Summary Session 2
Machine Studies

Ralph Aßmann & Giulia Papotti

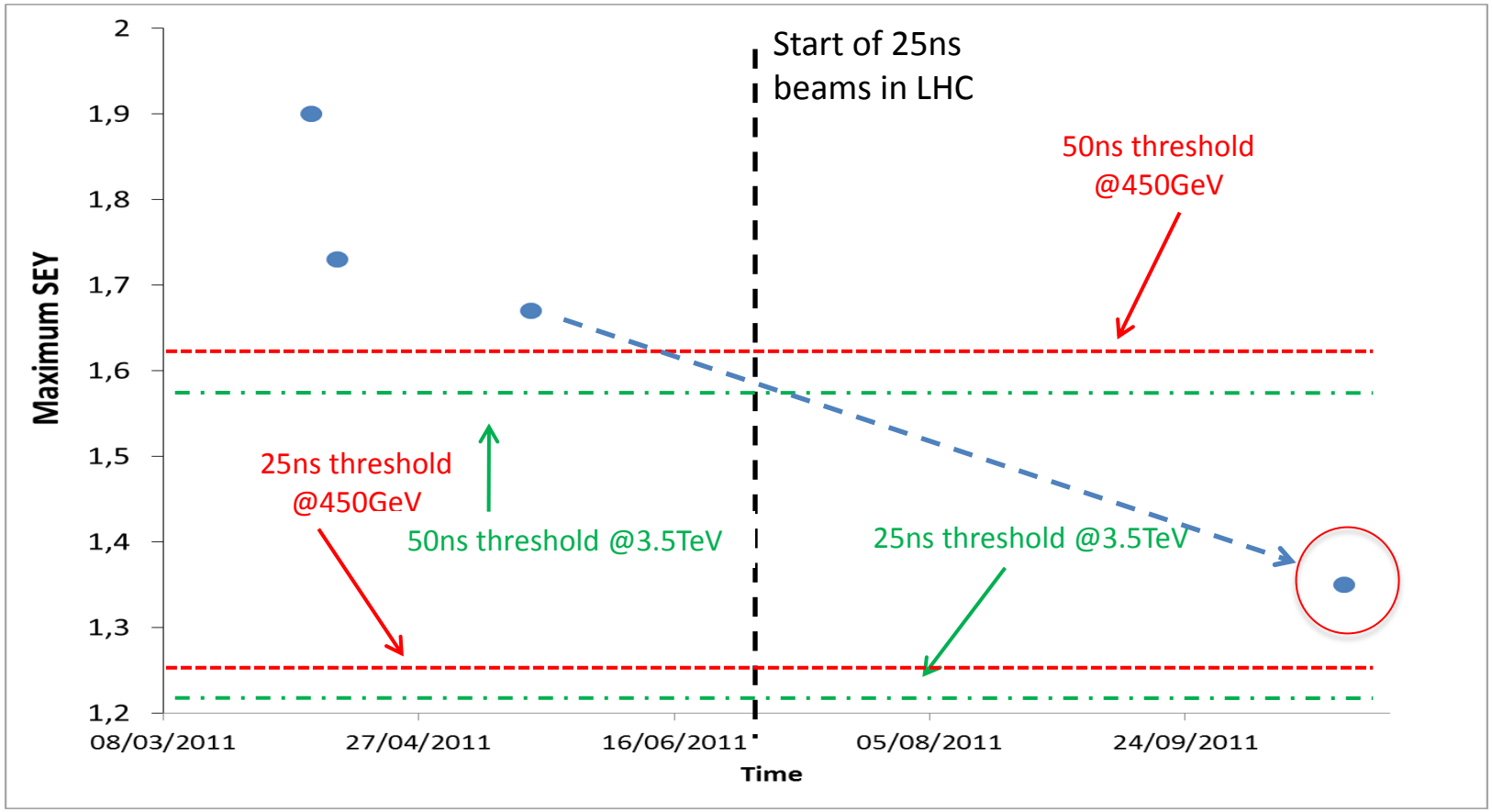
Thanks to Frank Zimmermann

LHC Performance Workshop, Chamonix, 6-10.2.2012

Session Program

- **G. Rumolo: LHC experience with different bunch spacings in 2011 (25 , 50 & 75 ns)**
- W. Herr: Observations of beam-beam effects in MDs in 2011
- E. Metral: Beam-induced heating/bunch length/RF and lessons for 2012
- R. Jones: Lessons in beam diagnostics
- M. Sapinski: Quench margins
- S. Fartoukh: First demonstration with beam of the Achromatic Telescopic Squeeze (ATS)

δ_{max} in the uncoated sections: results (25ns)



- Scrubbing with 25ns beam (~40h) has lowered δ_{max} to 1.35 !
- Again, we are not far from the threshold for 25ns beams, but further scrubbing is needed

