Transfer and injection into LHC, is this a bottleneck?

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Acknowledgments: BLM, OP, CO, RF, MPE, Collimation team

Outline

- Operation achievement in 2011
- Issues and possible limitations
- Studies for future operation (nominal emittance, 25 ns bunch spacing)
- Summary and Conclusions

Losses at Injection and Intensity Limitations

- Loss maxima per injected intensity (Verena's talk)

2010 ↓ 2011

Loss type	Losses in % of dump threshold B1/B2						
	8b	16b	24b	32b	48b	*96b*	*144b*
TCDI shower	1/2	3/5	4/6	5/8	23/24	*<50?*	*<75?*
Uncaptured beam	4/2	12/3	12/5	16/8	20/8	*<40?*	*<60?*

Unsafe beam (> 1×10^{12} p^+)

Linear extrapolation for 2011 operation, still ok without mitigation

Operation related intensity limitations, **no machine protection issue!!**

- Possible solutions for higher intensity:
  - Un-captured beam:
    - Abort gap and injection cleaning
    - Improved injectors diagnostics
    - TDI Shielding (×10 reduction at MQX BLMs)
    - ! BLM sunglasses
  - Cross-talks from TCDI:
    - TCDI shielding
    - TCDI larger aperture
    - ! BLM sunglasses
    - Increase BLM thresholds for short running sums

Presented in Chamonix 2011

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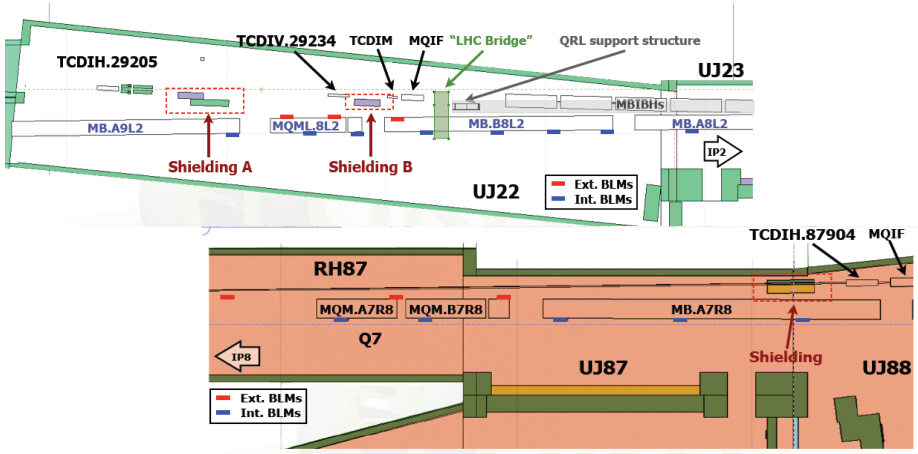
Presented in Chamonix 2011

Injection with 144 bunches is now operational !

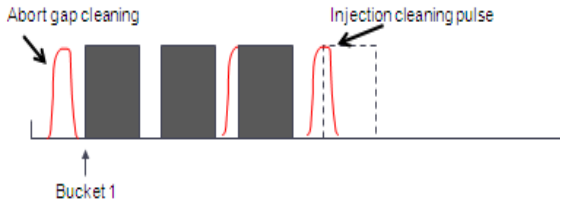
Applied Mitigations

Shielding to reduce crosstalk losses from TCDI installed in TI 2 and TI 8

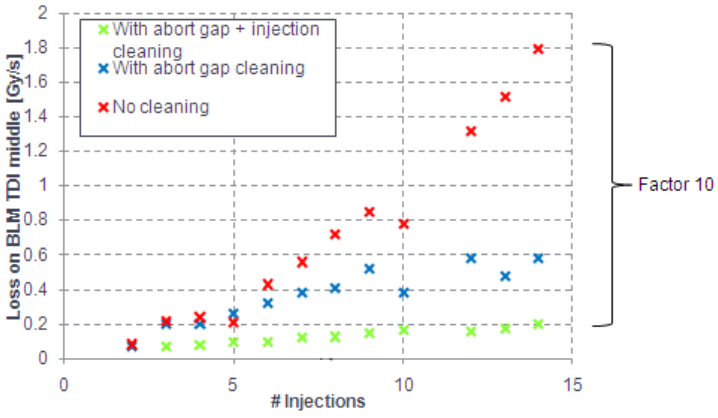


Loss reduction at downstream magnets by a factor of 2-3. Good agreement with FLUKA simulations: factor 4 predicted

