IV+CV Results for HGCal Proto A Sensors

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CMS HGCal Si Sensor Meeting

Outline

Proto A sensors measured

- Have measured 43 sensors in about 6 months
- 19 high density(HD) sensors(120um)
- 24 low density(LD) sensors(12 with 200um and 14 with 300 um)

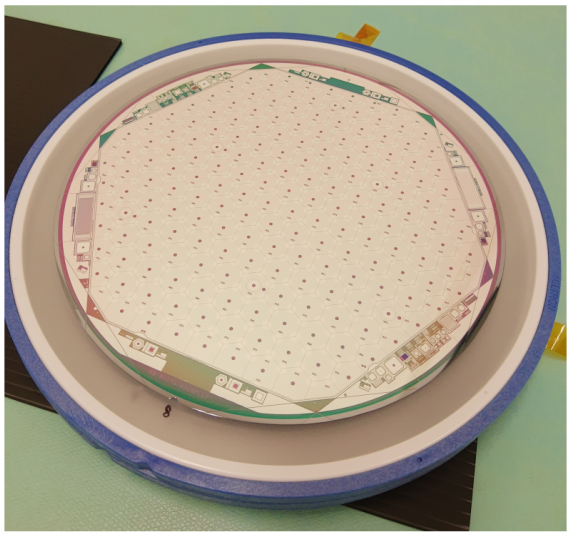


Figure: LD sensors

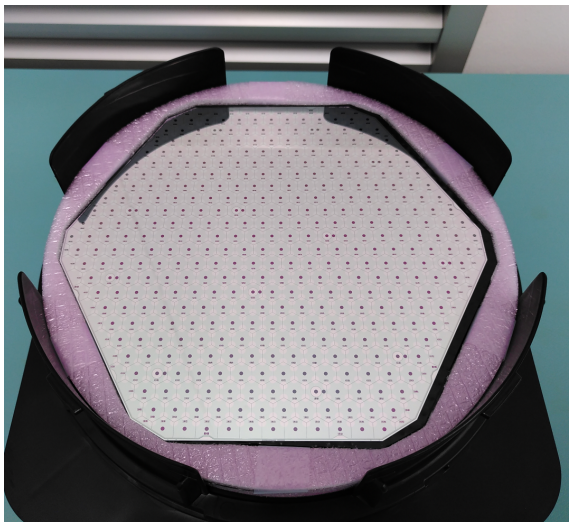


Figure: HD sensors

Measurement Setup: PM8 and ALPS

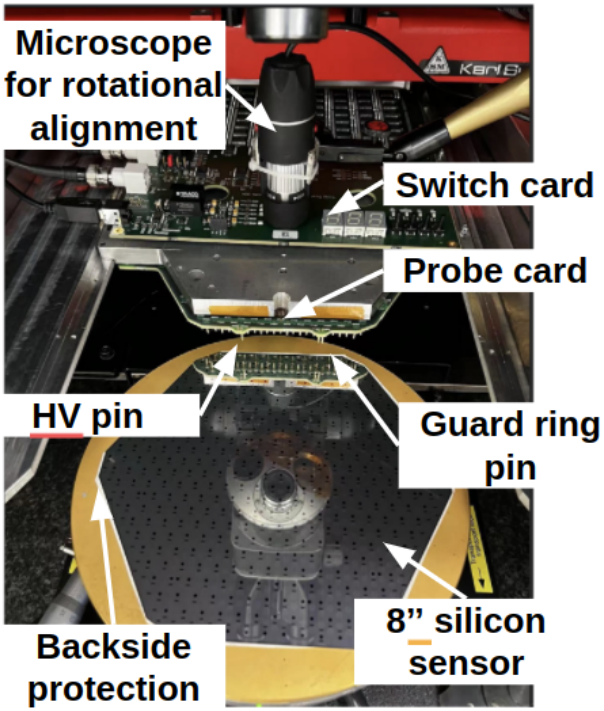


Figure: PM8

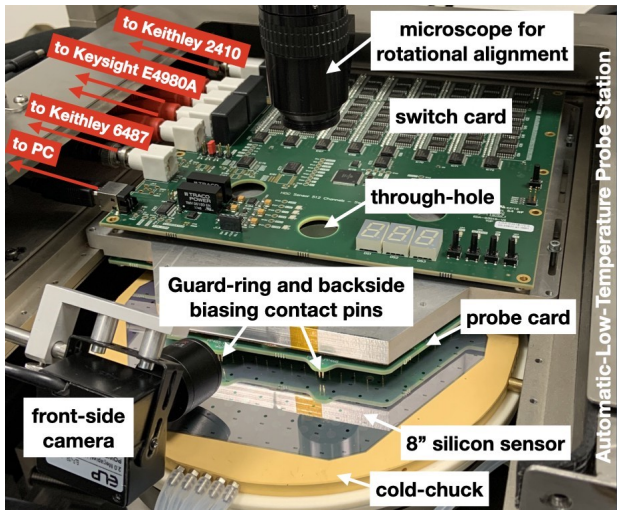


Figure: ALPS

- Pre-radiated sensors
  - Room temperaturef; humidity: 40% – 50% ; voltage up to -850V
  - Voltage provided through the HV pin to the backside
- LD sensor measured at ALPS; HD at PM8

