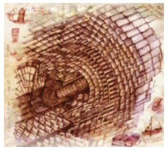

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R&D of Central European Consortium (CEC) Status & Plans (Sensor Technology)

Georg Steinbrück, Hamburg University

CEC: Sensor technology for the outer CMS tracker
(strips, short strips, strixel domain)
Working on: Sensor material, connectivity schemes, modules, cooling, power

This talk:
Common test structures
HPK run
Integrated pitch adapter
First results from ITE run
Simulation

Disclaimer: These slides do not cover any of our other activities, like modules, cooling, power

Status: Test Structures

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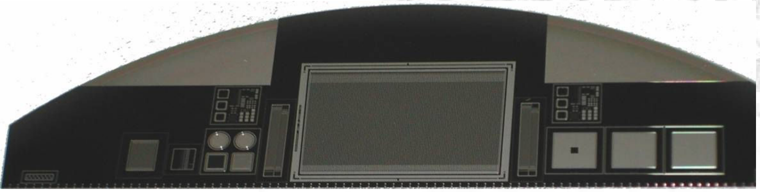
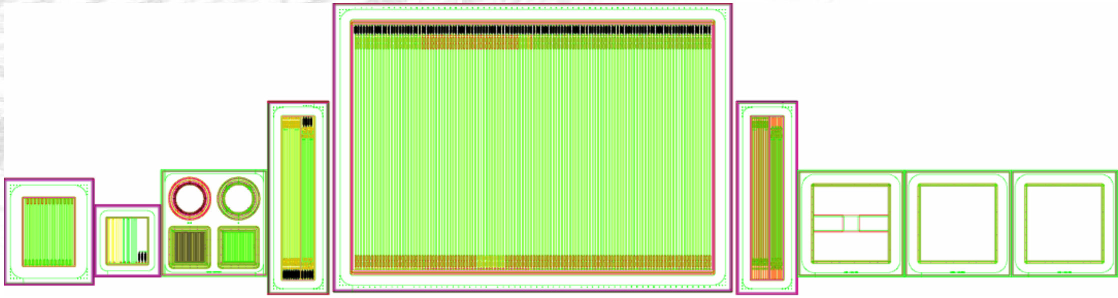
- Starting from the CMS halfmoon, a standard set of test structures has been developed. Implemented as gds files
- Implemented within a framework for easy use/adaptation
- Used in several projects:
    - **HPK/Marcello Order**
    - **Santander/CNM – Prototype Alignment Sensors**
    - **INFN – Sensor R&D Project CMS.08.03**
    - **VTT – request from Michael Moll**
    - **CEC with ITE Warsaw: first results from2nd run!**





Overlap & Interest in HPK Run

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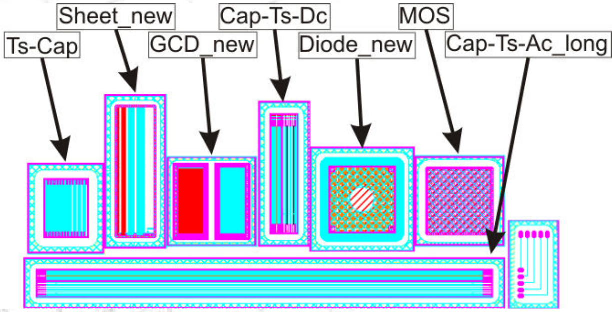
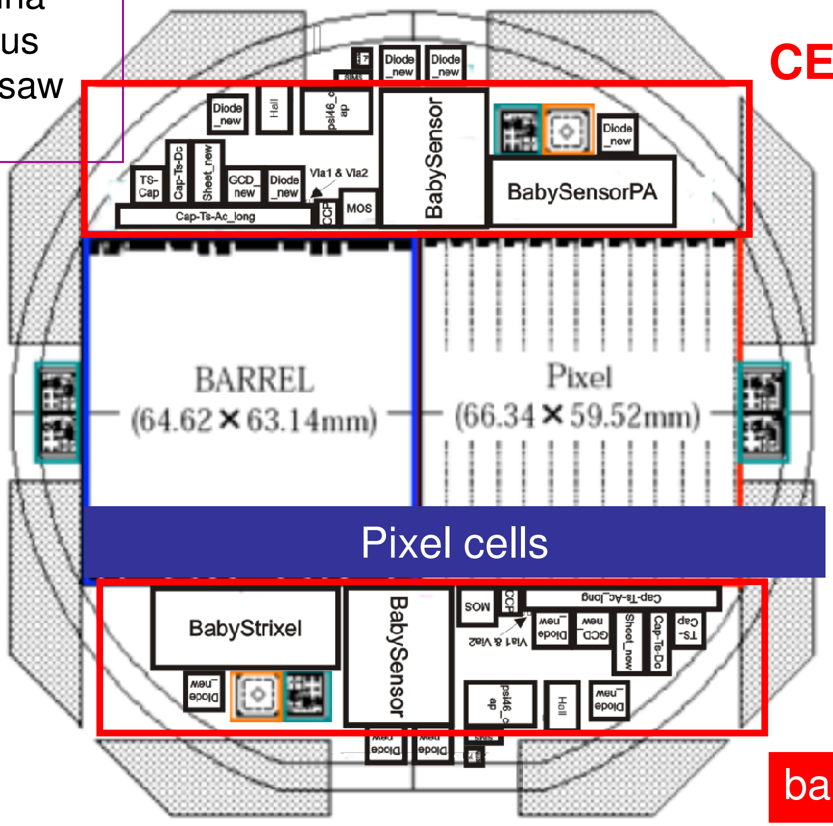
- Status: See Frank‘s talk

