RD39 Status Report 2013-2014

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

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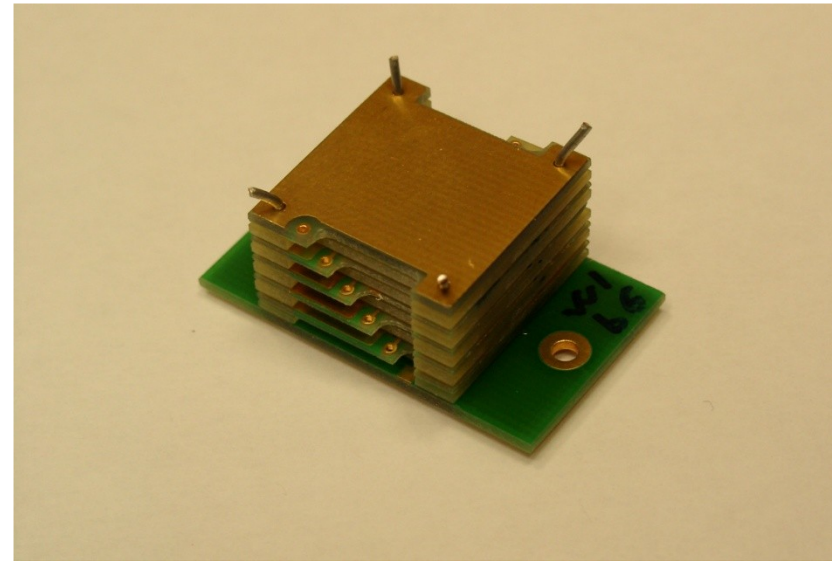
Outline

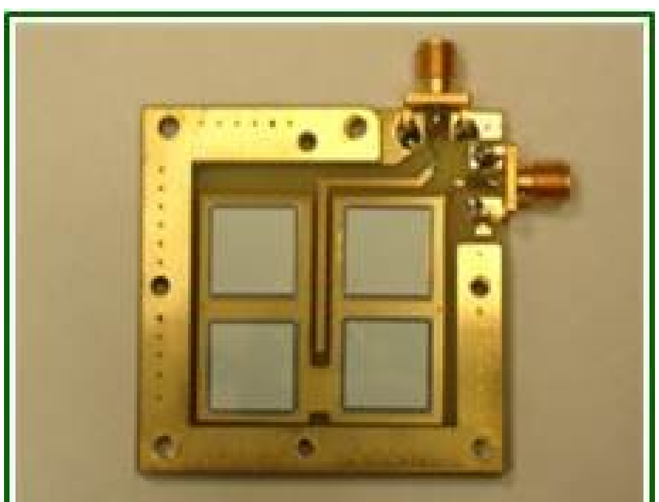
- Motivation and background
- Cryogenic Beam Loss Monitoring (BLM)

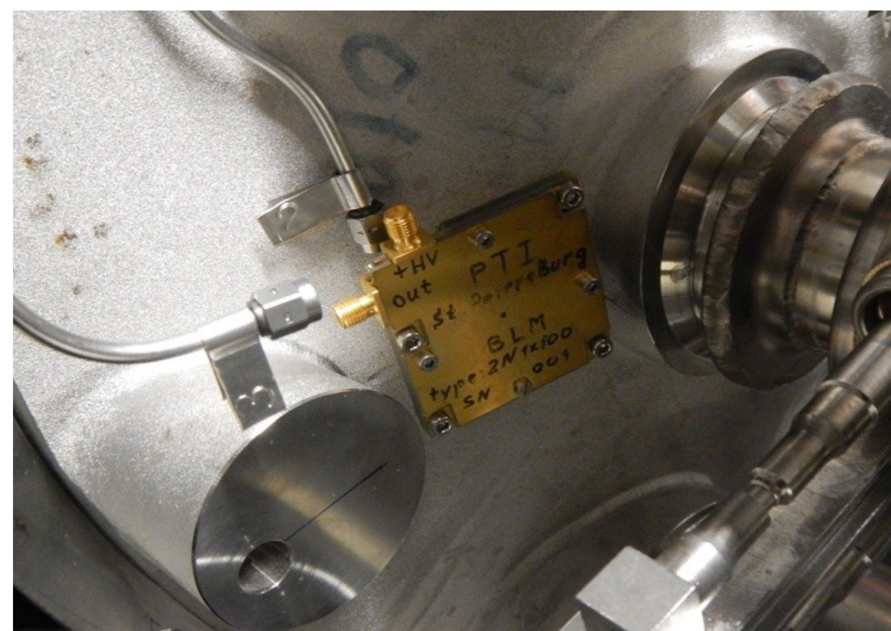
for LHC

- Radiation effects at very low temperatures
- BLM experimental results
  - Test beam results

