Status and Outlook of Si-Strip-Sensors from Infineon Technologies AG

Hacker Johannes, 2017-12-11

11th International “Hiroshima” Symposium on the Development and Application of Semiconductor Tracking Detectors (HSTD11)

HEPHY
INSTITUTE OF HIGH ENERGY PHYSICS

Infineon

CERN LHC ATLAS + CMS Phase-II Upgrades

Long Shutdown 3 (LS3) scheduled for 2024-2025

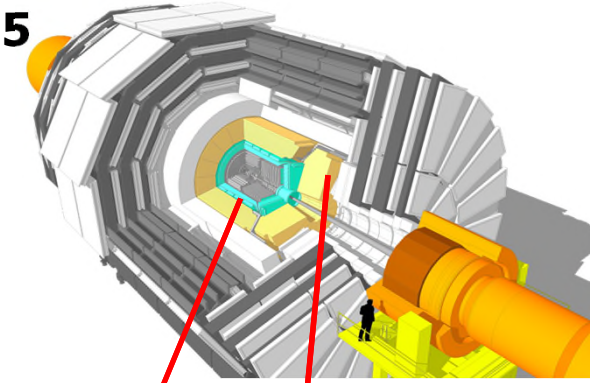
- Accelerator upgrade to High-Luminosity-(HL)-LHC
- Upgrade of experiments necessary
  - Existing systems reach end of life (radiation damage)
  - Increase in luminosity at HL-LHC: 300 → 3000 fb^{-1}

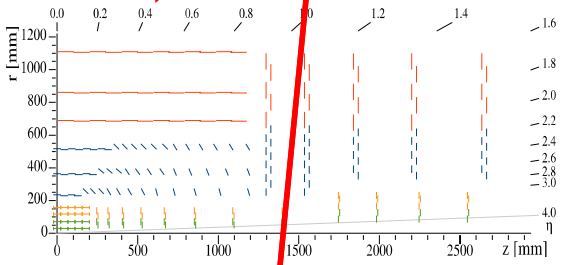
Phase-II Upgrade of ATLAS + CMS:

- Complete exchange of Outer Trackers
  → ~200 m^2 Si Sensors/experiment needed
- CMS: New Highly Granularity Calorimeter (HGCal)
  → 600 m^2 Si Sensors (8 inch)

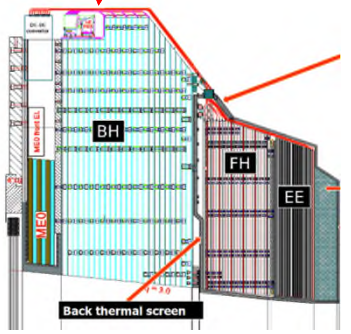
Both experiments need industrial parners

- Industrial production necessary due to large quantities
- → Cooperation HEPHY/Vienna & Infineon Technologies





Layout of Ph-II CMS tracker



Layout of CMS-HGCalorimeter

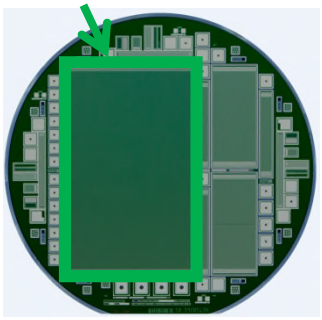
Collaboration HEPHY-Infineon Technologies

- HEPHY Vienna and Infineon Technologies cooperate since 2009 on the development of Si-sensors for HL-LHC-experiments
- Responsibilities
  - HEPHY: Layout-design, characterization, test-beams, irradiations, device-simulations
  - Infineon: Process-engineering, processing, establish series testing at Infineon
- Focus
  - Single sided planar AC-coupled n-in-p Si-strip sensors for Trackers of ATLAS + CMS Phase II Upgrades in 6”-technology Active thicknesses: 300/320 um and 240 um
  - Single sided planar DC-coupled n-in-p Si-pad sensors for HGC of CMS Phase II Upgrade in 8”-technology, 300, 200, 120 um
- Following measurements were done by HEPHY/Vienna if not stated otherwise

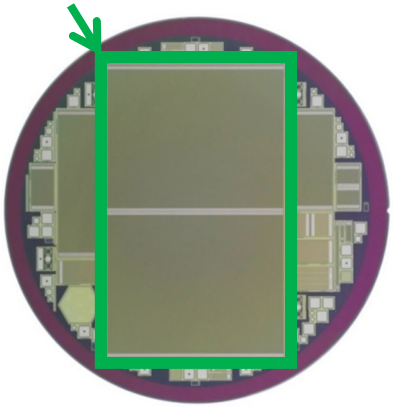
Achievements Overview

Wafer size	Polarity	Layout	Chipsize [cm²] main sensor	Thickness [µm] physical ≈ active
6"	p-in-n FZ	AC-Strip	10 x 7	200, 300
8"	n-in-p FZ	AC-Strip	15 x 10	200, 300
8"	n-in-p FZ	DC-Pad	18 x 16 hexagonal	140, 200, 300, 350
6"	n-in-p FZ	AC-Strip	5 x 10	240, 500

