
CERN

Analysis of loss plane

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CERN BE/OP

BLM Thresholds Working Group
15 May 2018

Introduction

Loss spikes and fast drops of lifetime are a concern for operating machine

- ↪ Beam lifetime is used an indication of the machine performance
- ↪ Monitor of beam quality along the LHC
- ↪ Optimise working (tune, chromaticity, octupoles) in collisions and MDs

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$$\frac{dI}{dt} = R_{\mathrm{loss}}$$ *Beam loss rate*

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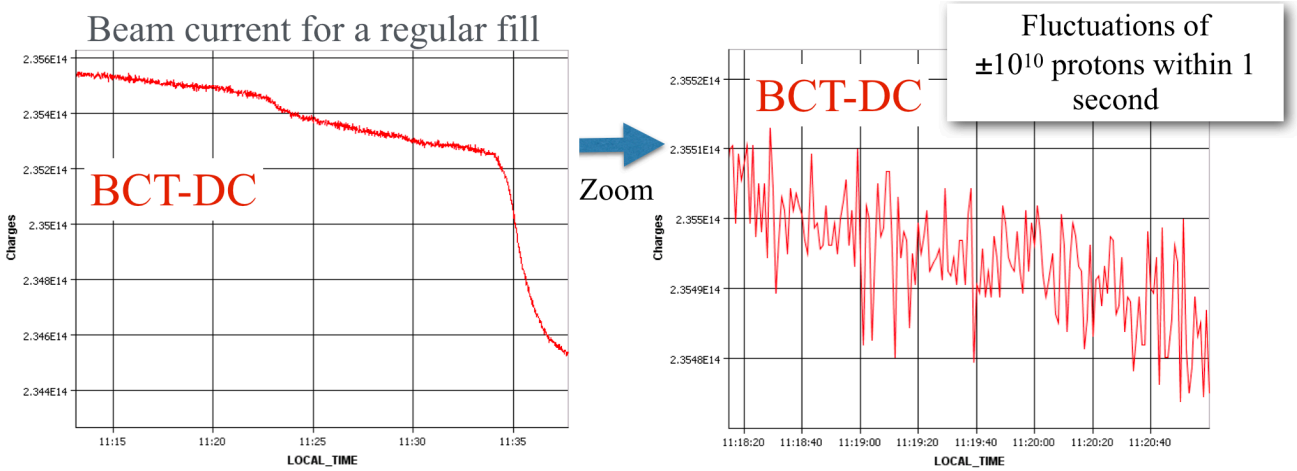

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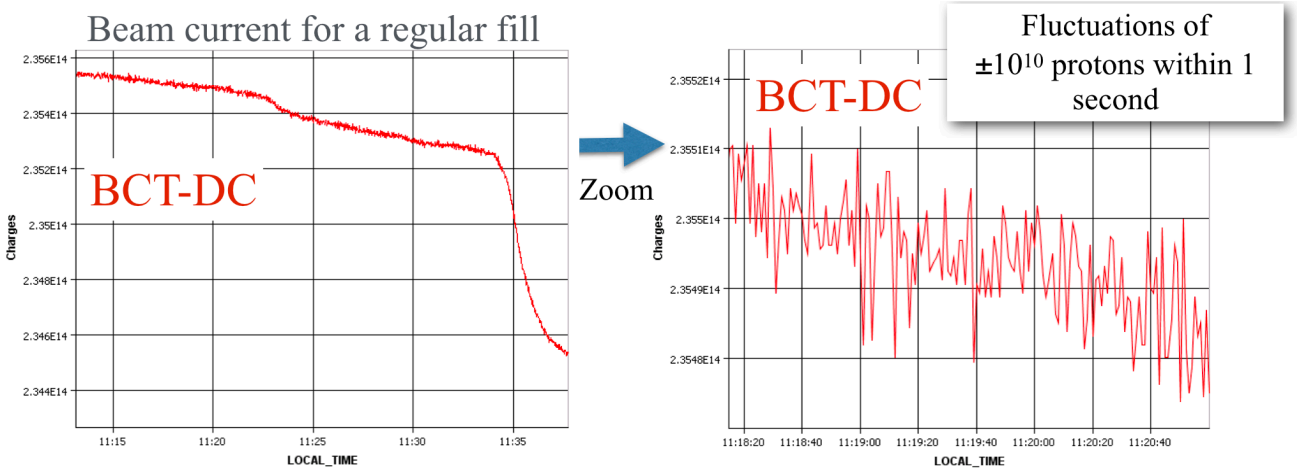

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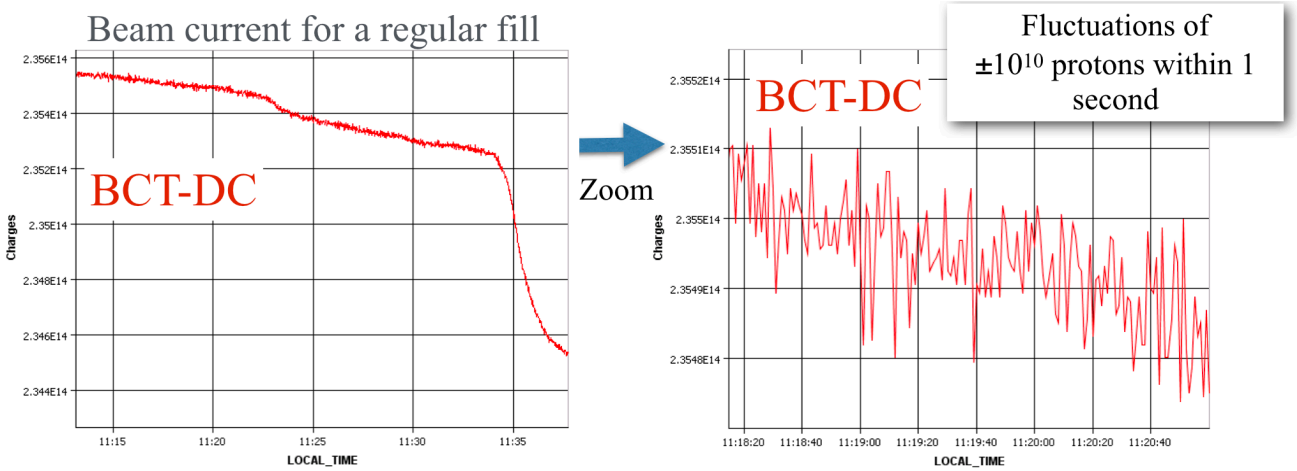

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Other devices such as beam loss monitors could be used for this measurement and have additional advantages for the measurement of the proton loss rate.

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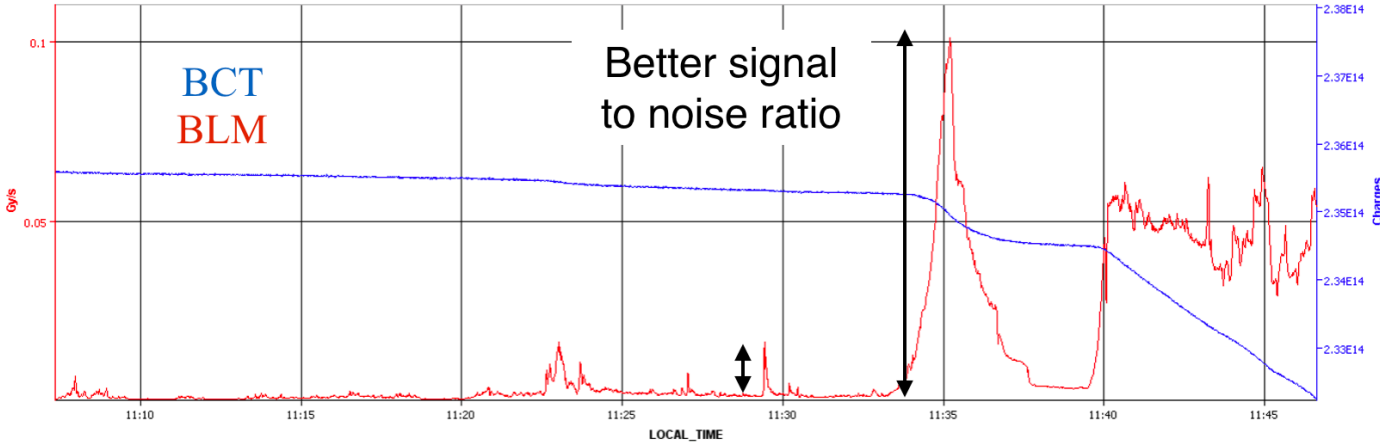

