New Measurements of Lorentz angle in (irradiated) silicon-strip-detectors

Wim de Boer, Alexander Dierlamm,

Andreas Sabellek, Mike Schmanau, *Michael Schneider*

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What is new?

- Measured real CMS ministrip sensors

  (instead of ministrips from HERA-B, which had smaller pitch)

  CMS sensors allowed to measure to much higher bias voltages, use 500 um for better sensitivity

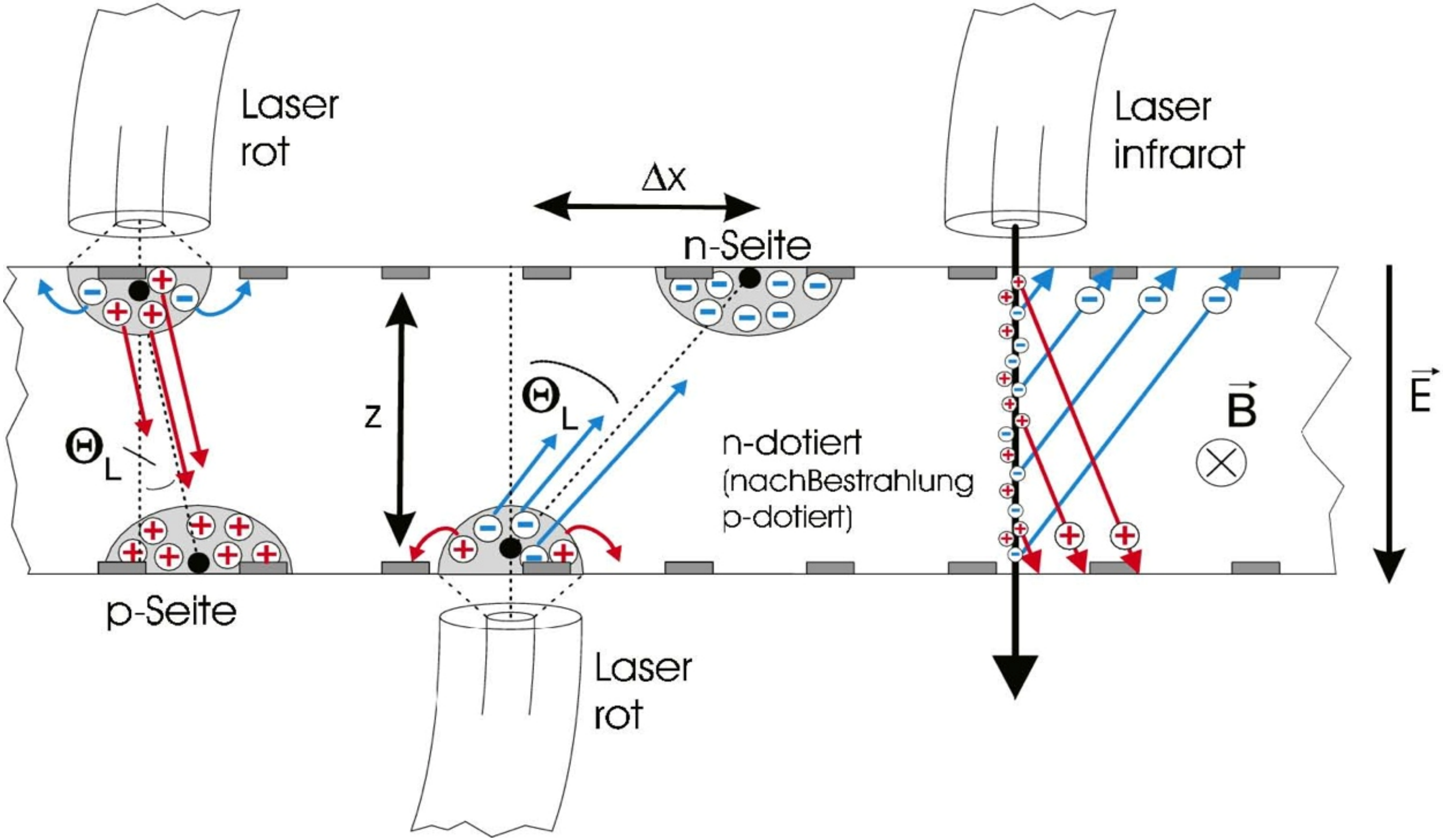
- Measured RD50 n-in-p sensors to get much better Lorentz angle measurements for electrons

- Measure Lorentz angle in highly irradiation sensors

Outline

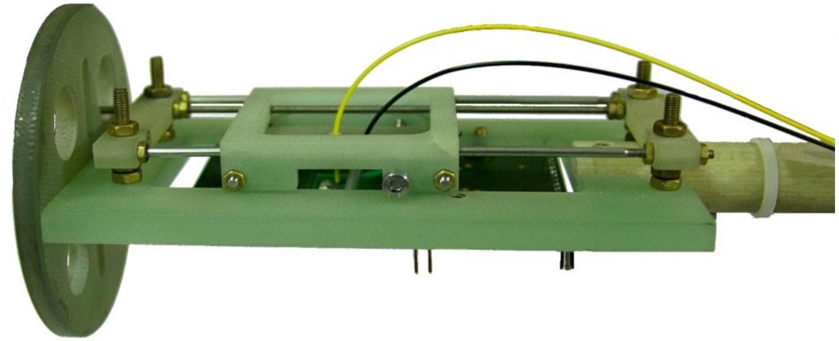
- Experimental Setup
- Sensors
- New parametrization of Lorentz angle model
- Results
- Comparison with CMS data
- Lorentz angle over fluence
- Summary

