



23rd RD50 Workshop
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Status of Silicon Strip Sensor Measurements at Liverpool

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- First results of room temperature annealing study with charge multiplication sensors
- Leakage current measurements of irradiated sensors
 - Determination of activation energy (E_g)
 - Determination of current related damage rate (α)



Annealing study

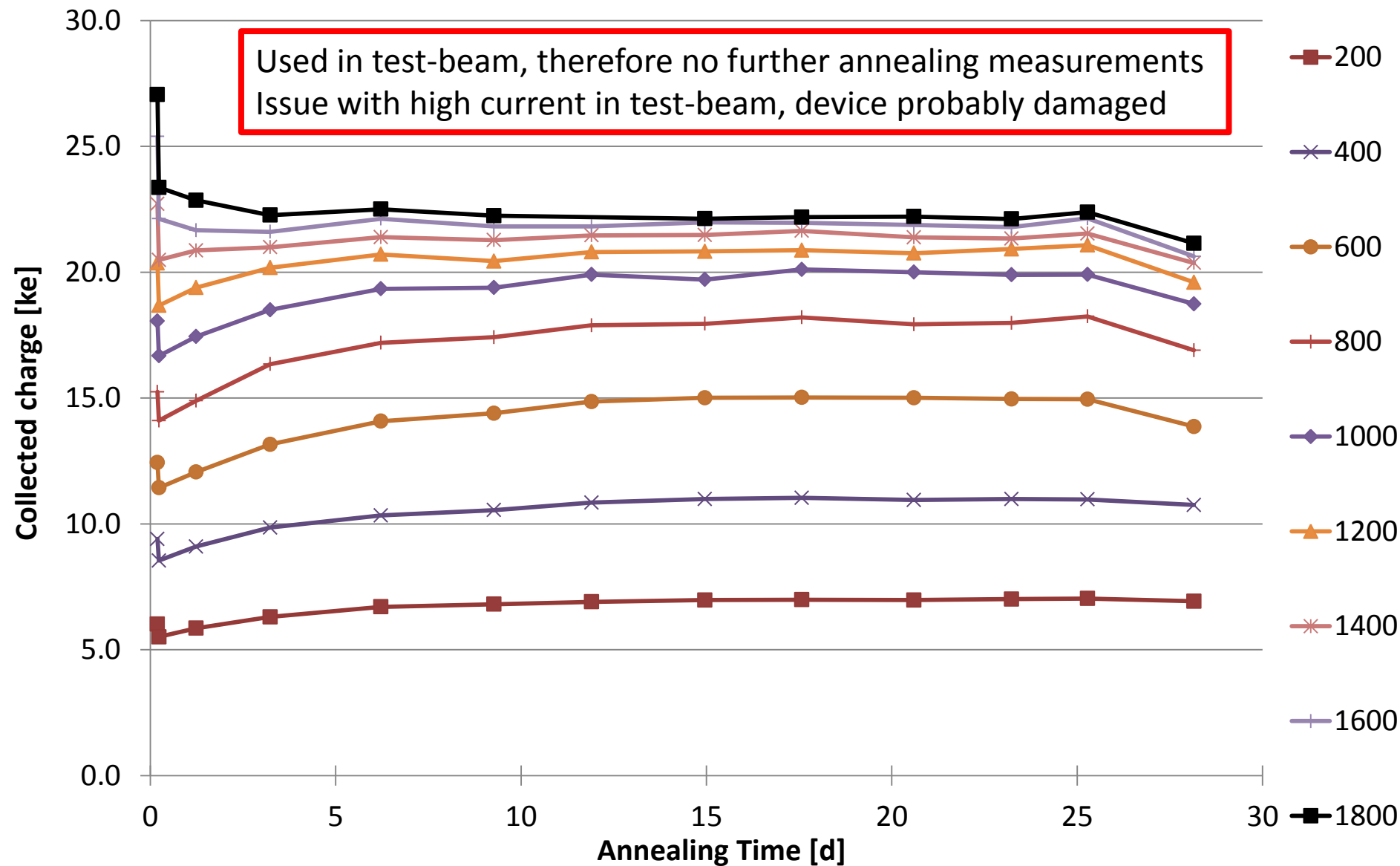


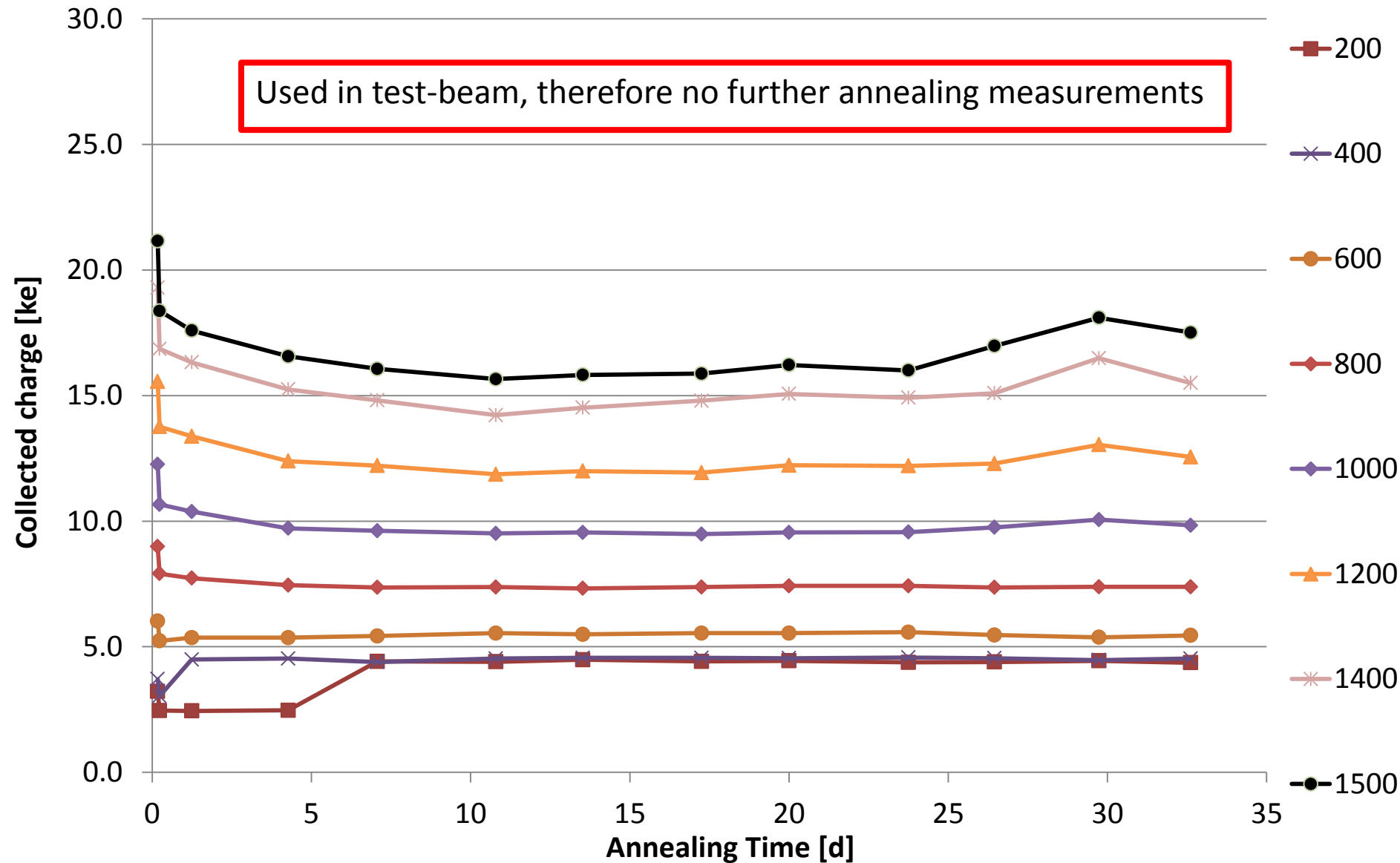
- Dedicated charge multiplication sensors, produced by Micron Semiconductor Ltd (UK)
- 1cm x 1cm, n-in-p FZ strip detectors
- Various strip pitch (P) and width (W)
- Some sensors with biased intermediate strips (I) between readout strips
- Irradiated to two different fluences
 - P80-W60 (standard); $1 \times 10^{15} n_{eq}/cm^2$
 - P80-W60 (thick); $5 \times 10^{15} n_{eq}/cm^2$
 - P80-W25-I35 (standard); $1 \times 10^{15} n_{eq}/cm^2$
 - P80-W25-I35 (standard); $5 \times 10^{15} n_{eq}/cm^2$

