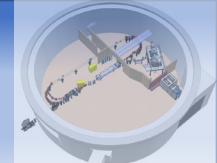




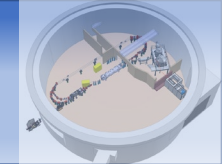
PERLE Beam Loss Monitor

Benjamin Cheymol

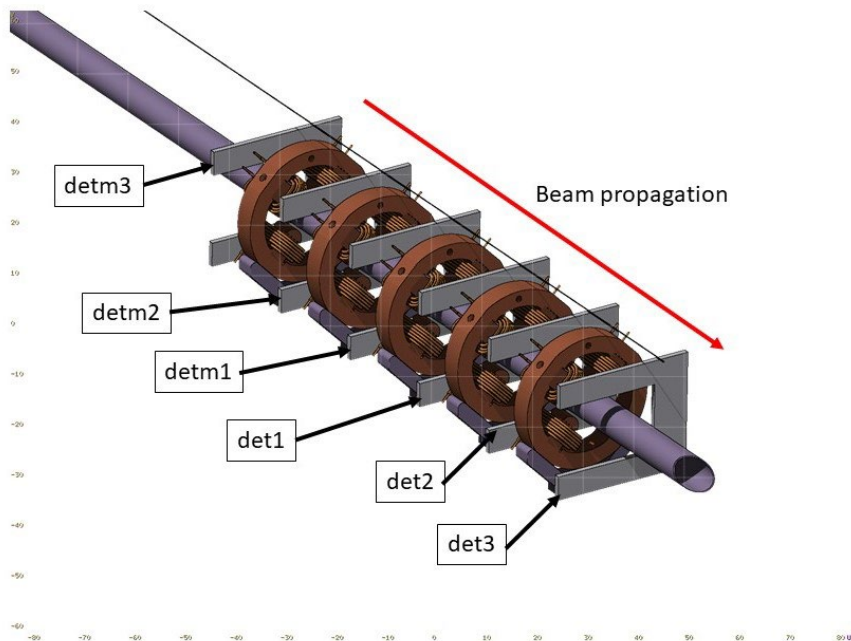
5 octobre 2026



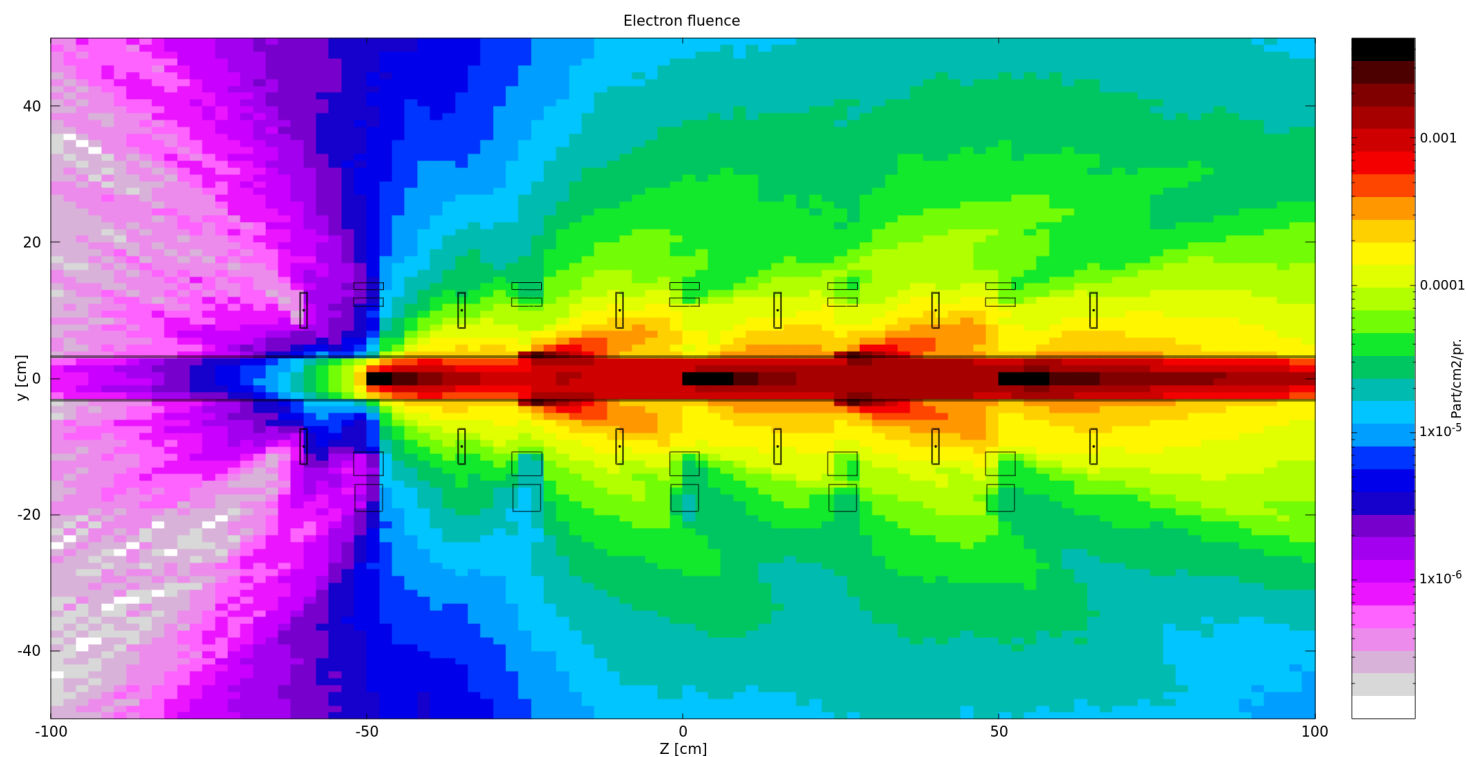
- The conceptual design of the BLM system has been released and can be found in atrium: [ATRIUM-1187616](#)
 - All the details can be found in this document
- The assumed requirements for the BLM were
