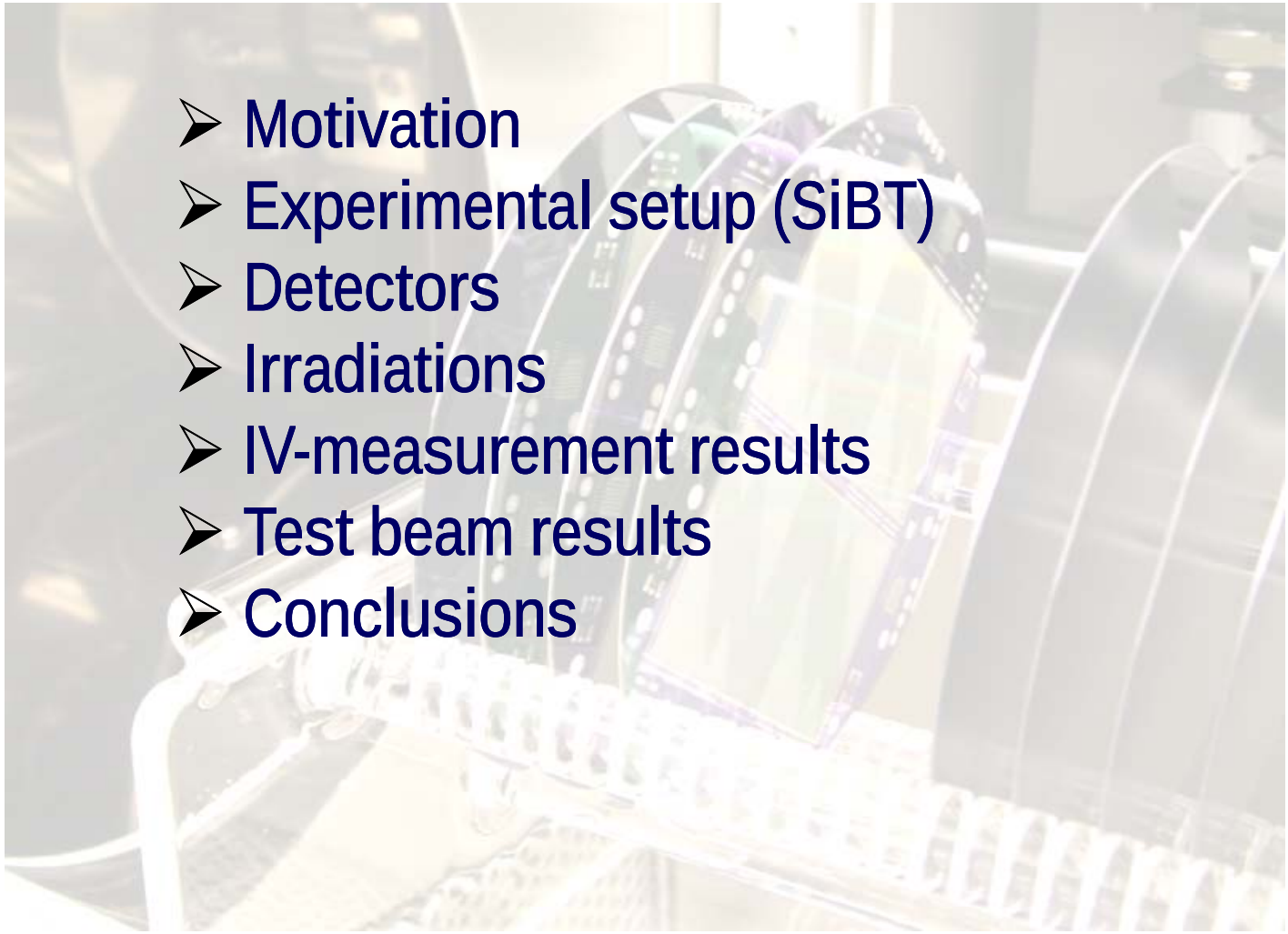
Test beam results of heavily irradiated magnetic Czochralski silicon (MCz-Si) strip detectors

