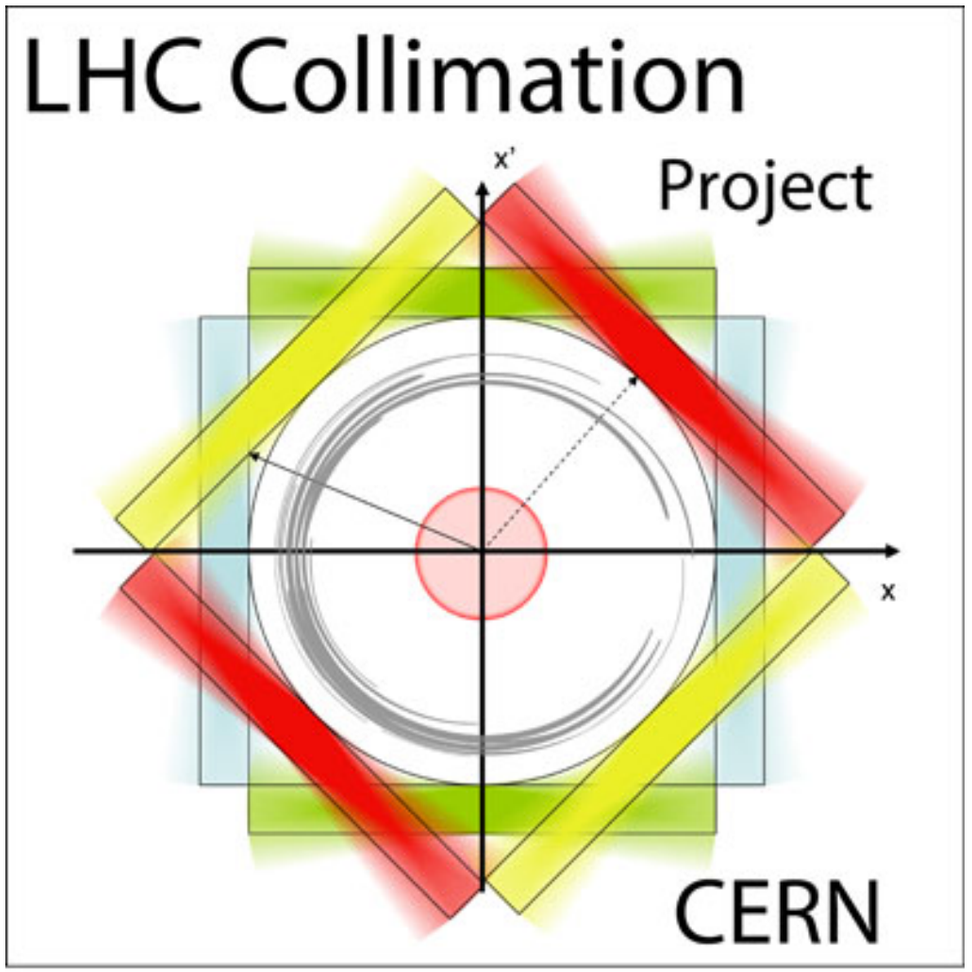
Beam lifetime & (d)BLMs



B. Salvachua and S.Redaelli
Acknowledgments: OP and ABP teams

M.Wyszynki, M.Pojer; J.Barranco, X.Buffat, M.Crouch, A.Gorzawski, T.Pieloni, C.Tambasco, J.Wenninger, C.Xu,

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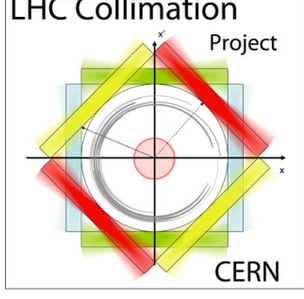

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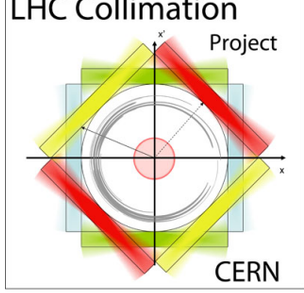

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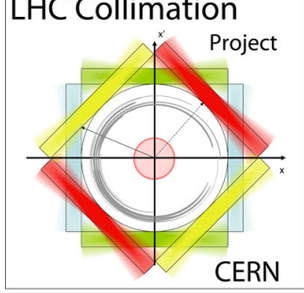

Loss spikes and fast drops of lifetime are a concern for operating machine

↪ they risk of **spurious dumps** for given thresholds of beam loss monitors.

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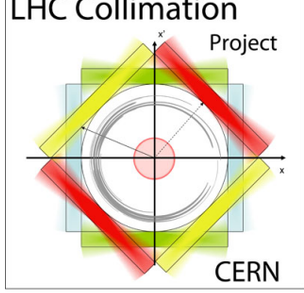

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N_{tot} : beam population [p]

τ_{beam} : beam lifetime [s]

$\frac{dN}{dt}$: loss rate [p/s]

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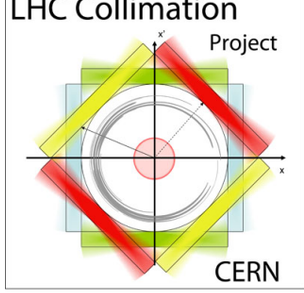

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Beam lifetime could be used as an indicator of the machine performance

↪ precise measurement of the **beam loss rate in p/s** is needed

$$\tau = -\frac{\Delta t}{\ln\left(1 - \frac{R_{loss} \times \Delta t}{N_{tot}}\right)}$$

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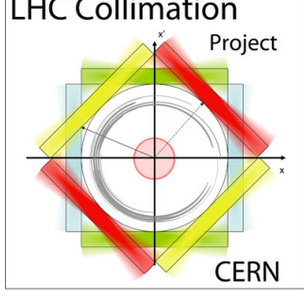
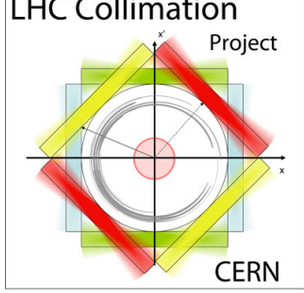


Measurement of beam losses



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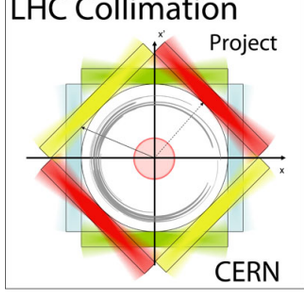

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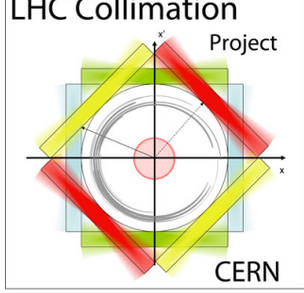

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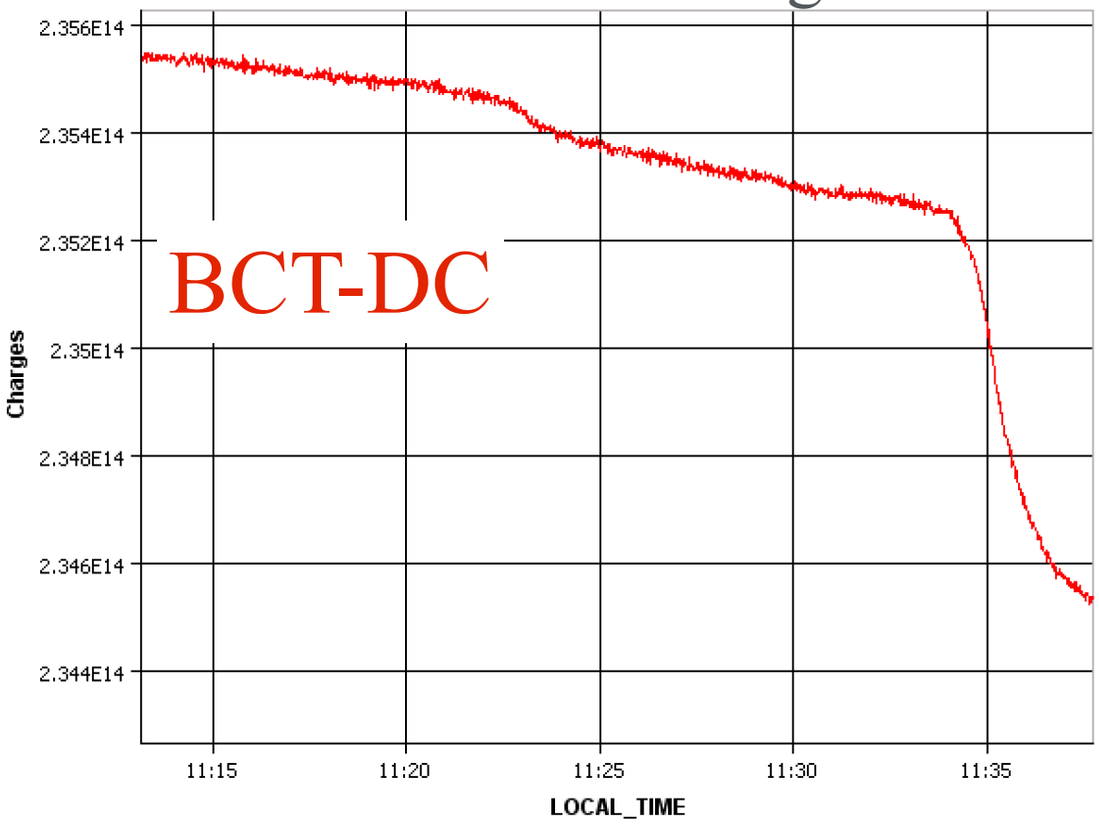

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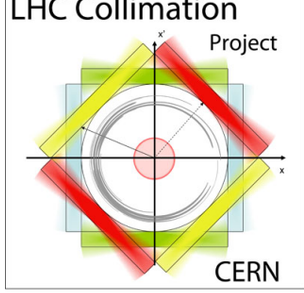

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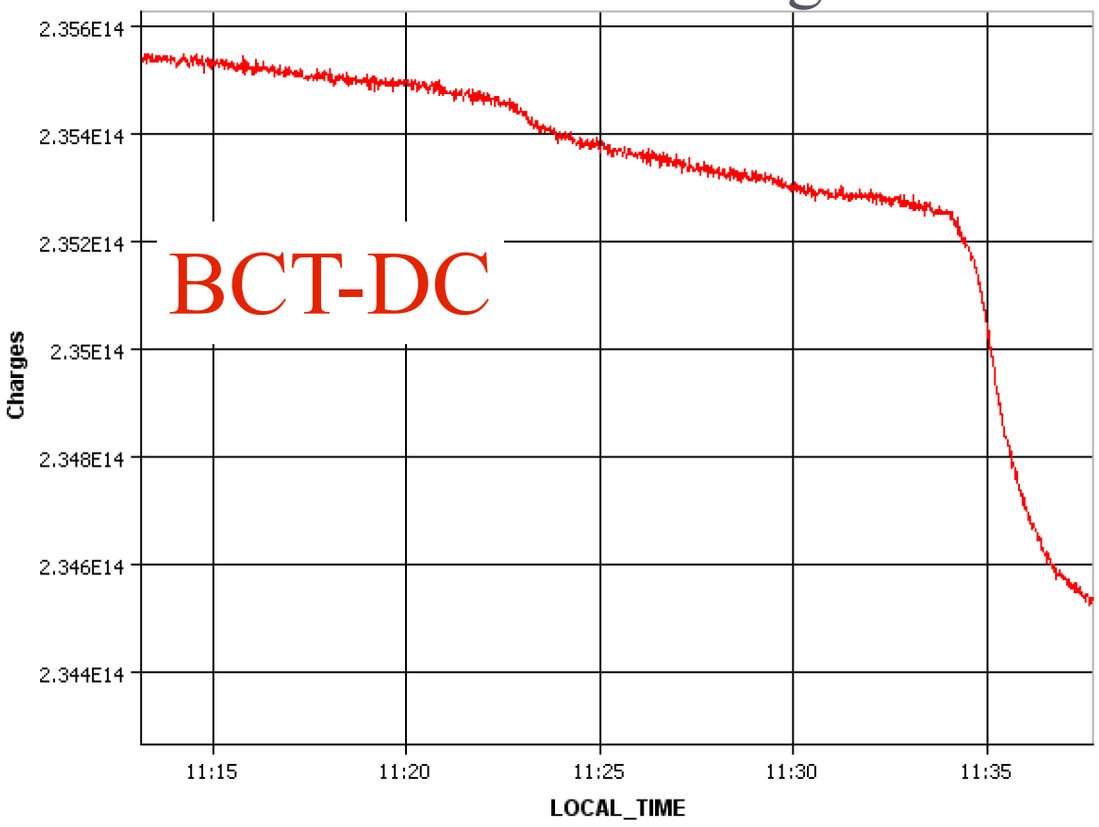

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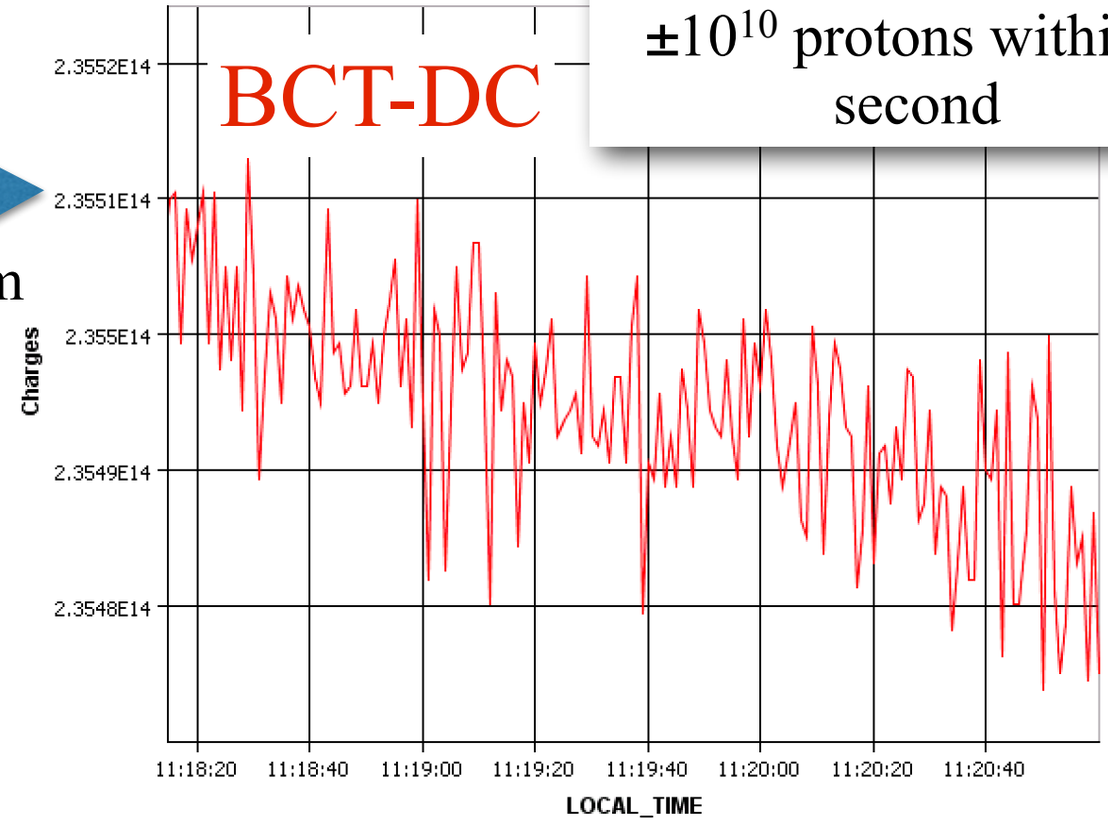

Fluctuations of $\pm 10^{10}$ protons within 1 second

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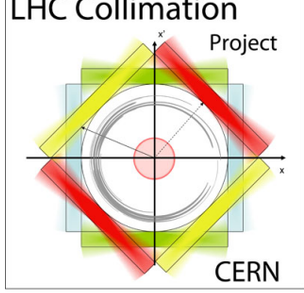

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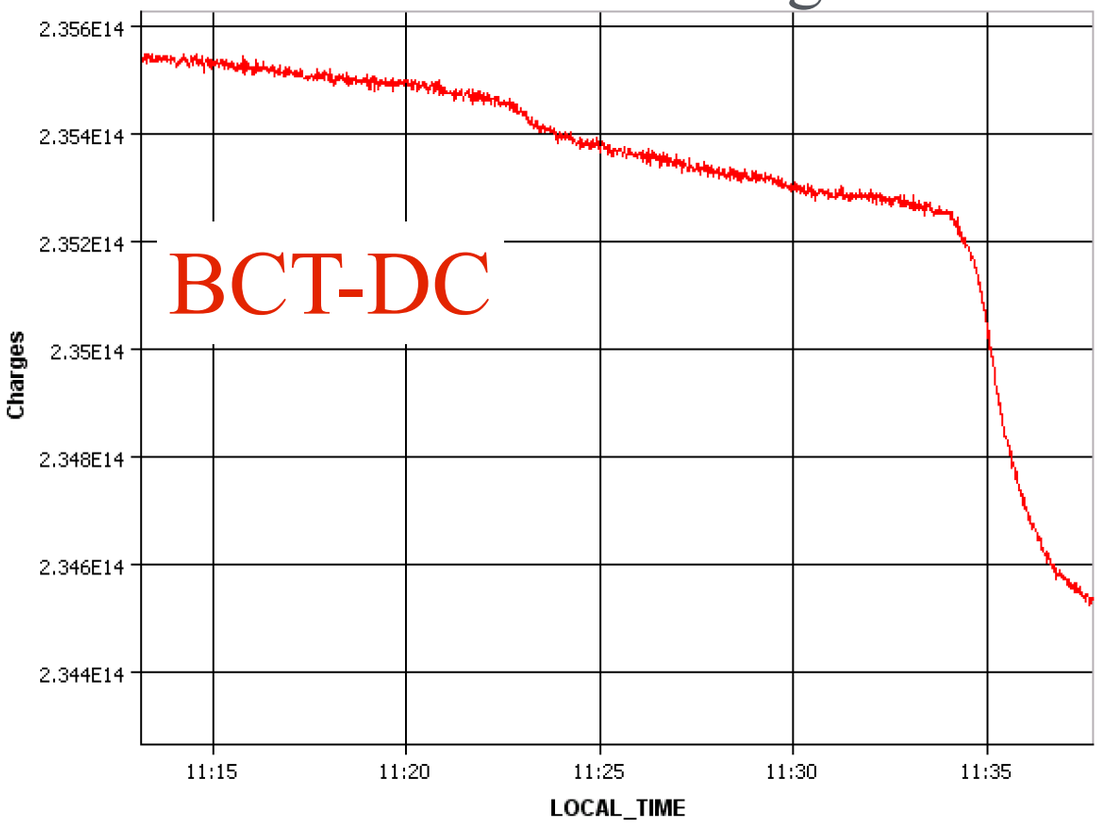

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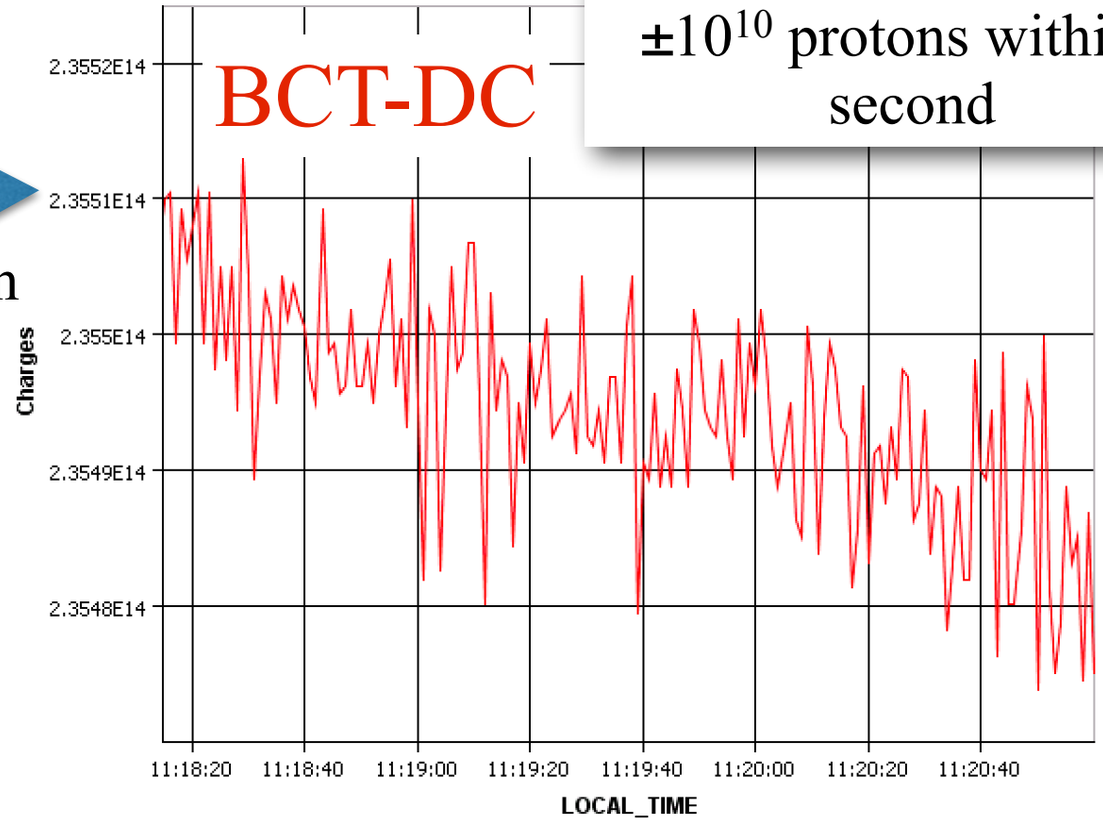

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A reduction of noise in the BCT signal will be very useful. Already the ADC24BIT of BCTDC has improved significantly the lifetime calculation, but the signal is not always available.

