IV+CV Results for HGCal Proto A Sensors

Pedro Almeida Oliwia Haluszczak **Huiling Hua** Lucie Linssen
Filip Moortgat Thorben Quast Kourosh Sarbandi Sicking Eva
Sicking Chaochen Yuan Philipp Zehetner **Marta Krawczyk**

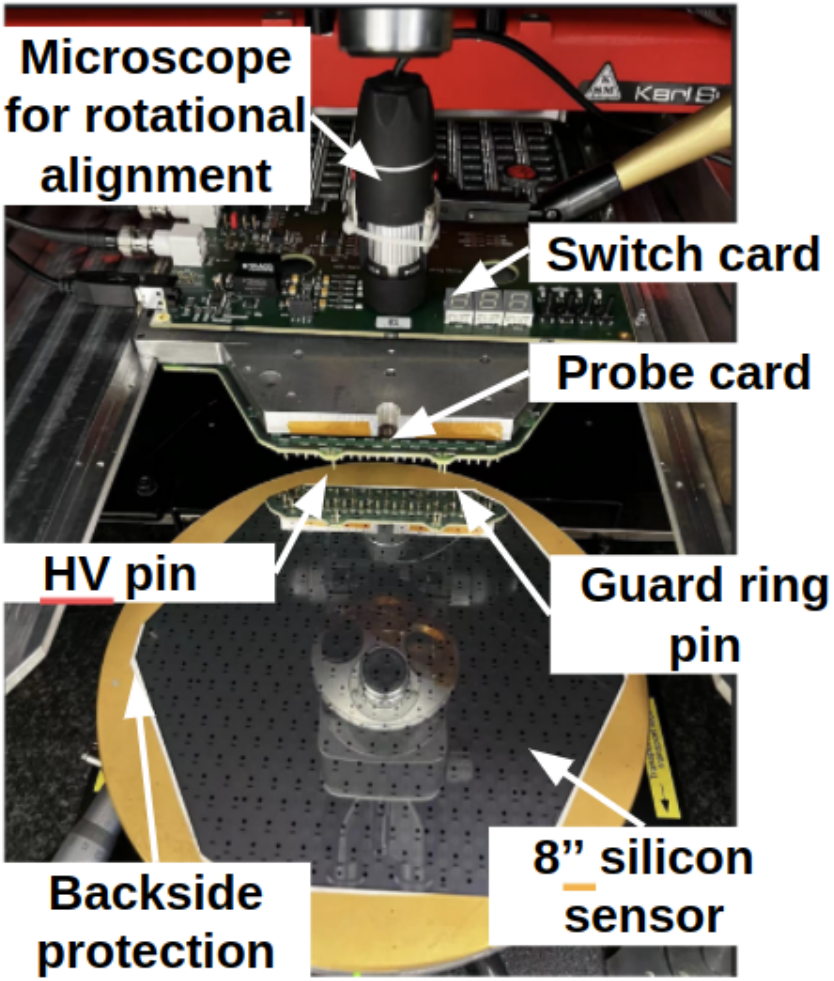
CMS HGCal Sensor Testing Weekly Meeting

Outline

Proto A sensors and their properties

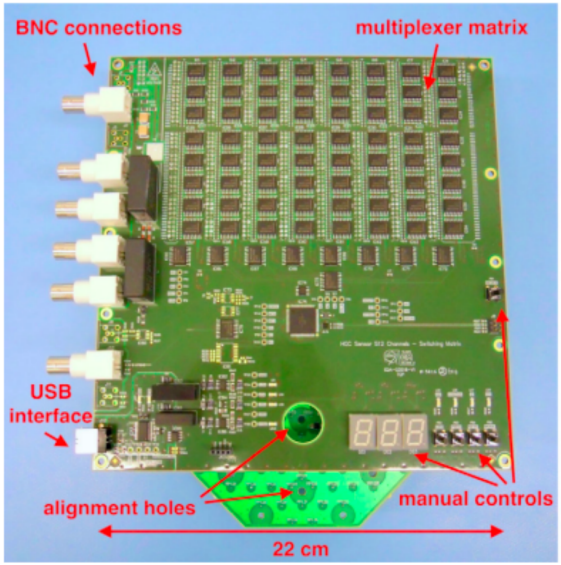
- 120 um:
  - 19 HD Sensors: 5 oxide type B, 8 oxide type C (3 common p-stop), 6 oxide type D
- 200 um:
  - 12 LD Sensors: 2 oxide type A, 3 oxide type B, 5 oxide type C (3 common p-stop), 2 oxide type D
- 300 um:
  - 12 LD Sensors: 2 oxide type A, 3 oxide type B, 4 oxide type C (common p-stop), 5 oxide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

