Workshop on "Simulations and Measurements of Long-Range Beam-Beam Effects in the LHC"
November 30th - December 1st, 2015
CERN, Geneva, CH

Halo Measurements using Collimators

Stefano Redaelli *for the collimation team:*
D. Mirarchi, B. Salvachua, G. Stancari,
G. Valentino, and many others.

Acknowledgements: BE-BI team

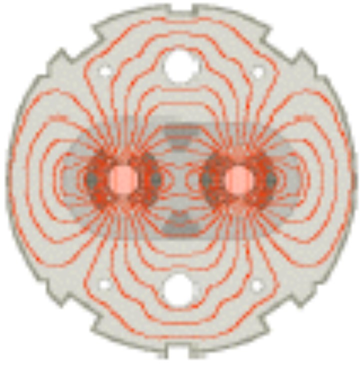
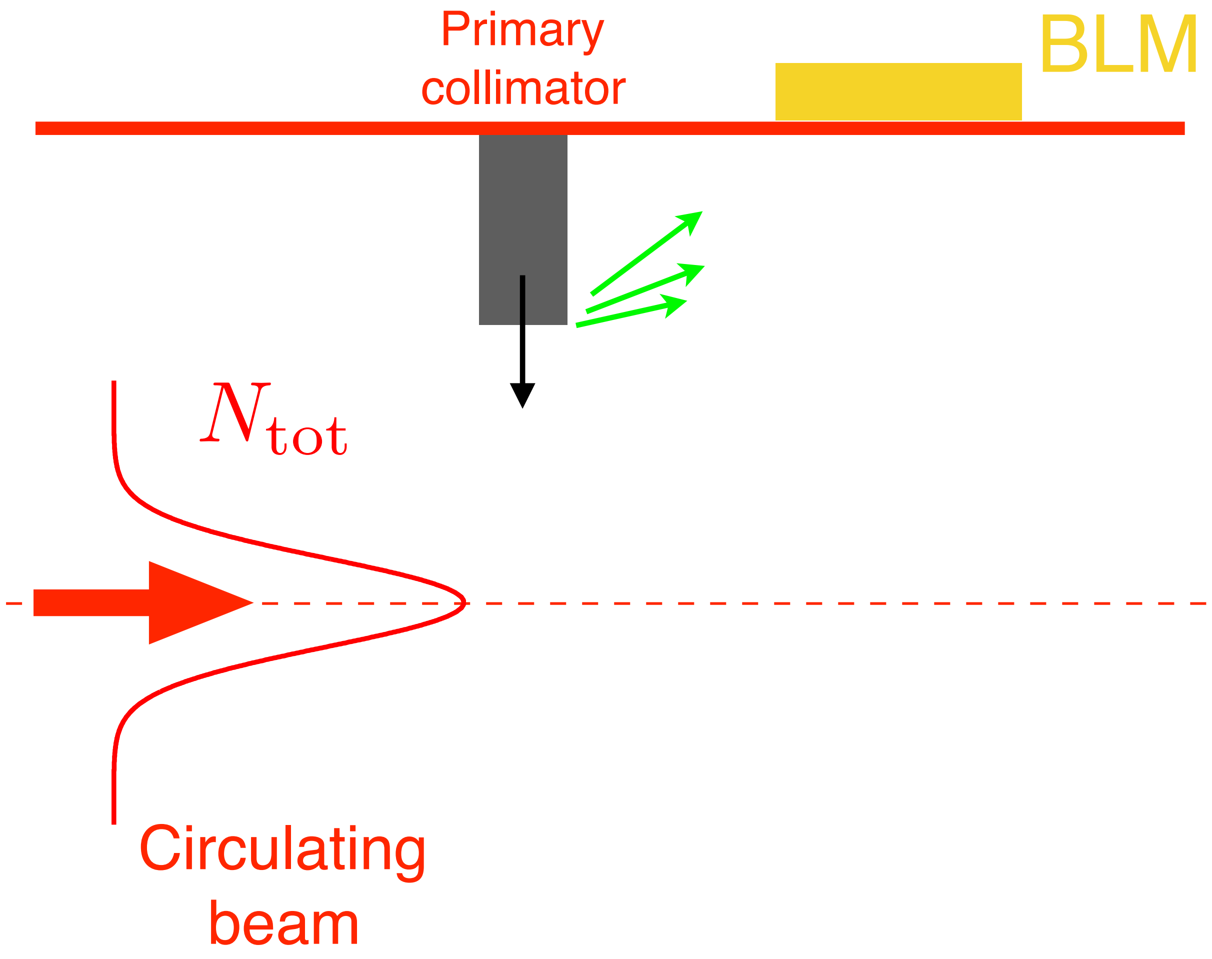


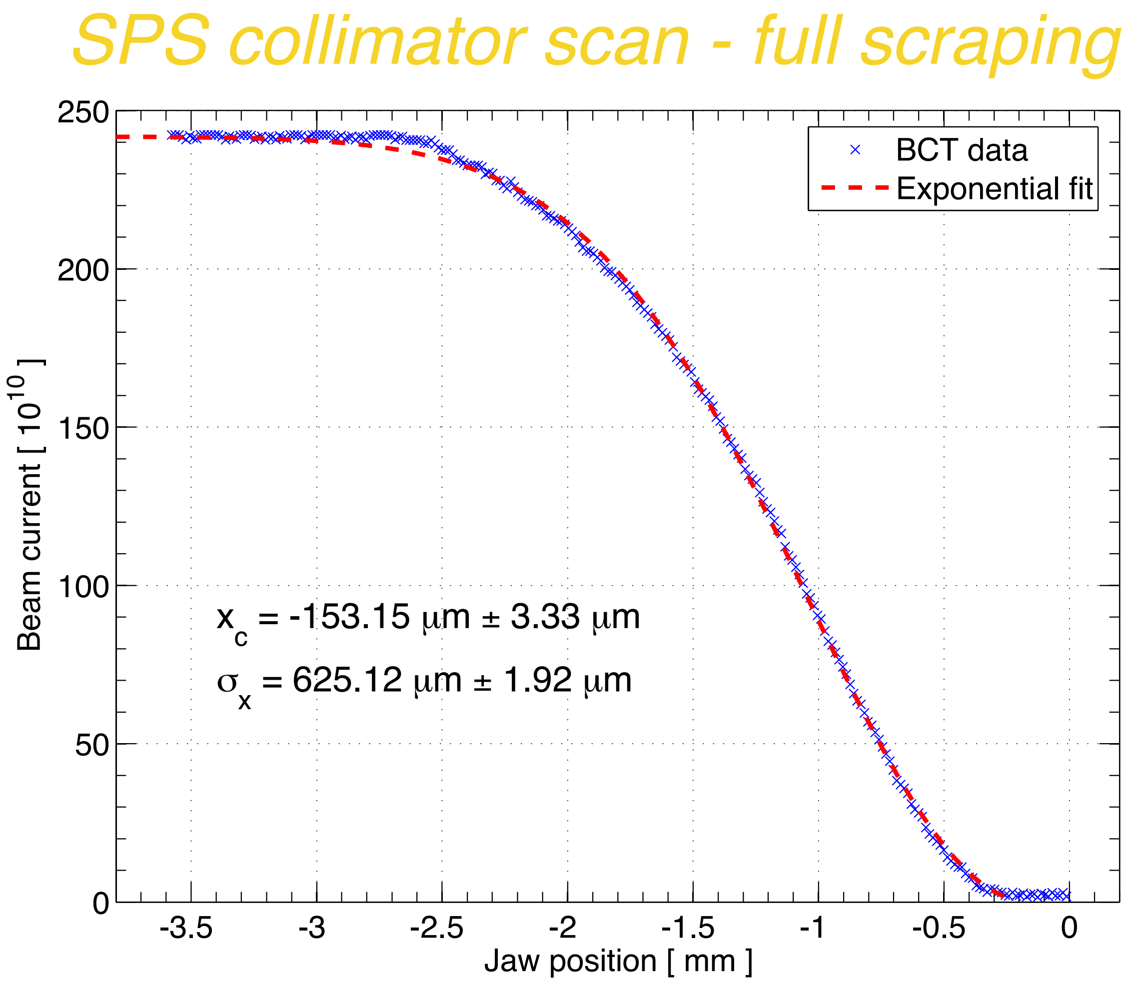
Table of Contents

Introduction

- **Halo cleaning** versus quench limits (super-conducting machines)
- Passive **machine protection**
  First line of defence in case of accidental failures.
- **Concentration of losses/activation** in controlled areas
  Ease maintenance by avoiding many distributed high-radiation areas.
- **Reduction total doses** on accelerator equipment
  Provide local protection to equipment exposed to high doses (like the warm magnets in cleaning insertions)
- **Cleaning of physics debris** (physics products, in colliders)
  Avoid magnet quenches close to the high-luminosity experiments
- Optimize **background** in the experiments
  Minimize the impact of halo losses on quality of experimental data
- Beam tail/halo **scraping**, **halo diagnostics**
  Control and probe the transverse or longitudinal shape of the beam

Linear scans with collimator jaws





Idea:

Move collimator jaw(s) into the beam.

Record losses: shower from the jaw/beam interaction or beam intensity.

Done with primary collimators (TCP): robust, in warm insertion.

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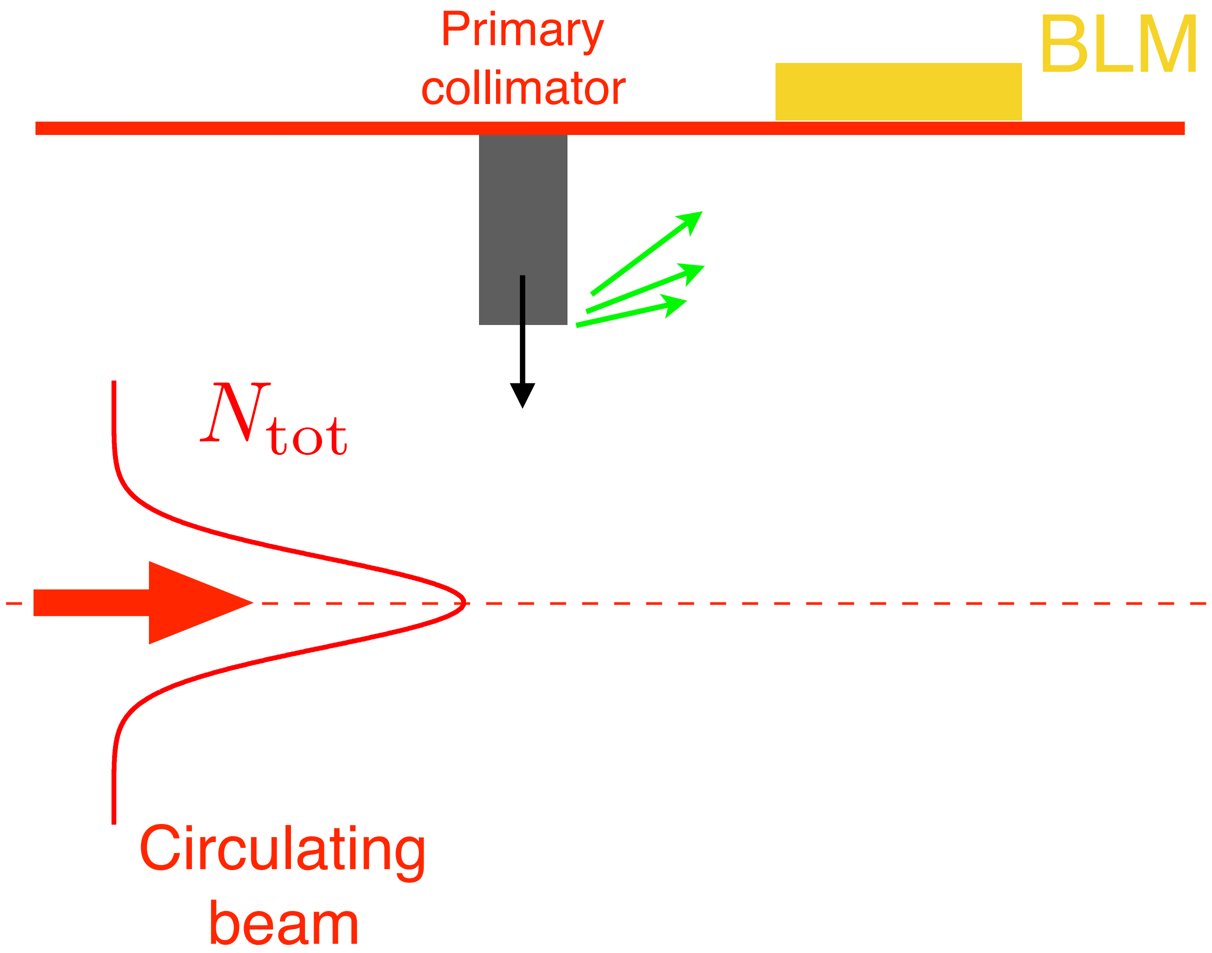