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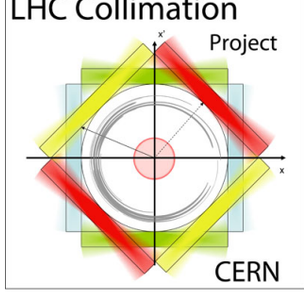

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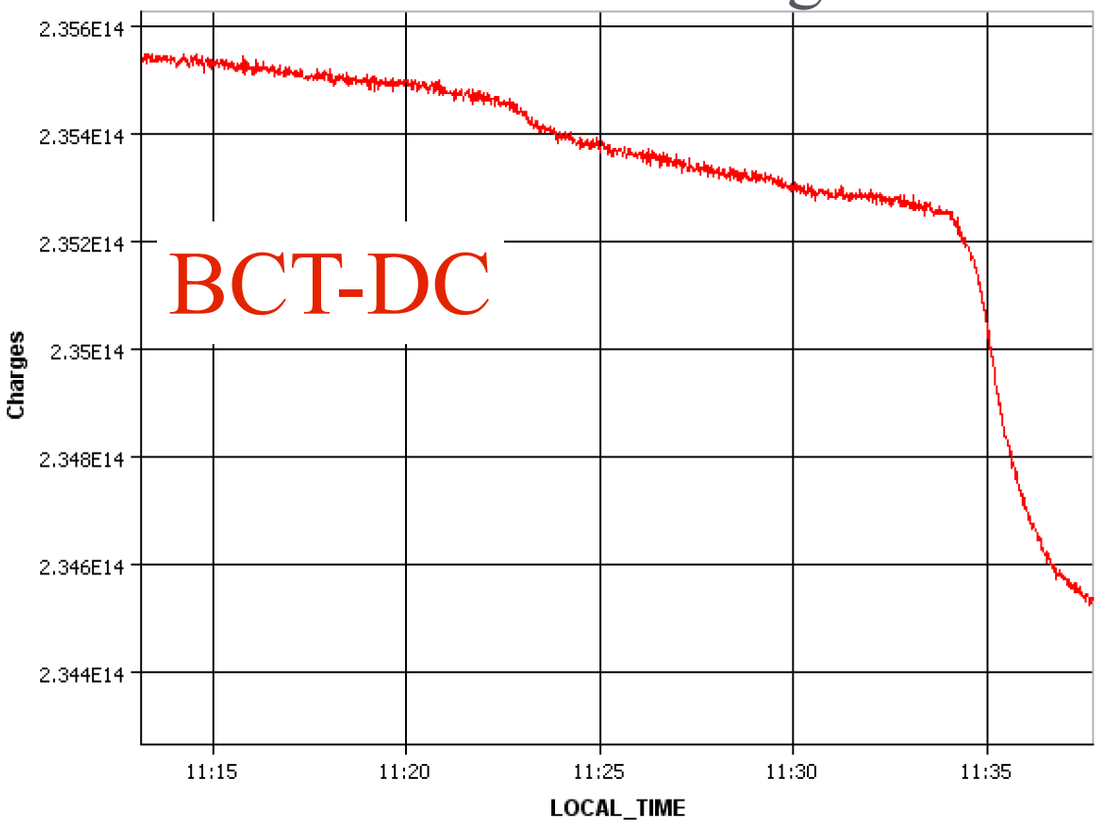

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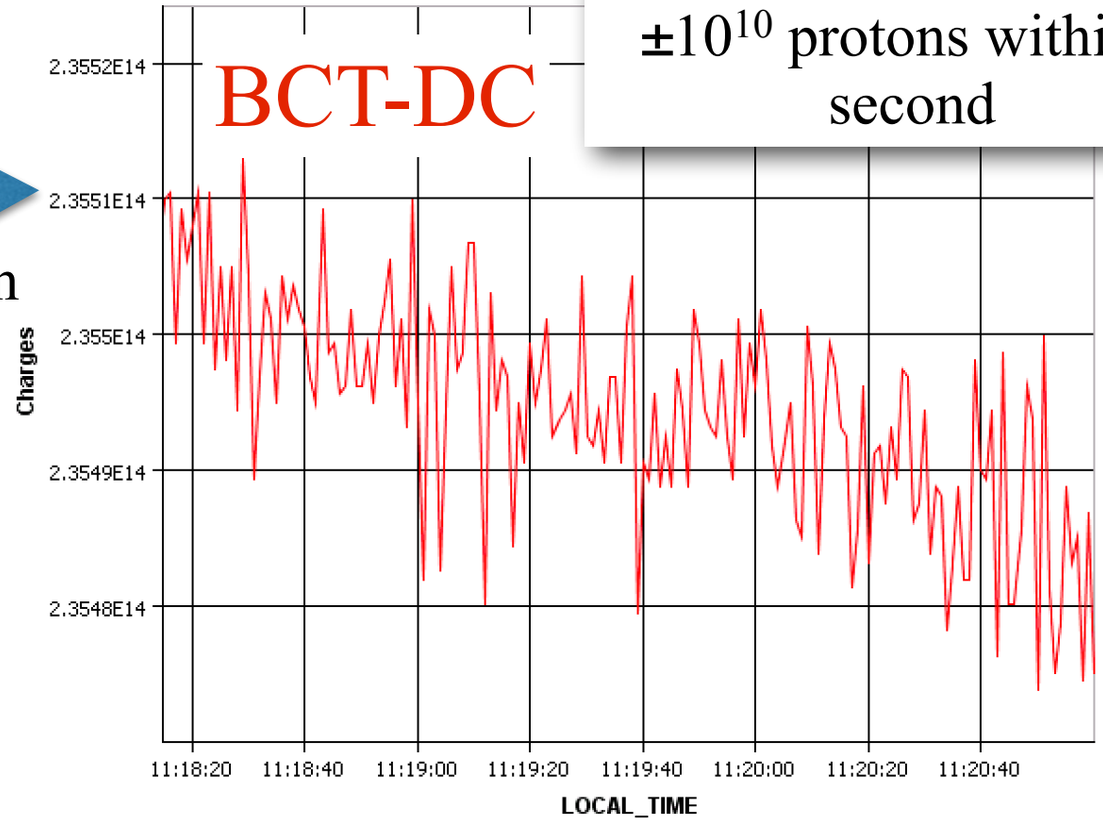

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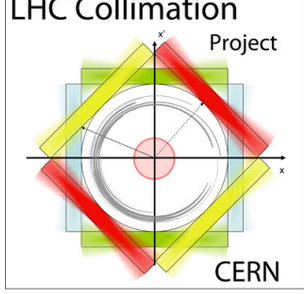
Other devices such as beam loss monitors could be used for this measurement and have additional advantages for the measurement of the proton loss rate.

Measurements of losses



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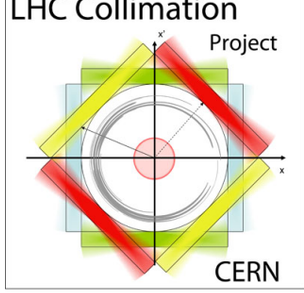

Assuming that **primary losses** occur **at the collimators**

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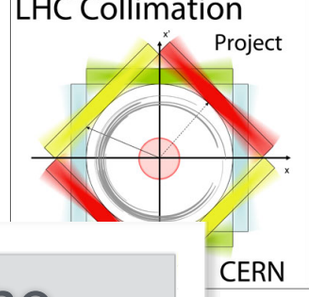

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True for most of the scenarios, except UFO

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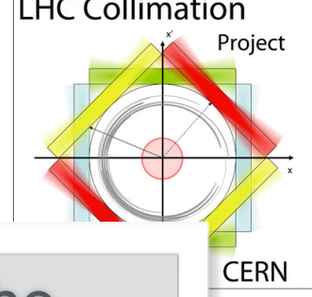

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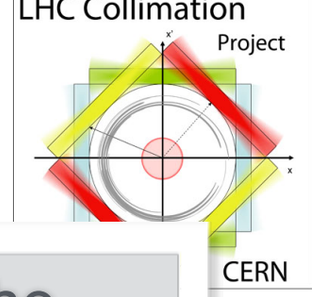

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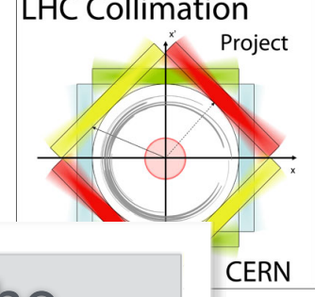

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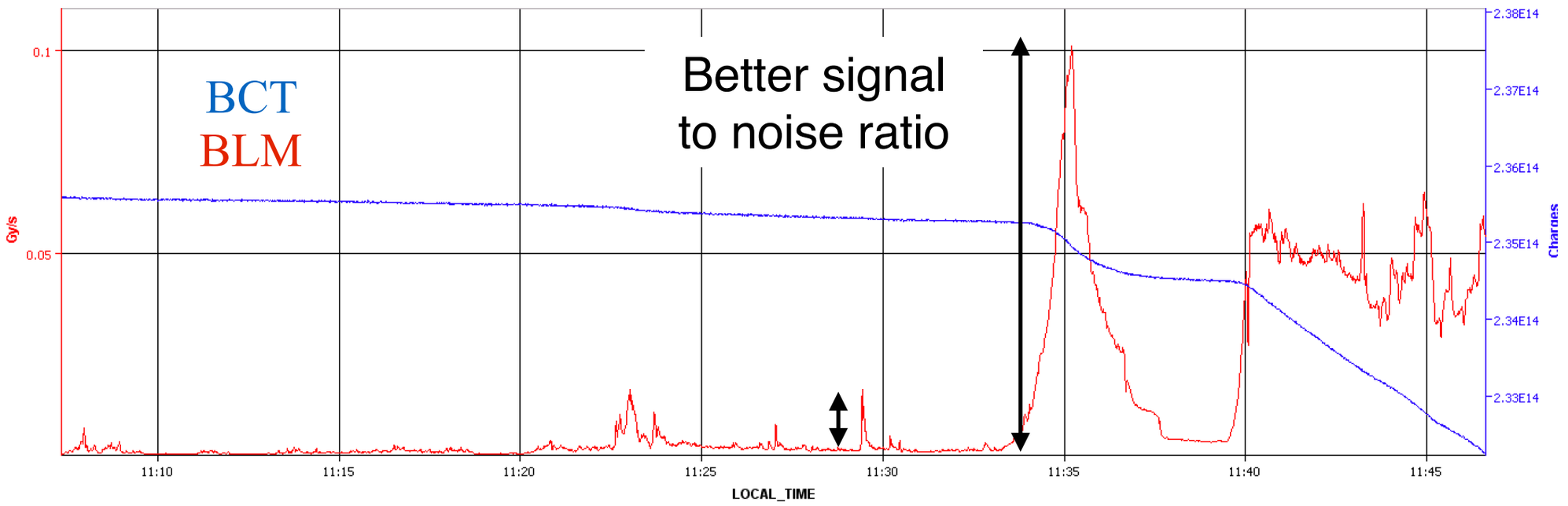

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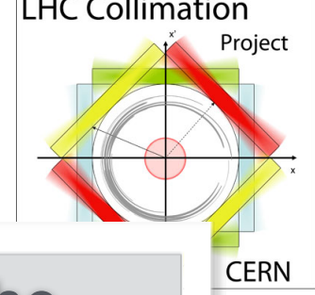

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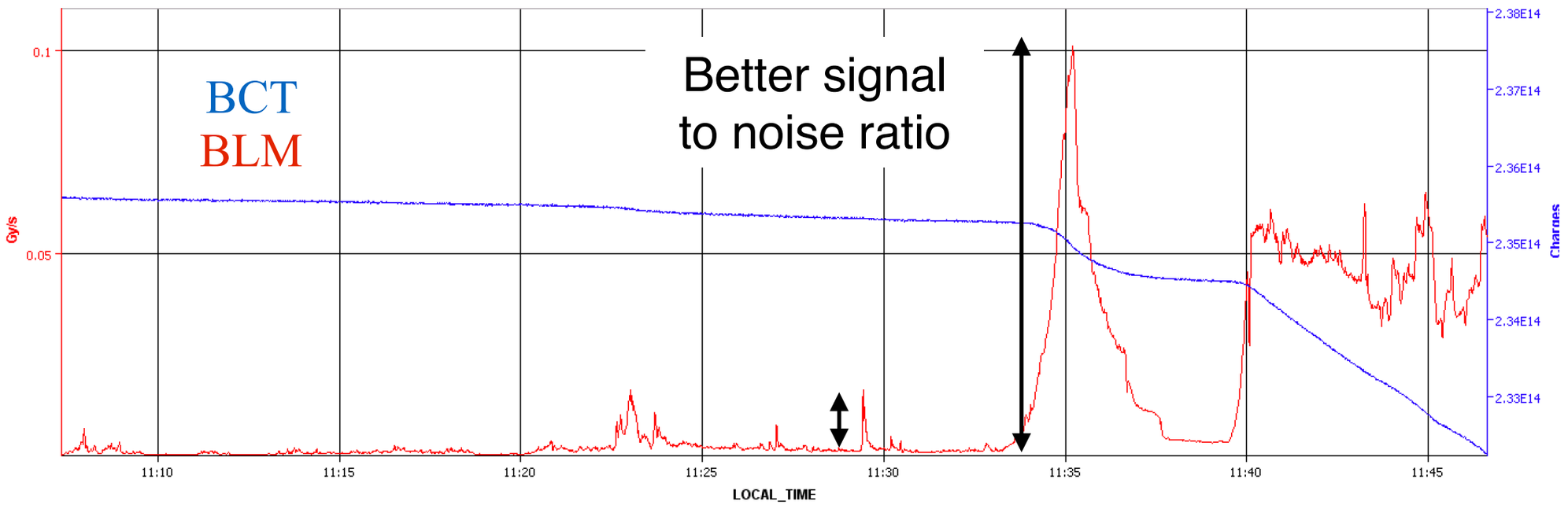
New!! Diamond detectors: extremely fast —> **bunch-by-bunch information**



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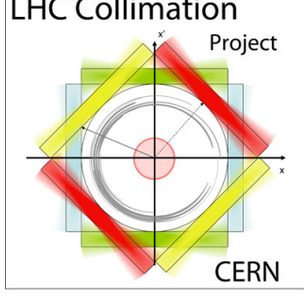

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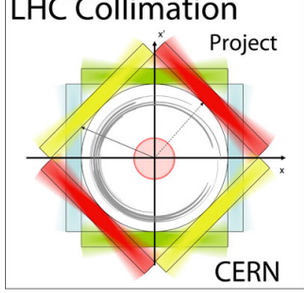

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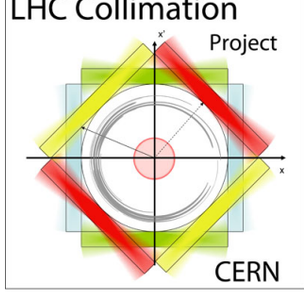

Calibration of BLMs from Gy/s to protons per second

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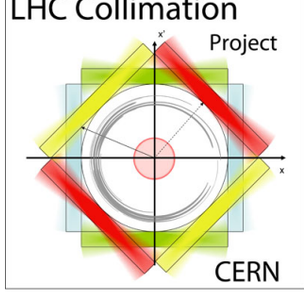

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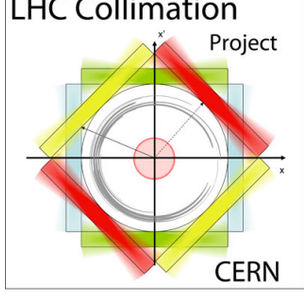

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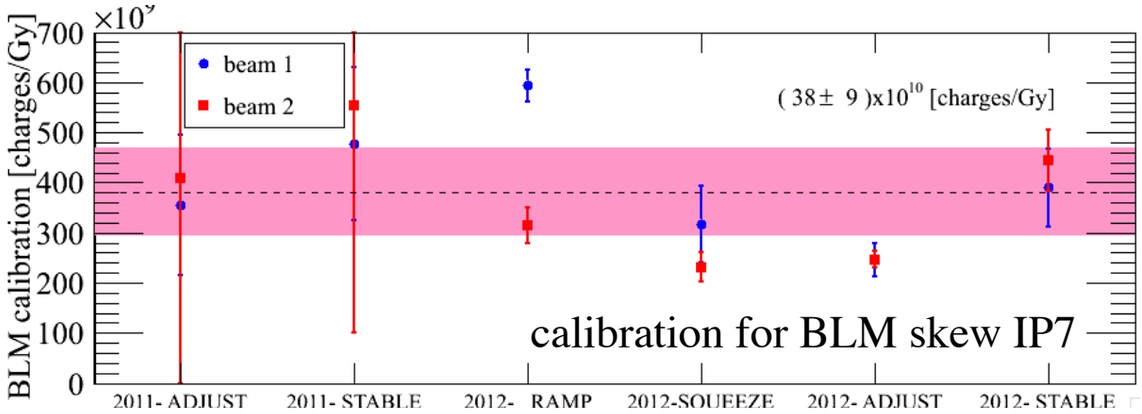

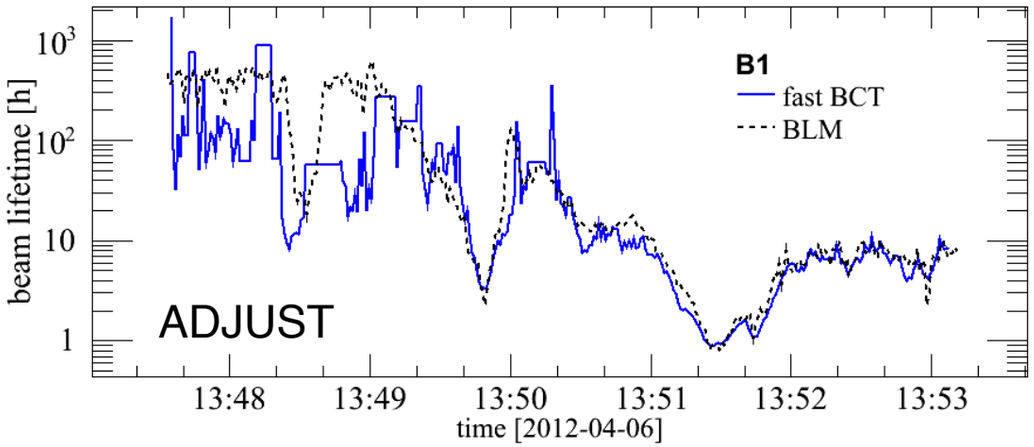

Belen et al. "Lifetime Analysis at High Intensity Colliders Applied to the LHC", IPAC2013

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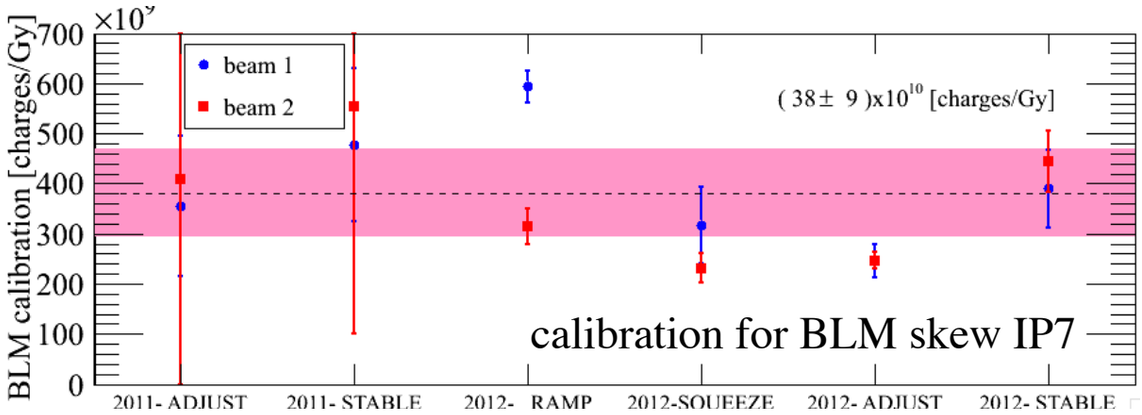

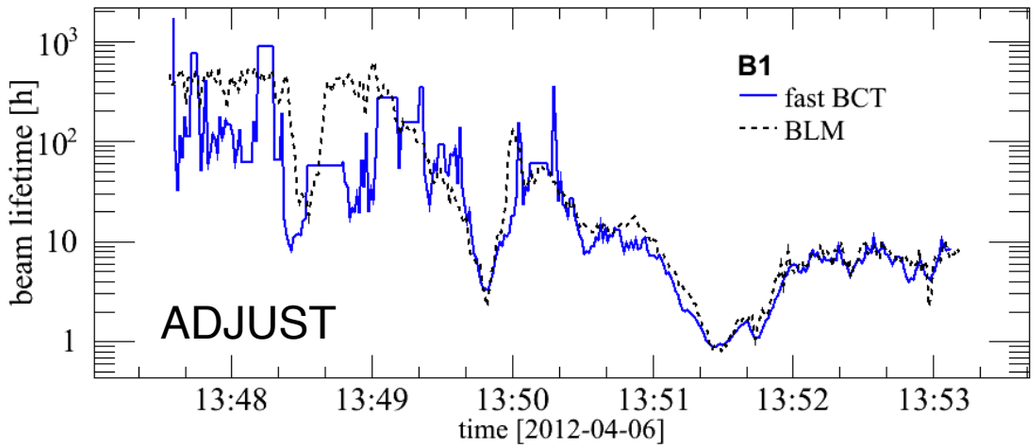

This gave good results, sensitive to fast losses and relatively good calibration for low losses

