LHC Performance Workshop - Chamonix 2009

Centre de Congrès "Le Majestic", Chamonix, France

2nd-6th February 2008

Are we ready for the 2009 beam operation?

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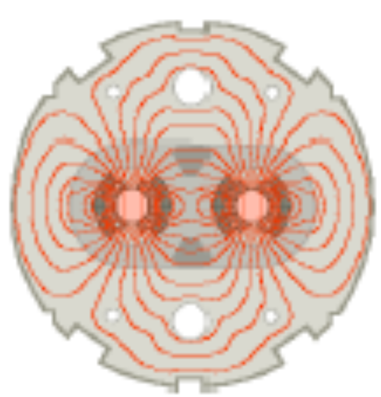
A. Macpherson, L. Ponce, W. Venturini for the Commissioning WG

Acknowledgments: G. Arduini, R. Assmann, E. Bravin, M. Ferro-Luzzi, M. Giovannozzi, J. Jowett, W. Herr, M. Lamont, J. Wenninger

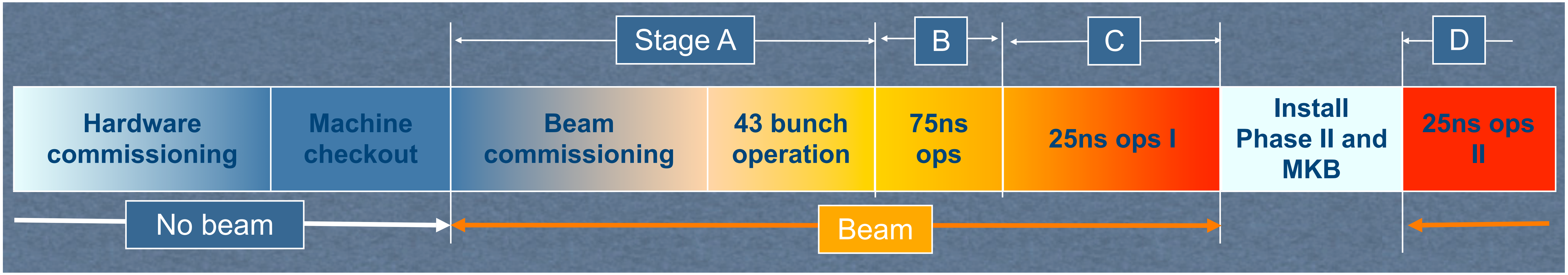


Outline

- **Introduction**
  - *Status of procedures for 7 TeV operation*
  - *New requirements and strategy*
- **Commissioning experience in 2008**
  - *How procedures were used*
  - *Feedback from beam experience*
- **Readiness for 2009+ operation**
  - *Energy ramp and betatron squeeze*
  - *Machine protection aspects*
  - *Luminosity and crossing angles*
  - *Detector background issues*
  - *Procedures for ion operation*
- **Conclusions**

Introduction - starting point as of 2008

Procedures have been prepared for the **7 TeV operation**. Overall strategy:



Stage A (43x43 ➠ 156x156) 1.1×10^{30} ➠ 1×10^{32} $cm^{-2}s^{-1}$

- *Beam commissioning ➠ first physics run*
- *No need for crossing angle (limit: 156b)*
- *Moderate intensities, partial squeeze*

Stage B (75ns operation) 1×10^{33} $cm^{-2}s^{-1}$

- *Establish multi-bunch operation*
- *Still relaxed machine parameters (squeeze, crossing)*

Stage C (25ns operation I) 2×10^{33} $cm^{-2}s^{-1}$

- *Nominal crossing angle, nominal β**
- *Can reach 50% of nominal intensity*

Stage D (25ns operation II) 1×10^{34} $cm^{-2}s^{-1}$

- *Push towards nominal and ultimate*
- *Required HW upgrade*

2008**: magnet tests showed issues with quench training. New baseline:* ***5 TeV, β*=3m *(Minor implications on procedures)*

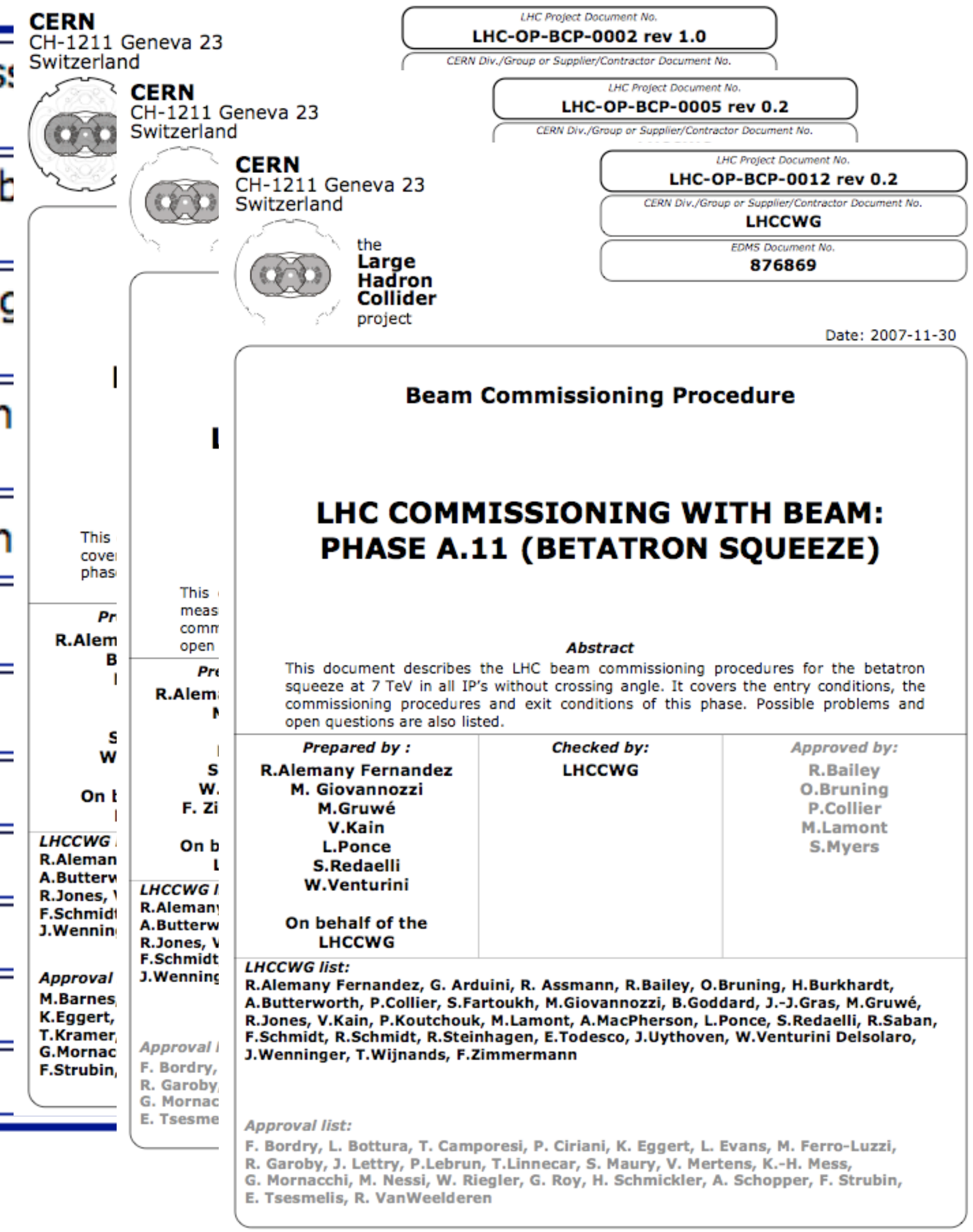
First proposed by R. Bailey: LHC-OP-BCP-0001 (2004)

Stage A - early physics at 7 TeV

- Procedures elaborated within the LHC Commissioning Working Group (LHCCWG)
  Put together operation team, commissioning team and "owners" of accelerator systems
- LHC Engineers in Charge and Commissioners worked out the details of each steps
  Initially discussed in detail at the LHCCWG, then presented and approved by the LTC
- Web-based documentation is the up-to-date source, strict approval of EDMS documents

Phase A.1	**First turn:** injection commissioning; threading, commis instrumentation. Ring 1, ring 2.
Phase A.2	**Circulating pilot:** establish circulating beam, closed orb ...
Phase A.3	**450 GeV initial commissioning:** system commissioning beam dump,...
Phase A.4	**450 GeV optics:** beta beating, dispersion, coupling, non aperture,...
Phase A.5	**450 GeV, increasing intensity:** prepare the LHC for un
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.10	**Top energy, collisions**
Phase A.11	**Squeeze:** Commission the betatron squeeze in all IP's
Phase A.12	**Beam commissioning with experimental magnets**

http://lhccwg.web.cern.ch/lhccwg/


CERN
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the Large Hadron Collider project

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

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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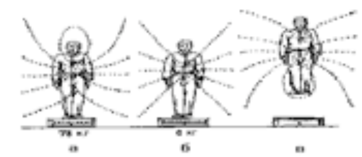
Details: steps of commissioning phases

Work in progress

Stage A

Pilot physics run



LHC Beam Commissioning

Phase A.4

450 GeV optics

Proced

Step	Activity
A.4.1	**Measurement and correction of th**
A.4.1.1	Measurement and correction of arcs an
A.4.1.2	Measurement and correction of each IF
A.4.1.3	Iterate after more detailed optics know
A.4.2	**Measurement and correction of th**
A.4.2.1	Commissioning of MQX linear corrector MQS circuits
A.4.2.2	Tune
A.4.2.3	Coupling (possibly needs another iterat
A.4.2.4	Beta-beat (needs another iteration wit
A.4.2.5	Dispersion (needs another iteration wit
A.4.2.6	Refined optics model -> Response matr
A.4.2.7	Generation of new reference settings f
A.4.2.8	Additional local beta measurements wi
A.4.3	**Measurement and correction of th**
A.4.3.1	Commission the software for sliding bu
A.4.3.2	Global aperture measurements
A.4.3.3	Local bumps to centre orbit into apertu
A.4.3.4	Iteration of A.4.3.1 and A.4.3.2 until w
A.4.3.5	Update/maintenance of the aperture d
A.4.3.6	Dedicated local aperture measurement
A.4.3.7	Commission other measurements (emi
A.4.4	**Detailed RF measurements**
A.4.4.1	Final commissioning of the radial loop v
A.4.4.2	Longitudinal profile [parasitic]
A.4.5	**Measurement of the momentum a**
A.4.5.1	Radial steering scans
A.4.6	**Beam commissioning of collimator**
A.4.6.1	Beam-based alignment of the required
A.4.6.2	Empirical measurements of local beta-f
A.4.6.3	Beam-based information into the datat
A.4.6.3	First estimate of setting reproducibility
A.4.7	**Measurements of the global non-li**

A.4.2 Measurement and correction of the linear optics [single bunch, I~1e10p; one beam at a time]

A.4.2.1 Commission MQX linear correctors (if not done in A4.1), polarity checks for MQT, MQS circuits

- Polarity checks and calibration of the required circuits, if needed

A.4.2.2 Detailed tune measurement

- Preliminary measurement before a coupling correction.
- Tune measurements with tune kicker + trajectory acquisition. See A.3.4 [item 5]. Might require tweaking of the chromaticity to get cleaner signals, see pages 8-9 of F. Zimmermann's talk [2].
- If already operational, rely on BBQ and/or PLL
- Correct if necessary
- Iterate again after coupling and beta corrections (A.4.2.3 and A.4.2.4), if needed

A.4.2.3 Coupling (possibly needs another iteration with 2 beams)

- The goal here is to commission the nominal injection optics (in case up to phase A.3 we were forced to used the commissiong tunes with large Qh/Qv tune split)
- If coupling feedback is commissioned and operational, repeat detailed measurement with nominal tunes
- If the coupling is not under control, go to the special working point with increased tune separation.
- Iterate until we can work with the nominal tunes

A.4.2.4 Beta-beat (needs another iteration with 2 beams)

- Phase-advance method proposed by R. Tomas [4, 5]
- Repeat A.4.2.2 if needed

A.4.2.5 Dispersion (needs another iteration with 2 beams)

