Experience with MPS during the 2010 run

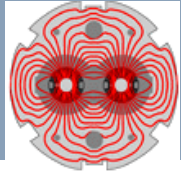
J. Wenninger
BE-OP-LHC

Acknowledgments: **M. Zerlauth (statistics !)**,
R. Schmidt, MPP(r) colleagues and UFO crews.

Outline

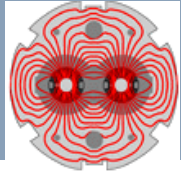
- Commissioning and intensity increase
- Reviews
- The surprises
- Statistics

MPS commissioning phase



- March and parts of April 2010 were largely devoted to commissioning with beam of the LHC MPS following predefined procedures.
  - *Test plan on WEB pages, results filled by the experts, checked by MPP responsible.*
  - ✓ *Good discipline in filling in test results, plans were followed.*
  - ✓ *No major issues or availability problems encountered in this phase.*
- The same period saw the first collimator setups, including validations with loss maps and de-bunched beams (asynchr. dump simulations).
  - *Setups verified. Re-checked periodically.*
  - *Fill-by-fill verification using post-mortem data by MPP responsible.*
  - ✓ *Very good stability of orbit and beam cleaning over the year.*
  - ✘ *But the stability is not yet sufficient for nominal tolerances.*

Steering the energy increase



- The intensity increase was steered through the restricted Machine Protection Panel* (*MPPr*).
  - *Composed of MPS experts from the main MP sub-systems.*
  - *Provided recommendations on MPS envelope / max. intensity, to be approved by the LMC.*
- From the beginning the plan foresaw 3 phases:
  - *Low intensity for commissioning and early experience.*
  - *Ramp up to 1-2 MJ followed by a period of ~4 weeks at 1-2 MJ.*
  - *Break the World record and move into 10's of MJ regime.*

But the real pace was eventually quite different !

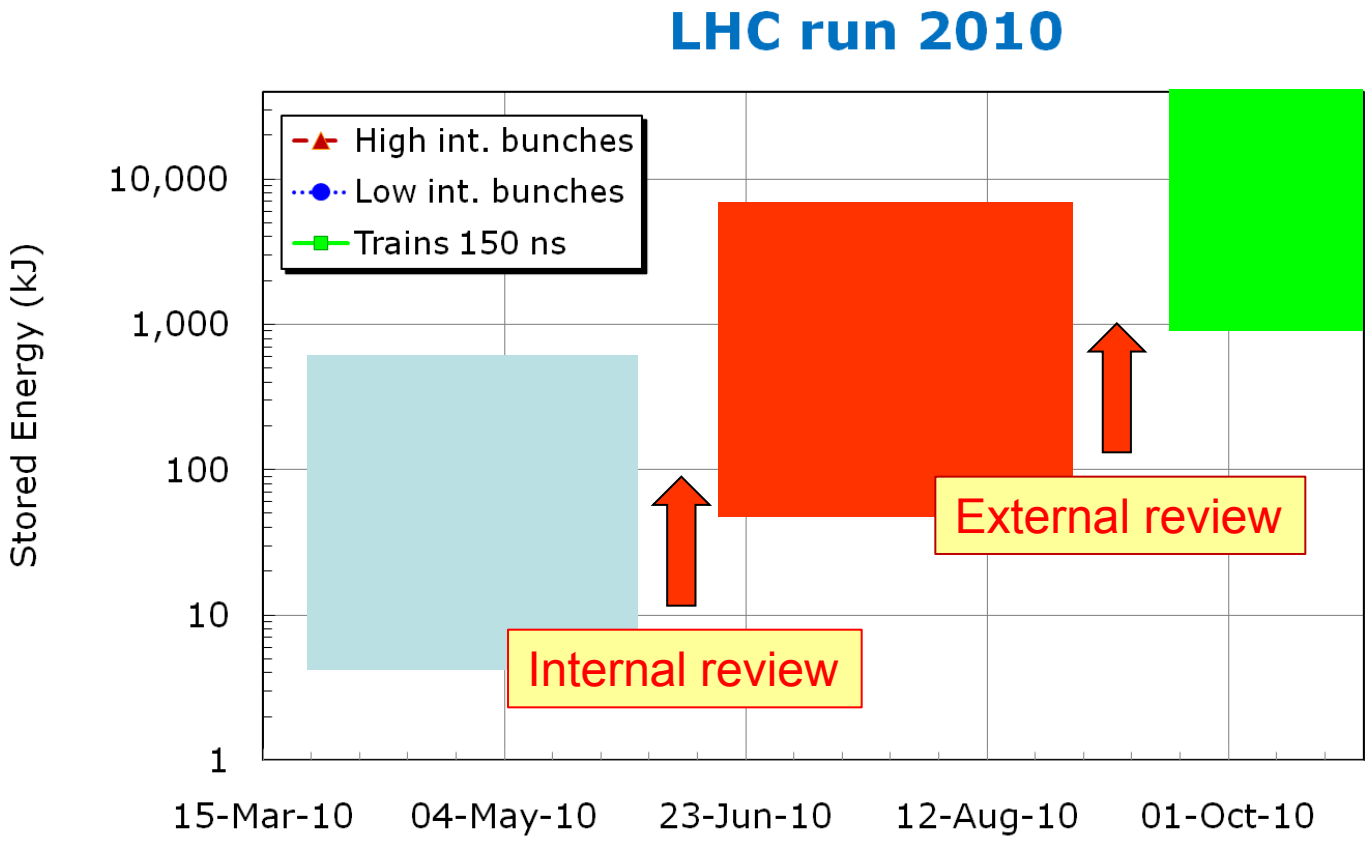
*** : R. Assmann, B. Goddard, J. Uythoven, B. Dehning, M. Zerlauth, A. Siemko, R. Schmidt, J. Wenninger, M. Lamont, M. Ferro-Luzzi**

Stored energy progression in 2010

Low bunch intensity operation, first operational exp. with MPS

Ramping up to 1 MJ, stability run at 1-2 MJ

Breaking the records !



