Multi-turn Losses and Cleaning in 2011 and 2012

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  - Alignment and Qualification Requirements
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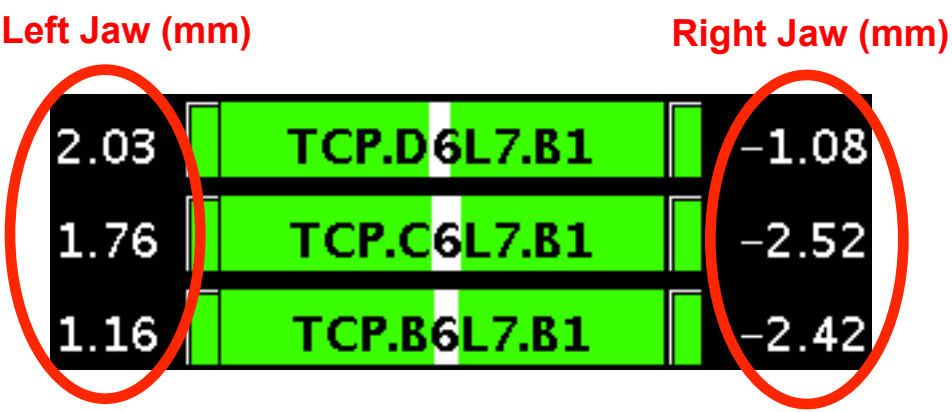
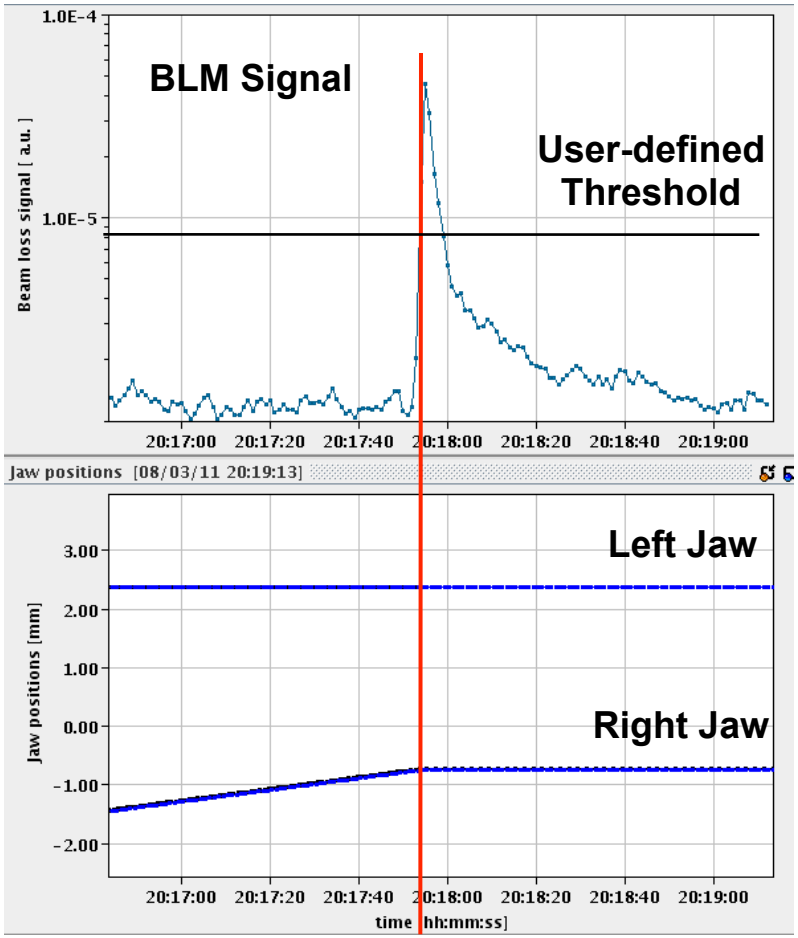
Introduction – LHC Collimation System

- Multi-stage cleaning and multi-turn losses.
- Momentum cleaning in IR3, betatron cleaning in IR7.
- No beam-induced quenches so far!
- Jaw gaps of **~3 – 4 mm** maintained throughout 2011:

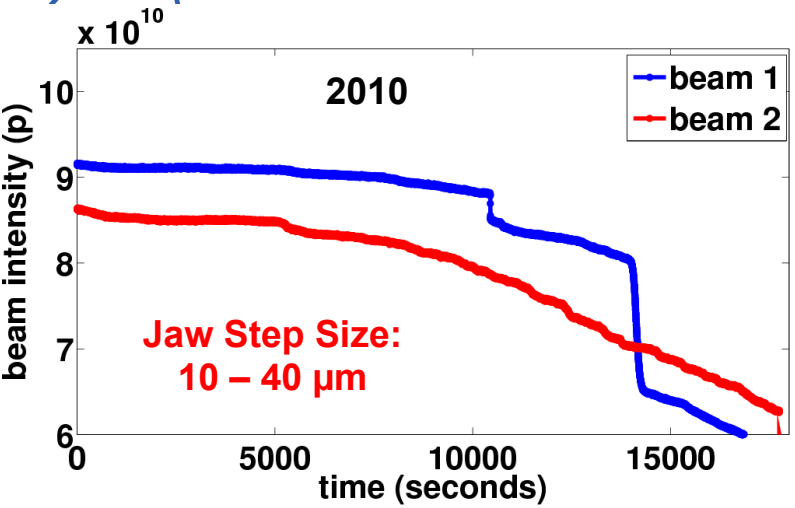


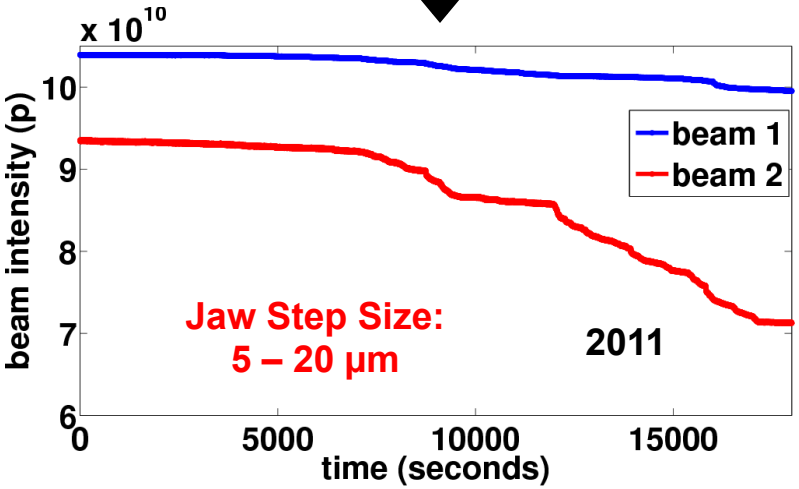
Collimator Beam-Based Alignment

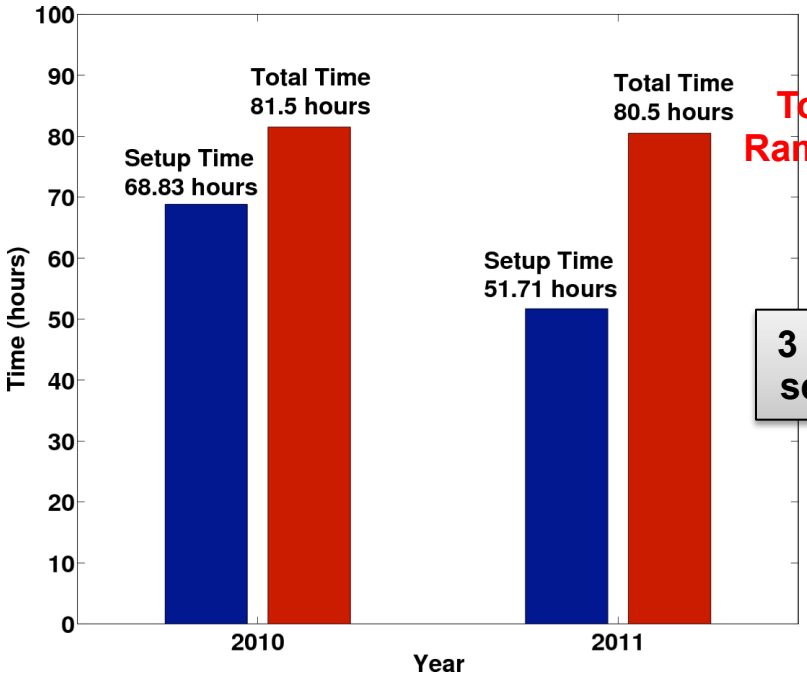
- **Aim of Beam-Based Collimator Alignment**
  - Determine the beam centres and sizes at the collimators
  - Maintain the correct collimation hierarchy
- **Jaw moved to the beam until a BLM loss spike is observed**
- **Semi-Automatic Setup Algorithm for 2011**
  (G. Valentino et al., IPAC 2011)
  - Jaw moves automatically and stops when BLM signal exceeds user-defined threshold
  - Parallel setup speeds up alignment
- **BLM Data Rate: 1 Hz**
- **Collimator Movement: 5 – 20 μm every second**