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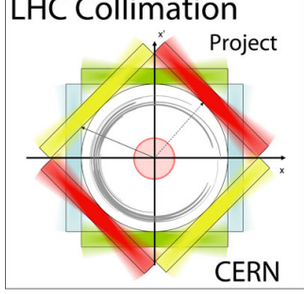

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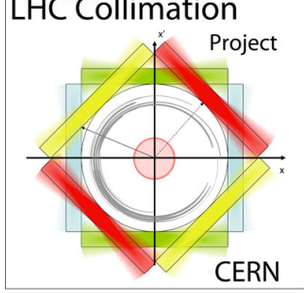

In addition to the BLM calibration we add the characterisation of the type of loss

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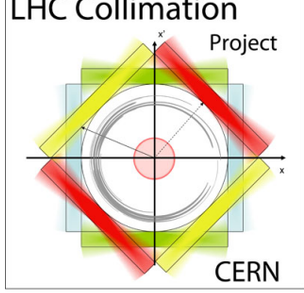

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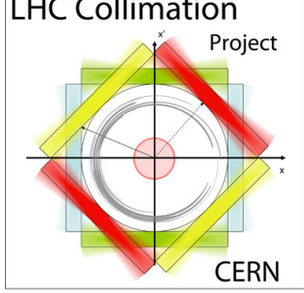

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Calibration through controlled loss scenarios parasitic to operation: ***LOSS MAPS***

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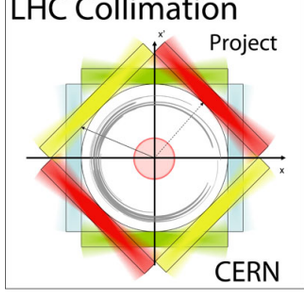

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Decomposition of loss profiles as linear combination of the well-defined scenarios

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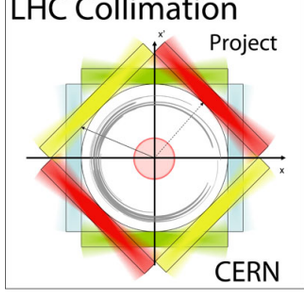

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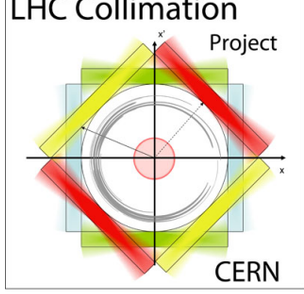
Calibration through controlled loss scenarios parasitic to operation: ***LOSS MAPS***

Decomposition of loss profiles as linear combination of the well-defined scenarios

Result		Matrix built from reference lossmaps		Measurement of BLMs
B1H				BLM 1
B1V				BLM 2
B2H	$=$	$(\cdots)$		$\vdots$
B2V				
B1 off mom.				
B2 off mom.				

M.Wyszynski
(LBOC and Coll. WG)

BLM calibration - Run II



In addition to the BLM calibration we add the characterisation of the type of loss

betatron losses in IR7 (vertical or horizontal) and off-momentum losses in IR3

Calibration through controlled loss scenarios parasitic to operation: ***LOSS MAPS***

Decomposition of loss profiles as linear combination of the well-defined scenarios

Result — Matrix built from reference lossmaps — Measurement of BLMs

$$\begin{pmatrix} \text{B1H} \\ \text{B1V} \\ \text{B2H} \\ \text{B2V} \\ \text{B1 off mom.} \\ \text{B2 off mom.} \end{pmatrix} = \begin{pmatrix} \cdots \end{pmatrix} \begin{pmatrix} \text{BLM 1} \\ \text{BLM 2} \\ \vdots \end{pmatrix}$$

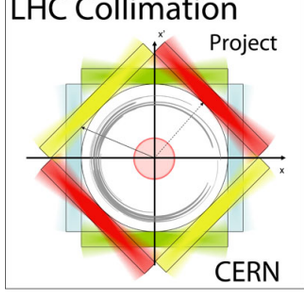
M.Wyszynski
(LBOC and Coll. WG)

Result is the number of protons lost per second due to each loss scenario

$$\text{BiH} + \text{BiV} + \text{Bi off mom.} \approx -\frac{dI(\text{Bi})}{dt} \qquad i \in \{1, 2\}$$

Online information

Online information



This **algorithm** to characterise the loss plane is **available for MDs**, included in the **LHC lifetime application.**

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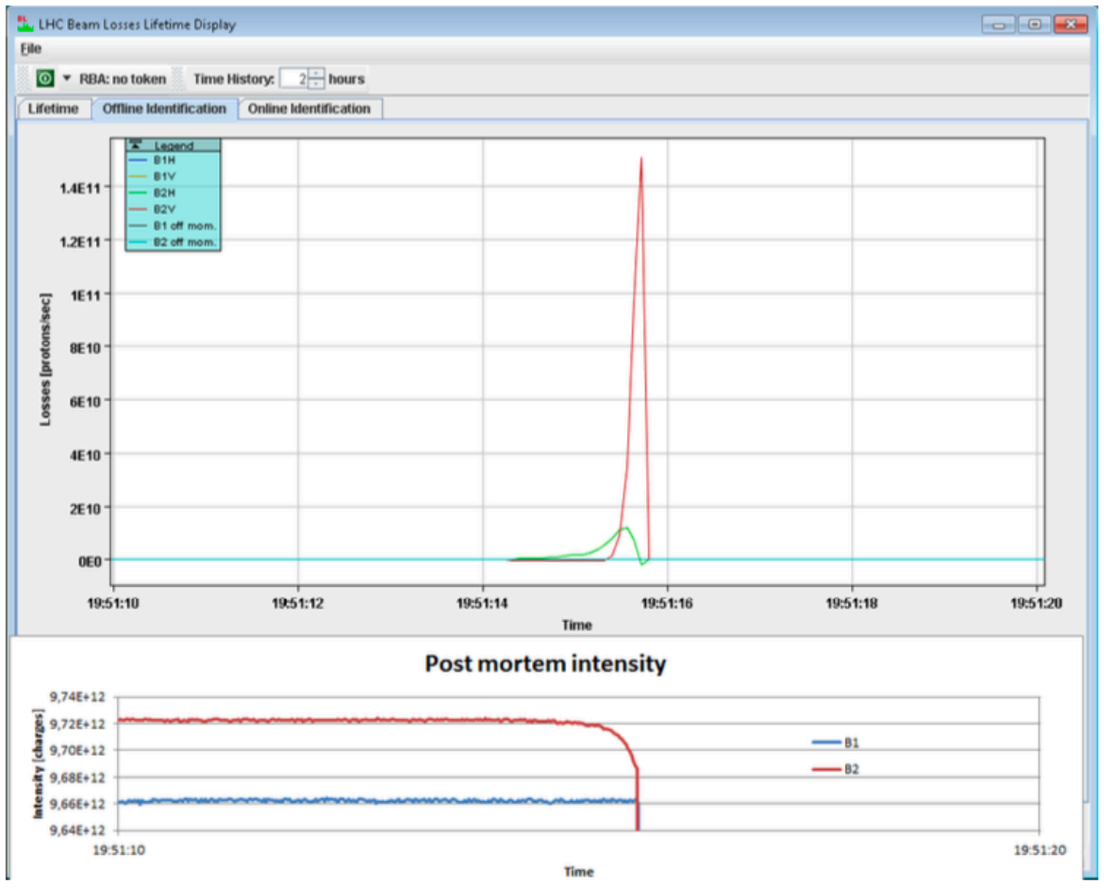
example of the online display: B2V instability



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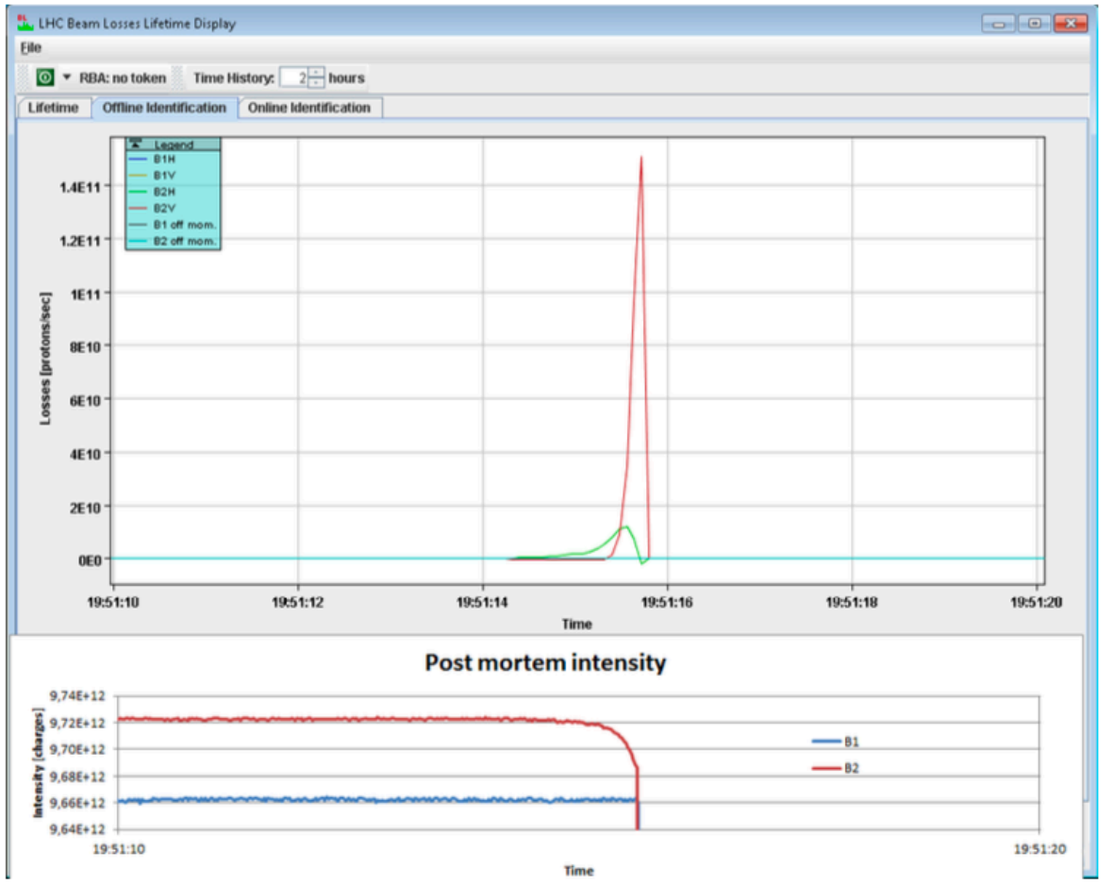

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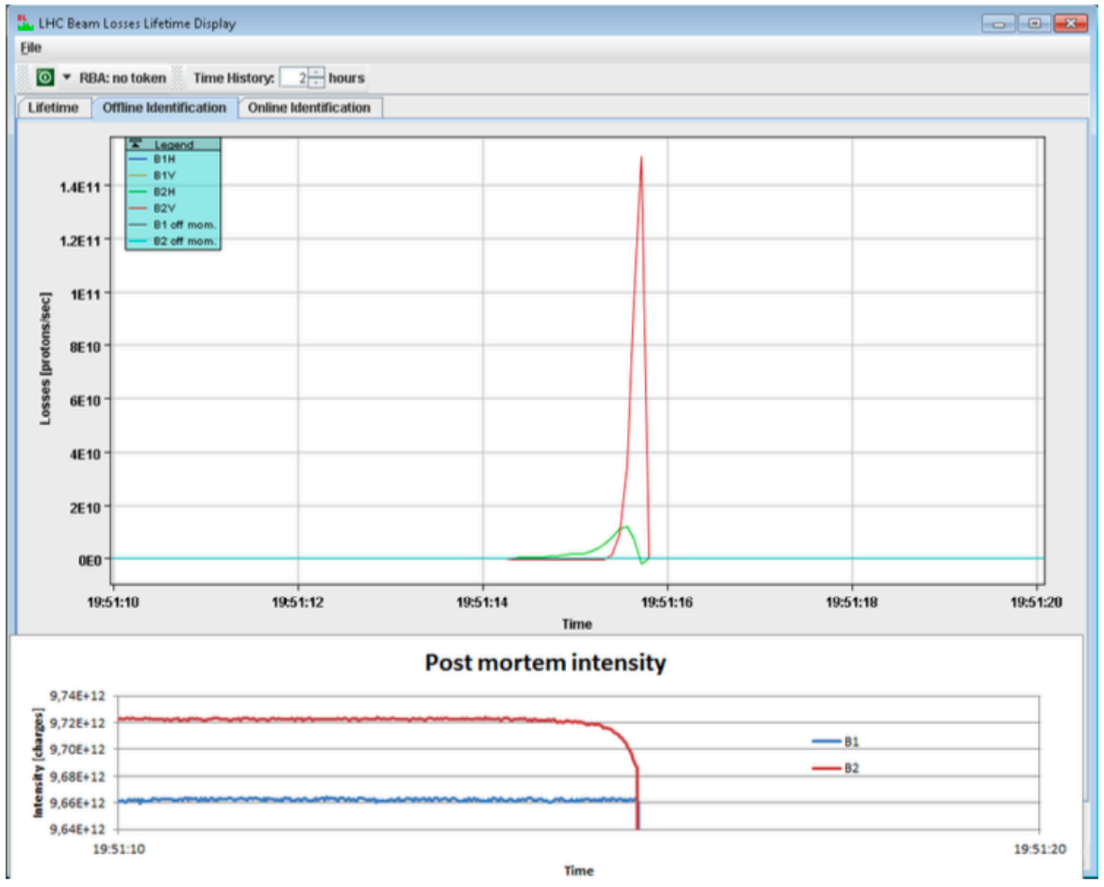
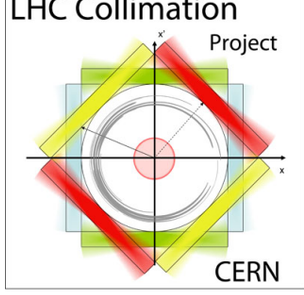


Result of algorithm:

1) Loss rate in protons per second
2) Identification of losses in:
   - IR3
   - IR7
3) Identification of loss plane for betatronic losses:
   - Vertical
   - Horizontal

Usage of BLM



Examples of usage of BLM data calibration and decomposition

Analysis of regular fills in 2016

- Beam lifetime analysis for Run I and Run II

- Study of losses during crossing angle change

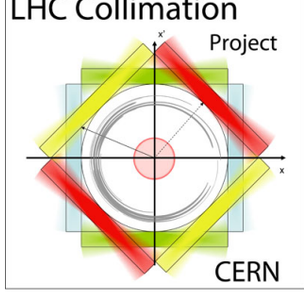
LRBB limits (change of crossing angle)

Study of lifetime drop during squeeze at 1.4m beta-star

Study of losses during collisions

LRBB MD

LRBB MD



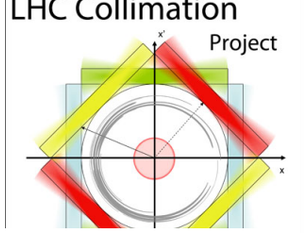
During beam-beam limits MD

LRBB MD

During beam-beam limits MD

Calculation of losses vs crossing angle

LRBB MD



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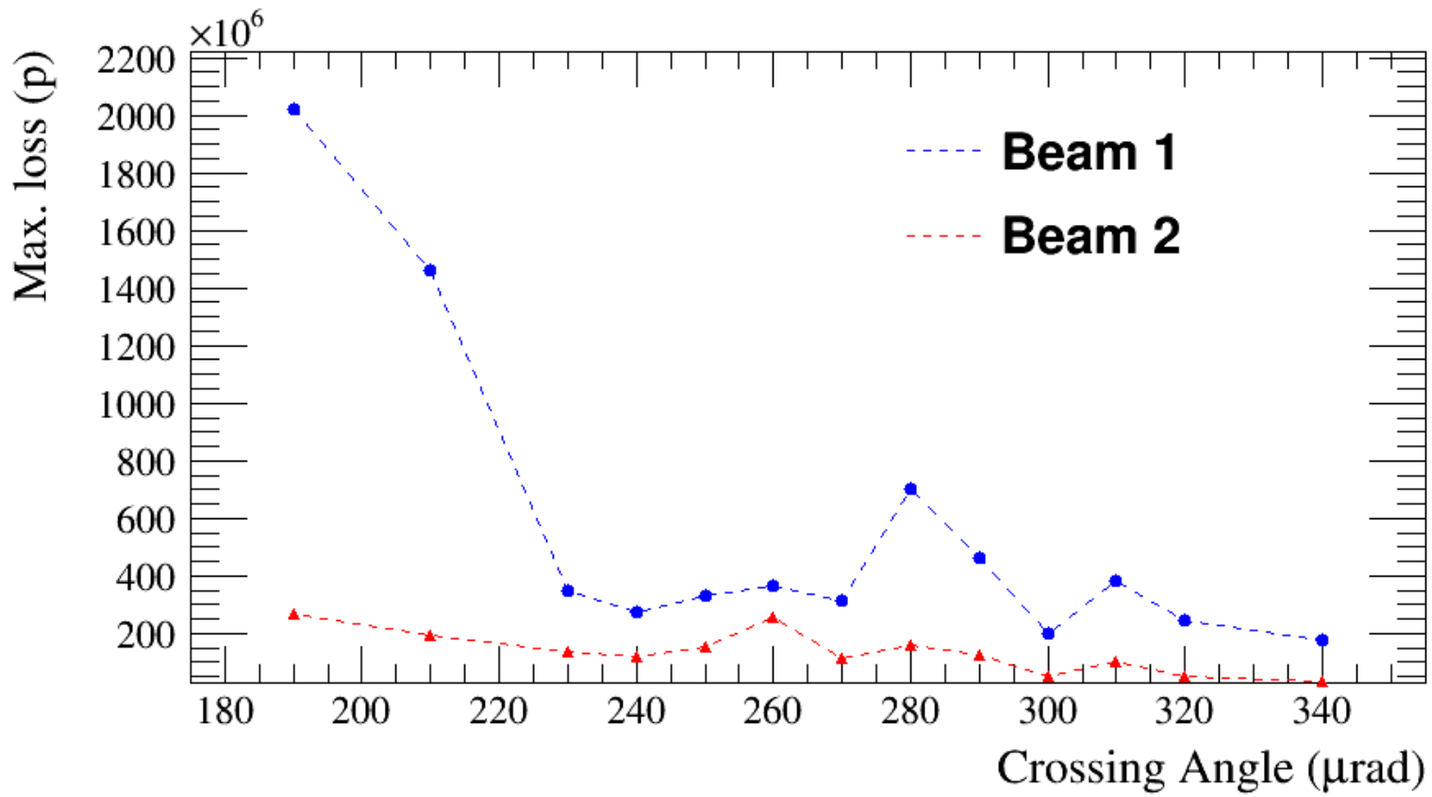

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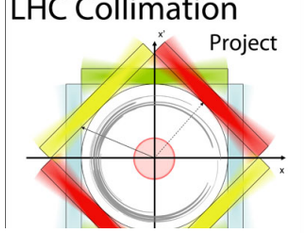

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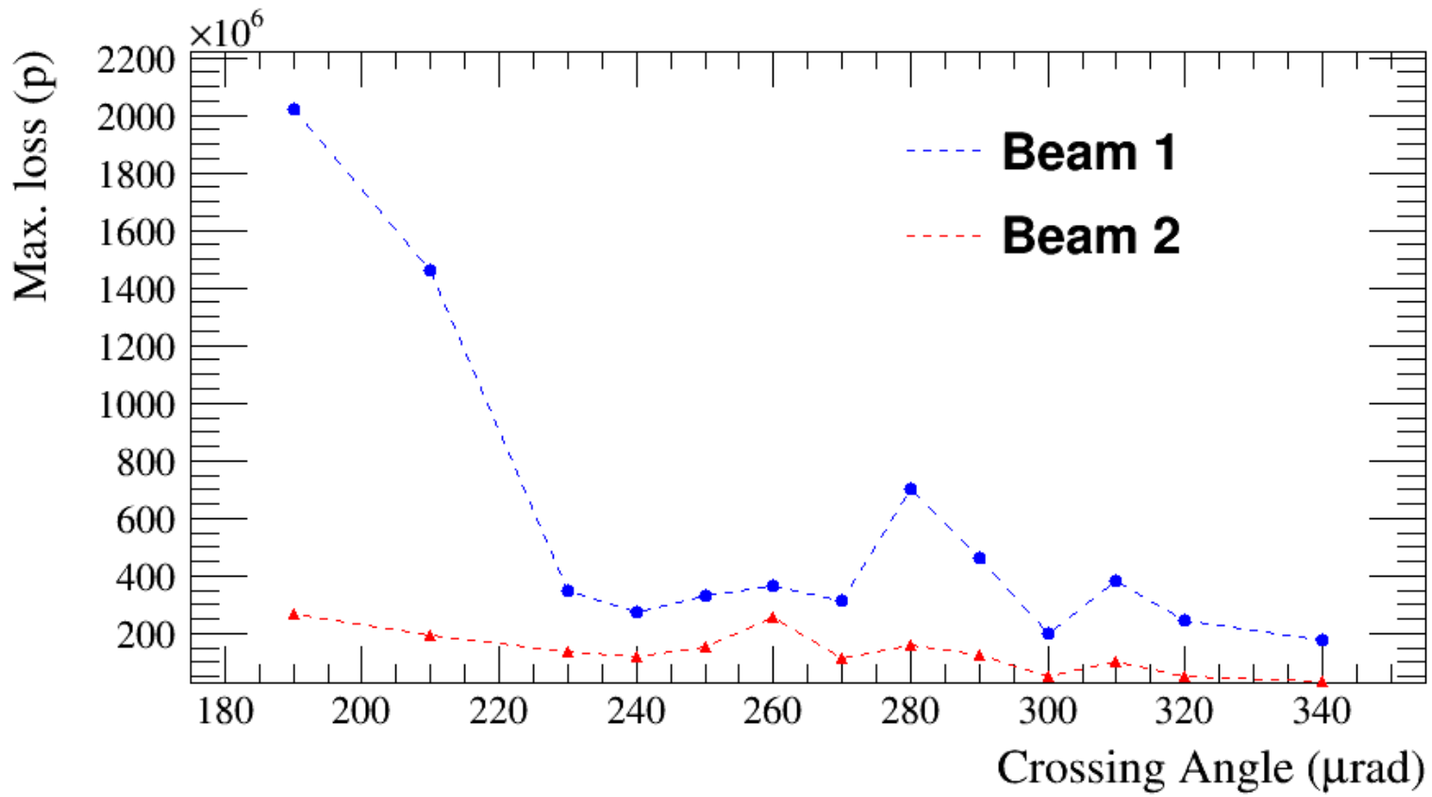
↪ **Observation of losses for Beam 1 starting at 230urad**



