Special Collimation Upgrade Specification meeting:

Internal review of "Tevatron hollow e-lens usage at CERN"

November 9th, 2012

CERN, Geneva, CH

Introduction and motivation

Stefano Redaelli, CERN, BE-ABP

Outline

- ☑ Introduction
- ☑ Basic concepts
- ☑ Scraping at the LHC
- ☑ Motivation for this review
- ☑ Possible timelines
- ☑ Conclusions

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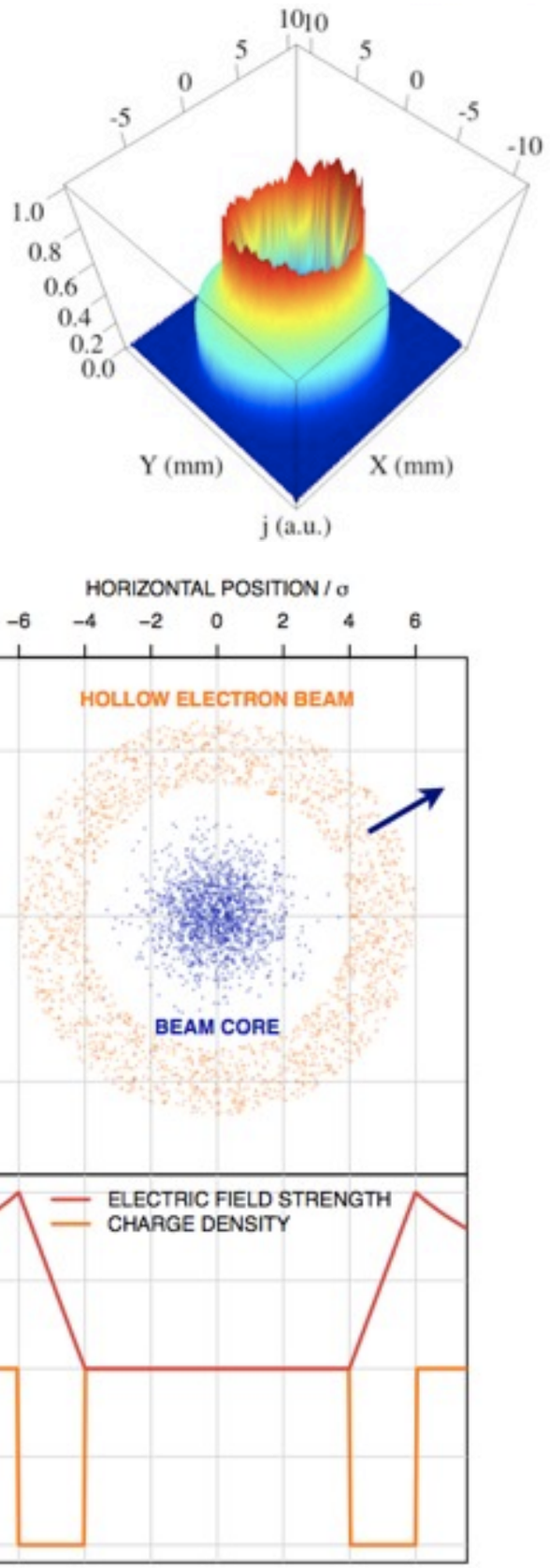
- This review if focused on the item (2)
  - *Ongoing work on (1) required understanding of minimum lifetime, quench limits, collimator settings scenarios for 7 TeV cleaning, etc...*

Basic concepts



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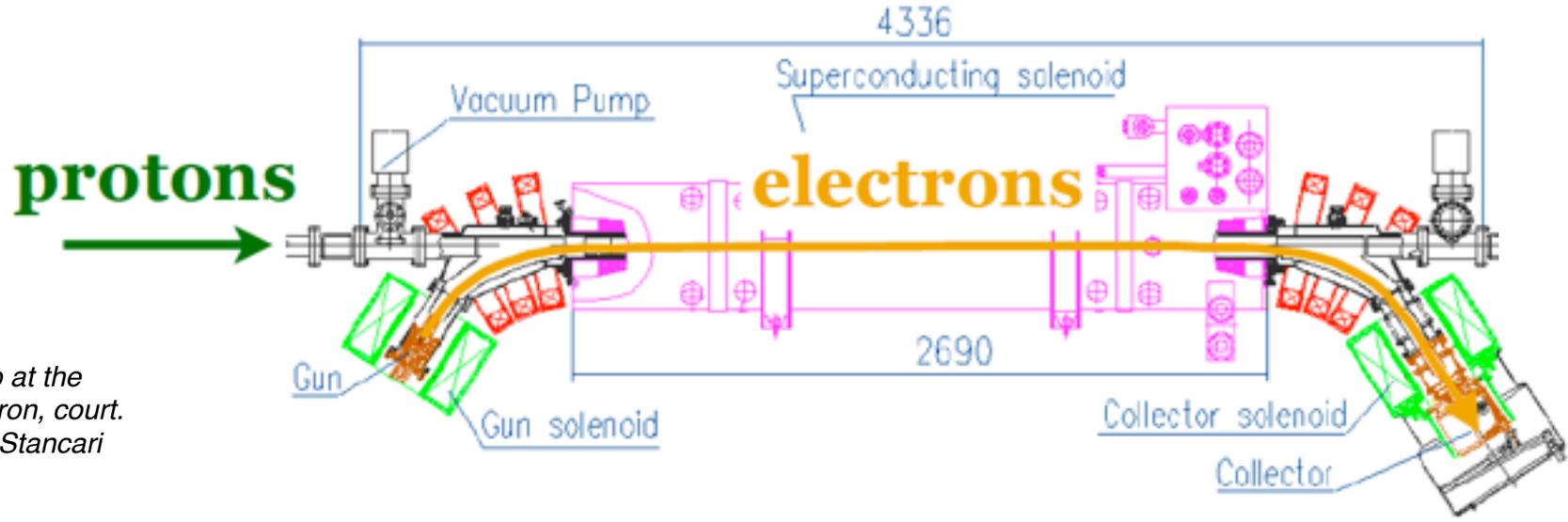

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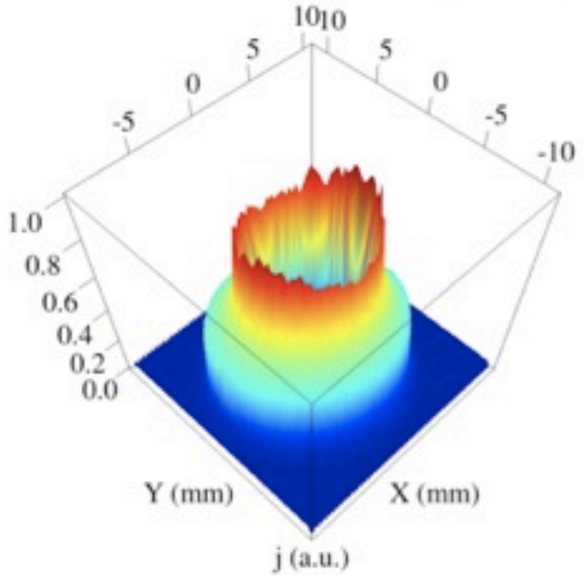

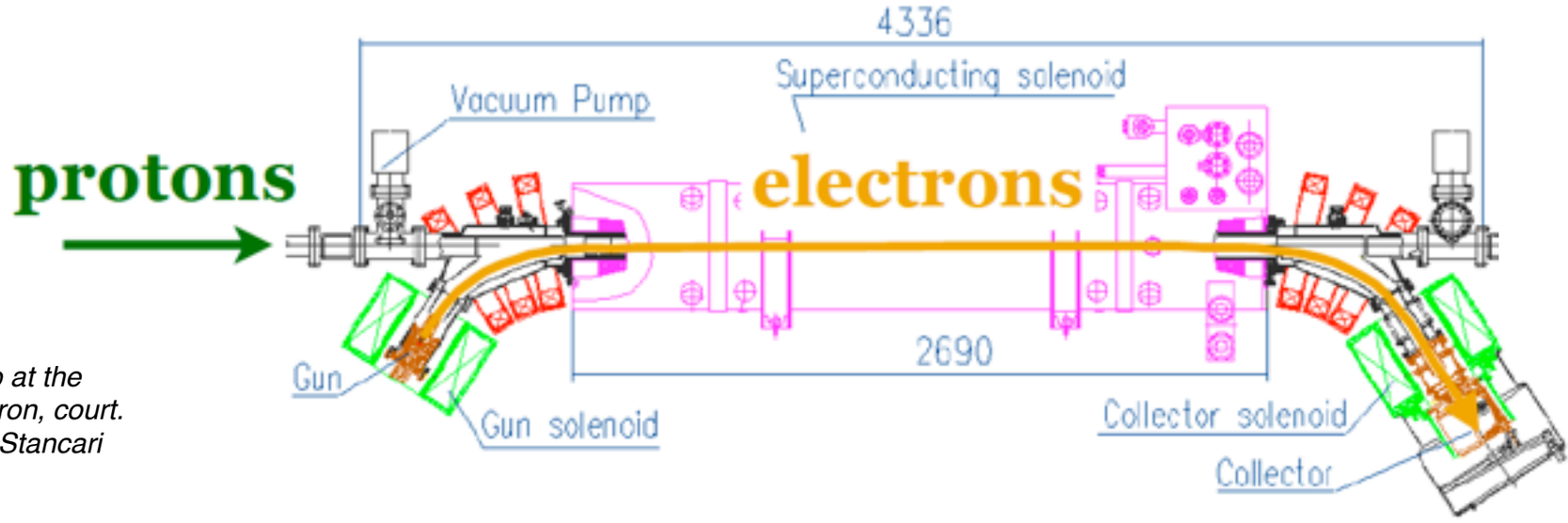

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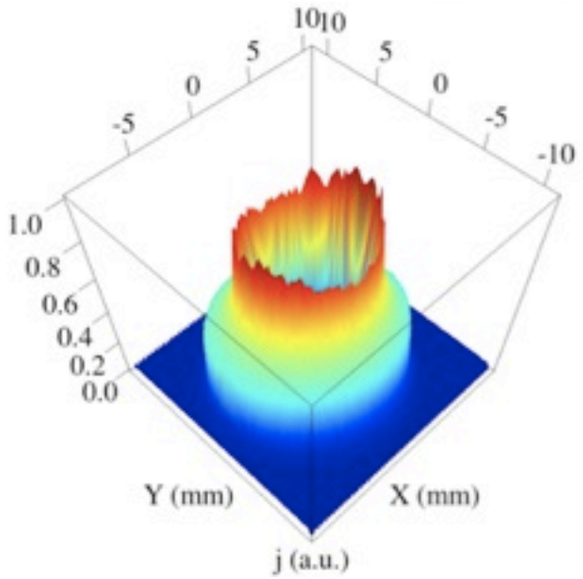

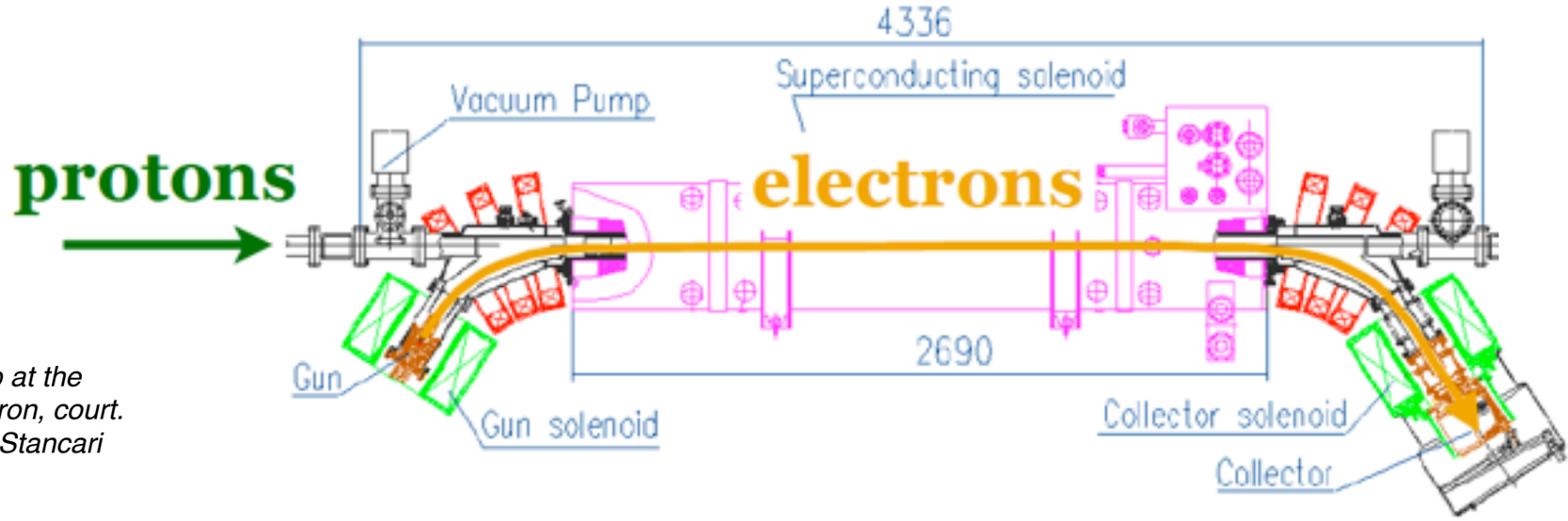

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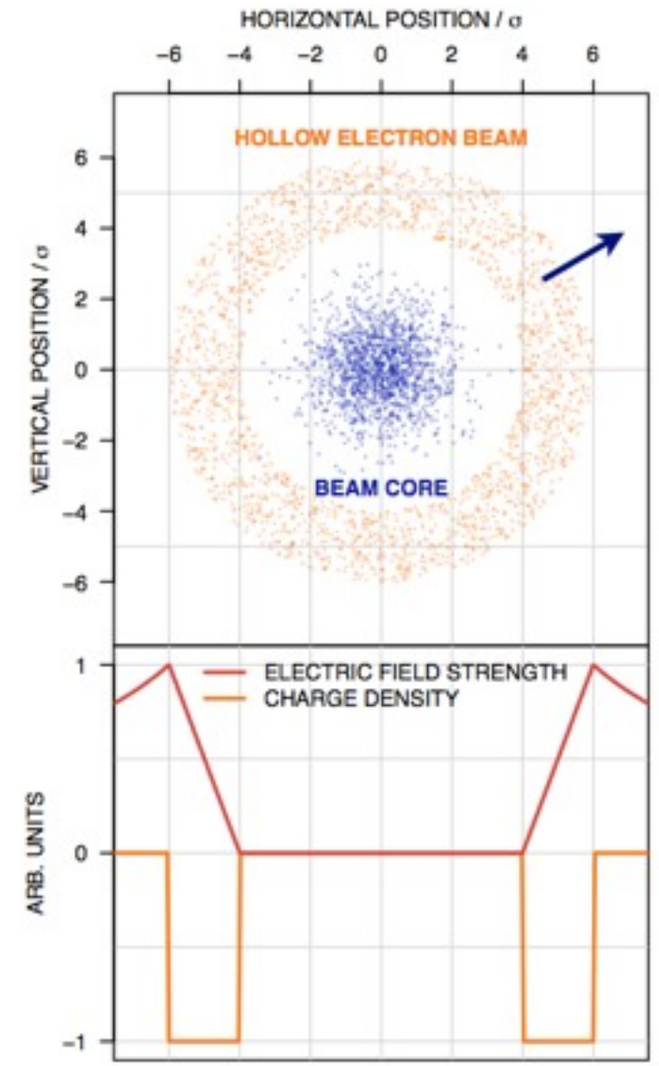

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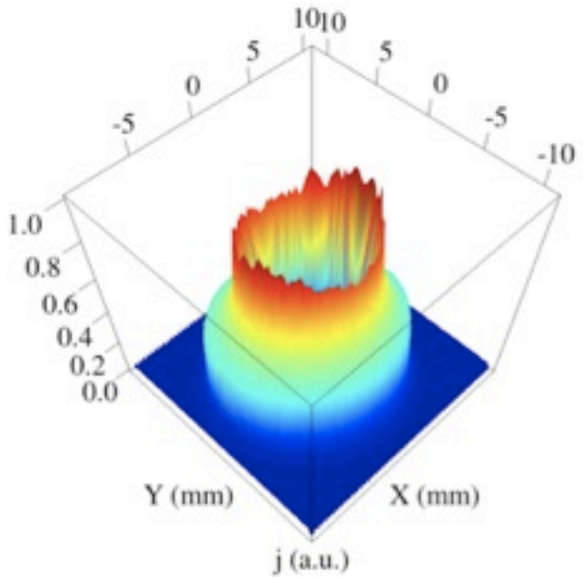

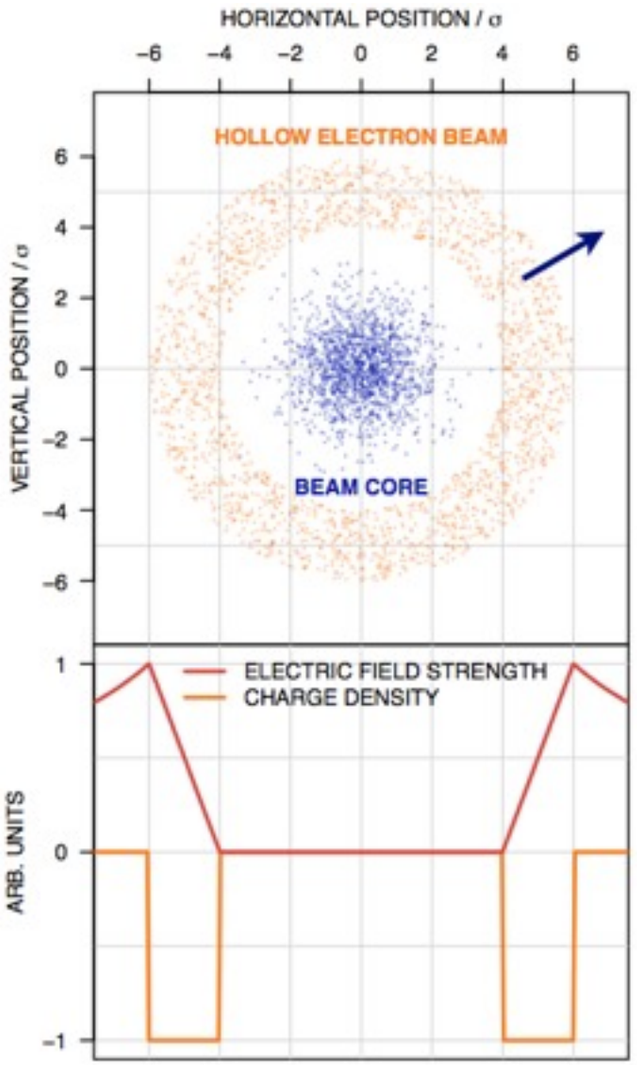

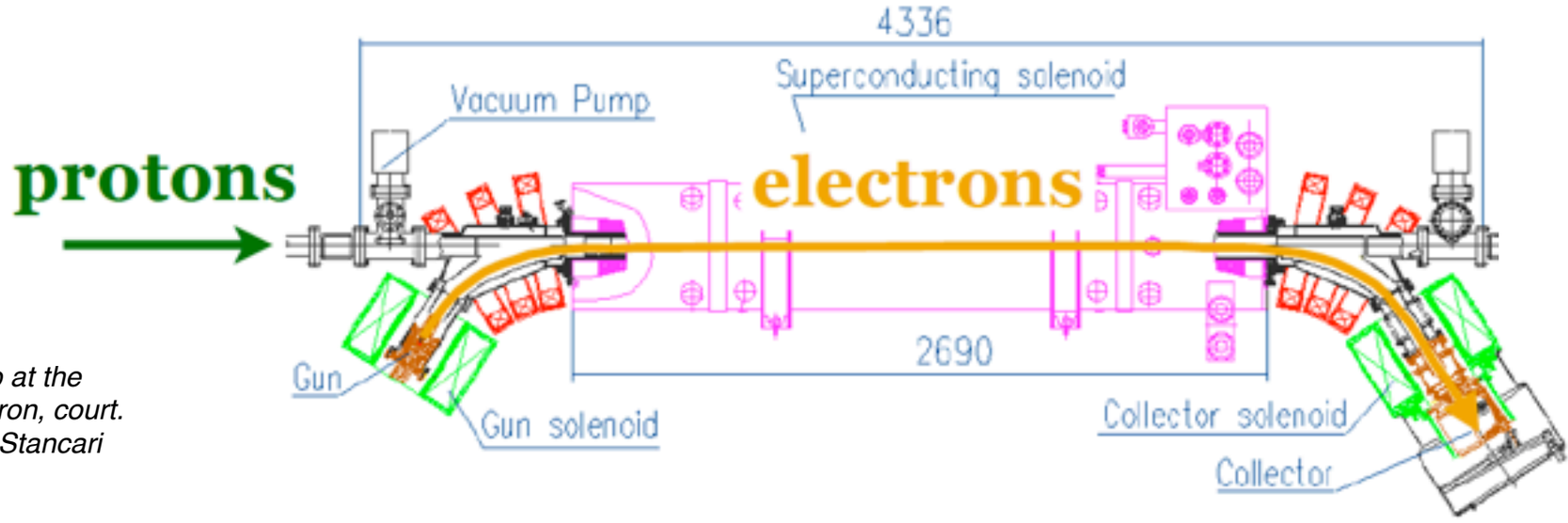

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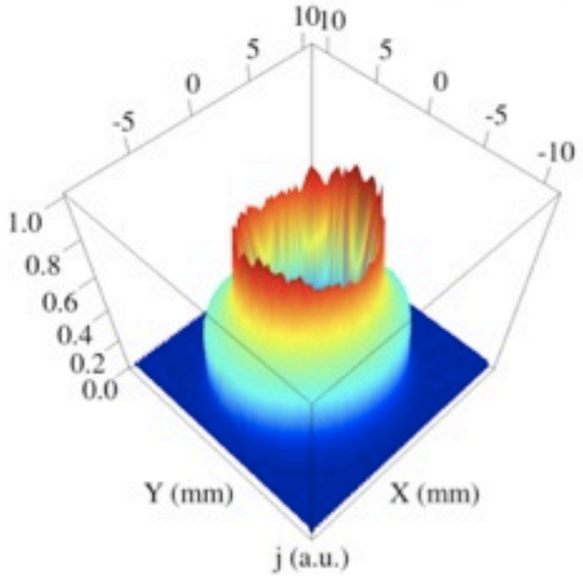

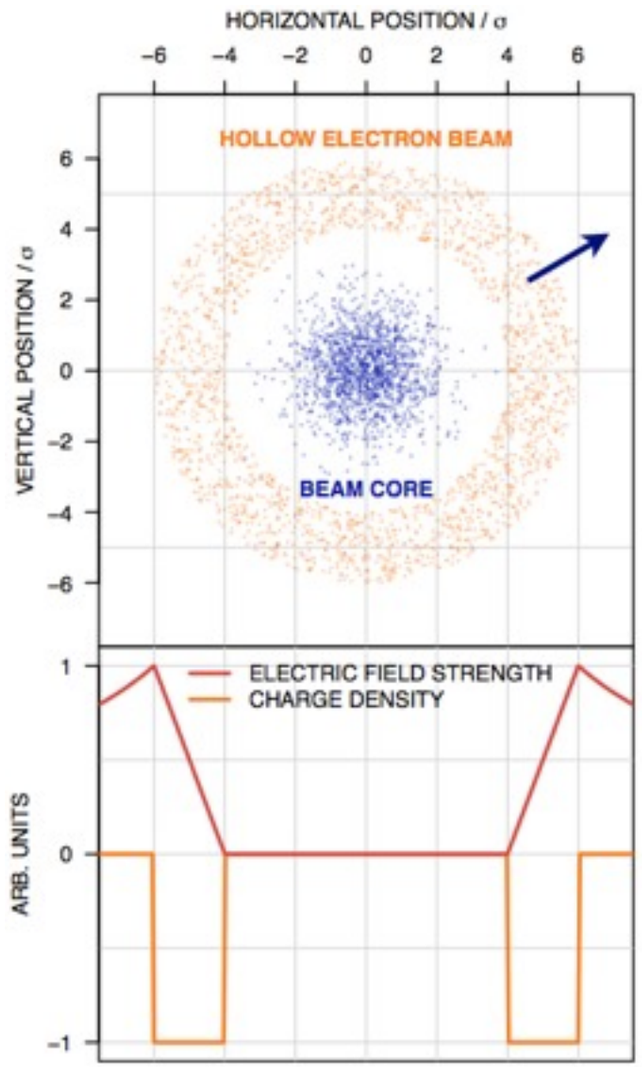

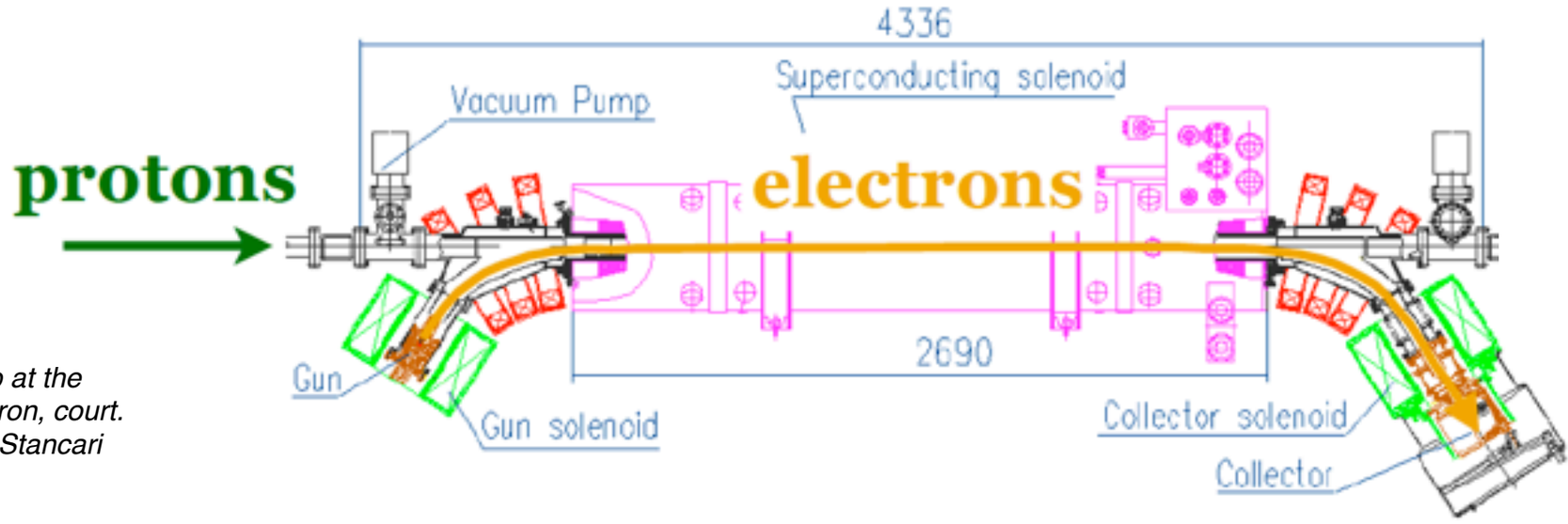

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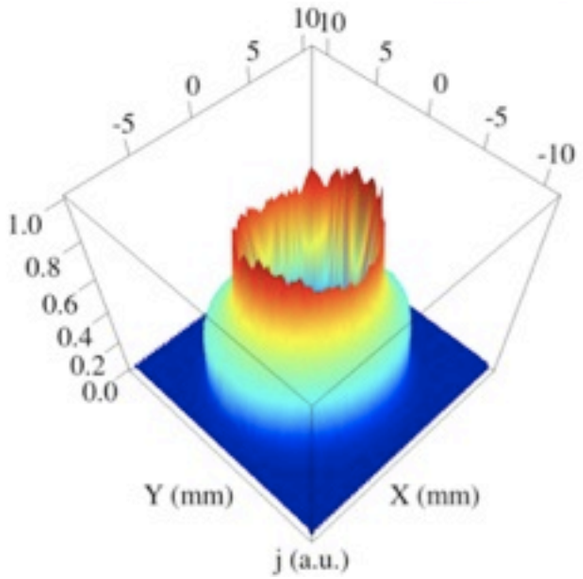