Plan (LMC 17th Feb 2010) versus reality

Plan:

Commissioning 'in the shadow' of physics OP.

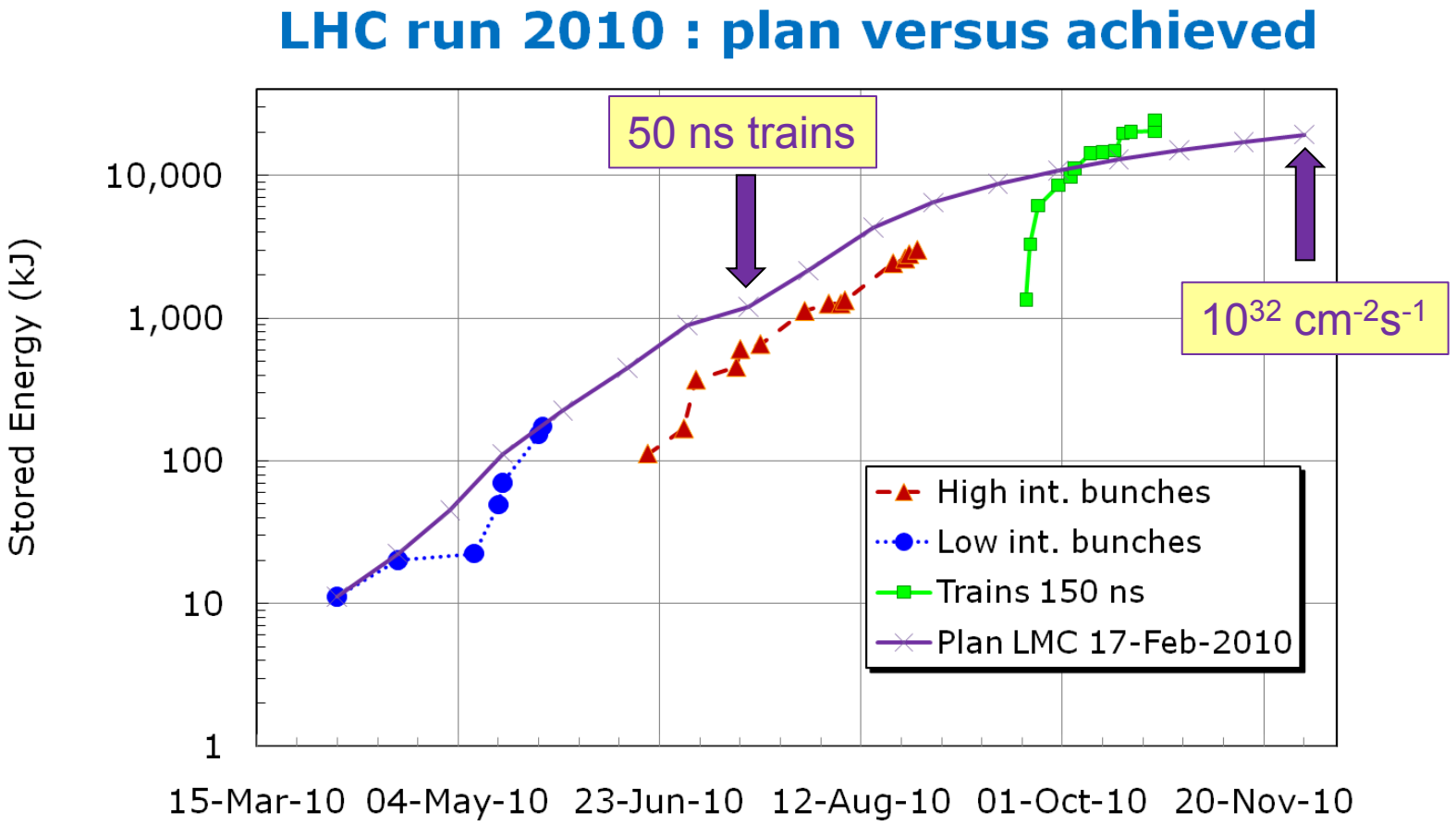
50 ns trains of 8×10^{10} p.

Reality:

Higher bunch charge.

