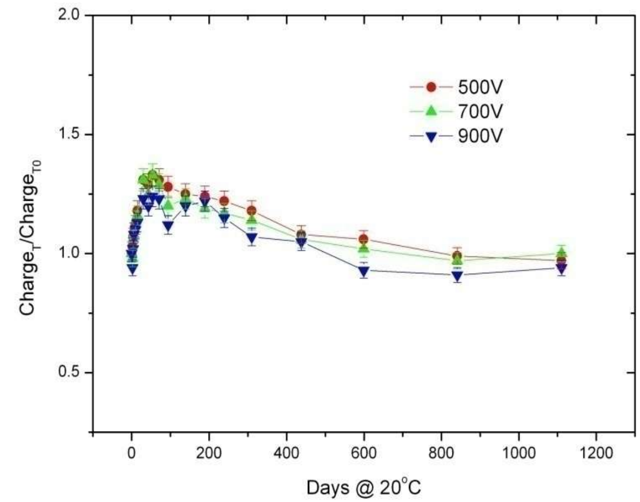
Results for Annealing of CCE in n-in-p Microstrip Sensors

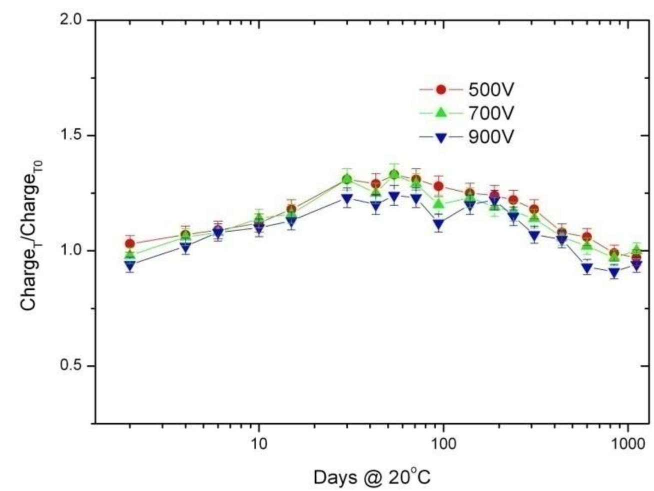


HPK, FZ, $1x10^{15}$ 1MeV n_{eq} cm^{-2}
(irradiated with neutrons)

Important conclusion:

V_{dep} doesn't seem to directly relate to the CCE (for n-in-p)