Setup Highlights of 2010 and 2011

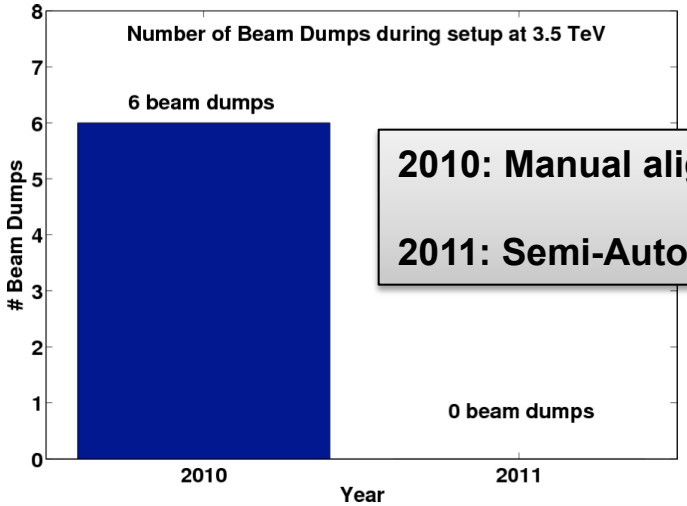






Total Time incl. Ramp, Squeeze, …

3 more 3.5 TeV setups in 2011



2010: Manual alignment

2011: Semi-Automatic Alignment

Collimation Hierarchy and Tolerances

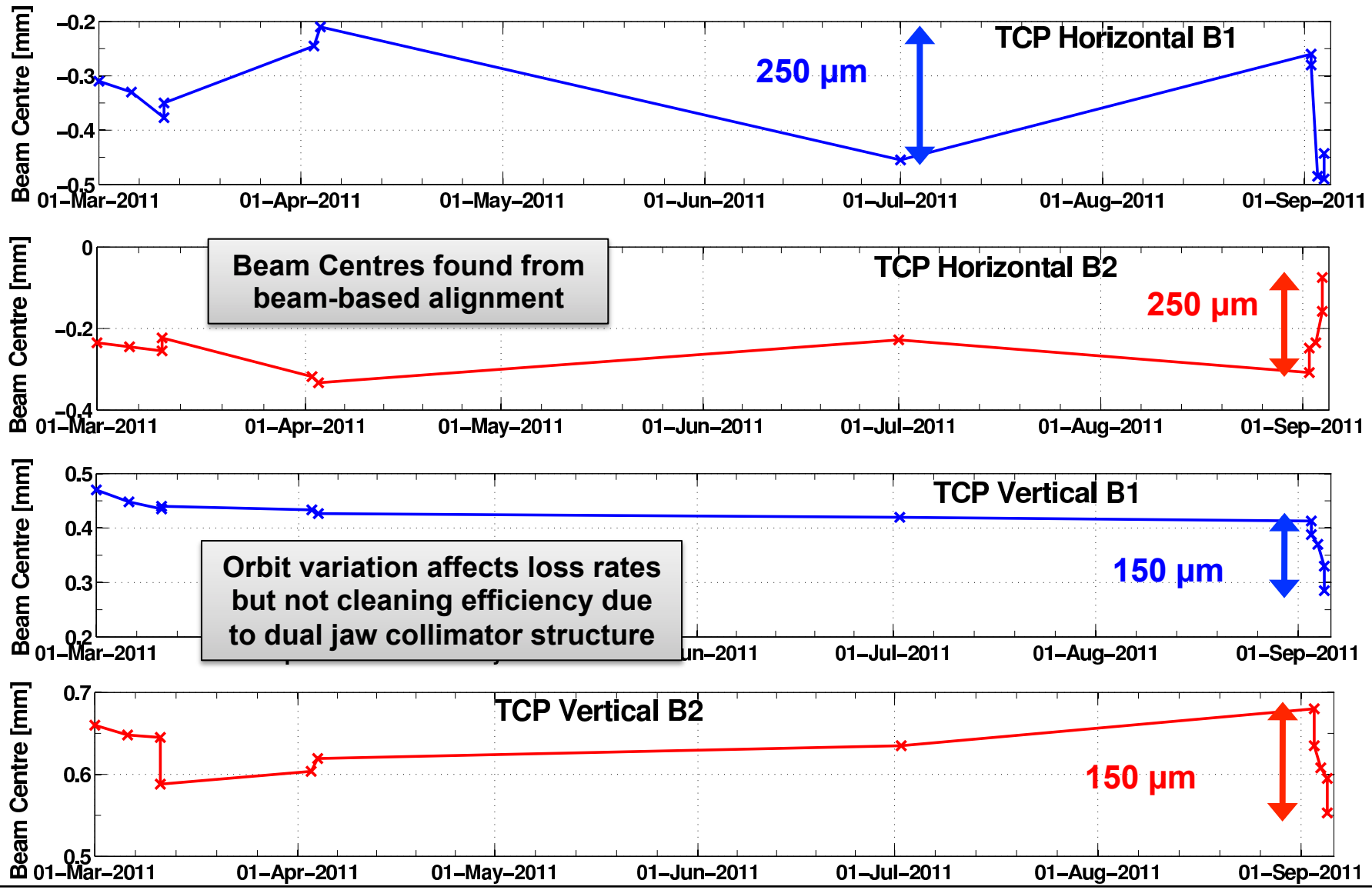
- Overview of the different collimator settings and the corresponding TCP-TCSG margins:

Collimator	Relaxed 3.5 TeV	Tight 3.5 TeV	Tight 4 TeV	Nominal 7 TeV
TCP IR7	5.7	4	4	6
TCSG IR7	8.5	6	6	7
Margin [σ]	2.8	2	2	1
Margin [μm]	1050	750	728	274

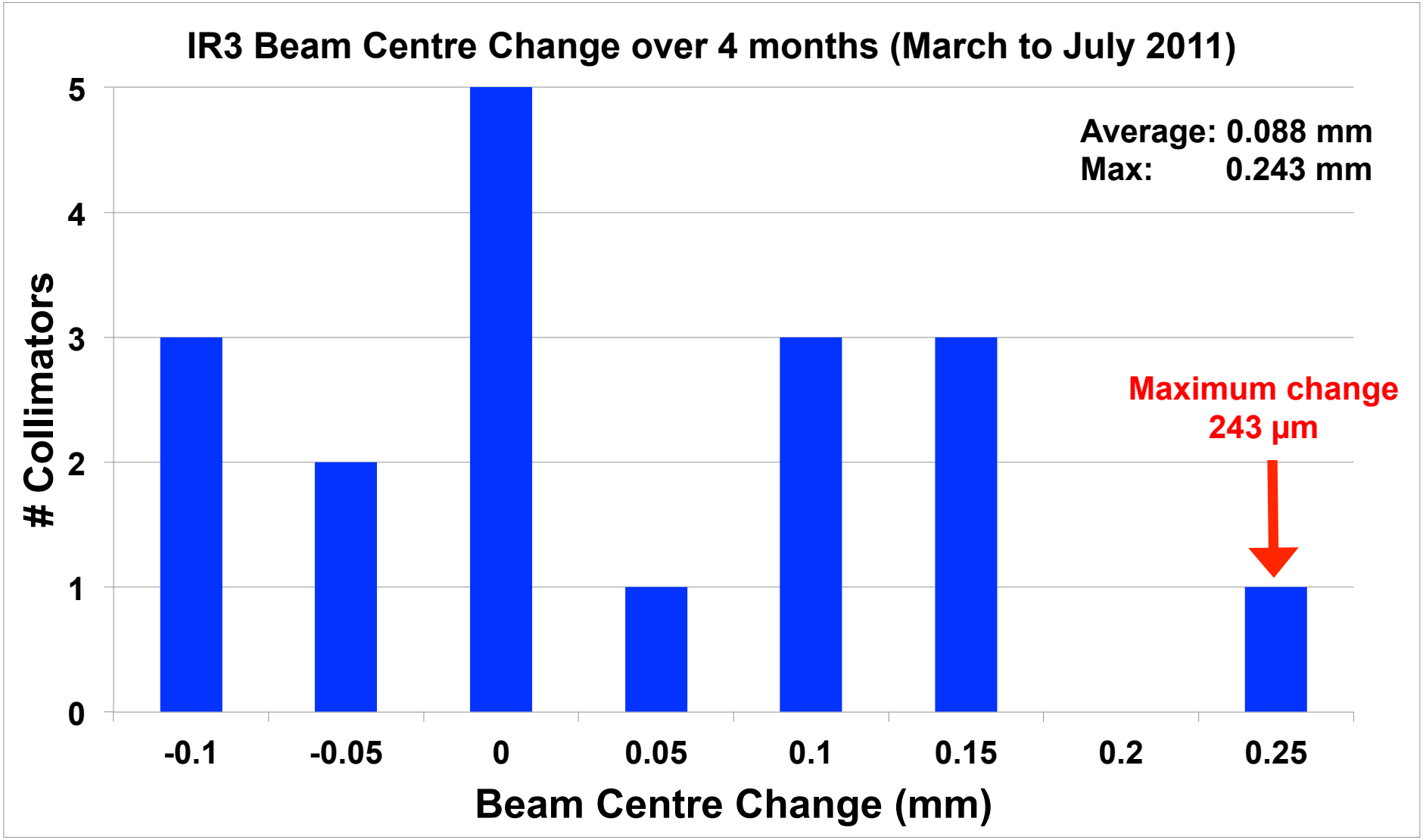
Margin between TCP and TCSG

Currently operational | **Tested in Tight Settings MD** | **2012 ?**

Setup Stability (1) – TCP Hor & Ver



Setup Stability (2) – IR3 collimators



ALICE Polarity Inversion: Beam-Based Alignment vs Orbit Model

- Polarity of ALICE dipole and solenoid switched from negative to positive for ions.