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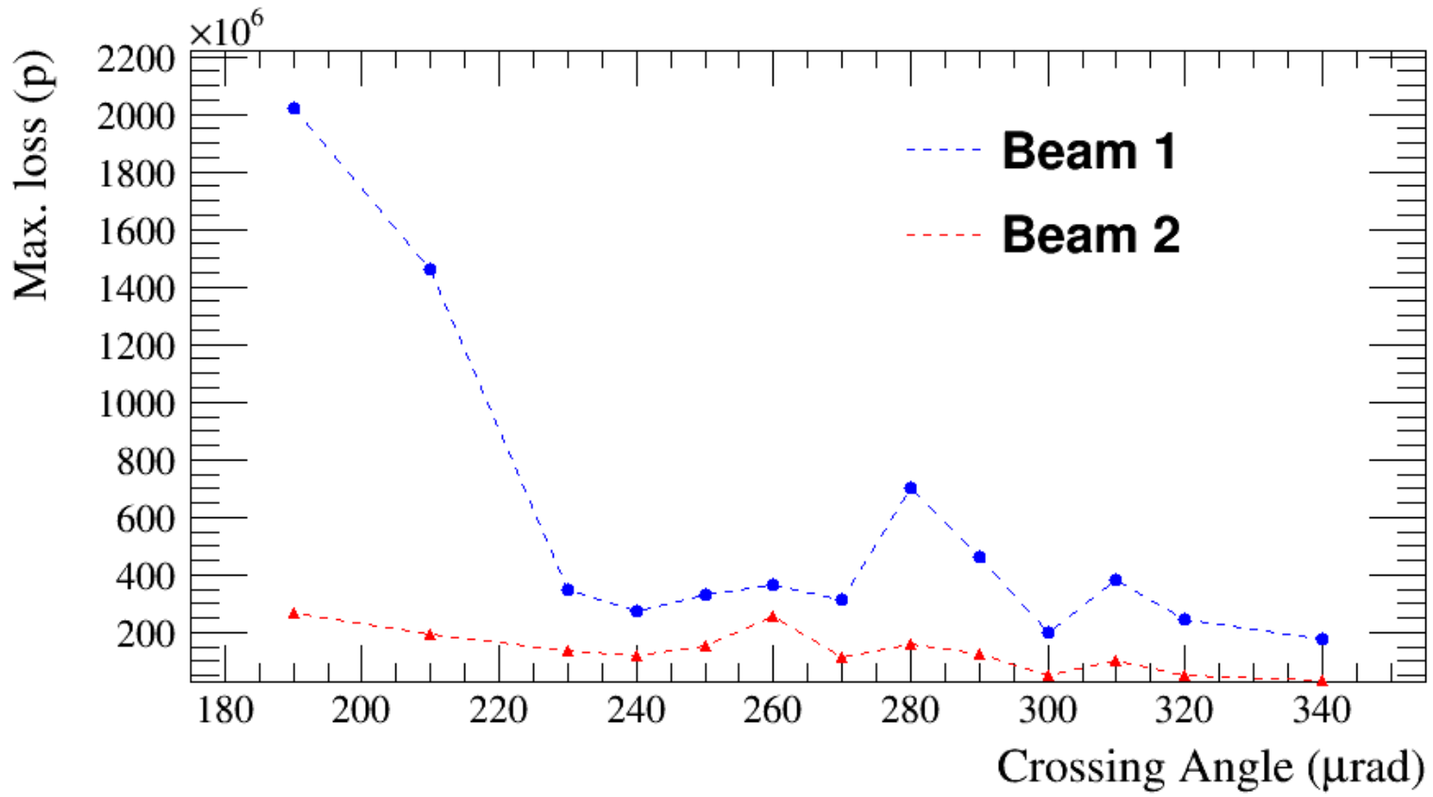
Decomposition of losses shows that are mainly in the **vertical plane**



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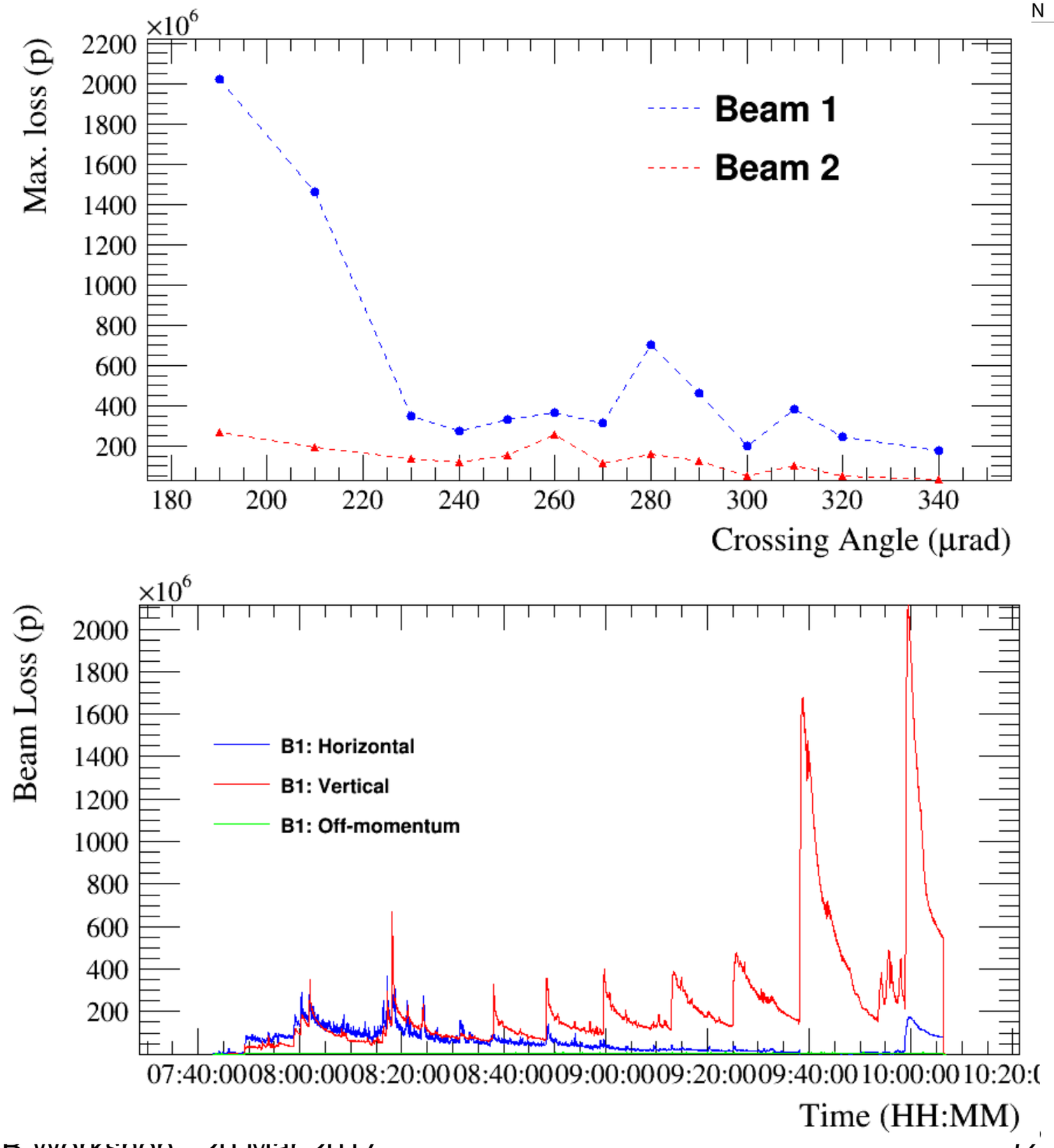

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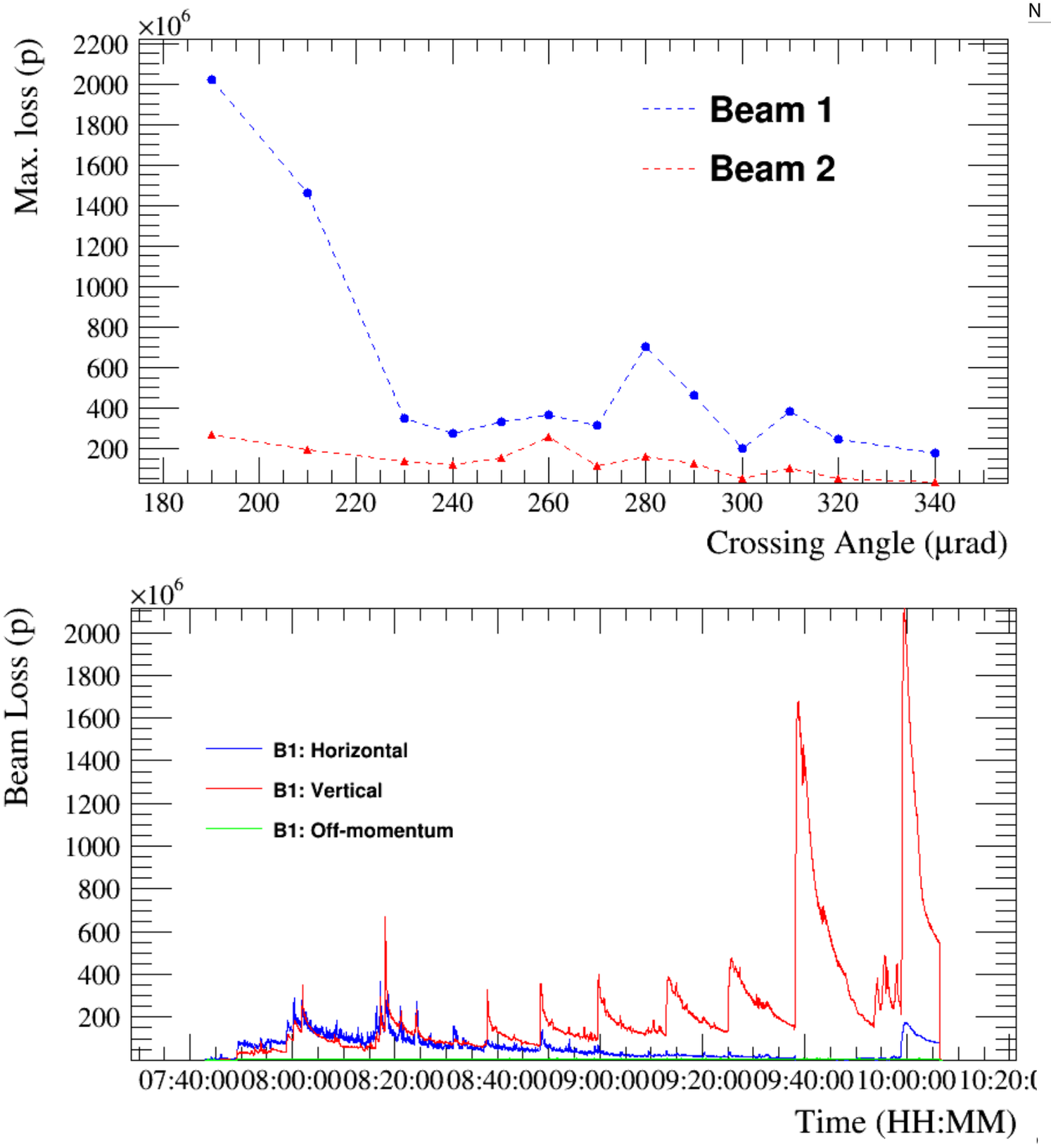

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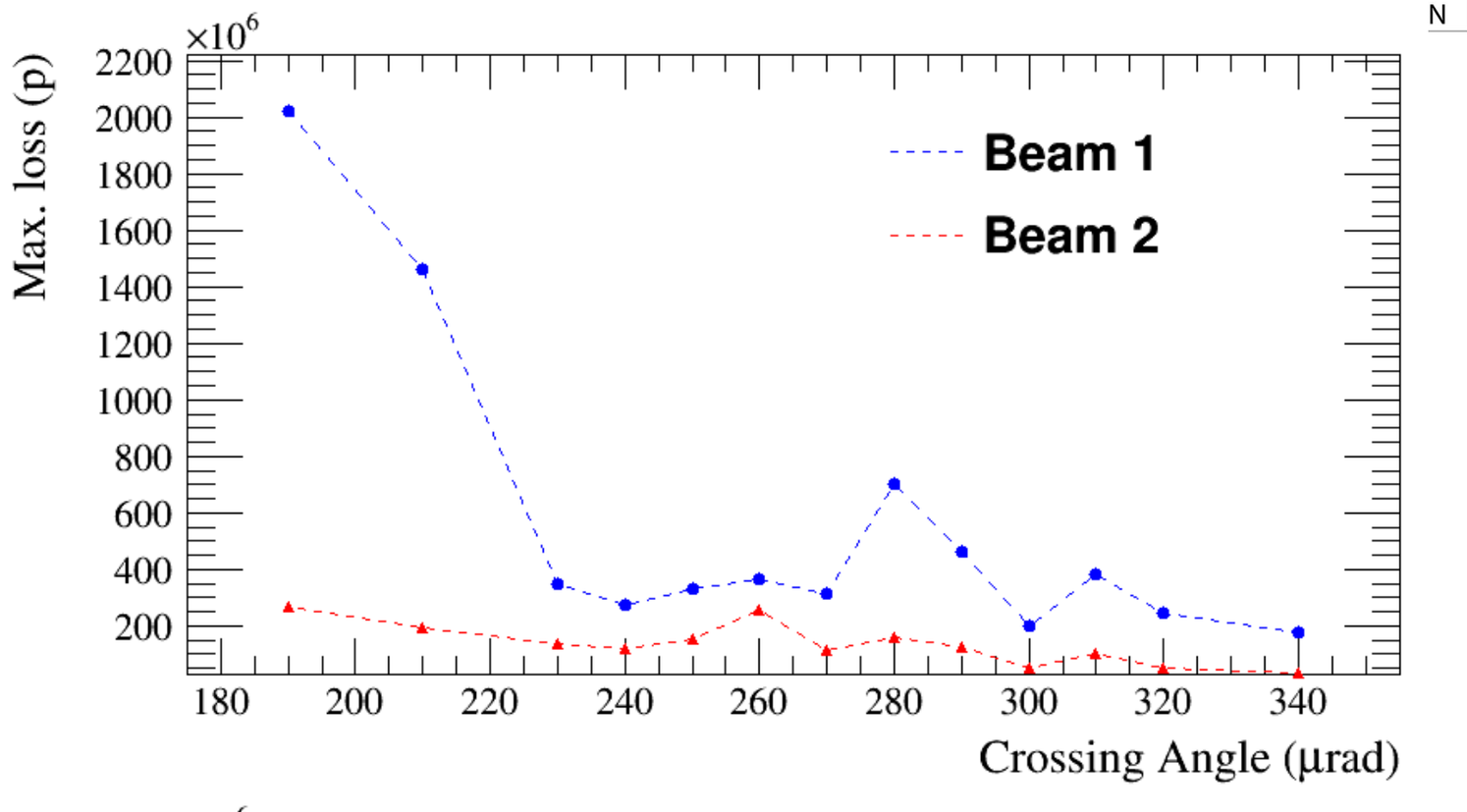
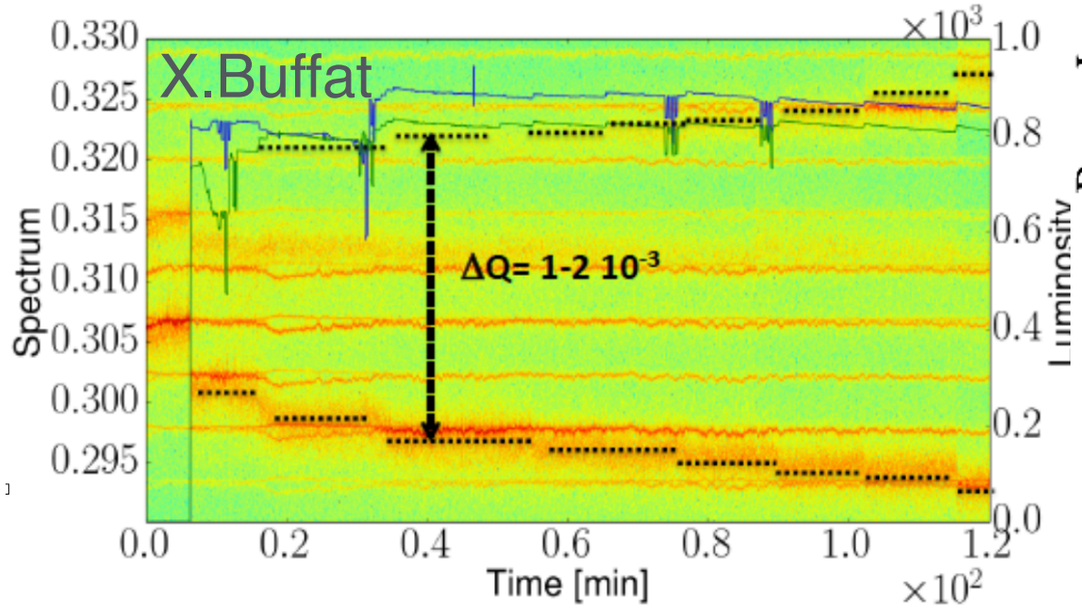
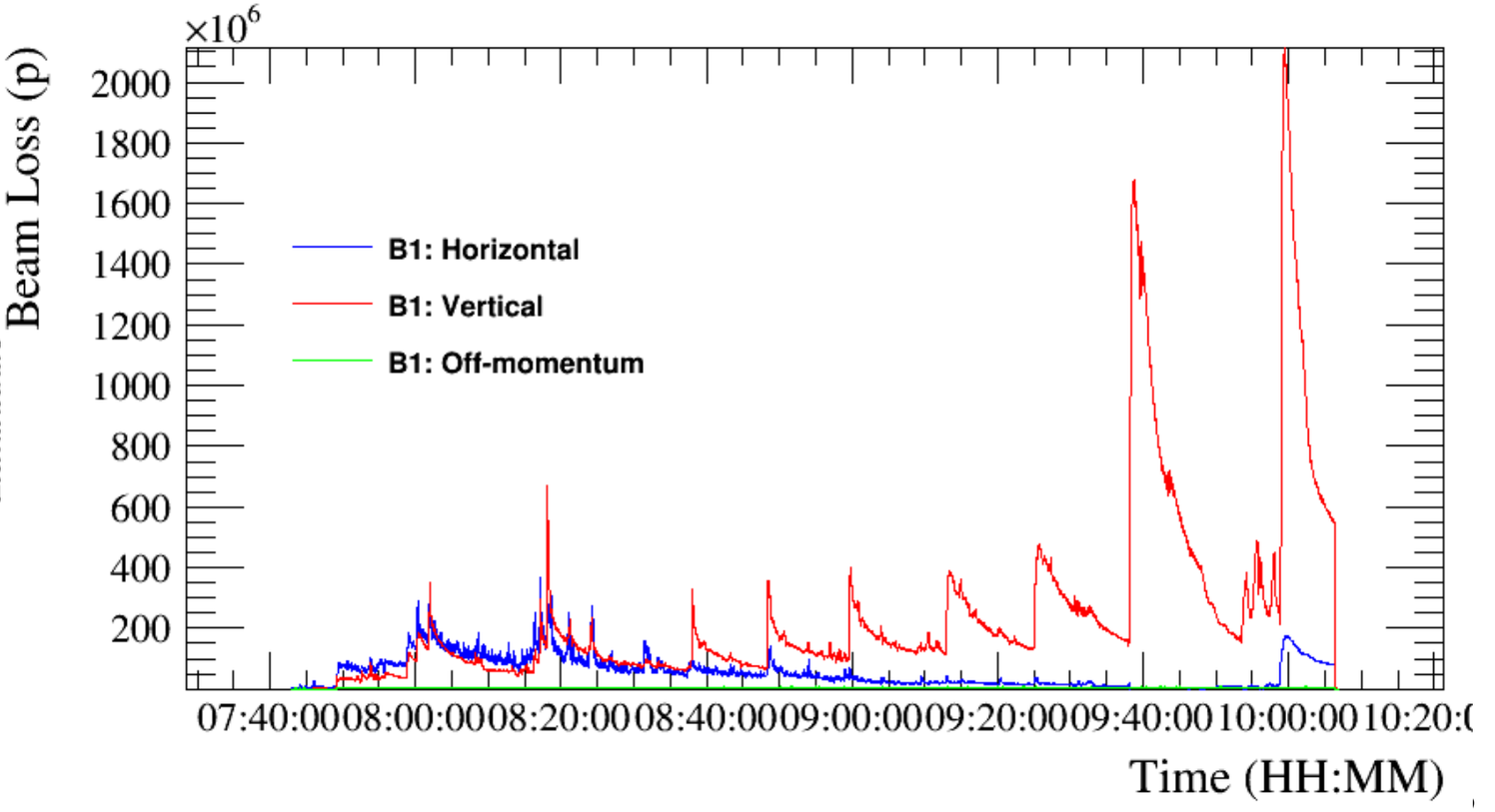
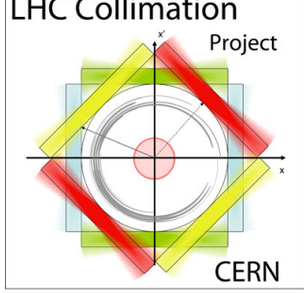






Losses crossing angle



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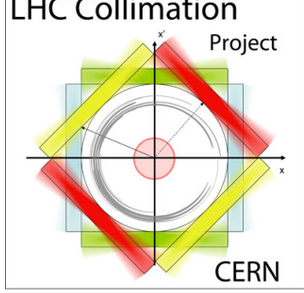
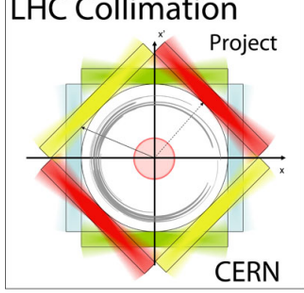


First indicator: drop in beam lifetime

↪ After squeeze during the reduction of crossing angle, lifetime drop for Beam 1 from > 100 h to below 10 h.

