CHERENKOV BEAM LOSS MONITOR TEST BENCH IN CLEAR TEST FACILITY

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Abstract

Beam Loss Monitors are fundamental diagnostic systems in particle accelerators. Beam losses are measured by a wide range of detectors with excellent results; most of these devices are used to measure local beam losses. However, in some accelerators there is the need to measure beam losses continuously localized over longer distances i.e., several tens of meters. For this reason, a beam loss detector based on long optical fibres is now under study. As part of the design, several simulations, comparing different possible detection scenarios, have been performed in FLUKA and bench-marked with experimental data. An experimental campaign was performed with an electron beam in the CERN Linear Electron Accelerator for Research (CLEAR) in November 2020. The light emitted from the optical fibre was captured using Silicon Photo-Multipliers (SiPM) coupled at each fibre's end. In this poster, the first results of a beam loss detector based on the capture of Cherenkov photons generated by charged particles inside multimode silica fibres are presented.

The readout

The layout consists of two printed circuits boards (PCBs) with two SiPM that have been attached to the both ends of the fibres. Hamamatsu S12572-010C, -025C MPPCs have been used, with an active area of 3×3 mm and 90000-14400 pixels, respectively. The standard module of the read-out system for an MPPC device comprises a low pass filter for the bias voltage and a high pass RC filter readout. The SiPM connects directly to the readout board and an FC-PC connector for the attachment of the optical fibre is implemented on the front of the module.

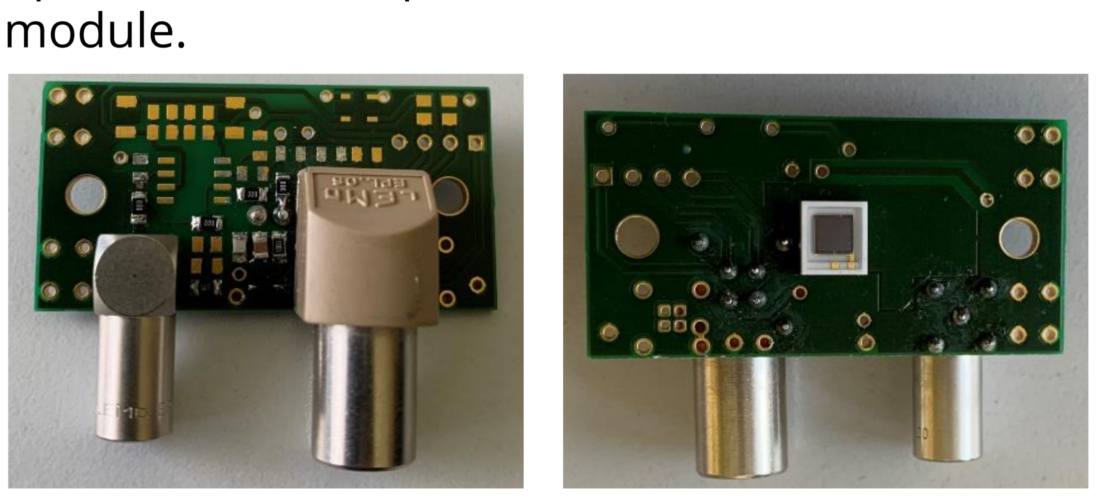


Figure 2. a. The PCB used for the OBLM; **b.** The SiPM S12572-010C from Hamamatsu with an active area of 90000 pixels.

The Cherenkov photon spectrum and the influence of attenuation on it for different fibre lengths are shown in figure 3. The optical spectrum for longer fibres is drastically reduced with the increase of the fibre length, while the red part on the curve remains almost unaffected. Therefore, it is clear that the attenuation becomes a critic parameter for longer fibres.

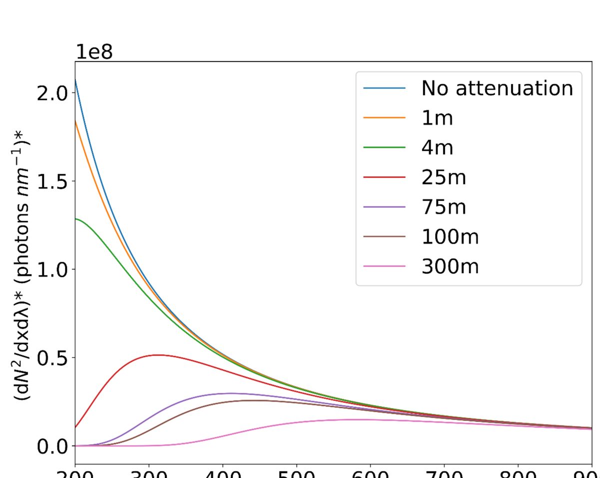


Figure 3. The Cherenkov photon yield in Silica (black line) and the spectrum attenuation after propagating in different lengths of optical fibre.

The SiPM used in this test are sensitive to lower optical wavelengths (peak sensitivity at 470-460 nm, figure 4.

