

IV+CV Results for HGCAL Proto A Sensors

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CMS HGCAL Sensor Testing Weekly Meeting



Outline

1 Introduction

2 IV Results

3 CV Results

4 Additional Measurements

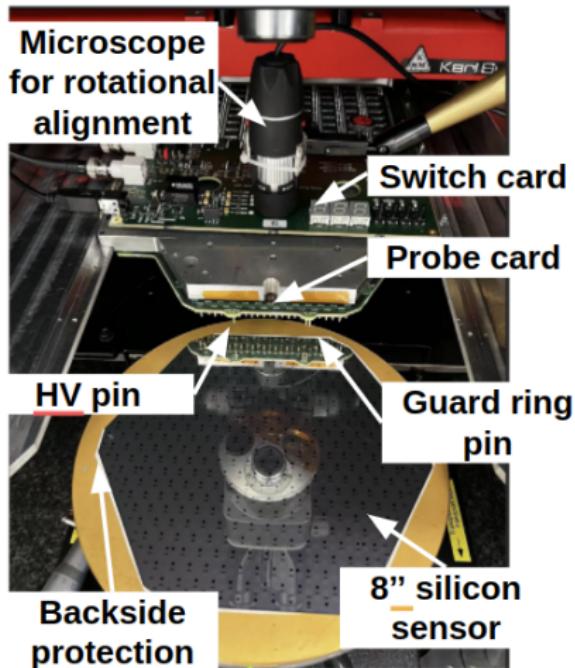


Proto A sensors and their properties

- 120 um:
 - ▶ 19 HD Sensors: 5 oxide type B, 8 oxide type C (3 common p-stop), 6 oxide type D
- 200 um:
 - ▶ 12 LD Sensors: 2 oxide type A, 3 oxide type B, 5 oxide type C (3 common p-stop), 2 oxide type D
- 300 um:
 - ▶ 12 LD Sensors: 2 oxide type A, 3 oxide type B, 4 oxide type C (common p-stop), 5 oxide type D

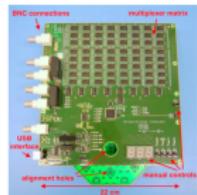


Measurement Setup



- Measurement at room temperature
- Humidity: 40% – 50%
- Voltage up to -850V
- Voltage provided through the HV pin to the backside

General Remarks



picture of a discharge

- Vulnerability to switch card breaks
- No discharges has been observed for proto A sensors
- Test throughput max. 20 per week

