RD39 Status Report 2011-2012

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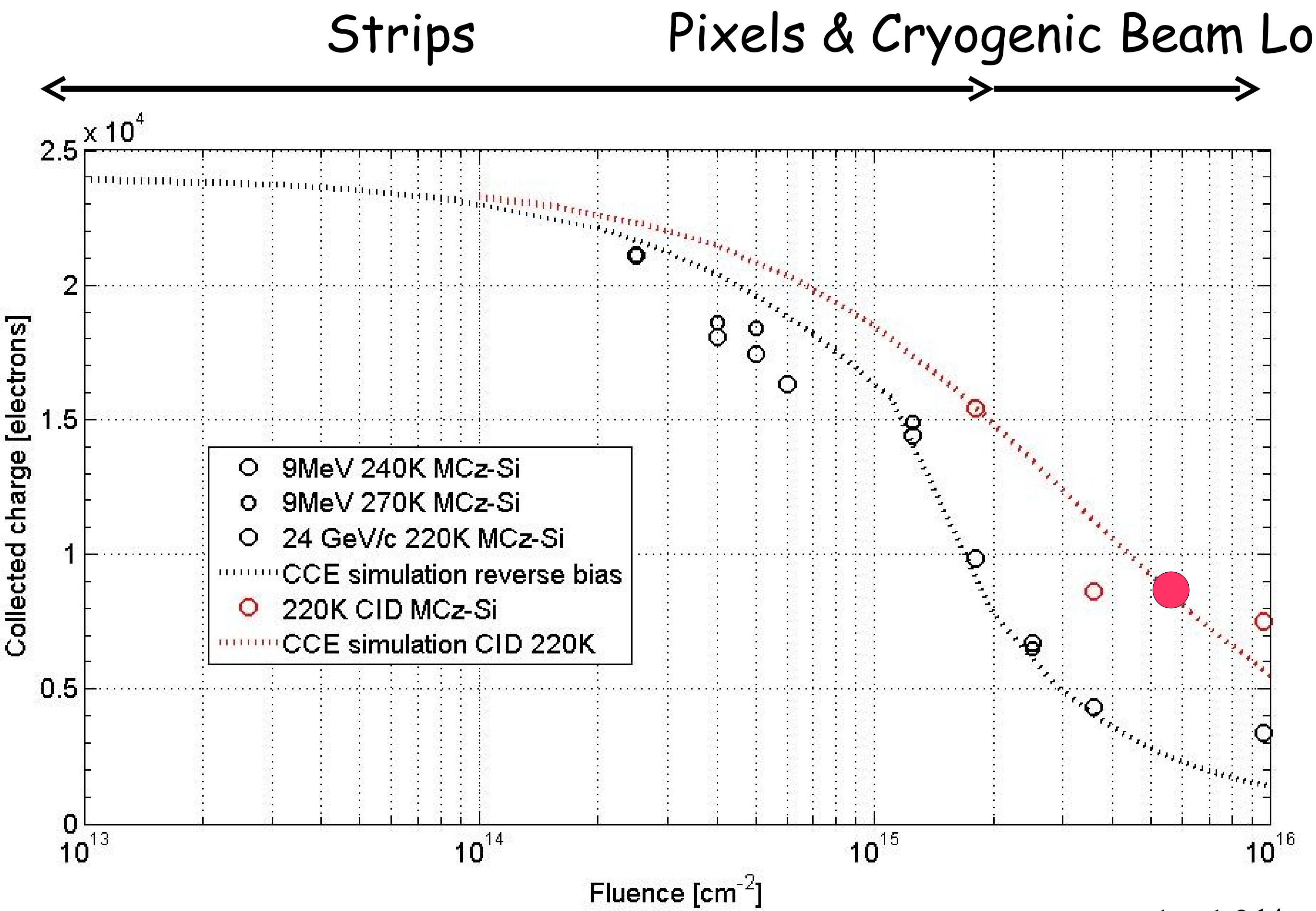
http://rd39.web.cern.ch/RD39/

Outline

- Review Charge Injected Detector (CID) development
- Cryogenic Beam Loss Monitoring (BLM) for LHC
- BLM experimental results
    - Test beams
    - Transient Current Technique (TCT) measurements with laser
- Near term plans of BLM project
- Summary

Expected CCE of CID at -50°C



- Simulation takes into account linear trapping
- β=0.01 cm⁻¹

√x E-field distribution is assumed

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

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

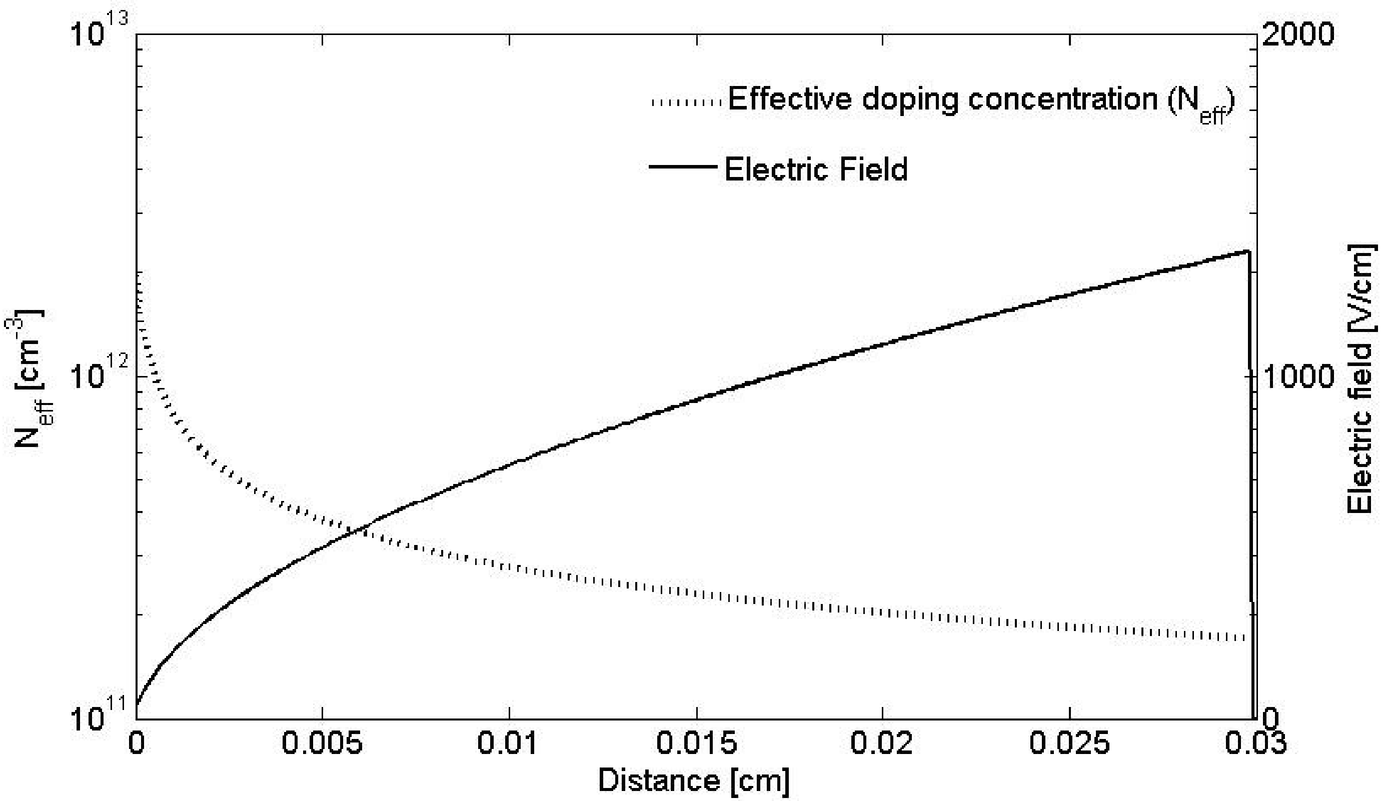
$$CCE = CCE_{Geometrical} \times CCE_{trapping} = \frac{w}{d} \times e^{-t_{dr}/\tau_{trapping}}$$

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

Charge Injected Detector (CID) –Operational Principle

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

$$\tau_{trapping} = \frac{1}{\sigma_{e,h} v_{th} N_t} \qquad \tau_{detrapping} = \frac{1}{\sigma_{e,h} v_{th} e^{\frac{-E_t}{kT}}}$$

