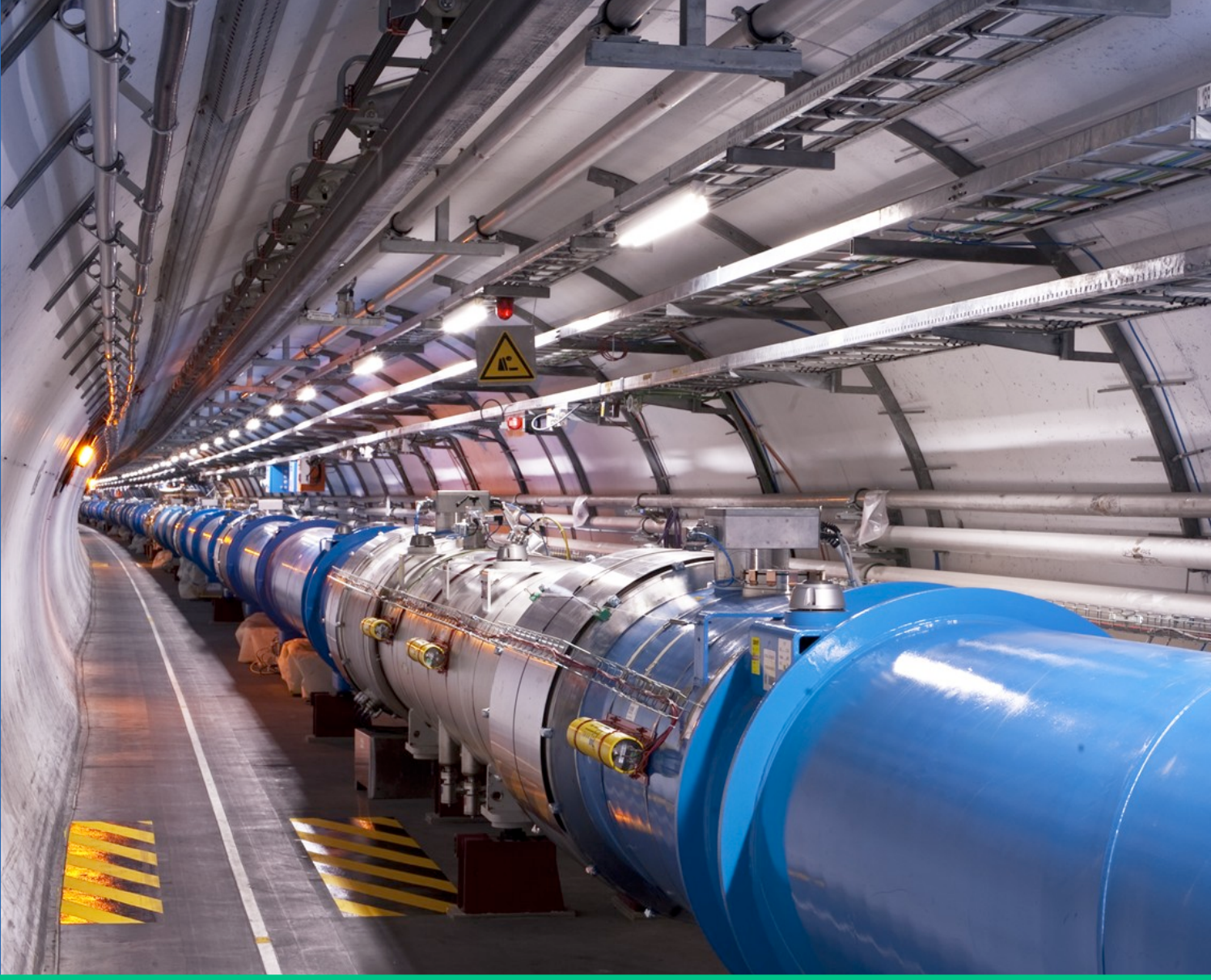
