

LHC Operation as viewed from the experiments

Thanks to many people who gave me comments,
suggestions or material for this presentation

- ❑ Overview of 2010 delivered physics
- ❑ Constructive criticism on 2010 LHC operation
 - filling the LHC
 - polarities
 - vdm scans
 - lumi leveling
 - data exchange
 - handshake
 - intensity increase

you'll find more details in
the EVIAN presentation

Physics fills, overview

- ❑ **1074 h** of stable beams (**p: 851 h** , **Pb: 223 h**) out of **~6600h**
- ❑ **147 fills** with stable beams:
 - **110 proton fills**
 - 1005 (30mar) to 1049 (19apr): low intensity, few bunches, inj optics
 - 1058 (24apr) to 1134 (05jun): low intensity, few bunches, **2m**
 - 1179 (25jun) to 1250 (28jul): up to 13 **nominal bunches**, 3.5m
 - 1251 (29jul) to 1309 (30aug): 25 to 50 nom bunches, 3.5m
 - 1364 (22sep) to 1453 (29oct): **150ns**, 50 to 368 nominal bunches, 3.5m
 - **37 ion fills**
 - 1482 (08nov) to 1485 (09nov): 2 to 17 supernominal bunches, 3.5m
 - 1488-1489 (12-13nov): 69b, 3.5m
 - 1490 (14nov) to 1535 (01dec): 121b, 3.5m
 - 1536 (04dec) to 1541 (06dec): 137b, 3.5m
 - for special runs, see next slide

More or less disturbing activities

Special activities

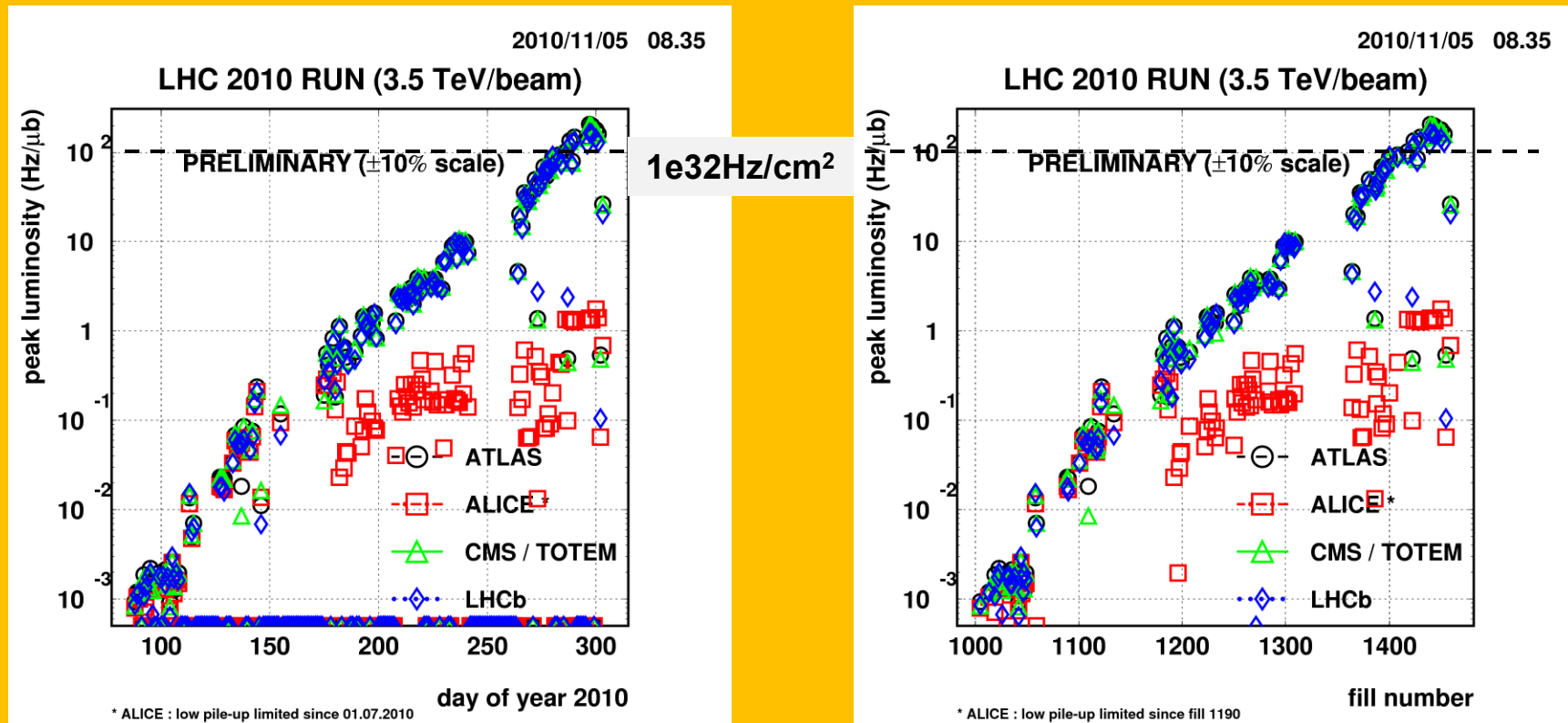
- ❑ 1058-1059 (24-26apr), 1089-1090 (8-10may): lumi calib (**vdm**)
- ❑ 1068-1069 (2-3may): **450 GeV**, few nom bunches, inj optics
- ❑ 1128 (27may): **450 GeV**, few nom bunches, inj optics
- ❑ 1359 (21sep): set up **TOTEM** + data, no stable beams
- ❑ 1386 (01oct) & 1422 (15oct): lumi calib (**vdm**)
- ❑ 1455 (30oct): special **TOTEM**, 5b, 3.5m
- ❑ 1459 (31oct): **50ns physics**, 109 nom bunches, 3.5m
- ❑ 1533 (30nov): contains lumi calib (ion **vdm**)

Spectrometer magnets in 2010

- ❑ ALICE: 5 polarity reversals and 1 switch off request
 - always both solenoid & dipole
- ❑ LHCb: 6 polarity reversals and 1 switch off request
- ❑ CMS: 1 switch off

2010 peak luminosity (protons)

You've done so well that ...