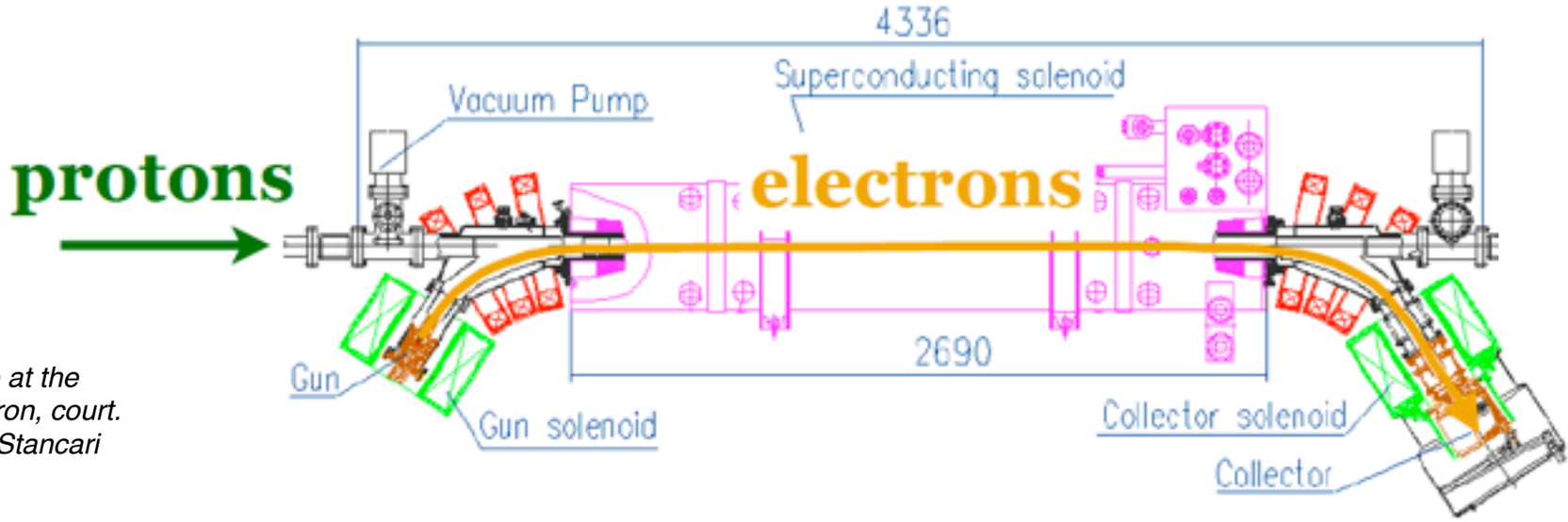

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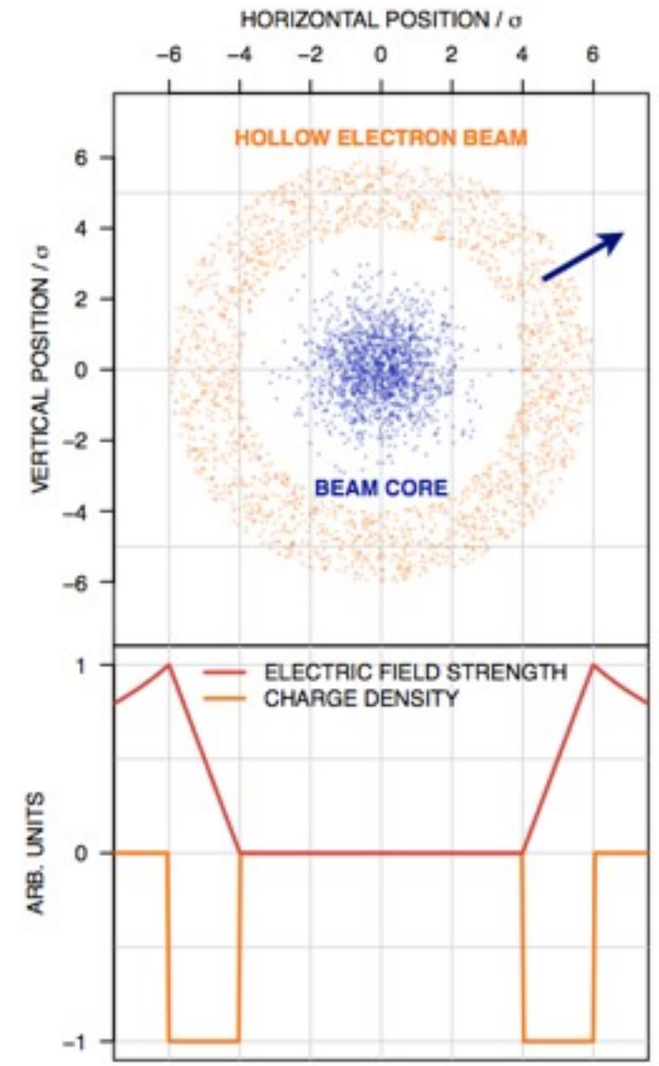

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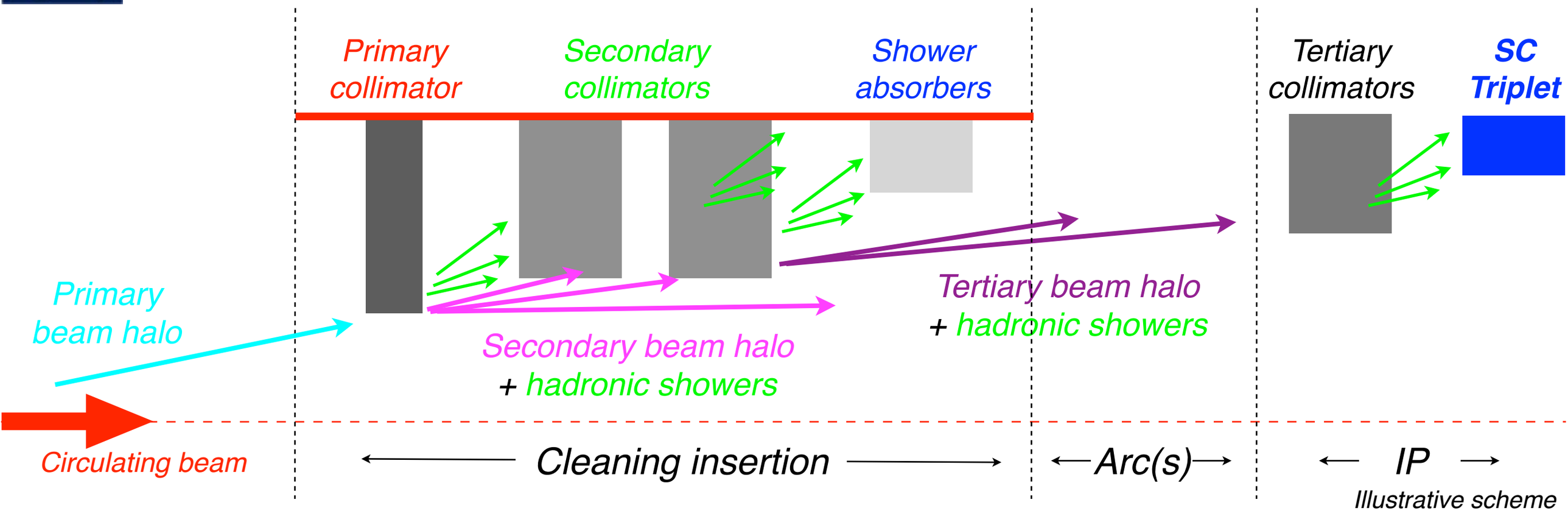
- Remove halo particles below the primary collimator cut.
- Conceptual **integration** in the LHC collimation system:
  - *The halo cleaning is done by the standard collimators.*
  - *(Small) effect on cleaning by tuning the impact parameter*

Integration in multi-stage cleaning



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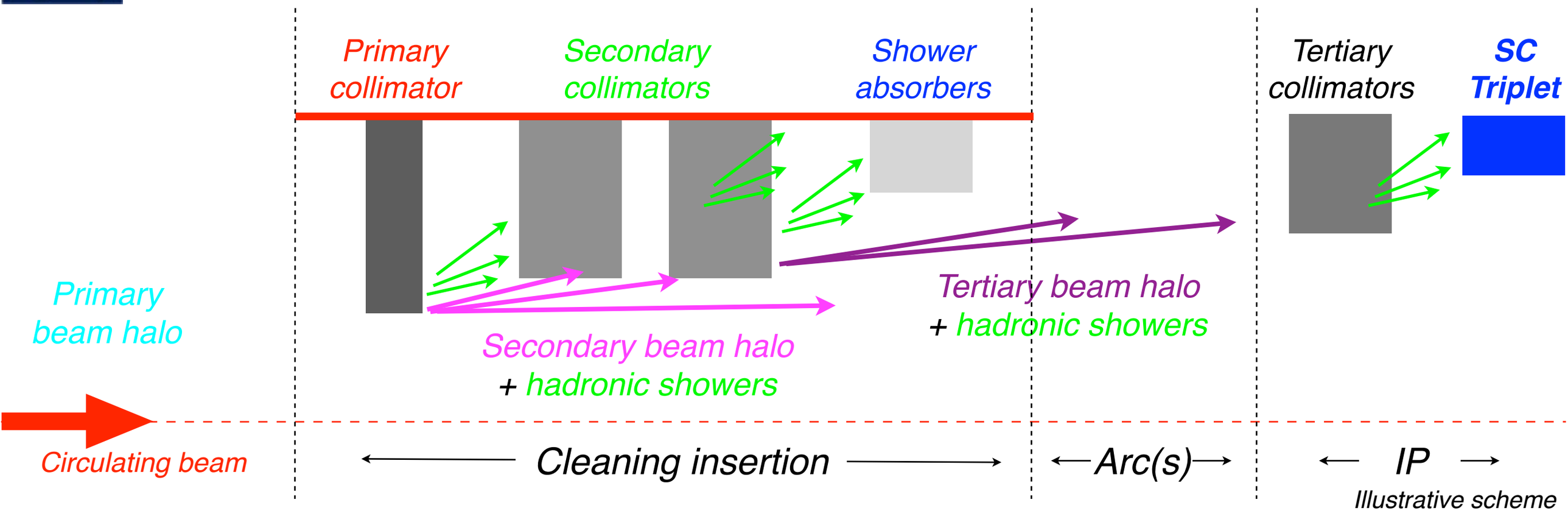

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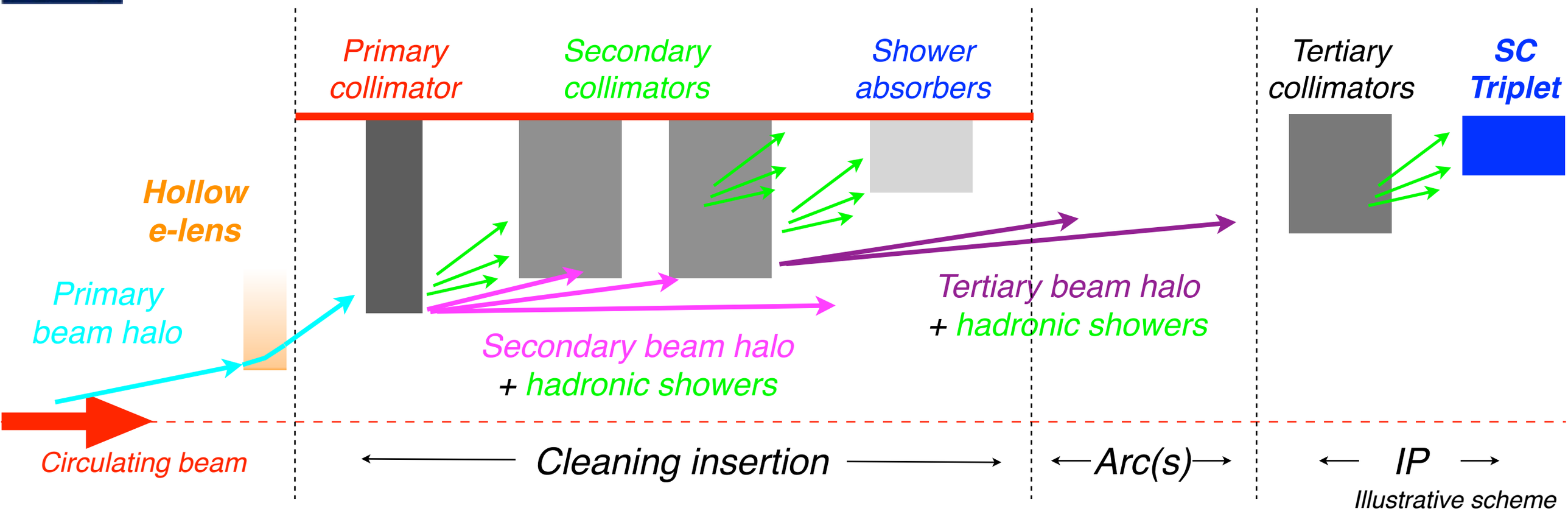

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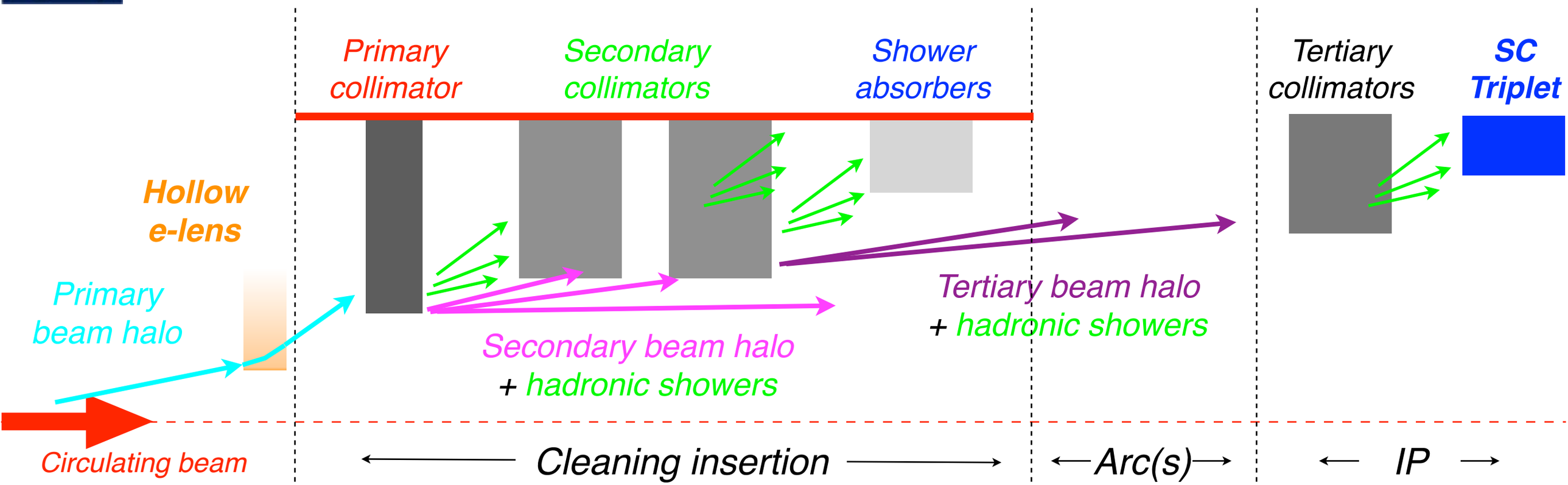
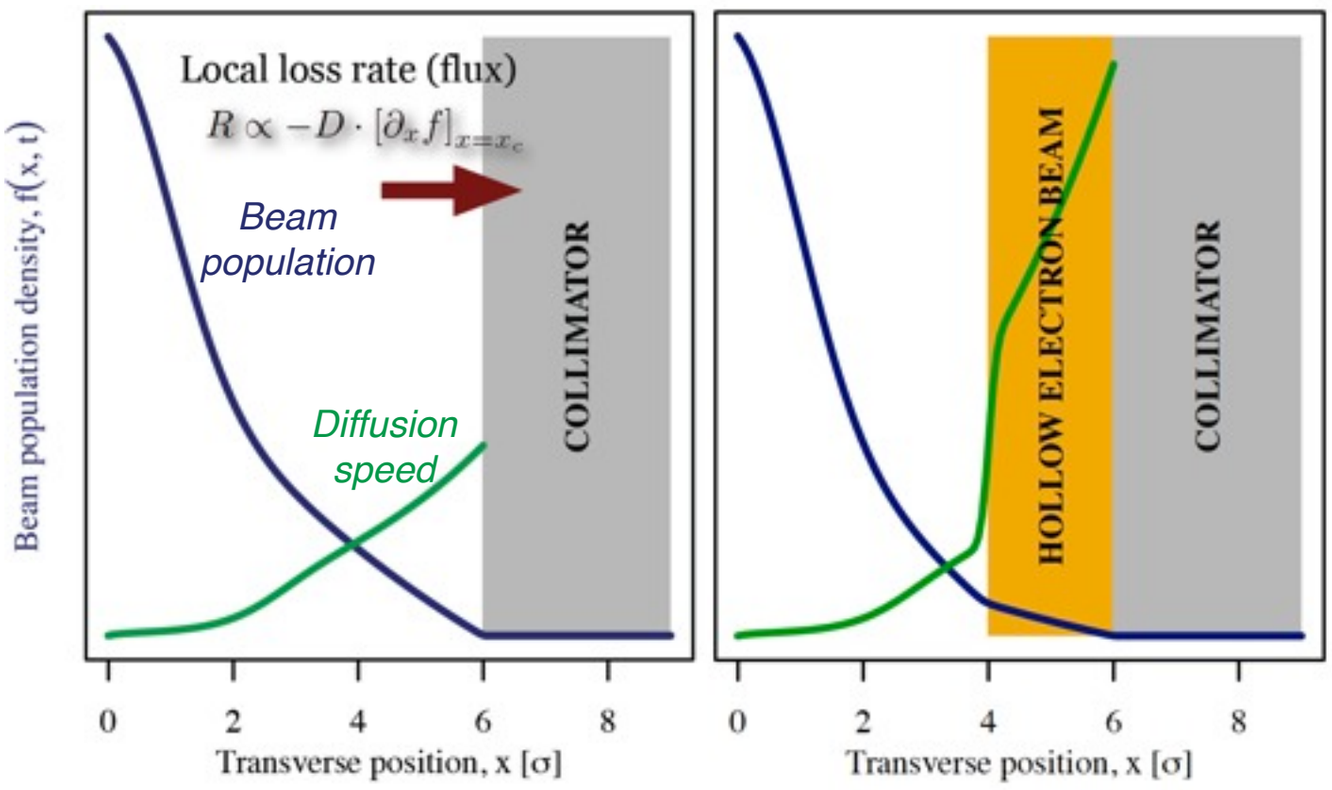


Illustrative scheme



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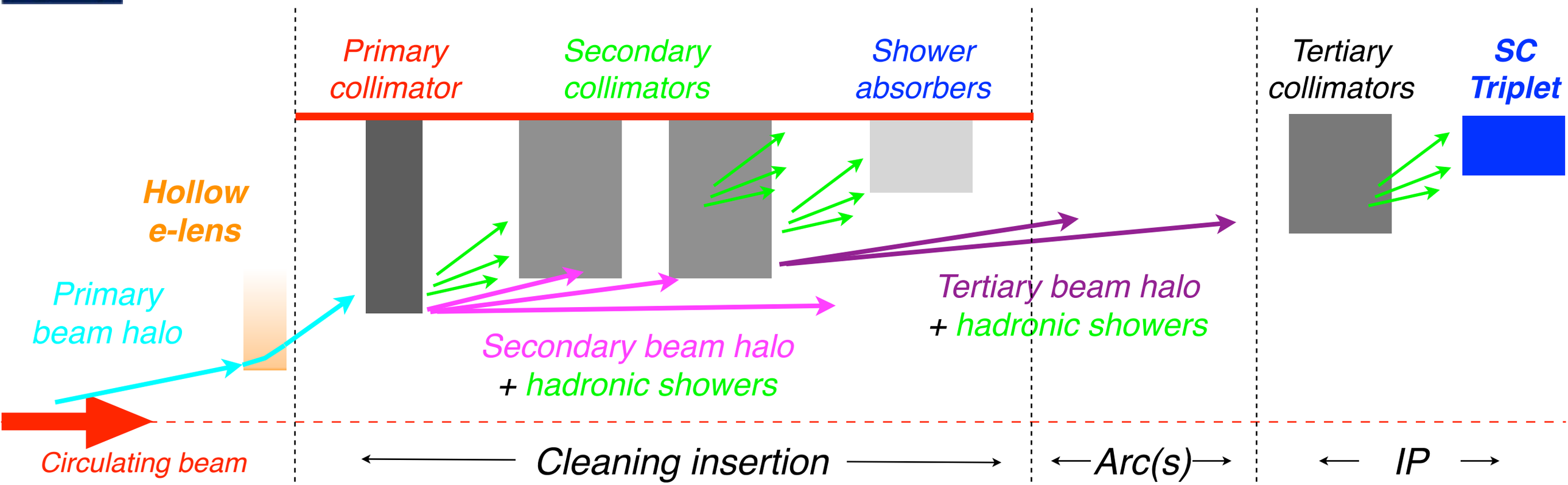