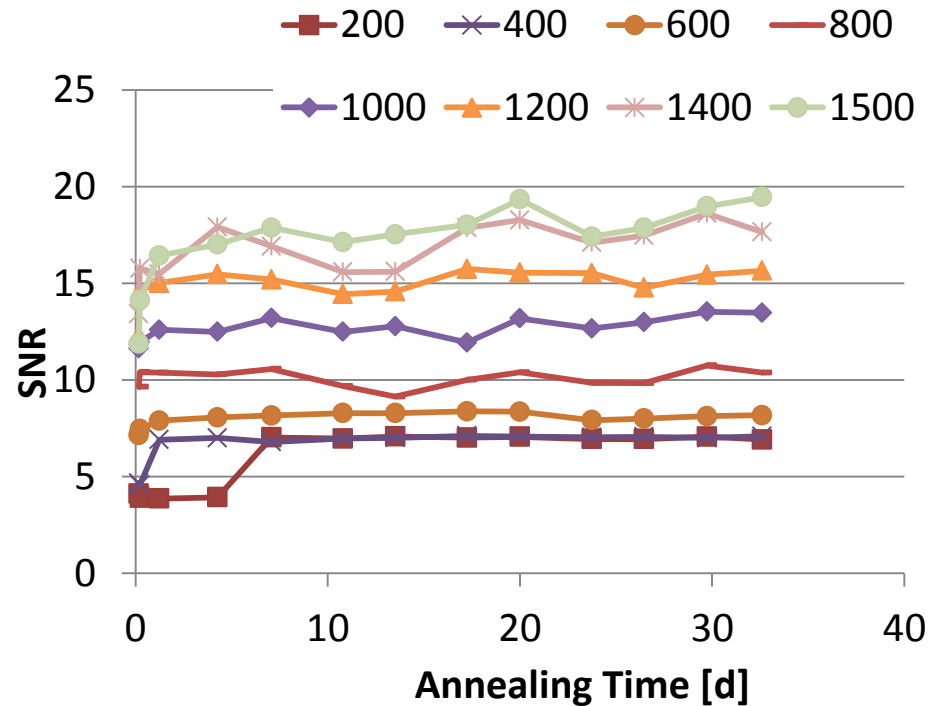
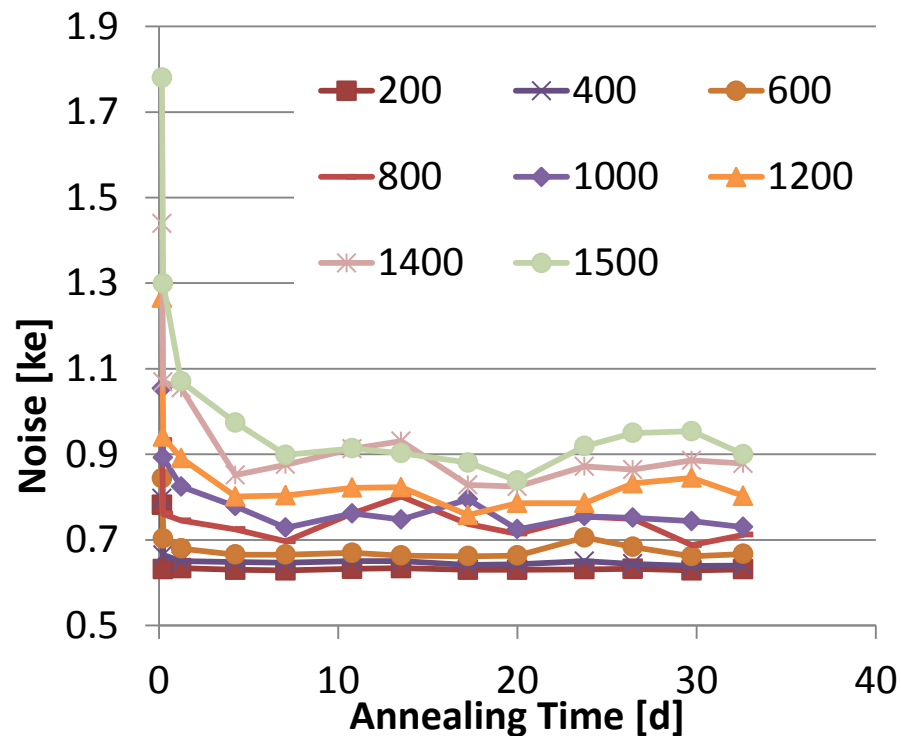


- Room temperature (20°C) annealing in nitrogen cabinet
- Charge collection measurements performed in Beta-setup with the ALiBaVa system
- Measurement every 100V at -23°C (in freezer)

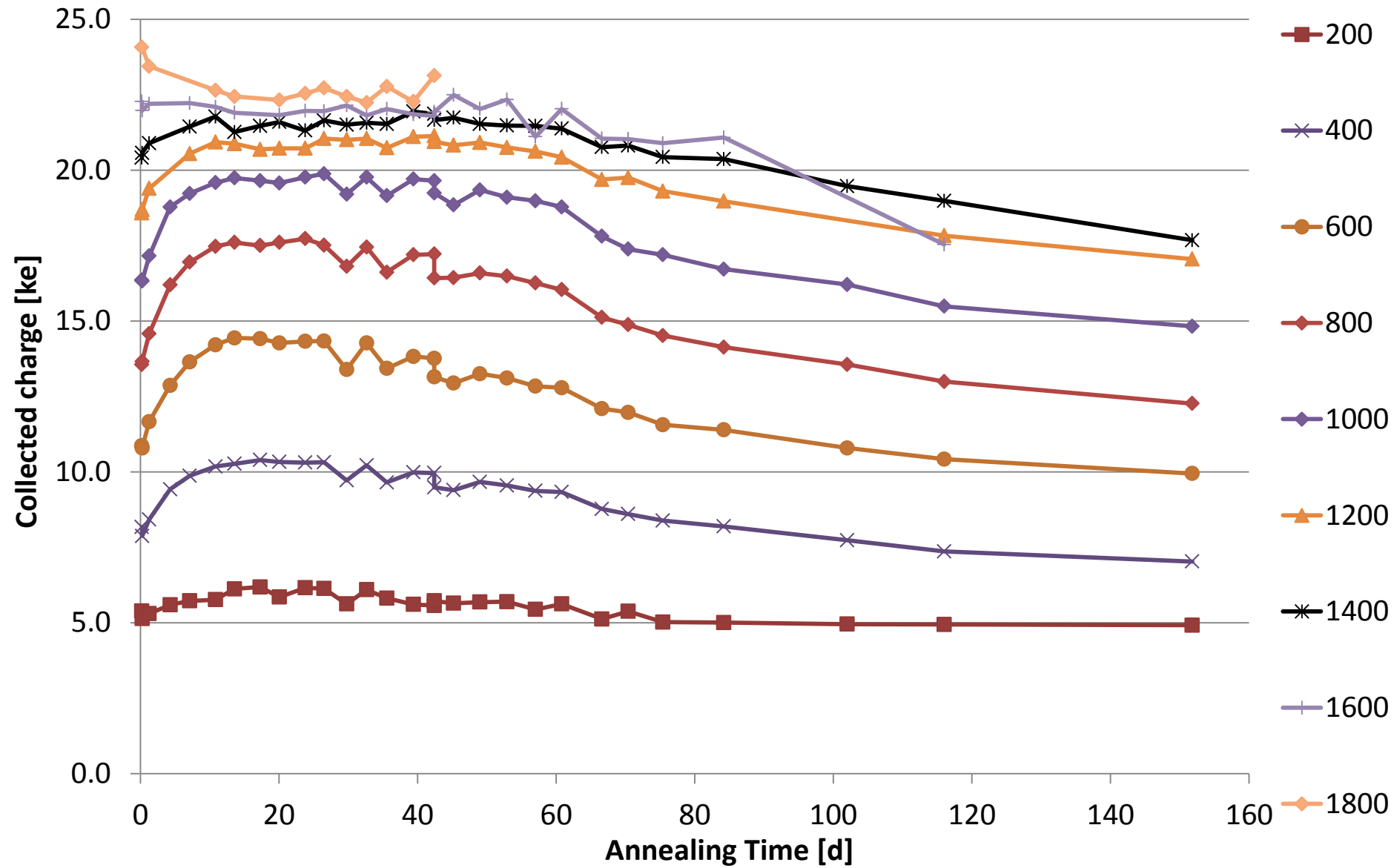
More details about first sensor measurements and ALiBaVa setup see talk of C. Betancourt (Charge Collection Measurements on Dedicated RD50 Charge Multiplication SSDs) this workshop

