scCVD diamond detector signal properties investigated with ion microbeams at elevated temperatures

ADAMAS 2019 workshop

GSI, Darmstadt

Andreo Crnjac
Ruđer Bošković Institute
Laboratory for Ion Beam Interactions

Co-authors

- Milko Jakšić
- Mauricio Rodriguez Ramos
- Milan Vićentijević
- Natko Skukan

Overview

Presentation sections
Diamond detector – characteristics and basic properties
Experimental procedure – ion microprobe, heating, signal processing, fast traces acquisition
IBIC characterization at room temperature
Irradiation
IBIC imaging at elevated temperatures
A few TCT traces…
Conclusions and next steps

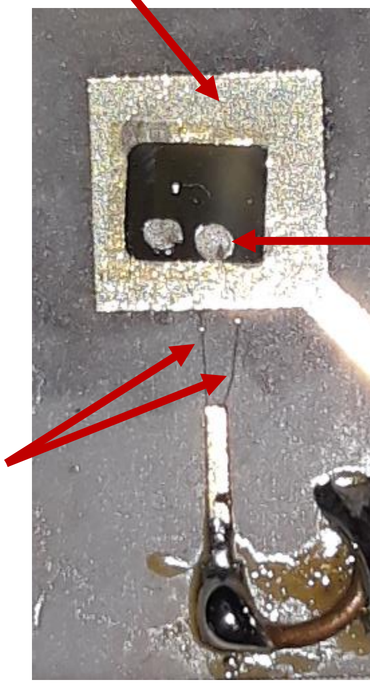
Diamond detector
Characteristics and basic properties

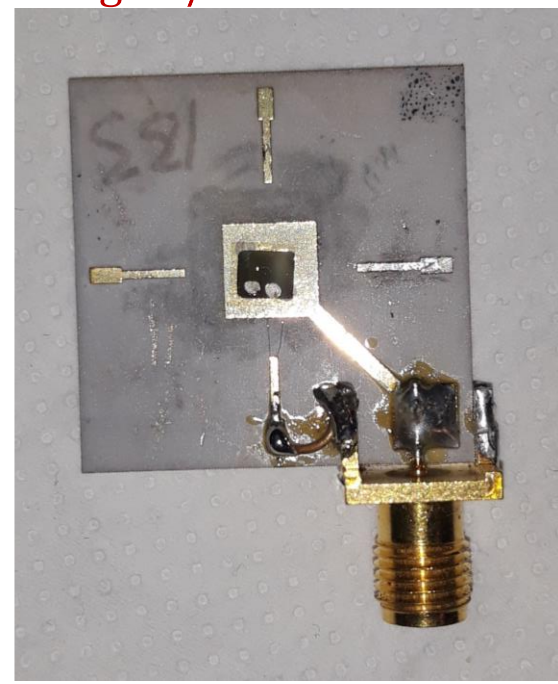
- ≈ 65 to 70 μm thick sc-CVD diamond from Element Six
- Front and back electrode: tungsten (wolfram)
- Active surface: $4 \times 4\ \text{mm}^2$

