RD39 Status Report 2012-2013

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

Outline

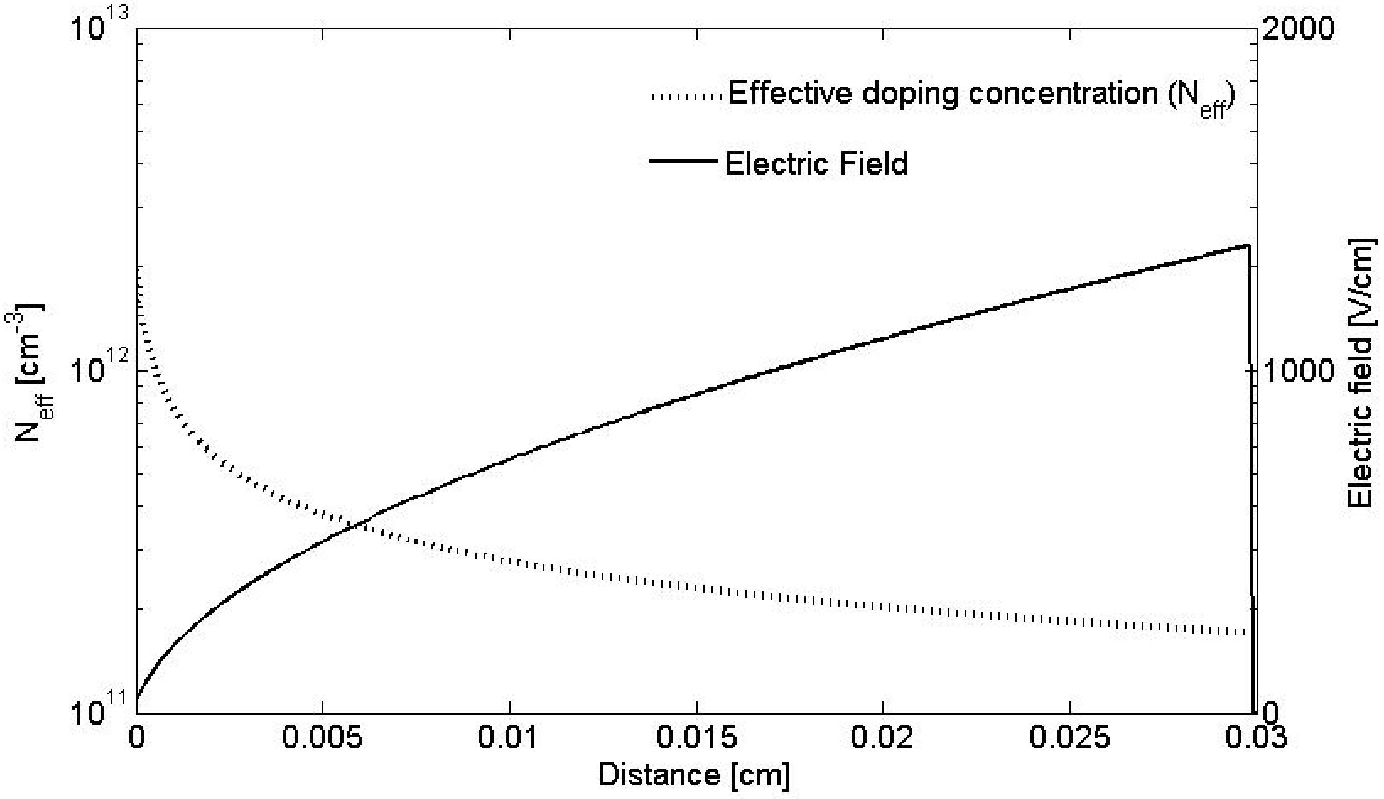
- Review Charge Injected Detector (CID) development
- Cryogenic Beam Loss Monitoring (BLM) for LHC
- BLM experimental results
    - Test beam results
    - Transient Current Technique (TCT) measurements with laser

- Near term plans of BLM project
- Summary

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 extended through entire bulk regardless of irradiation fluence.

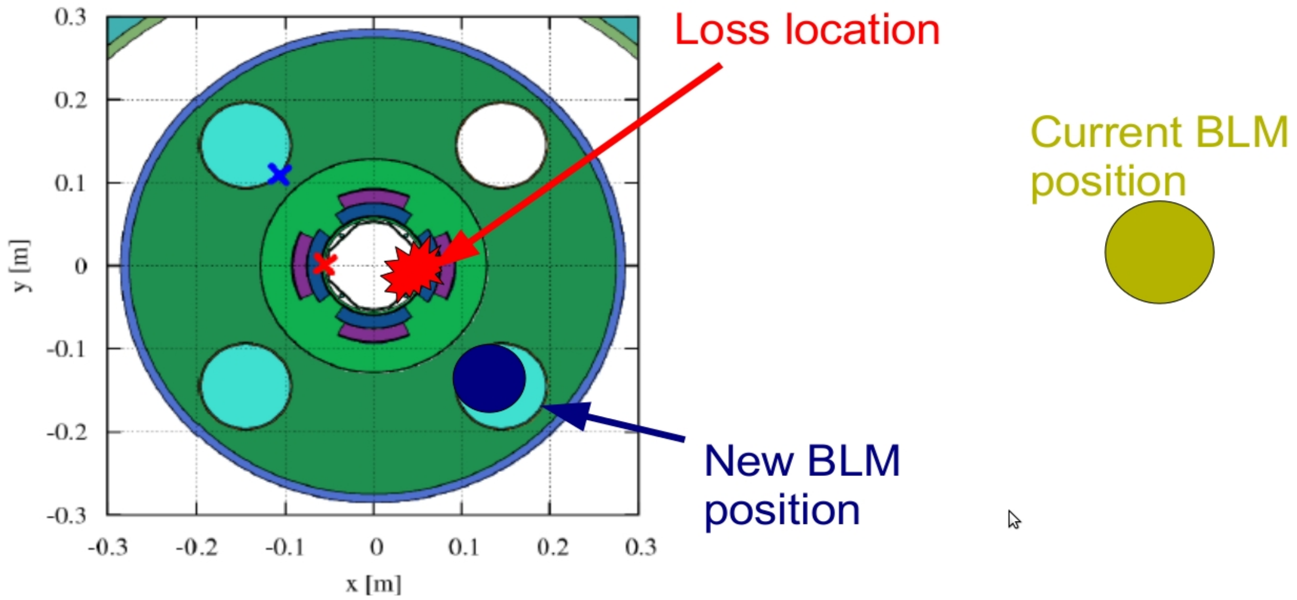
Electric field is proportional to square of distance E(x)~√x

