Investigation of the Use of Diamond, Silicon and Liquid Helium Detectors for Beam Loss Measurements at 2 K

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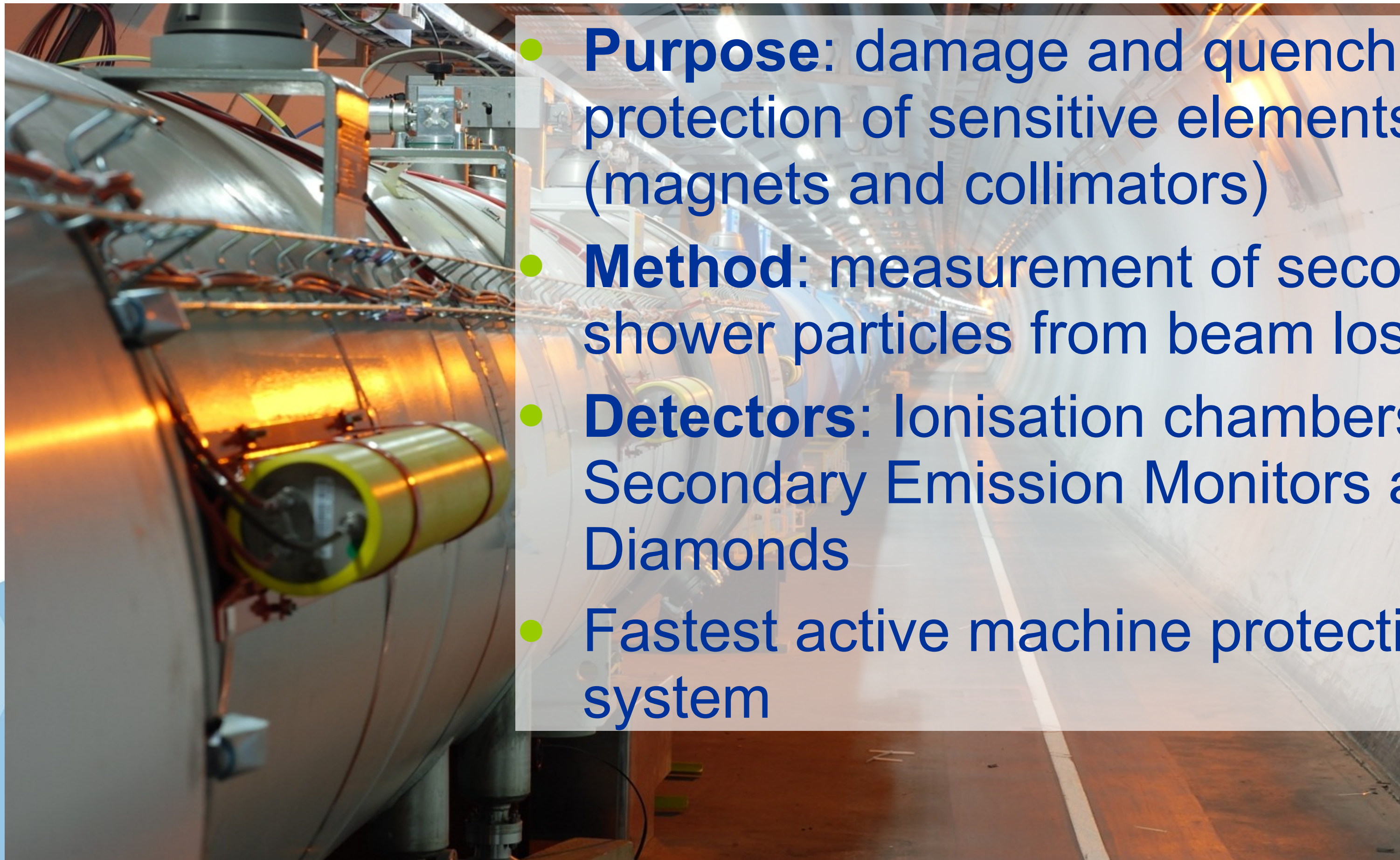
Outline

- Motivation
  - LHC Beam Loss Monitoring
  - CryoBLM project
- Beam test measurement setup
- Beam characteristics
- Results
  - Semiconductors
  - Liquid helium chamber
- Conclusions and outlook

LHC Beam Loss Monitoring



- **Purpose**: damage and quench protection of sensitive elements (magnets and collimators)
- **Method**: measurement of secondary shower particles from beam losses
- **Detectors**: Ionisation chambers, Secondary Emission Monitors and Diamonds
- Fastest active machine protection system