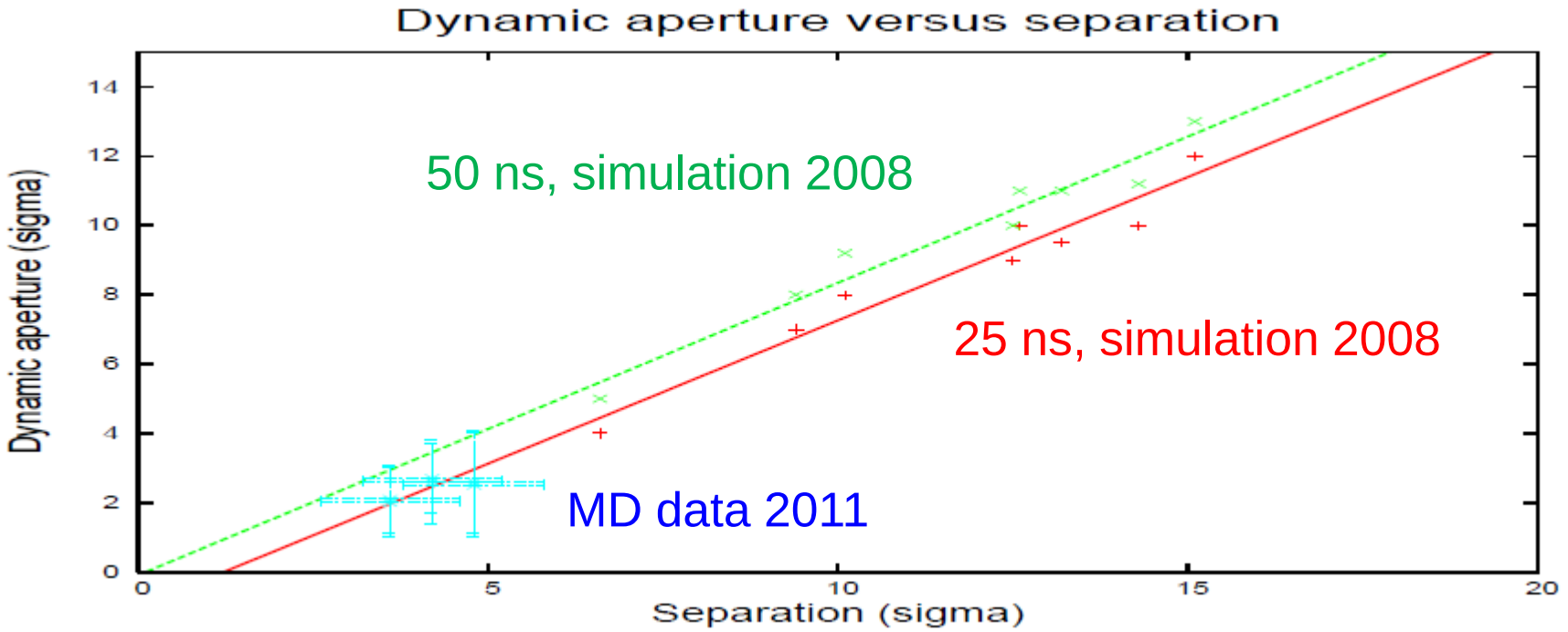
Lessons and Remarks e-Cloud

- The operation with high intensity beams in the LHC reduces successfully the secondary emission yield of electrons from the vacuum pipes ➔ **Scrubbing works!**
- No show-stopper from e-cloud problems for the LHC:
  - If the present level of machine conditioning was preserved, **'ecloud-less' operation of LHC with 50ns beams** up to high intensities should be possible in 2012
  - **2-3 days scrubbing with 25ns beams for 50ns operation** – clean parts of LHC open to air and check conditioning of arcs
  - Scrubbing of arcs for 25ns operation: up to **2 weeks machine time** (including also test ramps)
- Remarks:
  - More detailed time estimate of scrubbing for 25ns. Possible now?
  - Scheme with 12.5ns help for scrubbing? Not possible from injectors!?
  - Would special filling patterns allow more efficient scrubbing?

Session Program

- G. Rumolo: LHC experience with different bunch spacings in 2011 (25 , 50 & 75 ns)
- **W. Herr: Observations of beam-beam effects in MDs in 2011**
- E. Metral: Beam-induced heating/bunch length/RF and lessons for 2012
- R. Jones: Lessons in beam diagnostics
- M. Sapinski: Quench margins
- S. Fartoukh: First demonstration with beam of the Achromatic Telescopic Squeeze (ATS)

Beam-Beam Highlight (W. Herr et al)



- Dynamic aperture as function of normalized separation in drift space (W.Herr, D.Kaltchev, LPN 416, 2008)
- Simulations for 50 ns (x) and 25 ns (+)
- "Visible" losses expected for dynamic aperture below 3 σ
- Data estimated from separation scan (50 ns, 3.5 TeV, 1.25 10^{11}p)

