Characterization of micro-strip detectors made with high resistivity n- and p-type Czochralski silicon

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on behalf of the SMART Collaboration*

* A Collaboration of the INFN sections of Bari, Firenze, Padova, Perugia, Pisa

- Motivations
- Layout and materials used in the production of the SMART mini-sensors
- Pre-irradiation measurements and irradiation campaigns
- Results of the post-irradiation measurements
- Conclusions and outlook

7th International Conference on Position Sensitive Detectors, Liverpool, 15th September 2005

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Motivations

- A foreseen LHC upgrade ... later than 2010

	LHC	SLHC
Beam energy	7 Tev	12.5 TeV
Luminosity	10^{34} cm$^{-2}\times$s^{-1}	10^{35} cm$^{-2}\times$s^{-1}

✓The R&D activity of the SMART Collaboration on the μstrip sensors aims to find a solution for the tracker of the SLHC experiments at intermediate radii, where the fast-hadrons fluences will be around 10^{15}cm^{-2}.

	Radial distances of the 'present' CMS Tracker		Fluences foreseen at S-LHC
Pixel:	4 cm	=>	1.6×10^{16} cm^{-2}
	11 cm	=>	2.3×10^{15} cm^{-2}
Microstrip:	22 cm	=>	8×10^{14} cm^{-2}
	115 cm	=>	1×10^{14} cm^{-2}

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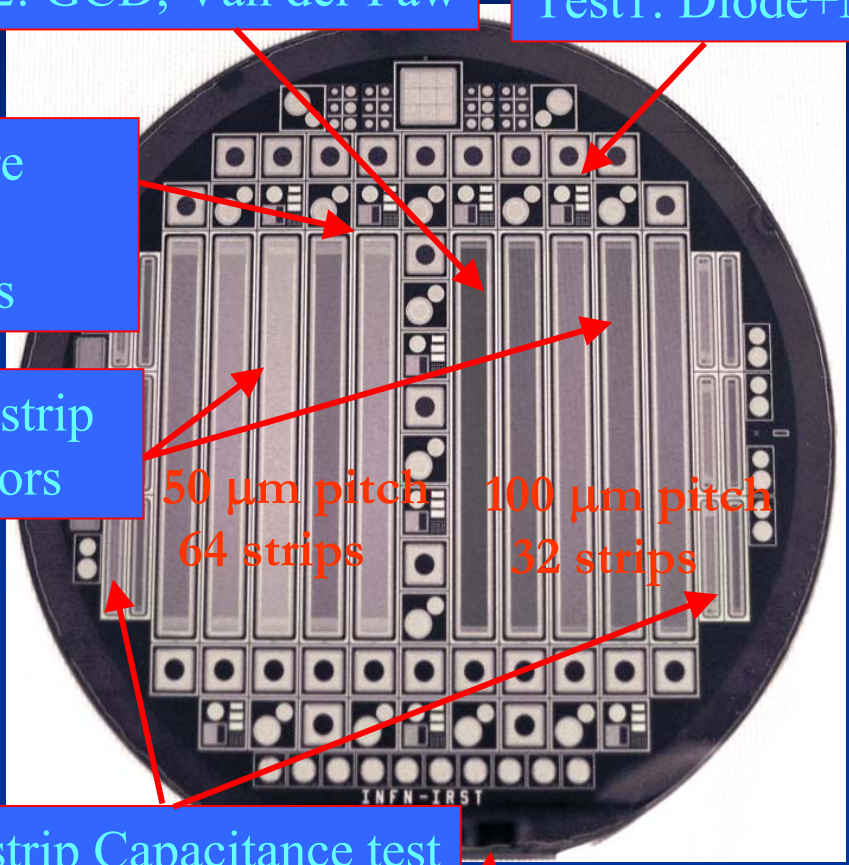
Wafer layout



- ✓ RD50 common wafer procurement
- ✓ Wafer Layout designed by the SMART Collaboration
- ✓ Masks and process by ITC-IRST
- ✓ 10 different strip geometries to explore their influence on the detector performances

µ-strip #	pitch (µm)	p+ width (µm)	Metal width (µm)
S1	50	15	23
S2	50	20	28
S3	50	25	33
S4	50	15	19
S5	50	15	27
S6	100	15	23
S7	100	25	33
S8	100	35	43
S9	100	25	37
S10	100	25	41

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Materials under investigation

See accompanying poster by G. Segneri et al.

"Radiation hardness of high resistivity n- and p-type magnetic Czochralski silicon" for the studies on the pre- and post-irradiated materials performed on the diodes of these production runs.

	MCz Samples	Fz Samples
RUN I p-on-n	p-on-n **MCz** <100>, ρ>500 Ω cm ✓Standard: LTO, sintering @ 420C ✓no LTO, sintering @ 380C ✓no LTO, sintering @ 350C ✓no LTO, sintering @ 380C + TDK	p-on-n **Fz** <111>, ρ>6KΩ cm ✓Standard Process ✓sintering @ 380C
RUN II n-on-p	n-on-p **MCz** <100>, ρ>1.8 KΩ cm ✓No over-glass passivation ✓Low dose p-spray (3.0E12 cm^{-2}) ✓High dose p-spray(5.0E12 cm^{-2})	n-on-p **Fz** , 200 μm, ρ>5KΩ cm ✓Low dose p-spray (3.0E12 cm^{-2}) ✓High dose p-spray(5.0E12 cm^{-2})

