A Toroid based Bunch Charge Monitor system with Machine Protection features for FLASH and XFEL

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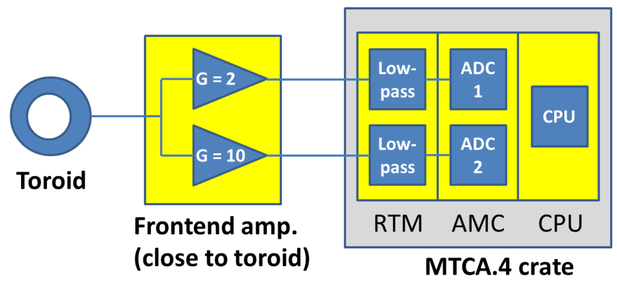
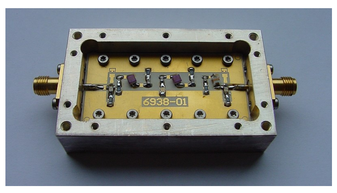
Abstract:

For the superconducting linear accelerators FLASH and XFEL, a new toroid based charge measurement system has been designed as a standard diagnostic tool. It is also a sensor for the bunch charge stabilization feedback and for machine protection. The system is based on MTCA.4 technology and will offer a high dynamic range and high sensitivity. The machine protection features will cover recognition of poor transmission between adjacent toroid sensors, bunch pattern consistency checks, and protection of the beam dumps. The concept, an overview of the algorithms, and the implementation will be described. A summary of first operation experience at FLASH will be presented.

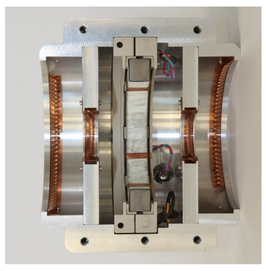
Simplified Hardware Setup:



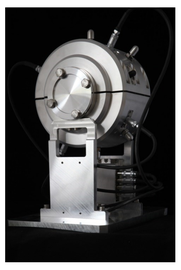
Some photos**:

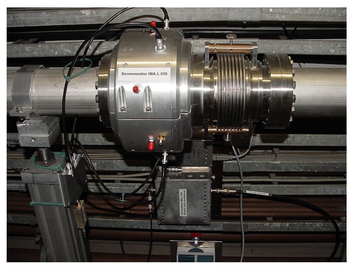


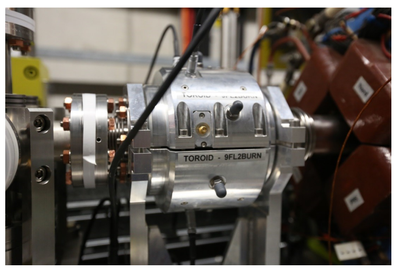
Lowpass filter (at frontend)


Toroid device without chamber, decomposable


Toroid chamber


Complete Toroid device


Toroid device test setup

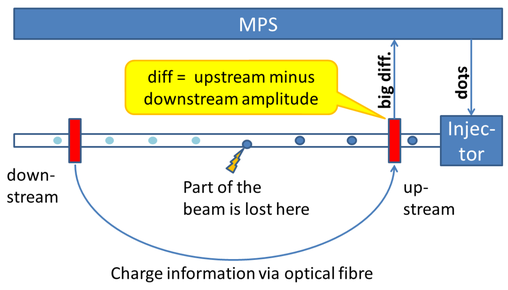


Toroid device in its accelerator environment

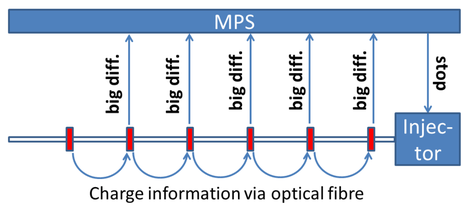
Differential Interlock:

Principle:

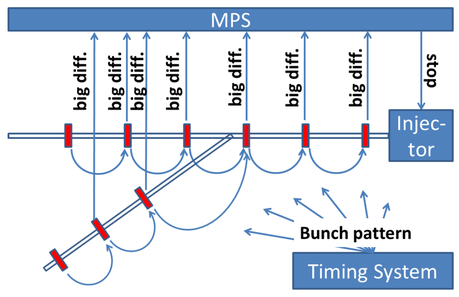
In order to detect beam losses with a latency below 1 µs, the bunch charges measured at successive monitors are compared by FPGAs using digital fibre links. If the difference is too big, an alarm is sent to the Machine Protection System (MPS) to stop the beam.