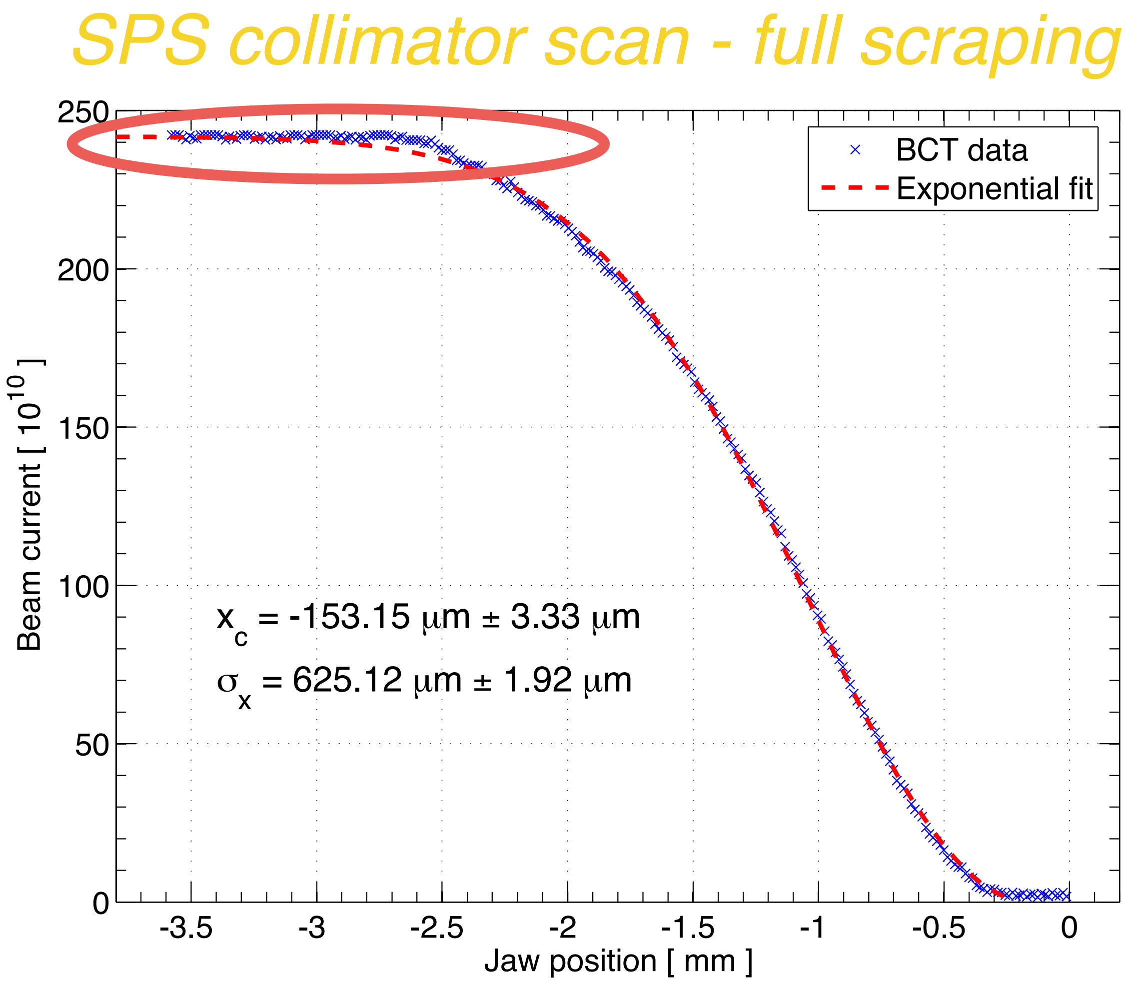

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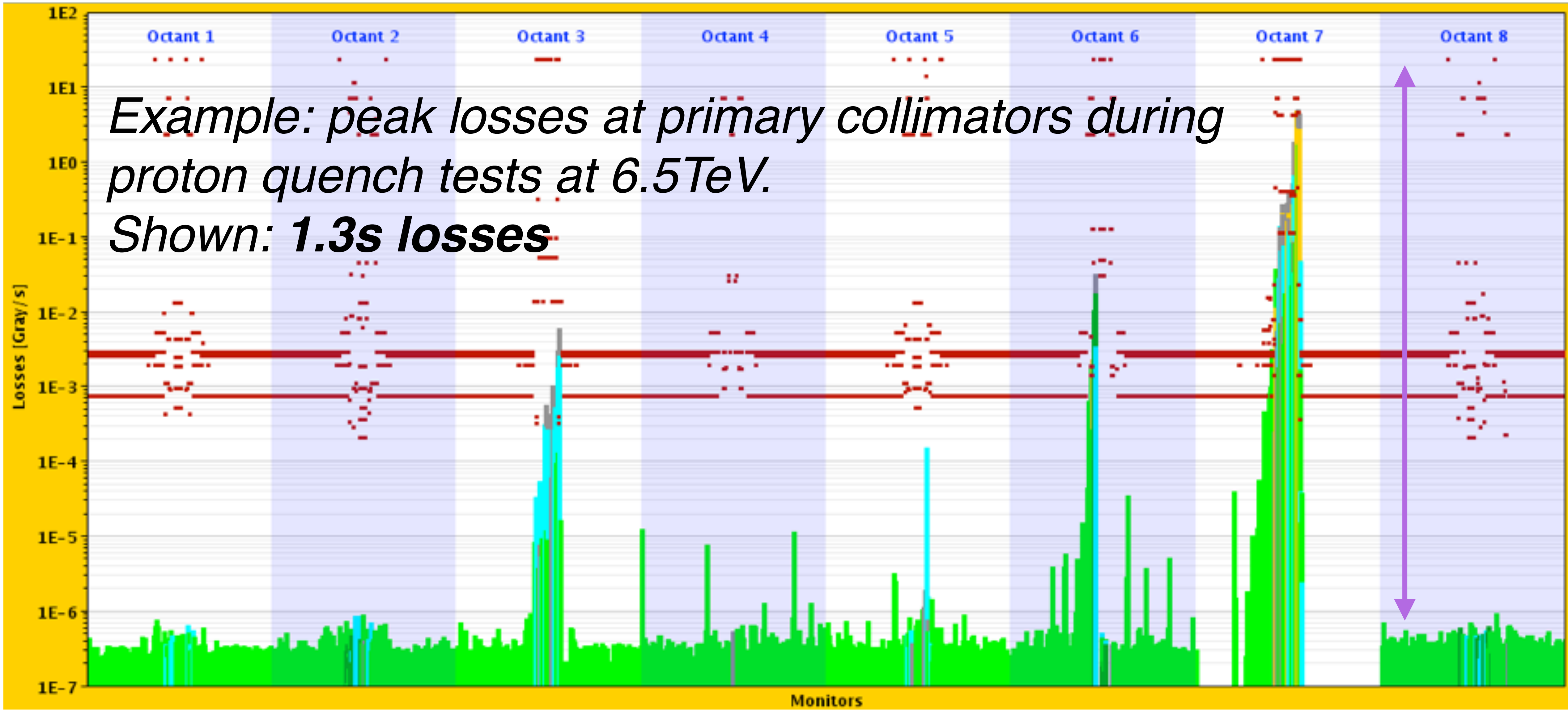
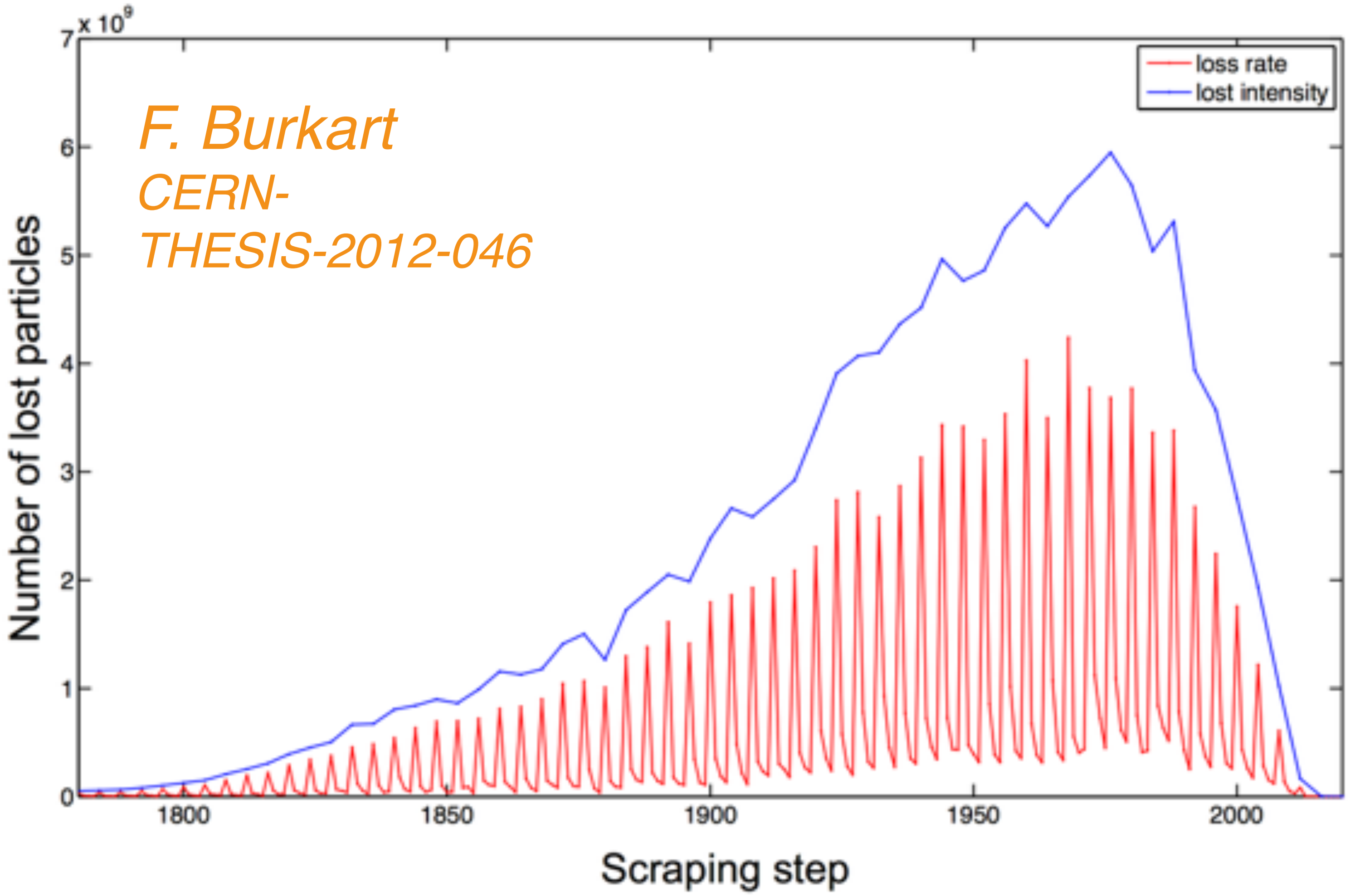
LHC beam loss monitoring



Dynamic range of more than 7 orders of magnitude provided by the LHC ionisation chambers. “Running sums” between 40µs and 80s.
Higher resolution than beam current measurements.
Measure absolute losses (not the difference of 2 big numbers).

Calibration: Gy/s to p/s (i)



Dedicated scraping exercises at injection and top energy - master thesis work in 2012.

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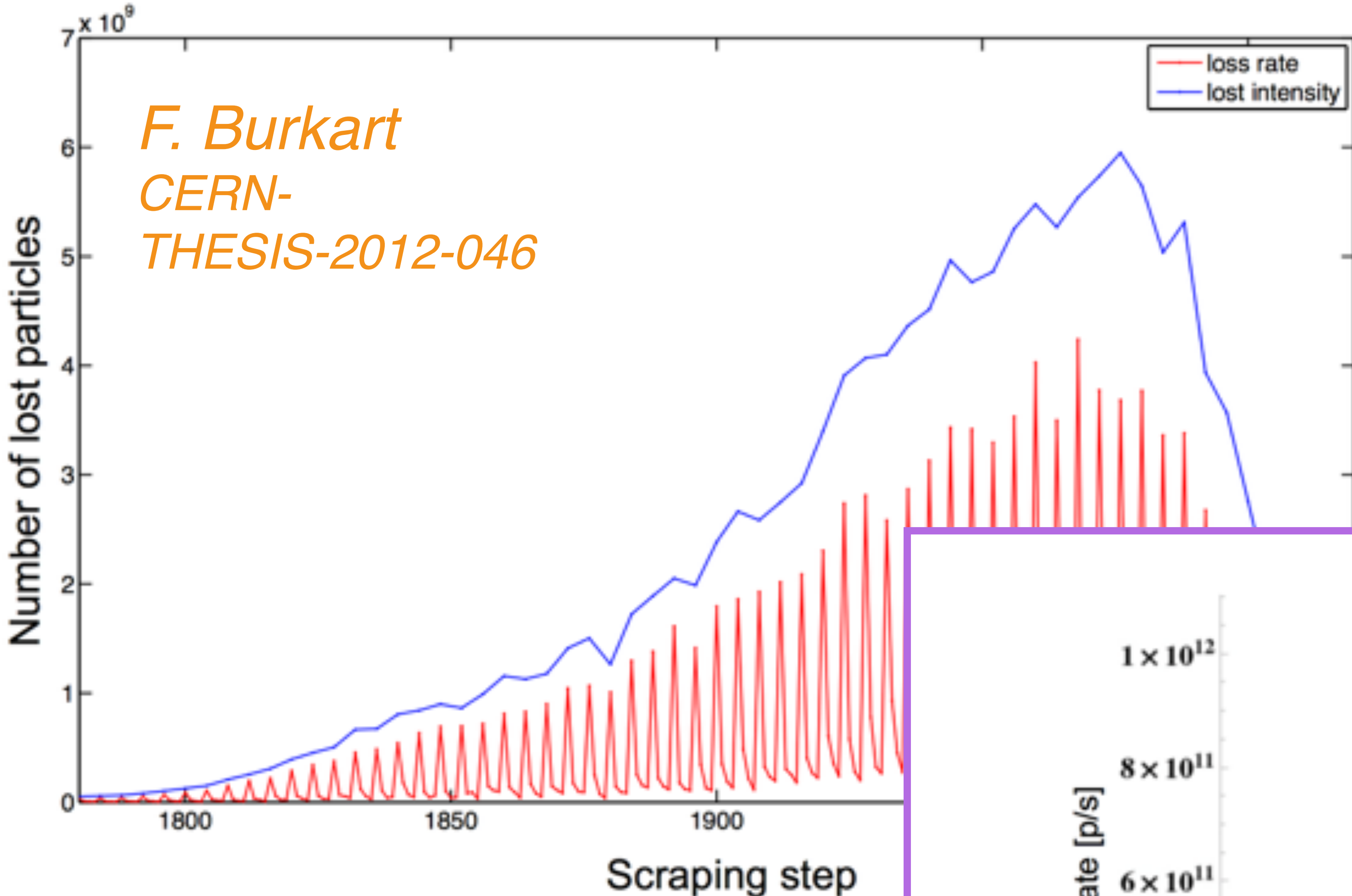

F. Burkart
CERN-THESIS-2012-046

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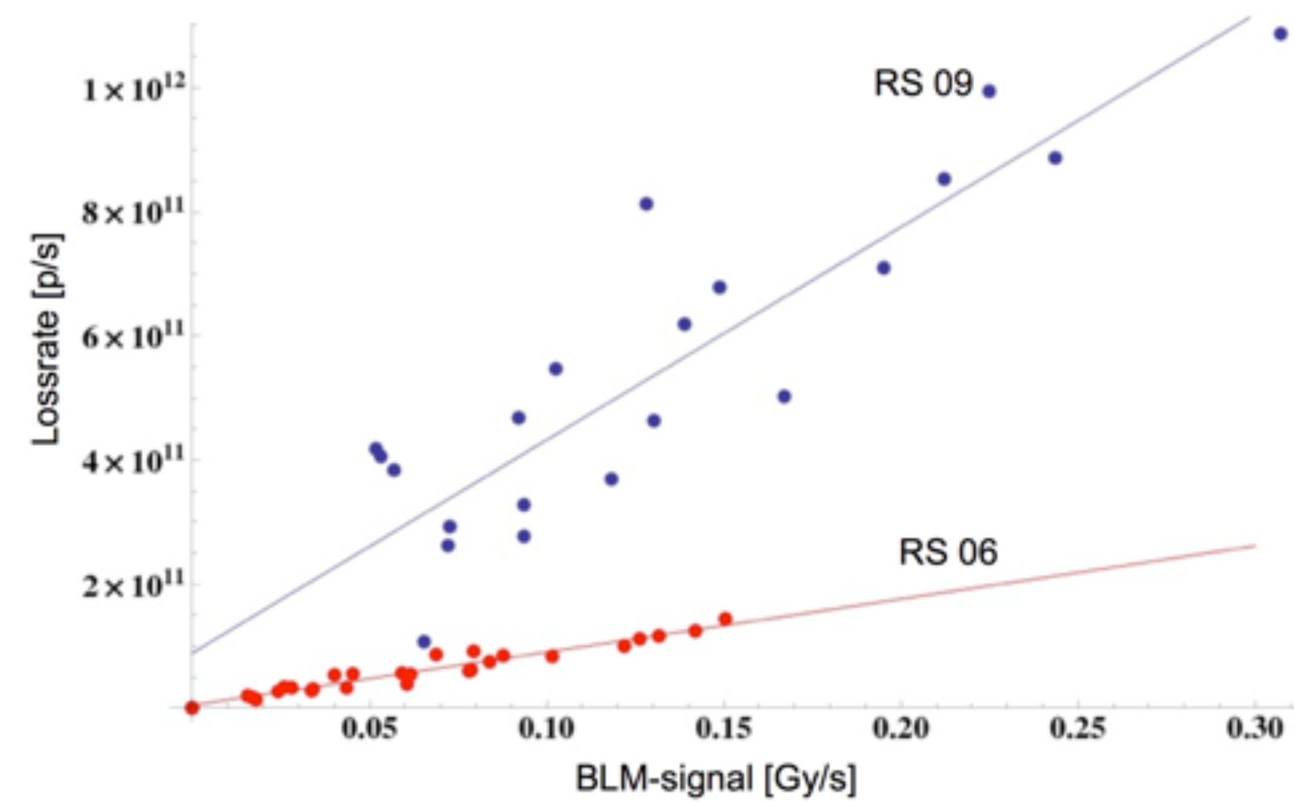
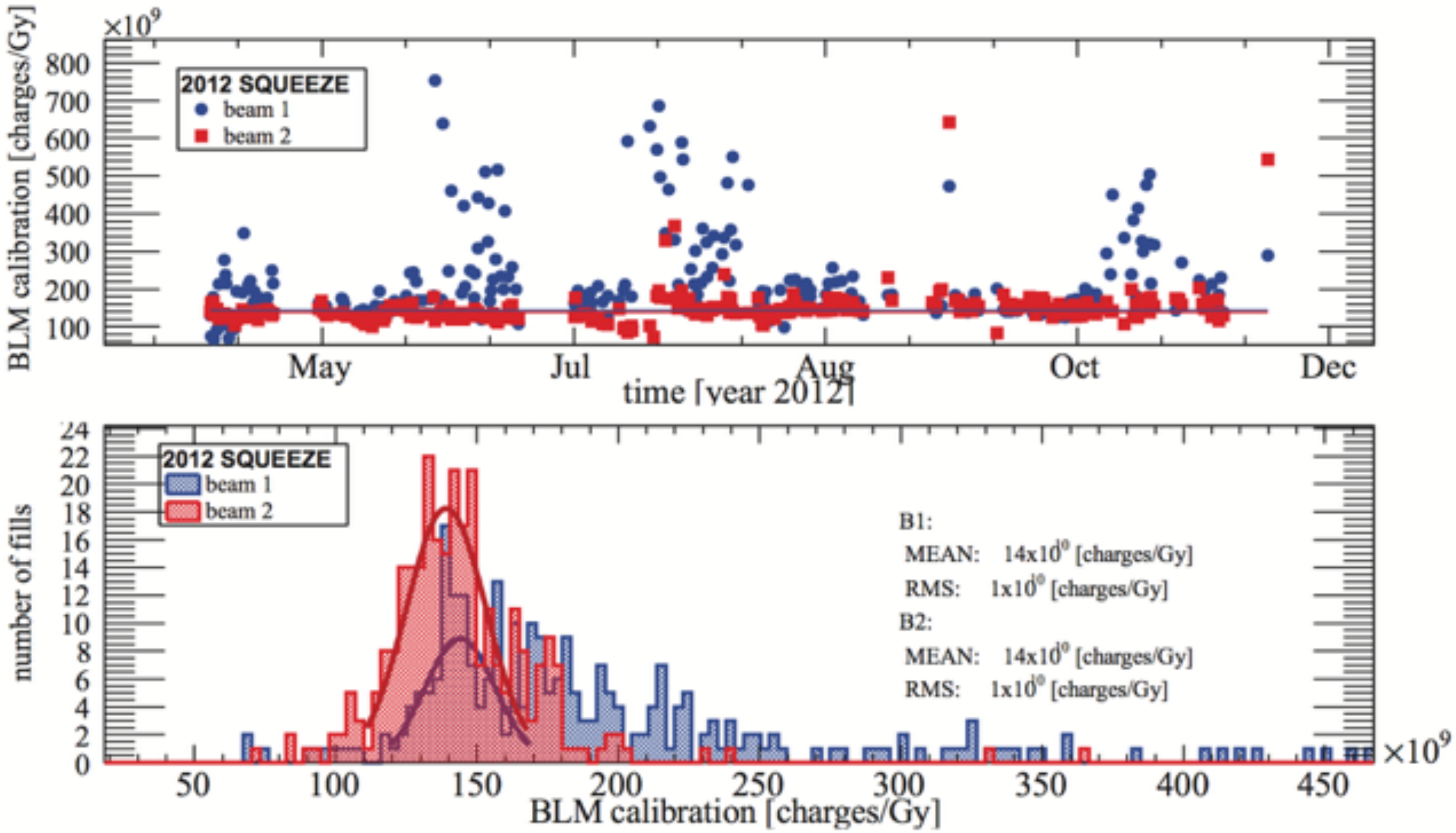


Fig. 7.1: Plot of the loss rate versus the BLM signal for RS09 (blue) and RS06 (red). The calibration factors were achieved from a linear fit of the data. They were calculated as 9.9×10^{11} p/Gy (RS09) and 3.4×10^{11} p/Gy (RS06).

