TCT+, eTCT and I-DLTS measurement setups at the CERN SSD Lab

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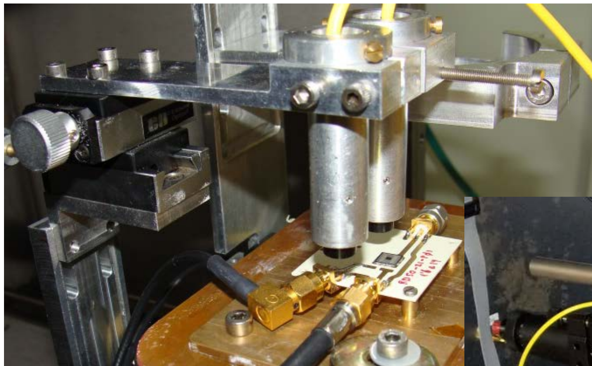
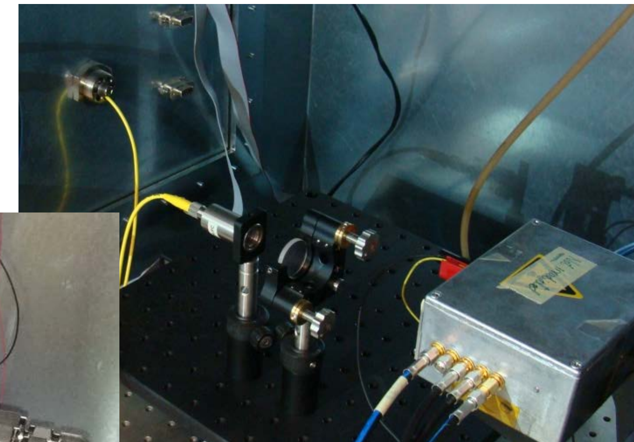
TCT Setups in the CERN SSD Lab



I-DLTS setup

TCT+ setup



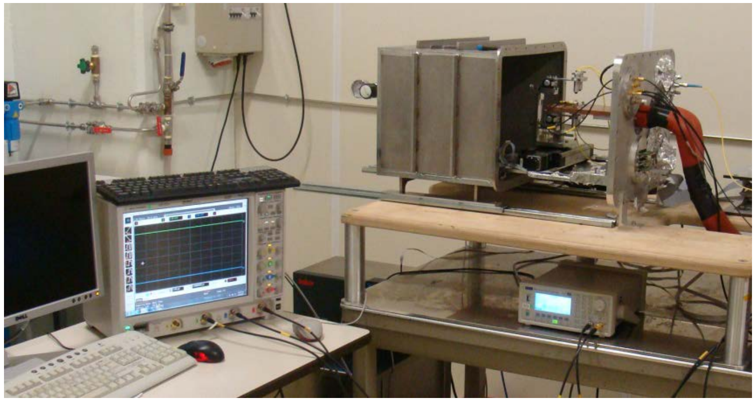
eTCT setup

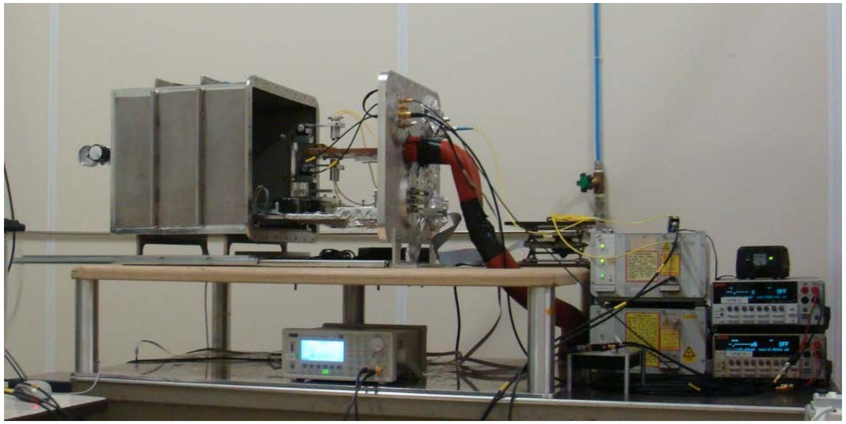
- I-DLTS setup based on former TCT setup
- eTCT setup
- TCT+ setup combines TCT and eTCT

Current-Deep Level Transient Spectroscopy (I-DLTS)

I-DLTS setup

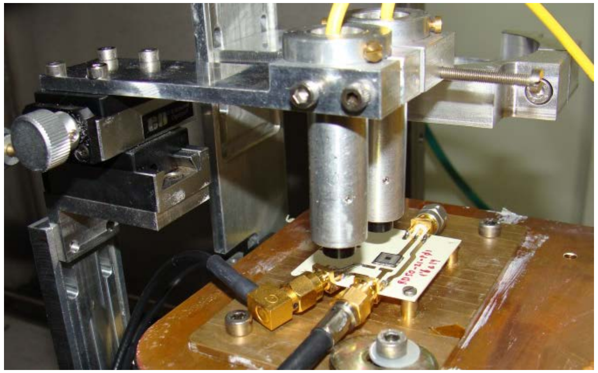
- Equipment
  - Huber CC505 chiller
    Temperature controlled (PT100)
    Minimum Temperature on the sample ca. -25C
  - µs-pulsed LASER
    - Red (660nm)
    - IR (1064nm)
  - Optics for red and IR illumination
    from top and bottom
  - Temperature measurement on the DUT
    (PT1000 with Keithley 2410)
  - Bias voltage up to 1000V
  - Bias Tee (V_{max} = 200V)
  - Shielded Box (Louvain-Box)
  - Agilent Scope (2.5GHz Bandwidth)
  - Reference diode for red and IR
- LabView based software to loop parameters
  - temperature, bias voltage, pulse width, pulse intensity and repetition

