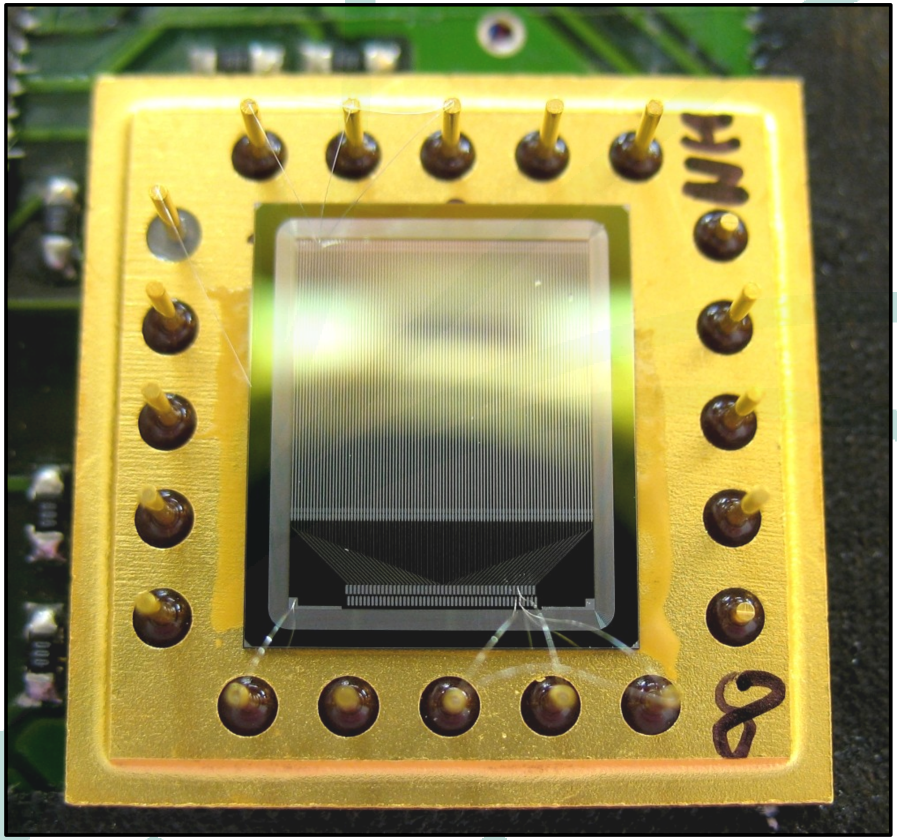
Low dose inter-strip isolations in n-in-p micro-strip sensors under X-ray irradiation



FSP 101 ATLAS GEFÖRDERT VOM
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Overview

- Motivation
- Measurement setup
- Devices under test
- Measurements
- Summary

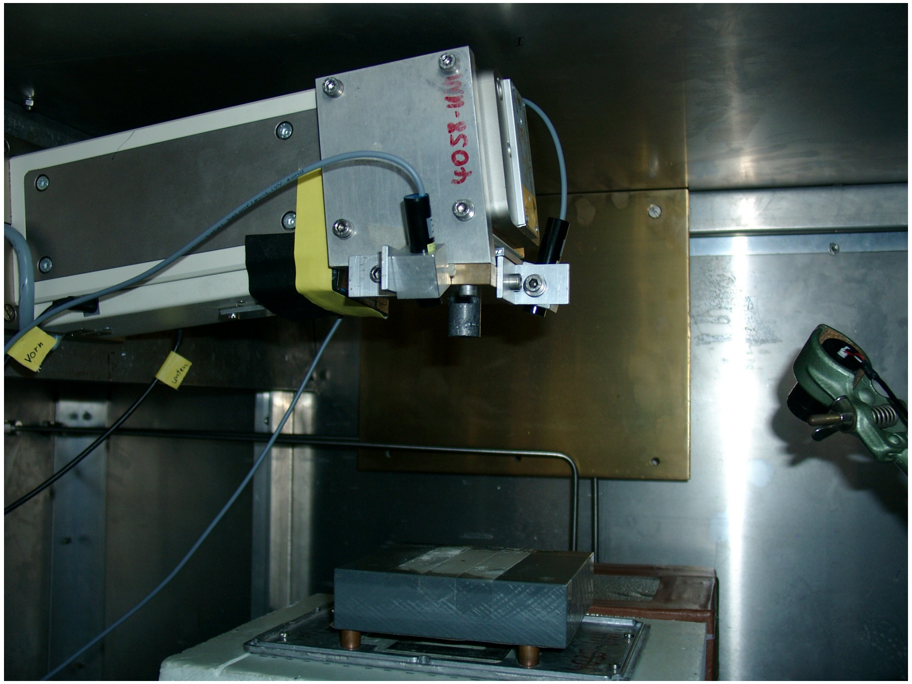
Motivation

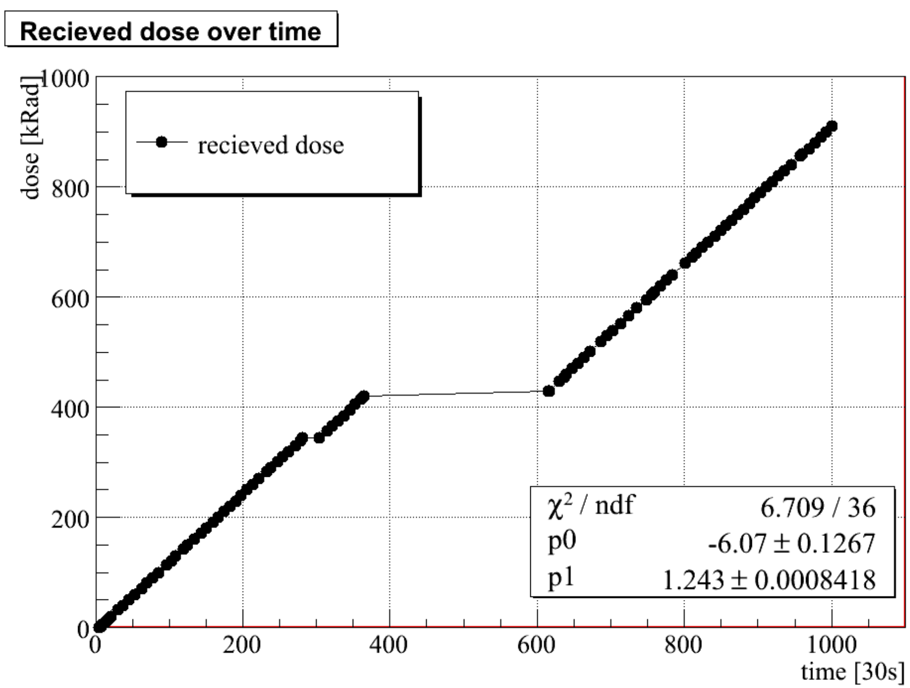
Motivation:

- Investigate effects of surface damage after low dose irradiations on detectors where the isolation is achieved with very low dose p-spray.
  - Many data already accumulated by other groups at high fluences with somewhat higher isolation doses

    (e.g. H. Sadrozinski et al.; NIMA 579 (2007) 769).
- Low dose isolation allows for smaller fields (i.e. higher break down voltages) and smaller C_{int},
- Can we live with an integrated isolation dose smaller than the oxide charge saturation value of ~2e12cm^{-2}?
- P-spray irradiation test of CiS <100> oriented sensors have not been done before.