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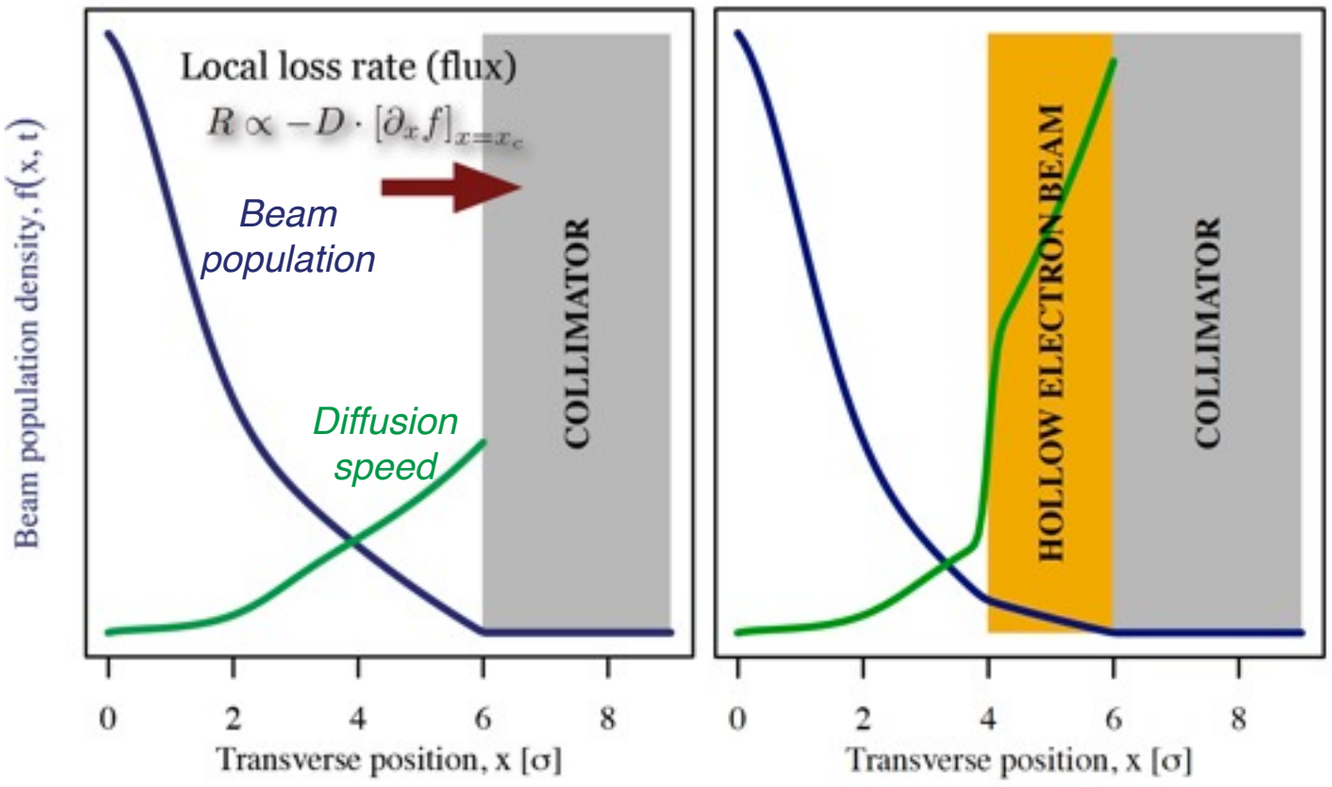
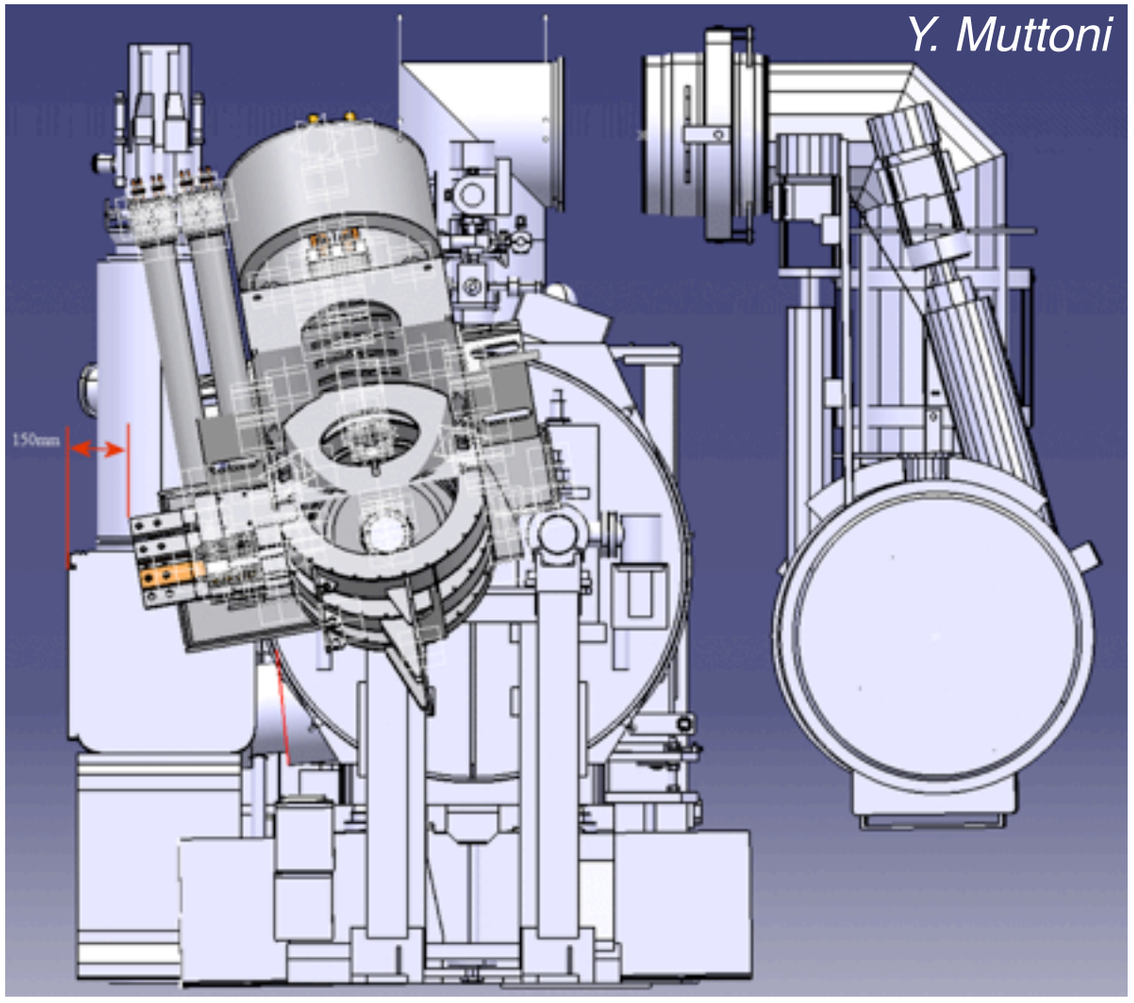
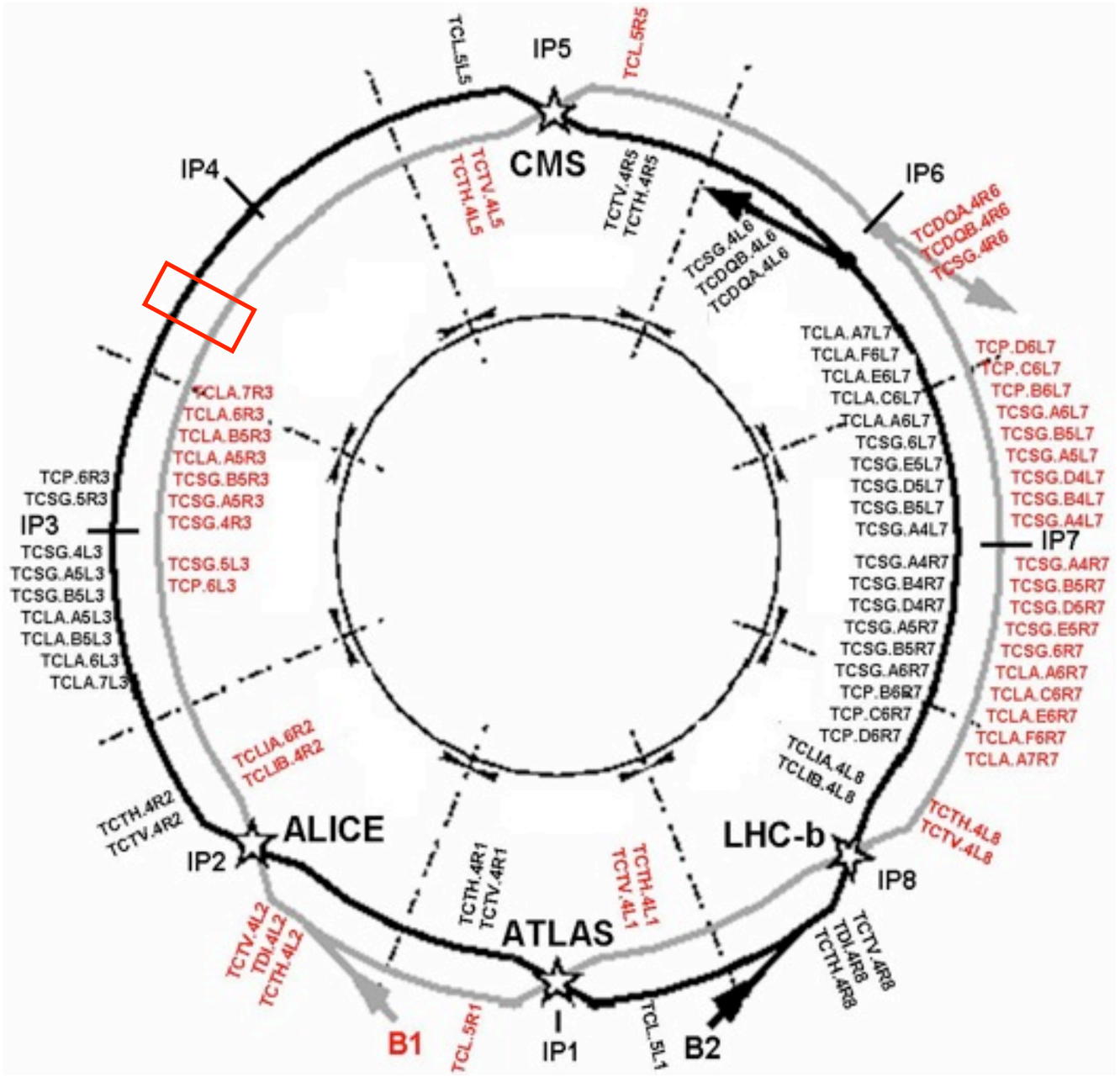


- The classical **multi-stage collimation** concept is maintained.
  - *No need to change present hierarchy*
- Ensures a full compatibility with present and future schemes
  - *E.g., compatible with crystals and also for ions.*
- "Hole" around core make losses insensitive to orbit drifts.
- Lens does not need to be in IR7
  - *Indeed, it better be elsewhere!*

Tentative LHC layout





Fullest details in Adriana's presentation

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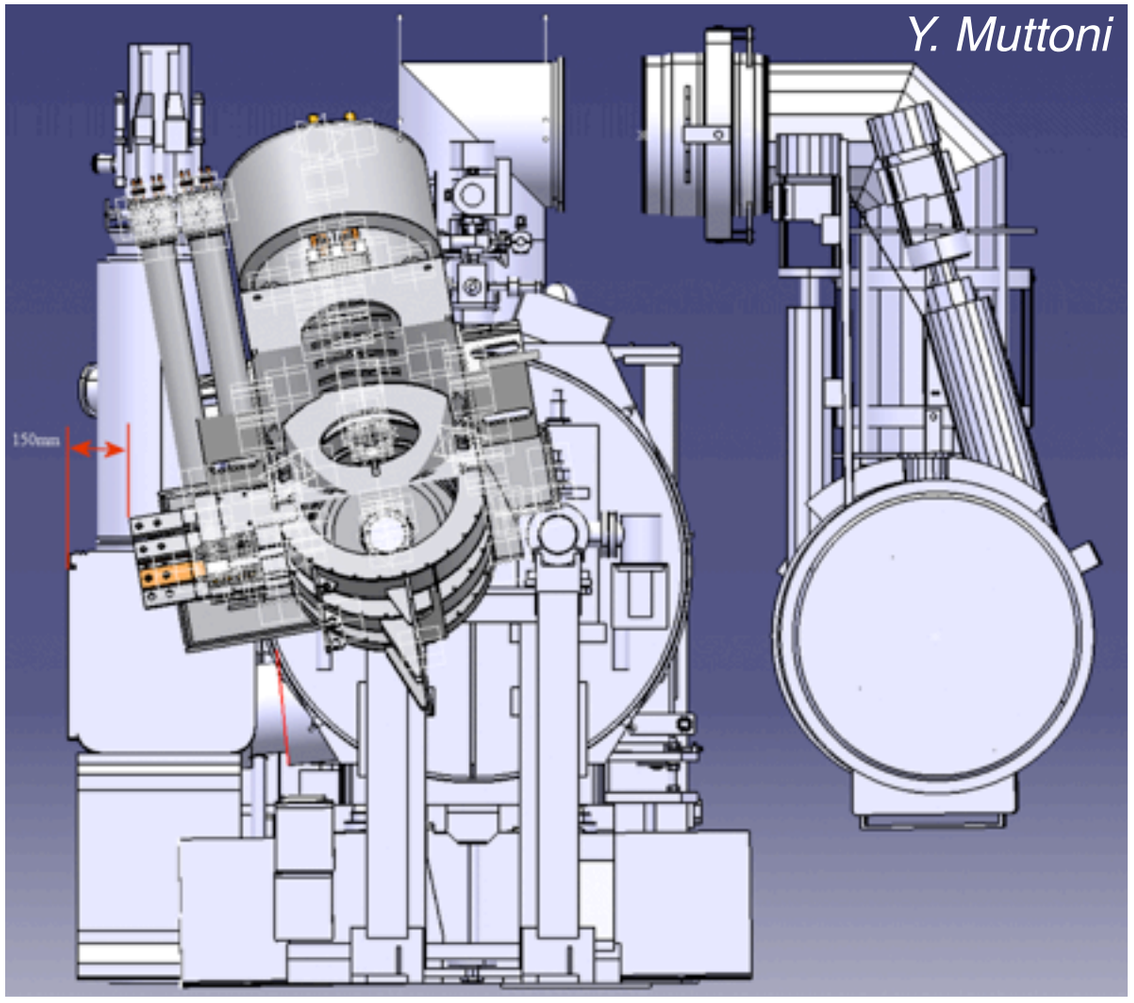

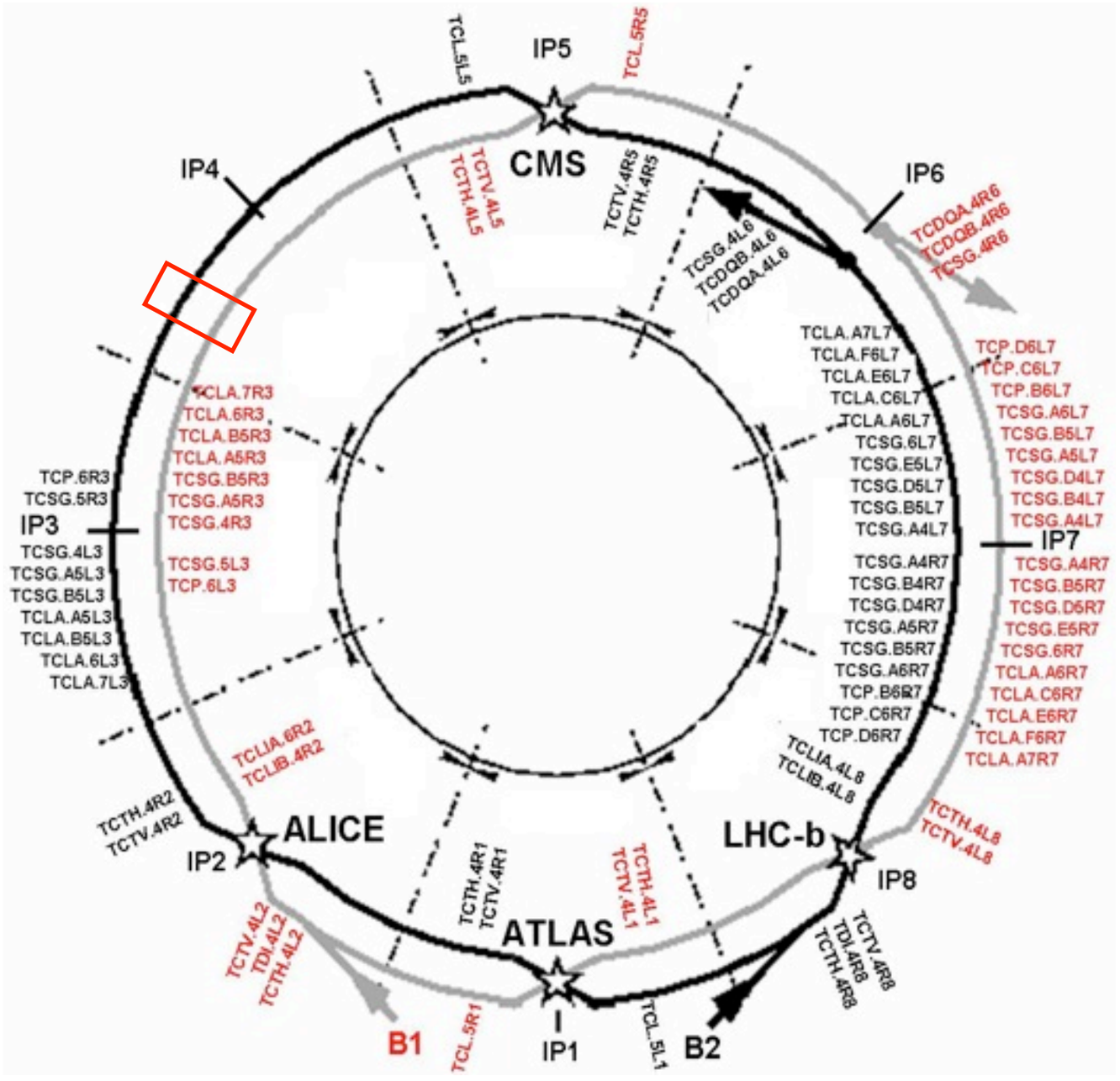

- Available Tevatron hardware could fit in the present layout: one beam only for MD studies.
- IP4 also considered as final option for a complete implementation for both beams.
- Need synergy with crab-cavity project.

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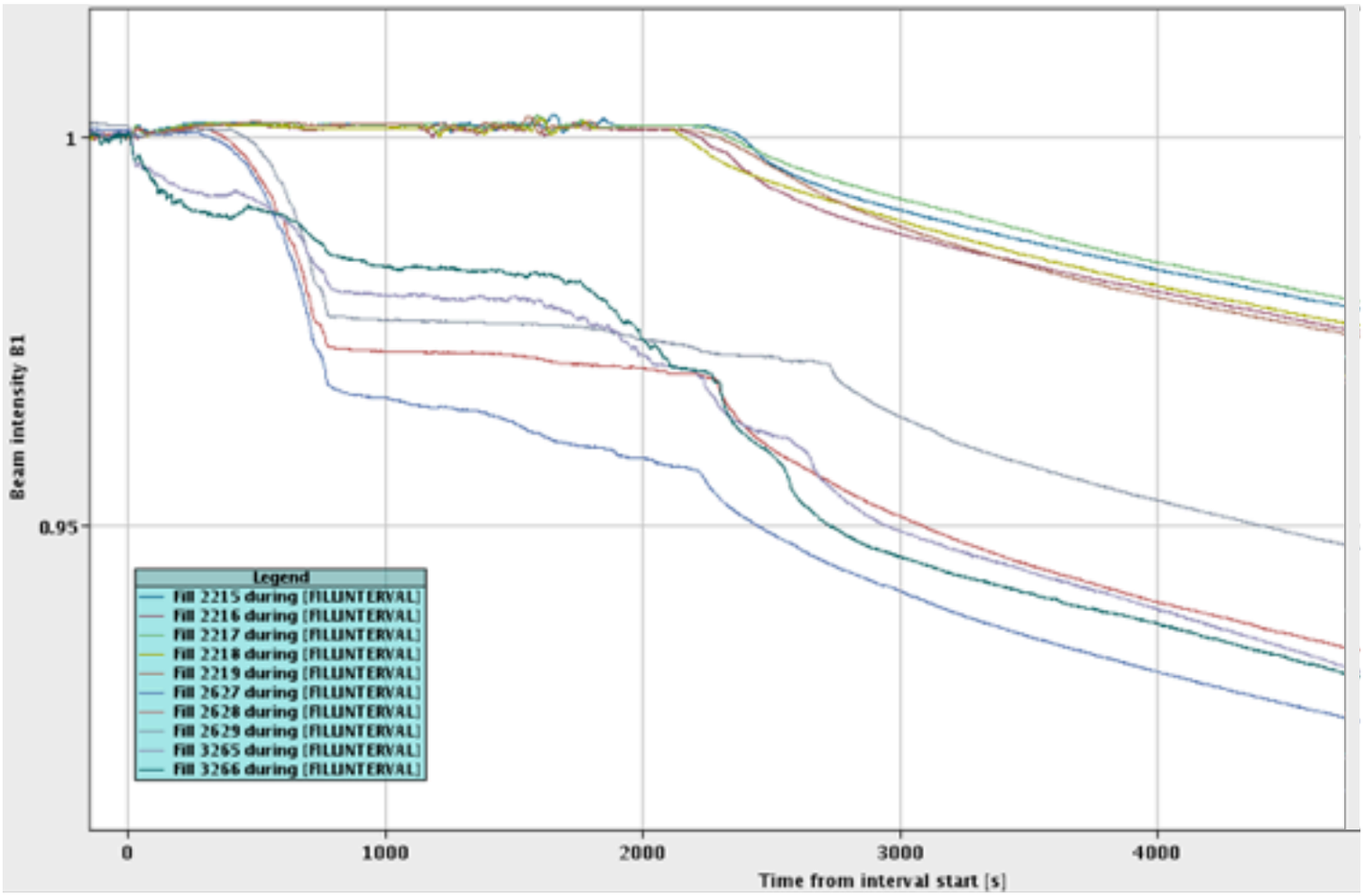

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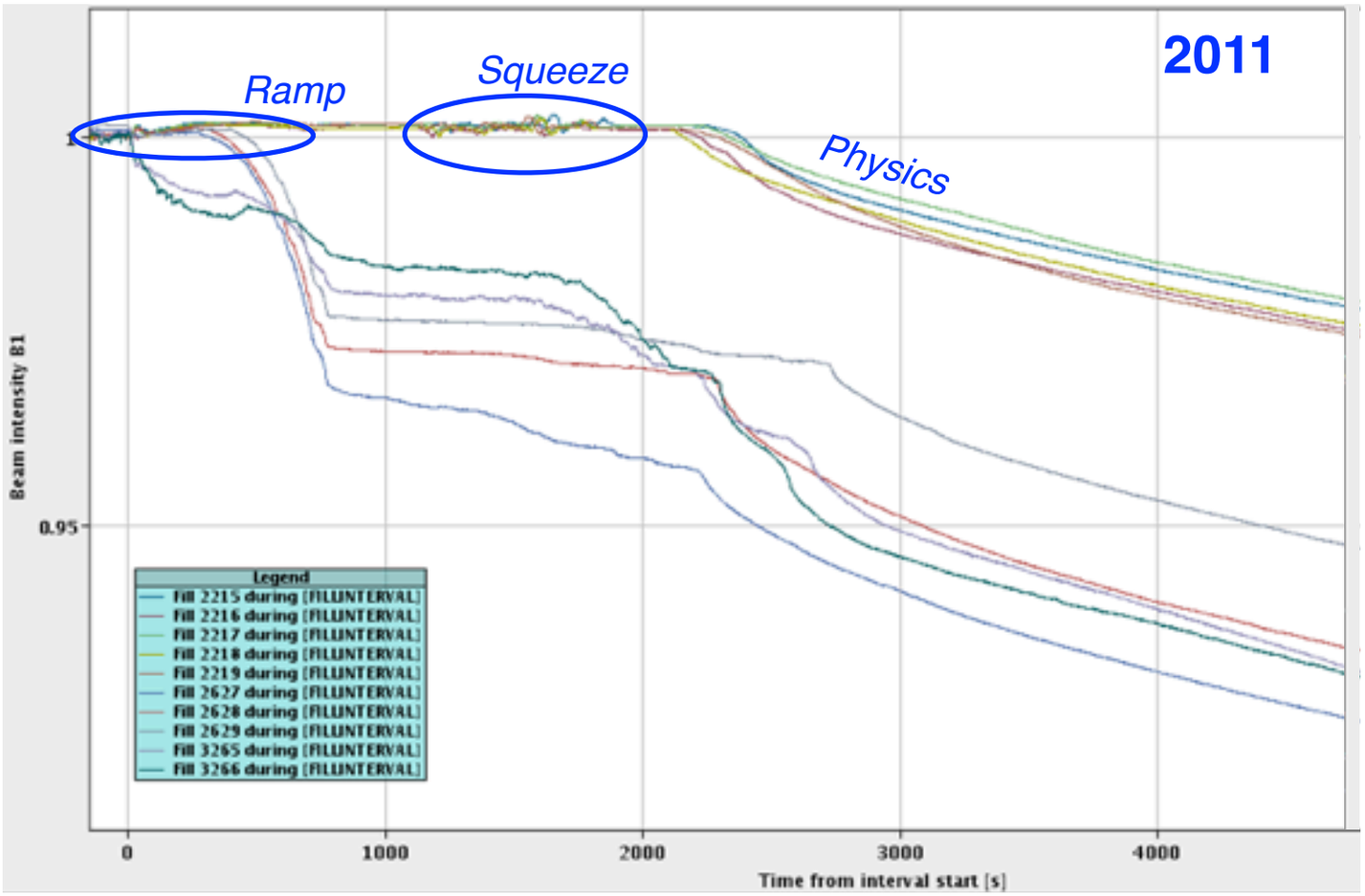

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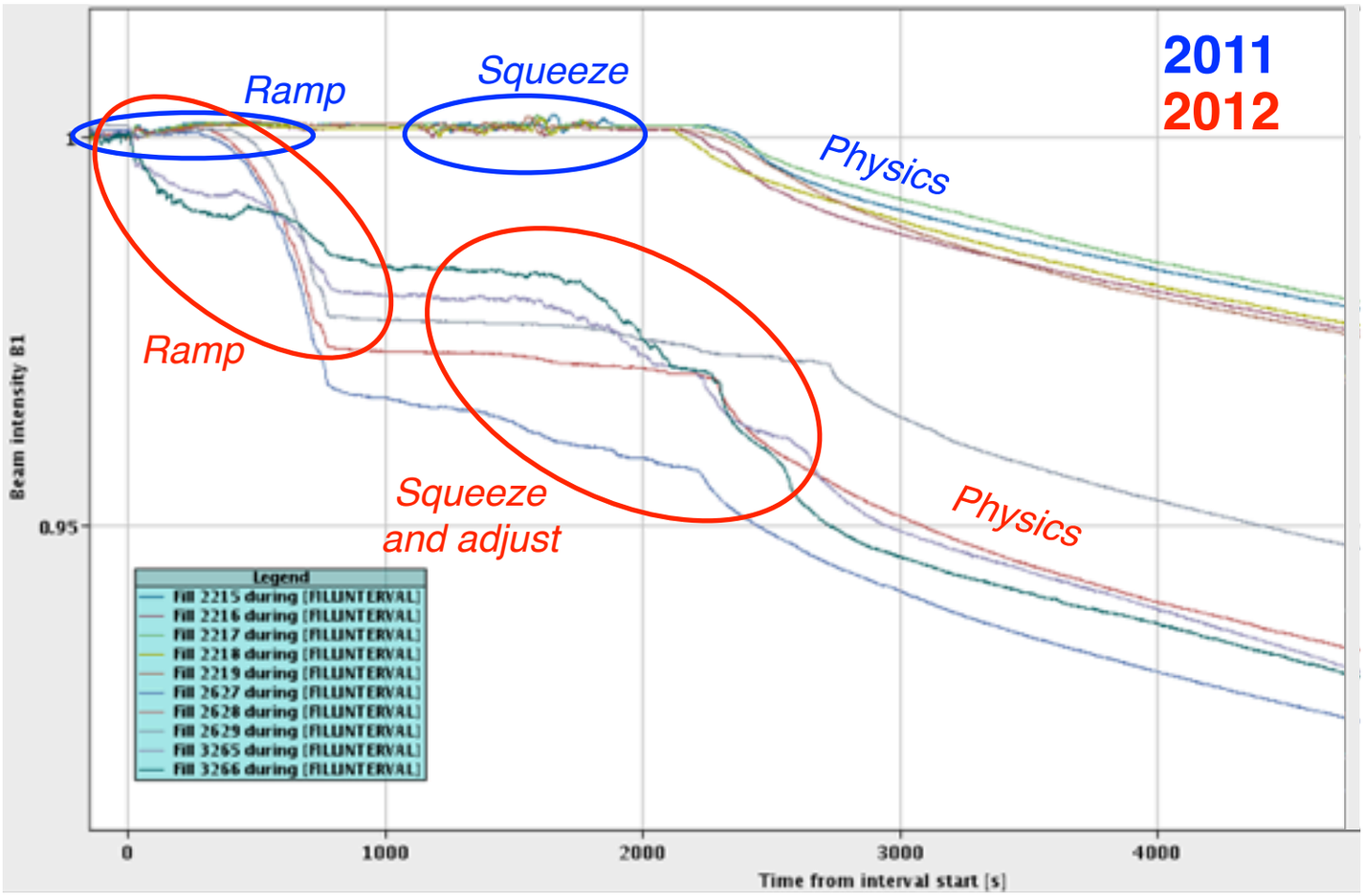