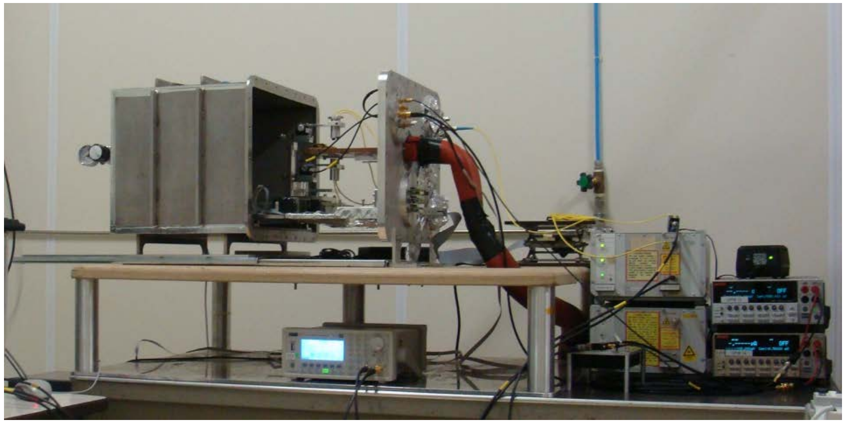




I-DLTS

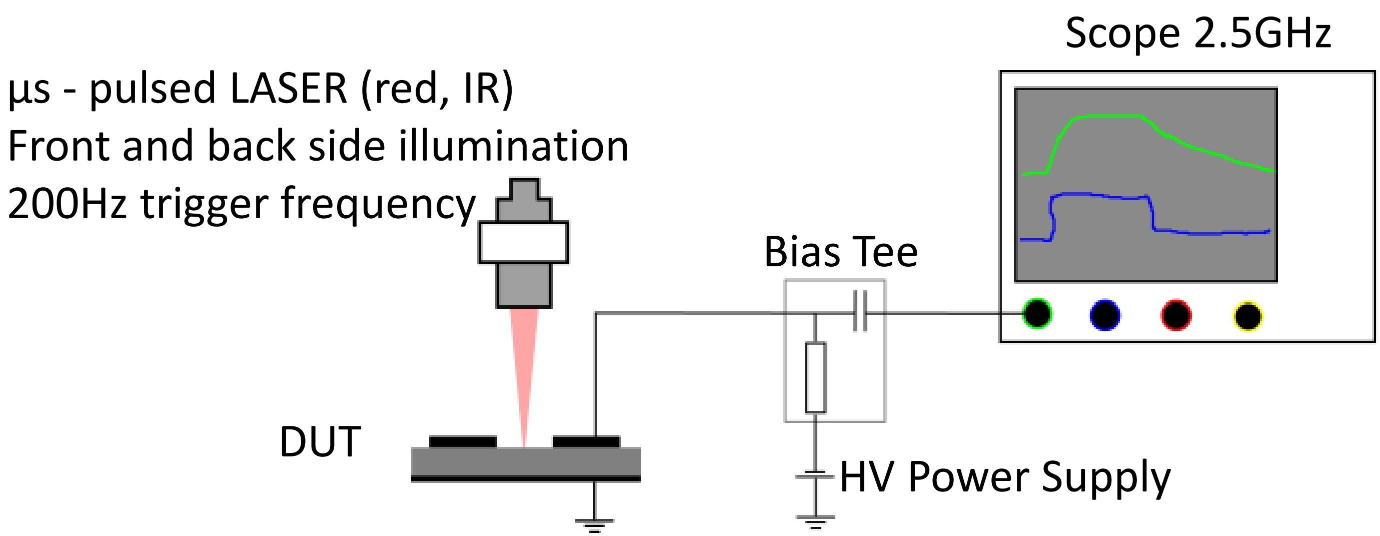
- Motivation
  - Improve understanding of charge carrier detrapping for defect characterization
  - Investigate energy levels and cross-section of detrapping centers





- Previous work:
  - G. Kramberger, et. al.; 2012 - JINST 7 P04006
    Determination of detrapping times in semiconductor detectors
  - M. Gabrysch, et.al.; 2012 - 21st RD50 Workshop
    Charge carrier detrapping in irradiated silicon sensors after microsecond laser pulses

I-DLTS Layout



- Illumination with μs-pulsed red and IR LASER pulses (> 0.5μs)
- Biasing up to 200V with maximum bandwidth (20kHz - 10GHz)
- No amplifier to keep maximum bandwidth
- Temperature controlled (> -25C)
- Scope with upper bandwidth limit 2.5GHz

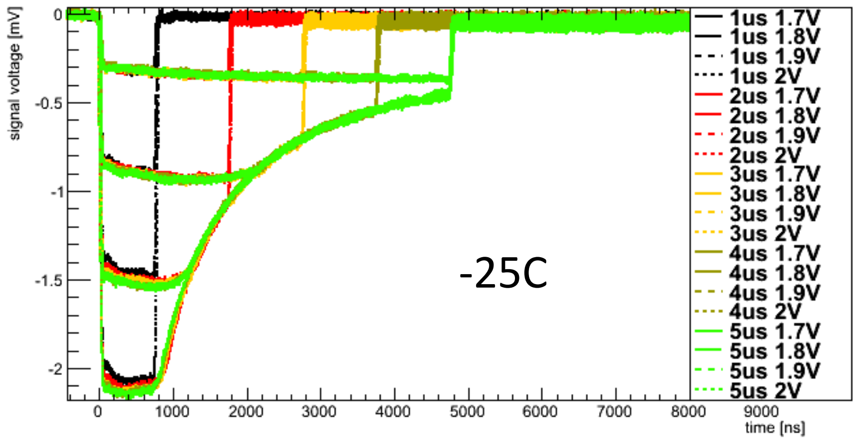
Samples and Parameter Space

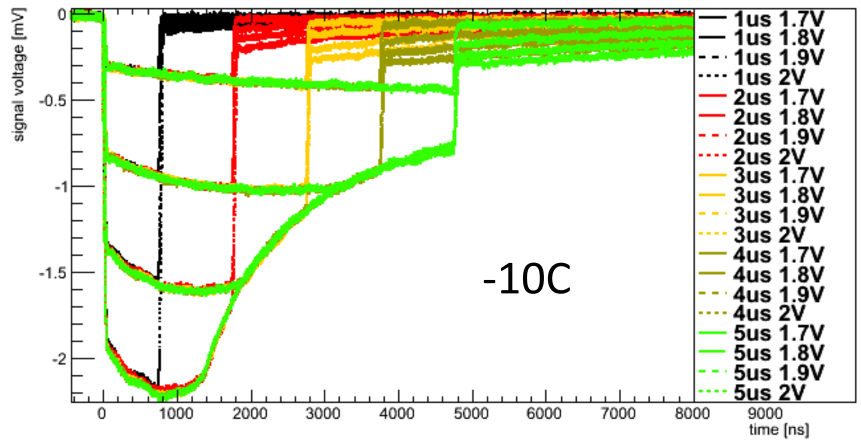
- Parameter space
  - Temperature
    - -20C to 20C in 5C steps
  - Voltage
    - 50V, 100V, 150V, 200V
  - Pulse width
    - 1us, 2us, 3us, 4us, 5us
  - LASER Intensity
    - 1.7V, 1.8V, 1.9V, 2.0V
  - Repetition:
    - Five repetitions for each scan point
- Micron Samples:
  - Thickness: 300µm
  - FZ and MCz n-in-p
  - Irradiation at CERN PS: 24GeV/c protons
  - Fluence: non irrad; 5×10^{13} p/cm^2 ; 5×10^{14} p/cm^2 ; 1×10^{15} p/cm^2
- Illumination: Red front

- Further measurements:
  - Scan parameter space with IR front, Red and IR back
  - Determination of most suitable parameter space for analysis

