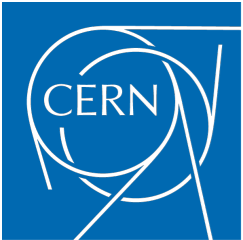


Beam Intensity for Collimator Alignment and Loss Maps

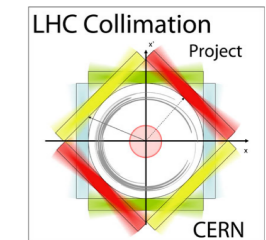
Machine Protection Working Group

May 23rd, 2014

***G. Valentino, R. Bruce,
S. Redaelli, B. Salvachua, D. Wollmann***

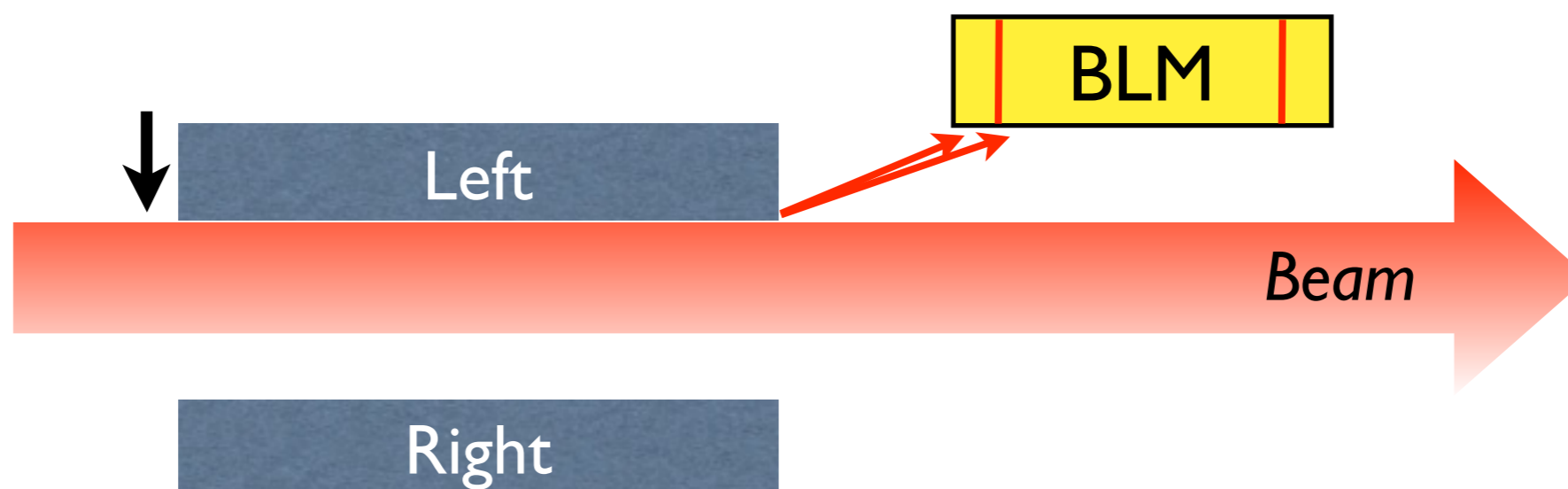


Outline



- The use cases: alignment and loss maps
- Proposed safe beam flag for 7 TeV
- Alignments: required intensity
- Loss maps: required intensity
- Operational efficiency

- **Alignment:** needed to measure the beam centre and beam size at each collimator to calculate the operational settings.
- **Procedure:** move in left and right jaws in 5 - 20 μm steps until a BLM signal spike appears.



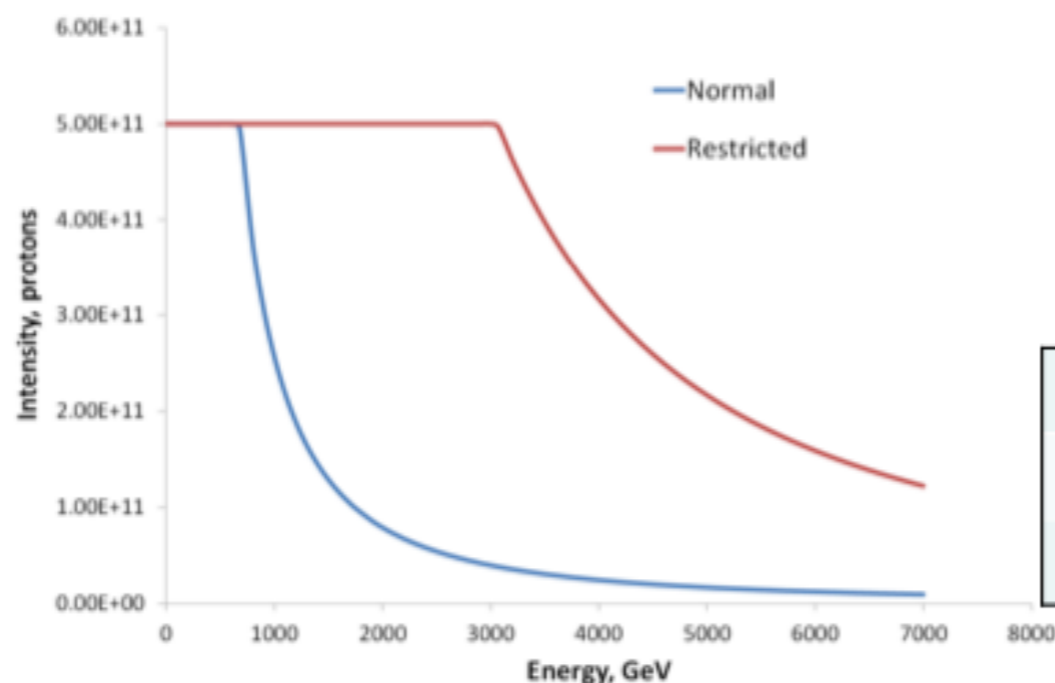
- **Beam parameters:**
 - **beam intensity:** defined by the “**Very Relaxed SETUP BEAM FLAG**”.
 - **bunch configuration:** typically used ~ 1 nominal bunch, but sometimes needed more for establishing collisions / performing loss maps after alignment in the same fill.

- **Beam loss maps:** used to measure the performance of the collimation system for a given set of settings.
- **Procedure:** in both cases, generate high losses around the ring:
 - Betatron offset: - pre-2012 → cross the 3rd order tune resonance in H/V.
 - post-2012 → beam blow-up using ADT in H/V.
 - Momentum offset: - RF trim ± 500 Hz for -ve / +ve off-momentum.
 - B1+B2 done in parallel to save time as losses typically dump beam.
- **Beam parameters:**
 - **beam intensity:** defined by the “**Very Relaxed SETUP BEAM FLAG**”.
 - **bunch configuration:** Typically used 1 nominal bunch per beam for tune resonance method, then moved to several bunches for ADT blow-up (combination of colliding / non-colliding for collisions).

Proposed setup beam flag for Run II (scaling with energy)

Proposal to ensure adequate protection and an efficient setup

- 1) Normal SBF: $1.1e10$ [ALL]
- 2) Restricted SBF: $1.4e11$ x 1 bunch [Only Special Users]
- 3) Restricted SBF: $1.1e10$ x 12 bunches [MDs with MP doc.]
 - SIS interlock on bunch intensity

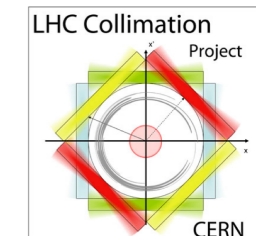


Limiting intensities for different-level SBFs at 6.5 TeV and 7 TeV

	6.5 TeV	7 TeV
Normal	$1.1e10$	$9.4e9$
Restricted	$1.4e11$	$1.2e11$



Proposed setup beam flag for Run II (scaling with energy)



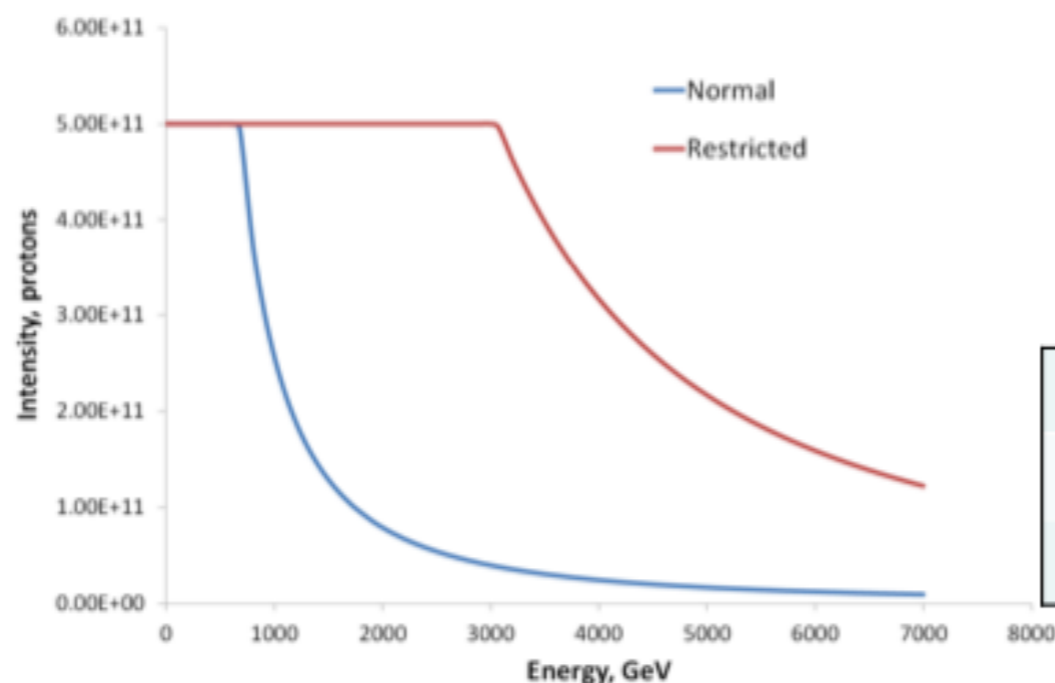
Proposal to ensure adequate protection and an efficient setup

Sufficient for collimation?

Compatible with efficient commissioning?

