LHC Collimation Working Group meeting

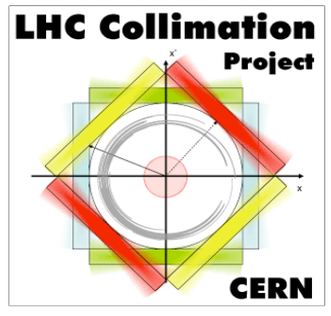
Geneva, 17th December 2008

Highlights of 2008 Collimator beam tests at the SPS

S. Redaelli, AB-OP

and R. Assmann, C. Bracco, T. Weiler, AB-ABP

Acknowledgments: Collimator controls team (A. Masi, R. Losito, M. Jonker); BLM team (B. Dehning, C. Zamantzas); OP crew (E. Veyrunes, J. Wenninger); MD planning (E. Métral); + K. Cornelis



Outline

- ☑ **Introduction - 2008 beam tests**
- ☑ **Beam losses with 26 GeV beam**

  Outline of tests

- ☑ **SPS collimation studies**

  Beam-based alignment

  Lifetime effects and loss tails

  Halo re-population

  Attempts to set jaw angle

  Fast BLM acquisitions

- ☑ **Conclusions**

Collimator beam tests in 2008

See S.R. at the Collimation WG meeting of June 16th, 2008

- **Requests from the BLM team:**

  - Calibration of BLM signal (pulsed beam at injection energy of 26 GeV)

  - Frequency spectrum of beam losses from LHC collimator prototype

- **Our request: 3 x 8h (E=270 GeV protons, stored beam, various intensities)**

  Goals: 1) Tests on time structure of beam loss measurement

  2) Study of absolute beam loss signals

  3) Study of beam-based collimator calibration

  4) Test of fast BLM acquisition with collimator movements

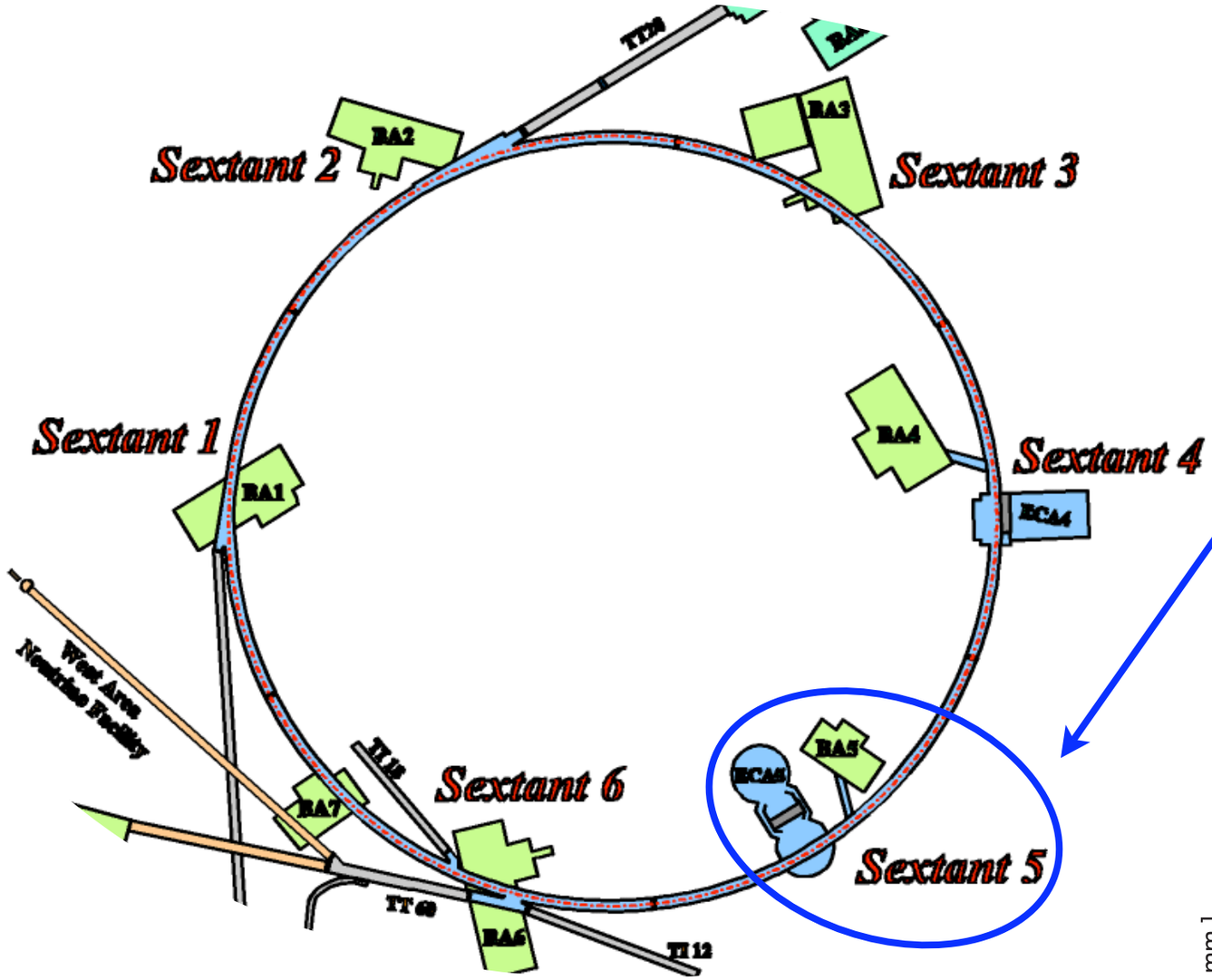
- **TI8 collimator beam commissioning:**

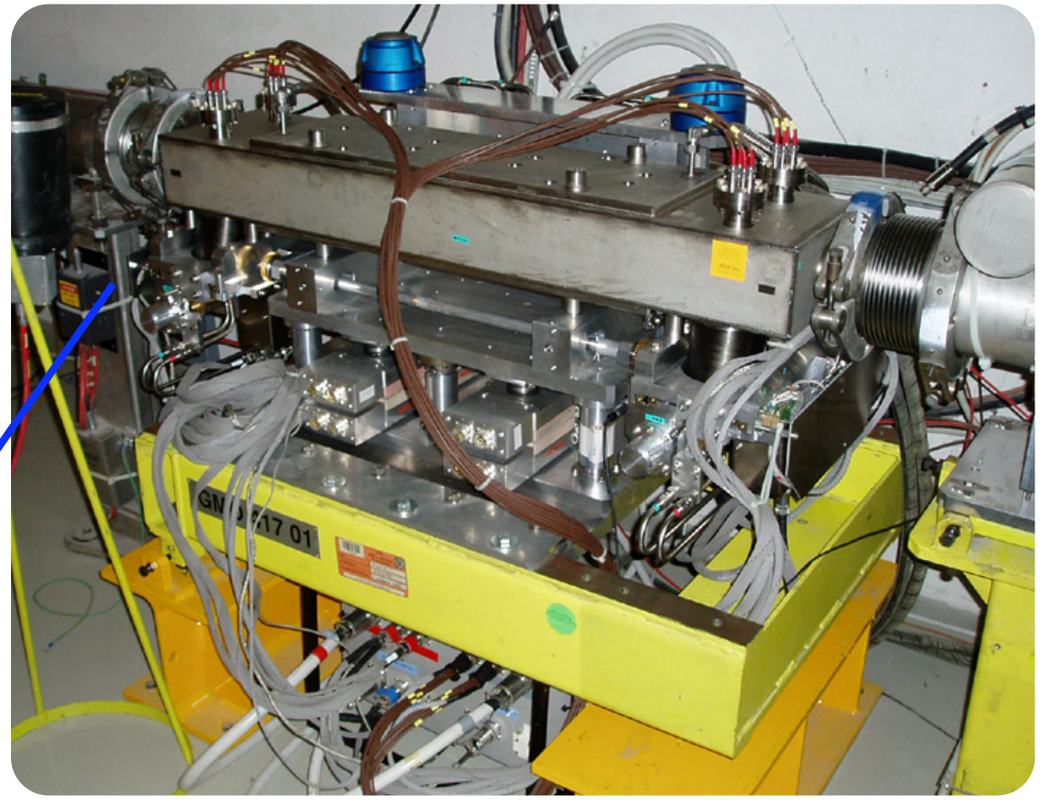
  - See S. Redaelli at CWG of 16/06/2008 and V. Previtali at LTI of 26/06/2008

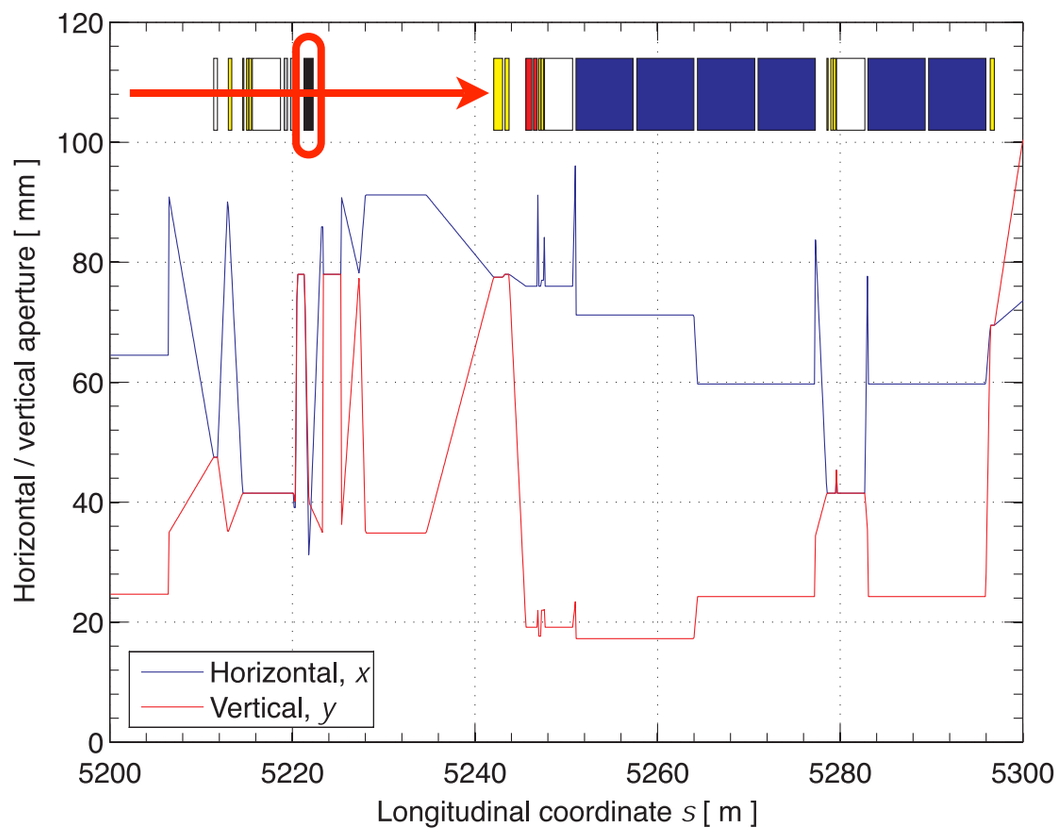
- **Sector tests and first LHC commissioning**

  - Not yet presented at the CWG meeting...

Reminder - SPS collimator layout

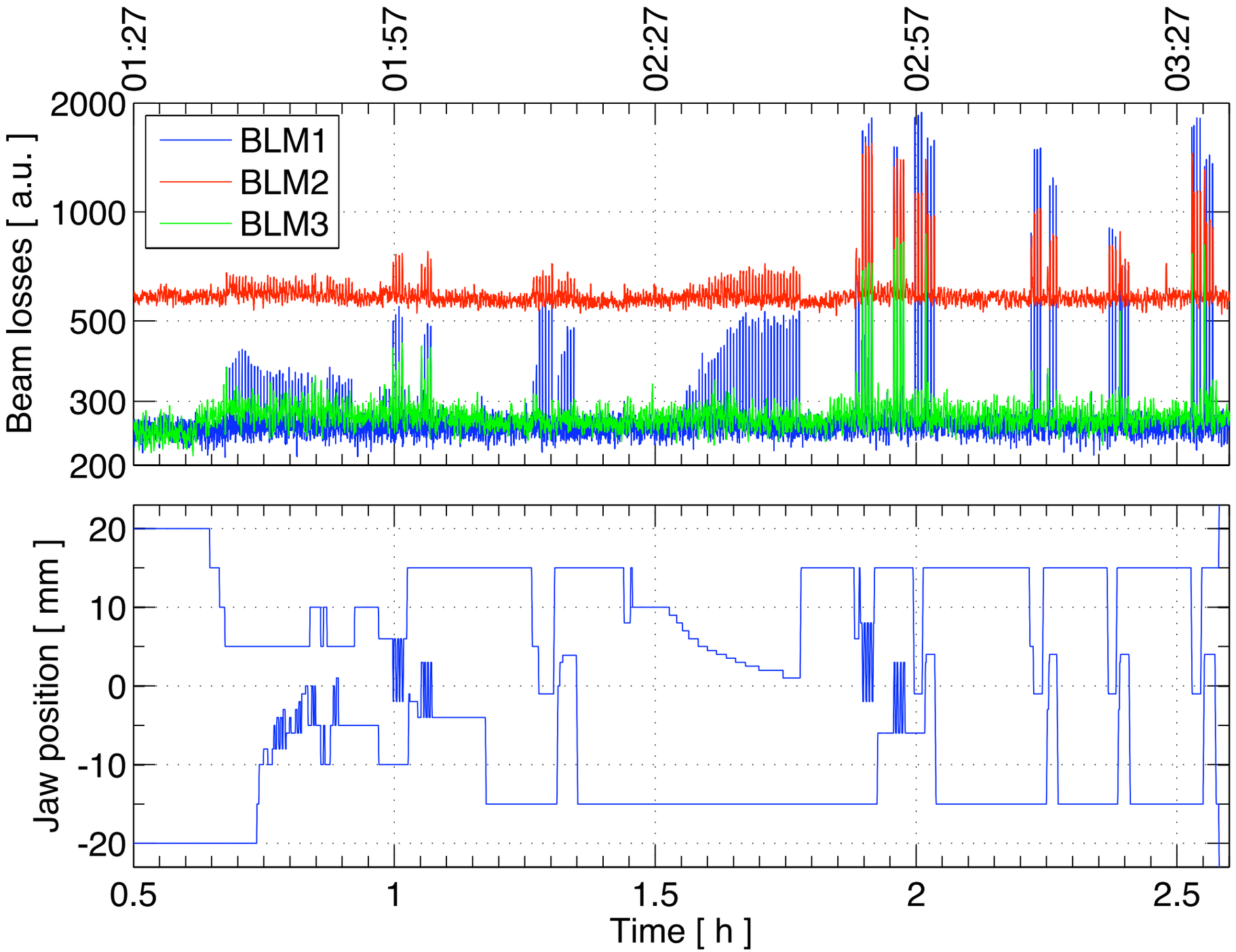






The first LHC collimator prototype (TCSG type, Carbon) was installed in SS5 in 2004 and has been kept operational for beam tests.

Beam loss studies (09/07/2008)



Beam losses studies with **injected beams (26 GeV/c)**; **25 ns** spacing, varying n_b.
Single-pass alignment + **loss studies** with different beam depths and intensities.

Details discussed in the next talk by Till.

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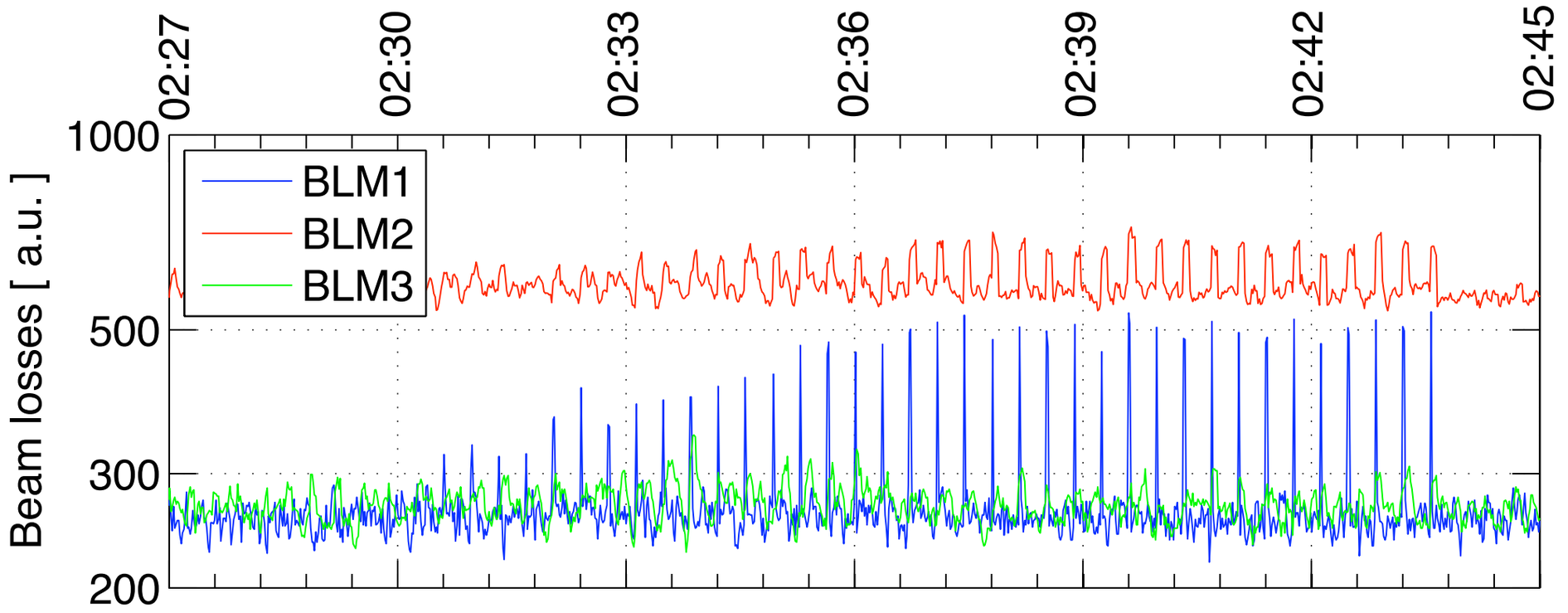

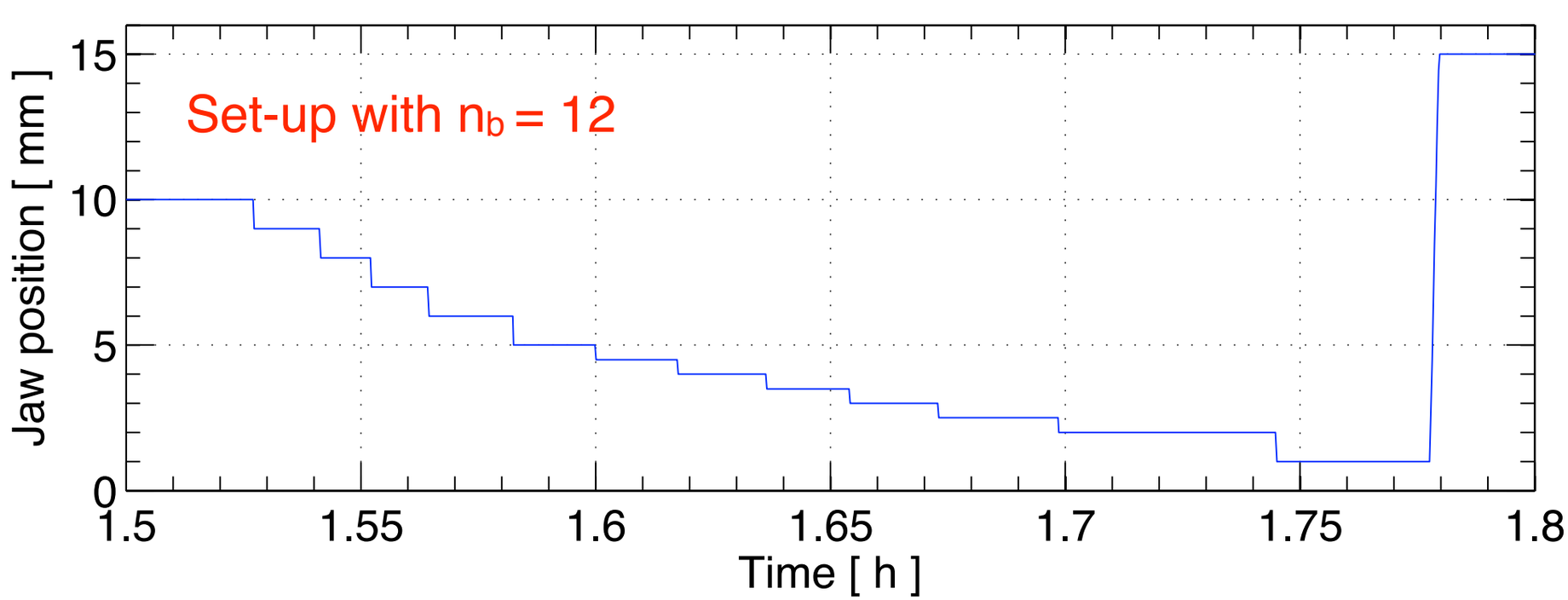

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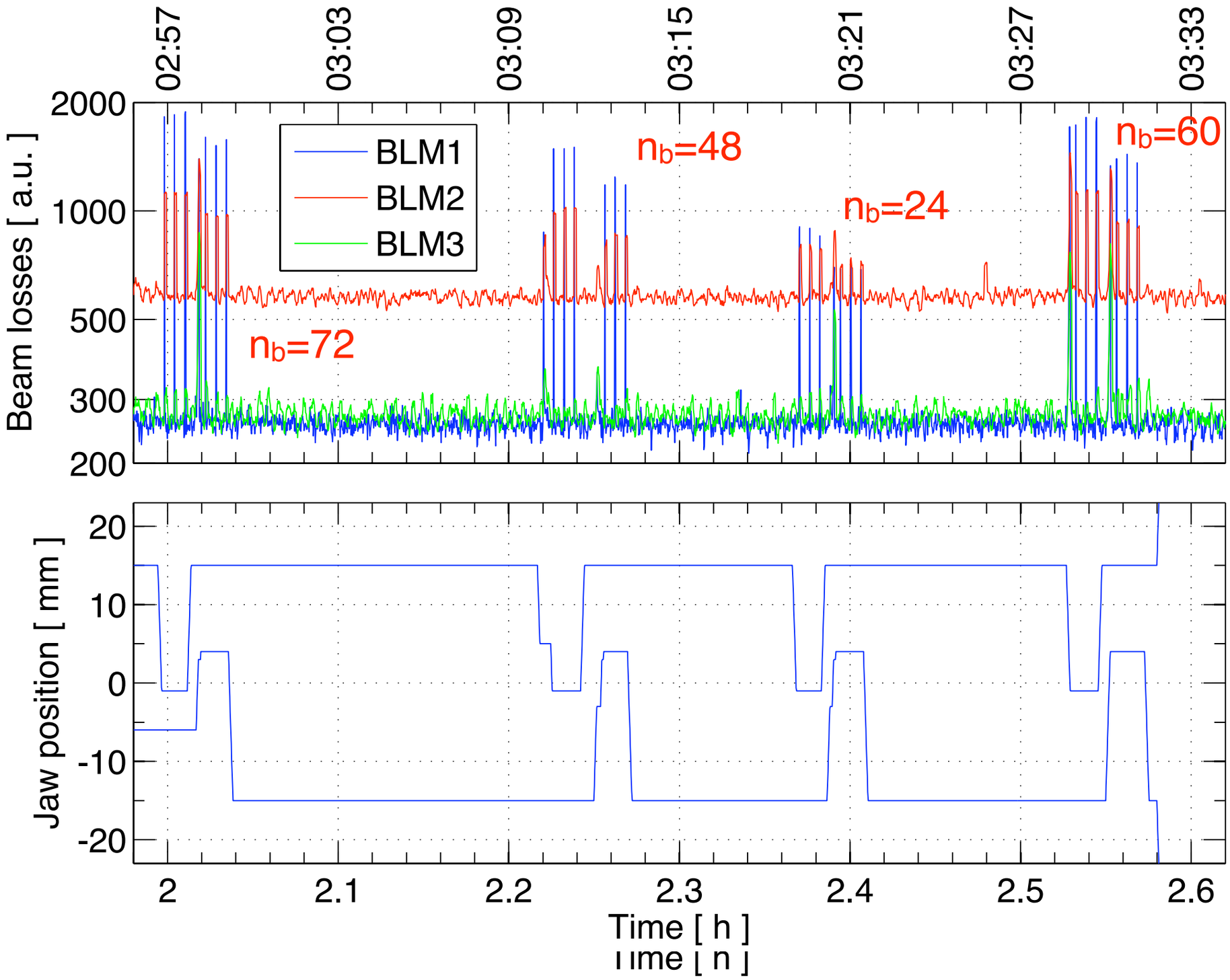