Losses crossing angle



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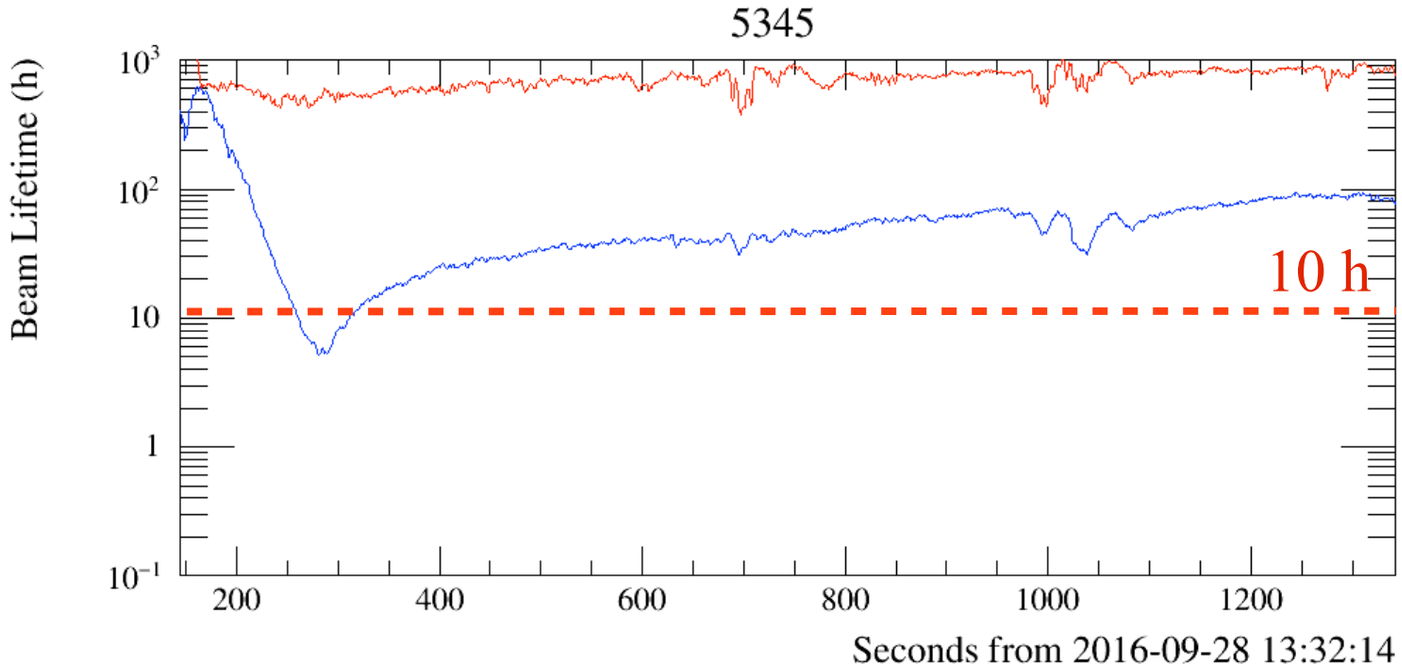

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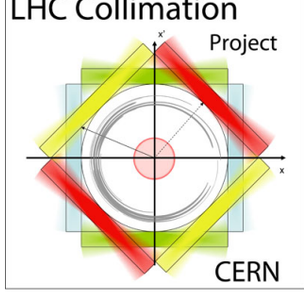

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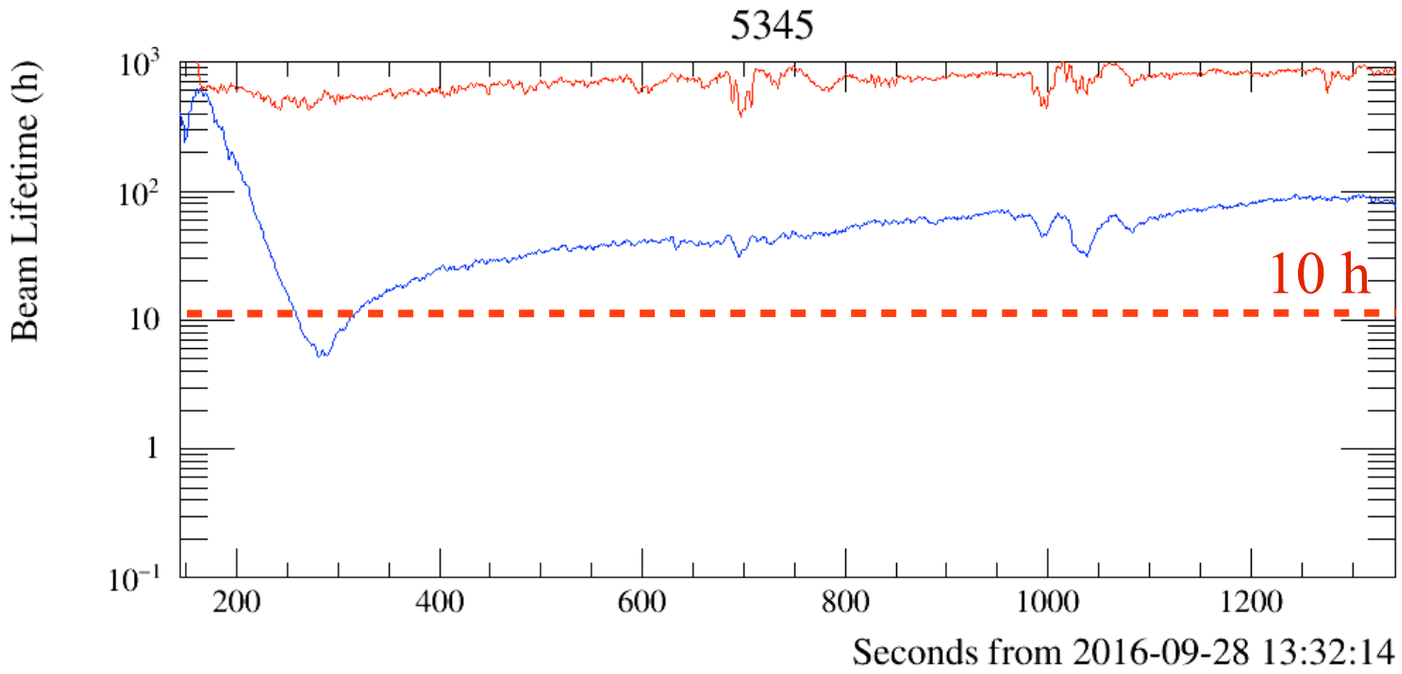

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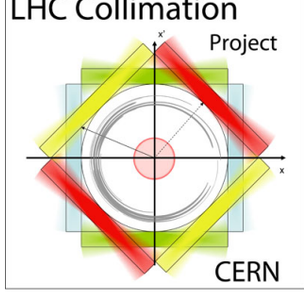

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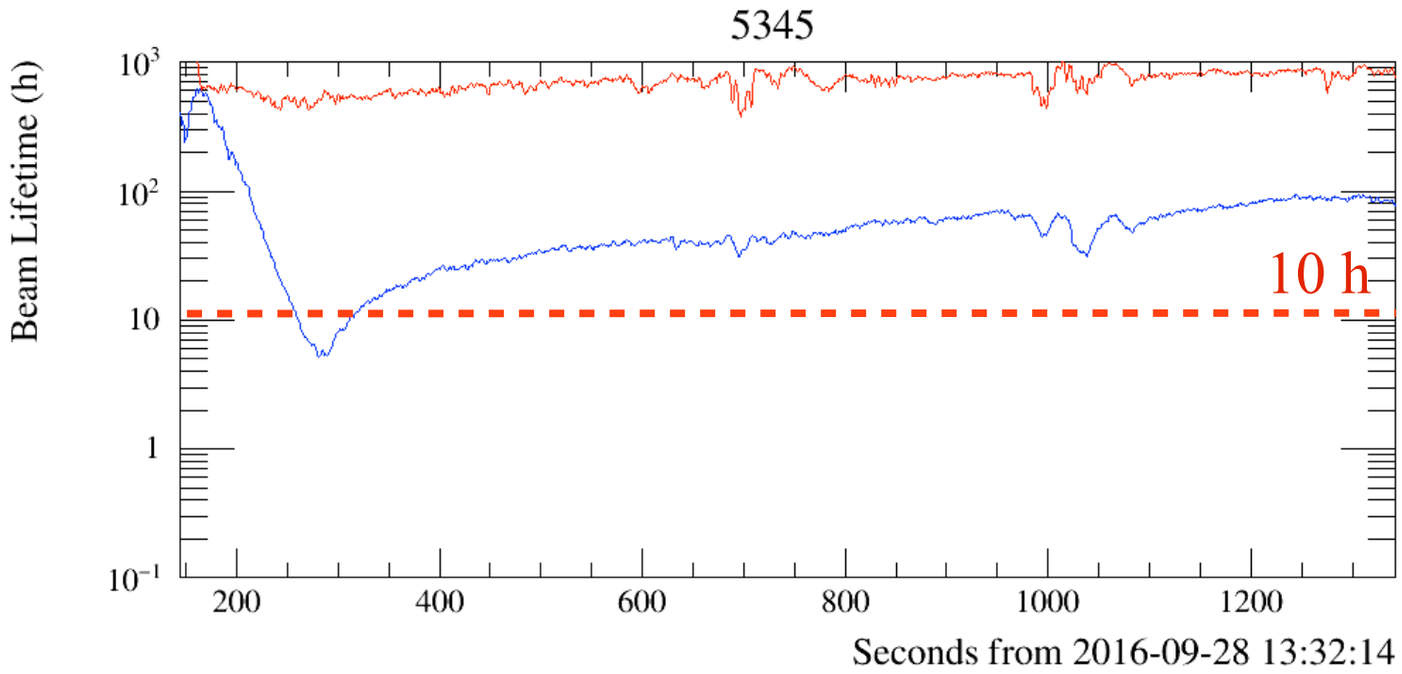

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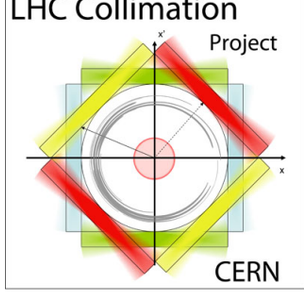

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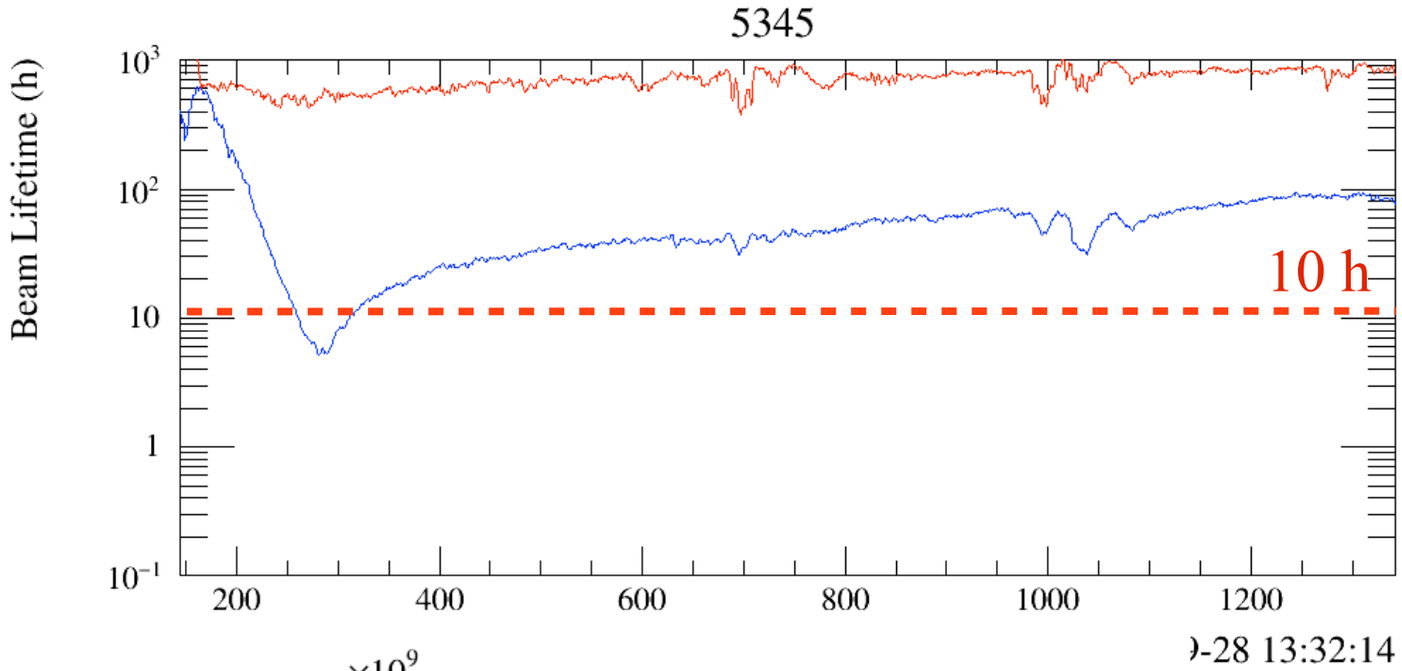

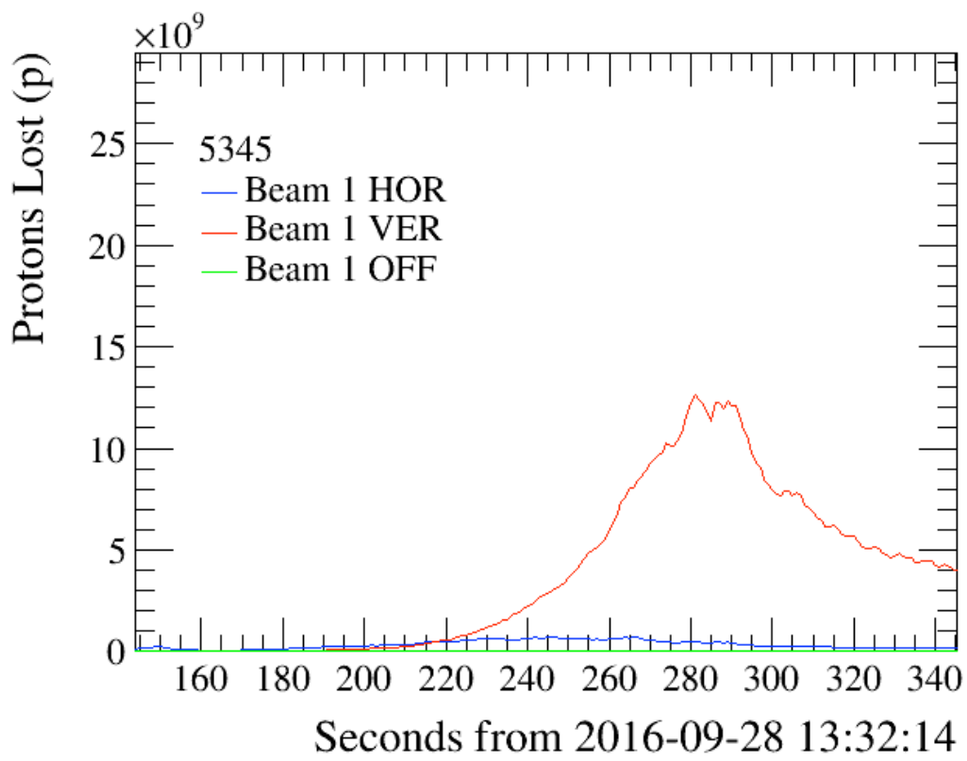

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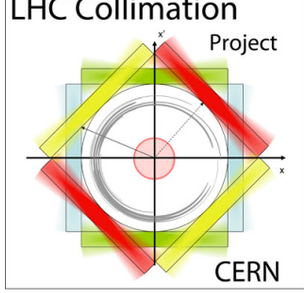

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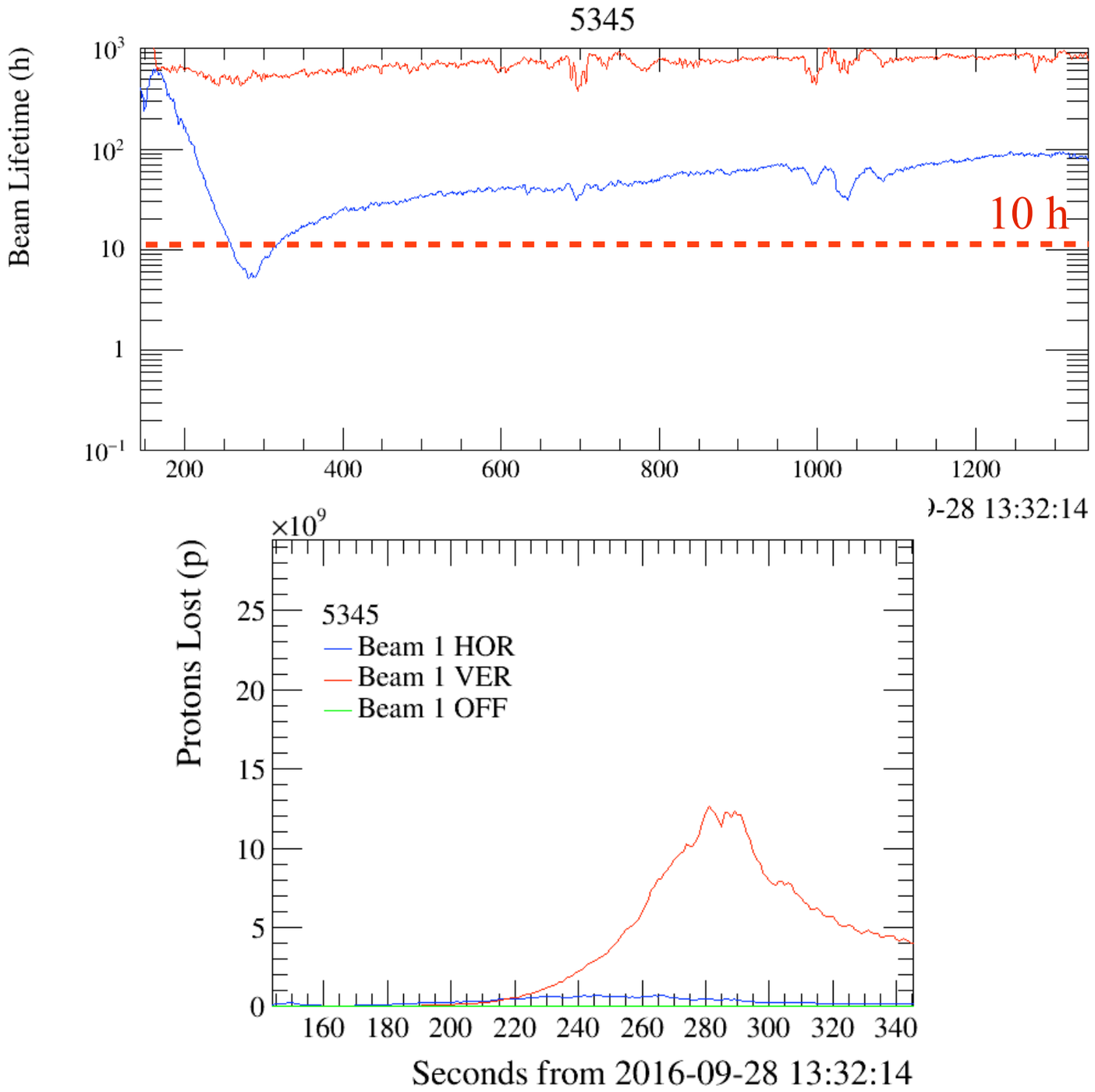
↪ Proposal to shift the B1-V tune



