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Strategy for the First Two Months of the 2015 Beam Commissioning

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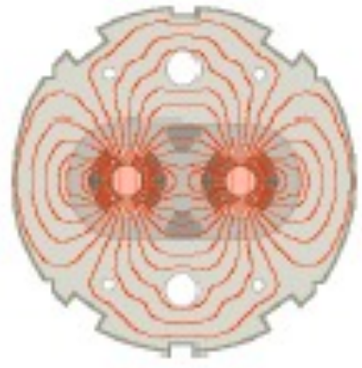
with G. Arduini, M. Giovannozzi, M. Lamont, R. Tomás, J. Wenninger

Acknowledgements: Colleagues in OP-LHC, ABP-HSS, ABP-HSC, collimation.

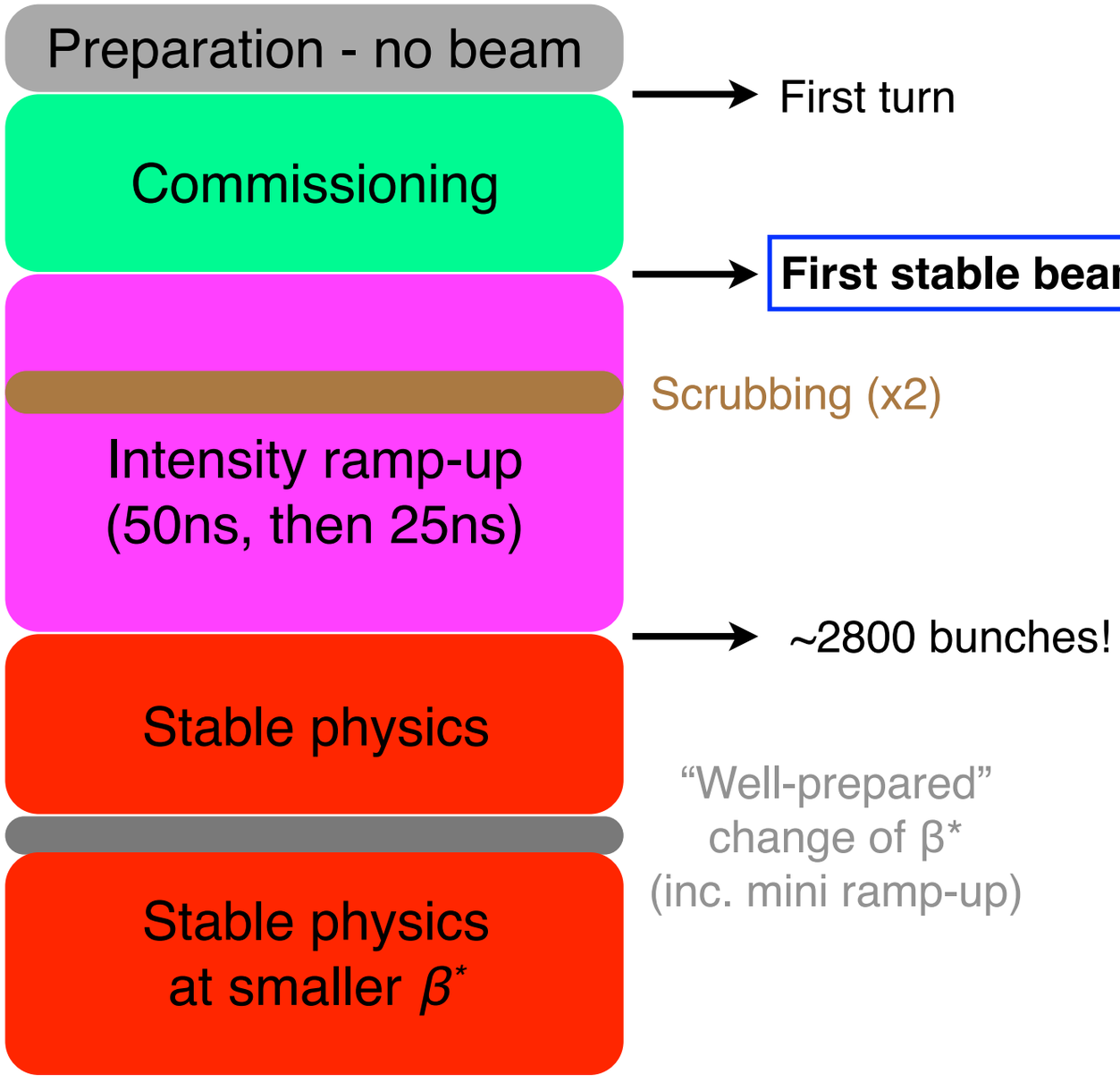


Outline

- ☑ Introduction
- ☑ Lessons from Run I
- ☑ Run II requirements
- ☑ New decision points
- ☑ Conclusions

Introduction

2015 LHC commissioning phases



Machine mode where all experiments are allowed to be completely switched ON.

Intensity ramp-up is done by increasing the number of bunches, keeping the same machine configuration (β^*, orbit, IR bumps, ...)

*Essentially, the beam commissioning of all systems must be **completed**, including **machine protection** (MP) validation.*

*Since the MP validation is lengthly, **changes** of machine configuration done after would be **very costly** in term of time!*

Goals of initial beam commissioning

What must be done before the first physics with 2-3 bunches:

- ☑ Establish the key beam commissioning steps

  First threading, beam capture, orbit and optics corrections, IR bumps, aperture, polarities, energy ramp, betatron squeeze, collisions, ...

- ☑ Commission with beam the key accelerator systems

  Feedback systems, collimation, RF, injection, dump, diagnostics, ...
  Remark: need to take into account the LS1 system changes!

- ☑ Execute relevant machine protection commissioning

  We want all MP-related systems in their final configs by the first stBeam!
  *Complete beam **validation** of the given machine configuration.*
  Remark: changes during might become very time consuming.

- ☑ **Validate by measurements the machine configuration**

  The challenges of the Run II require new measurements compared to the standard commissioning of previous years!

- ☑ **Prepare the scheduled β^* change planned for later in 2015.**

  What can be done to speed up the optics re-commissioning?

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  aperture, polarities, energy ramp, betatron squeeze

  Give for "granted" and not presented in detail here

- ☑ Commission with beam the key accelerator systems

  Feedback systems, collimation, RF, injection, dump
  Remark: need to take into account the LS1 syst

