Forward-bias operation of FZ and MCz silicon detectors made with different geometries in view of their applications as radiation monitoring sensors

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Outline

- I. Introduction

  Radiation monitoring at the LHC experiment
  Summary of previous results

- II. Devices under study
- III. Measurements
- IV. Radiation response of custom made devices
- IV. Conclusion

Radiation Monitoring at the LHC Experiments

All equipments present in the complex radiation field of the LHC will be affected by radiation damage.

- 2 major issues:

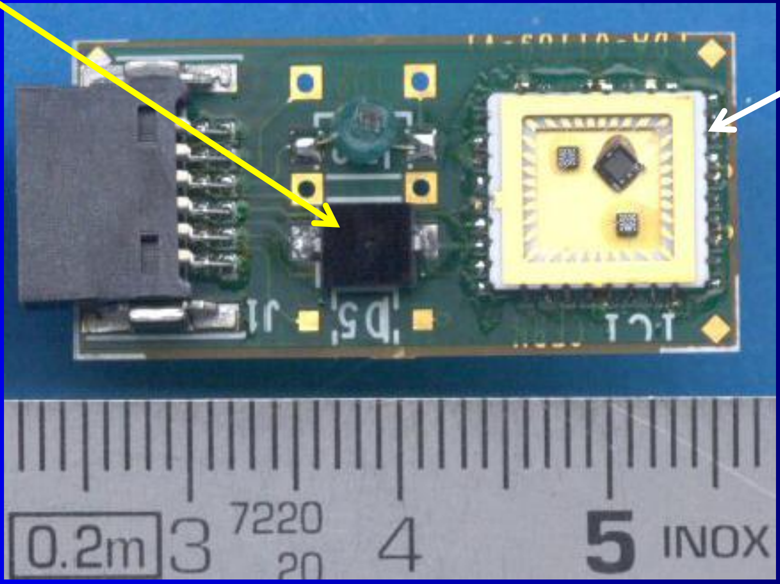
- **Measure of the 1-MeV Φ_{eq}**

→ $10^8 \leq \Phi_{eq} \leq 10^{14}$ -10^{15} n_{eq}/cm^2 for LHC

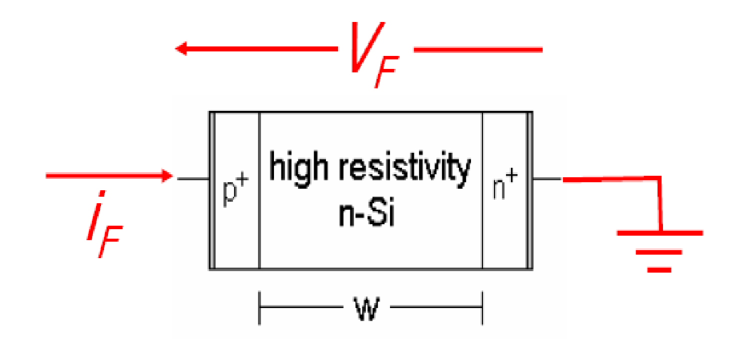
BPW34 Commercial silicon p-i-n diodes

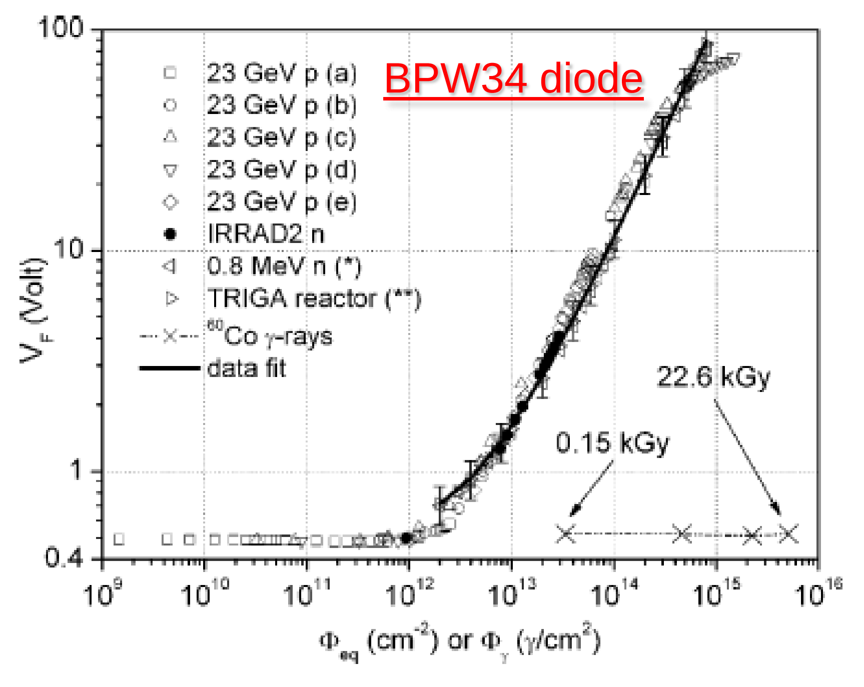
- Measure of *the TID*

2 types of RadFET:
250 nm oxyde thickness → REM,UK
1600 nm oxyde thickness → LAAS, France



Summary of previous results





F. Ravotti *et al., IEEE TNS, vol. 55, no. 4,pp. 2133-2140, 2008*

FORWARD BIAS

Fixed Readout Current I_F → $V_F \propto \Phi_{eq}$

I_F = 1 mA with a short pulse duration

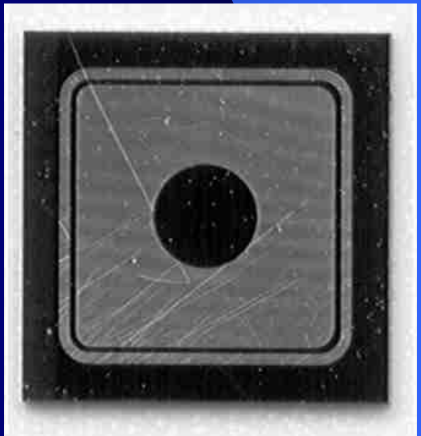