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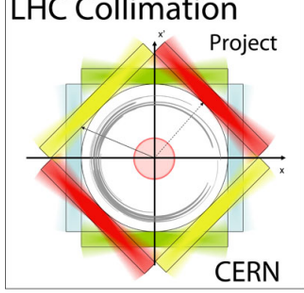

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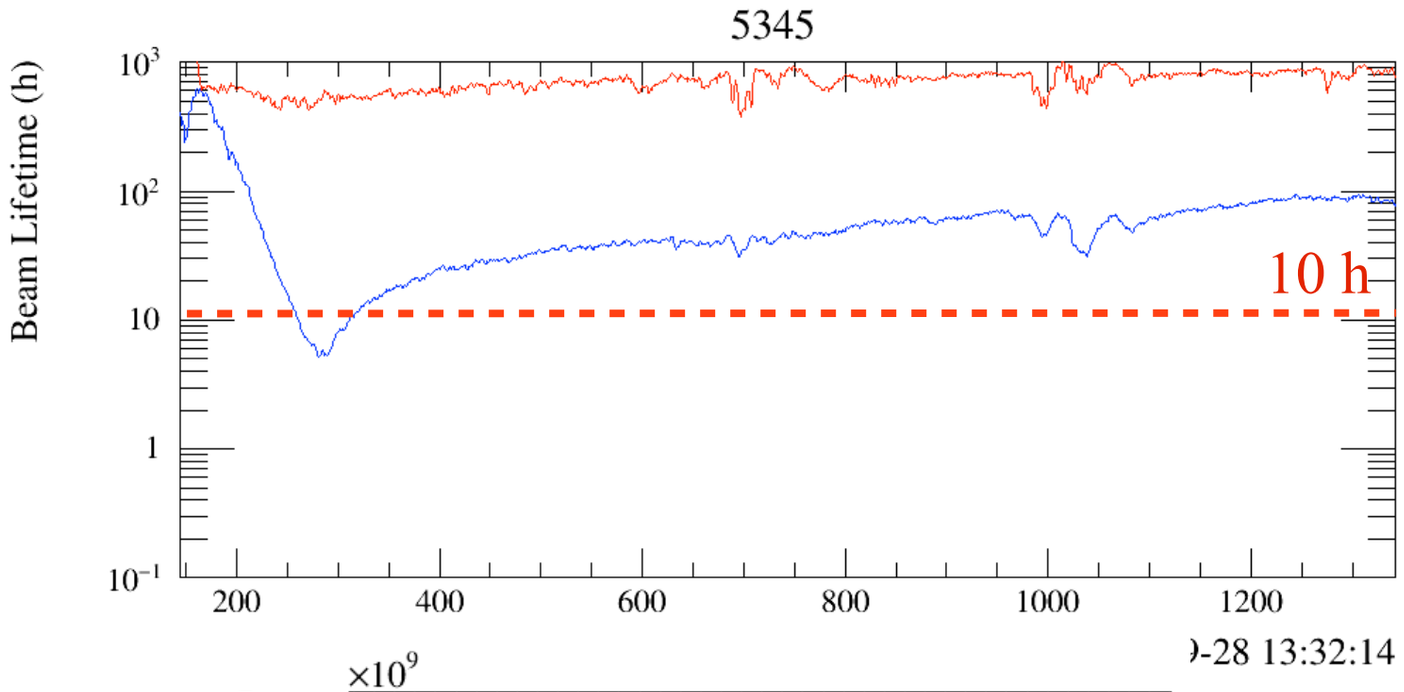
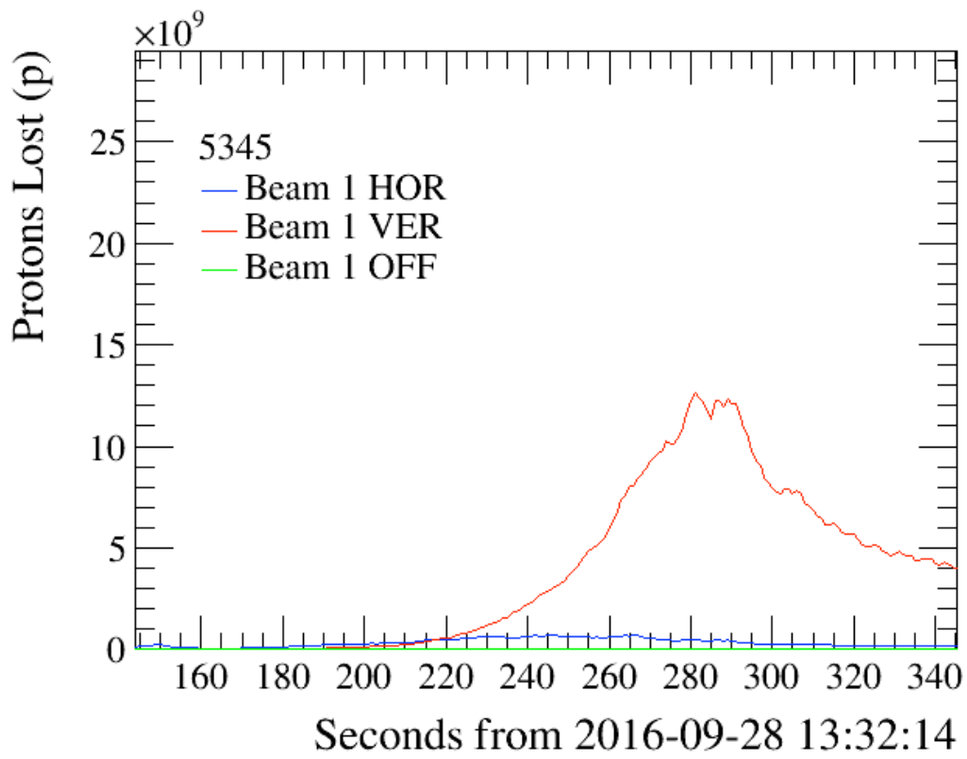
↪ Beam lifetime improves





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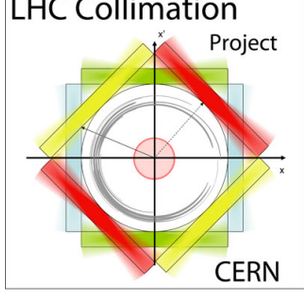

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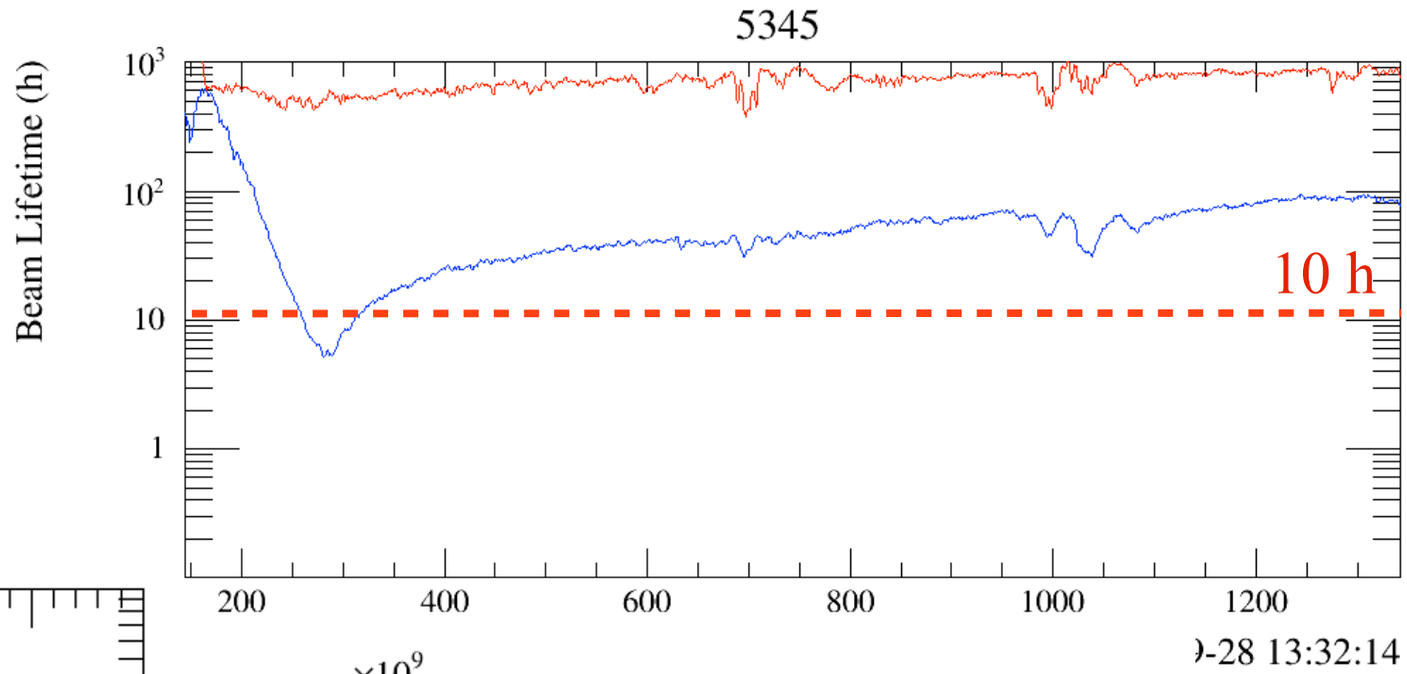

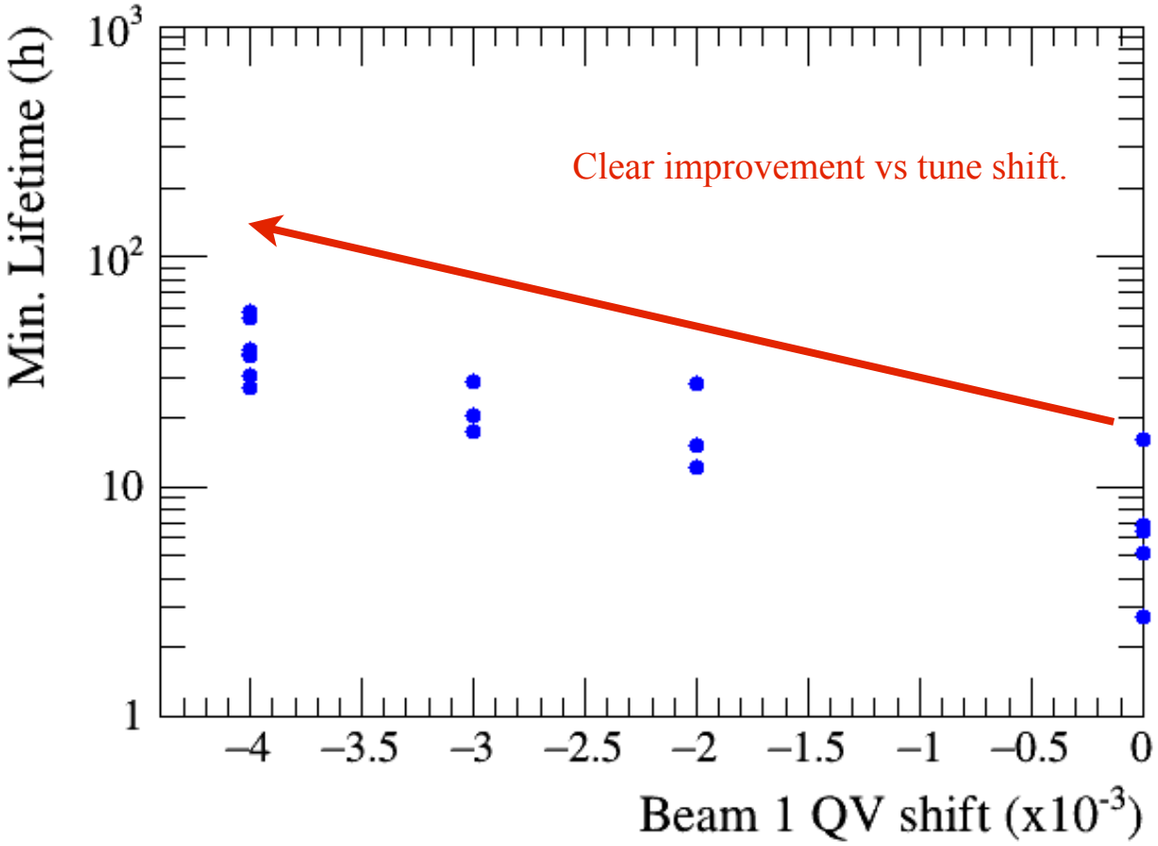

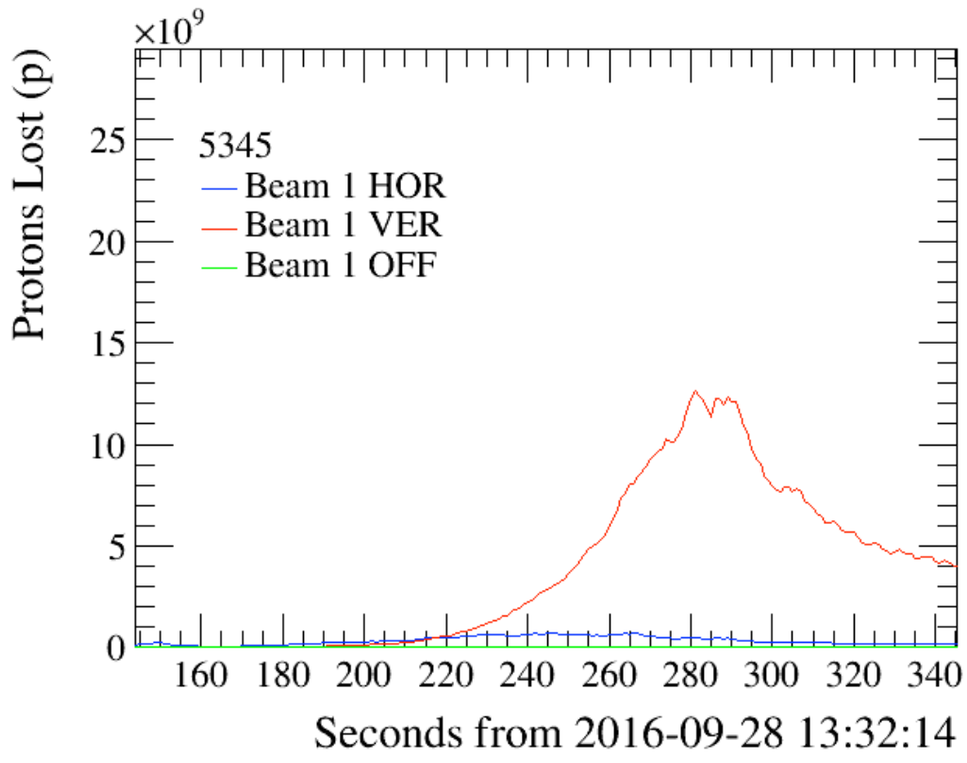

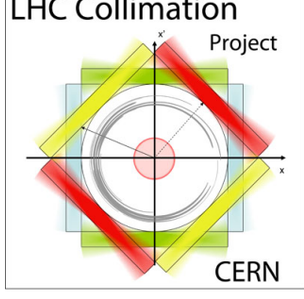

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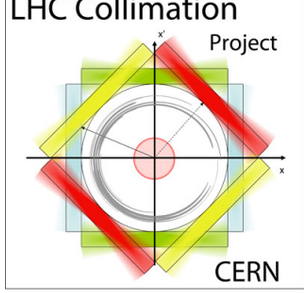
Diamond BLMs



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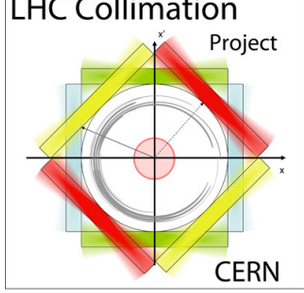
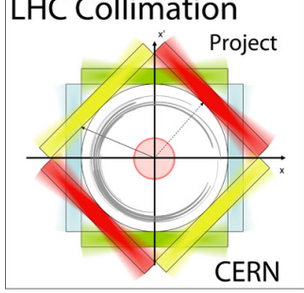


Complementary devices to provide ns range time resolution data

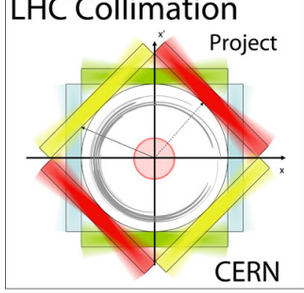
Diamond BLMs



Complementary devices to provide ns range time resolution data

Bunch-by-bunch information!!

Diamond BLMs



Complementary devices to provide ns range time resolution data

Bunch-by-bunch information!!

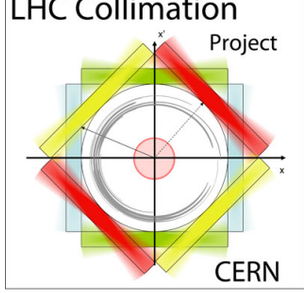
Several units installed in the LHC:

Injection/Extraction and IR7

In IR7, measuring circulating beam losses:

Beam 1 TCP (TimeLossHist, Waveform)
Beam 2 TCP (TimeLossHist)
Beam 1 Crystal (TimeLossHist)

Diamond BLMs



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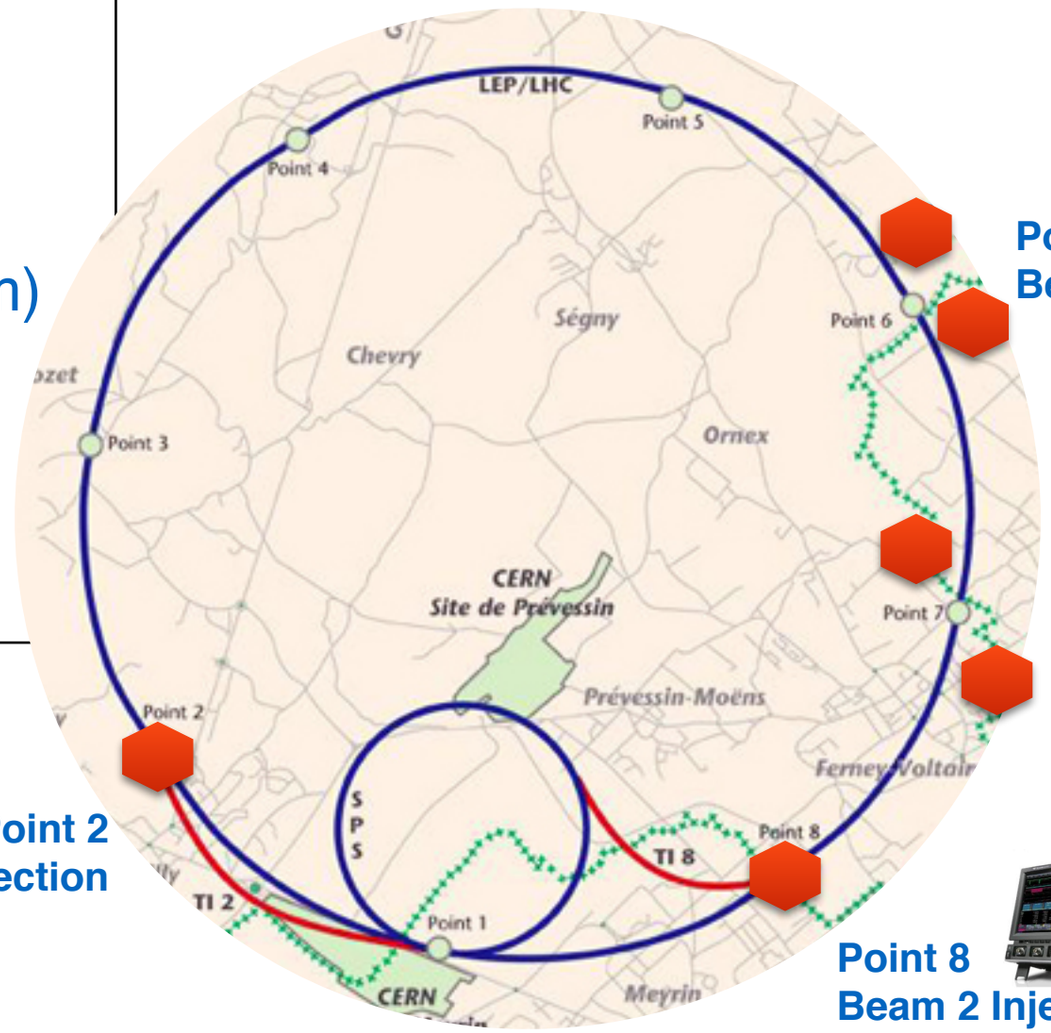