P. Luukka, J. Härkönen, T. Mäenpää, B. Betchart, S. Bhattacharya, S. Czellar, R. Demina, A. Dierlamm, Y. Gotra, M. Frey, F. Hartmann, A. Kaminskiy, V. Karimäki, T. Keutgen, S. Korjenevski, M.J. Kortelainen, T. Lampén, V. Lemaitre, M. Maksimow, O. Militaru, H. Moilanen, M. Neuland, H.J. Simonis, L. Spiegel, E. Tuominen, J. Tuominiemi, E. Tuovinen, H. Viljanen

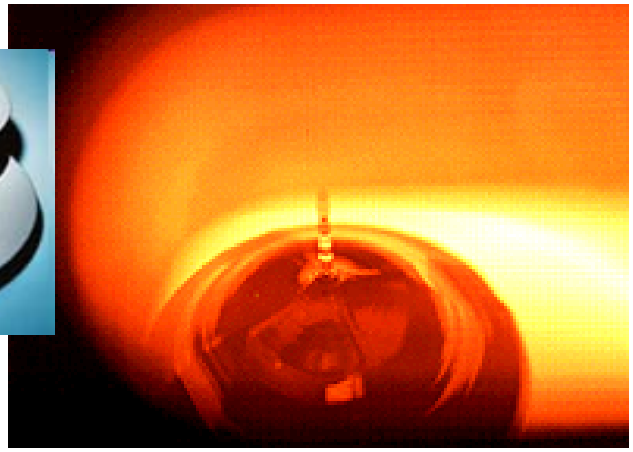
Outline



- Motivation
- Experimental setup (SiBT)
- Detectors
- Irradiations
- IV-measurement results
- Test beam results
- Conclusions

Motivation

- Magnetic Czochralski silicon (MCz-Si) has been found to be more radiation hard against protons than traditional Float Zone silicon material (Fz-Si) used in the current CMS Tracker.
- The objective of this study was to characterize MCz-Si strip detectors irradiated up to the fluence of 3×10^{15} 1 MeV n_{eq}/cm^{-2} in order to find out, if MCz-Si would be suitable material for the CMS SLHC tracking system.

