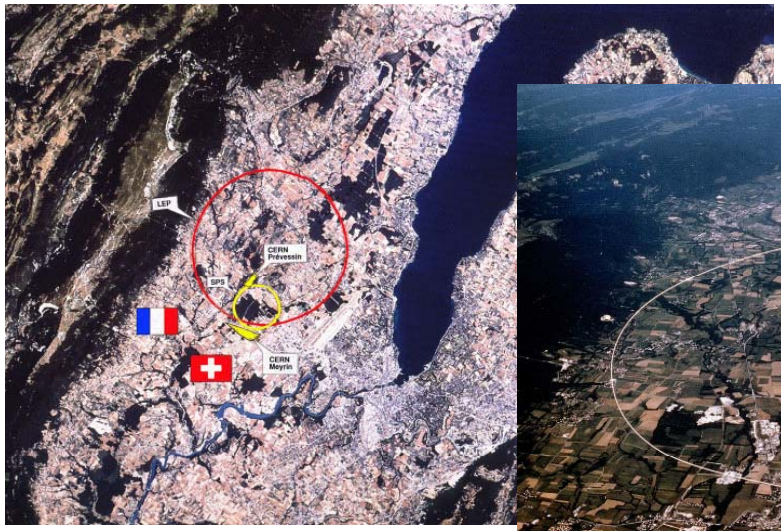
Status of the BLHC

….work in progress!



Mike Lamont
CERN/AB

Overview

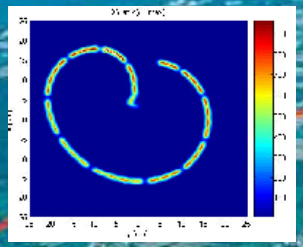
$$\mathscr{L} = f \frac{n_1 n_2}{4\sqrt{\epsilon_x \beta_x^* \epsilon_y \beta_y^*}} \quad . \tag{25.4}$$

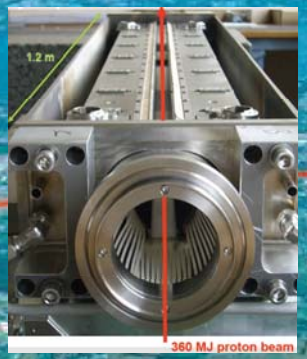
Thus, to achieve high luminosity, all one has to do is make high population bunches of low emittance to collide at high frequency at locations where the beam optics provides as low values of the amplitude functions as possible.

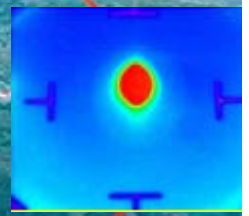
Review of Particle Physics, PDG, Chapter 25

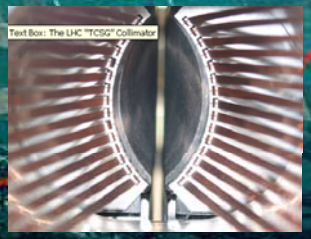
- Before beam
  - What's has to be done
  - Present status
  - Schedule
- With beam
  - Commissioning plans
  - Early luminosity expectations

8 essentially independent sectors
3.3 km of dipoles/quadrupoles++ mostly at 1.9 K