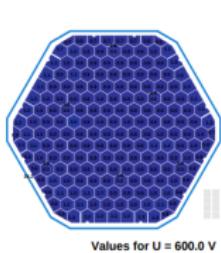


Proto-A: example IV+CV results



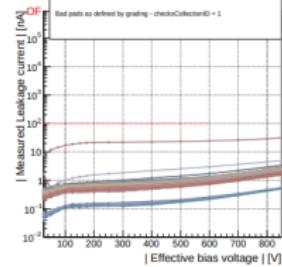
CERN IV
N4791_6

Cell current at 600 V

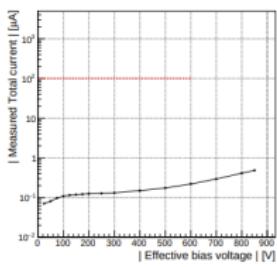


Values for $U = 600.0$ V

Channel IV curve

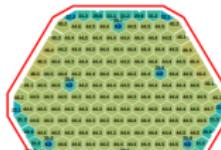


Total current curve



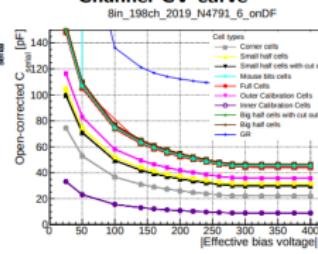
CERN CV
N4791_6

Capacitance at -400 V

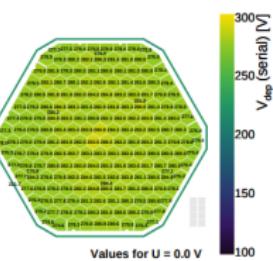


Values for $U = -400.0$ V

Channel CV curve



Depletion voltage



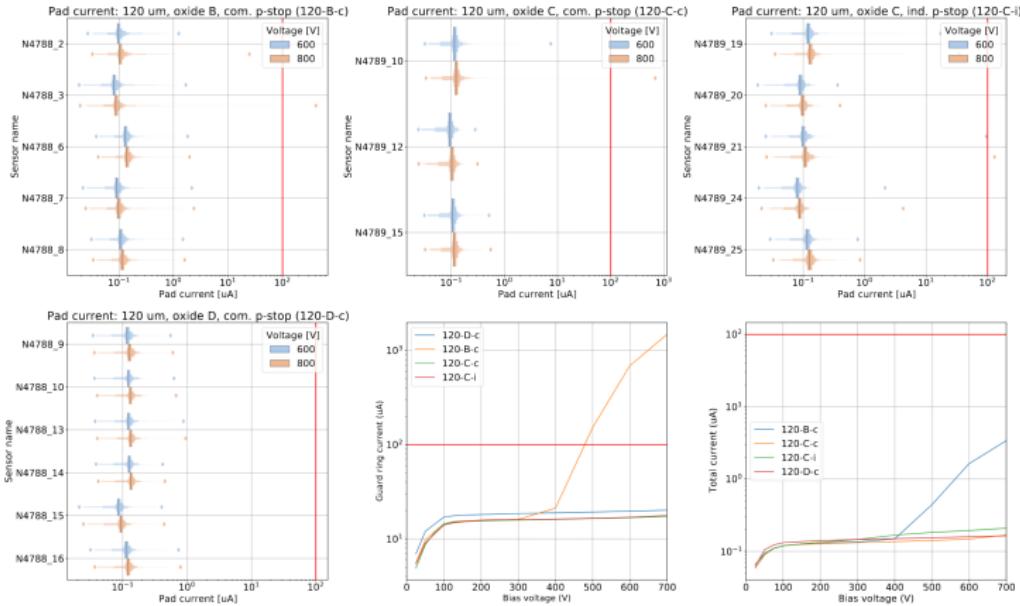
Values for $U = 0.0$ V



Outline



Proto-A, 120 um, IV results: HPK and CERN (on DF)

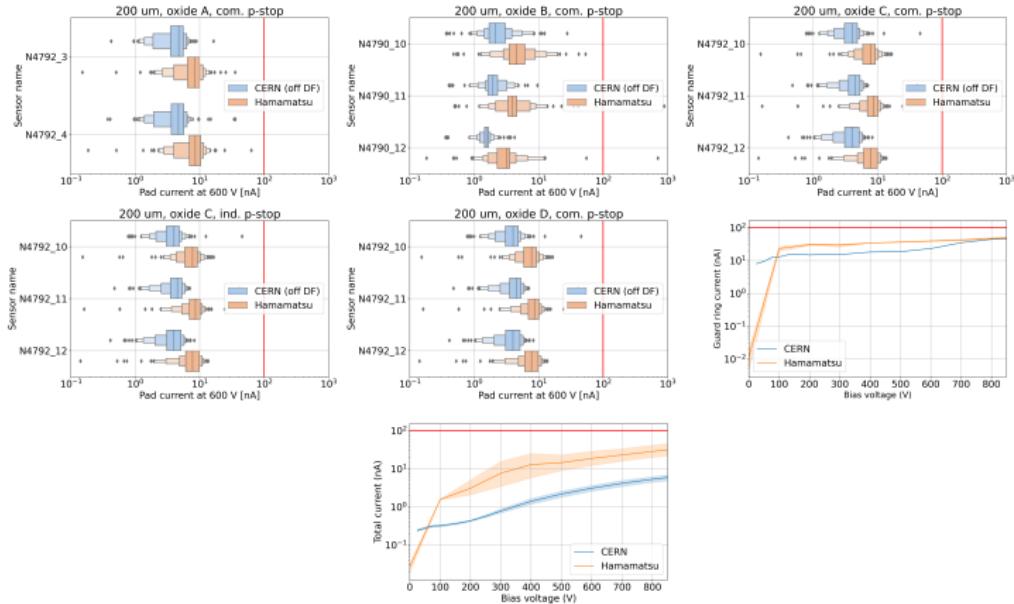


Proto-A, 120 um, IV grading comparison

tbd



Proto-A, 200 um, IV results: HPK and CERN (on DF)



