5th LHC Operations Workshop, Evian2014

June 2nd-4th, 2014

Hôtel Hermitage, Evian Les Bains, France

Strategy for the First Two Months and Key Early Measurements

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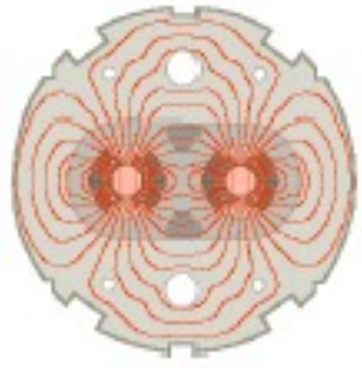
with G. Arduini, M. Giovannozzi, M. Lamont, R. Tomas, J. Wenninger

Ackn.: Elias, Nicolas, Stéphane, Tatiana, Roderik, Verena, many others



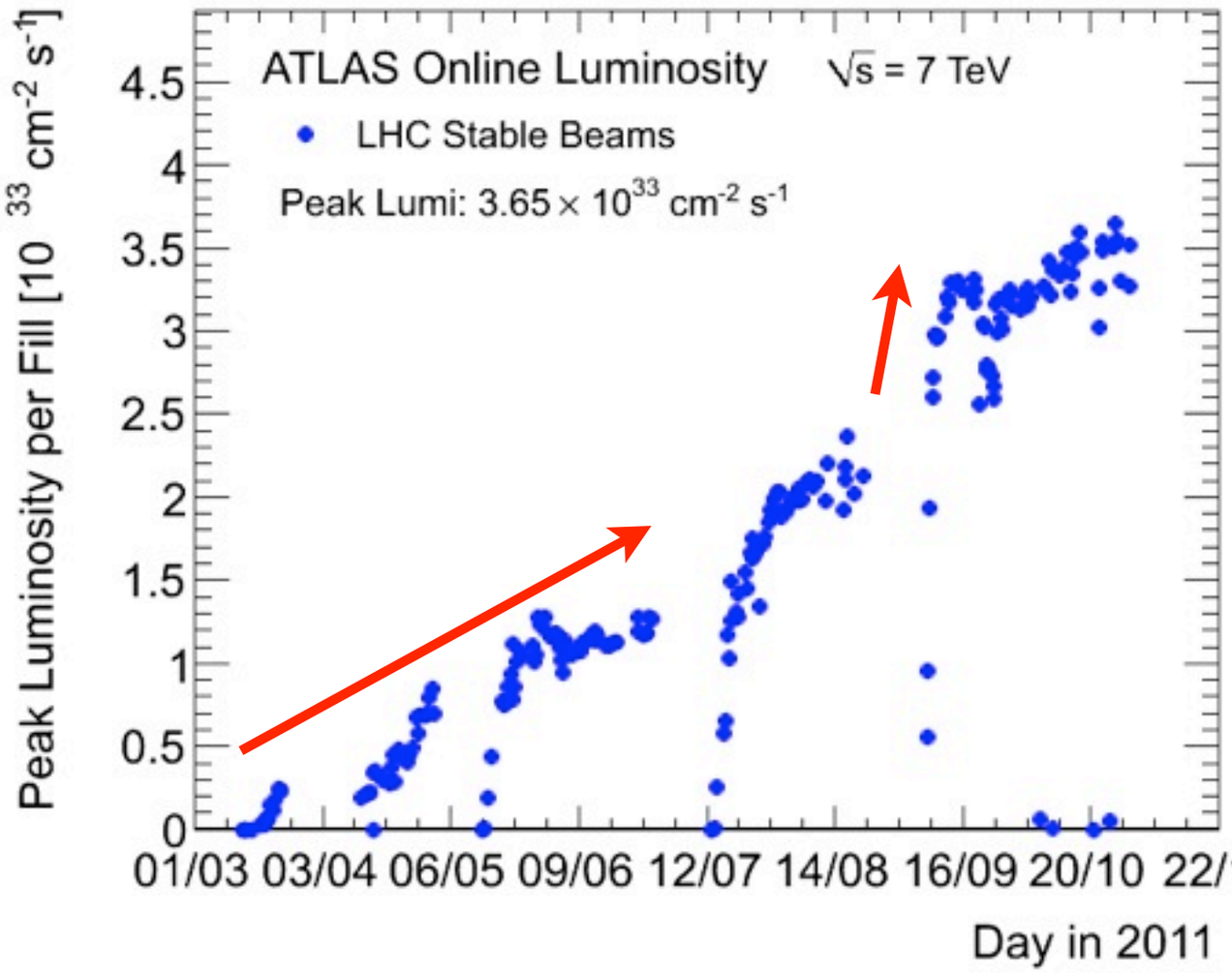
Outline

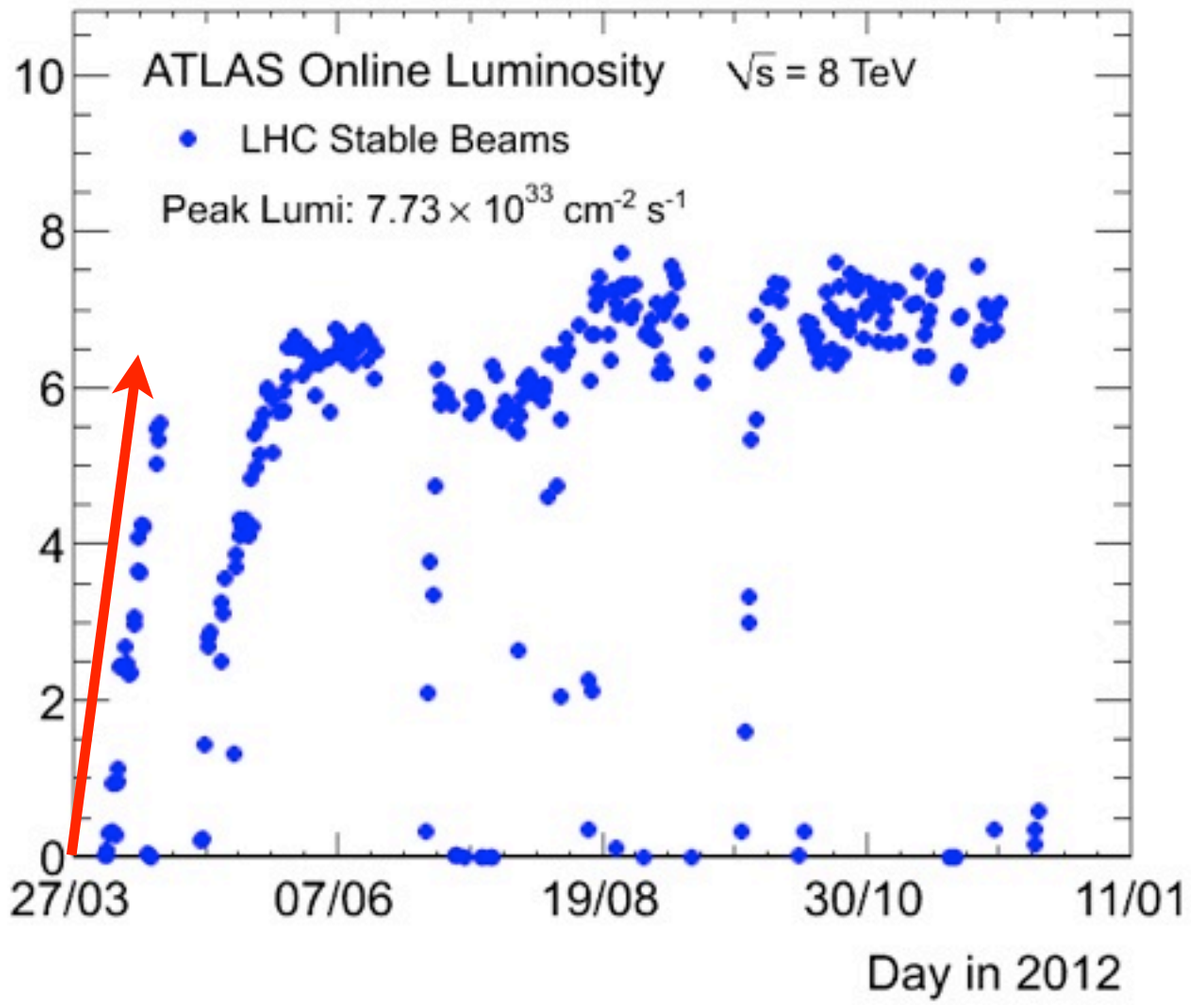
- ☑ Introduction
- ☑ Lessons from 2012
- ☑ Commissioning steps
- ☑ Decision points
- ☑ Conclusions