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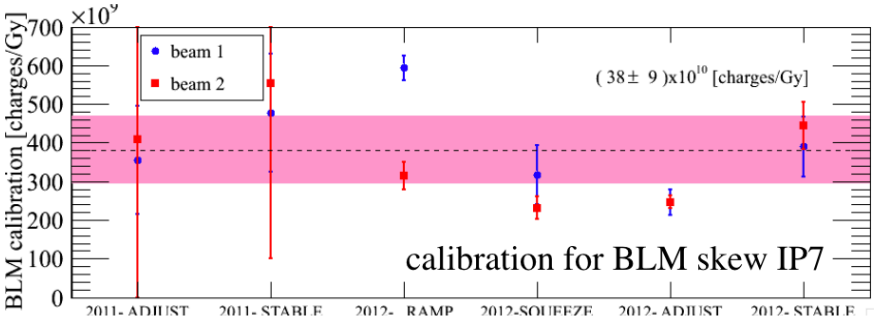

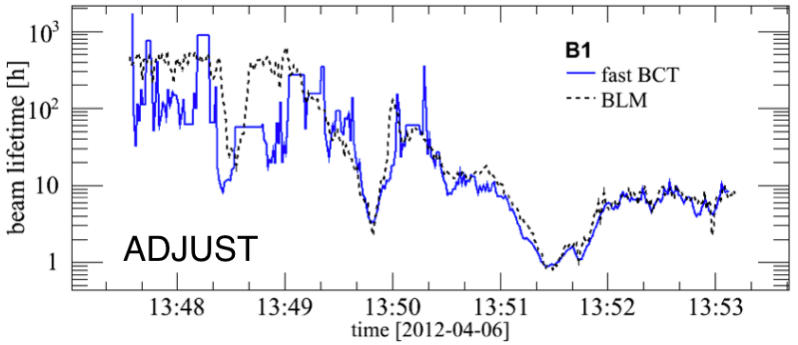

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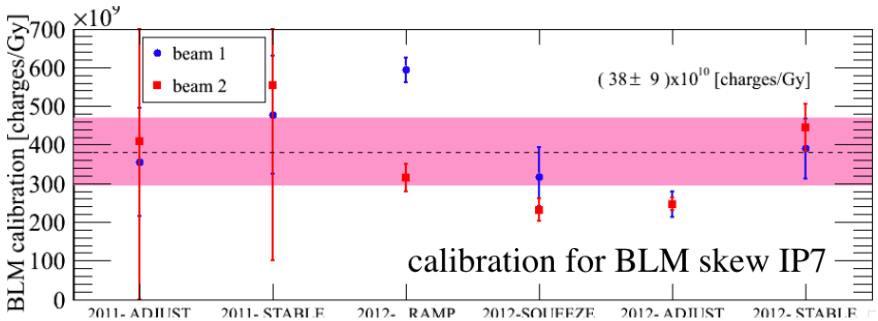

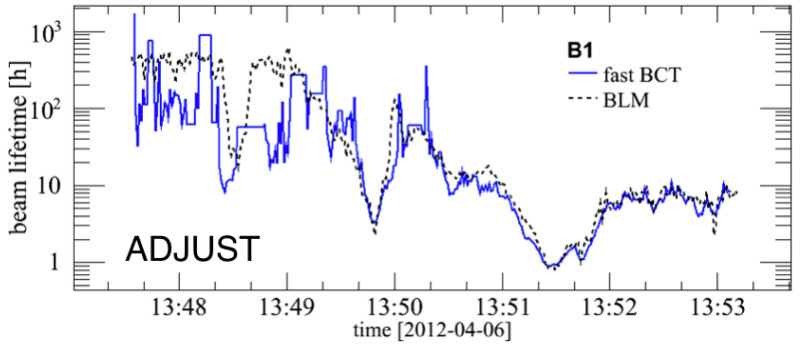

Belen et al. "Lifetime Analysis at High Intensity Colliders Applied to the LHC", IPAC2013

Previous studies by F. Burkart, PhD 2012 CERN-THESIS-2012-046 Beam Loss and Beam Shape collimators.

BLM Calibration: Run II

Review the idea of identifying loss patterns (A.Marsili PhD CERN-THESIS-2012-316)

Provide two type of calibrations:

- *Based on few BLMs not sensitive to the plane of losses.*
- *Based on more BLMs combined to get losses with different pattern (SVD).*

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ONLINE DIAGNOSTICS
Less sensitive to changes in collimation settings

OFFLINE ANALYSIS
More precise but more sensitive to collimation hierarchy

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Simple way to re-calibrate the BLMs used for the beam lifetime monitoring in the CCC that can be re-calibrated quickly if conditions change.

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$$\left.\frac{dI}{dt}\right|_{loss} = \alpha \cdot \sum_{i=1,4} \mathrm{BLM}_i$$

Calibrate the sum of all the monitors

$$\frac{dI}{dt} = \left.\frac{dI}{dt}\right|_{loss} + \mathcal{L} \cdot \sigma_{inelastic}$$

Including protons lost due to luminosity

Lifetime display

Lifetime display

- Calibration provided for Injection and Top Energy (6.5TeV).
- Linear interpolation through the RAMP.
- Lifetime in Stable Beam from BLMs including Burn-Off losses.
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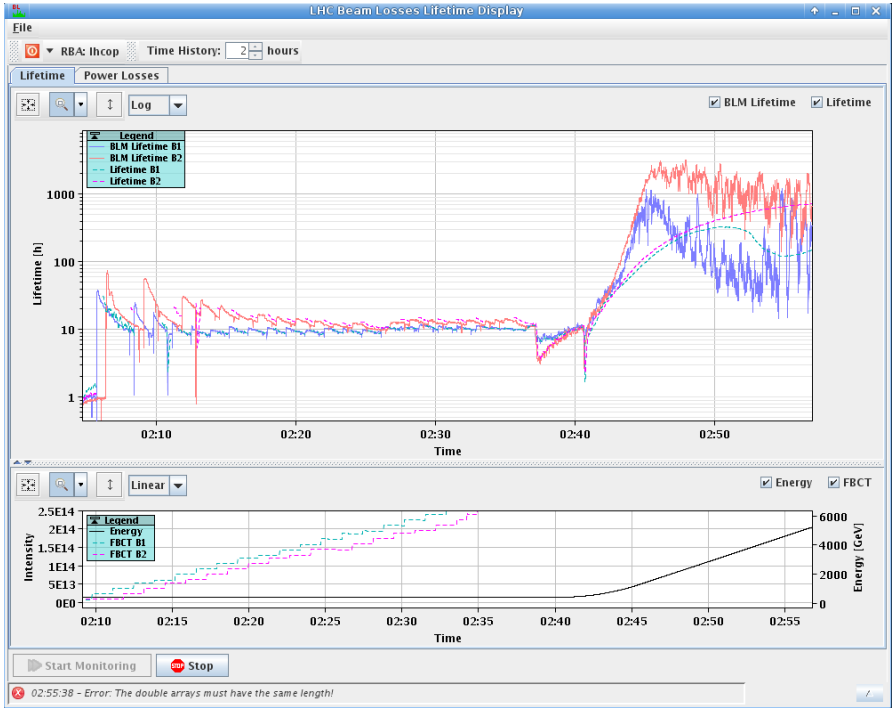

