



Evian 2011

Mike Lamont

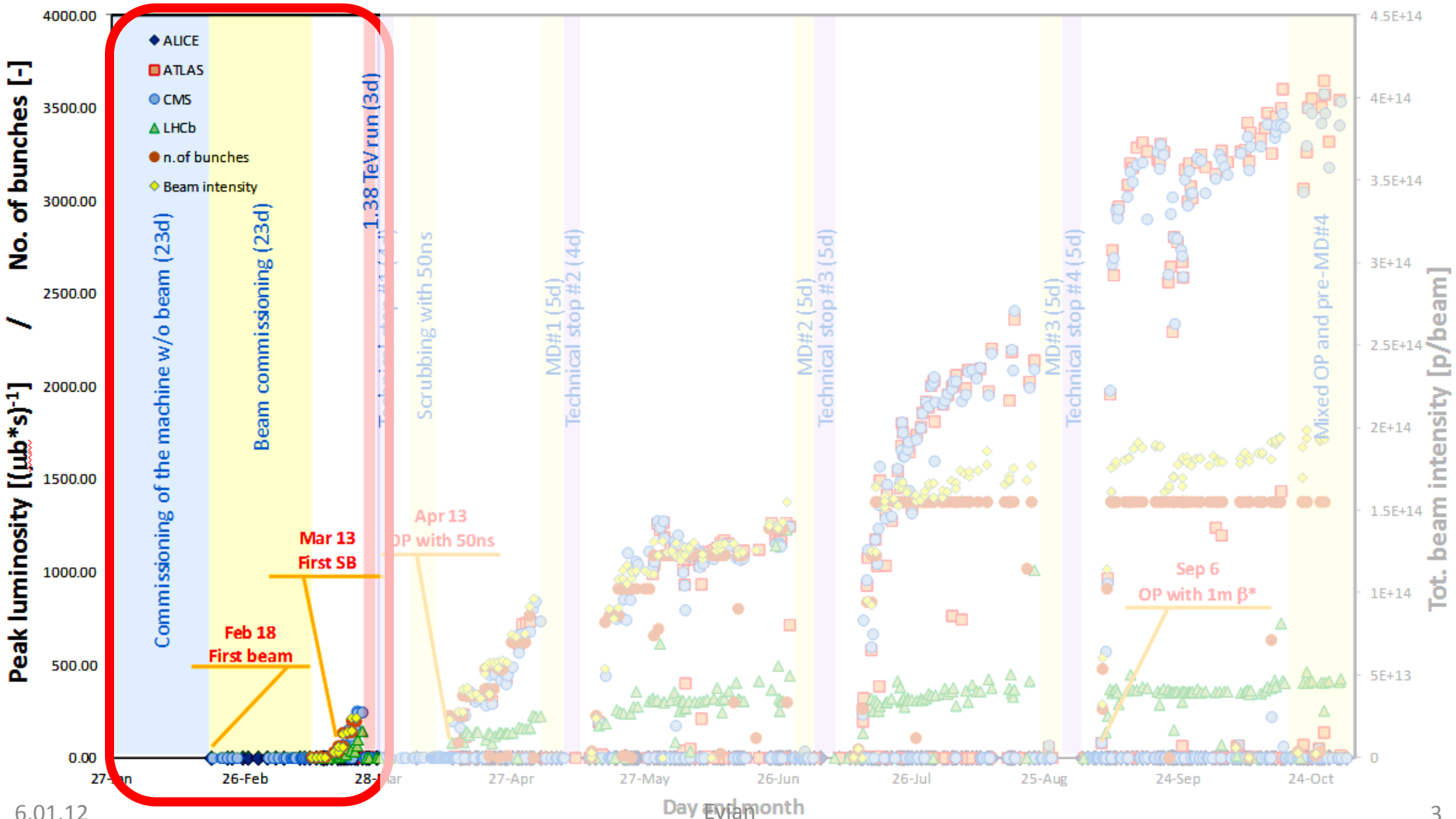
Evian 2011

- Lesson learnt in 2011
- Improvements for 2012
- Provisional parameter list for 2012
- Discussion of priorities and strategy for 2012
- Run up a bar bill

| | | |
|----------------------------------|--------------------|------------------|
| Review of 2011 | Jorg Wenninger | Giulia Papotti |
| Availability | Jan Uythoven | Mirko Pojer |
| Injection | Malika Meddahi | Alick Macpherson |
| Operational performance | Bernhard Holzer | Stefano Redaelli |
| Beam loss and machine protection | Brennan Goddard | Laurette Ponce |
| Systems operational performance | Eva Barbara Holzer | Reyes Alemany |
| Limitations | Gianluigi Arduini | Walter Venturini |
| 2012 | Ralph Assmann | Verena Kain |