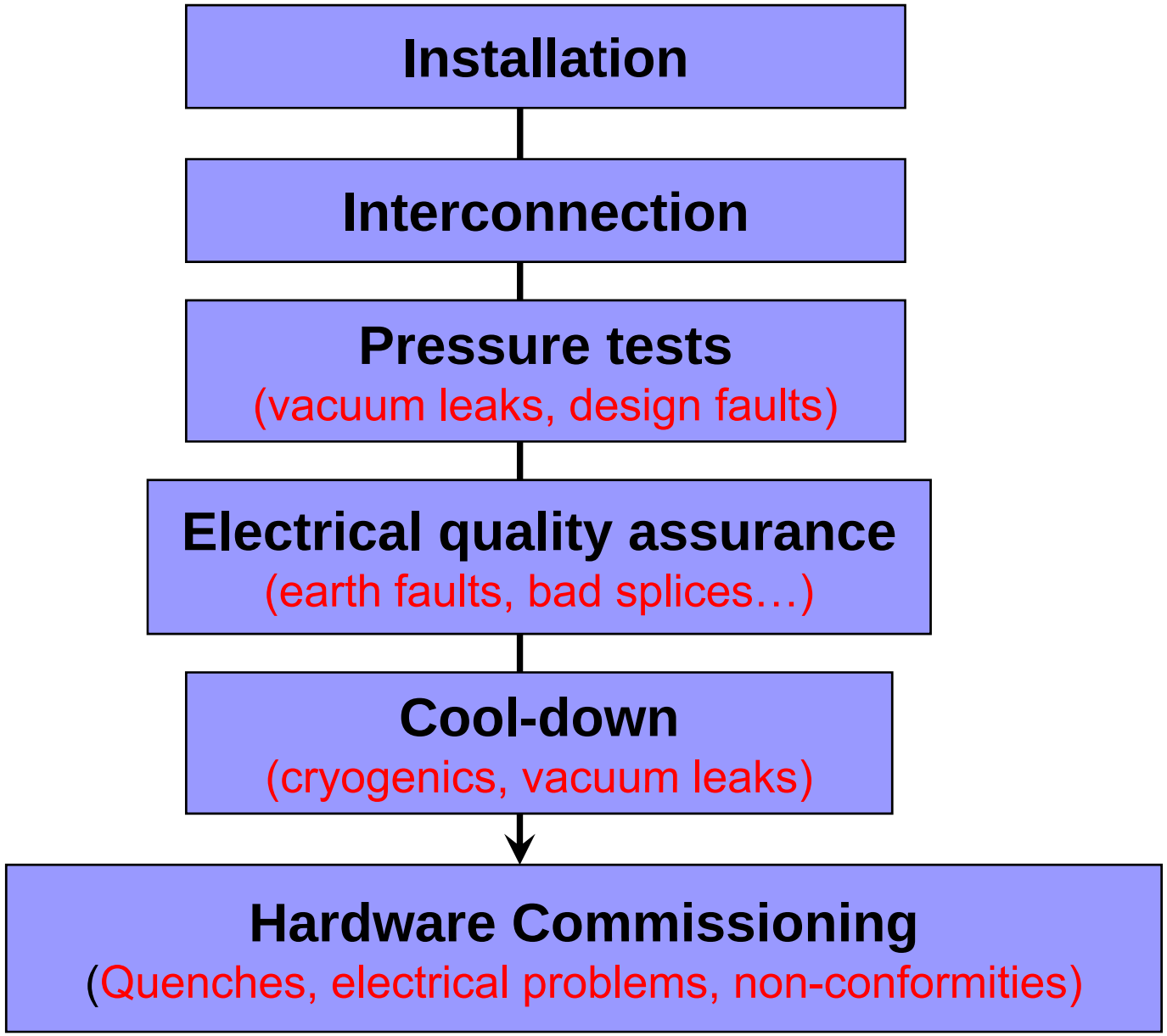






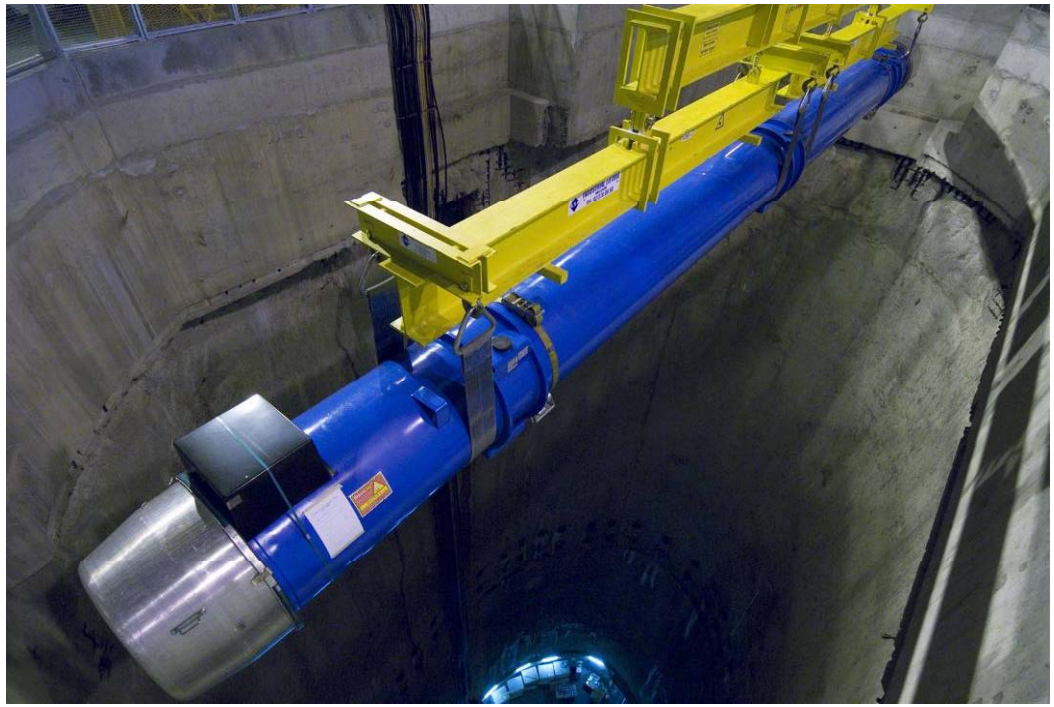


Pre-beam


Installation
Interconnection
Pressure tests
(vacuum leaks, design faults)
Electrical quality assurance
(earth faults, bad splices…)
Cool-down
(cryogenics, vacuum leaks)
Hardware Commissioning
(Quenches, electrical problems, non-conformities)