Calibration: Gy/s to p/s (ii)



Loss analysis in standard physics fills (>500 fills in 2011-12): average losses over 20s from current monitors versus 1.3s integral of losses recorded downstream of the primary collimators.

B. Salvachua, IPAC2013: MOPWO049

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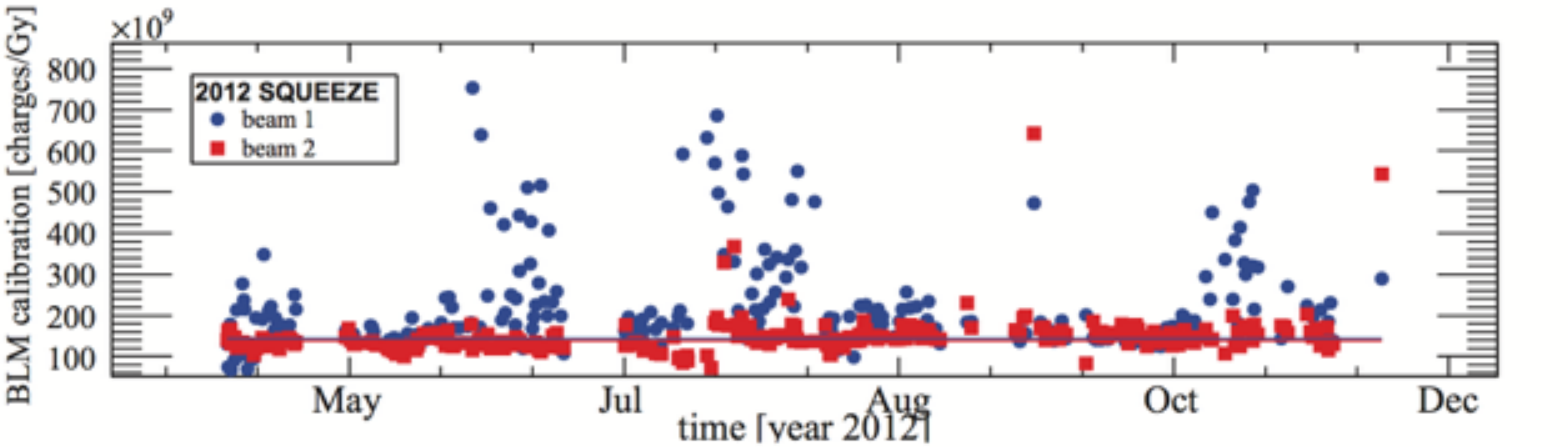

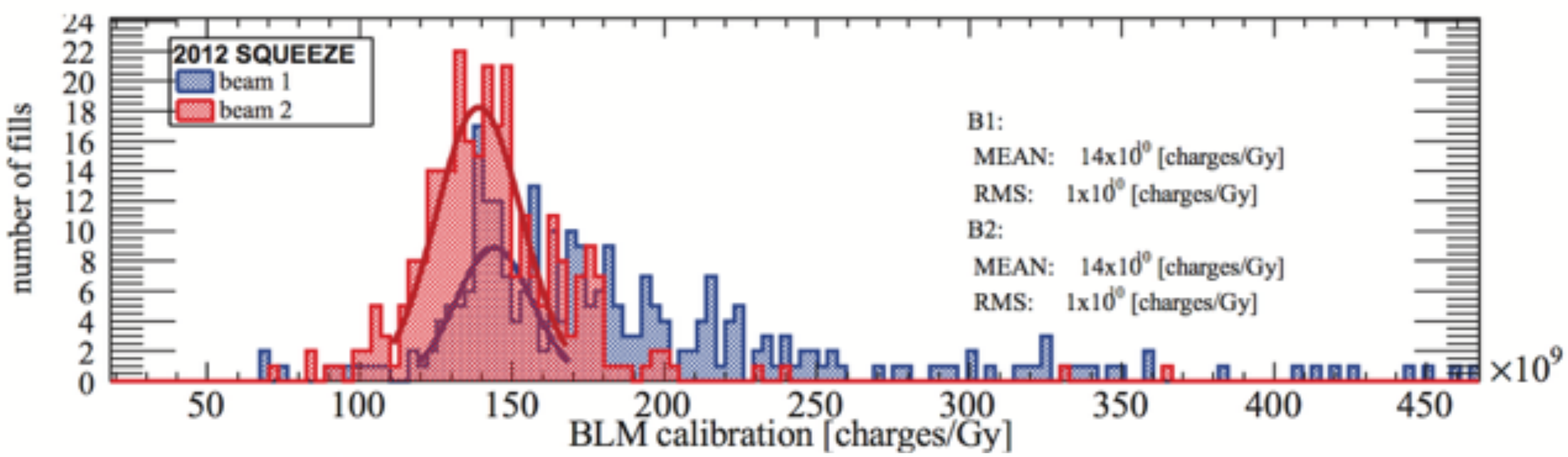

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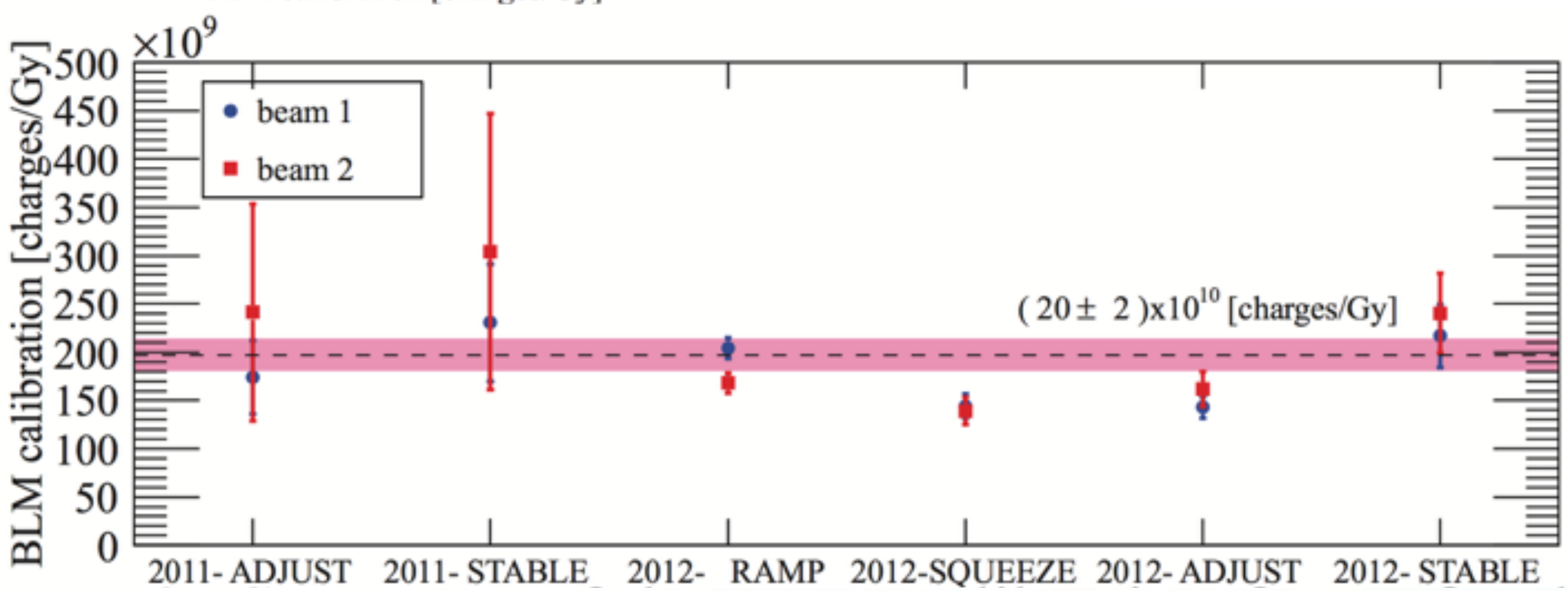
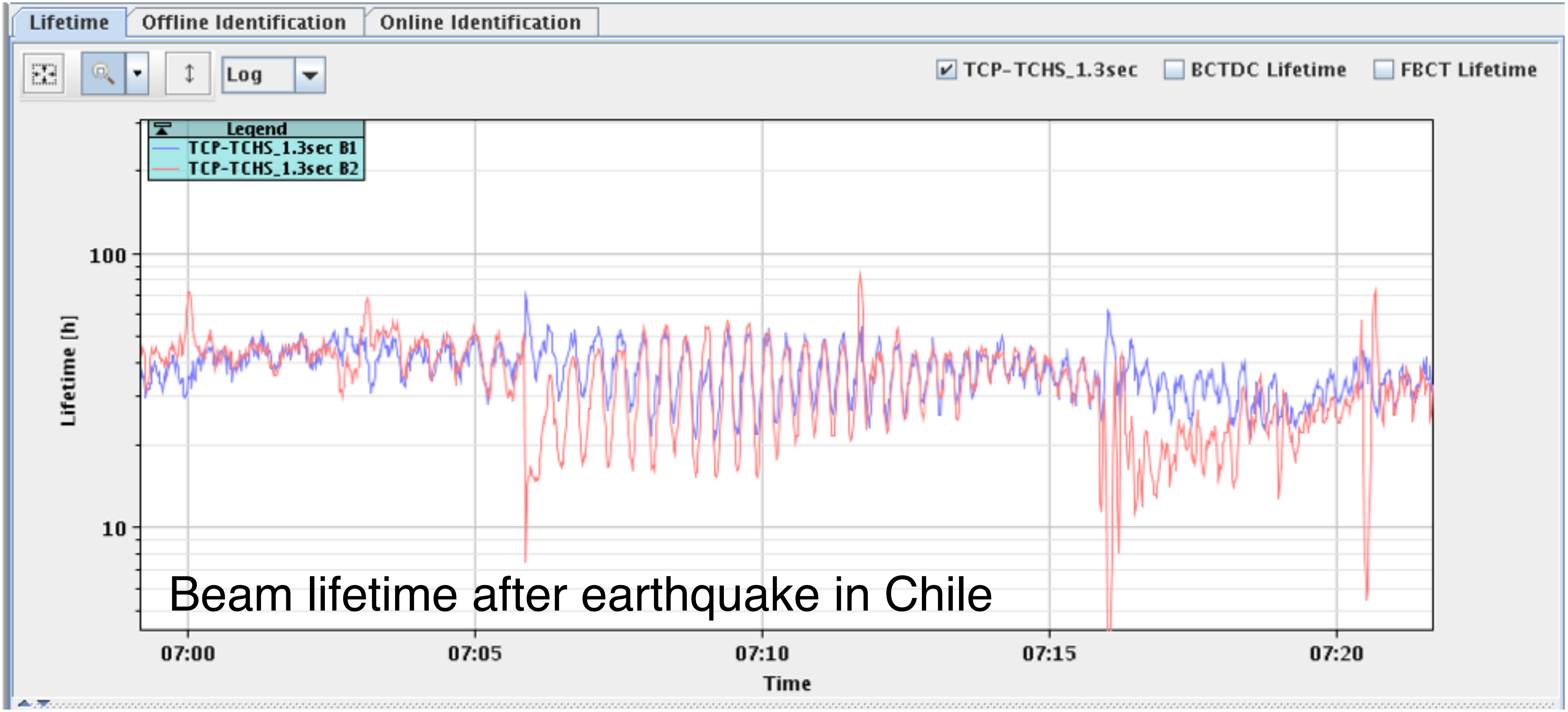


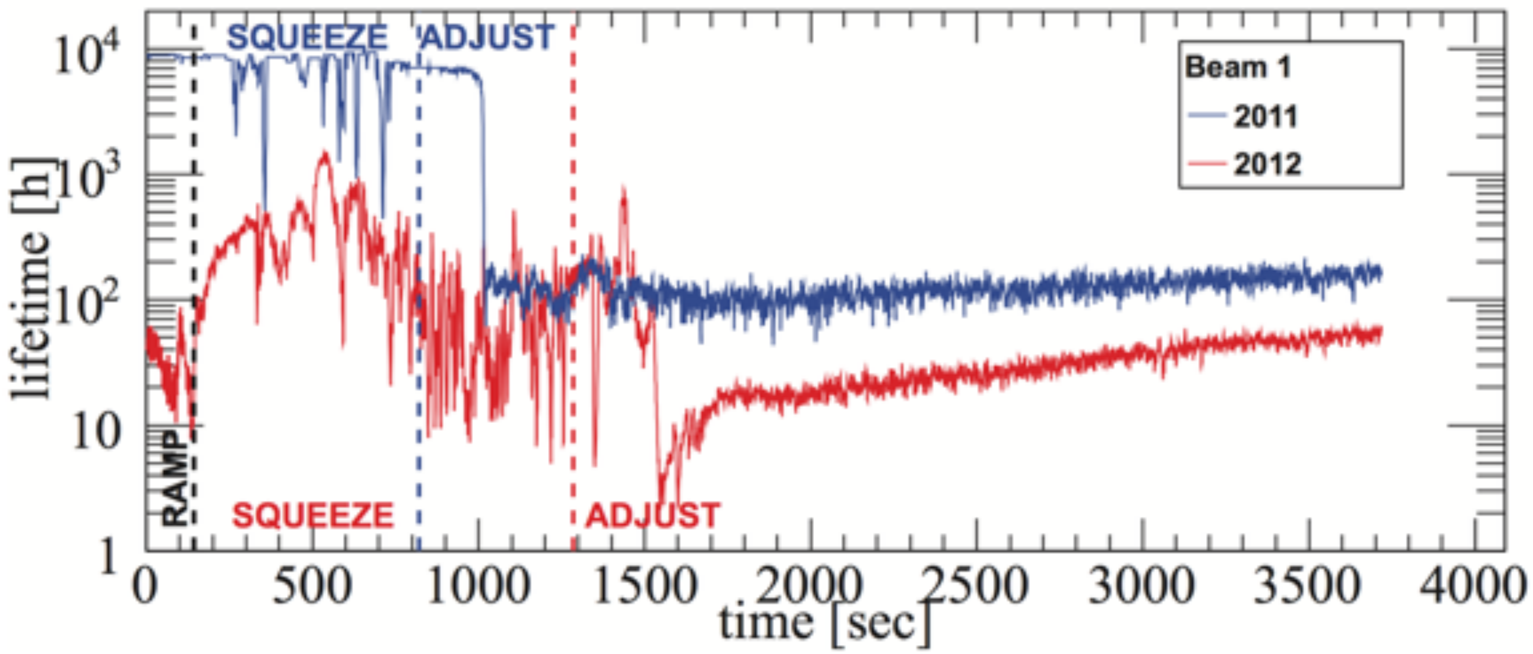
High Luminosity LHC

Applications - online lifetime (i)



Provided an application for online display of BLM-lifetime - very responsive and used a lot by the OP crew for immediate feedback on beam manipulations.

