Cryogenic BLMs for the LHC

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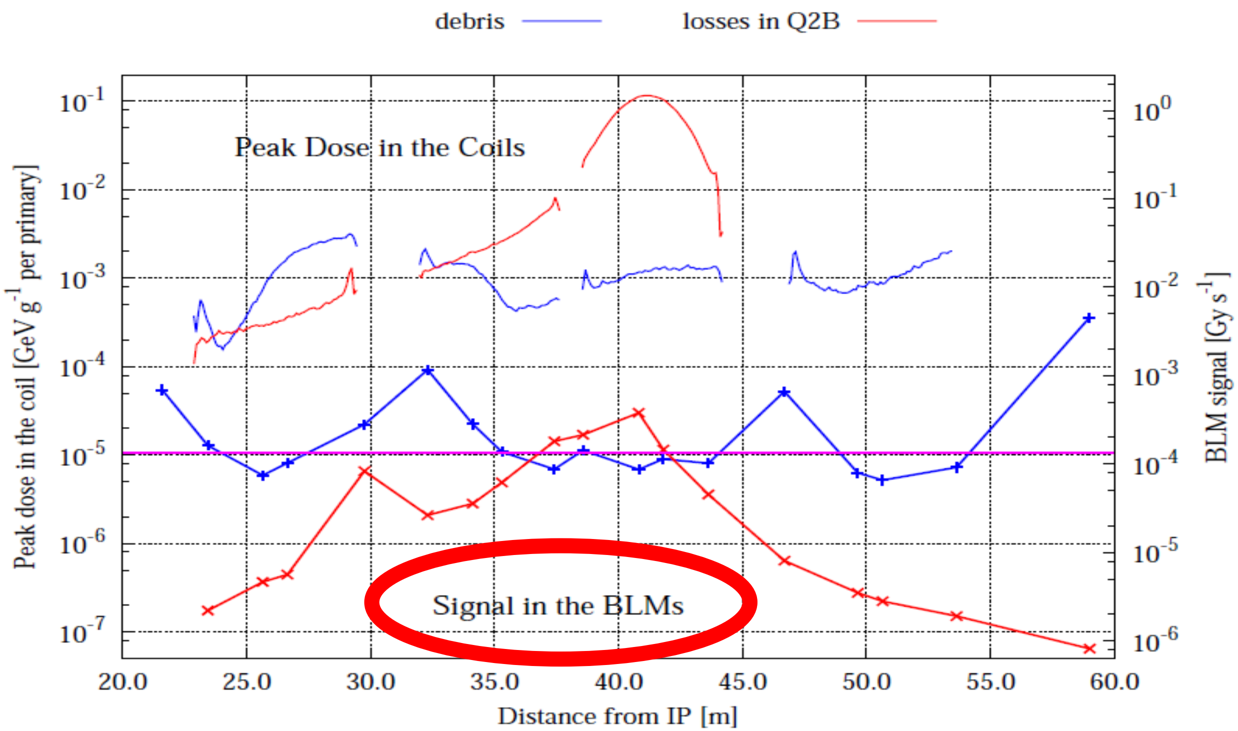
Outline

- Motivation
- Investigated detectors
- Beam test measurement setup
- Results
  - Semiconductors
  - Liquid helium chamber
- Conclusions and outlook

Limit close to interaction regions

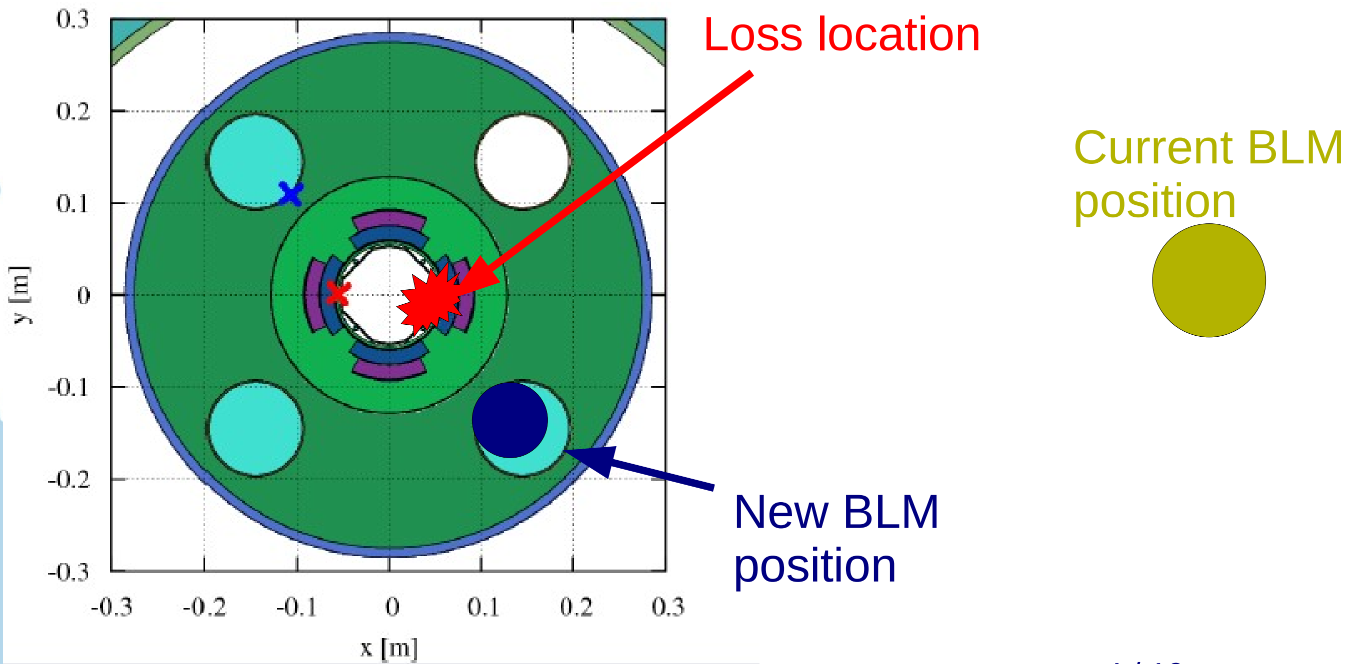
Problem: in triplet magnets signal from debris with similar height as simulated beam losses in steady state case

