RD39 Status Report 2007

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http://rd39.web.cern.ch/RD39/

Outline

1. Trapping effect on Charge Collection Efficiency (CCE) in SLHC
2. Operation of current-injected-detectors (CID)
3. CCE measurements on CID
4. How to demonstrate CID as segmented detector attached to read-out electronics and DAQ ?
5. Development of Edgeless detectors
6. Summary

Trapping effect on CCE in S-LHC

Trapping term

$$CCE = CCE_{GF} \times CCE_t = \frac{w}{d} \cdot e^{-t_{dr}/\tau_t}$$

Depletion term

Overall CCE is product of

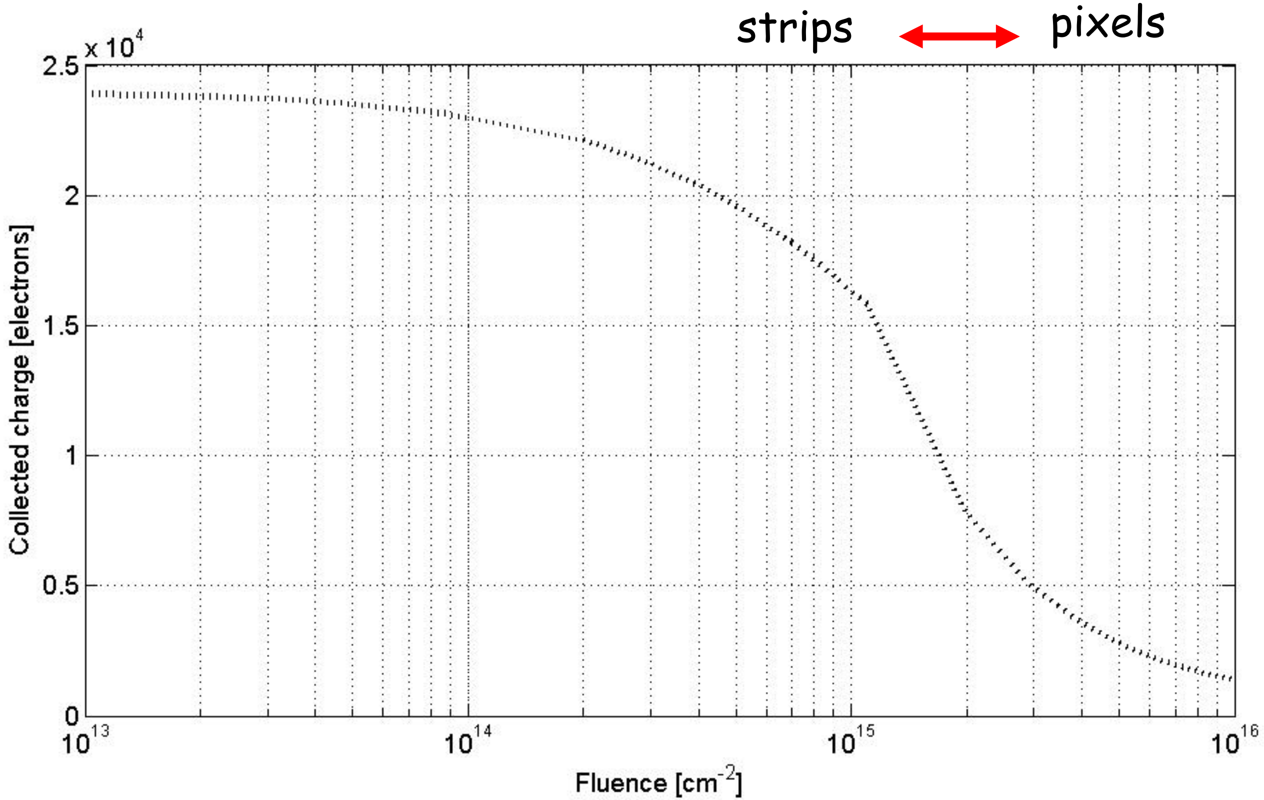
- CCE_t is trapping factor
- CCE_{GF} is geometrical factor

$$w = \sqrt{\frac{2\varepsilon\varepsilon_0 V}{eN_{eff}}} \text{ and } \frac{w}{d} = \sqrt{\frac{V}{V_{fd}}}$$

For fluence less than 10^{15} n/cm^2, the trapping term CCE_t is significant

For fluence 10^{16} n/cm^2, the trapping term CCE_t is a limiting factor of detector operation !

Expected Charge Collection Efficiency at 240K



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

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

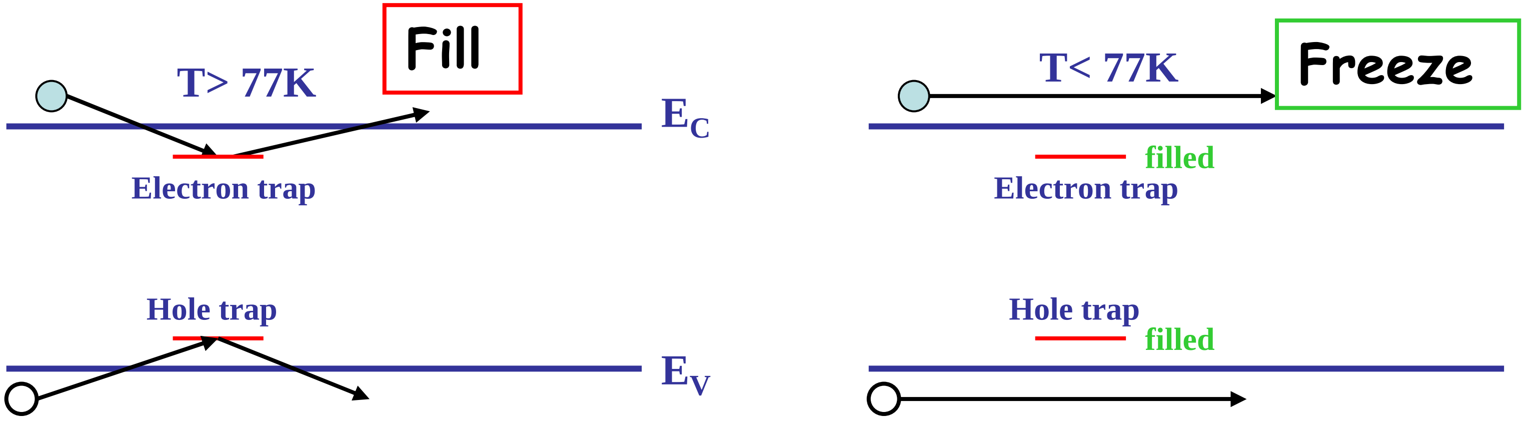
1×10^{14} n_{eq}/cm^2	τ_{trap}=10ns
1×10^{15} n_{eq}/cm^2	τ_{trap}=1ns
1×10^{16} n_{eq}/cm^2	τ_{trap}=0.1ns

Current Injected Detector CID –Operational Principle 1.