Detector is "fully depleted" at any bias or irradiation fluence

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



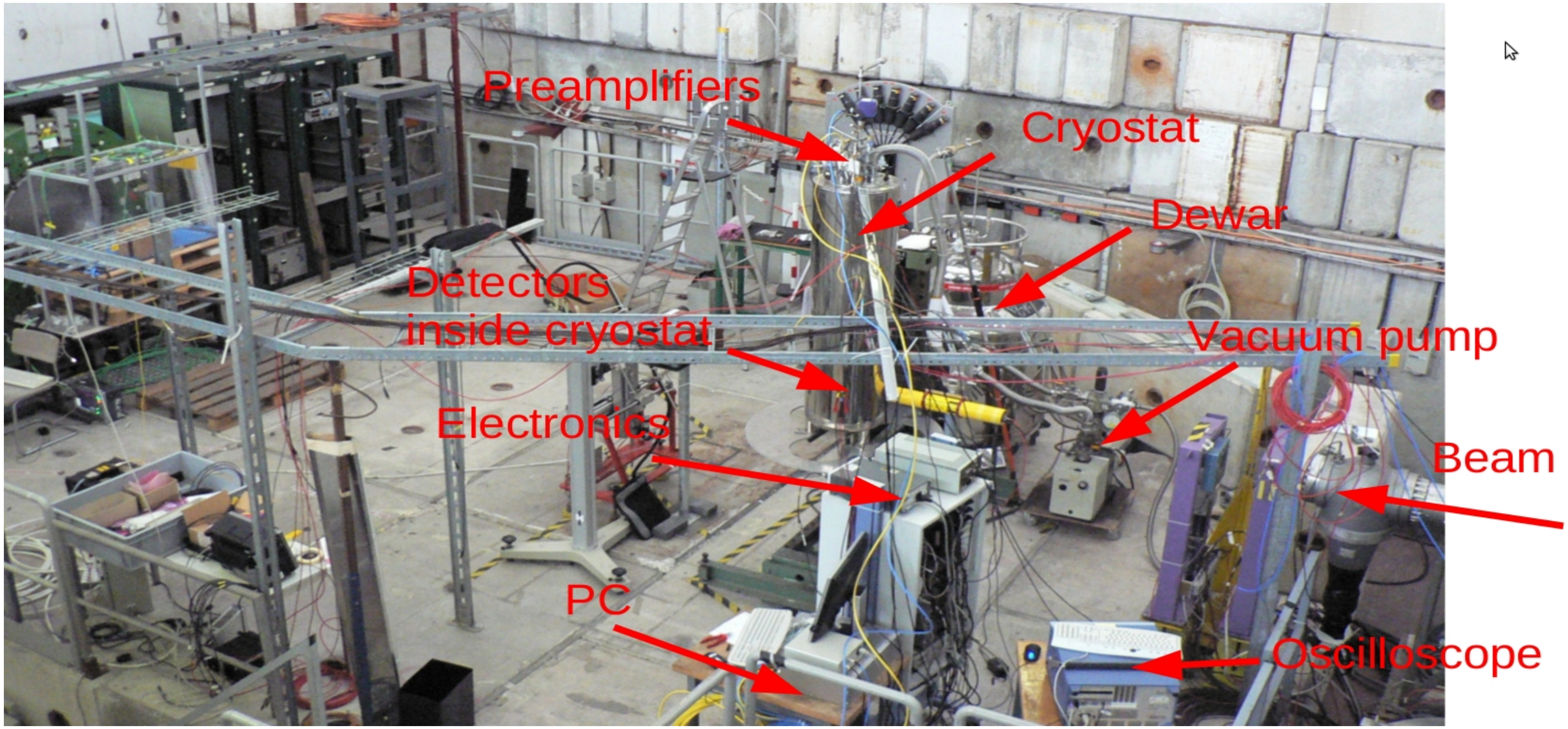
Loss location

Current BLM position

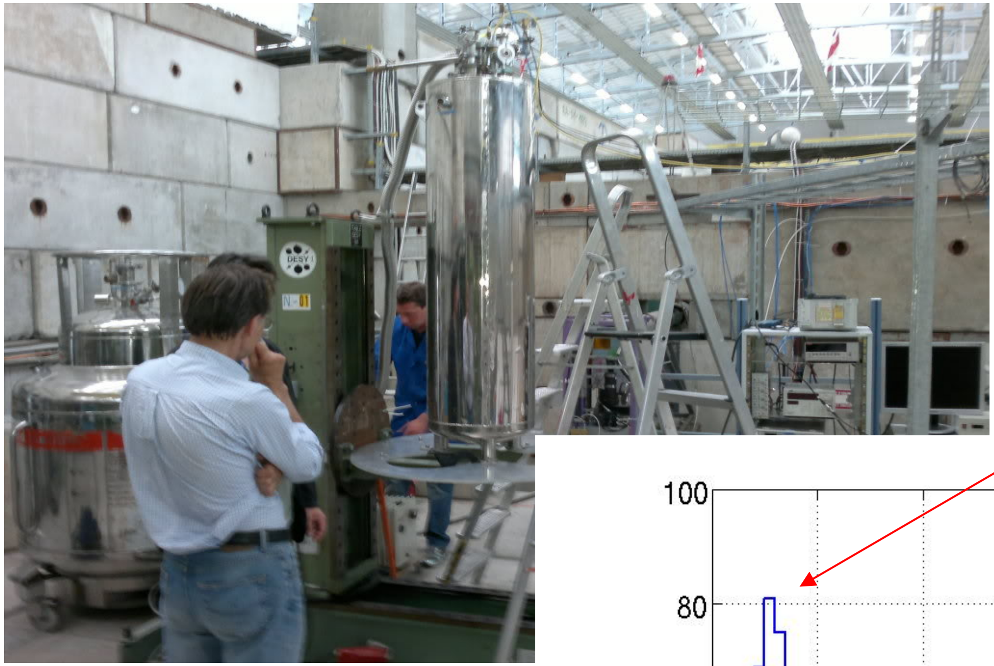
New BLM position

Experimental work this far

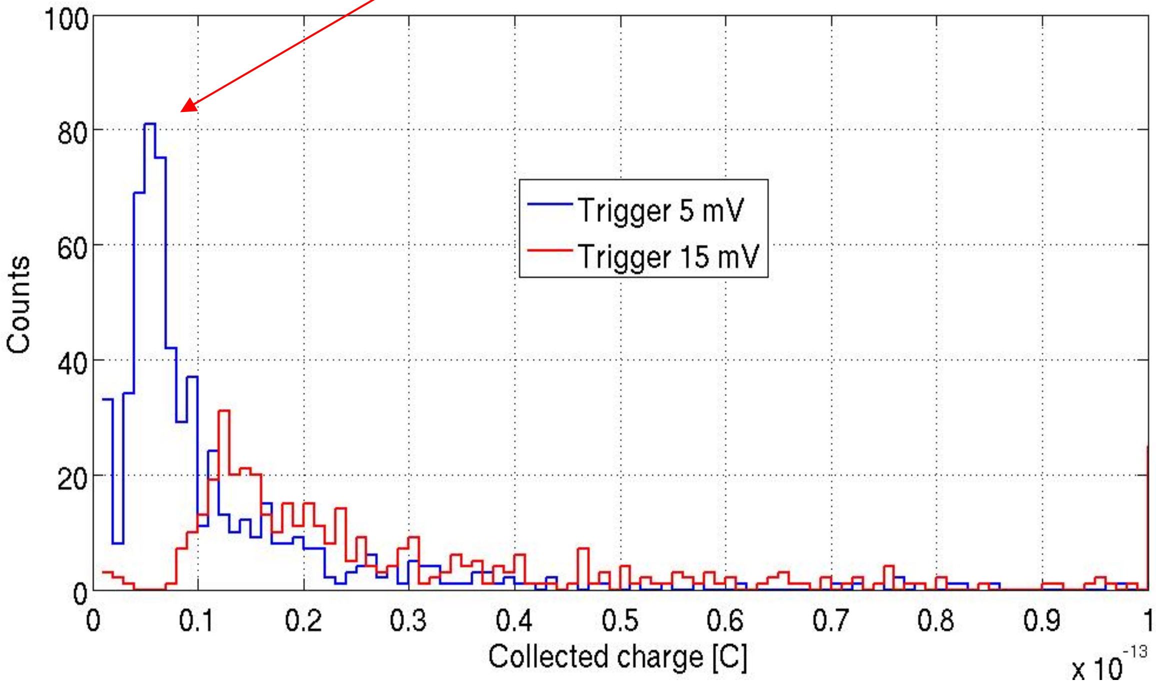
- Test beam measurements at CERN, 9 GeV particles from PS (spring and summer 2012)
