Update on the analysis of the SiBT summer 2009 beam test data

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on behalf of

SiBT Collaboration
http://www.hip.fi/research/cms/tracker/SiBT/php/home.php

In framework of

CMS Tracker Upgrade
RD39 Collaboration
RD50 Collaboration

Motivation and background

- Luminosity increase of LHC by factor of ~10 is beyond the radiation hardness of currently existing Si sensors.
- The future Tracker upgrades consume silicon sensors up to 500 m^2.
- Radiation hardness up to **1×10^{15}** n_{eq}/cm^2 is required for strip layers consisting >90% of total area. **1×10^{16}** n_{eq}/cm^2 for pixels.
- The radiation effects for Si detectors are
  - Increase of full depletion voltage (**V_{fd}**)
  - Increase of leakage current (**I_{leak}**)
  - Trapping of signal charge (characterized by trapping time constant **$\tau_{e,h}$**)

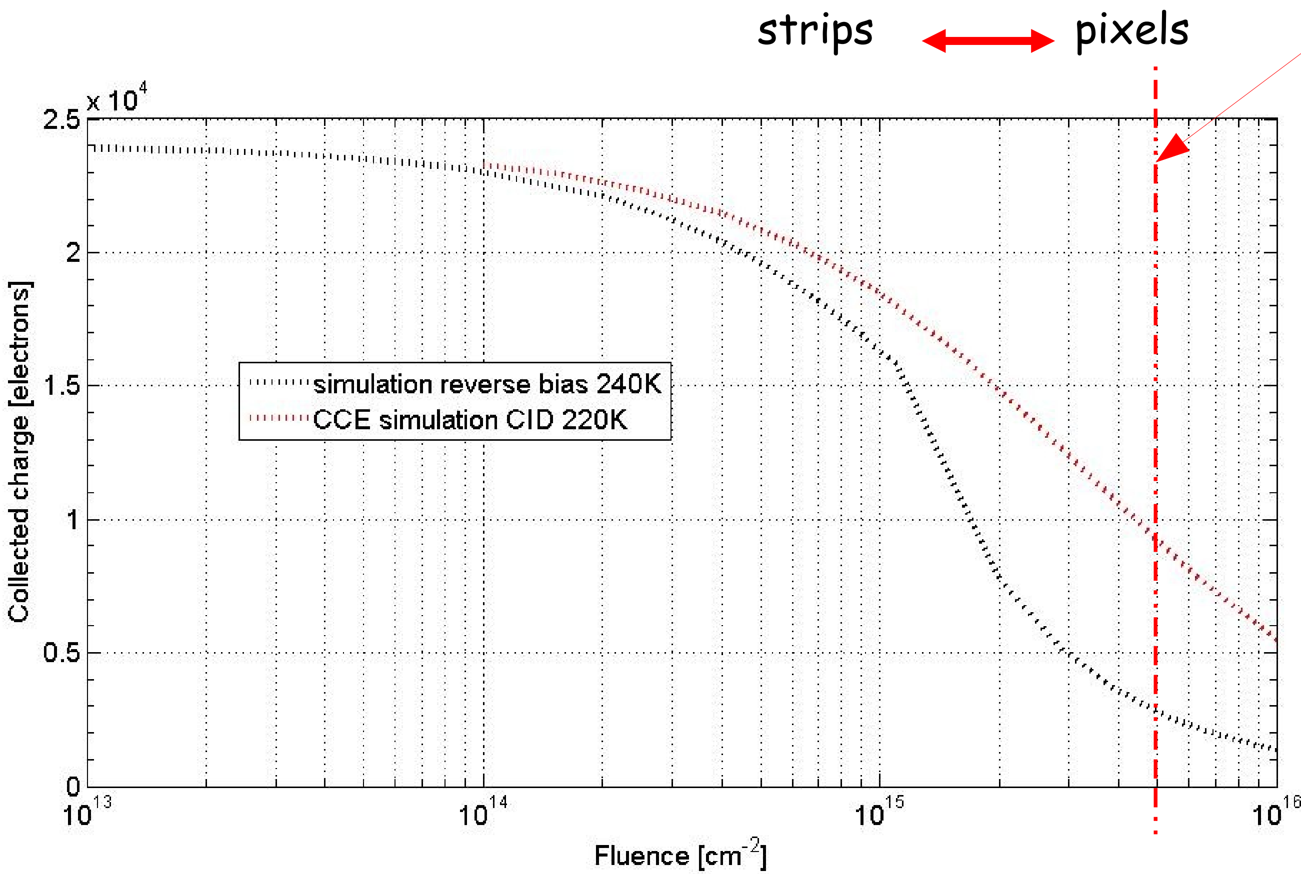
Background II -Methods to increase radhard of Si sensors