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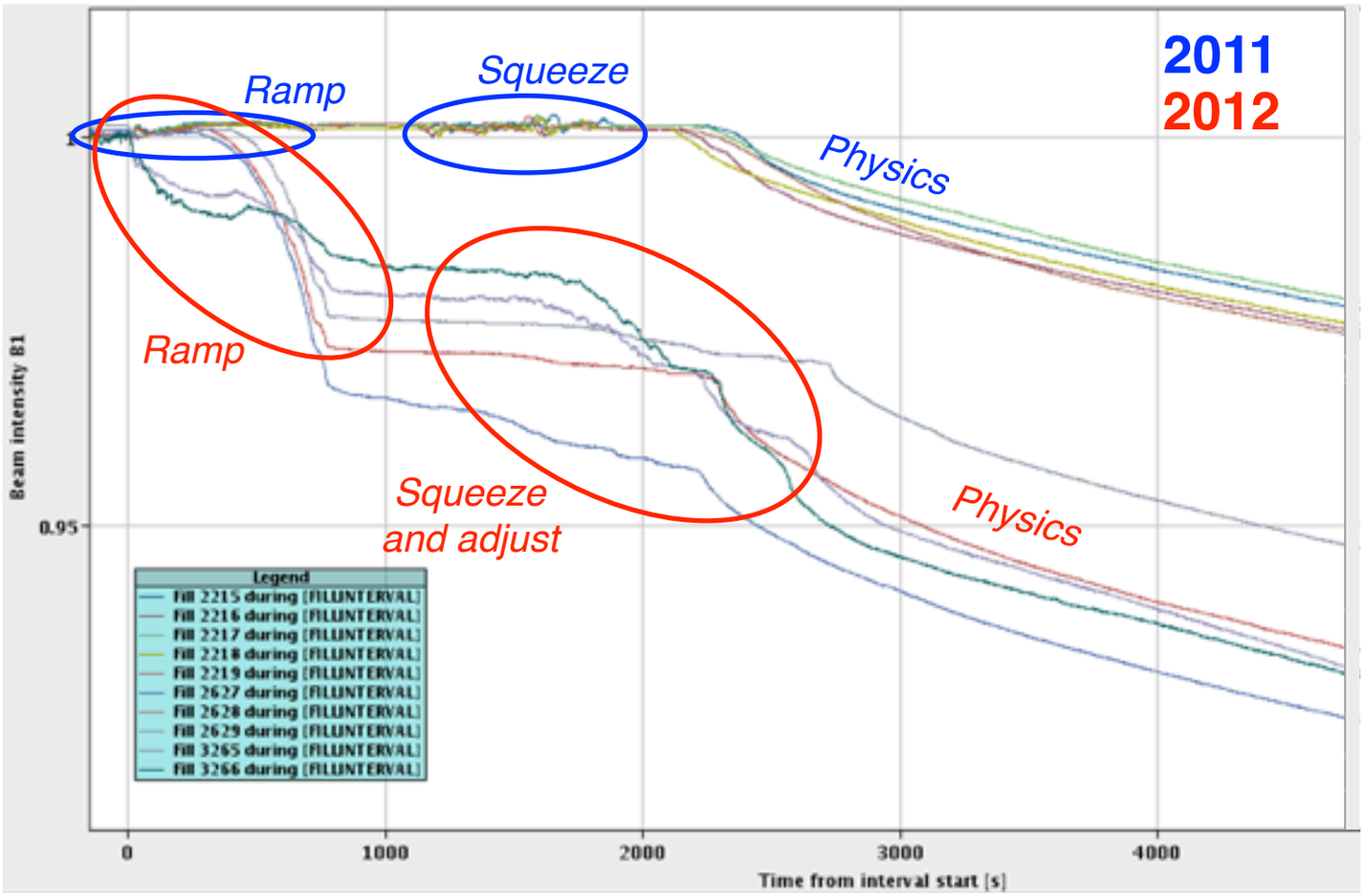

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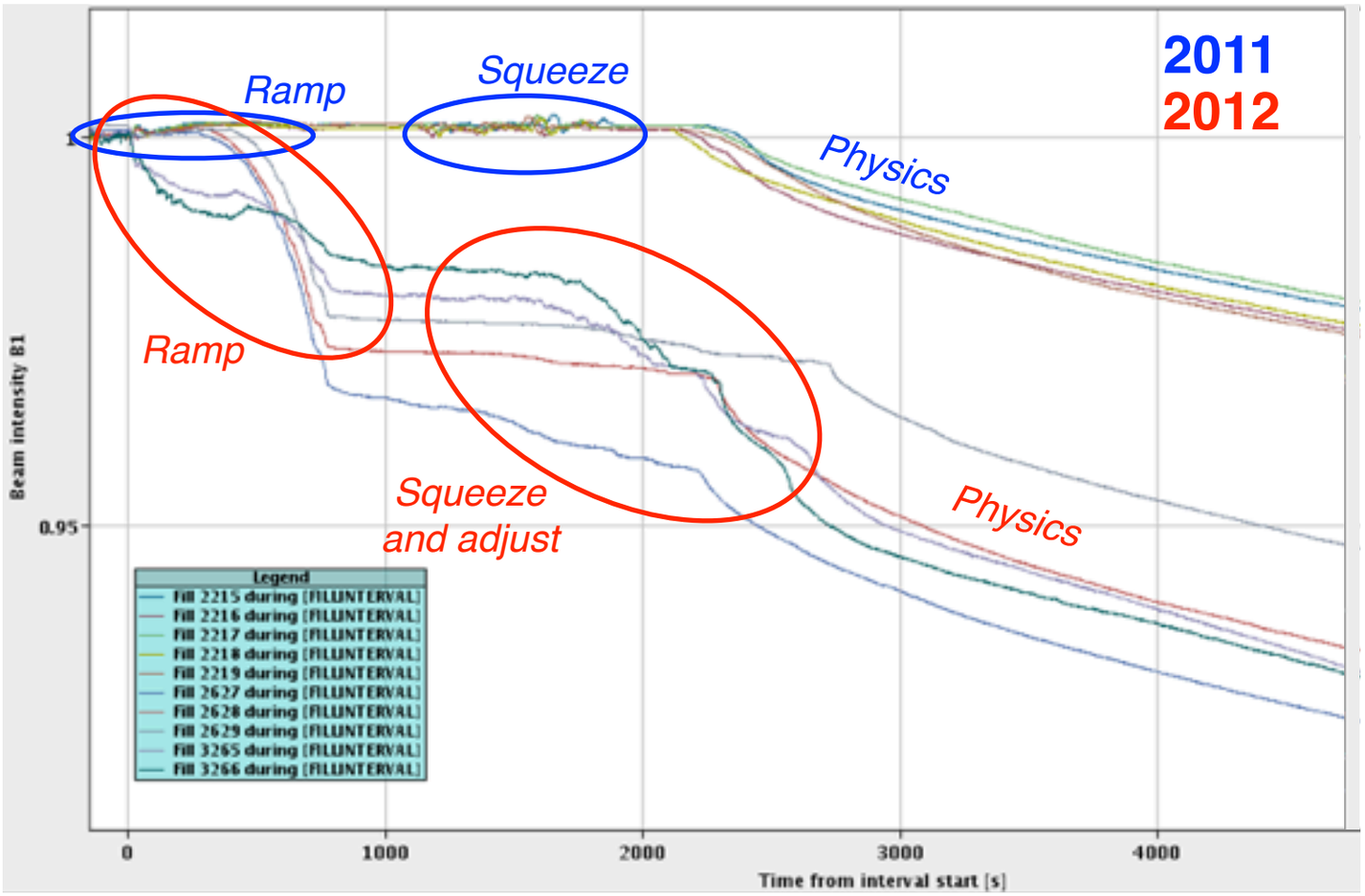

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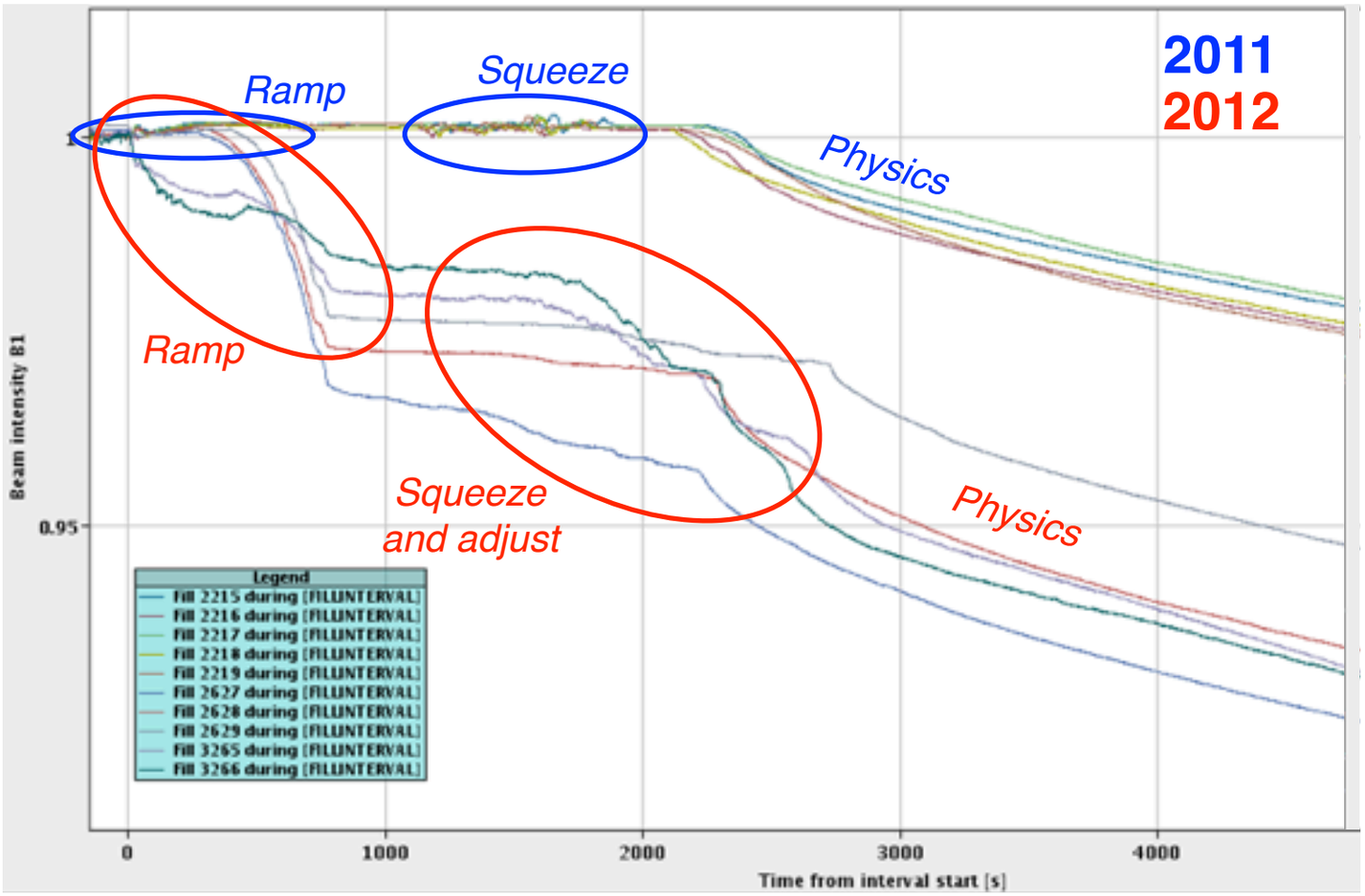

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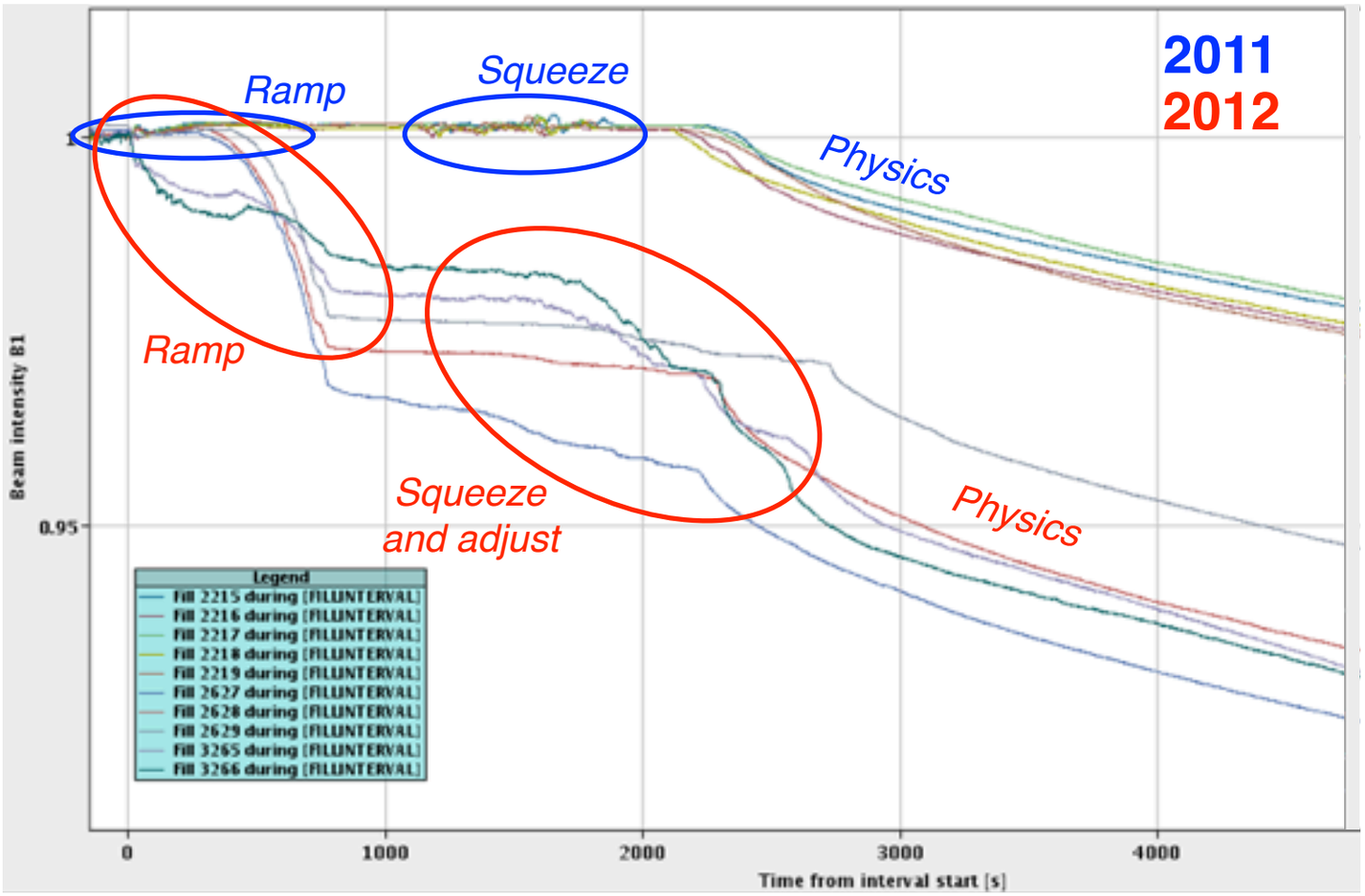

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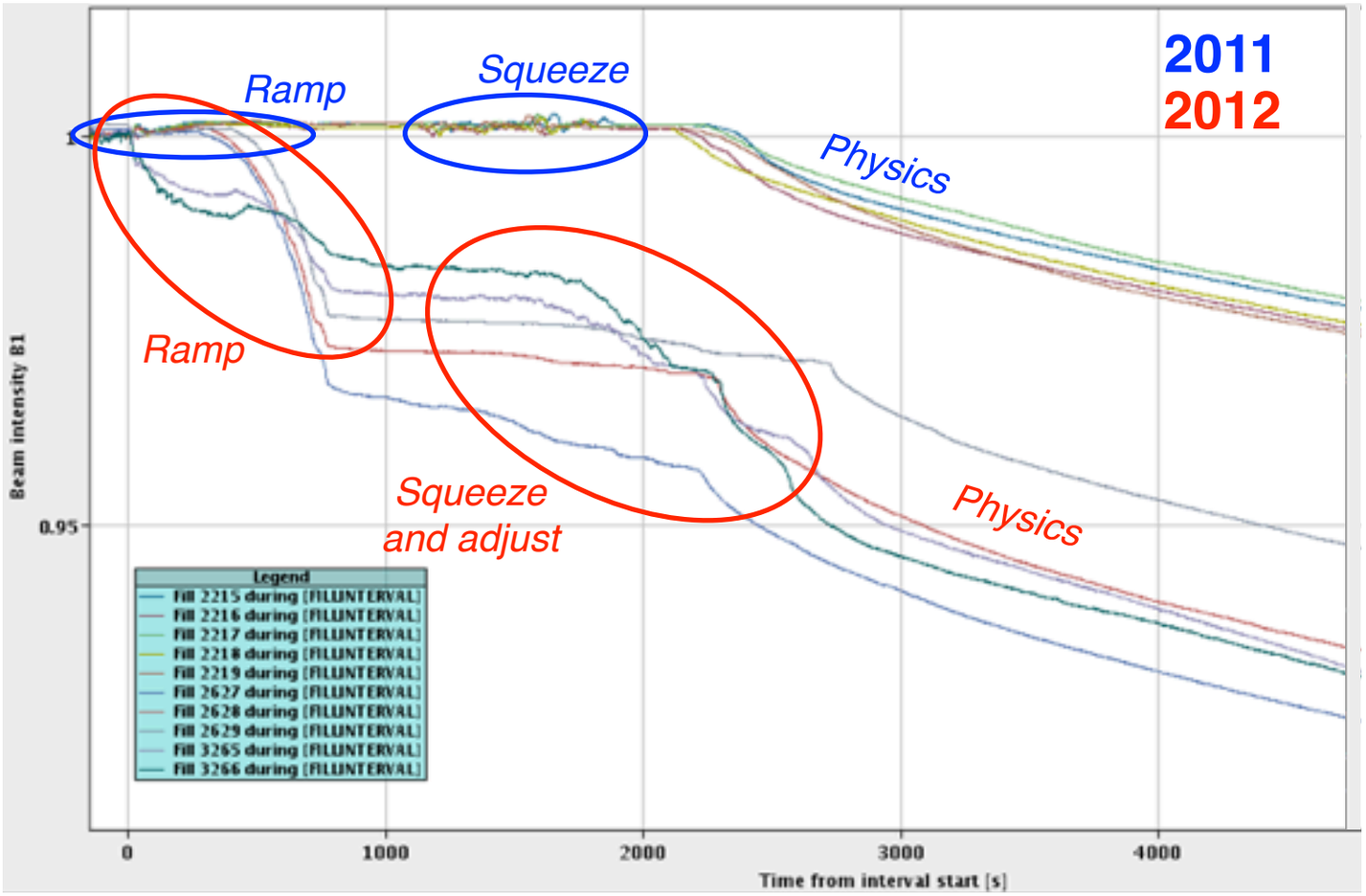

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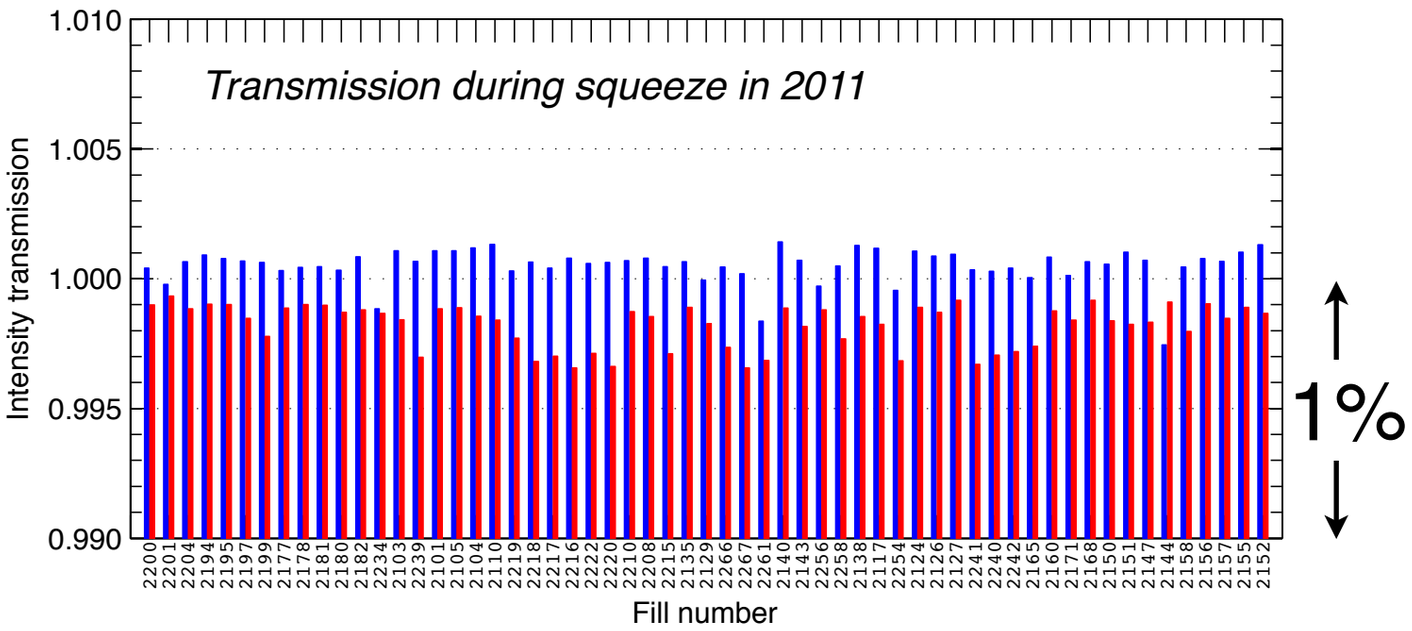

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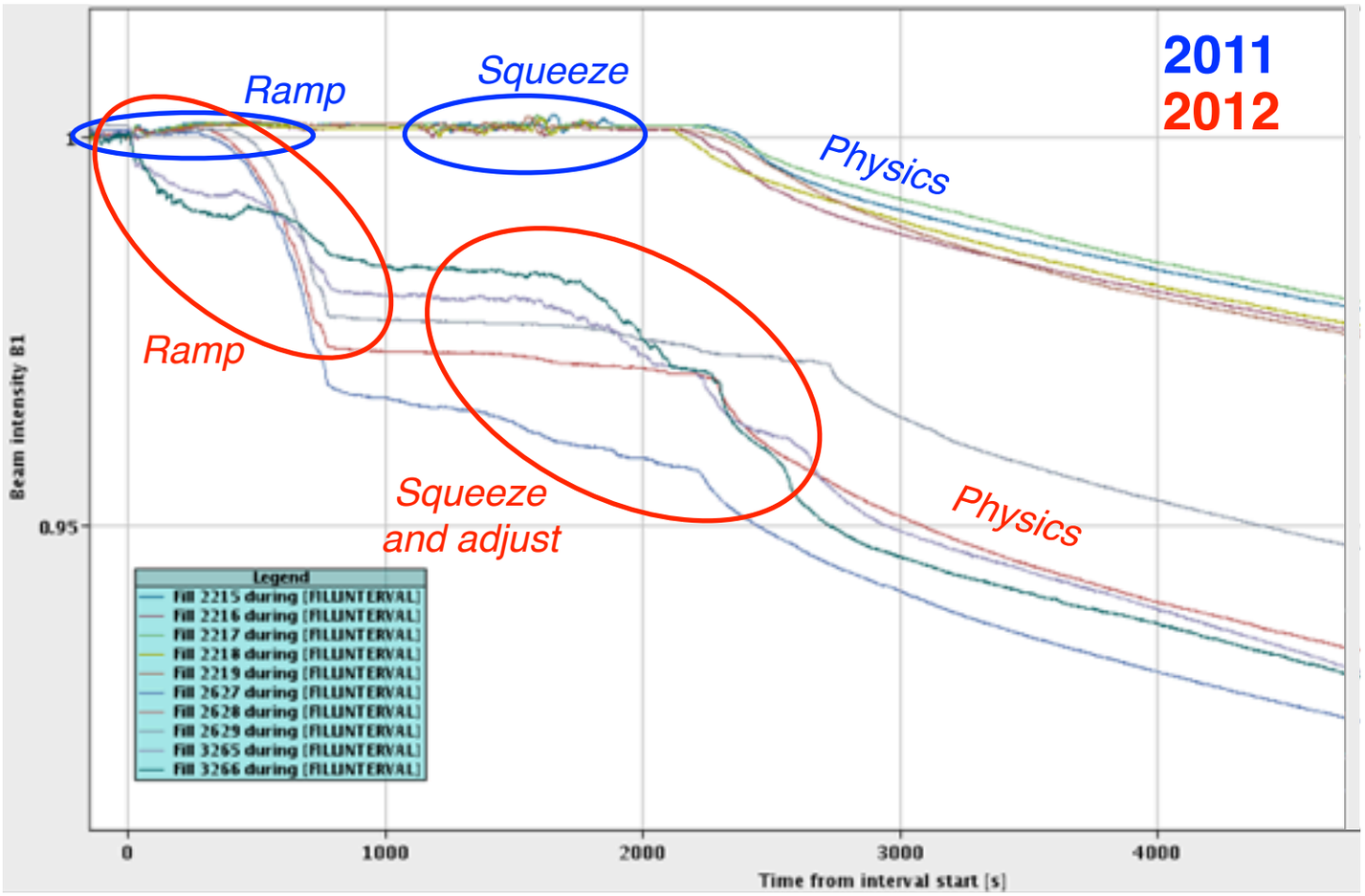

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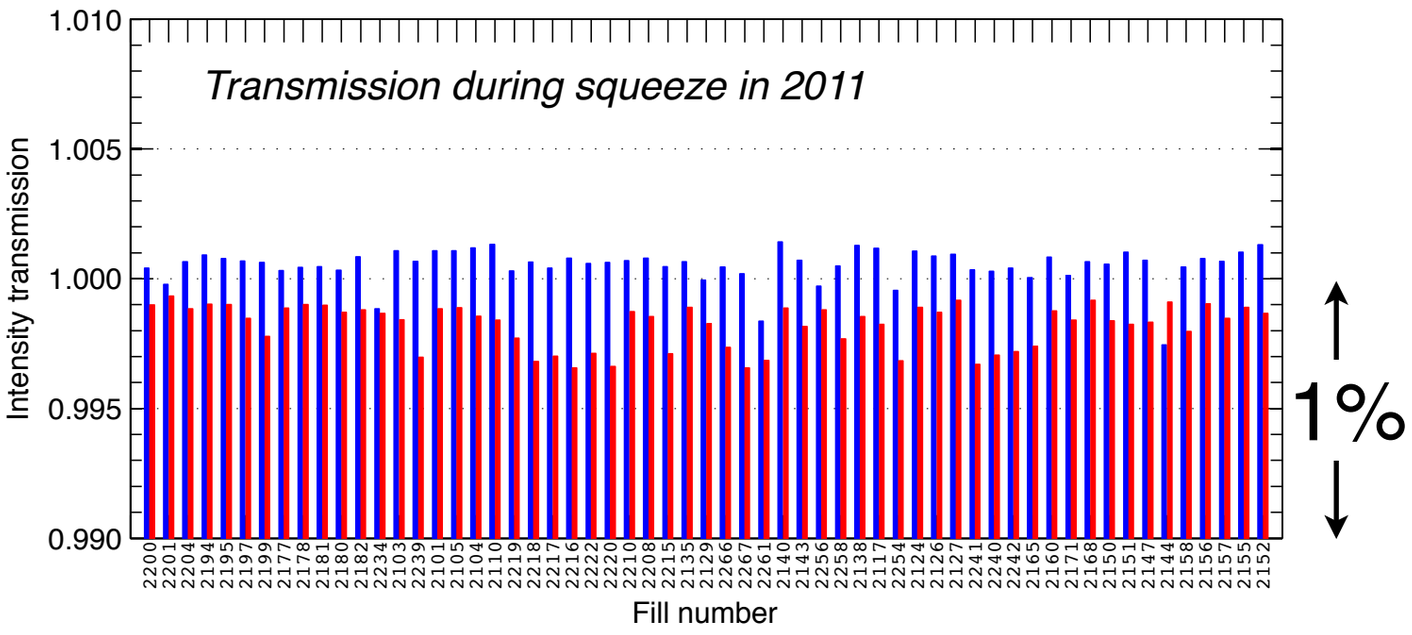

