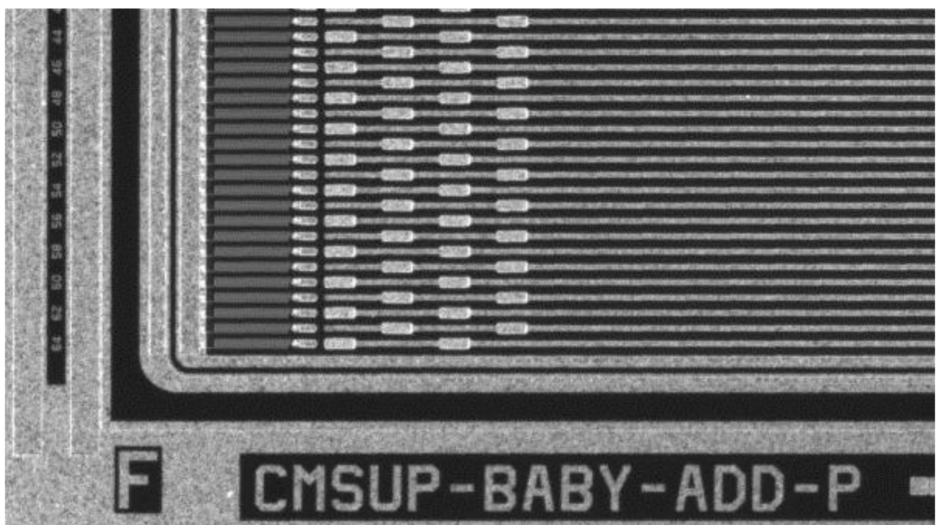
Lorentz angle measurements on irradiated strip sensors

Andreas Nürnberg

T. Barvich, W. de Boer, A. Dierlamm, F. Hartmann, Th. Müller, M. Schmenger, T. Schneider (ITEP), P. Steck

19th RD50 Workshop, CERN, 22 November 2011

Institut für Experimentelle Kernphysik

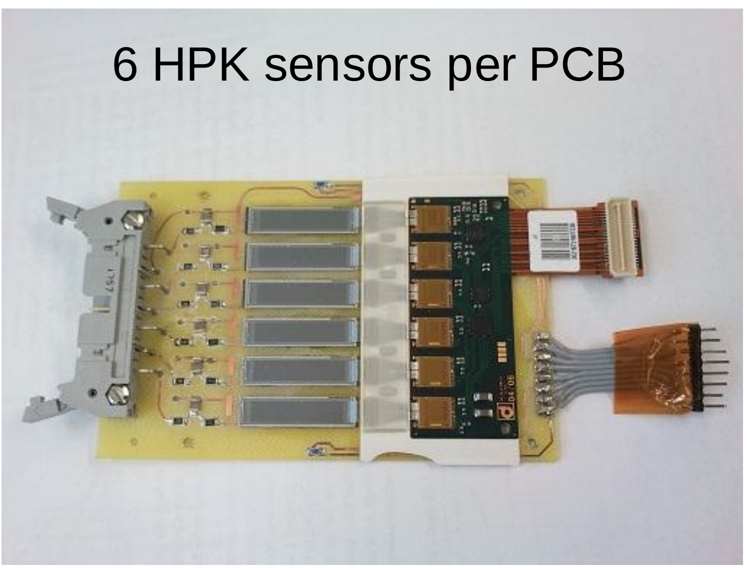


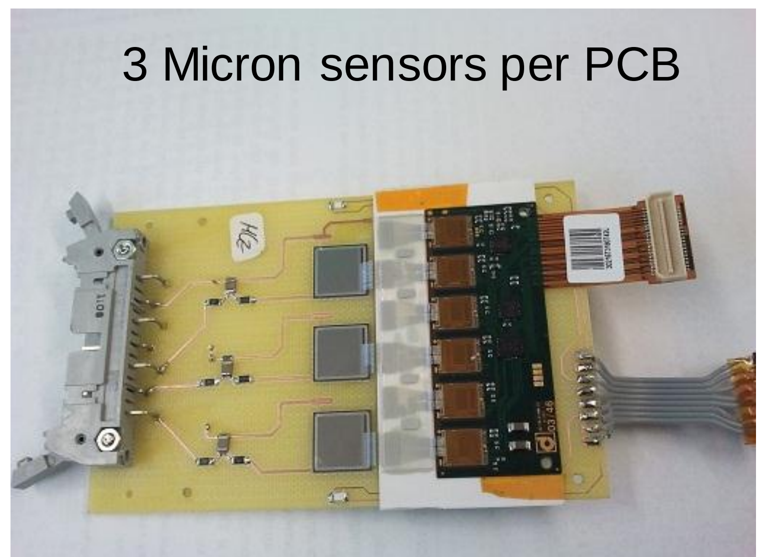
Outline

- Lorentz angle measurement in summer 2011
- Sensors used
- Jumbo magnet at ITEP
- Lorentz shift in irradiated sensors
- Lorentz shift vs. bias voltage
- Comparison to LA in CMS pixel sensor
- Summary & Outlook

Measurements in Summer 2011

- 2 ½ weeks of measurements at 8T-Magnet during summer
- 6 PCBs carrying 6 HPK sensors
- 2 PCBs carrying 3 Micron sensors (FZ & MCz N-on-P)
- Several fluences
- 2 annealing steps
- In total: ~16.000 single measurements of Lorentz angle





Sensors used

- HPK Sensors
  - 6 different materials (320µm, 200µm, Floatzone P-on-N & N-on-P (p-stop (p) & p-spray (y))
  - 80µm pitch
  - 6 Sensors per PCB
  - Mixed irradiation to 5 fluences (up to $5.8 \cdot 10^{15}$ neq/cm^2) + 1 non-irradiated sensor as reference
  - Annealing 4d@RT and ~27d@RT for Floatzone 320µm N & p-stop

- Micron Sensors
  - 2 different materials (FZ & MCz, N-on-P)
  - 80µm pitch
  - 3 Sensors per PCB
  - Proton irradiation to $2.5 \cdot 10^{14}$ neq/cm^2 and $1 \cdot 10^{15}$ neq/cm^2 + 1 non-irradiated sensor as reference
  - Annealing 2d@RT and ~25d@RT

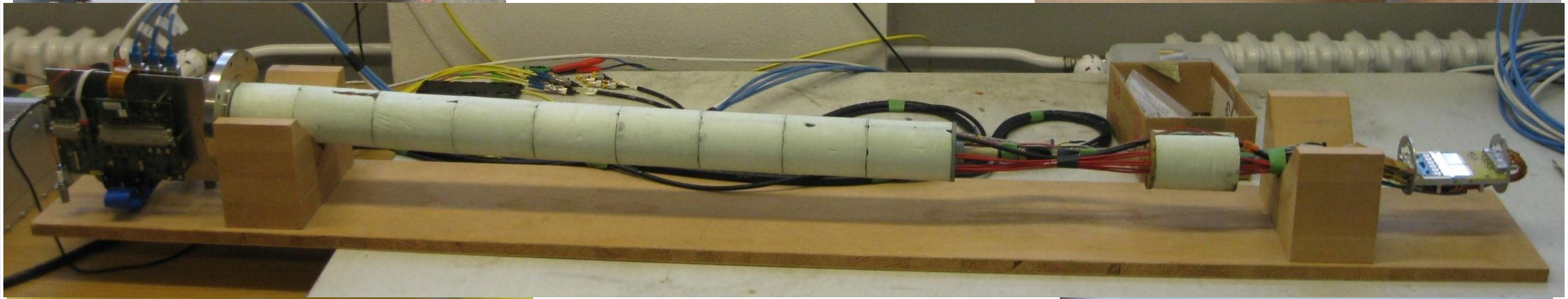
Jumbo magnet at ITEP, KIT

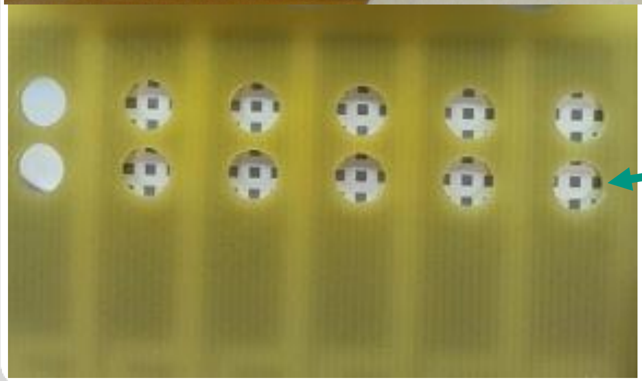
- Superconducting magnet at Institute for Technical Physics, KIT
- Up to 8T at room temperature
- Probe is thermally insulated from liquid helium
- 73mm diameter bore