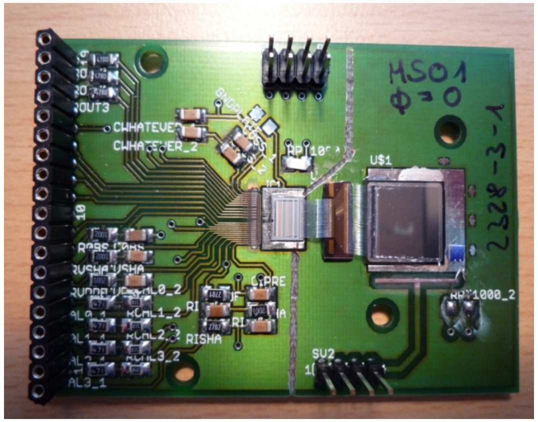
Experimental Setup (1)



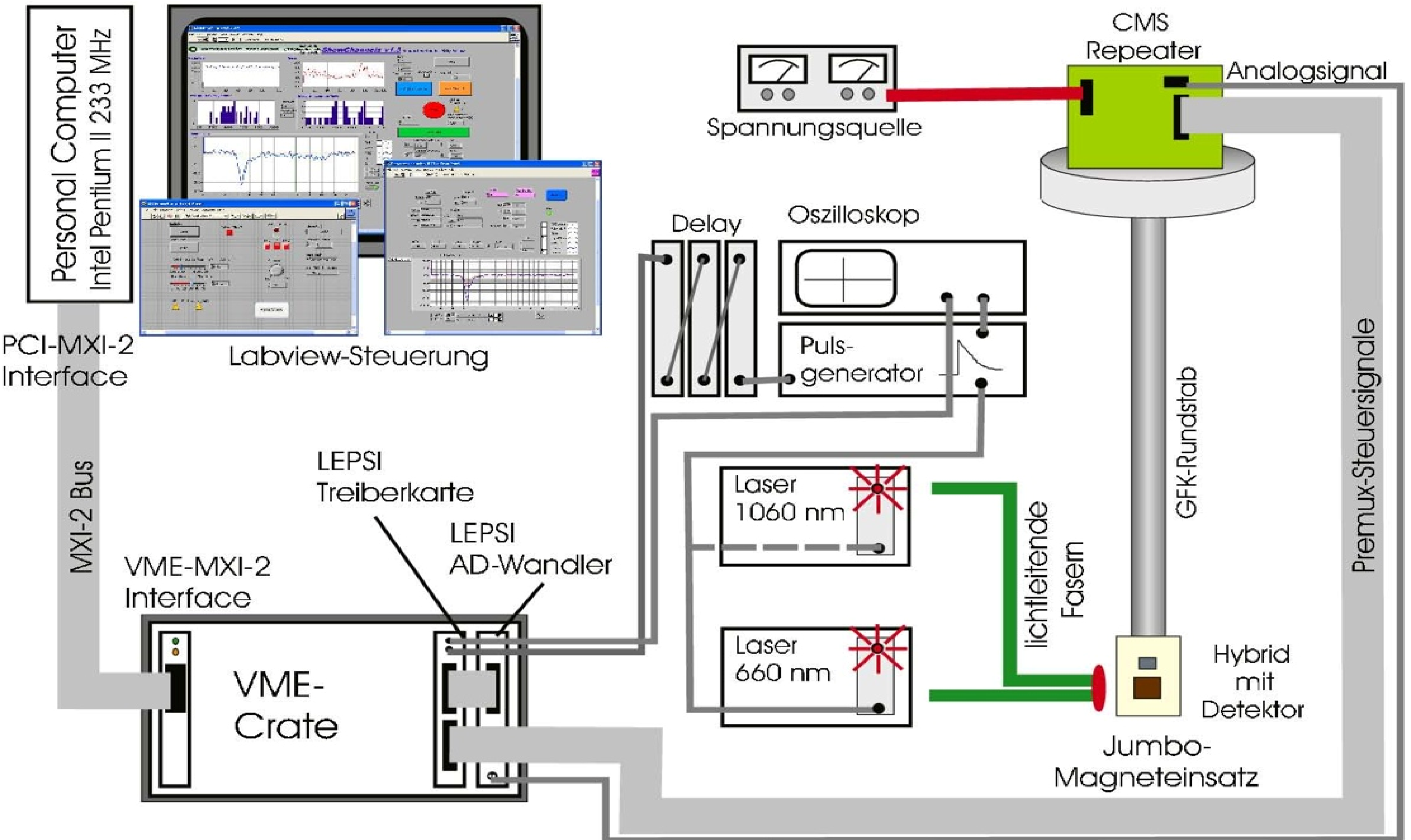
Experimental Setup (2)

- Sensor with readout-chip PreMux (=APV w.o. Pipeline) on hybrid
- Hybrid mounted on structure for magnet
- Optical fibers for laser
  - red laser for best signal
  - infrared laser for MIP-like signal





Experimental Setup (3)