Measurement Setup



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

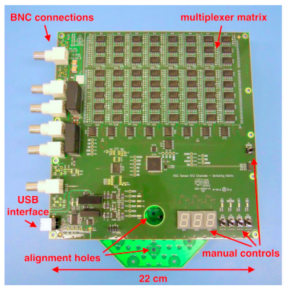
General Remarks



picture of a discharge

- Vulnerability to switch card breaks

General Remarks



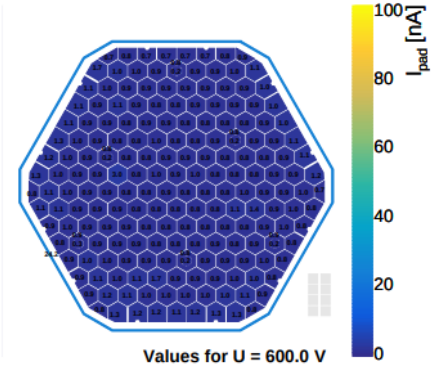
picture of a discharge

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

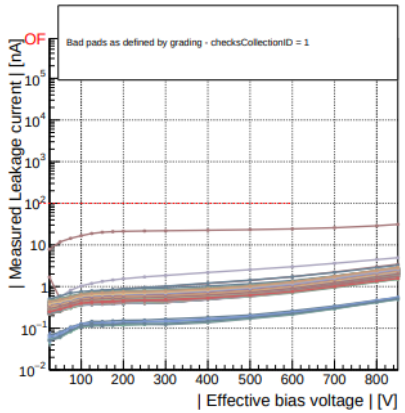
Proto-A: example IV+CV results

CERN IV N4791_6

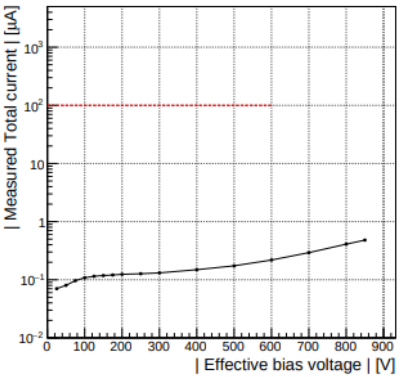
Cell current at 600 V



Channel IV curve

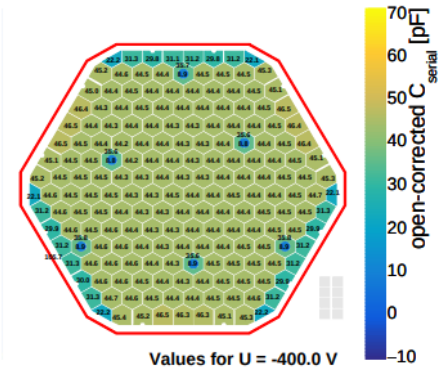


Total current curve

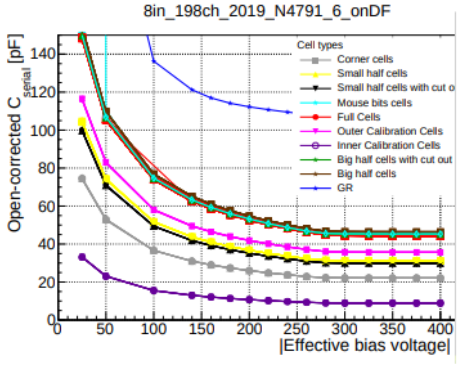


CERN CV N4791_6

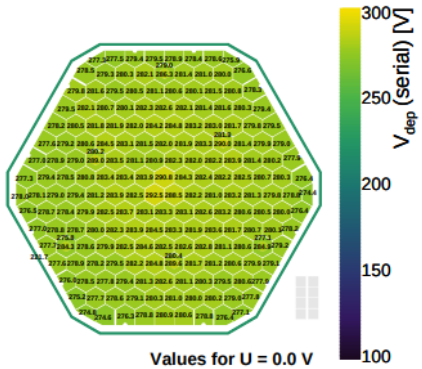