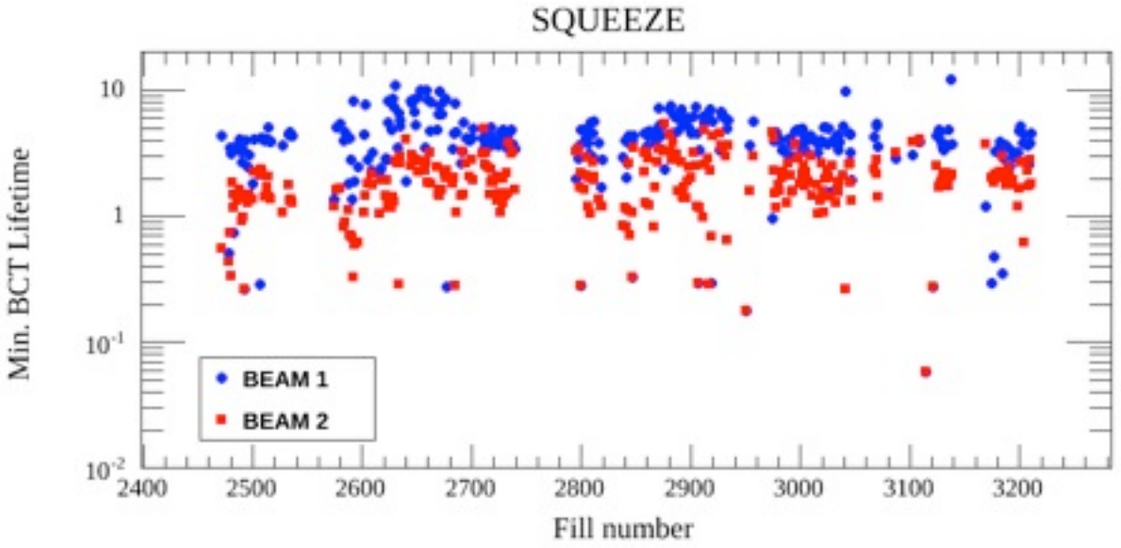

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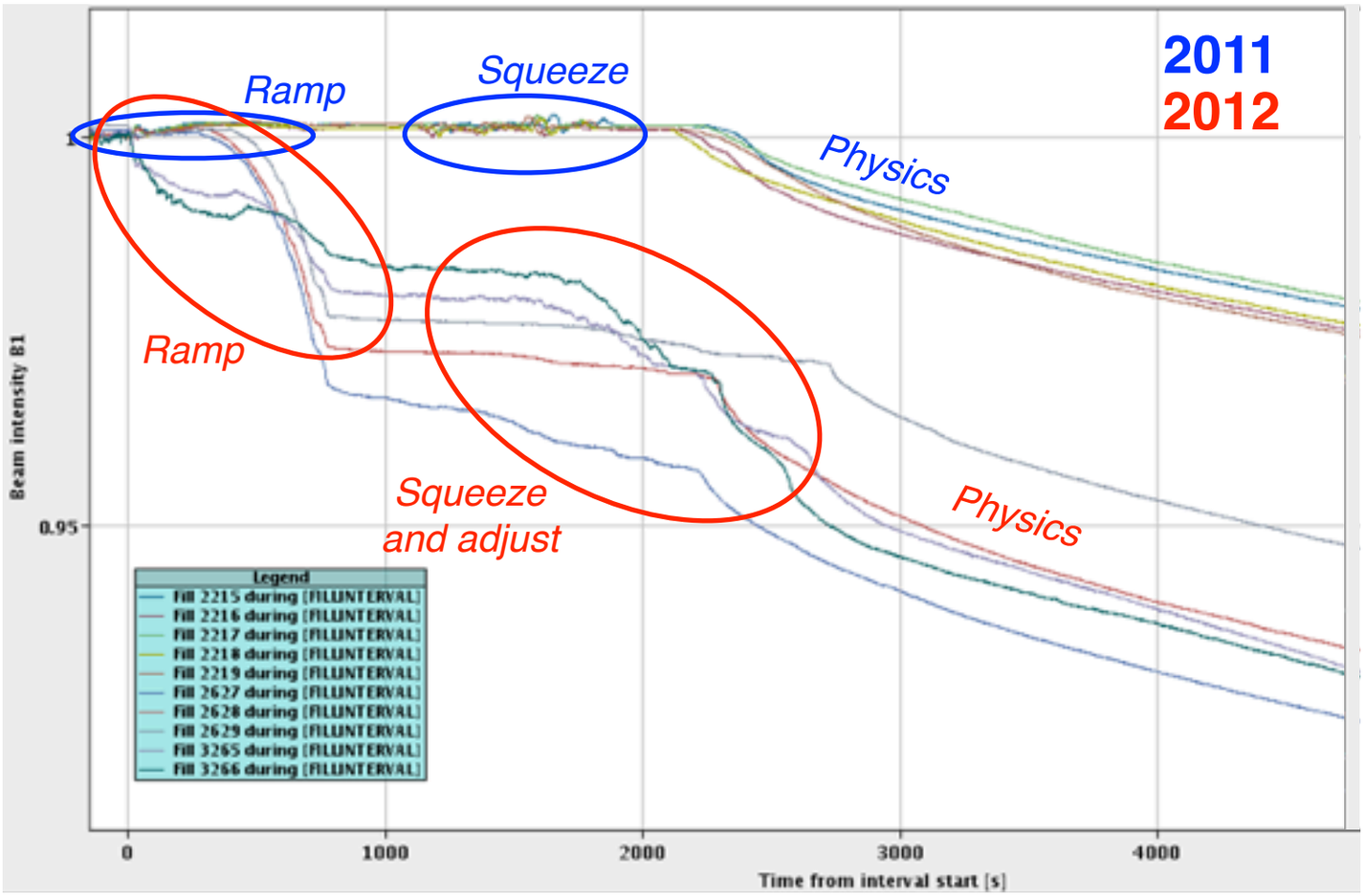

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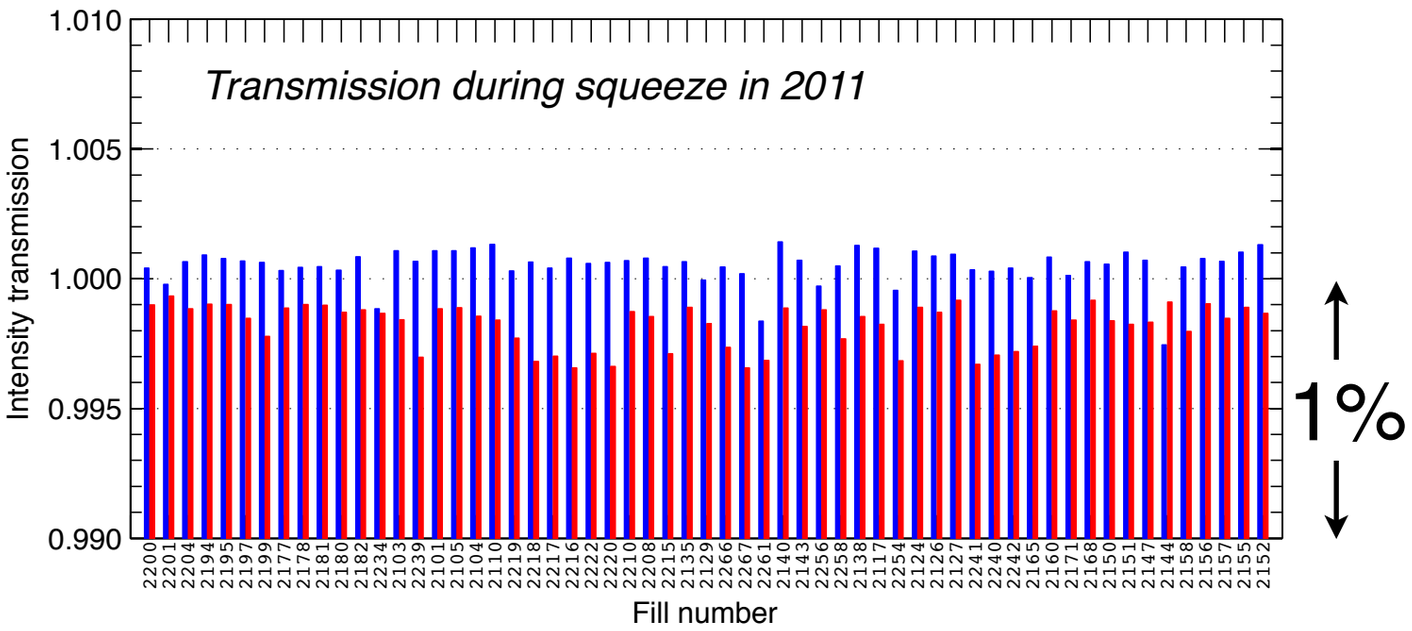
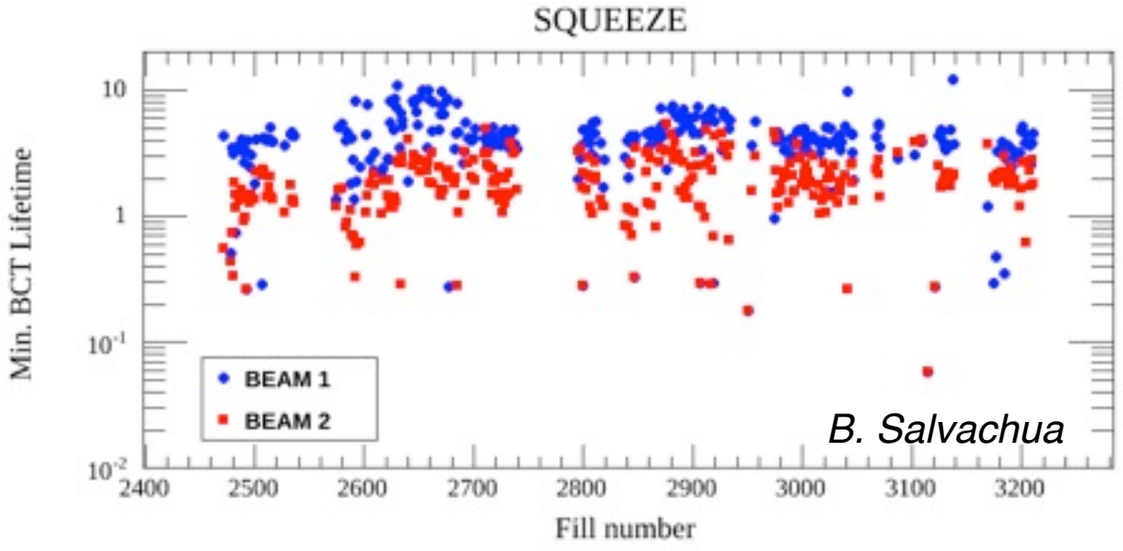
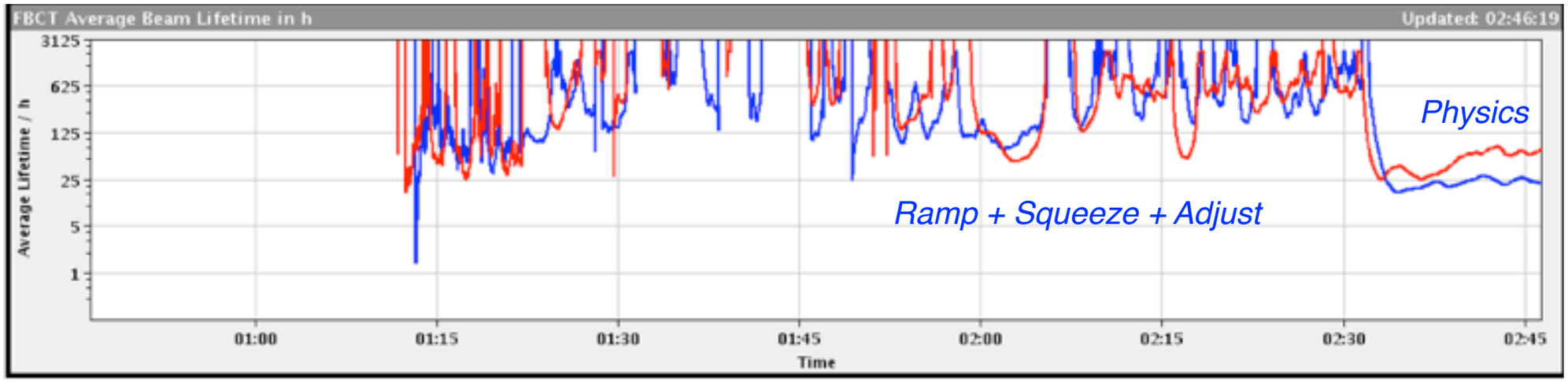




Beam lifetime during OP cycle

Couple of illustrative examples taken randomly from the LHC elogbook...



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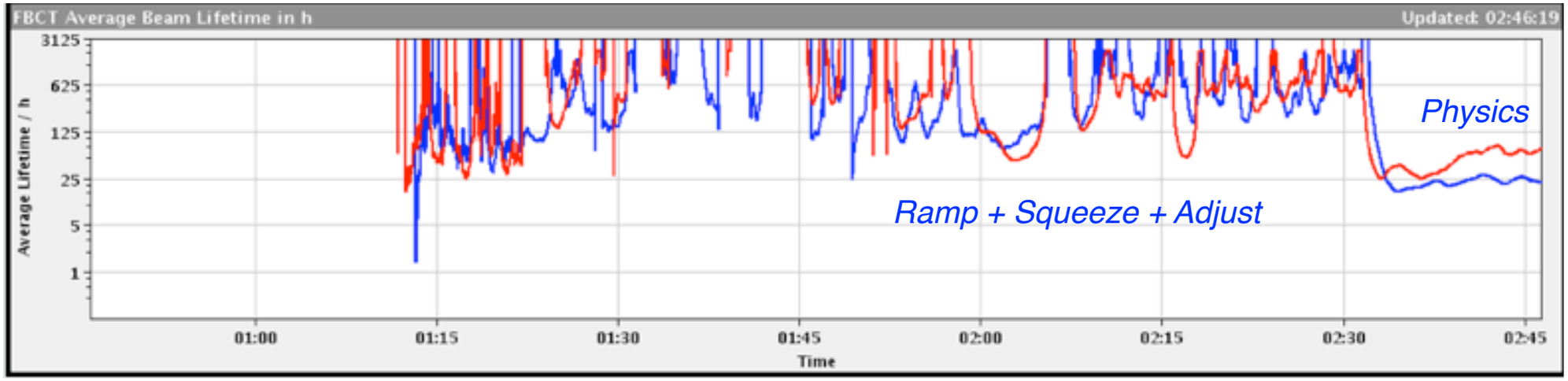

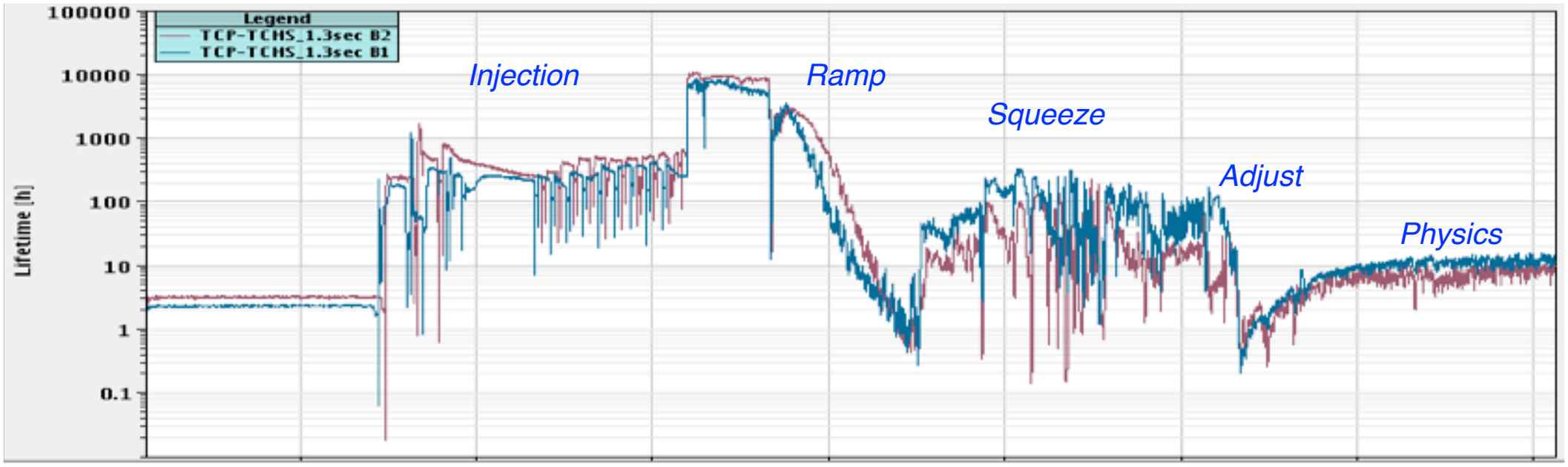

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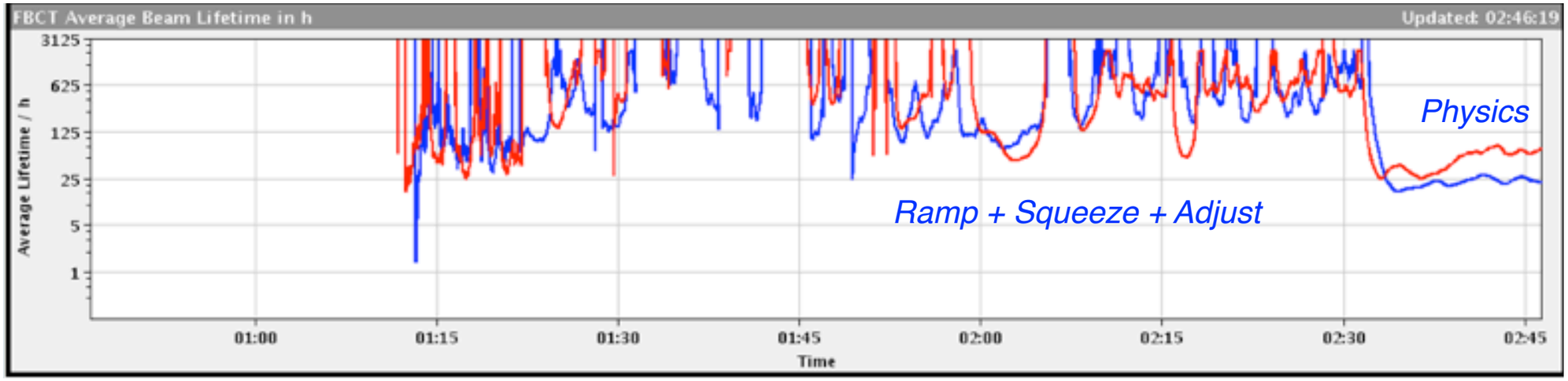
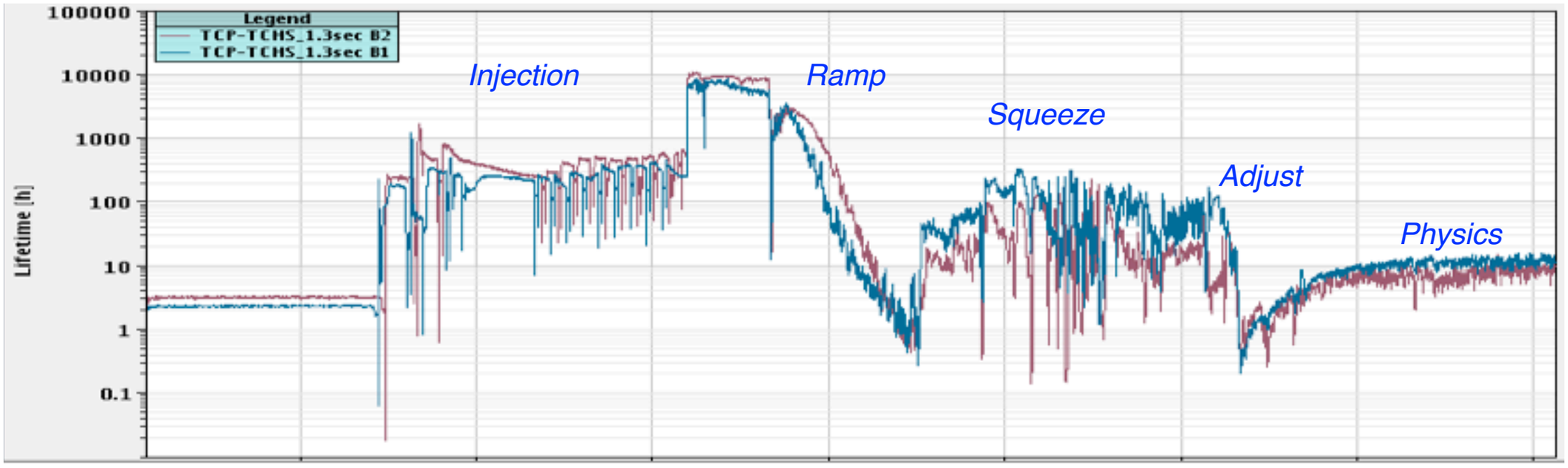




What could be cured/improved by scraping?

Ramp losses ➙ Loss profile in time can be optimized. Not critical though.

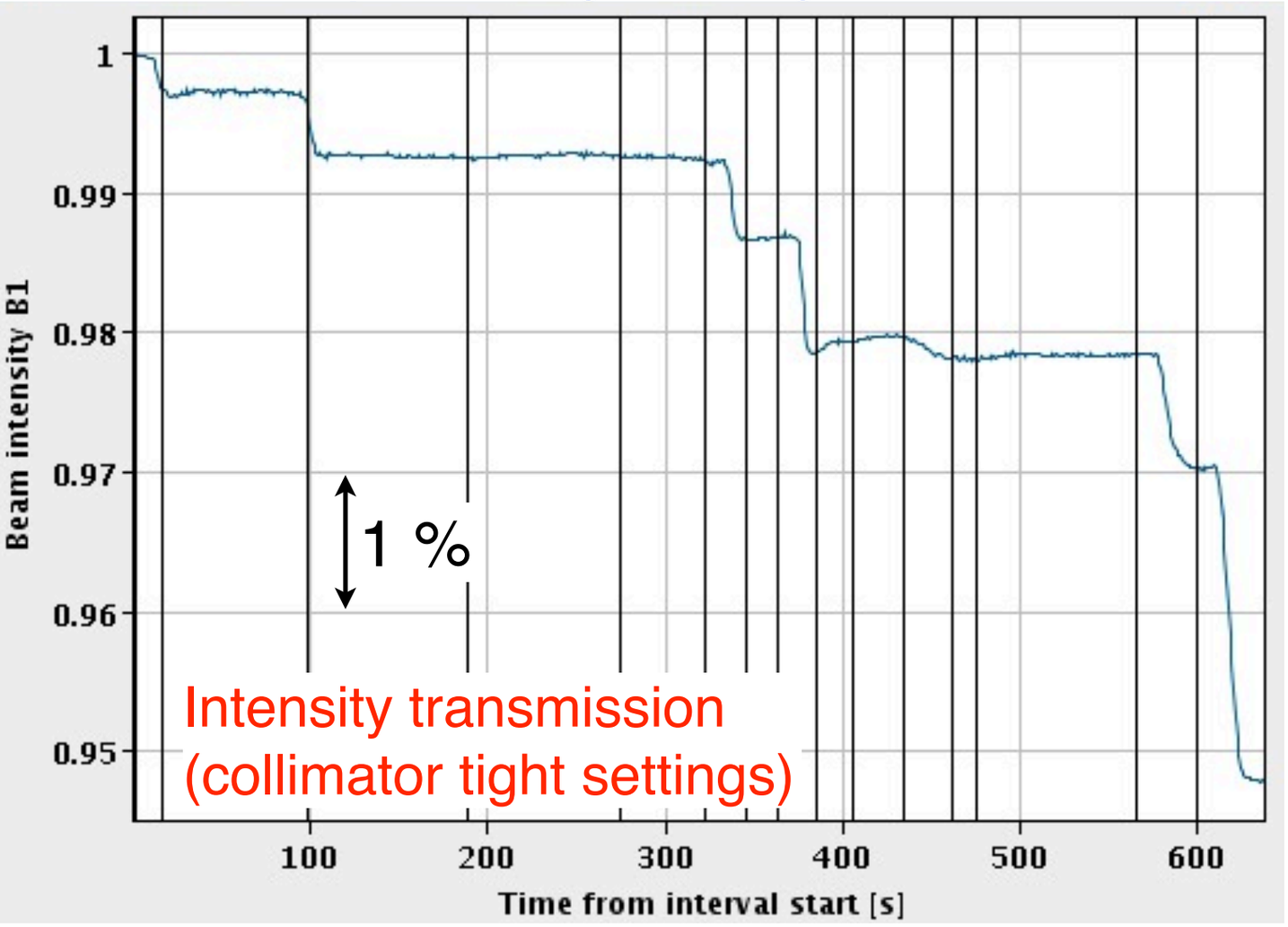
Squeeze losses ➙ Can be cured by removing correlation to orbit drifts!

