Summary of the neutron irradiation campaign

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LNL irradiation set-up

SiPM irradiation at CN-LNL – predefined slots

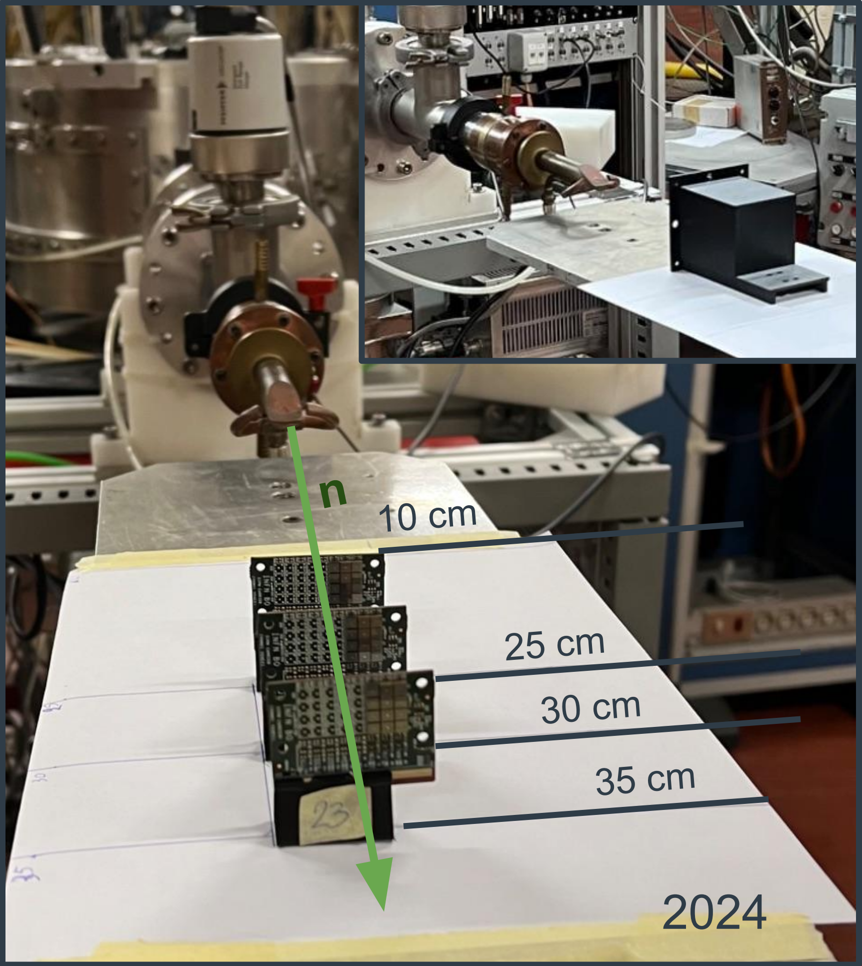
@ 100 nA current

	10^{11} nominal, 10^{11} in 24 h	10^{10} nominal, 10^{10} in 21 h	10^{9} nominal, 10^{9} in 3 h	10^{8} online, 10^{8} in 0.5 h
neutron flux	$4.3\ 10^{9}\ n_{eq}$ / h	$4.7\ 10^{8}\ n_{eq}$ / h	$3.5\ 10^{8}\ n_{eq}$ / h	$2.1\ 10^{8}\ n_{eq}$ / h
distance	100 mm	300 mm	350 mm	450 mm
lateral drop at 25 mm	35%	5.5%	4.3%	3.0%
position uncertainty ± 5 mm	22%	6.9%	5.9%	4.1%