- Processing of BLM / LHe dedicated silicon detectors (2012)
- Transient Current Technique (TCT) measurements at CERN Cryolab
- In-situ radiation test of silicon and diamond detectors at 1.8K (March 2013)



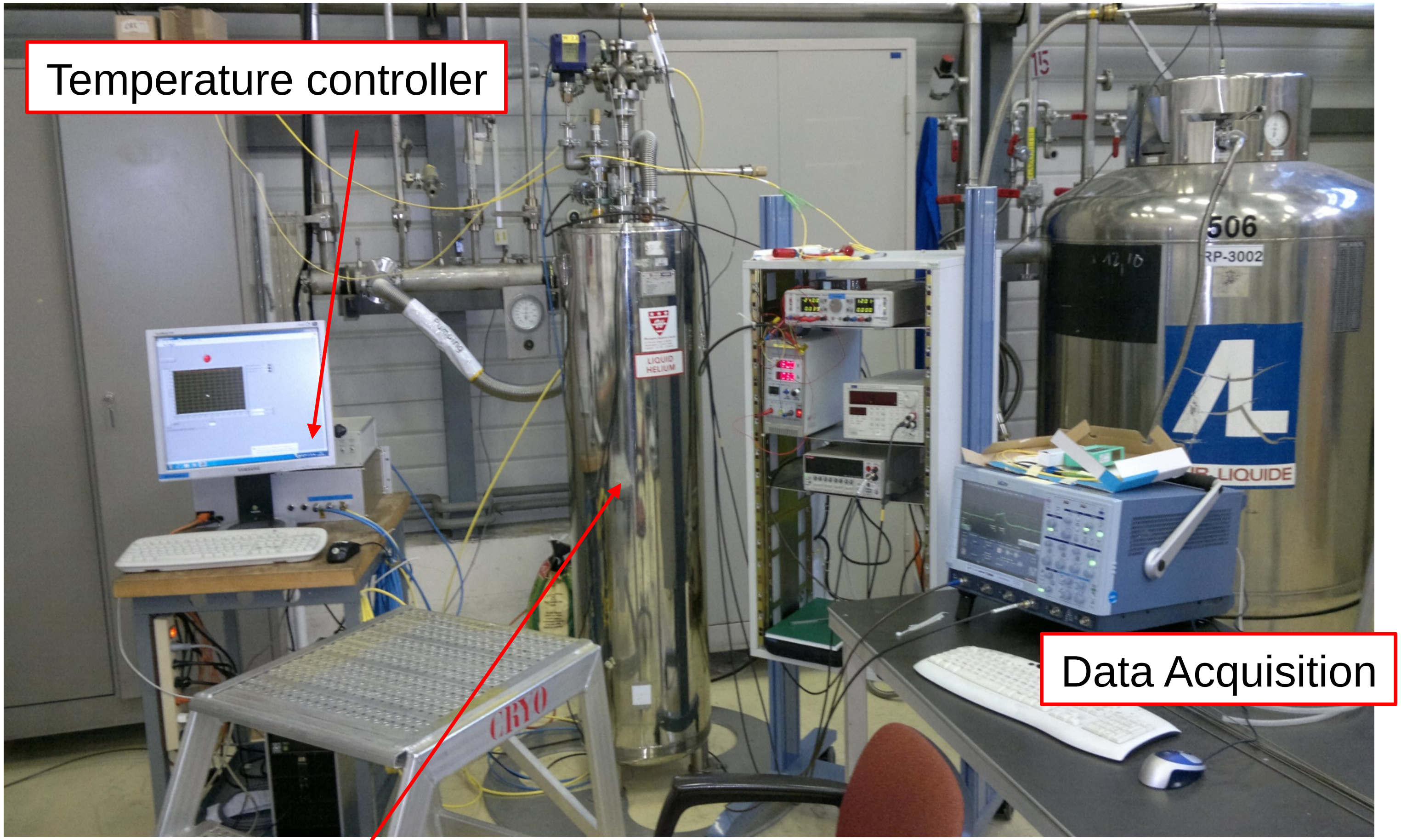
Test Beam at CERN PS



MPV ≈ 4fC i.e. 1 MIP charge



TCT setup @ Cryolab



Temperature controller

Data Acquisition

LHe cryostat

- 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)