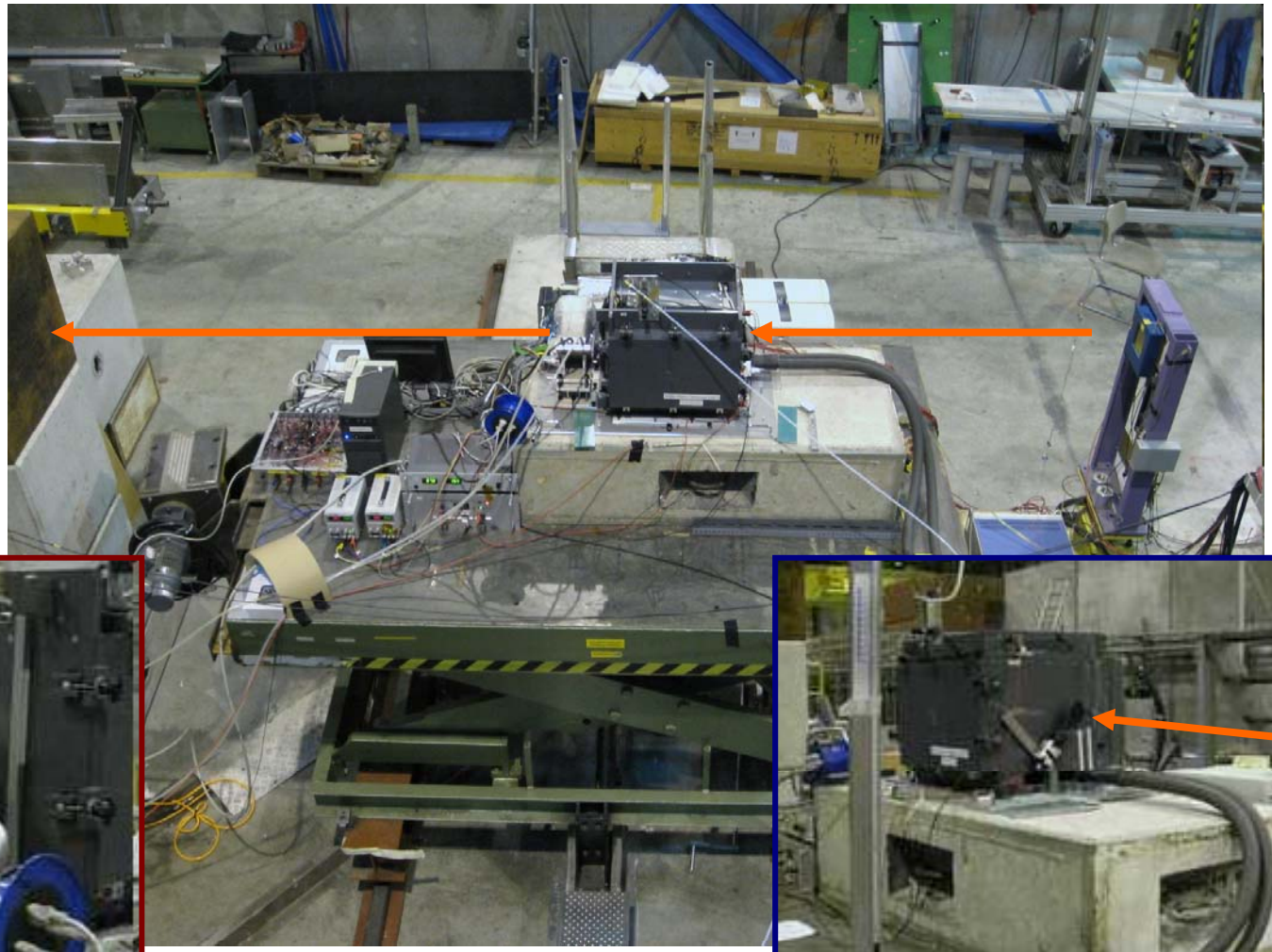


Telescope setup

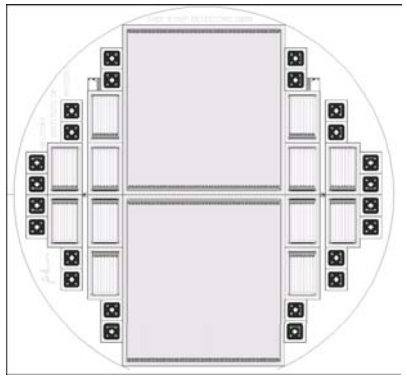
- The telescope reference planes + detectors under test are housed inside a cold chamber, in which the temperature can be adjusted by two water cooled 350 W Peltier elements.
- Reference planes are installed to ±45 degrees (due to the height limitation)
- Reference detectors are D0 Run IIb HPK sensors with:
  - 60 micron pitch and intermediate strips
  - size 4 cm x 9 cm
  - 639 channels
- Readout electronics: CMS 6-APV chip Tracker Outer Barrel hybrids (5 chips bonded)
- DAQ software: a modified version of the CMS Tracker data acquisition software XDAQ

Telescope setup

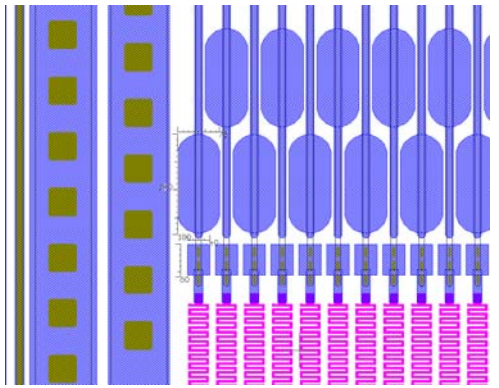
- An additional cold box was designed for operating very heavily irradiated detectros in cold temperature
- The box can reach a temperature of -52°C.