Proto-A, 200 um, IV grading comparison

Proto-A: CERN IV grading, 12/12 passed



CMS full probe card (off dicing frame)									
Sensor ID	Thick-ness	P- Stop	Oxide type	I_tot_600V <100uA	I_tot_800V < 2.5* I_tot_600V	1) Ncell with I600 > 100nA	2) Ncell with I800 > 2.5 * threshold I800>25nA & I600<10nA	3) More than 8 bad cells: requirement, 1) and 2)	4) More than two neighbour cells, bad: requirement, 1) and 2)
N4792_3	200	com	A	Passed	Passed	0	0	Passed	Passed
N4792_4	200	com	A	Passed	Passed	0	0	Passed	Passed
N4790_10	200	com	B	Passed	Passed	0	1	Passed	Passed
N4790_11	200	com	B	Passed	Passed	0	0	Passed	Passed
N4790_12	200	com	B	Passed	Passed	0	0	Passed	Passed
N4792_10	200	com	C	Passed	Passed	0	0	Passed	Passed
N4792_11	200	com	C	Passed	Passed	0	0	Passed	Passed
N4792_12	200	com	C	Passed	Passed	0	0	Passed	Passed
N4792_22	200	ind	C	Passed	Passed	0	0	Passed	Passed
N4792_23	200	ind	C	Passed	Passed	0	0	Passed	Passed
N4790_22	200	com	D	Passed	Passed	0	0	Passed	Passed
N4790_23	200	com	D	Passed	Passed	0	0	Passed	Passed

All sensors passed the grading at Hamamatsu as well

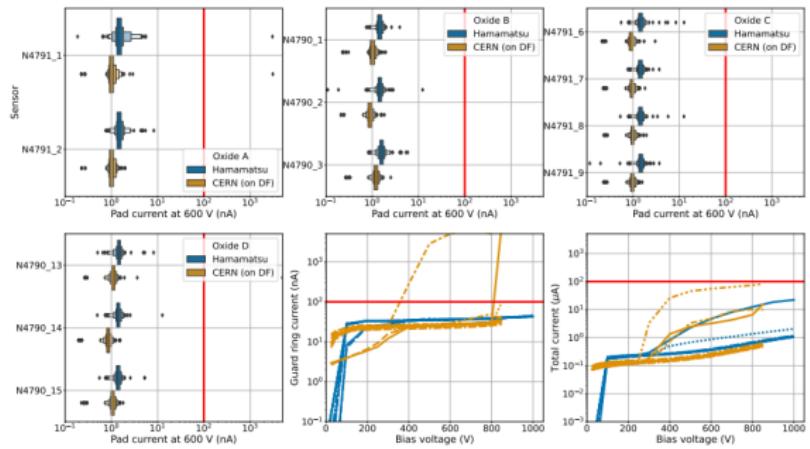
March 1, 2022

Marta Krawczyk, Low Density proto-A sensors

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Proto-A, 300 um, IV results: HPK and CERN (on DF)



- ▶ N4791_1 (oxide type 'A') also fails at CERN. Other 11 sensors also pass IV criteria at CERN
- ▶ Guard ring current tends to be higher at CERN than at HPK



