# Development of a Method for Continuous Functional Supervision of BLM Systems


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**Abstract:** It is of vital importance to provide a continuous and comprehensive overview of the functionality of beam loss monitoring (BLM) systems, with particular emphasis on the connectivity and correct operation of the detectors. At CERN, a new BLM system for the pre-accelerators of the LHC is currently at an advanced stage of development. This contribution reports on a new method which aims to automatically and continuously ensure the proper connection and performance of the detectors used in the new BLM system.


## Motivation

- Beam loss monitoring (BLM) very important in machine protection and optimization at CERN
- Continuous functional supervision of BLM system essential
- This feature doesn't exist in any accelerator to our knowledge

New BLM system in development for the LHC Injectors
→ *Aim:* development of a process ensuring an uninterrupted supervision of the entire BLM signal chain

## The suggested solution

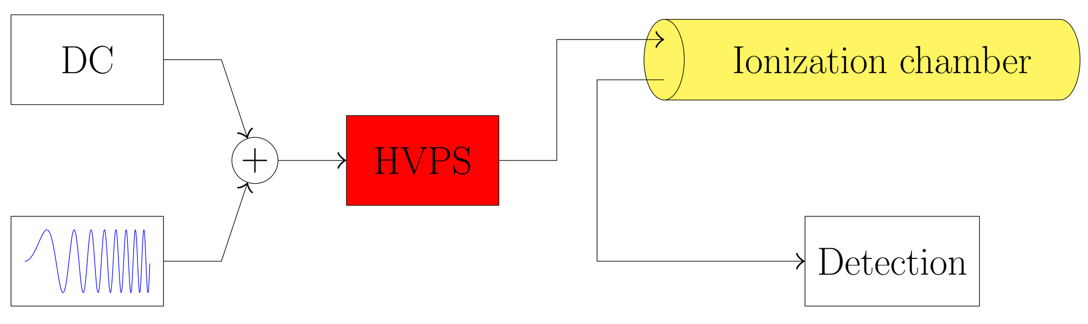



Fig. 1: Schematic view of the signal chain used for the modulation.

- LHC experience: modulation of HV → response in output current
- Injectors:
  - Continuous but pulsed operation → same scheme not usable
  - Usable frequency range far exceeds that at the LHC
  - Swept frequency (chirp) excitation possible → unique signature
  - Seamless enabling/disabling of modulation possible

→ "Gated" modulation: operational measurement and modulation separate

## Gated modulation

- Basic period: 1.2 s – at least 0.5 s without beam
- Modulation active when beam not present