Injection and abort gap cleaning to reduce losses at TDI and downstream elements



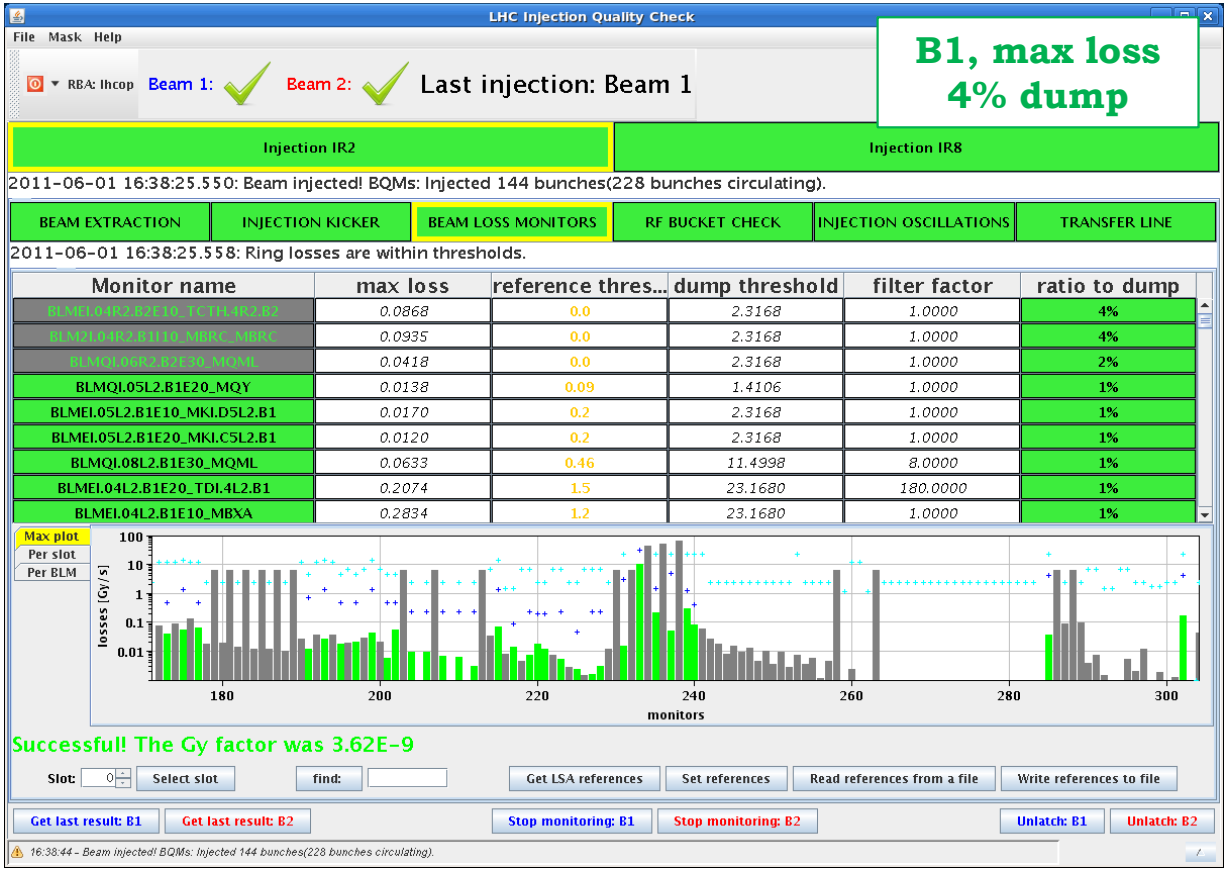
V. Kain, Chamonix 2011



Now operational (sequencer)

2011 Operation with 144 bunches

- First injection of 144 bunches for Physics (1st June)



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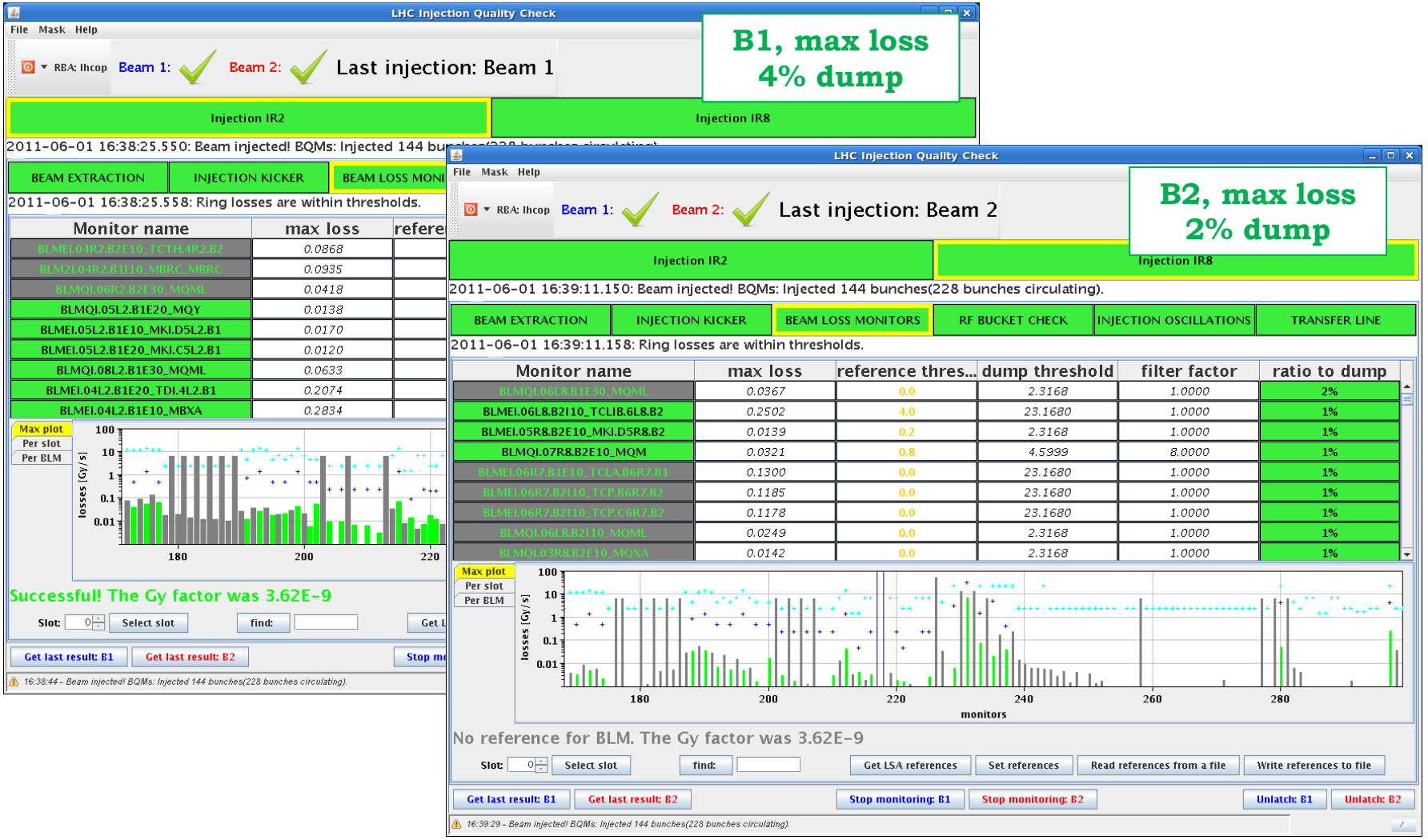
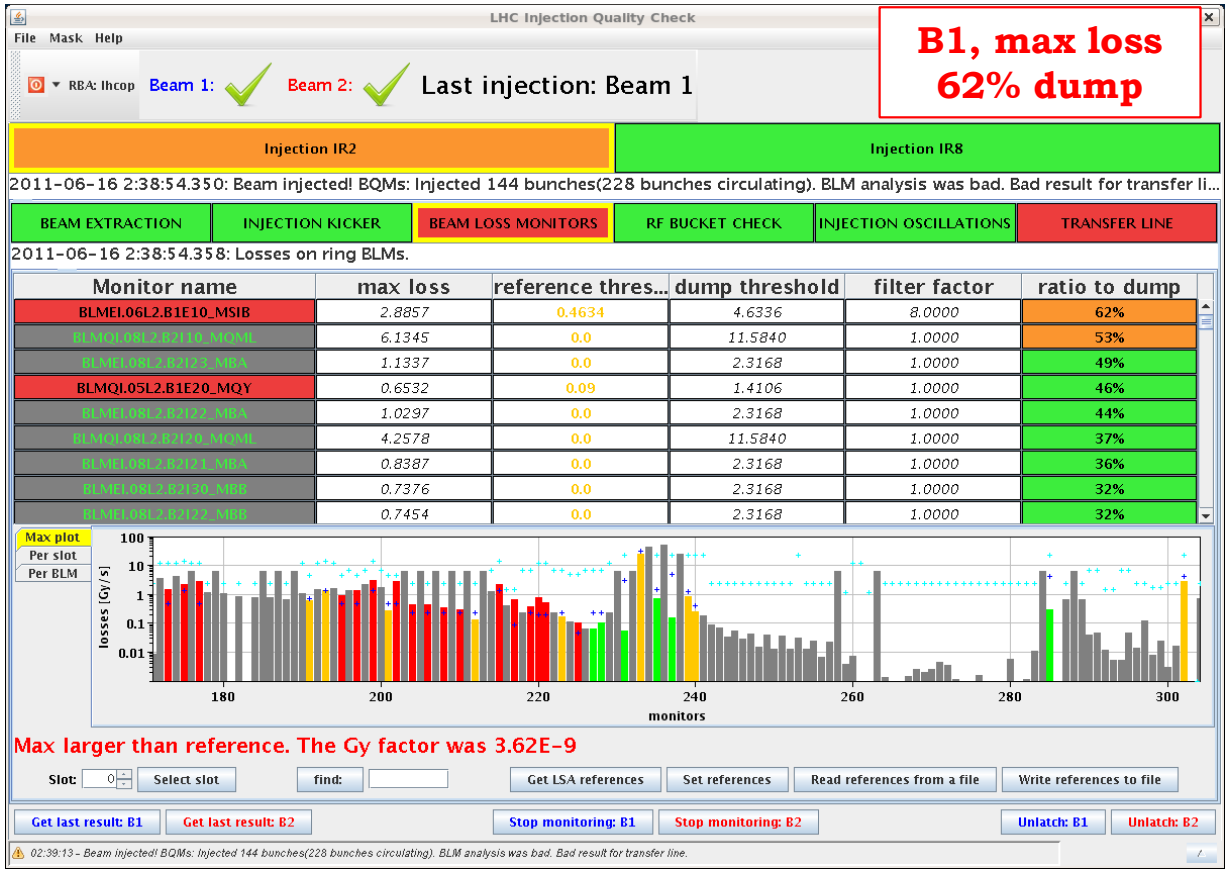