Applications - lifetime analysis (ii)



Consistently process all fills: lifetime analysis as input to future upgrades.

B. Salvachua

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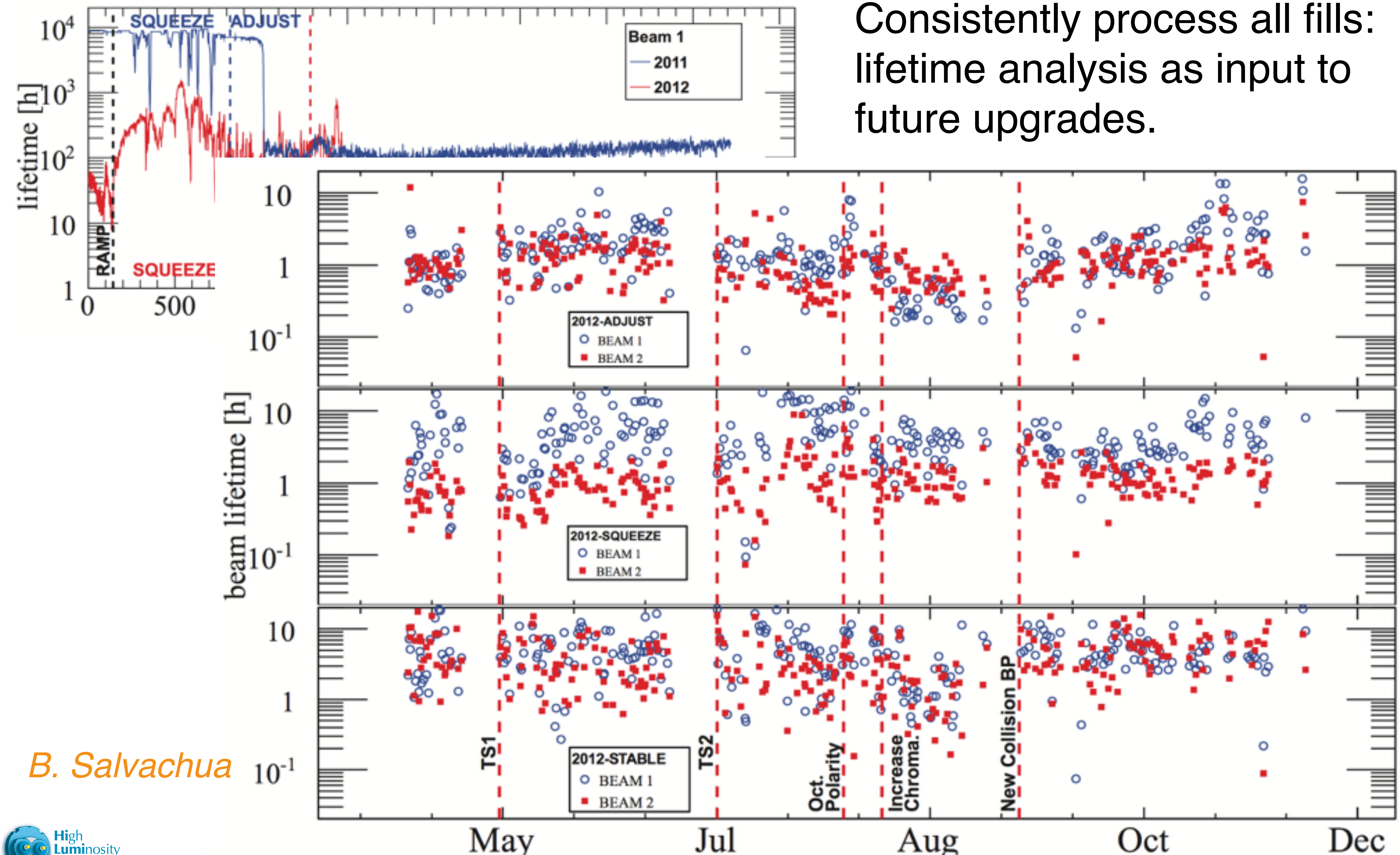

B. Salvachua

Outline

- Introduction
- Calibration and applications
- **Dedicated halo measurements**
- Observations in operation
- Conclusions

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **16**, 021003 (2013)

Beam diffusion measurements using collimator scans in the LHC

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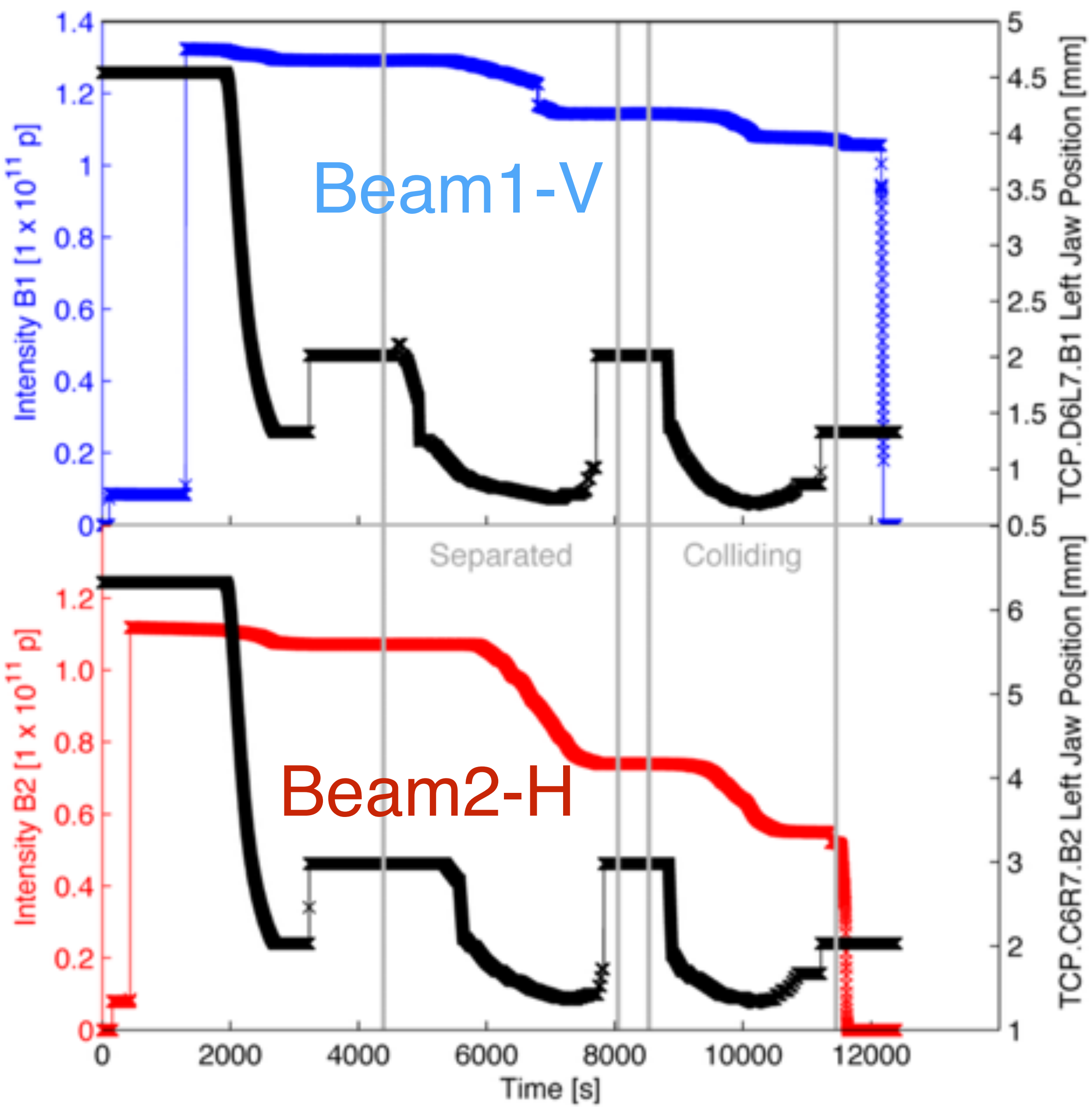
(Received 6 December 2012; published 19 February 2013)

Halo measurements at 4 TeV

First set of measurements of halo population and diffusion speed measurements at the LHC done in 2012 with collimator scans at 4 TeV.



Scan range: 7 to 1.7 sigmas (3.5 micron emittance)

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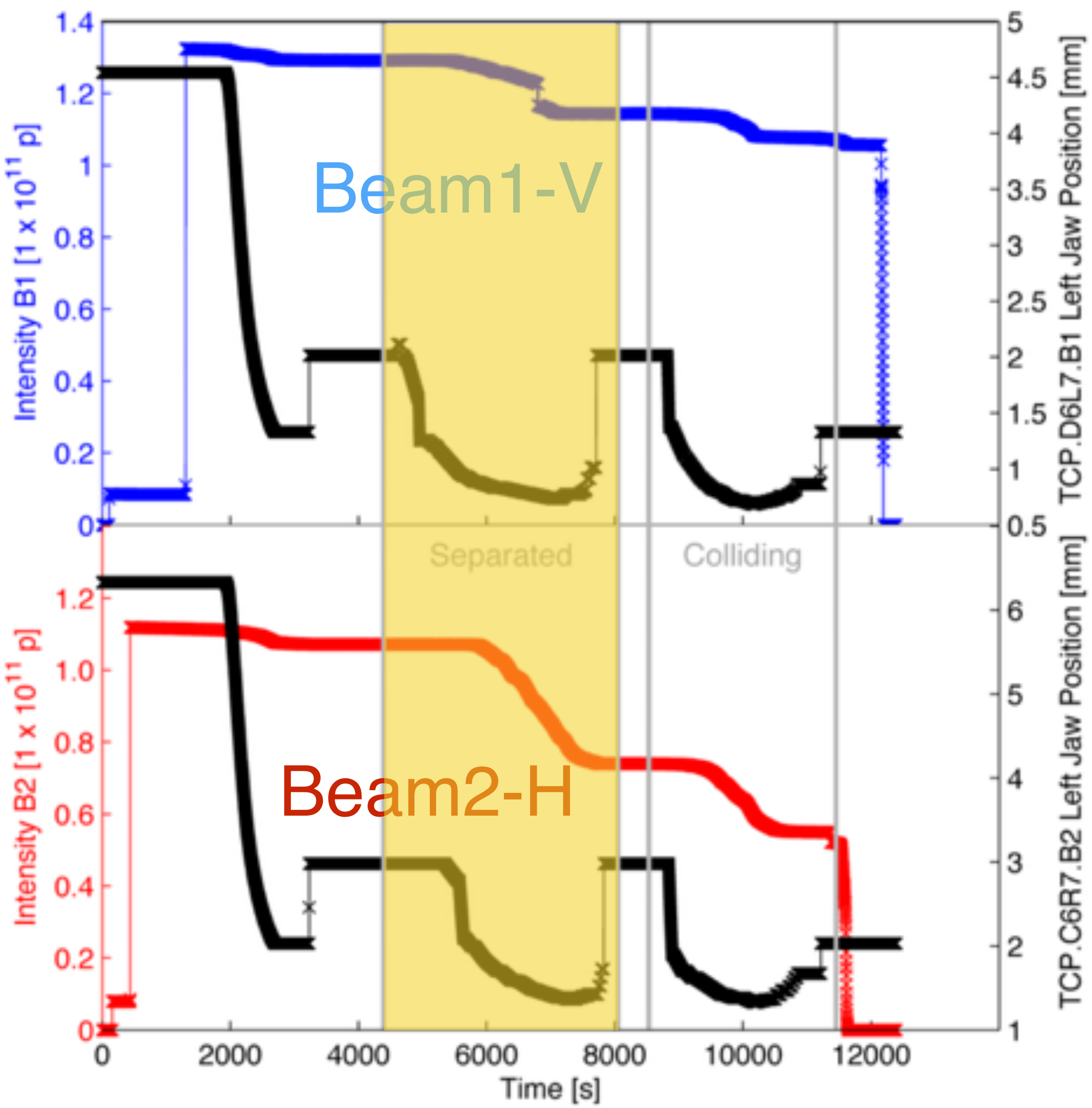

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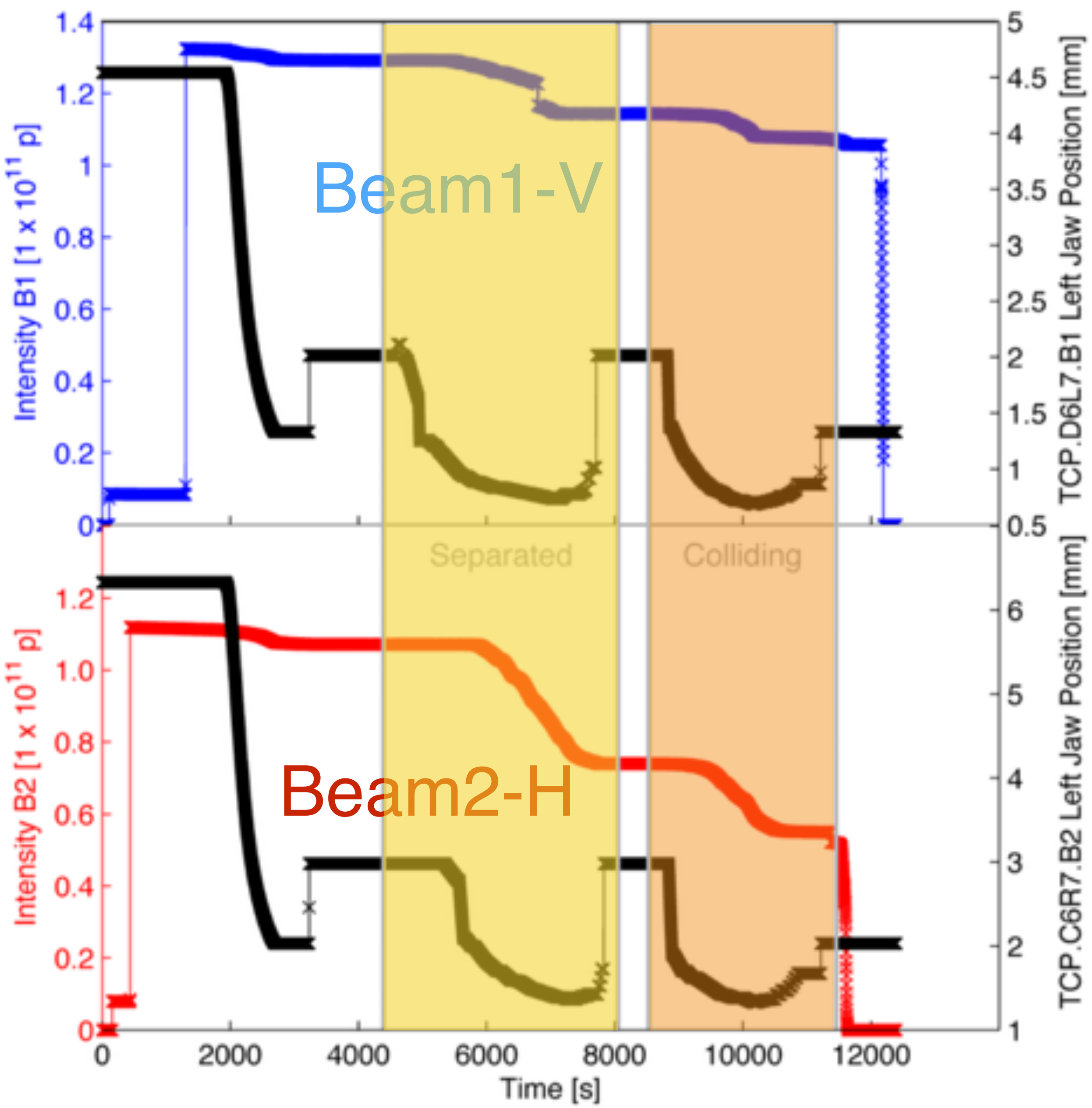

