Sensor R&D
Status and Plans

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Outline

Overview of the ongoing R&D (mostly from last Sensor WG meeting)

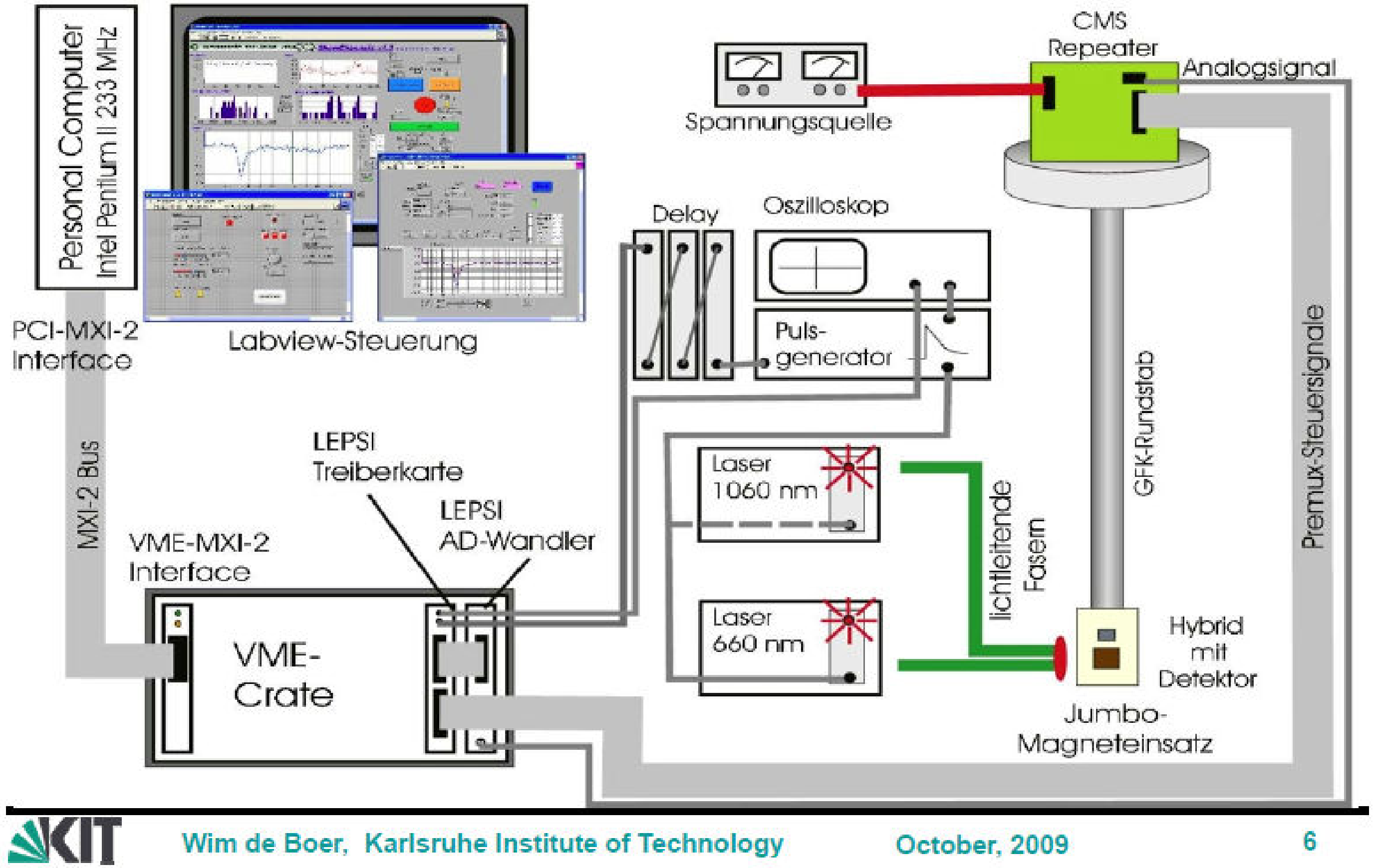
- **Lorentz angle studies**
- **Latest results on MCZ sensors (SiBT)**
- **Calibration of testing setups**
- **Precision capacitance measurements on Pixel sensors**
- **3D sensors development**

Central European Consortium will present their recent results

Discussion on HPK submission

Marcello (Status)
Frank (Plans)