Experimental Setup - Magnet

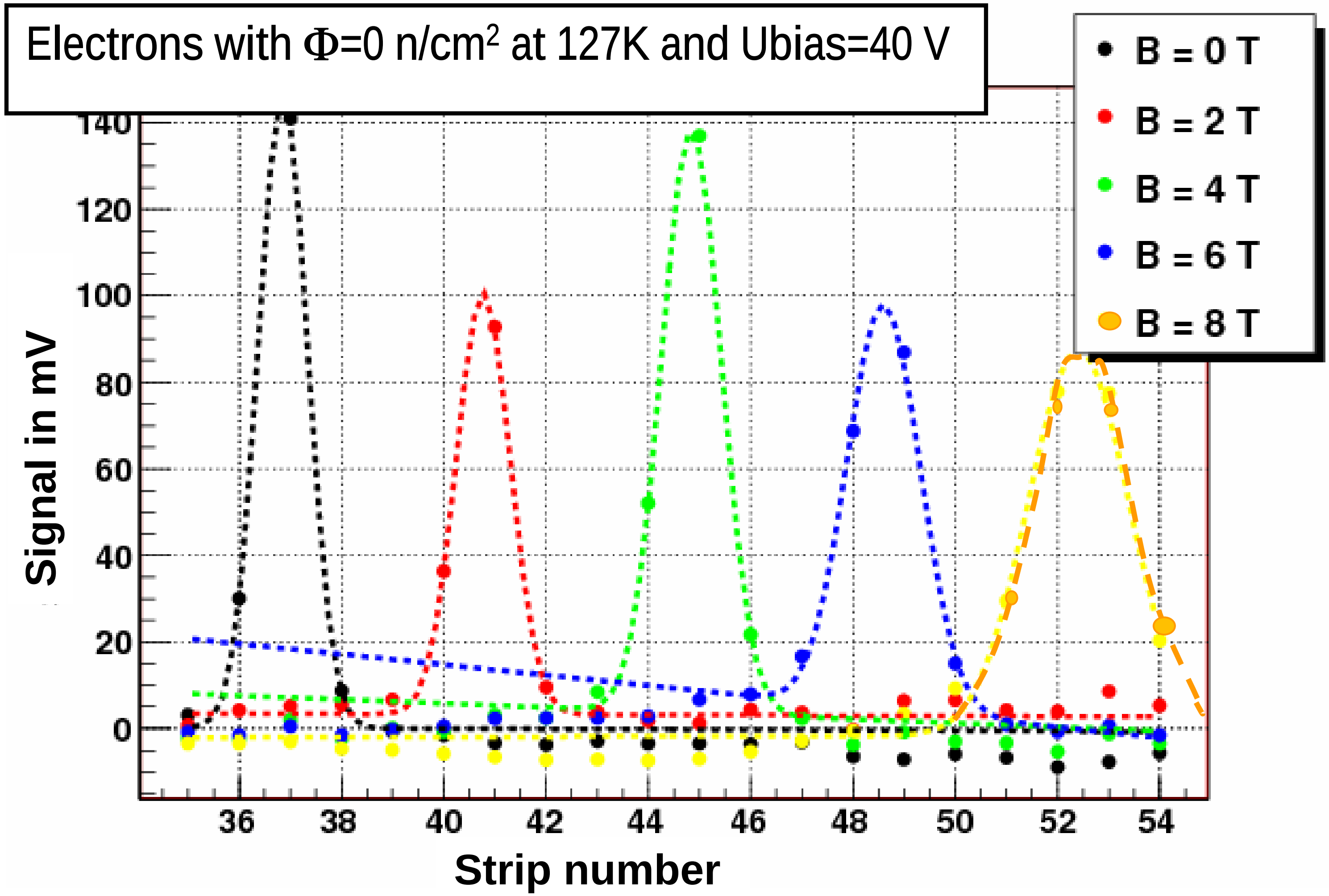
- Magnet lab of ITP at Forschungszentrum Karlsruhe
- Measurements of lorentz shift up to 8T

Sensors

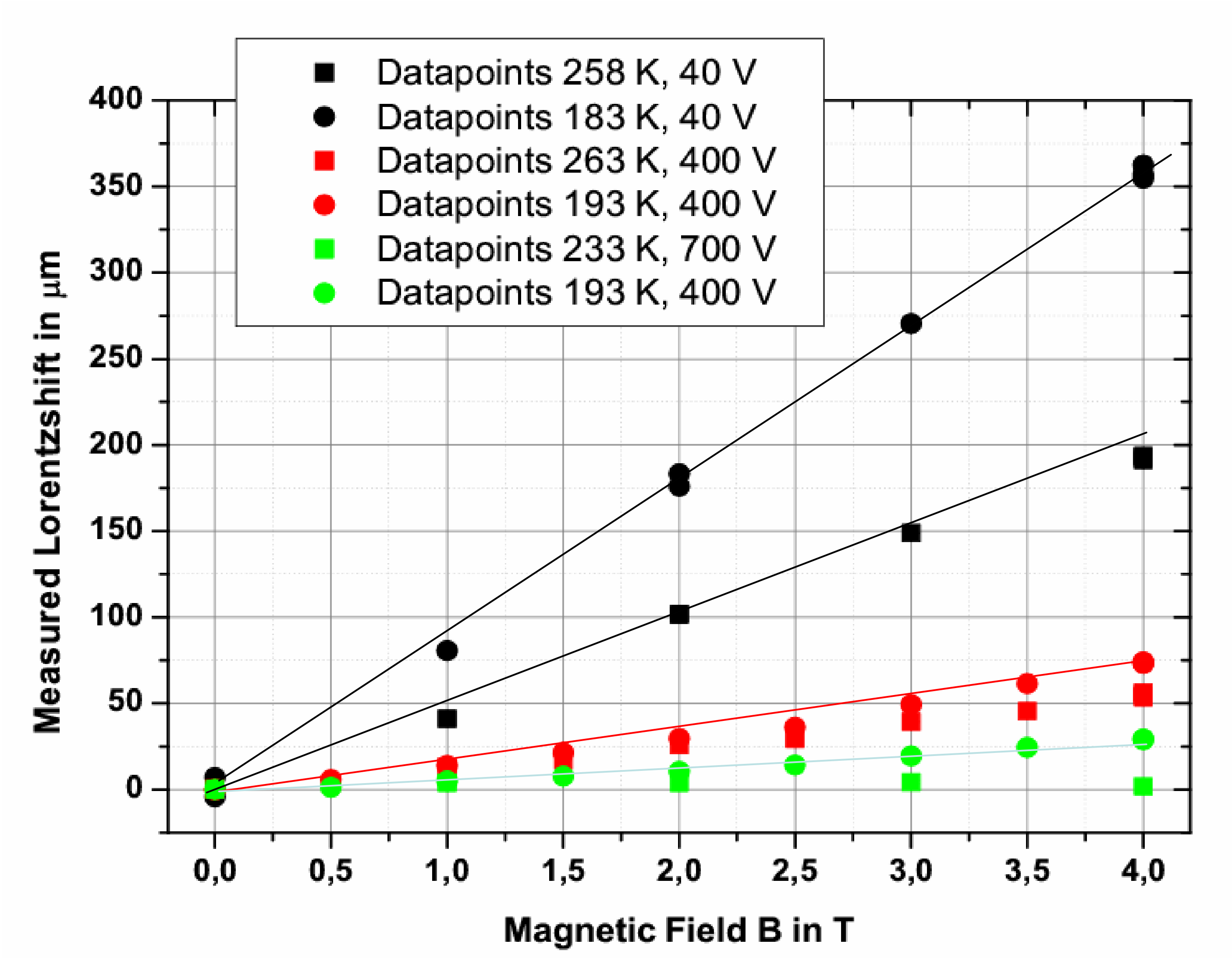
Sensorname	Manufacturer	Material	Thickness [μm]	U_{dep} [V]	Fluence [$\frac{n_{eq}}{cm^2}$]	Pitch[µm]
FZ-p-in-n-0-h-154-CMS	ST Microelectronics	FZ n-type	500	154	0	120
FZ-n-in-p-0-e-12	Micron / RD50	FZ p-type	300	12	0	80
FZ-n-in-p-1E15-e-1000	Micron / RD50	FZ p-type	300	≈ 1000	$1 \cdot 10^{15}$	
FZ-n-in-p-9.8E15-e-1000	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	$7.1 \cdot 10^{14}$	50
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
- Irradiated at Karlsruhe Kompaktzyklotron with 25 MeV protons
- Hardnessfactor 1.85

