# New Beam Loss Monitor System For SOLEIL

Libera Workshop
17 June 2020

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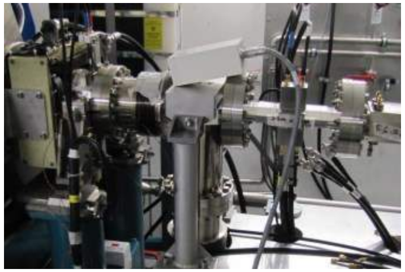
- **Calibration**
- **Installation**
- **Measurements with beam**

# Beam Loss Monitor Upgrade

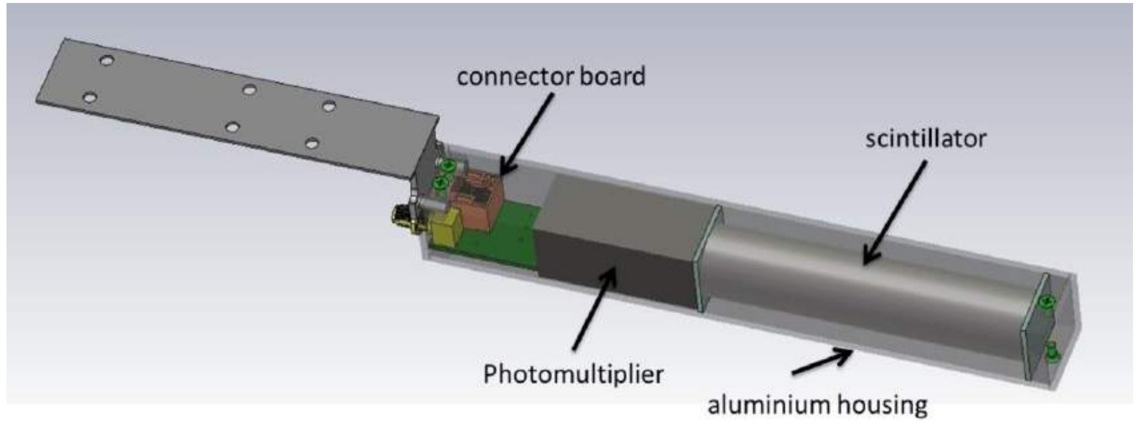


- **Objectives**:
  - Replacement of the previous pin diode based system:
    - 40 units distributed on the storage ring
    - Small detection angle
    - Slow measurements (used in counting mode)
    - No systematic placement (generally located at the entrance/exit of undulators)
  - Slow and fast losses measurement capabilities
  - Synchronous measurements
  - Higher detection angle
  - Better relative calibration between monitors:
    - less that 10% dispersion in detectors sensitivity after calibration
  - Provide the radioprotection group measurements to validate their simulation tools for the SOLEIL Upgrade

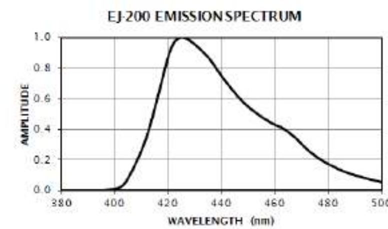
# Beam Loss Monitor Upgrade

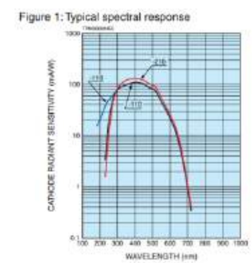
- **Schedule**:
  - 2017-2018: Procurement and test of  few different setups:
    - Scintillation (plastic) vs Cerenkov radiation (quartz)
    - Comparison of Hamamatsu photosensors
    - Tests of Libera BLM electronics
  - January-March 2019:
    - Assembly, tests, calibration and installation of 20 BLMs in 2 cells of the storage ring
  - March-December 2019:
    - Commissioning and operation of 20 BLMs
  - End 2019:
    - Assembly, tests and calibration of 60 BLMs
  - January 2020:
    - Installation on the 14 other cells of the storage ring
  - February-June 2020:
    - Commissioning of the full system
    - Development of high level interfaces

# Beam Loss Detector




- ESRF design:
  - EJ-200 plastic scintillator 100 mm rod:
    - Rise time: 0.9 ns
    - Decay time: 2.1 ns
  - Compact photosensor (Hamamatsu H10721-110):
    - PMT
    - High voltage power supply
    - Rise-time: 0.6 ns
  - Connector board
    - SMA for signal
    - RJ12 for power supplies
  - Aluminum housing




# Beam Loss Electronics

- Libera BLM
  - 4x125 MHz digitizers (14 bits)
  - Several configurable data rates
    - Triggered (ADC, TbT, averaged…)
    - Continuous flow
    - Counting mode
    - Postmortem
  - Power-supplies for the detectors


- Relative calibration:
  - Can be compensated by the electronics:
    - Detector sensitivity compensation (scintillator yield and photomodule sensitivity)
    - Photomodule gain compensation
    - Attenuation compensation

**Acal = Araw x BLDCalib x G x AT**

Where:

| | |
|---|---|
| Acal | calibrated amplitude |
| Araw | raw amplitude (no correction) |
| BLDCalib | BLDCalib ... It is a calibration constant specific to each channel and the PMT. |
| G | It is a relative gain factor that depends on the setting of the gain control voltage. |
| AT | It corrects for the 10^(Att/20) |

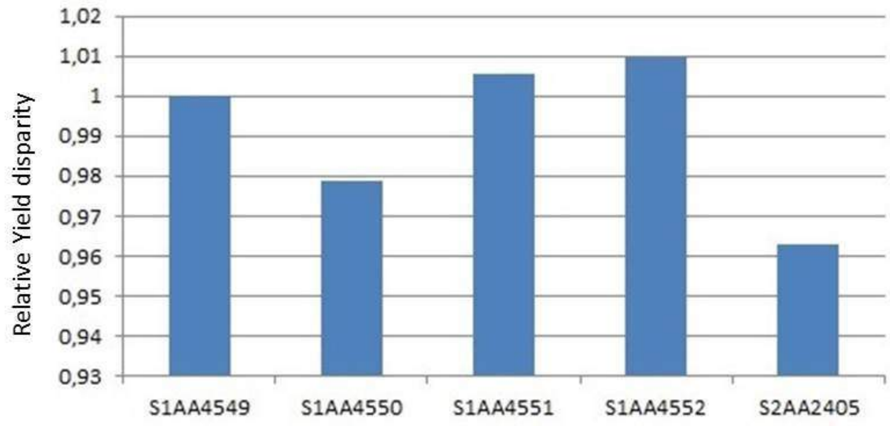
Source: Libera BLM user guide

# BLM Calibration

- Objective: calibrate/compensate BLMs individually to get <10% dispersion in their relative sensitivity:
  - Scintillator yield
  - Photosensor sensitivity
  - Photosensor gain linearity
  - ADC gain
  - Gain control power supply
  - Attenuators

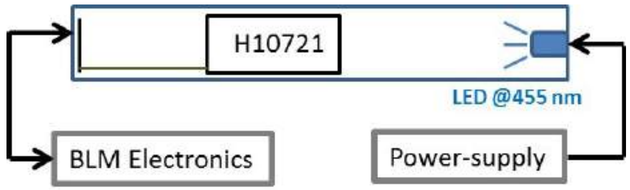
# Scintillator yield

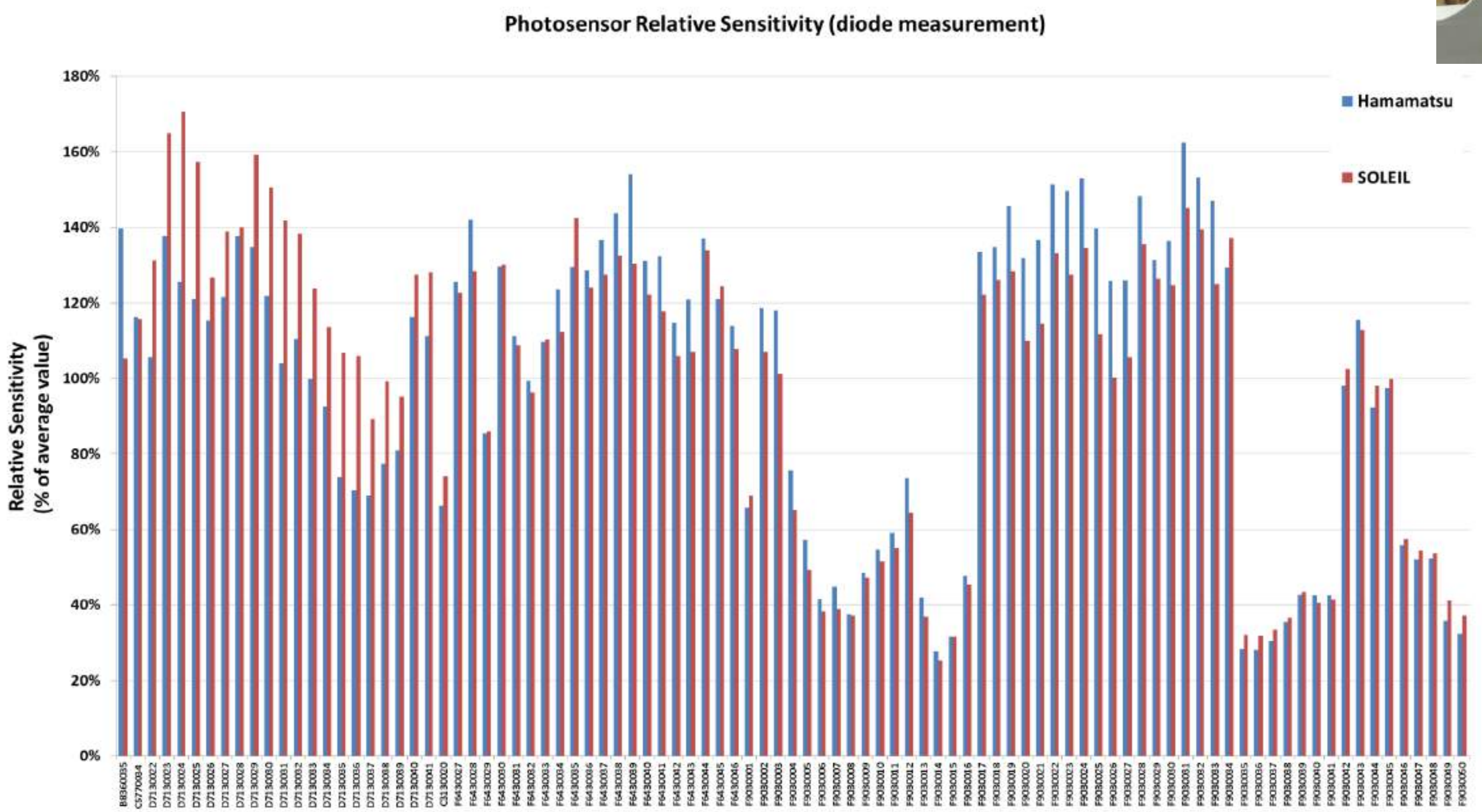
- Measured on a very small sample of scintillators (5 units)
- Cesium source
- Keeping same electronics and photosensor for each measurement
- Yield differences between 0 to 5 %
- Since the pair photosensor/scintillator is not supposed to be separated it has been decided to calibrate the pair together.



