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First measurements on mixed-irradiated mini strip sensors and outlook to Lorentz angle studies as part of the CMS HPK campaign

Andreas Nürnberg
W. de Boer, T. Müller, T. Schneider (ITEP), 18th RD50 Workshop, Liverpool, 24 May 2011

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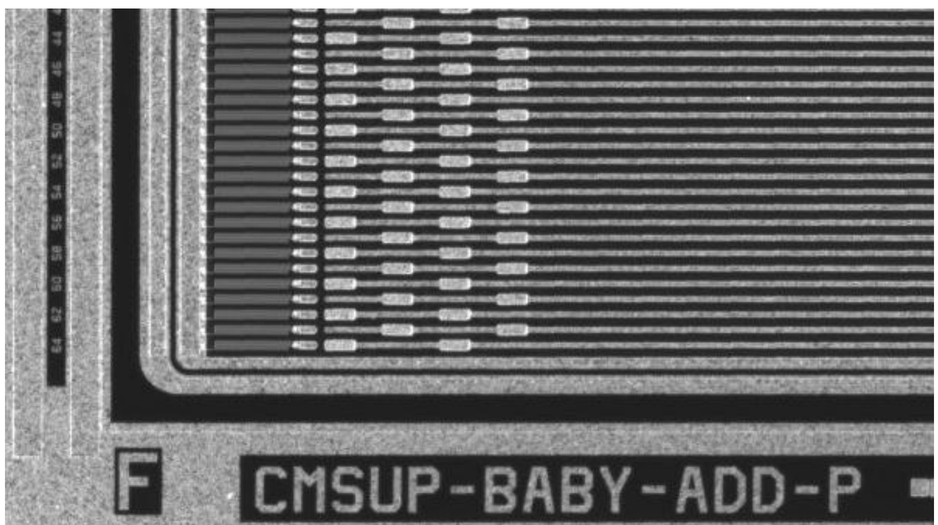
CMS Germany
BMBF FSP-CMS



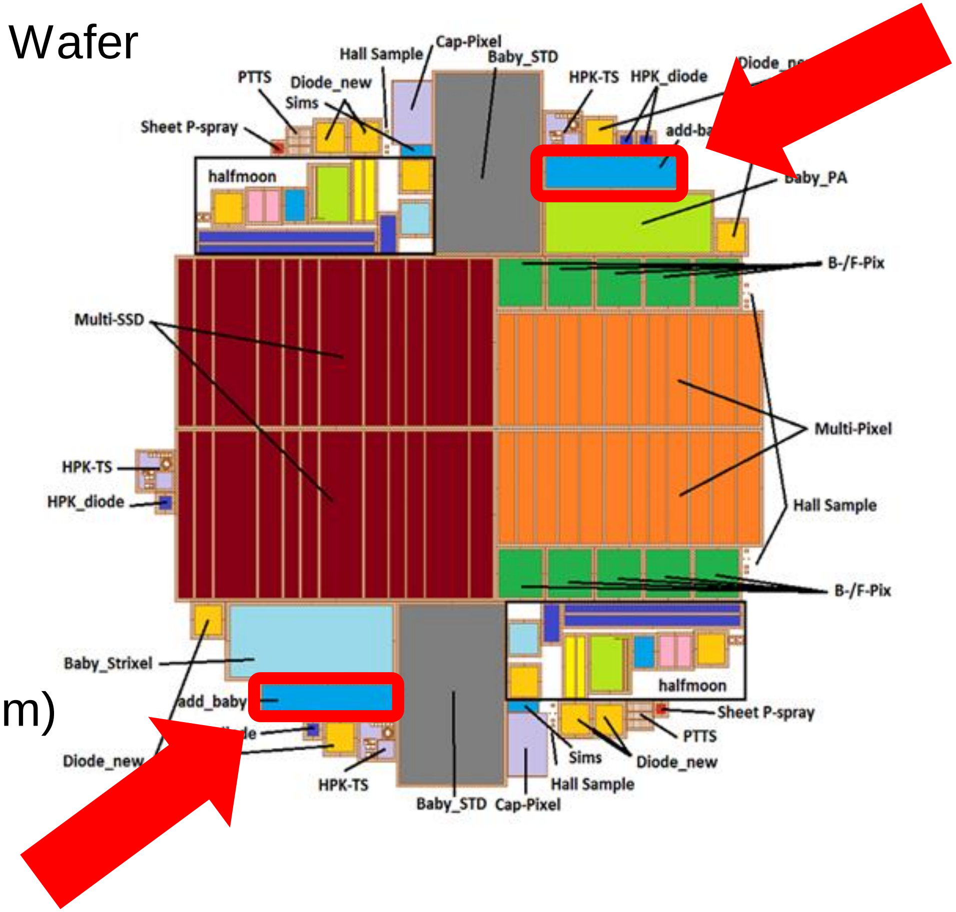
PHYSICS AT THE TERA SCALE
Helmholtz-Alliance

Outline

- CMS Hamamatsu campaign & Lorentz angle studies
- Irradiation plan
- Development of full depletion voltage & leakage current
- First Lorentz angle measurement
- Simulation
- Summary & Outlook

CMS Hamamatsu campaign

- Campaign to identify sensor baseline for next CMS tracker (→ A. Dierlamm)
- Dedicated sensor for Lorentz angle measurements
- Standard strip sensor, 2 pieces per Wafer
  - 64 strips
  - 80 µm pitch
- 6 Wafers per type and thickness
  - n-type
  - p-type with p-stops
  - p-type with p-spray
- Floatzone (120 µm, 200 µm, 320 µm)
- Magnetic Czochralski (200 µm)
- Epi (50 µm, 100 µm)



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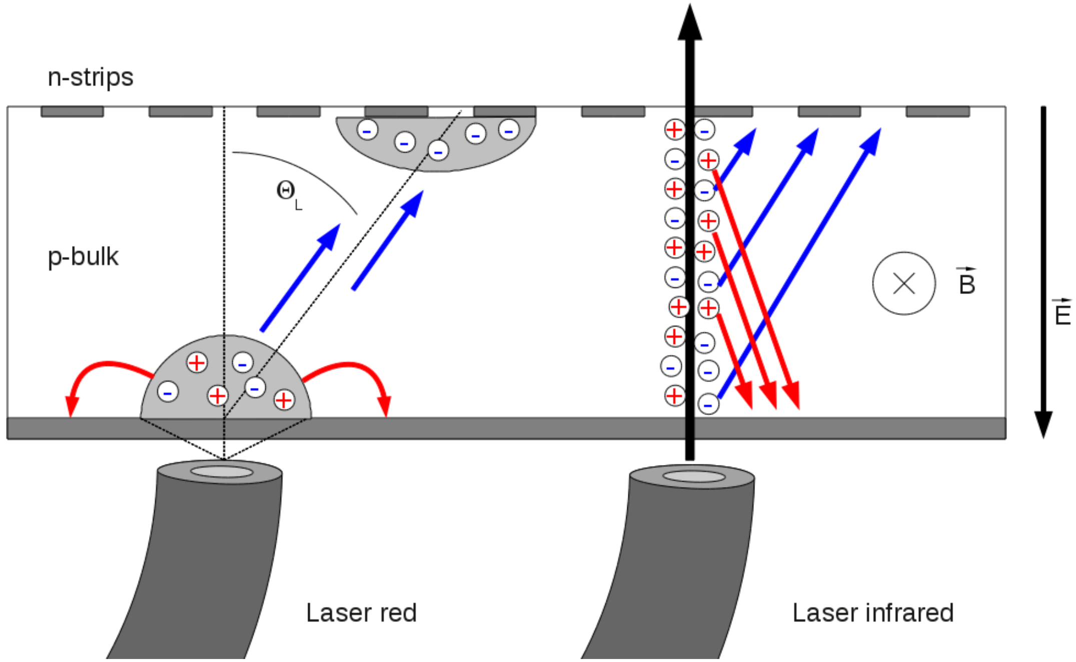
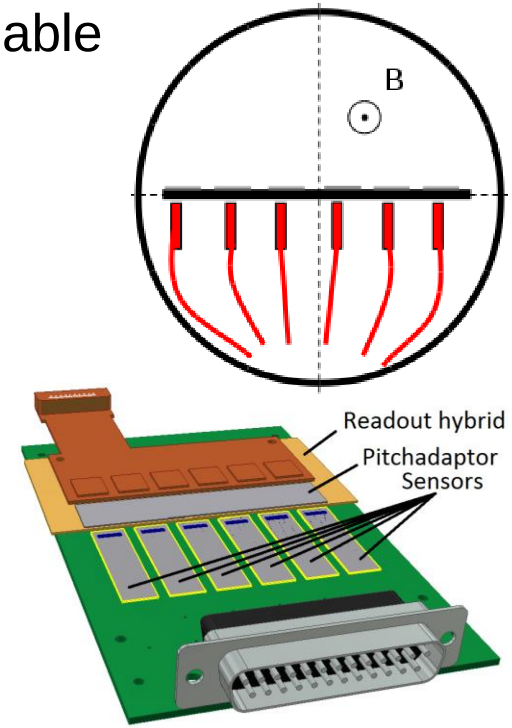
Lorentz angle measurement

