Characterization of RD53A pixel modules with passive CMOS sensors

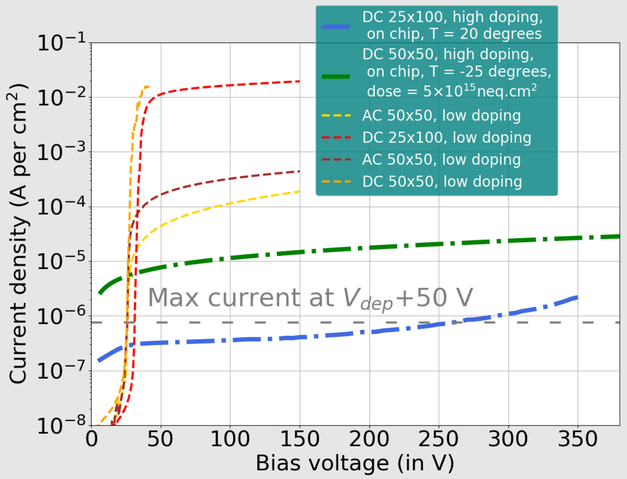
Franz Glessgen[a], Malte Backhaus[a], Florencia Canelli[b], Yannick Manuel Dieter[c], Jochen Christian Dingfelder[c], Tomasz Hemperek[c], Fabian Huegging[c], Arash Jofrehei[b], Weijie Jin[b], Ben Kilminster[b], Anna Macchiolo[b], Daniel Muenstermann[d], David-Leon Pohl[c], Branislav Ristic[a], Rainer Wallny[a], Tianyang Wang[c], Norbert Wermes[c], Pascal Wolf[c]

CMS market survey submission by LFoundry: | **n^+ in p** | **150 µm thickness** | **built using CMOS technology** | **25 × 100 µm² pixel size**

IV measurements

Phase 2 requirements:
0.75 µA per cm² at V_{dep} + 50 V
Breakdown > 300 V

- The first batch of bare sensors showed a very high leakage current ($V_{dep} = 40$ V).
- Fixed by increasing the backside implant doping.
- **Leakage current and breakdown voltage in compliance with the Phase-2 specifications.**
- The IV after irradiation is also well behaved.



CMOS sensors and stitching

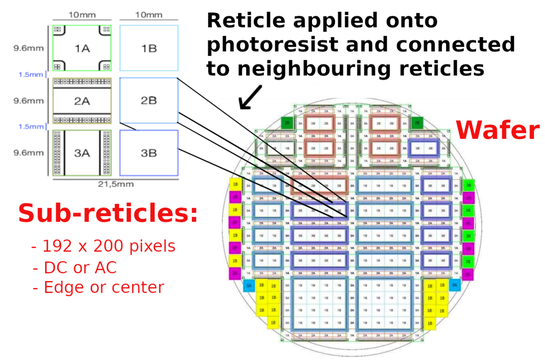
The characterized samples are passive planar n-in-p sensors for hybrid modules built in CMOS technology using the 150 nm production line of LFoundry and **the stitching process.**

Advantages of CMOS sensors:

- Reuse of CMOS libraries from the industry
- Large throughput and low cost
- Implementation of small on-pixel features

LFoundry on-sensor features:

- Metal layers on top of the sensor for signal redistribution
- DC or AC-coupled sensors
- Low and high resistivity polysilicon layers

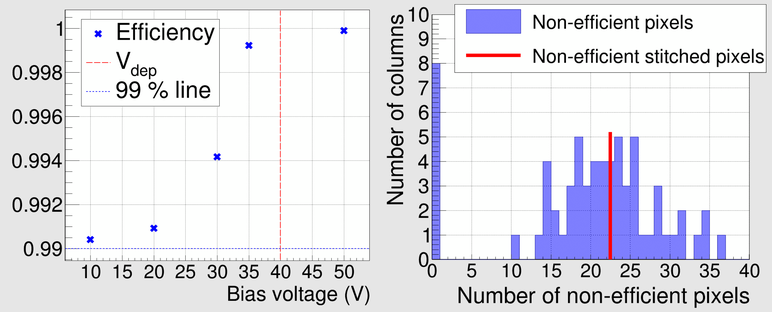


Efficiency

Phase 2 requirement:
99 % efficiency
at V_{dep} + 50 V

The efficiency is the probability of detecting a hit on the sensor within 500 µm of each reconstructed hit. Testbeam measurements give the following results.

- **The efficiency requirement is satisfied before the depletion voltage.**
- **The stitching process does not reduce the efficiency.**

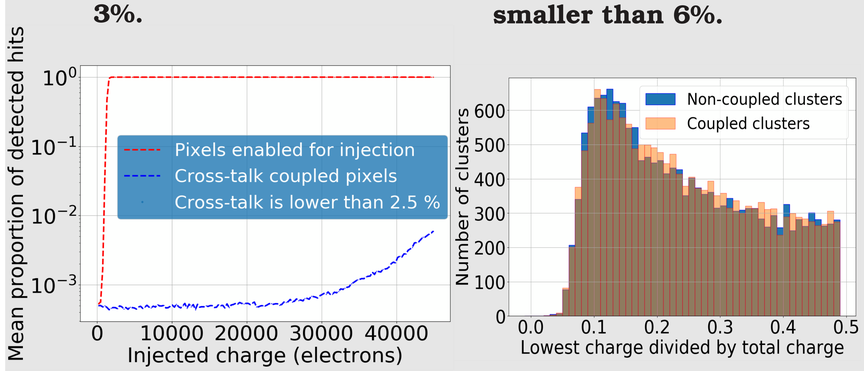


a: Institute for Particle Physics and Astrophysics, ETH Zürich, Zürich, Switzerland
b: Universität Zürich, Zürich, Switzerland
c: University of Bonn, Physikalisches Institut, Bonn, Germany
d: Physics Department, Lancaster University, Lancaster, U.K.

Crosstalk

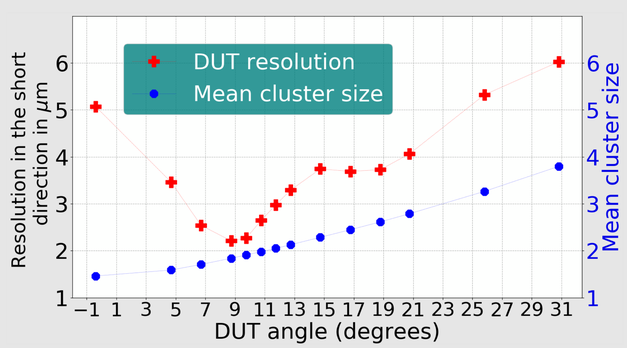
Capacitive coupling between neighbouring pixels leads to spurious hits and can deteriorate the sensor's resolution.

- Injection through the RD53A of a known charge showed that **the cross-talk is smaller than 3%.**
- The ratio of the lowest charge over the total charge for 2-pixel clusters showed that **the cross-talk is smaller than 6%.**



Resolution

Minimal resolution of **2.2 µm in the 25 µm direction** around 9.5 degrees. The CMS tracker has a Lorentz angle of 11.5 degrees.



Next steps

- Modules irradiated up to 10^{16} neq.cm^{-2} to be tested
- New sensor submission expected this year

Charge collection

- Time-over-threshold distribution from DESY testbeam runs.
- Charge calibration of the RD53A using fluorescent X-ray sources.

Full charge collection of approximately 12000 electrons is reached for a bias voltage of 40 V.