# Photosensor sensitivity

- Measurement with a blue LED in front of the photosensor:
  - High dispersion between modules
  - Some discrepancies compared to Hamamatsu measurements

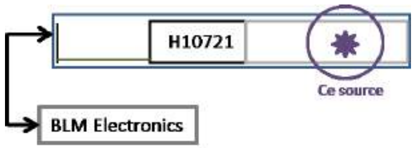


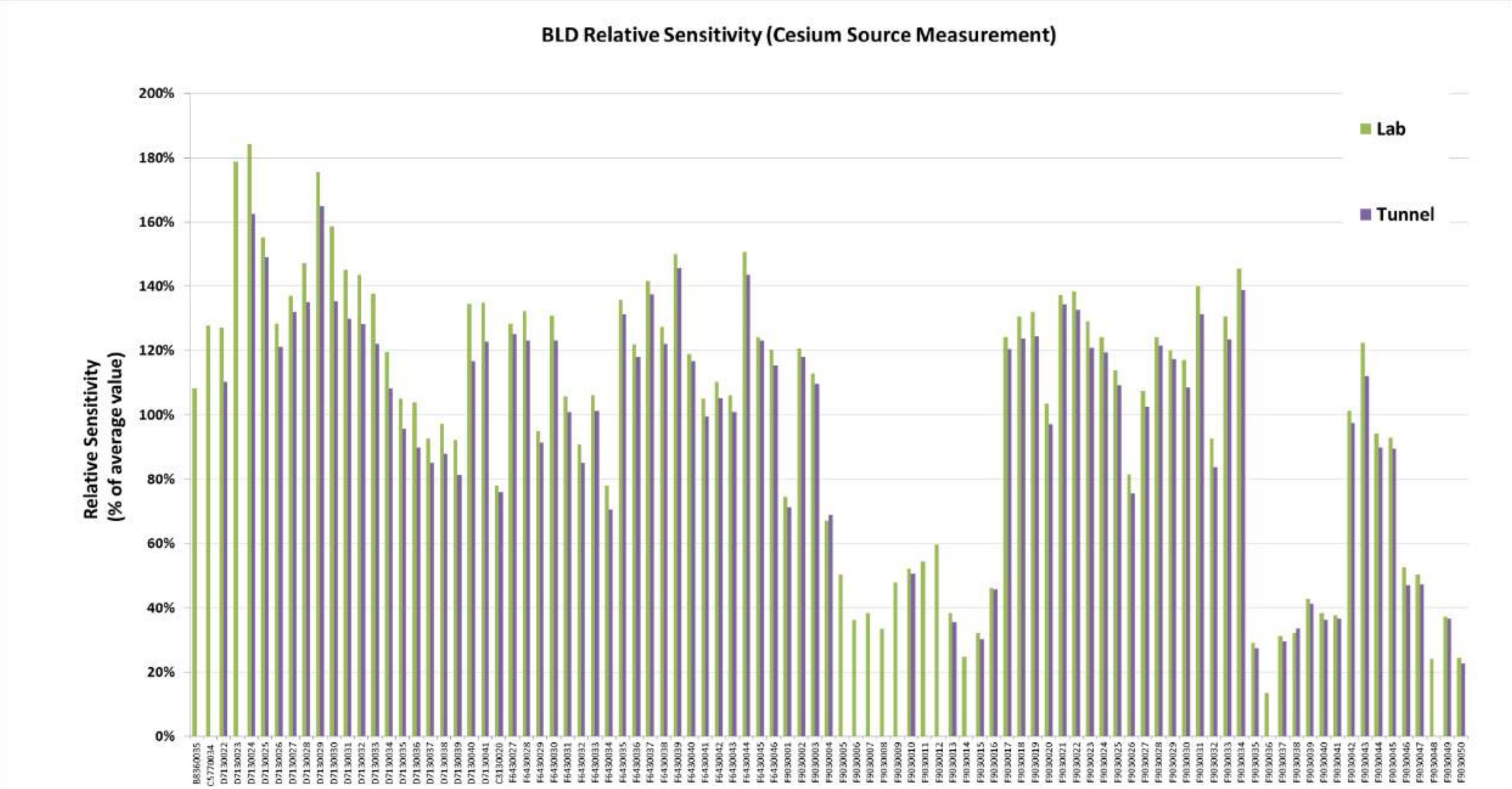




Photomodule sensitivity comparison (manufacturer data vs SOLEIL lab)

# BLD Sensitivity

- Cesium source based measurement:
  - Lab measurement
    - Same Libera BLM module and channel used for all sensors
  - Tunnel measurement
    - Include cabling and dedicated Libera BLM after offsets compensation (see next slides)
    - Possibility to repeat the measurement periodically

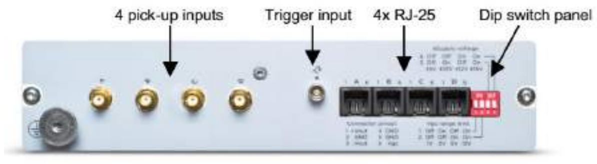


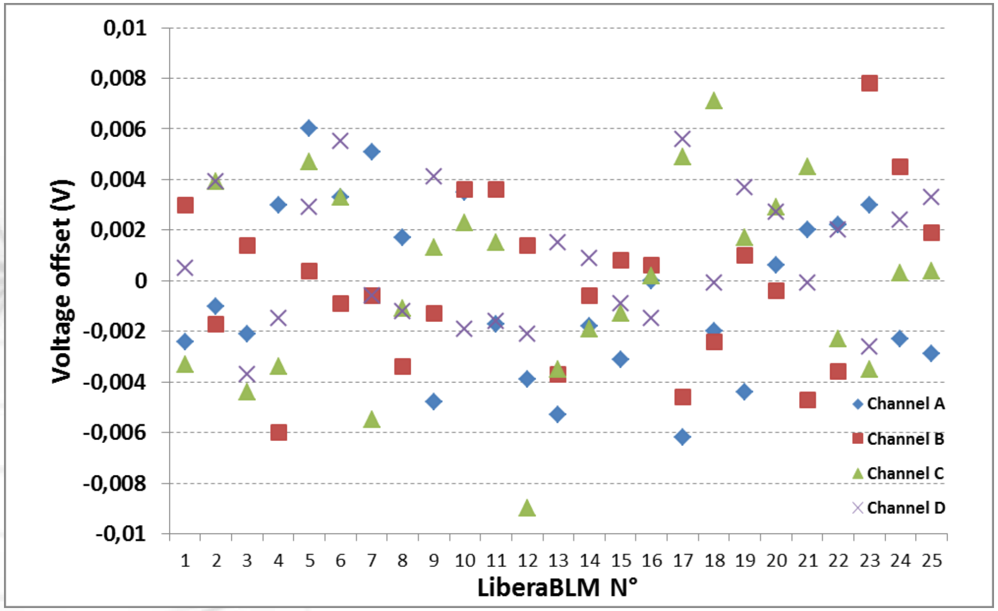




Photomodule sensitivity comparison (manufacturer data vs SOLEIL lab)

