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25th RD50 Workshop
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Status of Silicon Strip Sensor Measurements at Liverpool

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Overview

- Room temperature annealing of RD50 charge multiplication sensors and long-term bias test
- Activation energy (E_g) and current related damage rate (α) determination through IV measurements of irradiated HPK and Micron sensors with fluences up to 2×10^{16} n_{eq}/cm^2

Annealing
&
long-term bias test

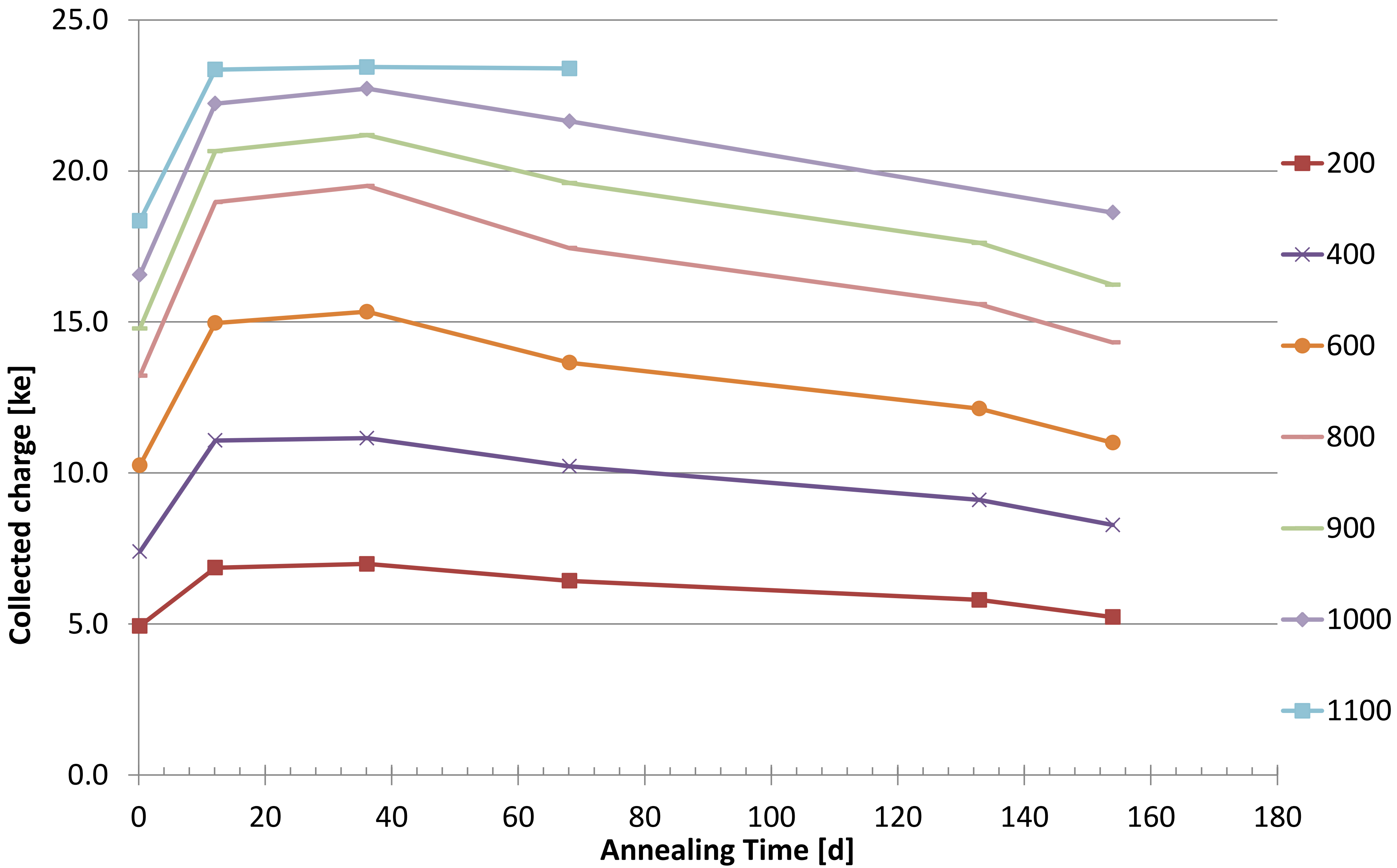
Charge Multiplication Sensors

- Dedicated charge multiplication sensors, produced by Micron Semiconductor Ltd (UK)
- 1cm x 1cm, n-in-p FZ strip detectors
- Various strip pitch (P) and width (W)
- Some sensors with biased intermediate strips (I) between readout strips
- Irradiated to two different fluences at Ljubljana
  - $1\times10^{15}\ n_{eq}/cm^2$
  - $5\times10^{15}\ n_{eq}/cm^2$