- Beam-based alignment re-done for vertical TCTs in IR2.

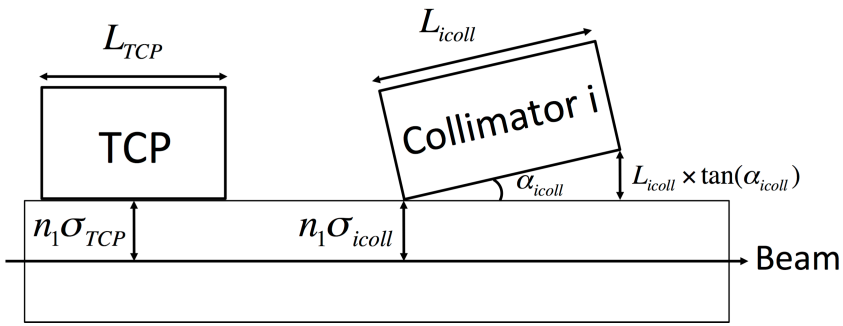
Collimator	Change in Centre (mm)			Difference between Alignment & Model (mm)
	Orbit Model	Beam-Based Alignment	BPM Interpolation	
TCTV IR2 B1	**- 4.698**	**- 4.805**	**- 4.55**	**- 0.107**
TCTV IR2 B2	**- 4.824**	**- 4.840**	**- 4.75**	**- 0.016**

Orbit model data provided by J. Wenninger

- **Good comparison** between measured and predicted beam centre shifts.

Collimator Misalignments

- Large beam sizes observed for TCTH.4L2.B1, TCLA.A7L7.B1, TCSG.A5L3.B2 w.r.t. nominal.
- Misalignments corrected in March Technical Stop **> 1.6 mrad found** (O. Aberle, P. Bestmann et al.)
- Beam-based alignment re-done after correction.



Adapted from R. W. Assmann & B. Goddard

- Before tunnel alignment:

Collimator	$\Delta\sigma_{icoll}$ (mm)	n_1	α (mrad)
TCTH.4L2.B1	0.424	3.63	**1.5**
TCLA.A7L7.B1	0.400	4.40	**1.7**
TCSG.A5L3.B2	0.442	3.68	**1.6**

- After tunnel alignment:

Collimator	$\Delta\sigma_{icoll}$ (mm)	n_1	α (mrad)
TCTH.4L2.B1	0.144	4.38	**0.6**
TCLA.A7L7.B1	0.064	4.64	**0.27**
TCSG.A5L3.B2	0.080	4.56	**0.3**

$$\alpha_{icoll} = \tan^{-1}\left(\frac{2n_1\Delta\sigma_{icoll} - \Delta icoll}{2}\right)$$

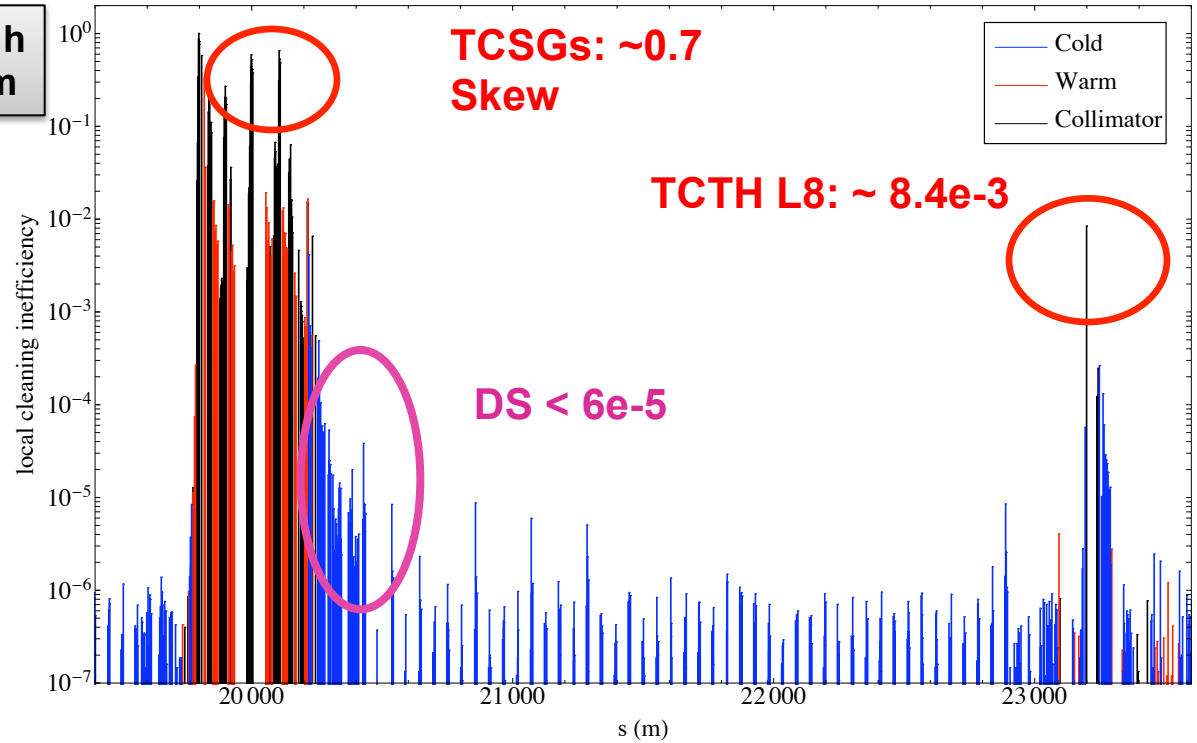
→ **Without β-beat effect (~ 5% to 10%)**

$\Delta\sigma_{icoll}$:- error in measured gap w.r.t. nominal
$\Delta icoll$:- measured position vs actual position error
α_{icoll} :- misalignment angle
L_{icoll} :- length of collimator
n_1 :- cut of TCP in units of sigma

Collimation Hierarchy Breakdown?

