First CCE and TCT measurements on irradiated diodes of the CMS-HPK-Campaign

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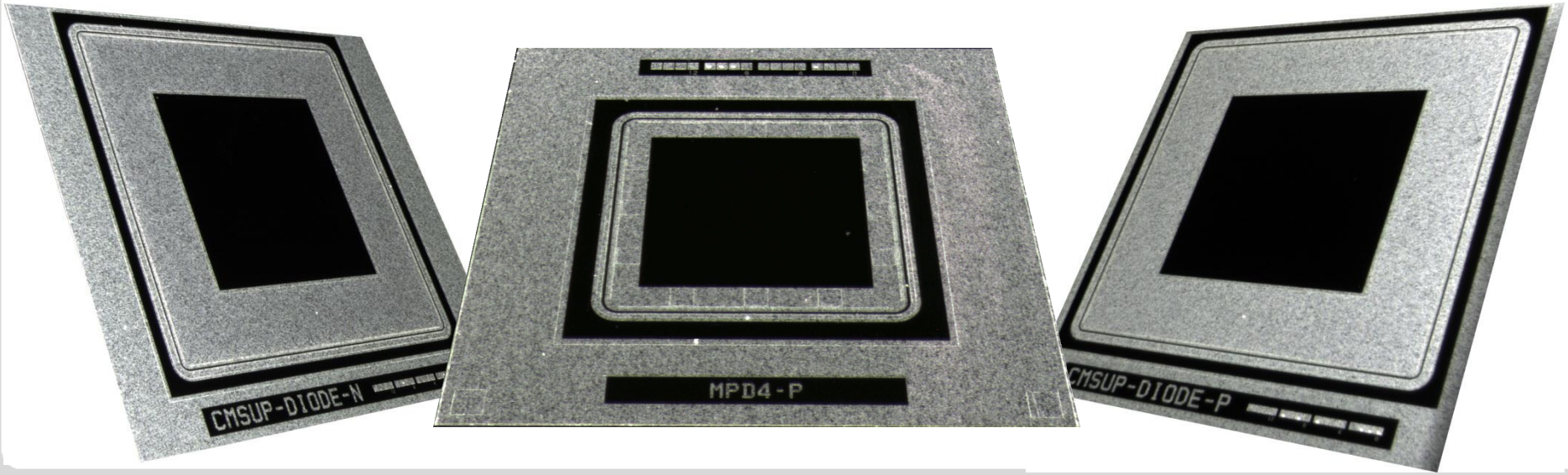

Outline

- Setups and Groups
- Preparation for TCT and CCE measurements
- Stability measurements
  - Backside measurements with 880nm
  - Comparison of FZ / MCz material
- Charge Collection of non-irradiated diodes
- CCE of irradiated diodes
- TCT of irradiated diodes
  - Trapping times
- Conclusion and Outlook

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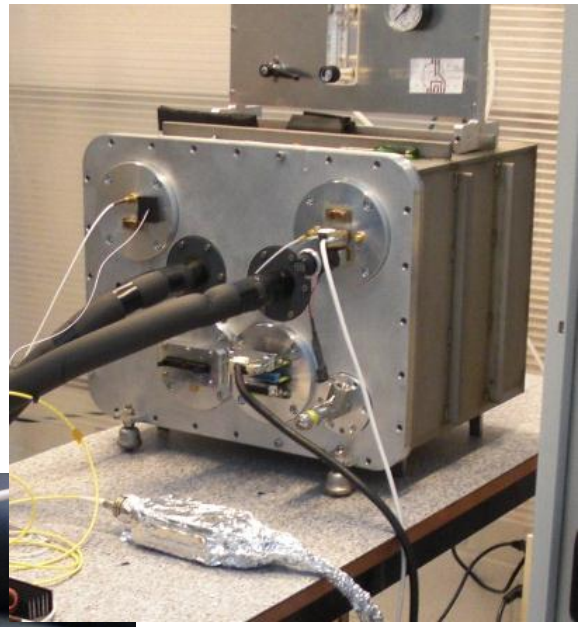
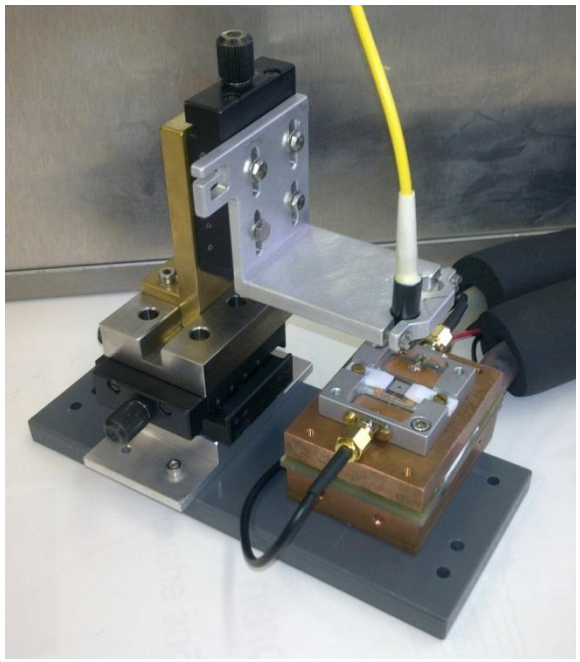
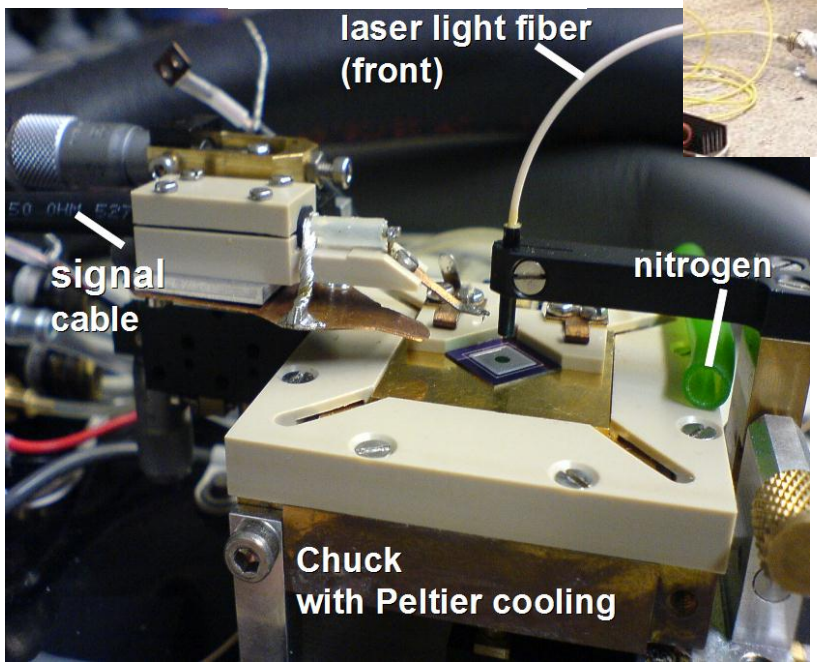
Setups for CCE and TCT measurements

- Institutes involved in diode measurements
  - CERN, Hamburg, Louvain, Karlsruhe







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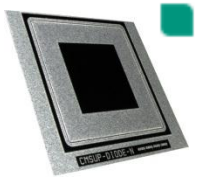
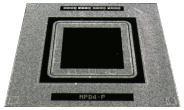
Specifications of CCE / TCT measurements



- CCE measurements
  - Measurement of charge collection, simulation of a MIP
  - Integrated signal important
- TCT measurements
  - Time resolved curves
  - Observation of 1 charge carrier through the diode
  - Needed for trapping times and electric field