2011 Operation with 144 bunches

- Injection degradation for B1 (16th June)



2011 Operation with 144 bunches

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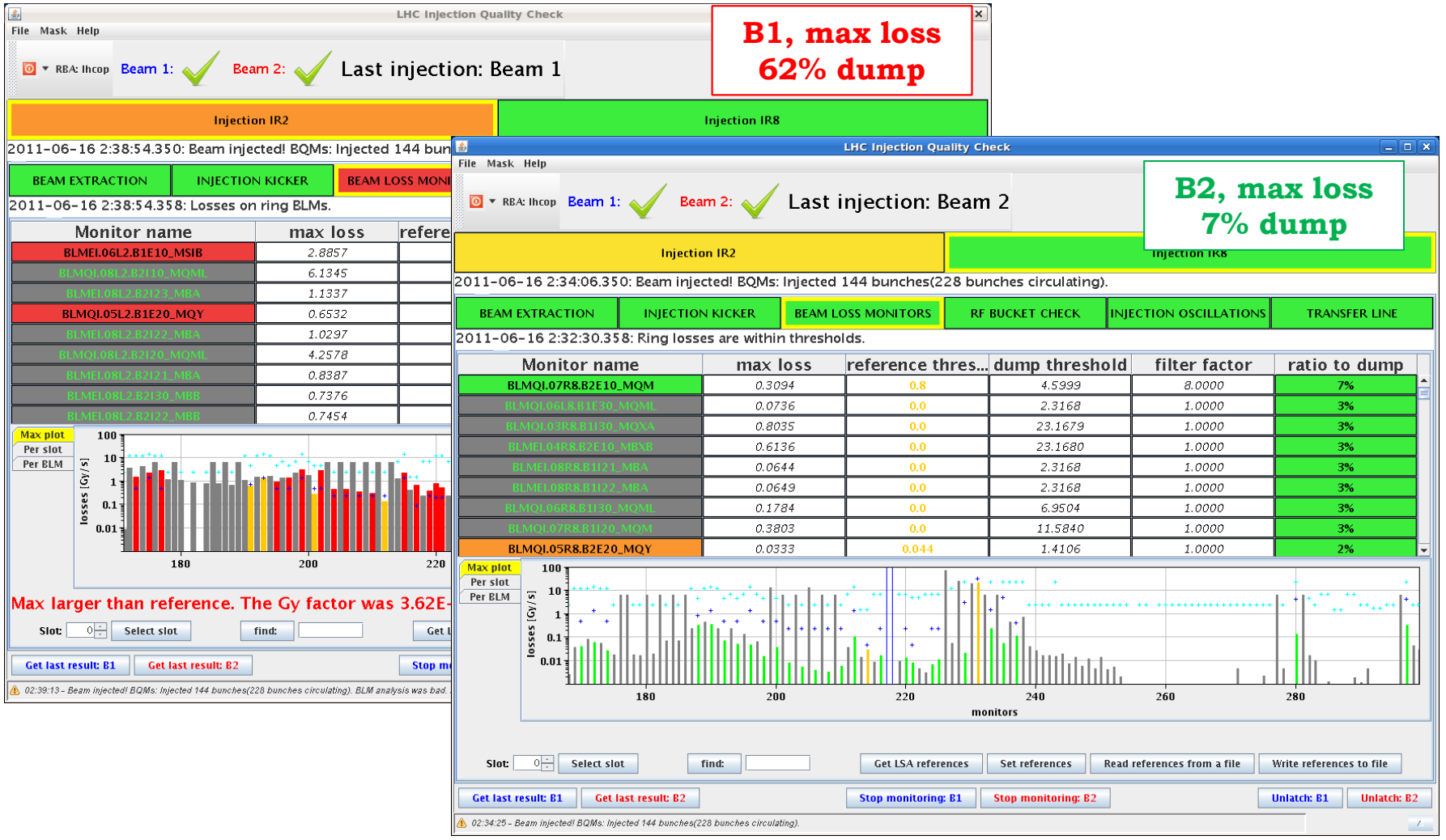