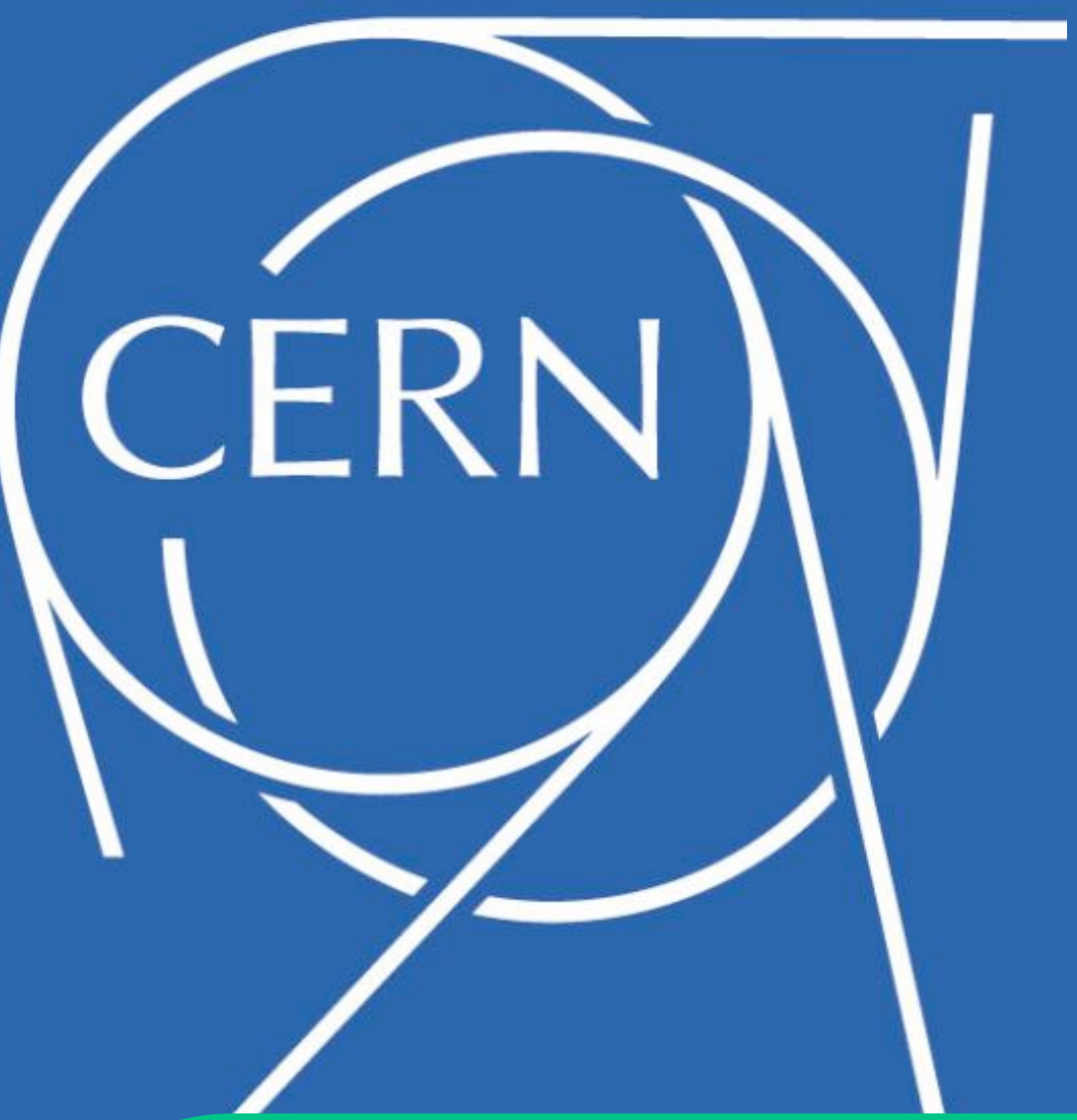