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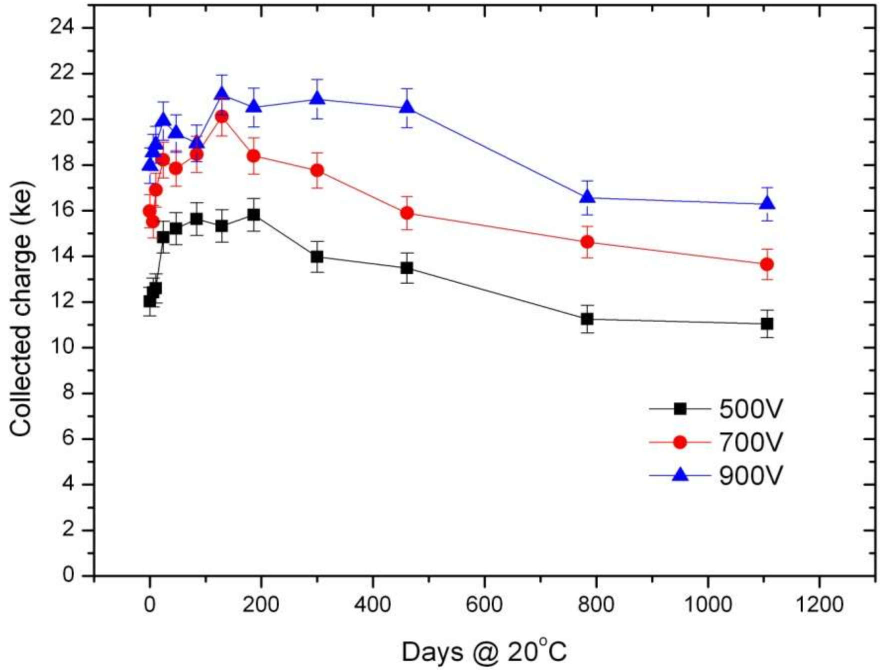
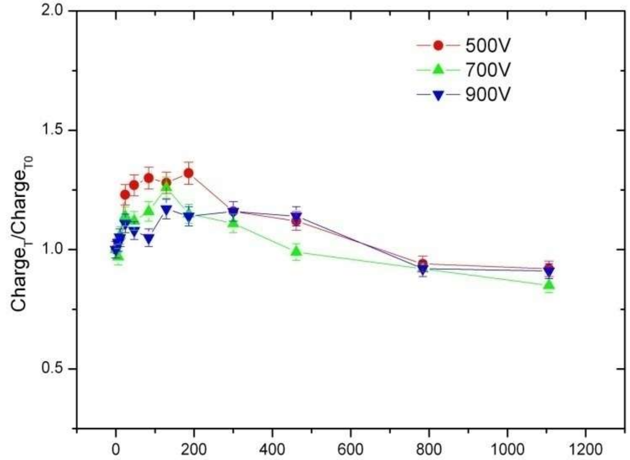
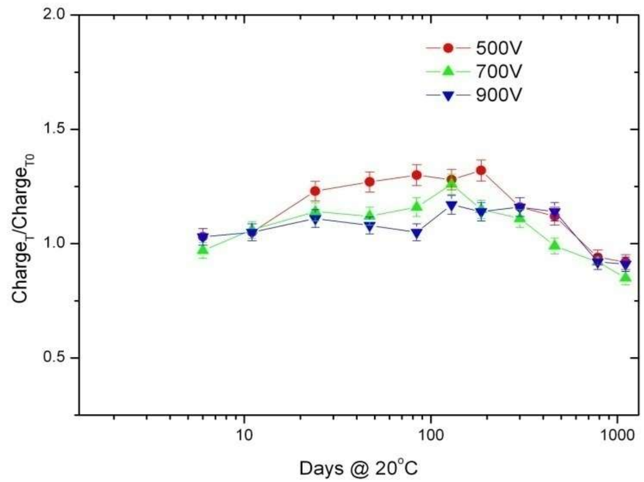
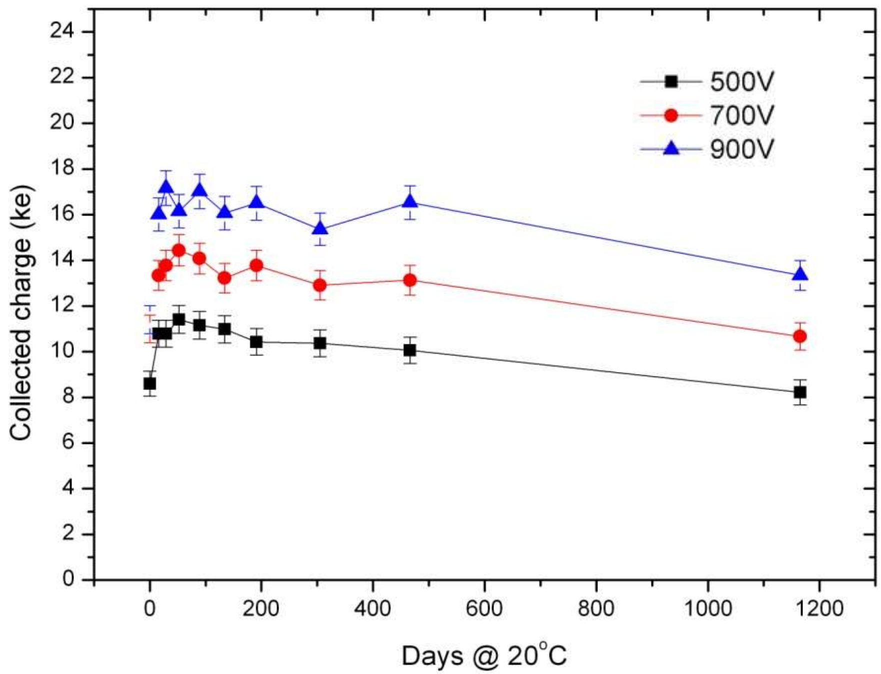


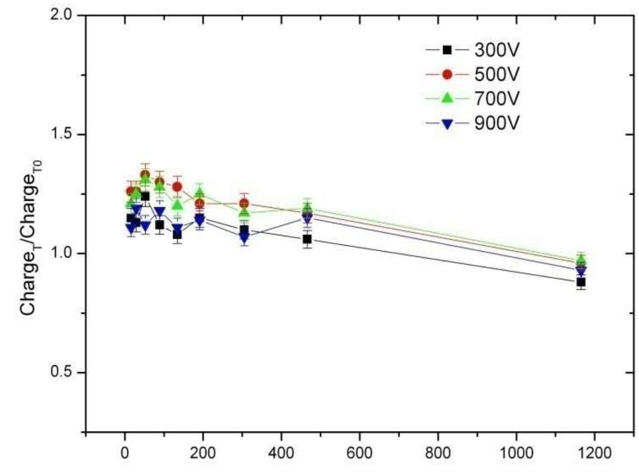


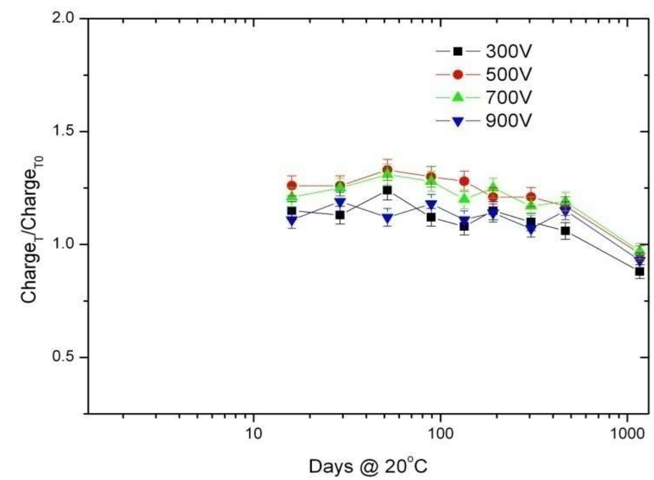


Micron, FZ, 1×10^{15} 1MeV n_{eq} cm^{-2}
(irradiated with 26MeV protons)