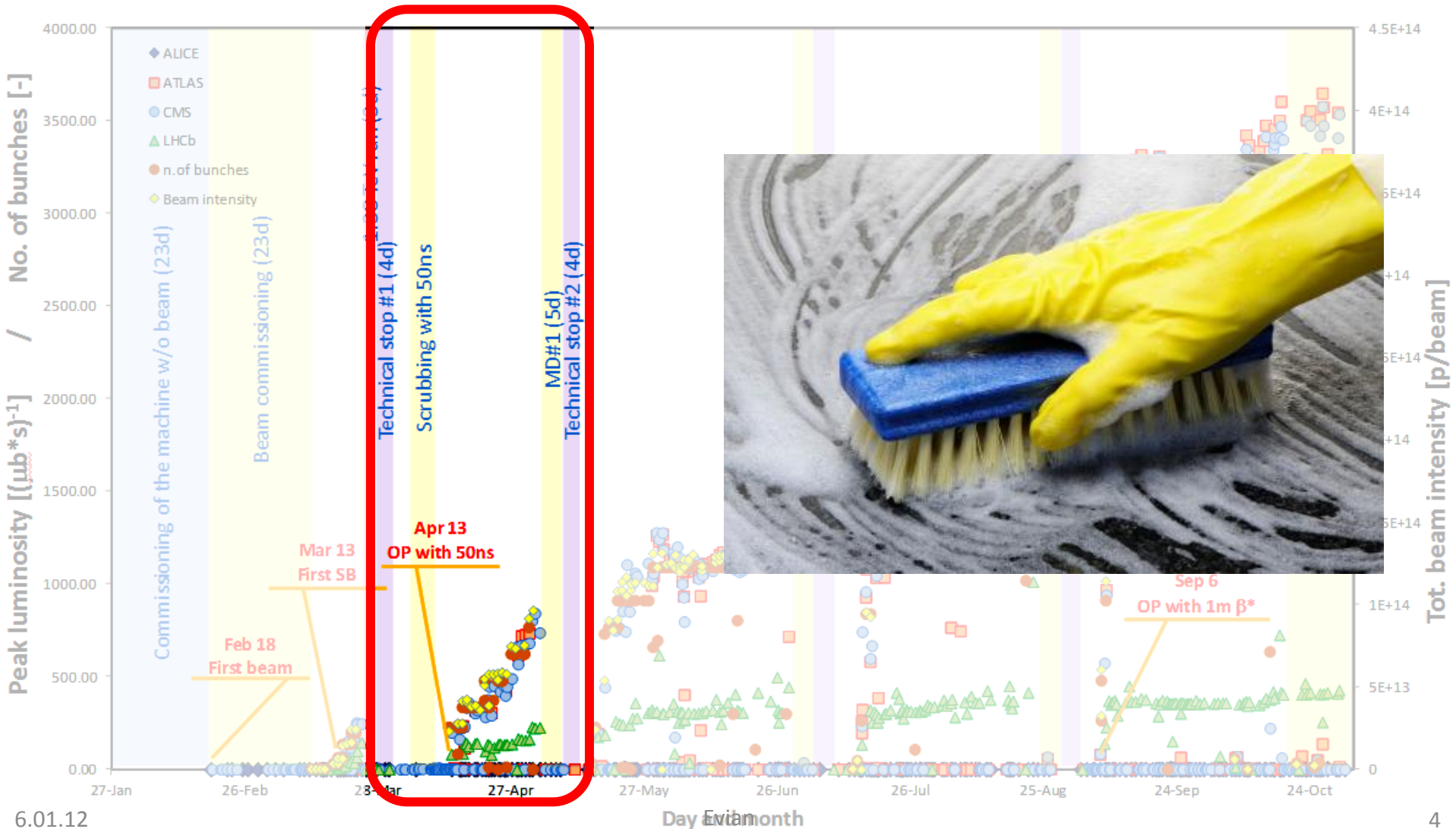
Initial commissioning

Mirko Pojer



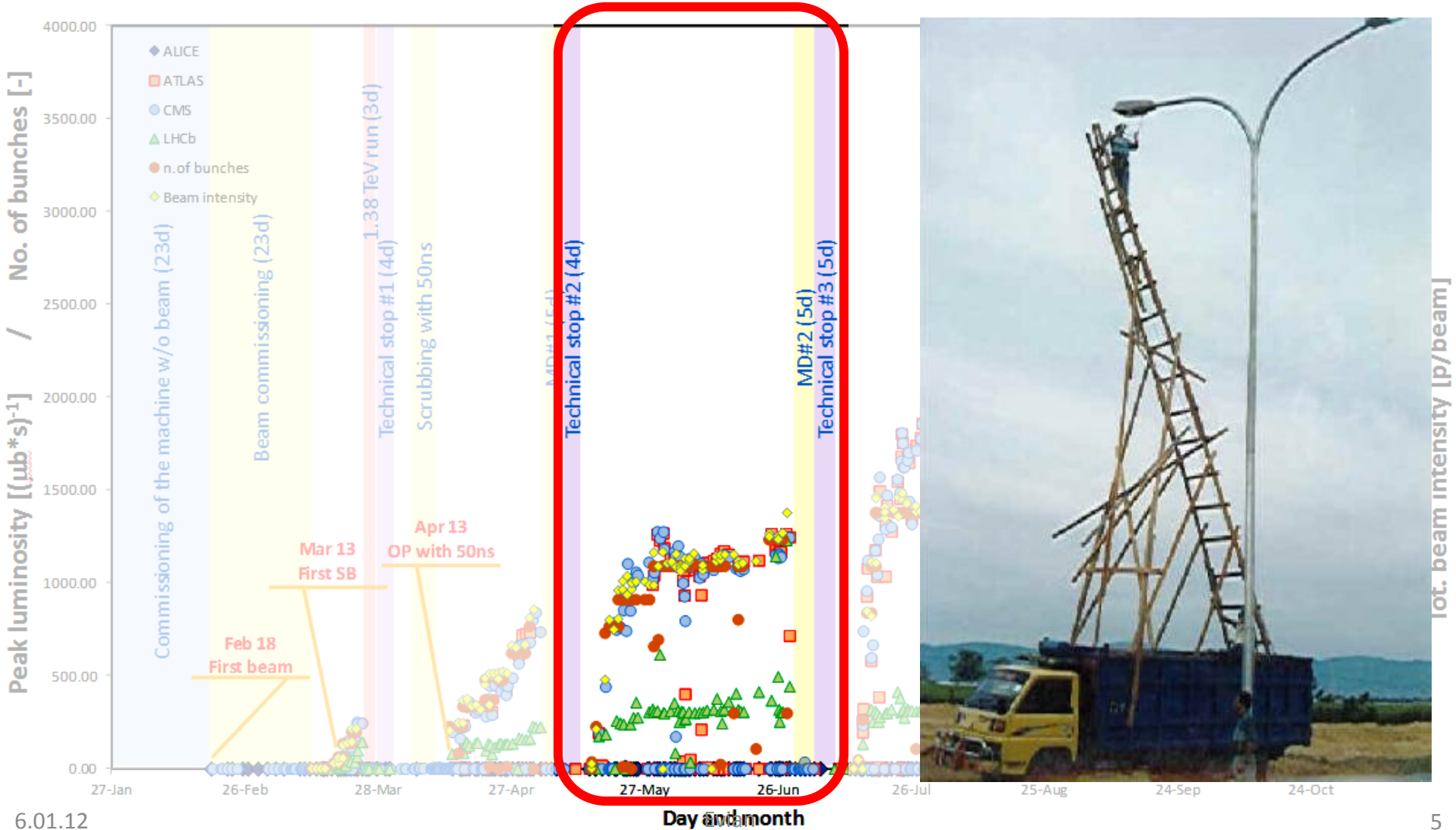
Scrubbing.....

