LHC Beam Preparation

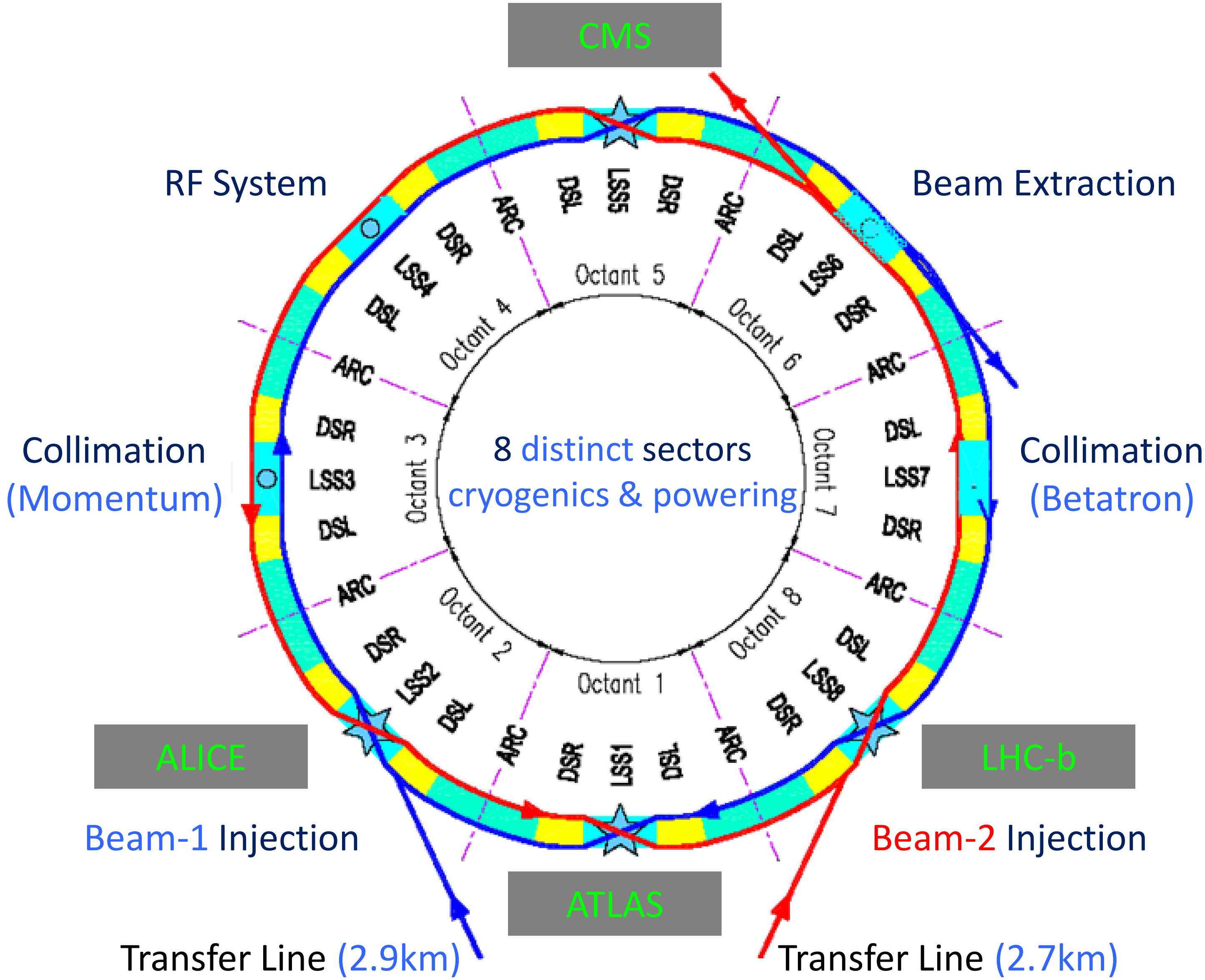
R. Giachino CERN

WAO 2010

Outline

1. Introduction
2. Timeline of the LHC
3. Hardware Commissioning
4. Dry run and Machine Checkout
5. Conclusions

LHC Schematic



LHC Timeframe

2002	2003	2004	2005	2006	2007	2008

LHC Timeframe

Tunnel: - - - LEP

2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008

Decommissioning of the LEP machine

LHC Timeframe

Tunnel: - - - LEP → ← Helium Distribution Line →

2002	2003	2004	2005	2006	2007	2008

27kms of helium line installed by supplier,
Significant problems with:
• Geometry • Leaks • Welds • Procedures …

LHC Timeframe

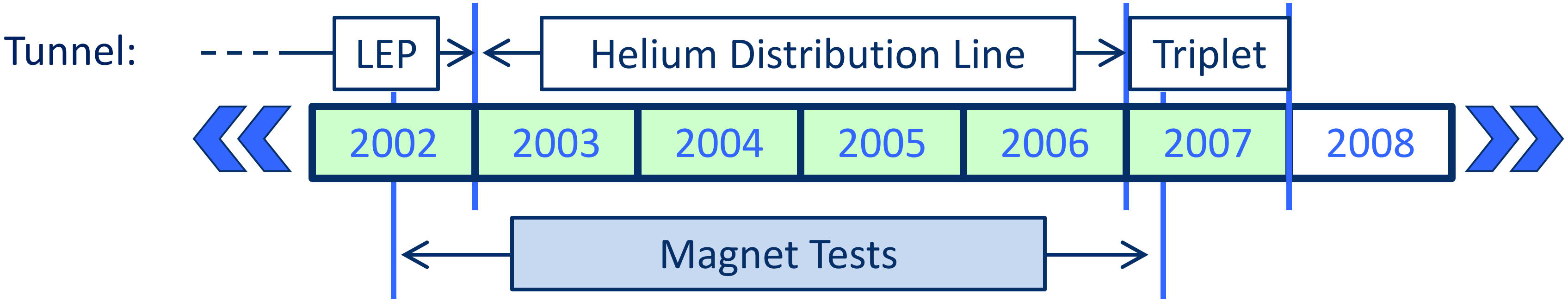
Tunnel: - - - LEP → ← Helium Distribution Line → Triplet