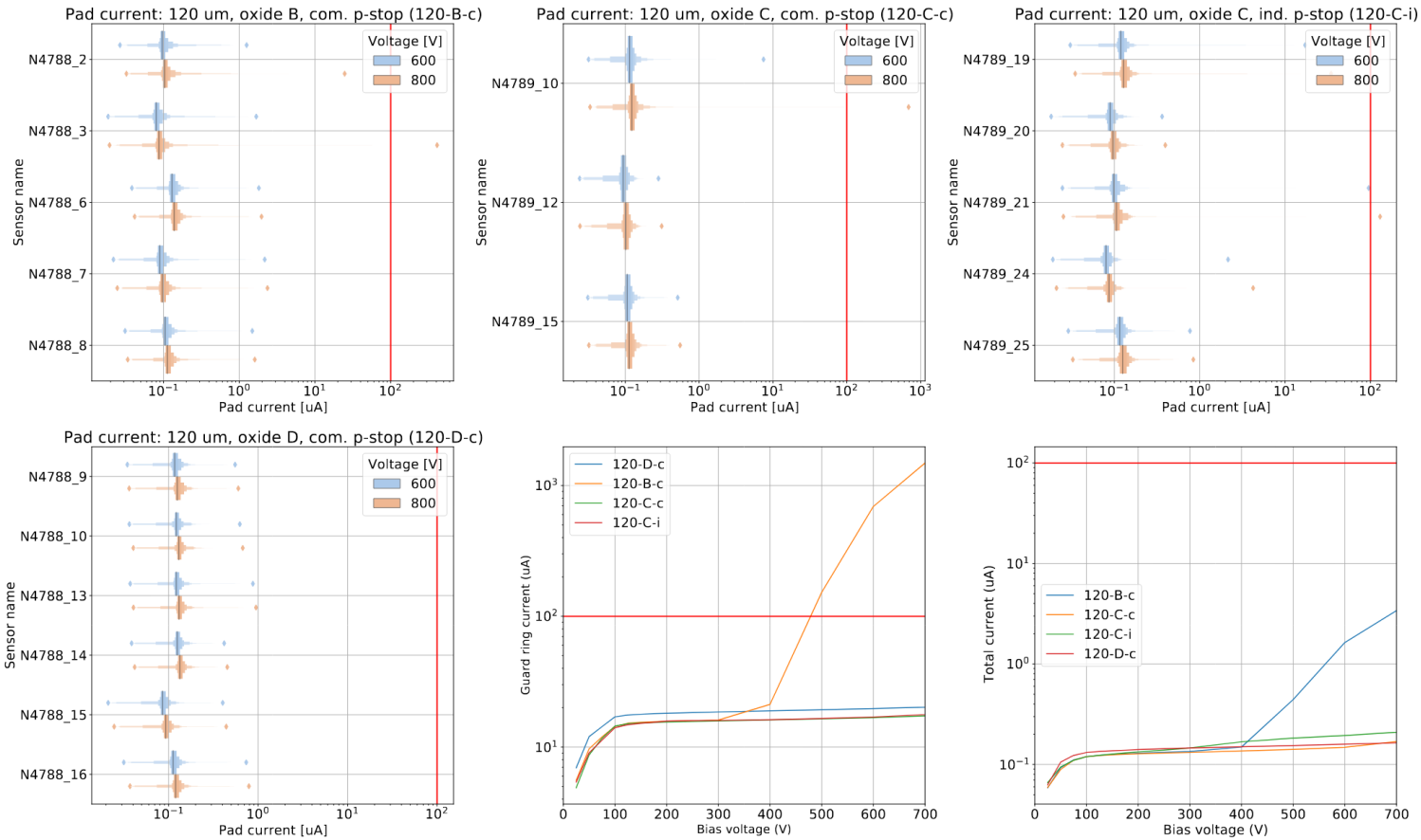
Outline

IV grading criteria

- Per-pad characteristics (bad pad definition)
  - $I_{600} > 100nA$
  - $I600 > 10nA$ and $I800 > 2.5 \times I600$
  - $I600 <= 10nA$ and $I800 > 25nA$
- Global characteristic
  - I600 (normalised to 20 deg Celsius)$<= 100\mu A$ (integrated over all pads)
  - $I800 < 2.5xI600$
  - Number of bad pads $<=$ 8for full-sized sensors
  - Allowed number of adjacent bad pads$<= 2$
- ChecksCollectionID 1

IV results at CERN

Comparison of IV results between HPK and CERN (on DF): HD



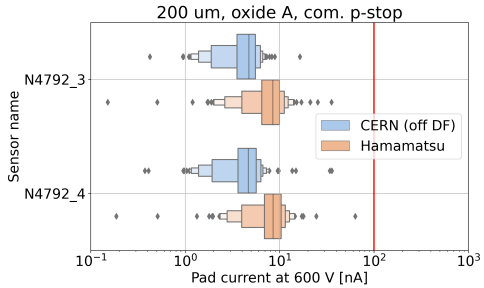
Summary for IV results

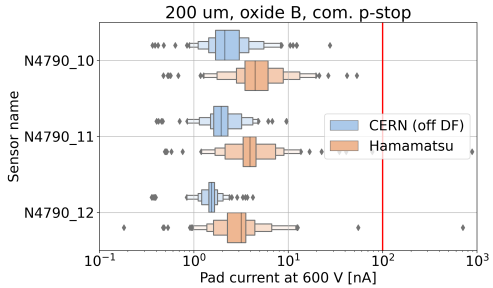
- 14 LD 300 um in Oliwia
- 12 LD 200 um Marta
- HD 120um Chaochen

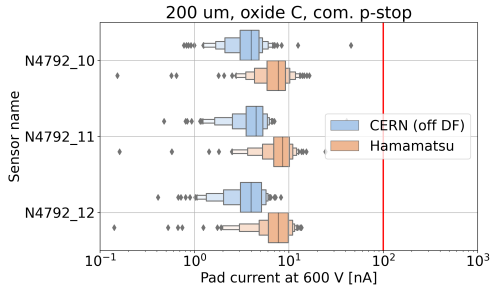
Proto-A, 120 um, IV grading comparison

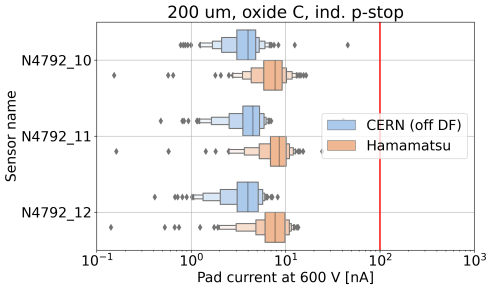
tbd

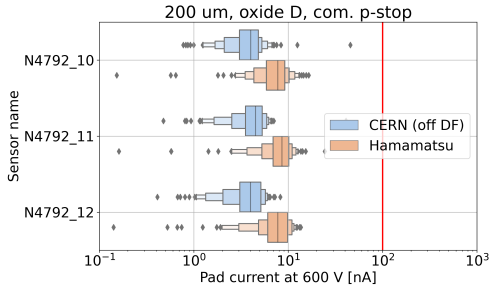
Proto-A, 200 um, IV results: HPK and CERN (on DF)