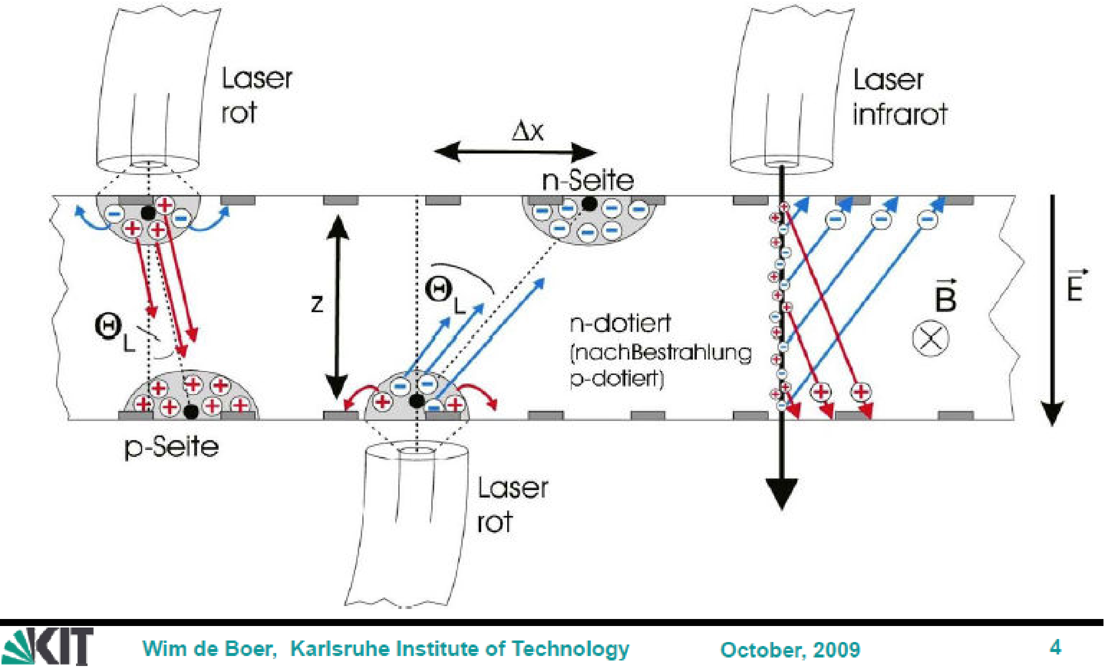
Lorentz angle studies



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

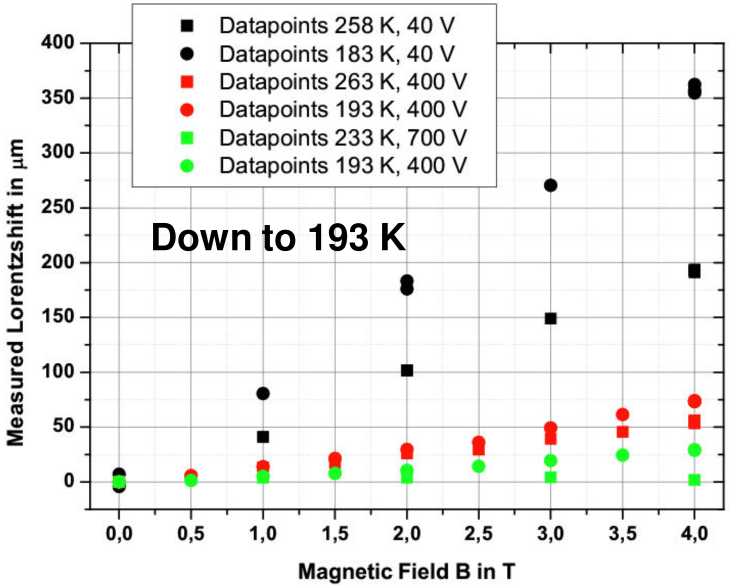
- **Measured RD50 n-in-p sensors to get much better Lorentz angle measurements for electrons**
- **Measure Lorentz angle in highly irradiation sensors**

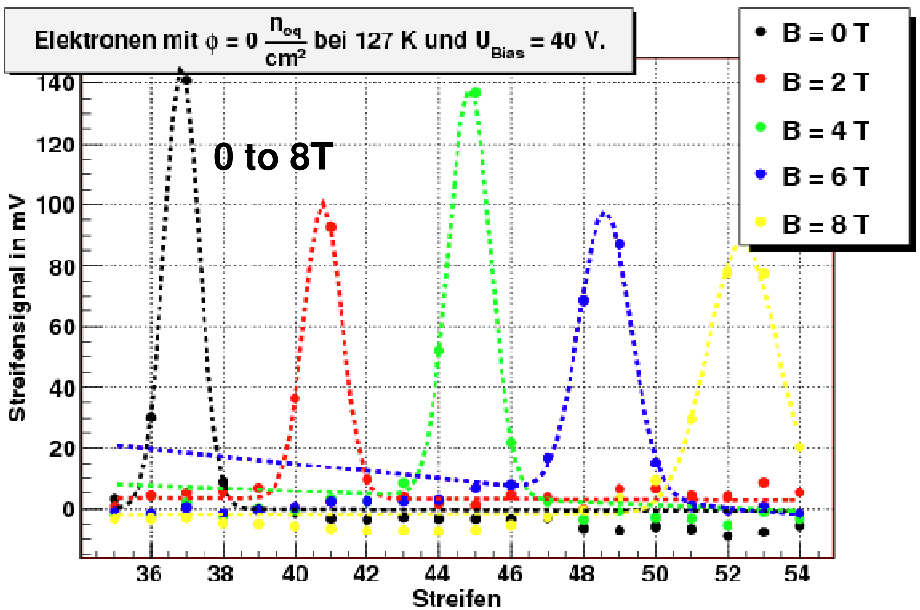
Capabilities



The setup allows for measurements of holes/electrons Lorentz angle. At different voltages and at different temperatures.

Sensors are readout through PreMux (=APV w.o. Pipeline) on hybrid.