1. Trapping is balanced by the detrapping. At the “low” temperature, the traps remain filled considerably long time (>>shaping time of Read-out electronics)

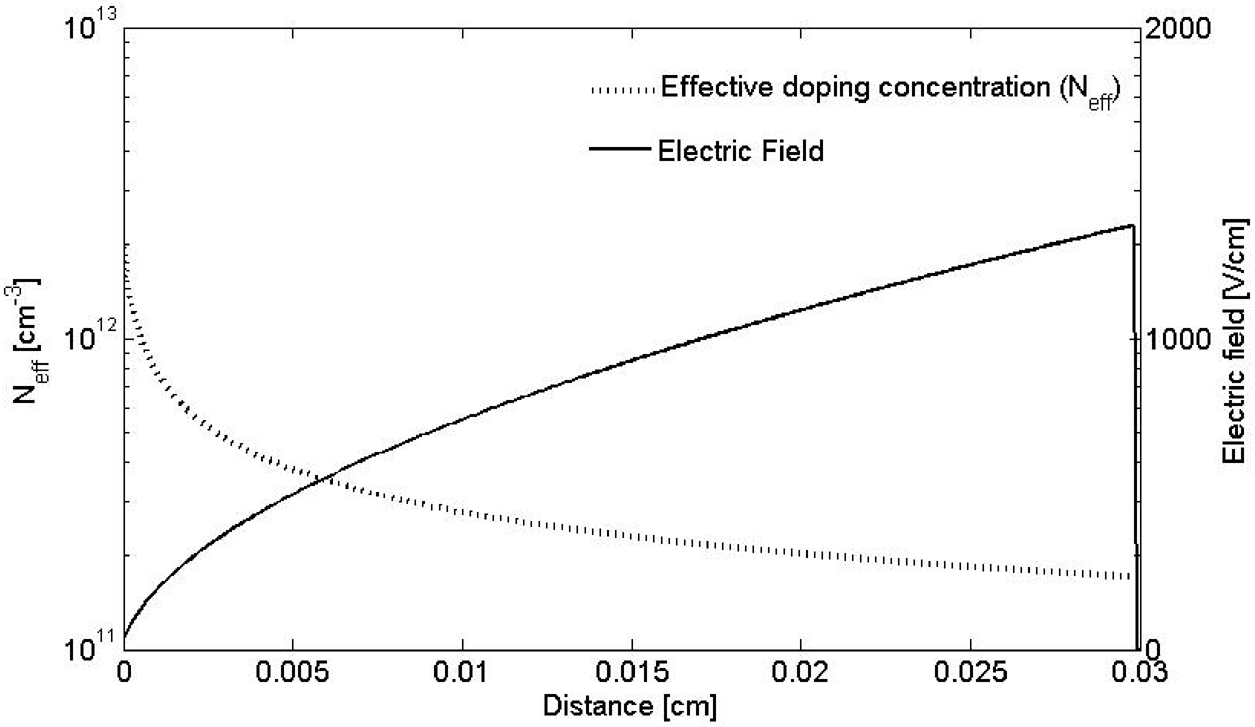
$$\tau_t = \frac{1}{\sigma v_{th} N_t}$$

$$\tau_d = \frac{1}{\sigma v_{th} N_C e^{-E_t/kT}}$$



CID –Operational Principle 2.

2. The electric field is controlled by charge injection, i.e. charge is trapped but not detrapped at “low” temperature



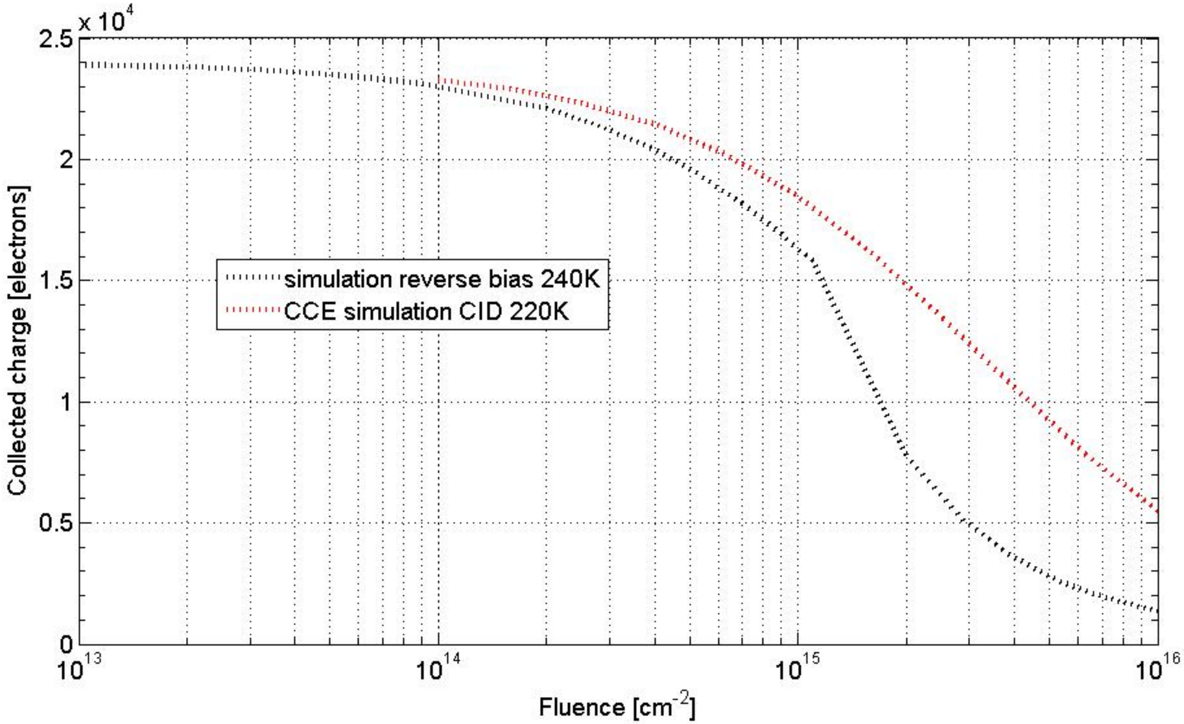
Electric field is extended through entire bulk regardless of irradiation fluence.

