Running in 2011 - Luminosity

- Great expectations
  - Massi Ferro-Luzzi
- Pushing the limits: beam
  - Elias Metral
- 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 HO tune shift can be ~ 2 times larger than nominal
- Ecloud => 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 would be seen

Pushing the limits: crossing angles, aperture and beta*

IP 1 & 5 beta* = 10 m in IP2; 3 m in IP8

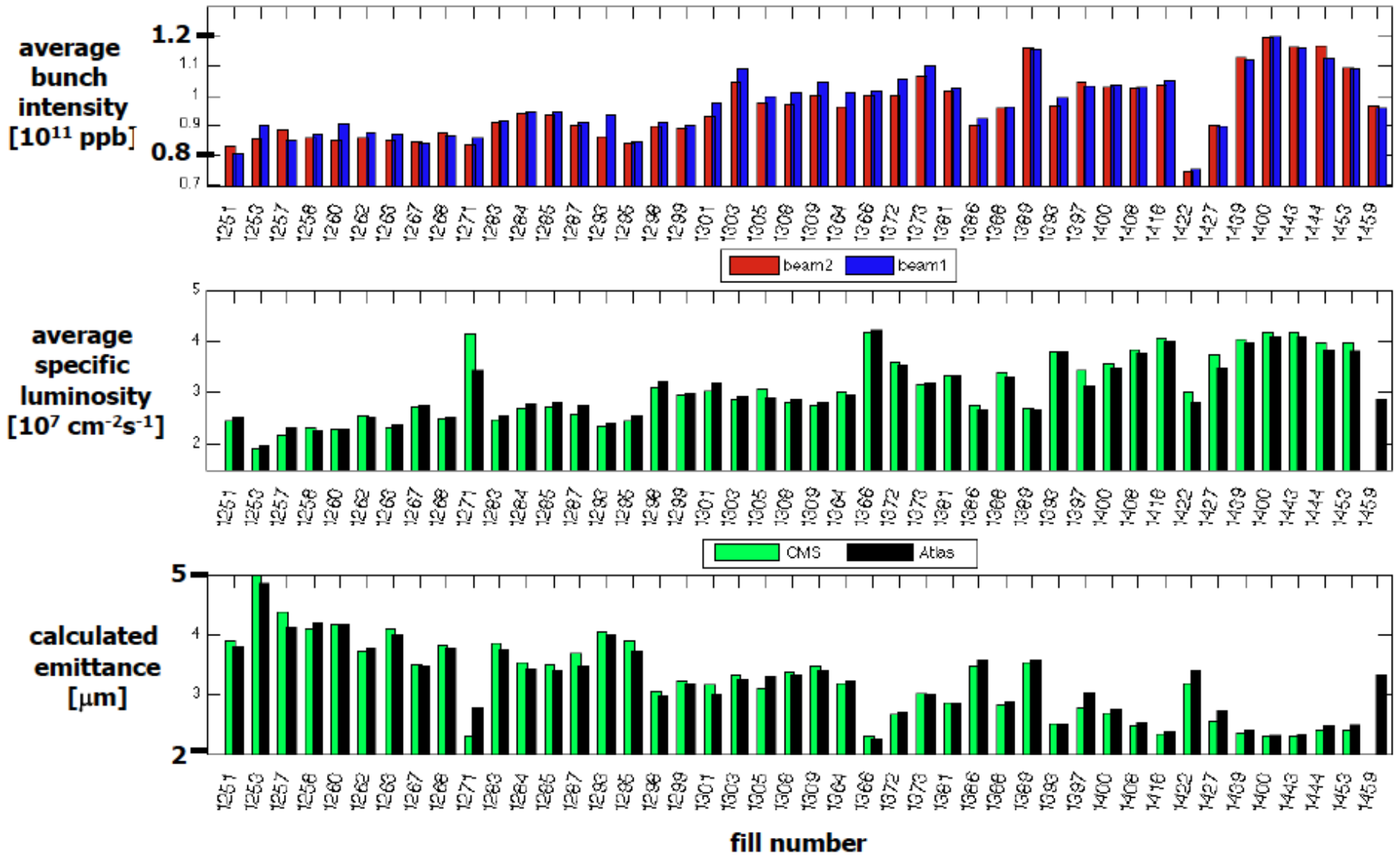
ϵ_n Energy	β^* (3.5 TeV)	β^* (4.0 TeV)	α (3.5 TeV)	α (4.0 TeV)
1.5 μm	1.4 m	1.4 m	$\pm$ 120 μrad	$\pm$ 120 μrad
2.0 μm	1.5 m	1.4 m	$\pm$ 120 μrad	$\pm$ 120 μrad
2.5 μm	1.6 m	1.5 m	$\pm$ 120 μrad	$\pm$ 120 μrad
3.75 μm	1.8 m	1.6 m	$\pm$ 140 μrad	$\pm$ 140 μrad

