VLDT-Overview UNI-HH
Georg Steinbrück

VLDT: Support

1. Irradiations, post-irradiation treatment
2. Measurement of microscopic and macroscopic damage parameters (new: multi-TCT)
3. Simulations for detector optimization

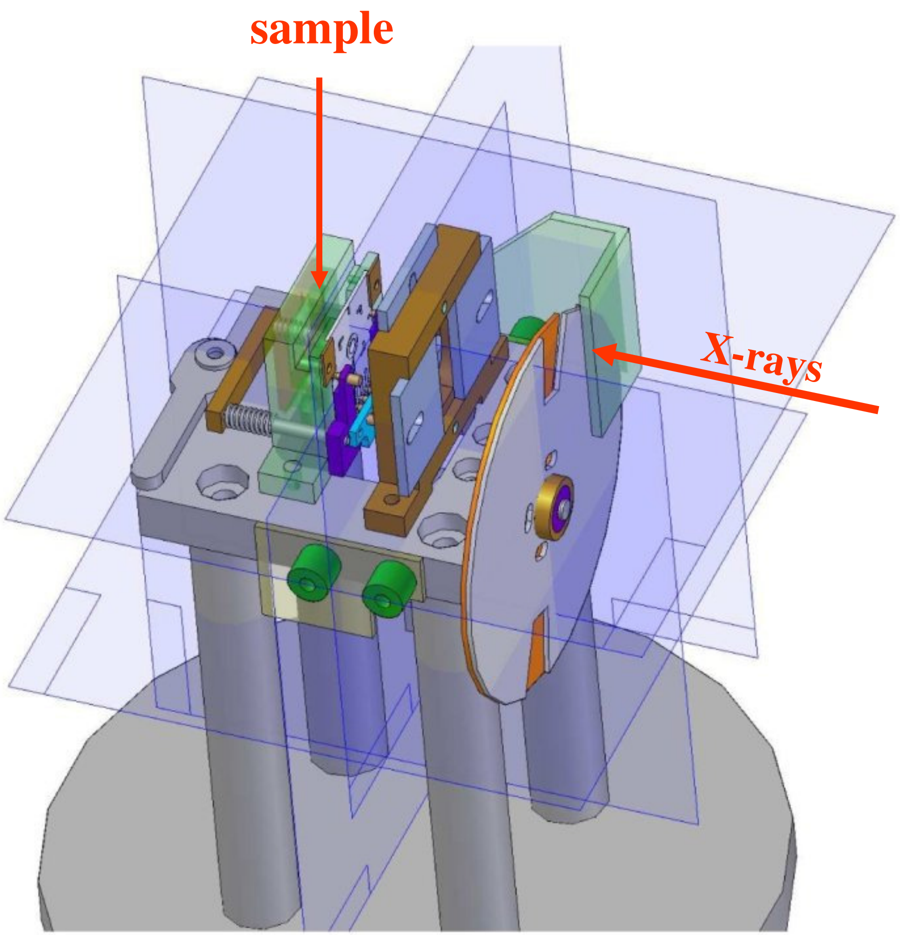
+ Data base irradiation base for different materials and types of irradiation

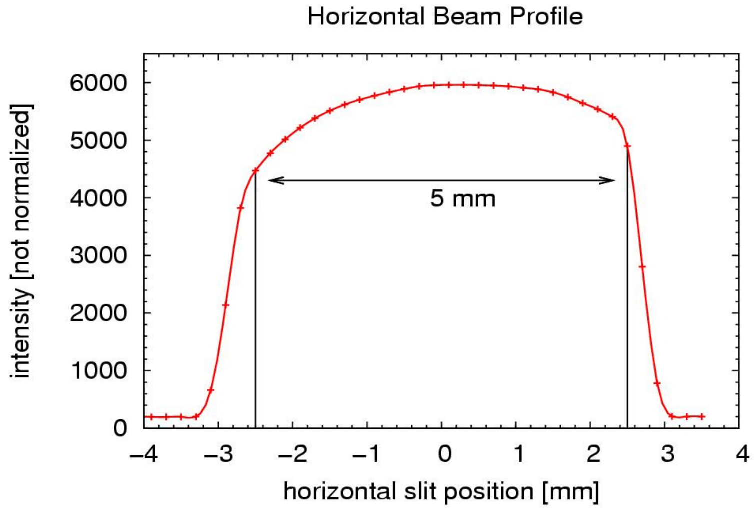
4. UHH involvement in development of radiation hard silicon for the sLHC: WP 2.4 + CEC