Experimental setup





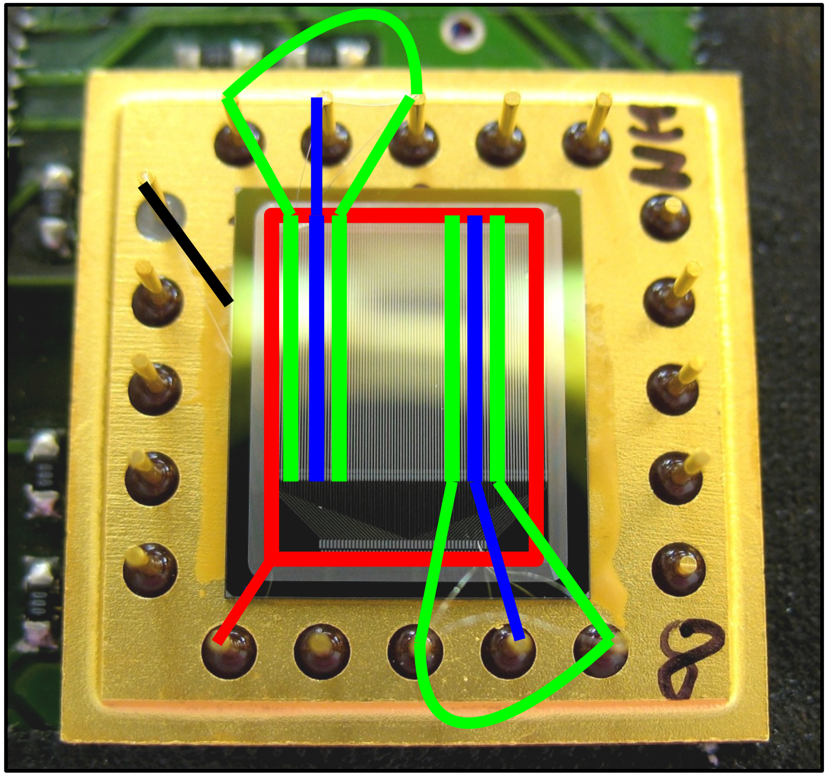
Karlsruhe X-ray tube:

- 35 keV MPV@60kV, 25mA
- X-ray dose rate around 149 kRad/h
- Maximum dose achieved: ~ 1 MRad

Measurements:

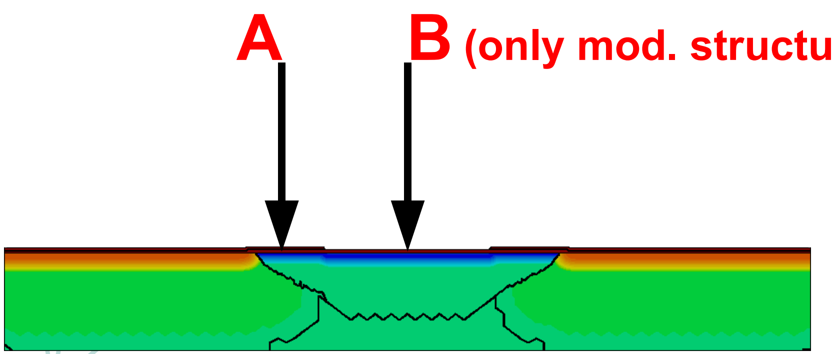
- I-V before, after irradiation
- I-V after 1 week RT annealing
- Continuous I-t and C_{int}-t
- C_{int}-V before, during, and after irradiation
- R_{int} before and after irradiation

Micro strip sensors



Micro strip sensors:

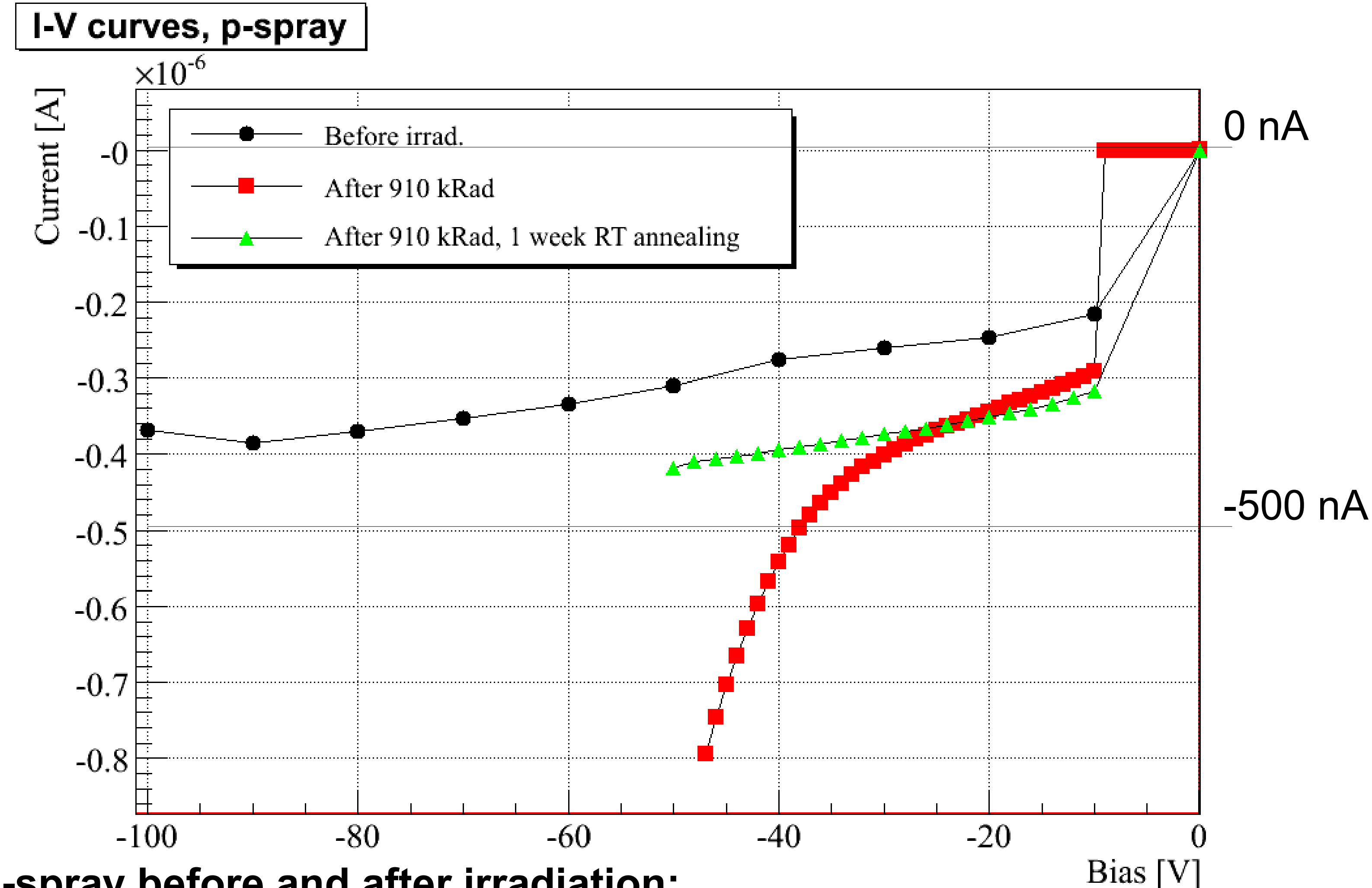
- CiS STDW07, W06 (n-in-p, <100>)
- 7mm strip-length
- 80um pitch, 30um contact width
- 1 x P-spray and 1 x moderated p-spray
- Thickness: 285um
- Resistivity: 9.71 kOhmcm
- Punch through bias