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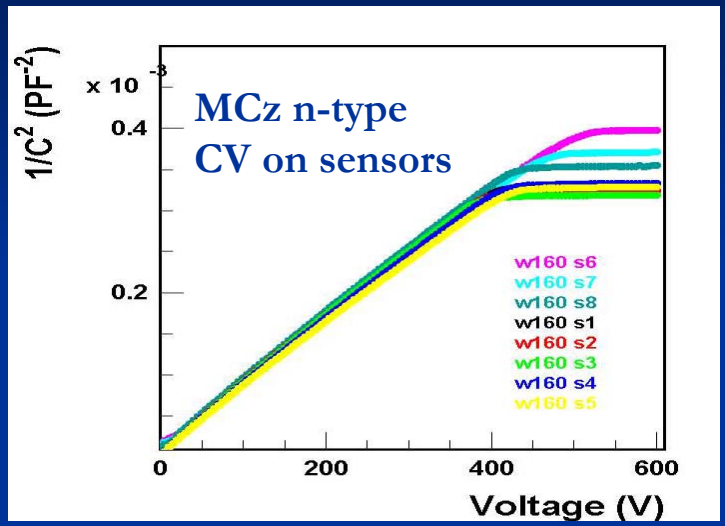
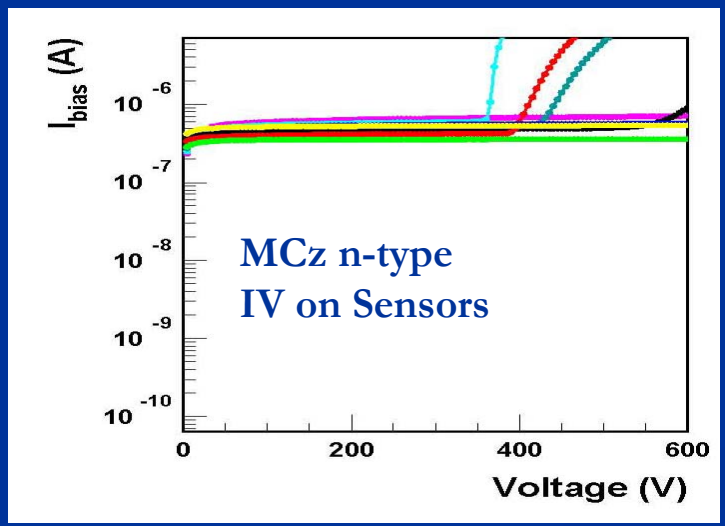
Pre-irradiation Characterization

✓Good performances of the n-type detectors in terms of breakdown voltages and uniformity

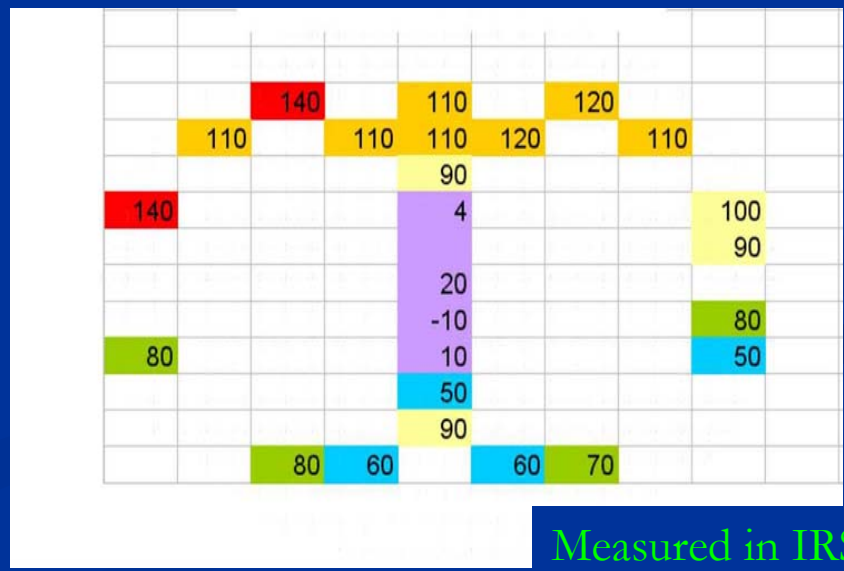




✓ Problems for the p-type detectors:

- ❖ low breakdown voltages for the 100 μm pitch detectors, probably due to the present implementation of the p-spray technique
- ❖ Disuniformity of the wafer resistivity, explained with a different oxygen concentration leading to a spread in the thermal donor activation.

Map of the diodes Vdepl in a p-type MCz wafer



Measured in IRST

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Measurement with a β source

A few mini-sensors have been assembled in a detector unit and tested with a LHC-like DAQ system

Measurement with a β source:

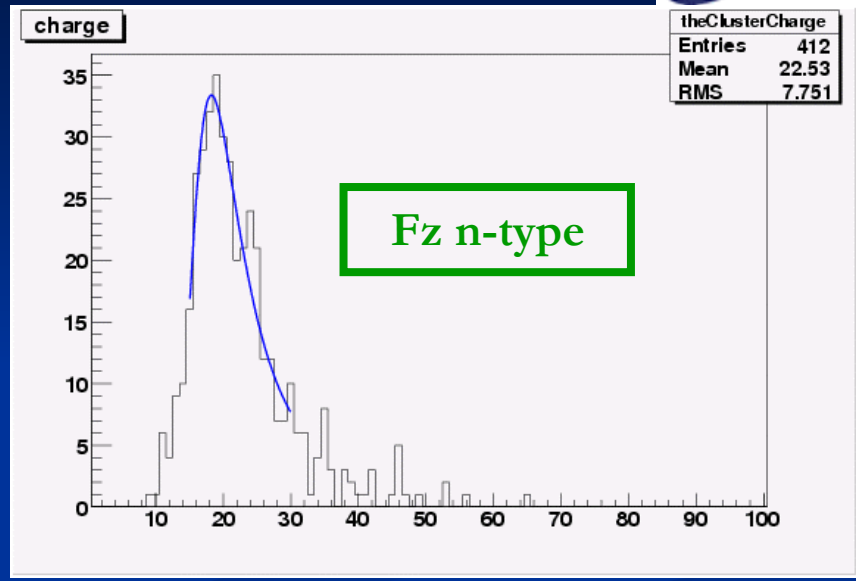
- DAQ system configured in ***peak mode***
- Measurement performed at over-depletion for not-irradiated sensors

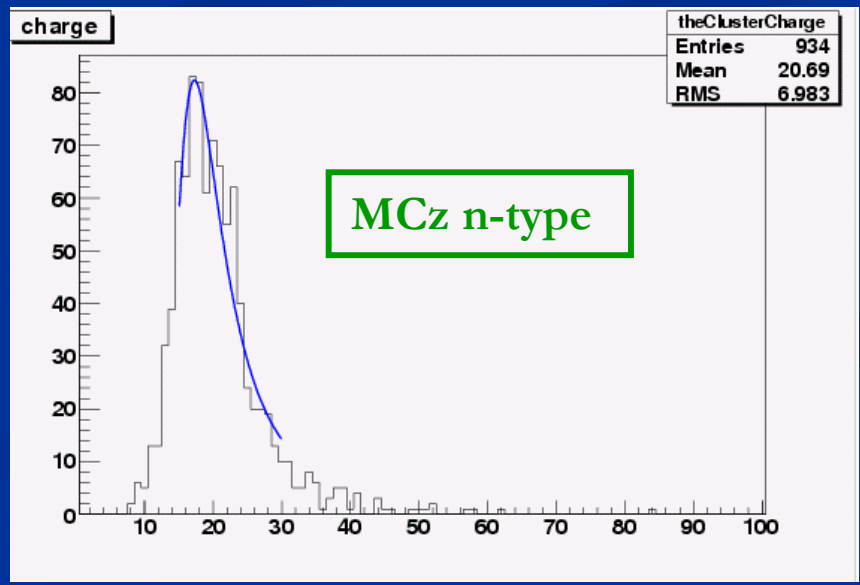
MCz Q=17.8 ± 0.2, N=1.02

S/N ~17.5 @ 500 V

Fz Q=18.8 ± 0.3, N=0.98

S/N ~19.2 @ 200 V





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Irradiation Campaigns

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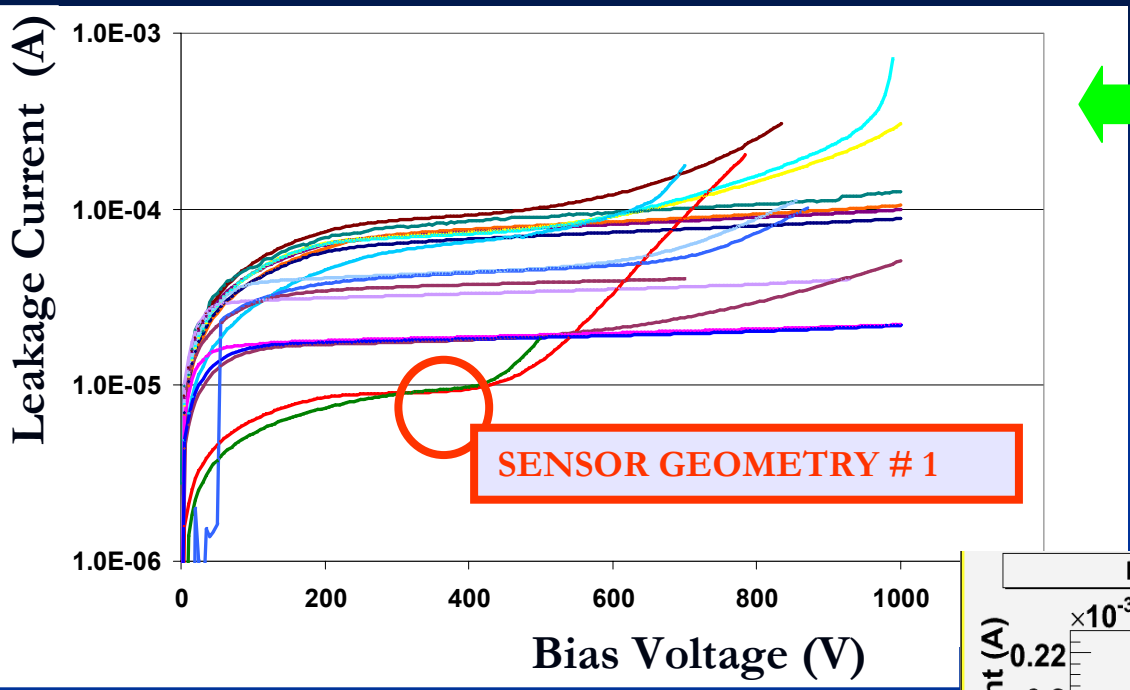
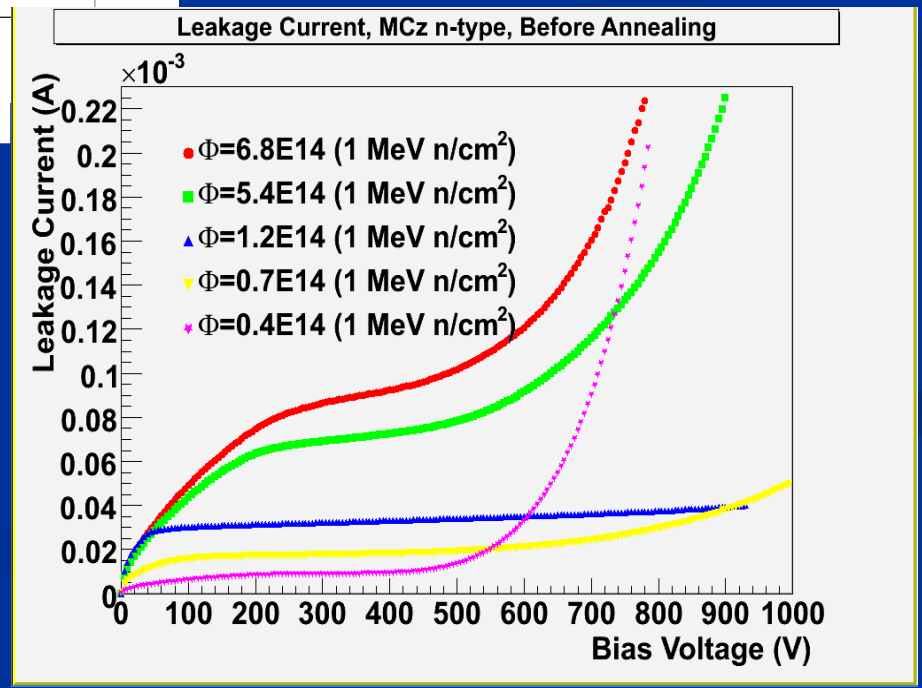
Preliminary Results of Post-Irradiation Measurements