- Using oxygen rich substrate material = Magnetic Czochralski silicon (MCz-Si) wafers as detector substrate material
  - MCz-Si is less prone for V_{fd} increase with irradiation
  - MCz-Si provides better electric field distribution E(x)in irradiated Si leading to better Charge Collection Efficiency (CCE)

- Low temperature (less than -30^{0}C) operation
  - Enables Charge Injected Detector (CID) operation.
  - CID is based on balanced trapping and detrapping at low temperature.
  - Radiation defects modify E(x) if filled by charge injection → detector is “fully depleted all the time.
  - >2× higher CCE is achieved in CID compared with standard reverse bias operation.

Evolution of CCE as function of irradiation

Tested up to this fluence during this campaign



- Simulation takes into account linear trapping
- β=0.01 cm^{-1}
- ∀ √x E-field distribution is assumed

$$w_{pin} \propto \left(1 - \frac{x}{d}\right)$$

$$w_{CID} \propto \sqrt{x}$$

$$CCE = CCE_{Geometrical} \times CCE_{trapping} = \frac{w}{d} \times e^{-t_{dr}/\tau_{trapping}}$$

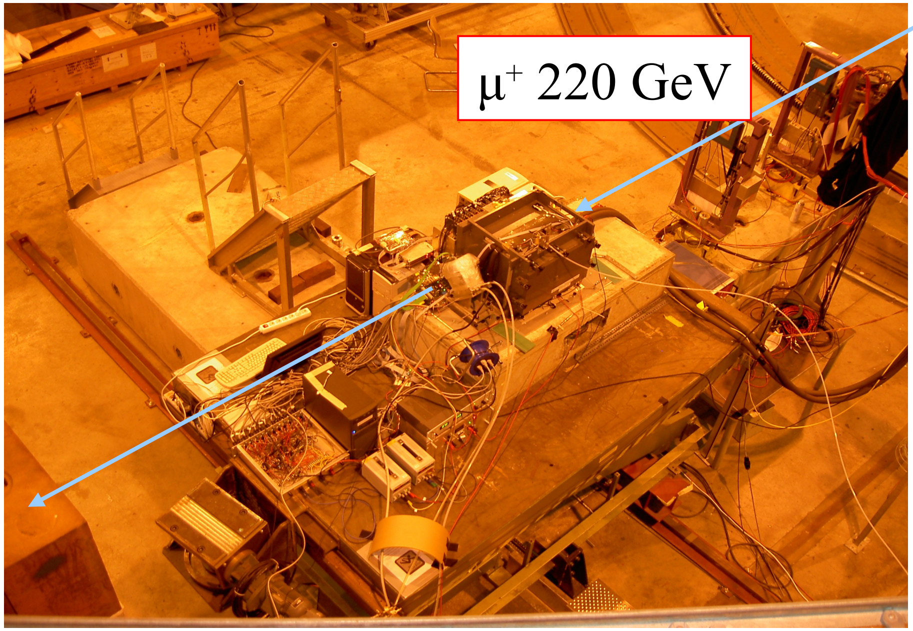
1×10^{14} n_{eq}/cm^2 τ_{trap}=10ns

1×10^{15} n_{eq}/cm^2 τ_{trap}=1ns

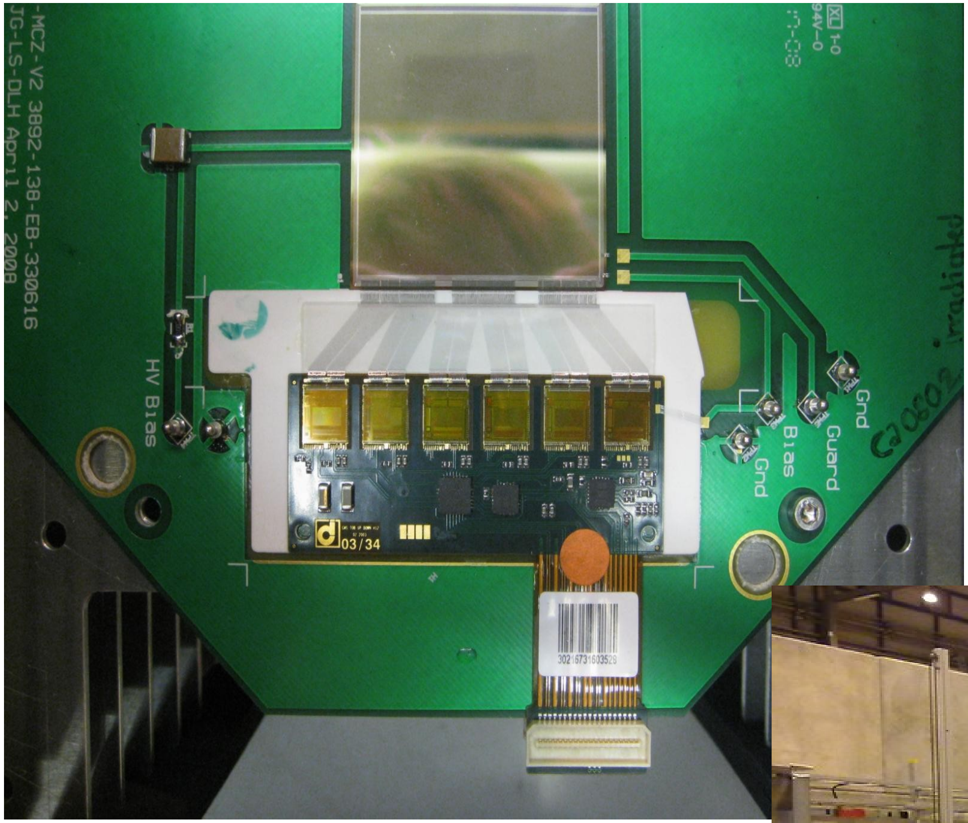
1×10^{16} n_{eq}/cm^2 τ_{trap}=0.1ns

How Si detector R&D is done at H2 test beam ?

- CMS based read-out electronics (APV25) and DAQ
- 8 detector planes providing reference tracks for DUT
- Measurement down to -50°C
- 50 000 events in about 15min
- Effective area 4cm × 4cm
- Telescope resolution ~4µm
- Detectors under test processed at Microelectronics Center of Helsinki University of Technology
- Irradiation at Univ. Karlsruhe, 26 MeV protons