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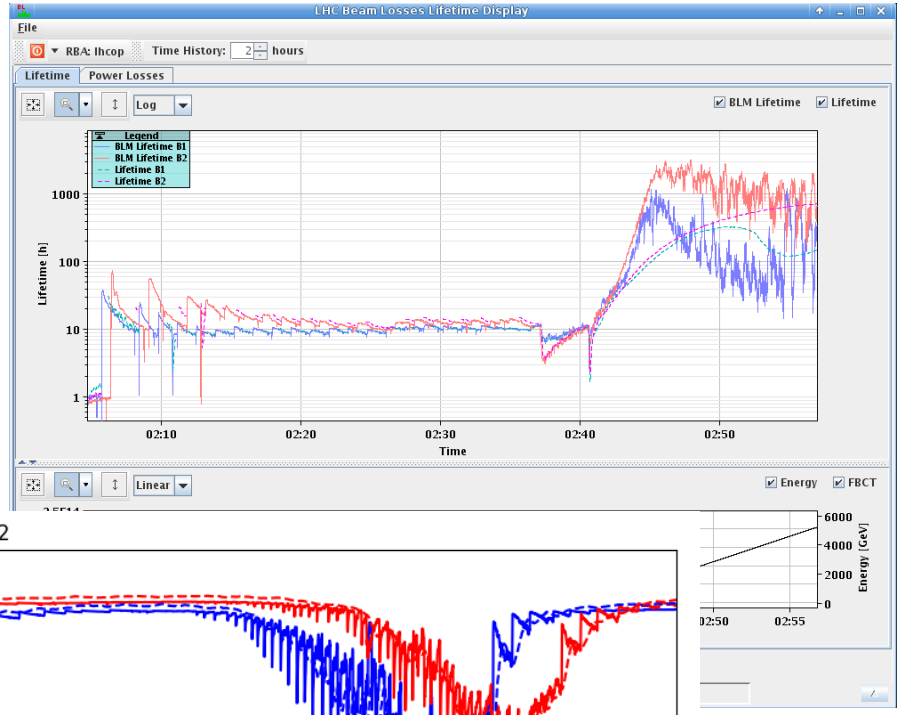

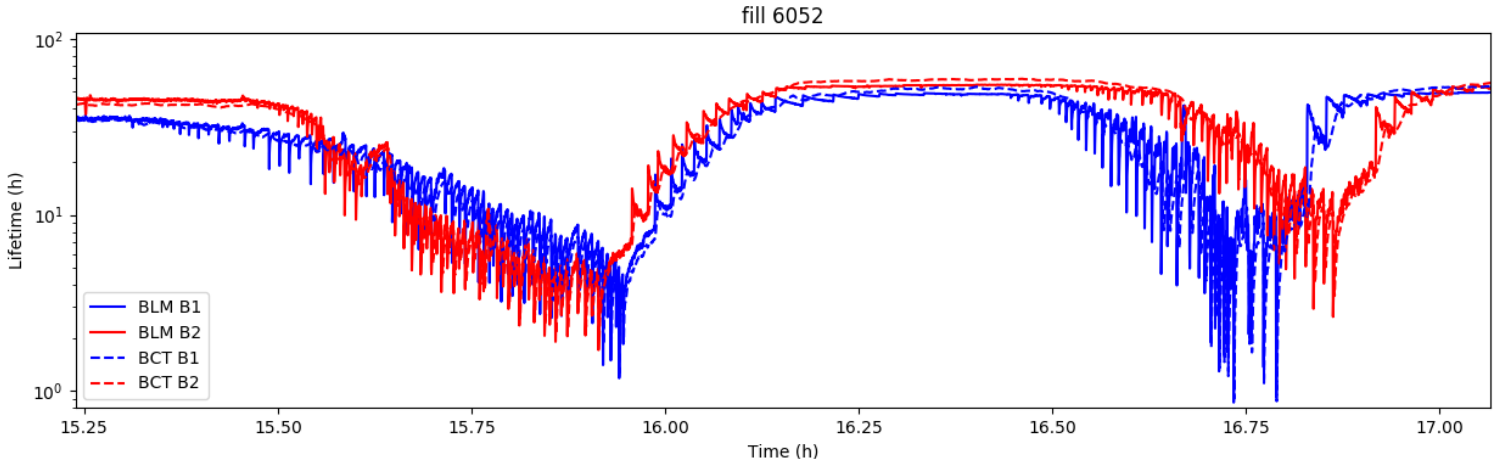

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Well defined loss scenarios:

IP7 H/V and IP3

Scraping with primary collimators

End-of-fill test

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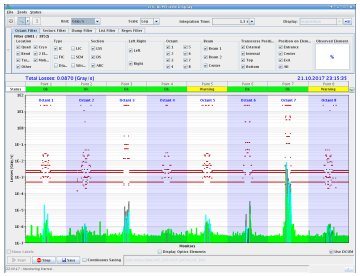
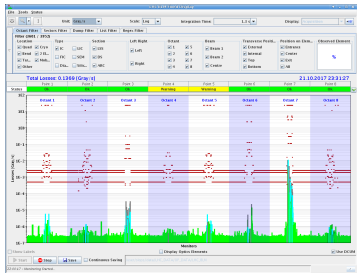
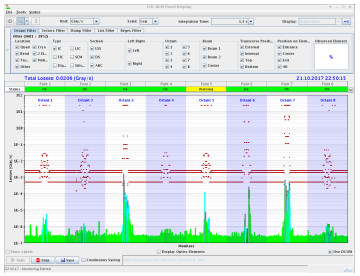
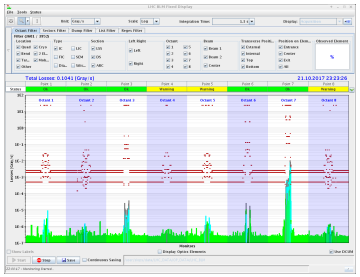


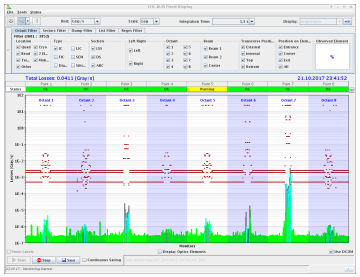
VERTICAL

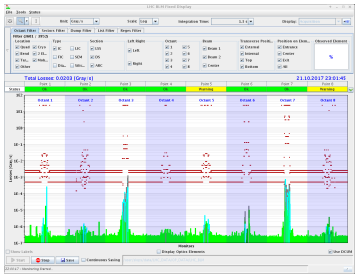


OFF-MOMENTUM

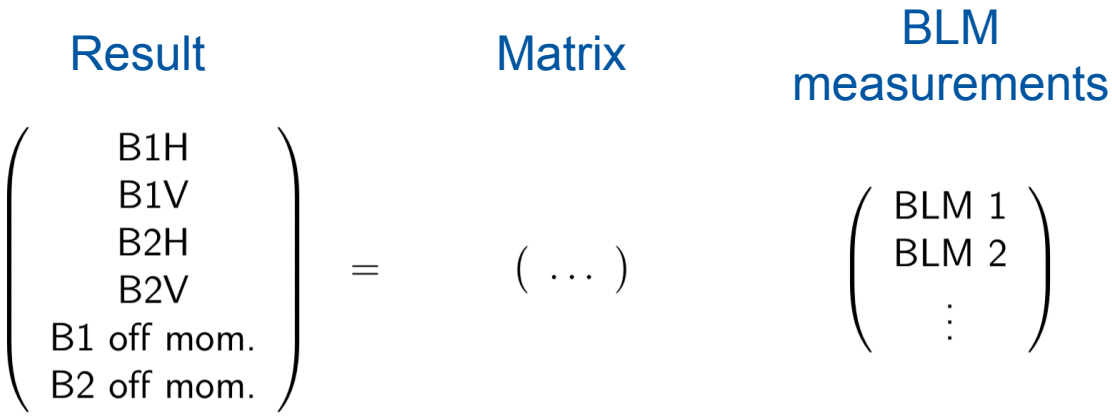








Using the matrix



1. Quantify protons lost and loss plane:
    1. during specific MDs: long range, wire collimator, ATS, etc.
    2. During the LHC cycle to asses the performance or study limitation. Example tune shift 2017 B1V.