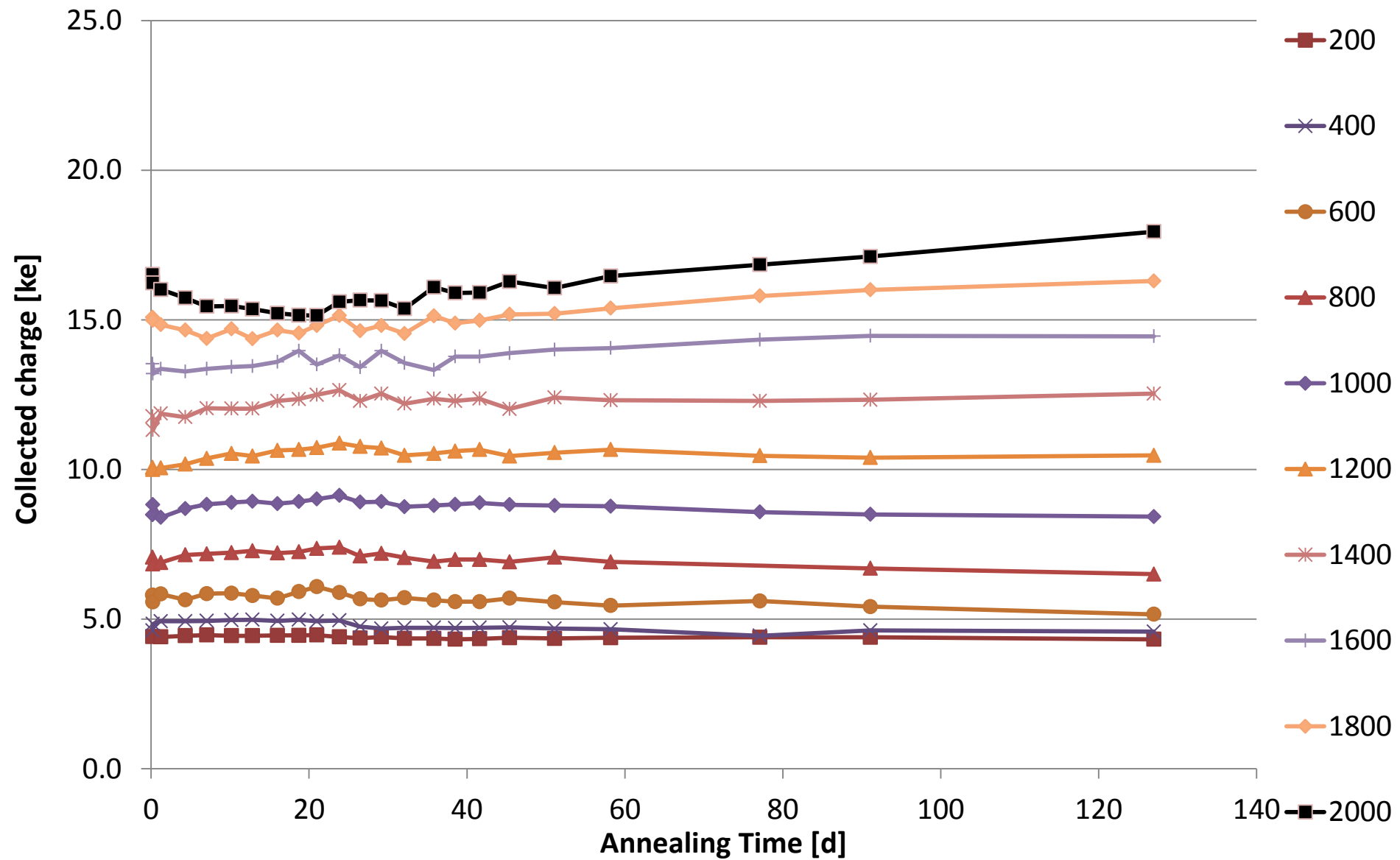






- Nearly constant noise which leads to nearly constant signal to noise ratio
- Only for this device such nice plots, for other high noise peaks in combination with current peaks
 - Flushing measurement box with nitrogen helps