    Near term plans of BLM project
- Summary





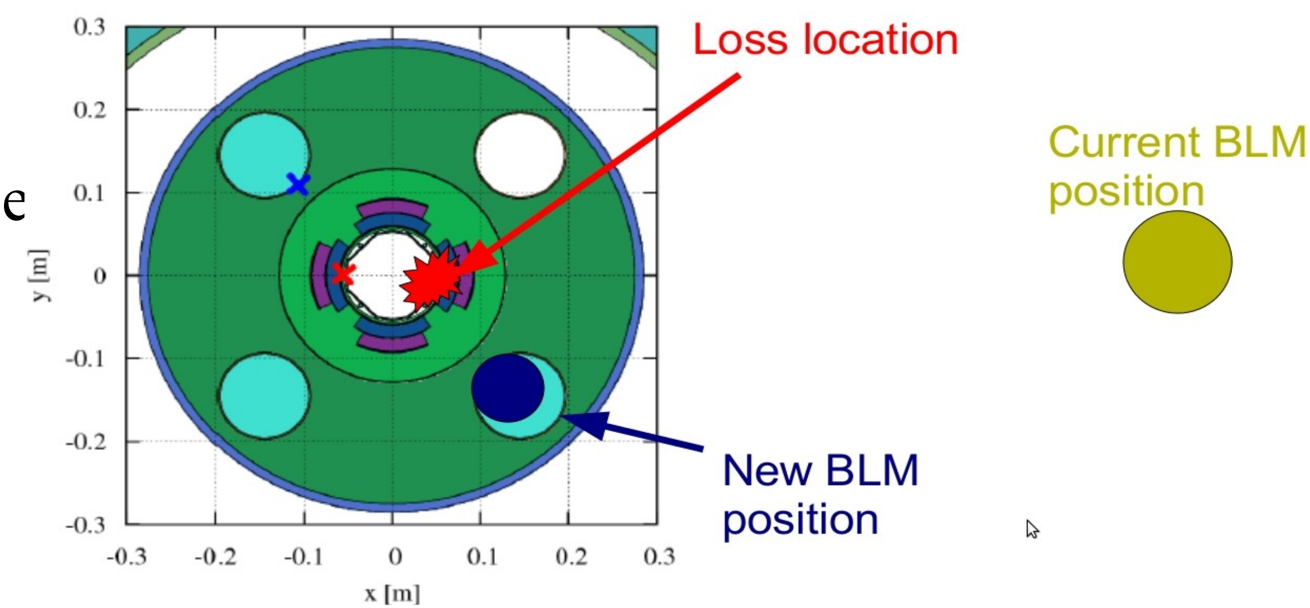


Motivation and background

- Beam Loss Monitors allow to **avoid magnet quenches** due to beam losses

- Current Beam Loss Monitors are gas ionization chambers installed **outside of the magnet cryostat**

- In some cases the large amount of material between beam loss location and the detector and presence of another radiation source leads to **masking of the signal at quench**.

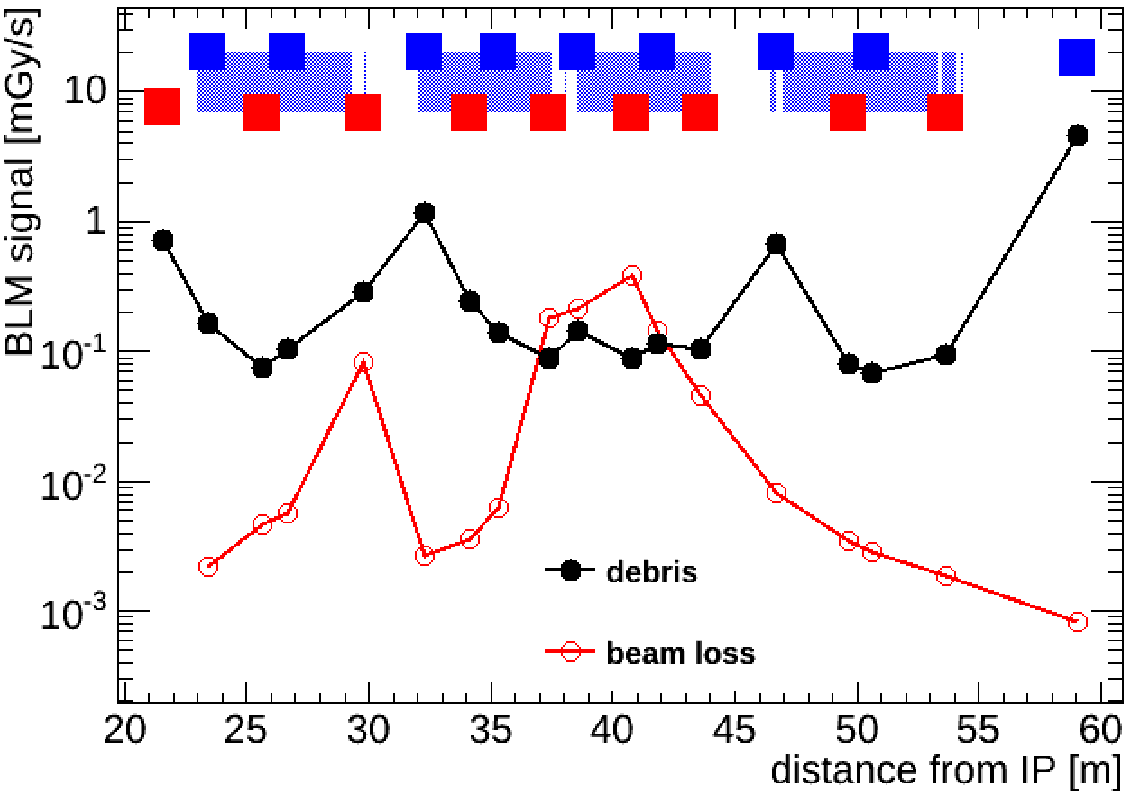


Motivation and background II

- Energy deposition from beam debris and/or beam loss might heat up LHe

- Fast pressure increase from 1.1 bar up to about 20 bar is possible resulting in irreversible damage to LHC

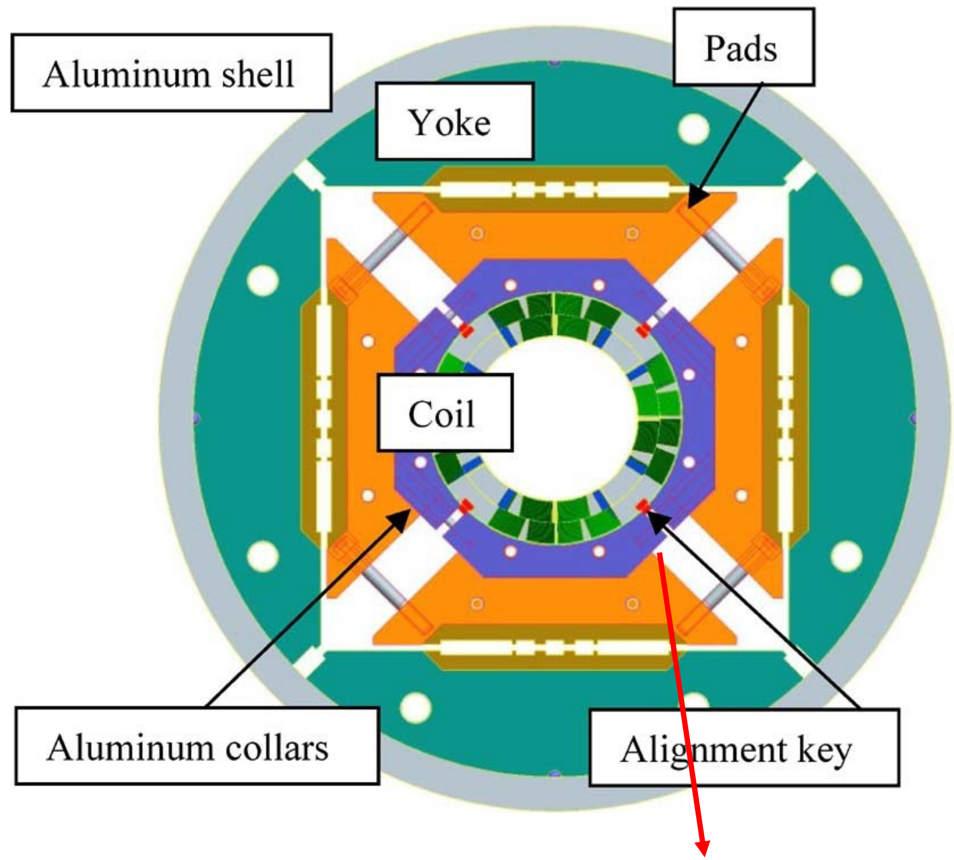
- Especially when the distance from IP is less than 30m, induces larger debris signal into BLMs than the beam loss