Introduction

- This talk will address:
  Commissioning strategy and key measurements for the first two months of operation in 2015.
  Definition: first turn to first stable beams with 2-3 bunches.
  Period presently allocated in the 2015 LHC schedule (M. Lamont et al,).
- **The 2015 beam commissioning plan will be based on our mature experience from the LHC Run 1**
  We hope that we can proceed as in 2012 . . .
  Realistically, the 2011 case will be more representative
- **The basic assumptions for machine configurations are taken as an input**
  Will not repeat the discussions of the 1st day of this Evian.
  Try to give some inputs on how to decide it...

Recap.: 2011 versus 2012





Intensity ramp up:

- Increase number of bunches,

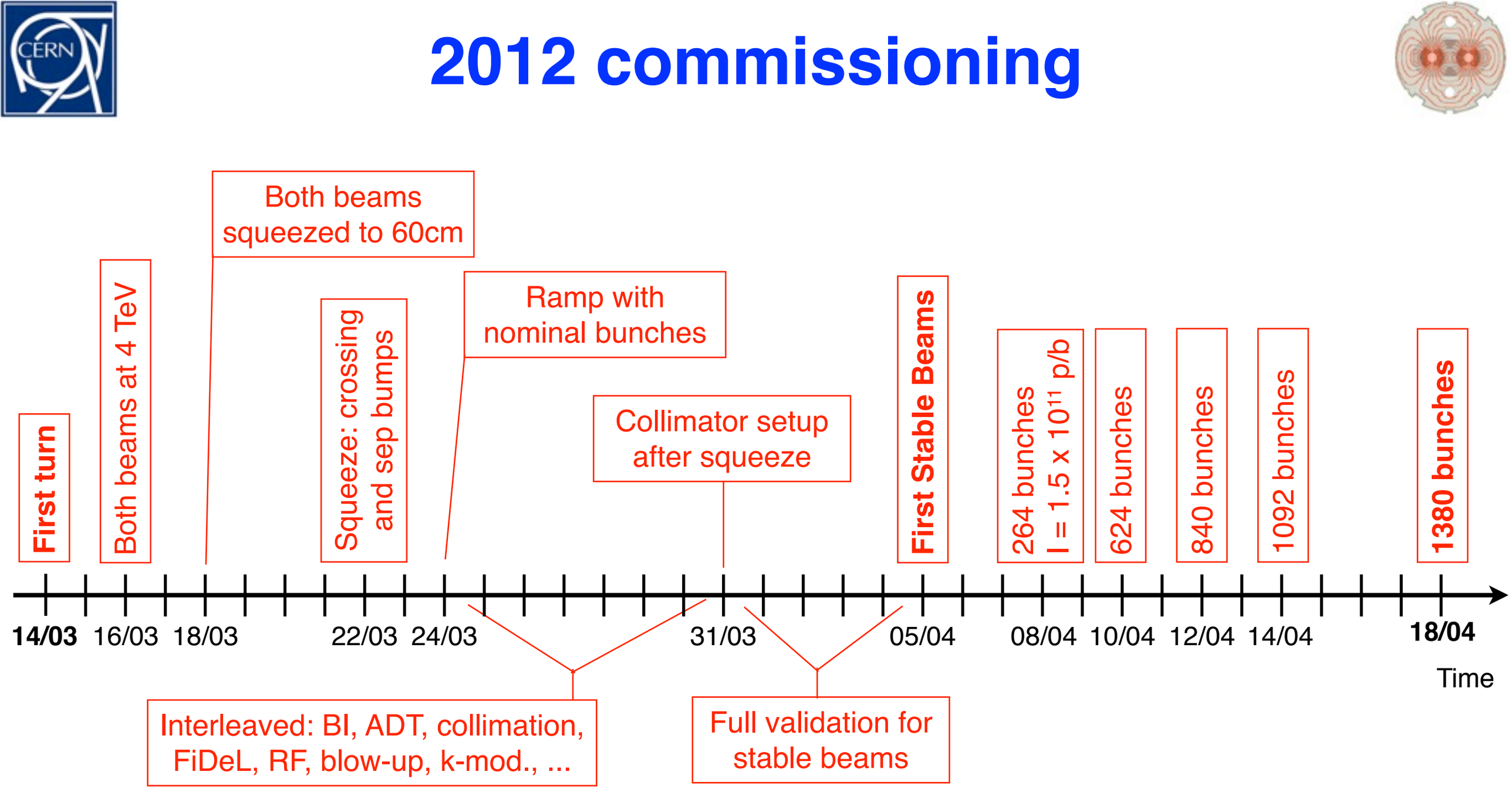
- then push bunch intensity

Followed by a re-commissioning of the optics.

Achieved "ultimate" parameters in record time, then fine tuning.

