Running in 2011 - Luminosity

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Presentations

Many thanks to all the speakers!

- Experiments' expectations
  - Massi Ferro-Luzzi
- Pushing the limits: beam
  - Elias Métral
- Pushing the limits: crossing angles, aperture and beta*
  - Werner Herr
- Luminosity analysis
  - Giulia Papotti
- Luminosity calibration
  - Simon White
- Heavy ions in 2011 and beyond
  - John Jowett
- Operational schedule 2011 & potential performance
  - Malika Meddahi

Pushing the limits: beam

- Very nice explanation of impedances and single-beam instabilities
- Small lattice nonlinearities => 1 “detrimental” and 1 beneficial effect:
  - Landau octupoles are needed to stabilize the single-bunch instability from transverse impedance
  - The head-on beam-beam tune shift can be ~ 2 times larger than nominal
- Electron cloud
  - 2010 observations are certainly due to ~ 2 < SEY < ~ 2.5, whereas 1.7 was usually the max value studied in the past
  - Miguel Jimenez: confident that rapid cleaning will be seen

Elias Métral

Beam from the injectors

Bunch spacing	From Booster	Np/bunch	Emittance H&V [mm.mrad]	No. of bunches from SPS
150	**Single batch**	**1.1×10^{11}**	**< 2.5 (1.6)**	**1 – 4 x 12**
75	Single batch	1.2×10^{11}	2	1 – 4 x 24
75	Double batch	1.2×10^{11} (?)	1.2 (?)	1 – 4 x 24
50	Single batch	1.45×10^{11}	3.5	1 – 4 x 36
50	Double batch	1.2×10^{11} (?)	1.5 (?)	1 – 4 x 36
25	Double batch	1.15×10^{11}	3.6	1 – 4 x 72

Note: delivered emittance depends on the bunch spacing and batch scheme

Pushing the limits: crossing angles, aperture and beta*

IP 1 & 5

ϵ_n Energy	β^* (3.5 TeV)	β^* (4.0 TeV)	α (3.5 TeV)	α (4.0 TeV)
1.5 μm	1.4 m	1.4 m	$\pm$ 120 μrad	$\pm$ 120 μrad
2.0 μm	1.5 m	1.4 m	$\pm$ 120 μrad	$\pm$ 120 μrad
2.5 μm	1.6 m	1.5 m	$\pm$ 120 μrad	$\pm$ 120 μrad
3.75 μm	1.8 m	1.6 m	$\pm$ 140 μrad	$\pm$ 140 μrad