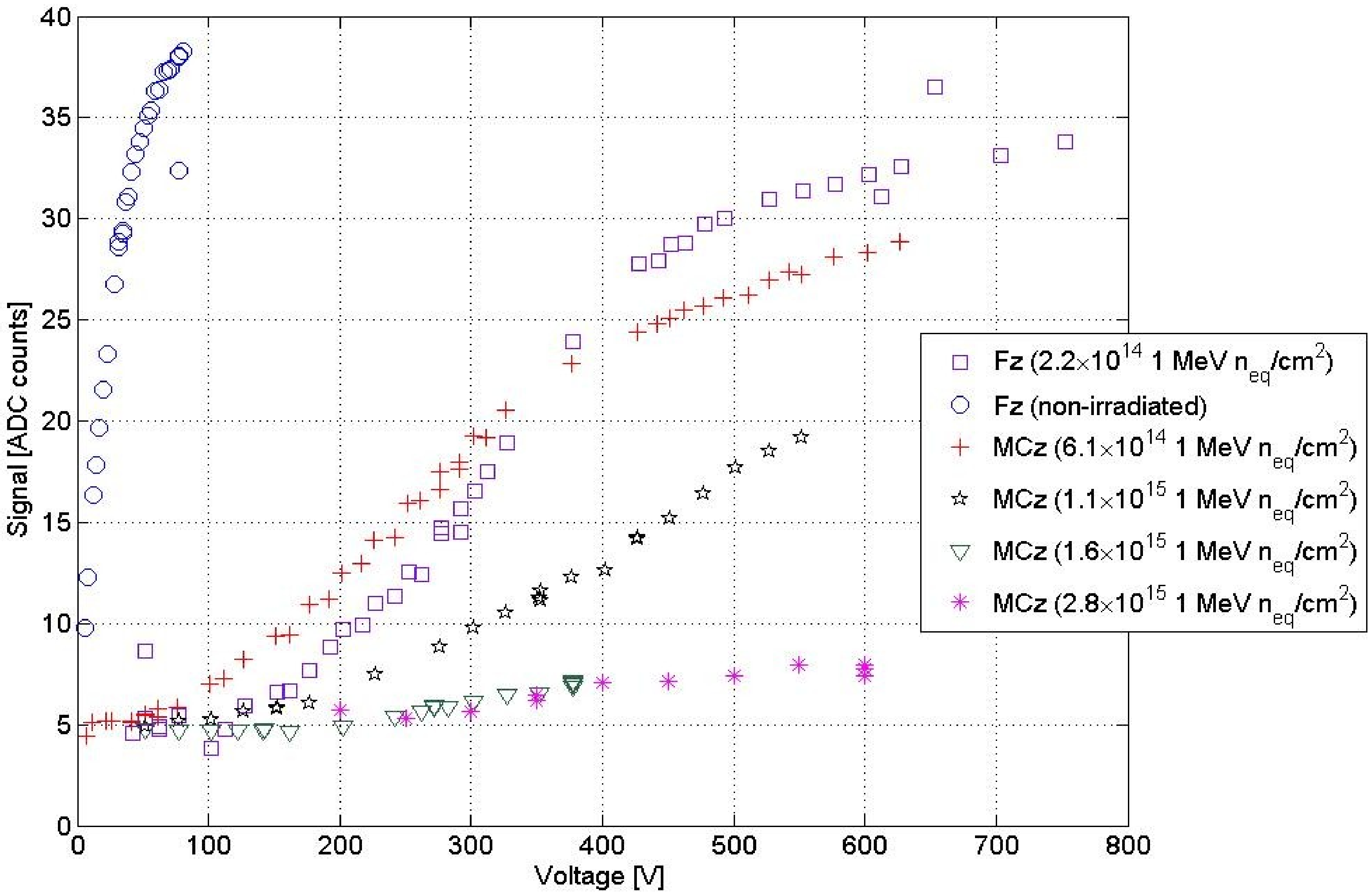


5×10^{15} n_{eq}/cm^2 irradiated MCz-Si detector with APV read-out



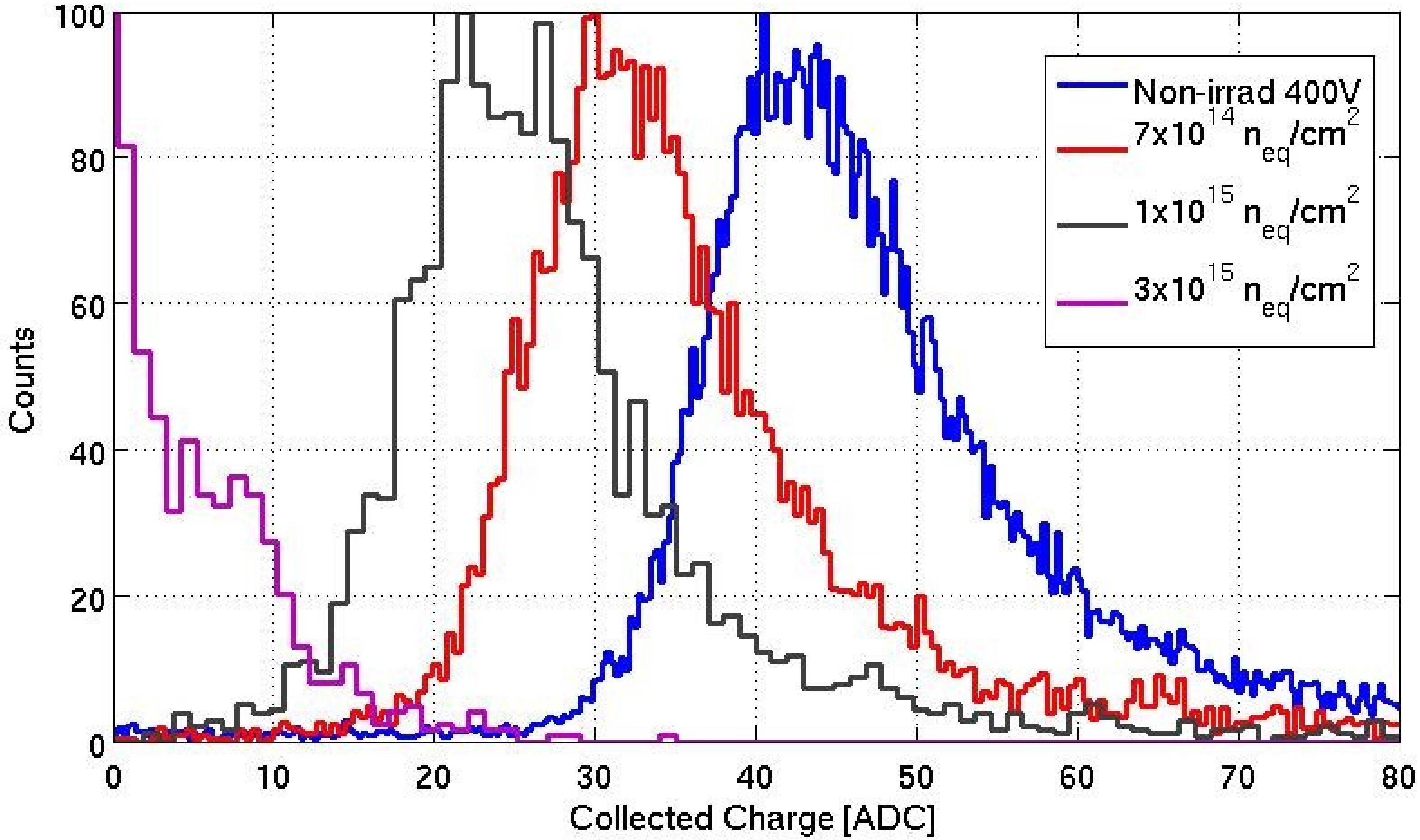
- 768 channels AC-coupled strip detector
- Detector and pitch adapter fabricated by HIP @ Micronova
- 26 MeV proton irradiation @ University Karlsruhe