Setup

6 sensors glued to PCB and bonded to APV-readout

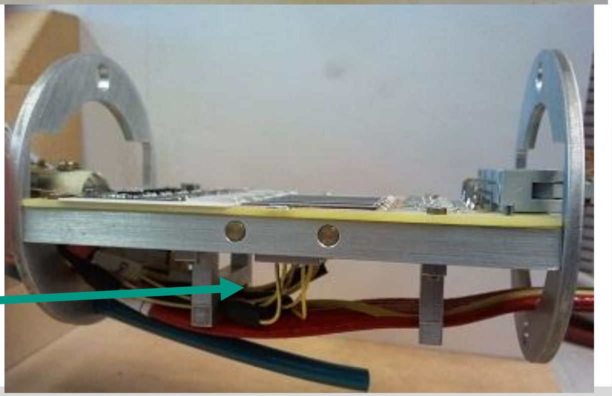
PCB mounted to aluminum support frame





Openings in backside metallization of HPK sensors

Optical Fibers



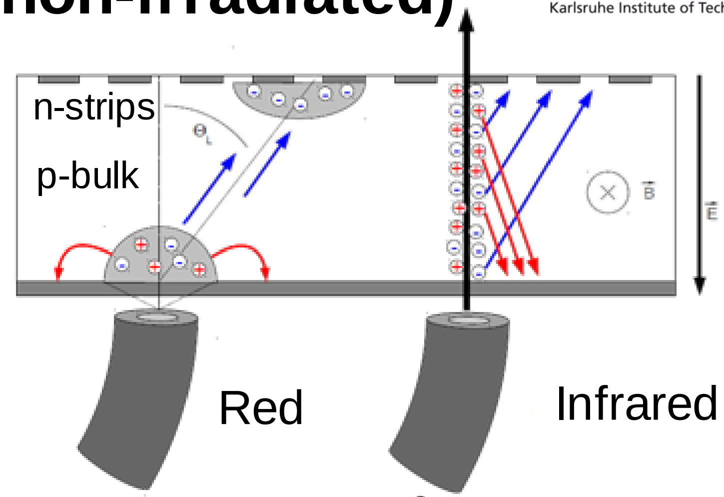
Lorentz shift vs. magnetic field (non-irradiated)

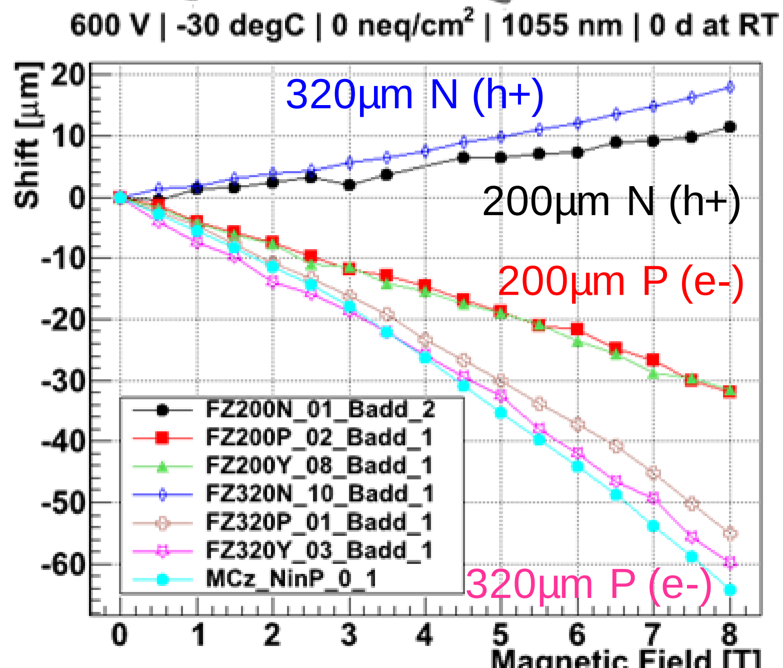
- Linear increase of Lorentz shift Δx with magnetic field B expected

$$\tan(\theta_L) = \frac{\Delta x}{D} = \mu_H B$$

- Hall mobility μ_H depends on temperature, bias voltage, irradiation, annealing,…

- Shift of electrons and holes in opposite direction
- Shift of electrons factor 3-4 larger than shift of holes
- Shift larger in thick devices





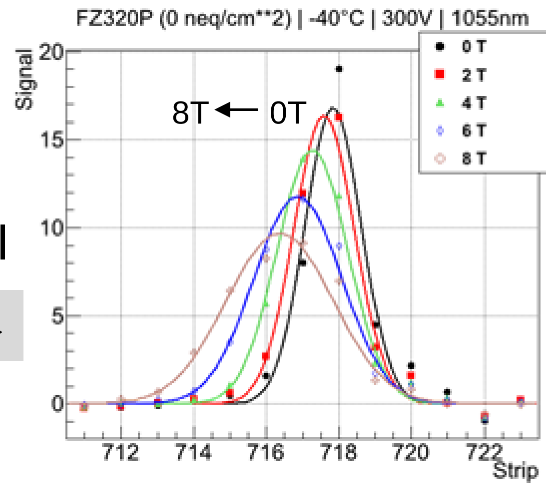
Cluster shape & laser wavelength

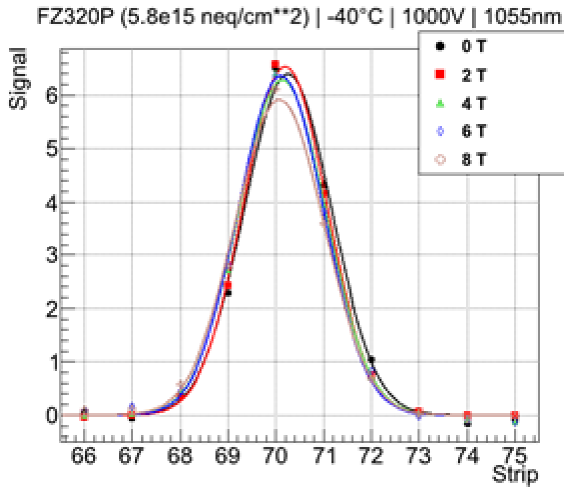
- Cluster shape depends on laser wavelength and irradiation
- Gaussian is not the ideal shape to fit to 1055nm signal

Φ = 0 neq/cm² ↓

Φ = 5.78*10¹⁵ neq/cm² ↓

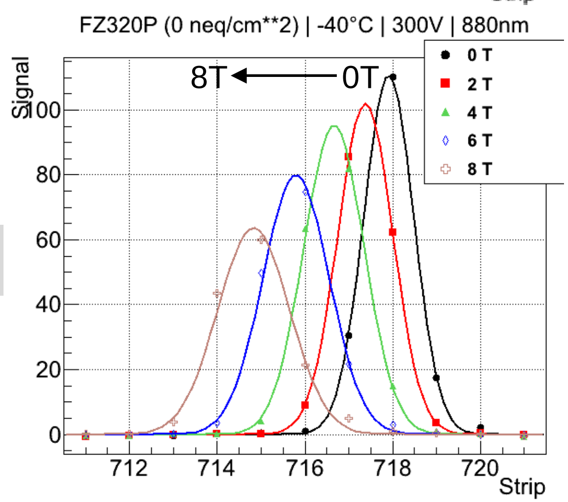
λ = 1055nm →

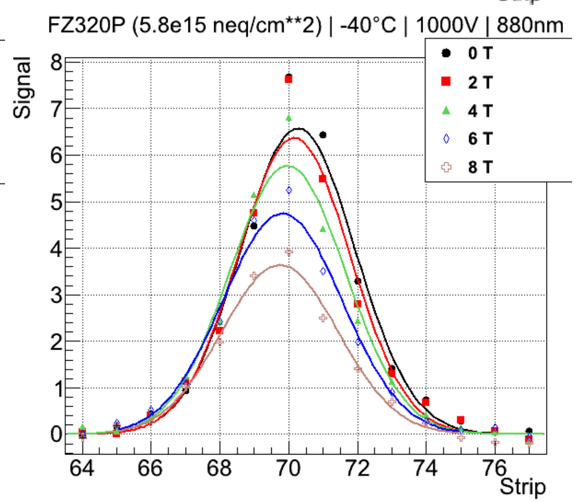




- FZ320P (-40°C)
- Lorentz shift of e⁻ (p-bulk) decreases with irradiation to almost zero (as expected from earlier measurements)