- 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
- Polarization effect may take place at very low temperatures

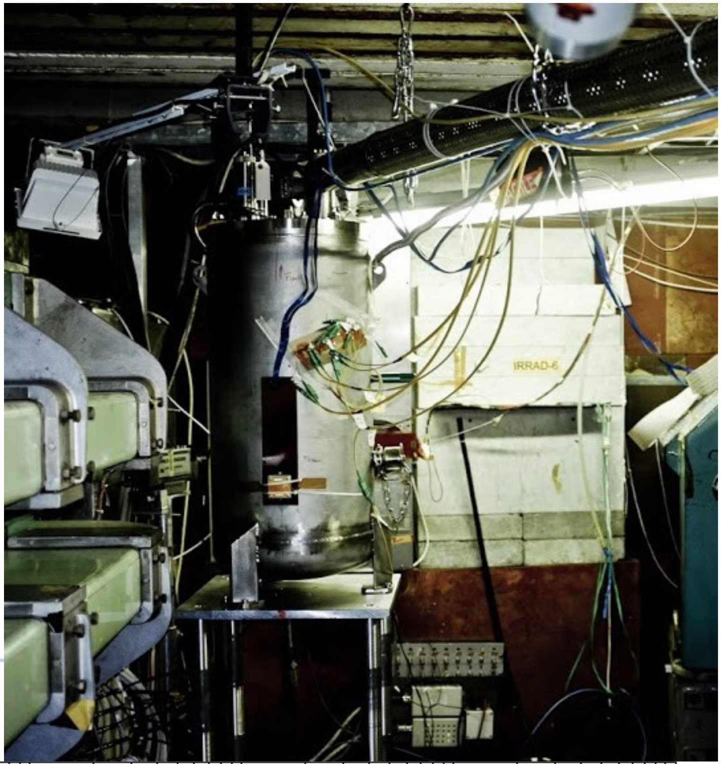
Requirements of beam loss measurement in upgraded LHC

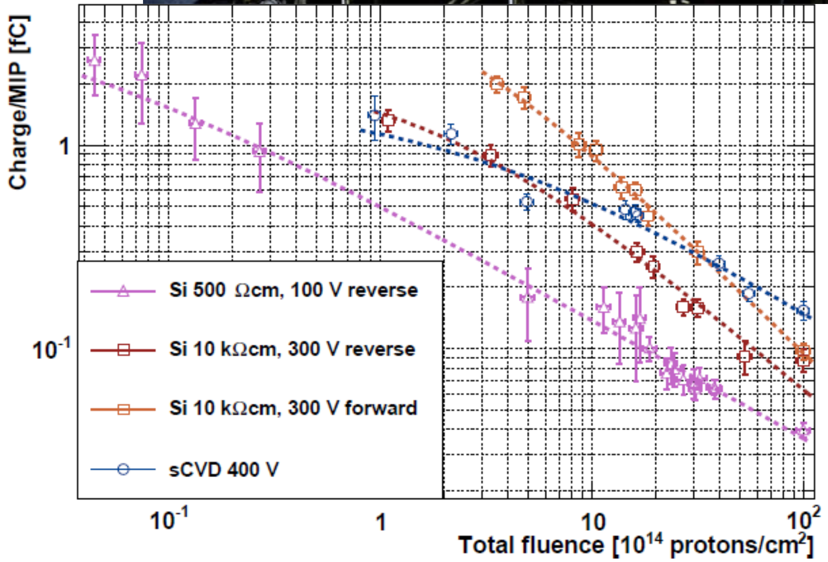
- Solution: Installation of radiation **detectors inside magnet** as close to the coils as possible
- Environment: **T=<2K**,
- **dose 2 MGy** in 20 years,
- B-field = 4 T,
- pressure up to 20 bar, time response <1 ms
- Various technologies investigated: **silicon and diamond** detectors and LHe ionization chamber chosen for further tests.



Irradiation test at 2 K

- Numerous tests done (MIP detection, source tests, TCTs, etc).
- Most challenging: 1 month at 2-4 K in PS irradiation area (T6) in summer 2013
- Good radiation hardness
- Rich documentation:
  - Ch. Kurfuerst et al., Radiation Tolerance of Cryogenic Beam Loss, Proceedings of IPAC13
  - Ch. Kurfuerst, PhD thesis, November 2013
  - M. Bartosik et al., Characterisation of Si Detectors for the Use at 2 K, Proceedings of IPAC13, CERN-ATS-2013-058