target

3

2023



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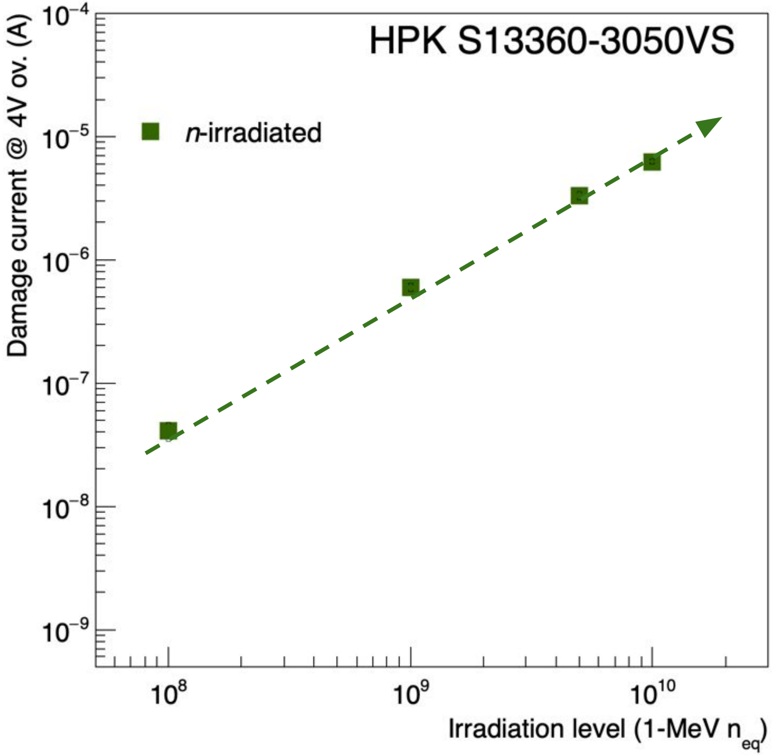
Irradiation target

serial number	irradiation mode	distance (cm)	charge (nC)	fluence (cm^{-2})	notes
19	NORMAL 10^{10}	25	7.60E+06	$1\ 10^{10}\ n_{eq}$	STANDARD OVEN
20	NORMAL $5\ 10^{9}$	30	1.03E+06	$5\ 10^{9}\ n_{eq}$	STANDARD OVEN
21	NORMAL 10^{9}	35	1.03E+06	$1\ 10^{9}\ n_{eq}$	OFFLINE FORWARD
22	NORMAL 10^{9}	35	1.03E+06	$1\ 10^{9}\ n_{eq}$	OFFLINE REVERSE
23	NORMAL 10^{9}	35	1.03E+06	$1\ 10^{9}\ n_{eq}$	INFRARED LAMP
24	NORMAL 10^{9}	35	1.03E+06	$1\ 10^{9}\ n_{eq}$	ELSE
25	SPARE	35			
26	SPARE				

Successful irradiation in 2023!
We see the linear increase with fluence as per NIEL hypothesis. But how does that compare with *p*-irradiated?



Damage current: current at given overvoltage after irradiation subtracted the current of a new sensor at the same overvoltage

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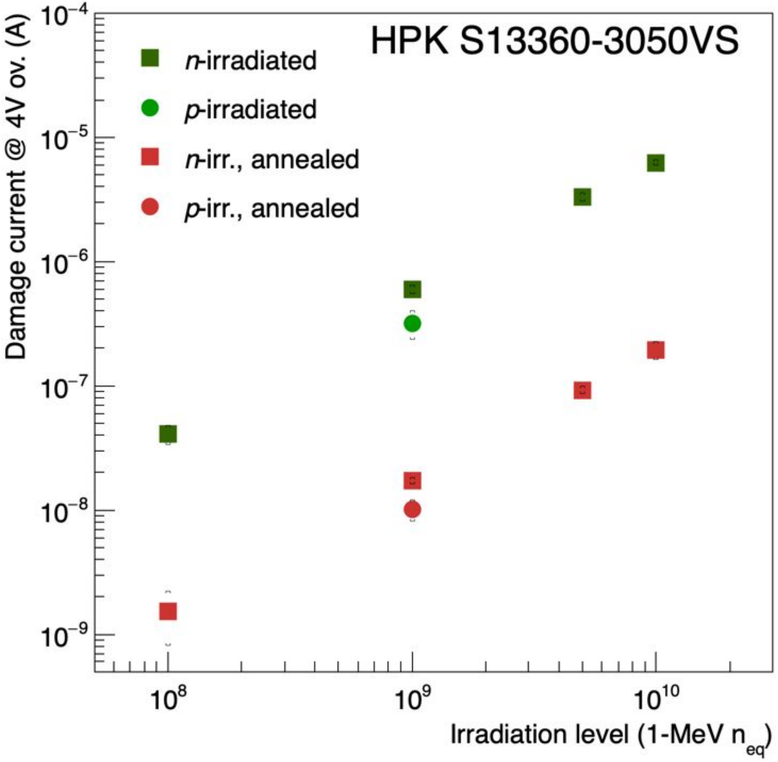
Irradiation target