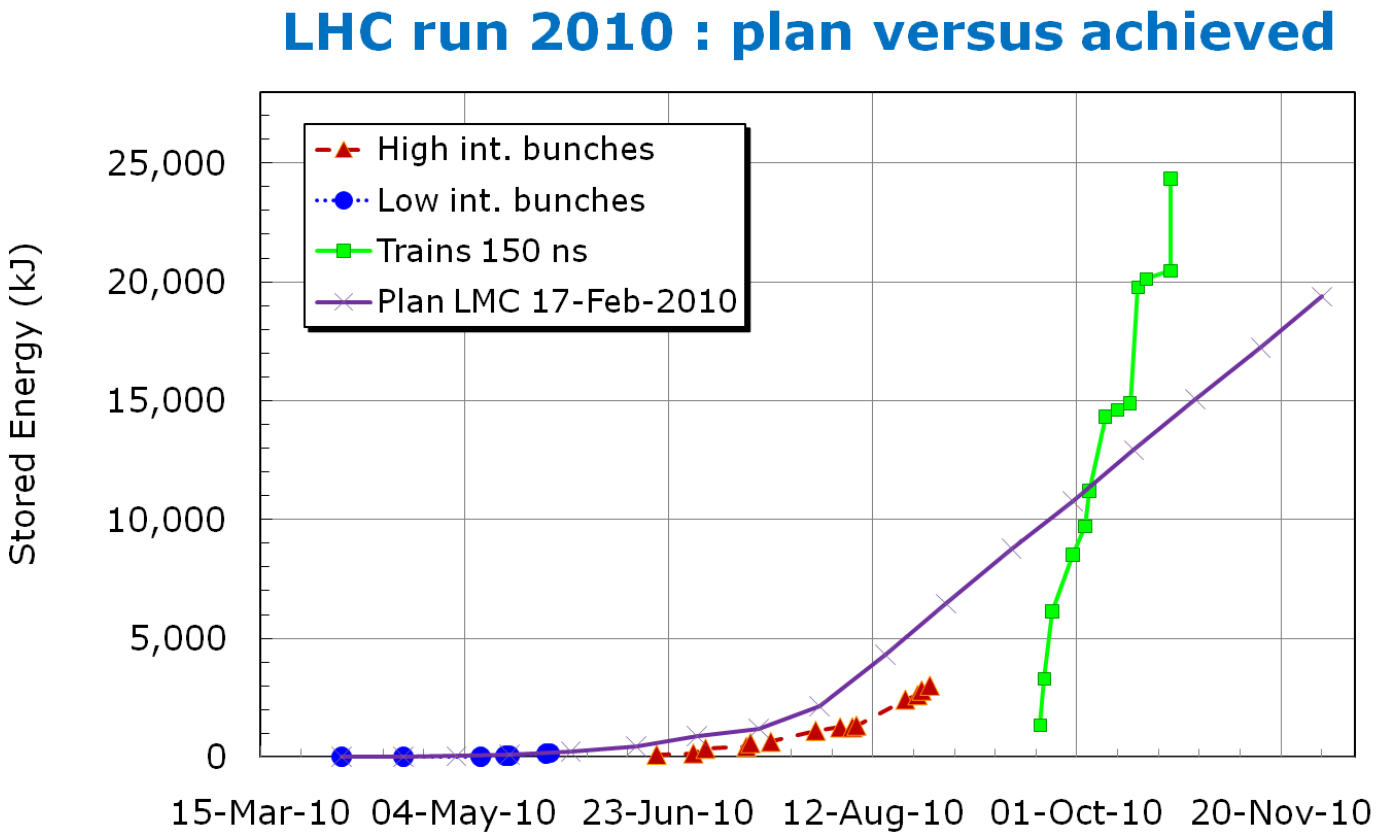
Commissioning not transparent.

Steeper slope because no problems were encountered.

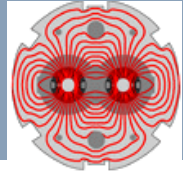


Plan versus reality (II)

In the final phase the slope was 4 times steeper than what we had 'guessed' – possible thanks to the excellent performance of the entire machine and in particular of the collimation and MPS.

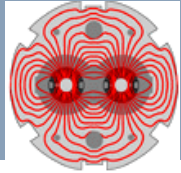


Too slow to too fast? (1)



- When everything went well it is easy to conclude (a posteriori) that we could have progressed faster!
  - *We tend to forget that we had a steep but also sometimes rocky learning curve (OP + MPS) in parallel to the intensity increase .*
- MPPr recommendations were the outcome of agreements (or compromises) among **ALL** MPPr members – some more conservative, some more aggressive.
  - *In many cases operational issues played a significant role (QFB versus damper, orbit stability…).*
  - *'Afterglow' of the TT40 incident was still on some minds.*
  - *More aggressive colleagues and coordinators were a bit frustrated…*

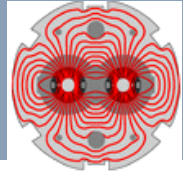
Too slow to too fast? (2)



- The intensity increase in the last phase corresponded to stored energy steps of ~3 MJ every 3 fills + 20 hours collisions.
  - *Within a factor 2 of a super-aggressive rate: 1 fill of 10 hours.*
  - *Issue of controlling UFOs in this phase:*
    - BLM threshold increase first by a factor 3, towards the end even by a factor 5.
  - *We could have considered larger steps towards the end when the fractional increase became rather small.*

- The intensity increase plan was reasonable given that we were in a commissioning year.
  - ✓ *Overall the progress followed recommendations of MPPr.*
  - ✘ *MPPr was over-ruled twice. Intensity within 'factor 2' of recommendations.*

Reviews



- Internal review (June 17th-18th 2010) – towards 1 MJ

  http://indico.cern.ch/conferenceDisplay.py?confId=97349

  - *Preparation for the external review.*

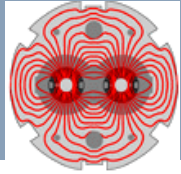
- External review (Sept. 6th-8th 2010) – towards 10's MJ

  http://indico.cern.ch/conferenceDisplay.py?confId=103908

  - *External committee (FNAL, BNL, GSI, DESY, SNS, CERN).*

- Sub-systems reviews:
  - *BLM FPGA code review.*
  - *LBDS TSU review (Trigger Synchronization Unit).*

External review



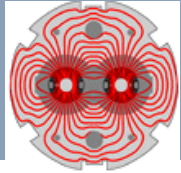
Report from the LHC Machine Protection Review

September, 28th, 2010

Submitted by the LHC Machine Protection Review Committee: Jerry Annala (FNAL), Reinhard Bacher (DESY, Chair), Mei Bai (BNL), Doug Curry (SNS), Stefan Lueders (CERN/IT, Co-Chair), Richard Jacobsson (CERN/PH), Jens Stadlmann (GSI), Dean Still (FNAL), Frank Zimmermann (CERN/BE)

- Review provided a detailed snapshot of the MPS state.
- 11 recommendations:
  - *No show-stopping item.*
  - *Strong concerns around configuration and sequencing.*
    - *Still with us in 2011…. see talk by L. Ponce.*
  - *All points have been (or will be) addressed.*

Surprise : quench free zone !



Not a single ACCIDENTAL beam induced quench was recorded with circulating beam !