 - Bunch by bunch beam loss measurement (at 40 MHz)
 - Dynamic range in excess of 10^6
 - Fast response time and decision time for catastrophic losses ($<1 \mu\text{s}$ for the BLM only)



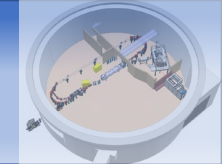
- The Monte Carlo Code FLUKA has been used for the simulations
- At first a simple line with 5 quads has been simulated



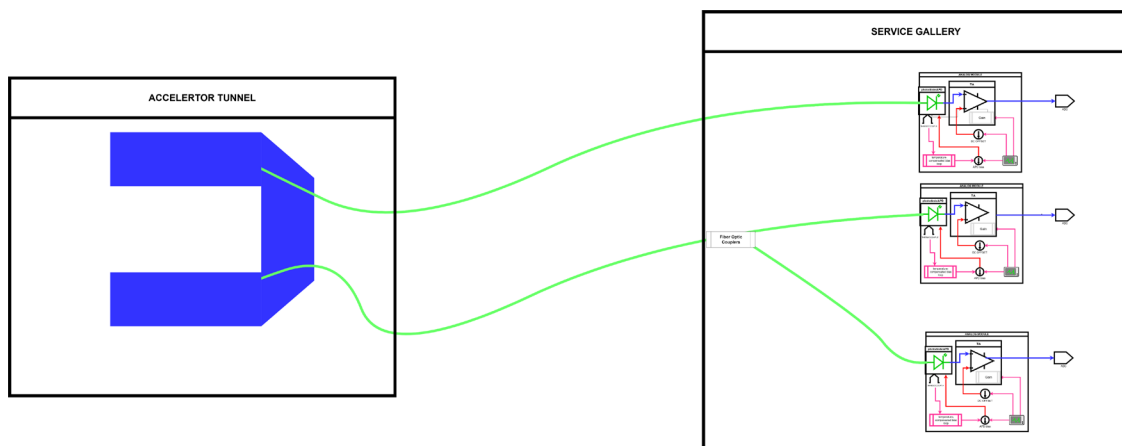
Geometry used in the Monte Carlo code FLUKA