Small emittance important for overall performance:

- **Allows lower β^* with moderate crossing angle**
- **Allows more flexibility for LHCb spectrometer**
- **Allows full field (at all times and configurations) for LHCb spectrometer**
- **Personal recommendation: rather give up on higher intensity and not on small emittance**

Werner Herr

Lumi analysis: statistics across fills



prepared by G. Trad

Giulia Papotti

Giulia's conclusions

150 ns spaced beam lifetimes

- luminosity lifetime (~20 h)
  - decay explained by emittance growth and intensity decay
  - fast and slow component
    - fast component dependence on collision pattern (PACMAN effect)
- intensity lifetime (~90 h)
  - single beam lifetime is excellent, need a hard number
  - drops after collisions
    - dependence on collision pattern
- emittance grows (ε_x: ~ 30 h; ε_y: ~ 20-40 h)
  - minimum overlap/orbit drifts
    - also verified with end-of-fill lumi scans
  - need to look at causes
    - probably not only IBS

Physics based model – incoming
Already exists for ions

Luminosity Calibration

Simon White

• **Luminosity calibration is important and useful both for physics and the understanding of the machine performance**

• **Machine parameters methods:**

⇒ **Very successful first experience, results went beyond expectations**

⇒ **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 BCTs and LDM**

• **High-β experiments:**

⇒ **TOTEM is commissioned and ready for physics at 90 m**

⇒ **ALFA will start commissioning, expects to be ready for summer**

⇒ **Optics are ready for commissioning, operational challenges very different from squeezed optics: start commissioning as soon as possible (~5 shifts)**

⇒ **Direct cross section measurement independent from machine parameters: would provide a very useful (and required) cross check of other methods**

⇒ **Physics: 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 devoted
- Upgrades critical to sustain performance ramp
  - Installation of DS collimators in IR2 should not be allowed to slip too far into the future

John Jowett

Ions - 2011

- Luminosity factors w.r.t. 2010
  - 1.5/3.5 from β*
  - 2-2.5 from bunch number and intensity

$$L = 1 - 1.4 \times 10^{26}\ \mathrm{cm^{-2}s^{-1}}$$

Integrated luminosity 30-50 $\mu\mathrm{b}^{-1}$

John Jowett

2011 – main goals

- Re-call motivation
- 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
  - Luminosity leveling via separation required to get close
- Ions: 30 μb-1 delivered to each of IP1, IP2 and IP5 at 3.5 TeV

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
- □* = 90m runs
  - □* = 90 m IP1/5 (10m IP2/8)
  - Setup time (MD): 5 shifts including RP beam-based alignment at 90m
- Luminosity calibration runs
- Totem & Alpha
  - Set-up & special runs

~ 10 days

Massimiliano Ferro-Luzzi

Assumed beam parameters for Physics

Beam parameters	
Energy	4 TeV – (3.5 TeV considered)
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

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 High intensity	124 to 144 (135 days for integrated L)