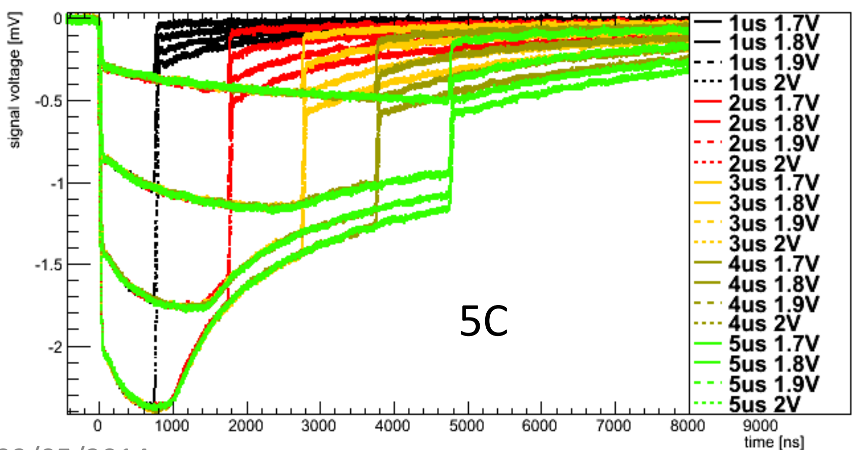
Current with Temperature

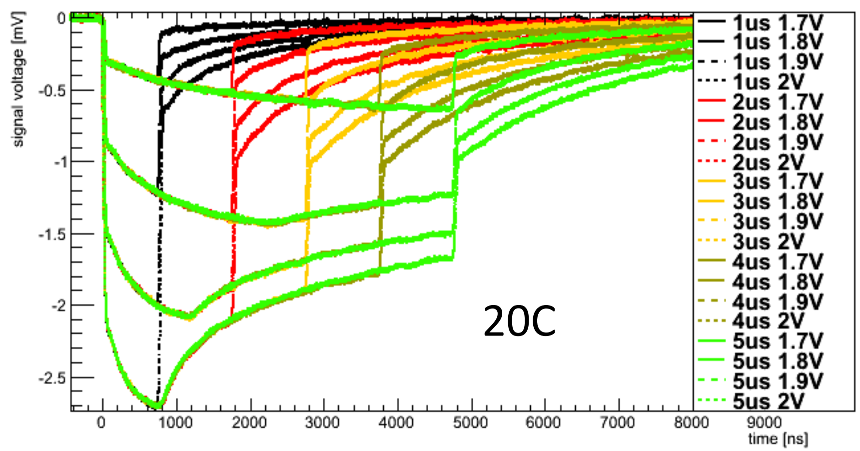
FZ n-in-p 1×10^{15} p/cm^2 at 200V
Intensity 2V



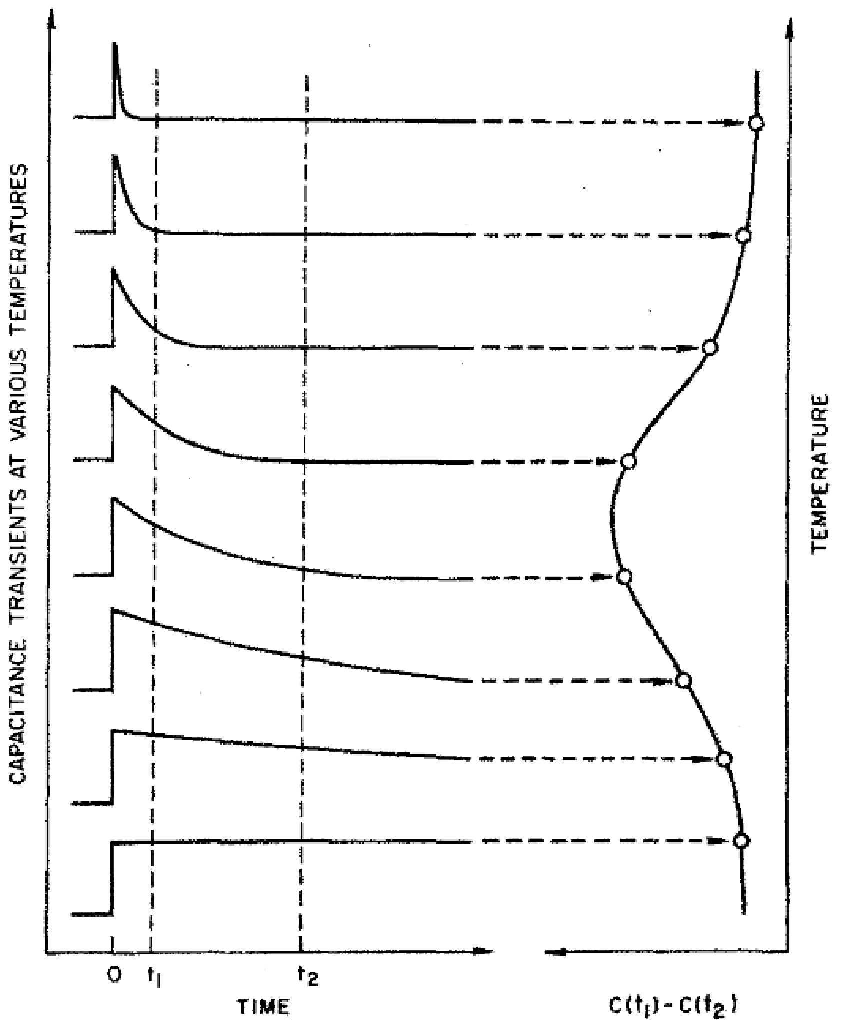


- Signal height after LASER pulse varies between 0mV at -25C and -1mV at 20C
- Current drop during pulse varies with temperature (also voltage)





Double Boxcar



- Select rate window defined by t_1 and t_2
- Determine signal variation Signal(t_1)-Signal(t_2) for different temperatures

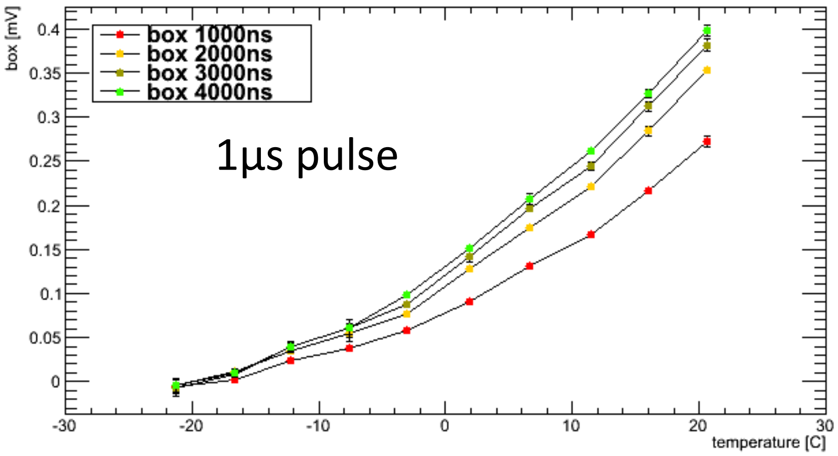
- Operation modes
  - t_1 fixed, vary t_2
  - t_2 fixed, vary t_1
  - t_1/t_2 fixed, vary t1 and t_2

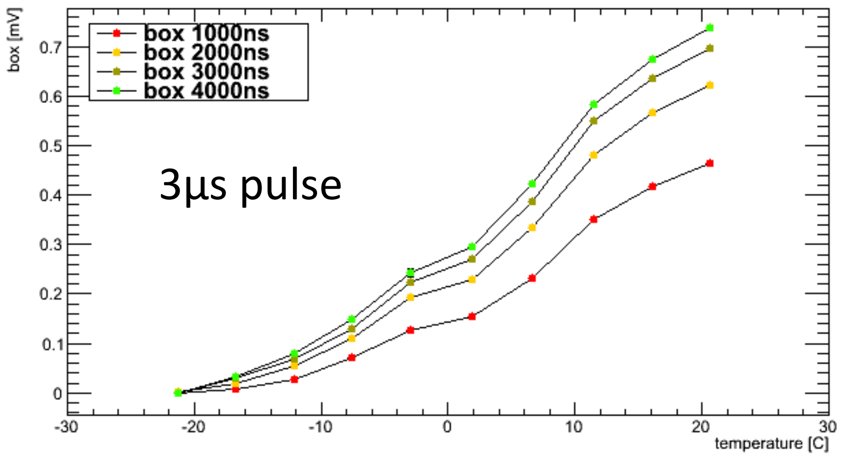
D. Lang; 1974 - J. Appl. Phys. 45
Deep-level transient spectroscopy: A new method to characterize traps in semiconductors