- Hierarchy breakdown observed on 02/04/2011 from loss map.
- Problems with the TCSG.D5R7.B1 (losses only factor 2 below TCP).
- B1 skew collimators re-aligned as a precautionary measure but same centres found (± 80 μm).
- **Causes: BPM filling pattern dependent shift + lost margin (power cut) + ver. loss map before hor. loss map** (see D. Wollmann and R. W. Assmann LMC talk for detailed analyses)

450 GeV B1 h
IR 7–8 Zoom



factor 260 times higher losses into IR8!

Courtesy of D. Wollmann

Collimation Qualification

- Collimation system hierarchy regularly qualified by creating multi-turn losses.
- **Betatron Losses:** cross a third integer tune resonance to create horizontal and vertical losses.
- **Momentum Losses:** change the RF frequency by ± 1000 Hz for positive and negative momentum offsets.
- Performed with one nominal bunch at 450 GeV and 3.5 TeV.
- Requires two dedicated fills: 30-50% of the beam is lost in 1-2s.
- Collimators are re-aligned to correct any anomalies in the hierarchy.
- The local cleaning inefficiency at any point in the ring is determined from the ratio to the highest loss:
  - E.g. cold aperture:

$$\eta_c = \frac{\text{Highest Leakage in Cold Aperture}}{\text{Highest Losses in TCP}}$$

Beam Time needed for Qualification

- **26 qualifications at injection** (450 GeV)
- Different settings: injection protection collimators IN / OUT (now doing both)
- 6 loss maps performed as EOF, 20 loss maps required dedicated fill
- **Total: 21.5 hours in 2011 (including overhead for dedicated fills)**

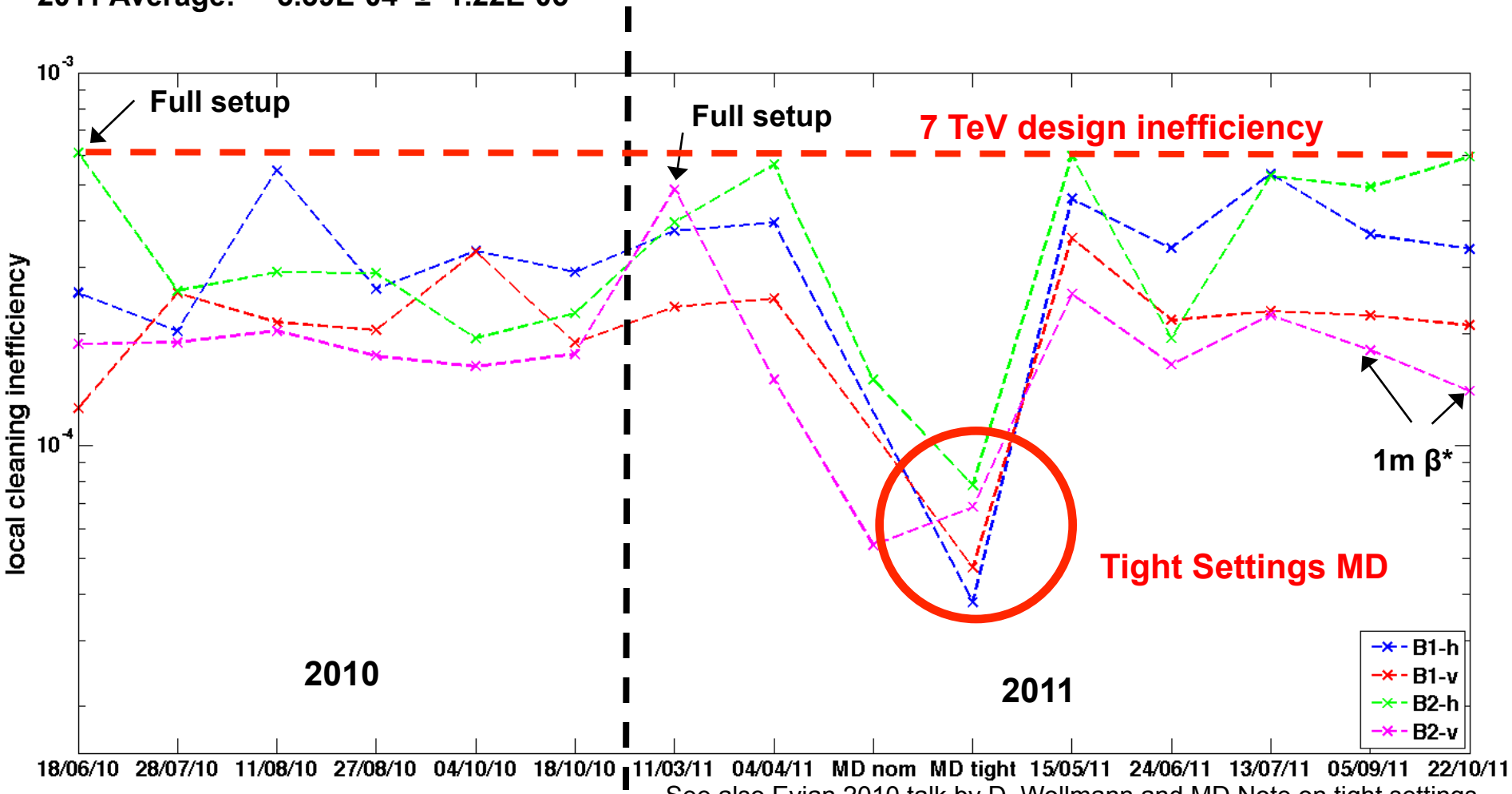
- **33 qualifications at 3.5 TeV**
- Different settings: flat top, squeezed, colliding, crossing angle, …
- 15 loss maps performed as EOF, 18 loss maps required dedicated fill
- **Total: 31.5 hours in 2011 (including overhead for dedicated fills)**

- **Grand Total: 53 hours (including overhead for dedicated fills)**

Proton Cleaning Inefficiency 2010/2011
3.5 TeV, 1.3s integration time (Q8 IR7)