Signals of unirradiated sensors



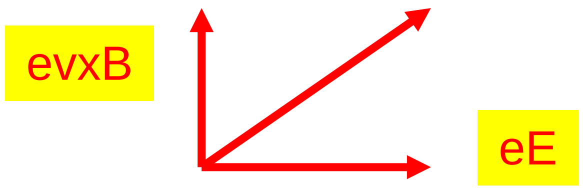
Lorentz-shift of unirradiated sensors



Parametrization of Lorentz angle model

An Algorithm for calculating the Lorentz angle in silicon detectors.
V. Bartsch, W. de Boer, J. Bol, A. Dierlamm,
E. Grigoriev, F. Hauler , S. Heising, L. Jungermann.
Nucl.Instrum.Meth.A497:389-396,2003.
e-Print: **physics/0204078**

$\tan\theta_L = evB/eE = v/E\ B = r_H \mu B$



r_H=Hall factor, depends on scattering mechanism

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

mobility

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

New fit of the 4 parameters:

- **shaping exponent β**
- **temperature exponents**

electrons

$$\mu_0 = 1417\frac{cm^2}{VS}(T/300K)^{-1.76\pm0.08}$$

$$\beta = (1.247 \pm 0.054)$$

$$v_{sat} = 1.0 \cdot 10^7 \frac{cm}{s}(T/300K)^{0.89\pm0.10}$$

holes

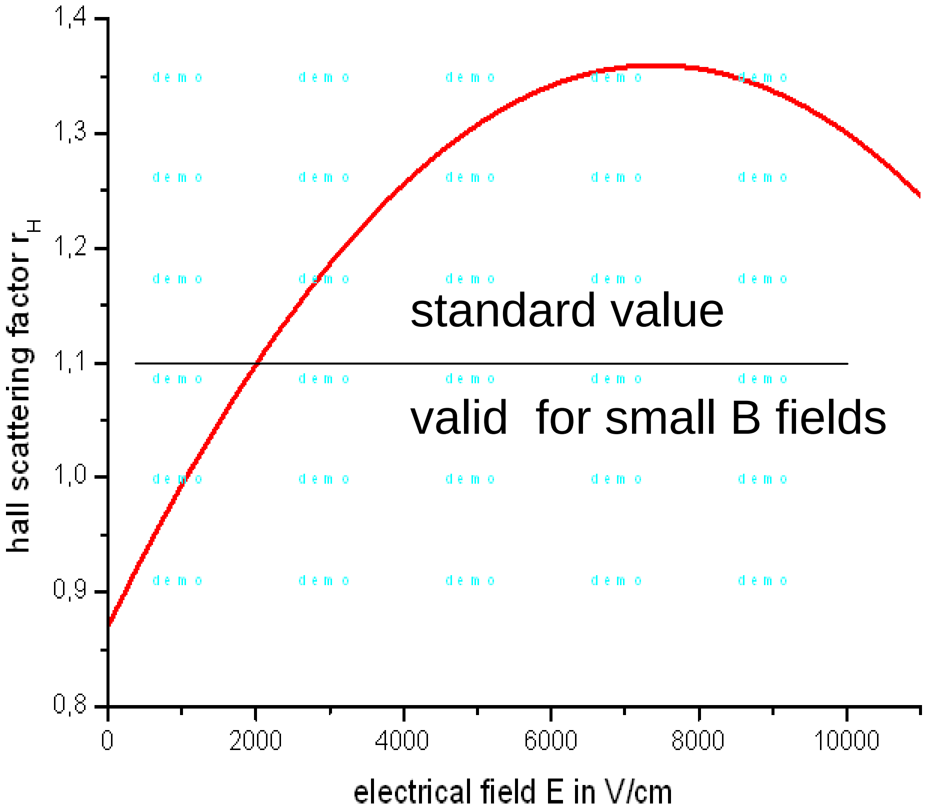
$$\mu_0 = 470.5\frac{cm^2}{VS}(T/300K)^{-2.60\pm0.03}$$