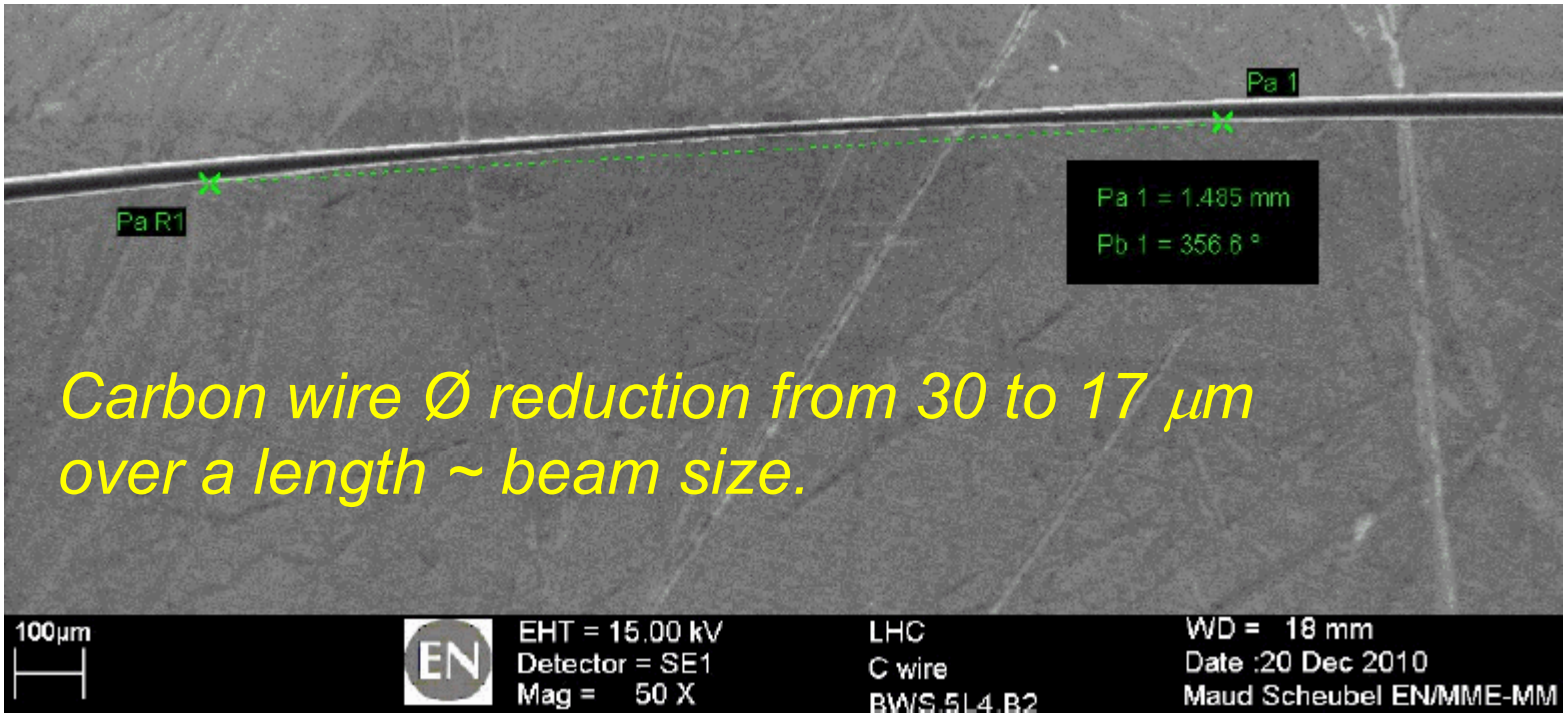
➔excellent performance of BLM and collimation systems !

NB: one should not assume that 2011 will be a quench free year !

Victim of the LHC beams

The only (known) damage to the LHC.

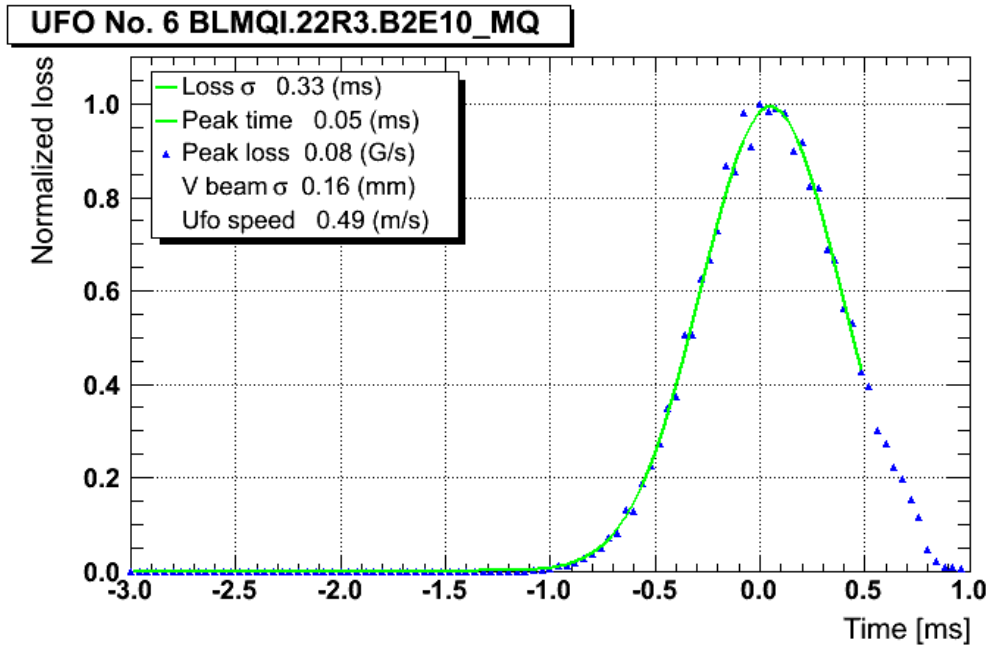
- *B2 wire-scanner almost evaporated during a quench test when the wire speed had to be reduced to 5 cm/s (from 1 m/s) to quench D4.*
- *Almost fatal to the wire – the D4 seems to be in good shape!*