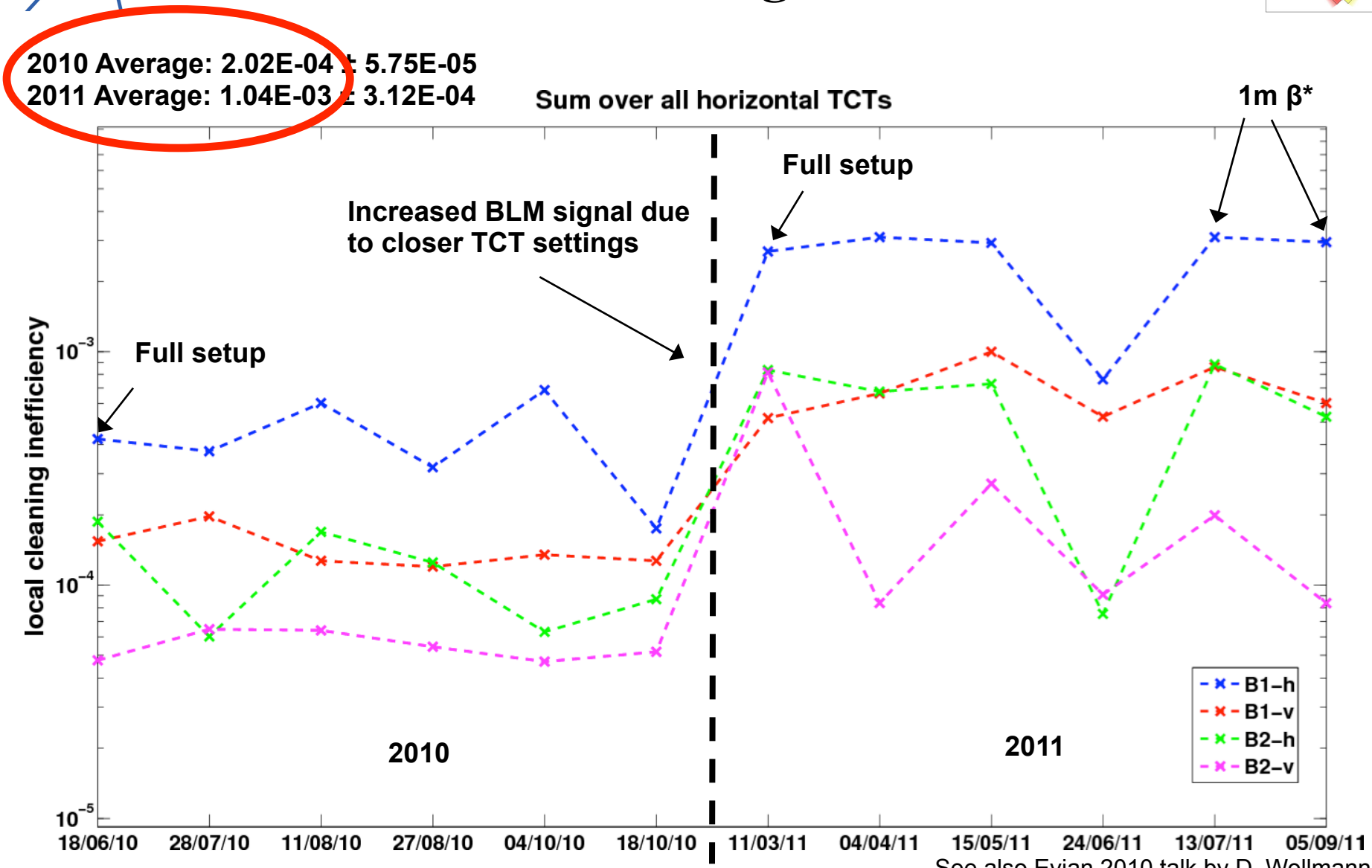
2010 Average: 2.57E-04 ± 6.69E-05
2011 Average: 3.39E-04 ± 1.22E-05

Cleaning Inefficiency in 2011 consistent with 2010



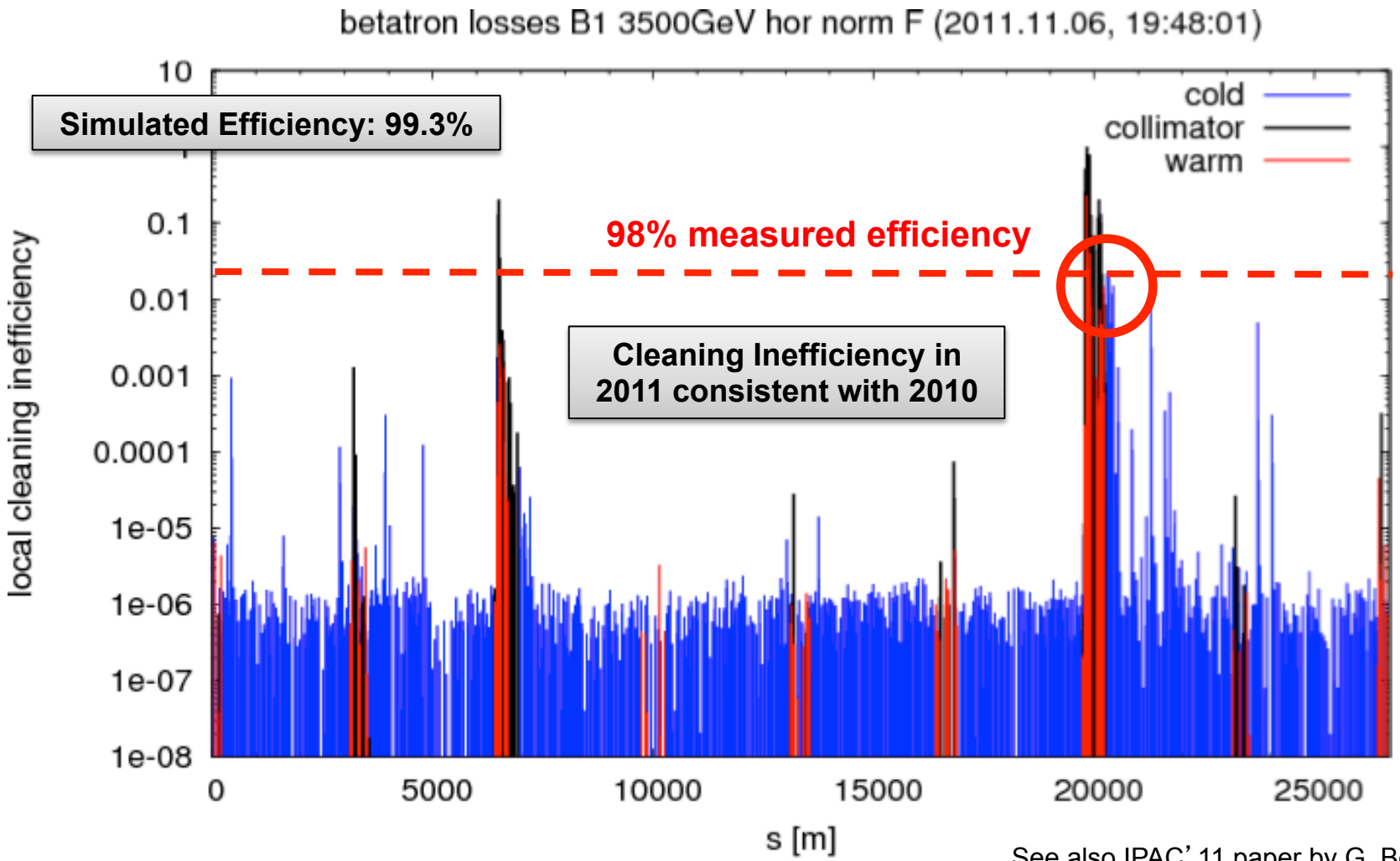
See also Evian 2010 talk by D. Wollmann and MD Note on tight settings