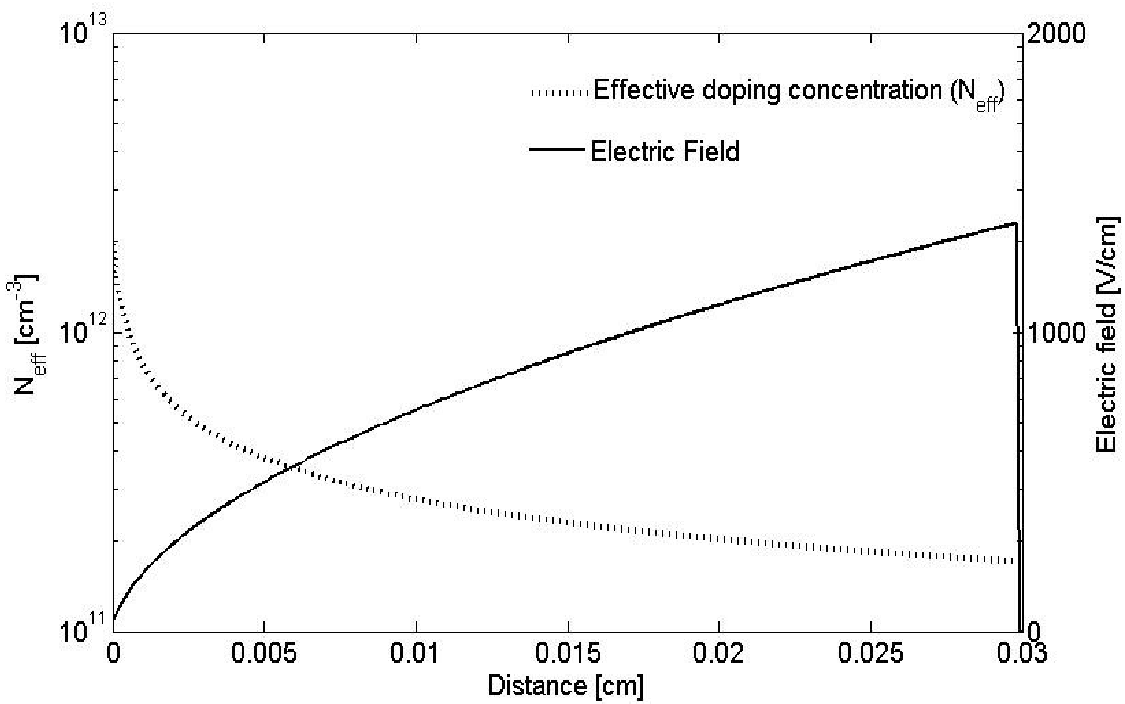




Radiation effects at very low temperatures

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

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



In case of charge injection, electric field is extended through entire bulk regardless of irradiation fluence.

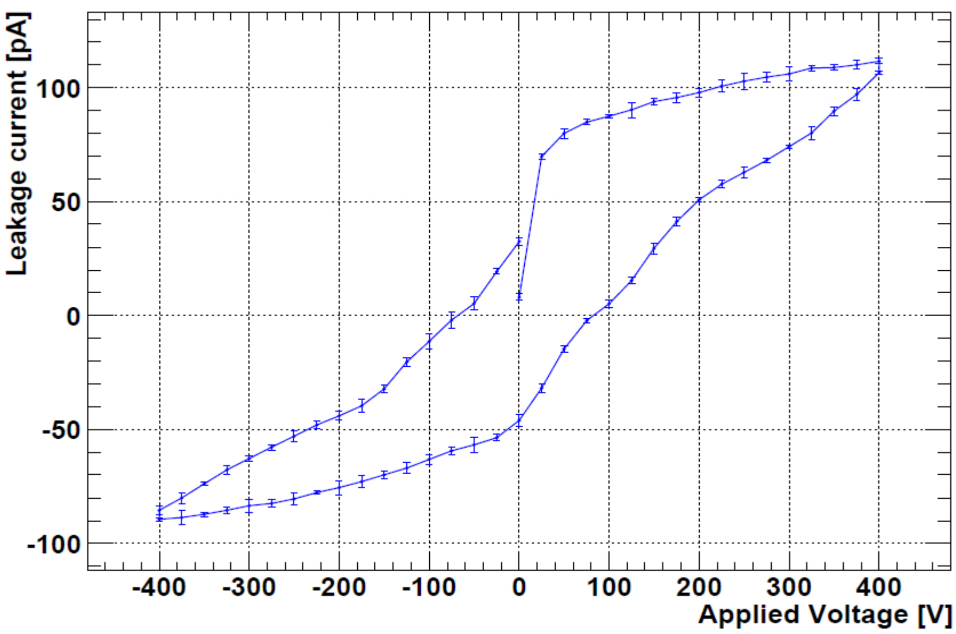
Electric field is proportional to square of distance E(x)~√x

No annealing of radiation induced defects

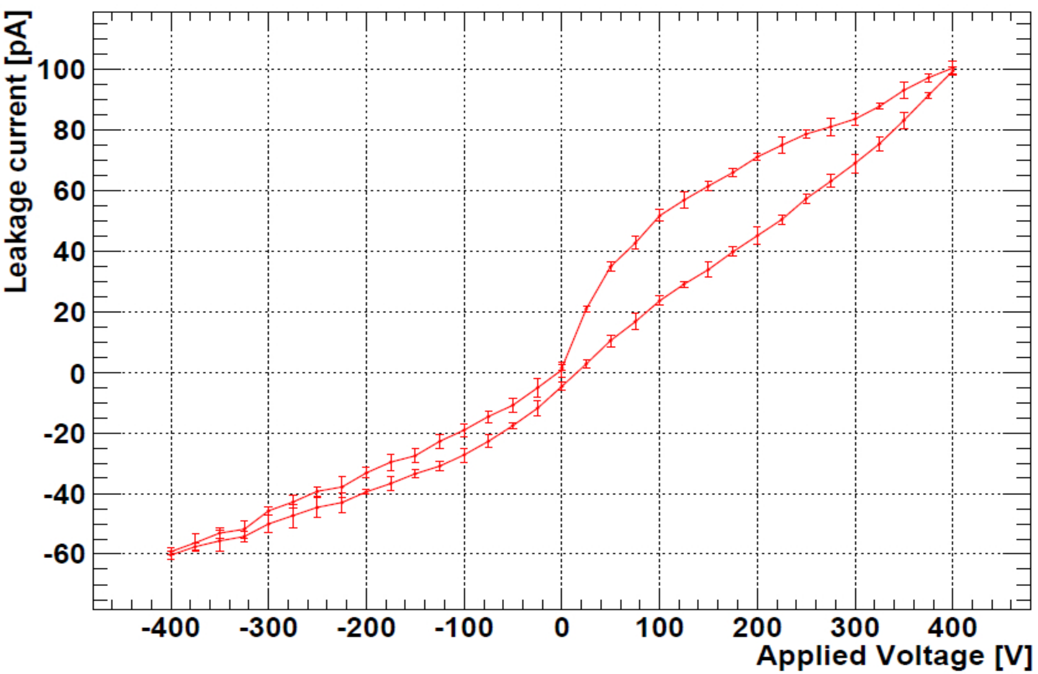
Detector is "fully depleted" at any bias or irradiation fluence

