TCT and CCE measurements for 9 MeV and 24 GeV/c irradiated n-type MCz-Si pad detectors

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Outline

- Samples and irradiations
- Measurement setup
- Red laser measurements (TCT)
- IR laser measurements (CCE)
- Summary
- References

Esa Tuovinen loading MCz-Si wafers into oxidation furnace at the Microelectronics Center of Helsinki University of Technoly, Finland.

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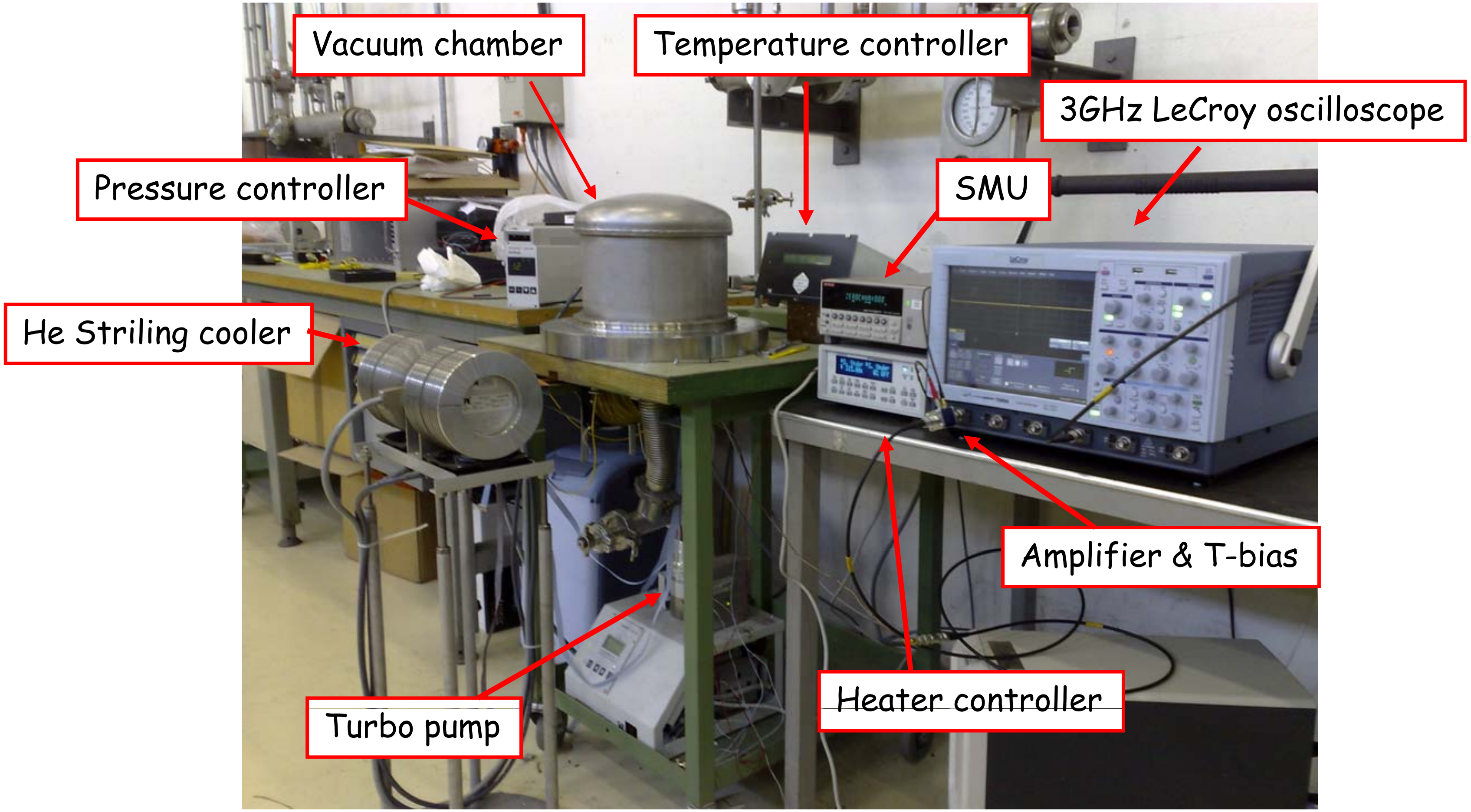
Cryogenic Transient Current Technique (C-TCT)