- Superconducting 8T magnet at Institute for Technical Physics at KIT
- 6 Sensors, Pitchadaptor and CMS readout hybrid mounted to PCB
- Setup attached to1,5m long GFK lance fitting magnet bore (Ø 73mm)
- 12 optical fibers: can measure up to 6 sensors simultaneously
- Pico-Laser: 680 nm, 880 nm and 1055 nm available





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Irradiation plan

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- 5 sensors per type irradiated (44 in total)
  - up to now only Floatzone sensors

- First irradiation: Neutrons at Ljubljana
- Second irradiation: Protons at Karlsruhe

Position	1	2	3	4	5	6
Neutron	0	4	5	6	8	8 (12)*
Proton	0	2,5	10	15	30	50 (130)*
Sum	0	6,5	15	21	38	58 (142)*

* only FZ120, not yet completed
All Fluences: x 1e14 neq/cm^2

- Measurements performed:
  - IV / CV before irradiation at +20°C
  - IV / CV after each irradiation step at -20°C (Annealing: 10min@60°C)

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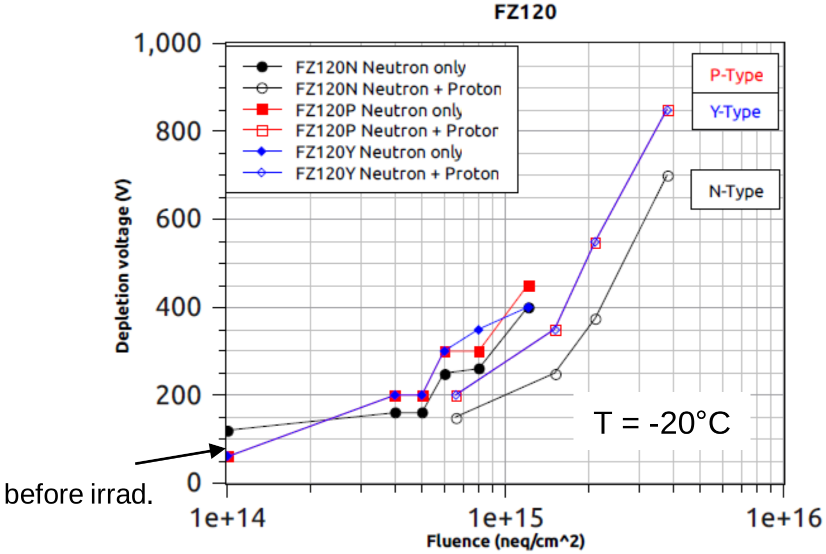
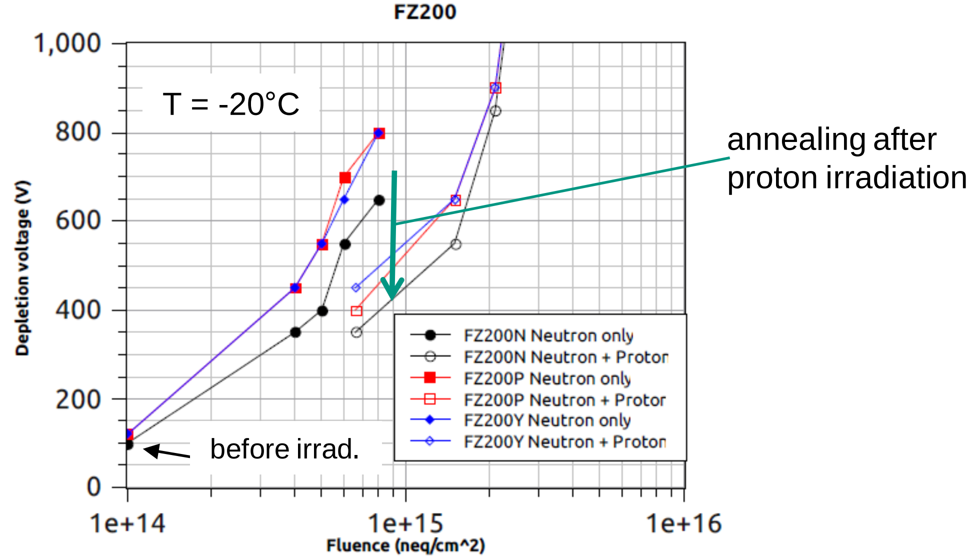
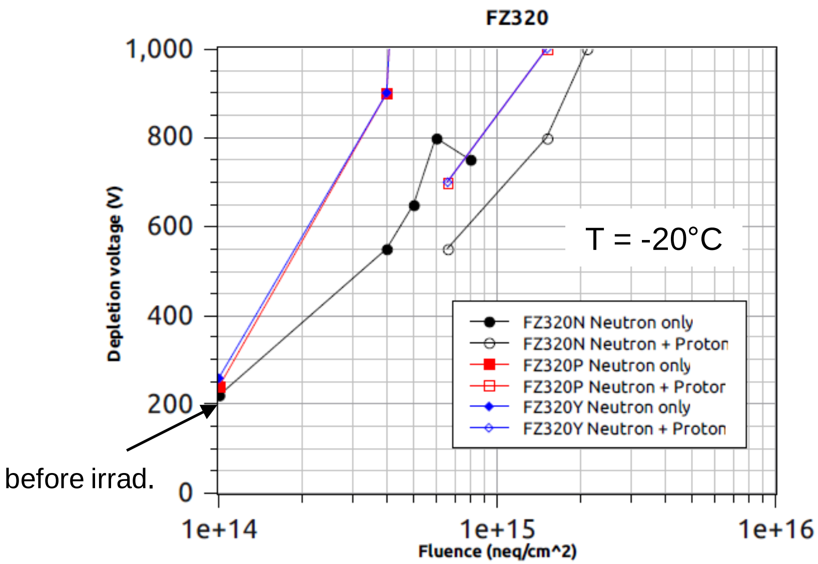
Full depletion voltage (by thickness)