in-situ radiation test of silicon (and diamond) detectors at 1.8K

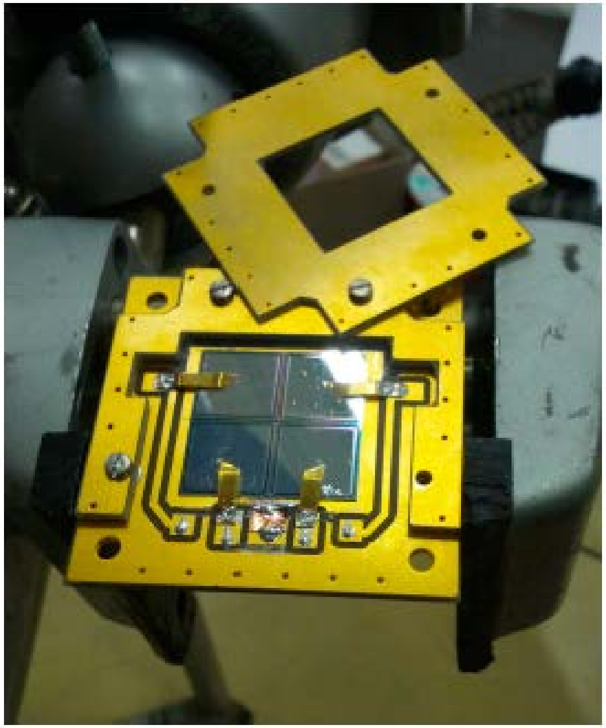
Aspects of the experiment

Beam, fluence, irradiation
Special Cryostat
Detectors
Beam alignment
Measurements
Data treatment

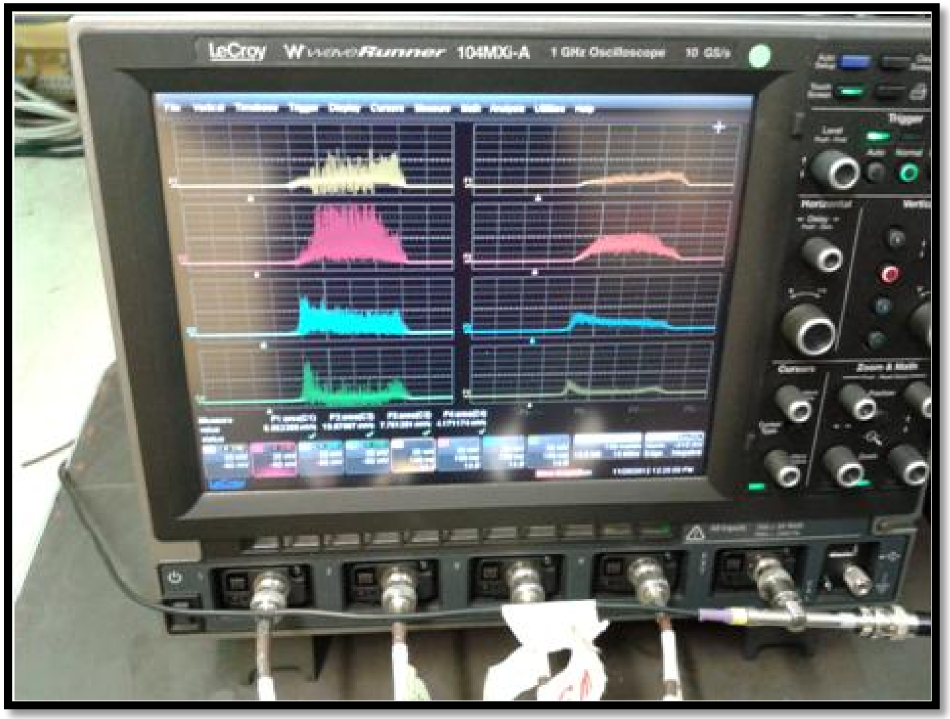
For the irradiation test p+-n-n+ silicon pad detectors processed by the consorsium of Ioffe Physical-Technical Institute, St. Petersburg, and Reserch Institute of Material Science and Technology, Zelenograd, both Russia,

#	material	Resistivity (Ωcm)	Thickness (μm)	Sensitive area (mm^2)	V_{fd} at RT (V)	Diagram for measurements
1	silicon	10^4	300	5x5	33	I-V, Q
2	silicon	10^4	300	1x1	33	Pulse signal (TCT)
3	silicon	500	300	5x5	670	I-V, Q
4	silicon	200	300	5x5	1670	I-V, Q
5	silicon	4.5	300	5x5	7.4×10^4	I-V, Q
6	diamond	isolator	500			I-V, Q
7	diamond	isolator	500			I-V, Q

Silicon Telescope for Beam alignment



Telepscope used for beam and hardware alignment developed in Ioffe Physical-Technical Institute



Spill shapes (examples measured by Si telescope)

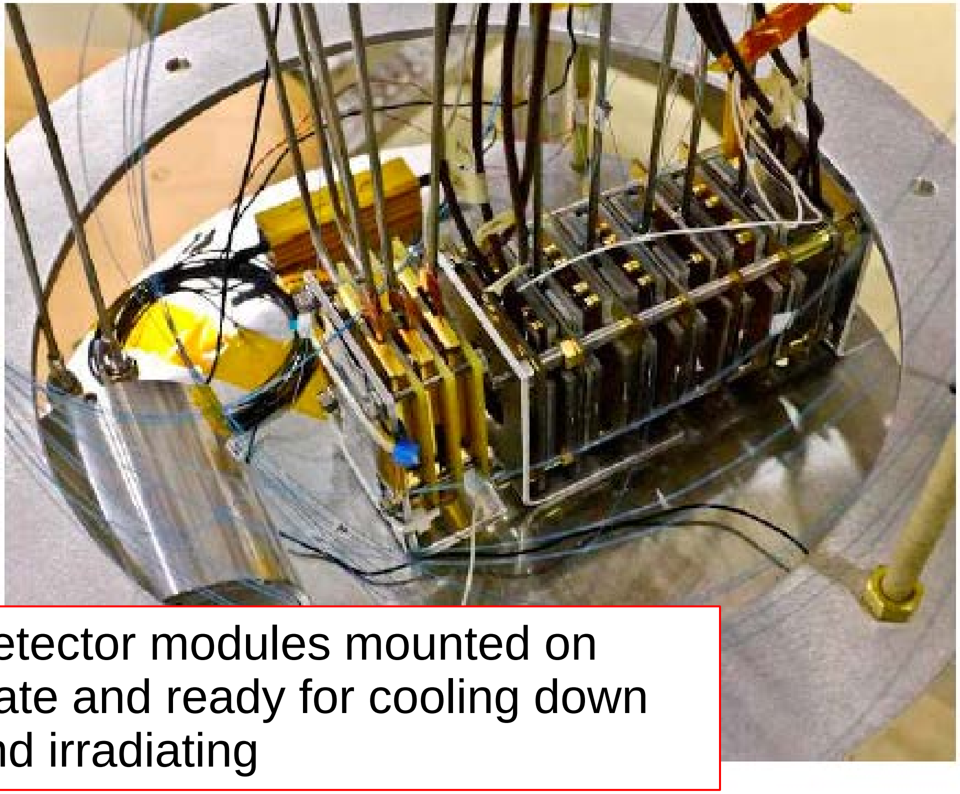
A silicon telescope at the outer positions of the detectors inside the cryostat allowed verifying the alignment with respect to the BPM on the outside. The telescope modules contain 4 silicon detectors each.