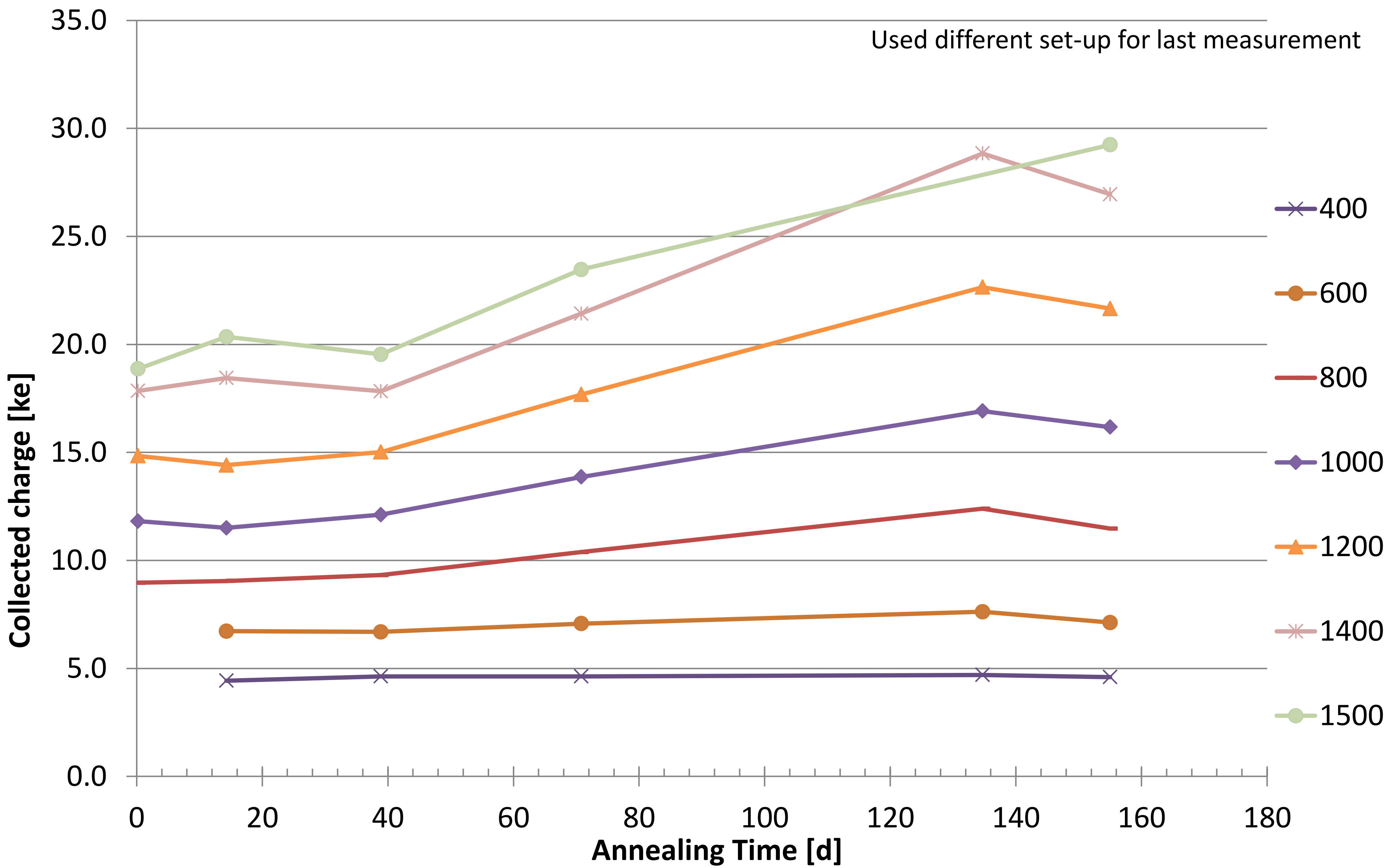
Annealing

- Room temperature (20°C) annealing in nitrogen cabinet
- Charge collection measurements performed in Beta-setup with the ALiBaVa system