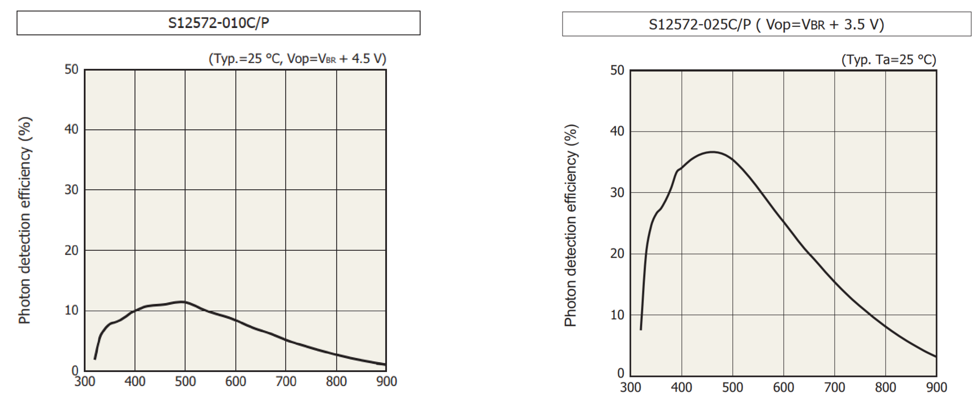


Figure 4. Photon detection efficiency vs wavelength for Hamamatsu SiPM S12572-010C, 025C. (Hamamatsu Technical Note, March 2017)

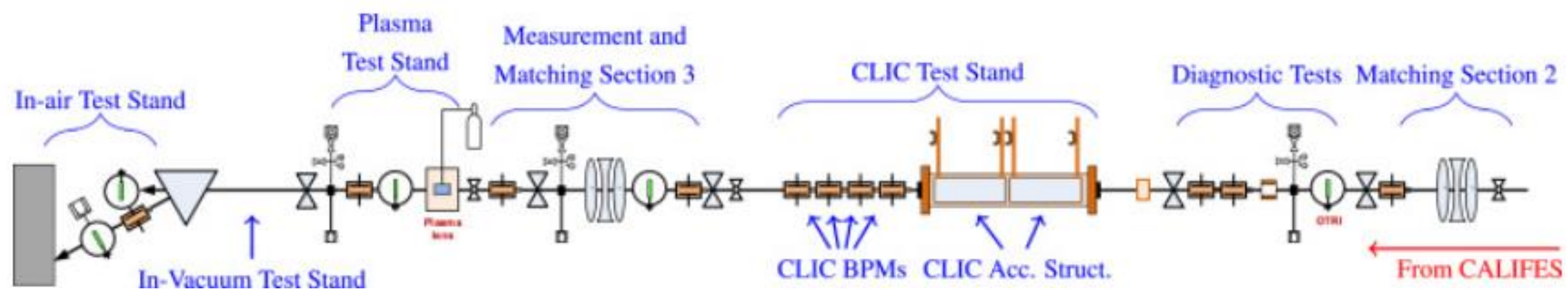


Figure 1. Layout of the CLEAR experimental beamline. The electron beam, coming from the CALIFES injector, travels from right to left.

The test bench

The system has been placed in the Open-Air section of the CLEAR facility. The beam parameters are presented in table 1.

Beam parameter (end of linac)	Value range
Energy	60-220 MeV
Bunch charge	0.01-0.5 nC
Normalized emittances	3 μm for 0.05 nC per bunch 20 μm for 0.4 nC per bunch (in both planes)
Bunch length	~100 μm-1.2 mm
Relative energy spread	<0.2% rms (< 1 MeV FWHM)
Repetition rate	1-5 Hz (25 Hz with upgrade)
Number of micro-bunches in train	1 and more than 100
Micro-bunch spacing	1.5 GHz

Table 1. The beam parameters at the end of the linac in CLEAR.

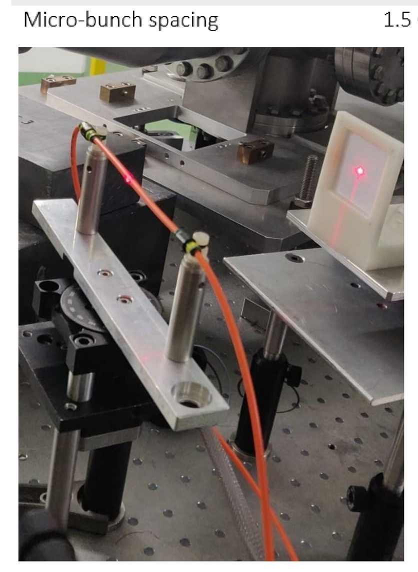


Figure 5 shows the rotational table where different core size multimode optical fibres (50, 105 and 200 μm, low-OH, 0.22 NA, Silica core) have been exposed to accelerator beam.

