Measurements of lorentz angle in highly irradiated silicon-strip-detectors

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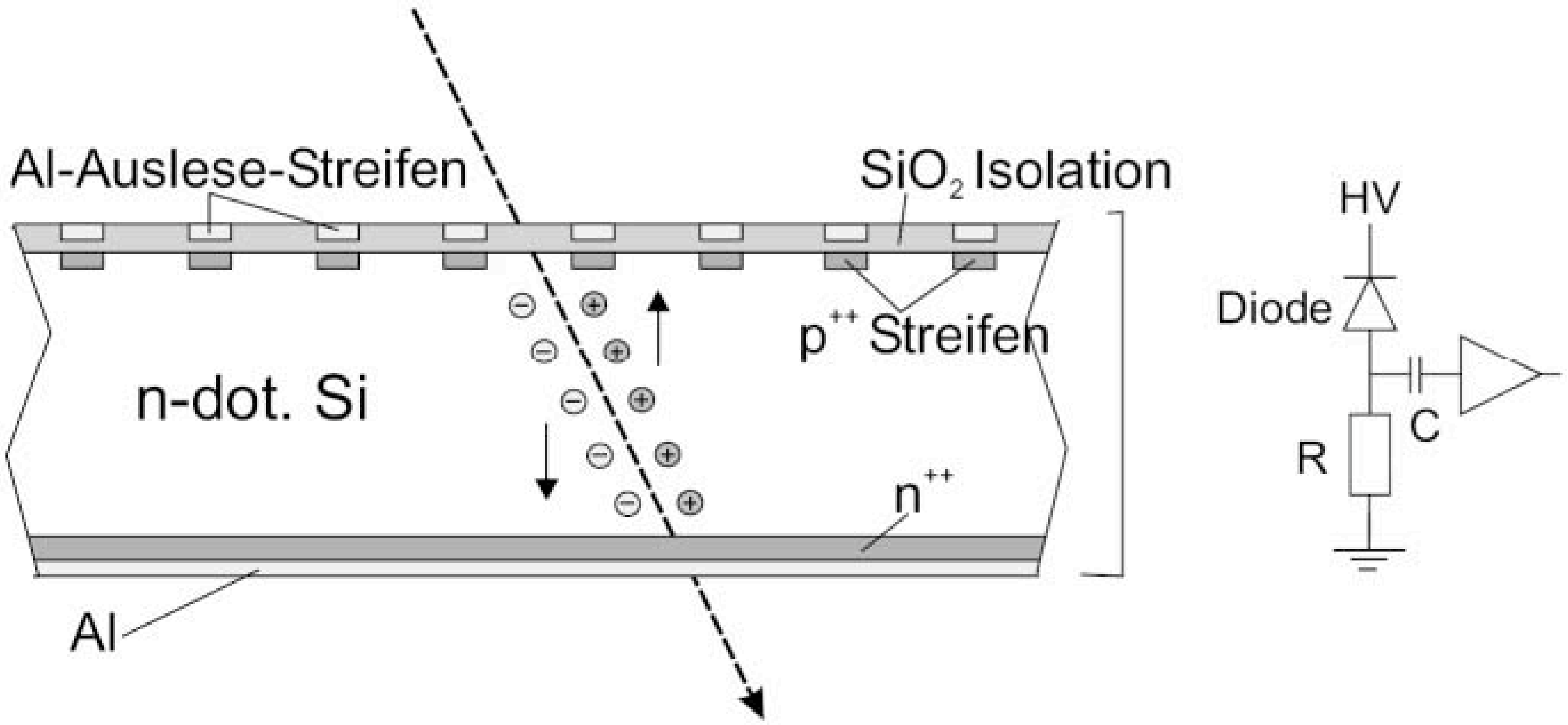
Content

- Lorentz angle
- Experimental setup
- Sensors
- Results
- Outlook

Lorentz angle (1)

- Particle crossing the sensor creates free charge carriers
- Transported to readout-stips by electric field
- Also affected by magnetic field



Lorentz angle (2)

- Shifted from their origin by lorentz shift Δx
- Sensor thickness d
- Therefore the lorentz angle is defined as

$$\tan \Theta_L = \frac{\Delta x}{d}$$

Lorentz angle (3)

- Lorentz angle can also be calculated to

$$\frac{\Delta x}{d} = \tan\Theta_L = r_H \mu B$$

- Mobility μ and hall scattering factor r_H
- One can parametrise the mobility as

$$\mu = \frac{\mu_0}{\left(1 + \left(\frac{E\mu_0}{v_s}\right)^{\beta}\right)^{1/\beta}}$$

Lorentz angle (4)

Holes	Electrons
$\mu_0 = 470.5 \frac{cm^2}{Vs} (T/300K)^{-2.42}$	$\mu_0 = 1417 \frac{cm^2}{Vs} (T/300K)^{-2.2}$
$v_s = 8.37 \cdot 10^6 \frac{cm}{s} (T/300K)^{0.52}$	$v_s = 1.07 \cdot 10^7 \frac{cm}{s} (T/300K)^{0.87}$
$\beta = 1.213 \cdot (T/300K)^{0.17}$	$\beta = 1.109 \cdot (T/300K)^{0.66}$

$$E(z) = \frac{U_{Bias} - U_{Dep}}{d} + 2\frac{U_{Dep}}{d}\left(1 - \frac{z}{d}\right)$$

Lorentz angle (5)

- Lorentz shift after Δd

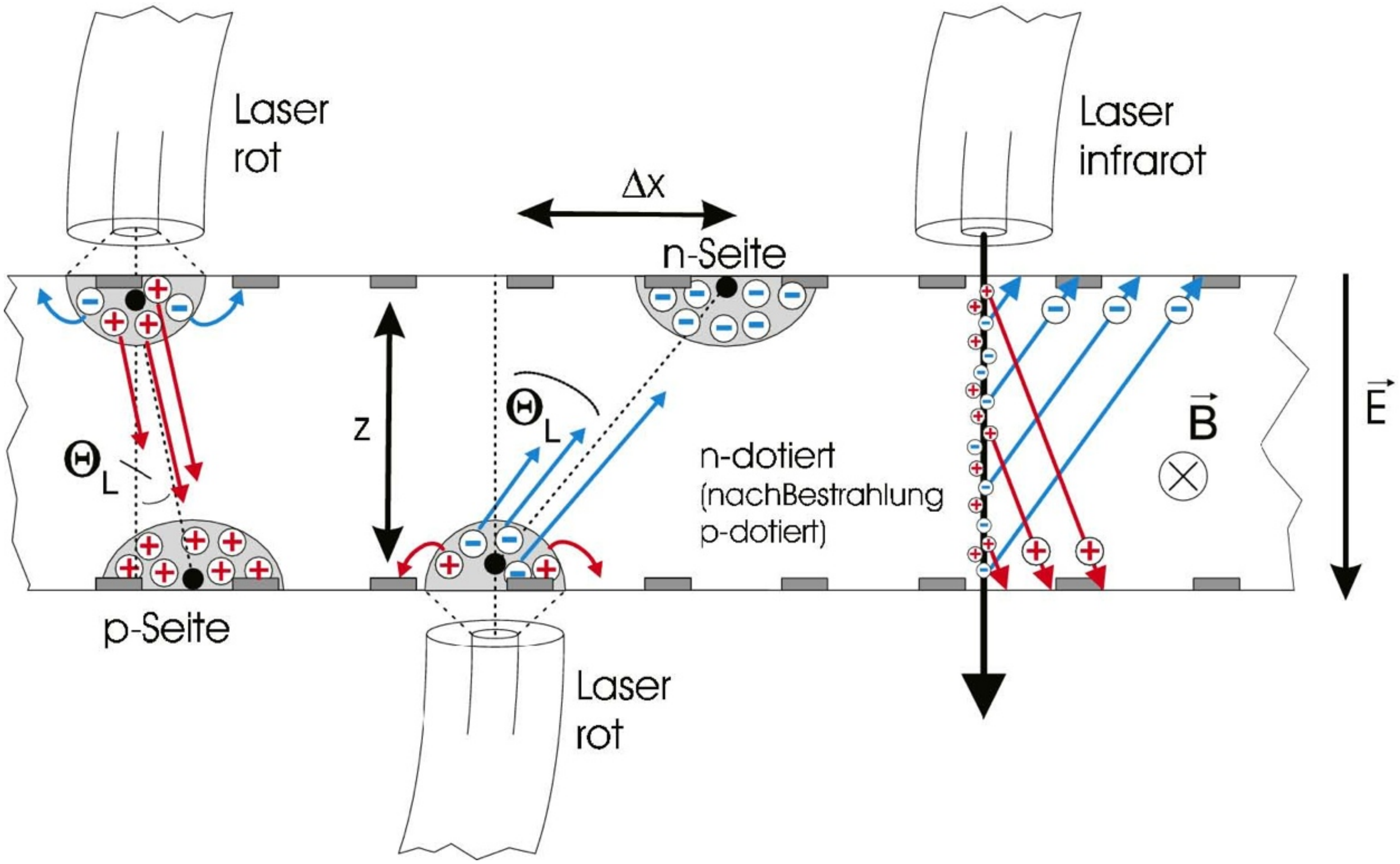
$$\Delta x = r_H \cdot \mu \cdot B \cdot \Delta d$$

- Therefore

$$\Delta x = \int_{z=0}^{d} r_H \cdot \mu(d) \cdot B \cdot \mathrm{d}d$$

- Calculated by summing over 100000 steps

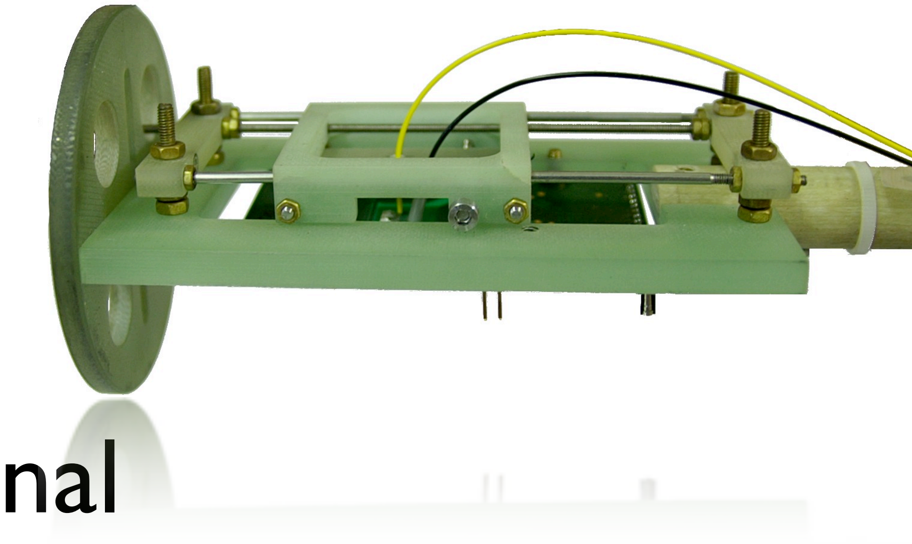
Experimental Setup (I)