Observations on B1

- TL trajectories were not reproducible from shot to shot ➔ different corrections proposed by YASP
- Local variations of trajectory at the location of the TCDI (end of the line: 29012-29509)
- High loss level at the MSIB already when injecting 12 bunches (5%)
- 500-600 μm oscillations coming from the line
- Difficult to correct and to find a good **tradeoff** between **injection oscillations** and **losses**

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Why is Beam 1 more critical?

1. Flattop of the SPS extraction kicker (MKE) longer for B1 than for B2 ➔ more **satellites** from the SPS?
2. MST septum in extraction channel
3. High dispersion collimator close to the end of the line (29205) ➔ more sensitive to any Δp or wrong SPS harmonic?
4. Higher sensitivity to steering ?

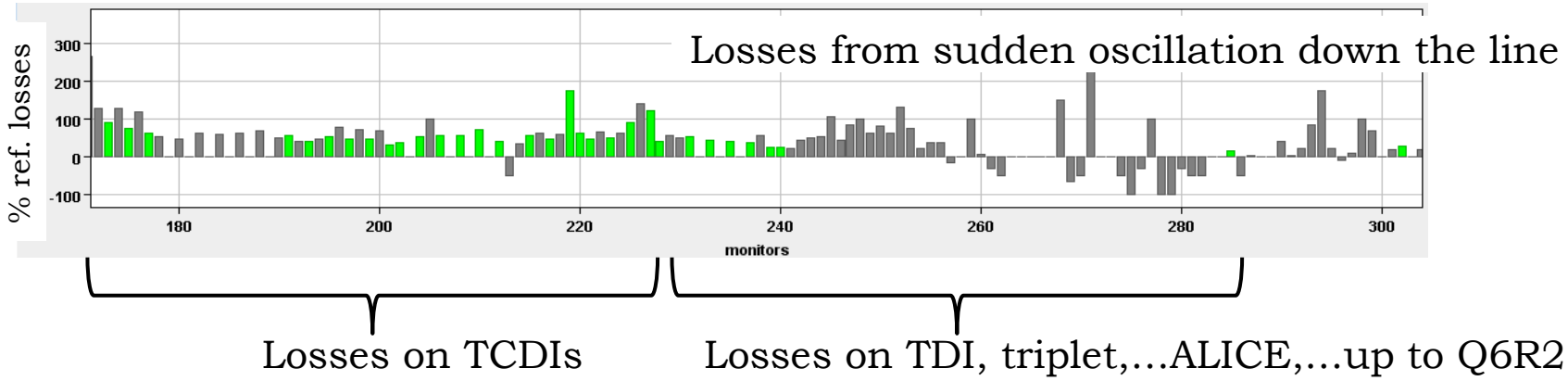
Dedicated MD to investigate these options and to check operation with **nominal emittance**.

MD: Effect of longitudinal parameters

Most cases gave low/same losses as reference:

- Bad radial steering
- Satellites from PS
- RF on for all booster rings
- SPS 800 MHz on wrong harmonic

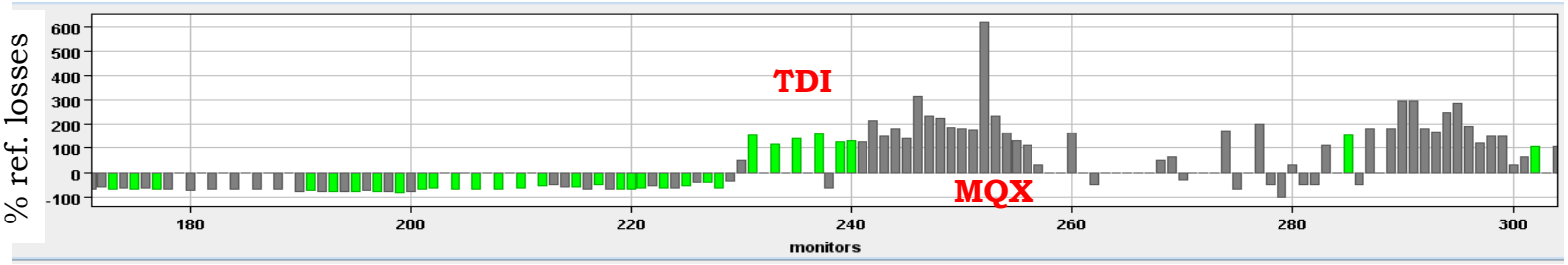
- Radial steering affected the scraping efficiency – but: radial steering can move the beam at the scraper → increase losses
- Longitudinal parameter changes determine similar increase in losses as sudden oscillations down the line from MSE ripple.



