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

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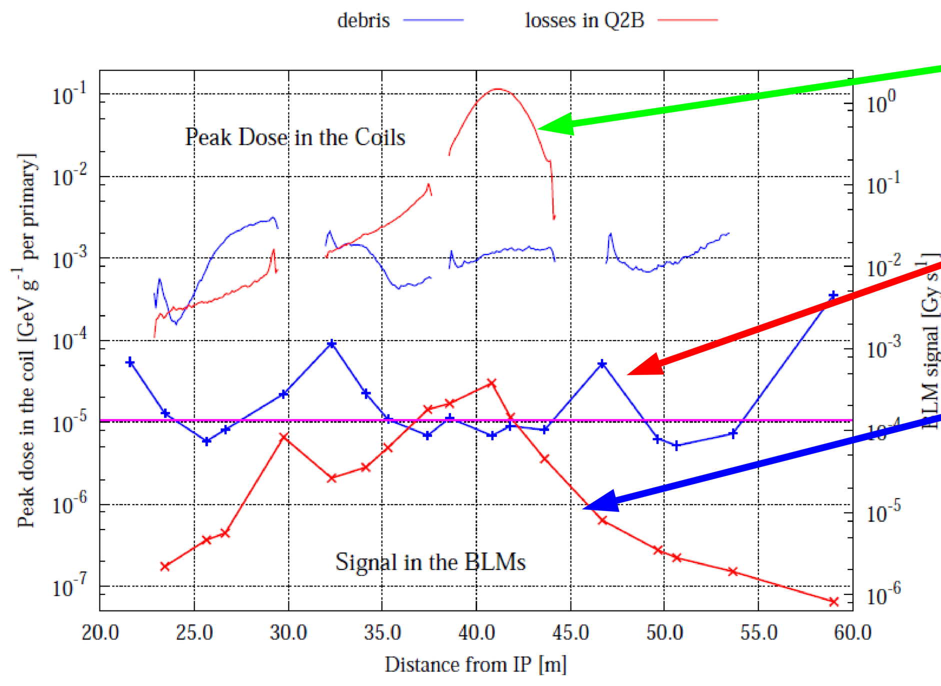
At the triplet magnets, close to the interaction regions of the LHC, the current Beam Loss Monitoring (BLM) system is very sensitive to the debris from the collisions. For future beams with higher energy and higher luminosity this will lead to a situation in which the BLM system can no longer distinguish between these interaction products and quench-provoking beam losses from the primary proton beams. The solution investigated is to locate the detectors as close as possible to the superconducting coil, i.e. the element to be protected. This means placing detectors inside the cold mass of the superconducting magnets at 1.9 K. As possible candidates for such loss monitors, diamond, silicon and a liquid helium chamber have been tested in a proton beam at liquid helium temperatures. The initial promising results from these tests will be presented and discussed in this contribution.

LHC BLM

Purpose: damage and quench protection

BUT

Limit at Triplet magnets



What we want to measure

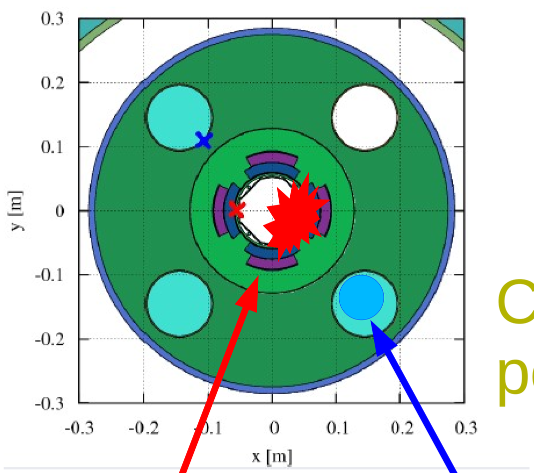
What we do not want to measure

What we measure

Doses in the magnet coil and signal in the BLM shown for two different situations: once for the debris from the interaction region and once simulated for a loss at one location. Debris can mask the signal from a dangerous loss.

BLM inside cold mass

Solution?



Current BLM position

Loss location

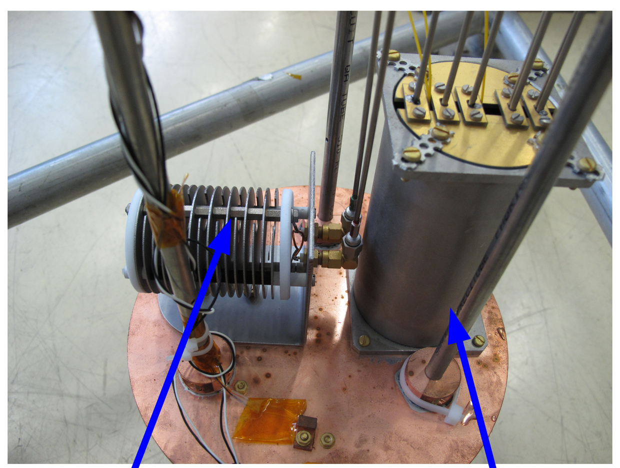
New BLM position in liquid helium

1.9 K
1 MGy
2 Tesla

Placing radiation detectors (CryoBLMs) inside cold mass close to the coils. Advantage: measured dose corresponds more precisely to dose deposited in superconducting coil.