Capacitance at -400 V



Channel CV curve

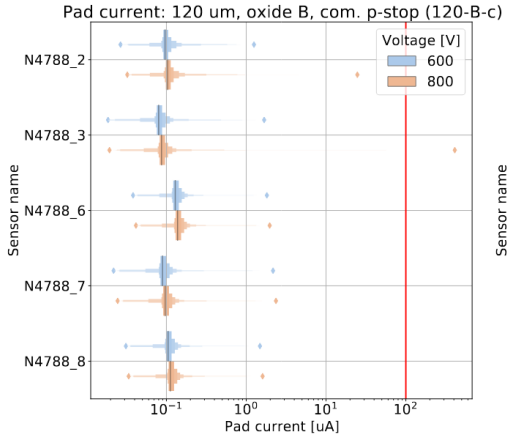


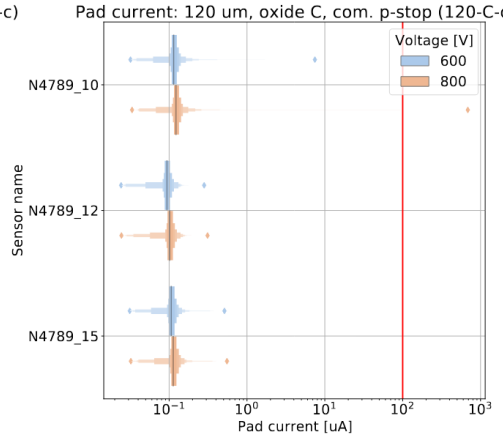
Depletion voltage

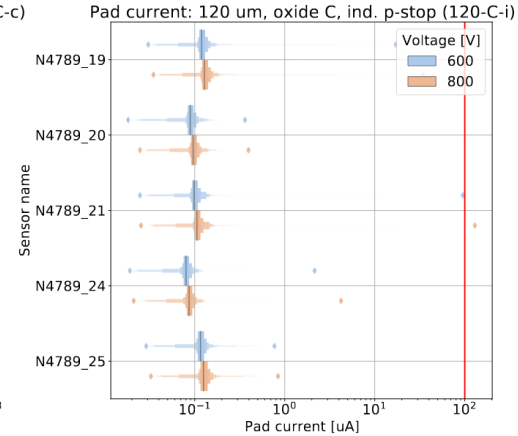


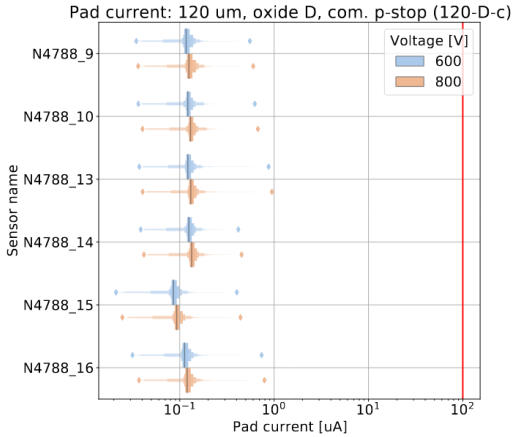
Outline

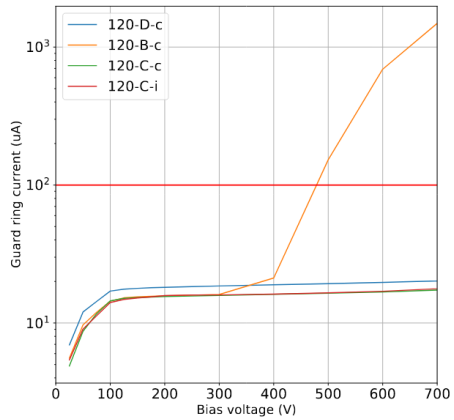
Proto-A, 120 um, IV results: HPK and CERN (on DF)

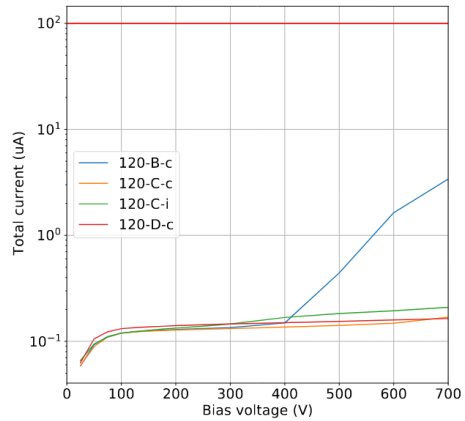








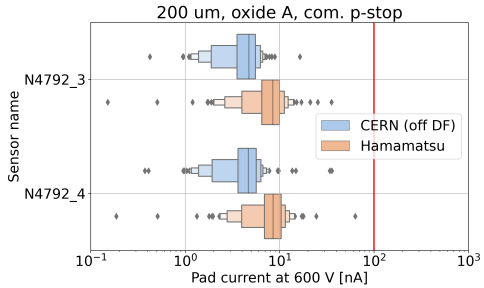


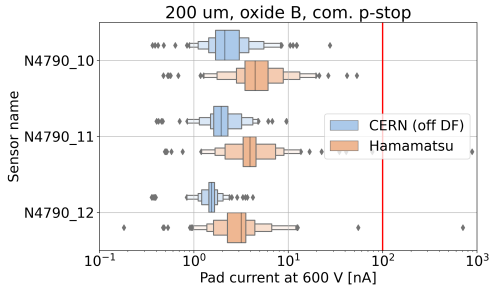


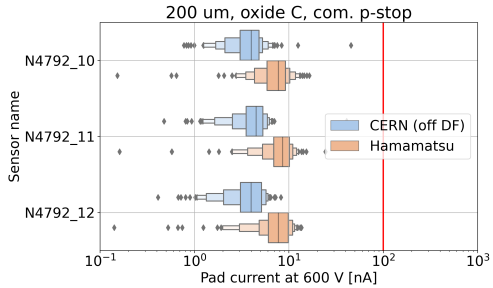
Proto-A, 120 um, IV grading comparison

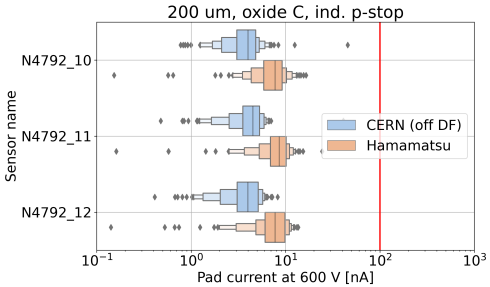
tbd

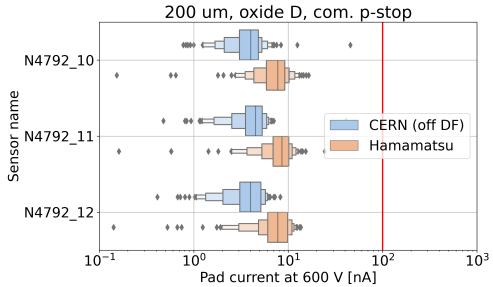
Proto-A, 200 um, IV results: HPK and CERN (on DF)