$$\beta = (1.383 \pm 0.052)(T/300K)^{0.07\pm0.05}$$

$$v_{sat} = 8.37 \cdot 10^6 \frac{cm}{s}$$

New: Parametrization of hall scattering factor

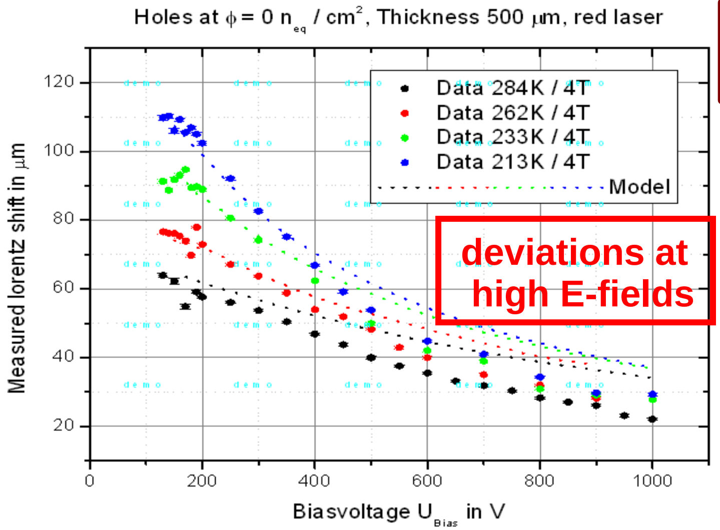
$$r_H = (0.87 \pm 0.02) + (1.32 \pm 0.09) \cdot 10^{-4} \cdot E - (0.89 \pm 0.09) \cdot 10^{-8} \cdot E^2$$



- Parabolic dependence of hall scattering factor on electric field
- Good description of data
- A constant r_H seems not appropriate (1.1 expected for small fields (i.e. small Lorentz angles, implying little curvature between scatterings)

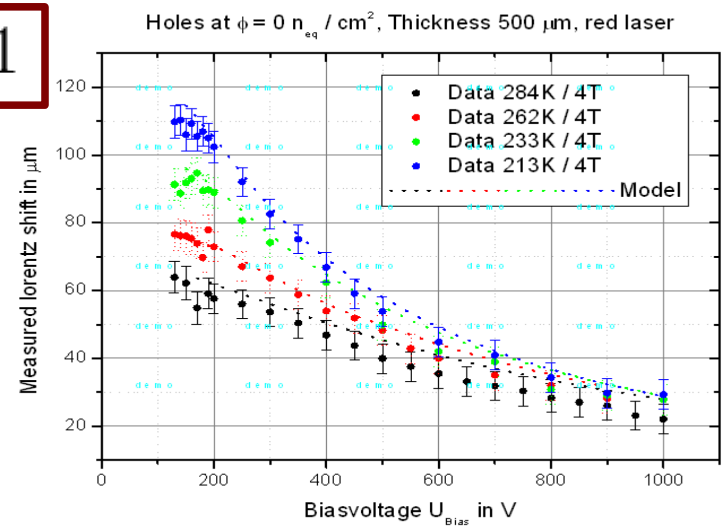
Results (1) holes CMS sensor (p-in-n)

