Study of total ionization does effects on IHEP-NDL LGAD sensors

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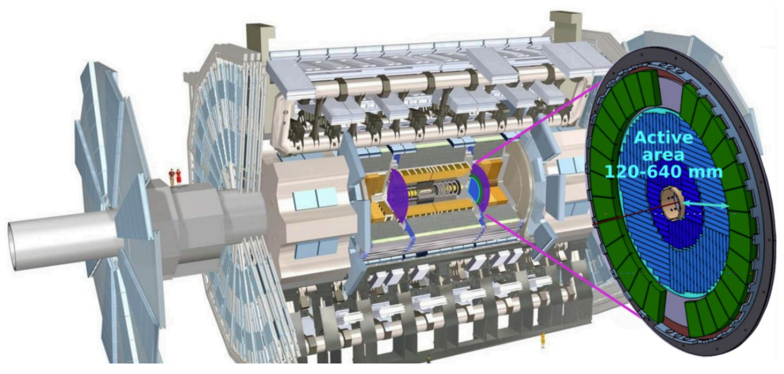
Introduction

❖ Low Gain Avalanche Detectors (LGAD) was developed to achieve high time resolution (30ns) to solve the pile up problem for for the ATLAS Phase-II upgrade.

❖ To operate in the harsh environment in high luminosity LHC, the LGAD sensor should be radiation hardness. This contribution focuses on total ionization does (TID) effects on LGAD sensors developed by NDL (Novel Device Laboratory) and IHEP.

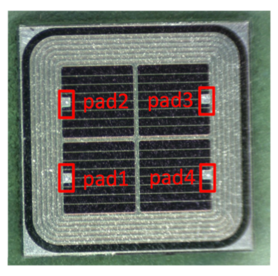
❖ 2x2 LGAD sensor with different doping profile, epitaxial resistance and guardring design were irradiated to 100kGy by MultiRad 160. The changes of key parameters of LGAD after x-ray irradiation were measured.

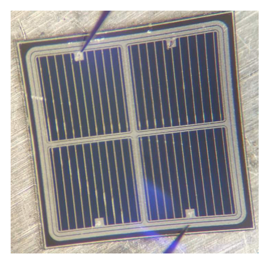


Property of NDL sensor

❖LGAD has a highly p-doped multiplication layer at the np-junction to obtain the high gain and high time precision.

❖IHEP-NDL designed four kinds of LGAD sensor.