SMART IV Characteristics after irradiation



- IV curves of n- and p-type detectors for the full fluence range before annealing (measured at 0°C):
- Current levels in MCz detectors are comparable with Fz at a given fluence
- Sensor geometry #1 show a lower breakdown voltage.

Leakage currents measured at Vdepl scale as the received fluences.



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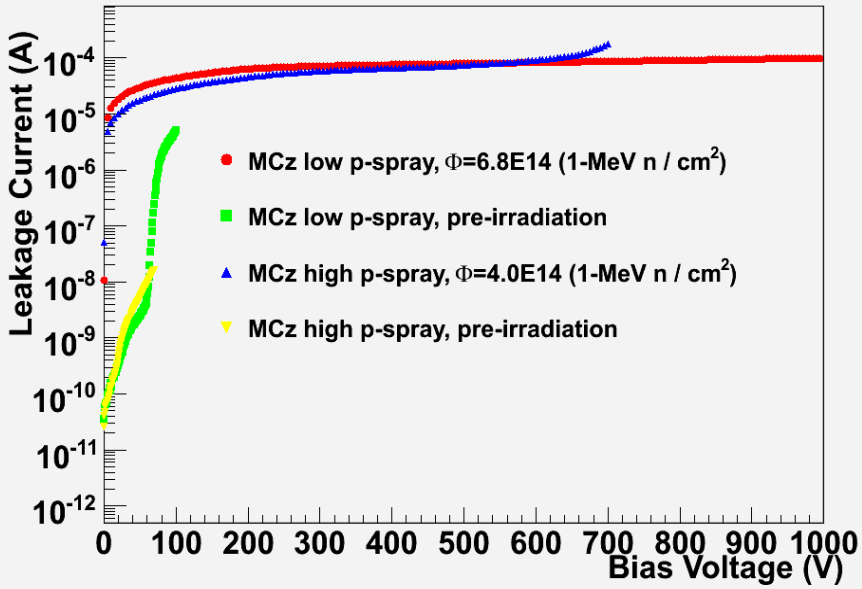
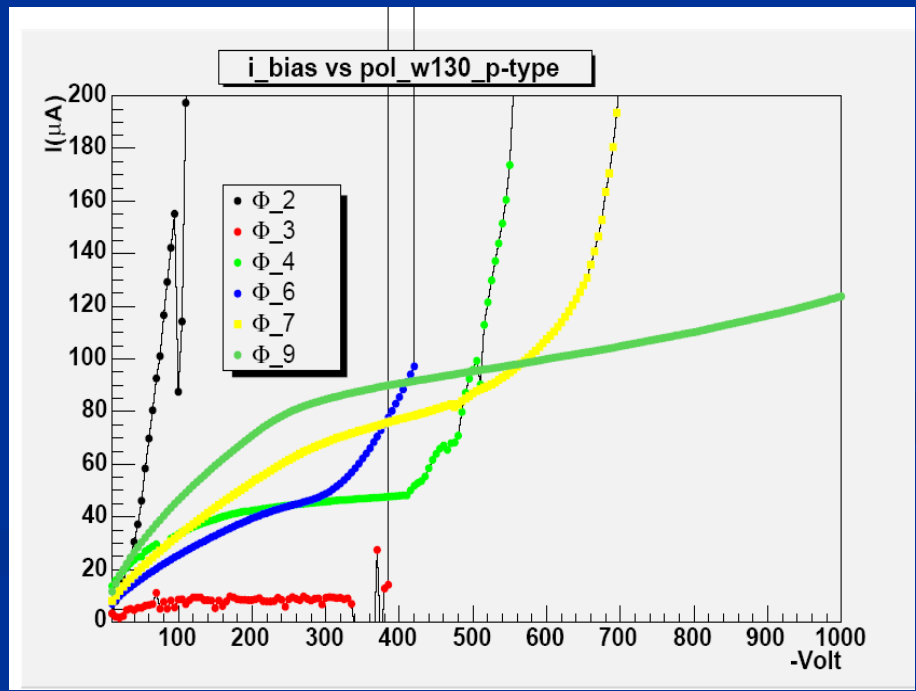
Performances of p-type detectors