beta* = 10 m in IP2
beta* = 3 m in IP8

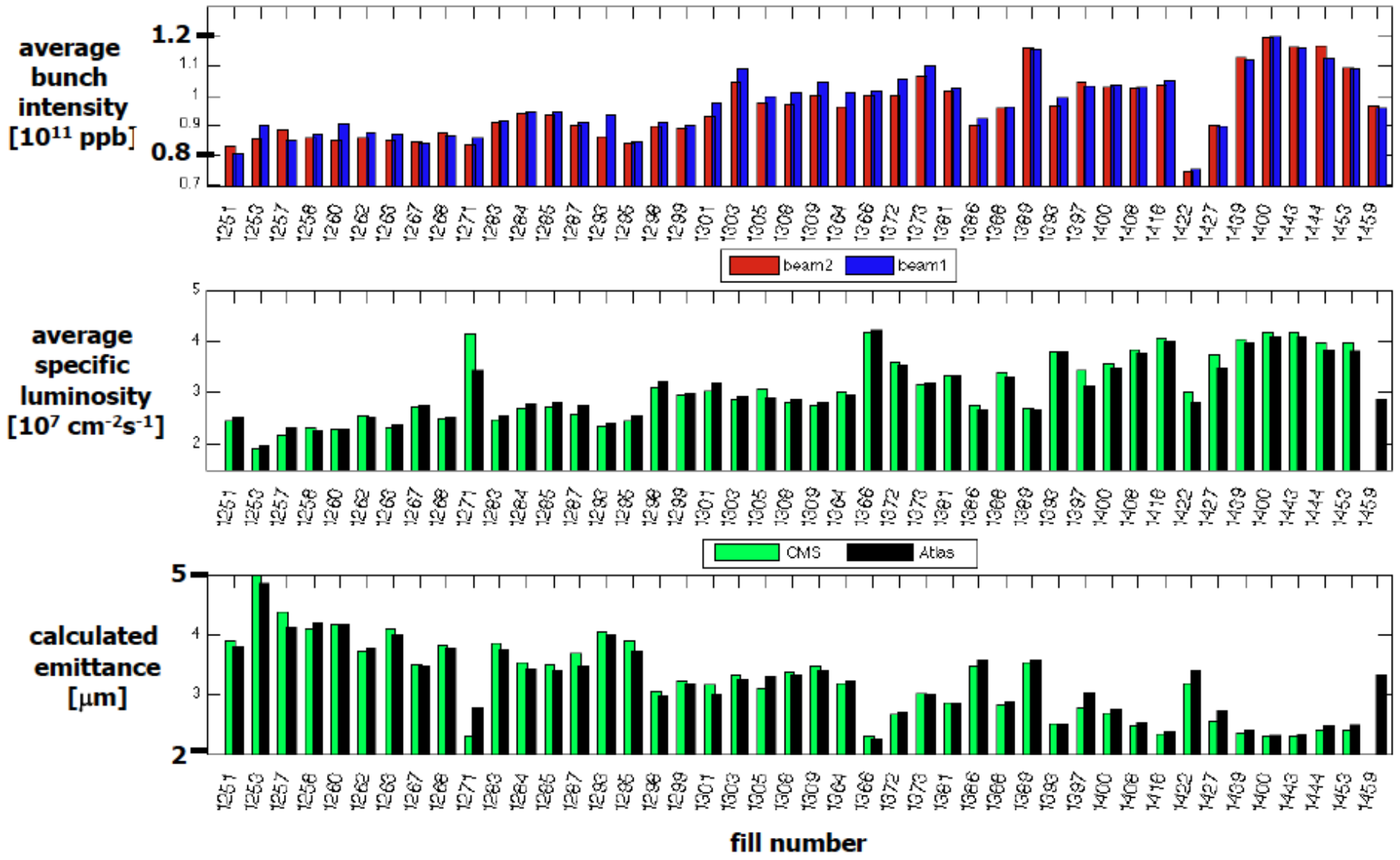
Werner Herr

Pushing the limits: crossing angles, aperture and beta*

- Small emittance important for overall performance
  - Allows lower beta* with moderate crossing angle
  - Allows more flexibility for LHCb spectrometer
  - Allows full field for LHCb spectrometer (at all times and configurations)
  - Werner's recommendation: rather give up on higher intensity than on small emittance
- Should find the head-on beam-beam limit early
  - will tell us the good parameter range
- Luminosity leveling in LHCb must be tested

Werner Herr

Luminosity analysis: statistics across fills



prepared by G. Trad

Giulia Papotti

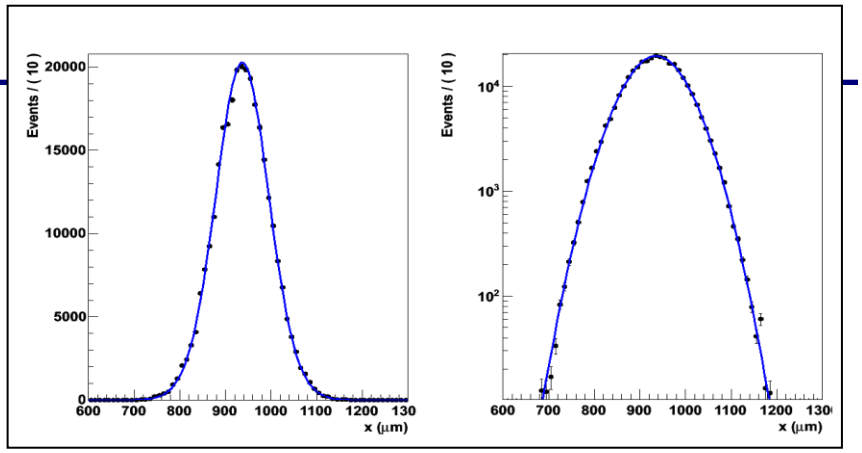
Beam lifetime

- Excellent single beam before collisions ~200 - 300 hours

With colliding beams:

- Luminosity lifetime ~15 - 20 hours
  - Reasonably well given by emittance growth and intensity decay
  - Minimal drifts in overlap – beams very stable
- Intensity lifetime ~90 hours
  - Luminosity burn, losses on collimators
- Emittance growth (x ~ 30 hours, y ~ 20 to 40 hours)
  - Intra Beam Scattering
  - and something else – at least sometimes “the hump”

Luminosity calibration



- Very well motivated!
- Machine parameters methods:
  - Very successful first experience,
    Expect to reach 5% accuracy for 2010, aim for <5% in 2011
- Special fills: 2 requested, conditions to be discussed, try to reduce setup time
- Developments & beam studies: a lot on the list, set priorities
- Hardware: lots of efforts already done and very much appreciated. Beam intensity measurements still limits the precision: set priority on the Bunch Current Transformers and Longitudinal Density Monitors