Box Plot for variable pulse width

FZ n-in-p 5 ×10^{14} p/cm^2 at 200V

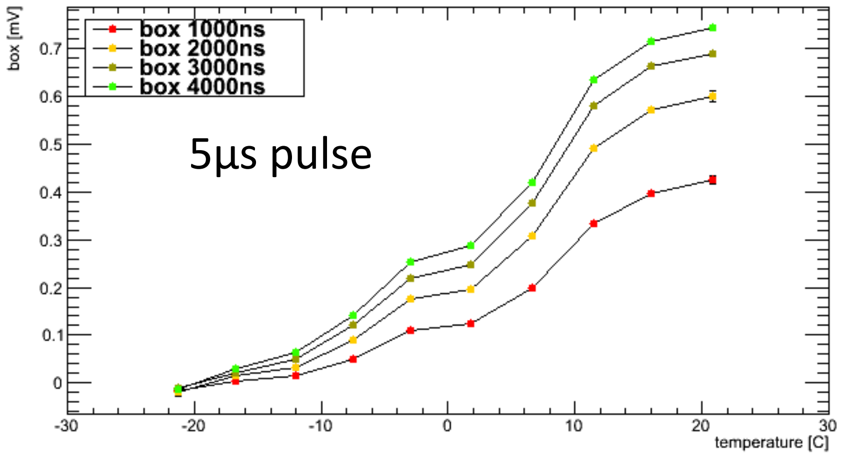
Intensity 2V





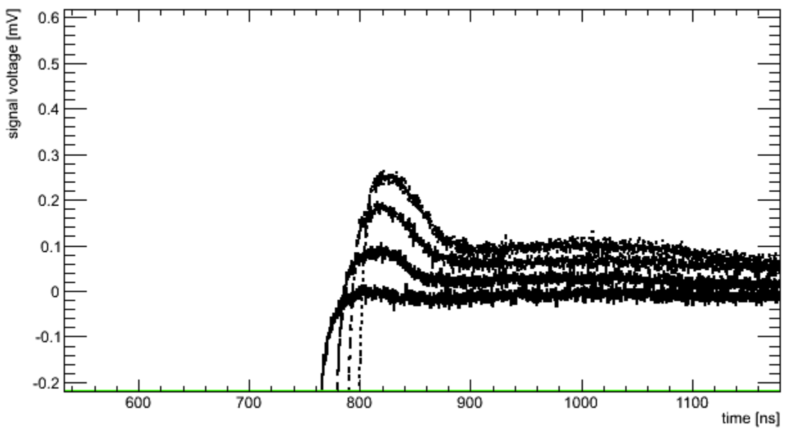
- t_1 fixed, 200ns after pulse
- vary t_2
  - Box width: 1μs, 2μs, 3μs and 4μs

- Box plot varies with LASER pulse width



Next Steps

- Influence of electronics on signal
  - Undershoot in unirradiated sample
  - Undershoot visible at low temperatures (low de-trapping)

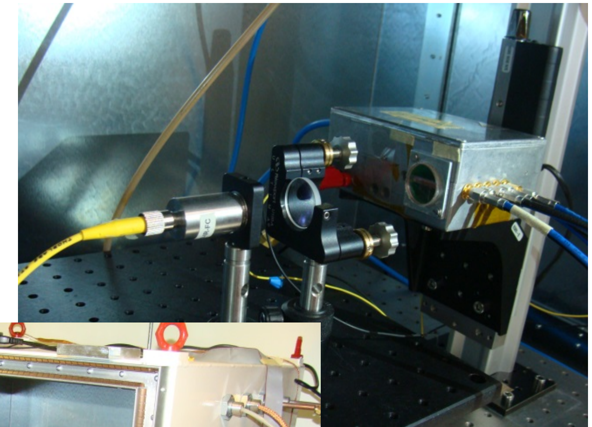


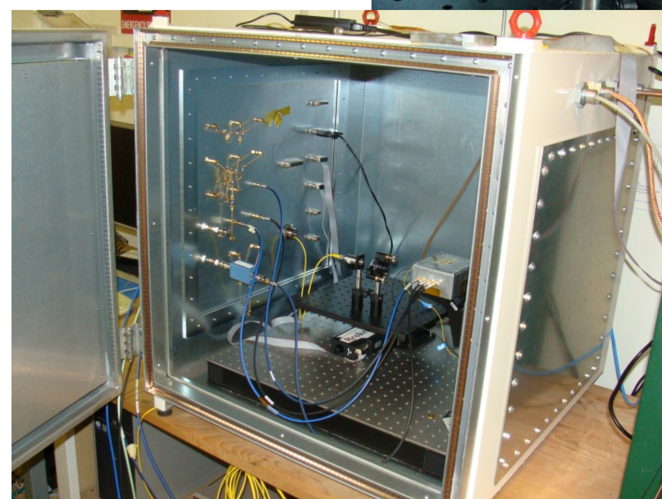
- Analysis following approach for TCT pulses (see: Kramberger, 2012 - JINST 7 P04006)
- Simulation
  - transient after laser pulse
  - Current drop during laser pulse

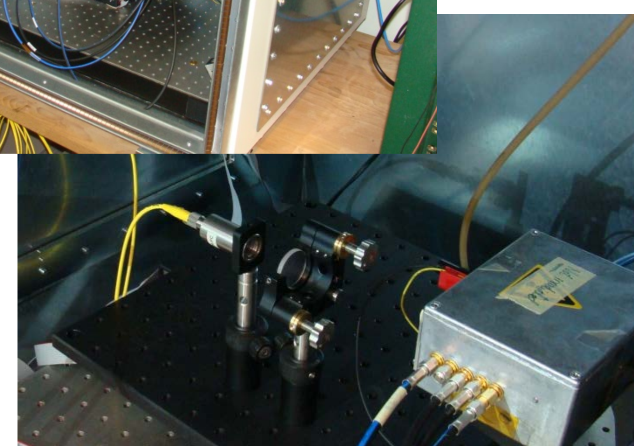
Edge-TCT

eTCT setup

- Equipment
  - Computer controlled Peltier cooling (PT1000)
    Min. Temperature on the DUT -20C
  - Annealing up to 60C directly in the setup
  - picosecond-pulsed IR LASER
  - Optics to illuminate the sample edge
  - Bias voltage up to 1000V
  - Wide bandwidth amplifier
  - Bias Tee for DC readout
  - EM shielded Box
  - Agilent Scope (2.5GHz Bandwidth)
  - XYZ stages with µm step width
- LabView based software to loop parameters
  - temperature, bias voltage and position

