High-temperature performance of solid-state sensors (500°C)

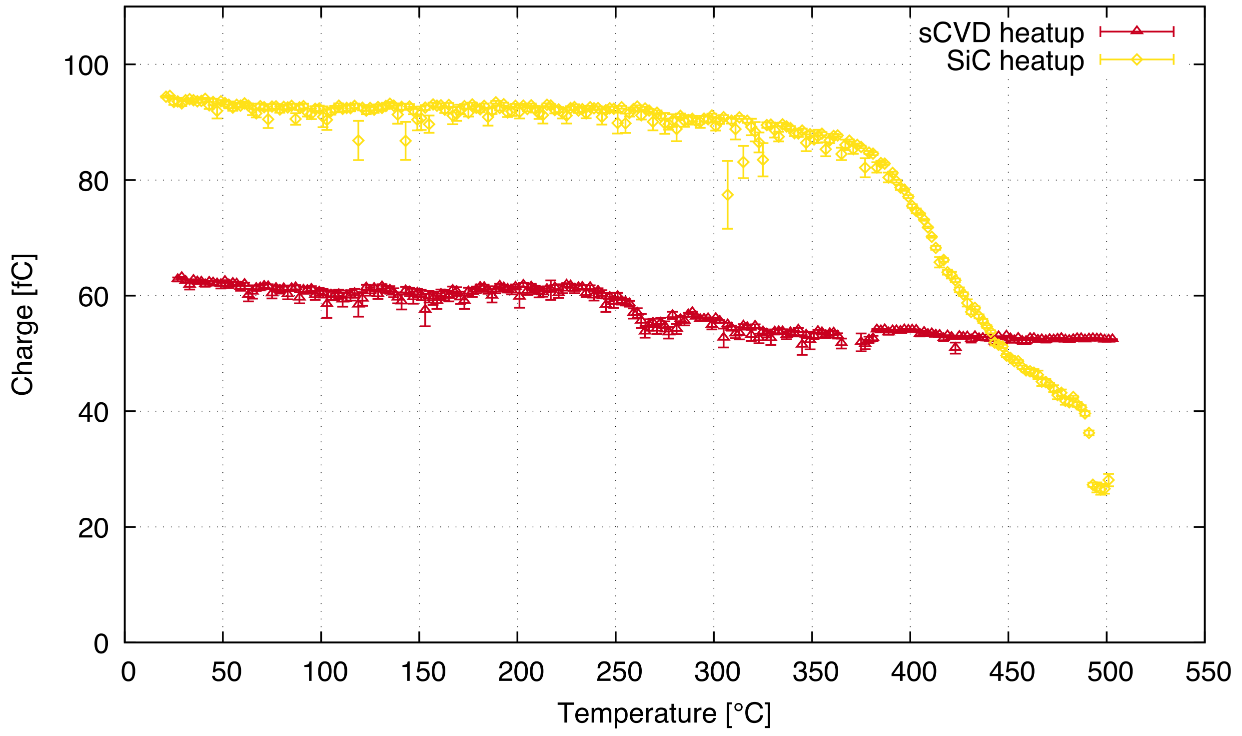
VCI2022, Vienna/Austria

C. Weiss[1,2], Jennifer Wilson[3,4], Georg Tiebel[3,4], Patrick Steinegger[3,4], H. Frais-Kölbl[5], E. Griesmayer[1,2], Rugard Dressler[3], Massimo Camarda[6], Maria del Mar Carulla Areste[3]

[1] TU Wien, Atominstitut, Vienna, Austria
[2] CIVIDEC Instrumentation GmbH, Vienna, Austria
[3] Paul Scherrer Institut, Villigen PSI, Switzerland
[4] ETH Zürich, Zurich, Switzerland
[5] University of Applied Sciences, Wiener Neustadt, Austria
[6] SenSiC GmbH, Park innovAARE, Villigen, Switzerland

Main result

- Both sensor materials show α-signals up to 500°C.
- Charge yield decreases with increasing temperature.
- First promising results of an ongoing research campaign.