High beta* experiments

- Forward detectors at CMS (TOTEM) and ATLAS (ALFA) interaction points will provide independent luminosity calibration based on optical theorem
- TOTEM is commissioned and ready for physics at 90 m
- ALFA expects to be ready for summer
- 90 m. optics are ready for commissioning, operational challenges very different from squeezed optics:
  - start commissioning as soon as possible (~5 shifts)
- Physics with 90 m.:
  - 4 fills, expect to reach 3% accuracy on the cross section (TOTEM)

Ions – conclusions

- The 2010 Pb-Pb run showed that the LHC can work well with heavy ions
- Beam physics is complex!
  - Needs more resources for study, analysis of data
- Substantial factor in luminosity possible for 2011
  - Options for filling etc, will be clarified in injector commissioning, experiments are flexible
- 2012 appears to be a good opportunity for p-Pb
  - Otherwise it will be a long time … interesting energy
  - Feasibility test in MD can be tried in 2011. If this realistically is to be considered for a run – a lot of effort needs to be made this year
- Upgrades critical to sustain performance ramp-up
  - Installation of DS collimators in IR2 should not be allowed to slip too far into the future

John Jowett

Ions 2011

- Luminosity factors with respect to 2010
  - 3.5/1.5 from beta*
  - 2 to 2.5 from bunch number and intensity

L = 1 to 1.4 x 10^{26} $cm^{-2}s^{-1}$

Integrated luminosity: 30 to 50 b^{-1} to each of IP1, IP2 and IP5

John Jowett

2011: main goals

- Motivation is clear!

fast, secure and far-reaching!

- 1 fb^{-1} delivered to each of IP1, IP5 and IP8 at 3.5 TeV
  - Can probably do better for IP1 and IP5
- It will be a challenge to deliver 1 fb^{-1} to IP8
  - Maximum luminosity : from 2e32 to 3e32
  - Luminosity leveling via separation required to get close
- Alice
  - pp run: 5e29 < L < 5e30, μ < 0.05

Massimiliano Ferro-Luzzi

Special runs

- Intermediate energy
  - Beam energy 1.38 TeV
  - 24b equalitarian scheme; 16 collisions at each IP => 200kJ
  - 3 shifts to commission; 4 days running at 50 M events to tape
  - Run was recommended by LHCC and endorsed by RB
- beta* = 90m runs
  - beta* = 90 m IP1/5 (10m IP2/8)
  - Setup time (MD): 5 shifts including RP beam-based alignment
- Luminosity calibration runs
- Totem & Alpha
  - Set-up & special runs

~ 10 days

Massimiliano Ferro-Luzzi

Assumed beam parameters for Physics

Beam parameters	
Energy	3.5 TeV
β* : IP1 – 5 – 2 – 8	1.5 – 1.5 – 10 – 3 m for 2.5 μm
Separation (Injection)	± 2 mm
Separation (Physics)	± 0.7 mm (reduction during the ramp)
B1 ½ external crossing angles (Inj.)	± 170 μrad (all IPs)
B1 ½ external crossing angles (Phys.)	+120 μrad (IP1&5); ± 80 μrad (IP2); - 235 μrad (IP8)

Beam parameters	150 ns	75 ns	50 ns
Bunch intensity [e11 p/b]	1.2	1.2	1.2
Normalised Emittance [μm]	2.5	2.5	2.5
Colliding bunches	368*	936	1404