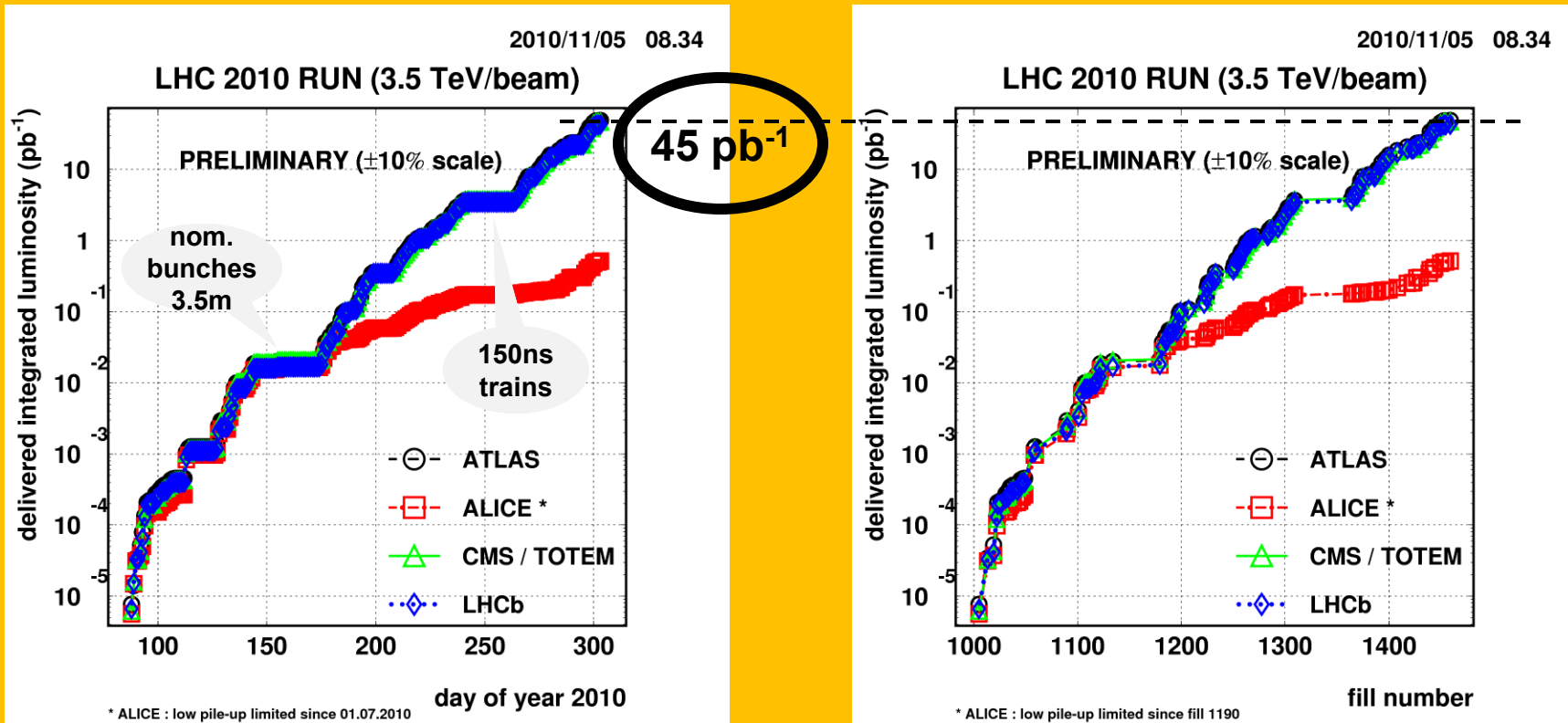


...8 TeV physics in 2011 will only restart when we're back at 2e32.

Anything before that will be *peanuts*. (but we like peanuts)

2010 integrated luminosity log scale (protons)

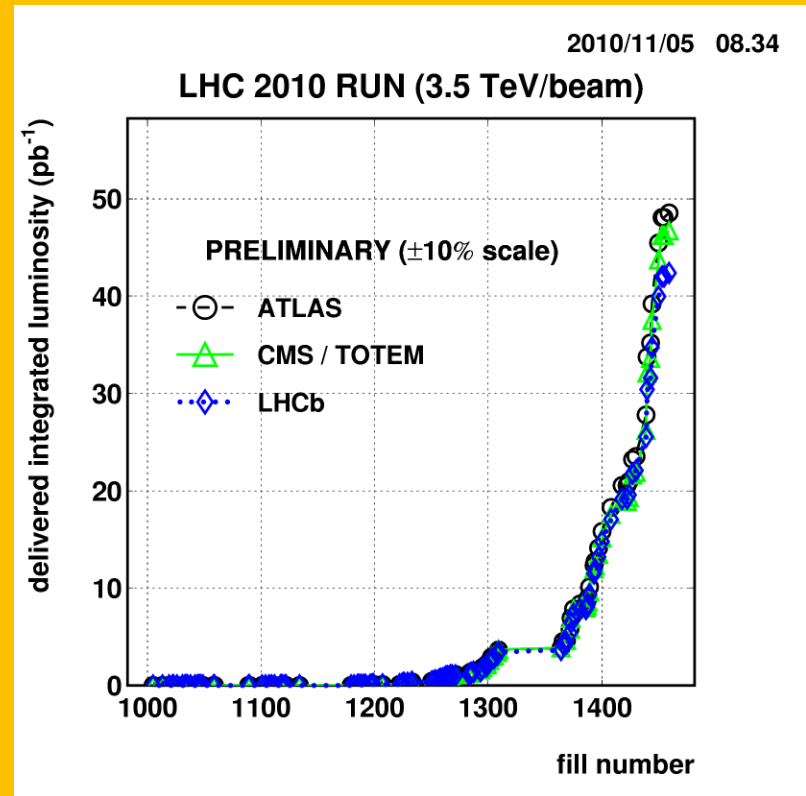
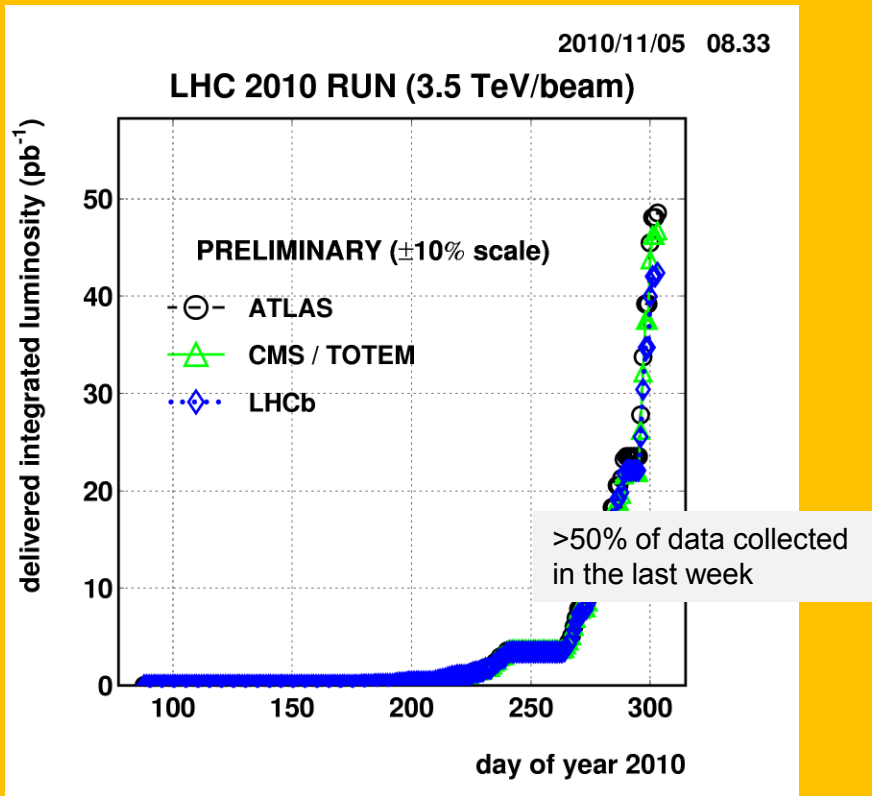
And that's the reason:



We have to collect **several tens of pb^{-1}** before we can speak of an 8 TeV physics start in 2011.

2010 integrated luminosity lin scale (protons)

This was great !