  Will recap. changes that affect the commissioning

- ☑ Execute relevant machine protection commissioning

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  Talk B. Salvachua

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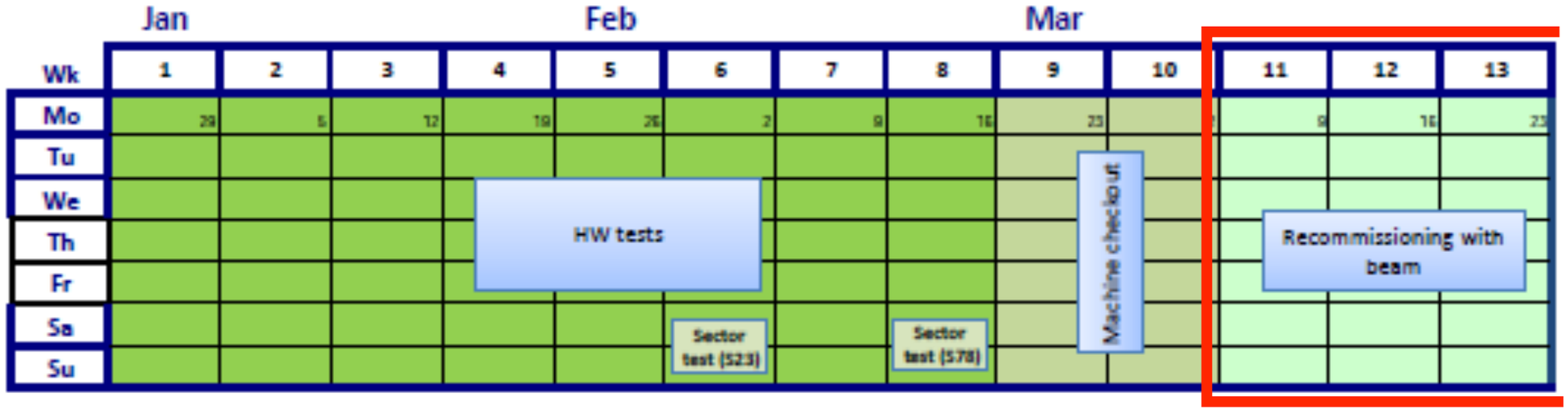
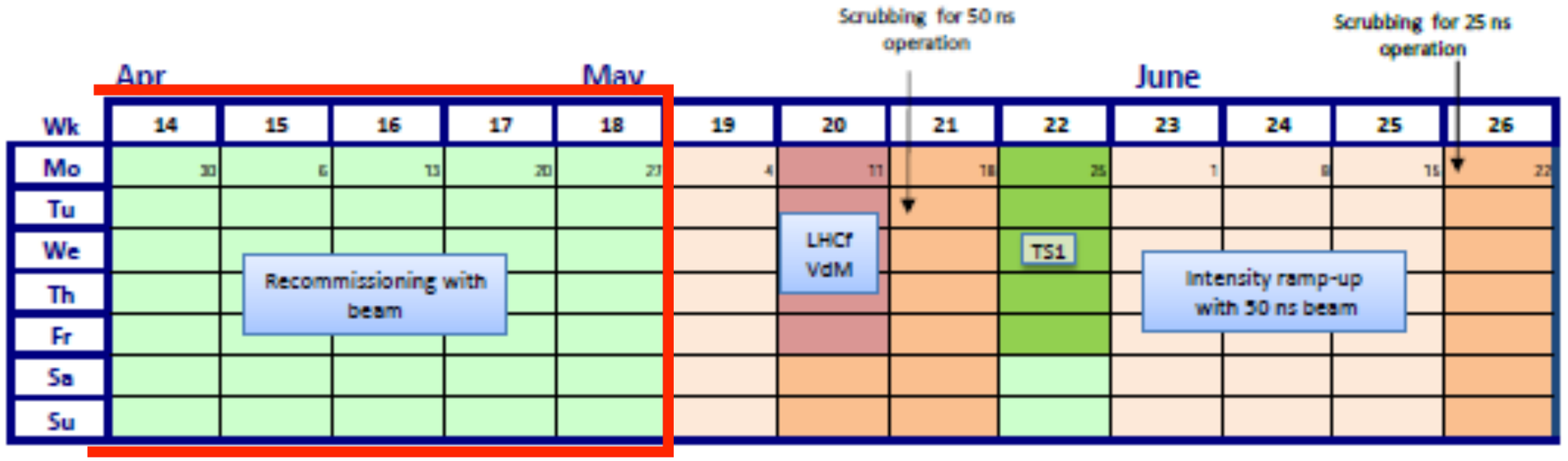
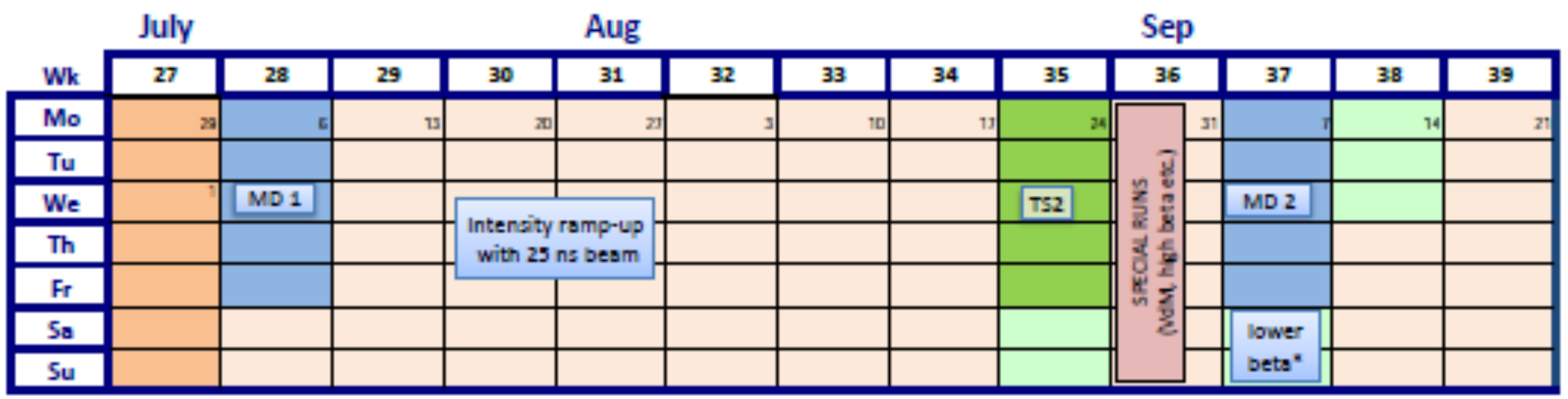
Baseline 2015 schedule







Initial commissioning: 2 months foreseen

M. Lamont

Initial commissioning: target parameters

Discussed in detail this morning, picked from R. Bruce's slides

Parameter	Value @ injection	Value @ collision
Energy [TeV]	0.45	6.5
β* (1/2/5/8) [m]	11 / 10 / 11 / 10	0.8 / 10 / 0.8 / 3
Half X-angle (1/2/5/8) [µrad]	-170 / 170 / 170 /170	-145* / 120 / 145* / -250
Tunes (H/V)	64.28 / 59.31	64.31 / 59.32
Separation (1/2/5/8) [mm]	2 / 2 / 2 / 3.5	0.55 / 0.55 / 0.55 / 0.55
Emittance (BCMS/standard) [µm]	≥ 1.3 / ≥ 2.4	≥ 1.7 / ≥ 2.7**
Bunch intensity [p]	≤ 1.3e11	≤ 1.2e11***
4 σ bunch length [ns]	1.2	1.25
Collimator settings	2012 (nominal)	2012 mm kept****

* Corresponding to 11 σ beam-beam separation. Room for increased angle if needed

** Assuming blowup from IBS only (M. Kuhn, Evian14). Much worse if scrubbing not successful (talk G. Iadarola)

*** Assuming 95% transmission

**** Room for increased margins for machine protection and impedance if needed

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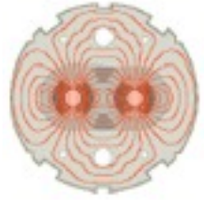
How we thought we could do it...



Baseline established in Jan. 2008

	Activity	Rings	Beam Time [day]
1	Injection and first turn	2	4
2	Circulating beam	2	3
3	450 GeV – initial commissioning	2	4
4	450 GeV – detailed optics studies	2	5
5	*450 GeV increase intensity*	*2*	*6*
6	450 GeV - two beams	1	1
7	*450 GeV - collisions*	*1*	*2*
8a	Ramp - single beam	2	8
8b	Ramp - both beams	1	2
9	7 TeV – top energy checks	2	2
10a	Top energy collisions	1	1
	TOTAL TO FIRST COLLISIONS at 7 TeV ($1.1 \times 10^{30} cm^{-2} s^{-1}$)		30

Foreseen frequent changes of optics in the year; ramp-up by bunch intensity and not number of bunches; a few big steps in Nb; ramp comm. for individual beams; ...

Planned first physics with156 on156 after 30 days of beam commissioning...

<u>Feedback for Run I commissioning experience</u>:

Awareness of collateral damage; need to avoid quenches in Run I;

Many operational details relevant for commissioning (e.g., bunch intensity for BI);

Validation of machine configuration is lengthy (collimation setup + loss maps);

Steps in intensity and speed of ramp-up determined by machine protection.

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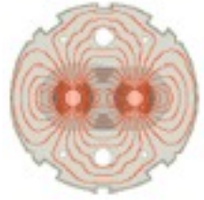