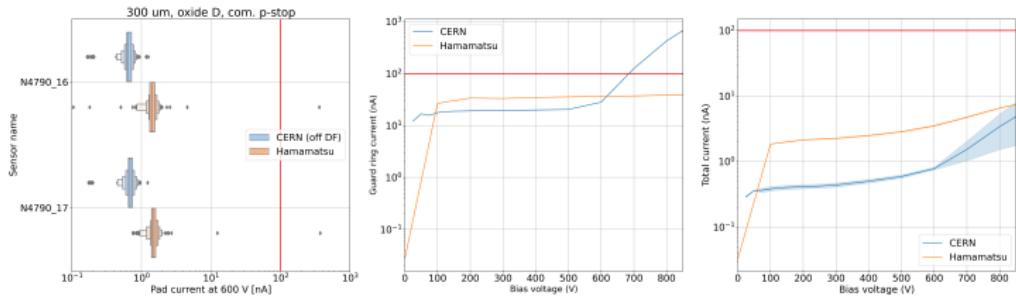
Proto-A, 300 um, IV grading comparison

Sensor ID	HPK full probe card				CMS full probe card (on dicing frame)				CMS full probe card (off dicing frame)			
	I_tot, 800V <100nA	I_tot, 800V <2.5°	I_tot, 600V	I_Ncell with 100Ω > 100nA	I_tot, 800V <100nA	I_tot, 800V <2.5°	I_tot, 600V	I_Ncell with 100Ω > 100nA	I_tot, 800V <100nA	I_tot, 800V <2.5°	I_tot, 600V	I_Ncell with 100Ω > 100nA
N4791_1	Passed	Failed	1	0	Passed	Passed	Passed	Passed	1	1	Passed	Passed
N4791_2	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4790_1	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4790_2	Passed	Passed	0	0	Passed	Passed	Passed	Passed	1	0	Passed	Passed
N4790_3	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_4	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_5	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_6	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_7	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_8	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_9	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_10	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_11	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_20	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_21	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4791_22	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4790_13	Passed	Passed	0	0	Passed	Passed	Passed	Passed	1	0	Passed	Passed
N4790_14	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed
N4790_15	Passed	Passed	0	0	Passed	Passed	Passed	Passed	0	0	Passed	Passed

Not available



Proto-A Batch 2, 300 μm , IV results: HPK and CERN (on DF)



Proto-A Batch 2, 300 um, IV grading comparison

HPK full probe card									
Sensor ID	Thickness	P- Stop	Oxide type	I_tot_600V <100uA	I_tot_800V < 2.5* I_tot_600V	1) Ncell with I600 > 100nA	2) Ncell with I800 > 2.5 * I600 & I600>10nA threshold I800>25nA & I600<10nA	3) More than 8 bad cells: requirem. 1) and 2)	4) More than two neighbour cells bad: requirem. 1) and 2)
N4790_16	300	com	D	Passed	Passed	0	0	Passed	Passed
N4790_17	300	com	D	Passed	Passed	0	0	Passed	Passed

CMS full probe card (off dicing frame)									
Sensor ID	Thickness	P- Stop	Oxide type	I_tot_600V <100uA	I_tot_800V < 2.5* I_tot_600V	1) Ncell with I600 > 100nA	2) Ncell with I800 > 2.5 * I600 & I600>10nA threshold I800>25nA & I600<10nA	3) More than 8 bad cells: requirem. 1) and 2)	4) More than two neighbour cells bad: requirem. 1) and 2)
N4790_16	300	com	D	Passed	Failed	0	1	Passed	Passed
N4790_17	300	com	D	Passed	Passed	0	0	Passed	Passed



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Proto-A, 120 um, CV results: HPK and CERN (on DF)

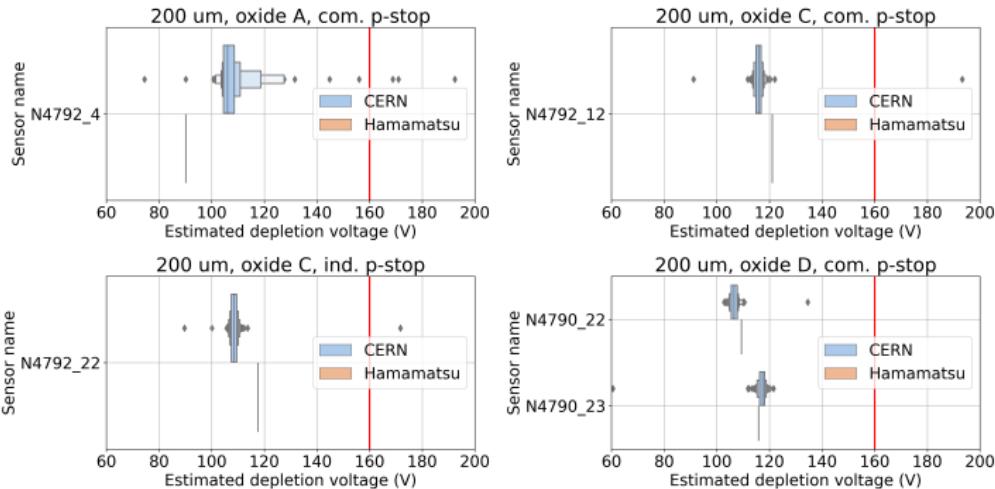
tbd



Proto-A, 120 um, CV grading comparison

tbd

Proto-A, 200 um, CV results: HPK and CERN (on DF)