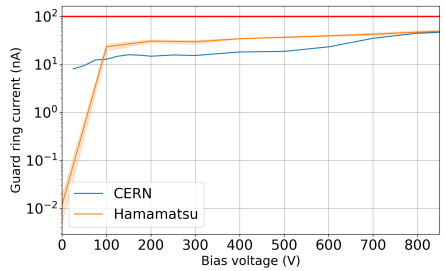


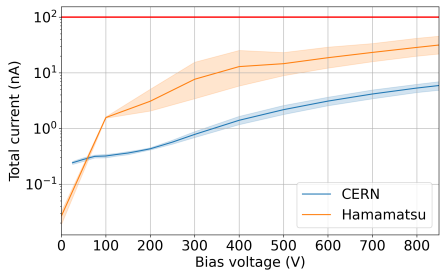












Proto-A, 200 um, IV grading comparison

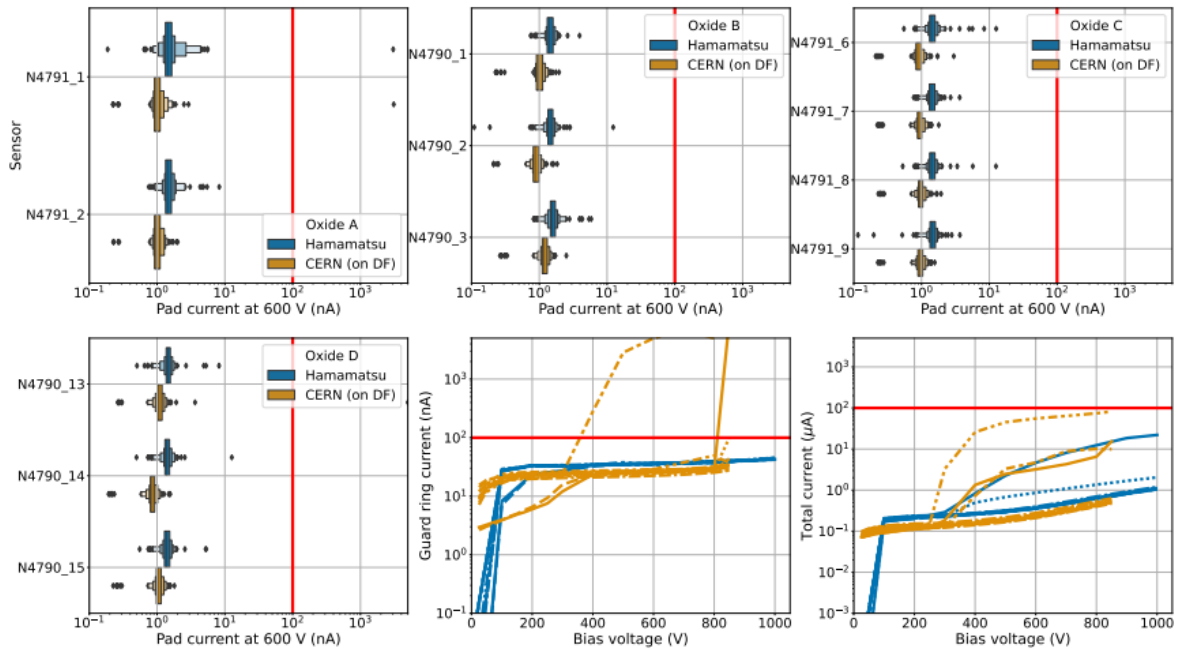
Proto-A: CERN IV grading, 12/12 passed

				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 * 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)
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 4