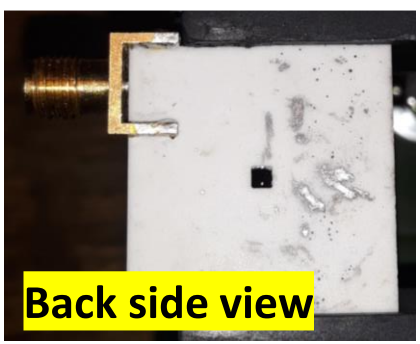
Gold contact plates

Ceramic plate with SMA Signal/BIAS connector

Golden wire bonding



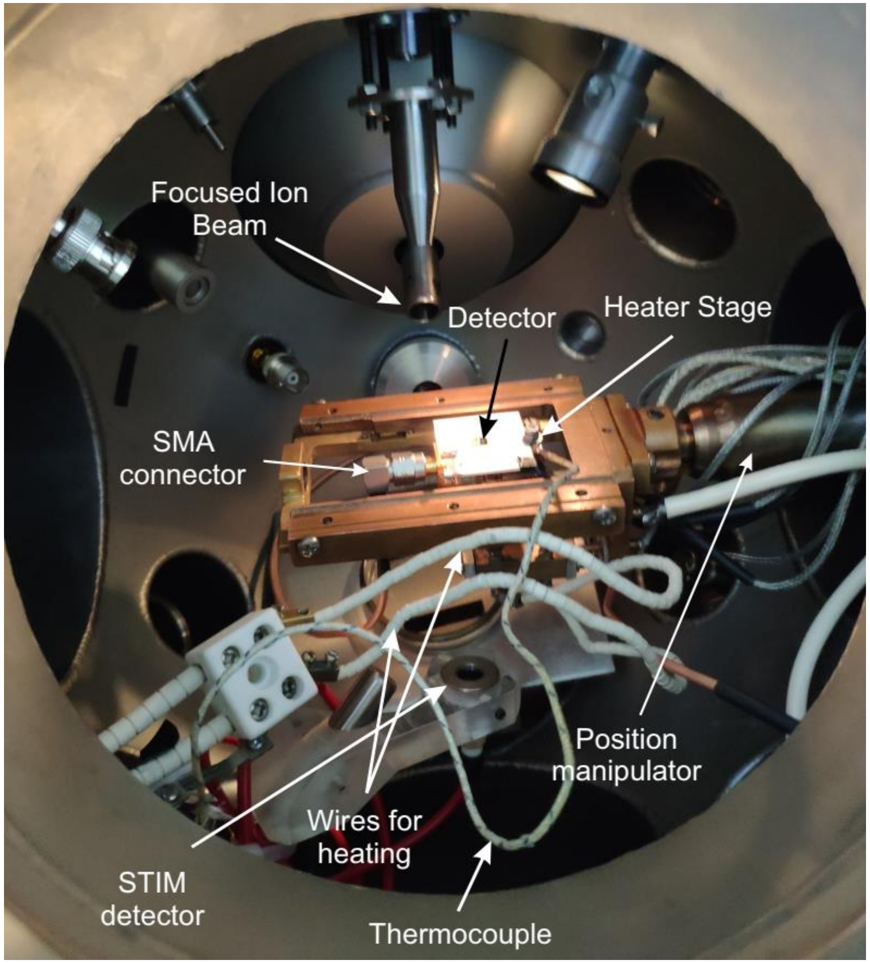


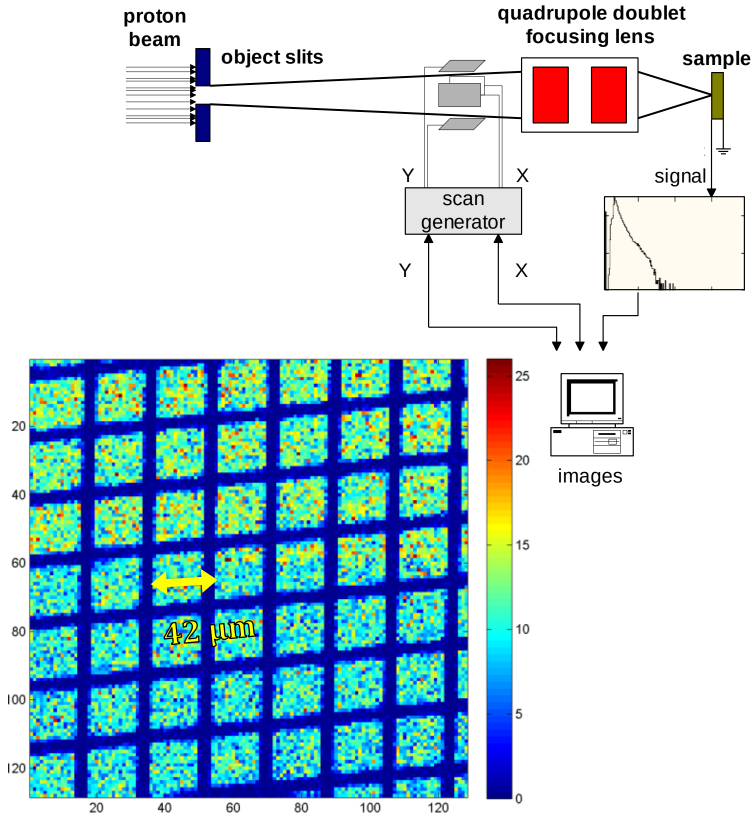


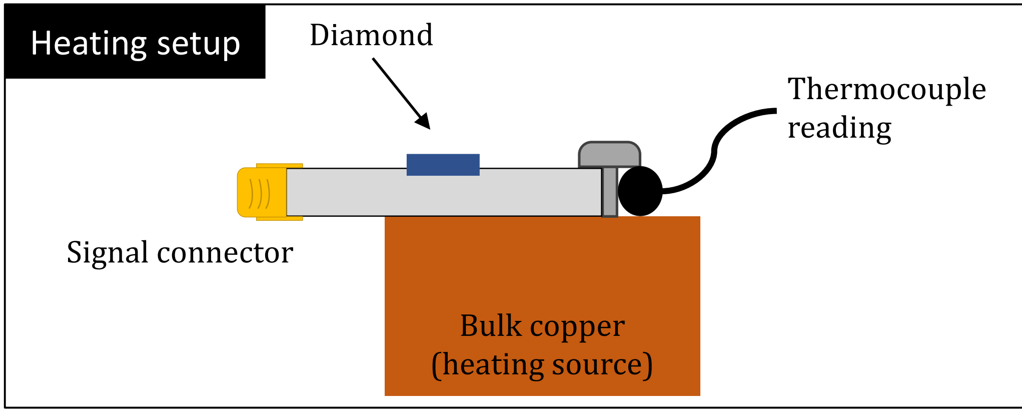
Transmission:
back side irradiation possible

Silver paste connection wolfram to gold wire

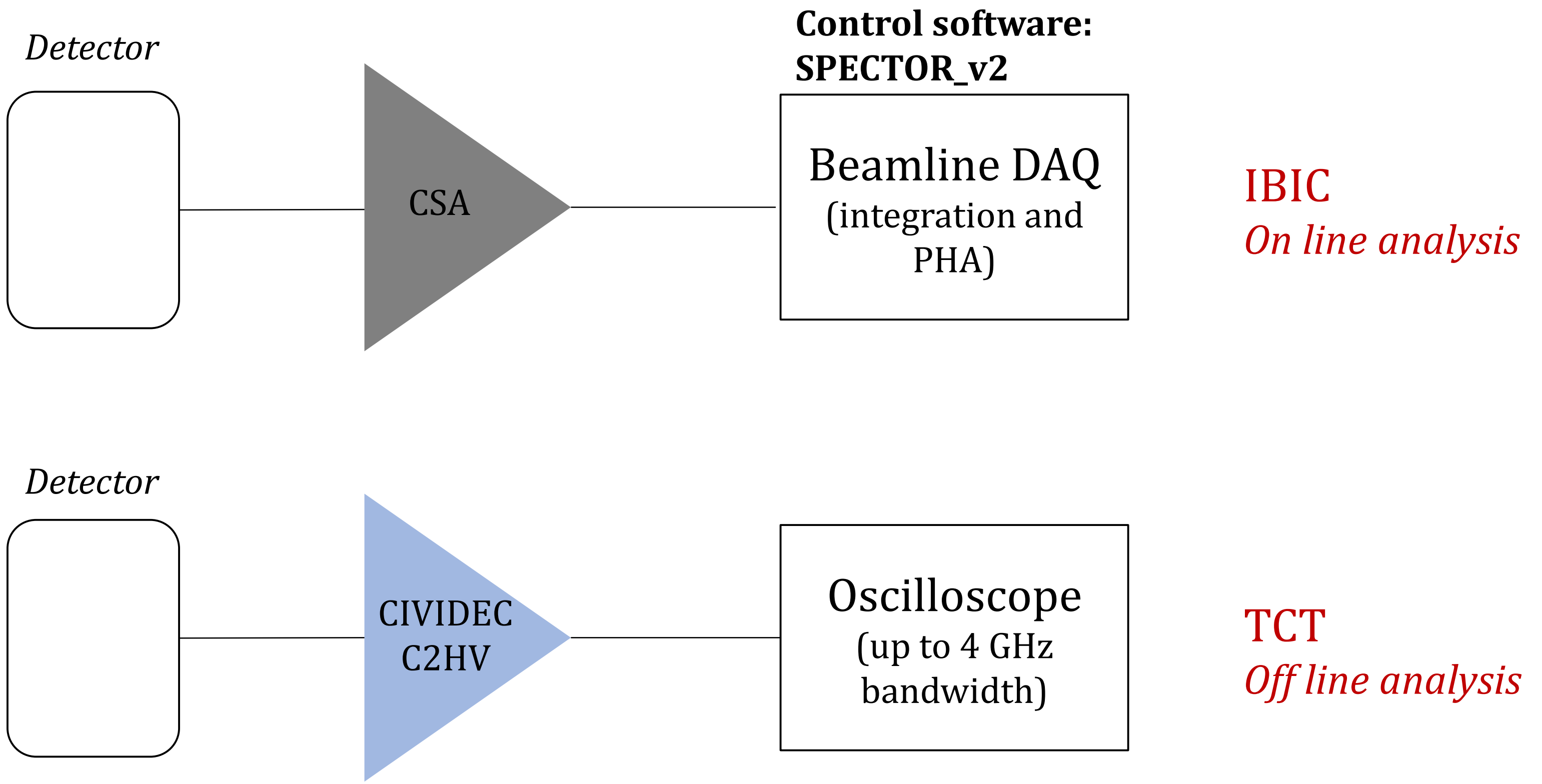
Experimental procedure
Ion microprobe, heating