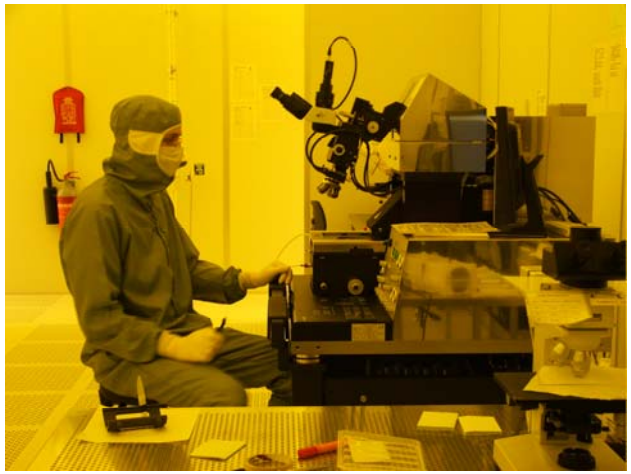


MCz-Si detectors



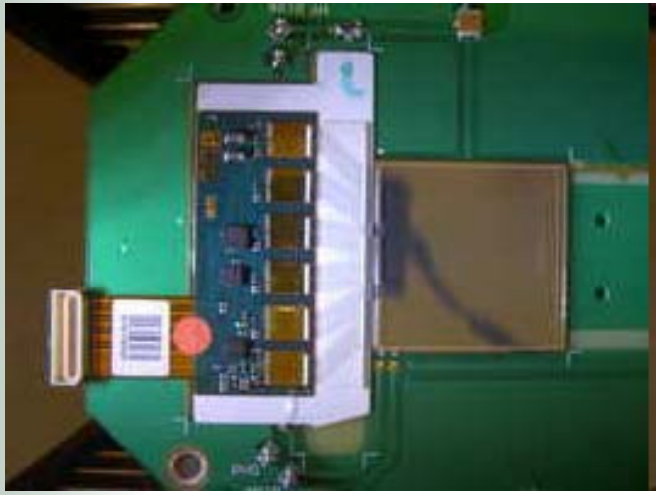
- Detector processing was done at the clean room of Helsinki University of Technology (TKK) Micro and Nanofabrication Centre (MINFAB)
  - Materials: n-type Magnetic Czochralski (Okmetic Ltd., Finland) wafers and n-type Float Zone wafers (Topsil, RD50 common order)
  - Detector characteristics:
    - AC-coupled
    - 4.1×4.1 cm^2 area
    - 50 µm pitch
    - strip width 10 µm, strip length 3.9 cm
    - 768 strips per detector (=6*128)
    - Designed for CMS (APV) readout
  - MCz detectors depleted with 330 V, Fz sensors with 10 V prior to the irradiation.





