Particle detection with sCVD and Si at LHe temperatures

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Outline

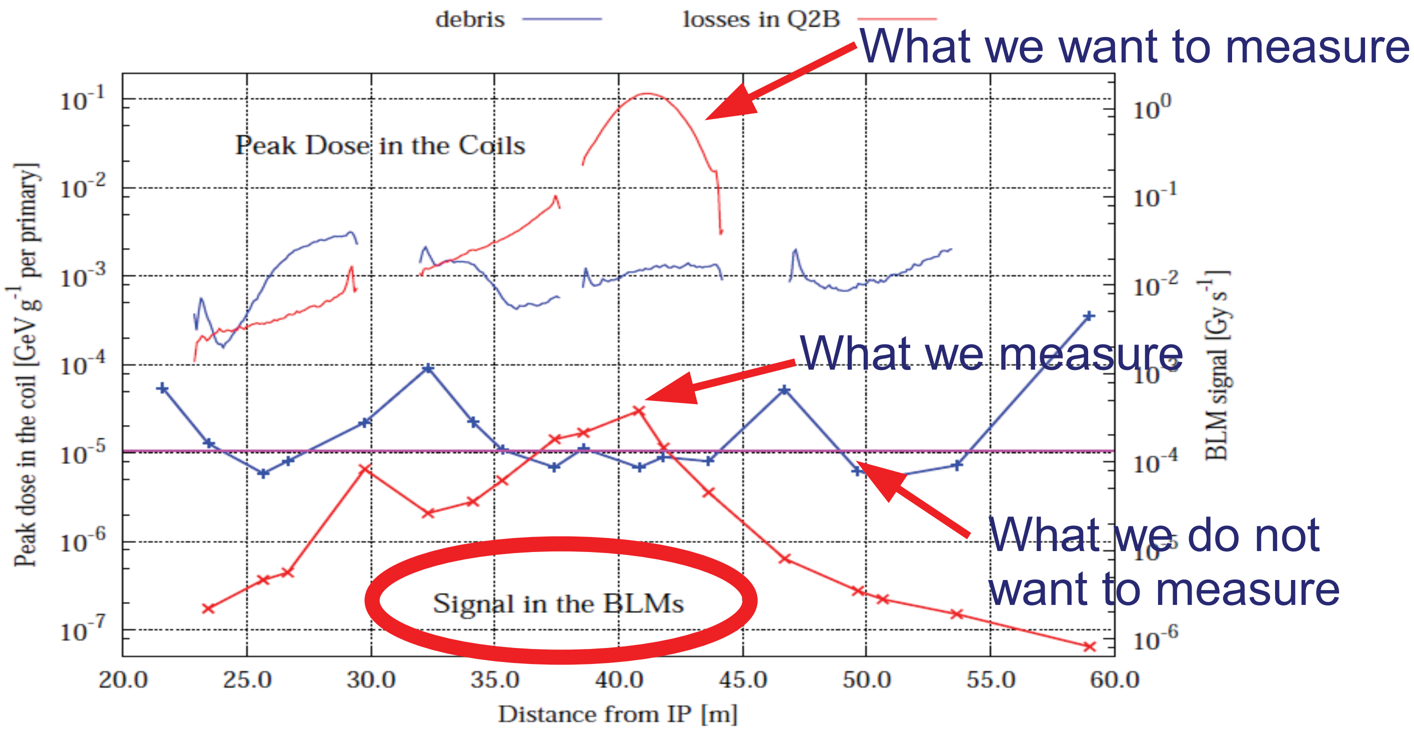
- Introduction
  - LHC Beam Loss Monitoring
  - CryoBLM project
- Beam test measurement setup
- Beam characteristics
- Single particle mode
- DC measurements
- Conclusions and outlook

LHC Beam Loss Monitoring

- **Purpose**: damage and quench protection of sensitive elements (e.g. 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