More details in Laurette's talk

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

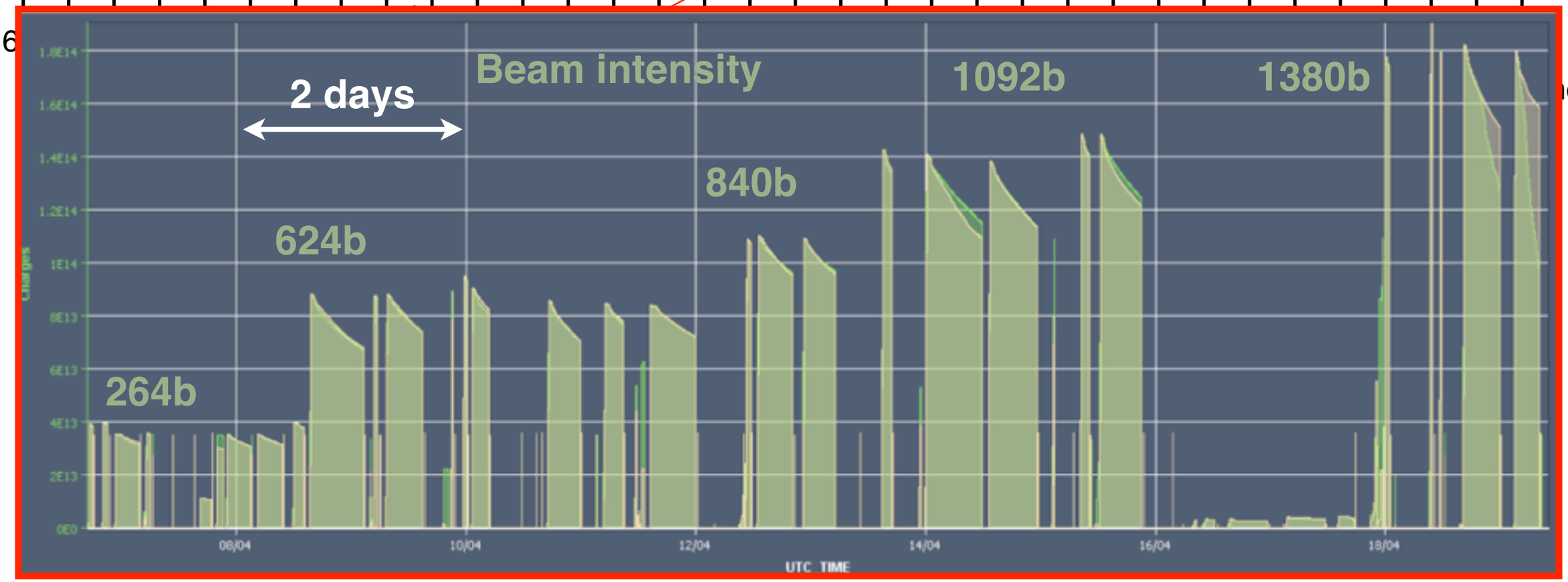
624 bunches

840 bunches

1092 bunches

1380 bunches

14/03 16



Keys for 2012 success

(in addition to Mike's 8 points)

We achieved safely a record setup time!

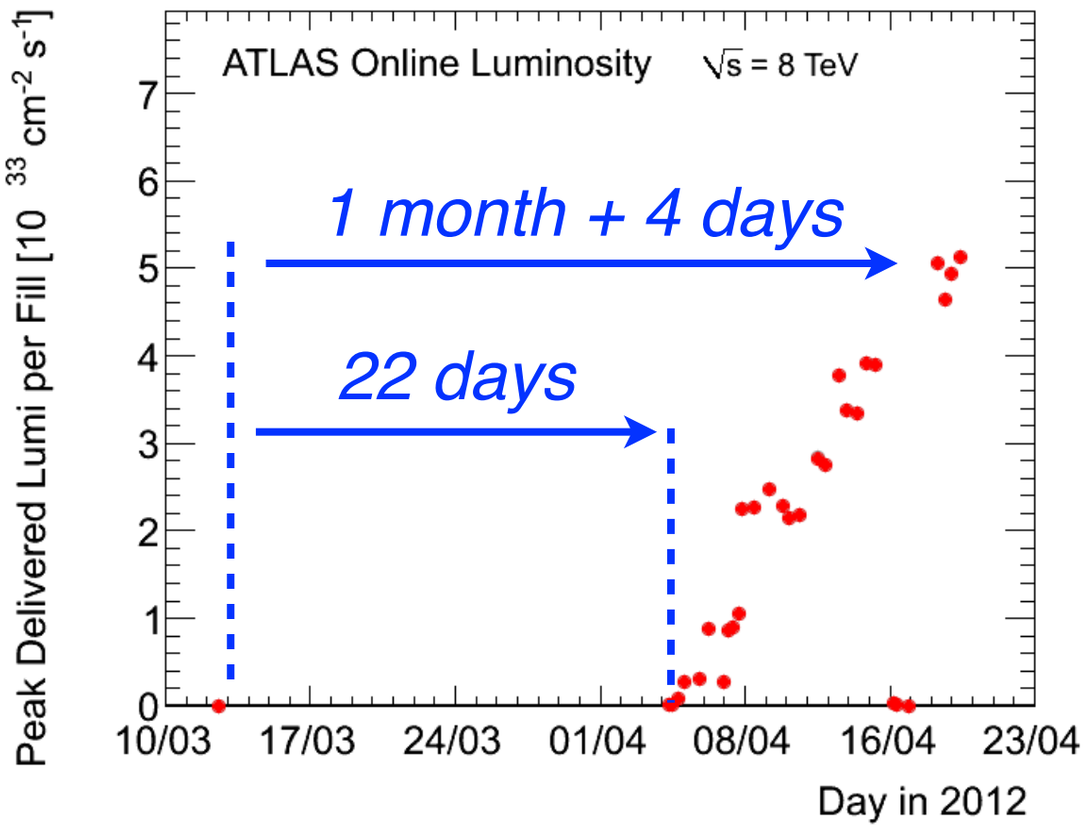
Among the many ingredients:

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?)

Ex.: 0.5 sigma margins compared to the 2011 estimates; beta-beating below 10%.

→ What is a reasonable risk for the startup after LS1?



Additional important aspects for the success:

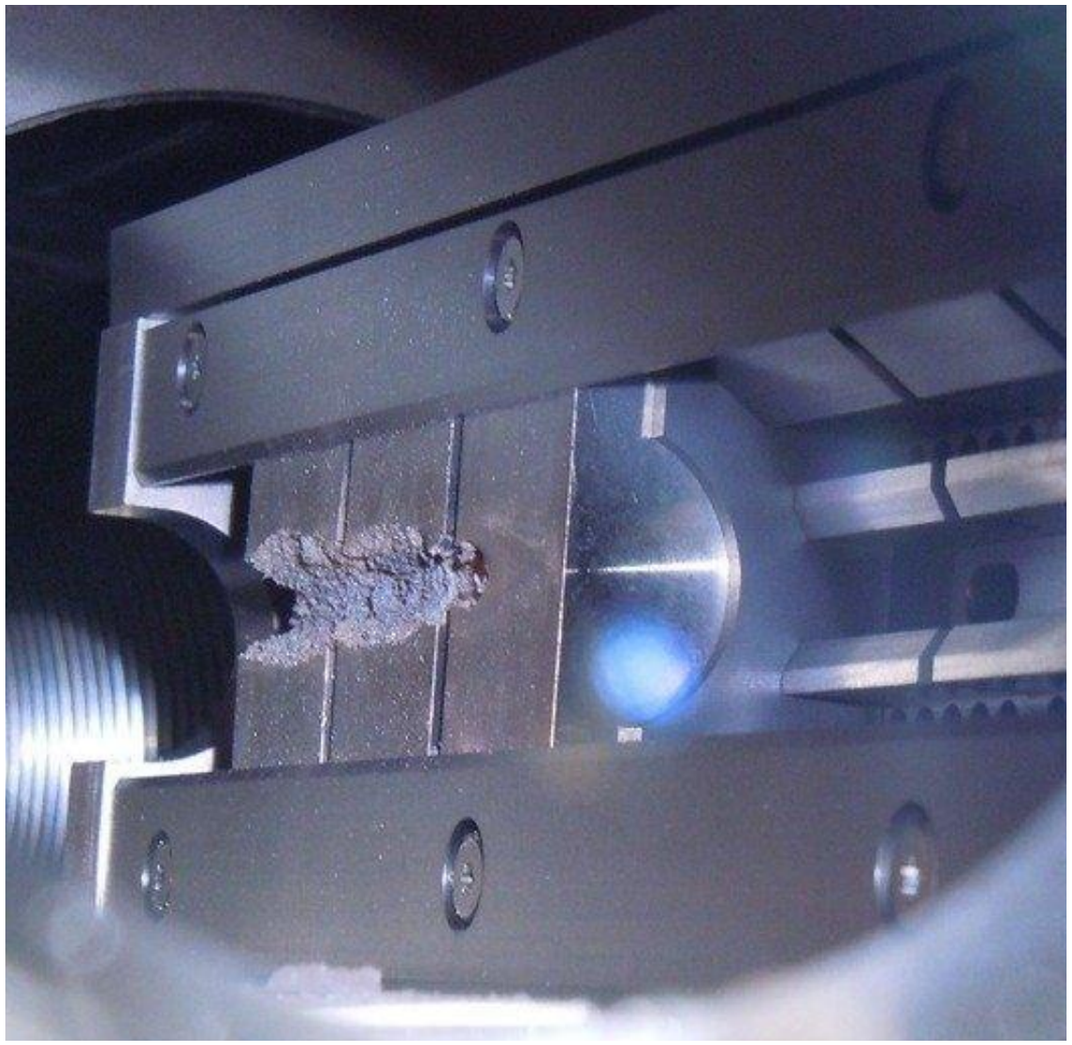
- *Commissioning effort was focused on high-intensity proton operation!*
- *Minimum (no?) hardware changes to cope with, from 2011.*
- *No changes in optics configurations compared to 2011.*
- *Relying that few nominal bunches at top energy were SAFE.*

This is not the case for the 2015 baseline!