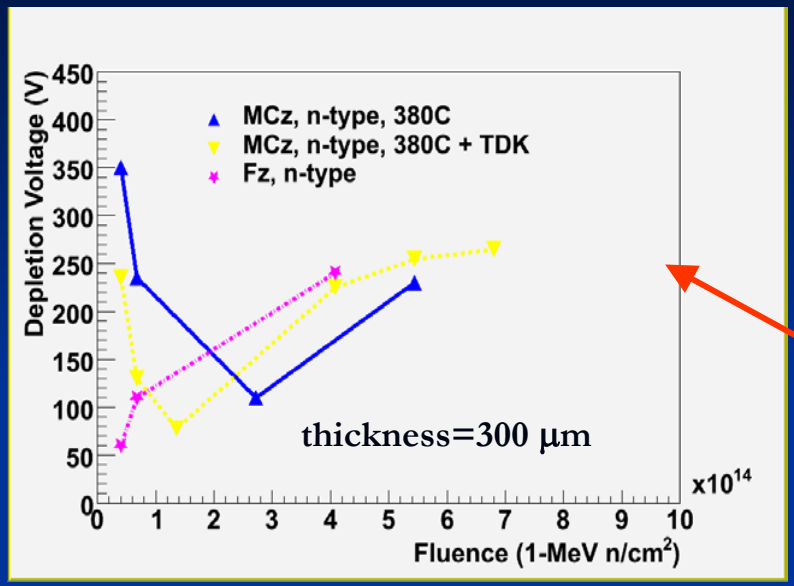
The performances of Fz and MCz p-type detectors, comprising sensors with 100 μm pitch, are much improved after irradiation.

Sensors with low p-spray have breakdown voltages comparable with n-type detectors in all the fluence range.

Detectors with a high p-spray dose still have breakdown problems at lower fluences (< 4.0 1-MeV n/cm^2) whereas they have very good performances at the highest fluences.



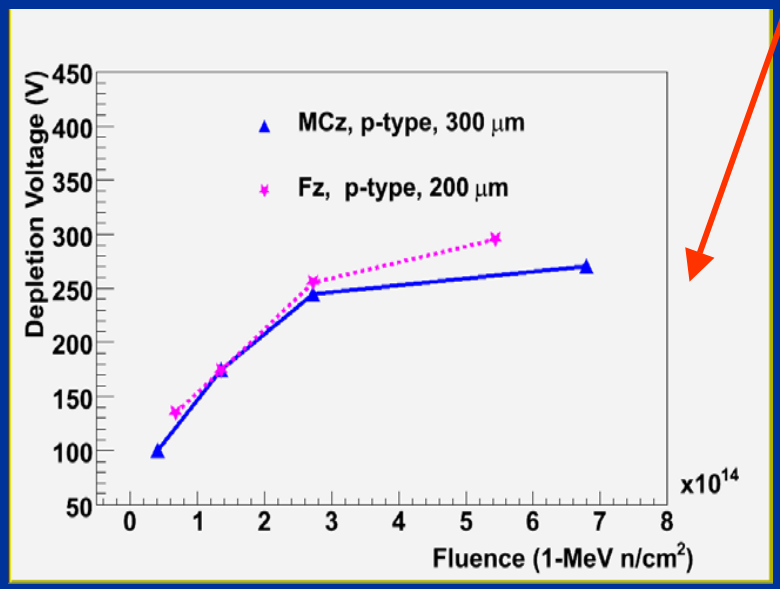
SMART Depletion Voltages after Irradiation

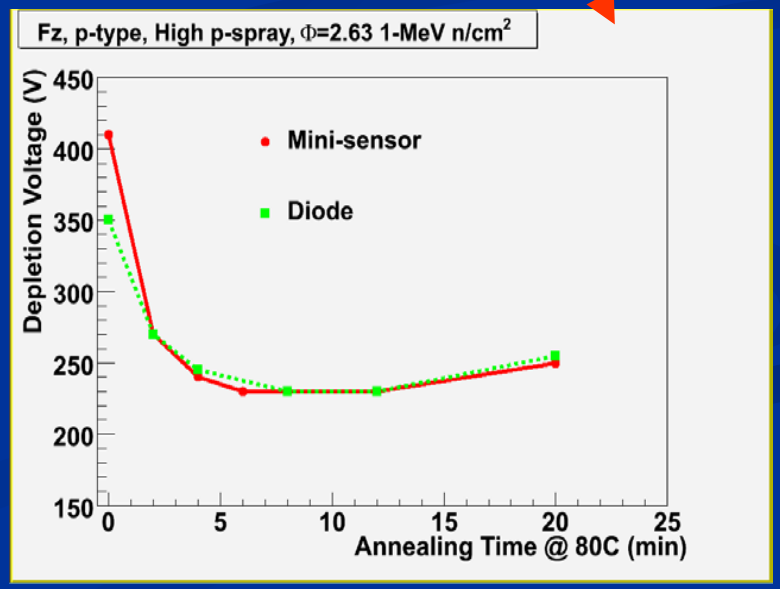


The depletion voltages of the mini-sensors follow the expected trends from the studies on the corresponding diodes (see accompanying poster).