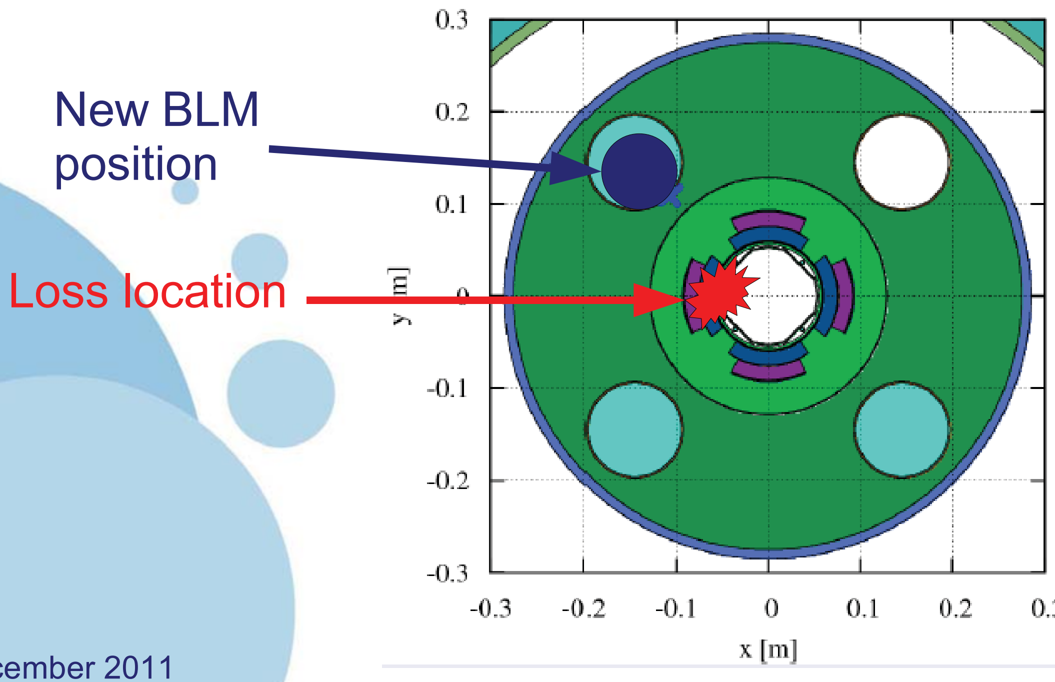
BLM issue close to interaction regions

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



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



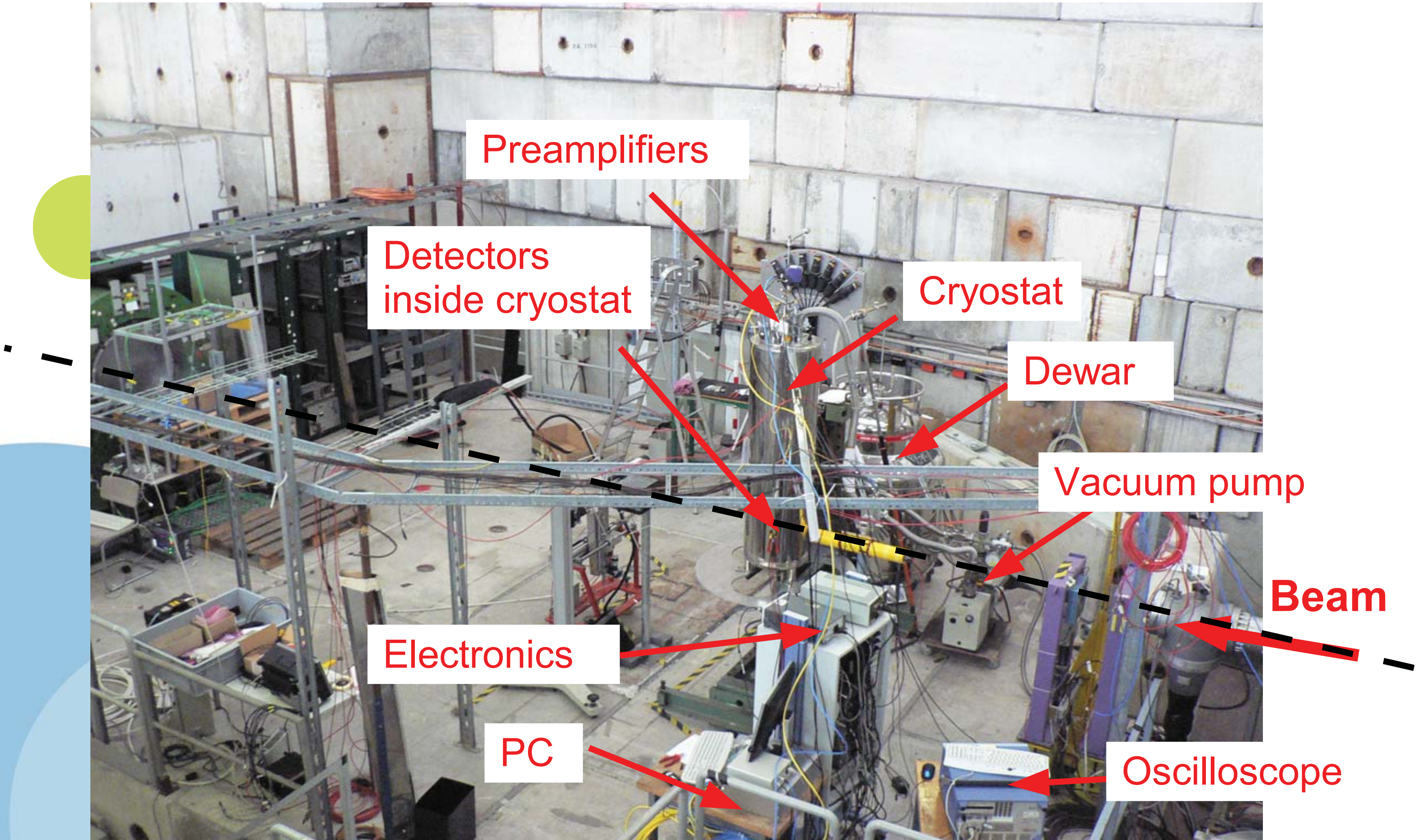
Specifications for CryoBLM

- 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
- Main contribution to radiation field comes from:
  - neutrons and
  - photons, but also charged particles are expected.
- 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

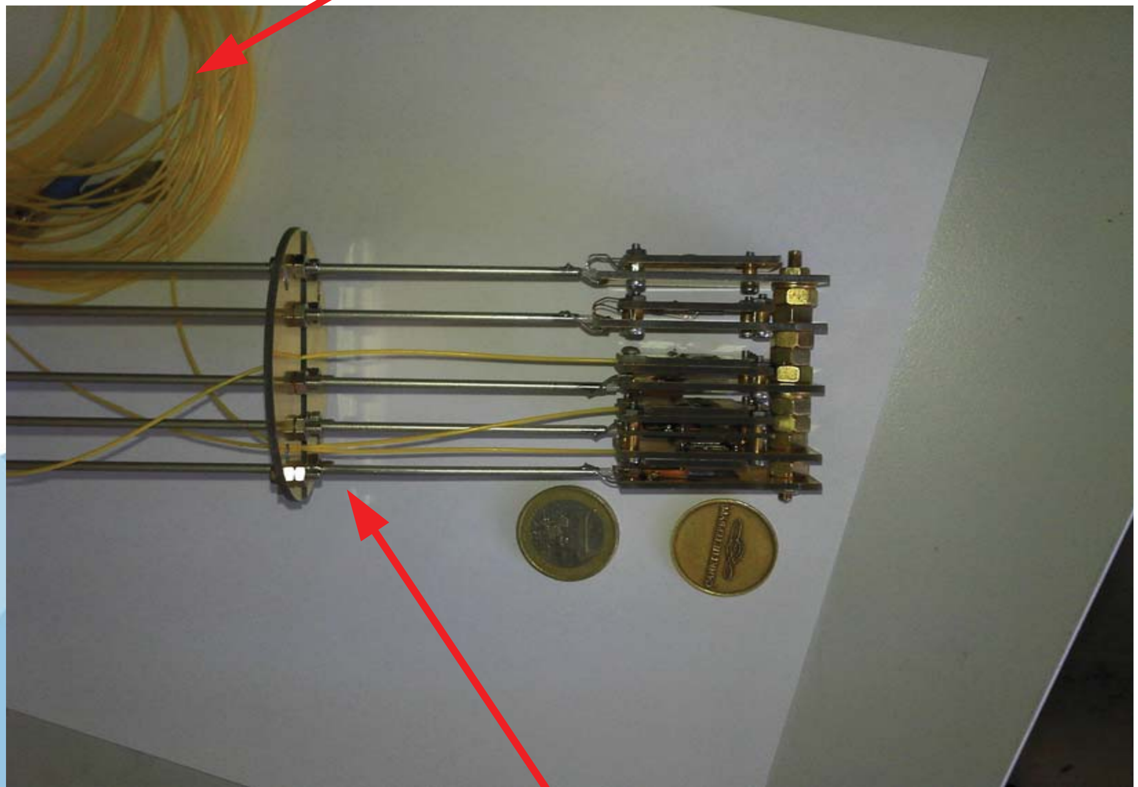
- Silicon
  - Successfully used at 1 K at CERN already
- Diamond (sCVD)
  - Successfully in use as LHC BLM at RT
- Liquid helium ionisation chamber
  - + No radiation hardness issue
  - - Slow (e-bubbles)