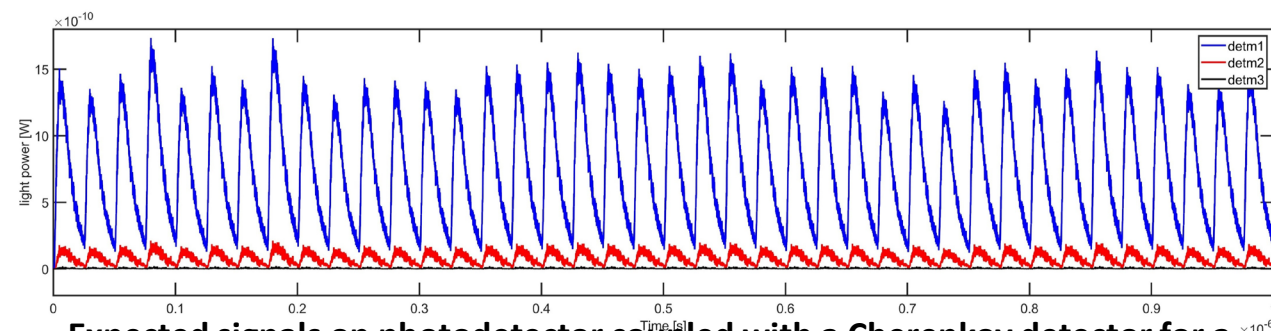
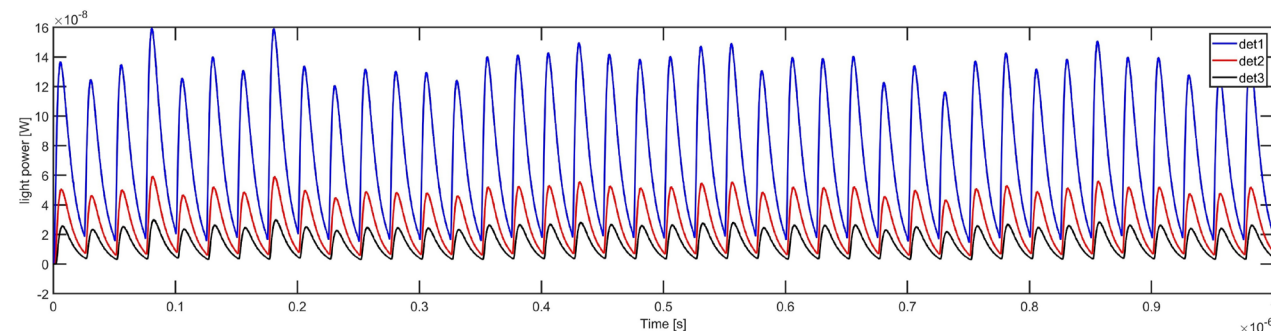
Electron fluence normalized per particle loss for a 89 MeV electron beam; the losses are equivalent in the 5 quads



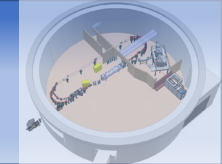
- For fast response, scintillator or Cherenkov detector are mandatory
 - Ionization chambers have a collection time in the μs to ms range
- Light will be collected with wavelength shifting fiber and transported with clear fiber to the gallery
 - Collection efficiency improved if the scintillator shape is complex
 - Less problem of noise
- Multiple fiber will be used to increase the dynamic range
- The system will use photodetector and TIA to convert light in volt before injection in a fast ADC