7 TeV, nominal luminosity



Cryogenic BLM as solution

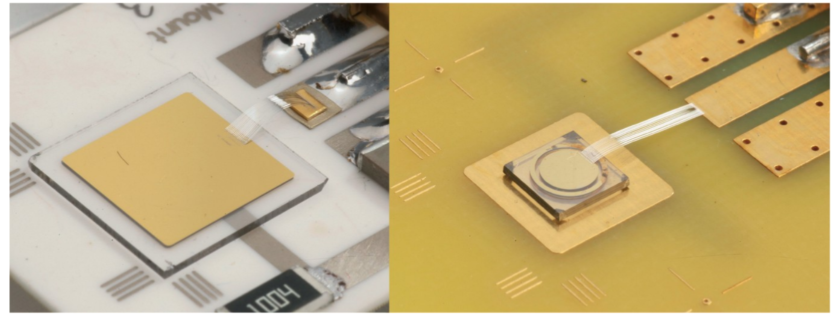
- Future BLMs placed closer to:
  - where losses happen and
  - the element needing protection (so inside cold mass of the magnet, 1.9 K)
- Measured dose then better corresponds to dose inside the coil



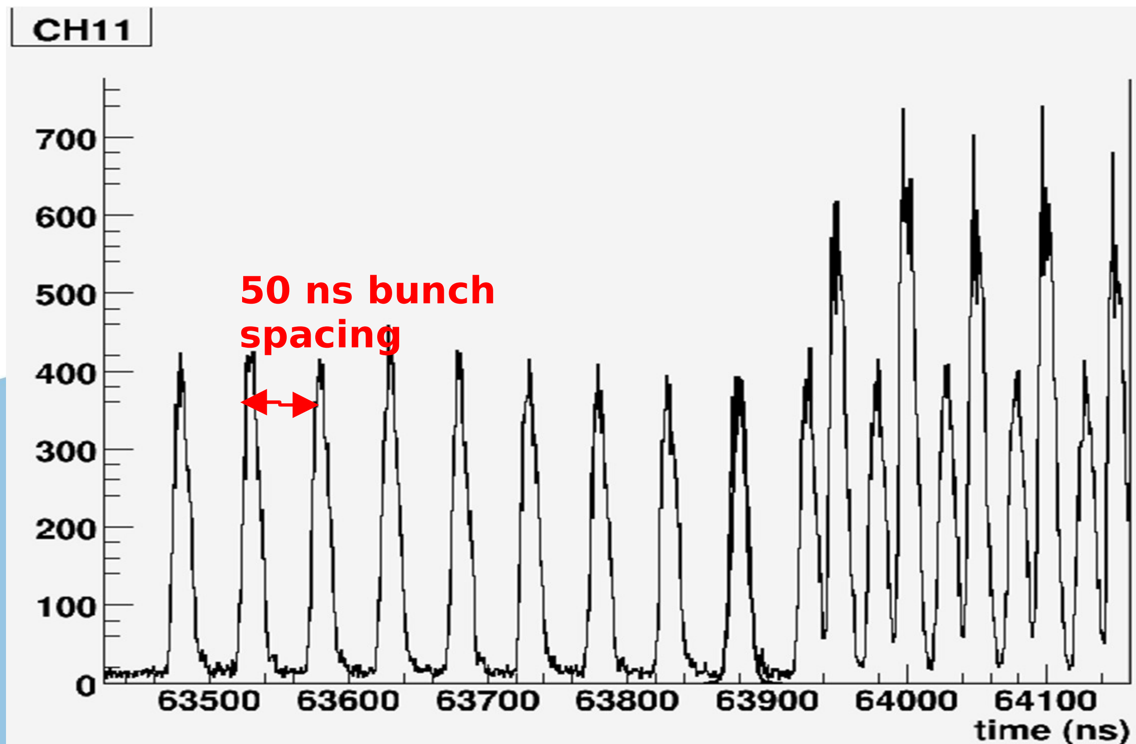
Investigated detectors

- **Silicon**
  - Successfully used at 1 K at CERN in 1976 - ““Frozen Spin” Polarized Target”
- **Diamond**
  - Successfully in use as LHC BLM at room temperature
  - Radiation harder than Si at room temperature (high displacement energy 43 eV)
  - Less leakage current than Si at room temperature (high band gap of 5.48 eV)
  - Low dielectric constant
- **Liquid helium ionisation chamber**
  - + No radiation hardness issue
  - - Slow (charge mobility of 0.02 $cm^2/V/s$)