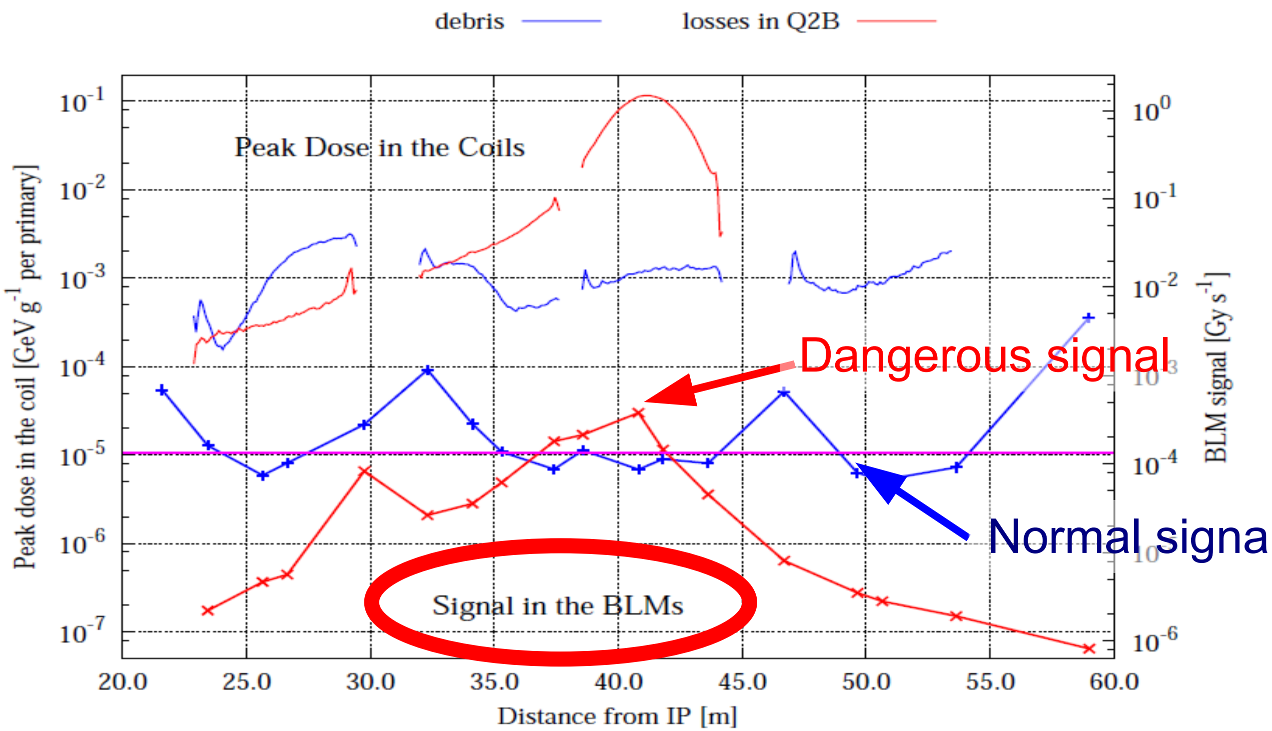
Fast Reliable Available

BUT

Limit close to interaction regions

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

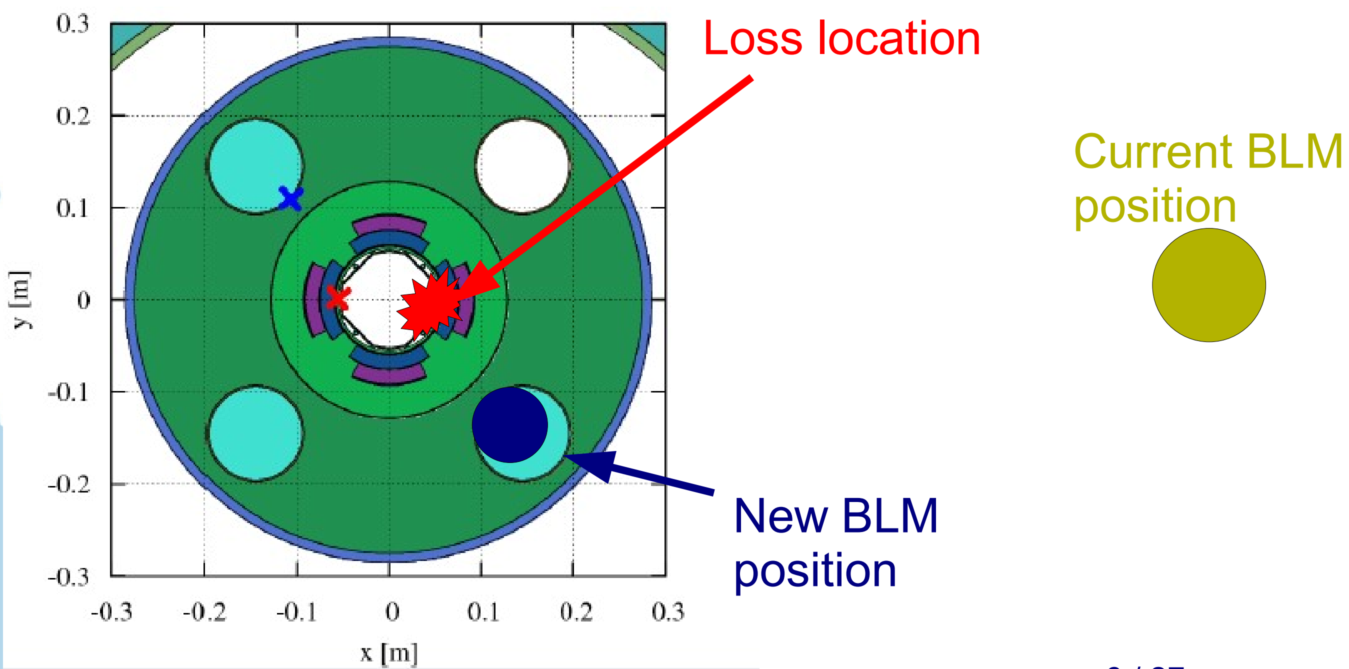
7 TeV, nominal luminosity



Also see poster THPPR039, M. Sapinski

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



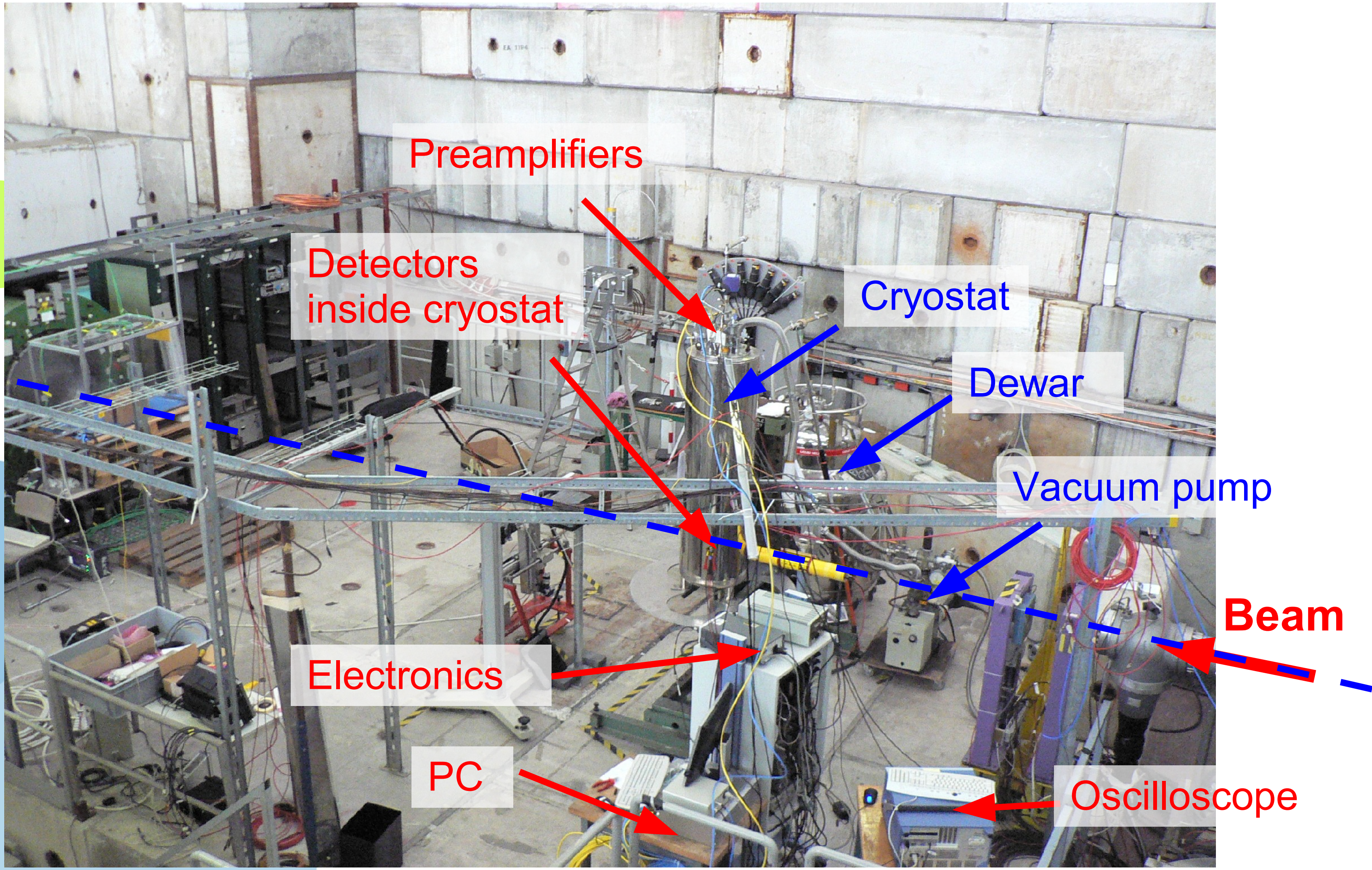
Specifications for CryoBLM

- Present conditions:
  - low temperature of **1.9 K** (superfluid Helium)
  - radiation of about **1 MGy** in 10 years
  - magnetic field of **2 T**
  - pressure of 1.1 bar, withstanding a fast pressure rise up to about 20 bar
- Linearity between **0.1 and 10 mGy/s**
- Detector response **faster than 1 ms**
- **Stability, reliability and availability:** after installation no access possible