2002	2003	2004	2005	2006	2007	2008

Inner Triplets – Either side of each experiment

Three superconducting magnet assemblies

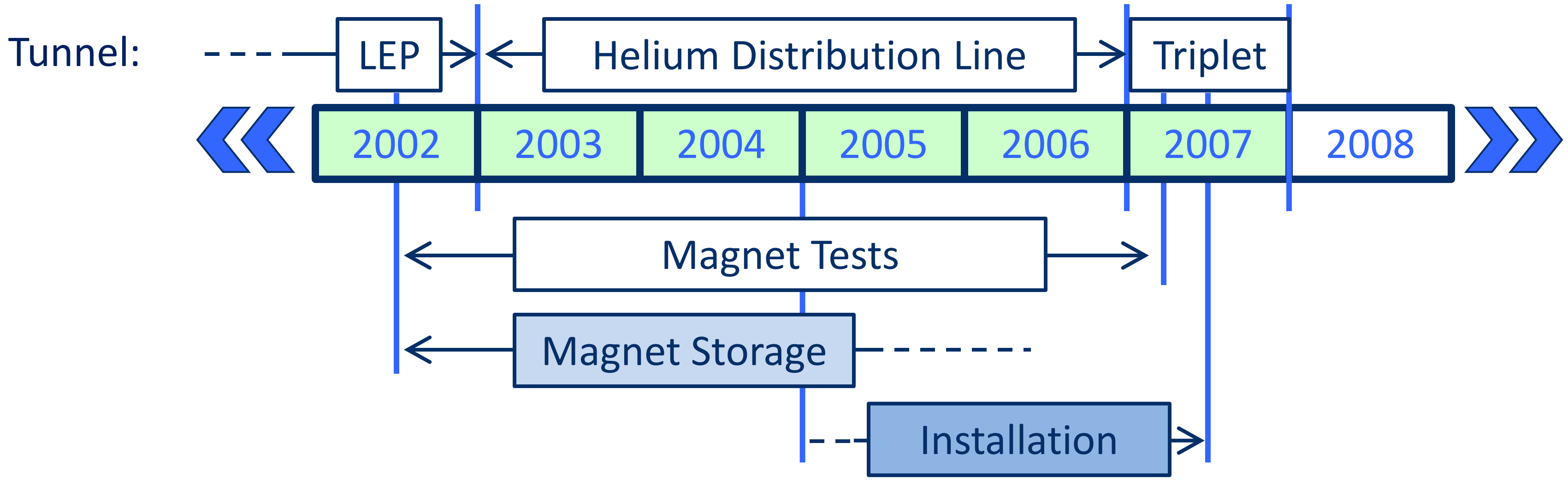
LHC Timeframe

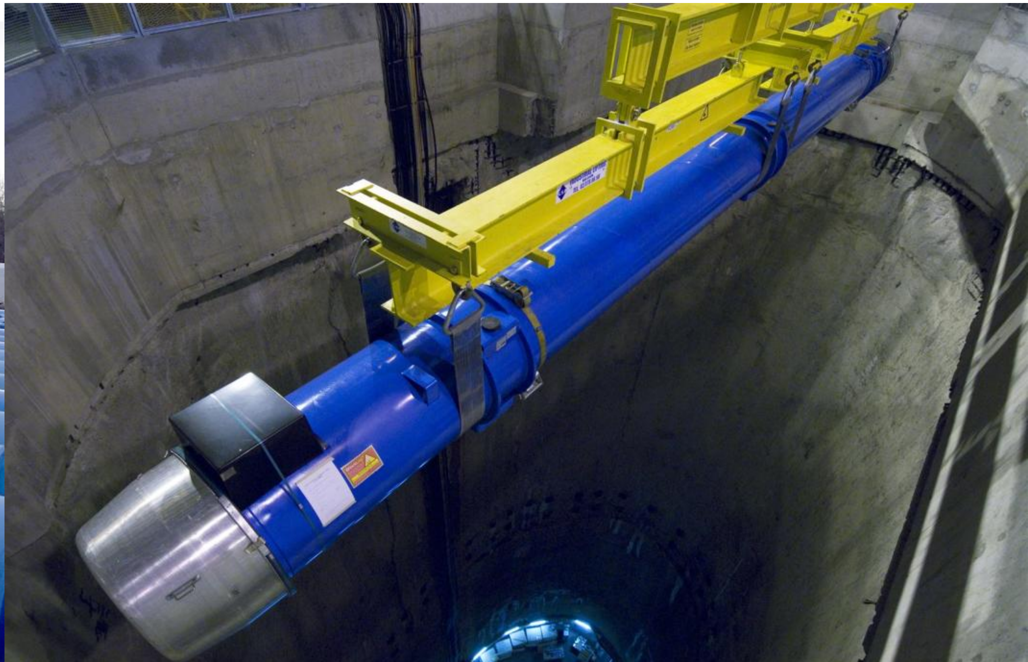


Magnets put into Cryostats

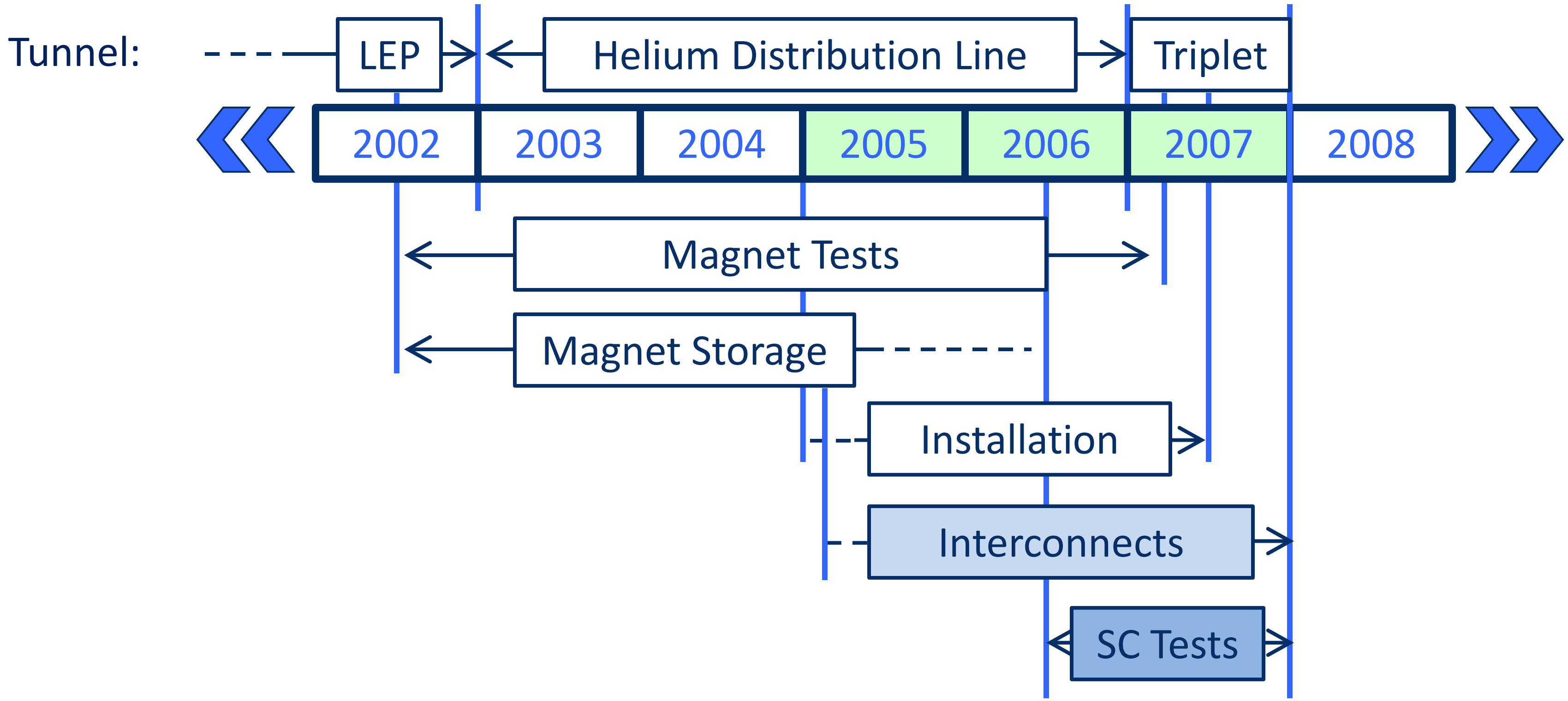
Magnets Tested and Characterised

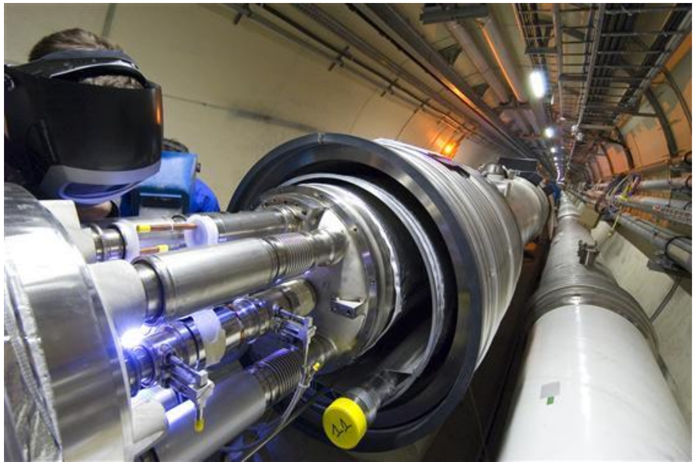
LHC Timeframe





LHC Timeframe



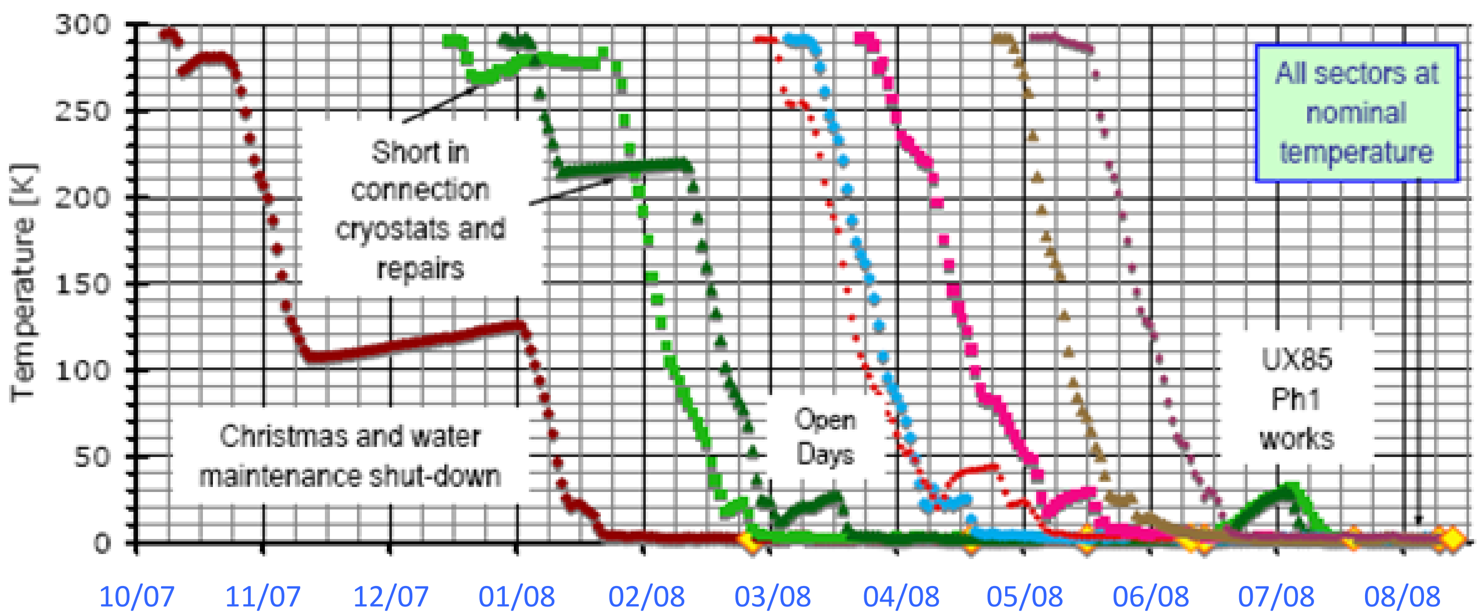


LHC Timeframe

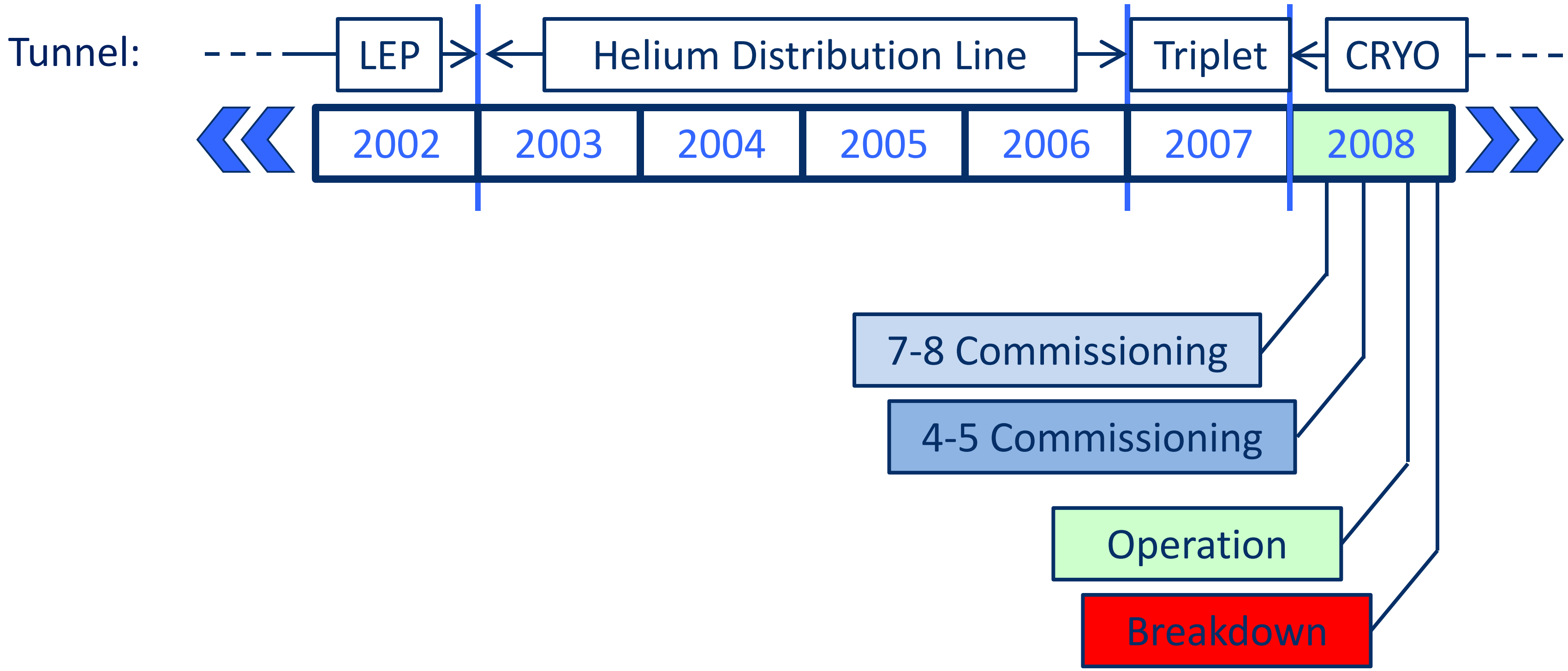