- Lasers:
  - >1000nm for CCE
  - Red for TCT (~680nm)
  - 880nm for backside TCT

- Laser intensity < 100 MIPs
- Repetition rate 200Hz
- Min. 5GS/s Oscilloscope
- Averaging of waveforms > 500

- Measurement steps:
  - 0V-1000V in 10V steps
    - No breakdown
  - Non-irradiated diodes
    - 20°C, 0°C, -20°C
  - Irradiated diodes
    - 0°C, (-10°C), -20°C, (-30°C)
    - Several annealing steps

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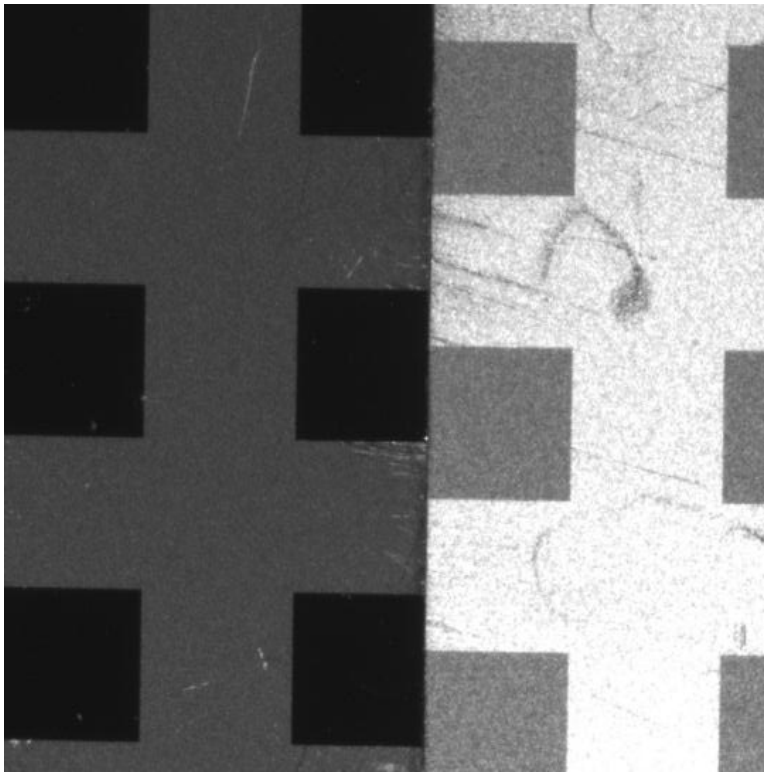
Backside measurements

- Backside TCT measurements not possible on thin diodes because of deep diffusion
- Signal generation possible in
  - 320µm thick FZ diodes
  - 200µm MCz diodes
- Due to relatively deep backside implantation and backside properties on FZ diodes – generation of charge carriers not possible with red Laser (680nm) on FZ
- IR Laser light shot an FZ backside generates only ~20% of frontside signal



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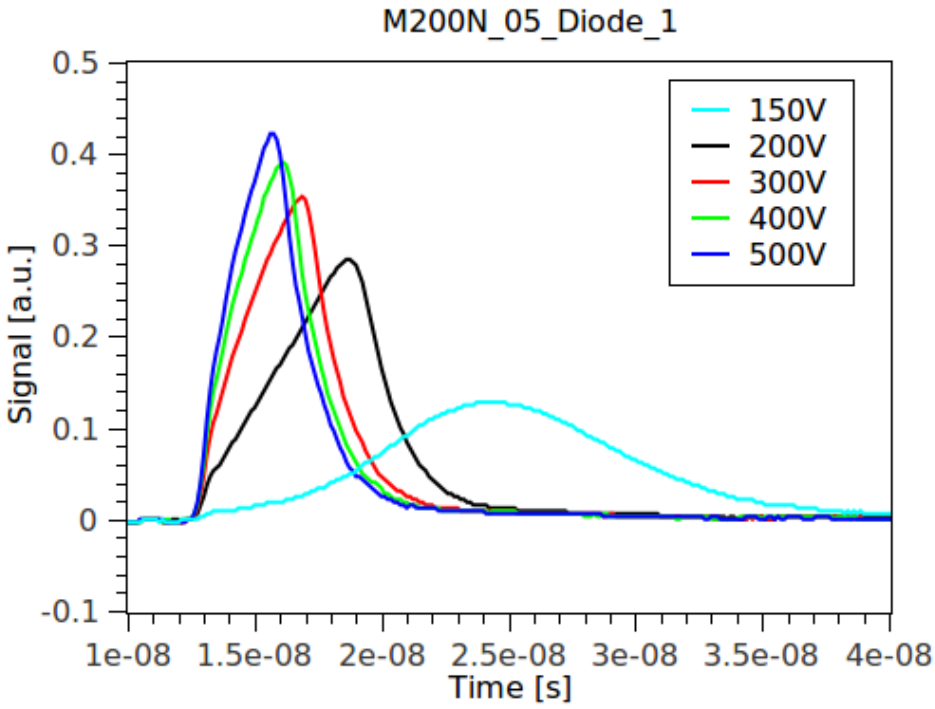
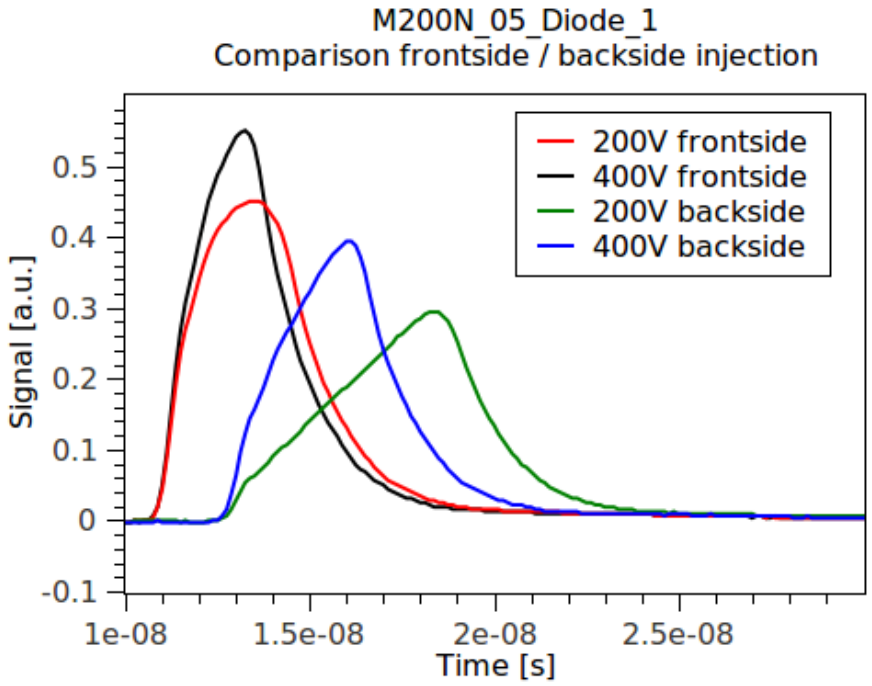
Backside measurements

- Red Laser works well for MCz diodes
- Not a deep implantation on the backside – different processing

- Back/front charge collection ~ 80%
- For comparison, FZ material with a physical thickness of 200µm is ordered and will arrive in autumn this year





