# A Systematic Measurement Analyzer for LHC Operational Data

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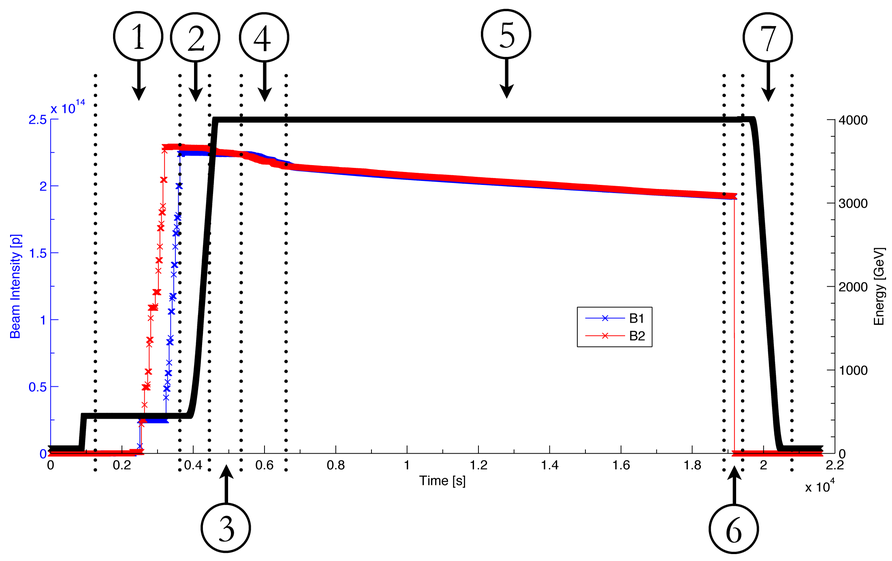
## Abstract

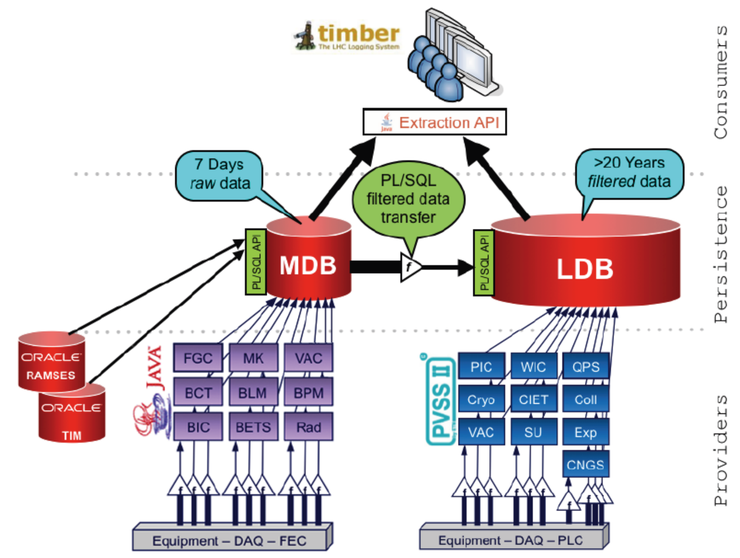
The CERN Accelerator Logging Service stores data from almost hundreds of thousands of parameters and measurements, mostly from the Large Hadron Collider (LHC). The systematic measurement analyzer is a Java-based tool that is used to visualize and analyze various beam measurement data over multiple fills and time intervals during the operational cycle, such as ramp or squeeze. Statistical analysis and various manipulations of data are possible, including correlation with several machine parameters such as β* and energy. Examples of analysis performed include checks of collimator positions, beam losses throughout the cycle and tune stability used for feed-forward purposes.

## LHC Machine Cycle




1. **Injection:** the LHC is filled with beam
2. **Ramp:** the beam energy is increased
3. **Flat top:** the LHC is at the operational energy for physics
4. **Squeeze:** the beam size in the experimental points is reduced
5. **Stable Beams:** LHC produces collisions for the experiments
6. **Beam Dump:** beam is ejected from the LHC.
7. **Ramp Down:** the current in the magnets is ramped down in preparation for the next fill.