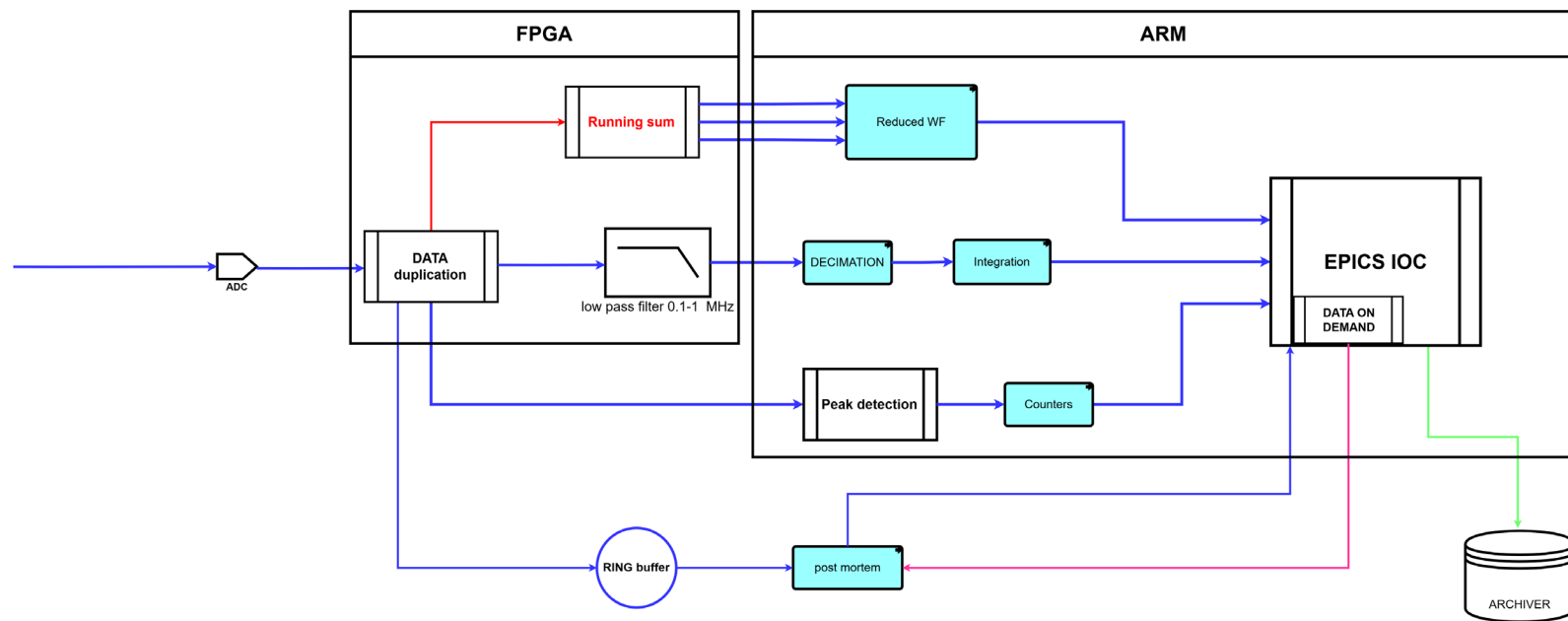
Proposal concept of the BLM for PERLE.



Expected signals on photodetector coupled with a Cherenkov detector for a beam loss equivalent to 0.1 Watt. On top detectors downstream the beam loss location, on bottom detectors located upstream the beam loss location

