Plan for Collimator Commissioning

R. Assmann, CERN/AB

7/12/2007

for the Collimation Project

LHC MAC

1) Installation Planning and Performance Reach

- Collimation is an performance-driven system: Low energy and low intensity requires much less collimators.
- Several systems defined for initial installation (160 DB locations):
  - Full system [as defined in LHC-LJ-EC-0002 (IR3/7), LHC-LJ-EC-0003 (tertiary collimators), LHC-LJ-EC-0010 (active absorbers), LHC-LJ-EC-0014 (passive absorbers) and LHC-T-EC-0001 (injection protection)] → **116 collimators**
  - Minimal system 7 TeV (only required collimators) → **70 collimators**
  - Minimal system for 450 GeV (Oct 2006) → **36 collimators**
  - Starting system for 7 TeV (June 2007-now) → **92 collimators**
- Every installation plan adapted to LHC performance goals, LHC schedule and collimator production schedule.
- Formalized in ECR. Ahead of planning since September!

Staged Installation Phase 1

June/Sep 2007

Installation until Apr08
92 collimators
29 vacuum sectors affected

Beam →

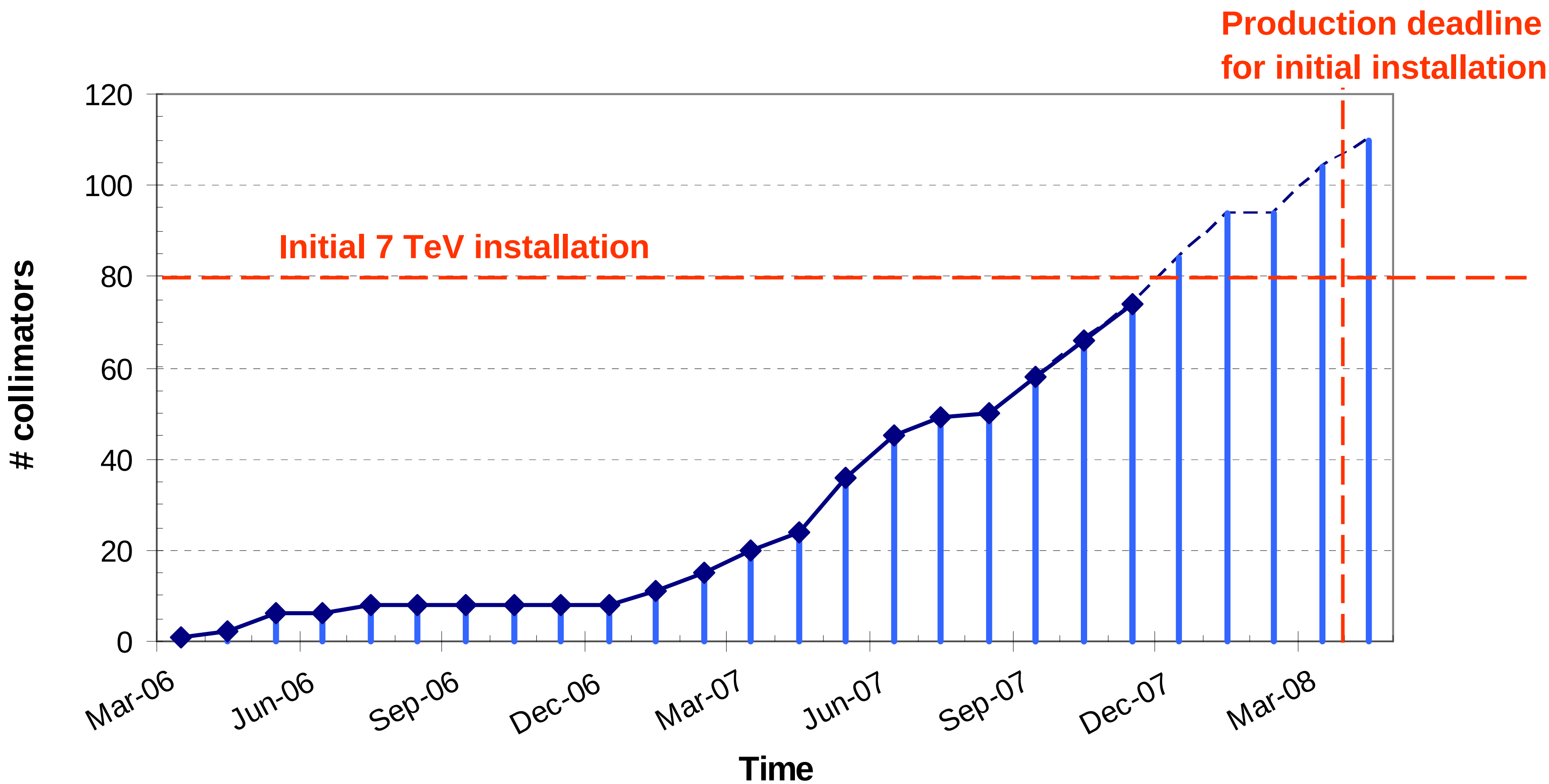
Installation 2008/9 shutdown
24 collimators

Ready for 7 TeV physics in May 2008!

1. Luminosity up to 10^{33} cm^{-2} s^{-1}.
2. Total stored intensity of up to 1×10^{14} p per beam.
3. Maximum injection of up to 1.7×10^{13} p per pulse.
4. Minimum β^* in IR1/IR5/IR8 of 2 m. **(or less)**
5. Minimum β^* in IR2 of 10 m. **(or less)**

Intensity reach at ~50% of full phase 1 system.

2) Progress: Industrial Production



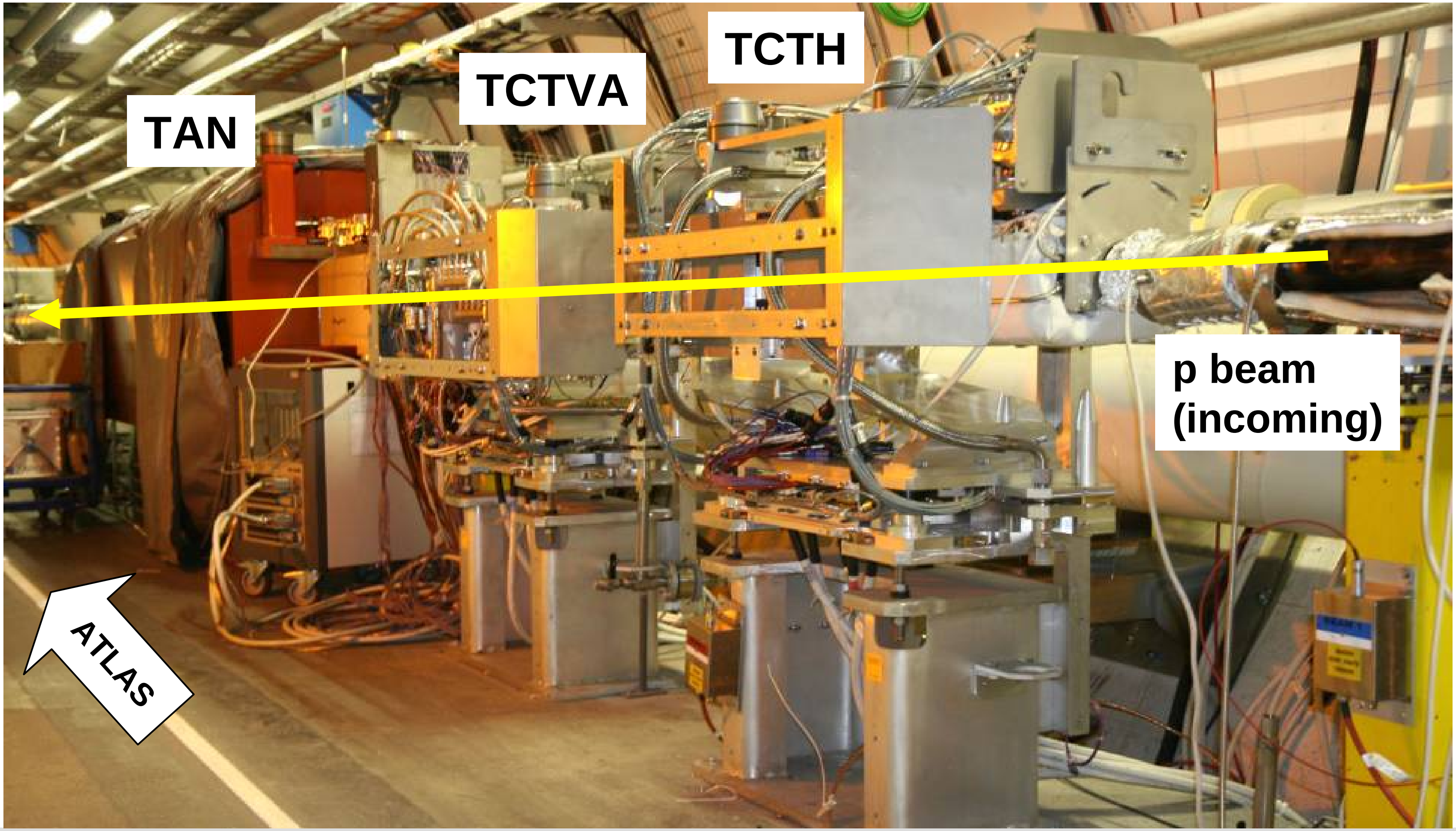
Industry: 94% of production for 7 TeV initial ring installation has been completed (75/80).

All collimators for initial installation should be at CERN by end of the year.

Total production of 110 collimators should be completed in April.

Installation: Status and IR1 Example

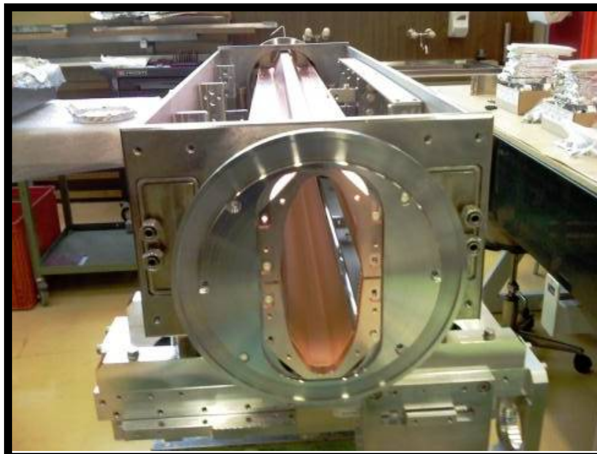
- We are installing presently about 4 collimators per week.
- At this time: 64 installed ➔ **~ 70% of total installation** completed.