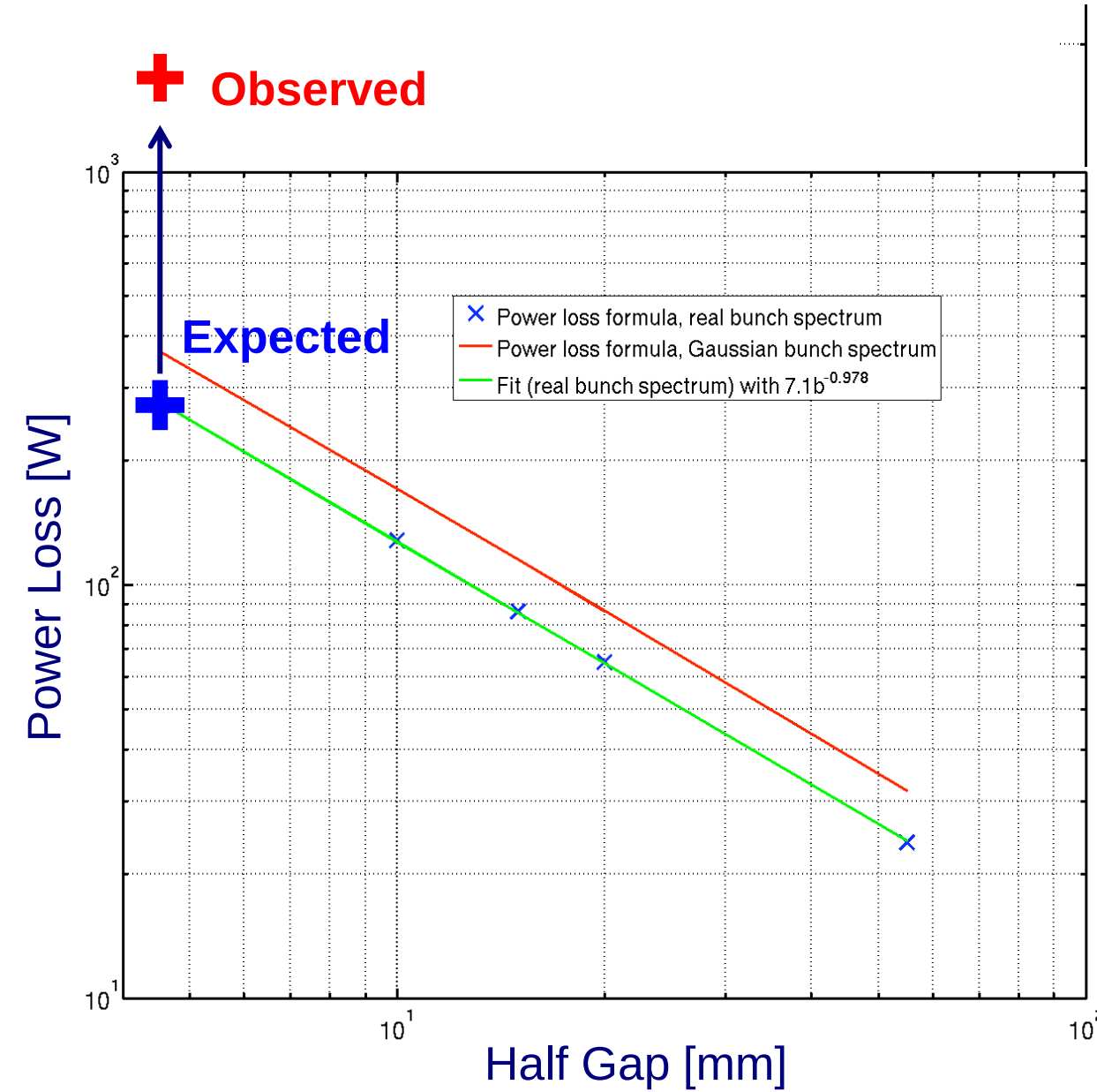
Lessons and Remarks Beam-Beam

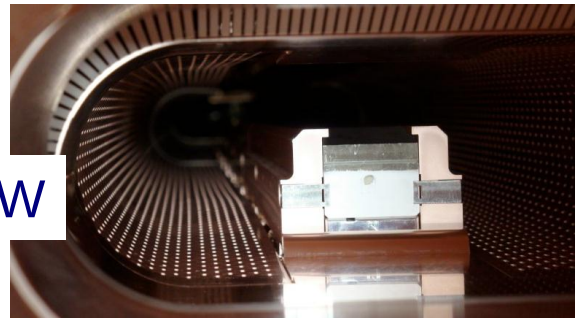
- Beam-beam (bb) in LHC is a critical issue, so far **under control, well understood and no surprises**:
  - LHC allows very large bb tune shift: demonstrated 0.018 bb parameter for two collisions points, a pileup of 35 per collision, lifetime above 30 hours. Well beyond nominal. Avoid noise and modulations.
  - Long-range bb effects behave like predicted. Provide sufficient separation through a sufficiently large crossing angle.
  - Luminosity leveling with transverse offsets routinely done ion IP2 and IP8 without detrimental effects.
- Remarks:
  - Prepare luminosity levelling with transverse offsets for IR1 and IR5, to be deployed in case of excessive pile-up.
  - Check the impact of the tilted crossing plane in IR8 on the symmetry of alternate crossing.
  - Study future possibilities for reduced crossing angle (approach the point where losses become limiting).