Mirko Pojer



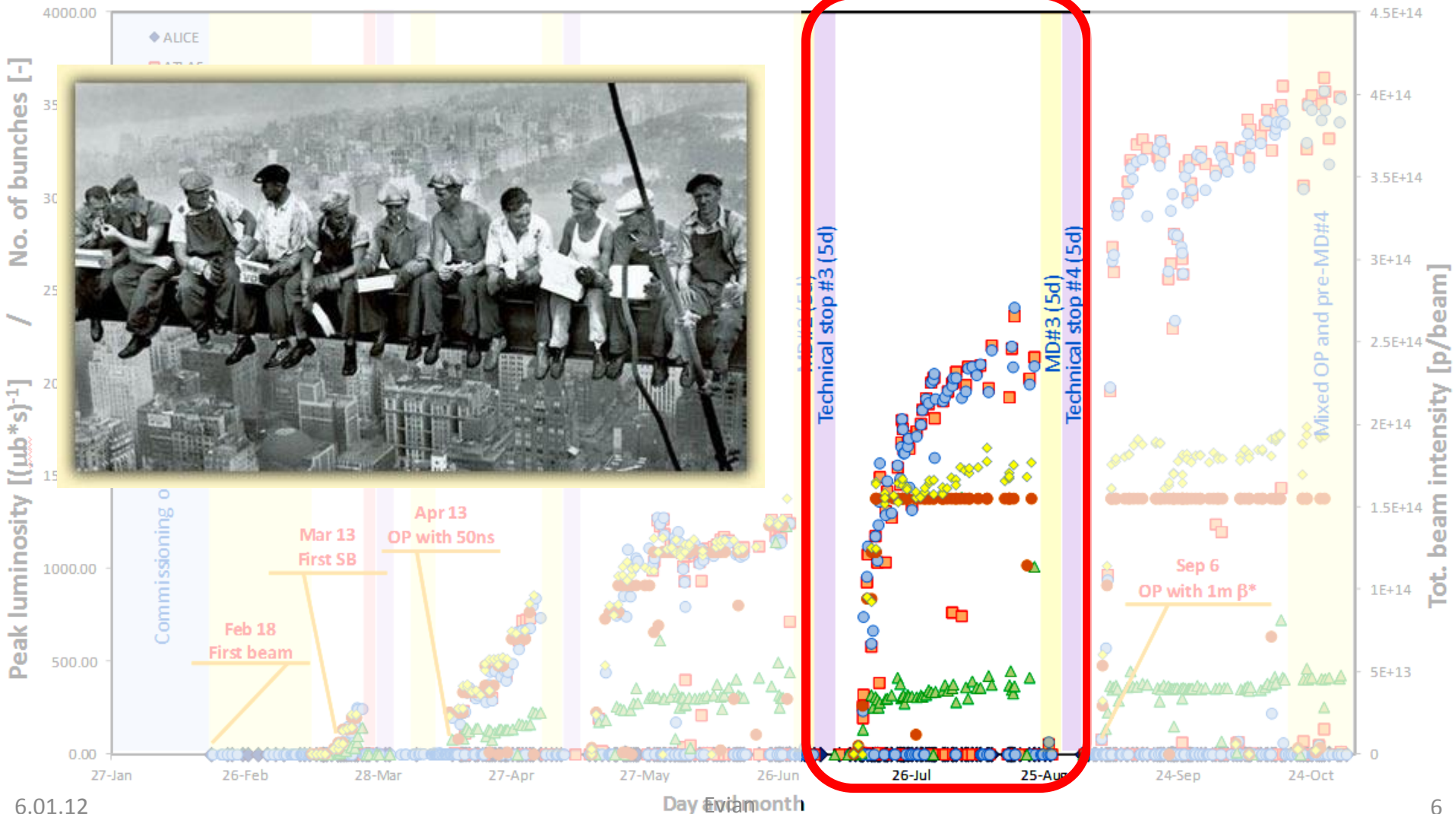
Consolidation

Mirko Pojer



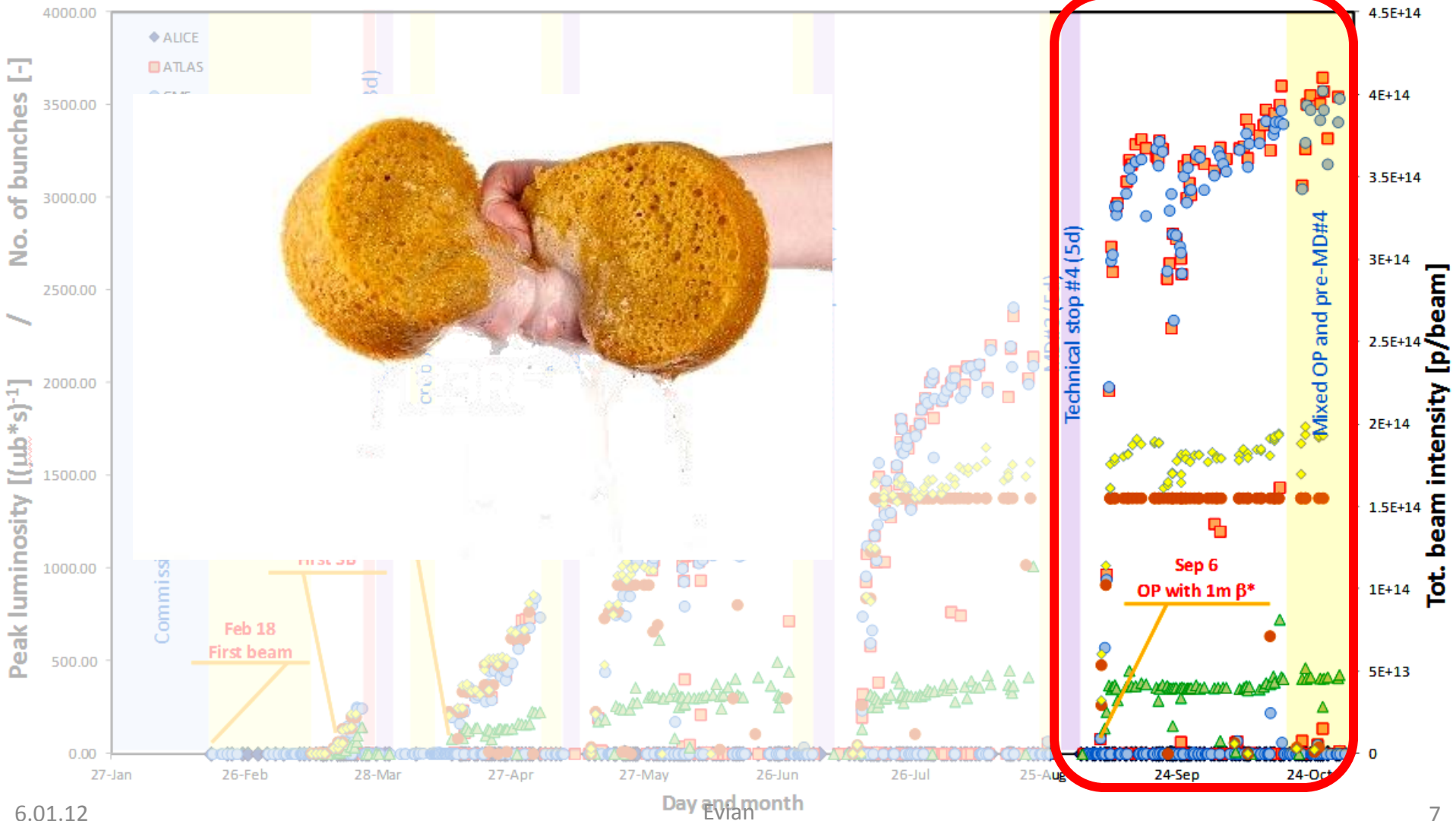
Working at height

Mirko Pojer



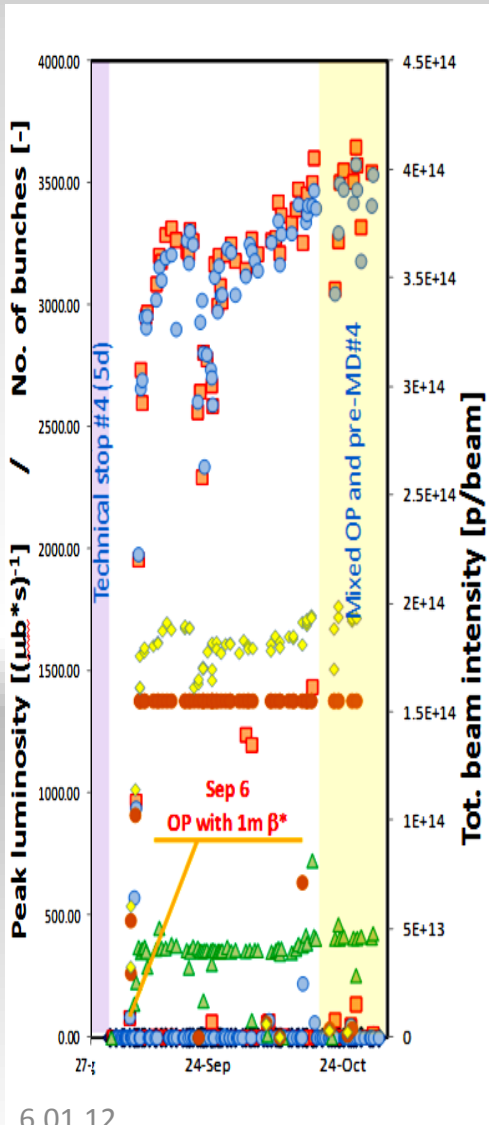
Squeeeeezing

Mirko Pojer

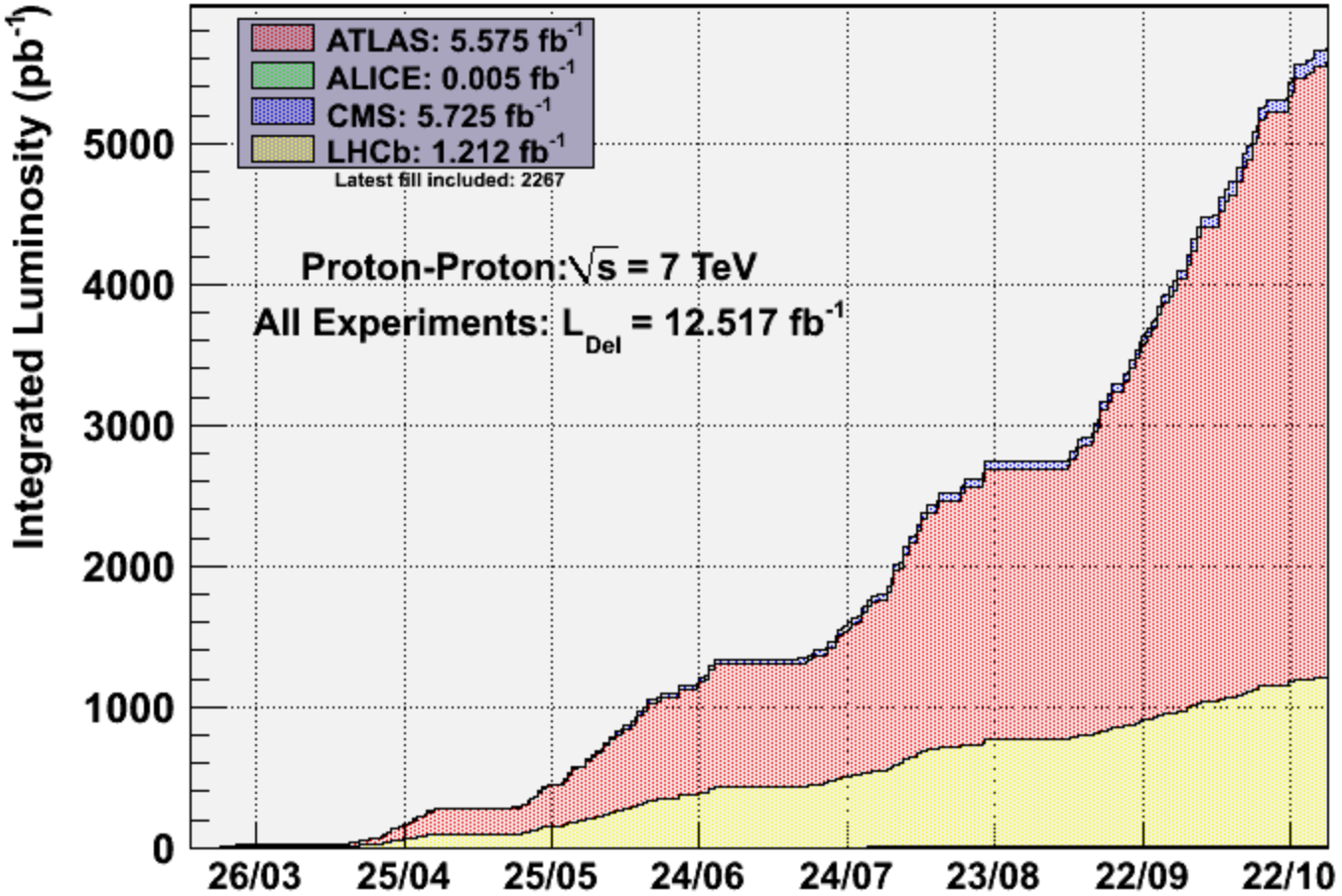


Impressive final run in

Mirko Pojer

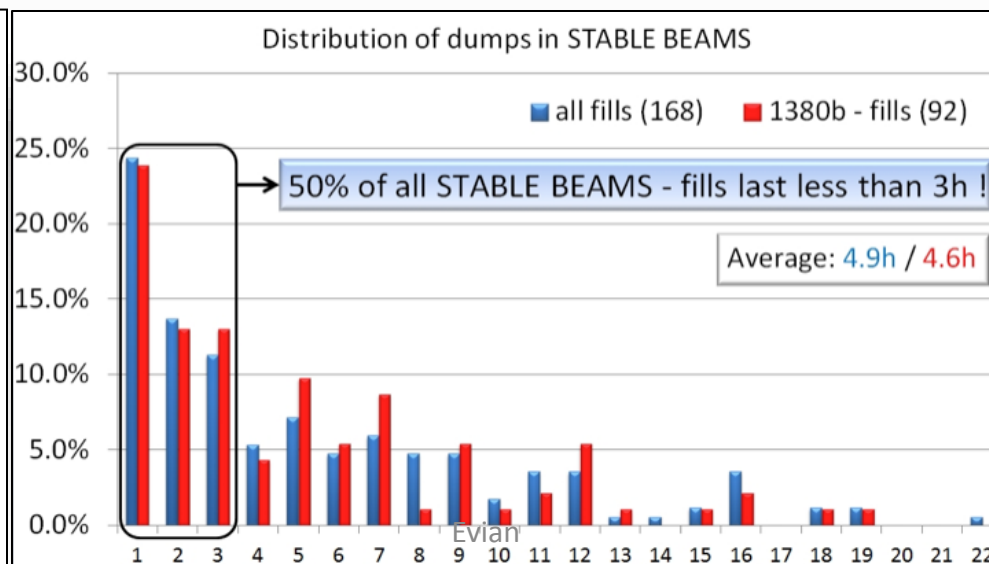
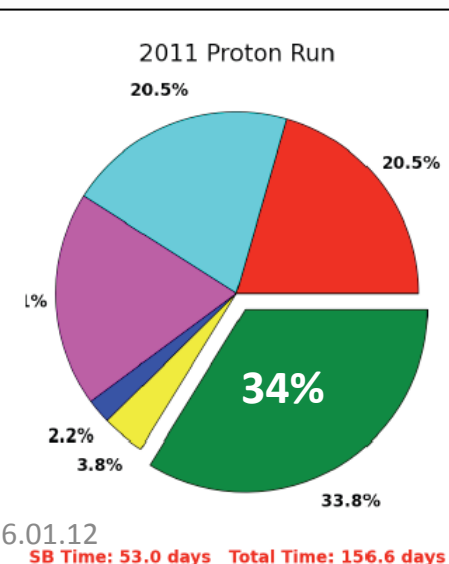


2011 Luminosity Production



Operation efficiency

- Overall efficiency
 - Pretty good considering that this is the LHC
 - Overall SB efficiency 34%
 - Improved fault tracking required
- Premature dumps
 - 50% of all STABLE BEAMS fills lasted less than 3 hours

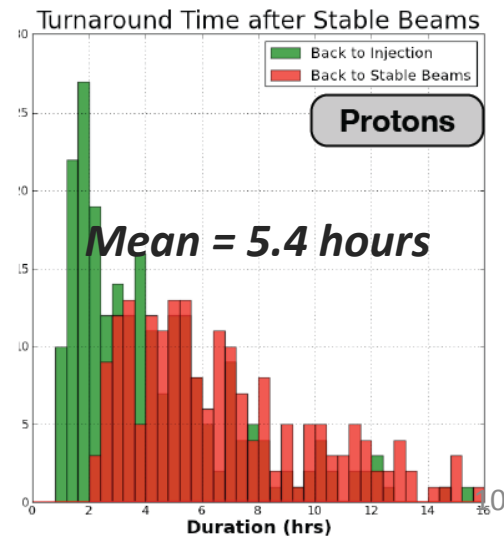


Markus Albert
Alick Macpherson

Turnaround

- Turnaround still largely dominated by machine availability.
- When there are no faults, **injection is the dominating factor**.
 - Beam preparation in injectors; Transfer line stability; Beam loss during the injection process.
- Improvements in due to automation/sequencing.
 - Ramp, squeeze, adjust...
 - **Also safer - fewer human errors**
- Potential improvements in 2012