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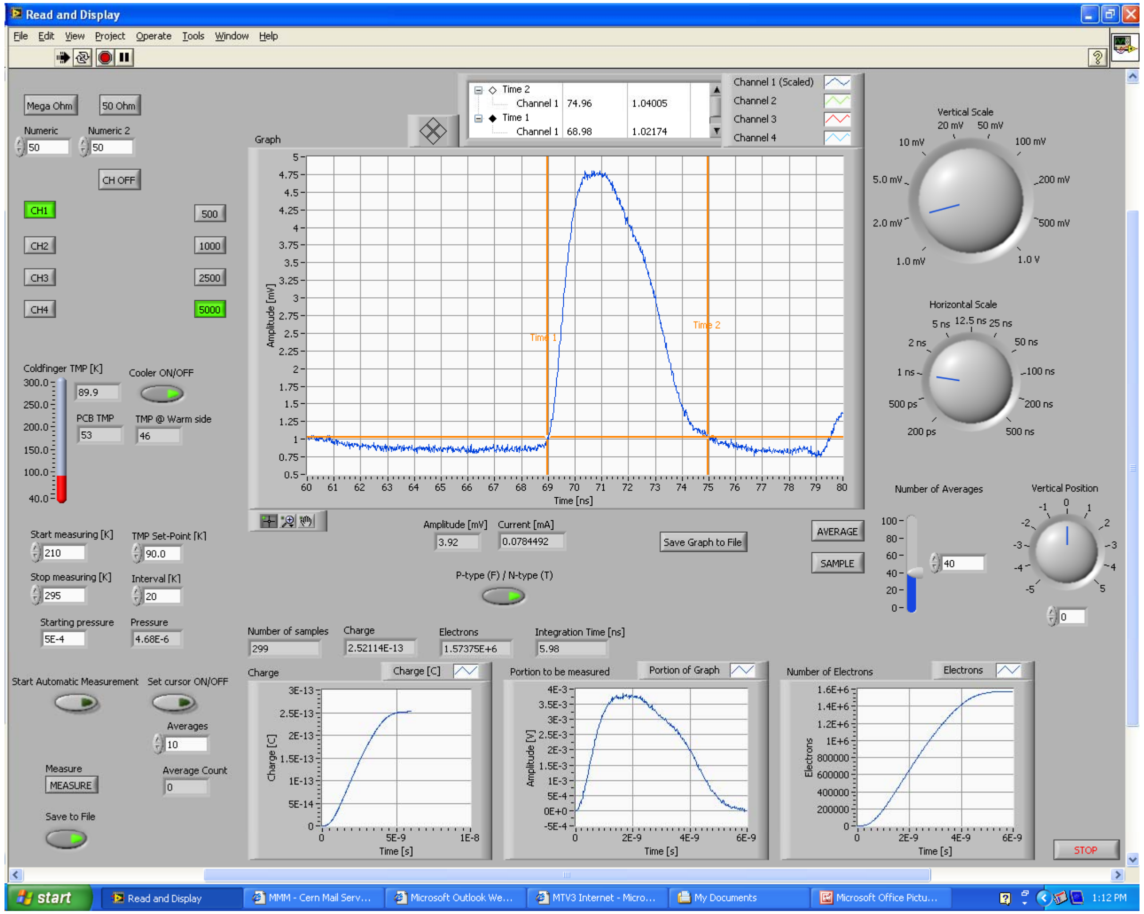
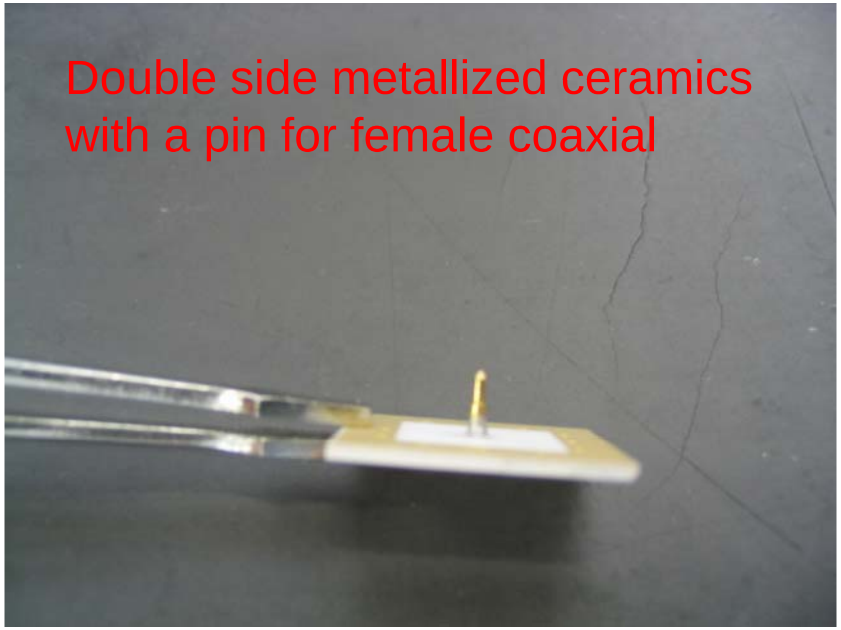
Properties of Setup

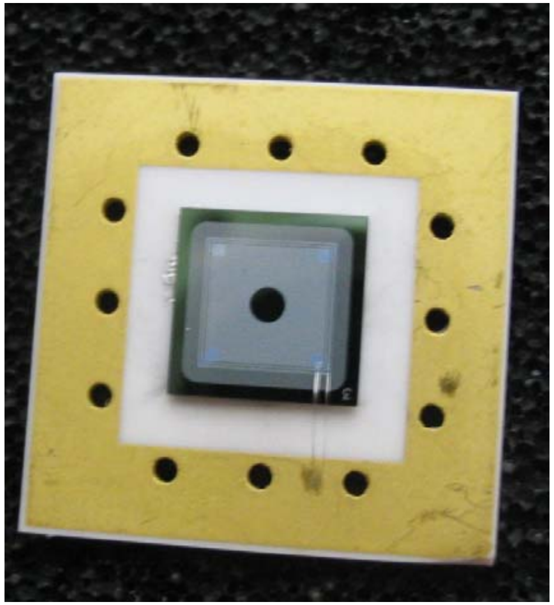


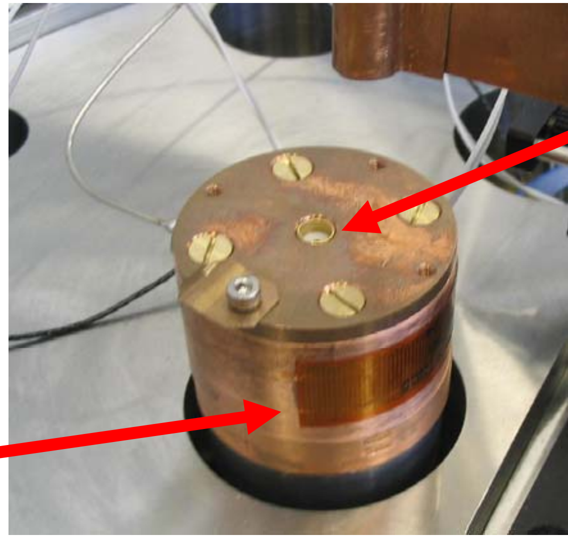
1. IR (1060nm) and RED (670nm) lasers.
2. Front side illumination only.
3. Temperature min 40K.
4. Fully computer control (system and DAQ).
5. Bias up to 600V.
6. High gain preamplifier for CCE (g≈600) and TCT (g≈35). Optimized for low injection level (CCE) and high bandwith (TCT)