- 1) Normal SBF: $1.1e10$
 - 2) Restricted SBF: $1.4e11 \times 1$ bunch
 - 3) Restricted SBF: $1.1e10 \times 12$ bunches
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Limiting intensities for different-level SBFs at 6.5 TeV and 7 TeV

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07.03.2014

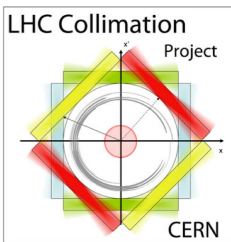
87th MPP Meeting

courtesy V. Chetvertkova

10



Questions to be addressed



- **Alignment**

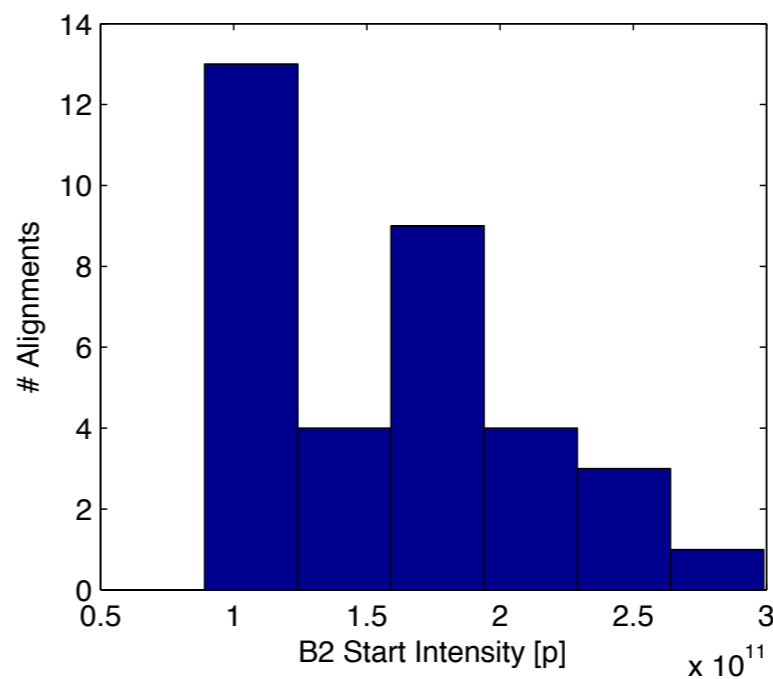
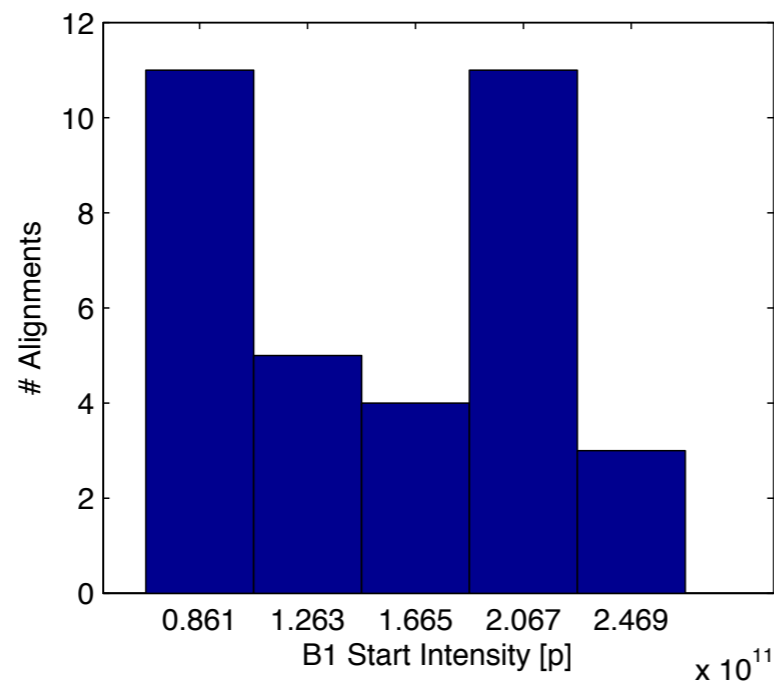
- What is the **minimum intensity** to see good BLM spikes during alignment, and to complete the alignment of all collimators in a single fill?
- **Operational efficiency:** would a reduced intensity be sufficient for multiple alignments + qualifications in the same dedicated fill?

- **Loss maps**

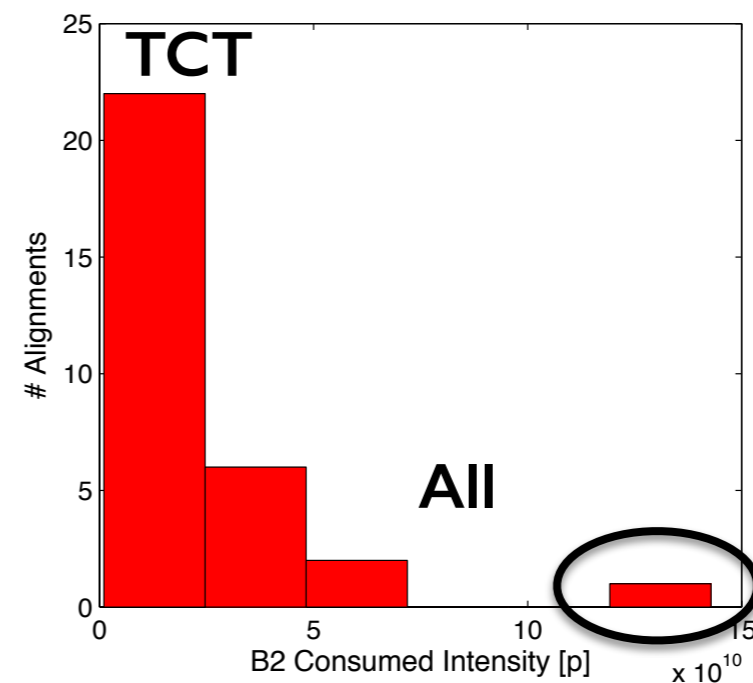
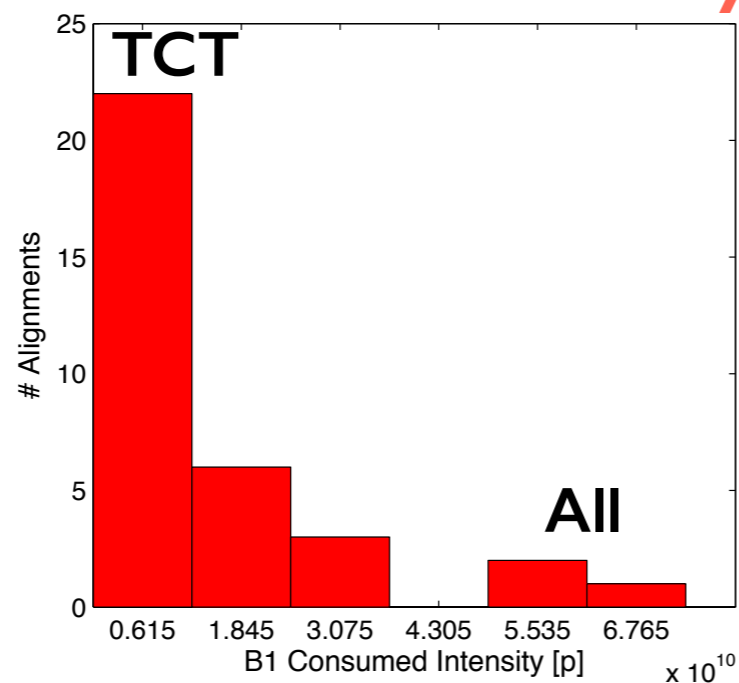
- What is the **minimum intensity** and needed to measure the collimation system performance?
- **Operational efficiency:** what is the required bunch configuration and intensity to perform all loss maps in the same dedicated fill?

Intensities during alignment (2011-2012)

Starting intensity



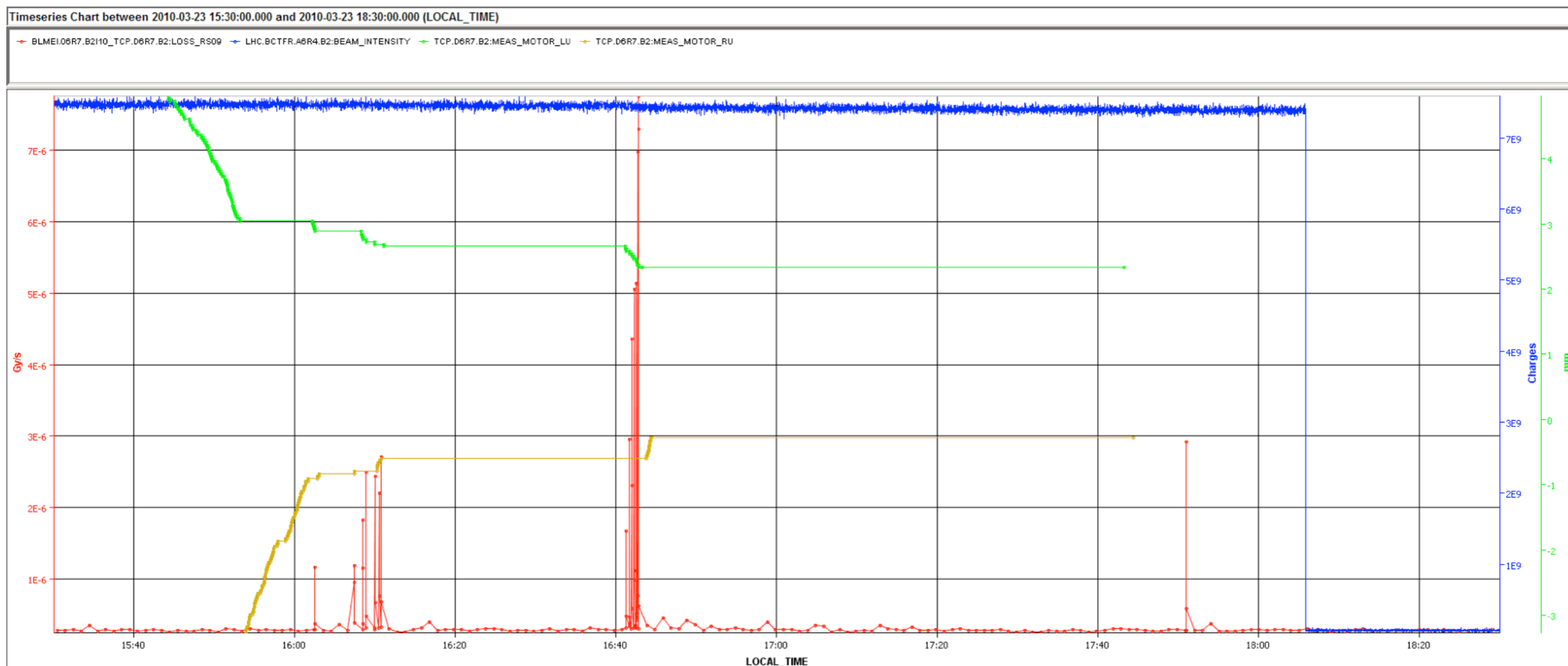
Intensity consumed



Flat top 2012

Minimum intensity required for alignment

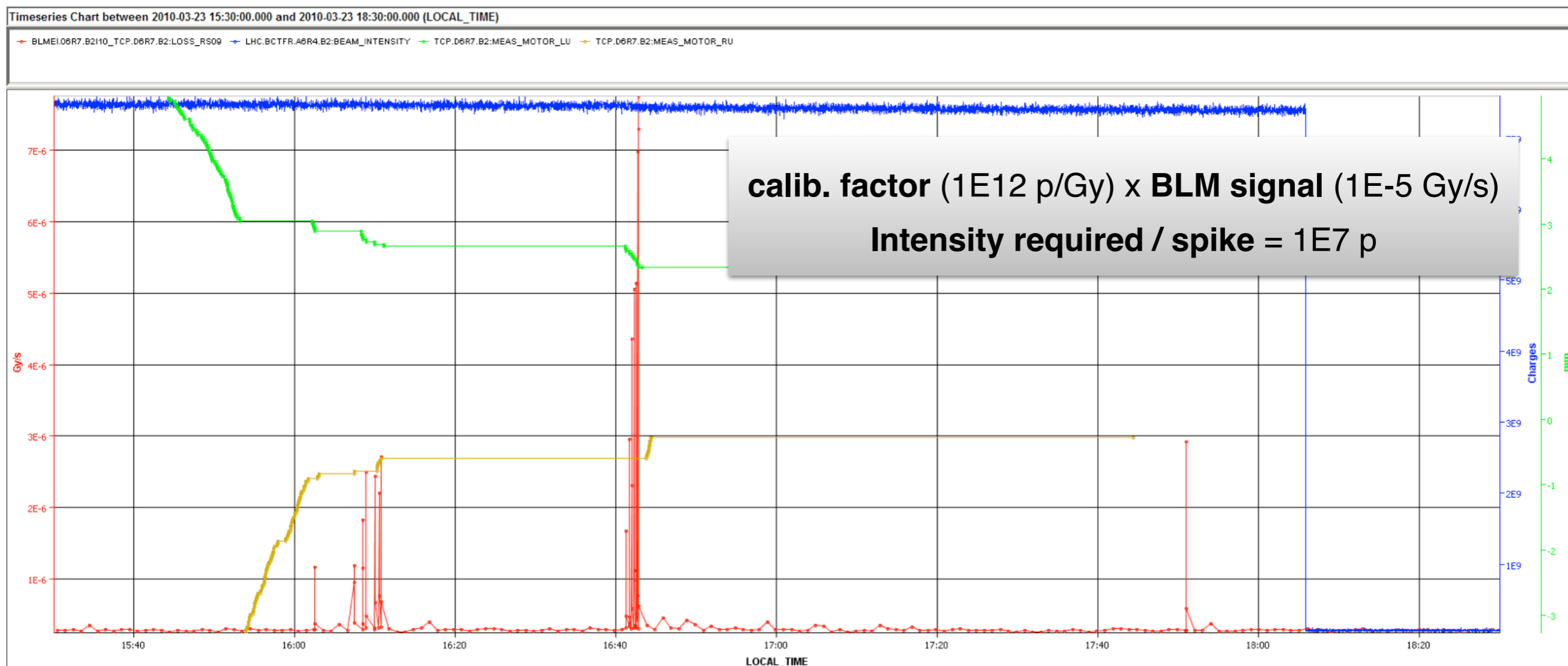
- Low-intensity ($7E9$) alignment at 3500 GeV, March 2010.
- BLM signal spikes of sufficient quality, even with pilot bunch intensity:



- Low intensity \rightarrow small meas-nom beam size ratio; halo not repopulated fast enough due to large step size required (D. Wollmann, IPAC'10).
- However, we use the nominal beam size at top energy, as setup error $>$ β -beat error (at least in 2010-2013).

