OP@BI Day 2012
After LS1

Jörg Wenninger

BE/OP/LHC

I could be brief…

We want measurements of all beam parameters that cover the full LHC dynamic range.

They should be

- *fast,*
- *accurate (give us 10 x better than what we need and we are happy),*
- *cool and cooled,*
- *bunch by bunch (all in //) and turn by turn,*
- *without gain changes or other operational hazards.*

Life after LS1

- The aim of LS1 is to fix the interconnections, and we should startup at an energy between 6.5 and 7 TeV depending on the re-training of the dipoles (call this **6.5+** TeV).
  - *6.5 or 7 TeV does not change much for OP/BI.*
- The LHC injectors will most likely deliver beams with higher brightness with a new bunch recombination scheme in the PS.
- Operation after LS1 is likely to start with 50 ns beams, with a switch over to 25 ns after ‘some time’.
  - *Experiments favor 25 ns (event pile-up),*
  - *We tend to favor 50 ns (easier – tbc).*
  - *Moment of switch over may not just depend on e-cloud conditions, also UFOs and other parameters may play a role !*

β* reach at 6.5+ TeV

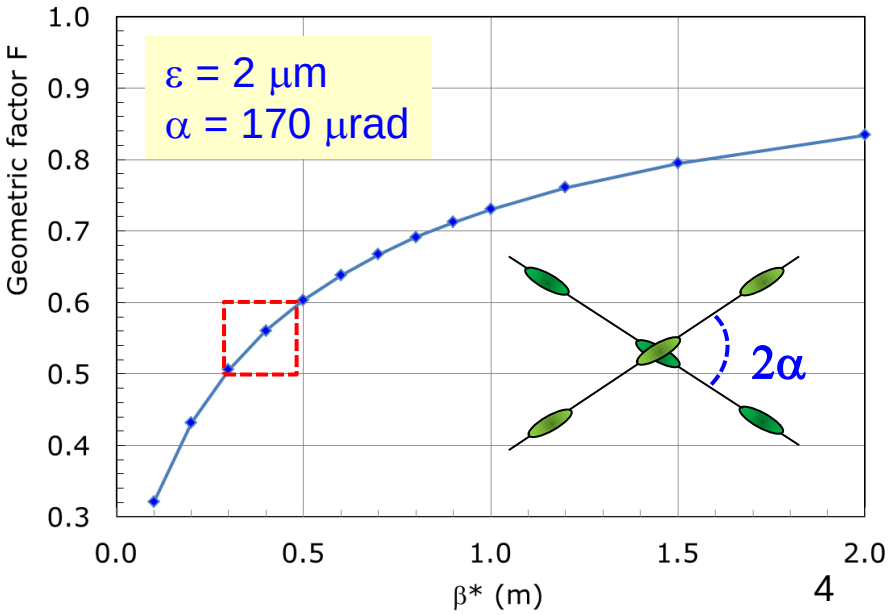
- The β* reach depends on:
  - *The collimator settings and margins between collimators and with respect to apertures (we have a few scenarios…),*
  - *The beam type & emittance (25 ns / 50 ns) → crossing angle.*

- Possible range of smallest β* at 6.5+ TeV:
  - 0.4 m ≤ β* ≤ 0.5 m for 25 ns beams,
  - 0.3 m ≤ β* ≤ 0.4 m for 50 ns beams.

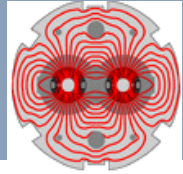
$$\sigma^*_{x/y} \approx 9\ \mu\text{m} \quad [\beta^* = 0.3\ \text{m}]$$

- At 6.5+ TeV the luminosity loss due to the geometrical effect (factor F) will reach 40-50% !

$$F = \frac{1}{\sqrt{1+\left(\frac{\sigma_s}{\sigma^*_{x/y}}\tan\alpha_{x/y}\right)^2}}$$