Results for Annealing of CCE in n-in-n Microstrip Sensors







Micron, FZ, 1.5×10^{15} 1MeV n_{eq} cm^{-2}

New program for Measuring the Annealing of CCE in p-in-n Microstrip Sensors

Manufacturer: micron (FZ-2535-9-5-1)

Mask Set: RD50, 6 inch

Wafer Technology: float zone

Structure: p-in-n

Size: 1cm x 3cm

Thickness: 300μm

Irradiation Type: neutrons @ Ljublijana (V. Cindro et al)

Irradiation Dose: 2×10^{14} 1MeV n_{eq} cm^{-2}

Annealing Step #	Temp (°C)	Hours	Days @ 20°C	Years @ 20°C
0	0	0	0	0.00
1	40	2	2	0.01
2	40	2	5	0.01
3	40	2	7	0.02
4	50	1	12	0.03
5	50	1	18	0.05
6	50	2	29	0.08
7	50	2	39	0.11
8	50	2	50	0.14
9	60	1	73	0.20
10	60	1	95	0.26
11	60	2	140	0.38
12	60	2	185	0.51
13	60	2	230	0.63
14	70	1	315	0.86
15	70	1.5	444	1.22
16	70	1.5	572	1.57
17	70	2	743	2.04
18	80	1	1065	2.92

Experimental Setup

^{90}Sr fast electron source used to generate signal.

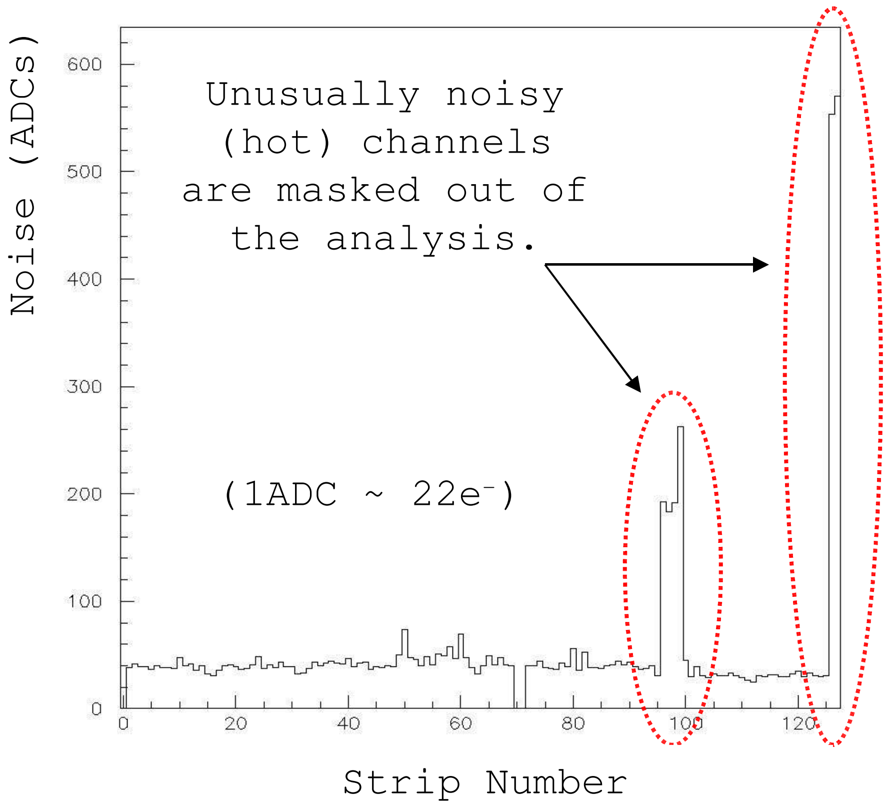
Readout triggered by scintillator.

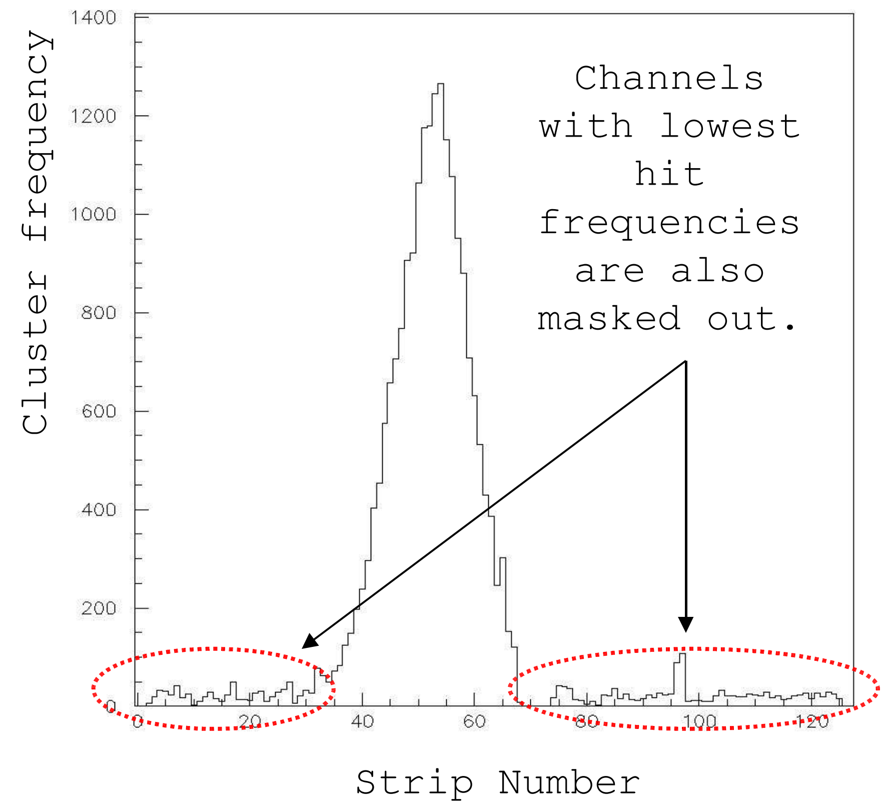
Charge collection was measured using an analogue electronics chip (SCT128) clocked at LHC speed (40MHz clock, 25ns shaping time).