Walter Venturini
Stefano Redaelli



Operational robustness

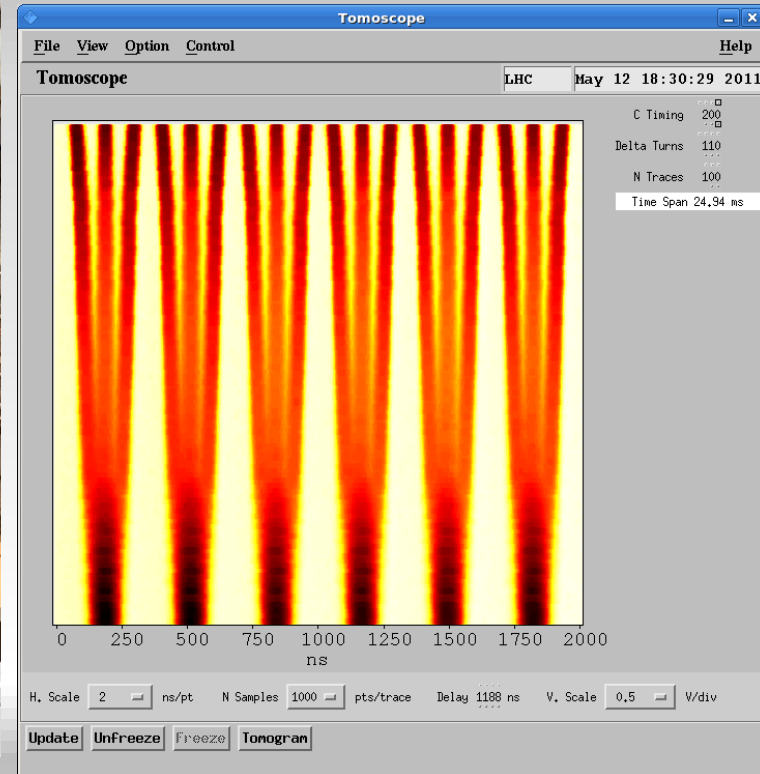
- Precycle, injection, 450 GeV, ramp & squeeze & collisions
- Some issues but in general:
 - If you got it in, you got it up
 - Excellent reproducibility and stability
 - Good transmission, lifetimes
 - Well over nominal bunch intensity with smaller than nominal emittances with only a few problems...
 - Not without some serious loving care and attention

Also of note

- Maturity of tools and procedures
- Maturing software (LSA, Sequencer, SIS, etc...)
- Controls
 - Even CCC ergonomics are getting better
- Databases
 - including the miracle of the logging database & Timber
- Understanding
 - vigorous machine development...
- **Confidence!**

En 2011 le nombre de requêtes au eLogbook a été de 17,487,427!

Beam from injectors



“Not in picture Steve Hancock and Bernard Vandorpe”

Excellent performance – years in the preparation

Karel Cornelis
Rende Steerenberg

Intensity ramp-up

Intensity ramp-up 2011

8b, 32b, 64b, 136b, 200b...

Baseline: three fills per step, in total 20h of Stable Beams

| | Scrubbing run | | | | physics program | | | | | | | | |
|----|---------------|----|-------|-----------|-----------------|----|----------------|------------|--------|---------------|----|------|--------|
| | Apr | | | | May | | | | June | | | | |
| Wk | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| Mo | 28 | 4 | 11 | 18 | Easter | 2 | 9 | EDF glitch | 23 | 30 | 6 | Whit | 13 |
| Tu | | | 3 b | | | | | 228 b | | | | | |
| We | | | 48 b | | | | | 480 b | | | | | |
| Th | | | 228 b | 480 b | | | Quench HITS | | | Ascension | | | |
| Fr | | | | G. Friday | | MD | RD3.LR4 | 768 b | | 1st May comp. | | | |
| Sa | | | 336 b | | | | AUG | | | | | | 1236 b |
| Su | | | | | 768b | | T12 | 912 b | 1092 b | | | | |

NB: Non-trivial issues encounter during 2011 ramp-up

2012: Reduce to 7 steps in 2012, 3 fills and 6 hours with 48b, 84b, 264b and 624b
3 fills and 20 hours with 840b, 1092b, 1380b

3 weeks for 1380b are within reach

Check list

Non-conform points: the intensity increase is put on hold pending a satisfactory understanding / resolution of the issue.

Magnet powering

No unexplained APOC failure in Fast Magnet for FMBX
No magnet quench after beam dump in RBS&ES
No unexplained quench of a magnet

No unexplained abort of the previous fills by magnet

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| Beam dump | Status | Who |
|---|--------|-----|
| Asynchronous dump understood? Protection worked correctly? | OK | JU |
| Periodic asynchronous dump data show no loss of protection. | OK | JU |
| No positioning errors on TOS/TCOD | OK | JU |
| No setting of thresholds (wrong sequences/unexplained faults on TOS/TCOD) | OK | JU |
| No unexplained MFD, MMB, MMR, ISS or BEITS faults | OK | JU |
| No potentially dangerous APOC or BPOC failure on MFD or MMB | OK | JU |
| No unexplained synchronization problem with TOS | OK | JU |
| Pressure and temperature rise in TOS above tolerances | OK | JU |
| Pressure and temperature rise in TOS above tolerances | OK | JU |
| Equipment protection OK at 400 Gev and 3.5 Tsr with pilot in case of any important component exchange | OK | JU |

- TCOD into 1.24 for 82 and in 10.5 for 81.
- BEITS running with reduced margin after compensation of exchange (will increase safety but possibly reduce availability).
- Pressure change around 0.04 bar max @ max 1 degree.
- Last BLM of TOS, as disabled APOC. They were faulty on 08/05 and repaired on 10/05, but still labeled as "not connected" by the BLM team. For this reason they need to remain labeled in the APOC analysis, but the APOC buffer can be read normally in case of any status. BLM enabled on 10/16, all ok.
- BEITS image was missing for a few dumps, but fixed by a camera reset.

Note: some items only relevant for increase injected intensity

| Injection | Status | Who |
|--|--------|-----|
| Injection oscillations within tolerance for all injections | OK | JU |
| Unexplained trip beam loss on TOS | OK | JU |
| No issues in injection procedure, settings or tolerances | OK | JU |
| Chim in injection region in tolerance and reference (tolerance < 0.3 mm) | OK | JU |
| Resetting of FL, transmitters and TOS done when needed | OK | JU |
| No increased rate of MFB fluctuations | OK | JU |
| No increased rate of MFB switch errors or missing | OK | JU |
| Unexplained MFB recovers in tolerance | OK | JU |
| No machine-protection related injection system hardware failures | OK | JU |

- Some steering required for 81 to correct oscillation - were above QC threshold, afterwards OK.
- One injection from SP5 without scrubbing, resulting in beam dump on BLM.
- MFB temperature increased to 84 degrees, measurements during run were not show loss of magnet inductance and injection interlock moved up to 80 degrees. Temperature going up less energy with longer bunches.
- During injection, oscillations above threshold with 72b. [QC took the risk] to continue injecting 144b without scrubbing and correcting trajectory using 120 as required by procedure. 100% interlocking should have prevented this - problem in the logic which resets the interlock if "no beam" is injected - needs to be fixed.
- During week 24 more problems with injection oscillations in T12, most likely related to ripple on the

Markus Zerlauth

Technical stops

Matteo Solfaroli

- No systematic source of trouble over the 5 TSs!
- It seems clear that we are improving in recovery...
- Need to improve fault details recording

X = number of days allocated

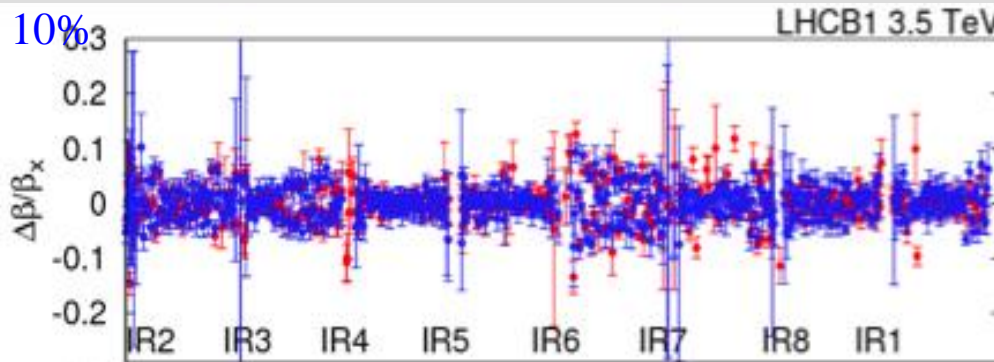
Allocated time for recovery = 24 h

| | Recovery + Beam commissioning | TOT TS time $(x-1)*24 + 12 + 24$ | Recovery coefficient (theoretical) | Recovery coefficient (real) |
|-------------|---|-------------------------------------|---------------------------------------|-----------------------------|
| TS#1 | 43 h | 108 h | 0.22 | 0.4 |
| TS#2 | 40 h (67 h including cryo stop) | 108 h | 0.22 | 0.37 |
| TS#3 | 44 h (130 h considering the power cut) | 132 h | 0.18 | 0.33 |
| TS#4 | 18 h | 132 h | 0.18 | 0.13 |
| TS#5 | 13 h | 132 h | 0.18 | 0.09 |