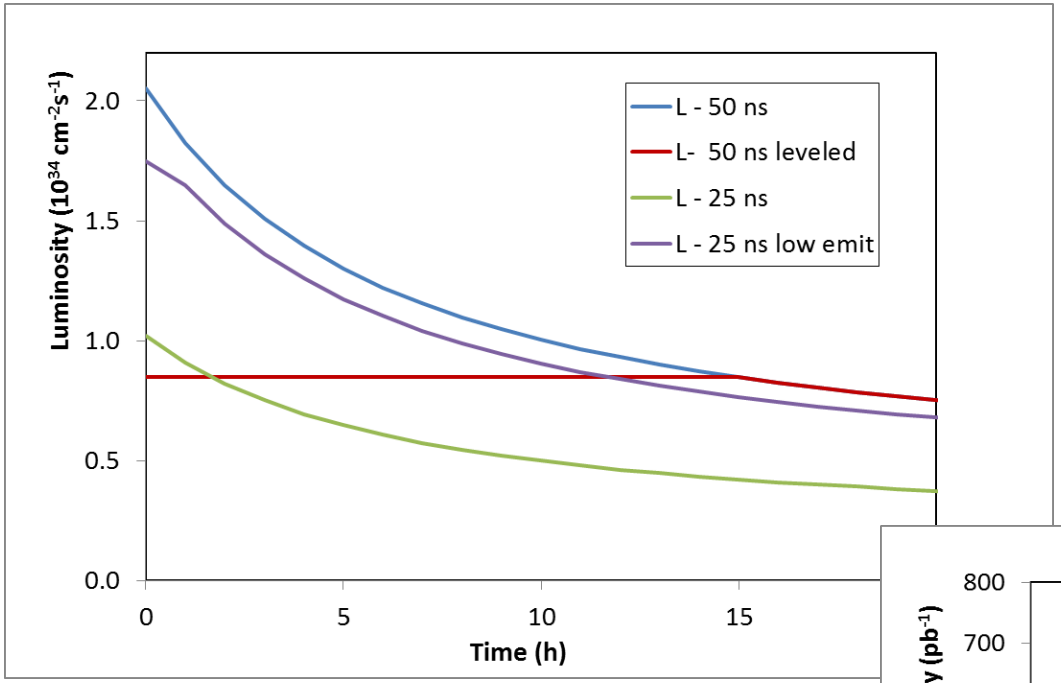
Luminosity scenarios at 6.5+ TeV



	k	N_b [10^{11} p]	ε [μm]	β* [m]	L [10^{34} cm^{-2}s^{-1}]	Pile-up	Int. L [fb^{-1}]
50 ns	1380	1.70	1.5	**0.4**	2.05	104*	~30
25 ns low emit	2600	1.15	1.4	**0.4**	1.73	47*	~50
25 ns standard	2800	1.20	2.8	**0.5**	1.02	25	~30

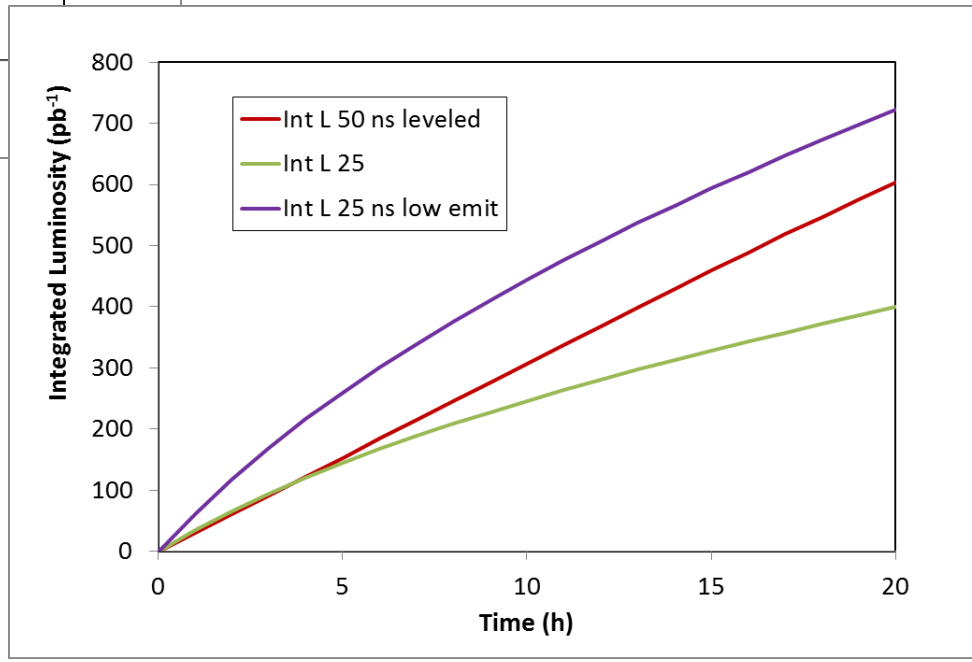
- Emittance growth of 30 % in LHC not included → scale L by 0.7.
- The 50 ns beam pile-up is too high. The luminosity must be leveled down to limit pile-up. Assuming max. pile-up of 40.
- The integrated Luminosity is based on 120 days of production, 35% efficiency.

Performance comparison



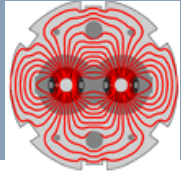
Standard 25 ns and
50 ns with levelling…

…are equivalent in integrated luminosity for fill lengths up to 5-6 hours.



Low emittance 25 ns provides higher performance due to higher luminosity for same or lower pile-up.

β* leveling and colliding squeeze

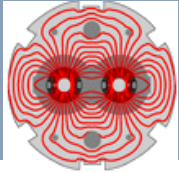


- Leveling by β* and squeezing with colliding beams are concepts that have appeared in 2012 as part of the scenarios for post-LS1.
  - *Different objectives and causes, but similar operational concepts.*
  - *Likely that they will be used.*
- Leveling by β* is used to keep a more-or-less constant luminosity (experiments are taking data – 'stable beams'). Each leveling step is in fact a small squeeze step with colliding beams.
  - *Reason: peak luminosity is too high for experiment(s). Profit from luminosity excess to provide quasi-constant luminosity…*
- Squeezing with colliding beams extends leveling to the entire squeeze – big squeeze step.
  - *Reason: stabilize beams using head-on beam-beam instead of octupoles, chromaticity and damper.*
  - *Challenge: keep beams in collisions all along the squeeze.*