Leakage into horizontal tertiary collimators 3.5 TeV, 1.3s integration time



See also Evian 2010 talk by D. Wollmann

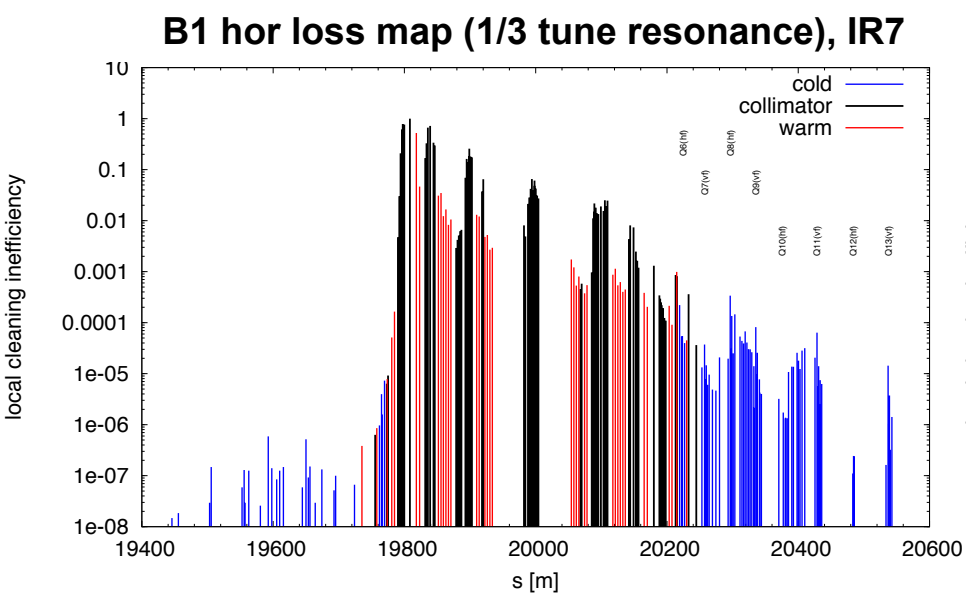
Ion Cleaning Inefficiency in 2011
3.5 TeV, 1.3s integration time

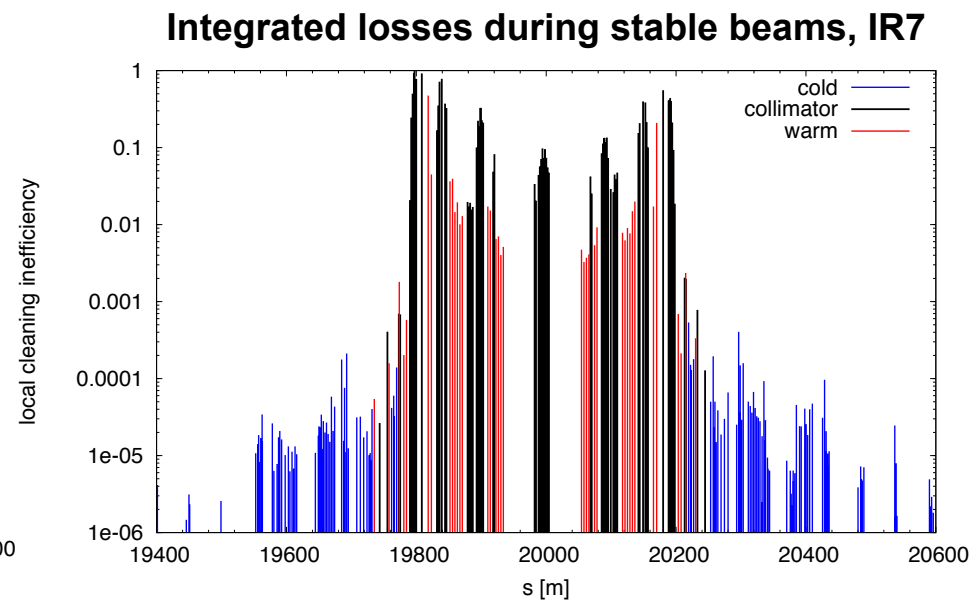


See also IPAC' 11 paper by G. Bellodi

Online Loss Maps

- Work in progress for online loss map display (BLM team, F. Follin).
- Attempt to decompose the losses observed during stable beams into separate horizontal and vertical B1 and B2 components with Singular Value Decomposition.
- Technique described in IPAC'11 paper (A. Marsili et al.)
- **Goal:** continuous monitoring of cleaning efficiency without need for dedicated fills.





Fast Automatic Collimator Setup

Faster alignment:

- Ongoing work to improve BLM data and collimator movement rates by **factor ~10** (thanks to R. W. Assmann, B. Dehning, A. Masi, S. Redaelli, C. Zamantzas)

Automatic alignment:

- Pattern recognition of BLM loss spikes during setup (up till now ~90% accuracy)
- Learning algorithm will be trained on simulator to make decisions taken by expert during alignment.
- Decisions include: Loss threshold selection, jaw step size, step repetition rate

→ decisions based on BLM signal

Alignment and Qualification Requirements for 2012

- **Collimator Alignment:**
  - Required frequency: **once per year** (except alignments due to change in optics).
  - Beam time required for a full collimator alignment (86 collimators) expected to decrease from ~18 hours to **~6 hours.**
  - Aim for **tight settings in 2012**.