Session Program

- G. Rumolo: LHC experience with different bunch spacings in 2011 (25 , 50 & 75 ns)
- W. Herr: Observations of beam-beam effects in MDs in 2011
- **E. Metral: Beam-induced heating/bunch length/RF and lessons for 2012**
- R. Jones: Lessons in beam diagnostics
- M. Sapinski: Quench margins
- S. Fartoukh: First demonstration with beam of the Achromatic Telescopic Squeeze (ATS)

Example: TDI Heating (E. Metral et al)





1 kW

100 W

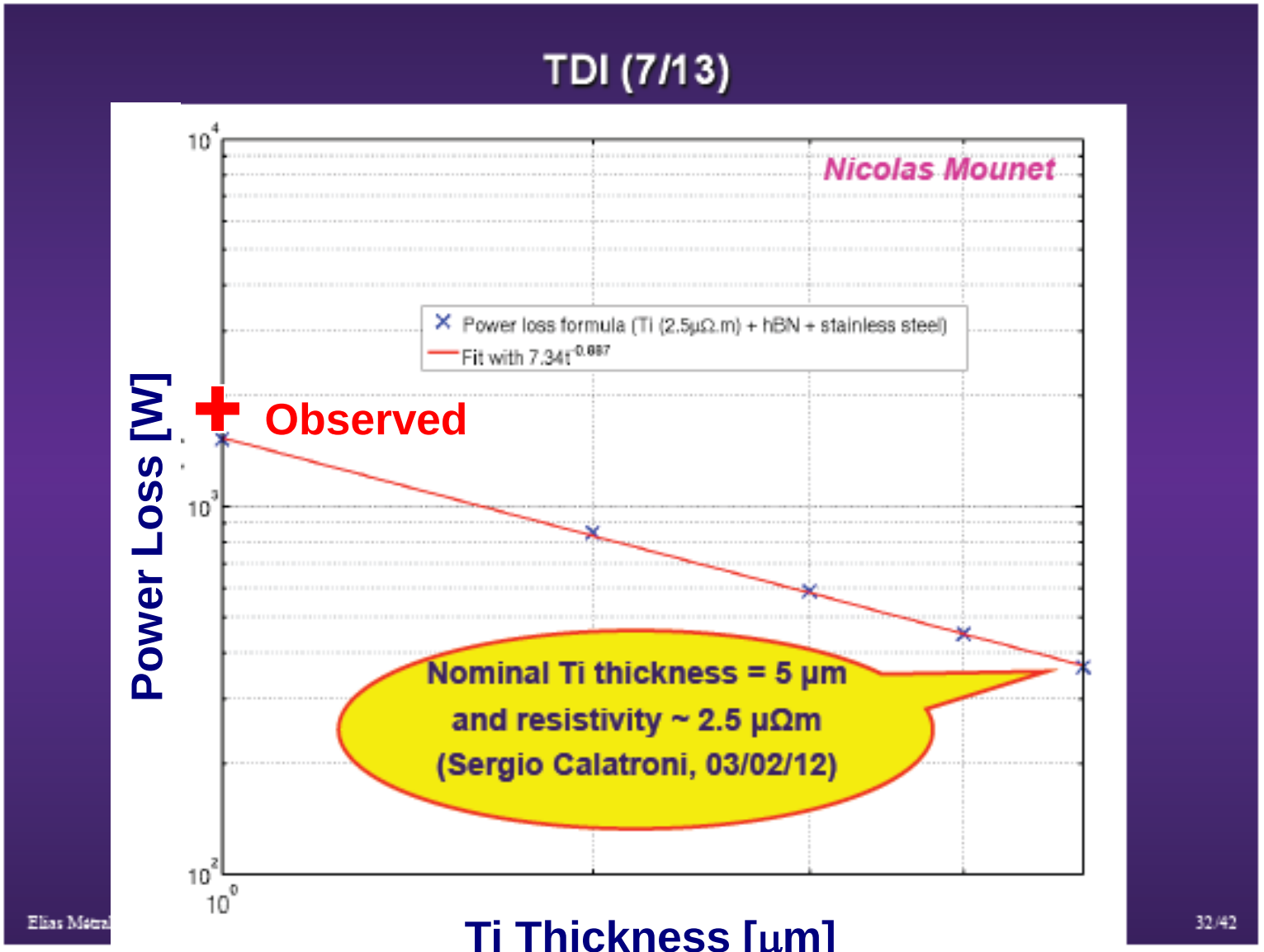
10 W

Heating: Resistive + trapped modes

Outgassing

Damage?

Effect from Ti Coating?