General issue: data storage and bunch data

- The demands for bunch-by-bunch (BbyB) and turn-by-turn (TbyT) is increasing rapidly.
  - *Driven by the multi-bunch beam instabilities,*
  - *And the simple things have been done…*
- Presently such data does not go into some form of official logging, but there are ad-hoc private solutions – everyone on its own…
- During LS1 CO should put in place a system to log any BybB data in large volumes (in collaboration with BI & OP). For example:
  - *Be able to store everything all the time,*
  - *By default could delete all (or a large amount of) data after 1-2 months, user having possibility to tag data for longer storage.*

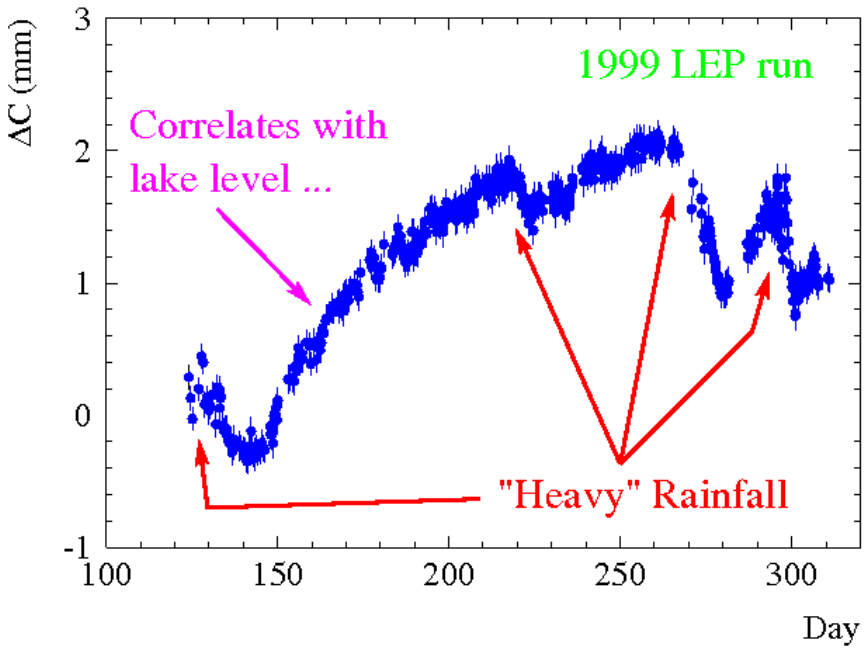
Orbit - BPMs

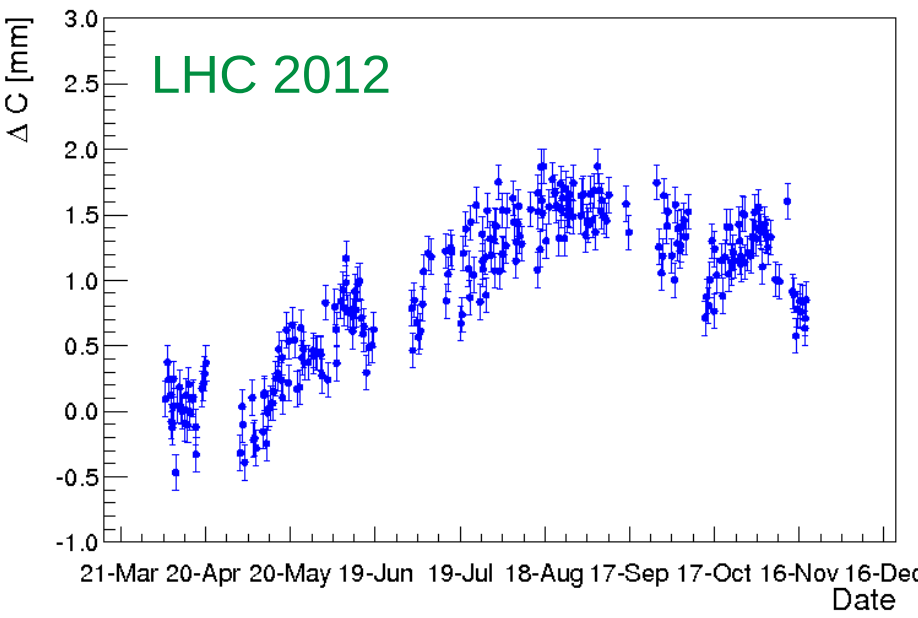


- All in all in the last 3 years the performance of the orbit measurement system has very good !
  - *Tight collimators and lower β^* made possible by excellent orbit stability – short term (OFB) and long term.*
- BPM quality issues / improvements:
  - *Better temperature control. One of the limiting factors for accuracy.*
    - *→ work foreseen in LS1.*
  - *Better correction of non-linearities in strip-lines – for IR bumps.*
  - *Beam pattern effects (in particularly in multi-bunch mode) can be annoying for some studies (beam-beam) – probably intrinsic to the system.*
  - *Accuracy of BPMs in / around common vacuum chambers will be critical for squeeze with colliding beams. Synchronous orbit, diode acquisition,…?*

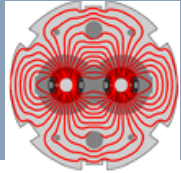
LEP-LHC comparison

- Comparison of the LEP and LHC circumference measurements based on BPM data seem to indicate that LEP BPM reproducibility was a bit better – LHC data more noisy…
  - LEP: circumference calculated from BPM readings (fixed RF frequency).
  - LHC : circumference calculated from the RF frequency set by the OFB on flat top (itself based on the BPM readings).