OLD → **NEW**

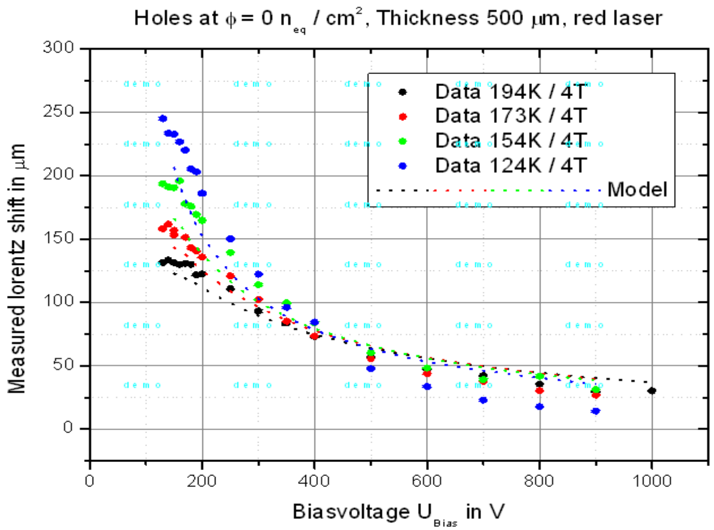


$$\chi^2/NDF = 1.1$$

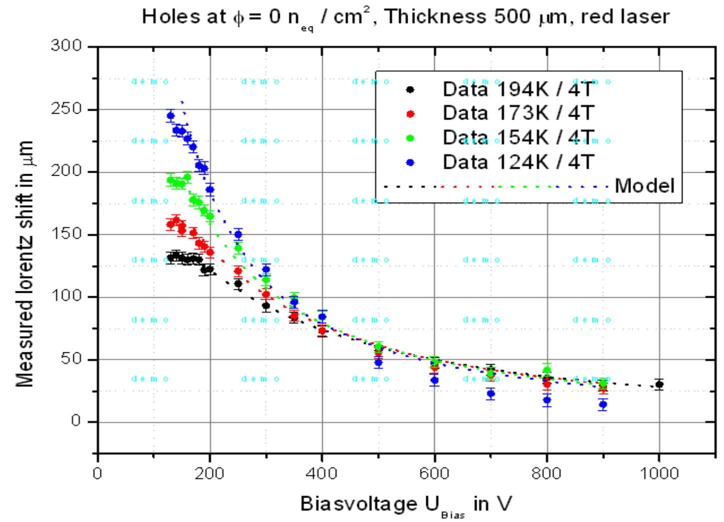
Fit →



holes

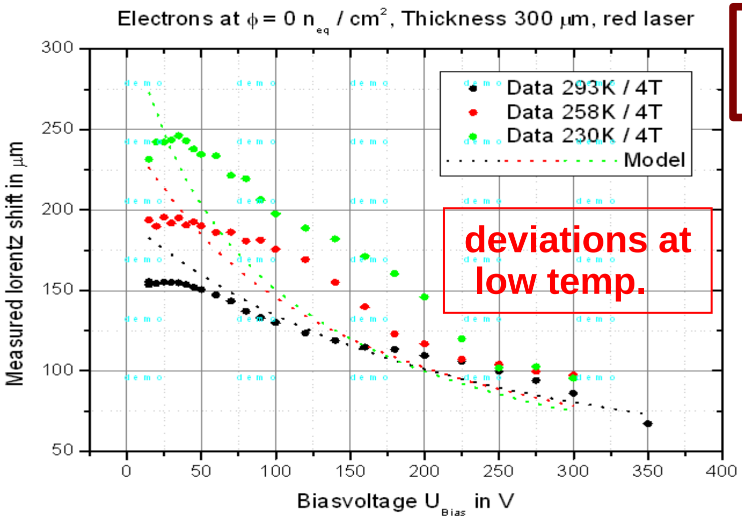


Fit →



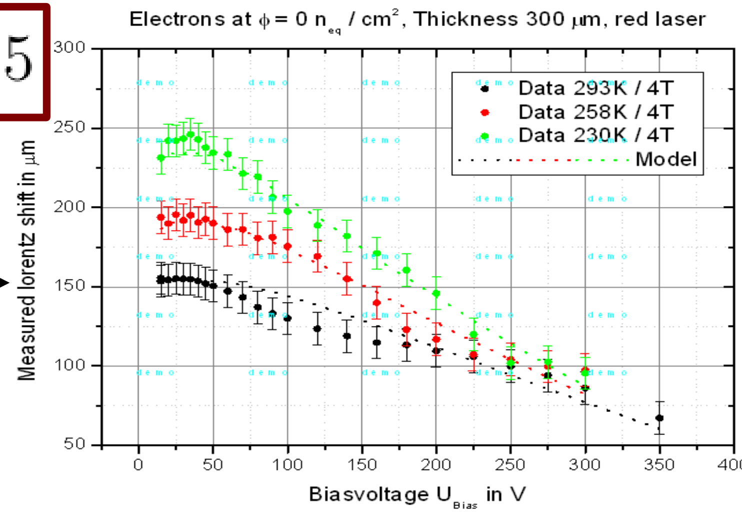
Results (2) electrons n-in-p (float zone)