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
  - Less leakage current than Si at room temperature
  - Does it work in liquid helium?
- Liquid helium ionisation chamber
  - + No radiation hardness issue
  - - Slow (charge mobility of 0.02 $cm^2/V/s$)

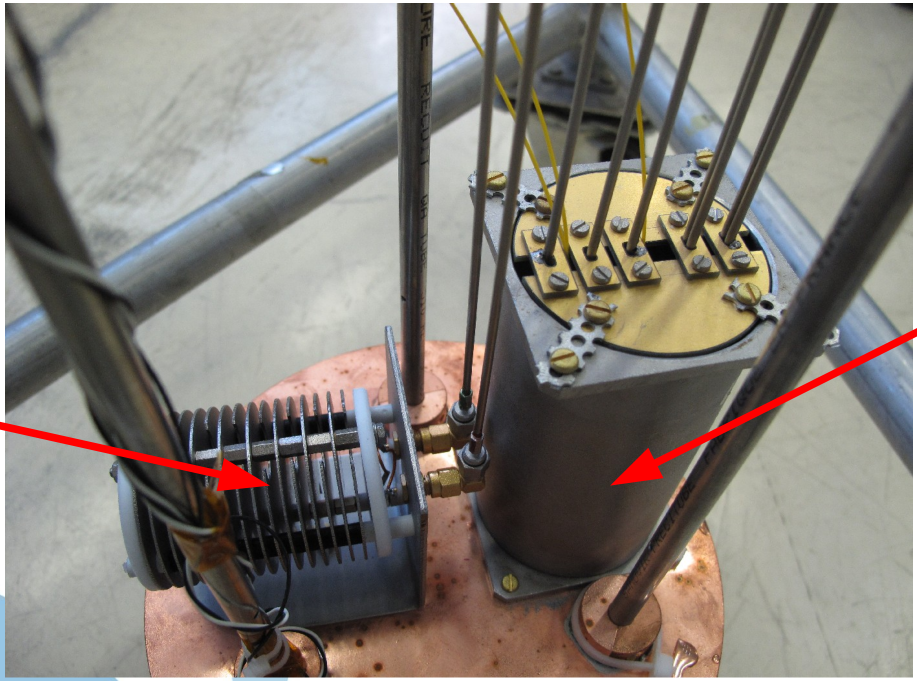
CERN PS Beam test area



Inside cryostat - detectors

LHe chamber

10 cm length

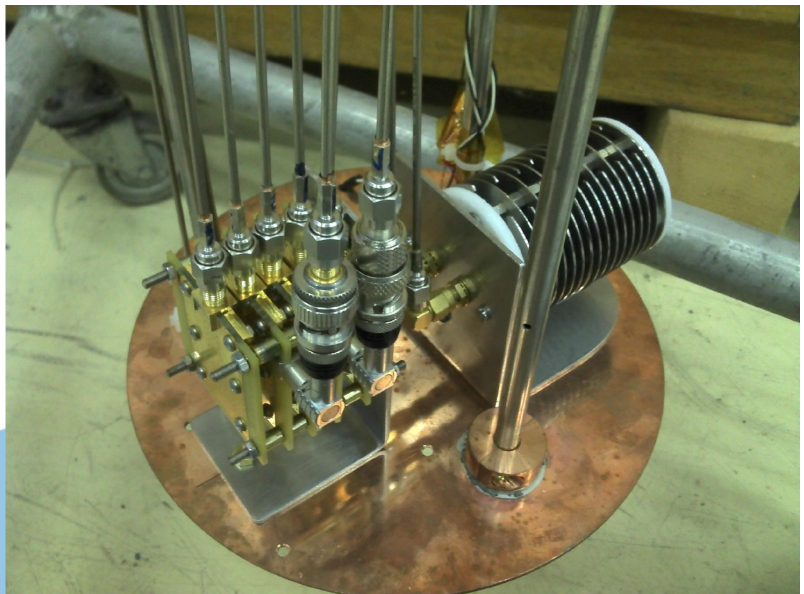


Semiconductors:

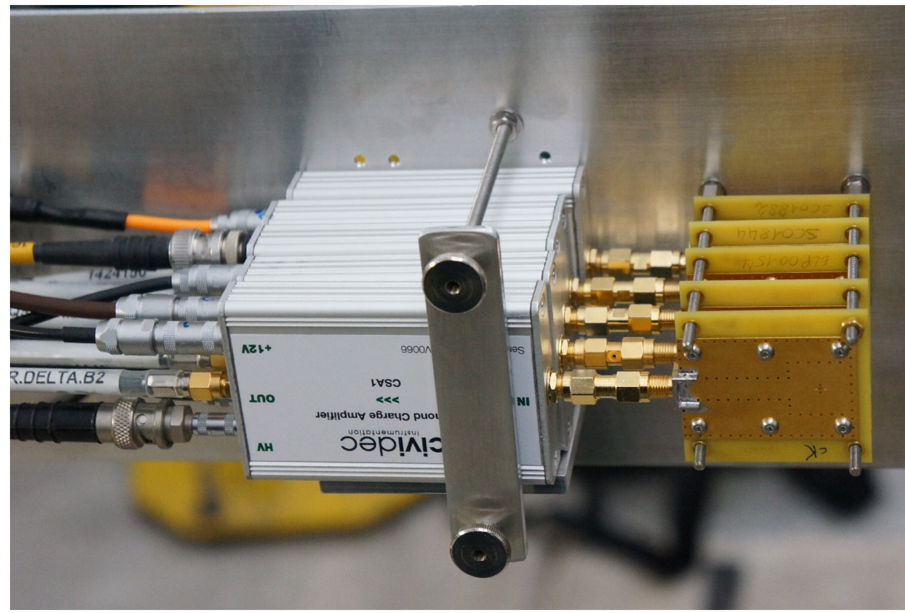
Silicon p^{+}-n-n^{+} with 300 µm thickness and single crystal chemical vapor deposition (CVD) **Diamond** with 500 µm thickness

New setups used just last week!