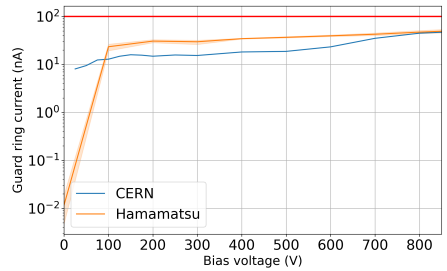


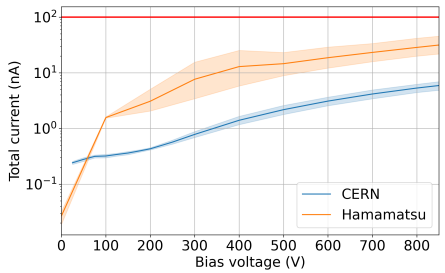












Proto-A, 200 um, IV grading comparison

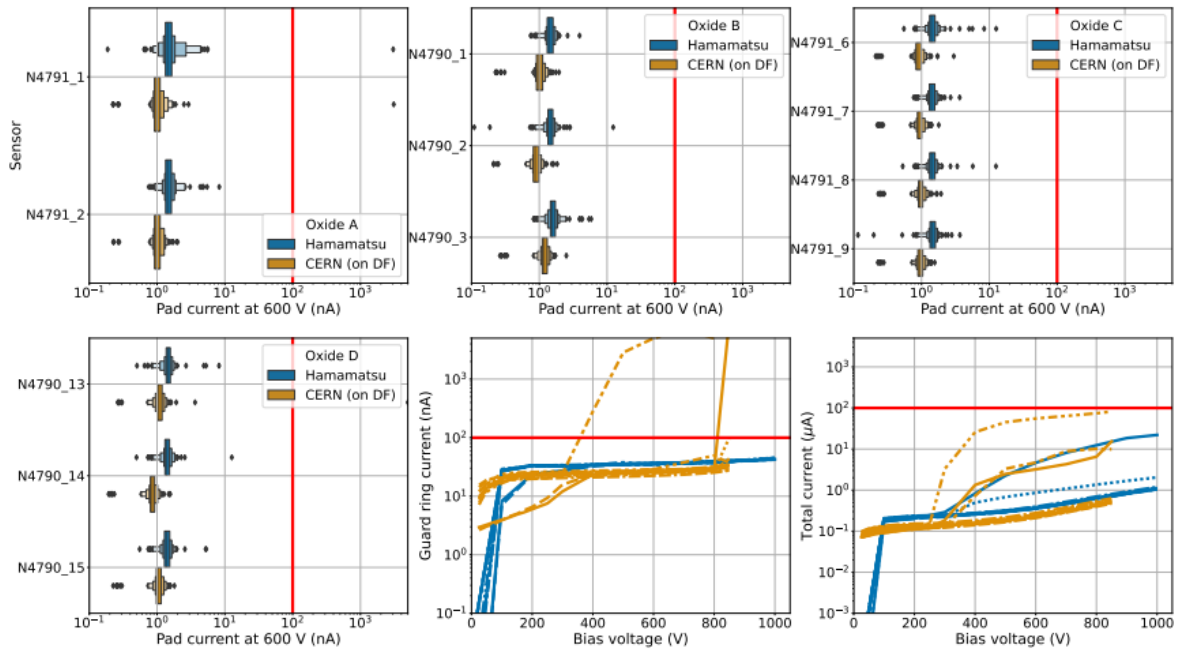
Proto-A: CERN IV grading, 12/12 passed

				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

HPK full probe card

Sensor ID	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)
N4791_1	Passed	Failed	1	0	Passed	Passed
N4791_2	Passed	Passed	0	0	Passed	Passed
N4790_1	Passed	Passed	0	0	Passed	Passed
N4790_2	Passed	Passed	0	0	Passed	Passed
N4790_3	Passed	Passed	0	0	Passed	Passed
N4791_6	Passed	Passed	0	0	Passed	Passed
N4791_7	Passed	Passed	0	0	Passed	Passed
N4791_8	Passed	Passed	0	0	Passed	Passed
N4791_9	Passed	Passed	0	0	Passed	Passed
N4791_18	Passed	Passed	0	0	Passed	Passed
N4791_19	Passed	Passed	0	0	Passed	Passed
N4791_20	Passed	Passed	0	0	Passed	Passed
N4791_21	Passed	Passed	0	0	Passed	Passed
N4790_13	Passed	Passed	0	0	Passed	Passed
N4790_14	Passed	Passed	0	0	Passed	Passed
N4790_15	Passed	Passed	0	0	Passed	Passed

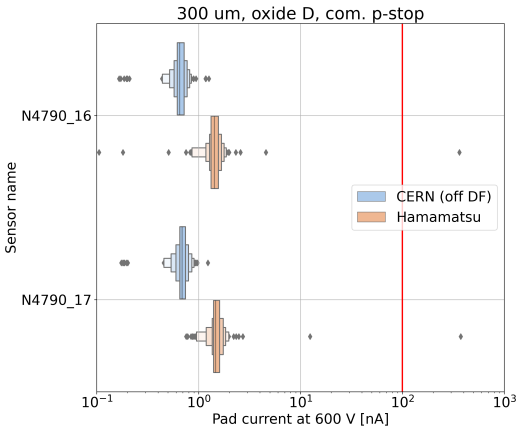
CMS full probe card (on dicing frame)

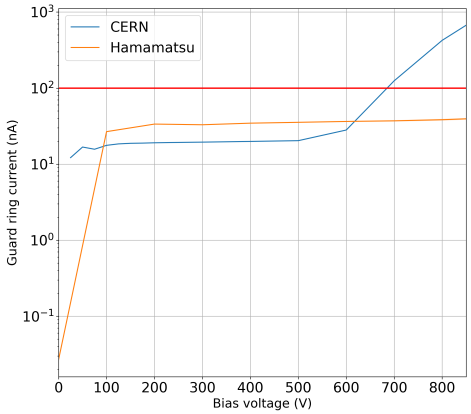
Sensor ID	I_tot_600V <100uA	I_tot_800V < 2.5* I_tot_600V	1) Ncell with I600 > 100nA	2) Ncell with I800 > 2.5 * I600 & I600>10nA threshold || I800>25nA & I600<10nA	3) More than 8 bad cells: requirem. 1) and 2)	4) More than two neighbour cells bad: requirem. 1) and 2)
N4791_1	Passed	Failed	1	1	Passed	Passed
N4791_2	Passed	Passed	0	0	Passed	Passed
N4790_1	Passed	Passed	0	0	Passed	Passed
N4790_2	Passed	Passed	1	0	Passed	Passed
N4790_3	Passed	Passed	0	0	Passed	Passed
N4791_6	Passed	Passed	0	0	Passed	Passed
N4791_7	Passed	Passed	0	0	Passed	Passed
N4791_8	Passed	Passed	0	0	Passed	Passed
N4791_9	Passed	Passed	0	0	Passed	Passed
N4791_18	Not available					
N4791_19						
N4791_20						
N4791_21						
N4790_13	Passed	Passed	1	0	Passed	Passed
N4790_14	Passed	Passed	0	0	Passed	Passed
N4790_15	Passed	Passed	0	0	Passed	Passed

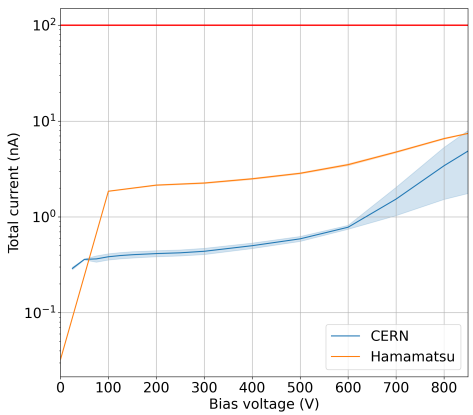
CMS full probe card (off dicing frame)

Sensor ID	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)
N4791_1	Passed	Passed	2	0	Passed	Passed
N4791_2	Passed	Failed	0	1	Passed	Passed
N4790_1	Passed	Failed	0	1	Passed	Passed
N4790_2	Passed	Failed	0	1	Passed	Passed
N4790_3	Passed	Passed	0	0	Passed	Passed
N4791_6	Passed	Failed	0	1	Passed	Passed
N4791_7	Passed	Failed	1	0	Passed	Passed
N4791_8	Passed	Passed	0	1	Passed	Passed
N4791_9	Passed	Passed	0	0	Passed	Passed
N4791_18	Passed	Passed	0	0	Passed	Passed
N4791_19	Passed	Passed	0	0	Passed	Passed
N4791_20	Passed	Failed	0	1	Passed	Passed
N4791_21	Passed	Failed	0	1	Passed	Passed
N4790_13	Passed	Passed	0	0	Passed	Passed
N4790_14	Passed	Failed	1	0	Passed	Passed
N4790_15	Passed	Passed	0	0	Passed	Passed