Detectors

Test

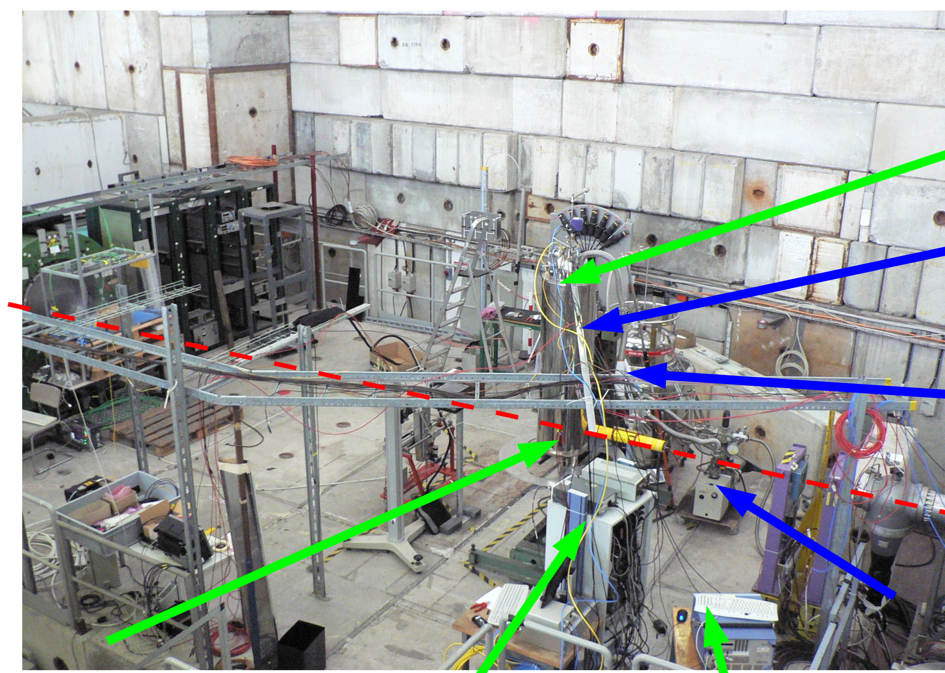


Liquid helium chamber

Semiconductors

Investigated detectors:
Diamond, Silicon and liquid helium chamber

Beam tests in cold



Amplifiers

Cryostat

Dewar

Beam line

Vacuum pump

Detectors

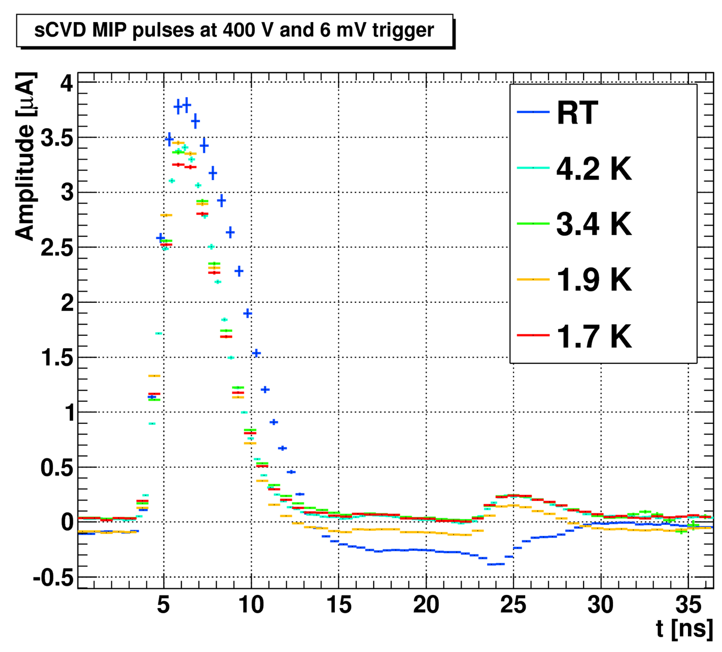
Electronics

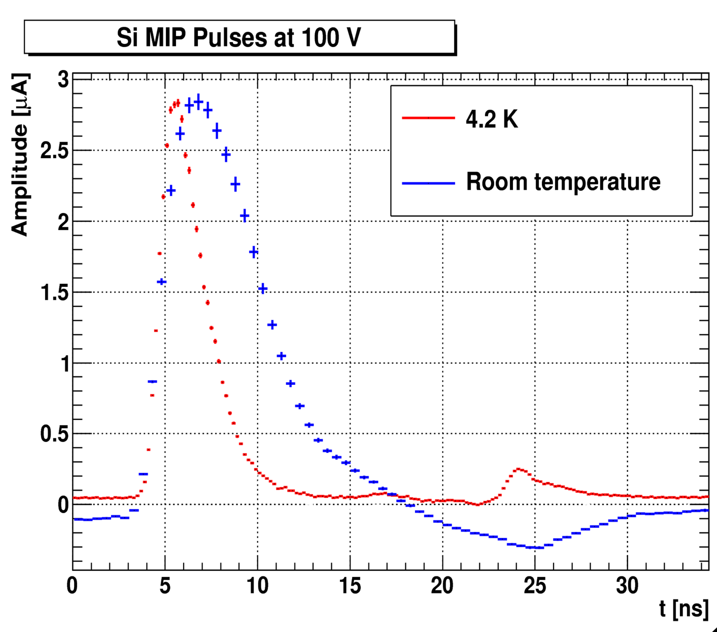
Oscilloscope

Beam tests to measure the characteristics of the detectors at low temperatures.
PS beam, protons (dominating), positive pions and kaons with about 9 GeV/c. The beam intensity is of 350 000 particles per spill with an RMS size at focus of about 1 cm^2.

Diamond and Silicon

Results

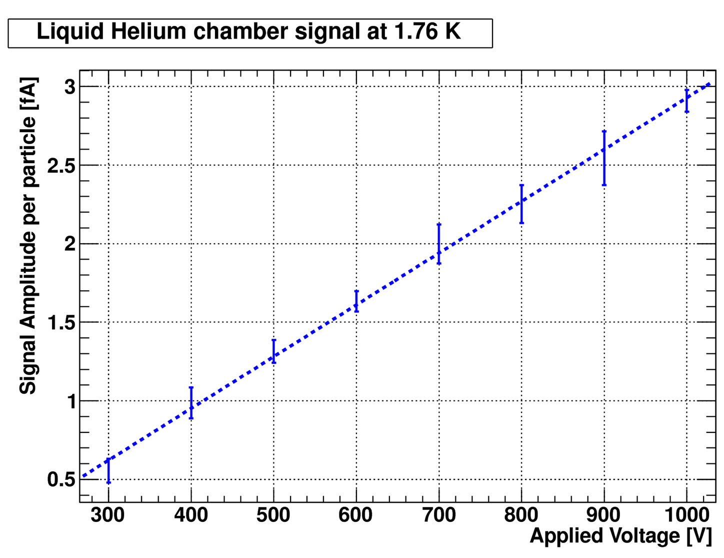




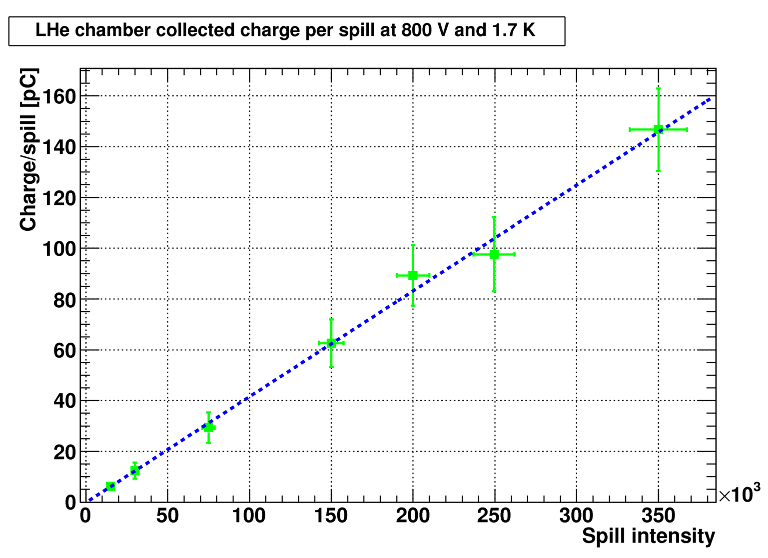
Single minimum ionising particle (MIP) measurements, with the semiconducting detectors,using 40 dB current amplifiers from CIVIDEC
Width of pulses show that at liquid helium temperatures charges drift faster
Curve shape at 25 ns corresponds to reflections between detector and amplifier, caused by imperfections in input impedance matching

Liquid Helium chamber

Results



The signal response in superfluid helium increases linearly with the applied voltage.



In the measurement range, the collected charge from one spill in superfluid helium increases linearly with the beam intensity.

Conclusion

All **detectors work at liquid helium** temperatures.
With Silicon and Diamond bunch by bunch resolution in the LHC possible. **Liquid helium chamber** elegant solution as CryoBLM in triplet magnets, **no issues with radiation hardness**.
Two critical points still need to be investigated: radiation hardness of the semiconductors at low temperatures and the charge collection time of the liquid helium chamber.
Both addressed during challenging beam tests in 2012.

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