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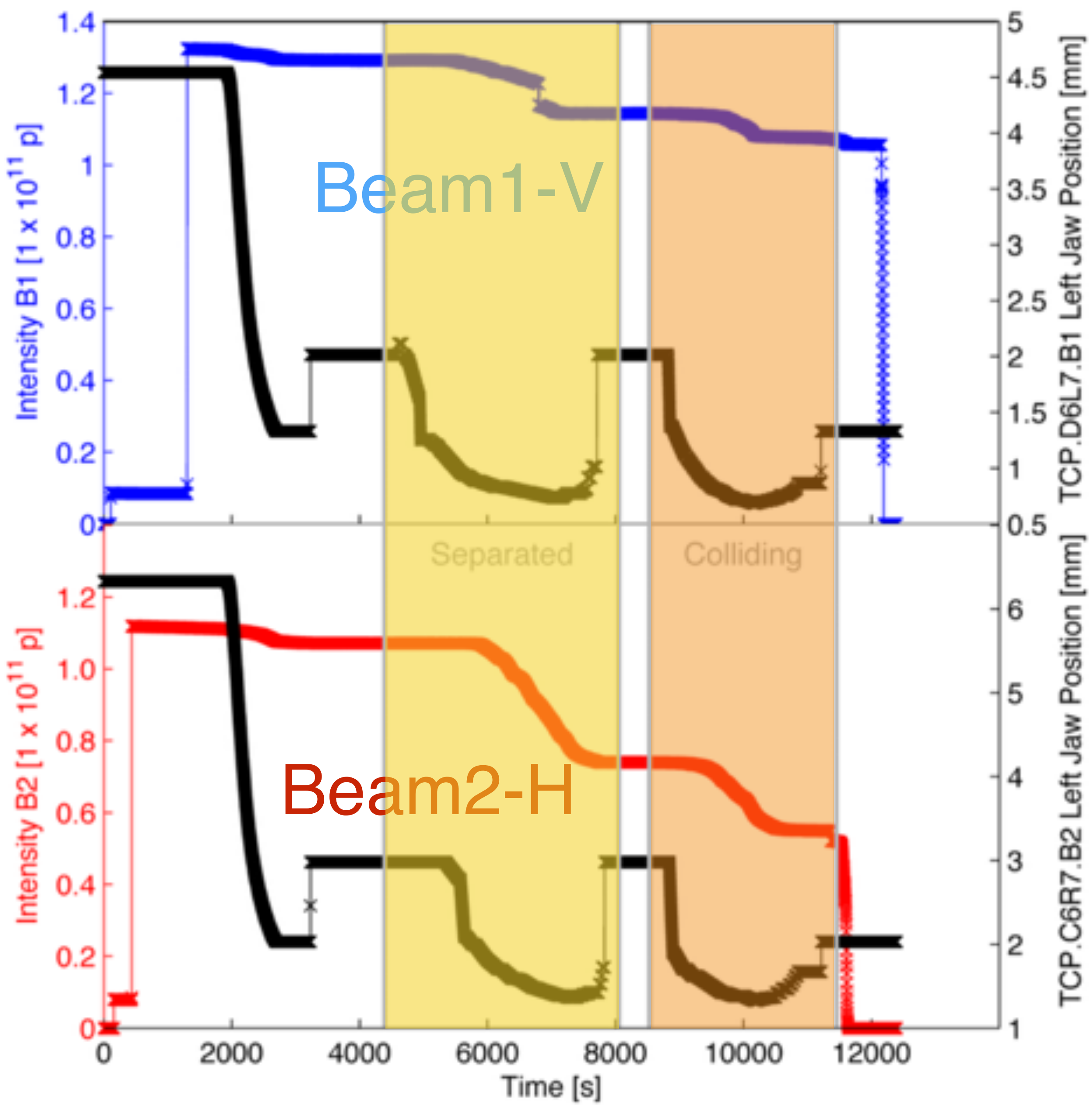

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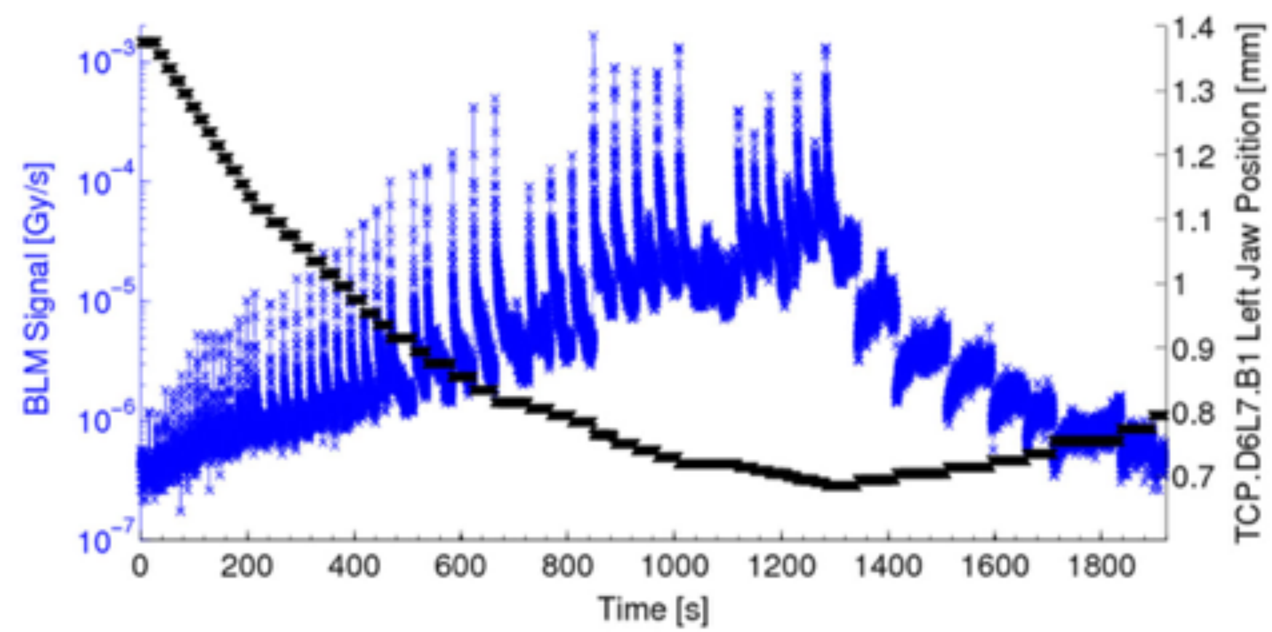
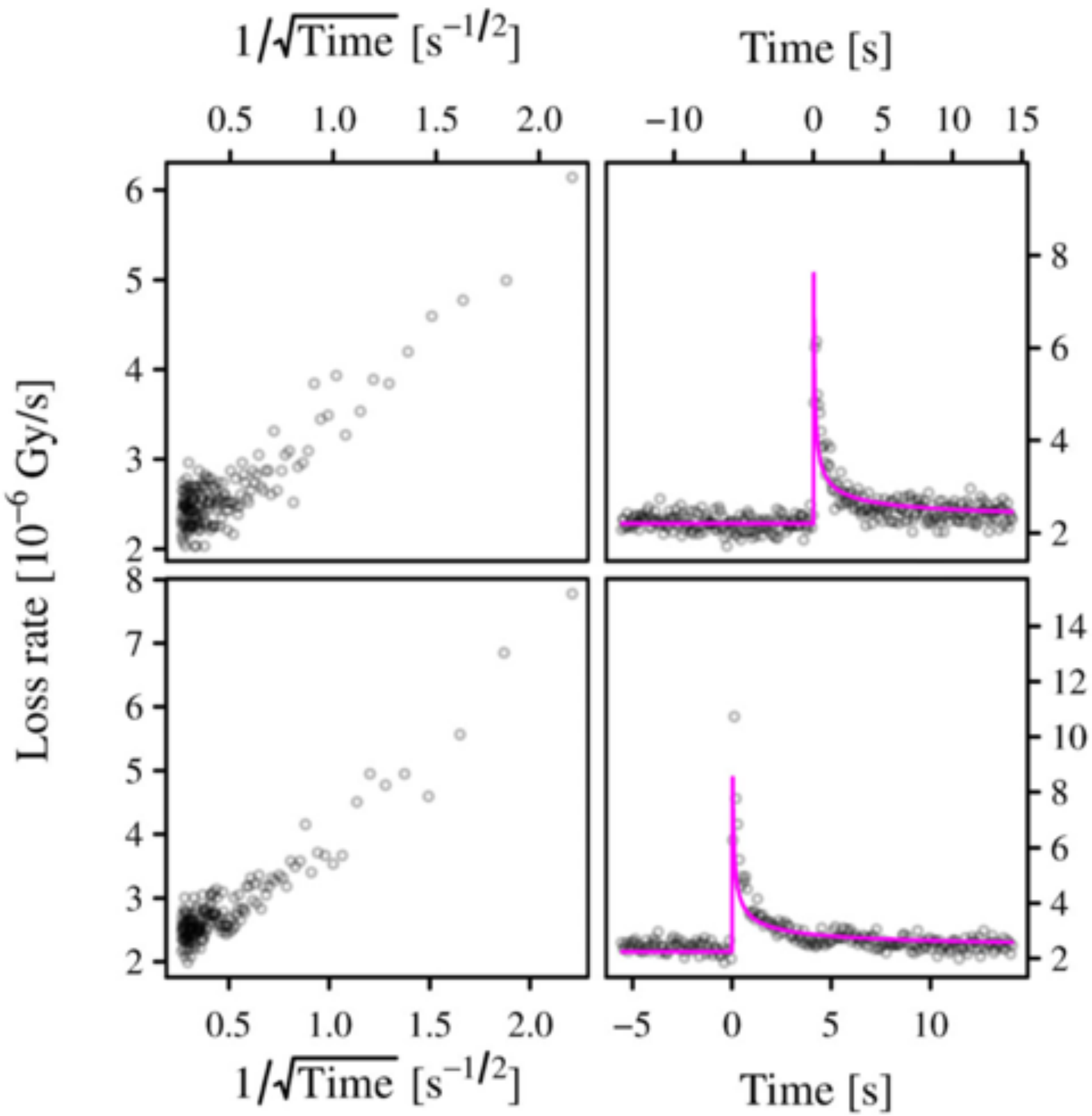


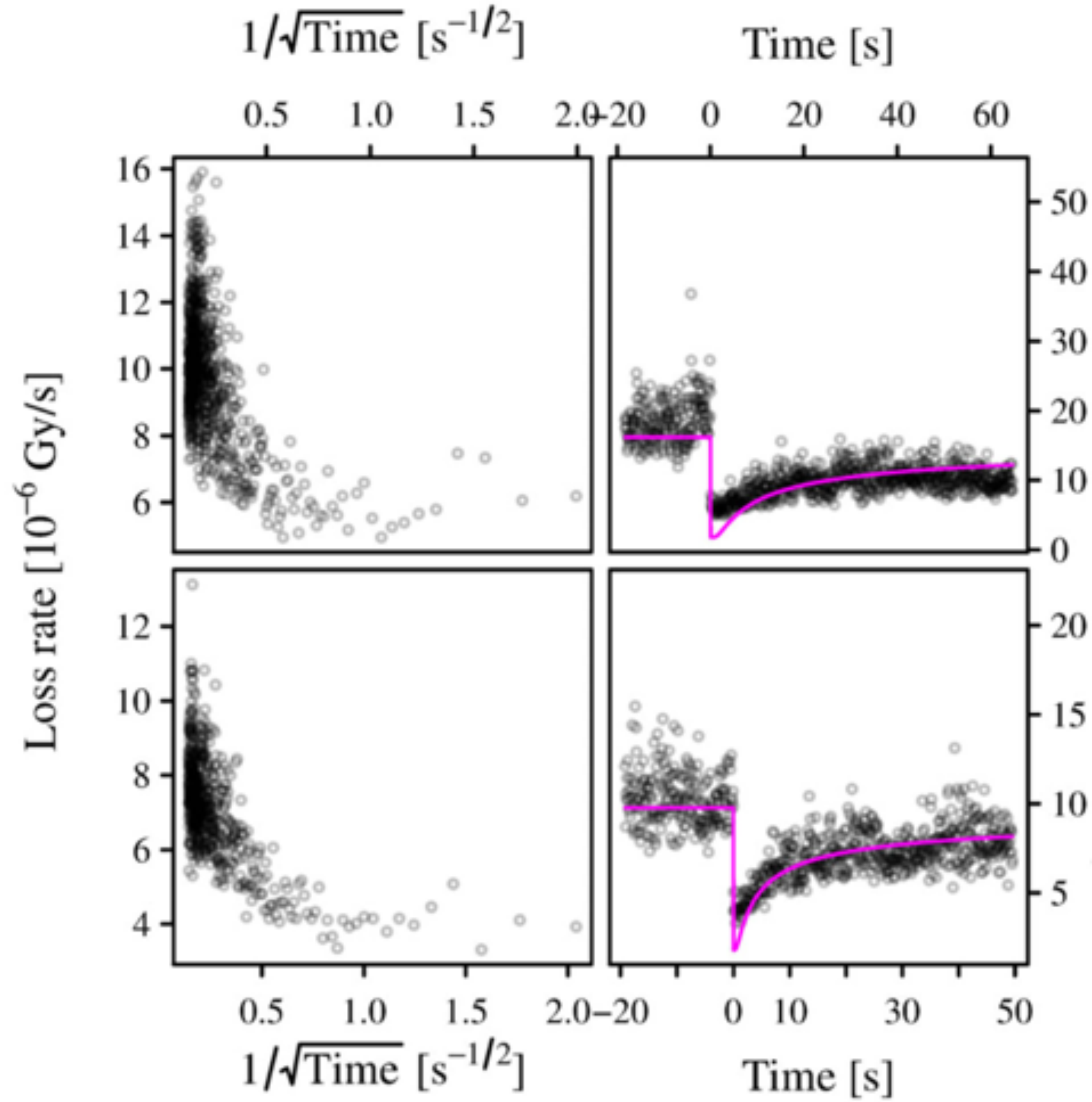
Beam data during experiment used to establish the Gy/s-p/s calibration .

Detailed analysis of loss spikes

Step IN - loss spikes



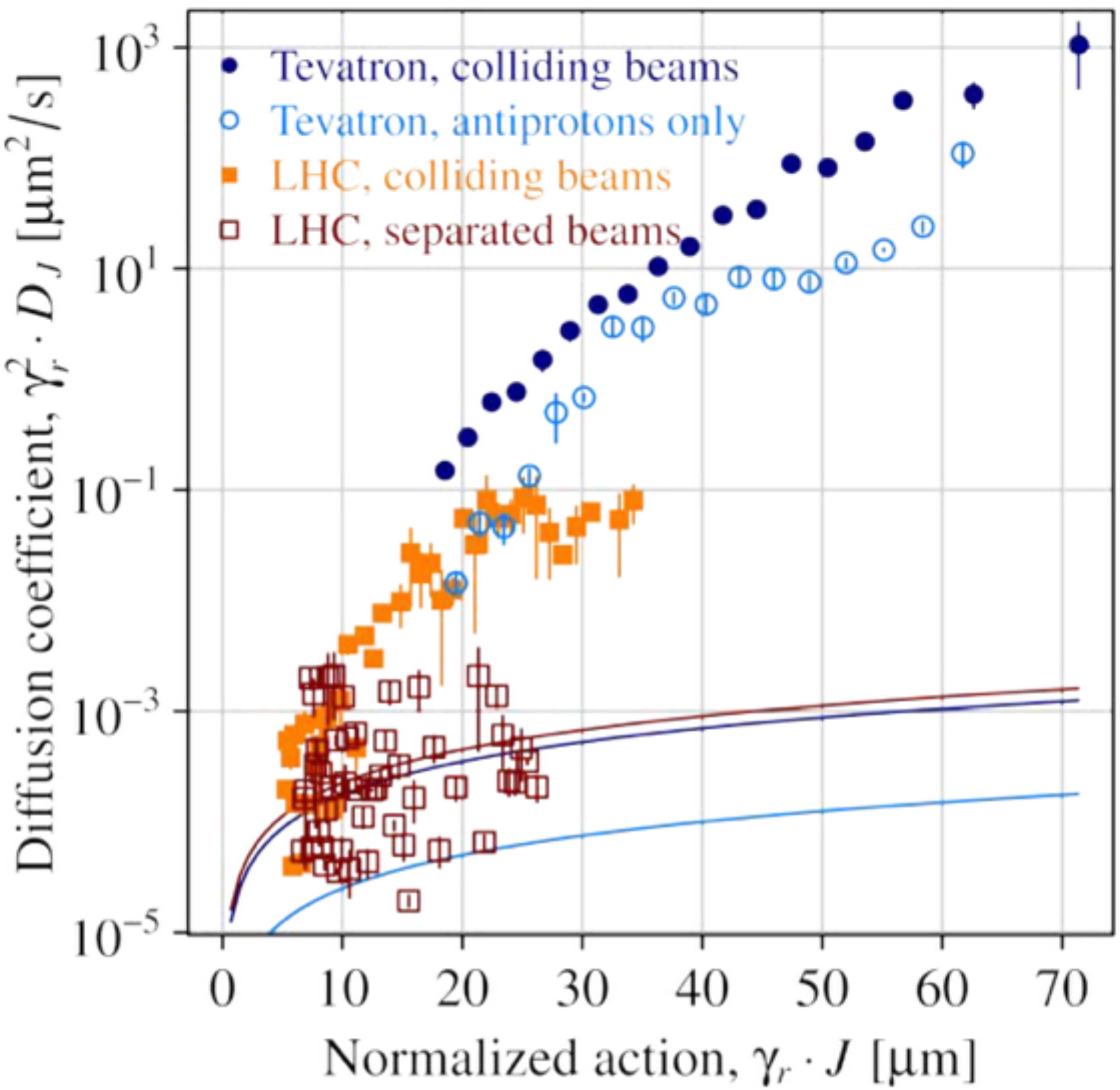
Step OUT - repopulation



G. Stancari,
G. Valentino

Tool to compare loss rates for different configurations - see later.