Electric field is proportional to square of distance E(x)~√x

Detector is “fully depleted” at any bias or irradiation fluence

Expected CCE of CID at 240K

strips ⟷ pixels

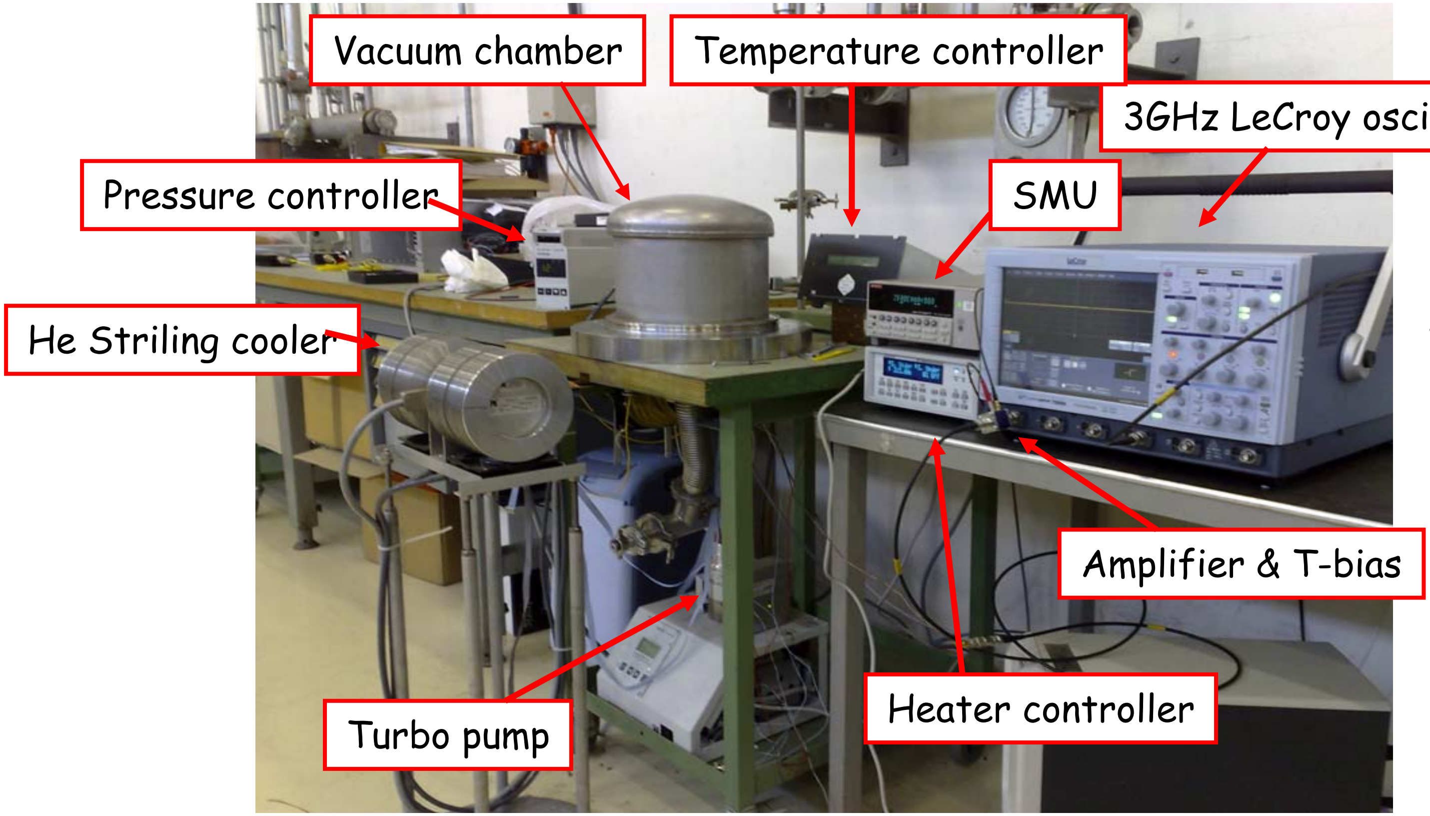


- Simulation takes into account linear trapping
- β=0.01 cm^{-1}
- √x E-field distribution is assumed

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

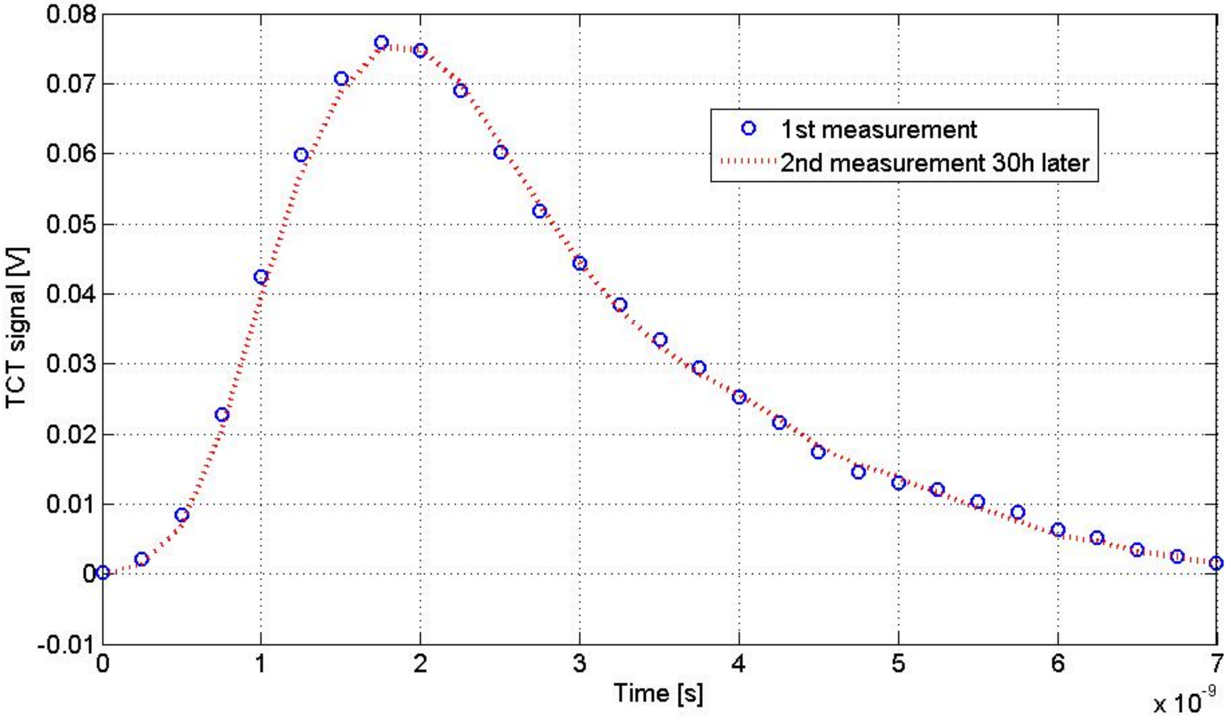
$$CCE = CCE_{Geometrical} \times CCE_{trapping} = \frac{w}{d} \times e^{-t_{dr}/\tau_{trapping}}$$

Cryogenic Transient Current Technique (C-TCT) -Tool to study trapping effects



Project completed this year.

