Lorentz angle studies in irradiated Silicon detectors between 77 K and 300 K

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Outline

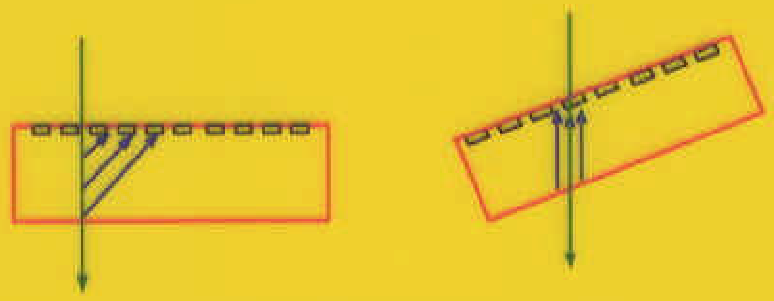
- **Motivation**
- **Definitions**
- **Results**

[a]Talk at: http://home.cern.ch/~deboerw

Motivation

KEY QUESTIONS:

- Should I rotate detectors to compensate Lorentz angle?



- Should I readout p- or n-side, i.e. electrons or holes?

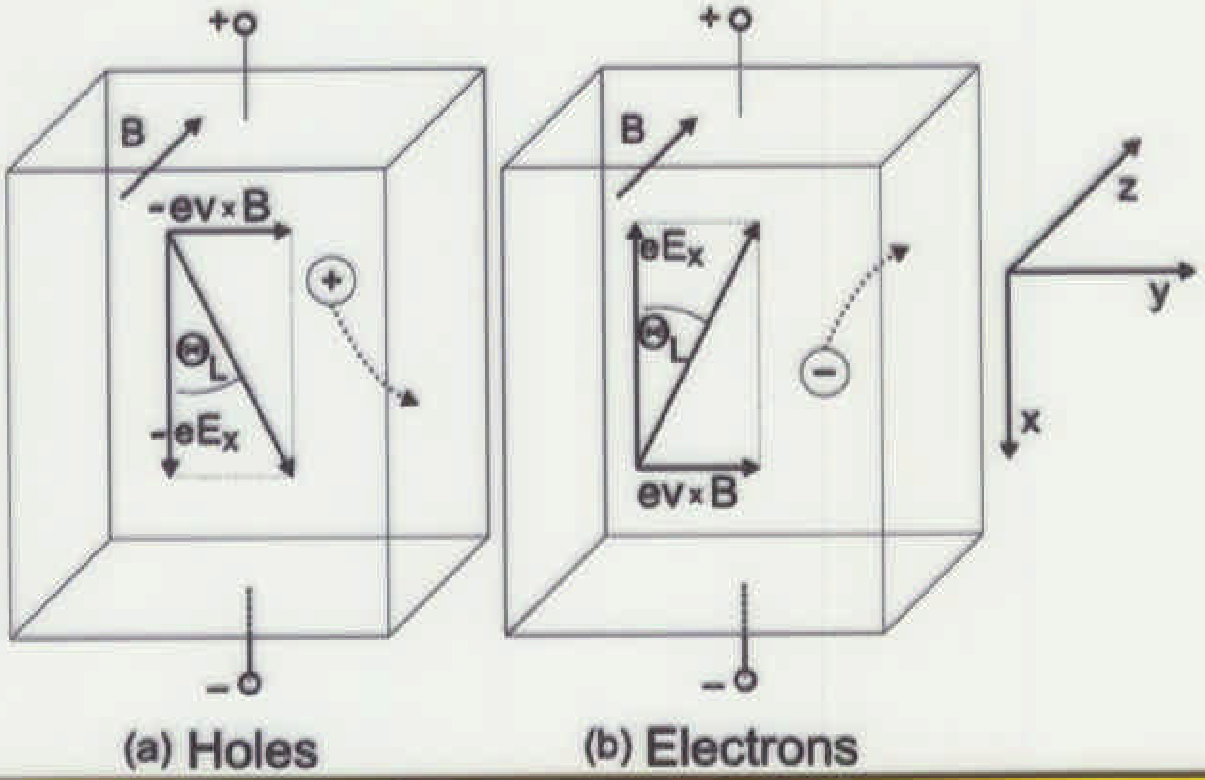
  Holes: cheaper and smaller Lorentz angle

  Electrons: large Lorentz angles, but larger signal, if detector cannot be depleted anymore after strong irradiation. In addition better charge sharing for electrons.