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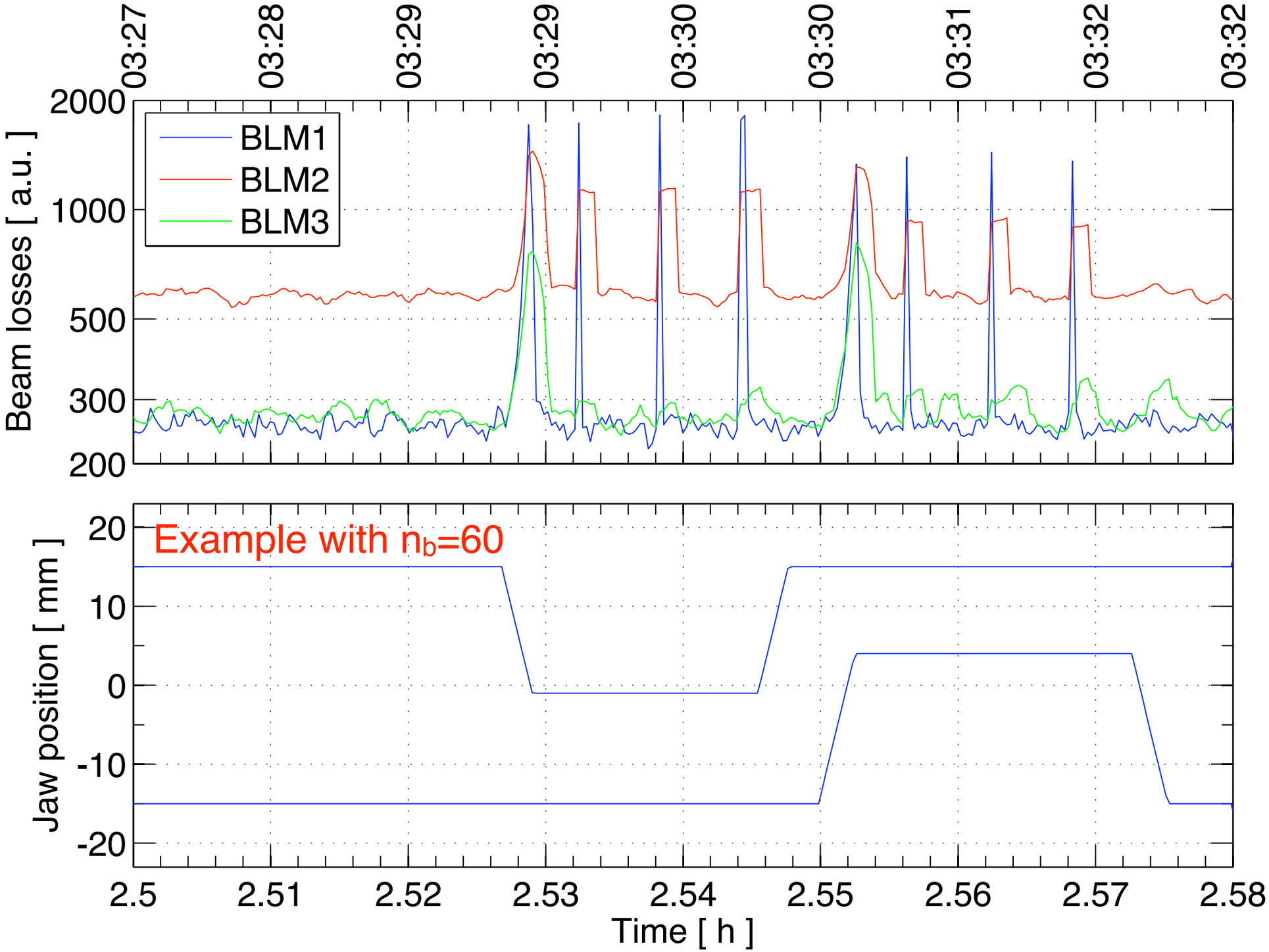

Beam losses studies with **injected beams (26 GeV/c)**; **25 ns** spacing, varying n_b.
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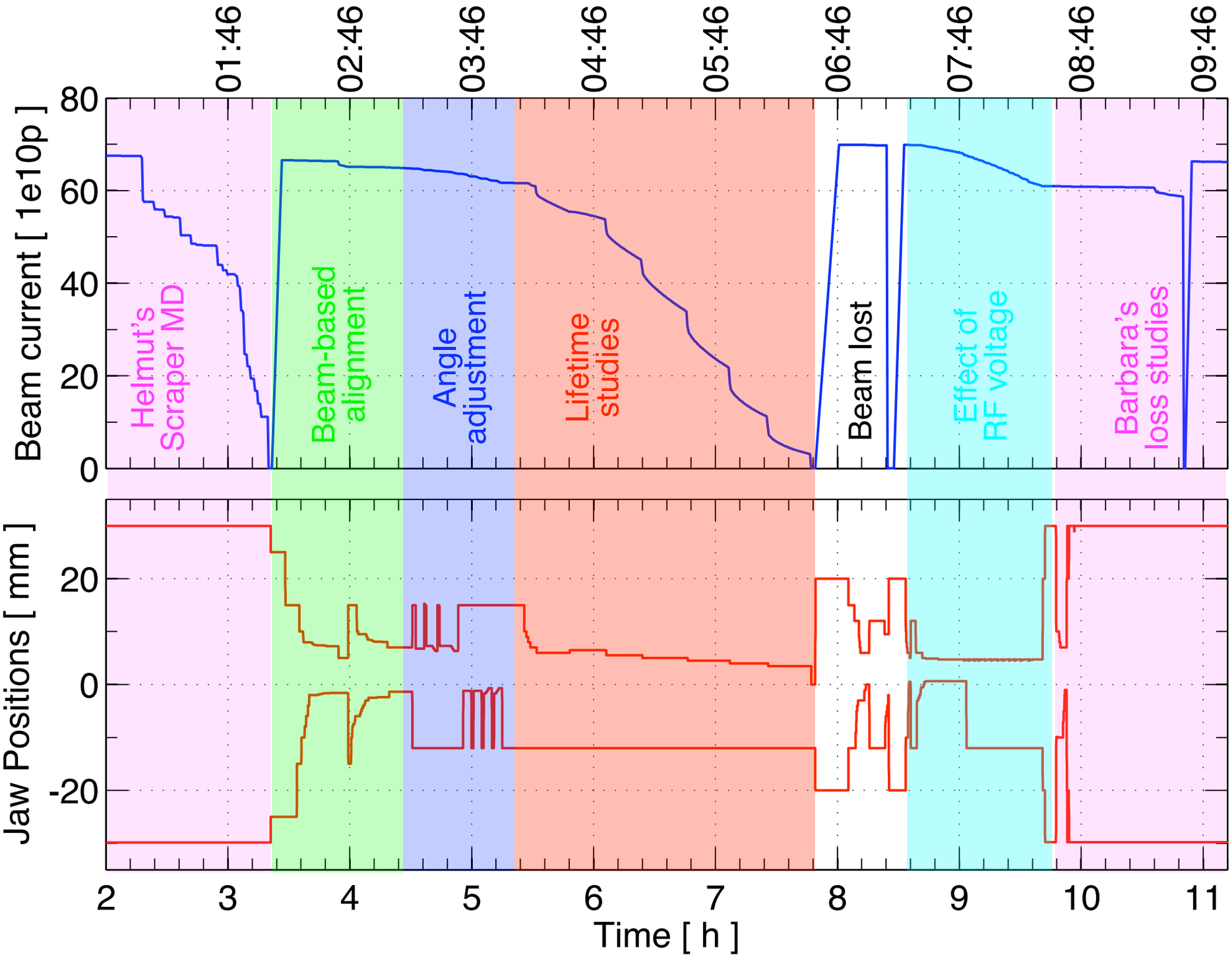
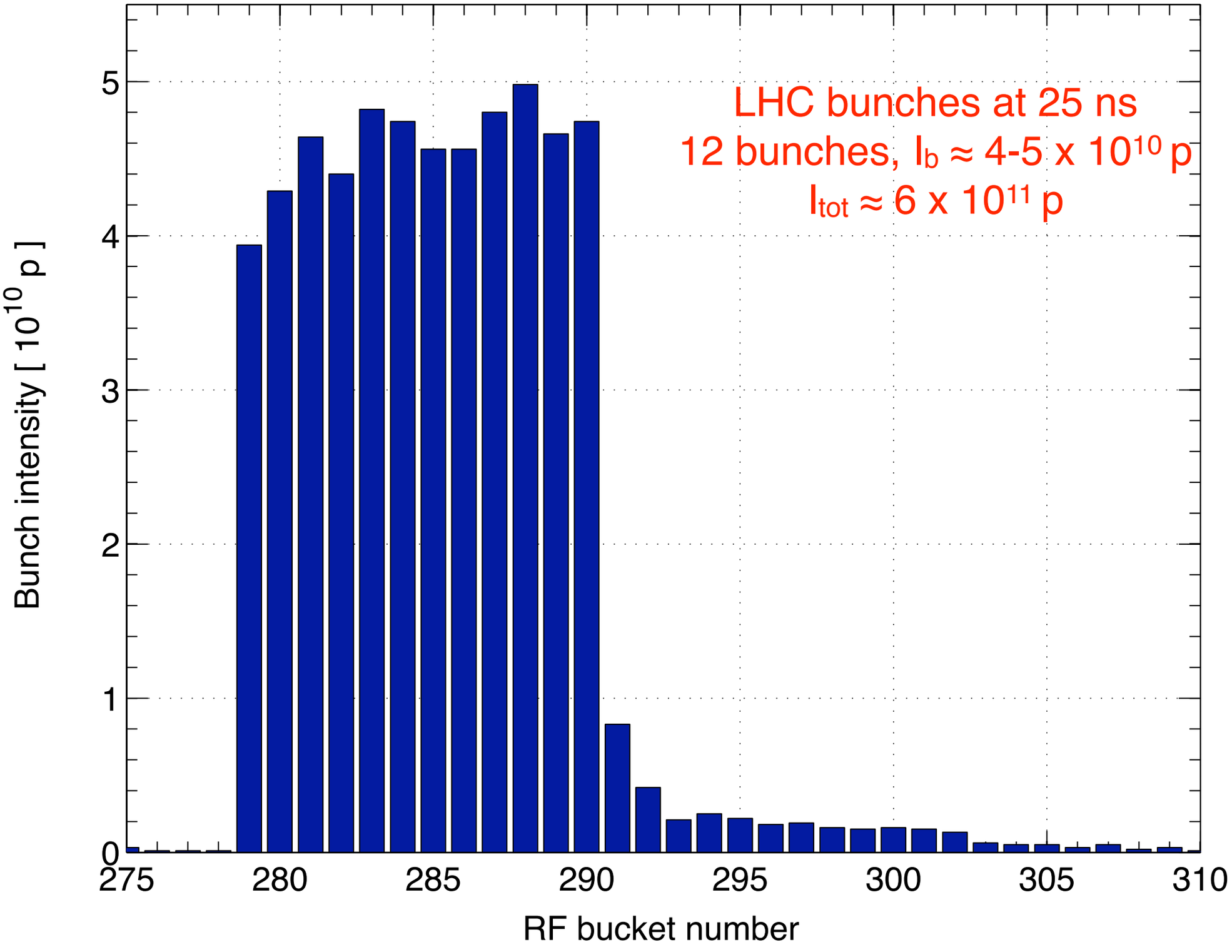
Collimator studies of 05/11/2008



Collimation studies: **coasting beam** at **270 GeV/c**. 12 LHC bunches (25 ns)
Standard beam-based alignment, lifetime studies, LHC BLM acquisitions.

Beam structure from fast BCT

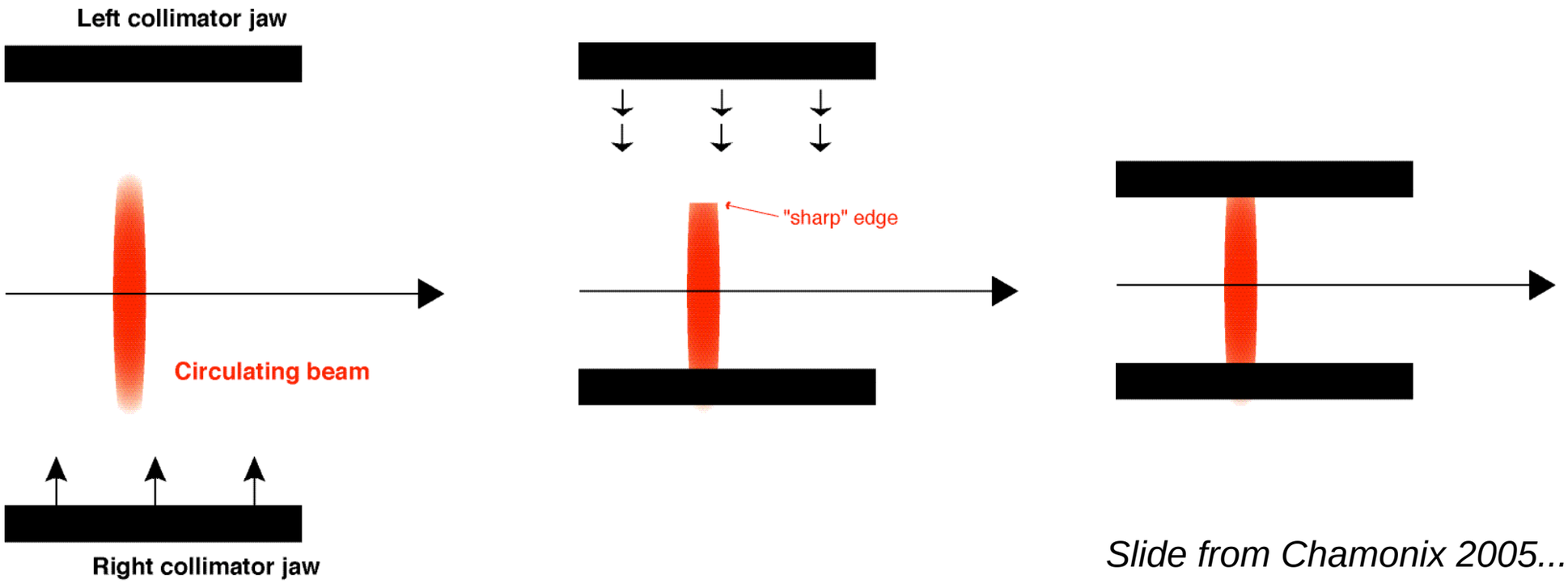


Beam-based alignment

1. Move one jaw in

2. Scrape the beam (sharp edge)

3. Move the other jaw until you see a signal on the BLM



Slide from Chamonix 2005...

Standard procedure for the beam-based measurement of the beam position at the collimator (tested at the SPS since 2004):

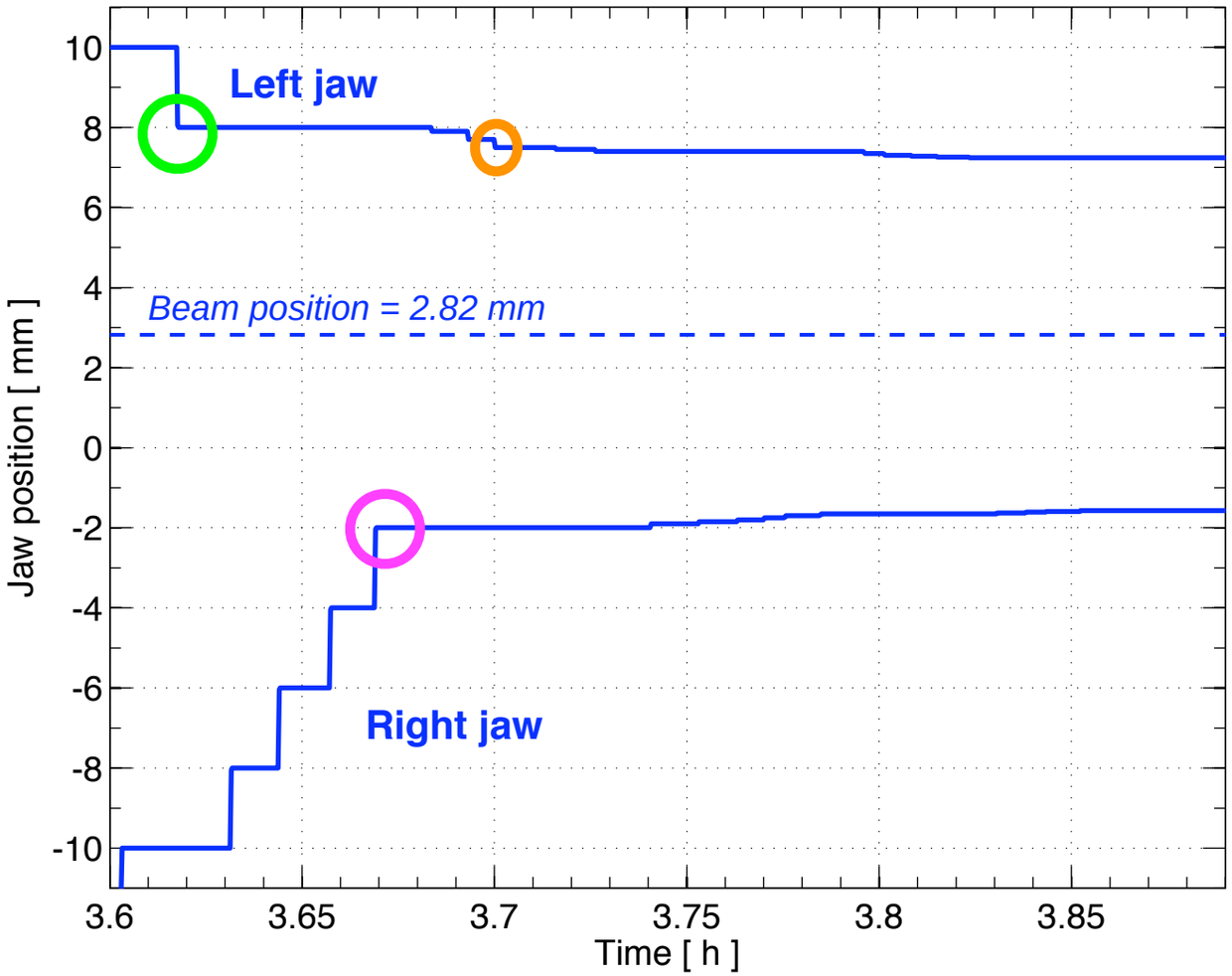
- *Based on beam loss signals (dedicated monitors at the collimator)*
- *Move one jaw closer to the beam / move the other until losses are seen*
- *Repeat with different step sizes to improve resolution*

Various methods to measure the local beam size (wire scanners, beam scraping...)