Samples adjustment

- Ceramic sample holders







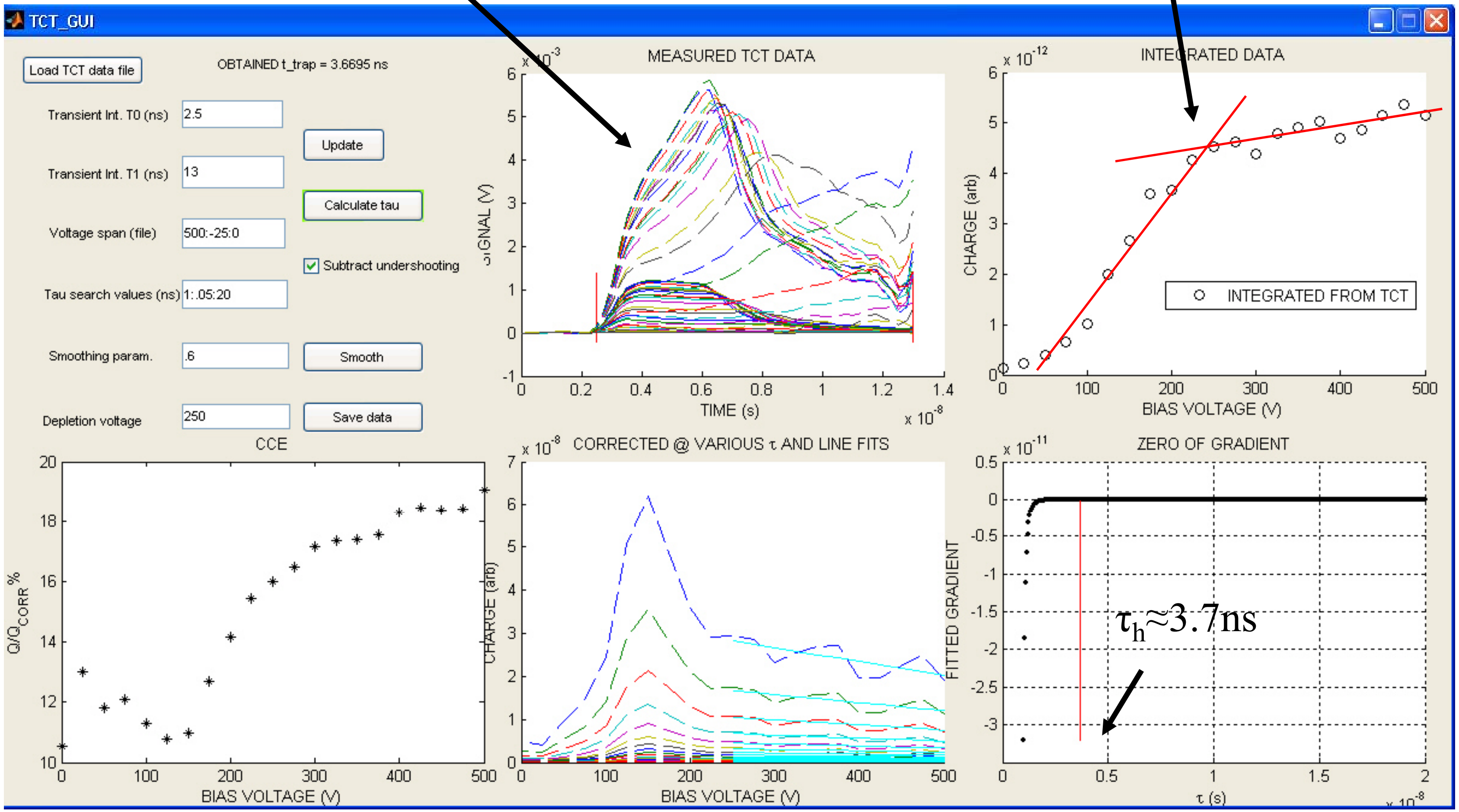
Cold finger and coaxial connector

Heating resistor provides faster temperature ramping

C-TCT data analysis

Trapping corrected transient

V_{fd}



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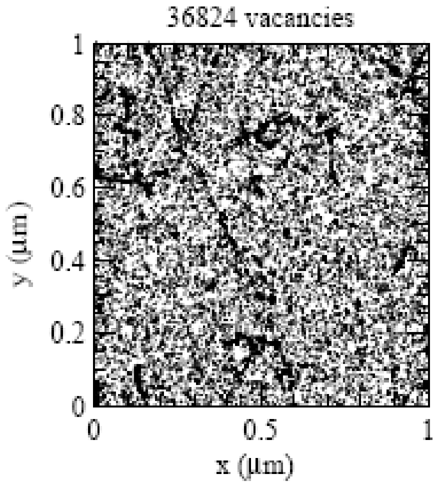
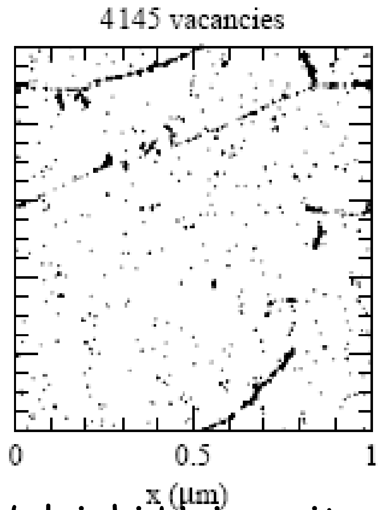
Samples and irradiations

- 9MeV proton irradiation at University of Helsinki Accelerator laboratory
- Fluencies up to 3×10^{15} n_{eq}/cm^2
- Hardness factor ~5

- 24 GeV proton irradiation at CERN Irrad1-facility
- Fluencies up to 1.6×10^{16} p/cm^2
- Hardness factor ~0.6





Mika Huhtinen, NIMA 491 (2002)

- Samples processed at MINFAB facility of Helsinki University of Technology on Okmetic MCz-Si wafers.
- "Standard" RD50 diode process and design

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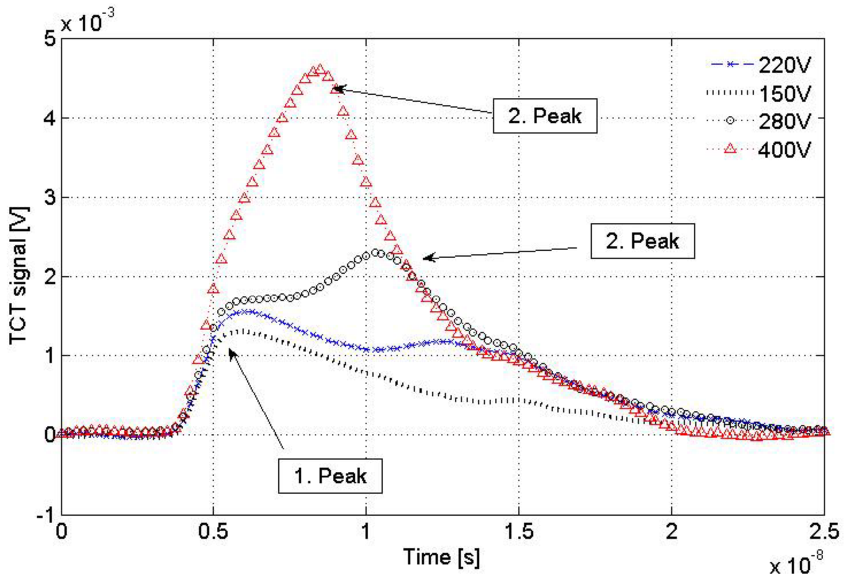
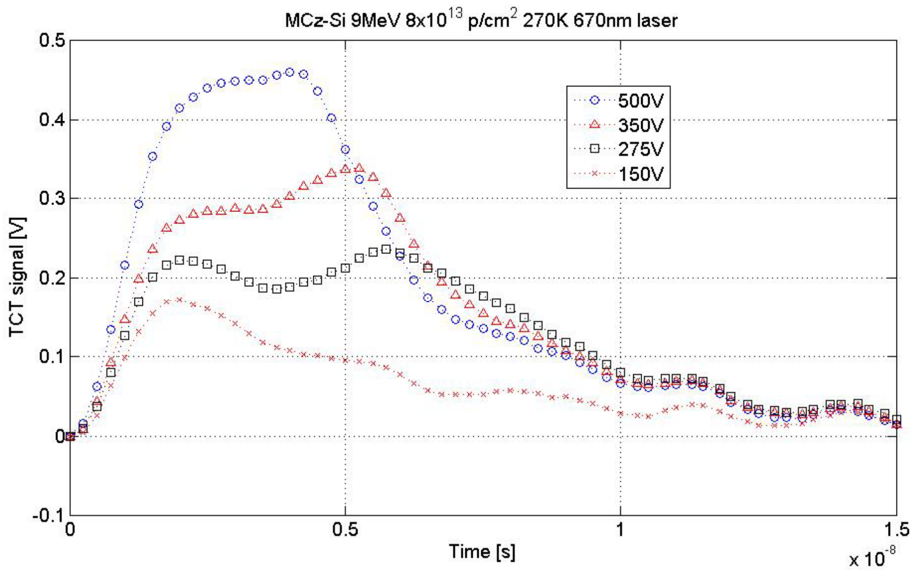
TCT red laser results low energy protons 1