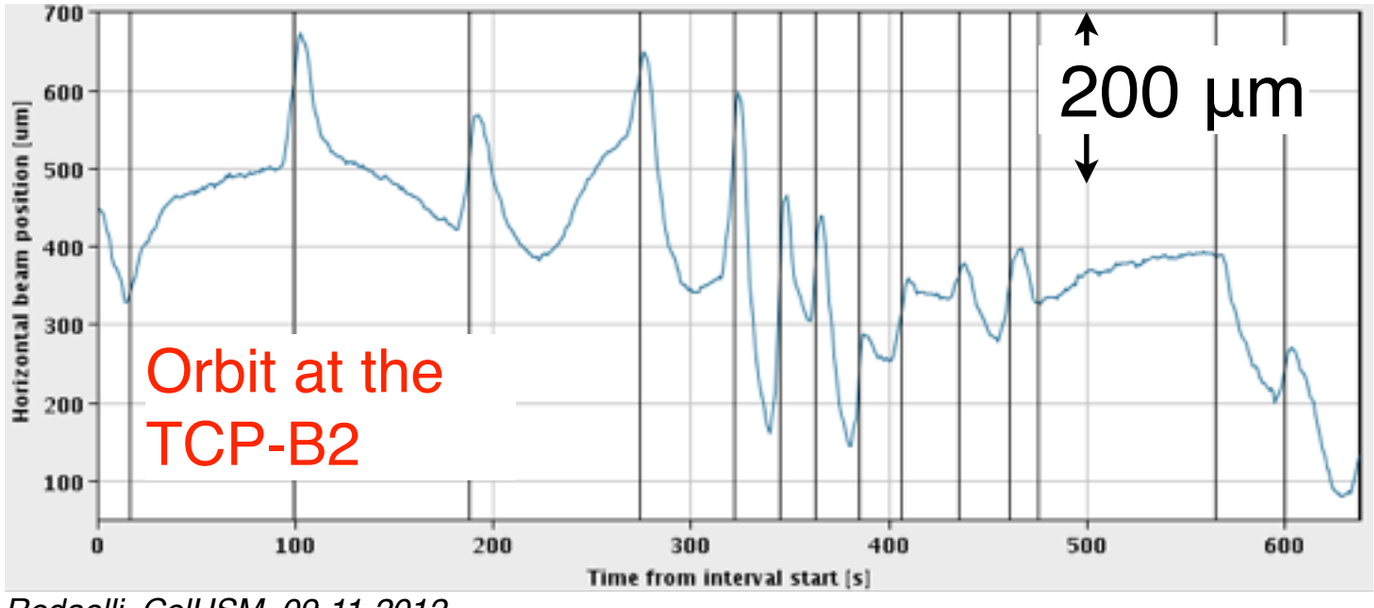
Instabilities ➙ Not obvious help from hollow e-lens.

Collision losses ➙ Possible mitigation if tails are removed before (to be demonstrated).

Orbit and losses during squeeze

Example from "tight" setting tests in 2011





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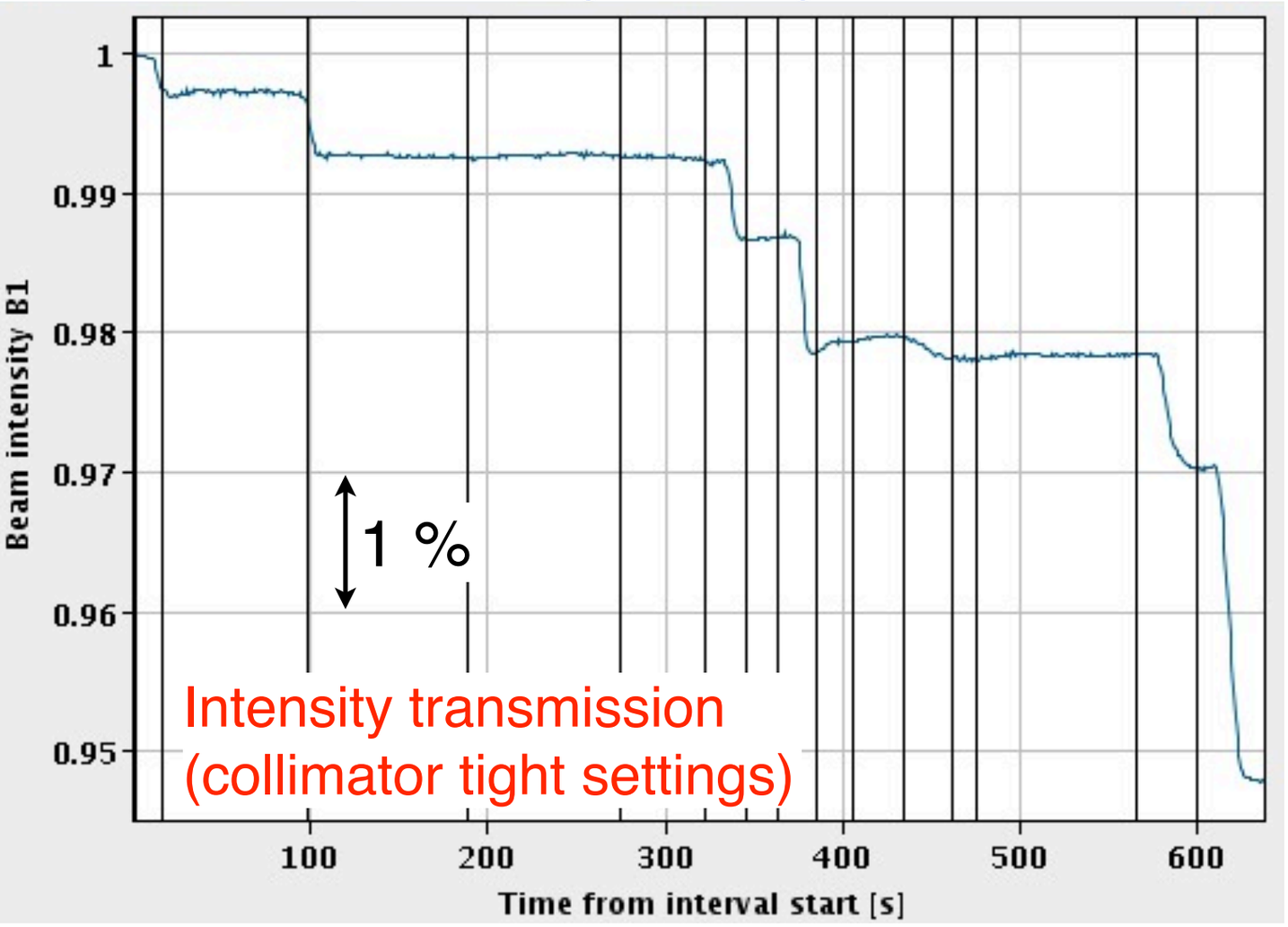

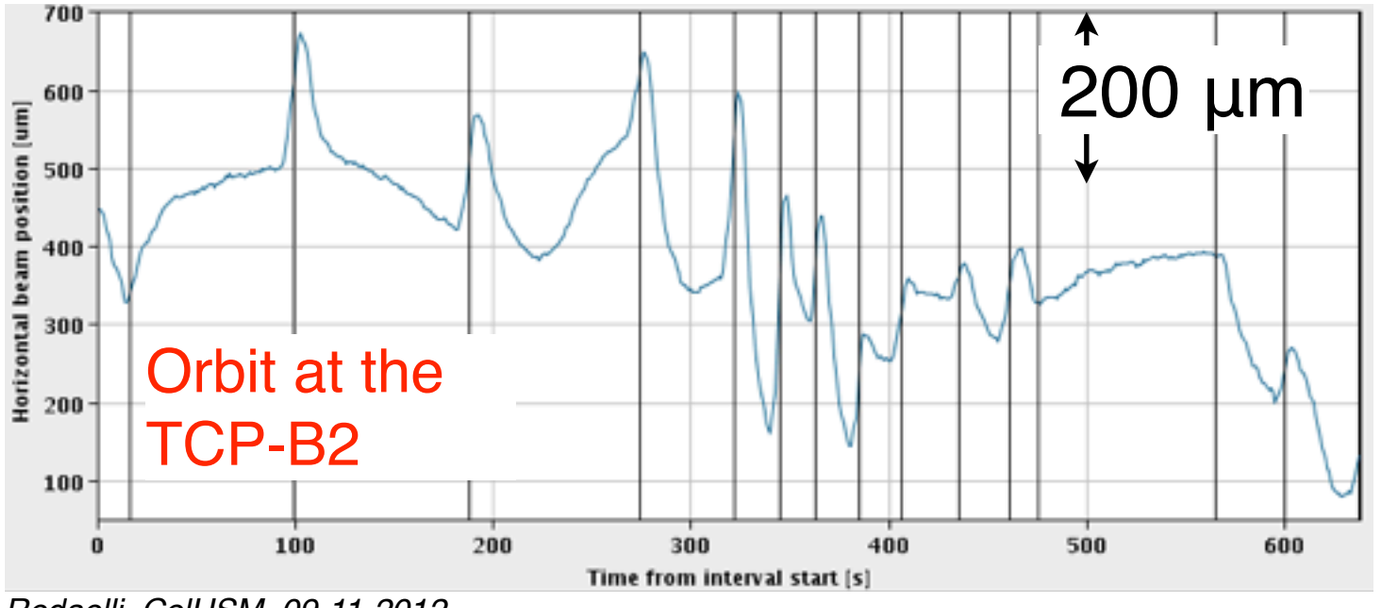

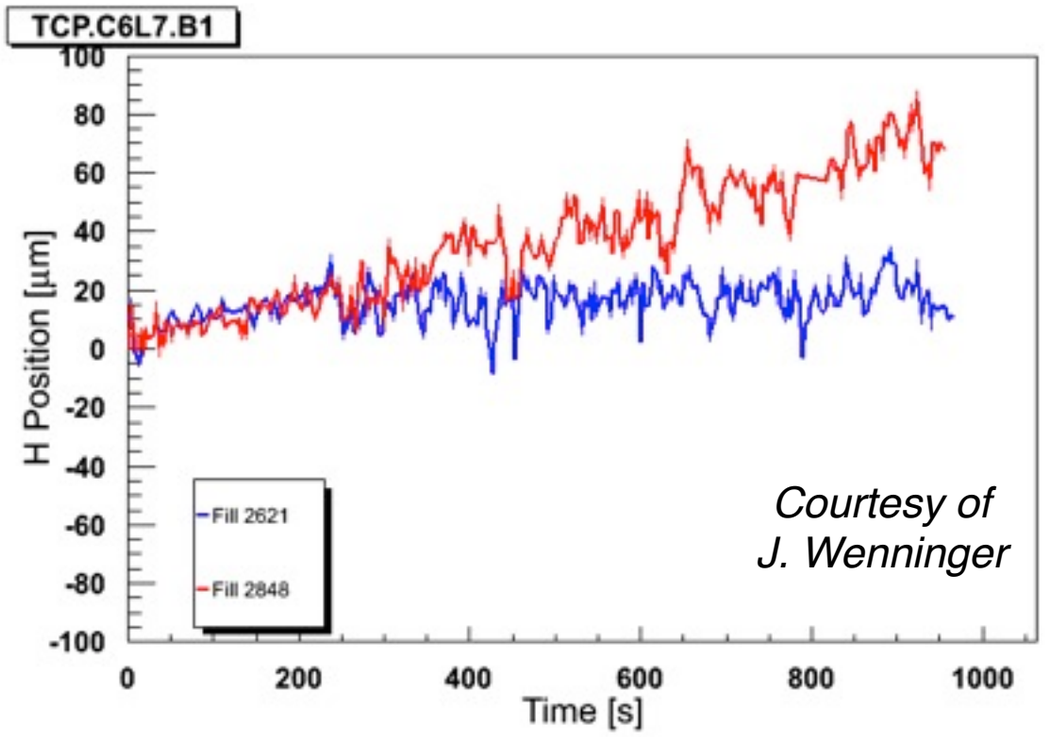

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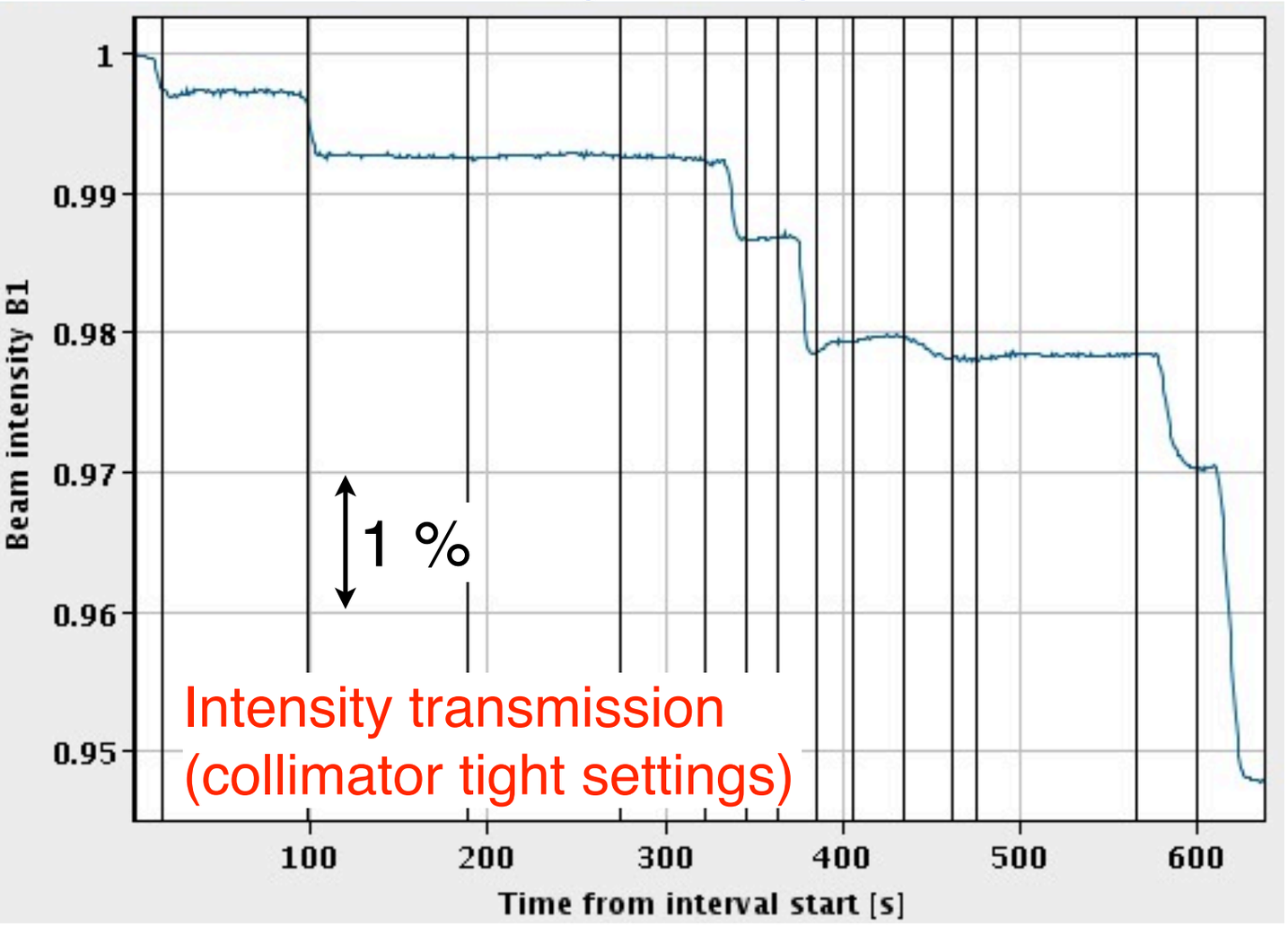
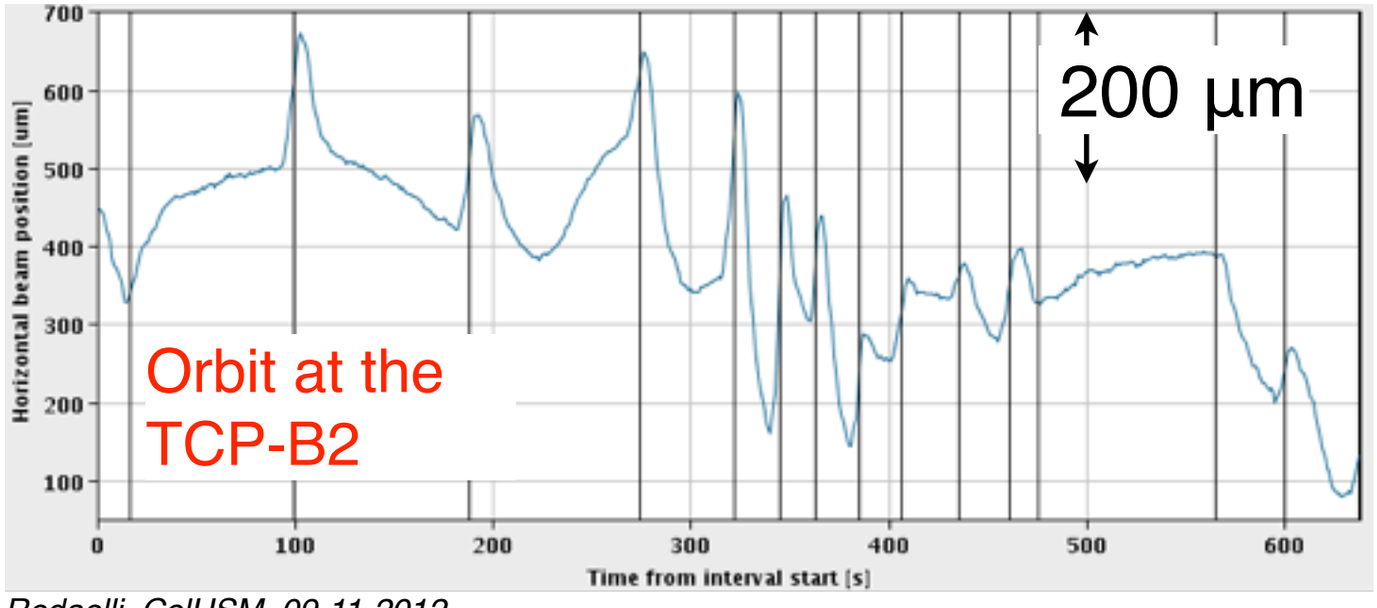
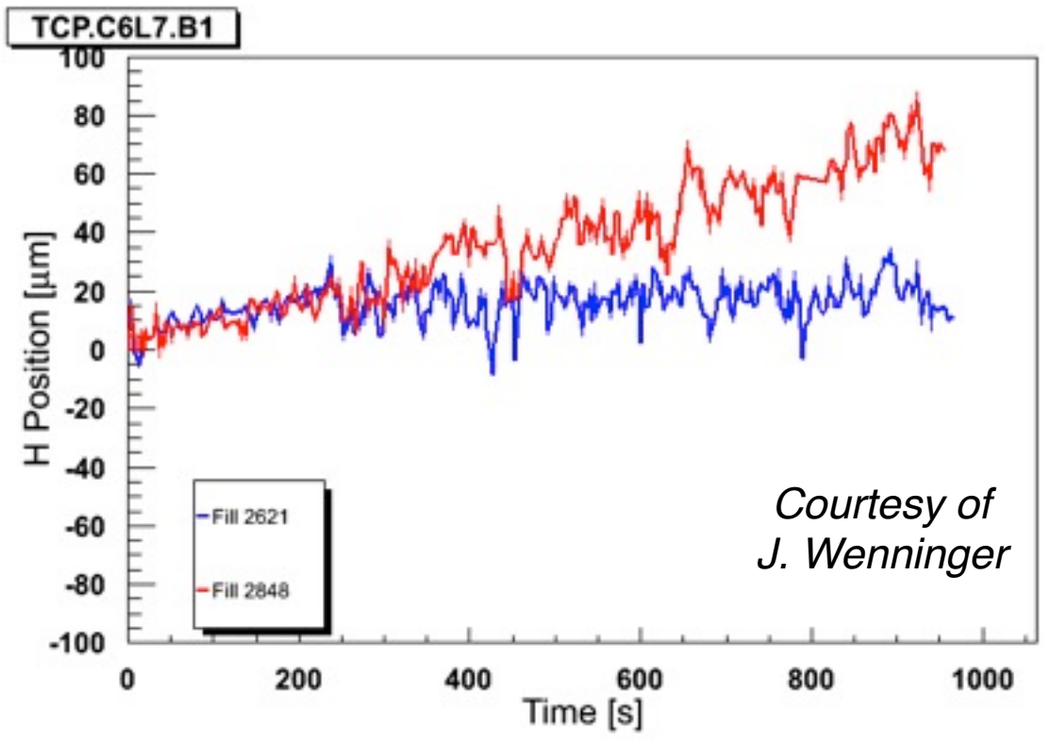






Situation improved significantly in 2012, but the issue remains.

Presently, after optimization of orbit during squeeze, depleting tails over **100 um** around the core could avoid loss spikes from fast orbit drifts.

No obvious gain for losses determined by beam instabilities.

Another requirement

Transverse Distribution

- Highly overpopulated tails observed:
  - *In horizontal plane about **4%** of beam beyond **$4\sigma_{meas}$***
  - *Corresponds to **≈20-25 MJ** with HL-LHC parameters.*
- Need to **deplete tails** (e.g. by **hollow electron lens**) such that crab cavity failures are compliant with collimation system specifications.

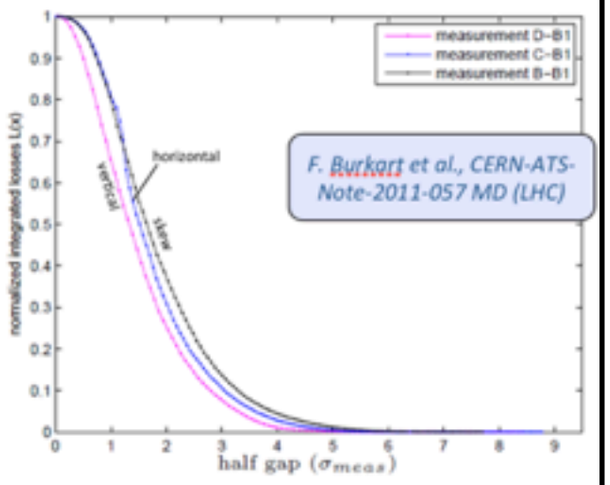
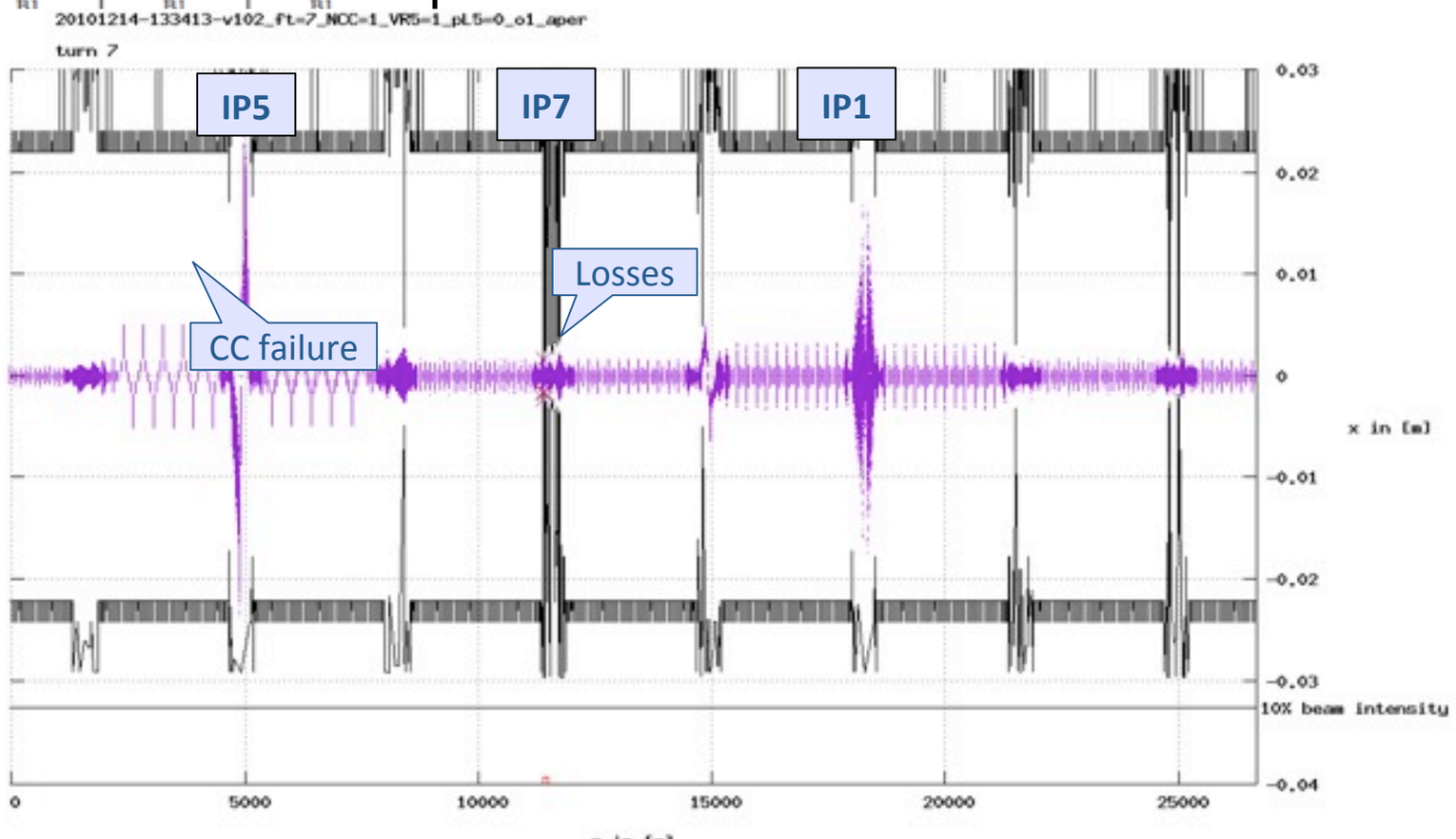


Table 3: Measured fraction of beam intensity in the tails of the beam outside selected multiples of the measured beam size, σ_{meas}, at 450 GeV.

u [σ_{meas}]	$I_{tot,lost}(u)/I_{total}$ vertical B1	$I_{tot,lost}(u)/I_{total}$ horizontal B1	$I_{tot,lost}(u)/I_{total}$ skew B1
4			
5			
5.7			

May, 11th 2012 Tobias Baer



- Continuous control of the tail population is mandatory for using the crab cavities in the HL-LHC era!
- This requires scraping **during stable beams**: cannot be done by moving with collimators!

S. Redaelli, ColUSM, 09-11-2012

Scraping at the LHC

Scraping at the LHC

- **Cases for scraping**
  - *Control speed of losses in **all operational phases** (ramp, squeeze, adjust);*
  - *Remove beam tails before going in collisions to reduce loss spikes;*
  - *Keep the halo "clean" (reduced population) during physics data taking;*
  - *Machine protection issues for single-turn failures: losses reduced if tails are cleaner (crucial for operation with crab-cavities).*

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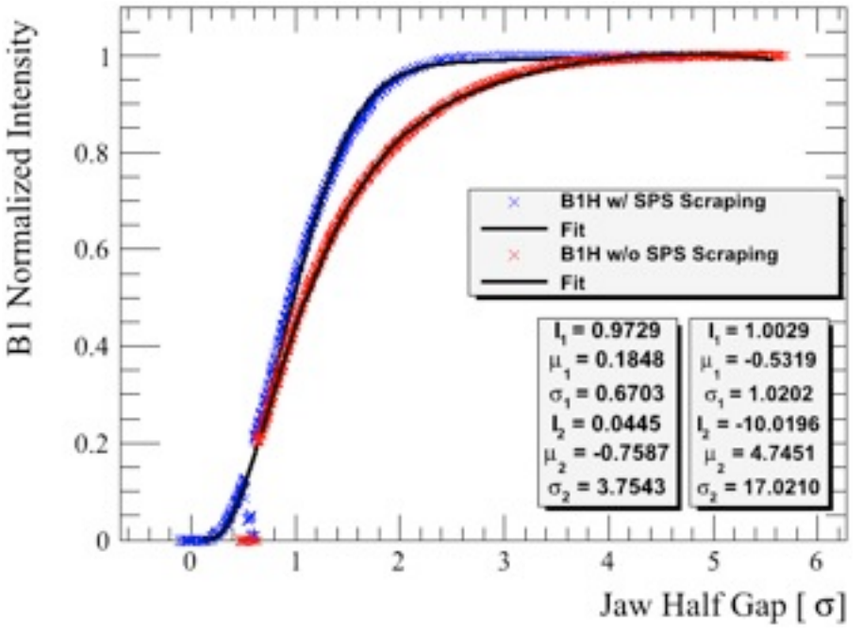
- **Can the hollow e-lens provide the required functionality?**
  - *Tevatron: mainly used in collision (large NL's). Limited tests with single beams.*
  - *Ramp and squeeze not addressed by beam tests.*
  - *Parameters of present hardware not optimized for 7 TeV.*

  ⇒ more beam tests would help answering this question.