Isolation (boron) implantation parameters:

- Nominal Implant dose: 5e12 cm^{-2}
- Energy: 100keV
- Integrated dose calculated by DIOS:
  - A) below p-spray: 7.4e11 cm^{-2}
  - B) below nitride opening in moderated p-spray: 4.23e12 cm^{-2}

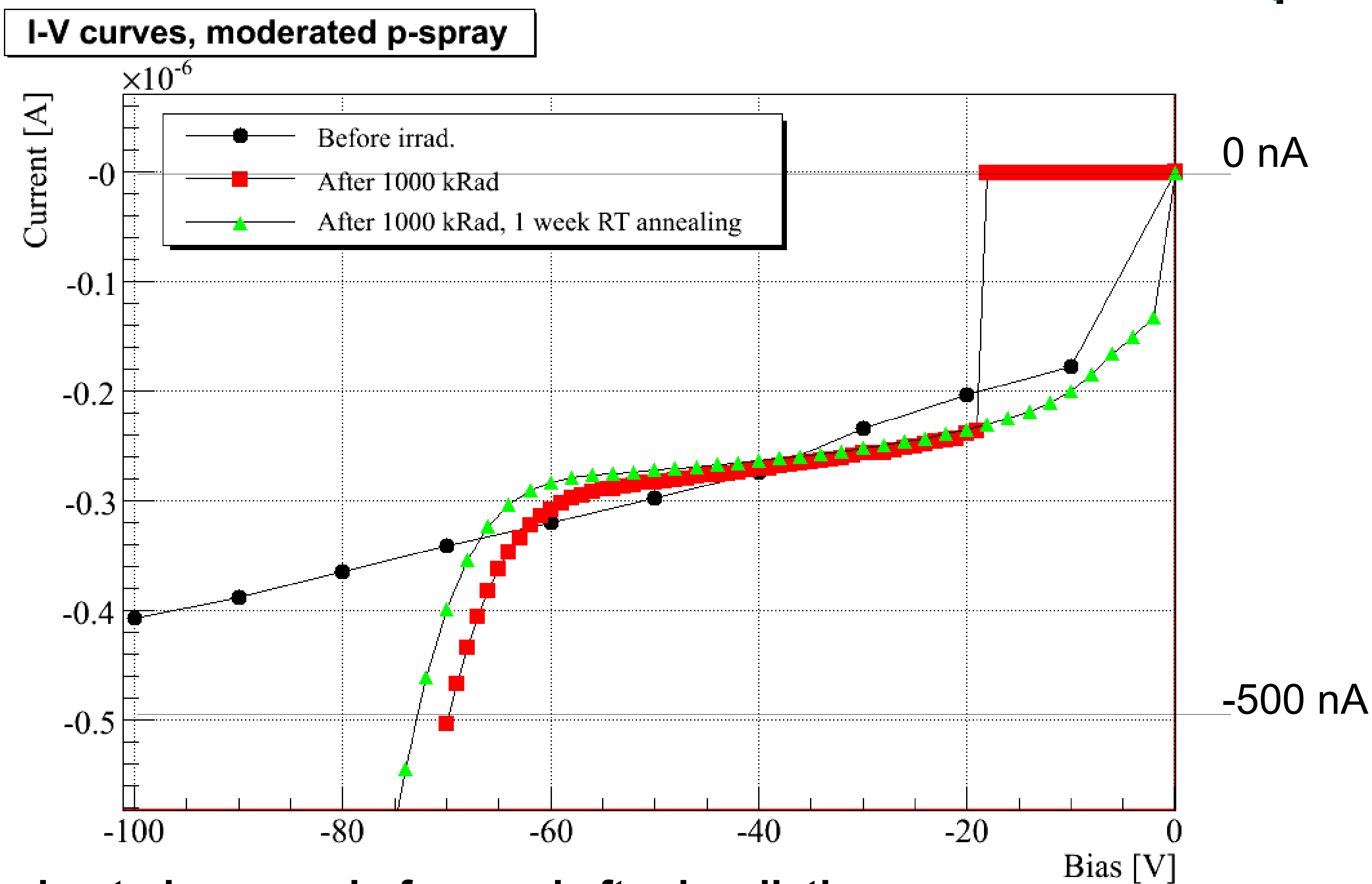
IV curves, p-spray



P-spray before and after irradiation:

- Step probably due to a contact problem in the Karlsruhe setup
- Increased leakage current and low break down voltage after surface damage
- BD voltage should be higher for p-spray after forming of oxide charges
- Some recovery after annealing