  (CMS: strip detectors: holes. Pixeldetectors: electrons)

- MIP Signal has contributions from BOTH holes and electrons. Holes have much smaller Lorentz shift. How does MIP signal look like in high magnetic field?
- How does Lorentz angle depend on temperature? (Detectors absolutely radiation hard below 150 K (LAZARUS effect))

Lorentz Angle



Lorentz angle θ:

$$\tan\theta = \mathbf{F_y}/\mathbf{F_x} = \mathbf{e\overline{v}x\overline{B}}/\mathbf{e\overline{E}} = \mathbf{vB}/\mathbf{E} \equiv \mu\mathbf{B}$$

Drift mobility: $\mu = \mathbf{v}/\mathbf{E}$.

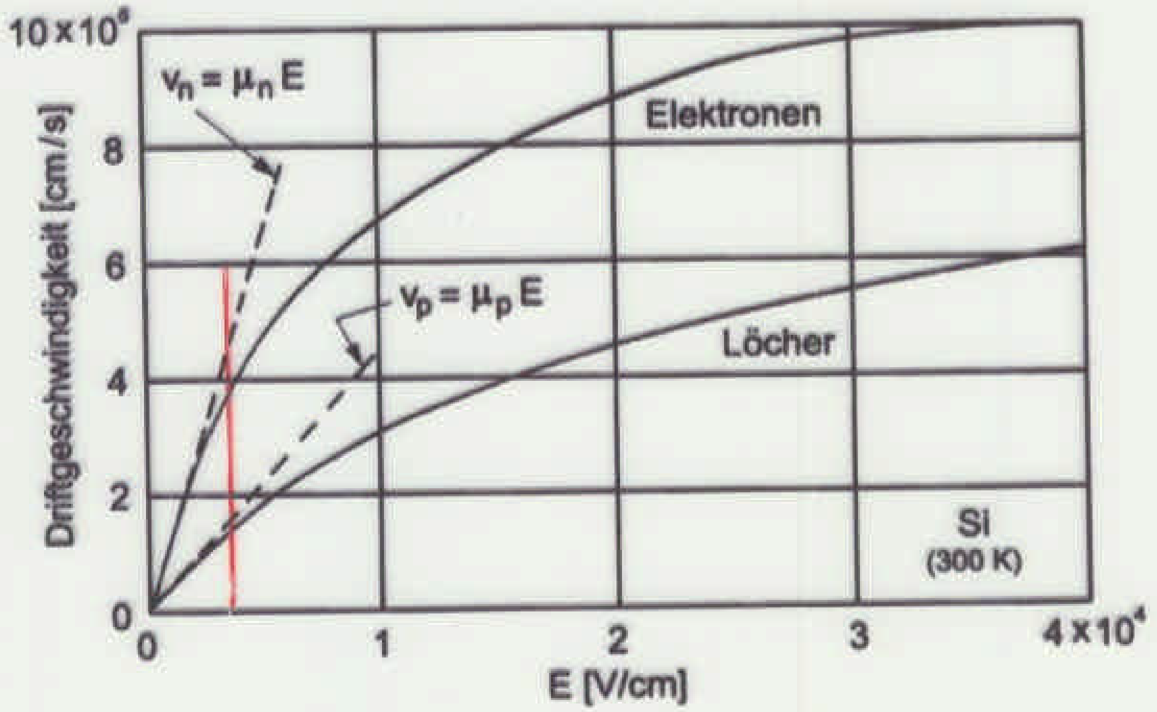
Second order effects:

$$\mathbf{F_x} \equiv \mathbf{m\dot{v}_x} = -\mathbf{eE_x} + \mathbf{ev_yB_z}$$

$$\mathbf{F_y} \equiv \mathbf{m\dot{v}_x} = \mathbf{ev_xB_z}$$

These coupled differential equations can be solved. Results for Lorentz angle as above.

Drift velocity vs Electric Field



Expect for Lorentz angle at V_{bias} = 50V, i.e. $< E > \approx 0.3 * 10^6$ V/m: electron drif velocity $v_e \approx 4 * 10^4$ m/s

$$\theta = \text{atan}(vB/E = 4{*}10^4 m/s{*}4T/0.3{*}10^6)$$

$\theta \approx 28°$ in 4T field.