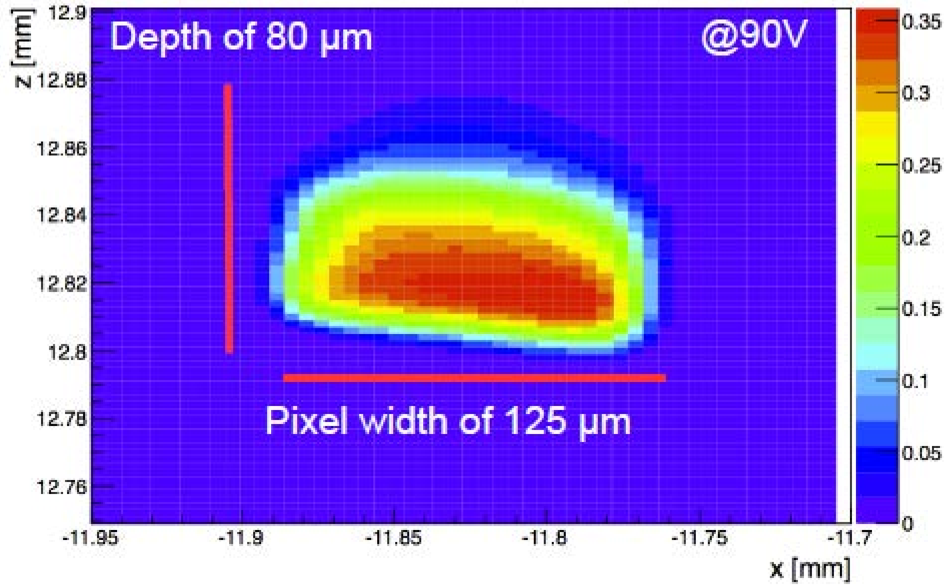




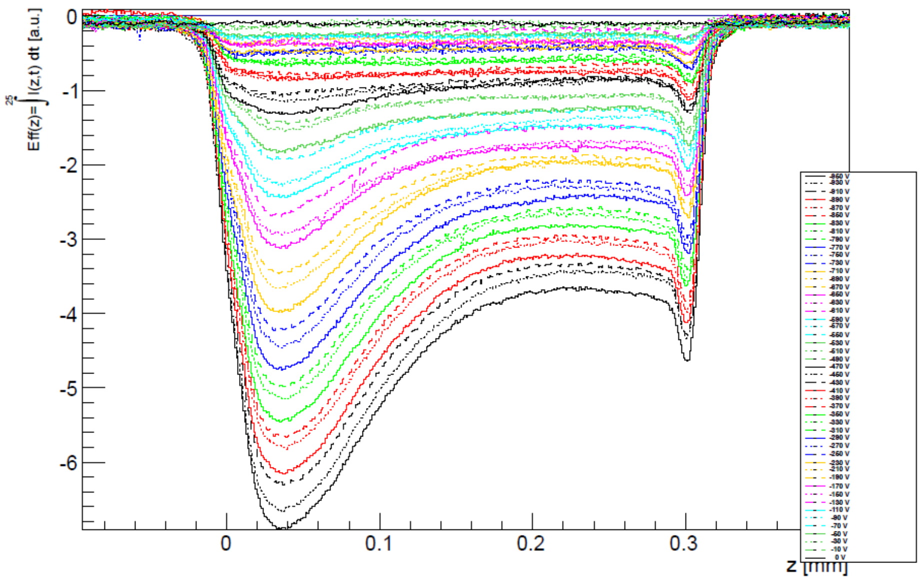


Recent eTCT measurements

- eTCT measurements on HV-CMOS
  - D. Muenstermann, et.al.; 2013 – 23rd RD50 Workshop
    Active pixel sensors in 180 nm HV CMOS technology for HL-LHC detector upgrades



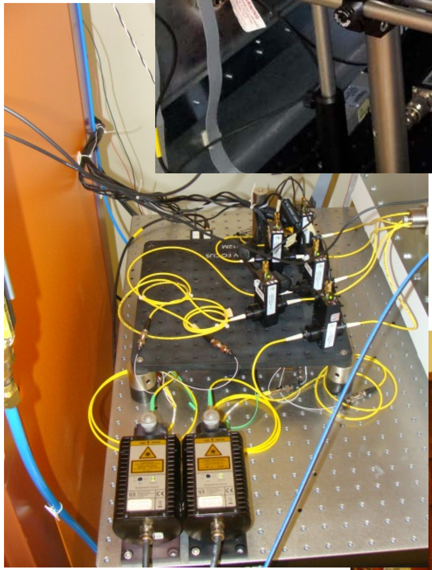
- Irradiated Micron strip sensors
  - S. Wonsak, et.al.; 2014 – 24th RD50 Workshop
    Status of Silicon Strip Sensor Measurements at Liverpool