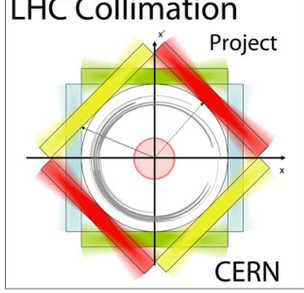
Point 6
Beam Extraction

Point 7
Primary Collimators

Point 2
Beam 1 Injection

Point 8
Beam 2 Injection

Diamond BLMs



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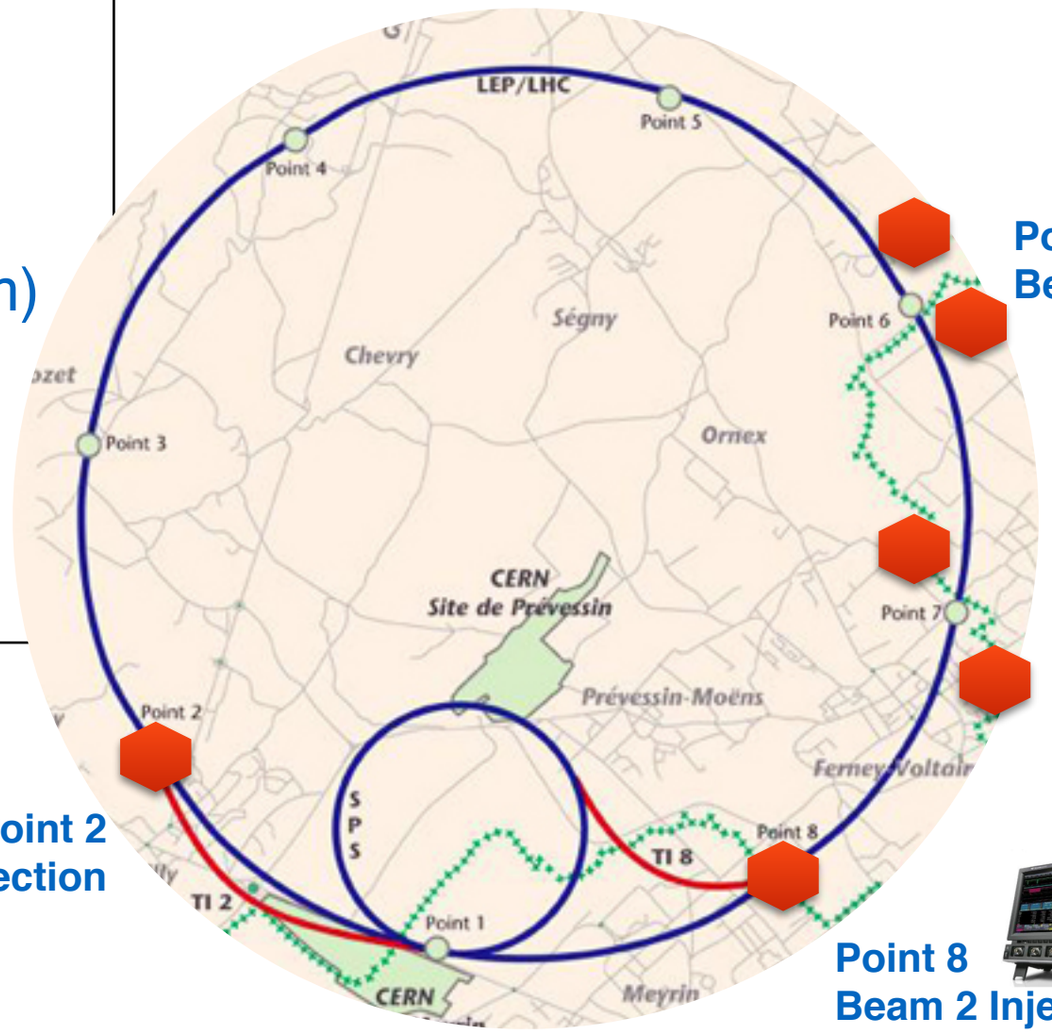

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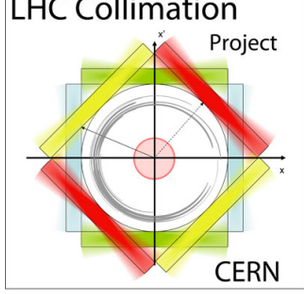
Focusing the rest of the presentation in the TimeLossHist read-out

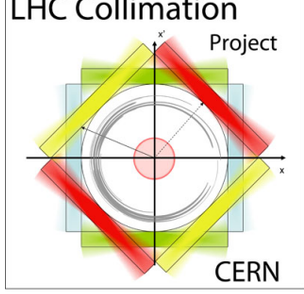
dBLM read-out (1)



dBLM read-out (1)

TimeLossHistogram

dBLM read-out (1)



TimeLossHistogram

Precise beam loss timing counts

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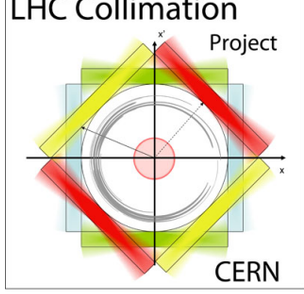

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Precise beam loss timing counts

Threshold of 25mV for histogram data, binning of 1.6 ns, cumulative counts over 1 second.

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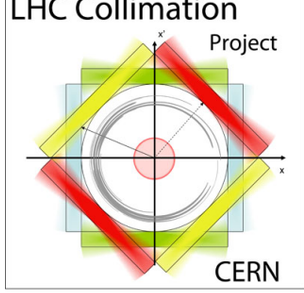

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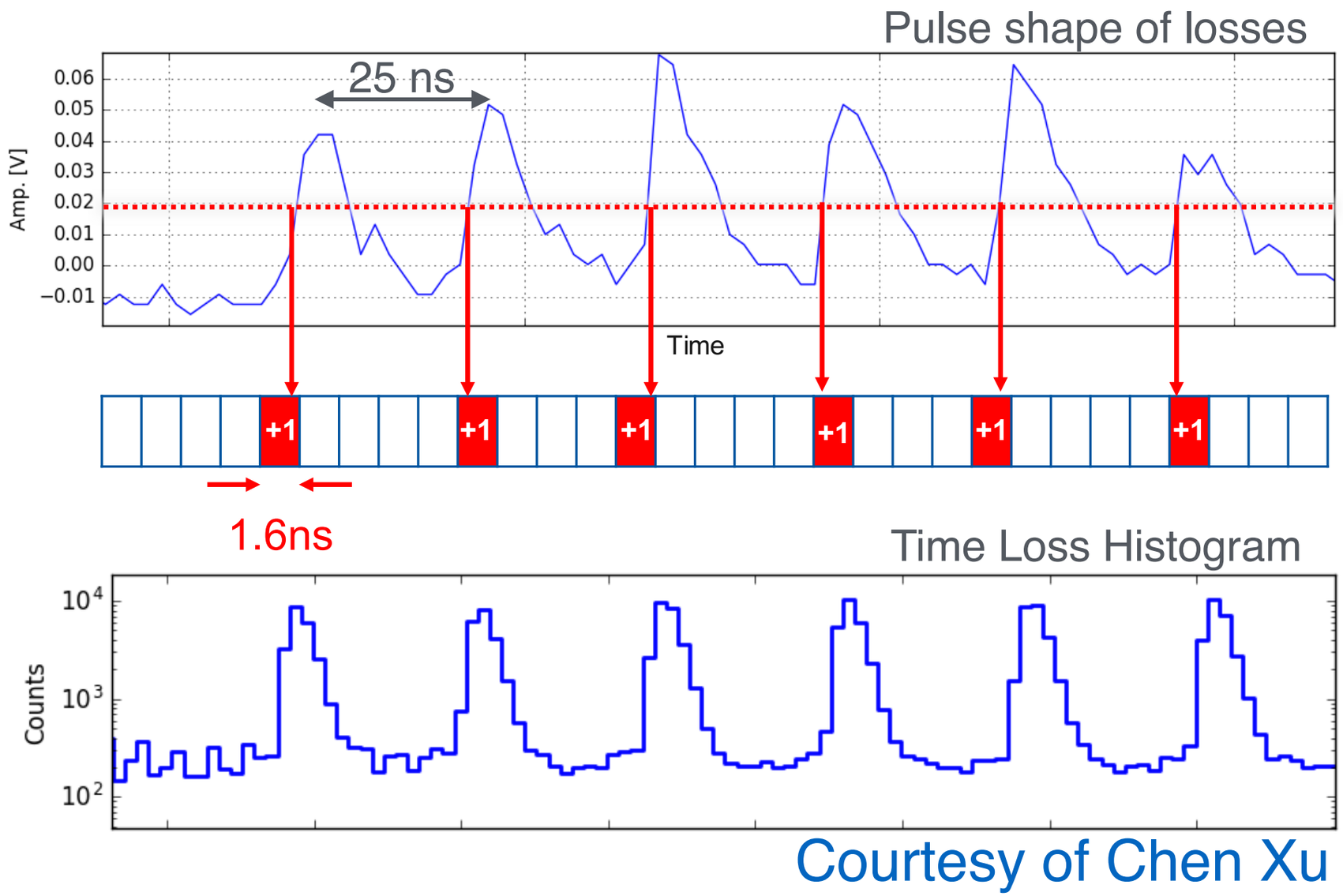
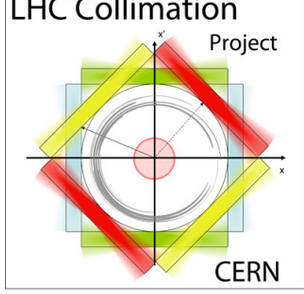


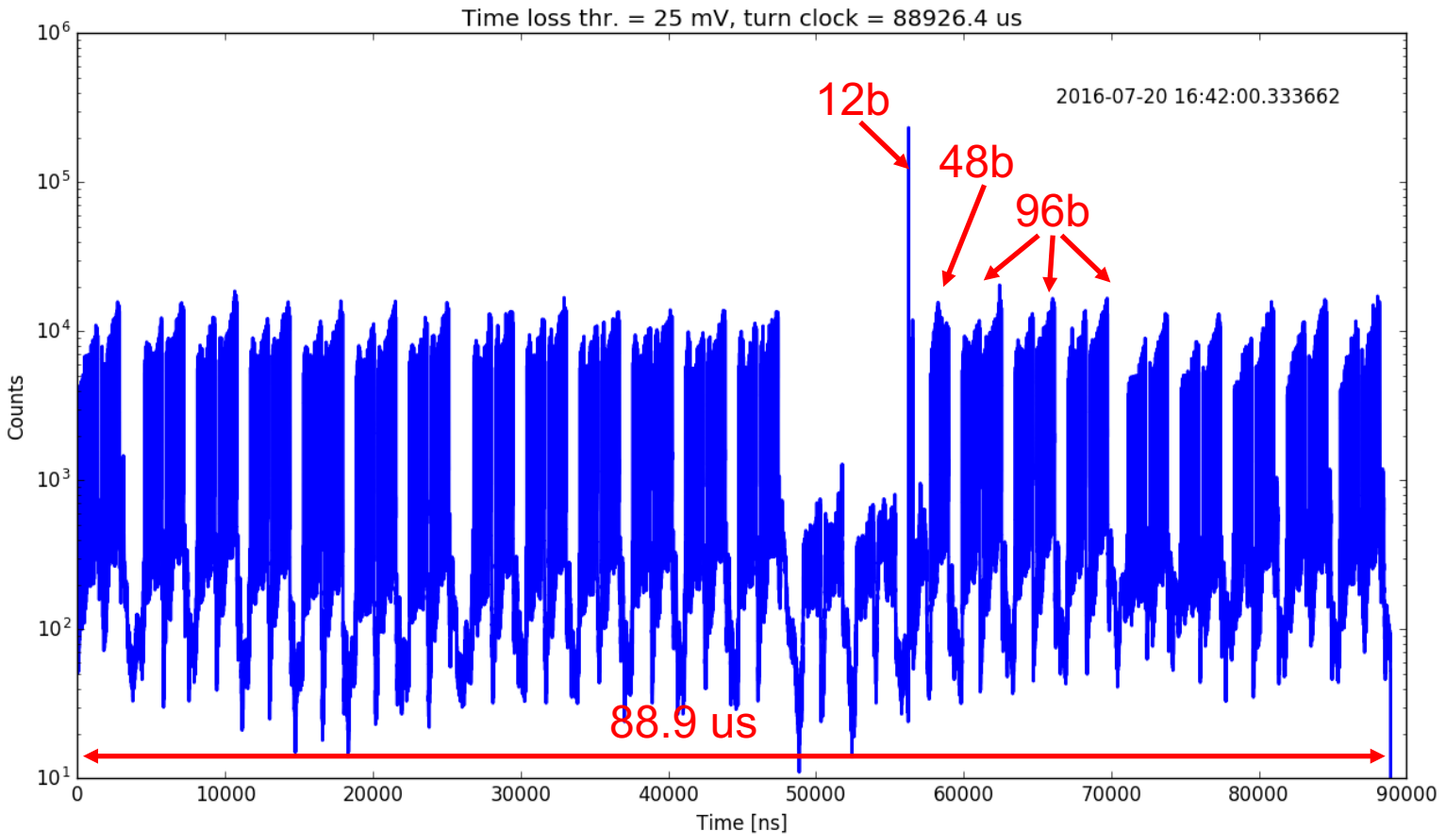
Courtesy of Chen Xu

dBLM read-out (2)



dBLM read-out (2)

Cumulative counts over 1 second, the span of the LHC ring 88.9 us, in bins of 1.6ns



Courtesy of A.Gorzawski

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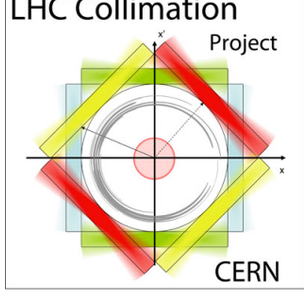

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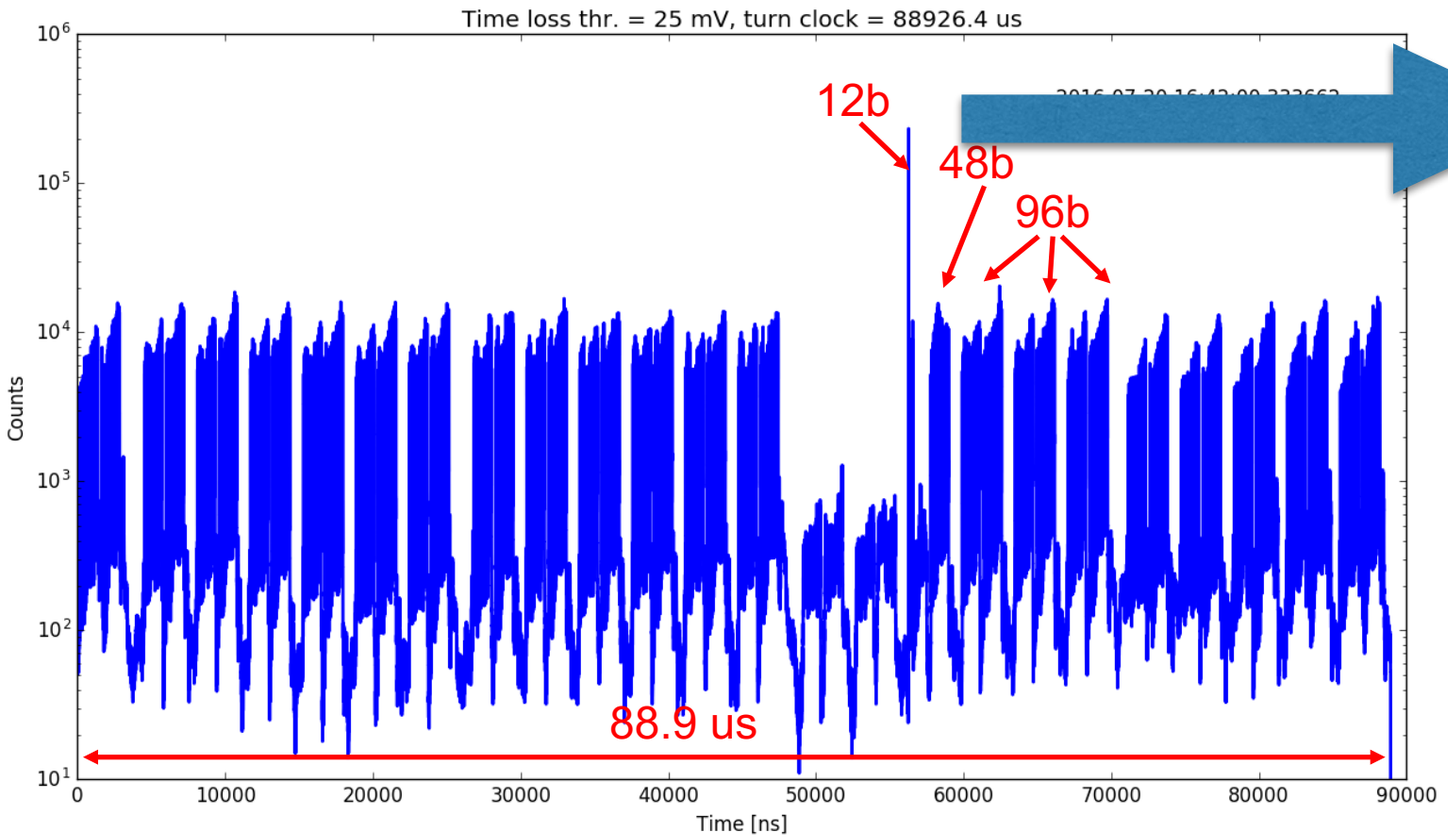

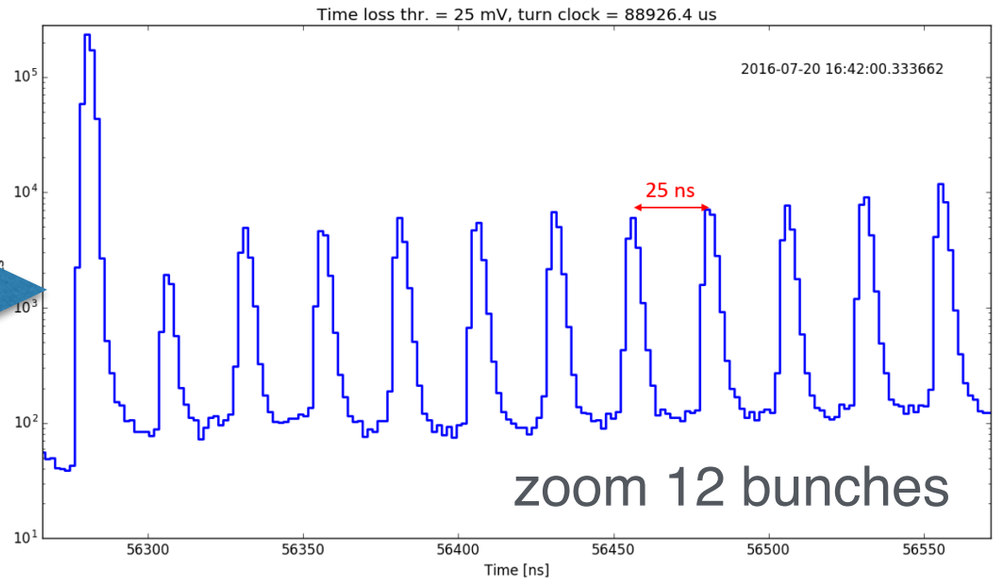

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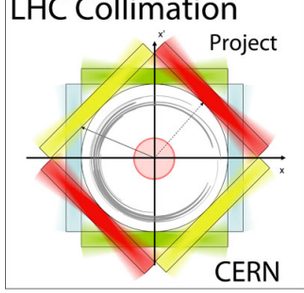