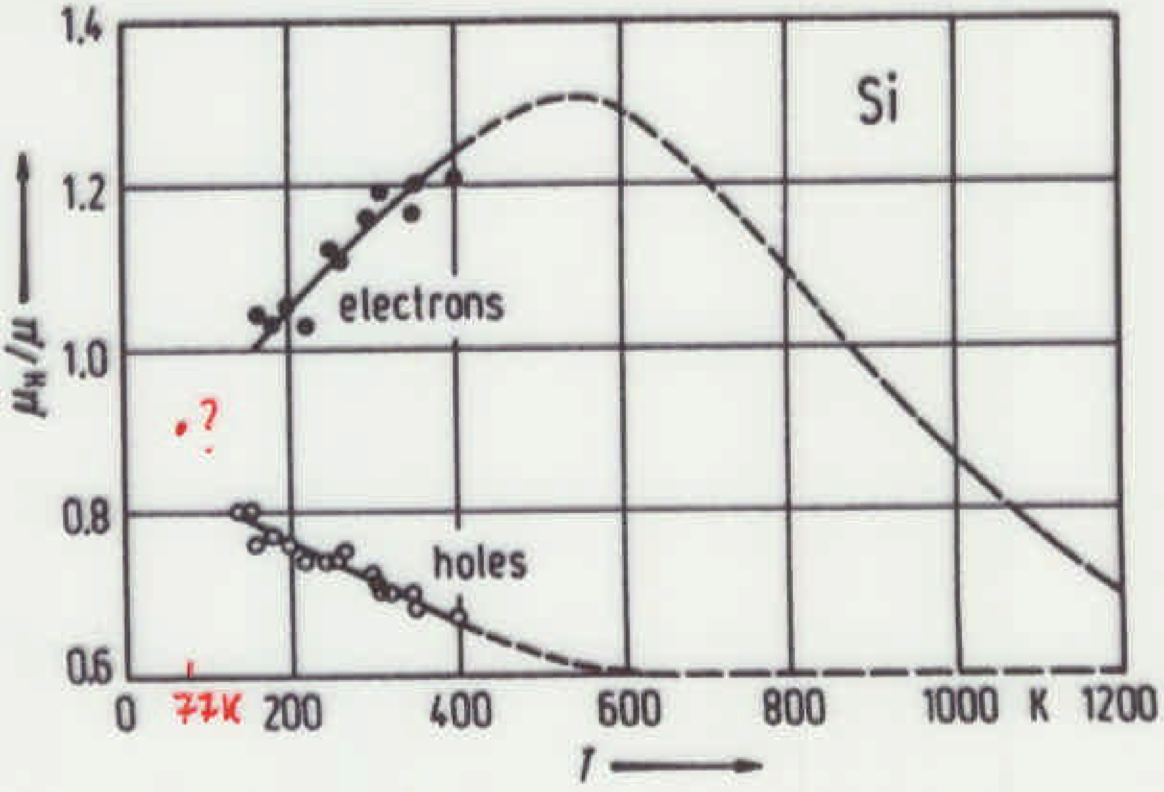
For holes a factor 2.5 lower.

Hall Scattering Factor

In magnetic field: different scattering cross sections → different effective driftvelocity → different Lorentz angle

$$\tan\theta = r_H \mu B \equiv \mu_H B$$

r_H **is called Hall scattering factor.**

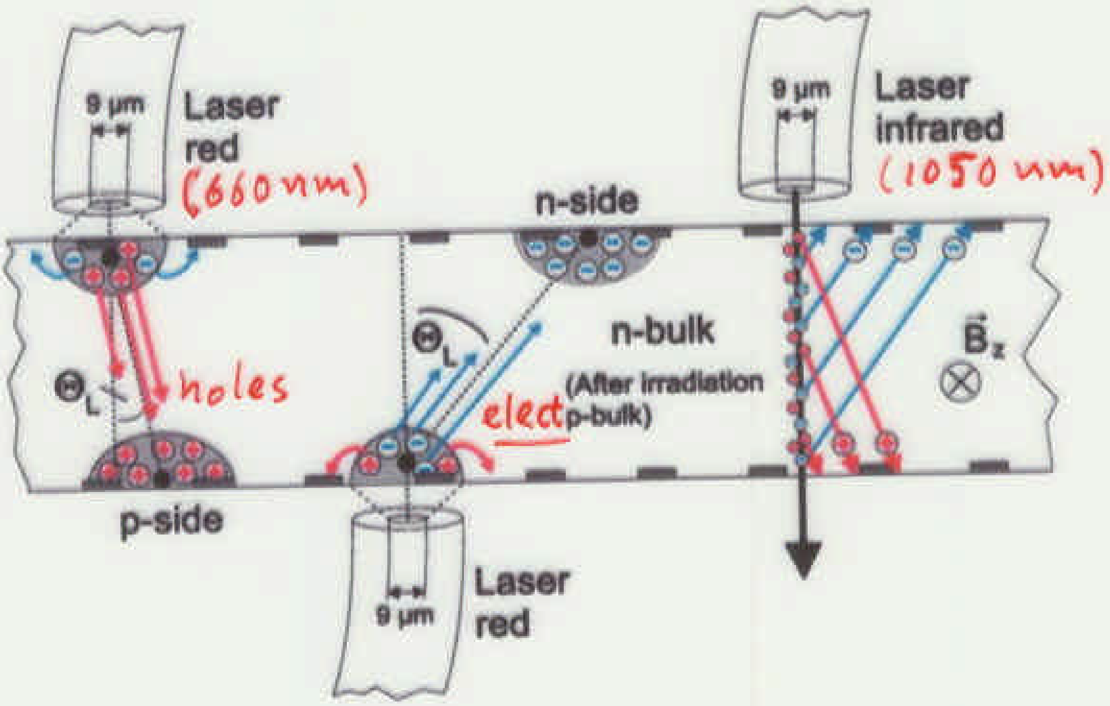


From Landau-Börnstein, (17a), Springer Verlag, Berlin, 1982.