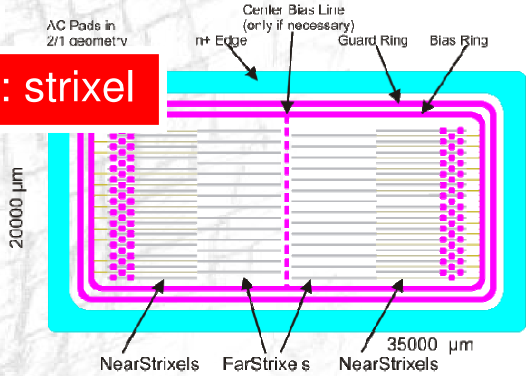
Detailed planning exists for irradiation/ testing campaign, see Frank‘s talk



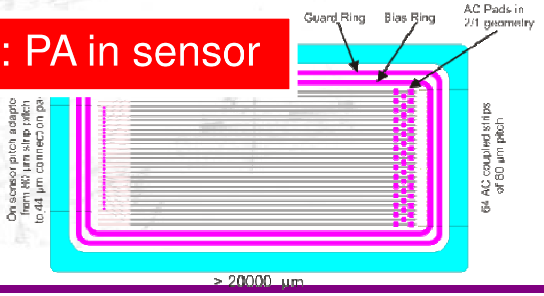
CEC



New structure: strixel



New structure: PA in sensor



baby sensor

Progress in PA Design

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Santander
Vienna
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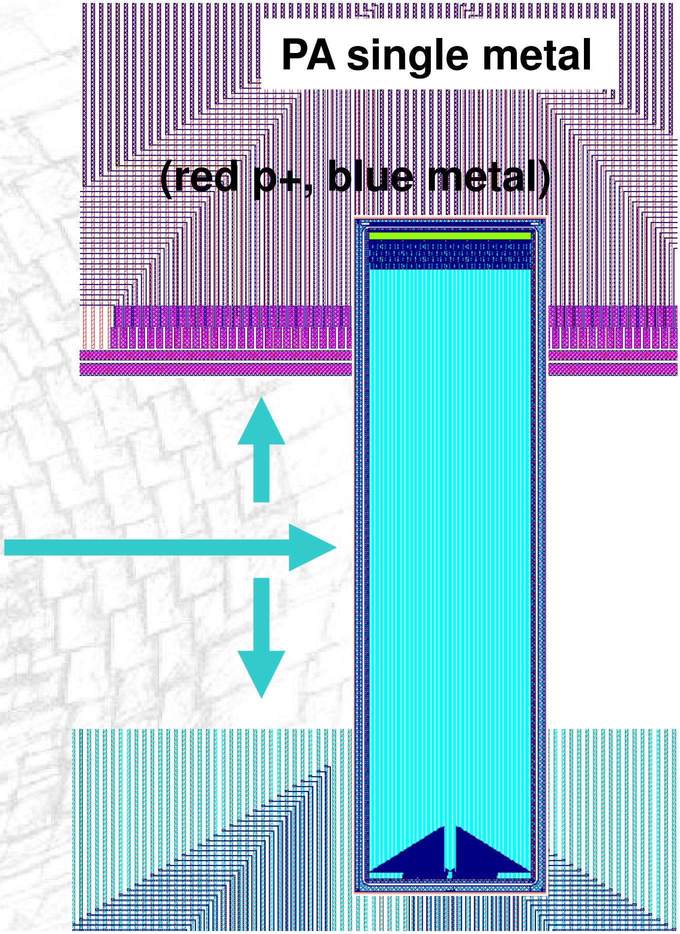
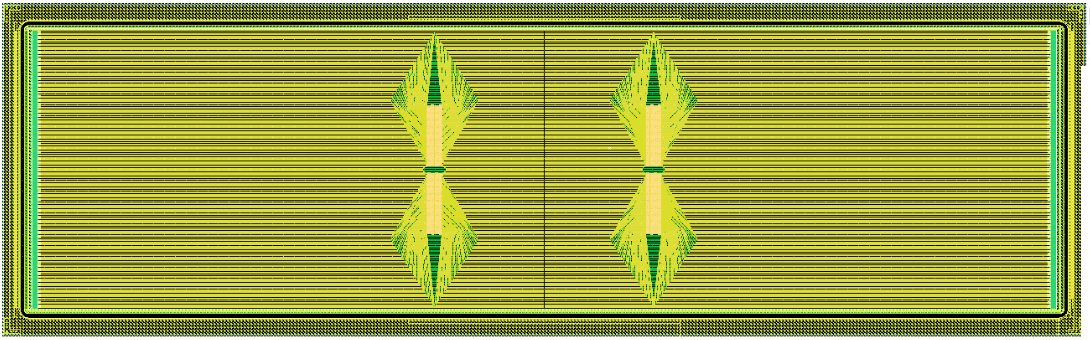
Warsaw