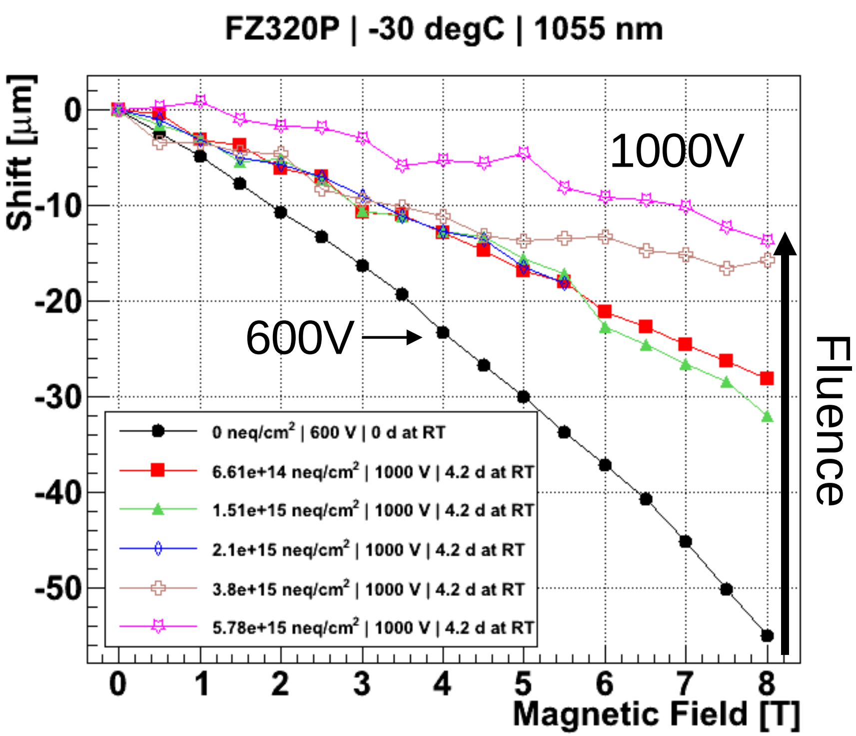
λ = 880nm →

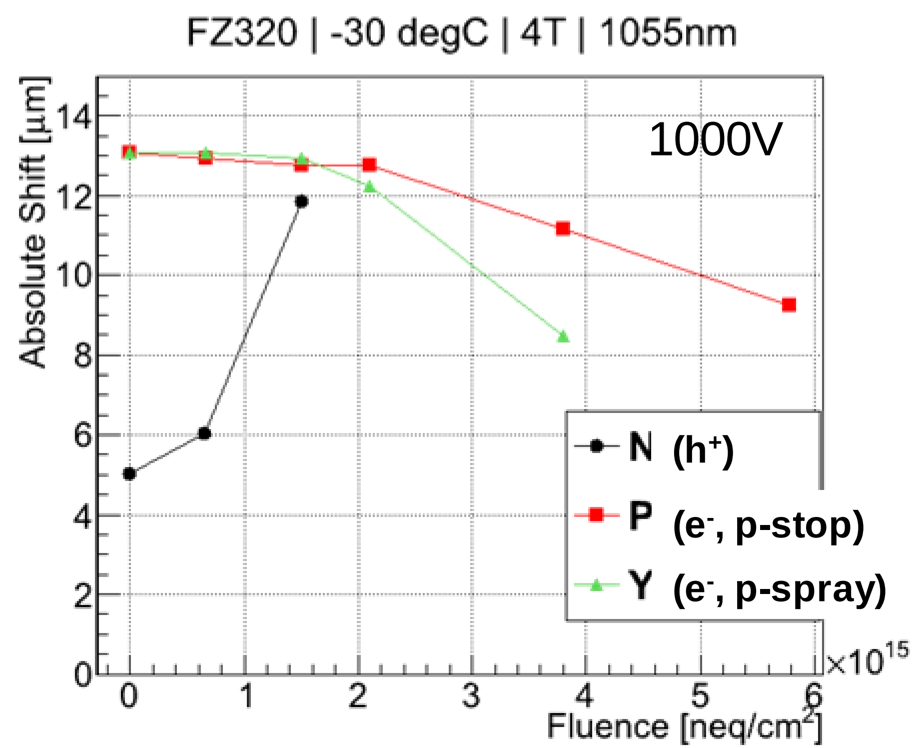




Lorentz shift (irradiated)

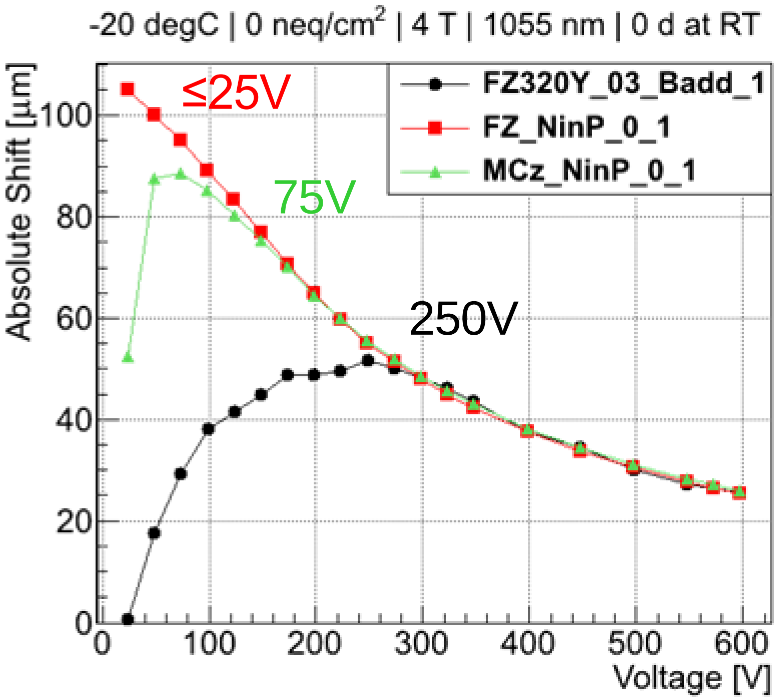
- FZ320P (electron readout)
- Shift increases linearly with magnetic field
- Irradiation reduces slope
  → decrease of shift with fluence
- Lorentz shift of electrons (P and Y) decreases with fluence
- Shift increases for holes (N)

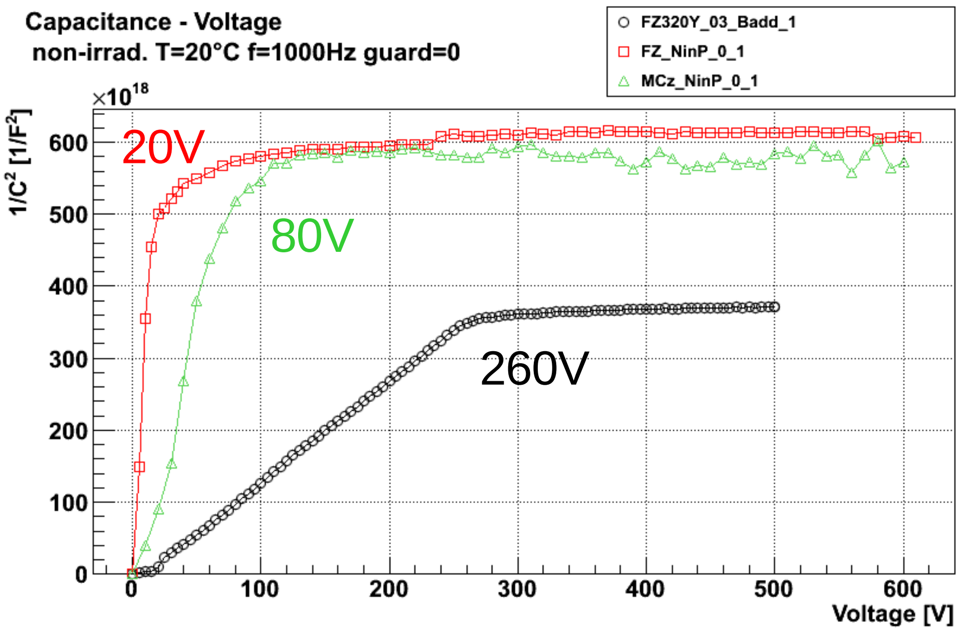




Bias voltage (non-irradiated)

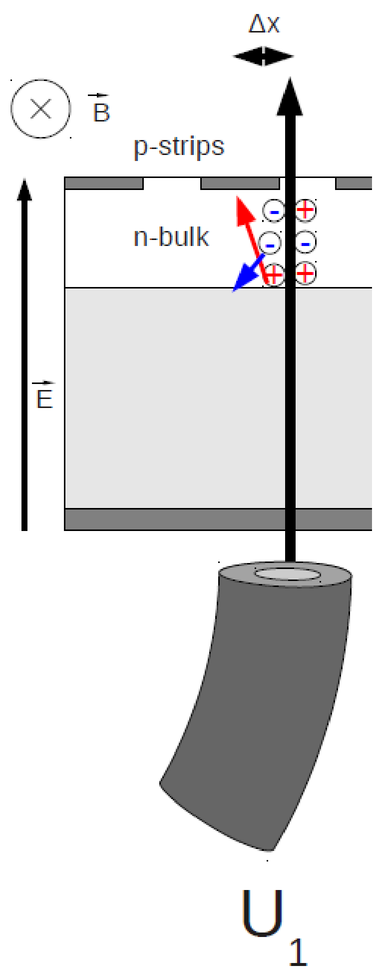
- Lorentz shift shows strong dependence on bias voltage, especially in non-irradiated sensors
- Largest shift at depletion voltage
- Bias voltage larger than depletion voltage: Shift independent of actual depletion voltage (p-type, 1055nm)