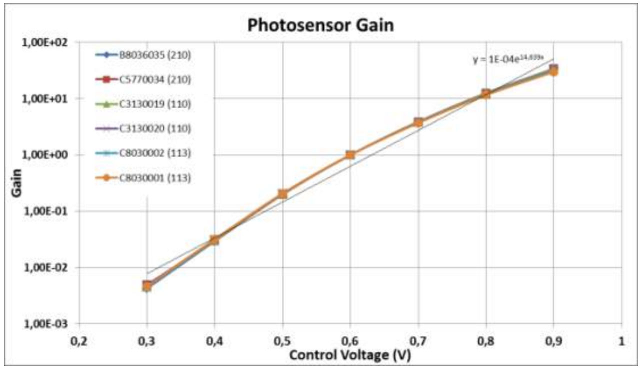
# Electronics Calibration

- Gain power-supply offset:
  - Libera BLM has dedicated voltage sources and outputs to drive photomodule gain
    - Voltage outputs present an offset (constant whatever amplitude)
    - Error on the applied gain value




Libera BLM Vgc power-supply offset distribution ( 100 channels)




Gain vs Vgc voltage

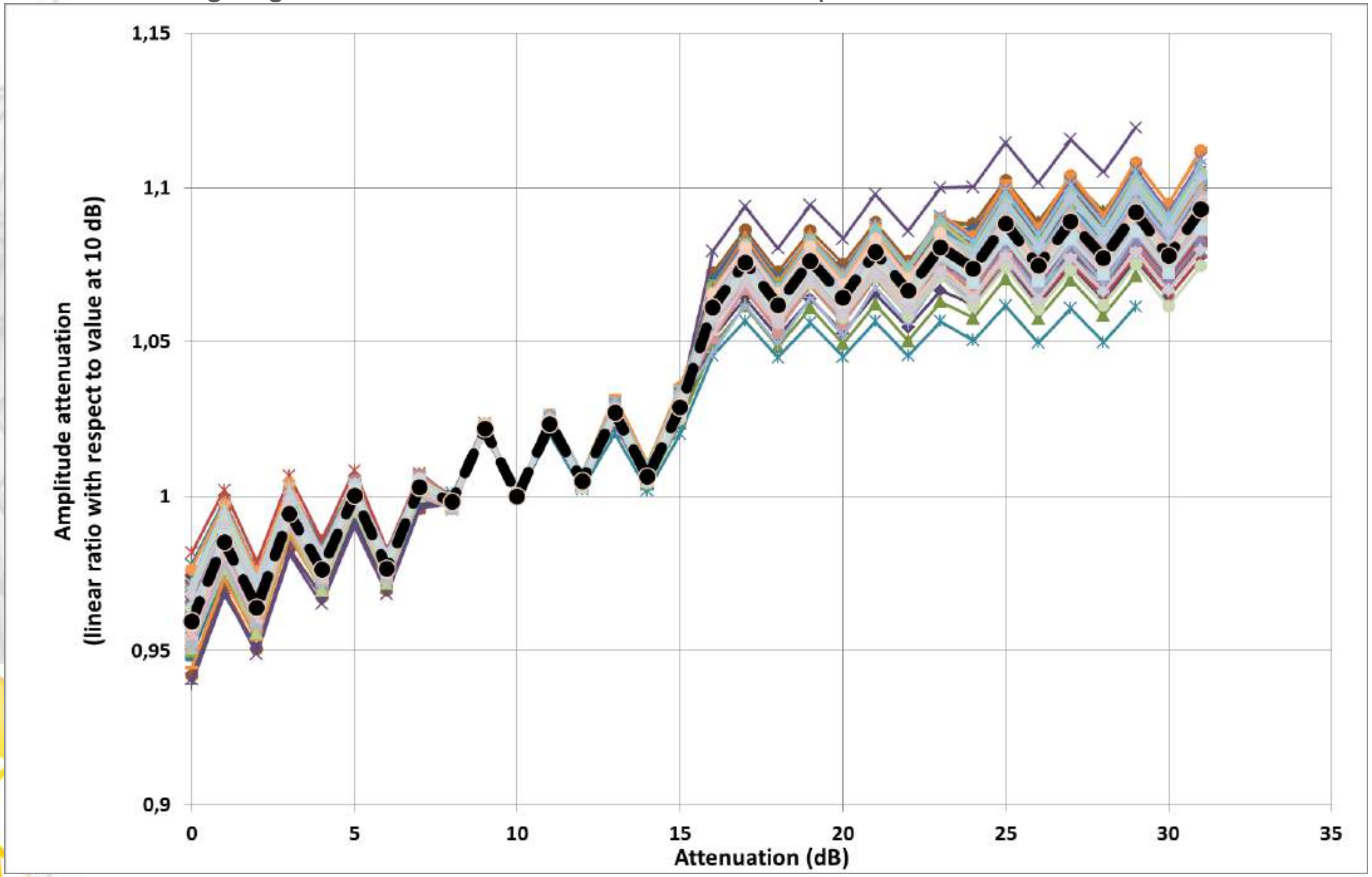
Offset p/p amplitude: 17 mV -> discrepancies up to 28% on the applied gain (around 0.6V).

offset compensation -> measured in the lab and automatically corrected by the high-level applications when applying gain value

# Electronics Calibration

- Attenuator error:
  - Libera BLM has a 31 dB variable attenuator to control input amplitude
  - For relative calibration, theoretical attenuation setting can be compensated
  - Measurements show non negligible attenuation error
  - Very similar pattern on all modules
  - On going discussion to find how it can be compensated

**Setup**:
- 1 MHz sine wave at inputs
- Move input amplitude and attenuation by 1dB steps




Libera BLM Attenuation Error (100 channels and average value)

# Assembly and Installation

- Assembly:
  - Individual pieces produced externally
  - Assembly/soldering done in-house

Scintillators and first assembled BLM

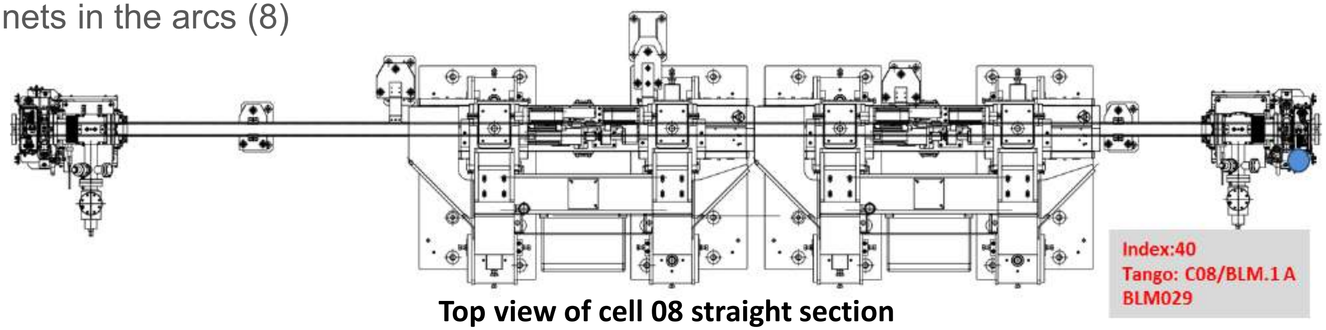
Photomodules soldered to their connector board

- Shieding
  - 3mm thick lead shielding
  - Damping of synchrotron radiation

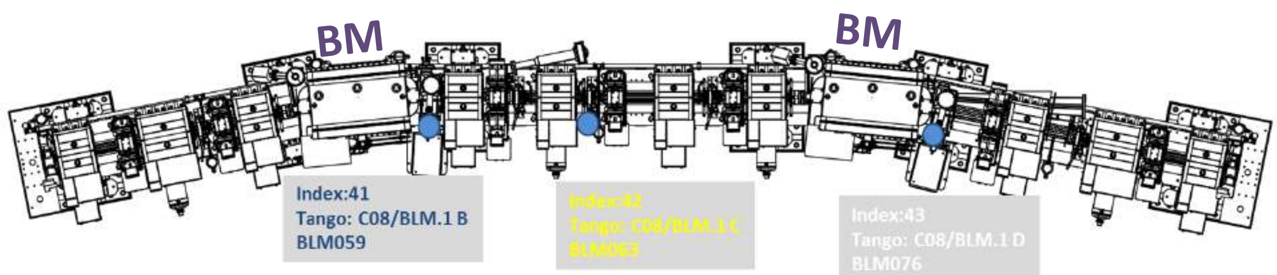
3 mm lead shielding

# Installation

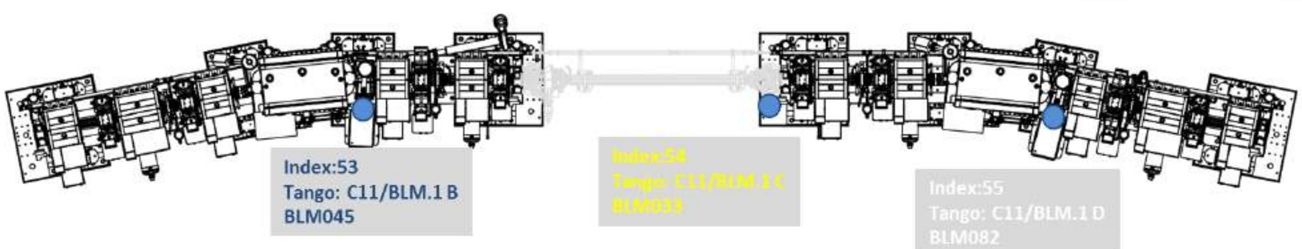
- At least 4 BLMs per cell (4 detectors, 1 Libera BLM):
  - Internal side of the storage ring
  - Downstream each bending magnet (32)
  - Downstream each straight section (24)
  - Between bending magnets in the arcs (8)