- Hadron sensitivity range from 2 10^{12} to 4 10^{14} n_{eq}/cm^2.
- How to measure Φ_{eq} < 2 10^{12} n_{eq}/cm^2 ?
  - A solution exists → pre-irradiation
  - With the intention to evaluate new options : **Study of custom made devices**

Custom made devices

- Tested devices were made from n-type FZ and MCz silicon wafers.

- Geometry dependence on the detector’s radiation response has been evaluated.
  → 2 different active areas: 2.5 2.5 mm^2 and 5 5 mm^2
  → 2 different thicknesses: 300 µm and 1000 µm

- Manufactured by 2 different research institutes:
  → Helsinki Institute of Physics (HIP), Finland
  → Centro National de Microelectronica (CNM), Spain



Measurements

- Silicon detectors exposed to 24 GeV/c proton beam
- Fluences ranging from $3 \cdot 10^{9}$ up to $4 \cdot 10^{14}$ n_{eq}/cm^{2}
- Measurements performed at room temperature
- Readout protocol: 8 currents
  - ✓ I_F = 10 µA
  - ✓ I_F = 100 µA
  - ✓ I_F = 1 mA
  - ✓ I_F = 5 mA
  - ✓ I_F = 10 mA
  - ✓ I_F = 15 mA
  - ✓ I_F = 20 mA
  - ✓ I_F = 25 mA

Radiation response of custom made devices

- Comparison between FZ and MCz silicon detectors
- Influence of the active area
- Influence of the thickness

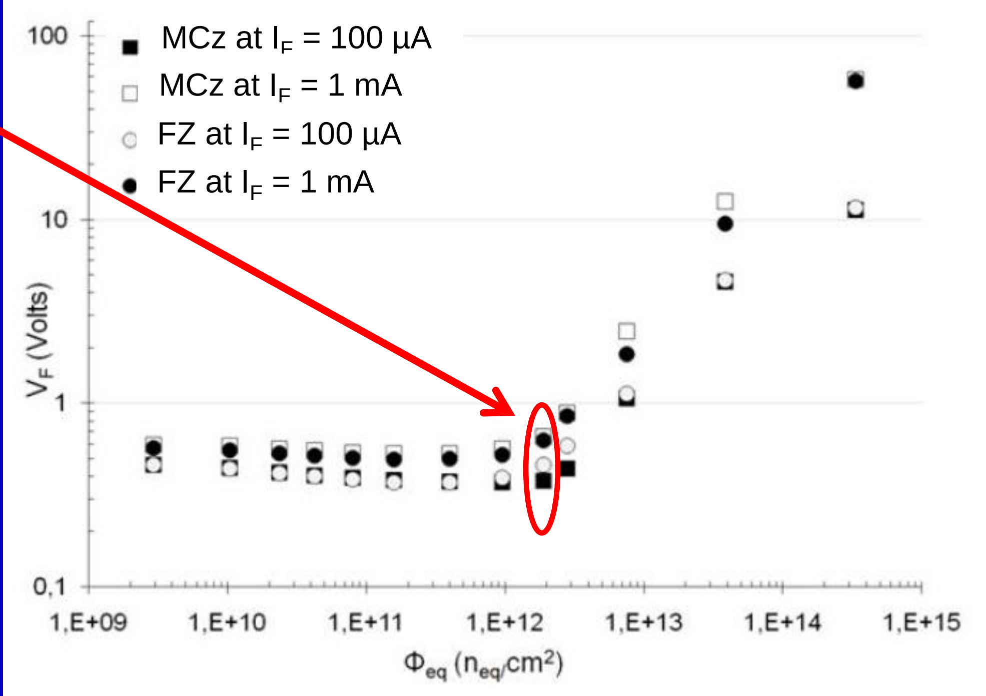
Comparison between FZ and MCz Silicon detectors

