PREPARING FOR THE sLHC: ACTIVITIES BY THE CEC

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Outline

- Motivation and the CEC
- Scope of our activities
  - Sensor development and extensive testing
  - Data base development
  - Simulation
  - Advanced tracker modules
  - Cooling
  - Powering
- Distribution of work
- Status and future

Motivation and the CEC

CEC = Central European Consortium for sLHC Sensor Development

- sLHC tracker will be a challenge:
  - Higher rates (granularity of sensors, number of r/o channels)
  - Higher fluences (radiation hardness of sensors)
  - Need for trigger information from the tracker
  - Material budget (lighter and thinner design)
  - Powering and cooling
- 'foundation' of the CEC by F. Hartmann et.al., DESY joined in 2008

CEC

https://twiki.cern.ch/twiki/bin/view/CMS/CEC

- ***Members***

  Uni KA, Uni HH, DESY, RWTH Aachen, IHEPHY Wien, Louvain, UC-CSIC Santander, IET Warsaw, Uni Vilnius

- ***Goal***

  of the Central Europe Consortium of institutes is to ***explore the available materials and technologies for silicon sensor modules*** and to develop them further in a coordinated effort for the upgrade of the CMS tracker at SLHC. The project is primarily focused on detector layers equipped with standard strip sensors and sensors with short strips (strixel). It should provide ***a solid basis for a final choice for the sensor material*** and should build and test a limited number ***of fully developed module geometries***, including the interconnection scheme to the readout chips and the cooling. The studies should furthermore show to which maximum irradiation levels and occupancies – hence to what minimum detector radius – this technology can be implemented in a future tracker of CMS. All aspects are viewed from a common point with the goal to combine as much functionality as possible, like cooling, structure and electric elements.

Sensor Materials

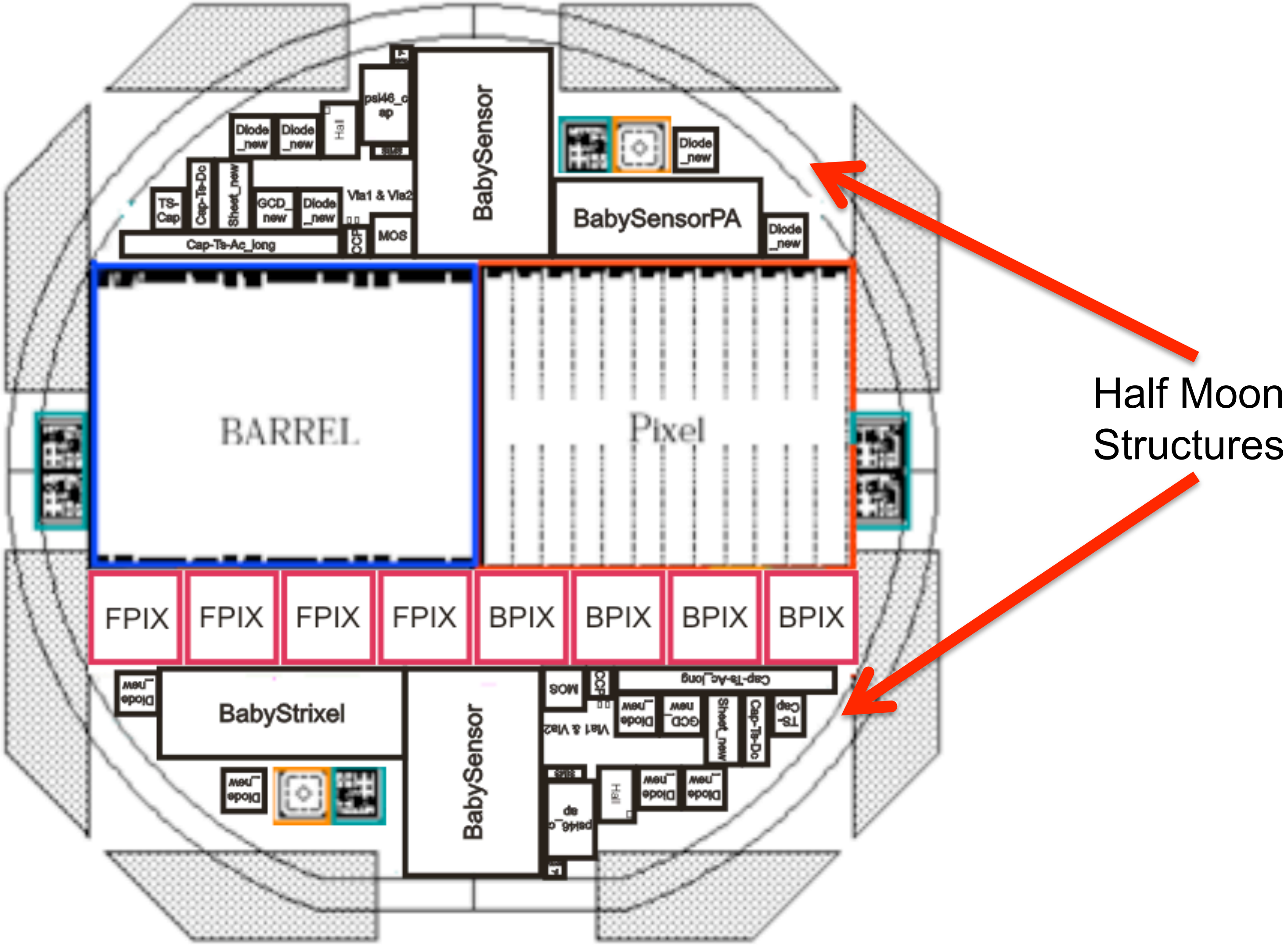
Identification of relevant sensor technologies:

substrate type & Active Thickness	FZ 200um carrier	MCZ 200um thinning	FZ 100um carrier	epi 100um	epi 75um	FZ 300um	Total
P-on-N Production	6	6	6	6	6	6	36
N-on-P Production p-spray	6	6	6	6	6	6	36
N-on-P Production p-stop	6	6	6	6	6	6	36
2'nd metal production P-on-N	6						6
2'nd metal production N-on-P p-stop	6						6
2'nd metal production N-on-P p-spray	6						6
Total	36	18	18	18	18	18	$\boxed{126}$

Sensor Processing

- Hamamatsu Photonics (HPK) will produce test wafers with identical layout but different technologies.
- Special parts (test structures) of the wafers will be separated (cut). 'Half Moon'
- Test structures will be investigated in a combined irradiation and measurement campaign (organized by the CEC)
  - Different scenarios: SLHC proton, SLHC neutron, mixed irradiation
  - Always interleaved with measurements (Data base)
- Precise logistics needed

Sensor Layout



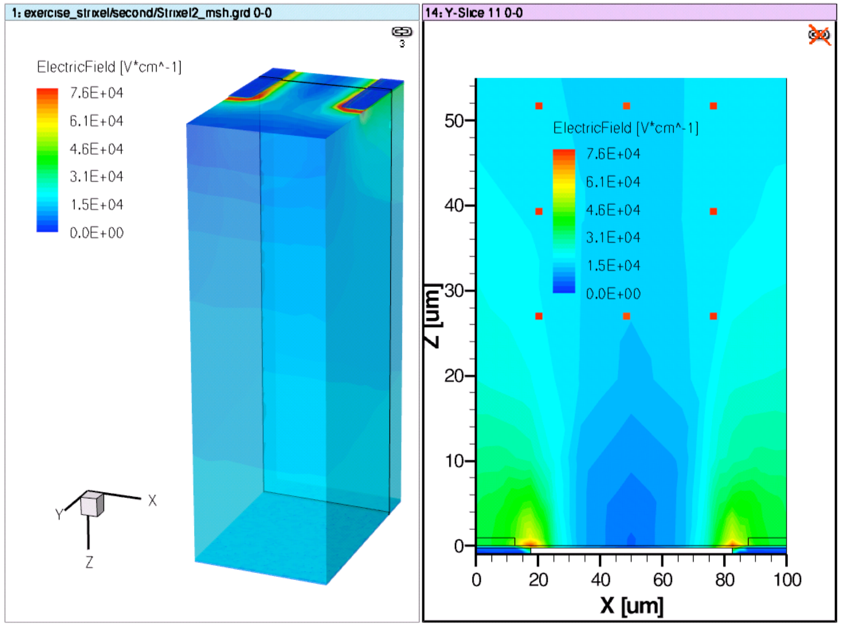
Sensor Measurements

- ‘Calibration of participants’ (cross calibration done this summer)
- Setups – warm & cold (+20C & -20C)
  - Strip / Long pixel measurements (probe station)
  - TCT (Transient Current Technique: bulk properties, traps, space charge etc: test structures)
  - CCE ^{90}Sr (charge collection efficiency measured with a source: strips, strixels)
  - CV, IV (current vs. voltage and capacitance vs. voltage: sensors and test structures)
- Irradiation facilities, precise annealing oven
- Measurement equipment
  - LCR 100Hz – 1MHz
  - Electrometer, pA-Meters
  - Power Supply > 1000V
  - TCT setup
  - Readout a la CMS or ALIBAVA or equivalent *(wanted ~25ns shaping time)*
  - Cold chuck in semi-automatic probe station (measurement of subsequent strips)
  - Switching matrix