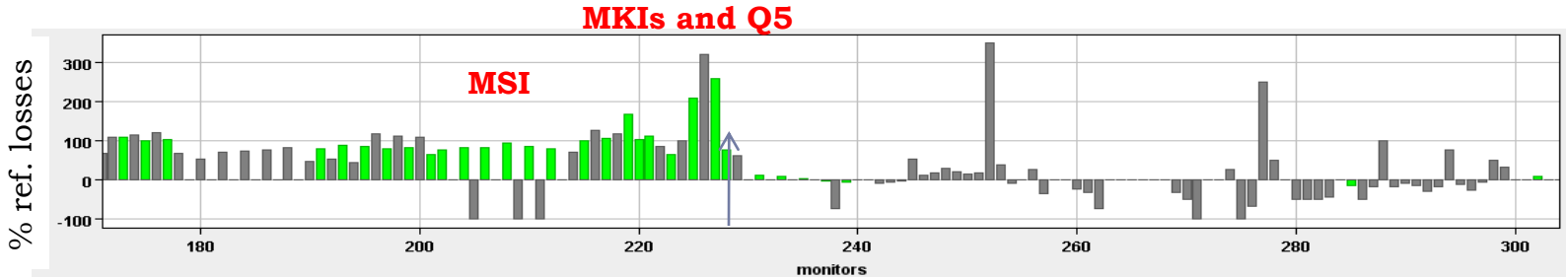
Courtesy of L. Norderhaug Drosdal

MD: Effect of longitudinal parameters

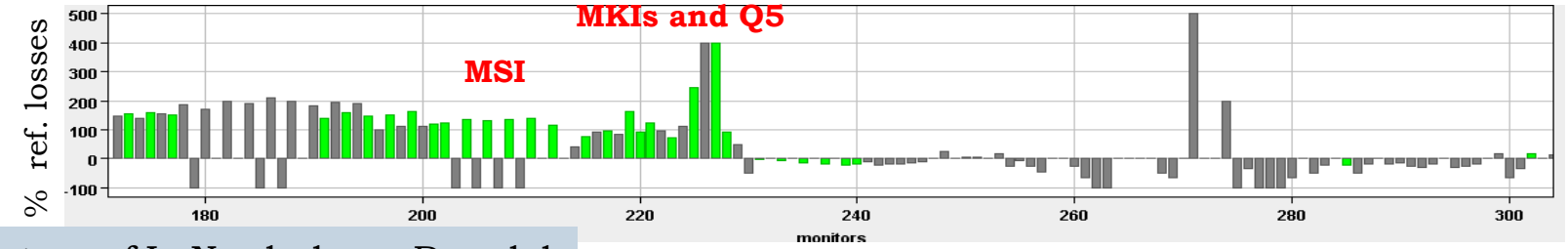
- **Increased injected bunch length into the SPS**: 4.1 → 4.9ns (SPS BQM warning, but no interlock) ➔ Observed losses on the TDI/MQX



- **Increased Δp/p at extraction:** bunch length at extraction: 1.5 → 2.2 ns ➔ Losses on the TCDIs



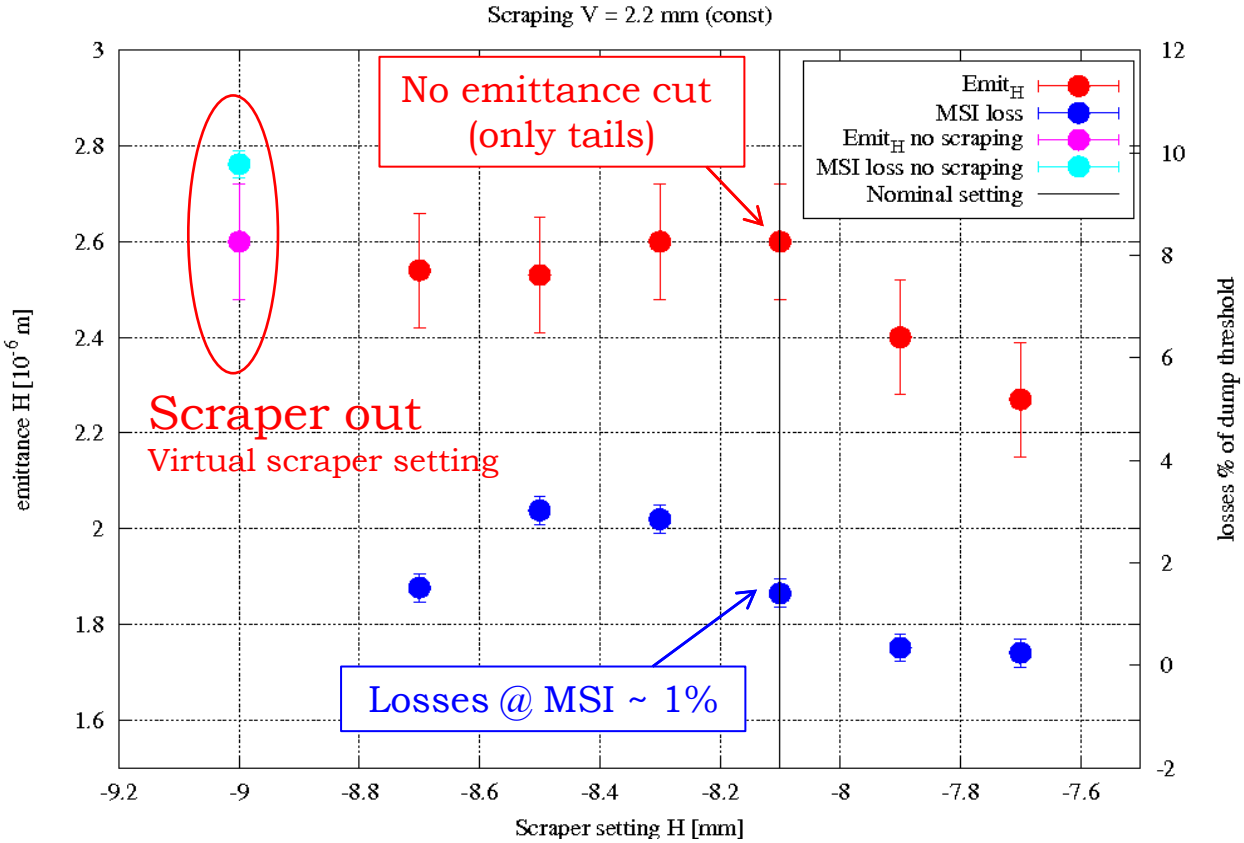
- **Turned off the 800 MHz in SPS ➔** Losses on the TCDIs