Diamond



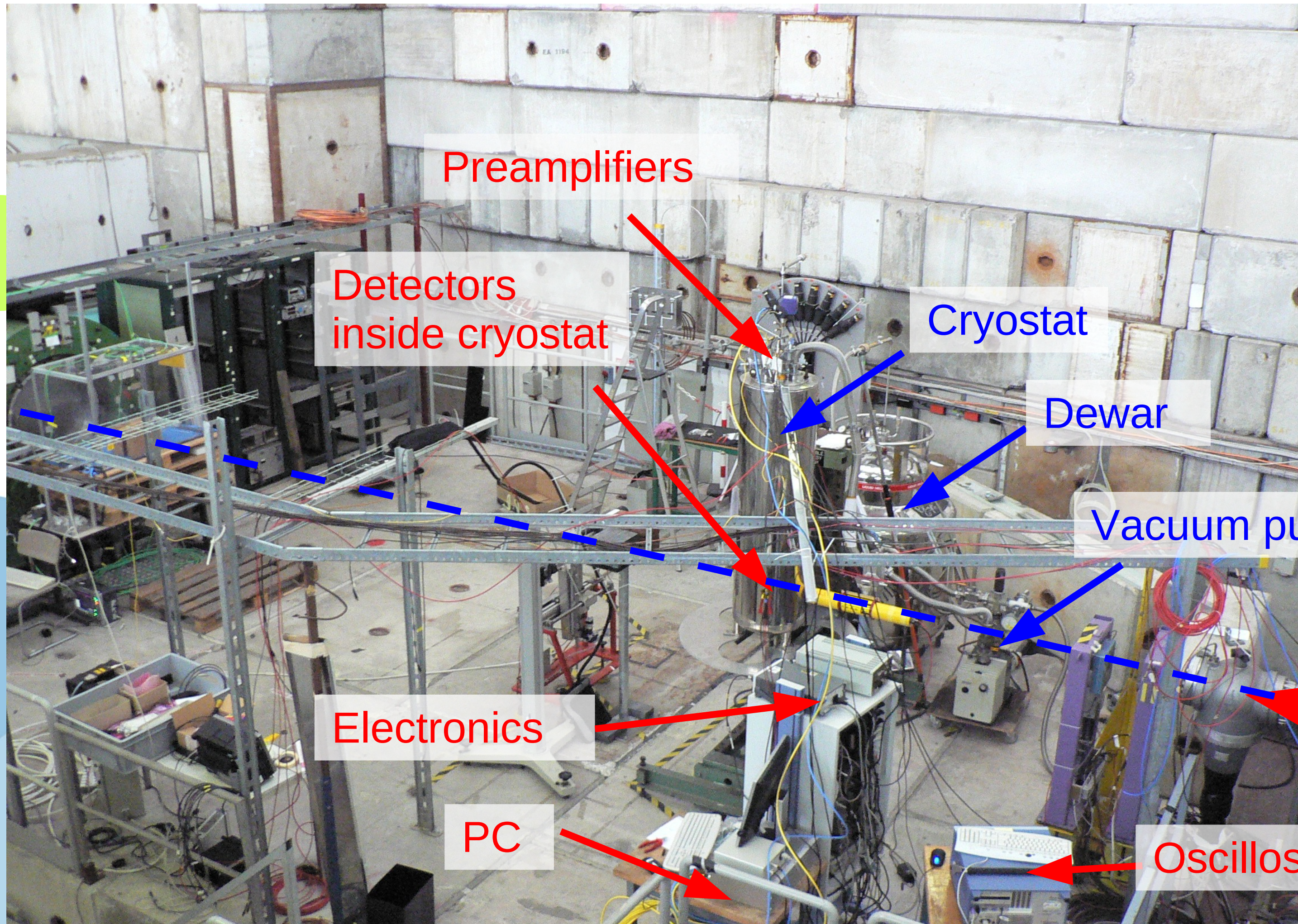
Signal from LHC Diamond BLM



Losses from beam and interaction

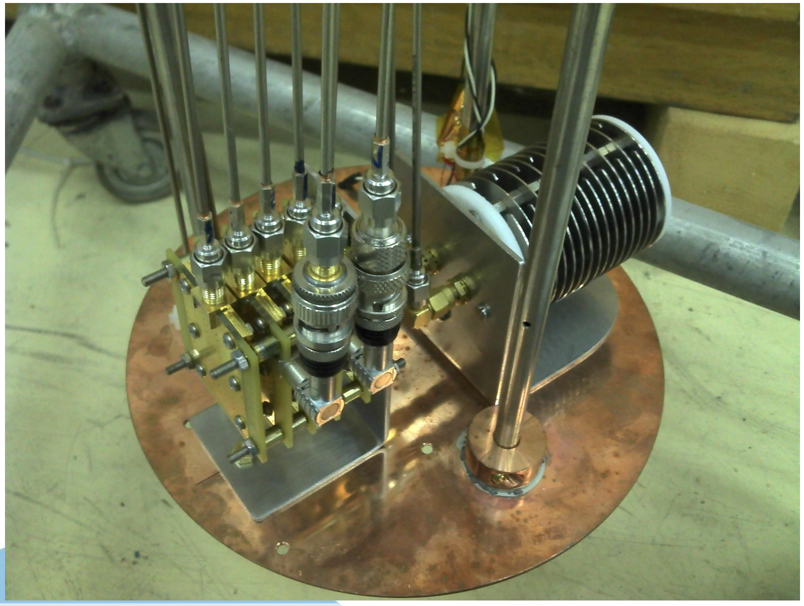
Losses from beam

CERN PS Beam test area



Setups used

In liquid helium



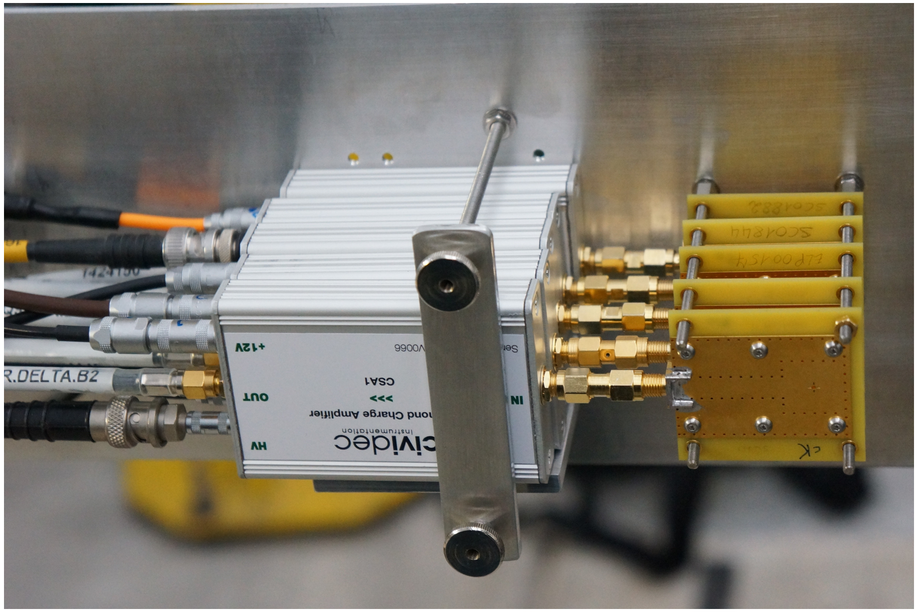
Semiconductors:

Silicon p$^+$-n-n$^+$ with 300 µm thickness and single crystal chemical