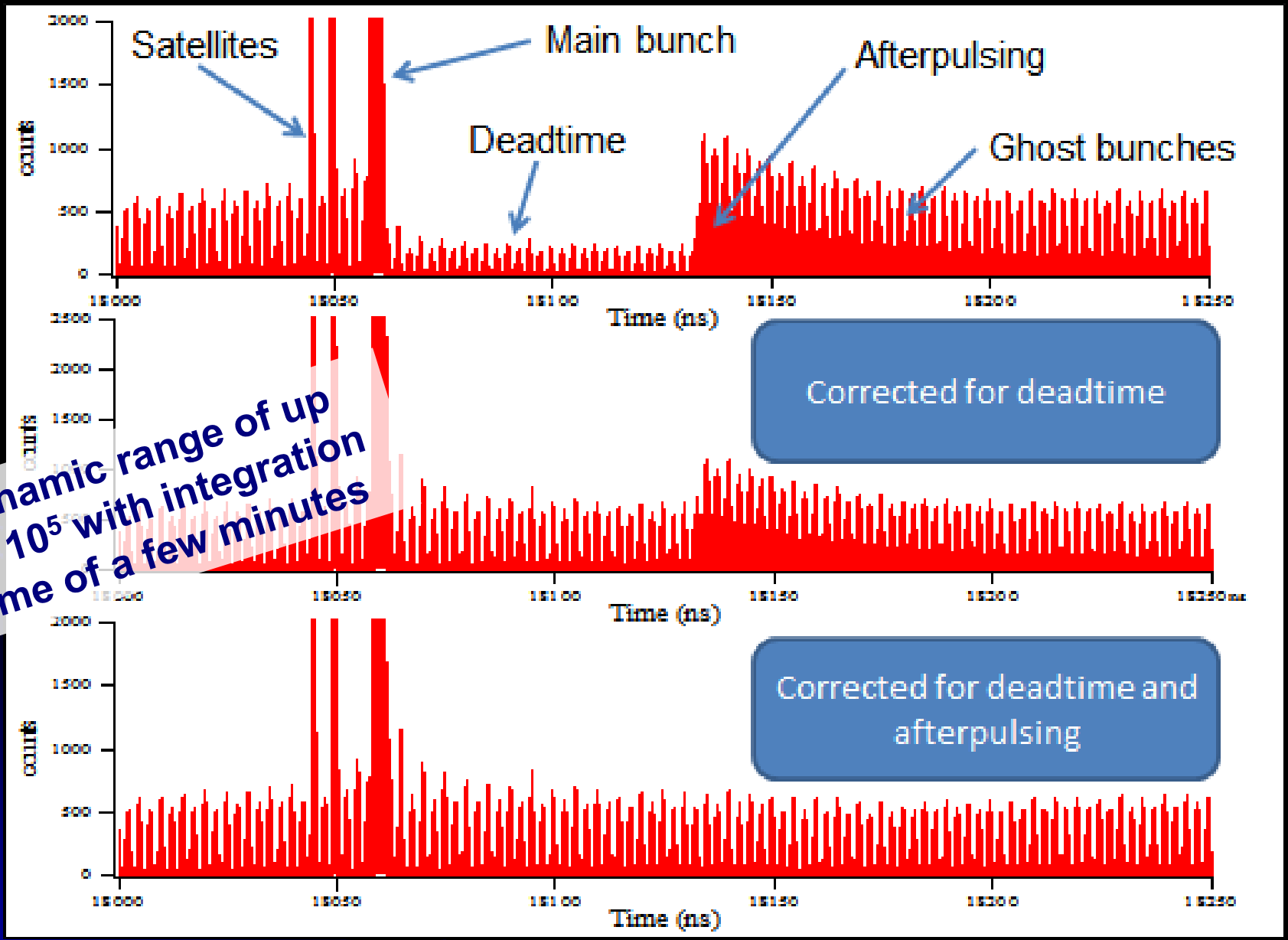
Lessons and Remarks Heating & Impedance

- **RF induced heating** observed in several hardware pieces around the LHC ring:
  - VMTSA (RF bellows with long RF fingers): No impedance problem but heating due to loss of RF contact. Task force. Review all contacts.
  - TDI (injection protection): Higher than expected heating. Effect from Ti coating? Close only when needed! Add copper coating?
  - MKI (injection kicker): Heating as expected. Improve cooling?
  - ALFA (detectors): Only install for low intensity physics? Cooling?
- Remarks:
  - Establish the safe maximum intensity for 2012, e.g. during scrubbing.
  - Add temperature monitoring to the most exposed LHC hardware.
  - Define the constraints on LHC bunch length to be respected, if any.
  - Consider replacing long protection devices by several shorter objects, like LHC collimators (avoid issues/damage from thermal expansion of very long jaws).