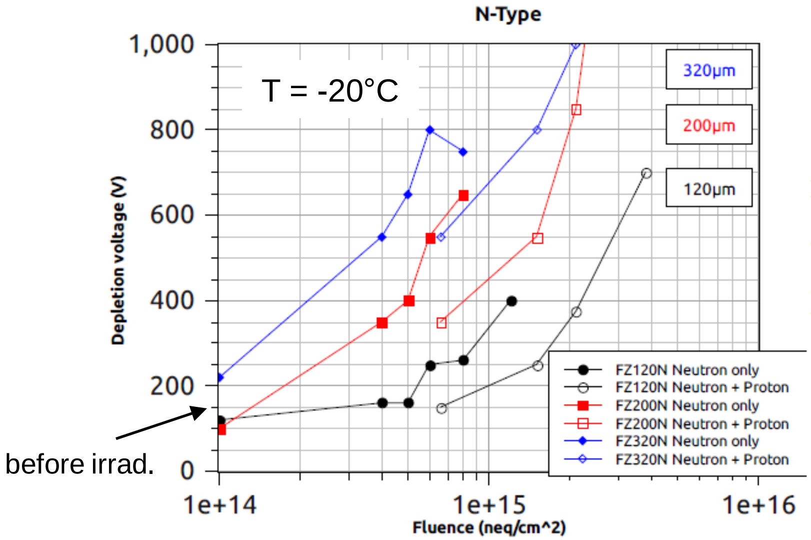


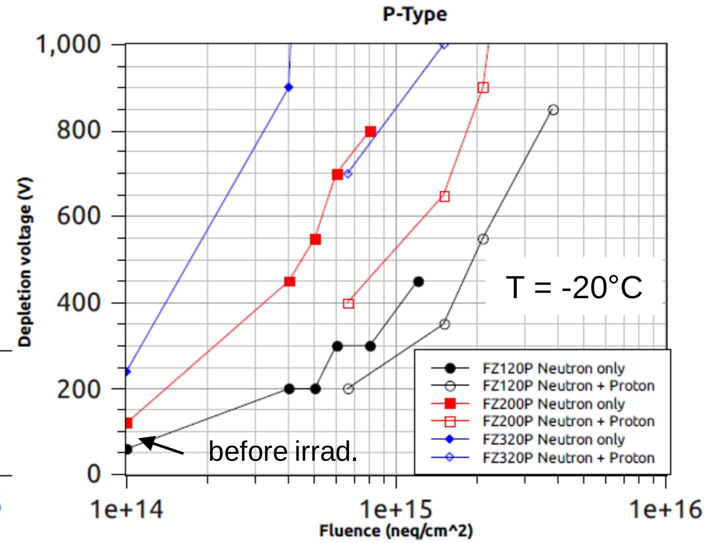


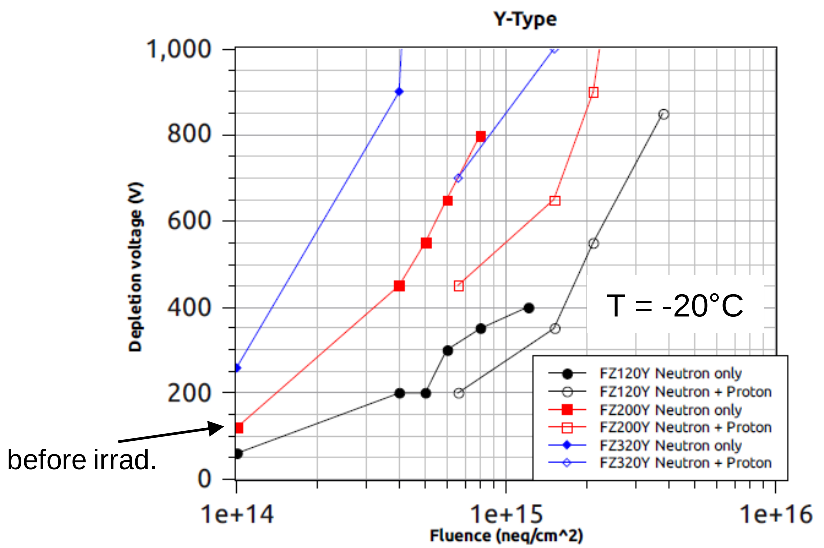
- Measurements done with and without guard ring connected to ground
- All shown measurements were taken with guard ring contacted

- Strong increase of depletion voltage with fluence
  - n-type: lower depletion voltage than p-types
  - no evident difference between p-stop and p-spray

Full depletion voltage (by type)







- Strong increase of depletion voltage with fluence
  - n-type: lower depletion voltage than p-types
  - no evident difference between p-stop and p-spray
  - Thin devices: lower depletion voltage

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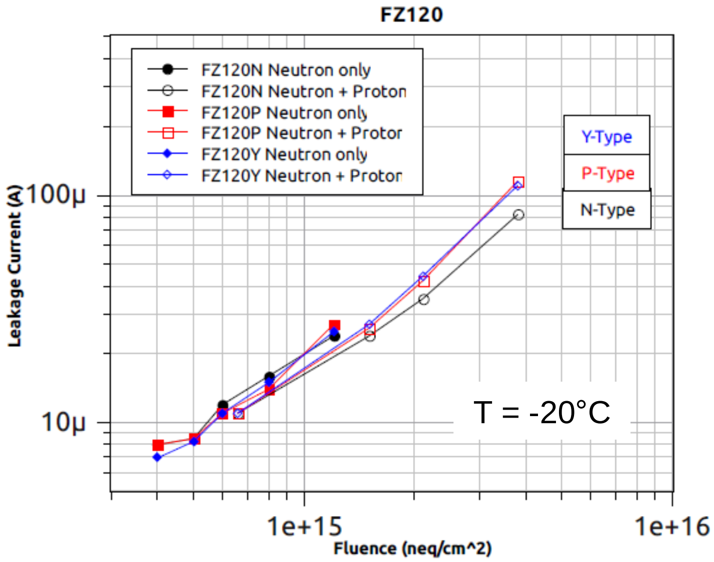
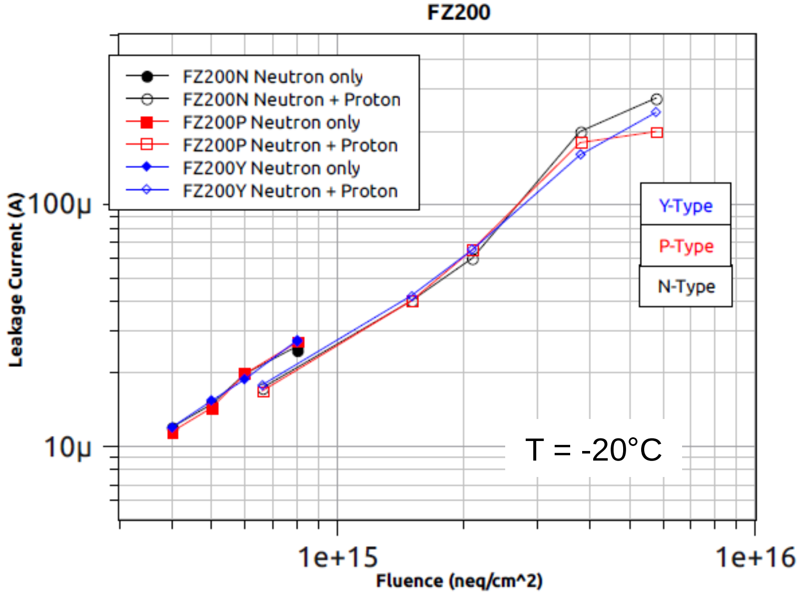
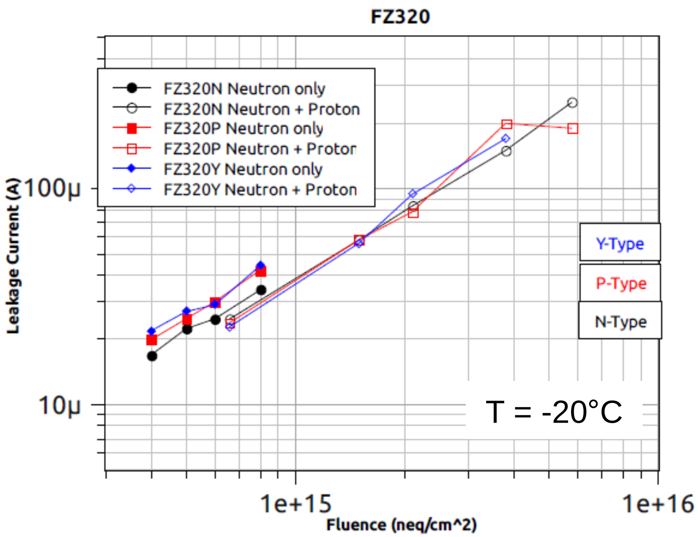
Leakage Current (by thickness)