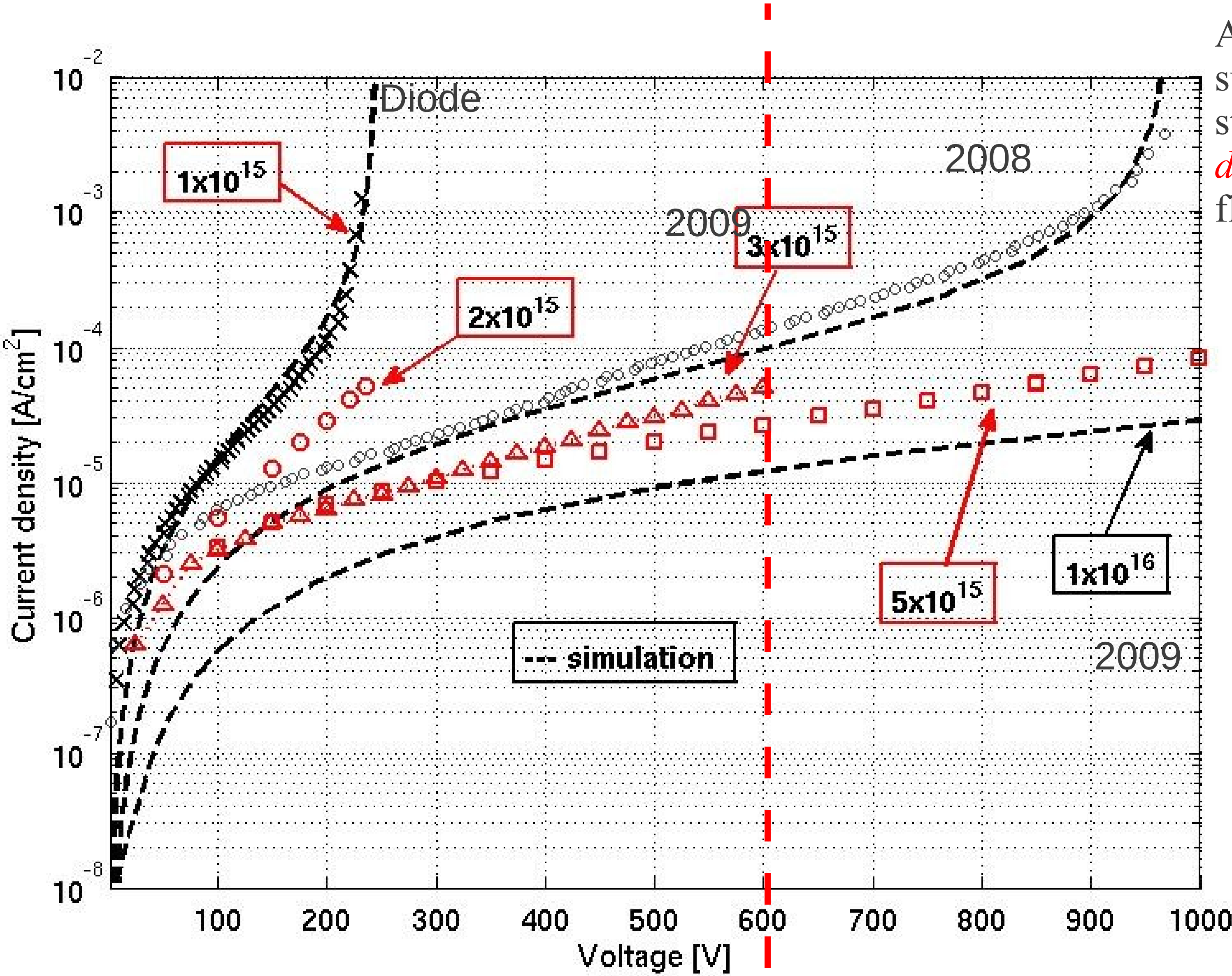


Electric field is <u>extended through entire bulk</u> regardless of irradiation fluence.

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

Detector is "fully depleted" at <u>any bias or irradiation fluence</u>

Forward IV characteristics of CID

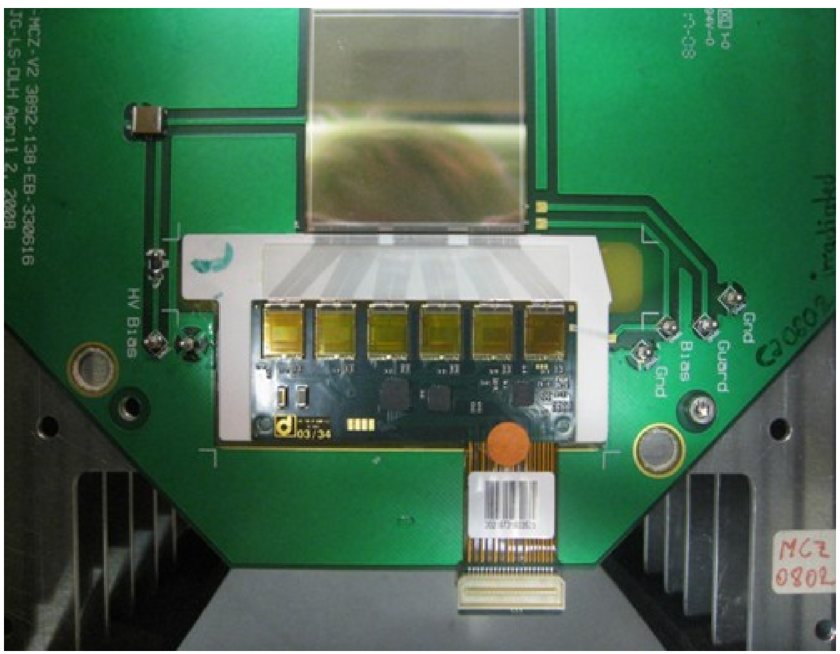


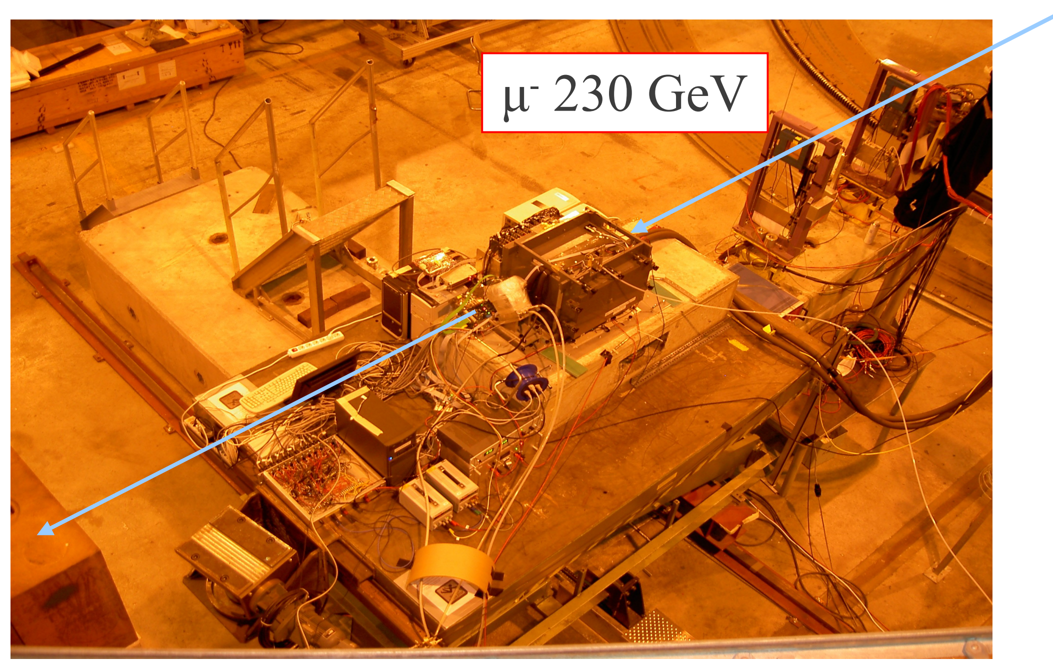
At given voltage, ensuring sufficient electric field E(x) strength, forward current *decreases* when irradiation fluence increases