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

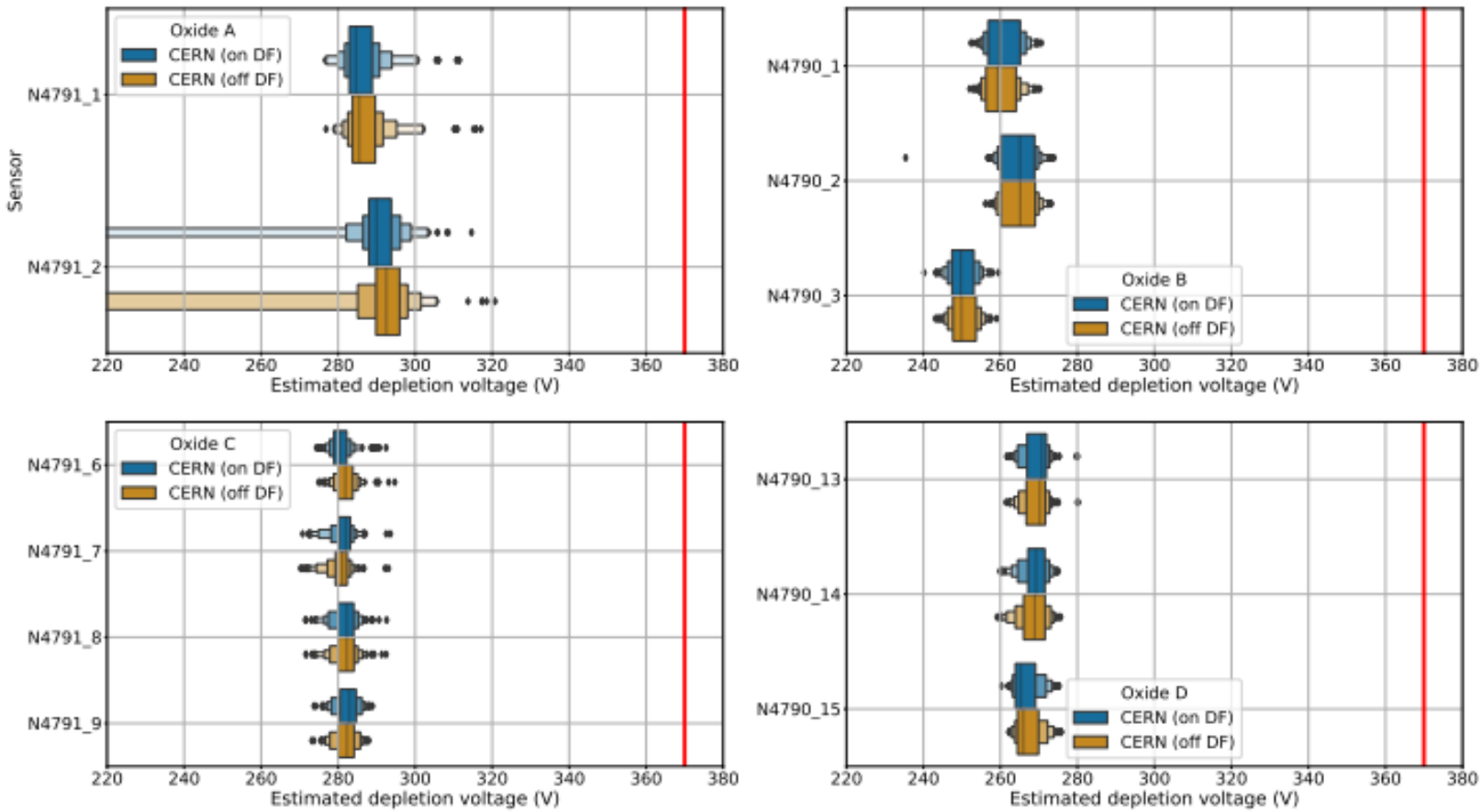
				CMS full probe card (off dicing frame)					
Sensor ID	Thick-ness	P- Stop	Oxide type	I_tot_600V <100uA	I_tot_800V < 2.5* I_tot_600V	1) Ncell with I600 > 100nA	2) Ncell with I800 > 2.5 * I600 & I600>10nA threshold || I800>25nA & I600<10nA	3) More than 8 bad cells: requirem. 1) and 2)	4) More than two neighbour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

CV grading criteria

- Global characteristic from full hexagonal pads only
  - Depletion voltage $median(V_{dep})$:
    - $< 370V$ for thickness 300 um
    - $< 160V$ for thickness 200 um
    - $< 70V$ for thickness 120 um
  - Depletion voltage uniformity ($IQR_{68\%}(V_{dep})$):
    - $< 0.1 * median(V_{dep})$
  - Thickness uniformity $\Delta thickness$:
    - $< +/- 10um$

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



▸ Proto-A, 300 um

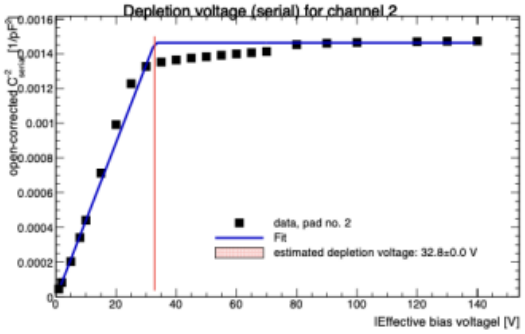
Proto-A, 300 um, CV grading (all passed)

	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			

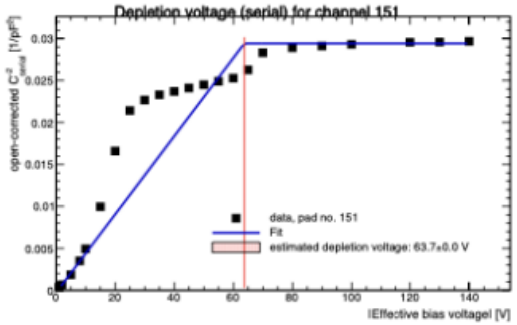
Proto-A, 120 um, depletion voltage fit fails for some cells

N4788_2 as an example

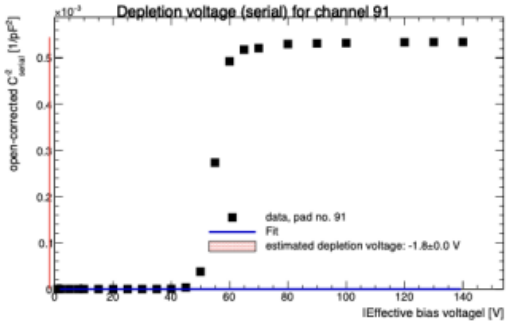
Three kinds of fit, similar for all 13HD sensors, set HD sensor N4788_2 as an example



normal fit: increase ->flat



strange fit: increase->flat->increase again->flat



no fit: random cells for different sensors

Similar behavior in raw data from Florida
No such behavior in LD sensors

Independent of P-stop

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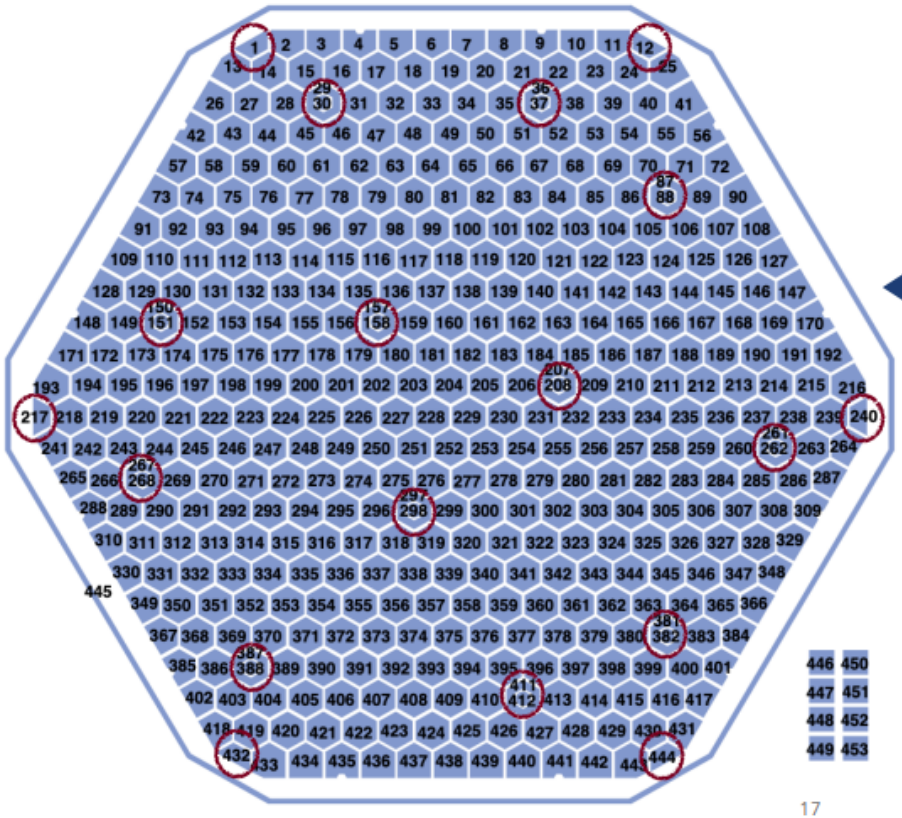
▸ Proto-A, 120 um

Proto-A, 120 um, failed fits, cell distribution



Cells with strange fit:
- calibration cell or edge cell
- same for different sensor