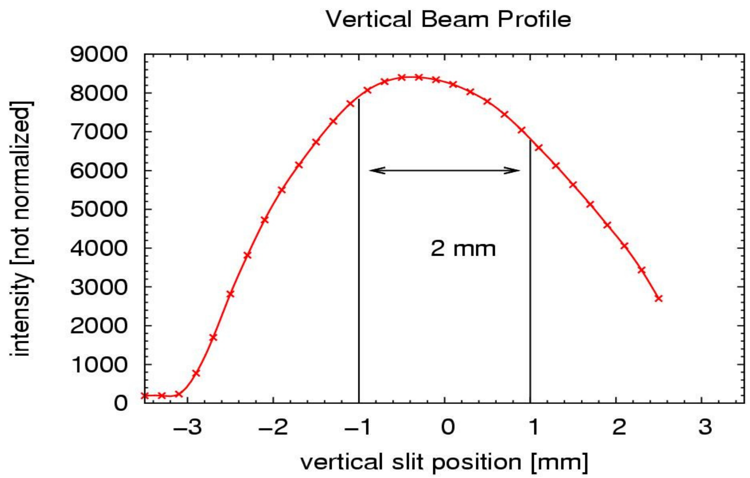
Infrastructure for Si characterization/irrad.

- Existing: I/V, C/V, TCT, DLTS + T-annealing working and continuously upgraded
- New-1: X-ray irradiation (F4@DORIS)
  - 10 keV (Γ~10 keV)
  - spot: 5 mm x 2 mm (scanning → larger areas)
  - dose (SiO_2-surface): 0.5-150 kGy/s
  - T-control
  - on-line biasing