- **Collimation Qualification**
  - **In 2011**: **7 full qualifications** (~1 per month).
  - Tight settings: valid over full year (as verified in MD).
  - **In 2012**: **3 full qualifications** (e.g. April / July / October) + online loss maps.
  - **ADT blow up method:** MD requested, see IPAC'12 paper (W. Höfle et al.)

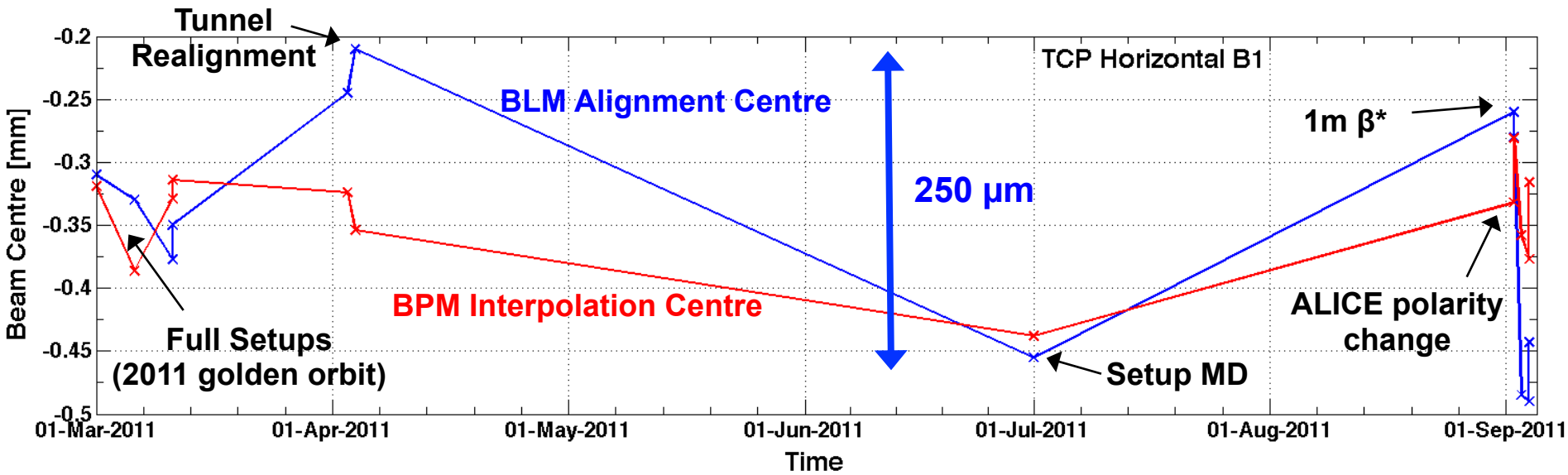
- **Further Work & Info**
  - See talks at Chamonix 2012: R. W. Assmann (intensity limits), R. Bruce (tight collimator settings), S. Redaelli (upgrade needs).

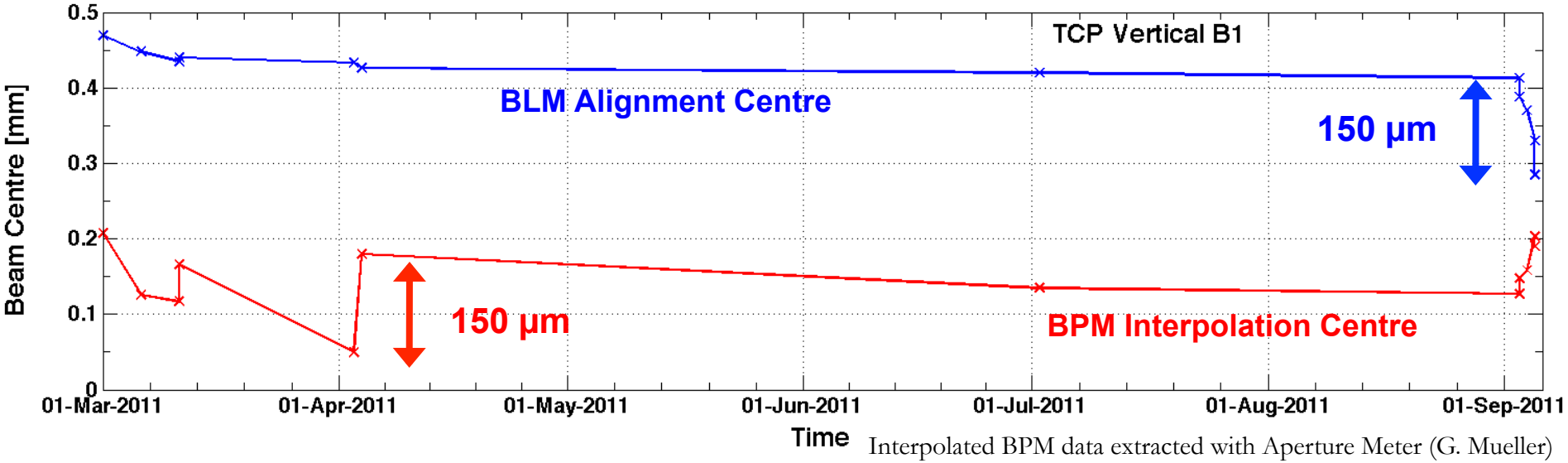
Summary

- Proton cleaning efficiency of **99.97%** for 2010 maintained in 2011.
- Semi-automatic tool has improved collimator operation during alignment (reduced setup time and eliminated beam dumps during setup).
- Collimator misalignments can be detected from beam-based setup.
- Aim for **tight collimator settings in 2012**: should improve efficiency by **factor ~8**, but reduce TCP-TCSG margin by **factor ~1.5** at 4 TeV.
- Aim for **qualifications every 3 months**, complemented by online monitoring.
- Work in progress: **-** Faster and fully automatic setup procedure (~6 hours)
  - **-** Online loss maps
  - **-** ADT blow up qualification method

RESERVE SLIDES

BPM Interpolation Comparison





Interpolated BPM data extracted with Aperture Meter (G. Mueller)

Leakage into vertical tertiary collimators
3.5 TeV, 1.3s integration time