## CERN Accelerator Logging Service

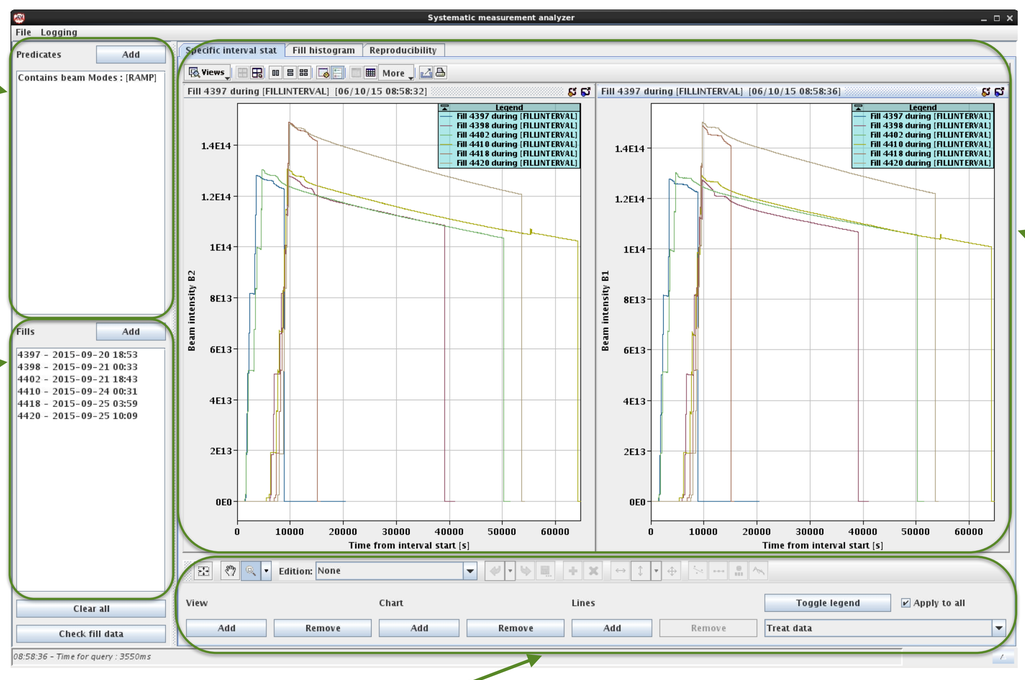



➡ CALS [1] stores almost 1 million signals from thousands of devices in CERN's accelerator infrastructure. This amounts to 50 PB/year of data.

➡ Two Oracle databases are used for storage. The Measurement database (MDB) is used to store raw data for a short period of time, while the Logging database (LDB) is used for indefinite storage of filtered data.

➡ A Java application called Timber can be used to extract and visualize individual signals, however it cannot be used for detailed fill-to-fill analyses.

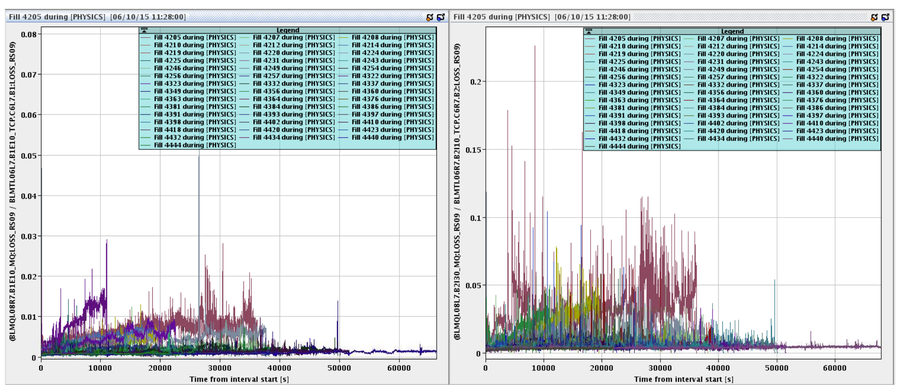
## Analyzer Graphical User Interace




## Use Case: Collimation Cleaning Performance

➡ The LHC collimation system [2] protects the machine against damage due to beam losses. Almost 100 collimators consisting of double-sided jaws form a four-stage hierarchy to intercept, scatter and absorb highly energetic halo particles.