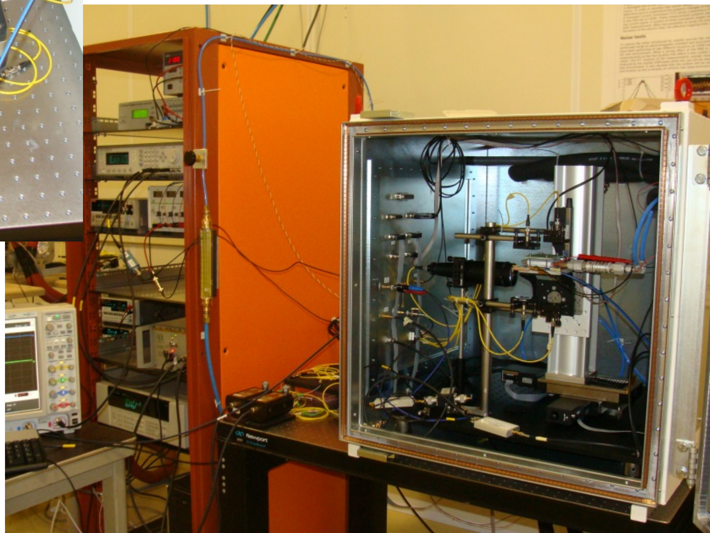


TCT+ a common setup for TCT and eTCT

TCT+ Setup

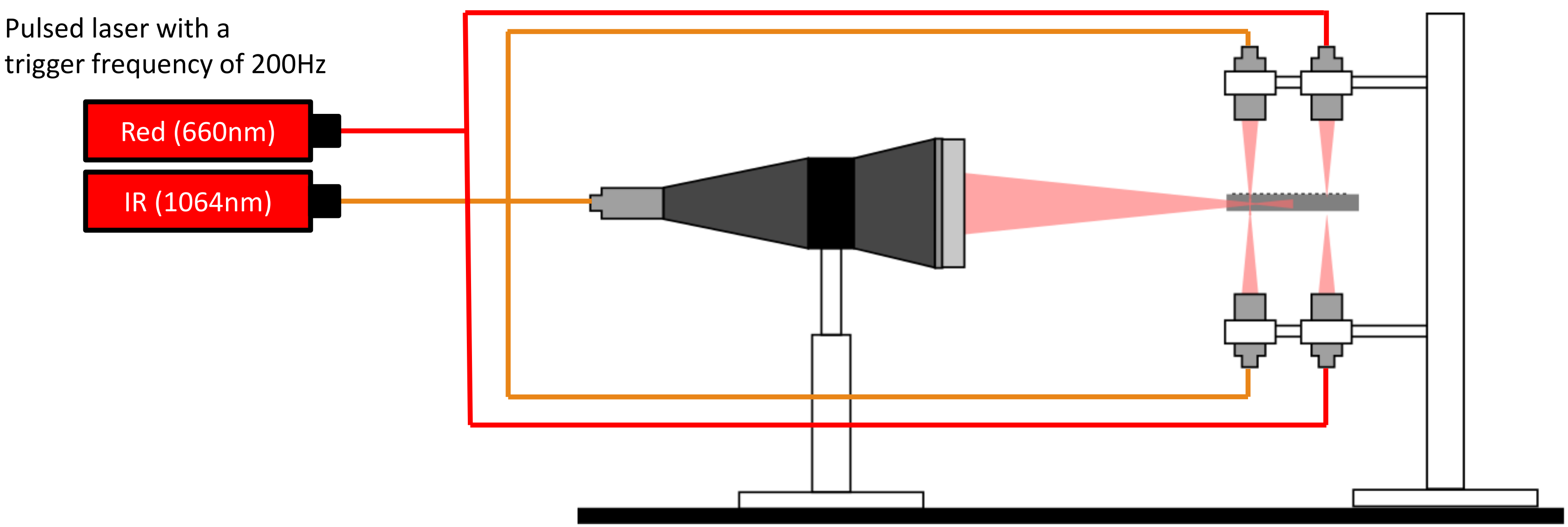
- Equipment
  - Computer controlled Peltier cooling (PT1000) with Huber CC505 chiller Min. Temperature on the DUT -20C
  - picosecond-pulsed LASER
    - Red (660nm)
    - IR (1064nm)
  - Optics for illumination
    - Top red and IR
    - Bottom red and IR
    - Sample edge IR
  - Bias voltage up to 1000V
  - Wide bandwidth amplifier
  - Bias Tee for AC readout
  - EM shielded Box
  - Agilent Scope (2.5GHz Bandwidth)
  - XYZ stages with µm step width
- LabView based software to loop parameters
  - temperature, bias voltage, position and repetition





TCT+ Layout

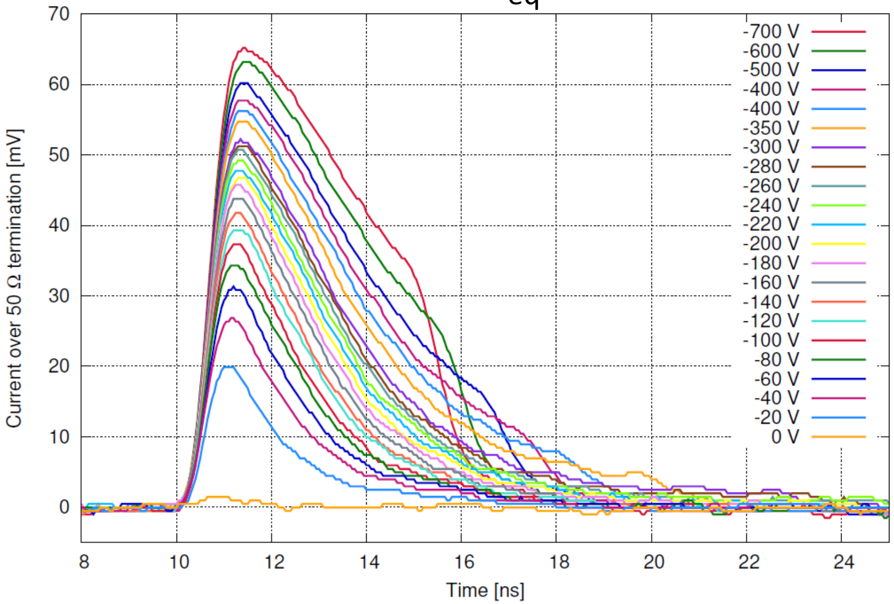
- Combination of a conventional red and IR TCT setup with an edge-TCT setup
- Temperature controlled Peltier/Chiller cooling system.
- Stage system provides µm steps in X, Y and Z



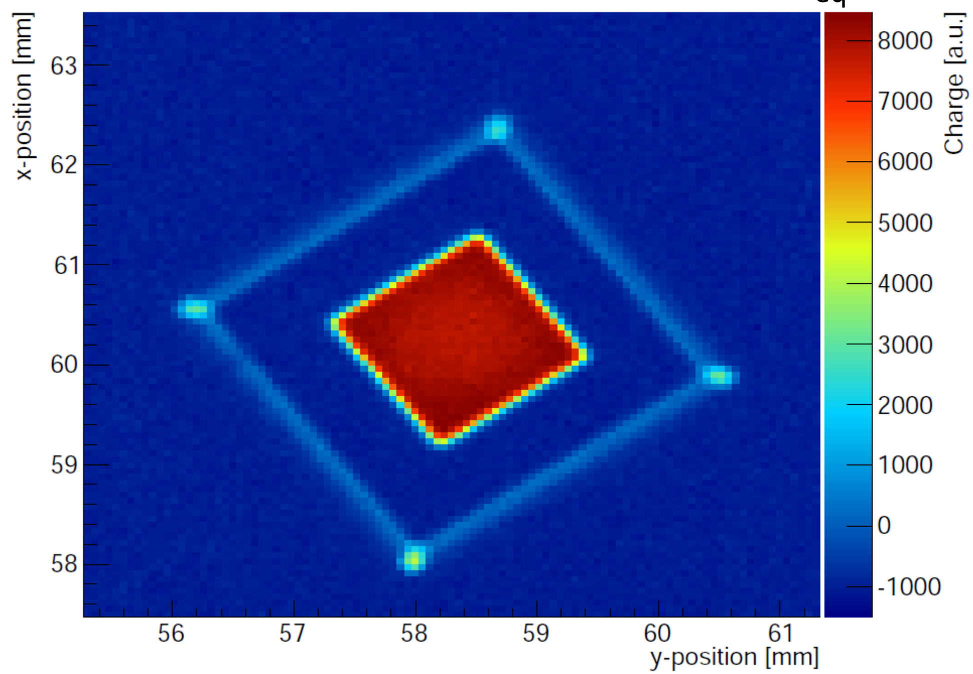
Measurements with TCT+ Irradiated MCz diodes

- Irradiated MCz diodes (70MeV protons)