serial number	irradiation mode	distance (cm)	charge (nC)	fluence (cm^{-2})	notes
19	NORMAL 10^{10}	25	7.60E+06	1 10^{10} n_{eq}	STANDARD OVEN
20	NORMAL 5 10^{9}	30	1.03E+06	5 10^{9} n_{eq}	STANDARD OVEN
21	NORMAL 10^{9}	35	1.03E+06	1 10^{9} n_{eq}	OFFLINE FORWARD
22	NORMAL 10^{9}	35	1.03E+06	1 10^{9} n_{eq}	OFFLINE REVERSE
23	NORMAL 10^{9}	35	1.03E+06	1 10^{9} n_{eq}	INFRARED LAMP
24	NORMAL 10^{9}	35	1.03E+06	1 10^{9} n_{eq}	ELSE
25	SPARE	35			
26	SPARE				

Successful irradiation in 2023!
We see the linear increase with fluence as per NIEL hypothesis. The results from the *n*-irradiated clashes with the ones from the *p*-irradiated, showing roughly twice the damage current



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Irradiation target

serial number	irradiation mode	distance (cm)	charge (nC)	fluence (cm^{-2})	notes
19	NORMAL 10^{10}	25	7.60E+06	$1\ 10^{10}\ n_{eq}$	STANDARD OVEN
20	NORMAL $5\ 10^9$	30	1.03E+06	$5\ 10^9\ n_{eq}$	STANDARD OVEN
21	NORMAL 10^9	35	1.03E+06	$1\ 10^9\ n_{eq}$	OFFLINE FORWARD
22	NORMAL 10^9	35	1.03E+06	$1\ 10^9\ n_{eq}$	OFFLINE REVERSE
23	NORMAL 10^9	35	1.03E+06	$1\ 10^9\ n_{eq}$	INFRARED LAMP
24	NORMAL 10^9	35	1.03E+06	$1\ 10^9\ n_{eq}$	ELSE
25	SPARE	35			
26	SPARE				

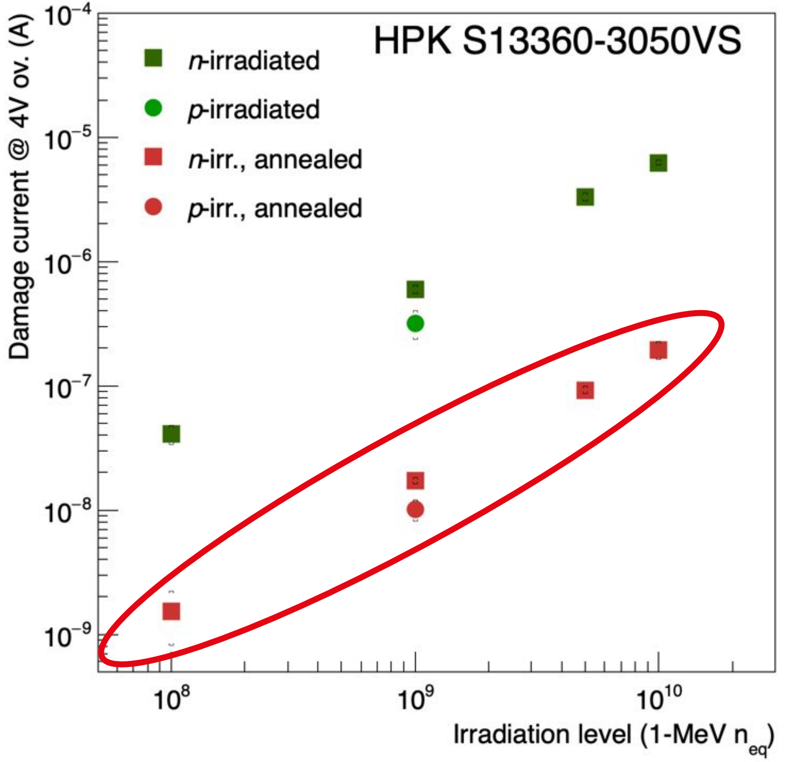
serial number	distance (cm)	charge (nC)	fluence (cm^{-2})	time (hours)	notes
19	25	5.28E+06	$1\ 10^{10}\ n_{eq}$	16.3	repeat LNL 2023
20	30	3.80E+06	$5\ 10^9\ n_{eq}$	11.7	repeat LNL 2023
23	35	1.03E+06	$1\ 10^9\ n_{eq}$	3.2	repeat LNL 2023
24	35	1.03E+06	$1\ 10^9\ n_{eq}$	3.2	repeat LNL 2023
25	35	1.03E+06	$1\ 10^9\ n_{eq}$	3.2	repeat LNL 2023
28	35	1.03E+06	$1\ 10^9\ n_{eq}$	3.2	NEW
26	35	1.03E+05	$1\ 10^8\ n_{eq}$		repeat LNL 2023