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

<table>
<tr><th></th><th colspan="6">HPK full probe card</th><th colspan="6">CMS full probe card (on dicing frame)</th><th colspan="6">CMS full probe card (off dicing frame)</th></tr>
<tr><th>Sensor ID</th><th>I_tot_600V <100uA</th><th>I_tot_800V < 2.5* I_tot_600V</th><th>1) Ncell with I600 > 100nA</th><th>2) Ncell with I800 > 2.5 * I600 & I600>10nA threshold || I800>25nA & I600<10nA</th><th>3) More than 8 bad cells: requirem. 1) and 2)</th><th>4) More than two neighbour cells bad: requirem. 1) and 2)</th><th>I_tot_600V <100uA</th><th>I_tot_800V < 2.5* I_tot_600V</th><th>1) Ncell with I600 > 100nA</th><th>2) Ncell with I800 > 2.5 * I600 & I600>10nA threshold || I800>25nA & I600<10nA</th><th>3) More than 8 bad cells: requirem. 1) and 2)</th><th>4) More than two neighbour cells bad: requirem. 1) and 2)</th><th>I_tot_600V <100uA</th><th>I_tot_800V < 2.5* I_tot_600V</th><th>1) Ncell with I600 > 100nA</th><th>2) Ncell with I800 > 2.5 * I600 & I600>10nA threshold || I800>25nA & I600<10nA</th><th>3) More than 8 bad cells: requirem. 1) and 2)</th><th>4) More than two neighbour cells bad: requirem. 1) and 2)</th></tr>
<tr><td>N4791_1</td><td>Passed</td><td>Failed</td><td>1</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Failed</td><td>1</td><td>1</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>2</td><td>0</td><td>Passed</td><td>Passed</td></tr>
<tr><td>N4791_2</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Failed</td><td>0</td><td>1</td><td>Passed</td><td>Passed</td></tr>
<tr><td>N4790_1</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Failed</td><td>0</td><td>1</td><td>Passed</td><td>Passed</td></tr>
<tr><td>N4790_2</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>1</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Failed</td><td>0</td><td>1</td><td>Passed</td><td>Passed</td></tr>
<tr><td>N4790_3</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td></tr>
<tr><td>N4791_6</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Failed</td><td>0</td><td>1</td><td>Passed</td><td>Passed</td></tr>
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<tr><td>N4791_9</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td></tr>
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<tr><td>N4791_21</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Failed</td><td>0</td><td>1</td><td>Passed</td><td>Passed</td></tr>
<tr><td>N4790_13</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>1</td><td>0</td><td>Passed</td><td>Passed</td><td>Passed</td><td>Passed</td><td>0</td><td>0</td><td>Passed</td><td>Passed</td></tr>
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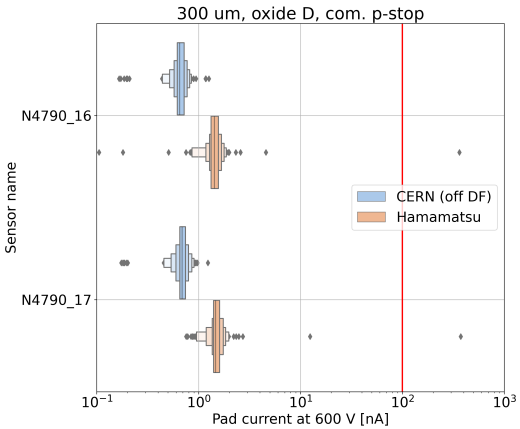
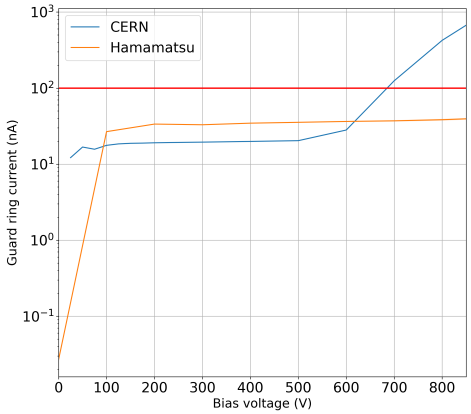
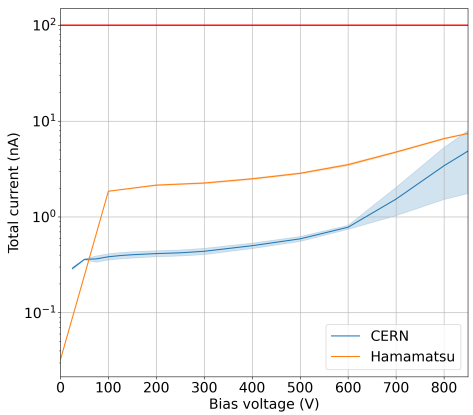
Proto-A Batch 2, 300 um, IV results: HPK and CERN (on DF)







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

				HPK full probe card					
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 * 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	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 * 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

Outline

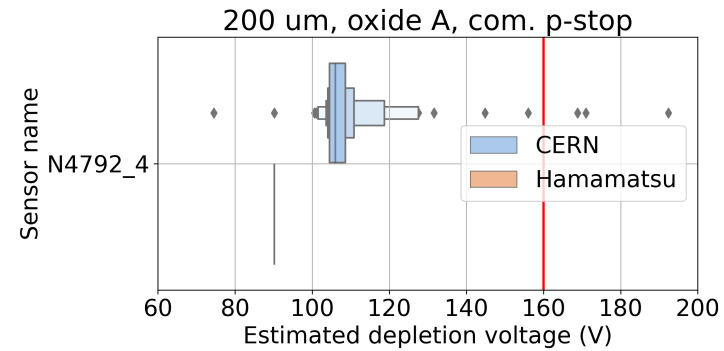
Proto-A, 120 um, CV results: HPK and CERN (on DF)