System calibrated to the most probable value of the MIP energy loss in a non-irradiated 300μm thick detector (~23000 electrons).

All measurements performed in freezer at temperature of −10°C with N_2 flush.

Analysis Procedure





Take charge collected by strip with largest S/N ratio and the two strips either side of it.

(The S/N ratios have to be greater than given threshold values).

Analysis Procedure

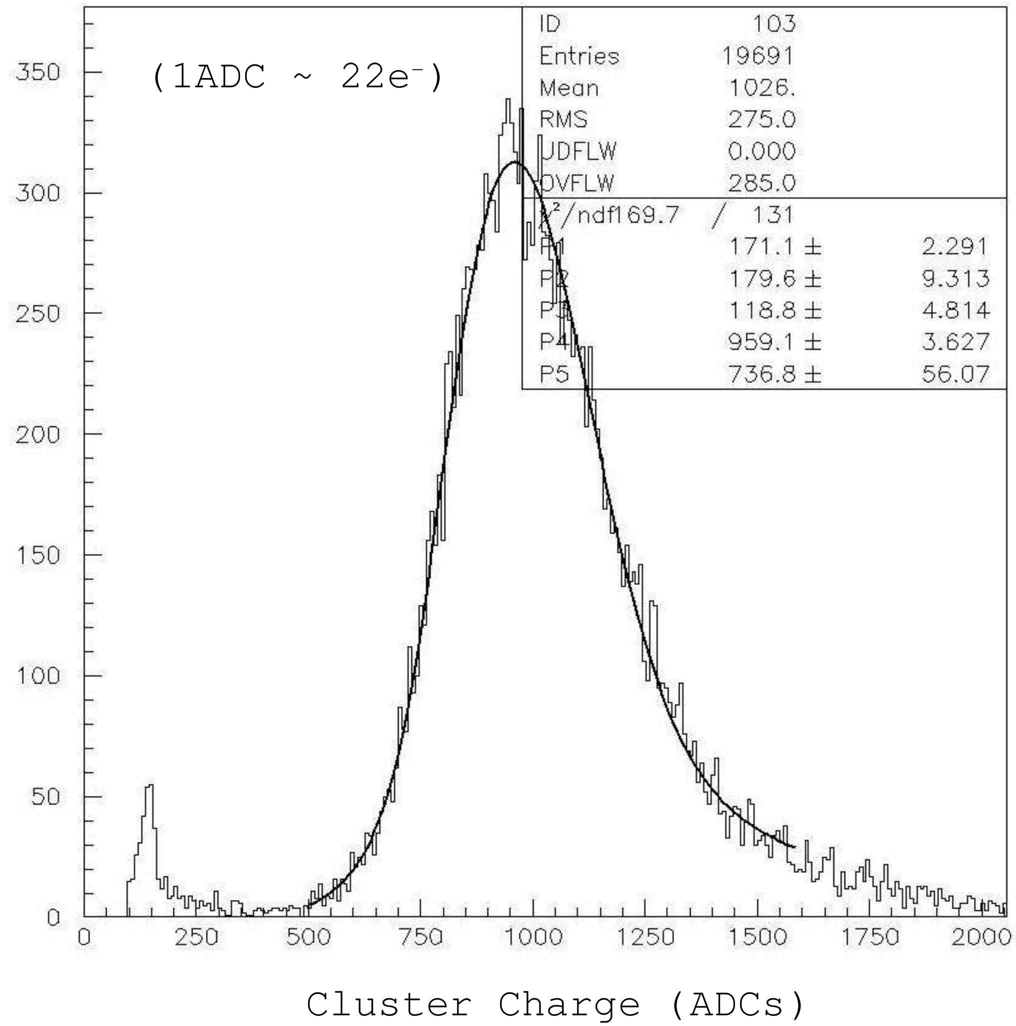
A landau convoluted with a gaussian is fitted to the resulting distribution of the collected charge.

Most probable value is recorded.