- Idea: Reduce dead area and material budget by integrating PA on sensor.
- Challenge: Cross talk, response in PA region, breakdown
- Alternative layouts being drafted
- Simple version implemented for HPK order
- More advanced structures for ITE
- Being simulated and implemented in future test structures to test if feasible and which design is best
- First results look promising

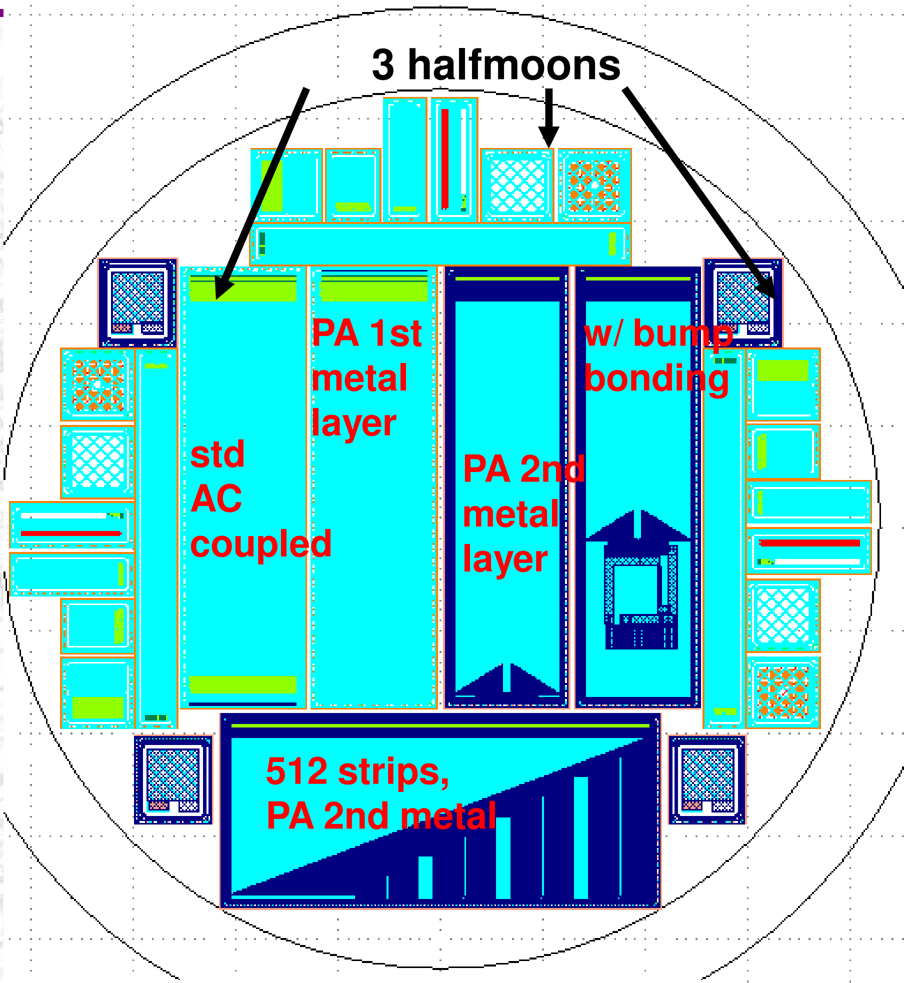




PA double metal: Routing in 2nd layer
r/o metal covers entire strip
→higher ε in PA region compared to single metal, less cross talk
More steps, more expensive

Single and Double Metal Structures for ITE, Testbeam

- New run on 4 inch wafers with ITE Warsaw
- Routing; connection; parasitic coupling
  - Implement double metal process
    - →gain exp. For HPK mask design
  - Stop processing for some wafers after 1st metal
    → for better comparison
    → similar to HPK Order
- Current test structures (single metal)
- Test sensors with integrated pitch adapters (single and double metal)
- Bump bonding area