Tunnel: LEP → ← Helium Distribution Line → Triplet ← CRYO

2002	2003	2004	2005	2006	2007	2008

Cool down the machine for operation



LHC Timeframe



LHC Hardware Commissioning

Commissioning of the magnets & circuits follows predefined test steps.

(power converter, quench protection, interlocks..)

1’700 circuits, 10’000 magnets Commissioning time ~5 months

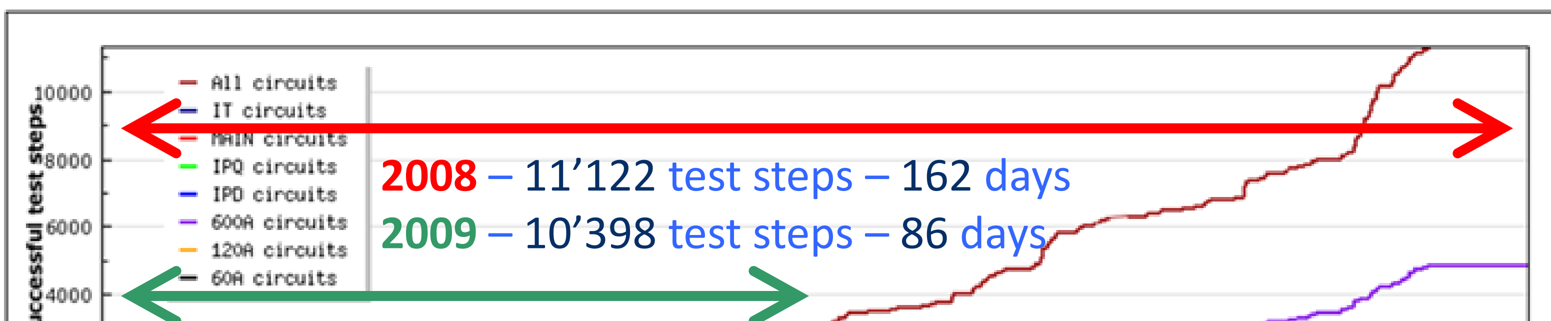
LHC commissioned for a beam energy of:

2008: 5.5 TeV (5 TeV target for physics).