Session Program

- G. Rumolo: LHC experience with different bunch spacings in 2011 (25 , 50 & 75 ns)
- W. Herr: Observations of beam-beam effects in MDs in 2011
- E. Metral: Beam-induced heating/bunch length/RF and lessons for 2012
- **R. Jones: Lessons in beam diagnostics**
- M. Sapinski: Quench margins
- S. Fartoukh: First demonstration with beam of the Achromatic Telescopic Squeeze (ATS)

LDM On-Line Correction



Dynamic range of up to 10^5 with integration time of a few minutes

Lessons and Remarks BI

- The CERN Beam Instrumentation group operates a high number of distributed/individual instrumentation for the LHC.
- Overall **very good performance in 2011 – MD time vital**:
  - for a better understanding of these systems
  - to test improvements before making them operational
- Main Objectives for 2012
  - BPM: Make the LSS BPMs more reliable
  - BCT: Finalise dI/dt electronics
  - LDM: Should be fully automatic with improved fixed display
  - Wire scanner: Introduce automatic gain & filter settings
  - BSRT: Achieve 10 times faster bunch-by-bunch measurement
  - BGI: Provide independent continuous emittance measurement
- Remarks:
  - The emittance measurement at 3.5TeV should be a priority.

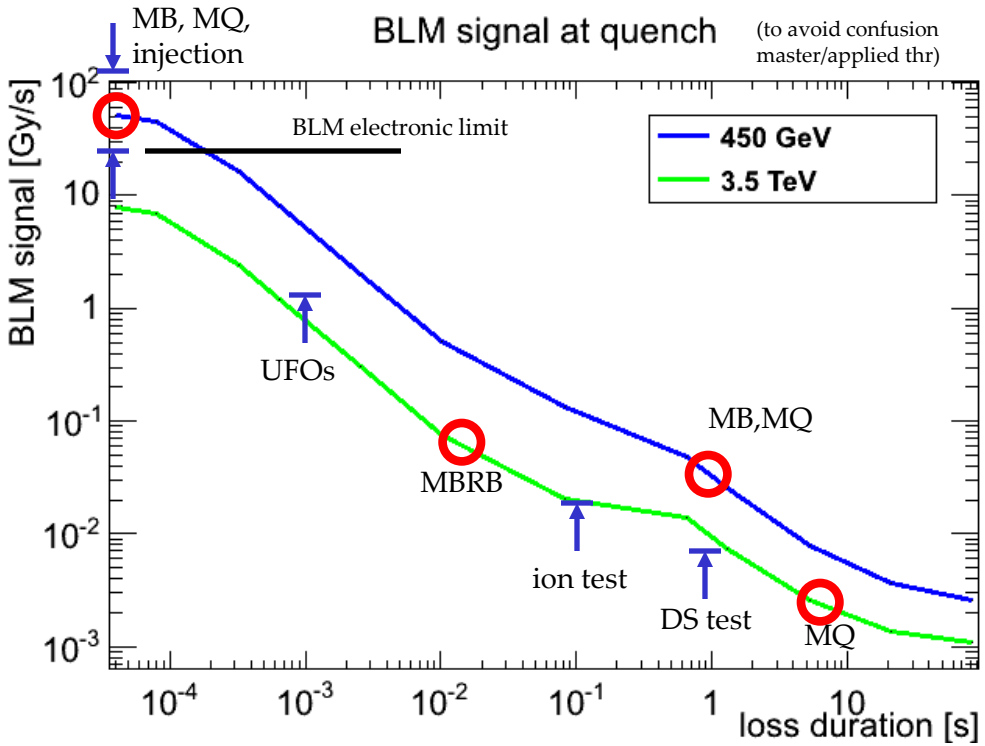
Session Program

- G. Rumolo: LHC experience with different bunch spacings in 2011 (25 , 50 & 75 ns)
- W. Herr: Observations of beam-beam effects in MDs in 2011
- E. Metral: Beam-induced heating/bunch length/RF and lessons for 2012
- R. Jones: Lessons in beam diagnostics
- **M. Sapinski: Quench margins**
- S. Fartoukh: First demonstration with beam of the Achromatic Telescopic Squeeze (ATS)

What have we learned from Quench Tests?

- 14R2 quench test (2010)
- Wire scanner quench test
- Dispersion suppressor quench tests