CCE with infrared laser

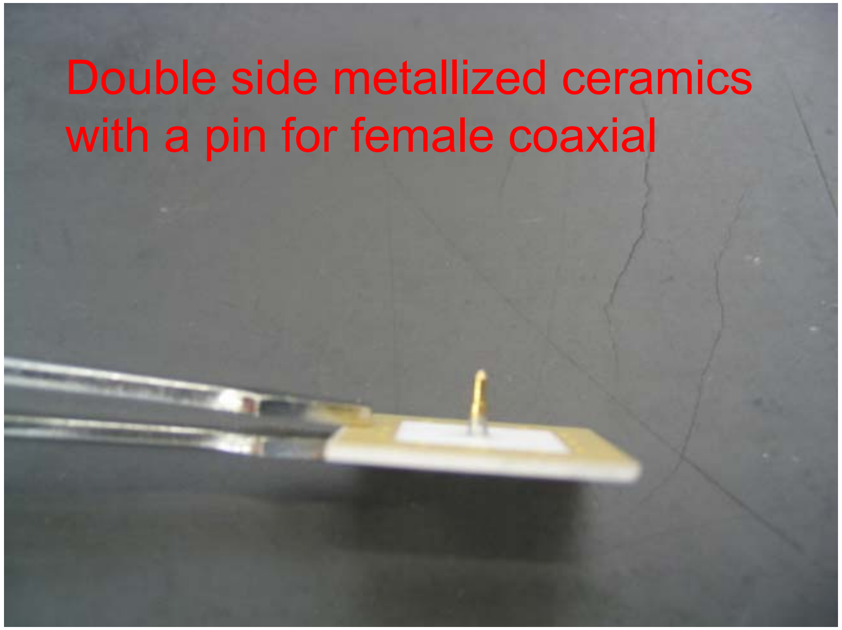


- Comparison of irradiated sample and non-irradiated reference
- Samples prepared *excatly* same manner
- High gain (~600) amplifier
- Injection level 10-20 MIPs