Beam test area



Semiconductors holder from Vladimir Eremin

Optical fibers
for TCT with Si

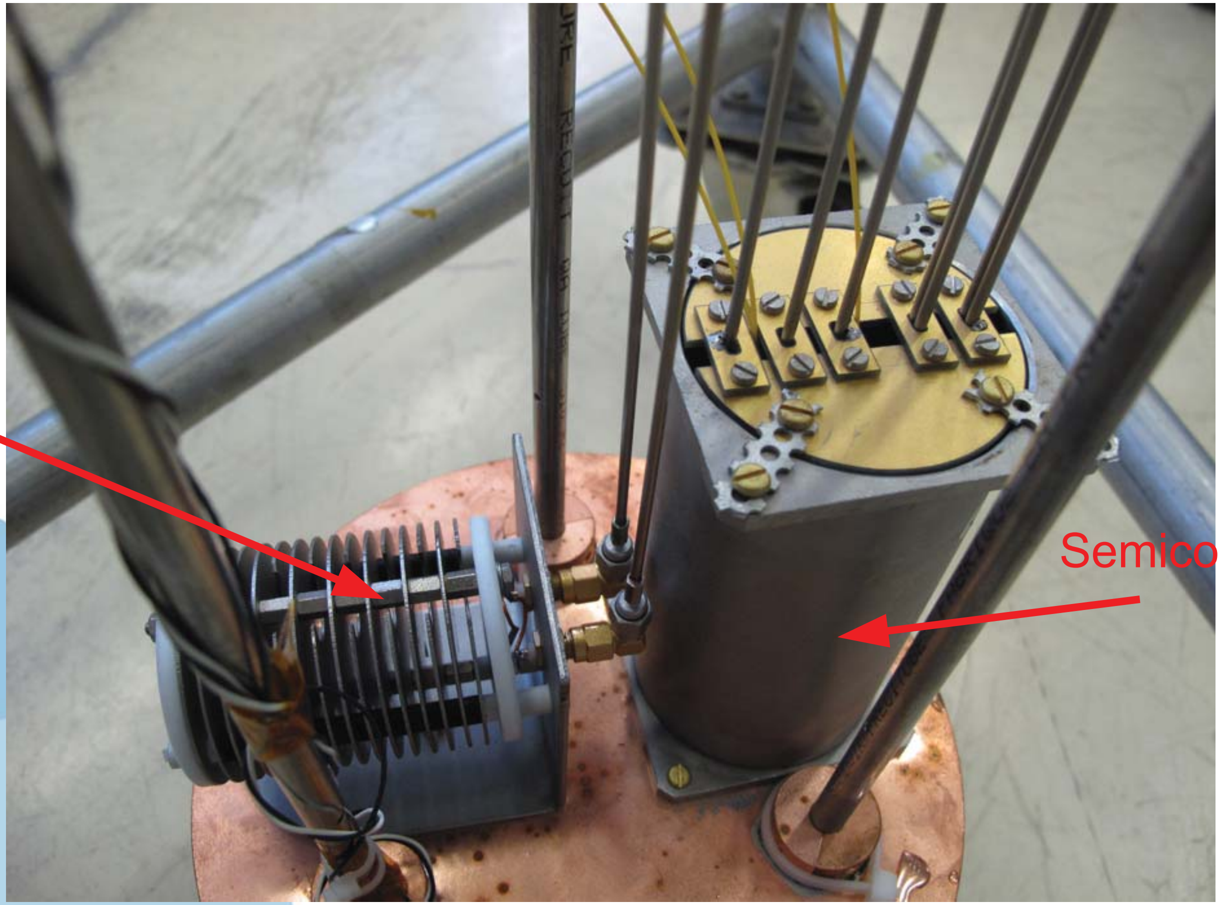


Stainless steel cables for
low heat introduction

- 4 Silicon detectors
- 1 single crystal diamond (sCVD)

Inside cryostat - detectors

LHe chamber



Semiconductors

Inside cryostat

Cable length between detectors and preamplifiers ~ 2 m

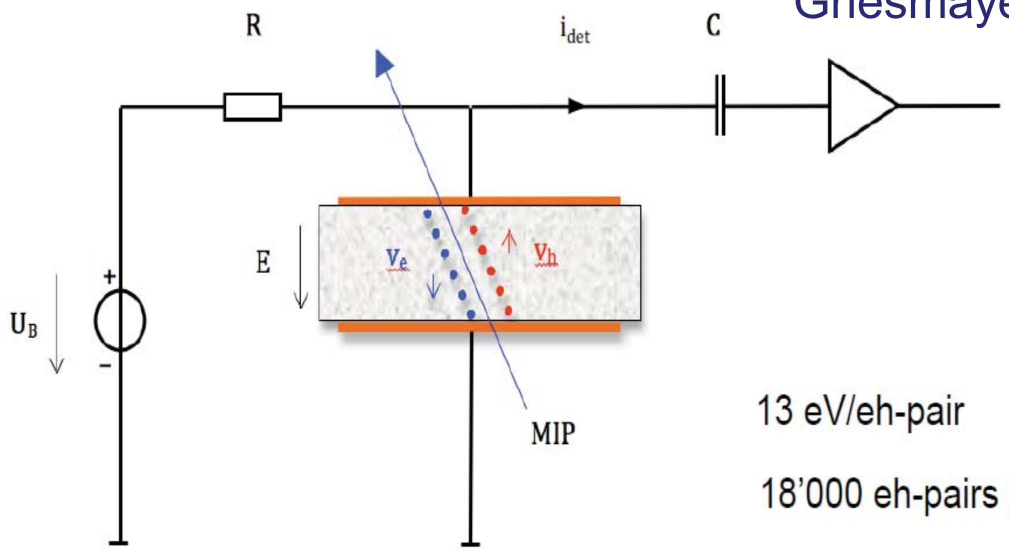
Due to long cables advantage of no noise at LHe temperatures is partly lost.

T9 Beam characteristics

- Beam generated by directing PS beam onto target
- Particles consist of **protons** (dominating), positive pions and kaons
- **10 GeV/c** particles
- Beam intensity **350 000 particles/spill**
- Size at focus about 1 cm^2
- Spill duration of 400 ms (about 875 particles/ms)
- One spill every 45 s

Single Particle detection

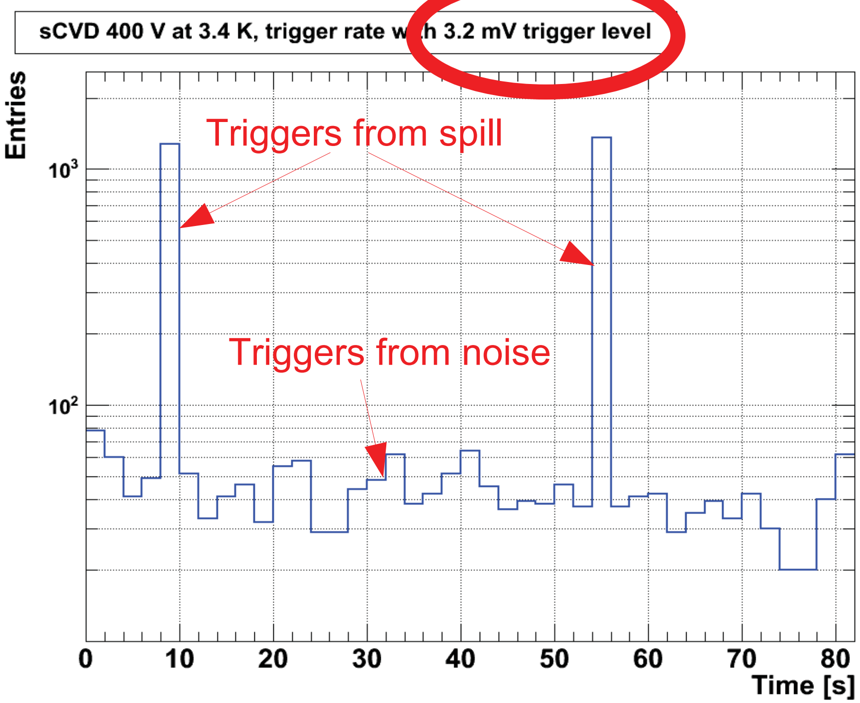
40 dB current amplifier from CIVIDEC (see also Erich Griesmayers talk)