BV170& BV60

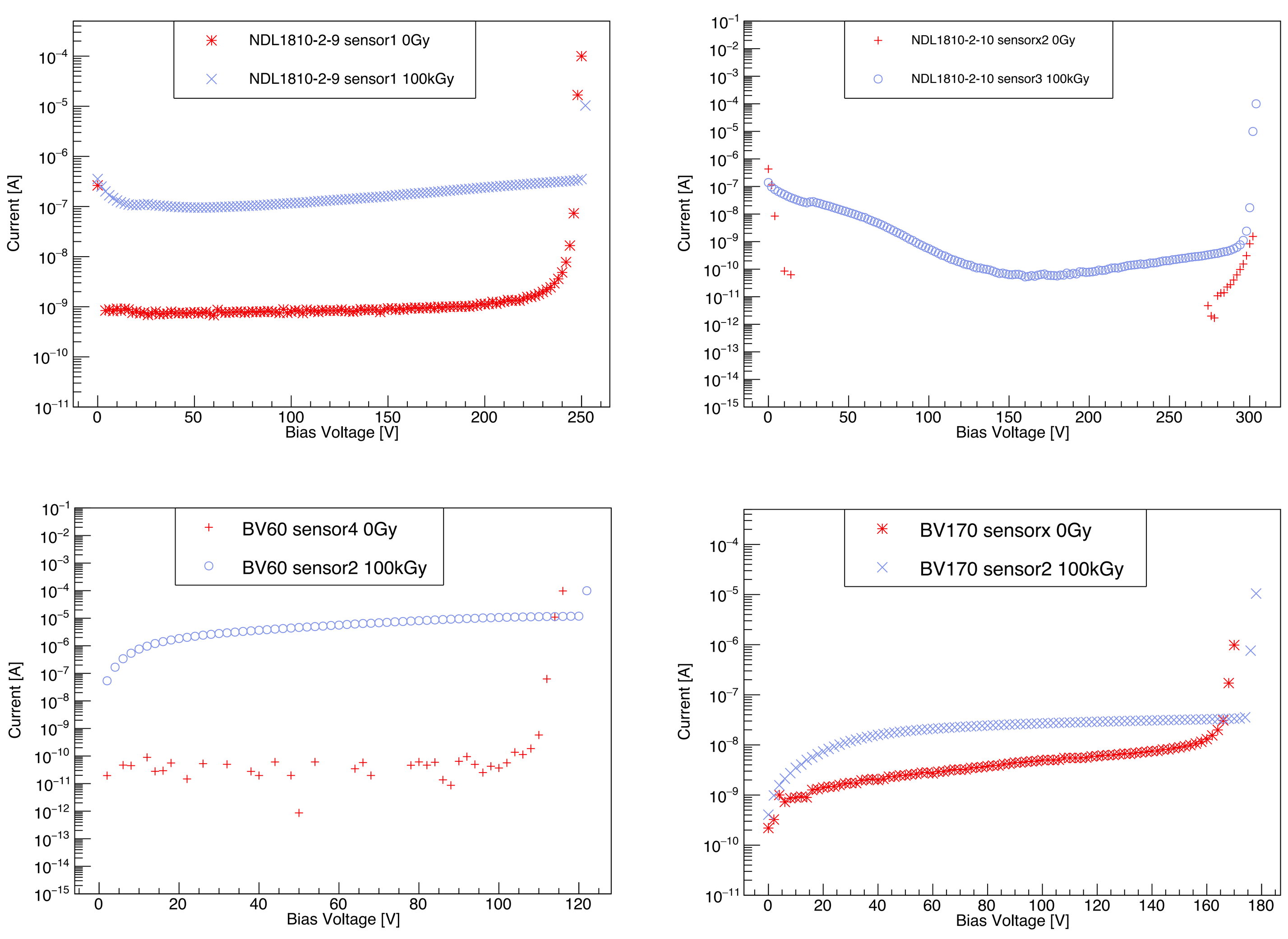

NDL 9 & 10

LGAD	High resistance silicon	Low resistance silicon	Number of Guard Ring	Guard Ring with metal contact
NDL1810-2-9	No	Yes	2	Yes
NDL1810-2-10	No	Yes	2	Yes
BV60	No	Yes	6	No
BV170	Yes	No	6	No

After irradiation: IV — leakage current and breakdown

❖ After 100kGy irradiation, the leakage currents of the IHEP-NDL LGAD sensor decrease. The NDL1810-2-10 has the smallest leakage current.

❖ The breakdown voltage increases except NDL1810-2-10.



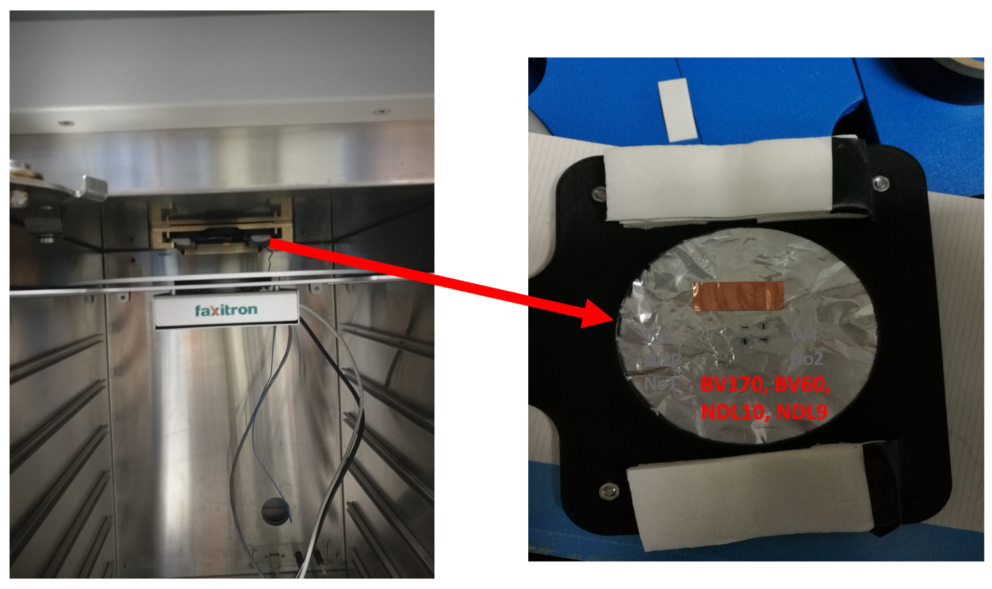
Conclusion: 2

❖ The guard ring design could improve the inter-pad isolation and the TID hardness irradiation;

❖ High resistance silicon could improve the depletion performance.