BEFORE ANNEALING

DURING ANNEALING





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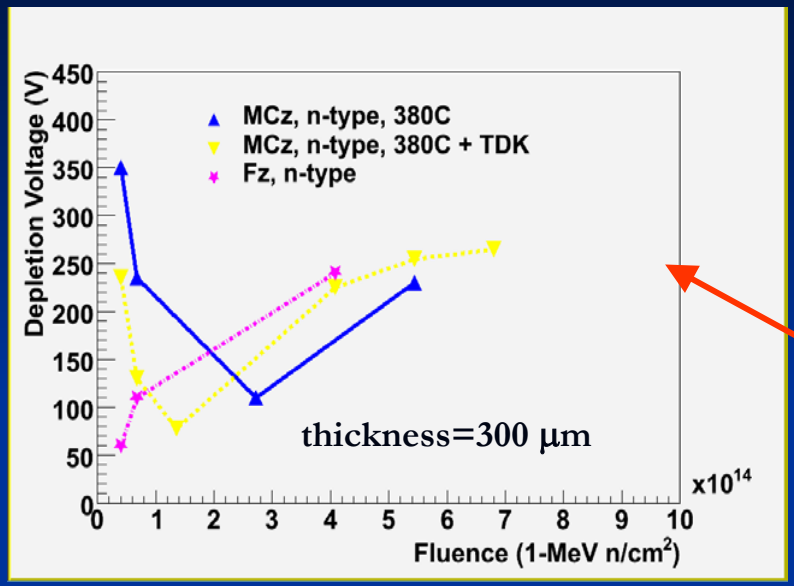
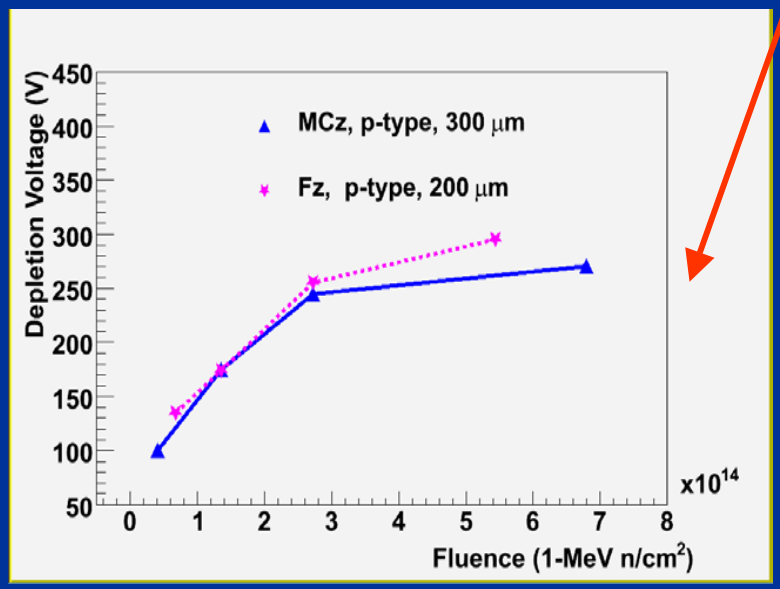
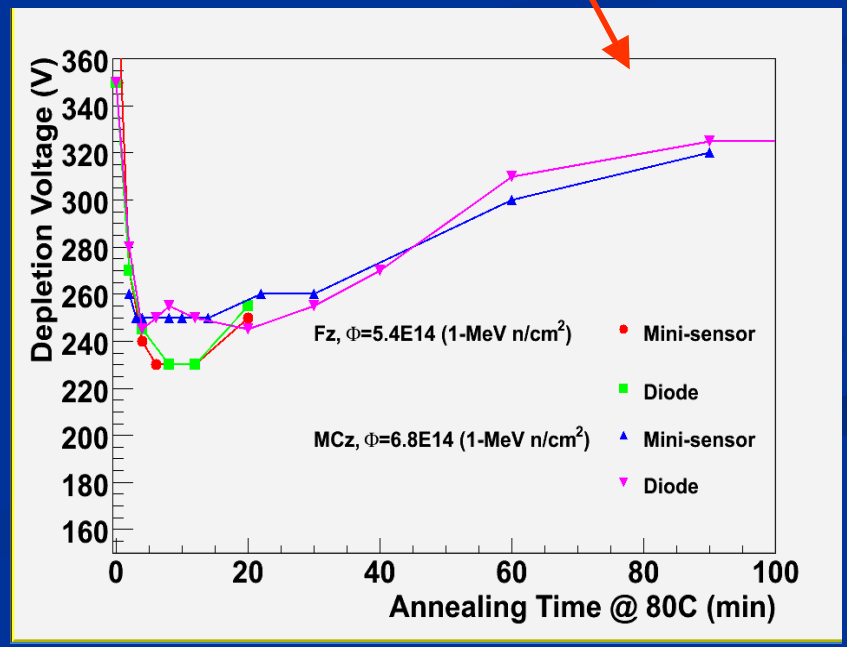