Successful irradiation in 2023!
We see the linear increase with fluence as per NIEL hypothesis. The results from the *n*-irradiated clashes with the ones from the *p*-irradiated. We try to repeat the measurement to see if we did something wrong, using (mostly) the same boards*

Irradiation target

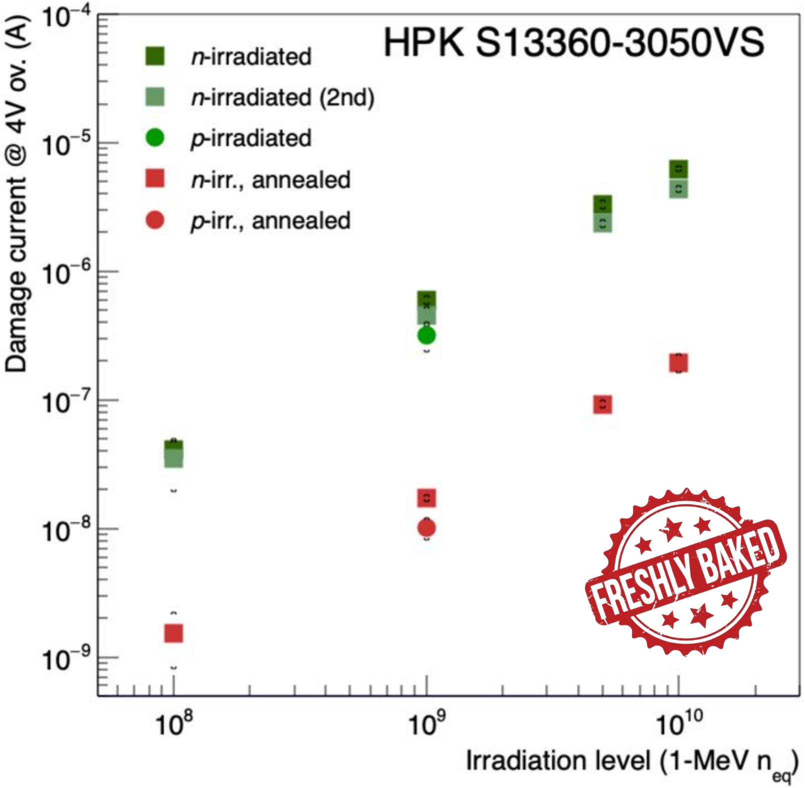
*they have been “scratched” with annealing (more than what is shown, not all are shown), they will have a residual damage (~3%) to deal with but we characterise them before irradiation

serial number	distance (cm)	charge (nC)	fluence (cm^{-2})	time (hours)	notes
19	25	5.28E+06	1 10^{10} n_{eq}	16.3	repeat LNL 2023
20	30	3.80E+06	5 10^{9} n_{eq}	11.7	repeat LNL 2023
23	35	1.03E+06	1 10^{9} n_{eq}	3.2	repeat LNL 2023
24	35	1.03E+06	1 10^{9} n_{eq}	3.2	repeat LNL 2023
25	35	1.03E+06	1 10^{9} n_{eq}	3.2	repeat LNL 2023
28	35	1.03E+06	1 10^{9} n_{eq}	3.2	NEW
26	35	1.03E+05	1 10^{8} n_{eq}		repeat LNL 2023