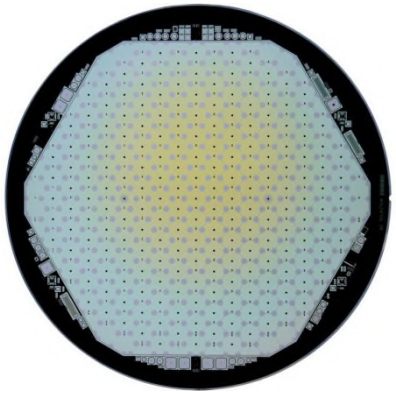
2012



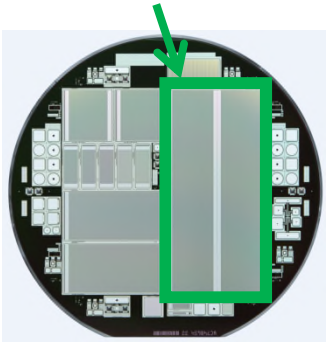
2015



2016

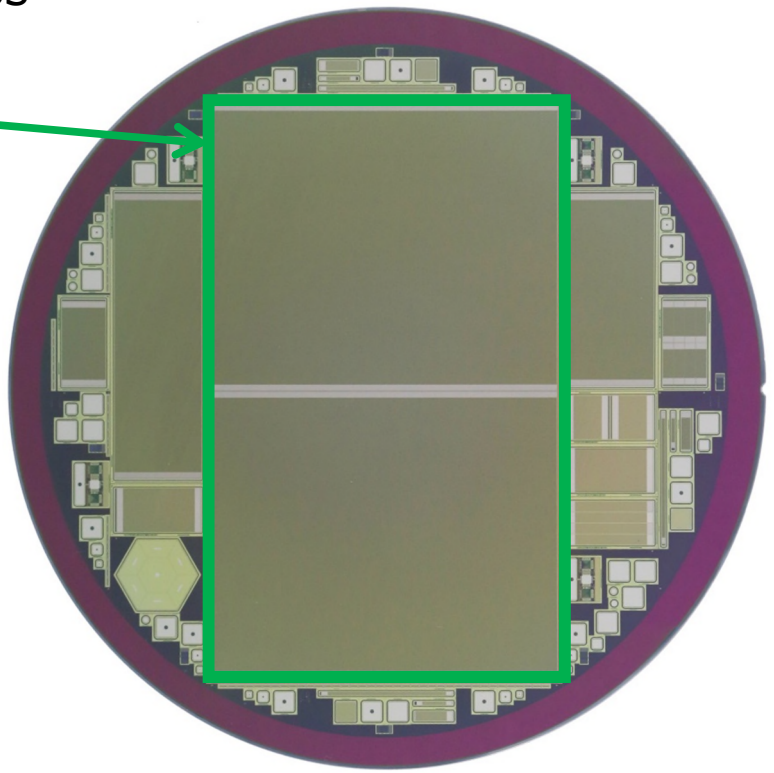


2017

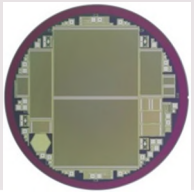


World's first AC-coupled Sensors on 8" Wafers

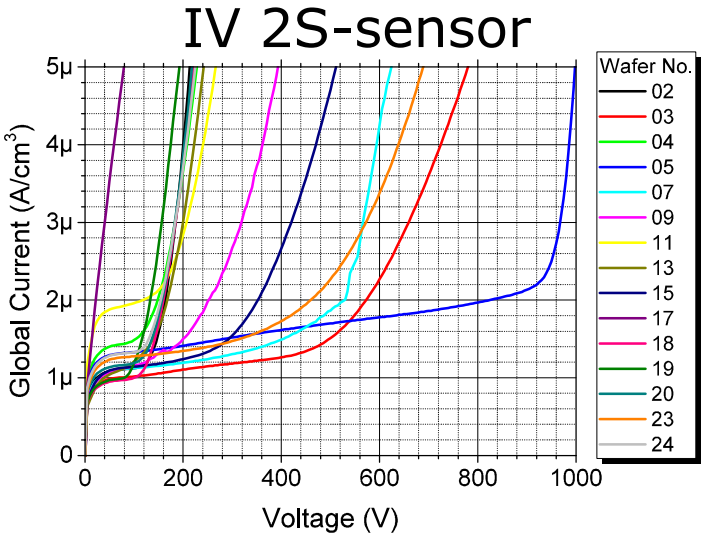
- Wafer for CMS-Phase II-Upgrade-Strip-Tracker
  - Wafer diameter (8" wafer): 200 mm
  - Resistivity 3..8 kΩcm, n-on-p float zone, orientation <100>
  - 200 µm and 300 µm physical thickness
- Main Sensor
  - Size: 94.183 x 153.4 mm^2
  - Strips: 2032, Strip length: 75.6 mm
  - Strip Pitch: 90 µm, P-stop: Atoll
- Split groups for runs:
  - p-stop / p-spray, Dose, Profile
  - Different R_poly doping