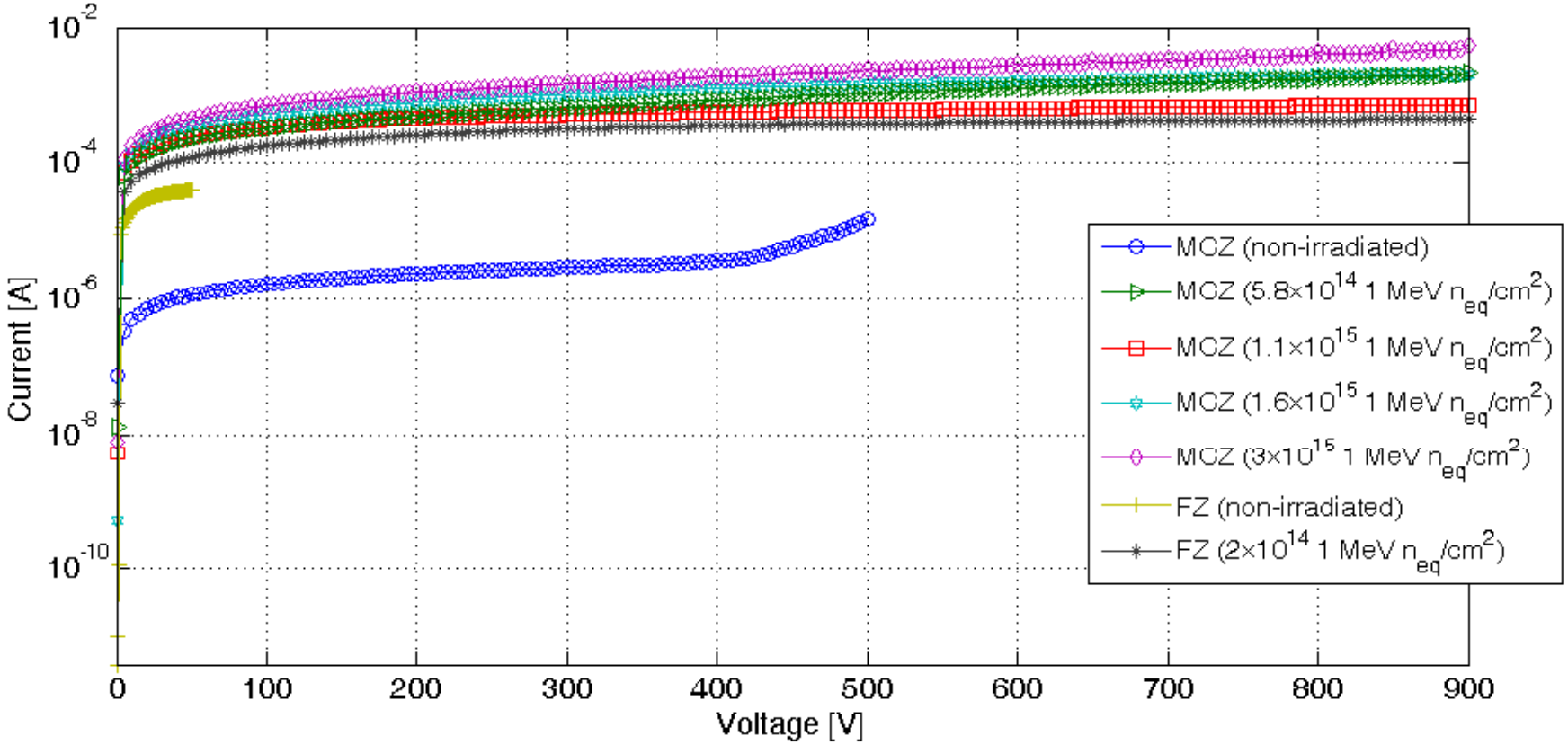
Irradiations

- The detectors were irradiated to the fluences ranging from 2×10^{14} to 3×10^{15} 1 MeV n_{eq}/cm^2 with 26 MeV protons in Karlsruhe and 3 MeV – 45 MeV neutrons (average spectrum 20 MeV) in Louvain.