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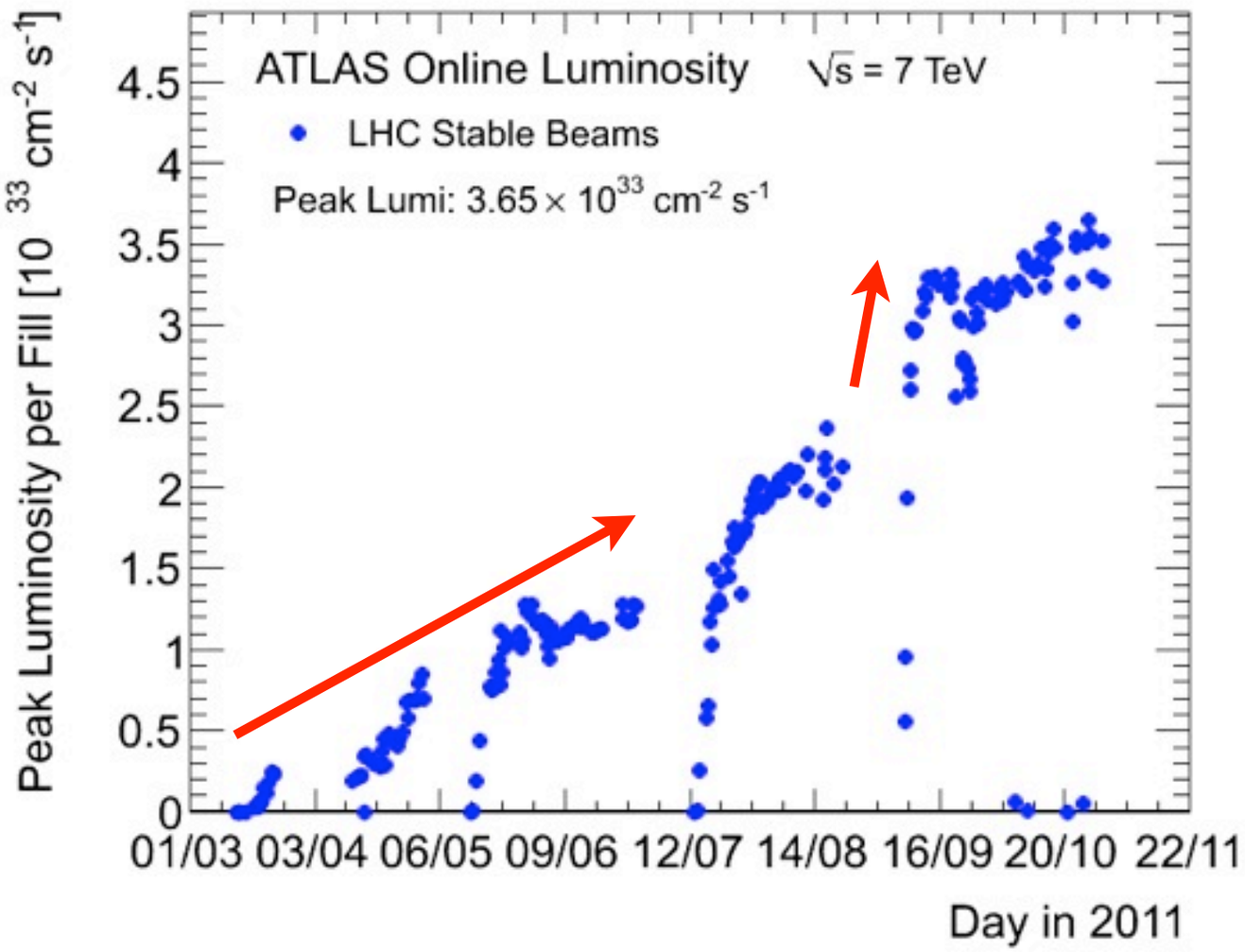
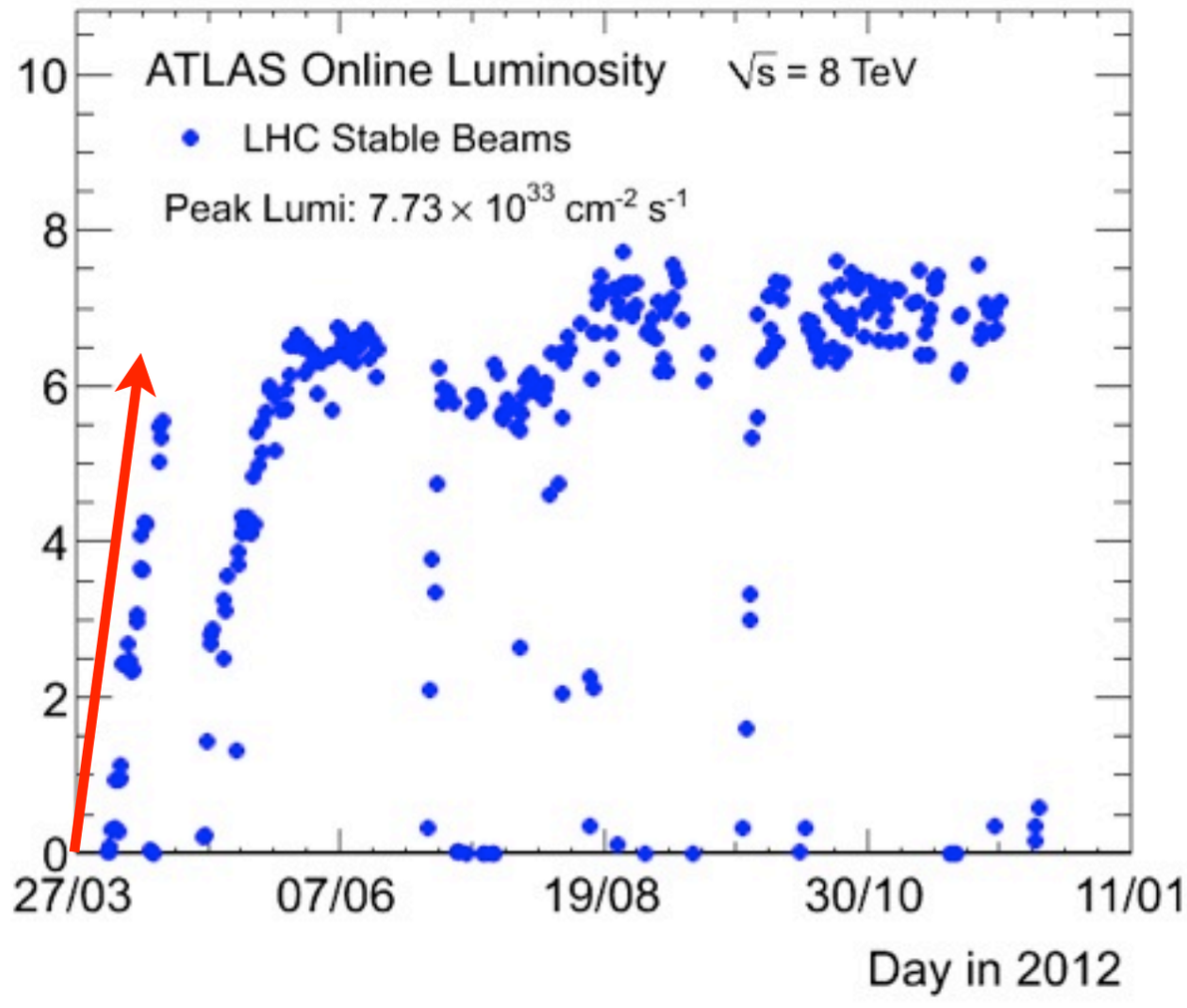
Clearly, the commissioning baseline for 2015 relies on the mature experience of 2012.

Recap.: 2011 versus 2012





Intensity ramp up:

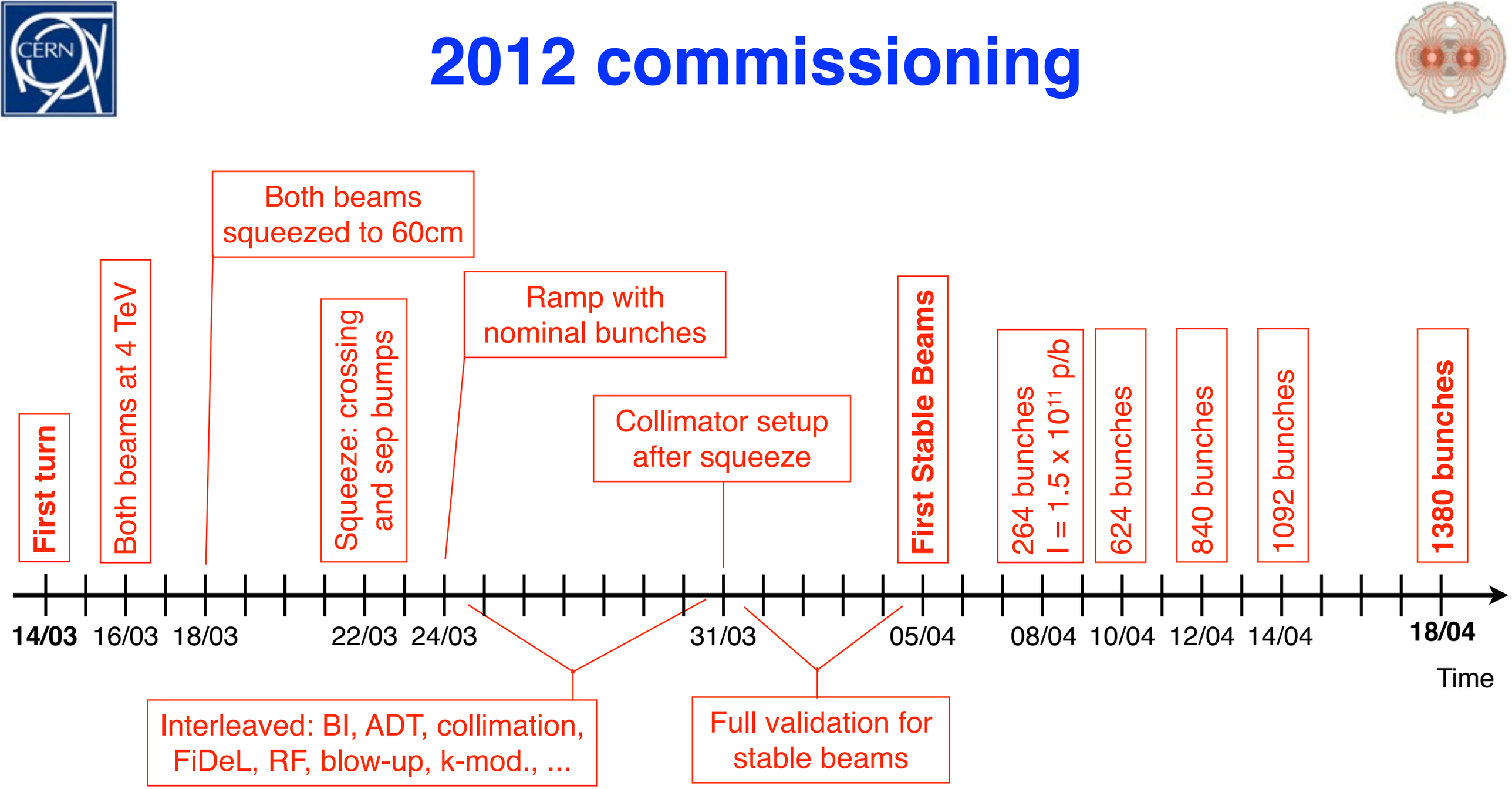
- Increase number of bunches,

- then push bunch intensity.

Followed by a re-commissioning of the optics (β^*=1.5m → 1.0m).

Achieved "ultimate" machine parameters in record time, then optimized bunch intensity and ε. Same β^*=60cm throughout 2012.

2012 commissioning



2012 commissioning

First turn

Both beams at 4 TeV

Both beams squeezed to 60cm

Squeeze: crossing and sep bumps

Ramp with nominal bunches

Collimator setup after squeeze

First Stable Beams

264 bunches I = 1.5 x 10^{11} p/b

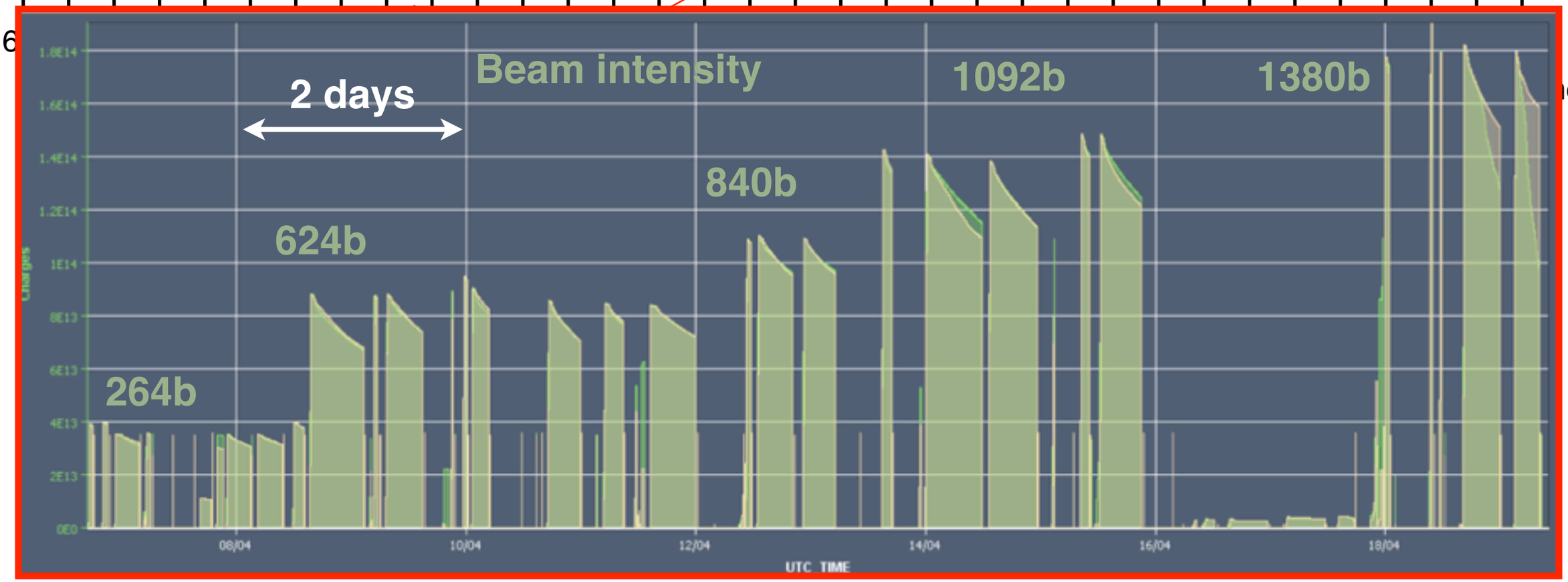
624 bunches

840 bunches

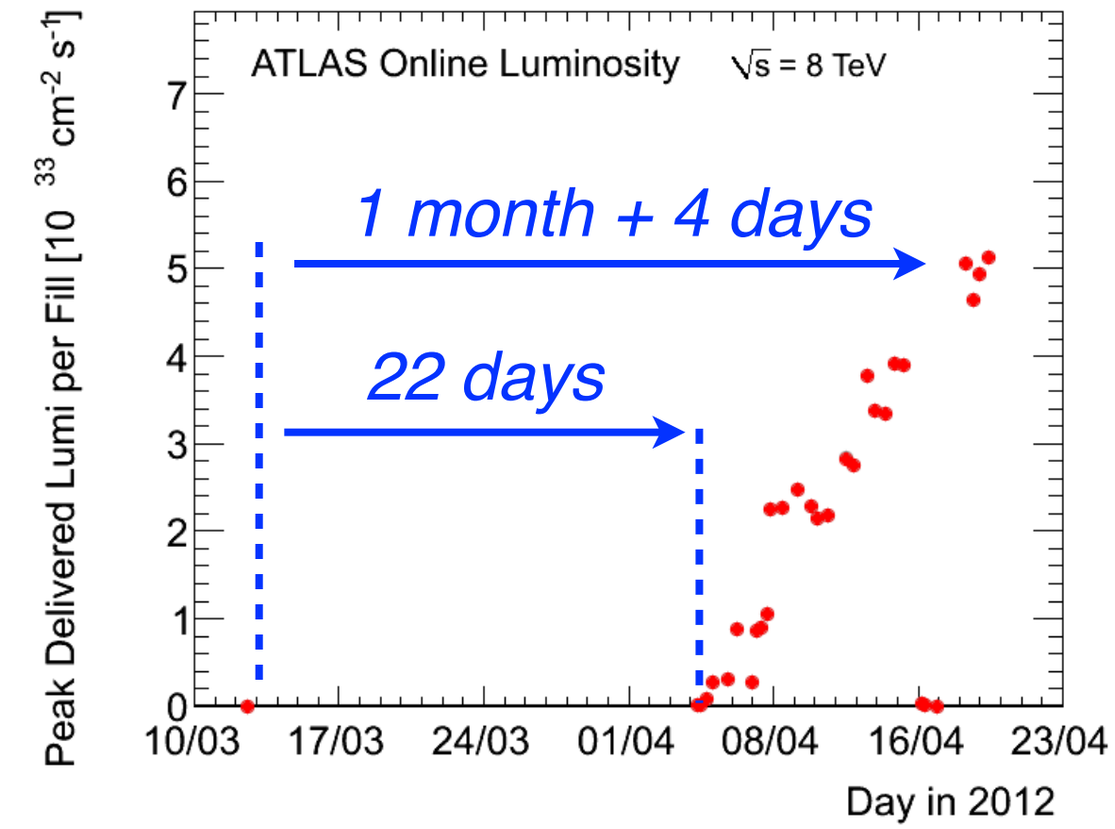
1092 bunches

1380 bunches

14/03 16



Feedback from 2012 commissioning



(Among the many ingredients...)
Excellent performance and knowledge of accelerator systems and of the machine (stability, reproducibility, ...).
A careful choice of parameter set, with reasonable risks (and some luck?)
Rather "small" steps in β from one year to the other, based on solid knowledge of optics and machine aperture.*