Figure 5. The optical fibre installed on the rotational table in the Open-Air section of CLEAR facility at CERN.

Angle scan for a single bunch

A starting point (0º) has been defined as the perpendicular point between the beam and the fiber. The anticlockwise and clockwise movements (negative and positive angles, respectively) have been set within the range [-80º, 80º], in 3º–5º degree steps approximately. The electron beam has been adjusted to a single bunch with a fluctuation of charge within the range [20-40] pC and a spot size 1.1×2 mm².

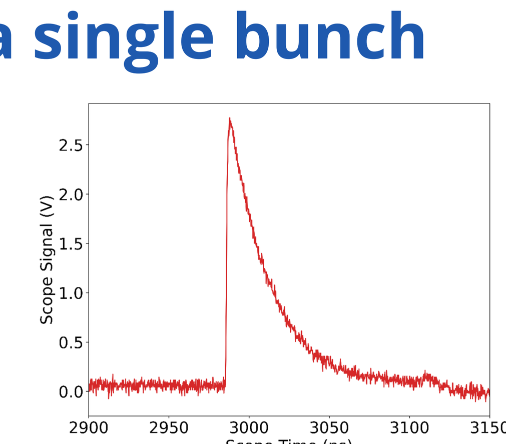


Figure 6. Signal obtained from the angle scan for a fixed fibre at the angle of 47,7◦. The electron beam was set up to a single bunch.

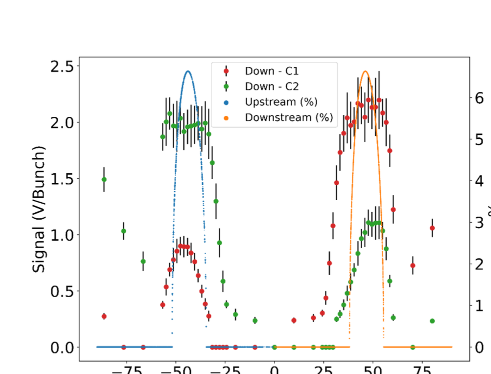


Figure 7. Probability of light capture in the 105 μm fibre

Figure 7 shows the result of the angular scan performed in the test for the 105 μm diameter fibre. The values of maximum probability of capture are close to the Cherenkov angle θ ≈ ± 47° for silica fibres.

Intensity scan for multi bunches

A secondary test performed at CLEAR has been the exposition of the fibre to different beam intensities at the same angle for all the shots (≈47.7°). 30 bunches beam has been set up in order to stabilize the charge from shot-to-shot. The curve of the intensity scan (Fig. 8) for all the shots indicates that the photo-detectors start to saturate from a bunch charge above 20 pC.

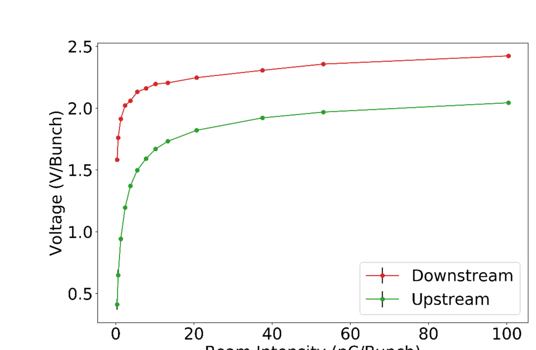
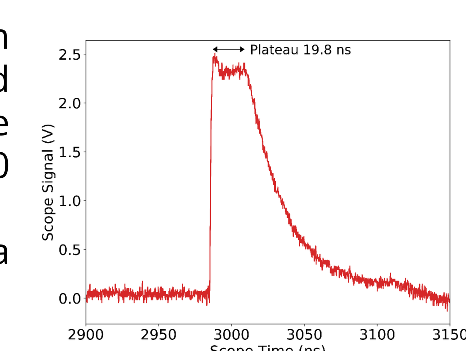


Figure 8. The intensity scan shows the amount of input charge that the fibre can detect. Saturation in the photo-sensors can be observed before the charge of 20 pC.

The signal during one of the shots of 30 bunches (110 pC total charge) reveals a horizontal plateau (Fig. 9) which corresponds to the total time of beam exposition.

Figure 9. Signal obtained from the intensity scan for a fixed fibre at the angle of 47,7◦. The electron beam was set up to 30 bunches.
The resultant signal for a charge of 110 pC is shown.



Summary

A novel prototype of a BLM Cherenkov detector has been tested at CLEAR. The signal from single bunch impacts in the fibre was analysed: the readout PCB was modified to obtain a clear signal with rise time of ~1-4 ns and decay time of ~ 50 ns and the capture light was studied and compared with the expected simulated model. The signal from multi-bunched beam impacting the fibre was studied: the readout confirms a good scaling of the received light with time; the signal saturation was analysed, showing that the first saturation effect appears at approximately 20 pC, however still dependance with the charge is observed.

References

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