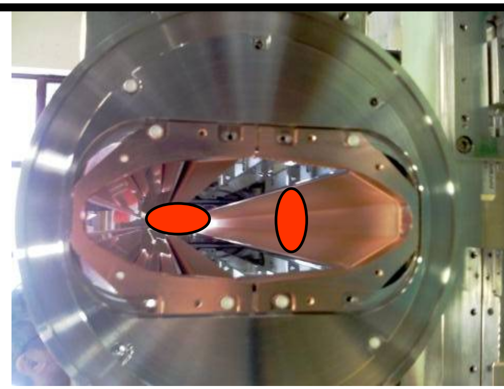


CERN Production

- In total 15 special collimators produced at CERN.
- Last for initial installation will arrive in week 11.
- Fully on track with production.

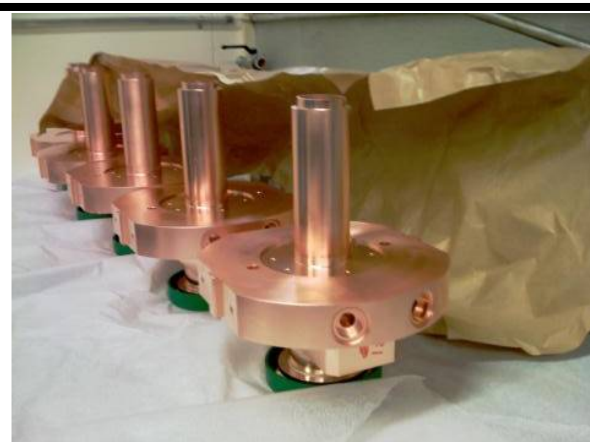
Collimator	Quantity	Availability
TCDD #1	1	week 39
TCAPA	4	week51
TCAPB	2	week 5
TCAPC	2	week 8
TCTVB #1	1	week 5
TCTVB #2	1	week 7
TCTVB #3	1	week 9
TCTVB #4	1	week 11
TCLIA #1	1	week 13
TCLIA #2	1	week 15





Two-beam collimator

Passive Absorber



3) Hardware Commissioning & Cold Checkout

System commissioning:	R. Assmann, T .Weiler	AB-ABP
	S. Redaelli	AB-OP
	M. Jonker, *M. Sobczak*	AB-CO
	R. Losito, A. Masi + team	AB-ATB (low-level)
	O. Aberle, R. Chamizo, Y. Kadi + team	AB-ATB (hardware)
Special functionalities	Injection team, Dump team,	(with beam only)
(protection, physics,...)	Ion collimation team, TOTEM, ...	

➔ Collaborative effort between several teams and groups.

HWC Procedure Defined and in MTF

LHC Collimation Project
CERN

CERN
CH-1211 Geneva 23
Switzerland

the Large Hadron Collider project

LHC Project Document No.
LHC-AB

CERN Div./Group or Supplier/Contractor Document No.
AB/ABP, AB/ATB

EDMS Document No.
000-2007-1234

Date: 2002-04-15

Test Procedure

COLLIMATOR FINAL ASSEMBLY AND HARDWARE COMMISSIONING FOR LHC

Page 3 of 30

Table of Contents

S. Redaelli
R. Saban
Th. Weiler

HWC procedures specified (EDMS document by **T. Weiler**): cover all production phases.

HW commissioning in preparation of beam operation **MTF structures**.

Close collaboration: **ABP**, **ATB**, **OP**, **CO**, **HCC**

Final validation of single collimator functionalities!

MTF *Equipment Management Folder*

Home | H

Search : Equip

Profile Workflow

Profile for **TC**
Description: **Collimator**

Main | Profile data | Workflow

Actions : Add step

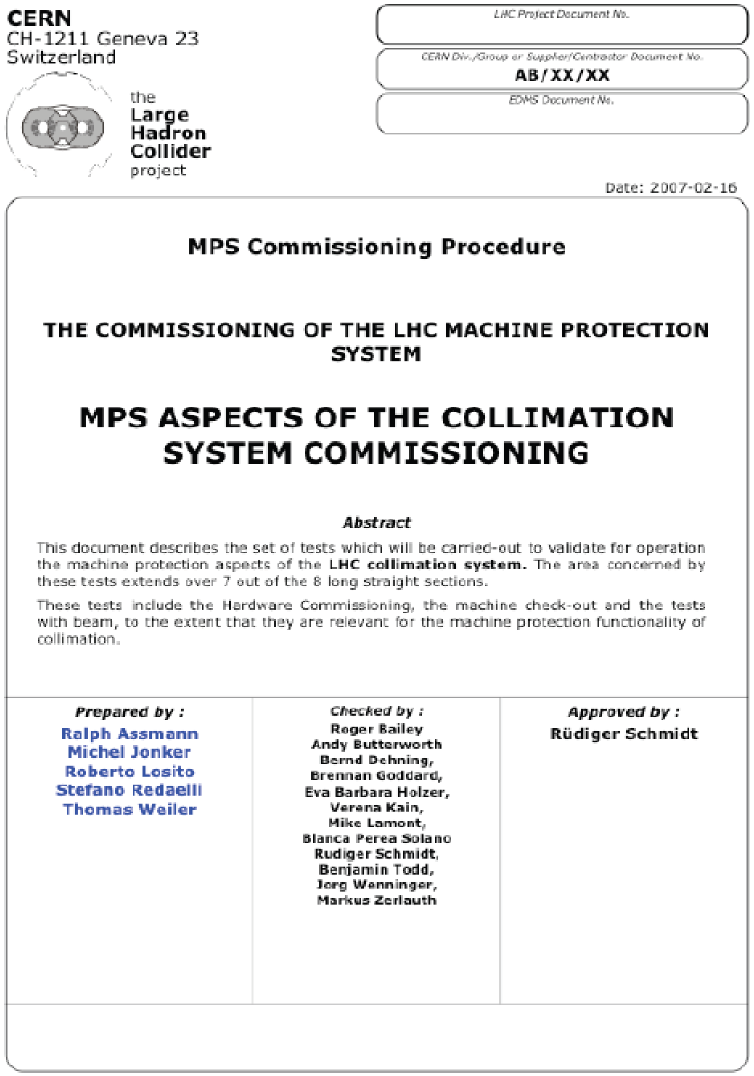
Workflow diagram

No Workflow Diagram defined

Workflow Steps

Step	Other name	Description name
MTF013485	()	10-BS Cooling Water Infrastructure
MTF013486	()	12-BS Final Cabling and Plug-in Check
MTF013487	()	14-TE Removing Blocking of Jaws
MTF013488	()	16-TE Water Tightness - Flow Rate Adjustment
MTF013489	()	18-TE Jaw Movement and Pos. Sensor Response
MTF013490	()	20-TE Temperature Sensor Response Check
MTF013491	()	22-FS Auto-retraction Test
MTF013492	()	24-FS LVDT and Resolver Calibration
MTF013493	()	26-FS Interlock Chain Check
MTF013494	()	28-FS Communication Check
MTF013495	()	30-FSV Auto-Retraction Tests
MTF013496	()	32-FSV Measurement of Mechanical Play
MTF013497	()	34-FSV LVDT and Resolver Calibration Check
MTF014798	()	IND10. Initial alignment

Machine Protection Commissioning Being Formally Defined



CERN
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the Large Hadron Collider project

LHC Project Document No.

CERN Div./Group or Supplier/Contractor Document No.
AB/XX/XX

EDMS Document No.

Date: 2007-02-16

MPS Commissioning Procedure

THE COMMISSIONING OF THE LHC MACHINE PROTECTION SYSTEM

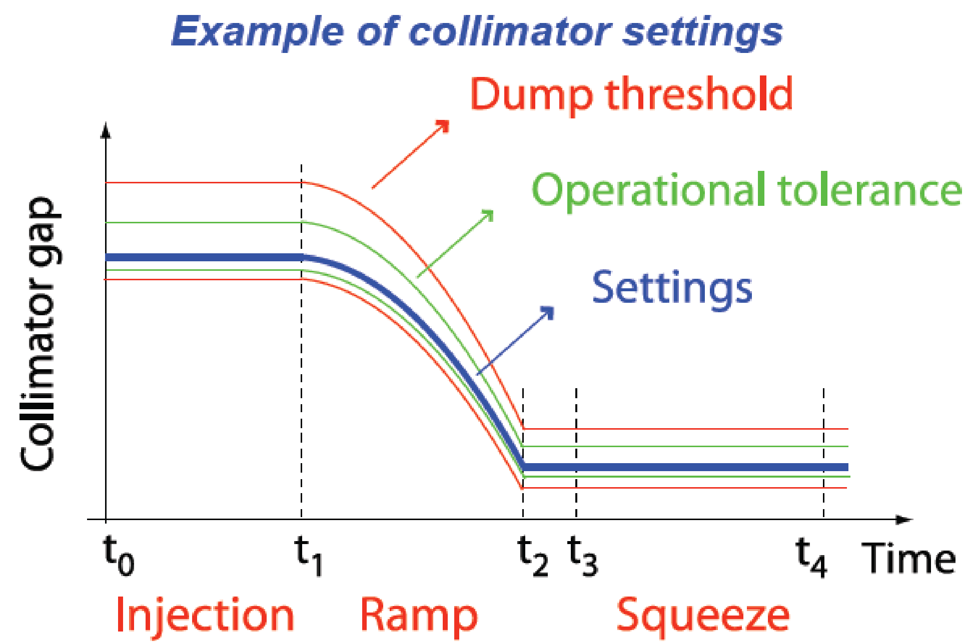
MPS ASPECTS OF THE COLLIMATION SYSTEM COMMISSIONING

Abstract

This document describes the set of tests which will be carried-out to validate for operation the machine protection aspects of the **LHC collimation system.** The area concerned by these tests extends over 7 out of the 8 long straight sections.