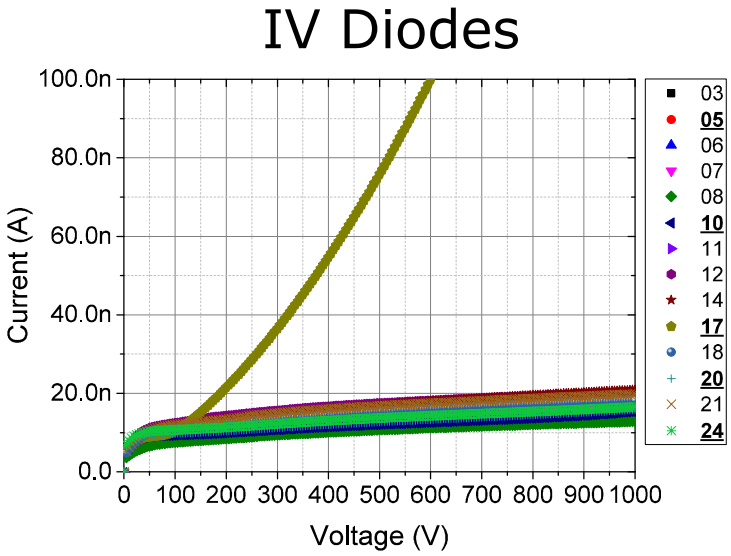


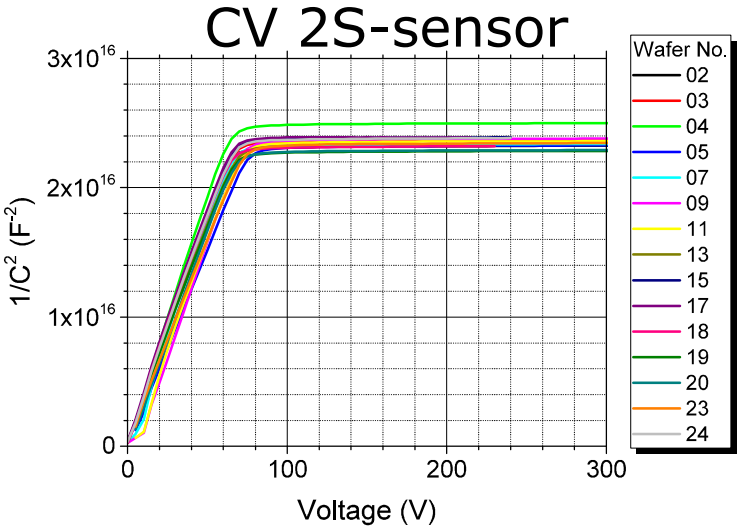
AC-coupled Strip-Sensors on 8” Wafers
Global parameters IV and CV



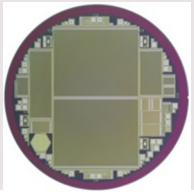
- Sensor-size: 15 cm x 9 cm
- Full depletion voltage of ~ 75 V
- Sensor-HV-stability to be improved
- Diodes are HV-stable