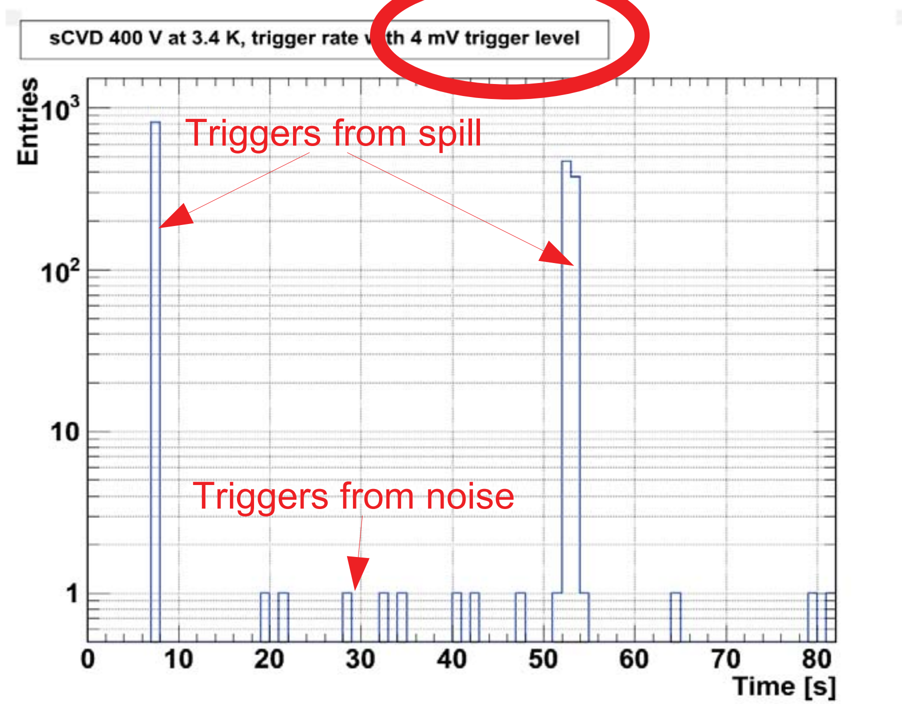


13 eV/eh-pair

18'000 eh-pairs per MIP

Oscilloscope trigger level

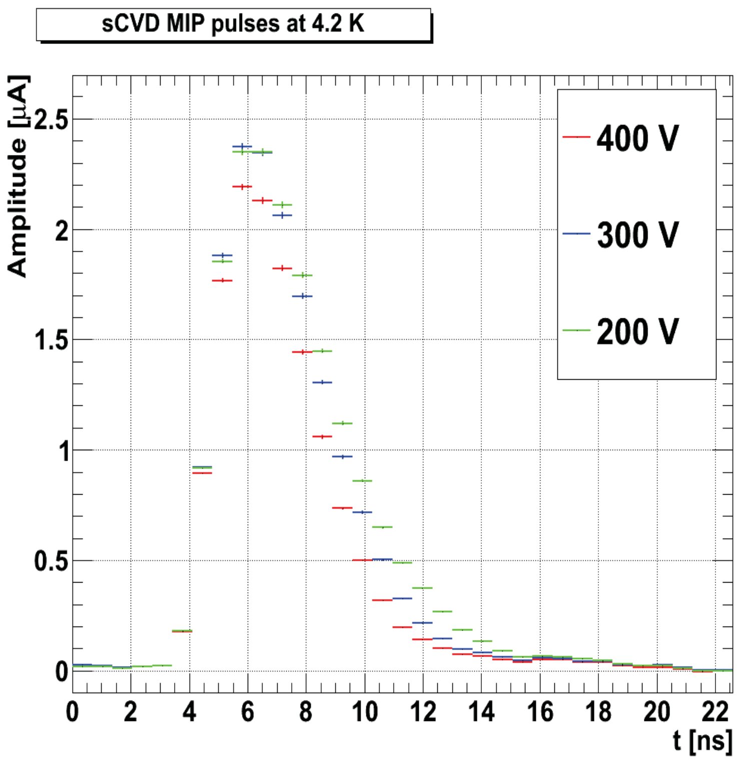




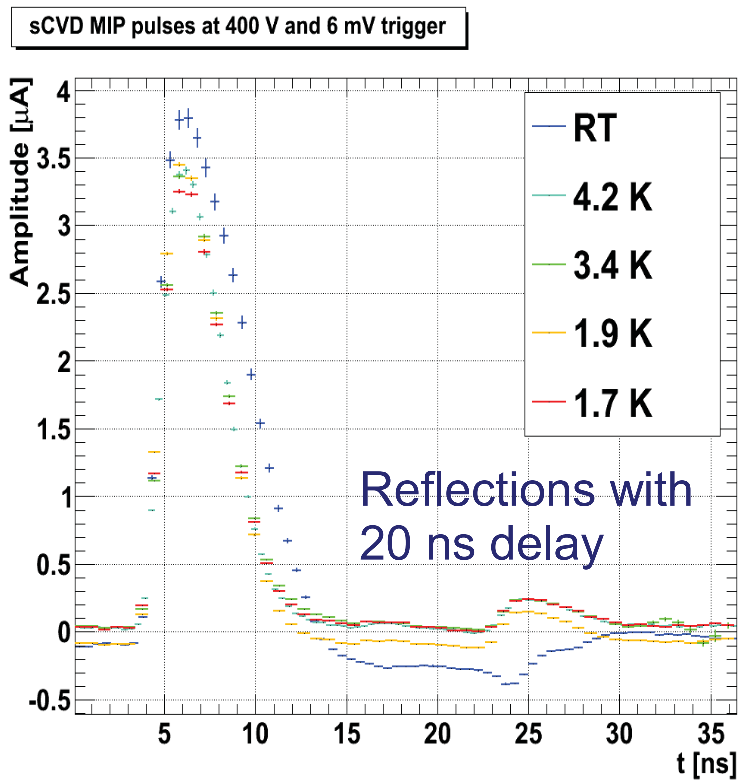
The following analysis might:

- contain pulses from noise peaks or
- have a bias due to triggering

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

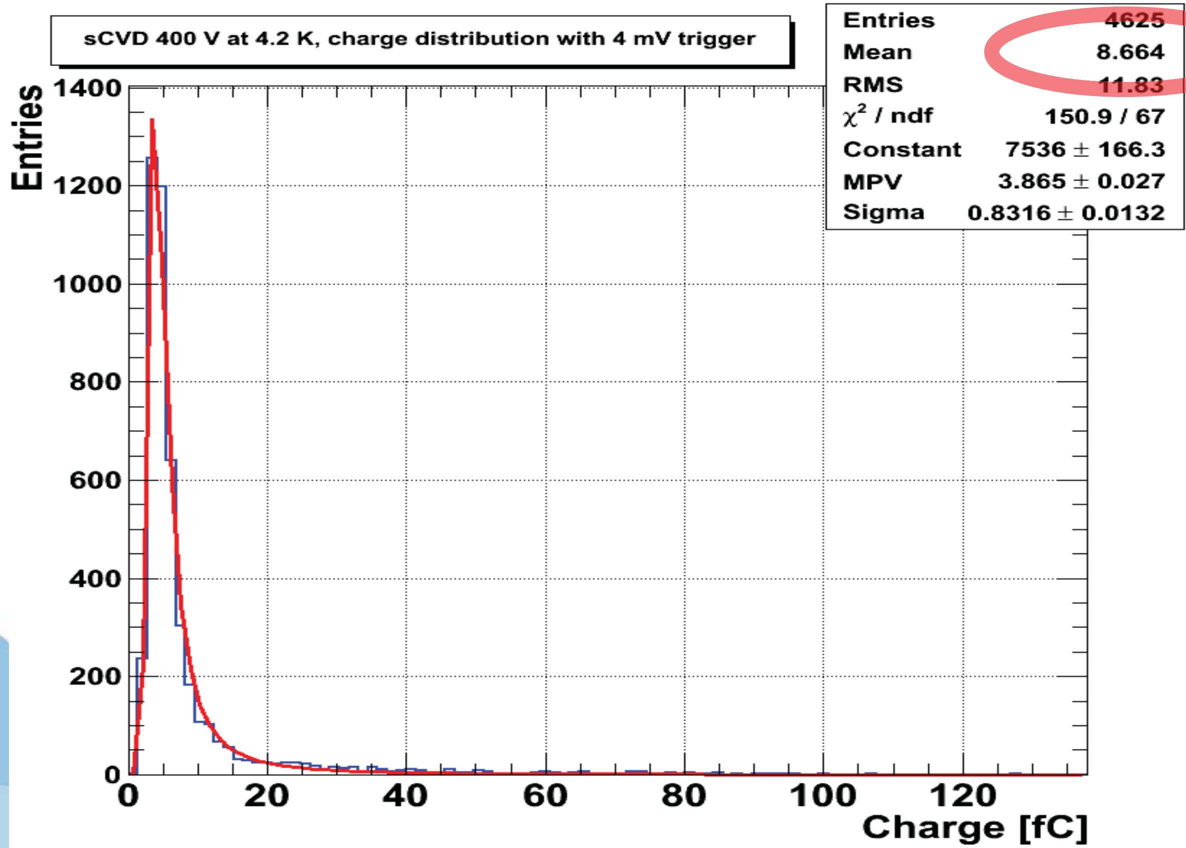


Voltage scan with 4 mV trigger



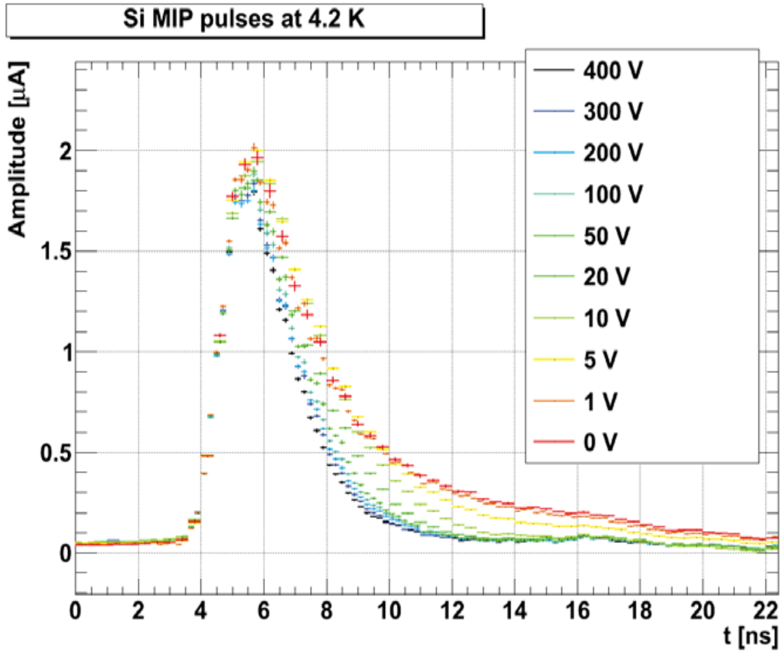
Temperature comparison with 6 mV trigger

Diamond results at 4.2 K, 400 V Single particle detection



Estimated: 3.79 fC (difference might be due to trigger level)

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



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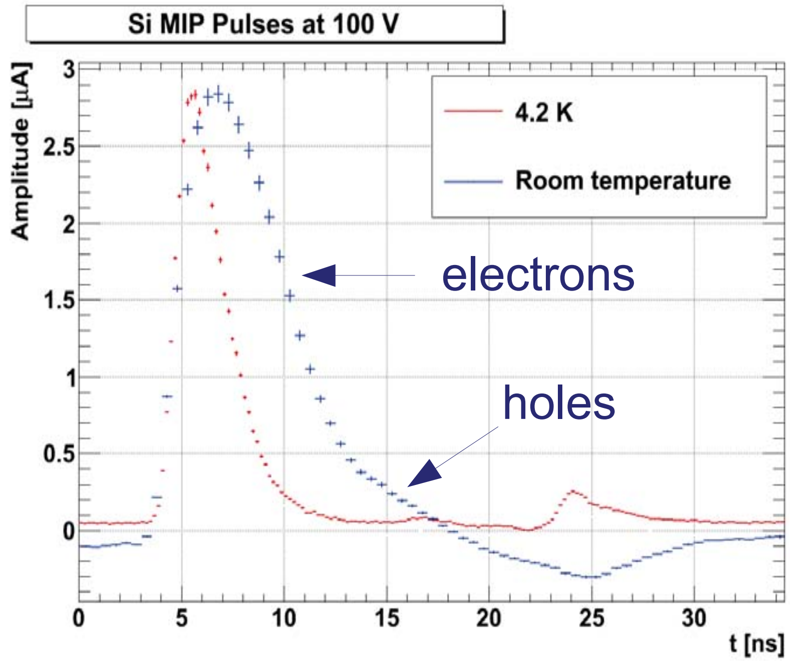
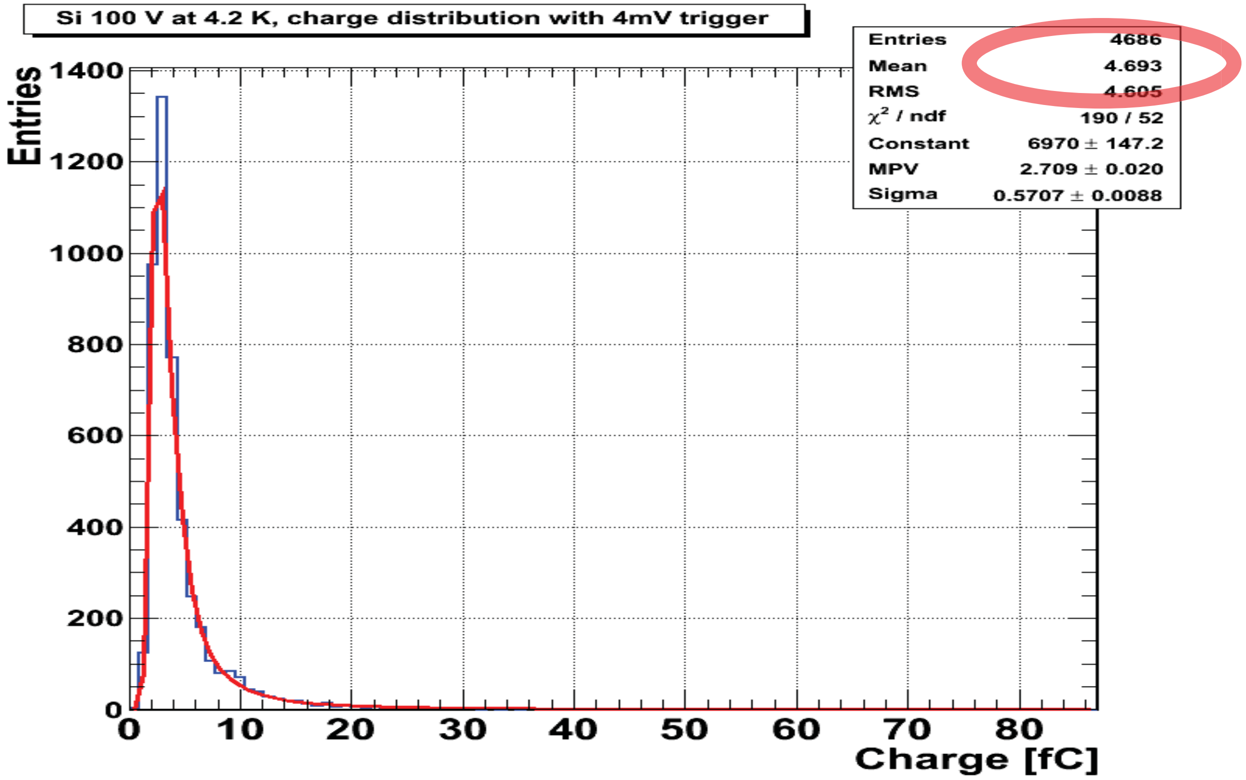