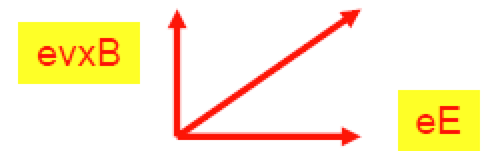




Parametrization of Lorentz angle model

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

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

<u>New fit of the 3 parameters:</u>

- shaping exponent β
- temperature exponents

electrons

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

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

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

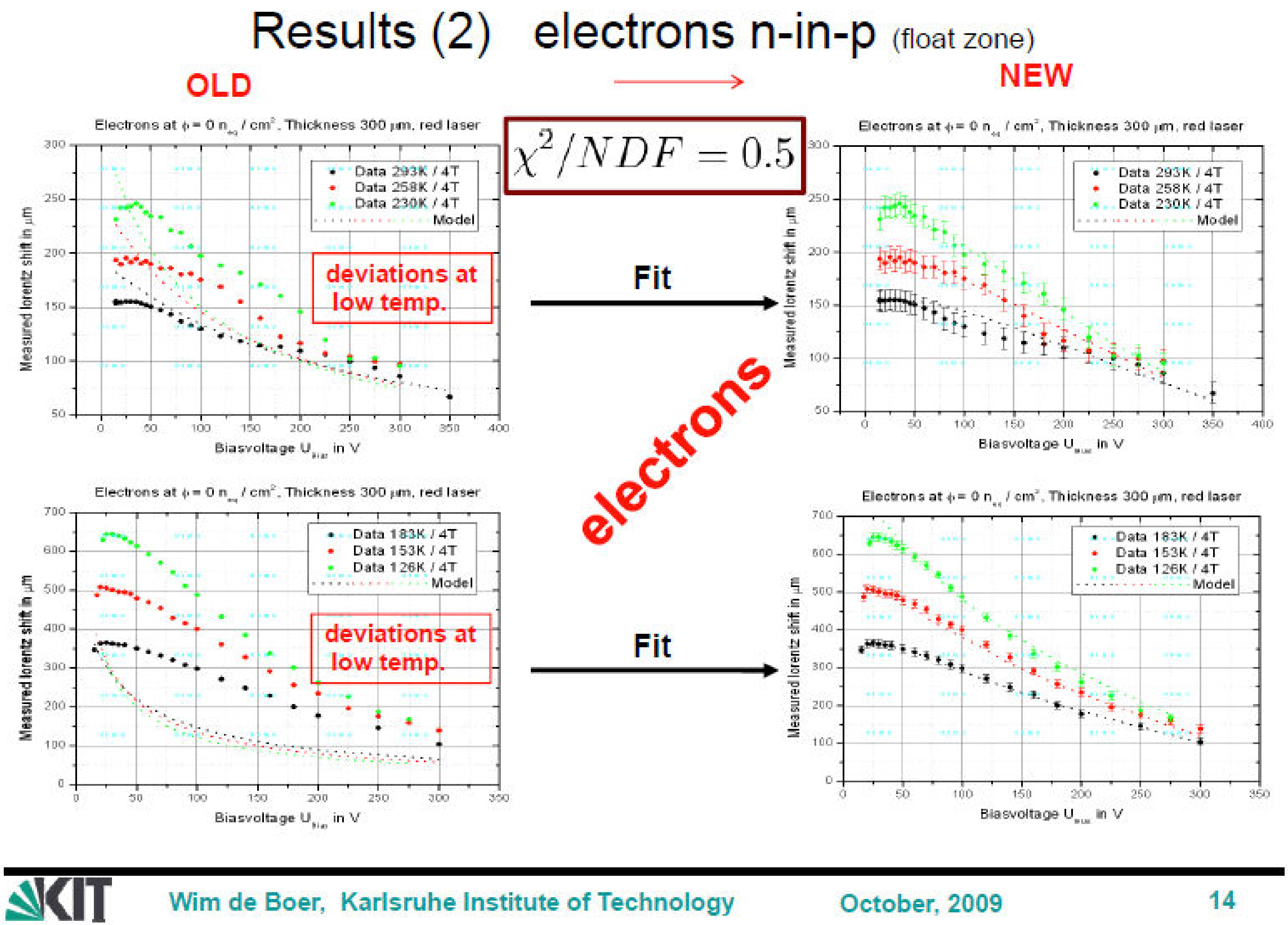
holes

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

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

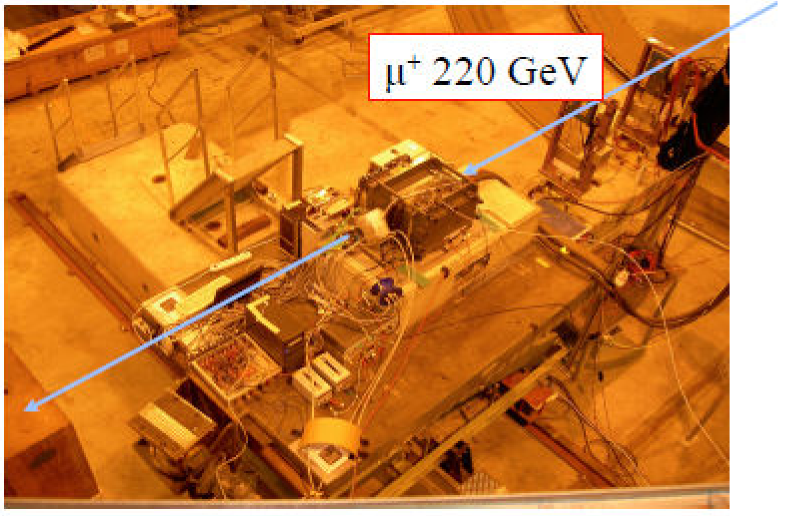
$$v_{sat} = 8.37 \cdot 10^6\frac{cm}{s}$$

Model and Data (both e- and h+)



How Si detector R&D is done at H2 test beam ?

- CMS based read-out electronics (APV25) and DAQ
- 8 detector planes providing reference tracks for DUT
- Measurement down to -50°C
- 50 000 events in about 15min
- Effective area 4cm × 4cm
- Telescope resolution ~4μm
- Detectors under test processed at Microelectronics Center of Helsinki University of Technology
- Irradiation at Univ. Karlsruhe, 26 MeV protons



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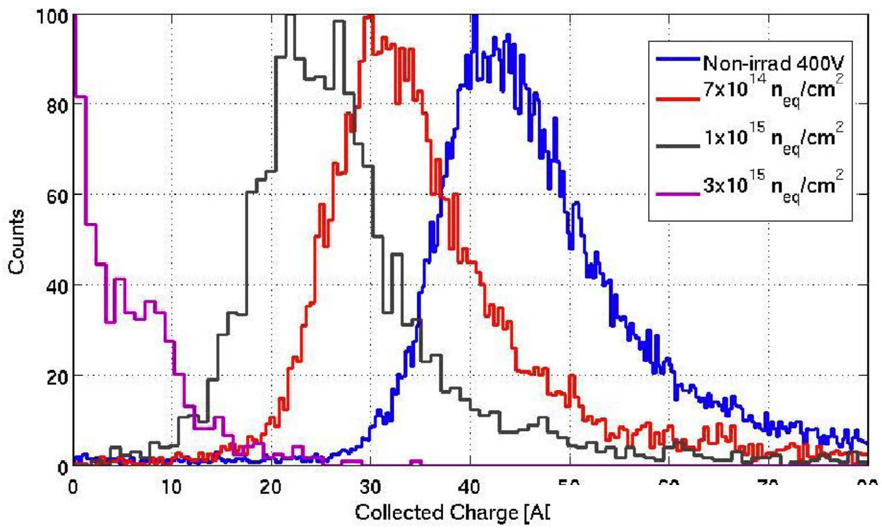
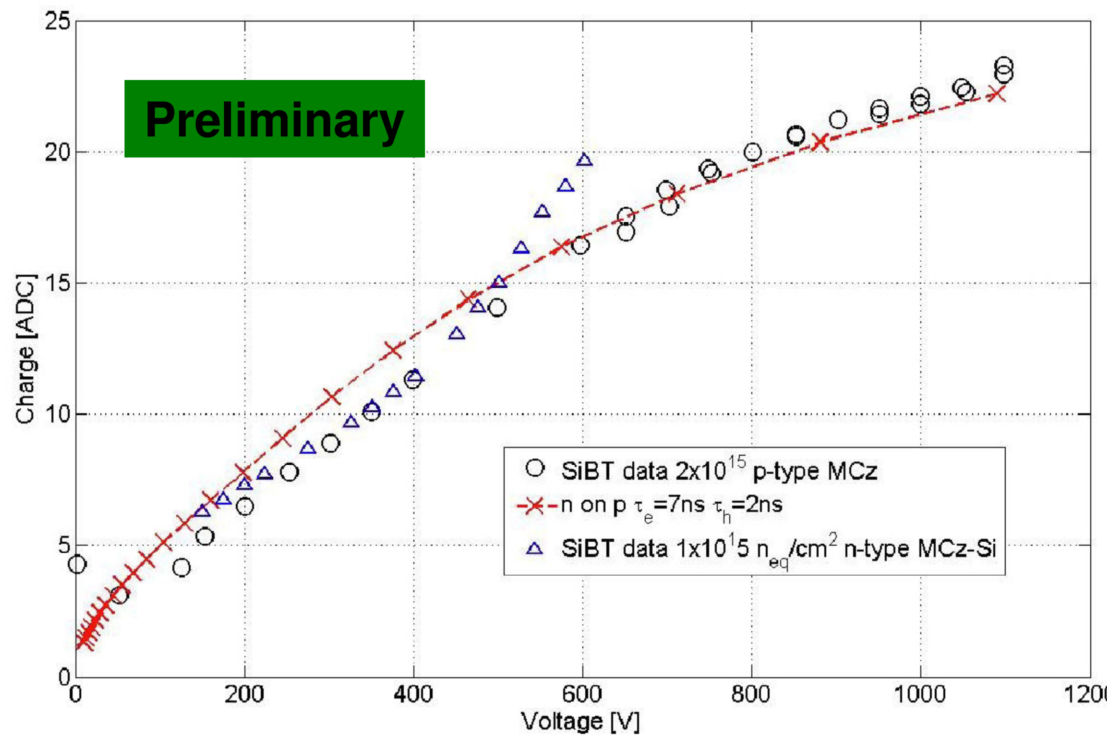
e- and h+ charge collection