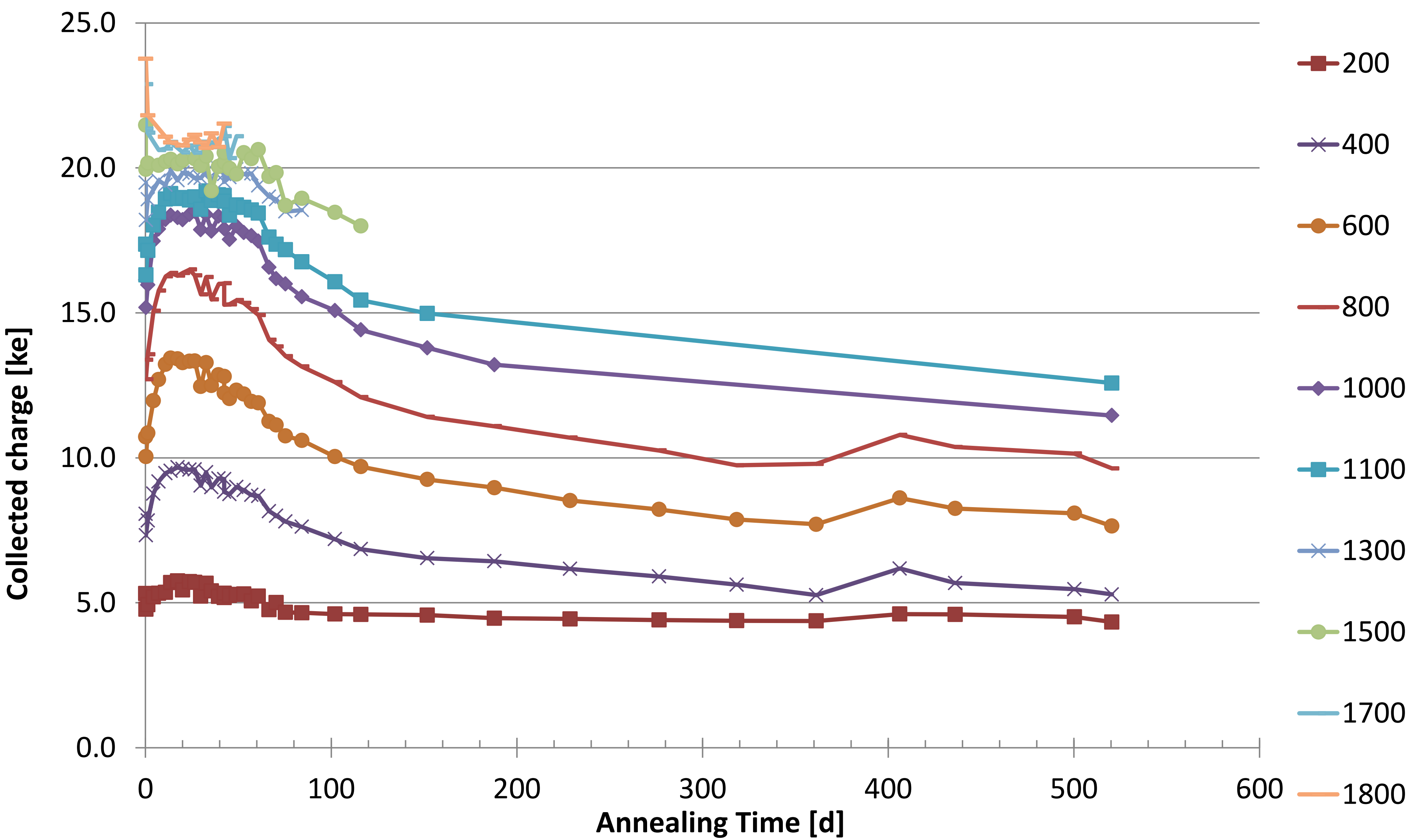
P80-W25; $1\times10^{15}\ n_{eq}/cm^2$



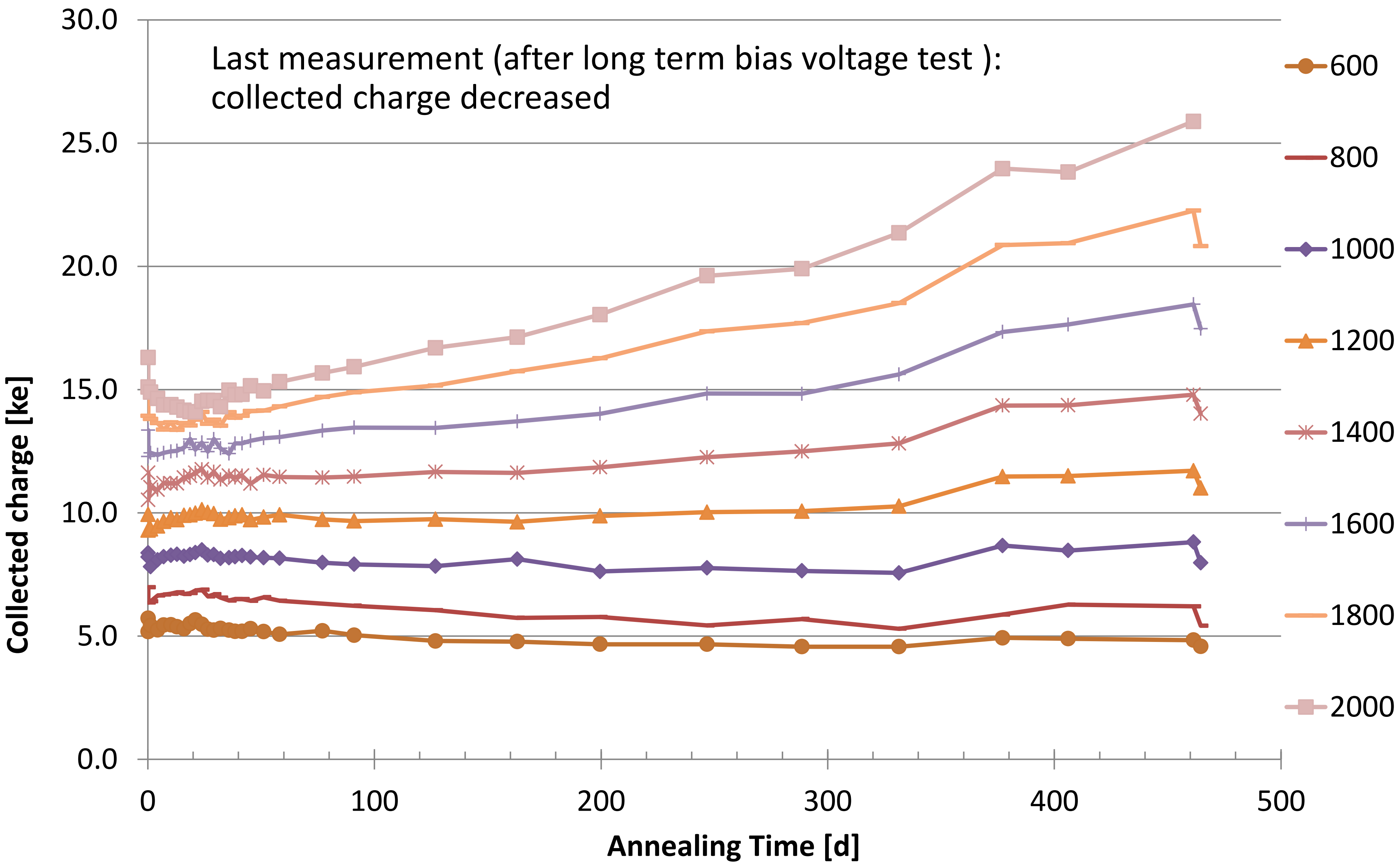
P80-W25; 5×10^{15} n_{eq}/cm^2



P80-W25-I35; $1\times10^{15}\ n_{eq}/cm^2$



P80-W25-I35; $5\times10^{15}\ n_{eq}/cm^2$



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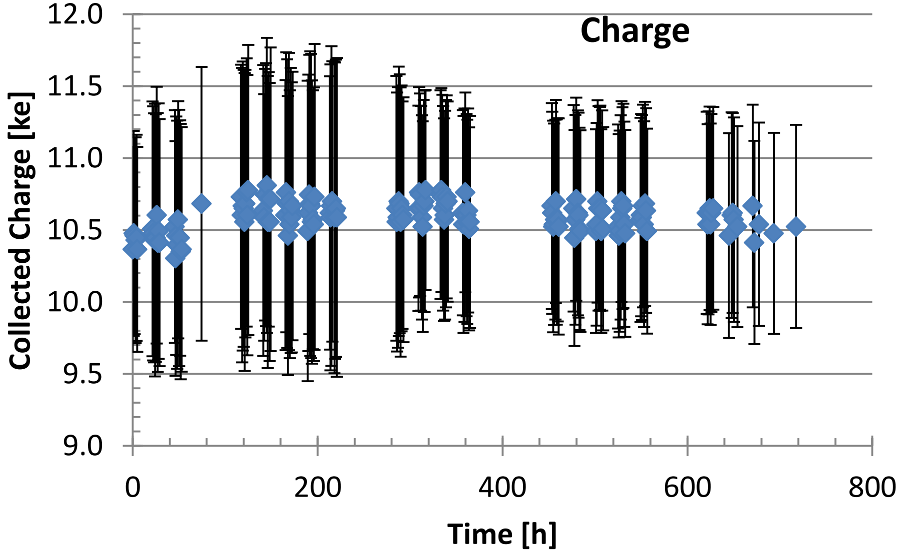
Long-term measurements

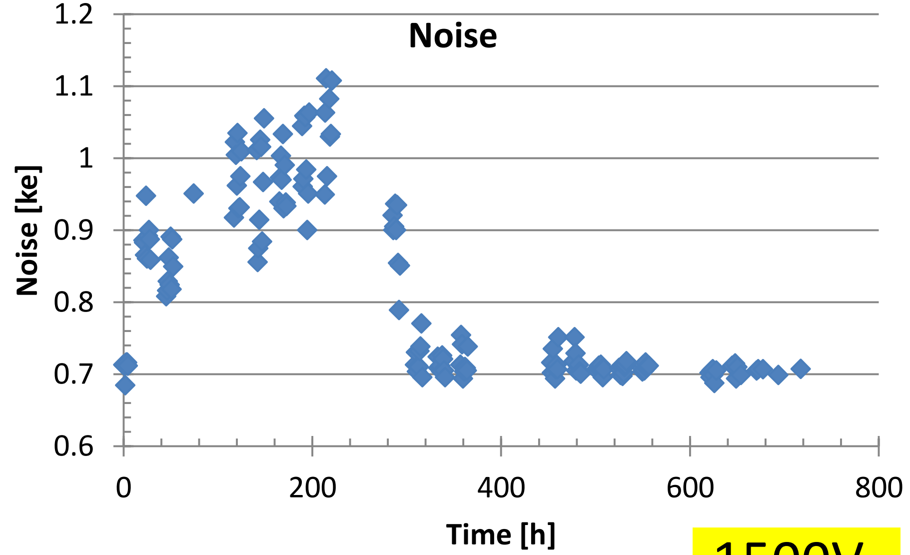
– Irradiated sensors
– Sensor constantly biased
– β source (≈300MBq) the whole time above sensor