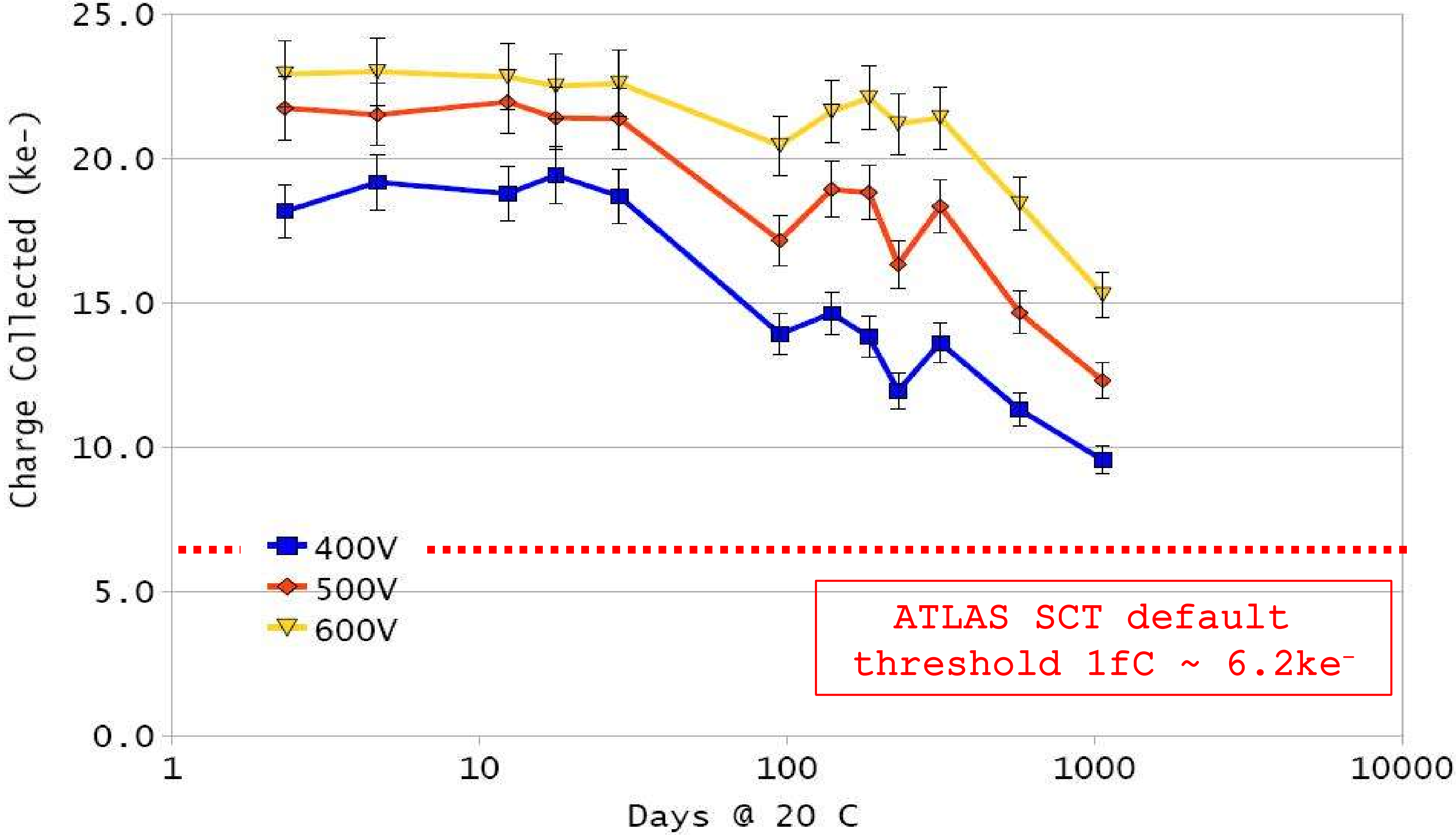
For each annealing point, charge collection measurement is made at 3 different V_{bias}:

400V, 500V and **600V**

(ATLAS SCT operates at maximum V_{bias} ~450V)