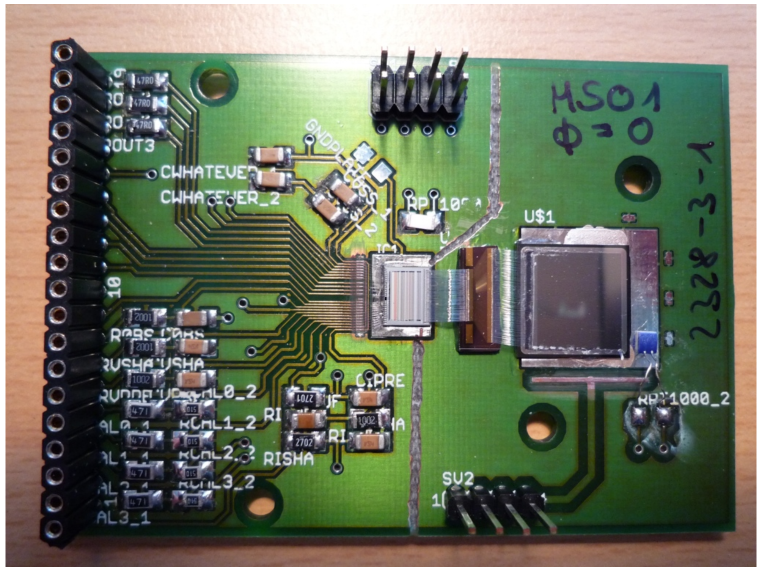


- Lasersystem to generate charge carriers

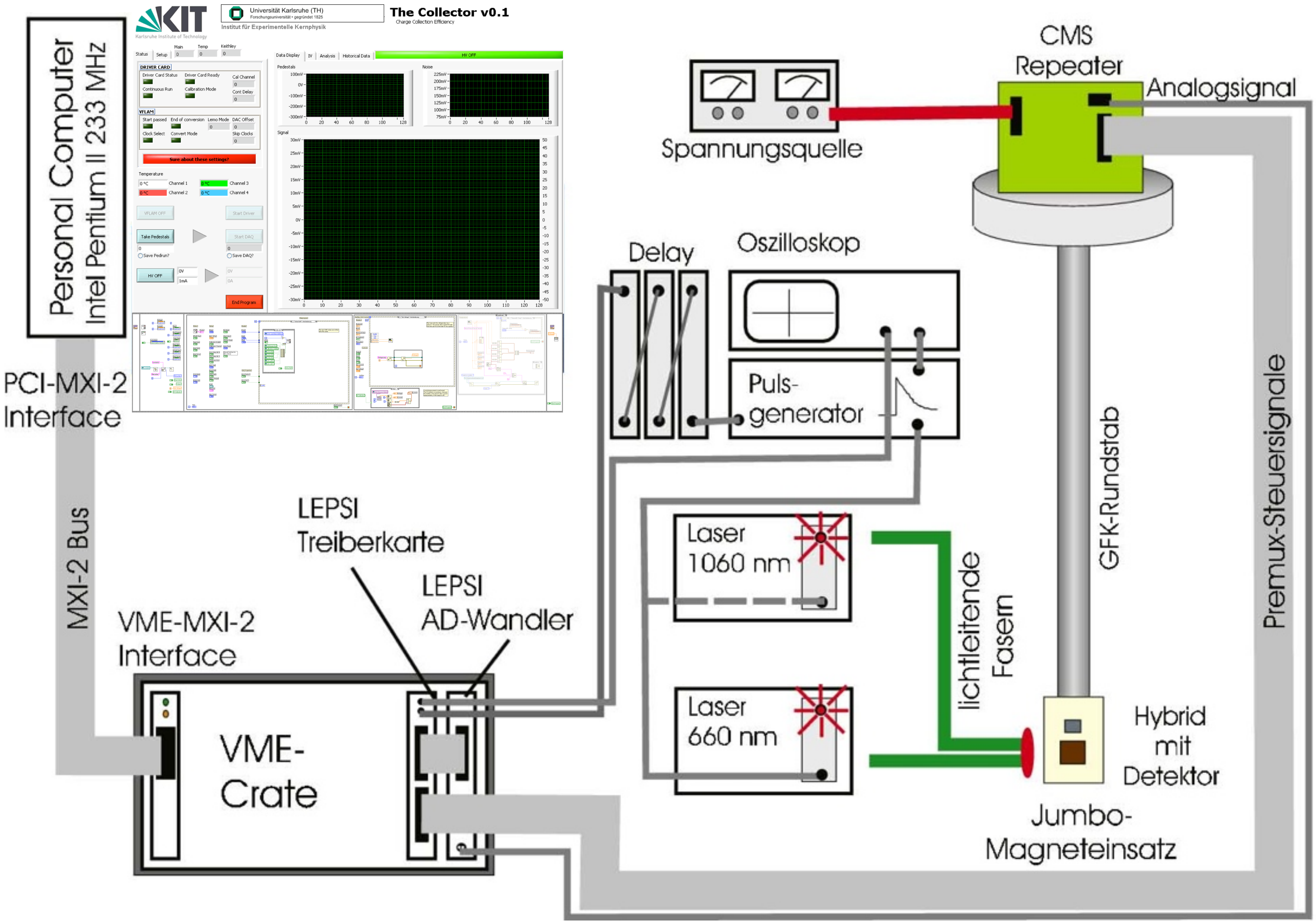
Experimental Setup (2)

- Sensor with readout-chip PreMux on hybrid
- Hybrid mounted on structur for magnet
- Optical fibers for laser
    - red laser for best signal
    - infrared laser for MIP-like signal



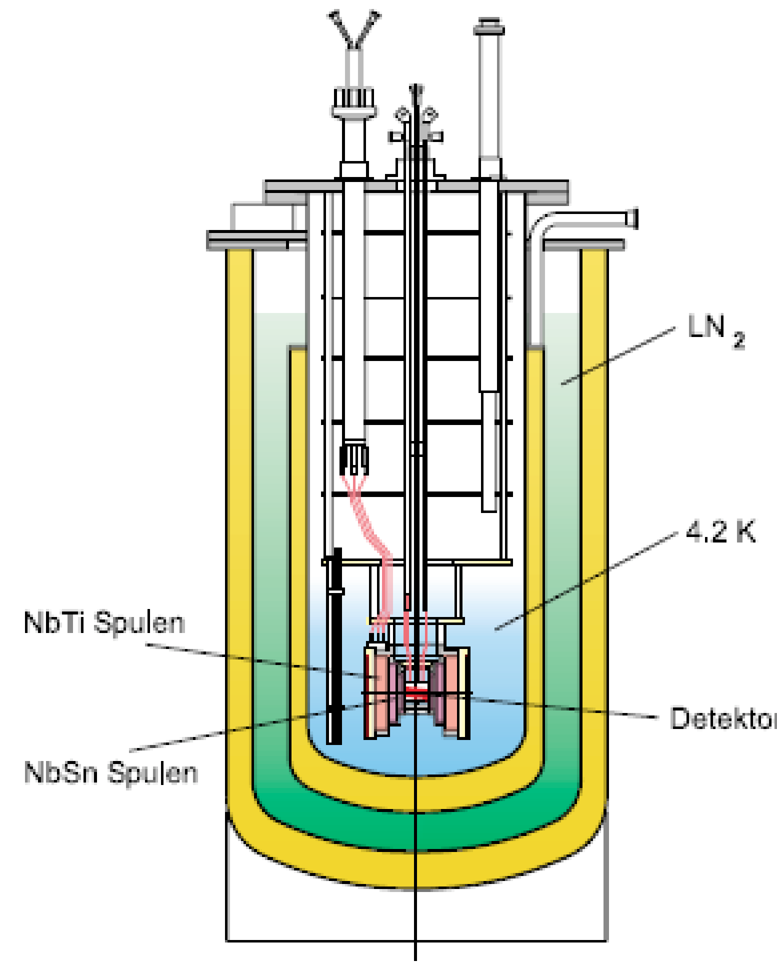


Experimental Setup (3)



Experimental Setup - Magnet

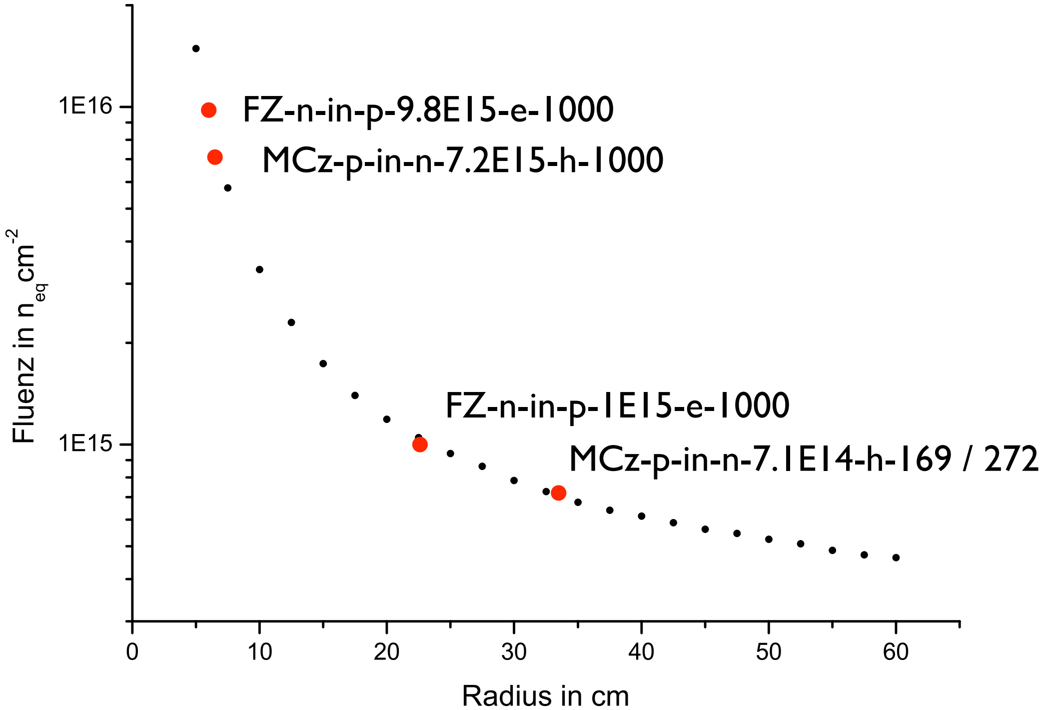
- Magnet lab of ITP at Forschungszentrum Karlsruhe
- Measurements of lorentz shift up to 8T



Sensors (I)

Sensorname	Manufacturer	Material	Thickness [μm]	U_{dep} [V]	Fluence [$\frac{n_{eq}}{cm^2}$]
FZ-p-in-n-0-h-154-CMS	ST Microelectronics	FZ n-type	500	154	0
FZ-n-in-p-0-e-12	Micron / RD50	FZ p-type	300	12	0
FZ-n-in-p-1E15-e-1000	Micron / RD50	FZ p-type	300	≈ 1000	$1 \cdot 10^{15}$
FZ-n-in-p-9.8E15-e-1000	Micron / RD50	FZ p-type	300	> 1000	$9.8 \cdot 10^{15}$
MCz-p-in-n-7.1E14-h-169	HIP	MCz n-type	300	169	$7.1 \cdot 10^{14}$
MCz-p-in-n-7.1E14-h-272	HIP	MCz n-type	300	272	$7.1 \cdot 10^{14}$
MCz-p-in-n-7.2E15-h-1000	HIP	MCz n-type	300	> 1000	$7.2 \cdot 10^{15}$
MCz-p-in-n-0-h-347	HIP	MCz n-type	300	347	0

- Measurement of depletion voltage by finding the knee in the $1/C^2$ over U plot

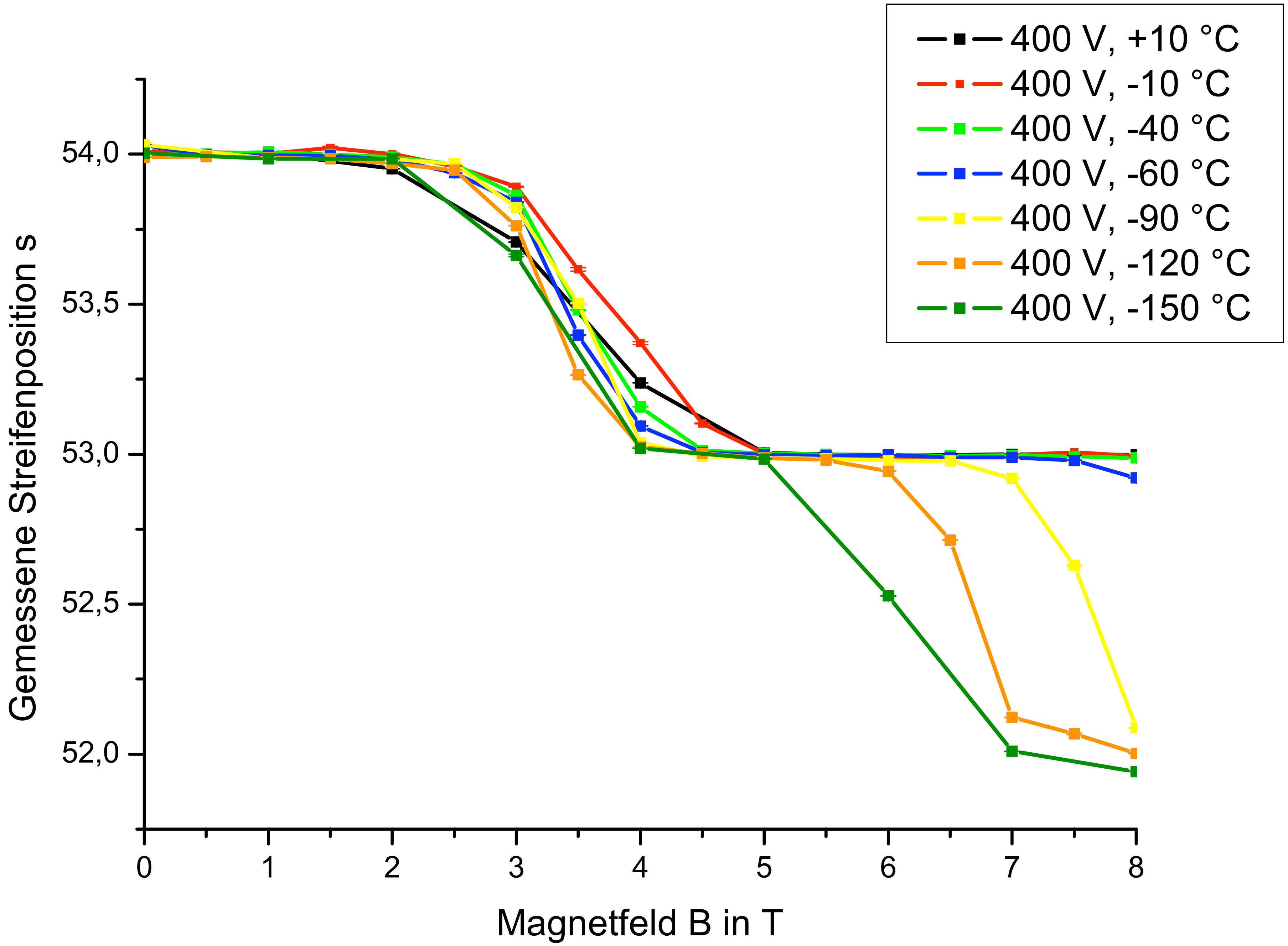


Sensors (2)

- Irradiated at Karlsruhe Kompaktzyklotron
- Protons with 25 MeV
- Hardness factor of $\kappa = 1.85$