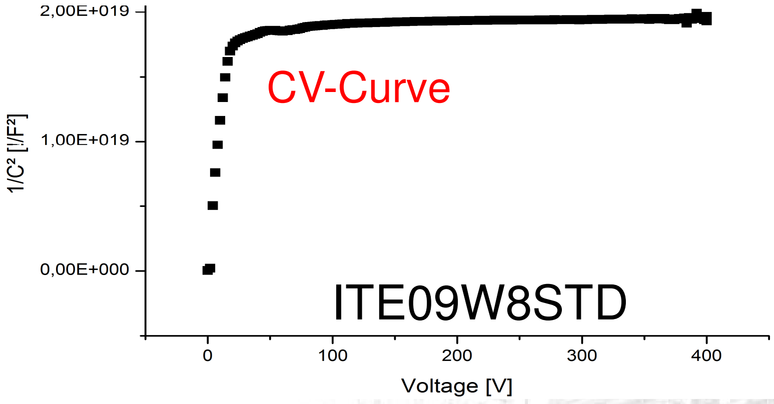
Modules built with existing hybrids/ APV chips. Done within a few weeks!

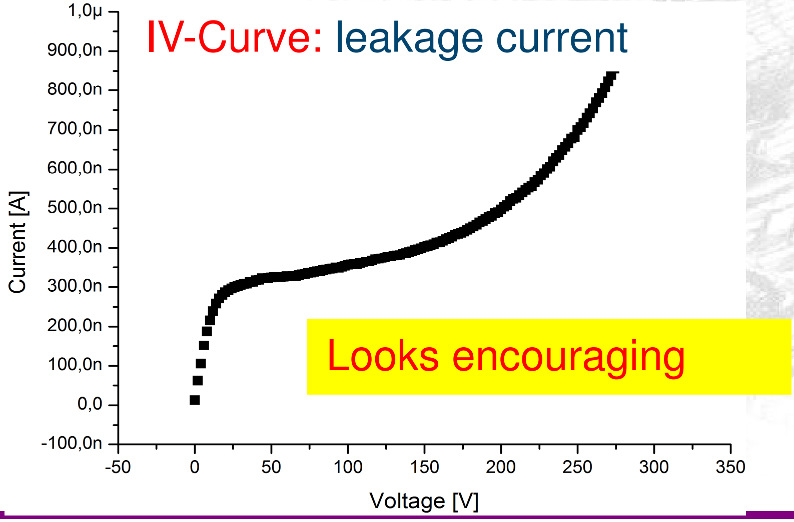
Characterization in testbeam at SPS end of August. Analysis started

First Results for ITE Sensors

Example CV-curve for test sensor to measure V_{FD}

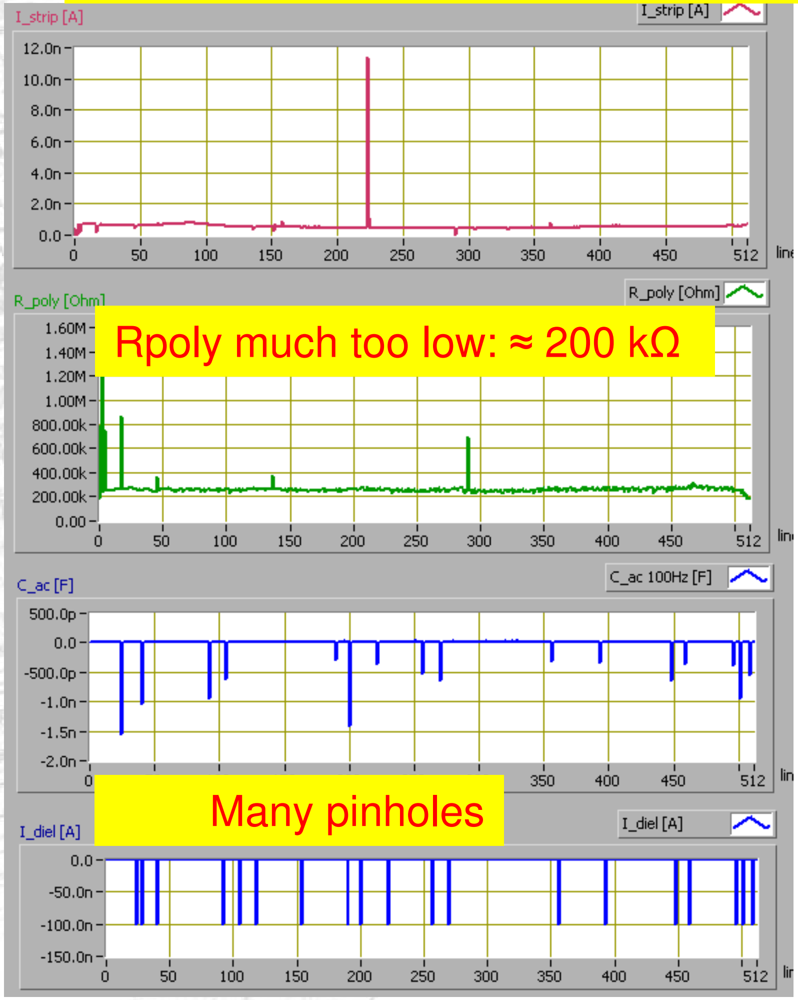
- V_{FD} ≈ 25 V, most sensors are stable up to 100V
- Bulk Resistivity ≈ 12.5 kΩcm, w/i specs