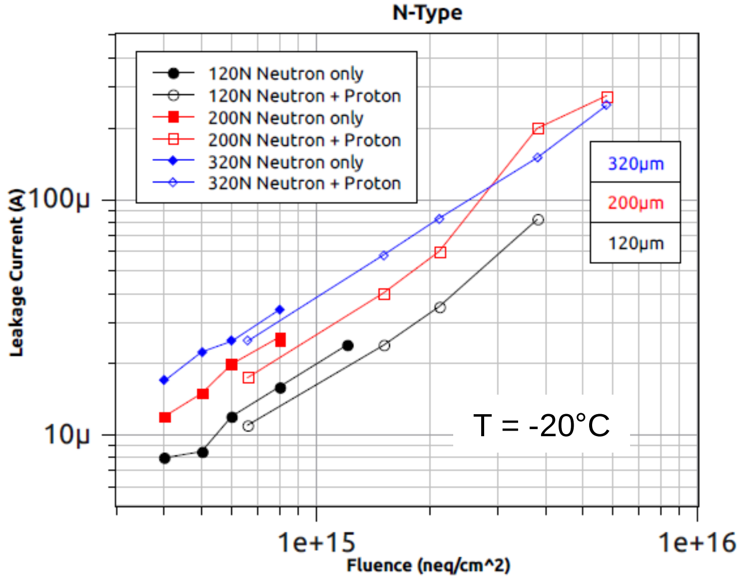


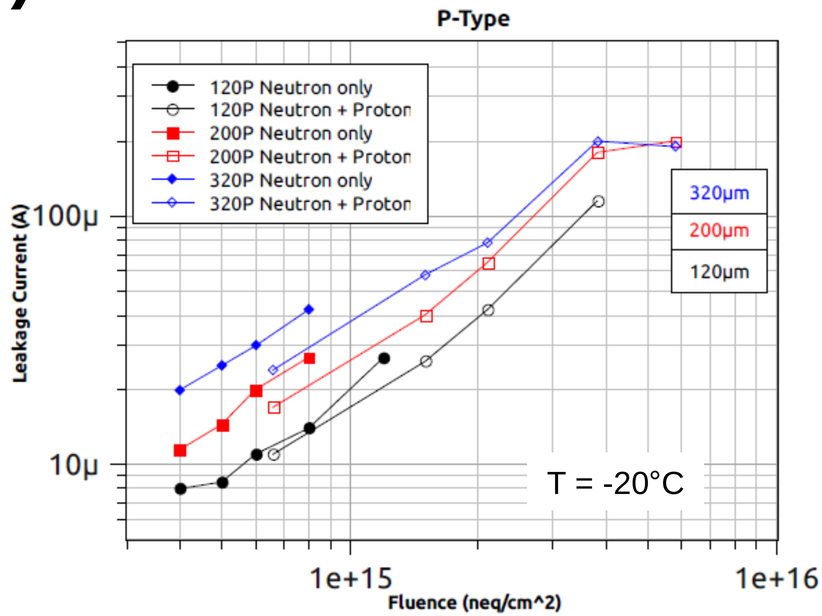


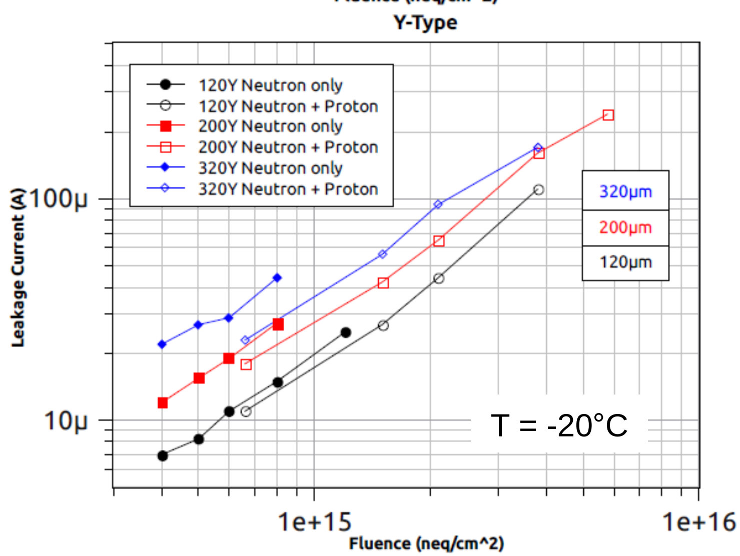


- Linear increase of leakage current with fluence
- No difference in leakage current between n-type and p-type of a certain thickness
- Gap between Neutron and Proton irradiated samples: annealing after second irradiation reduces current and depletion voltage further

Leakage Current (by type)







- Linear increase of leakage current with fluence
- Thick devices: higher current than thin ones
  - Before irradiation, thin devices show higher current due to deep defused backside (→ A. Junkes)

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Leakage Current (normalized to volume)

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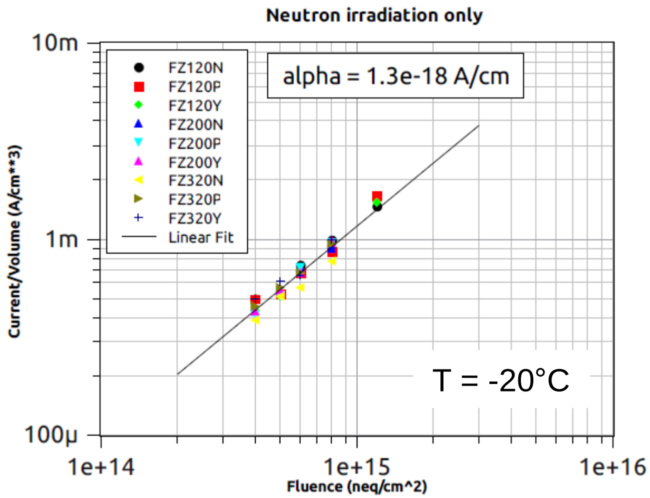
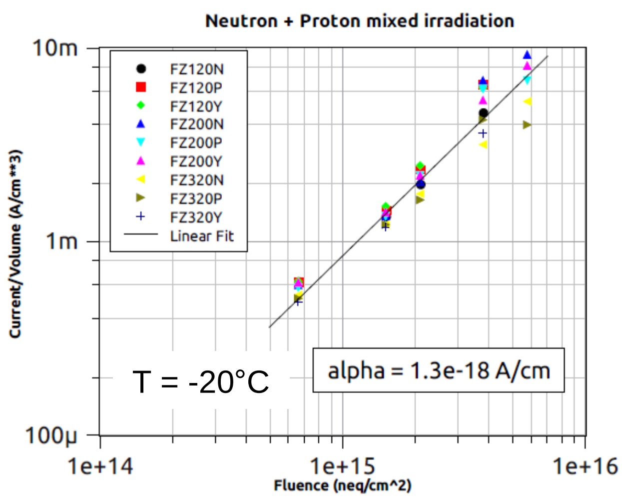
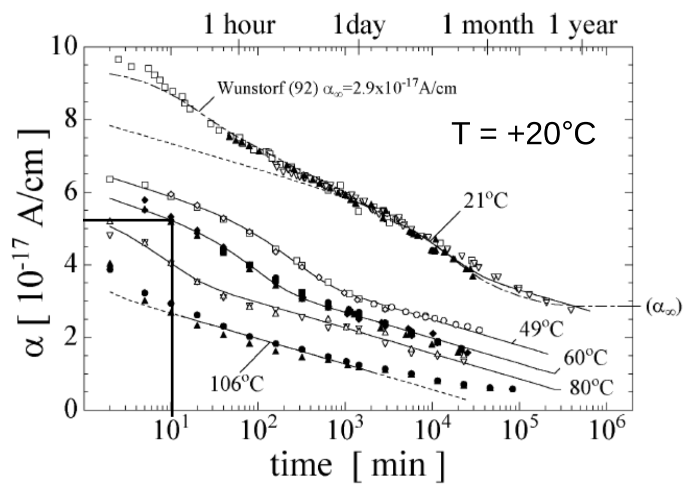