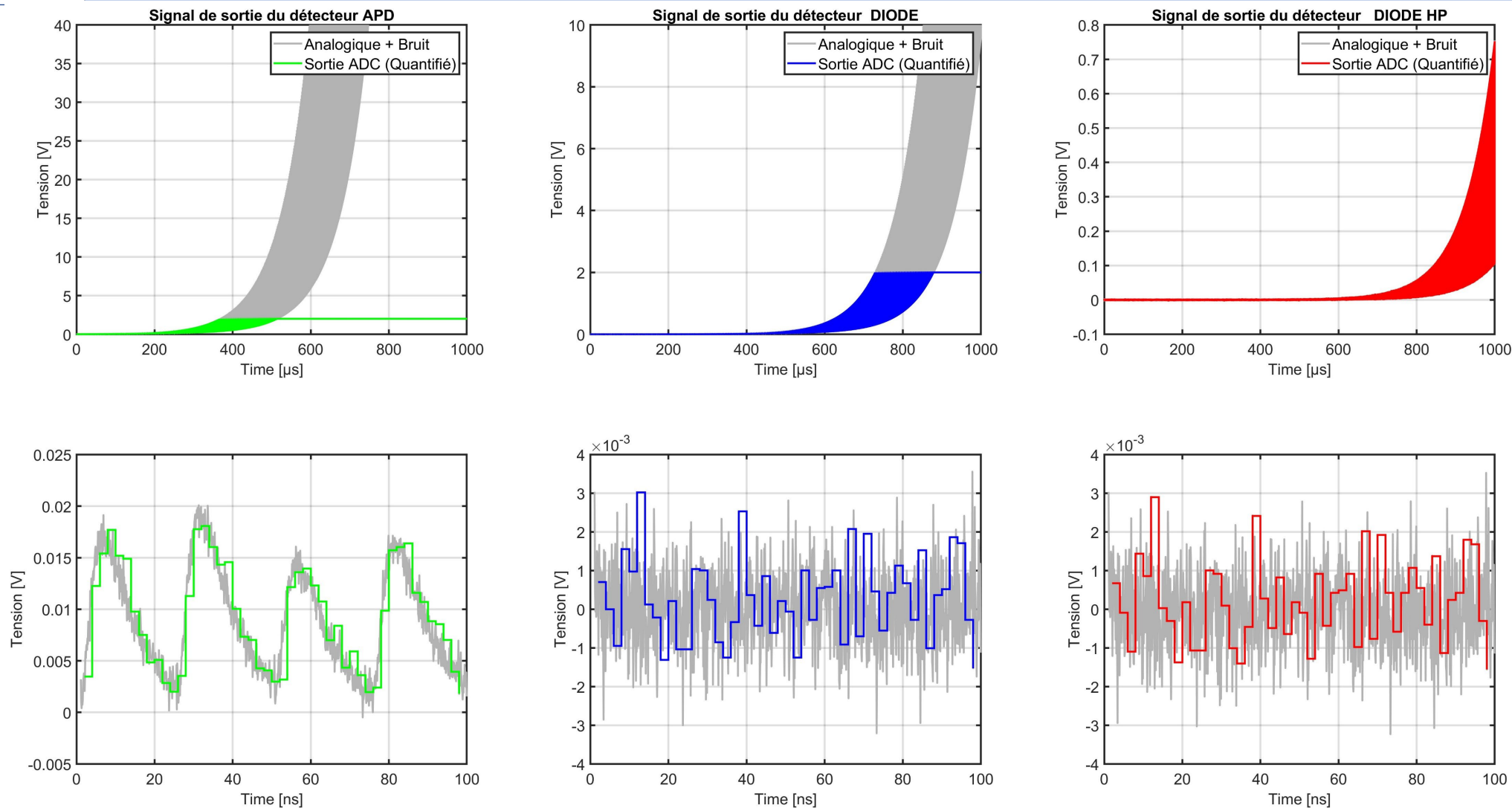
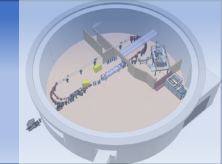


- The data processing shall be 100% digital, the main functions shall be
 - Filter the signal from ADC
 - perform integration over multiple time windows
 - perform threshold comparison for warning and beam abort
 - Note that the threshold will depends on beam destination and beam duty cycle
 - send a binary signal to the Machine Protection System (MPS) based on threshold comparison
 - aggregate the health status of the various subsystems and send a global health status to the MPS
 - Manage and process the data for post-mortem, display and archiving
- Note: Ideally the protection functions and the control/data display shall be clearly separated