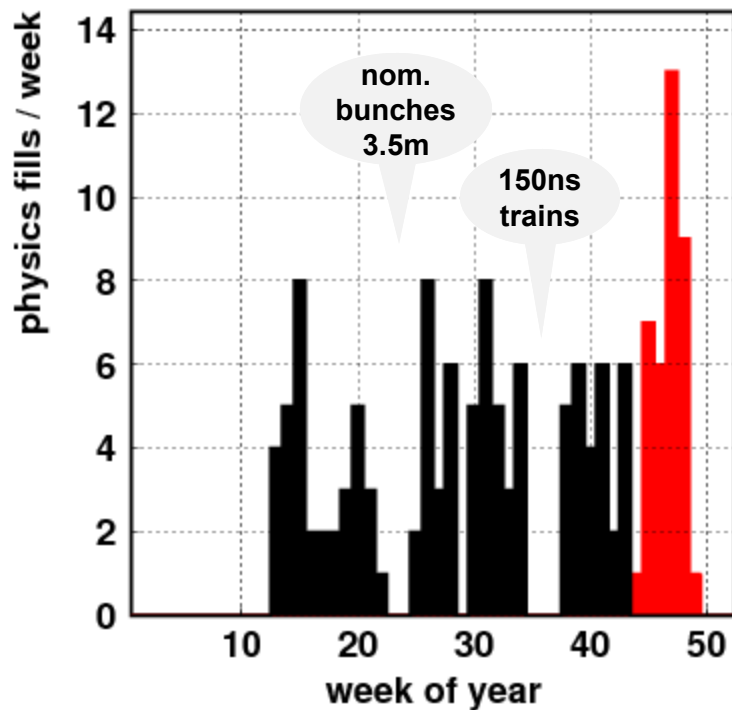
and so frustrating...

In 2011: go up **quickly to $2\text{e}32$** , then gradually increase to $\sim\text{e}33$.

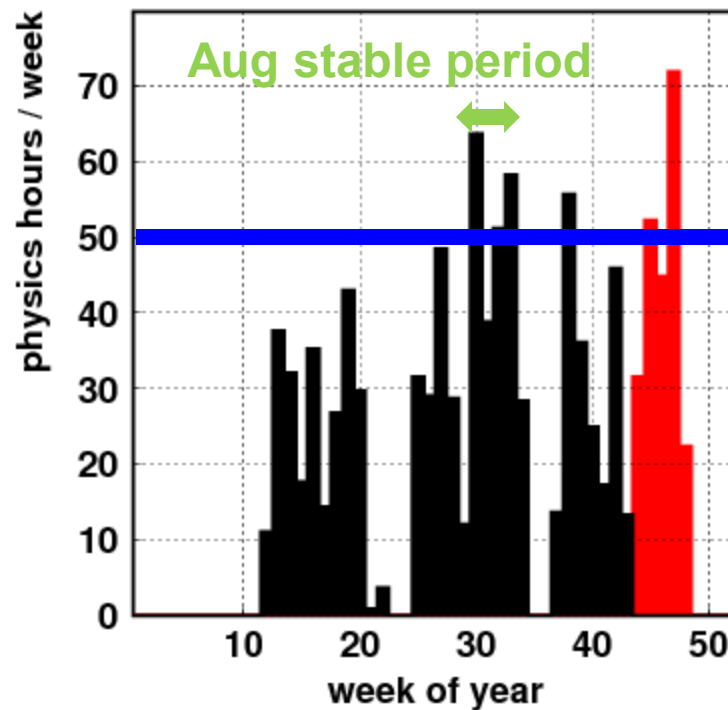
Physics per week

■ p ■ Pb

2010 physics operation



2010 physics operation



1 week = 168 hours → ~30% stable beams operation was achieved over periods of ~1 month

Filling the LHC

Need very much *much* flexibility!!

LHC is not LEP. LHC = 6 experiments with widely different scopes!

Limitations encountered in 2010:

- ❑ Could not switch dynamically nr of booster bunches during LHC filling.
 - Forced start with <10b. Had 8b trains (no 12b) → loss of collisions in 150ns: 3x8b (no 2x12b)
- ❑ Intermediate intensity batch (< ~1e12p) after the probe complicated the construction of physics filling schemes. Sometimes up to 19 injections!
 - Connected with previous point . 8b to start, hence 8b all the way => no 12b, less collisions.
 - But intermediate batch also “consumes” one injection, i.e. comes along with a 950ns gap.
- ❑ AGK window: limitation when almost full machine (>300b at 150ns).
 - AGK window length (8us) didn't match max train length used (~5us with p and ~3.5us with Pb).
- ❑ No low intensity bunches next to the nominal bunches
 - Not really a limitation for ALICE, as the separation leveling worked nicely,
 - But would have been useful for TOTEM
 - BPM “blindness” to a few small bunches... Is this really an MP issue ?
- ❑ Sloooooow filling process. No dedicated LHC filling. IQC limitation, etc.
 - see Mike and Stefano later

LHC filling: desired improvements (1)

- ❑ Enable dynamic switching nr of booster bunches during LHC filling.
 - Not only after the first SPS batch! Anytime during the filling, such as to match the first one and maintain the 4-fold symmetry in LHC.
- ❑ Controls of SPS2LHC transfers to be improved
 - reduce nr of lost requests
 - IQC of last injected ring A will not affect request of ring B.
- ❑ Faster (automated?) beam quality checks at injection ?
- ❑ Dedicated LHC filling (not interleaved with other beams)
 - CPS: better for tuning, more flexibility
 - Strive toward one SPS2LHC transfer per 21s (incompressible time)
 - Allow several (3 ? 4 ?) LHC beam types in same supercycle

OP

OP

OP

OP

the LHC should drive how the injector complex operates, and not the opposite

LHC filling: desired improvements (2)

- Intermediate batch: other solutions ? main purpose: verify TL traj for the high intensity cycle

ABT

- Consider one “overinjectable” intermediate batch ? NO goal: no addition of 0.95us gap
- Consider probe→intermediate→dump→probe→full ?
- In any case, devise a scheme that works for all filling patterns (75, 50, 25ns)

- AGK window: I assume we will probably need the full 8us in 2011
 - scrubbing at 50ns, 4x36 batches desirable
 - In the end, if we can use full 8us batches, this is an advantage for physics

OP
MP

- Allow few small bunches next to the nominal (main bunch series)
 - Was already done in one special 2010 TOTEM fill and in the only 50ns fill
 - Specify limits / envelope: how many small bunches ? what min/max charge?
 - Will allow TOTEM to collect low- μ data “parasitically” (commission T1)
 - only as long as enough space in the machine (no lumi cost for other expts)
 - Could be used in future for ALICE in place of displacing/defocusing
 - Could allow parallelizing any study related to beam-beam effects

Spectrometer magnets

- ❑ **Polarity reversal: important for reducing systematics**
 - Note: the more often conditions change, the more flips will be asked
 - ALICE/LHCb wish to equalize size of data sets in each polarity at every “new set of beam conditions”
 - Typically, one reversal per month (to be matched with evolving circumstances)
- ❑ **Can the transparency of polarity reversal be improved ?**
 - Ideally: make it routine... “flip and go” (no test ramp, etc.)
 - Maybe ok for IR8, but problem in IR2 ? (compensation scheme only in one plane... cannot give full closure due to solenoid coupling)
- ❑ Define, validate and save two settings of TCTs for IR2 10m in IR2 → triplet in shadow of arc
 - not needed for IR8, because fixed external angle
- ❑ Keep in mind:
 - Expts might request some “fields-off” data. How to insert this with minimum impact ?
 - In 2011: ramp LHCb dipole (at least partly) for “bad” polarity (minus)
 - note: ramping causes “fatigue” on magnet



see W.Herr, session 7

- ❑ 2010 experience: Top!
- ❑ Very nice collaboration, excellent support
 - ABP, OP, BI, etc.
- ❑ Impressive results for first attempts
 - $dL/L \sim 5\%$
 - NB: Tevatron still living on two 2% accurate Optical Theorem measurements that disagree by 7.5%
- ❑ BCTs came under the spotlights!
 - very positive reaction from BI experts
 - Bunch Current Normalisation working group (BNCWG) started on 21jun as a joint machine-expts effort (complement to LBS)
 - <https://lpc.web.cern.ch/lpc/bcnwg.htm> from cern.ch/lpc

see “[LHC lumi days](#)”*

Many thanks for your participation
Proceedings coming up

* see Simon White’s talk

**Bunch Current Normalisation Working Group**

[LPC home](#)

This working group has been jointly started by LHC-BI, LBS and LPC in order to understand and reduce the uncertainties of the LHC bunch currents which enter the luminosity calibration measurements.