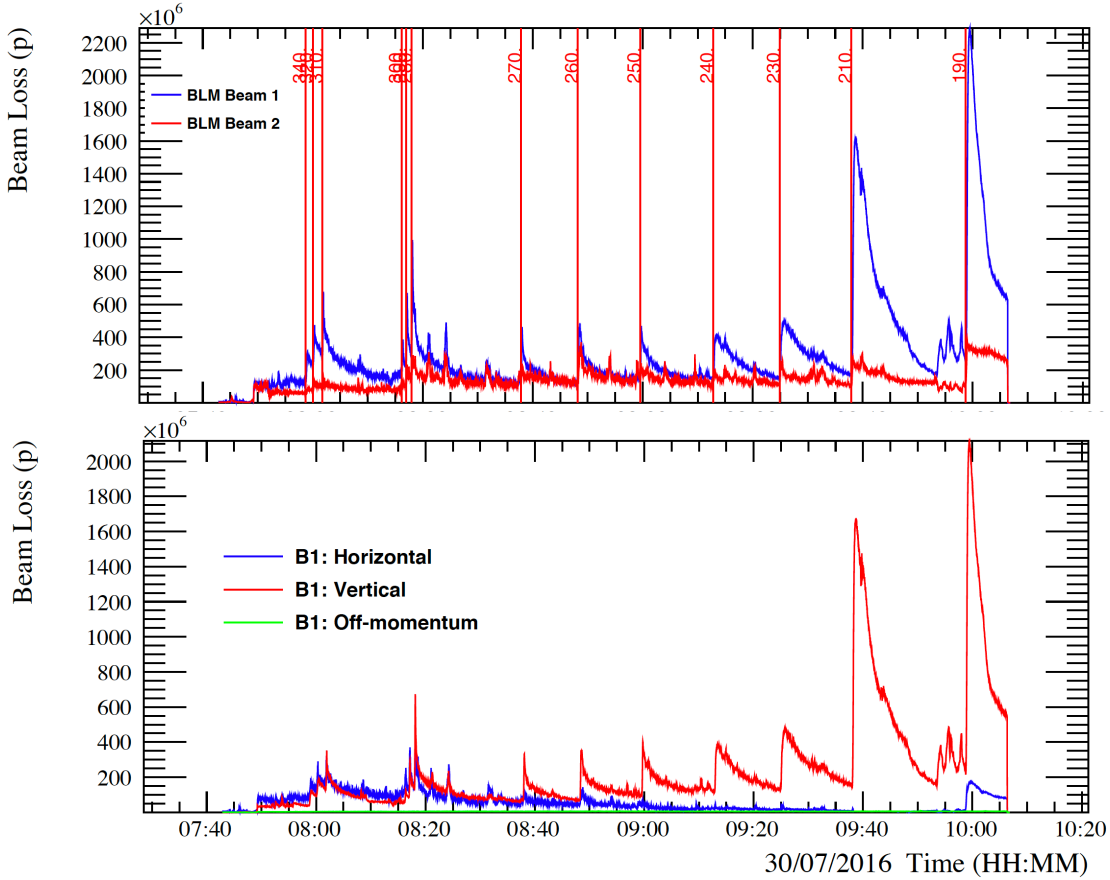
Different Crossing Angles at LHC

Impact of different crossing angles were tested in different MDs in order to explore the limitation due to long range beam-beam effects.

A train of 144 bunches colliding ATLAS/CMS

Half-Crossing from 185-90 urad Both ATLAS/CMS

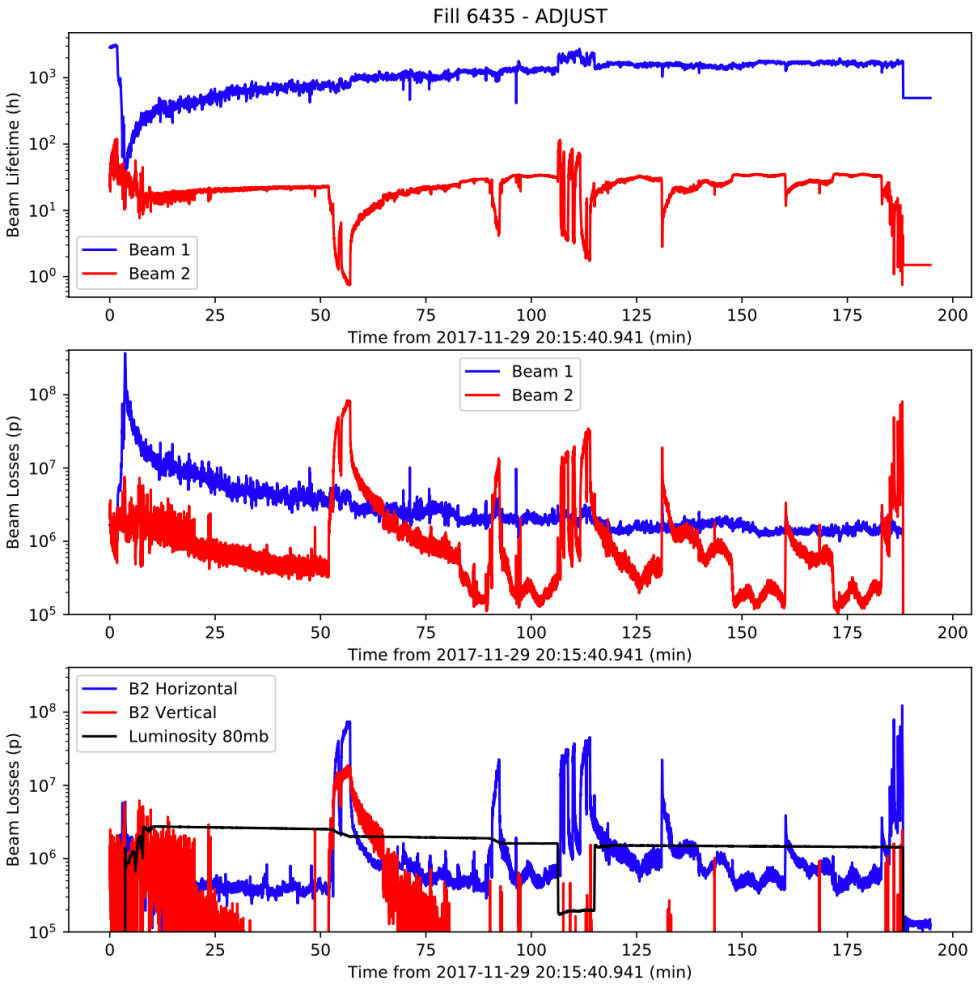
Observed that losses only in Beam 1, mainly in the Vertical Plane



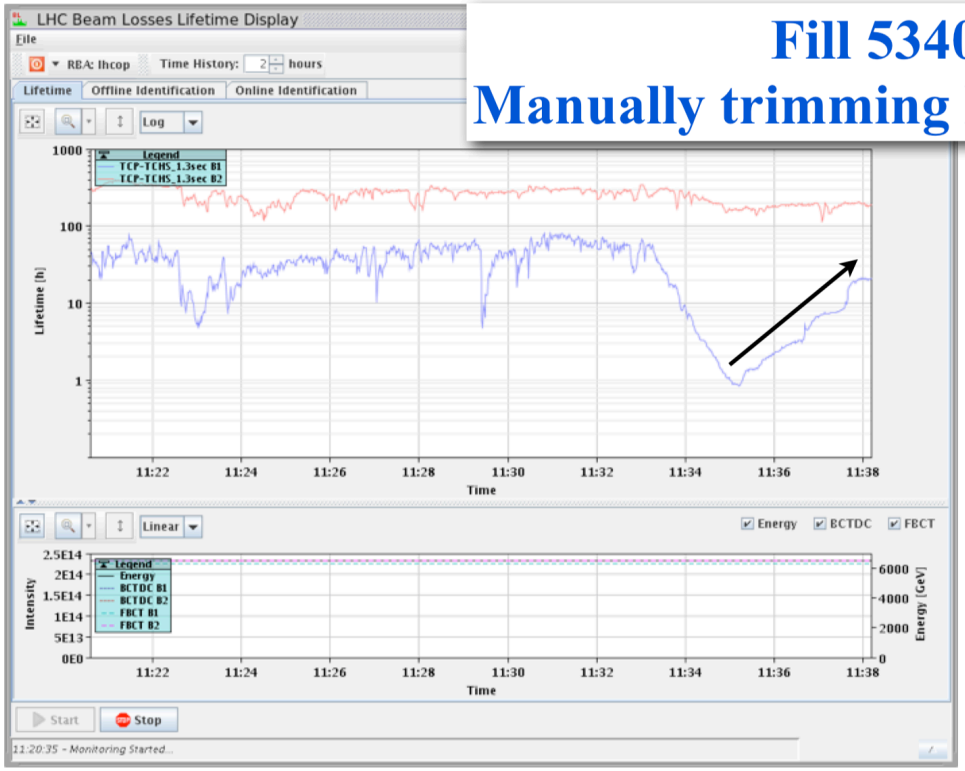
IPAC 2017 B.Salvachua et al.