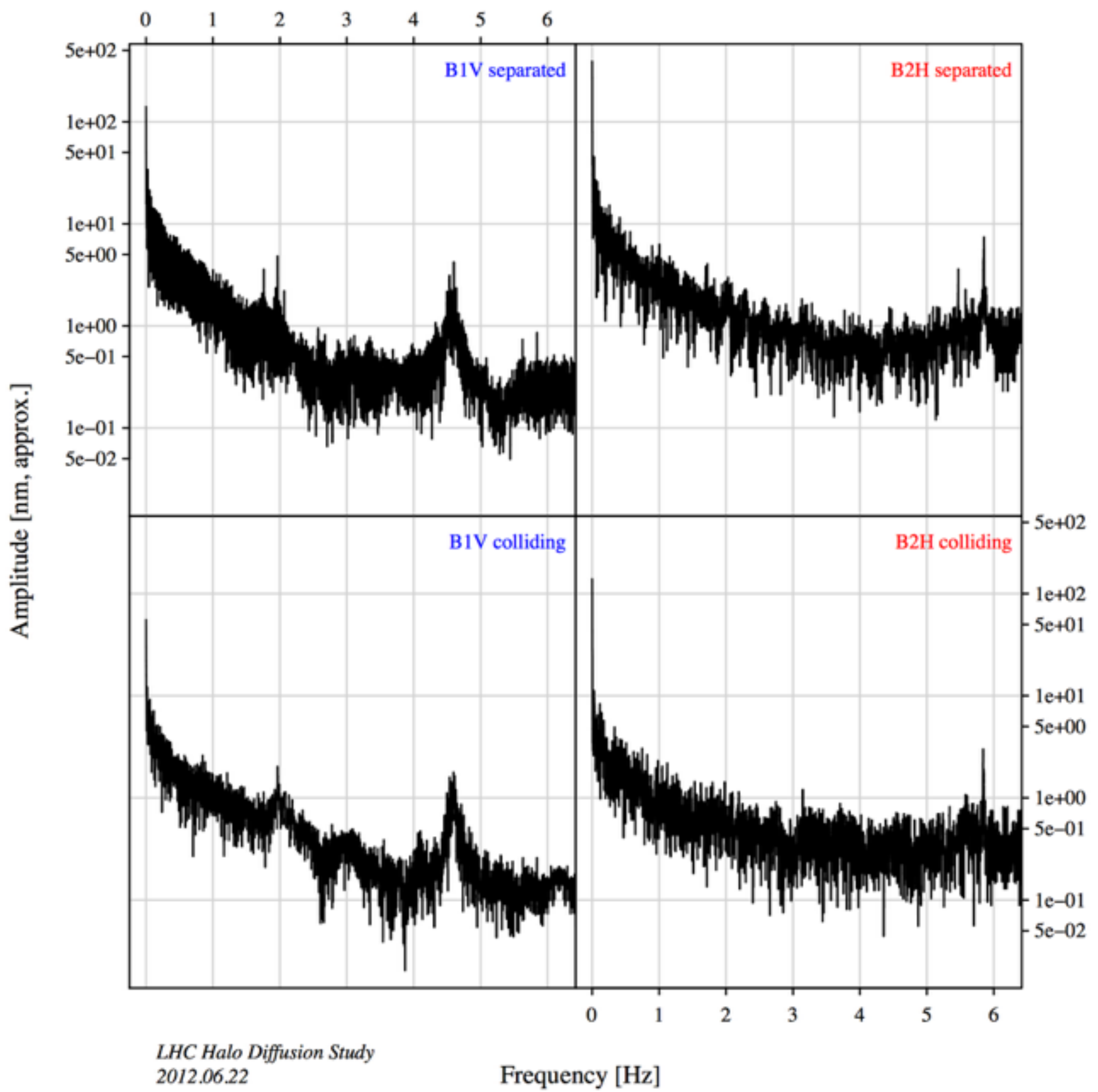
Measurement of diffusion speed



G. Stancari

Orbit jitter from collimator losses

Collimator jaw fixed at 3.75σ from circulating beam (4TeV). Monitor 12 Hz BLM data.



FERMILAB-FN-0950-APC

Outlook: 6.5TeV measurements

Measurements also done for the first time at 6.5TeV in MD3

Same procedure as in 2012, before and after collisions. Analysis ongoing.
New: attempt to make an absolute calibration with controlled beam excitations.
Wanted to have an end-of-fill with trains but this did not happen this year.

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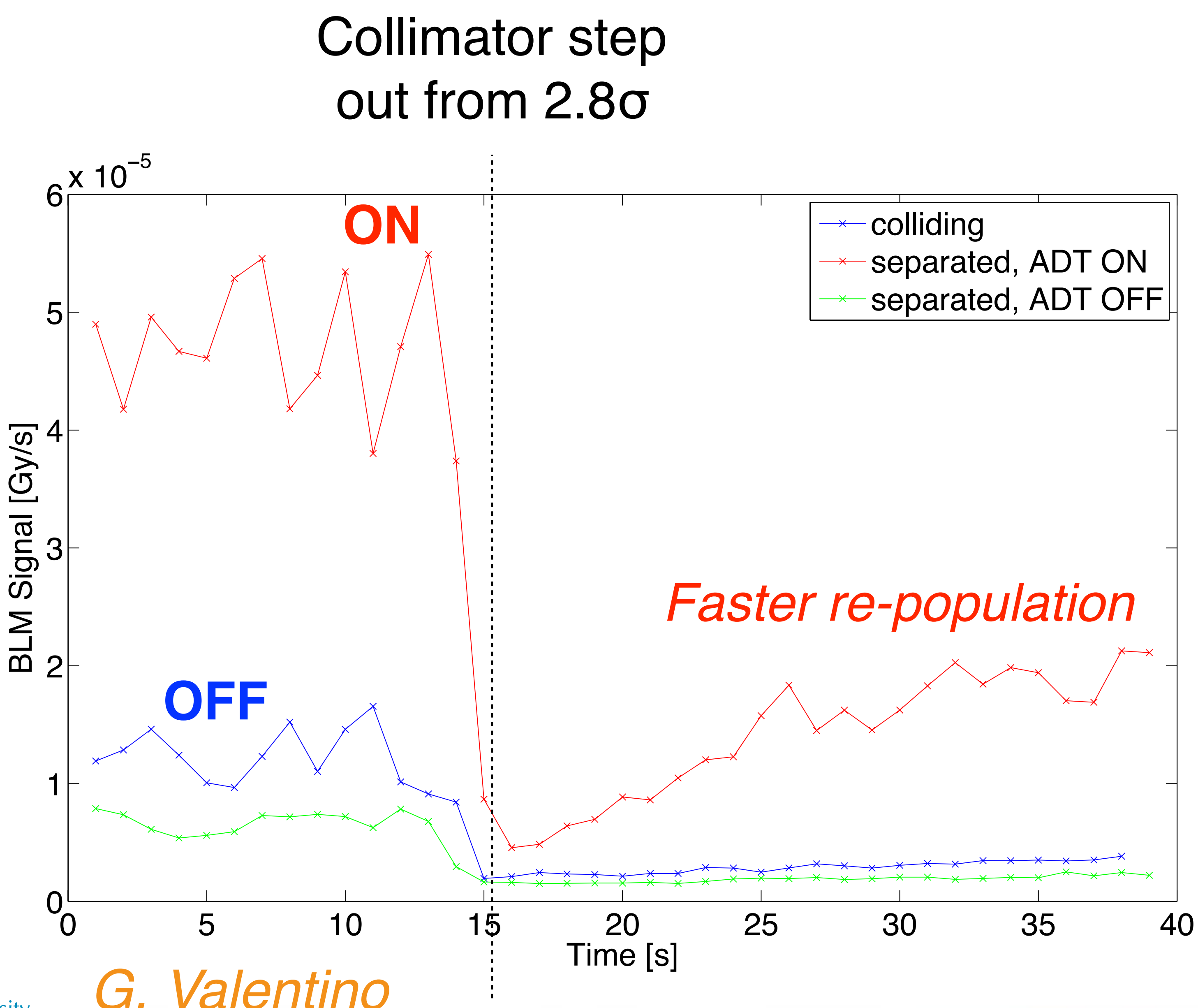

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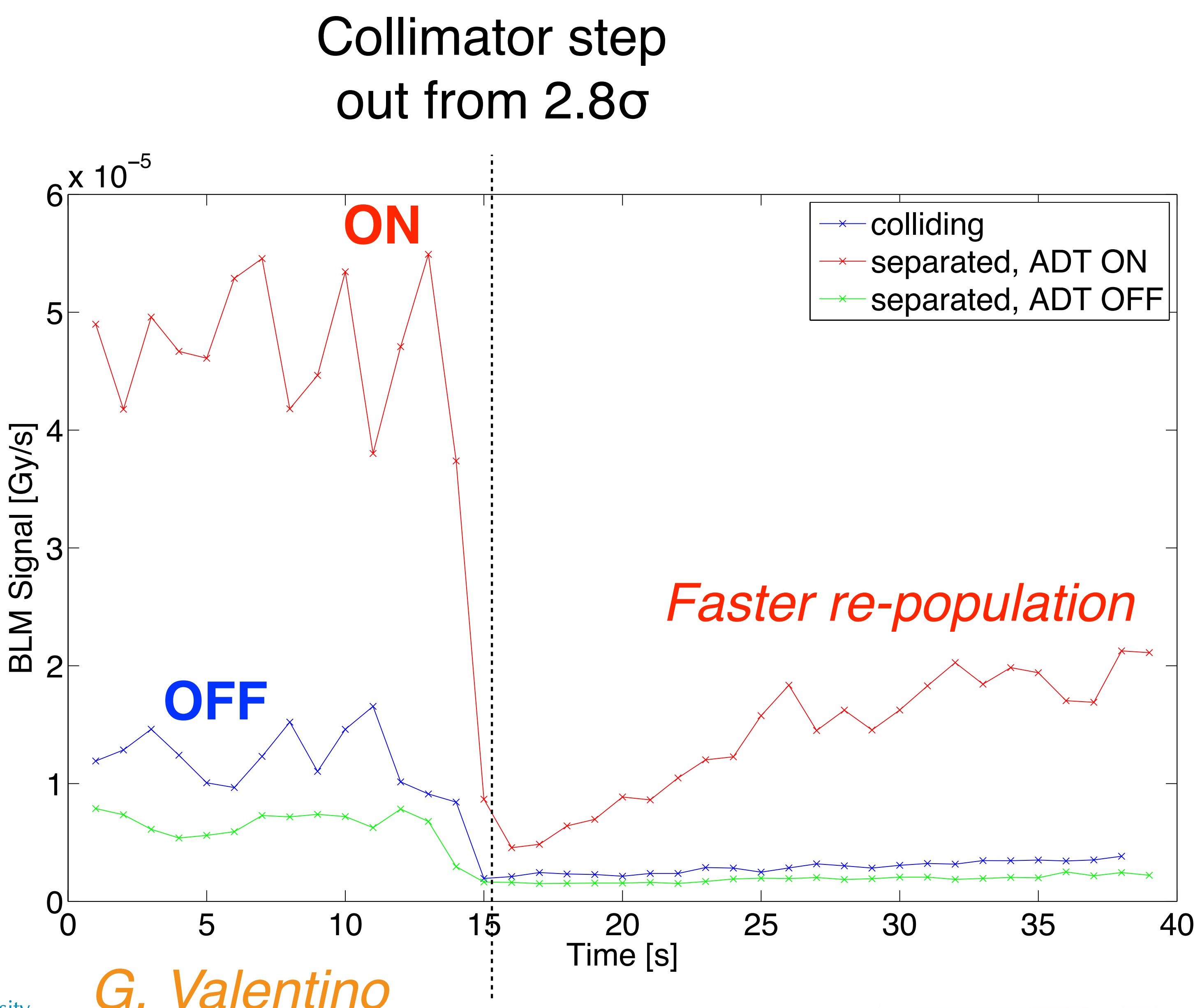

G. Valentino

Ongoing: understand and calibration diffusion speed from the excitation strength (RMS and amplitude of transverse damper used to excite the beam).

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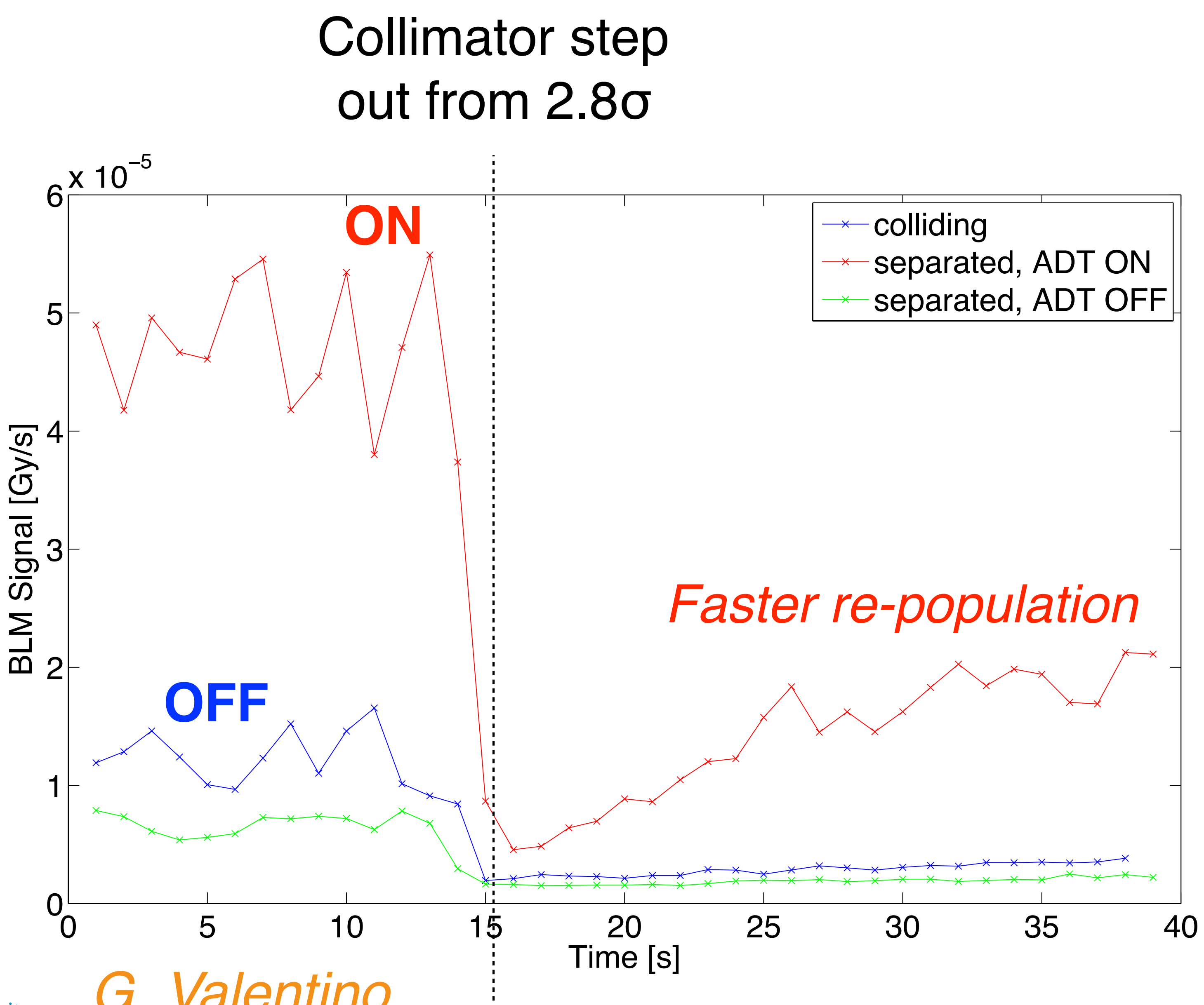

G. Valentino

Ongoing: understand and calibration diffusion speed from the excitation strength (RMS and amplitude of transverse damper used to excite the beam).