– Bias voltage above 1000V to see behaviour of charge multiplication

More in talk from Christopher Betancourt Thursday:
Long-term HV stability of the collected charge in charge multiplication sensors

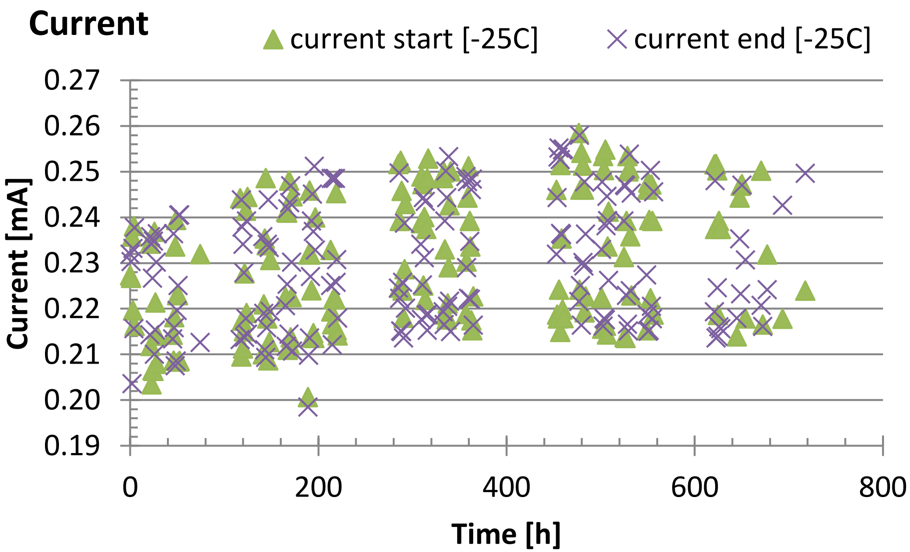
P80-W25-I10; 5×10^{15} n_{eq}/cm^2

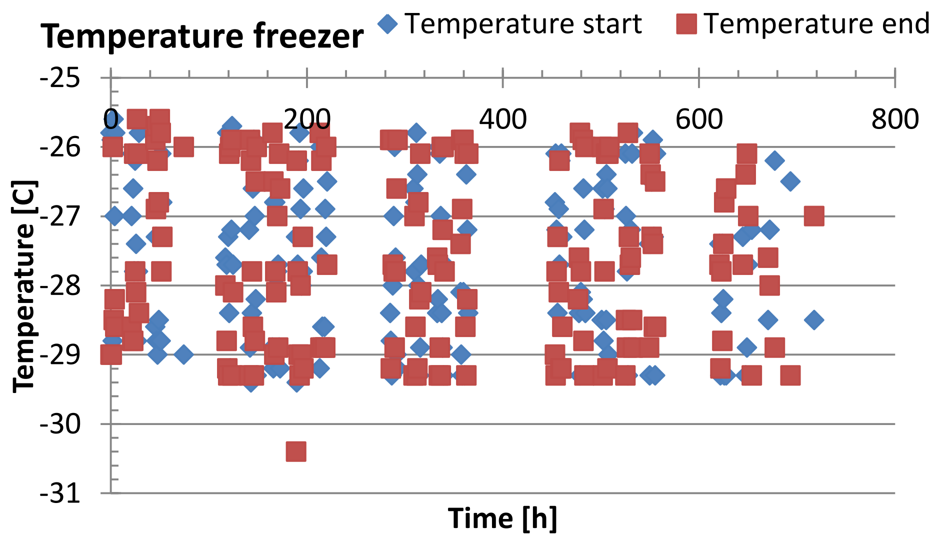




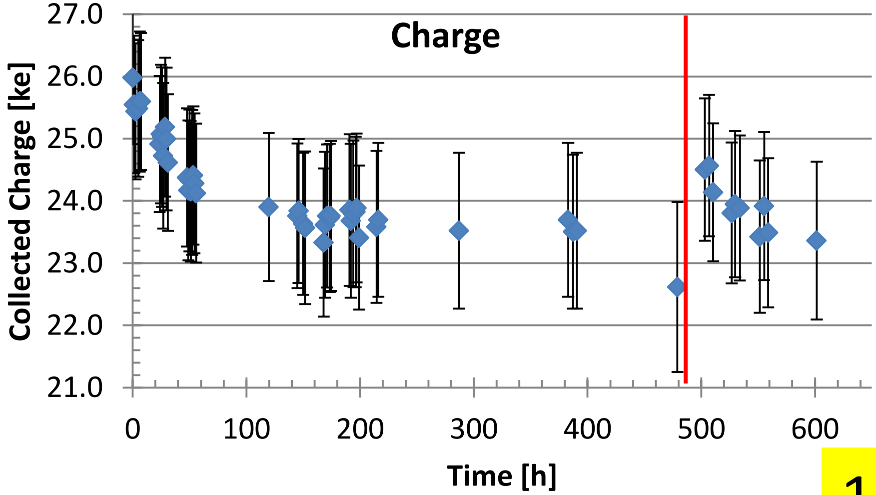
1500V

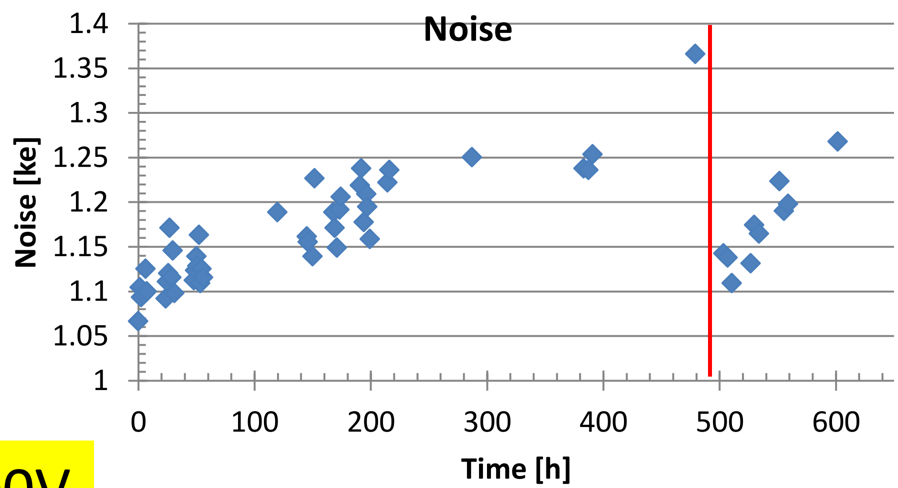
No "charge multiplication" in first CCV measurement; not annealing