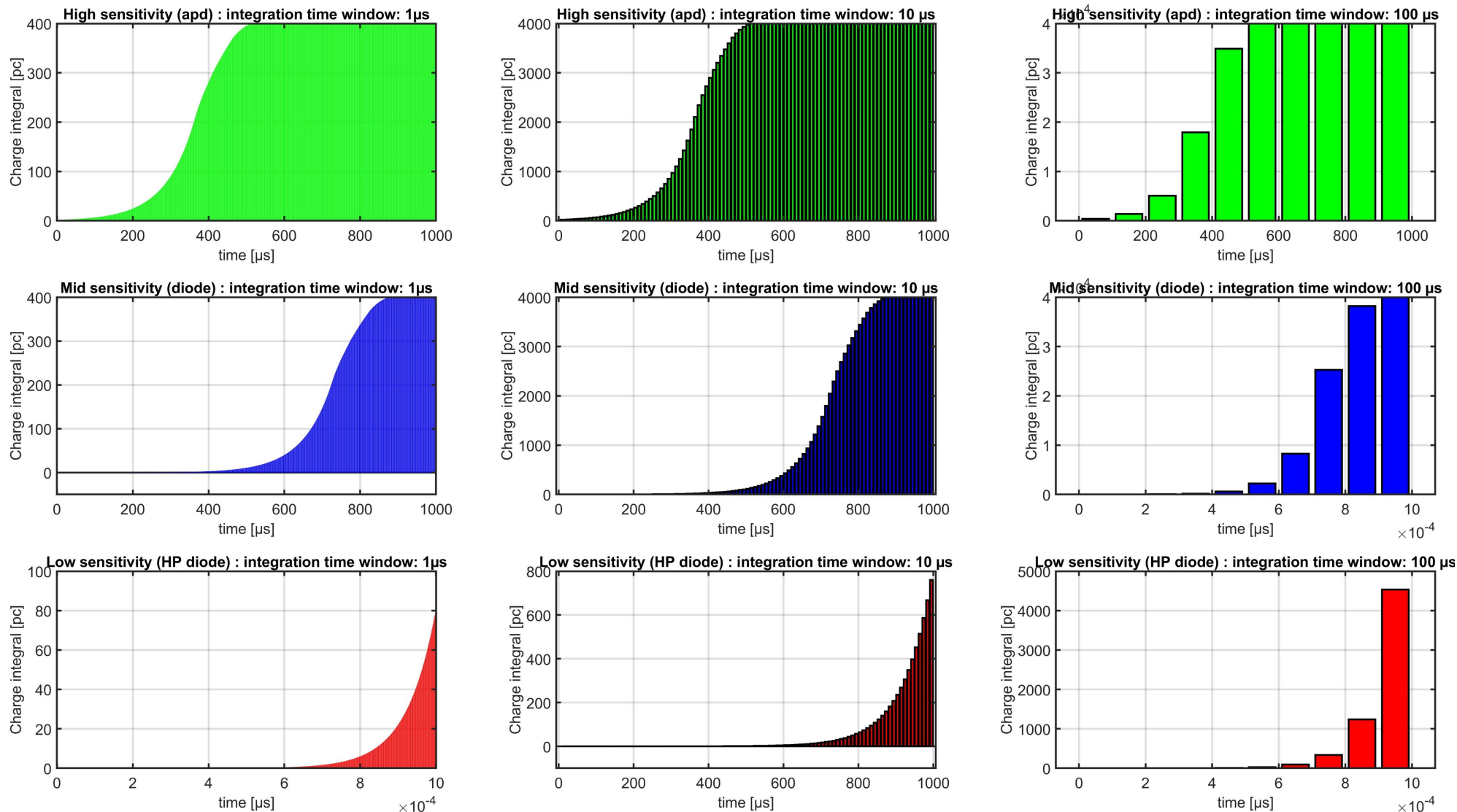
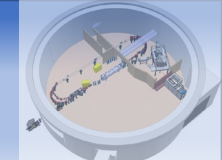
Proposal for BLM digital signal processing

Example of catastrophic loss on one detector



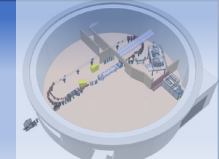
Expected signals on the 3 channels of the detector det1, in gray the analog signal at the TIA output, in color the signal at the ADC output, beam loss is equivalent to 0.01 W to 50 kW.