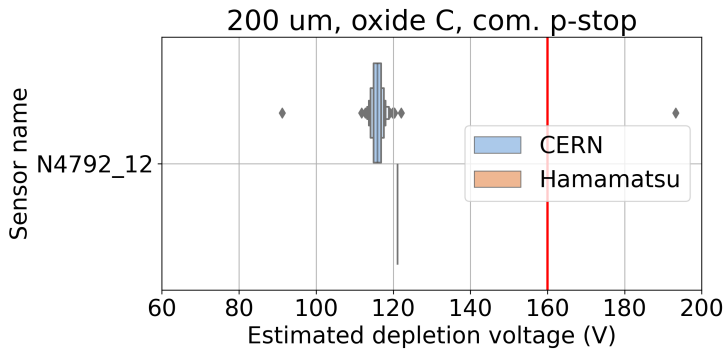
tbd

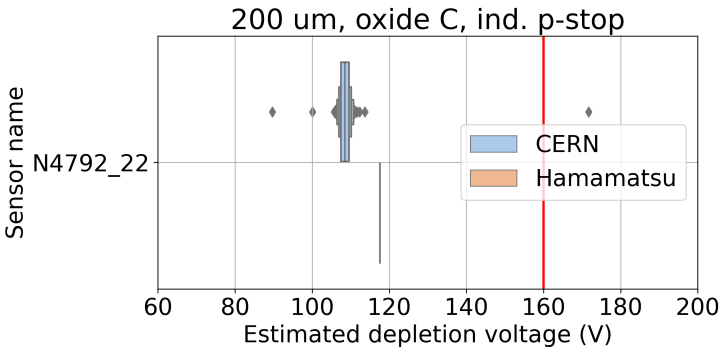
Proto-A, 120 um, CV grading comparison

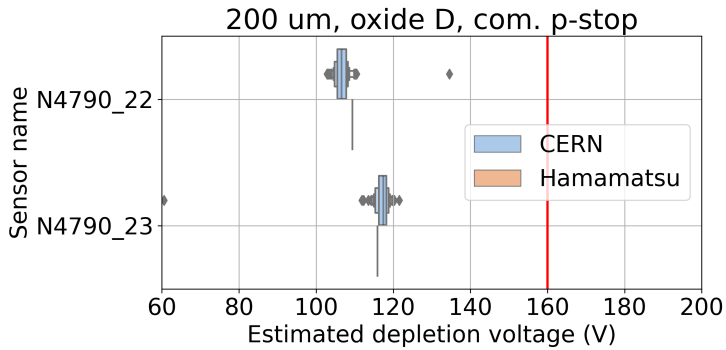
tbd

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





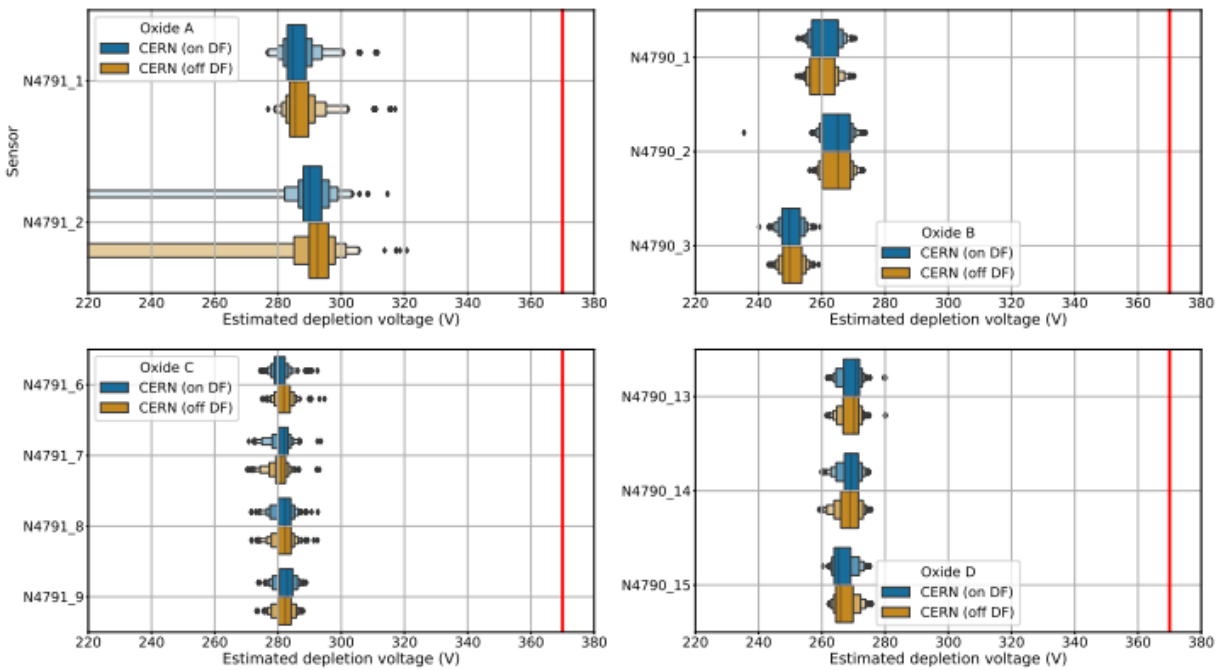




Proto-A, 200 um, CV grading comparison

				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 ± 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: 118.2V < 160V	passed: 0.5%	passed: 0.6% = 1.2um