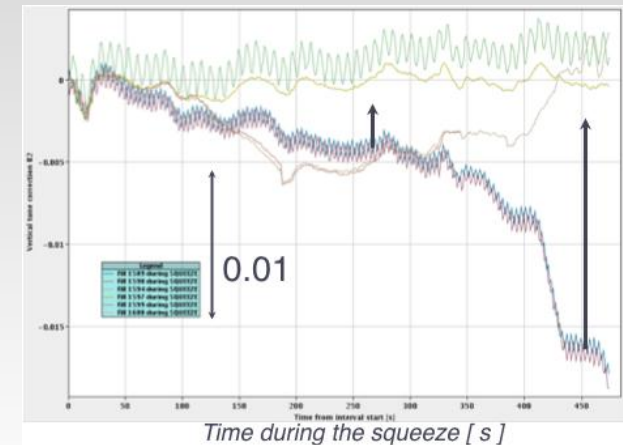
Optics

Commissioning and operation of optics/squeeze etc. under very good control

optics checks & correction: $\Delta\beta/\beta =$



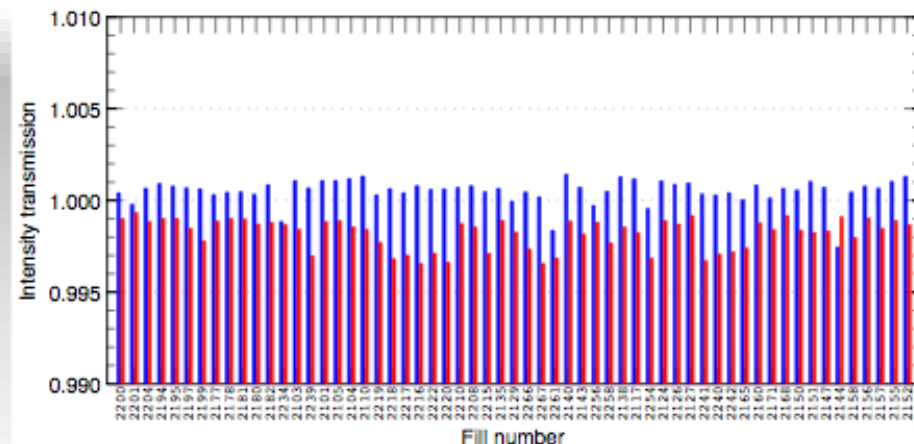
Squeeze feed-forward



2011 parameter table

| Parameter | Injection Feb.-Dec. | Squeeze 1 Feb.-Aug. | Squeeze 2 Sep.-Oct. | Squeeze ions Nov.-Dec. |
|-------------------------------------|------------------------|------------------------|------------------------|---------------------------|
| Energy [GeV] | 450 | 3500 | 3500 | 3500 |
| β^* IP1/5 [m] | 11.0 | 1.5 | 1.0 | 1.0 |
| β^* IP8 [m] | 10.0 | 3.0 | 3.0 | 3.0 |
| β^* IP2 [m] | 10.0 | 10.0 | 10.0 | 1.0 |
| Sep. [mm] | 2.0 | 0.7 | 0.7 | 0.7 |
| Xing ^{IP1/5} [μ rad] | 170 | 120 | 120 | 120 |
| Xing ^{IP2} [μ rad] | 170 | 80 | 80 | 80 |
| Xing ^{IP8} [μ rad] | 170 | 250 | 250 | 250 |
| Ramp [s] | 1020 | 1020 | 1020 | 1020 |
| Squeeze [s] | - | 475 | 558 | 1233 |
| Collision [s] | - | 56 | 56 | 260 |

Losses during squeeze well below 1 %

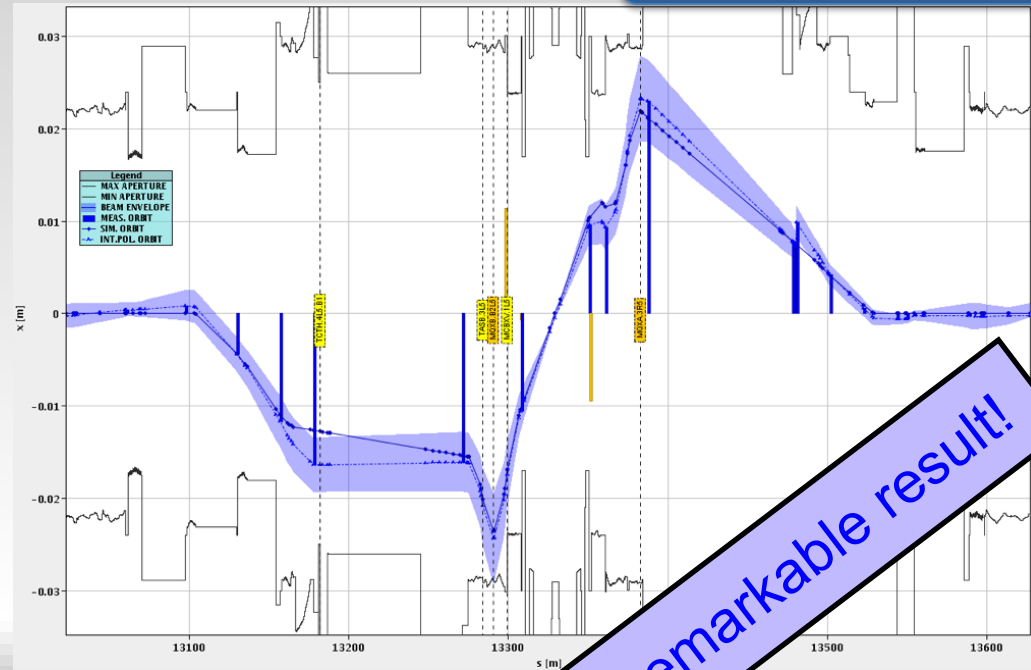


IR1 and IR5 aperture at 3.5 TeV

Stefano Redaelli

2011's "Platinum mine"

| IR | Plane | Type of bump in standard optics | Aperture [σ] |
|----|-------|---------------------------------|-----------------------|
| 1 | H | Separation | 19.8 – 20.3 |
| 1 | V | Crossing | 18.3 – 18.8 |
| 5 | H | Crossing | 19.8 – 20.3 |
| 5 | V | Separation | > 20.3 |



Remarkable result!

We got **4-6 sigmas** more than the expected 14 sigma

Triplet aperture compatible with a well-aligned machine, a well centred orbit and a ~ design mechanical aperture (small tolerance)

BUT: only one side measured

The additional margin (4 to 6 σ) allows $\beta^* = 1 \text{ m}$ at $120 \mu\text{rad}$ if the orbit is corrected like at 1.5 m and if the beta-beat is the same

Striking Platinum and then mining it

Optics and aperture

- LHC optics and aperture are good
 - Major achievement for all the teams involved
 - Reached performance beyond expectations and beyond design
- Successful squeeze commissioning and operation in 2011
 - Many improvements from 2010: shorter and more robust operation
 - Commissioning of new optics has become routine
 - Optics behaves well and is correctable to within $\sim 10\%$!
- The LHC aperture is good
 - Injection aperture $> 12\sigma$ \rightarrow nominal aperture achieved (with margins!)
 - In 2011 first “gentle” IR aperture measurement at 3.5 TeV.
 - This allowed a 50% step in peak luminosity
- Outlook for 2012
 - A couple of implementation issues for the squeeze settings addressed
 - Orbit stability in the squeeze must be improved to allow tight coll settings
 - Aperture must be re-measured at injection and at top energy.

Reach in β^* with tight settings

| old | 3.5 TeV | 4 TeV | 7 TeV |
|---------------------|---------|-------|-------|
| gamma | 3730 | 4263 | 7461 |
| TCP 7 | 4 | 4.3 | 5.7 |
| TCSG 7 | 6.0 | 6.4 | 8.5 |
| TCLA 7 | 8.0 | 8.6 | 11.3 |
| TCSG 6 | 6.8 | 7.3 | 9.6 |
| TCDQ 6 | 7.3 | 7.8 | 10.3 |
| TCT | 9.1 | 9.6 | 12.6 |
| aperture | 10.9 | 11.6 | 15.0 |
| Φ (μ rad) | 143 | 134 | 110 |
| β^* (m) | 0.7 | 0.7 | 0.6 |

| new | 3.5 TeV | 4 TeV | 7 TeV |
|---------------------|---------|-------|-------|
| gamma | 3730 | 4263 | 7461 |
| TCP 7 | 4 | 4.3 | 5.7 |
| TCSG 7 | 6.0 | 6.3 | 7.7 |
| TCLA 7 | 8.0 | 8.3 | 9.7 |
| TCSG 6 | 6.8 | 7.1 | 8.5 |
| TCDQ 6 | 7.3 | 7.6 | 9.0 |
| TCT | 8.2 | 8.6 | 10.4 |
| aperture | 9.4 | 9.9 | 12.1 |
| Φ (μ rad) | 155 | 145 | 126 |
| β^* (m) | 0.6 | 0.6 | 0.45 |

- Tight settings, old method:

- IR6 and IR7 fixed in mm at the 3.5 TeV tight settings
- Adjusting other margins IR6-TCT-aperture with expected beam size

- Tight settings, new method:

- primary collimator stays at 4σ 3.5 TeV position in mm, but using σ at 4 TeV for margins in IR7 and IR6-IR7

Fall-back solution in case of unexpected problems:
intermediate settings, linear margins, $\beta^*=0.9$ m

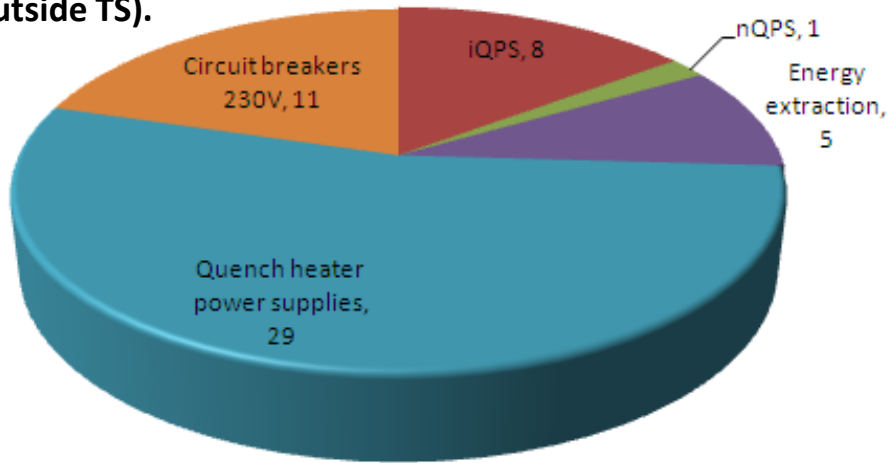
SYSTEM PERFORMANCE

Excellent performance of RF system: Philippe Baudrenghien!

Availability - QPS

... has demonstrated its reliability and capability to ensure the integrity of the protected superconducting elements.