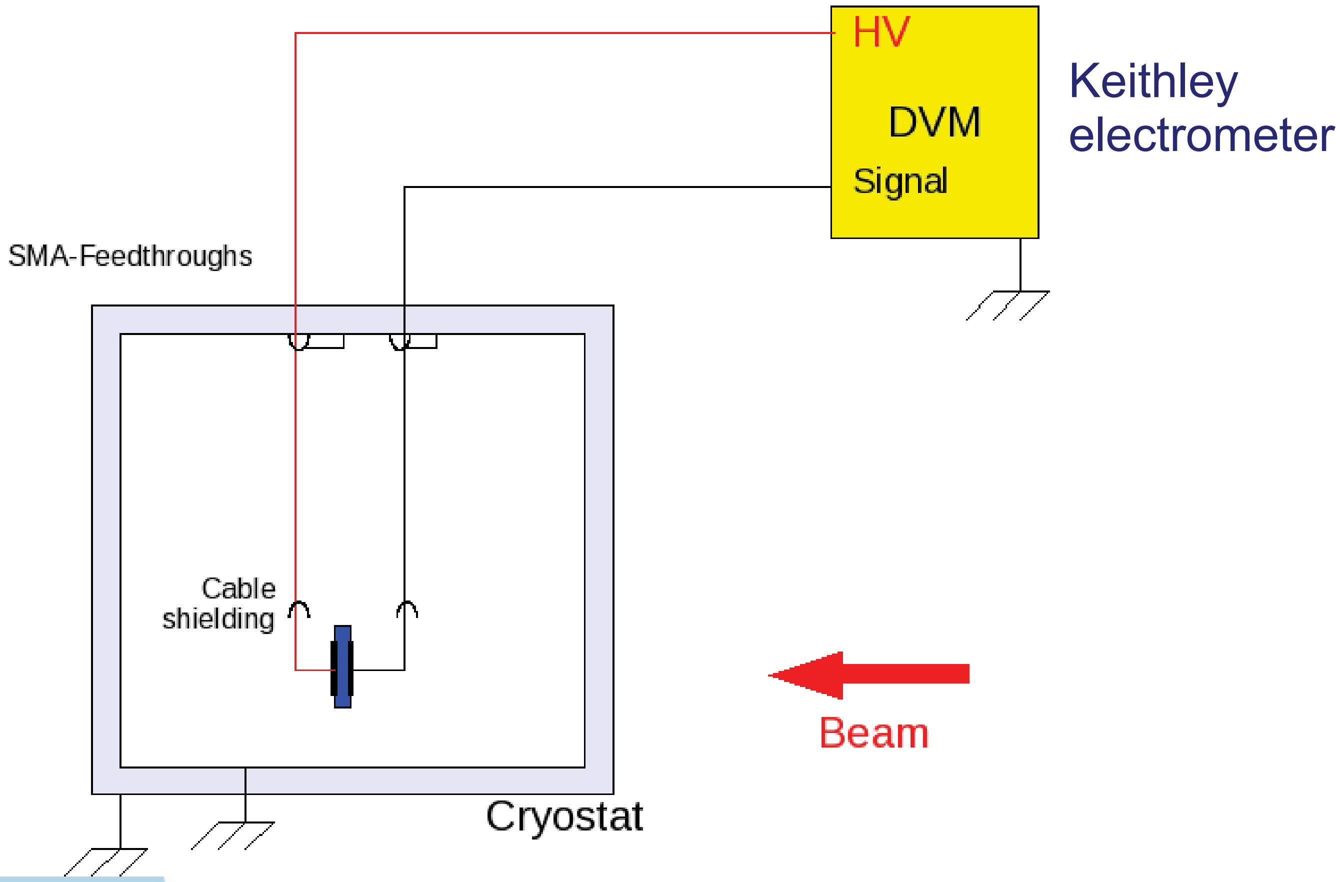
Temperature comparison with 6 mV trigger