Minimum intensity required for alignment

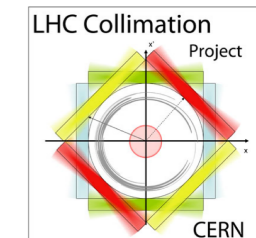
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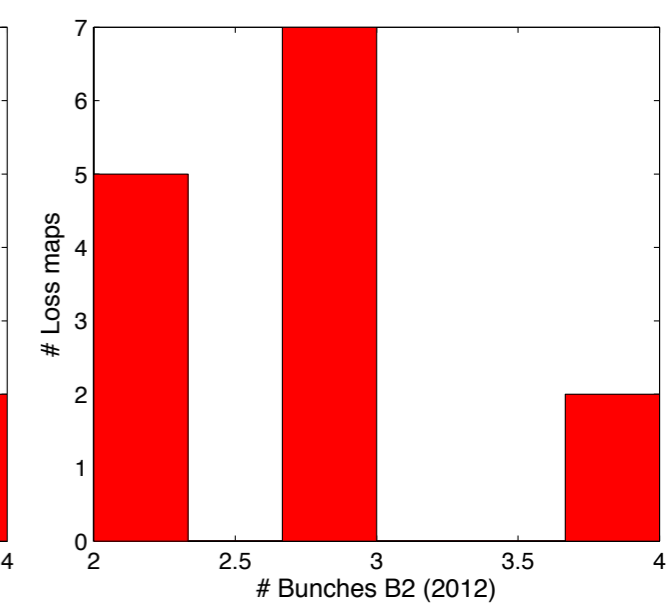
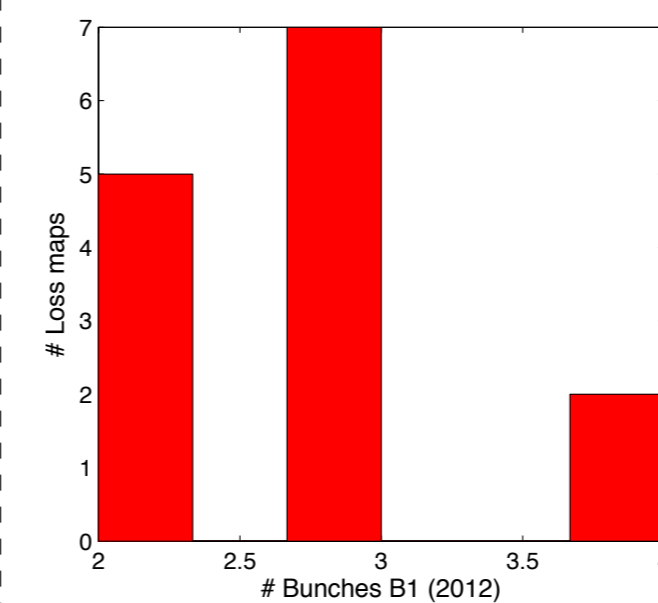
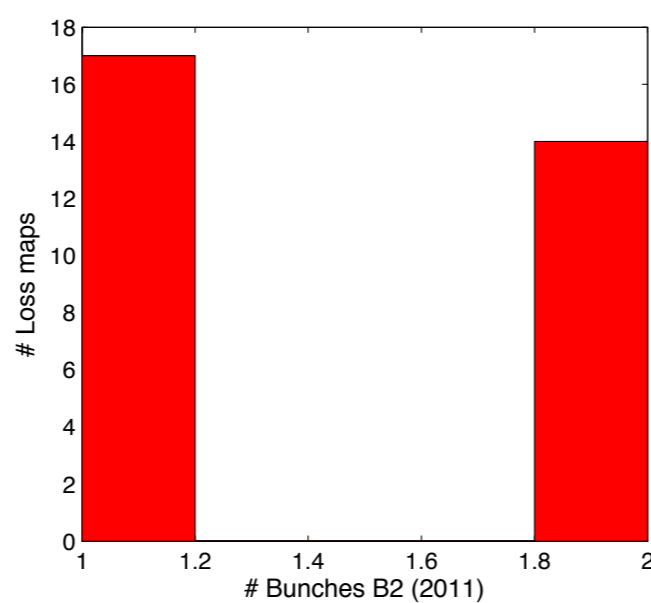
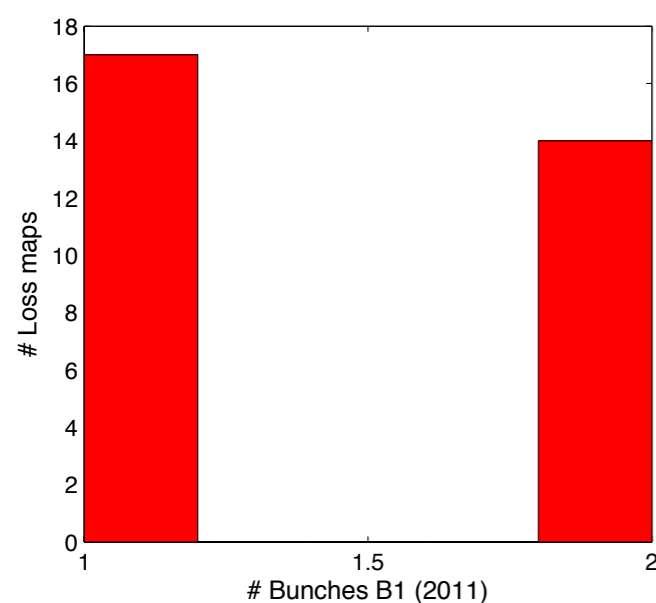
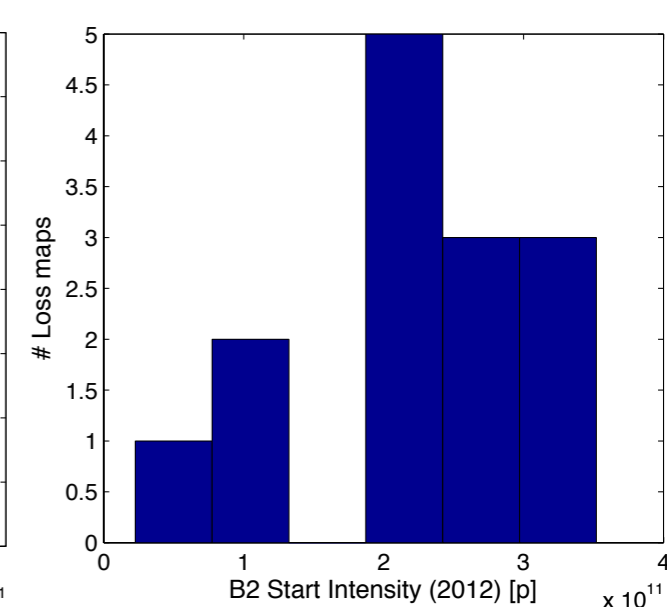
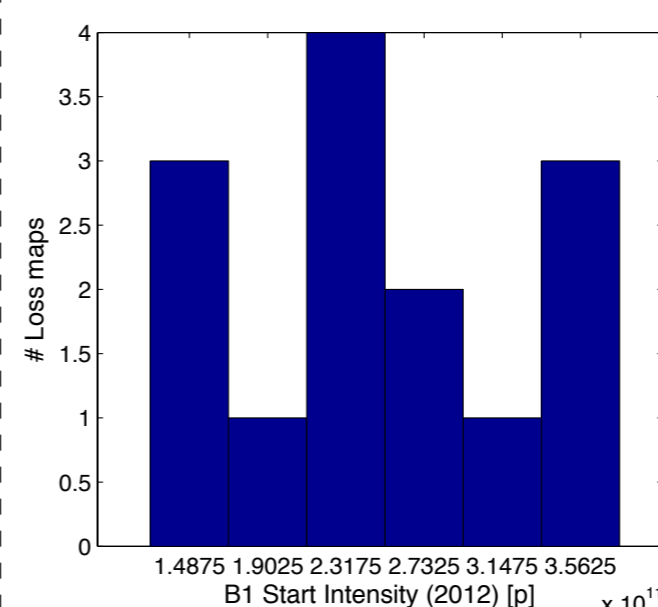
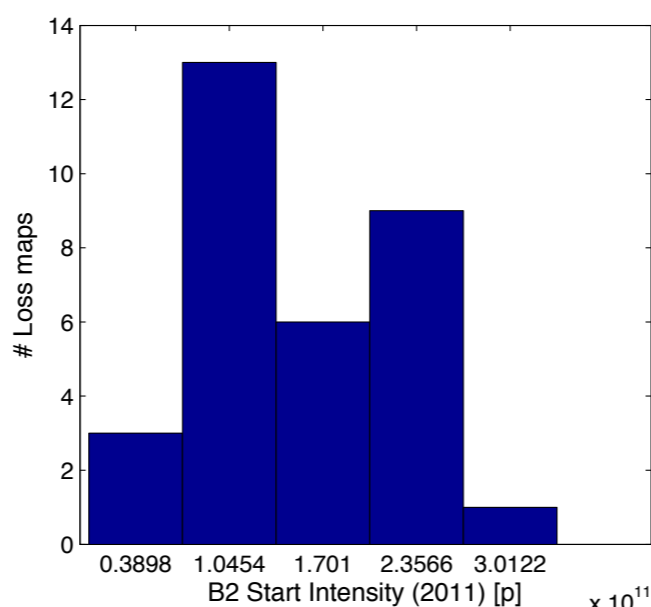
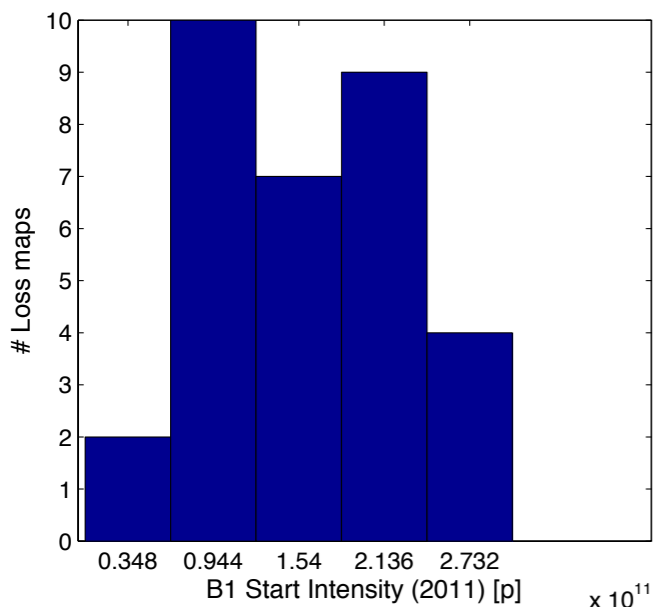