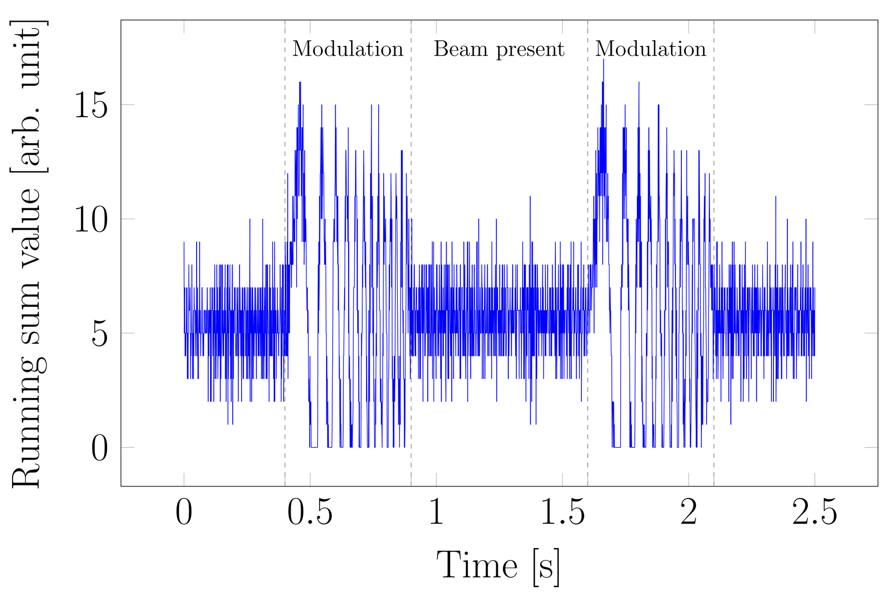
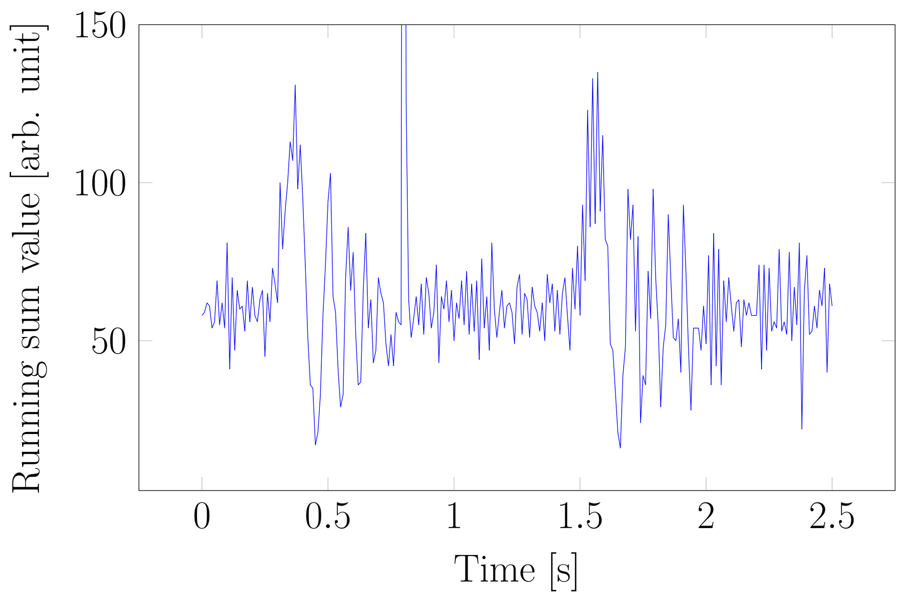
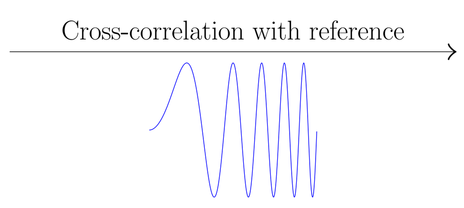



Fig. 2: Response to a 0 – 50 Hz chirp excitation in the lab.

## Detecting the modulation



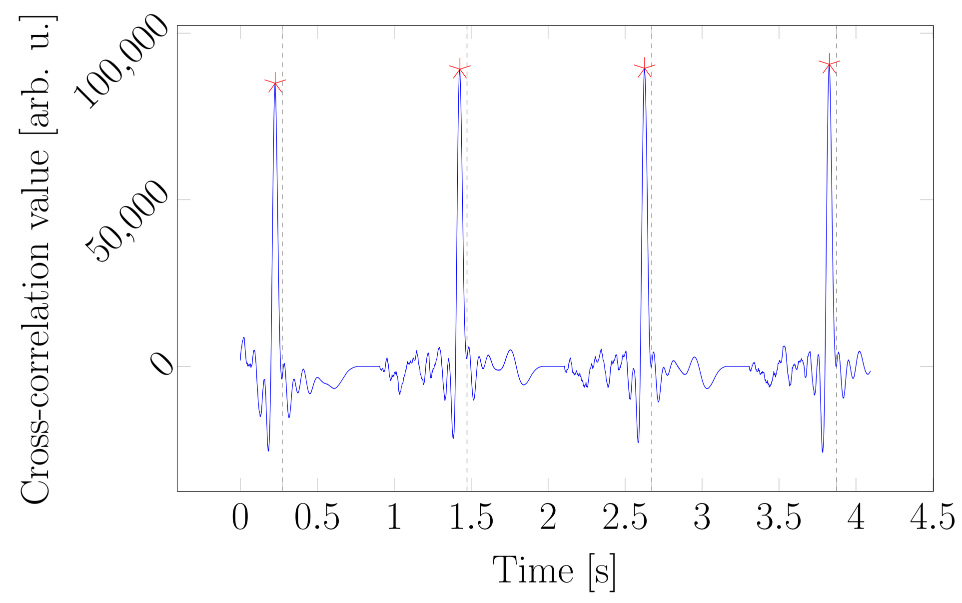




Fig. 3: Response to a 0 – 20 Hz chirp excitation at the PSB.