TID test setup

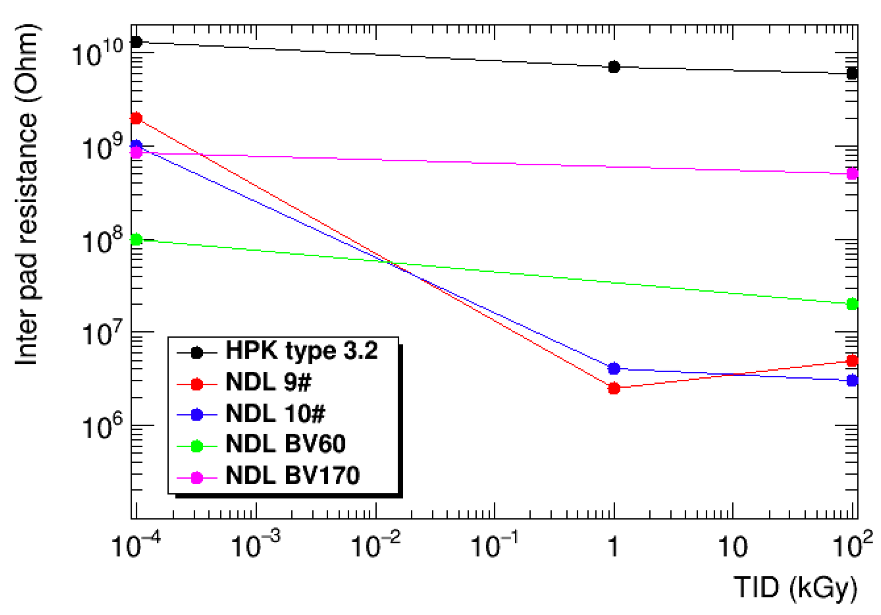
❖ LGAD sensors were irradiated with MutiRad 160.
–Dose rate: 174.5Gy/min
–Filter: 0.09mm Al
–Dose: 0, 1kGy, 10kGy, 100kGy



After irradiation: Inter-pad resistance

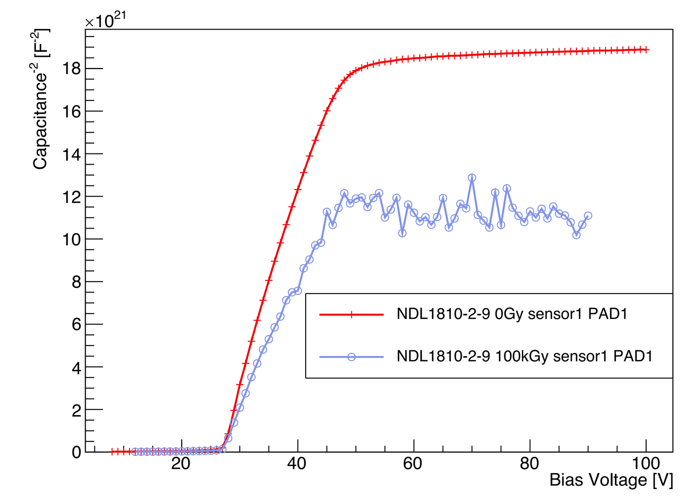
❖ NDL 2x2 sensors : 6GR design has better Inter-pad resistance than 2GR design after irradiation.

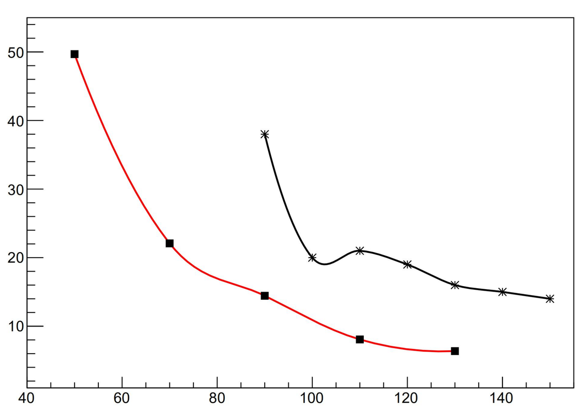
❖ Compared with HPK 3.2 (5x5): HPK showed better inter-pad isolation after irradiation.

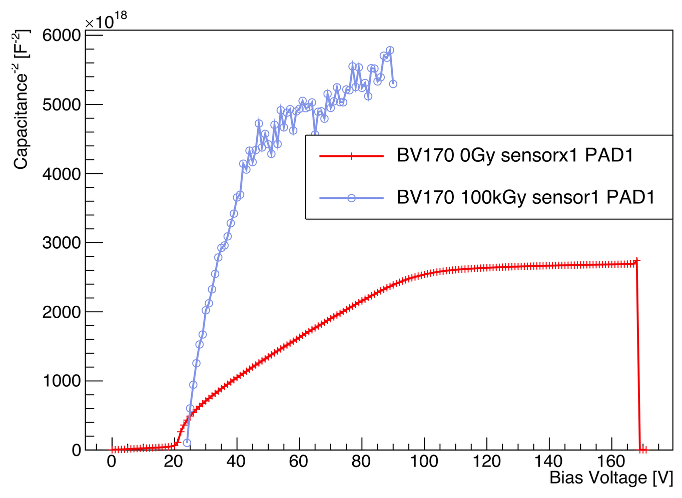


After irradiation: CV and timeresolution

❖ After 100kGy irradiation, fully depleted voltage was slightly increase except NDL1810-2-10.







Conclusion: 1

❖ Leakage current of NDL1810-2-10 is better than the other sensors even compared with HPK sensors(T3.1, T3.2).