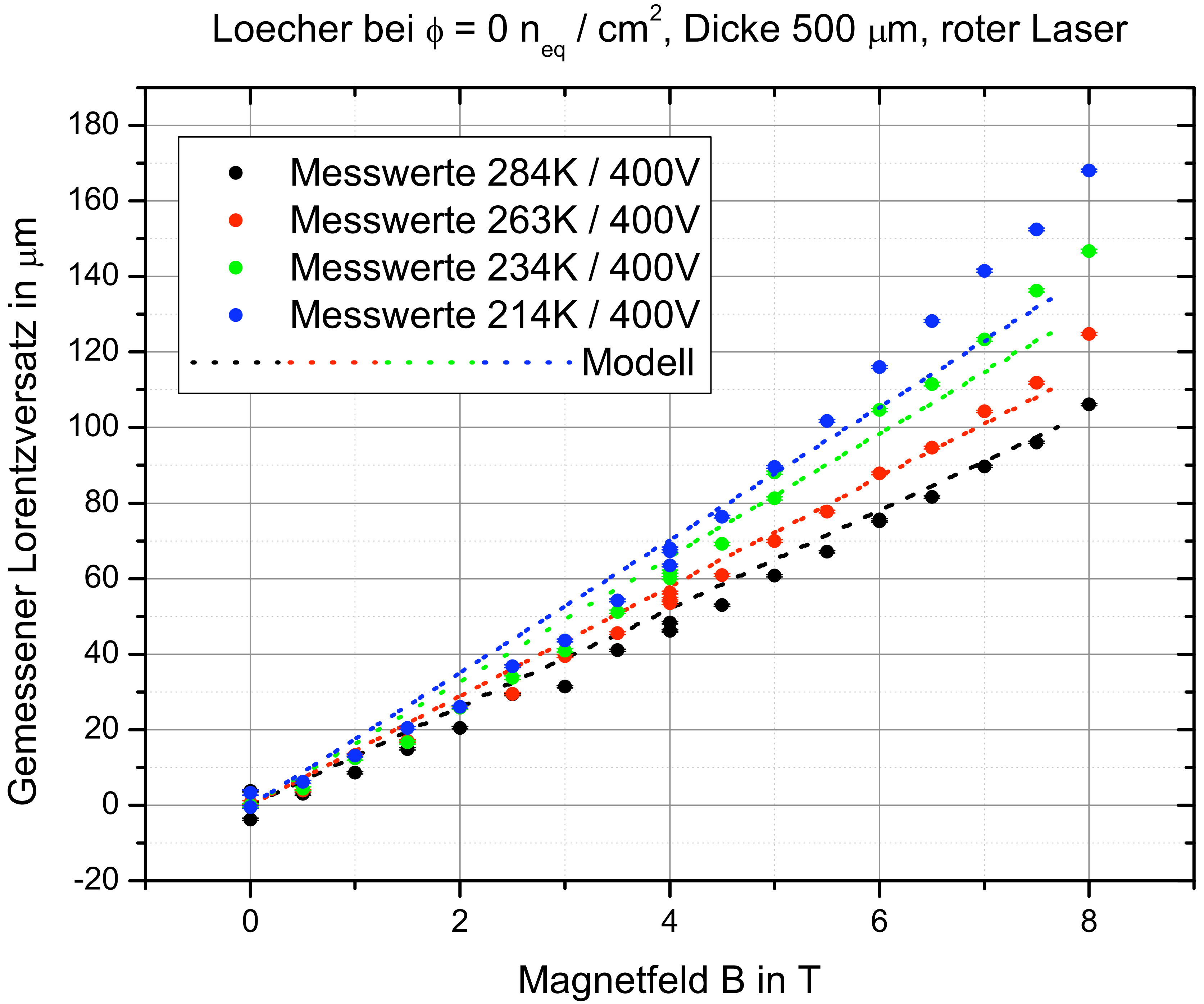
Results - Strip effects

- Charge collection between strips not linear



Results - Holes / FZ

Fluence 0 n_{eq} / cm^2, thickness 500 µm, red laser



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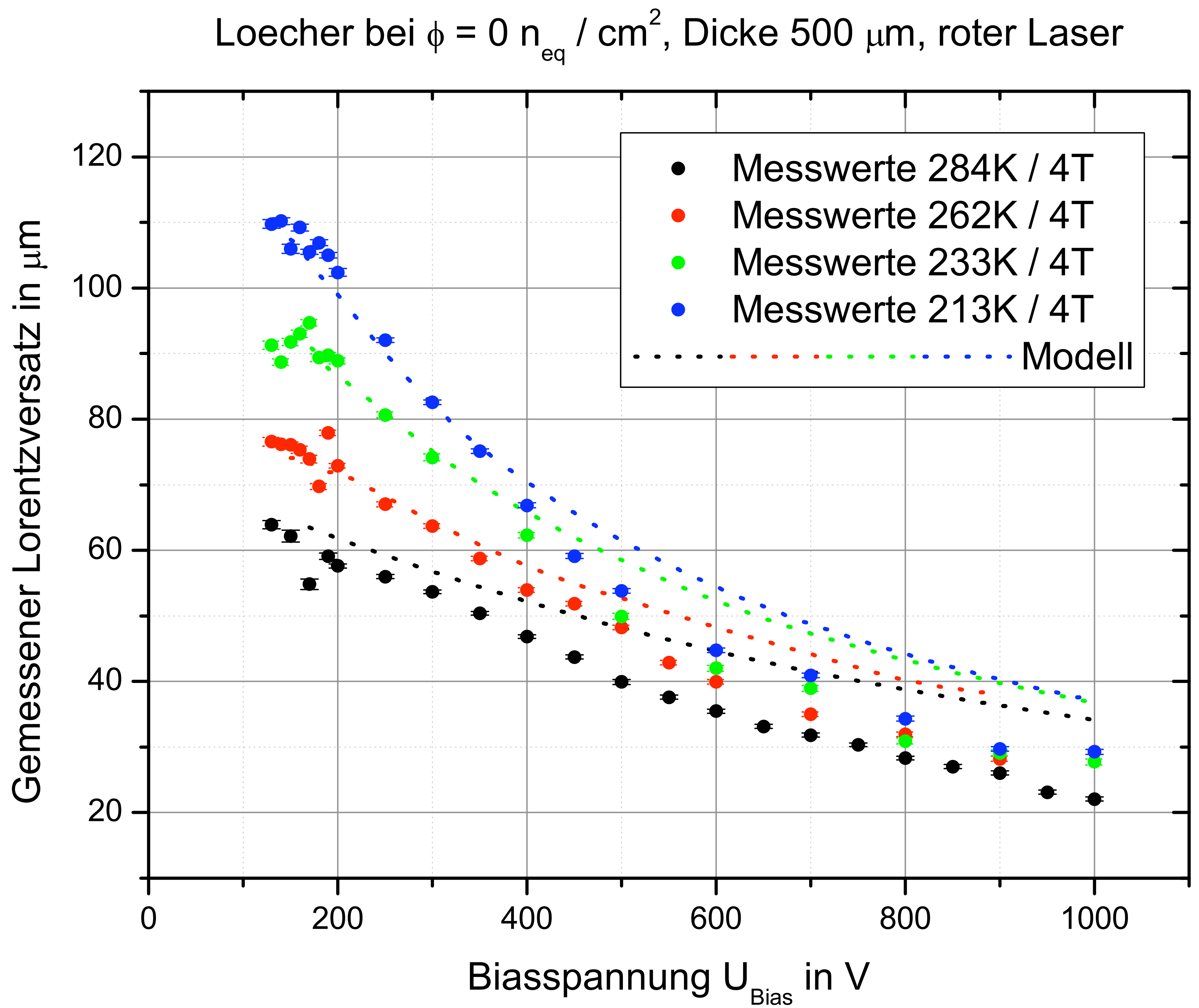

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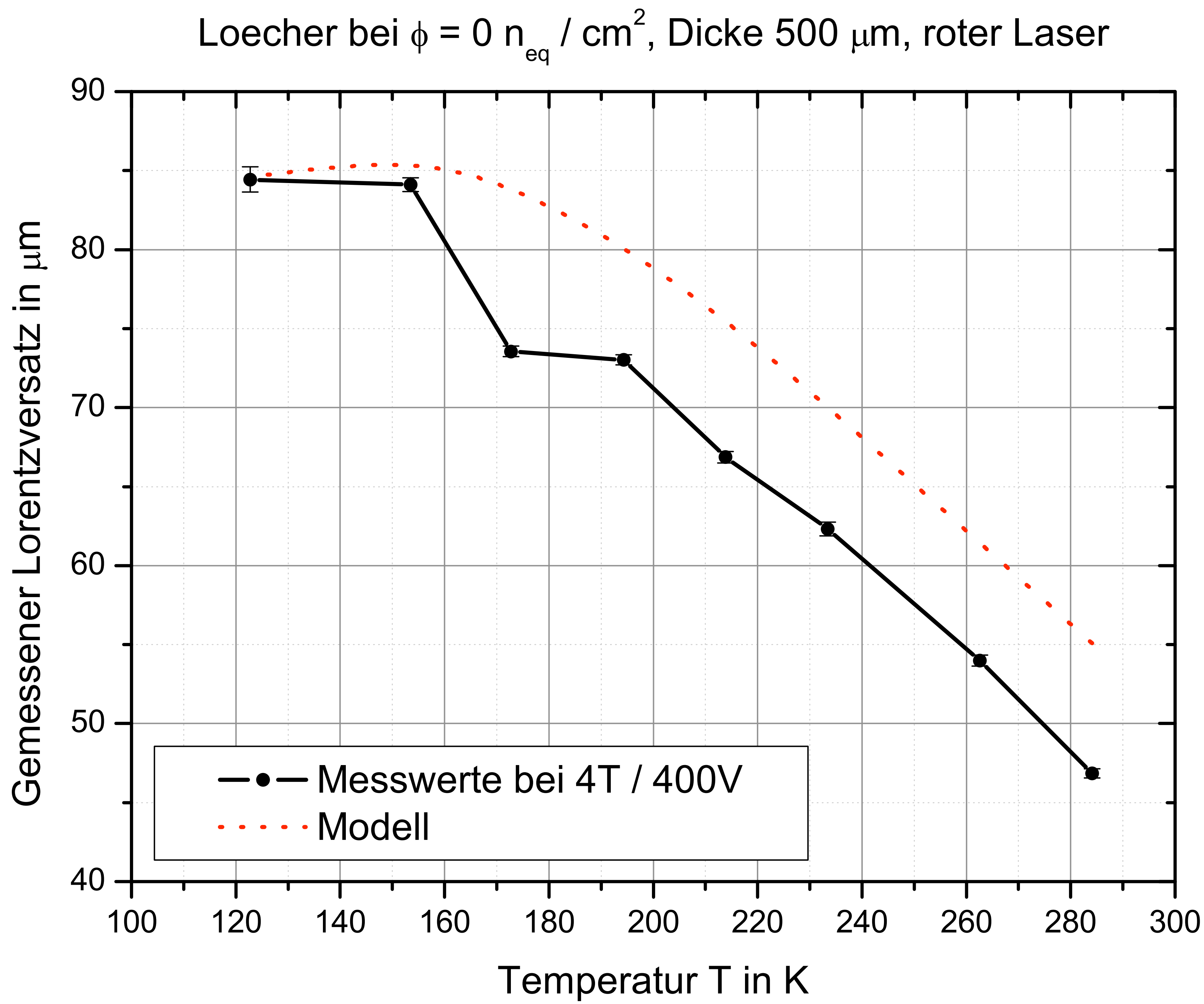
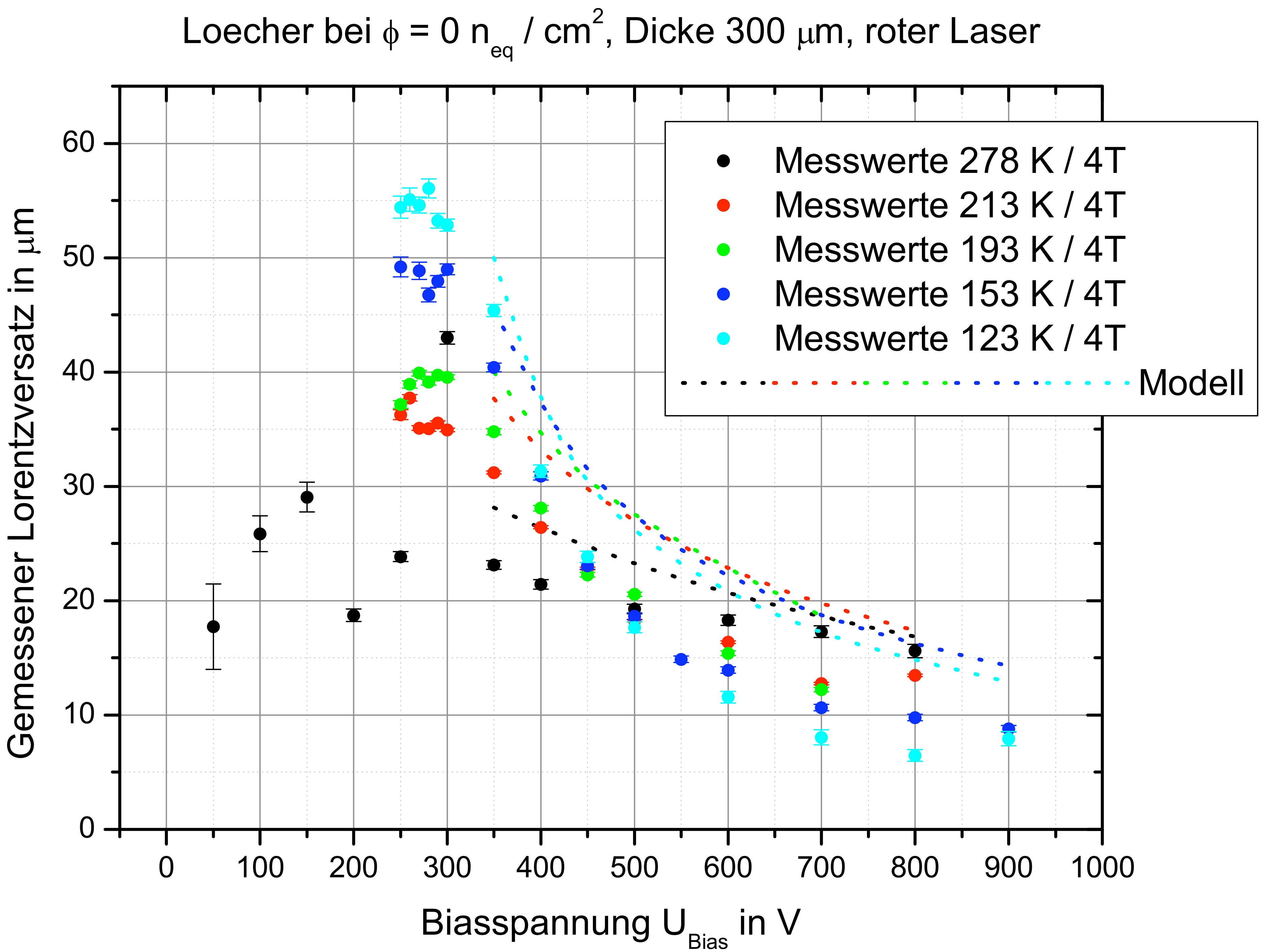