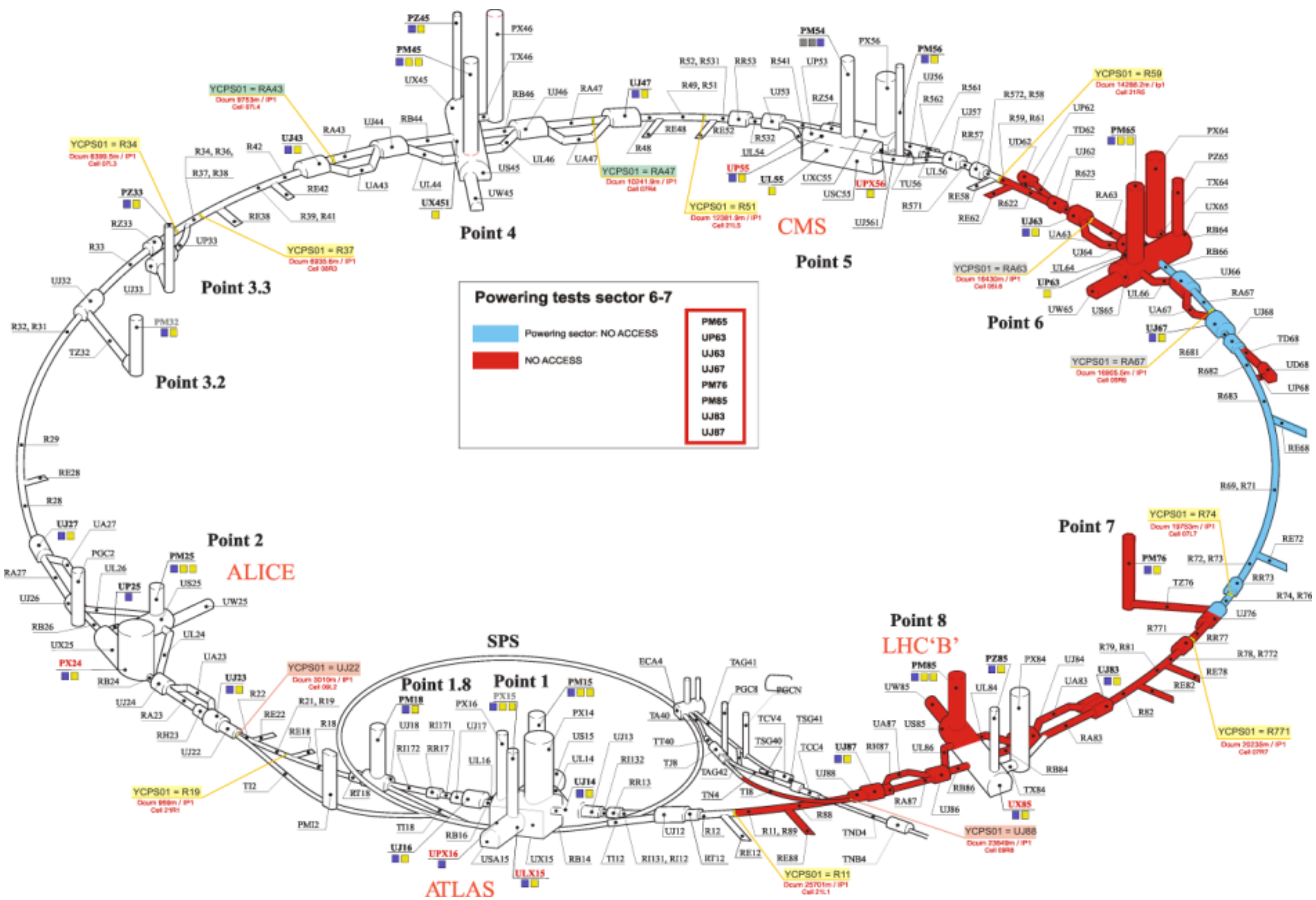
Issue with Magnet re-training required above ~6 TeV.

2009: 1.2 TeV (incident, commissioning delays).

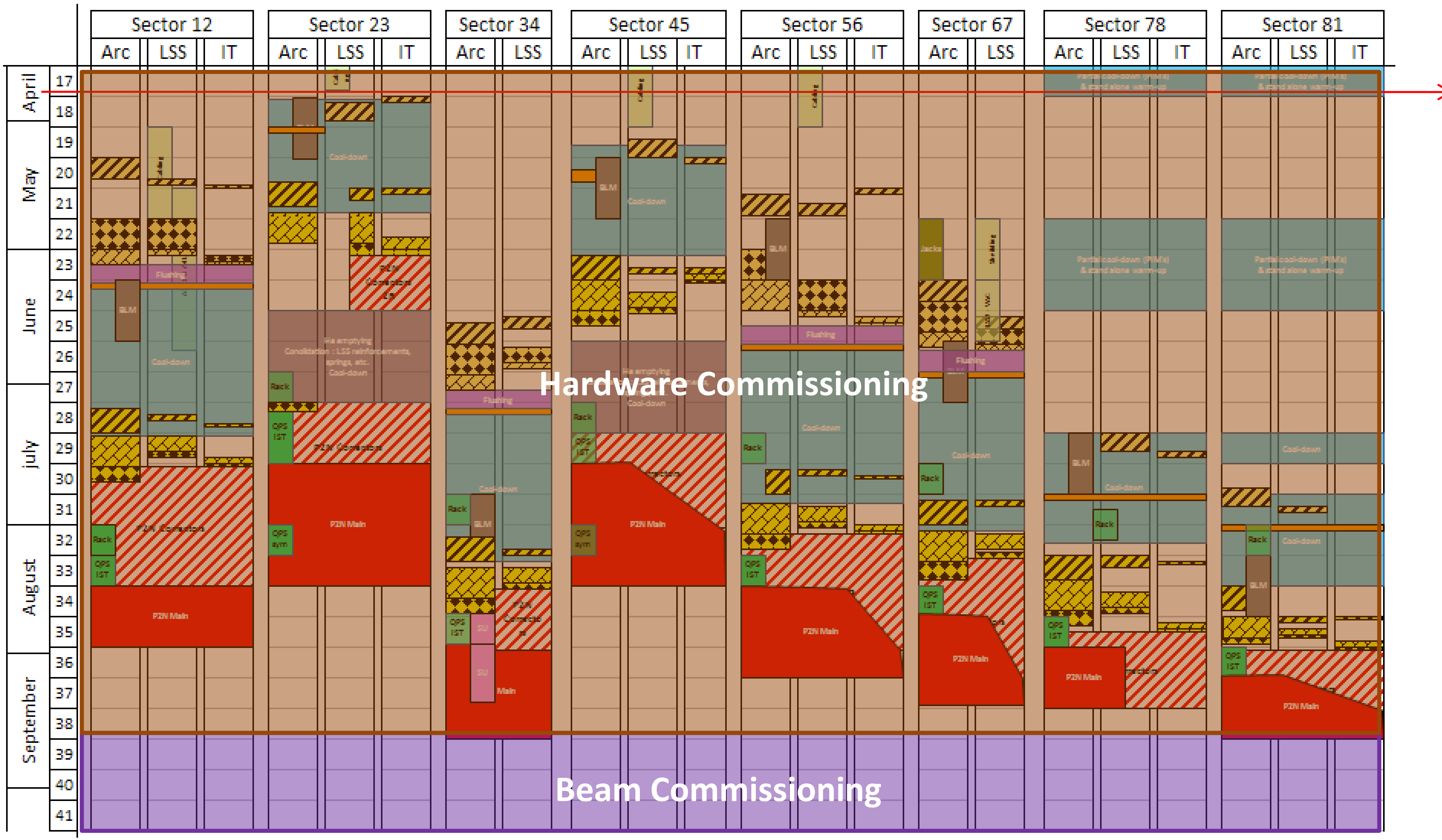
2010: 3.5 TeV (limited by joint quality).