INTRODUCTION AND EXPERIMENTAL SETUP

Introduction

Introduction

- Follow-up measurement campaign of published results up to 200°C [1].

- Systematic investigation of solid-state sensor performance up to 500°C:
  - sCVD[2] sensor with 140 μm thickness.
  - SiC[3] sensor with 30 μm depletion zone.

Motivation

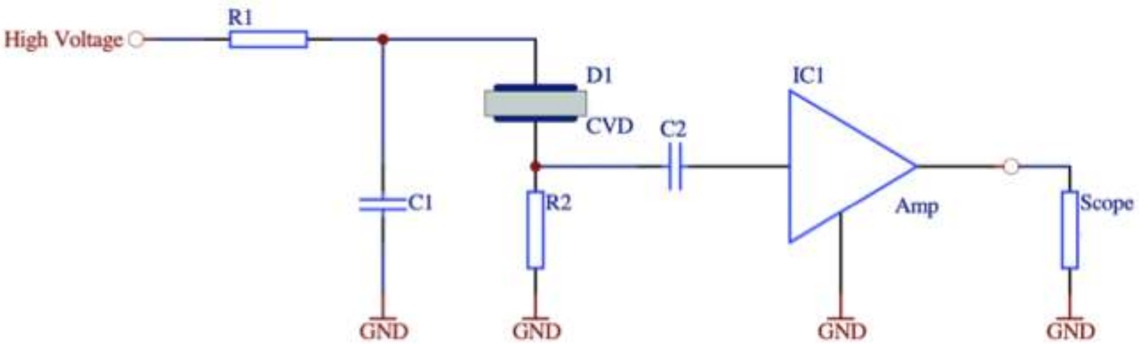
Applications needing spectroscopic measurement of particles up to high temperatures:

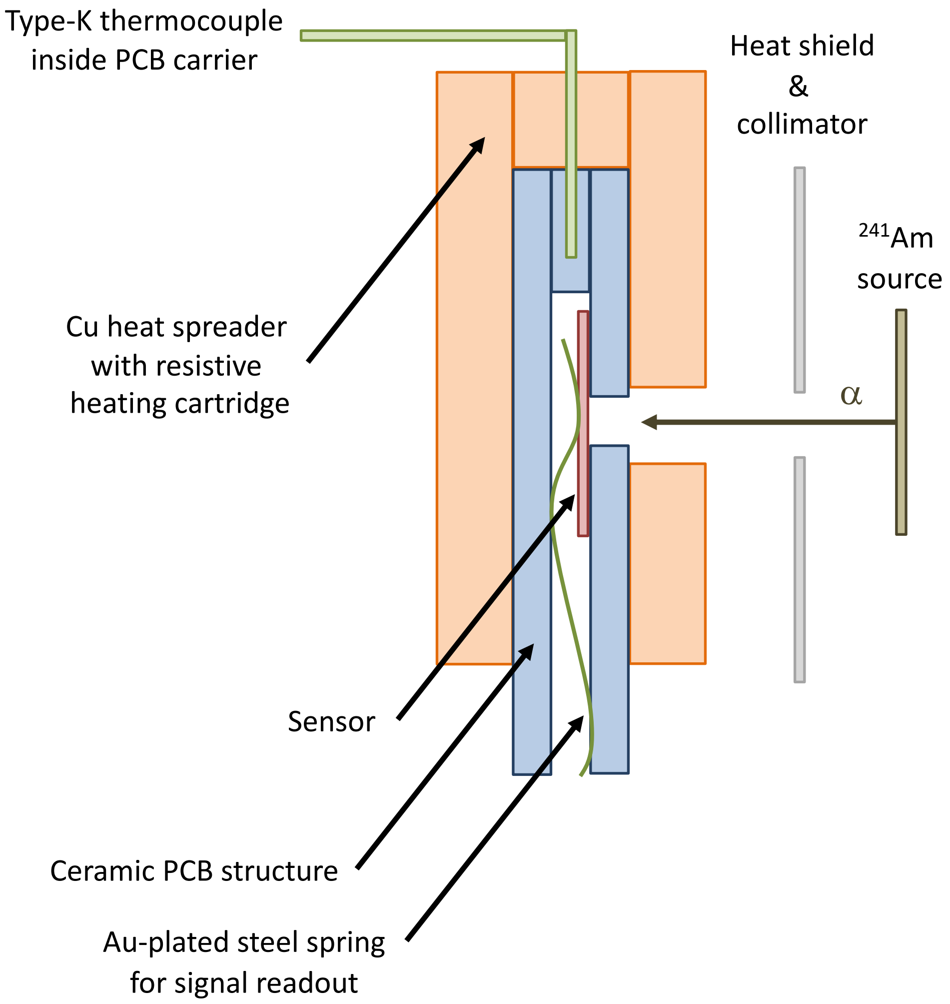
1. Superheavy element chemistry: experiments using vacuum chromatography $T < 1000$°C.
2. Fusion research: $T < 500$°C.
3. Geodetic applications: $T < 250$°C.