New-1: X-Ray irrad. set-up

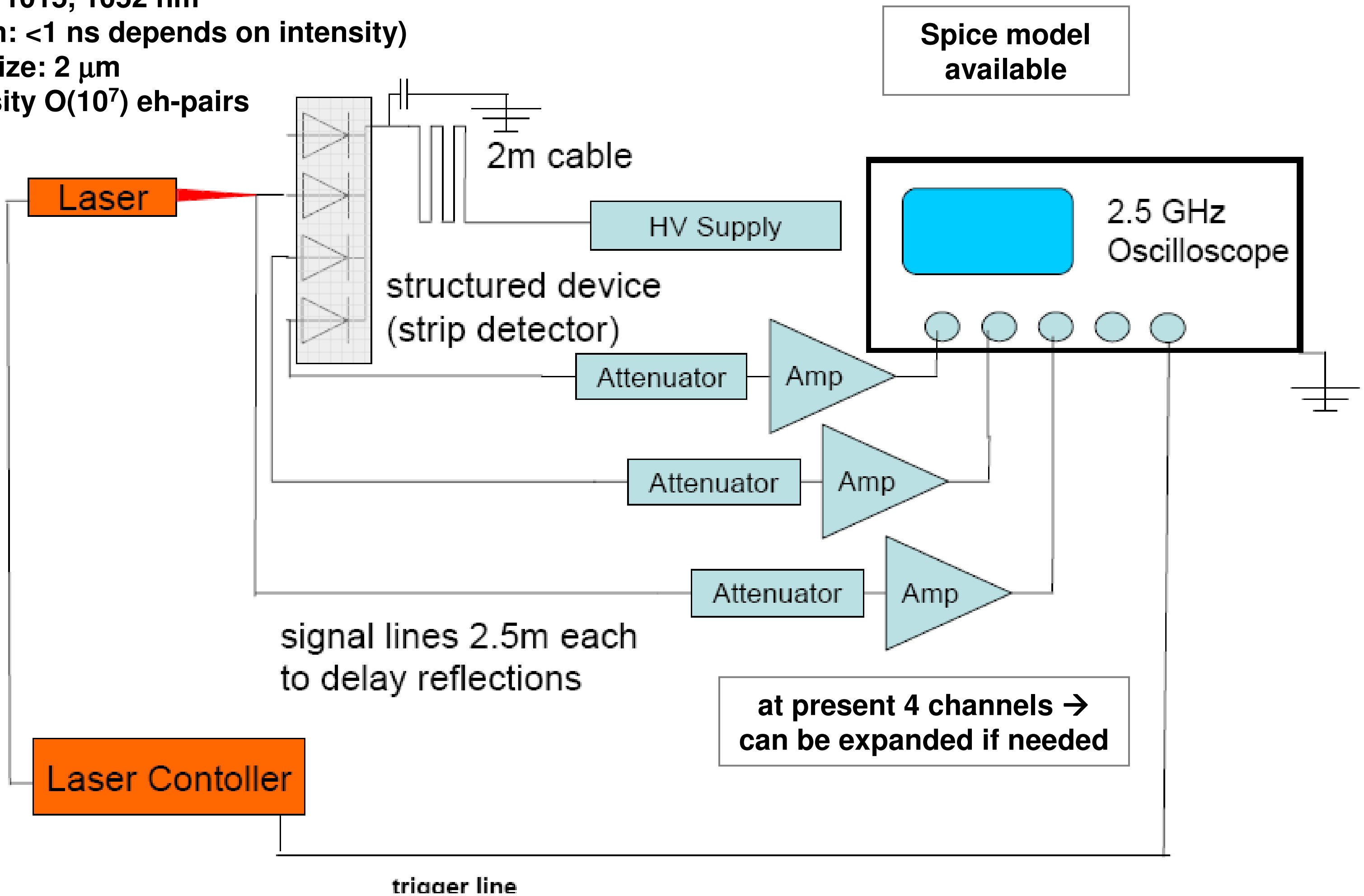




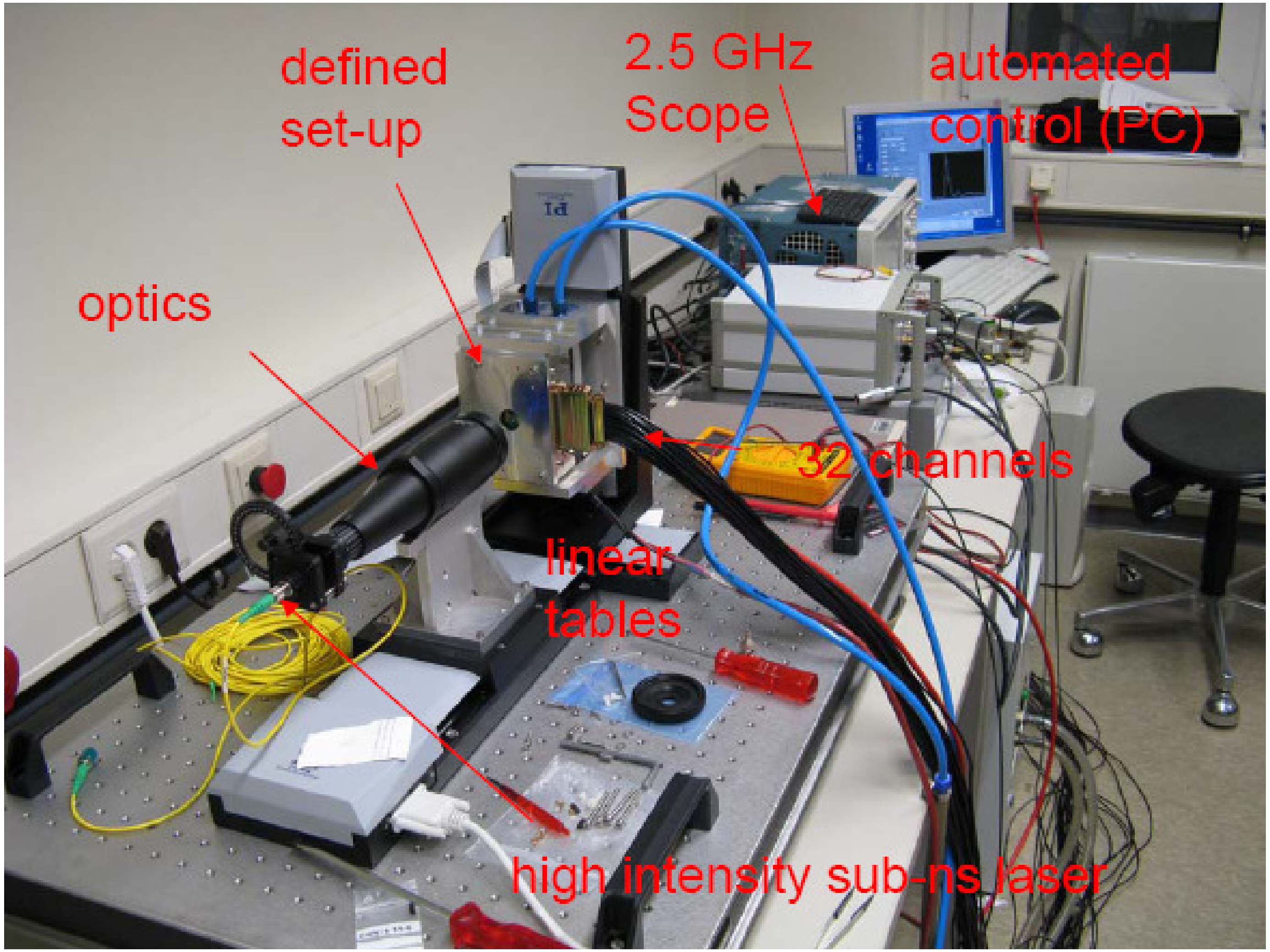


New2: Multi-TCT

Laser: 660, 1015, 1052 nm
Pulse-width: <1 ns depends on intensity)
Min. spot-size: 2 µm
Max. intensity O(10^7) eh-pairs