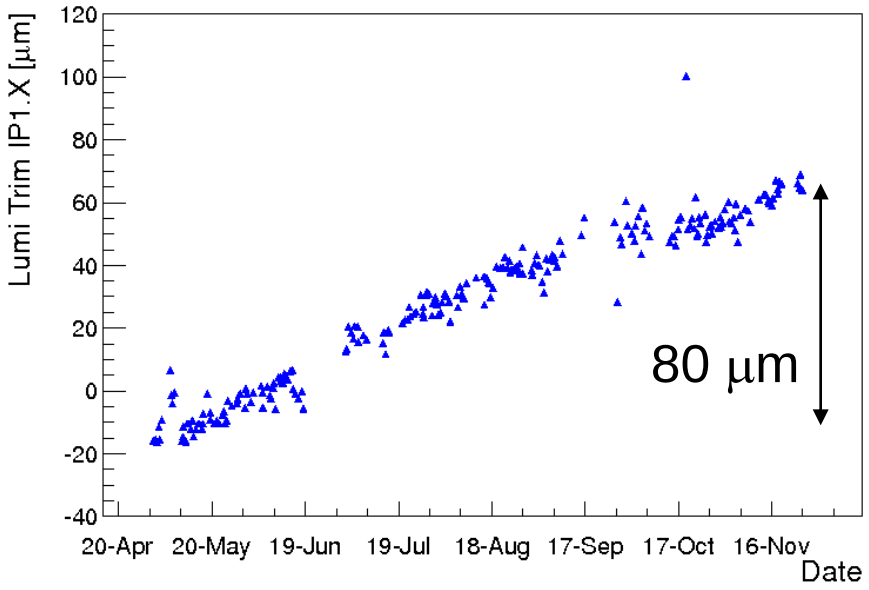


Orbit FB



- LHC does not work without orbit FB and overall performance 2010-2012 has been remarkable.
  - *Basically from day 1… LHC does not work without OFB.*
- Current correction quality limits (not yet a real problem):
  - *Arcs + most of the LSS: BPM F2F reproducibility – 50 μm rms. OK!*
  - *Common regions 1,2,5 & 8, ~ 200 μm rms.*
    - *correction strength (number eigenvalues in SVD) ↔ sensitivity to 'bad' BPMs.*
    - *common correctors not used in OFB (slow, QPS !).*
- Orbit FB as it stands now should be able to cope with LS1+.
- Some improvements:
  - *Handling of response matrices (to OP?) and references (OP+BI),*
  - *Filtering of bad elements (use existing unused code + improvements).*

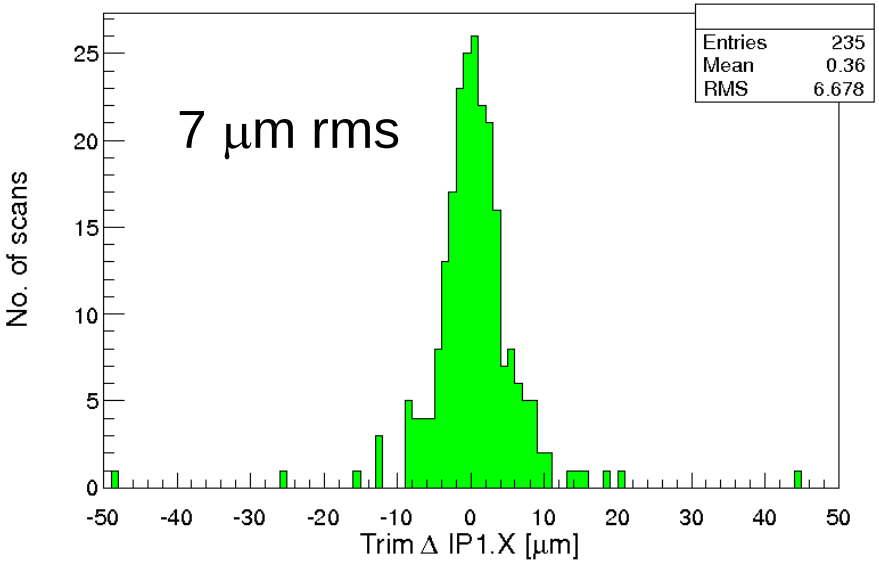
IP reproducibility



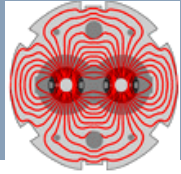
Orbit correction at IP to bring beams head-on (here B1H correction).

Slow drift over the year →not corrected by OFB.

The F2F difference is very small and sufficiently good (↔ squeeze in collision).