IV-Curve: leakage current

Looks encouraging

Some problems, under investigation

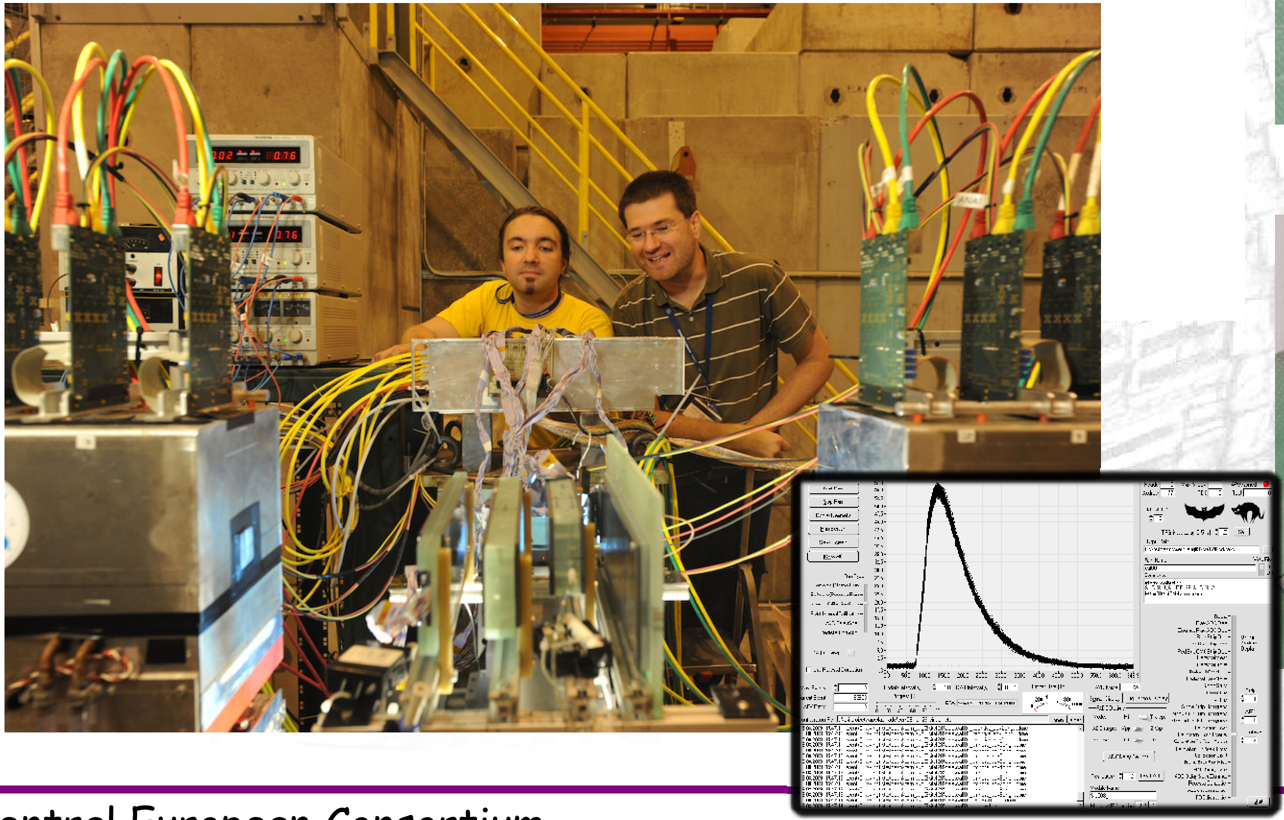

Rpoly much too low: ≈ 200 kΩ

Many pinholes

ITE Sensors in SPS Testbeam

In testbeam (SPS, 120 GeV hadrons):

- 9 ITE sensors (3 x 512, 2 x STD, 2xPAS, 2 x PAD)
- 2 x Alignment Modules
- 2 x Pt Module
- 2 x SiLC halfmoon for stereo measurements
- Stack of last years multigeometry sensors for calibration