Top view of cell 08 straight section



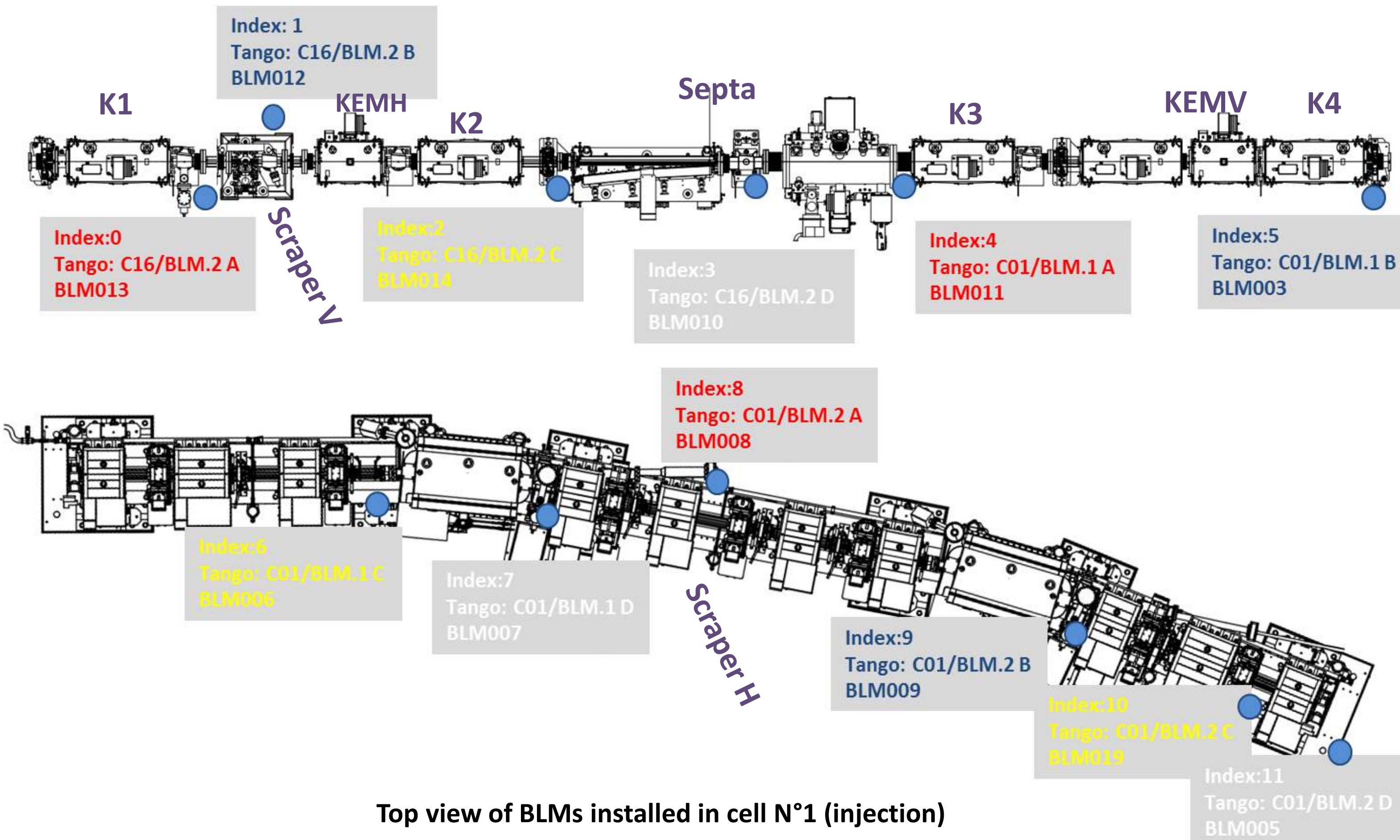

Top view of cell 08 arc section




Top view of cell 11 arc and short straight sections

# Installation

- Few cells equipped with more BLMs:
  - Cell N°1, injection section (8)
  - Cell N°4, former test cell (4)
  - Cell N° 13, around in-vacuum canted undulators (4)