Silicon results at 4.2 K, 100 V
Single particle detection

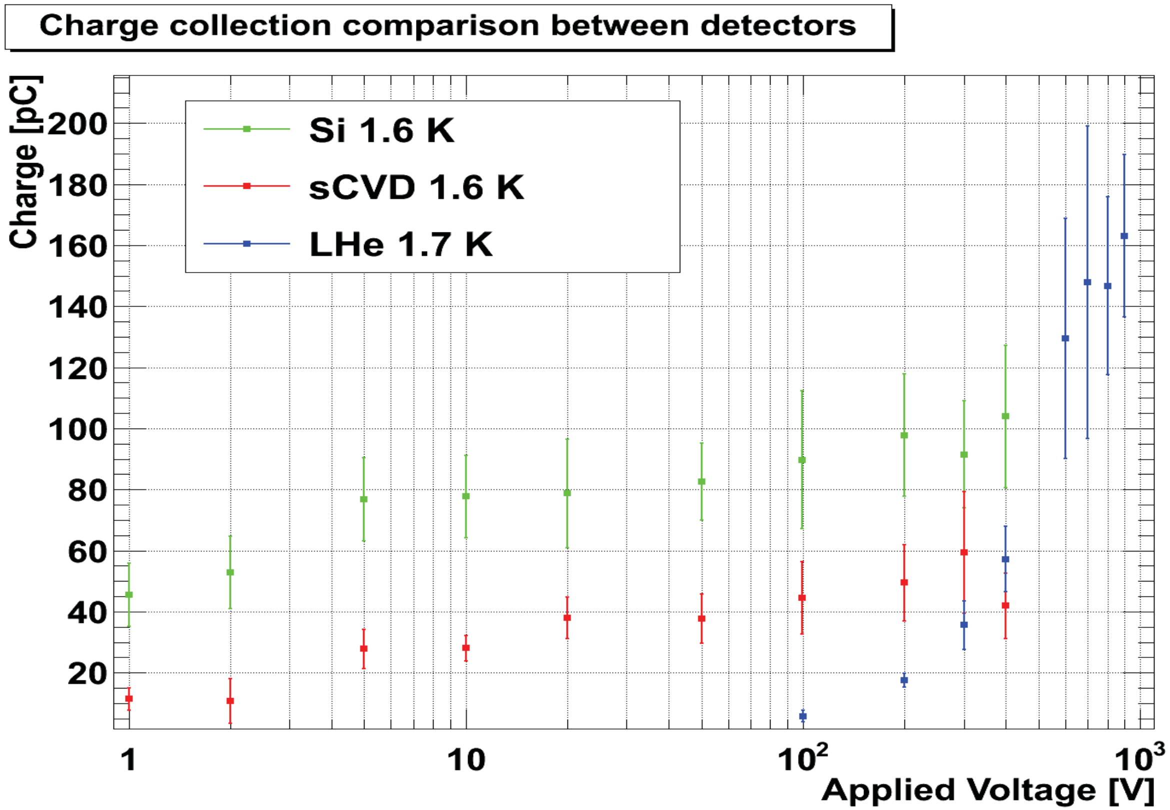


Estimated: 5.68 fC

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



Charge collection comparison



- Main contribution to error bars from beam intensity uncertainty
- Ratio between sCVD and Si as expected

Conclusions and outlook

- All tested detectors work at superfluid helium temperatures
- Not fully understood:
  - “Avalanche” pulses
  - Diamond polarization at 1.9 K
- Critical missing information:
  - Radiation hardness of semiconductors at 1.9 K (tests in 2012)
- Ongoing analysis of the beam test data
- In parallel further measurements done in the laboratory:
  - Silicon (TCT) charge generation with laser and alpha source
  - sCVD (TCT) charge generation with alpha source

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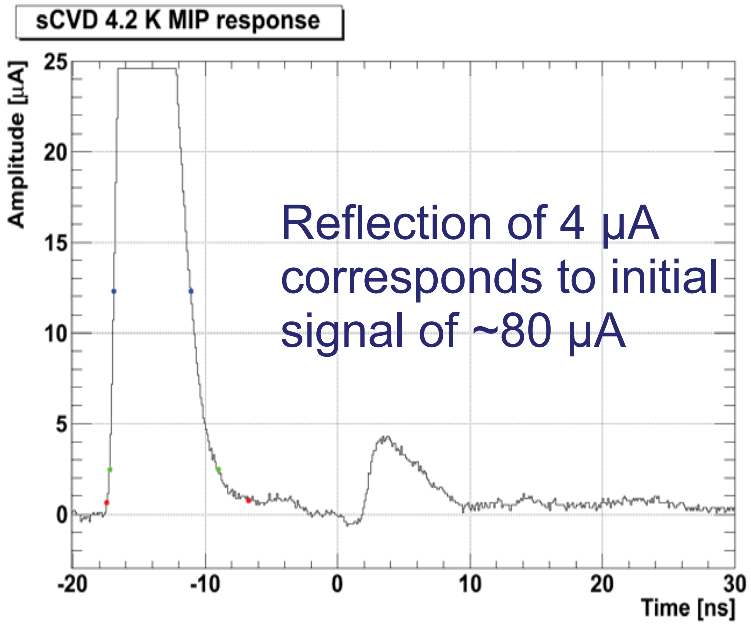

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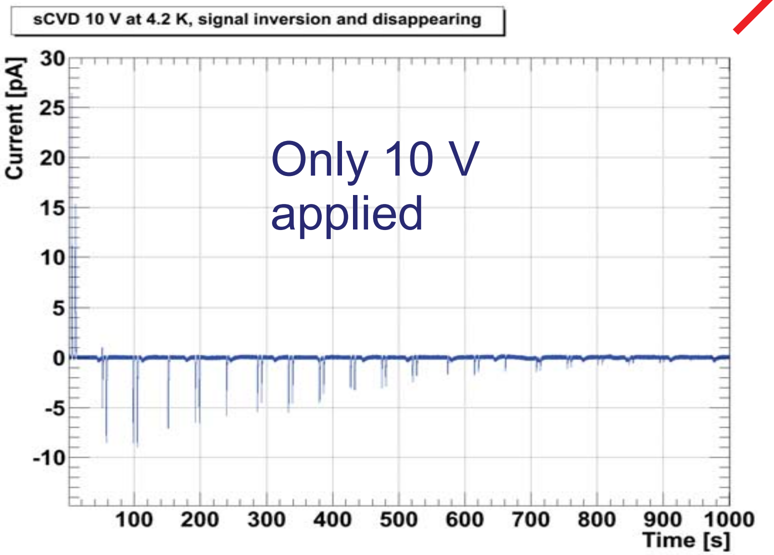

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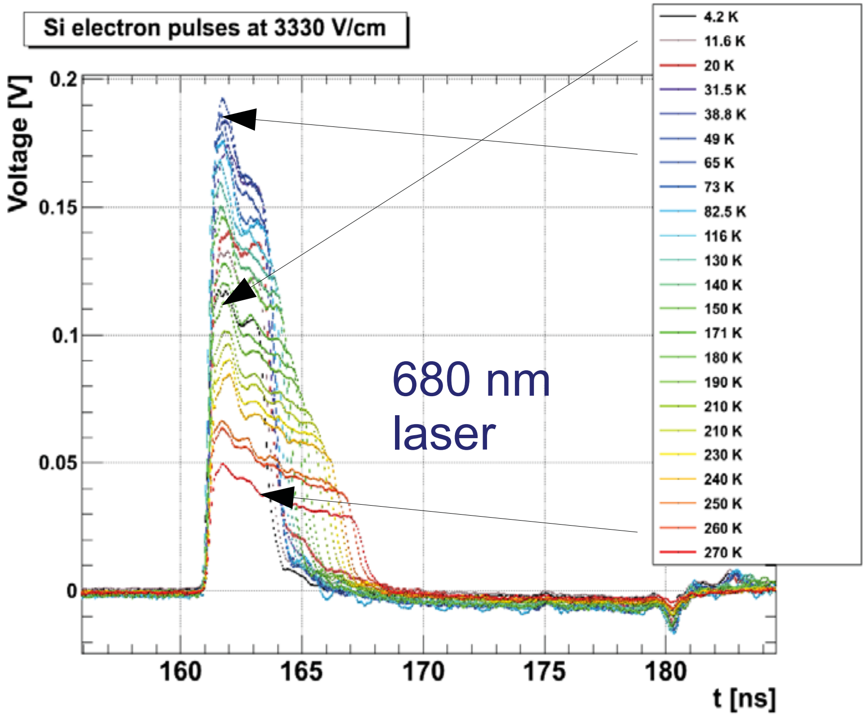

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Acknowledgements
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- **Bernd Dehning** for sending me to this workshop and his help in many ways