Results from 2008 (1)



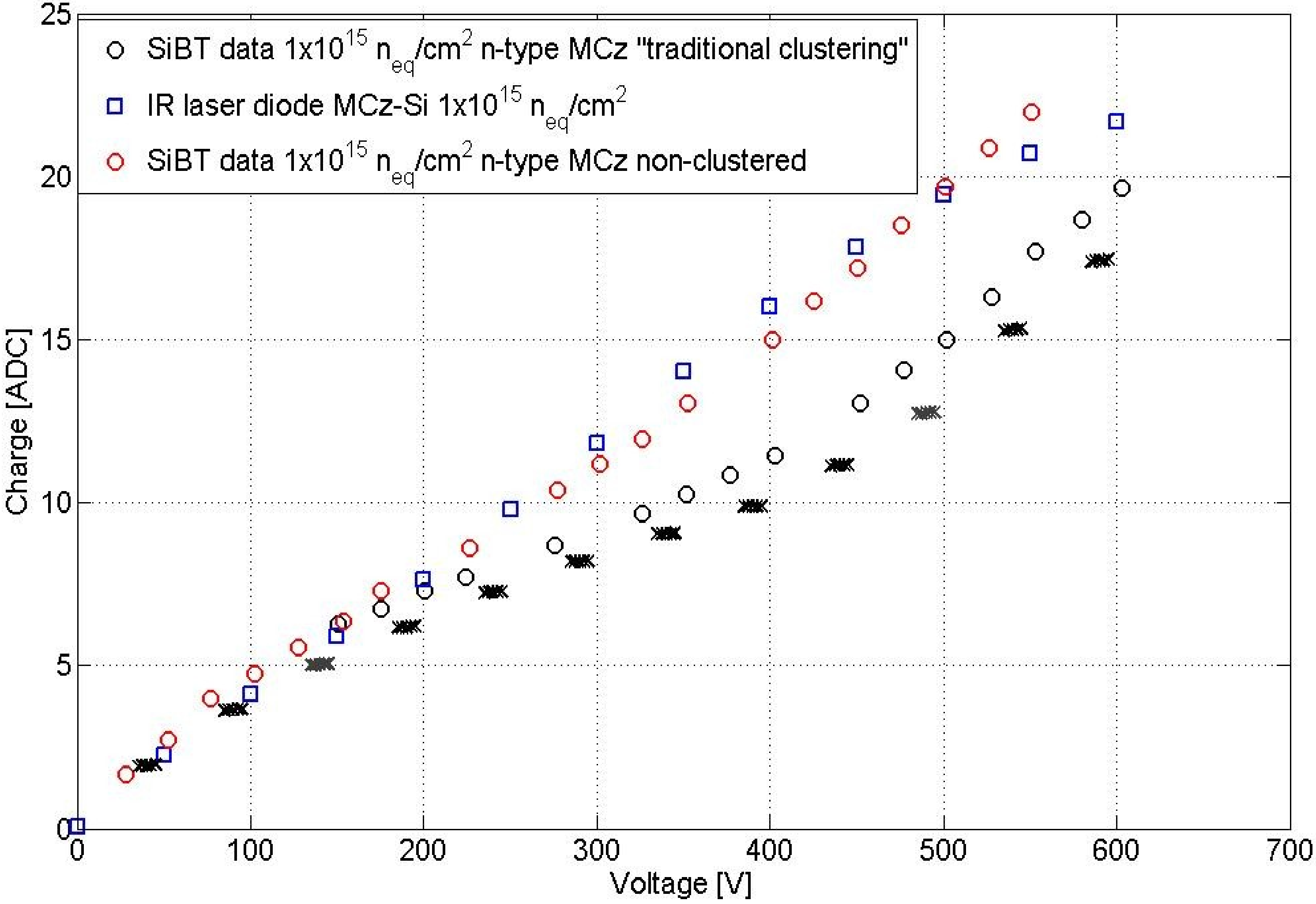
Results from 2008 (2)