[1] B.Kraus et al., NIMA 989 (2021) 164947.
[2] Single-crystal Chemical Vapour Deposition Diamond.
[3] Silicon-Carbide.

Experimental setup

- ^{241}Am α-source, measurement in vacuum.
- Sensor mounted in heated, ceramic structure.
- Electrical connection via mechanical clamping.
- Sensor HV = 150 V, electron-drift readout.
- Signal readout on ground side of sensor.
- Dark current (I_{dark}) measurement via HV supply line.
- Temperature (T) measurement close to sensor.





Electronic readout

- Analogue electronics:
  1. Broadband current amplifier, 2 GHz, 40 dB: for Transient-Current Technique (TCT) measurements to investigate sensor physics.
  2. Charge sensitive amplifier: spectroscopic measurements to investigate the charge yield of the sensors.

- Data taking:
  - Each sensor signal recorded with LeCroy digital oscilloscope.
  - Dark current (I_{dark}) measurement of the sensors with Keithley 2470 source meter.
  - Temperature (*T*) measurement with Lutron thermometer.

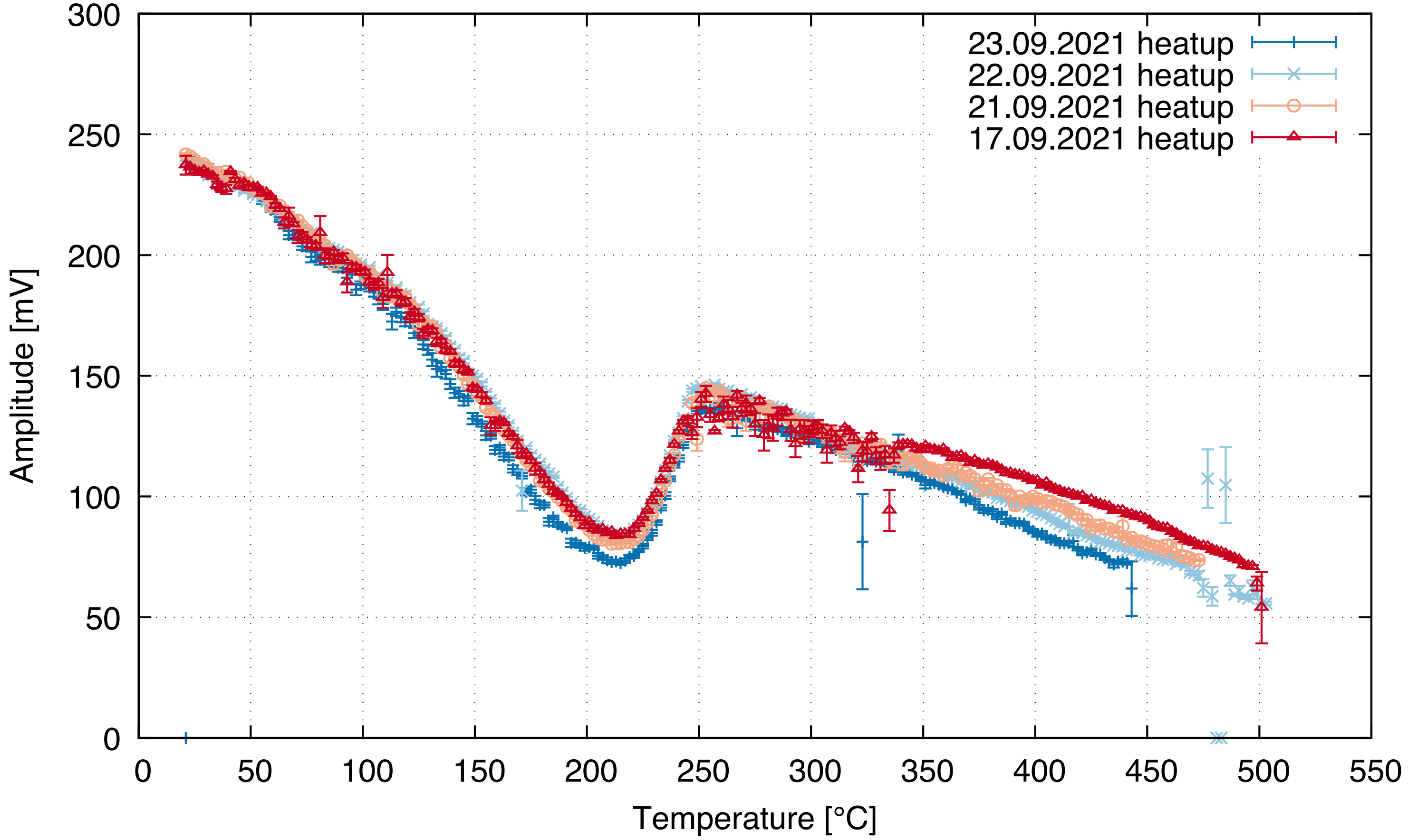
- Data analysis offline:
  1. Signal analysis for amplitude, FWHM, area and baseline noise.
  2. Synchronization of signals with *T* and I_{dark}.

- 4 measurement campaigns.
- Reproducible results for signal amplitude, FWHM, deposited charge and dark current of sensor.