**Top view of BLMs installed in cell N°1 (injection)**

# Installation

After dipole


Arc

Downstream straight section

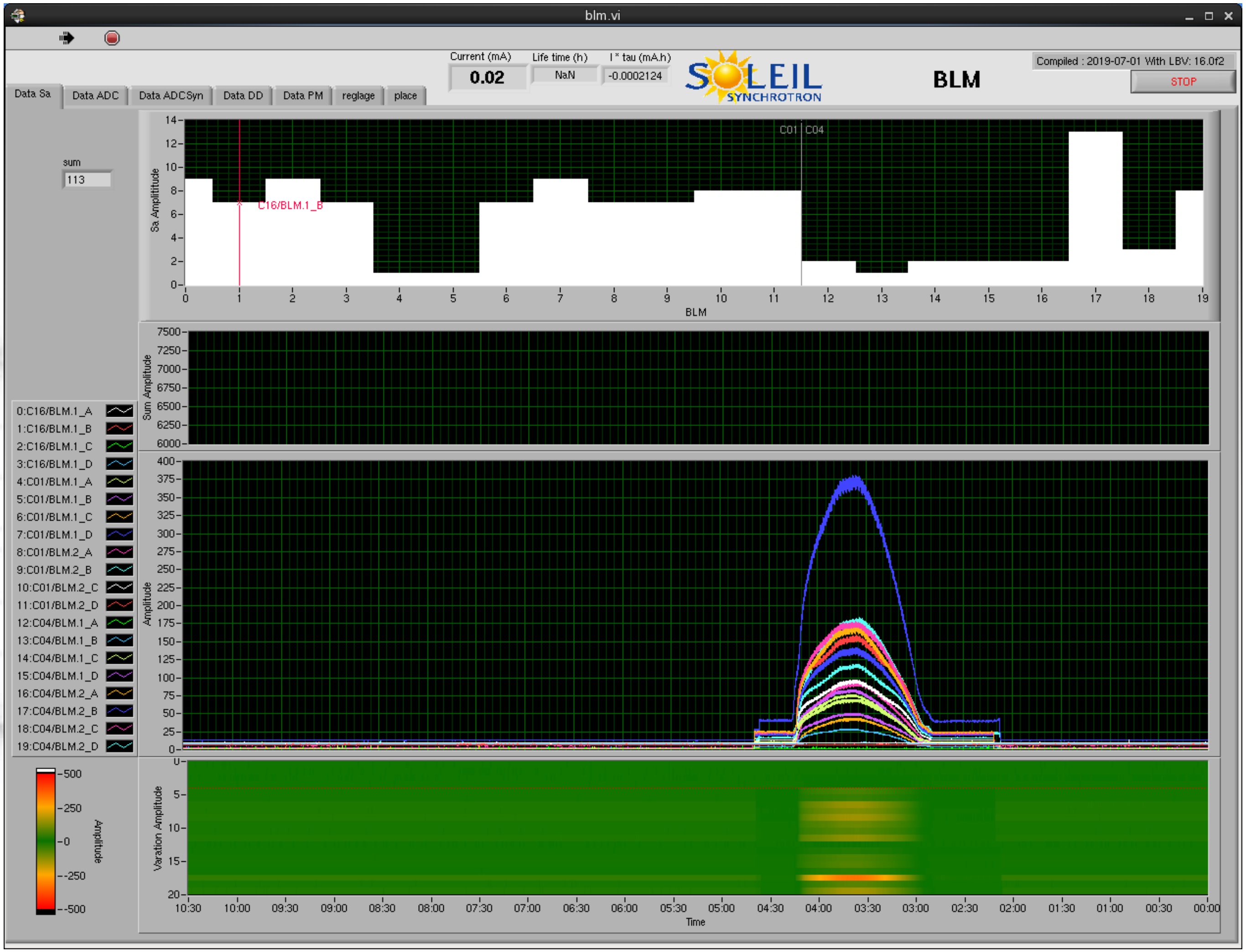
Between septa

In front of vertical scraper


In front of horizontal internal scraper

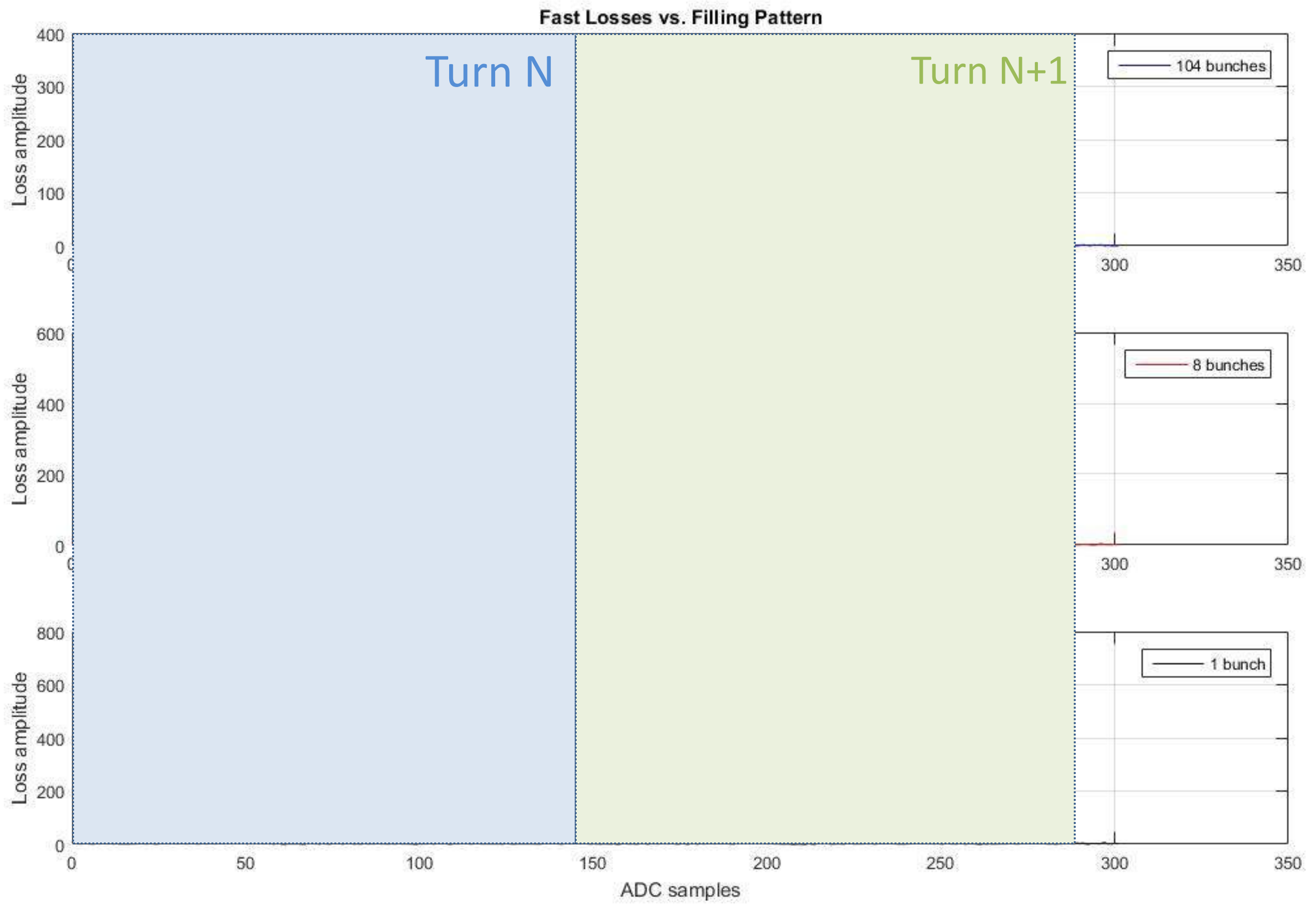
# Ground perturbation

- Perturbation seen on BLMs without beam:
  - Quickly correlated with sublimation on Titanium sublimation pumps
  - Perturbation coming from ground
  - Electrical isolation between BLD and its support in the tunnel



# Beam Measurements

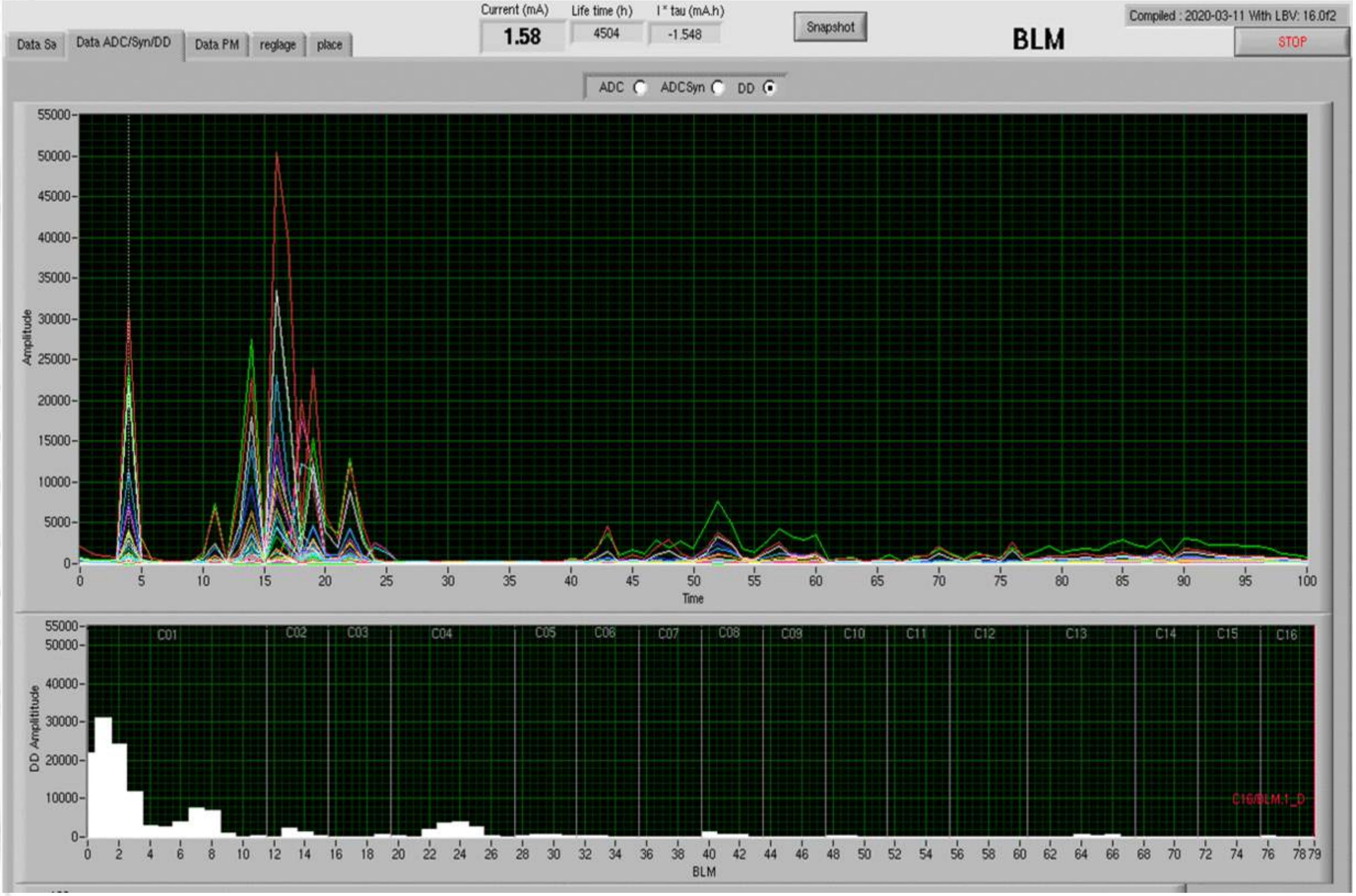
- Fast Losses:
  - Stored beam, scraper slightly inserted, vertical excitation
  - ADC data: 147 samples/turn




Losses measurement (ADC data) for 104 consecutive bunches (top), 8 bunches (middle) and single bunch (bottom). Records on BLM 1 in front of the vertical scraper.