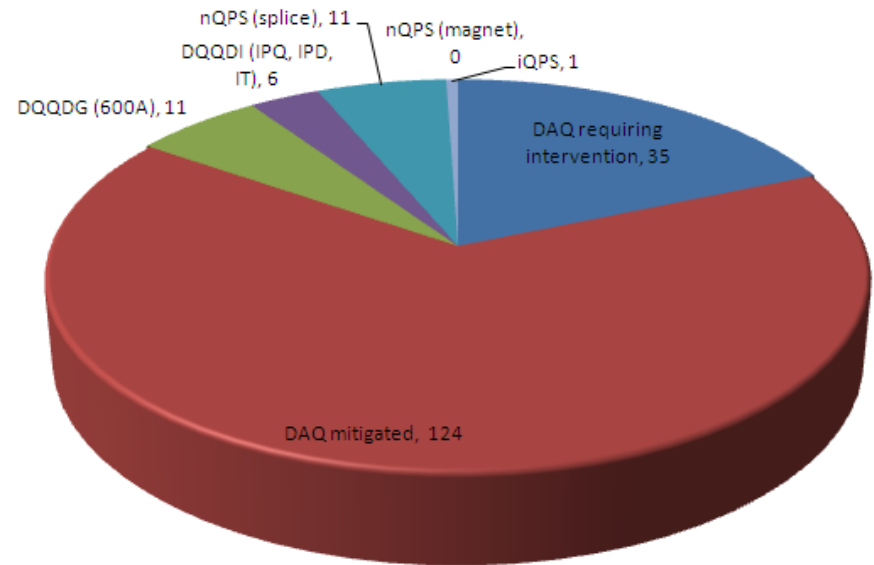
QPS and QPS related hardware faults causing interventions (54 outside TS).



“While most of the radiation induced faults are transparent to LHC operation, the number of beam dumps caused by spurious triggers is close to the maximum admissible limit.”

None of the observed faults caused a total loss of magnet and/or circuit protection.

Reiner Denz

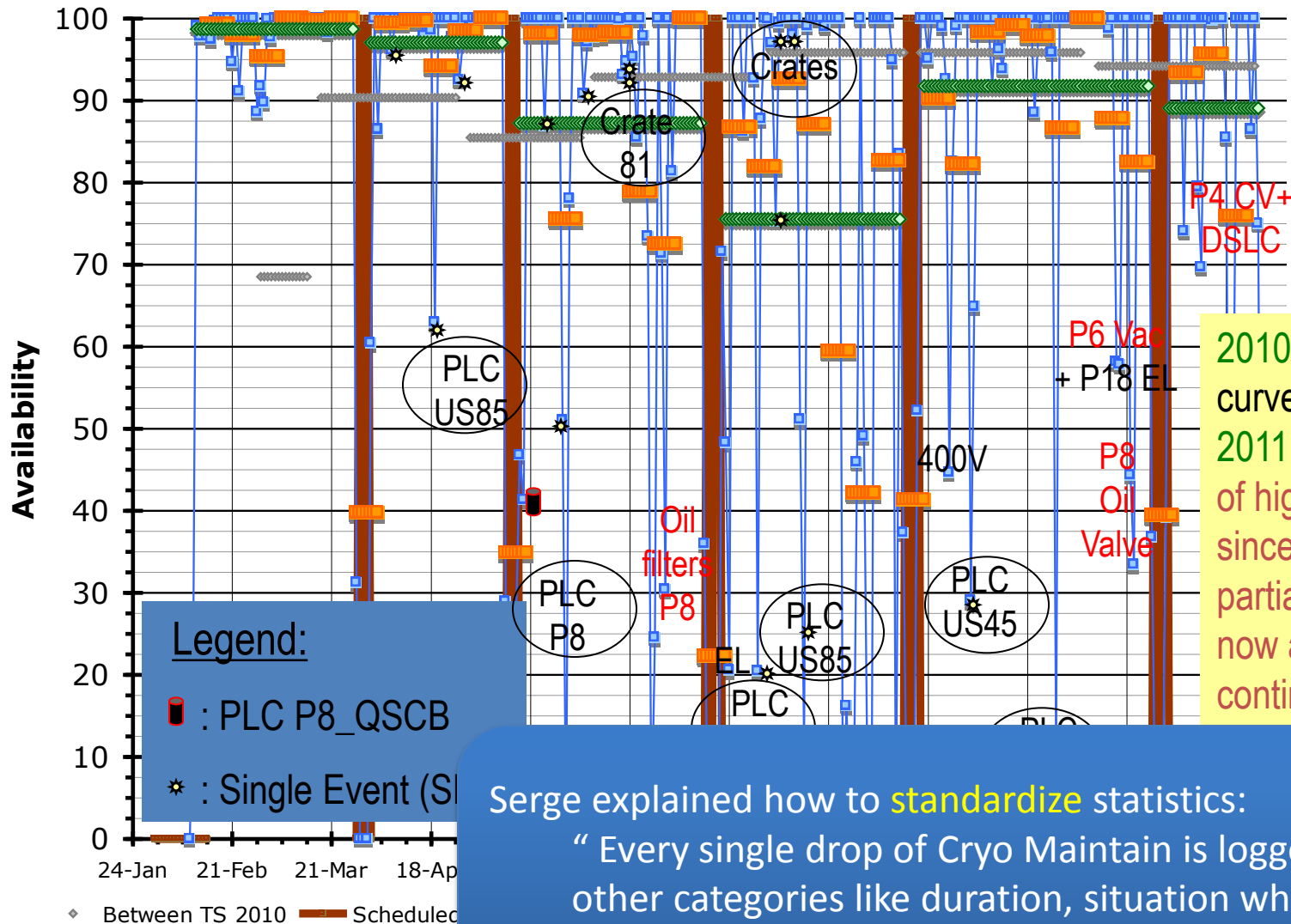


QPS radiation induced faults (190).

Availability - QPS

- Consolidation measures over Xmas TS will not lead to zero radiation induced trips, but limit the number of faults despite increased luminosity
- Tune feedback - detection settings for 2012 run (ECR in preparation)
 - $\pm 2\text{V}$, $t_{\text{EVAL}} = 190 \text{ ms}$, $|I| < 100 \text{ A}$
 - $\pm 100 \text{ mV}$, $t_{\text{EVAL}} = 190 \text{ ms}$, $100 \text{ A} \leq |I| \leq 200 \text{ A}$, $|I_{\text{MAX}}| \leq 200$
- Comprehensive program of mitigation and consolidation ongoing (DAQ, nQPS splice protection, IPQ/IPD/IT, 600 A....)

LHC Cryo global availability





Cryogenics - Summary

- Major issues of 2010 (Cold Compressors - sub atmospheric filters - instrumentation) have been corrected and we have done our best to provide a correct availability this year again, despite serious discoveries (degraded QRL45 or Bearings/Compressors)!
- For beams, Cryo availability for 2011 (89.7%) has reduced by mostly:
 - Various types of SEU, treatment to be completed at Xmas
 - Cryo (Compressors - CCs diagnostics) issues to be consolidated at Xmas
 - Supply EL (ext.+int.) increased failures this year
 - And bad luck with concentration of problems at P8 with the longest recovery!
- With beams, interesting tuning for beam induced effects and interactions with beam vacuum (beam screen cooling loops), to be continued with increased luminosity!
- Very positive signs of good cryo performance observed on the majority of the sectors, allowing to consider 95% global availability reachable (Energy ≤ 5 TeV)
- Looking forward to this intense and interesting Xmas break for our consolidations and training, in order to be ready for the best integrated luminosity in 2012 !!!

Serge Claudet

Injection and Dump Systems – Summary

1/2

Chiara Bracco

| Equipment | Problems In 2011 | Applied Solution | 2012 Operation |
|-----------|---|---|---|
| LBDS | Internal triggers | Electronics, faulty components exchanged | Ok, new power supplies. Testing time during machine checkout for new HW/SW/FW |
| | No async. dumps | | Ok |
| TCDQ | Load thresholds/settings, energy limits and position interlocks | Repeat sequence | Ok, β^* interlock + new potentiometer electronic → more precise position reading |
| | Mechanical Offset | Compensation with beam based alignment | Ok |
| MKI | Flashover | SIS interlock to inhibit injection in case of vacuum exceeding thresholds | Ok if Injection protection collimators correctly set up and detectors off during injection |
| | Erratic | Faulty components replaced + diagnostic + faster electronics with lower voltage threshold | Ok if Injection protection collimators correctly set up and detectors off during injection |
| | Temperature | SIS at 62 °C + softstart to measure rise-time (inductance) | Ok if T does not increase further since close to Curie limit. New diagnostic to measure delay |
| | Vacuum | HW interlock + MKI cond. | Ok but waiting time between |

Injection and Dump Systems – Summary

2/2

| Equipment | Problems in 2011 | Applied Solution | 2012 Operation |
|----------------------|---|---|--|
| TDI | Angular offset | Compensation with beam based alignment | Ok |
| | Vacuum and ALICE background | Parking position to $\pm 55\text{mm}$ | Ok |
| | Controls (LVDT noise) | Relaxed gap interlock | Ok, if noise not worse |
| TDI/TCLI/TCDI | Association to “bad” beam process → wrong position | | Not Ok, Separate beam process needed |
| XPOC | Missing data, faults | New release, filters, cards.... | Ok, stronger filters + BI data collection improvements (directly into PM system) |
| IQC | Missing data, injection not detected | New release | Ok but needs to become clearer (closer to operation, easier steering). Risk of 144 bunches overinjection must be eliminated |