Important aspects for the rapid initial commissioning in 2012:

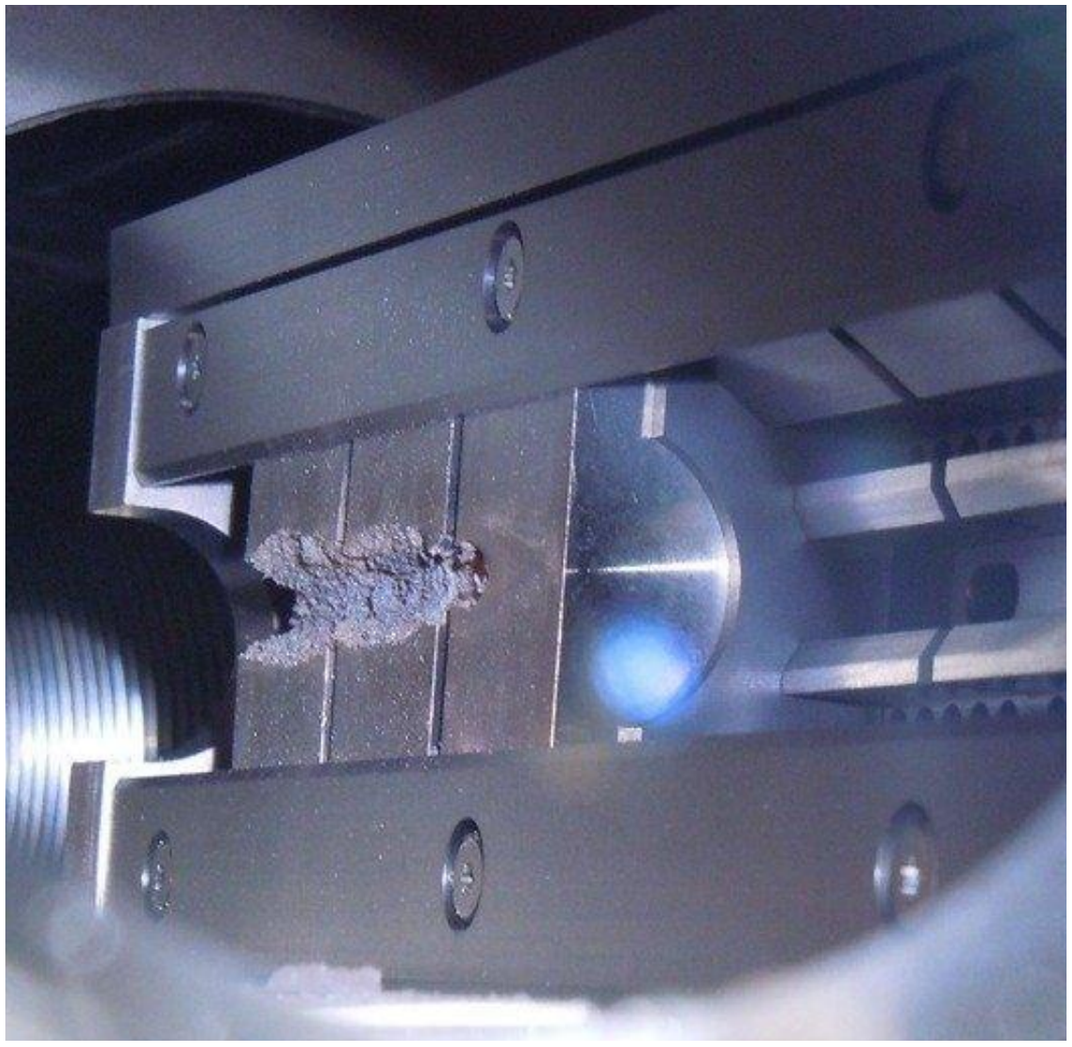
- *Commissioning effort was focused on high-intensity proton operation!*
- *Minimum (no?) hardware changes to cope with, compared to 2011.*
- *Working in the assumption that few nominal bunches at top energy were SAFE.*

This is not the case for the re-commissioning in 2015!
We should expect a longer setup phase.

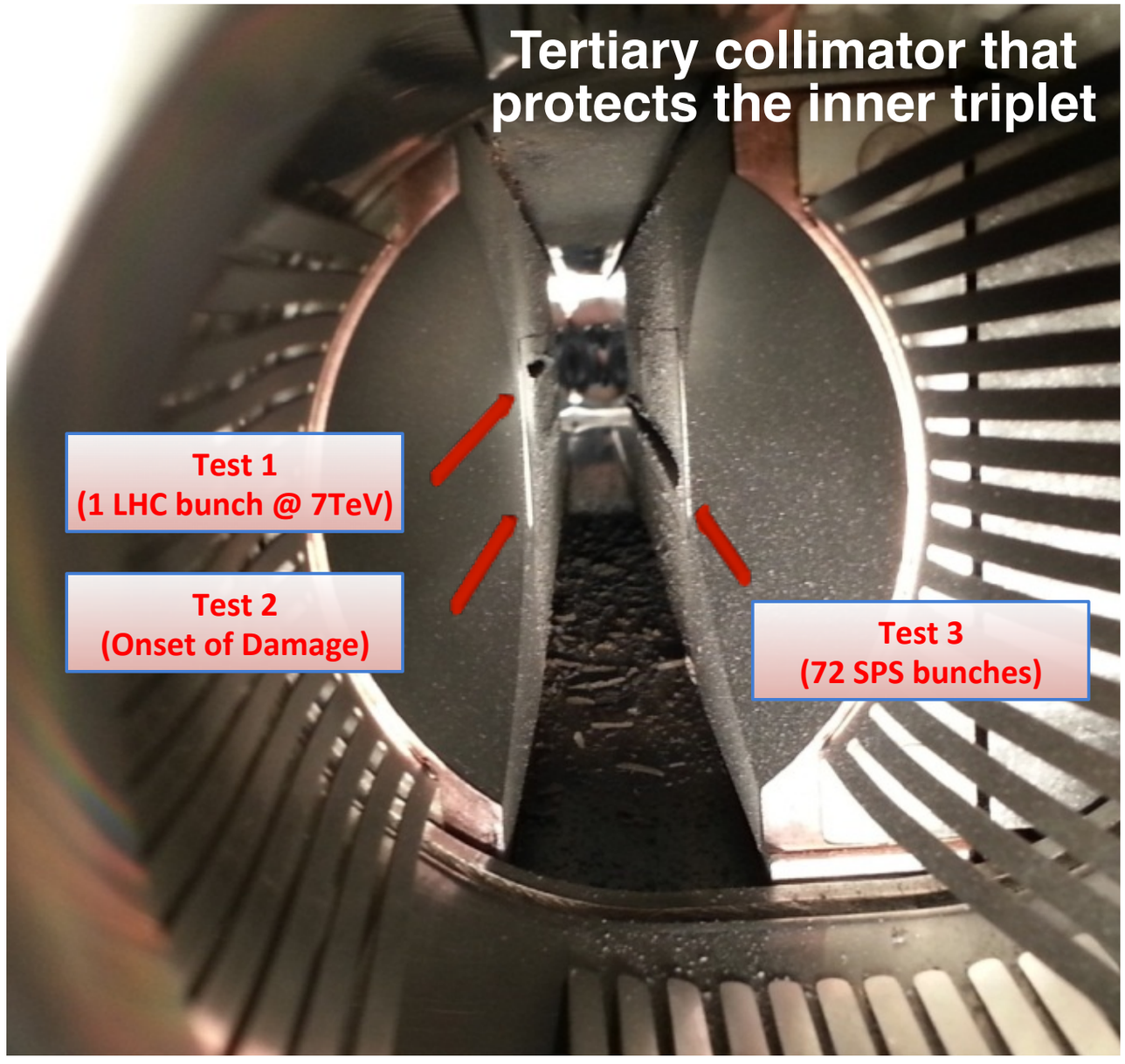
MP implications on commissioning

- New damage limits proposed in line with updated accident scenarios (Annecy '13):
  - **Onset of plastic damage : 5×10^9 p**
  - **Limit for fragment ejection: 2×10^{10} p**
  - **Limit of for 5th axis compensation (with fragment ejection): 1×10^{11} p**