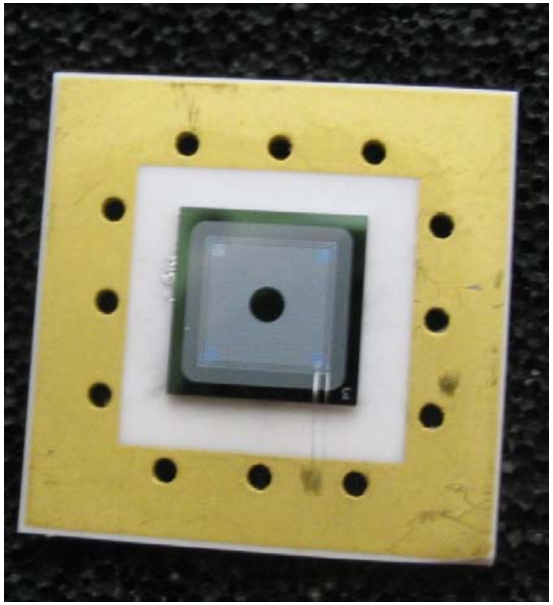
Stability of IR laser over ~30 hours

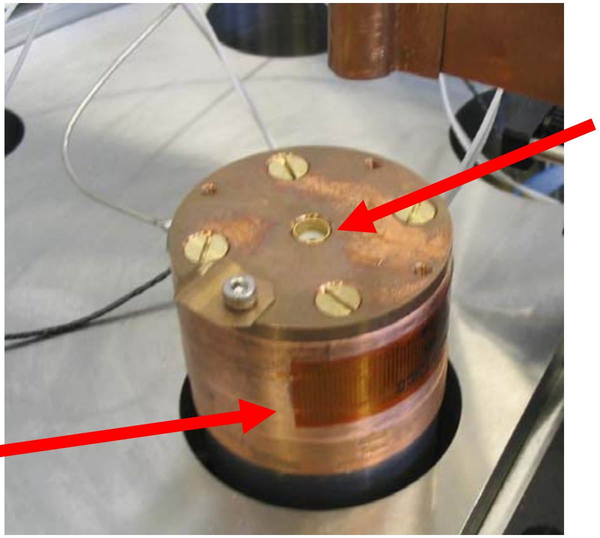
Samples adjustment

- Ceramic sample holders



Double side metallized ceramics with a pin for female coaxial

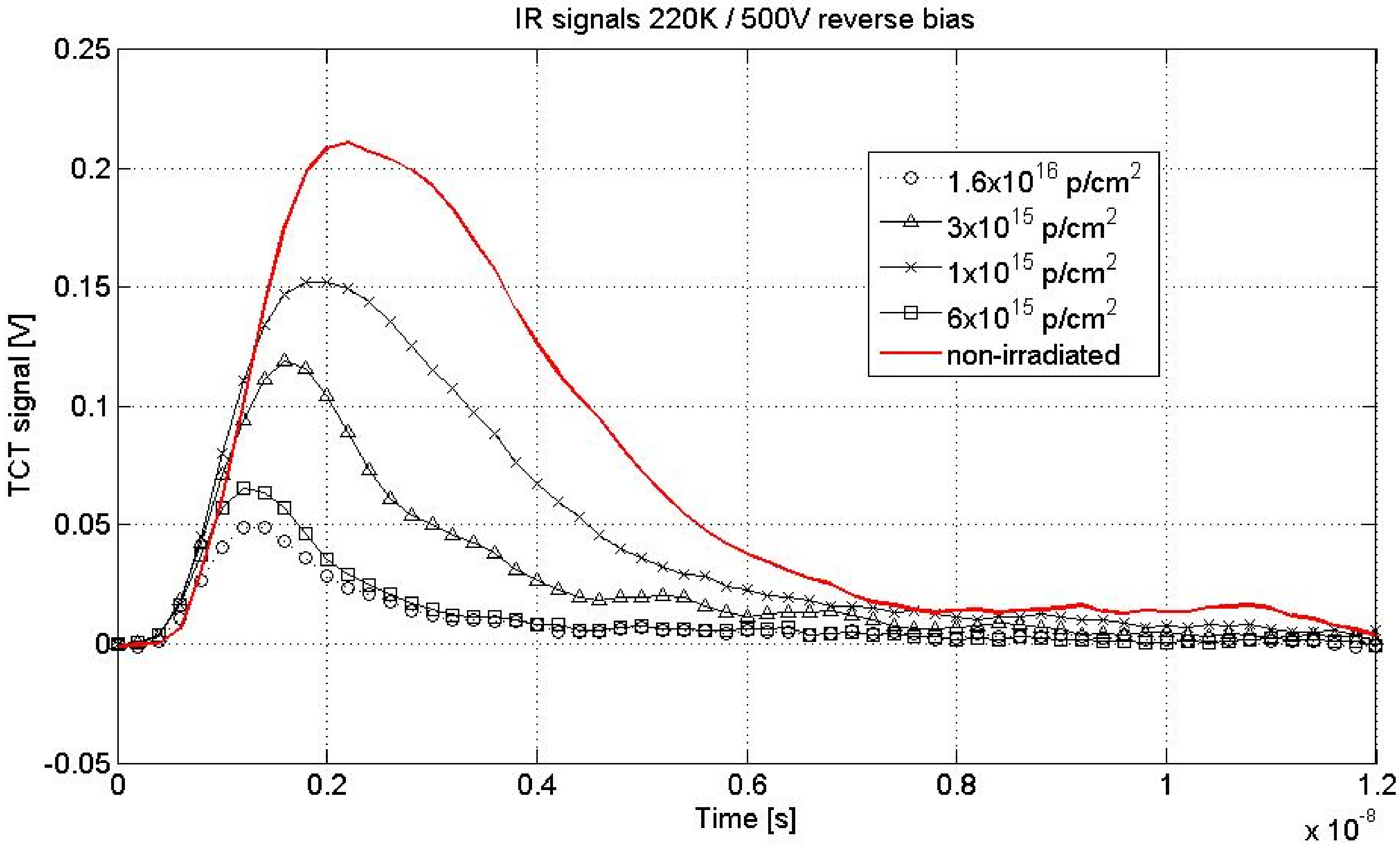




Cold finger and coaxial connector

Heating resistor provides faster temperature ramping

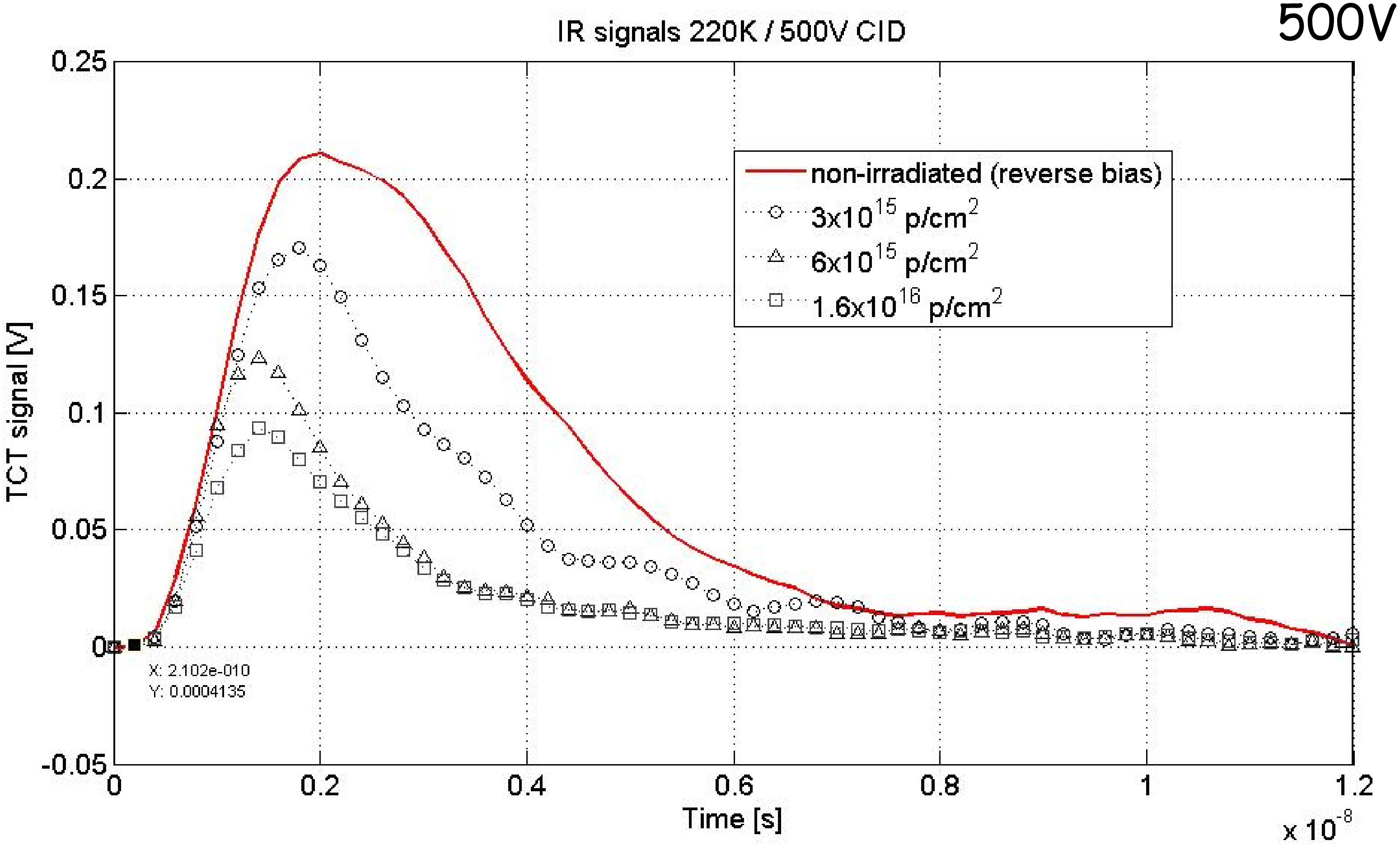
IR signals of 24 GeV/c irradiated pad detectors (Reverse bias)