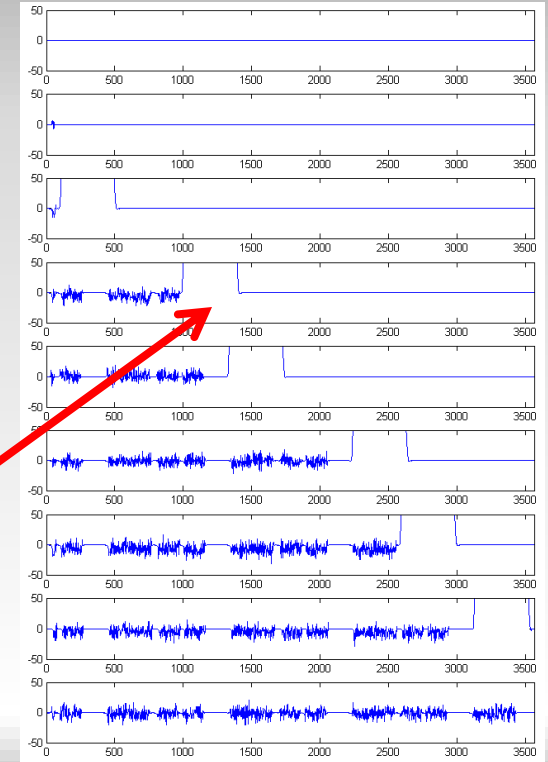
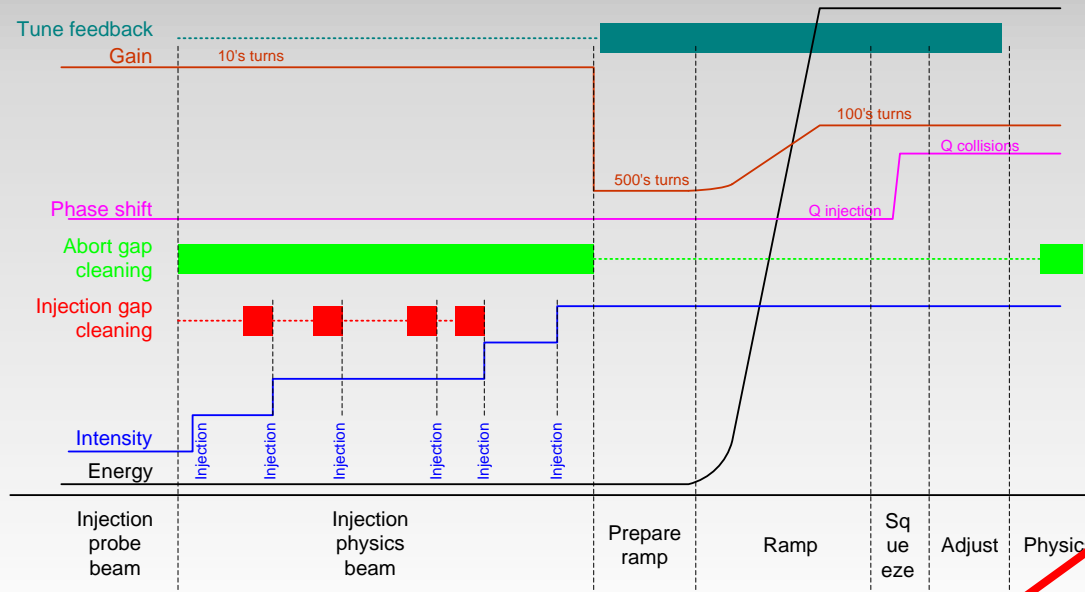
Ready for 2012 operation but:

- Dedicate enough time w/wo beam to properly test components (new electronics, SW, FW....) and set up (collimators, IQC references for steering...)**
- Respect safety instructions (Experiments off during injection, MKI vacuum and temperature interlocks)**

Safe operation and reduce downtime!!!

Chiara Bracco

Transverse feedback system



All the time!

- Injection oscillations
- Injection gap cleaning
- Abort gap cleaning
- Emittance preservation
- Coherent instabilities

Daniel Valuch
Wolfgang Hofle

Collimation

Left Jaw (mm)

Right Jaw (mm)

| | | |
|------|-------------|-------|
| 2.03 | TCP.D6L7.B1 | -1.08 |
| 1.76 | TCP.C6L7.B1 | -2.52 |
| 1.16 | TCP.B6L7.B1 | -2.42 |



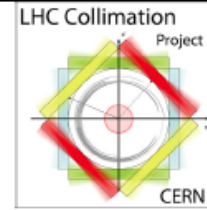
- Proton cleaning efficiency of 99.97% for 2010 maintained in 2011.
- Semi-automatic tool has improved collimator operation during alignment (reduced setup time and eliminated beam dumps during setup).
- Aim for tight collimator settings in 2012: should improve efficiency by factor ~ 8 , but reduce TCP-TCSG margin by factor ~ 1.5 at 4 TeV.
- Aim for qualifications every 3 months, complemented by online monitoring.
- Further improvements in the pipeline.

Gianluca Valetino



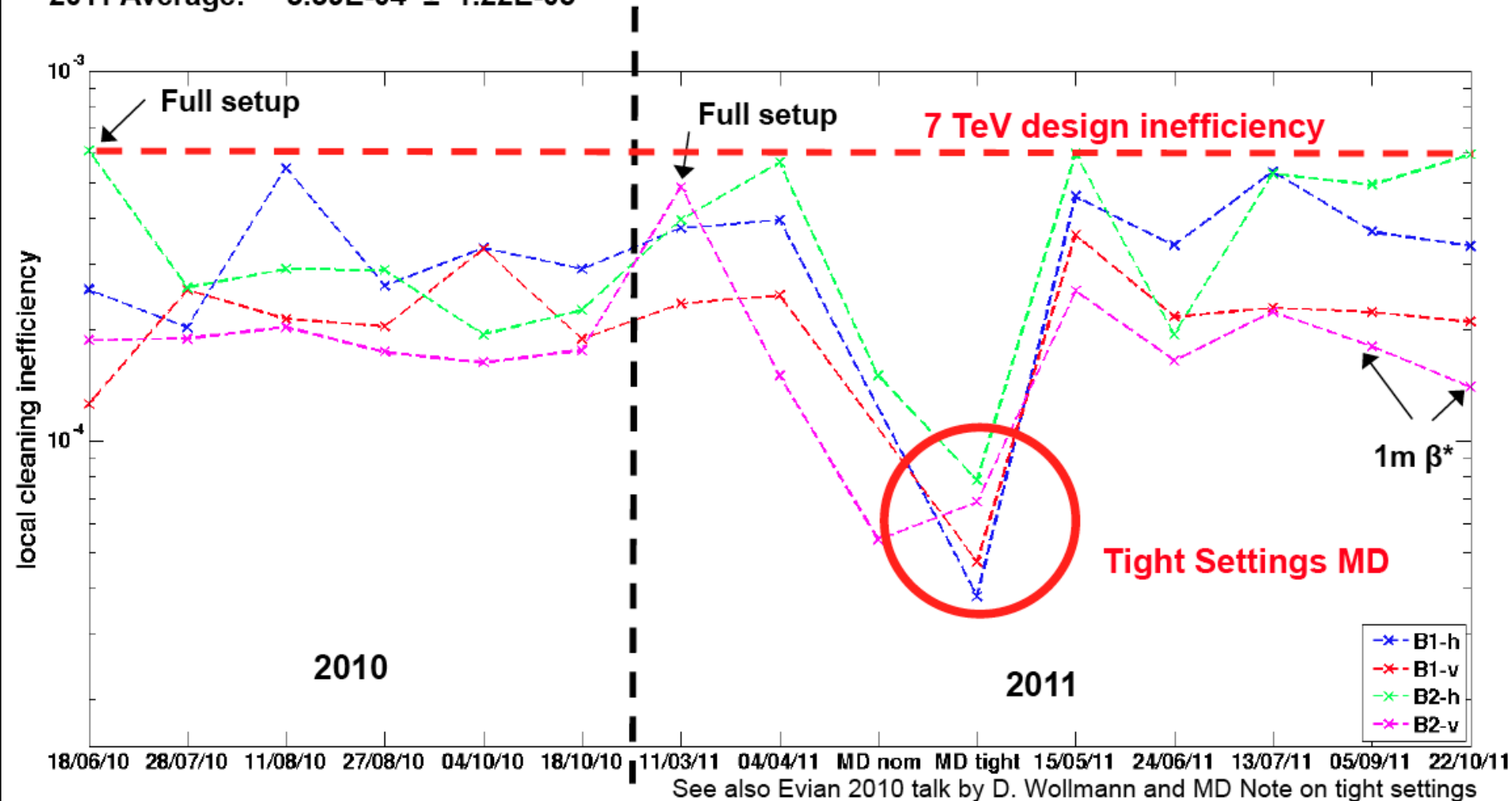
Proton Cleaning Inefficiency 2010/2011

3.5 TeV, 1.3s integration time (Q8 IR7)



2010 Average: $2.57E-04 \pm 6.69E-05$
2011 Average: $3.39E-04 \pm 1.22E-05$

Cleaning Inefficiency in 2011 consistent with 2010



Machine Protection

- Unpinned by superb performance of machine protection and associated systems
 - Had to be taken as given to even start the intensity ramp-up
 - Rigorous machine protection follow-up, qualification and monitoring (Post Mortem analysis, MPP, rMPP)
- **Routine collimation of 110 MJ LHC beams** without a single quench from stored beams.