NEW YORK,
NY, USA
5-11 October

During LHC operation, a campaign to validate the configuration of the LHC collimation system is conducted every few months. This is performed by means of loss maps, where specific beam losses are voluntarily generated with the resulting loss patterns compared to expectations. The LHC collimators have to protect the machine from both betatron and off-momentum losses. In order to validate the off-momentum protection, beam losses are generated by shifting the RF frequency using a low intensity beam. This is a delicate process that, in the past, often led to the beam being dumped due to excessive losses. To avoid this, a feedback system based on the 100 Hz data stream from the LHC Beam Loss system has been implemented. When given a target RF frequency, the feedback system approaches this frequency in steps while monitoring the losses until the selected loss pattern conditions are reached, so avoiding the excessive losses that lead to a beam dump. This paper will describe the LHC off-momentum beam loss feedback system and the results achieved.

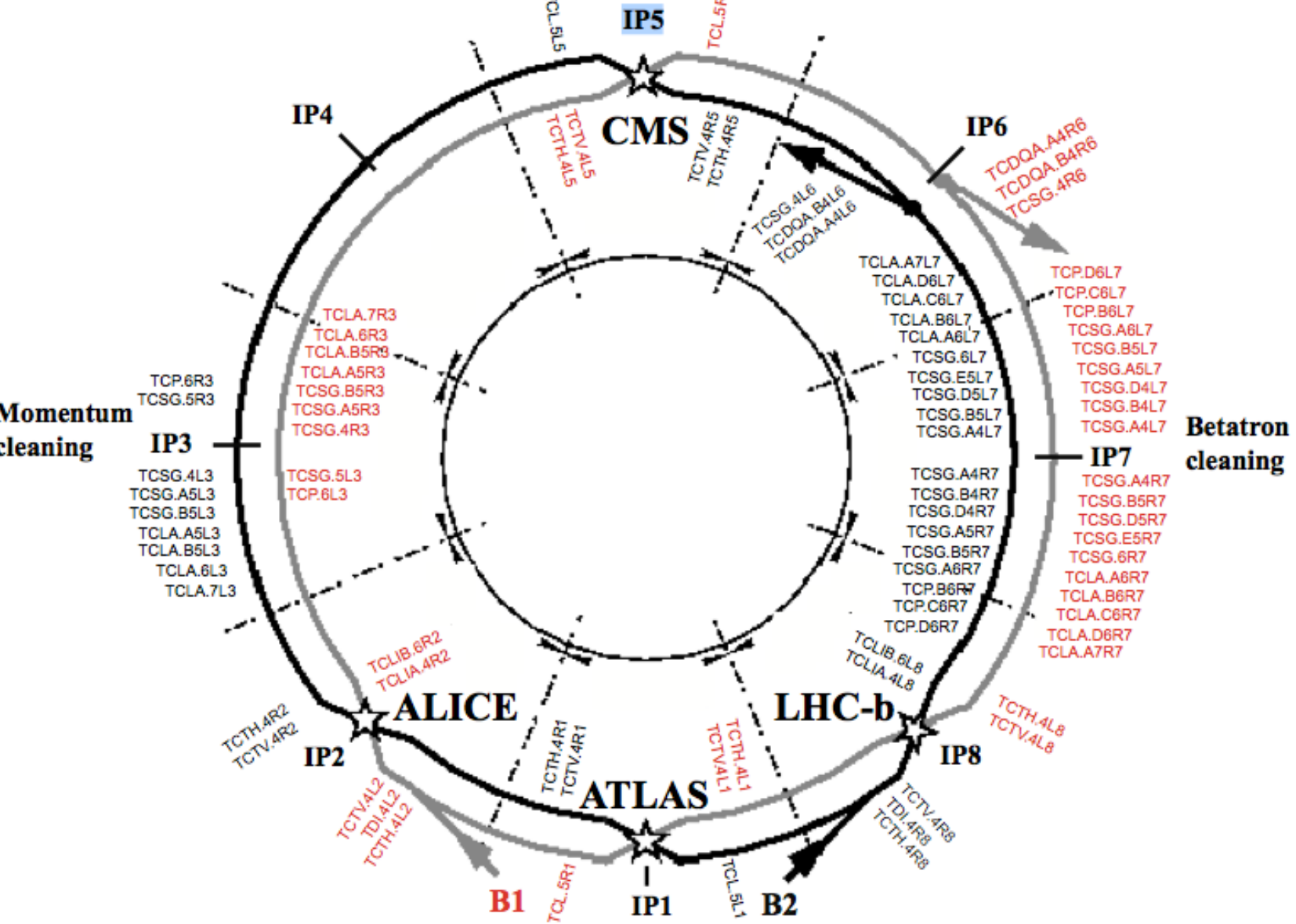
INTRODUCTION

In the Large Hadron Collider two counter-rotating beams collide in 4 experiments at a centre-of-mass energy of up to 14 TeV.

A collimation system protects the machine against beam losses. The loss of a very small fraction of the circulating beam is a concern because this may induce a magnet quench, where a superconducting magnet enters the normal conducting state, initiating a beam dump or, in extreme cases even damaging machine components.

More than 100 collimators are located in the LHC ring in order to concentrate beam losses in warm areas. Main betatron cleaning occurs in LHC Insertion Region 7 (IR7) and off-momentum losses in LHC Insertion Region 3 (IR3).

The hierarchy of the collimation system has to be validated and verified at least every three months of machine operation. The validation is done by means of beam loss maps. Off-momentum cleaning is verified by shifting the Radio-Frequency (RF) by a fixed amount of +/-500 Hz leading to higher beam losses in IR3; the beams are completely lost on the IR3 collimators. Off-momentum loss maps reduced significantly the machine availability for physics. **In order to perform the off-momentum loss maps in a controlled way without losing the beam a feedback based on the signal from beam loss monitors located downstream from each collimator was developed together with a graphical user interface.**