Cells with no fit:
- random for different sensor

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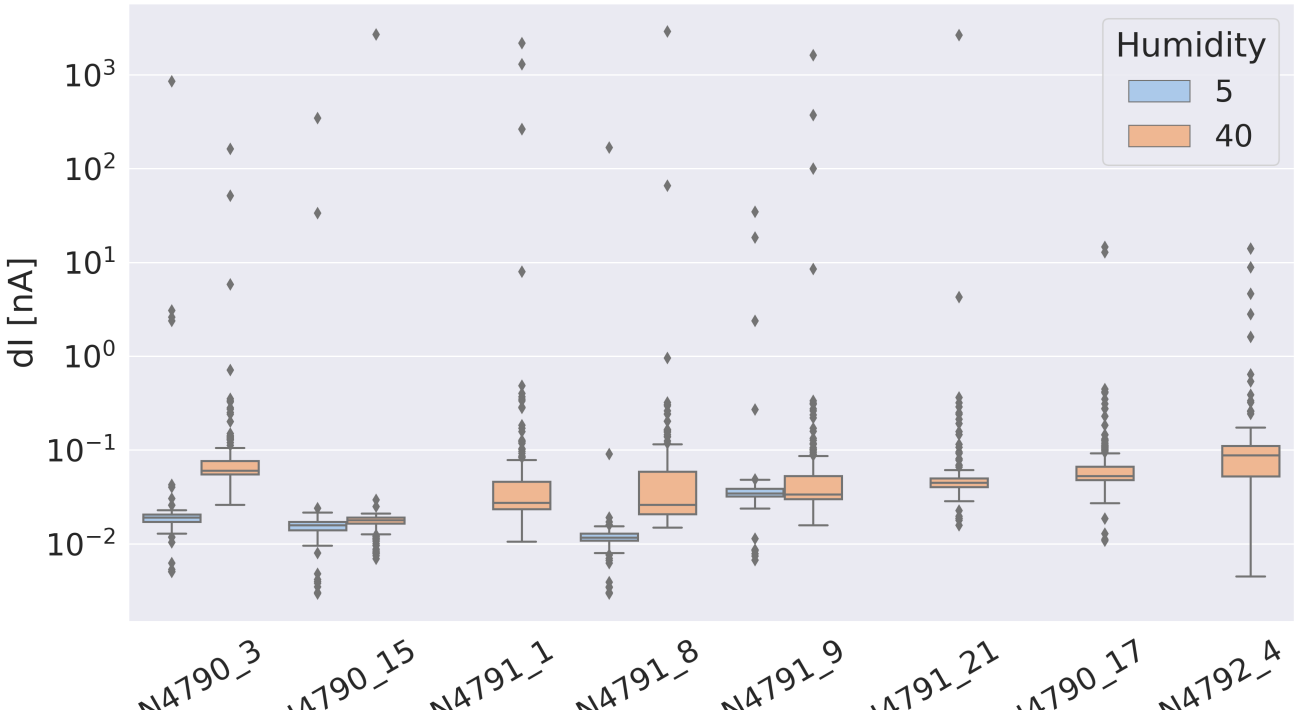
Summary for CV results

- CV results are good for all proto-A LD and HD sensors
- CV grading passed before and after Dicing Frame Removal
- Longterm leakage current instability can be observed for some channels

Outline

Longterm Leakage current stability

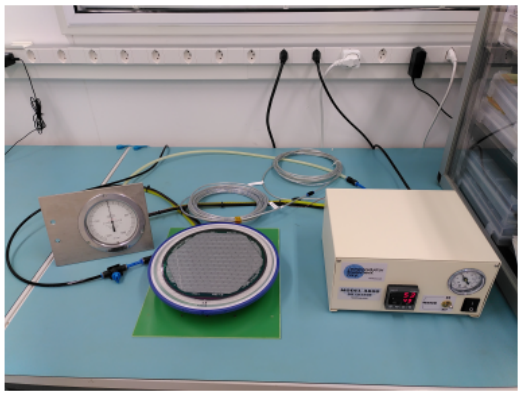


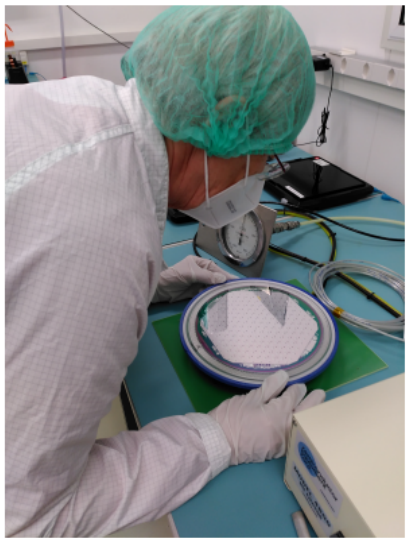
▸ Longterm Current

Dicing Frame removal at CERN

Backup
Dicing frame removal

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

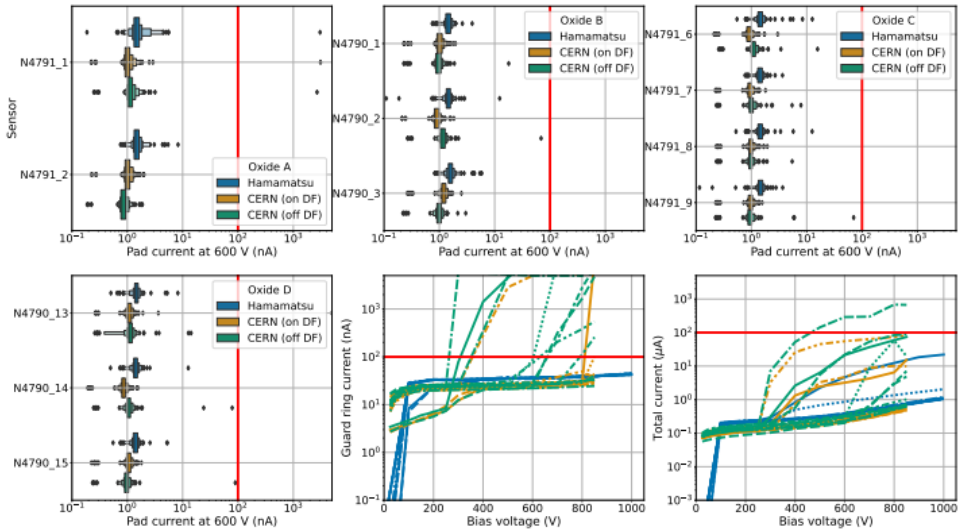




▸ Dicing Frame (Slide 24)

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

- No discharges has been observed for proto A sensors
- Test throughput 20 sensors per week
- Longterm leakage current instability can be observed for some channels
- Shortage of LCR meters problem resolved

Backup

backup

Sensor list: HD

Sensor ID	P-stop	Flat band voltage voltage	Oxide quality	P-stop conc	Material	I-V	I-V remeasure	C-V
N4788_2	com	-2V	B	STD	epi	passed	-	Not conclusive
N4788_3	com	-2V	B	STD	epi	failed	failed	Not conclusive
N4788_6	com	-2V	B	STD	epi	passed	-	Not conclusive
N4788_7	com	-2V	B	STD	epi	passed	-	Not conclusive
N4788_8	com	-2V	B	STD	epi	failed	-	-
N4789_10	com	-2V	C	STD	epi	failed	passed	Not conclusive
N4789_12	com	-2V	C	STD	epi	passed	-	Not conclusive
N4789_15	com	-2V	C	STD	epi	passed	-	Not conclusive
N4789_19	ind	-2V	C	STD	epi	passed	-	-
N4789_20	ind	-2V	C	STD	epi	passed	-	Not conclusive
N4789_21	ind	-2V	C	STD	epi	passed	-	Not conclusive
N4789_24	ind	-2V	C	STD	epi	passed	-	-
N4789_25	ind	-2V	C	STD	epi	passed	-	-
N4788_9	com	-2V	D	STD	epi	passed	-	Not conclusive
N4788_10	com	-2V	D	STD	epi	passed	-	Not conclusive
N4788_13	com	-2V	D	STD	epi	passed	-	-
N4788_14	com	-2V	D	STD	epi	passed	-	-
N4788_15	com	-2V	D	STD	epi	passed	-	Not conclusive
N4788_16	com	-2V	D	STD	epi	passed	-	Not conclusive