Data Base, Simulation

- SQL based Data Base is currently being developed: all measurements and sensor treatments will be stored there
- Simulation of the semiconductor behaviour is simulated:
  - Comparison between simulation and measurement will improve our understanding of radiation damage and annealing
  - Simulation is also ‘cross calibrated’ (Louvain, KA, HH, Zeuthen)

Example:
Simulation of the distribution of the electric field in silicon sensor material (strip implants on the top)



Tracker Modules – Improvements

Sensors

- Reduce thickness from 320um/500um to 200um

Electronics

- Thinner front-end chips
- Smaller size of front-end chips
- Integrate Pitch-Adapter in Sensor

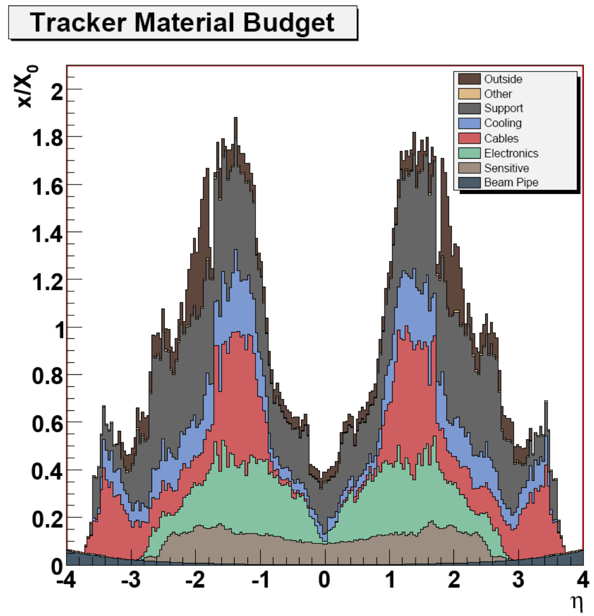
- Larger number of r/o channels ➟ more front-end chips
- Higher power consumption

Cables

- Re-use existing cables ➟ powering scheme (DC/DC, serial)
- Probably no improvements possible

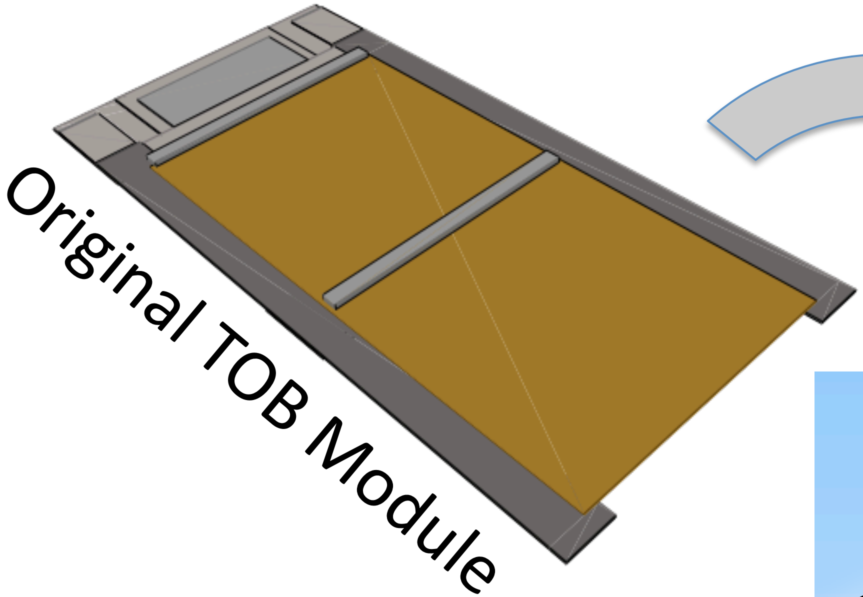
Cooling

- Switch from C_6F_{14} to CO_2 cooling
- Improvement already due to coolant
- Improvement due to smaller pipe diameters (1x1.6)