These tests include the Hardware Commissioning, the machine check-out and the tests with beam, to the extent that they are relevant for the machine protection functionality of collimation.

Prepared by :	Checked by :	Approved by :
Ralph Assmann Michel Jonker Roberto Losito Stefano Redaelli Thomas Weiler	Roger Bailey Andy Butterworth Bernd Dehning, Brennan Goddard, Eva Barbara Holzer, Verena Kain, Mike Lamont, Blanca Perea Solano Rudiger Schmidt, Benjamin Todd, Jorg Wenninger, Markus Zerlauth	Rüdiger Schmidt



All **machine protection functionality based on interlocks on position readings** (redundancy).

Can be commissioned without beam.

Foreseen for March/April.

HWC: Tracking Jaw Positions

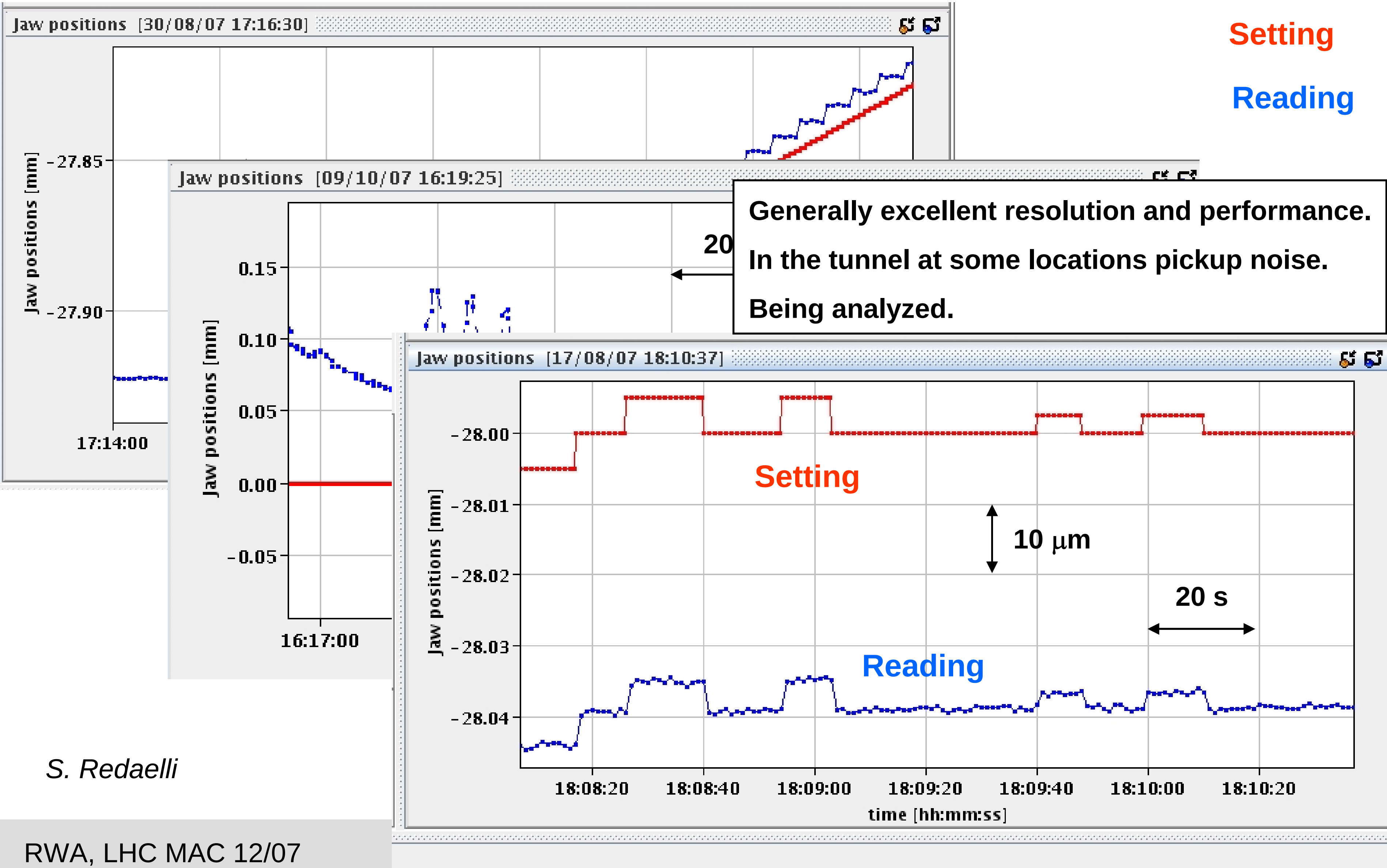
Setting

Reading

Generally excellent resolution and performance.

In the tunnel at some locations pickup noise.

Being analyzed.

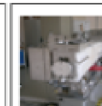
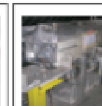
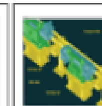
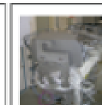
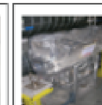
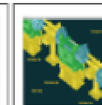
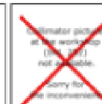
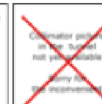
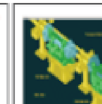
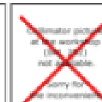
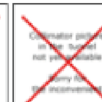
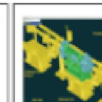
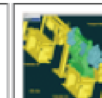
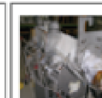
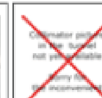
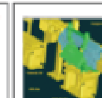
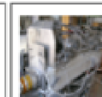
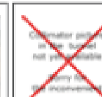
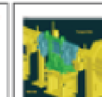
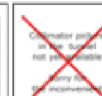
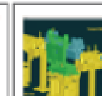


S. Redaelli

Deliverables

- Outcome of the **collimator hardware commissioning**:
  - Validation of single collimator, all relevant functionality
  - Settings and sensor readouts (position, temperature, switches,...) verified
  - Control of each collimator from CCC is declared “**safe**”
  - Machine protection functionality (without beam) partially established
- **Cold checkout** focused on:
  - Control an *ensemble* of collimators
  - Address timing and synchronization issues
  - Function-driven motion, “tracking” tests with other equipment
  - Establish full machine protection functionality without beam
  - Verify interfaces to other accelerator systems
    - Beam loss monitors: configuration/acquisition of distributed system
    - Sequencer driven commands, machine modes
    - Verify logging of distributed systems (big data sets!)
  - Consistency and sanity checks; global system status

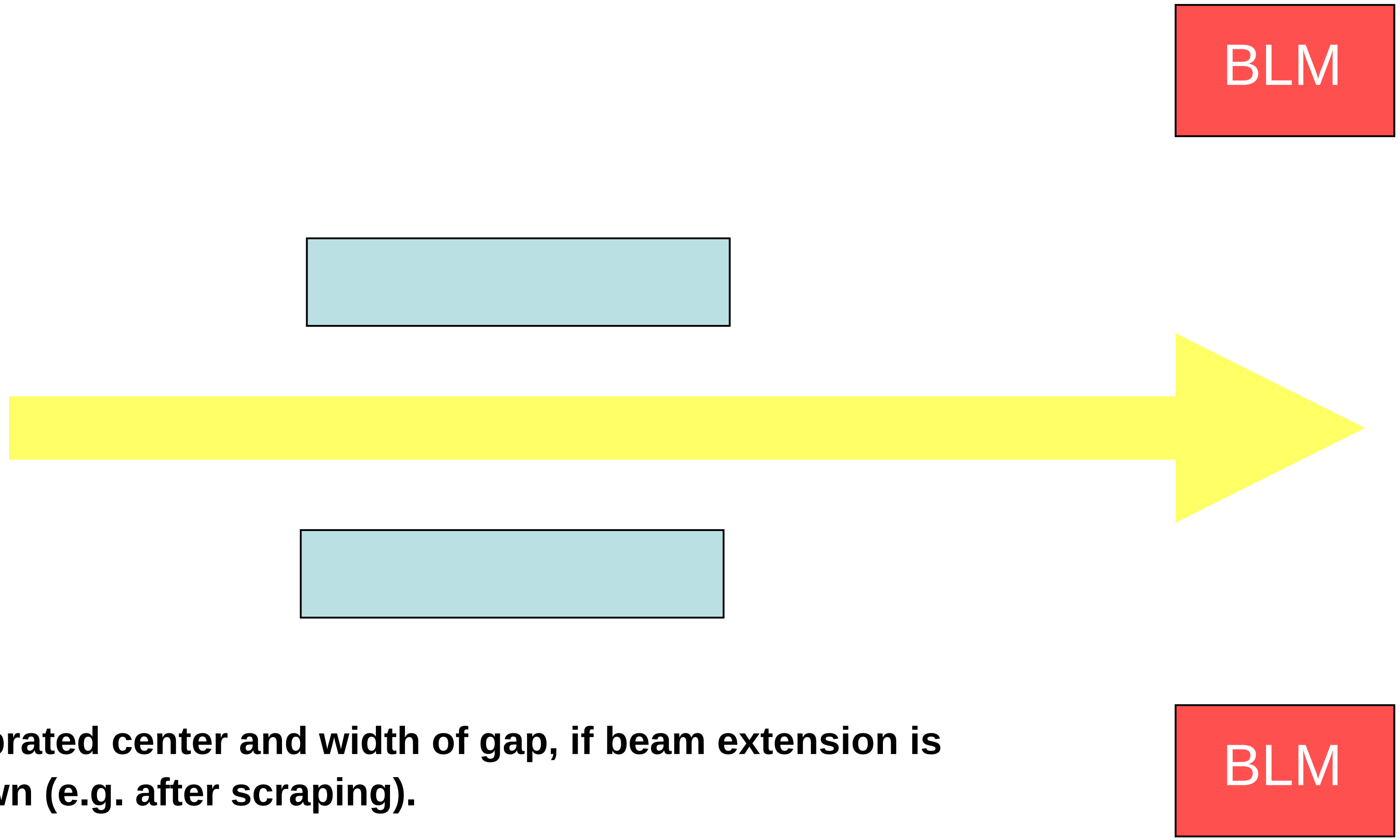
Results in Collimation Project Web

DEVICE_NAME	MTF link	FAMILY	IP	BEAM	ANGLE	Config Angle	Jaw Orientation	Summary	Photo 252	Photo LHC	3D Layout	Last modified
TCSG.252.TEST		TCSG	7	B1	135.0							
TCP.D6L7.B1	TCP109 Acceptance (extra)	TCP	7	B1	90.0	-90.0	D/B/C/A	xls/pdf				31/07/2007
TCP.C6L7.B1	TCP101 Acceptance (extra)	TCP	7	B1	0.0	0.0	C/A/D/B	xls/pdf				31/07/2007
TCP.B6L7.B1	TCP102 Acceptance (extra)	TCP	7	B1	127.0	-53.1	C/A/D/B	xls/pdf				01/08/2007
TCSG.A6L7.B1	TCS020 Acceptance (extra)	TCS	7	B1	141.2	-38.9	C/A/D/B	xls/pdf				01/08/2007
TCSG.B5L7.B1		TCS	7	B1	143.5							
TCSG.A5L7.B1	TCS021 Acceptance (extra)	TCS	7	B1	40.7	-139.3	D/B/C/A	xls/pdf				25/10/2007
TCSG.D4L7.B1	TCS029 Acceptance (extra)	TCS	7	B1	90.0	-90.0	D/B/C/A	xls/pdf				10/08/2007
TCSG.B4L7.B1	TCS032 Acceptance (extra)	TCS	7	B1	0.0	0.0	C/A/D/B	xls/pdf				10/08/2007