Fig. 4: Cross-correlation waveform at the PSB with a linear chirp from 0 Hz to 20 Hz.

- Cross-correlation on FPGA: time domain, fixed arithmetic → resource-efficient
- Need to eliminate beam loss contributions like the clipped peak on Fig. 3 → windowing and average suppression applied to signal
- Maximal cross-correlation value (⋆ on Fig. 4) registered in each basic period, amplitude and time of detection compared to acceptance limits

## Cross-correlation at the PSB

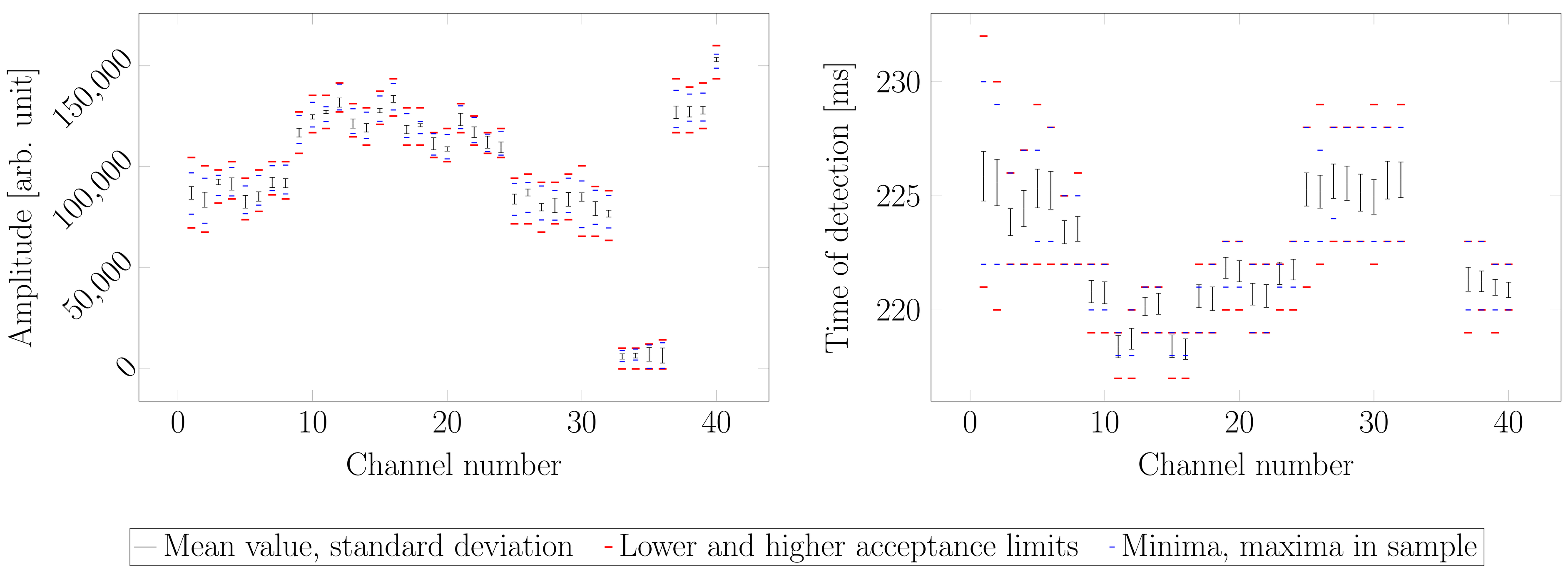



Fig. 5: Cross-correlation peak amplitude and detection time statistics and acceptance limits per channel at the PSB.