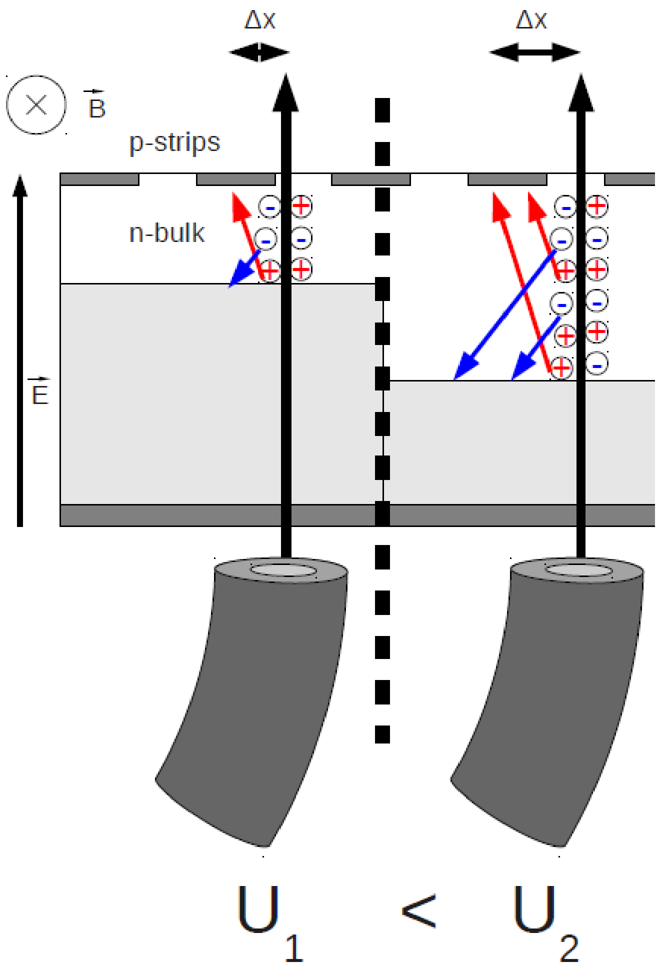
Bias Voltage

- Small depleted volume: small Lorentz shift



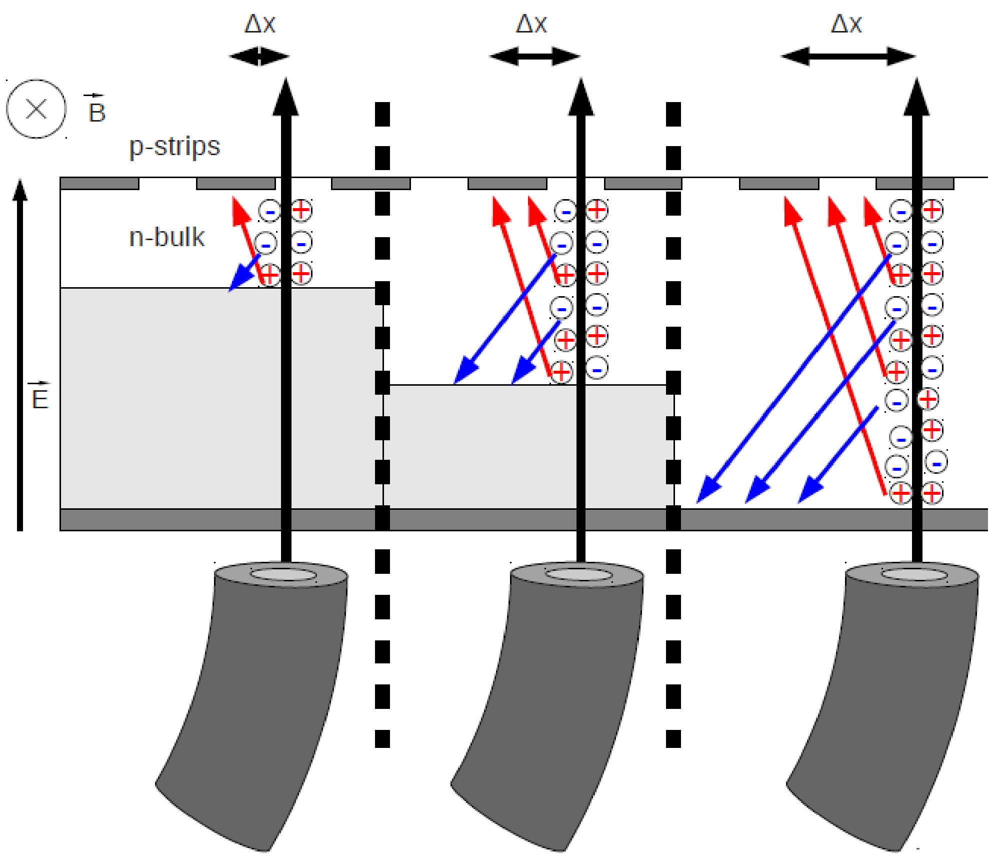
Bias Voltage

- Small depleted volume: small Lorentz shift
- Increase in bias voltage: increasing shift



Bias Voltage

- Small depleted volume: small Lorentz shift
- Increase in bias voltage: increasing shift
- Bias at depletion voltage: shift reaches maximum

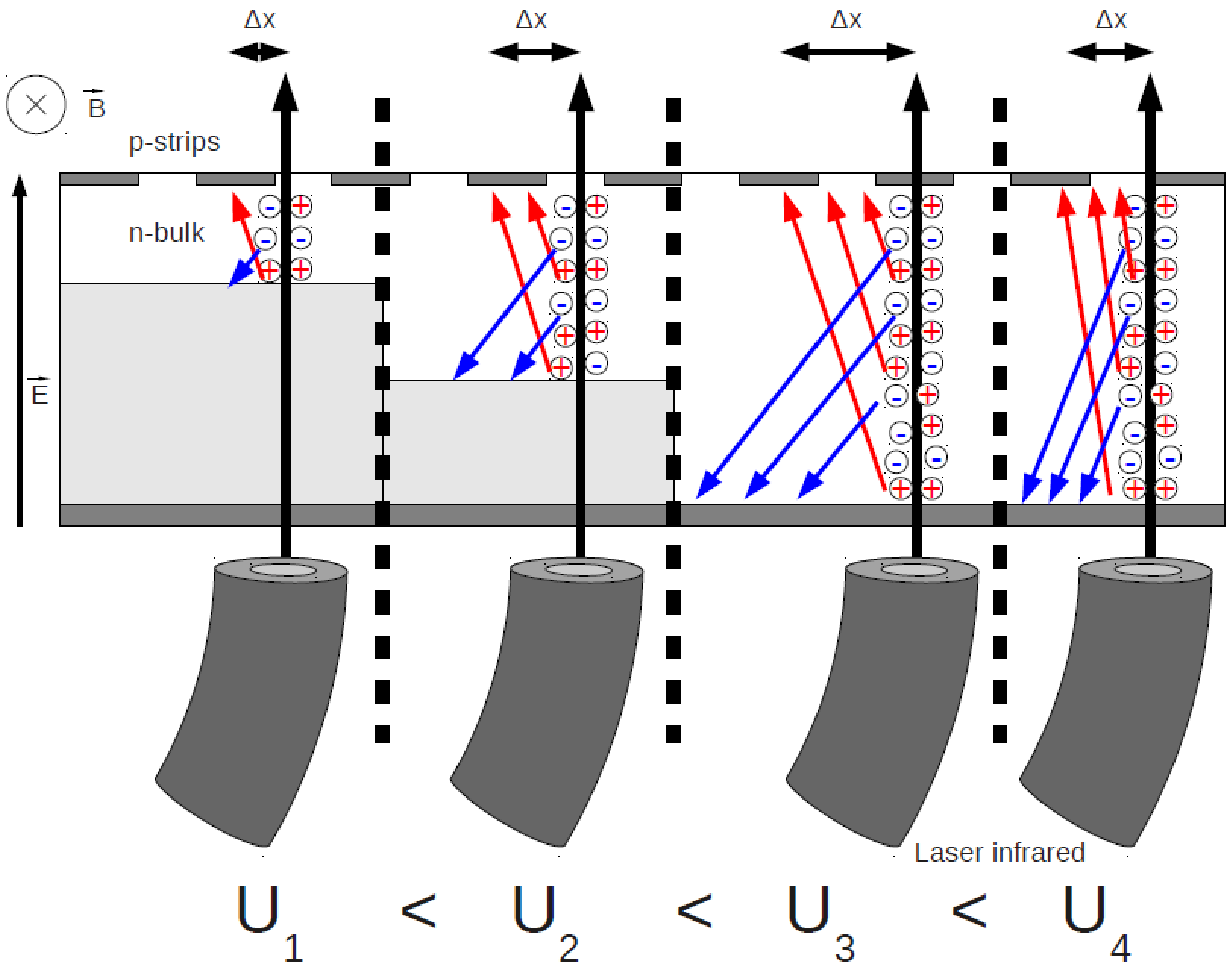


$U_1 < U_2 < U_3$

Andreas Nürnberg
Institut für Experimentelle Kernphysik, KIT

Bias Voltage

- Small depleted volume: small Lorentz shift
- Increase in bias voltage: increasing shift
- Bias at depletion voltage: shift reaches maximum
- Bias larger than depletion voltage: Increasing electric field leads to higher drift velocity → smaller shift