3) Beam Commissioning

- Beam commissioning of collimators will involve many aspects:
  - Proton losses around the ring.
  - Energy deposition in accelerator devices, including SC magnets.
  - Quenches induced by beam loss.
  - Activation.
  - Radiation.
  - Background in the experiments.
  - Vacuum and heating in the collimation regions.
  - Cooling capacity.
- All has been addressed over the last 5 years (CWG web site).
- These issues are all driven by collimator settings (~500 degrees of freedom) and performance.
- In this talk, focus on **how to get to nominal settings and performance**.

Set-up of single collimator

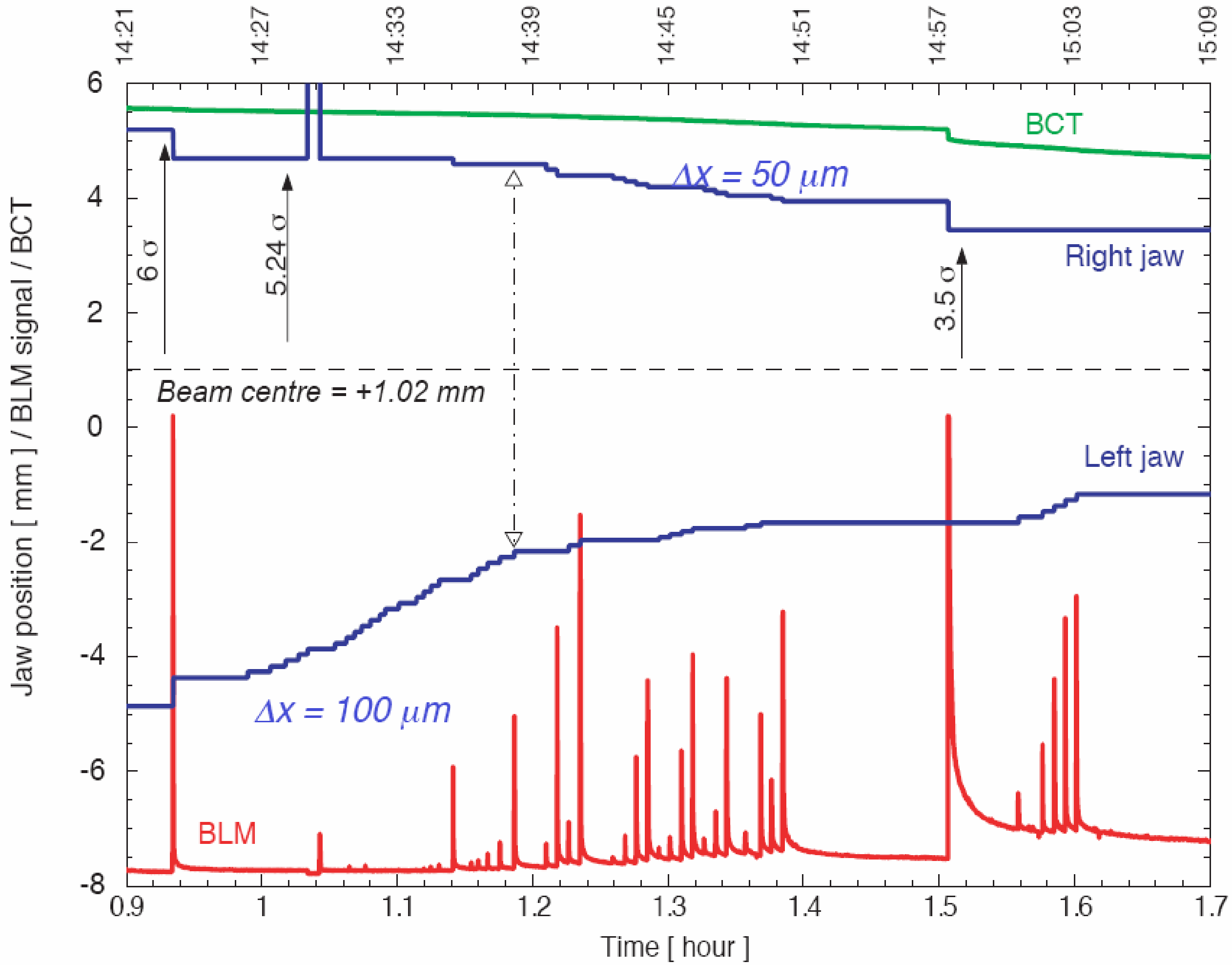


Calibrated center and width of gap, if beam extension is known (e.g. after scraping).

Advance with experience! Rely on BLM system...

SPS Test for LHC Collimator: BLM-based Calibration

$\sigma_x \approx 0.7$ mm



Required time ***< 1h****; Centring repeated at every new coast: ~15 minutes*

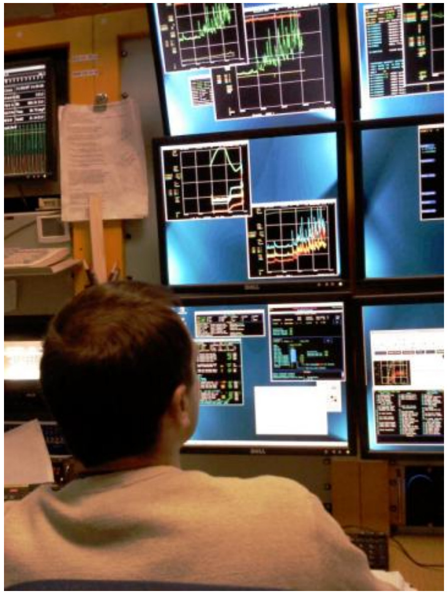
S. Redaelli, Chamonix2005

Learning from Tevatron

- We do now have our own guns at CERN (collimators)!
- Tevatron has the bullets (knowledge how to make collimation work).
- Visits to Fermilab, especially by younger members of the collimation project:
  - S. Readelli (EIC)
  - V. Previtali (PhD)
- Several visits from FNAL experts to CERN.
- Also contacts with BNL on this.

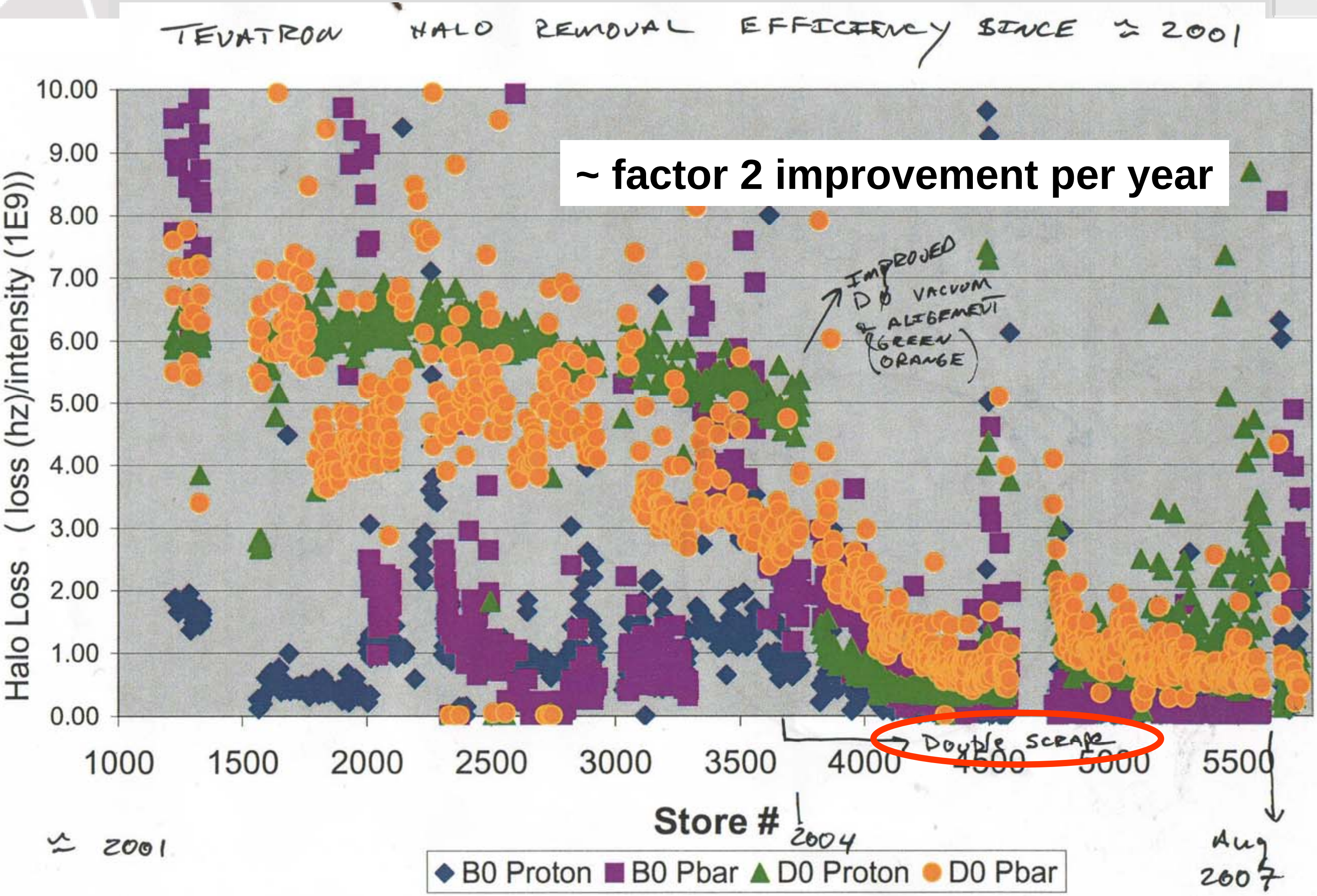
Tevatron Collimation

- Two collimation activities ongoing in parallel last Friday in the Tevatron control room: main injector and Tevatron.
- Must get used to this at CERN…
- Tevatron collimation system is the second system (other less powerful system was used for run I).