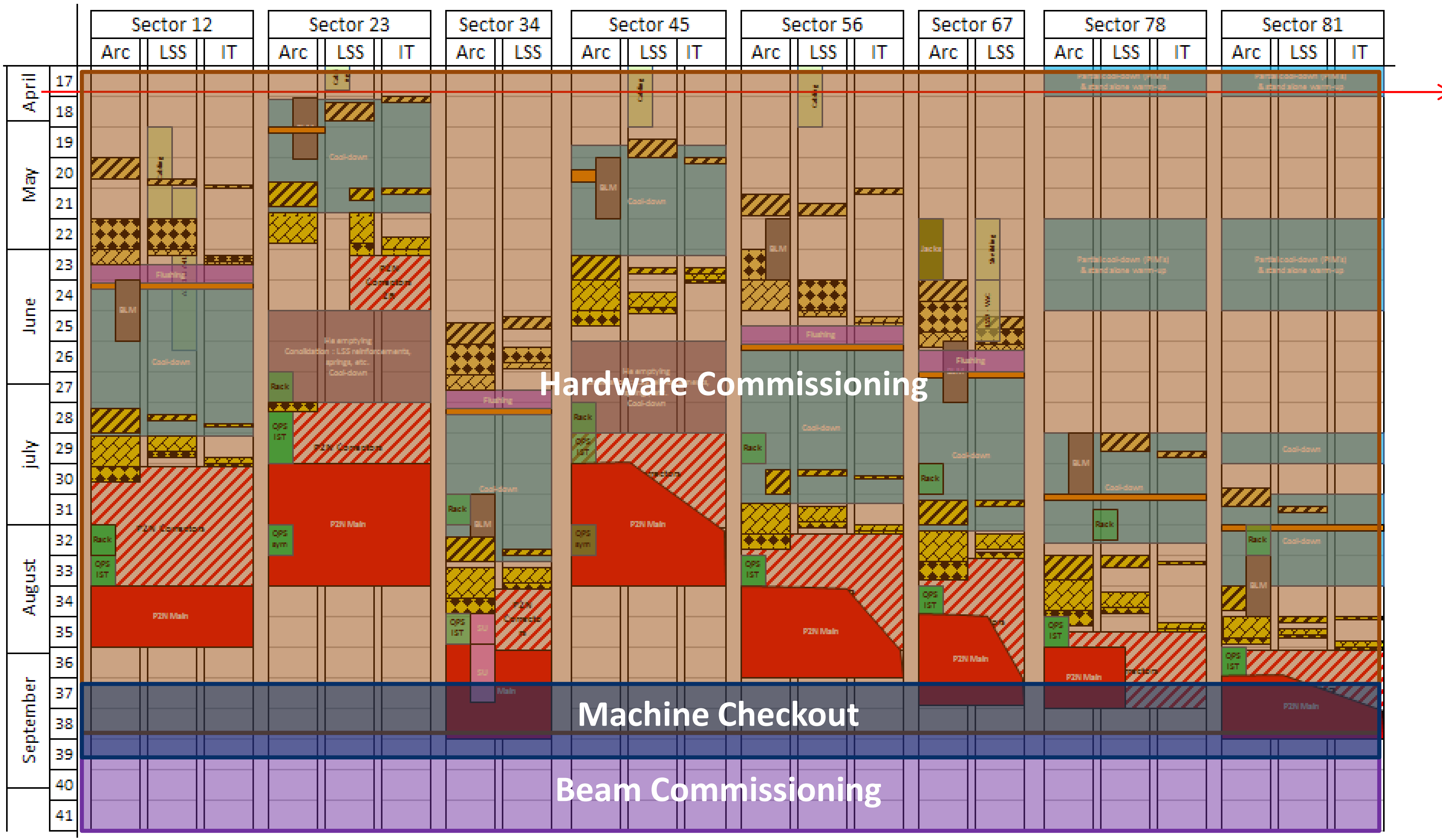
IF hardware intervention NO possible power on the adjacent sectors



