Measurement of silicon-sensor prototypes for the CMS High-Granularity Calorimeter Upgrade for HL-LHC

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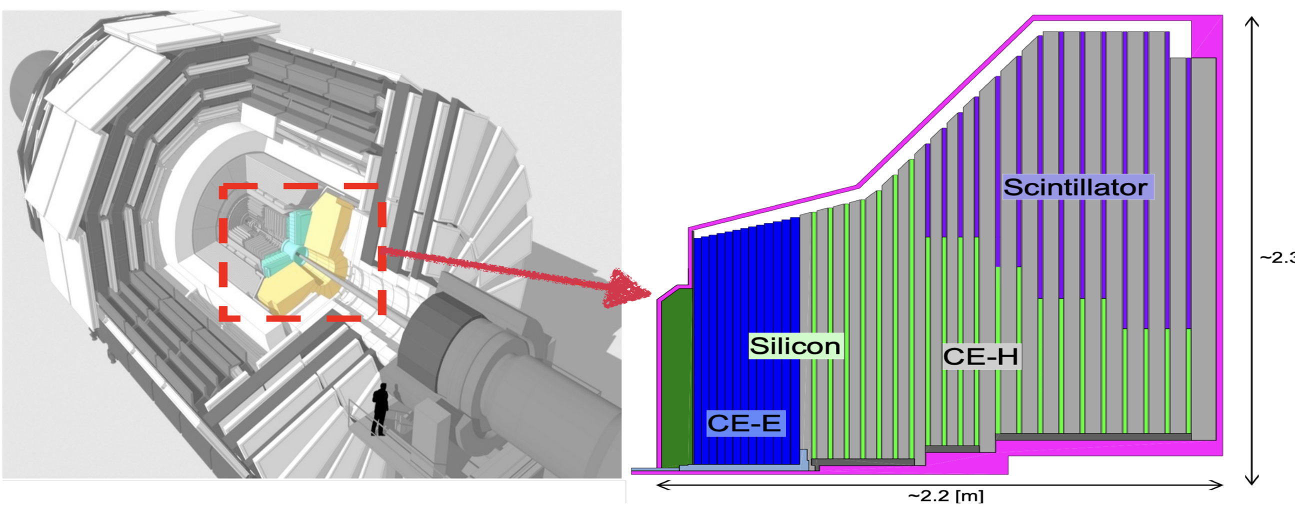
Overview of HGCal

Key parameters for the HGCAL:

- HGCAL covers 1.5 $<\eta<$3.0
- Full system maintained at -30 °C
- ~26000 Si modules
- Power at end of HL-LHC: ~125 kW per endcap
- ~620 m^2 of silicon sensors
- ~370 m^2 of scintillators
- 6M Si channels, 0.6 or 1.2 cm^2 cell size

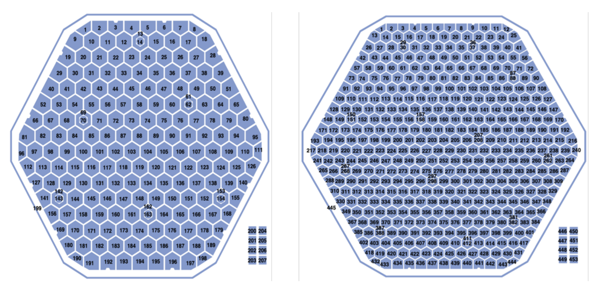


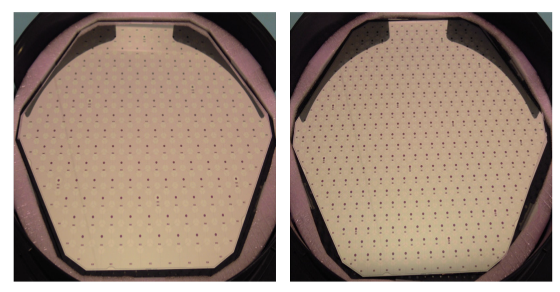
- Endcap Electromagnetic calorimeter (CE-E): Si, Cu & CuW & Pb absorbers, 26 layers, 27.7 X_0.
- Hadronic calorimeter(CE-H):Si & scintillator, steel absorbers, 21 layers, ~8.5 λ
- First 5D imaging calorimeter to operate in a collider experiment