Sensor list

ID	P- Stop	Thickness	Flat band voltage	P-stop concentration	Oxide quality	Material
N4792_3	com	200	-5V	STD	A	FZ
N4792_4	com	200	-5V	STD	A	FZ
N4790_10	com	200	-2V	STD	B	FZ
N4790_11	com	200	-2V	STD	B	FZ
N4790_12	com	200	-2V	STD	B	FZ
N4792_10	com	200	-2V	STD	C	FZ
N4792_11	com	200	-2V	STD	C	FZ
N4792_12	com	200	-2V	STD	C	FZ
N4792_22	ind	200	-2V	STD	C	FZ
N4792_23	ind	200	-2V	STD	C	FZ
N4790_22	com	200	-2V	STD	D	FZ
N4790_23	com	200	-2V	STD	D	FZ

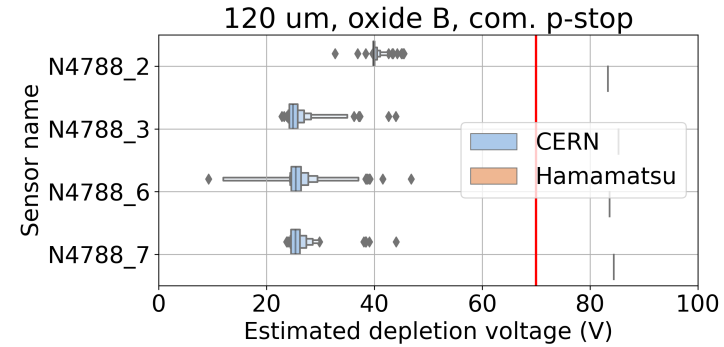
Sensor list

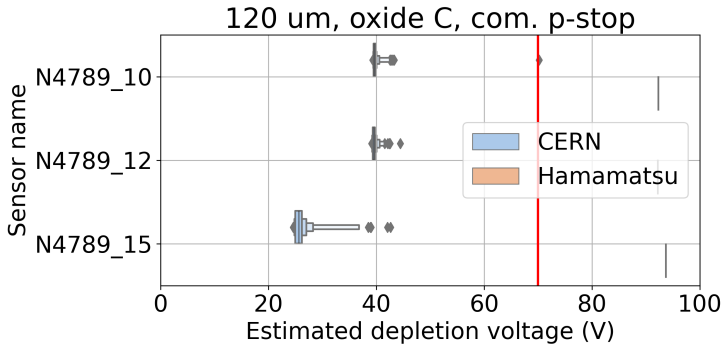
Sensor ID	Scratch pad ID	Thick-ness	P-Stop	Oxide type	Flat band volt. (V)	P-Stop conc.	Proc.	Full-wafer
N4791_1	100088	300	com	A	-5	STD	FZ	CERN
N4791_2	100089	300	com	A	-5	STD	FZ	CERN
N4791_3	100090	300	com	A	-5	STD	FZ	HPK
N4791_4	100091	300	com	A	-5	STD	FZ	HPK
N4790_1	100076	300	com	B	-2	STD	FZ	CERN
N4790_2	100077	300	com	B	-2	STD	FZ	CERN
N4790_3	100078	300	com	B	-2	STD	FZ	CERN
N4790_4	100079	300	com	B	-2	STD	FZ	HPK
N4790_5	100080	300	com	B	-2	STD	FZ	HPK
N4790_6	100081	300	com	B	-2	STD	FZ	HPK
N4791_6	100093	300	com	C	-2	STD	FZ	CERN
N4791_7	100094	300	com	C	-2	STD	FZ	CERN
N4791_8	100095	300	com	C	-2	STD	FZ	CERN
N4791_9	100096	300	com	C	-2	STD	FZ	CERN
N4791_10	100097	300	com	C	-2	STD	FZ	HPK
N4791_11	100098	300	com	C	-2	STD	FZ	HPK
N4791_12	100099	300	com	C	-2	STD	FZ	HPK
N4791_13	100100	300	com	C	-2	STD	FZ	HPK
N4791_18	100105	300	ind	C	-2	STD	FZ	CERN
N4791_19	100106	300	ind	C	-2	STD	FZ	CERN
N4791_20	100107	300	ind	C	-2	STD	FZ	CERN
N4791_21	100108	300	ind	C	-2	STD	FZ	CERN
N4791_22	100109	300	ind	C	-2	STD	FZ	HPK
N4791_23	100110	300	ind	C	-2	STD	FZ	HPK
N4791_24	100111	300	ind	C	-2	STD	FZ	HPK
N4791_25	100112	300	ind	C	-2	STD	FZ	HPK
N4790_13	100082	300	com	D	-2	STD	FZ	CERN
N4790_14	100083	300	com	D	-2	STD	FZ	CERN
N4790_15	100084	300	com	D	-2	STD	FZ	CERN
N4790_16	100085	300	com	D	-2	STD	FZ	HPK
N4790_17	100086	300	com	D	-2	STD	FZ	HPK
N4790_18	100087	300	com	D	-2	STD	FZ	HPK

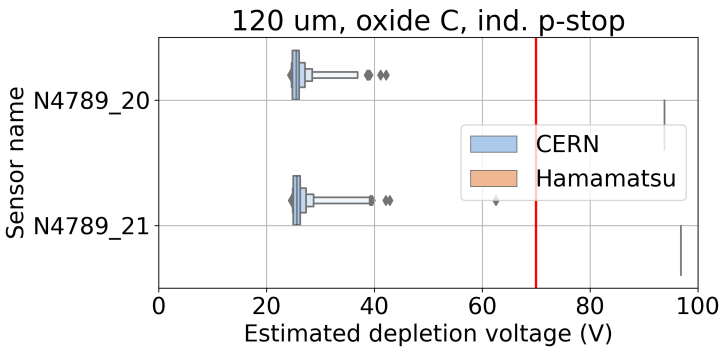
Sensor ID	Scratch pad ID	Thick-ness	P-Stop	Oxide type	Flat band volt. (V)	P-Stop conc.	Proc.	Full-wafer
N4792_2	200089	200	com	A	-5	STD	FZ	UCSB
N4792_3	200089	200	com	A	-5	STD	FZ	HPK
N4792_4	200089	200	com	A	-5	STD	FZ	HPK
N4790_7	200075	200	com	B	-2	STD	FZ	UCSB
N4790_8	200076	200	com	B	-2	STD	FZ	FSU
N4790_9	200077	200	com	B	-2	STD	FZ	FSU
N4790_10	200078	200	com	B	-2	STD	FZ	HPK
N4790_11	200079	200	com	B	-2	STD	FZ	HPK
N4790_12	200080	200	com	B	-2	STD	FZ	HPK
N4792_6	200092	200	com	C	-2	STD	FZ	UCSB
N4792_7	200093	200	com	C	-2	STD	FZ	UCSB
N4792_8	200094	200	com	C	-2	STD	FZ	FSU
N4792_9	200095	200	com	C	-2	STD	FZ	FSU
N4792_10	200096	200	com	C	-2	STD	FZ	HPK
N4792_11	200097	200	com	C	-2	STD	FZ	HPK
N4792_12	200098	200	com	C	-2	STD	FZ	HPK
N4792_13	200099	200	com	C	-2	STD	FZ	HPK
N4792_18	200104	200	ind	C	-2	STD	FZ	UCSB
N4792_19	200105	200	ind	C	-2	STD	FZ	UCSB
N4792_20	200106	200	ind	C	-2	STD	FZ	UCSB
N4792_21	200107	200	ind	C	-2	STD	FZ	UCSB
N4792_22	200108	200	ind	C	-2	STD	FZ	HPK
N4792_23	200109	200	ind	C	-2	STD	FZ	HPK
N4792_24	200110	200	ind	C	-2	STD	FZ	HPK
N4790_19	200081	200	com	D	-2	STD	FZ	UCSB
N4790_20	200082	200	com	D	-2	STD	FZ	FSU
N4790_21	200083	200	com	D	-2	STD	FZ	FSU
N4790_22	200084	200	com	D	-2	STD	FZ	HPK
N4790_23	200085	200	com	D	-2	STD	FZ	HPK
N4790_24	200086	200	com	D	-2	STD	FZ	HPK
N4790_25	200087	200	com	D	-2	STD	FZ	HPK