  (protons and ions)
- Injection quench events

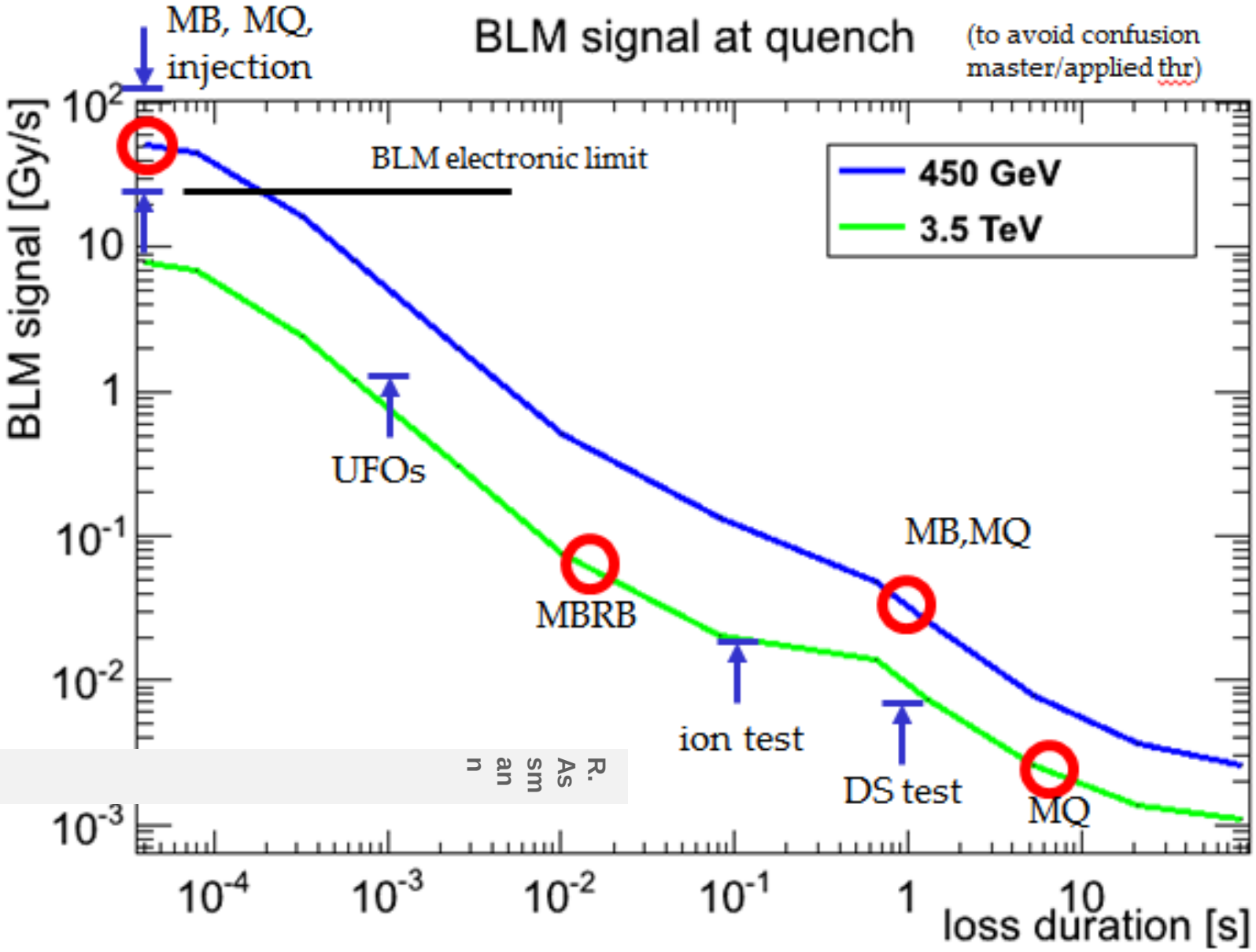


We measure BLM signals and lost beam intensity.

R. Assmann

lude about Quench Limits [mJ/cm3].

What have we learned from Quench Tests?