Example of running sum implementation

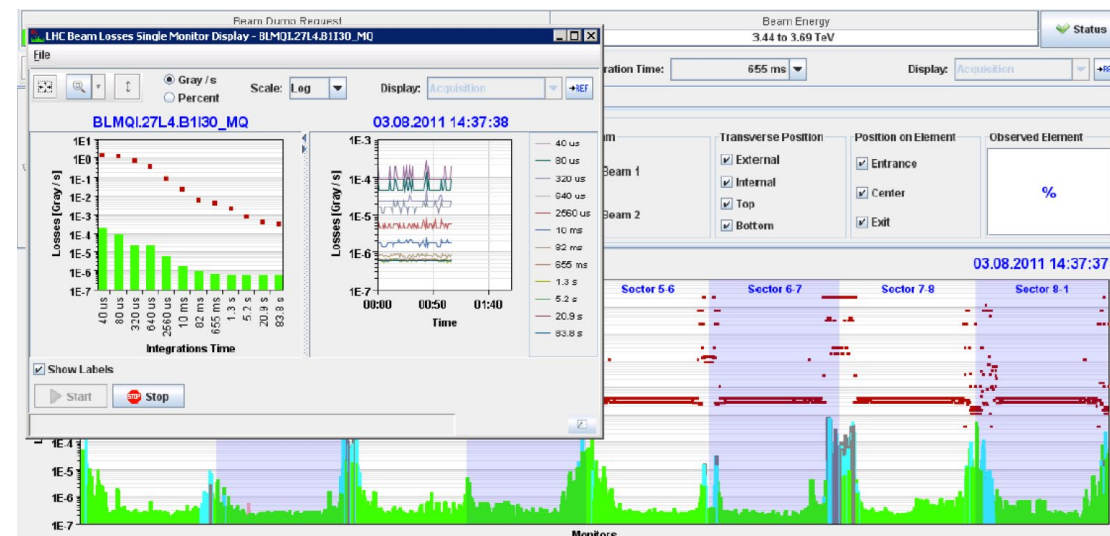
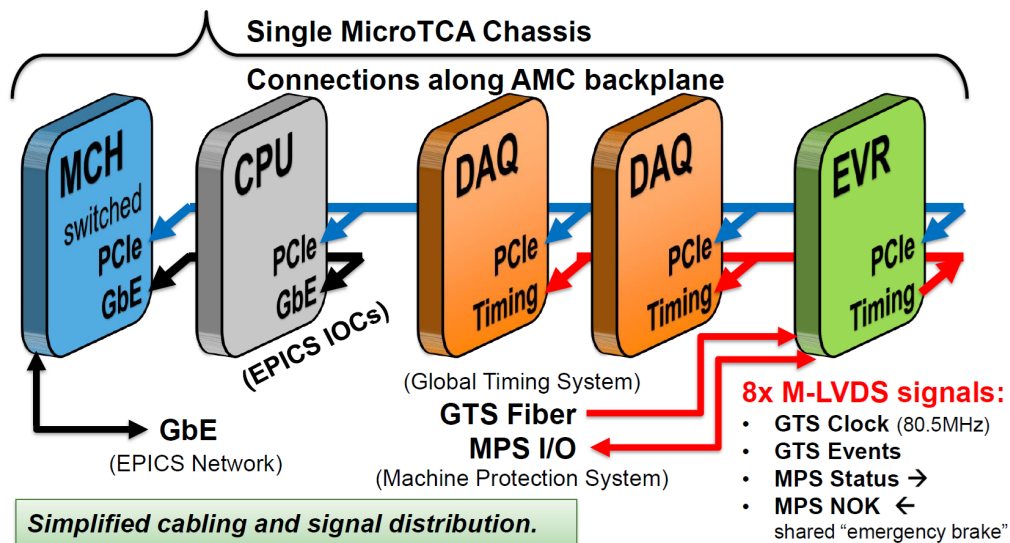
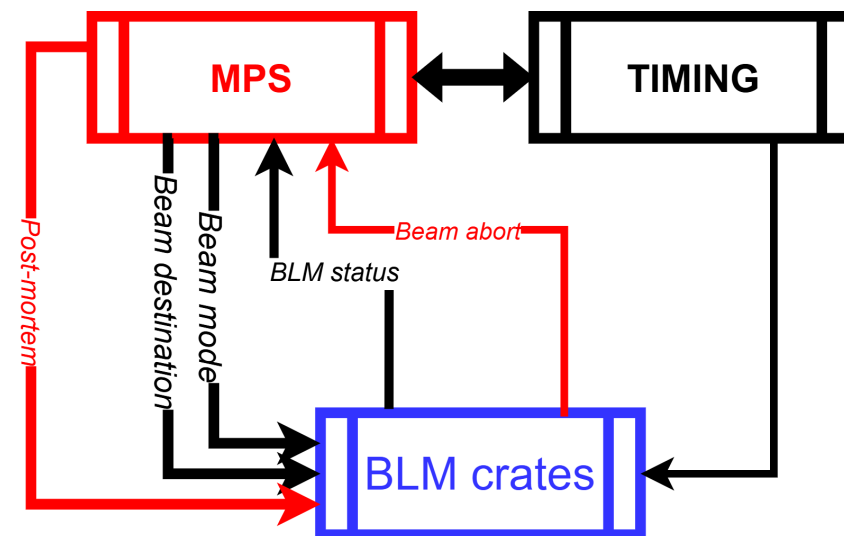