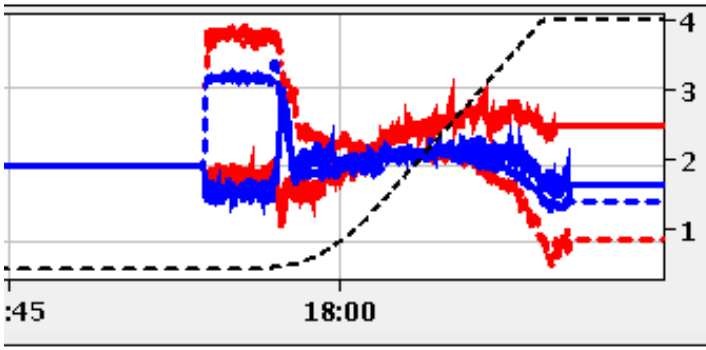
Interlock BPMs



- …suffer a lot from the sensitivity switching / ranges.
  - *In 2012 rather well tuned for the operational high intensity beams. No more issues once everything was well setup.*
  - *But not so compatible with other tests (like proton-Lead)…*
  - *More diagnostics?*
- Ideas for a more ‘robust’ system are welcome. This will surely be discussed at the Machine Protection Workshop in March 2013 (most likely in Annecy).

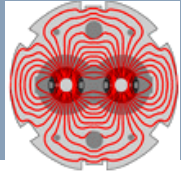
Tune (with FB)

- Three ‘issues’ of the tune (BBQ) systems in past year(s):
  - *Compatibility with damper for high intensity beams,*
  - *Tune FB triggering QPS (too fast voltage change) due to poor Q peak quality,*
  - *BbyB measurements.*



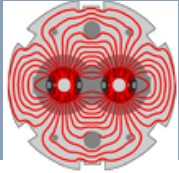
- All issues solved / improved.
  - *Gated BBQ (→ ADT compatibility & BbyB),*
    - *but need software for BybB Q.*
  - *QPS threshold increase (TE/MPE).*
- Due to the insufficient Q signal quality at 4 TeV, we have operated in 2012 without QFB in squeeze - for the entire year.
  - *Based on feed-forward with low intensity bunches done in April.*
  - *Highlights the excellent reproducibility of the machine (magnets). This also worked for other cycles (highbeta).*

Tune FB after LS1



- QFB as it stands now should be able to cope with LS1+.
- Compatibility with QPS.
  - *TE/MPE considers introducing 3 threshold levels after LS1 (instead of 2). Thresholds are not yet defined.*
- 2012 has shown that QFB precision is more important than bandwidth (squeeze super-reproducible) for regular OP.
  - *Could consider modes: similar to present mode for setup, low bandwidth mode for regular OP?*
  - *Reduce sensitivity to multiple peaks in spectrum??*
- QFB operation may be tricky with squeeze in collision - tune spectrum width, multiple peaks. But we can probably live with feed-forward – similar to 2012.
  - *Need special filling schemes (or non-colliding bunches) to measure Q and Q' (no colliding bunches).*