$\Phi = 5 \times 10^{14}\ n_{eq}/cm^2$



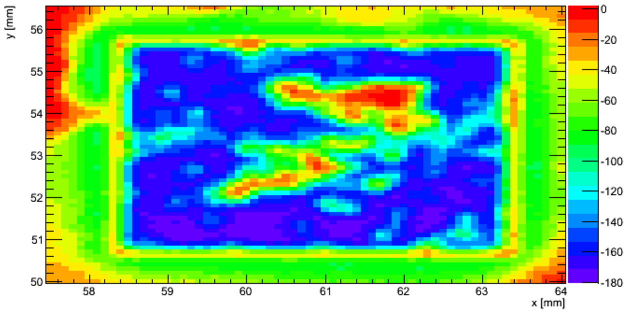
$\Phi = 1 \times 10^{13}\ n_{eq}/cm^2$



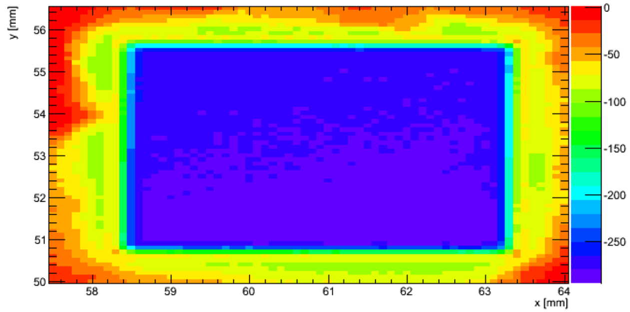
- R. Carney – Master Thesis; University of Edinburgh
  Investigation of Magnetic Czochralski diodes using novel TCT setup for future silicon detectors

Measurements with TCT+ Diodes with amplification

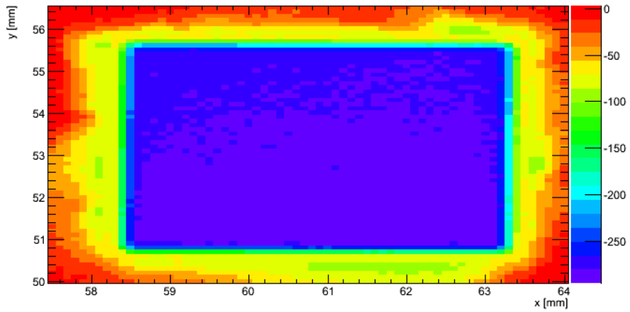
Surface scan with red LASER front



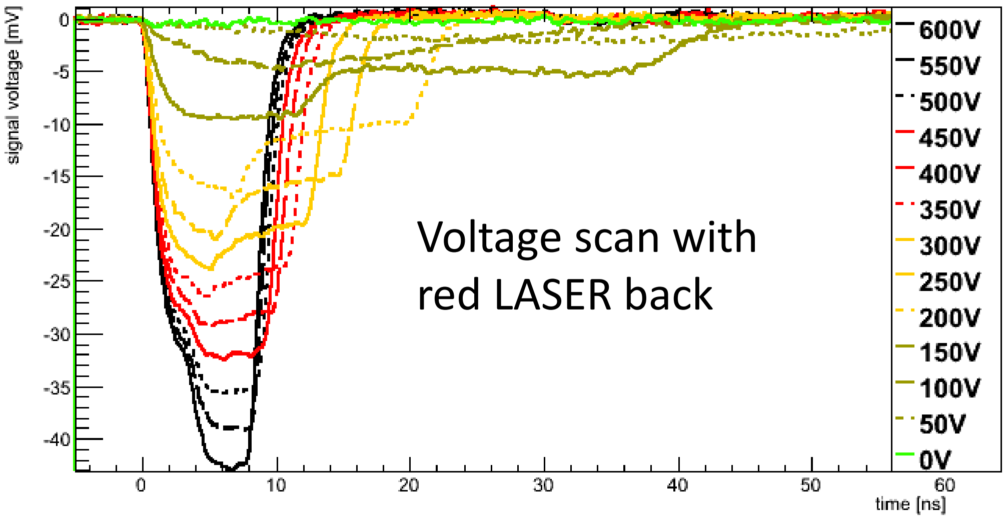
Bias = 50V



Bias = 150V



Bias = 150V

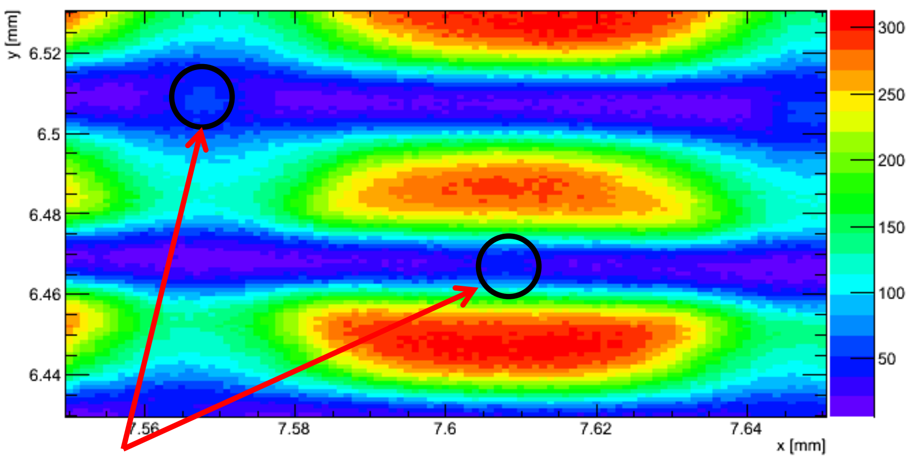


- V. Greco , et.al.; 2014 – 24th RD50 Workshop
  Preliminary results on proton irradiated LGAD PAD detectors

Measurements with TCT+ 3D strip diodes

- Single sided 3D strip diodes on SOI from CNM

Surface scan with IR LASER at 70V



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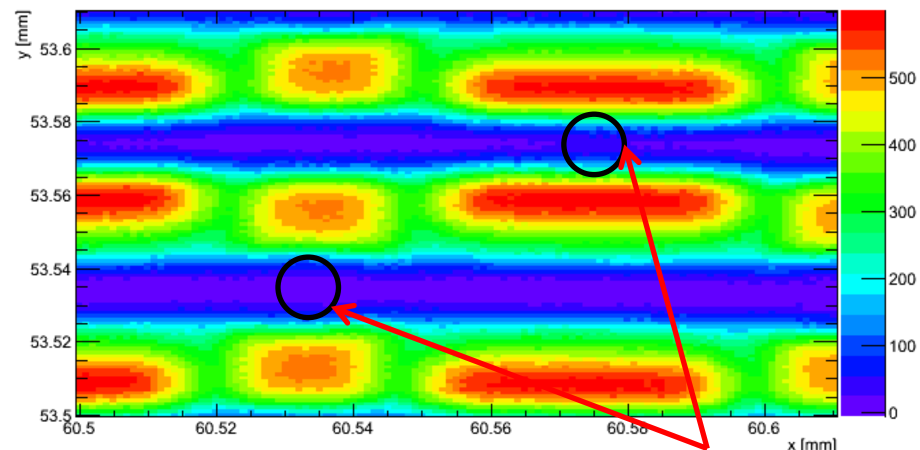
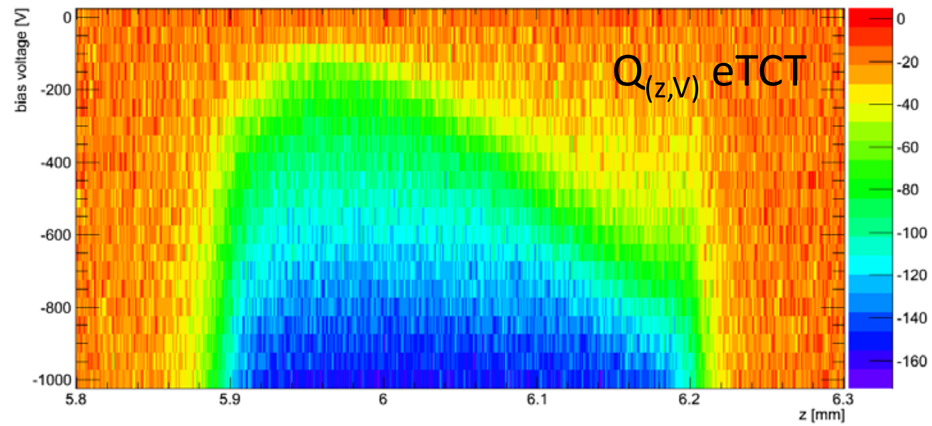
Surface scan with red LASER at 70V