MCz-Si 7×10^{14} n_{eq}/cm^2 by 50 MeV protons



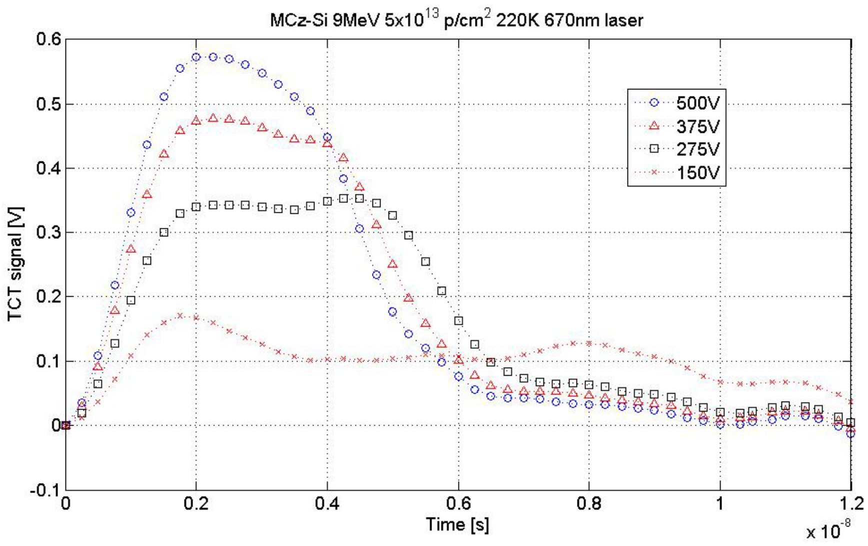
MCz-Si 4×10^{14} n_{eq}/cm^2 by 9 MeV protons



- No trapping correction
- DP arises in 50MeV and 9MeV both

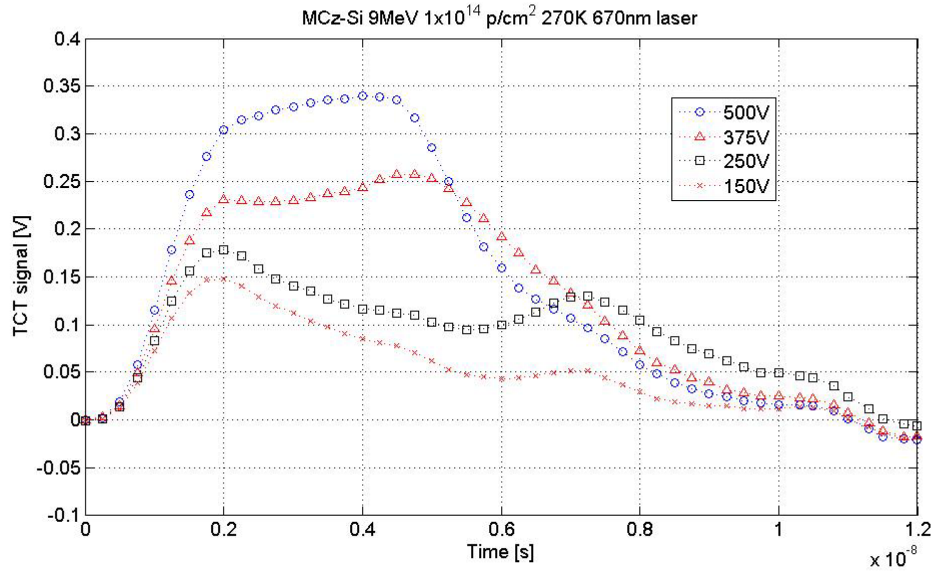
TCT red laser results low energy protons 2

MCz-Si 2.5×10^{14} n_{eq}/cm^2 by 9 MeV protons



- No trapping correction
- Slight tendency for DP

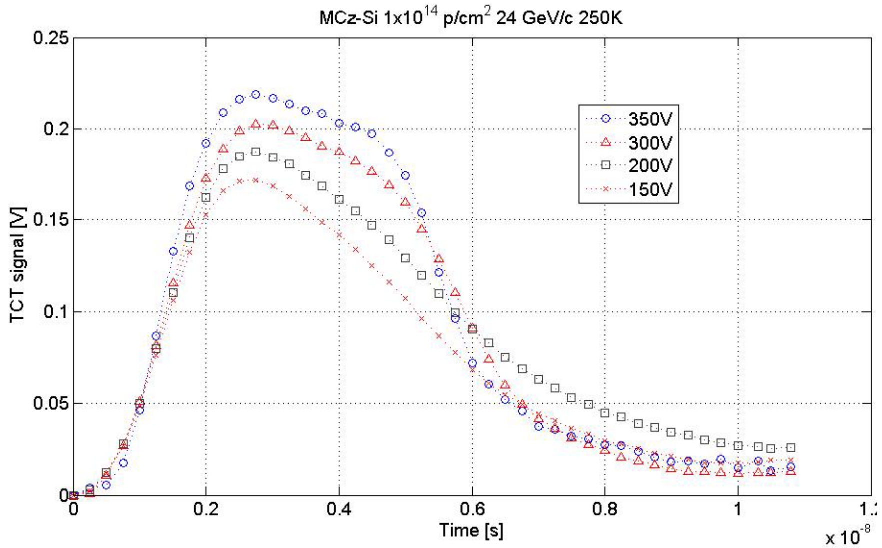
MCz-Si 5×10^{14} n_{eq}/cm^2 by 9 MeV protons



