

Update on HGCal silicon sensor studies

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Outline



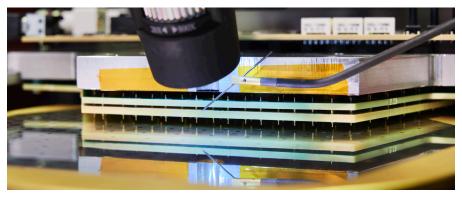
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- 8-inch 120 µm thick
- New 6-inch "jumper" sensor results
- + irradiation campaign
- Sensor noise studies
 - Modifications on the new 8-inch Hexaboard for probe-station measurements
- Light injection setup for Charge collection efficiency
 - Alternative light source investigation
 - Multiple cell illumination setup
- New probe station installation







8-inch 198-ch 120 µm sensors

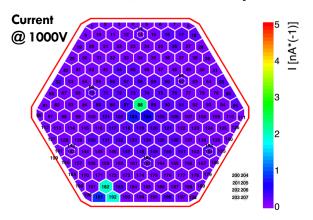
current and capacitance vs voltage

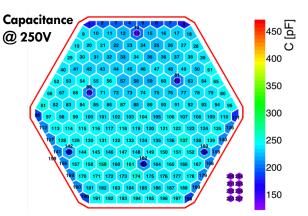


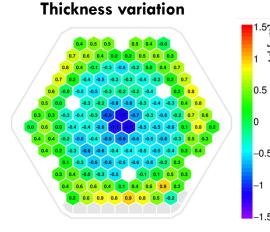


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- IV shows a **systematic cell** with **higher current**, always close to the sensor center
 - Matches with **scratch** in sensor **front side**, produced during sensor fabrication
- Capacitance measurement for **individual cells**, as well as for the **full sensor** (with all cells shorted)
 - Shorted capacitance measurement indicates a sensor thickness of ~116 µm (parallel plate approx.)
 - Combined with individual cells capacitance, thickness variation can be estimated
- In addition, 200 and 300 µm thick sensors were also measured











6-inch 239-ch "jumper" 120 µm sensors

ARRAY system

(link to paper)

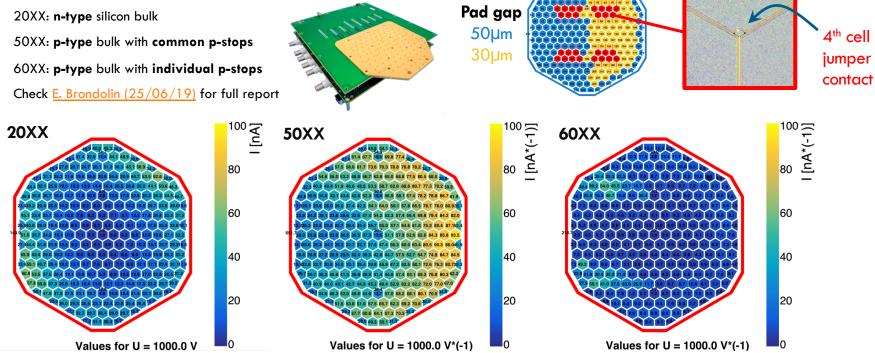




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current vs voltage





6-inch 239-ch "jumper" 120 µm sensors

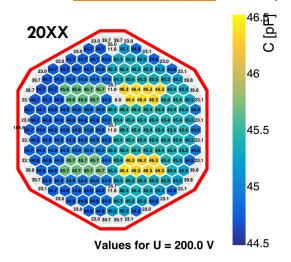
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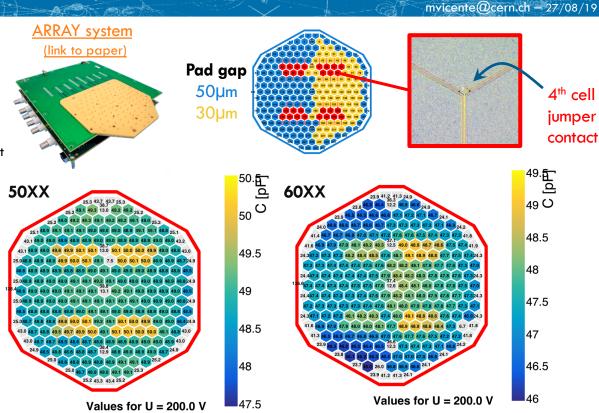