TCT MEASUREMENTS WITH DIAMOND

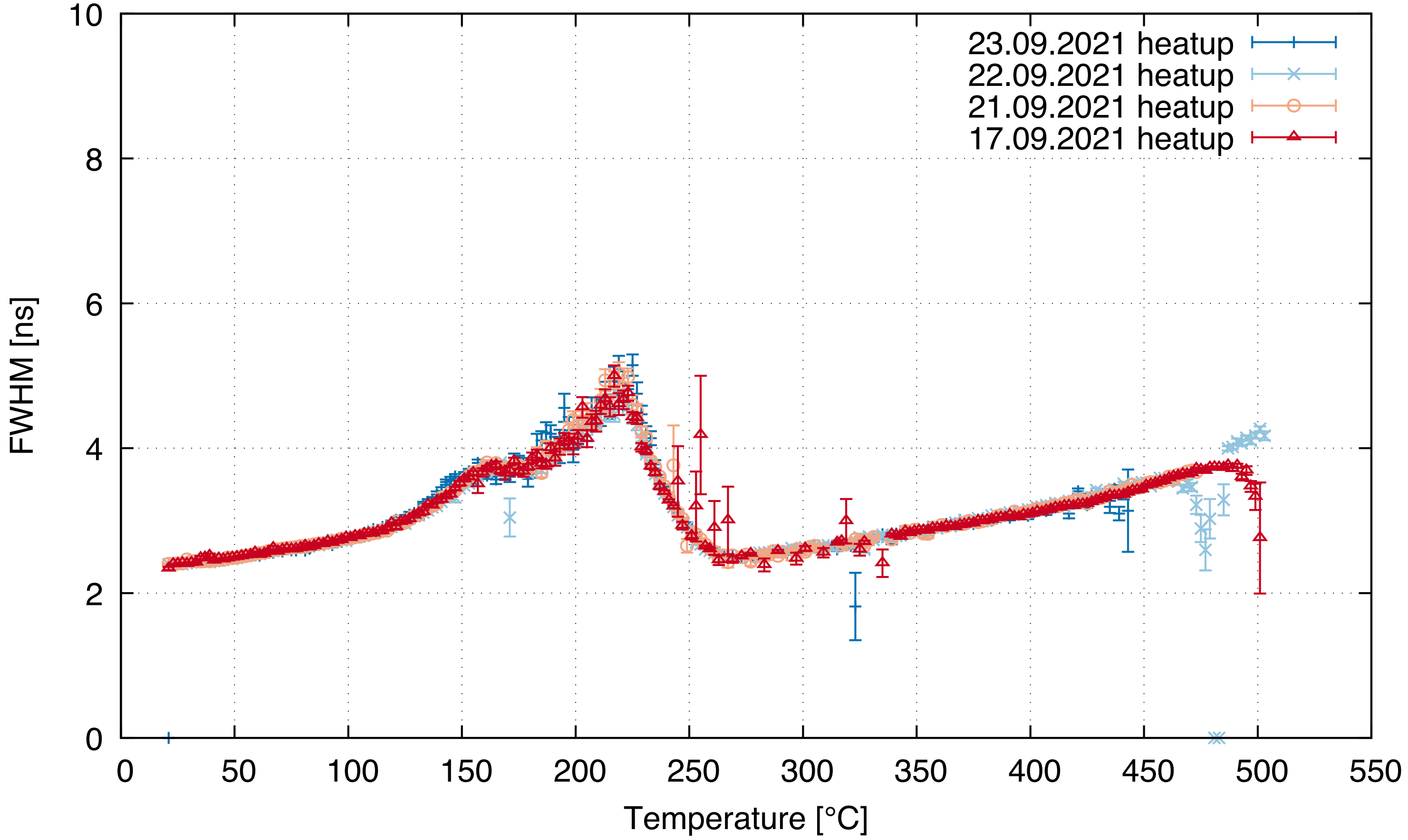
TCT with sCVD - Amplitude

- Measurements during heating up of sensor.
- Reproducible response for signal amplitude between measurement campaigns.
- Characteristic non-linearity between 60°C < T < 250°C.