- Signal distributions of n-type MCz-Si detectors
- 100% charge ~40 ADC



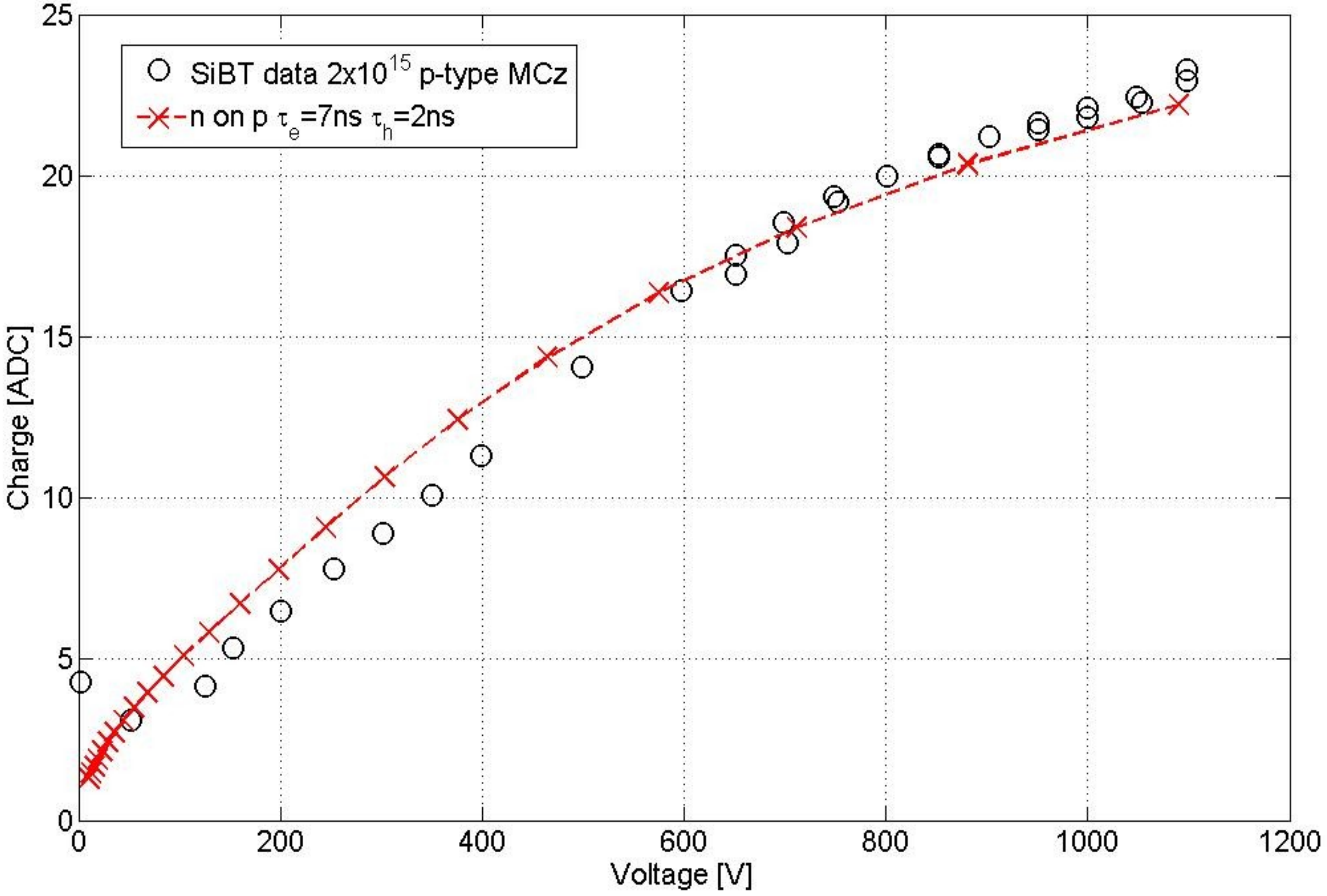
Results from 2008 (3)

The results are reproduced by IR laser measurements on diodes and calculations of classical electron-hole transport equations.