- No trapping correction
- Increasing transient and DP

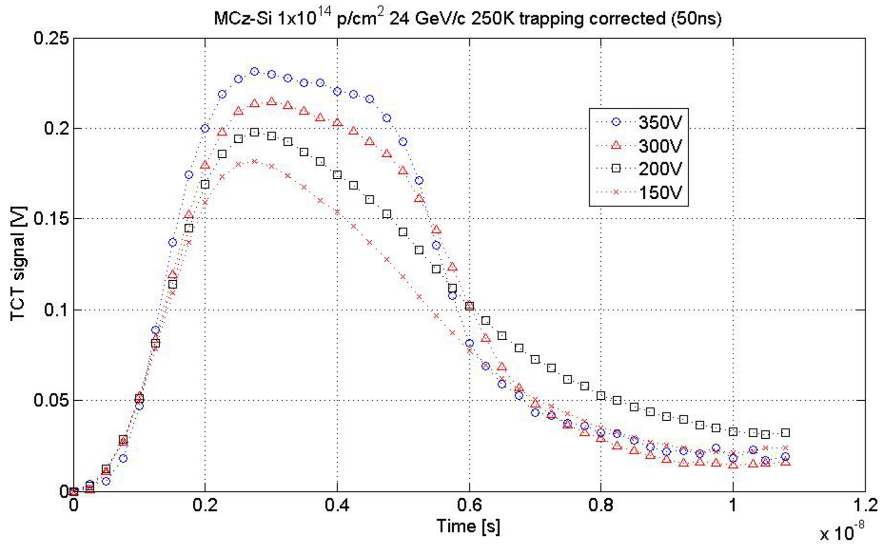
TCT red laser results high energy protons 1

MCz-Si 6×10^{13} n_{eq}/cm^2 by 24 GeV/c protons



- No trapping correction

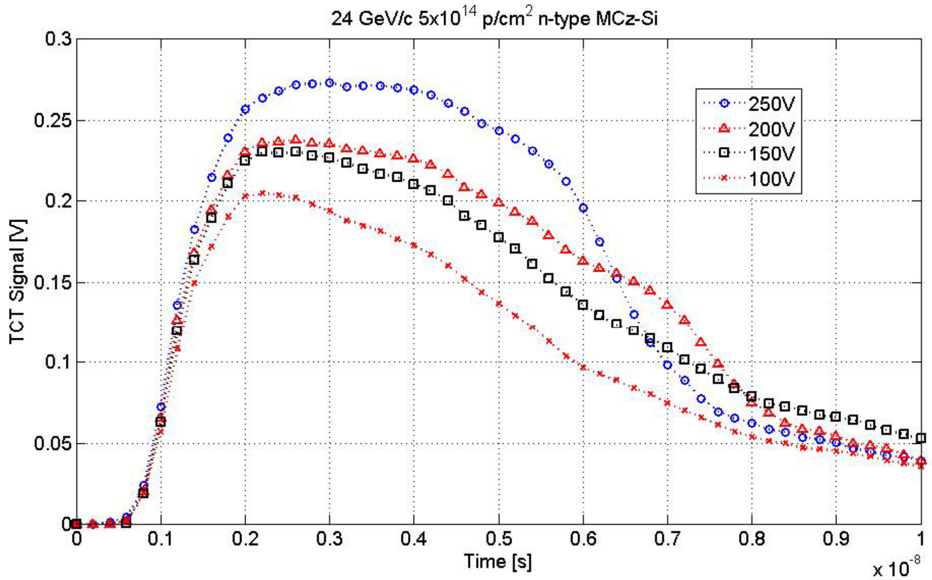
MCz-Si 6×10^{13} n_{eq}/cm^2 by 24 GeV/c protons



- Trapping corrected by 50ns
- $V_{fd}\approx200V$
- Trapping effects negligible

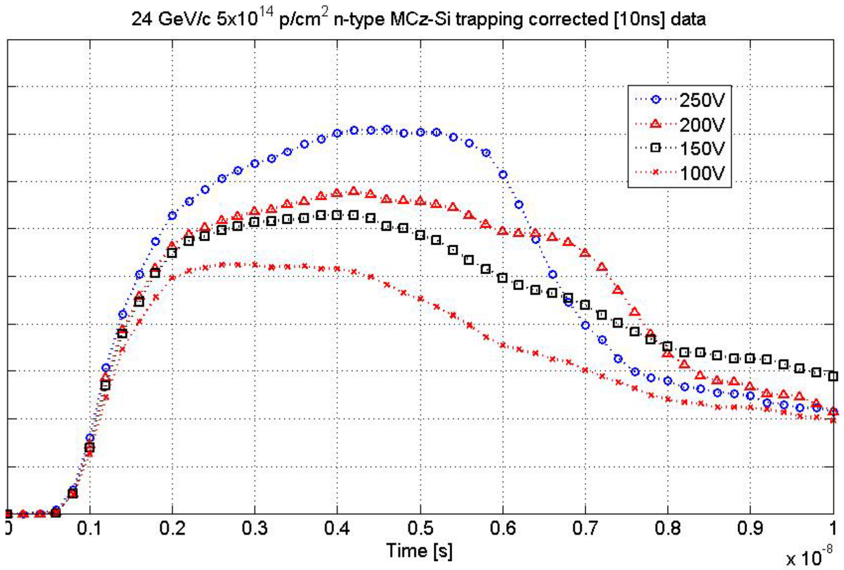
TCT red laser results high energy protons 2