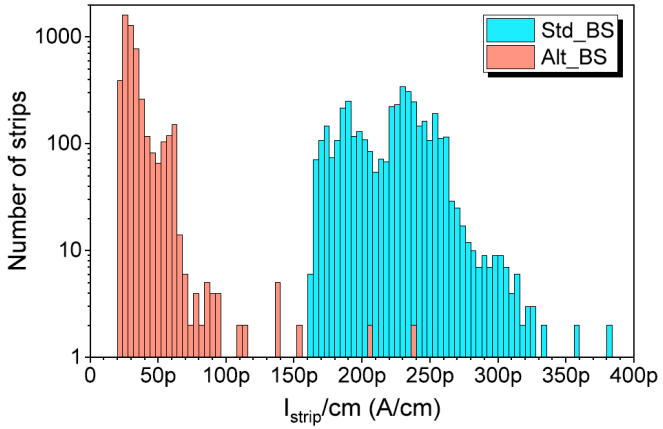




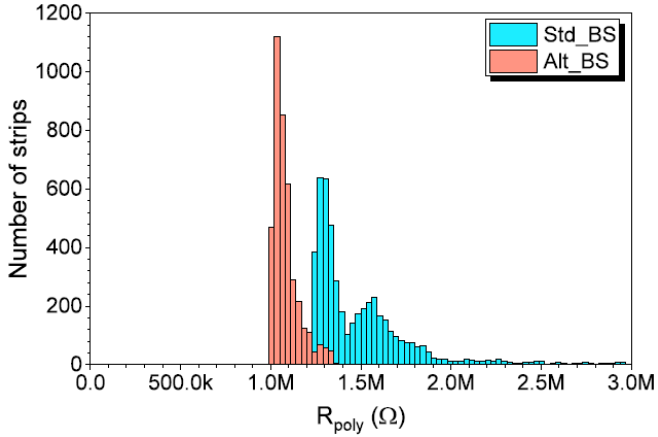
AC-coupled Strip-Sensors on 8” Wafers
Strip parameters of 9 2S_long sensors



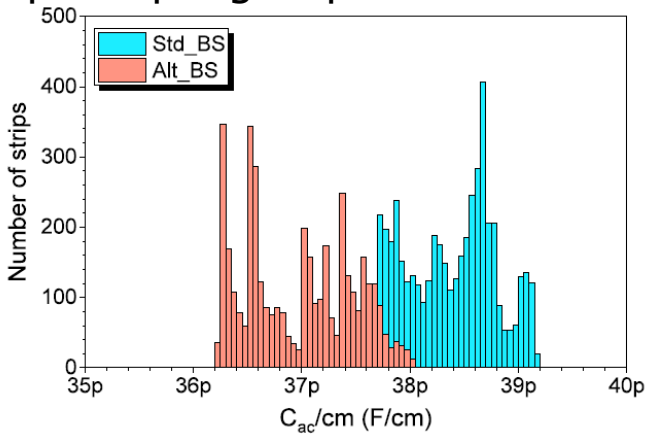
- Single Strip Current



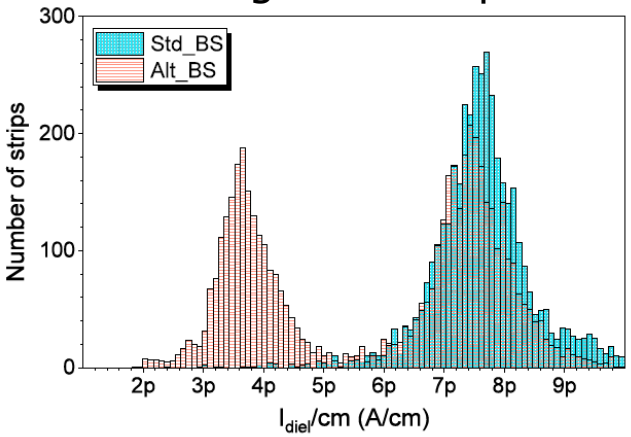
- Polysilicon Resistance



- Strip Coupling Capacitance

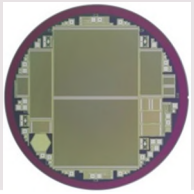


- Current Through the Strip Dielectric

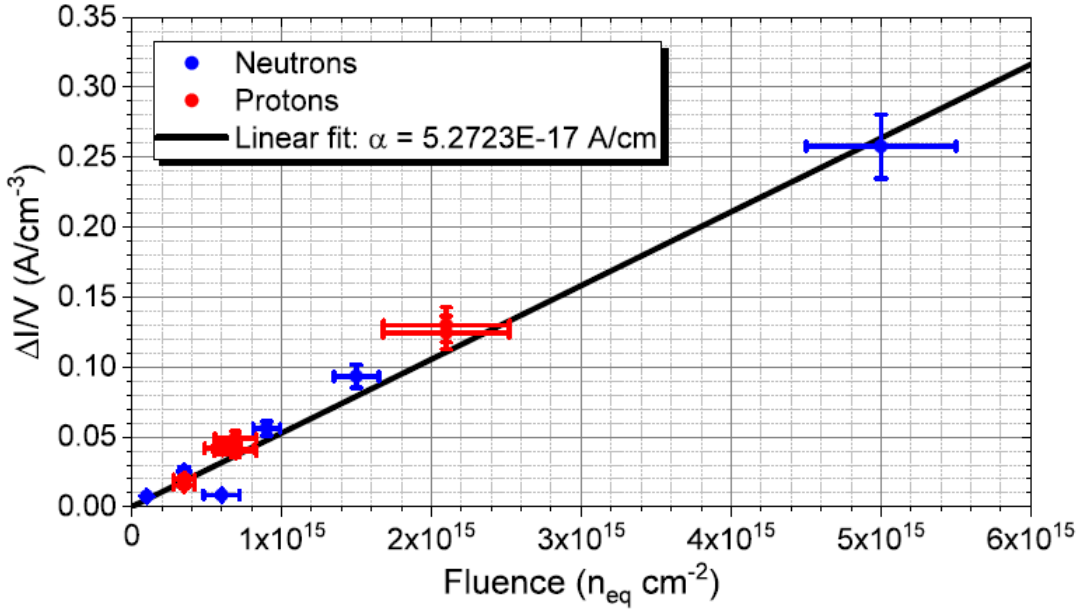


- All strip-parameters of target-process „Std_BS“ are in spec.