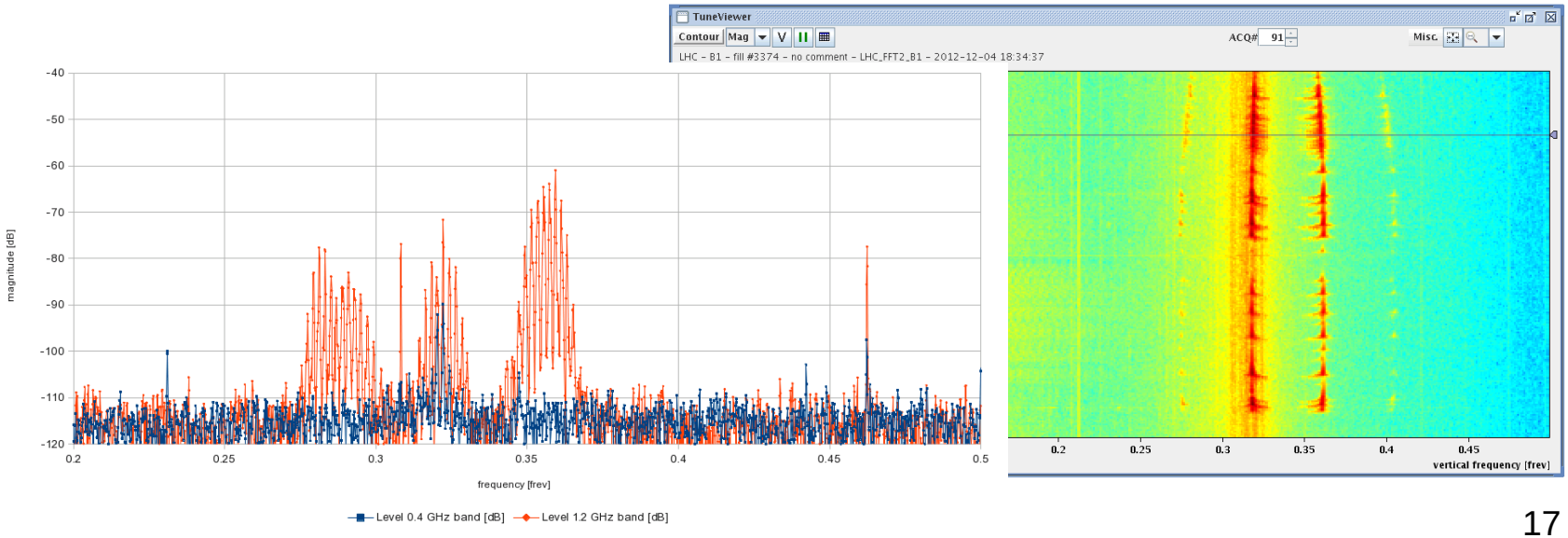
Tune systems - Chromaticity



- Feedback on chromaticity (Q') not an issue because:
  - *Reproducibility of the LHC is excellent.*
  - *Decay at injection and snapback well corrected with the FIDEL feed-forward schema (magnetic model).*
  - *Operation at 4 TeV with high Q' (~ 15) less critical wrt Q' stability than operation with Q' ~2.*
- At 6.5+ TeV Q' changes at injection will ~ double – but the way we operate now should be OK.
- Of course transparent measurements during high intensity operation can only help, but they are not as critical as we may have feared initially…

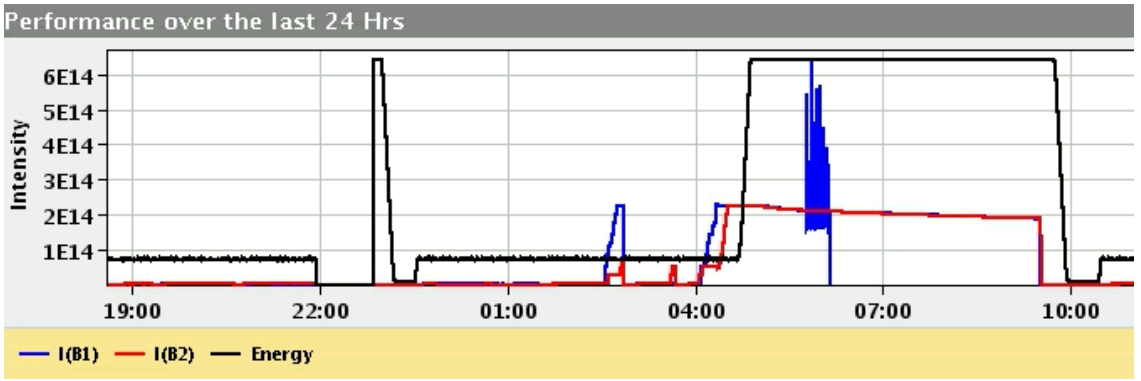
Instabilities

- Observation of instabilities relies mainly on BBQ spectra and ADT activity (more tricky).
  - *Gated BBQ measurements not used yet… (→ software).*
- Ralph's new BBQ with filters in different frequency bands is attractive, also 'relatively' simple.
  - *Reluctance by users to use / believe results (+ pretty expert).*
  - *Some user would like to see the instability in time domain (Head-tail oscillation), but not evident in terms of sensitivity and trigger !*



BCT

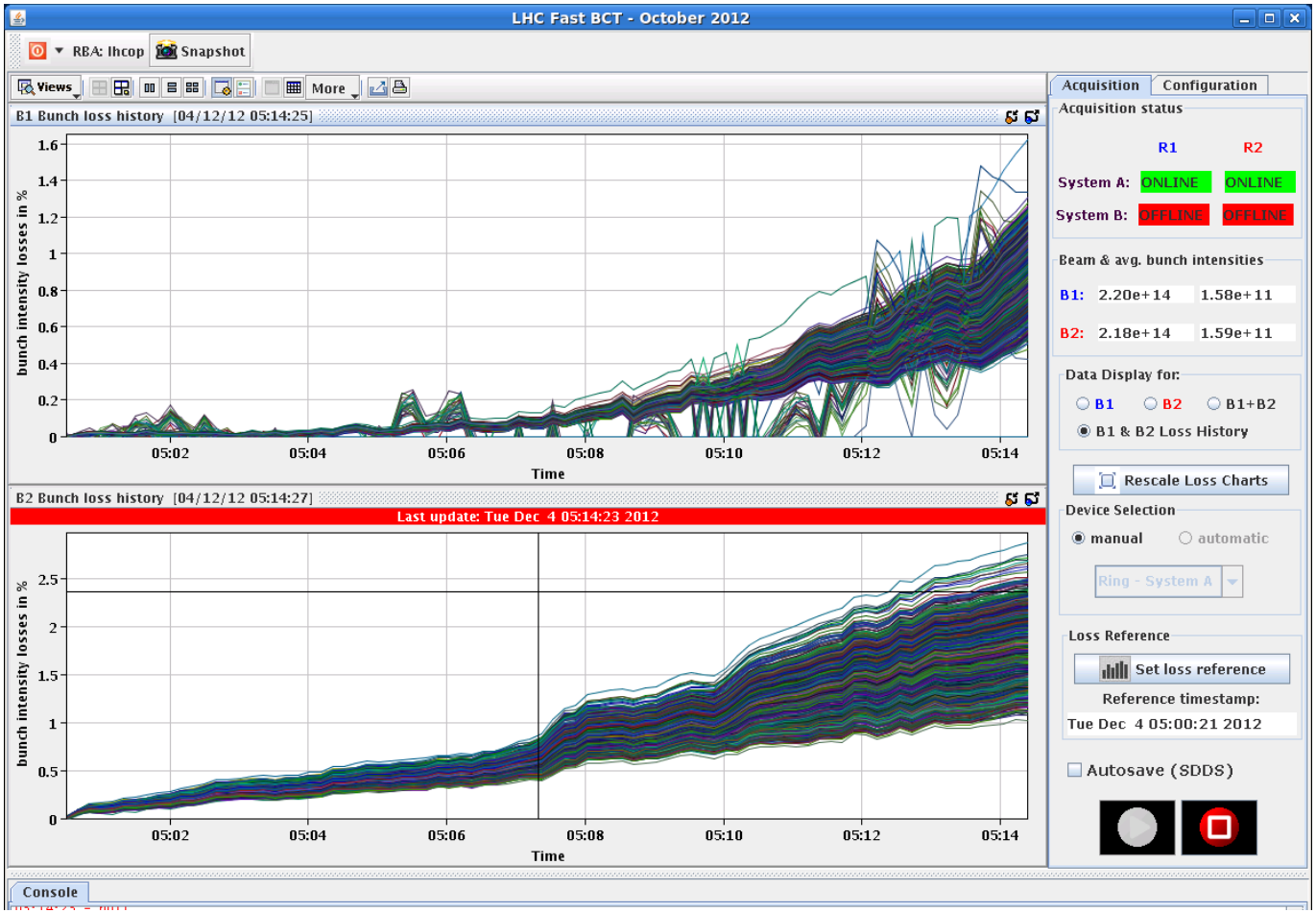
- The BI system that is really in the page1 spotlight.
  - *Reboots, crashes and features do not go unnoticed...*