- Active area : 2.5   2.5 mm^2
- Thickness : 300 µm

- Not sensitive up to 2 10^{12} n_{eq}/cm^2
- Start to be sensitive at the same Φ_{eq} than the BPW34 diode. (300 µm)

$$\Delta V_F = c \times \phi_{eq}$$

I_F	1/c (MCz)	1/c (FZ)	1/c (BPW34FS)
100 µA	9.1×10^9	9.1×10^9	1.7×10^{10}
1 mA	3.1×10^9	4.2×10^9	9.1×10^9
25 mA	2×10^9	2.3×10^9	6.7×10^9



- Sensitivity to radiation damage is on the same order of magnitude

Influence of the active area

- Material: Float Zone
- Thickness : 1000 µm
- Manufacturer: CNM

- Saturation observed at $\Phi_{eq} \approx 8\ \ 10^{12}\ n_{eq}/cm^2$
  Detector becomes ohmic-like [1]

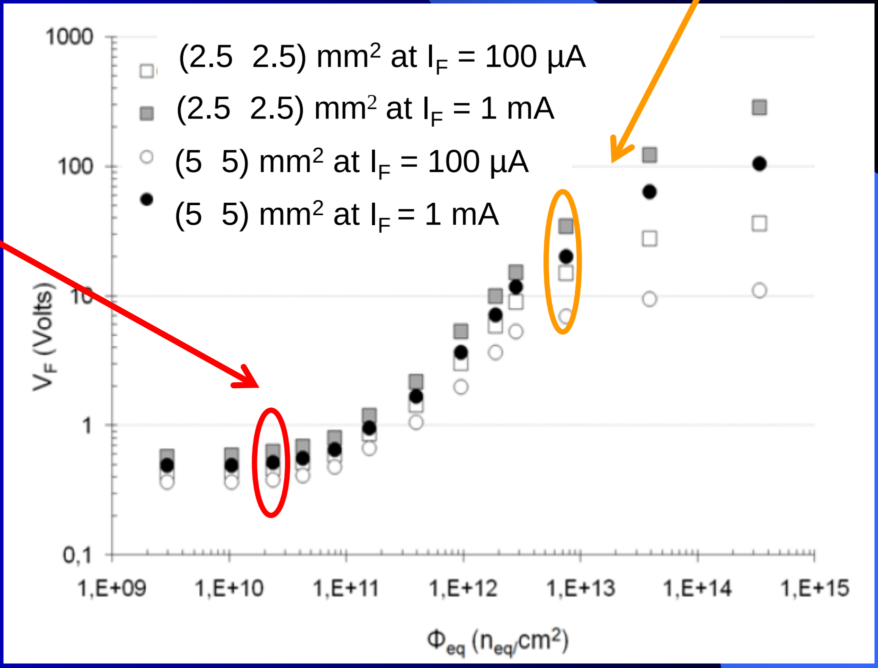
[1]J. Mekki et *al., will be published in IEEE TNS, August 2010.*

- Investigated active areas: (5 5) mm^2 and (2.5 2.5) mm^2

- For both detectors :
- Sensitivity starts at $\Phi_{eq} \approx 2\ \ 10^{10}\ n_{eq}/cm^2$

$$\Delta V_F = c \times \phi_{eq}$$

I_F	1/c ((2.5×2.5) mm^2)	1/c ((5×5) mm^2)
100 µA	3.1×10^8	5.6×10^8
1 mA	1.9×10^8	2.8×10^8
5 mA	1.3×10^8	2.1×10^8