Sensors tested

- 20XX: **n-type** silicon bulk
- 50XX: p-type bulk with common p-stops
- □ 60XX: p-type bulk with individual p-stops
- Check E. Brondolin (25/06/19) for full report





6-inch 239-ch "jumper" 120 µm sensors

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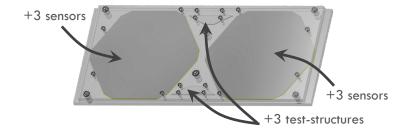


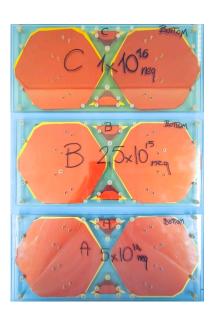
Irradiation at Ljubljana

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- Irradiation doses
 - $0.5 \times 10^{15} \, n_{eq}/cm^2$
 - 2.5 x 10^{15} n_{eq}/cm²
 - $10 \times 10^{15} \, n_{eq}/cm^2$
- Sensors to be irradiated (2 at each fluence)
 - 6x n-type + 6x test-structures

 - 6x p-type ind. + 6x test-structures





*arrived in Ljubljana on 9th August Irradiation started this week



6-inch 136-ch 300 µm sensors

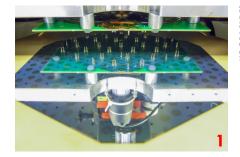
Noise measurement

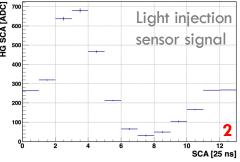


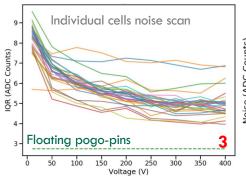


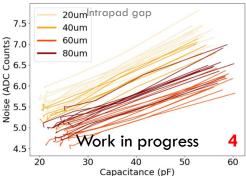
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- 1 Noise measurement w/ Hexaboard probe-card
 - Detector module read-out board adapted for probe-station measurements using pogo-pins (replacing wire-bonds)
- 2 Sensor signal with a digitized read-out
 - 4x Skiroc2_CMS read-out ASICs
 - Signal measurement with a low and high gain 13-deep SCA (Switched Capacitor Array)
- **3 Noise** is measured as function of the HV bias applied for individual sensor cells (while no charge injection)
- 4 The HV on each cell can be converted to a measured capacitance from previous CV measurements
 - Linear relationship btw. noise and capacitance is measured
 - Influence on intrapad distance/capacitance influence on noise being investigated









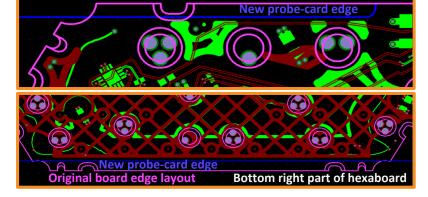


Original board edge layout

- With working methodology, noise measurements will follow on irradiated sensors (high priority measurement!)
 - A probe-station with a cold-chuck is needed to test the sensors after irradiation
 - Avoid thermal run-away from the higher leakage currents with cooling
- Next HGCal detector module uses a 8-inch sensor
 - Modifications on the new 8-inch Hexaboard were made for production of a 8-inch Hexaboard probe-card
 - Pass-through pogo-pin (instead of SMD pogo-pins) → Enable signal measurement (TCT) independent of read-out ASIC
 - **Longer pogo-pin** for VCSEL placement (more on slide #10)
 - Extra jumper resistors to disconnect pogo-pin from the RO chip (only on 4 cells)
 - Board edge reduced for sensor guar-ring access with needles
 - Signal re-routing for PCB opening for card/sensor alignment