IV data recorded at -50^0C

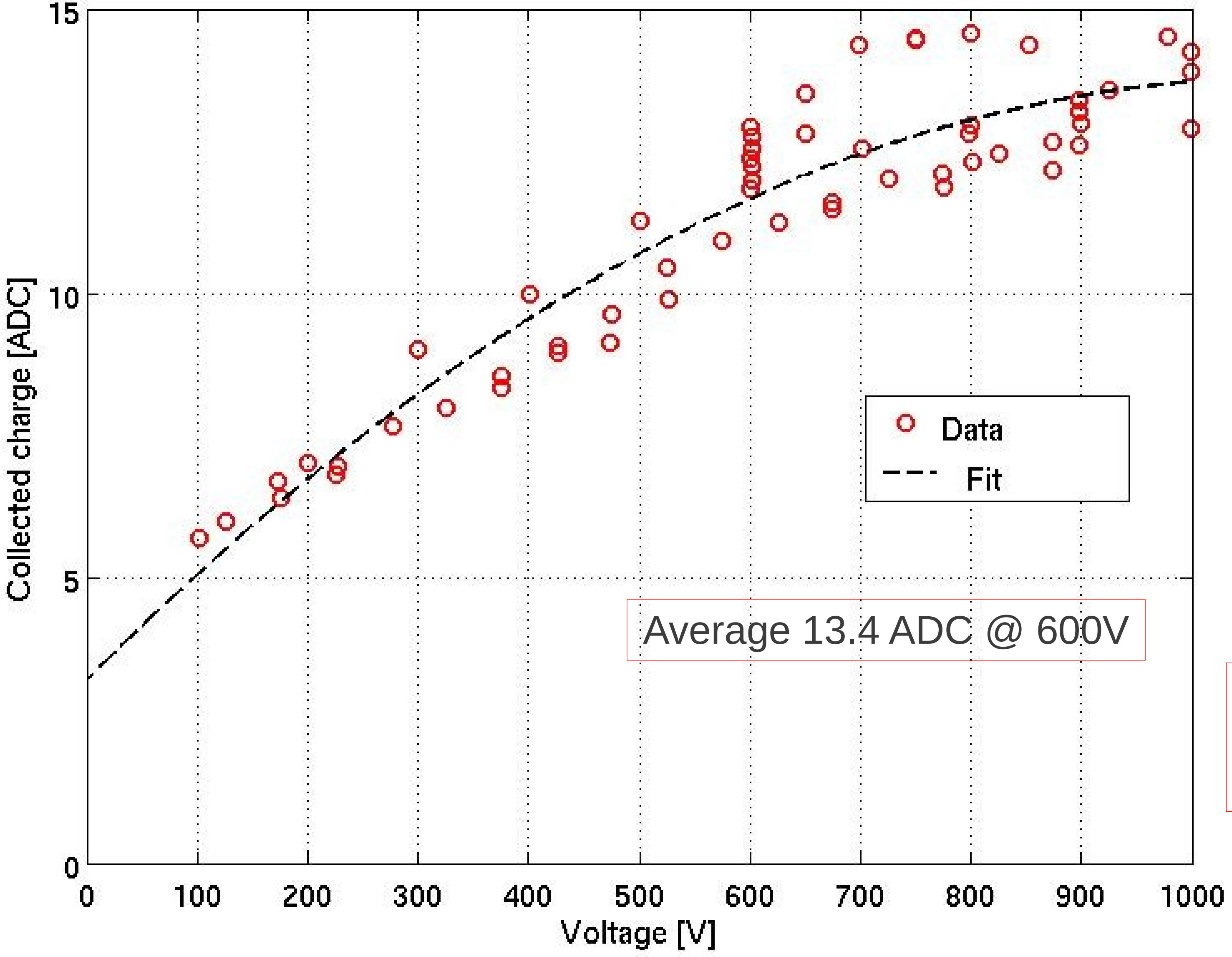
Test Beam experiment on CID detectors

- Sensors investigated
  - 2×10^{15} n_{eq}/cm^2 $n^+/p^-/p^+$ MCz-Si
  - 5×10^{15} n_{eq}/cm^2 $p^+/n^-/n^+$ MCz-Si (in 2008 3×10^{15} n_{eq}/cm^2 $p^+/n^-/n^+$ MCz-Si)





5×10^{15} n_{eq}/cm^2 results -Collected charge vs V



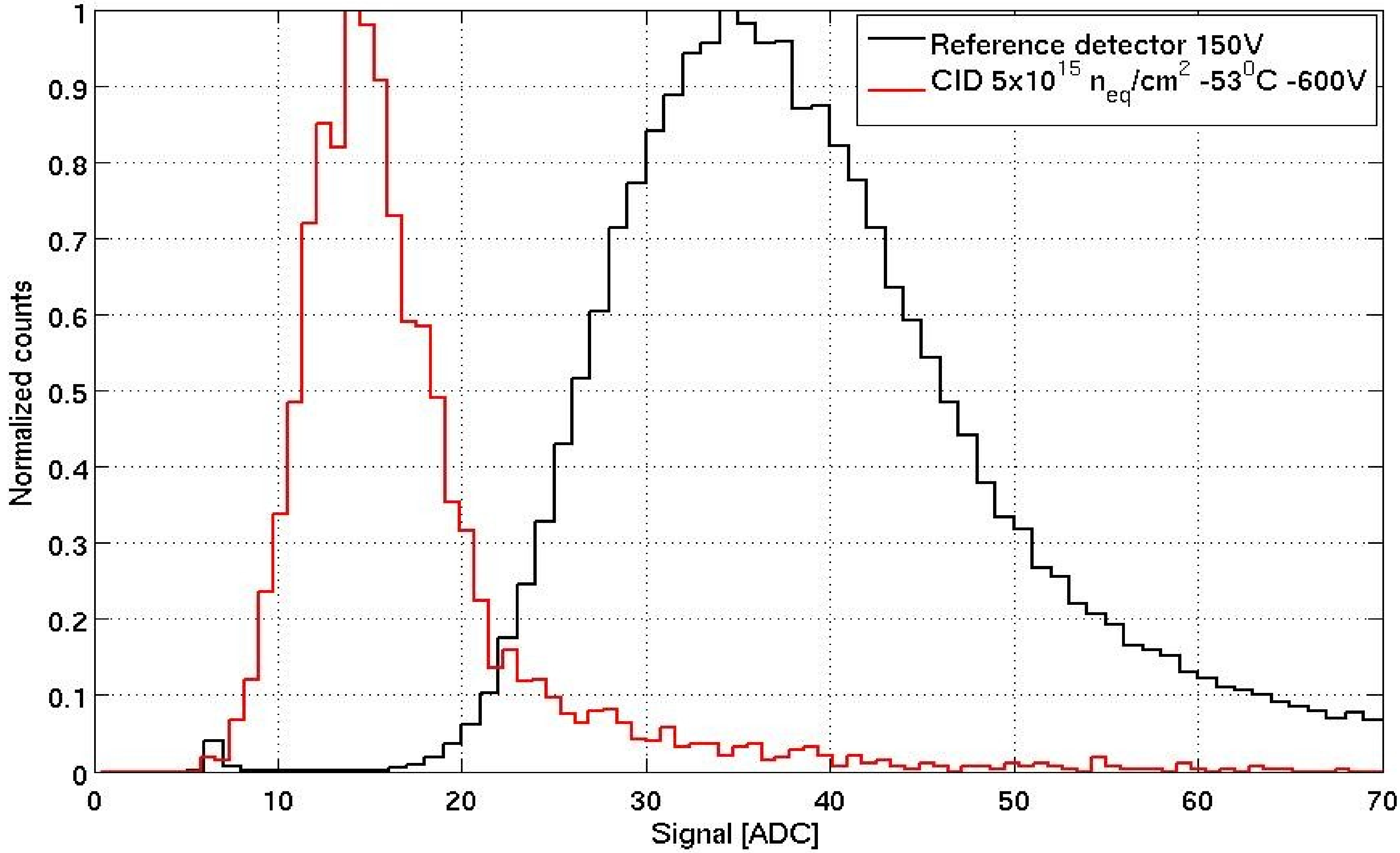
1 ADC ≈ 600e$^-$

Full charge measured by 12 reference planes is 40 ADC

One data point ○ is MPV of typically >20 000 events seen by telescope

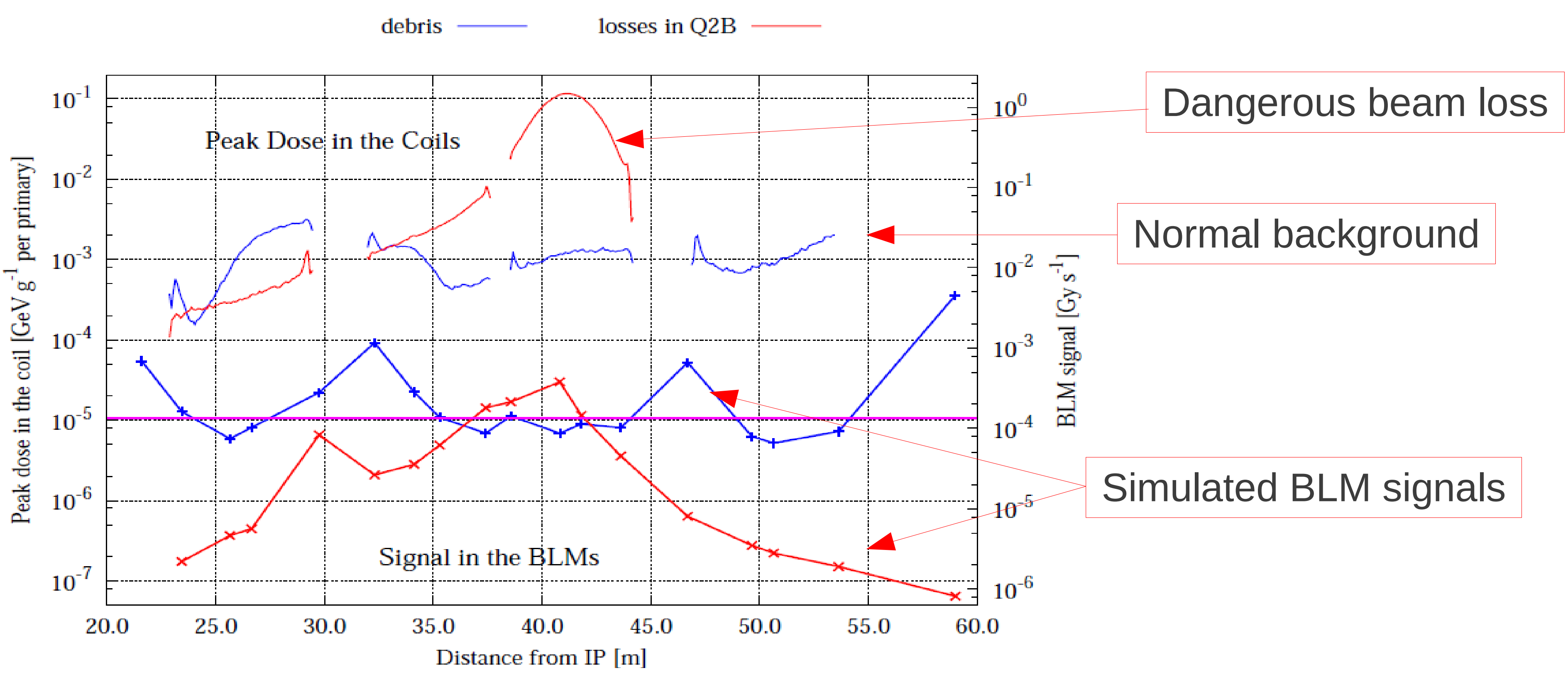
Relative Charge Collection Efficiency is about 33% while the noise ≈ 1000e$^-$