vapor deposition (CVD) **Diamond** with 500 µm thickness

LHe chamber

3.9 cm active length

At room temperature



With **Erich Griesmayer** and **Christina Weiss**

Inside cryostat

Cable length between detectors and preamplifiers ~ 2 m

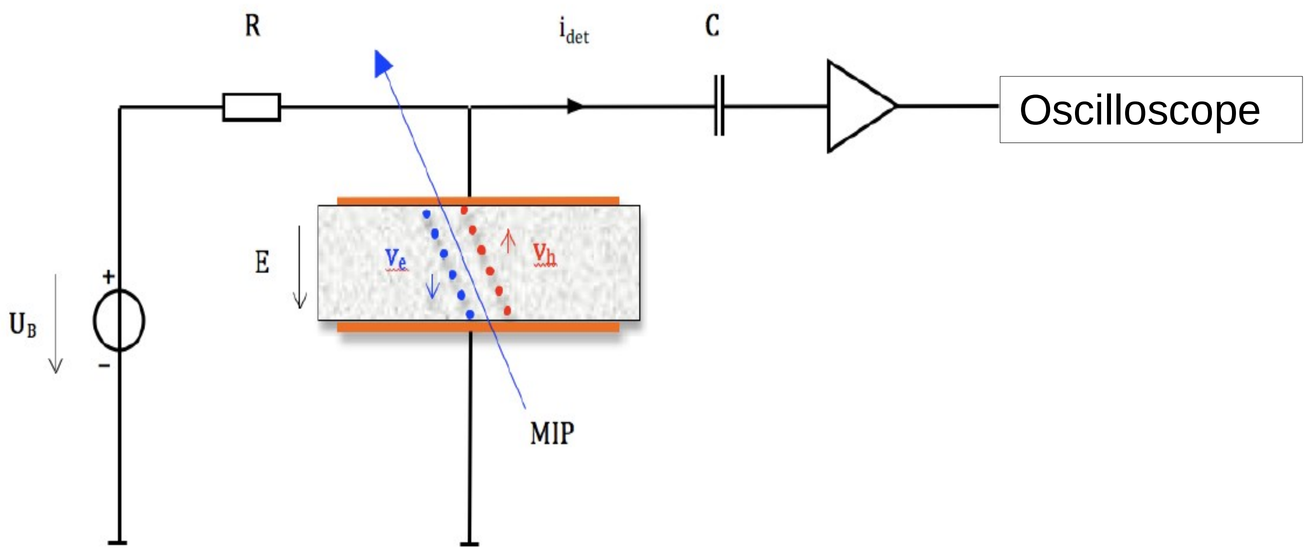
Due to long cables advantage of low noise at LHe temperatures is partly lost.