Mandate:

Provide all LHC users with best possible estimation of LHC beam and bunch intensities, including uncertainties, by using all information available (from machine instrumentation and from the experiments). Document the results. Make recommendations to LMC.

Present contact persons:

BALAGURA, Vladislav (PH-LBD, LHCb experiment)
BURKHARDT, Helmut (BE-ABP-LCU, ex-officio, as chair of LBS study group)
DEILE, Mario (PH-TOT, TOTEM experiment)
FERRO-LUZZI, Massimiliano (PH-LBD, ex-officio, as LPC)
GAGLIARDI, Martino (PH-UA1, ALICE experiment)
GRAS, Jean-Jacques (BE-BI, LHC Beam Instrumentation)
ZANETTI, Marco (PH-UCM, CMS experiment)
KOZANECKI, Witold (PH-UAT, ATLAS experiment)
TAKI, Kazuya (PH-UHC, LHCf experiment)

Members/participants: see [e-group](#)

Meetings: see Indico agenda pages [here](#)

For the luminosity calibration measurements, see [here](#).

Literature references:

2011: aim at dL/L ~ 1-2% ??? (not given!!)

- 2010 issues / 2011 wishes, most being already addressed

- FBCT:

- bunch length / position dependence
- offset & linearity
- use A+B

- DCCT:

- LHC pattern dependence,
- scale factor / stability
- use A+B
- precise calibs

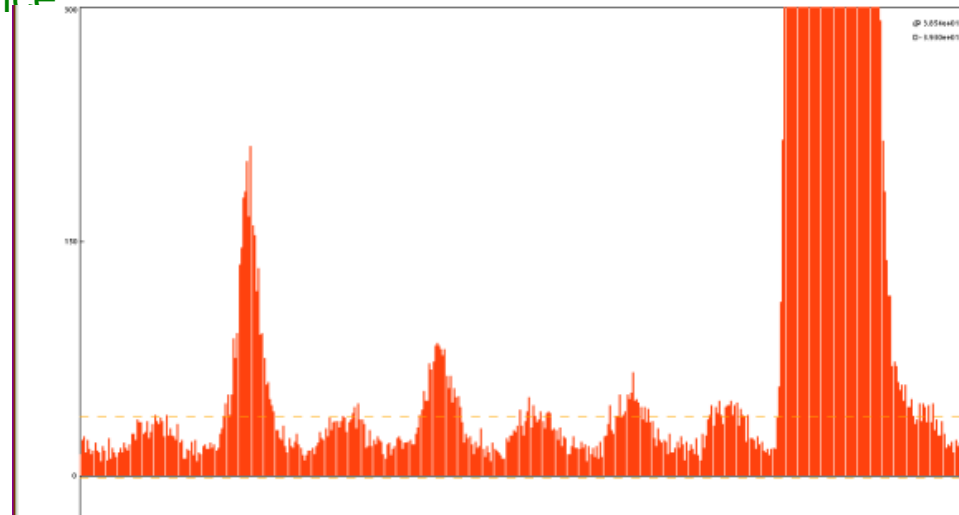
- LDM: ghost charge / satellite bunches vs nominal bunches

- commission both rings, calibrate (linearity !)

- Emittance: easy b-by-b, calibrations (BGI, BSRT, WS)

- IR scan application:

- file-driven sequence
- co-moving TCTs => no collimator validation needed if VdM at 10m/11m ?
- all-IP //scans



BI

LBS
MP
OP

2011: aim at $dL/L \sim 1\text{-}2\%$??? will need some studies

- ❑ A few “eof” studies (as much as possible in nominal stable beams)
 - All-IP //scans and systematic effects due to IR steering “cross-talk”
 - Position reproducibility
 - Co-moving TCTs
 - Minimizing (and meas)
 - B-by-b emittance ctrl (t
 - VdM scan reproducibility tests (to be agreed upon machine & experiments)
 - scans more useful if can go to ± 3 sigma separation
 - the faster, the better (<1 hour)
 - probe and nominal bunch in same fill: compare small vs large N^2 in IP1&5
 - requires BCTs to work in physics conditions (short spacing)
 - exact conditions & procedure to be defined
- ❑ Complementarity: **VdM** and **beam-gas imaging** methods (LHCb)
 - mostly different systematics, but correlated BCT systematics
- ❑ Complementarity: **Direct** (Vdm/BGI) vs **Indirect** methods (elastic/total)
 - widely different systematics, comparable accuracy reach

Handshakes: went well, in general

Discussed in MPP (**R. Alemany**, A. Macpherson, J. Wenninger + expts ...)

Documentation:

- ❑ LHC-Expts handshake protocol over DIP
<https://edms.cern.ch/document/1031913/>
- ❑ LHC Modes
<https://edms.cern.ch/document/1070479/>

More ?
(state machine doc ?)

To be improved:

- ❑ Loss of beam time during handshakes
 - Improved injection and dump handshake agreements
- ❑ Automated use of beam modes
 - state machine ?
- ❑ Clear “eof mark”
- ❑ Rigorous fill number change

Dump handshake:

- STABLE BEAMS: LHC sends dump warning
- 5 min later: unless >0 expt declared PROBLEM, LHC changes to DUMP and dump beams
- Expts commit to declare PROBLEM in extreme cases only (not enough that one sub-detector did not lower HV)

Data exchange (DIP)

Discussed in LBS/LPC meetings (**A. Macpherson**, H. Burkhardt, +expts +...)

Documentation:

- ❑ LHC=>expts: <http://wikis.cern.ch/display/expcomm/Beam>
- ❑ expts=>LHC: <https://edms.cern.ch/document/1026129/>
 - obsolete ?
 - LHCf=>LHC: <https://edms.cern.ch/document/969919>
- ❑ vdm scans: <https://edms.cern.ch/document/970037>