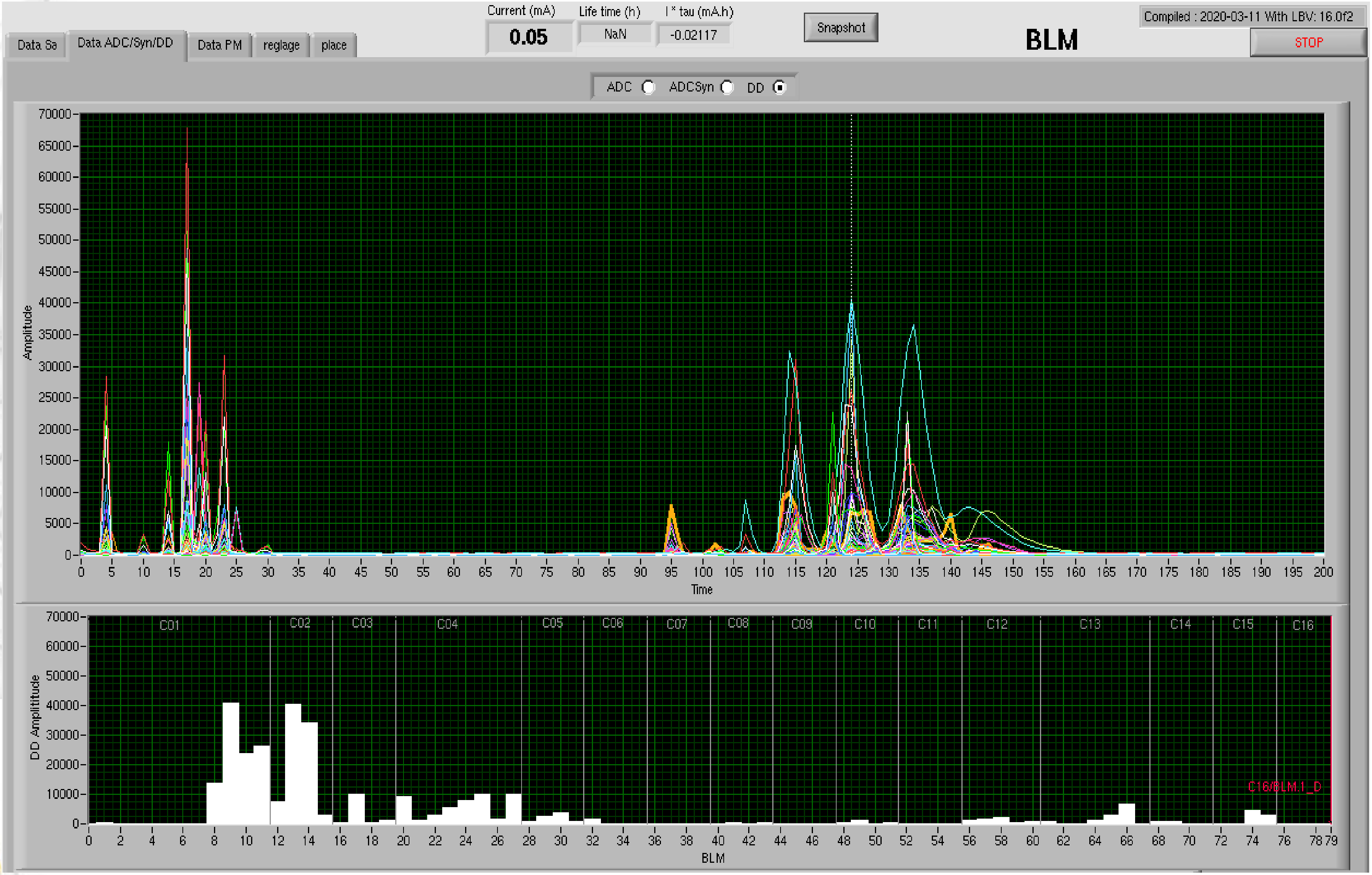
# Beam Measurements

- Turn by Turn Losses at injection:



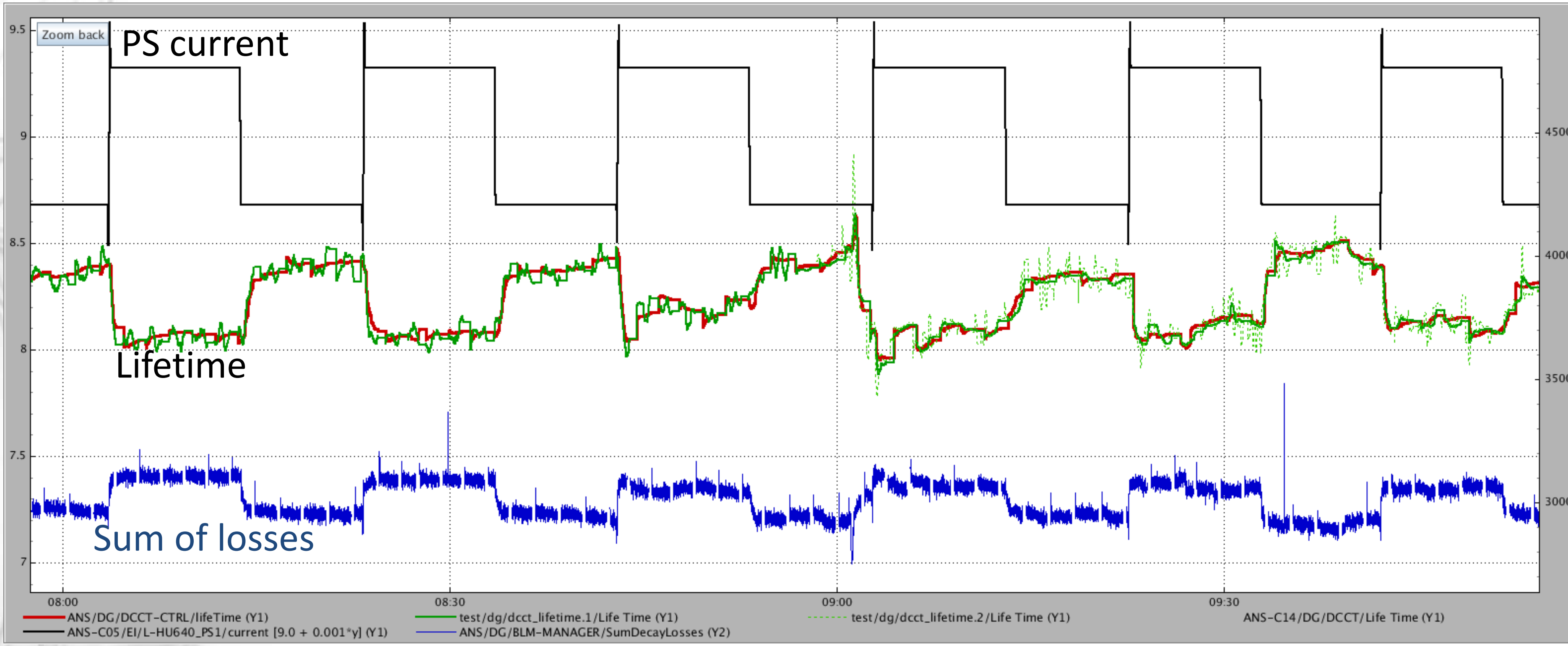
# Beam Measurements

- Turn by Turn Losses at injection: RF switched OFF



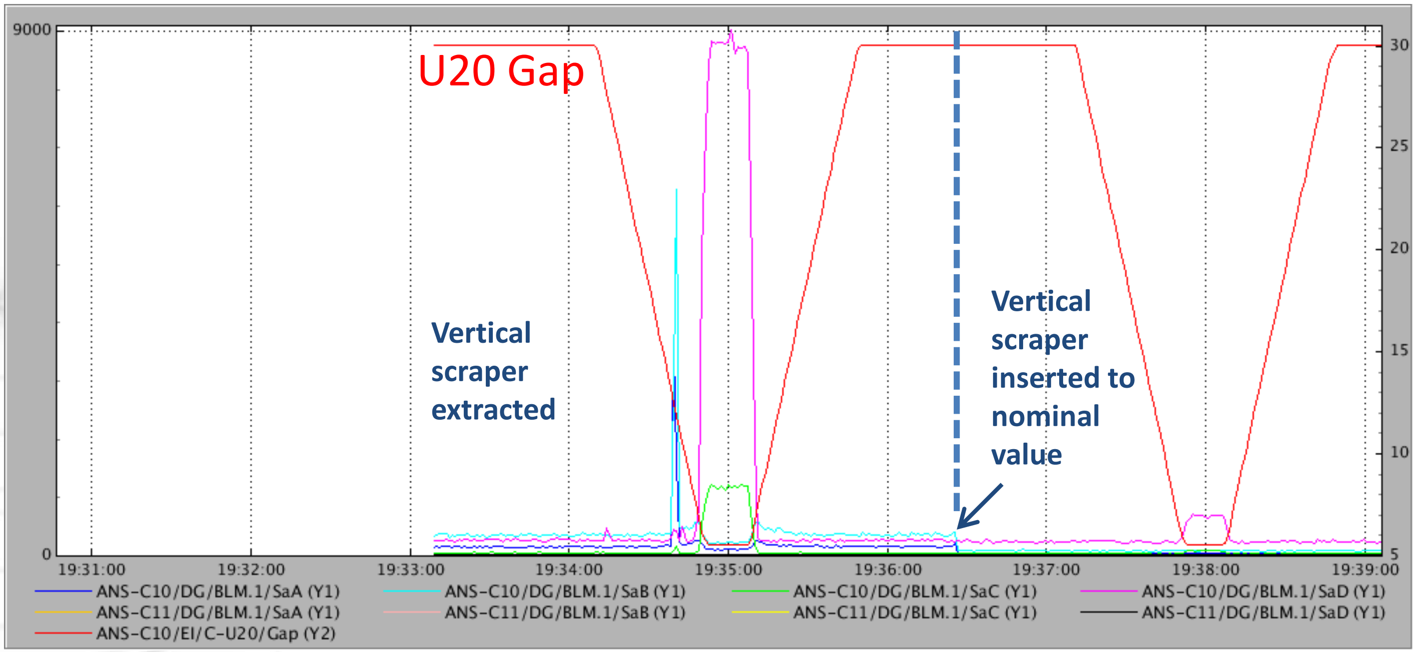
# Beam Measurements

- Slow losses:
  - Lifetime variation with undulator (HU640) cycling power-supply (+-500A)

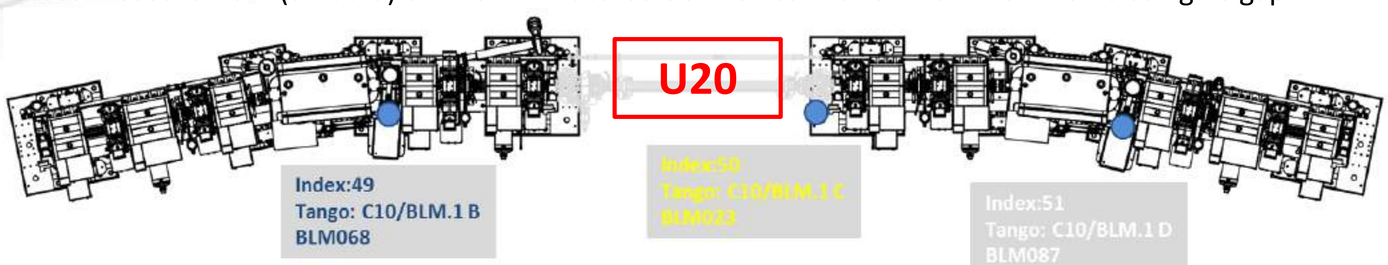


# Beam Measurements

- Slow losses:
  - Reduction of the physical aperture by in vacuum undulators
    - Undulator magnet protection verification
    - Additional diagnostic to determine the undulator mechanical center

