# A FAST CVD DIAMOND BEAM LOSS MONITOR FOR LHC

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*Abstract*

CVD diamond detectors were installed in the collimation area of the CERN LHC to study their feasibility as Fast Beam Loss Monitors in a high-radiation environment. The detectors were configured with radiation resistant 2 GHz preamplifiers. Despite the 250 m cable from the detectors to the readout system, single MIPs were resolved with time resolution of less than 1 ns. Two modes of operation were applied. For the analysis of unexpected beam aborts, the loss profile was recorded in a 1 ms buffer and, for nominal operation, the histogram of the time structure of the losses was recorded in synchronism with the LHC period of 89.2 µs. Measurements were done during the LHC start-up (February to December 2010). The Diamond Monitors gave an unprecedented insight into the time structure of the beam losses resolving the nominal bunch separation of 25 ns.

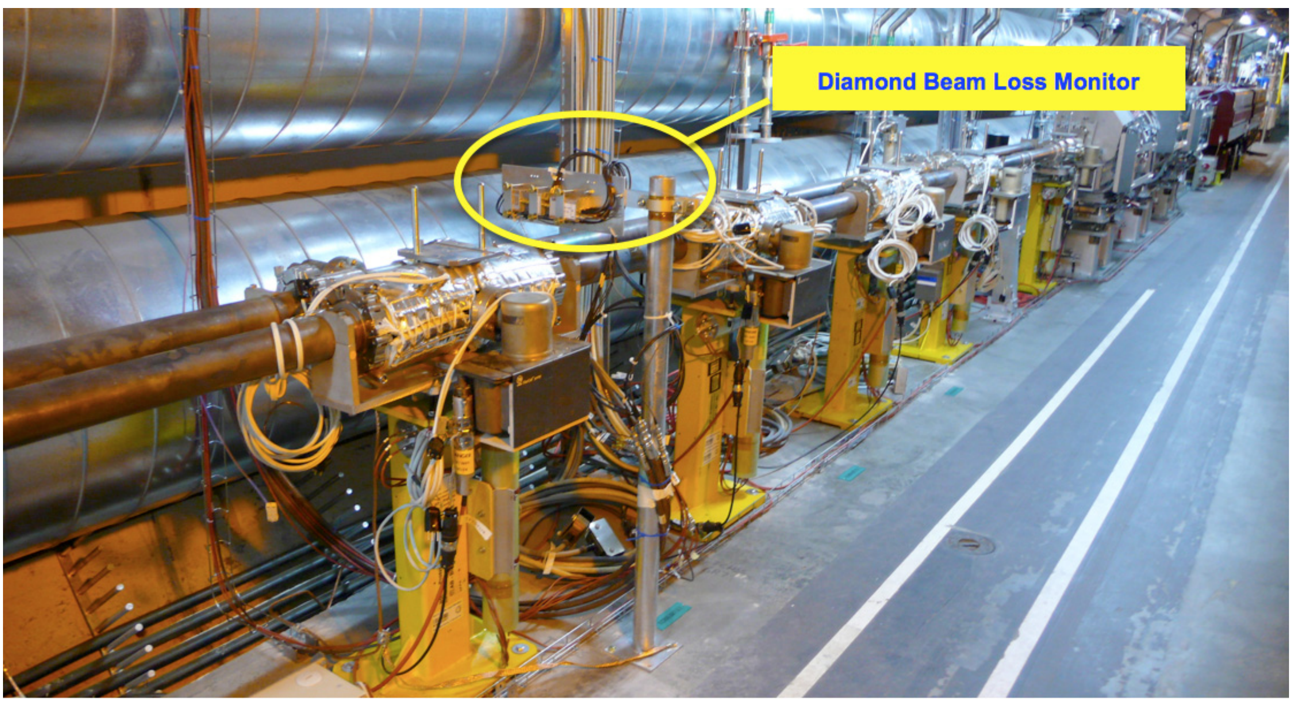


Figure 1: Installation of Diamond Beam Loss Monitor in the LHC tunnel in IP 7.

## INSTALLATION

Four Diamond Beam Loss Monitors (DBLM) were mounted in the LHC tunnel in the collimation area in IP7, one on the lefthand side (TCLA.D6L7.B2) and three on the righthand side (TCHSS.6R7.B2), each next to primary collimators (Figure 1).

The DBLM consists of the diamond detector, an AC-DC splitter and a preamplifier. The DBLM is mounted on an aluminium plate and a stand, which is screwed to the LHC tunnel floor. The stand is electrically connected to the LHC ground and the DBLM is electrically isolated from this ground point. The DBLM received its ground from the control room (UJ76).

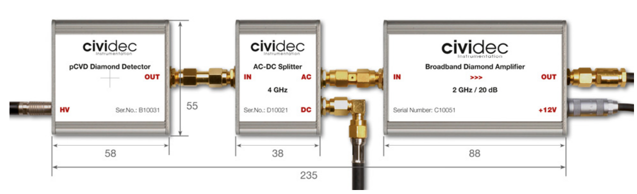


Figure 2: The Diamond Beam Loss Monitor consists of the pCVD Diamond Detector, the AD-DC Splitter and the 40 dB, 2 GHz Amplifier.