K. Kostro

A. Macpherson

E. Tsesmelis

D. Macina

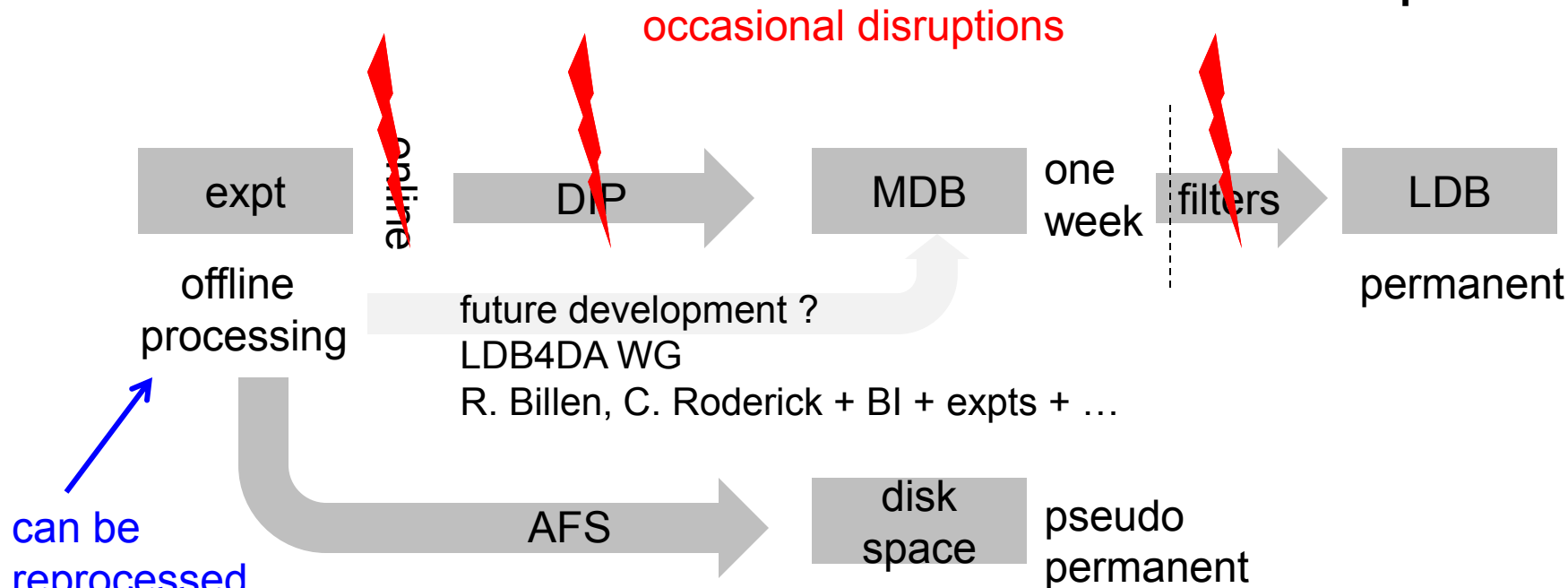
S. White

To be improved:

- ❑ Documentation
 - one doc or web page with all variables, units, publication policy, main clients, LDB name mapping, etc.
- ❑ Data completeness
 - some fields were not ready to be published online LHC & Expts!!
- ❑ Data stability (DIP, ...)
 - some data never made it to the CCC or to the LDB
- ❑ Data accuracy/validity
 - e.g. vtx resolution unfolding for lumi region sizes Expts!!

Data from expts to LHC

Alick Macpherson, LBS



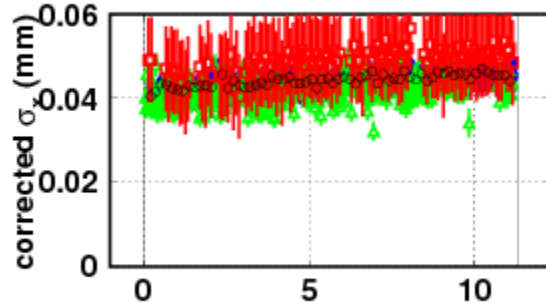
can be reprocessed.
More accurate,
more complete,
more reliable.

The data sets are not complete, but still give a solid basis.
Go either via this link (for a quick graphical view of selected data):
<https://lpc-afs.web.cern.ch/lpc-afs/cgi-bin/webpage.sh>
Or, for more direct retrieval, via the AFS directory:
</afs/cern.ch/user/l/lpc/w0/2010/measurements/>
This file explains what the data are:
</afs/cern.ch/user/l/lpc/w0/2010/measurements/README.filecontents>
Will be continued/improved for 2011 (MFL & Colin Barschel's assistance)

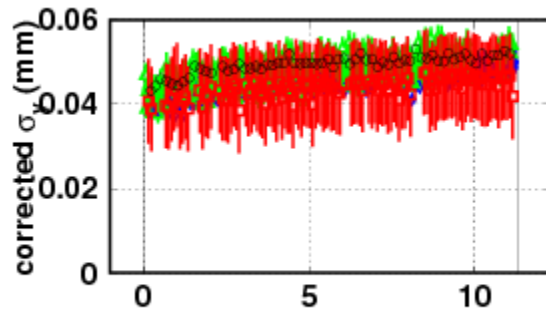
Luminosity leveling by separation ALICE 2010

- ❑ 2010 IR2 (ALICE):
Used 3 to 3.8σ separation .
- ❑ Worked very well
- ❑ Nice stable conditions
- ❑ Lumi size as in other IPs

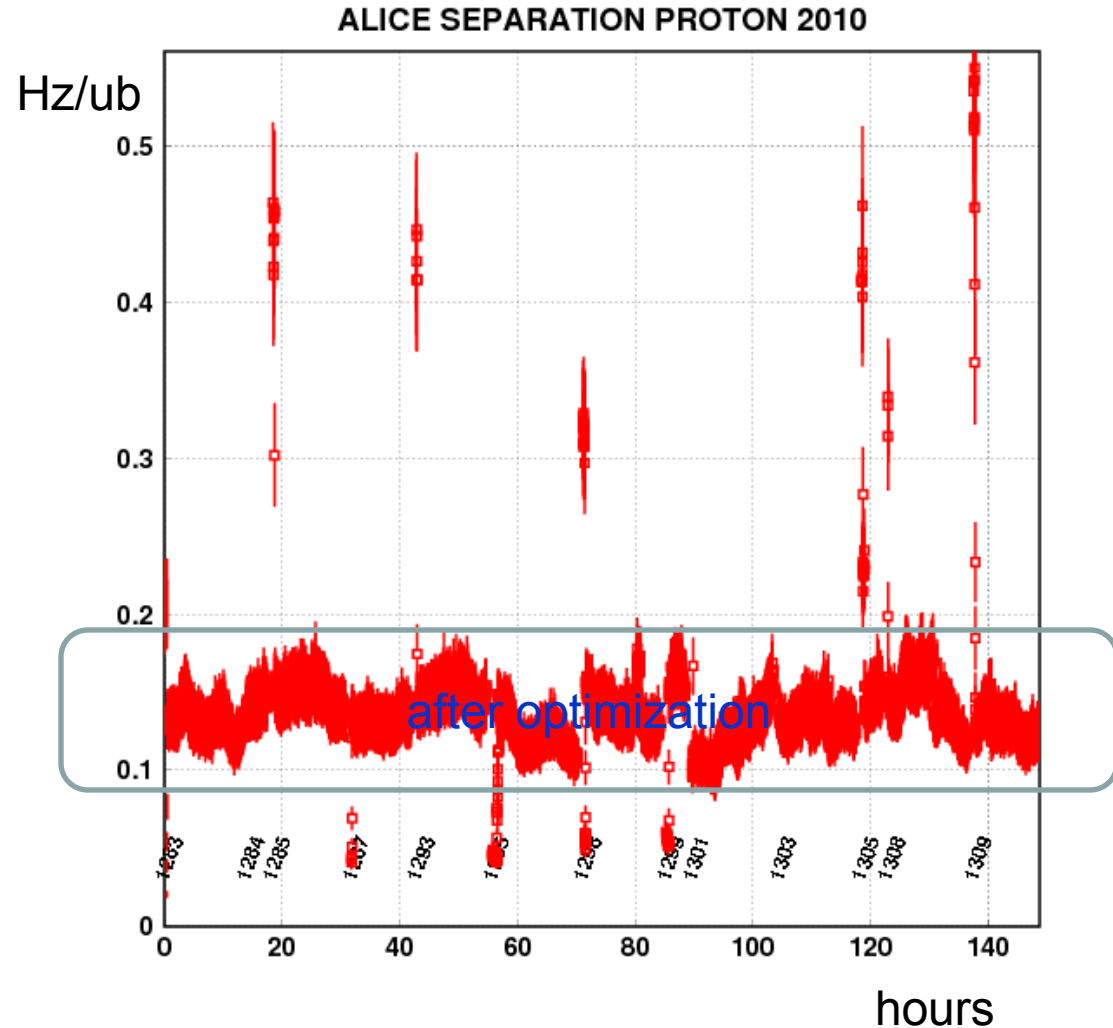
1309 PRELIMINARY



time from 29.8 18:17 CET (h)



time from 29.8 18:17 CET (h)