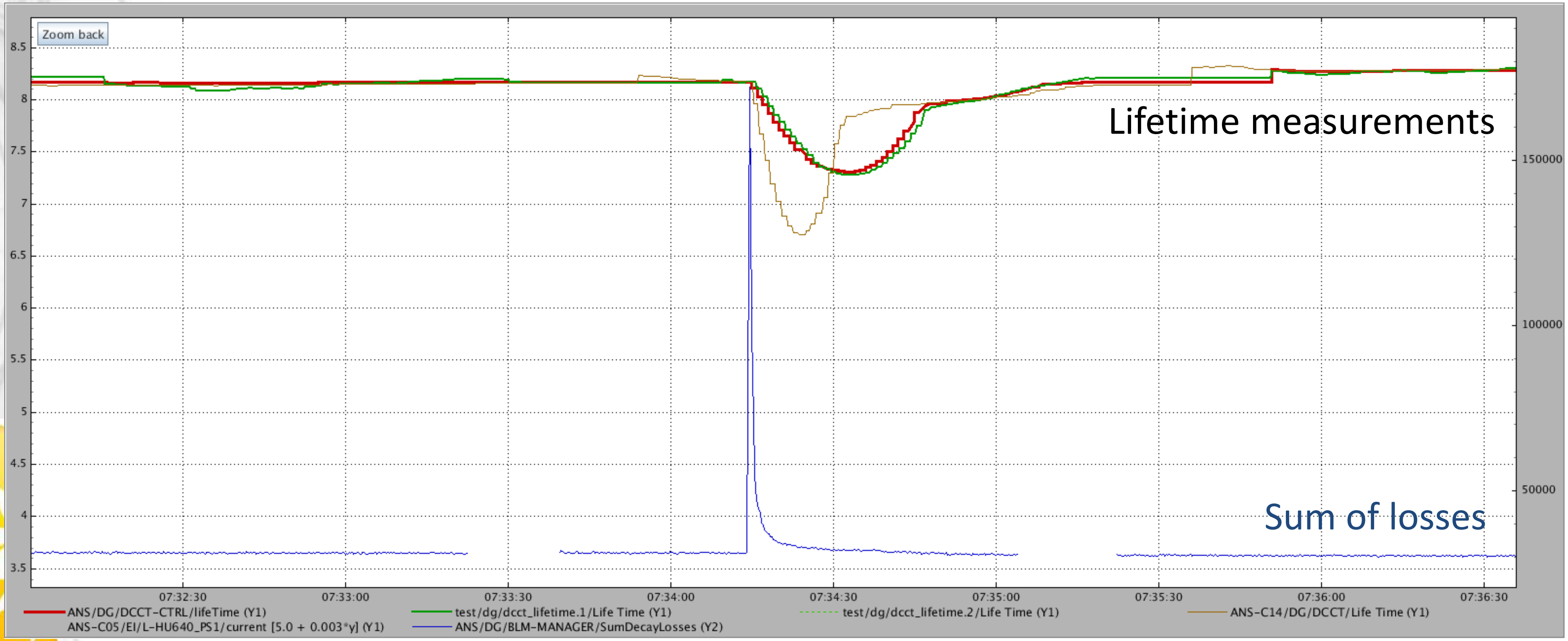



Losses measurement (SA data) on the BLM located downstream U20 in SDC10 when closing its gap.



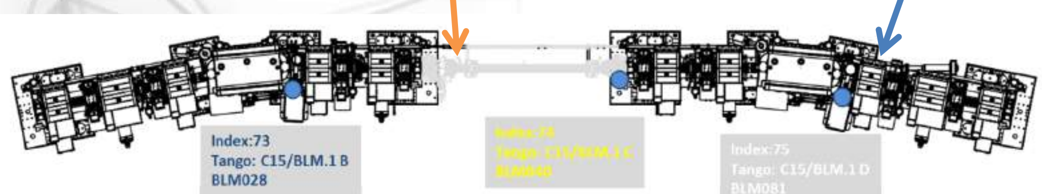
# Beam Measurements

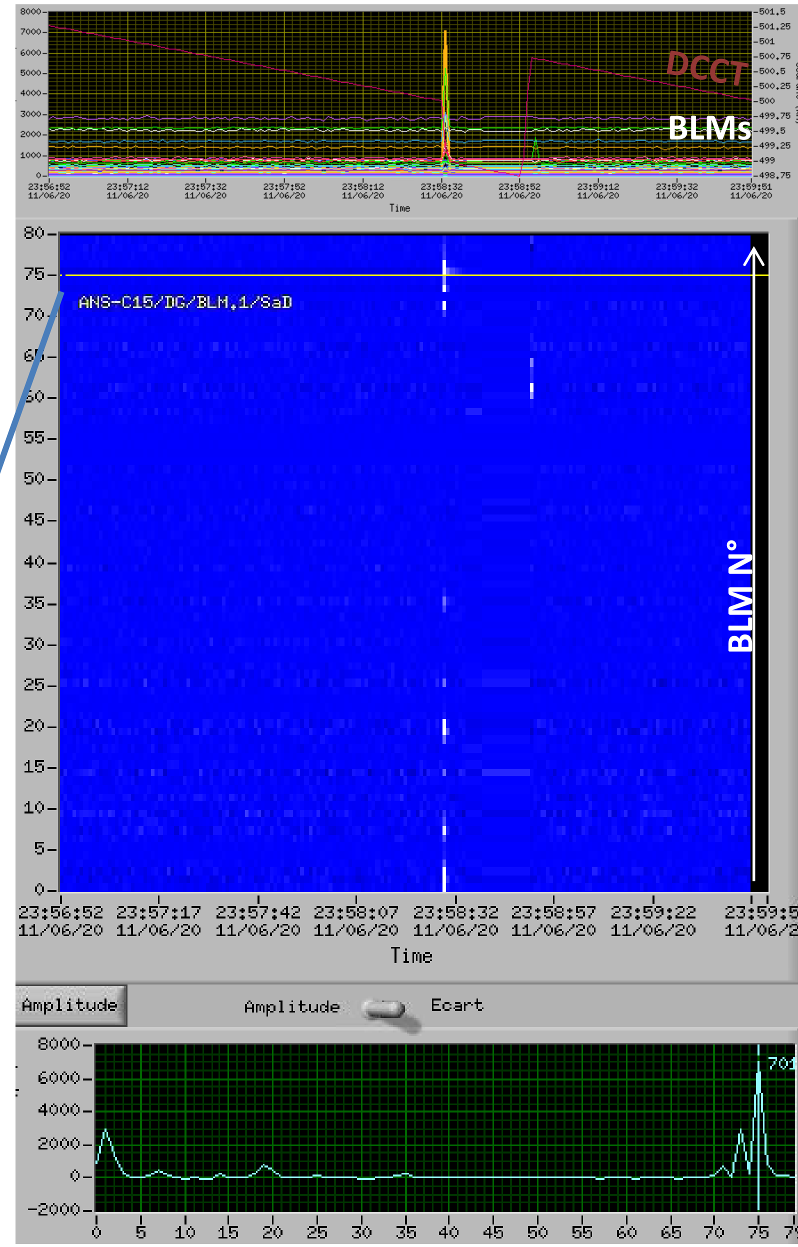
- Sudden partial loss:
  - Seen by the lifetime measurements but hardly visible by eye on current (DCCT)
  - Generally confirmed by the BLMs