Courtesy M. Scheubel/A. Lechner

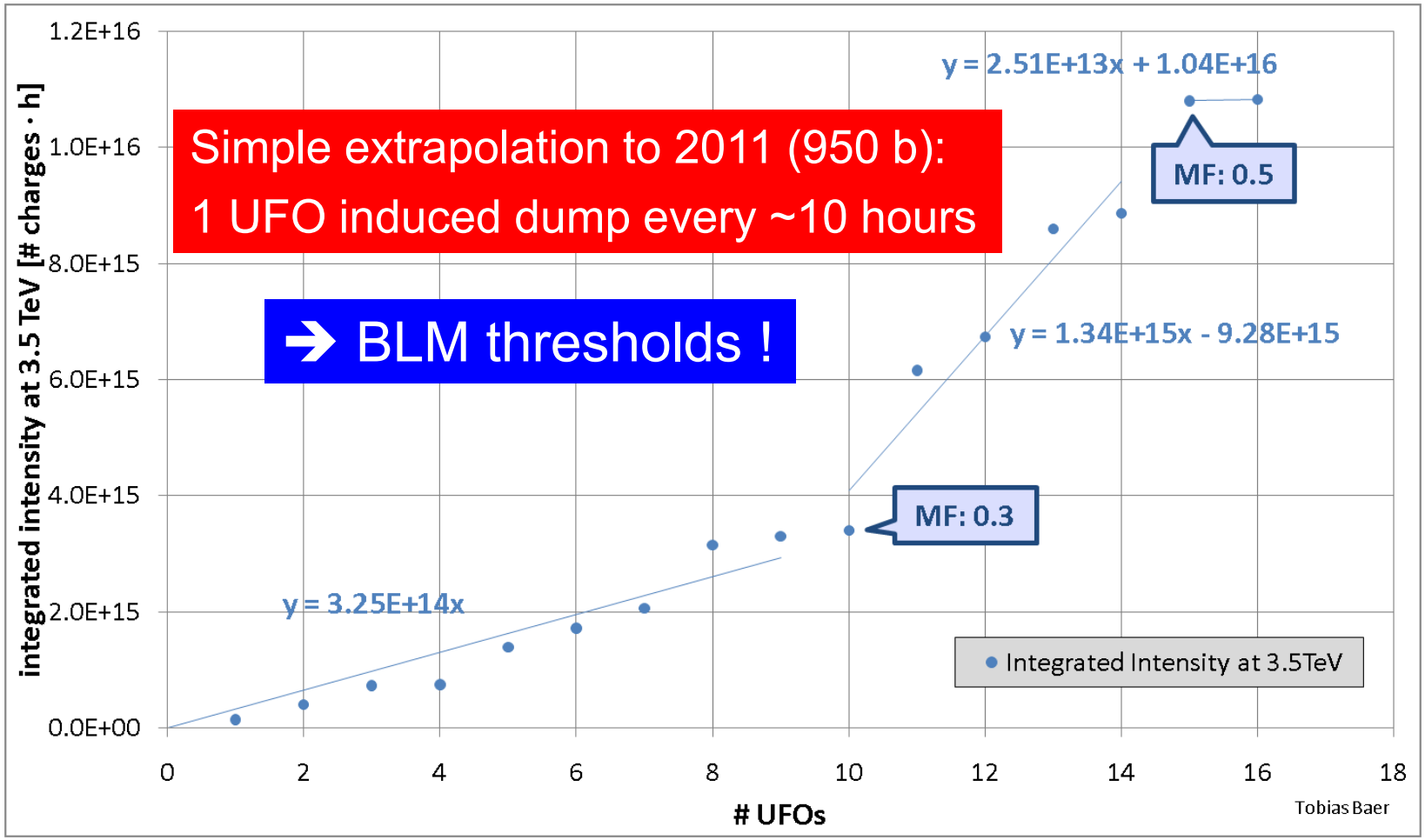
Surprise, surprise !

- Very fast beam loss events (~ ms) in cold regions of the machine have been **THE other surprise** of 2010 – nicknamed UFOs (acronym borrowed from nuclear fusion community).
  - *18 dumps by UFO-type events*
- Most likely small (10's μm) objects (dust…) 'entering' the beam.
  - *Some events correlated in time and space to roman pot movements.*
  - *Possibly re-expelled after charging up by ionization (F. Zimmermann et al).*
  - ***More details in the talk by M. Sapinsky.***



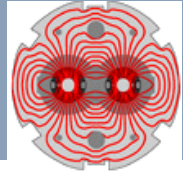
UFO rate

After the increase of the BLM Monitor Factor by a factor of 3 there were about **4.1 times fewer UFO related beam dumps.**



Courtesy T. Baer

Asynchronous dump



- First asynchronous dump on beam1 recorded Friday November 19th at 450 GeV with a circulating pilot bunch.
  - *'Favourable' conditions for such an event (as seen from MPS).*
- Diagnostics and reactions to the event were correct.
  - ✓ *Fault detection by LBDS IPOC & XPOC.*
  - ✓ *Test dump revealed missing trigger (redundancy reduced).*
  - ✓ *Access to repair followed by revalidation.*
- The dump was however 'double' asynchronous: it involved 2 kickers and not one as expected.
  - *Due to a change in the trigger fan out signal distribution following reliability analysis.*

➔ *The cabling of the trigger fan outs will be restored in 2011 to initial 'specifications'.*