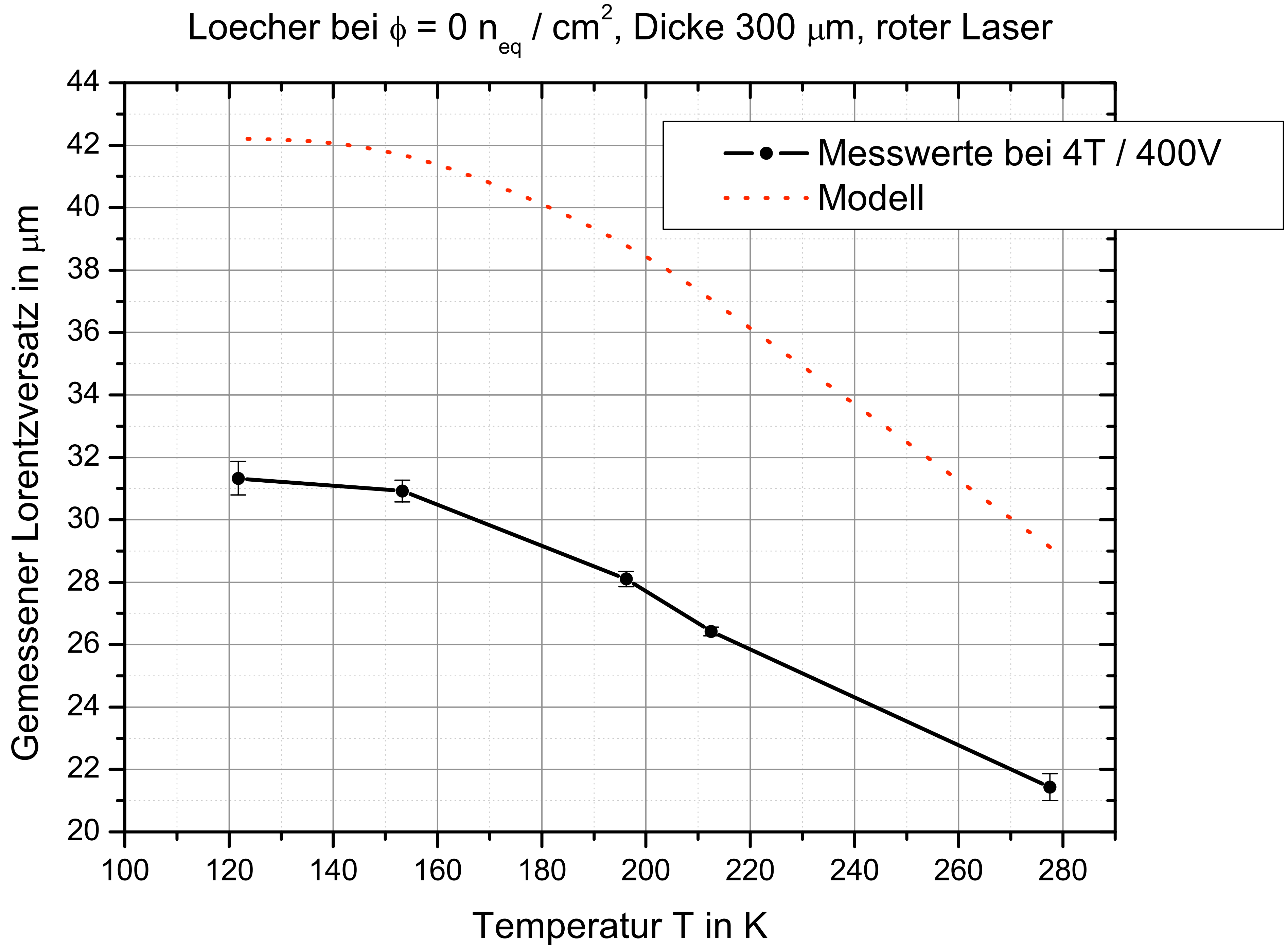
Results - Holes / MCz

Fluence 0 n_{eq} / cm^2, thickness 300 µm, red laser



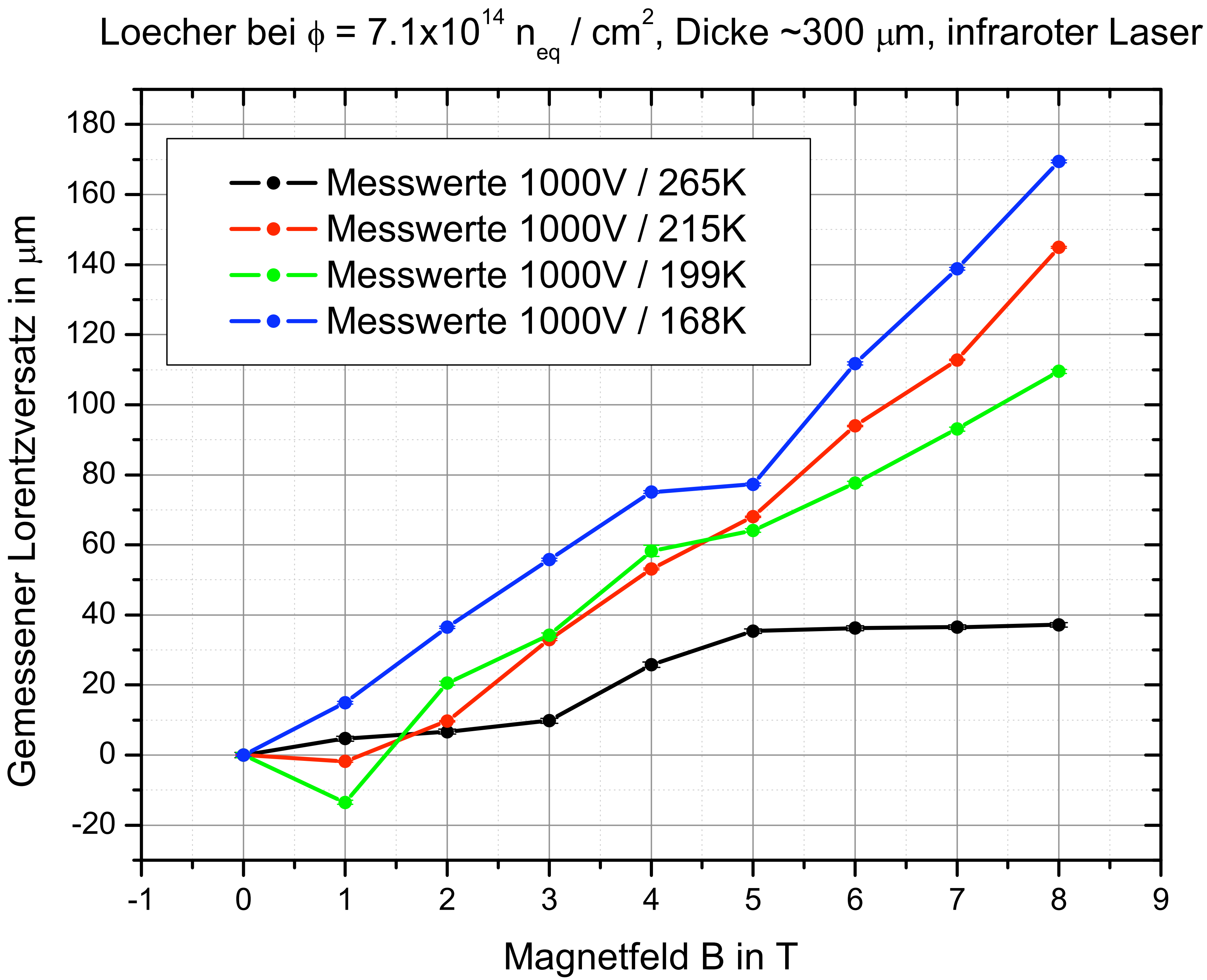
Results - Holes / MCz

Fluence 0 n_{eq} / cm^2, thickness 300 μm, red laser



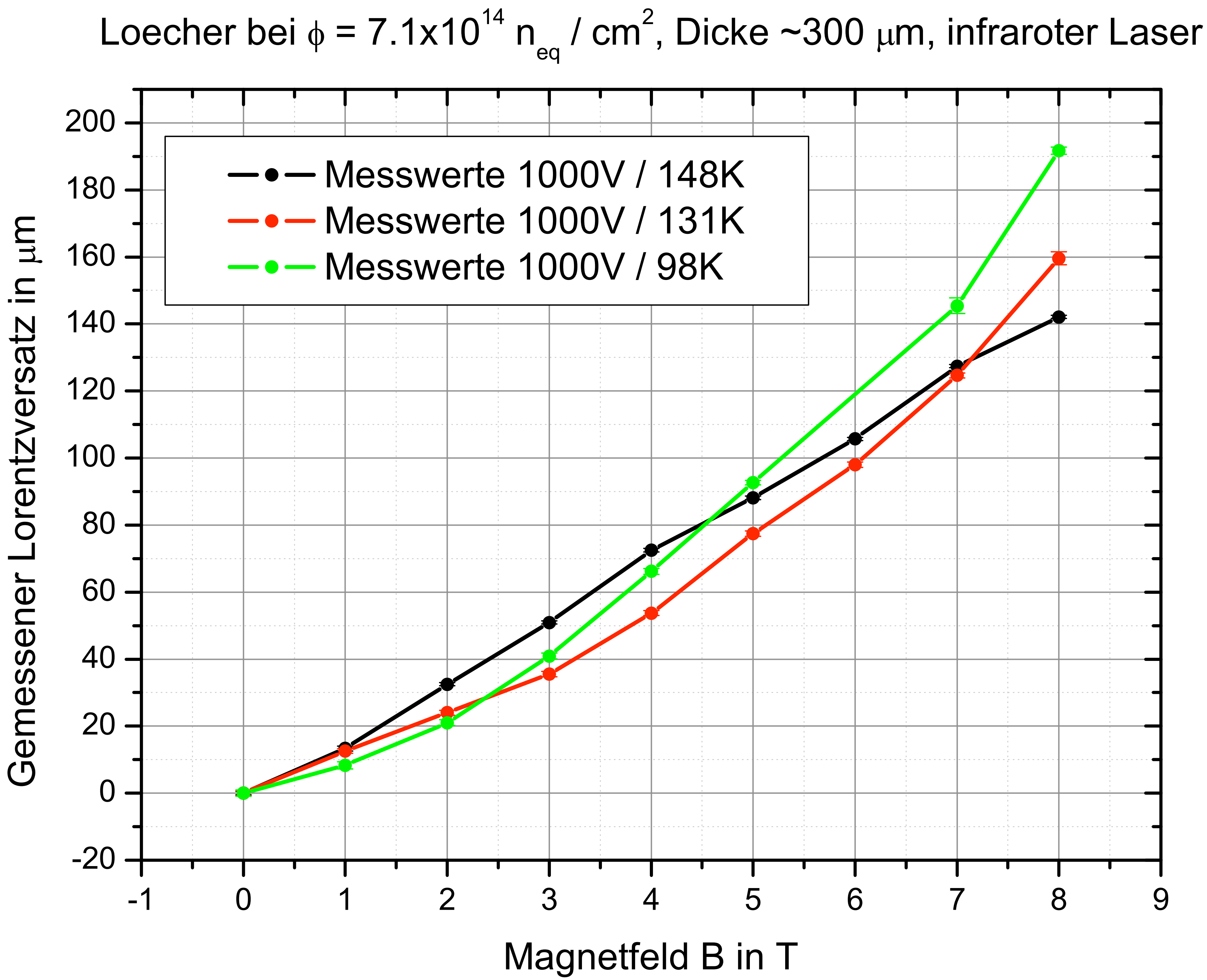
Results - Holes / MCz

Fluence 7.1 10^{14} n_{eq} / cm^2, thickness 300 µm, IR laser



Results - Holes / MCz

Fluence 7.1 10^{14} n_{eq} / cm^2, thickness 300 µm, IR laser



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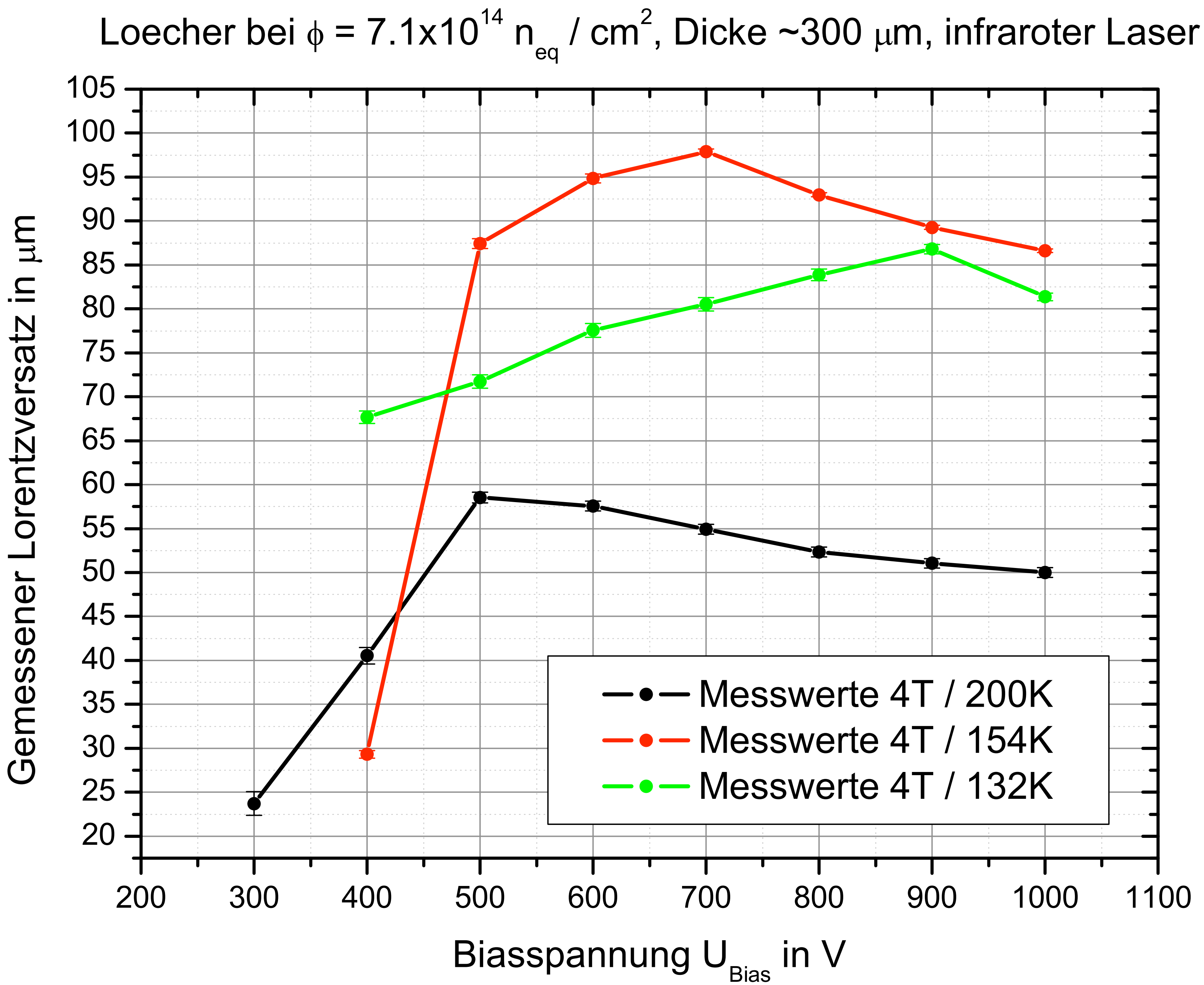
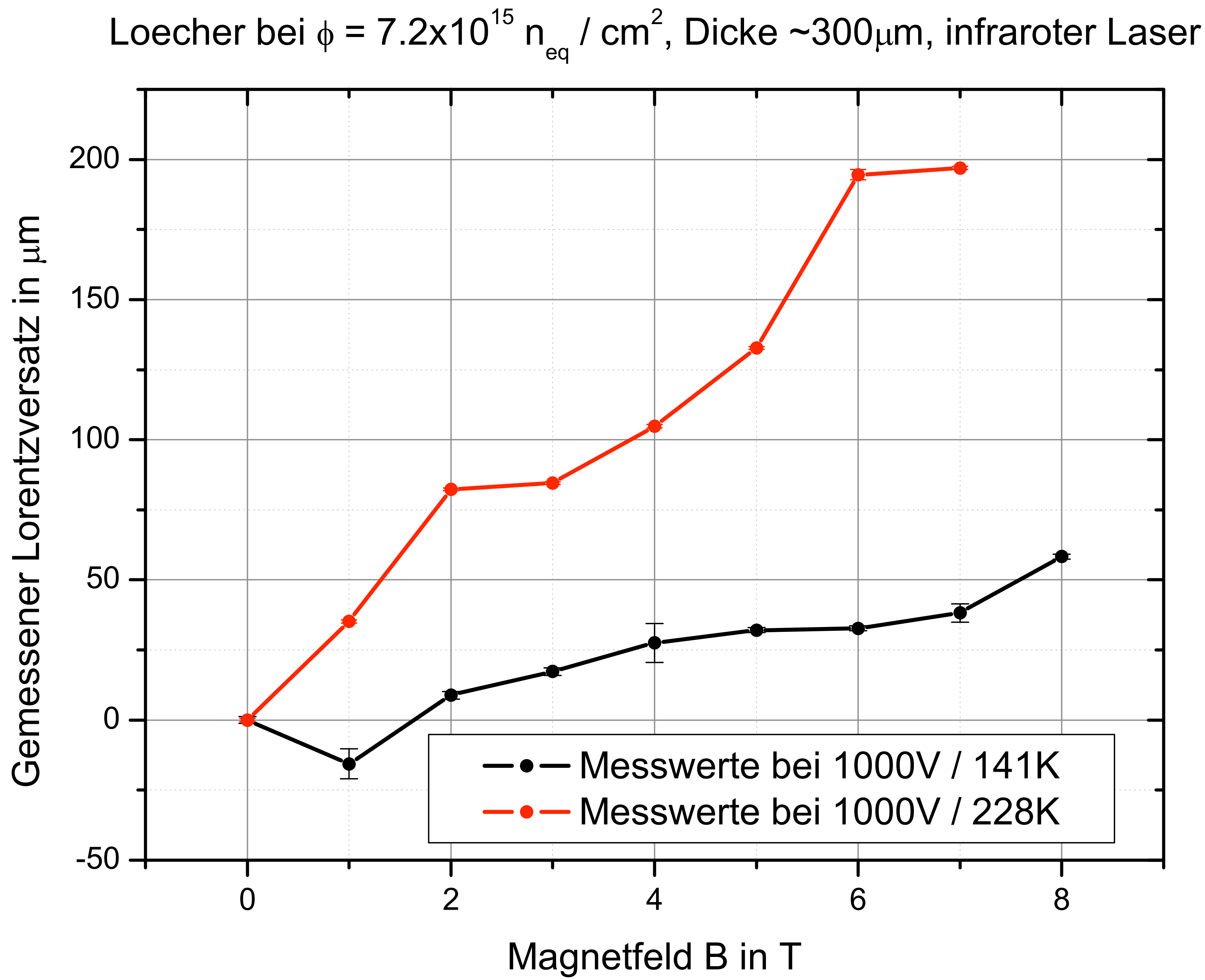