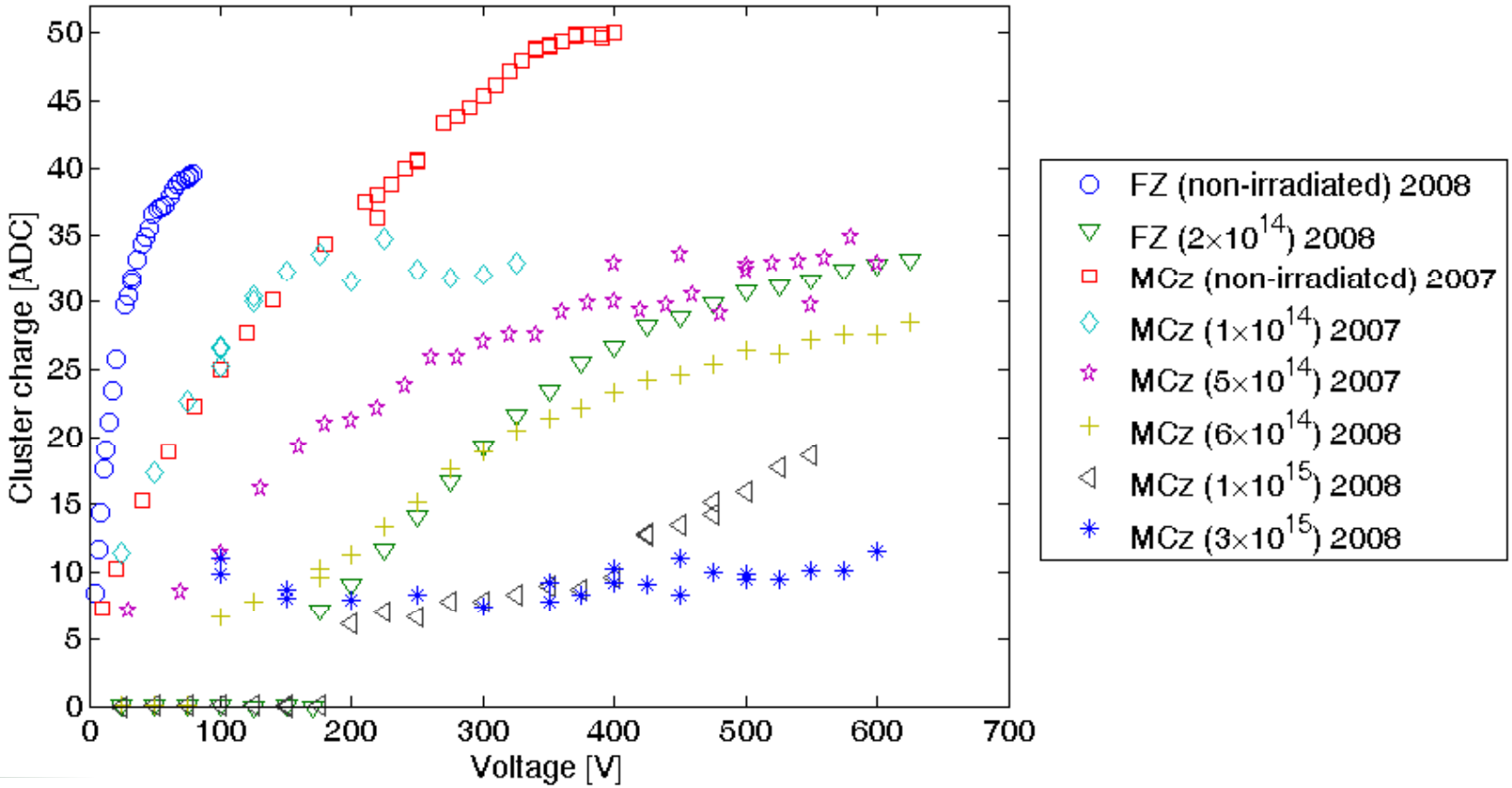


Irradiation fluences		
Material	**Fluence**	**n/p**
MCz	**6.1×10^{14}±20%**	**n/p mix**
MCz	**1.1×10^{15} ±20%**	**n/p mix**
MCz	**1.6×10^{15} ±20%**	**n/p mix**
MCz	**2.8×10^{15} ±20%**	**p**
MCz	**non-irradiated**	
Fz	**2.4×10^{14} ±20%**	**p**
Fz	**non-iradiated**	