- Same as for beta-beat [4, 5]

A.4.2.6 Refined optics model: Update response matrices and BPM calibrations for feedback, if necessary

- Compute again the response matrix needed for the correction algorithms (YASP, feedbacks, ...). See A.3.4
- Use a few new COD scans (enough data should be available from previous steps)
- For references, see J. Wenninger's talk [9]
- No beam time needed, use parasitically the data from other measurements

A.4.2.7 Generation of new settings for various correctors, if necessary

- With the best optics knowledge, revise the settings of orbit, tune, coupling and beta corrections, if needed

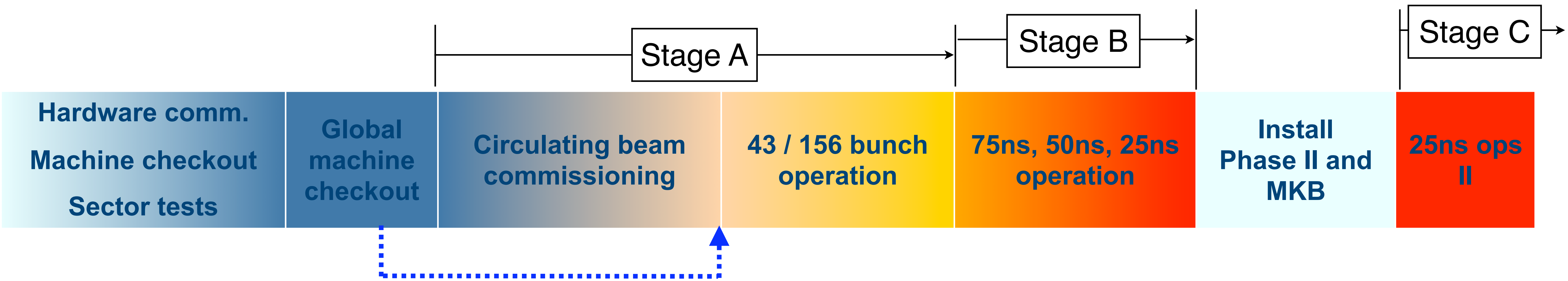
A.4.2.8 Additional local beta measurements with K-modulation (IR's, wires, collimators, ...)

- Detailed local beta measurements with K-modulation
- Proposed list of locations: Wire scanners, collimator/dump regions, triplets, ...
- Only possible for independently powered quadrupoles during 2008 run (see LTC minutes of August 28th, 2007). K-modulation not possible in the arcs.

New overall commissioning strategy

New strategy must foresee:

- *Physics runs at energy below 7 TeV, imposed by hardware*
- *Co-existence of HWC, checkout and sector tests before circulating beam commissioning*
- *Full machine checkout and machine protection commissioning AFTER first beam OP*



Three beam commissioning stages:

- **Stage A** → Simplest machine configuration (no crossing, moderate squeeze)
- **Stage B** → Up to intensity limit (fill pattern depends on experiment requests)
- **Stage C** → Towards nominal and ultimate performance

The following **critical** beam operation modes still need beam commissioning:

- *Energy ramp / Betatron squeeze*
- *Operation with un-safe beams*
- *Luminosity optimization and operation with crossing angles*
- *Ion operation during first beam run ("early" physics)*

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“Steps” covered in 2008

First turn (A.1)

Beam 1

- Commissioning of the last 100 m of the transfer line and the injection
- First commissioning of key beam instrumentation
- Commissioning of the trajectory acquisition and correction
- Threading the beam around the two rings (first turn)
- Closing the orbit

Circulating beam (A.2)

Beam 2

- Establishing closed orbit
- Commissioning of additional instrumentation: BPM intensity acquisition
- Preliminary orbit, tune, coupling and chromaticity adjustments
- Obtaining circulating beam (few thousand turns)
- SPS-LHC energy matching
- Commissioning of RF capture

Initial commissioning at 450 GeV (A.3)

- Commissioning of beam instrumentation
- Improving lifetime
- Rough optics checks
- Initial commissioning of beam dumping system

Detailed measurements at 450 GeV (A.4)

.... Beta-beat measurements; initial commissioning of beam dump, ...

Role of the sector tests

Commissioning phase A0 - Sector tests

A0.1 - Commissioning of injection region
- *Region downstream of TED with TDI closed*
- *Timing synchronization of MKI*
- *SPS-to-LHC timing aspects*

A0.2 - Single-pass threading in the LHC

A0.3 - First BPM calibration and optics response matrices
- *First polarity checks of BPM's and COD's*
- *Timing of BPM acquisitions*

A0.4 - First commissioning of additional BI
- *Screens, BLM's*
- *BCT if possible*

A0.5 - SPS/LHC energy synchronization (LHC master)
- *Dispersion measurements*

A0.6 - Aperture measurements
- *Injection region*
- *Arcs / IR's / dump line*

A0.7 - Polarity checks

A0.8 - Beam-induced quench tests

A0.9 - First commissioning of the dump line (Beam 2)

A0.10 - Basic beam checks for collimators (BLM calibr., VAC, temperature, ...)

September 10th would have been VERY different without the sector tests. Beam commissioning speeded up!

We propose to collect these procedures in a dedicated "A0" phase.

Feedback from operation

- **The procedure preparation has been a good exercise for the commissioning team**
  - *- Helped in follow-up hardware readiness.*
  - *- Allowed a clear definition of milestones for each step.*
- **BUT: the procedures were NOT used directly by the OP crew in CCC**
  - *- Systems not yet handed over to operation.*
  - *- Rather than the procedures themselves, the entry conditions and expected outcome(s) were found to be useful for shift crew and machine coordinators.*
- **Online flexibility is essential to proceed with the commissioning**
  - *- Required changes on the fly (Ex. not need of BPM-intensity)*
  - *- Adapt priorities depending on the system/expert availability (Ex. resp. matrix overnight)*
- **Clearly, we will have to be more strict for machine protection aspects (see later)**
- **Traceability of commissioning steps:**
  - *- No tools yet in place to trace the advancement of commissioning steps*
  - *- Follow-up done by hand in 2008 (web page maintained by Mike and Roger)*
  - ***PROPOSAL**: set-up an MTF structure, mapped to the commissioning Phases/Steps, to be maintained by the machine coordinators. Other options being considered.*

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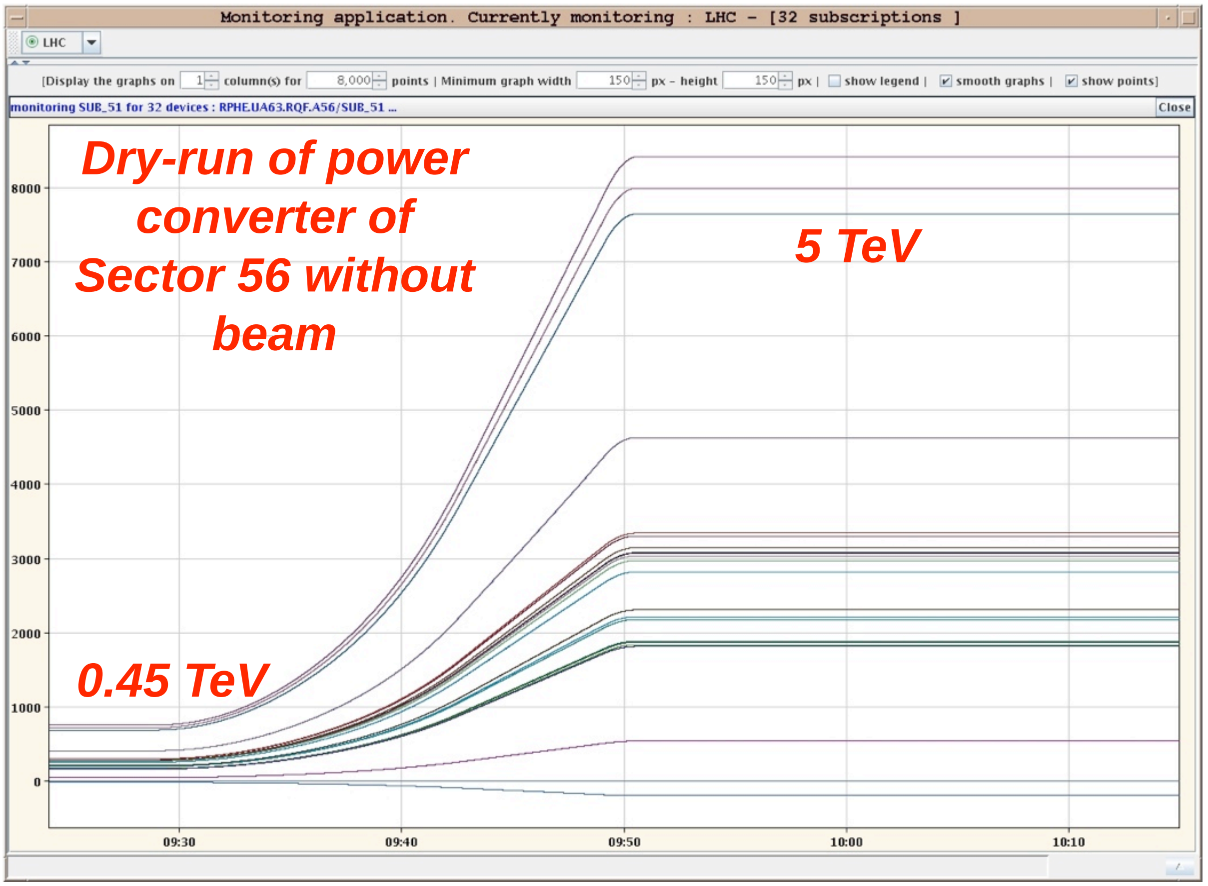
Energy ramp



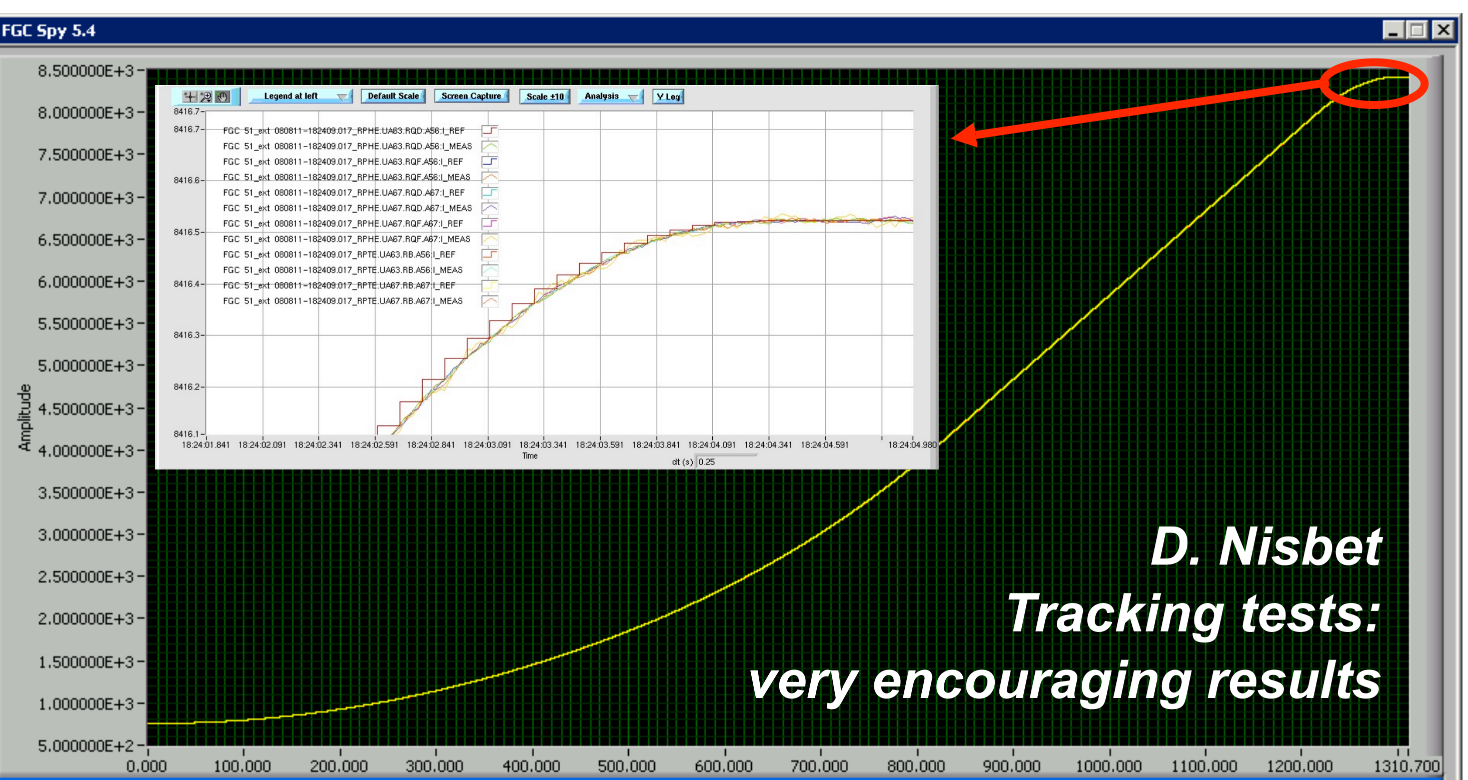
Synchronized ramp tests performed with all the systems concerned (PC's, RF, collimators)