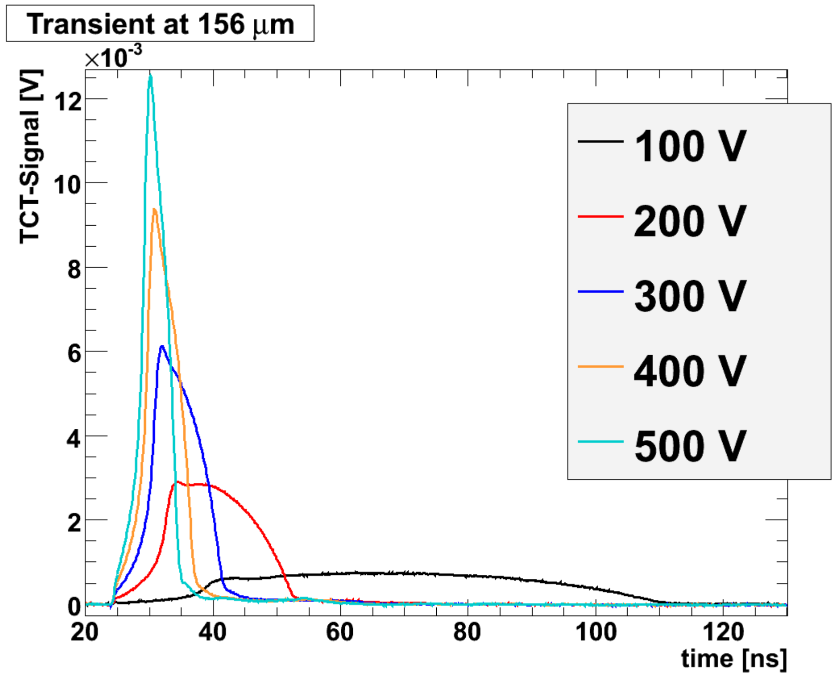


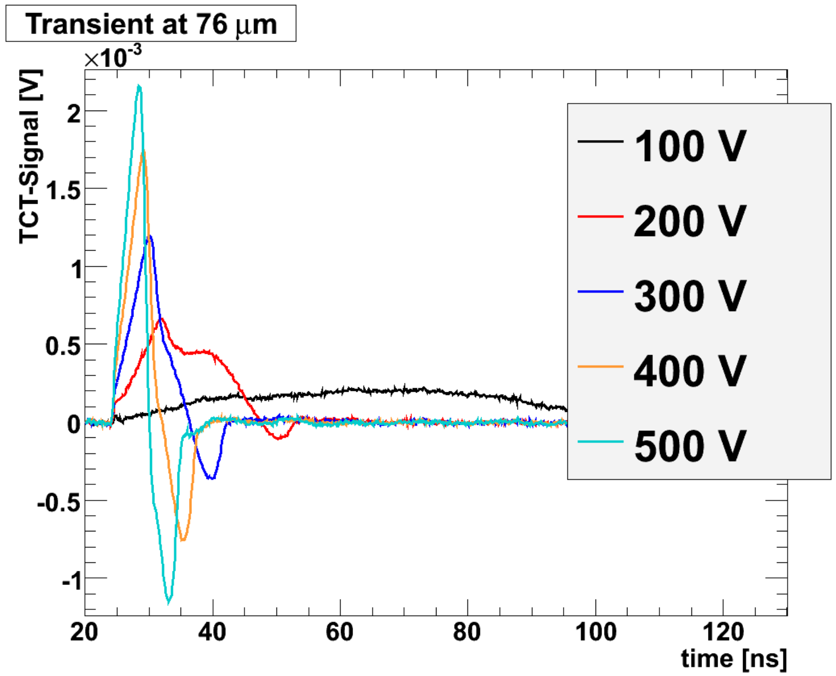
New2: Multi-TCT



New2: Multi-TCT

80 μm strip detector, n-type, U_{dep}= 63 V, 9.1 10^6 eh-pairs (285 mips), spot ~2 μm, 3 μm penetration on n^+-side





Laser centered on readout strip | **Laser centered on neigbour strip**

→Induced signal + increased charge spread at lower voltages due to Plasma effect

Goal: for irradiated detectors disentangle E-field, mobility and e/h-lifetimes

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

New 3: Simulation tools for sensor optimization

Synopsis-TCAD running start to gain experience with DC-simulation
(incl. radiation damage)

Study of Macroscopic Properties
through IV, CV, TCT

Study of Microscopic Defects
through DLTS, TSC

➔ N_{eff}, I, $\tau_{e,h}$ depending on Doping, Irradiation, Annealing

Sensor Simulation/ Optimization
E, I, C as function of Irradiation, Material,...

Simulation of Charge Collection in Detector
dE/dx ⊗ sensor ⊗ FE electronics

➔ Efficiency, spatial resolution, …

Verification
through multi-channel TCT, Testbeam

still under development progressing…

start by comparing to CMS-test beam data
(irradiated detectors)

WP 2.4 Radhard Si-sensors for the sLHC

Proposal HGF-Alliance:

1. Improve intrinsic radiation hardness of material (HH+KA)
2. Optimize design for radiation hardness (HH)
3. Participate in CMS-pixel prototype (HH+KA+PSI+…)
4. Build + characterize Si-strips using m-Czochralski (KA)

1.Materials

- Systematic study of different materials ongoing – lots of work!
- Goal: Understand Scaling of macroscopic parameters (e.g. N_{eff}, T, f …). Progress being made…
- Breakthrough in prediction of macroscopic effect due to microscopic defects
- Satisfactory model for effects of trapping missing (includes the under-standing of > 100 % CCE at high irradiations and high fields)
- Mixed irradiations (KA) have to be done systematically and probably understood also on the microscopic level
- Setting up of data base of macroscopic damage parameters for different materials, fluences and radiation types started – necessary input for design optimisation

Lots of work, progress is (in most cases) good

For more details see Alexandra Junkes (micro-macrosopic properties) and Jörn Langes presentations (charge collection for rad. damaged Si)

2. Radiation hard design

Use input from 1. (macroscopic and microscopic) to

1. optimize DC design (eg using Synopsis-TCAD): E-field, I_{dark}, C

→ work ongoing, big effort to understand/check results; now several groups have started similar work, needs lots of cross-checking and collaboration (Post-doc)

[NB. program TASCA from WIAS could also be used!]

2. optimize charge collection, charge sharing signal shapes as function of sensor design, radiation dose, applied voltage, B-field, electronics shaping, cross-talk with the aim to optimize dx, ε using as input micro- and macroscopic measurements

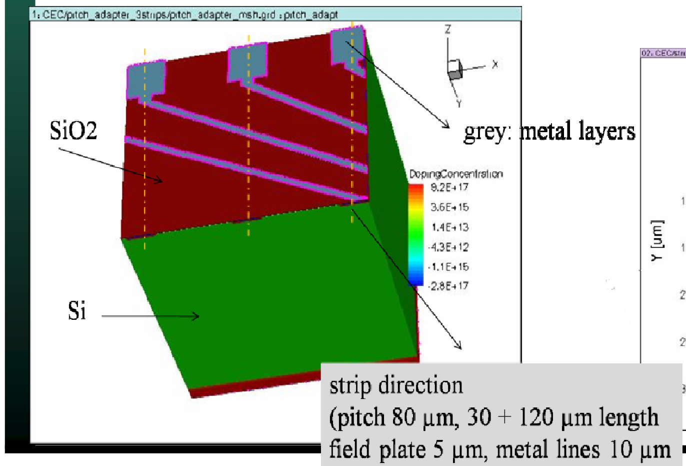
→ first version of program running and under debugging; next: compare to CMS-Si- strips test beam data (w/wo irradiation) and m-TCT pulse shapes; possibility to compare to other data (PhD-thesis)