Intensities and bunch config during loss maps



2011 - resonance crossing

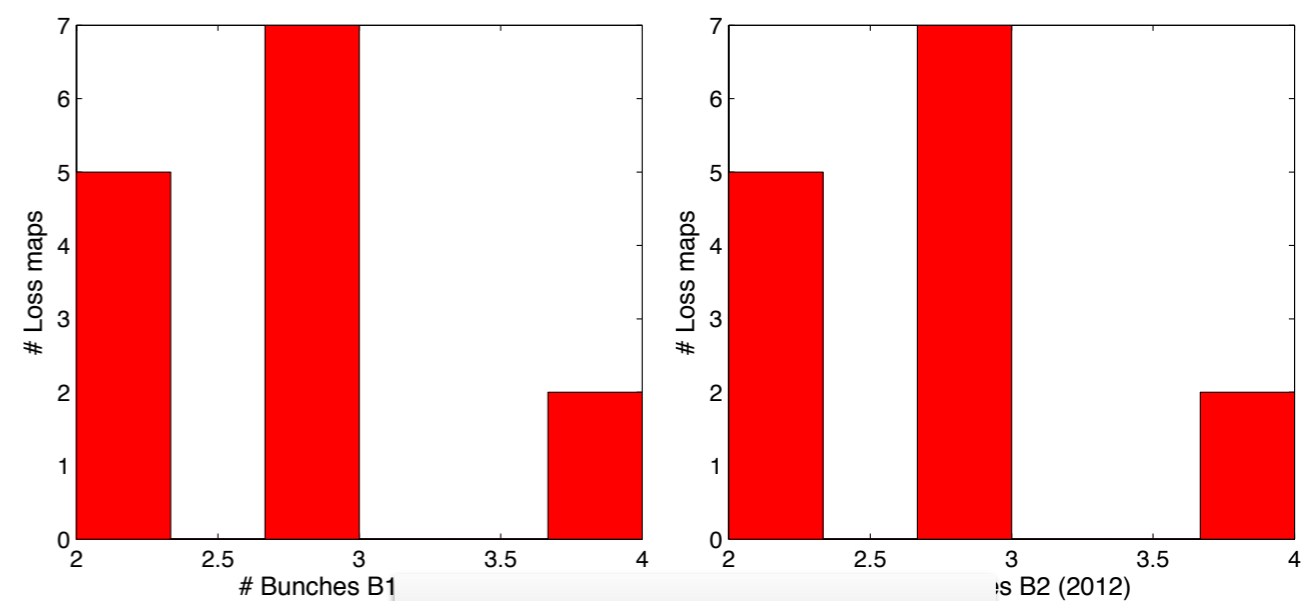
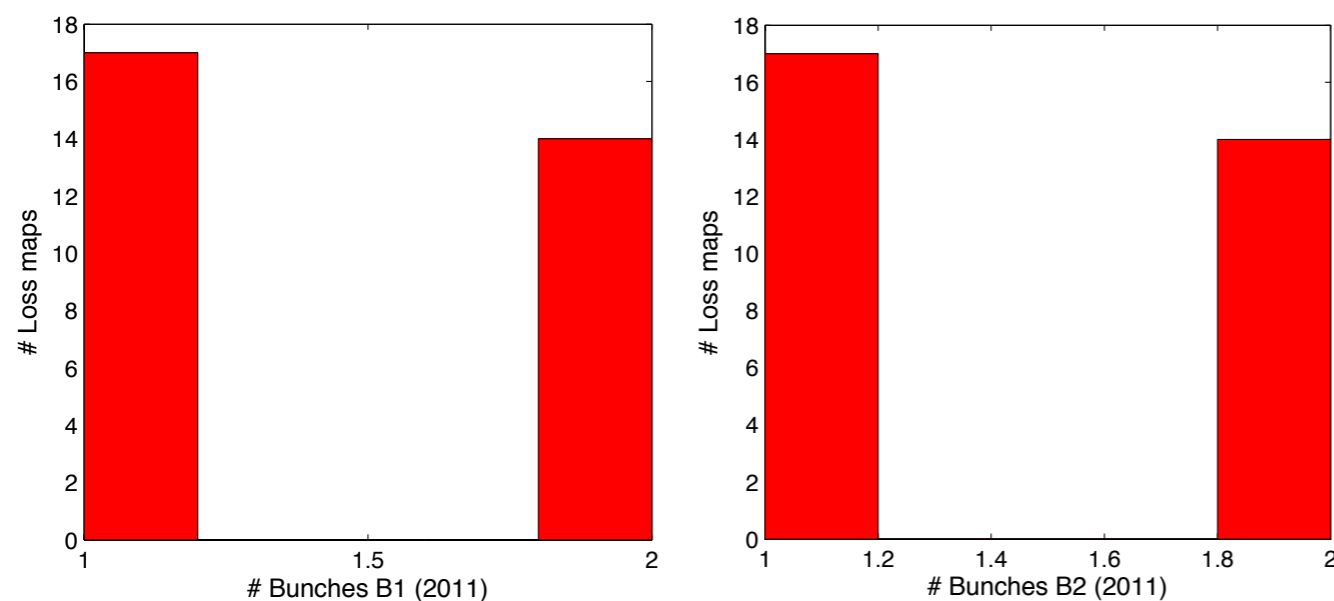
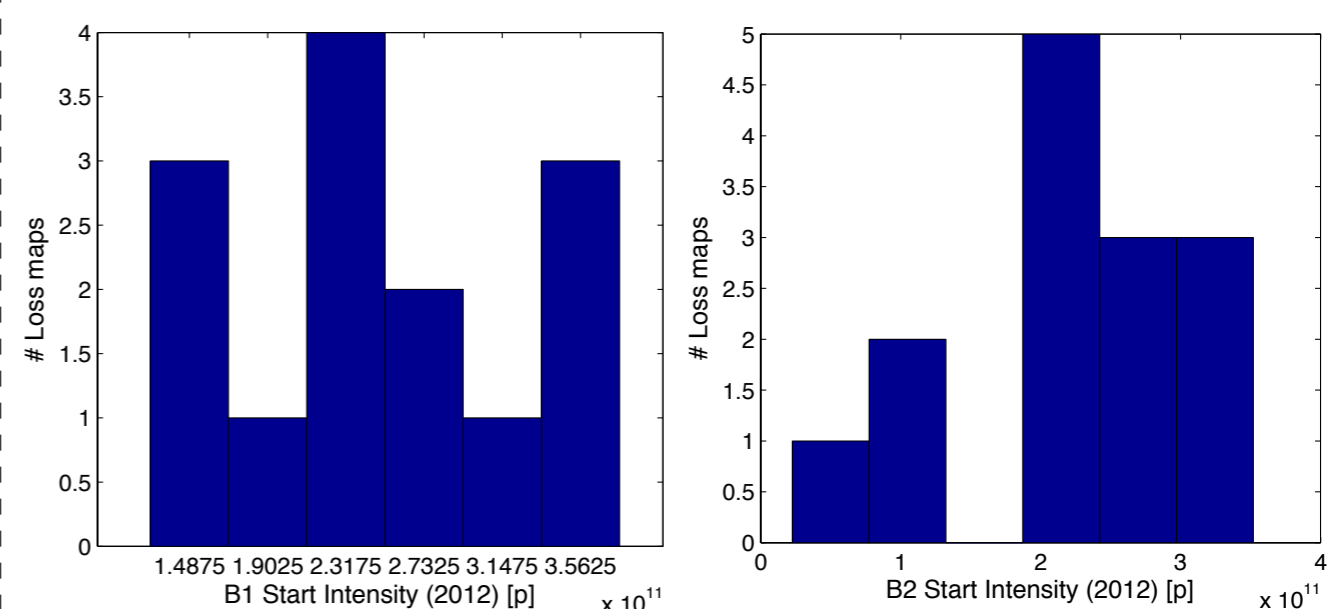
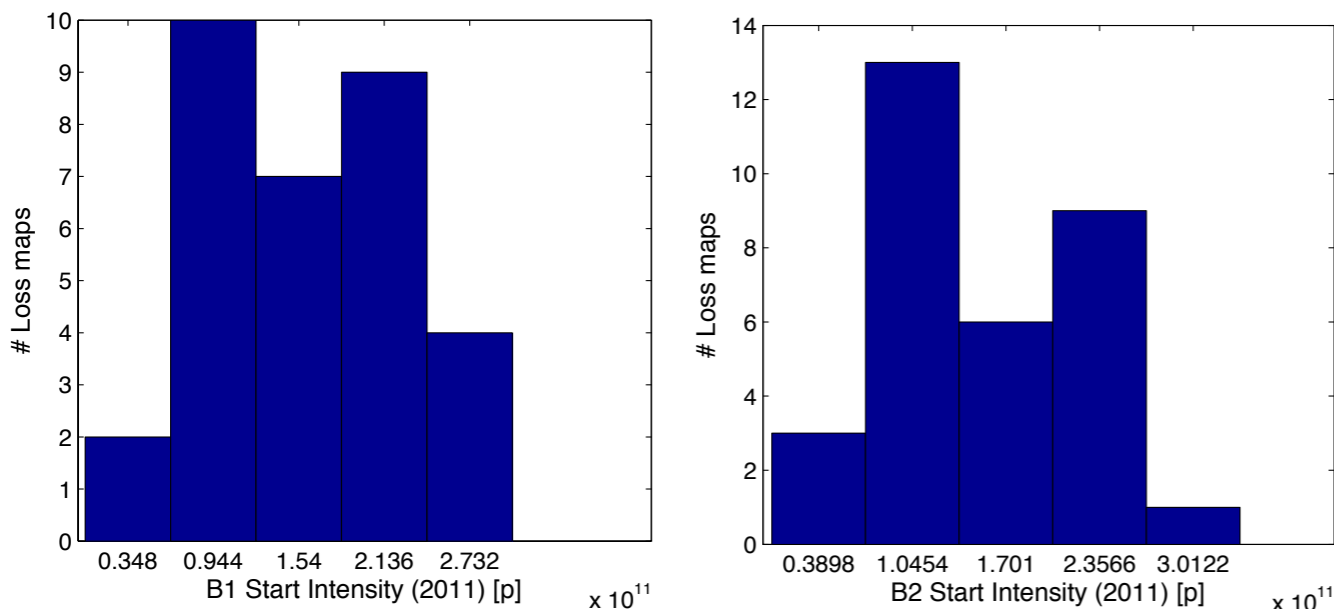
2012 - ADT blow-up



Intensities and bunch config during loss maps

2011 - resonance crossing

2012 - ADT blow-up



> 2 bunches for ADT crosstalk!