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

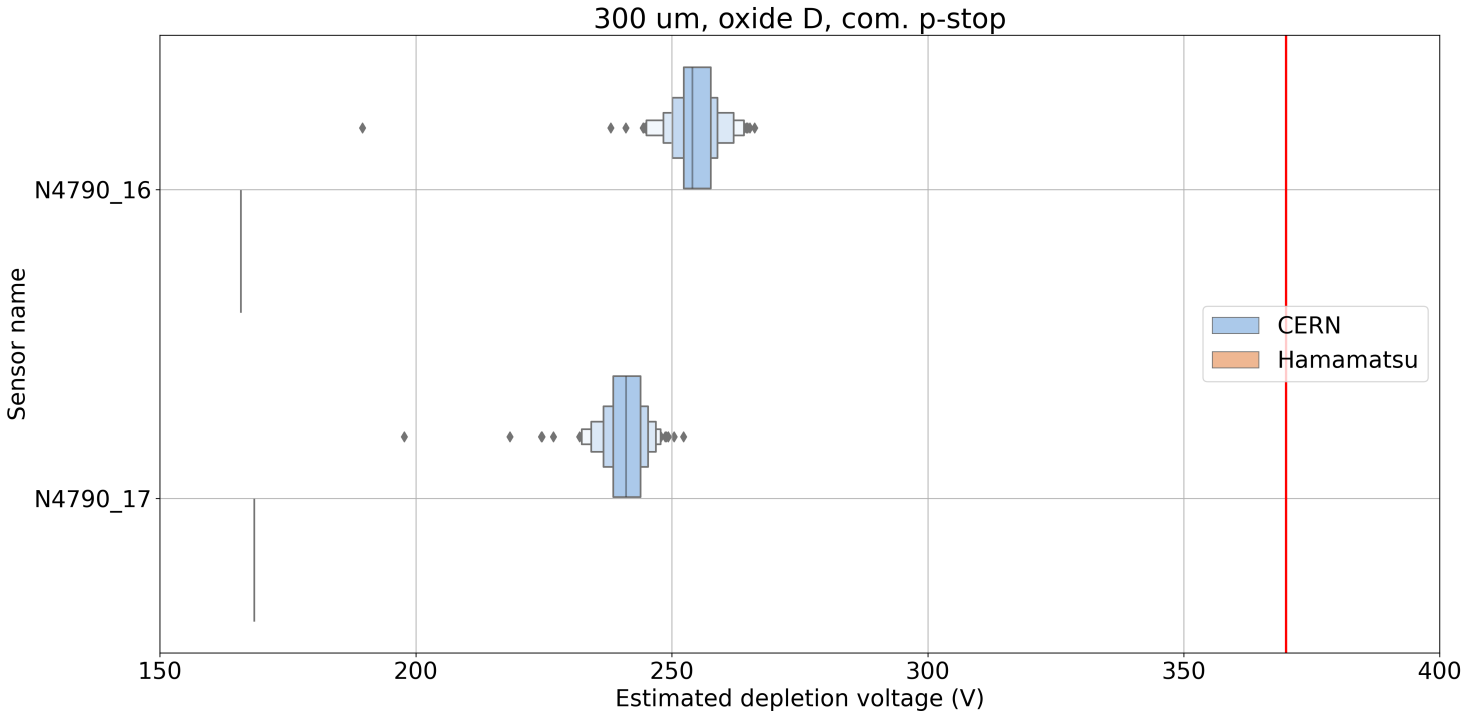


- Note difference in depletion voltage between oxide types
- Oxide types B-D pass CV criteria
- Oxide type A also pass CV criteria, but many pads with spurious C-readings

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: 290.3V<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: 0.3%	passed: 0.3% = 0.9 um	passed: 281.6V<370V	passed: 0.3%	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: 281.2V<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: 2.8%	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 um, CV results: HPK and CERN (on DF)



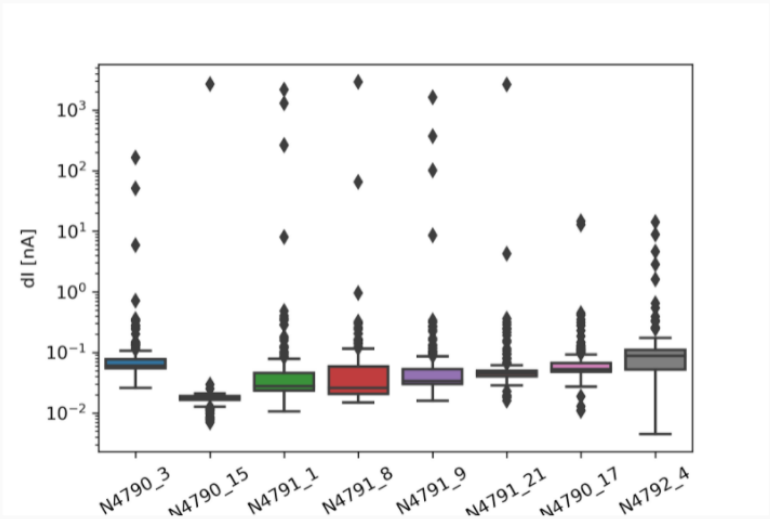
Proto-A, Batch 2, 300 um, CV grading comparison

				CMS full probe card (off dicing frame)		
Sensor ID	Thick-ness	P- Stop	Oxide type	V dep corresponding to thickness	Maximum variation of Vdep across sensor of ± 10%	Thickness variation < 10 µm
N4790_16	300	com	D	passed: 258.0V<370V	passed: 1.2%	passed: 0.4% = 1.2 um
N4790_17	300	com	D	passed: 240.2V<370V	passed: 0.9%	passed: 0.4% = 1.2 um