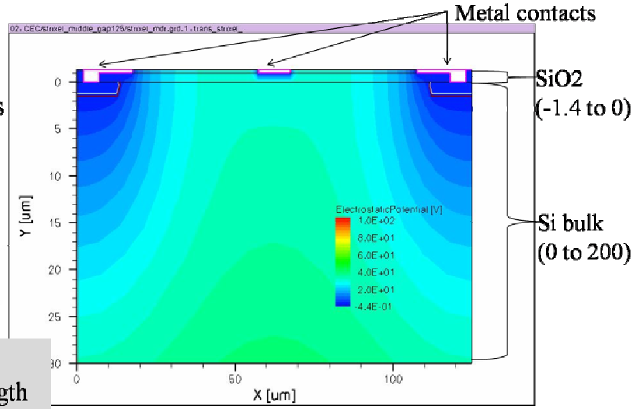
CEC Simulation effort

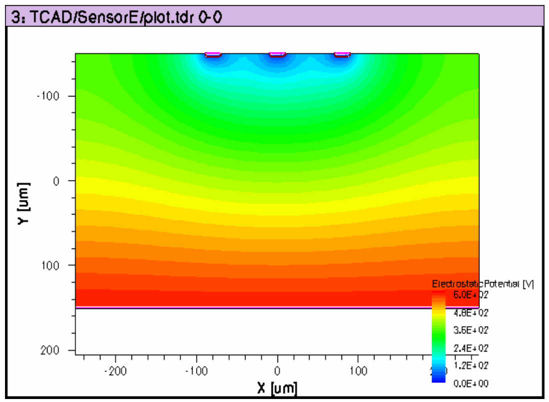
Regular meetings have started

- Next steps
  - 3-D simulations needed in most cases: started
  - Double metal and connectivity schemes
  - Radiation effects
- Work started and progressing to evaluate improvements of
  - Test structures
  - Strixel design (4 strixels, no double metal)
  - Integrated pitch adapter onto sensor

CEC simulations mainly by
Louvain
Hamburg
Karlsruhe
Vilnius







3. sLHC detectors

Alliance Proposal: HH+KA with PSI develop prototype pixel sensors

→ abandoned (HH) in favour of CEC the Central European Consortium*)

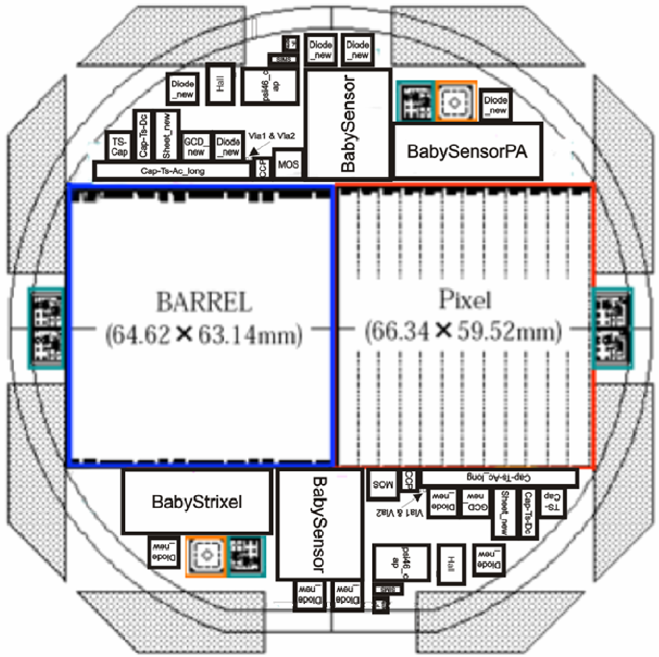
- R&D project to develop materials, technologies and simulations for silicon sensor modules at intermediate to large radii of a new CMS tracker for SLHC
- Members: AC, DESY, HH, KA, Louvain, Vienna, Vilnius, Santander, Warzawa
- Topics (large overlap with alliance → "synergy" + system aspects):
  - Investigate sensor materials
  - Sensor design and optimization
  - Investigate connection schemes for strixels (wire bonding, bump bonding, 2nd metal layer)
  - Develop common test-structures
  - Investigate CO_2-cooling
  - + close contact to CMS physics performance studies
- Goal: Find a single material and module design for the outer tracker and determine the minimum radius for which the modules can be operated
- Proposal approved by CMS