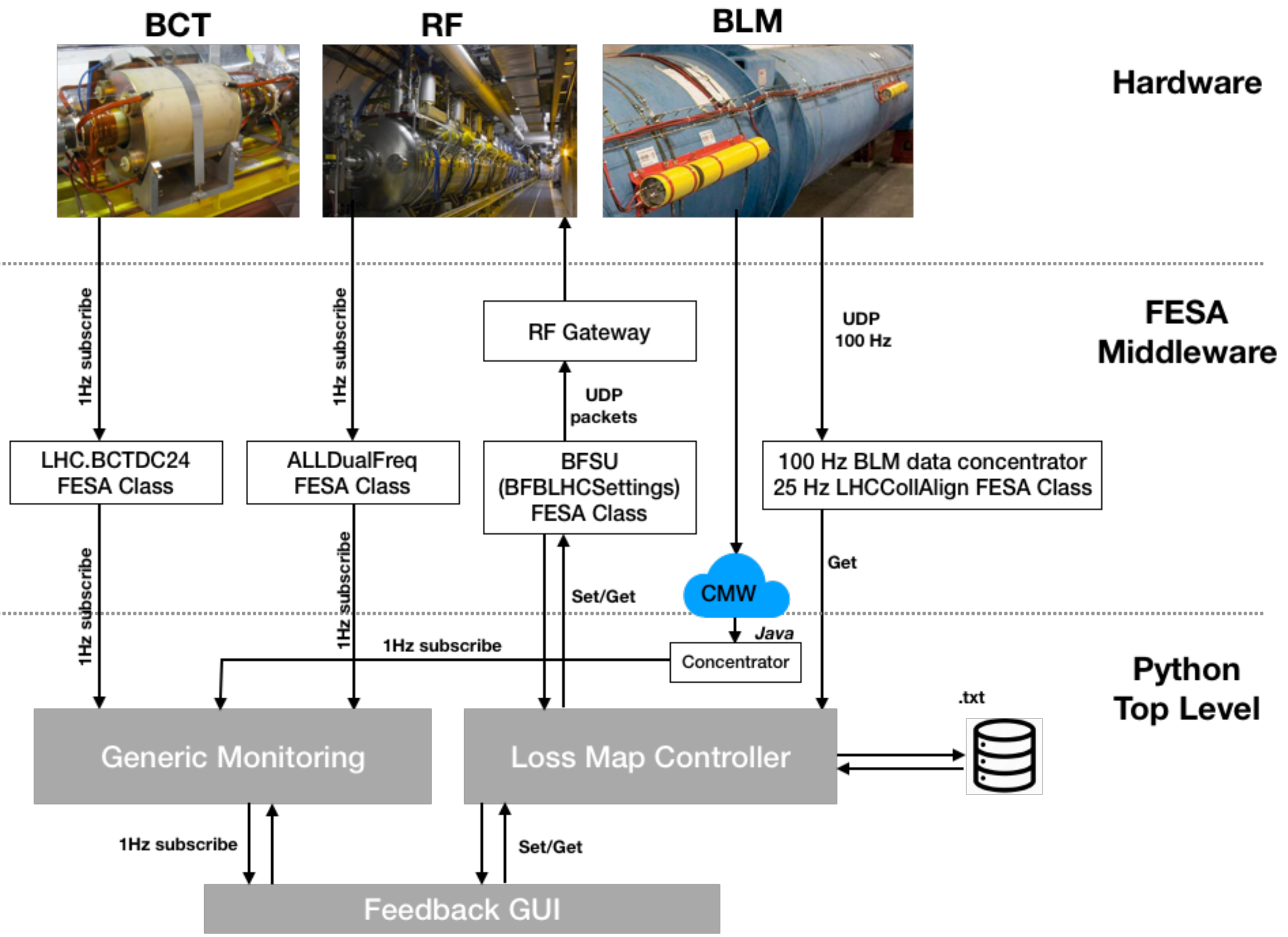


FEEDBACK CONTROLLER

The new feedback controller is fully based on Python, although low level processes in FESA still control the RF trim and provide the fast BLM data. Active trims to the hardware and acquisition actions are performed via a Java API for Parameter Control (JAPC).

The project is organised in three categories:

- **Hardware:** involving beam current transformers (BCT) for monitoring of total beam charges, RF cavities for the frequency change and BLM detectors.
- **FESA Middleware:** read/writing to hardware is done via the FESA classes.
- **Python Top Level:** interaction with the user with a Graphical User Interface (GUI). Monitoring of the signals (BCT, BLM and RF frequency) and feedback controller is done at a lower level in the Python language.



AN OFF-MOMENTUM BEAM LOSS FEEDBACK CONTROLLER AND GRAPHICAL USER INTERFACE FOR THE LHC

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FEEDBACK OPERATION AND GUI

The feedback can be started in three different configurations defined by the user via the GUI:

- **Loop mode** using 1 Hz BLM data.
- **Feedback mode** using 1 Hz BLM data.
- **Feedback mode** using 100 Hz BLM data.