Radiation effects at very low temperatures II

At very low temperatures. polarization can be significant.
IV curves measured at LHe after 1×10^{16} p/cm^2 irradiation



Hysteresis at LHe –
electric field polarization



Hysteresis at LHe is insignificant

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

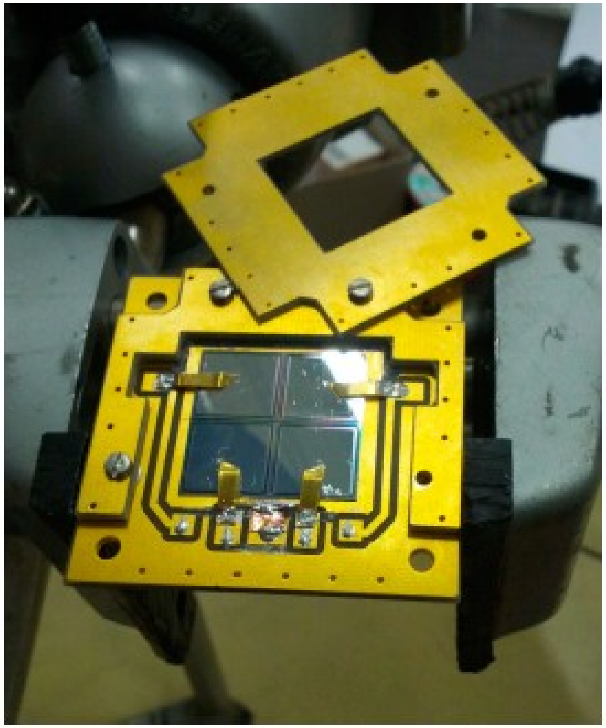
Aspects of the experiment

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

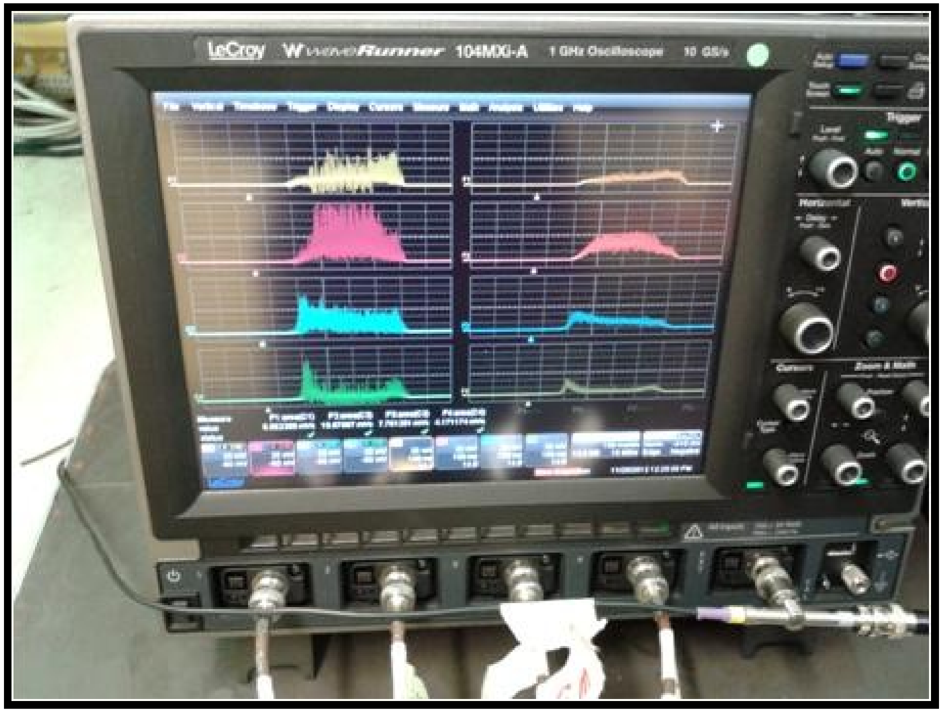
For the irradiation test p+-n-n+ silicon pad detectors processed by the consorsium of Ioffe Physical-Technical Institute, St. Petersburg, and Reserch Institute of Material Science and Technology, Zelenograd, both Russia,

	Resistivity [Ωcm]	Area [mm^2]	Thickness [μm]
Silicon 1	10k	5×5	300
Silicon 2	10k	3×3	300
Silicon 3	500	5×5	300
Silicon 4	4.5	5×5	300
Diamond	undoped	4.7×4.7	500

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)

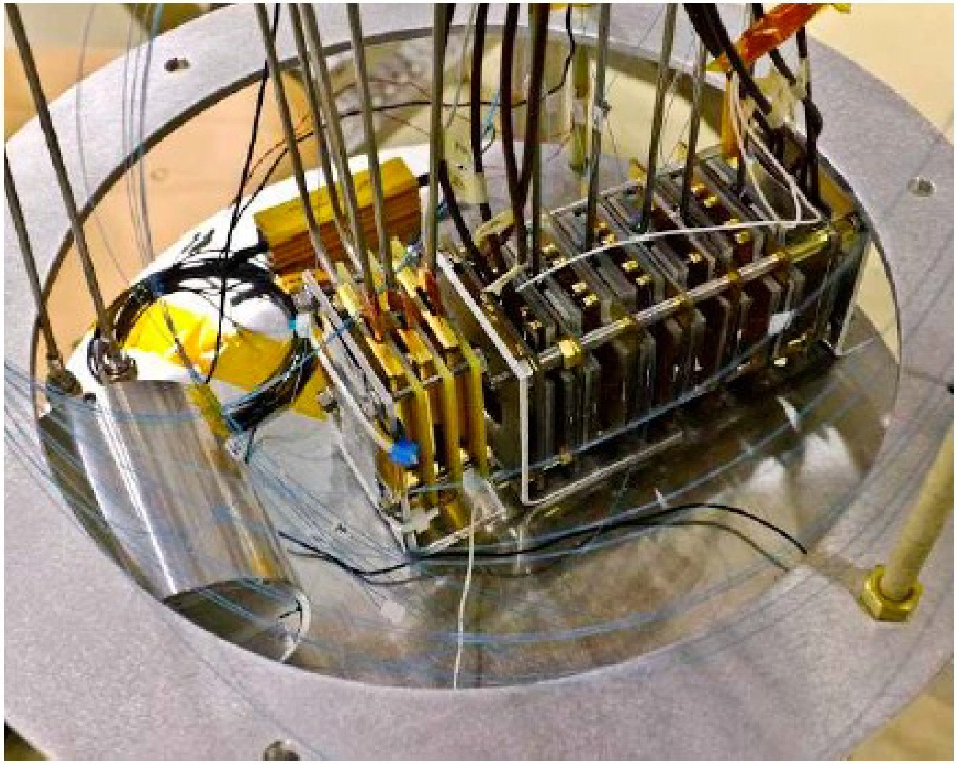
A silicon telescope at the outer positions of the detectors inside the cryostat allowed verifying the alignment with respect to the BPM on the outside. The telescope modules contain 4 silicon detectors each.