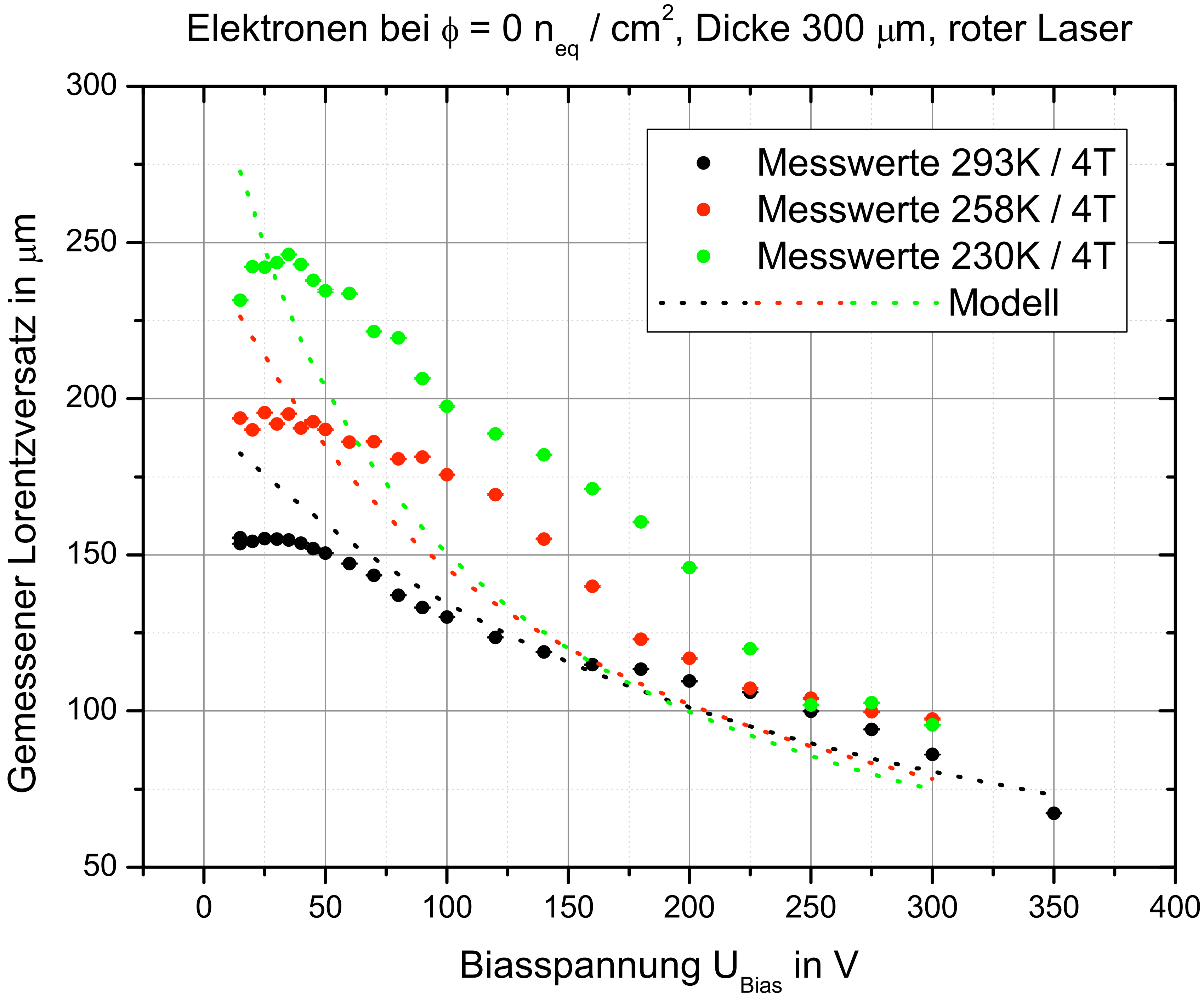
Results - Holes / MCz

Fluence 7.2 10^{15} n_{eq} / cm^2, thickness 300 µm, IR laser



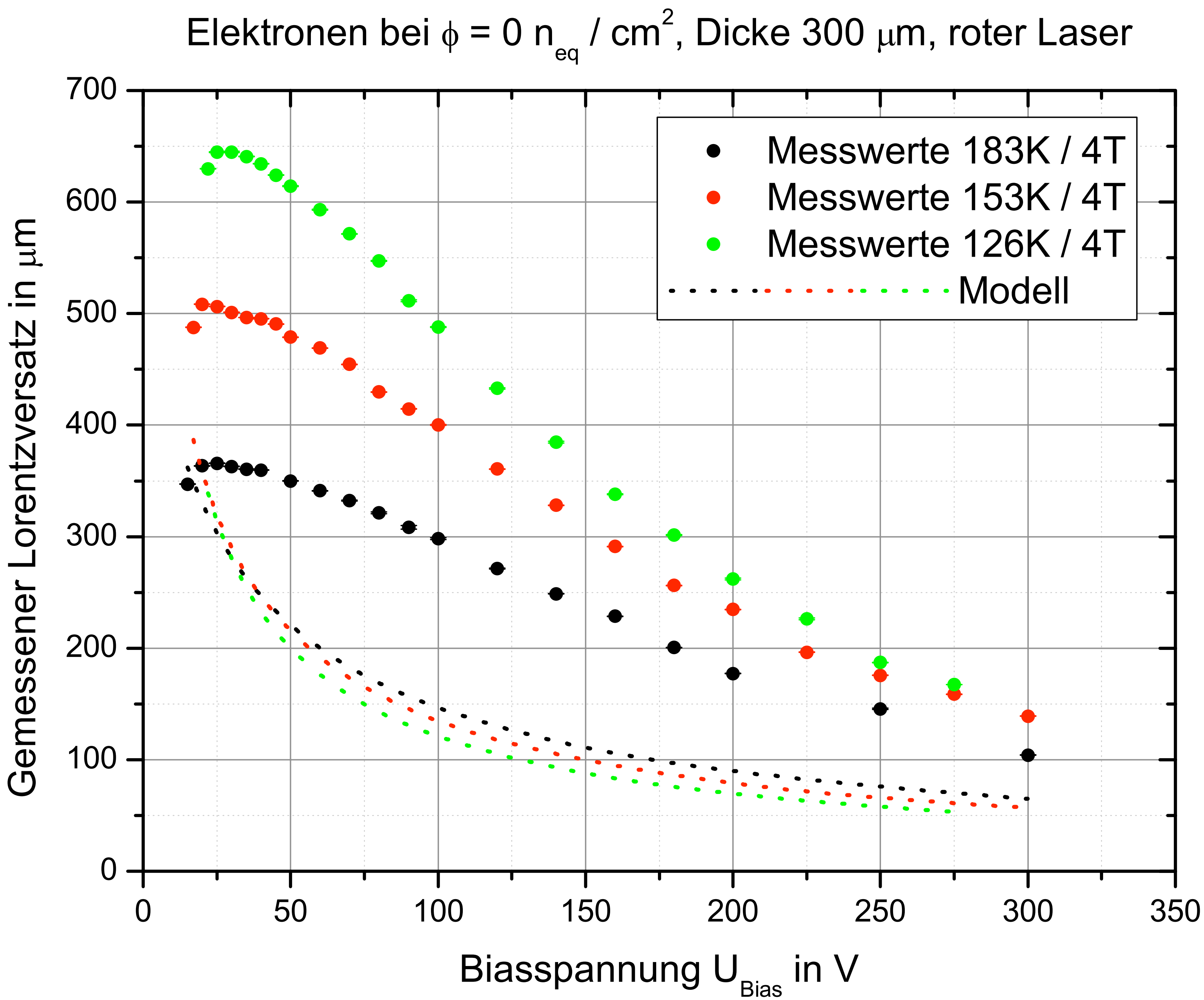
Results - Electrons / FZ

Fluence 0 n_{eq} / cm^2, thickness 300 µm, red laser



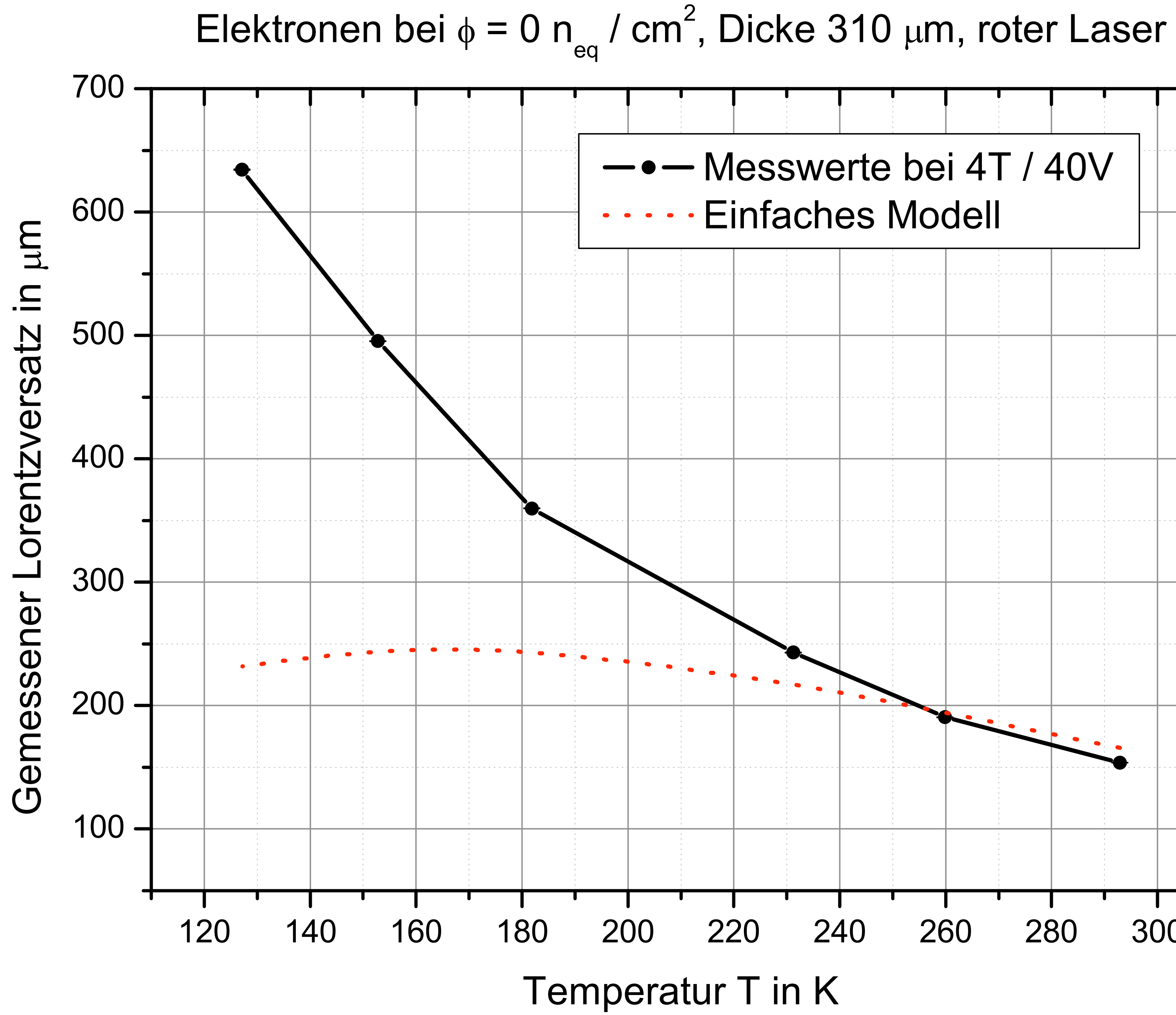
Results - Electrons / FZ

Fluence 0 n_{eq} / cm^2, thickness 300 µm, red laser



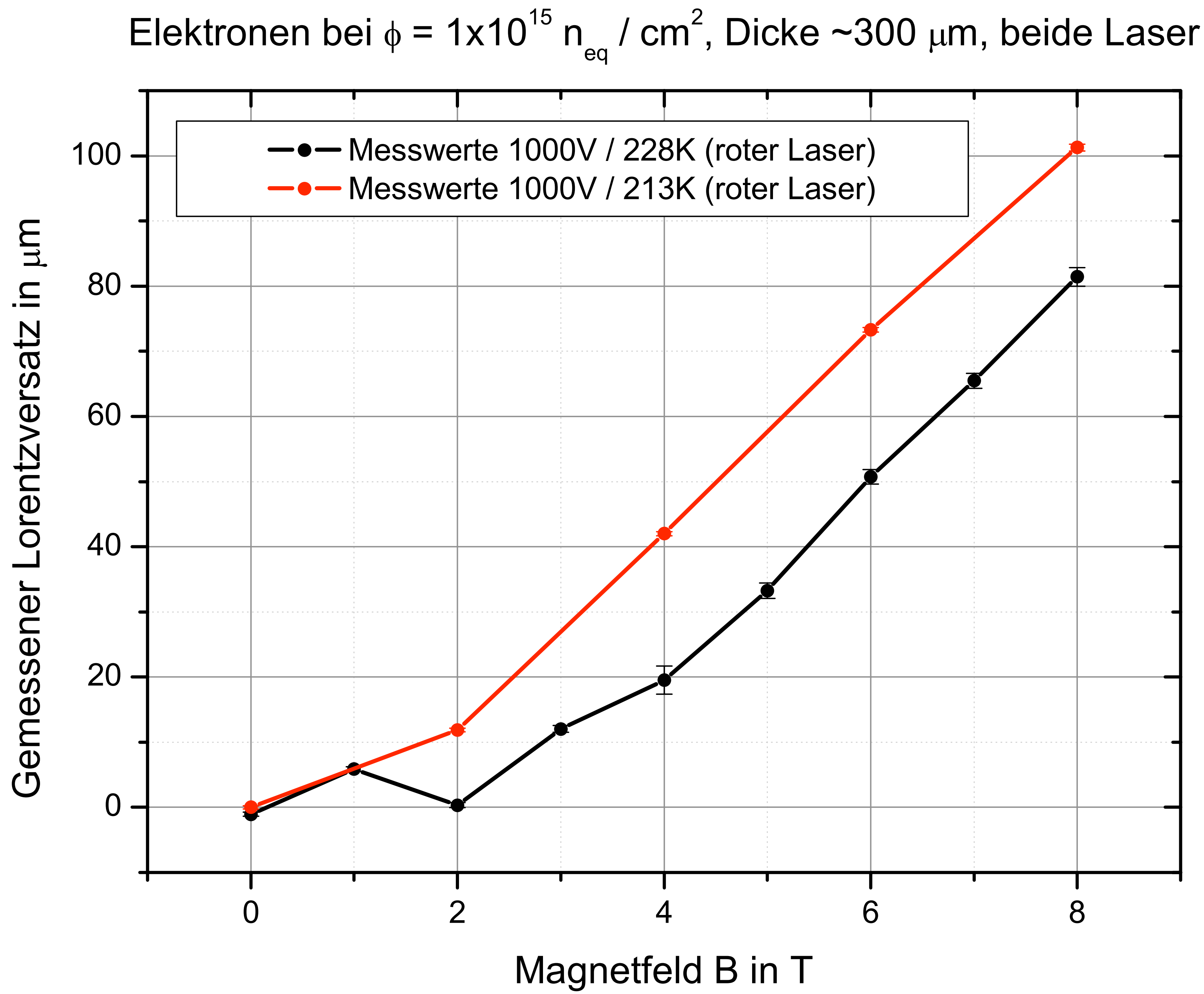