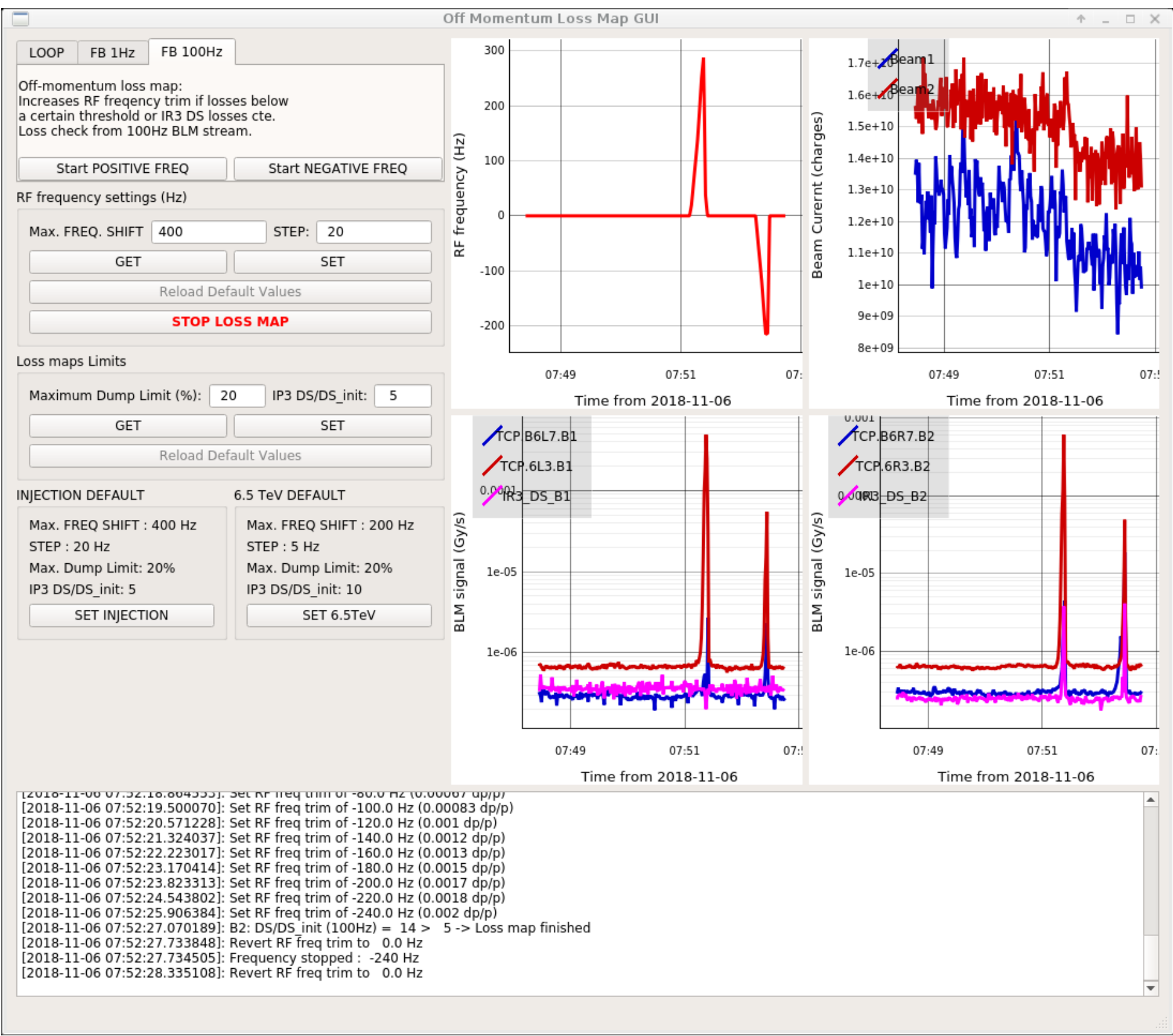
All of them are initiated in the same way, the user specifies the **initial parameters**:

- Maximum RF frequency
- Step size in Hz

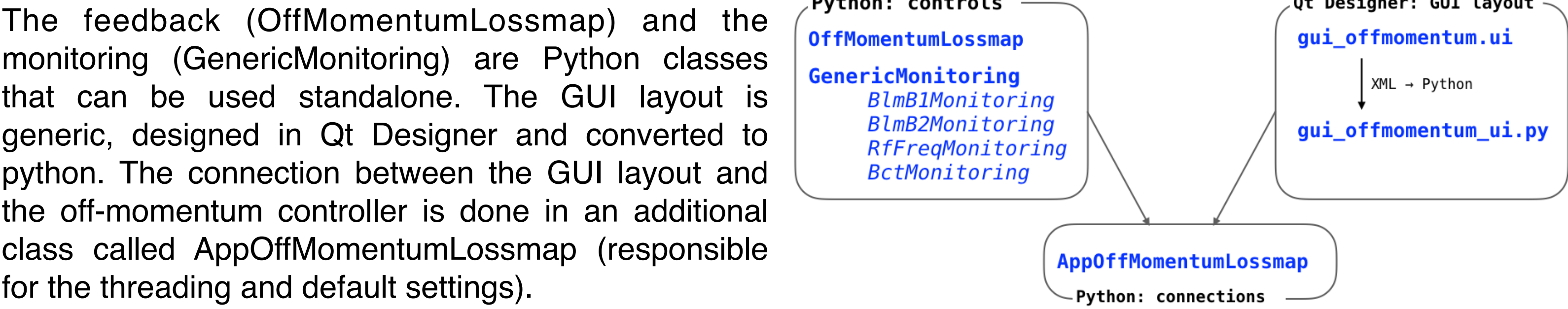
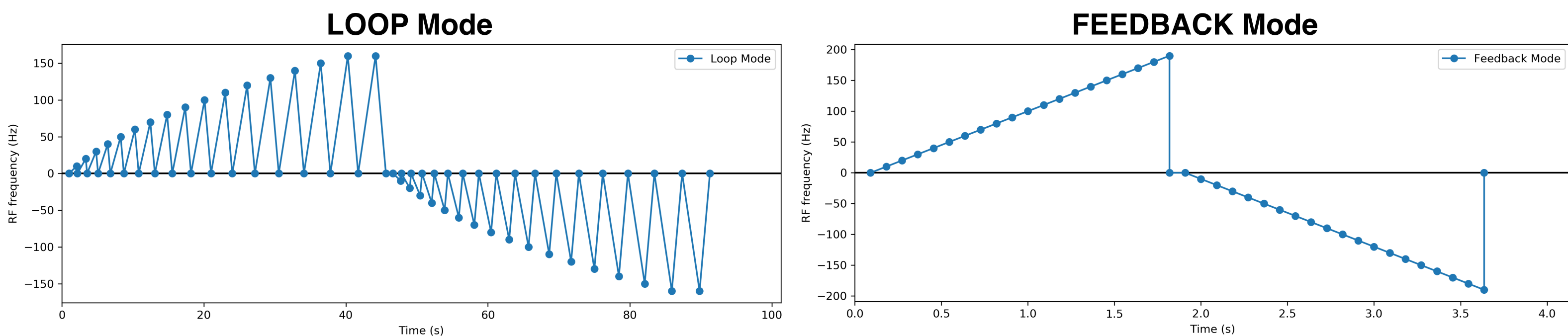
All of them share the **settings of the conditions to be reached**:

- Maximum Dump Limit (%): maximum ratio to dump limit.
- DS Relative Limit: maximum ratio to the initial loss in the dispersion suppressor magnets of IR3 (8L3 and 8R3).

Default settings for injection and top energy are also provided as well as online monitoring of relevant parameters such as Beam Current signals, Beam Losses and RF frequency over time.