Measurements of Si (and sCVD) detector characteristics

Three different detector holders were used in the experiment:

1. 3 holders for DC measurements
2. 5 holders for TCT measurements
3. 2 holders with 4 silicon detectors each, as telescope

The DC holder has two cryogenic coaxial UT 85 cables, for low heat introduction, one is for signal readout and the other for voltage application.

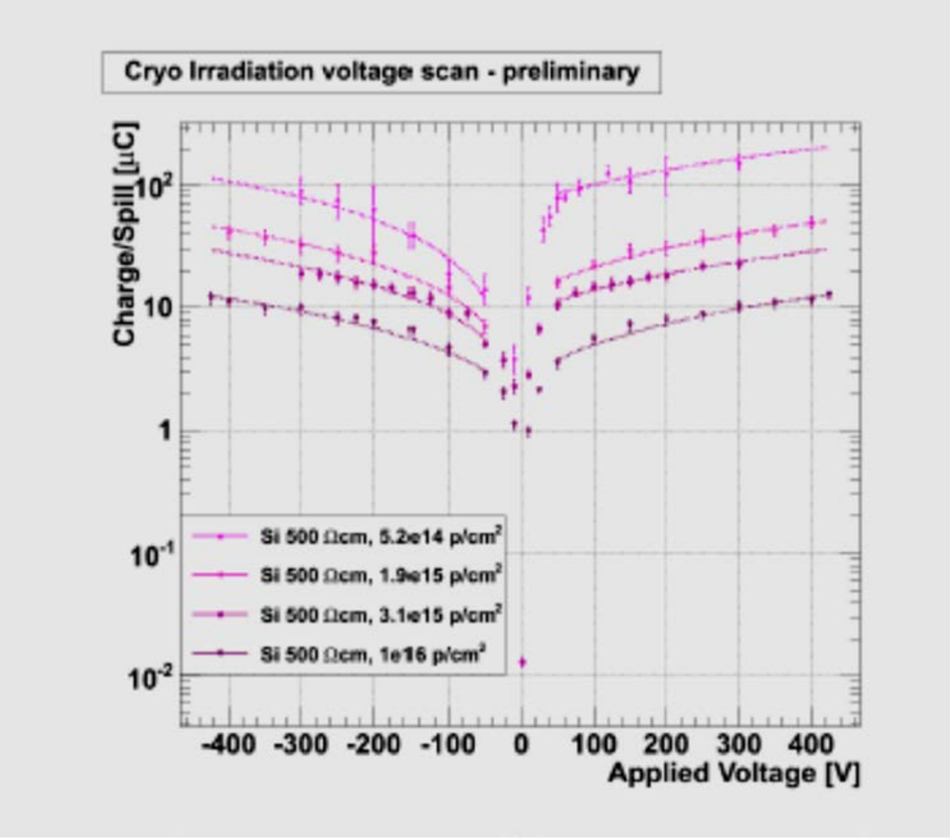


Detector modules mounted on plate and ready for cooling down and irradiating

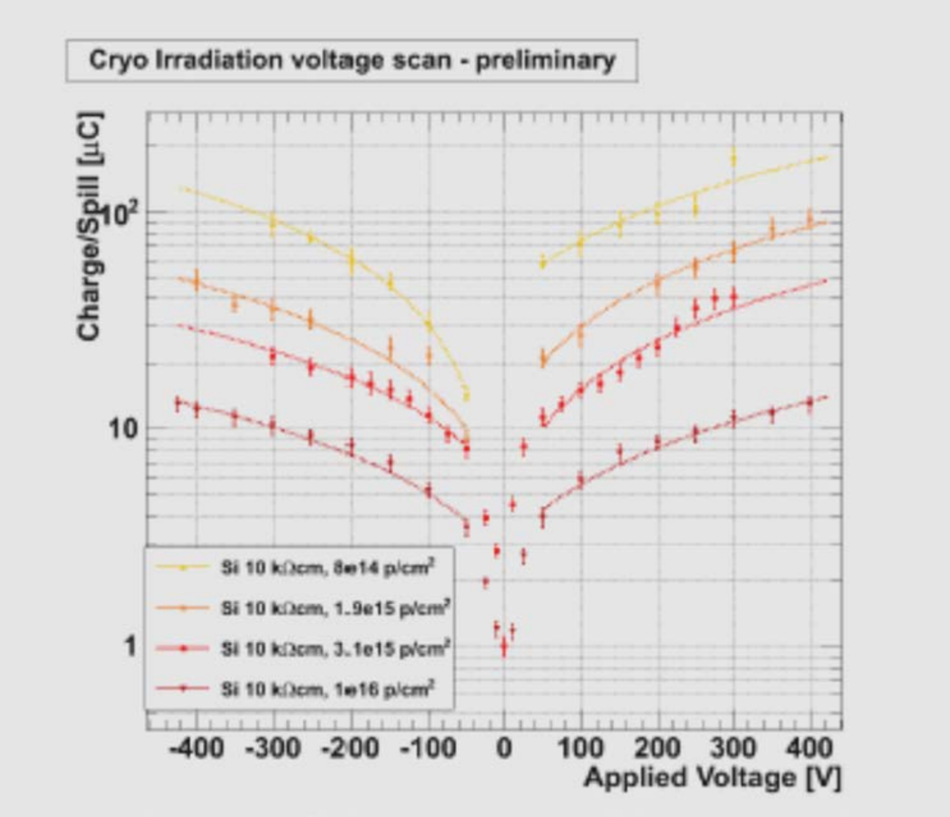
DC measurements:

- I-V characteristics;
- detector current
- charge
- Charge vs. proton fluence
- voltage scans of the charge