7 TeV equiv. inferred from HRM beams



Inermet 180, 72 bunches



A. Bertarelli *et al.*

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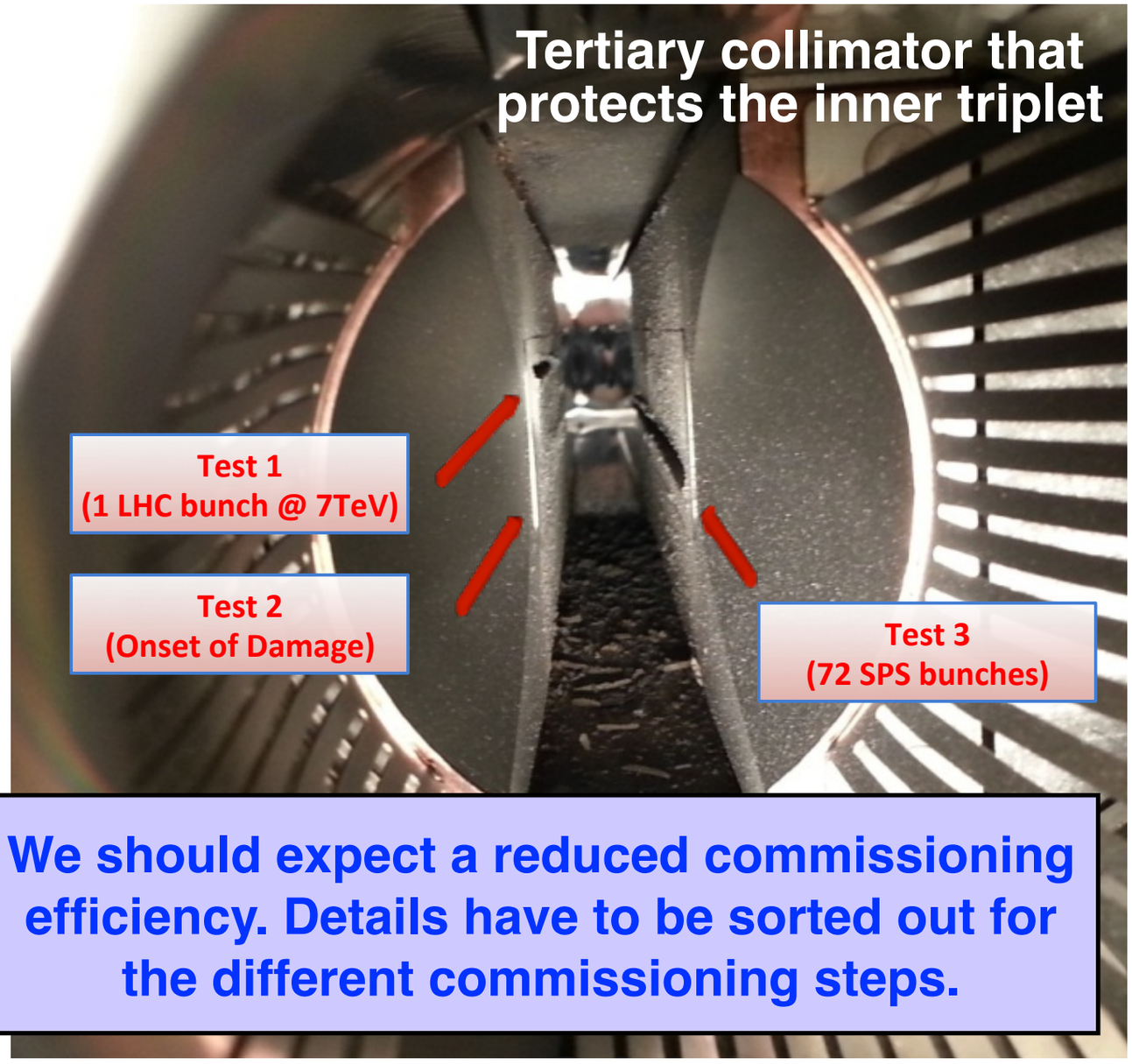
7 TeV equiv. inferred from HRM beams

No issue experienced in Run I, but might need to revise this in light of the problem with 5th axis.

Several new constraints in 2015:
- Protection settings for first ramp and for setup at top energy;
- Definitions for safe setup conditions and impact on validation procedures;
- Details of intensity ramp-up plan
- . . .



We should expect a reduced commissioning efficiency. Details have to be sorted out for the different commissioning steps.

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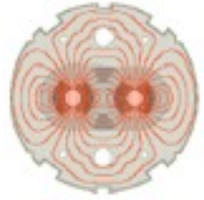
2015 commissioning requirements (i)



- **New operational challenges** (obviously...)
  - *See complete overview in Mike's slides this morning*
- **Experiments's requests**
  - *Special runs now needed early on*
    (implying the early commission of more optics):
    Dedicated optics setup for VdM scans (de-squeeze).
    Low-luminosity data taking for LHCf.
  - *Alignment and setup of more Roman pots following TOTEM upgrade requested as part of the collimation setup.*
- **Injection and dump systems** *(see talk by W. Bartmann)*
  - *Validation of new hardware "gap" interlocks (in the beam energy tracking system);*
  - *New hardware of the injection (TDI) and dump (TCDQ) protection;*
  - *Repeat measurements only done at the beginning of Run I:*
    - *detailed aperture;*
    - *kicker waveforms;*
  - *Request for specific checks of TDI heating.*

2015 commissioning requirements (ii)

☑ Collimation

- ***New hardware with BPMs**: dedicated tests must be foreseen at injection and top energy [18 new collimators with BPMs]*
- *Verification of new IR layouts with TCL collimators [8 new devices];*
- *Improve / optimize validation procedures:*
  Need to re-establish safe loss maps procedures at top energy;
  Plan to test methods for more efficient off-momentum loss maps.

☑ Beam instrumentation (detailed discussions at Evian)

- *Beam size measurements;*
- *BLM system: new lower-sensitivity monitors in IR2/8;*
- *New threshold setup;*
- *New instruments for interlock purposes;*
- *New "DOROS" BPM's, in addition to the ones in collimators.*

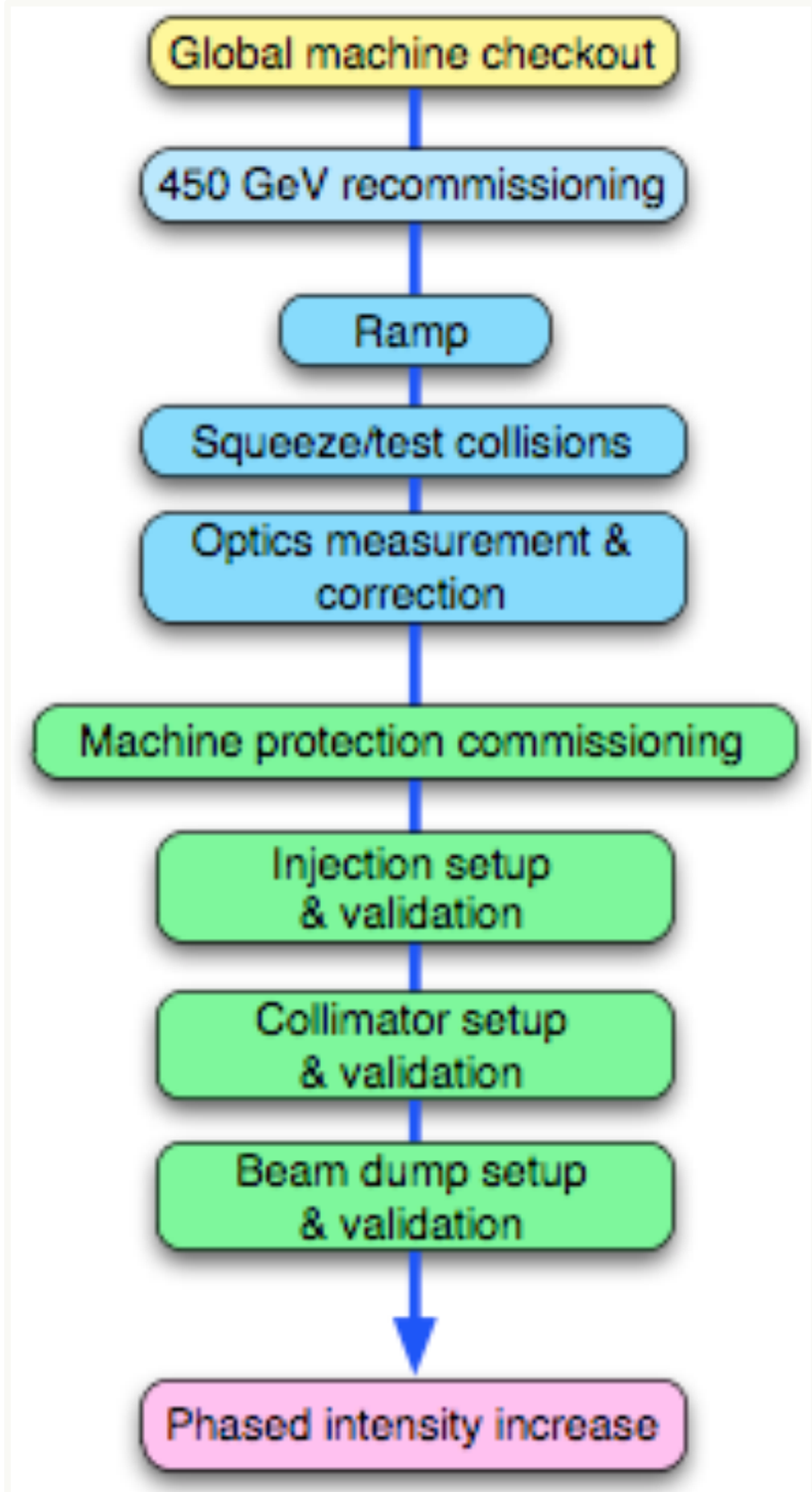
☑ Main RF system and transfer damper (ADT)