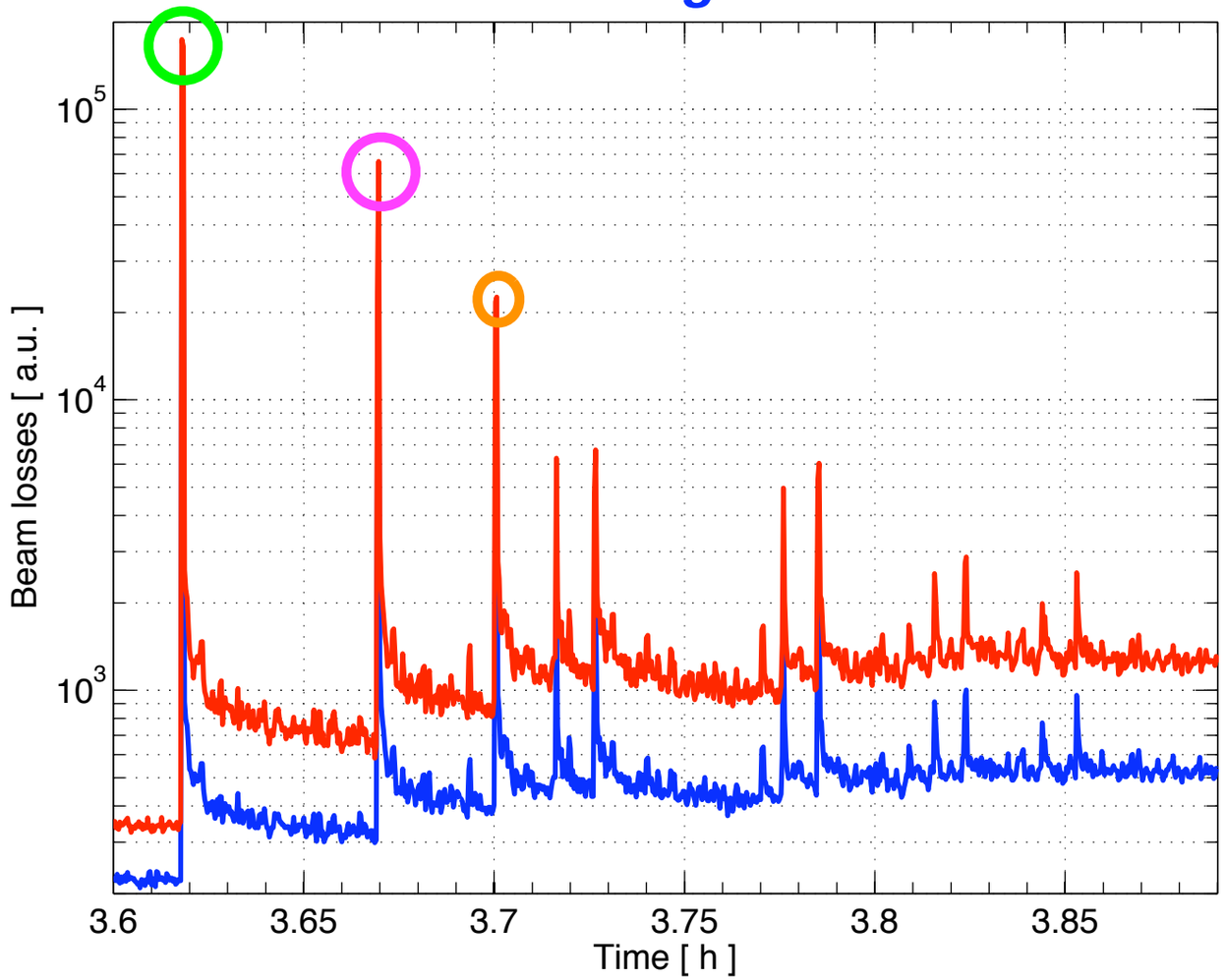
No detailed studies this MD, focused on lifetime and BLM studies. *See Chiara's thesis!*

Beam-based alignment

Collimator jaw positions



BLM signal



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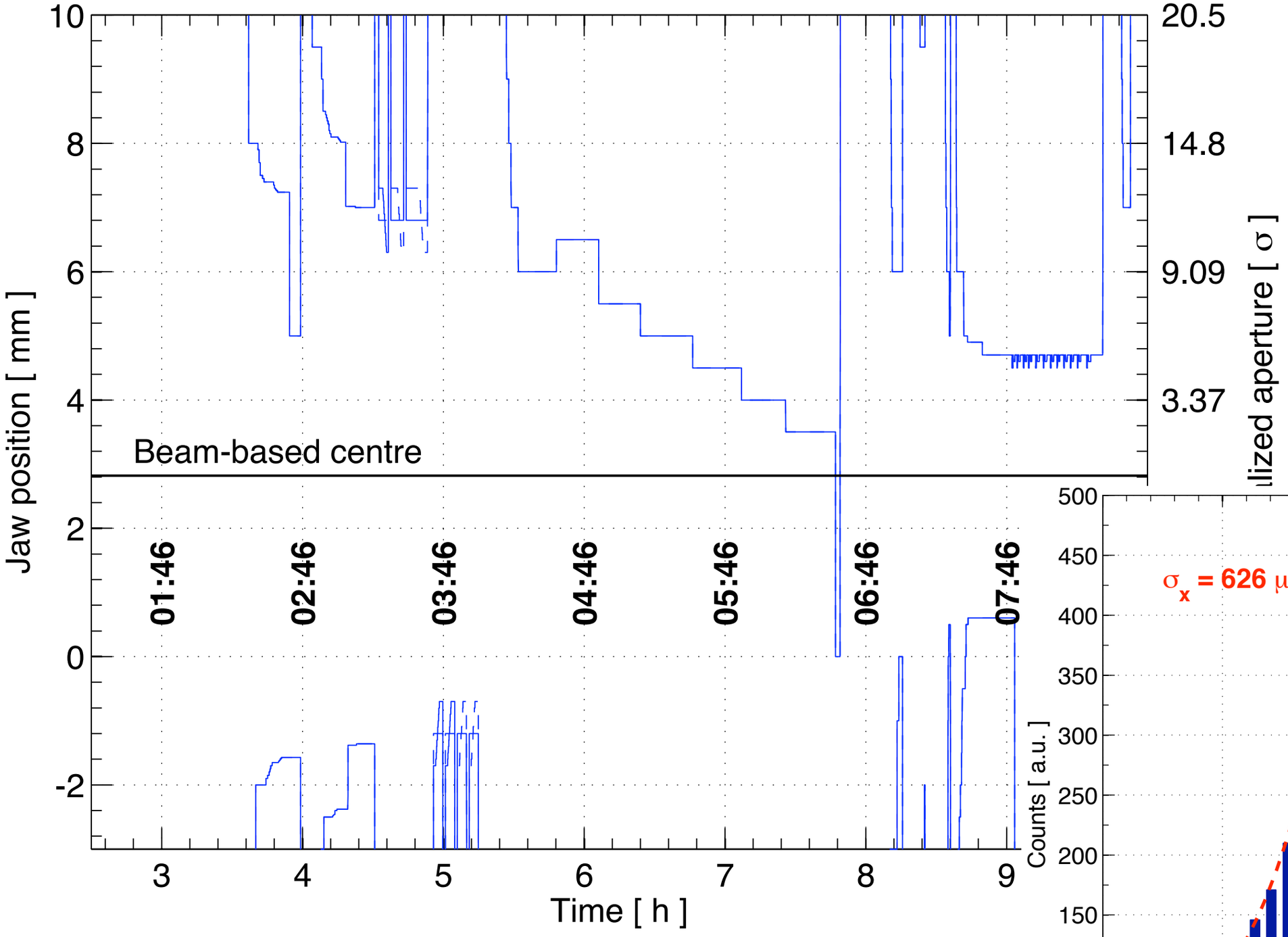
Jaw positions in sigma units

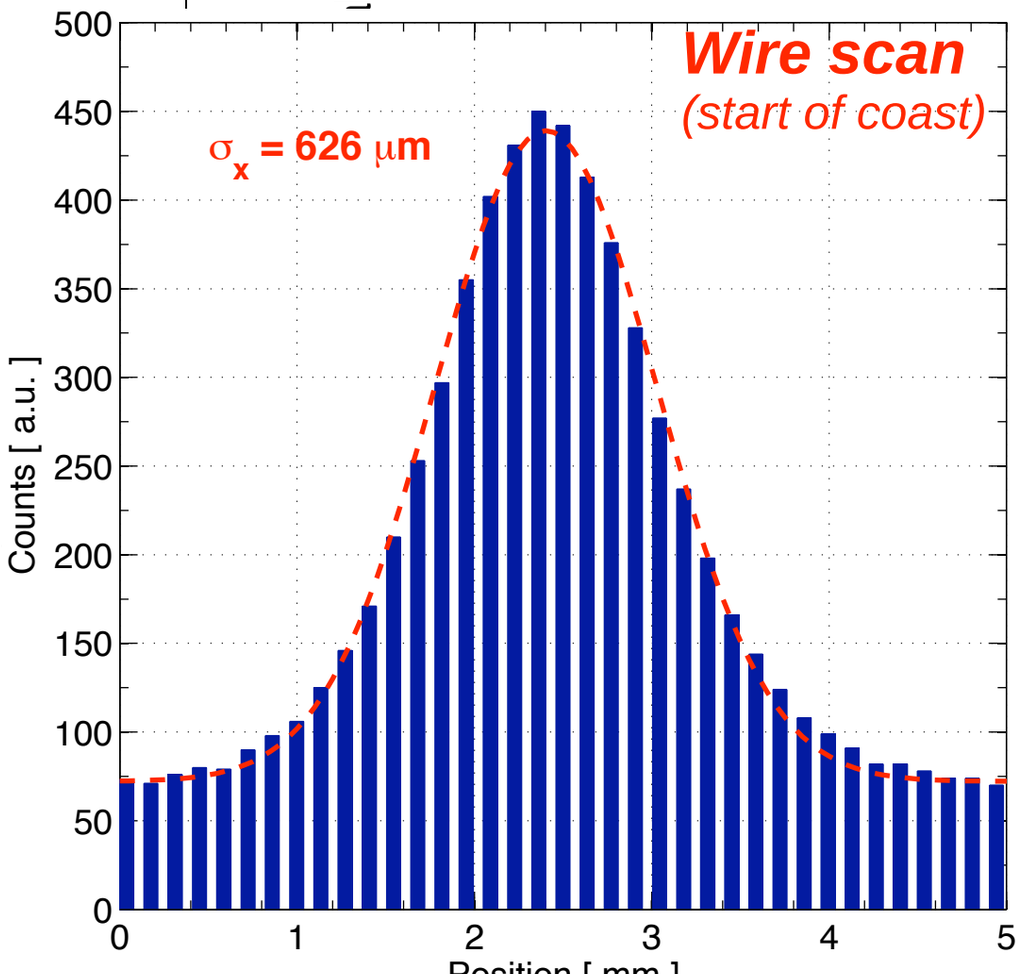


$\varepsilon_x = \varepsilon_y \cong 1.5$ μm

$\sigma_x \cong 350$ μm

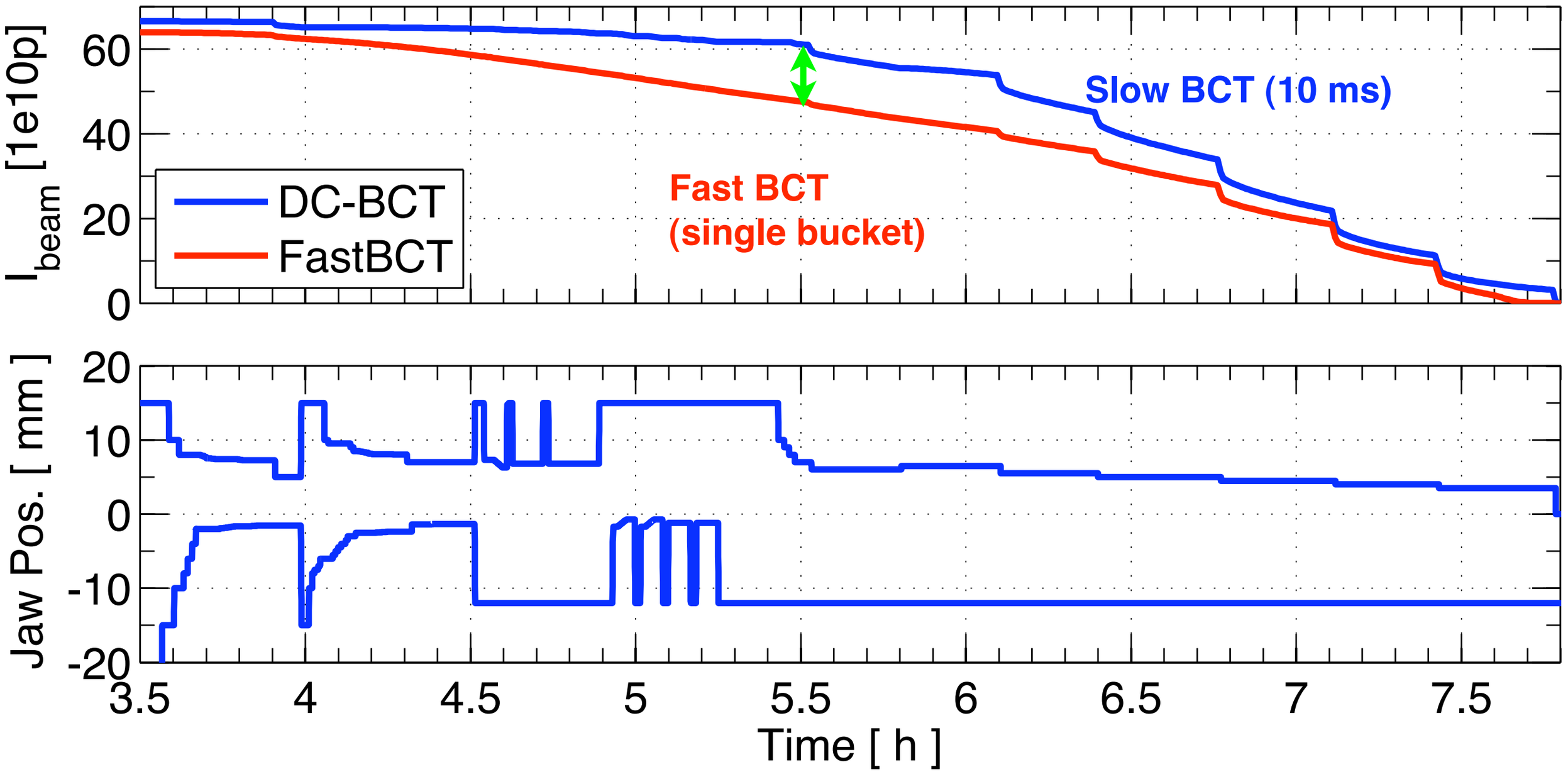
(inferred from flying wires, D_x neglected)

$$\sigma_x^{\mathrm{coll}} = \sigma_x^{\mathrm{WS}} \sqrt{\frac{\beta_x^{\mathrm{coll}}}{\beta_x^{\mathrm{WS}}}}$$



Beam-based alignment + calculation of local beam size: can express collimator settings in **beam sigma units**!

Beam intensity evolution (coast 1)



The lifetime of the bunched beam is SHORTER than the one of the bunched beam! Beam-based set-up typically carried out on the un-bunched beam! Any implications for the collimation set-up at the LHC??

Beam intensity evolution (coast 1)

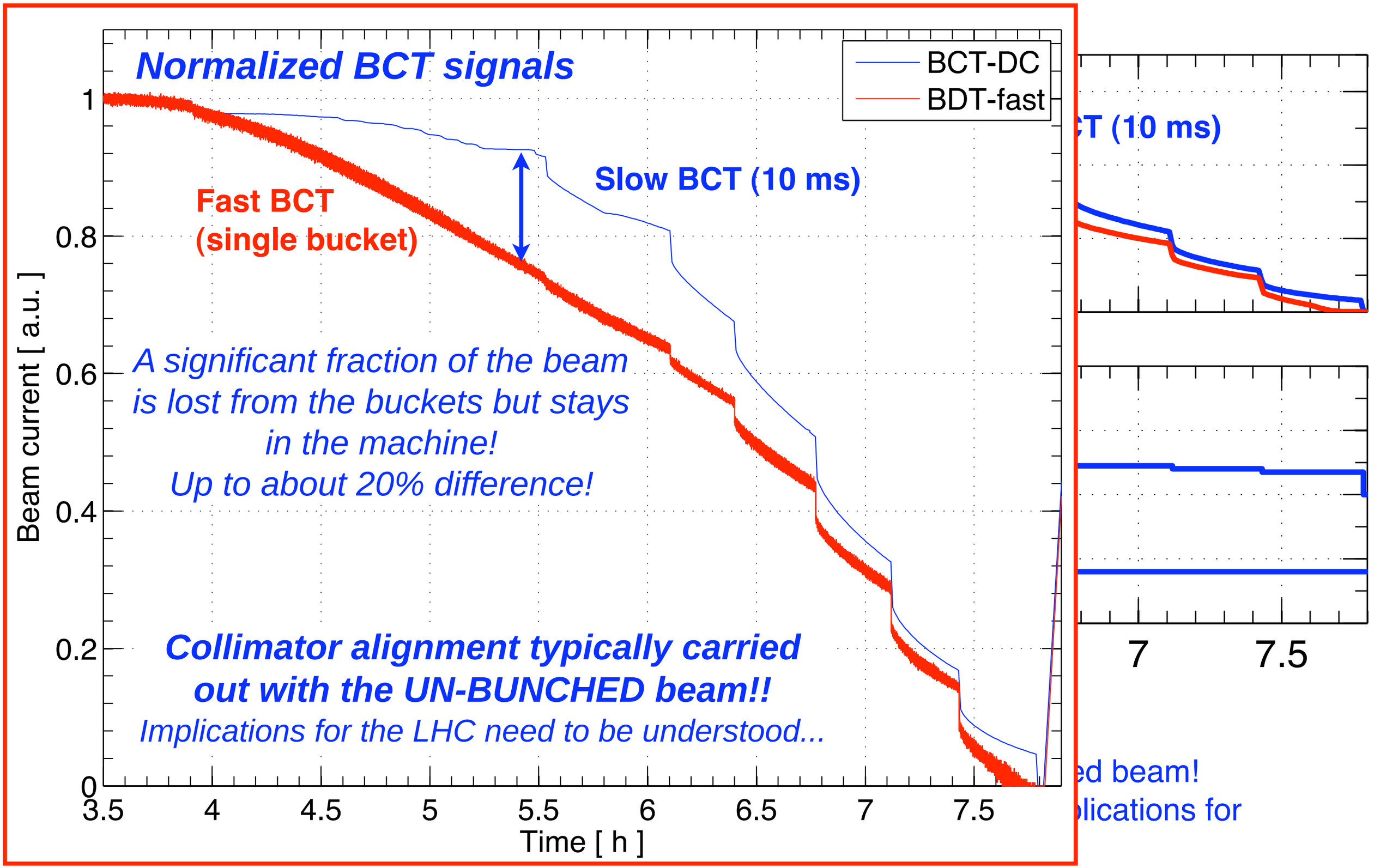
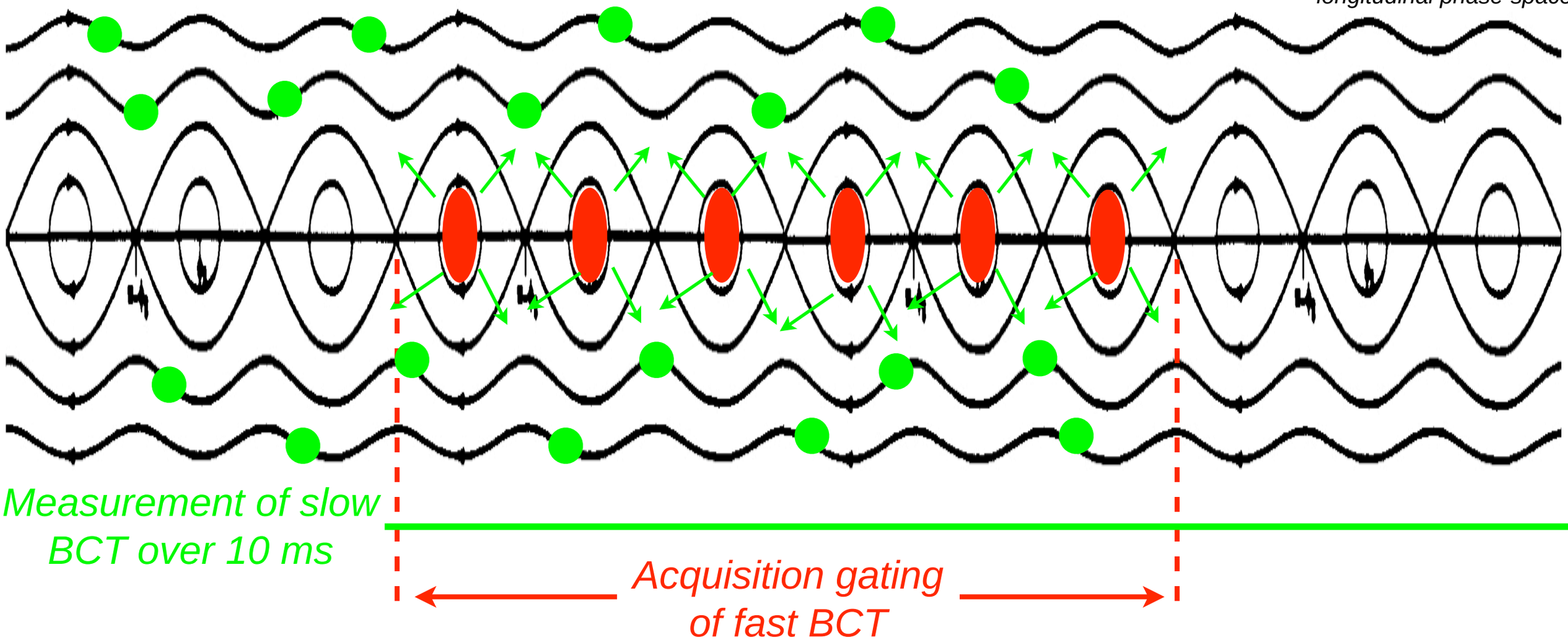


Illustration of what happens

Illustrative scheme of the longitudinal phase-space



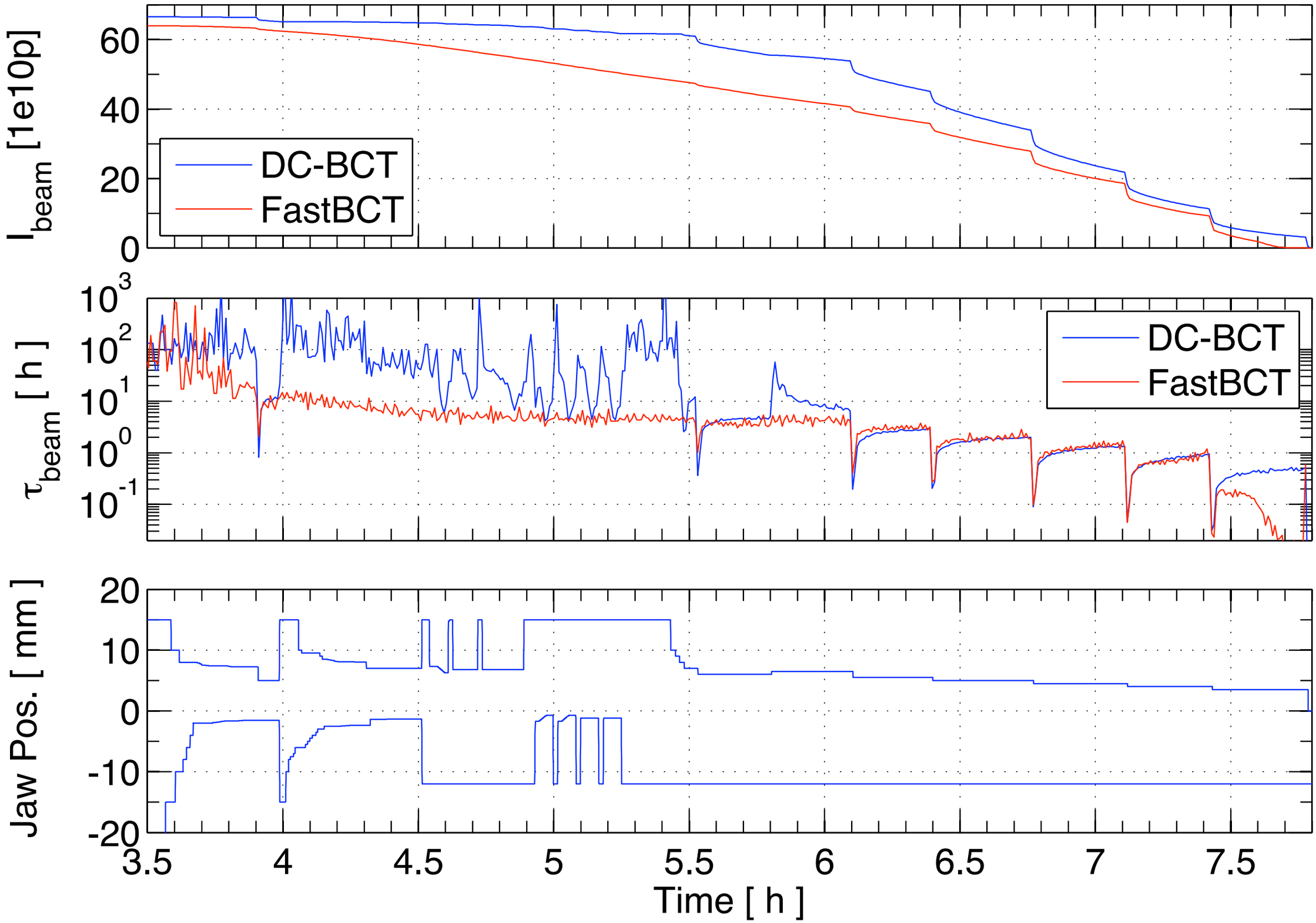
Bunch particles are lost from the bucket (they jump out of the separatrix).
Sources: Intra-Beam Scattering / **Vacuum** / **RF noise**? No detailed investigation was done.