Results - Electrons / FZ

Fluence 0 n_{eq} / cm^2, thickness 300 μm, red laser



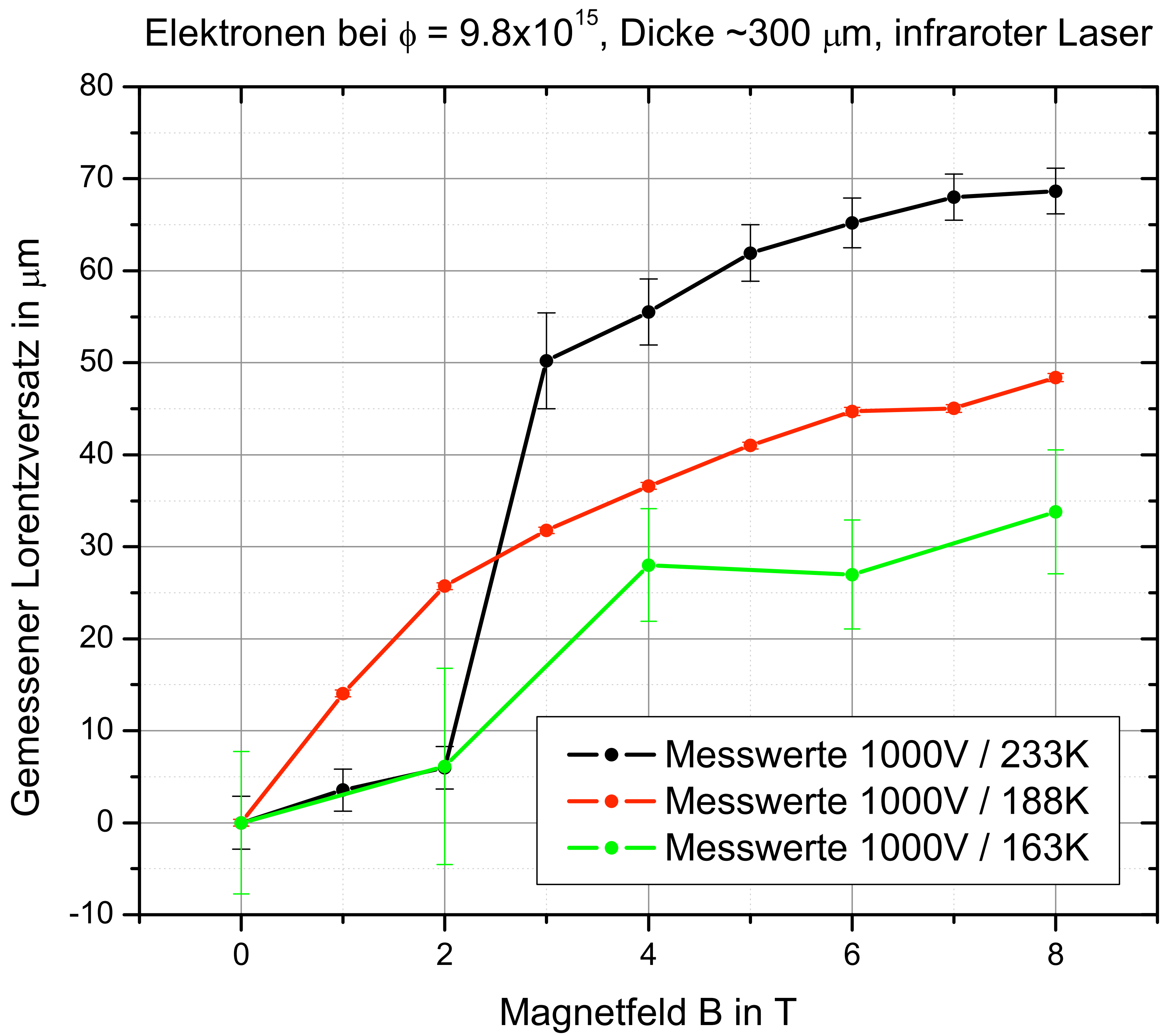
Results - Electrons / FZ

Fluence 1.0 10^{15} n_{eq} / cm^2, thickness 300 µm, red laser



Results - Electrons / FZ

Fluence 9.8 10^{15} n_{eq} / cm^2, thickness 300 µm, IR laser



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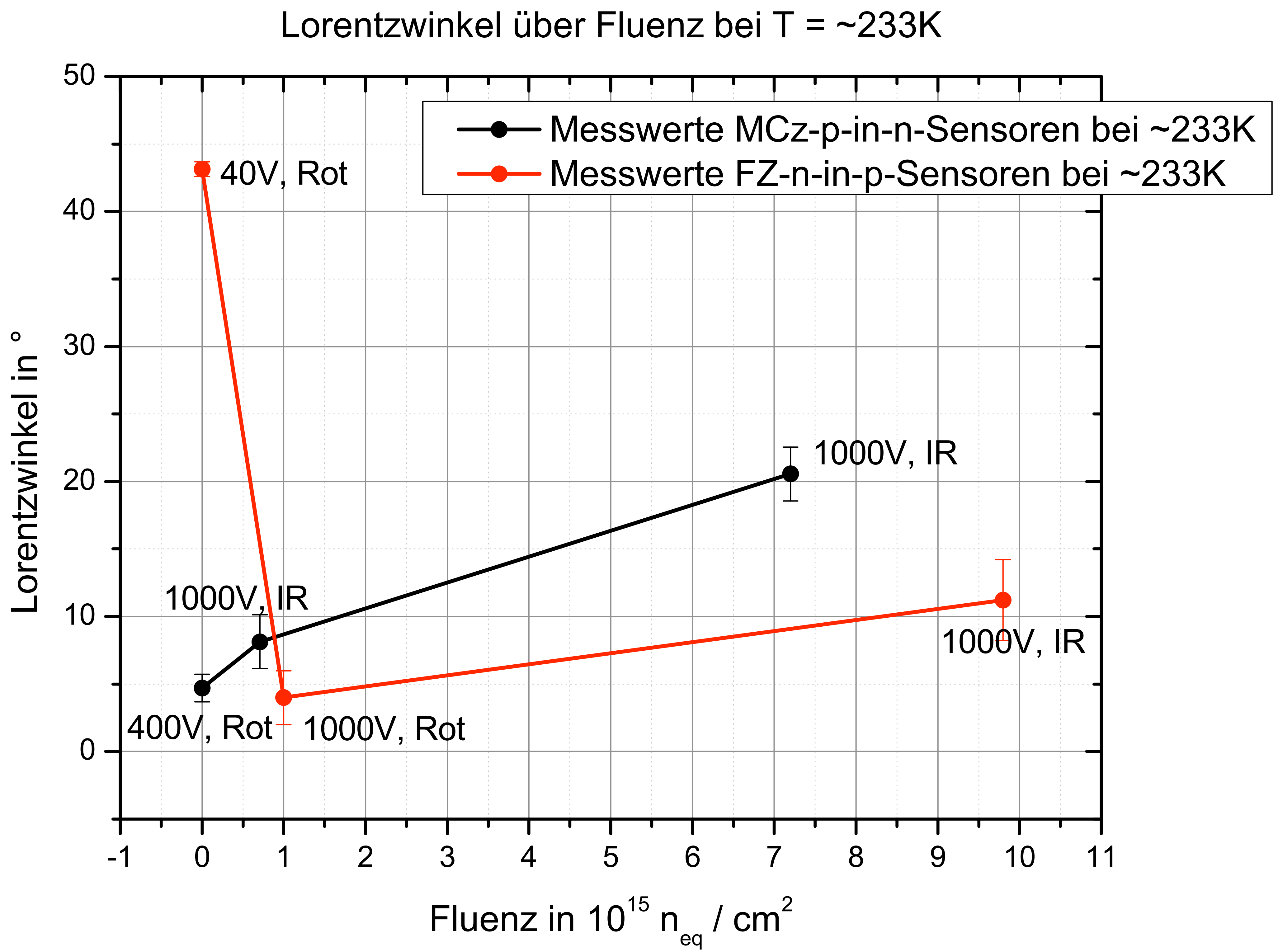
Results - Comparison