AC-coupled Strip-Sensors on 8” Wafers Irradiation

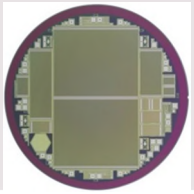


- Proton + Neutron irradiations of sensors and diodes were performed
- Difference in current before and after irradiation divided by the active volume after annealing of 10 min at 60 °C vs the 1 MeV neutron equivalent fluence, measured at -20 °C, scaled to 20 °C

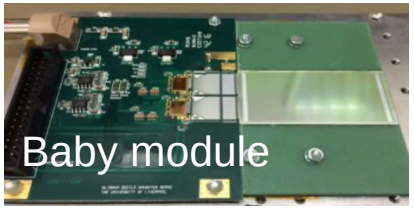


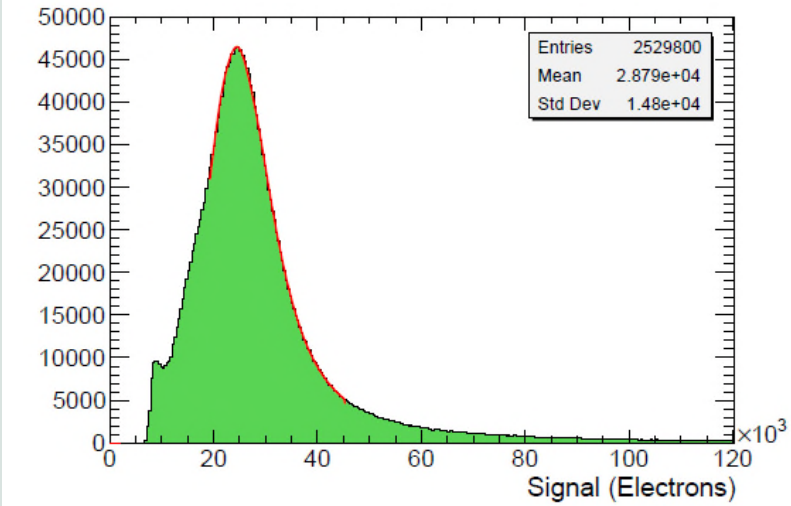
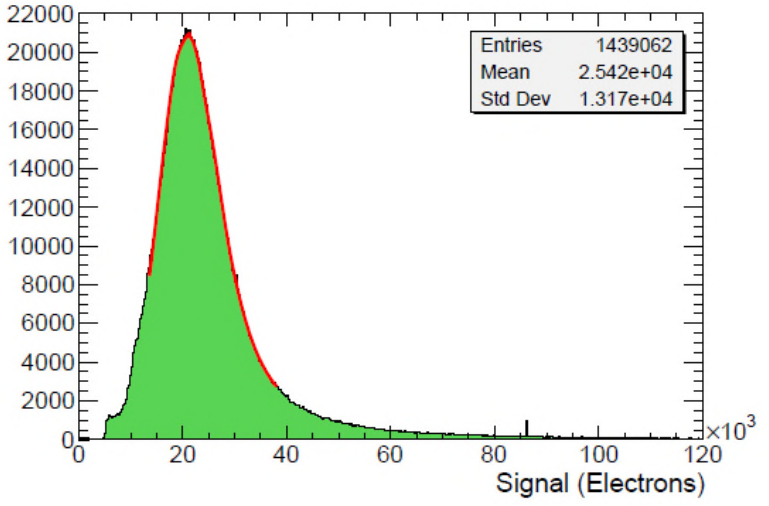
- α-value: $(5.27 \pm 0.23) \cdot 10^{-17}$ A/cm in line with theoretical expectations
- Radiation hardness of sensors of Infineon validated

AC-coupled Strip-Sensors on 8” Wafers Beam-Test: Most Probable Value

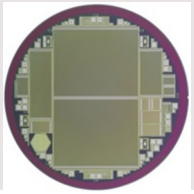


- Electron beam test conducted at DESY using a ALiBaVa Readout System



Unirradiated sensor	Irradiated sensor with neutrons $3.5 \cdot 10^{14}$ n_{eq} cm^{-2} @ TRIGA/JSI
	