- Both sensors with P80-W60 show the expected behaviour after room temperature annealing. There is a sign that the 5×10^{15} neq/cm² irradiated device has a maximum of the collected charge at approximately 30 days.
- The collected charge of P80-W25-I35 (1×10^{15} n_{eq}/cm²) increase slightly within the first 10 days and decrease then.
- The collected charge of P80-W25-I35 (5×10^{15} n_{eq}/cm²) is nearly constant for bias voltages up to 1200V. For higher voltages the charge is increasing.



IV study

COLLABORATION WITH LANCASTER



- IV scaling:

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

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

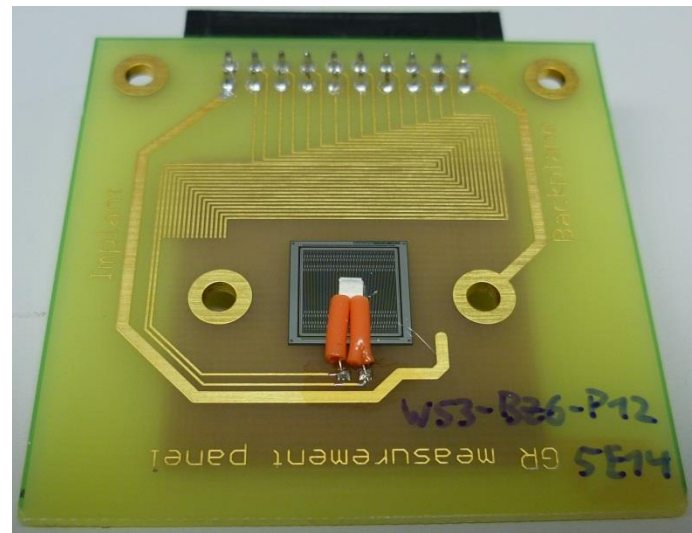
$$\frac{I(\Phi_{eq}) - I(\Phi_0)}{V} = \alpha \Phi_{eq}$$

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

Determination of α from measurements

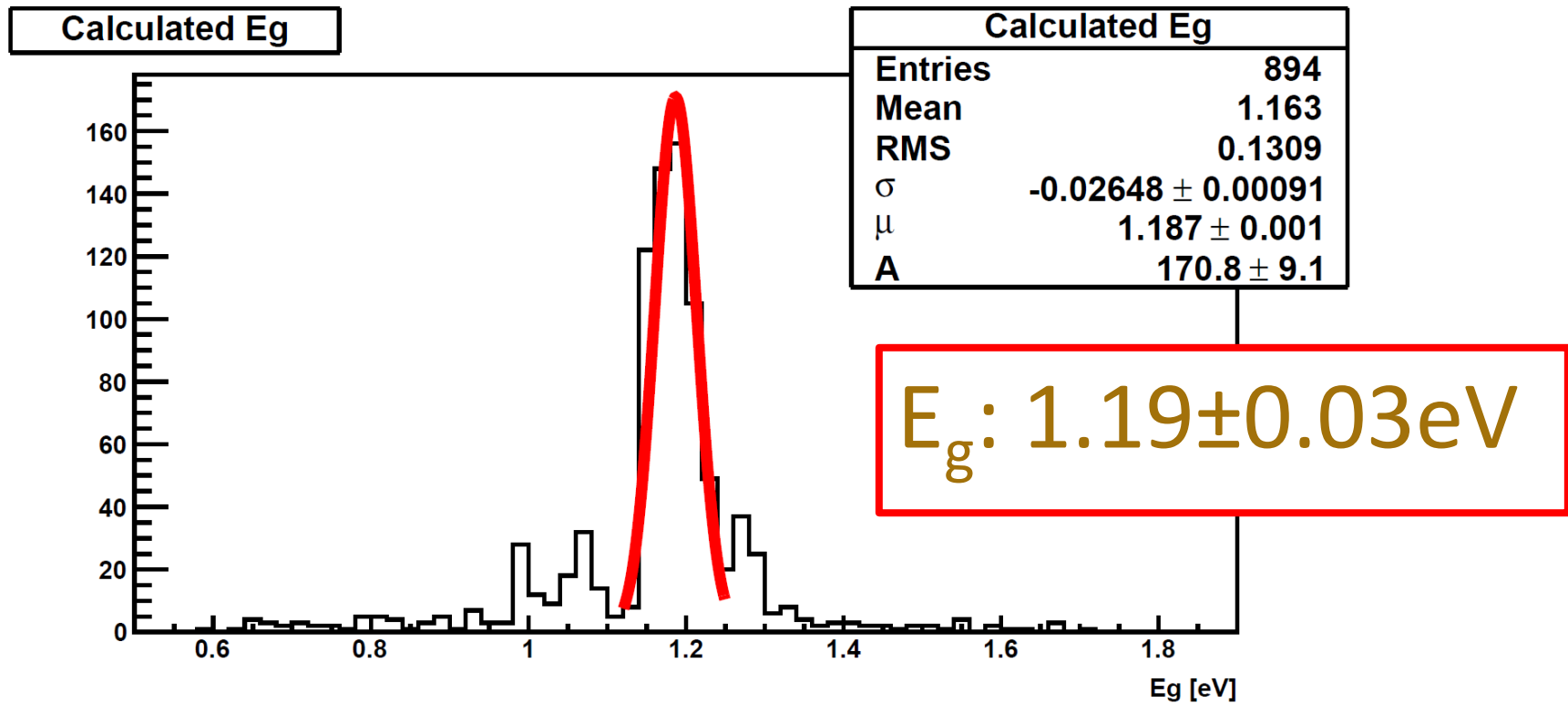
[1]: A. Chilingarov; *Temperature dependence of the current generated in Si bulk*; **2013_JINST_8_P10003**