Conclusion

- Lorentz angle is strongly dependent on bias voltage and temperature
- Simple modell doesn‘t describe the data very well
- Lorentz angle changes with increasing fluence

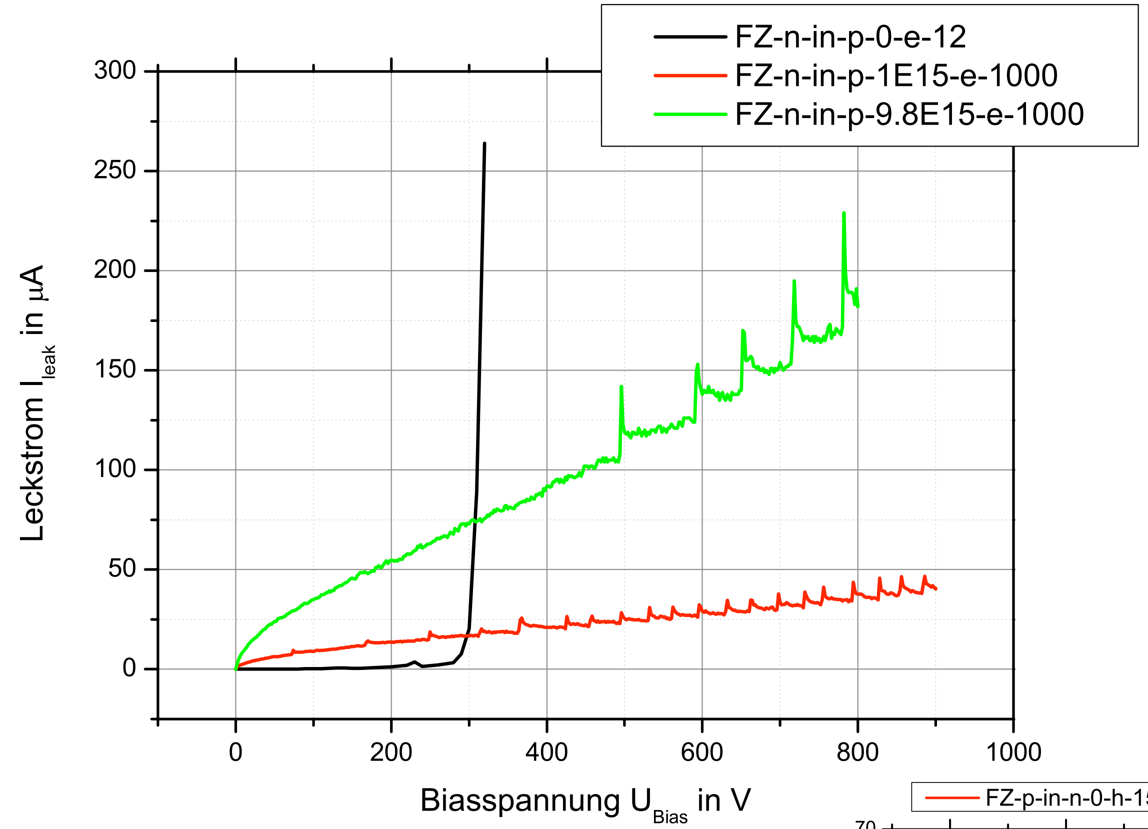
Outlook

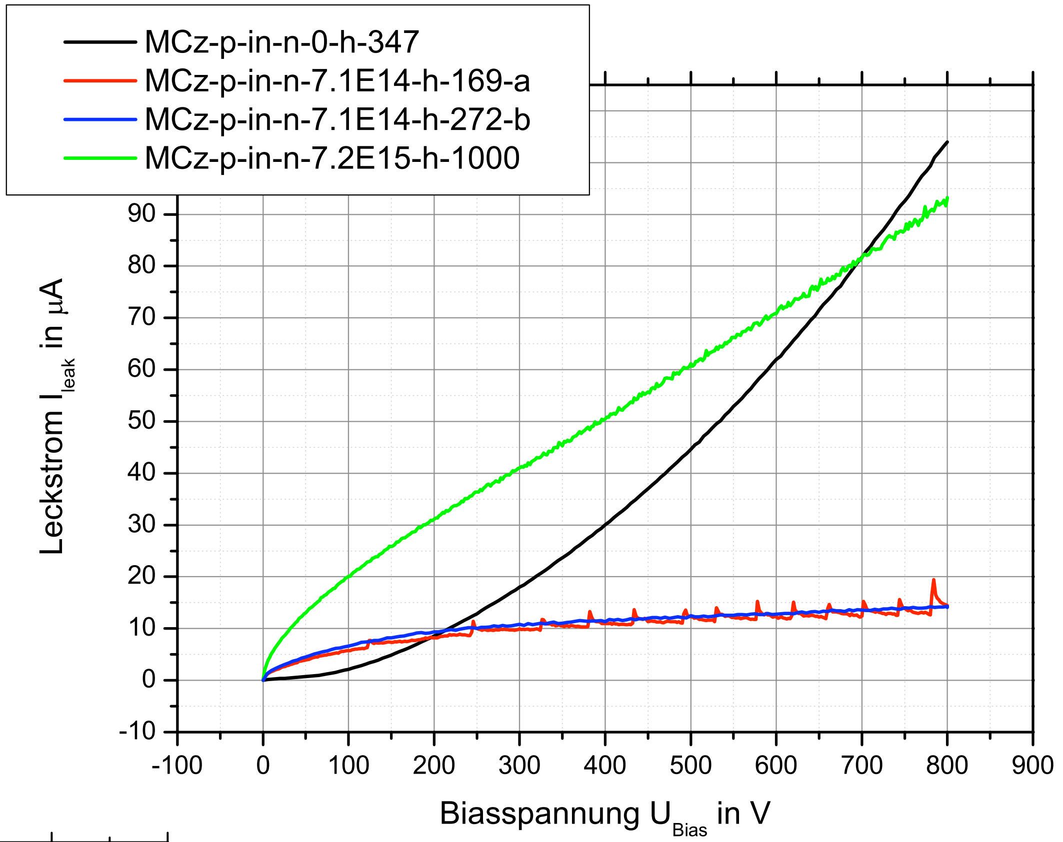
- New fit of the modell parameters (mainly saturation velocity) using our data
- Therefore getting to a better prediction of the lorentz angle
- Increasing lorentz angle with increasing fluence: further study will be needed

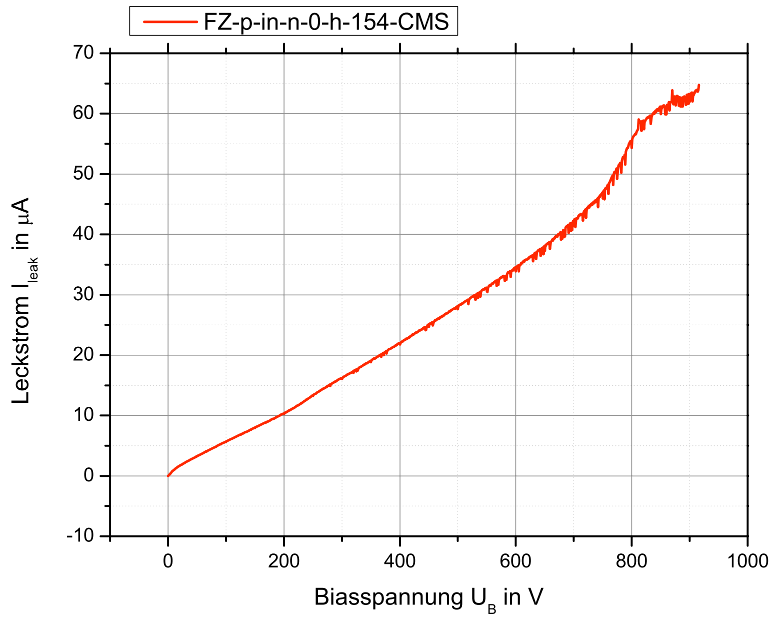
Thank you. Questions?

Backup-slide (1)

IV measurements

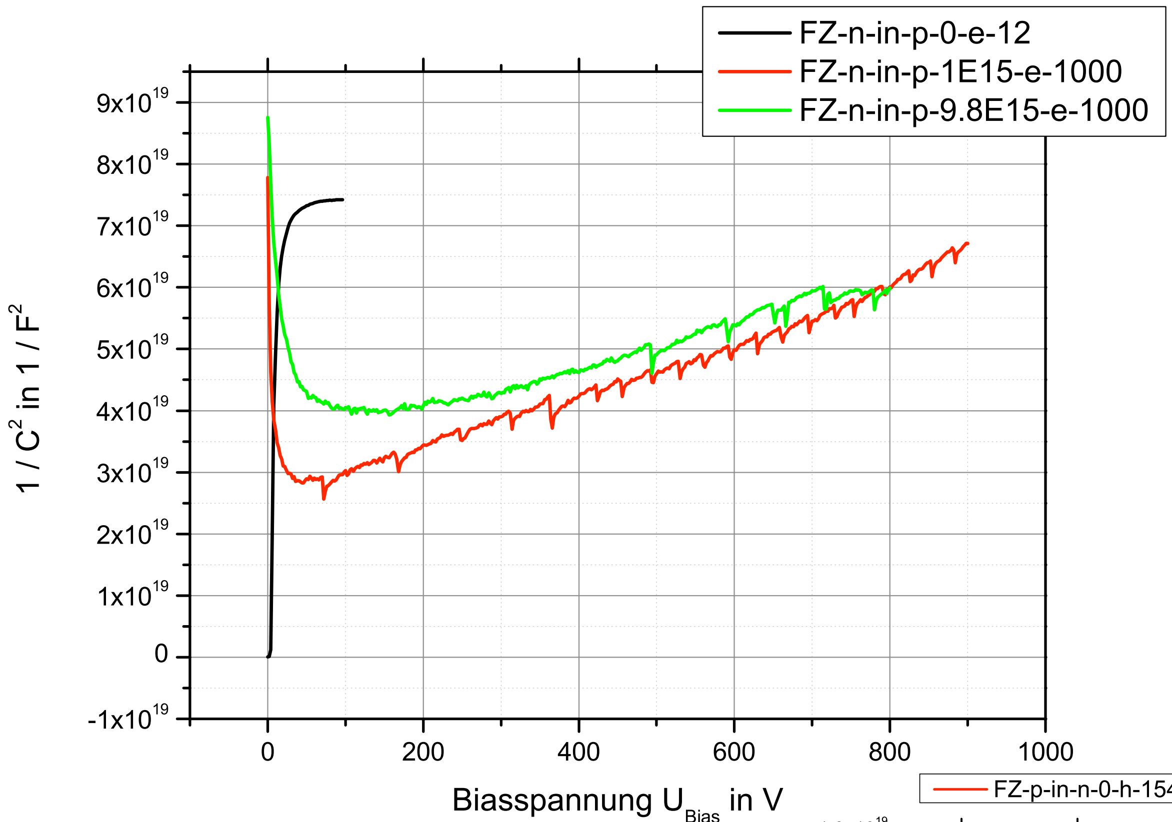


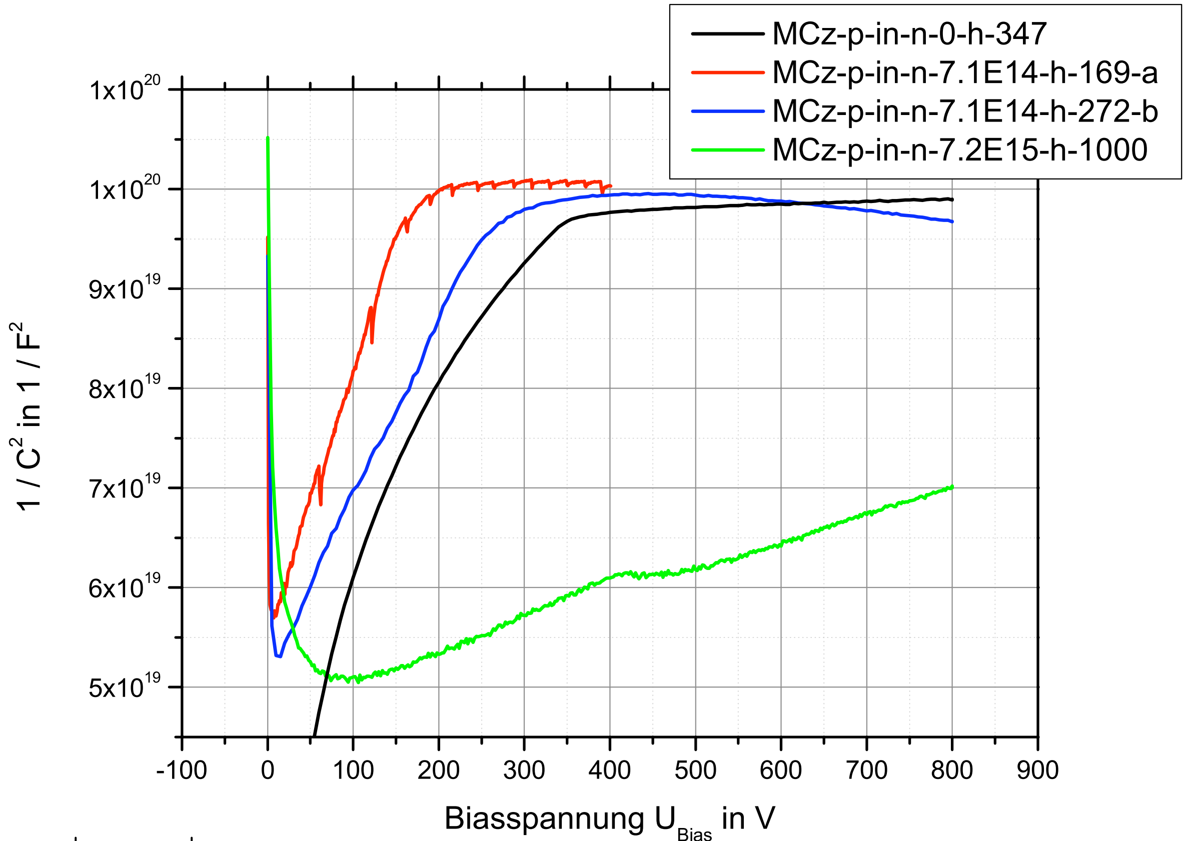


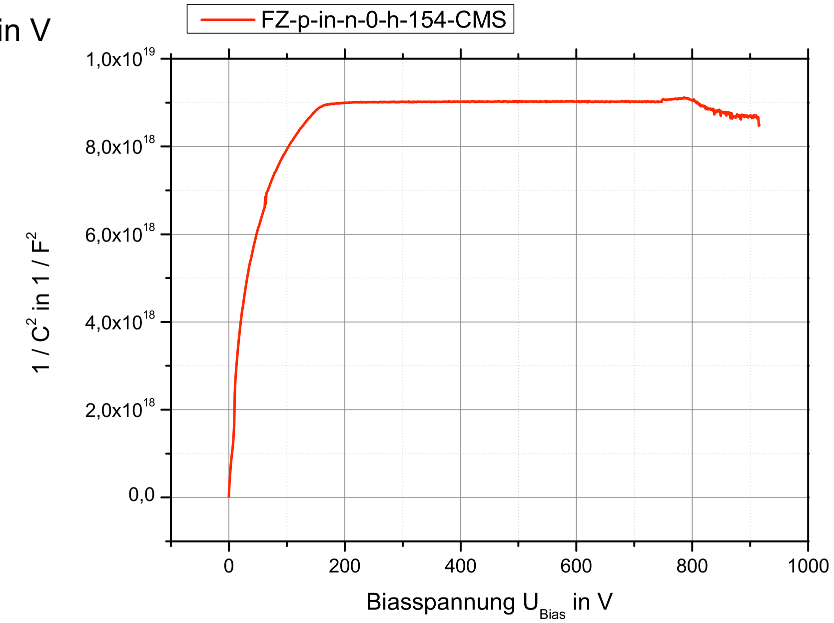


Backup-slide (2)