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.

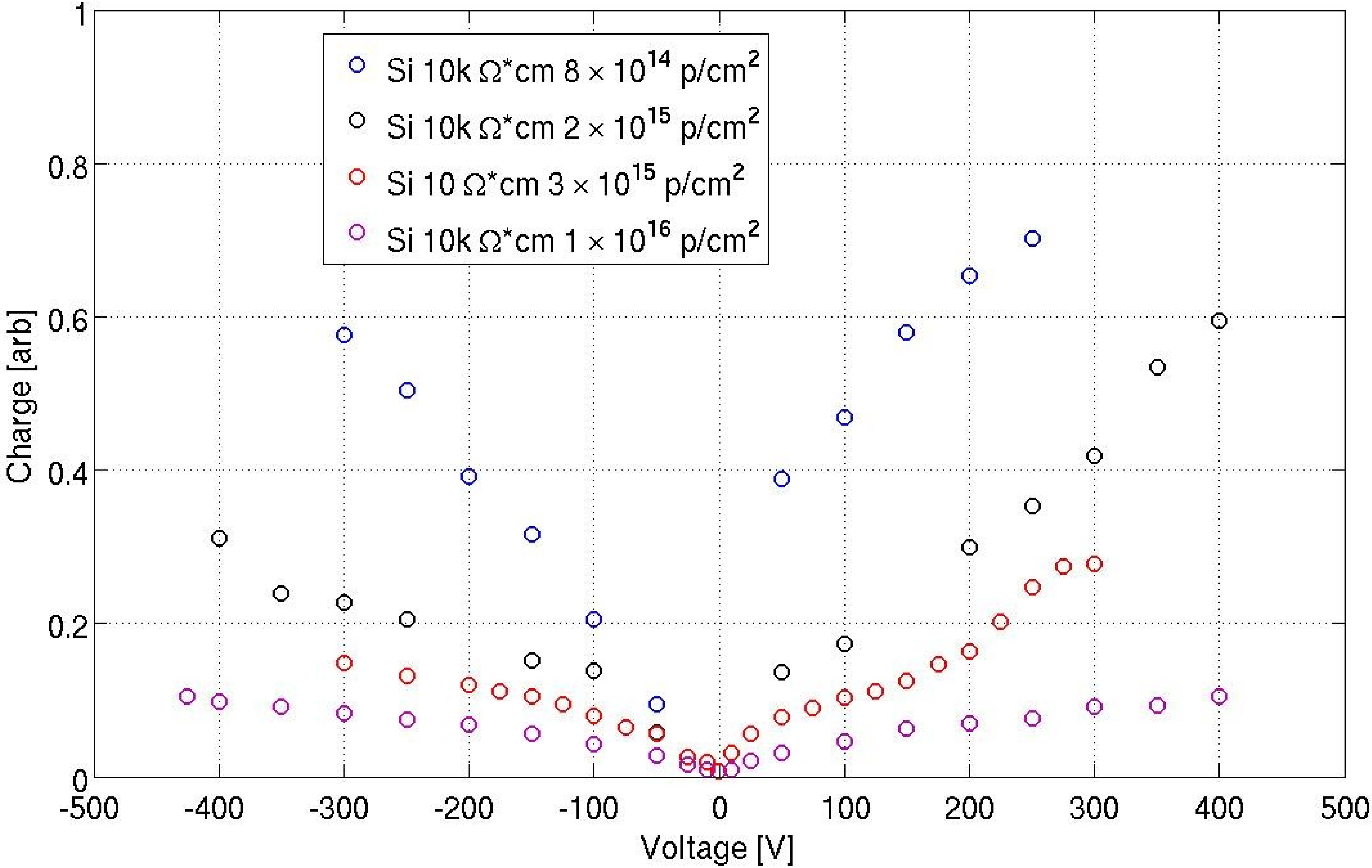


Detector modules mounted on plate and ready for cooling down and irradiating

DC measurements:

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

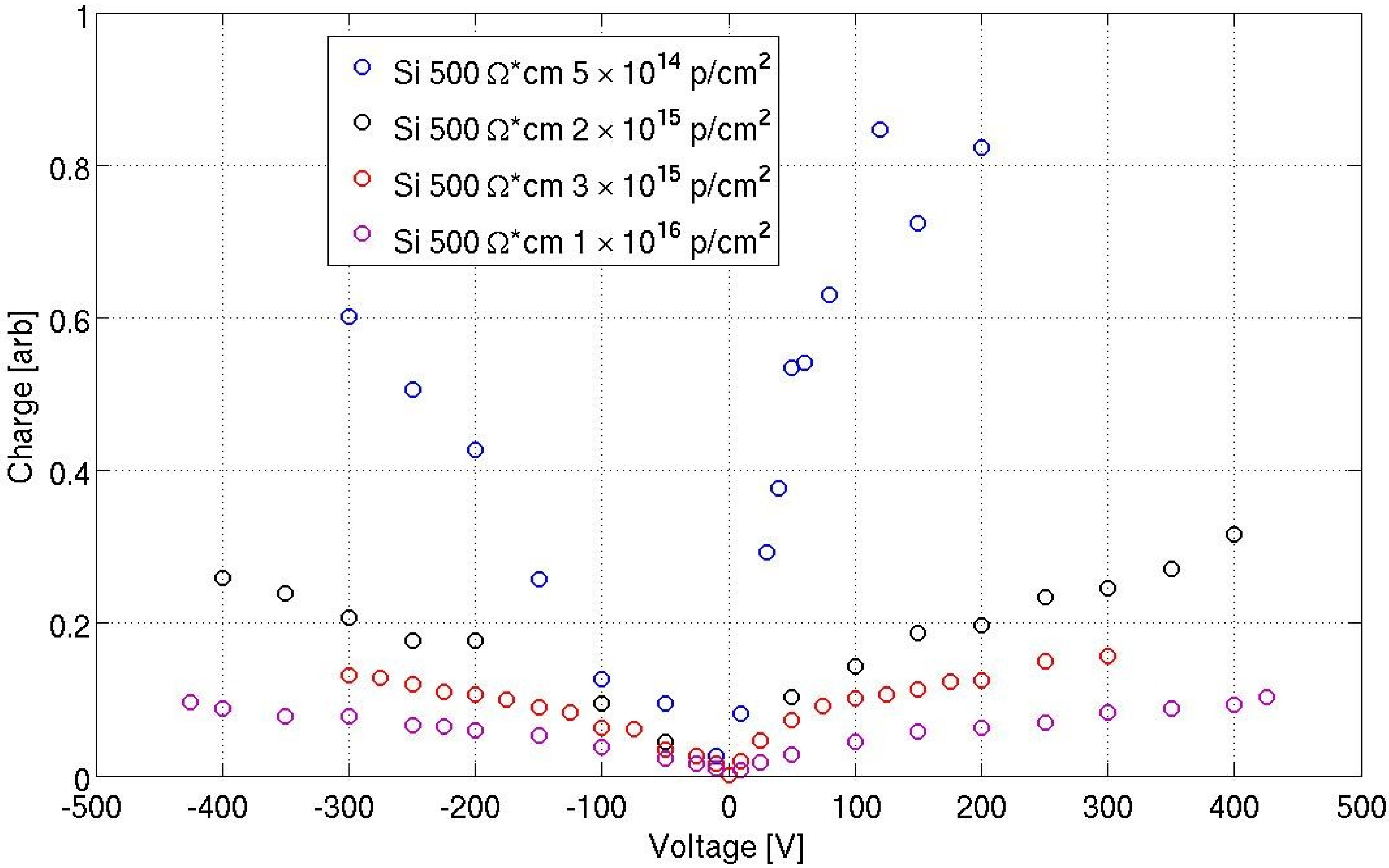
Collected Charge
- High resistivity silicon 10k Ωcm