Courtesy of L. Norderhaug Drosdal

MD: SPS Scraping and Nominal Emittance

No blow up
H scraping (V constant)



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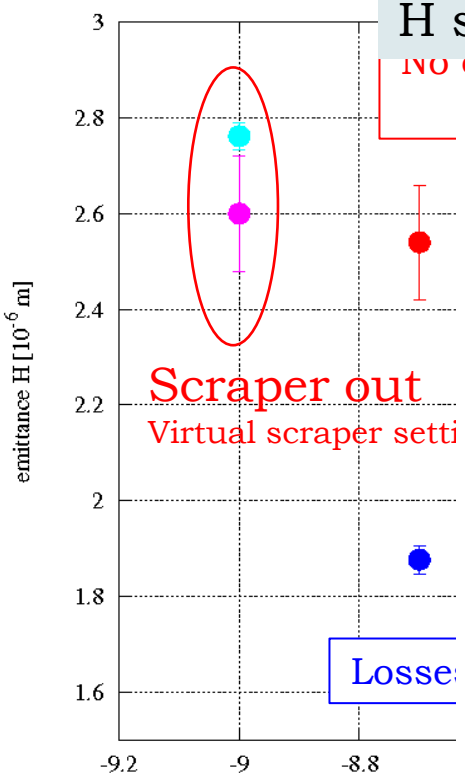

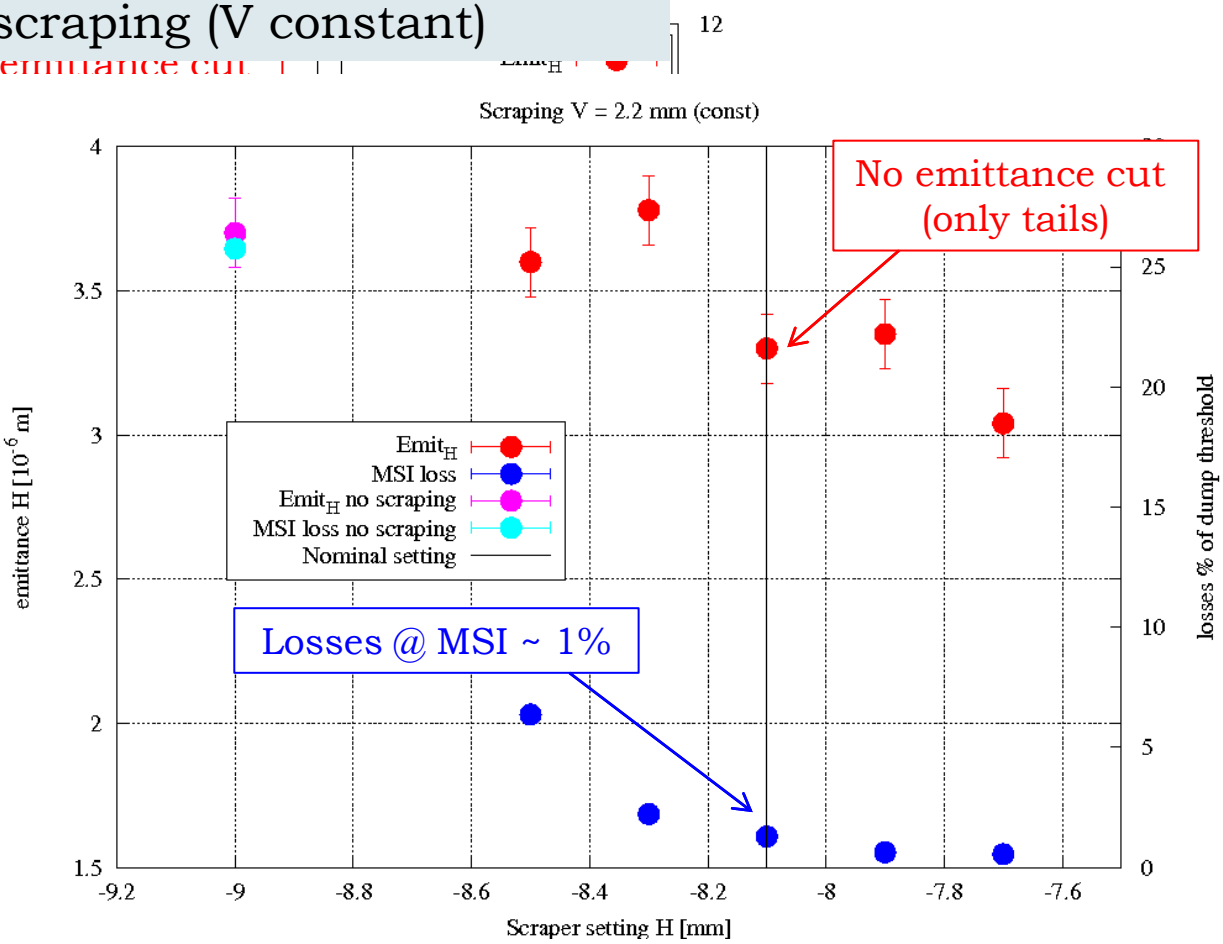

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No limitations expected!