We have **two types of beams** that behave differently!

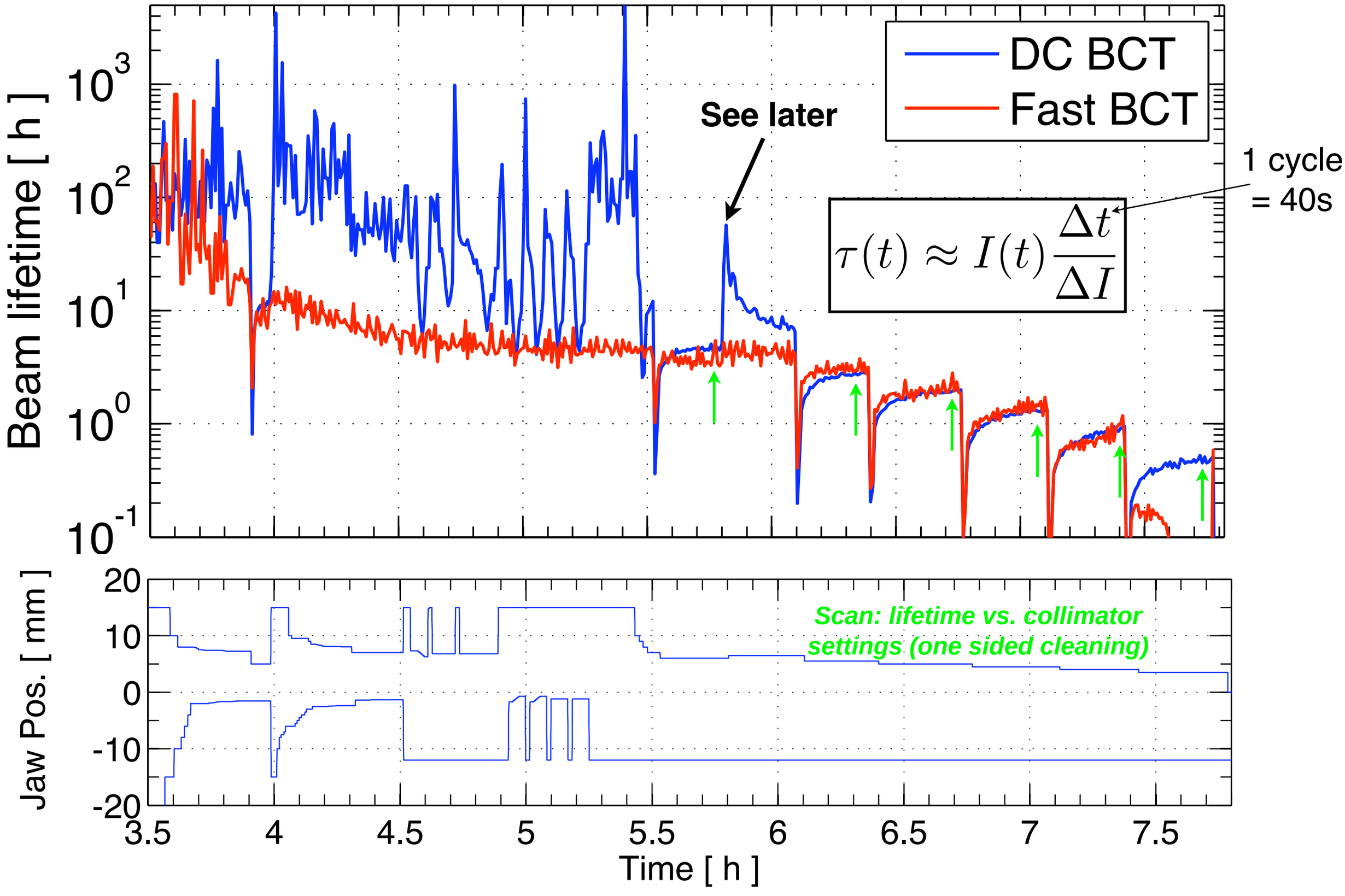
(Clearly seen at the Tevatron during crystal experiment - thanks to J. Annala and D. Still)

At the SPS we can only measure differences in the **beam current**: no other measurements have the required time resolution. ***LHC → upgrade for the BLM system?***

Lifetime: bunched vs. total beam



Lifetime: bunched vs. total beam



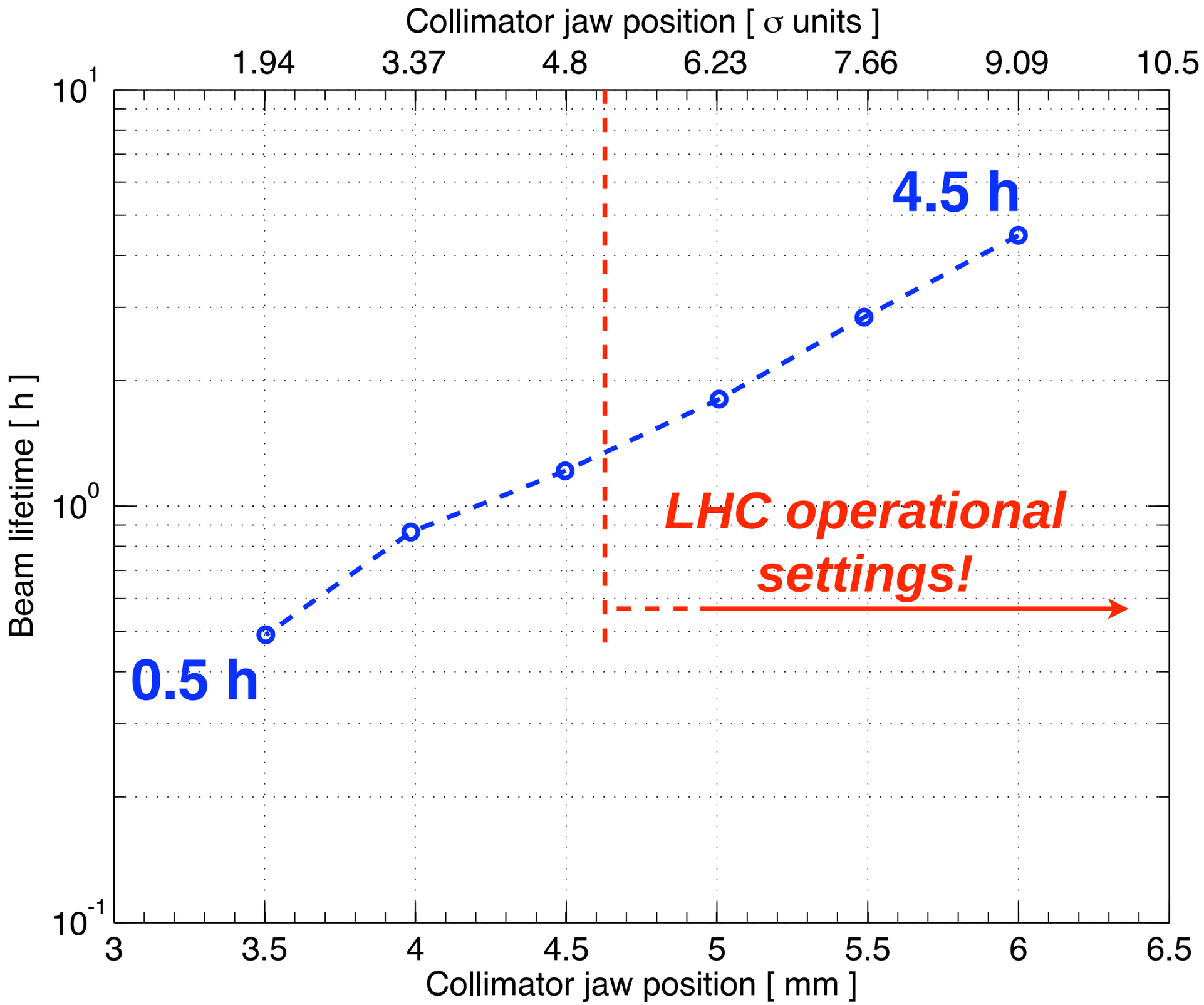
Lifetime vs. collimator aperture

Beam:
25 ns, 12 bunches
Bunch charge: 0.5 I_{nom}

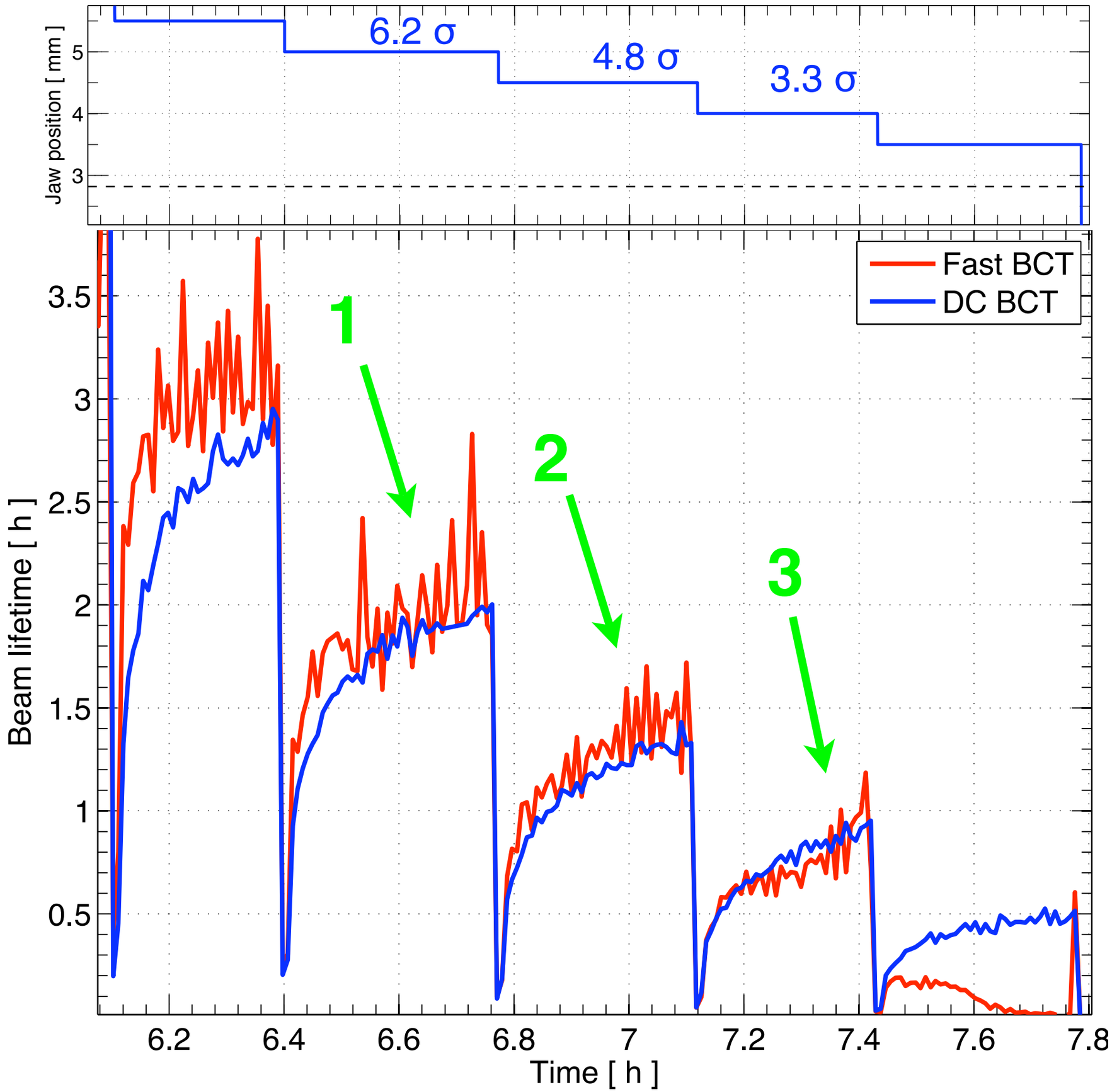
Collimator settings:
1-sided cleaning;
other jaw > 40 σ_x

Graph:
Each point is the "asynthotic" value of τ, 20-30 min after collimator movement

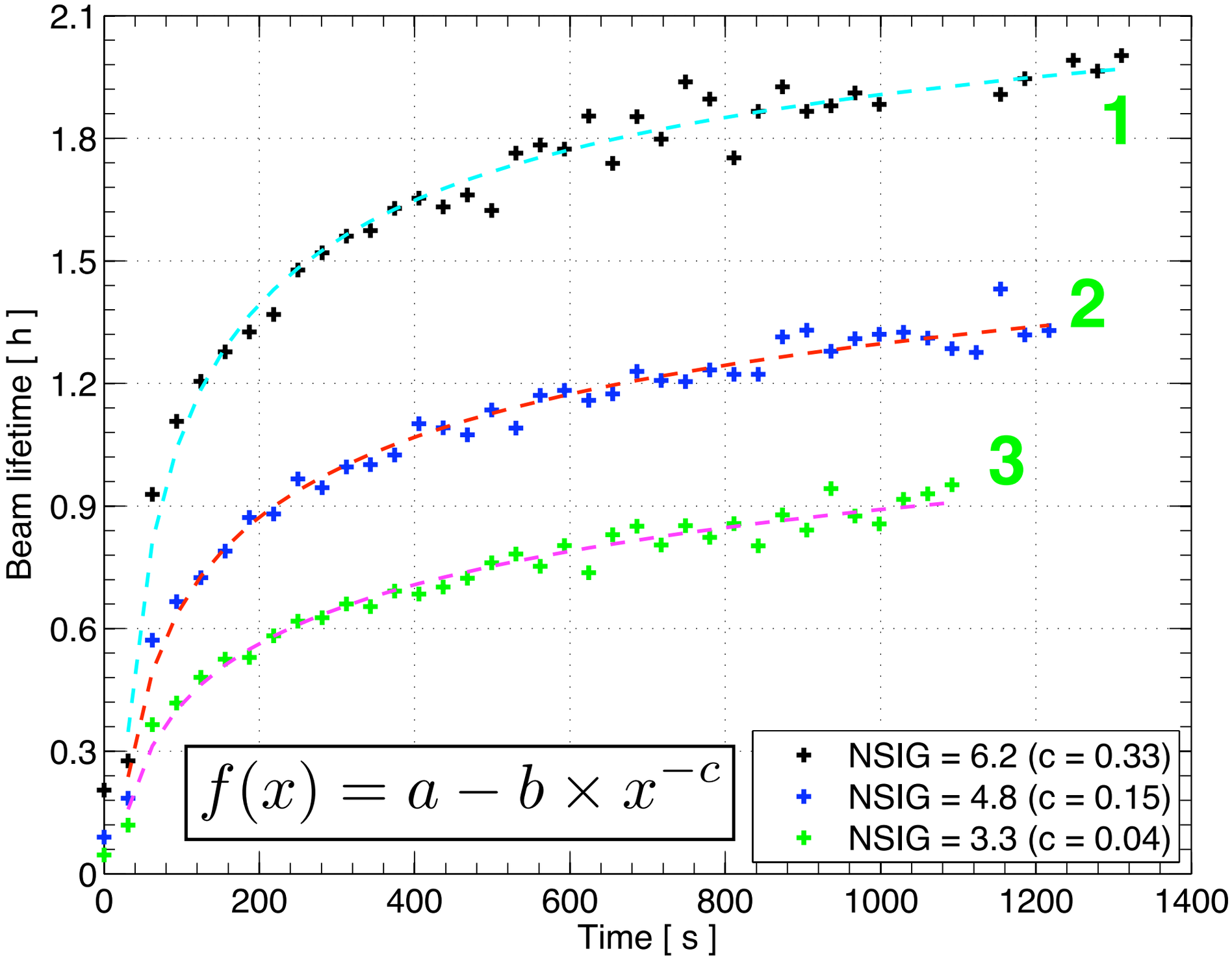
"Disclaimer":
Beam size meas. at the beginning of the coast; no cross check of alignment



Lifetime versus time

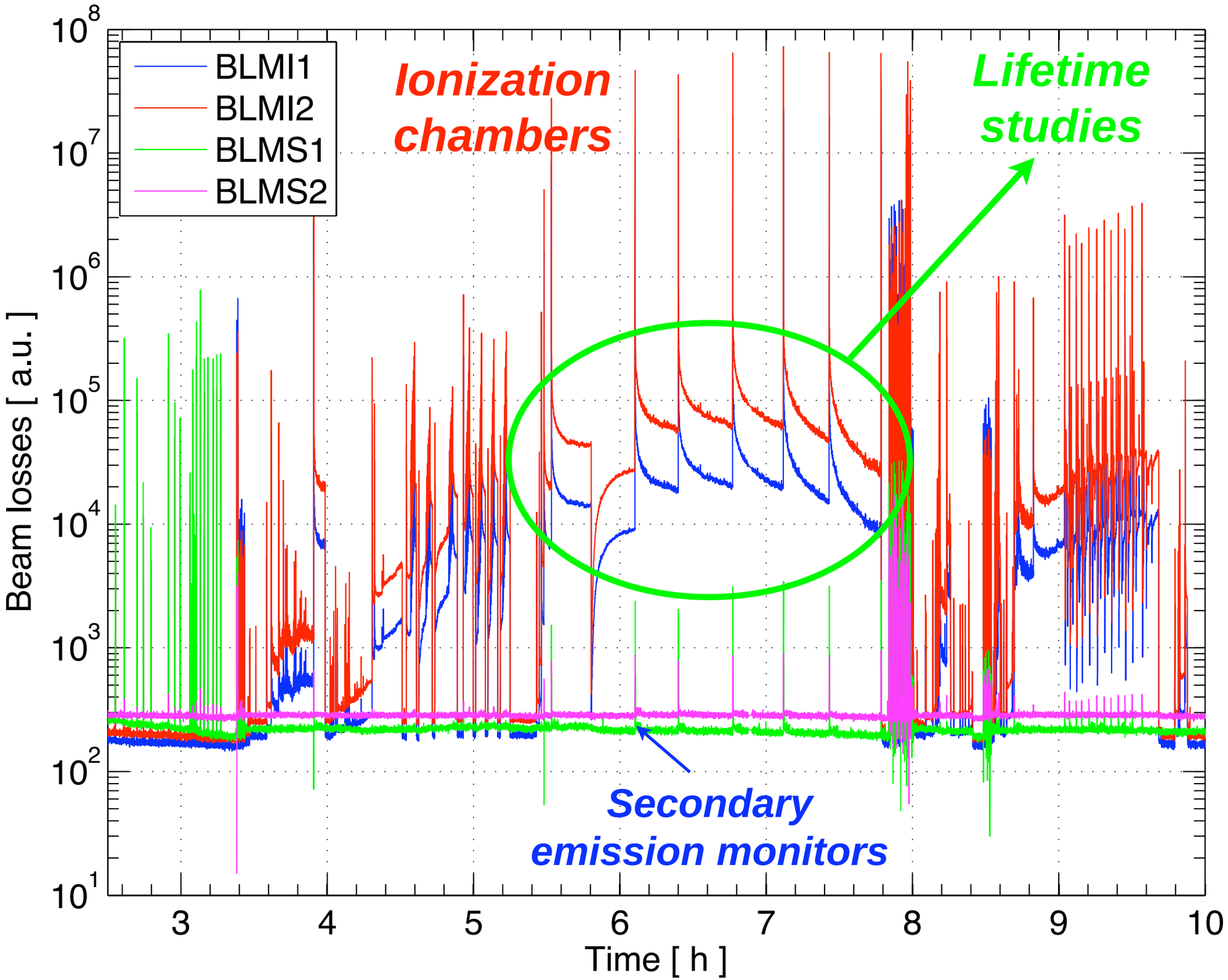


Lifetime versus time

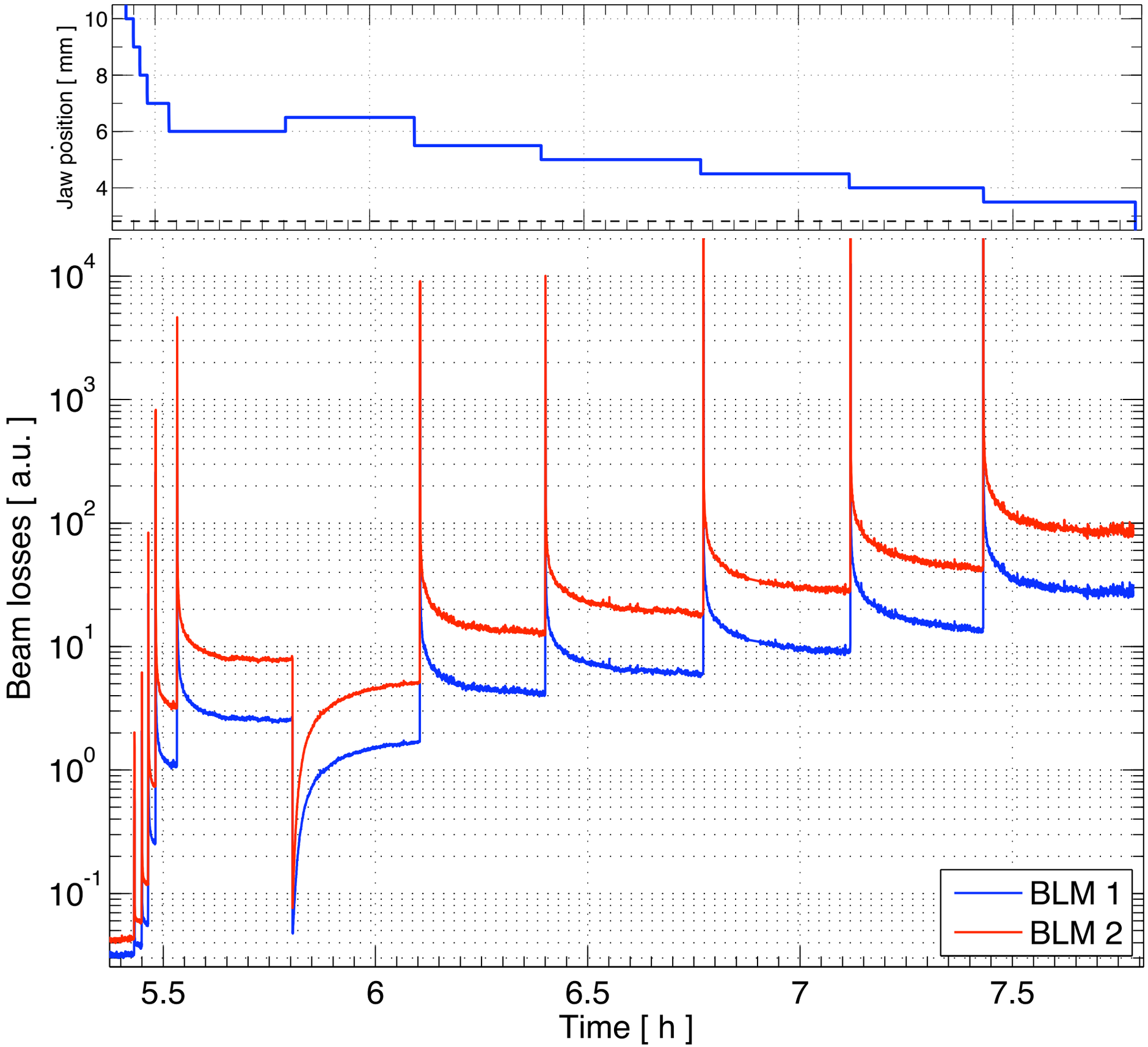


Simulations of “noisy” beam dynamics on-going to try and reproduce this behaviour (S. Redaelli, K. Cornelis)