Measure $r_H \approx 2$ at 77 K for electrons??

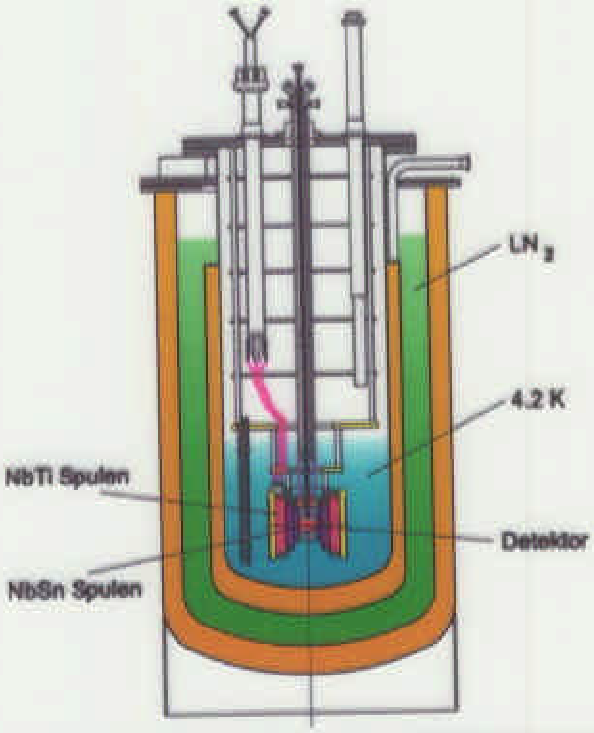
We

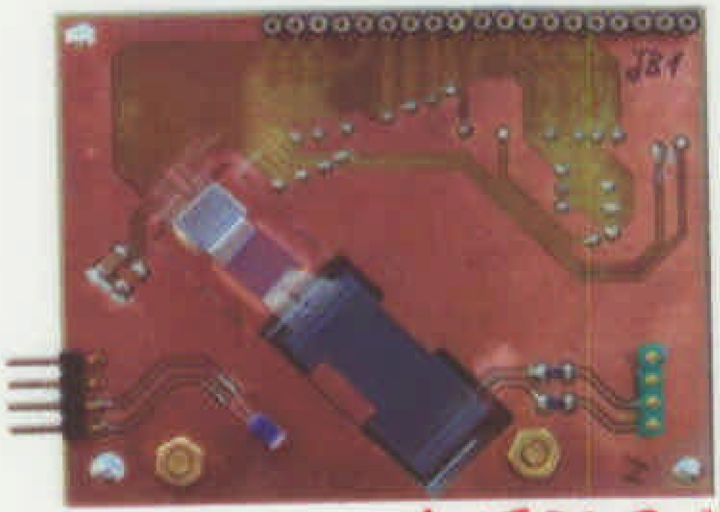
Lorentz Angle Measurement



Lasersignals on both sides

The 10T JUMBO Magnet (FZ Karlsruhe)