Top left part of Hexaboard



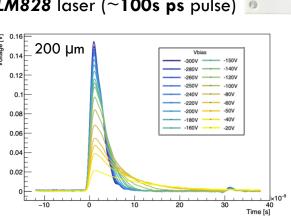
6-inch 136-ch sensor test-structures

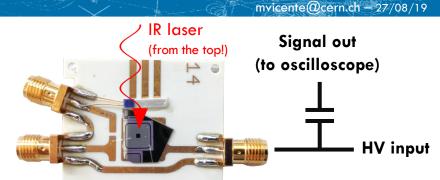
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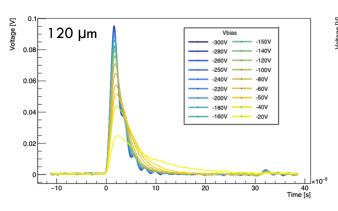


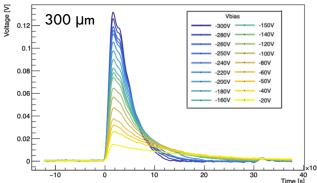
Light injection setup development

- Charge Collection Efficiency (CCE) measurements
 - TCT and Hexaboard probe-card measurements
 - Before and after irradiation
- Initial tests with 3 test-structures for setup development
 - 120, 200 and 300 µm active thickness
- Measurements with the PicoQuant SLM828 laser (~100s ps pulse)









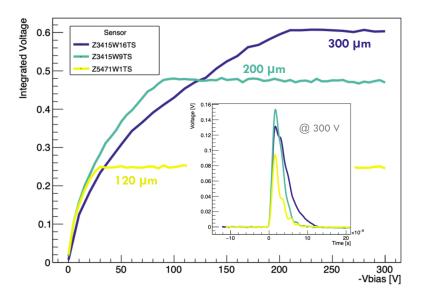
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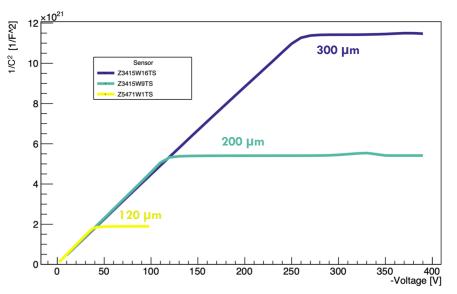
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Light injection setup development

- □ First CCE results! Total collected charge (integrated voltage) as function of HV
 - Total collected charge increases until the HV plateau region, when the sensor is fully depleted and all charge created is collected
 - Depletion voltage matches stand-alone capacitance measurement





6-inch 136-ch sensor test-structures

Light injection setup development

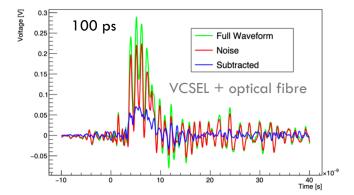


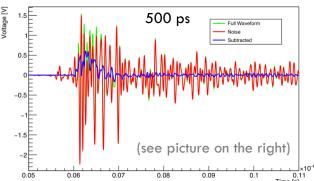


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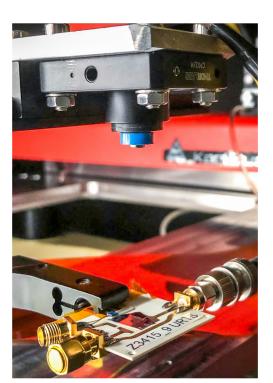
PicoQuant laser alternatives

- **VCSEL** (Vertical Cavity Surface Emitting Light) sources
 - Available as a **die** or in a **TO** (transistor outline) package
 - Some packages can be coupled directly to an **optical fiber**
- Pulse length can be tuned with the driving pulse generator
- We found out that the wire-bonded test-structure is a good antenna for **EMI noise**
 - Such as **RF** noise from the pulsing **VCSEL** or the labs fluorescent light powering on