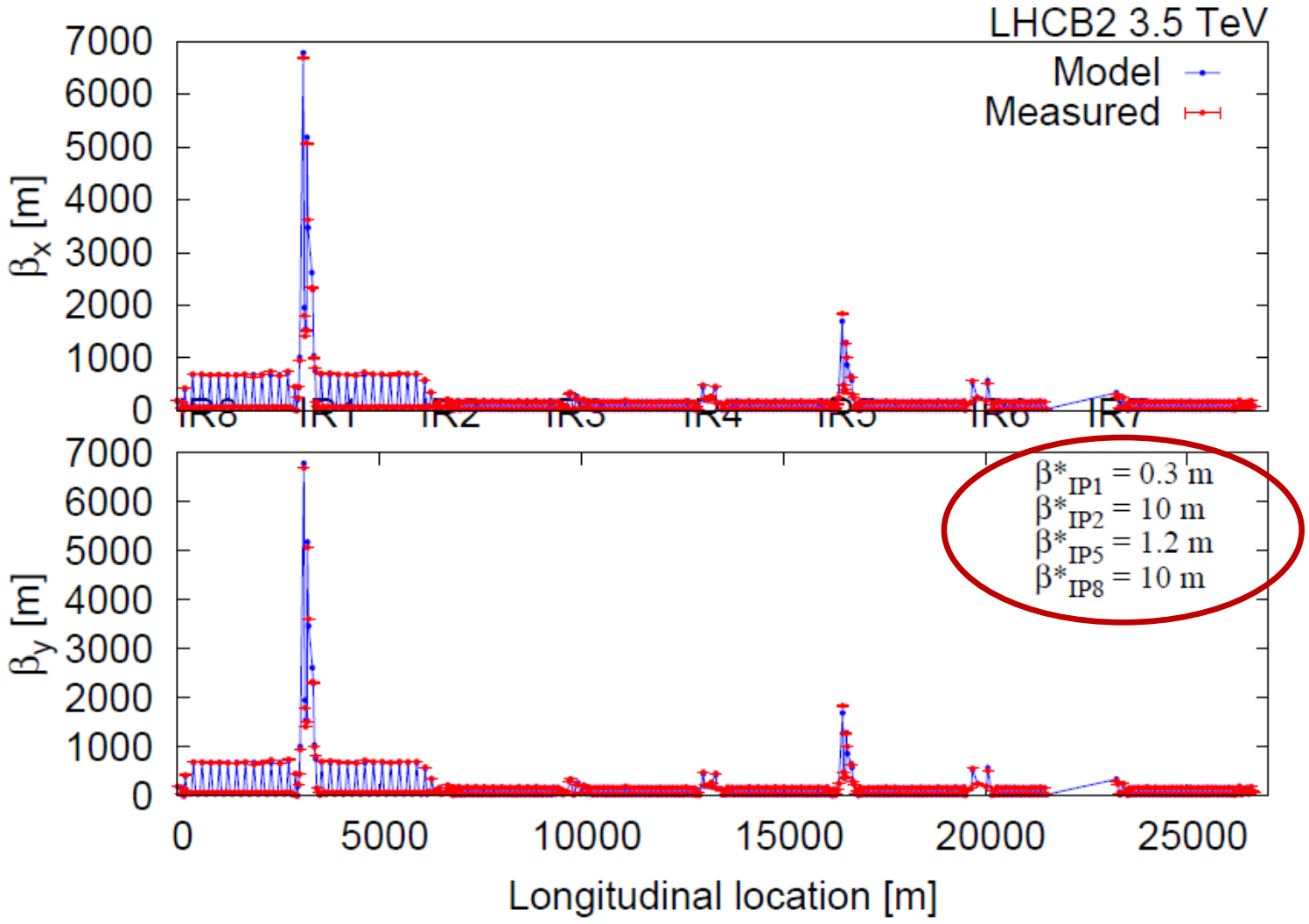
Lessons and Remarks Quench Margin

- Experimental basis (is considered limited):
  - 10 quenches during scheduled quench tests
  - 3 quench events from irregular injection
  - 3 MD's in 2011 tests where no quench was achieved (lower limits)
- Quench tests led to BLM threshold optimiz. (max. factor 5)
- **Beam-induced quenches no issue for 2012 operation.**
- Learn from quenches. Additional quench tests in 2012: UFO quench limit and steady-state. Panel to prioritize requests.
- Remarks:
  - Must avoid massive quenches in 2012. Decide whether ~4 proposed quenches are acceptable. Try to schedule tests at the end of 2012.
  - Study use of laboratory tests for understanding quench margins instead of LHC beam time.
  - Management will take final decision on these tests.

Session Program

- G. Rumolo: LHC experience with different bunch spacings in 2011 (25 , 50 & 75 ns)
- W. Herr: Observations of beam-beam effects in MDs in 2011
- E. Metral: Beam-induced heating/bunch length/RF and lessons for 2012
- R. Jones: Lessons in beam diagnostics
- M. Sapinski: Quench margins
- **S. Fartoukh: First demonstration with beam of the Achromatic Telescopic Squeeze (ATS)**

- **Telescopic principle (×4) demonstrated in IR1**



Lessons and Remarks ATS

- For the LHC:
  - The **nominal β* (55 cm) or below (40 cm) is within reach** (from the optics point of view)!
- For the ATS & HL-LHC
  - So far so good … **still a lot of work for 10 cm** (local coupling, β-beating, phase-beating corr. at 40 cm, tune knobs & Q-feed-back,…)
- 2012 plans:
  - Prepare clean, then safe 40 cm pre-squeezed optics (no X-angle)
  - Approach, reach & measure the 10 cm β^* with pilot beam.
  - If time permits, flat pre-squeezed/squeezed optics
- Remarks:
  - Define β* strategy for IR2 and IR8 with an ATS optics.
  - Perform the planned beam tests to establish the chromatic limits of the standard optics and the β* after which ATS is needed.
  - Prepare the ATS optics as backup for the 2012 run?

Conclusion

- Six highlight topics from the 2011 MD's were discussed (other topics in other sessions, not discussed here: RF, collimation, aperture, β^*, …).
- Results very reassuring for immediate and far LHC future:
  - **e-cloud is under control**: Scrubbing works, short scrubbing runs OK, 50ns operation in 2012 without e-cloud effects, 25ns in reach.
  - **Beam-beam is under control**: routine operation with brightness beyond nominal, long-range bb as expected, levelling operational.
  - **Impedance is under control**: Routine operation with very high currents, heating effects worrisome but understandable, 2012 OK.
  - **Beam instrumentation works very well**: Stringent MD program to calibrate and improve the many systems.
  - **Beam loss and quenches under control**: No quenches expected in 2012. MD data to extrapolate to future running at 6.5/7 TeV.
  - **Optics under control**: Many ATS lessons. β^* of 30cm reached. Nominal optics in reach. Upgrade optics path is prepared.
- LHC not at its limit in 2012 → bright future & MD's ahead…