Evaluation of Performance of the p-stop Process Splits in ATLAS18 strip sensors, Pre- and Post-Irradiation

J. Kozáková[a], A. Affolder[b], K. Affolder[b], A. Awais[c], E. Bach[d], G.A. Beck[c], P. Bernabeu[e], A. J. Bevan[c], Z. Chen[c], V. Cindro[f], B. Crick[g], J. Dandoy[h], I. Dawson[c], V. Fadeyev[b], P. Federičová[a], C. Fleta[d], P. Gallus[i], C. Jessiman[h], S. Katznelson[b], J. Keller[h], C. T. Klein[h], T. Koffas[h], J. Kroll[a], M. Kůtová[a], J. Kvasnička[a], C. Lacasta[e], I. Mandić[f], R. R. Marcelo Gregorio[j], F. Martinez-Mckinney[b], M. Mikeštíková[a], P. S. Miyagawa[c], L. Morelos-Zaragoza[b], R. S. Orr[g], Q. Paddock[b], C. Solaz[e], U. Soldevila[e], E. Staats[h], P. Tůma[a], M. Ullán[d], Y. Unno[k], M. Vansteenkiste[g], P. Wishart[g], S. C. Zenz[c], Y. Zhao[h]

[a] Institute of Physics, Czech Academy of Sciences, Na Slovance 2, 18200 Prague 8, Czech Republic
[b] Santa Cruz Institute for Particle Physics (SCIPP), University of California, Santa Cruz, CA 95064, USA
[c] Particle Physics Research Centre, Queen Mary University of London, G.O. Jones Building, Mile End Road, London E1 4NS, United Kingdom
[d] Instituto de Microelectrónica de Barcelona (IMB-CNM), CSIC, Campus UAB-Bellaterra, 08193 Barcelona, Spain
[e] Instituto de Física Corpuscular, IFIC/CSIC-UV, C/Catedrático José Beltrán 2, E-46980 Paterna, Valencia, Spain
f Experimental Particle Physics Department, Jožef Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia
[g] Department of Physics, University of Toronto, 60 Saint George St., Toronto, Ontario M5S1A7, Canada
[h] Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario, K1S 5B6, Canada
[i] UJP PRAHA a.s., Nad Kamínkou 1345, 156 10 Prague – Zbraslav, Czech Republic
[j] Department of Nuclear Physics & Accelerator Applications, The Australian National University, Canberra ACT 2600, Australia
[k] Institute of Particle and Nuclear Study, High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan

Motivation

- HL-LHC upgrade – ATLAS Inner Detector using ATLAS18 sensors
- ATLAS18 QA tests found low interstrip isolation in some batches
- this test production evaluates process variations (types 2–4) and their irradiation performance

type	p-stop process variation
1	Conventional process condition (reference)
2	Lower temperature than type 1
3	Little lower temperature than type 2
4	Another method condition

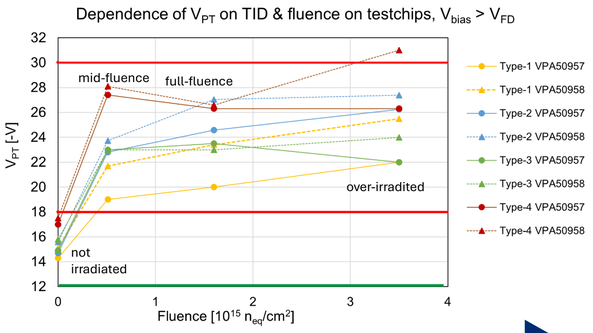
Sample batches VPA50957, VPA50958 were produced by Hamamatsu Photonics K. K. (HPK)