Beam losses at the collimator

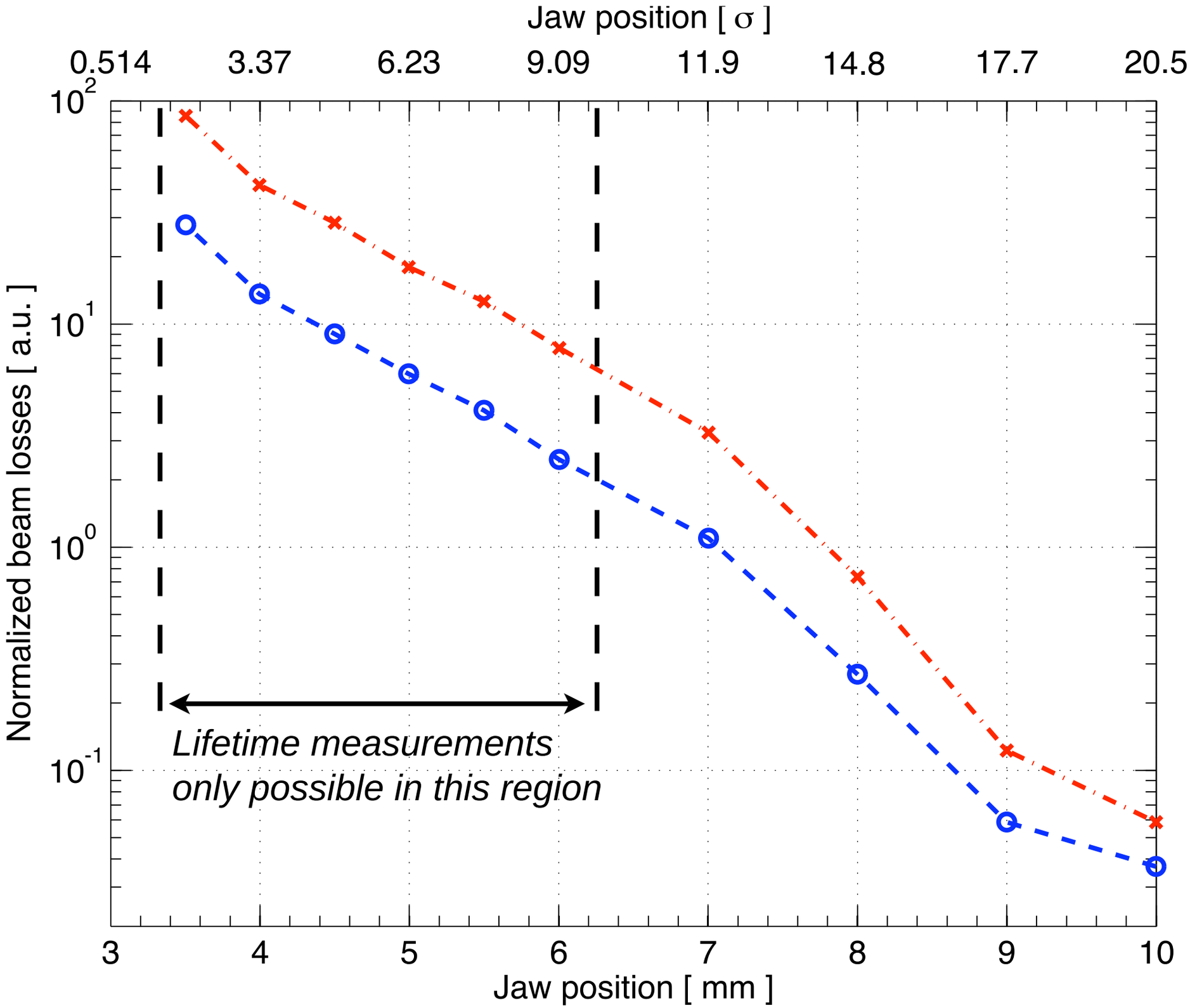


Beam losses normalized with I_b

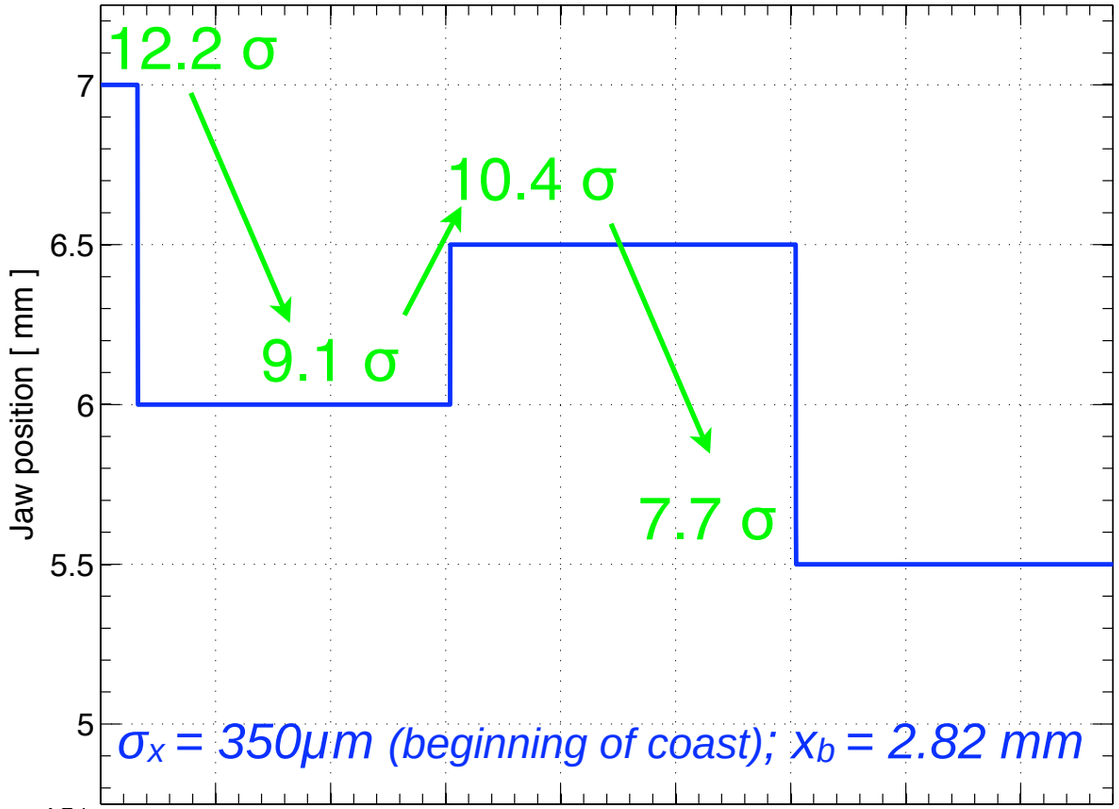


$$\frac{BLM(t)}{I_b(t)}$$

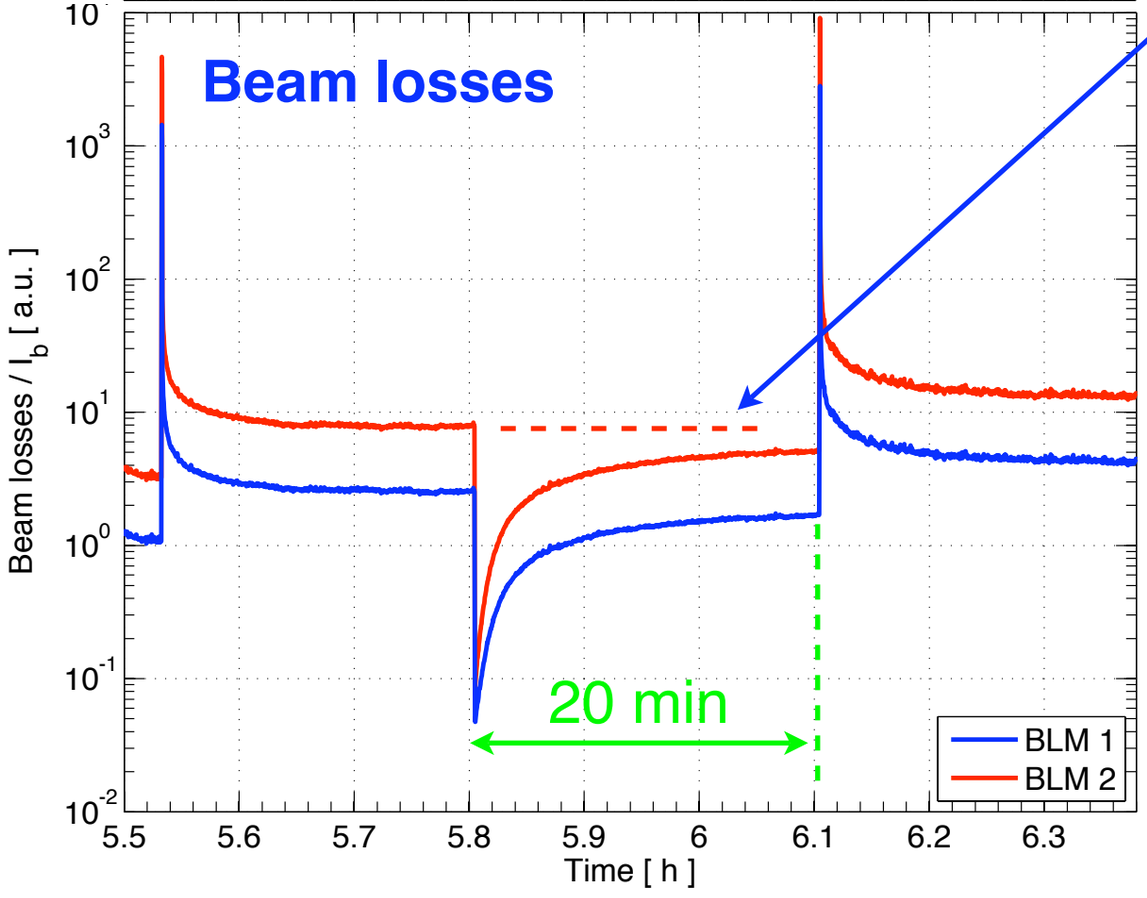
Beam losses vs. jaw position

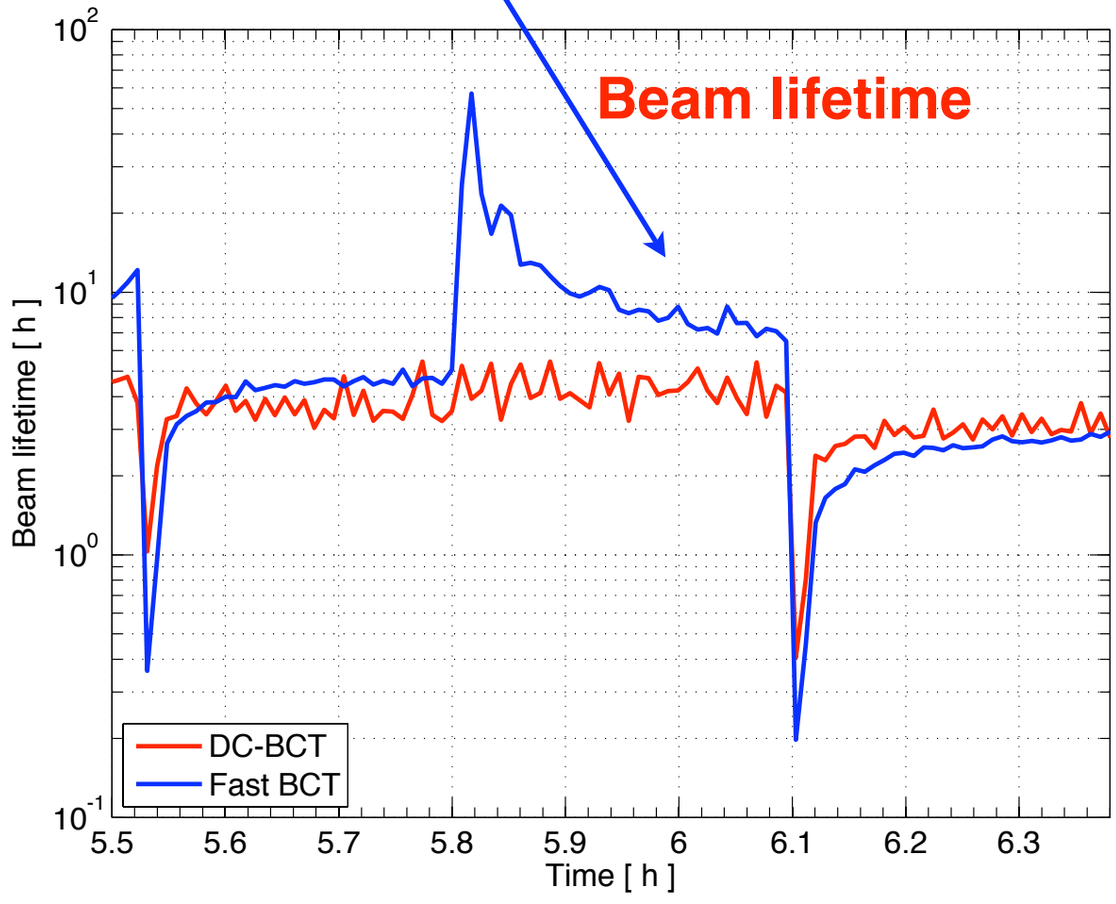


Halo: tail re-population

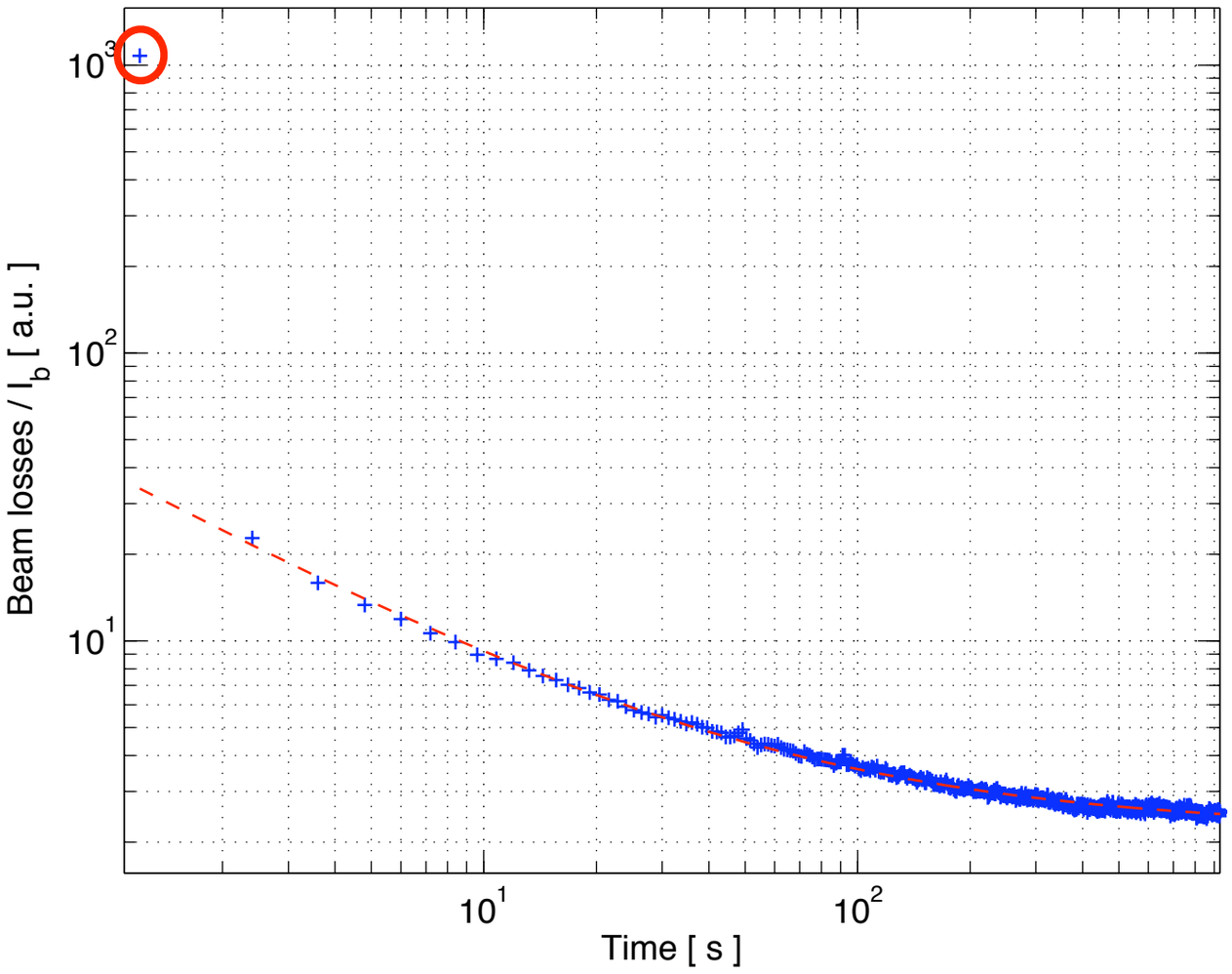


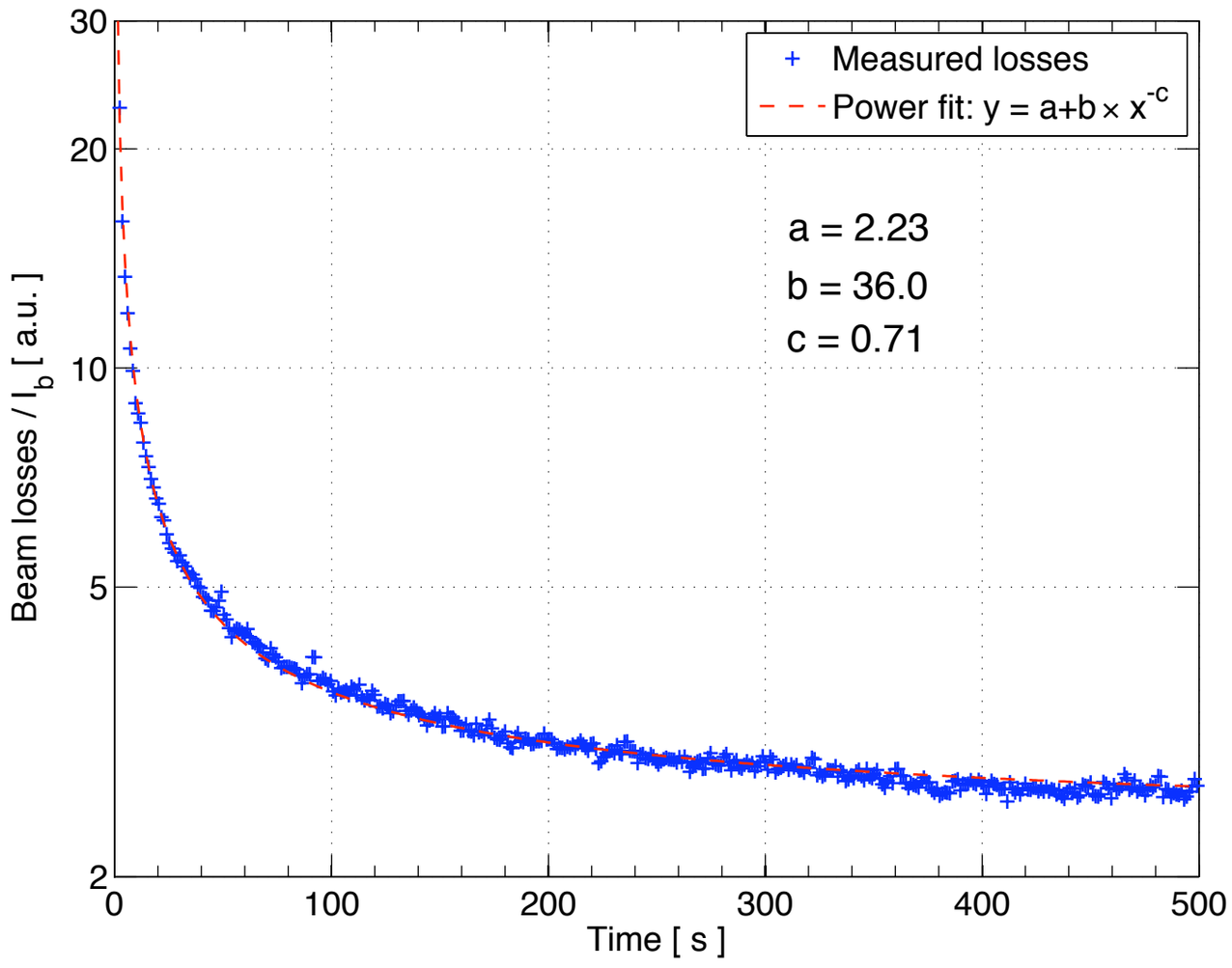
Re-population of beam tails:
About **>30 minutes** for the beam to diffuse from 9.1 to 10.3 σ (Δσ=1.3)
[Approximate figure: no recent measurement of σ]
Same results from BLM and lifetime meas.!
Similar effect seen in previous studies, e.g. when moving one jaw out → halo reaches the other jaw.