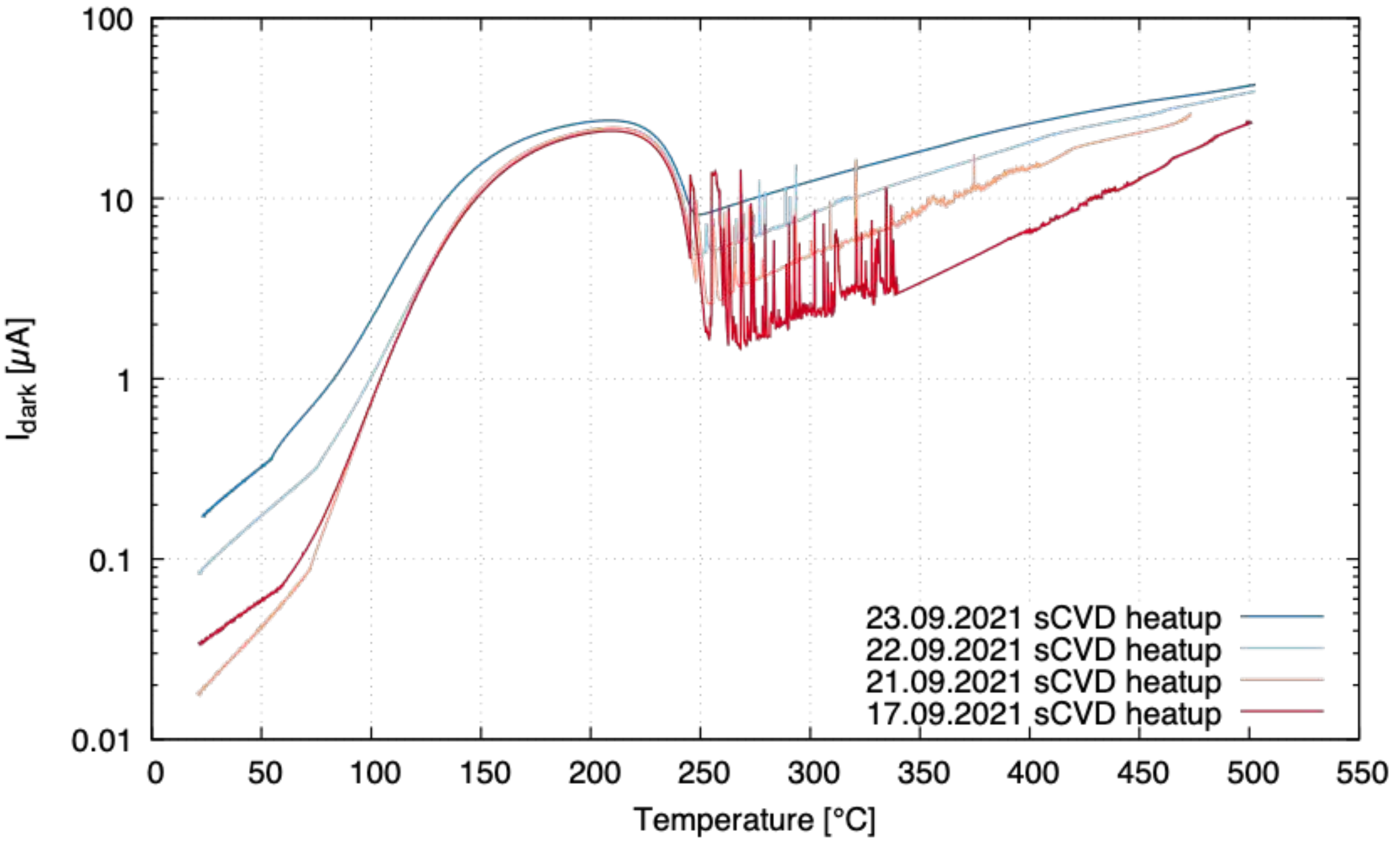
TCT with sCVD - FWHM

- Measurements during heating up of sensor.
- Reproducible response for signal FWHM between measurement campaigns.
- Characteristic non-linearity between 60°C < T < 260°C.