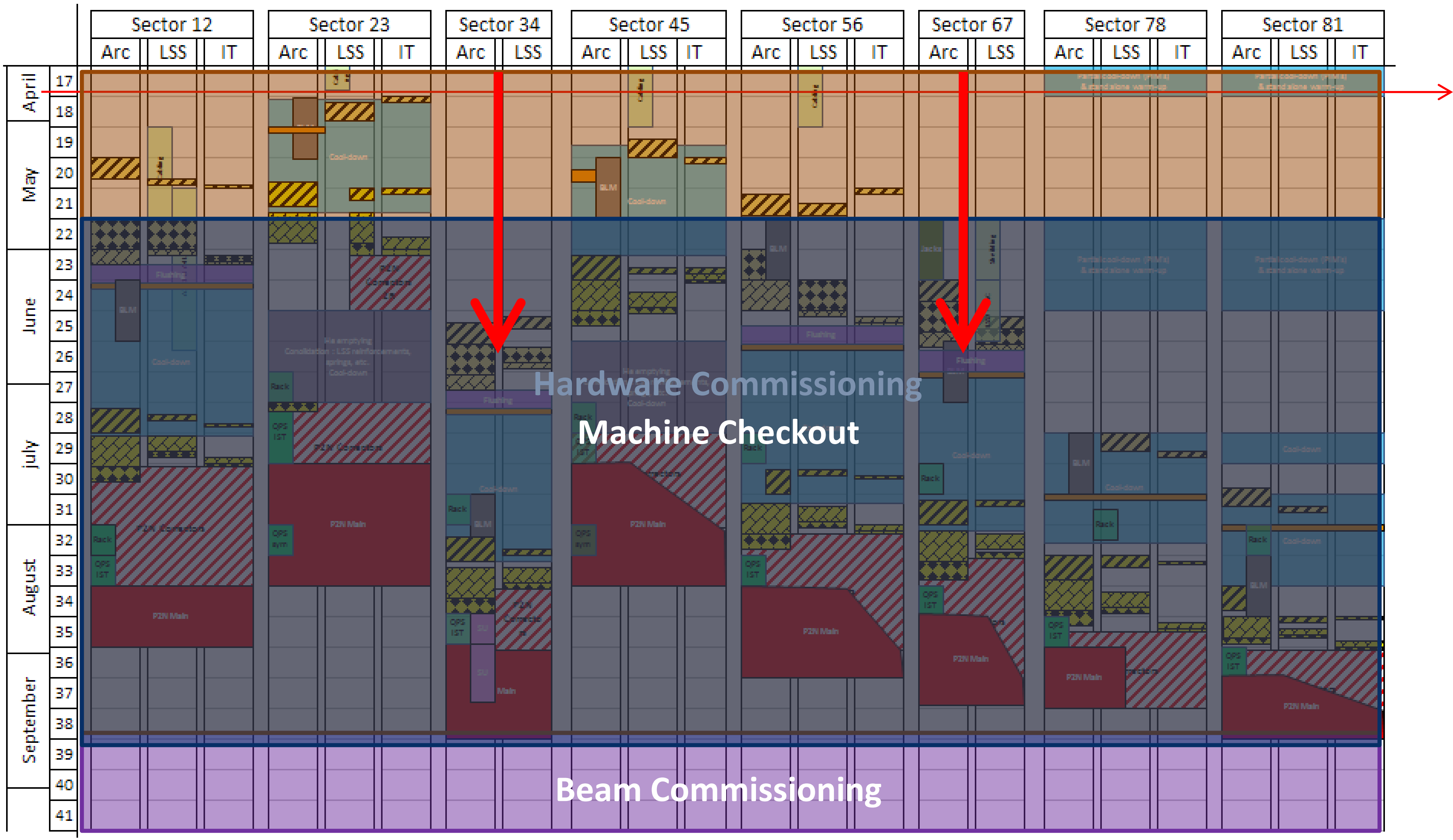
LHC schedule



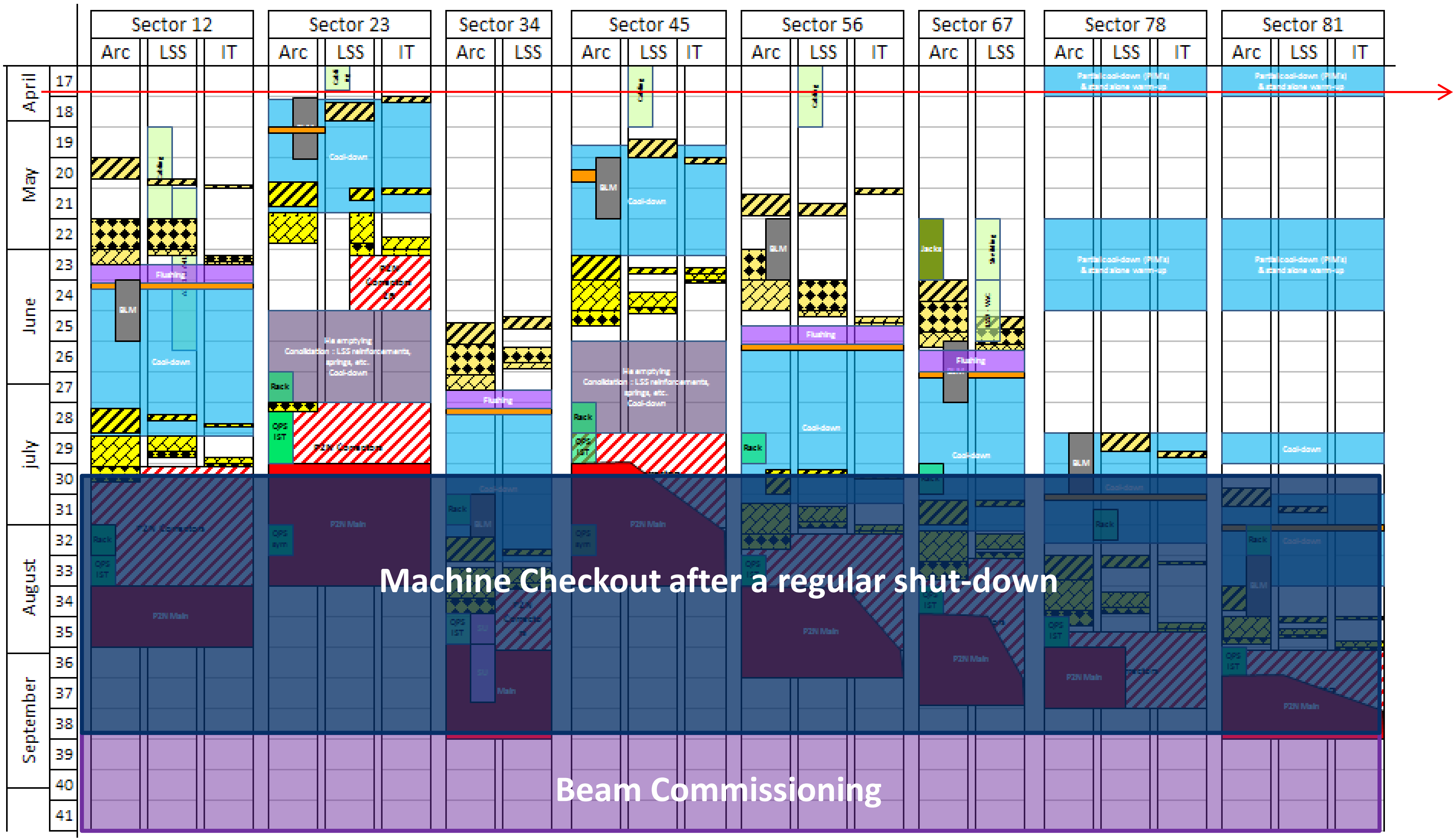
LHC schedule



LHC schedule



LHC schedule



Machine Preparation for Beam

Dry runs

- Started in 2003 (injection lines)
- Individual system tests conducted by the equipment groups
- Blocks of few days spaced by few weeks for analysis and correction of the problems
- In Cern Control Centre using operational software
- Driven by System Experts, System Commissioners and EiCs

Machine check-out

- Test of the different circuits/sectors in unison and in operational conditions (acceleration rates, settings) once released by Hardware Commissioning
- Integration of the various accelerator systems (injection, beam dump, RF, collimators, beam interlocks, alarms, etc.) once debugged in Dry Runs.
- In Cern Control Centre using operational software
- Driven by the “users” (EiCs, Operators)

verifying the operation of several systems, mimicking different operational phases
(e.g. Injection, ramp, squeeze, beam dump, interlocks tests, etc.)

Machine Check-Out

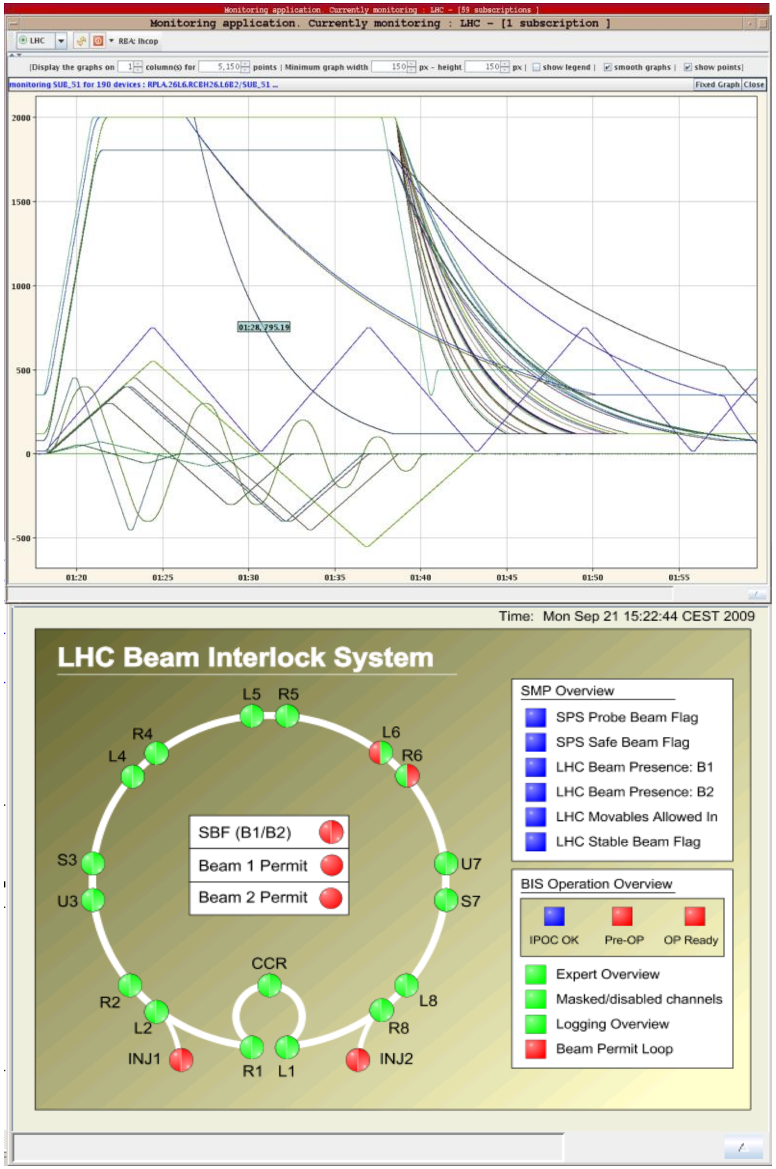
Verification of the remote control functionalities for the various systems as they became available from Hardware Commissioning:

- Magnetic circuits
- Injection & extraction elements
- Beam instrumentation

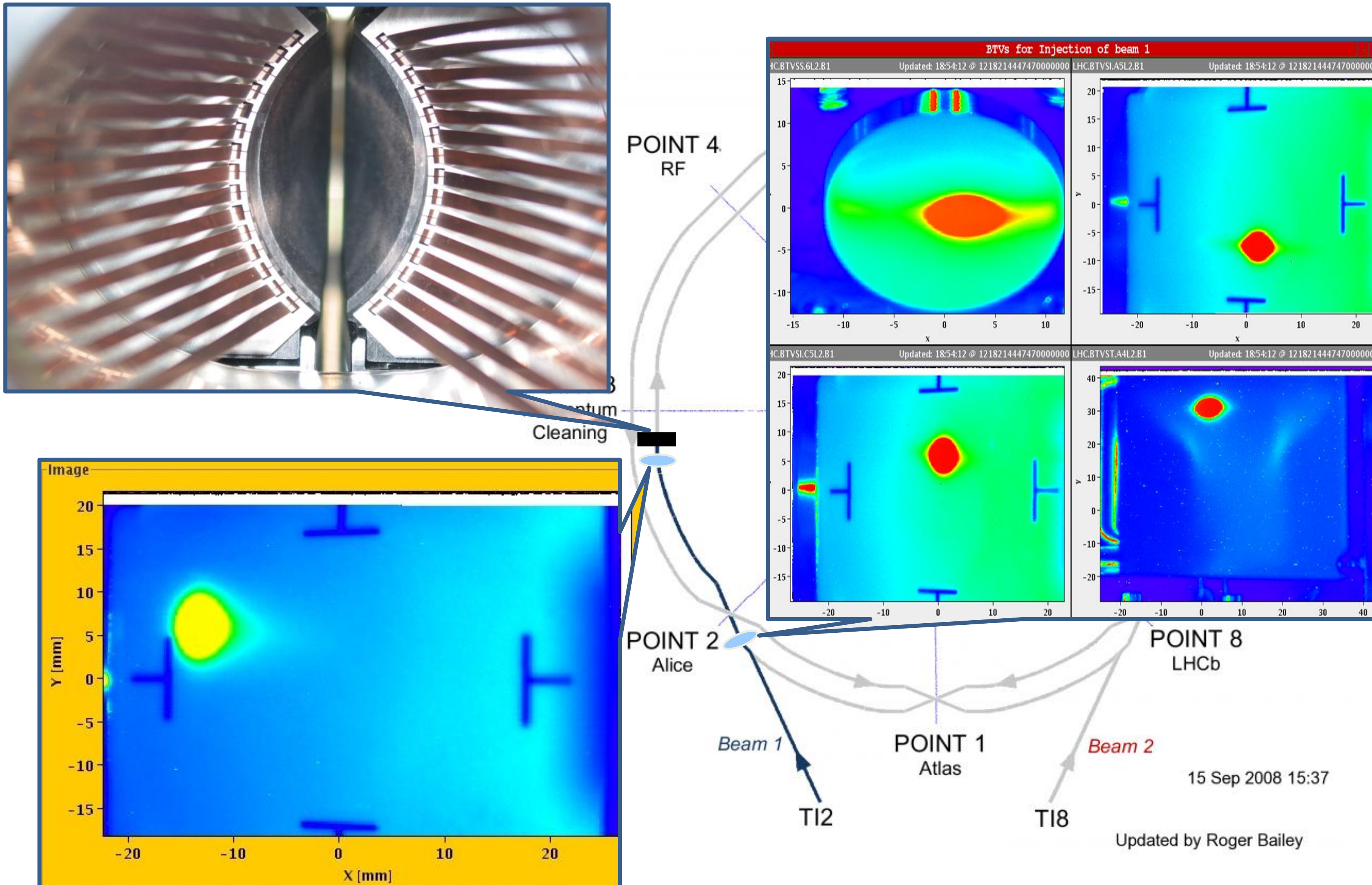
Synchronous powering of circuits together with other systems (e.g. collimators, RF)

Validation of the Beam Interlocks

- Vacuum valves
- Power converters
- Beam Loss Monitors
- Experiments



1st Beam Injection Test (8-10 Aug.)