Silicon-sensor plays a crucial role

Overview of the sensor

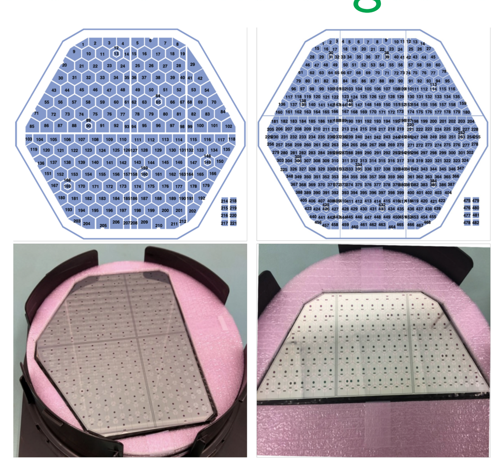
Overview of full-sized sensors

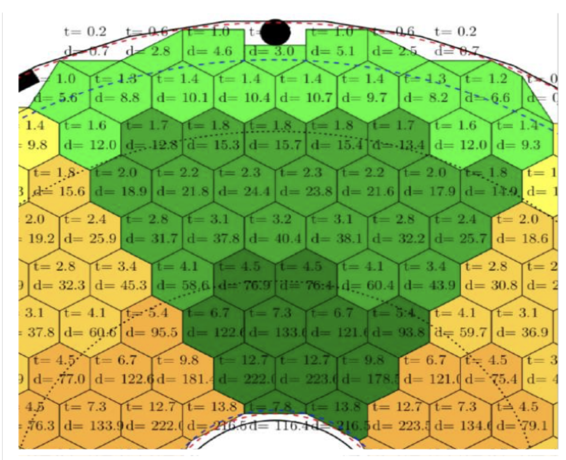




- 8" full-sized sensors with different number of channels
- 3 different oxide quality: B, C, D
- 3 different thicknesses 120μm, 200μm, 300μm
- Some of them have been irradiated up to around 10^{16}neq/cm^2