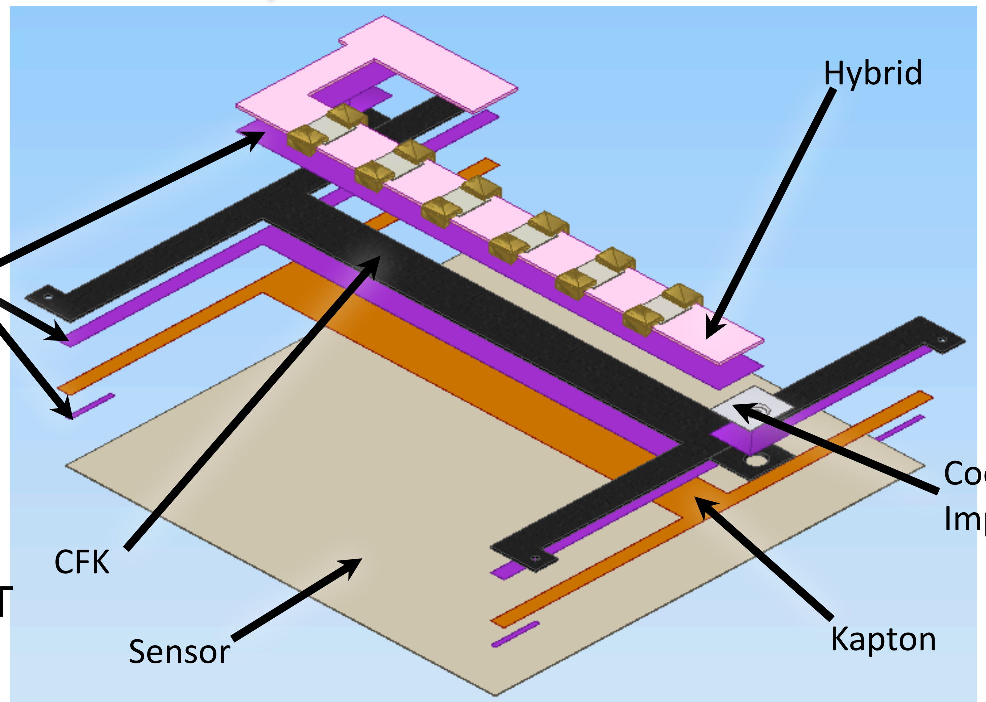


Grey - support
Blue - cooling
Red – cables
Green - electronics
Brown – sensors

Tracker Modules – Improvements



Idea of a new design:
Structures and services are embedded in a multi-layer structure



- Leakage current increases with fluence
- Leakage current doubles every 7K

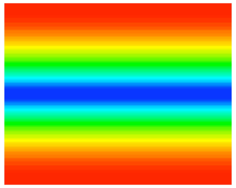
- Must keep sensors at ~ -25°C
- Minimum CO_2 temperature ~ -35°C
- Need a good thermal design to keep ΔT as small as possible

➡ avoid thermal runaway

Tracker Modules – Simulations

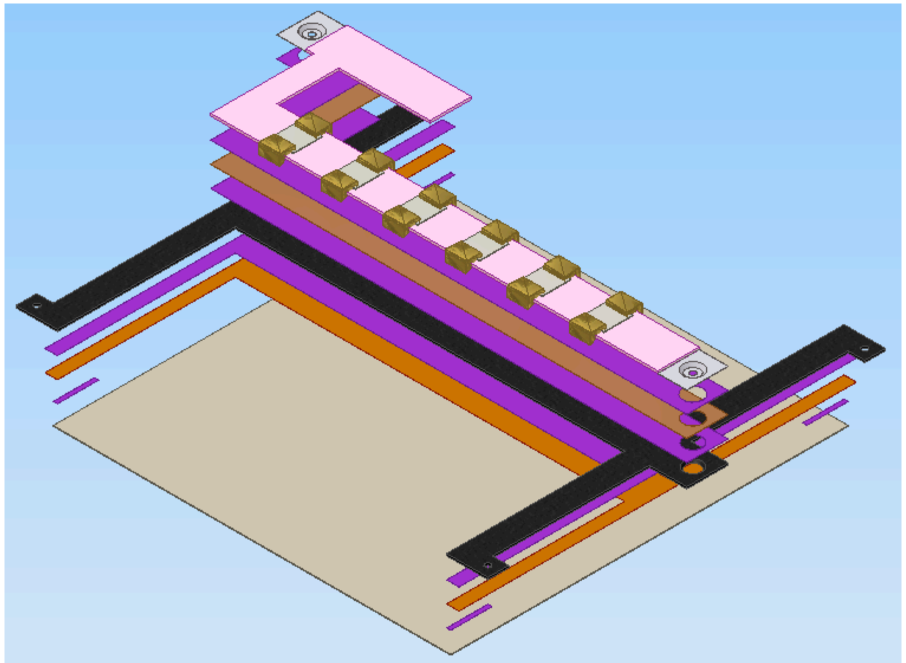
- Single cooling strip in middle of sensor implies cooling pipe running under sensor