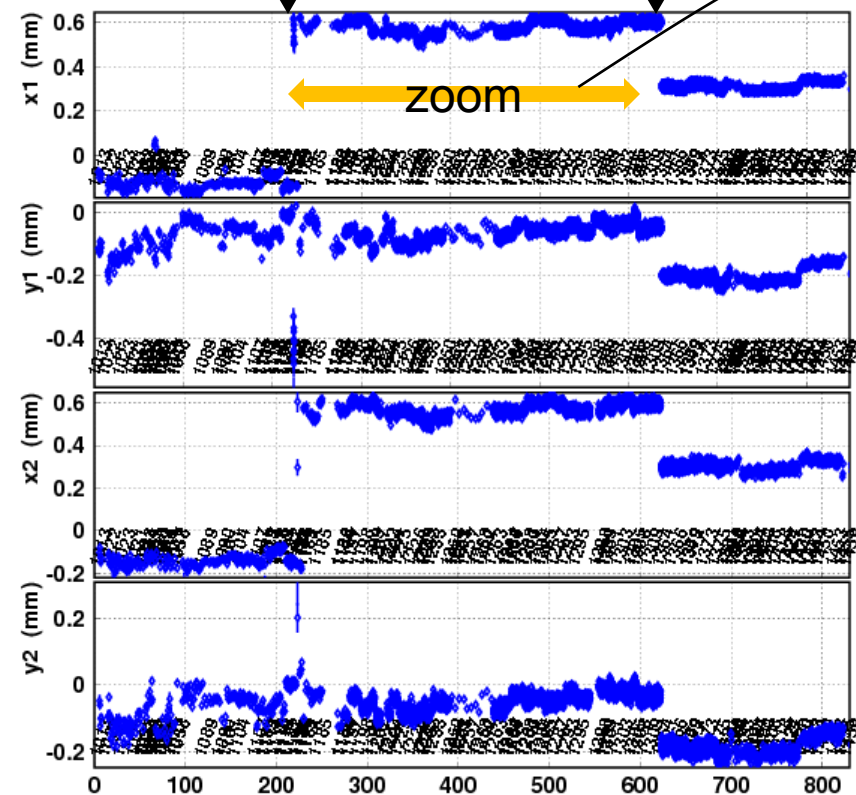
Beams stability at IR from beam-gas imaging (here IR8)

moved from
2m to 3.5m

turned on
external angle

LHCb OVERVIEW 2010 from BEAM-GAS

zoom

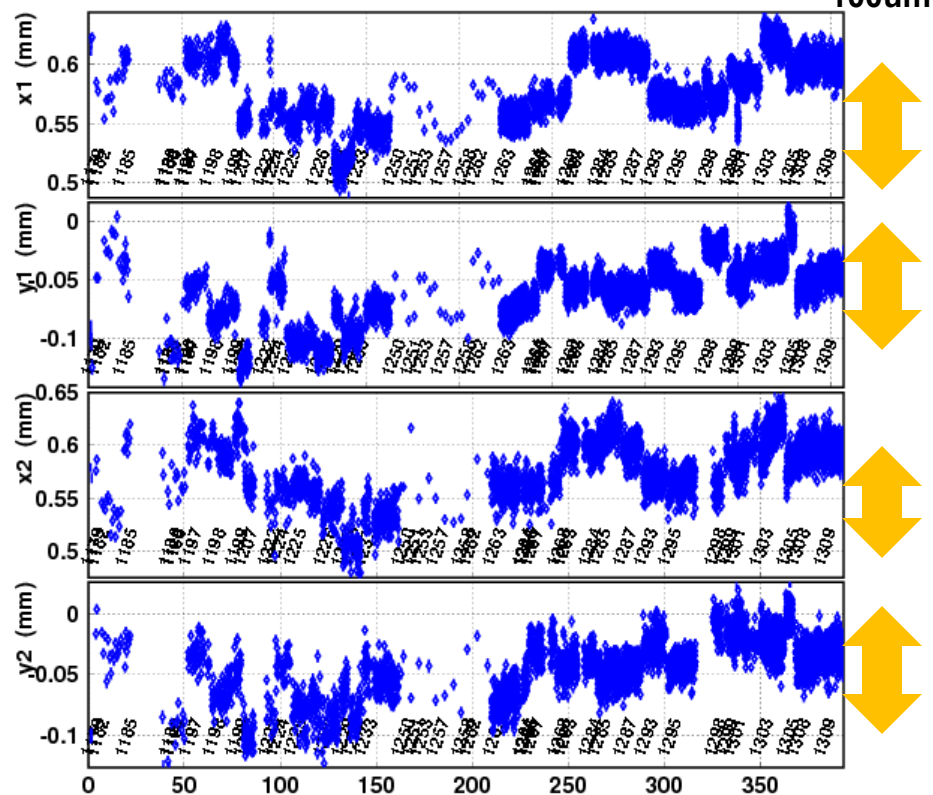


hours (turn around gaps removed)

two months

LHCb OVERVIEW 2010 from BEAM-GAS

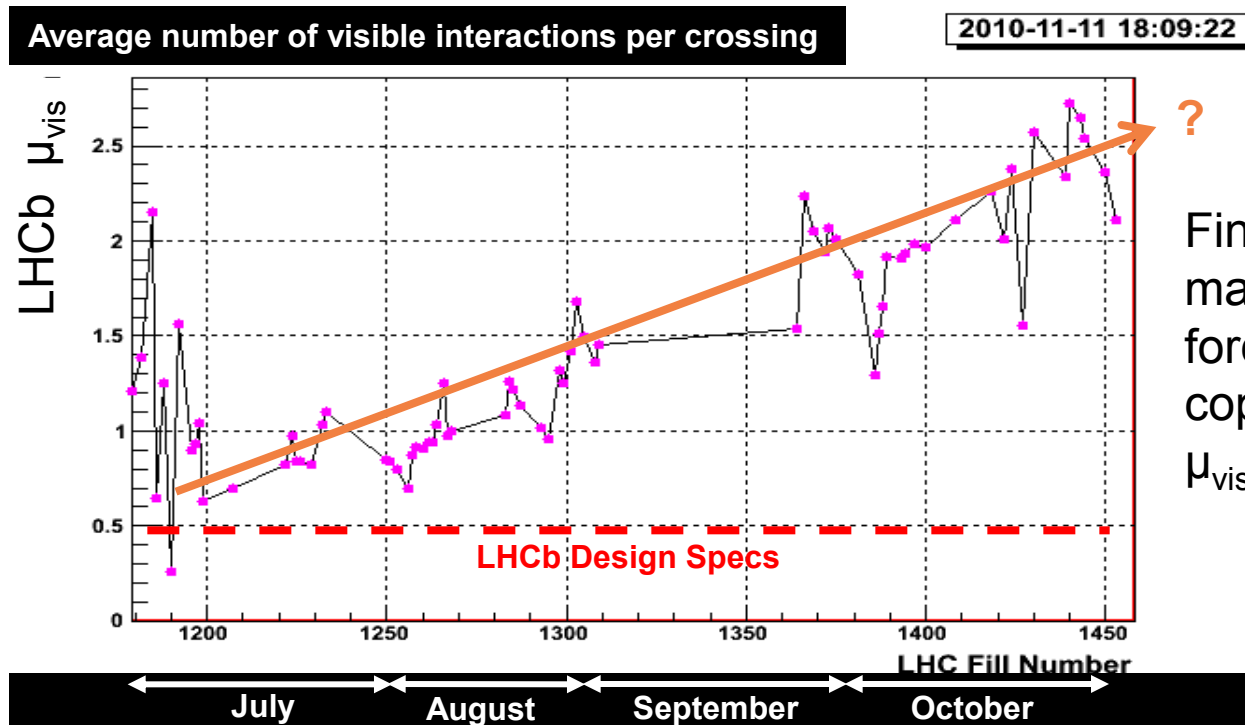
100um



hours

2010 Challenges – Extreme conditions for LHCb

- ❑ LHCb: forward physics detector => a lot of particles => sophisticated trigger
- ❑ Experiment designed for 2808 bunches at $2e32 \Rightarrow \mu_{vis} \sim 0.4$
- ❑ LHC2010: reached that luminosity with 7 times less bunches
- ❑ June commissioning to go to $1e11$ p/b and THEN increase nr of bunches was very beneficial for lumi production, but pushed LHCb into a dilemma: **collect less integrated luminosity or push the limits of the detector to keep the luminosity ?**