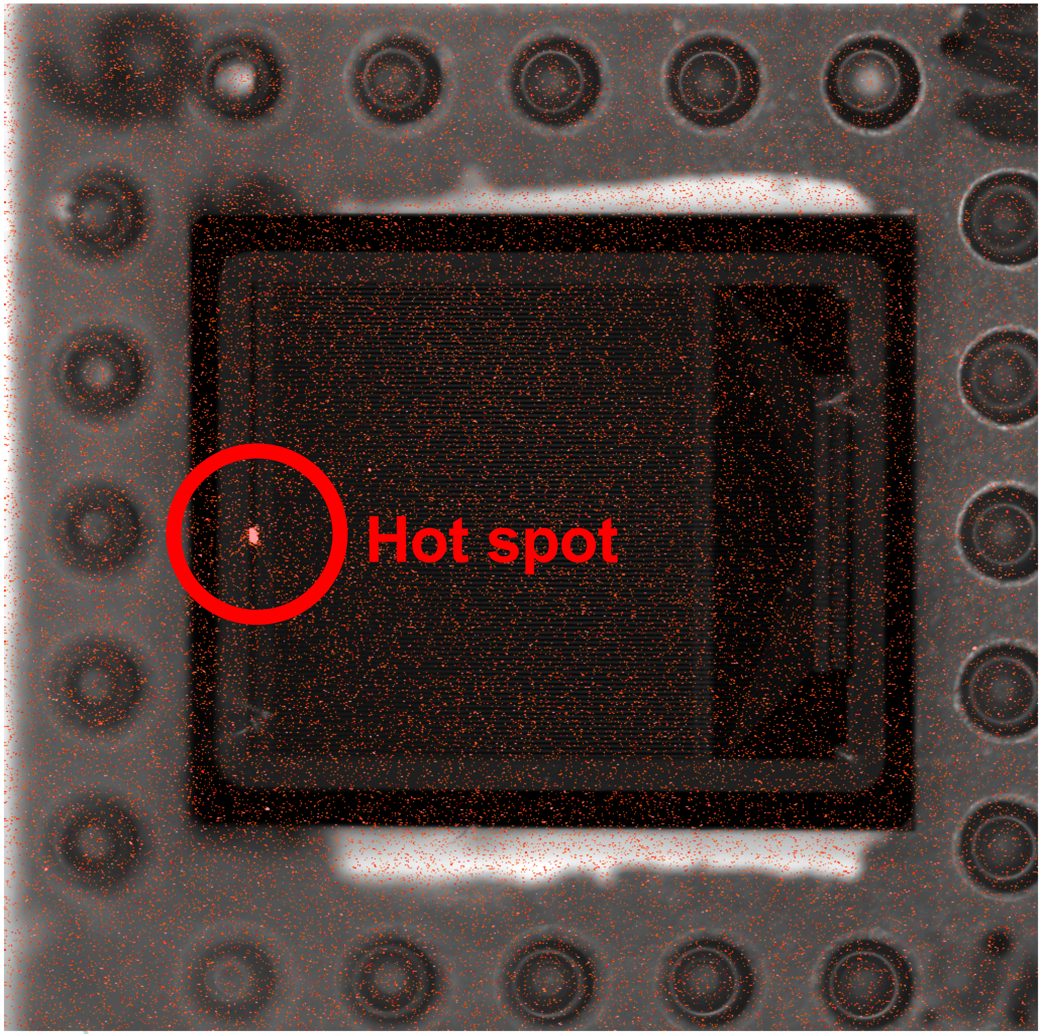
IV curves, moderated p-spray



Moderated p-spray before and after irradiation:

- About equal leakage current below 60V
- Early break down after irradiation at around 60V
- Further measurements only possible at reduced voltage
- Phemos observations to shed light on this problem

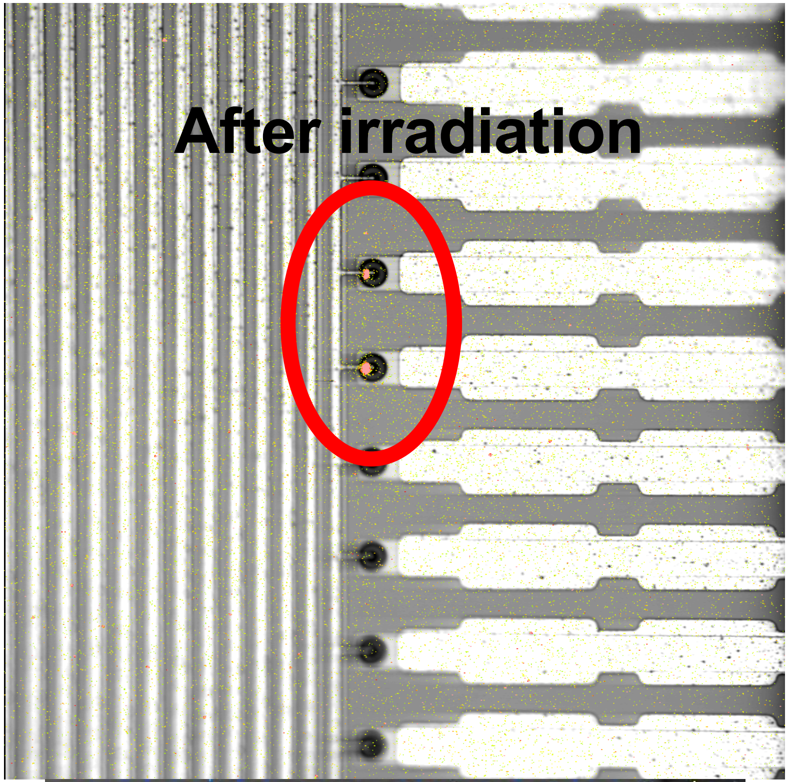
Phemos measurements

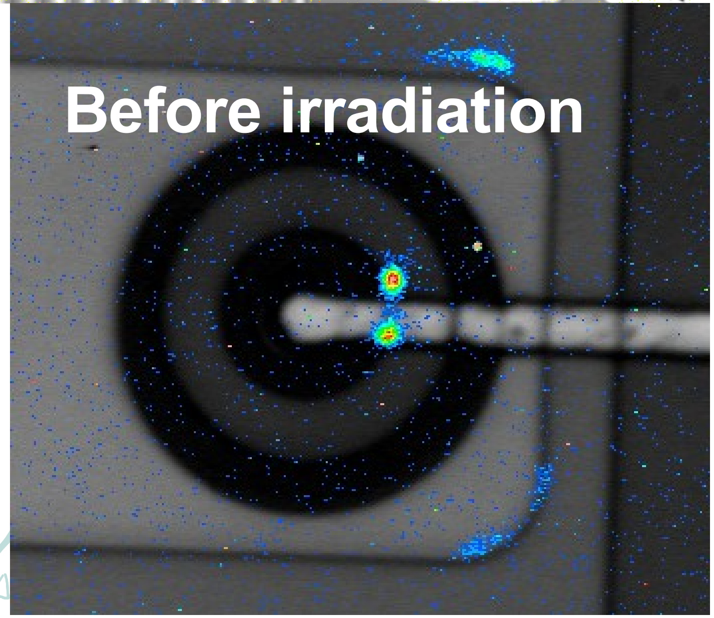


Phemos:

- Probe station equipped with a CCD microscope
- Electrons accelerated in hot spots (break down regions) are decelerated in low field regions.
- Bremsstrahlung is emitted and measured with the CCD camera.
- Depending on the break down current exposure times between 1 and 10 minutes were used.

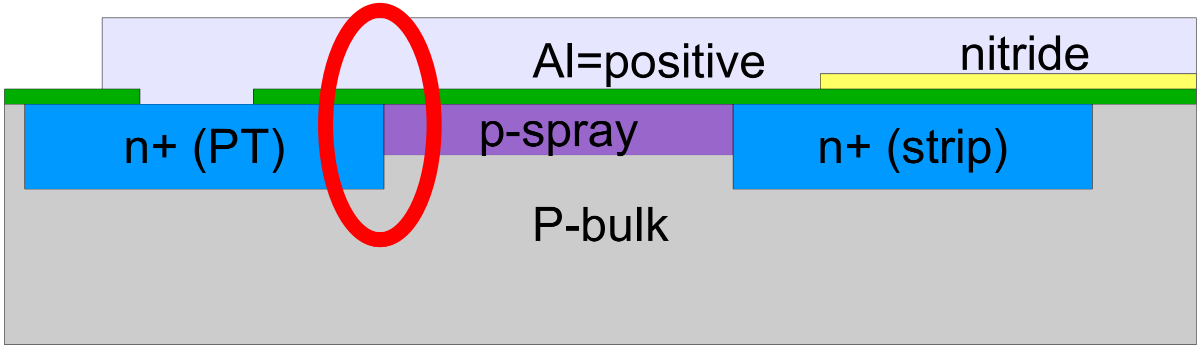
Phemos measurements





Hot spots:

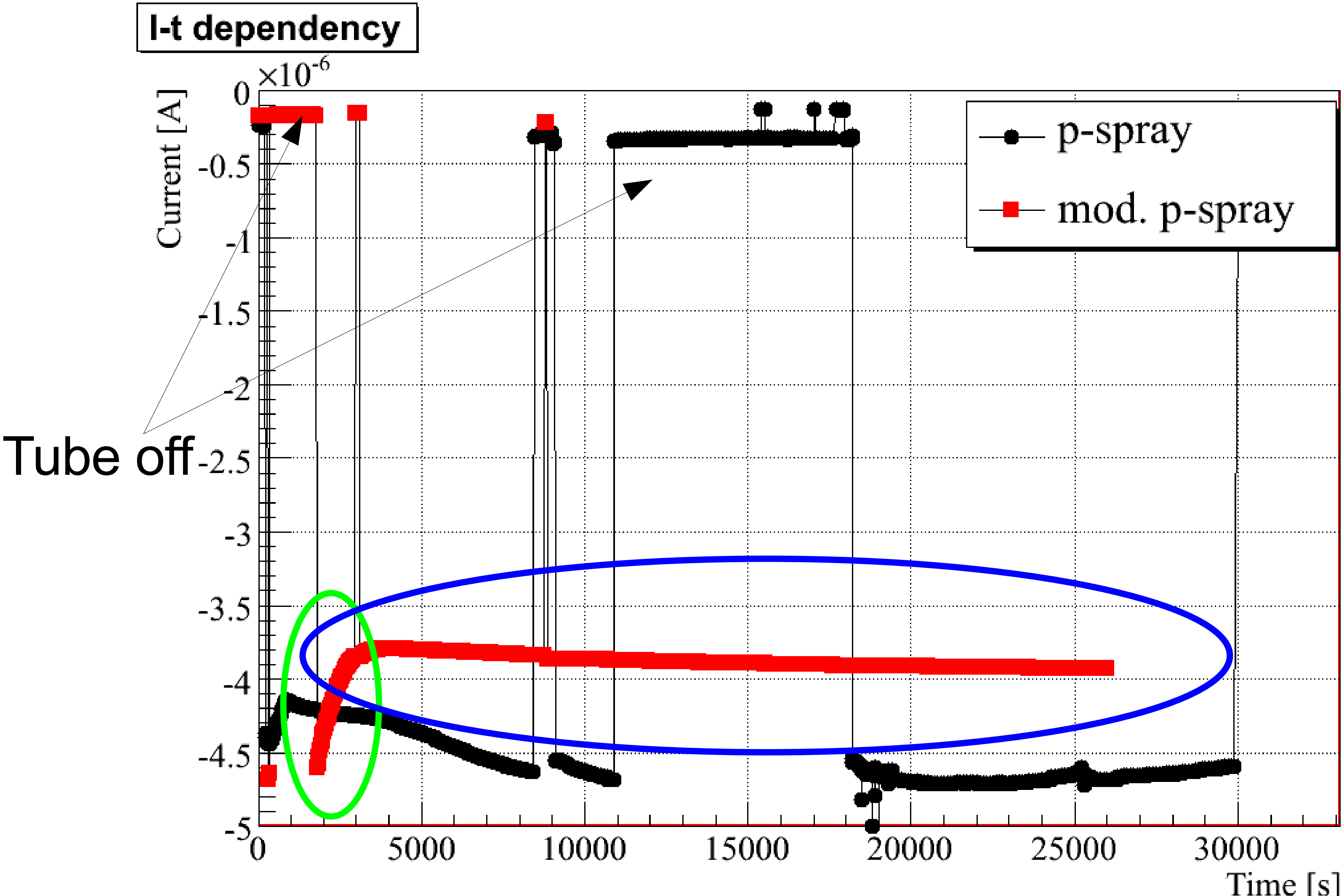
- Only visible in the punch through (PT) region.
- They were also causing the cause of break downs before irradiation at higher bias voltages.
- Potential reasons:
  - Surface charges (H. Sadrozinski)
  - Higher p-spray dose in PT area: 4.23e12 cm^{-2}



Irradiation effect:

- Break down seen at lower voltages
- Even higher fields?

Time dependent current

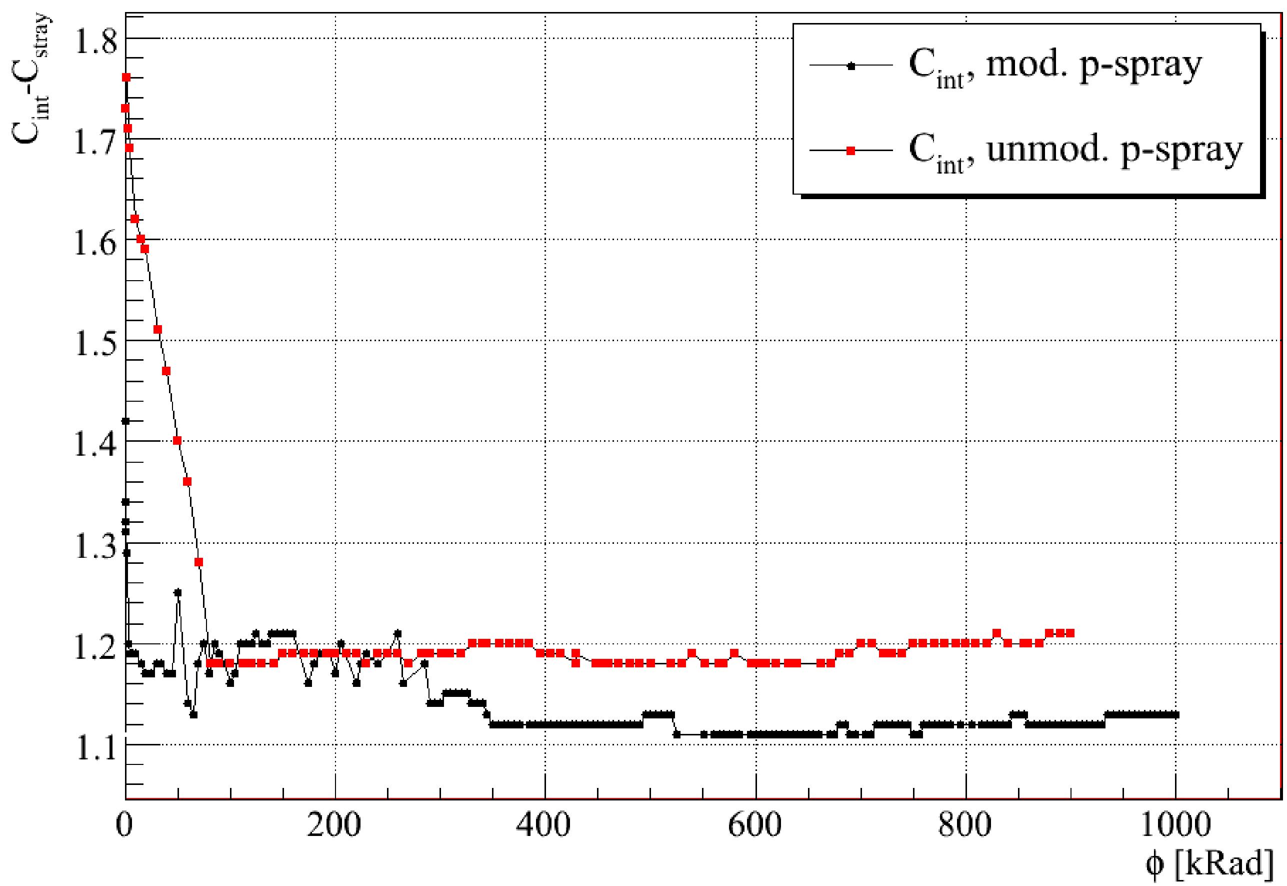


Reverse current under irradiation, V_{bias}=40V:

- Decrease during the first 1000s ~ 40 kRad
- Afterwards slow increase

Inter-strip capacitance

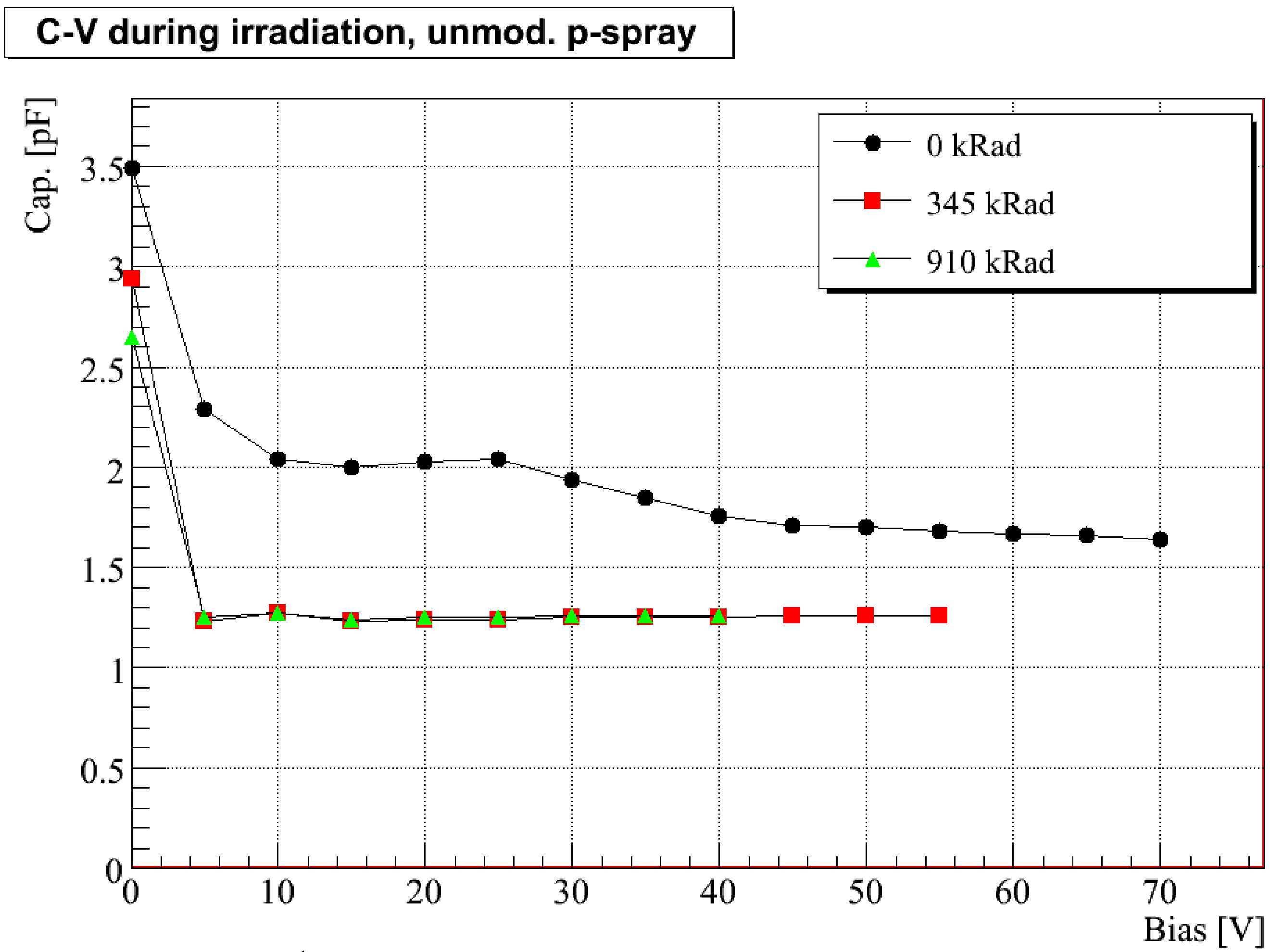
C-ϕ dependence



Inter-strip capacitance, V_{bias}=40V:

- Capacitance saturates after 100 and some 300 kRad
- Low capacitance of 1.1-1.2 pF shows that isolation is still working.
- Short-cut strips would show a higher capacitance.