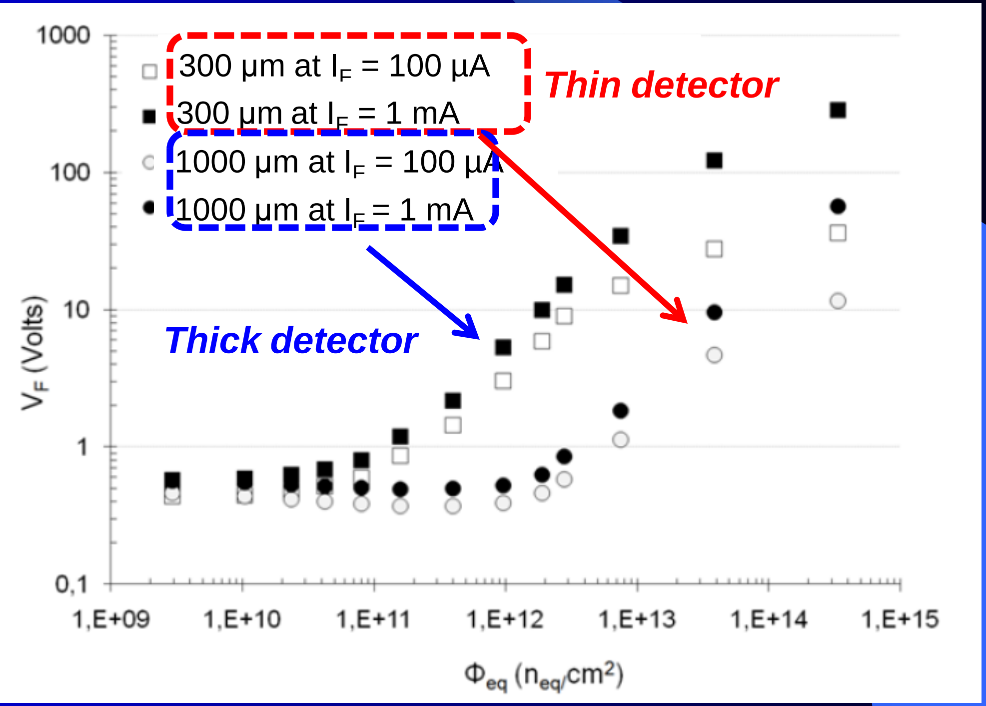
- When the active area is reduced by 4 sensitivity is increased by 1.5

- Sensitivity to radiation damage is on the same order of magnitude

Influence of the thickness

- Material: Float Zone
- Active area : (2.5 2.5) mm^2

- Investigated thicknesses: 300 µm and 1000 µm.



Influence of the thickness

- Material: Float Zone
- Active area : (2.5 2.5) mm^2

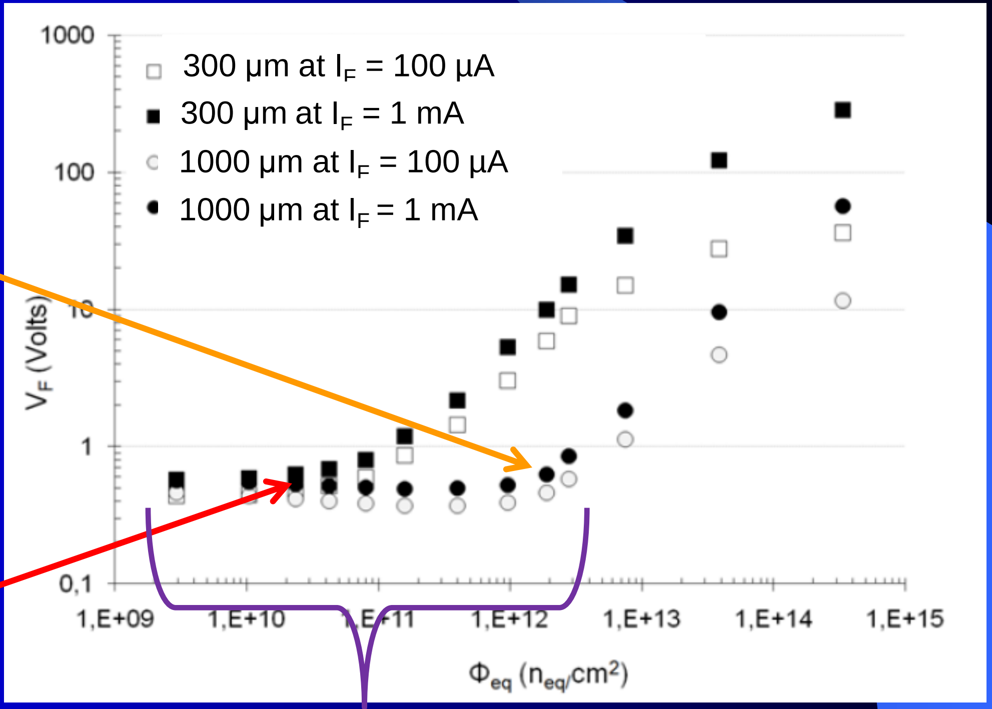
- Investigated thicknesses: 300 µm and 1000 µm.