Scraping at injection

Recent MD (cour. G.Valentino+Inj team)



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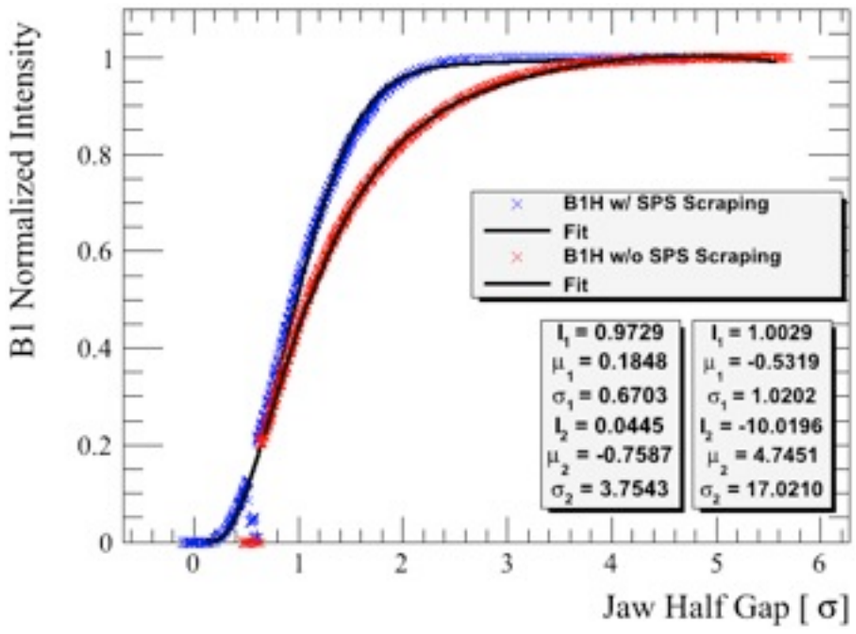
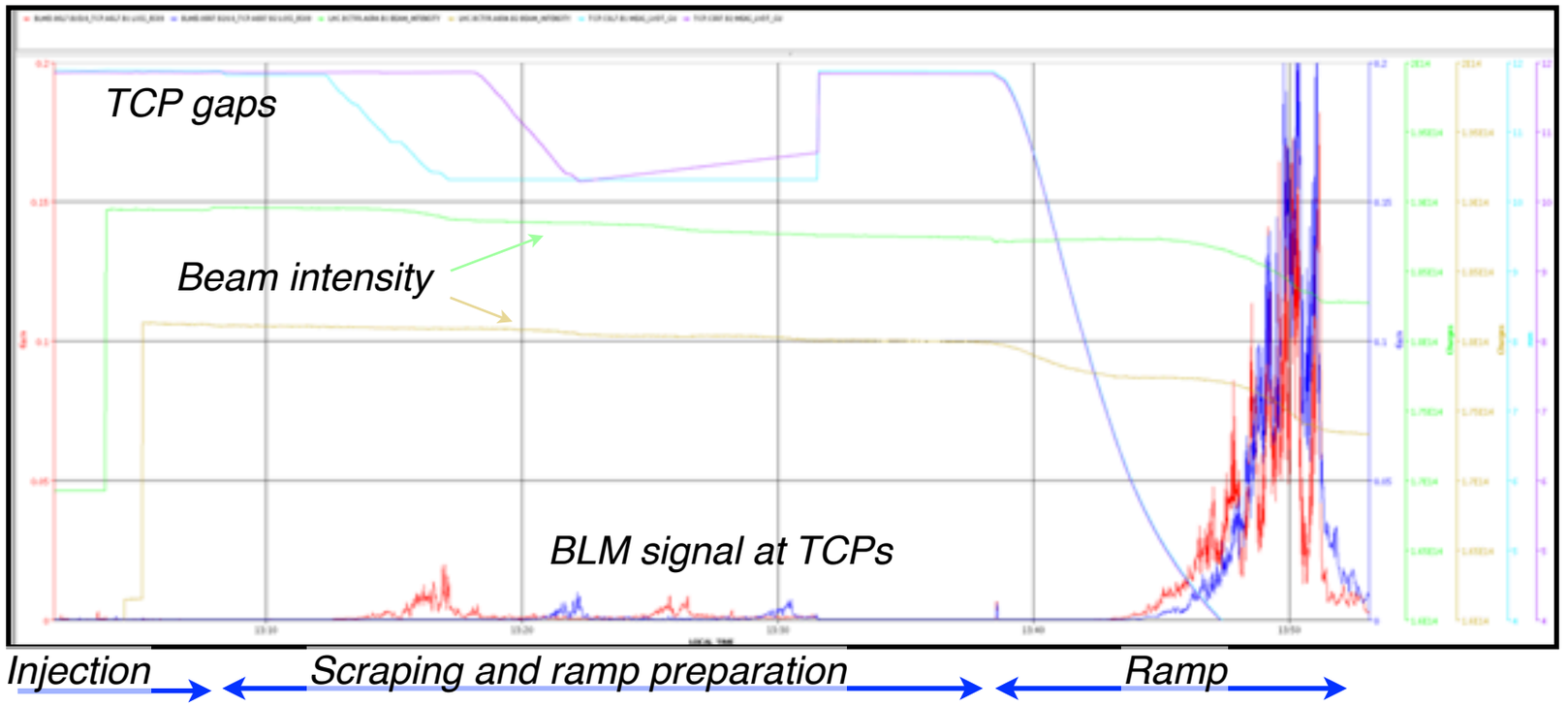


Scraping of full injected beam (1380b) on May 15th, 2012



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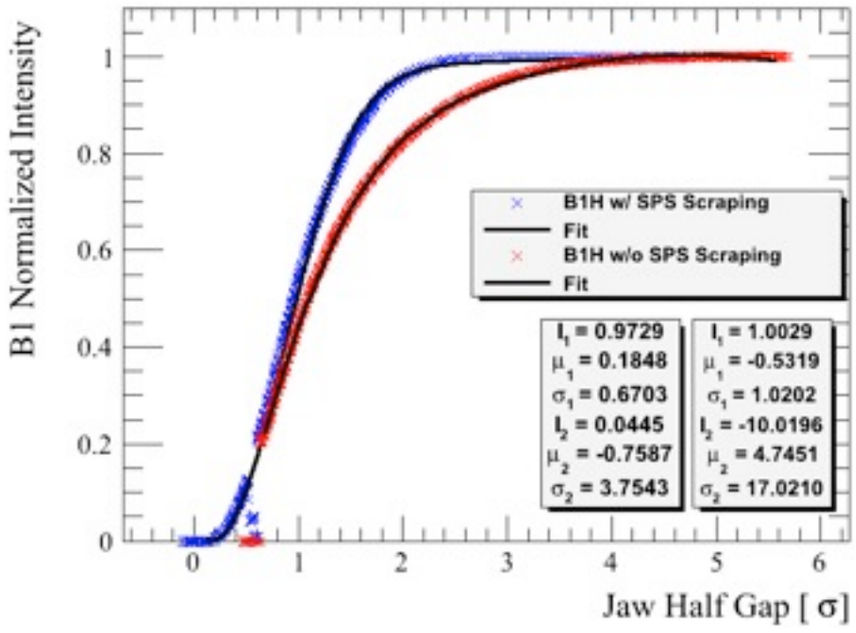

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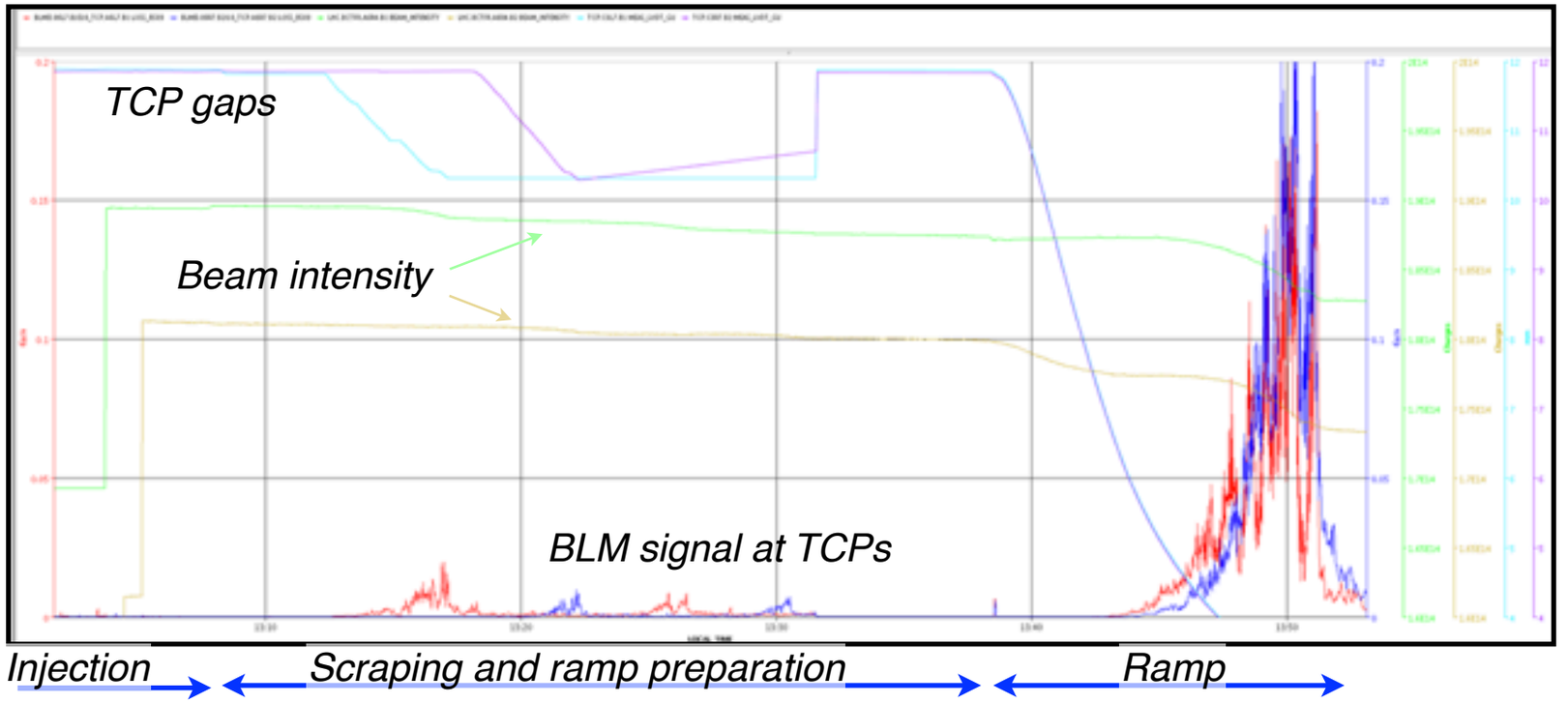

- **Two scraping tests:**
  - **SPS before extraction.**
  - **LHC flat-bottom.**
- Scraping worked well but it **did NOT cure** the ramp losses!
- Caveat: **very scarce** beam experience! Only 1 test!

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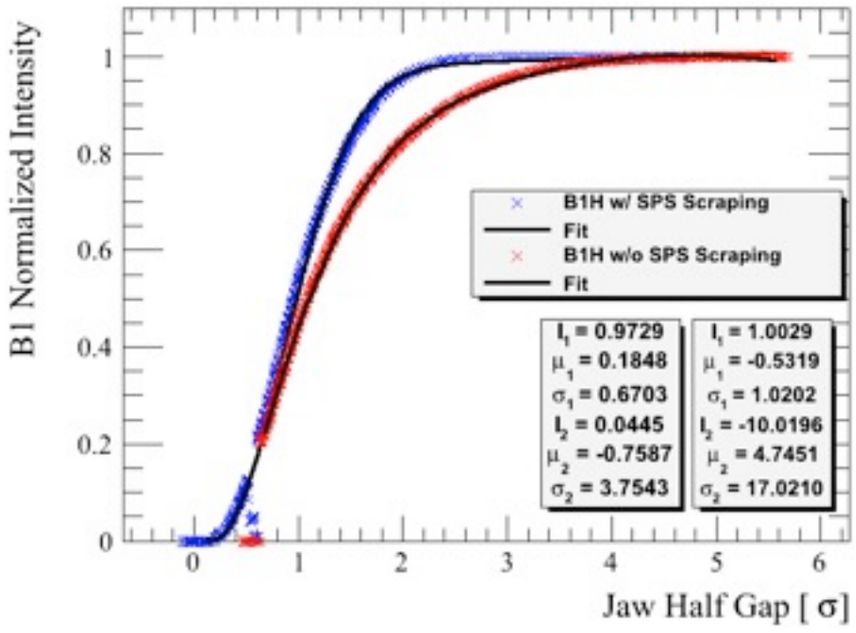

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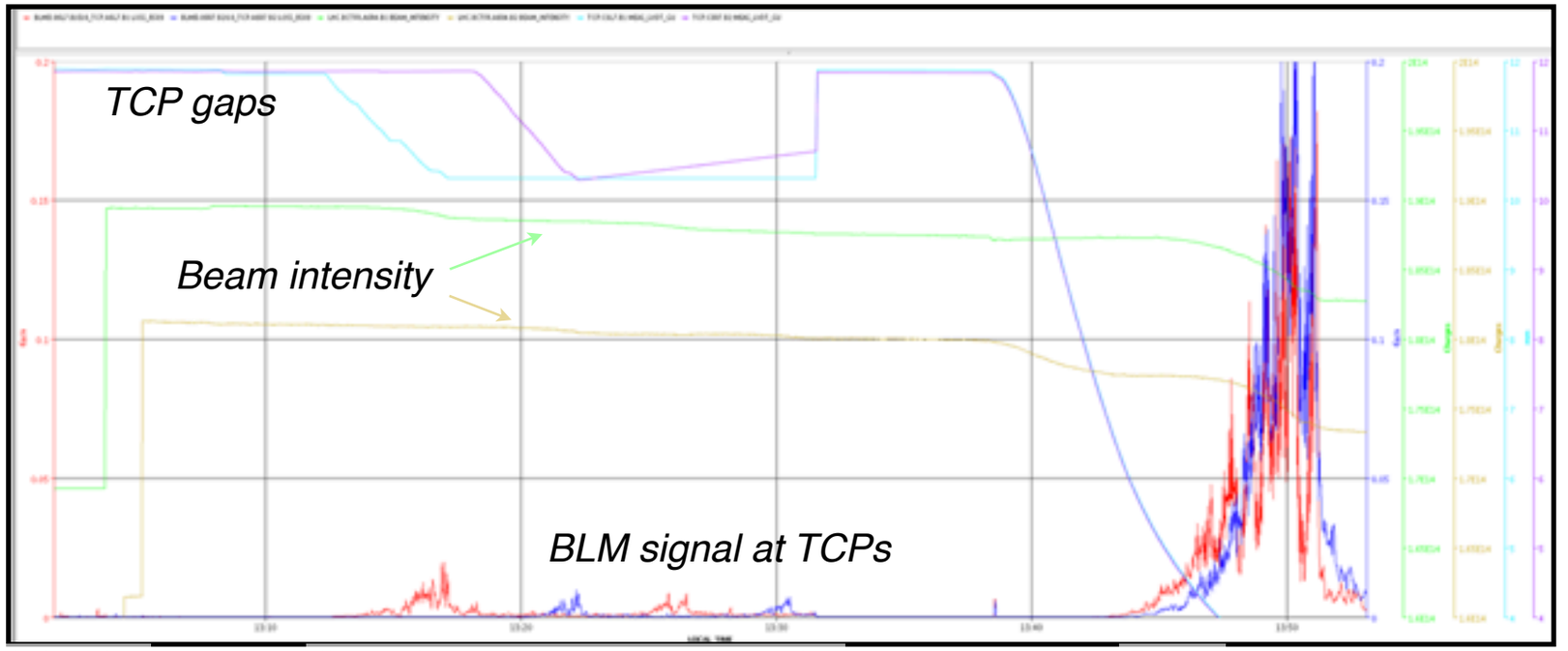

Injection → *Scraping and ramp preparation* → *Ramp*

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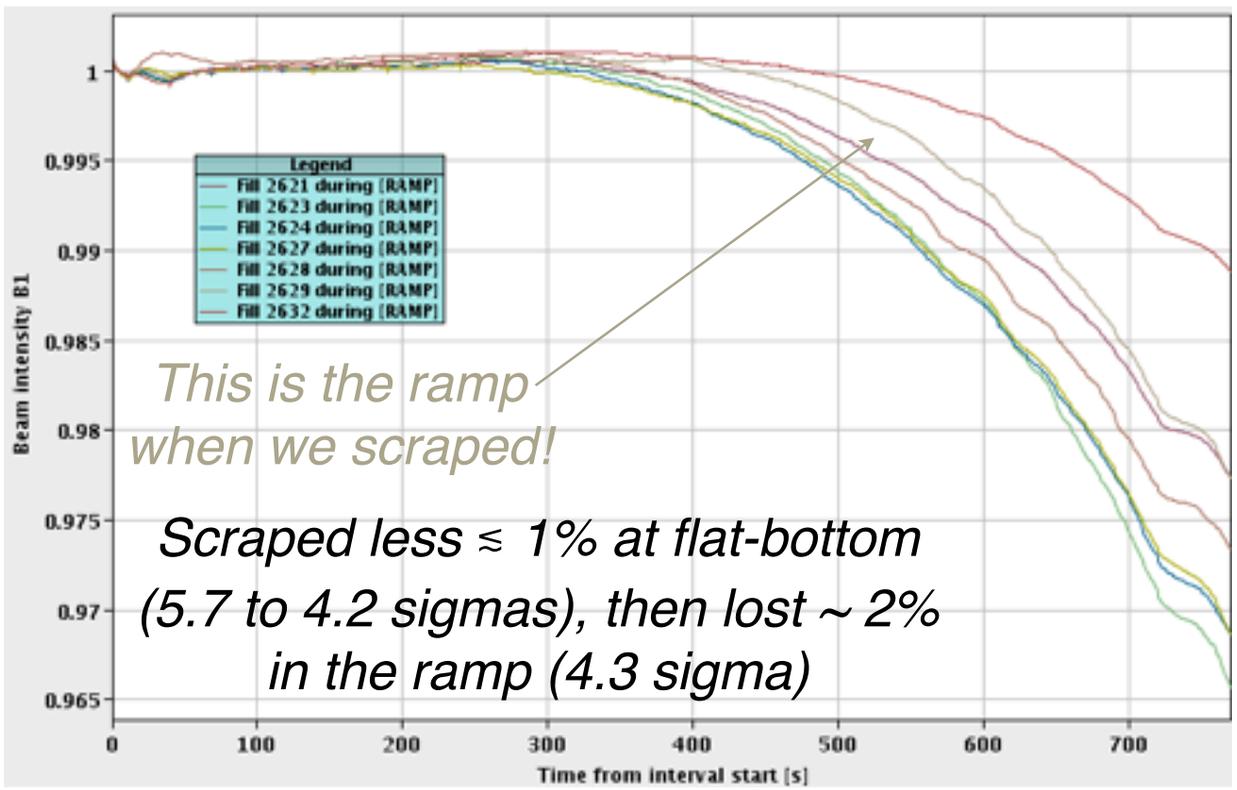
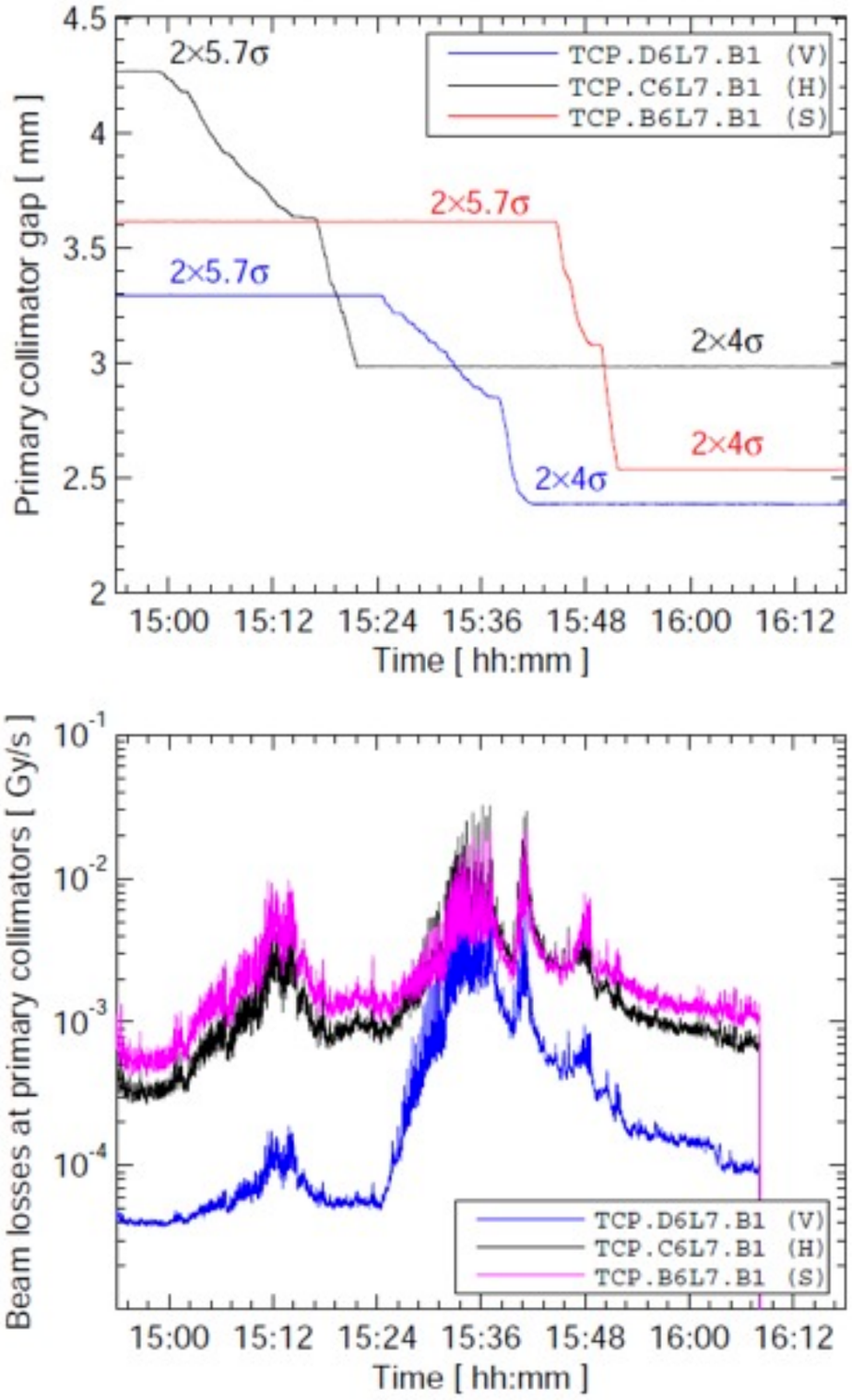
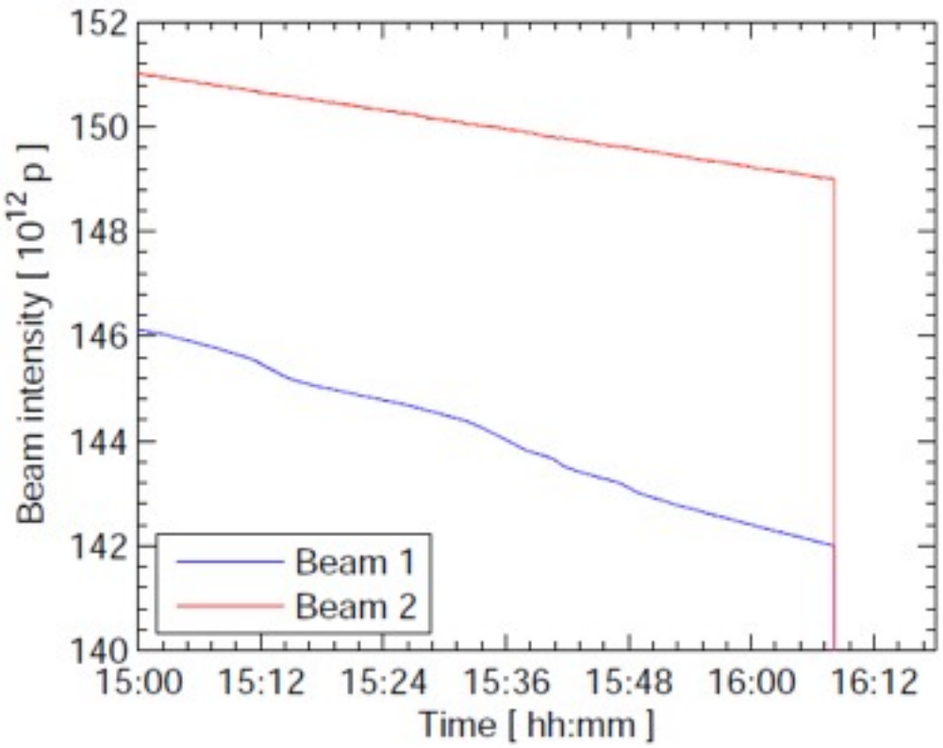
Intensity transmission during the ramp

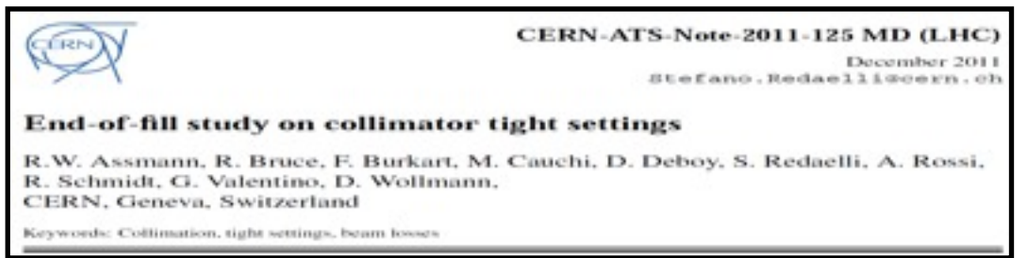


Scraping at top energy (1)





- **One test done in 2011 at the end of a physics fill with 1400b at 3.5 TeV**
- The scraping took more than 30 minutes, limited by high loss spikes.
- Can we do it at 7 TeV with reduced margins for quench?
- TCP smallest gap limited by impedance?