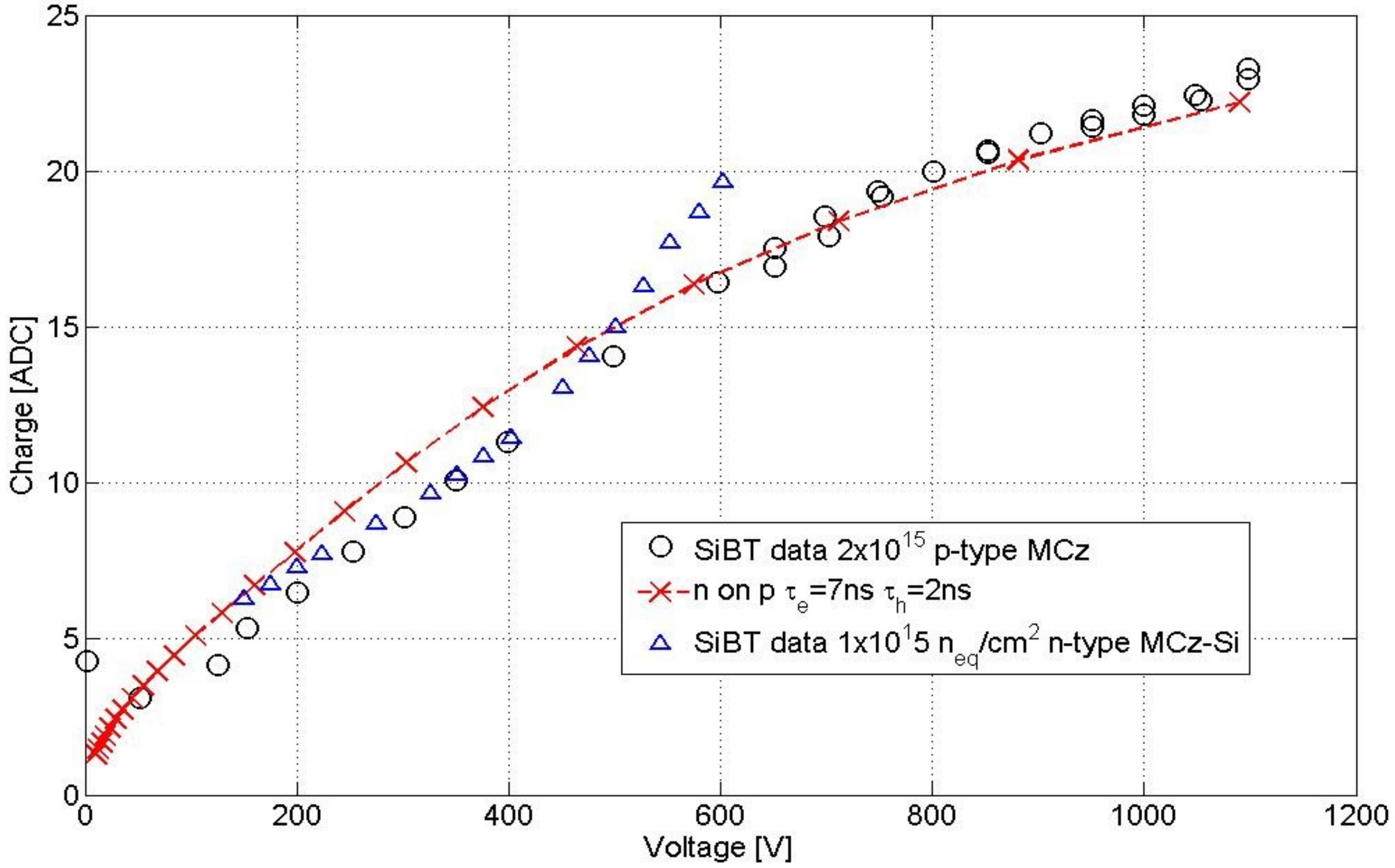
Results 2009 -Preliminary

$n^+/p^-/p^+$ MCz-Si irradiated $2\times10^{15} n_{eq}/cm^2$

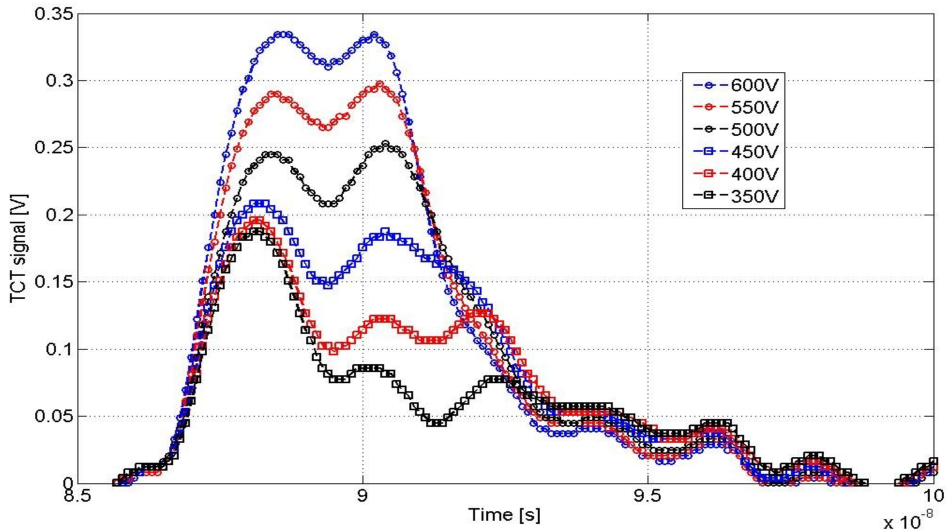


Comparison on n-type and p-type heavily irradiated MCz-Si detectors

At 600V the n-type MCz-Si shows comparable CCE with p-type MCz-Si irradiated with 2 times higher fluence

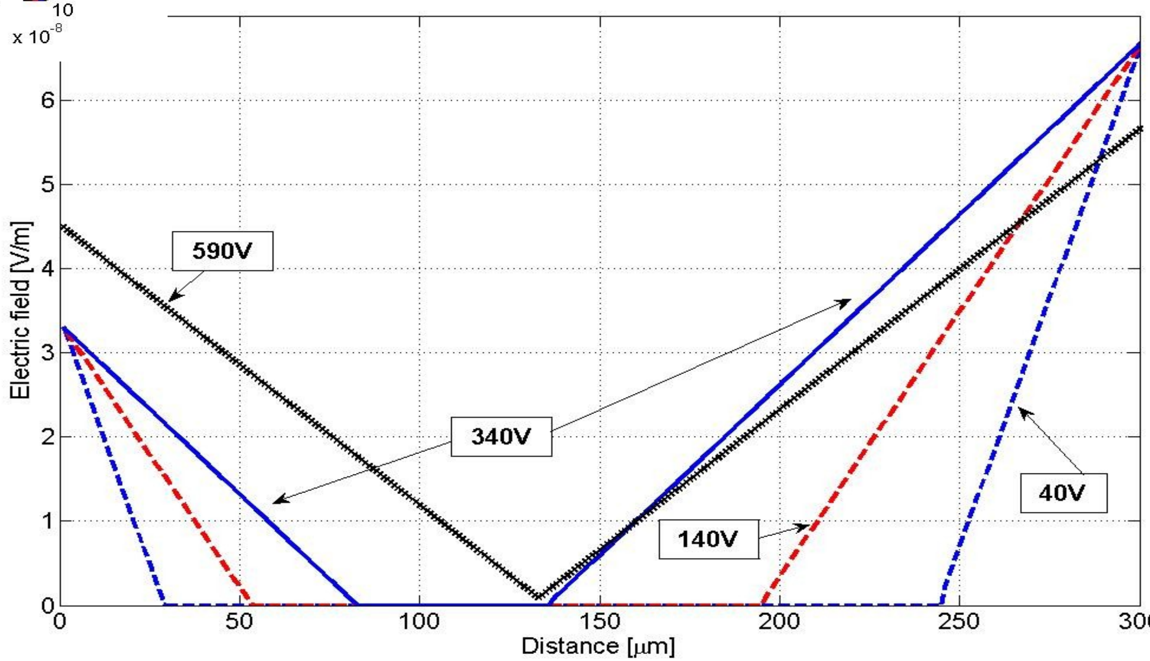


Electric Field distributions used in simulations - n-type



•RED laser TCT on 1×10^{15} irradiated n-type MCz-Si diode shows clearly Double Junction

E(x) distribution used in simulation



Summary of test beam period 28.06.-13.07.2009

- > 1Tb High quality data was taken.
- Several different novel detectors were measured, including CID, 3D, thin MCz-Si, p on n structures etc.
- The comprehensive off-line data analysis will take several months. Results will be reported in RD39 and RD50 Workshops and CMS Tracker Upgrade meetings.
- Preliminary results show nice coincidence with classical models for p and n-type MCz-Si both.
- Increase of CMS TK Up Si sensor R&D test beam activity is foreseen in coming years