MCz-Si 3×10^{14} n_{eq}/cm^2 by 24 GeV/c protons



- No trapping correction
- DP arises in 5×10^{14} n_{eq}/cm^2

MCz-Si 3×10^{14} n_{eq}/cm^2 by 24 GeV/c protons



- Trapping corrected by 10ns
- $V_{fd}\approx200V$

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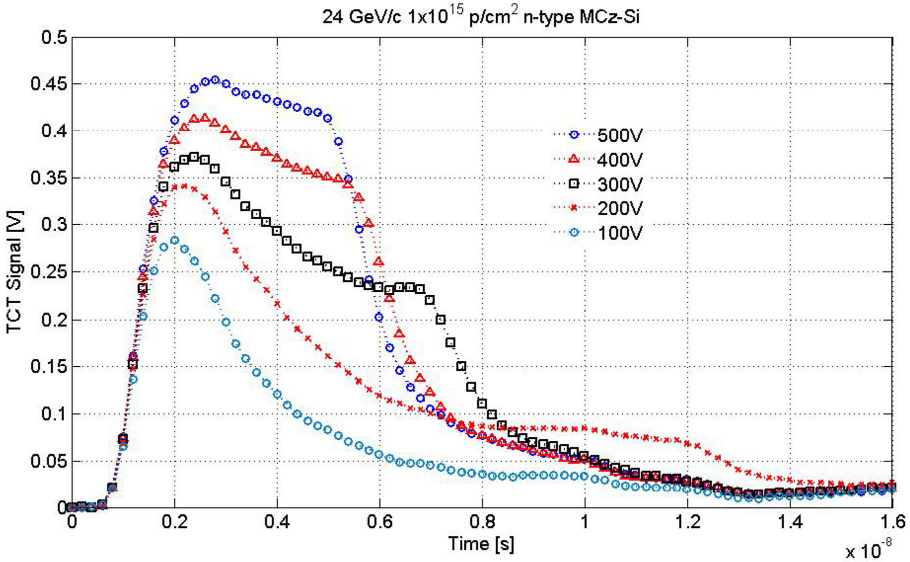
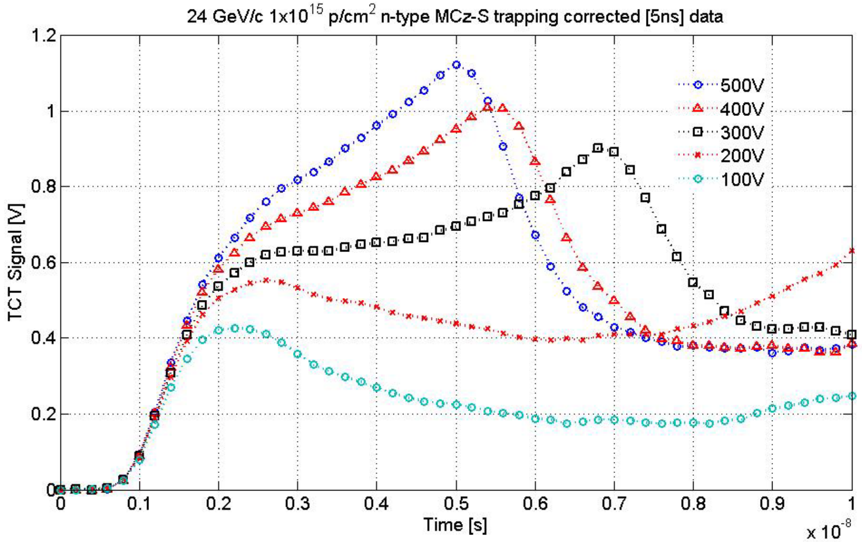
TCT red laser results high energy protons 3

MCz-Si 6×10^{14} n_{eq}/cm^2 by 24 GeV/c protons



- No trapping correction

MCz-Si 6×10^{14} n_{eq}/cm^2 by 24 GeV/c protons



- Trapping corrected by 5ns

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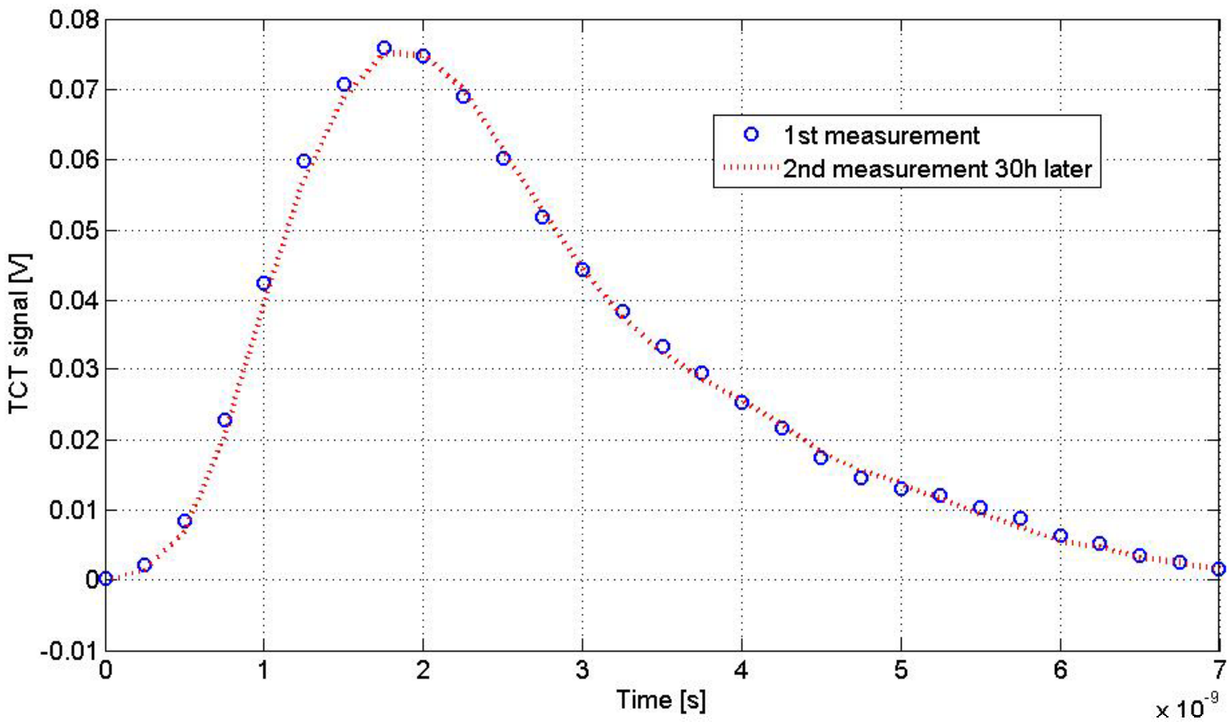
CCE with infrared laser



- Comparison of irradiated sample and non-irradiated reference
- Samples prepared *excatly* same manner
- High gain (~600) amplifier
- Injection level 10-20 MIPs