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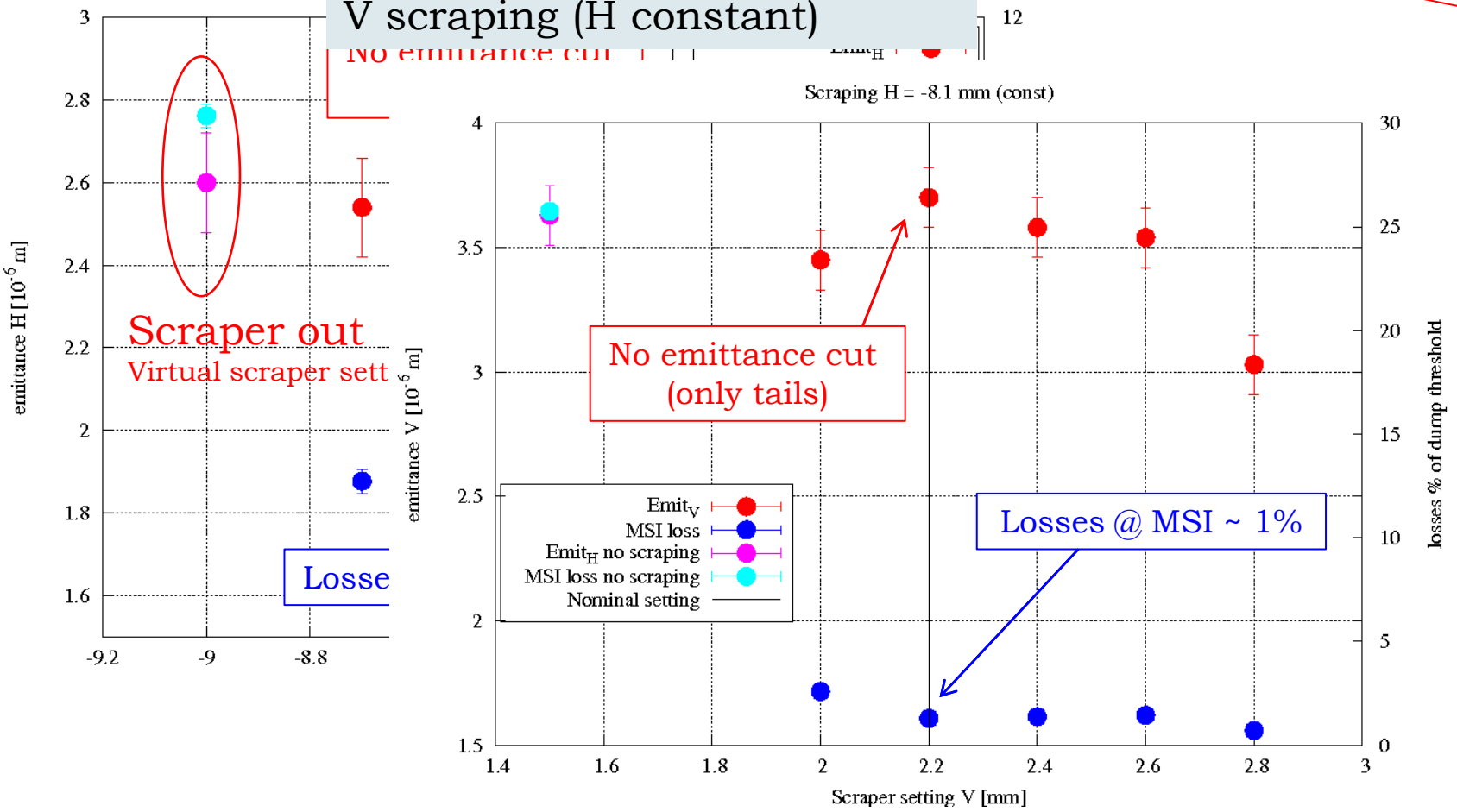