- Current per volume increases linearly with fluence
- Valid for all thicknesses and types
- Valid for neutron only and mixed irradiation

$$I_{leak} = \alpha \cdot \Phi_{eq} \cdot V$$

- With alpha (from fit) = 1.3e-18 A/cm
- Expected value: alpha = 0.95e-18 A/cm

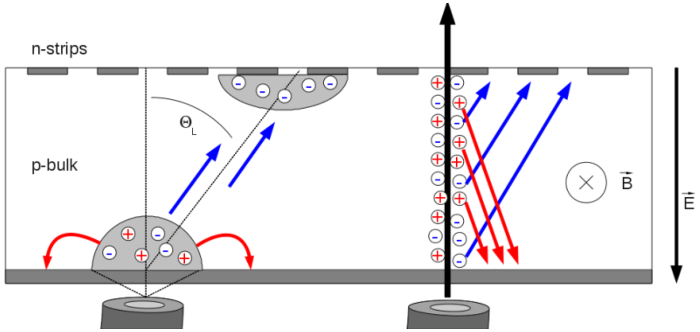


Radiation Damage in Silicon Particle Detectors, Michael Moll, PhD Thesis, 1999

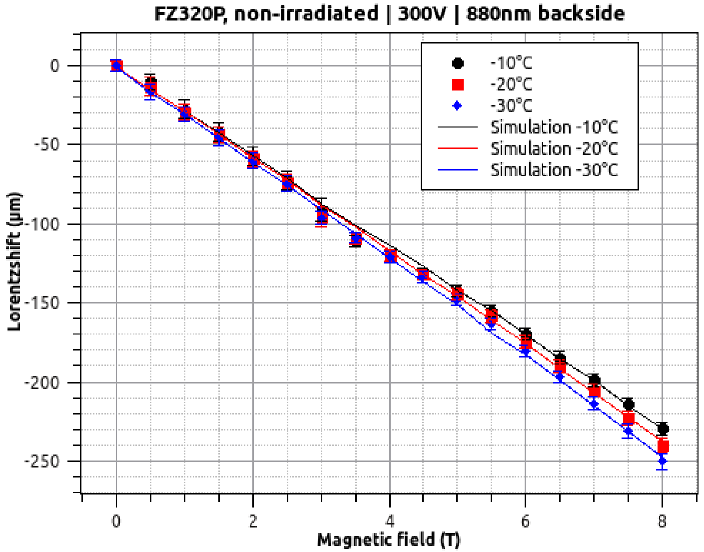
Andreas Nürnberg
Institut für Experimentelle Kernphysik, KIT

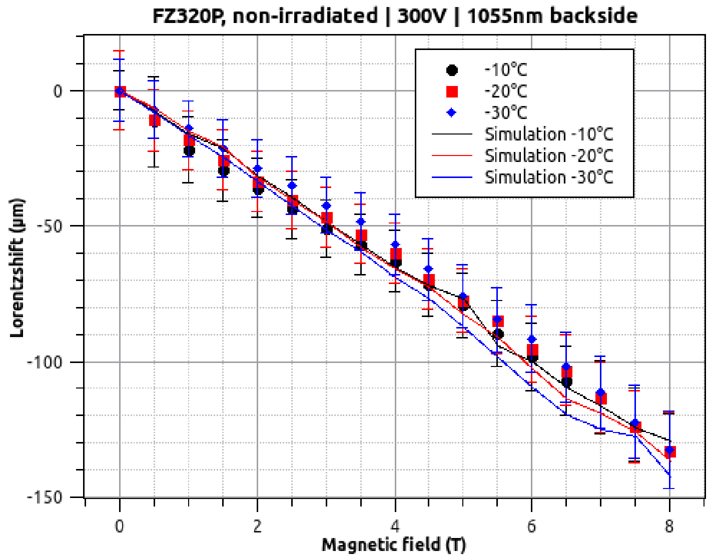
First Lorentz angle measurement

- Lorentz angle measurement on a single non-irradiated FZ320P sensor (n-on-p, p-stop) performed
  - Magnetic field scan @ fixed voltage (300V)
  - Voltage scan @ fixed magnetic field (4T) (not shown here)



- Lorentz shift increases linearly with magnetic field
- Shift is reproduced by simulation
- Temperature dependence modelled correctly





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Simulation: Charge carrier drift

- Synopsis T-CAD cannot handle magnetic fields
  - Not the proper tool to do lorentz angle studies → own simulation neccesary
  - Started to look at Silvaco Atlas, not further considered here

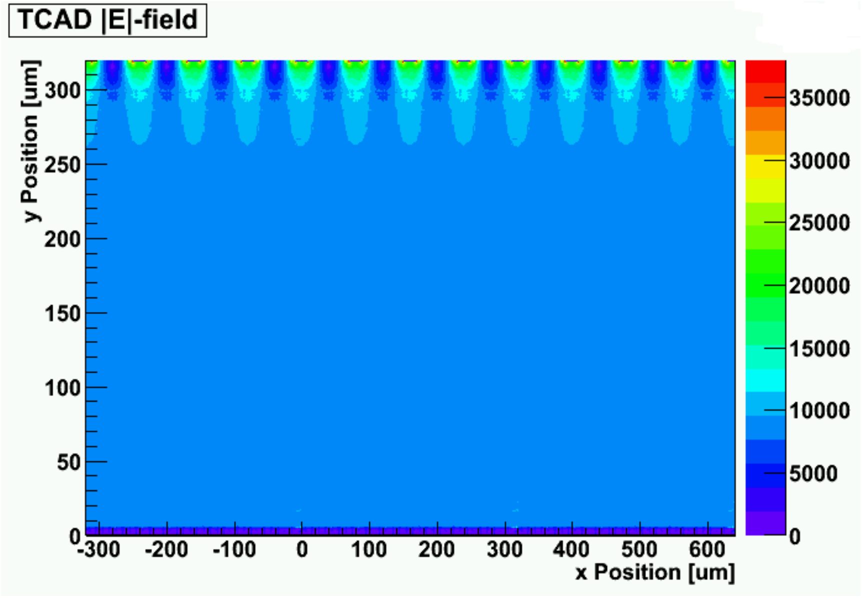
- Calculating the electric field inside the sensor using Synopsis T-CAD
- Estimate deposited charge depending on laser wavelength and temperature
- Track charge carriers though the sensor volume considering electric and magnetic field
  - Interpolation of electric field between T-CAD mesh needed
  - Parametrisation of mobility needed
  - Consider diffusion
  - Consider impact ionization