$\mathrm{MPV_{Baby}} = 23660\ \mathrm{e^-}$	$\mathrm{MPV_{Irrad}} = 20150\ \mathrm{e^-}$

AC-coupled Strip-Sensors on 8” Wafers Beam-Test: Charge collection efficiency



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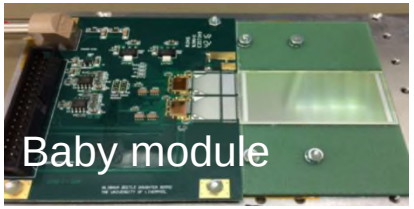


Irradiated sensor with neutrons $3.5 \cdot 10^{14}$ n_{eq} cm^{-2} @ TRIGA/JSI

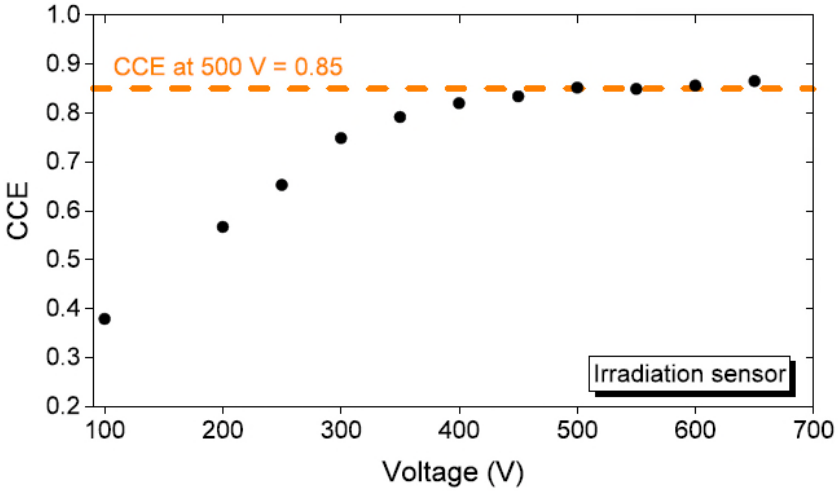
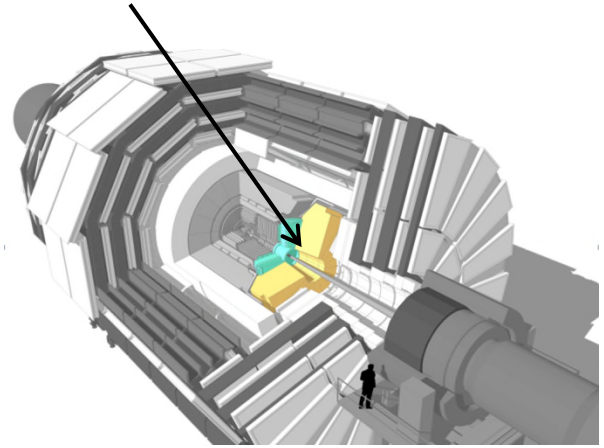


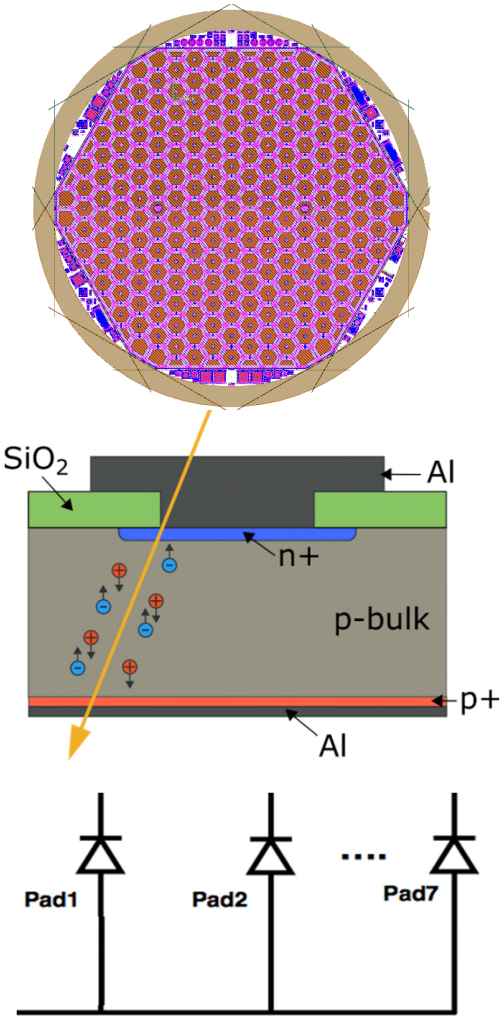
Figure 9.19.: Charge collection efficiency vs. bias voltage of the neutron irradiated sensor.