$5 \times 10^{15}\ n_{eq}/cm^2$ results -Collected charge vs non-irrad



Beam Loss Monitoring (BLM) for LHC

- There are currently about 4000 BLMs in LHC
- BLM is needed in order to give warning signal of a beam loss that might result in magnet quenching.
- In current BLM devices, it is possible that signal of a dangerous beam loss is hidden behind of background induced by normal beam debris.

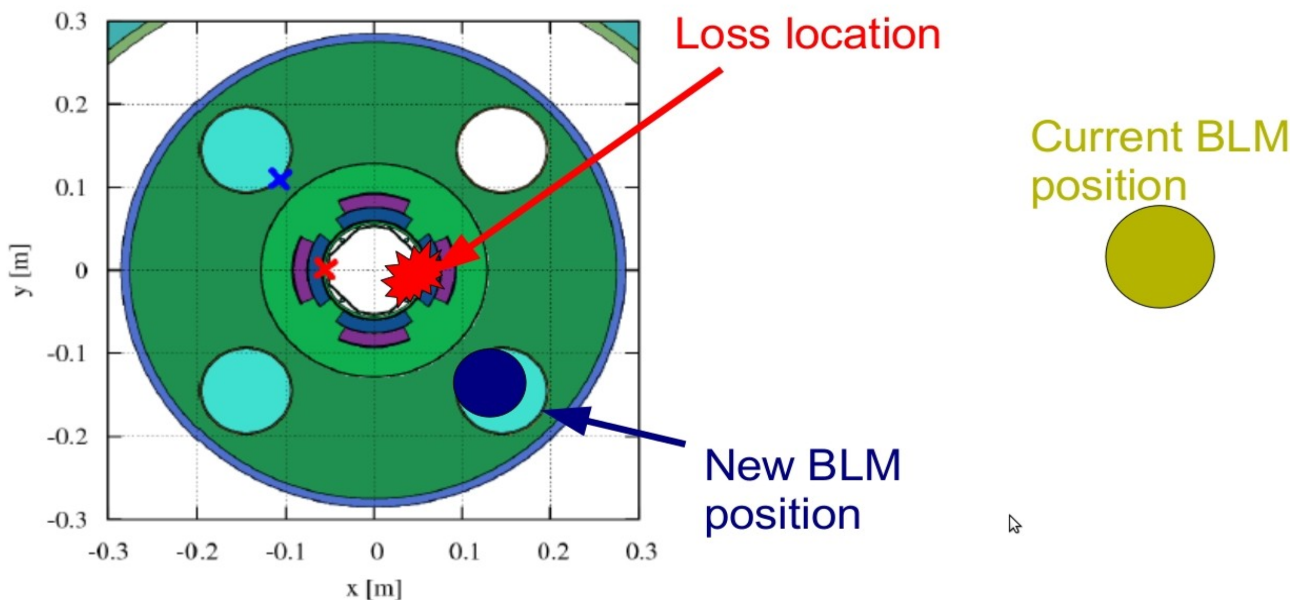


Fluka Simulations for Assessing Thresholds of BLMs Around the LHC Triplet Magnets, A. Mereghetti and M. Sapinski, http://indico.cern.ch/conferenceDisplay.py?confId=156472

Proposed solution

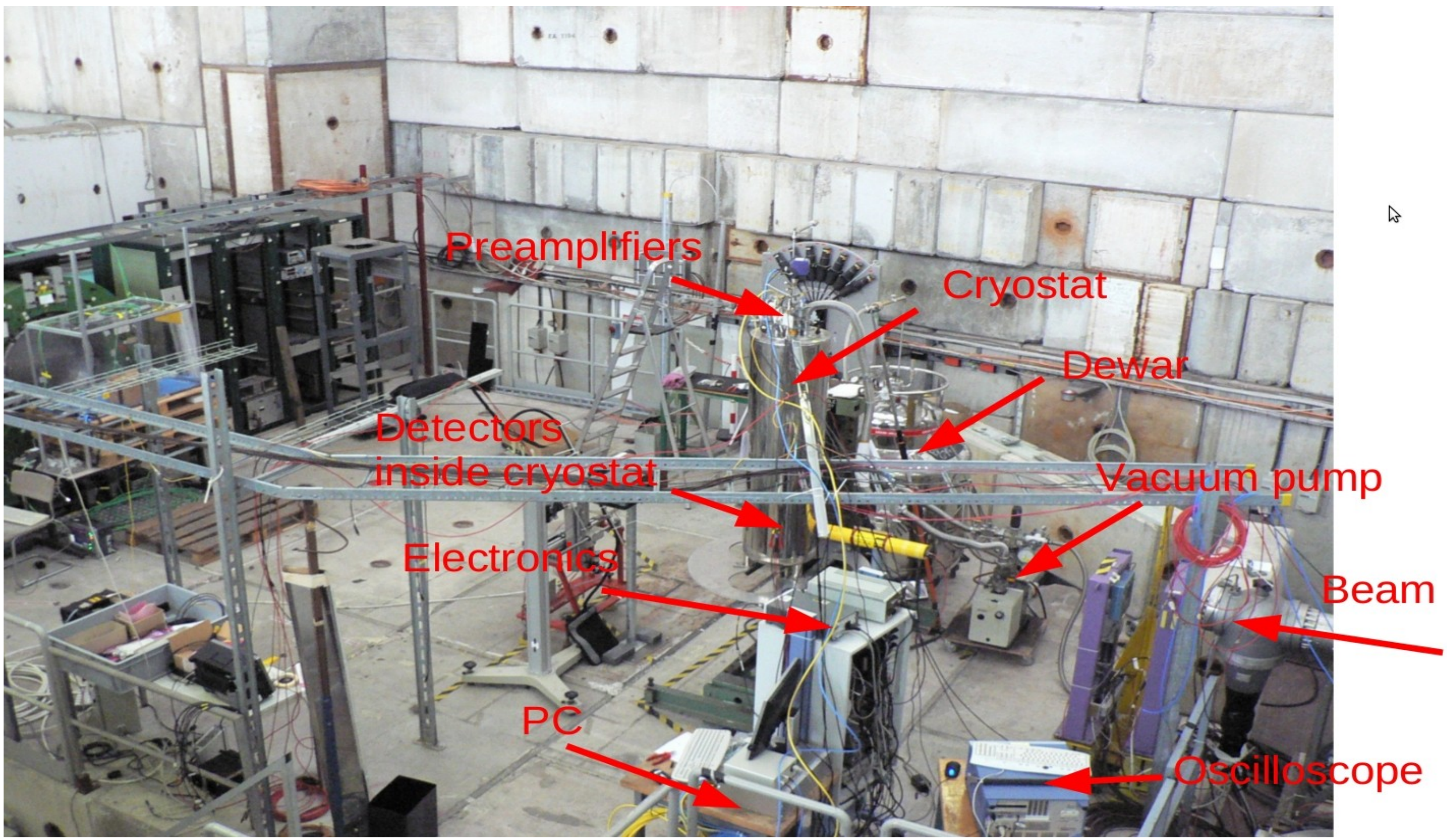
- Place the BLM inside of cold mass, close to interaction point
- CERN workgroup: B. Dehning, M. Sapinski, T. Eisel, C. Kurfuerst
- Challenge: Si detector should operate at LHe temperature <2K and should simultaneously be radiation hard up to 1 MGy.
- At LHe temperature there is no annealing of radiation defects + shallow donor/acceptor impurities are not ionized
- For more information about BLM project see “Cryogenic Beam Loss Monitors workshop”