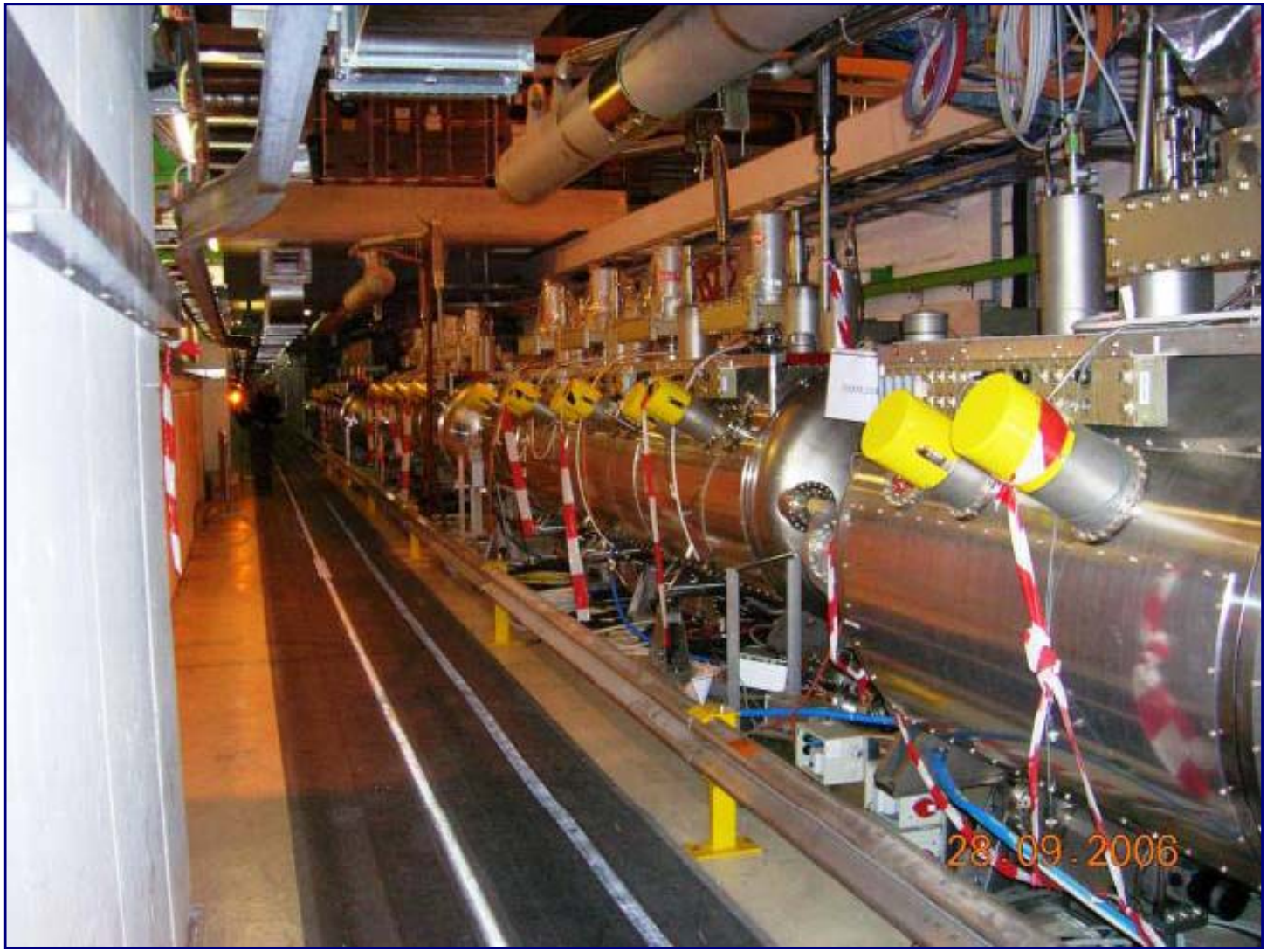
Installation - dipoles

Descent of the last magnet, 26 April 2007



30’000 km underground at 2 km/h

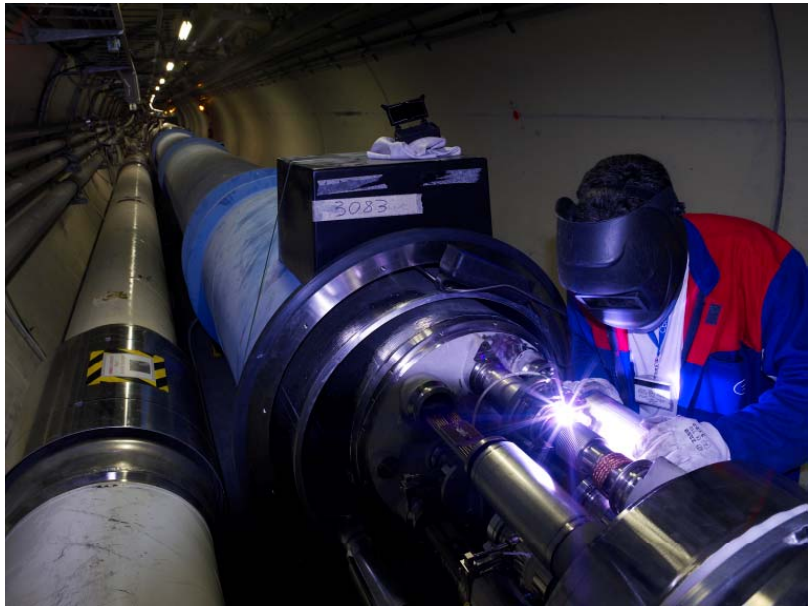
Installation - RF

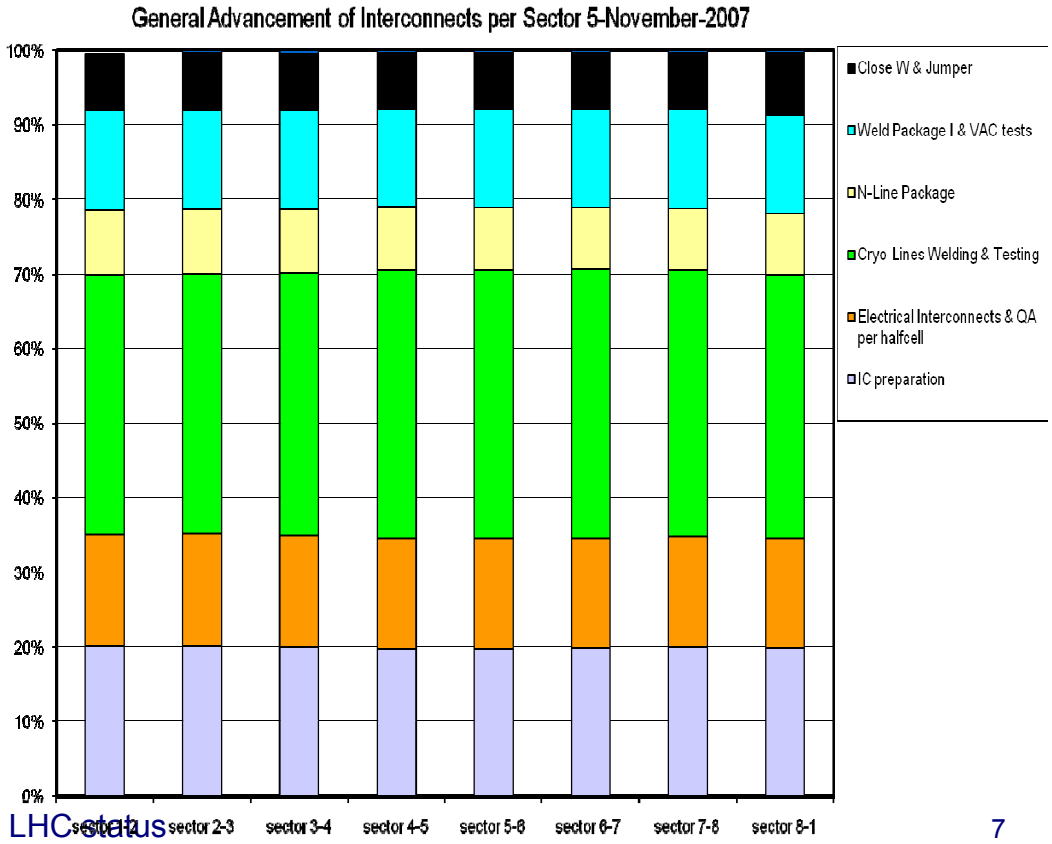


Plus collimators, beam dump, injection hardware, instrumentation etc…