Minimum intensity loss for loss maps

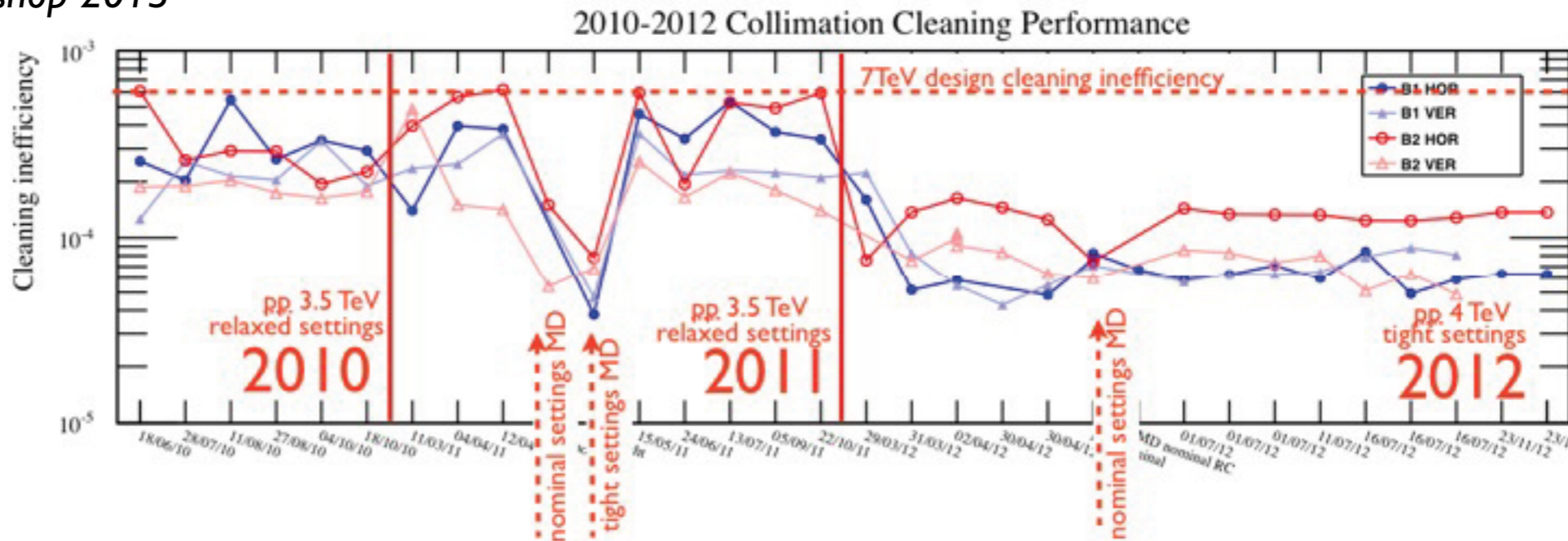


B. Salvachua, MP Workshop 2013

The minimum bunch intensity is defined by the minimum BLM signal that we need to measure the cleaning inefficiency at Q8 IR7.

$$BLM^{Q8} = \eta_c \times BLM_{min}^{TCP} > BLM^{noise}$$

$$BLM_{min}^{TCP} > \frac{3 \cdot 10^{-7} [Gy/s]}{5 \cdot 10^{-5}} = 6 \cdot 10^{-3} [Gy/s]$$



Minimum Intensity lost to measure the cleaning inefficiency at Q8 IR7

$$BLM_{min}^{TCP} > 6 \cdot 10^{-3} [Gy/s] \rightarrow \approx 8 \cdot 10^9 [protons/s]$$

This was tested during the p-Pb run, the loss maps were done by exciting single bunches of few 10¹⁰ protons/bunch. The plot shows that with 1 pilot bunch we got enough resolution to measure the cleaning in IR7 at 4TeV.

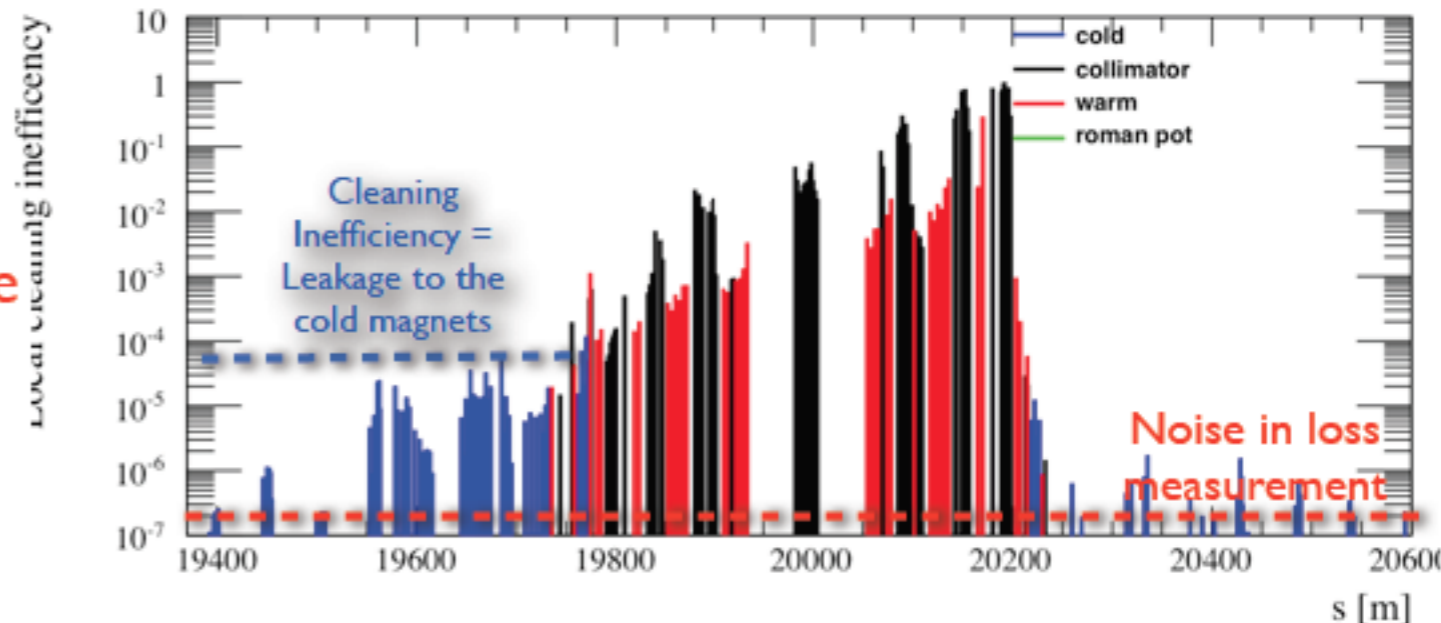
We could excite smoothly the bunch keeping the losses below the dump threshold

→ No need to mask BLMs

→ Loss maps could be done with “unsafe” intensities

see M.Solfaroli presentation

betatron losses B2 4000GeV vertical 2013-02-02 06:58:06





Minimum intensity loss for loss maps

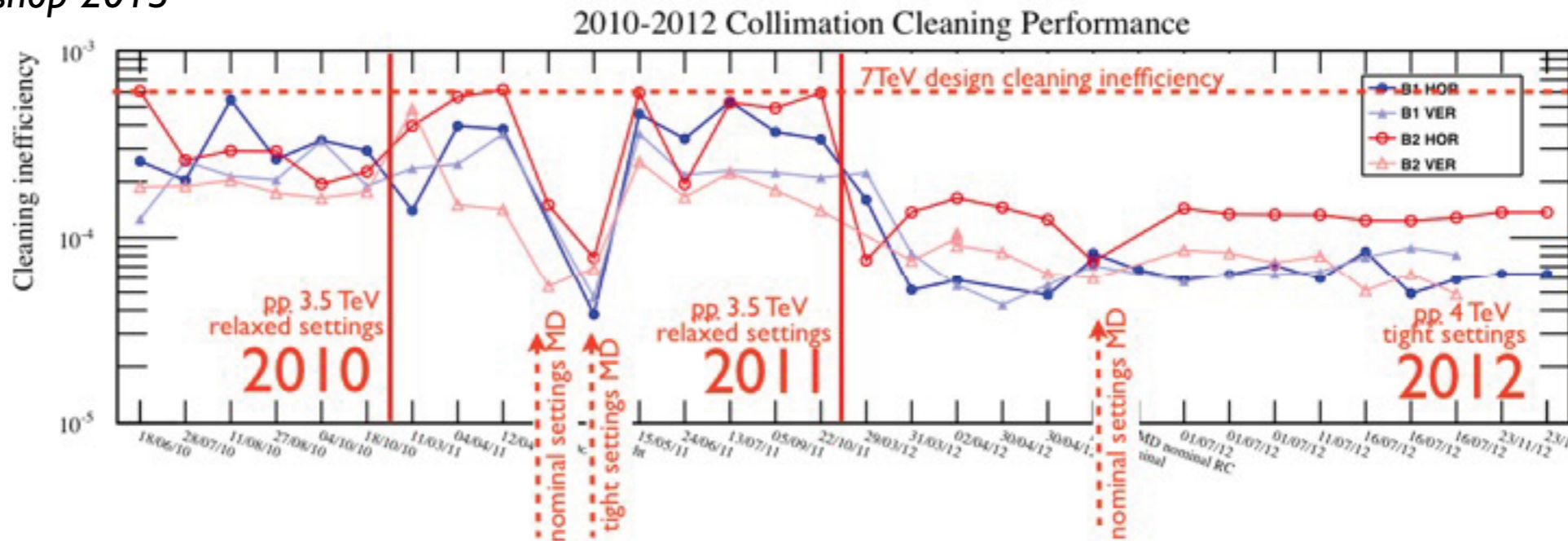


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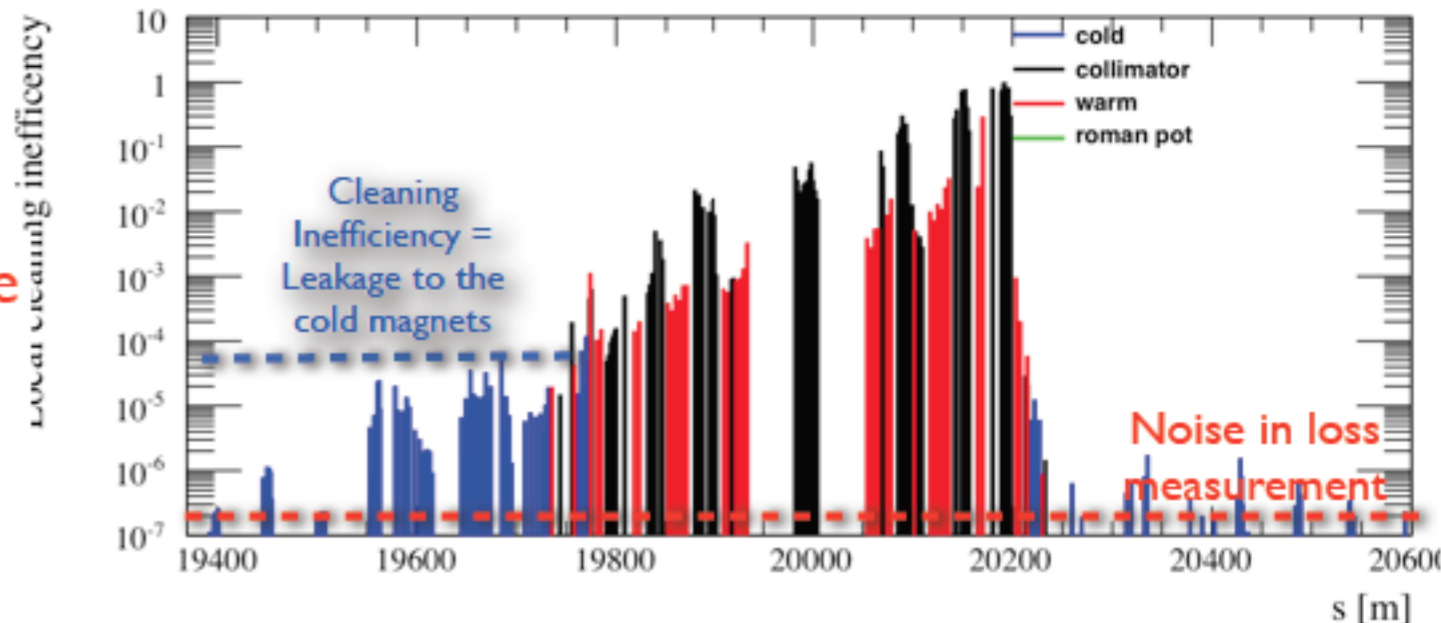