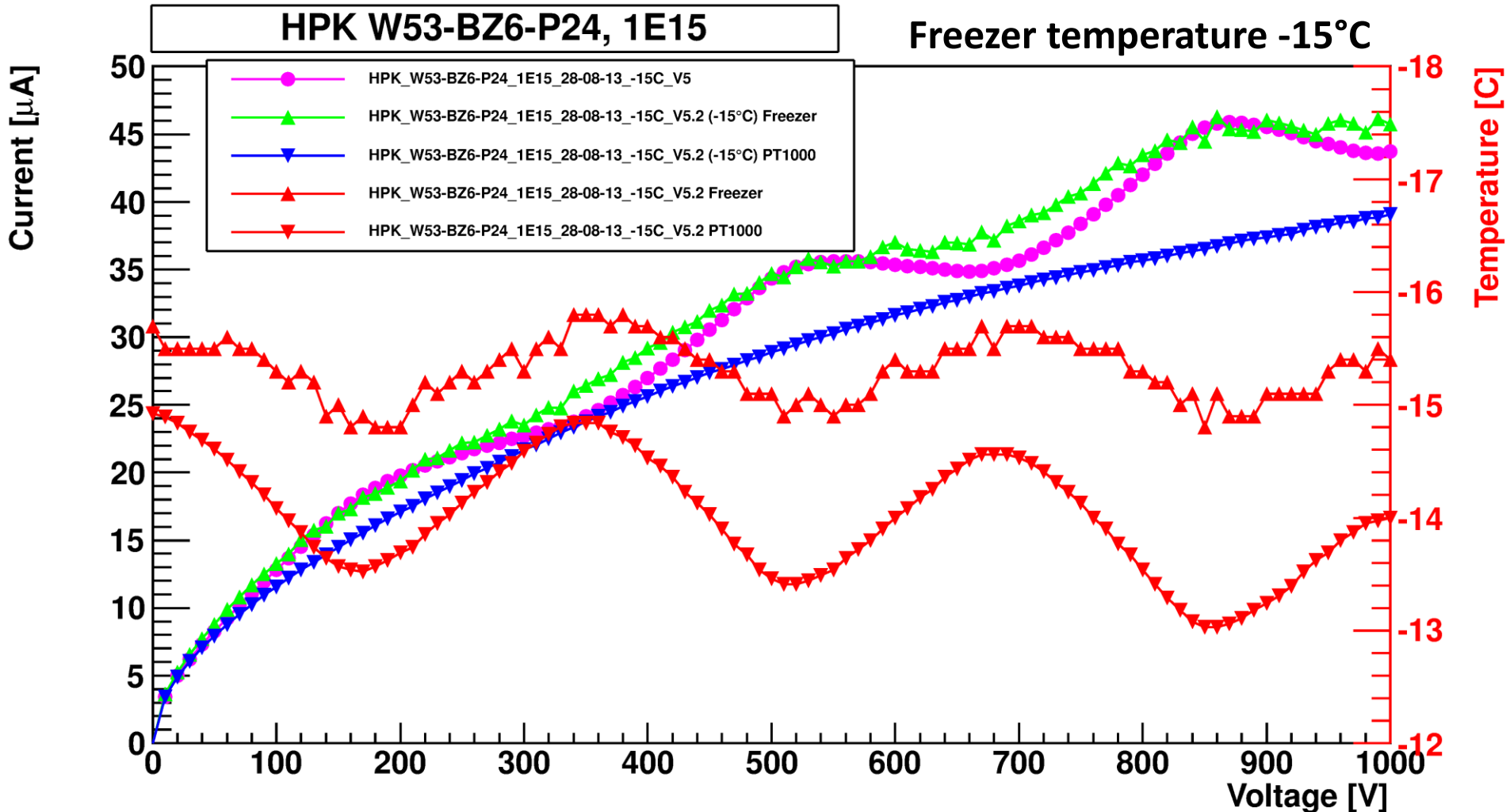
- Irradiate ATLAS07 sensors to different fluences
 - Doses [n_{eq}/cm^2]: 1×10^{12} , 5×10^{12} , 1×10^{13} , 5×10^{13} , 1×10^{14} , 5×10^{14} , 1×10^{15}
 - Irradiate more sensors with higher doses
- One set of sensors measured at Liverpool, second set send to Lancaster
- Glued PT1000 temperature sensor on sensor (annealing time 470min)
- Perform IV/CV measurements in a freezer at different temperatures (-23°C , -18°C , -15°C)