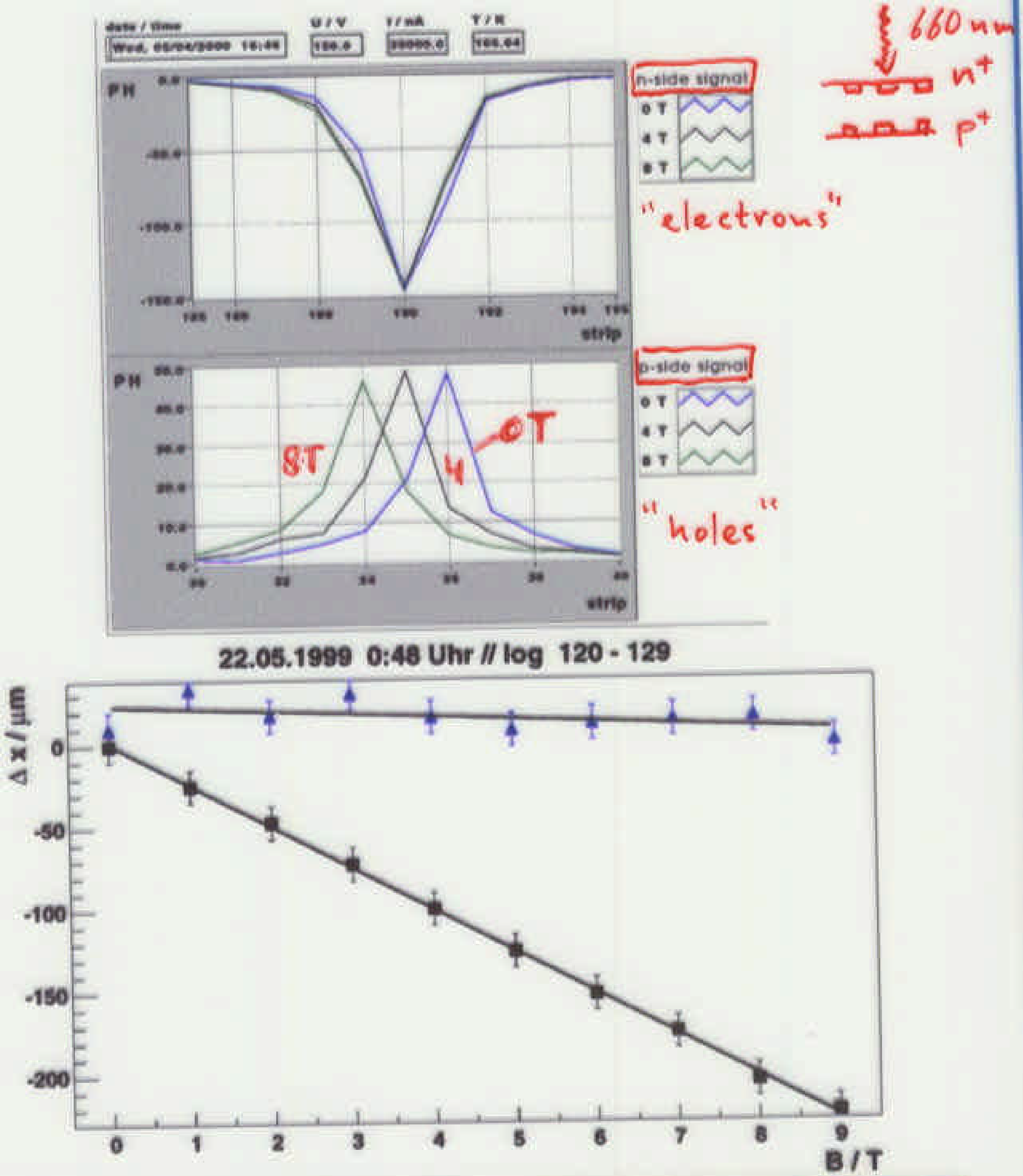




Hybrid with sensor, pitch adapter and amplifiers.
Pitch of double-sided Sintef sensor (from I. Abt):
p-side: 50 μm; n-side: 80 μm.

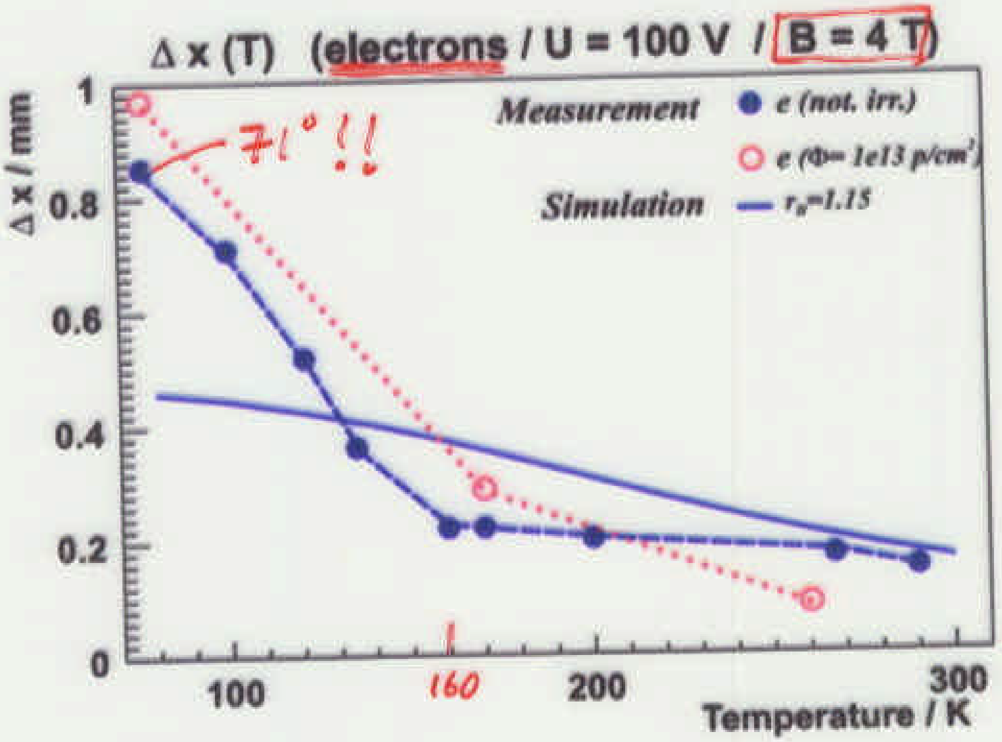
Sensor under 45° in order to measure on both sides.