Overview of multi-geometry sensors

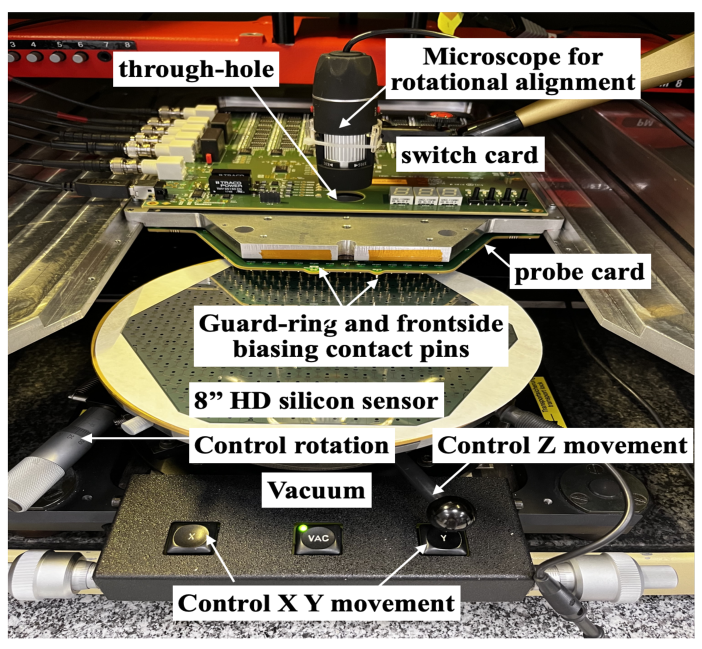


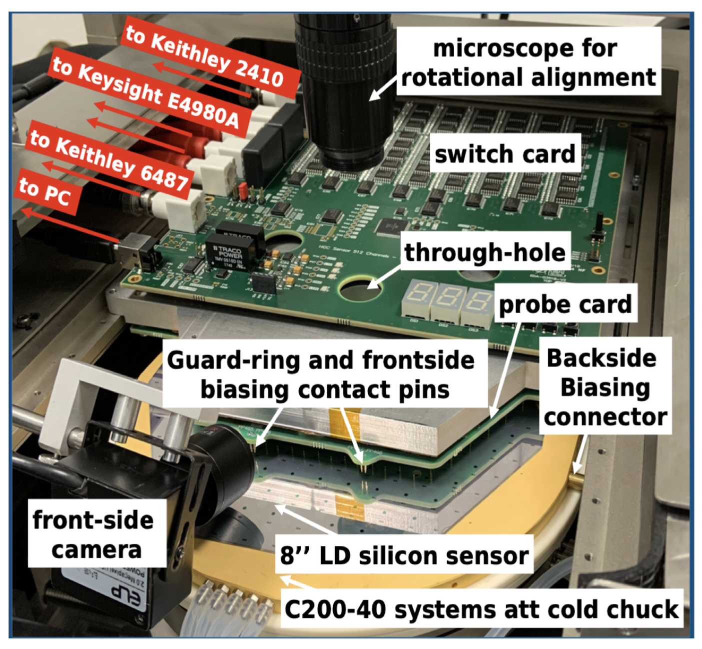


- 8" multi-geometry sensors with different number of channels
- 3 types of thicknesses
- Produce "partial sensors" to tile inner and outer edges
- 7 cut types, oxide quality: C

Measurement setup

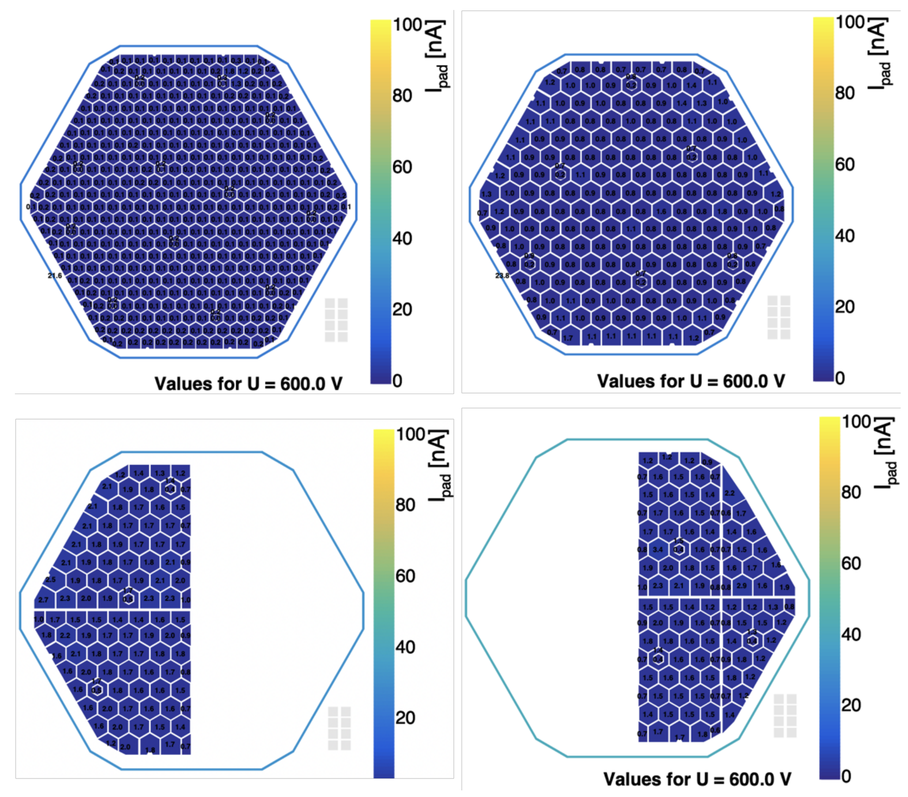
Measurement setup





- Sensors on chuck with backside protection
- Temperature: room temperature; humidity: 4%-8%
- Voltage up to -850V
- Only used for non-irradiated sensors
- Sensors on chuck without backside protection
- Temperature: -40°C; humidity: 4%-8%
- Voltage up to -850V from backside
- Annealing at 60°C,target time of 80 mins

Leakage current measurement before irradiation



Grading

Global characteristics:

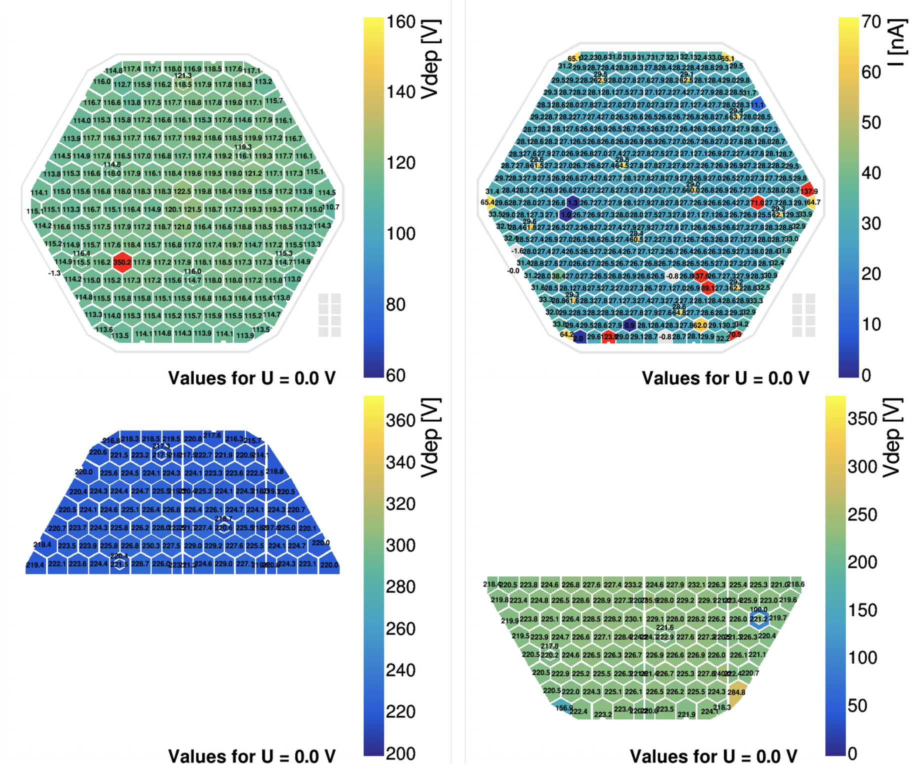
- Total current at 600V(I_{600})<100μA
- I_{800}<2.5 * I_{600}
- Bad pads number≤ 8(full-sized)
- Adjacent bad pads number ≤ 2

Define bad pads:

- Pad current at 600V > 100 nA/pad

- Measure full-sized sensors, and multi-geometry-sensors.
- Leakage current less than 100μA at 600V, all passed

Depletion voltage measurement before irradiation



Grading

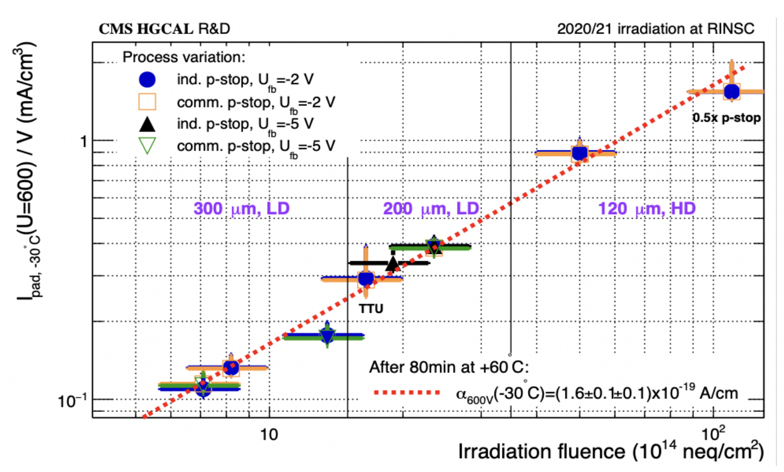
Global characteristics:

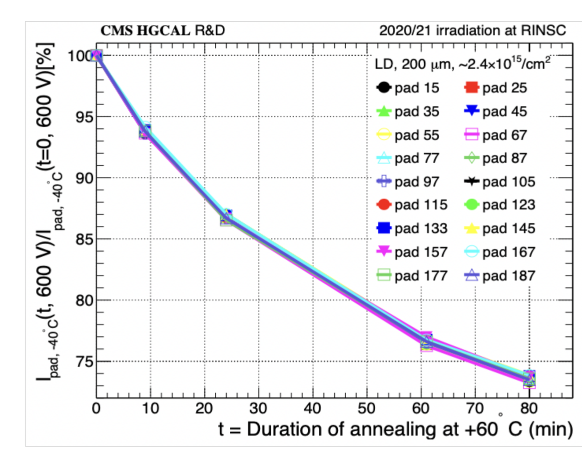
- Full depletion voltages
  V_{dep}:median of depletion voltages across cells
- V_{dep}<370V for 300μm thickness
- V_{dep}<160V for 200μm thickness
- V_{dep}< 70V for 120μm thickness

Depletion voltage sensitive to thickness

Depletion voltage all passed the grading

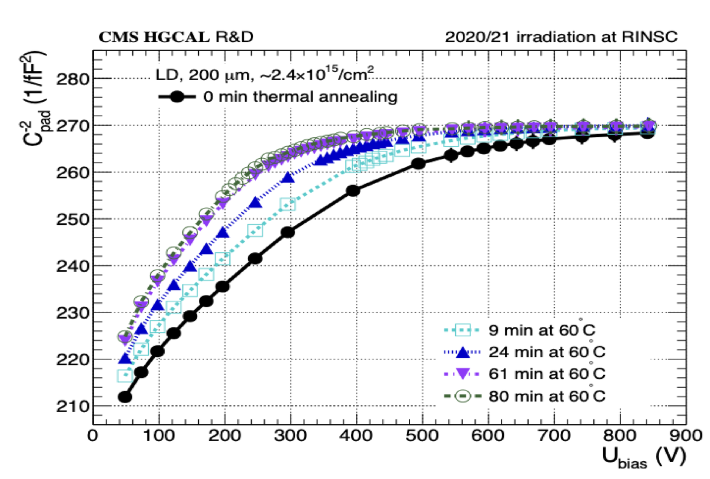
Leakage current measurement after irradiation

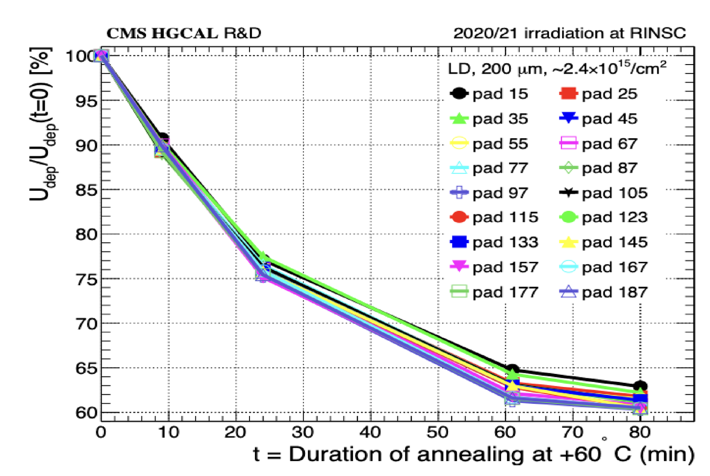




- $\frac{\Delta I}{V}=\alpha*\Phi_{eq}$($\Delta$I: change of leakage current, α: current related damege rate, Φ_{eq}: irradiation fluence, V: volume)
- Linear relationship between leakage current and irradiation fluence
- $\frac{\Delta I(t)}{\Delta I(0)}=be^{-\frac{t}{\tau}}$(b: corresponding amplitude, t: annealing time, τ: time constant)
- Leakage current drop with annealing

Depletion voltage measurement after irradiation





- The change of depletion voltage is dominated by short annealing term $N_A=\Phi_{eq}*g*e^{-\frac{t}{\tau}}$(g: introduction rate)
- Depletion voltage decreases with annealing time

Next step

- Start the irradiation test for multi-geometry sensors with higher fluence
- Measure pre-series sensors
- Prepare measurement infrastructure and procedure for mass measurement

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