Magnet interconnections

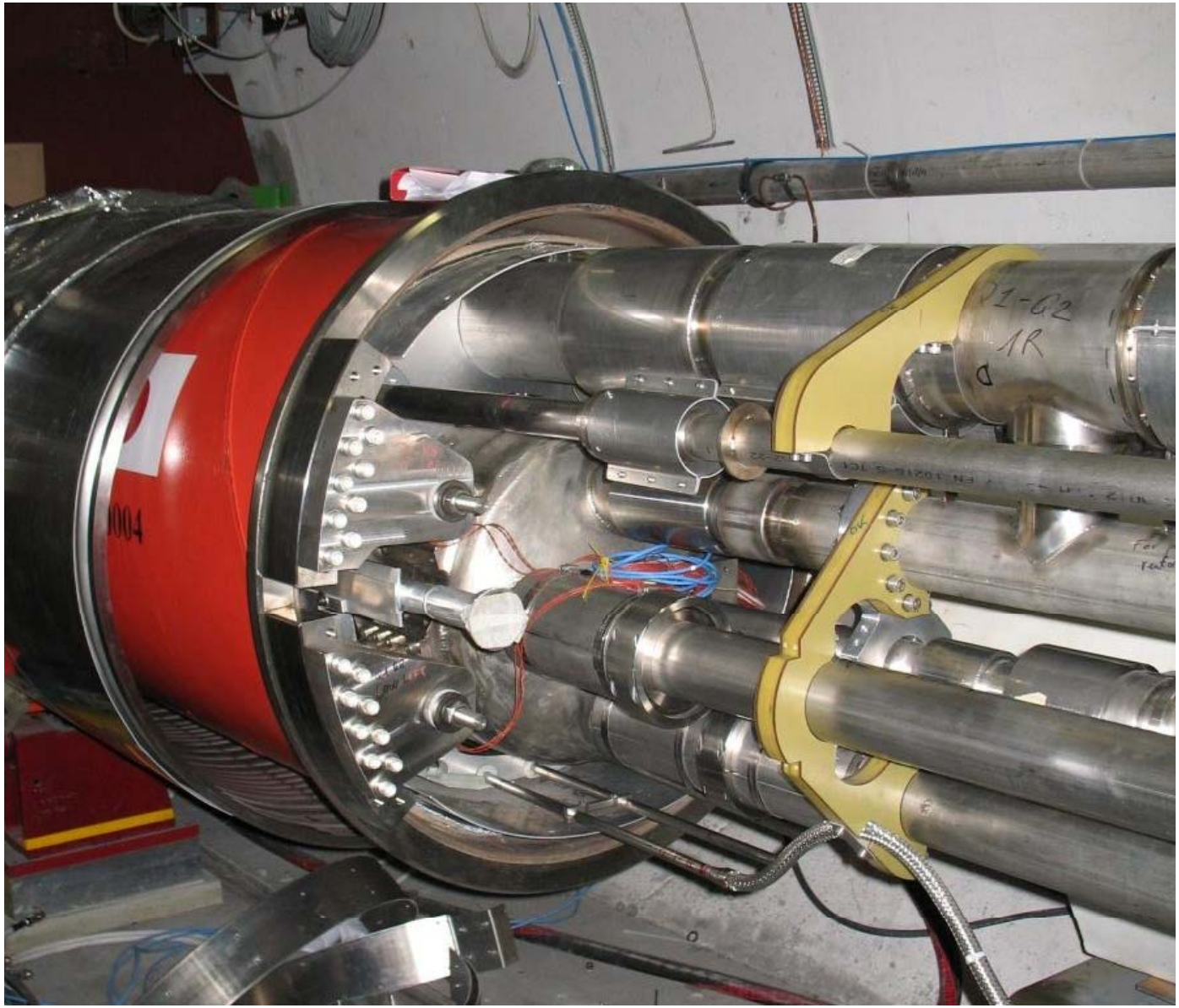
- Vacuum, bellows, RF contacts plus leak checks
- Thermal shield, heat exchanger
- Bus bars: superconducting splices x 10,000 (induction welding)
- Corrector circuits: splices x 50,000 (ultrasonic welding)