A Look at Tevatron

D. Still



My Tevatron Lessons

- Collimation can perform very well if effort is spent.
- Tevatron collimation is only set up by experts (actually ONE expert: Dean Still). Operators only execute pre-defined automatic sequences.
- In order to tune up collimator positions, the beam is touched and small amounts of beam are lost:
  - During collimator tuning the target losses in magnets go up to ~80% of quench threshold.
  - If something goes wrong in collimator tuning a magnet can and will quench.
  - BLM's are bypassed due to excessive rate of false beam dumps.
  - Tevatron has a stable algorithm with a peak maximum loss rate of $6 \times 10^{-3}\ s^{-1}$.
  - Stability is achieved by stopping BLM-based tuning when reaching maximum intensity loss, indicated by fast intensity measurement (kind of cut off at the 3σ point of the Gaussian bean[…]ess stable halo).

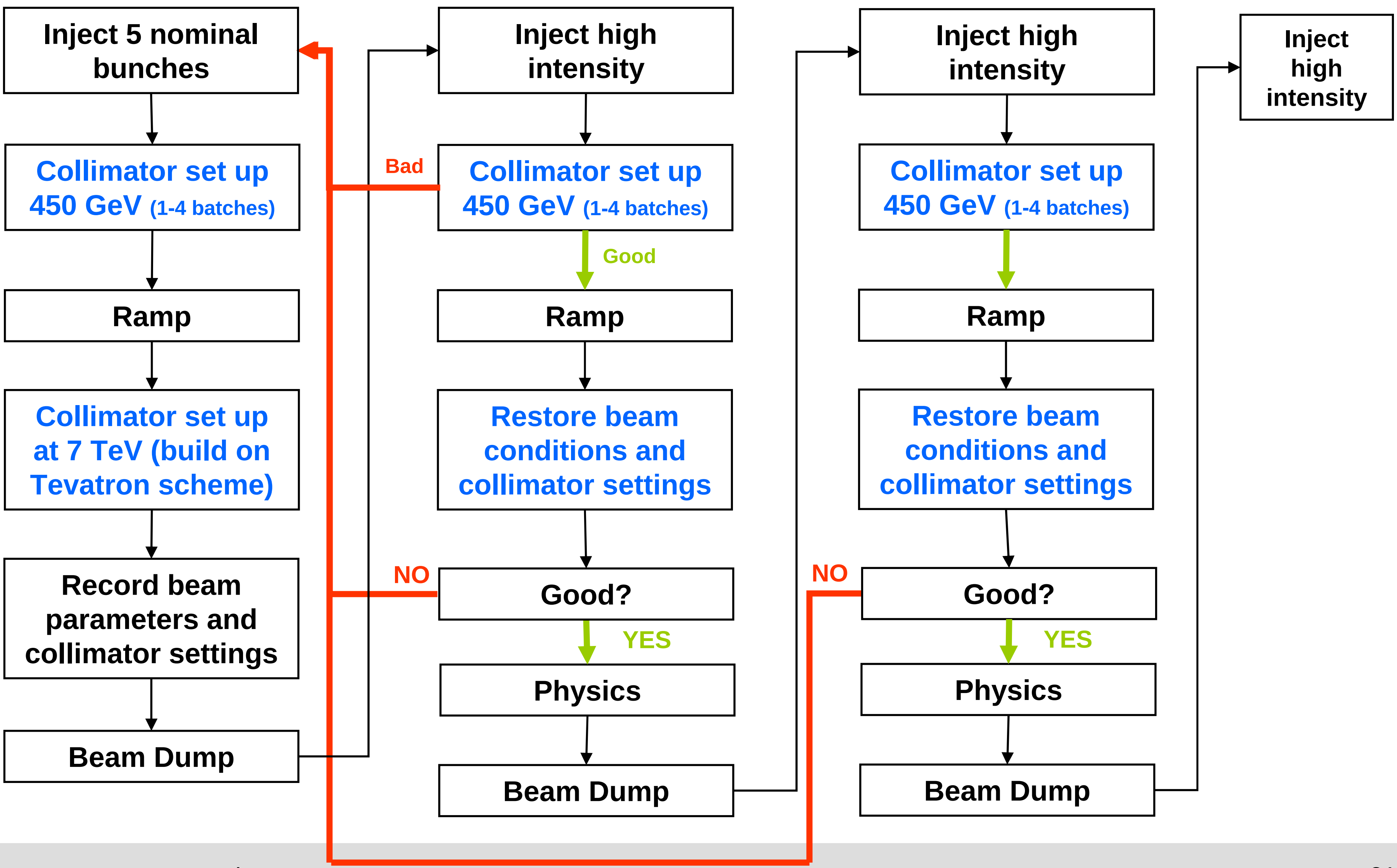
6 times the specified maximum beam loss rate at the LHC with collimation fully set up!

For LHC Collimation

- Train and keep collimation experts for commissioning the LHC system:
  - **S. Redaelli**, 4 years collimation work (fellow + EIC), staff in operations group.
  - **C. Bracco**, 3 years collimation work (PhD), start fellowship in June 08.
  - **V. Previtali**, 1 year collimation work (PhD).
  - **T. Weiler**, 2 years collimation work (present fellow).
  - **M. Jonker**, 3 years collimation work (staff).

  Connected: G. Robert-Demolaize (PhD on LHC collimation).
- Automatic procedures must be in place: Work ongoing (see presentation by M. Jonker at last MAC).
- The intensity information must be added with good rate (100 Hz). To be done.
- Collimator set up in the LHC must work differently than in Tevatron:
  - Nominal LHC at 7 TeV has 200 times higher stored energy than Tevatron.
  - For same quench threshold and set up method, can only allow for 0.5% of LHC beam (14 bunches out of 2808). Note: LHC quench thresholds are even lower!
  - Collimator set up in LHC is foreseen with a few nominal bunches (determined from simulation results on single stage cleaning efficiency – consistent with Tevatron).

Principle for Collimator Set-up at 7 TeV



Set Up Strategy

- Rely on reproducibility of the machine for the baseline.
- This is helped by only working with bunches of ONE intensity – only change number of bunches, not bunch intensity.
- Good **reproducibility and stability** is crucial for the LHC!
- Feedback from orbit measurements to collimator settings, if orbit is not stabilized as specified or not reproducible.
- In parallel work on more advanced methods:
  - Understand changes from 450 GeV to 7 TeV ➔ adjust 7TeV collimator settings with 450GeV data?
  - Do 7 TeV collimator set-up on secondary halo or pattern of beam loss measurement?
  - Phase 2: buttons in jaws for deterministic setup of collimators (center around beam by equalizing pick up signal of two buttons, coupled to jaws).
- Reproducibility is not evident. However, advanced methods challenging!

Definition of “Good” and “Bad”

- Collimation efficiency will be measured after every set-up.
- Measurement method:
  - Generate diffusive beam losses in one plane (will always end up on primary collimator after collimator setup). Can be done with transverse feedback, tunes, kicker, …
  - Measure intensity loss rate (p/s).
  - Record beam loss monitor readings.
  - Increase diffusion speed until the target loss rate (efficiency) is reached.
  - For example with phase 1 we should reach **1×10^{11} p/s** (conclusion: efficiency OK).
  - **Performance reach:** Increase diffusion speed while recording intensity loss rate. Push up to quench or BLM generated abort.

Measured Cleaning Efficiency

- Measure $(dI/dt)_{max}$ at the abort limit of the BLM or until we quench.