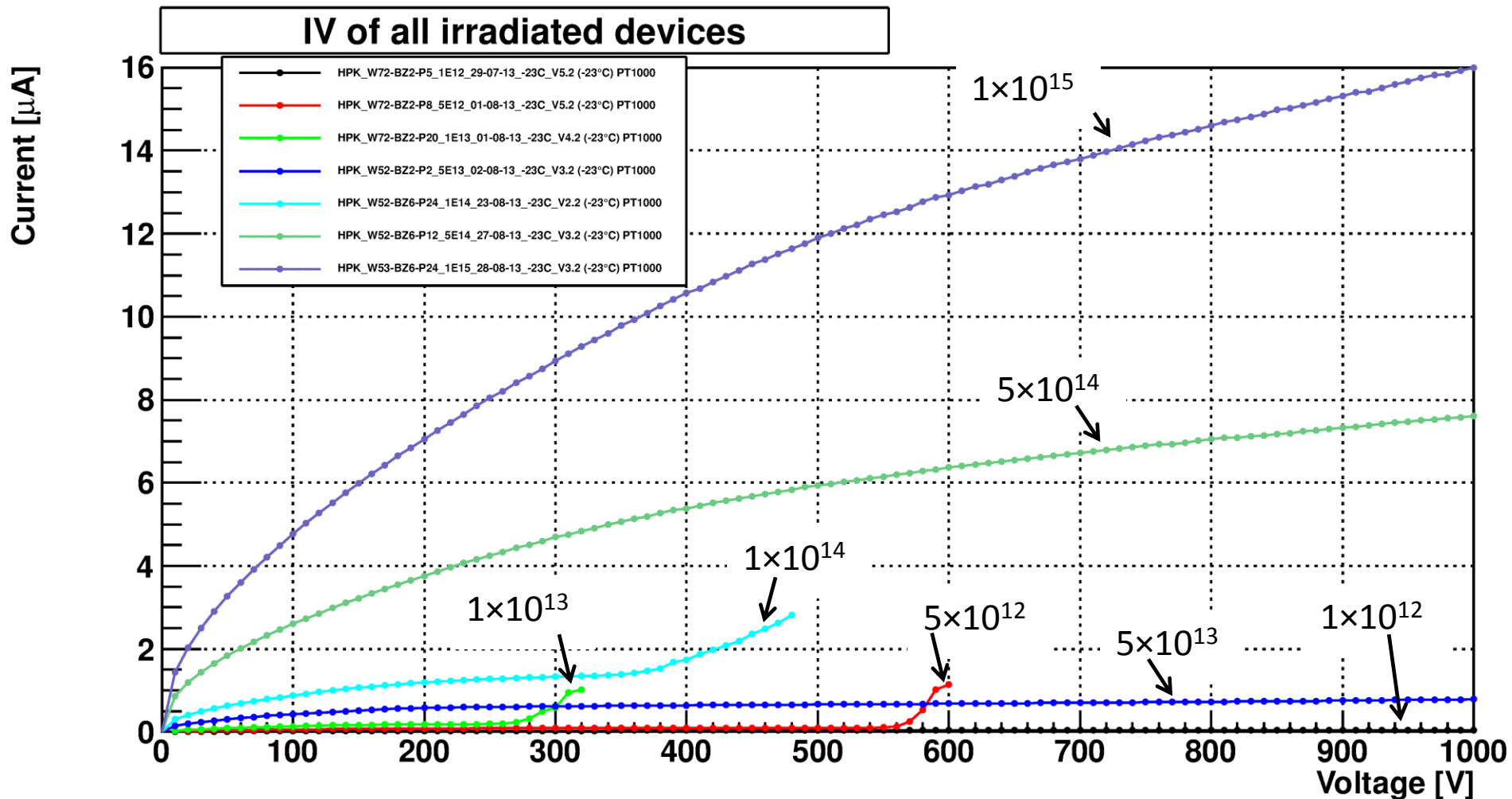


- Calculate E_g for all data points of all measurements
- Gauss fit to find centroid and error