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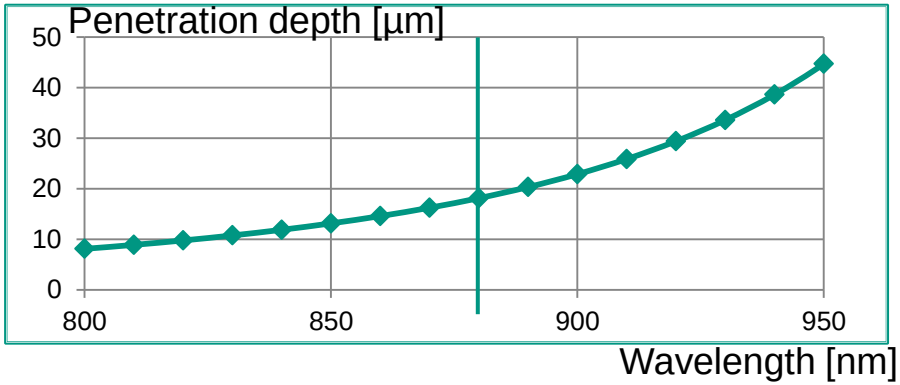
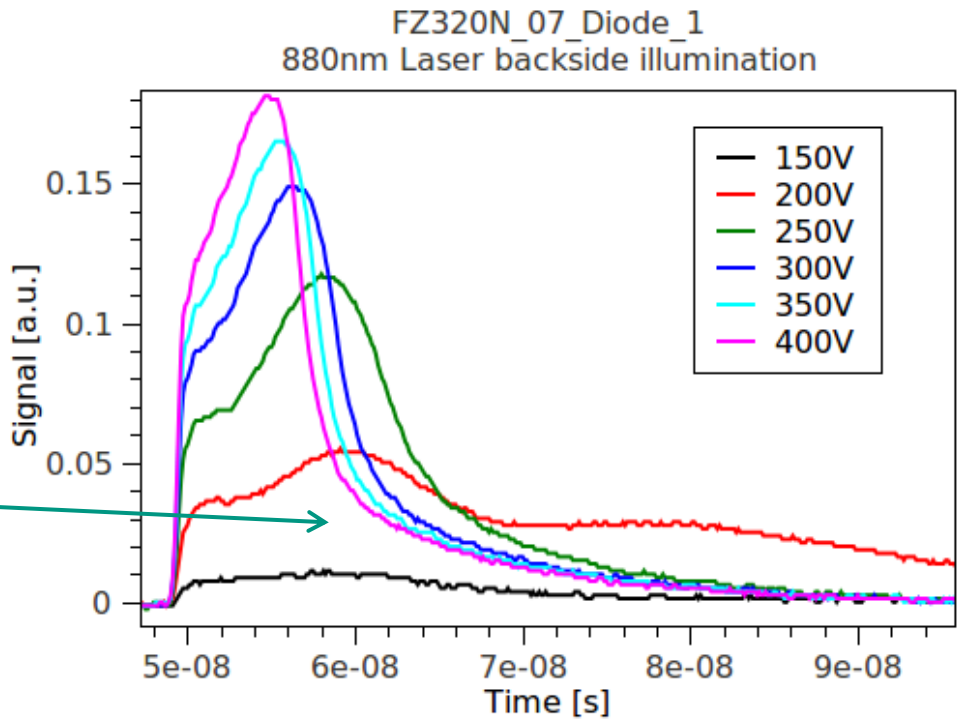
Backside measurements

- Use 880nm Laser for illumination on the backside for FZ material
- Signal looks almost like a *red* one
- Possibility to look at one charge carrier in FZ 320µm material
- At low voltages
  - Broad signal coming from diffusion out of the deep diffusion region
- At higher voltages
  - Long tails at the end of signal
- First small peak in signal due to electrons (n-type diode)
- Useful for analysis?





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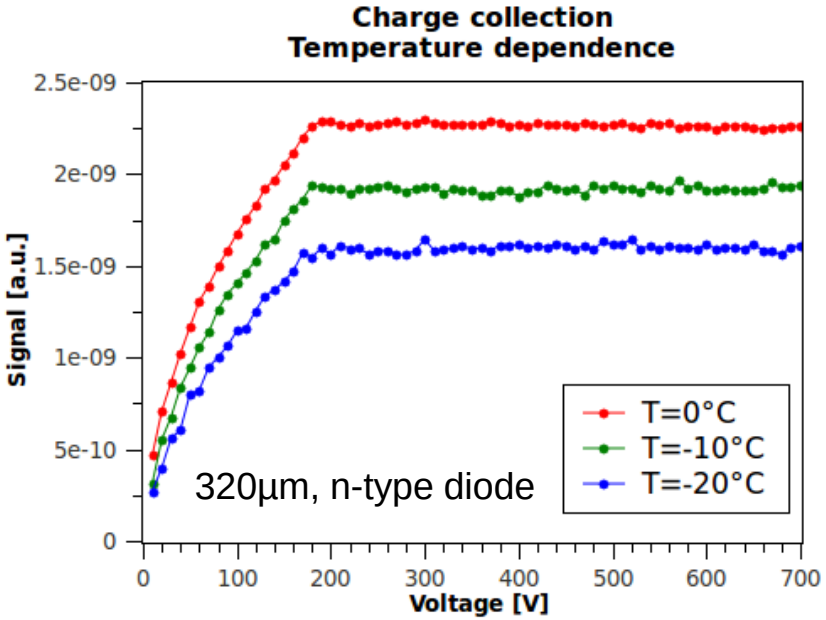
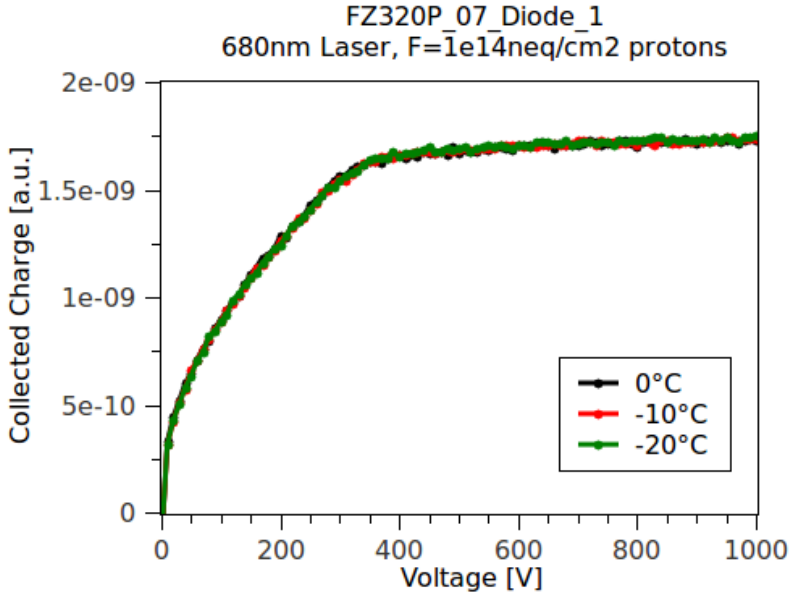
CCE measurement of unirradiated diodes

- Signal generation with infrared Laser (1055nm)
- Because of indirect bandgap in silicon, fewer charge carriers are produced
- Calibrate signal for different temperatures

- Red Laser always generates the same amount of charge carriers when shot on frontside (irradiated diode example)