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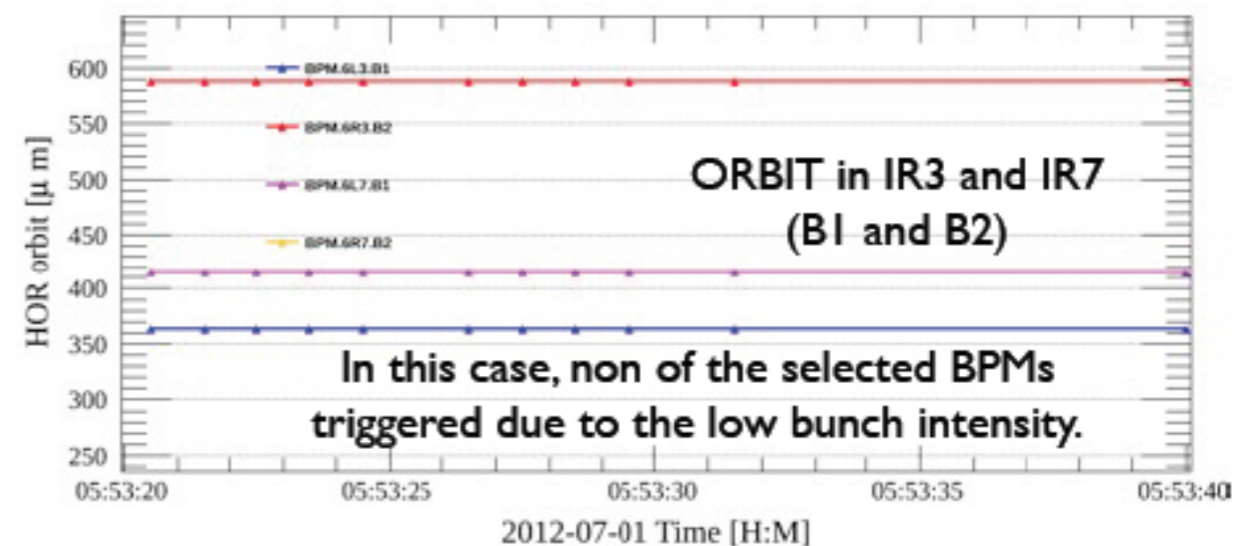
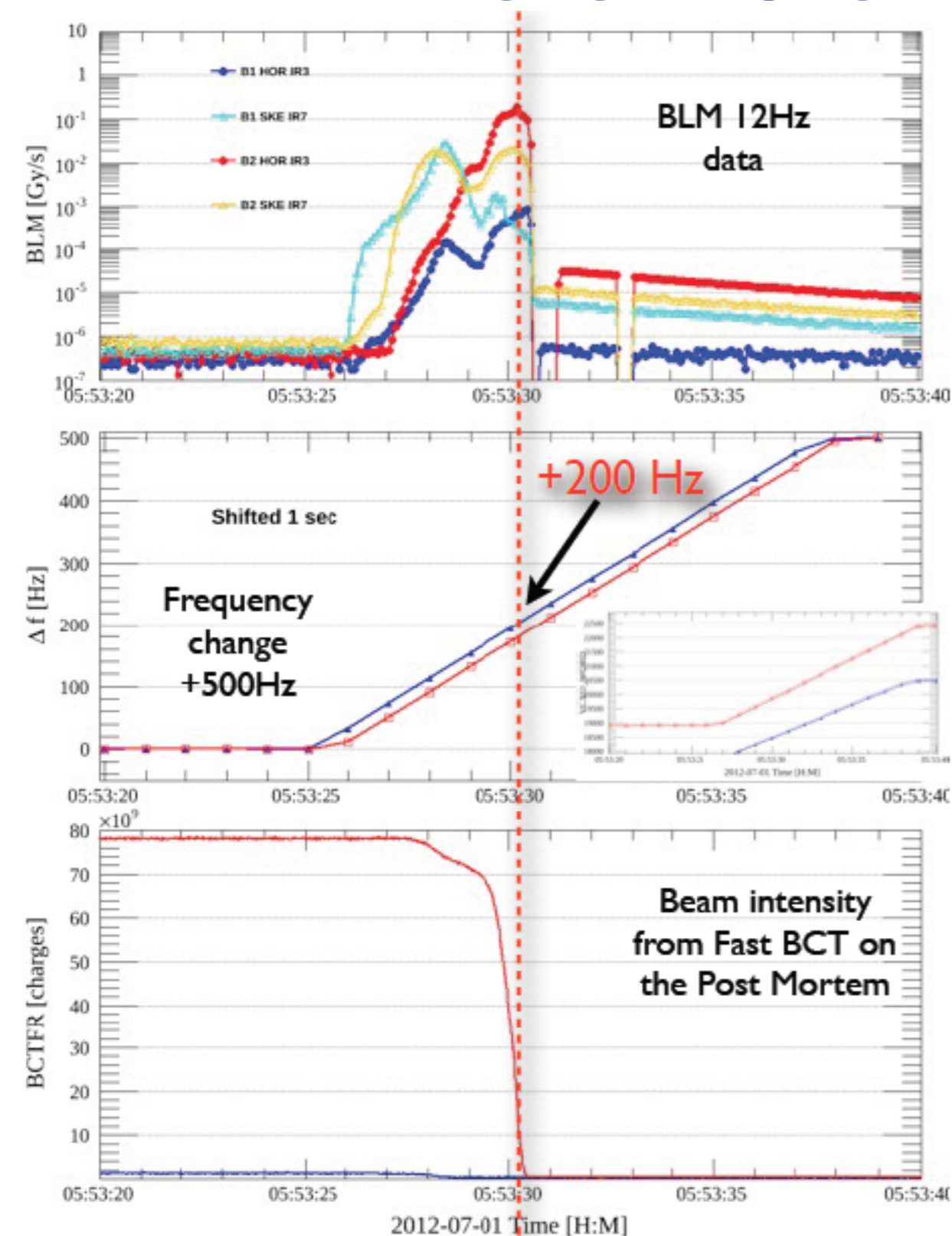
betatron losses B2 4000GeV vertical 2013-02-02 06:58:06



These estimates will have to be re-assessed for 7 TeV!

Loss maps could be done with unsafe intensities see M.Solfaroli presentation

Off-momentum loss maps: The efficiency bottle-neck!



Conclusion from the 4 cases analyzed:

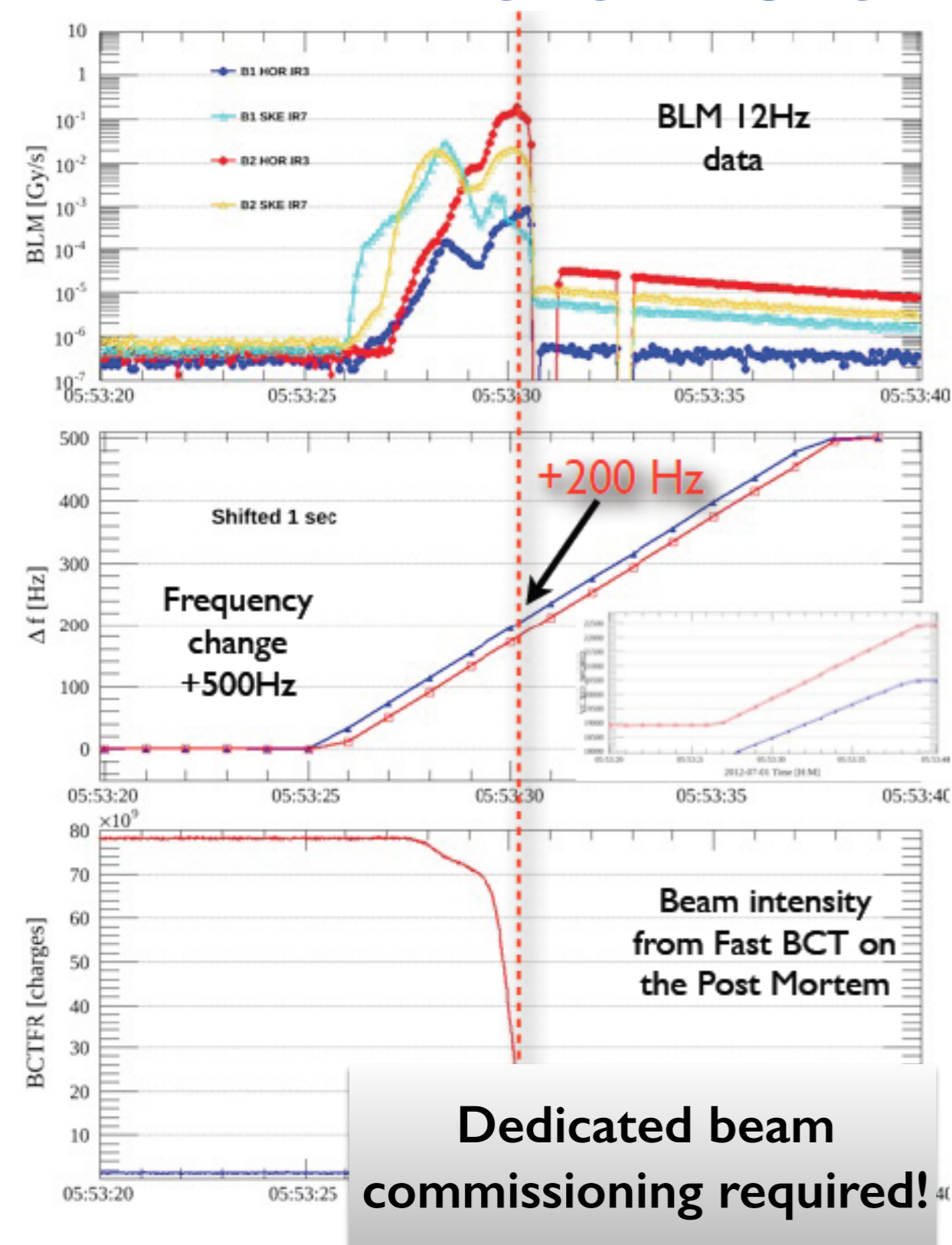
The maximum loss at the TCP in IR3 occurs when we reach around +/- 150 to 200Hz frequency change.

Orbit drift at the TCP IR3 of about 3-4 mm.

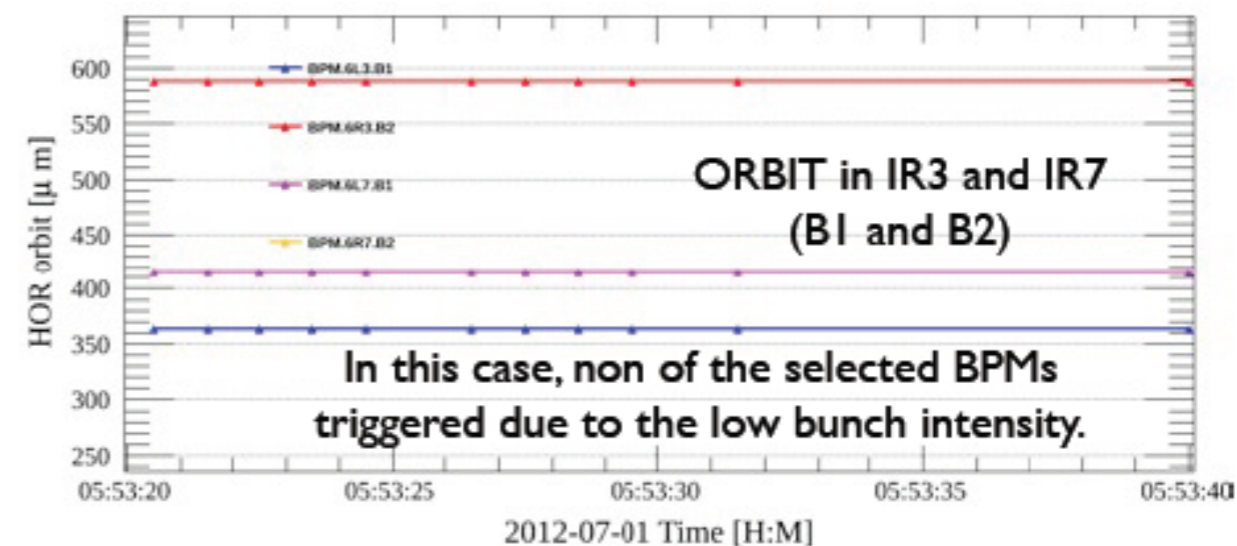
off-momentum losses appear when the beam is at 4-5 nominal sigmas of the collimator jaw. (TCP IR3)

We cannot promise now (beam tests are needed) but it seems possible to find a frequency with higher losses in IR3 before dumping.