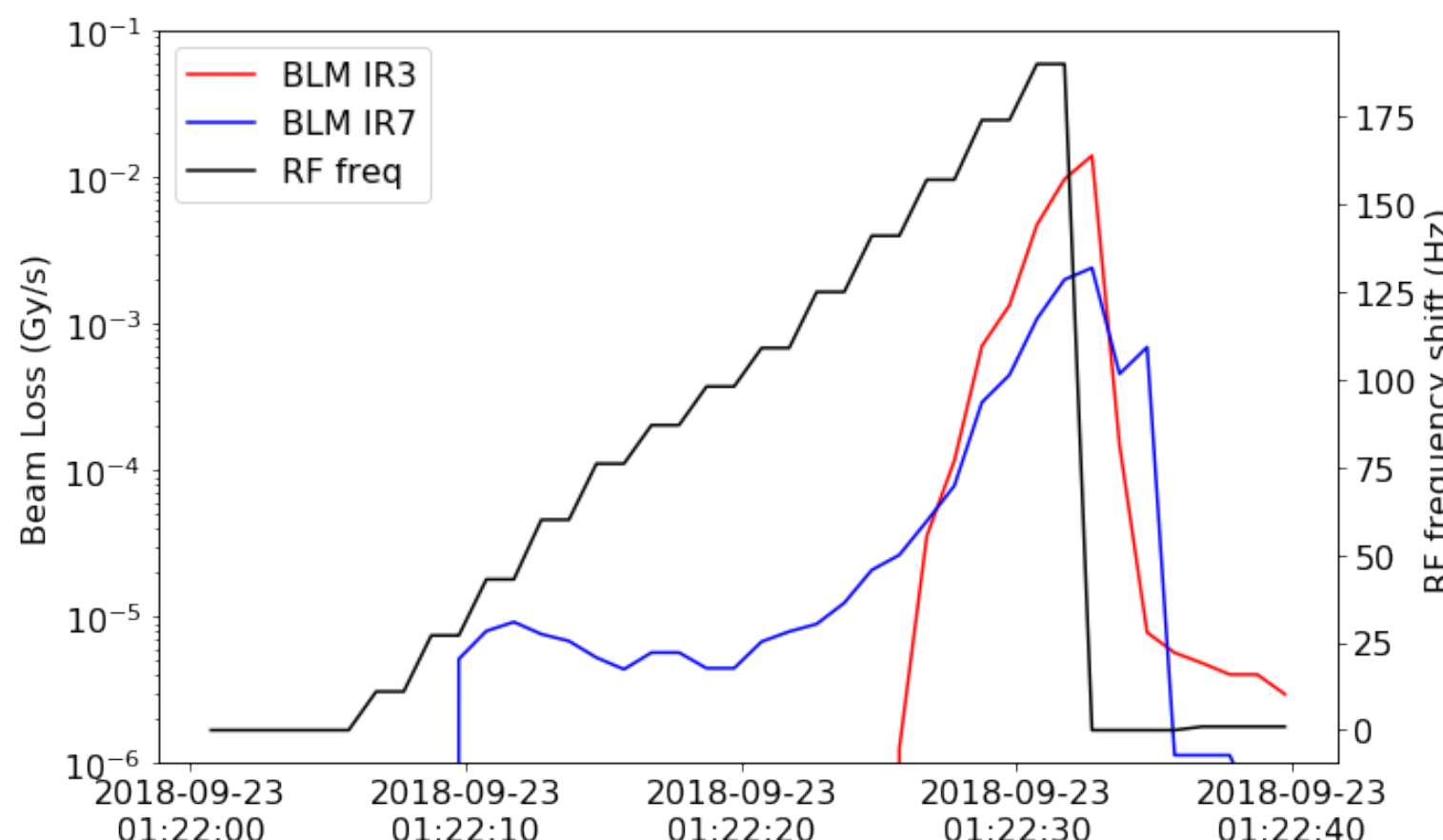


Depending on the mode of operation the target frequency could be reached in different ways:



During 2018, several off-momentum loss maps were successfully done using the described feedback.

Example: beam loss over time while the RF frequency is changing. The data is displayed at 1 Hz although the feedback was acting at higher rate.



Example: loss map achieved using this feedback.

From August 2018, this off-momentum feedback was the default software used on the LHC to validate the off-momentum configuration.