Beam characteristics

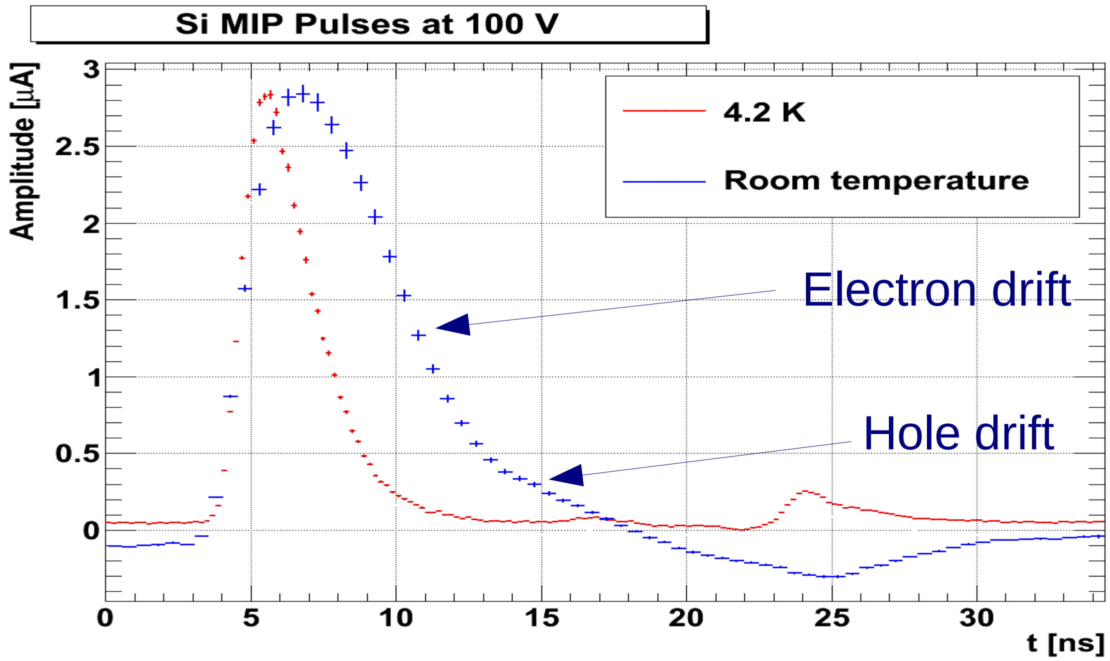
- Particles consist of **protons** (dominating), positive pions and kaons
- **9 GeV/c** particles -> **MIPs**
- Beam intensity **350 000 particles/spill**
- Size at focus about 1 cm^2
- Spill duration of 400 ms (**less than 1 particle/μs**)
- One spill every 45 s

Single Particle detection

40 dB current amplifier from CIVIDEC, bandwidth 1 MHz – 2 GHz



Silicon results
Single particle (response averaged from ~5000 pulses)