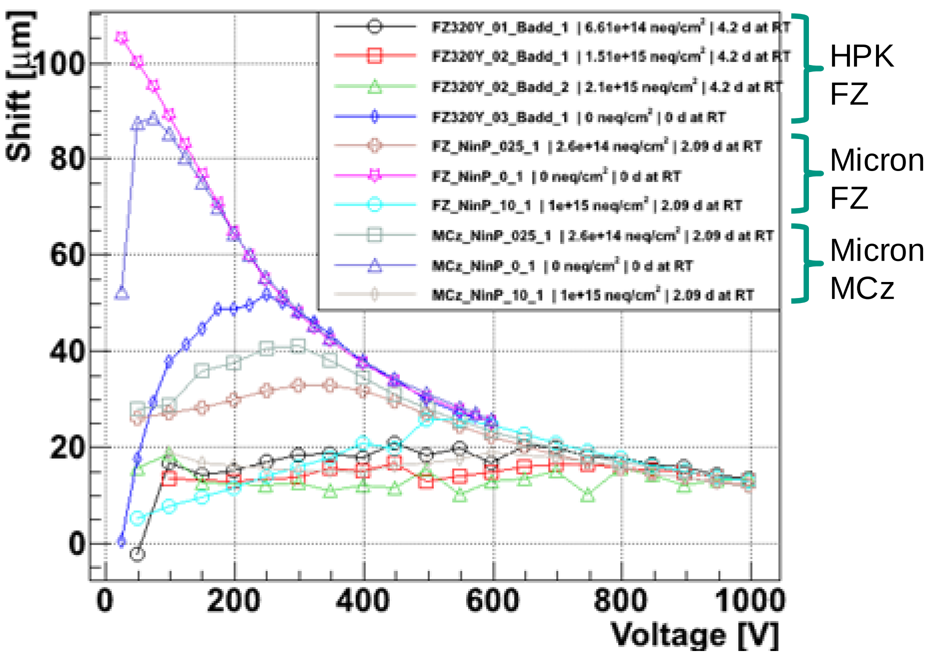


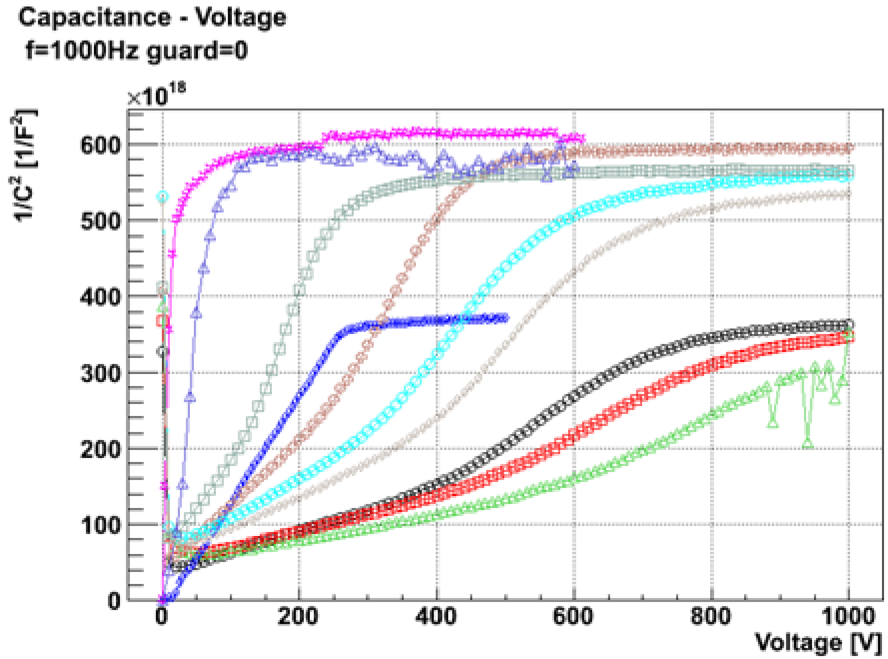
Bias Voltage (irradiated)

Karlsruhe Institute of Technology

- Irradiated p-type sensors (V_depl < 1000V) added to plot
- Above depletion voltage, Lorentz shift still independent of depletion voltage and irradiation fluence (p-type, 1055nm)
- Valid for mixed irradiated HPK sensors and proton irradiated Micron sensors of same thickness

-20 degC | 4 T | 1055 nm



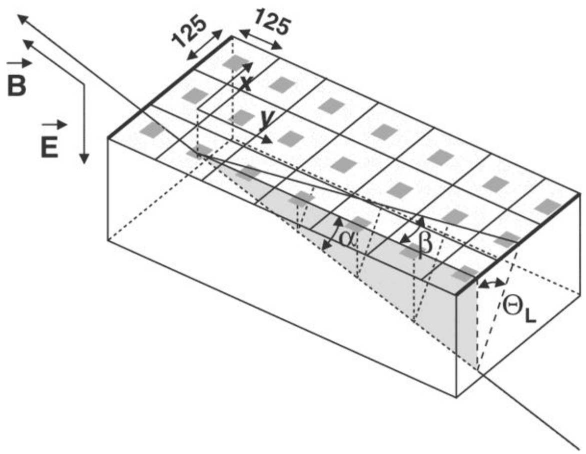


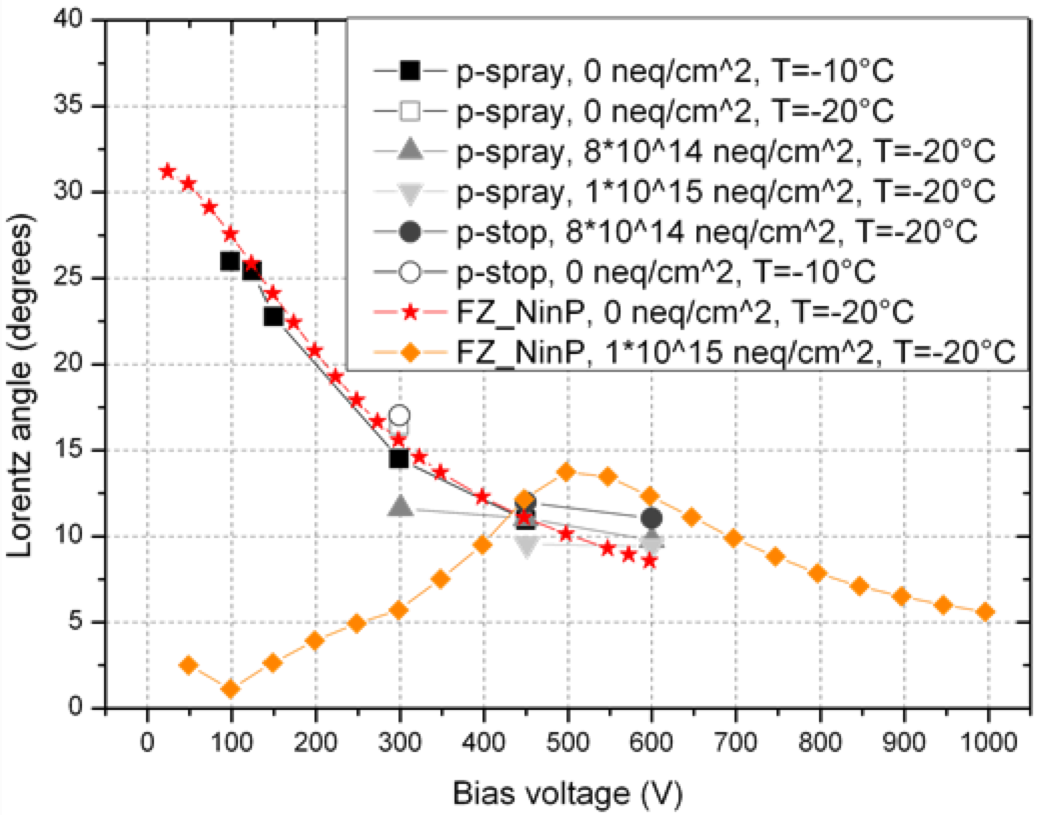
Andreas Nürnberg
Institut für Experimentelle Kernphysik, KIT

Comparison to LA in CMS pixel sensor

- CMS n-on-n pixel sensor
- Direct measurement of the charge drift in the magnetic field using the grazing angle method in pion testbeam
- Projection of particle track to sensor surface gets deflected

- Micron FZ n-on-p strip sensor: good agreement with data from pixel testbeam





From: A. Dorokhov et al.,Tests of silicon sensors for the CMS pixel detector, Nucl. Instr. and Meth. A 530 (2004), 71-76

Summary & Outlook

- Lorentz angle has been measured on HPK floatzone and Micron floatzone and magnetic-czochralski mini strip sensors
- Lorentz shift vs. magnetic field shows linear behavior
  - Shift of electrons decreases with fluence
  - Shift of holes increases with fluence
- Lorentz shift depends strongly on bias voltage
  - Lorentz shift obtained with 1055nm laser in p-type sensor is independent of depletion voltage, if bias voltage is larger than depletion voltage

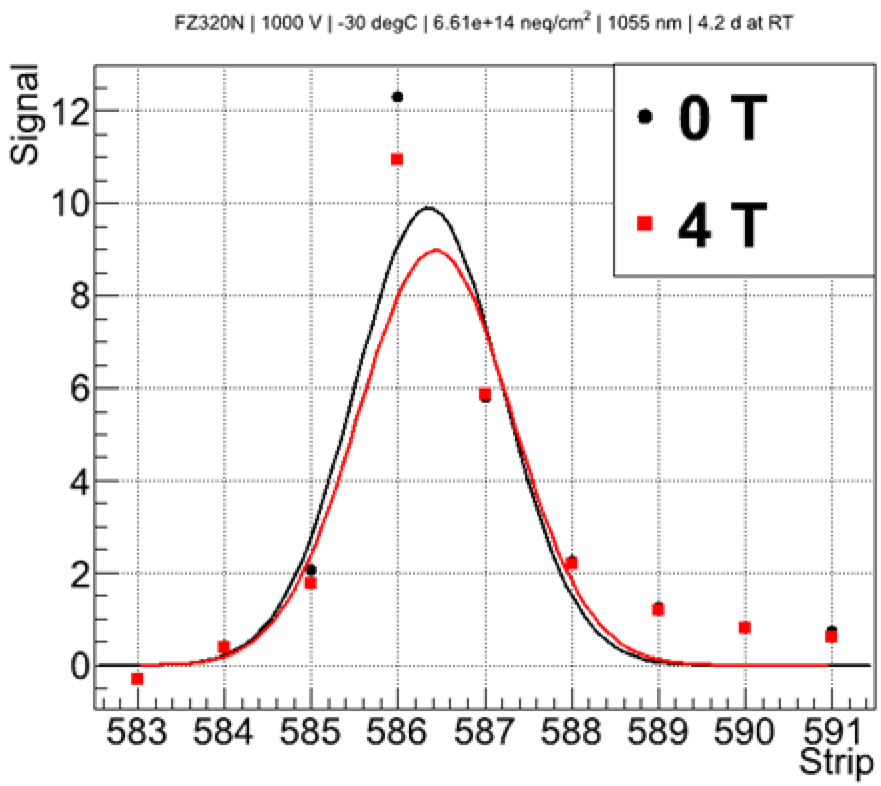
- Comparison to Lorentz angle measurement in CMS pixel sensor shows good agreement

- Next measurement time at magnet is planned for the first half of 2012
  - Investigate magnetic-czochralski sensors produced by HPK
  - Perform further annealing step