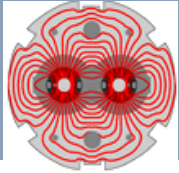
- For lifetimes the (F)BCT is now frequently replaced by a/few BLM signal(s) at the primary collimators.
  - *With rough calibration the BLMs provide a very reactive lifetime display (~ 1/loss rate) that is now frequently preferred for tuning.*
- Suggestions:
  - *Provide OP with a tool to do the FBCT phasing?*

BbyB / FBCT

- A system where the BbyB data is used daily in the CCC (with BSRT) – software adapted to the data + needs.



BLM system

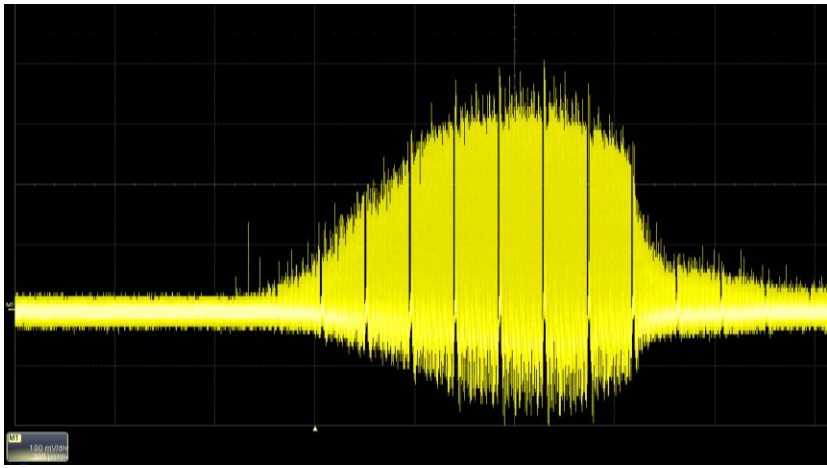


- Very reliable and central system for safe LHC operation.
  - *At 4 TeV we have now well tuned thresholds.*
- Heavily used in CCC and for analysis in all phases of the LHC.
  - *Some suggestions on the table for improvements of PM data etc.*
- Known issues:
  - *Saturation for very fast losses (mainly injection) ➔ introduction of LICs & filters (not so nice) etc for injection and other fast losses.*
  - *HV breakdown → LS1 fixes.*
- Threshold adjustments required after LS1.
  - ***High luminosity IRs**: scaling current thresholds shows that for luminosity of 10^{34} we would dump the beams on triplet losses…*
  - ***UFOs** : arc thresholds to be tuned for UFOs and not for local beam impact (never seen and well protected by interlocks).*

.