- Summary Beam-Test-Results: Sensors perform very well

CMS High Granularity Calorimeter

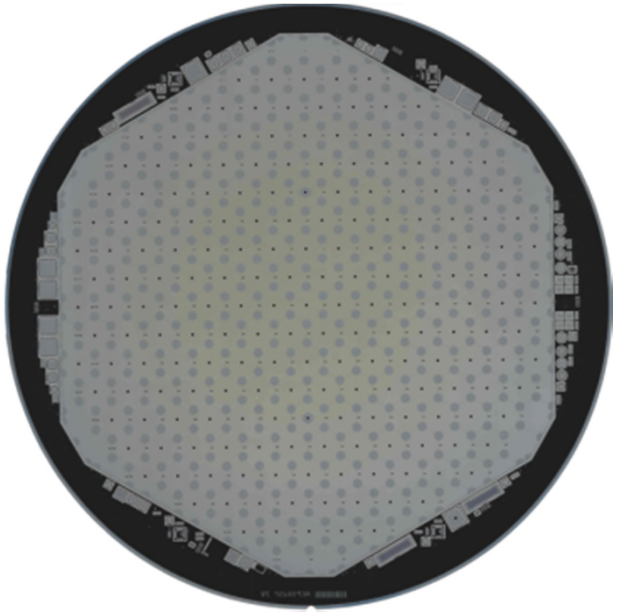
- CMS will upgrade it‘s forward calorimeter
- Si-sensors+Scintilators
- 600 m² Si-sensors
- 8“ technology baseline
- Active thicknesses
  - 300, 200, 120 um
- 183 connected hexagonal diodes/pads
  - No common biasing (no bias ring)
  - Each pad is basically an individual diode
  - Biasing through the readout chip in module
  - For testing all pads have to be biased as well
  - This complicates sensor testing



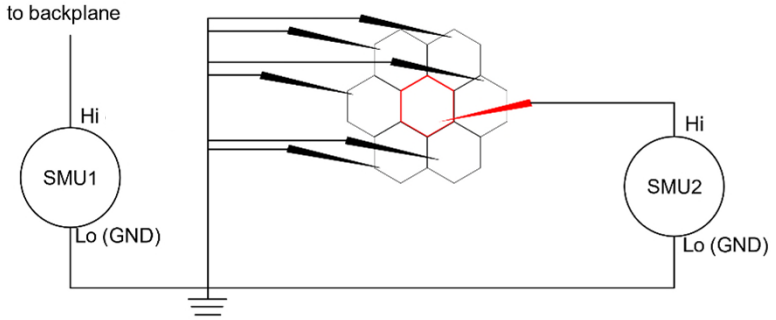


CMS High Granularity Calorimeter
8‟ planar n-in-p technology

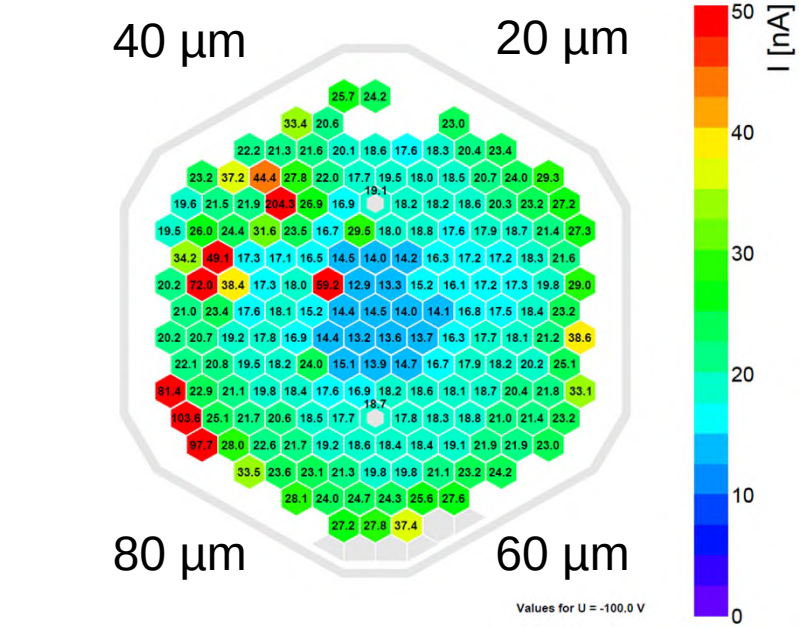
- World‘s first 8‟-HGC-wafers were produced and characterized



- High voltage-stability needs to be improved
- New processing-concept is currently in processing