In liquid helium



At room temperature



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

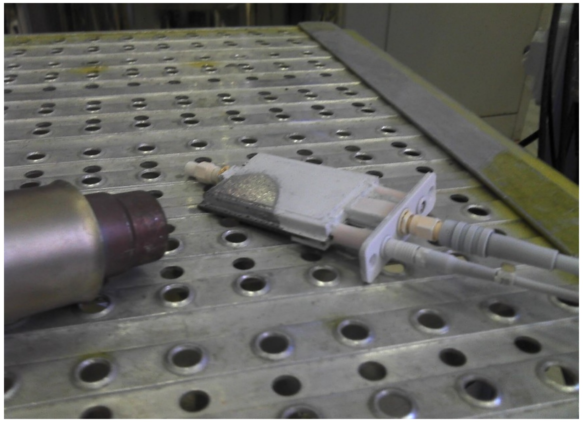
Inside cryostat

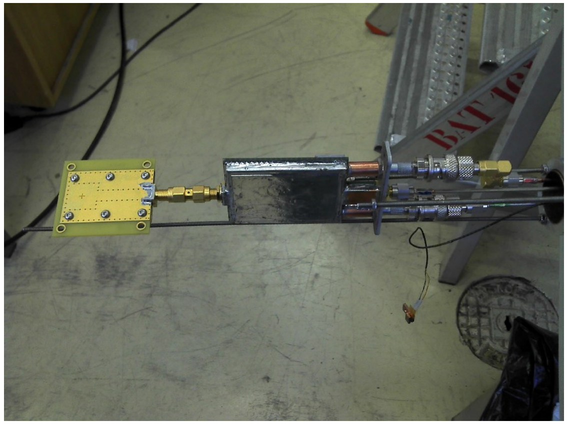
Cable length between detectors and preamplifiers ~ 2 m

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

Remark - Cold Amplifier
Courtesy CIVIDEC

Goal: No noise at 2 K, no long cable





Tested in liquid nitrogen and liquid helium with pulser and alpha source

Amplifier survives cold+vacuum

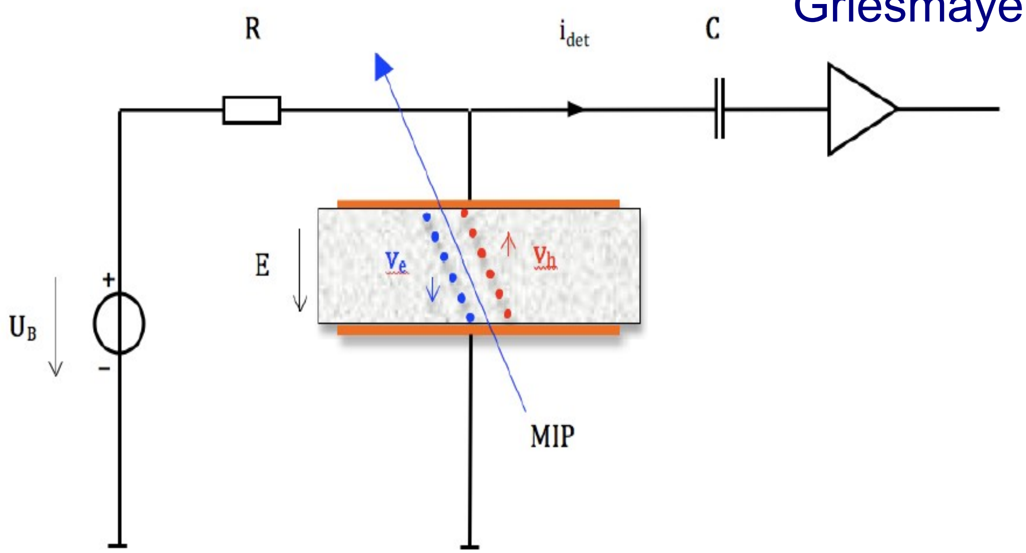
Downsides: characteristics change, 1 W power dissipation, 3 feedthroughs needed

→ Not used for beam tests

Beam characteristics

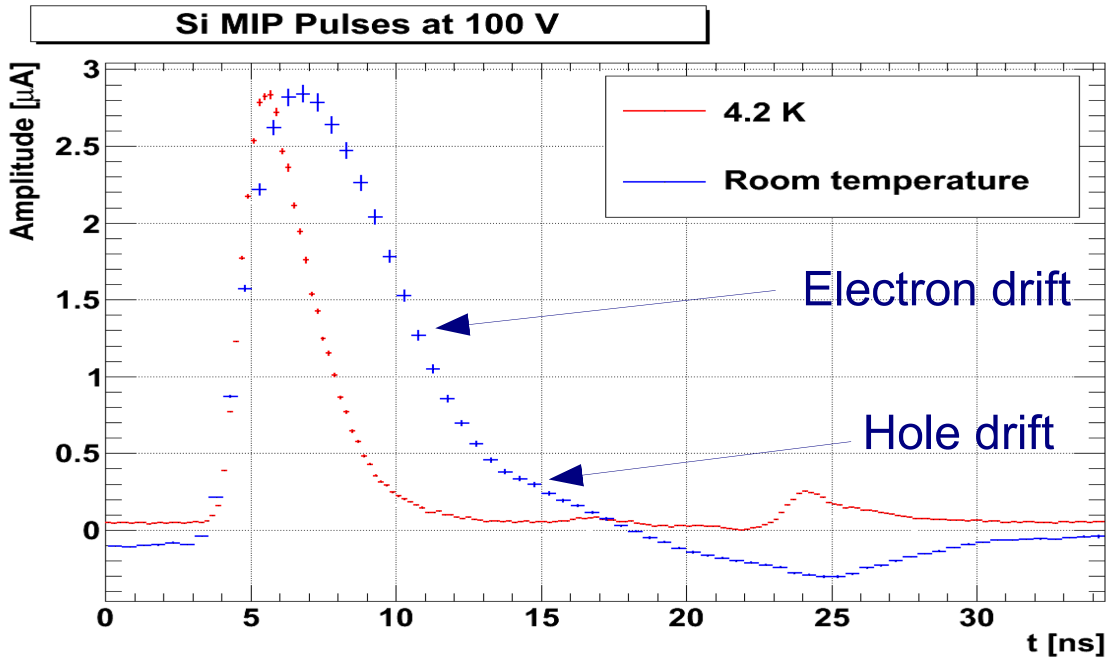
- Particles consist of **protons** (dominating), positive pions and kaons
- **9 GeV/c** particles
- Beam intensity **350 000 particles/spill**
- Size at focus about 1 cm^2
- Spill duration of 400 ms (**less than 1 particle/µs**)
- One spill every 45 s

Single Particle detection



40 dB current amplifier from CIVIDEC (courtesy Erich Griesmayer)