Light output



Light injection setup development

Next steps with full sensor

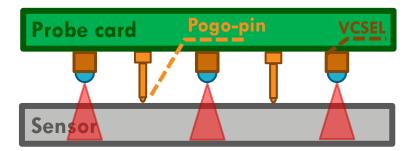


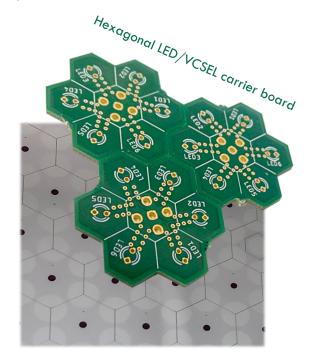


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- □ **FNAL probe-card** with **7 pogo-pins** (1 for cell readout + ground for 6 cells)
 - PicoQuant laser and VCSELs
 - EMI might be different by replacing wire-bonds with pogo-pins
- Multiple cell light injection (VCSELs only)
 - TCT measurement with FNAL board
 - Hexaboard probe-card measurement
 - Digitized readout does not show EMI influence (see #2, slide 6)

Towards... A probe-card with multiple cell light injection capabilities





New ALPS installation and commissioning

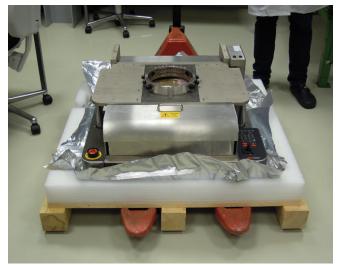
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Automatic Low-temperature Probe-Station

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- New (semi) automatic probe-station with a cold-chuck installed in the LCD HGCal clean-room (bldg. 186)
- Arrived at CERN on 31 of July
 - installing + training + commissioning through August









New ALPS installation and commissioning

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Automatic Low-temperature Probe-Station

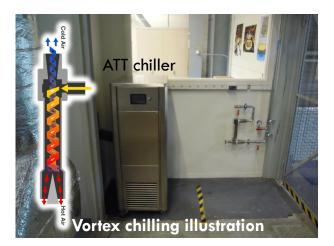
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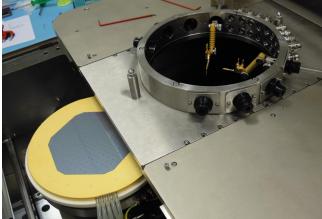
ATT vortex based chiller

- □ Chiller can consume 400 liter per minute!
- Outside the room to avoid fight between room's AC system and hot air exhaustion from chiller

ATT chuck

Rated from -40 °C up to +200 °C, successfully tested









New ALPS installation and commissioning

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Automatic Low-temperature Probe-Station

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- 1 Needle probing configuration tested with real sensor and automatic movement of the chuck
- 2 Probe-card enclosure was installed and probe-card positioned
- 3 Happy crew with successful installation and training
- Next steps
 - Improve light-tightness of system
 - Calibrate the sensor/chuck temperature measurement
 - IV, CV, noise and CCE measurements with **irradiated full-wafer sensors** in the near future







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Summary

- IV and CV campaign with 6-inch "jumper" sensors
 - All sensors behave as expected with a total current O(10 μA) at 1000 V
 - Current per **cell** is O(100 nA) at 1000 V, without any cell breaking down
- Sensor noise measurement setup ready
 - Sensor measurement before and after irradiation, thanks to the new ATT cold chuck
 - Modifications on the new 8-inch Hexaboard for probe-station measurements
 - New pogo-pins will allow an additional capability for TCT measurement
- Light injection setup for CCE with first results for test-structures
 - Alternative light source shows possibility to simultaneous light injection on multiple cells
 - Measurements with the full sensor to follow
- New probe station successful installation
 - On-going commissioning by replicating the 6-inch IVs, CVs, and noise measurements
 - Irradiated sensor measurements to follow with highest priority

