Particle detection with sCVD and Si at LHe temperatures
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

![Graph showing peak dose in the coils and BLM signal vs. distance from IP (in meters)]
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)
Semiconductors holder from Vladimir Eremin

- Optical fibers for TCT with Si
- 4 Silicon detectors
- 1 single crystal diamond (sCVD)

Stainless steel cables for low heat introduction
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 cm²**
- 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)

Voltage scan with 4 mV trigger

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
Conclusions and outlook

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- Not fully understood:
  - “Avalanche” pulses
  - Diamond polarization at 1.9 K
- Critical missing information:
  - Radiation hardness
- Ongoing analysis of the:
- In parallel further measurements in laboratory:
  - Silicon (TCT) charged with alpha source
  - sCVD (TCT) charged

Reflection of 4 μA corresponds to initial signal of ~80 μA
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:
  - Hardness of semiconductors at 1.9 K
  - Basis of the beam test data
  - Newer measurements done in the
  - $^\Gamma$) charge generation with laser and
  - $^\alpha$) charge generation with alpha source
Conclusions and outlook

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- Not fully understood:
  - “Avalanche” pulses
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- Critical missing information:
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- Ongoing analysis of the beam test data
- In parallel further measurements done in the laboratory:
  - Silicon (TCT) charge generation with laser and alpha source
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Conclusions and outlook

- All tested detectors work at low temperatures
- Not fully understood:
  - “Avalanche” pulses
  - Diamond polarizers
- Critical missing information
- Radiation hardness
- Ongoing analysis of
- 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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Signal Estimation

- Estimations done with:
  - Stopping power of material \( P_{\text{stop}} \)
  - Density of material \( \rho \)
  - Electron-hole Pair creation energy \( E_{\text{pair}} \)
  - Dimensions of detector (active area \( A_{\text{active}} \) and length \( l \))
  - Beam characteristics (beam size \( A_{\text{beam}} \), 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

\[
Q = \frac{P_{\text{stop}} \cdot \rho \cdot l}{E_{\text{pair}}}
\]

\[
Q_{\text{spill}} = \frac{P_{\text{stop}} \cdot \rho \cdot l}{E_{\text{pair}}} \cdot n_p \cdot \frac{A_{\text{active}}}{A_{\text{beam}}}
\]
Signal Estimation
(Check done to see if signals measurable)

Estimated collected charge from T9 beam

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.