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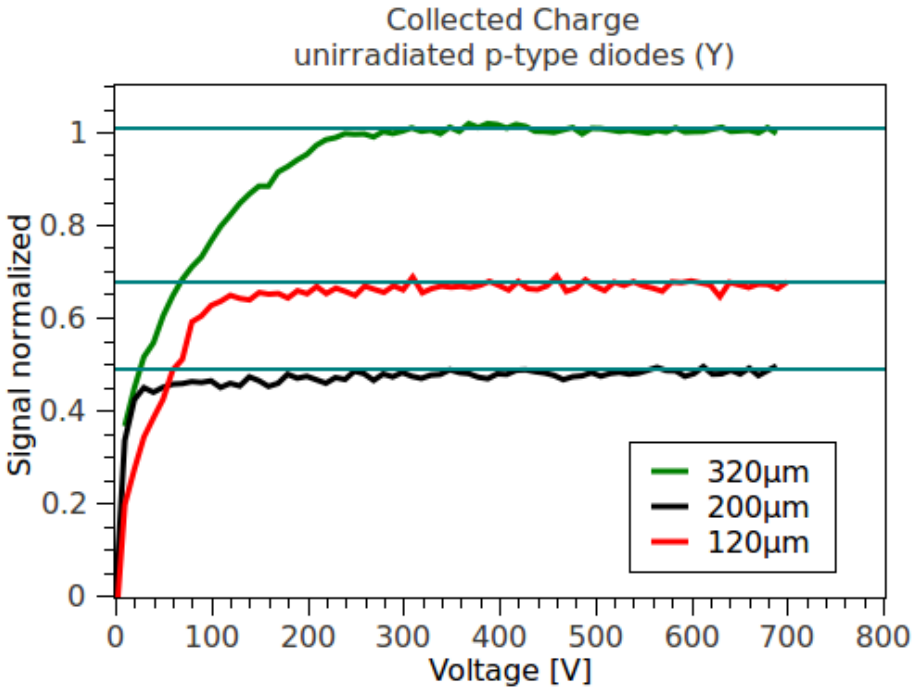
CCE measurement of unirradiated diodes

- Signal generation with infrared Laser (1055nm)
- CCE normalized to the 320µm thick diode of same type
- Slight increase in CCE(V) seen for 200µm and 120µm thick diodes
  - Gain more acitve thickness due to deep diffusion at high voltages
- Charge collection ratio in expected range
  - 63% for 200µm, (67% for 215µm)
  - 38% for 120µm, (45% for 145µm)



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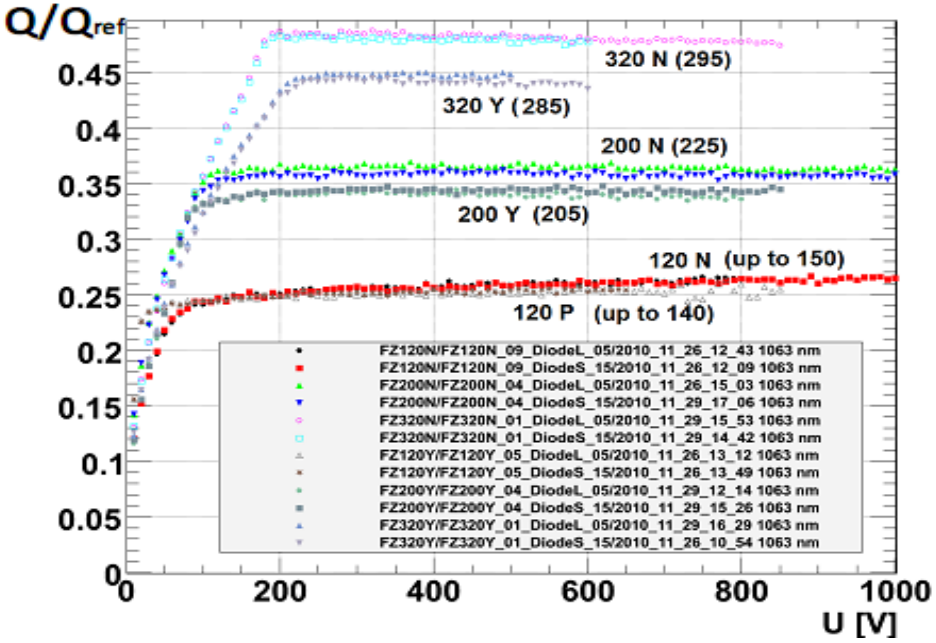
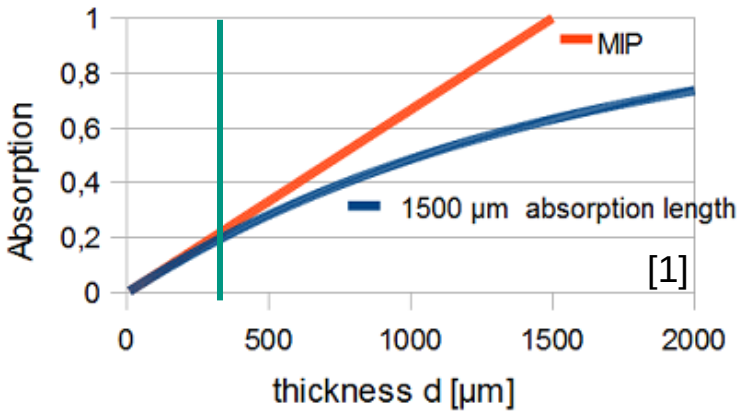
Charge collection on different wafers





Collected charge compared on different types of wafers. [1]

- Taking into account
  - Attenuation length of laser
  - Measured thickness from CV
- Deviations of max. 5% from mean value

diode	d_{max}	Absorption A	Q_{meas}	Q_{meas}/A	Q/A / mean
120N	150	0,1	0,26	2,732	1,02
200N	225	0,14	0,36	2,584	0,97
320N	295	0,18	0,48	2,689	1,01
120Y	140	0,09	0,25	2,806	1,05
200Y	205	0,13	0,34	2,662	1
320Y	285	0,17	0,45	2,572	0,96