Off-momentum loss maps: The efficiency bottle-neck!



Dedicated beam commissioning required!



Conclusion from the 4 cases analyzed:

The maximum loss at the TCP in IR3 occurs when we reach around +/- 150 to 200Hz frequency change.

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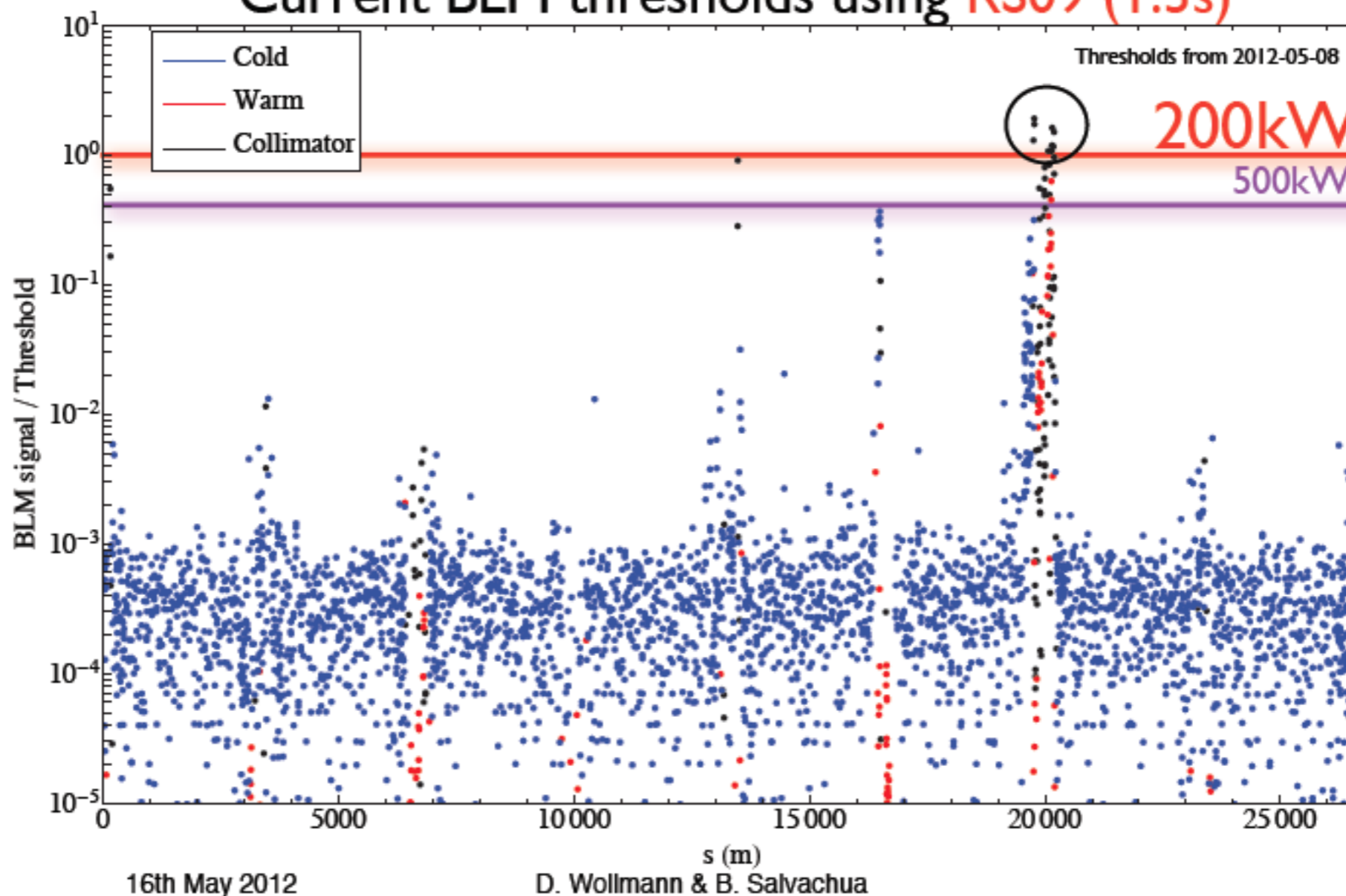
We cannot promise now (beam tests are needed) but it seems possible to find a frequency with higher losses in IR3 before dumping.

Some considerations

- **The bottle-neck:** two nominal bunches are required for establishing and optimizing collisions.
 - i.e. we need 2 nominal + non-colliding probes (1 per plane) for loss maps.
- **Constraint from BPM intensity sensitivity:**
 - will not allow nominal bunches to be reduced to pilot intensities safe for alignments / loss maps.
 - sensitivity limit: $5E10$ for all BPMs, now reduced to $2E10$ for interlocked BPMs (E. Calvo).
- **If the SBF is too low:**
 - we may need to do loss maps with unsafe beam and without masking the BLMs.
 - What is the max RF trim which we can apply for off-momentum loss maps?
 - More creative schemes: alignment with emittance blow-up, remove intensity margin just before loss maps.

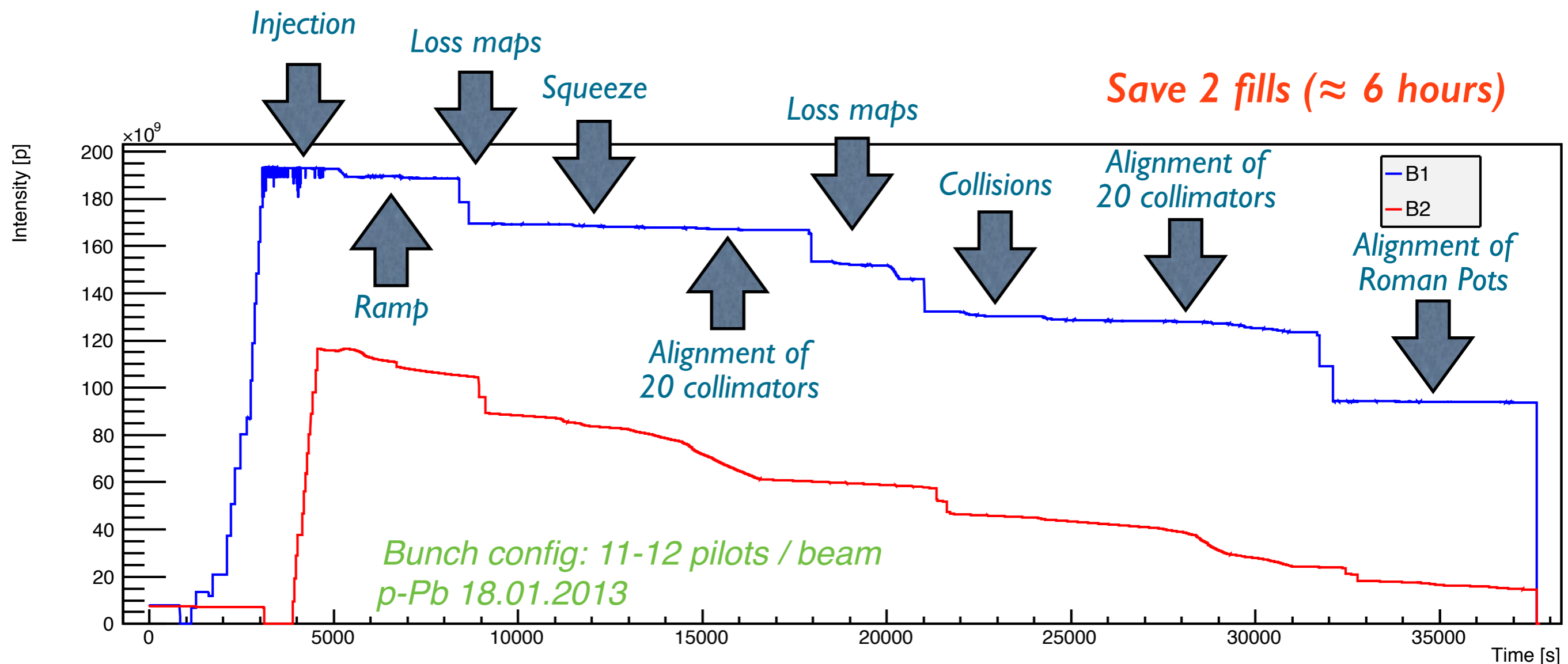
Margin to dump during loss maps in 2012

Comparison of expected losses for 200kW with
Current BLM thresholds using **RS09 (1.3s)**



- If intensity > SBF, we may be limited by BLM thresholds during loss maps (no masking).
- Only one example, no time for a detailed study..

- As of 2012, it is possible to complete the alignment of all 86 ring collimators in a single fill.
- Thanks to the ADT, it is also possible to align in different machine modes and perform qualification loss maps at each stage:



- Not representative of the p-p run, but could aim for 2 nominal + pilots after experience is gained.

What we would need..

- For the start-up commissioning (1-2 fill per machine mode; 3rd fill for async dump):

Same fill

Same fill

	Alignment		Betatron Loss Maps		Momentum loss maps	
Machine Mode	Intensity (E11)	Bunch Config	Intensity (E11)	Bunch Config	Intensity (E11)	Bunch Config
Injection	2	2 nominal	2	2 nominal (H/V)	2	2 nominal
Flat Top	1.5	1 nominal	1.5	2 probes (H/V)	1.5 / 1*	prev. config / 1 nominal*
After Squeeze	1.5	1 nominal	1.5	2 probes (H/V)	1.5 / 1*	prev. config / 1 nominal*
Collisions	2.2	2 nominal	2.2	2 nominal + 2 non-coll probes (H/V)	2.2 / 1*	prev. config / 1 nominal*

*if we dump on the first off-momentum loss map and have to re-fill

What we would need..

- For the start-up commissioning (1-2 fill per machine mode; 3rd fill for async dump):

Machine Mode	Alignment		Betatron Loss Maps		Momentum loss maps	
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Flat Top	1.5	1 nominal	1.5	2 probes (H/V)	1.5 / 1*	prev. config / 1 nominal*
After Squeeze	1.5	1 nominal	1.5	2 probes (H/V)	1.5 / 1*	prev. config / 1 nominal*
Collisions	2.2	2 nominal	2.2	2 nominal + 2 non-coll probes (H/V)	2.2 / 1*	prev. config / 1 nominal*

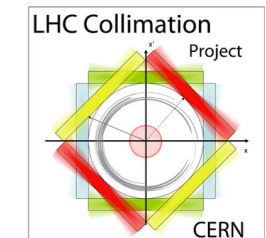
***if we dump on the first off-momentum loss map and have to re-fill**

- For eventual frequent configuration changes which require alignments and loss maps, we can have 1 fill for squeeze + colliding, and inject 2.5E11 p directly from the start.
- Once experience is gained with embedded BPMs in TCTs, alignment in squeeze + collisions won't consume any intensity.
- Would prefer 3 nominal bunches for collisions for operational margin..

- Alignments have been performed with low intensities (down to $5E9$ p) **without** issues in measuring the beam centre, but **with** issues in measuring the beam size. Typical consumption for a full alignment is $5E10$ p.
- A minimum intensity of $8E9$ p is required to obtain a loss map from which the cleaning efficiency can be measured.
- Reducing the allowed intensity for alignment and loss maps **could reduce the operational efficiency**. The **bottle-neck** is the requirement of 2 nominal bunches to align and qualify the machine in collisions mode.
- Proposal to move in BPM-equipped TCSP in IR6 with IR7 TCP during alignment to increase protection in the event of asynch dump (as done for some TOTEM data-taking runs).
- **Other:**
 - **New embedded collimator BPMs:** M. Gasior confirms that it will be possible to make orbit measurements at beam intensities of $5E9$ p.
 - **Roman pot alignment + data-taking:** request 2 bunches of $7E10$ due to pile-up (M. Deile).