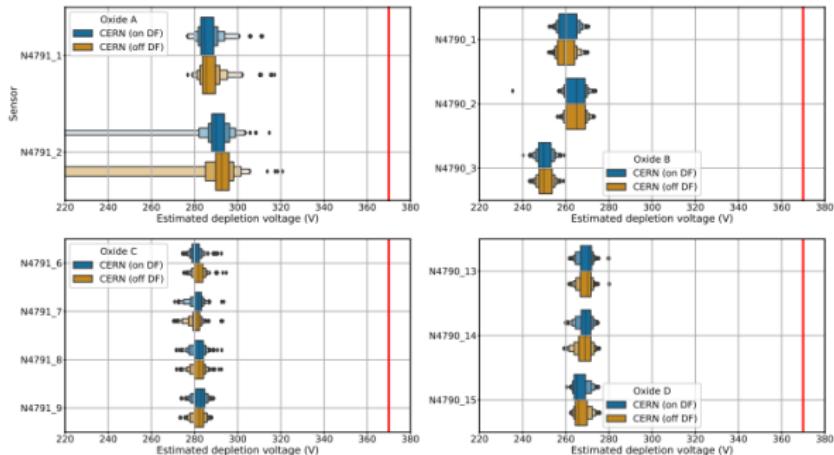


Proto-A, 200 um, CV grading comparison

CMS full probe card (off dicing frame)						
Sensor ID	Thick-ness	P- Stop	Oxide type	V dep corresponding to thickness	Maximum variation of Vdep across sensor of $\pm 10\%$	Thickness variation < 10 μm
N4792_4	200	com	A	passed: 94.5V < 160V	passed: 7.9%	passed: 0.5% = 1.0um
N4792_12	200	com	C	passed: 117.2V < 160V	passed: 0.9%	passed: 0.4% = 0.8um
N4792_22	200	ind	C	passed: 109.4V < 160V	passed: 0.8%	passed: 0.4% = 0.8um
N4790_22	200	com	D	passed: 106.9V < 160V	passed: 0.7%	passed: 0.6% = 1.2um
N4790_23	200	com	D	passed: 116.2V < 160V	passed: 0.5%	passed: 0.6% = 1.2um



Proto-A, 300 um, CV results: HPK and CERN (on DF)



- ▶ Note difference in depletion voltage between oxide types
- ▶ Oxide types B-D pass CV criteria
- ▶ Oxide type A also pass CV criteria, but many pads with spurious C-readings