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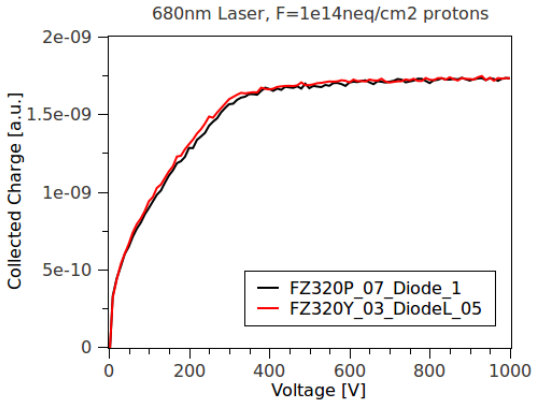
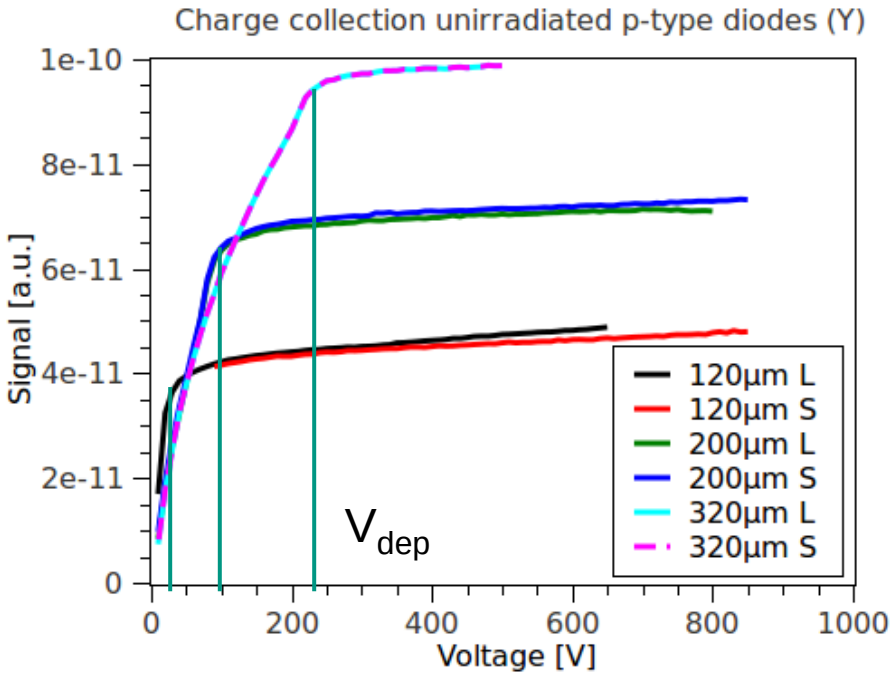
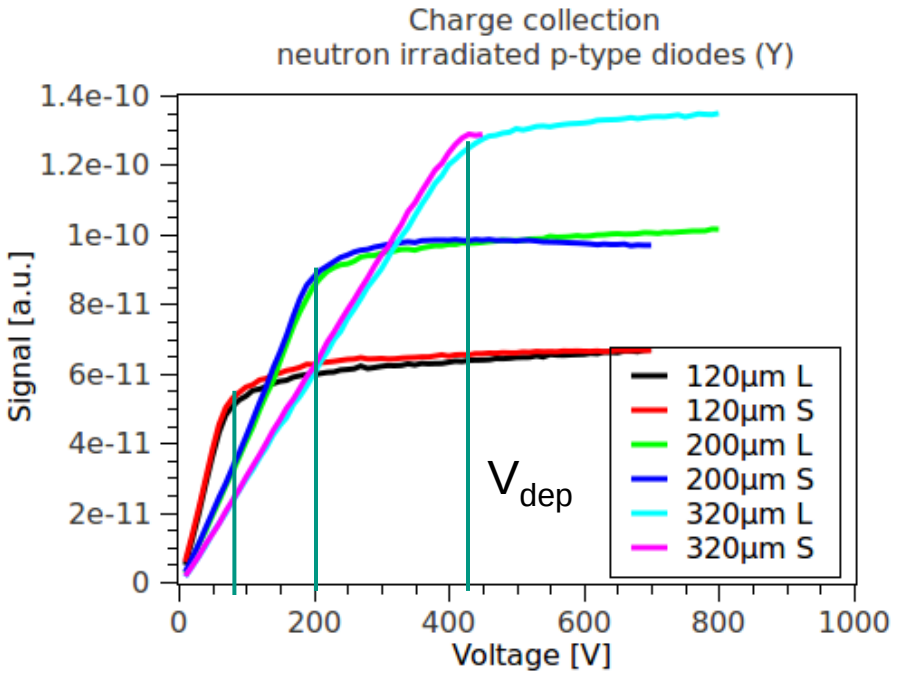
CCE measurement of irradiated diodes

- Deviations in charge collection between small and large diodes negligible
- After irradiation
  - Almost same charge collection seen between L and S

- Different irradiation step – same Charge collection







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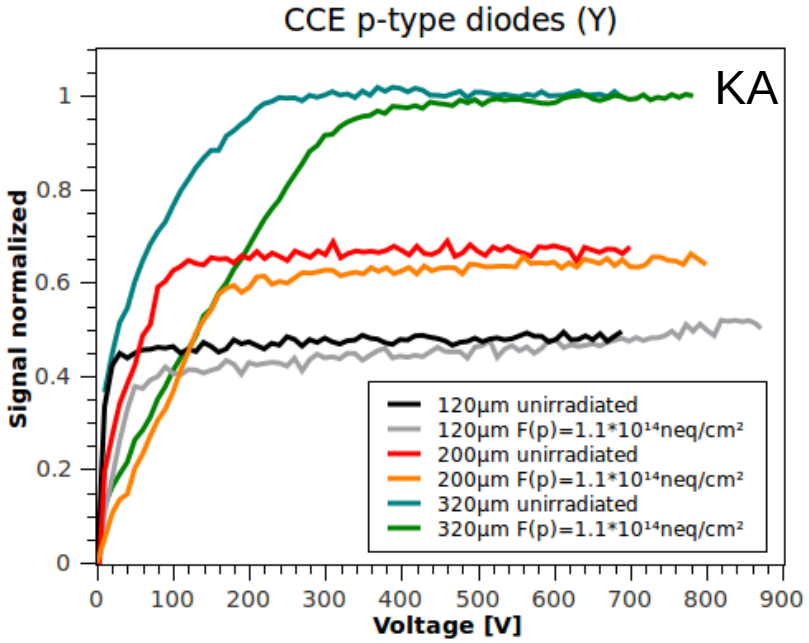
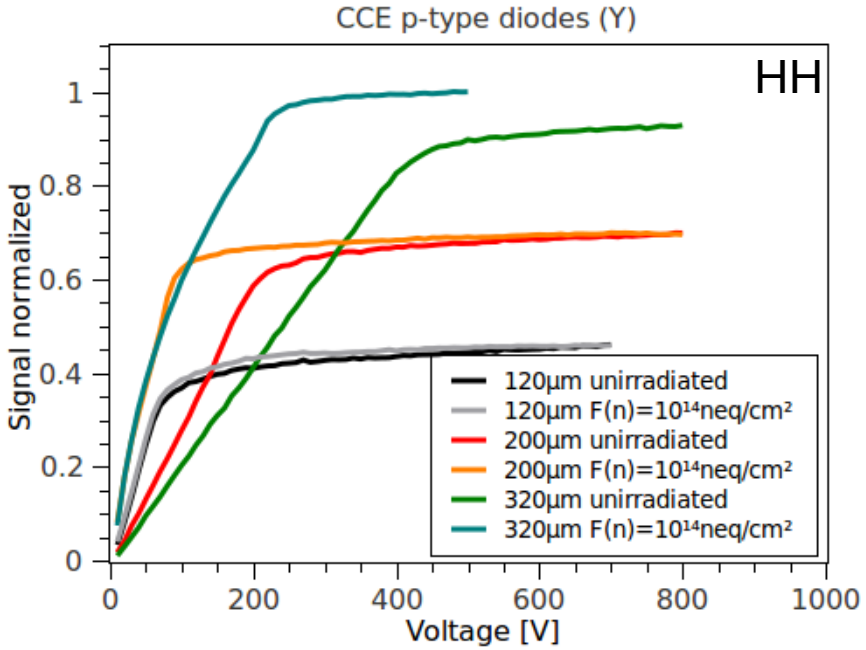
CCE measurements of irradiated diodes

- Proton irradiated p-spray diodes reach 100% charge collection after irradiation
- Differences in charge collection of FZ200µm seen
  - Not same diode, different active thickness (not corrected)
- 120µm
  - Higher electric fields - Gain even more active thickness after irradiation