LRBB test 2017

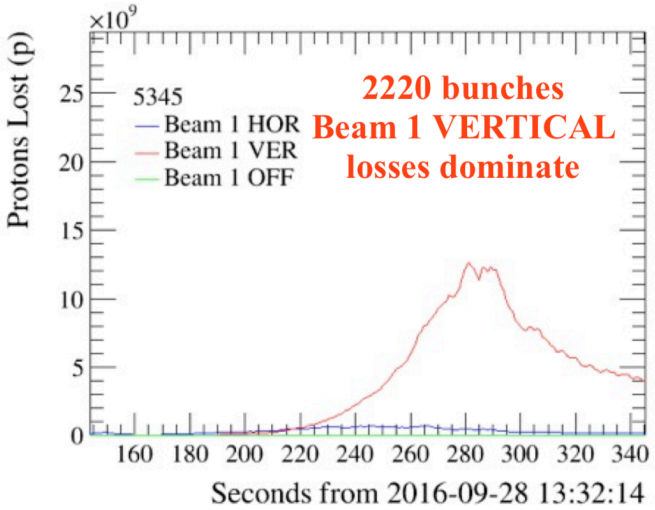
- Beam test using wires installed in collimators to compensate the octupolar term of the beam-beam in IR5.
- There was an initial B2H blow-up, followed by additional losses in B2H as the wires were switched on and off.
- The ML algorithm correctly classified the 3 spikes in losses which were ~1e8 p. There was one misclassification (though here the losses in B1 and B2 are ~equal & ~1e7 p).

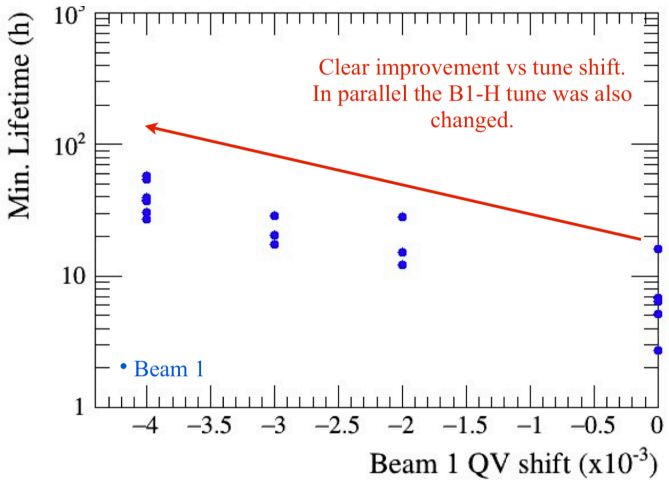


Losses Squeeze 2016



Fill 5340
Manually trimming B1V:





Breakdown of losses in SB 2017

Applying the **BLM calibration** and decomposition we could **quantify the NON burn off losses.** It confirms that losses in Beam 1 are about a factor of 2 higher than for Beam 2.

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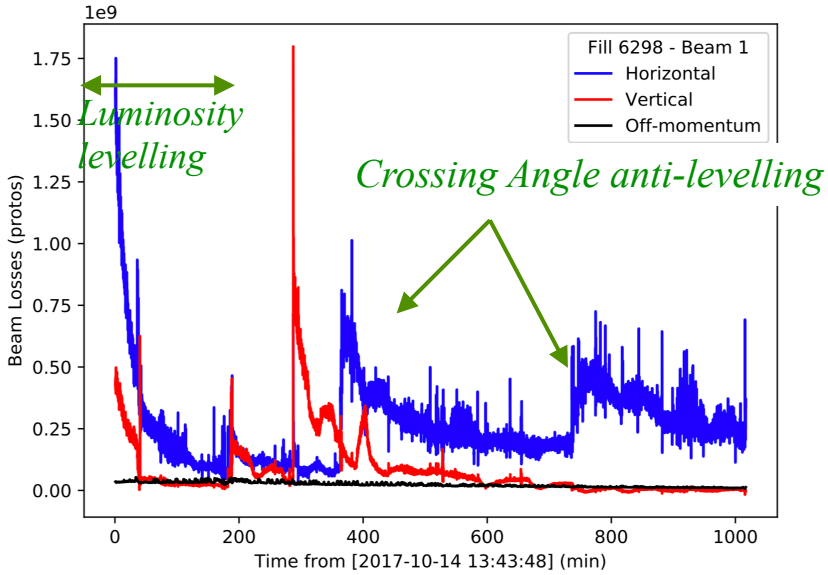
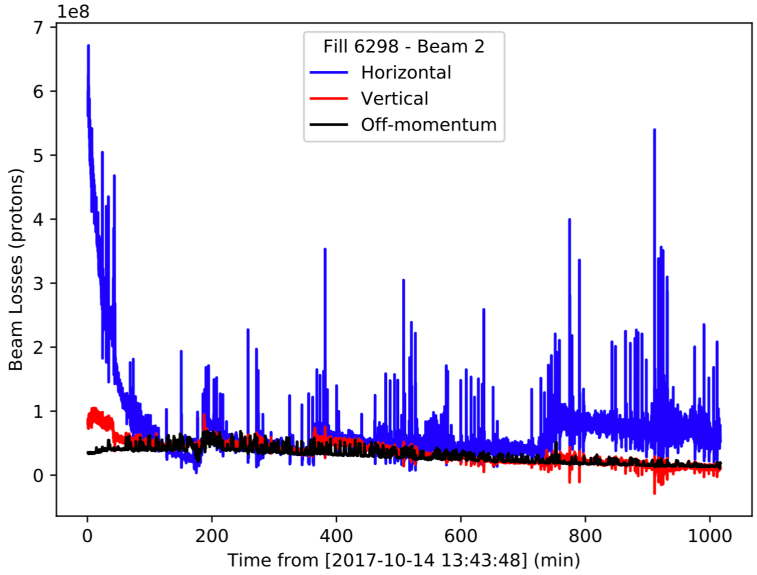
- Off-momentum losses have a small contribution.
- Loss steps are correlated with changes of crossing angle (Horizontal plane) and optimisations.