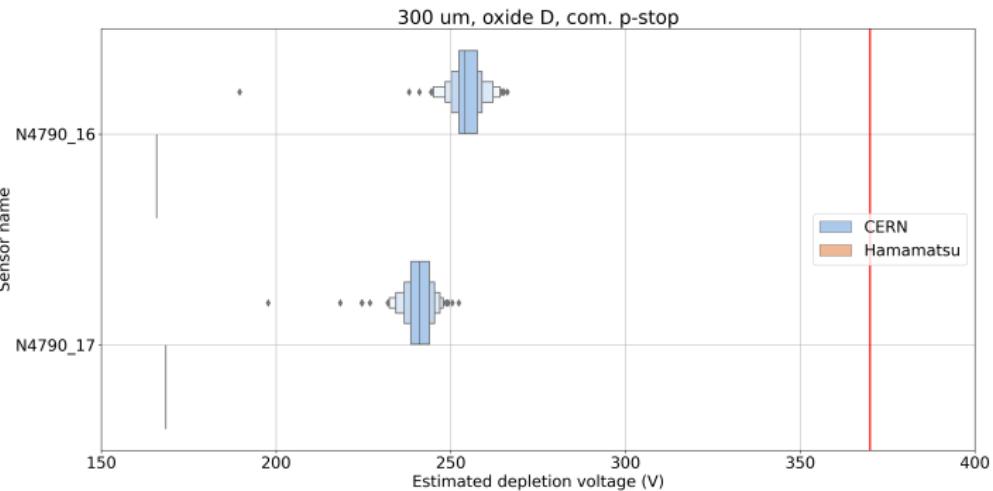


Proto-A, 300 um, CV grading comparison

	CERN full probe card (on dicing frame)			CMS full probe card (off dicing frame)		
Sensor ID	V dep corresponding to thickness	Maximum variation of Vdep across sensor of ± 10%	Thickness variation < 10 µm	V dep corresponding to thickness	Maximum variation of Vdep across sensor of ± 10%	Thickness variation < 10 µm
N4791_1	passed: 284.9V<370V	passed: 0.9%	passed: 0.8% = 2.4 um	passed: 285.8V<370V	passed: 0.9%	passed: 0.9% = 2.7 um
N4791_2	passed: 280.3V<370V	passed: 0.7%	passed: 0.8% = 2.4 um	passed: 293.1V<370V	passed: 0.7%	passed: 0.8% = 2.4 um
N4790_1	passed: 262.7V<370V	passed: 1.2%	passed: 0.4% = 1.2 um	passed: 261.8V<370V	passed: 1.2%	passed: 0.4% = 1.2 um
N4790_2	passed: 267.7V<370V	passed: 1.1%	passed: 0.4% = 1.2 um	passed: 267.6V<370V	passed: 1.2%	passed: 0.4% = 1.2 um
N4790_3	passed: 251.0V<370V	passed: 0.9%	passed: 0.6% = 1.8 um	passed: 251.2V<370V	passed: 0.9%	passed: 0.6% = 1.8 um
N4791_6	passed: 281.2V<370V	passed: 0.4%	passed: 0.4% = 1.2 um	passed: 282.7V<370V	passed: 0.5%	passed: 0.4% = 1.2 um
N4791_7	passed: 282.3V<370V	passed: 0.9%	passed: 0.3% = 0.9 um	passed: 281.6V<370V	passed: 0.9%	passed: 0.4% = 1.2 um
N4791_8	passed: 283.0V<370V	passed: 0.4%	passed: 0.5% = 1.5 um	passed: 283.0V<370V	passed: 0.4%	passed: 0.5% = 1.5 um
N4791_9	passed: 283.5V<370V	passed: 0.4%	passed: 0.4% = 1.2 um	passed: 283.0V<370V	passed: 0.4%	passed: 0.5% = 1.5 um
N4791_18	Not available			passed: 281.1V<370V	passed: 0.2%	passed: 0.4% = 1.2 um
N4791_19				passed: 282.1V<370V	passed: 0.3%	passed: 0.6% = 1.8 um
N4791_20				passed: 281.5V<370V	passed: 0.4%	passed: 0.8% = 2.4 um
N4791_21				passed: 276.2V<370V	passed: 0.5%	passed: 0.6% = 1.8 um
N4790_13	passed: 271.3V<370V	passed: 0.4%	passed: 0.5% = 1.5 um	passed: 271.0V<370V	passed: 0.4%	passed: 0.5% = 1.5 um
N4790_14	passed: 269.8V<370V	passed: 0.5%	passed: 0.4% = 1.2 um	passed: 269.6V<370V	passed: 0.7%	passed: 0.4% = 1.2 um
N4790_15	passed: 266.8V<370V	passed: 0.9%	passed: 0.3% = 0.9 um	passed: 267.4V<370V	passed: 1.0%	passed: 0.3% = 0.9 um
N4790_7				passed: 111.4V < 160V	passed: 2.9%	passed: 0.2% = 0.4um
N4790_8	passed: 111.0V< 160V	passed: 1.7%	passed: 0.3% = 0.6um			
N4790_9	passed: 111.3V< 160V	passed: 1.7%	passed: 1.0% = 2.0um			
N4792_6				passed: 126.6V < 160V	passed: 2.2%	passed: 0.3% = 0.6um
N4792_7				passed: 124.6V < 160V	passed: 2.7%	passed: 0.3% = 0.6um
N4792_9	passed: 121.7V< 160V	passed: 2.4%	passed: 2.2% = 4.4um			
N4792_18				passed: 121.2V < 160V	passed: 2.7%	passed: 0.3% = 0.6um
N4792_19				passed: 111.3V < 160V	passed: 2.7%	passed: 0.3% = 0.6um
N4792_20				passed: 118.5V < 160V	passed: 2.9%	passed: 0.3% = 0.6um
N4792_21				passed: 119.3V < 160V	passed: 2.4%	passed: 0.3% = 0.6um
N4790_19				passed: 115.3V < 160V	passed: 1.9%	passed: 0.3% = 0.6um
N4790_20	passed: 115.5V< 160V	passed: 2.0%	passed: 0.9% = 1.8um			
N4790_21	passed: 110.3V< 160V	passed: 2.6%	passed: 0.4% = 0.8um			