- *Many new features / hardware changes;*
- *Measurements on bunch length and longitudinal profile.*

☑ . . . .

Can we fit all that in 2 months?

Preliminary break-down of steps



In reality, blocks are ***interleaved*** *with each other!*

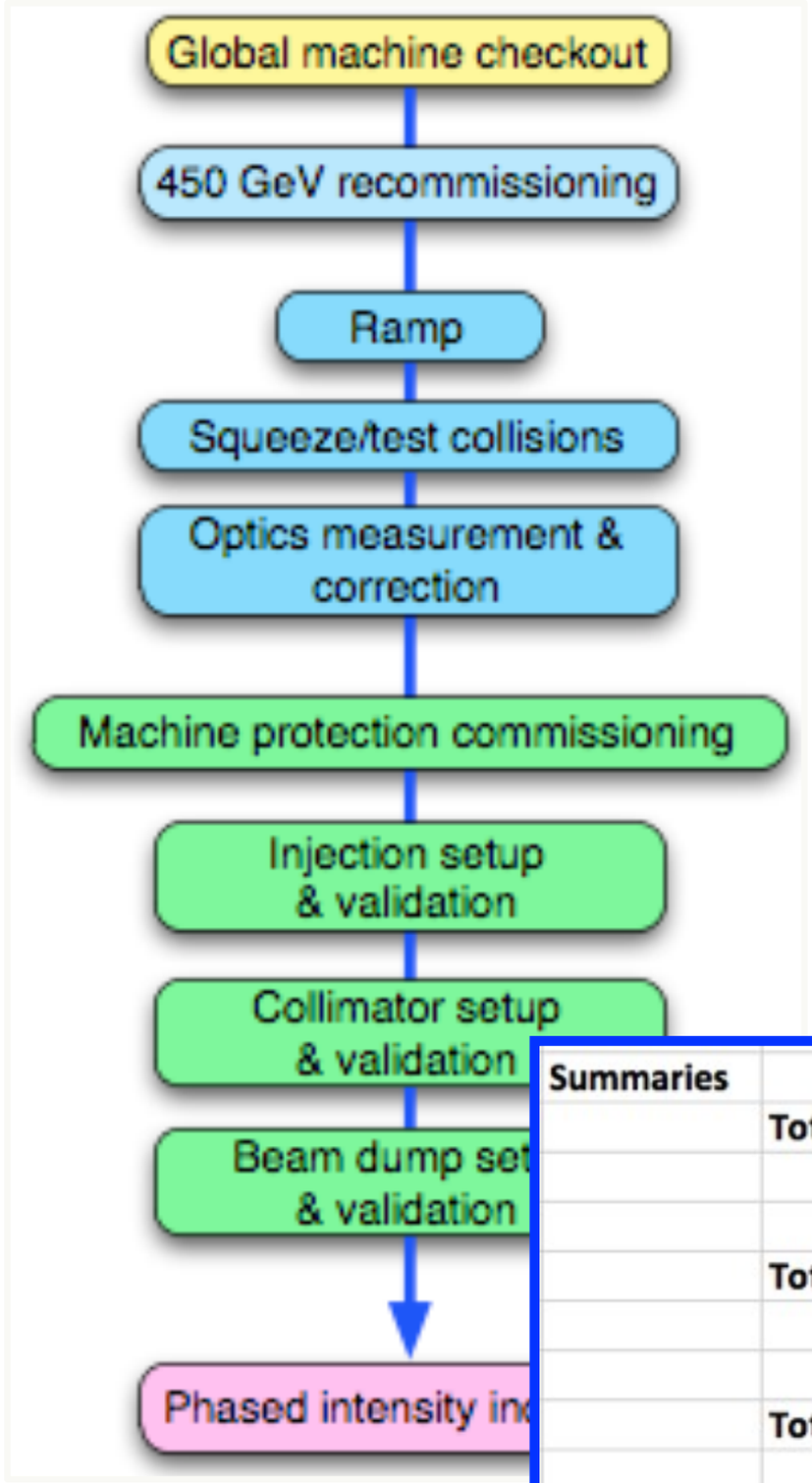
Recap. of key "standard" activities, from Run I:

Threading, capture, initial BI
Initial orbit and optics, more BI, polarities, etc.
System commissioning: feedback systems, collimation, RF, injection, LBDS, detailed BI, ...
Optics measured and corrected. Aperture.
Flat orbit setup followed by IR bump commissioning.
Ramp. FiDeL, decay, saturation. Feedbacks.
Squeeze. Steps followed by continuous functions.
Re-iterate on orbit, optics, aperture, ...
Collisions.
Machine protection and validation.

Basic setup at injection			
	System	Action	Time (h)
	OP	Beam Threading	8
	RF	Beam capture	8
	RF	Delays, buckets	4
	RF	Commission loops	8
	BI	Basic instruments checks	24
	OP	Cleaning closed orbits (probe)	4
	OP	Tune and chroma	8
	OP+ABP	Dispersion and beta-beat measurements	12
	ABP	Optics correction	8
	OP+RF	Energy matching to SPS	8
	OP+ABT	Injection correction and setup	12
	Collimation	Collimator to coarse	12
	OP	Decay measurements (Q and Q')	24
	ADT	Calibration and basic setup	32
	ADT	Blow-up setup	8
	OP	Orbit corrector polarities	24
	OP+ABP	Higher order circuit polarities	24
	MP	BLM MP tests	16
	MP	SIS MP tests	16
	ABP	Various ABP measurements	24
	OP+BI	Feedback commissioning and tests	16
Nominal intensity at injection			
	System	Action	Time (h)
	OP	Reference closed orbit	8
	OP	Separation/Xing bumps	8

Detailed work on-going to collect beam requests and allocate time for each step...

Preliminary break-down of steps



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Detailed work on-going to collect beam requests and allocate time for each step...

Summaries					
	Total	Basic setup at injection	300	hours	**Recent figures indicate 45 (net) days until first stable beams** (J. Wenninger) **It start getting tight...**
			37.5	shifts	
			12.5	days	
	Total	Nom int at injection	328	hours	
			41	shifts	
			13.7	days	
	Total	Ramp, squeeze and collide	444	hours	
			55.5	shifts	
			18.5	days	
	Intermediate total		44.7	days	to first atable beams with 3 bunches