Stability of IR laser over ~30 hours

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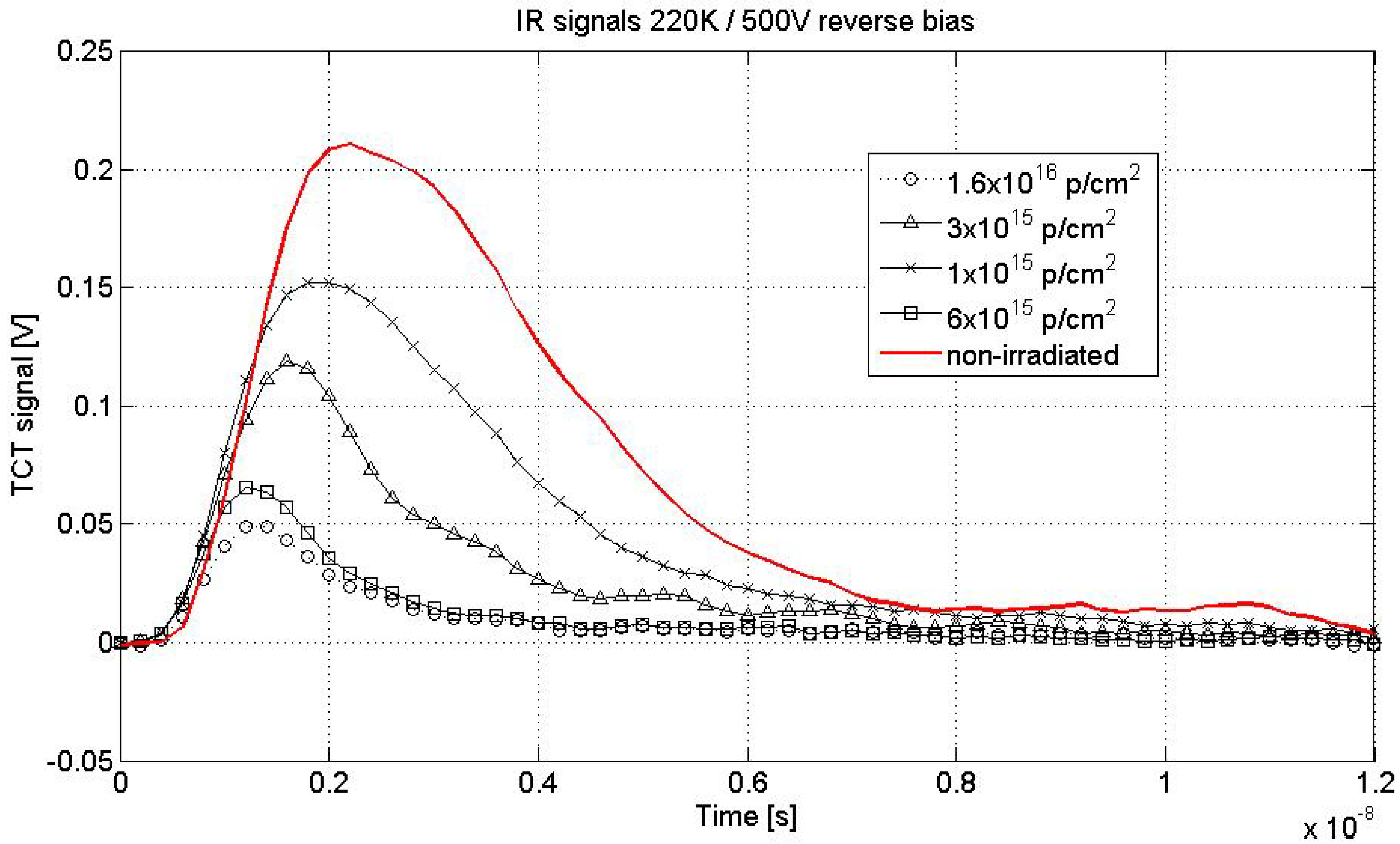
IR transients of 24 GeV/c irradiated MCz-Si