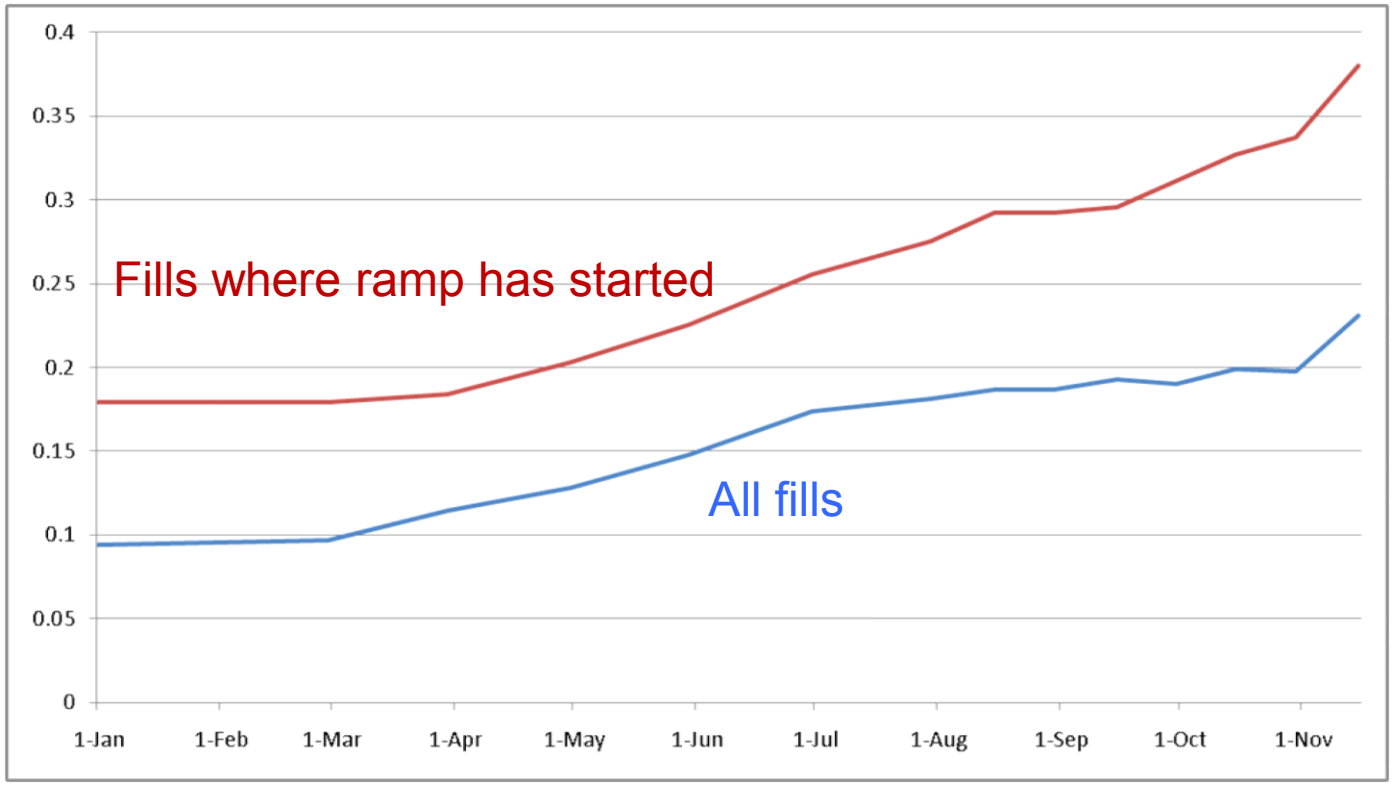
Machine 'availability' and MPS

'Measure' of availability: fraction of fills terminated with a programmed dump (counted from a given date until the end of the 2010 run)

- Yearly average: 8% of all fills, 17% of ramped fills
- During Ion run: 23% of all fills, 38% of ramped fills

Learning curve on top of the intensity increase of factor >10^4

Courtesy M. Zerlauth

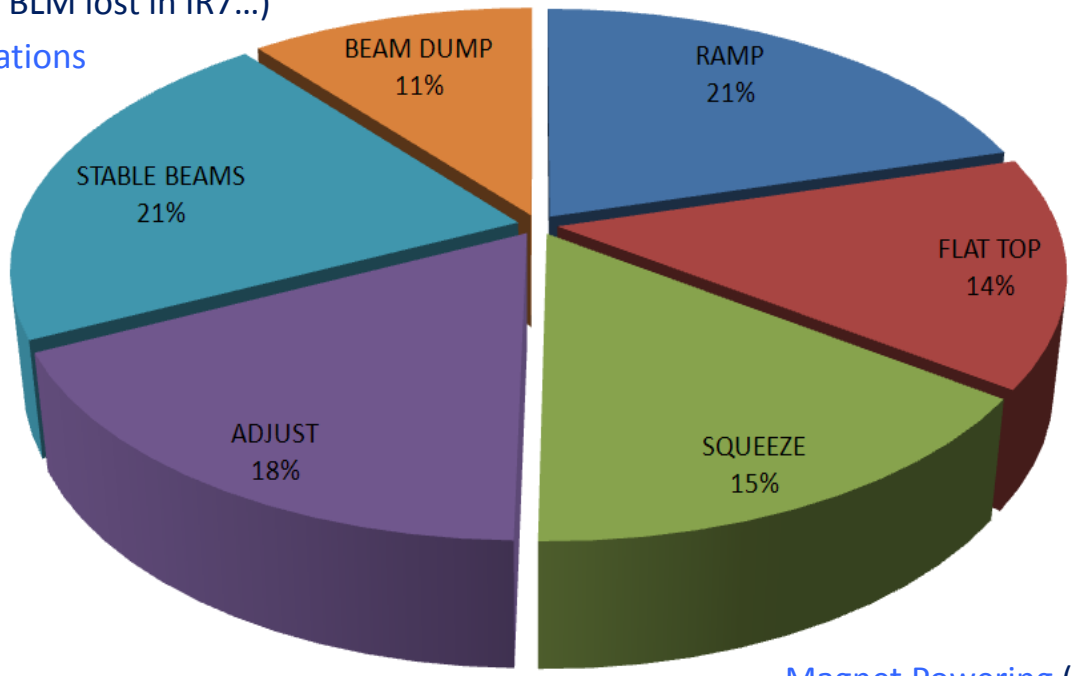


Challenges during 2010 above injection

Beam dumps in different beam mode for fills where energy ramp started, and main causes of loosing the beams…

» Fast Losses (UFOs)
Magnet Powering (QPS, CRYO, PC,..)
SW Permit (Orbit, BLM lost in IR7…)
Electrical Perturbations

SIS (TCDQ Position, missing energy)
Magnet Powering (Orbit Feedback, etc..)
Collimator interlocks during ramp