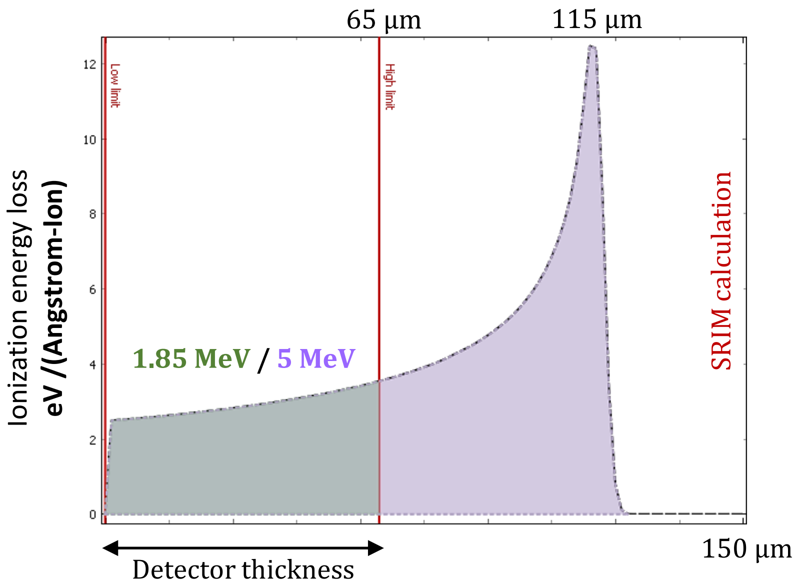


Experimental procedure
Signal processing, fast traces acquisition

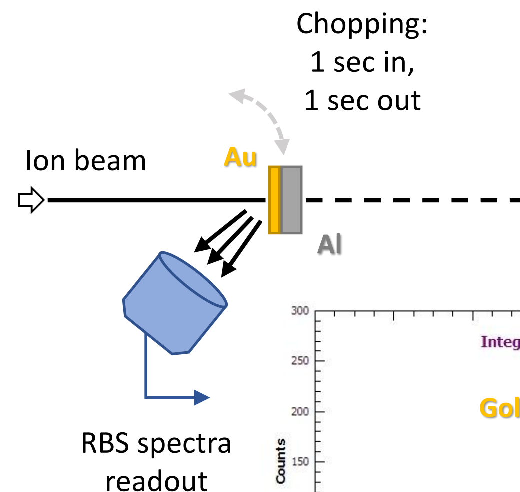


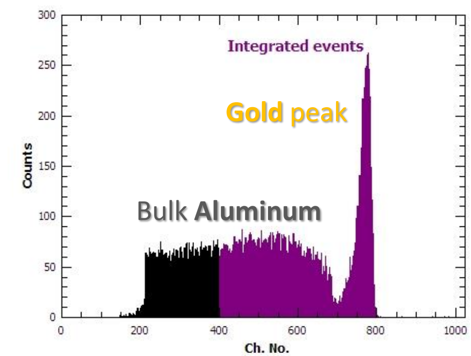
Irradiation
5 MeV proton beam

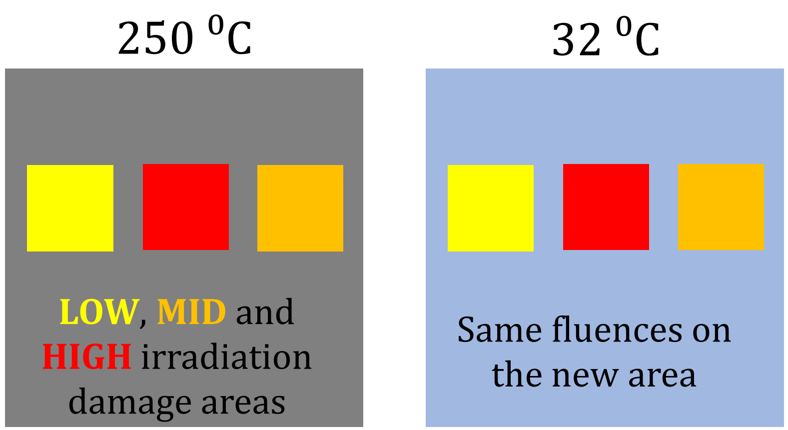
$ions/cm^2$	LOW DAMAGE	MID DAMAGE	HIGH DAMAGE
32 deg C	3.82E+12	7.03E+12	1.40E+13
250 deg C	3.76E+12	6.83E+12	1.43E+13



High ion current during irradiation – beam chopping + RBS spectra for flux calculation







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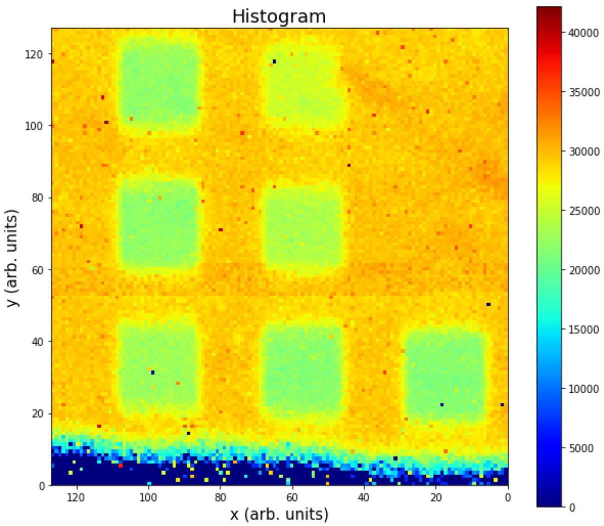
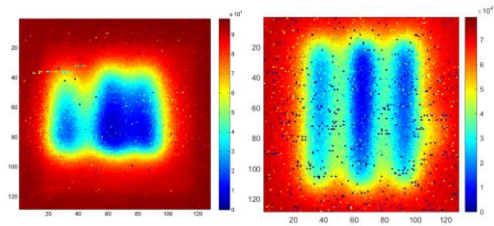


⇦ How the IBIC map usually looks like

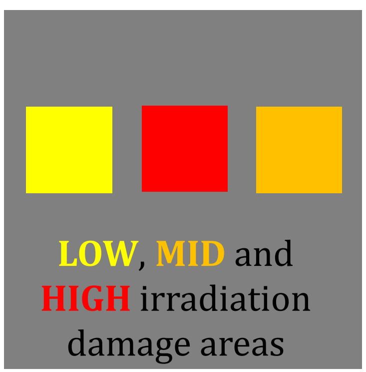
High ion current during irradiation – beam chopping + RBS spectra for flux calculation

⇩ What we got

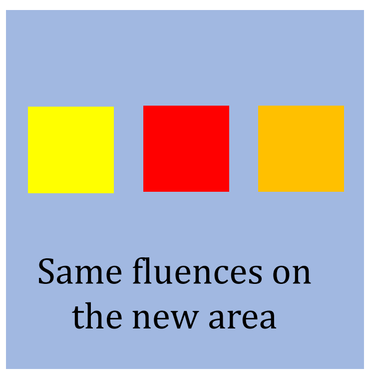


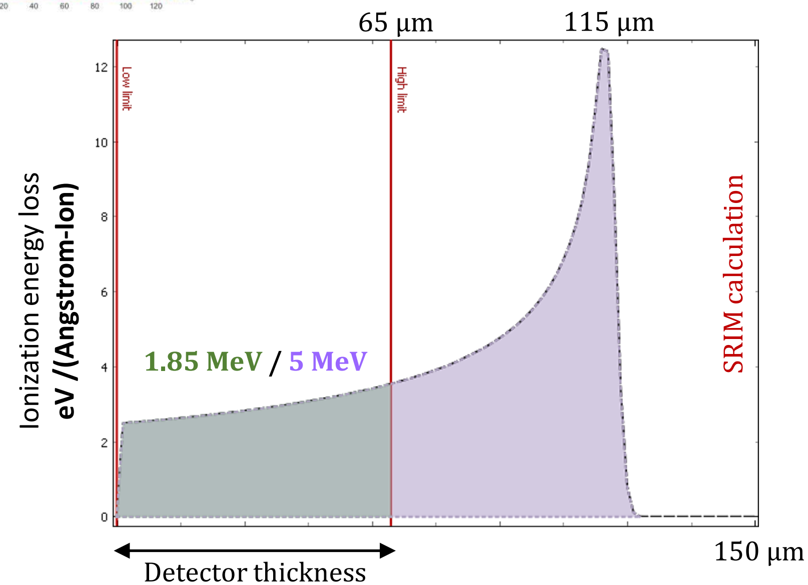
Problem – after irradiation, IBIC maps showed irregular shapes of the damaged areas – fluence estimated