  http://indico.cern.ch/conferenceDisplay.py?confId=156472

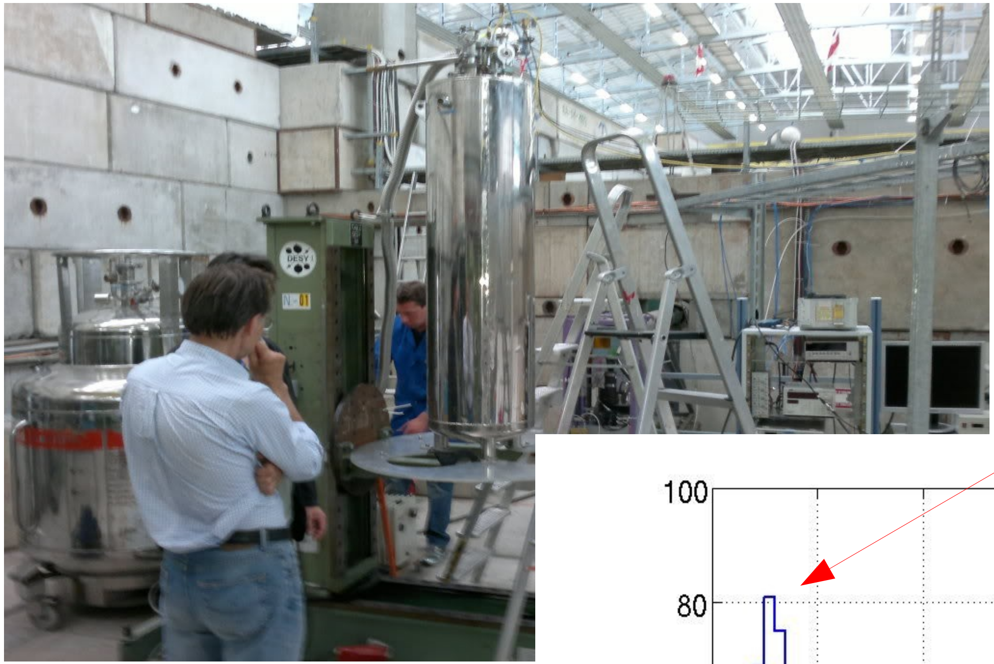


Experimental work this far

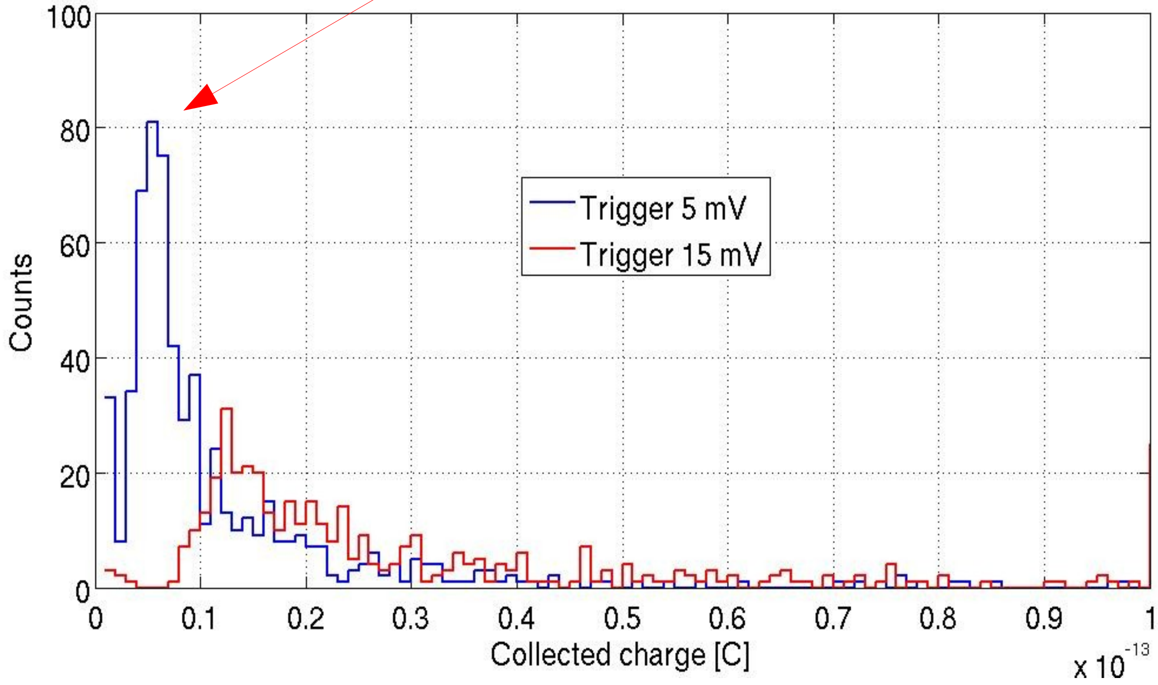
- Test beam measurements at CERN, 9 GeV particles from PS
- Transient Current Technique (TCT) measurements at CERN Cryolab