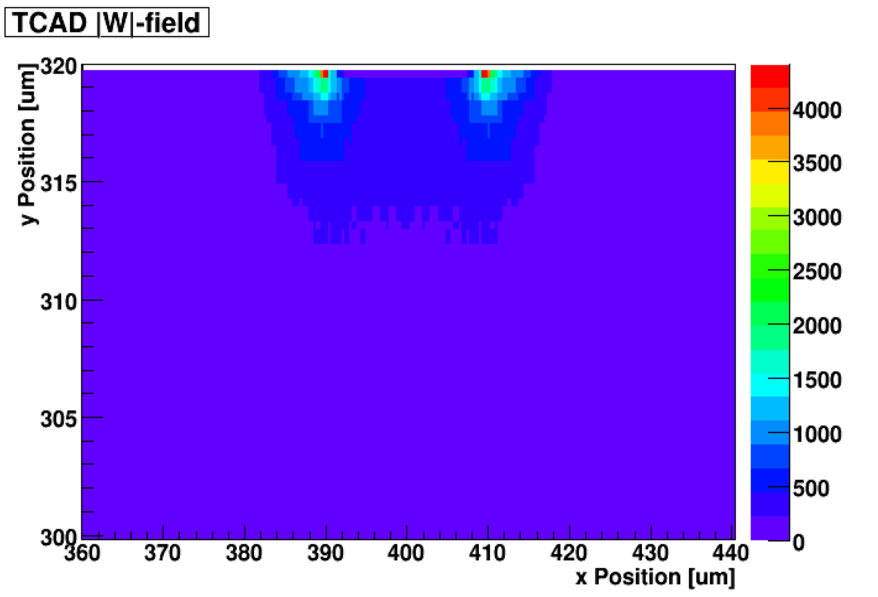
Simulation: Charge carrier drift

- Moving charge induces signal to the readout strips
- Induced current to strip number i is calculated using ramo theorem

$$I_i = q\vec{v} \cdot \vec{W}_i(\vec{x})$$

- Integration of current over time → total induced charge as seen by the readout chip





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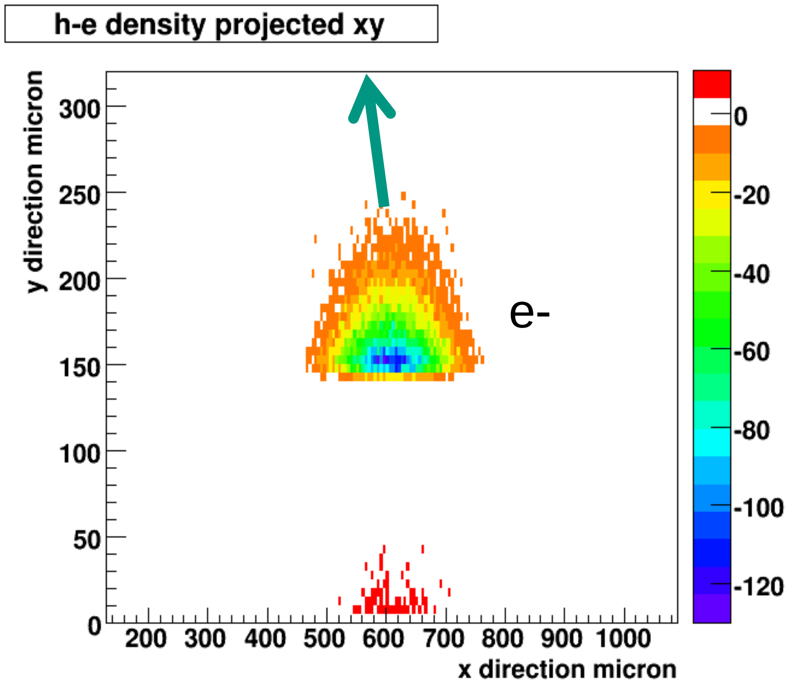
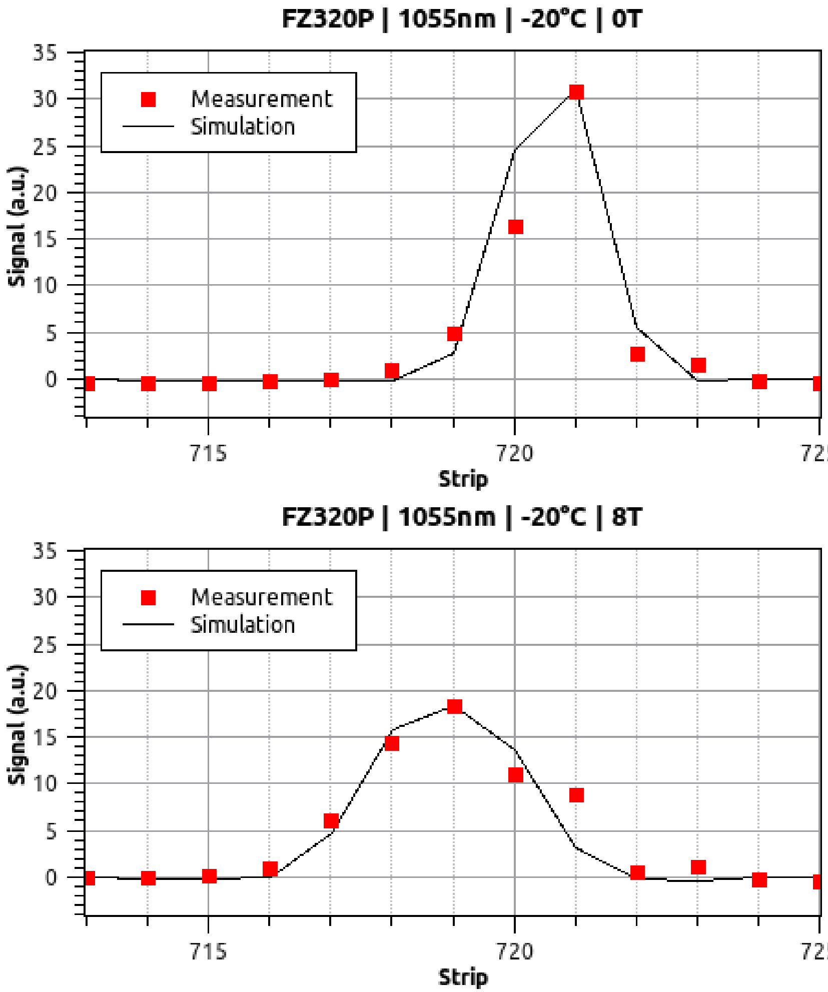
Simulation: Charge carrier drift

- „Screenshot“ of drifting charge cloud (880nm laser)





- Cluster shape is reproduced by simulation (1055nm laser)

Summary & Outlook

- 44 FZ sensors irradiated with neutrons and protons up to fluences of 1.4e16 neq/cm^2
- IV / CV measurement before and after each irradiation step

- Full depletion voltage
  - thick devices: higher depletion voltage than thin ones
  - p-types: higher depletion voltage than n-type
  - no difference on p-stop or p-spray

- Leakage current
  - thick devices: higher current than thin ones
  - linear increase of radiation induced current with fluence
  - alpha = 1.3e-18 A/cm @ -20°C (expected 0.95e-18 A/cm)

- Lorentz angle
  - First measurement on non-irradiated sensor shows expected Lorentz shift for electrons
  - Good agreement with simulation
  - Measurement of irradiated sensors in the course of this year