Beam loss tails





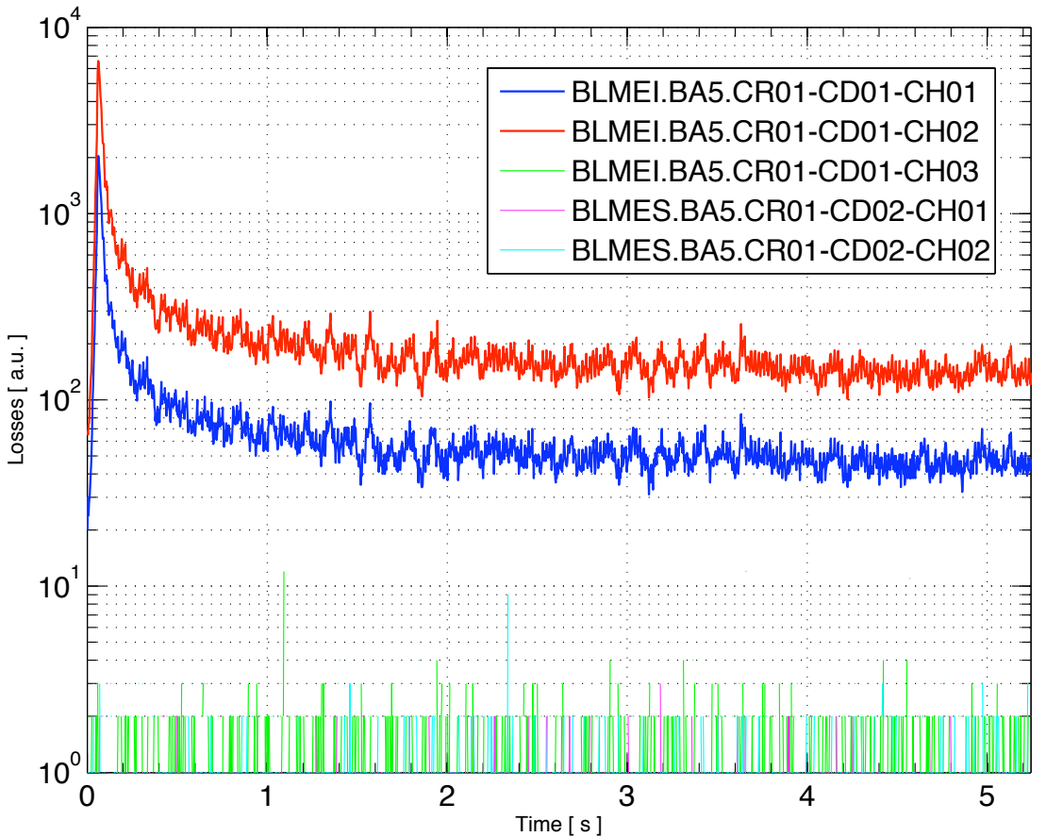
First loss spike integrates losses during collimator motion.

[Δx = 1 mm (V=2mm/s)→ Δσ=2.9 in 0.5 sec.; BLM acq. frequency = 1 Hz!!]

Then, long beam loss tail, fit well by a power function (first point excluded).

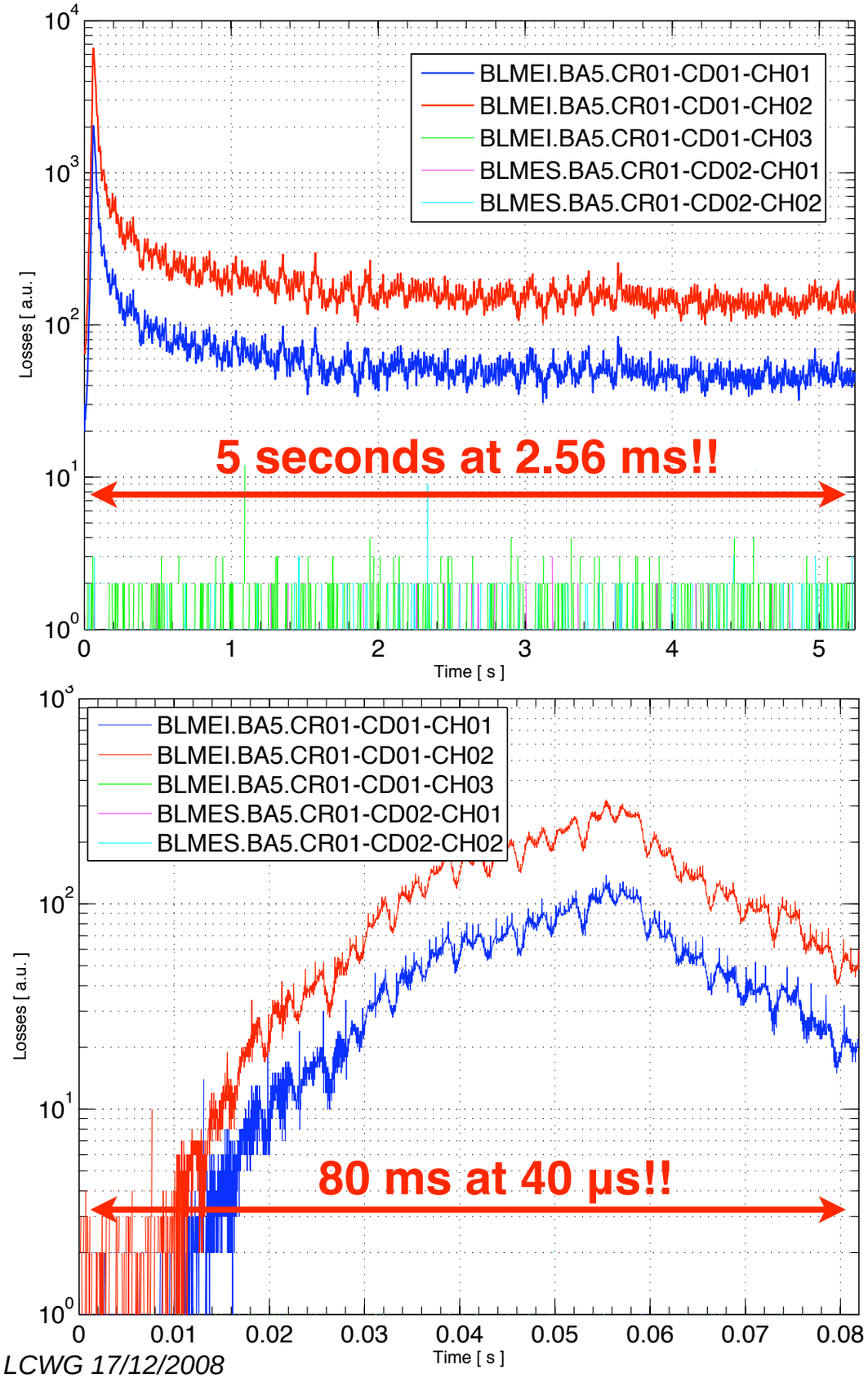
Simulations on-going to reproduce this behaviour (SR, KC).

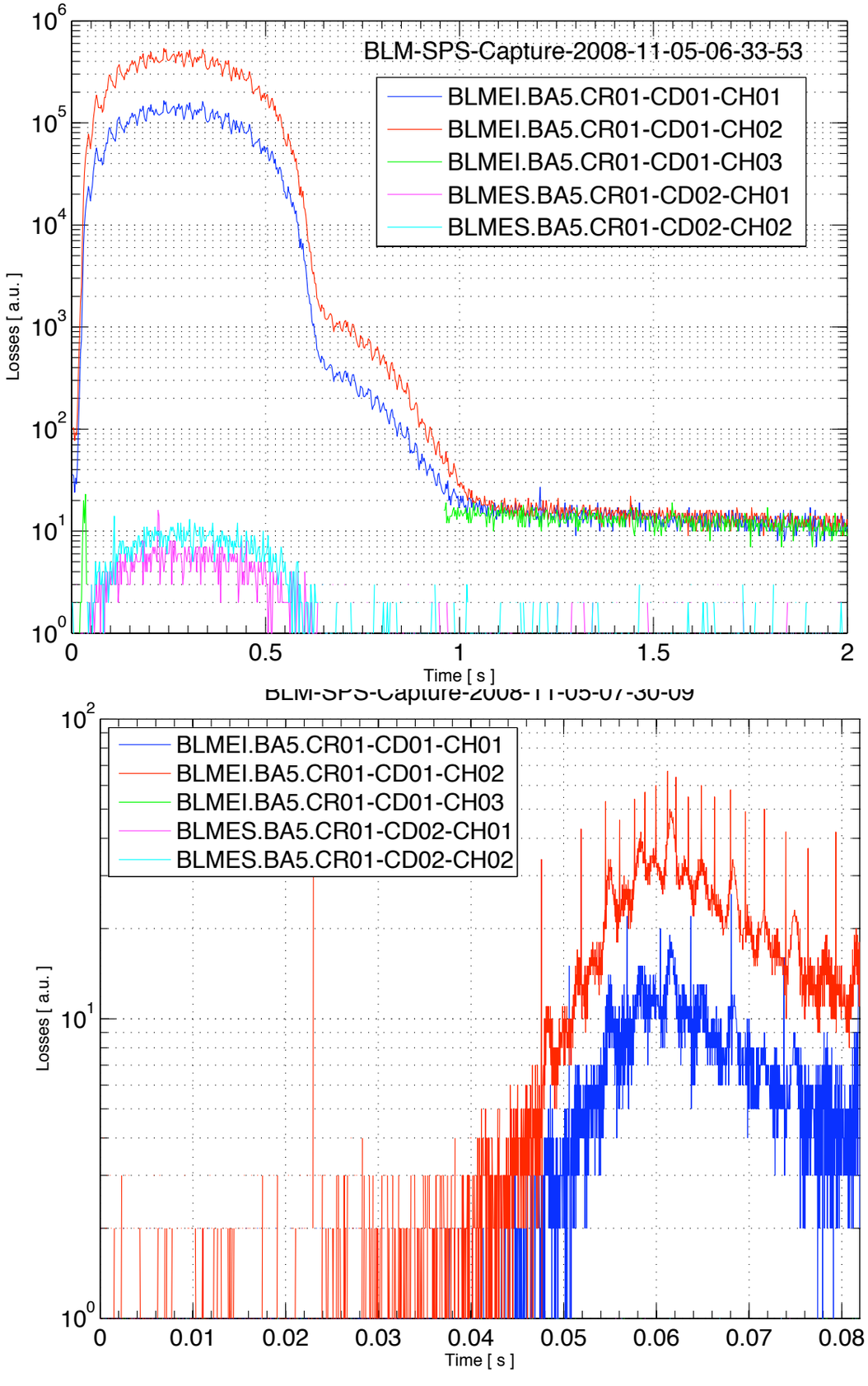
Fast BLM measurements



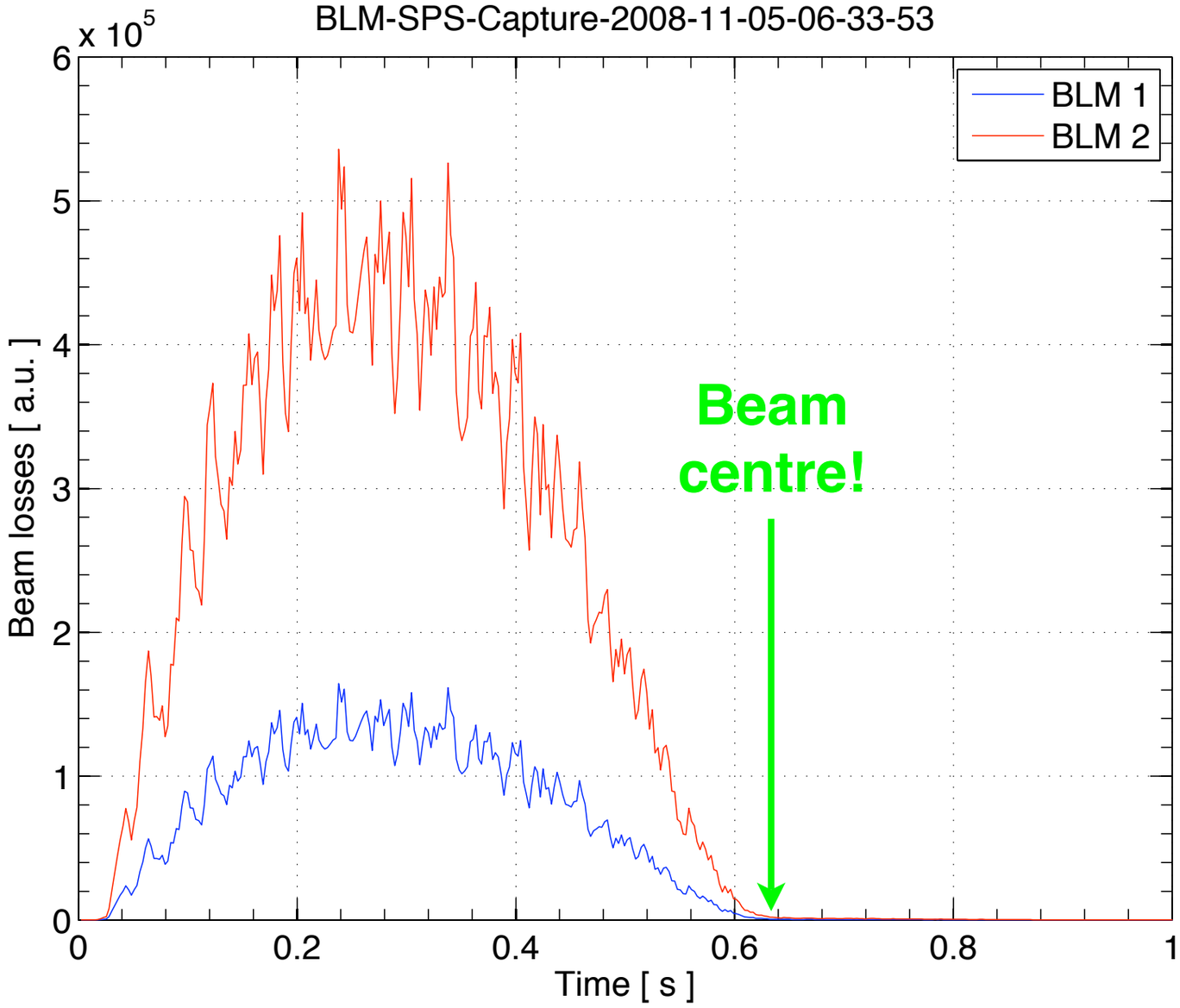
LHC “Capture” acquisition tested for the first time with circulating beam!
buffer of 2048 points at 2.56 ms or 0.04 ms

Fast BLM measurements

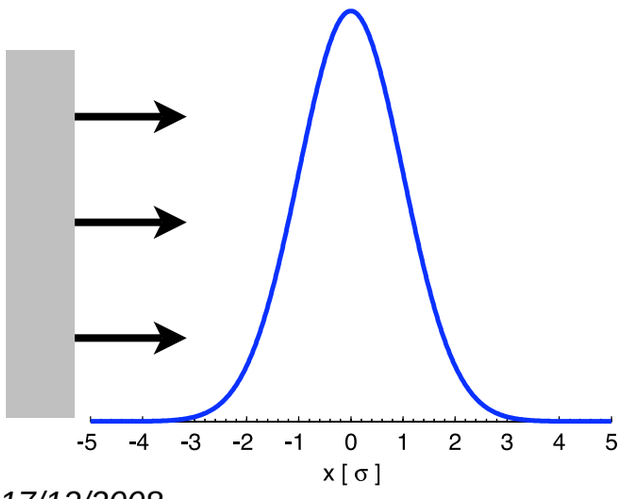




Beam centre from fast BLM data



- *See details in SR, CWG of Jan. 31, 2005.*
- Could not compare systematically against standard BB alignment: detailed timing of prototyped "capture" data mode was missing
- Scraping done starting from 2.5 sigmas: no Gaussian distribution! Difficult to extract beam size.



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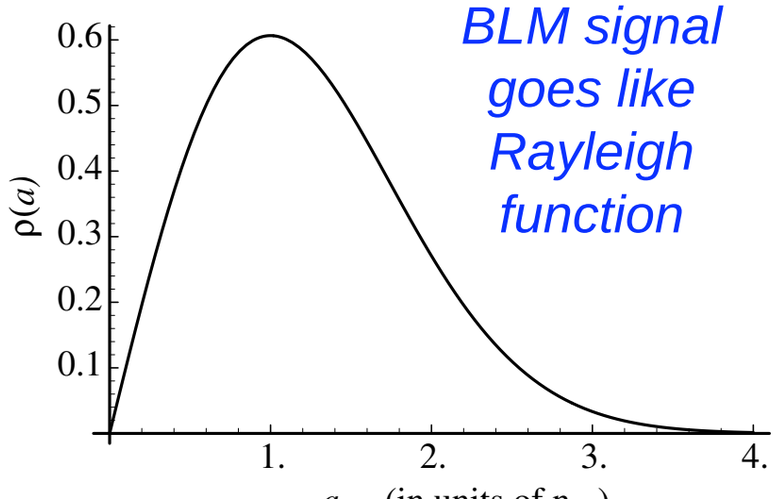
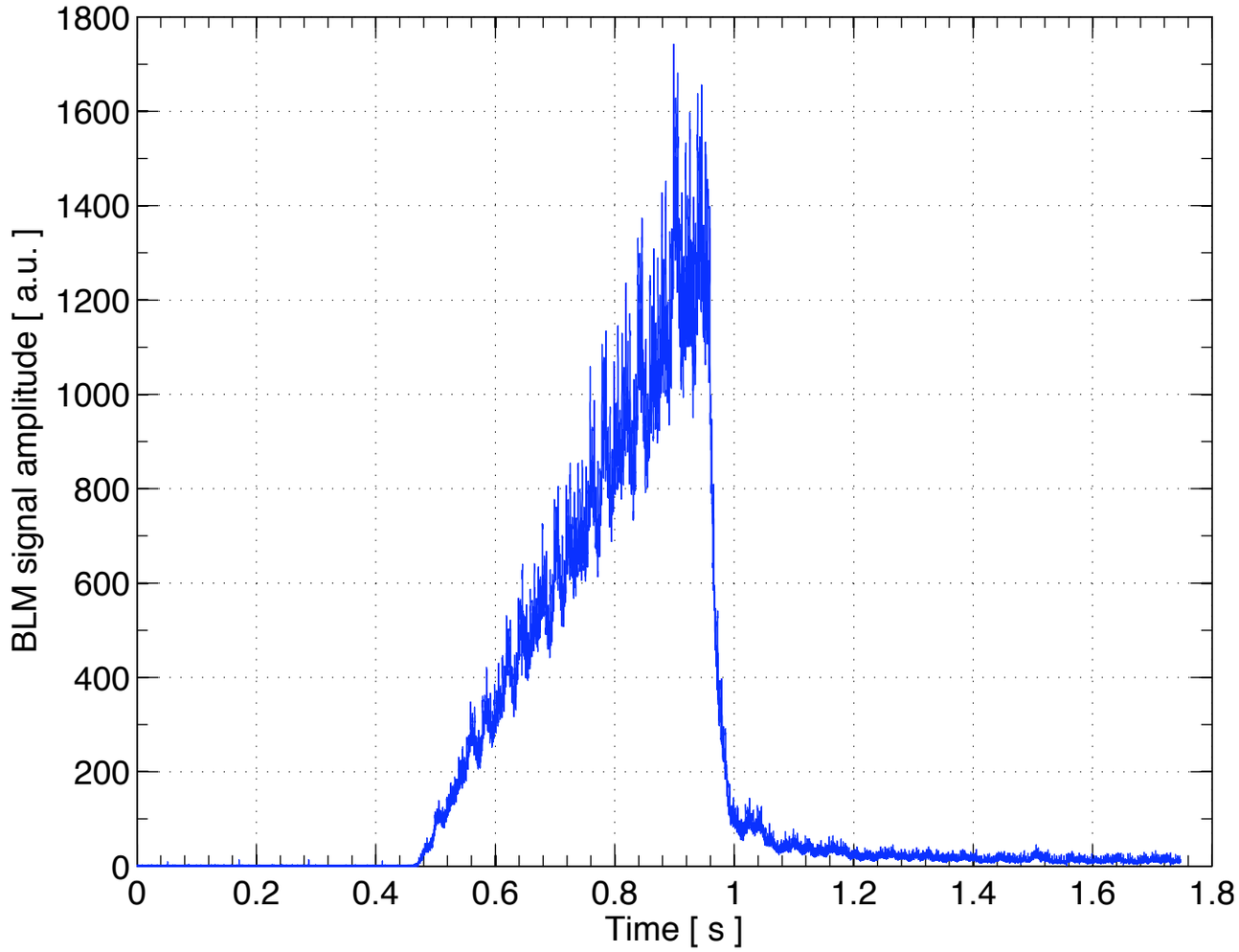
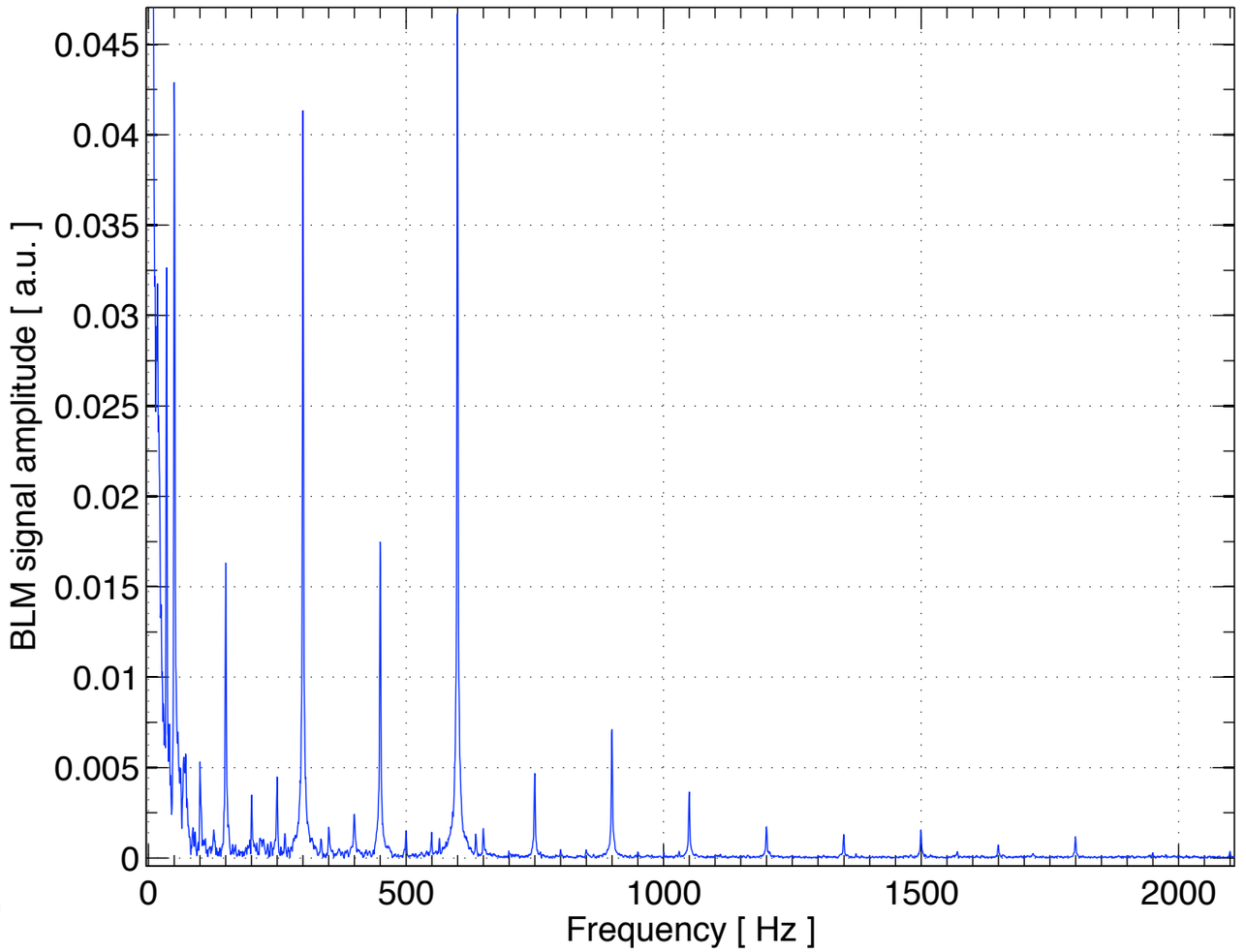