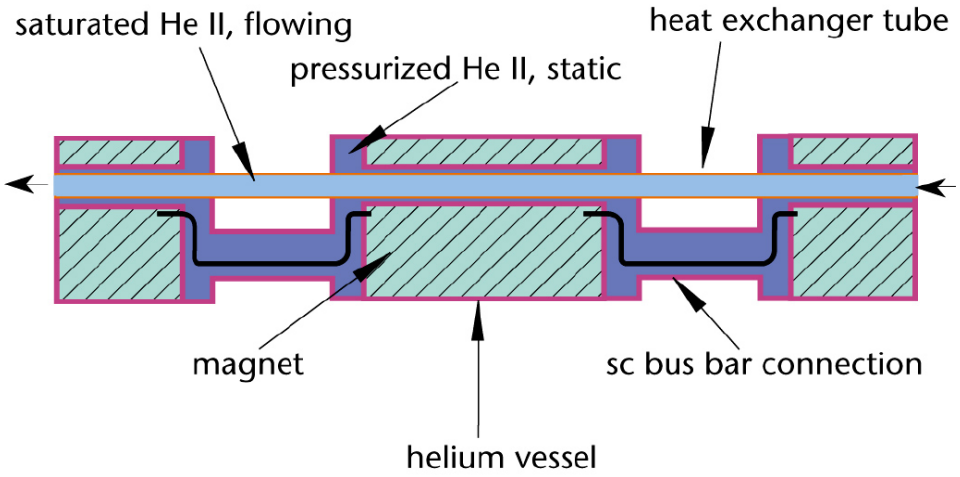


Closure of continuous cryostat - November 07

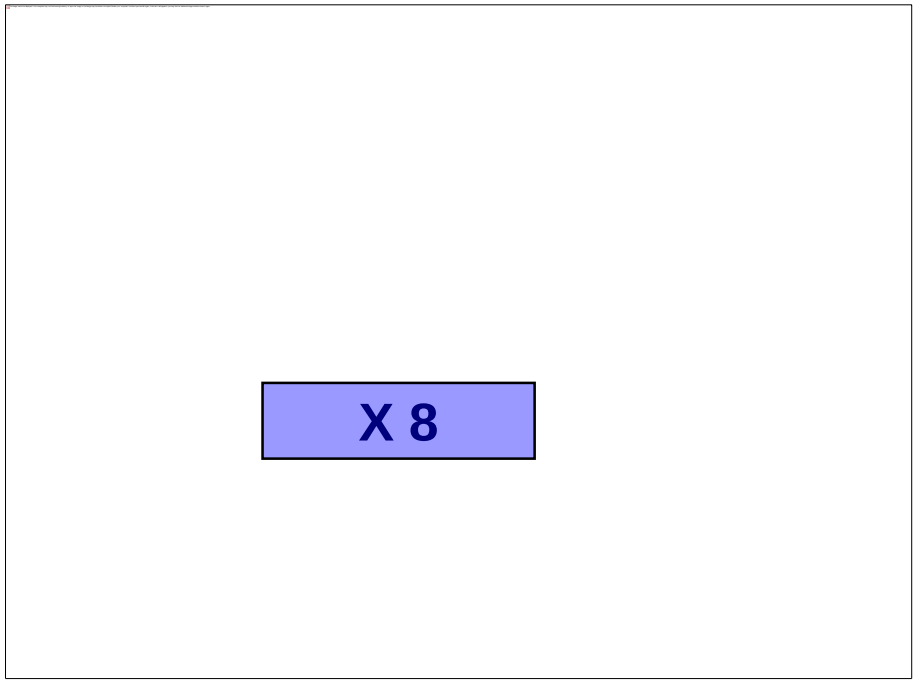
Pressure tests

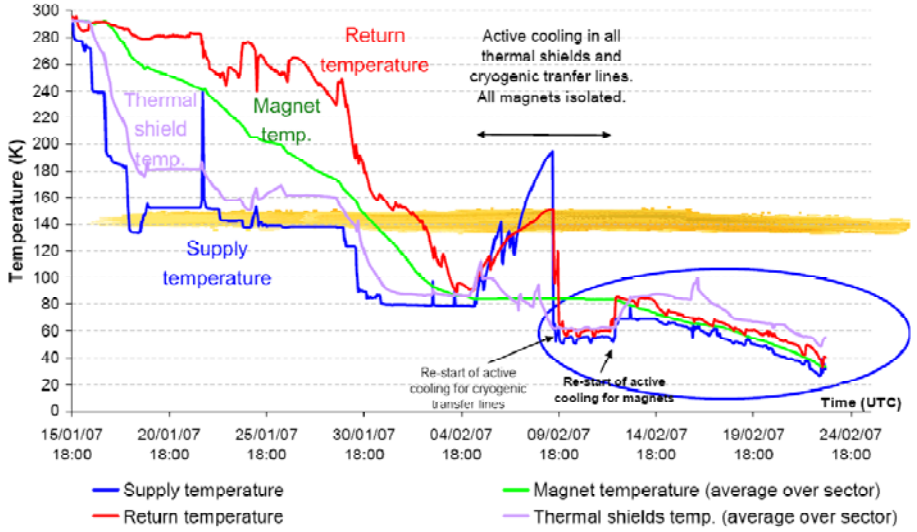


Cryogenics – huge system



- ~120 tonnes of He
- 10,000 tonnes LN2
- Cold mass 31,000 tonnes





Cryogenics flushing…

QUI return line filter after 1st phase of flushing QRL81

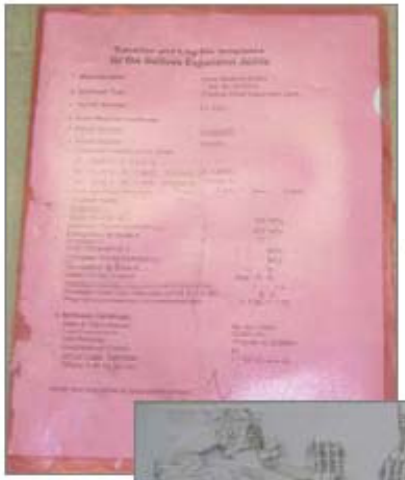
20 h / 260g/s – C to D

20 h / 160g/s – C to B

20h / 210g/s – E/F to D

SC - 21Sept'07

New dust since 2005!



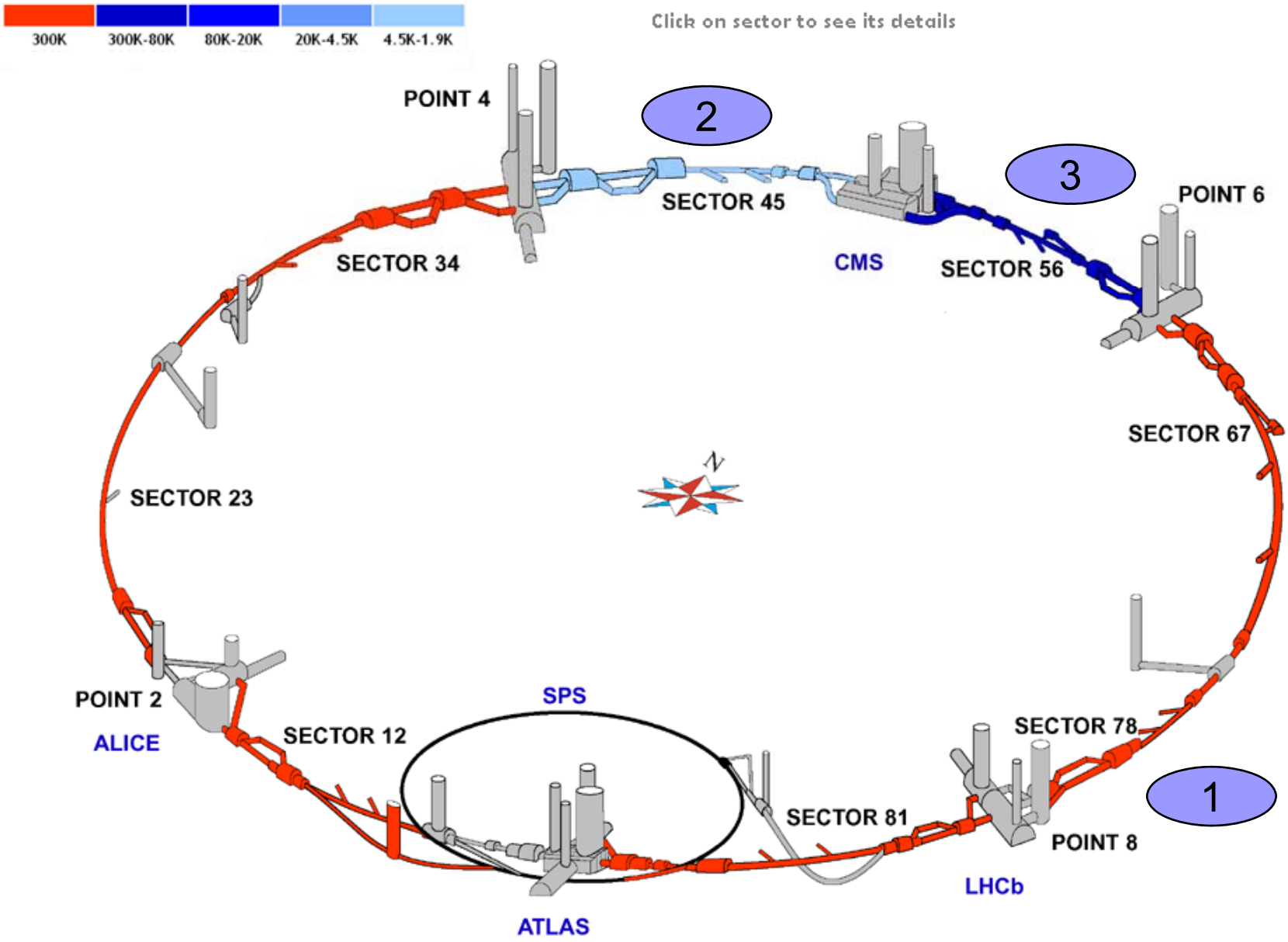
Paper found in line E when connecting QRL81 to QUI