First results

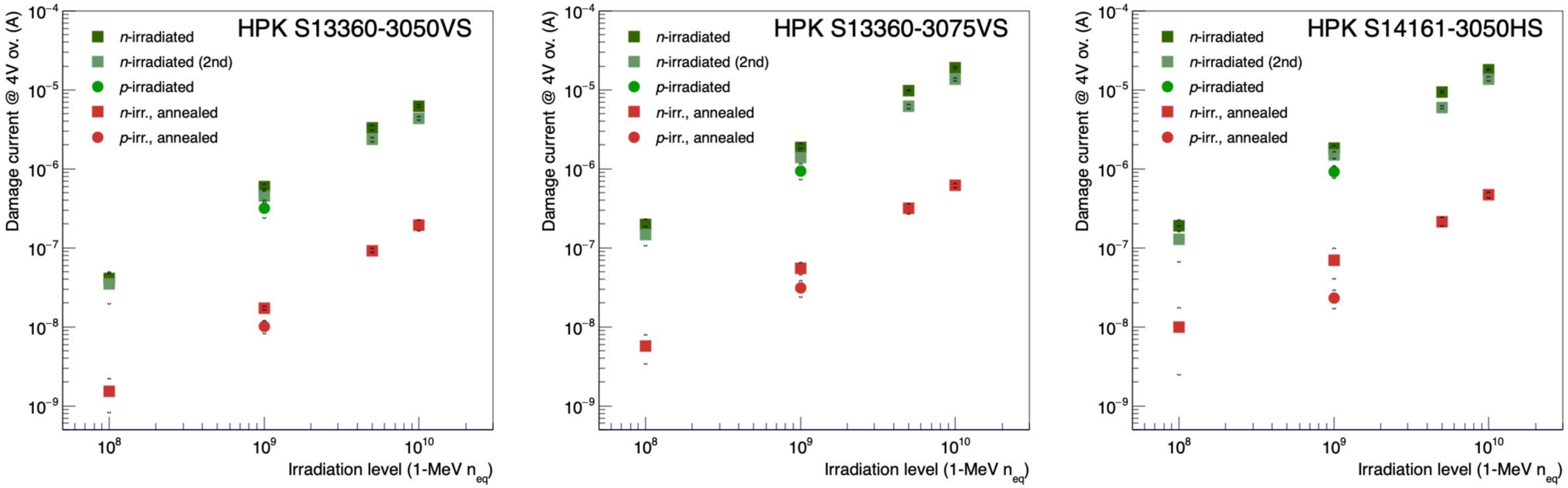
Characterisation finished yesterday for the last two fluences, so they are (very) freshly baked results!



Damage current: current at given overvoltage after irradiation subtracted the current of a new or "scratched" sensor at the same overvoltage

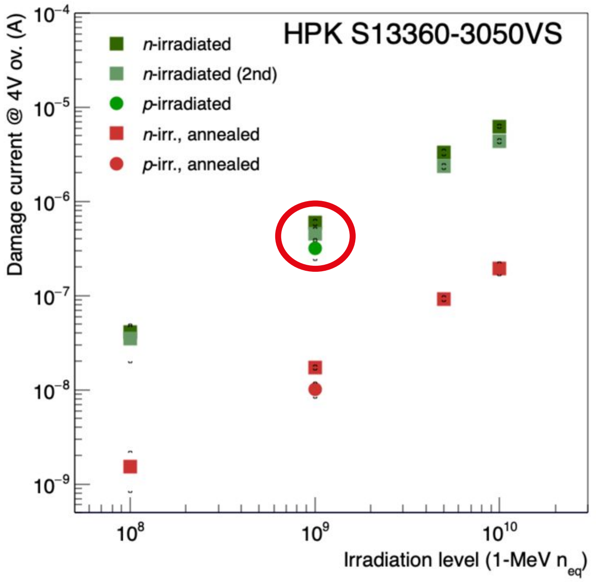
First results

The linearity is still preserved, but we seem to have a consistently lower damage across all fluences.