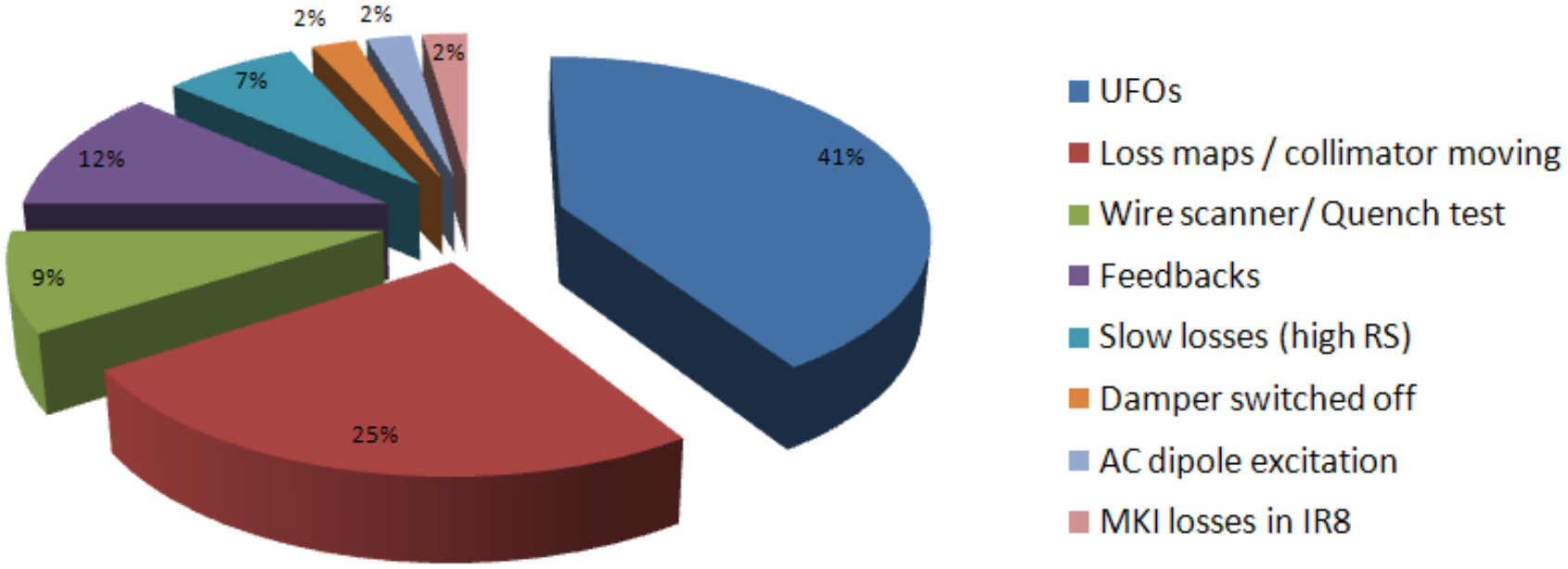
Magnet Powering (OFB/QFB, QPS sector trip, ..)
Loss Maps, Collimator setup, Fast losses
ATLAS

Loss maps, wire scanner tests, collimators moving…
SW Permits (TCDQ position,…)
Magnet Powering (Mostly PC issues, …)

Magnet Powering (Mostly PC issues + FB, CRYO,..)
Fast losses, loss maps,…
SW Permits (TCDQ position, trip of DOCs)

BLMs as ‘ultimate’ protection

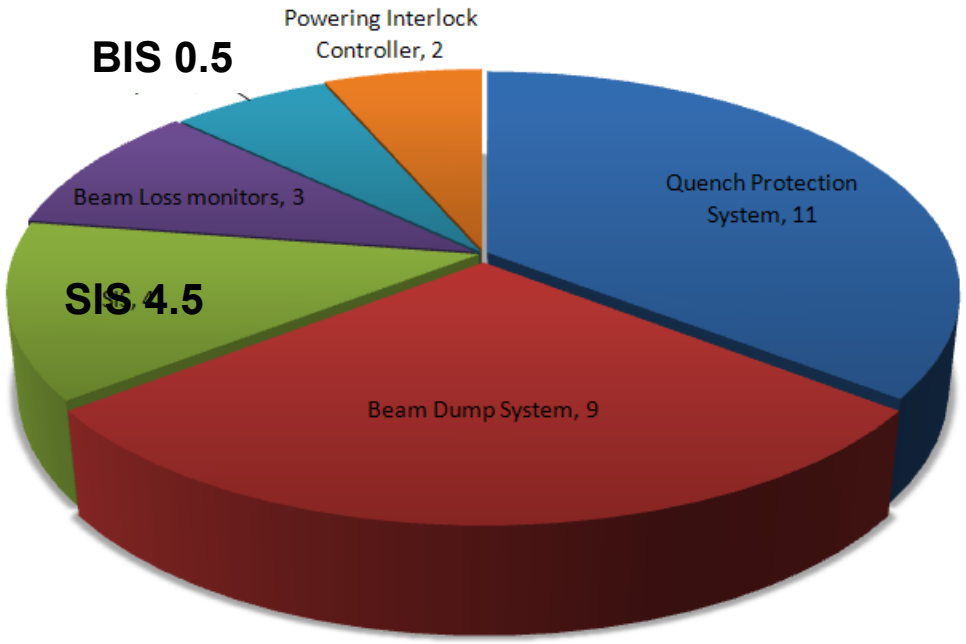
- 47 of 370 (~ 13%) of Protection Dumps (above 450 GeV) were triggered by BLMs.
- Most of dumps prior to increase of BLM thresholds on various cold/warm elements (factor 3 on cold elements).
- UFOs dominant, other triggers mostly during MPS tests /setup such as loss maps, wire scanner / quench tests.
- All failures (including few ‘real’ equipment failures) captured by BLMs before quenching any magnet (QPS providing ‘ultimate’ redundancy)



Courtesy M. Zerlauth

Dependability of MPS

Dependability / Availability of the machine protection systems has been a major design criteria and subject to extensive studies and Failure mode, effects and criticality analysis (FMECA).