Paper found at end of line E, blocking valve CV994 in QRL Return Module

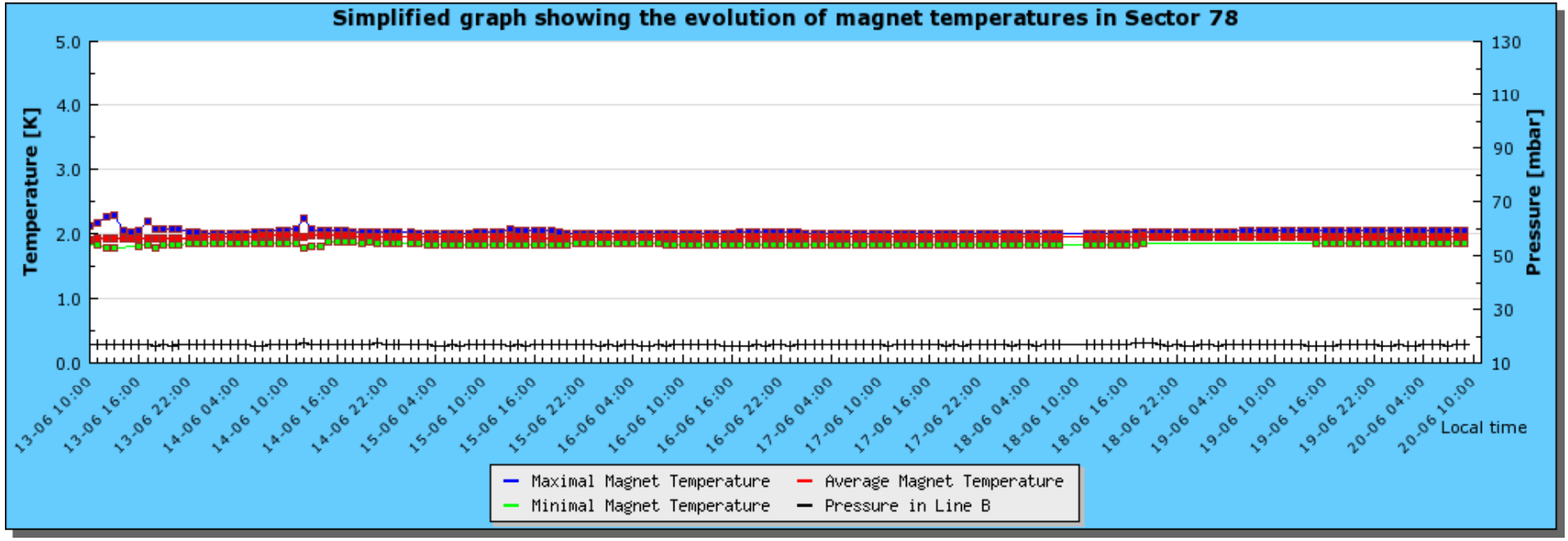
Valve in B blocked in QUI (more plastic ?)

Sector 81

Cool down


300K
300K-80K
80K-20K
20K-4.5K
4.5K-1.9K
Click on sector to see its details
POINT 4
2
SECTOR 45
3
POINT 6
SECTOR 34
CMS
SECTOR 56
SECTOR 67
SECTOR 23
N
POINT 2
ALICE
SPS
SECTOR 12
SECTOR 78
1
SECTOR 81
POINT 8
LHCb
ATLAS