Finally, LHCb managed “tour de force” and was able to cope with up to $\mu_{vis}=2.5$

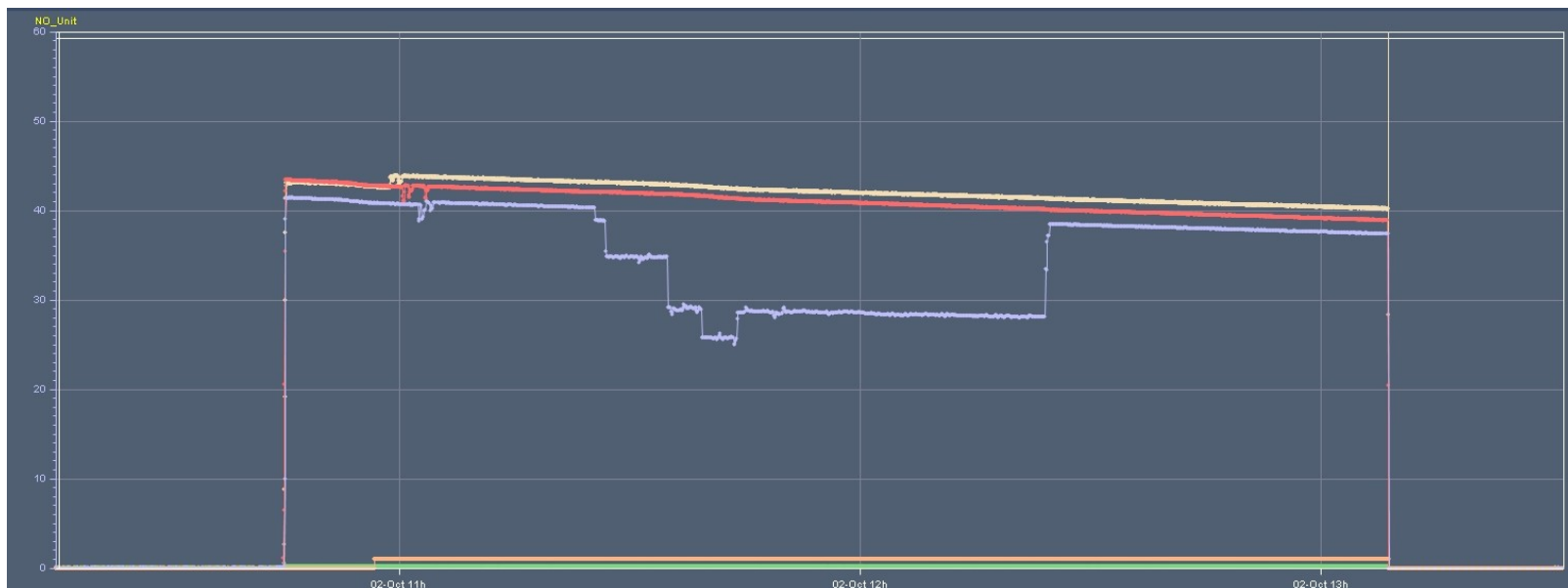
- Faced with preparations without knowledge about the ultimate parameters
- Cannot formulate running conditions and operate this way in 2011

Luminosity leveling by beam separation: test in IP8

- Tested also at IP8 several times during 2010
 - separation scans
 - 152 bunches x $1E11$ @ 150ns up to more than 1 sigma
 - 100 bunches x $0.9E11$ @ 50ns up to 6sigma
 - Beam-beam limit yet to be explored...

no effect seen on other IPs

important for 2011-2012



Gentle criticism on intensity increase

Or ... how to make many enemies in one slide

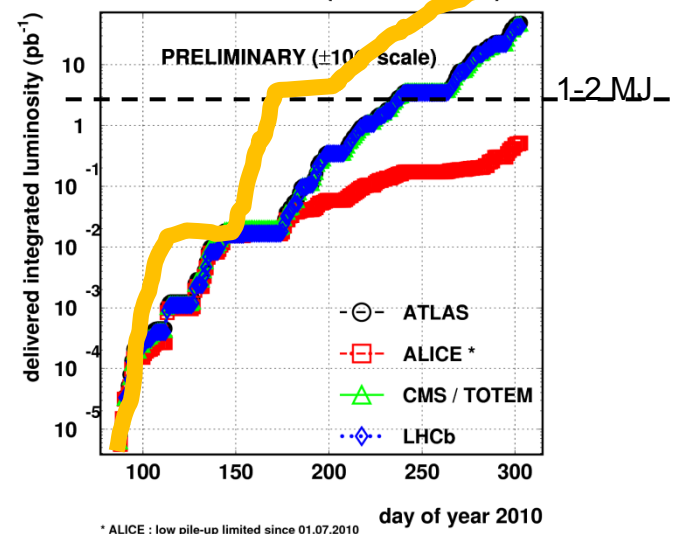
Some questions:

- ❑ Have we not been too dogmatic ? (not flexible enough ?)
- ❑ Have our choices been driven by observations (good or bad) of the machine protection ?
- ❑ Have we not occasionally mixed performance & operation issues with protection issues ?
- ❑ Why do these loss maps take so much beam time ?
 - 2011: single bunch blow-up ?

The positive side:

- ❑ I was never mobbed
- ❑ Very dedicated people around
- ❑ And $2e32$ remains a great achievement

Could we have reached 100pb^{-1} ?



2011 intensity increase , for discussion

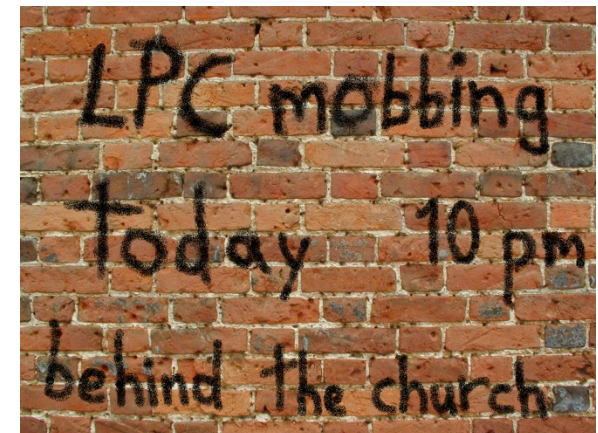
- Currently proposed: 3 weeks of commissioning + 2 weeks of ramp up to 300 bunches (50-100-150-200-250-300)

week	8	9	10	11	12	13	
	recommissioning			50b=>300b		T-Stop	
	recommissioning			1.38TeV	50b =>300b	T-Stop	consider

- What is driving this ?
- Multi-MJ physics at $<2e32$ is not requested by the experiments
- On the other hand: there are low intensity physics requests
 - 1.38TeV/beam run ~ 200 kJ/beam, 3-4 fills
 - 5% accurate vdm scans, especially if $E \neq 3.5$ TeV/beam, sub-MJ
 - TOTEM low intensity run with RPs at 5σ , sub-MJ
- Could this not *replace* part of the intensity ramp-up ?
 - plays as warm-up for the EiCs and operators “tour de chauffe”
 - provides time to digest the commissioning period
 - this applies even if not exactly the same machine as for high lumi physics

And now, let's be polemic

- ❑ If Machine Protection is declared OK for 5 MJ, is it not also OK for 100 MJ ?
- ❑ What difference between 100b and 300b ?
- ❑ Considering them different: could that stimulate “*wrong feeling of being safe*” ?