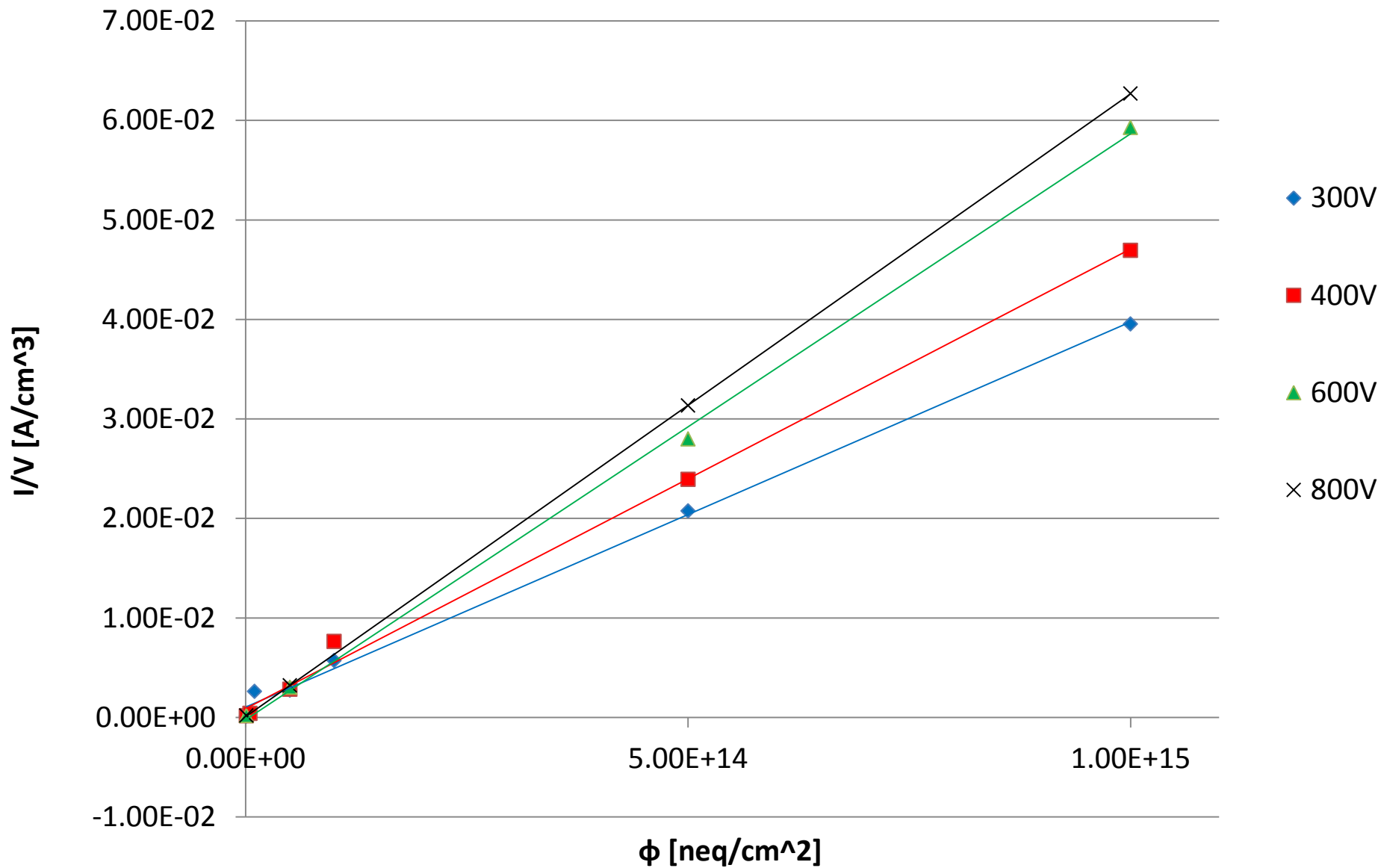
Example of temperature scaling for one IV measurement:
Scaling to PT1000 temperature lead to smooth curve



IV plot of all irradiated devices (after rescaling to -23°C): with increasing dose the current increase



Alpha Determination





- Linear Regression with data values
 - 300V: $(3.90 \pm 0.10) \times 10^{-17} \text{A/cm}$
 - $(5 \pm 1) \times 10^{-17} \text{A/cm}$ (only depleted sensors)
 - 400V: $(4.65 \pm 0.13) \times 10^{-17} \text{A/cm}$
 - $(5.47 \pm 0.07) \times 10^{-17} \text{A/cm}$ (only depleted sensors)
 - 600V: $(5.93 \pm 0.13) \times 10^{-17} \text{A/cm}$
 - 800V: $(6.305 \pm 0.005) \times 10^{-17} \text{A/cm}$
- Literature Value (470min annealing at 21°C) [2]
 - $6.37 \times 10^{-17} \text{A/cm}$

Used “depleted” area: $(0.846 \times 0.846) \text{cm}^2$, 314 μm thickness

[2]: formula and parameters from:

M. Moll, *Radiation Damage in Silicon Particle Detectors*, **PhD thesis**



- The determined activation energy from the measurements ($E_g=1.19\pm0.03\text{eV}$) is in good agreement with the literature value ($E_g=1.214\pm0.014\text{eV}$).
- The alpha value of $(6.305\pm0.005)\times10^{-17}\text{A/cm}$ at 800V is of the same order as the prediction $6.37\times10^{-17}\text{A/cm}$ for 470min annealing at 21°C.
- Further measurements after several annealing steps will be performed to determine the alpha value.
- More sensors will be irradiated to doses up to 5×10^{16} $n_{\text{eq}}/\text{cm}^2$



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- We would like to thank the irradiation teams and Birmingham, Ljubljana and Karlsruhe
- The RD50 community as a whole