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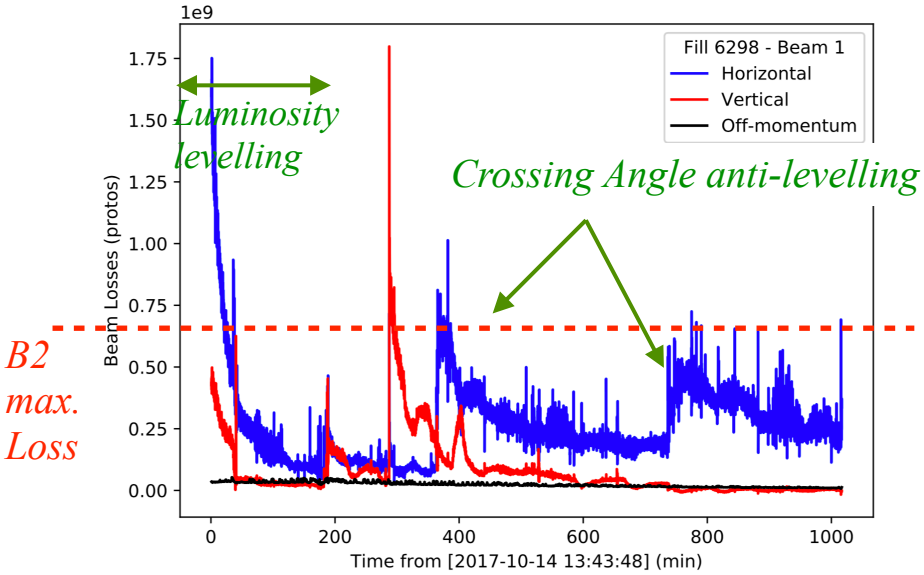
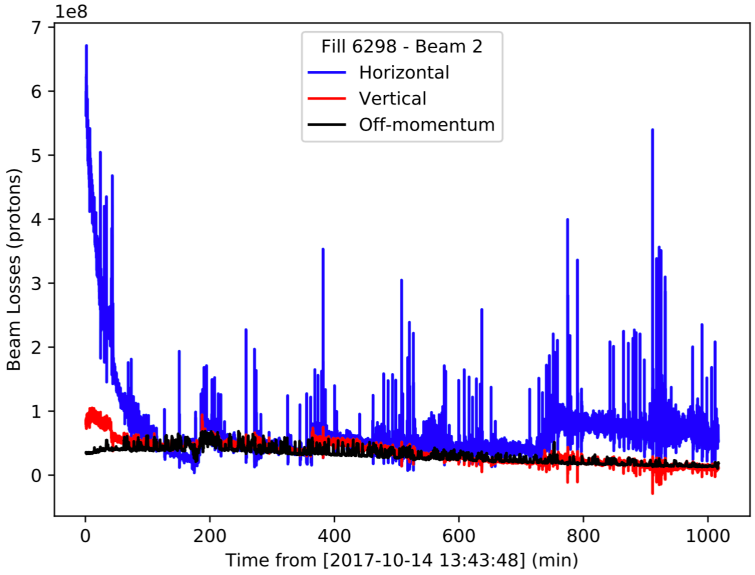
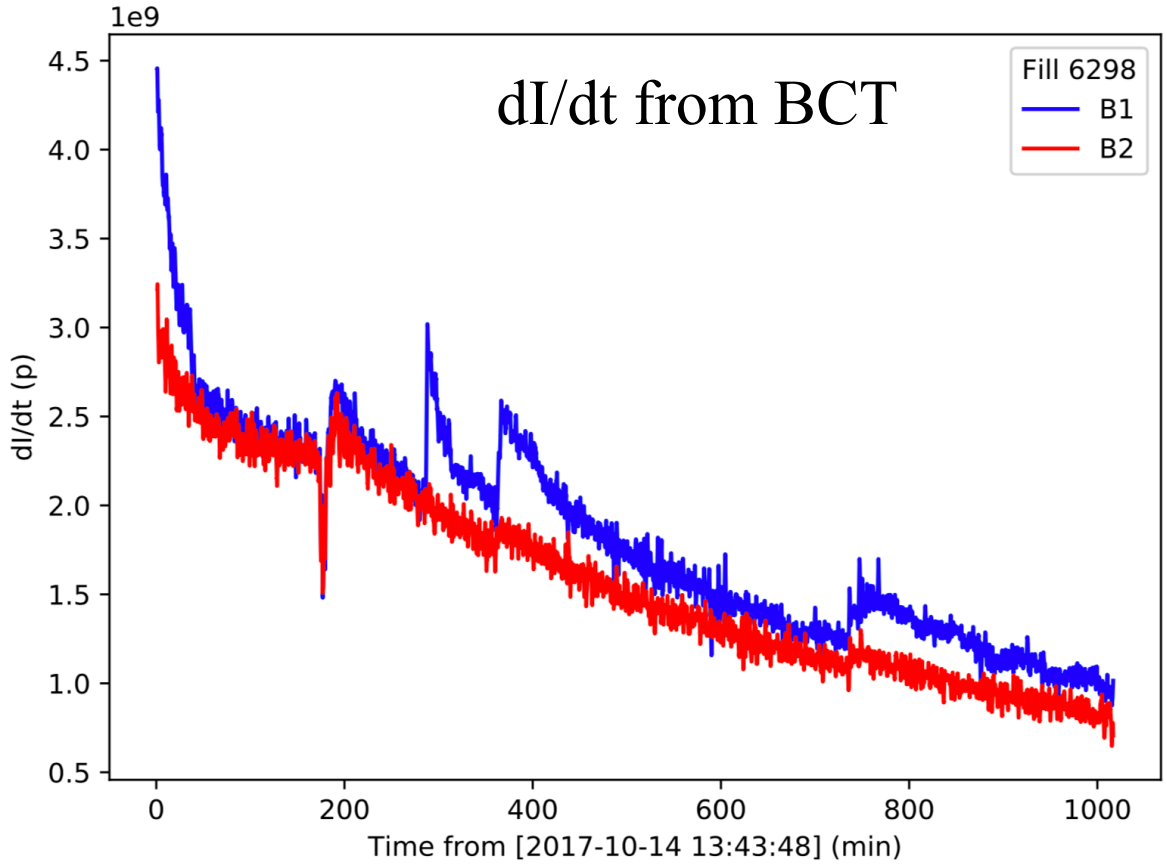




Luminosity losses

dI/dt from BCT where Beam 1 lifetime is worse than Beam 2



Luminosity losses

dI/dt from BCT removing the contribution from collimators

losses measured by the BLMs calibrated with decomposition matrix

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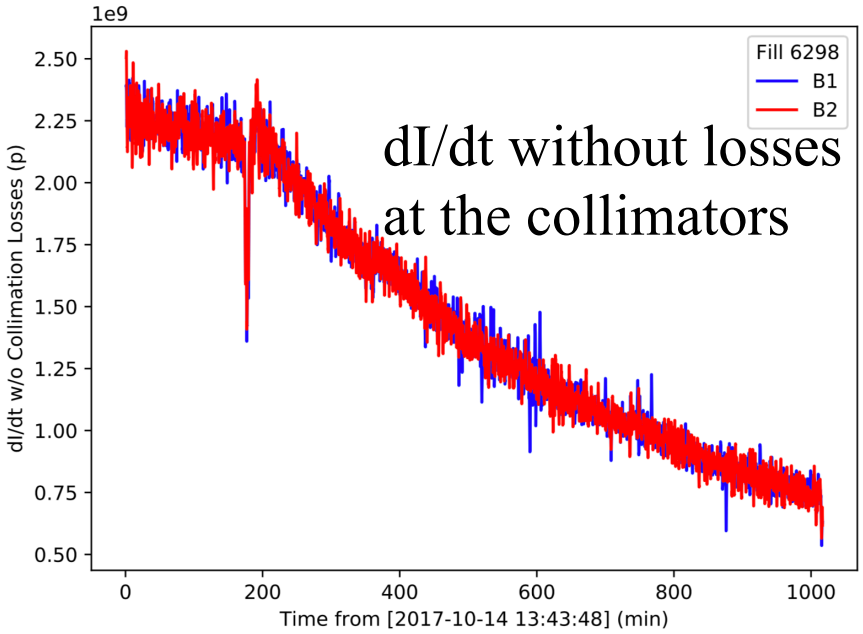