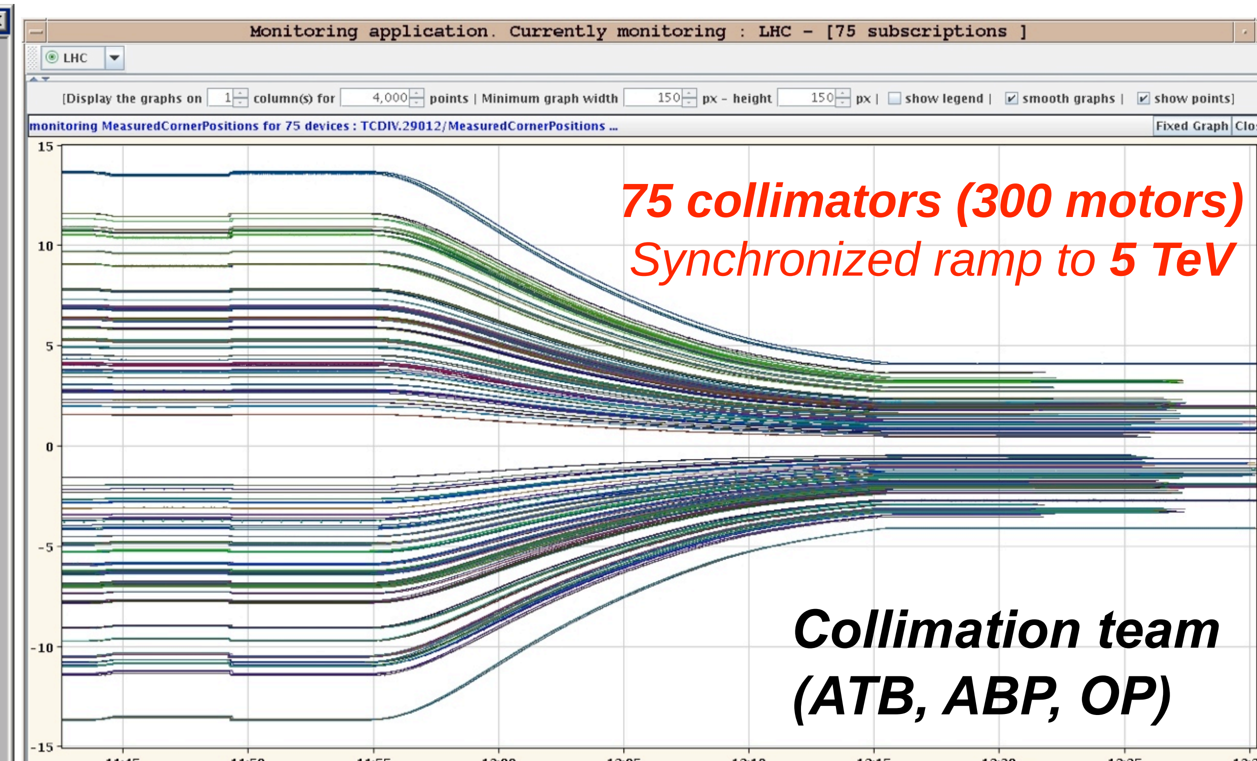
- *Power converts determine the E(t) function*
- *FiDeL used for generation of ALL circuits!*
- *E(t) function used for RF, Collimators, ...*

Tracking tests show encouraging results

Synchronization by timing worked well!

LSA is flexible - easy to generate beam processes at any energy *(0.6, 1, 2, 4.13, 5, 7 TeV available!)*



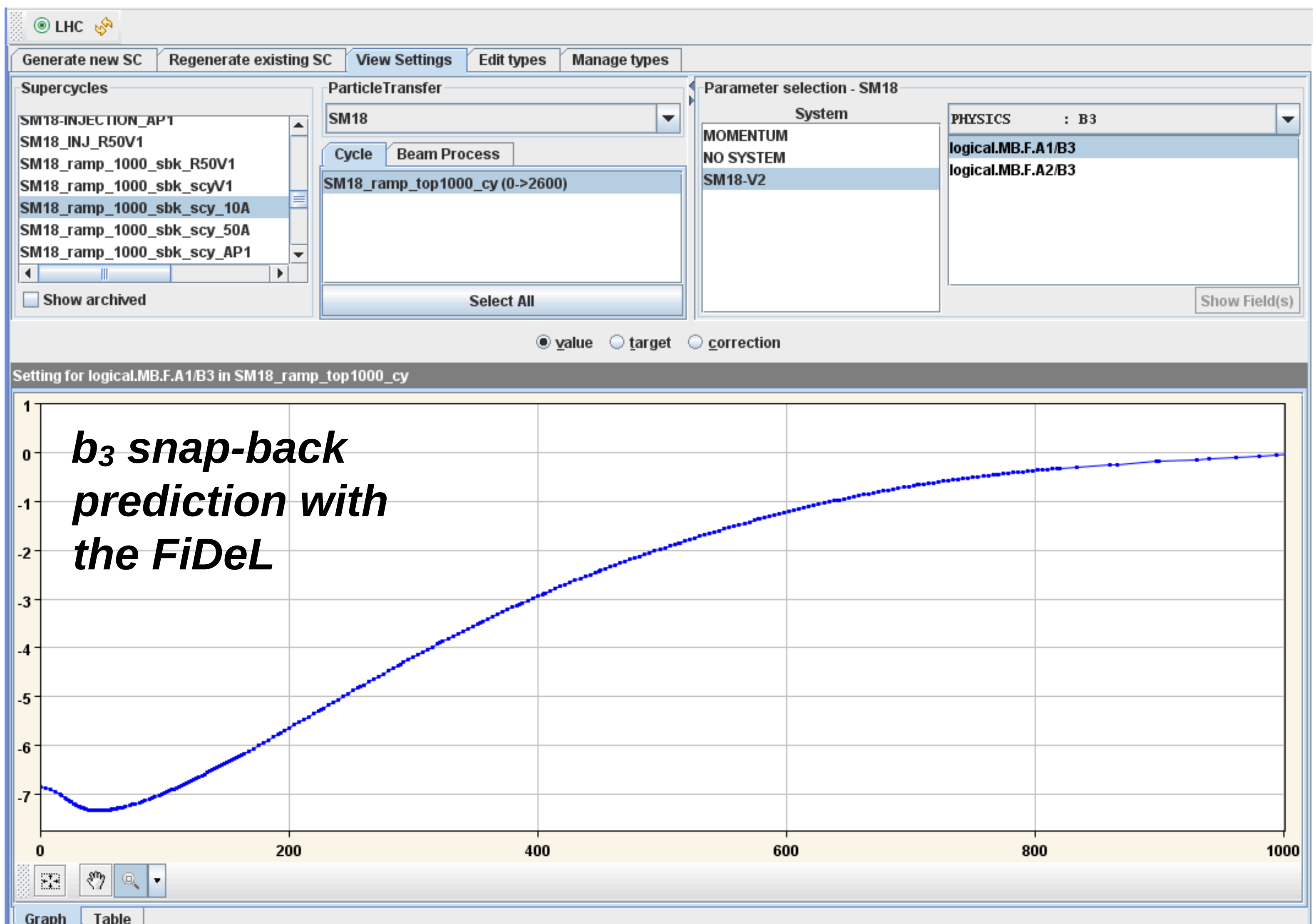


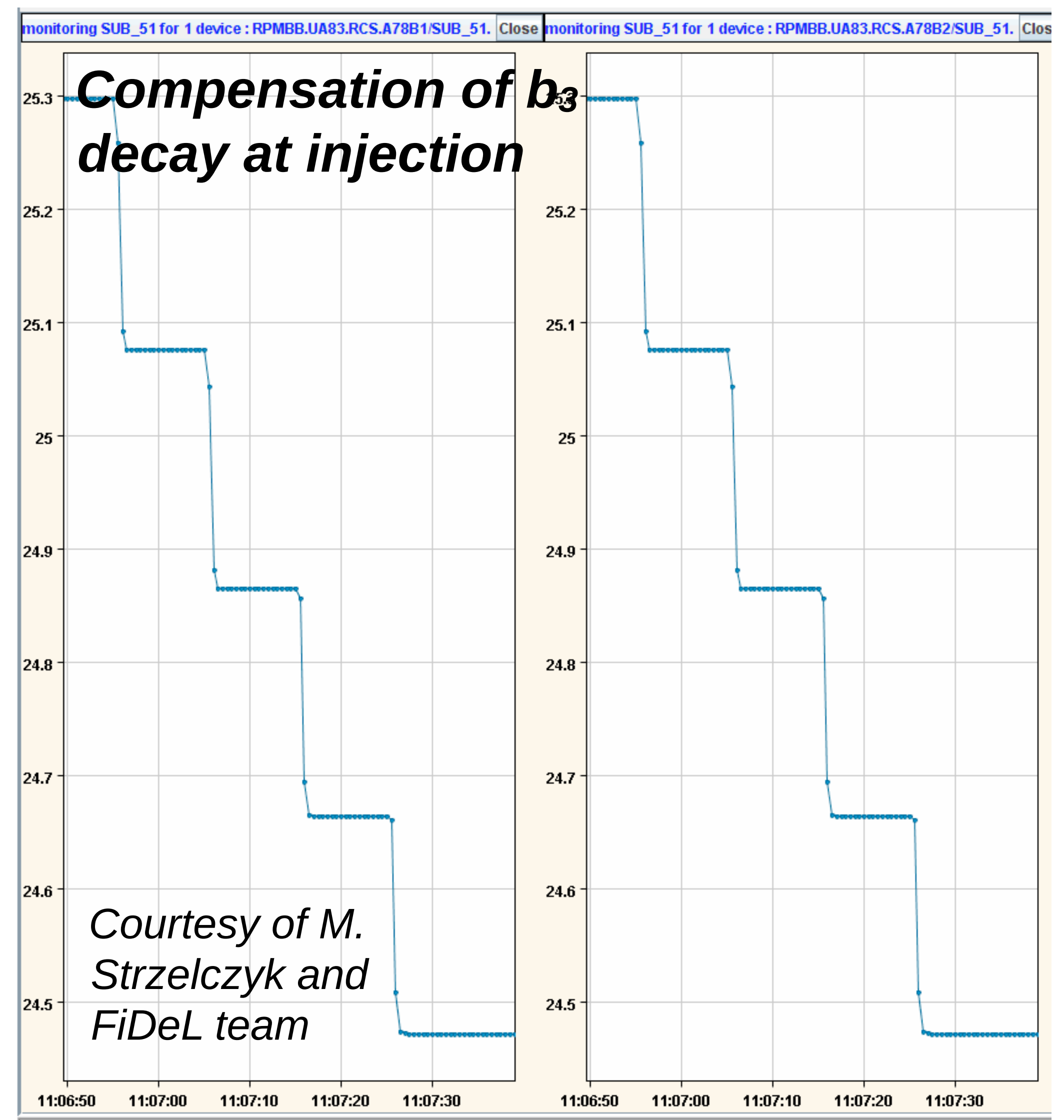
Dynamic correction of magnetic fields

- **FiDeL** (Field Description for the LHC, see Luca's talk) is used to **generate the currents for all magnet types** and allows **calculation/compensation of dynamic effects**
- **Implementation in the LHC Software Application (LSA) is well advanced**

  Tests during cold-checkout: calculate decay/snap-back; send corrections to power converters to compensate for it (as "actual" trims)

  Need to ***optimize*** *the fill-to-fill incorporation of the settings*
- Beam measurements needed to cross-check/improve the model, clearly!