Backup

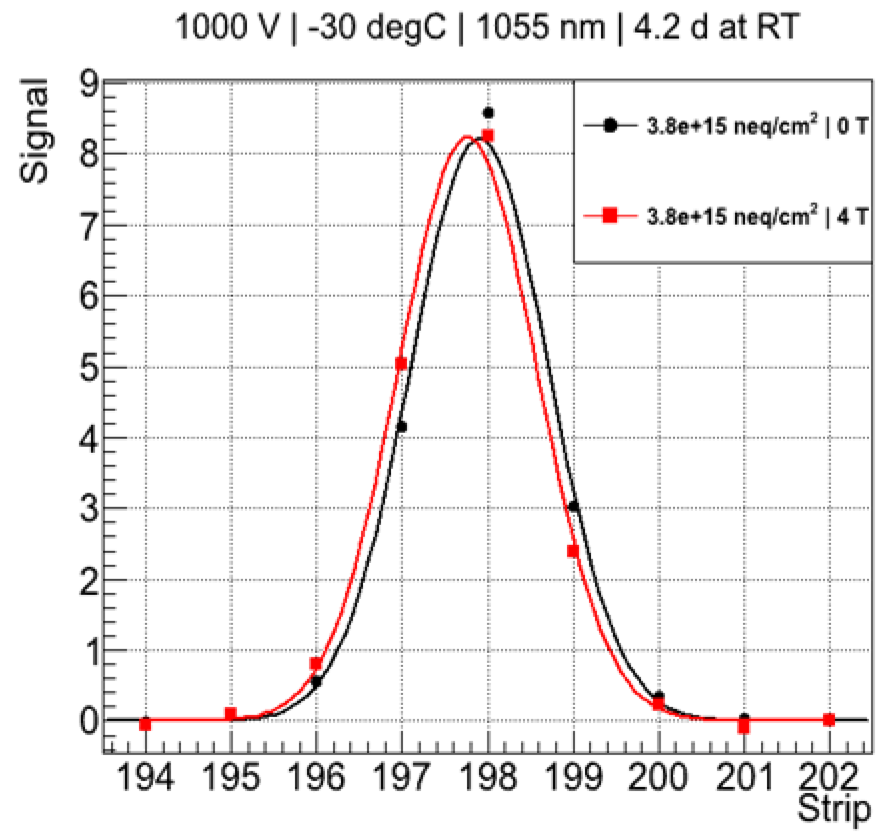
Shift: 6 µm

FZ320N $6.6 \cdot 10^{14}$

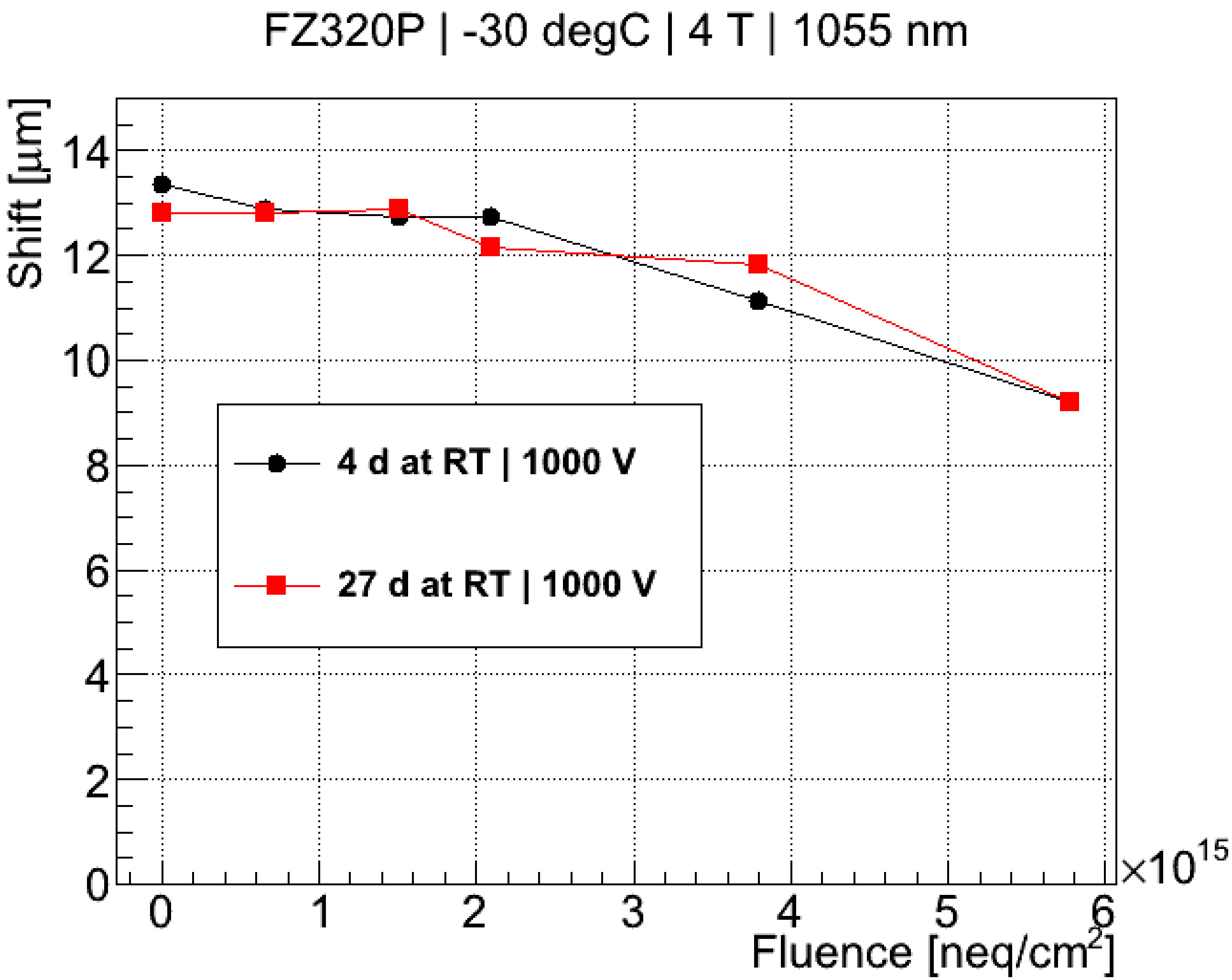


Shift: 11 µm

FZ320P $3.8 \cdot 10^{15}$

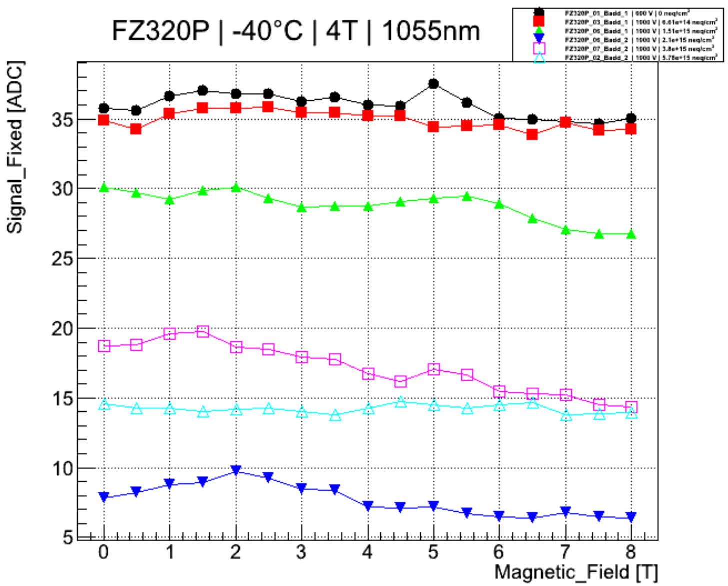


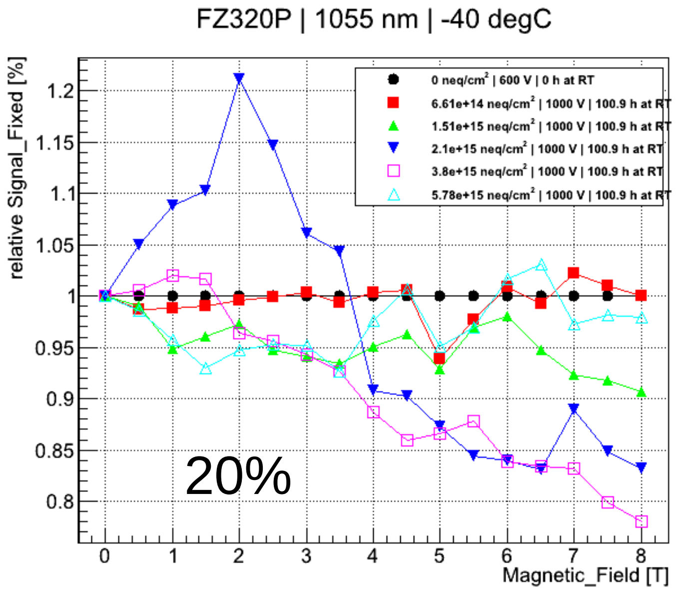
Annealing

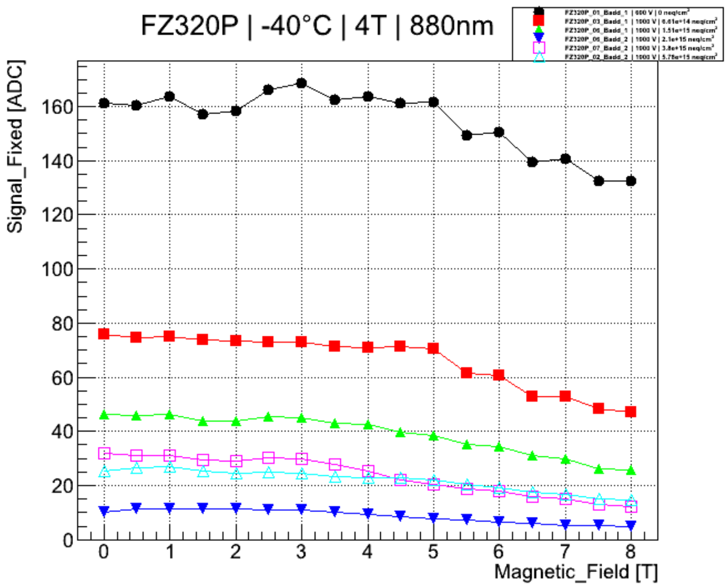


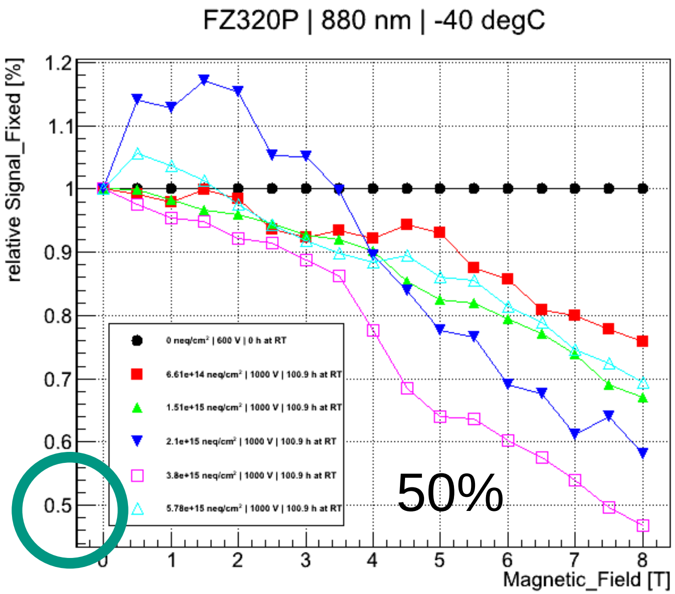
Andreas Nürnberg
Institut für Experimentelle Kernphysik, KIT