Conclusion

2010 has been terrific
demonstrated the excellence of the LHC and
of the people who built/commissioned/operated it

2011 could be the year of discovery
[see Bill Murray's talk in session 4](#)

The challenge:

$>5 \text{ fb}^{-1}$ at IP1

$>5 \text{ fb}^{-1}$ at IP5

$>1 \text{ fb}^{-1}$ at IP8

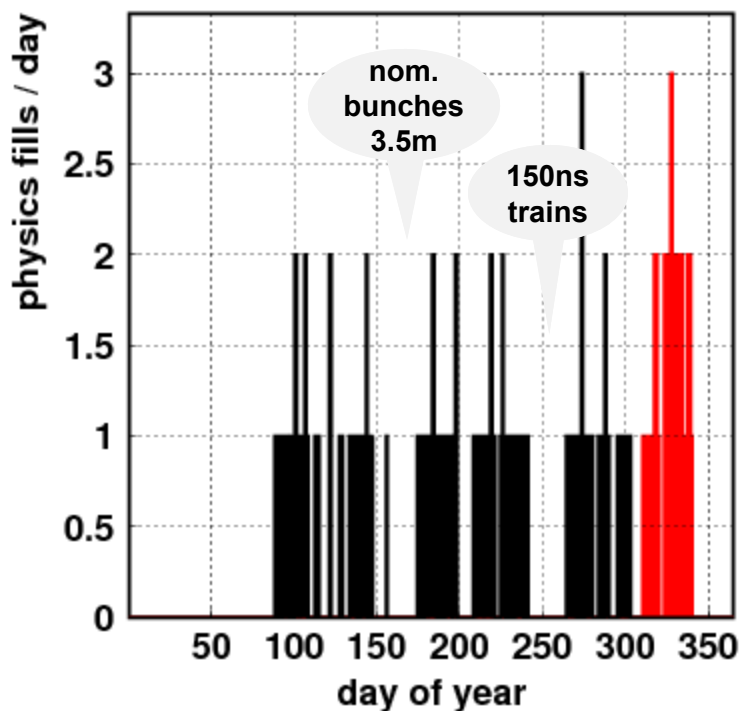
thank you for your attention

Physics per day

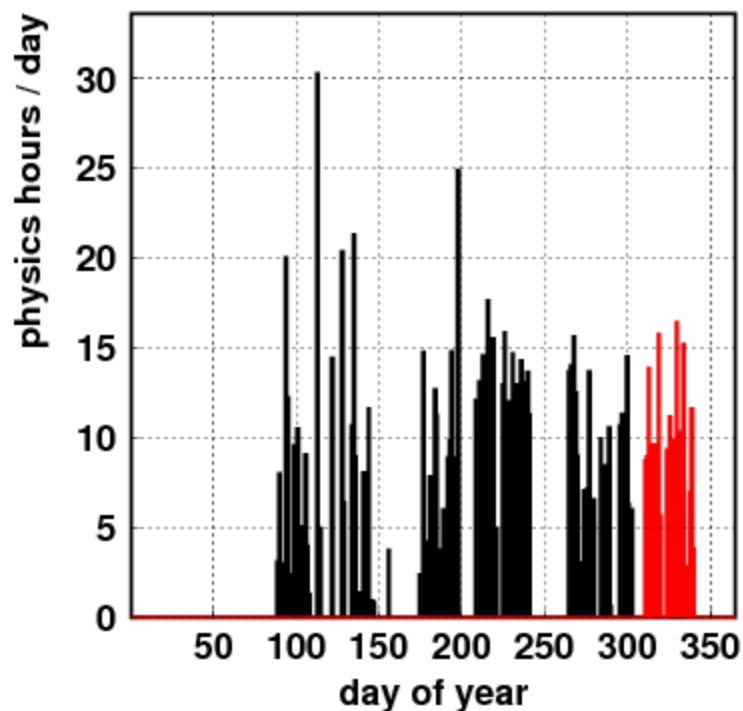
30 hours in one day ! Gosh!

■ p ■ Pb

2010 physics operation



2010 physics operation

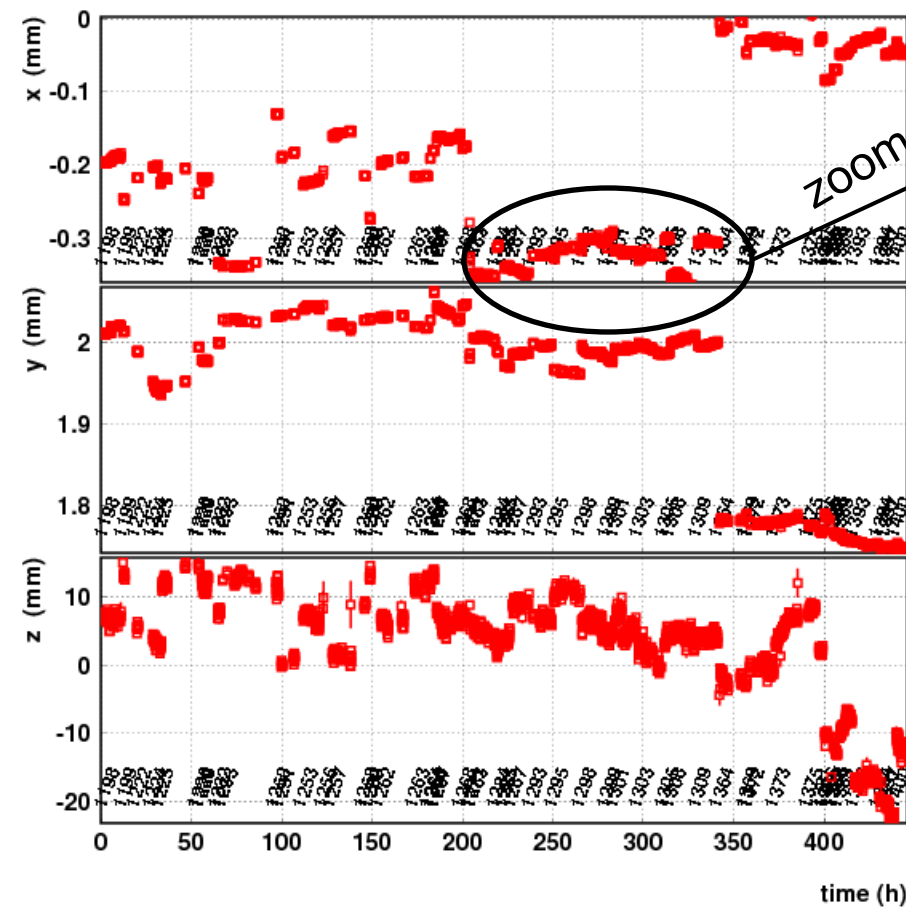


better show it per week

Lumi region positions with leveling by separation of beams

Lumi region position at IP2

ALICE SEPARATION PROTON 2010



ALICE SEPARATION PROTON 2010