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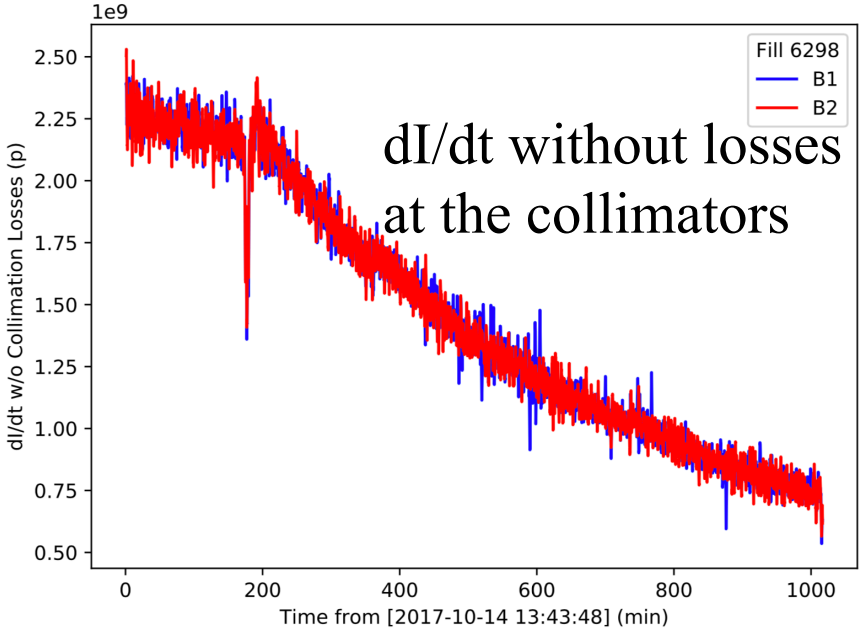
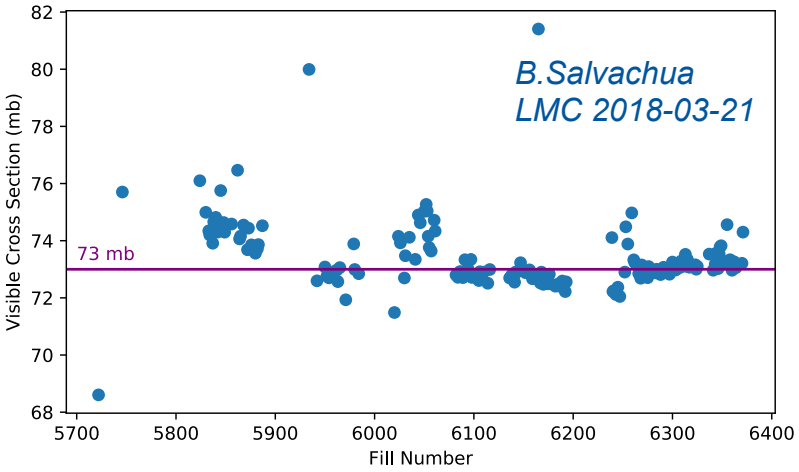


$$\frac{dI}{dt} = \left.\frac{dI}{dt}\right|_{loss} + \mathcal{L} \cdot \sigma_{inelastic}$$



$$\sigma_{inel} = \sigma_{visible} + \sigma_{correction}$$

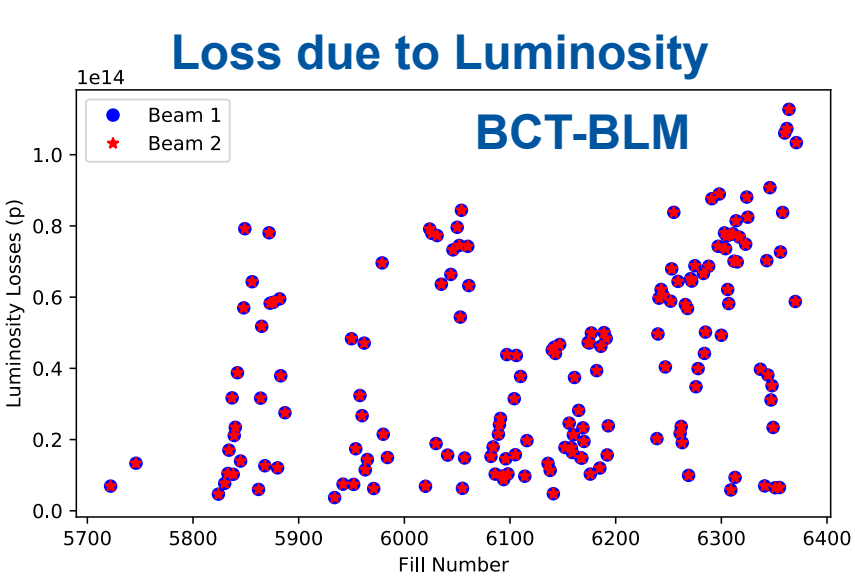
$$\sigma_{inel} = 72.9 + 5.55 = 78.5 \text{ mb}$$

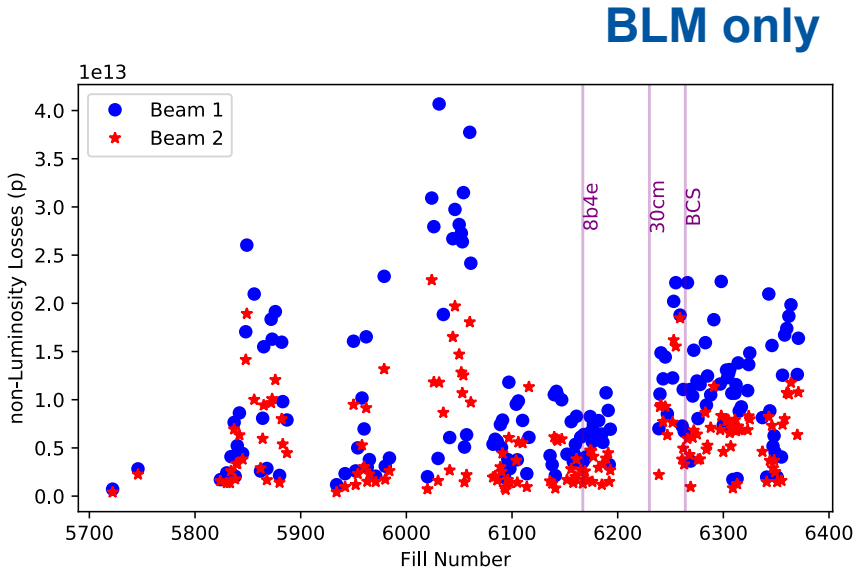
6.5TeV measured at the LHC (BCT-BLM)

Fill by fill analysis - I

Integrated dI/dt without collimation losses, no cross section assumption is done here. The calculation comes ONLY from BCT and BLMs.

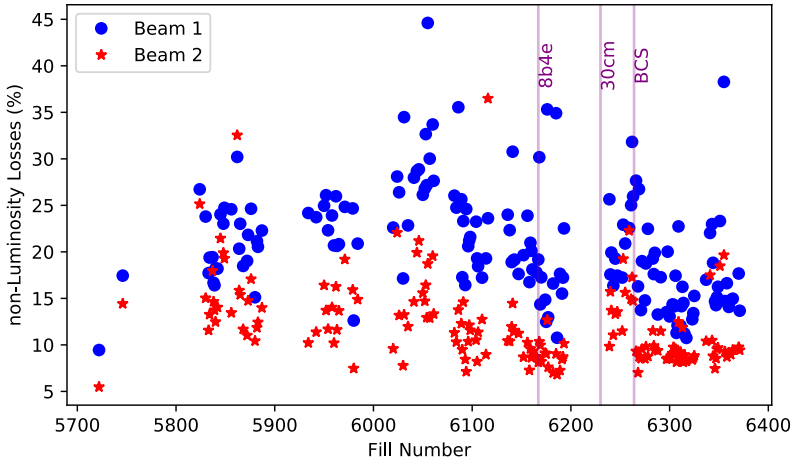
- (**LEFT**) Both Beam 1 and Beam 2 have the same amount of protons lost not at the collimators —> expected as burn off losses. Differences between fills are due to different peak luminosity and fill length.
- (**RIGTH**) Beam 1 has more losses at the collimators as observed.