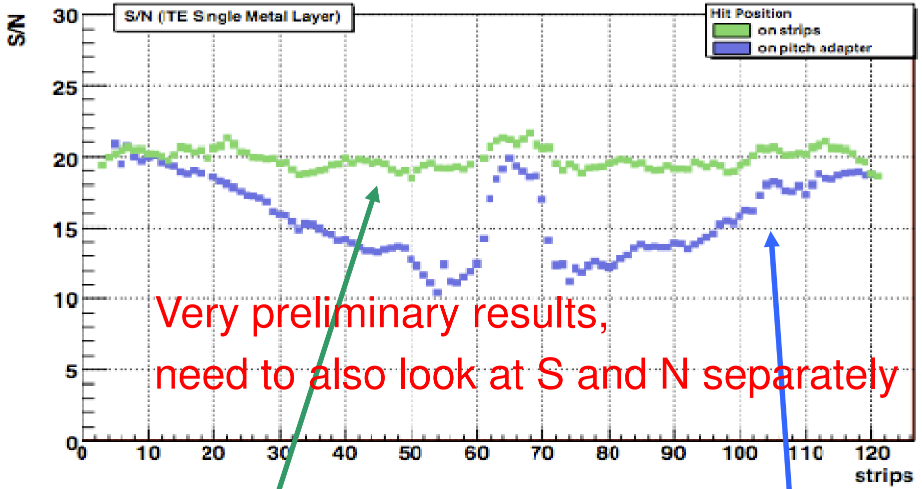


Testbeam modules

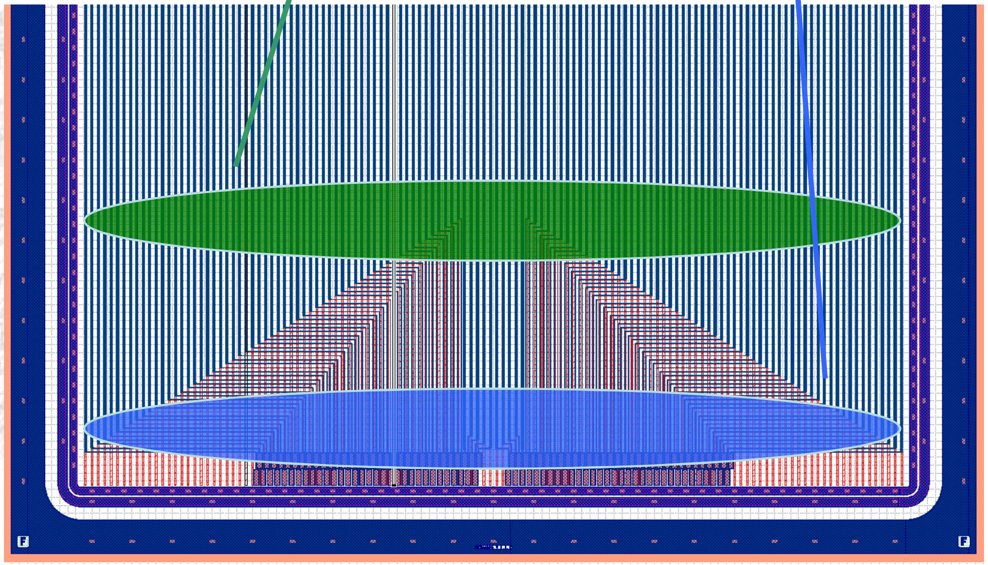
ITE Sensors in SPS Testbeam

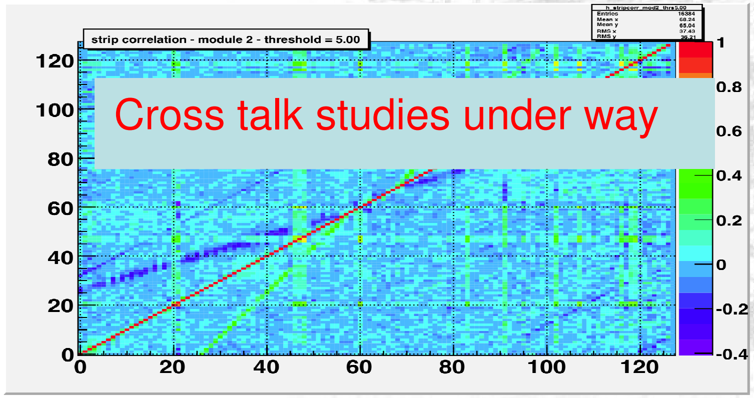
Integrated PA in single metal layer „PAS“