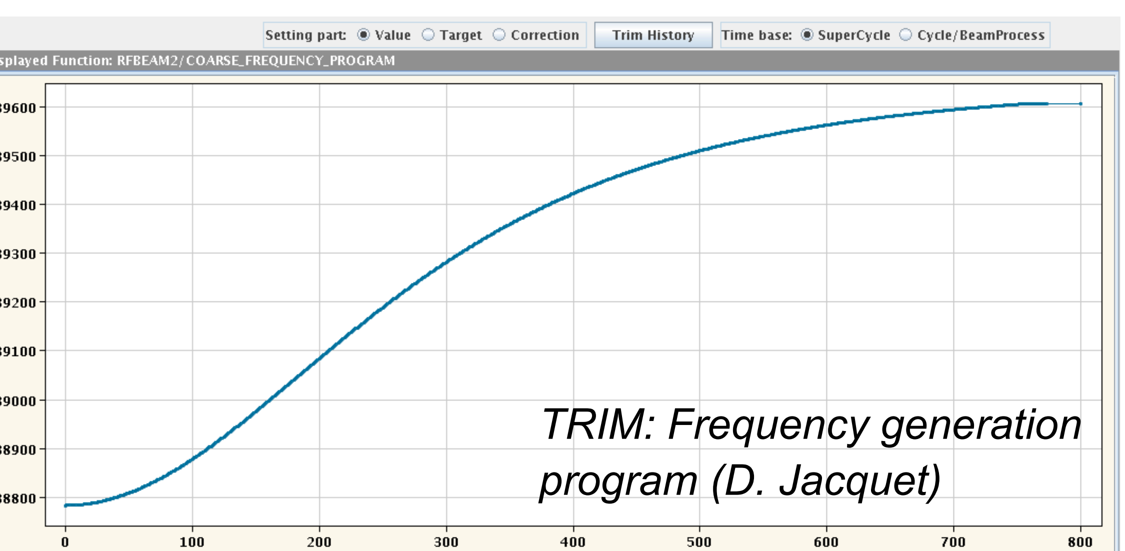




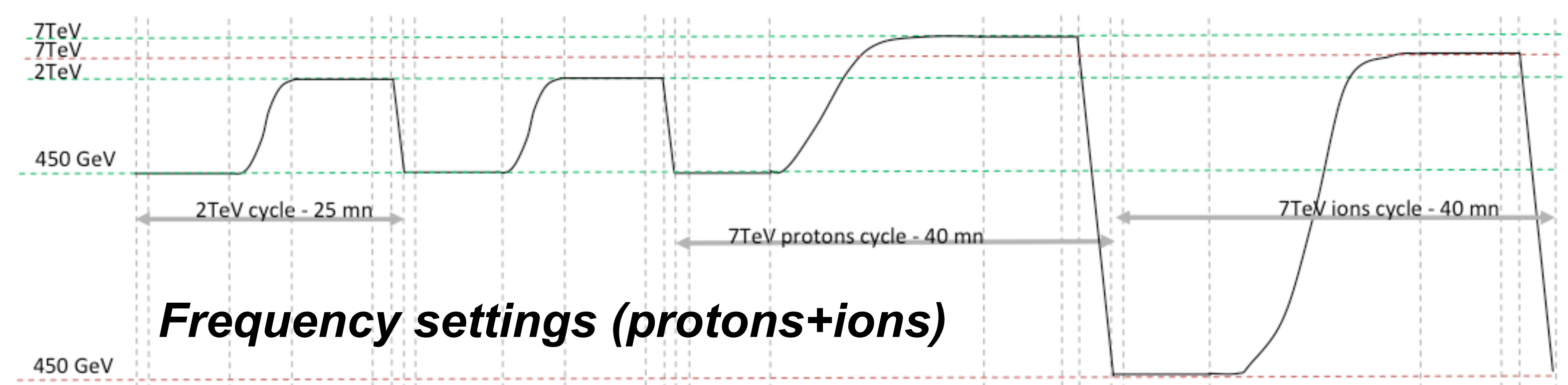
RF aspects

(cf. E. Ciapala's talk)

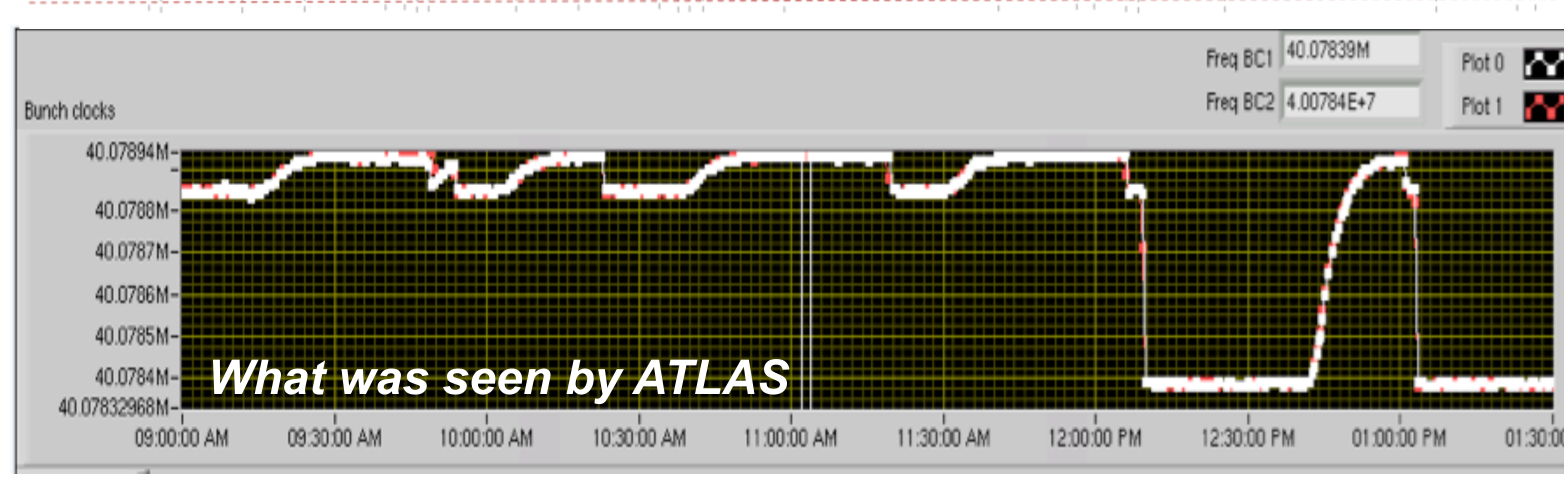
- **RF hardware (power/synchronization) available for proton and ion operation in LHC!**
  - *All 16 cavities tested with all loops; LHC mastership on SPS and injectors commissioned*
  - *Check-out tests to ramp and distribute RF synch to experiments - worked well!*
- **Testing of HW+SW for fine synchronization of hw timing and bucket frequency**
  - *Needed at top energy for experiments. Not available in 2008. Comm. will require beam time*
- **Minor upgrade of LSA needed to handle A/Z ratio of ions**
- **It will be possible to un-lock the B1 and B2 frequencies** *(radial tuning, measurements)*
- **Request of OP tools from the CCC:** *Operational OASIS for RF measurements; Scopes for CCC real-time (video streams) longitudinal bunch profile...; Sets of ADC for beam quality checks.*



TRIM: Frequency generation program (D. Jacquet)



Frequency settings (protons+ions)



What was seen by ATLAS

Courtesy of RF commissioning team, in particular A. Butterworth, T. Bohl and E. Ciapala.

Betatron squeeze

Mechanics of the squeeze successfully dry-tested during cold check-out:

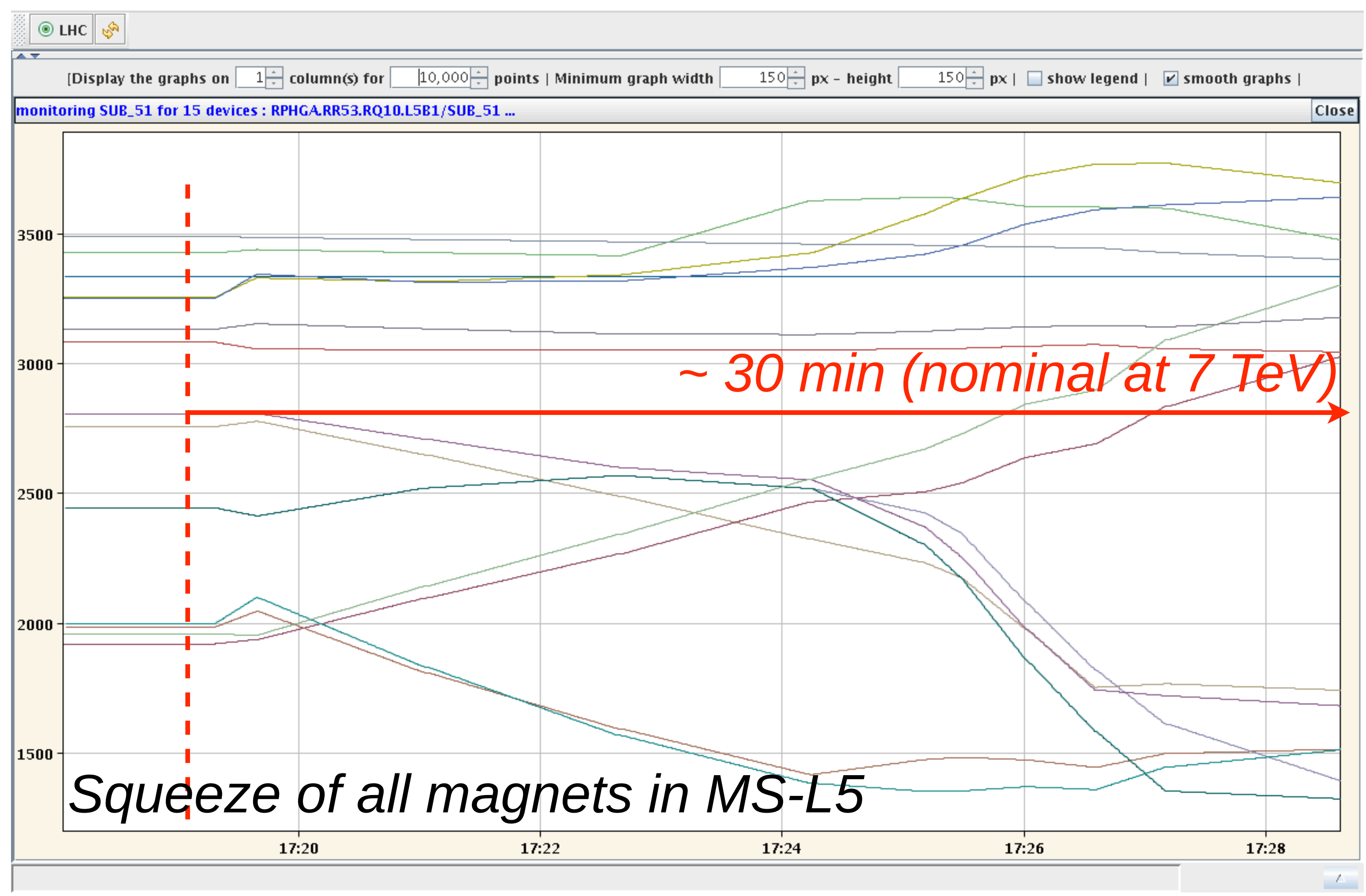
- *Squeeze function generation in LSA uses intermediate “matched” optics provided by ABP*
- *No issues expected from synchronization and tracking (same as for ramp, tests confirm!)*
- *Power converters determine overall length (~30 min for to reach b*=0.55m at 7TeV)*

Agreed baseline for squeeze commissioning:

- *Done at **maximum energy**; start simple (one beam / one IP at a time, no detector magnets)*
- *Pre-defined stopping points, detailed measurements*
- *Increase the number of matched optics if un-expected problems occur*
- *Will need tuning of triplet field model in FiDeL*

Required functionalities are available and will ensure operational flexibility!