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

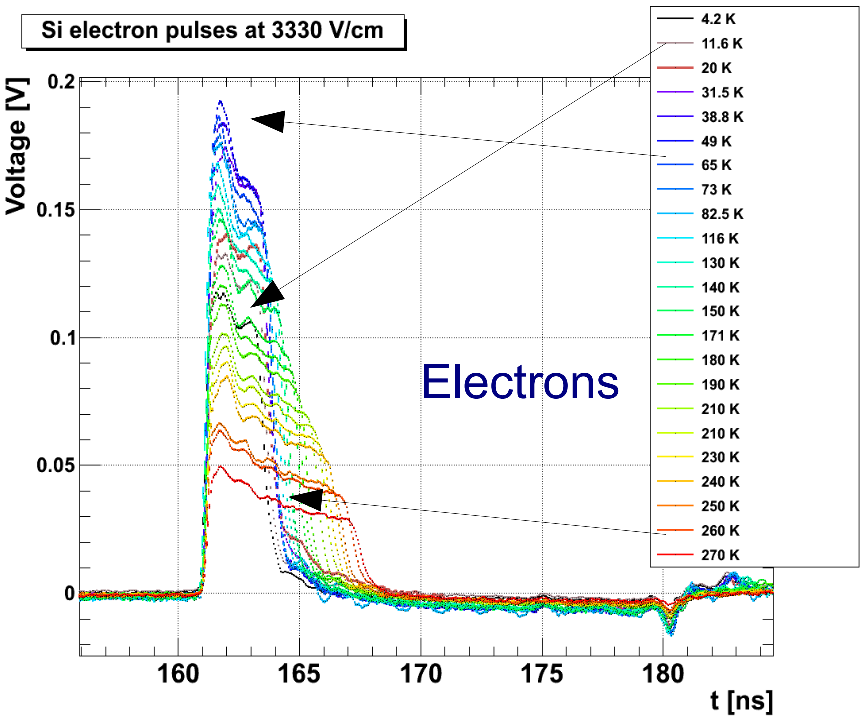


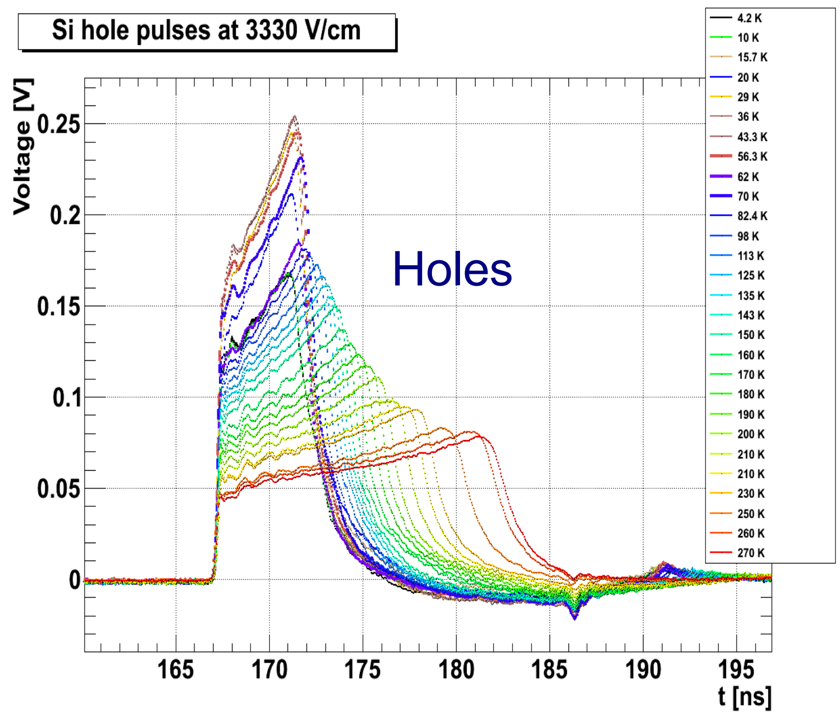
Drift time change at liquid helium temperatures of 54%

Additionally: leakage current below pA at liquid helium temperature

Silicon 680 nm laser measurement

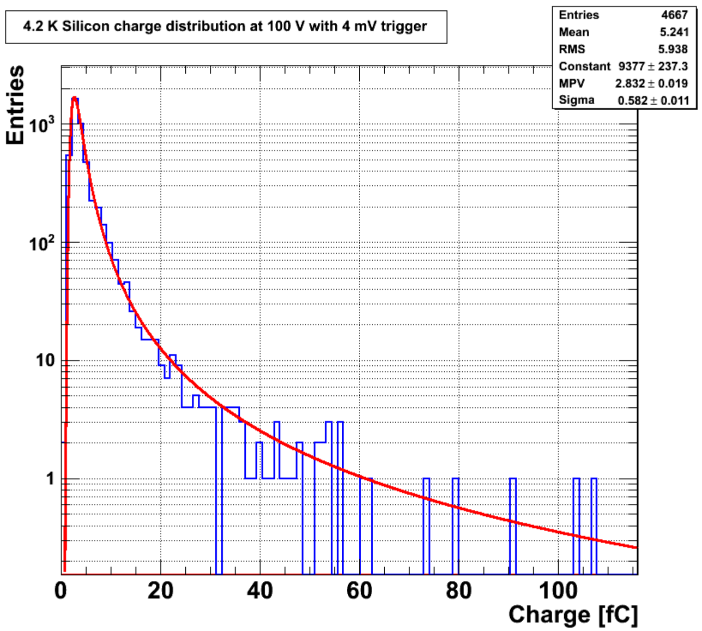
Transient current technique measurements: laser applied on one side of Silicon. Charges travel through bulk, giving information about their characteristics.