CV measurements





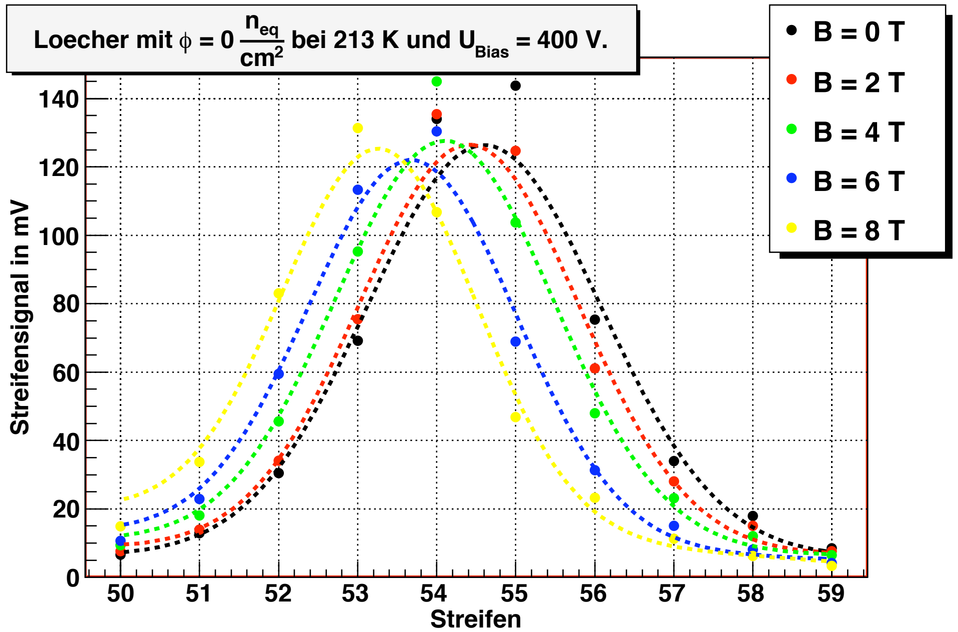


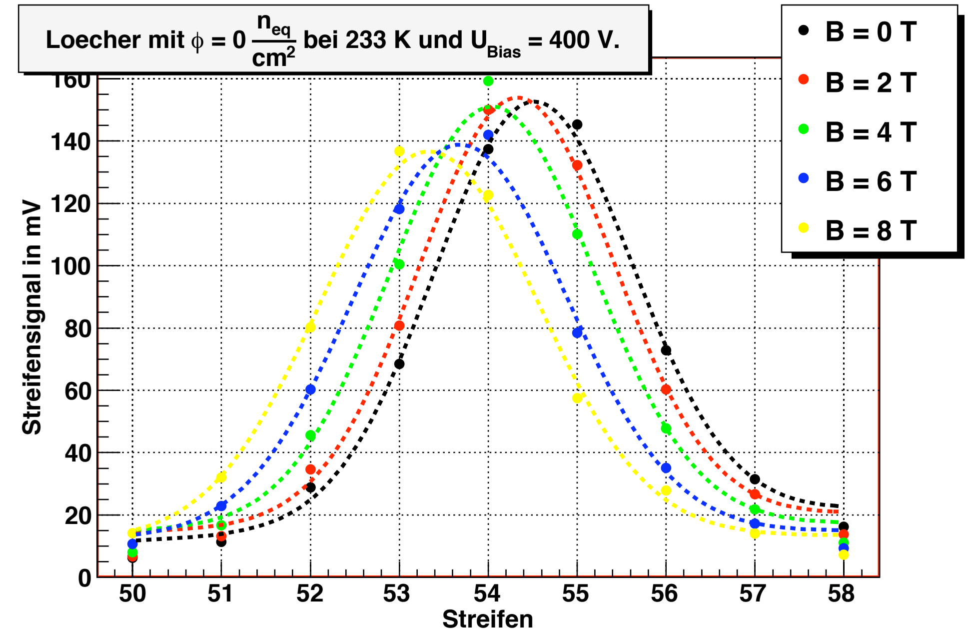
Backup-slide (3)

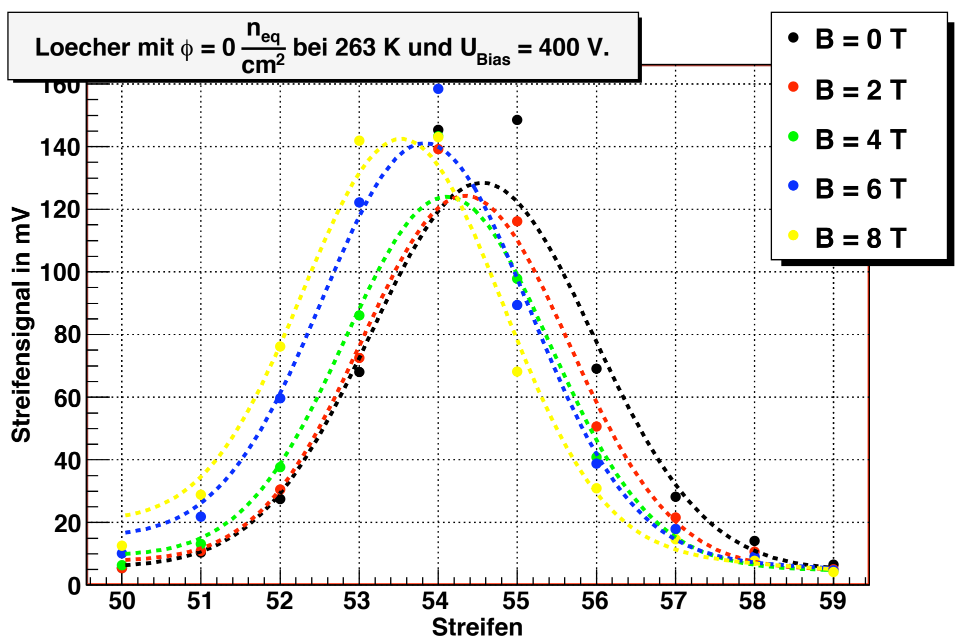
- Pedestal and common-mode-correction
- Gaussfit to measured data
- Also center-of-gravity calculation:
  - Sum of strip times value / sum of strip
- Results were compatible
- So gaussfits were used

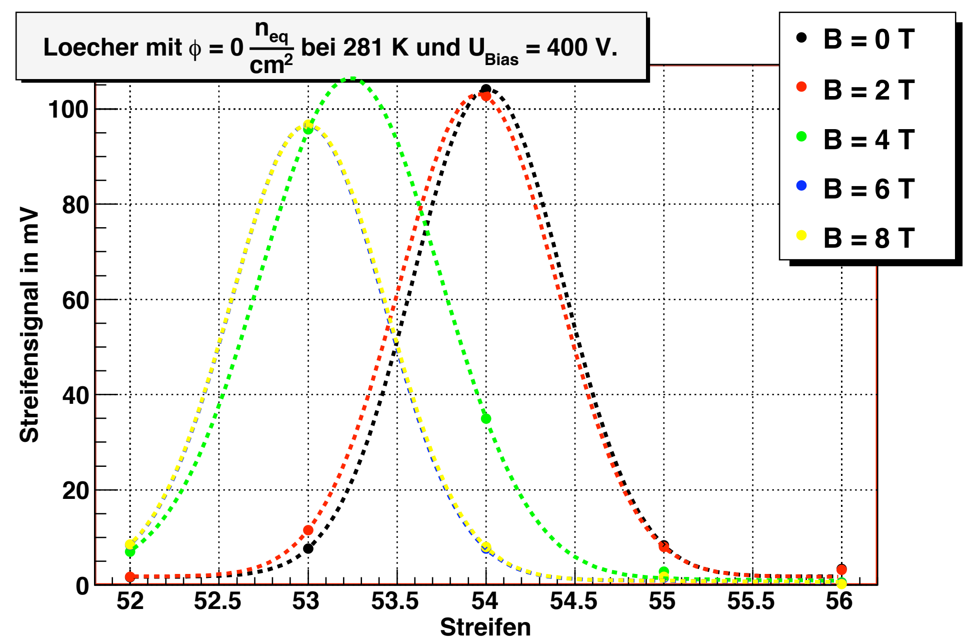
Backup-slide (4)

Some raw data from CMS-sensor



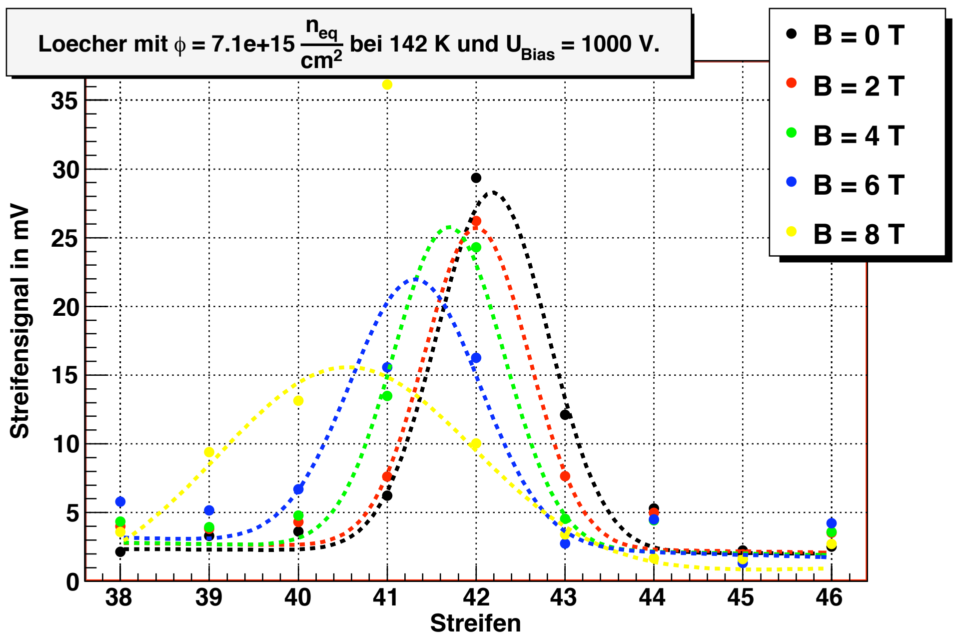


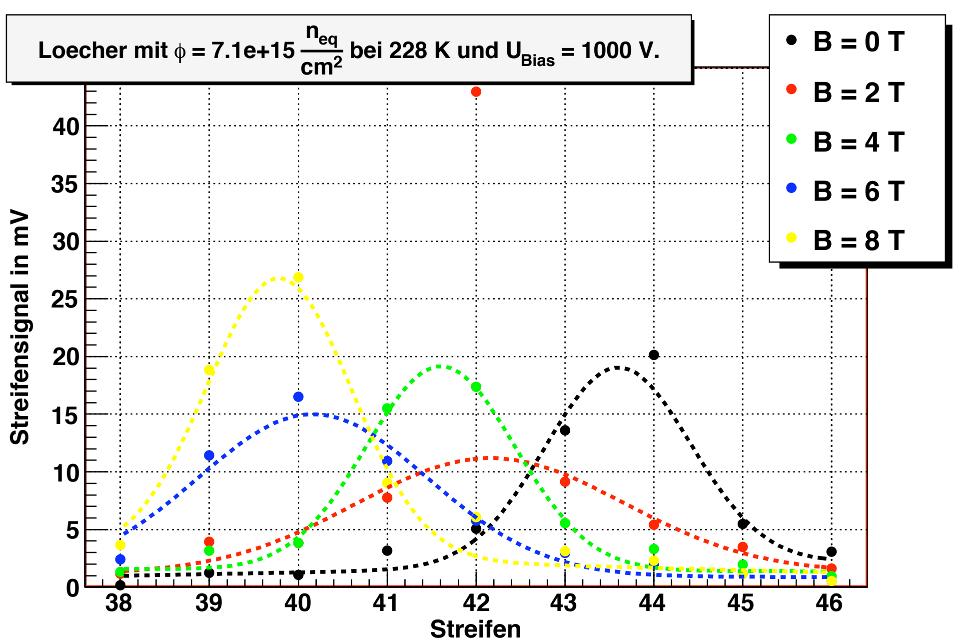




Backup-slide (5)

MCz highly irradiated





FZ highly irradiated