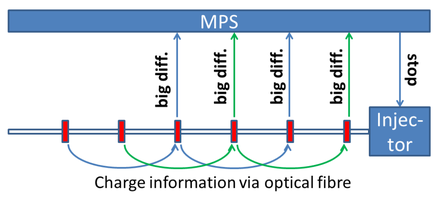
Basic fibre chain:



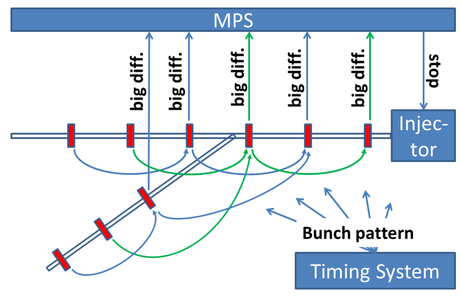
… with branch:



Redundant fibre chain:



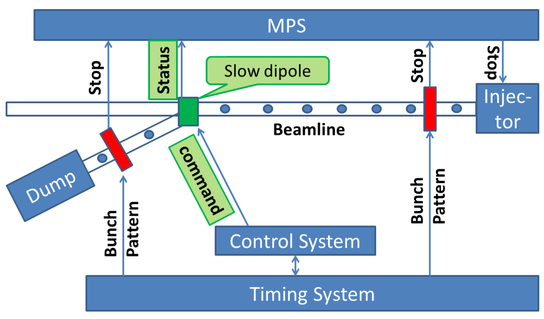
… with branch:



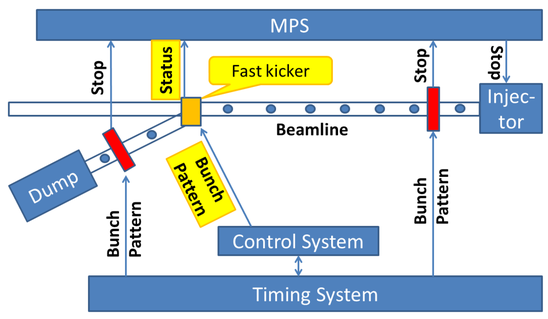
Dump Protection:

The Bunch Charge Monitor (BCM) system helps to protect the dumps (main dumps and diagnostic dumps). The temperature inside the dumps is estimated from the charge, and the beam is switched off if a threshold is exceeded.
For minimum latency, a BCM device close to the injector is used in combination with the bunch pattern information.

… with slow dipole:

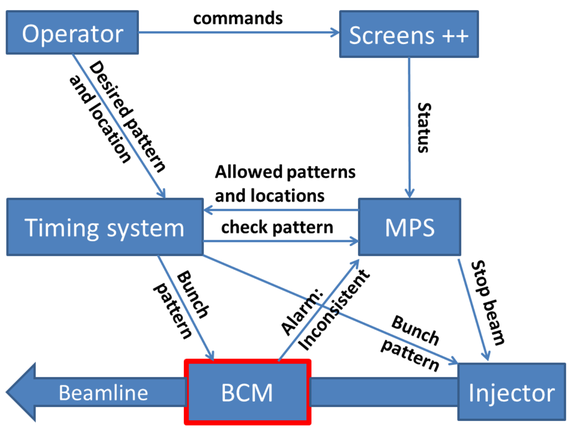


… with fast kicker:



Bunch pattern consistency check:

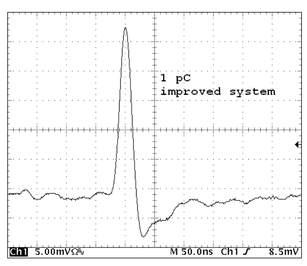
The BCM system checks if the bunch pattern is consistent with the desired parameters. Otherwise, the beam is stopped.



Test results:

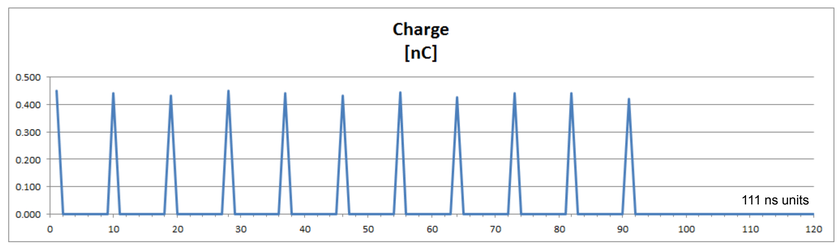
Lab test with a charge of 1 pC

Even with a charge as low as 1 pC, the resulting signal was easily visible.



Self-triggered acquisition in FLASH

Operation in the “self-triggered mode” (independent of trigger and clock signals from the Timing System) could be demonstrated successfully at FLASH with 11 bunches (repetition rate: 1 MHz).



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** Photos by Dirk Noelle, DESY

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