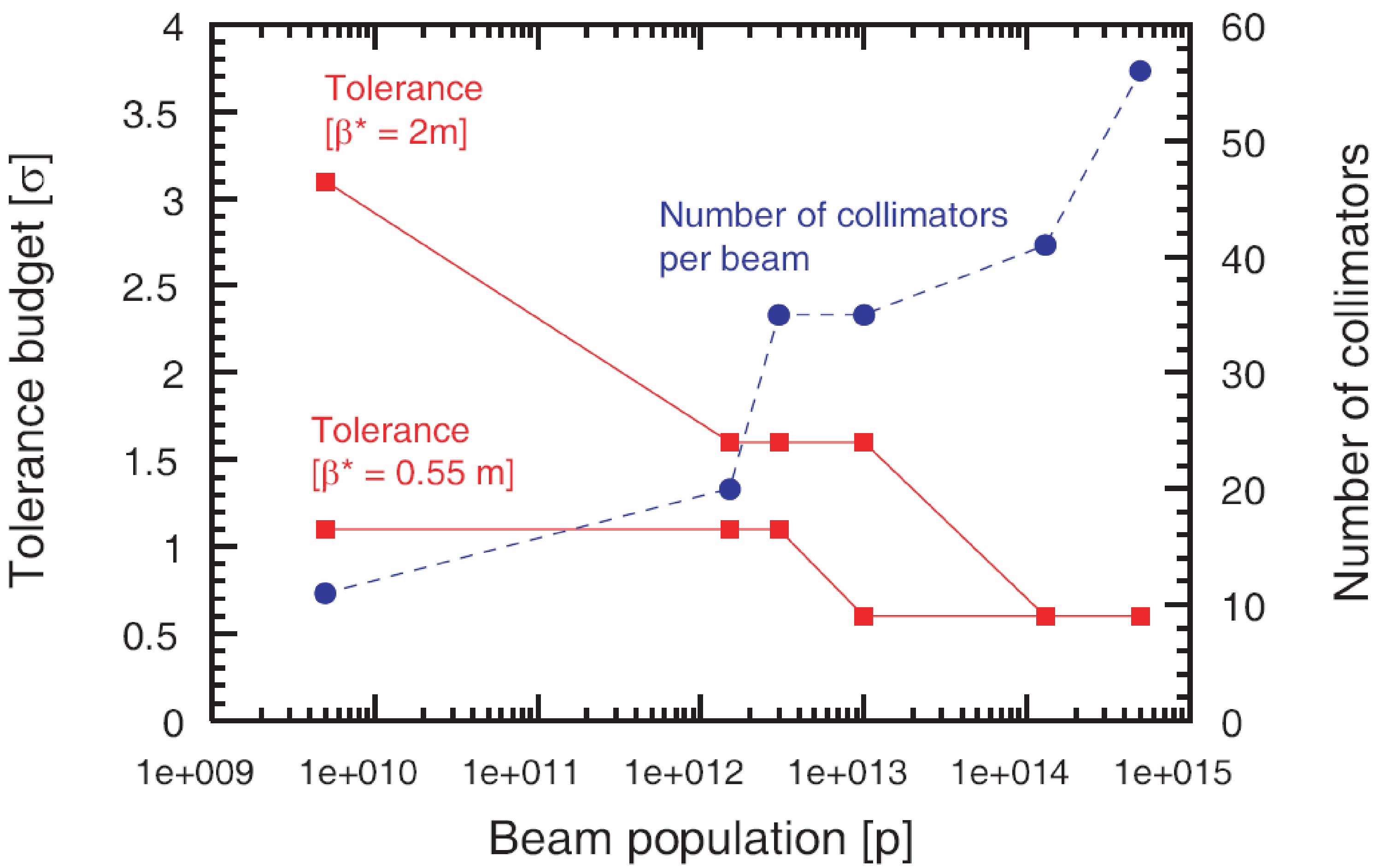
$$(dI/dt)_{\max} = \frac{R_q}{\tilde{\eta}_{ineff}} \quad \Rightarrow \quad \tilde{\eta}_{ineff} = \frac{R_q}{(dI/dt)_{\max}}$$

Known… (R_q)

Measure ($(dI/dt)_{\max}$)

- Deliverable of the collimation system: Target cleaning efficiency (support DC betatron beam losses of up to **1.6×10^{11} p/s at 7 TeV – 200 kJ/s**).
- Once design has been reached, the collimation is commissioned.
- Can be achieved, once full phase 1 is installed: **2009**. Should be able to reach 0.8×10^{11} p/s with 2008 system.

Commissioning Preparations: Start with Less Collimators and Relaxed Tolerances

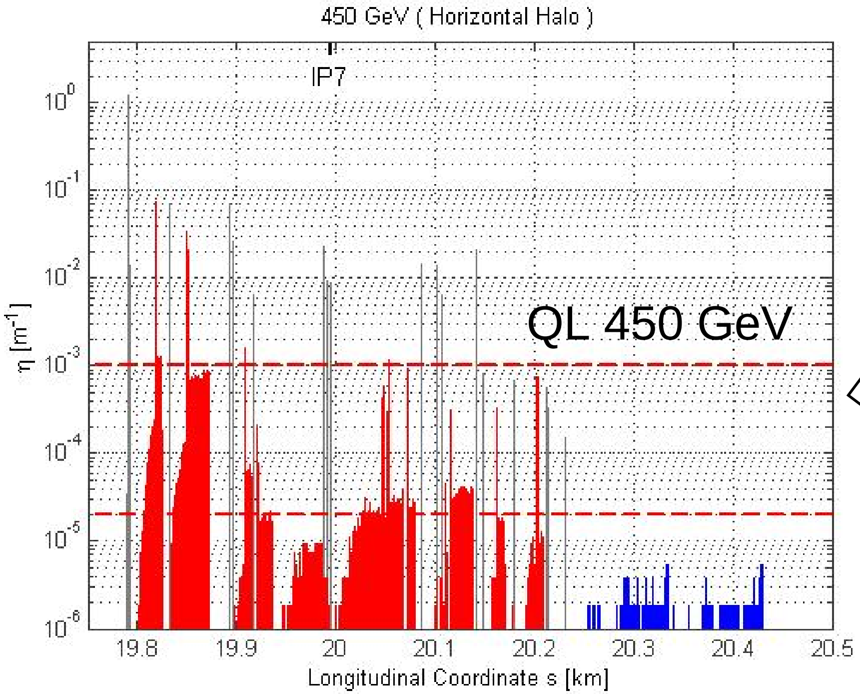


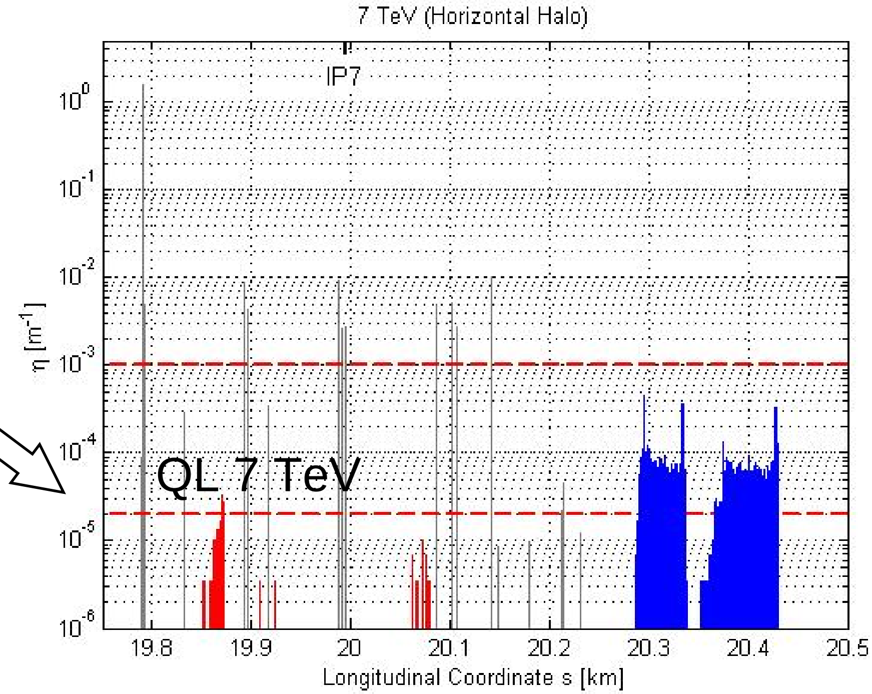
Commissioning Preparations: 7 TeV Settings for Various Intensities

Intensity	β^* [m]	n_1 [σ]	n_2 [σ]	n_a [σ]	n_3 [σ]	n_{tcdq} [σ]
5.0×10^9	2.00	10.0	-	-	17.0	13.5
1.5×10^{12}	2.00	6.0	-	10.0	17.0	8.0
3.0×10^{12}	2.00	6.0	9.5	10.0	17.0	8.0
1.0×10^{13}	2.00	6.0	8.0	10.0	17.0	8.0
1.3×10^{14}	2.00	6.0	7.0	10.0	17.0	8.0
5.0×10^{14}	2.00	6.0	7.0	10.0	17.0	8.0
5.0×10^9	0.55	6.0	-	-	8.3	7.5
1.5×10^{12}	0.55	6.0	-	10.0	8.3	7.5
3.0×10^{12}	0.55	6.0	8.0	10.0	8.3	7.5
1.0×10^{13}	0.55	6.0	7.0	10.0	8.3	7.5
1.3×10^{14}	0.55	6.0	7.0	10.0	8.3	7.5
5.0×10^{14}	0.55	6.0	7.0	10.0	8.3	7.5

Commissioning Preparations: Efficiency and Quench Limit During the Ramp

C. Bracco





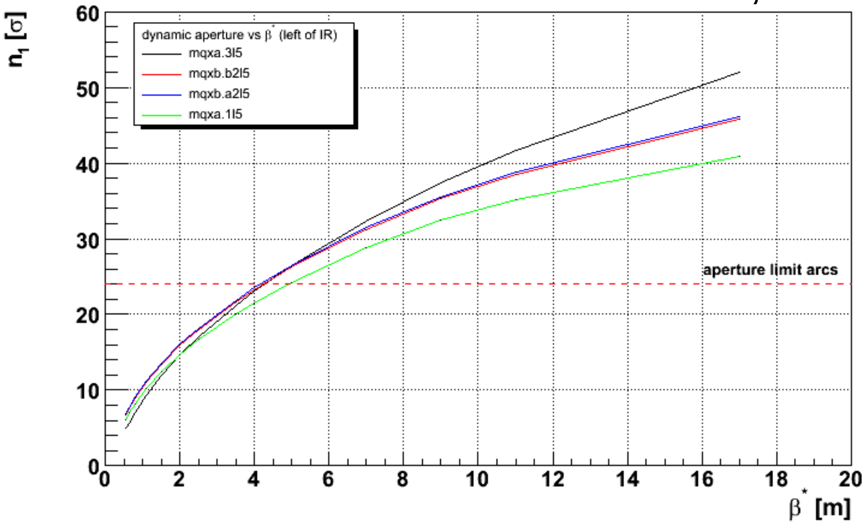
Two observations: 1) Quench limits go down.

2) Local losses in DS go up because collimator not closed!