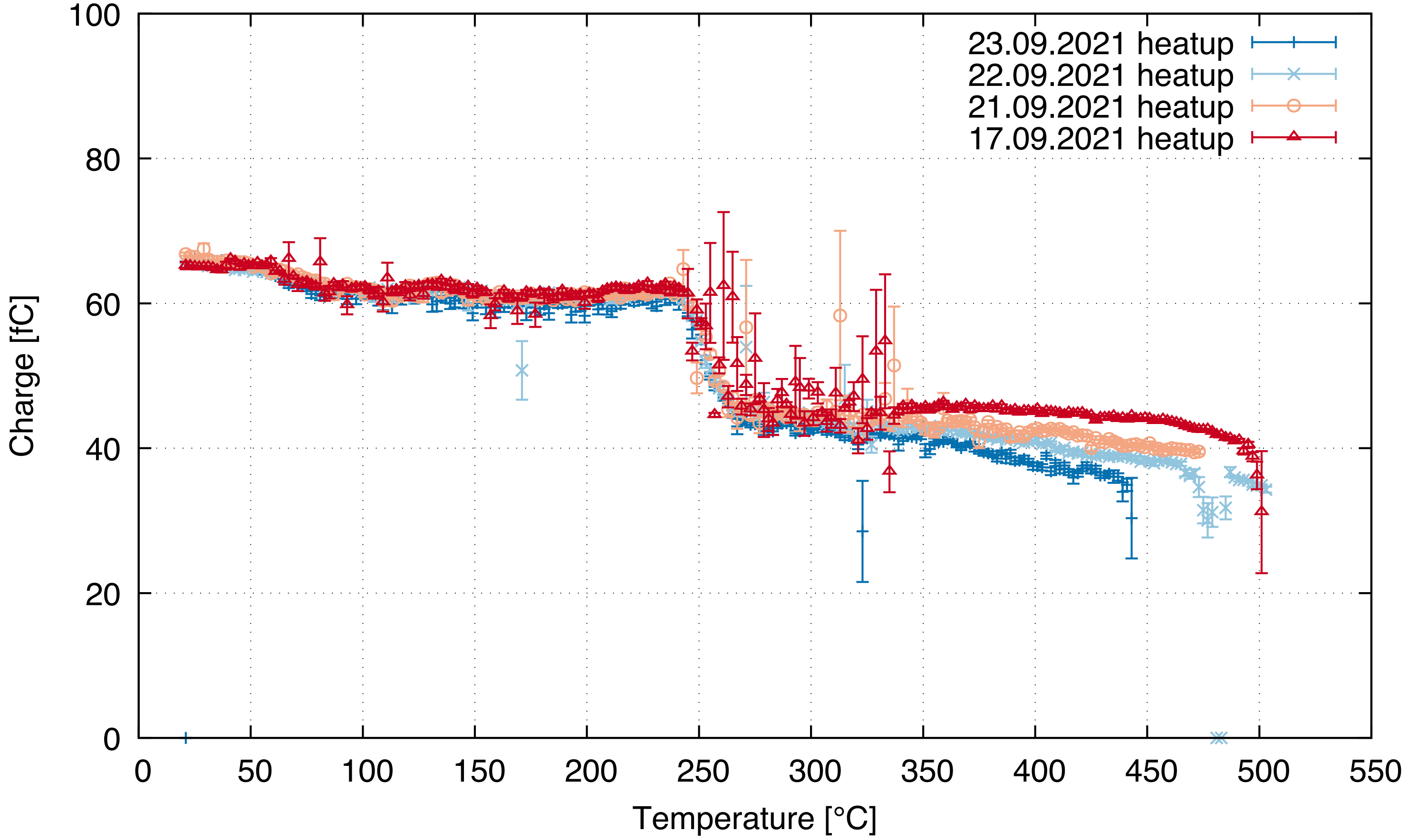
TCT with sCVD - I_{dark}

- Measurements during heating up of sensor.
- Increase of I_{dark} as function of T.
- Increase of I_{dark} as function of run number/date.
- Characteristic non-linearity between 60°C < T < 250°C.
- Peak structures for T > 250°C probably due to auto-scale function of Keithley 2470.



TCT with sCVD - Charge

- Deposited charge [1] reproducible between measurement campaigns.
- Drop of charge yield between 250°C and 270°C and linear decrease above.
- Increased uncertainty between 250°C and 350°C.
- Quantitative analysis of charge yield with spectroscopic electronics – see next slides.



[1] Area of TCT signal = deposited charge.