1st Beam Injection Test (8-10 Aug.)

What we did:

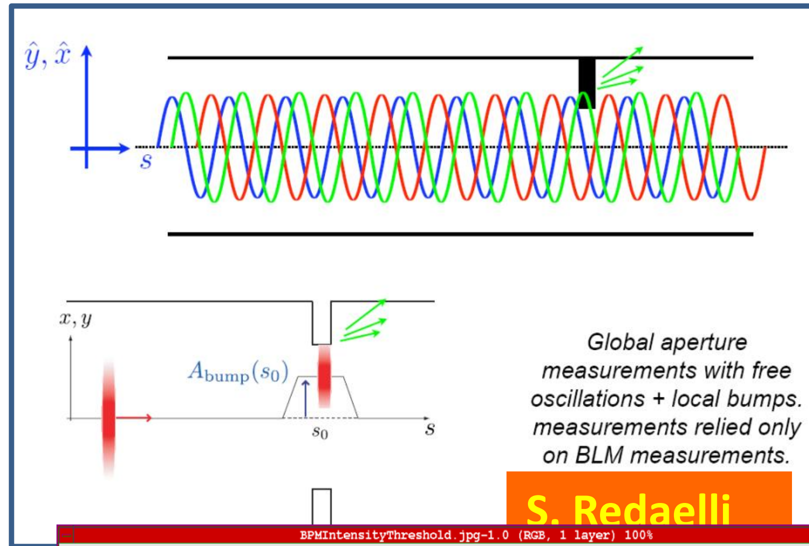
- Trajectory correction
- Optics measurements
- **Physical aperture measurements**
- Instrumentation setup

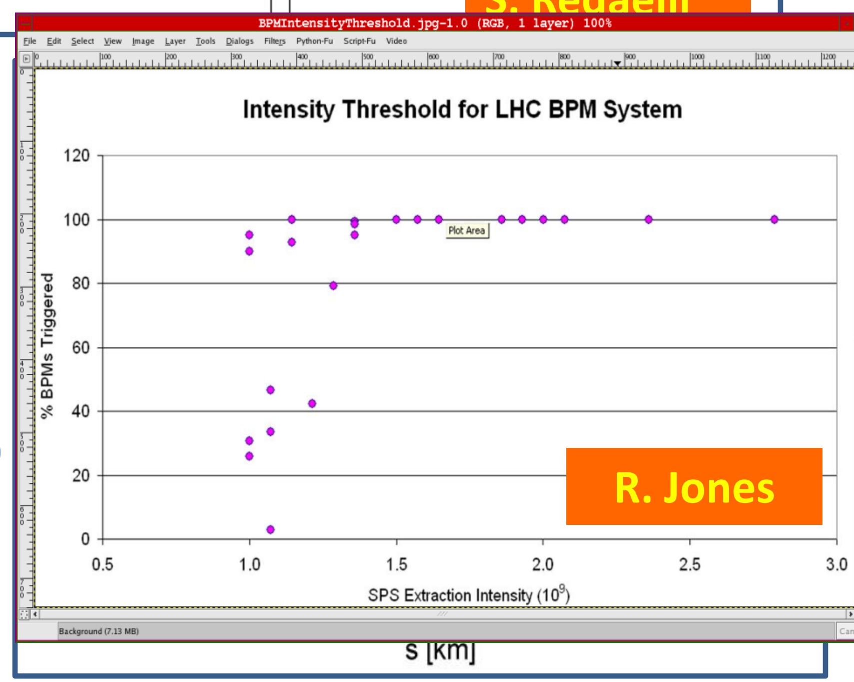
What we found:

- Quench limit: ~4×10^9 p (as expected)
- **BPM sensitivity (excellent)**
- Injection aperture restriction

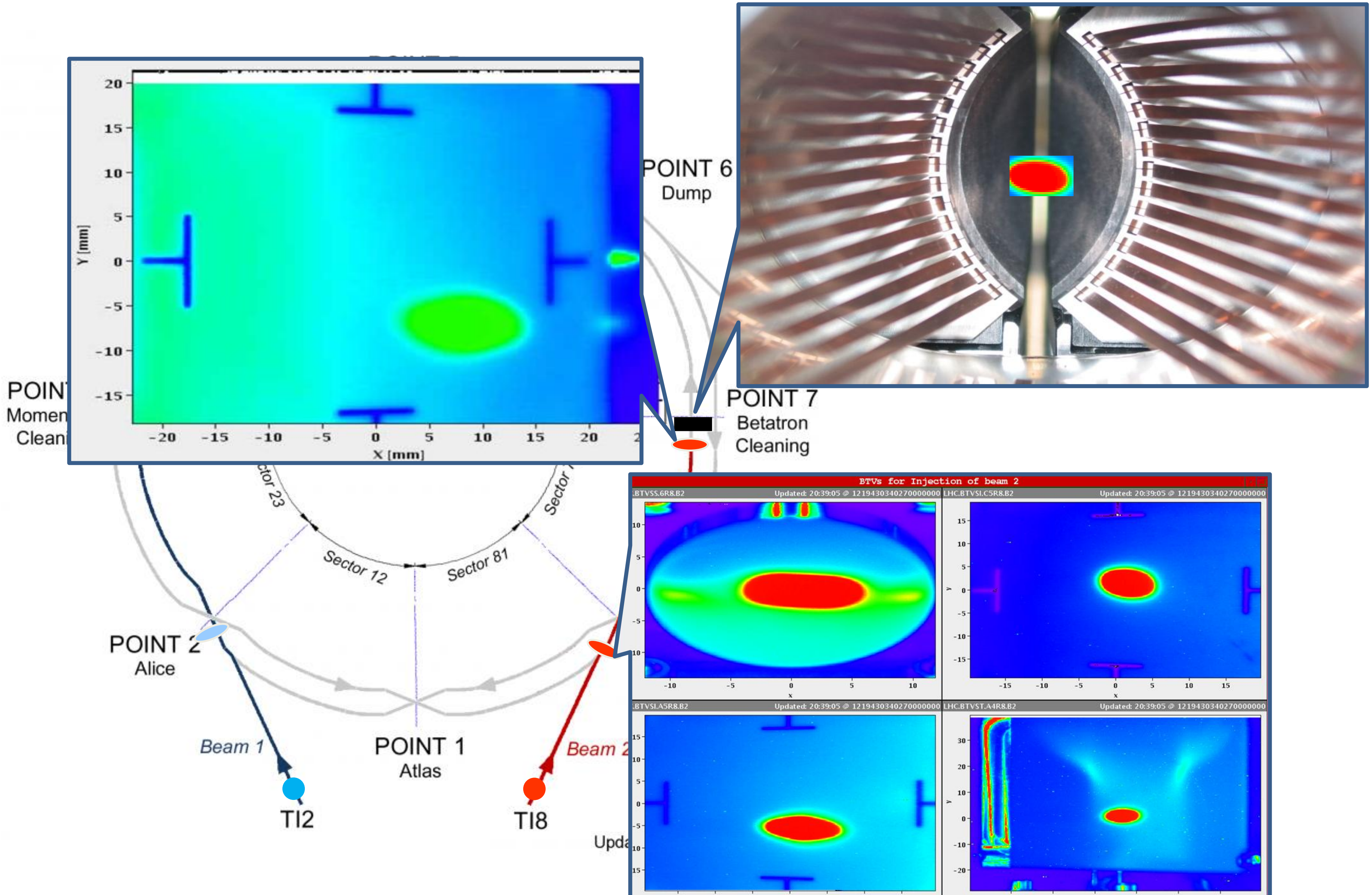
  misaligned vacuum port (corrected)
- **Optics problem point 3**

  trim quadrupole polarity errors (corrected)