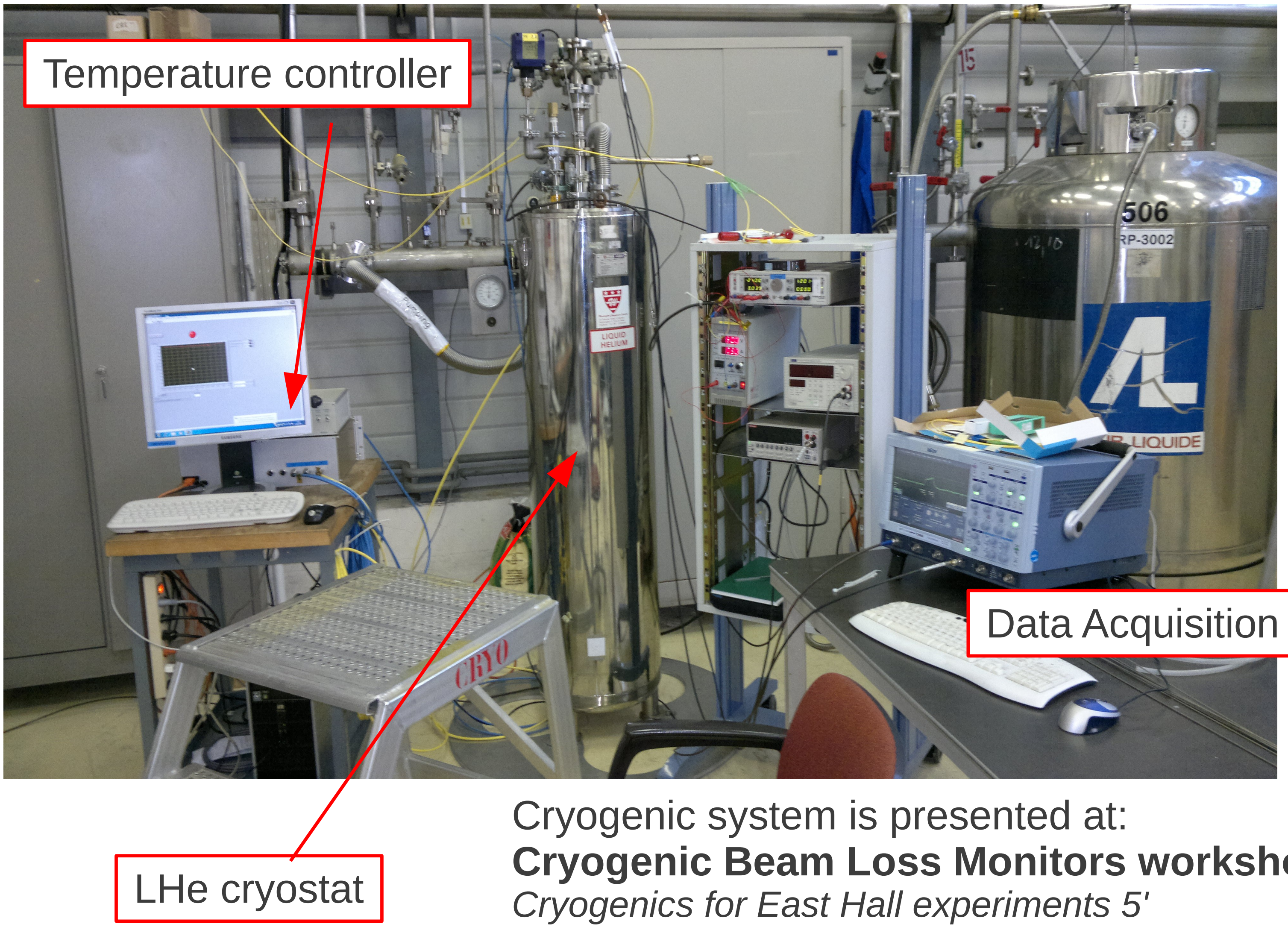
Test Beam at CERN PS



MPV ≈ 4fC i.e. 1 MIP charge



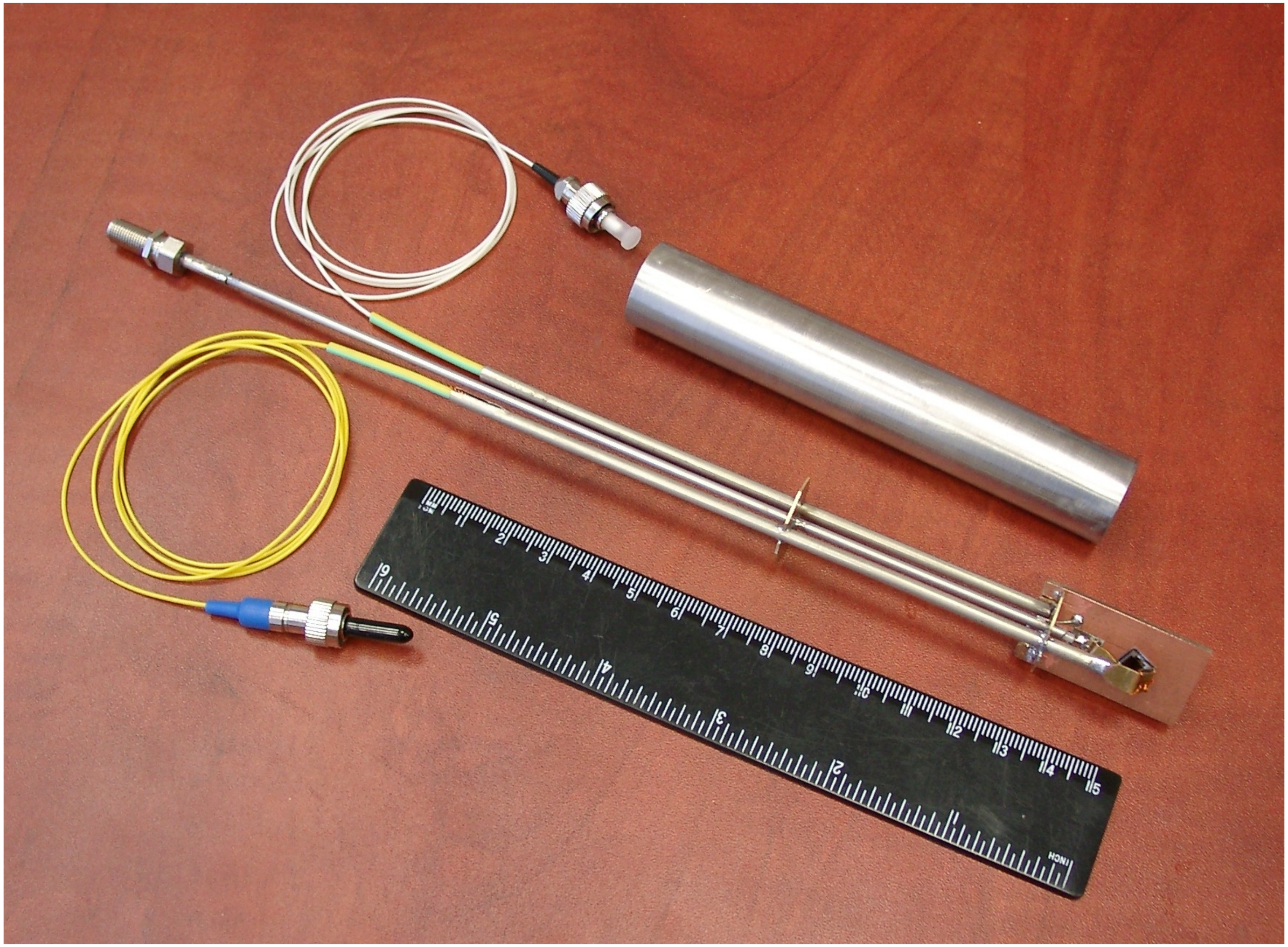
TCT setup @ Cryolab



- RD39 Cryo-TCT
- LHe cryosystem made by Thomas Eisel

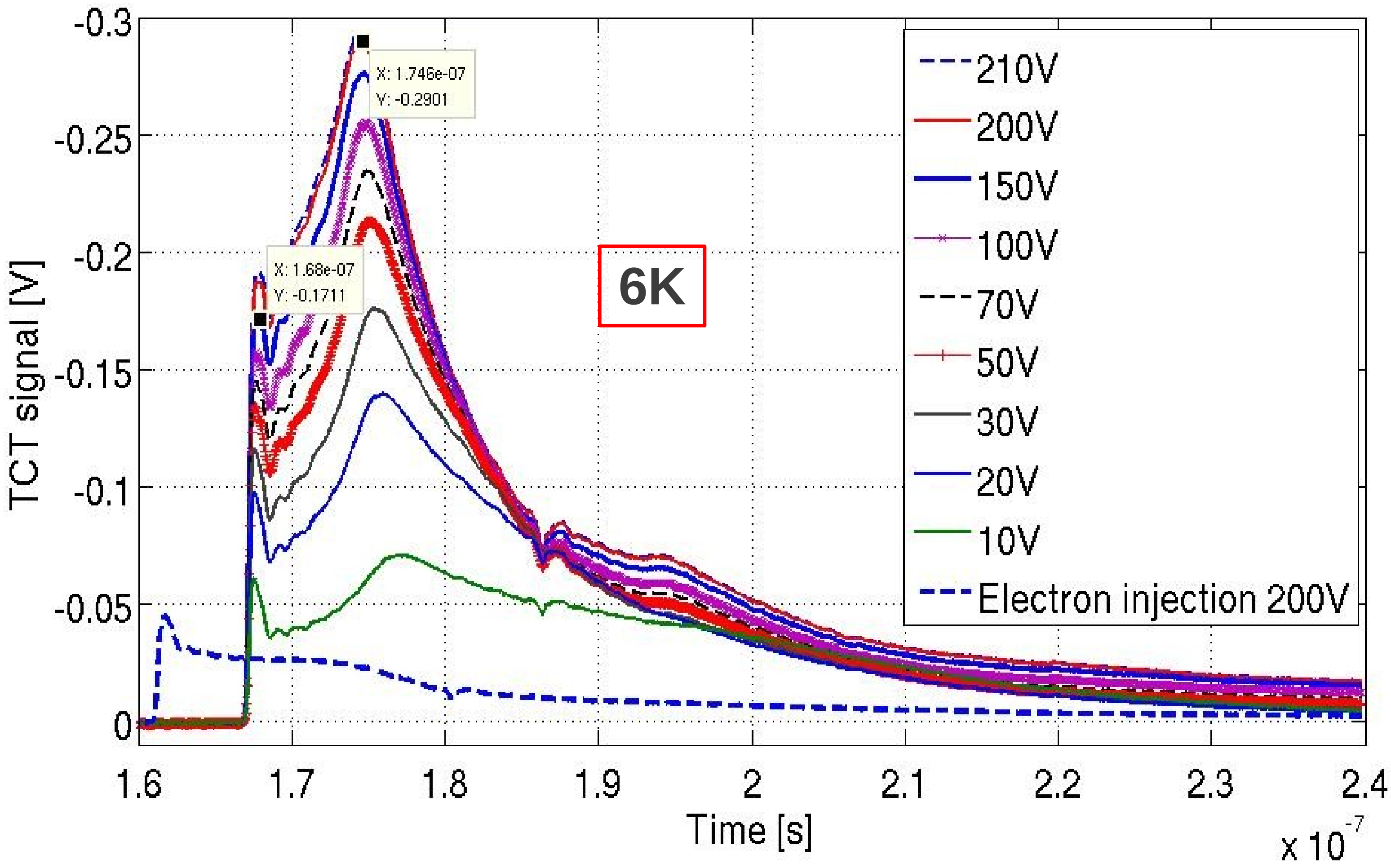
Cryogenic system is presented at:
Cryogenic Beam Loss Monitors workshop
Cryogenics for East Hall experiments 5'
Speaker: Thomas Eisel (Technische Universitaet Dresden)

Detector arrangement



- Detector delivered by PTI
- Degenerately doped $p^+/n^-/n^+$ sensor
- Thickness 300µm
- Optical illumination both sides
- Sample holder etc designed by Vladimir Eremin