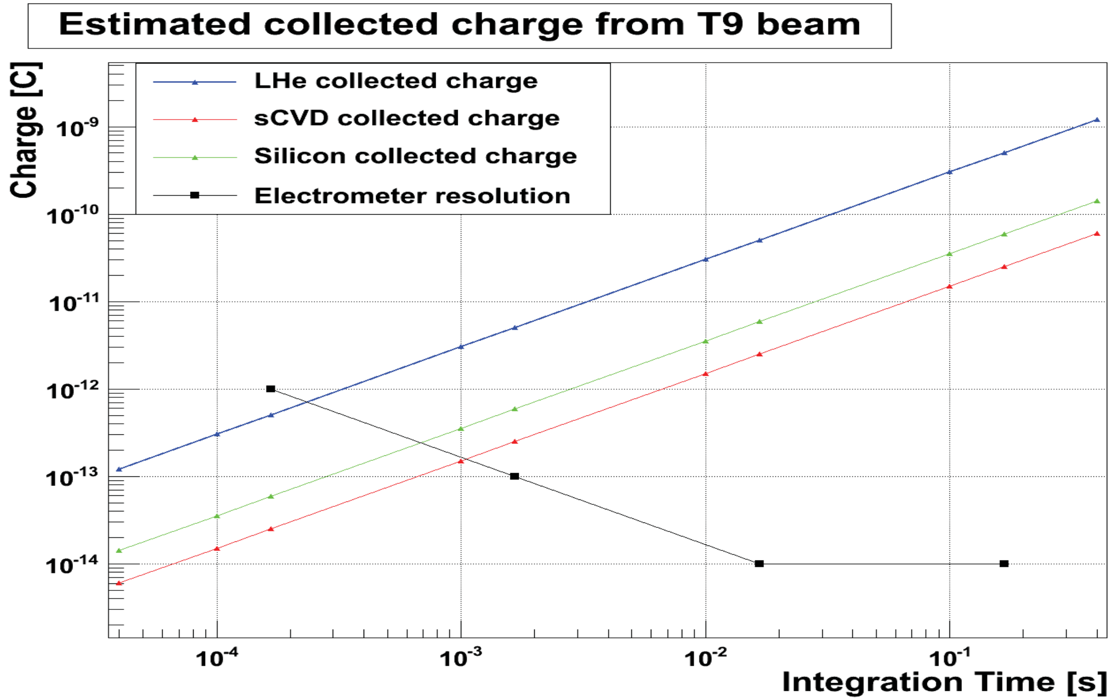
Signal Estimation

- Estimations done with:
  - Stopping power of material P_{stop}
  - Density of material ρ
  - Electron-hole Pair creation energy E_{pair}
  - Dimensions of detector (active area A_{active} and length l)
  - Beam characteristics (beam size A_{beam}, number of particles n_p and spill duration)
- Charge per particle:
  - Liquid helium: **12.2 fC**
  - sCVD: **3.79 fC**
  - Si: **5.68 fC**
- Charge per spill:
  - Liquid helium: **3.66 nC**
  - sCVD: **182 pC**
  - Si: **426 pC**

$$Q = \frac{P_{stop} \cdot \rho \cdot l}{E_{pair}}$$

$$Q_{spill} = \frac{P_{stop} \cdot \rho \cdot l}{E_{pair}} \cdot n_p \cdot \frac{A_{active}}{A_{beam}}$$

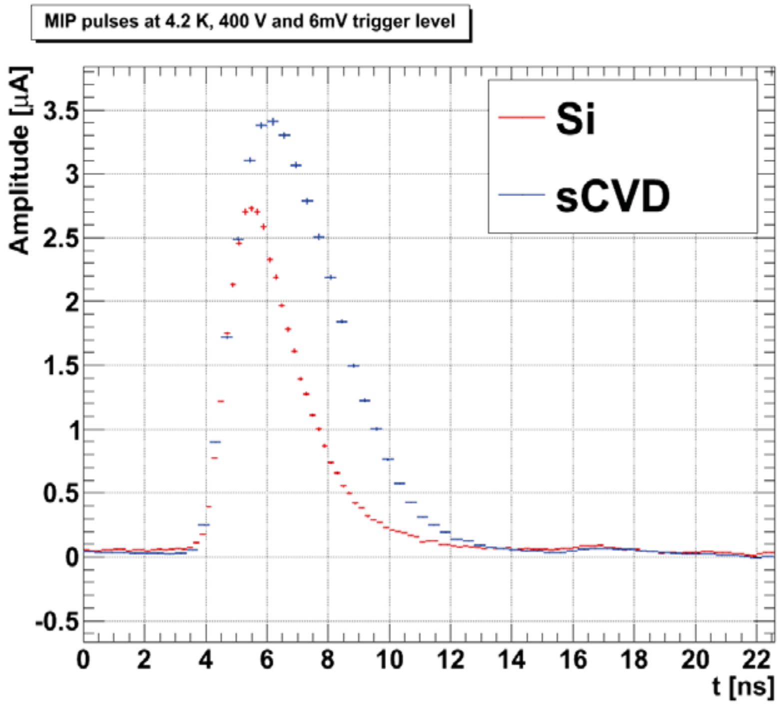
Signal Estimation
(Check done to see if signals measurable)

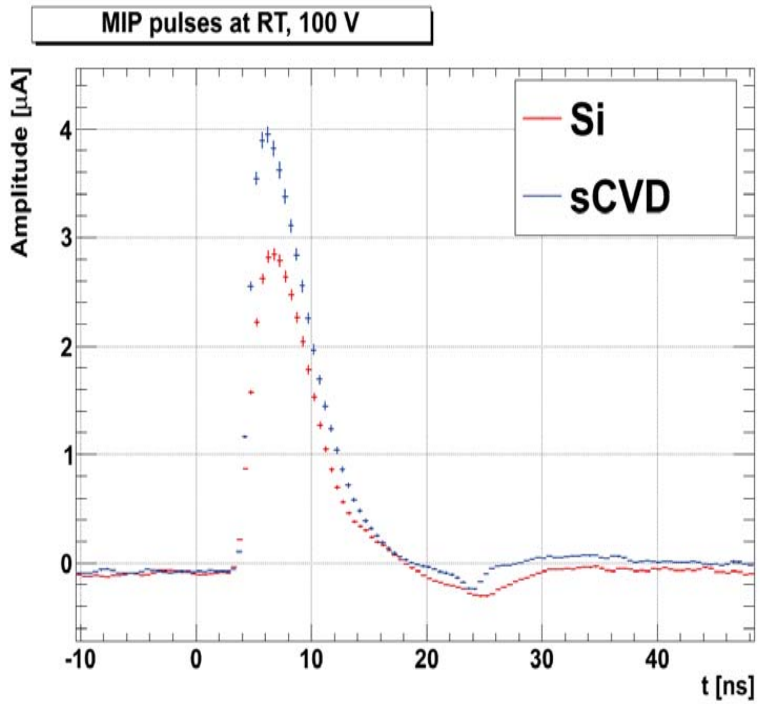


Estimated currents from particles:

- LHe chamber: **9.14 nA**
- sCVD: **454 pA**
- Si: **1.07 nA**

Comparison sCVD and Si
Single particle detection





For single particle detection, more charge observed for sCVD than for Si. This might come from the trigger settings.