500V / 220K

IR signals of 24 GeV/c irradiated pad detectors CID

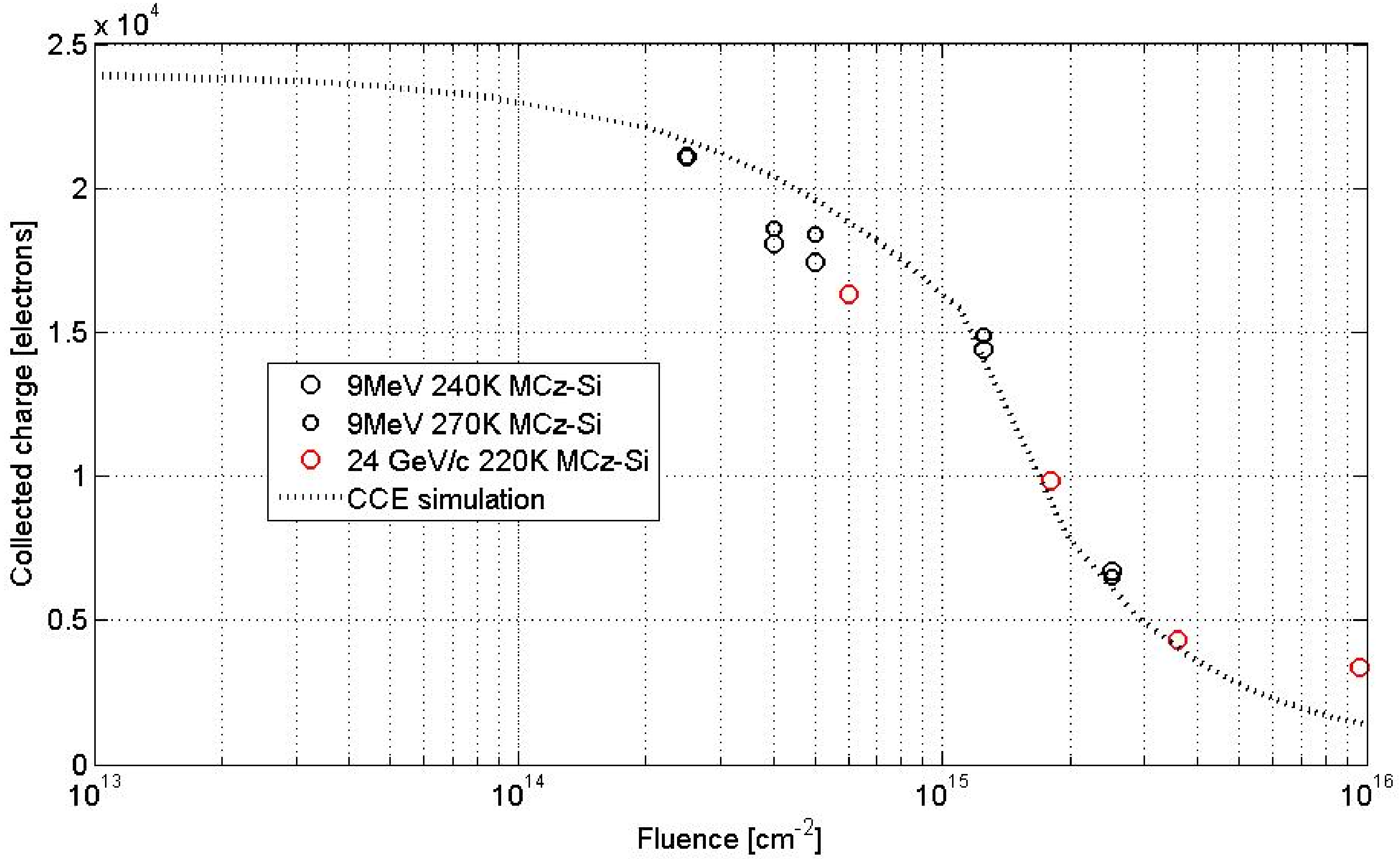
500V / 220K



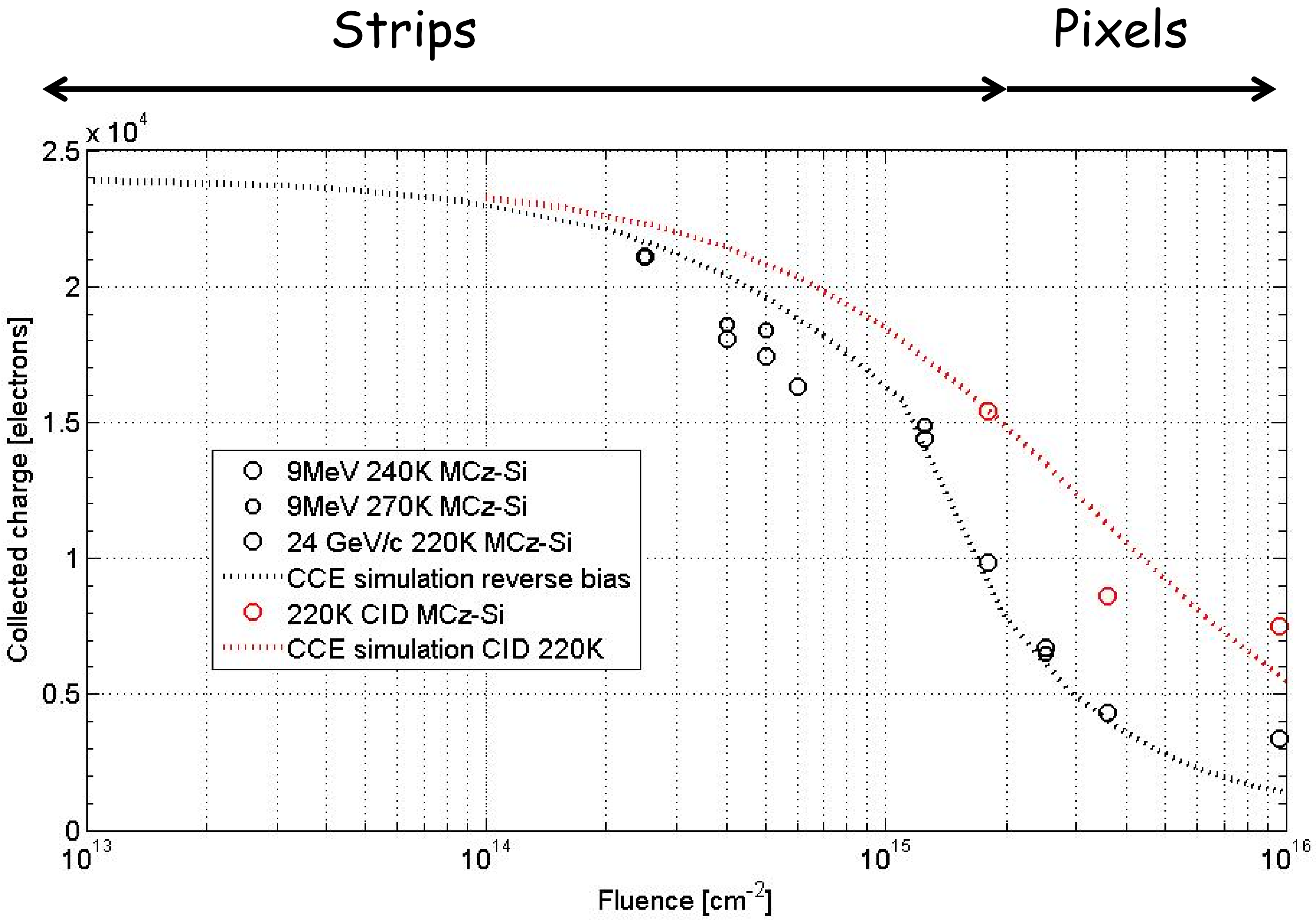
Charge Collection Efficiency (Reverse bias)