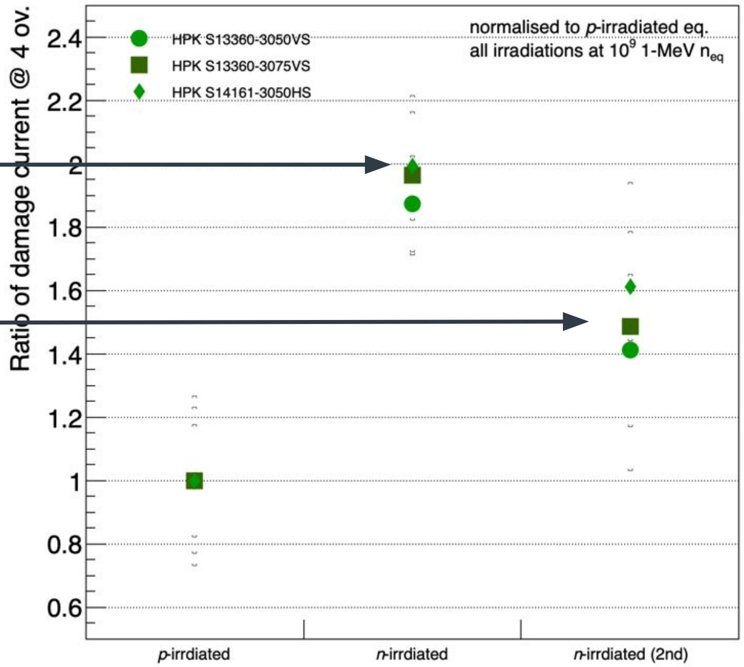
First results

The linearity is still preserved, but we seem to have a consistently lower damage across all fluences.



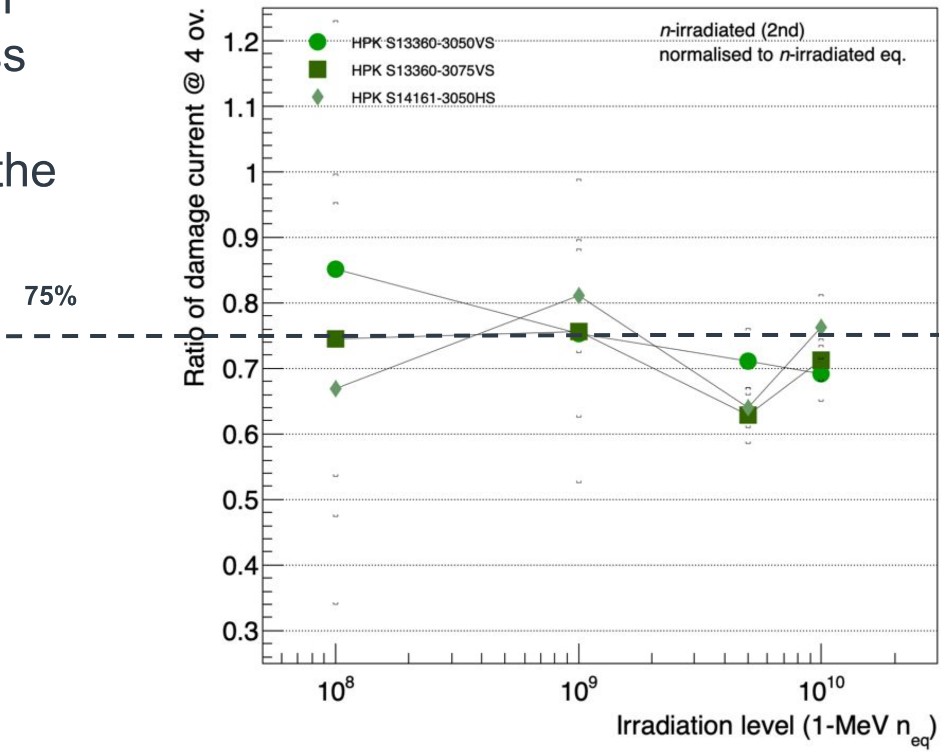
~2x w.r.t. *p*-irradiated

~1.5x w.r.t. *p*-irradiated



First results

The linearity is still preserved, but we seem to have a consistently lower damage across all fluences.
For all sensors we seem to have ~75% of the damage we had the first round.



Conclusions

The LNL-puzzle saga continues and will need further investigation on what is the source of these discrepancies.
We successfully irradiated and characterised all target boards.

Up next:
laser measurements to evaluate window damage

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Thank you!
Any questions?

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Back-up