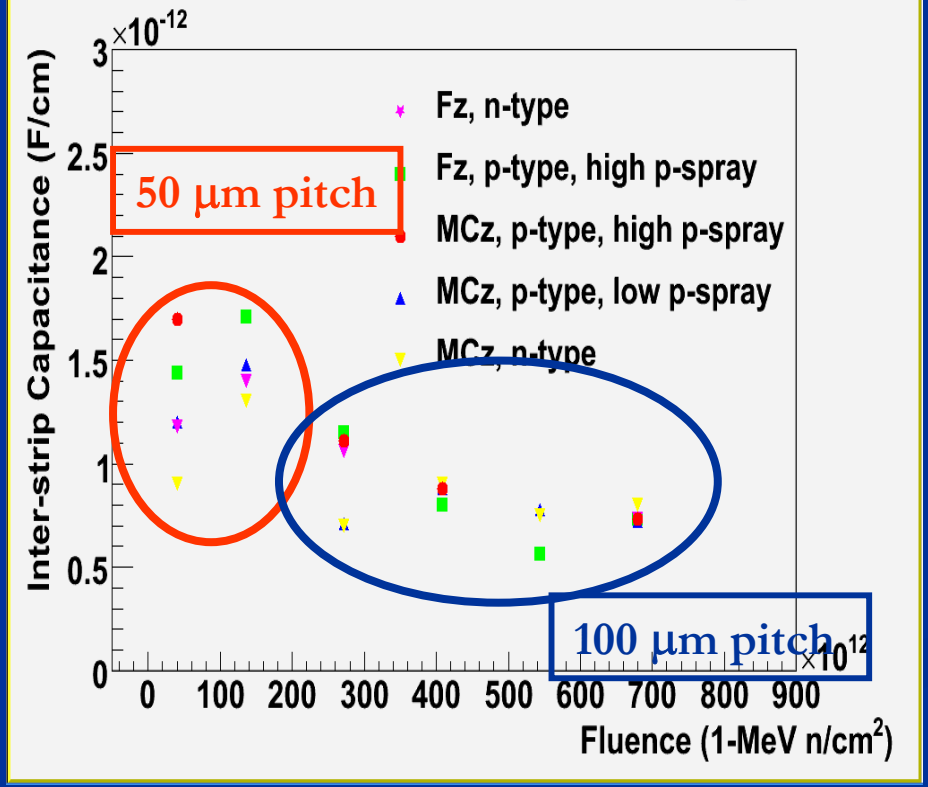


SMART Inter-strip Capacitance after Irradiation

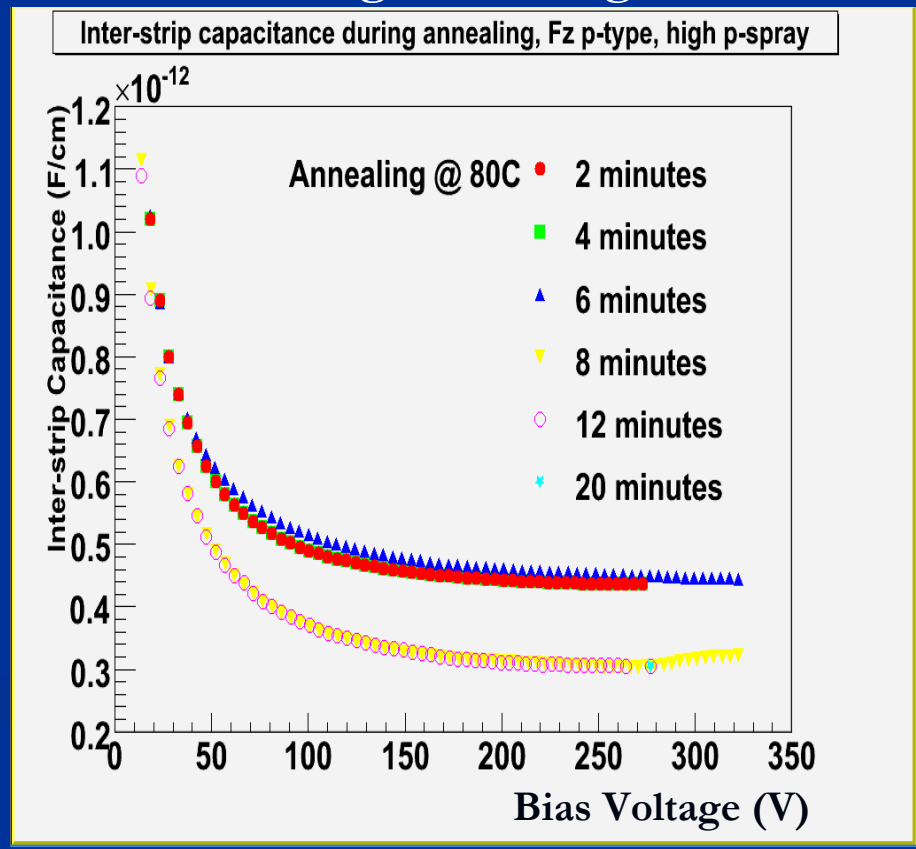
- One of the most important sensor parameters contributing to the determination of the S/N ratio .
  - Depends on the width/pitch ratio of the strips and on the strip isolation technique.
  - Post-irradiation behaviour affected by the surface damage (positive charges introduced in the SiO_2 layer and at the Si- SiO_2 interface).