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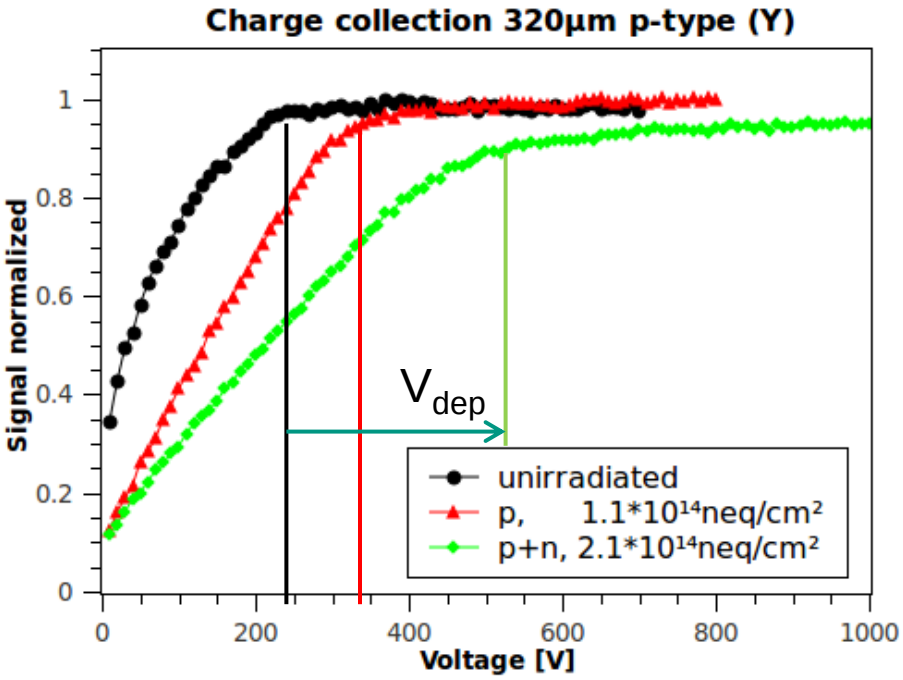
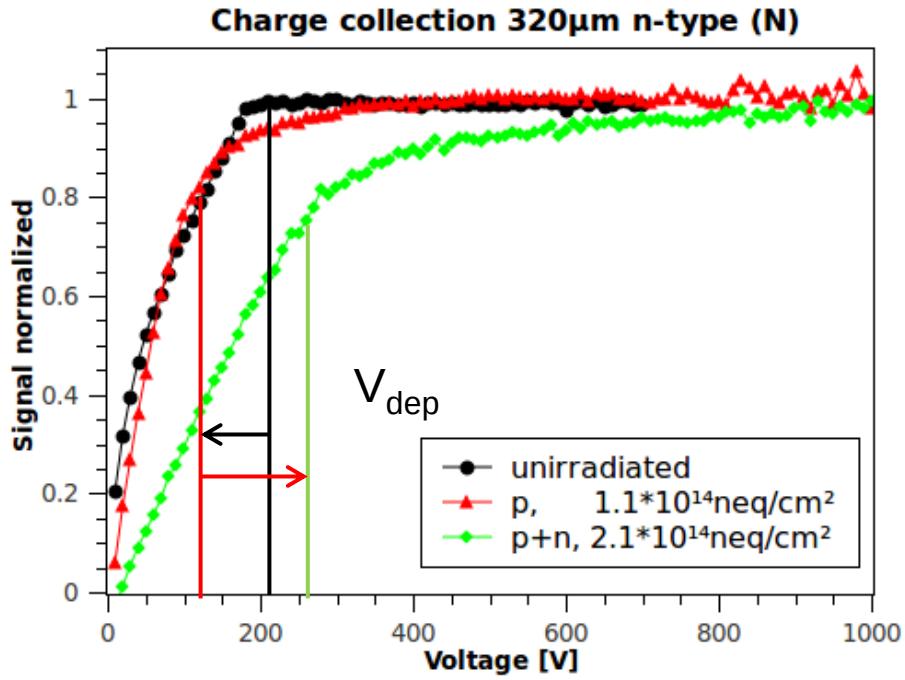
CCE measurement of irradiated diodes

- Comparison of 320µm thick diodes at T=0°C
- Irradiation: F(p) = 1.1*$10^{14}n_{eq}/cm^2$, F(n) = $10^{14}n_{eq}/cm^2$
- Annealing: 10min@60°C





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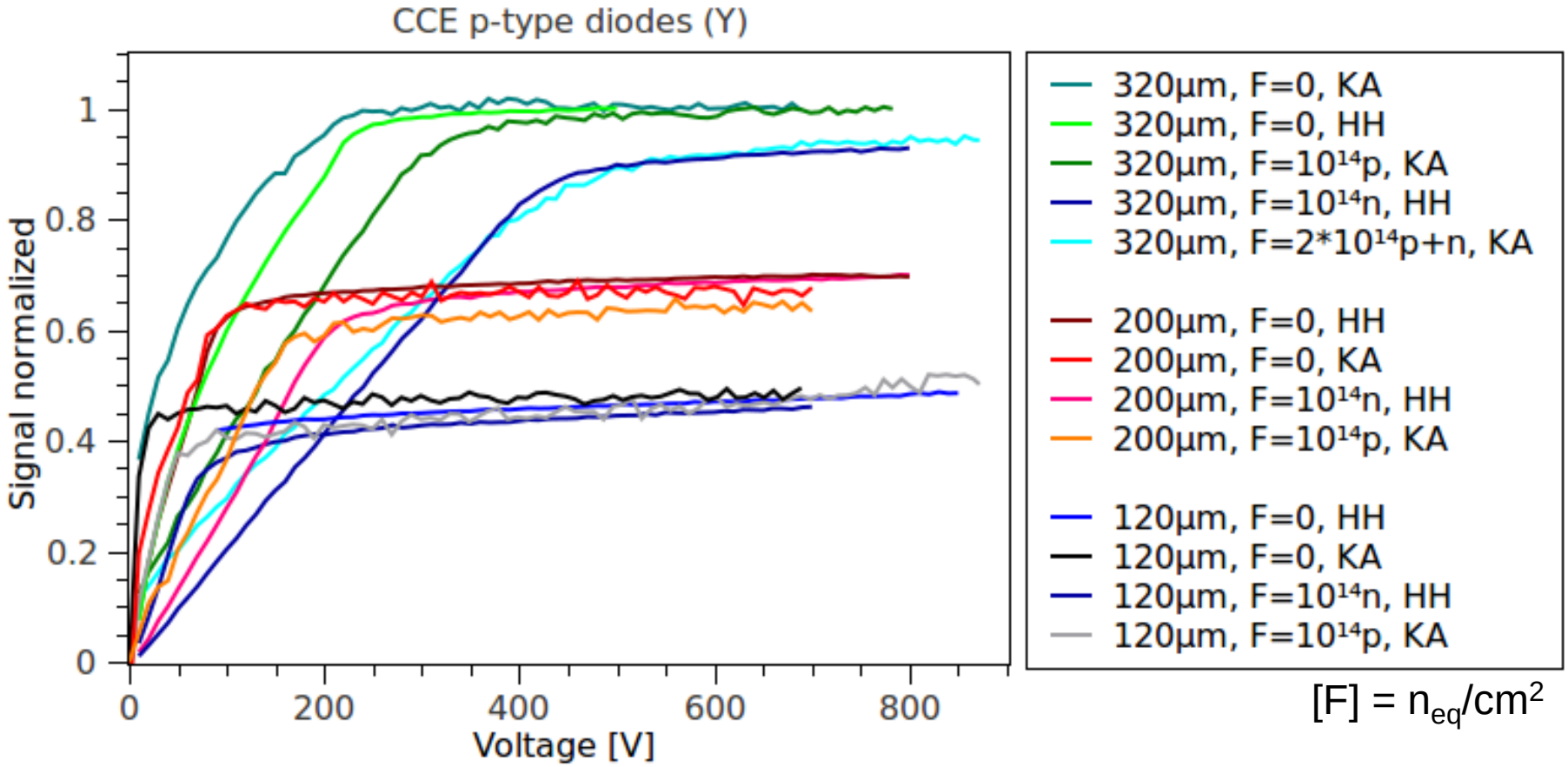
CCE measurements of irradiated diodes