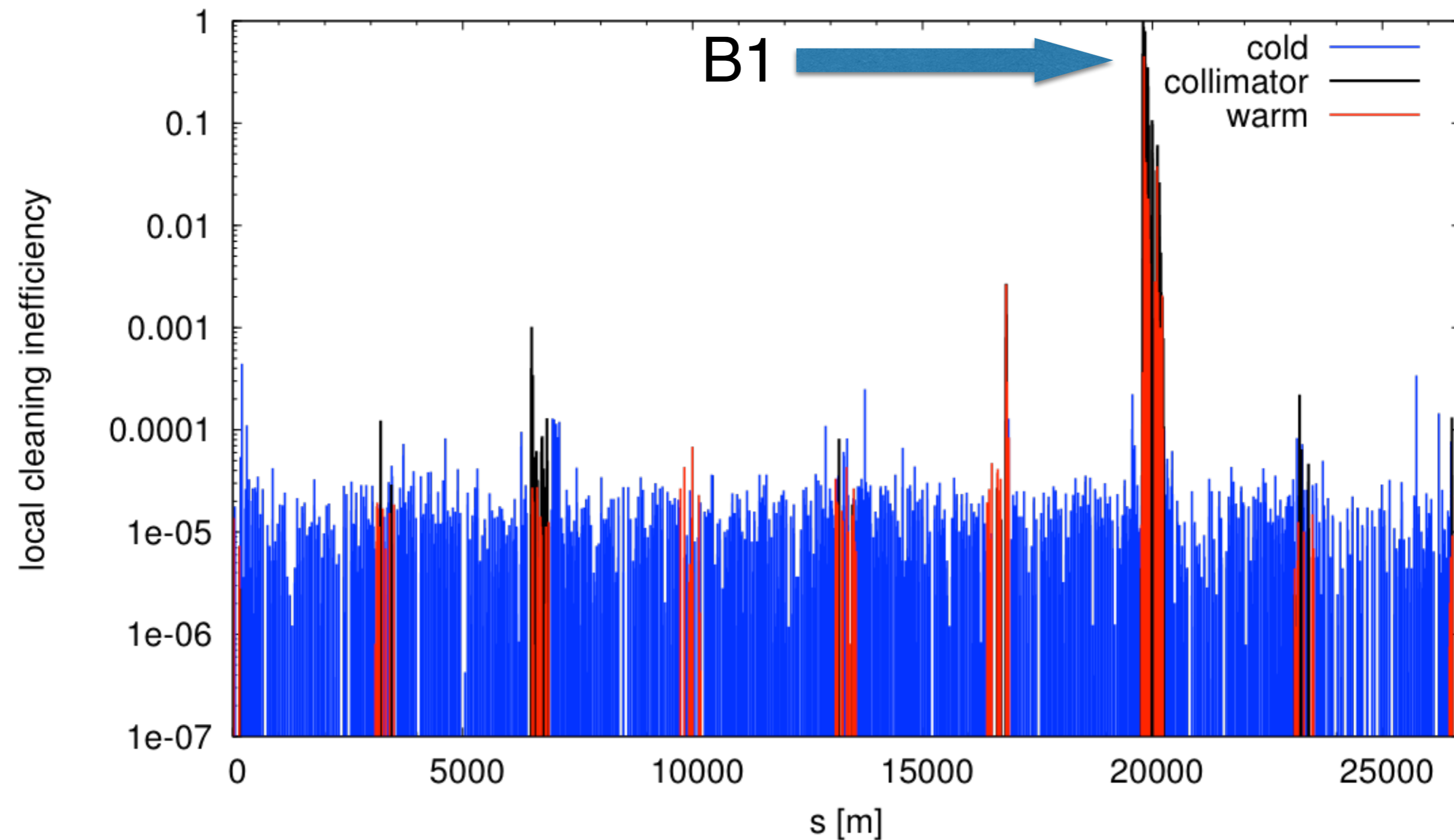


Reserve Slides



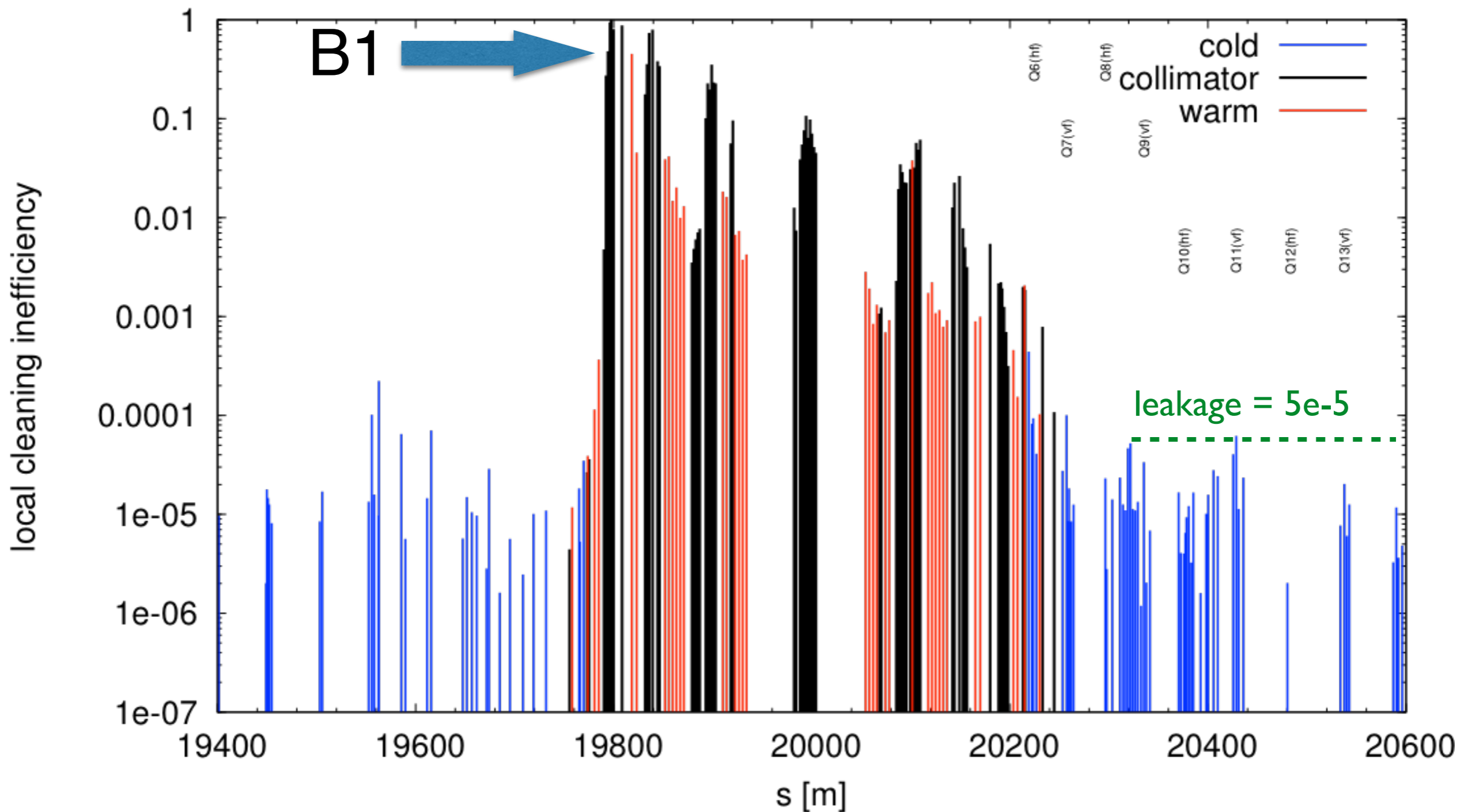
Typical betatron loss map

betatron losses B1 4000GeV hor norm F (2012.04.02, 23:17:01)



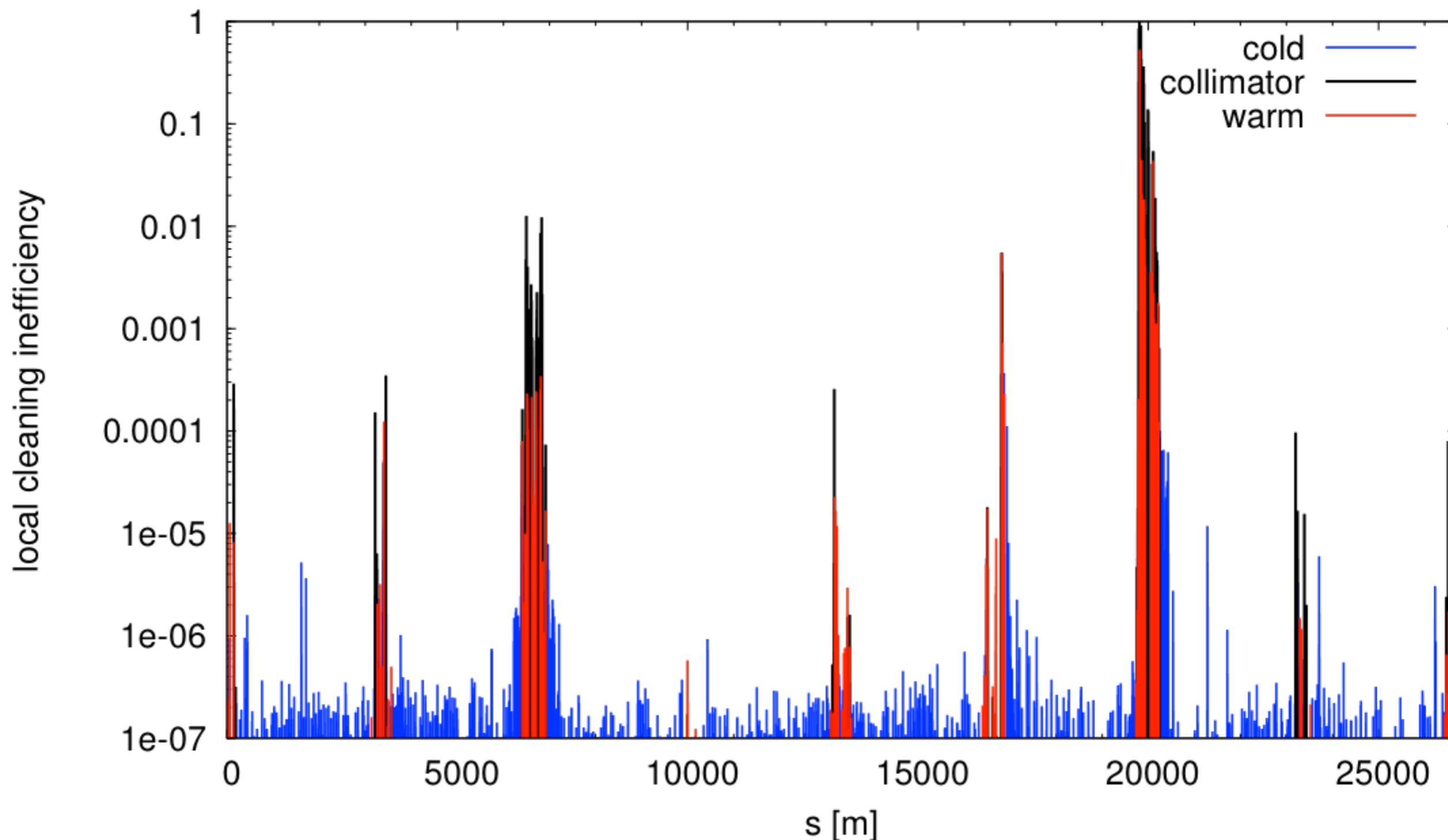
Zoom in IR7

betatron losses B1 4000GeV hor norm IR7 (2012.04.02, 23:17:01)



Typical off-momentum loss map

momentum losses B1 and B2 4000GeV neg offset norm F (2012.04.02, 23:58:03)



Zoom in IR3

momentum losses B1 and B2 4000GeV neg offset norm IR3 (2012.04.02, 23:58:03)