*) F. Hartmann (KA) + D. Eckstein, G. Steinbrück (HH) coordinators

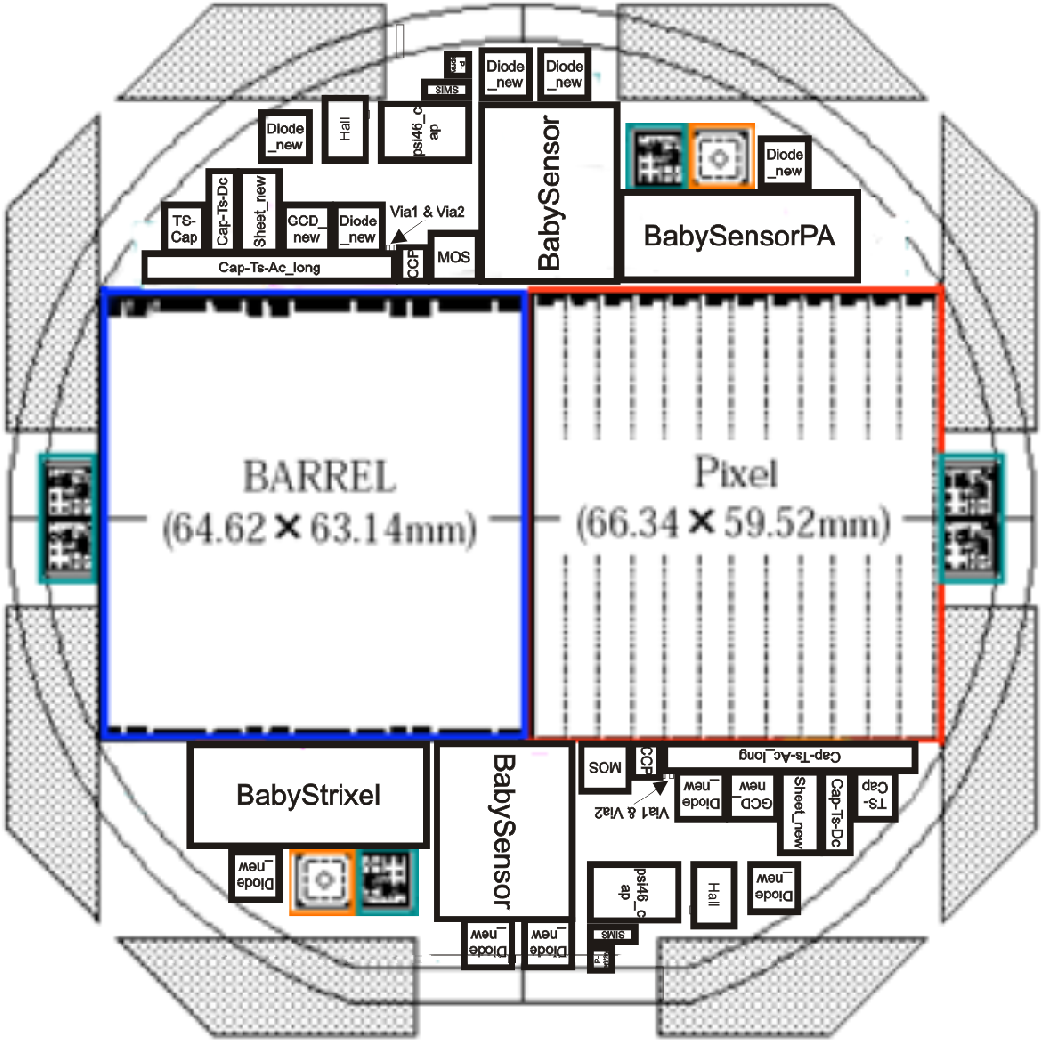
CMS Wafer Submission

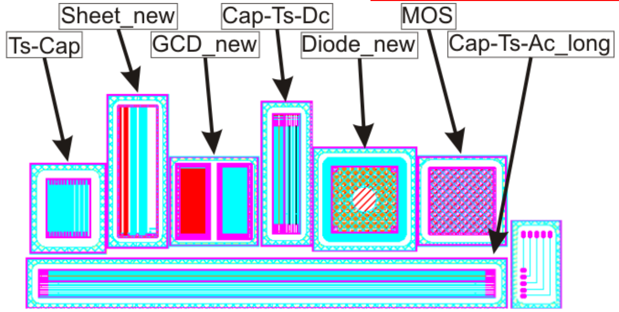
- Producer HPK
- Submission soon
- Contains large strip and pixel structures
- Additional teststructures defined by our R&D project
- Materials and thicknesses:
  - **n-MCz: 200µm**
  - **p-MCz: 200µm***
  - **n-Epi: 50µm, 100µm**
  - **p-Epi: 50µm*, 100µm***
  - **n-FZ: 320mm, 200µm, 100µm and 200µm+double metal**
  - **p-FZ: 320mm, 200µm*, 100µm* and 200µm+double metal (p-stop only)**

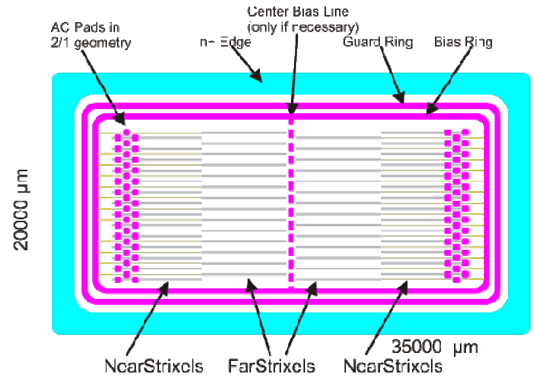
  *2 versions with p-stop or p-spray isolation

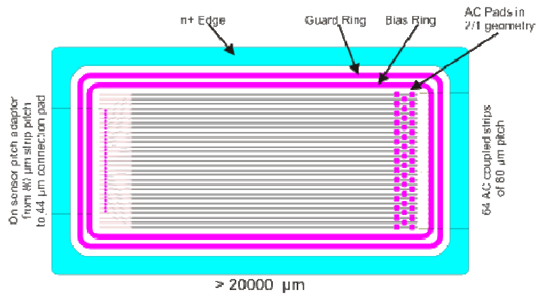


CMS Wafer Submission









Detailed Planning for HPK Run

CEC has set up detailed measurement program:

- The measurement specifications
  - Multi-TCT, IV/CV, strip measurements (mainly Cint&Cb), DLTS
  - Test structure characterization
  - Special structure (PA&strixel) characterization
- The teams for measurement/irradiations
- Logistics (e.g. cross-calibration, redundancy, shipping, time)

- Planned studies: (There will be 6 wafers per thickness/technology)

1. PROTON SLHC scenario; ONE (both halfmoons)
   - 4 steps to mimic real operation:
     - Measure-irradiate-light annealing-measure-irradiate …
2. NEUTRON SLHC scenario; ONE (both halfmoons)
3. MIXED (n+p) irradiation (full annealing study); TWO (halfmoons + multigeometry)