OLD → **NEW**

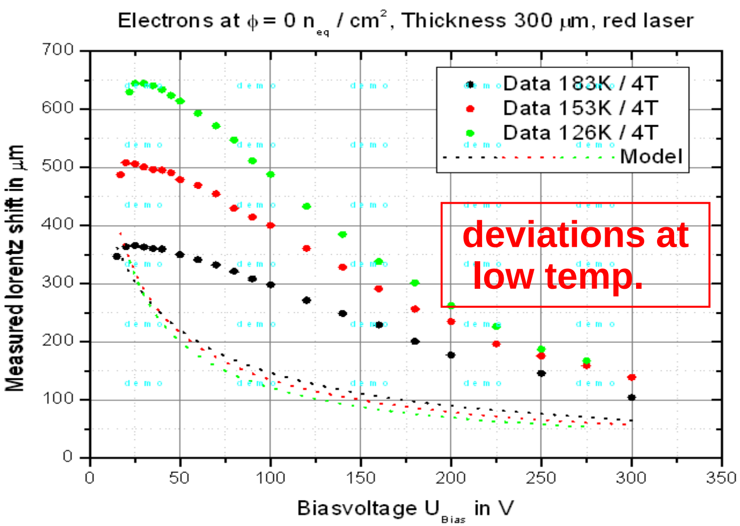


$$\chi^2/NDF = 0.5$$

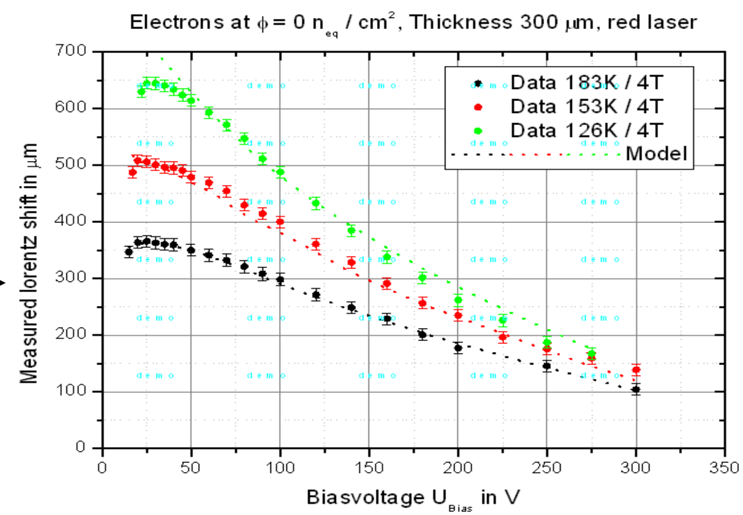
Fit



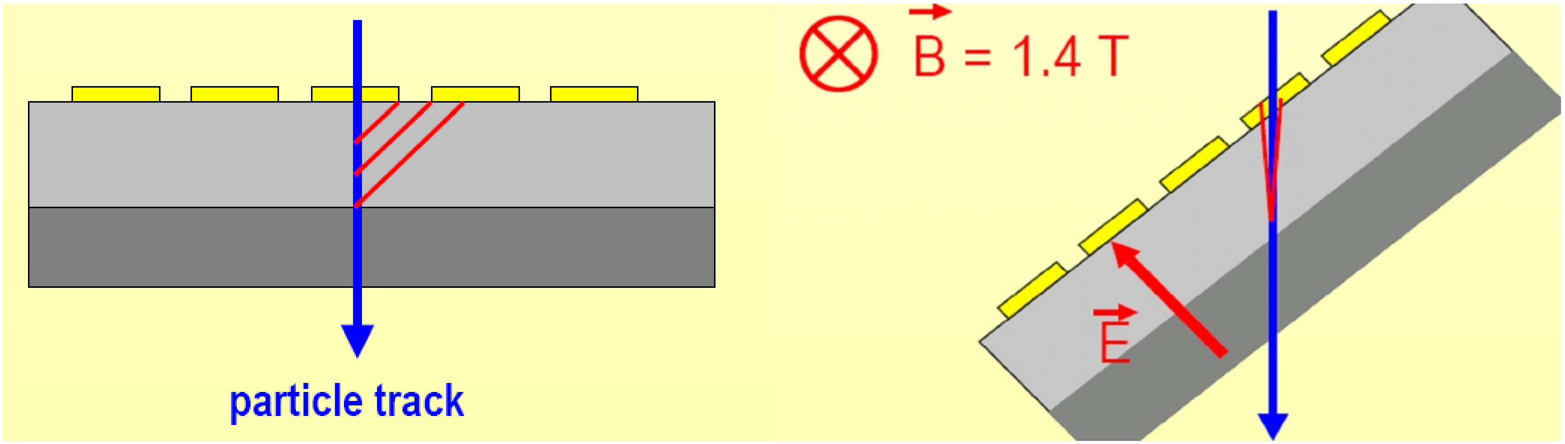
electrons

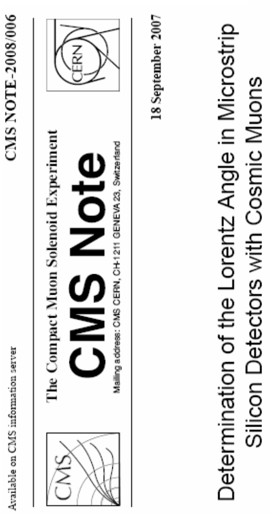


Fit



Lorentz angle from cluster width in CMS




CMS NOTE-2008/006
Available on CMS information server
The Compact Muon Solenoid Experiment
CMS Note
Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland
18 September 2007
Determination of the Lorentz Angle in Microstrip Silicon Detectors with Cosmic Muons
V. Ciulli, R. D'Alessandro, S. Frosali, C. Genta

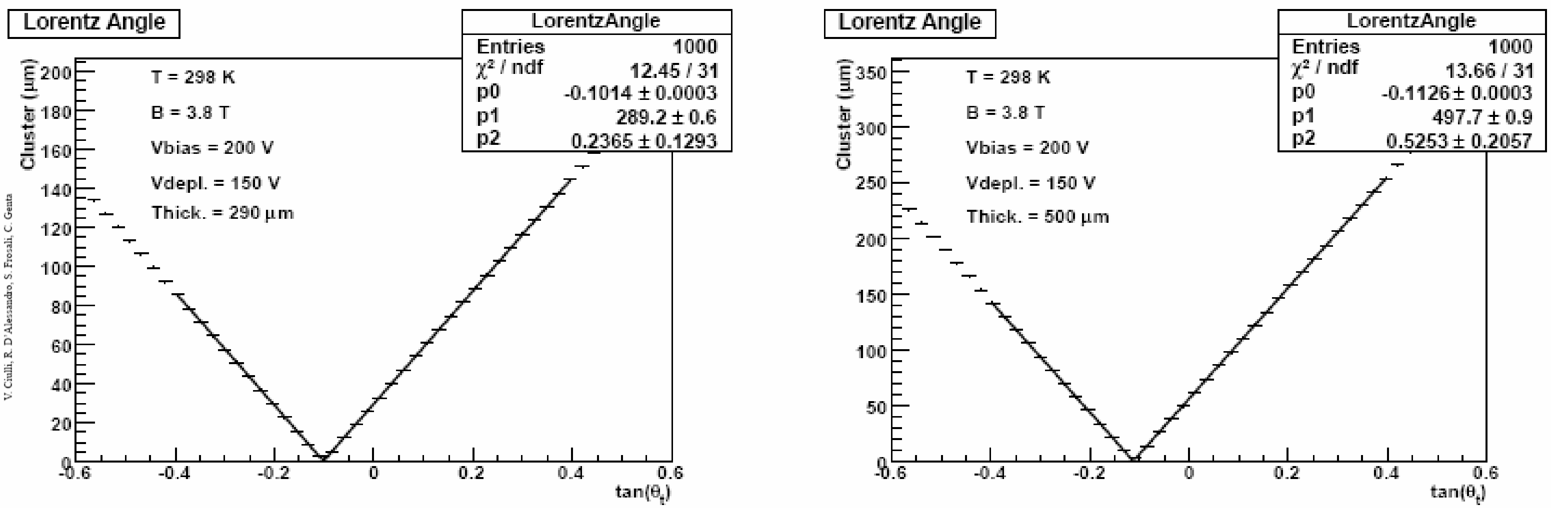
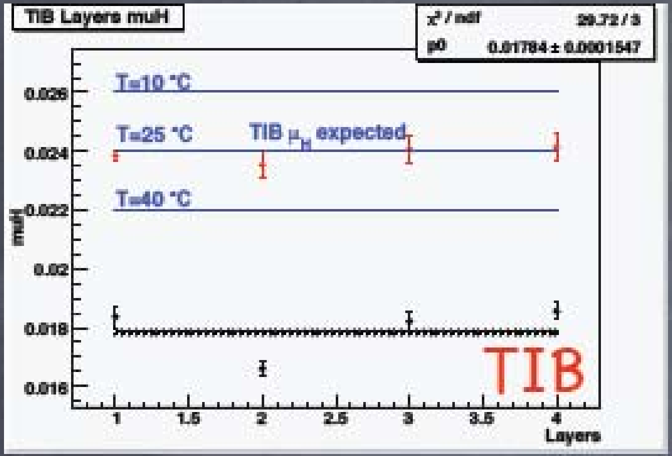
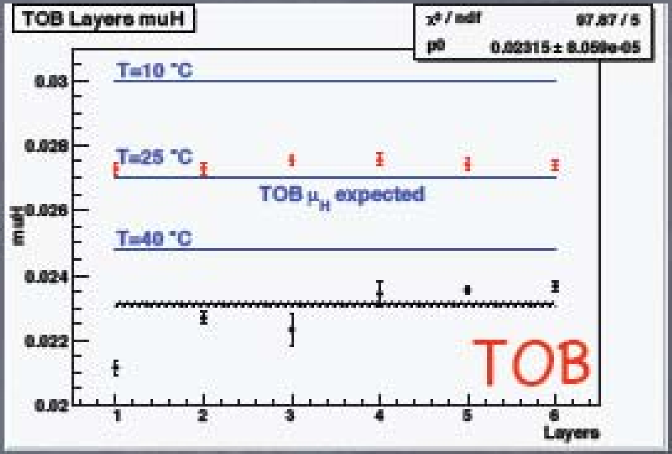