N-type MCZ

Hard to find a Landau after 3E15 fluence.

When Collecting electrons there is a factor of two in fluence (given the same charge collected).



Summary and outlook

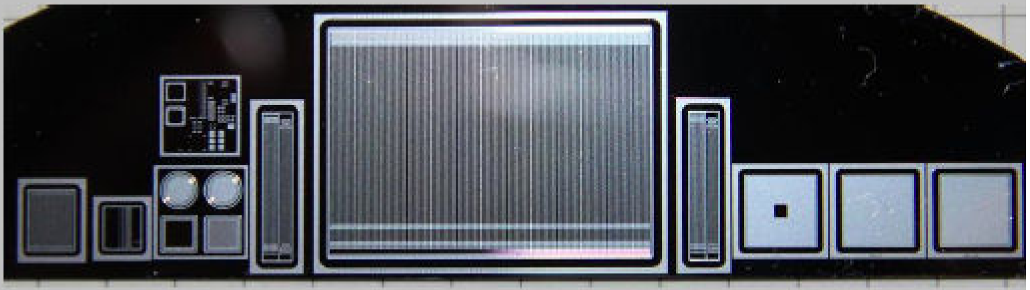
Summary of test beam period 28.06.-13.07.2009

- > 1Tb High quality data was taken.
- Several different novel detectors were measured, including CID, 3D, thin MCz-Si, p on n structures etc.
- The comprehensive off-line data analysis will take several months. Results will be reported in RD39 and RD50 Workshops and CMS Tracker Upgrade meetings.
- Preliminary results show nice coincidence with classical models for p and n-type MCz-Si both.
- Increase of CMS TK Up Si sensor R&D test beam activity is foreseen in coming years

28/09/09 Jaakko Härkönen, Upgrade Sensor Working Group meeting, CERN 30 September 2009 13

calibration program

Karlsruhe measured several non-irradiated former CMS teststructures (HPK 300µm)



Participants:

- Desy 15.07
- Florence 1.09
- Hamburg 15.07
- Louvain 15.07
- Pisa 1.09
- Rochester 1.08
- Vienna 15.07

some parameters and settings:

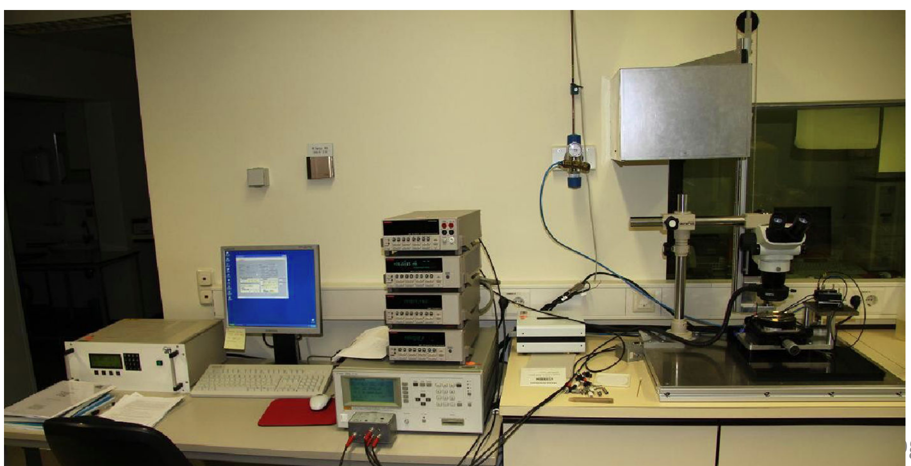
- measurement to be done at room temperature (21°C) and relative humidity < 30%
- frequencies for capacitance measurements:
  - CV 1kHz
  - CC 100Hz
  - Cint 1MHz
- all strip measurements at Vbias = 600V

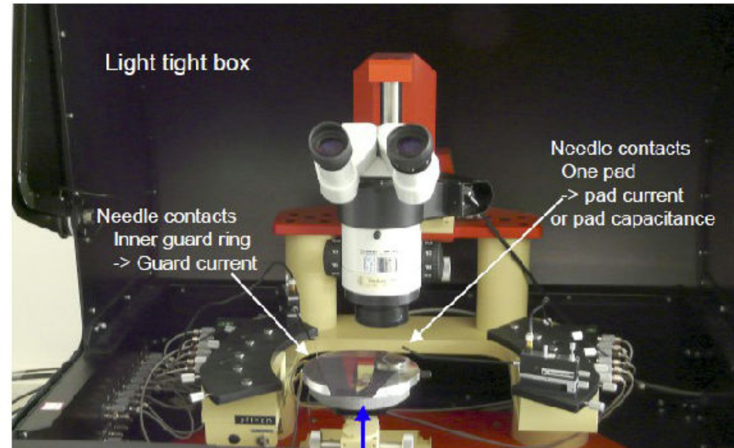
http://www-ekp.physik.uni-karlsruhe.de/~hartmann/Calibration_and_final_measurement.3.doc