Negative polarity– reverse bias

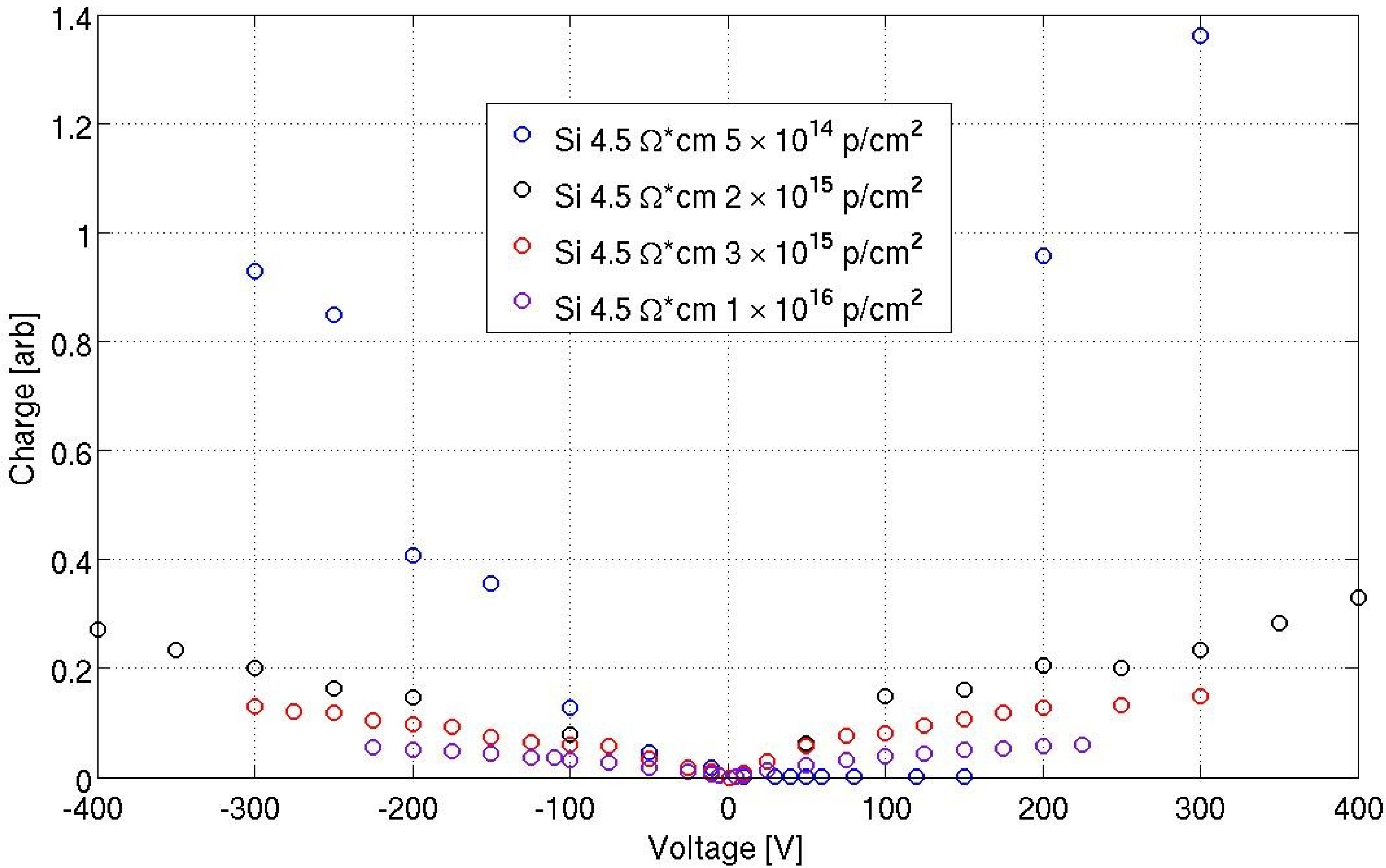
Positive polarity – forward bias

Collected Charge
- Medium resistivity silicon 500 Ωcm



at 1×10^{16} p/cm^2 collected charge is about 10% of an unirradiated detector

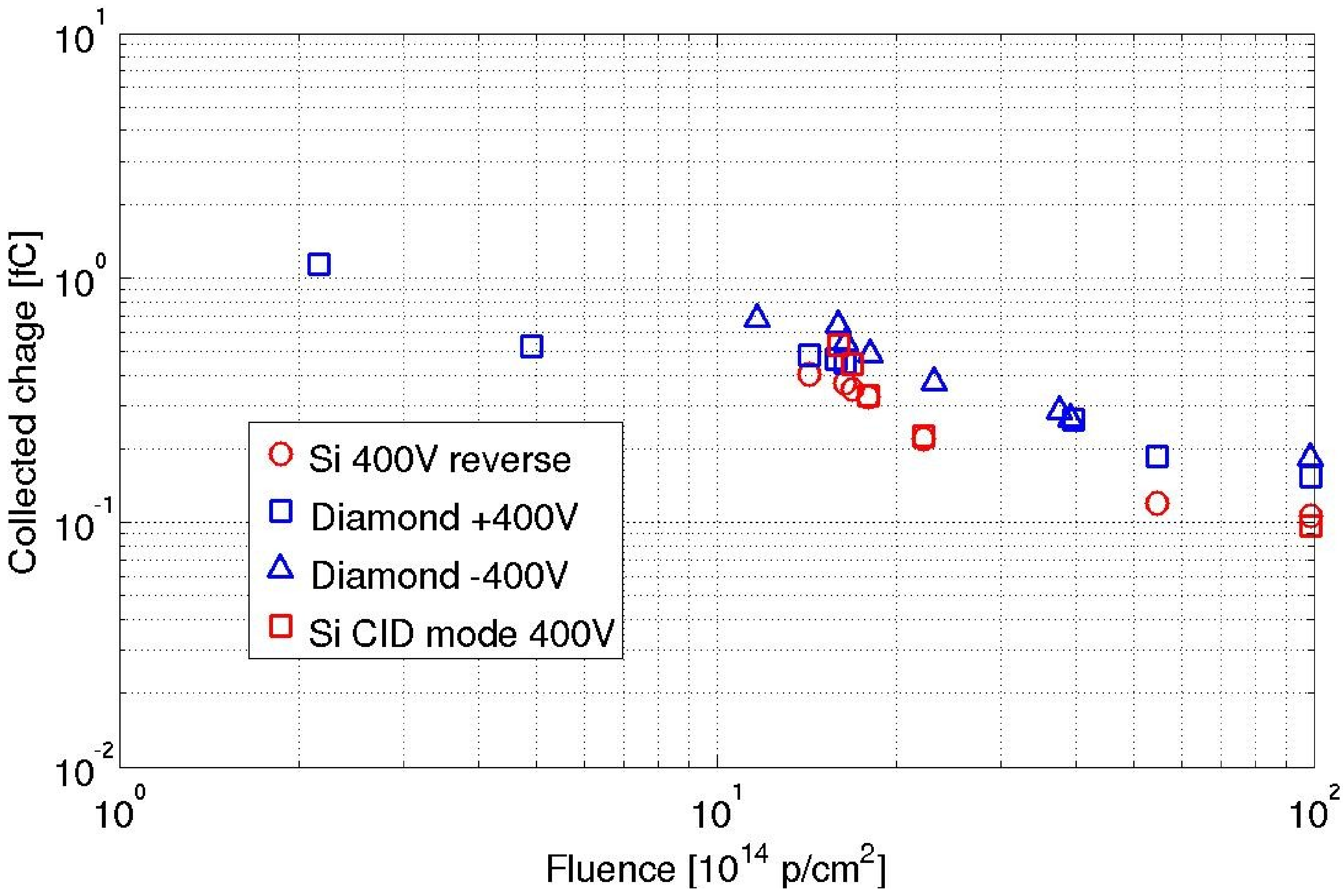
Charge (Qc) measured in Si detectors at LHe temperature - Low resistivity silicon 4.5 Ωcm



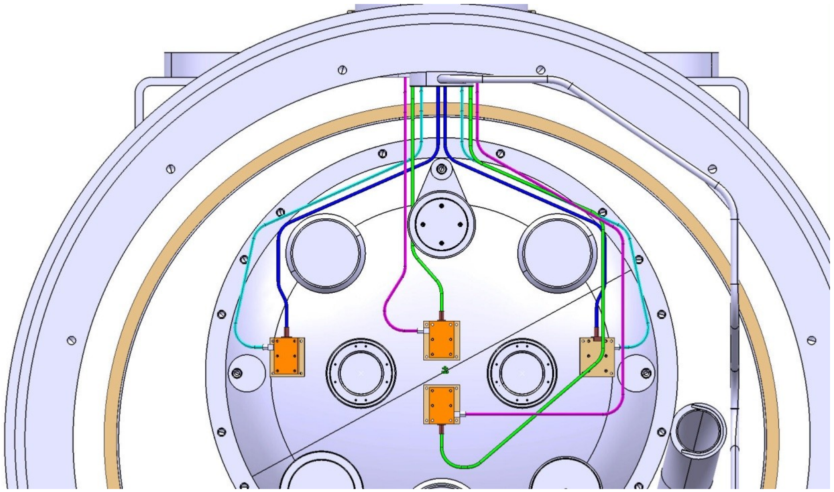
In detectors irradiated to **medium proton** fluence **charge is larger** at forward bias (detector operates as CID) – agrees with RT operation (left)

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

Collected charge at LHe – Si vs Diamond



Test installation on LHC magnets



- 8 detectors (6 silicon, 2 diamond) installed in 2 locations were high losses expected during LHC operation.

- Installation is ON cold mass, in insulation vacuum (i.e. T=~2K but no LHe environment)

- It is a long-duration test of the technology before installation inside magnets in 2018

- (11T dipole) and 2024 (new triplet magnets)

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.
- After 1×10^{16} p/cm^2 collected charge is about 10% of an unirradiated detector. The signal produces by beam loss is readable at LHe temperature after 1×10^{16} p/cm^2 irradiation.
- Trapping at LHe temperature is significantly more than predicted at RT. This is due to non-existent defect annealing at LHe.
- Resistivity of Si and reverse/forward bias does not significantly affect on CCE at LHe/1×10^{16}
- 8 detectors (6 silicon, 2 diamond) installed into LHC magnets.