Karlsruhe Institute of Technology

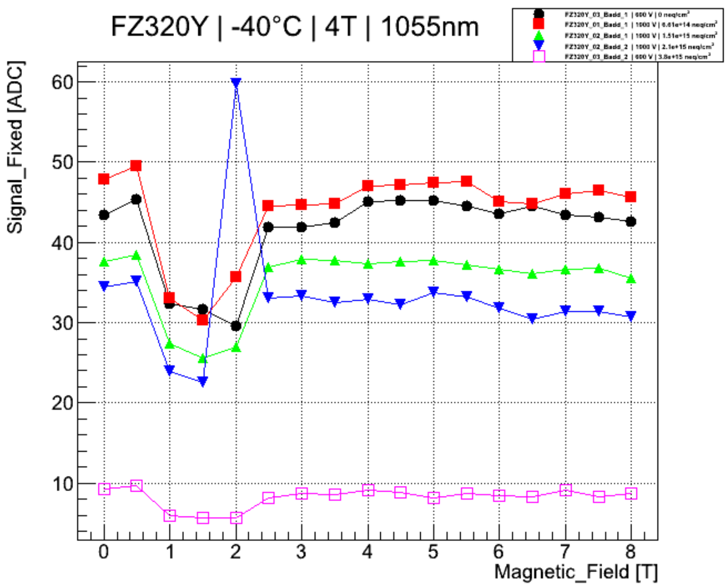


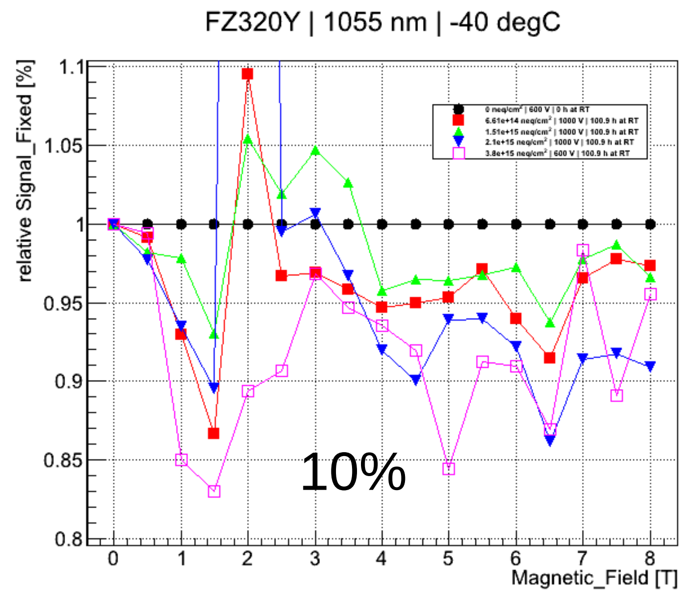




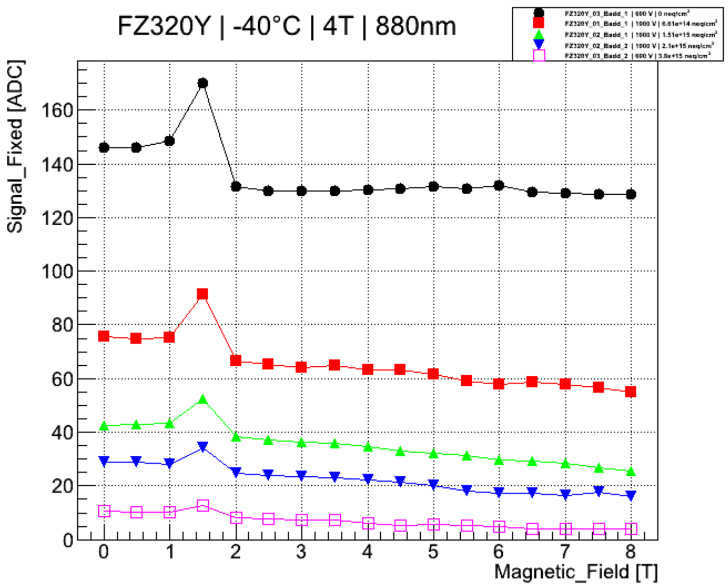


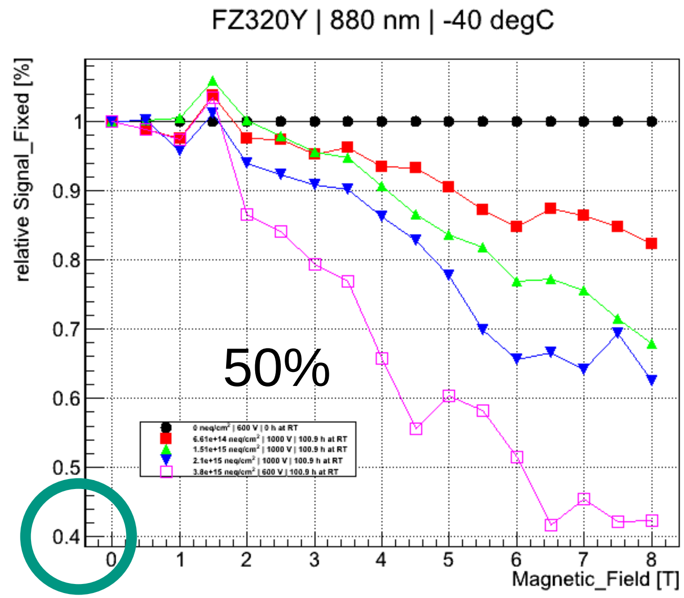
- HPK FZ320P
- Normalized to 0T
- Normalized to 0 neq/cm^2



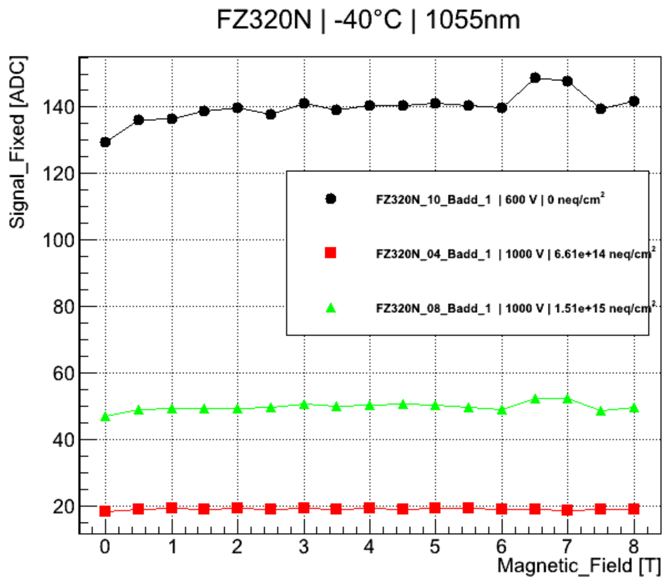


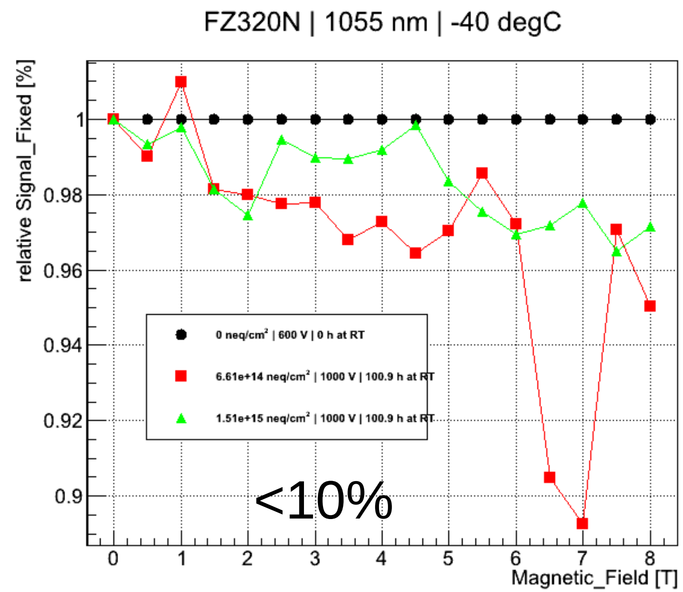
- HPK FZ320Y
- Normalized to 0T
- Normalized to 0 neq/cm^2