Results

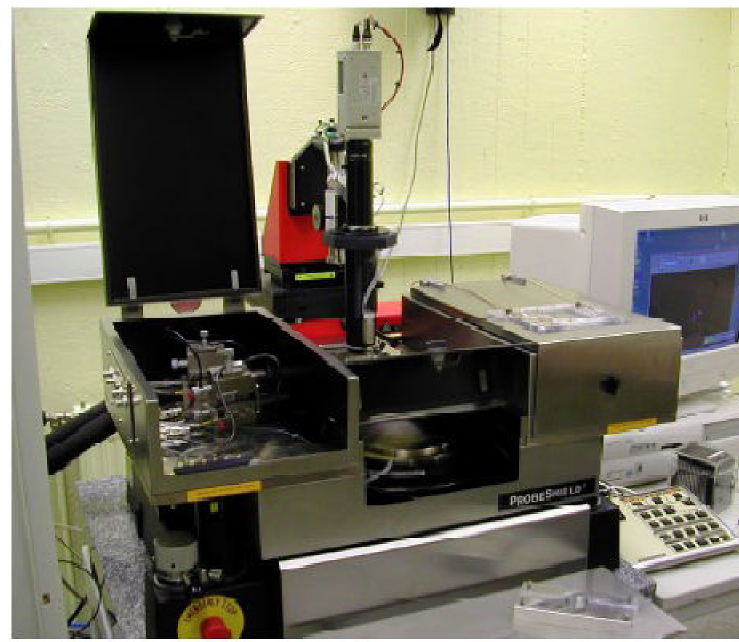
Minisensor strip measurements

results [Karlsruhe]	Hamburg	Vienna	Louvain	Desy	Rochester
Rpoly [MOhm] [1,41 - 1,49]	1,51	1,43		1,43	1,44
CouplCap[pF] [68,0 - 69,6]	69,4	69,4	21 - 72	73,1	80,3
Rint [Gohm] [> 5]	> 40		> 4	above limit	
Cint [pF] [0,63 - 0,66]	0,71		0,64 - 1,2	0,68	
Ileak [pA] [< 120]	< 26	mean ~ 60		< 12	
Pinhole [pA] [< 389]	< 1	< 1000		no current measured	
Time per strip [55 s]	~ 25 min			~ 35 min	





Backplane contacted via Al table ('+' of high voltage)_



Calibration of testing setups (conclusions)

Conclusion II

- we achieved comparable results for most measurements
- we found some issues to be improved
- so far we did no voltage scans on single strips => next round!
- switching between the single measurements has to be automatic in order to cope with the huge number of sensors (strips) to be qualified. Time varied between 1 and 35 min per strip.
- cold chucks need to be installed in order to measure irradiated halfmoons

Plans:

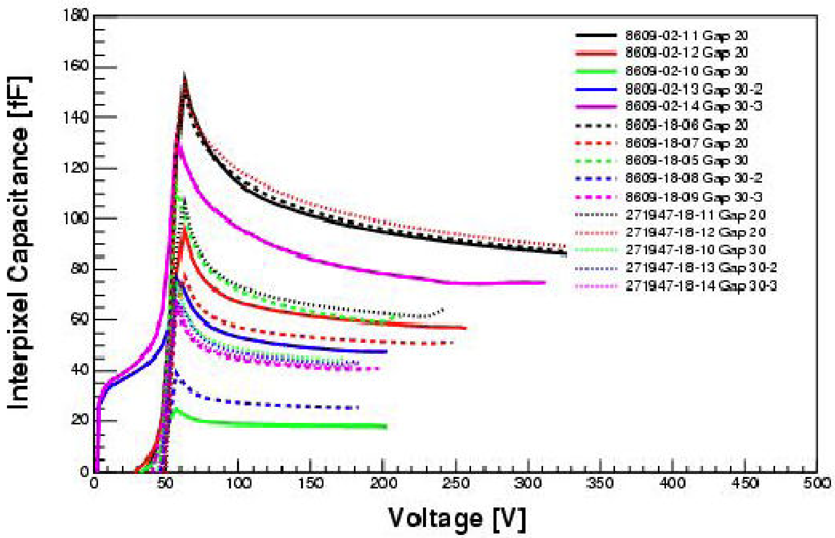
4 irradiated halfmoons are in Karlsruhe, but need to be measured. Will be ready for shippment by 19th of October.

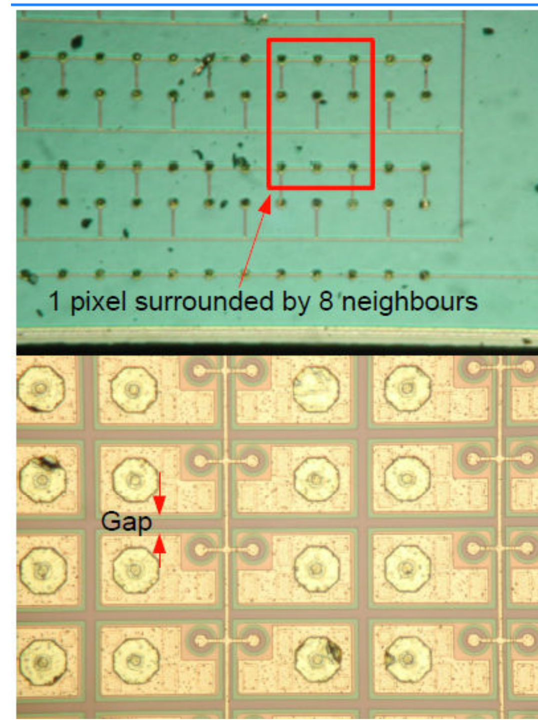
Pixel capacitances

Capacitance measurements of CMS pixel barrel sensors

T. Rohe[1], F. Bechtel[2], V. Radicci[3], J.Sibille[1,3]

[1] Paul Scherrer Institut
[2] University of Hamburg
[3] University of Kansas



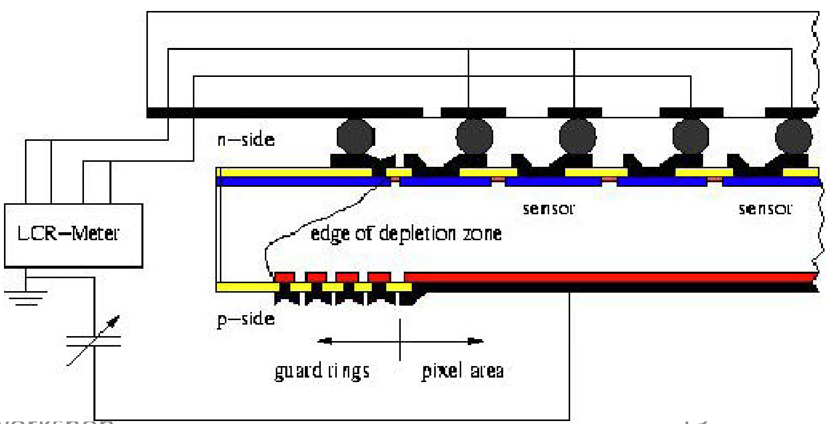


Inter pixel capacitance in bias dependent and saturates about 300-350V

- **Increasing the gap from 20 to 30 mm results in a drop of C(150V) ~100 to 70 fF**
- **Large fluctuations and some outliers**