- Readout metallization used to route strip to readout pads
- No metallization over strip in PA region
- Higher C per strip due to routing
- Signal loss due to higher resistivity of p+ compared to aluminium
- Efficiency drop in single metal, double metal solution ok



Very preliminary results,
need to also look at S and N separately





Cross talk studies under way

Simulation Effort

Mainly:
Louvain
Hamburg
DESY
Karlsruhe
Vilnius

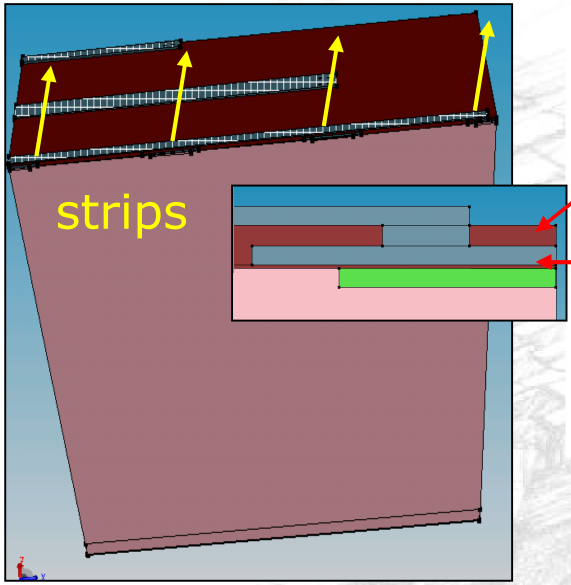
- Goal: Evaluate different technology choices and designs with respect to:
  - Charge collection
  - High voltage performance →breakdown
  - Radiation damage effects
  - Inter-strip coupling/ cross talk: Special interest: connectivity scemes, integrated PA, single vs. double metal layer

- The tool: Synopsis TCAD
  - Commercial device simulation program. 2D or 3D
  - Only possible to simulate small part of a sensor: Few strips
  - Possible to obtain detailed E-field map and potential distributions

- Also: Detailed simulation of CMS silicon sensors under way, based on PixelAV
  - Possible to do detailed resolution and efficiency studies, as a function of geometry, irradiation, incident angles, etc.
  - Uses field map from TCAD as input

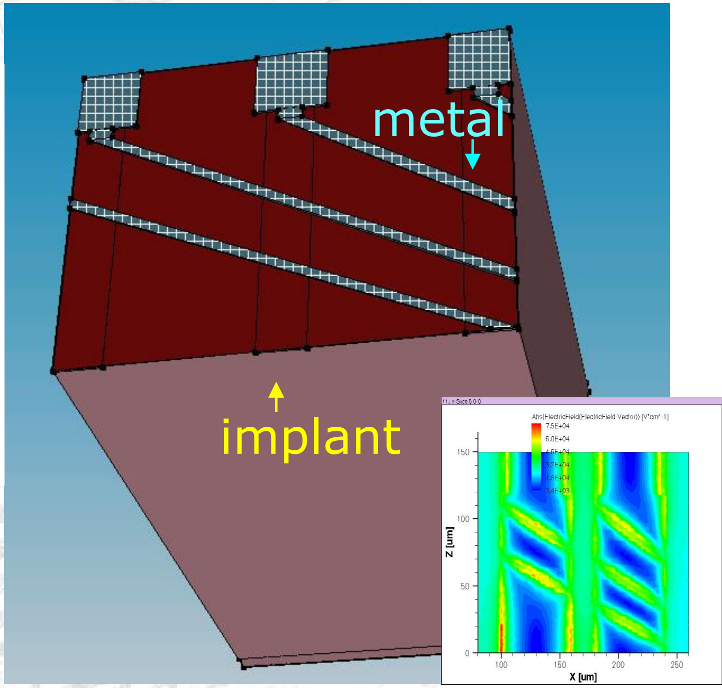
Simulation: Connectivity schemes

Double metal layer



Details:
- Si thickness: 300 µm
-SiO_2: 0.5 and 1 µm (btwn. AC pad and routing)
- SiO_2: 0.2 µm (coupling oxide)
- Metal AC: 1 µm
- Metal routing lines 1 µm
- Vias between metal AC and metal routing lines

Incorporated PA, single metal



Preliminary conclusions (double metal layer)

- Studied thickness of oxide between metal layers
- High electric field in silicon oxide. 0.2 µm thickness not enough. 0.5 µm ok, 1 µm: no additional gain seen.
- Studied all cross-capacitances. Largest impact of oxide thickness seen in capacitance between AC-pad and other routing lines.

Preliminary conclusions (PA single metal)

- High electric field in silicon oxide
- Capacitance between two consecutive implants more than two times higher than two consecutive metal lines
- C(implant, crossing metal line from other strip) << C(Implant, r/o strip) → promising!