BLM signal goes like Rayleigh function

From H. Burkhardt, AB-2004-032

VERY fast BLM measurements



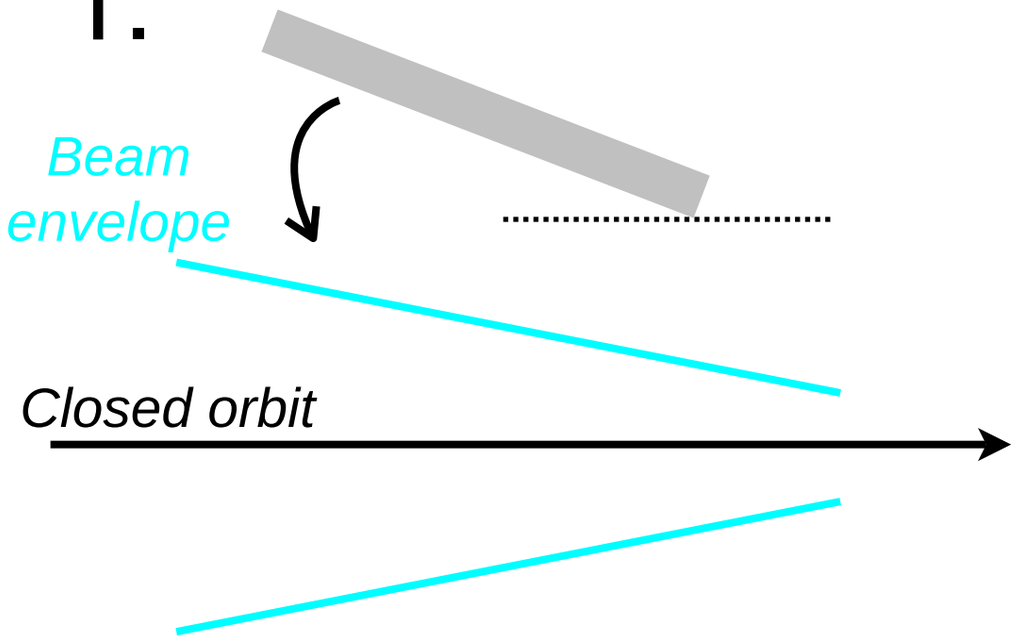


- Special acquisition to get **Post-Mortem BLM buffer**: 43000 points at 40 µs !!
- Can see **tune modulations on the loss patterns**: 3-phase SPS magnets (D. Kramer)
- A lot of data collected for different amplitudes of collimator movements:

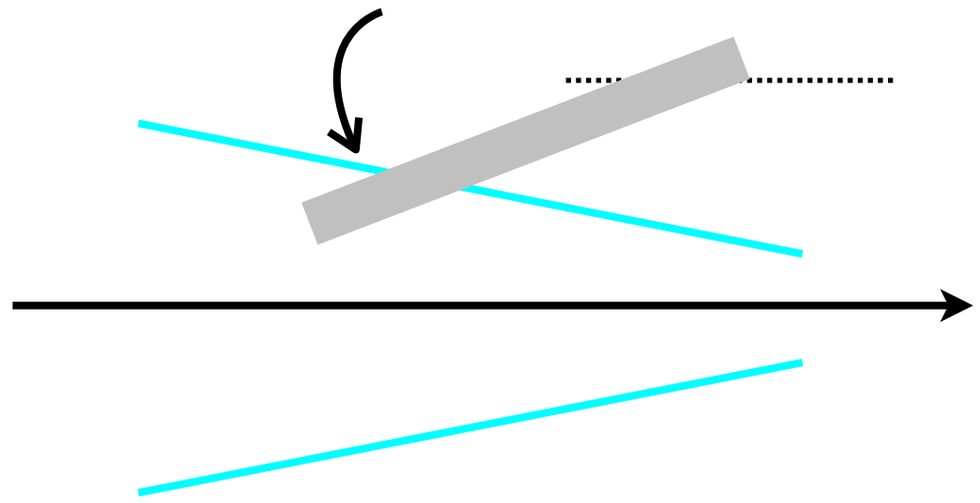
  Data potentially interesting for automatic alignment procedures!
- Experienced some performance issues: delays of acquisitions, reliability of acquisition.

Idea for jaw angle adjustment

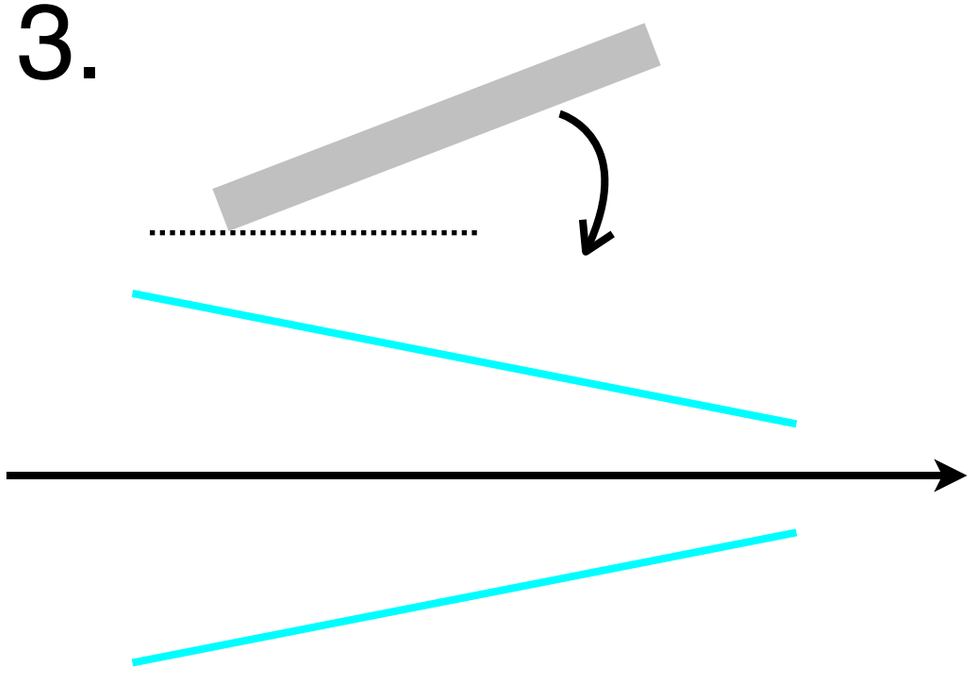
1.



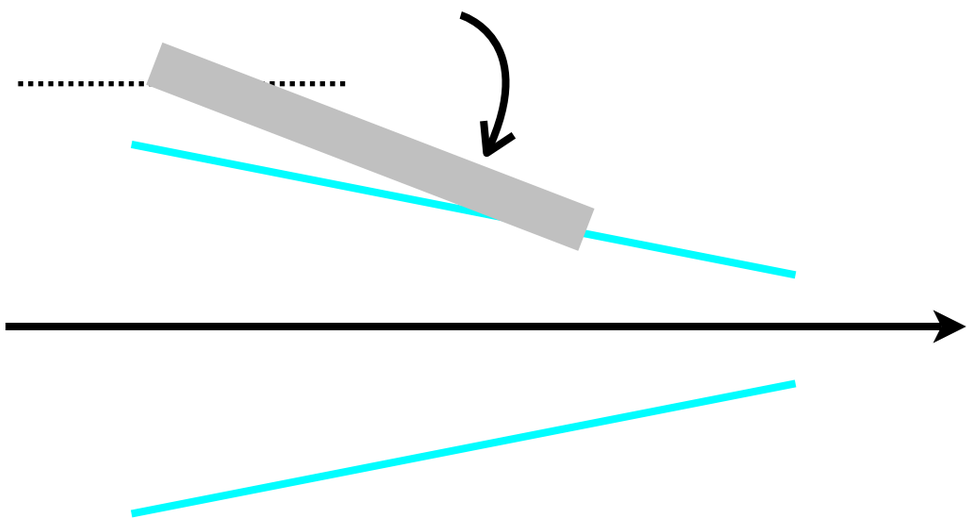
2.



3.

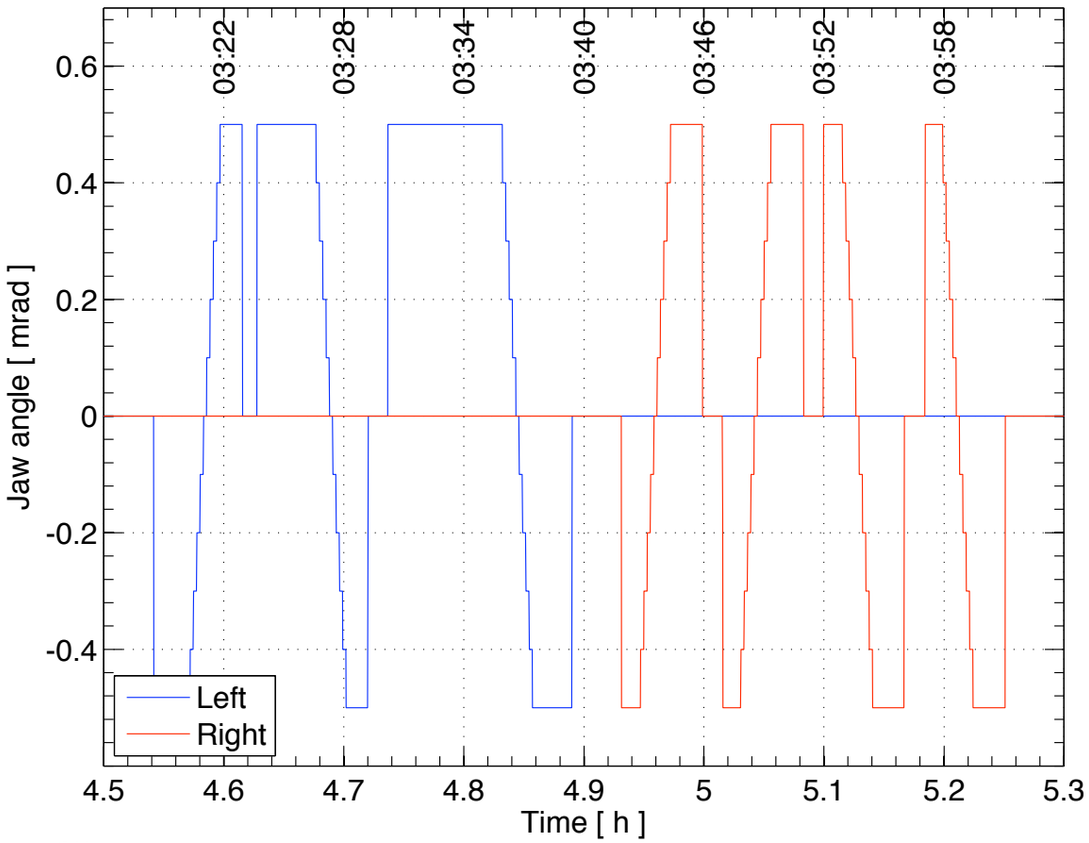


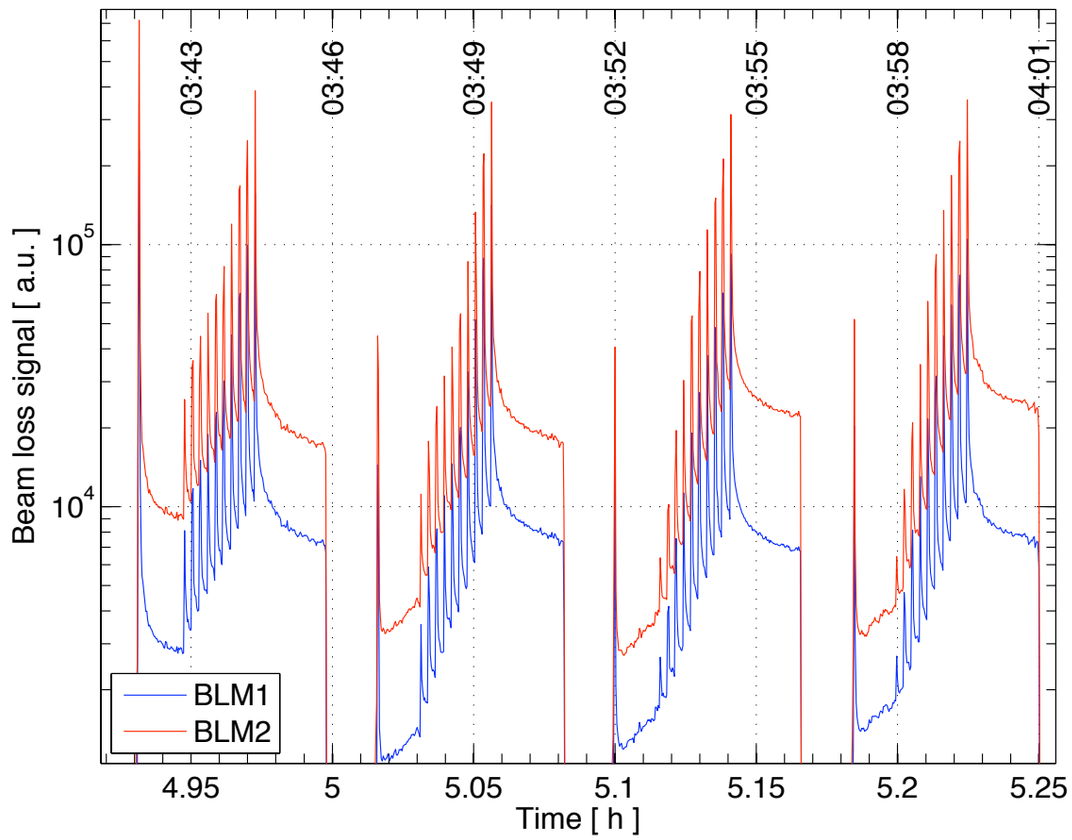
4.

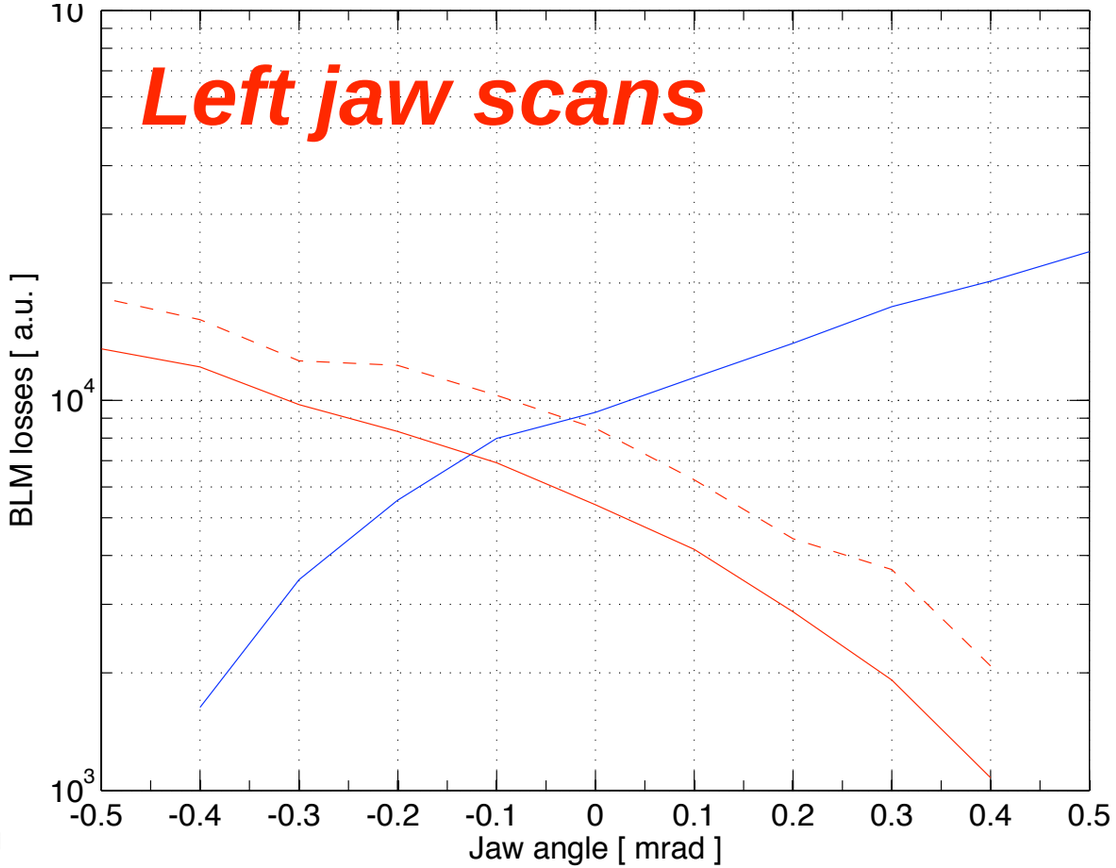


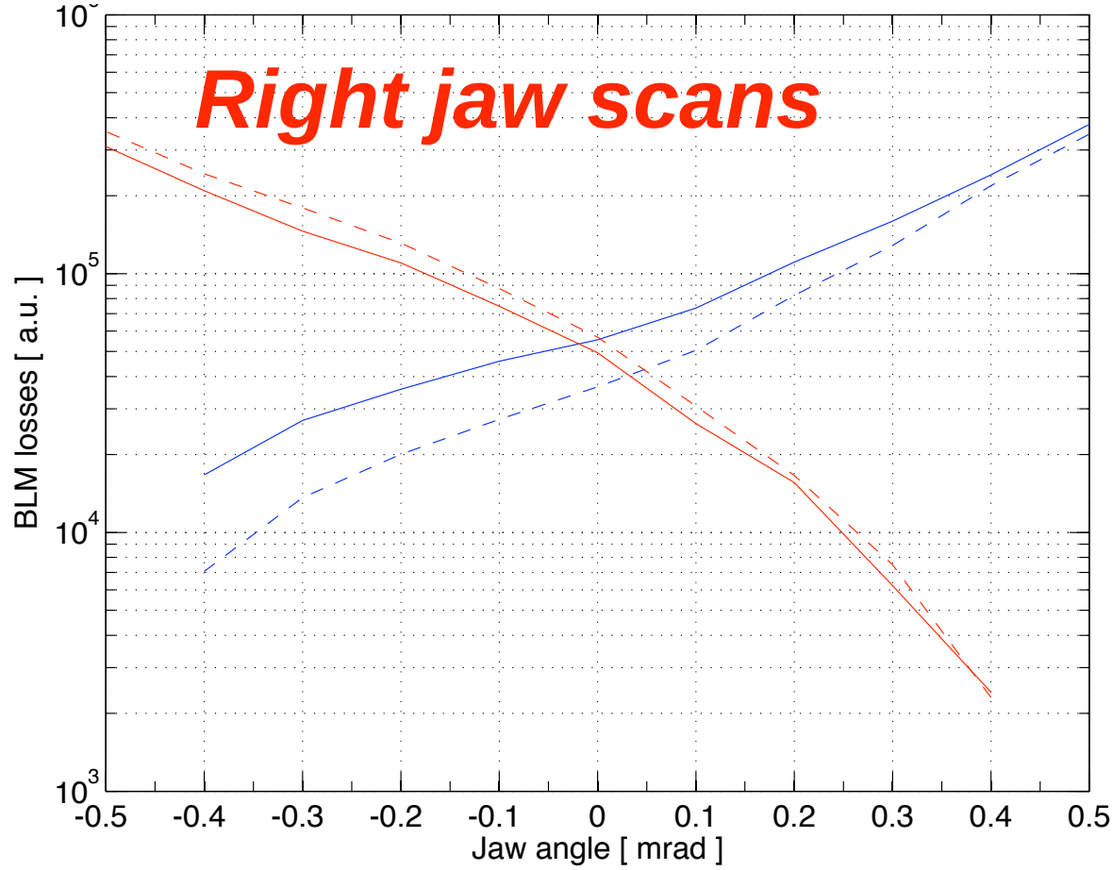
Expect a “step” change of losses when second edge gets closer to the beam!