# Beam Measurements

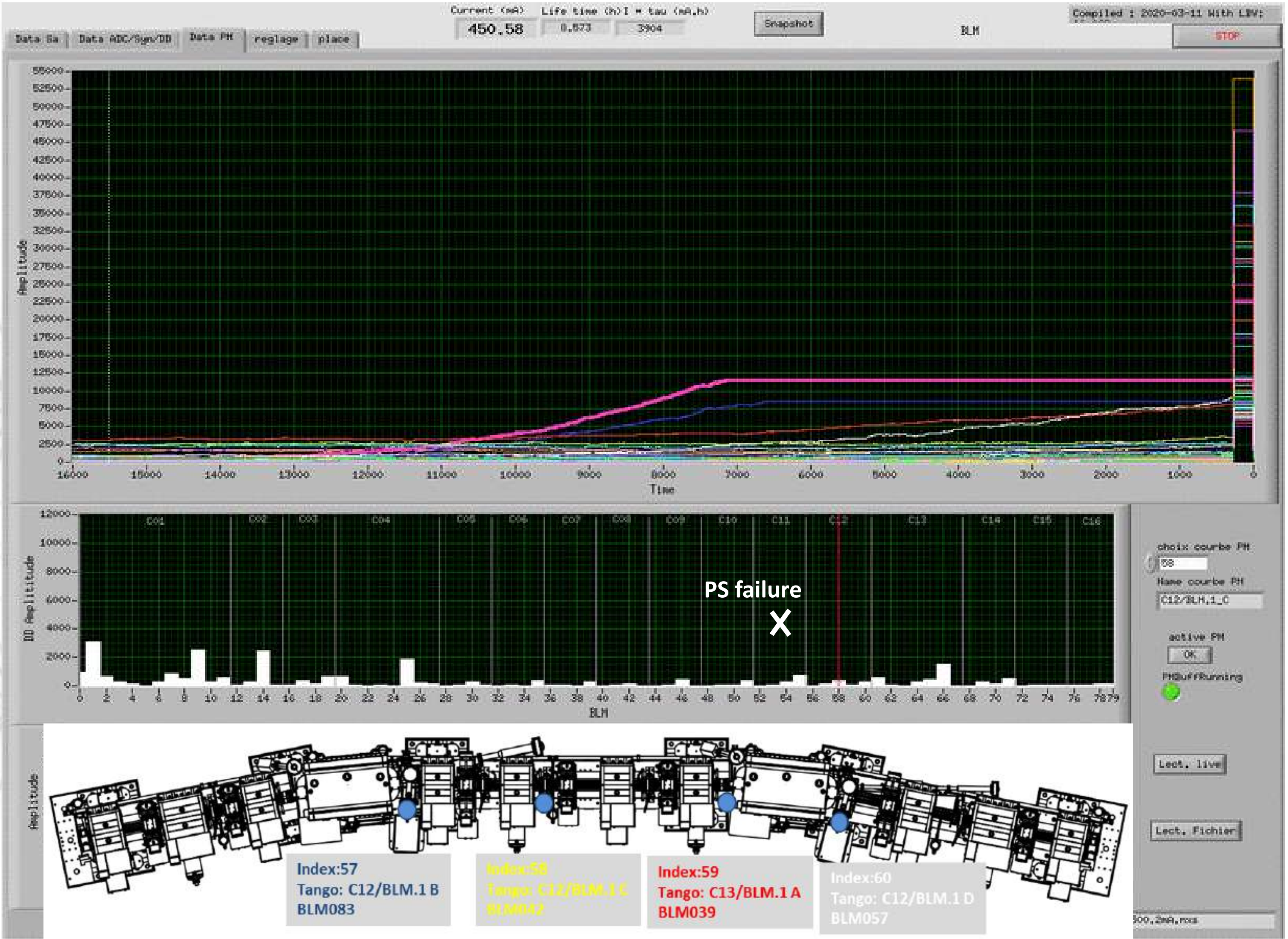
- Sudden partial (1mA) loss:
  - Losses and Vacuum pressure rise are well located at the same place

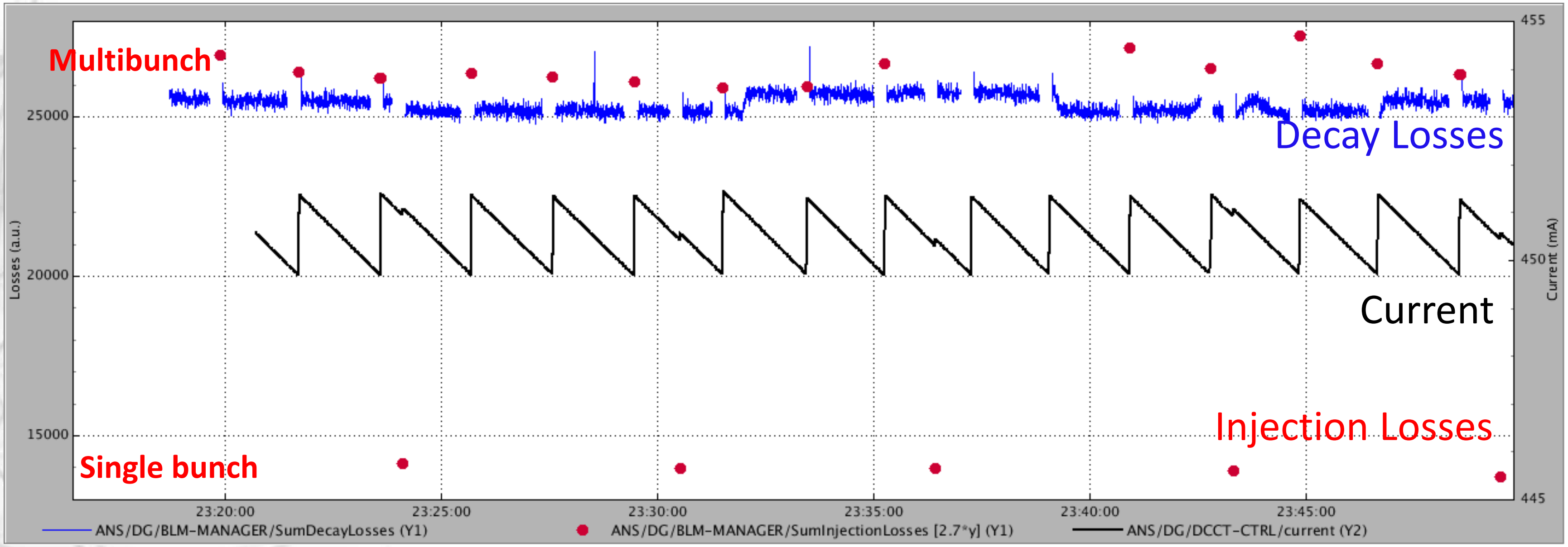
# PostMortem

- Power-supply failure (spike on a vertical corrector in cell 11):



# High level interfaces

- Python Tango device under development:
  - Manage BLMs configuration
  - Automatically switch between decay (high impedance) and injection (50 ohms) configurations
  - Retrieve injection losses for each shot (1 value per BLM, up to 3 Hz)




Sum of the losses during the decay of the beam (SA data in blue) and at each injection (average data, red) during hybrid filling pattern operation.

- Current discussion to archive shot to shot injection losses (and also injected charges) @3 Hz:
  - Archiving base is currently limited to 1 Hz

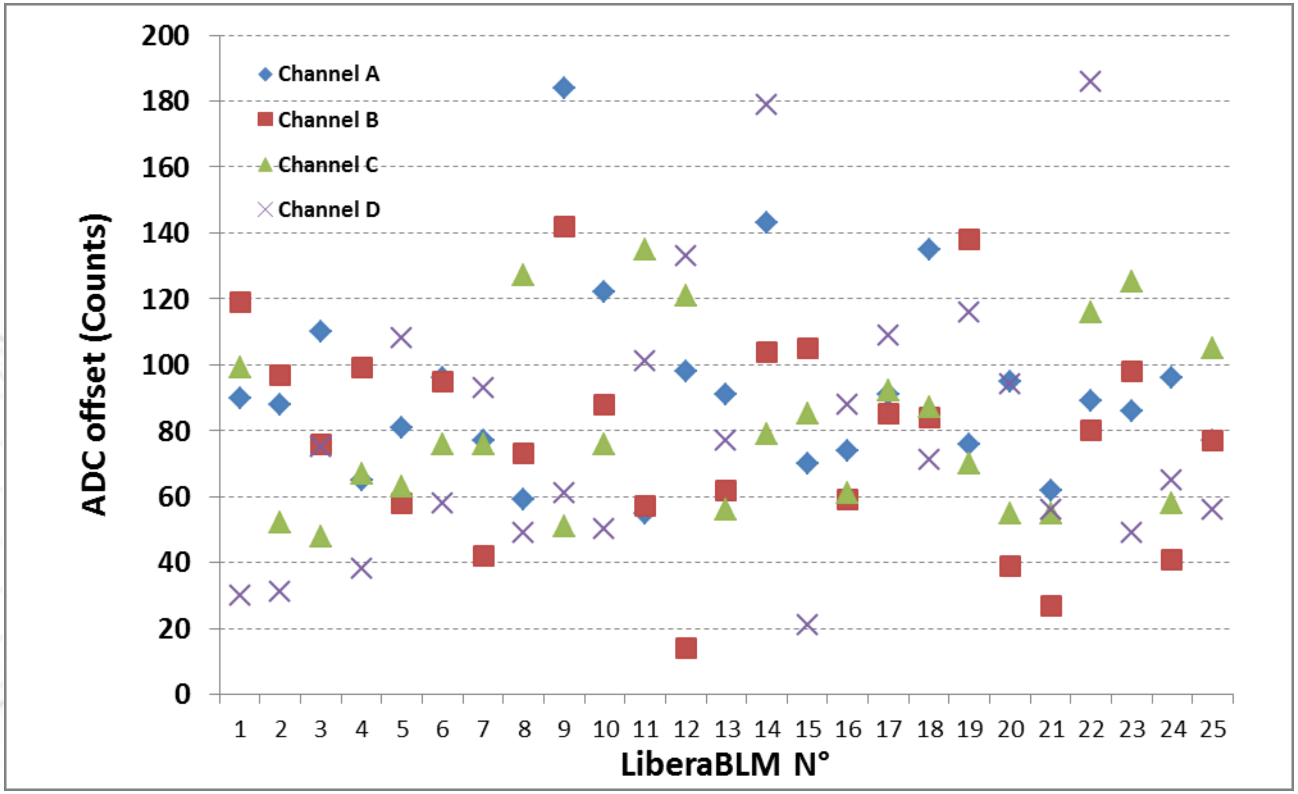
# Conclusion

- 80 new Beam Loss Monitors have been mounted and installed on the storage ring and are now in operation.
- Big effort puts on relative calibration:
  - Compensation for attenuator error to be implemented
- High level tools to exploit fully BLM measurement capabilities are still under development
- Radioprotection group will soon use those detectors to cross check their radiation codes.

Thank you!
Do you have questions?

# Electronics Calibration

- ADC offset:
  - Measured with 50 ohms termination at the channel inputs
  - Compensated by the electronics




Libera BLM ADC offset distribution ( 100 channels)