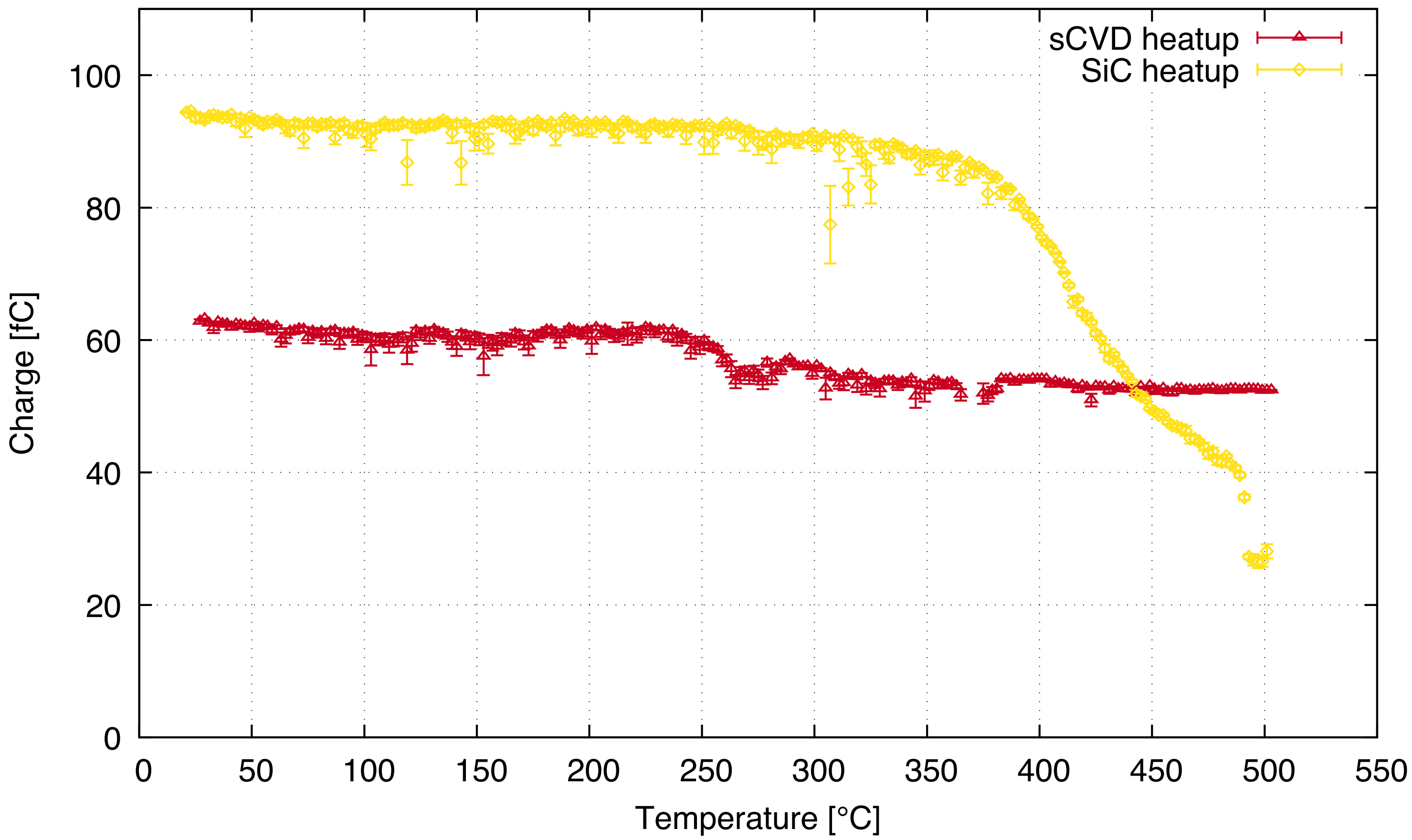
Ongoing measurement campaign => presentation of first results:

- Signals measured for sCVD and SiC up to 500°C.
- Systematic measurements for reproducibility and qualitative judgement are ongoing.

CHARGE YIELD OF DIAMOND AND SIC

Charge yield sCVD and SiC

- Measurements during heating up of sensors to 500 °C.
- 1 measurement series per sensor.
- sCVD:
  - Drop of charge yield by 15% at T = 250°C.
  - Droop between 260° and 500°C.
  - Overall decrease of 10%.
- SiC:
  - Decay of charge yield at T = 380°C.
  - Droop between 380° and 500°C.
  - Overall decrease of 60%.



Summary

Conclusions

sCVD:

1. Signal response up to 500°C.
2. 15% overall drop of charge yield.
3. Systematic TCT-study for e-readout:
   - Reproducible signal response up to 500°C.
   - Increase of drift time with temperature.
   - Strong non-linearity between 250°C and 350°C.

SiC:

1. Signal response up to 500°C.
2. 60% overall drop of charge yield.

Outlook

- Further measurements for SiC:
  - TCT measurements
  - Reproducibility of charge yield
- Further measurements for sCVD:
  - TCT measurements for hole readout
  - Reproducibility of charge yield for electron and hole readout.

Thank you for your interest!

christina.weiss@cividec.at