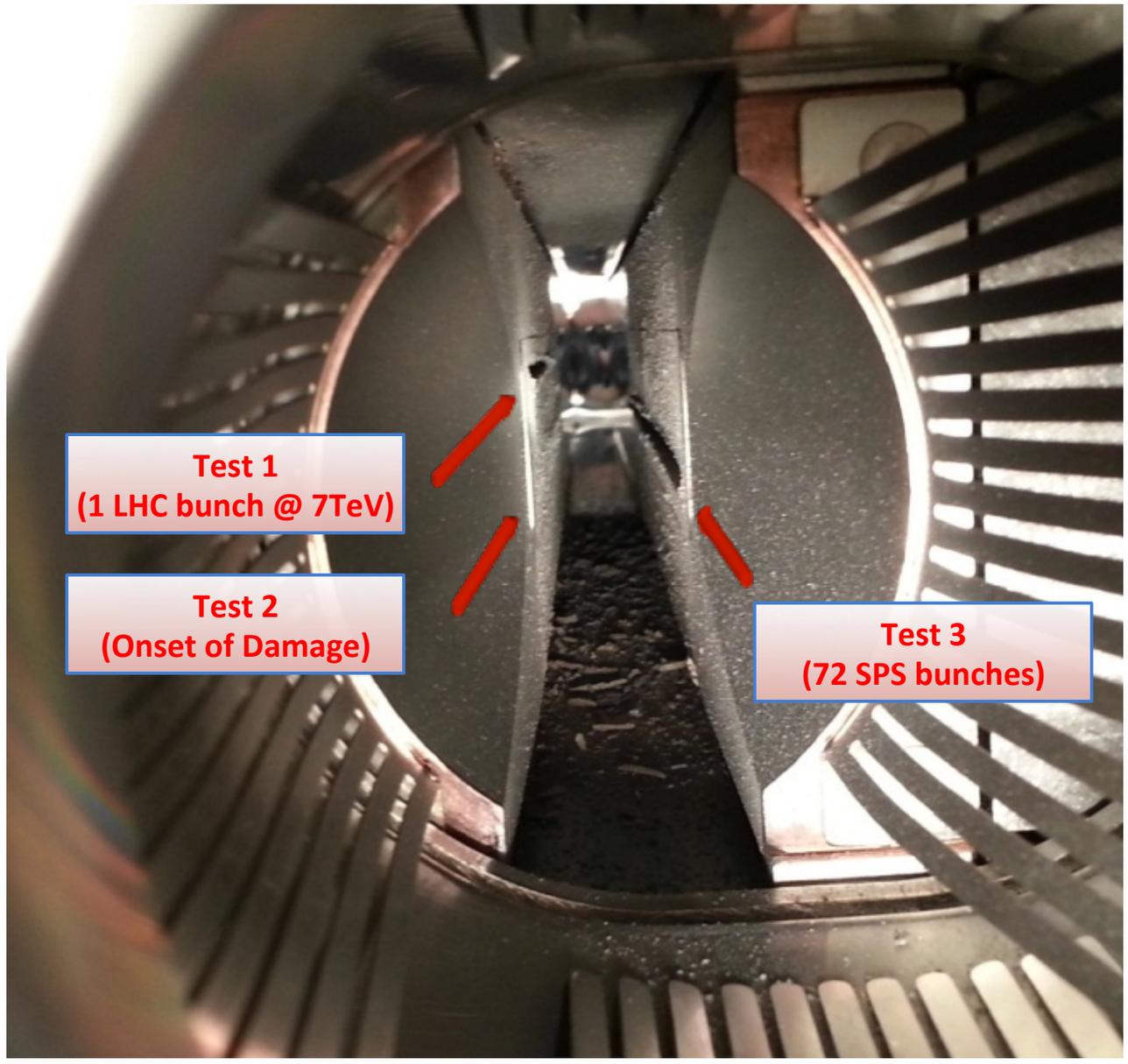
MP implications on commissioning

- 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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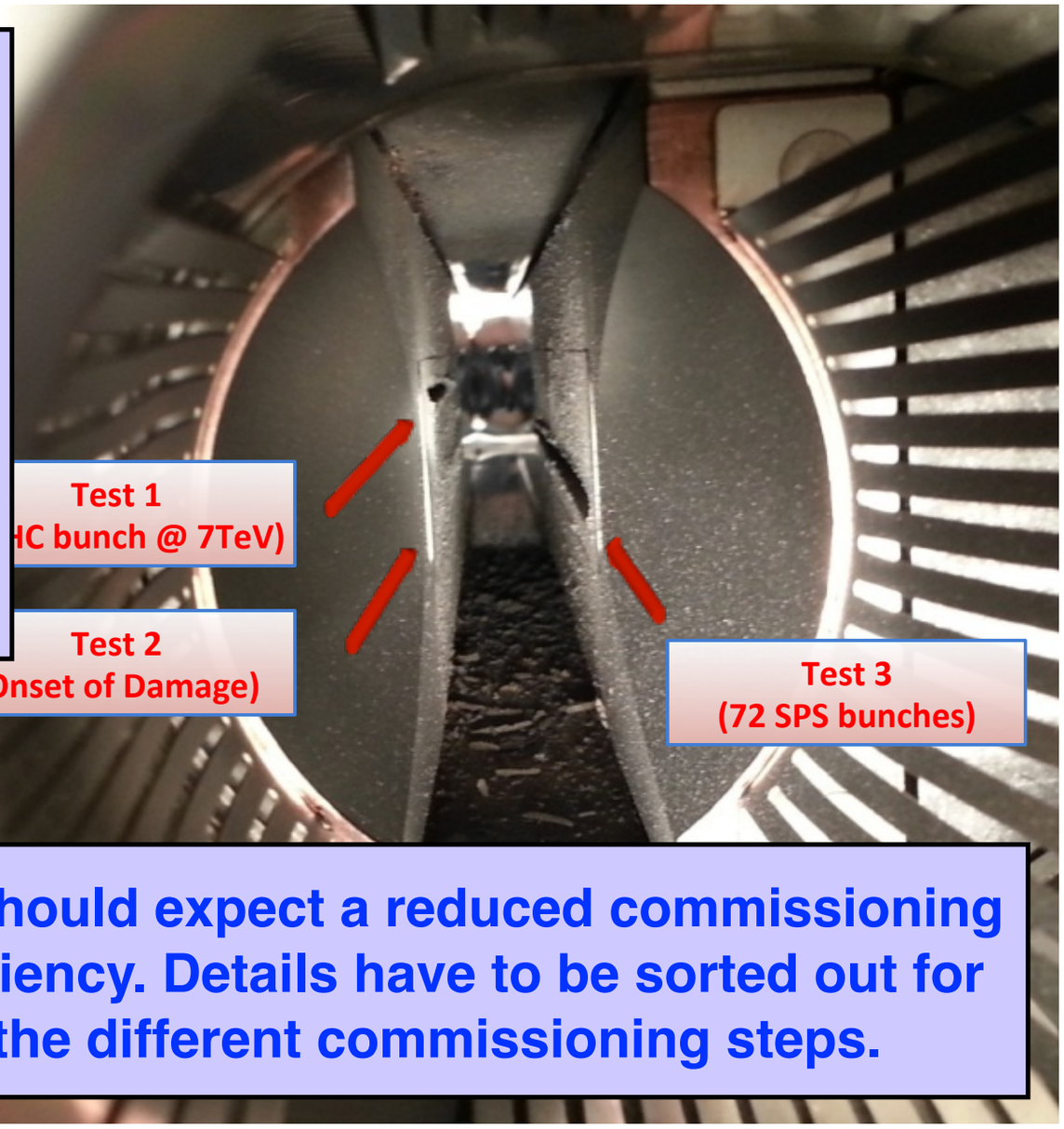
7 TeV equiv. inferred from HRM beams