Charge (Qc) measured in Si detectors at LHe temperature



Left – Si 500 Ωcm
Negative polarity– reverse bias

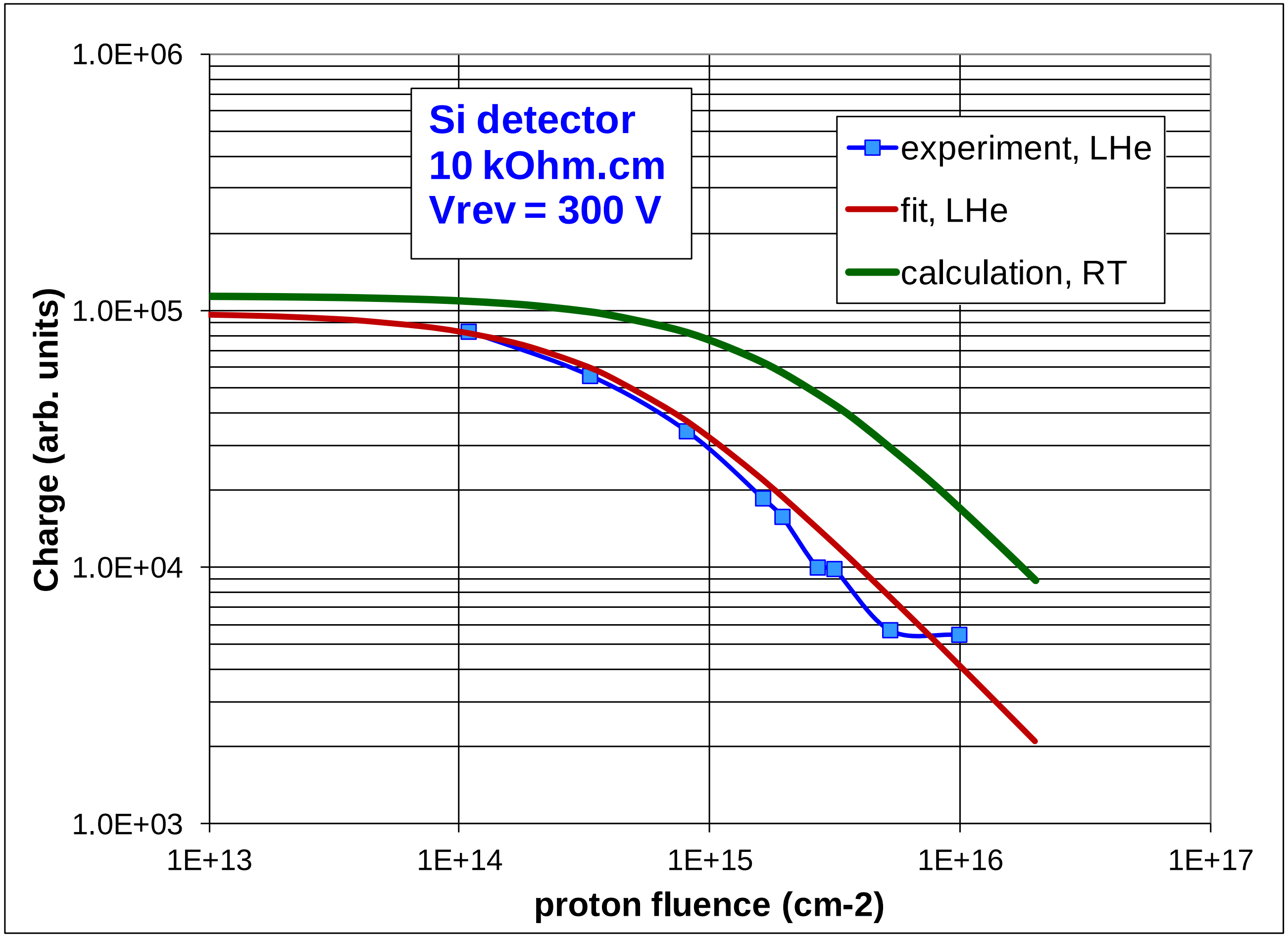


Right – Si 10k Ωcm;
Positive polarity – forward bias

In detectors irradiated to **medium proton** fluence **charge is larger** at forward bias (detector operates as CID) – agrees with RT operation (left)

1×10^{15}-1×10^{16} cm^{-2} the **same charge** is measured at forward and reverse bias (right)

Charge measured in Si detectors: experiment and fit



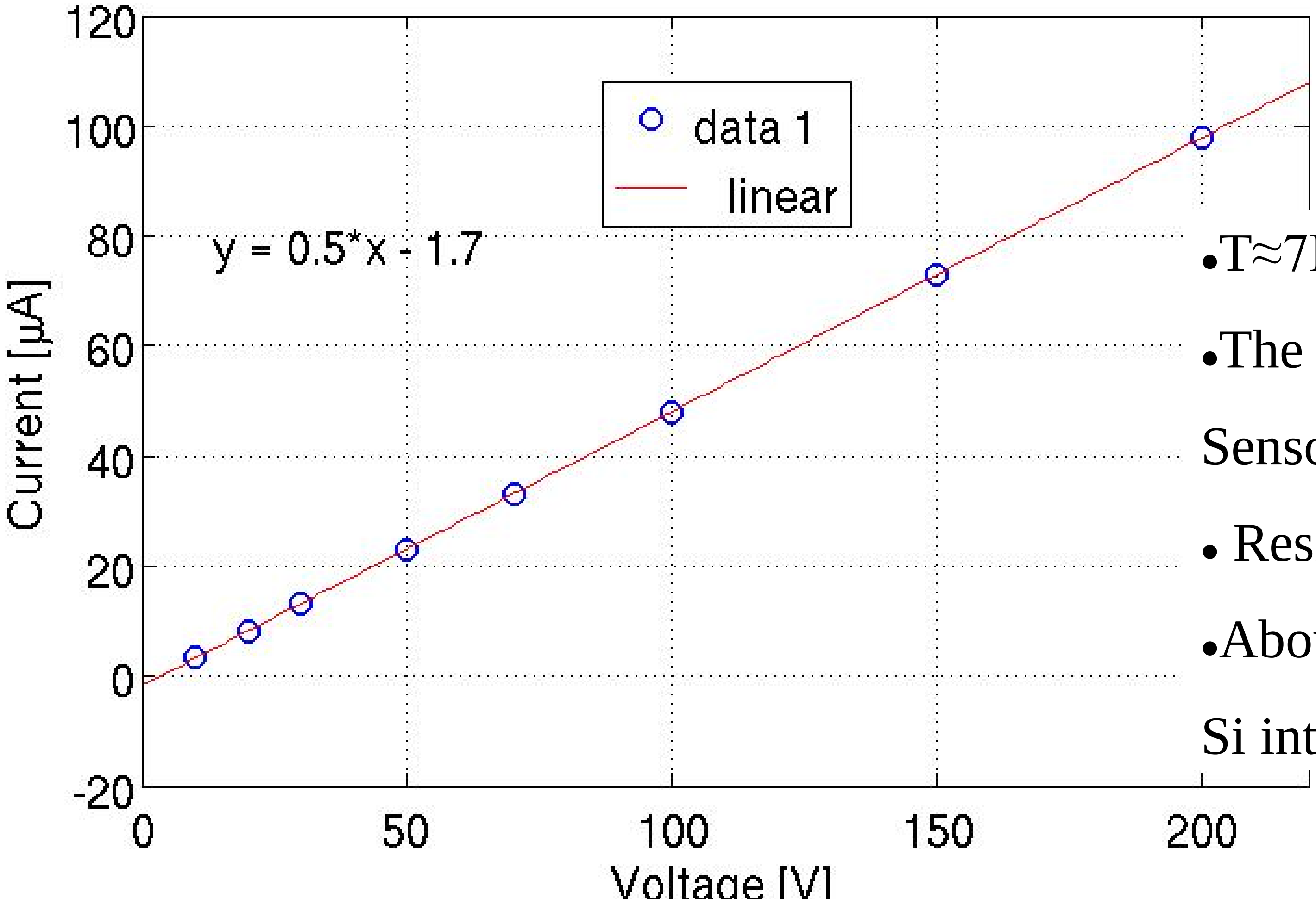
The fit and calculation are performed using analytical equation for the measured charge vs. fluence
$Q = f(v_{drift}, t)$