➡ more material



ΔT = 2.2 K

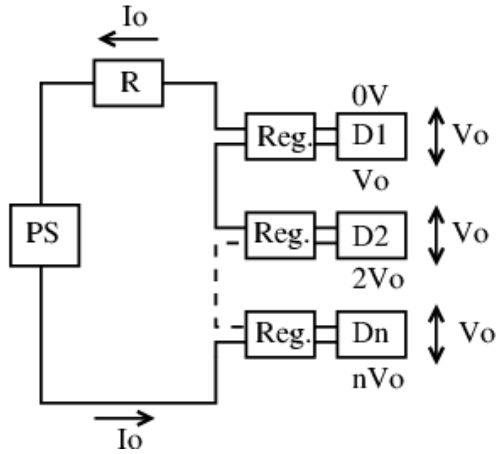
- Alternative: Cooling pipe on the sides of sensor
- same as in current tracker
- Improve temperature gradient by „fancy“ materials with high and selective heat conductivity



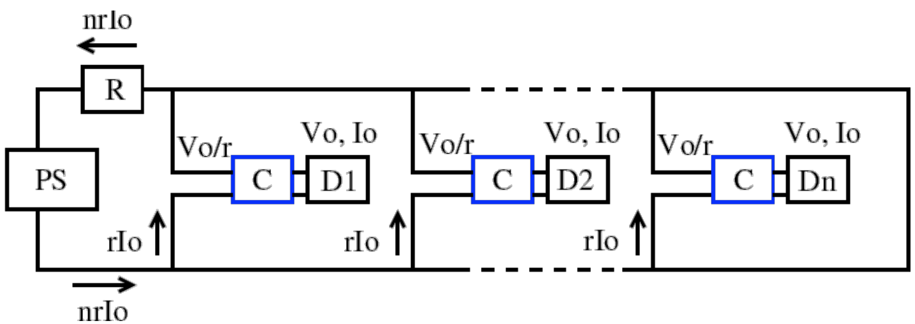
Tracker Modules – Powering

- External (outside CMS) regulation of supply voltages introduce high losses in the cables (P = I^2*R)
- Two alternative approaches:
  - ***Serial powering*** (modules connected in series)

$$V_{drop} = R \cdot I_0$$
$$P_{drop} = R \cdot I_0^2$$



  - ***Parallel powering*** with local DC/DC conversion



Conversion ratio $r = V_o / V_{in} < 1$

$\Rightarrow$ Lower input currents and power losses:

$I_{in} = I_0 \cdot r$ and $P_{drop} = R_{cable} \cdot I_0^2 \cdot r^2$

Distribution of Work

- Aachen University, Germany - module design, DC/DC powering
- Deutsches Elektronen-Synchrotron DESY, Germany
  - Hamburg - module design, ‘thermal’ and ‘mechanical’ simulation
  - Zeuthen – measurement campaign (probe station), data base, simulation
- Institut für Experimentalphysik, Universität Hamburg, Germany - simulation, measurement campaign (TCT, probe station)
- Institut für Experimentelle Kernphysik, Universität Karlsruhe (TH), Germany - measurement campaign (probe station, control), irradiation (p), simulation, module design
- Louvain, Belgium – irradiation (n), simulation
- Instituto de Física de Cantabria (UC-CSIC), Santander, Spain - sensor and test structure design (layout)
- Institut für Hochenergiephysik der Österreichischen Akademie der Wissenschaften, HEPHY, Vienna, Austria - measurement campaign (probe station), sensor layout
- Institute of Materials Science and Applied Research, Vilnius University, Lithuania - ?
- Institute of Electron Technology, Warsaw, Poland - sensor design, measurements

Status and Future

- CEC is a working collaboration
- Regular meetings
- Well defined and tight schedules
- Cross calibration for simulation and measurement campaign done
- Ready for HPK measurements and irradiation (spring 2010 > ?)
- Work on future tracker modules started, goal: prototype within a few years
- After HPK measurements recommendation for sensor technology planned

Thank You!