   - Proton dominated equal to r=10 cm
   - Neutron dominated equal to r=40cm
     - CCE and resolution with SR90 and cosmics
4. STANDARD iso-thermal annealing study; all diodes of ONE wafer
   - Irradiate to 5 (6) different fluences

- With some structures from campaign (1,2,3) → test beam study

CEC:
Aachen
DESY
Hamburg
Karlsruhe
Louvain
Santander
Vienna
Vilnius
Warsaw

Funding applications

→ **for HH:**

- large overlap (synergy) WP 4.2 and CEC contributions

- strengthening of detector group by HGF-alliance has been important for a strong involvement in CCE

Funding applications

- bmbf-Verbundforschung: FSP-CMS
- ✔ XFEL: rad. hardness for X-ray science + plasma effects in Si-sensors
- ✔ MC-PAD: Marie Curie Training Network (2 PhD positions, candidates being interviewed)

Summary

VLDT:

- "Existing" infrastructure in good shape and used; continuous upgrades ongoing
- Promised upgrades of "new" infrastructure in good shape
- Progress in simulations (sensor + charge collection) being made
- So far no customers from Alliance (but from MPI, DESY and WIAS related to X-ray science)

WP2.4:

- Pixels abandoned in favour of CEC-strixels
- Material studies: new surprises and hopes; new materials and structures via CMS-CEC
- Simulation effort (sensors + performance) started in earnest.

→ **Overall: satisfactory progress, waiting for submission of test-wafers to HPK**