Several new constraints to cope with:
- 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
- . . .

Need to followup the transverse collimator movements in IR1/5!

Inermet 180, 72 bunches



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

A. Bertarelli *et al.*

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- ☑ **Commissioning steps**
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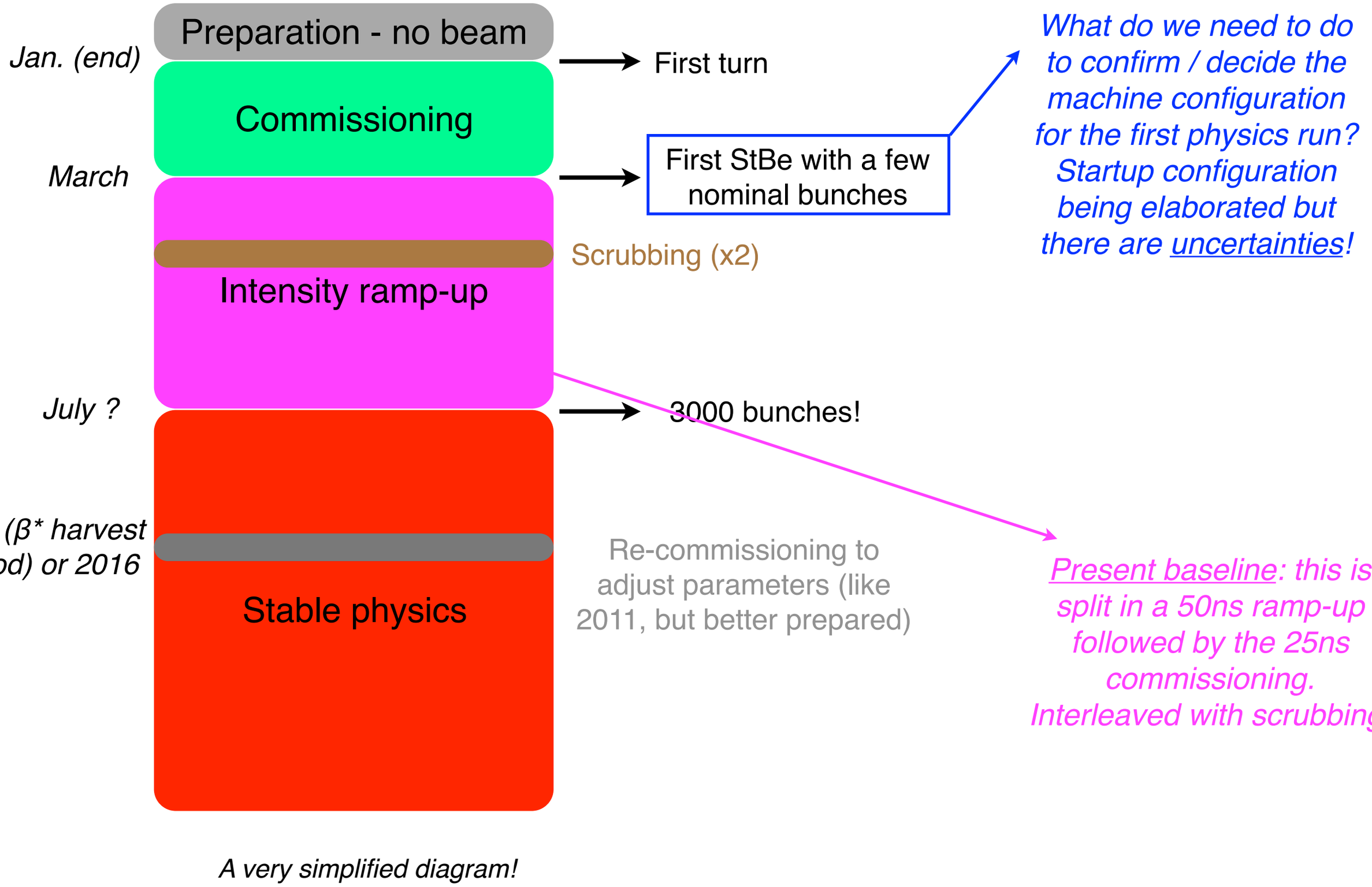
Assumptions