– more statistics

– check dependence on technology parameters (mainly p-spray dose)



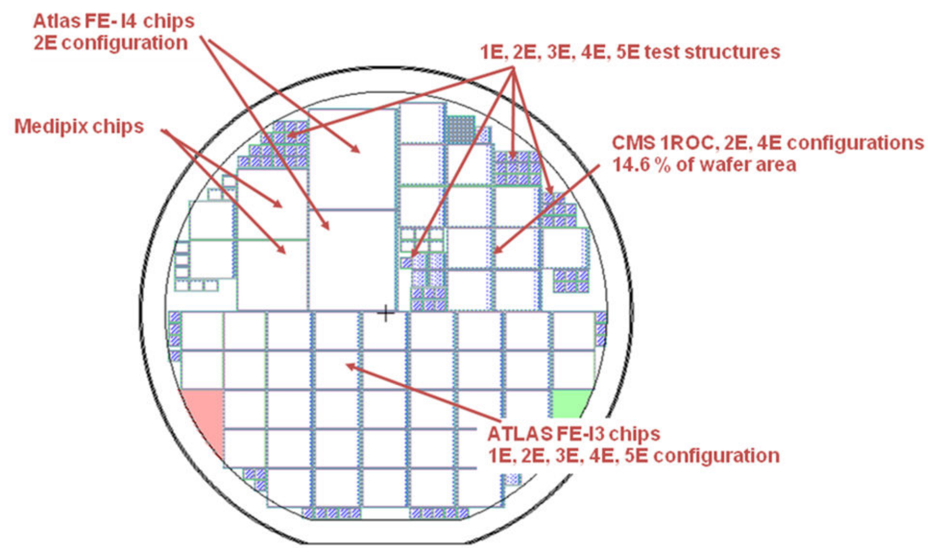
3D Sensors

Major accomplishments

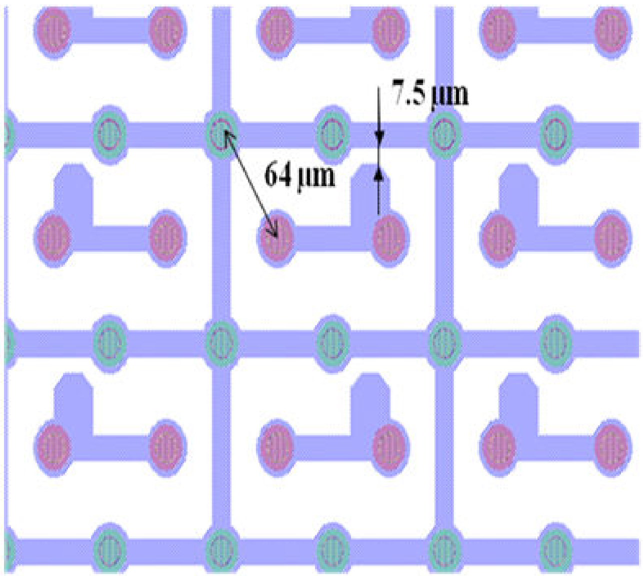
1. We have collaborated with groups in ATLAS and MEDIPIX and funded a run of 3D sensors with SINTEF.
2. The layout of the wafer is shown in Fig 1.
    1. Two sensors matching the PSI46 ROC with 2 and 4 columns (CMS-2E and CMS-4E).
3. We have performed simulations of CMS-2E and CMS-4E sensors before and after irradiation.
4. Successful fabrication of the devices at SINTEF
5. Measurements of several devices were done at SINTEF (I-V curves).
    1. Test metal for electrical measurement was deposited on the devices to short circuit all n-electrodes. This test metal layer was then removed and replaced by the final metallization.
6. Two wafers were sent to IZM for bum-bonding the good devices to PSI46 ROCs.

Proposal from Purdue and FNAL

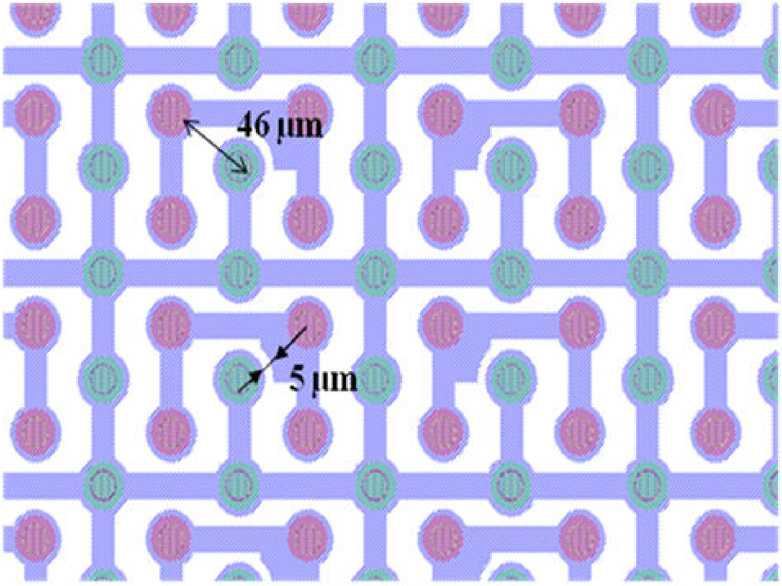
Strong collaboration with industrial partner (Sintef) to produce cutting edge devices for the pixel innermost layer/s