$\Phi_{eq} = 2\ \ 10^{12}\ n_{eq}/cm^2$

Thin detector

$\Phi_{eq} = 2\ \ 10^{10}\ n_{eq}/cm^2$

Thick detector



Region dominated by the W/L ratio[2]

[2] J. M. Swartz *et al., J. Appl. Phys., vol. 37, no. 2,pp. 745-755, 1966*

Influence of the thickness

- Material: Float Zone
- Active area : (2.5 2.5) mm²

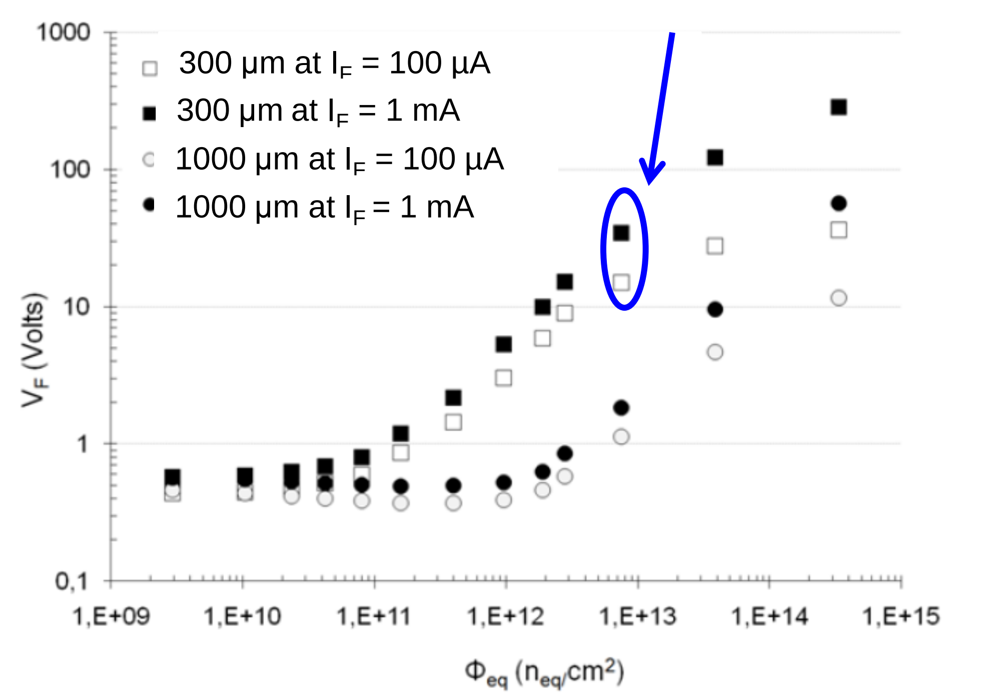
- Investigated thicknesses: 300 μm and 1000 μm.

$$\Delta V_F = c \times \phi_{eq}$$

I_F	1/c (300 μm)	1/c (1000 μm)
100 μA	9.1×10^9	3.1×10^8
1 mA	4.2×10^9	1.9×10^8
5 mA	2.3×10^9	1.3×10^8

$\Phi_{eq} \approx 8\ \ 10^{12}\ n_{eq}/cm^2$

Thick detector



Sensitivity is increased by a factor ≈ 25

Conclusion

- Several devices have been investigated
- Outcome:
  - No significant difference between MCz and FZ silicon detectors.
  - Main parameter: Thickness
- Thicker devices start to be sensitive at lower Φ_{eq}.
- Sensitivity is ≈ 25 times greater than for thin detectors.
- Thick silicon detectors should be considered for monitoring low LHC/SLHC fluences
- Limited to their utilization at low fluences.
- Solution for monitoring full LHC fluences: Thick and thin detectors on the same board.

Thank you for your attention