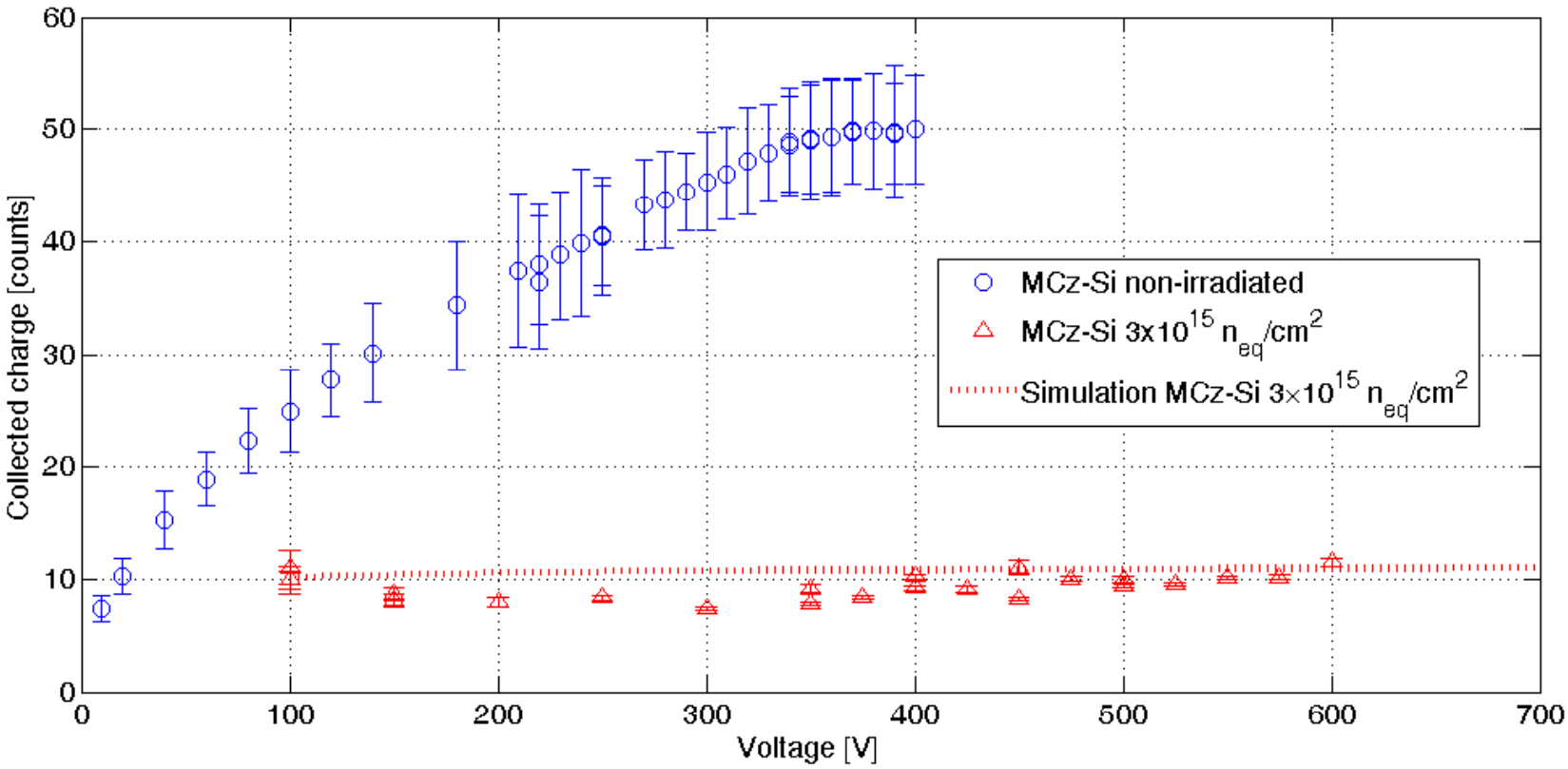
IV-measurements



Test beam results (results from 2007 included)



Test beam results



➢The signal of the MCz detector irradiated to the fluence of 3×10^{15} 1 MeV n_{eq}/cm^2 is approximately 20% compared to the non-irradiated device.

Conclusions

- N-type MCz-Si strip detectors have an acceptable S/N at least up to the fluence of 1×10^{15} 1 MeV n_{eq}/cm^2.
- Thus, MCz-Si detectors are a feasible option for the outer strip layers of the SLHC CMS tracker.

- After the fluence of 3×10^{15} 1 MeV n_{eq}/cm^2 the collected signal is approximately 20 % of the signal of a non-irradiated device.