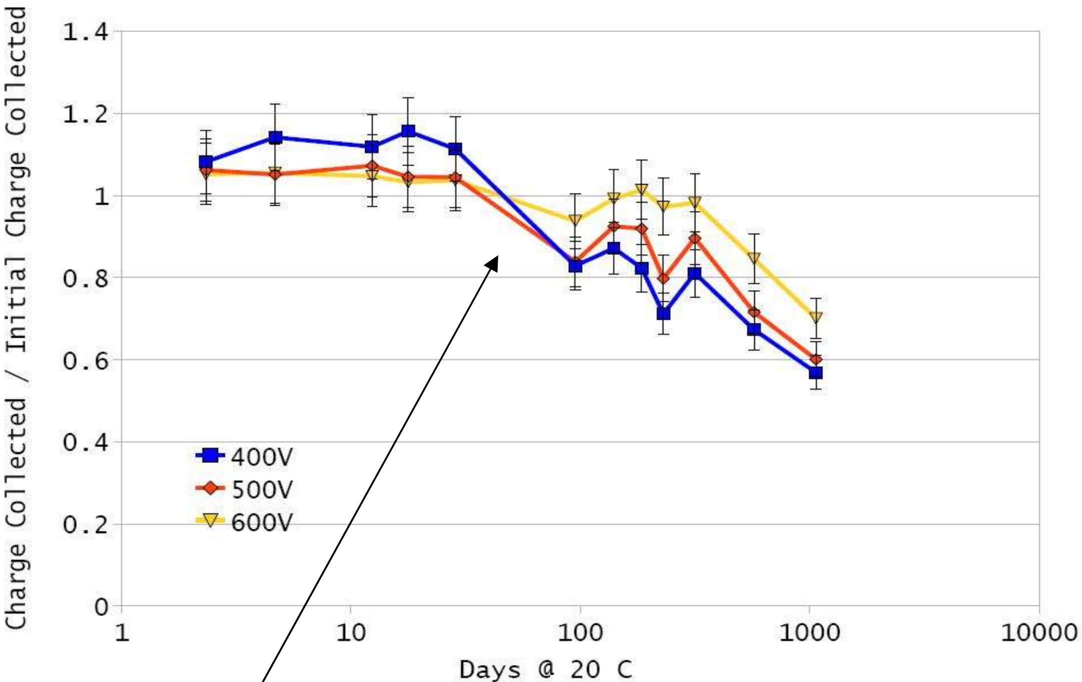


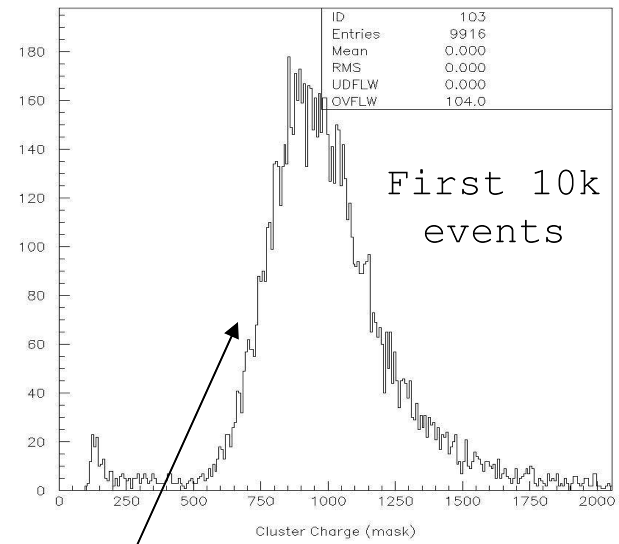
Charge Collection Results

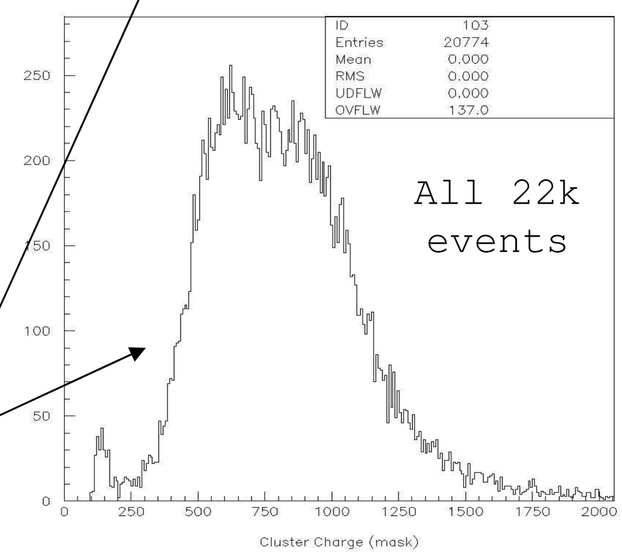


- No sharp drop in the collected charge is observed.
- A rather smooth fall-off starting after ~100 days.
- Still significant charge collected after 1000 days.