Understanding the absolute scale is challenging but potentially very interesting.

Considerations for discussion

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Advantages of collimator scan method

Robust and reliable. Very powerful tool for diagnostics.

Most precise method available at the LHC for halo measurements (my claim).

Immediate feedback on beam manipulations (tested up to 12 Hz).

Very precise knowledge of transverse amplitude, as two-sided collimators are aligned to the beam with < 50 μm accuracy.

LHC: scans available in horizontal, vertical and skew planes.

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Aspects to be improved

This is a destructive method.
Approaching the beam might perturb distributions.
Duration of measurements is ~30min, limited by spike decay/repopulation time and by total losses vs BLM dump thresholds
Scan range is limited by total beam current.

Presently using 1Hz or 12Hz data - <u>no bunch-by-bunch measurements</u>. We are looking forward to see in operation the diamond BLM in IR7!
Absolute calibration needs some "love and care".

Outlook

- Introduction
- Calibration and applications
- Dedicated halo measurements
- **Observations in operation**
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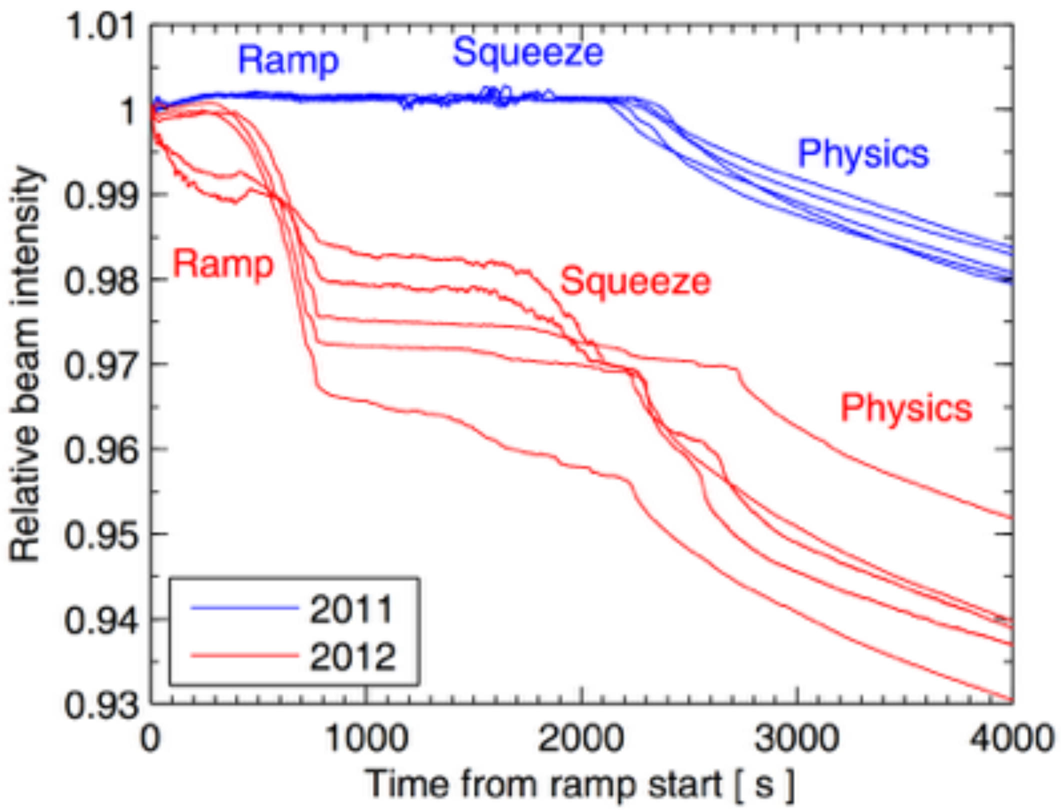
EXPERIENCE WITH HIGH-INTENSITY BEAM SCRAPING AND TAIL POPULATION AT THE LARGE HADRON COLLIDER

S. Redaelli, R. Assmann, F. Burkart, R. Bruce, D. Mirarchi, B. Salvachua, G. Valentino, D. Wollmann, CERN, Geneva, Switzerland

Beam losses in the ramp (2012)



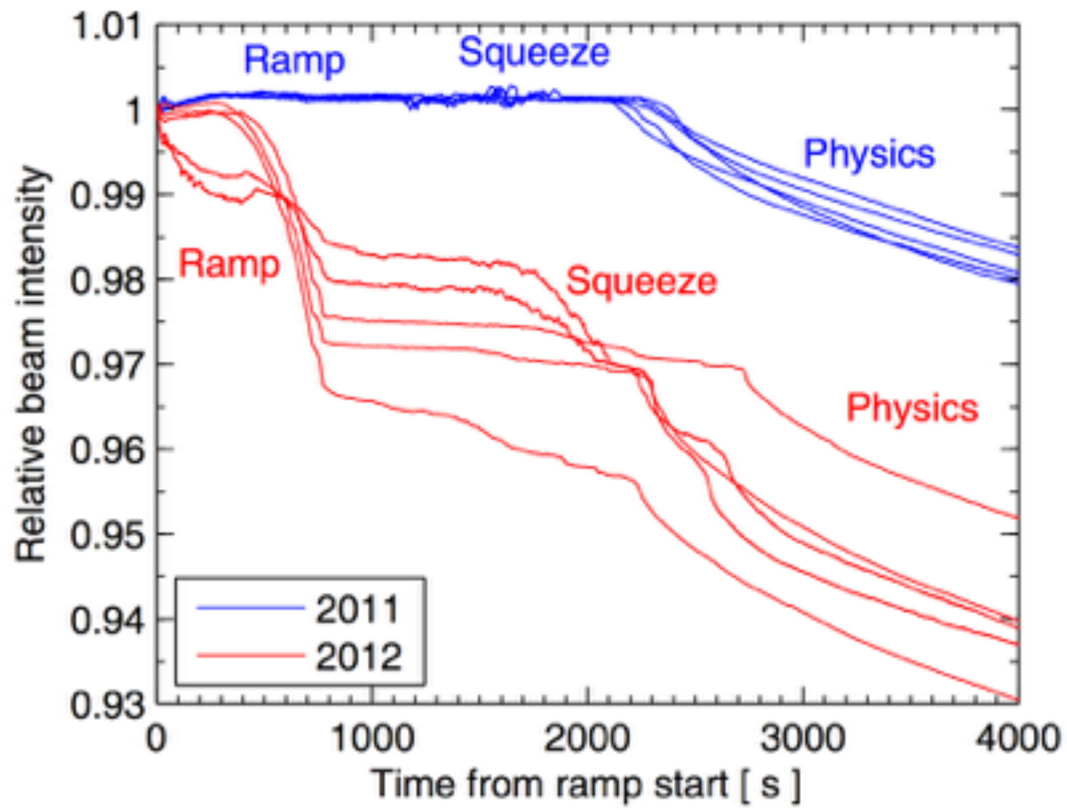
Qualitatively different loss behaviour between 2011 and 2012:

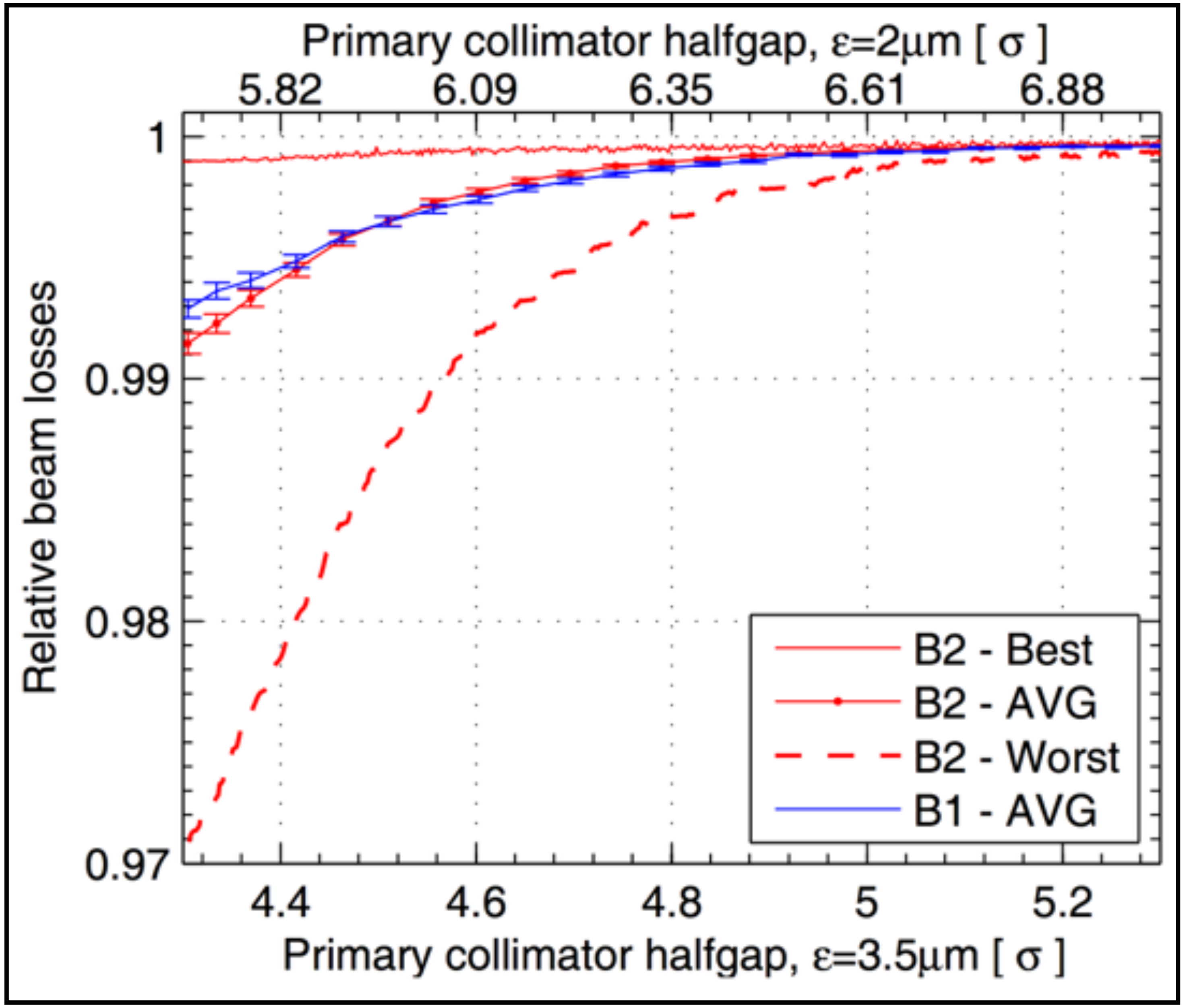
"tight" collimator settings deployed to fit 60 cm β* at 4TeV.

Primary cut: 5.7σ - 4.3σ (ε=3.5μm) during the ramp.

"Slow" losses at the end of the ramp; sensitive on orbit jitters in the squeeze.

Beam losses in the ramp (2012)





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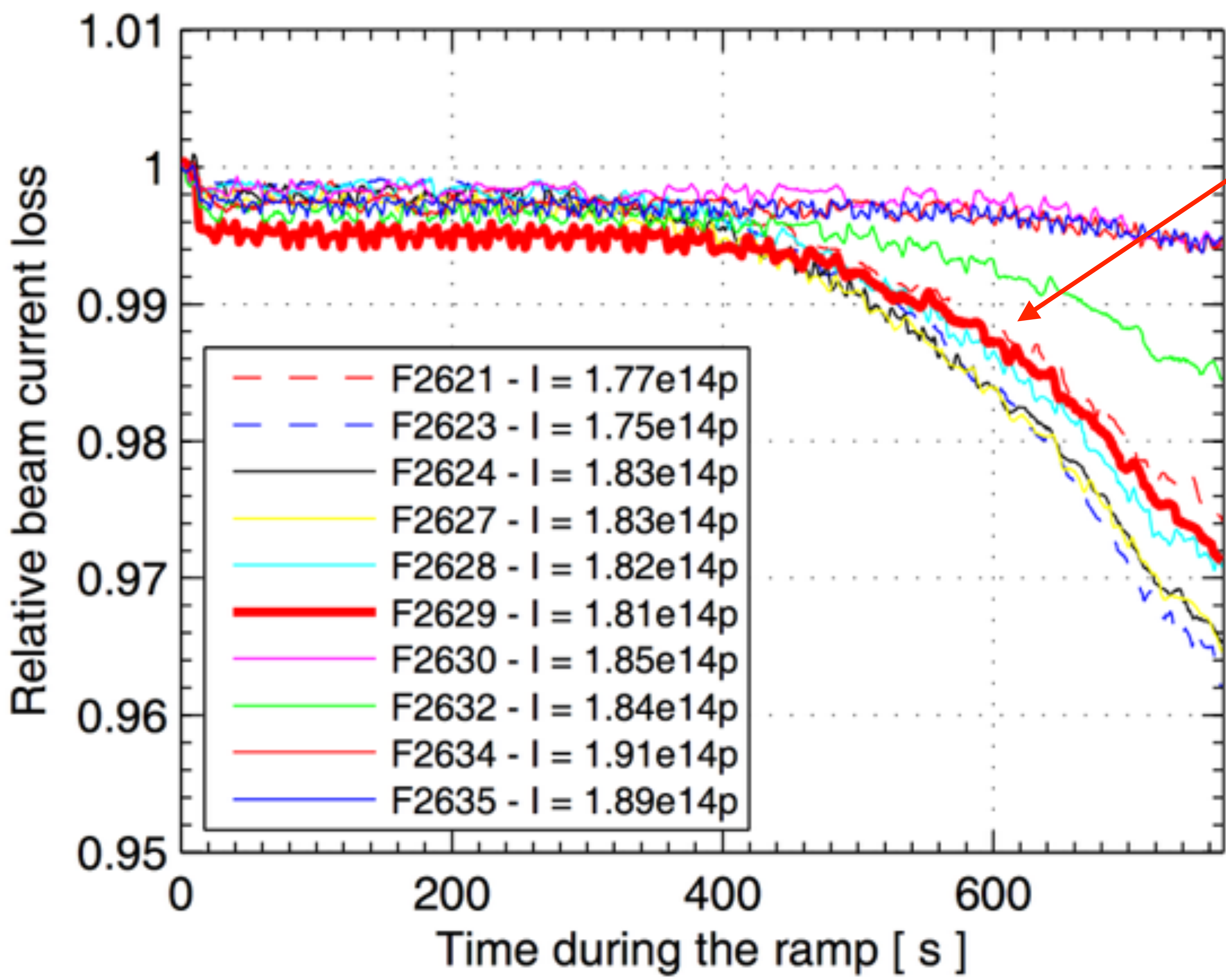
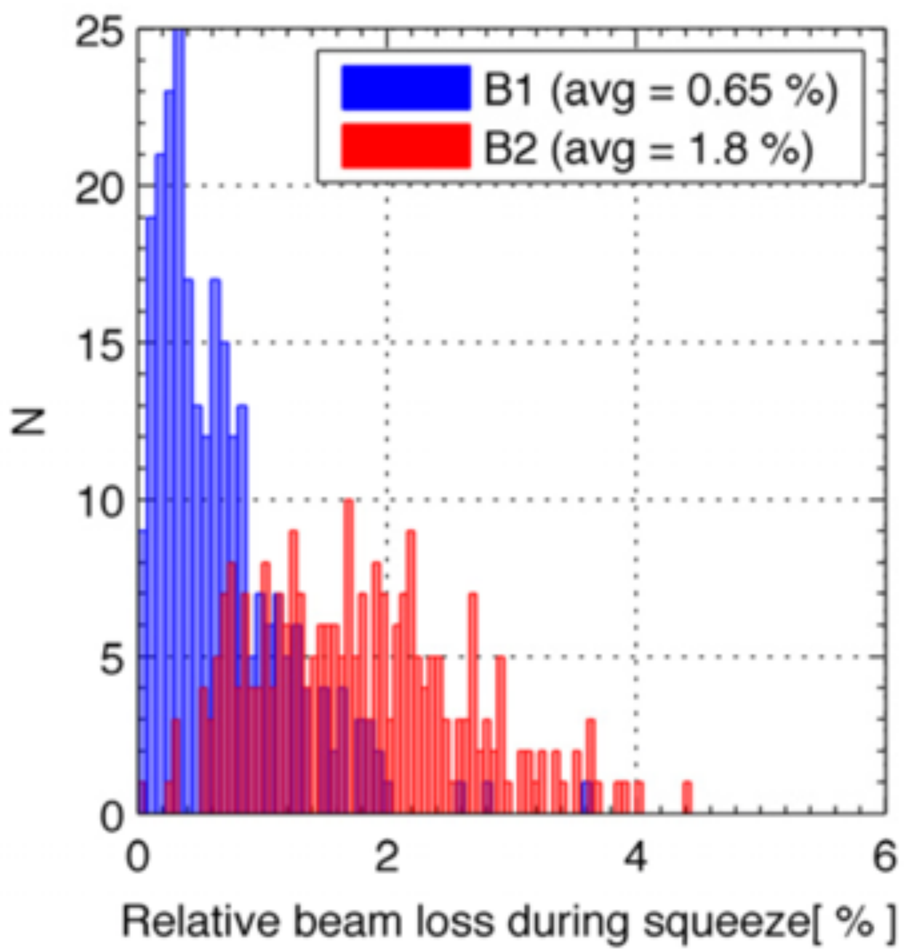
Ramp losses - source?