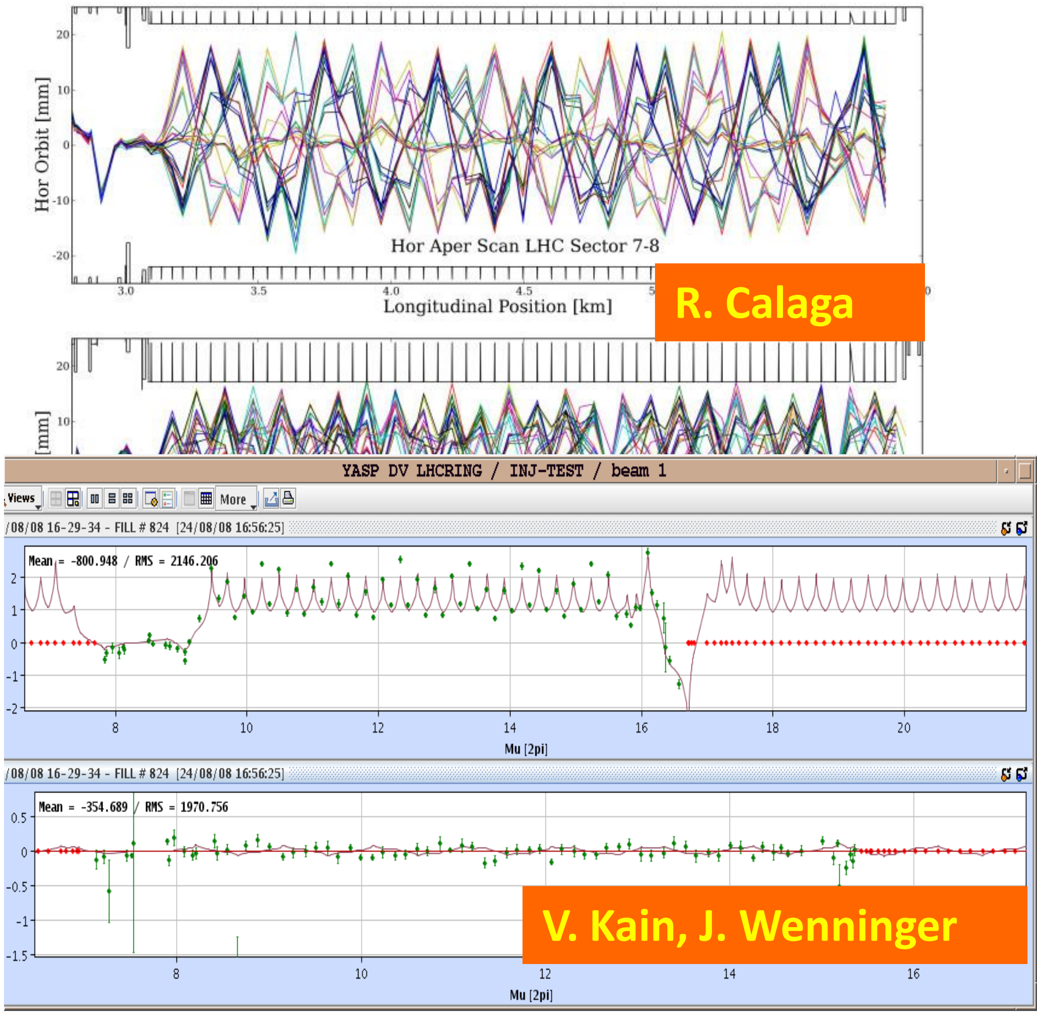
2nd Beam Injection Test (22-24 Aug.)



2nd Beam Injection Test (22-24 Aug.)

What we did (Beam1 & Beam2):

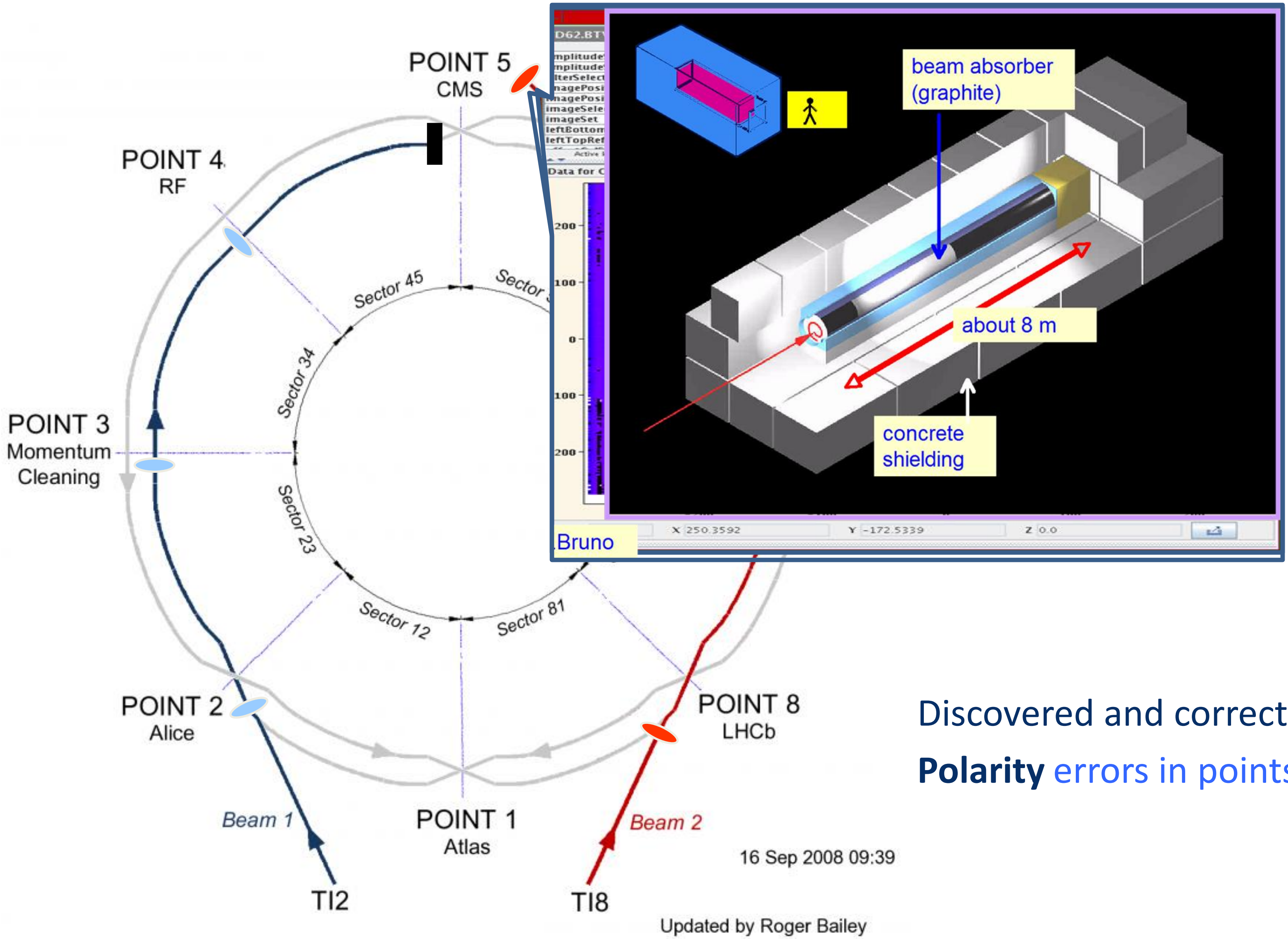
- **Trajectory** correction
- **Optics** measurements
  some polarity corrections
- Physical **aperture** measurements
  injection aperture OK
- Optic ok after **polarity** correction



What we found:

- **Optical Problem** at end of TI8 line
  being investigating.

3rd Beam Injection Test (5-7 Sep.)



Discovered and corrected:

Polarity errors in points 7 and 4

September 10th

Conclusions

The rapid progress of Beam commissioning:
Injection, circulate, ramp, collision at 450 GeV and 3.5 TeV without hindrance show the importance of the Machine Check Out.