P80-W25-I35; $5\times10^{15}\ n_{eq}/cm^2$

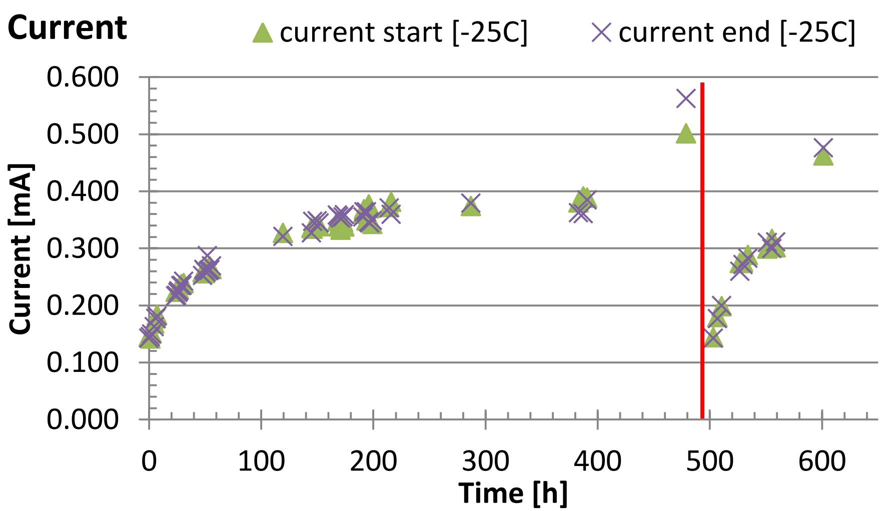


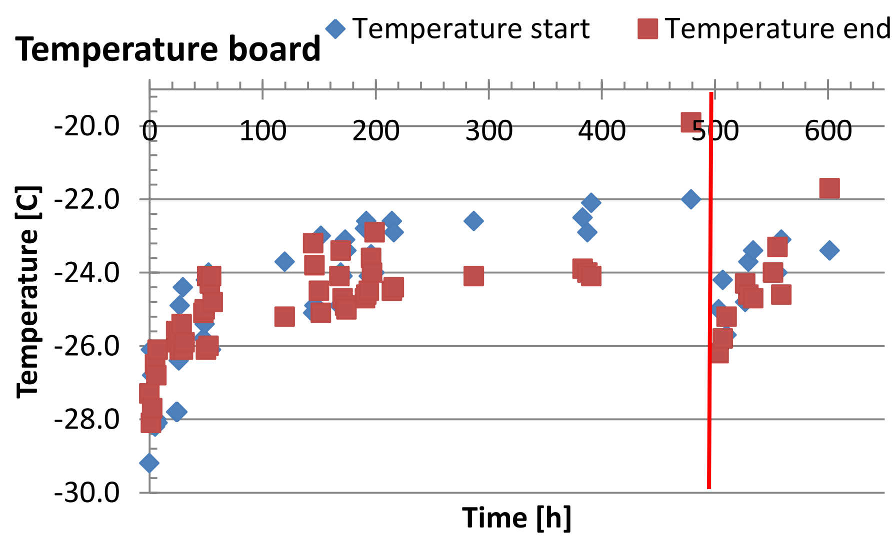


1700V

“charge multiplication” after annealing

During measurement sensor reached compliance (red line) => ramp to 0V, no bias for 1d, then back to 1700V





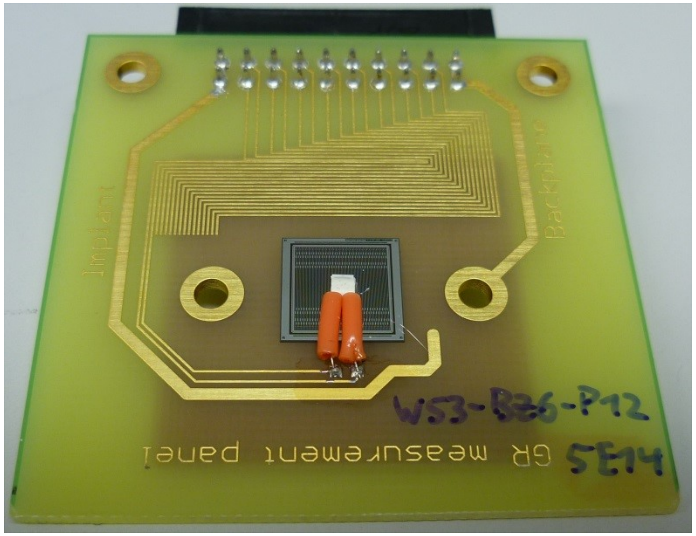
IV Study

For more details see my talk at RESMDD14:
Leakage Current Measurements of highly irradiated Silicon Strip Sensors

Sensors/Measurements

- Silicon sensors (~1 x 1 cm, n-in-p FZ) irradiated to different fluences
  - **ATLAS07 MINI**: 1×10^{12}, 5×10^{12}, 1×10^{13}, 5×10^{13}, 1×10^{14}, **2×10^{14},** 5×10^{14}, 1×10^{15}, **2×10^{15},** 5×10^{15}, 1×10^{16}, 1.5×10^{16}, 2×10^{16} [n_{eq}/cm^2]
  - **Micron 2437 (143µm)**: **2×10^{14}, 5×10^{14}, 1×10^{15}, 2×10^{15},** 5×10^{15}, 1×10^{16}, 2×10^{16} [n_{eq}/cm^2]
  - **Micron 2923 (108µm)**: **2×10^{14}, 5×10^{14}, 2×10^{15},** 5×10^{15}, 1×10^{16}, 2×10^{16} [n_{eq}/cm^2]