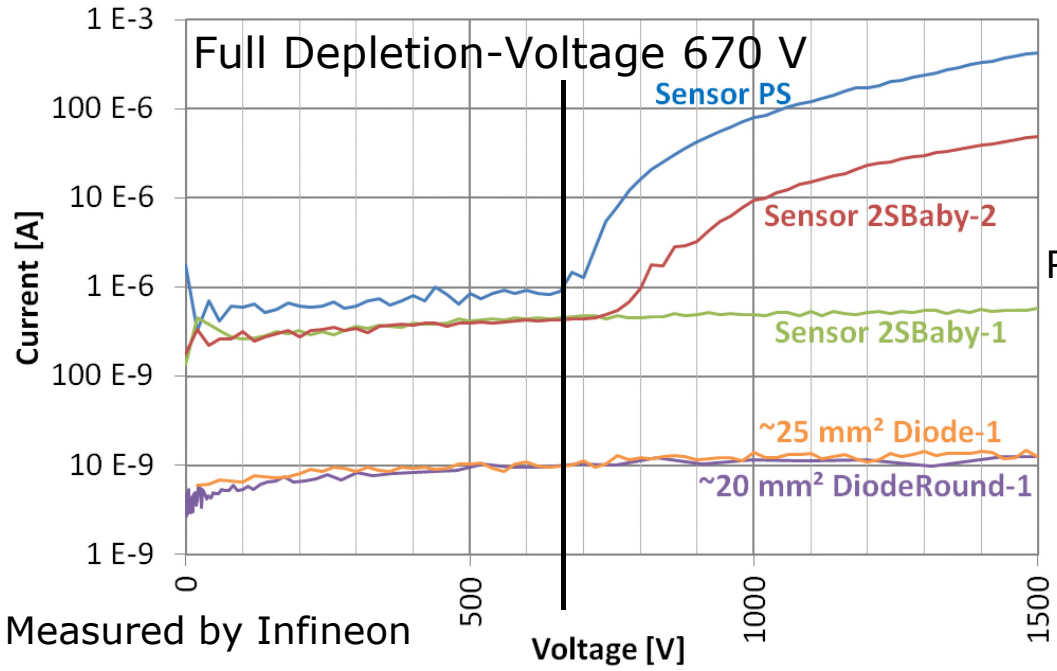
Current: 13 nA to 200+ nA (BD)

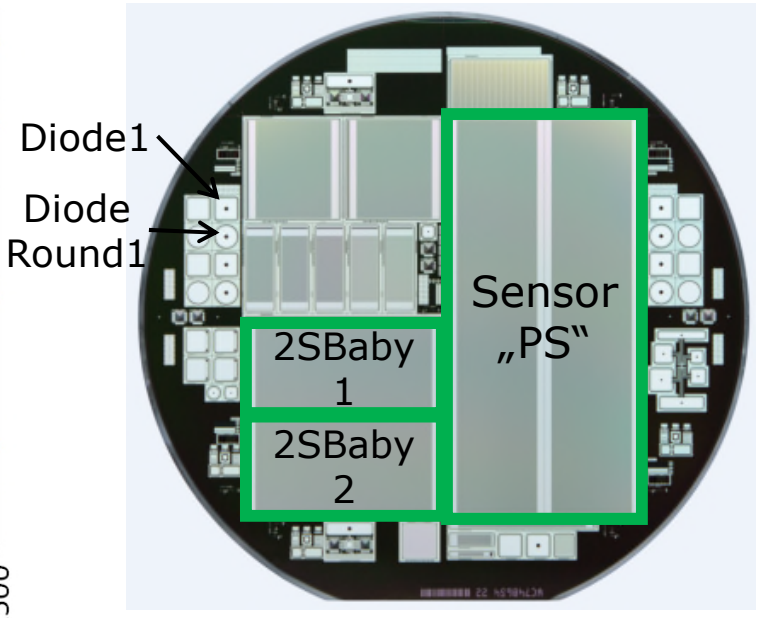


Current at -100 V IFX_8in_237_15

CMS-Tracker PS-Sensors 2017

- New design with CMS-Tracker „PS"-Sensor 5 cm x 10 cm
- 500 um active~phyiscal thickness by intention for development





- Smaller Sensor & Diodes stable up to more than 1500 V
- Larger Sensors: HV-stability-improvement is ongoing

Summary and Conclusions

- Processes for both 6“ and 8“ planar n-in-p strip & pad-sensors are created and characterized
- Strip parameters are in spec
- Radiation hardness is demonstrated
- Beam-Test: very good performance
- HV-stability needs to be improved
  - Infineon is working on solving this issue
- Thanks for the work by HEPHY/Vienna

  T. Bergauer, M. Dragicevic, A. König, E. Pree
  V. Hinger, D. Blöch, M. Valentan

- Thanks for your attention!

Part of your life. Part of tomorrow.

infineon