3D Sensors: pixel details

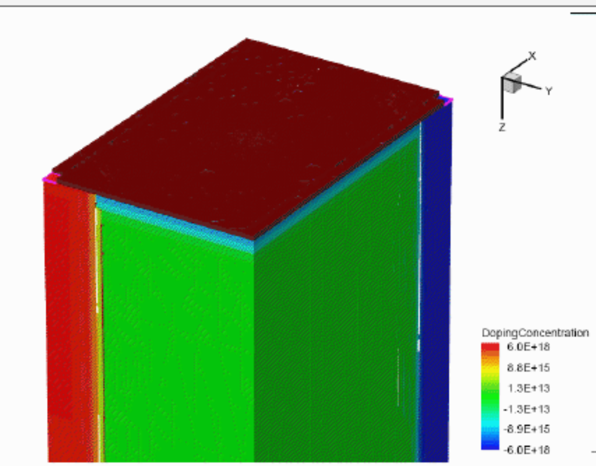


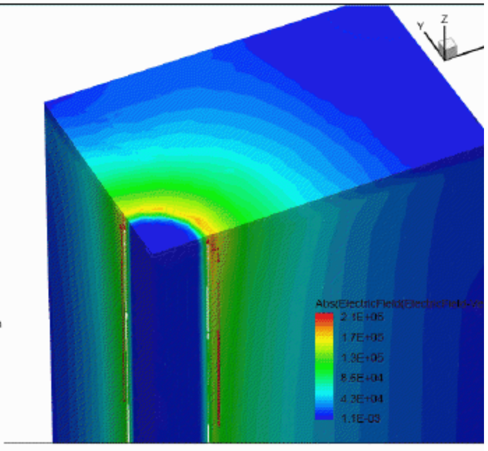
2E configuration



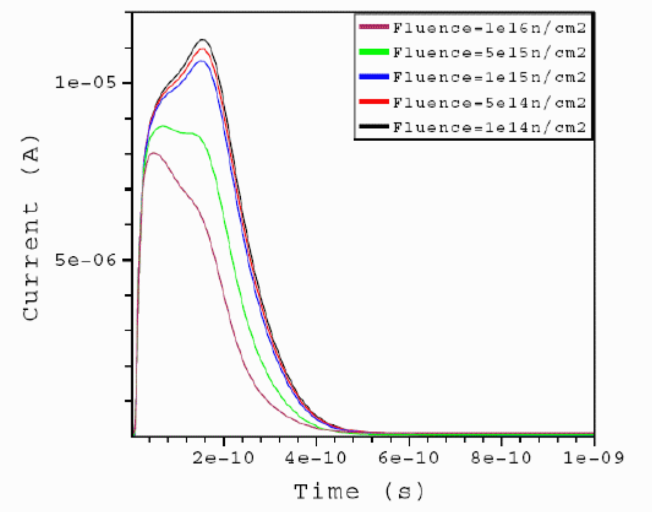
4E configuration

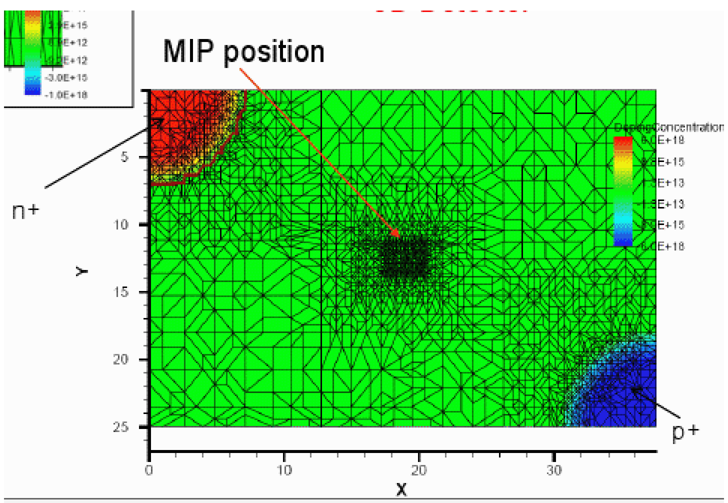
1. **2 and 4 column pixels**
   1. **Different distance between n+ and p+ electrode**
2. **Not possible to implement a bias GRID**
   1. **Need for a temporary metallization to short all the pixel together**
      1. **To be replaced before bumping.**
3. **Devices are were simulated with Sentaurus (O. Koybasi, Purdue)**



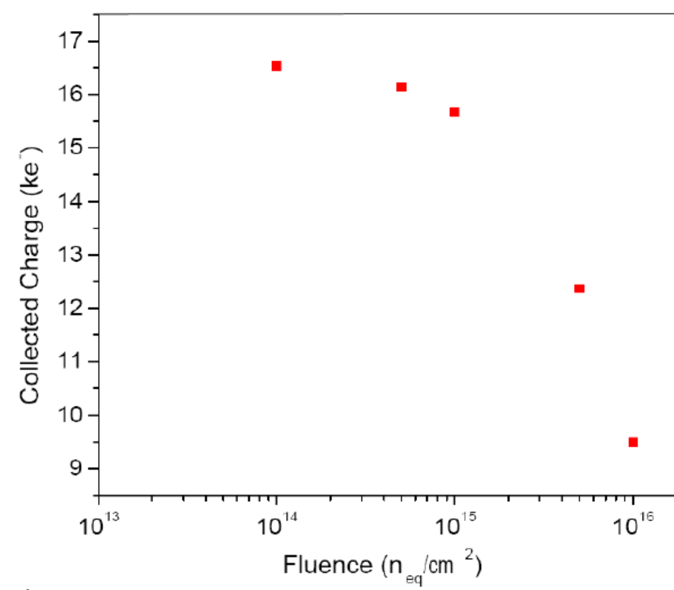


Charge collection:



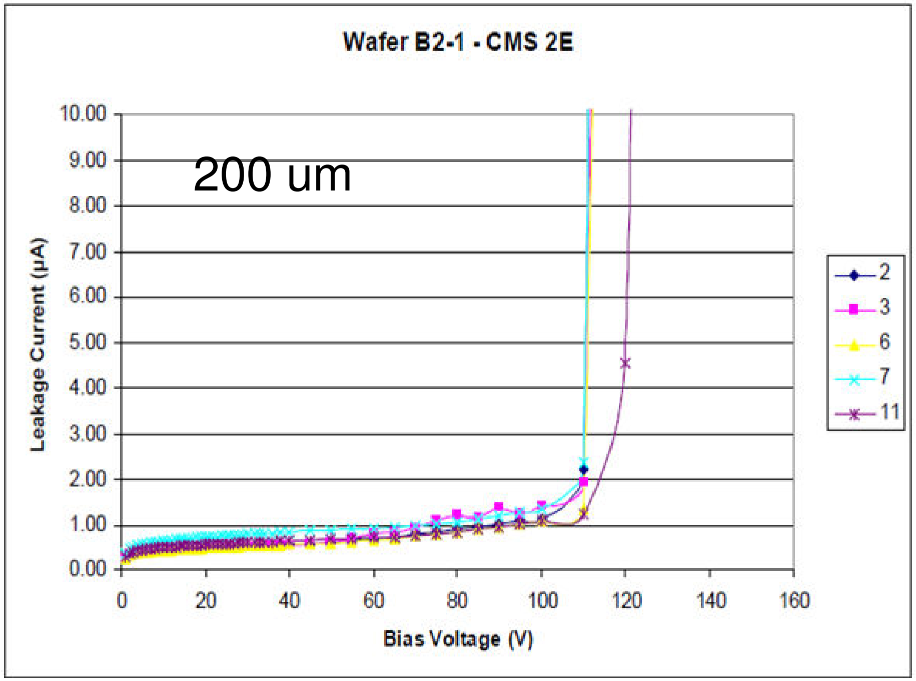


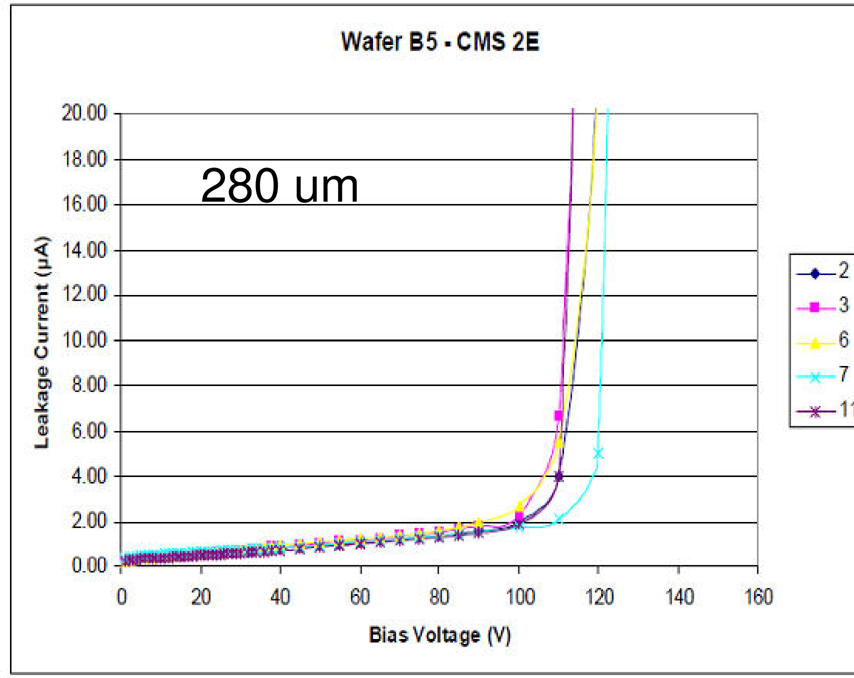
Charge Collection Efficiency:



CCE versus radiation damage.

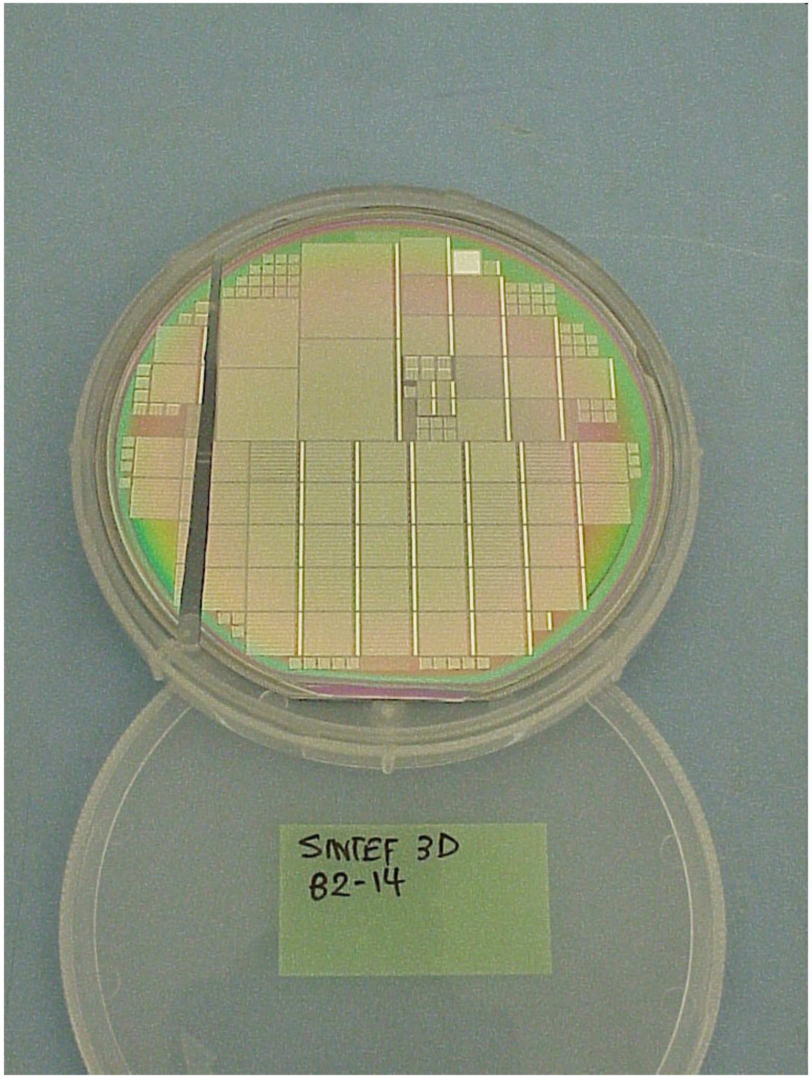
3D Sensors: IV characteristics





1. **Leakage current in the order of 1 uA/cm^2 before breakdown (100 nA/cm^2 at Vdep)**
   1. **There is a theory that some of this current might be due to the temporary metal layer**
      1. **To be verified after bumping**
2. **Depletion voltage around 15-20 V**

3D Sensors: bumping



1. Two wafers sent to IZM for bumping
   1. PSI46 ROC ready since production of FPIX
2. Total of 15 good sensors (out of 22)
3. One wafer was broken during shipping
   1. CMS devices not affected but wafer alignment marks are now in two different pieces
4. 2 more wafers from Sintef are now ready to go to IZM
5. We expect bumped sensors back from IZM within the calendar year
6. Plan:
   1. Characterize them at Purdue (IV)
   2. Mount them on readout boards and get them in the FNAL test-beam

HPK Status

- Order finally placed ~ February
  - Central European Consortium, CERN, INFN, PSI, US
- Detailed specs agreed
  - Wafer procurement Done
- Wafer Layout finalized
  - Later from Marcello
- Testing and irradiation program
  - Later from Frank
- Now a presentation from CEC.