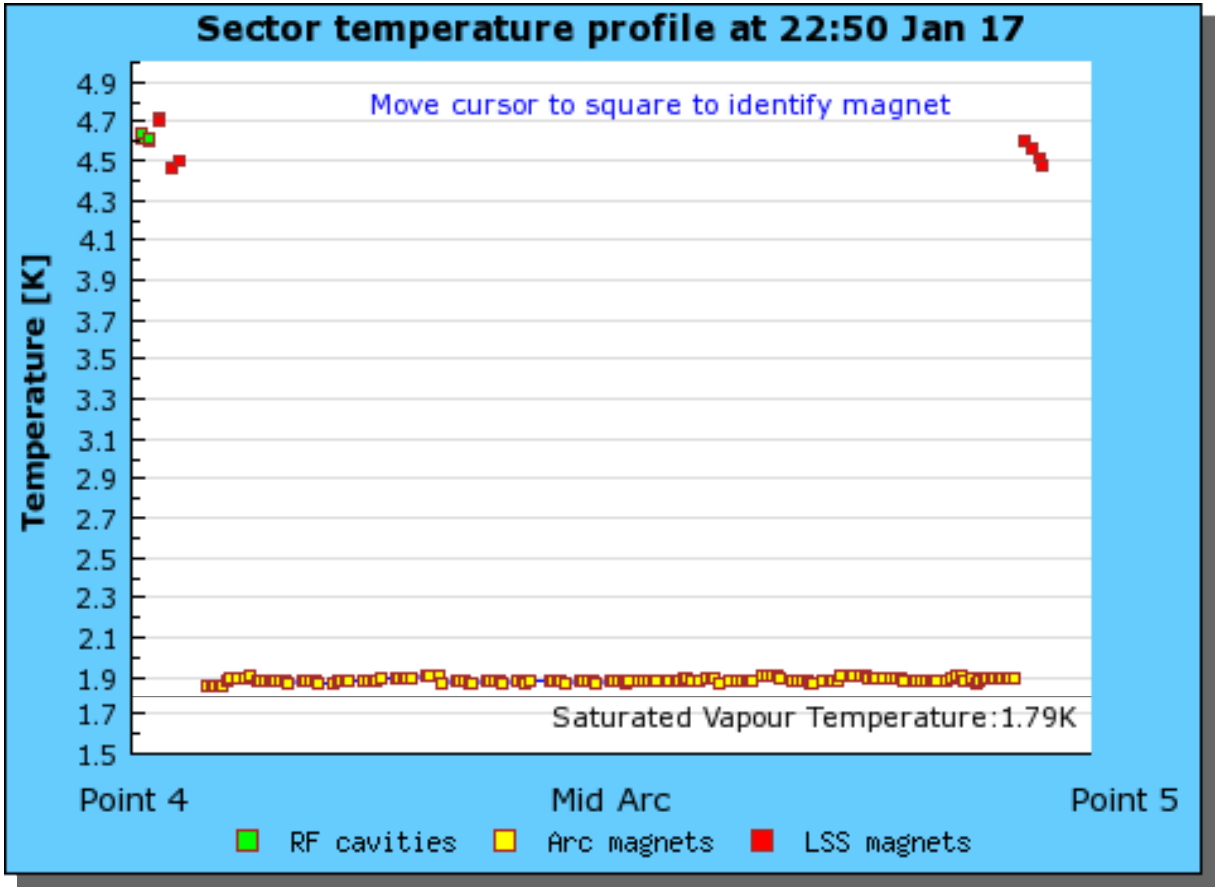
Cool down



Sector 7-8 June 2007

Cool down

Sector 4-5 today



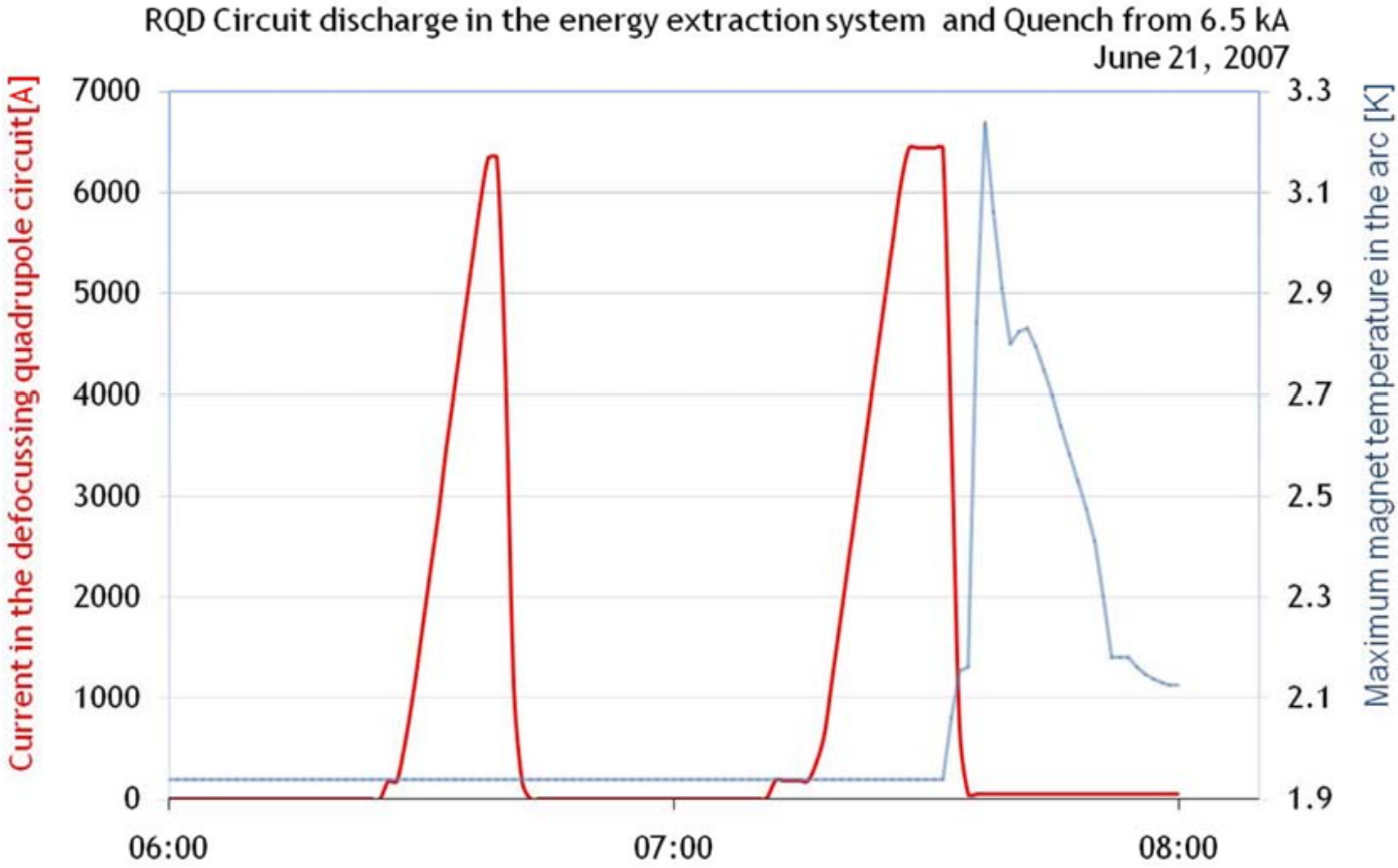
Hardware Commissioning (HWC)

- Commissioning of continuous arc cryostat & LSS cryostats (insertion quadrupoles…, inner triplet, etc.)
  - **Cryogenics, Vacuum, QPS, PIC, Powering**:
    - Electrical Quality Assurance,
    - Tests prior to powering,
    - **Powering (QPS, PC, MPS) of all circuits one by one**,
      - Magnets, busbars, DFBs, services, UPS, AUG, controls…
    - **Powering of all the circuits of a sector together**
    - Power converters: protection, calibration, ramp tests performed
    - Interlocks, compatibility tests, protection tests

Stored magnetic energy up to 1.29 GJ per sector.

[154 dipoles per sector powered in series: ~11700 A at 7 TeV]

HWC - example


RQD Circuit discharge in the energy extraction system and Quench from 6.5 kA
June 21, 2007
Current in the defocussing quadrupole circuit[A]
Maximum magnet temperature in the arc [K]
7000
6000
5000
4000
3000
2000
1000
0
3.3
3.1
2.9
2.7
2.5
2.3
2.1
1.9
06:00
07:00
08:00