Strips

Pixels



Charge Collection Efficiency (Reverse bias and CID)

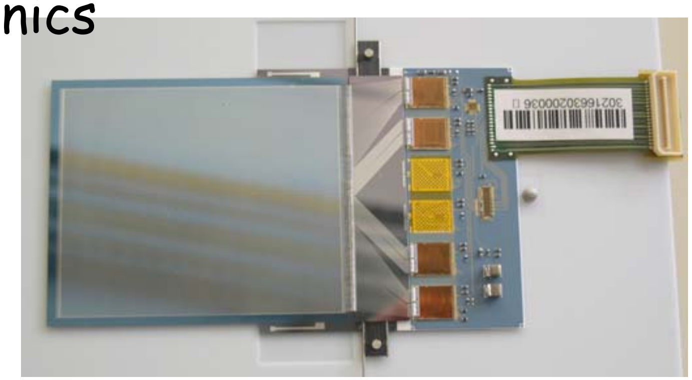


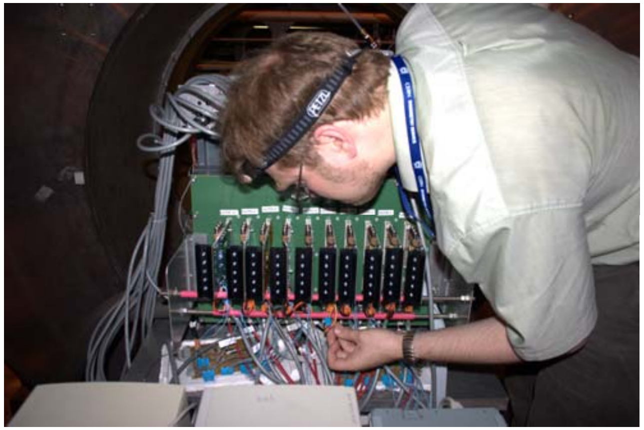
How to implement CID for segmented devices with read-out ?

- Beam telescope (SiBT) with CMS electronics and DAQ was build and tested this year
- SiBT Collaboration:

- Helsinki Institute of Physics (RD39)
- Universität Karlsruhe (RD39)
- Université Catholique de Louvain (RD39)
- Fermilab
- Università di Padova
- University of Rochester

http://eija.home.cern.ch/eija/sibt.html





Cooling box designed to operate at -20^{0}C. Additional cooling for irradiated sensor is needed

Reference detectors

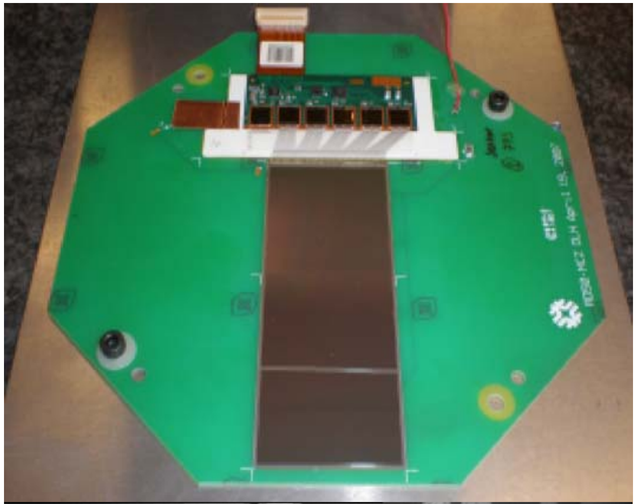
- Reference detectors are Hamamatsu sensors made for Fermilab D0 run IIb
  - 60 micron pitch
  - intermediate strips
  - size 4 cm x 9 cm
  - 639 channels

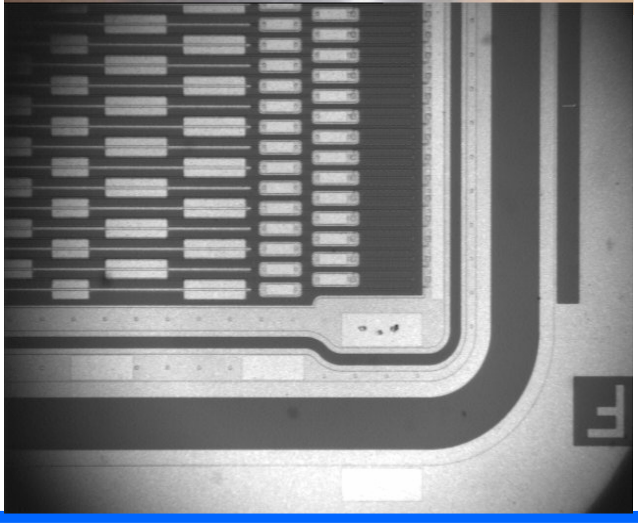
- Readout electronics: CMS 6-APV chip Tracker Outer Barrel hybrids (5 chips bonded)

- The reference detector modules were built in Fermilab.

- The interpolated position resolution of the SiBT was found to be 9 μm, it has a S/N of 25, and an active area of 4 x 4 cm^2.