Backup

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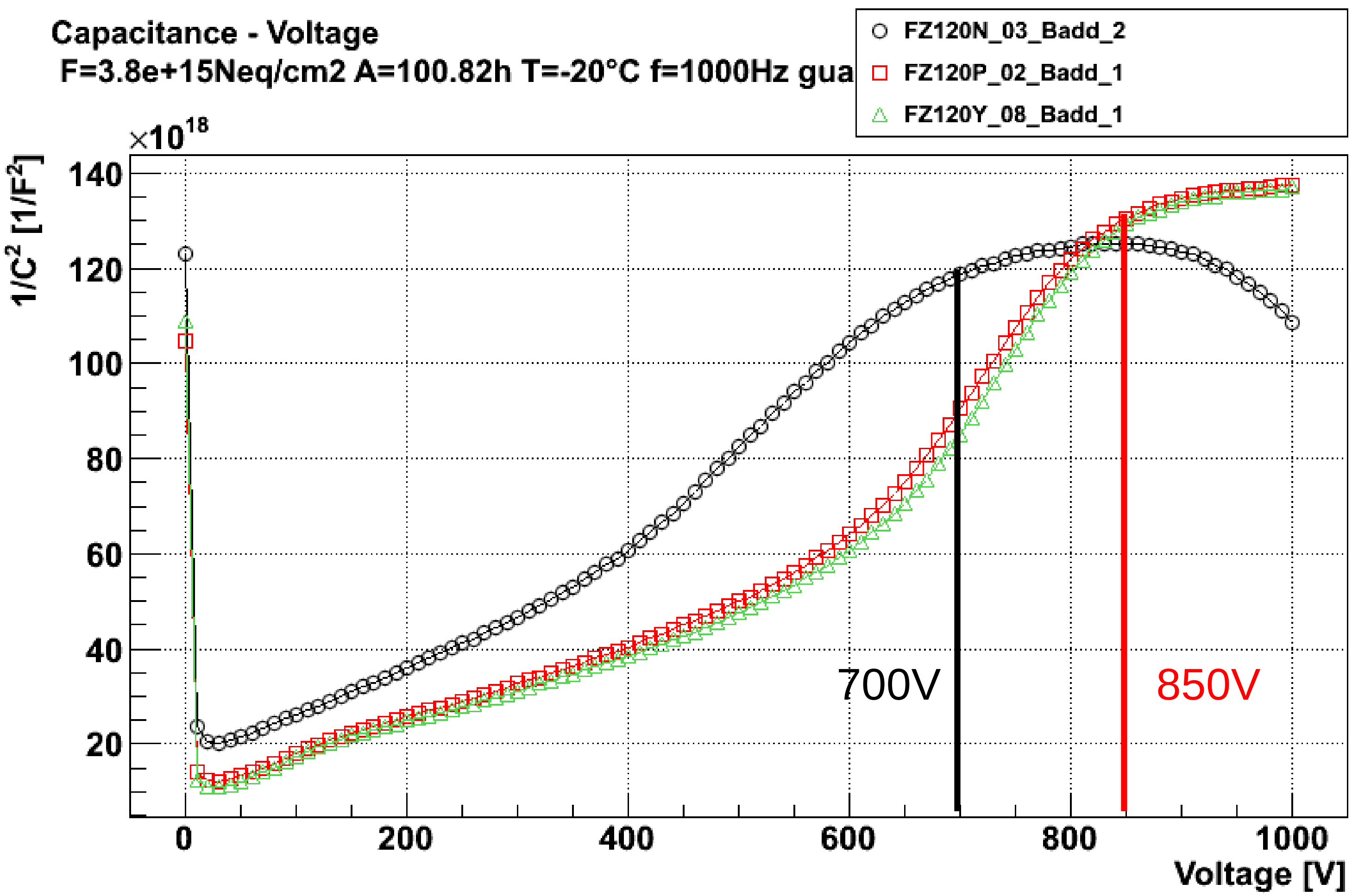
Example CV - FZ120 - 3.8e15 Neq/cm^2

- Depletion voltage determined from CV „by eye“



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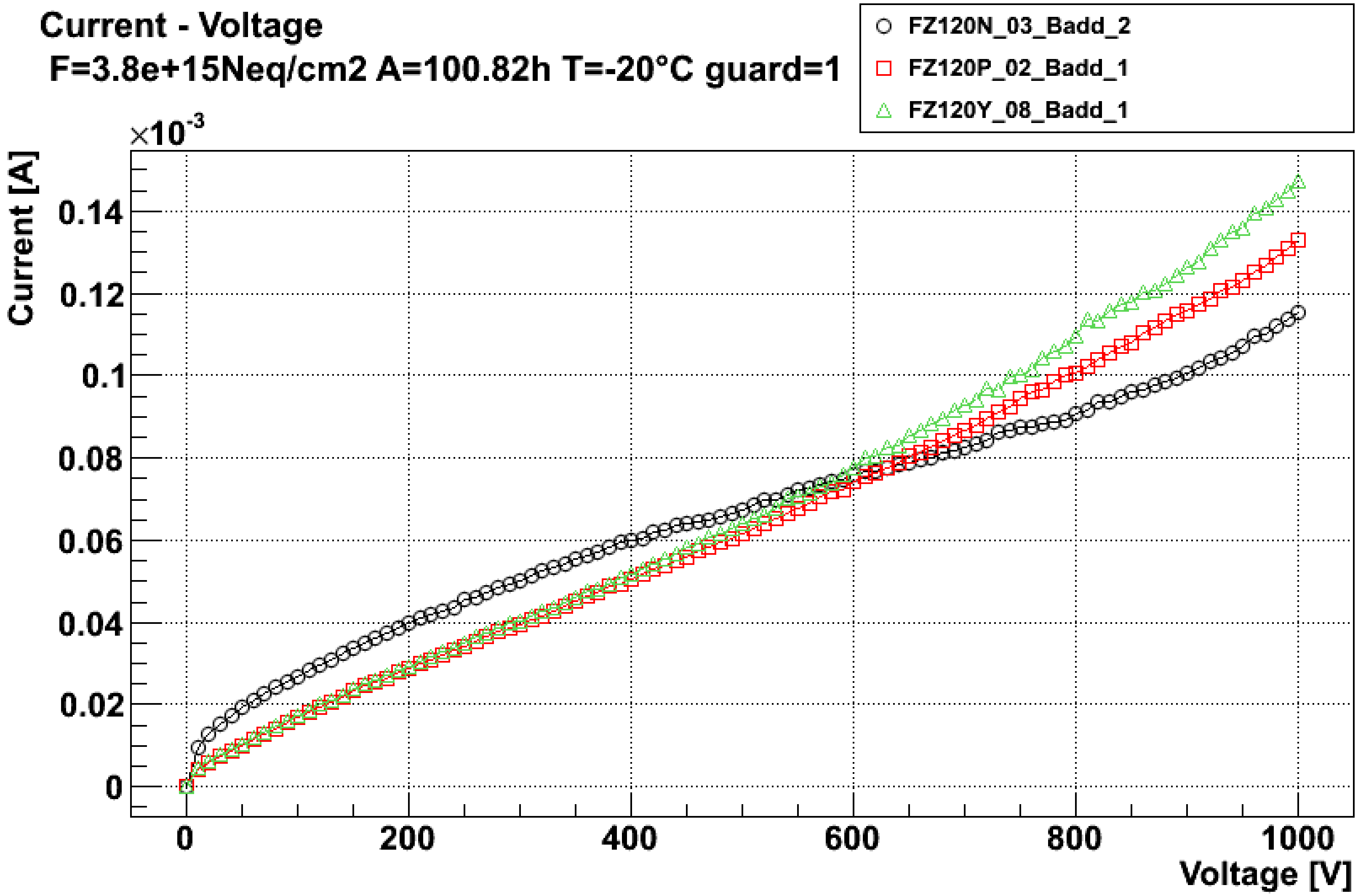
IV FZ120 3.8e15 Neq/cm^2