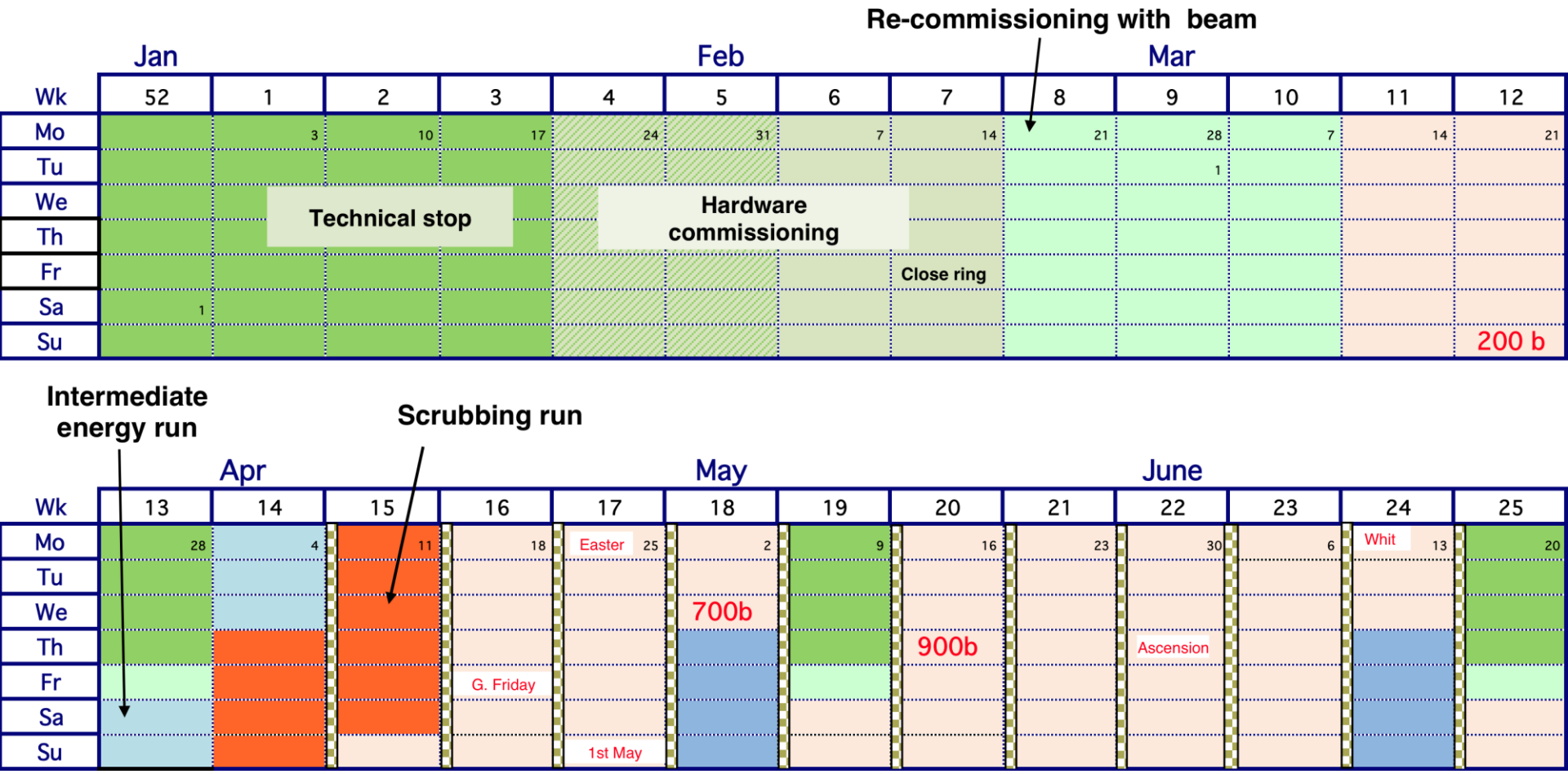
HWC : one extra week needed for 4 TeV operation – Mirko Pojer

Malika Meddahi

Preferred scenario

- Beam commissioning – 3 - 4 weeks
  - Exit - stable beams with low number of bunches
- Ramp-up to ~200 bunches (75 (or 150 ns)) – 2 weeks
  - Multi-bunch injection commissioning continued
  - Stable beams
- Technical Stop – 5 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 - MP and OP qualification
- Physics operation 75 ns – 930 b

Possible 2011 LHC schedule



Estimated Peak and Integrated Luminosity

$\beta^* = 1.5m$

days	H.F	Comm with	Fills with	kb	Nb e11	ε μm	ξ/IP	L Hz/cm^2	Stored energy MJ	L Int fb^{-1} 4 TeV	L Int fb^{-1} 3.5 TeV
160	0.3	150 ns	150 ns	368	1.2	2.5	0.006	~5.2e32	~30	~2.1	~1.9
135	**0.2**	**75 ns**	**75 ns**	**936**	**1.2**	**2.5 2 1.8**	**0.006 0.007 0.008**	**~1.3e33 ~1.6e33 ~1.8e33**	**~75**	**~3 ~3.8 ~4.2**	**~2.7 ~3.3 ~3.7**
125	0.15	50 ns	50 ns	1404	1.2	2.5	0.006	~2e33	~110	~3.2	~2.8

Malika Meddahi

Conclusions

- Good understanding of instabilities, e-cloud and why the LHC needs octupoles
- Minimum beta* 1.5 m in 1 & 5 (with possibility of squeezing slightly further – to be pursued)
- Excellent progress in luminosity calibration – work in progress – BE-BI working hard on BCT improvements
- Physics goals for 2011 clearly stated…
- Luminosity of 10^{33} cm^{-2} s^{-1} is within reach with 75 ns beams, beta* = 1.5 m and excellent emittances supplied by injectors

Luminosity projections for 2011

- Base: 1 fb^{-1}
- Stretched: 3 fb^{-1}
- Bob the builder “YesWeCan” coordinator special: 5 fb^{-1}
- Super-duper stretched limo somewhere over the rainbow experiments’ special: 10 fb^{-1}

Thanks to all the speakers for an excellent set of presentations