IV tests

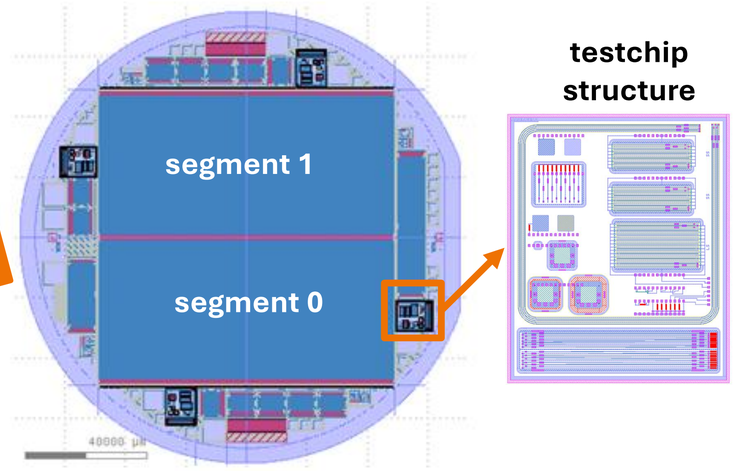
- **before irradiation** – all samples passed QC specs (V_{BD} > 500 V, I < 0.1 μA/cm^2) [1]
- **after irradiation** – no influence of p-stop type on early breakdown observed

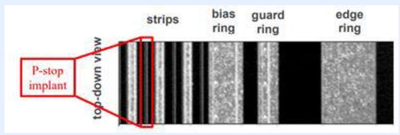
Punch-through voltage tests

- **punch-through voltage V_{PT}** – voltage at half value of effective resistance [2]
- **before irradiation** – all samples passed QC specs (12–18 V)
- **after irradiation**
  - **testchips** – passed specs limit (18–30 V)
  - **main sensors** – no segment dependence observed
    - type 1 not measured
- V_{PT} behavior varied only slightly among the four tested sensor types, with all sensors meeting QC specs before and after irradiation [1]

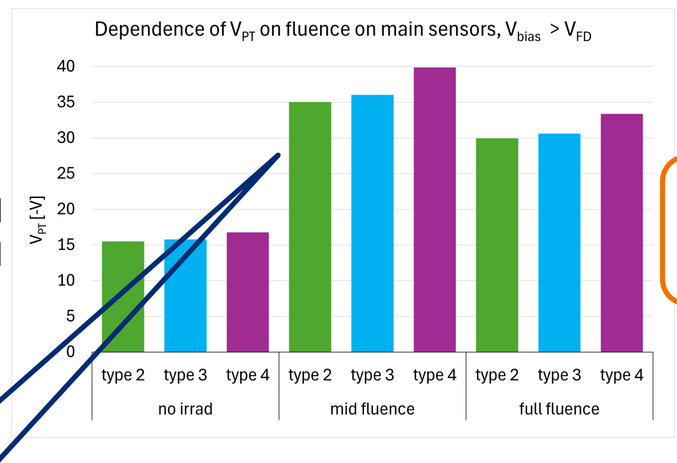


V_{PT} tends to increase with TID and fluence





p-stop implant – *p*-doped rail surrounding the *n*-strips



at mid-fluence, V_{PT} is unexpectedly higher than that of full fluence, this is under investigation

Samples

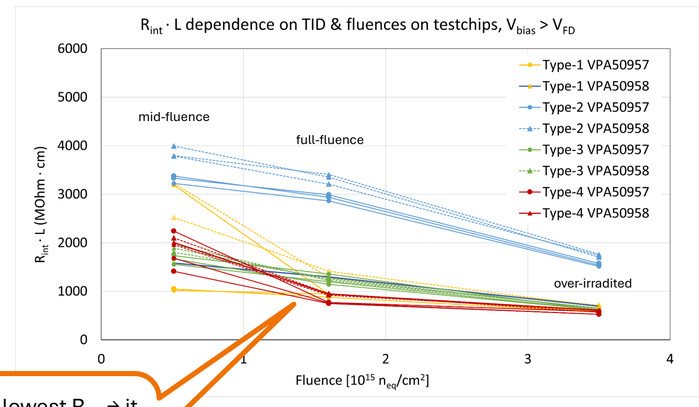
- radiation-hard n^+-in-p ATLAS18 micro-strip sensors
  - six barrel long strip main sensors (9.795 cm x 9.762 cm) – 2 segments, 1282 strips per segment, strip length 4.835 cm [1]
  - testchips, miniature sensors