Diamond BLMs

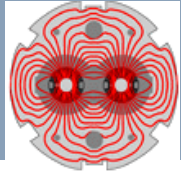
- There is increasing interest in diamond detectors for diagnostics of ByB & TbyT losses.
  - *Injection, UFOs, instabilities.*
- Main issue is that the systems are not well integrated and not easily usable. Basically experts only…
- Suggestions for LS1+:
  - *Improved acquisition to deliver BbyB losses, not scope traces. This will reduce data volumes and make the data more 'analyzable'.*
  - *Provides pre-configured settings / triggers for users in the CCC.*
  - *Provide good data for PM (injection).*



Emittance

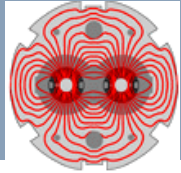
- Much has been said already…
- Given limitations of wire-scanners we have to rely on BGI/BSRT for nominal operation.
  - *Fast BbyB acquisition of BSRT is the only way to really know what is going on in terms of blow up – essential to get BSRT back in shape.*
  - *If BGI could give reliable average and BSRT BbyB info, we would have a reasonable operating mode.*
  - *Wire-scanner will remain limited to 'low' intensity and cross-calibration – no miracle to expect from intercepting devices…*
- The dream would consist in performing wire-scans in PSB, PS and SPS on the same beam in …. one click.
- Development of VELO-like tracking detector based on beam-gas imaging – the future? Attractive given the success of VELO.
  - *Much more complex devices than what we presently have?*

Luminosity



- We are mainly using LHC experiments luminosity data for performance ‘analysis’.
- BRANs used as backup when experiments not available.
  - *Can be essential during setup and in MD !*
  - *Essential for a squeeze in collision (cannot rely on experiment's data?).*
- The BRANs provide fast relative measurements for BbyB that are not really used – suggestion to improve this and use it online for diagnostics, as data from experiments are offline.

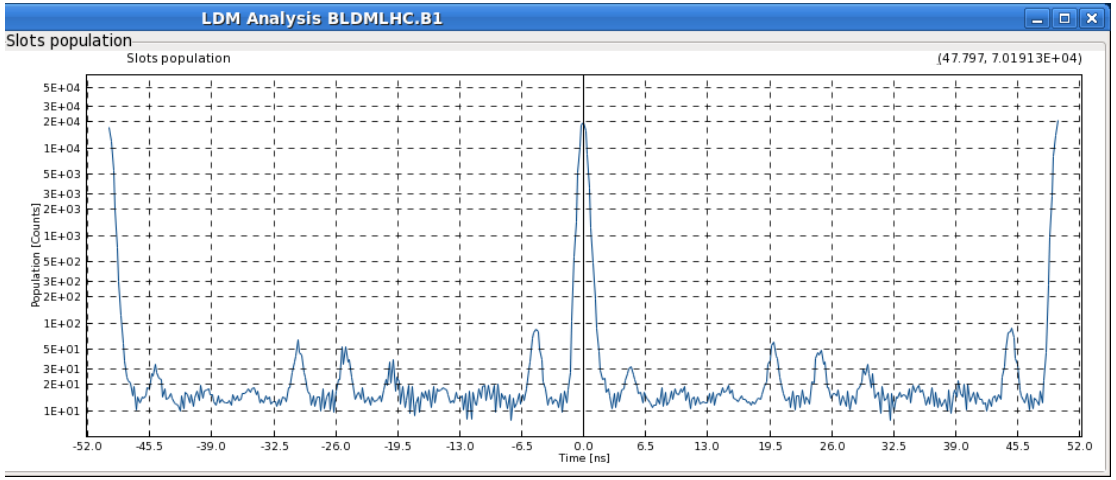
Abort gap monitor



- After may discussions etc we got in the end a rather reliable system – when the BSRT is ‘working’.
- Many discussions on the system, nobody so far came up with a much better system.
  - *During the BSRT crisis, attempts to obtain the abort gap population from the experiments were not so successful: need collisions, need beam sizes, beam offsets at IPs etc.*
- Discussion to be expected at the MP workshop in March.
- The VELO-like tracking detector studied in the context of emittance measurements may also provide abort gap monitoring by beam-gas events.
  - *Rate?*

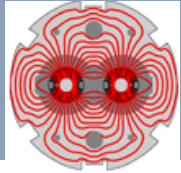
LDM

- In 2012 the LDM was a fashionable device since it is the only instrument that can measure the charge in the 25 ns satellite bunches that we are colliding in IR2 (main-sat collisions).



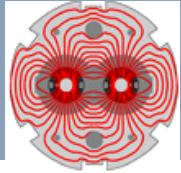
- With 25 ns beams we have to go back to main-main collisions, the interest will then shift back to satellites at injection and luminosity calibration runs.

Bunch length



- An area where RF and BI tend to be in ‘competition’.
  - *Avoid duplicate work?*
- The LHC bunch length measurements are dominated by the RF wall current monitor (WCM) system – alias BQM (‘Beam Quality Monitor’).
  - *Well working system, with good software and high availability.*
- BI WCM is in the ‘second row’. To avoid duplication could concentrate on other beam aspects.
  - *Frequency spectrum of beam (but also there the RF is doing similar things – but so far not CCC usage).*
  - *Fast measurement of larger satellites – mainly for luminosity calibration.*

Conclusion



- This talk could only give a superficial overview, and I had to skip some instruments.
- The core **beam control** instruments, tune and orbit, are doing pretty well, they can profit from quality improvements during LS1.
  - *We should be careful to preserve the system performances.*
- This year the focus has shifted heavily towards **BbyB data** to diagnose instabilities, and further BbyB diagnostics should be developed for the future.
- A challenge with BbyB data is to provide useful online analysis in the CCC and to be able to log lot's of data at the right moment (trigger).