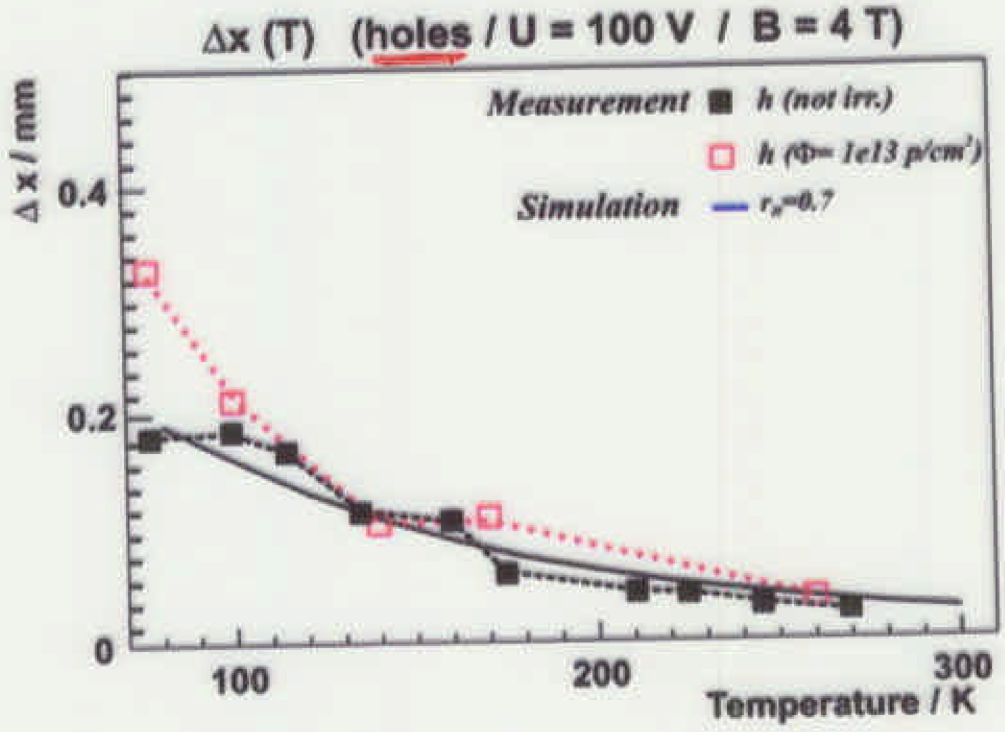
Lorentz shift vs magnetic Field



Displacement ∝ to magnetic field up to 9T!
Slow change on p-side due to finite penetration depth of red laser light.