Figure 4: *Estimate of the tangent of the Lorentz angle (p_0) provided for the model, for TIB (left) and TOB (right) modules, at the MTCC working conditions.*

Comparison with previous results

CRAFT REPRO





- **Black**: (μ_H)measured ; **Red**: (μ_H)expLy ;
  Blue line: (μ_H)expected (TIB/TOB)
- In the plots the mean and the error on the mean obtained from the gaussian fit for each layer are shown
- We measure μ_H values lower than the expected ones, ~25% for TIB and ~14% for TOB

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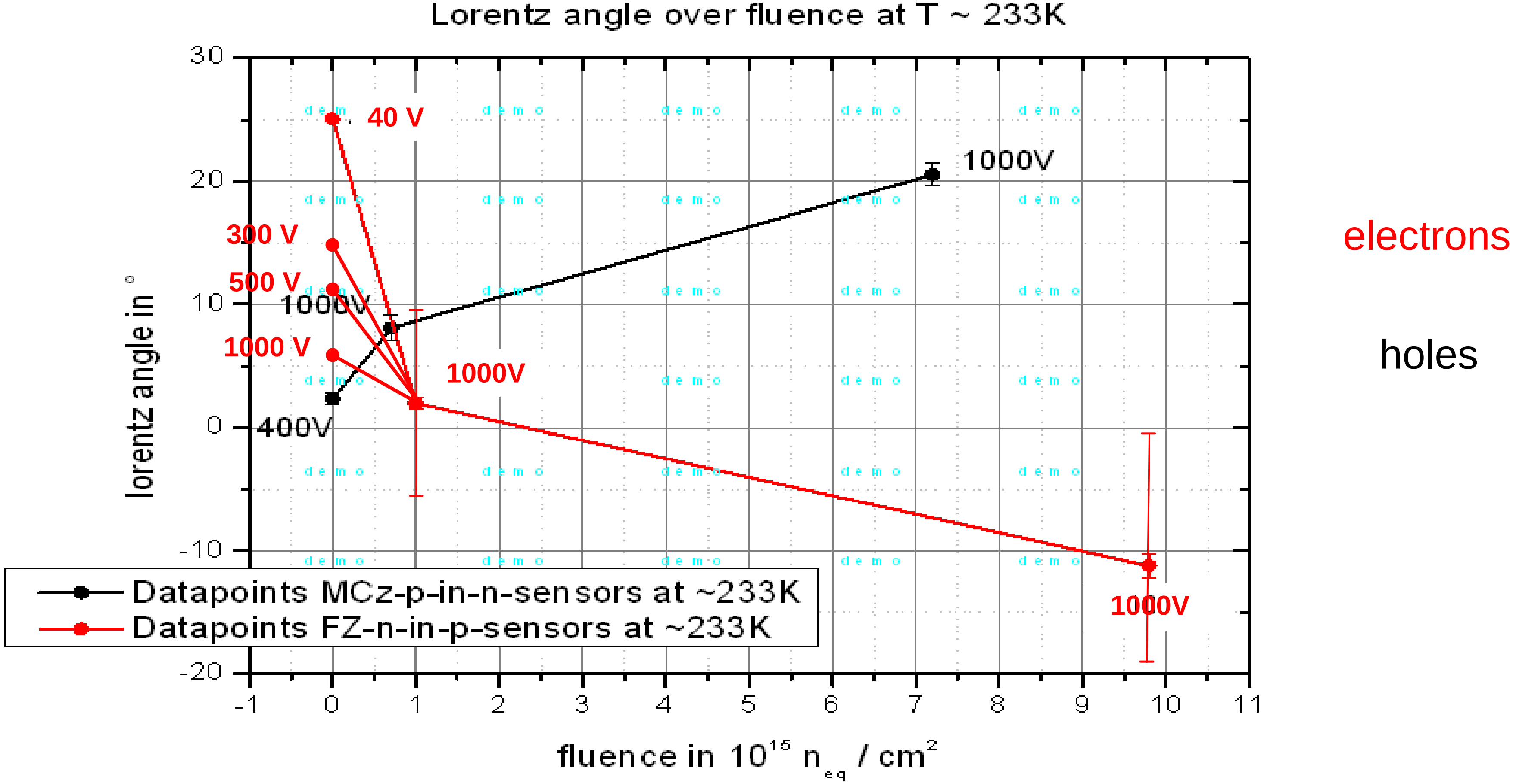
Lorentz angle versus fluence



- Strong dependence of Lorentz angle on fluence?
- Change of sign at high fluences for electrons??
  Non uniform E inside thin depletion zone?

Summary

- New Lorentz measurements for holes with real mini-CMS sensors (100 orientation, previous partially 111)
- Slight changes, but still incompatible with CMS minimal cluster width method
- Since Lorentz angle varies with fluence, in situ measure-ment by analog read out is needed for SLHC.
- Completely new parametrization for detectors with electron drift
- Strange change in sign of Lorentz shift of electrons at high fluences??