Photo:Lenny Spiege, FNAL





See talks:

Panja Luukka: Silicon beam telescope for CMS SLHC detector studies (SiBT)

Martin Frey: Results of a beamtest with irradiated M-Cz sensors

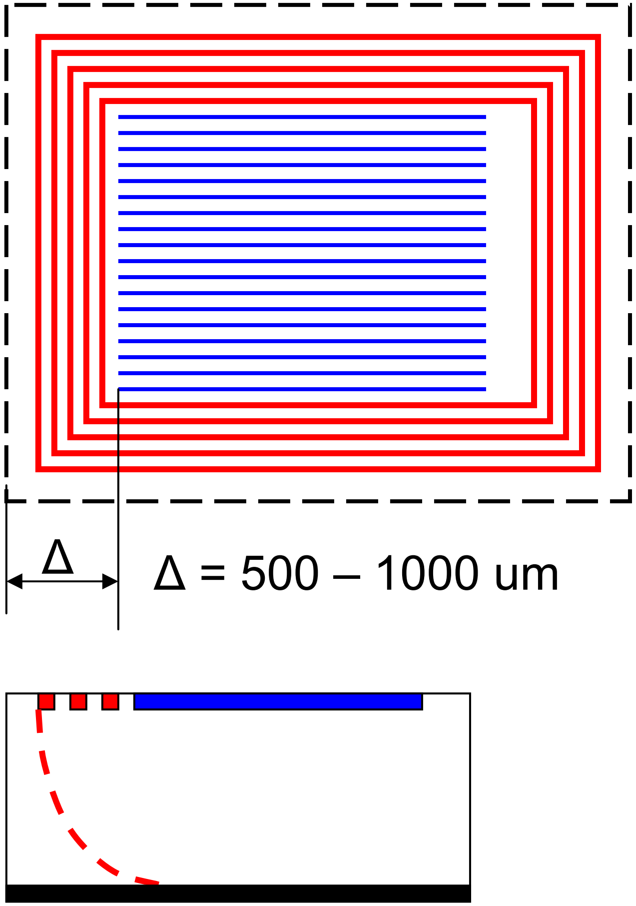
http://indico.cern.ch/conferenceOtherViews.py?view=cdsagenda&confId=22469

Burt Beckhart: Recent results on MCz microstrip devices

http://indico.cern.ch/conferenceDisplay.py?confId=18863

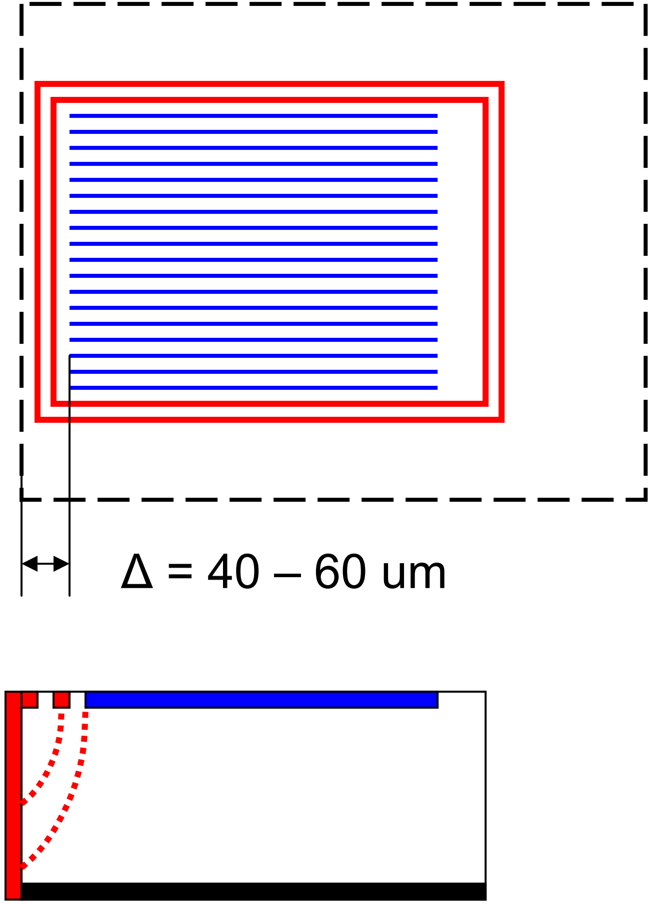
Existing approaches for edgeless detectors

Regular detectors
Voltage Terminating structure (=guard ring)



Δ = 500 – 1000 um

Current Terminating Structure (CTS)
edgeless detectors for TOTEM

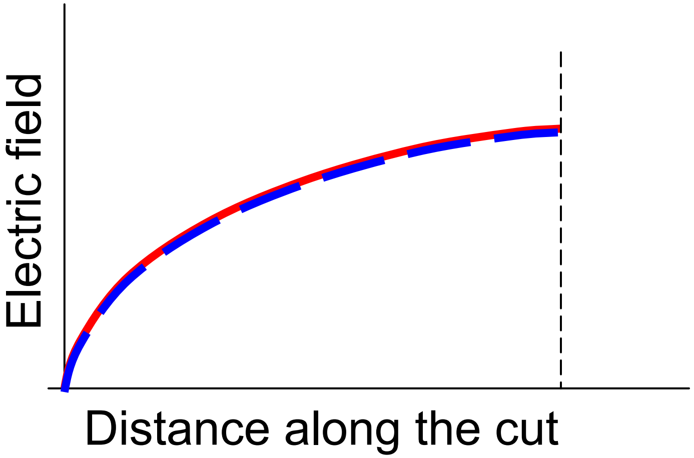


Δ = 40 – 60 um

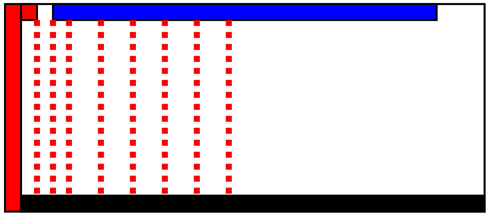
“UpToEdge” sensitive detectors

Physical bases and the related advantages:

1. The electric field distribution in the bulk is controlled by the injected current
2. The electric field along the sensitive edge is controlled by the current injection
3. Both fields has the same distribution in the detector
4. The electric field is not affected by the fluence
5. The diffusion effect is suppressed by the high field at the cut and in the bulk
6. No limit for the operational bias range



“UpToEdge” detector



Conclusions

- The C-TCT project has been successfully completed and CCE measurements on CID has begun
- Normal detector operation possible by 300μm MCz-Si up to 2×10^{15} n_{eq}/cm^2 fluence, i.e. strip layers in Super-LHC trackers.
- CID detectors provide two times higher CCE than detectors operated under normal conditions.
- CID operation possible up to 1×10^{16} n_{eq}/cm^2 fluence.
- Collected charge equals $\approx$7000e^- and 30%.
- Beam tests are planed for segmented CID in 2008
- Read-out electronics, DAQ, irradiated MCz-Si sensors bonded to the CMS RO already exist.
- Ongoing activity to cool down to -50^{0}C the irradiated MCz-Si module.