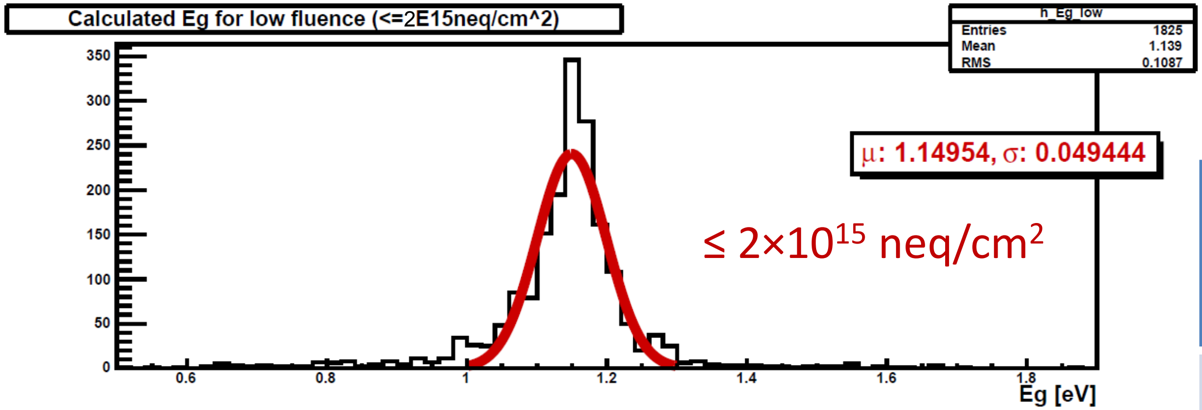
New measurements (0.3d)

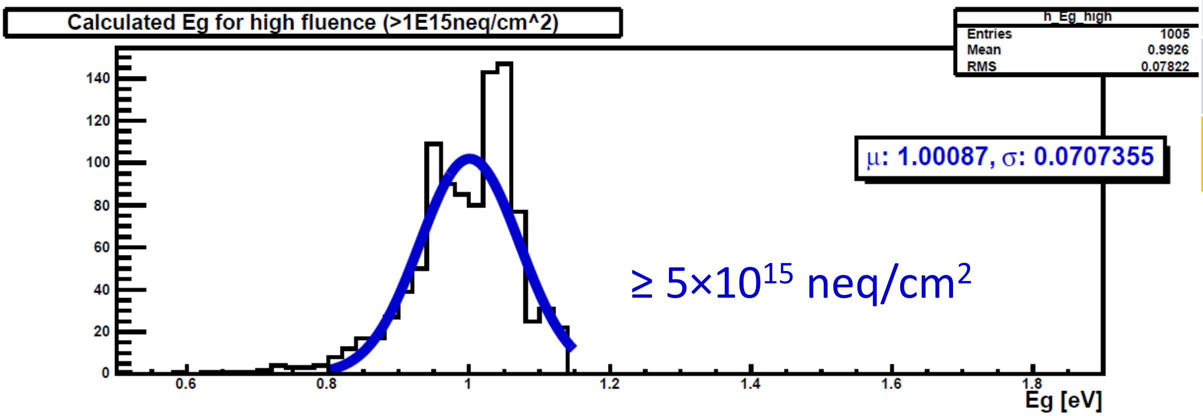


- PT1000 temperature sensor glued on silicon
- IV measurements in freezer at different temperatures from -23°C to -15°C (at least 2 per sensor)
- Different annealing steps (0.3d after glueing, 10d, 30d)

E_g 0.3d

Difference between low fluence ($\leq 2\times10^{15} n_{eq}/cm^2$) and high fluence ($\geq 5\times10^{15} n_{eq}/cm^2$)