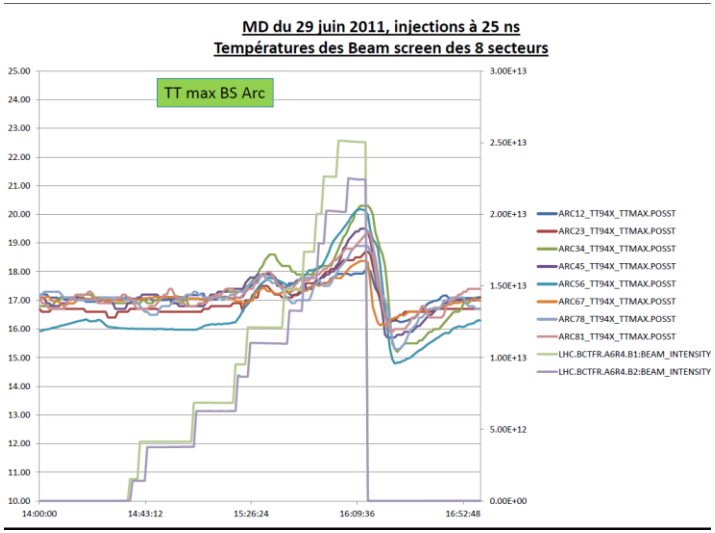
Courtesy of L. Norderhaug Drosdal

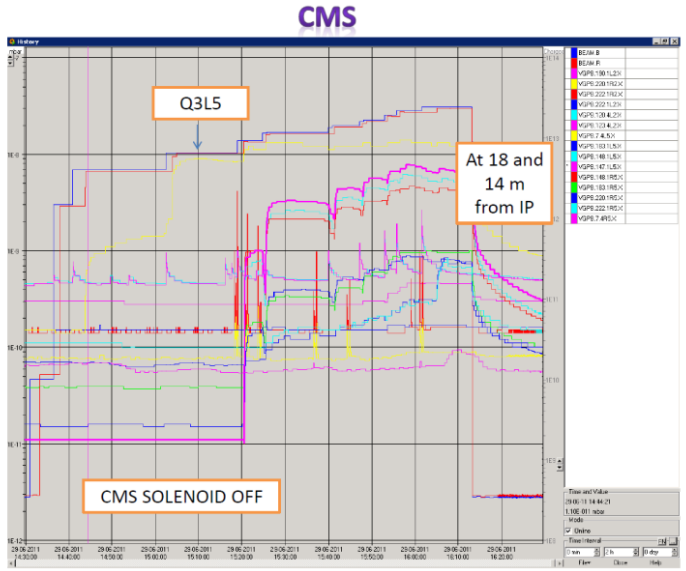
Operation with 25 ns Bunches

MD: injection of 24 nominal bunches separated by 25 ns

- 2.8 μm normalized emittance
- SPS Scraping ON
- Good trajectories without steering (50 ns reference)
- Clean injection with low transversal and longitudinal losses
- Accumulation of 216 bunches in the LHC, preliminary RF and damper setup ➔ some emittance blowup to be studied
- Slight increase in beam screen temperature (T_{max} ~ 20 K)
- Moderate vacuum activity (e-cloud higher intensity?)

No limitations expected !

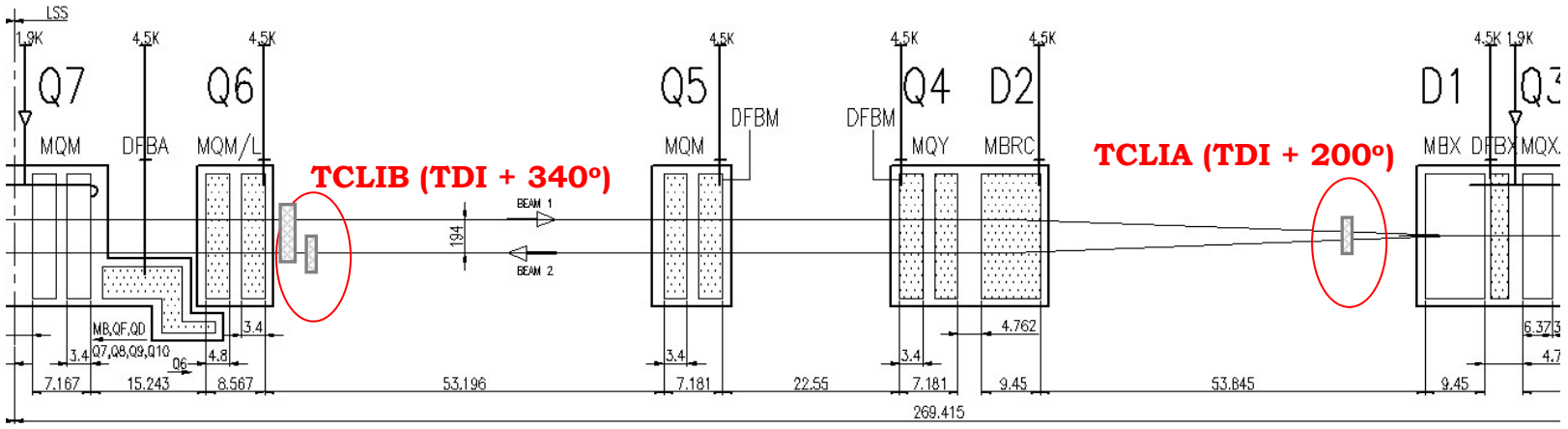




MKI Flashover

- 18/04/2011 MKI D flashover
  - 36 bunches hitting the TDI with 75-90% of the nominal MKI deflection
  - Nearly all p+ of these 36 bunches impacted TDI/TCLIB ➔ 12 magnets quenched

- Follow-up:
  - TDI setup, in particular angular alignment (4 m long jaw: 1 mrad tilt ➔ 4 mm offset), re-checked ➔ improved MP!
  - TCLIB aperture relaxed by 1.5σ to reduce the load of primary protons on Q6 (right downstream) ➔ OK for half nominal injected intensity (validations required for higher intensity)
  - **Check loss rate at Q6 w.r.t. TCLIB setting ➔ scale for 288 bunches (MD)**



Quench Margin at Injection (MD)

With view to better understand BLM thresholds in injection regions…..

- First Method (gentle):
  - Checked **BLM (@ TCLIB, Q6** and **Q7**) and **QPS** for different TCLIB settings from nominal (8.3 σ) to 1.3 σ + offset (full beam on TCLIB).
  - Repeated measurements for 3 different intensities: 1e10p+, 2e10p+ and 3e10p+

No quench/quenchino observed

- Second Method (aggressive):
  - Injection of 2e9 p+ with a horizontal bump at Q6 (21-23-25 mm)

Losses at 1000% above dump thresholds but

No signal from QPS ➔ Can we increase BLM thresholds?

Summary and Conclusions

- Nominal operation with 144 bunches reliably achieved (TCDI shielding + injection and abort gap cleaning)

- B1 seen to be more critical in operation
  - **Periodical re-steering** of the TL (with 12 bunches) is needed
  - **Good tradeoff** between **injection oscillations** and **losses** to define
  - MD studies to define origin of Beam 1 problems:
    - **No evidence of strong dependenc**e on **SPS longitudinal parameters** (**BQM** already "selecting good beams")
    - **Nominal settings of SPS scraper** provide the best solution to reduce losses without reducing emittance (**orbit control** at the scraper, not too high losses at SPS)
    - Still pending: sensitivity of TI 2 to steering

- MD results:
  - Injection with **nominal emittance** does **not** look like a **limit** (provided correct scraping)
  - Injection with **25 ns** does **not** look like it will be a **limit** – to check 144 bunches and more (next MD)

- Possible improvements in case of continued issues:
  - Maybe needs more frequent setup of TCDIs….each 4-6 weeks?
  - Relaxed setting of TCDI to 5σ (factor of 4 improvement)
  - Better understanding/increase of BLM thresholds, sunglasses,…..