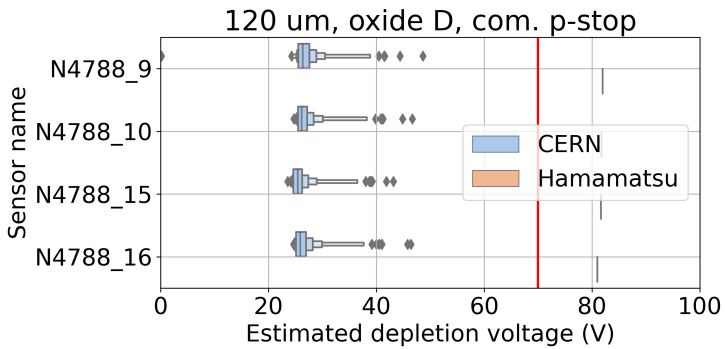
List of ProtoA Sensors

Proto-A, 120 um, CV results: HPK and CERN



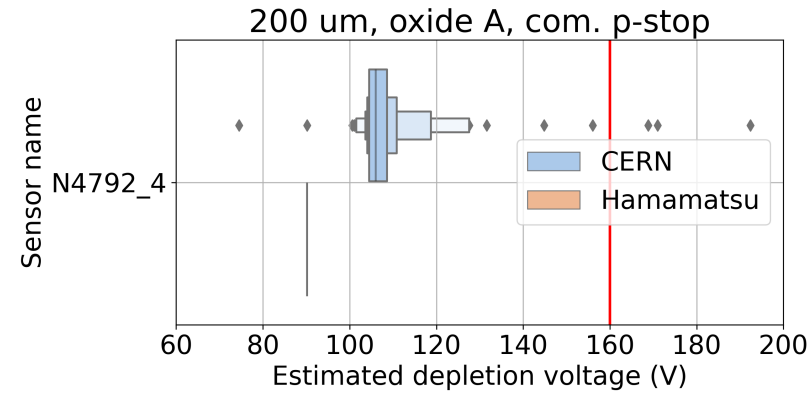


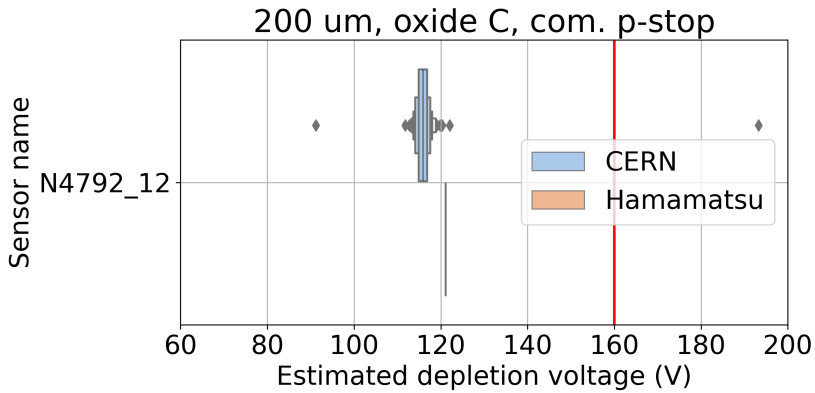


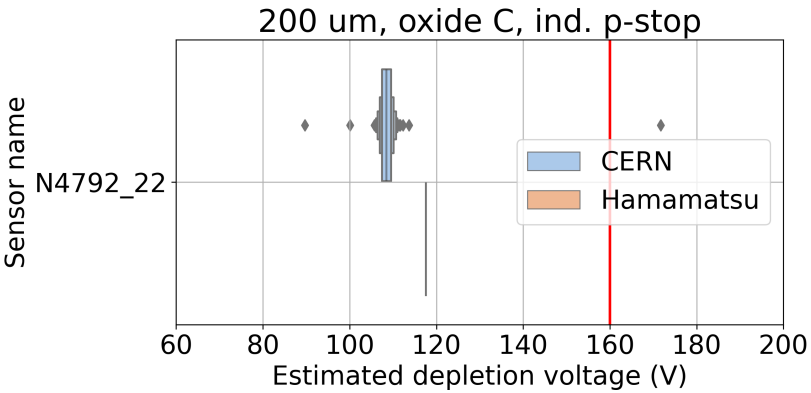


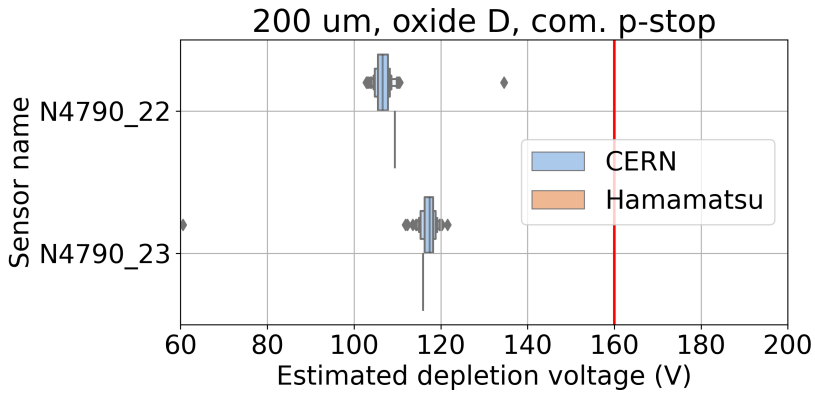
- Hamamatsu results are outside the treshhold. CERN results are good.
- Hamamatsu measures one diode, while CERN measures all channels.
- Hamamatsu measures on Dicing Frame, which CERN off Dicing