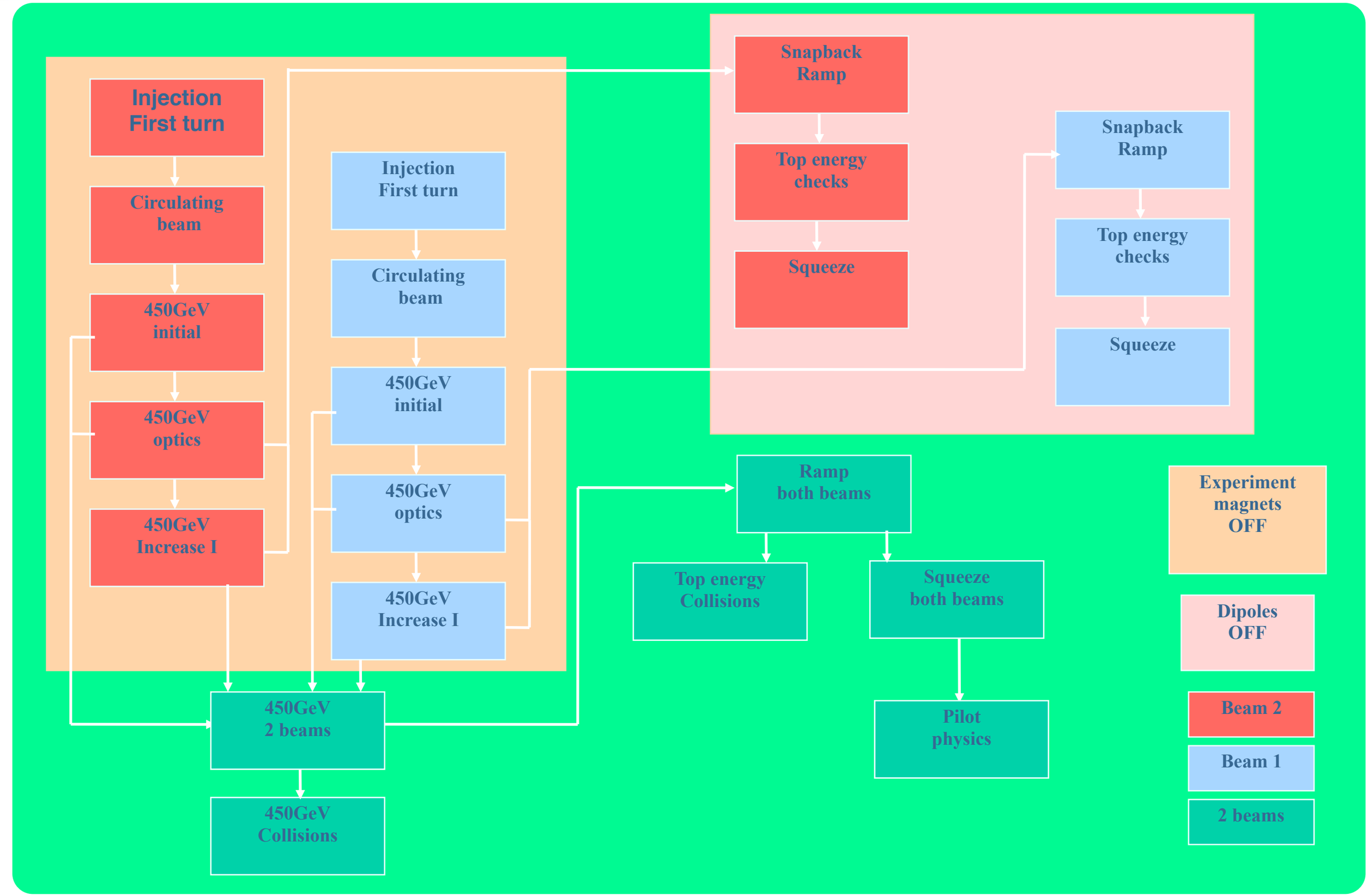
- **2015 machine configuration** (inputs from sessions 1-2)**:**
  - *Beam energy ≤ 6.5 TeV;*
  - *Same excellent aperture in interaction regions;*
  - *Same optics correction accuracy below 10%;*
  - *Collimator hierarchy as in 2012 (mm settings);*
  - *11 real sigmas for crossing angle (3.75 micron emittance);*
  - *Assume that there is no need of additional margins if optics changed;*
  - *Machine reproducibility as in Run 1.*
- **This gives about 65 cm β***
  - *If we go from day 1 at the aperture limit!*
  - *70 cm would provide some margins...*
- **What is the decision on collide&squeeze / levelling?**
  - *1 slide late on implications, not put in my commissioning plan.*
- **I do not treat the fall back option of 50 ns.**
- **Hardware change: collected inputs from sessions 1-5**

Overall commissioning strategy



A very simplified diagram!

Commissioning phases as foreseen

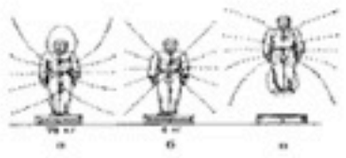


Commissioning phases as foreseen

Work in progress

Stage A

Pilot physics run



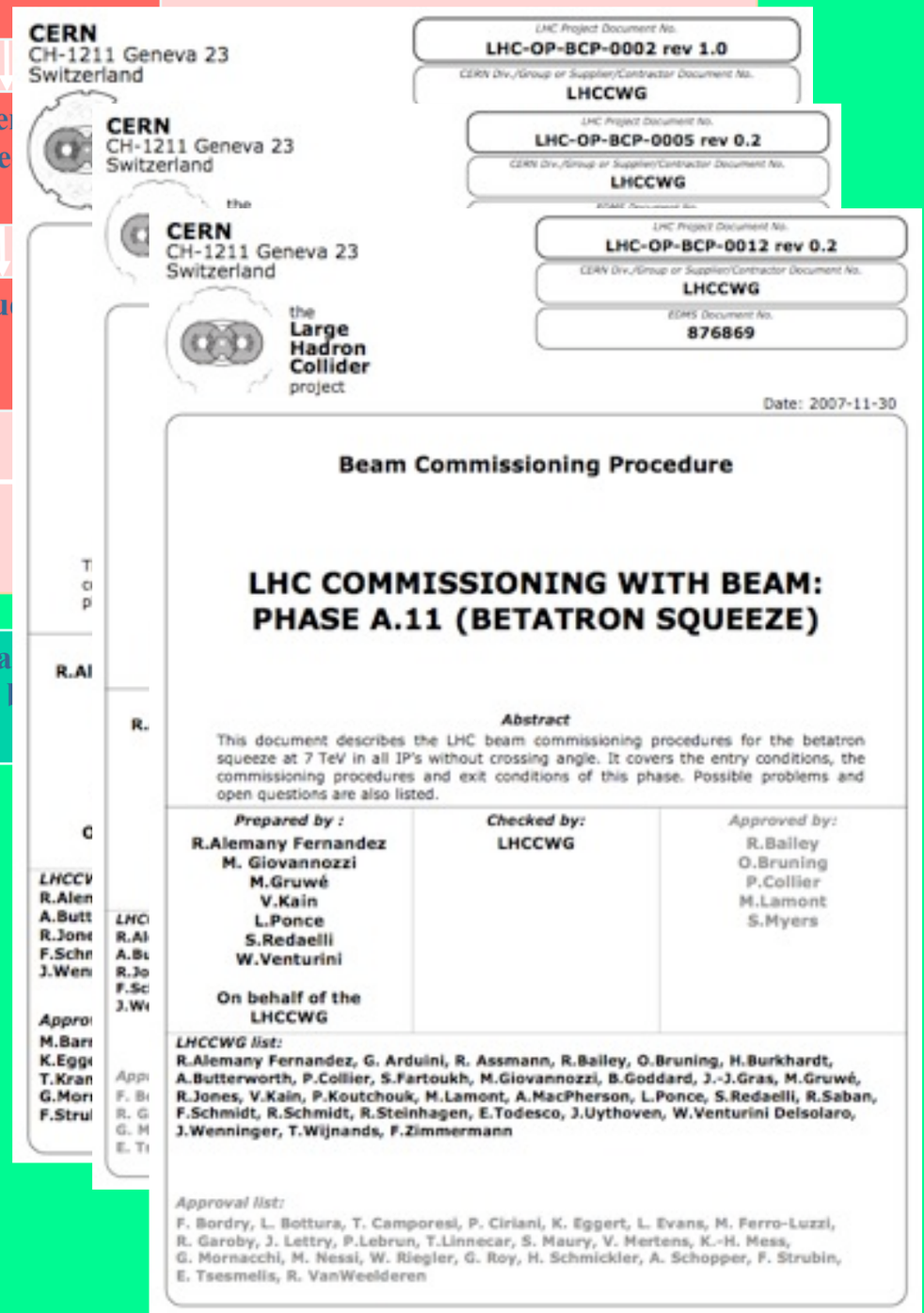
LHC Beam Commissioning

Home

Phase A.1	**First turn:** injection commissioning; threading, commissioning beam instrumentation. Ring 1, ring 2.
Phase A.2	**Circulating pilot:** establish circulating beam, closed orbit, tunes, RF capture, ...
Phase A.3	**450 GeV initial commissioning:** system commissioning: instrumentation, beam dump,...
Phase A.4	**450 GeV optics:** beta beating, dispersion, coupling, non-linear field quality, aperture,...
Phase A.5	**450 GeV, increasing intensity:** prepare the LHC for unsafe beam
Phase A.6	**450 GeV, two beam operation**
Phase A.7	**450 GeV, collisions**
Phase A.8	**Snap-back and ramp:** single beam/two beams
Phase A.9	**Top energy checks**
Phase A.9.5	**Beam commissioning with experimental magnets**
Phase A.10	**Top energy, collisions**
Phase A.11	**Squeeze:** Commission the betatron squeeze in all IP's

apback
Ramp

450GeV
Collisions



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LHC Project Document No.
LHC-OP-BCP-0002 rev 1.0
CERN Div./Group or Supplier/Contractor Document No.
LHCCWG