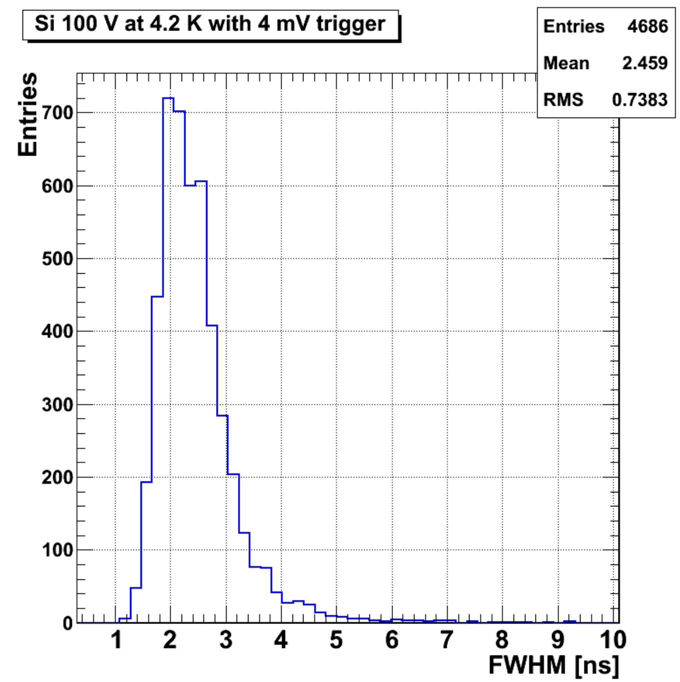




Temperature scan

Silicon characteristics at 4.2 K with 4 mV trigger

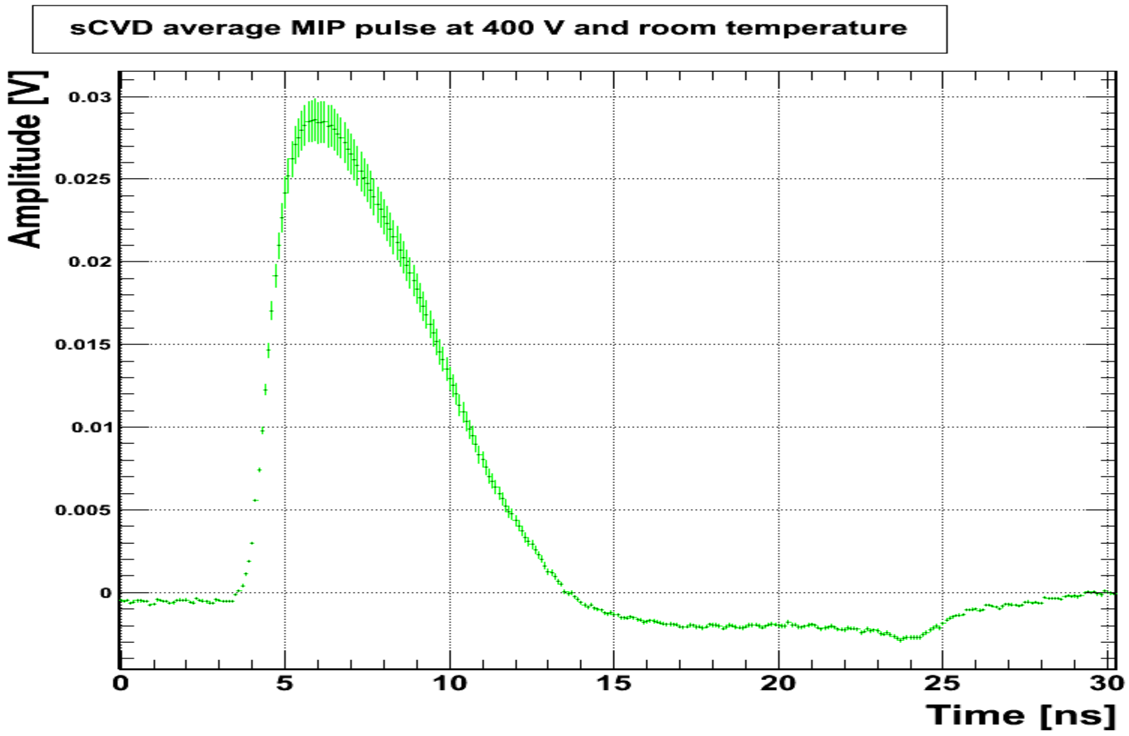




Mean charge: 5.2 fC

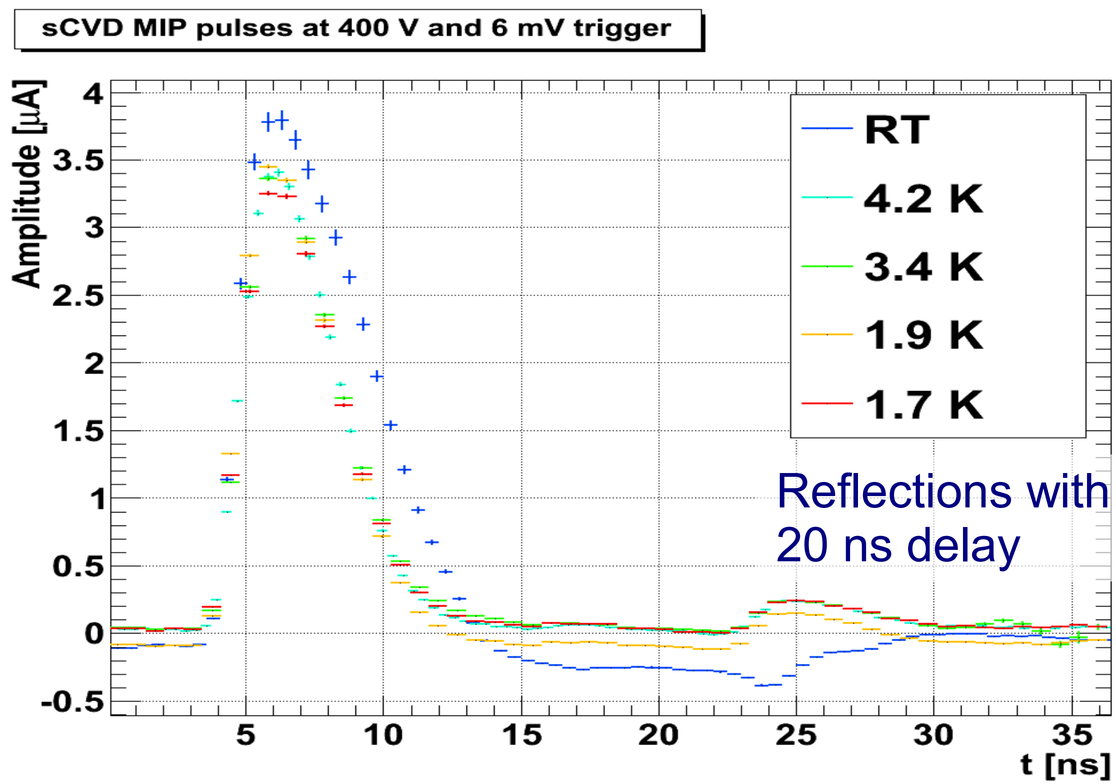
Mean FWHM: 2.5 ns

Single particle signal in diamond at room temperature



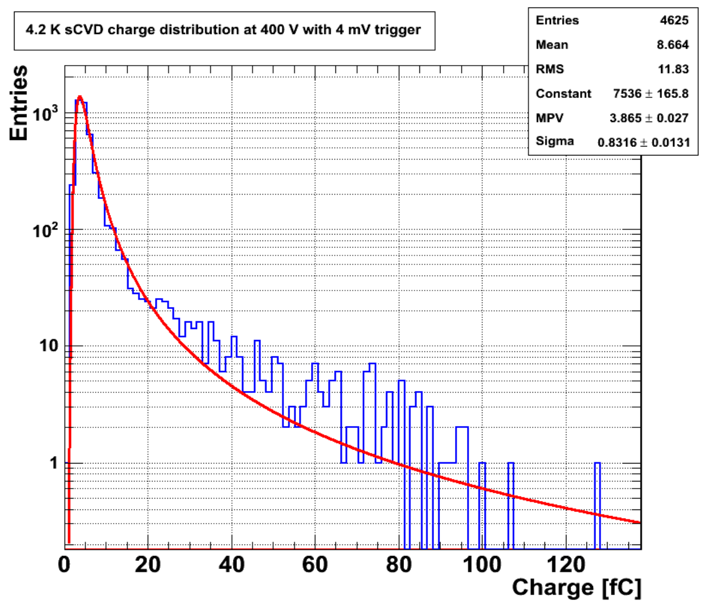
Does diamond work in liquid helium?