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



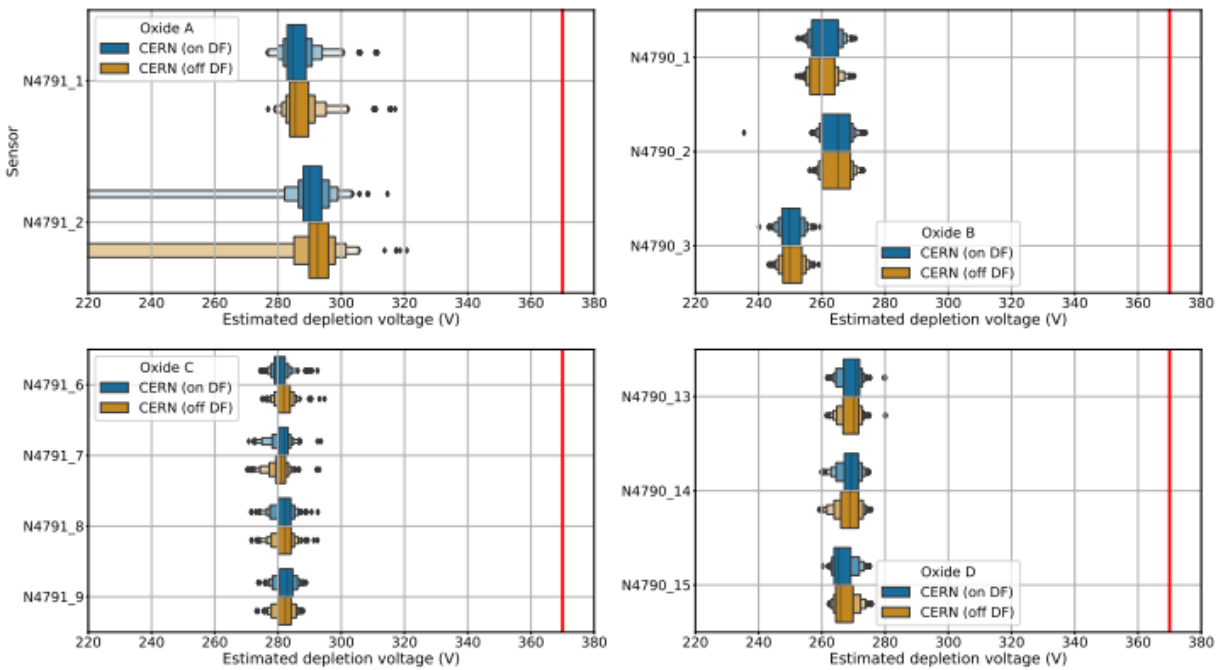






▸ Proto-A, 200 um

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

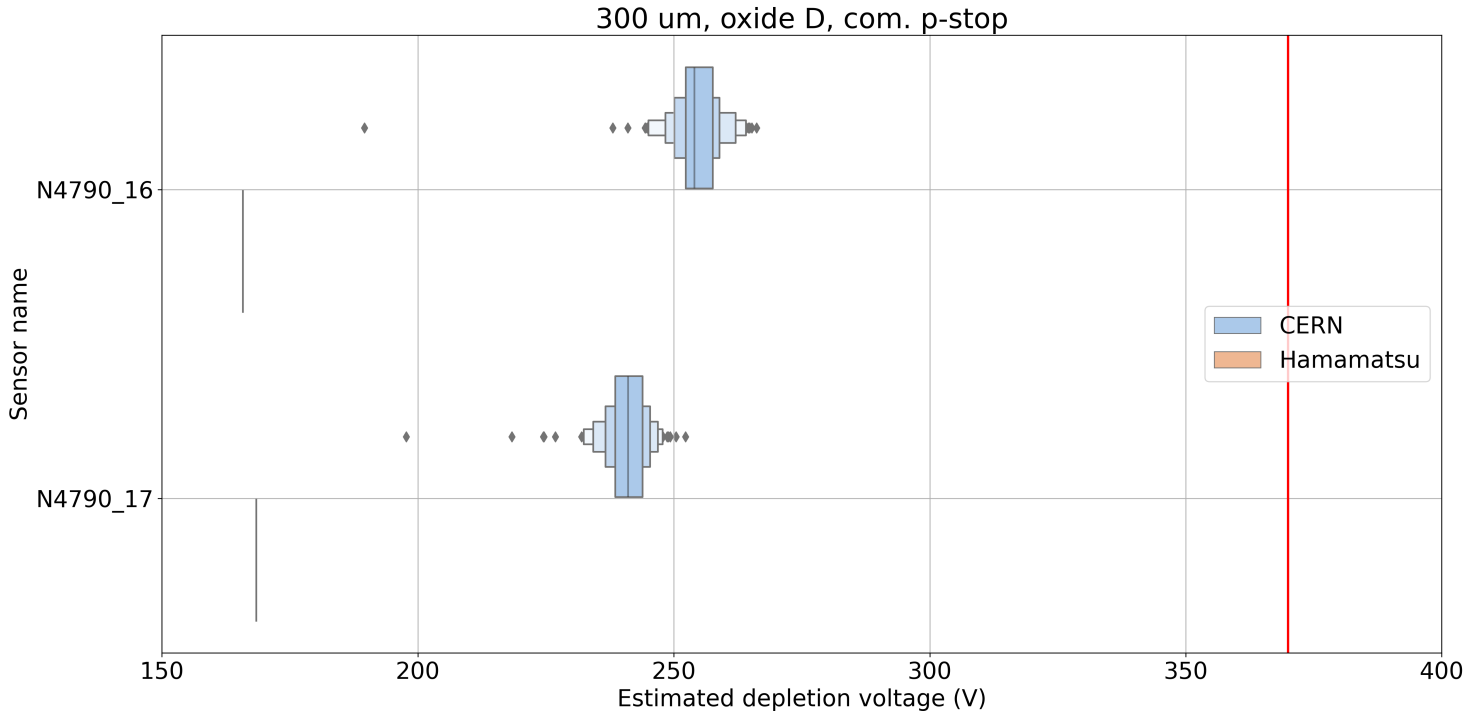


- Note difference in depletion voltage between oxide types
- Oxide types B-D pass CV criteria
- Oxide type A also pass CV criteria, but many pads with spurious C-readings

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

Longterm Leakage current stability, sensors

ID	P- Stop	Thick-ness	Flat band voltage	P-stop concen-tration	Oxide quality	Material
N4791_1	com	300	-5V	STD	A	FZ
N4790_3	com	300	-2V	STD	B	FZ
N4791_8	com	300	-2V	STD	C	FZ
N4791_9	com	300	-2V	STD	C	FZ
N4791_21	ind	300	-2V	STD	C	FZ
N4790_15	com	300	-2V	STD	D	FZ

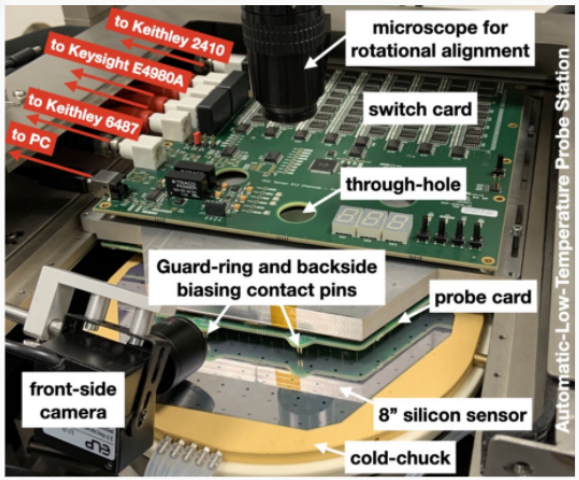
Frame removal at CERN

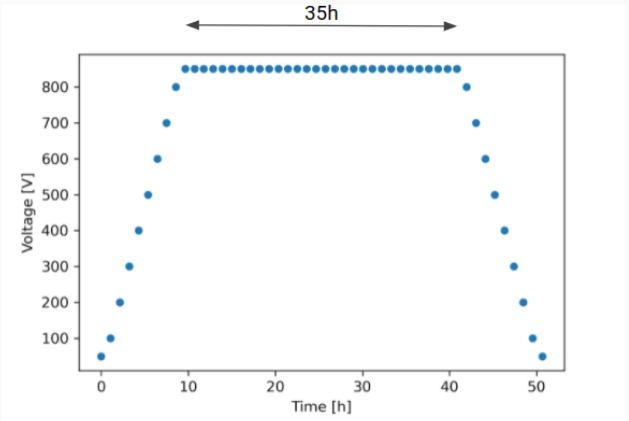
N4790_17	com	300	-2V	STD	D	FZ
N4792_4	com	200	-5V	STD	A	FZ

Frame removal at HPK

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

Proto-A: example IV+CV results