Irradiation, Doses and Fluences

- gamma irradiation at UJP Praha, Terabalt ^{60}Co source
- neutron irradiation at JSI Ljubljana, TRIGA reactor
- mid-fluence – 21–25 Mrad + 5.1×10^{14} n_{eq}/cm^2
- full-fluence – 66 Mrad + 1.6×10^{15} n_{eq}/cm^2
- over-irradiated – 66 Mrad + 3.5×10^{15} n_{eq}/cm^2

Interstrip resistance tests

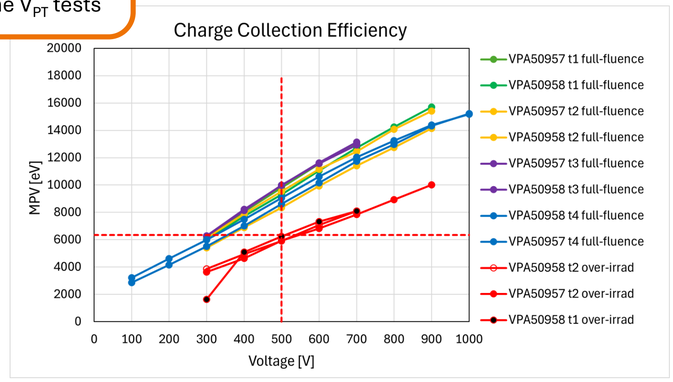
- R_{int} is temperature dependent → all values are normalized to -20 °C
- R_{int} decreases with increasing dose and fluence, but all sample types still meet specs(R_{int}>15 kΩ) [1]



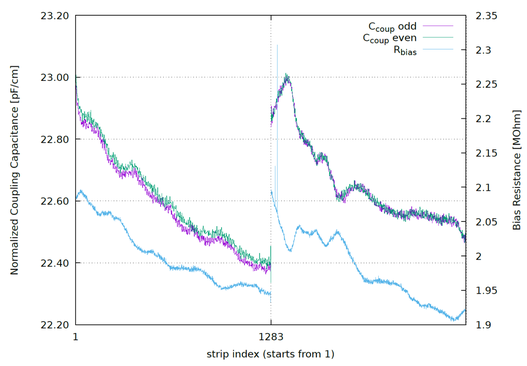
type 4 has lowest R_{int} → it may indicate a lower effective p-stop doping, contrary to the V_{PT} tests

Charge collection efficiency tests

- all miniature sensors irradiated to full-fluence met specs (> 6350 eV at -500 V)
- over-irradiated samples do not meet specs



Type 4 sample irradiated to full-fluence



Striptests

- no problematic strips observed in any p-stop implant type before and after irradiation

Conclusions

- various p-stop types were studied; results are valuable feedback for HPK, even though they will not be used in the ITk detector
- all parameters passed QC specifications
- differences in V_{PT} and R_{int} among p-stop implant types were minimal and negligible for the specification of Itk strip sensors and the expected operational conditions
- a trend of anti-correlation between V_{PT} and R_{int} is observed when going from type 2 to type 4, contrary to the expectation that V_{PT} and R_{int} are positively correlated with p-stop density → under investigation

References

[1] Y. Unno, et al. Specifications and Pre-production of n⁺-in-p Large-format Strip Sensors fabricated in 6-inch Silicon Wafers, ATLAS18, for the Inner Tracker of the ATLAS Detector for High-Luminosity Large Hadron Collider, (2023) JINST 18 T03008

[2] Y. Unno, et al. Evaluation of test structures for the novel n⁺-in-p pixel and strip sensors for very high radiation environments, (2013) NIMA 731

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