Nota bene: only fills > injection

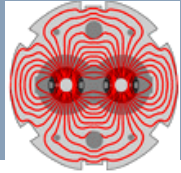
False dumps

System	Expected	Observed
LBDS	4	9
BIC	0.5	0.5
BLM	17	3
PIC	1.5	2
QPS	16	11
SIS	---	4.5
Total	41± 6	31

MPS dependability studies are ≈ confirmed – with some deviations.

Note: 'observed' data only includes dumps > 450 GeV.

Summary (1)

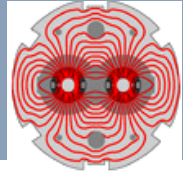


- LHC Machine Protection Systems have been working extremely well during 2010 run thanks to the commitment and rigor of operation crews and MPS experts.
- Most failures are captured before effects on beam are seen, no quenches with circulating beam.

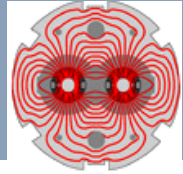
  Not a guarantee for a quench-free 2011 – 'UFO tuning'.
- Controlling (and understanding) UFOs could become a main issue in 2011 – BLM thresholds to be adjusted (shape wrt loss time scale).
- Steering of the intensity increase through MPPr should be pursued in 2011. Intensity increase plan to be defined.

  We should integrate what was learned in 2010, and re-optimize the plans.

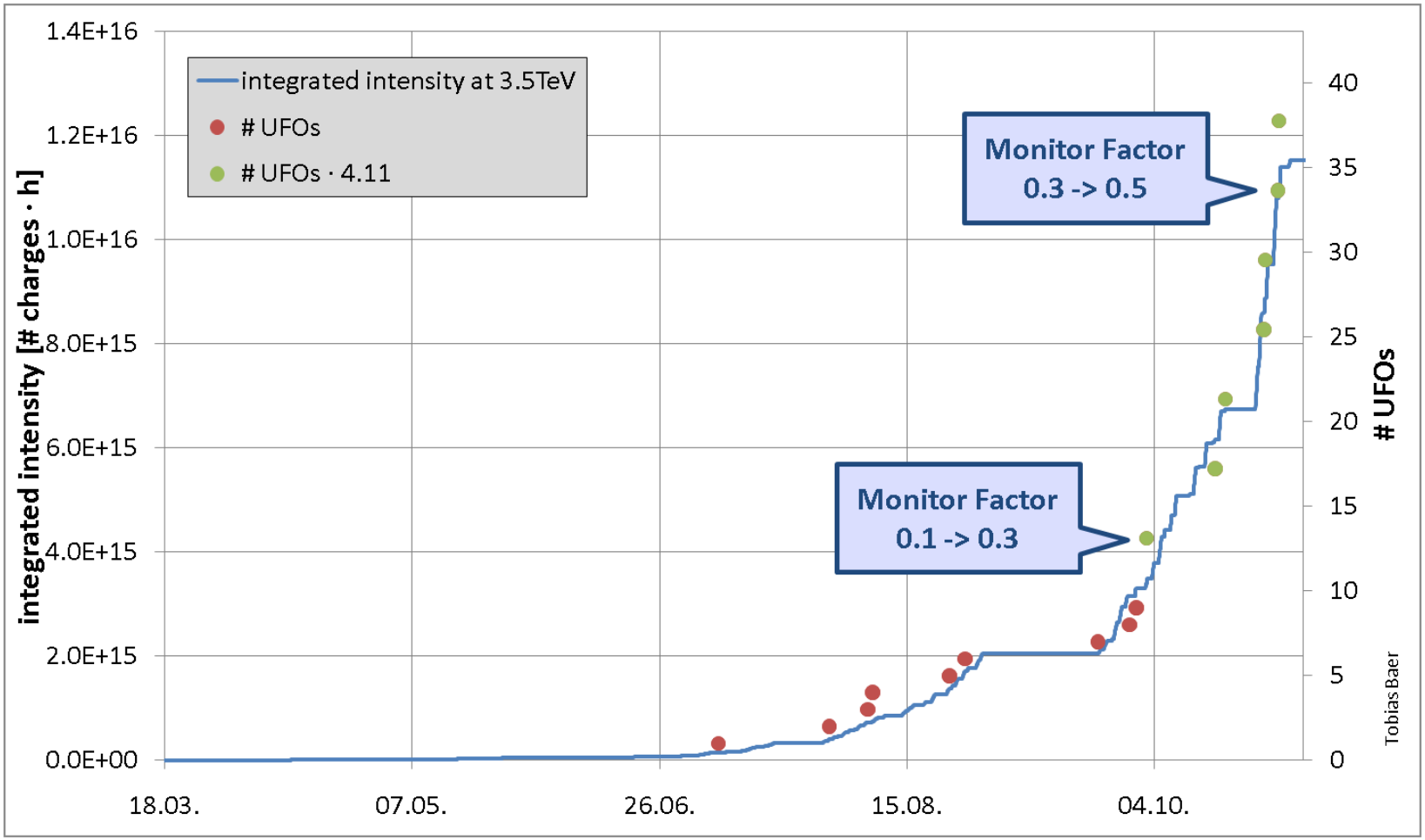
Summary (2)



- An improved tracking system for ALL MPS changes must be put in place for 2011.
- There is room for improving the PM analysis and providing more sophisticated online analysis results.
- Watch out for MDs – a safe recovery and pre-flight MP compatibility checks will be essential.



UFO rate


integrated intensity at 3.5TeV
UFOs
UFOs · 4.11
Monitor Factor
0.3 -> 0.5
Monitor Factor
0.1 -> 0.3
integrated intensity [# charges · h]
UFOs
1.4E+16
1.2E+16
1.0E+16
8.0E+15
6.0E+15
4.0E+15
2.0E+15
0.0E+00
40
35
30
25
20
15
10
5
0
18.03.
07.05.
26.06.
15.08.
04.10.
Tobias Baer