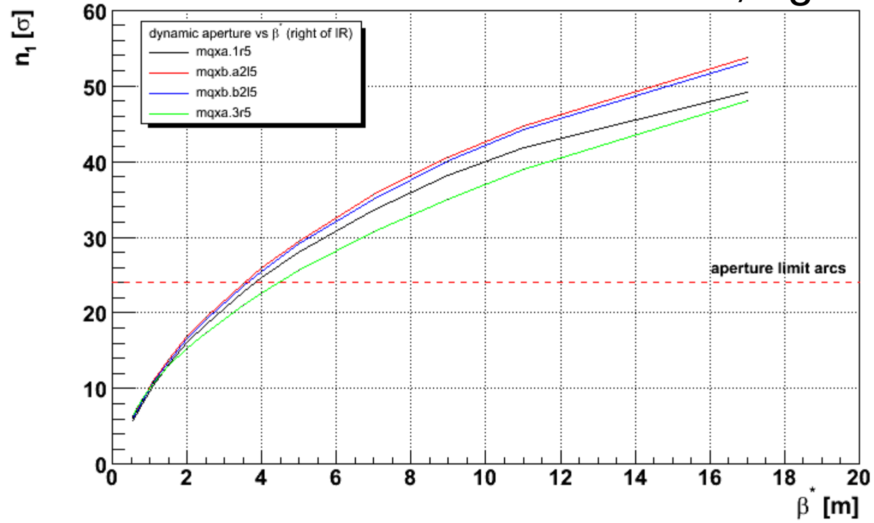
Commissioning Preparations: Triplet Aperture During Squeeze