250 ^{0}C



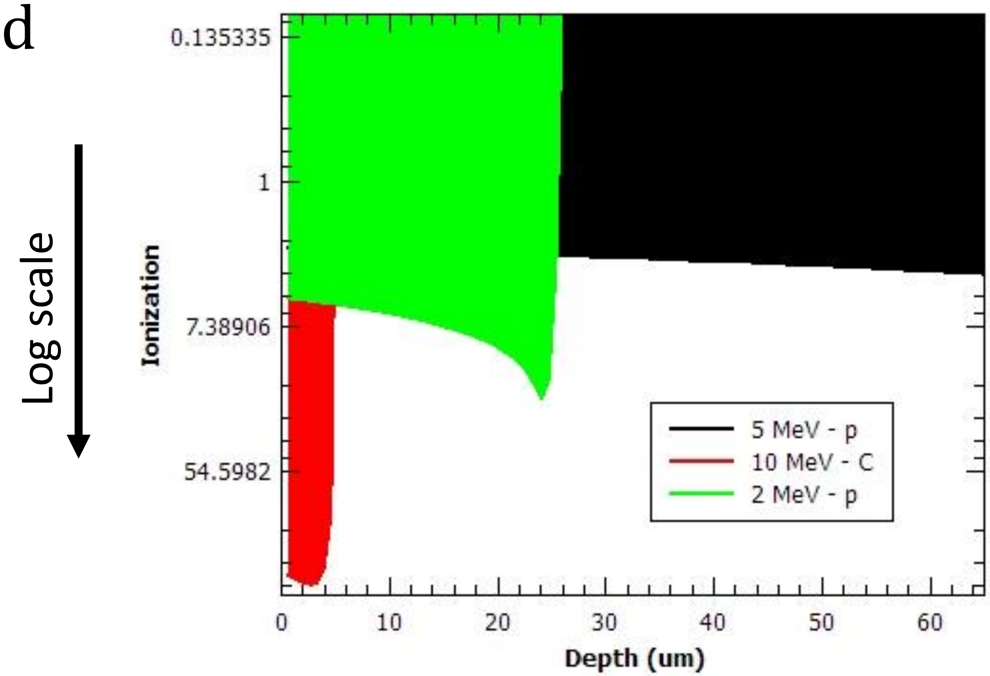
32 ^{0}C





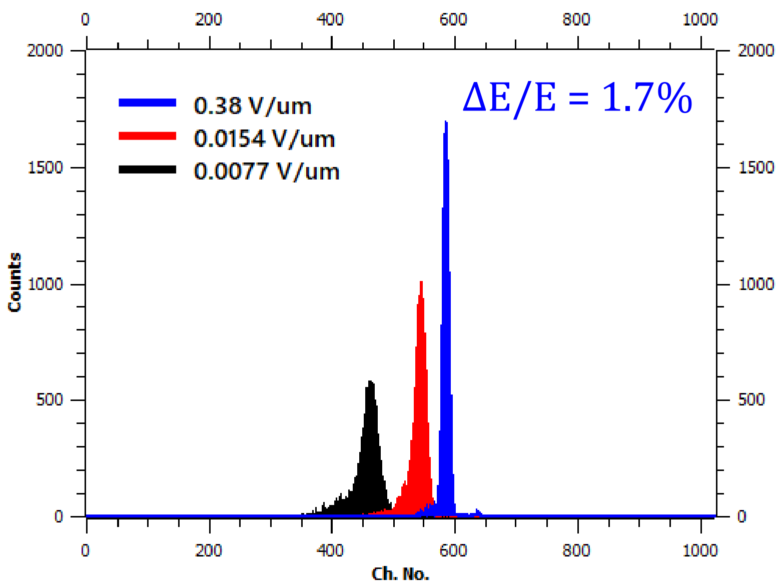
Ion beam properties

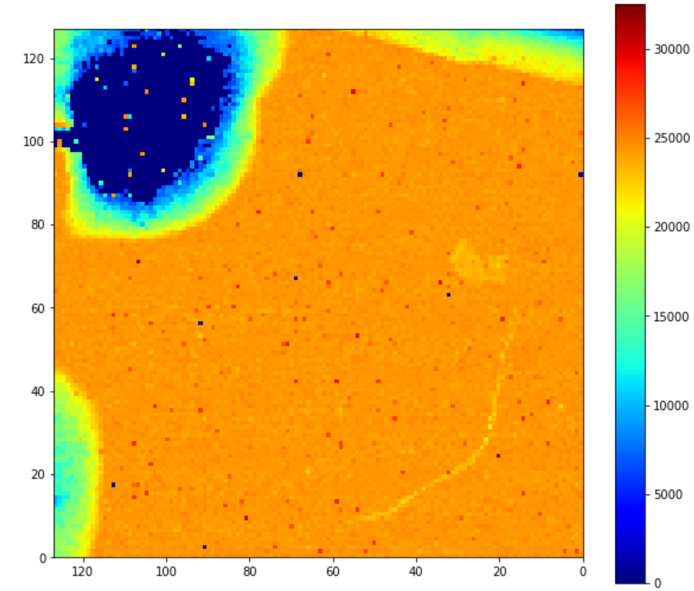
- **5 MeV p(+) beam** used for damage regions creation (irradiation)
- **2 MeV p(+) beam** used for IBIC imaging – before and after irradiation
- **10 MeV C(3+) beam** used for IBIC imaging – only after irradiation