Charge Collection Results





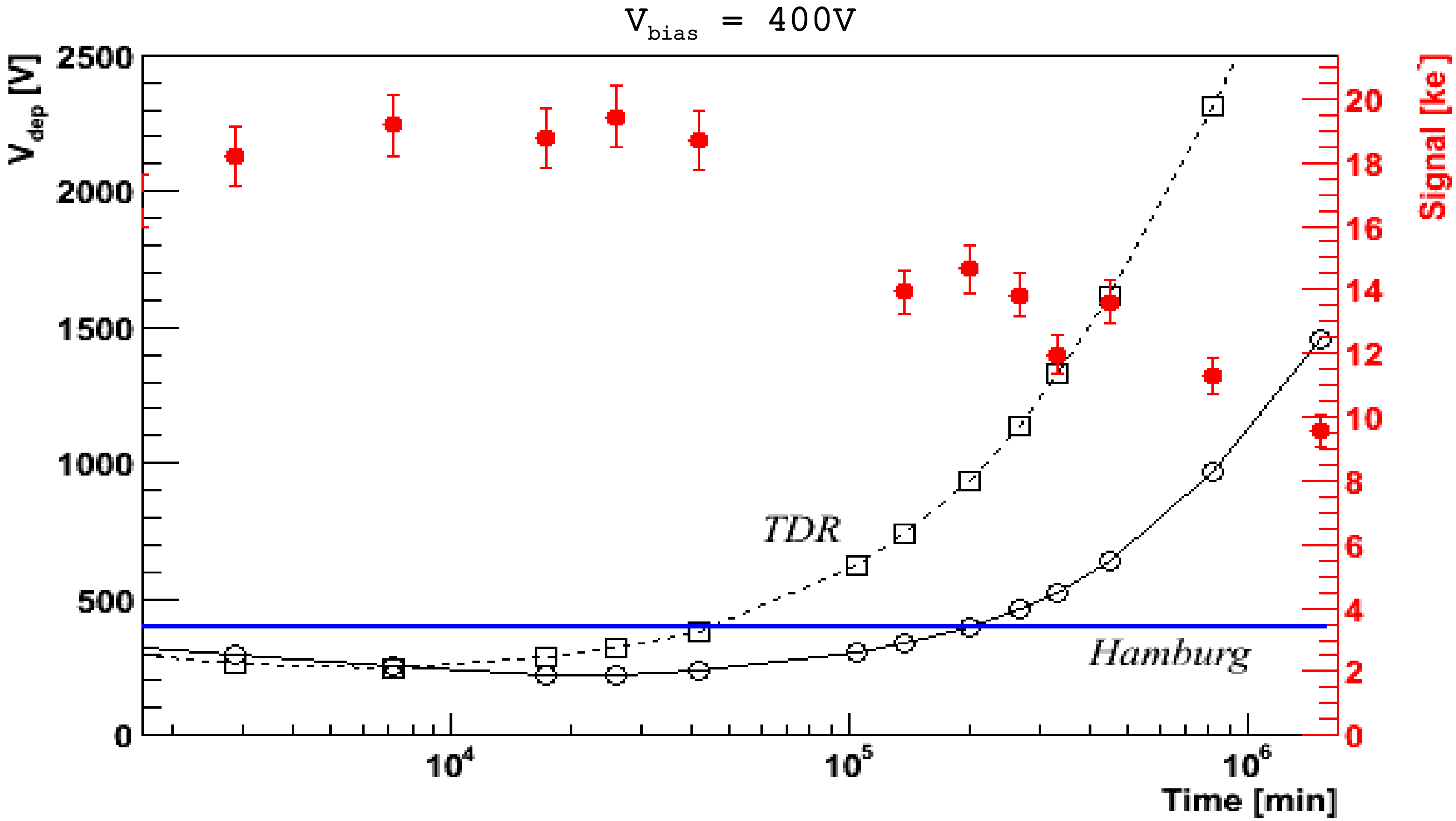


Problem in this region identified as faulty (loose) cable.

Chip became un-initialised during runs.

Effect can be seen in distribution of cluster charge.

Comparison of Signal to Predicted V_{dep}



- No sharp drop in signal when V_{bias} drops below the V_{dep} predicted by either model.
  - Significant charge even when presumed under-depleted.

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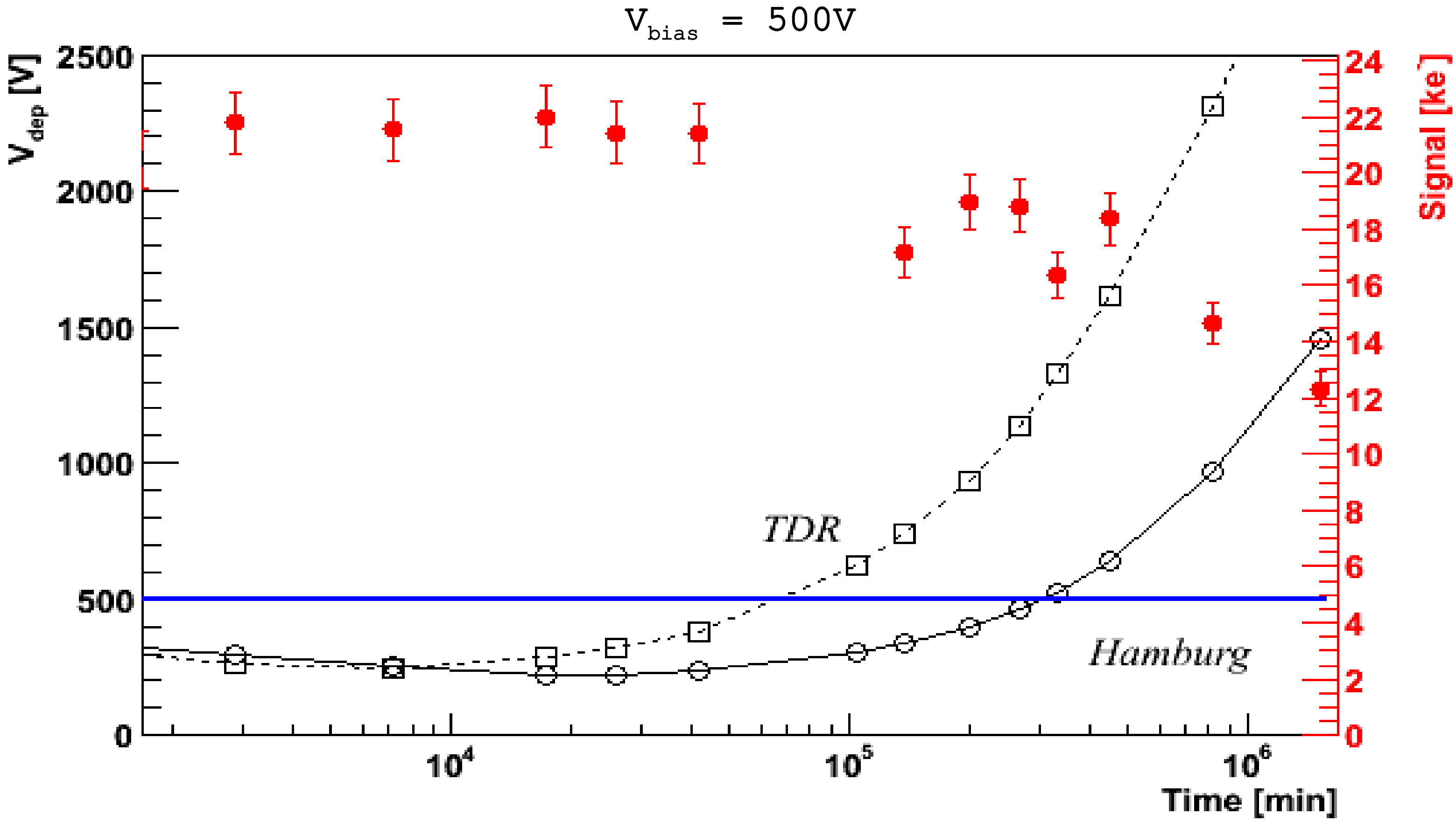