Simulation: Radiation damage

Implemented 4 trap model for n-type MCz Si in TCAD:

Trap type	Energy level (eV)	$\sigma_{n,p}$ (cm^2) from exp.	σ_n (cm^2) (*)	σ_p (cm^2) (*)	η (cm^{-1})	Main effect
$E_5^{(-/0)}$	E_c-0.46	1.00×10^{-14} , 1.00×10^{-13} (estimated)	3.00×10^{-15}	4.00×10^{-13} ** 4.1×10^{-13}	0.6 ***12.4	Leakage current
$H152K^{(0/-)}$	E_v+0.42	Unknown, 2.3×10^{-14}	3.05×10^{-13}	3.1×10^{-13} ** 1.0×10^{-13}	0.06 **** 0.04	Neg. space charge
$C_iO_i^{(+/0)}$	E_v+0.36	2.05×10^{-18}, 1.64×10^{-14}	1.64×10^{-14}	2.24×10^{-14}	1.1	Pos. space charge
$E30K^{(0/+)}$	E_c-0.1	2.3×10^{-14} , 2.7×10^{-15}	2.77×10^{-15}	2.0×10^{-15}	0.017	Pos. space charge

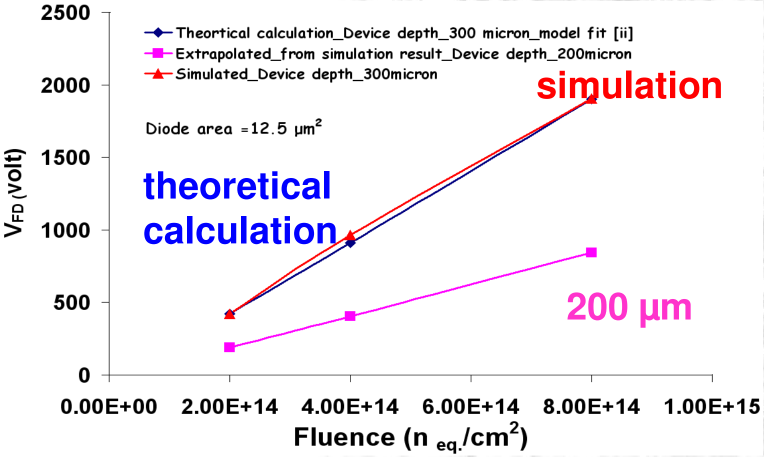
Cluster defects

Ref.
1) M. Petasecca et al, IEEE TNS VOL. 53, NO. 5,2006

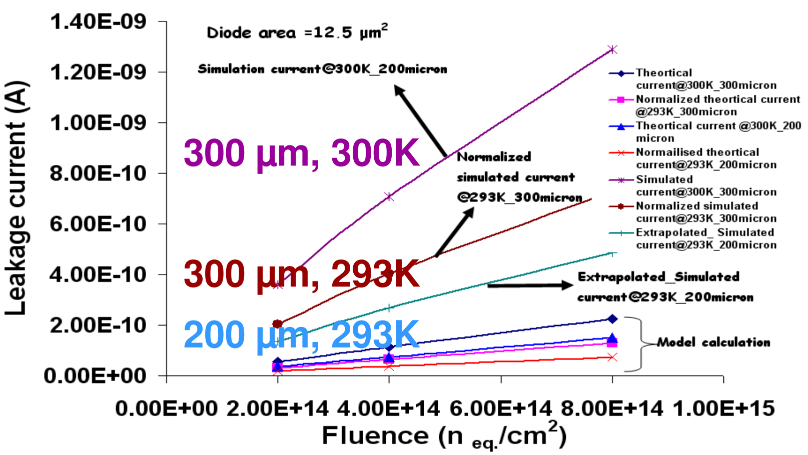
2) F.Moscatelli at al., NIMB, 186, 2002, 171-175

Effective model: Cross sections and introduction rates fitted to subsume several physical defects.

First results: Agreement of V_{FD} and I_{leak} between simulation and measurement data. More work to be done…



pad diodes for calibration



See: Ajay Srivastava:

Poster at IEEE 2009, Orkando, FL

Conclusions: CEC sensors

- CEC: Strong group working on various aspects of outer tracker modules and sensors
- HPK submission central ingredient for the CEC program.
    - several structures designed by CEC on HPK wafer
- Strong partners: ITE Warsaw and CNM Barcelona
    - Possible to test new designs/ ideas quickly and with little financial effort.
- ITE structures (focus on connectivity schemes):
    - Loads of data from SPS testbeam are waiting to be analysed
    - First promising results were obtained very fast!
- Progress in simulation: Have TCAD and full sensor level simulation in hand.
- Awaiting arrival of HPK sensors. I‘m convinced that we will learn a lot!