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### Diamond Detector

The diamond detector consists of a 10 mm × 10 mm × 0.5 mm pCVD diamond substrate coated on each side with a 200 nm thick gold electrode with a size of 8 mm × 8 mm, Figure 3. The detector capacitance is typically 8 pF. The bottom electrode is glued to a ceramic PCB and the top electrode is bonded with 10 µm thick aluminium bonding wires. The detector is mounted in an aluminium box with extra RF shielding.

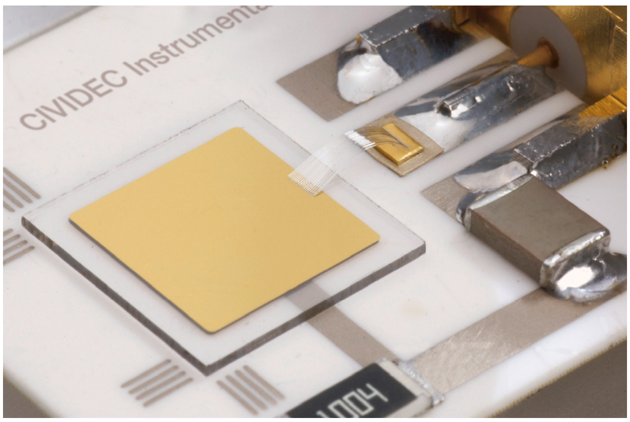

Figure 3: The Diamond Detector.

### AC-DC Splitter

The 4 GHz AC-DC Splitter decouples the detector's DC dark current from the AC signals. It has an analogue bandwidth of 4 GHz and provides the DC path to ground. This makes it possible to separate the measurement of single particle losses and particle loss cascades.

### Preamplifier

A 40 dB broadband current amplifier with a bandwidth of 2 GHz was used for the tests. This preamplifier is optimized for use with pCVD diamond detectors. It is radiation resistant up to 1 MGy and has a dedicated input protection according to IEC61000-4-2 (±8 kV, 2 A for 1 µs). The preamplifier can intrinsically provide a rise time of 180 ps, a pulse width of 300 ps and a fall time of 400 ps, which is crucial for the measurement of the fast pulses from the diamond detector. The preamplifier provides a SNR of 5 for single MIP pulses with 1.6 fC.

## MEASUREMENTS

### Amplitude Response

The data was recorded with an oscilloscope with 1 GHz bandwidth and 5 GSPS. A Landau fitting procedure was used to reconstruct pulses. The amplitude histogram of pulse amplitudes and the baseline noise is given in the Figure 4. The noise has a sigma of 0.414 mV and the amplitude distribution shows a mean value of 16.859 mV and a maximum close to 100 mV.

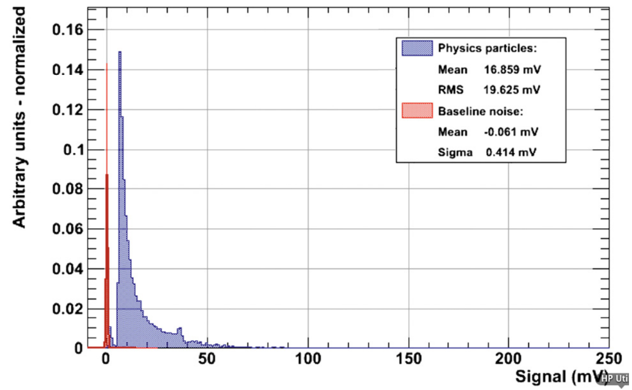


Figure 4: Amplitude distribution of the noise (red) and losses (blue).

### Time Response

The timing properties of the DBLM show a rise time of 1.5 ns, a fall time of 6.5 ns and a pulse width of 6.2 ns. The time resolution of the DBLM has been determined by comparing the response time of two channels for individual events. Figure 5 shows the timing histogram with a time resolution of 615 ps for a single detector.

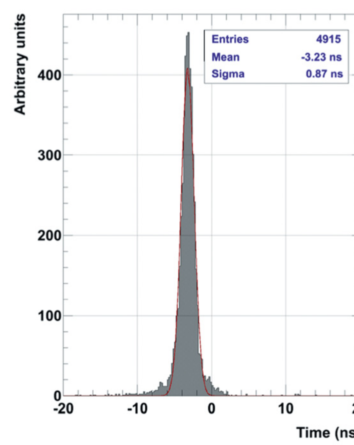


Figure 5: The time resolution for one channel is 615 ps.

### Loss Measurements

The LHC clock was used as a trigger signal in order to resolve the position of individual particle losses. These positions correlate with the bunch number in the machine. The Figure 6 shows the LHC turn clock with its period of 89.2 µs and the position of six individual loss pulses.