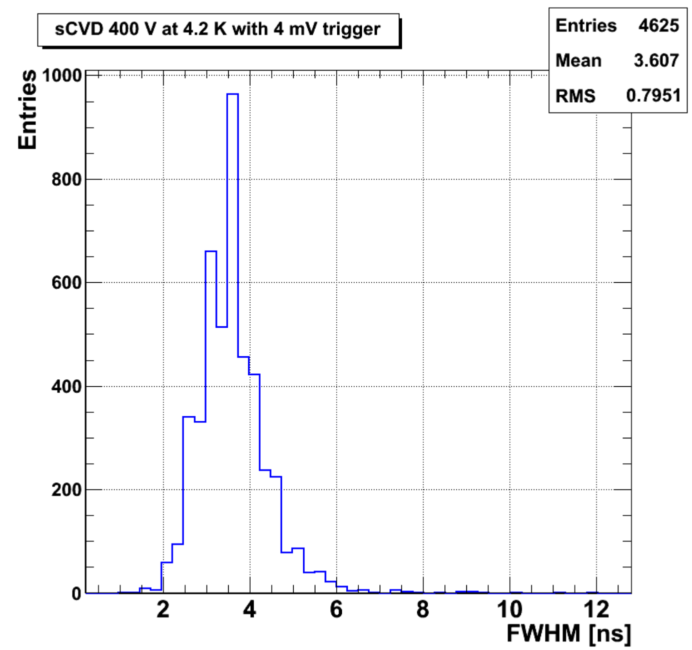
Diamond results
Single particle (response averaged from ~5000 pulses)