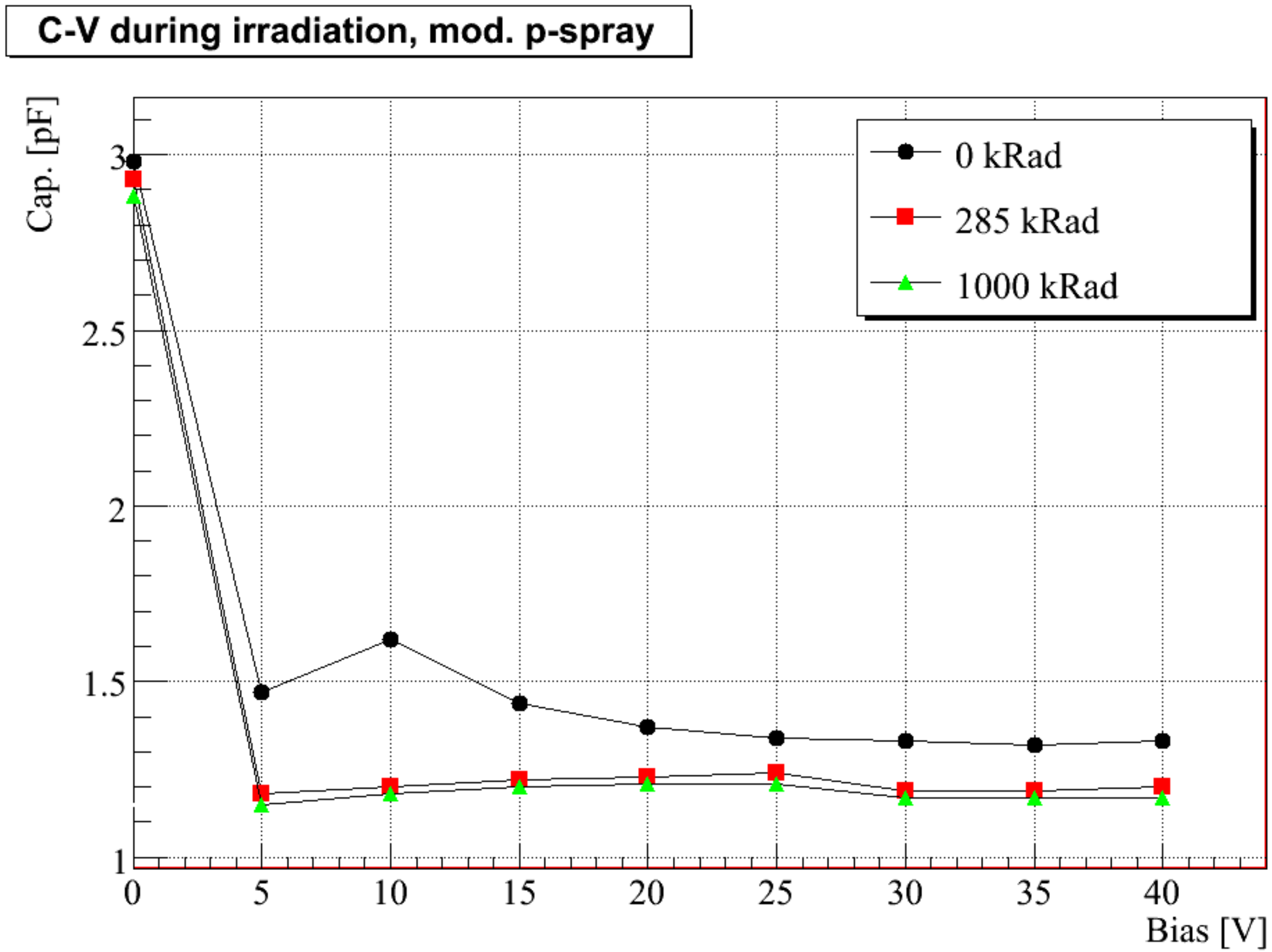
C-V during irradiation, p-spray



C-V measurements:

- Capacitance saturated before 345 kRad

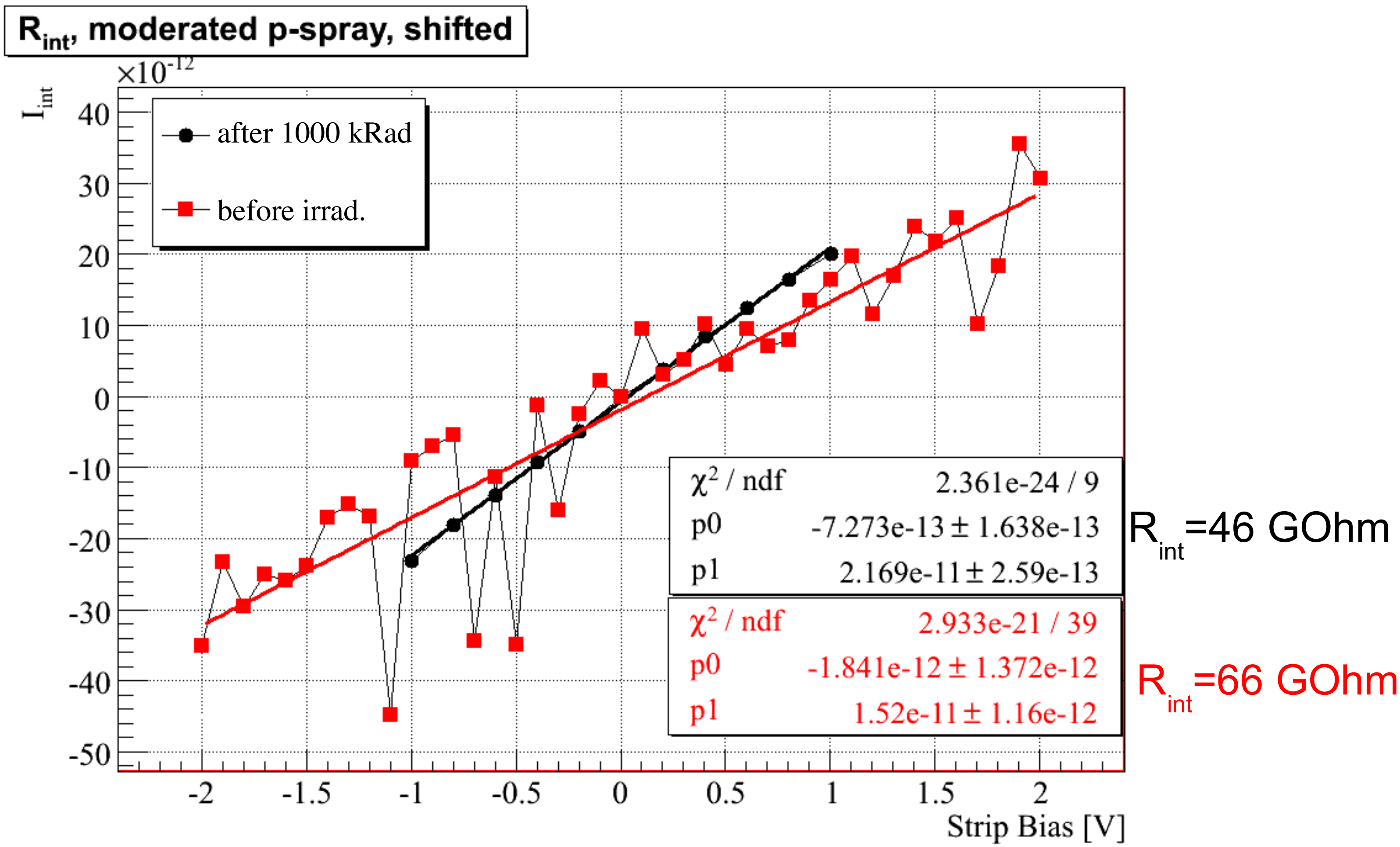
C-V during irradiation, moderated p-spray



C-V measurements:

- Capacitance saturated before 285 kRad

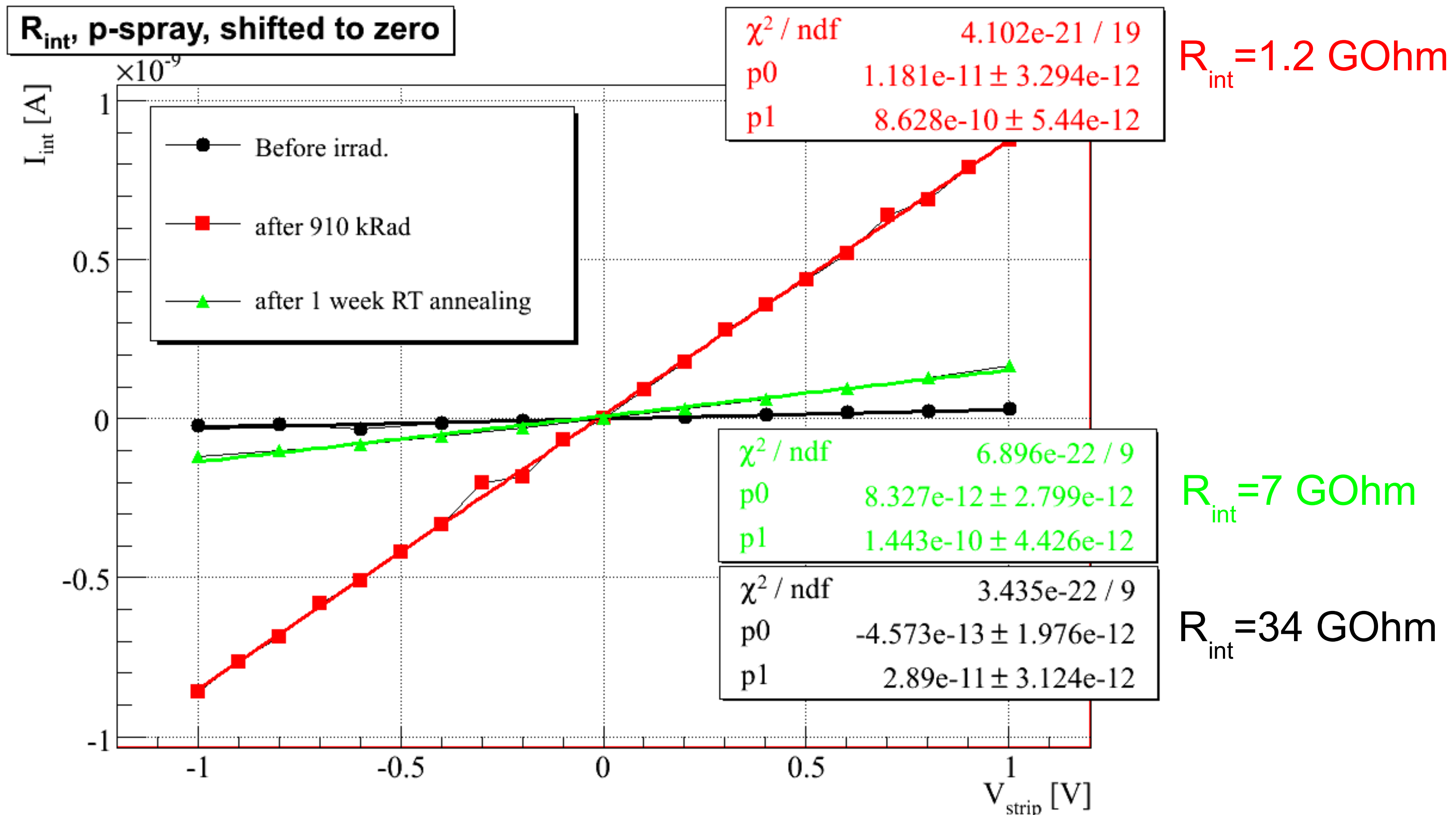
Inter-strip resistance, moderated p-spray



Inter-strip resistance:

- V_{bias}=40V
- Almost no changes after irradiation

Inter-strip resistance, p-spray



Inter-strip resistance:

- V_{bias}=40V
- Inter-strip resistance gets less but is still orders of magnitude above the bias resistance (around 1 MOhm)
- Recovery of the inter-strip resistance to 7 GOhm

Conclusion

- X-ray irradiations up to 1 MRad were carried out on micro-strip sensors with very low dose p-spray and moderated p-spray.
- Strips show early break down due to punch through problems
- Isolation still holds for both sensors even for the low dose p-spray after irradiation.
- There seems to be a balance between positive oxide charges and negative interface-state charges.
- This might be dose-rate dependent
  - see Sergey Rashkeev et al.: IEEE Trans. Nucl. Sci. Vol 49 No 6 p.2650, Dec 2002 (“Physical Model for Enhanced Interface-Trap Formation at Low Dose Rates”) and Phys. Rev. Lett. Vol 87 No 16 , Oct 2001 (“Defect Generation by Hydrogen at the Si-SiO2 Interface”)
- One week of RT annealing recovers part of the decreased inter-strip resistance.

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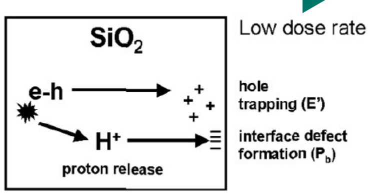
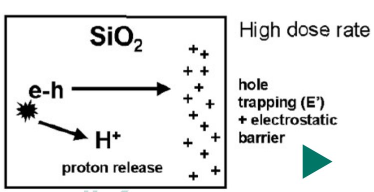
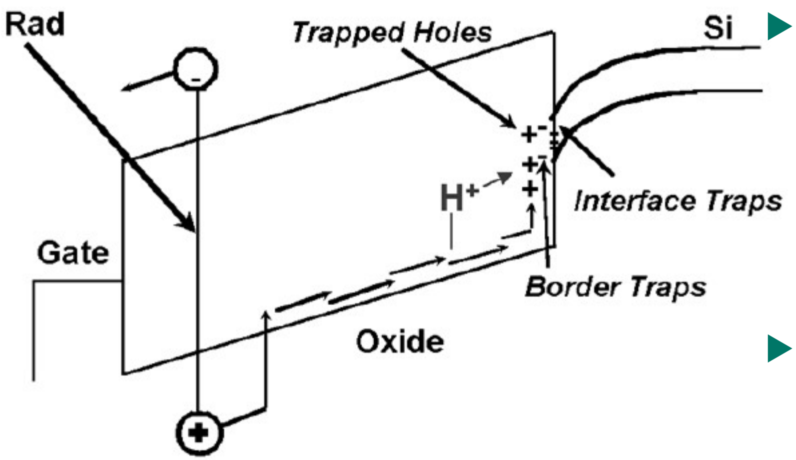
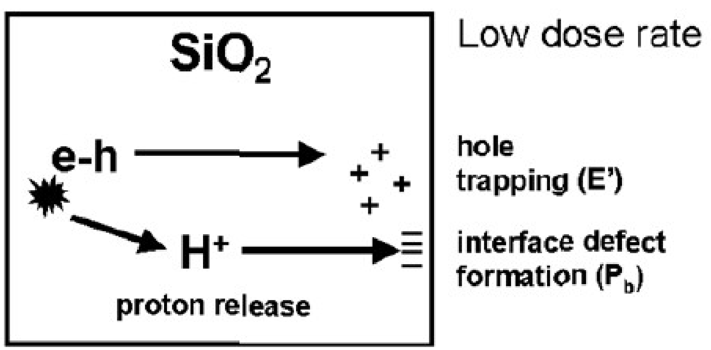
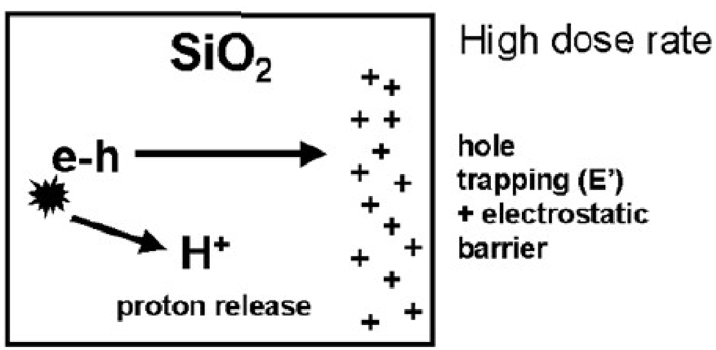




Backup







- General:
  - e-h pairs are created in SiO2
  - Some recombine and release energy
  - H+ ions are created with this energy
- Low dose rate:
  - Holes and protons move to the interface
  - Only protons can depassivate dangling bonds: SiH + H+ -> Si+ + H2
  - Si+ can react with bulk electrons and positive charge is removed.
- High dose rate:
  - Hole drift to the interface dominates
  - Mobility for holes is larger than for H+
  - Holes are trapped and form an electrostatic barrier
  - H+ do not reach the interface
  - No removal of positive charges
  - More positively charged SiO2