[F] = n_{eq}/cm^2

- Some diodes showed variation measuring several times - remeasure
- Different Setups at HH / KA in quite good agreement when normalized to 320µm thick diode
  - Errors ±5%
- Different Annealing! KA: 10min@60°C, HH: 2h@RT

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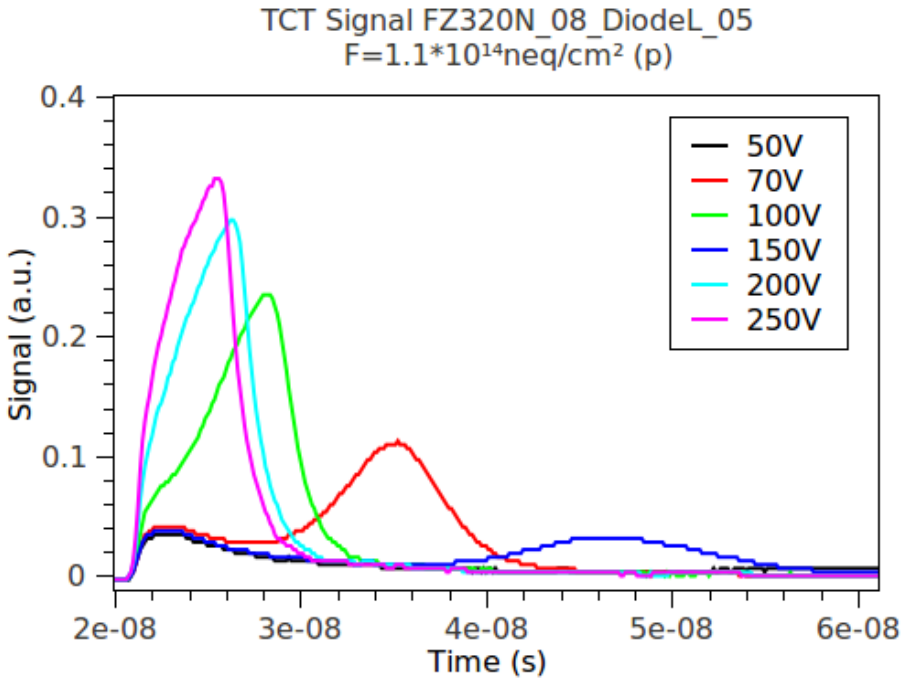
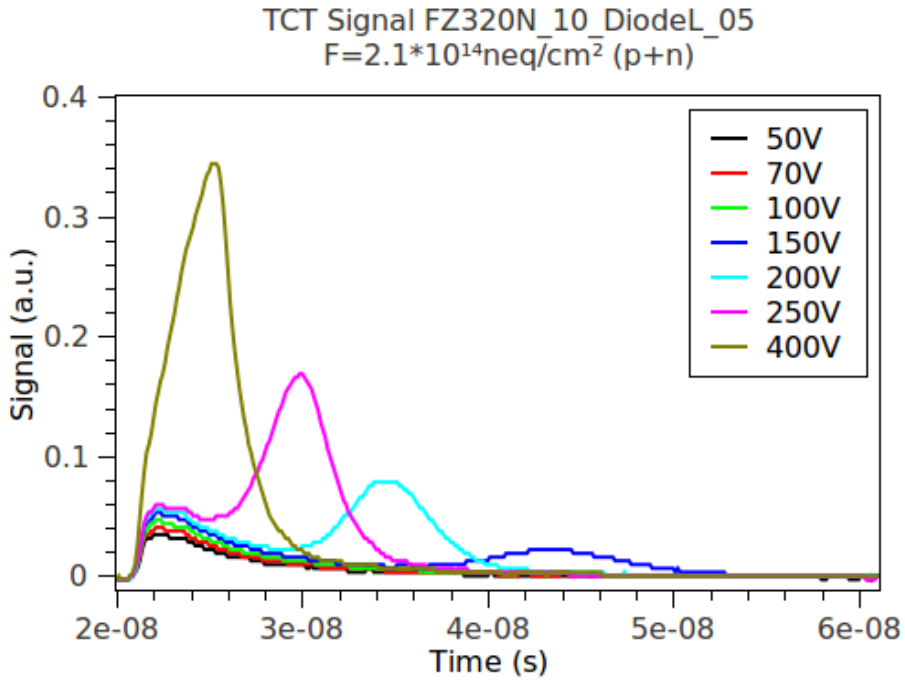
TCT measurements on irradiated diodes

- TCT measurements
- Signal shape of irradiated diodes
  - Red Laser (680nm)
- Here: Large 320µm n-type diodes
- Very nice double peak for n-type diodes (electrons)
- Time resolution should improve with small diodes (lower capacitance)





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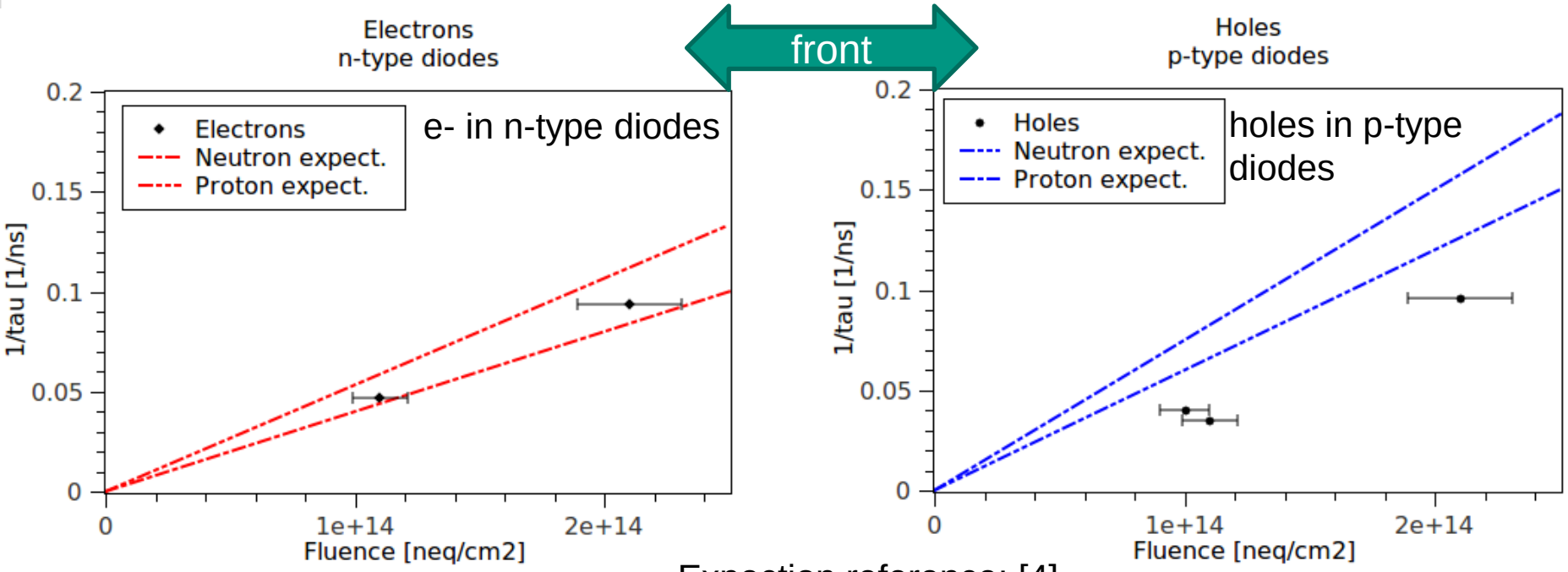
TCT measurements on irradiated diodes

- Red Laser shot on frontside of diodes
- Trapping times calculated with charge correction method (CCM)
- Annealing: ~50h at RT

- Used model for effective trapping times:
- $I(t) = I_0(t) * e^{\left(\frac{t-t_0}{\tau}\right)}$
- What to do with thinner devices?