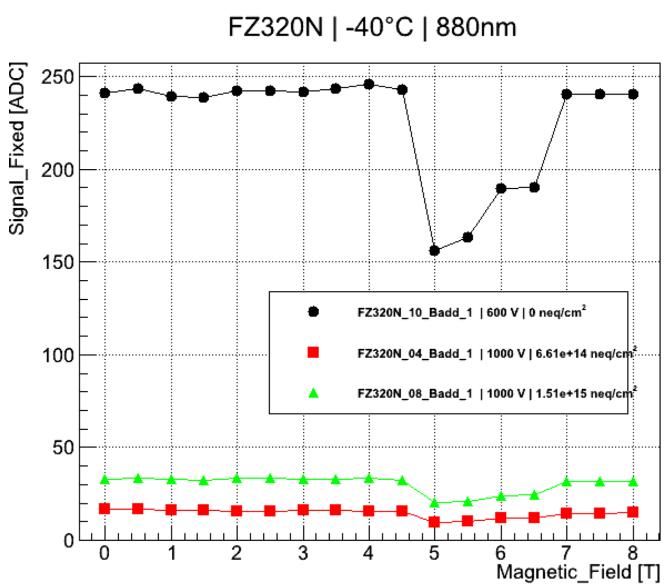


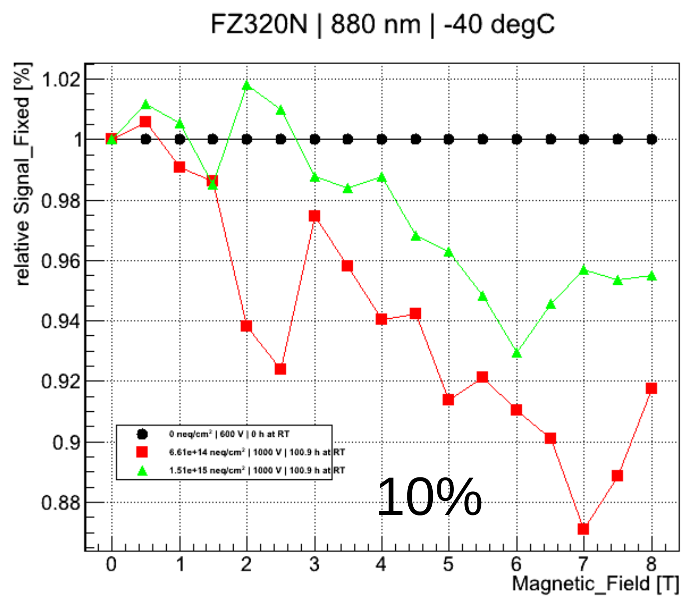
Karlsruhe Institute of Technology

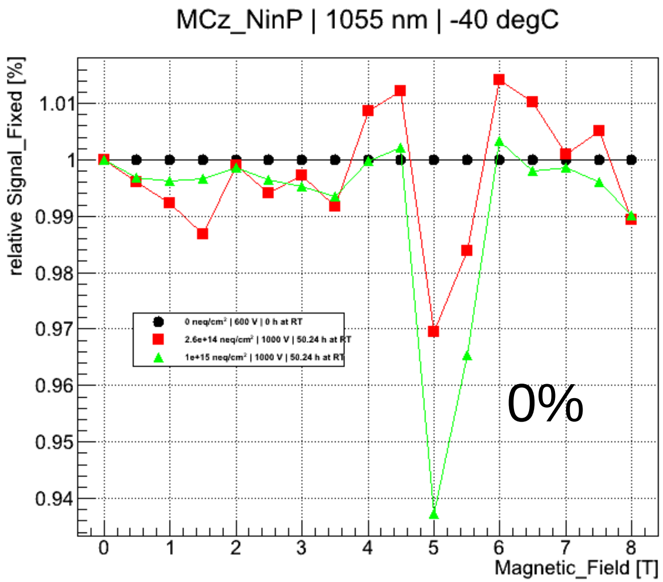


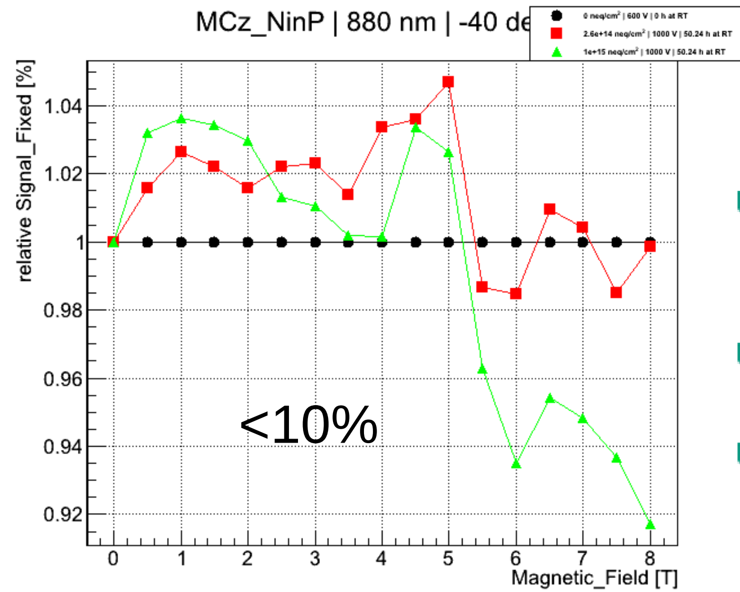


- HPK FZ320N
- Normalized to 0T
- Normalized to 0 neq/cm^2

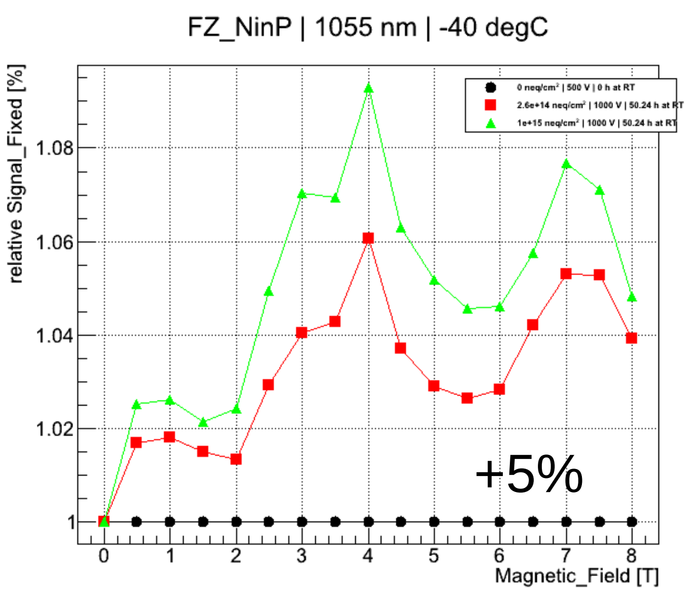


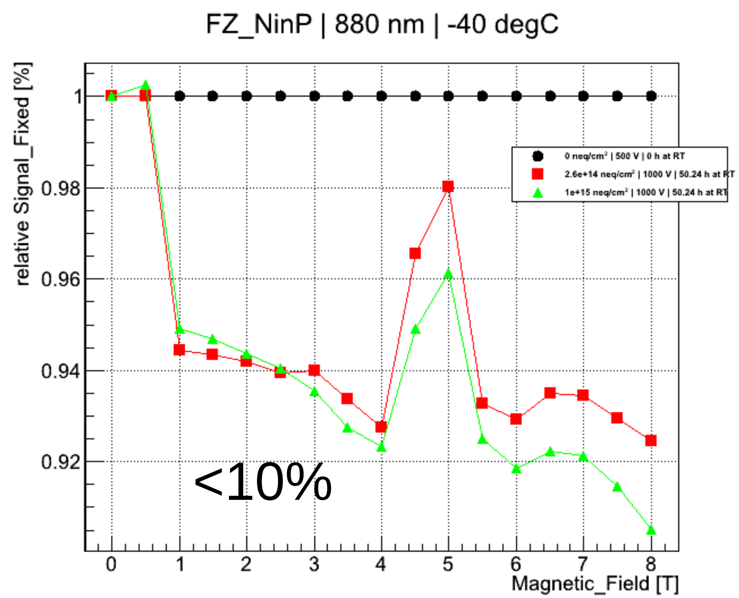






- Micron NinP FZ & MCz
- Normalized to 0T
- Normalized to 0 neq/cm^2





Abstract

- Lorentz angle measurements on irradiated strip sensors
- Lorentz angle measurements on mixed-irradiated mini strip-sensors have been performed as part of the CMS HPK Campaign. Up to now, the study covers 320µm and 200µm thick n- and p-bulk floatzone sensors at a magnetic field of up to 8T at different temperatures and after two annealing steps. In addition to that, proton irradiated magnetic-czochralski and floatzone n-on-p sensors produced by Micron were examined. This talk gives an overview of the obtained results.