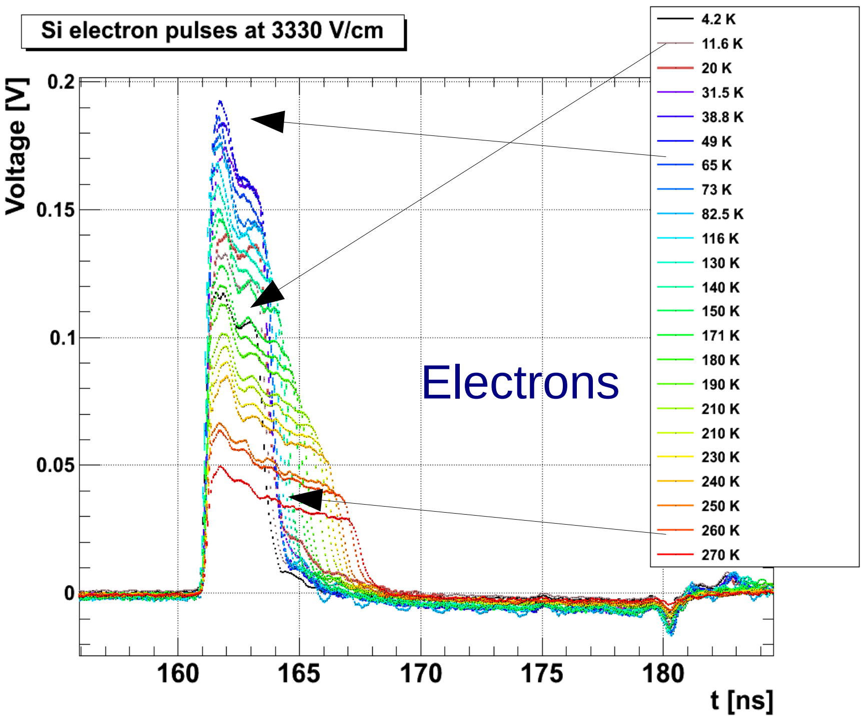


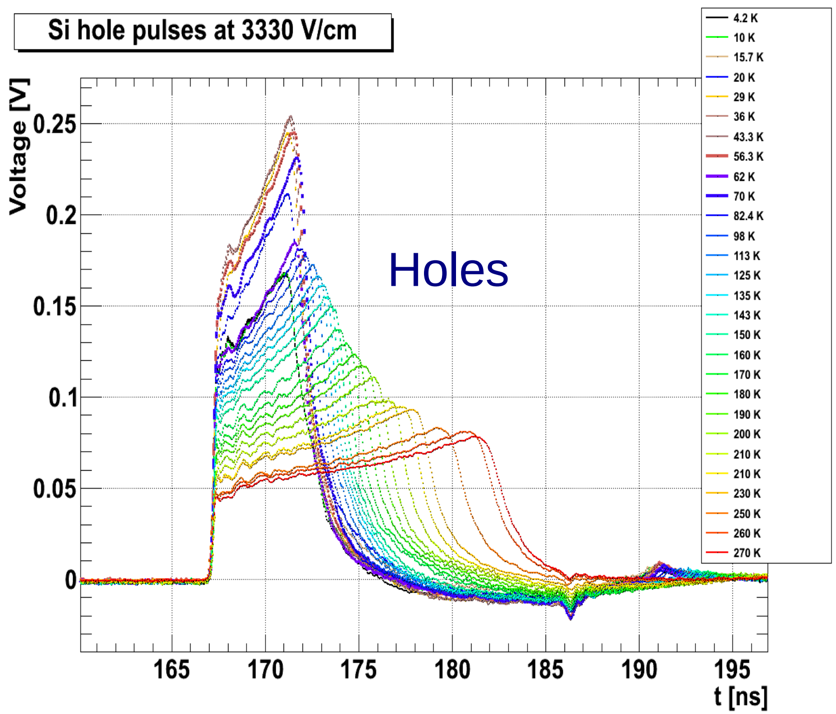
Drift time change at liquid helium temperatures of 54%

Additionally: leakage current below pA at liquid helium temperature

Silicon 680 nm laser measurement

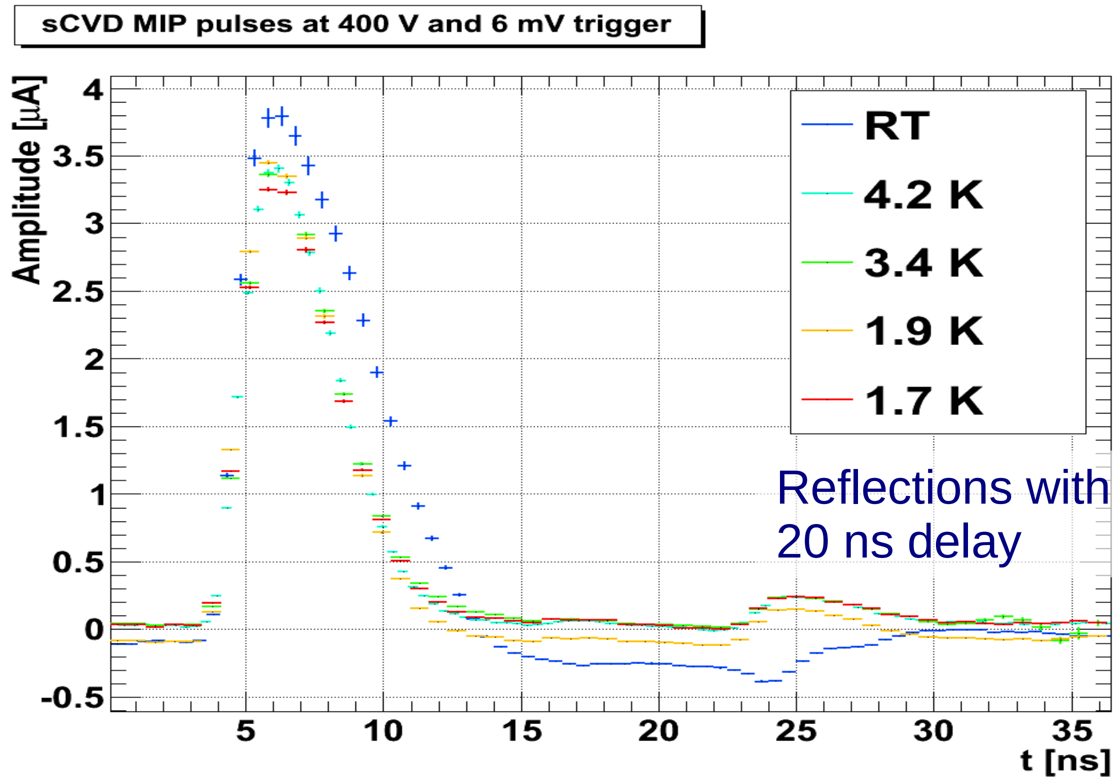
Transient current technique measurements: laser applied on one side of Silicon. Charges travel through bulk, giving information about their characteristics.