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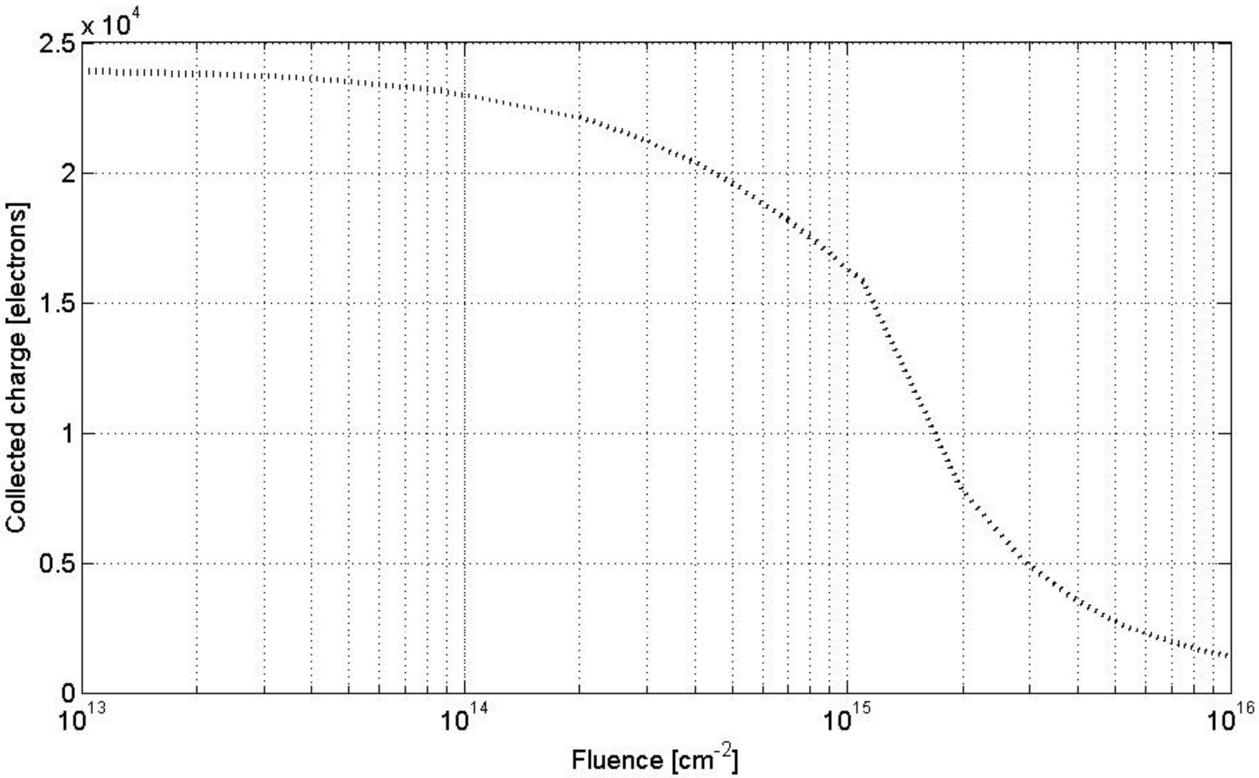
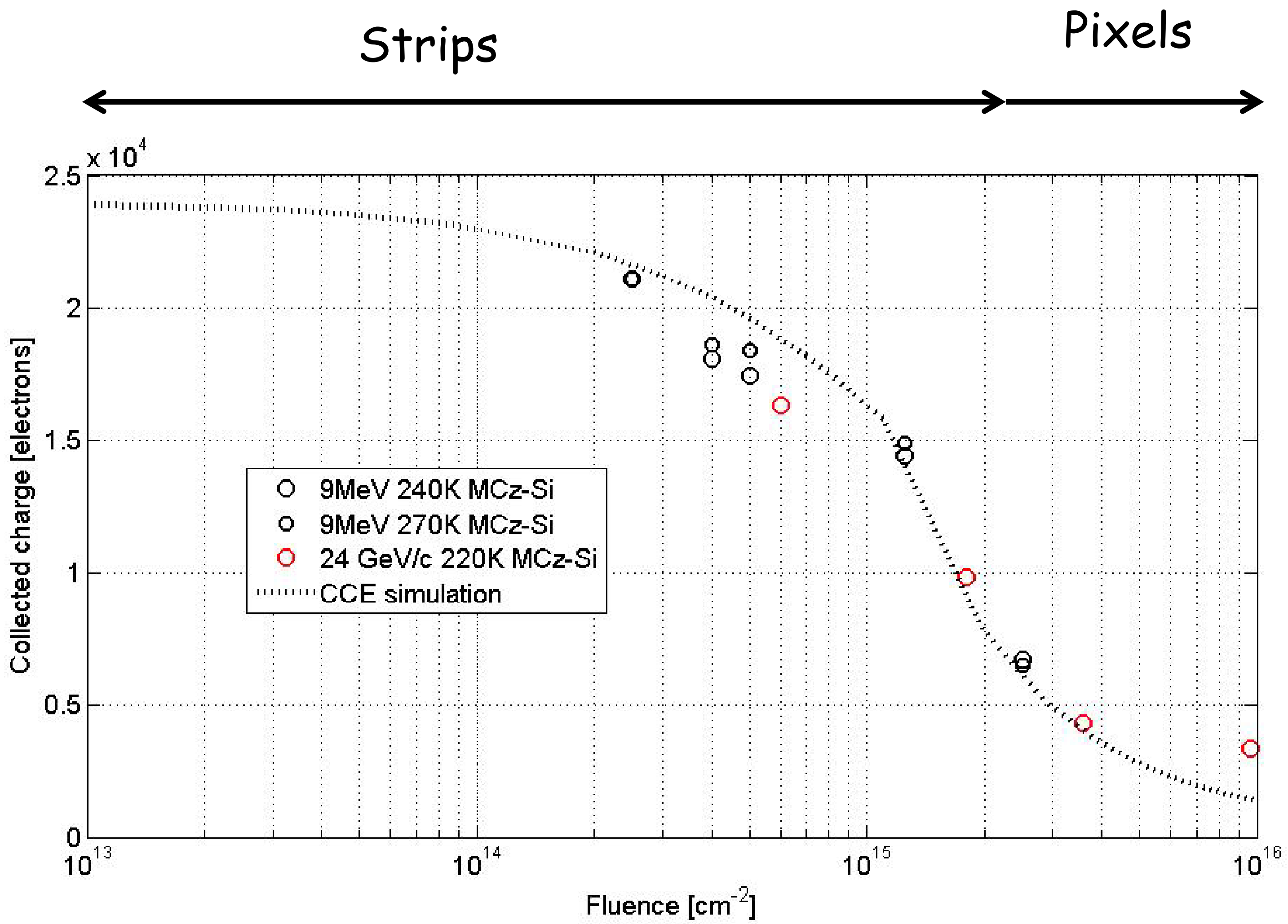
Expected Charge Collection Efficiency



- Simulation takes into account linear trapping and evolution of V_{fd}
- β=0.01 cm^{-1}
- Linear E-field distribution is assumed

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

Charge Collection Efficiency



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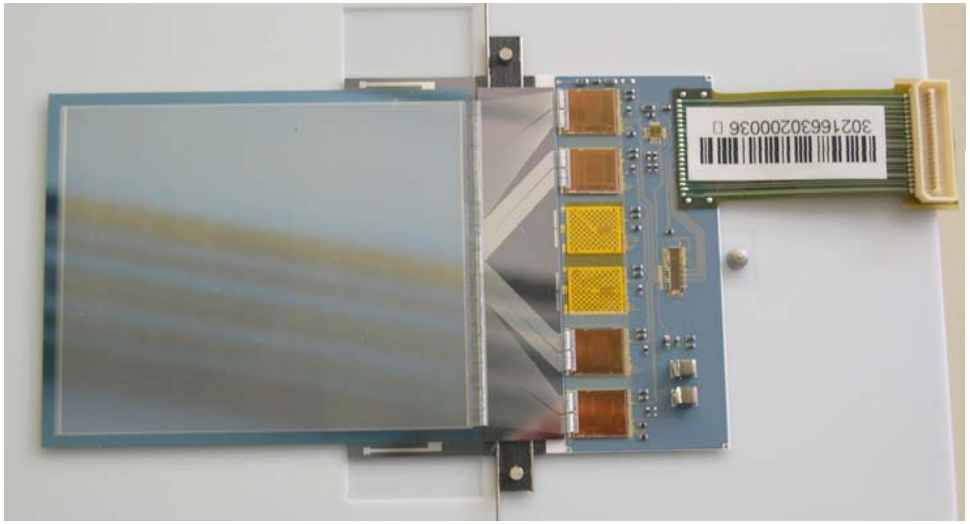
Summary

- MCz-Si shows different red laser response when irradiated by low energy and high energy protons.
- Low energy protons TCT transients reveal Double Junction and SCSI without trapping correction.
- High energy protons TCT transients reveal Double Junction and SCSI when trapping effects are taken into account.
- CCE at 2×10^{15} cm^{-2} is about 30% / $8000e^{-}$. Thus, 300μm thick MCz-Si is feasible for strip layers but not for pixel barrel.
- The CCE is limited by trapping and elevated V_{fd}.
- Pad detector characterization does not include possible weighting field effects >> systematic test beam experiments with segmented detectors and appropiate RO electronics are needed



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