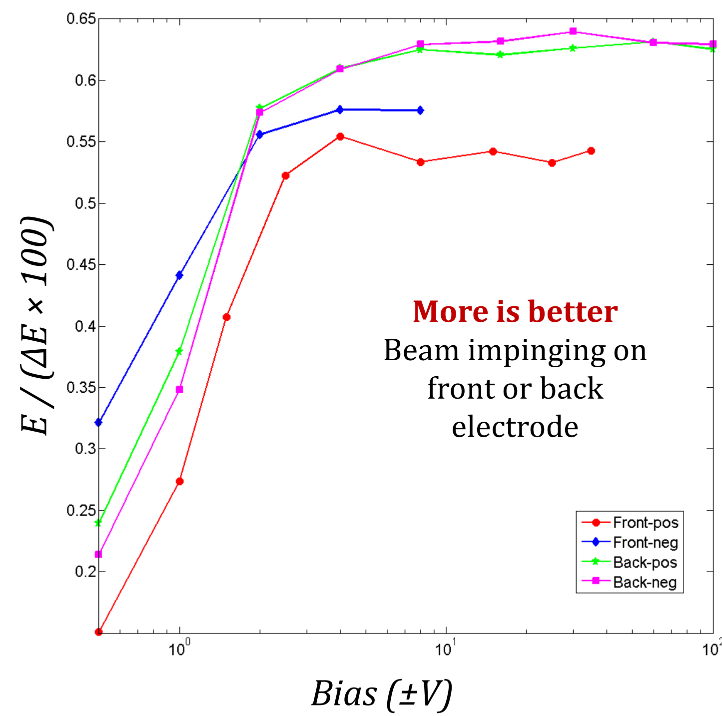
IBIC characterization

2 MeV proton beam



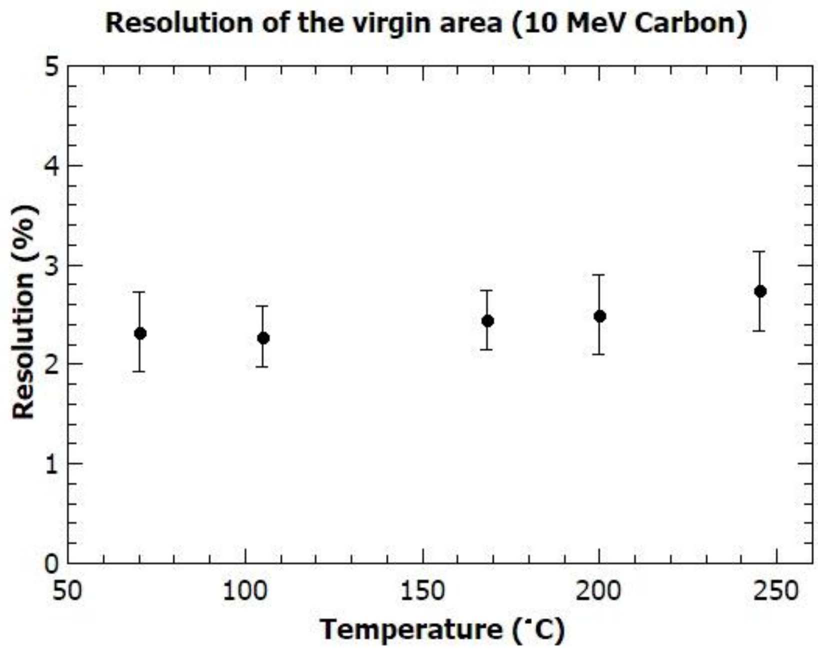


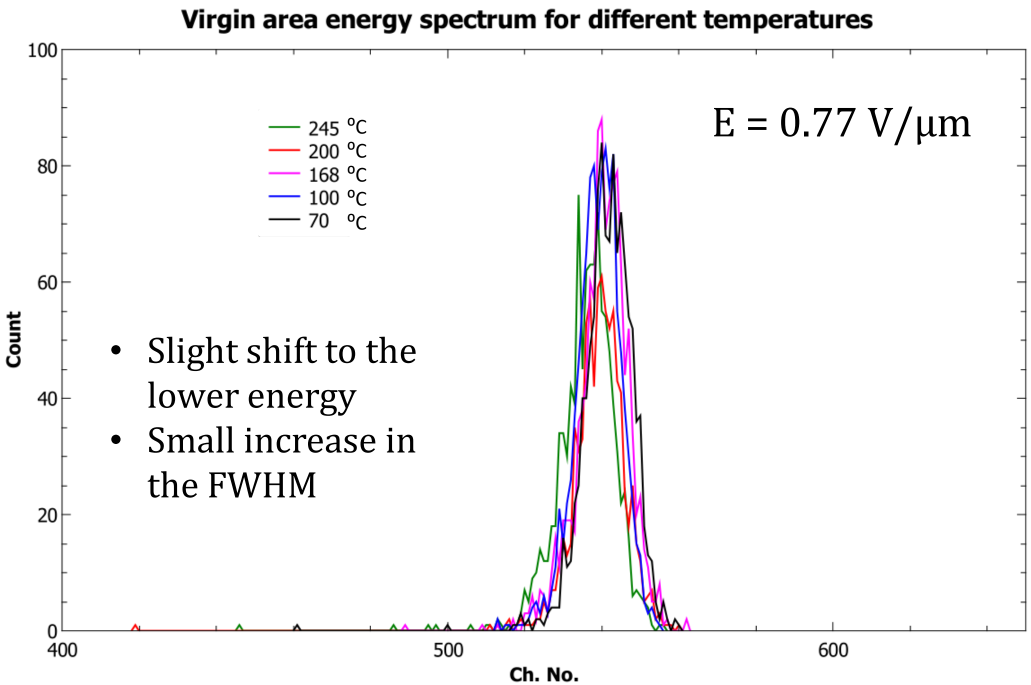
Degradation of the full energy peak starts below **2V** (0.03 V/µm)



IBIC imaging at elevated temperatures

Virgin area properties





- Slight shift to the lower energy
- Small increase in the FWHM

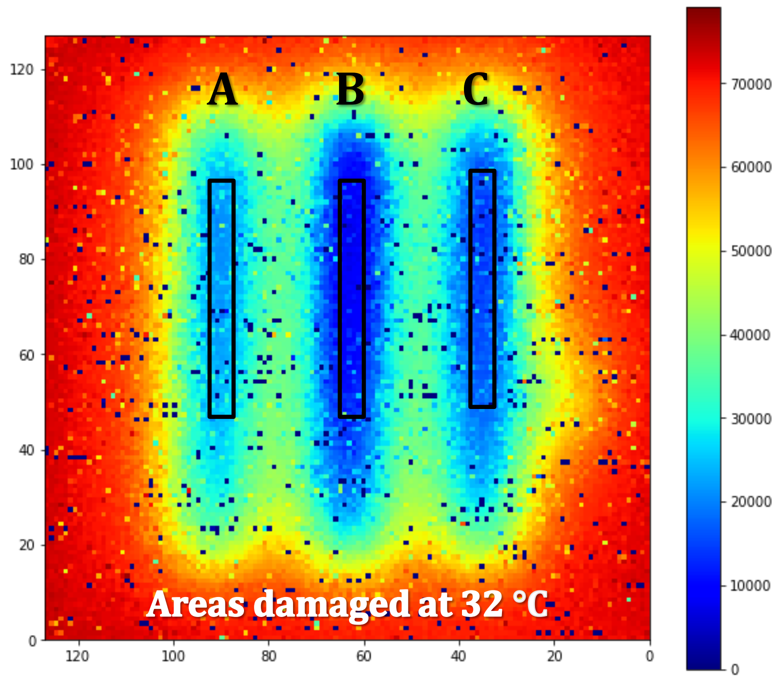
1. CCE remains ≅ 100%
2. No leakage current
3. Noise level is stable

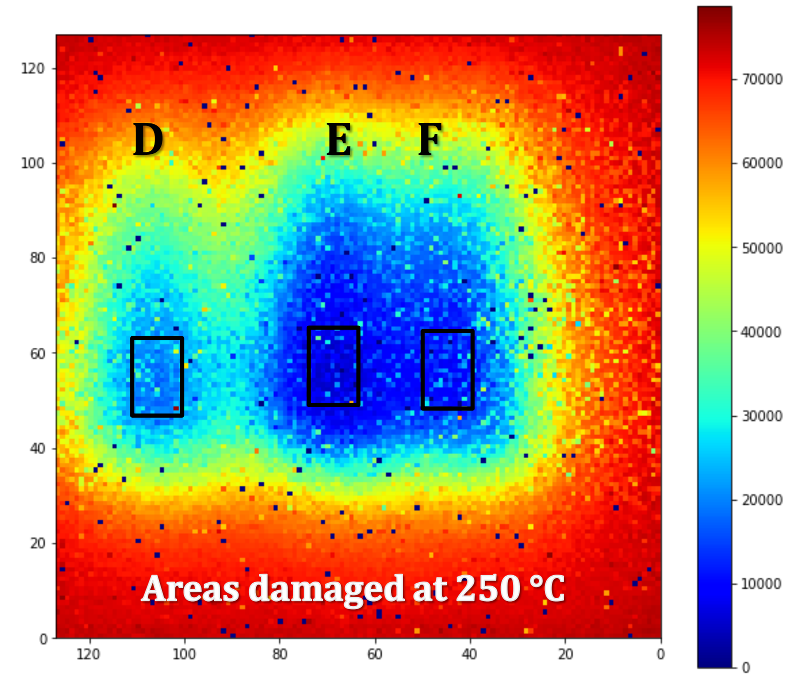
IBIC imaging at room temperature

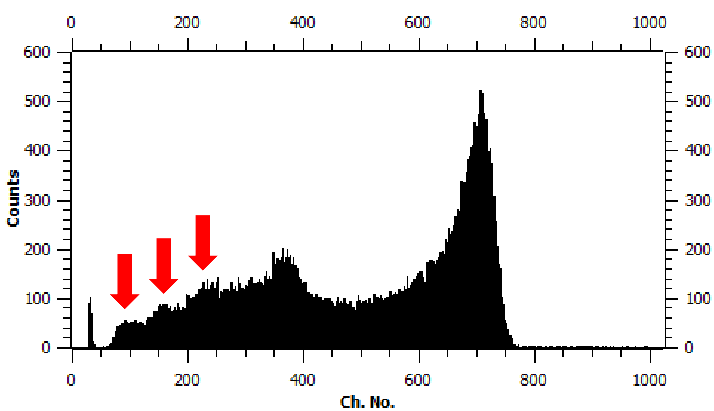
Irradiated area properties

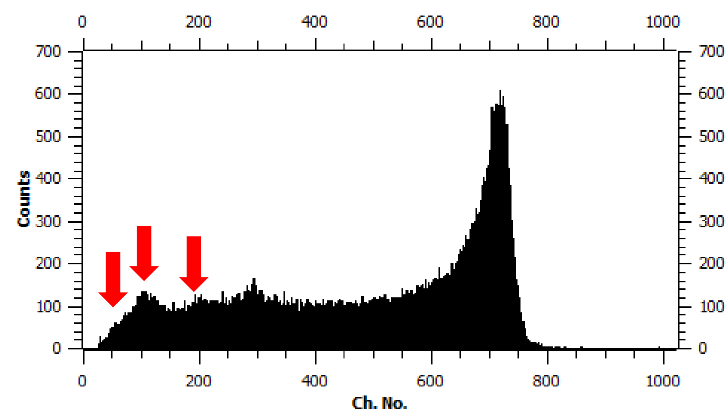
E = 0.15 V/μm

Histogram color bars are in the same scale!