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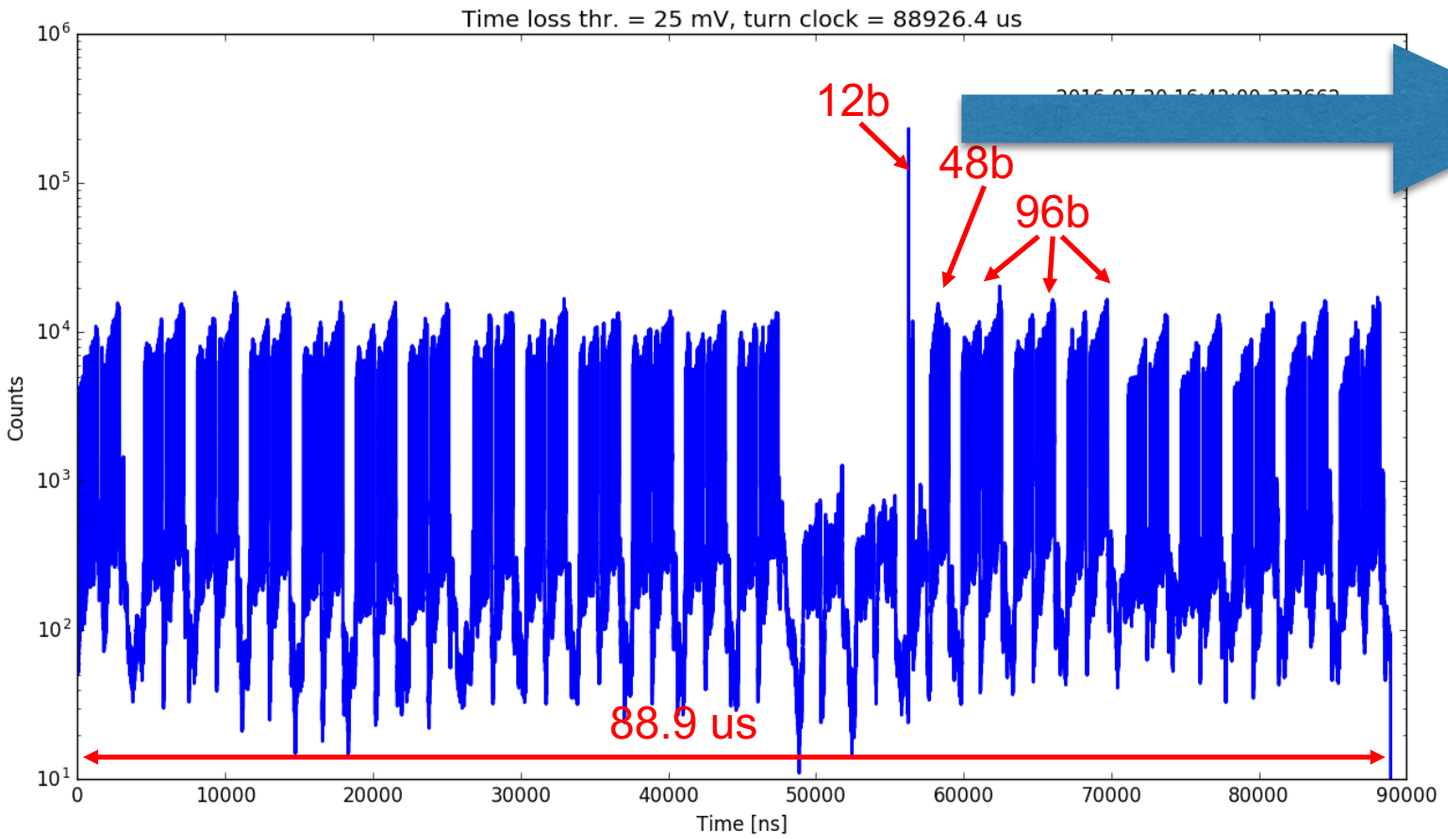
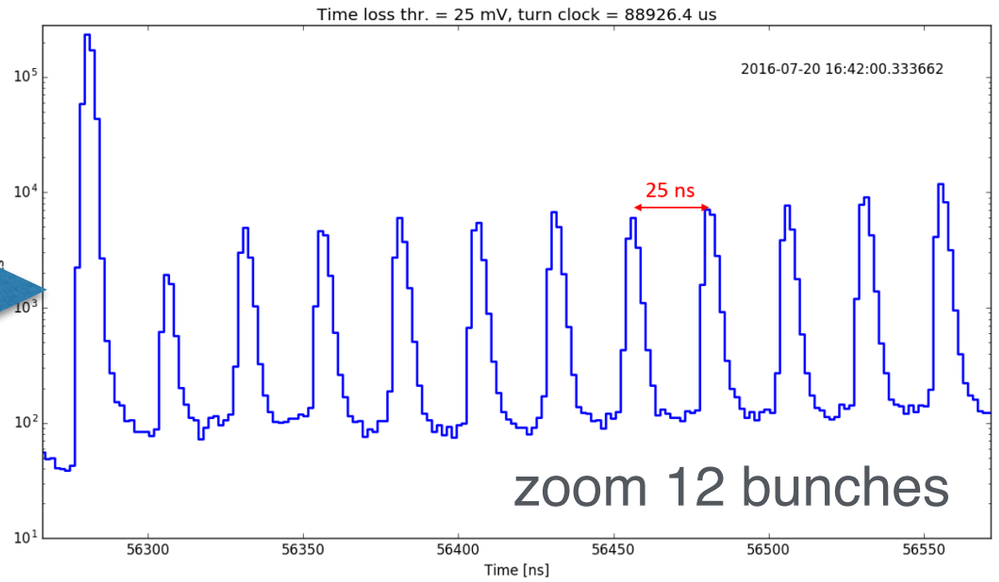
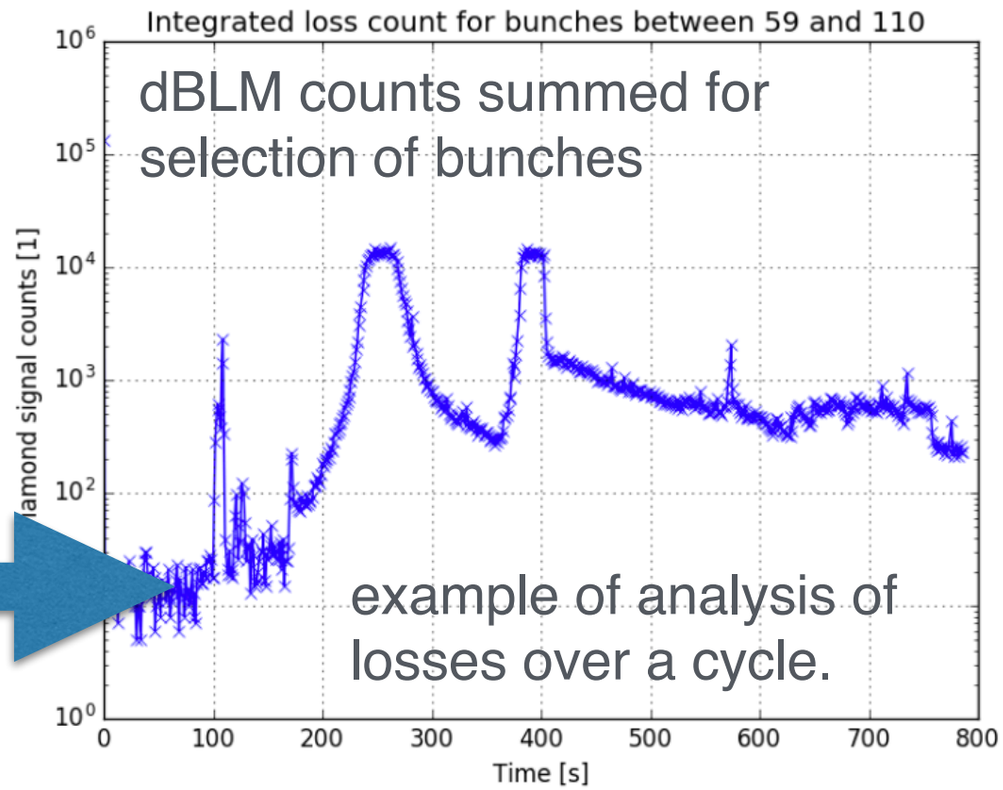


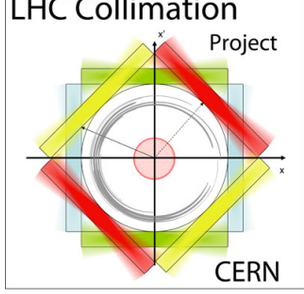




Post-processing: sum dBLM counts for all bunches or a selection of bunches.

Courtesy of A.Gorzawski

Usage of dBLM



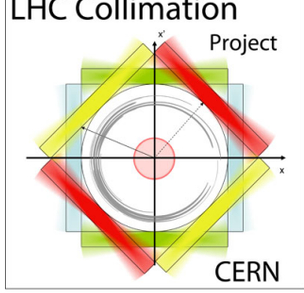
Examples of usage of dBLM data for Collimation

Analysis of regular fills in 2016

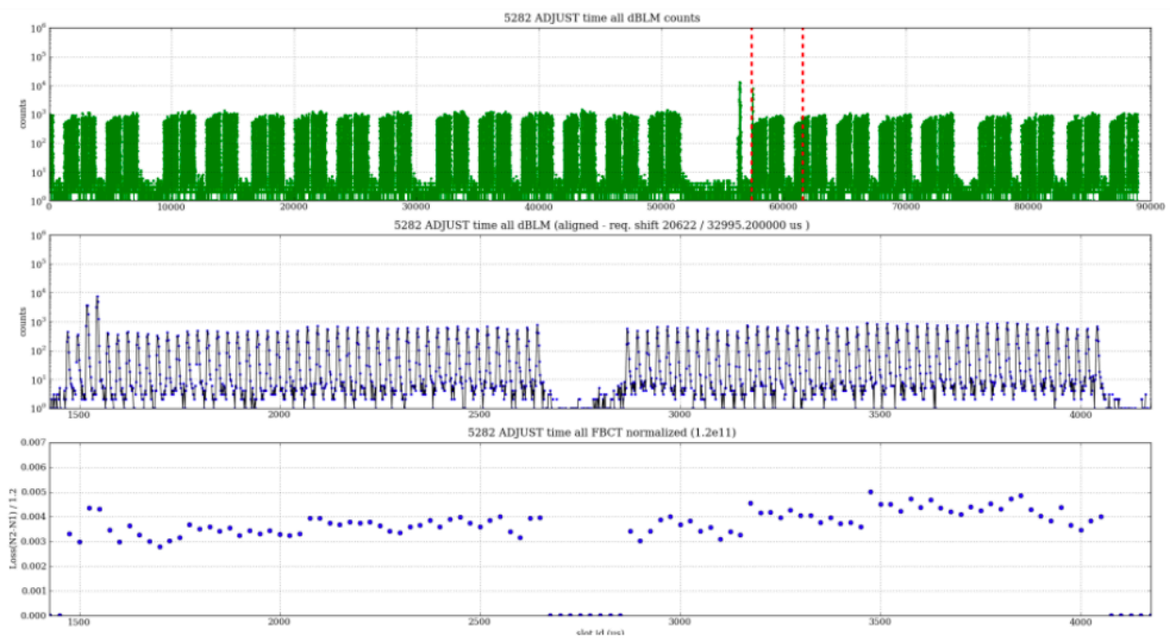
EoF Halo scraping (collimator movement)

LRBB limits (change of crossing angle)

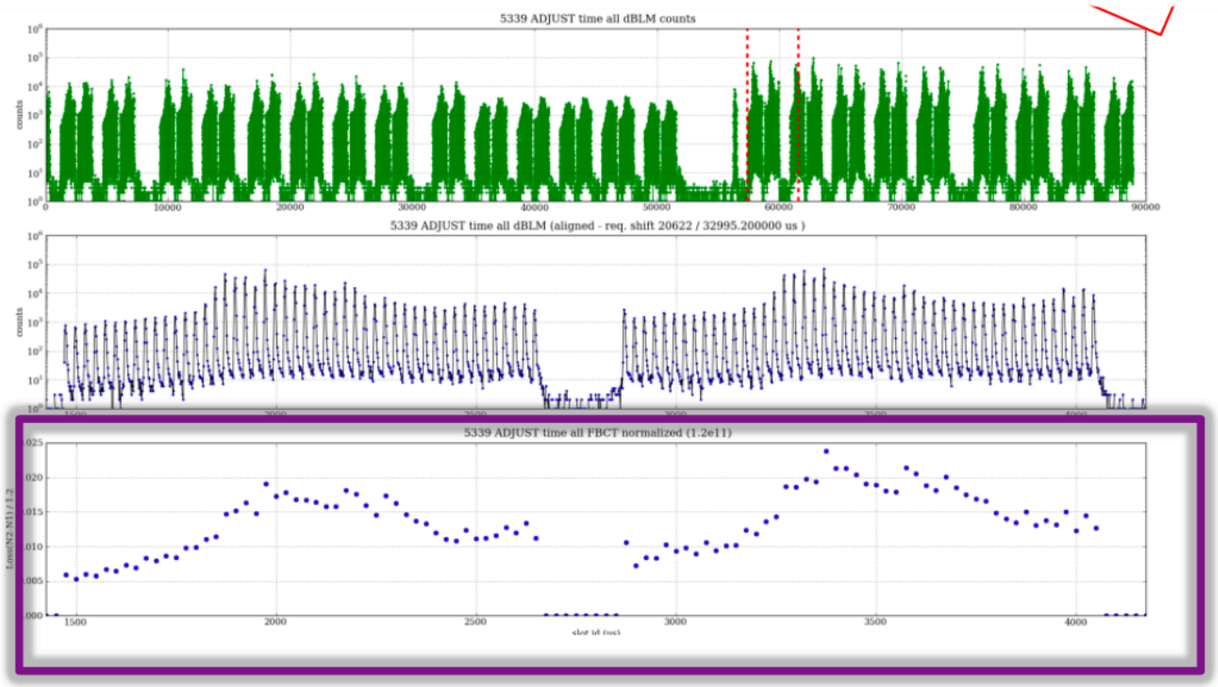
Change of crossing



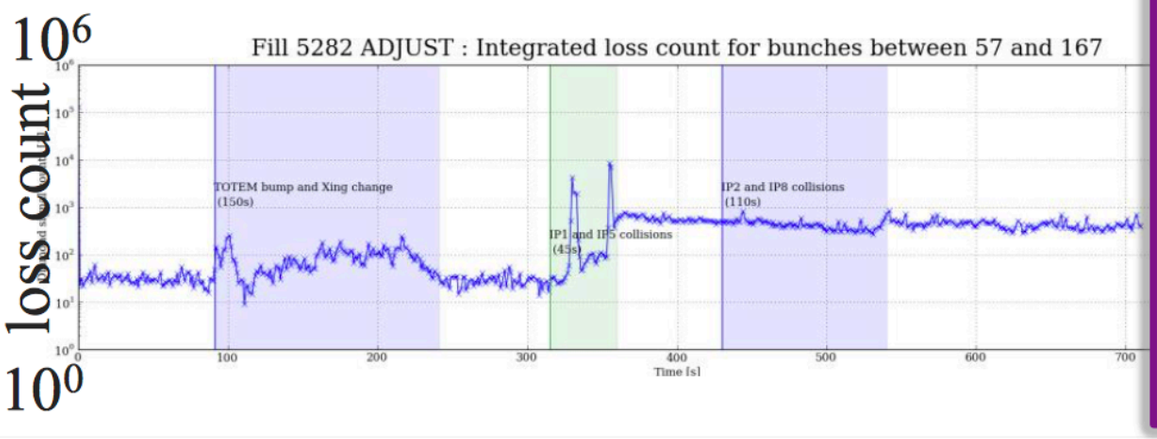
185µrad

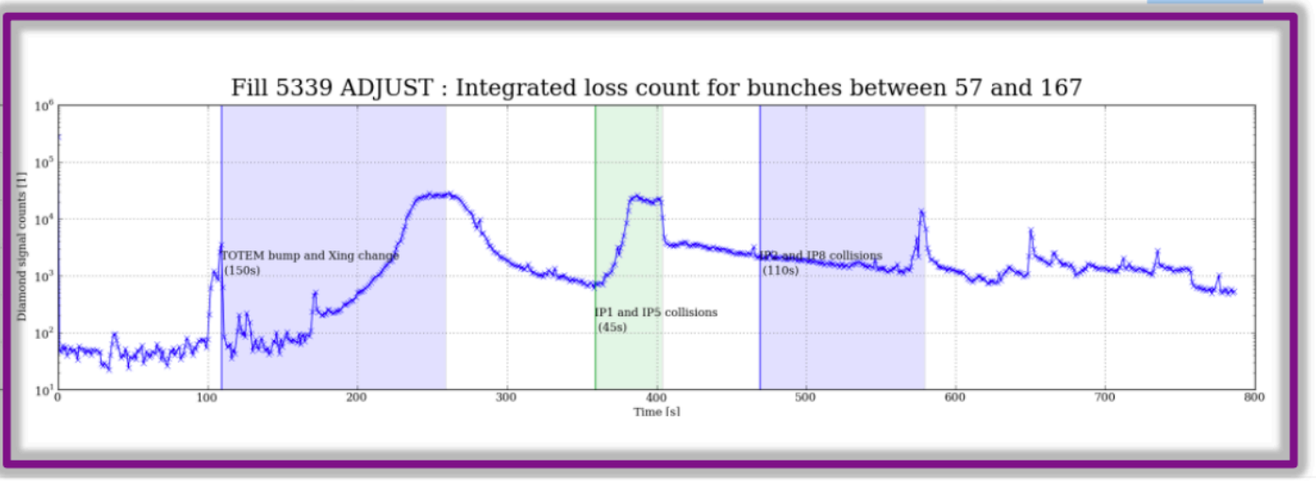


140µrad



Visible change in the loss distribution (slots/time)





Courtesy of A.Gorzawski

LRBB MD

LRBB MD

Study of different loss pattern as a function of the bunch position

Bunches with many Long Range collisions had more losses

A.Gorzawski
ColUSM

LRBB MD

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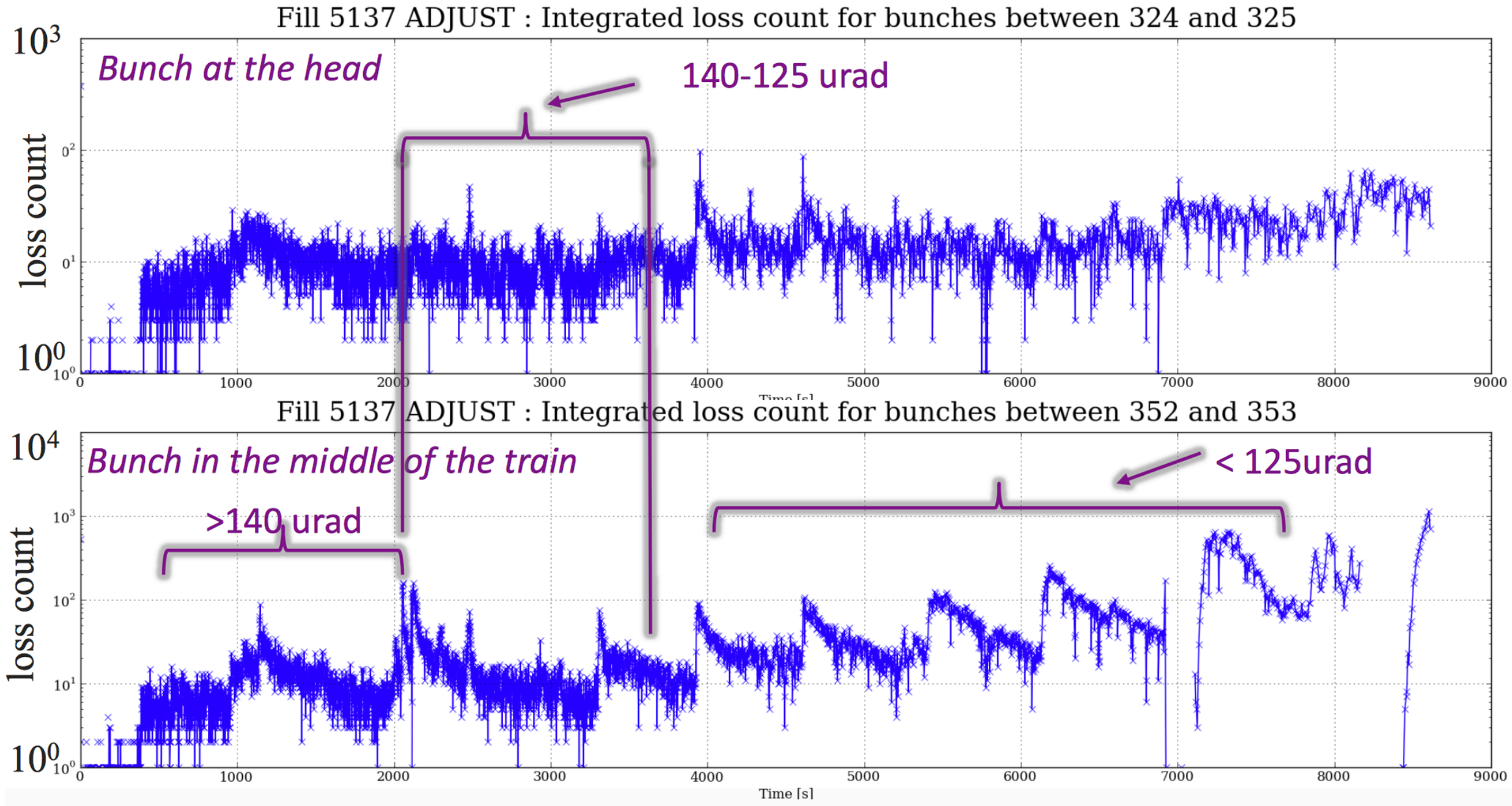
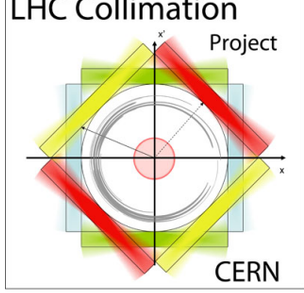


Conclusion



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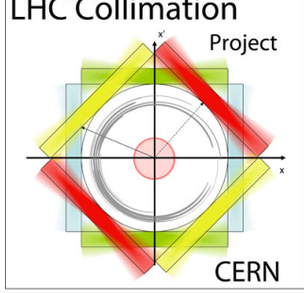
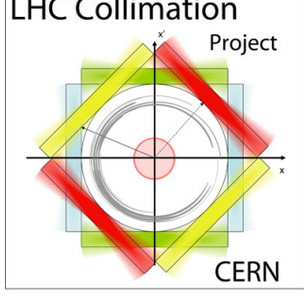


Beam lifetime is a quick indicator of machine performance

Calculation from regular BLMs is possible with the cross-calibration with the BCT.

↪ Useful for MD and sensitive to small losses.

Conclusion



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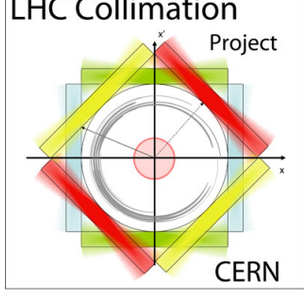

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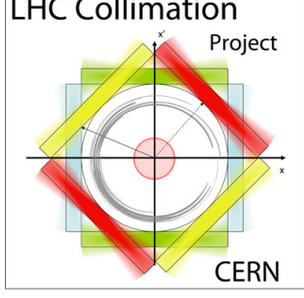

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