Drift time change of about 28%

Diamond characteristics at 4.2 K with 4 mV trigger

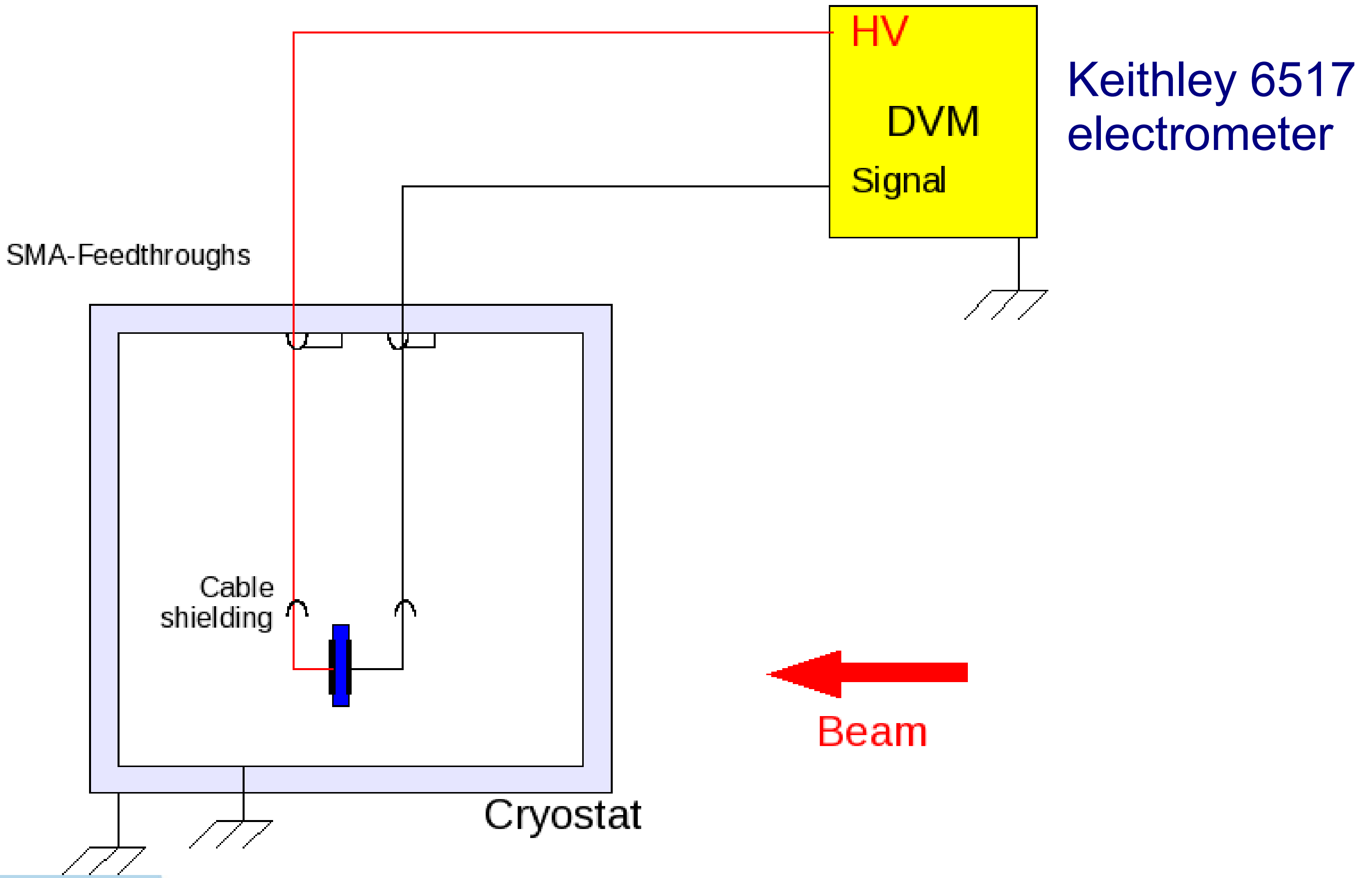




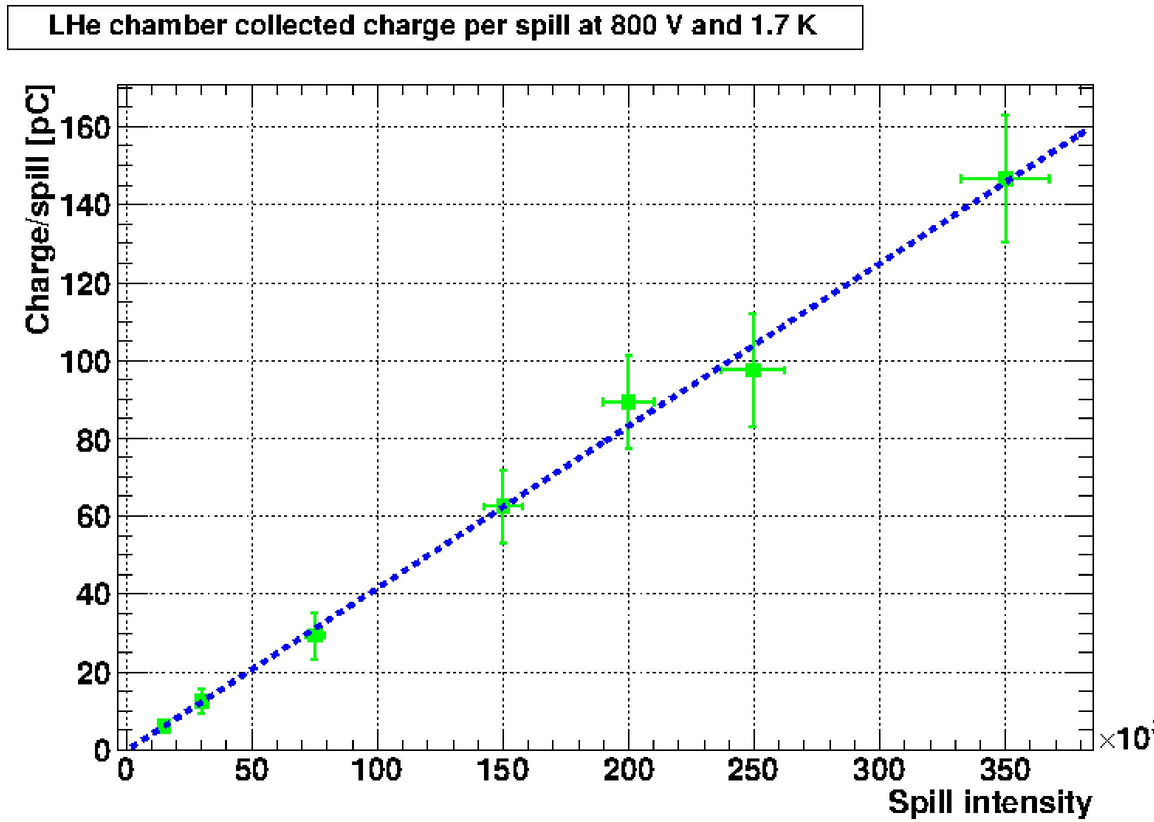
Mean charge: 8.7 fC

Mean FWHM: 3.6 ns

Electronic setup for DC measurements
(preferred for final BLM application)



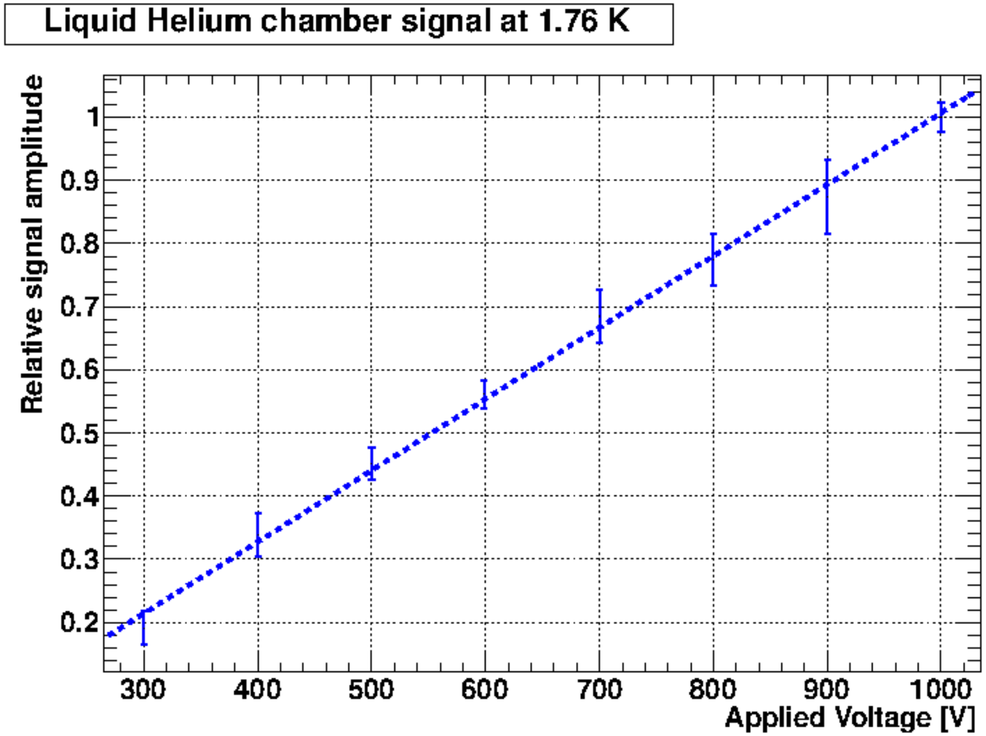
Liquid helium chamber
Intensity variation



Linearity is observed in the range from 5 to 140 pC

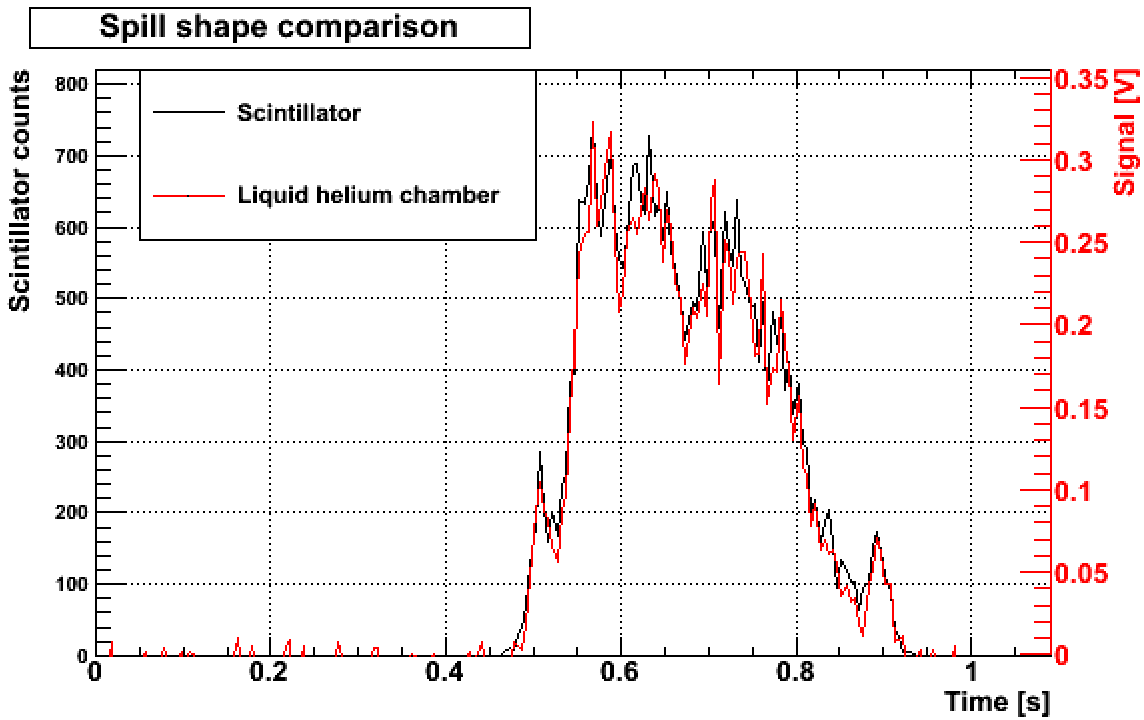
Applied voltage

Current BLM Ionisation chamber operated at 1.5 kV in proportional region → no influence of voltage variation on detector signal
Situation in liquid helium:



Liquid helium chamber fast read out (from last week)

Preliminary



Goal: find **timing properties** of LHe chamber

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

Two critical missing characteristics

1. **Radiation hardness** of the semiconductors at low temperatures - no annealing effect
2. Exact **charge collection time** of the liquid helium chamber

Issues will be addressed during challenging irradiation beam tests in 2012.

Acknowledgements

Thank you!!!

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