Keys for success with beam: defined measurements program at every step; establishment of “golden” references; machine reproducibility. Safety...



Betatron squeeze and collimators

Full 2009 system will be in place for 2009 operation

- *No limitations of β^* in IP2 and IP8 from triplet protection (TCTVB's available for 2009)*

Every β step will need, in principle, checks/adjustments of collimator settings

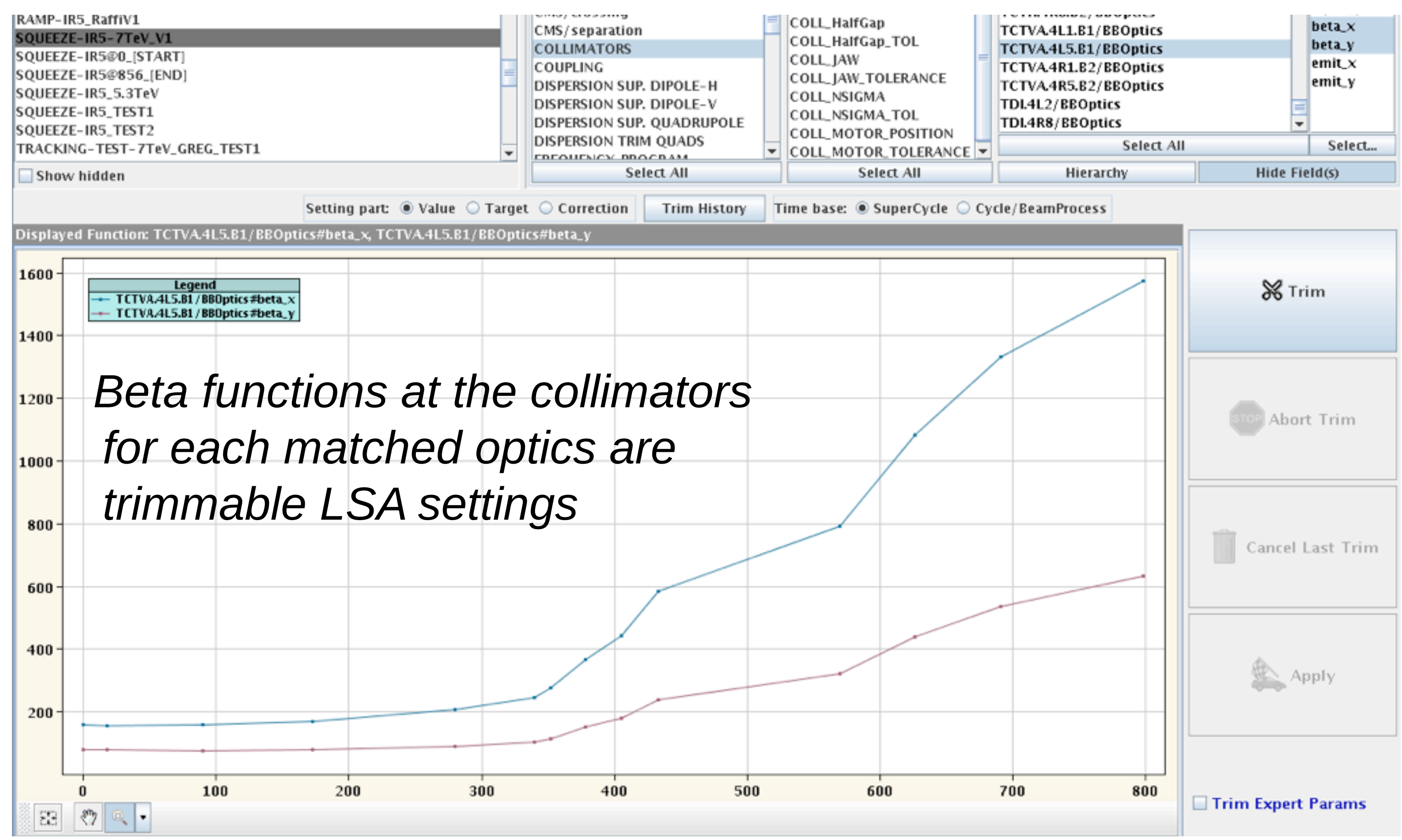
- *Cleaning collimators in IR7; dump protection in IR6; tertiary collimator for MQX protection*
- *In practice, only needed when triplet aperture becomes bottleneck (Ex.: $\beta^* \leq 6$m at 7 TeV)*
- *Move collimator to tighter settings before trimming squeeze to **MQX ensure protection***

Mechanics of the squeeze dry-tested during cold check-out (as for power converters):

- *Functions generated within LSA like for the power converters*
- *New functionality: **"interrupt"/"re-start"** at matched points (A. Masi). Tests ongoing.*

*Lot of work from the collimation team to define **optimized settings**:*
R. Assmann: Cham.2006 + LHCCWG num. 18
<u>C. Bracco's thesis</u> - see chapter on "Optimized strategy for LHC collimator commissioning"

Need updated settings for final operational scenario of energy and β^*



Squeeze combined with ramp

Pro's: save time (by overcoming PC limitations); beams less dangerous at lower energy.

Con's: add complication to ramp; mechanical aperture limits the minimum β* (see WH talk); critical steps only possible at 7 TeV; beam-beam is worst (parasitic crossing).

LSA gives all the flexibility needed to combine ramp and squeeze!

Baseline for operation:

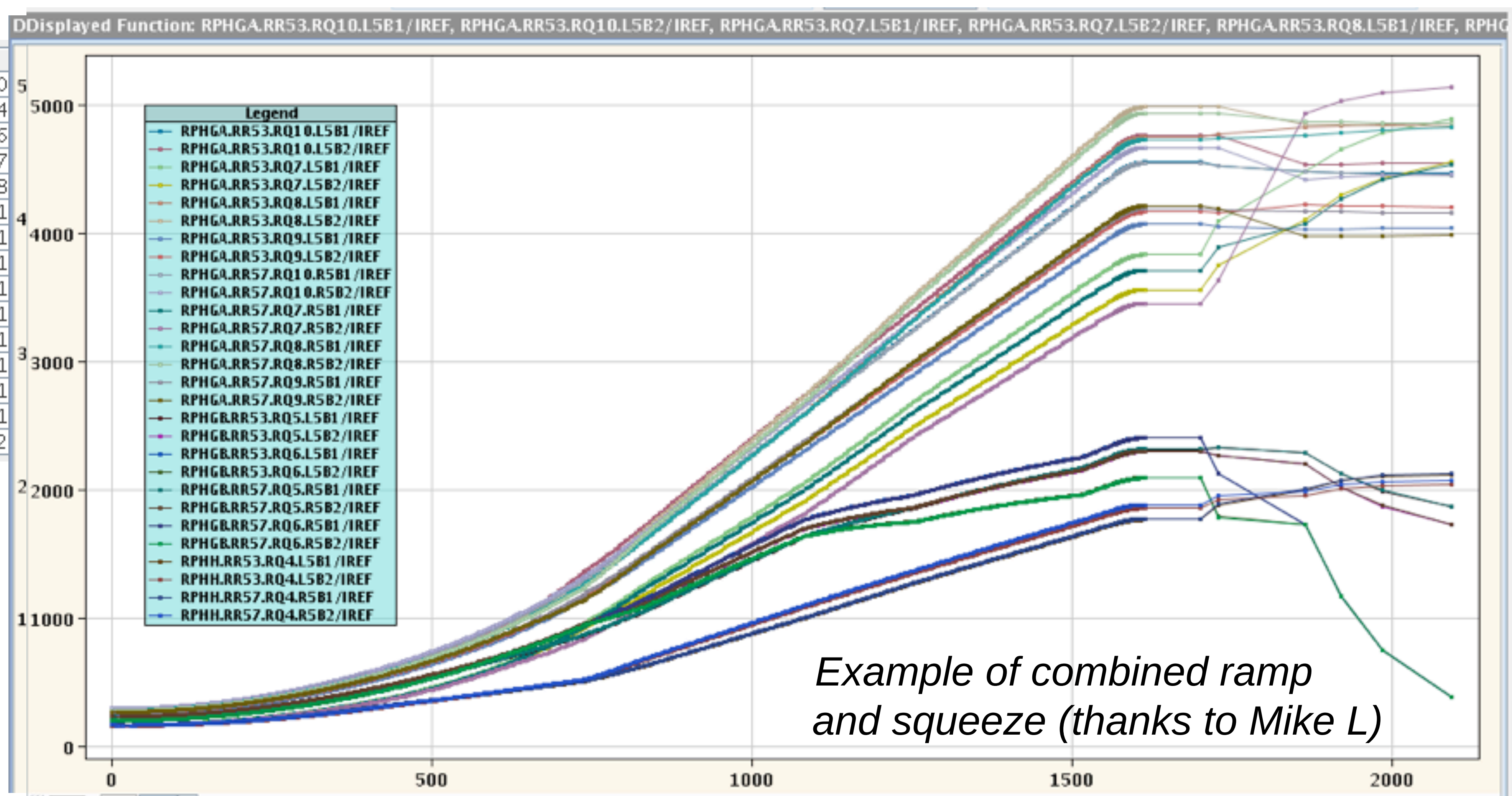
- only do it if really needed.

- only do it on a commissioned ramp, after we have mastered well the squeeze.

Optic Name	Energy	
A1100C1100A1000L1000	450.0	0
A1100C900A1000L1000	1000.1676	4
A1100C700A1000L1000	1505.2014	6
A1100C500A1000L1000	1996.0389	7
A1100C400A1000L1000	2505.8593	8
A1100C350A1000L1000	3997.9646	1
A1100C250A1000L1000	4992.7014	1
A1100C200A1000L1000	6555.8593	1
A1100C200A1000L1000	7000.0	1
A1100C200A1000L1000	7000.0	1
A1100C150A1000L1000	7000.0	1
A1100C110A1000L1000	7000.0	1
A1100C80A1000L1000	7000.0	1
A1100C65A1000L1000	7000.0	1
A1100C55A1000L1000	7000.0	2

Tests ongoing with G. Kruk, S. Page

Reminder: pre-squeeze required anyway for IP2 and 8 at energies above 6.6 TeV!