Series of acquisitions from all 40 channels currently available at the PSB

- 1024 contiguous samples of cross-correlation maxima → about 20 minutes
- Channels with longer cables: channels 1-8, 25-32
  - Lower amplitude, higher standard deviation
- Channels with shorter cables: channels 9-24
  - Shorter delay in time of detection, lower standard deviation
- Disconnected channels: channels 33-36
  - Separate amplitude range → good detectability
  - Time of detection unpredictable
- Acceptance limits
  - Unique per detector
  - Tuned further based on subsequent acquisitions

## Failure cases covered

Tests in the lab and at LINAC4: all possible cable disconnection scenarios covered

- Disconnection of the HV or signal cable, at the electronics or at the detector
- LHC implementation: filter capacitor variation → modulation phase variation
  - Faulty soldering, capacitor degradation due to radiation
- Injectors: different frequency range, different behavior expected (see Fig. 6)
  - Filter capacitor variation → amplitude variation, no change in phase behavior
  - Simulation results confirmed by measurements
  - High amplitude variation (see Fig. 5) → wide acceptance window → reduced sensitivity to filter capacitor deterioration

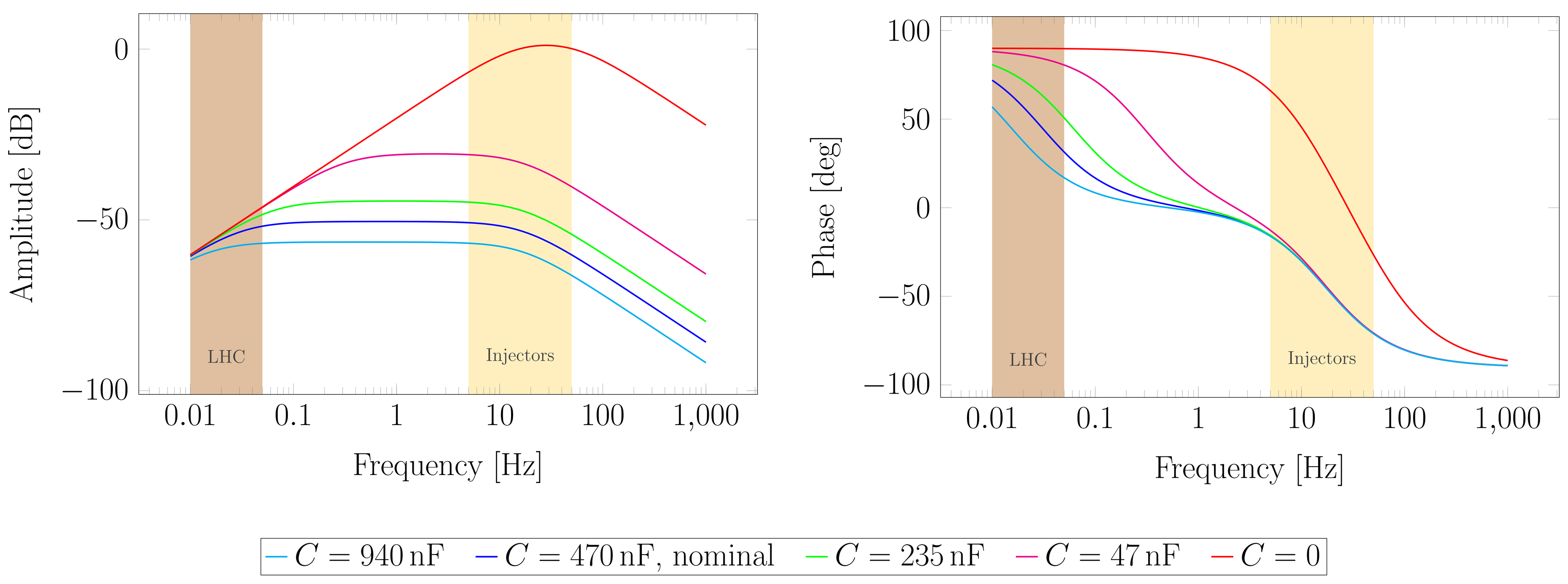



Fig. 6: Simulated Bode plot of the input current digitized by the front-end card for different filter capacitor values.

## Conclusions

The method presented above is a promising candidate for continuous functional supervision of the new BLM system
*Future work:* Refinement of the currently used acceptance windows is desirable in order to improve the sensitivity of the method
*Question for the future:* Is the detection of other failure cases possible with this method?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