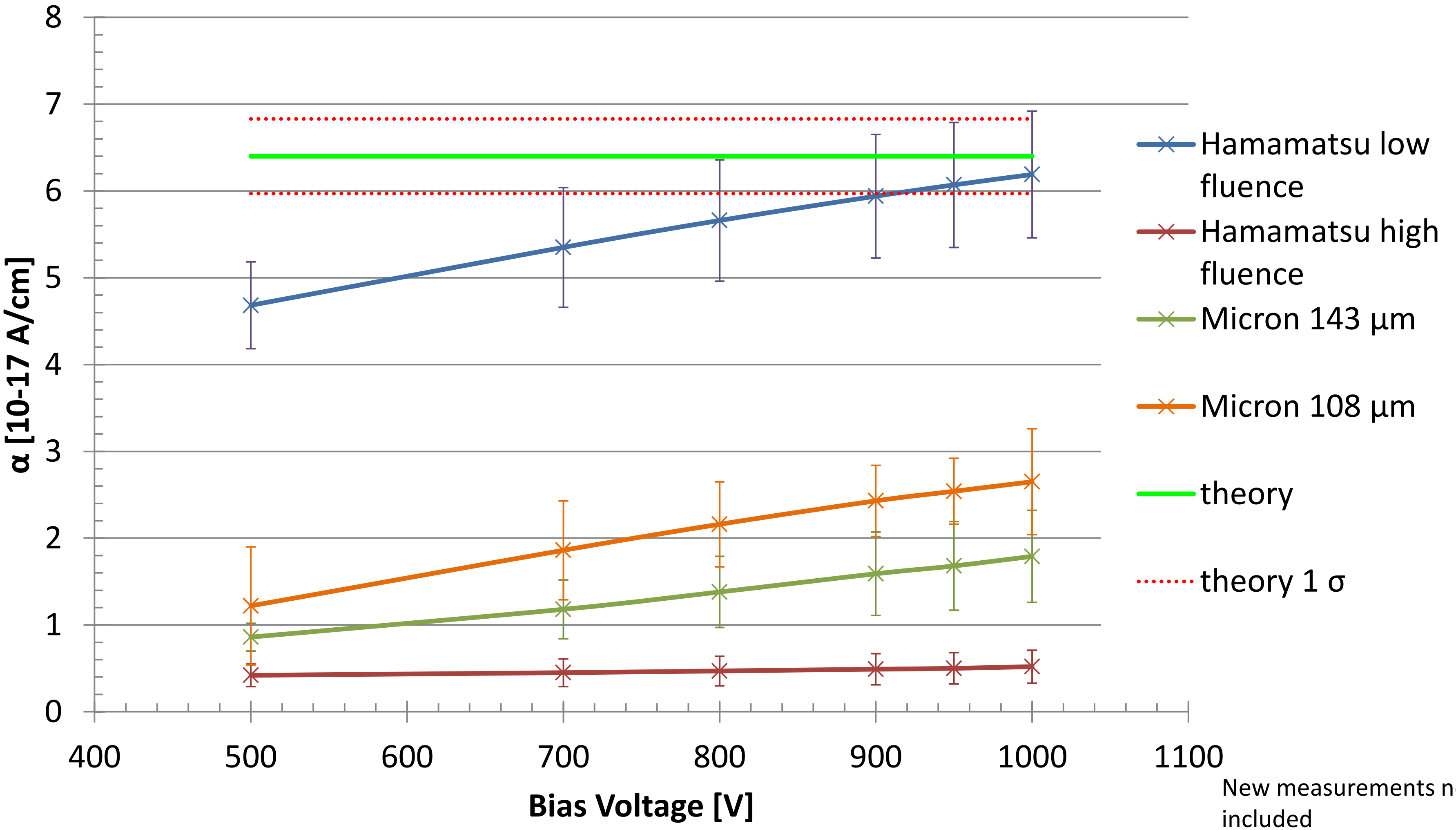


Annealing time	E_g [eV] low fluence	E_g [eV] high fluence
0.3d	1.15±0.05	1.00±0.07
10d	1.17±0.02	1.05±0.06
30d	1.17±0.03	1.07±0.08
theory	1.214±0.014	

Alpha Values (0.3d)

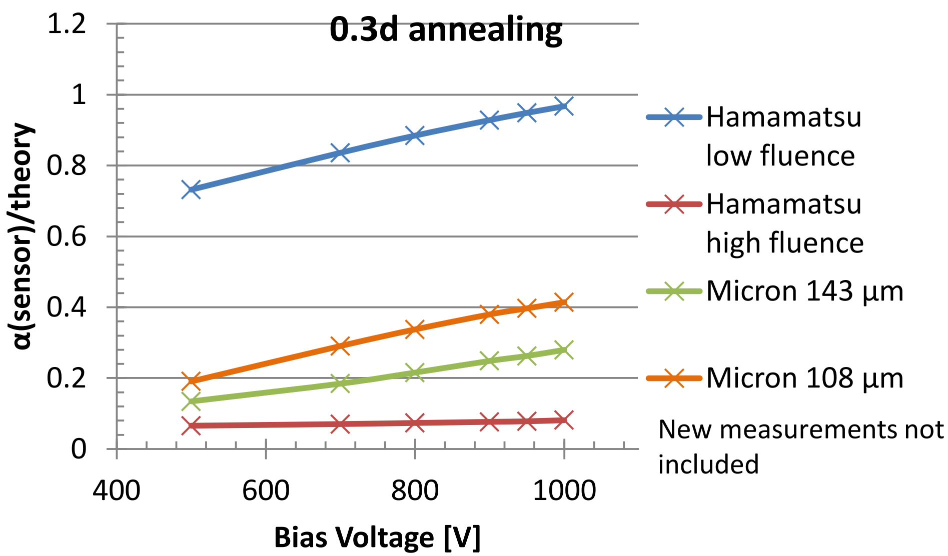
Using the average E_g value for each sensor to calculate the α value:

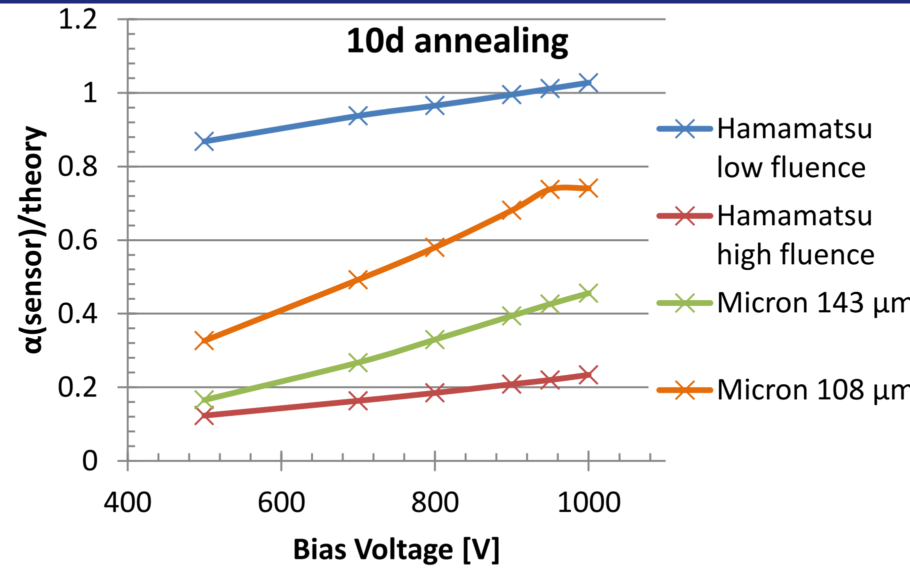
Straight line fit to 'ΔI/V vs ϕ' plot

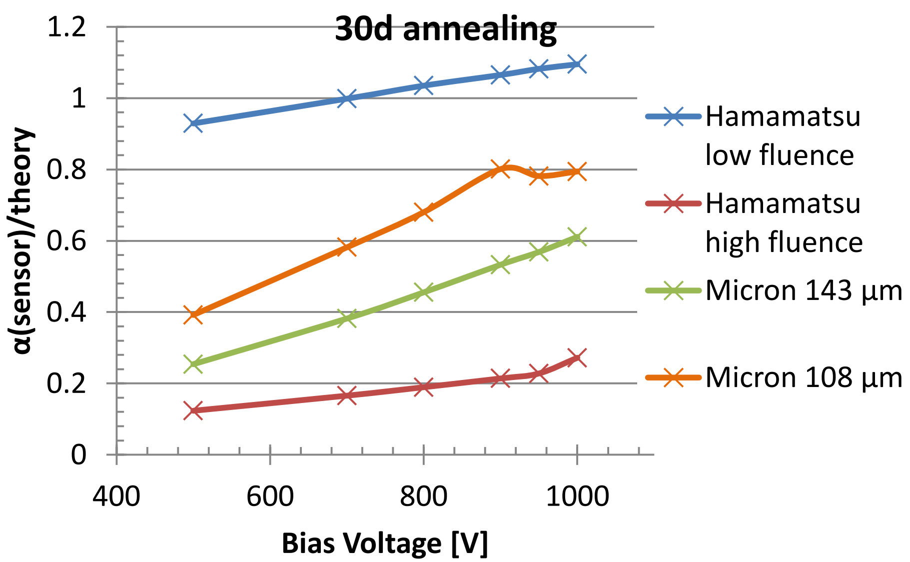


New measurements not included

Relative α after annealing



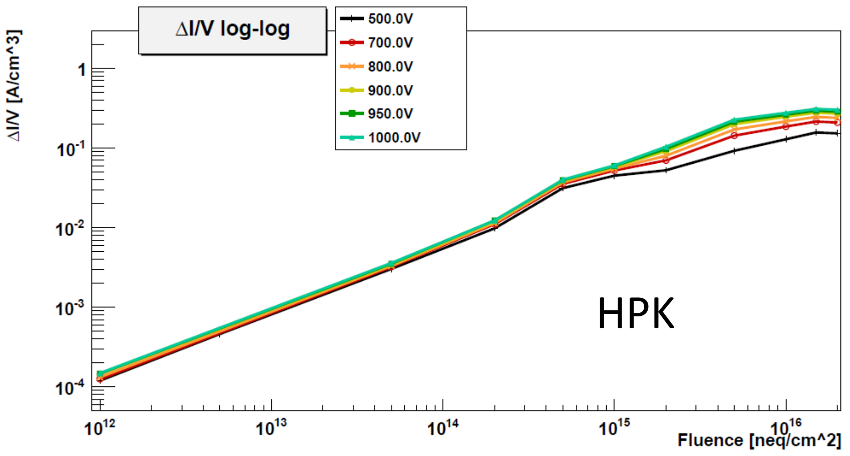


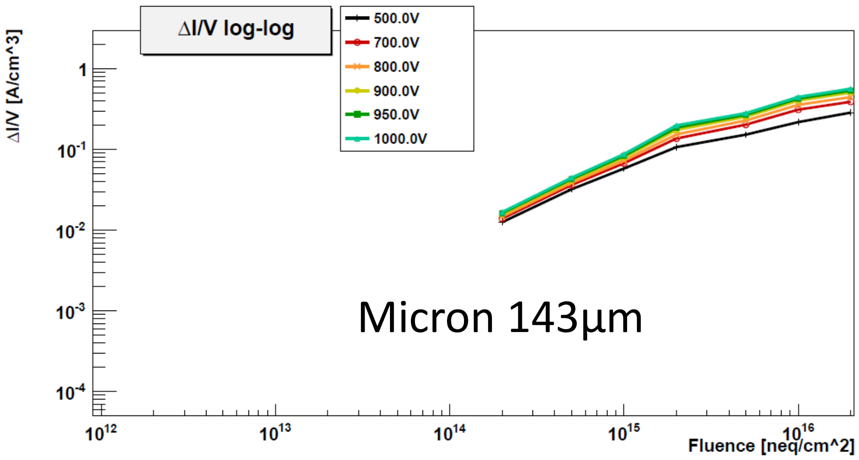


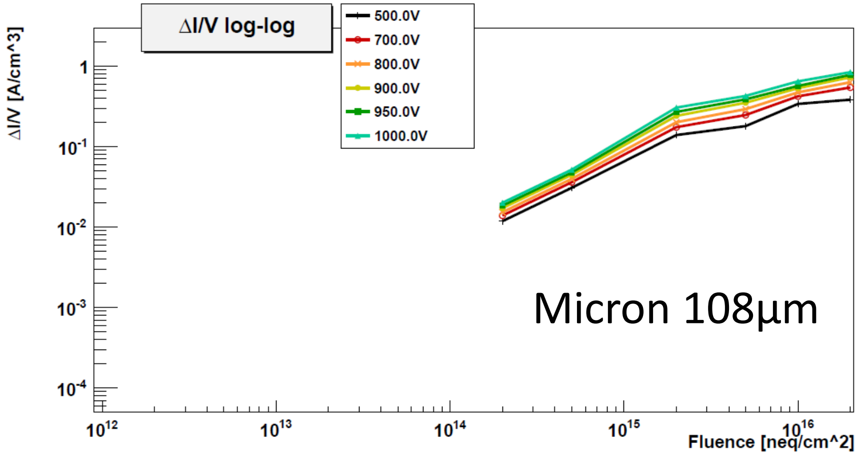
Alpha values divided by theoretical value

Annealing time [min]	α [10^{-17}A/cm] at 21°C
0.3d (=470 min)	**6.40±0.43**
10d (=14400min)	**4.32±0.29**
30d (=43220min)	**3.50±0.23**

ΔI/V vs ϕ (0.3d)







- ΔI/V as function of fluence
- 0.3d annealing
- New measurements included

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Summary

- Room temperature annealing of irradiated RD50 charge multiplication sensors
  - 1×10^{15} n_{eq}/cm^2: expected annealing profile
  - 5×10^{15} n_{eq}/cm^2: increasing collected charge with increasing annealing time -> charge multiplication
- Long-term bias voltage test
  - No clear systematics observed from the presented measurements
    - See talk of C. Betancourt (this workshop, Thursday) for more details
- IV study:
  - Difference of the activation energy E_g for low fluence ($\leq2\times10^{15}$ n_{eq}/cm^2) and high fluence ($\geq5\times10^{15}$ n_{eq}/cm^2) sensors
    - Low fluence ≈ (1.17±0.03)eV
    - High fluence ≈ (1.05±0.08)eV
  - Also different current related damage rate α
    - High fluence significantly lower
    - With increasing annealing time the difference between the high fluence α and the theoretical value decrease

Backup

IV Measurement Aim

- IV scaling:

$$\frac{I(T_2)}{I(T_1)} = \left(\frac{T_2}{T_1}\right)^2 exp\left(\frac{-\boldsymbol{E_g}}{2k_B}\frac{T_1 - T_2}{T_1 T_2}\right)$$

  E_g: activation energy (1.214±0.014eV [1]); T_1: measurement temperature,T_2: scaling temperature; k_B: Boltzmann constant

  Use for scaling of current to different temperatures, determination of E_g from measurement

- Investigate behaviour of current for irradiated sensors

$$\frac{I(\Phi_{eq}) - I(\Phi_0)}{V} = \boldsymbol{\alpha}\Phi_{eq}$$

  Only valid up to ~1×10^{15} n_{eq}/cm^2

  V: depleted volume; Φ_{eq}: equivalent fluence; $I(\Phi_0)$: nonirradiated current ; α: current related damage rate

  Determination of α from measurements

[1]: A. Chilingarov; *Temperature dependence of the current generated in Si bulk*; **2013_JINST_8_P10003**