Example of combined ramp and squeeze (thanks to Mike L)

Operation of detector magnets

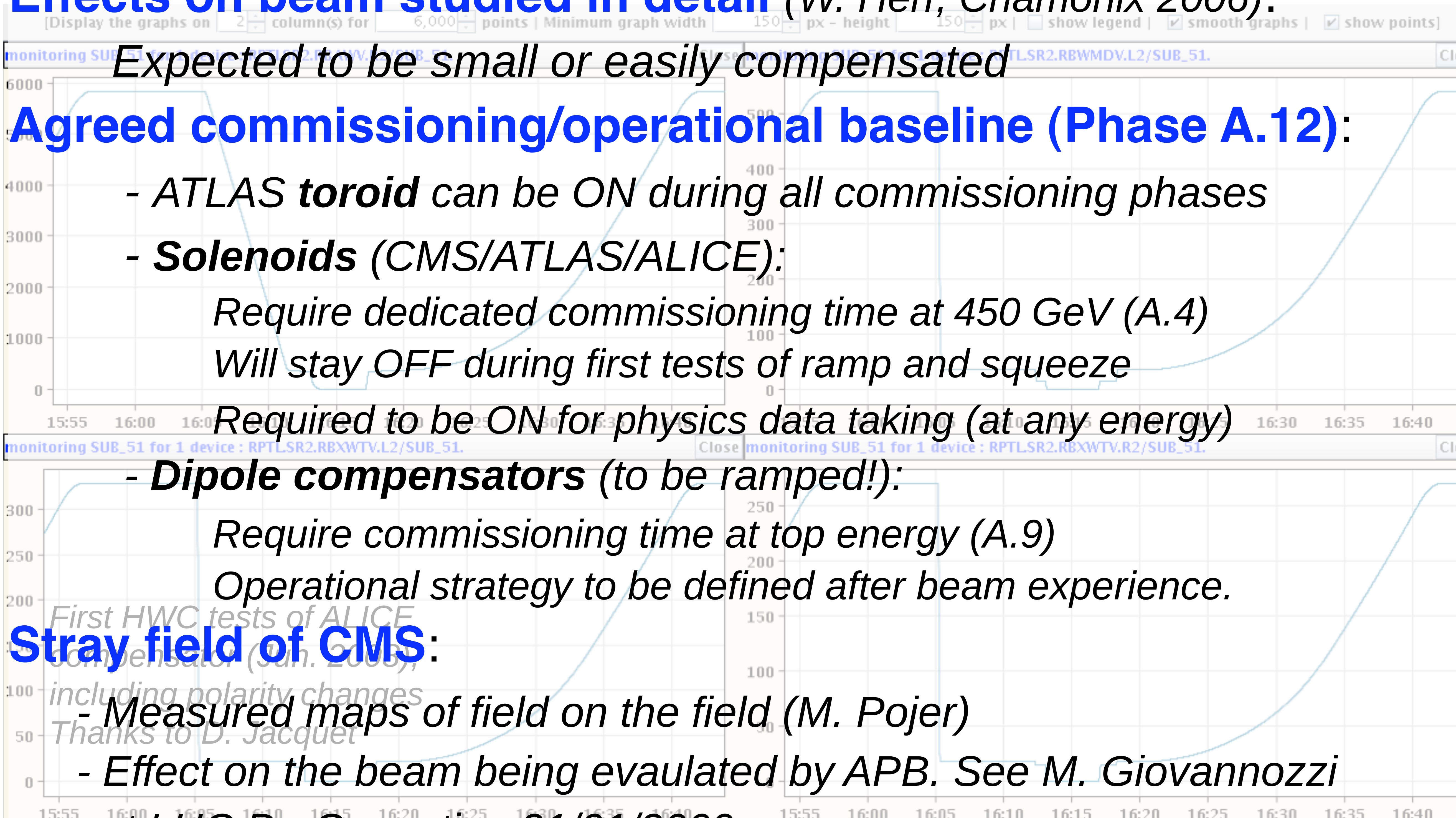
Operation aspects tested during cold-checkout in 2008

Effects on beam studied in detail *(W. Herr, Chamonix 2006)*:

Expected to be small or easily compensated

Agreed commissioning/operational baseline (Phase A.12):

- *ATLAS* ***toroid*** *can be ON during all commissioning phases*
- ***Solenoids*** *(CMS/ATLAS/ALICE):*
  - *Require dedicated commissioning time at 450 GeV (A.4)*
  - *Will stay OFF during first tests of ramp and squeeze*
  - *Required to be ON for physics data taking (at any energy)*
- ***Dipole compensators*** *(to be ramped!):*
  - *Require commissioning time at top energy (A.9)*
  - *Operational strategy to be defined after beam experience.*



First HWC tests of ALICE compensator (Jun. 2008), including polarity changes
Thanks to D. Jacquet

Stray field of CMS:

- *Measured maps of field on the field (M. Pojer)*
- *Effect on the beam being evaulated by APB. See M. Giovannozzi at LHC PerC meeting 21/01/2009*

Luminosity optimization

Required instrumentation will be available:

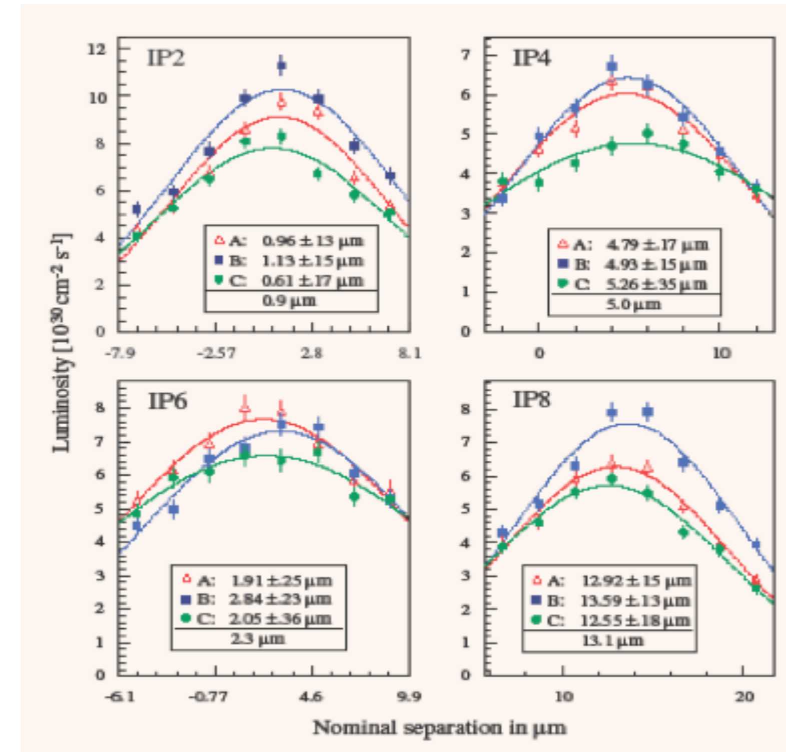
- *All BRAN's in all IP's available for 2009 operation (CERN/CEA-LETI + CERN/LARP)*
- *Signals from experiments available through DIP (tested!)*
- *Fixed displays and operational tools available*

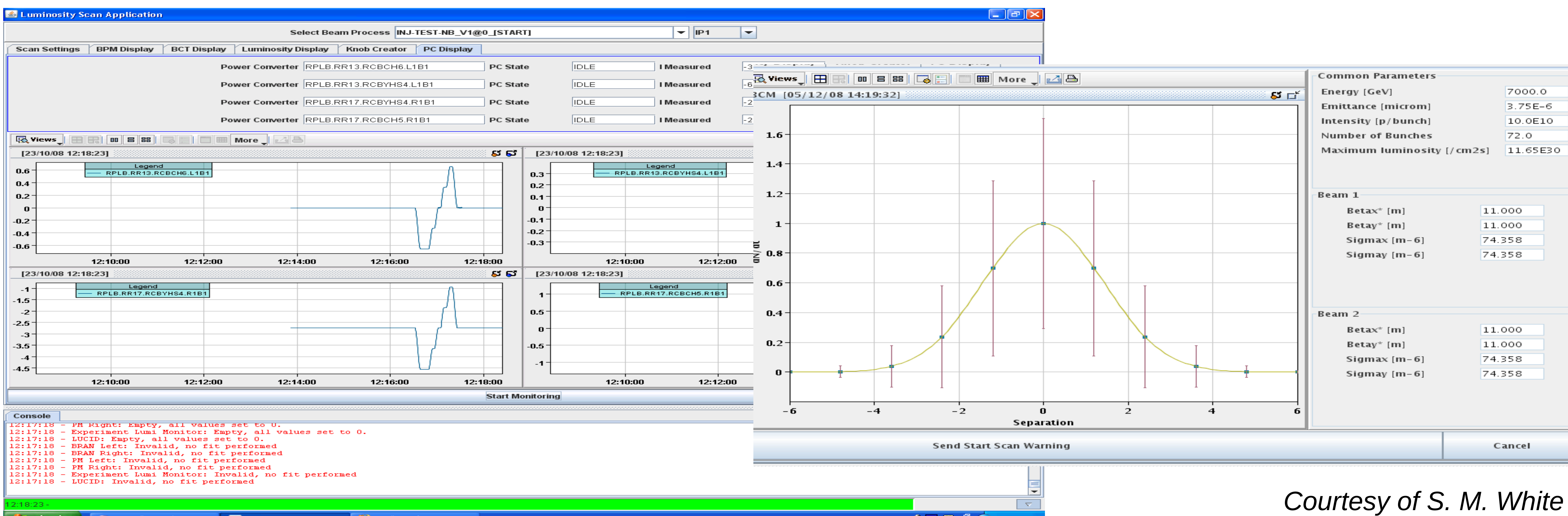
Set-up of tools for luminosity optimization is on-going

- *Funct. specs by R. Alemany, M. Lamont, S.M. White (PhD stud.)*
- *First prototype of application tested with relevant signals*

Operation with crossing angles can use the same tools

Luminosity scans at LEP





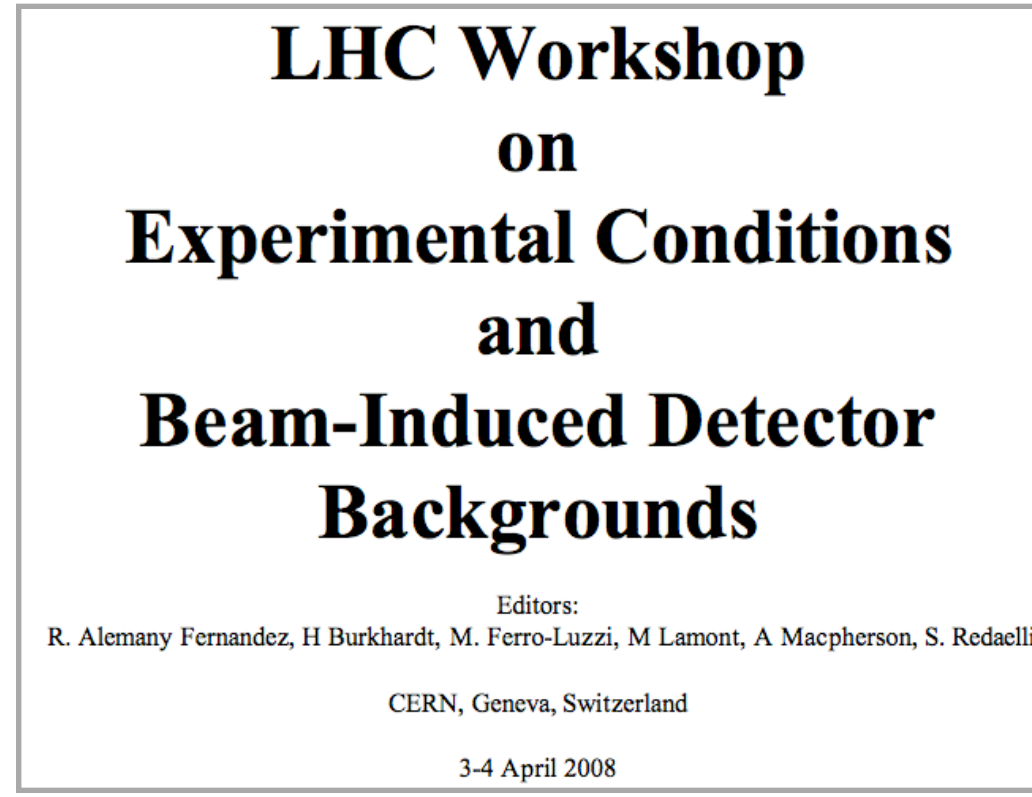
Courtesy of S. M. White

Detector background issues

A workshop on Experimental Conditions and Beam-Induced Detector Background took place at CERN in April 2008:

- *Experience and recommendations from Tevatron, HERA and RHIC*
- *LHC conditions: what can be expected and optimized*
- *What do experiment require and provide for optimization?*

→ *Yellow report with proceedings under publication*


LHC Workshop
on
Experimental Conditions
and
Beam-Induced Detector
Backgrounds

Editors:
R. Alemany Fernandez, H Burkhardt, M. Ferro-Luzzi, M Lamont, A Macpherson, S. Redaelli

CERN, Geneva, Switzerland

3-4 April 2008

Recommendations / open points:

- ***Need an homogeneous definition of background to provide to the machine for tuning***
- *Re-iterated that background is not expected to be an issue for high-lumi detectors, BUT:*
  - *Required updates of vacuum estimates*
  - *Required more homogeneous simulations and exchange of inputs*
- *Possible problem for ALICE:*
  - *Review operation of tertiary collimators (no closer than strictly needed); debris from IP1/5*
- *Optimization of conditions must wait for experience of beam operation*

All these open points are being followed up by a new Background working group (H. Burkhardt)

Procedures for ion commissioning

Commissioning plan elaborated by ion team (see talk by JJ). In particular, throughout the existing phases need to worry about:

RF, BI, Collimation, protection, BLM quench thresholds (the rest should work as for pp)

- New EDMS document will be circulated for approval
- Web documentation is being updated by JJ: specific ion aspects addressed for each step
- Will be maintained in the future together with the p procedures

http://lhc-commissioning.web.cern.ch/lhc-commissioning/ions/stage_1_EarlyIons.htm

Stage I: From start to first collisions of Early Ion Beam

Assume we slice commissioning procedures to the minimum required to get 2 Early Ion beams to 7 Z TeV (or some lower energy to be decided upon) and collide them unsqueezed. We should be starting from a machine that already does the equivalent with protons so many procedures can be skipped or compressed.