CERN-ATS-Note-2011-125 MD (LHC)

December 2011

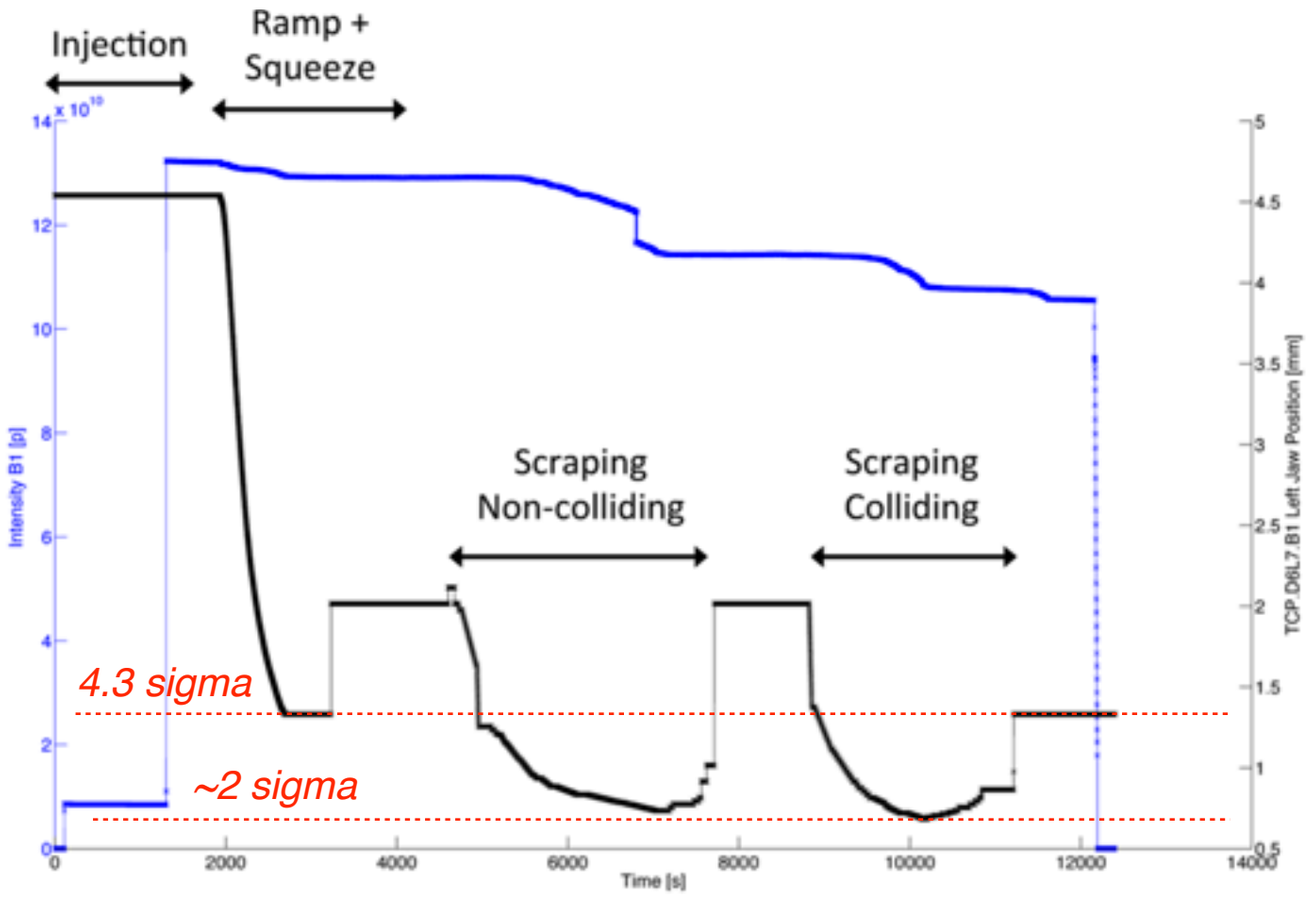
Stefano.Redaelli@cern.ch

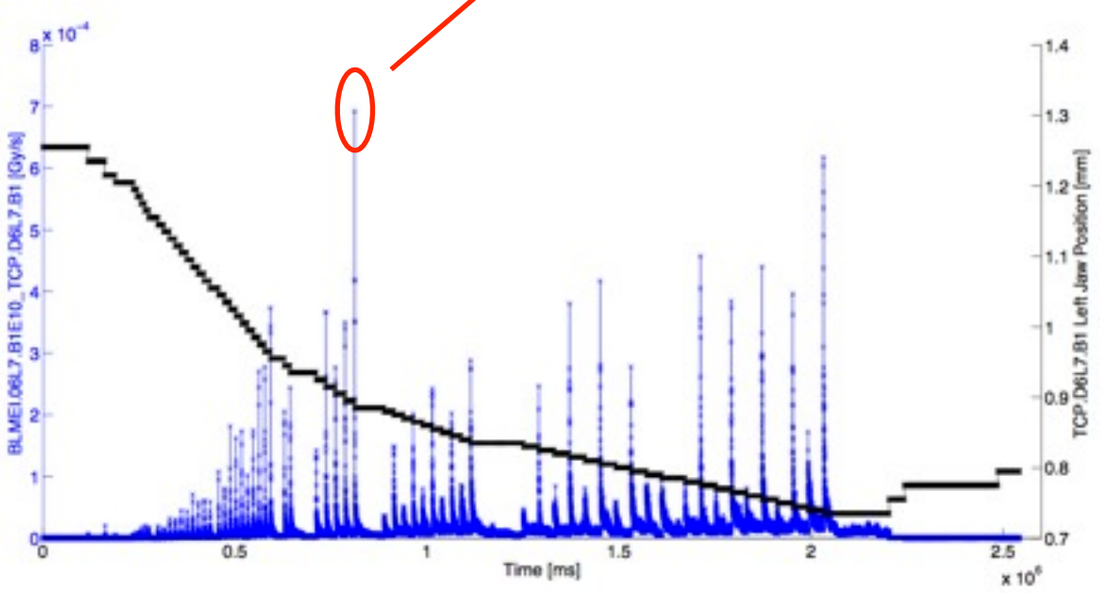
End-of-fill study on collimator tight settings

R.W. Assmann, R. Bruce, F. Burkart, M. Cauchi, D. Deboy, S. Redaelli, A. Rossi, R. Schmidt, G. Valentino, D. Wollmann,
CERN, Geneva, Switzerland

Keywords: Collimation, tight settings, beam losses

Scraping at top energy (2)





- **Beam scraping with squeezed beams** done in 2012 for diffusion studies.
- Scaling of losses measured with single bunches show that it will be challenging to do that at every fill!
- Also note that there are indications of blow-up during the squeeze: scraping during ramp might not be enough.

CERN-ATS-Note-2012-074 MD

24 September 2012

Gianluca.Valentino@cern.ch
Stancari@fnal.gov

Halo Scraping, Diffusion and Repopulation MD

G. Valentino, R. W. Assmann, R. Bruce, F. Burkart, S. Redaelli,
B. Salvachua, CERN, Geneva, Switzerland
V. Previtali, G. Stancari, A. Valishev, Fermilab, Batavia, IL, USA

Keywords: LHC beam scraping, diffusion, halo repopulation

Outline

- ☑ Introduction
- ☑ Basic concepts
- ☑ Scraping at the LHC
- ☑ **Motivation for this review**
- ☑ **Possible timelines**
- ☑ **Conclusions**

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- **What beam tests and studies are needed?**
- **Are there other possible functionalities for the electron lens at the LHC?**
  - *Used as abort gap cleaner in the Tevatron.*
  - *Non-hollow beams conceived beam-beam tune shift compensation (Tevatron, RHIC)*
  - *Certainly useful for diagnostics, depending on achievable time structure.*

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This means having 2 hollow e-lens devices ready for the LHC.

Different scenarios must be comparatively assessed:

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   - *Too late for that now!*
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If the Tevatron lens works well, can it be keep it in the LHC and build 1 only?

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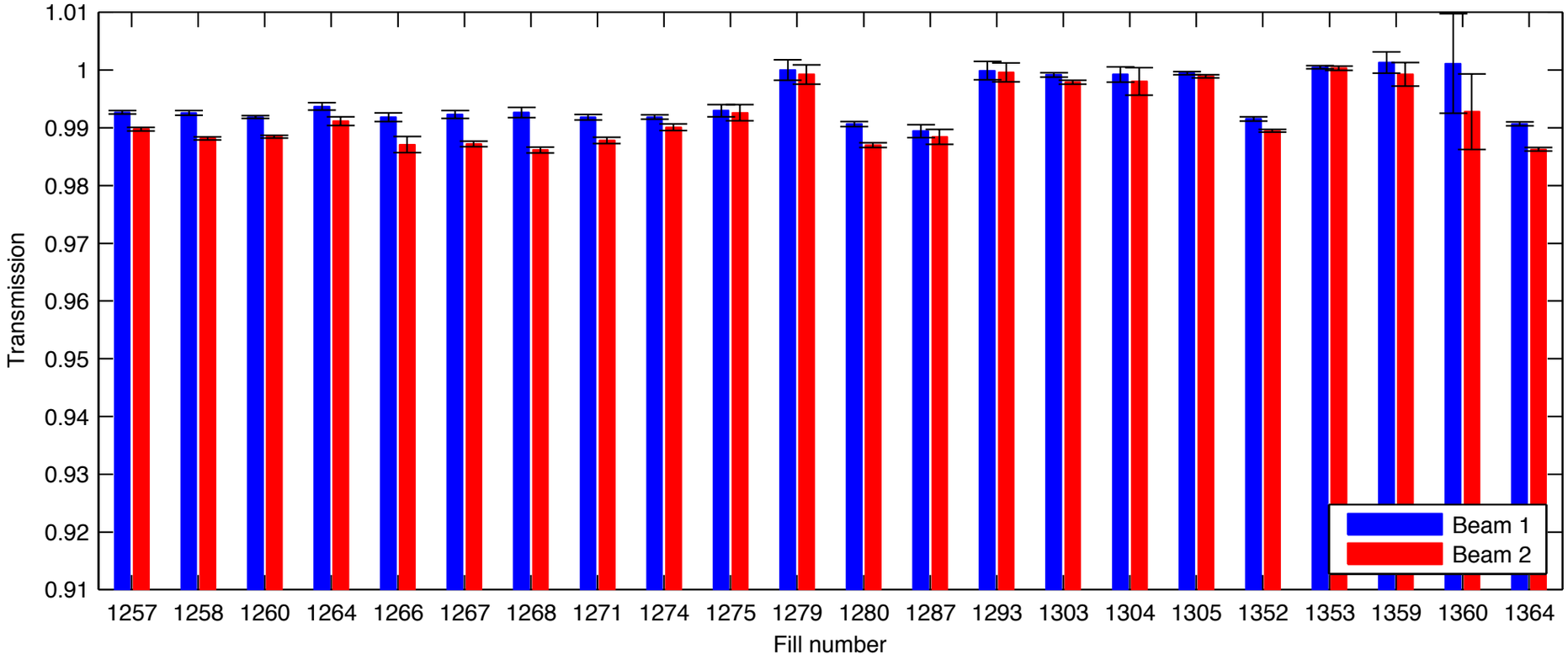
- Need to define appropriate strategy and an action list by early 2013!

Reserve slides

Ramp losses in 2012



Typical intensity transmission during the 3.5 TeV ramp (2010/2011), relaxed collimator settings

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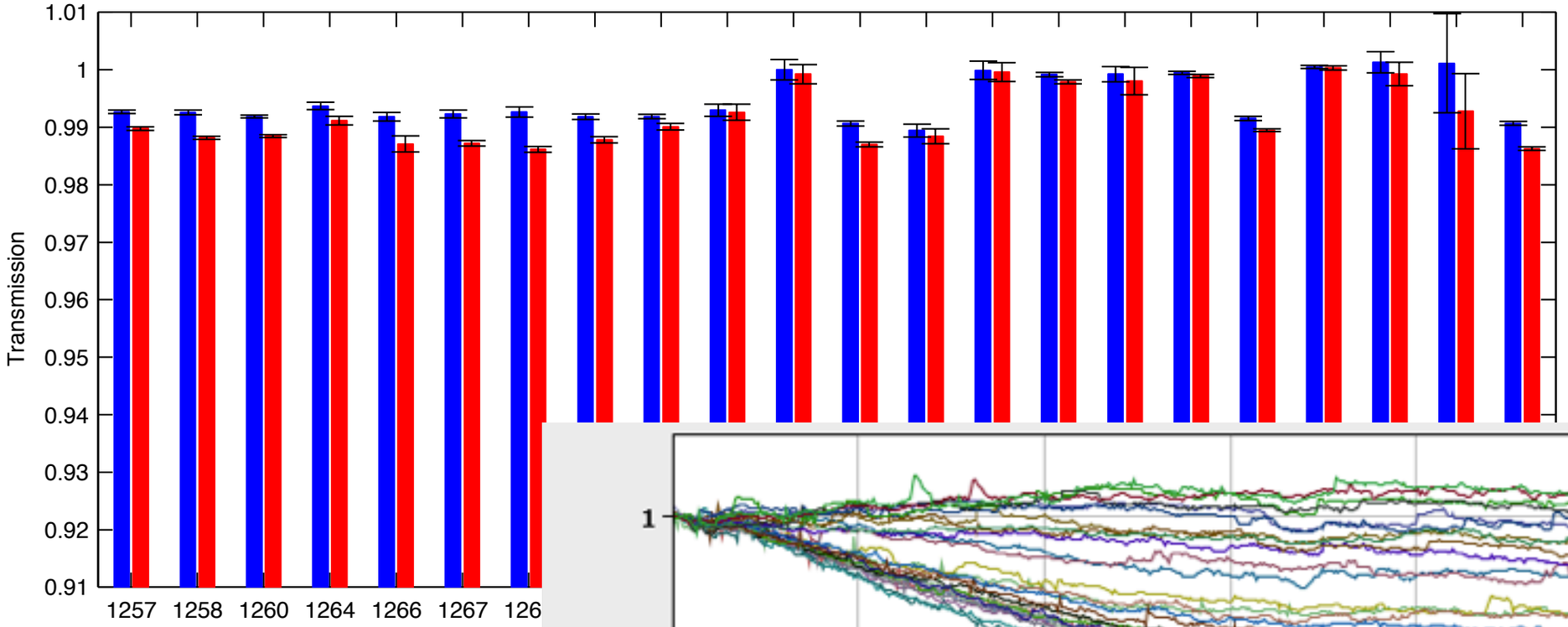

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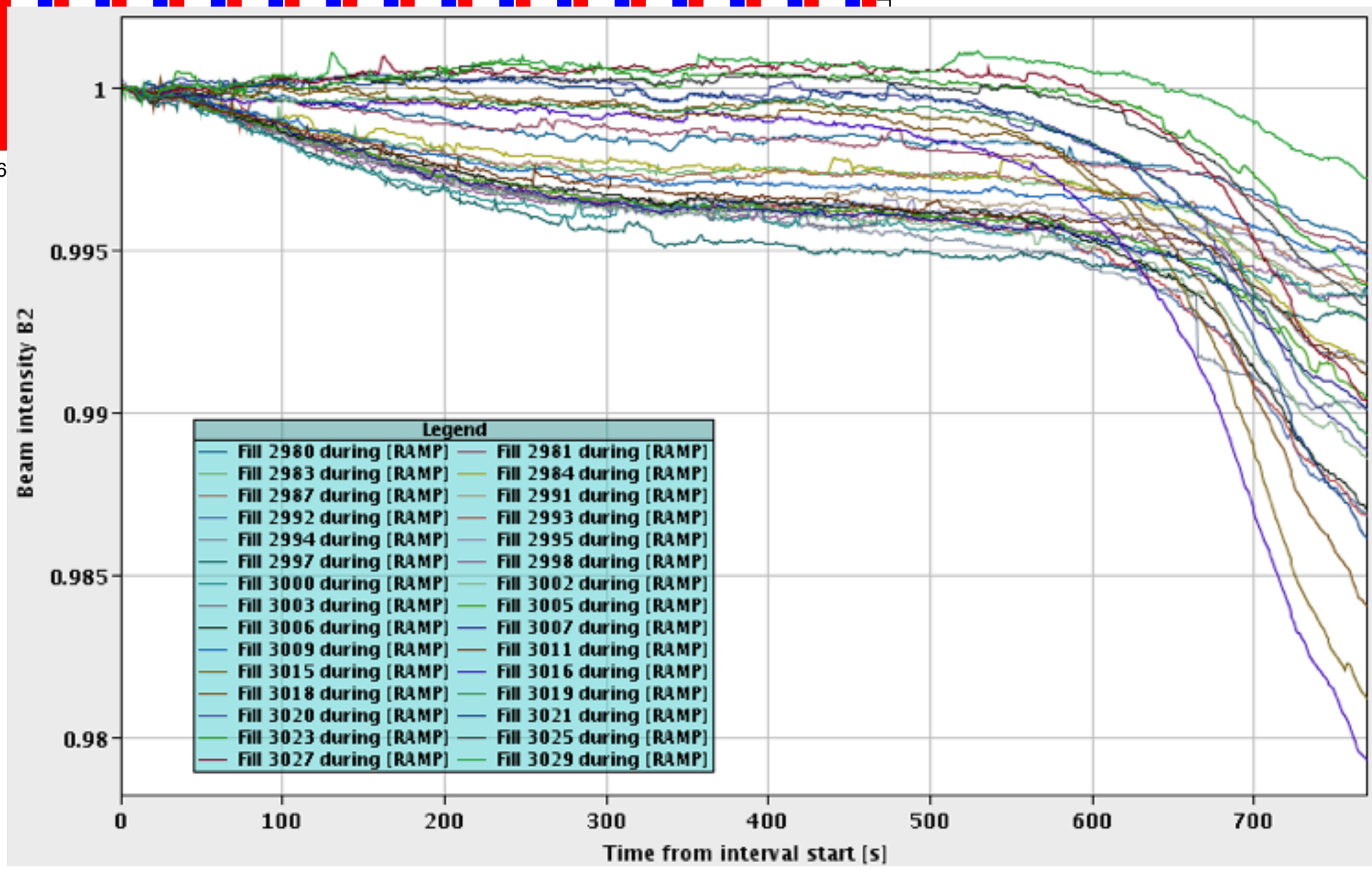
Transmission during the energy ramp in recent physics fills at 4 TeV, tight collimator settings.



Intensity reach from collimation cleaning

The performance reach does not only depend on the collimation cleaning!

LHC total intensity reach from collimation:

$$N_{\mathrm{tot}} = \frac{\tau R_q}{\tilde{\eta}_c}$$

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Caveats/assumptions:

- So far, we did NOT quench → Figures for R_q are **conservative**
- It is assumed that the **lifetime** will be the **same** at **larger E and smaller β***
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- There are uncertainties on **quench limit** and **cleaning** performance at **larger E**

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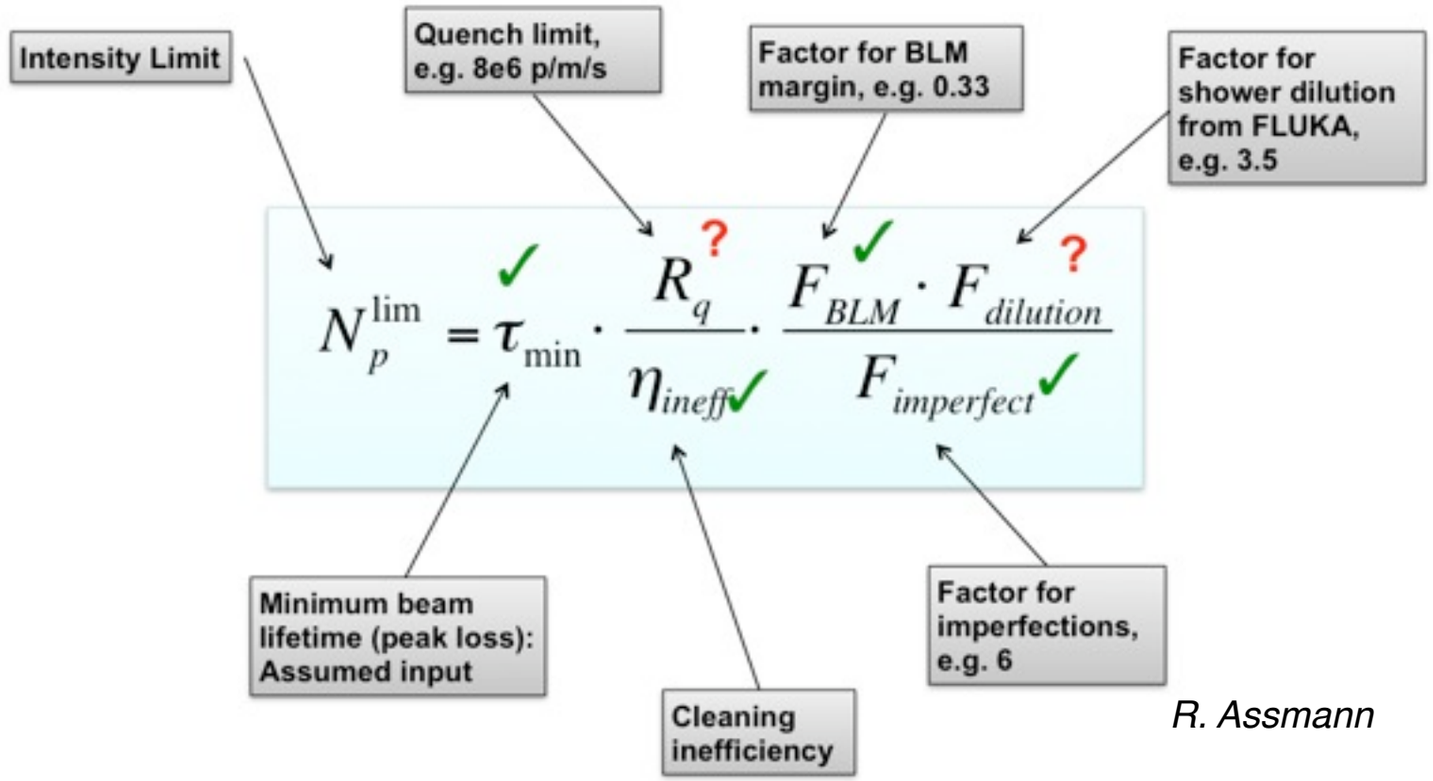

R. Assmann

Our design specification:

Mode	T [s]	τ [h]	R_{loss} [p/s]	P_{loss} [kW]
Injection	cont.	1.0	0.8×10^{11}	6
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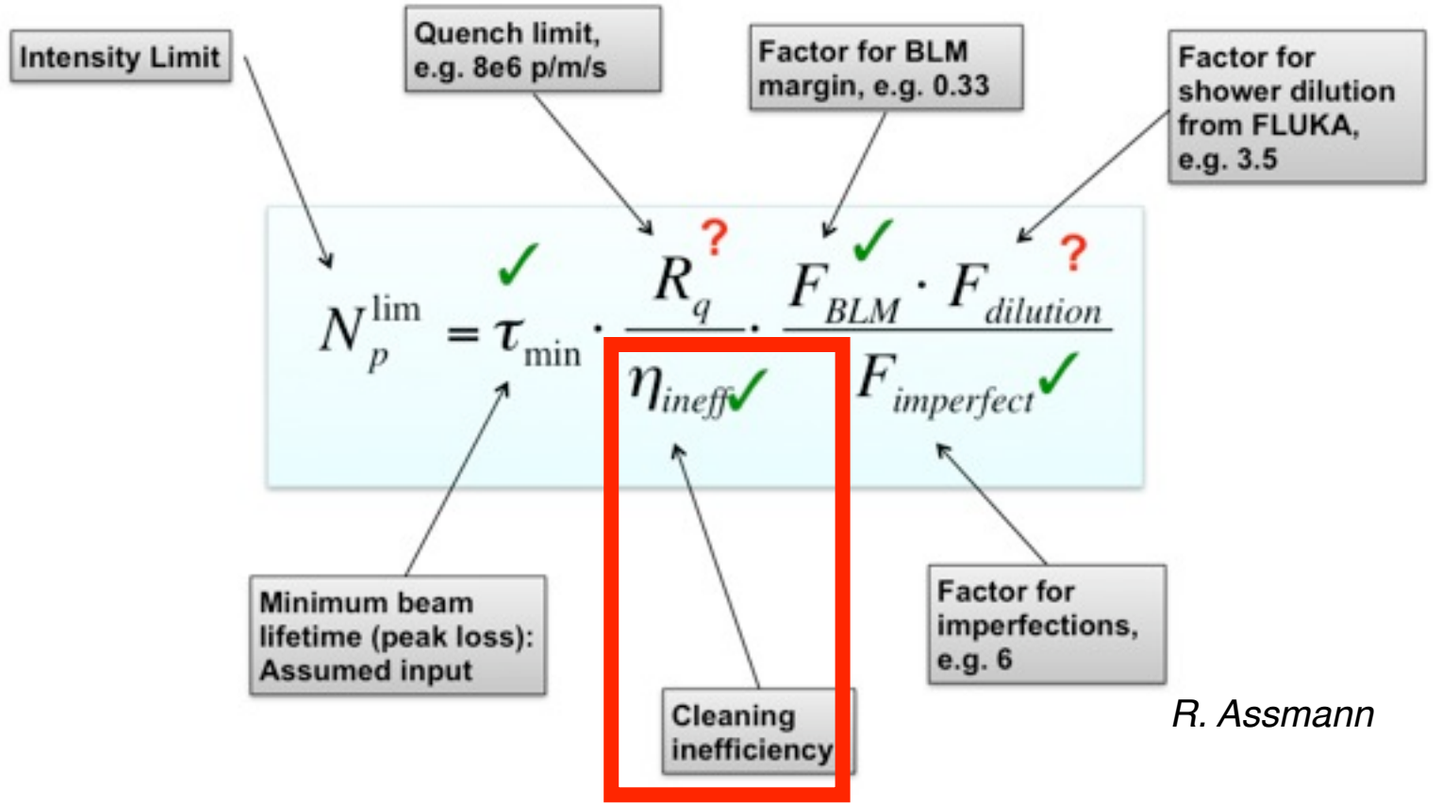

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