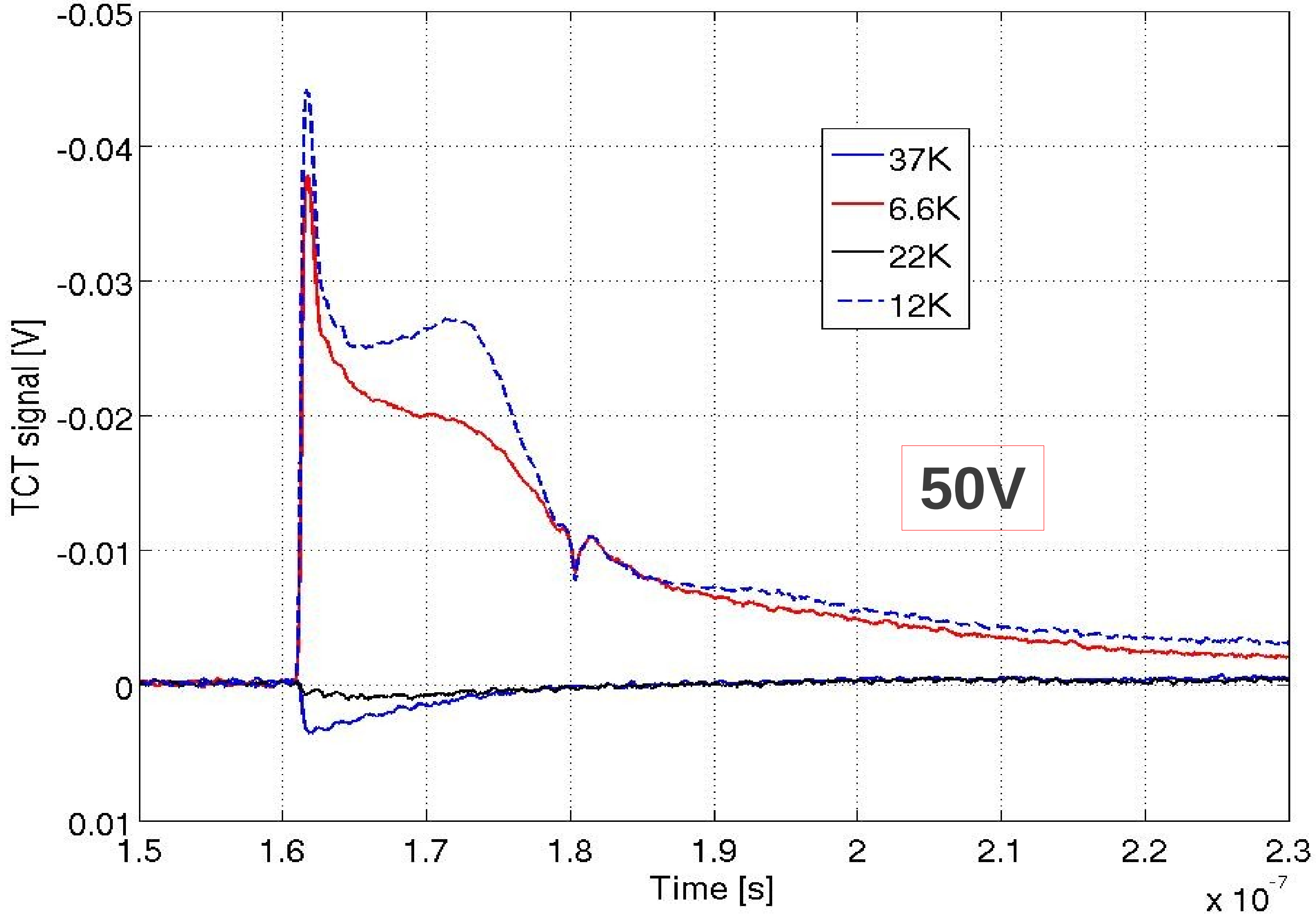
TCT measurement in CID mode



- Detector ***non-irradiated***
- CID operation up to 200V
- Forward current ~100µA
- Drift time ≈6-7ns for holes
- Very long ~50ns tail in signal

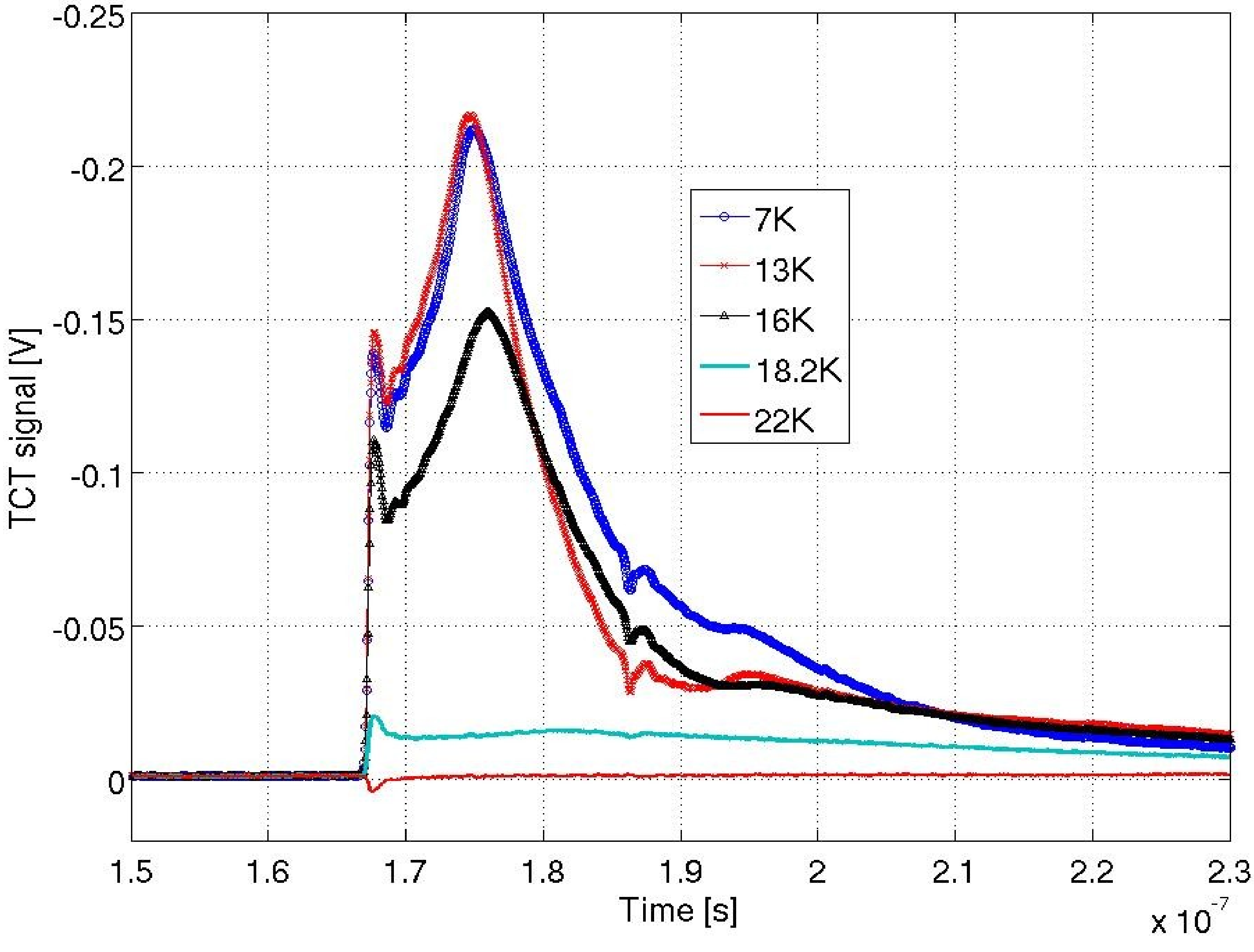
Back side illumination, i.e. hole current transient

CID Electron current transient vs Temperature



- In principle, CID concept should not work unless detector is heavily irradiated, i.e. lot of deep levels.
- Nice signal T<15K
- T>15K signal polarity inverts and amplitude decreases