The time estimates for each step are provisional pending experience with protons. Some steps may be skipped or adapted at short notice according to circumstances and priorities.

		Ring factor	Total Time [days] both rings	Comments
I1	Injection and first turn	2	0.25	Magnetically identical to protons; 1 bunch/beam.
I2	Circulating beam	2	0.25	Magnetically identical to protons. Synchronisation of tr -5 kHz frequency shift. Check lifetime in particular (IBS?).
I3	450 Z GeV initial commissioning	2	0.25	Beam instrumentation slightly different. Optics OK.
I4	450 Z GeV optics measurements	2	.5	Magnetically identical to protons but do minimal check
I6	450 Z GeV - two beams	1	.5	>0.4 nominal bunch intensity, otherwise magnetically i
I7	Collisions at 450 Z GeV	1	1 ?	If interesting. Performance to summarise.
I8	Snapback and ramp	2	0.5	Single and then two beams, Magnetically identical to p Check beam dump at various energies.
I9	7 Z TeV flat top checks	2	0.5	Single beam initially, performed following successful r
I12	Commission experimental magnets			Included already since done for protons.
I10	Setup for collisions - 7 Z TeV	1	0.5	
	Physics un-squeezed	1	-	Zero crossing angle in ALICE, leave as-is in CMS & A
	TOTAL to first collisions		6	
I11	Commission squeeze	2	2	Commission squeeze of ALICE to same as presently ac ATLAS (with ATLAS and CMS unsqueezed). May h Check separation. Include CMS & ATLAS squeeze depending on time.
I5	Increase intensity	2	1	Increase bunch number to 62 (Early Scheme).
	Set-up physics - partially squeezed.	1	2	
	Pilot physics run			Parasitic measurements during physics (BLMs, ...) of g

Machine protection aspects

Preparation for un-safe beams treated in a dedicated phase (A.5)

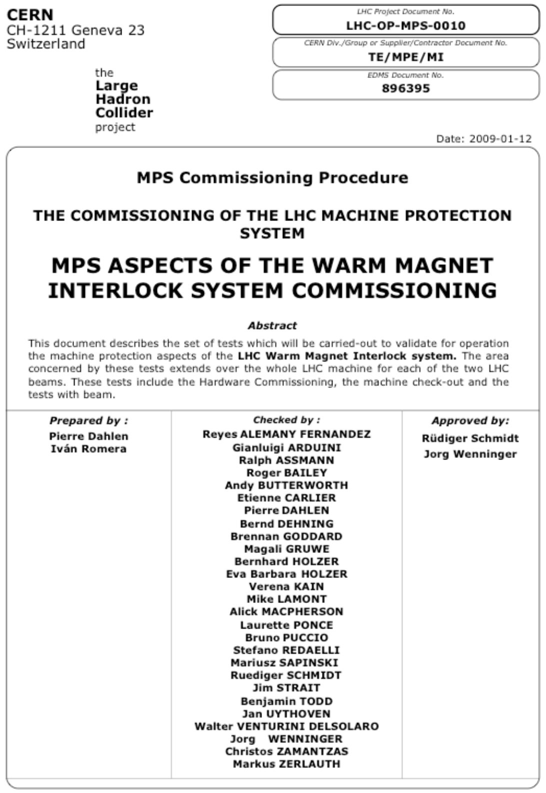
- *Increase total stored energy: higher intensities at injection or higher energies*

Hardware preparation of systems relevant for Machine Protection followed up by @#PP (J. Wenninger, see talk of yesterday)

- *First draft of commissioning procedures before 2008 operation (J. Uythoven, MPS meeting)*
- *Updated versions with detailed procedures will be released by spring 2009*

What we have to do:

- ***Prepare / follow-up the commissioning before beam operation (part of cold-checkout)***
- ***Agree on definition of SAFE beam parameters vs. energy for safe beam commissioning***
- ***Match critical milestones of MP aspects to the existing beam comm. procedures***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the Large Hadron Collider project

LHC Project Document No.: LHC-OP-MPS-0010
CERN Div./Group or Supplier/Contractor Document No.: TE/MPE/MI
EDMS Document No.: 896395

Date: 2009-01-12

MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

MPS ASPECTS OF THE WARM MAGNET INTERLOCK SYSTEM COMMISSIONING

Abstract

This document describes the set of tests which will be carried-out to validate for operation the machine protection aspects of the **LHC Warm Magnet Interlock system.** The area concerned by these tests extends over the whole LHC machine for each of the two LHC beams. These tests include the Hardware Commissioning, the machine check-out and the tests with beam.

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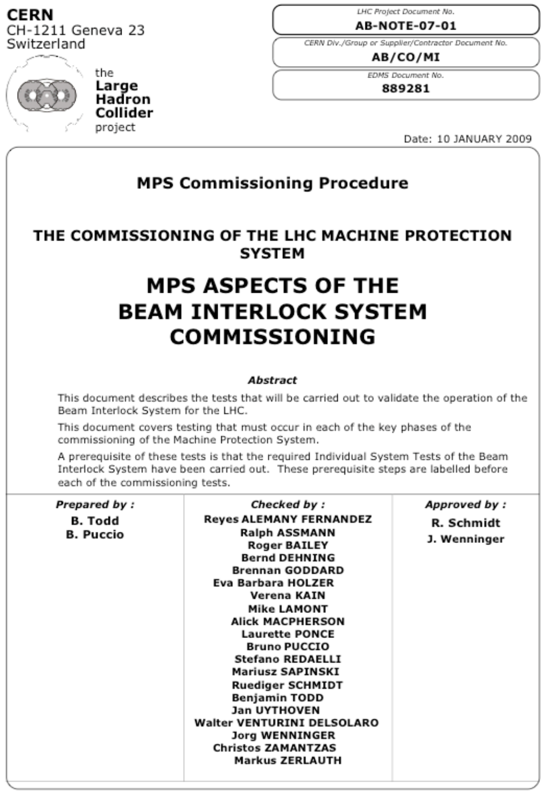
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LHC Project Document No.: AB-NOTE-07-01
CERN Div./Group or Supplier/Contractor Document No.: AB/CO/MI
EDMS Document No.: 889281

Date: 10 JANUARY 2009

MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

MPS ASPECTS OF THE BEAM INTERLOCK SYSTEM COMMISSIONING

Abstract

This document describes the tests that will be carried out to validate the operation of the Beam Interlock System for the LHC.

This document covers testing that must occur in each of the key phases of the commissioning of the Machine Protection System.

A prerequisite of these tests is that the required Individual System Tests of the Beam Interlock System have been carried out. These prerequisite steps are labelled before each of the commissioning tests.

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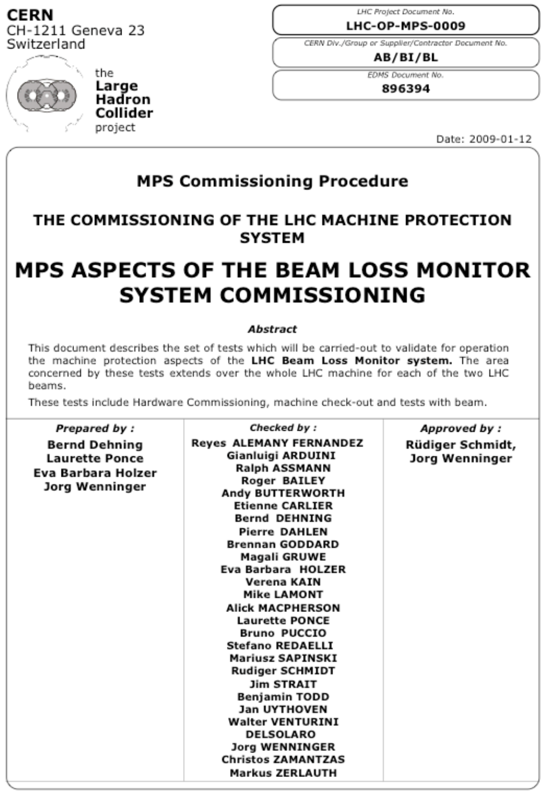
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LHC Project Document No.: LHC-OP-MPS-0009
CERN Div./Group or Supplier/Contractor Document No.: AB/BI/BL
EDMS Document No.: 896394

Date: 2009-01-12

MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

MPS ASPECTS OF THE BEAM LOSS MONITOR SYSTEM COMMISSIONING

Abstract

This document describes the set of tests which will be carried-out to validate for operation the machine protection aspects of the **LHC Beam Loss Monitor system.** The area concerned by these tests extends over the whole LHC machine for each of the two LHC beams.

These tests include Hardware Commissioning, machine check-out and tests with beam.

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Conclusions

- **Path to 7 TeV well thought of**

  First version of procedures finalized before 2008 operation

  Used for the (limited) commissioning steps covered by beam operation

  *Need to be updated to match the **new baseline commissioning strategy***

- **We believe that we are ready for the 2009 operation**

  We know - on paper - how to do what we need to do...

  We are more confident than 1 year ago that the tools will be available (dry-tests!)

- **The machine protection procedures have to be systematically built into the existing procedures**

- **We need to know the scenario for 2009+ operation**

  Collision energy, β^*, desired bunch filling scheme, collisions at injection, ...

- **Will start dry-tests as soon as possible to be ready**

  ... then the beam will tell!