Proto-A Batch 2, 300 μm , CV results: HPK and CERN (on DF)



Proto-A, Batch 2, 300 um, CV grading comparison

CMS full probe card (off dicing frame)						
Sensor ID	Thickness	P- Stop	Oxide type	V dep corresponding to thickness	Maximum variation of <u>Vdep</u> across sensor of $\pm 10\%$	Thickness variation $< 10 \mu\text{m}$
N4790_16	300	com	D	passed: 258.0V<370V	passed: 1.2%	passed: 0.4% = 1.2 μm
N4790_17	300	com	D	passed: 240.2V<370V	passed: 0.9%	passed: 0.4% = 1.2 μm



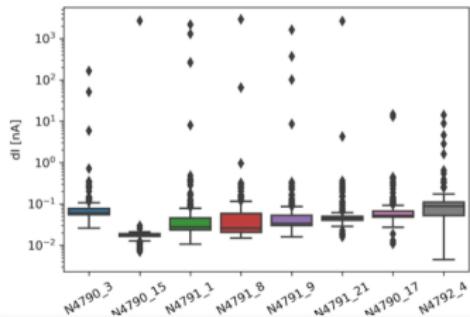
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Longterm Leakage current stability

Ranges of current variations



Most channels show small variations. The outliers show current in the range of uA.

February 1, 2022

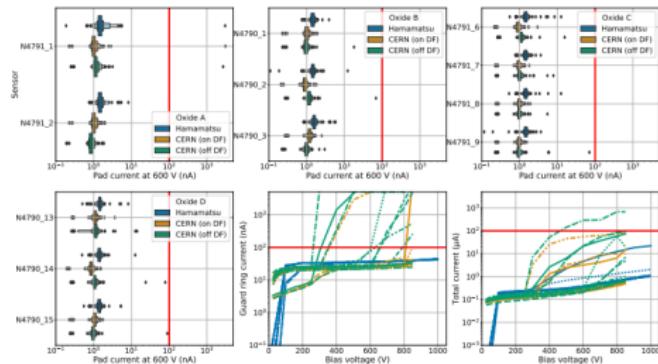
Marta Krawczyk, 50 hours leakage current measurements

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Dicing Frame removal at CERN

Proto-A: Our DF removal worsened IV



- ▶ 6/11 previously good sensors now fail at least one of the total current requirements
- ▶ Guard ring and total current (driven by guard ring) higher.



Summary

- Vulnerability to switch card breaks
- No discharges has been observed for proto A sensors
- Test throughput max. 20 per week



Backup

backup



List of ProtoA Sensors



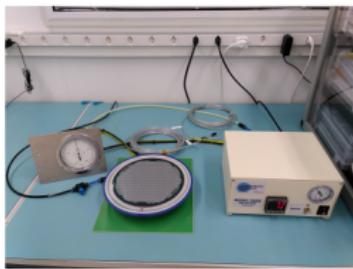
Dicing Frame removal at CERN

Backup

Dicing frame removal



- ▶ UV illumination
- ▶ Heating up to 50°C
- ▶ 600 mbar vacuum



November 12, 2021

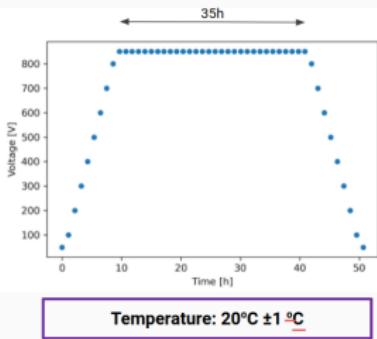
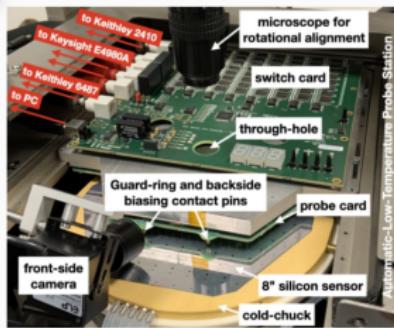
Oliwia Haluszczak: HGCAL Readiness Review

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Longterm Leakage current stability

Measurement in ALPS probe station



Courtesy of T. Quast

February 1, 2022

Marta Krawczyk, 50 hours leakage current measurements

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