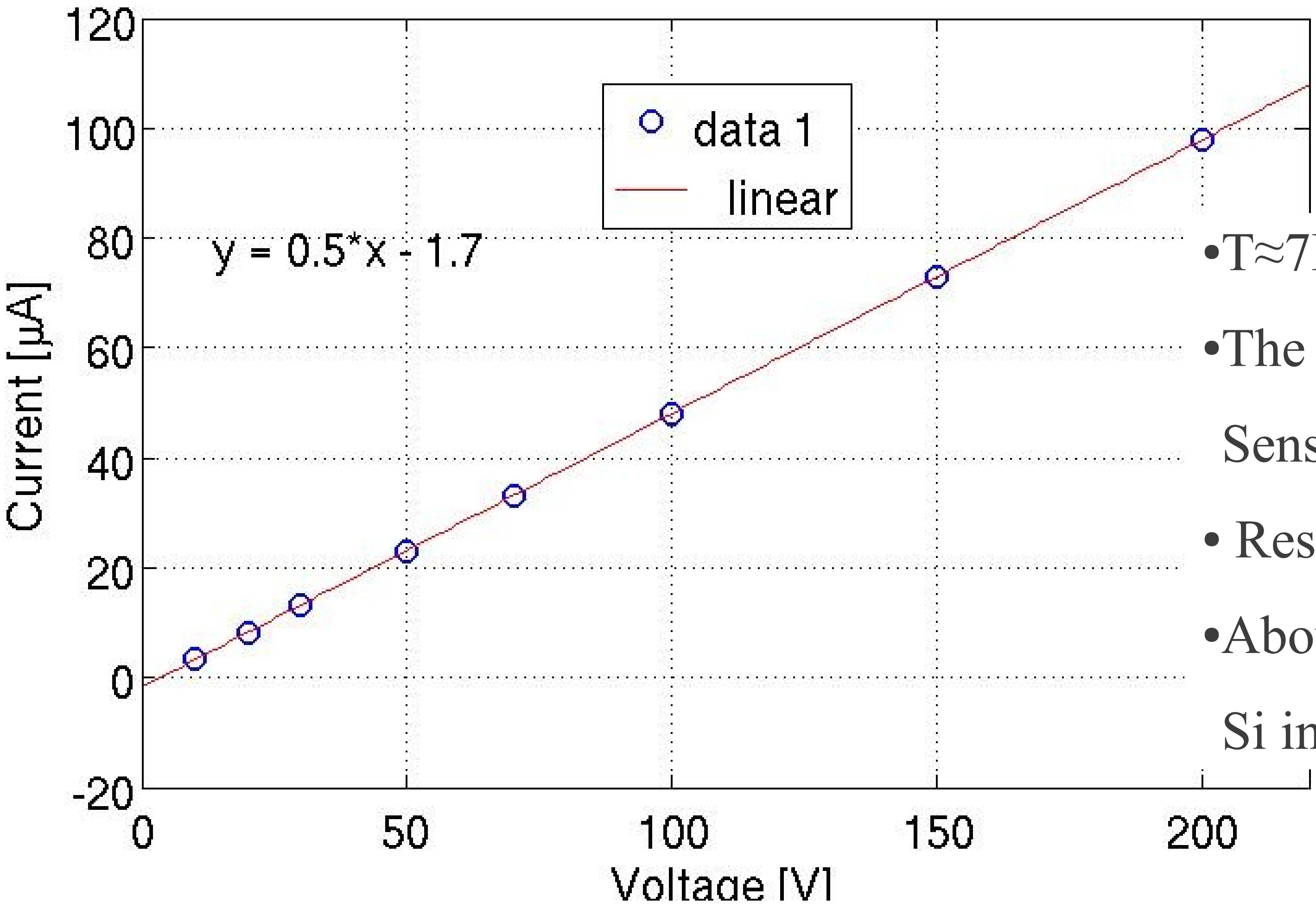
CID Hole current transient vs T



- Nice signal T<15K
- T>15K signal polarity inverts and amplitude decreases

50V

Ohmic behaviour with forward bias

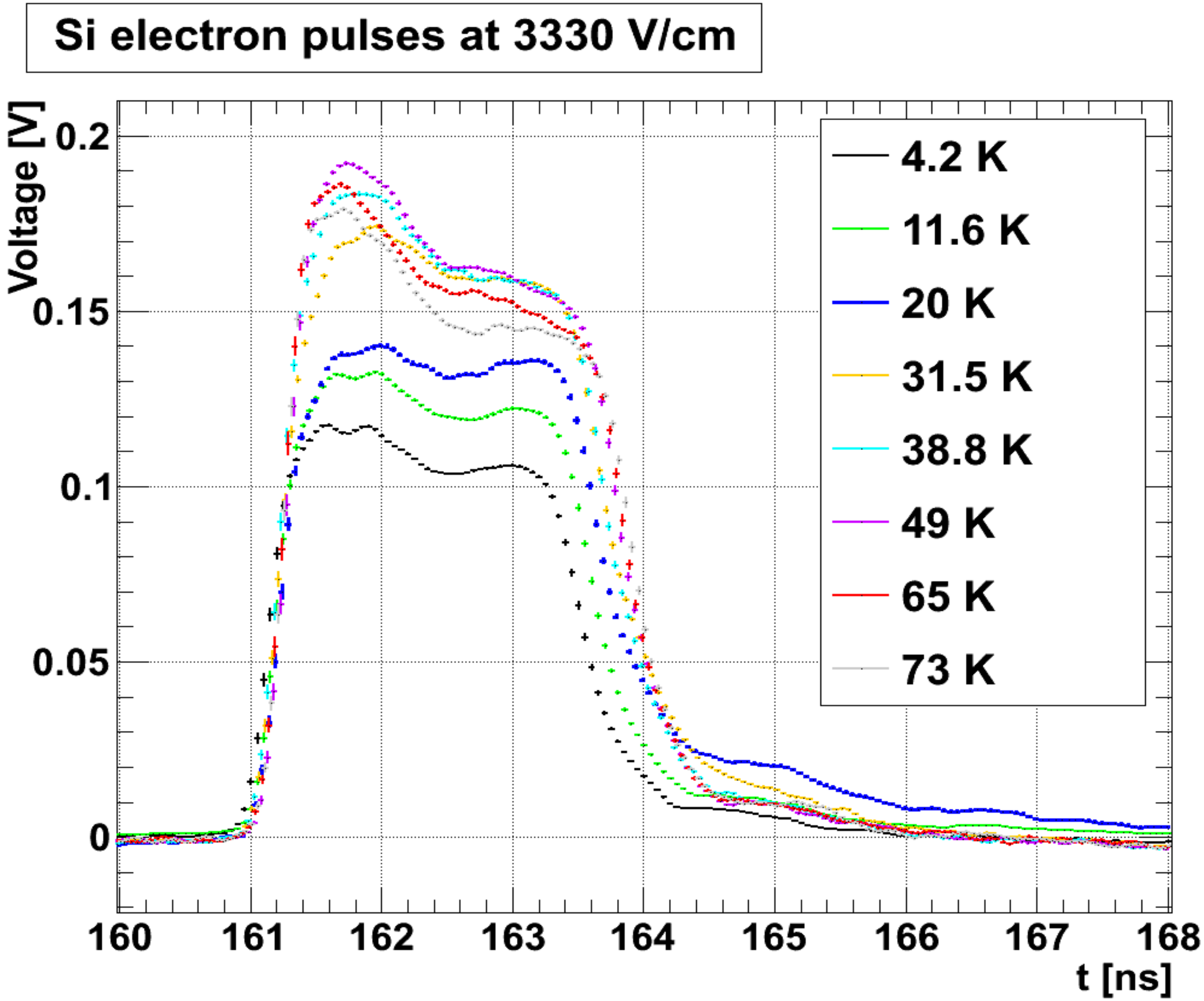


- T≈7K
- The resistance is 2M Ω

  Sensor 0.5cm x 0.5cm x 0.03cm
- Resistivity ≈ 17M Ωcm.
- About 50 times more than

  Si intrinsic resistivity at RT

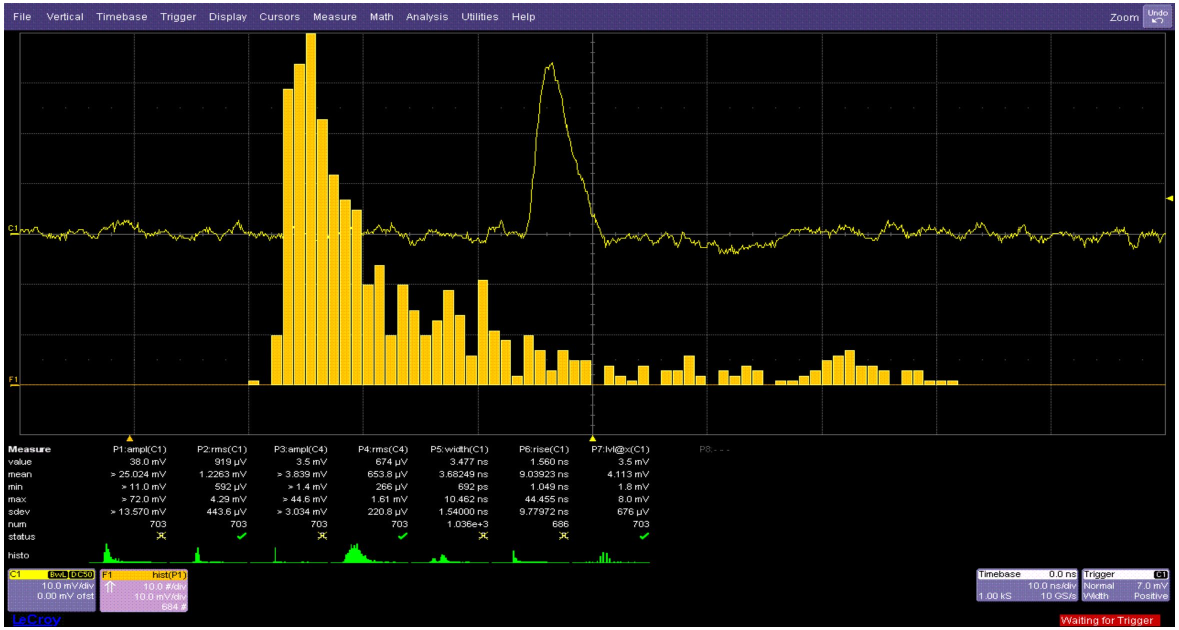
Reverse bias operation



Measurement by
C. Kurfürst

Near term plans

- August 2012 “warm” test in a beam
- November 2012 high intensity (irradiation) test beam with cryogenics at CERN PS T7 area.
- Production of BLM dedicated silicon detectors ongoing. Activity coordinated by Vladimir Eremin, Ioffe PTI



Summary

- Si detectors produces by RD39 are successfully tested in particle beams and by laser TCT setups
- Non-irradiated detector provides signal T<15K, i.e. below shallow level freeze-out T in Si
- Polarization due to radiation defects at deep cryogenic temperature is likely to be a major challenge > CID operation might be mandatory.
- At very low temperatures and CID mode, symmetrical behaviour, i.e. electron and hole current transients apparent, both.
- IV is ohmic with forward bias
- Current is ≈ 0 reverse bias
- When dopant freeze-out, Si bulk turns into insulator.
- Forward current establishes *E(x)* over 2MΩ resistor
- Reverse bias operation of a non-irradiated detector rather “normal” T<15K