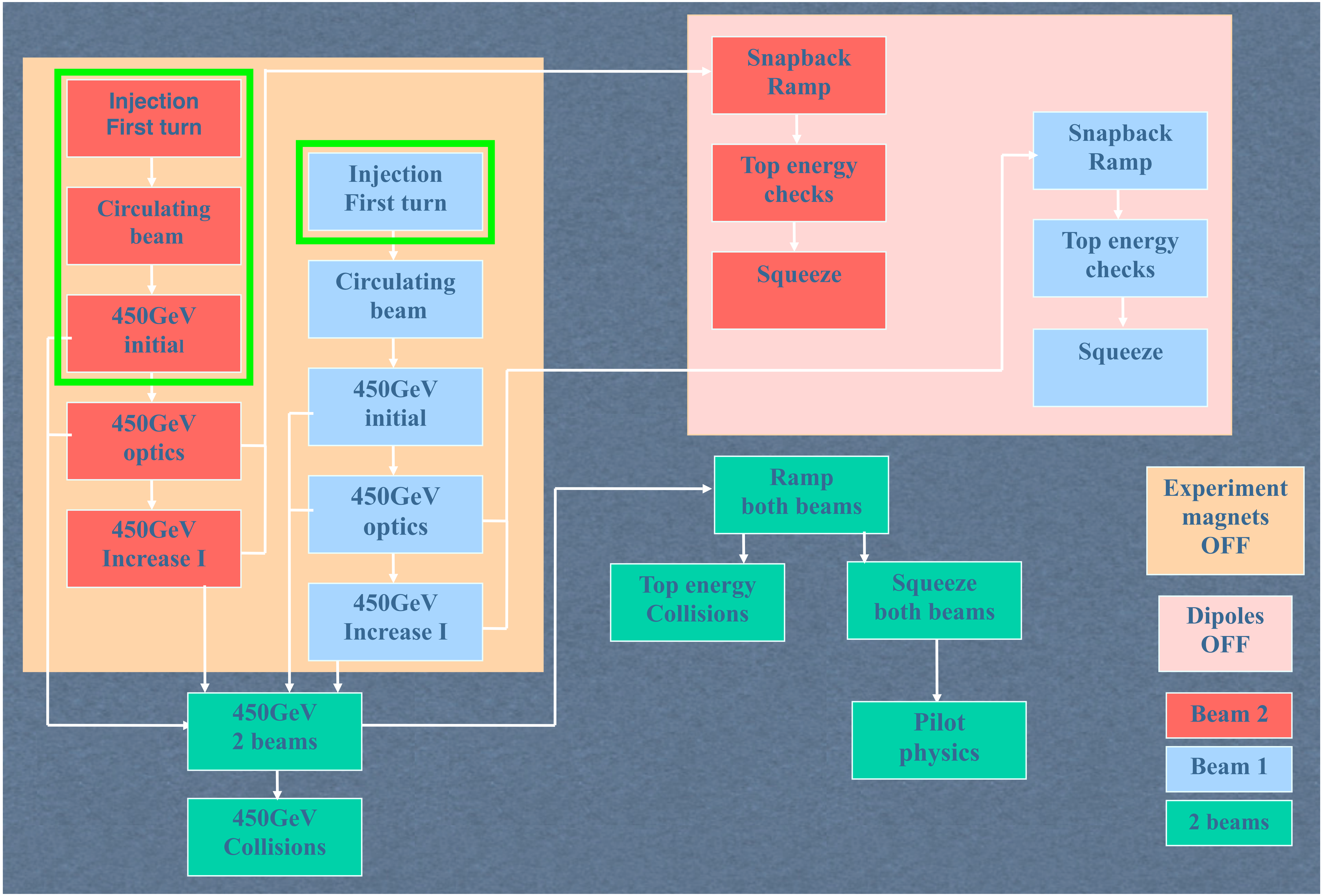
Reserve slides

Parameter table for 7 TeV operation

Parameters			Beam levels		Rates in ATLAS and CMS		Rates in Alice and LHCb		
k_b	N	β^* 1,5 (m)	I_{beam} (p)	E_{beam} (MJ)	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing	Luminosity ($cm^{-2}s^{-1}$)	Events/ crossing	Stage
43	4 10^{10}	11	1.7 10^{12}	2	1.1 10^{30}	<< 1	1.2 10^{30}	0.15	Stage A
43	4 10^{10}	2	1.7 10^{12}	2	6.1 10^{30}	0.76	1.2 10^{30}	0.15	Stage A
156	4 10^{10}	2	6.2 10^{12}	7	2.2 10^{31}	0.76	4.4 10^{30}	0.15	Stage A
156	9 10^{10}	2	1.4 10^{13}	16	1.1 10^{32}	3.9	2.2 10^{31}	0.77	Stage A
936	4 10^{10}	11	3.7 10^{13}	42	2.4 10^{31}	<< 1	2.6 10^{31}	0.15	Stage B
936	4 10^{10}	2	3.7 10^{13}	42	1.3 10^{32}	0.73	2.6 10^{31}	0.15	Stage B
936	6 10^{10}	2	5.6 10^{13}	63	2.9 10^{32}	1.6	6.0 10^{31}	0.34	Stage B
936	9 10^{10}	1	8.4 10^{13}	94	1.2 10^{33}	7	1.3 10^{32}	0.76	Stage B
2808	4 10^{10}	11	1.1 10^{14}	126	7.2 10^{31}	<< 1	7.9 10^{31}	0.15	Stage C
2808	4 10^{10}	2	1.1 10^{14}	126	3.8 10^{32}	0.72	7.9 10^{31}	0.15	Stage C
2808	5 10^{10}	1	1.4 10^{14}	157	1.1 10^{33}	2.1	1.2 10^{32}	0.24	Stage C
2808	5 10^{10}	0.55	1.4 10^{14}	157	1.9 10^{33}	3.6	1.2 10^{32}	0.24	Stage C

All values for nominal emittance, 7TeV and 10m β^* in Alice and LHCb

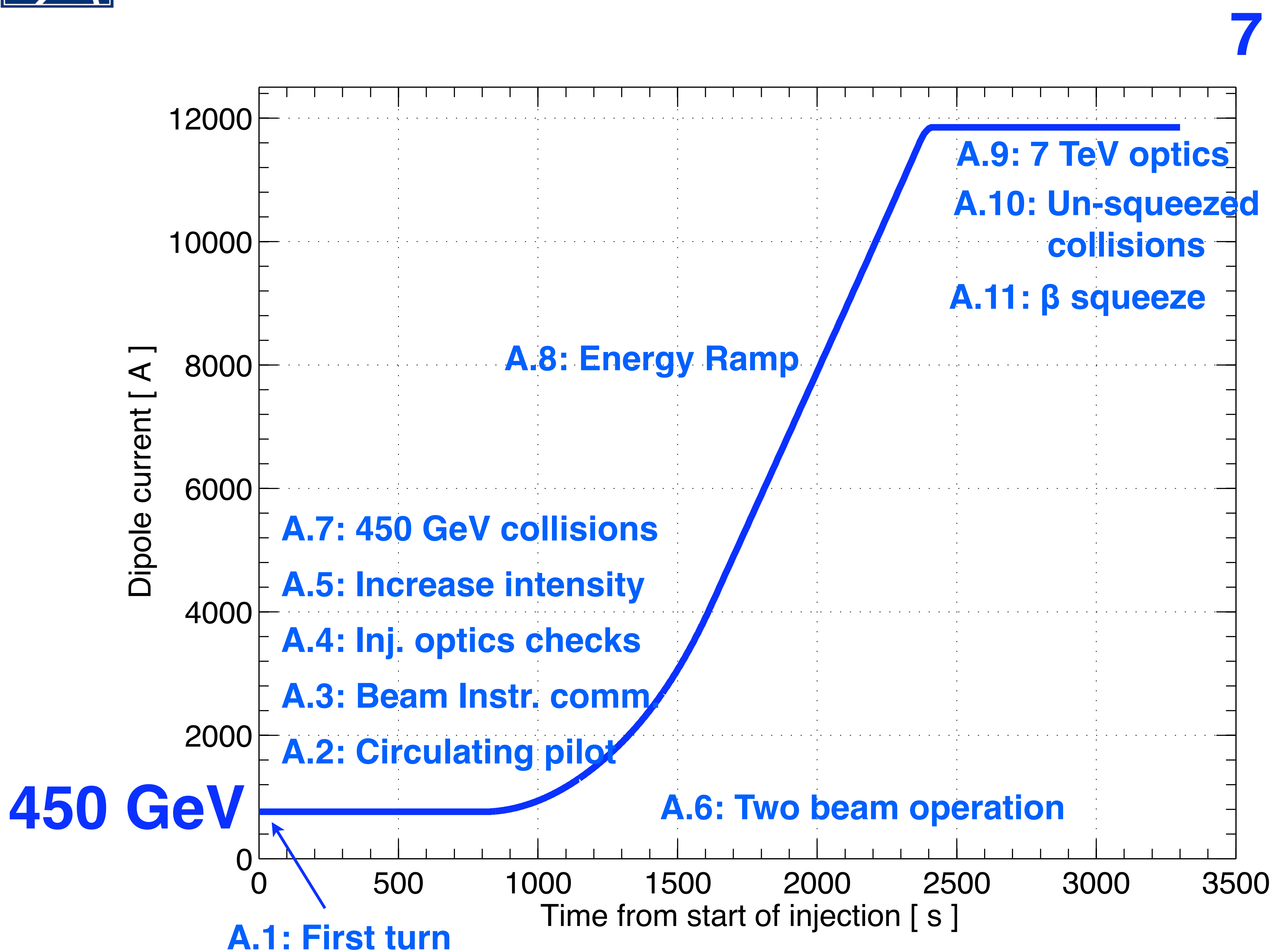
Flow chart of phases



Time estimates for commissioning

	Activity	Rings	Beam Time [day]	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	
11	*Commission squeeze*	*2*	*6*	
10b	*Set-up physics - partially squeezed*	*1*	*2*	
	TOTAL TO PILOT PHYSICS RUN ($\sim 1.1 \times 10^{32} cm^{-2} s^{-1}$)		44	

Geography of Stage A



Milestones: goals vs achievements

First turn (A.1)

Commissioning of TI 8 and TI 2 end, injection and thread around ring
Trajectory acquisition and correction commissioning
BPM: acquisition, auto-triggered asynchronous mode, first polarity checks
BTV: acquisition, profiles
BLM: acquisition, first adjustment of thresholds
FBCT: acquisition, first calibration cross-check.
Measurements
Partial polarity and calibration error checks in correctors and BPMs
Dedicated polarity and calibration error checks in correctors and BPMs
Dedicated aperture checks
Systematic kick/response optics measurements
Energy mismatch between arcs and SPS to LHC corrected to 0.1%
6-poles: polarities checked
D1/D2: transfer functions checked
Measurements of quench limits and BLM response
Machine protection [note 2]
BIS operational with all beam and injection permits
Safe LHC Parameters for beam injection permits
SIS operational with all beam permits
Controls and applications
BI data acquisition, applications, displays and logging
Sequencer, independent and interleaved beam 1 / beam 2 injection
Extensive high level control application suite
Shot-by-shot beam quality check for post mortem commissioned for injection
Injection system
MKI kicker operational with beam at nominal voltage
MKI kicker coarse timing and synchronisation
Orthogonal steering of injection point across TL/LHC interface
MSI aperture measured
Magnets
List of CODs that are found wrong (polarity and coarse calibration).
MBs: Injection settings generated with FiDeL checked out
MQs: Major errors disturbing integer tune found and possibly corrected
MB currents adjusted to correct energy mismatch to the 0.1% level
MBs: Stability of injection after recycling magnets

Circulating beam (A.2)

Machine parameters according to tolerances [note 1]
Beam captured
Beam instrumentation
BPM: acquisition, intensity mode
Measurements
Fast physical aperture scans, free oscillations with BPM intensity meas.
Controls and applications
RF signals and triggers in OASIS (phase pick-up, wall current monitor, peak detected signal, f_{rev}, f_{RF},….) available
Synchronization diagnostics tools tested (Injection bucket error and mountain range applications)
RF controls (frequency, voltage, phase, bucket position, …..)
Multi-turn trajectory acquisition
RF systems
RF cavities operational with pilot bunches
Phase-loop operational
Synchro-loop operational
Observation equipment set-up (wall-current monitor)
Fine synchronization SPS/LHC commissioned
Magnets
MQs: Major errors disturbing integer tune found and possibly corrected
MBs: Energy mismatch between arcs and SPS to LHC corrected to few 10^{-4}

Milestones: goals vs achievements

Initial commissioning at 450 GeV (A.3)

All RF diagnostics and loops commissioned at 450 GeV pilot intensity to 3x10^{10} p+
BPM/orbit corrector system fully commissioned
Orbit flattened in injection and dumping region
Other beam instrumentation commissioned
BCT systems fully commissioned
Tune/chromaticity measurement systems fully commissioned
Wire scanners fully commissioned
Undulator commissioned at 450 GeV
BSRA commissioned
Synchrotron light monitor commissioned
Rest gas ionisation monitor commissioned
BLMs parasitic commissioning if occasion (beam induced quench)
BLM commissioning with quench on purpose
Orbit/tune/coupling feedback tested
Orbit/tune/coupling feedback for injection optics fully commissioned
Measurements
Basic optics checks with multi-turn data
First emittance measurements with wire scanners
Longitudinal losses determined
Longitudinal profile and bunch length measured vs. time
Liftetime optimised to > 1 h
Cycling machine established
Injection protection
Rough setting-up of TDI, TDI in
Full commissioning of beam dumping system with pilot and 3 x 10^{10} p+ for 450 GeV
MKD synchronization verified with beam
Extraction region and dump line aperture measured
Beam position at TDE verified/adjusted
All BI acquisition for XPOC verified with beam
TCDQ and TCS roughly set up
IPOC and XPOC references adjusted