Outline

Longterm Leakage current stability

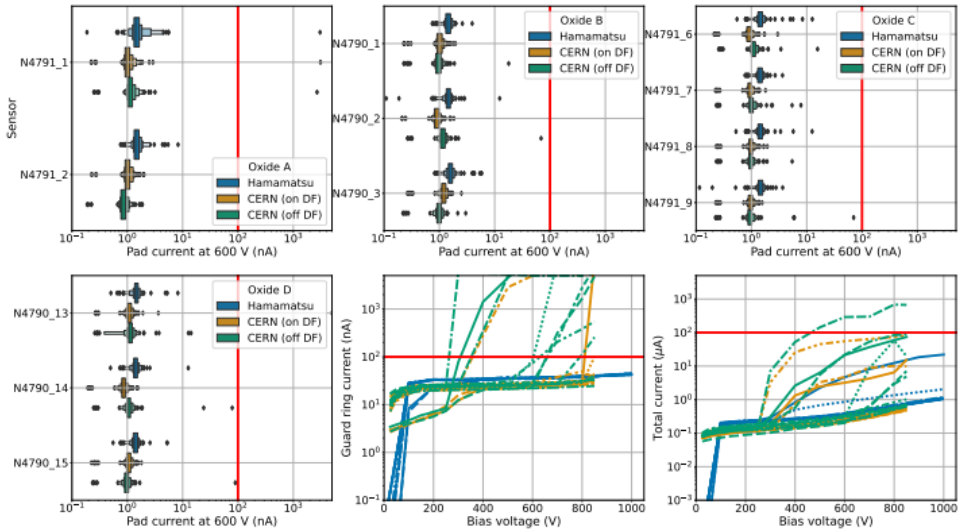
Ranges of current variations



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

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

tbd

Backup

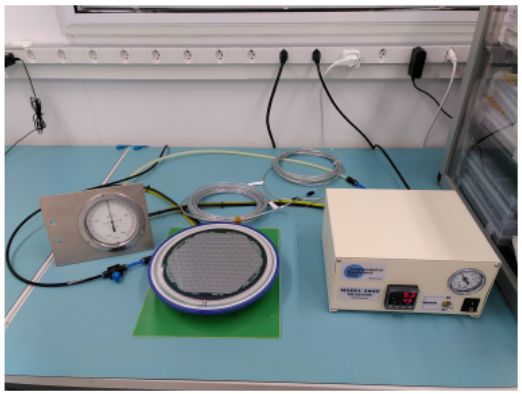
backup

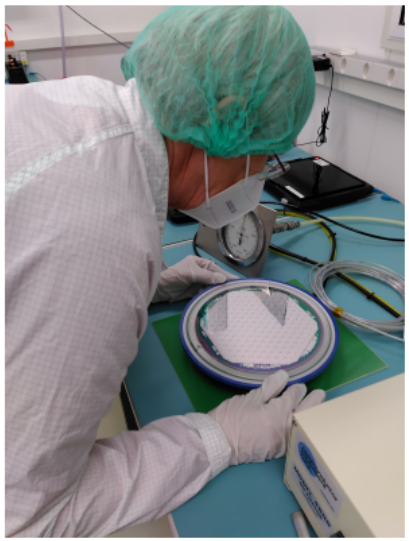
List of ProtoA Sensors

Dicing Frame removal at CERN

Backup
Dicing frame removal

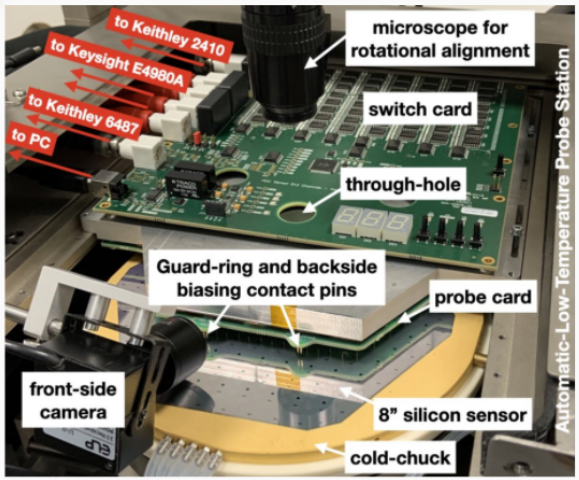
- UV illumination
- Heating up to 50°C
- 600 mbar vacuum

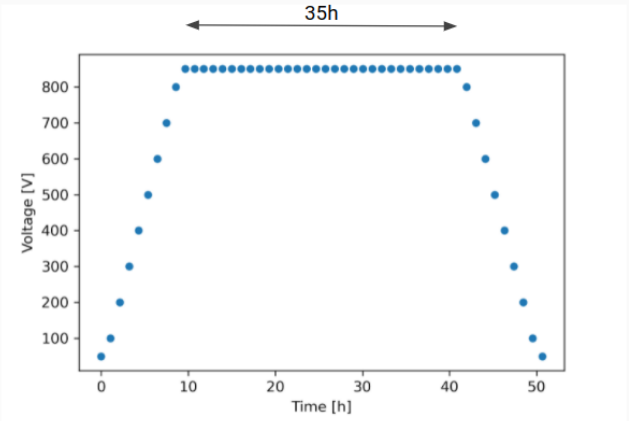




Longterm Leakage current stability

Measurement in ALPS probe station





Temperature: 20°C ±1 °C

Courtesy of T. Quast

February 1, 2022 Marta Krawczyk, 50 hours leakage current measurements 4