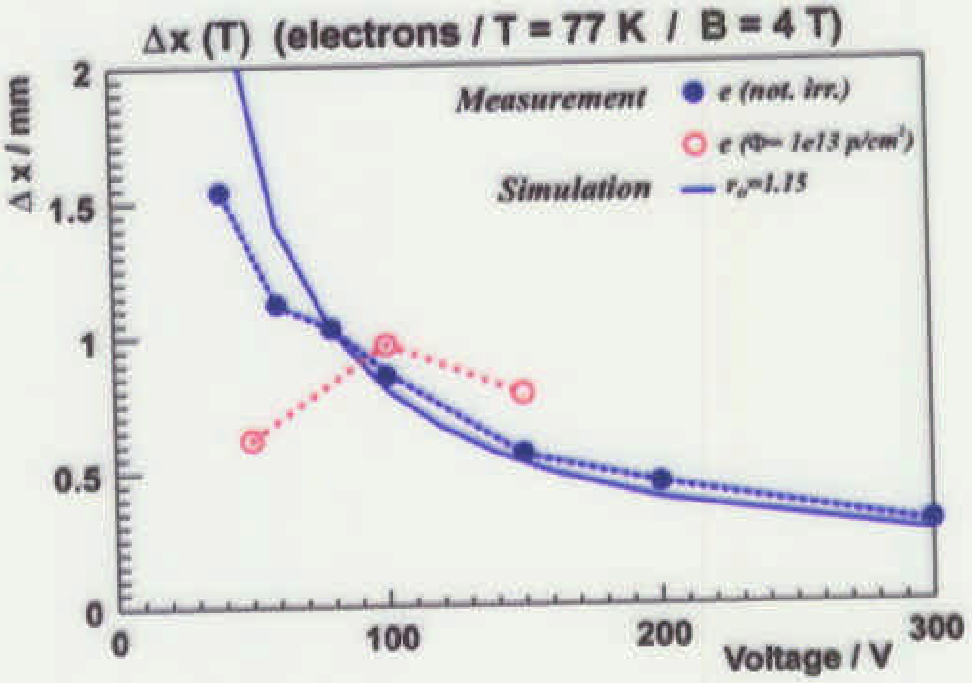
Lorentzshift vs Temperature

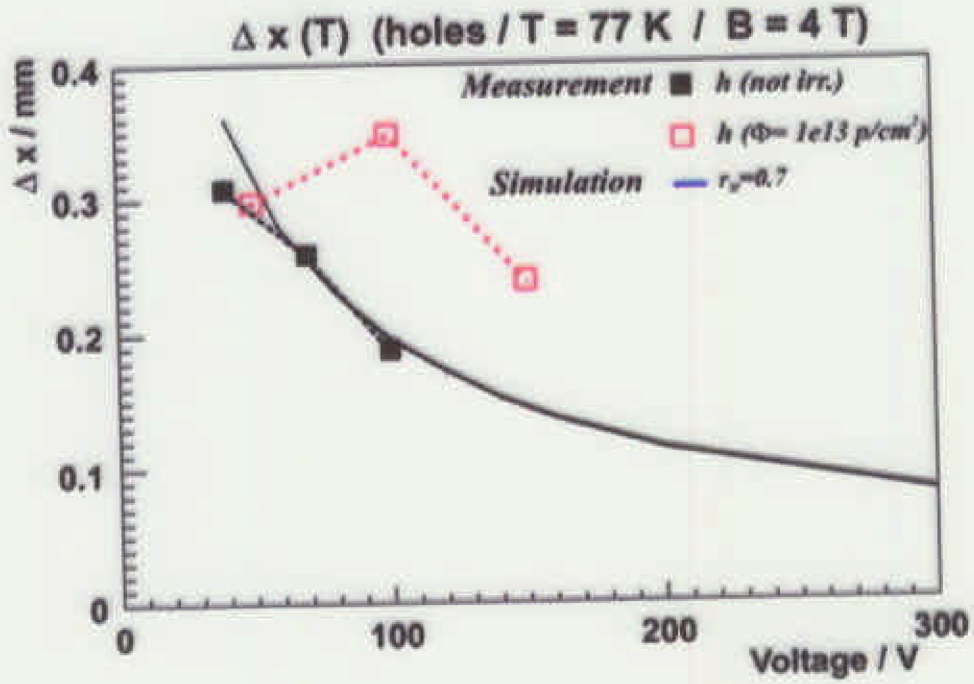




Davinci simulation cannot describe temperature dependence for electrons! with $r_H = 1.15$

Lorentzshift vs Biasvoltage





Davinci simulation ok for E-field dependence.
Irradiated detector depletes at 100 V!

Lorentz angles and displacements

300

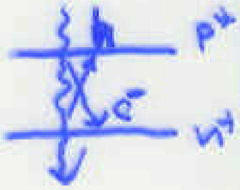
Assume ~~280~~ μm detectors at 4T

Bias[V]	Elec. (280 K) Θ	Elec. (280 K) $\Delta[\mu m]$	Holes (260 K) Θ	Holes (260 K) $\Delta[\mu m]$	Elec. (77 K) Θ	Elec. (77 K) $\Delta[\mu m]$	Holes (77 K) Θ	Holes (77 K) $\Delta[\mu m]$
40	$33°$	192	$6.5°$	34	$79°$	1539	$46°$	309
100	$30°$	170	$7.2°$	38	$71°$	852	$32°$	184
200			$5.9°$	31	$56°$	449		
300			$4.8°$	25	$45°$	295		