Charge is controlled by trapping time constant t dependent on fluence at both RT and LHe

Trapping probability $1/\tau$
is **factor of seven higher** at LHe than at RT

Normalization: Q are normalized to the same value of generated charge

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

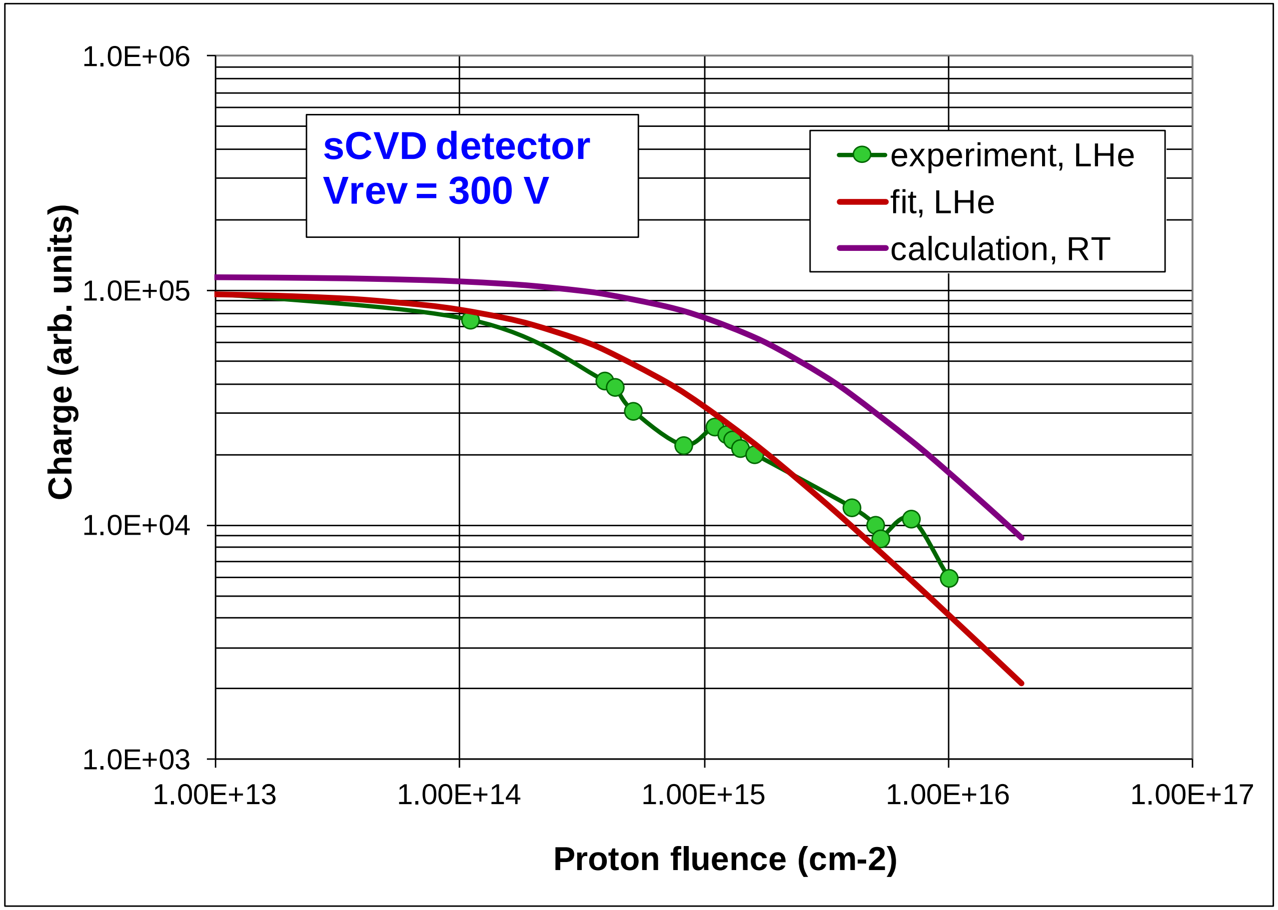
Si intrinsic resistivity at RT

Summary

- Si detectors produces by RD39 are successfully tested in particle beams and by laser TCT setups
- Detectors were irradiated up to 1×10^{16} p/cm^2 fluence and signal/charge was monitored in-situ at LHe temperature.
- The signal of Si detector at LHe temperature is readable after 1×10^{16} p/cm^2 irradation.
- Trapping at LHe temperature is about 7 more than predicted at RT.
- sCVD diamond of comparable size produces at LHe temperature about 30% higher signal than Si detectors. This is presumably due to different trapping characteristics of diamond and Si at very low temperatures.
- Results are still preliminary and need better understanding and further investigations.

Backup slides

Charge measured in diamond detectors: experiment and fit



Q(F) in sCVD detector is described by the same equation as in Si detector

The difference is in trapping probabilities 1/t:
it is in 30% larger in Si detector

TCT measurements

Detector from 10 k Si (processed by PTI/RIMST consorsium

Setup developed by RD39

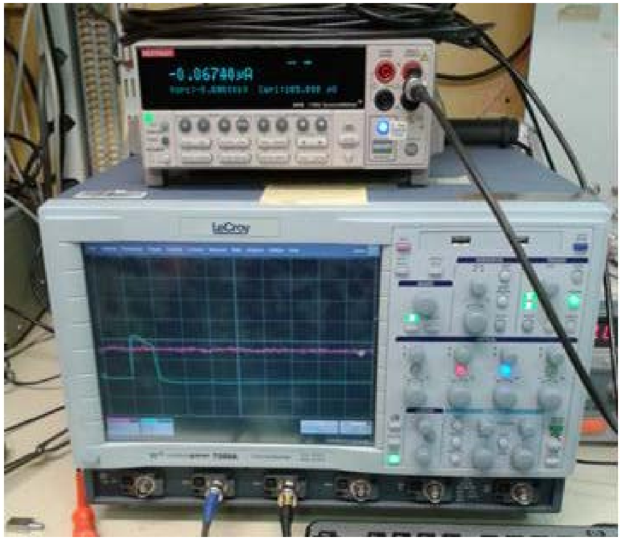
-3 GHz LeCroy oscilloscope;
-picosecond laser (generated by a PiLas Digital Control Unit (EIG1000D) and an optical head for 680 nm) ;
- special rad-hard cables