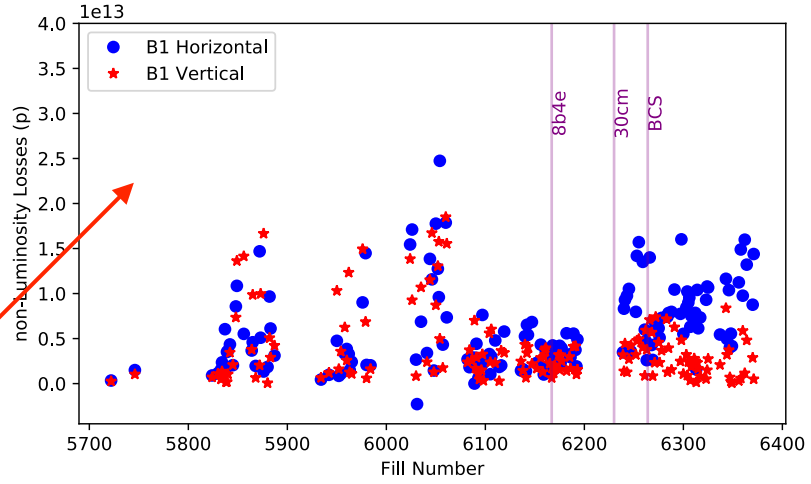


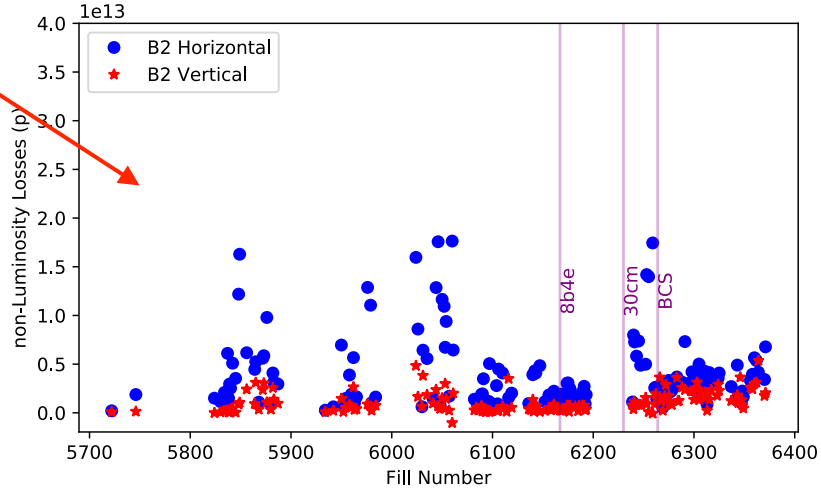


Fill by fill analysis - II

Here we take the non-luminosity losses and we see the amount lost in Horizontal plane (blue) and the amount lost in Vertical plane (red)



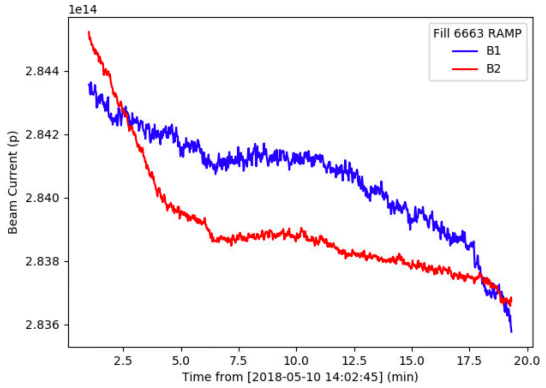


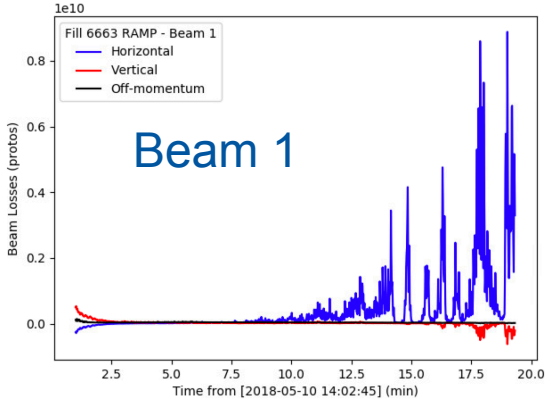


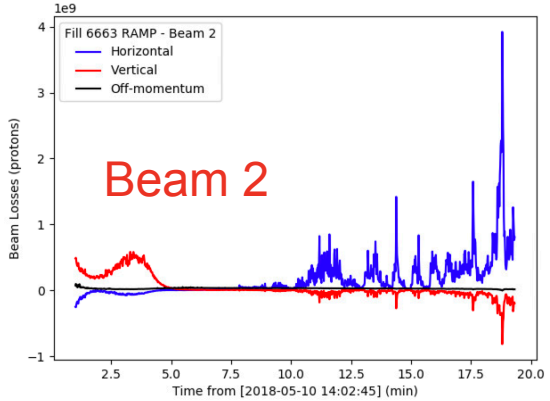
2018 losses

The calibration on 2017 data was applied to 2018 and results are still very accurate, although a dedicated calibration fill will be needed to check calibration and to apply a similar approach for the dBLM detectors.

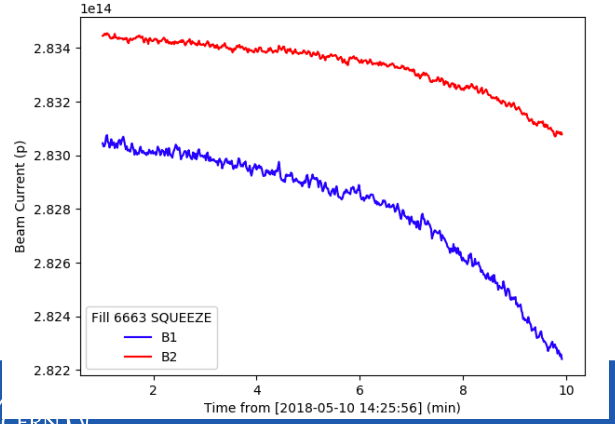
Losses during the RAMP 2018

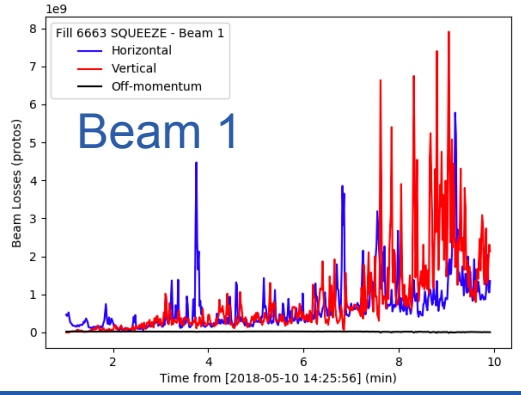


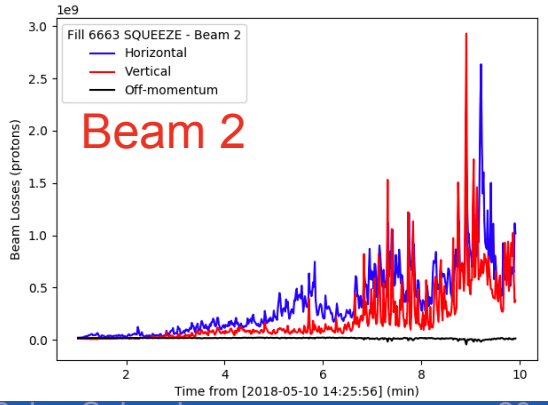




Losses during the SQUEEZE 2018

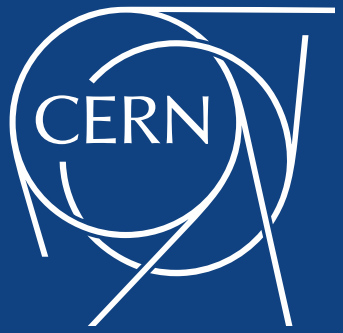






Summary

- **Improved BLM calibration** to calculate protons lost and **beam lifetime with 2017 configuration.**
- Simple calibration for online diagnostic
- Decomposition matrix for offline analysis: identification of loss plane, horizontal, vertical and off-momentum



Thank you!