Measurement results

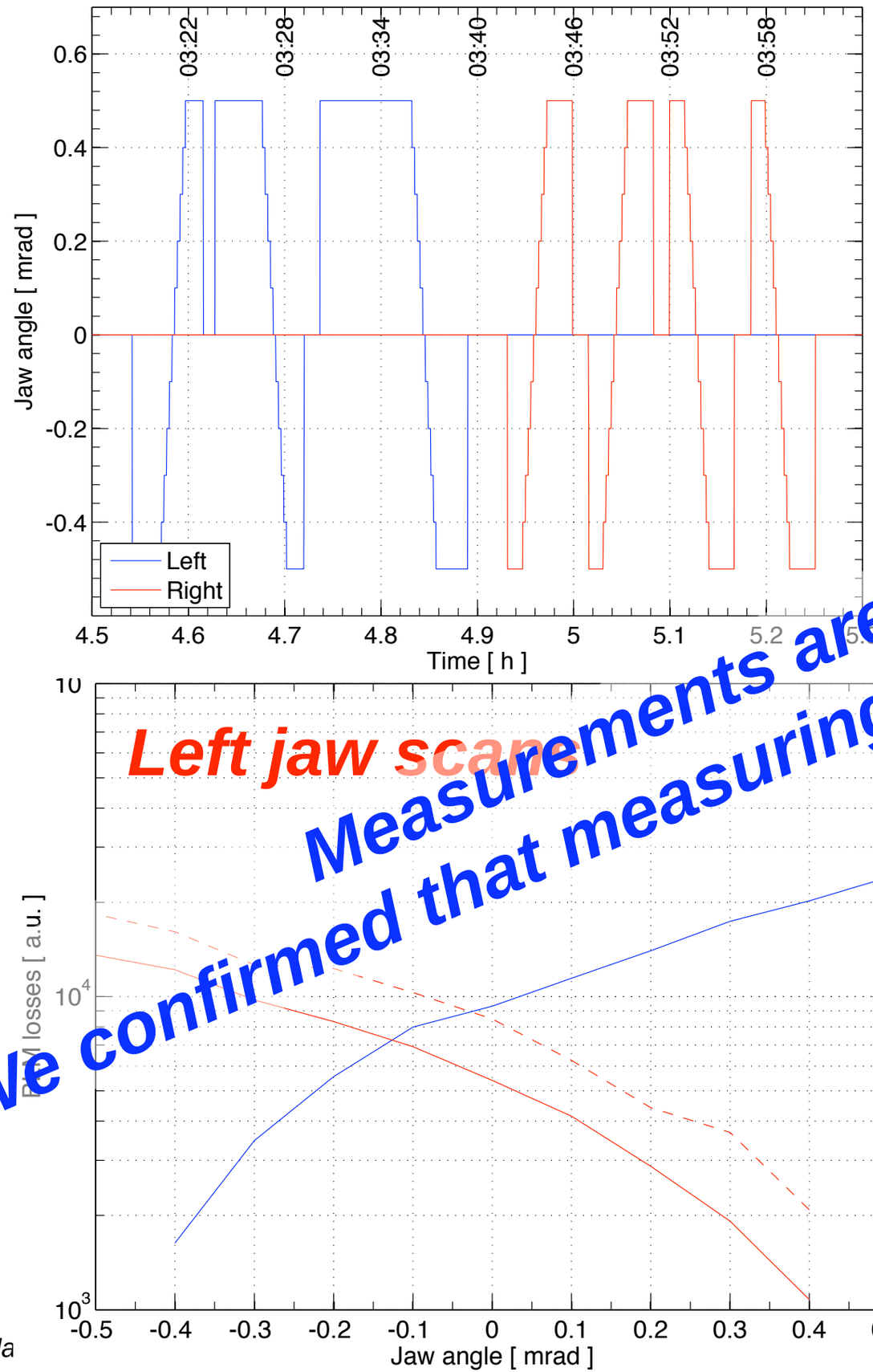


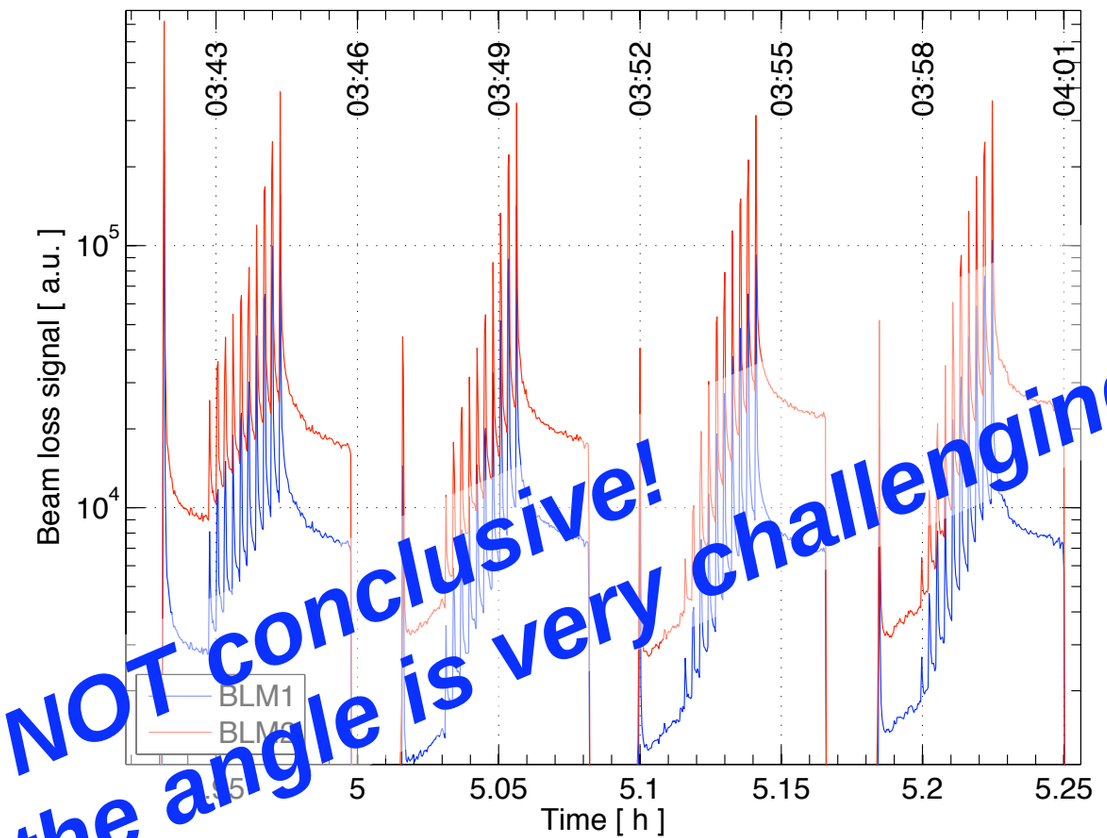






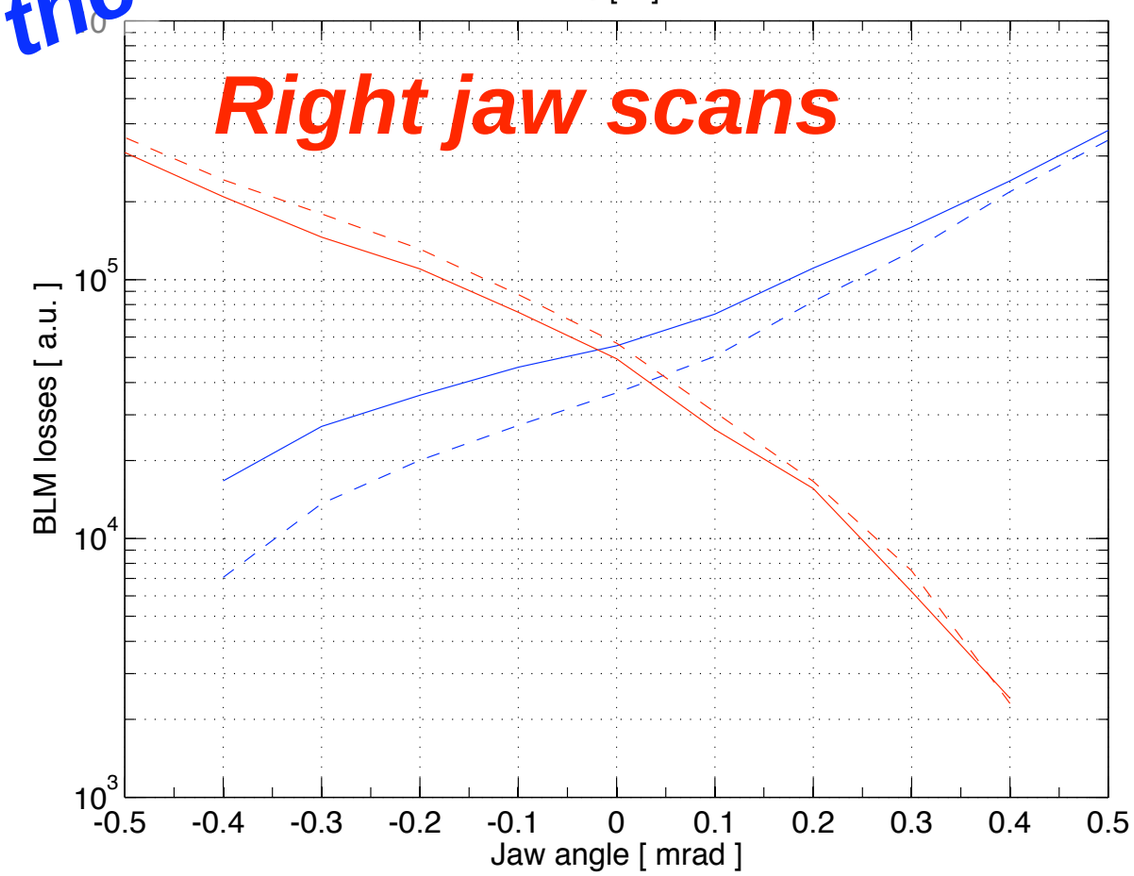
Measurement results





Measurements are NOT conclusive!

We confirmed that measuring the angle is very challenging!

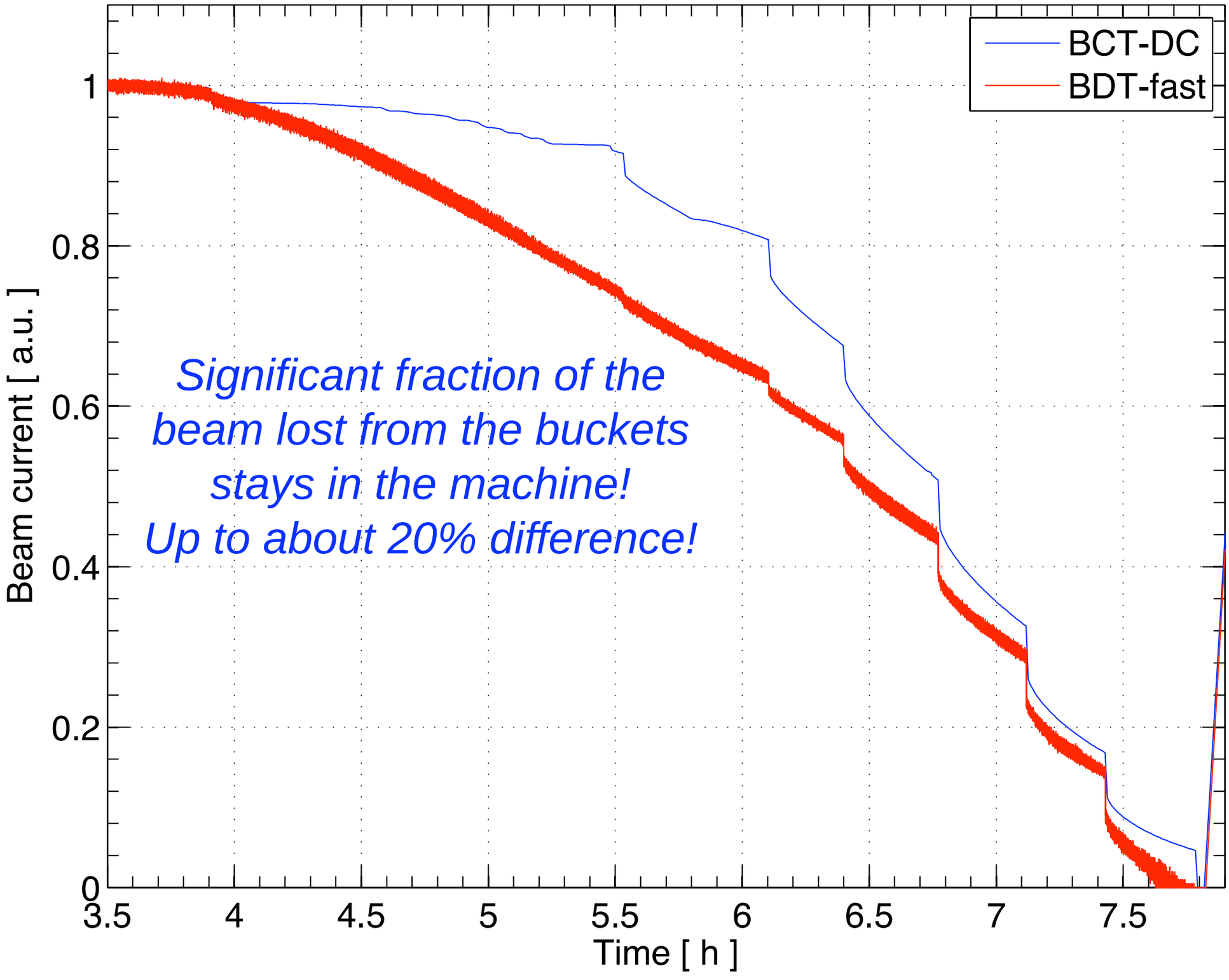


Conclusions

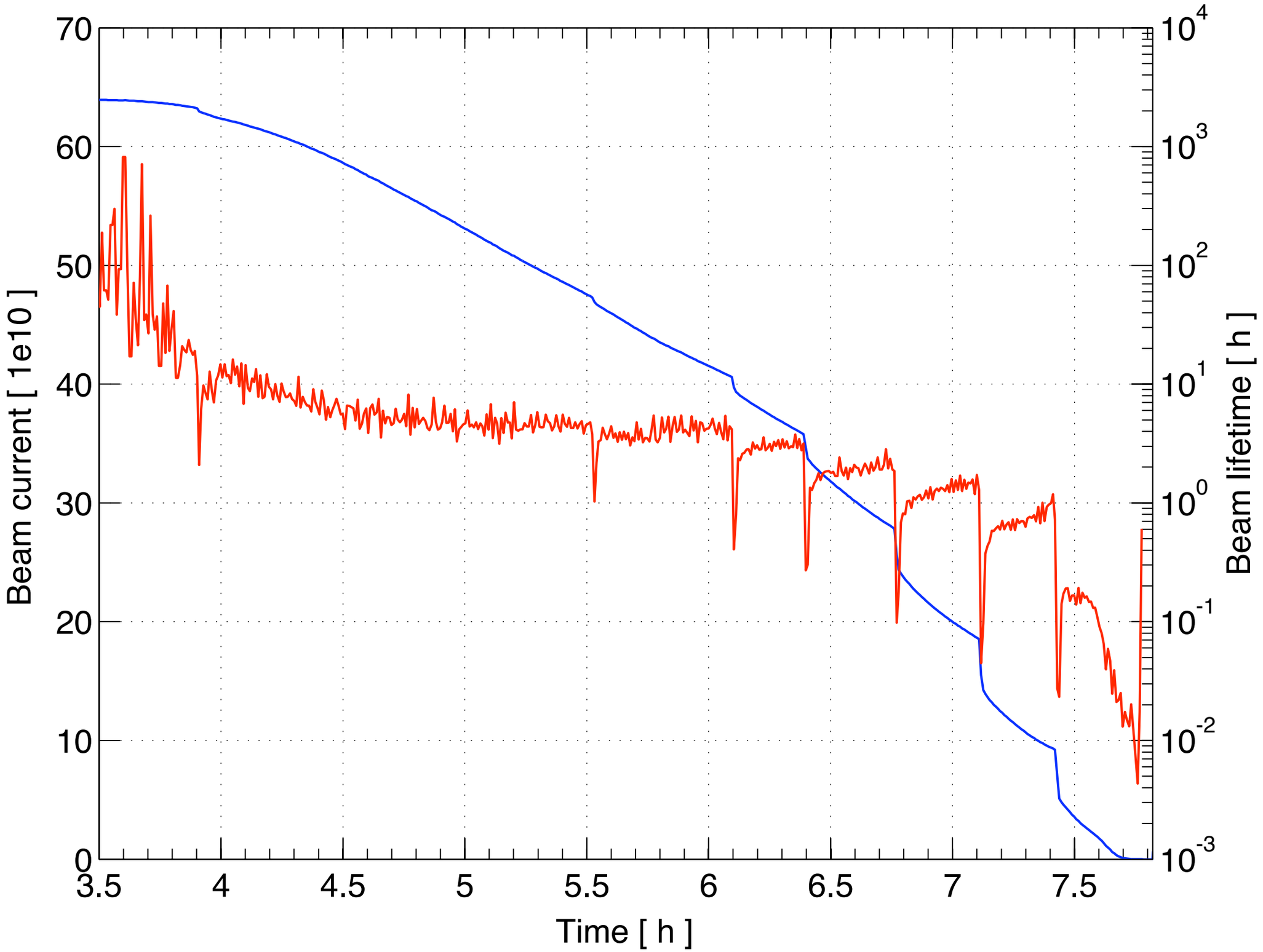
- Presented the results of **2008 collimator beam tests** at the **SPS**
- Focus this year was put on **lifetime / loss studies**
  - *Significant reduction of beam lifetime when collimator jaws at 6-10 σ*
  - *Discussed long loss tails and re-population*
- Observed different behaviours for **bunched** and **un-bunched beams**
  - *Implications for beam-based collimator set-up at the LHC??*
- Acquisitions of **fast** and **“very” fast BLM** signals with LHC system
  - *Successful implementation of various LHC acquisition modes*
  - *No dedicated studies on automatic alignment*
- **Angle** adjustment of collimator jaws to beam envelope not easily possible
- **Simulations** of beam losses in noise-dominated regimes are on-going to reproduce the findings (only preliminary results so far)

Reserve slides

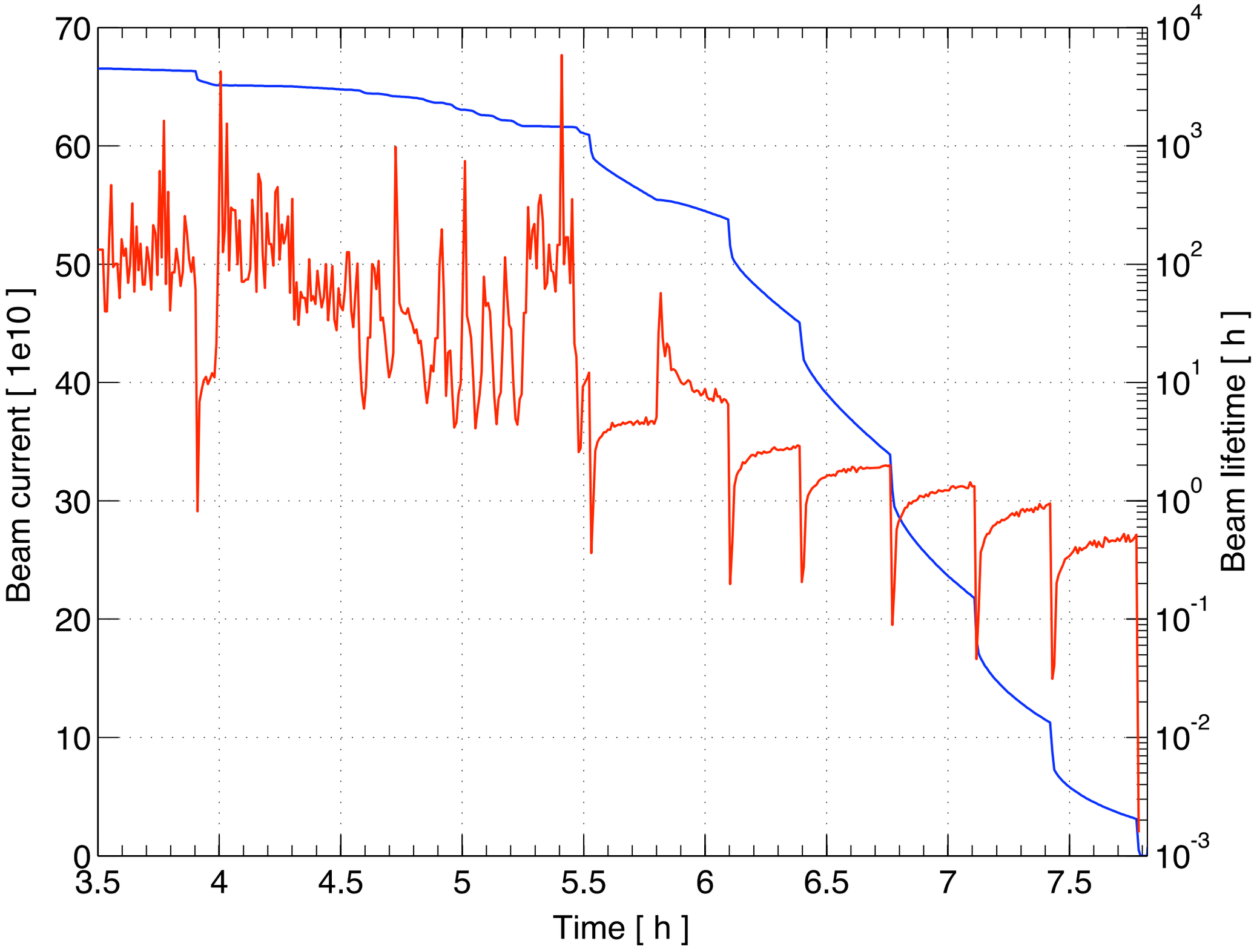
Beam intensity evolution



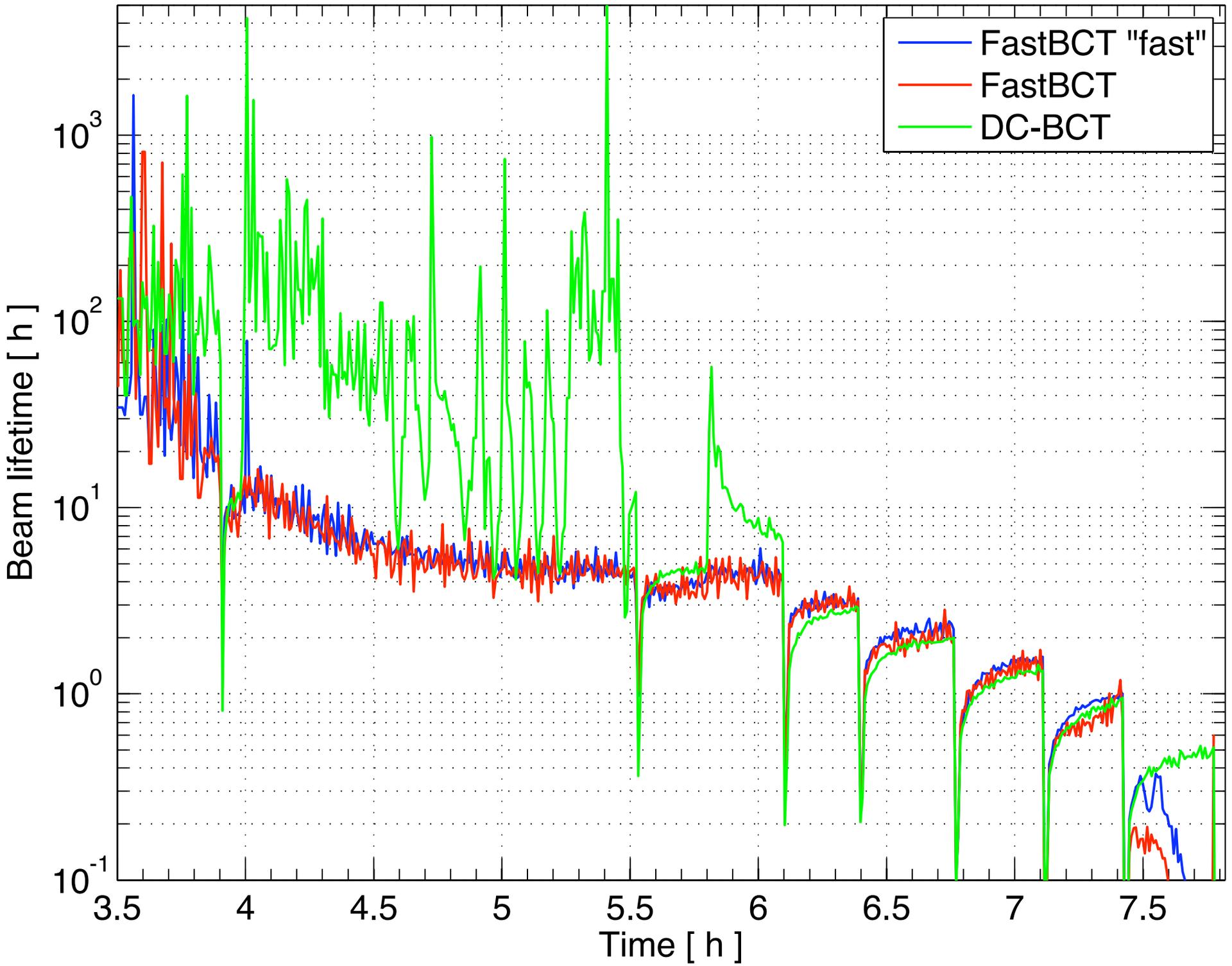
Bunched beam lifetime



Total intensity lifetime



Comparison


FastBCT "fast"
FastBCT
DC-BCT
Beam lifetime [h]
10^3
10^2
10^1
10^0
10^{-1}
3.5
4
4.5
5
5.5
6
6.5
7
7.5
Time [h]

Lifetime coast 3