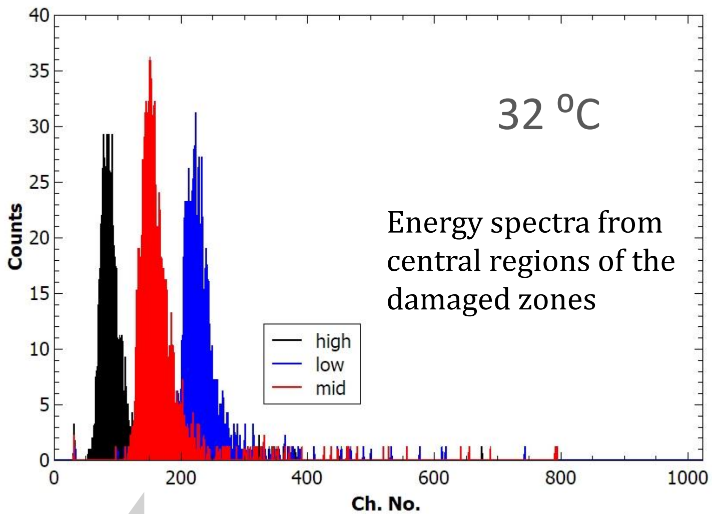


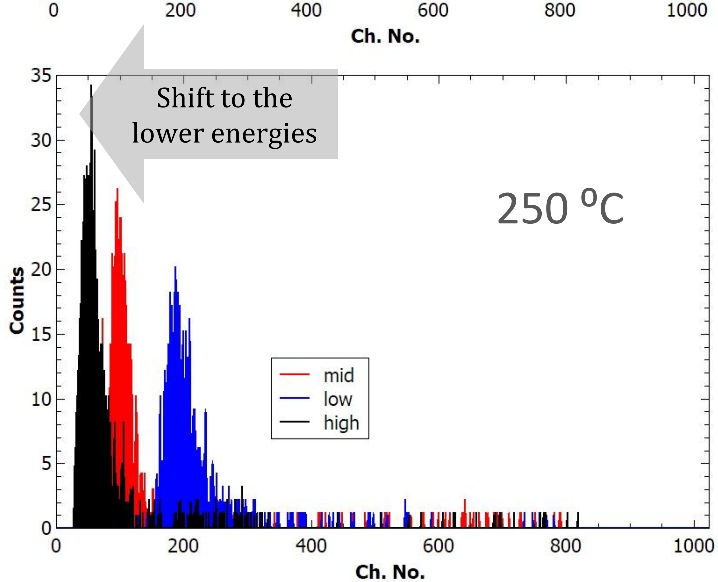


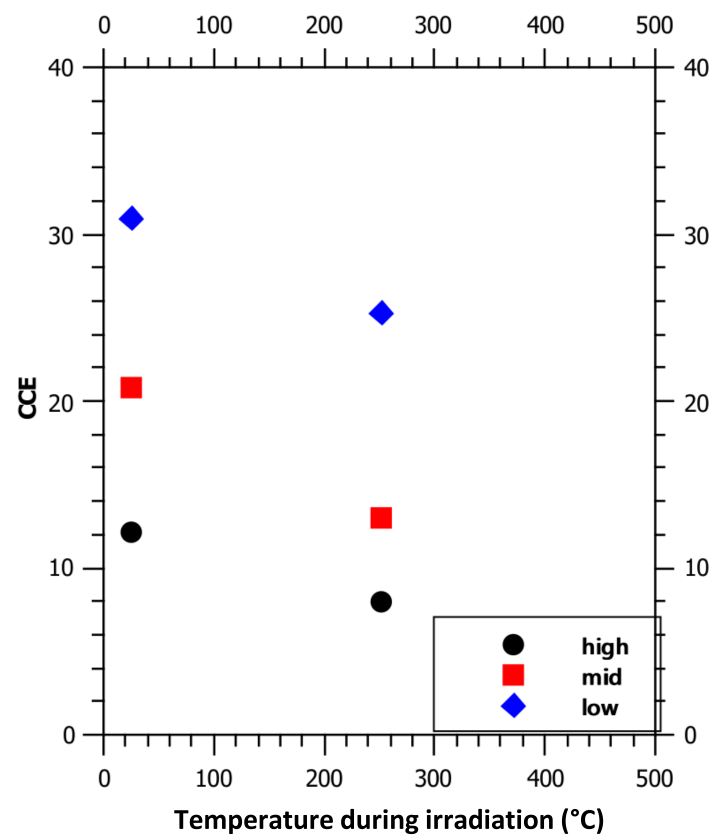
IBIC imaging at room temperature

E = 0.15 V/μm

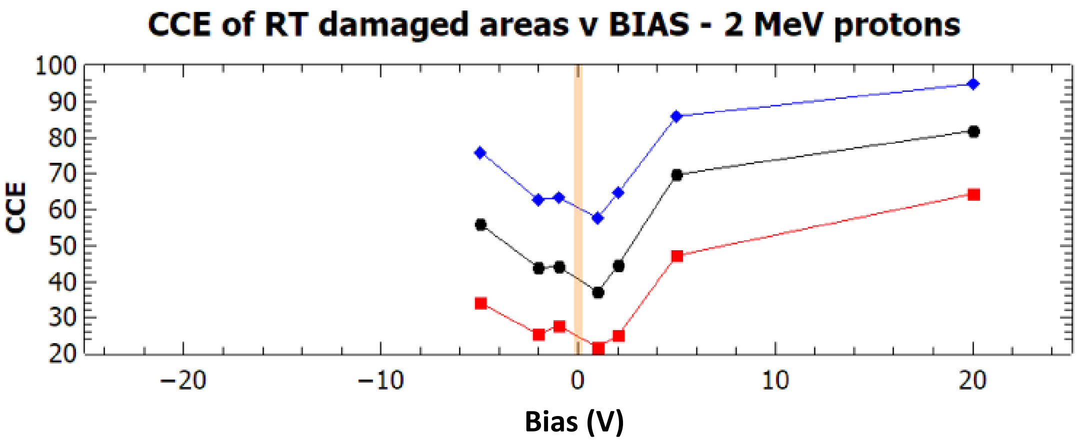
Irradiated area properties

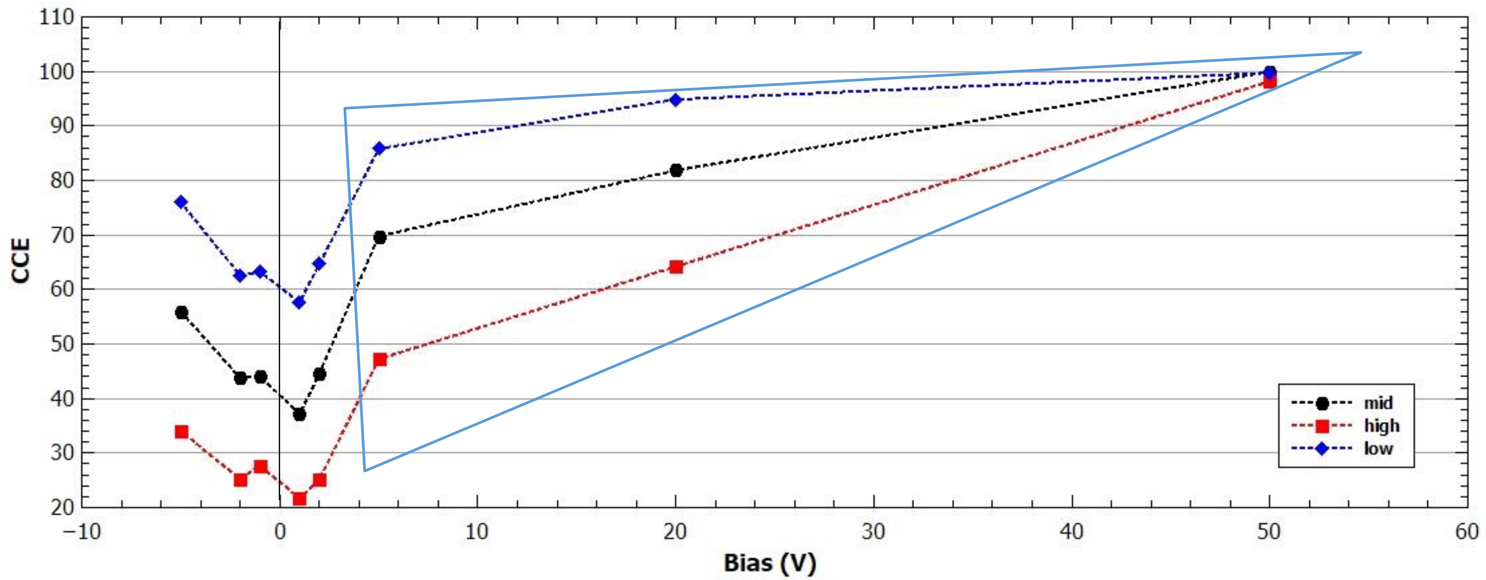






IBIC imaging at room temperature
Irradiated area properties



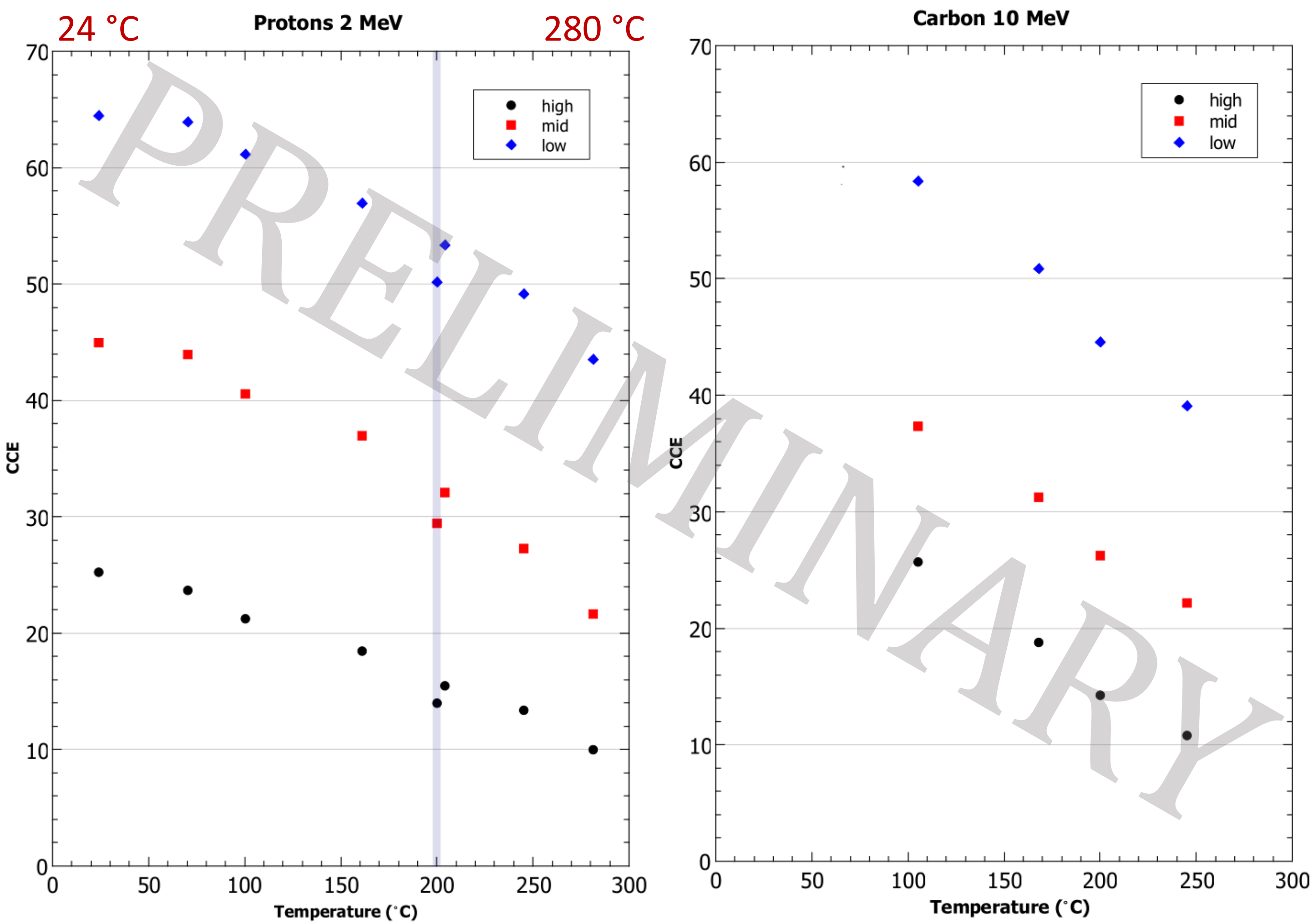


IBIC imaging at elevated temperatures

CCE evolution

Results only for areas irradiated at 250 ºC

Results with 10 MeV C were obtained first

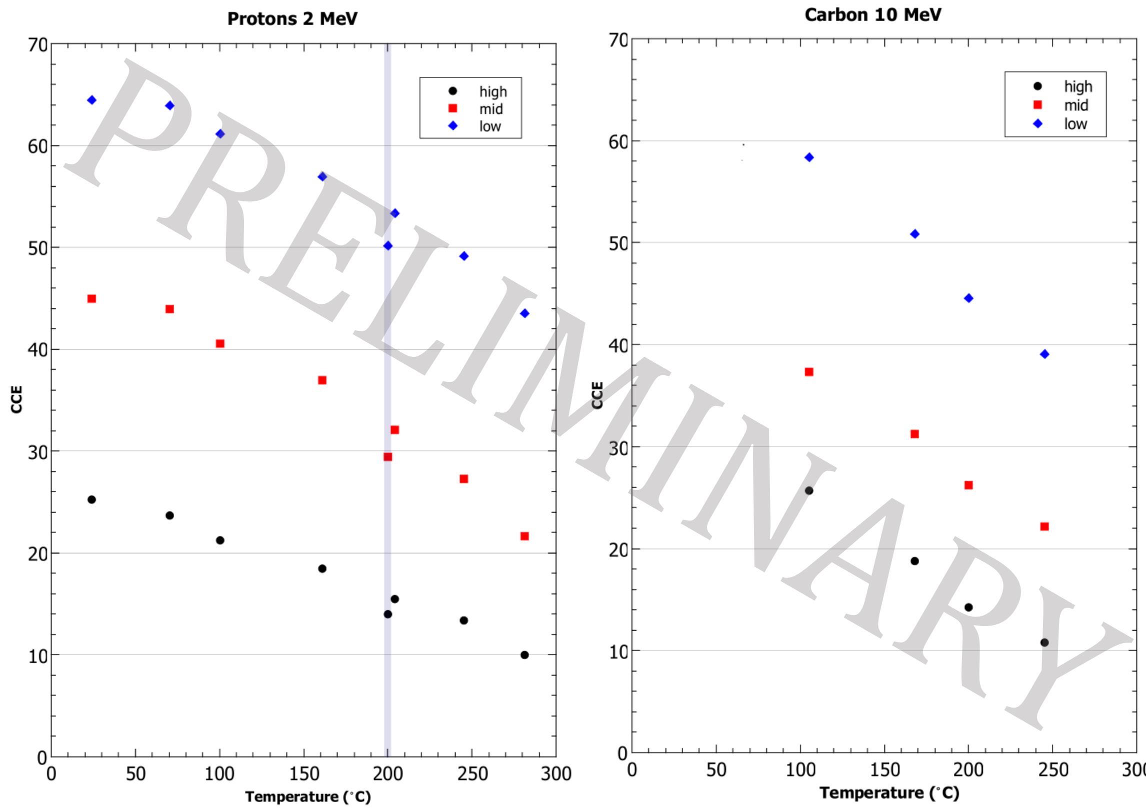


***Noise** level increase at **280 °C** soldering contact problem?*

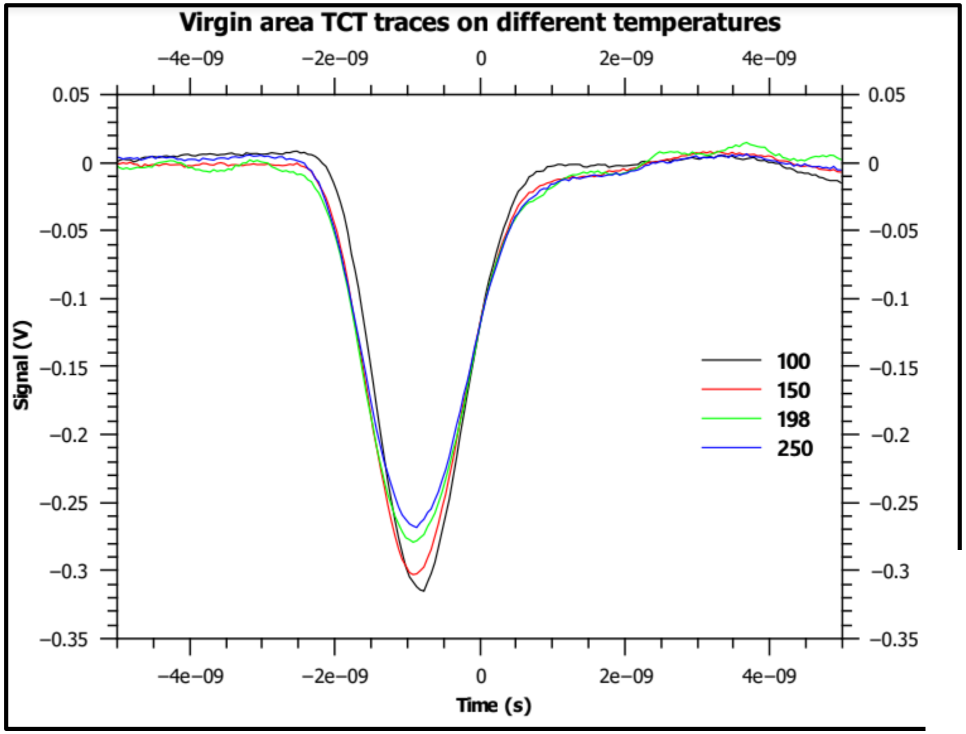
IBIC imaging at elevated temperatures
CCE evolution

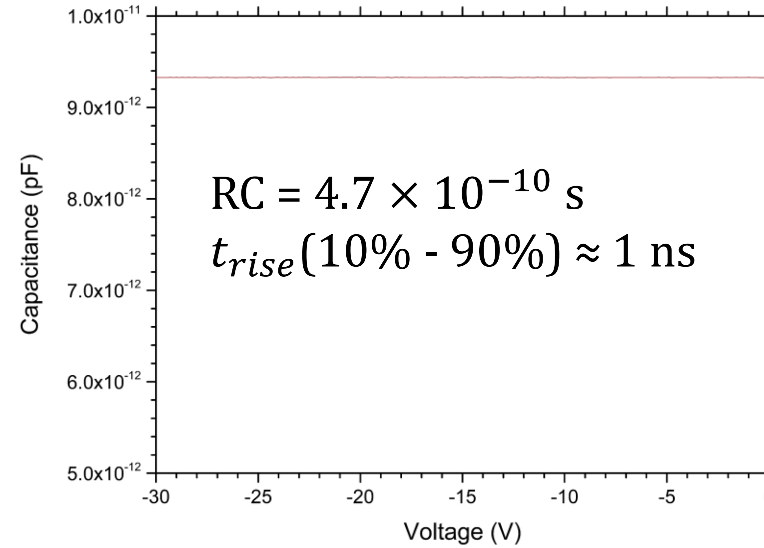
Explanation of the behavior:
- No annealing of the traps for these temperatures