Temperature scan

Diamond results
Single particle (response averaged from ~5000 pulses)

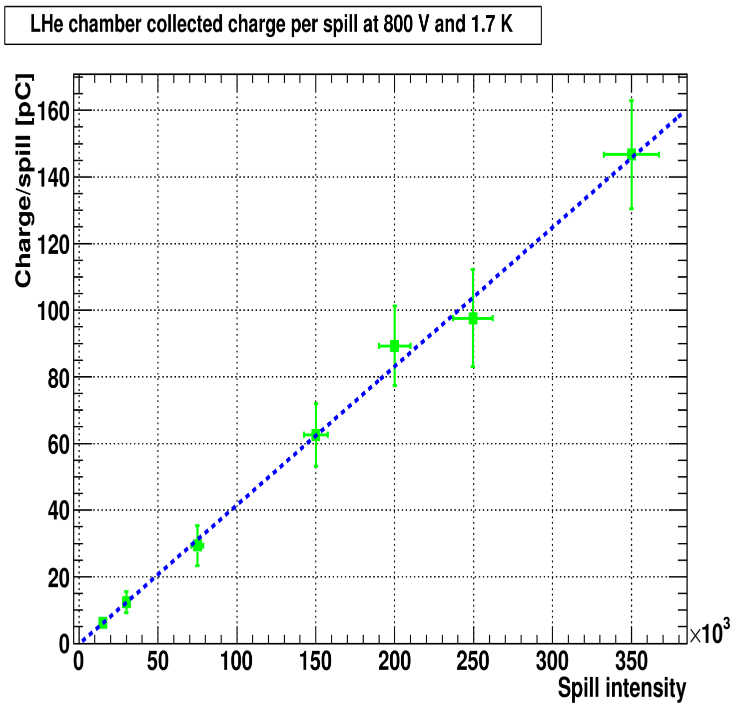


Reflections with 20 ns delay

Drift time change of about 28%

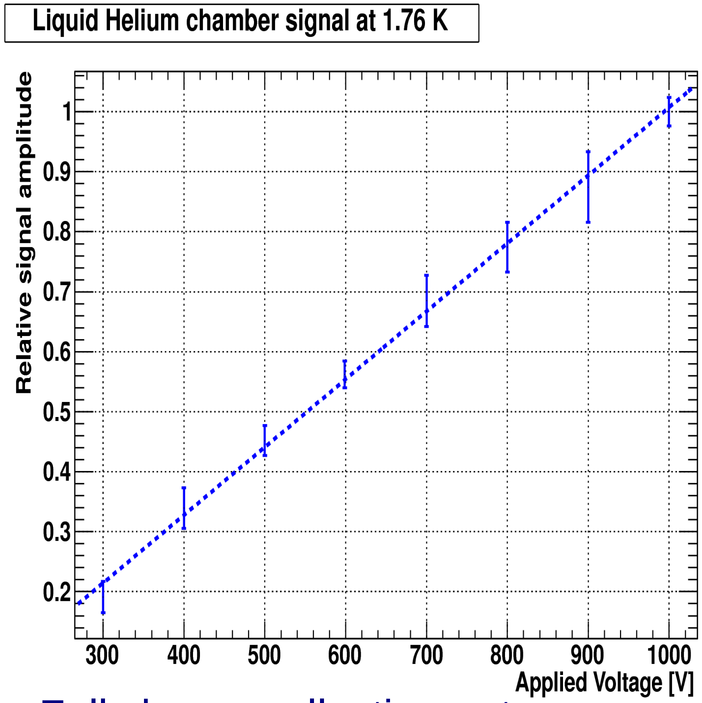
Liquid helium chamber

Intensity variation



Linearity is observed in the range from 5 to 140 pC

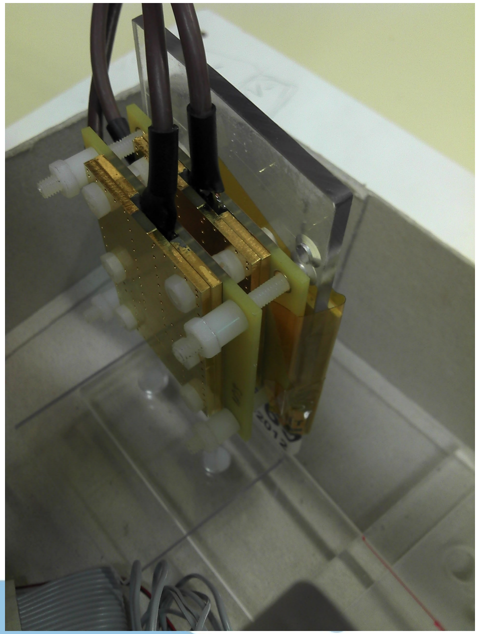
Voltage variation

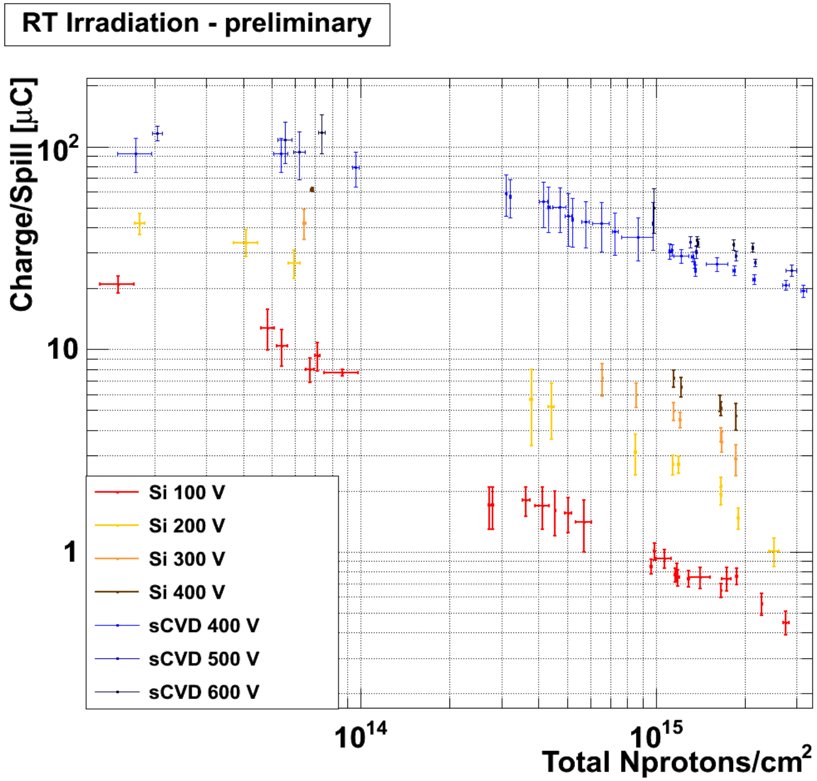


Full charge collection not reached at an electric field of 3.33 kV/cm

Charge collection time in the order of several 100 µs, only interesting for steady state losses

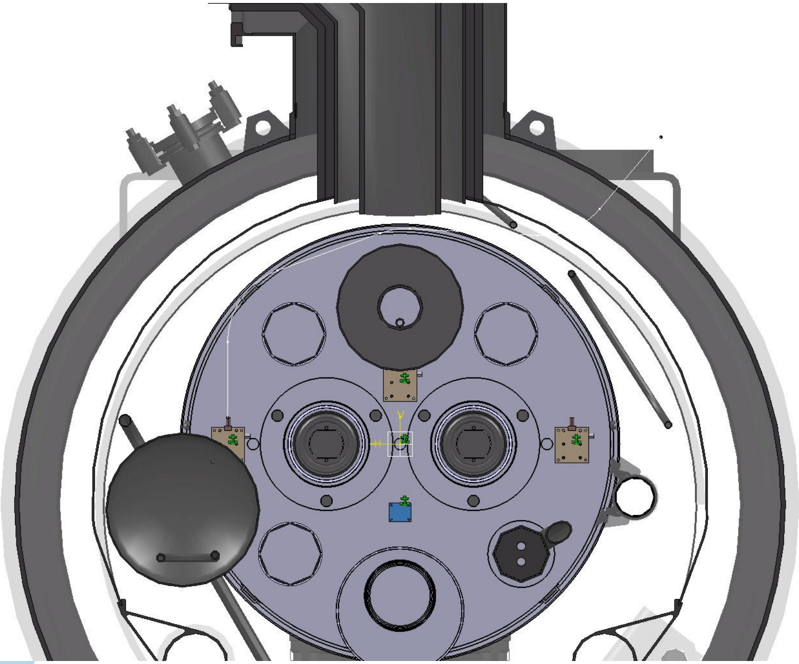
Radiation hardness – Room temperature





Main disadvantage of Si is its leakage current (45 µA at 100 V and a fluency of 1e15 p/cm^2). In cold Si leakage current expected to stay below pA. Radiation hardness tests repeated in cold in November.

First cryogenic LHC detectors



Technical drawing
Thierry Renaglia

Installation of 2 Silicon and 2 Diamond detectors in Q7 at 1.9 K planed for October 2012.

Conclusions

- All tested **detectors work** at superfluid helium temperatures:
  - Reduction of the drift time by 28 % for Diamond and 54 % for Silicon
  - Reduction of Silicon dark current from 5 nA at 100V at room temperature to below pA at 2 K
- With semiconductors a **fast detection system** for **bunch by bunch resolution** in the LHC and DC measurements for steady state losses possible
- Liquid helium chamber elegant solution as CryoBLM in the triplet magnets - **no issues with radiation hardness**
- Ongoing tests and data analysis

Acknowledgements
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