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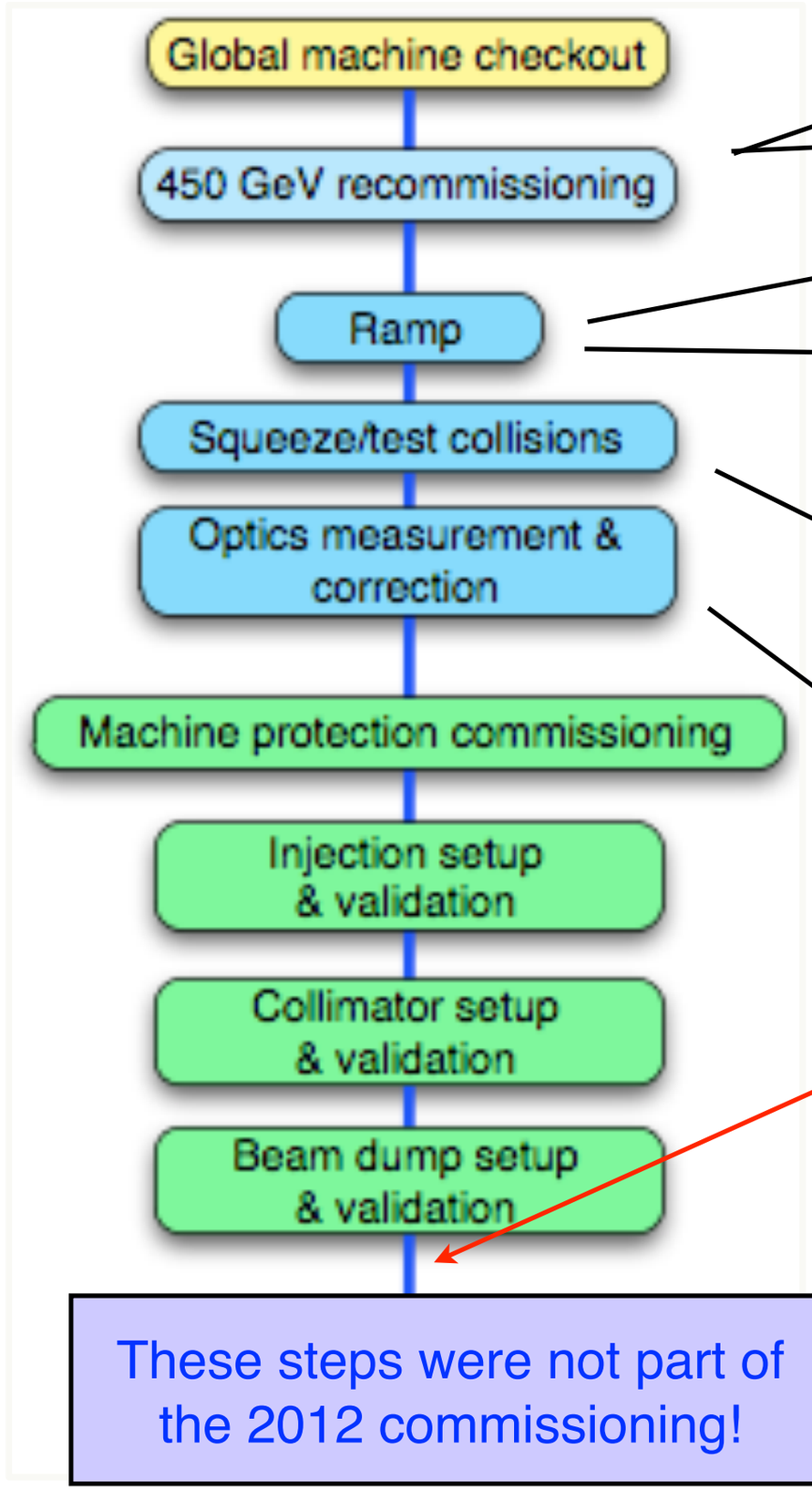
Key “decision points”



IR aperture at injection (bumps): first check of beta* reach

De-tuning versus amplitude and detailed MCO/MDO setting

Finalize strategy for combined ramp and squeeze

With nominal bunches at top energy:
Clean measurements of Q’ and effect of octupoles
Single-beam stability limits (check point for BCMS bunches?)
Collimator impedance → confirm simulations/new settings

Optics measurements and corrections down to 40 cm

Dedicated “local” IR optics / orbit corrections

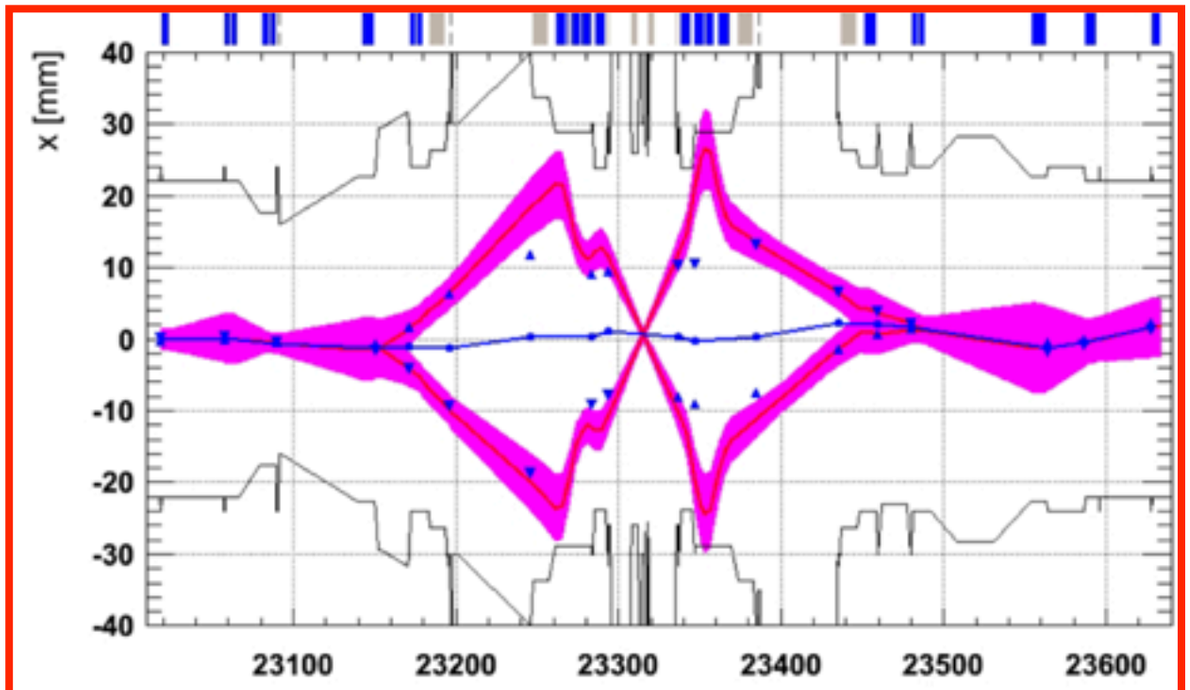
IR aperture measurements for final beta* validation

Final decision on machine configurations, before ramp-up (changes are very time costly after this point).

Only during intensity ramp-up (no details in this talk):
- ecloud → several dedicated discussions
- beam-beam - iteration on crossing angles
- two-beam effects and octupoles
- monitoring of machine stability and UFO’s

Triplet aperture measurements

- **Early local triplet measurements** at **injection** can provide the first feedback on the **aperture reproducibility after LS1**: crucial for first iteration on β^* choice for 2015!
  - *Was only done in 2009, but recent analysis indicated that it can give a good feeling of beta* after squeeze!6*
- **Rigorous aperture checks** will then follow at **top energy** with squeezed beam, for final parameter validation (and potentially at smaller β^*).
  - *Techniques for safe measures at top energy well established.*
  - *Might take longer than in the due to new MP constraints!*



Example from 2009 - later confirmed by aperture at top energy

Collimation and impedance

- **Monitor regularly the performance: cleaning, machine stability, loss spikes.**
  - *More frequent loss maps at startup?*
- **Assess by beam measurements the simulations of collimation impedance**
  - *Tune-shift measurements versus collimator settings*
- **Compare different collimator settings**
  - *“mm-kept”, “2 real sigma retraction”, “nominal settings”*
  - *Pre-collision settings during the squeeze*
- **Assess single bunch stability limit** (input from E. Métral)
  - *Cleaner measurements for different Q’ and octupole settings;*
  - *Q’ reproducibility (measure in different ramps);*
  - *Rise-time of instability for different settings;*
  - *Review the interest in BCMS beams then?*

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On-going effort to establish a **measurement plan**: **what can we learn initially with single bunches?**

Conclusions

- **We had the machine under good control in Run I**
  - *The fast and safe commissioning in 2012 and 2011 was recalled.*
  - *This provides a mature basis for the re-commissioning of Run II !*
- **The strategy for the startup in 2015 was reviewed**
  - *Focus on the initial commissioning, aimed at re-establishing in safe conditions collisions in all experiment at 6.5 TeV, before intensity ramp.*
- **Several challenges for 2015 and new needs were reviewed**
  - *New operational challenges and demanding requests from the experiments;*
  - *Several changes of key accelerator systems;*
  - *The impact of machine protection aspects should not be underestimated.*
- **Additional "decision points" have been identified to assess the machine configuration choices for 2015**
  - *Experience in 2012 showed that several key measurements must be done earlier in order to prepare well the commissioning*
- **Can we achieve all what is needed in two months?**
  - *Probably feasible if all goes well, but it seems quite challenging;*
  - *We are working on a consistent commissioning plan...*