LHC Project Document No.
LHC-OP-BCP-0005 rev 0.2
CERN Div./Group or Supplier/Contractor Document No.
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LHC Project Document No.
LHC-OP-BCP-0012 rev 0.2
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EDMS Document No.
876869

the Large Hadron Collider project

Date: 2007-11-30

Beam Commissioning Procedure

LHC COMMISSIONING WITH BEAM: PHASE A.11 (BETATRON SQUEEZE)

Abstract

This document describes the LHC beam commissioning procedures for the betatron squeeze at 7 TeV in all IP's without crossing angle. It covers the entry conditions, the commissioning procedures and exit conditions of this phase. Possible problems and open questions are also listed.

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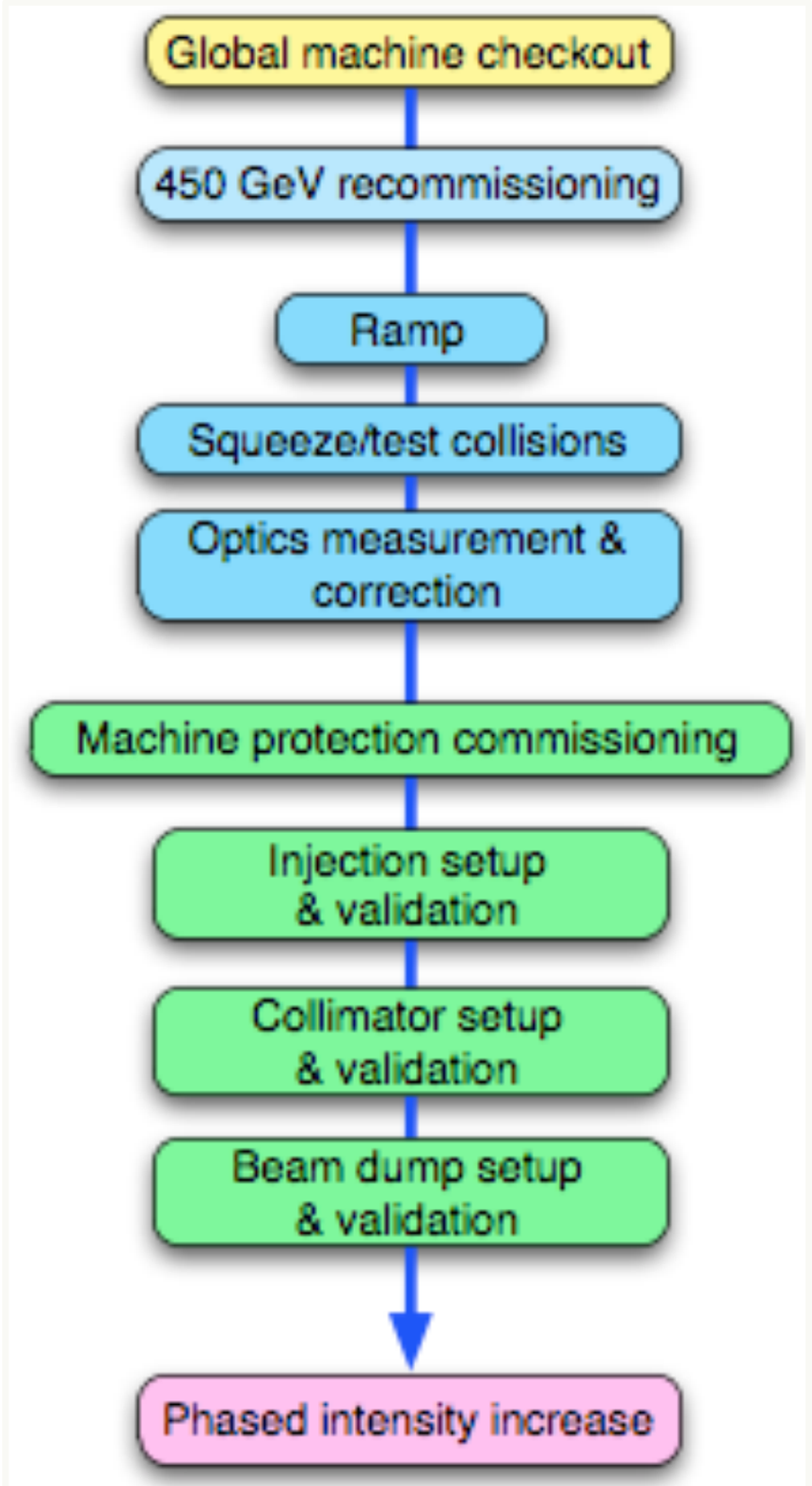
Building on Run 1 experience...



In reality, blocks are interleaved with each other!

Key activities:

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.
Flat orbit setup followed by IR bump commissioning.
Beam measurements: aperture for given
Ramp. FiDeL, decay, saturation. Feedbacks.
Squeeze. Steps followed by continuous functions.
Re-iterate on orbit, optics, aperture, ...
Collisions.
Machine protection and validation.

No details on the “standard” phases in this presentation.
Emphasis on:
- New requirements following LS1 changes
- New key measurements to determine LHC configuration.

New commissioning requirements (i)

Experiments

- *Special runs needed early on.*
- *Dedicated optics setup for VdM scans.*

Operations

- *New measurements/corrections for FiDeL (saturation);*
- *Cleaner corrections in IRs (optics, orbit);*
- *“Exponentially increasing” number of optics to measure precisely*
- *. . .*

Collimation

- *New hardware with BPMs: dedicated tests;*
- *Verification of new IR layouts with TCL collimators;*
- *Improve / optimize validation procedures.*

New commissioning requirements (ii)

☑ Beam instrumentation

- *Beam size measurements;*
- *BLM system: new LIC's in IR2/8;*
- *New threshold setup?*
- *New BI for interlock purposes;*
- *New DOROS BPM's, in addition to the ones in collimators.*

☑ RF / ADT

- *Many new features / hardware changes;*
- *Measurements as in Philippe's talk.*

☑ Injection and LBDS

- *Validation of new BETS interlocks;*
- *New TDI and TCDQ block hardware; check TDI heating;*
- *Wave form scans and kick response;*
- *Repeat measurements previously not done yearly (see Wolfgang).*

Can we fit all that in 2 months?