T. Weiler

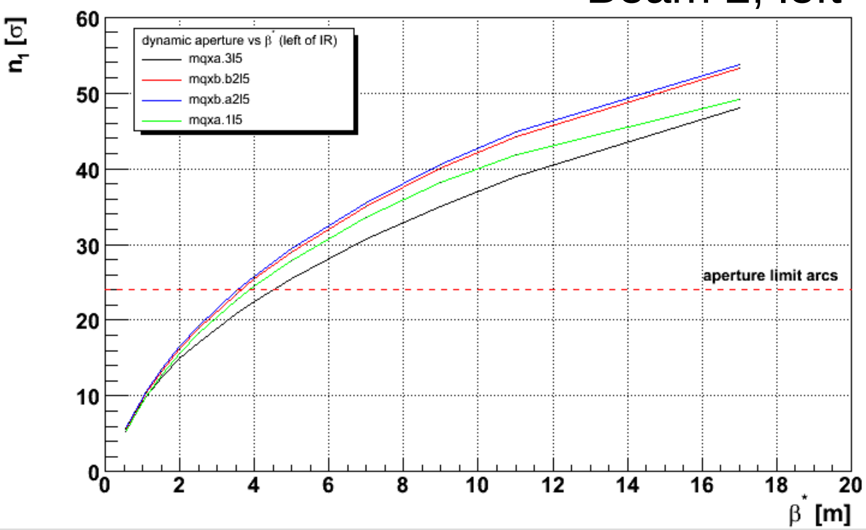
Beam 1, left



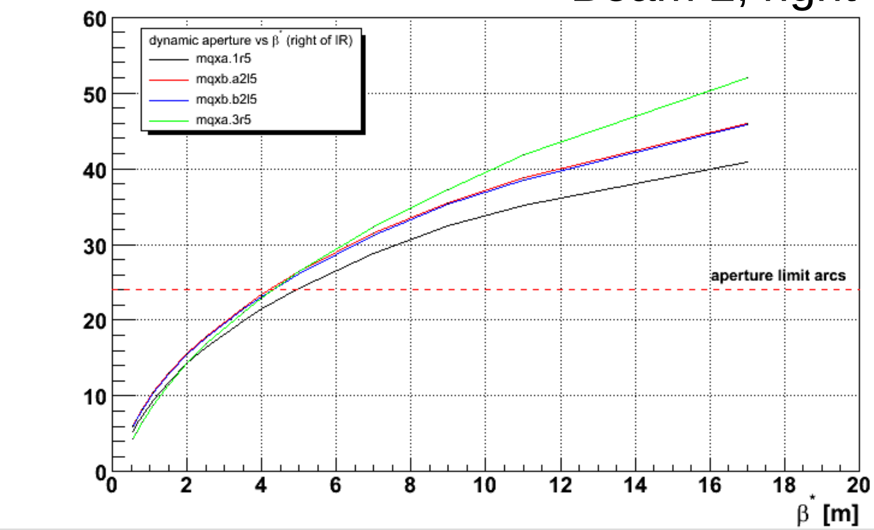
Beam 1, right



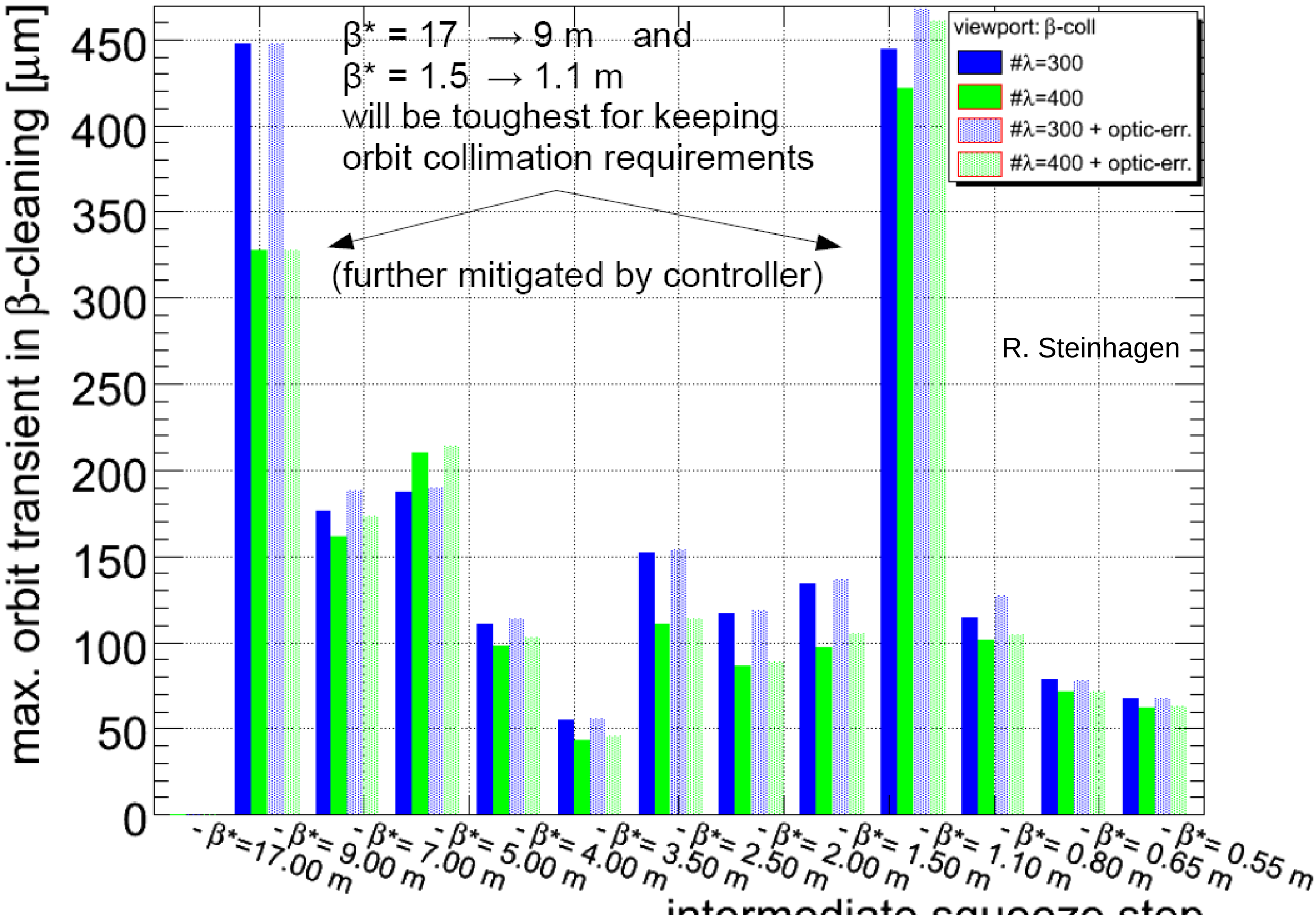
Beam 2, left



Beam 2, right

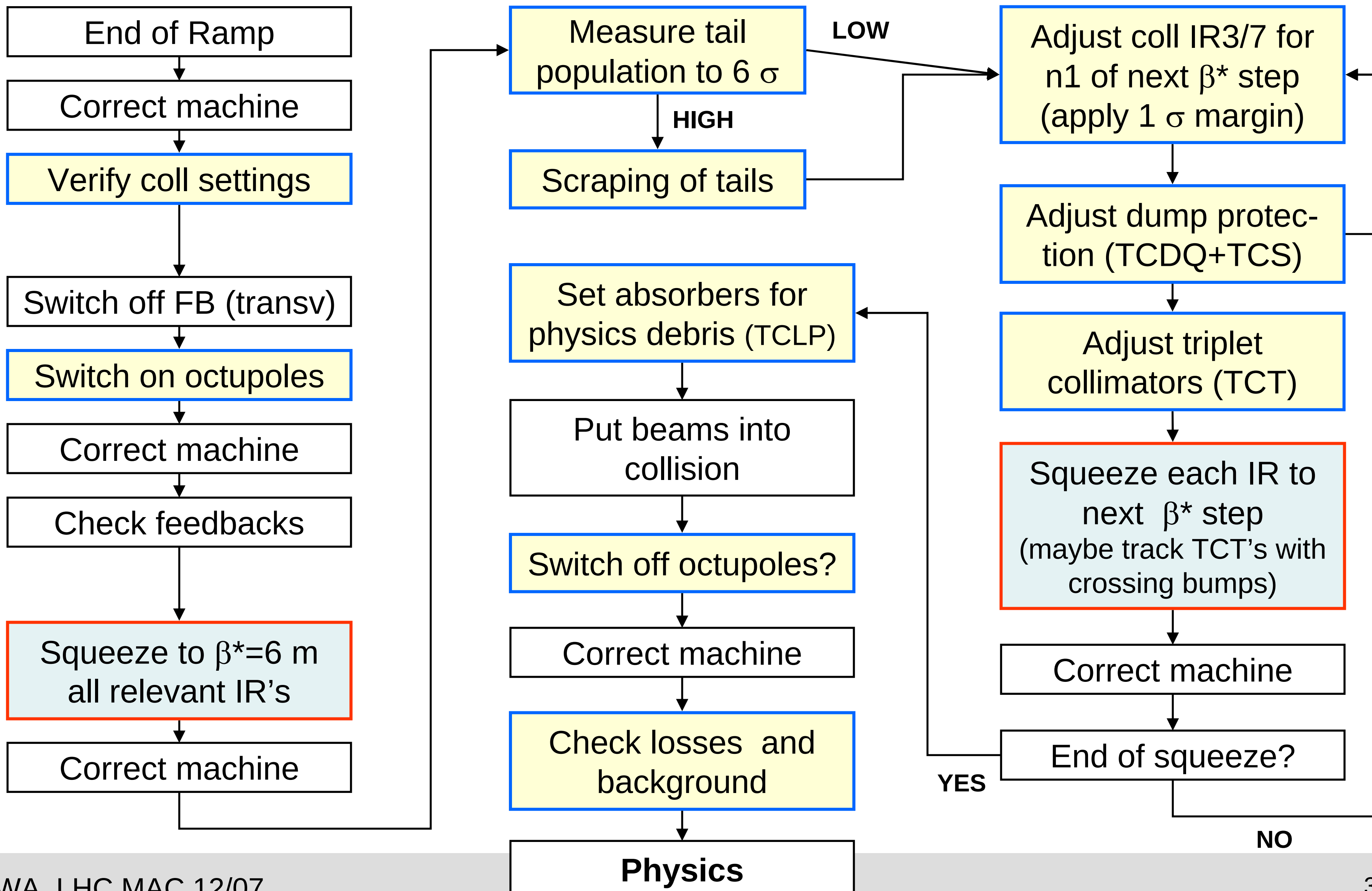


Transient in Collimation Insertion vs. Squeeze Step
- moderate global orbit correction only (commissioning)

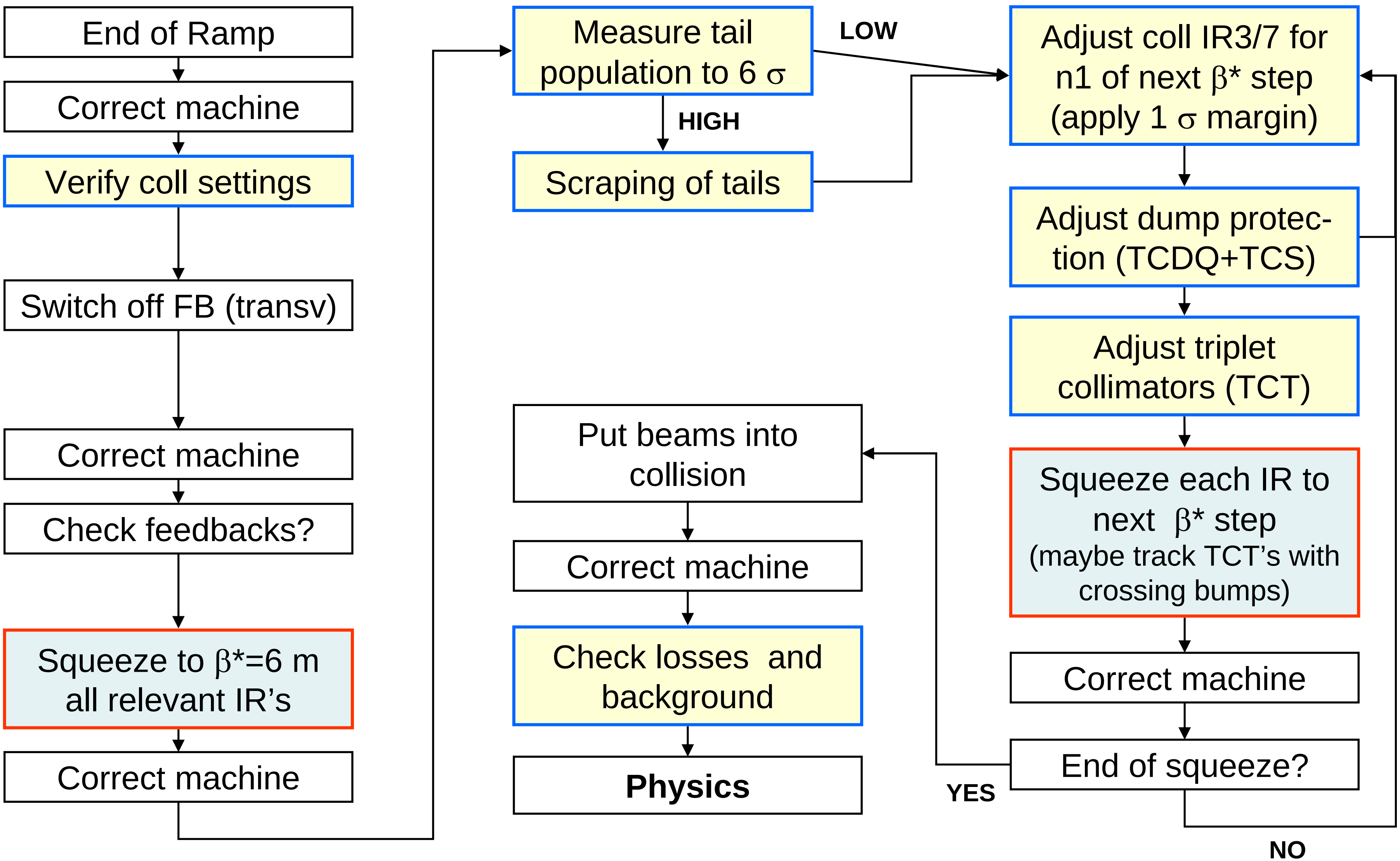


based on 10^5 orbit samples

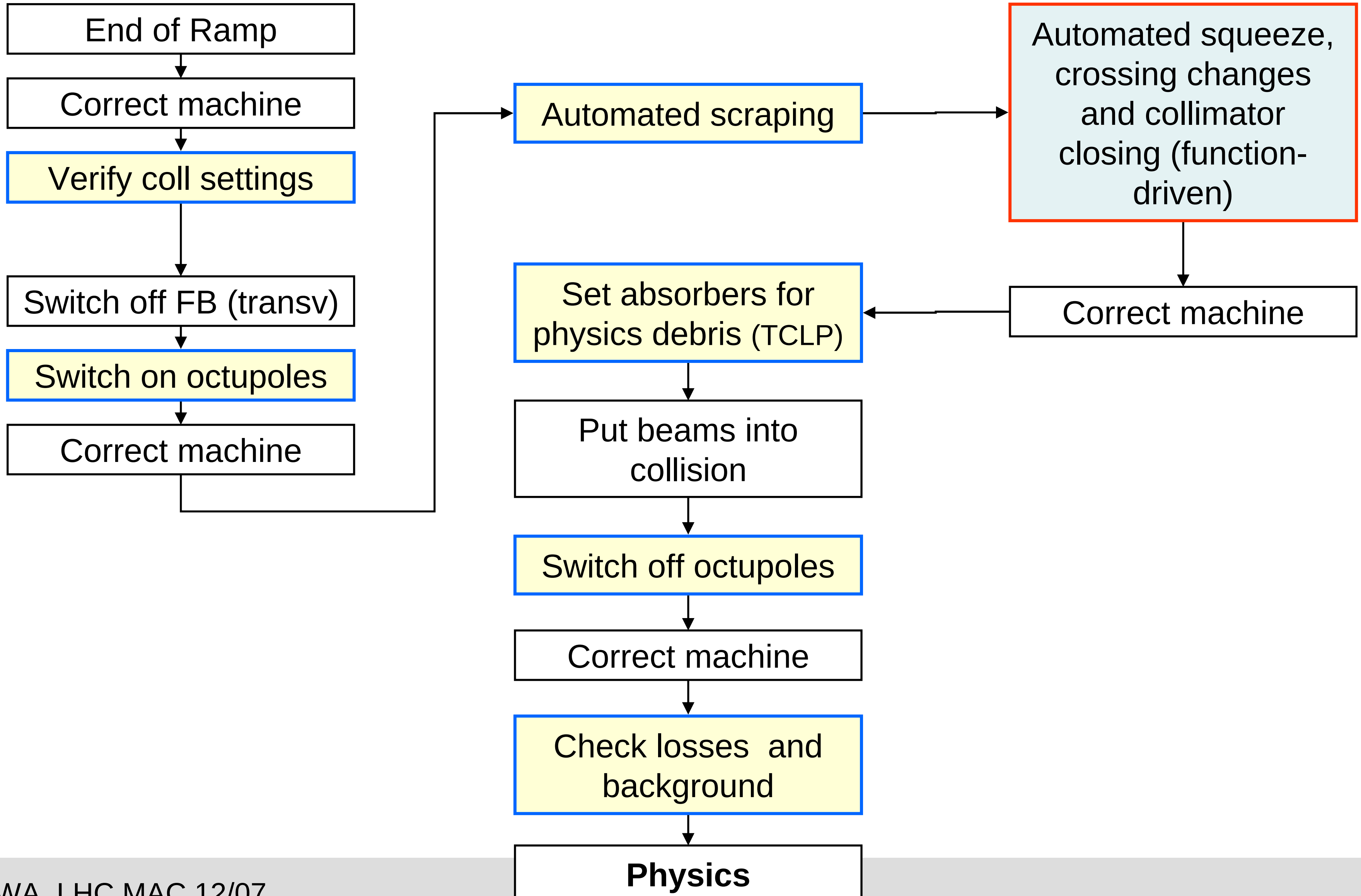
Commissioning Preparations: Collimation During the Squeeze



Commissioning Preparations: Collimation During the Squeeze (Low Intensity)



Commissioning Preparations: Squeeze Routine Operation Procedure



Summary

- LHC collimation on track for beam in May 2008.
- Thorough hardware commissioning and cold checkout is establishing known collimators with safe position monitoring.
- Results look very promising with some issues being addressed.
- All results from production, HWC and cold checkout documented on project web site (easily accessible from the control room).
- A **strong team has been trained for collimator commissioning**. Try to learn as much as possible from Tevatron and RHIC. PhD on commissioning: May 2008.
- Collimation set-up is necessarily different from Tevatron! Procedures have been worked out, based on detailed LHC simulations (number of collimators versus performance, ramp, squeeze, …).
- ‘Phase 1’ collimation commissioning must be supported by ‘phase 2’ implementation, such that performance can be continuously improved (Tevatron: factor 2 per year over 6 years).