Malika Meddahi

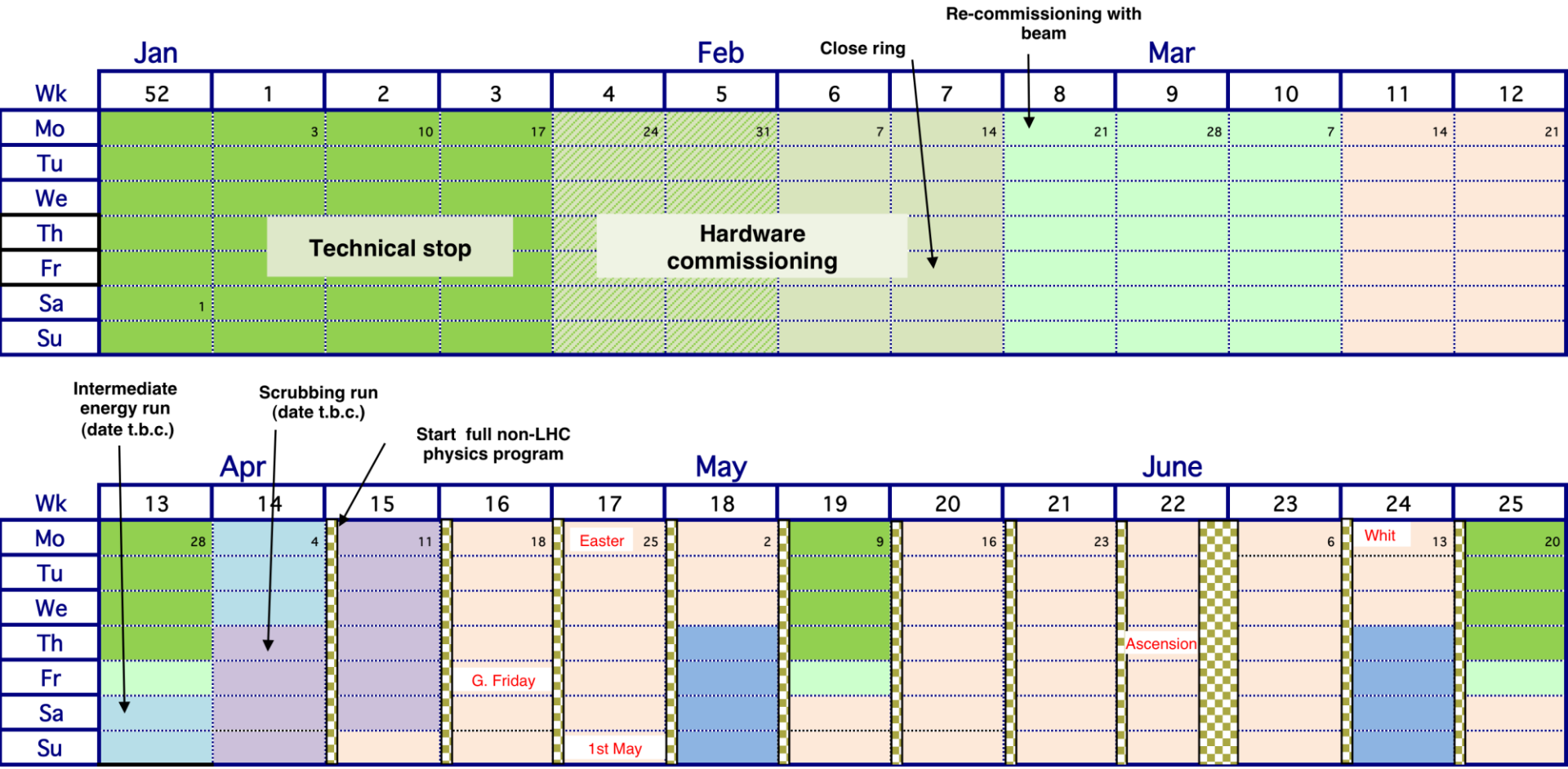
2011 - Days for Luminosity operation

PHASE	Days
Total proton operation	264
5 MDs (4 days)	- 20
6 TS (4+1 days)	- 30
Special physics runs	- 10
Commissioning	- 20 to -30
Intensity ramp up	- 30 to -40
Scrubbing run	- 10
Total at around peak intensity	125 to 145

Baseline scenario

- Beam commissioning: 3 - 4 weeks
  - Exit - stable beams with low number of bunches
- Ramp-up to ~200 bunches (75 ns): 2 weeks
  - Multi-bunch injection commissioning continued
  - Stable beams
- Technical Stop – 4+1 days
- [Intermediate energy run – 5 days]
- Scrubbing run: 10 days including 50 ns injection comm.
- Resume 75 ns operation and increase no. bunches: 3 weeks
  - 300 – 400 – 600 – 800 – 930 - MPS and OP qualification
- Physics operation 75 ns: ~930 bunches

Possible 2011 LHC schedule QQ1/Q2



Estimated Peak and Integrated Luminosity

Energy	3.5 TeV
Beta*	1.5 m
Bunch spacing	75 ns
Bunch intensity	1.2 x 10^{11}
Stored beam energy	75 MJ
Days at peak luminosity	135
Hübner factor	0.2

Emittance [mm.mrad]	Beam-beam parameter	Peak Luminosity [cm^{-2} s^{-1}]	Integrated Luminosity [fb^{-1}]
2.5	0.006	1.3 x 10^{33}	~2.7
2.0	0.007	1.6 x 10^{33}	~3.3
1.8	0.008	1.8 x 10^{33}	~3.7

Malika Meddahi

150 ns: ~1.9 fb^{-1}
50 ns: ~2.8 fb^{-1}

Conclusions

- Good understanding of instabilities, electron cloud and why the LHC needs octupoles
- Beam from injectors in good shape
  - some characteristics to be established
- Minimum beta* 1.5 m in 1 & 5
- Excellent progress in luminosity calibration
  - work in progress, BE-BI working hard on BCT improvements
- Physics goals for 2011 clearly defined…
- Luminosity of 10^{33} cm^{-2} s^{-1} could be within reach with 75 ns beams, beta* = 1.5 m and emittances supplied by injectors
- 1 to 3 fb^{-1} looks achievable in 2011
  - Remembering the incoming challenges: stored beam energy, UFOs, e-cloud, R2E…