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- ☑ **Decision points**
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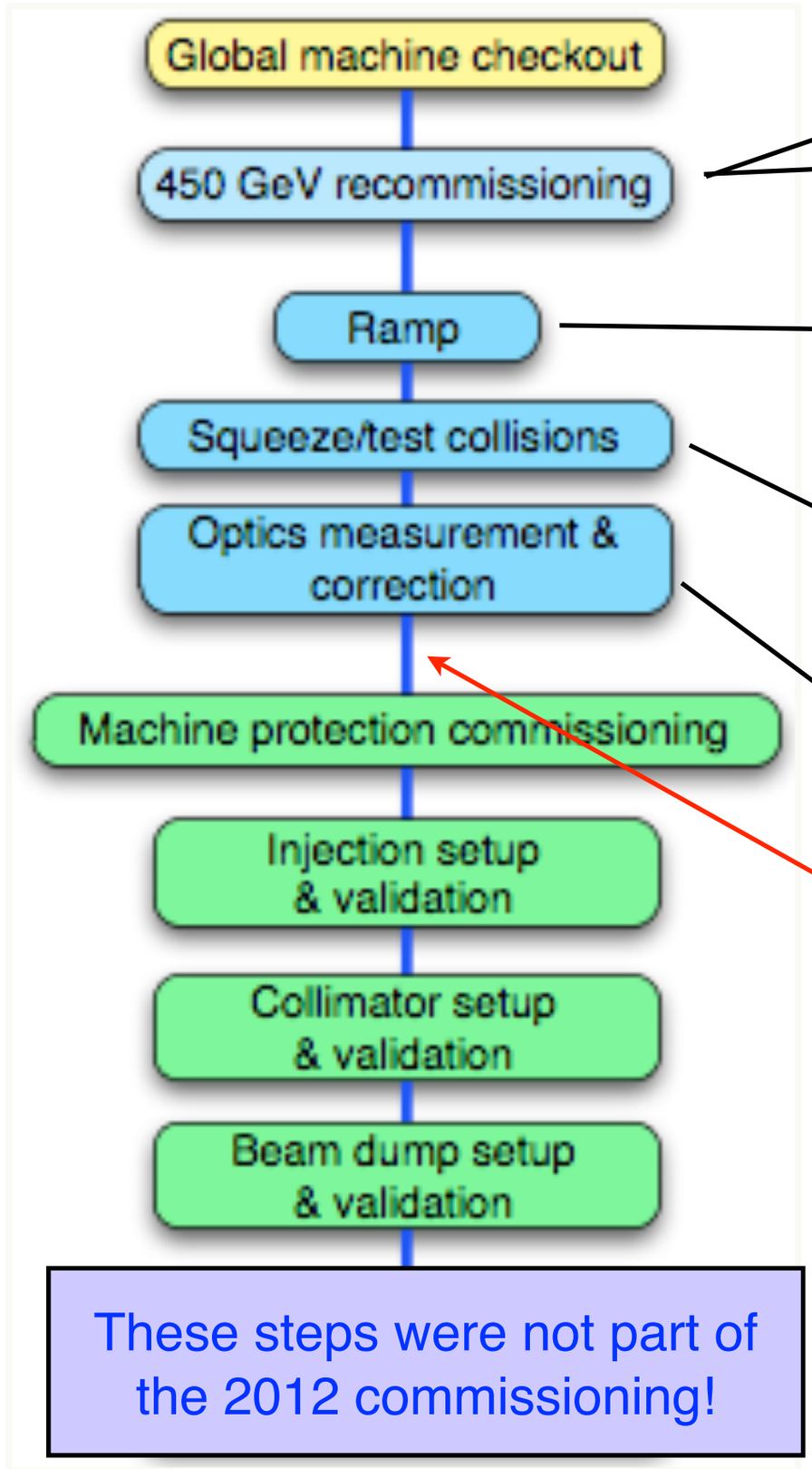
Key “decision points”



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

De-tuning versus amplitude and detailed MCO/MDO setting

With nominal bunches at top energy:
Clean measurements of chromaticity and effect of octupoles
Single-beam stability limits
Collimator impedance → iteration on baseline settings?

Optics measurements and corrections down to **40 cm**
Dedicated “local” IR measurement / corrections
Specific ATS optics tests (like asynch dumps)?

IR aperture measurements for 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
- multi-bunch impedance
- beam-beam - iteration on crossing angles
- two-beam effects and octupoles
- monitoring of machine stability and UFO’s

Aperture

- **Propose to foresee early on a measurement with bumps at injection: first iteration on beta***
  - *Was only done in 2009, but recent analysis indicated that it can give a good feeling of beta* after squeeze!*
  - *Should be done after establishing 450 GeV orbit and optics*
  - *0.5-1.0 shift to cover IR1/5*
- **Then, require aperture checks and detailed measurements at top energy, squeezed for final parameter validation.**
  - *Different iterations following optics corrections;*
  - *Detailed plan of validation of provided protection levels (as 2012);*
  - *Note that we will need to be more careful at higher energy!*

Non-linear correctors

- **We will need known and clean starting conditions to optimize the effects of Landau octupoles**
- **Models of de-tuning with amplitude not fully understood: discrepancy at 450 GeV**
  - *Need to understand better effect of MCO's (and MDO's)*
- **In addition, the optics team proposes:**
  - **improved check of MCS correctors.**
  - **settings up of MSS as measured in MDs.**
- *Rogelio can provide the full details.*

Collimation measurements

- **Need to comparatively assess different setting options against impedance, with <u>nominal bunches</u>**
  - *Tune-shift measurements versus settings?*
  - *Recap.: "2 sigma retraction" give a significant gain compared to 2012 settings in mm <u>if</u> ok for impedance.*
- **Propose to explore "pre-collision" settings with individual secondaries more open.**
  - *Tricky in several aspects (cleaning vs MP): do not want to rely on new schemes if not validated by measurements.*
  - *Becomes critical in case of problem with the relaxed settings.*
  - *See RB's presentation at an LBOC in Feb. 2014.*
- **At least initially, monitor regularly performance: cleaning, machine stability, loss spikes.**
  - *Anticipate MDs on halo studies/control in case of problems.*

Impedance, 2 beams and octupoles

- **In my opinion, the goal during commissioning should be to conclude as soon as possible about the need for collide and squeeze in IR1/5.**
  - *<u>But</u> firm conclusions can only come during the intensity ramp.*
- **Clean measurements of Q', including reproducibility, must be part of the initial commissioning**
  - *Foresee dedicated fills for measurements, single vs 2 beams*
- **Instability threshold measurements.**
- **What other measurements can we do with single bunches?**
  - *Ongoing preparation by Elias' team*

Collide&Squeeze/Squeeze-in-collision

- **We need to decide as soon as possible if this is part of the first commissioning!**
  - *The choice has a major impact on the commissioning plan.*
- **Two options are under discussion**
  - *(1) Levelling in stable beams for LHCb;*
  - *(2) Collide&Squeeze in IR1/5 for beam stability purposes.*
- **Both scenarios have important impacts:**
  - *Special commissioning of optics corrections, in particular for (1). "exponential increase" of optics configurations.*
  - *Adequate validation strategies have to be defined. Optimizations possible, but the validation of (1) will not come for free!*
  - *Challenges: prepare commissioning with "minimum" impact in case fall back is required.*

Conclusions

- **We had the machine well under control in Run 1**

  Recalled commissioning achievements in 2012 and 2011

- **An ambitious restart plan is now on the table**

  Necessary system re-commissioning will require time.
  New optics conditions and operational scenarios not fully proved.
  Inputs from Evian2014 must now be put into a complete program.

- **Are two months enough to fit all that? Is there room to optimize the number of scenarios?**
- **Key "decision points" will confirm (decide?) the 2015 LHC configuration: presented a first list.**
- **MP impact on efficiency should not be underestimated.**
- **The overall performance would profit from a well prepared re-commissioning after some stable physics**

  More relaxed startup conditions to easy and fasten the commissioning
  Then re-tune more precisely parameters after we have re-learnt.
  Can happen in Sep. 2015 or be postponed until the Christmas stop.