Modules for TCT measurements
developed in Ioffe Physical-Technical Institute

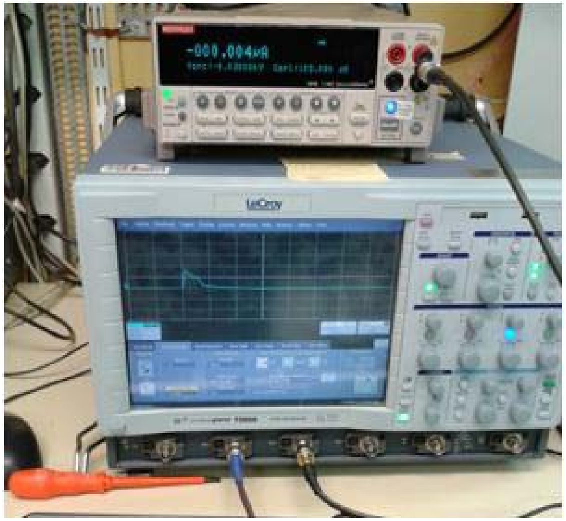
Changes of current pulse response (TCT with a pulse laser)

Before irradiation

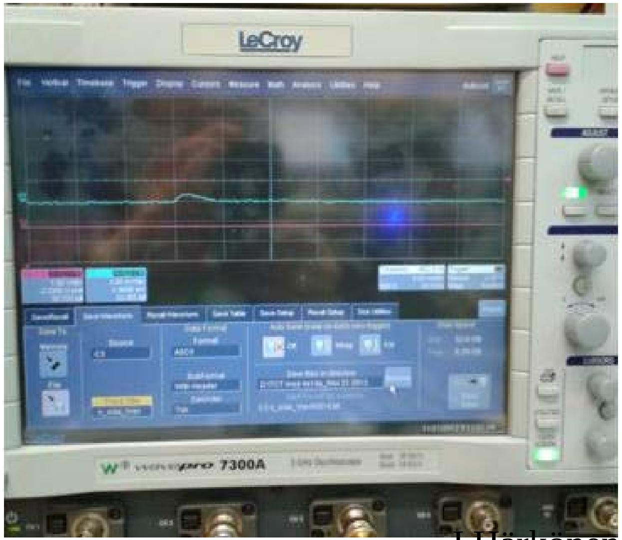
Room temperature



LHe

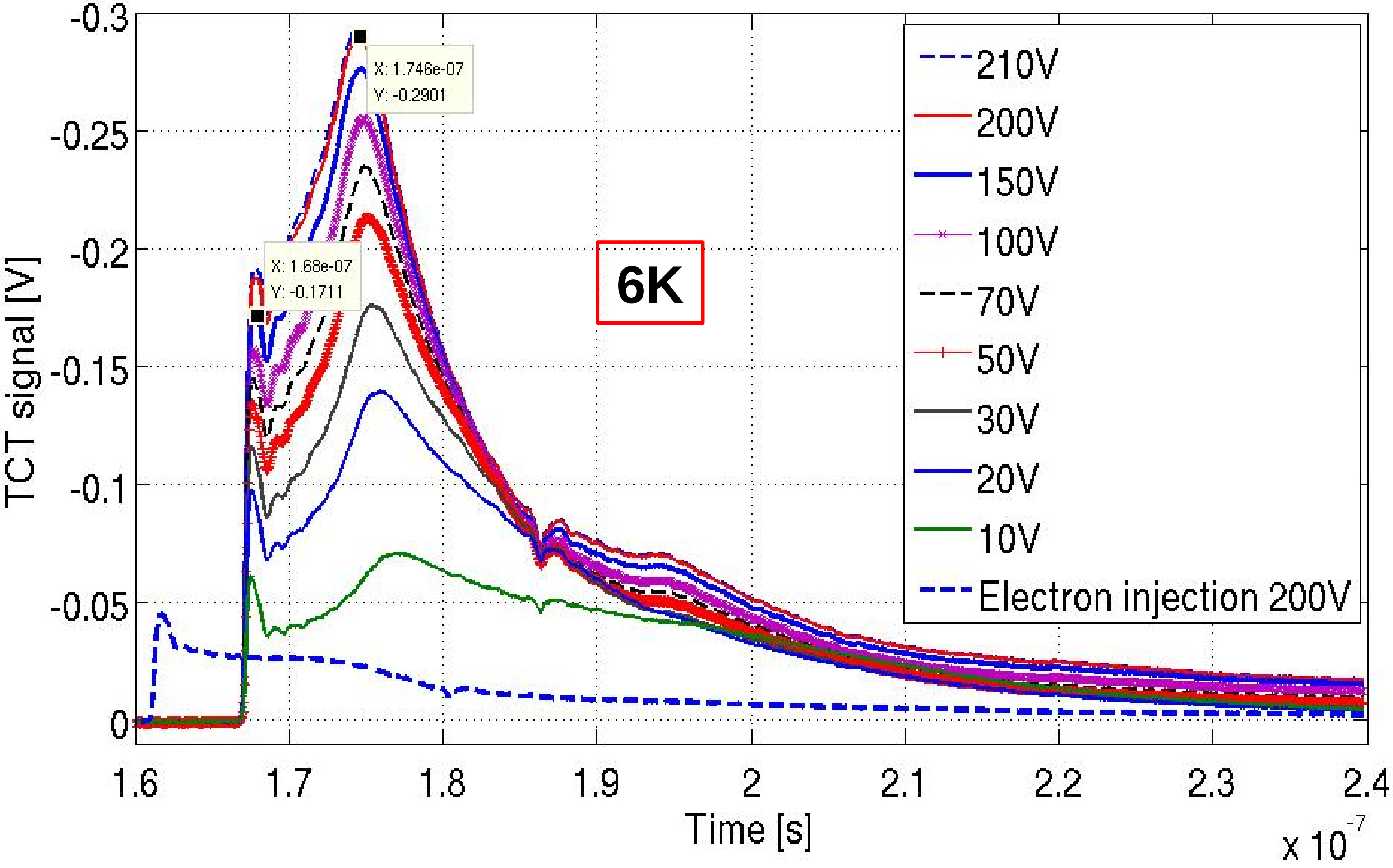


Pulse width is smaller due to higher carrier mobility at LHe



Pulse response after irradiation to ~8e14 p/cm2

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