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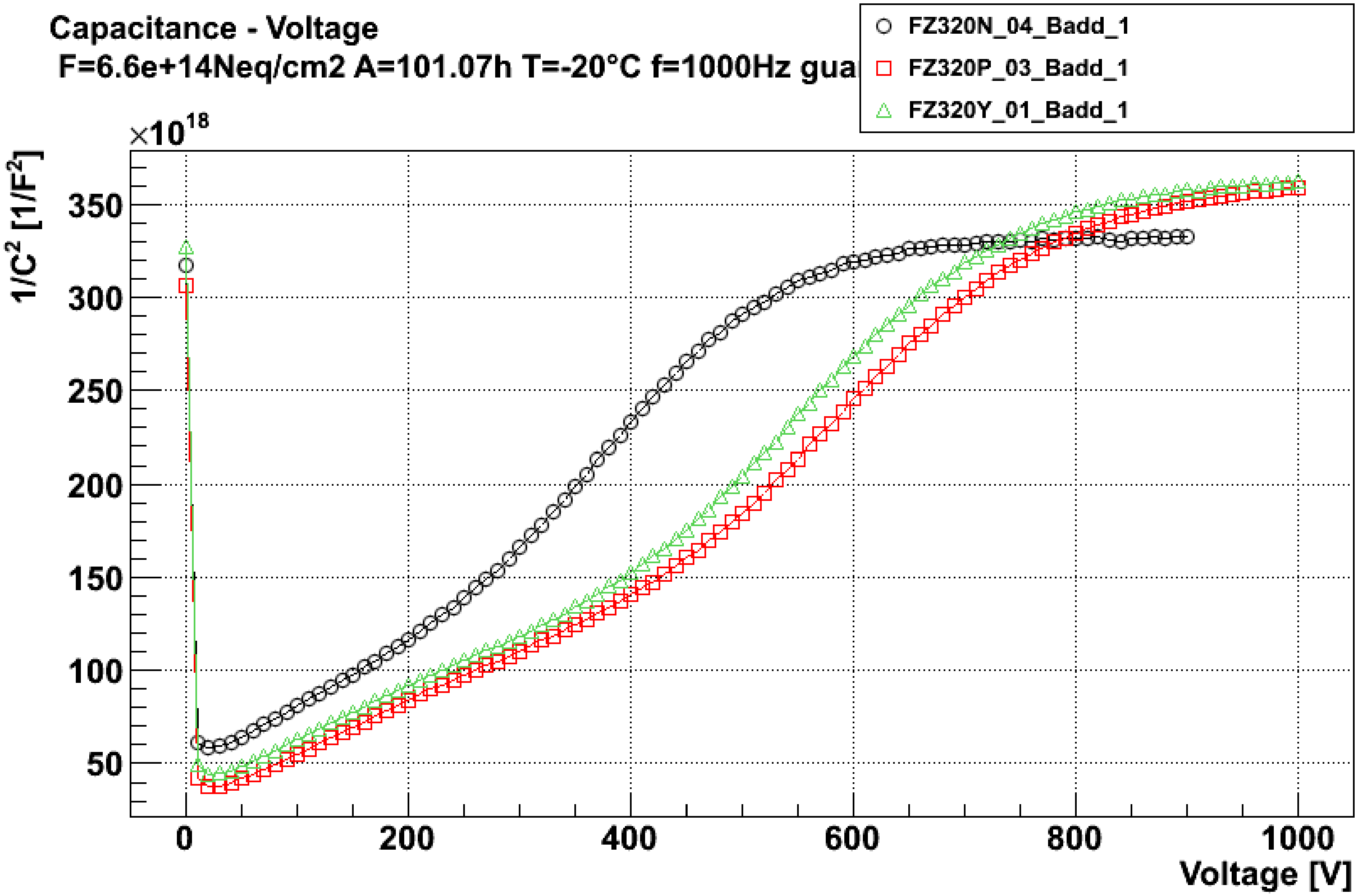
CV FZ320 6.6e14 Neq/cm^2



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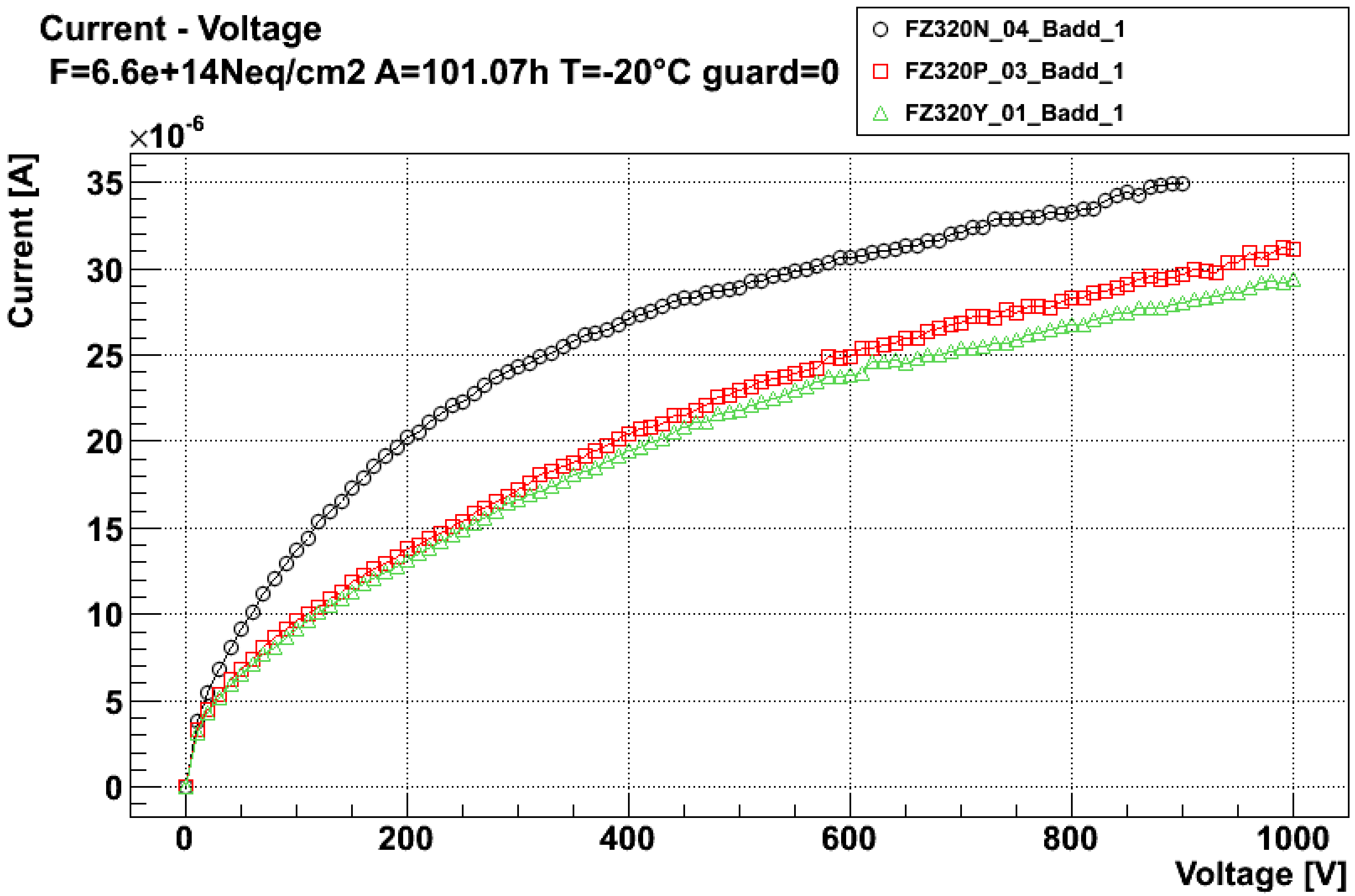
IV FZ320 6.6e14 Neq/cm^2



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Institut für Experimentelle Kernphysik, KIT