Before Annealing

Cint measured with the sensor over-depleted



During Annealing



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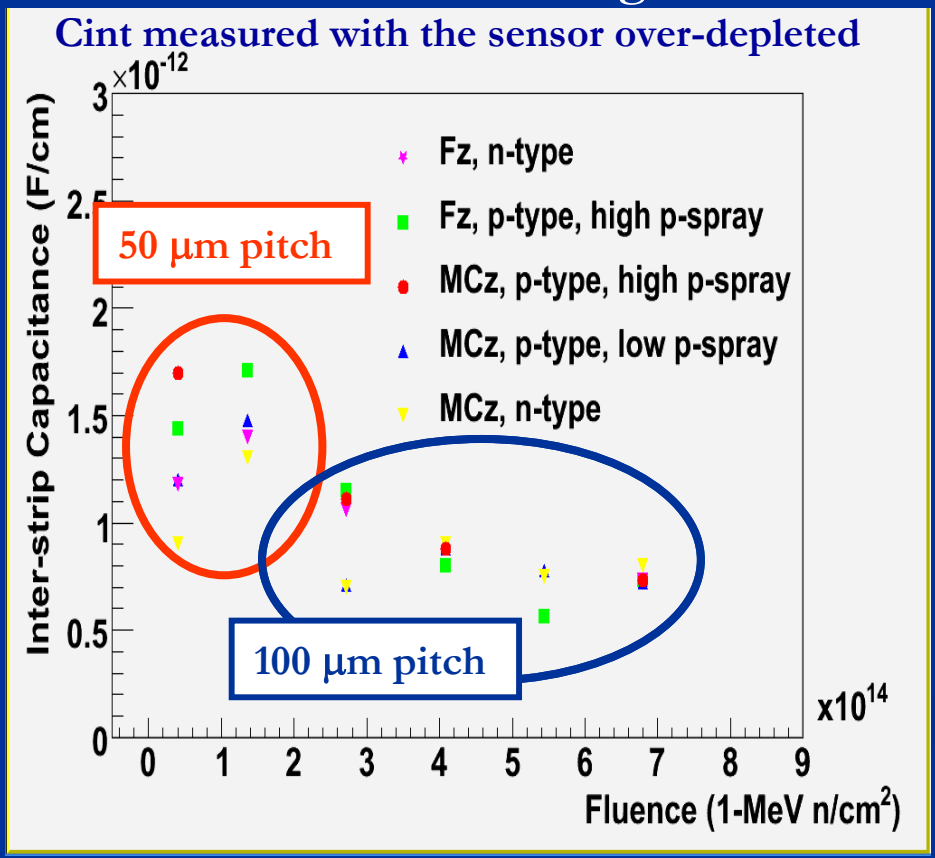

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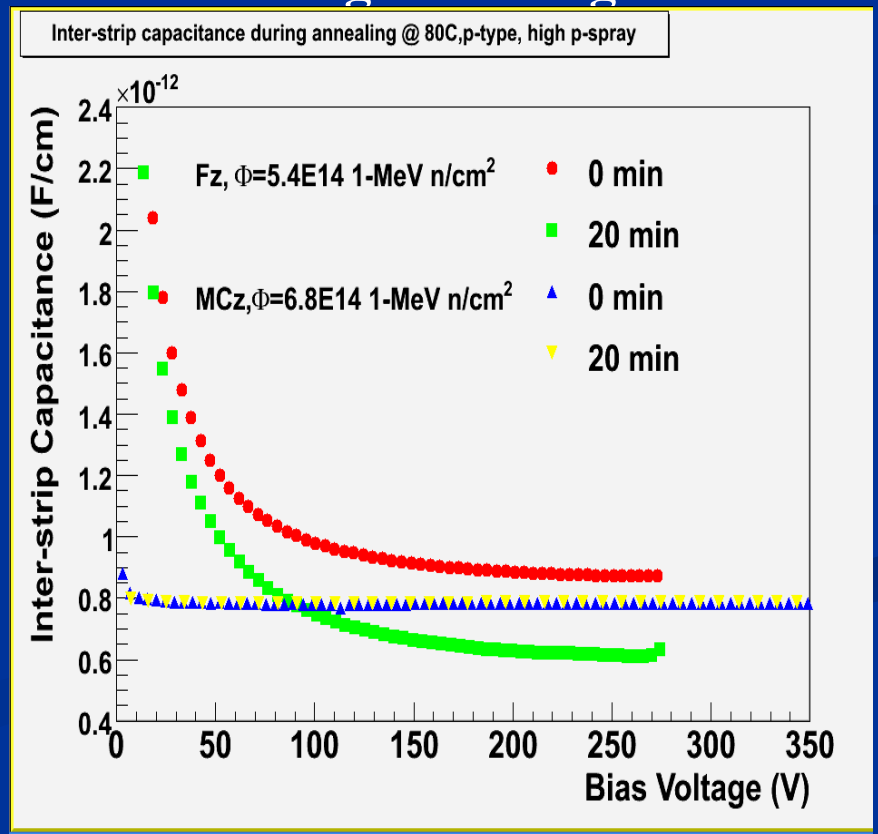

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Summary and Outlook

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✓ The MCz detectors of the SMART production are fully comparable with Fz regarding leakage currents values and breakdown voltages.

✓ Depletion voltages follow the different behaviour in the two materials observed in the corresponding diodes.

✓ A new production run is foreseen to study an improved strip isolation technique for the p-type detectors.

✓ The study of the detectors properties during the annealing procedure must be completed.

✓ Measurements of the Charge Collection Efficiency of irradiated MCz detectors are under way.