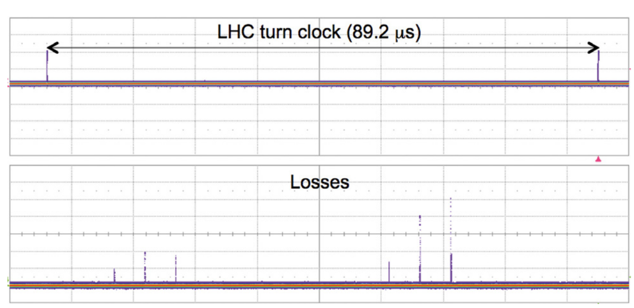


Figure 6: The LHC turn clock and six bunch locations.

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### *Post Mortem Analysis*

In the following figures, data of an unscheduled beam abort, taken with the Diamond Beam Loss Monitors, is shown. Starting with the buffer size of 10 ms, a zoom into the memory in five stages is provided (corresponding to time scales 1 ms/div, 100 µs/div, 10 µs/div, 1 µs/div, 100 ns/div and 10 ns/div). For this measurement the sampling rate was set to 1 GSPS.

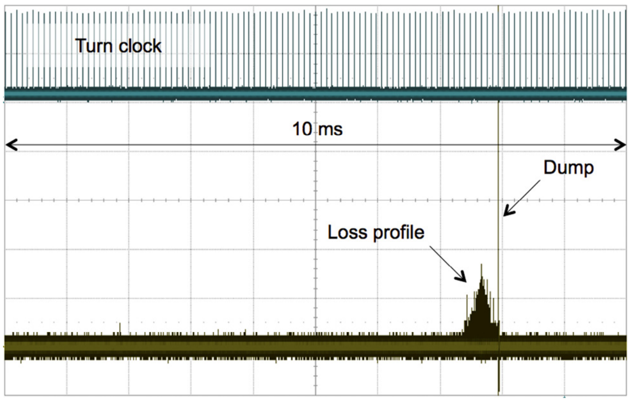


Figure 7: The 10 ms buffer (1 ms/div) shows the characteristics of the event and the turn-clock signal of LHC (89.2 µs). The dump causes a high pulse at the end of the loss pattern.

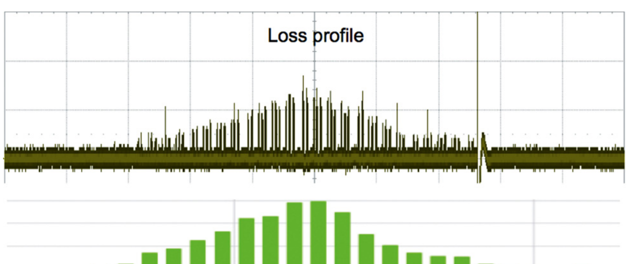


Figure 8: Zoom factor $10^1$ (100 us/div): the time structure of the bunch trains can be estimated. The corresponding measurement from the ionization chambers is shown at the bottom and shows an excellent agreement between the DBLM and the ionization chambers.


Figure 9: Zoom factor $10^2$ (10 µs/div): The bunch-train structure shows 8x16 and 3x8 bunch trains, corresponding to 152 bunches in total.

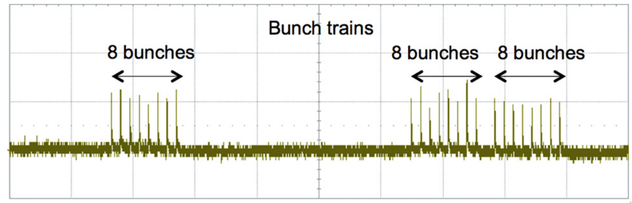


Figure 10: Zoom $10^3$ (1 µs/div): The bunch-train structure shows 8 bunches per bunch train. On the left side there is one train and on the right side there are two consecutive trains.

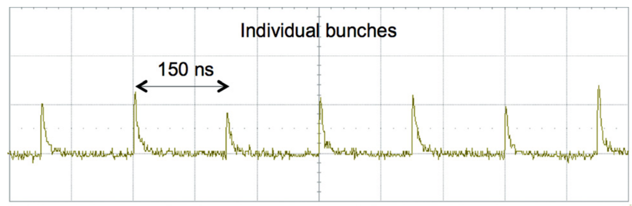


Figure 11: Zoom $10^4$ (100 ns/div): Bunches are separated by 150 ns.

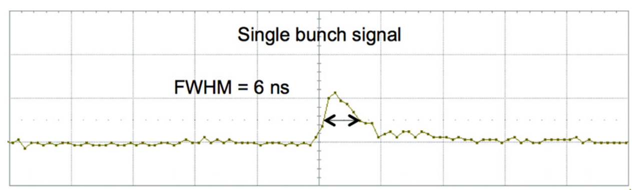


Figure 12: Zoom $10^5$ (10 ns/div): A single bunch signal with an amplitude of 128 mV, a rise time of 2.67 ns and a pulse width of 5.80 ns. The amplitude corresponds to some 50 particles hitting the detector simultaneously.

## REFERENCES

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