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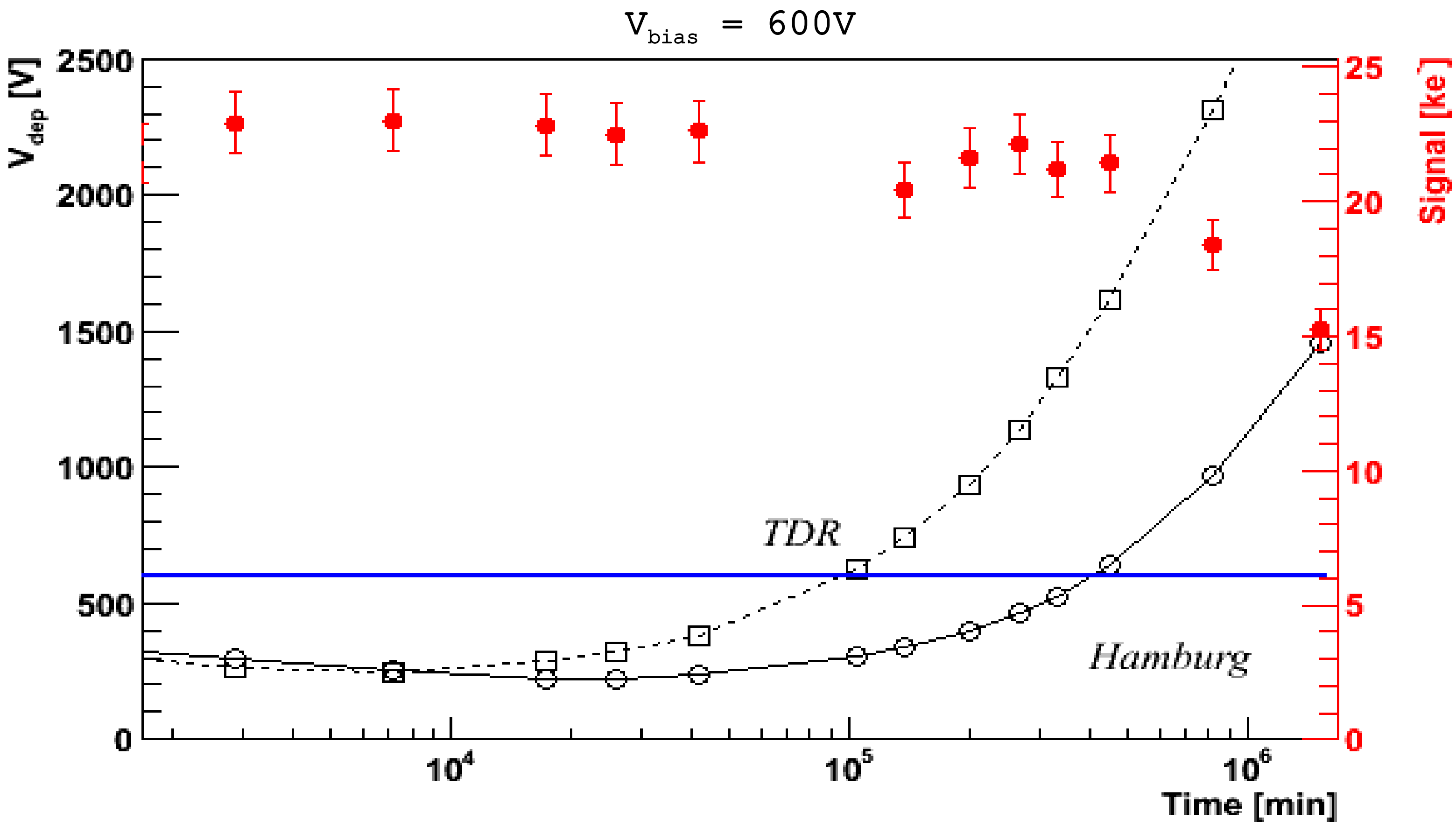

- No sharp drop in signal when V_{bias} drops below the V_{dep} predicted by either model.
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Conclusions and Future Plans

A program for measuring the annealing of CCE in p-in-n microstrip sensors has been started.

No sharp drop in collected signal when sensor goes under-depleted.

Slow drop with annealing time, giving significant charge even when V_{bias} is well below V_{dep}.

For ATLAS SCT this means operational range defined by V_{dep} prediction alone is over-pessimistic.

Further measurements planned:

4 ATLAS SCT mini sensors are being irradiated to $2x10^{14}$ 1MeV n_{eq} cm^{-2}.

A full set of I-V, C-V and S/N measurements as a function of annealing time will be performed.

Results will be used for more detailed comparison to the predictions of the different parameterisations.