Transverse tails scraped at injection - no difference in losses (note - low statistics: tried only once).

Squeeze losses



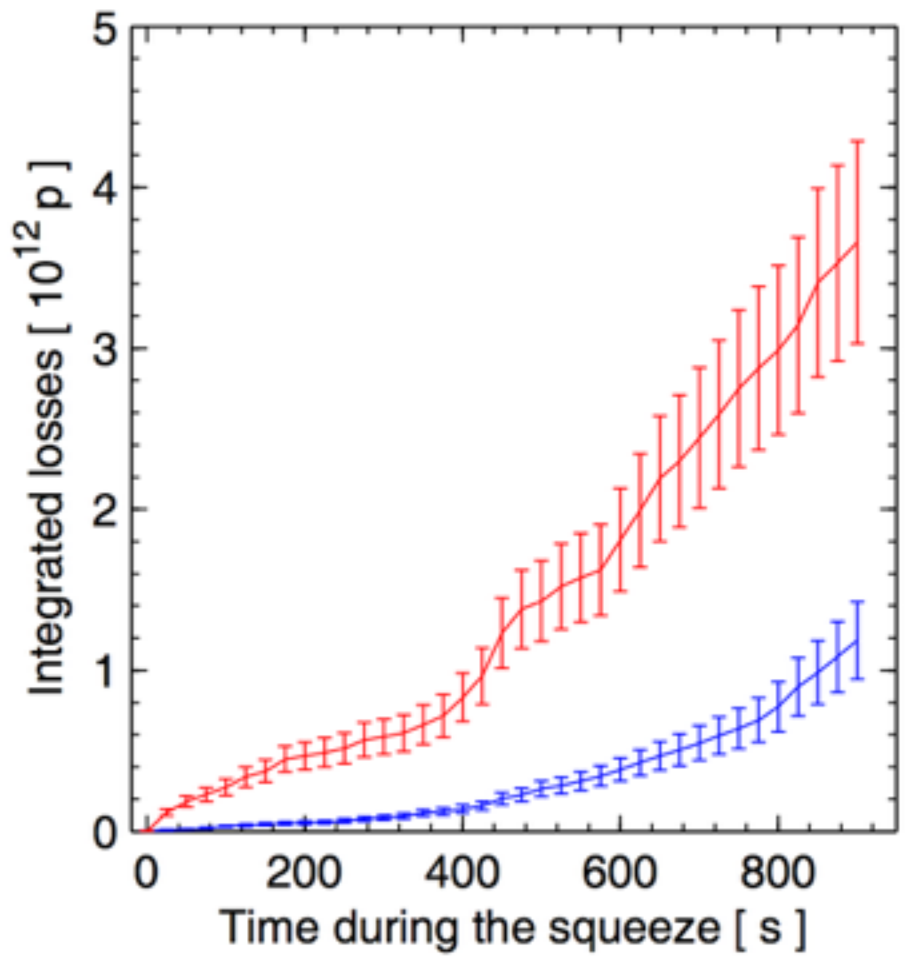
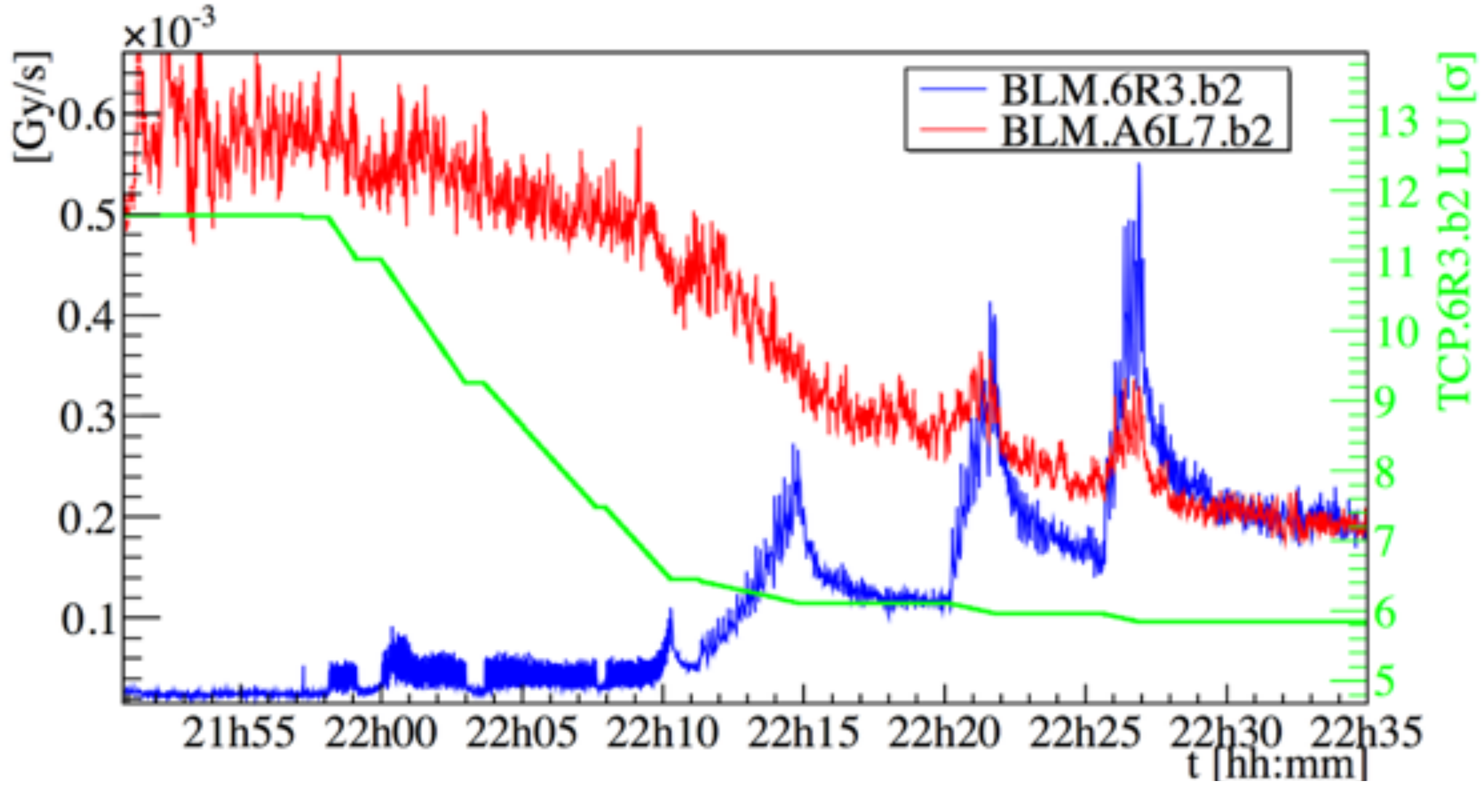


Table 1: Tail populations measured in ramp and squeeze of standard physics fills in 2012.

	Ramp		Squeeze	
	B1	B2	B1	B2
Percent losses	0.7 %	0.9 %	0.7 %	1.8 %
Amplitude, σ_{nom}	4.3-5.7	4.3-5.7	4.0-4.3	3.9-4.3

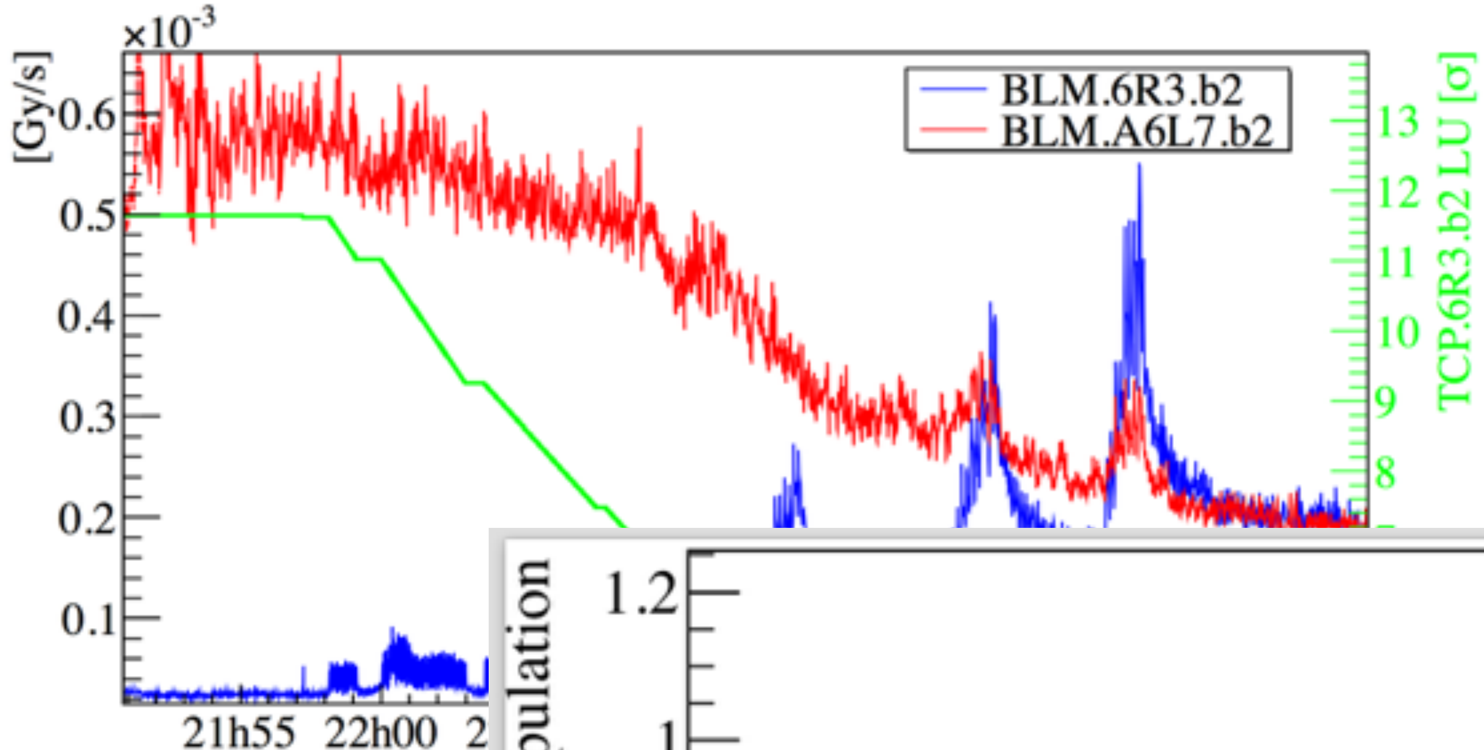
Off-momentum tail population

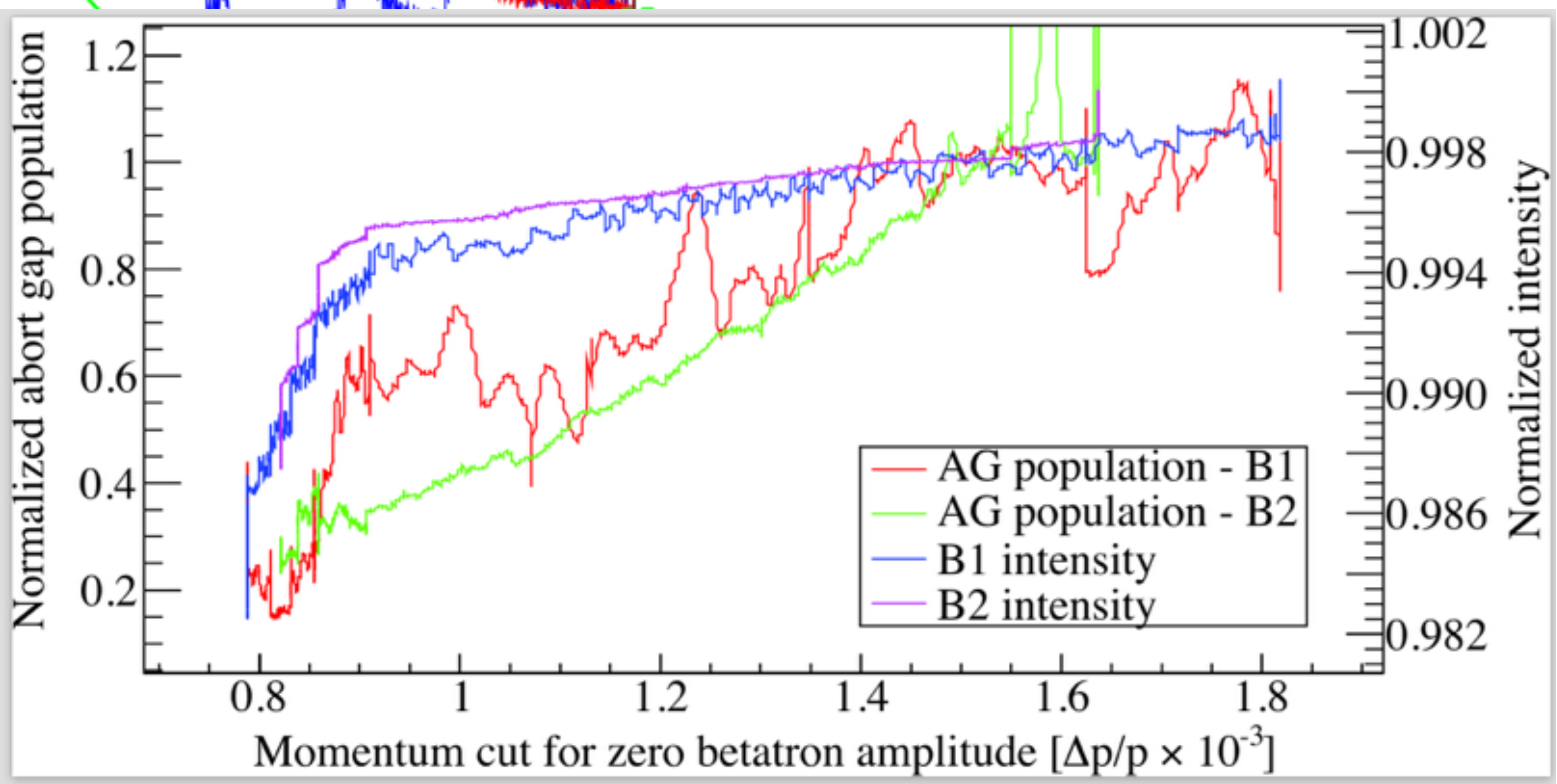


End-of-fill study in 2012: 400 bunches at 25ns spacing.

D. Mirarchi

Off-momentum tail population





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- **Reviewed the experience with collimator scans for halo measurements at the LHC**
  - *Scans can provide a nice diagnostic tool for high-accuracy halo measurements down to below 2 beam sigmas.*
  - *Lot of nice accelerator physics behind!*
  - *Advantages and areas of improvements were listed for discussion.*

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- **Our interest: understanding performance limitations from collimation losses for present LHC and future upgrades**

  One important ingredient together with collimation cleaning and quench studies.
  Fruitful collaboration with FNAL (and others) for hollow e-lens studies.

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- **In the context of measurements with wire-collimators**

  Clearly, this can be a powerful complement to standard beam diagnostics.
  We should extend the tests to bunch trains. Can be tested next year.
  Must have bunch-by-bunch loss measurements at primary collimators.