Simulations of the running sums of the 3 channels of detector det1, in green the high sensitivity channel (APD), in blue the middle sensitivity channel (photodiode) and in red the low sensitivity channel (diode+light attenuation), beam loss is equivalent to 0.01 W to 50 kW.

BLM implementation

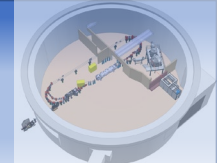


- The BLM must be interfaced with the MPS and the timing system
 - The beam parameters shall be published to all the system
 - i.e the beam destination and beam mode
 - Interface to MPS for beam abort, post mortem shall be defined as soon as possible
- Threshold database and board configuration shall be protected
 - Operators shall not be allowed to change the threshold and/or the configuration
- COTS AMC board and FMC are the preferred solution
 - No time, resource and need to design new boards
- EPICS IOC to be implemented at the board level

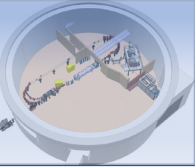


MicroTCA data bus distribution at FRIB

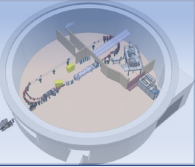
LHC BLM data display



- The definition of the MPS is on the critical path
 - The philosophy and the hardware of the MPS shall be discussed and defined at the facility level
 - Definition of fast and slow Beam interlock system (BIS)
 - Define the list of inputs for the MPS
 - Define the protocol of transmission
 - This should be one of the highest priority of the project
- Interface with the timing system has to be defined as soon as possible
 - Is the beam mode/destination published by the timing system?
- Beam dynamic simulations dedicated to beam losses are mandatory
 - MC simulations can be endless if all cases have to be simulated
 - Most probable beam losses scenarios shall come from BD simulations
- BLMs shall not be the only system for protection
 - The beam presence and beam transmission could be performed with current transformer
 - Long term dose monitor could be measured with other detectors



- Requirements for the BLM system still vague
 - 10 μ s response time for the full MPS is challenging
 - *For comparison, ESS: 100 μ s*
 - Bunch by bunch measurement complexify the system
 - If this two specs are dropped, the system can be simpler
- RH problem
 - For now there is no one for electronic and software development
- Planning
 - With enough resource, such system will not be ready before 3 to 4 years



- Optimization and prototype of the detector
 - Optimization of the geometry
 - Calibration of the MC simulation
 - Possibility of dedicated detector for cryomodule protection and experience
- Build the full Accelerator in the MC code
 - FLUKA team has recently introduced a module to generate geometry from MAD-X file
 - See the effect of magnetic field
 - Optimize the position and number of BLMs
- Find collaboration for the project
 - IPHC and IP2I Lyon interested and contacted
- Start the development of the analog electronic
- Start the implementation in the μ TCA crate