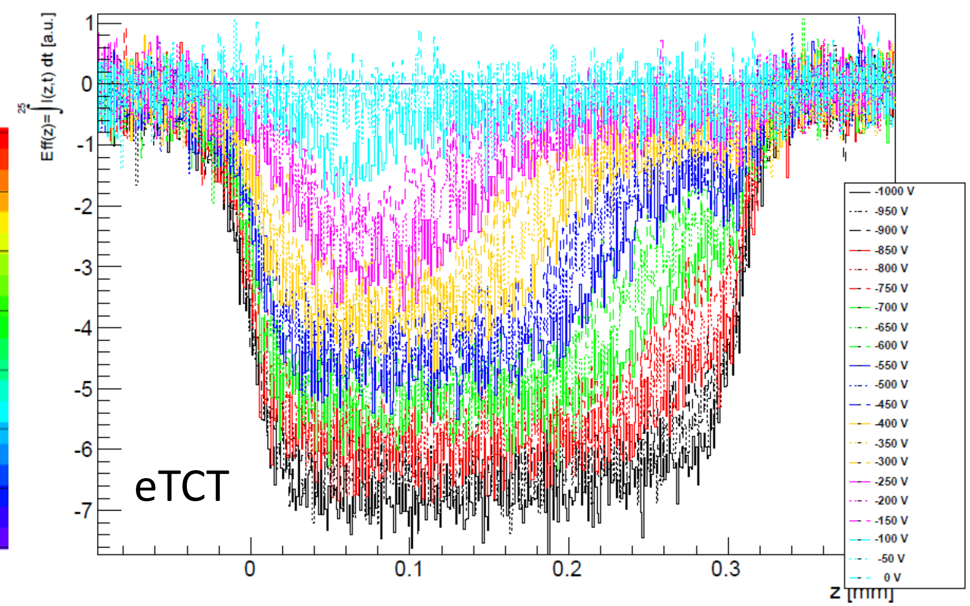


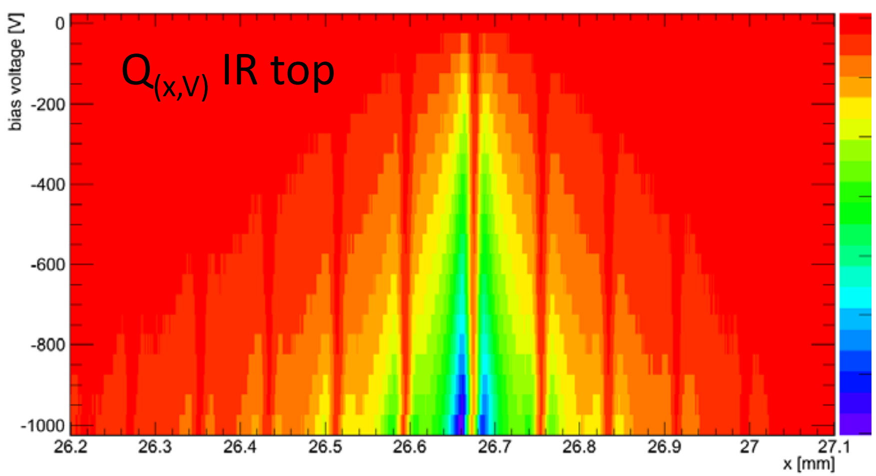
columns

Measurements with TCT+ irradiated strip sensors from Micron

- TCT and eTCT on $1\times10^{15}\ n_{eq}/cm^2$ irradiated strip sensors
  - S. Wonsak, et.al.; 2014 – 24th RD50 Workshop Status of Silicon Strip Sensor Measurements at Liverpool

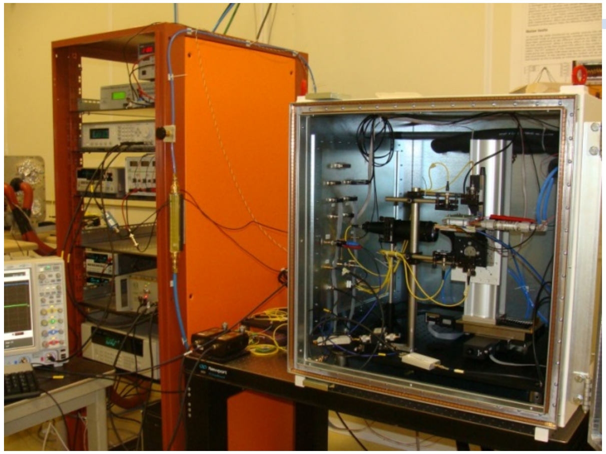


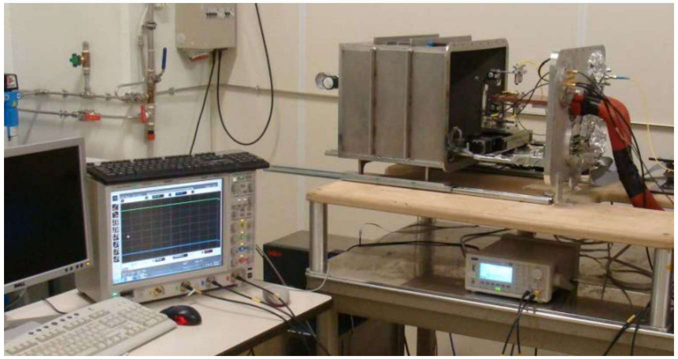




Upcoming measurement

- Irradiated Micron diodes 24GeV/c protons (FZ, MCz)
  - non-irrad., 5.9×10^{13} p/cm^2 , 1.0×10^{14} p/cm^2 , 5.3×10^{14} p/cm^2 , 9.8×10^{14} p/cm^2 , 2.0×10^{15} p/cm^2 , 4.4×10^{16} p/cm^2
- Irradiated Micron strip sensor 24GeV/c protons (FZ, MCz)
  - non-irrad., 6.9×10^{14} p/cm^2, 9.7×10^{14} p/cm^2, 1.9×10^{15} p/cm^2, 3.1×10^{16} p/cm^2
- Pion irradiated STMicroelectronics diodes
  - non-irrad., 1×10^{11} π/cm^2, 3×10^{11} π/cm^2, 1×10^{12} π/cm^2, 3×10^{12} π/cm^2, 1×10^{13} π/cm^2, 3×10^{13} π/cm^2, 1×10^{14} π/cm^2, 3×10^{14} π/cm^2, 7×10^{14} π/cm^2





Thanks for your attention

Questions?