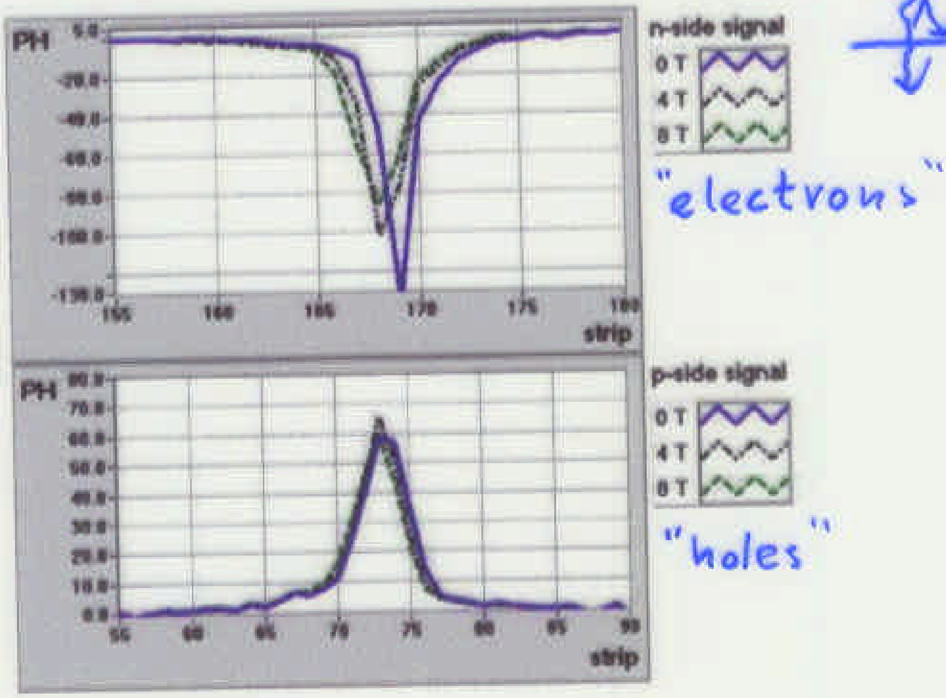
After irradiation with $10^{13}\ p/cm^2$:

Bias[V]	Elec. (280 K) Θ	Elec. (280 K) $\Delta[\mu m]$	Holes (260 K) Θ	Holes (260 K) $\Delta[\mu m]$	Elec. (77 K) Θ	Elec. (77 K) $\Delta[\mu m]$	Holes (77 K) Θ	Holes (77 K) $\Delta[\mu m]$
50	$21°$	117	$8.5°$	45	$65°$	630	$45°$	297
100	$23°$	127	$8.0°$	42	$73°$	970	$48°$	329
150	$23°$	126	$7.6°$	40	$69°$	785	$37°$	228

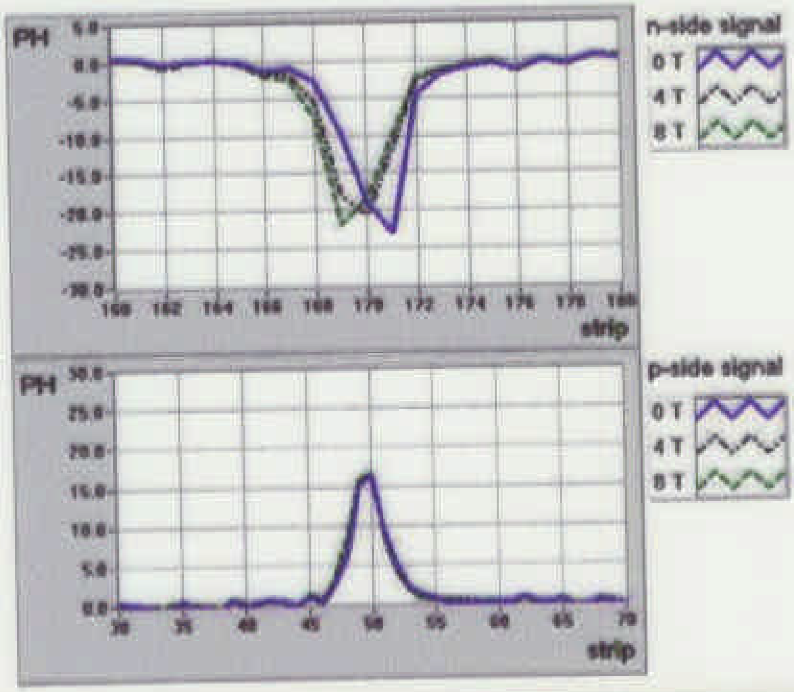
Pulse shapes for 1060 nm laser



Irradiated detector ($10^{13}\ p/cm^2$)



Non-irradiated detector:



Pulse shape not strongly affected by radiation damage.

Summary

- The Lorentz shift for electrons (ca. 200μm for 280 μm thick detectors at 4 T) is 4 to 5 times the Lorentz shift for holes at room temperature.
- At liquid nitrogen temperatures the Lorentz shift for electrons increases dramatically by a factor 2 to 8 in disagreement with ~~present simulation programs.~~ expectations
- Overdepletion can reduce this Lorentz shift.
- Pulse shapes not significantly changed by irradiation in a 4 T field with standard electronics.
- Irradiation reduces Lorentz shift of electrons at room temperature by 25%, but increases Lorentz shift at temperatures below 200 K.
- Irradiation hardly affects Lorentz shift of holes. at room temp.