Markus Zerlauth

Orbit and tune feedbacks

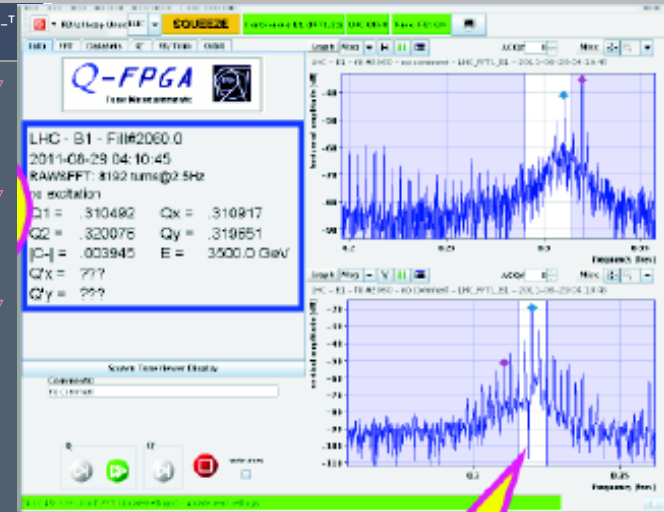
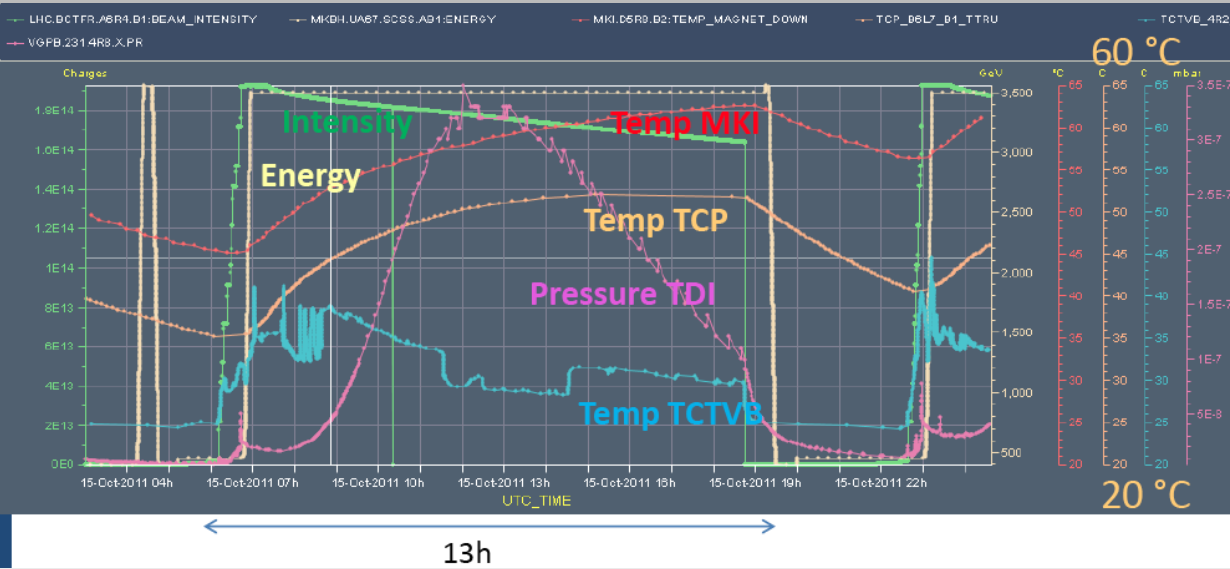
- Clearly essential to operations: we can't live without them
- Most of the dumps (~33) we had in 2011 should be avoided next year thanks to:
 - Change of QPS thresholds to avoid RQTs trips
 - HW modifications to avoid BBQ saturation
- **Should be left with 2-3 dumps!**
- Proposal to improve tune measurement to be tested at the beginning of the run:
 - ADT gating in combination with BBQ gating...
- Problem with real time trims in H plane to be sorted out to allow FF, already exploited as much as we could in 2011.

Laurette Ponce

Beam Instrumentation

- Great performance overall
 - instrumentation has allowed a profound understanding of the machine and paved the way for the impressive performance increase
 - Pushing performance – pushing demands on the systems...
- **Emittance** grows 20 % - 30 % from SPS extraction to LHC collisions
 - Need accurate, bunch by bunch measurement of beam size through the cycle with cross-calibration between the different measurements
 - See Verena Kain – this session
- **Orbit stability** and thus BPM stability and accuracy
 - LSS BPMs should be more reliable (needs commissioning time for checks)
 - Automatic filter selection - improved orbit position resolution
 - Temperature dependence still there

Mariusz Sapinski
Rhodri Jones



POTENTIAL LIMITATIONS

Limitations

Impedance effects on beam stability

- Head-tail (SB & CB) and coupled bunch coherent modes combatted with Landau damping (octupoles) and transverse damper
- Tight collimator settings with high bunch intensity
 - Christmas tree in August
 - Octupoles to 550 A
 - Stricter Q' control

Nicolas Mounet

Beam induced heating

- MKI injection kicker (delays injection)
- double bellow module VMTSA (broken spring, dangling fingers)
- TCP collimator in IR7 (1 dump, interlock increased)
- TCTVB collimator
- TDI collimators
- Beam screens (all, longer bunch length eased operation + scrubbing)
- Q6R5 – cooling margin

Benoit Salvant

e-cloud and vacuum instabilities

- Scrubbing...
- Vacuum instabilities
 - Points 2 & 8
 - CMS
 - MKI
 - TDI

Giovanni Rumolo
Giuseppe Bregliozzi

Tickling the tail of the dragon

R2E

2011: ~70 dumps events

@ Predicted 100 in Chamonix 2011

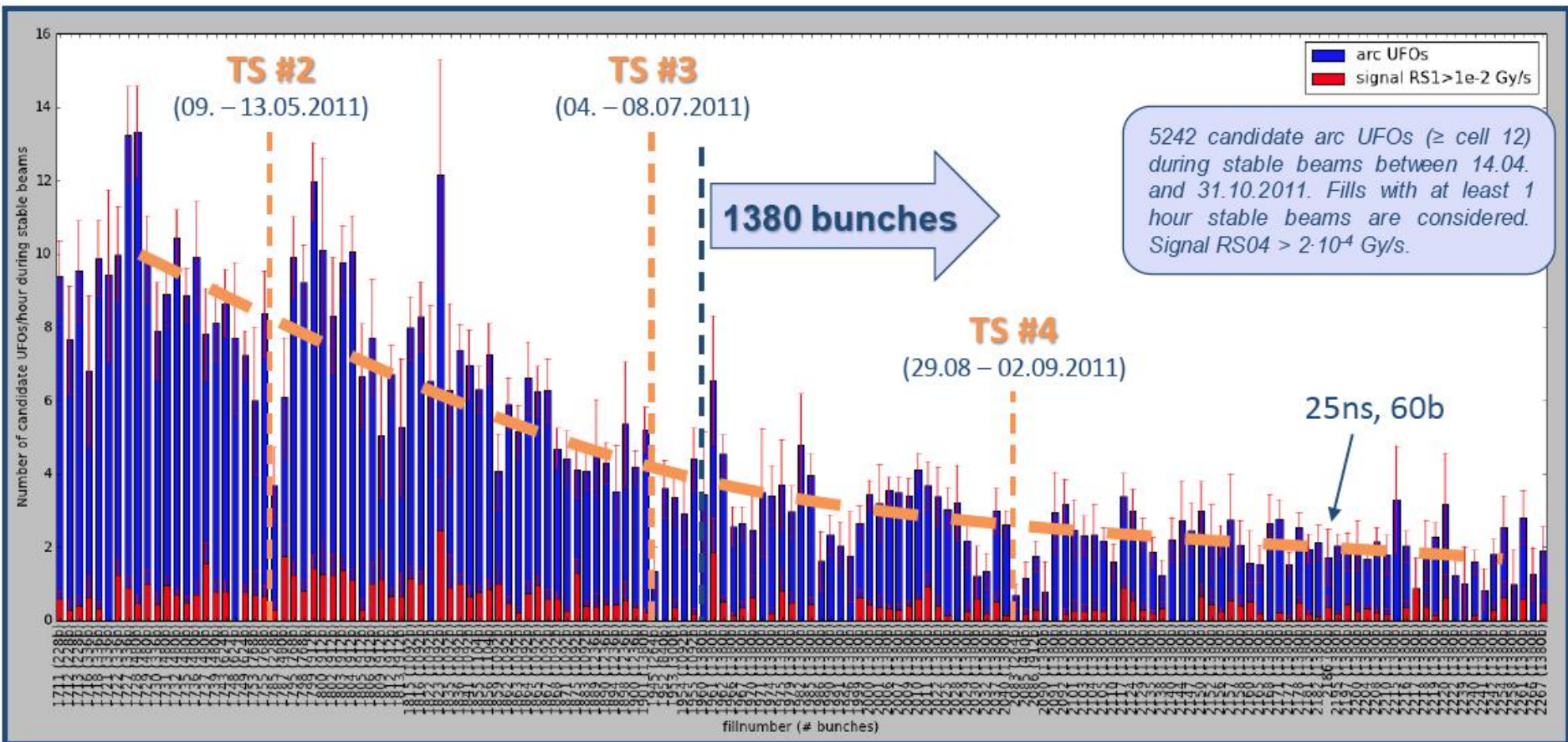
@ Good agreement (considering on fly mitigations)

2012: ~30-50 dump events expected

@ Mitigation actions (patch solutions, shielding and relocation) are crucial to reduce dump events

Giovanni Spiezia
Markus Brugger

UFO rate 2011



Decrease of UFO rate from ≈ 10 UFOs/hour to ≈ 2 UFOs/hour.

Concerted program of investigations, simulations, tests with beam ...

Tobias Baer

Tentative 2012 run configuration

| | | |
|---------------------|-------|---|
| Energy | 4 TeV | <ul style="list-style-type: none">• As detailed by F. Bordry• Low number of quenches assumed – stay conservative on BLM thresholds• Re-evaluation of risk profile |
| Atlas & CMS beta* | 60 cm | <ul style="list-style-type: none">• Start with 60 cm and tight settings• 70 cm if tolerance prove too tight• 90 (80?) cm if tight settings problematic |
| Alice & LHCb beta* | 3 m | <ul style="list-style-type: none">• Natural satellite/main collisions (drop enhanced collisions) |
| LHCb crossing angle | H/V | <ul style="list-style-type: none">• Move from H to V crossing going into collision• New separation leveling scheme |

Tentative 2012 run configuration

| | | |
|--------------------------|----------|--|
| Collimator settings | tight | <ul style="list-style-type: none">• Add tolerances in quadrature• Review orbit stability versus tolerances• Octupoles to 550 A• Stricter chromaticity control |
| IR6 optics | rematch | <ul style="list-style-type: none">• Optimize phase advance between MKD kicker and TCSG |
| Optics in general | | <ul style="list-style-type: none">• Updated sequence to reflect recent modifications• Requirements for non-linear correctors established by ABP |
| Bunch length on flat top | increase | <ul style="list-style-type: none">• Increase from start as per RF recommendation• Impact on luminosity to be established |

Action list recently presented in LMC, follow-up in LBOC etc.

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 - Fabiola Gianotti
 - Pierluigi Campana
 - Simone Giani
 - Paolo Giubellino
 - Guido Tonelli

and now you have a problem for 2012
“gimme twenty!”