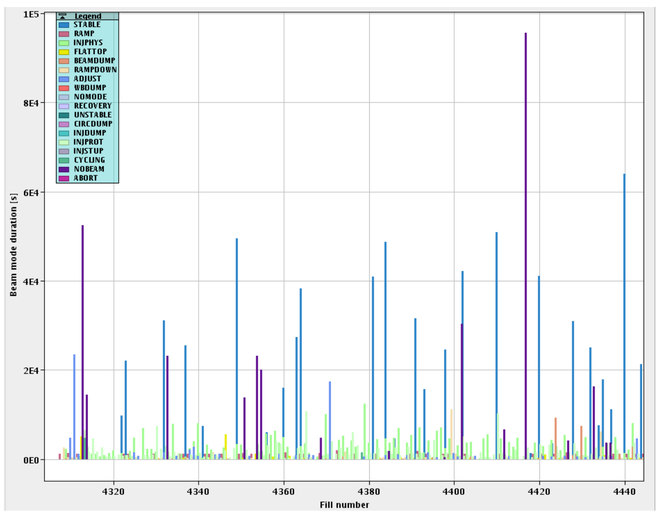
➡ 3600 Beam Loss Monitors (BLMs) measure the losses at specific locations in the LHC. The ratio of the losses in the IR7 dispersion suppressor to the losses at the primary collimator closest to the beam give a measure of the cleaning inefficiency of the collimation system.




## Use Case: Beam Mode Duration

➡ Bar charts can be made to visualize the time spent in each of the 18 LHC machine modes in each fill.

➡ The chart below is for all fills in September 2015.

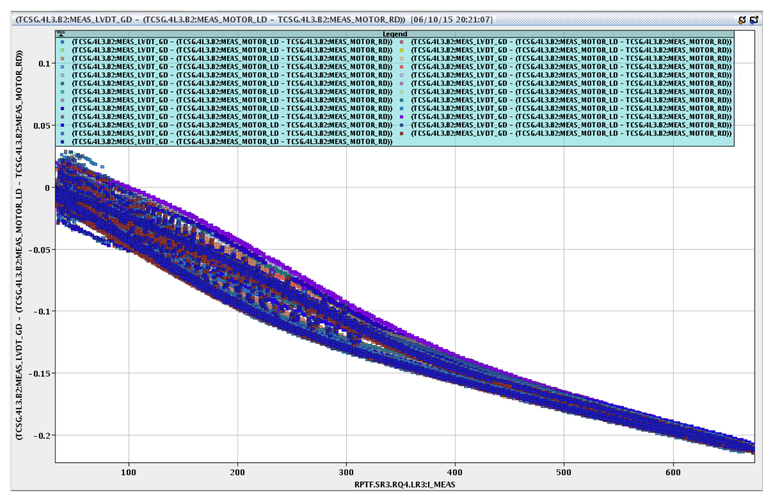



## Use Case: Collimator LVDT - Magnet Current Correlation

➡ Linear Variable Differential Transformers (LVDTs) provide an independent read-out of the collimator jaw position.

➡ At some collimators, the readings were found to be susceptible to EM interference from nearby magnets [3]. The plot shows the difference in the collimator gap measured by the LVDT and calculated from the left and right jaw motor positions as a function of the magnet current during several LHC pre-cycles.

➡ A new design (I2PS) is now in place and gives a constant reading for a given collimator gap.




## Conclusions and Outlook

This paper documents a tool which is useful for performing fill-to-fill analyses needed to monitor the performance and behaviour of the LHC and its equipment. Further enhancements of the tool include curve fitting, which could be used to calculate the beam lifetime evolution during stable beams, for example.

## References

[1] C. Roderick, L. Burdzanowski, G. Kruk, ``The CERN accelerator logging service - 10 years in operation: a look at the past, present and future". In Proceedings of ICALEPCS'13, San Francisco, CA, USA, pp. 612-614, 2013.

[2] R. W. Assmann et al., "Requirements for the LHC collimation system". In Proceedings of EPAC'02, Paris, France, pp. 197-199.

[3] G. Valentino, "Follow-up of collimator LVDT drift analysis". Presented at the 167th LHC Collimation WG meeting, 04.11.2013

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