Expection reference: [4]

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Summary and conclusions

- First irradiation of diodes successful (neutrons, protons, $F=10^{14}n_{eq}/cm^2$)
- Comparability of setups in last step (CCE) quite good
- Beginning investigations on TCT curves
- Trapping times: electrons fit to expected values, holes do not
  - More investigation necessary
  - Thin devices
  - Define method in the diode group to get trapping times (probably not CCM)

Outlook

- First standard irradiation of the CMS-HPK-Campaign soon
- More irradiations and additional irradiation steps for diodes
- More materials involved in next irradiations: FZ, MCz, Epi
- Start comparison of CCE of different materials, bulk dopings and mixed irradiation scenarios

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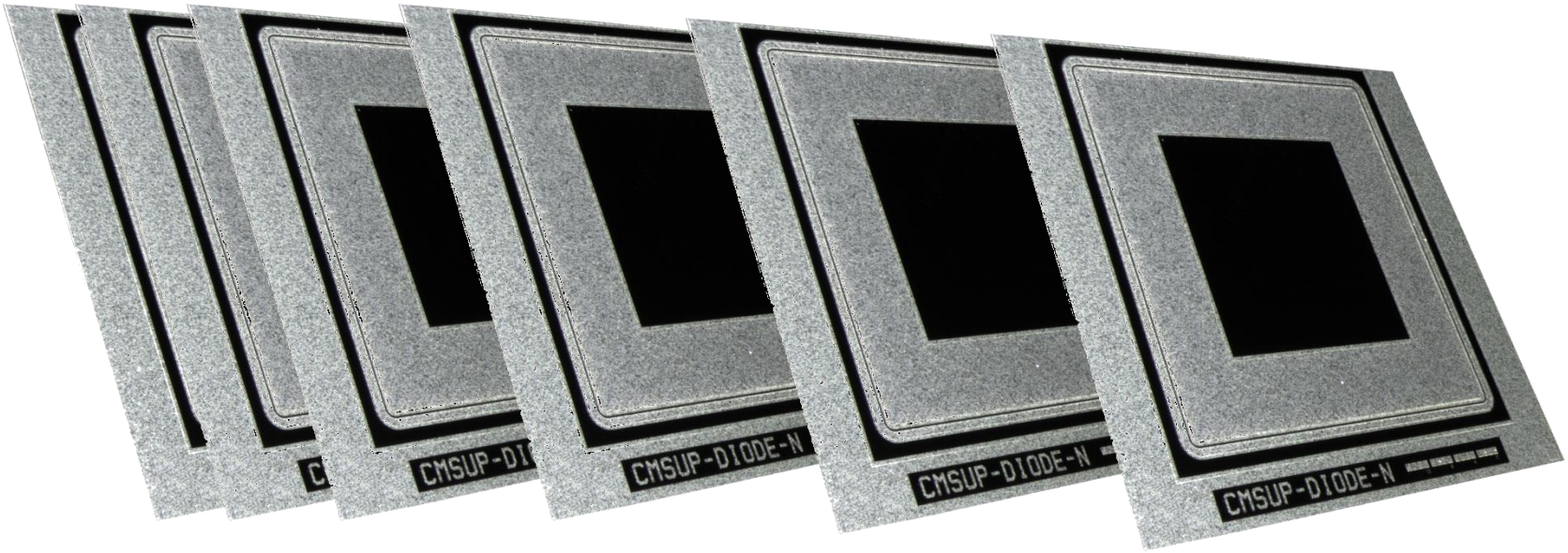

THANK YOU FOR YOUR ATTENTION!

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References

[1] Diode meeting, April 24th 2011, Thomas Pöhlsen; Institut für Experimentalphysik, Universität Hamburg.
https://indico.cern.ch/conferenceDisplay.py?confId=132650

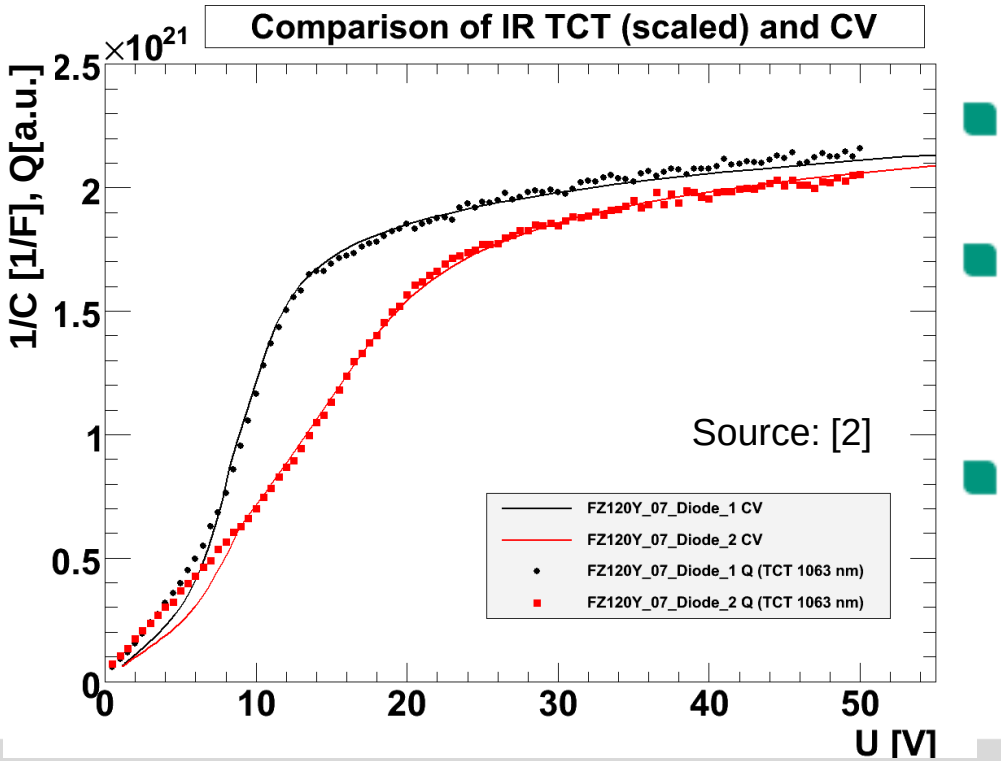
[2] Sensor upgrade meeting, Feb. 17th 2011, Georg Steinbrück, Thomas Pöhlsen; Institut für Experimentalphysik, Universität Hamburg.
https://indico.cern.ch/conferenceDisplay.py?confId=125774

[3] Measurements of irradiated diodes, Christian Scharf; Institut für Experimentalphysik, Universität Hamburg.

[4] G. Kramberger et al., Nuclear Instruments and Methods in Physics Research A 481, 2002, 297-305

CCE measurement of unirradiated diodes

- CV and CC measurements are compared with respect to differences between Diode_1 and Diode_2 of the same wafer



- Collected charge: deposited charge in depleted volume + outdiffusing charge deposited in undepleted volume
- Neglecting diffusion
  - Q ~ depletion width ~ 1/C
- CCE determined with IR Laser from frontside
- No corrections for reflections or absorption
- CCE measurements confirm CV measurements qualitatively

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