- Trapping time increases with temperature, mainly because of a decrease in charge drift velocity

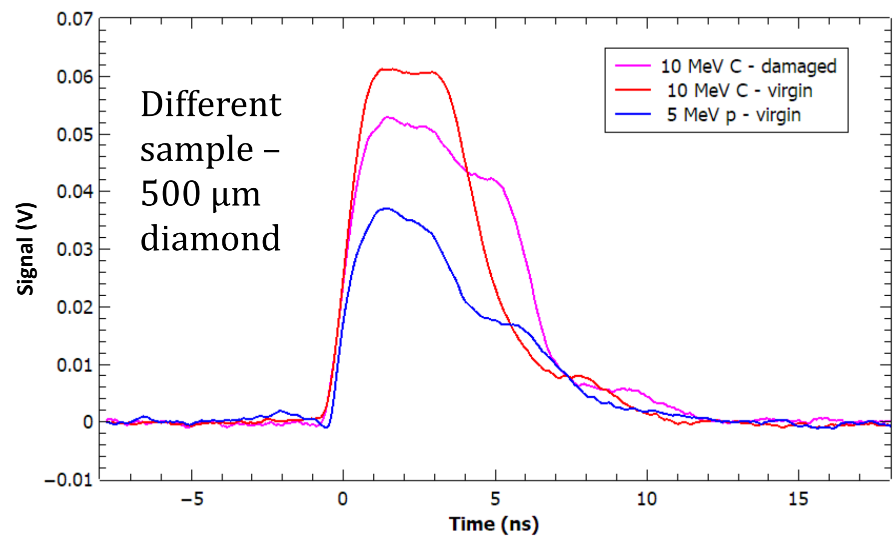
$$\frac{1}{\tau_c} \sim v_{drift}(T)$$



A few TCT traces...







Ongoing active research exploiting TCT traces

Conclusions and next steps

CONCLUSIONS

- Good properties at room temperature: 1.7% energy resolution @2MeV
- Noise and full energy peak properties stable until 280 ^{0}C – soldering contact to be replaced with a better solution
- IBIC analysis of irradiated areas at elevated temperatures: CCE decreases (proportionally with damage dose) → *higher trapping probability and no observation of defect annealing*
- TCT – capacitance masks important signal shape properties

NEXT STEPS

- Repeat experiment ⇨ make well defined irradiation areas!
- Going to 500 ^{0}C („*and beyond*”)
- New diamond sample for obtaining TCT at high temperatures

Info: Transnational access to RBI facilities

2015-2019: AIDA 2020

- 18 experiments funded !
- 9 using IBIC
- 8 done at diamond

2019-2023: RADIATE project !!

- Simple and fast response to experiment proposals
- 10 funded experiments per year (at RBI)
- Project supports: travel, accommodation and beam time !
- Detector characterization capabilities: IBIC imaging; ion induced TCT; in situ damaging; temperature dependences (LN2 to 750 ^{0}C); single event upset tests

https://www.ionbeamcenters.eu/radiate/radiate-transnational-access/application-for-transnational-access/

Acknowledgements:

PaRaDeSEC

Expanding Potential in Particle and Radiation Detectors, Sensors and Electronics in Croatia

Horizon 2020 - The EU Framework Programme for Research and Innovation

CEMS

CENTER OF EXCELLENCE FOR ADVANCED MATERIALS AND SENSING DEVICES