LHC Status – January 2008

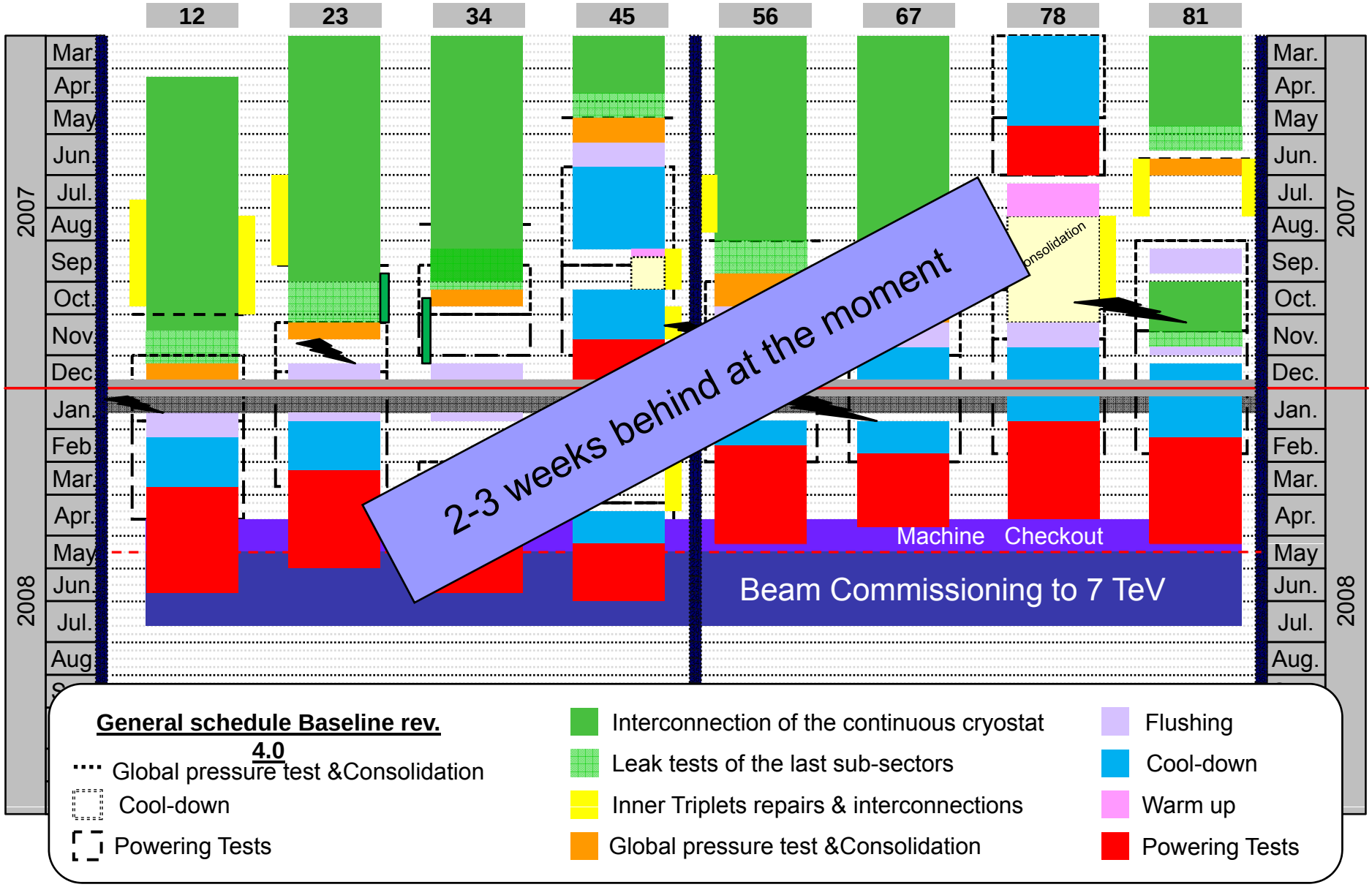
1-2	Global leak test completed. Leak localization and repair.
2-3	Start cryogenics purging and flushing week 5
3-4	Pressure test. Leak repair.
4-5	Sector cold at around 2 K. **Seen 8.5kA in main dipole circuit.**
5-6	Cool-down will be re-started w.5. **~120 K at the moment**.
6-7	Cool-down delayed until week 8-9.
7-8	Start cool-down in week 4. **Has been at 1.9 K already**.
8-1	Start cool-down in week 6.

LHC status – January 2008

- Installation effectively complete
- Interconnection work effectively complete
- First two sectors cooled down to nominal temperature and operated with super-fluid helium
- Power tests progressing well
- Third sector in cool-down

Priority now is to get the machine cold and leak tight.

Latest schedule – October 9



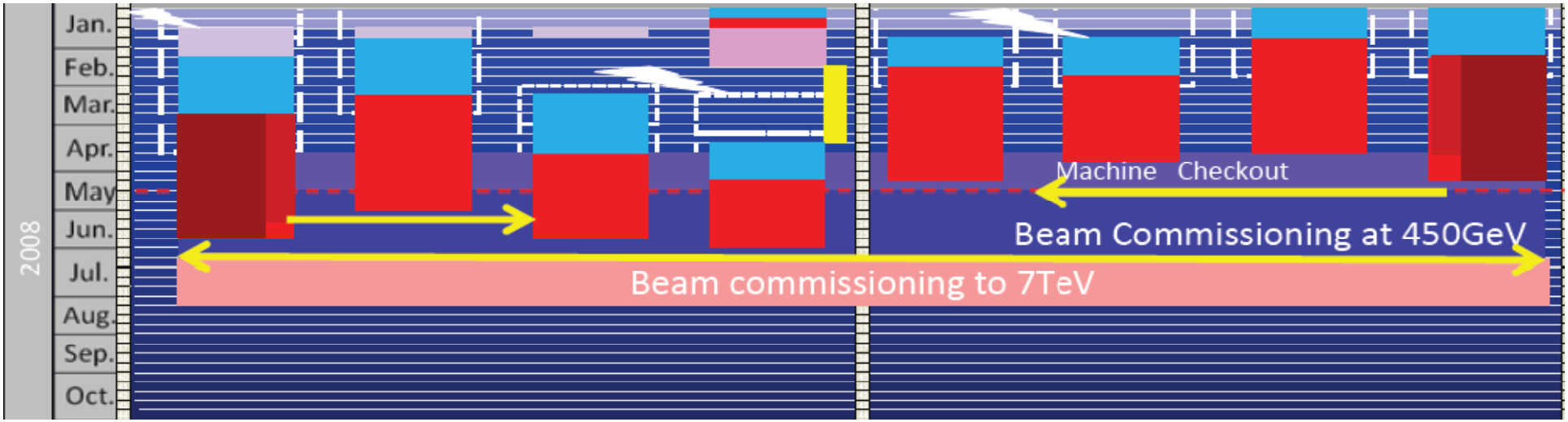
Schedule 2008

- High parallelism for the power tests
- Machine closed April 2008
- The machine should be entirely cold beginning of June
- Will take 450 GeV beam once machine is cold, even if some sectors are not qualified for 7 TeV.

- Success-oriented schedule. Acknowledge possibility of possible problems requiring additional warm-up/cool-down of sector
  - Quantum of 2-3 months
  - Delay in one sector or more → possible sector test

Machine cold – beam in at 450 GeV

- 450 GeV beam commissioning before main circuits fully commissioned to 7 TeV
  - Important checks with beam – aperture, magnets
  - Provides some lead time for problem resolution
- Interleaf with commissioning circuits to 7 TeV



Beam - energy

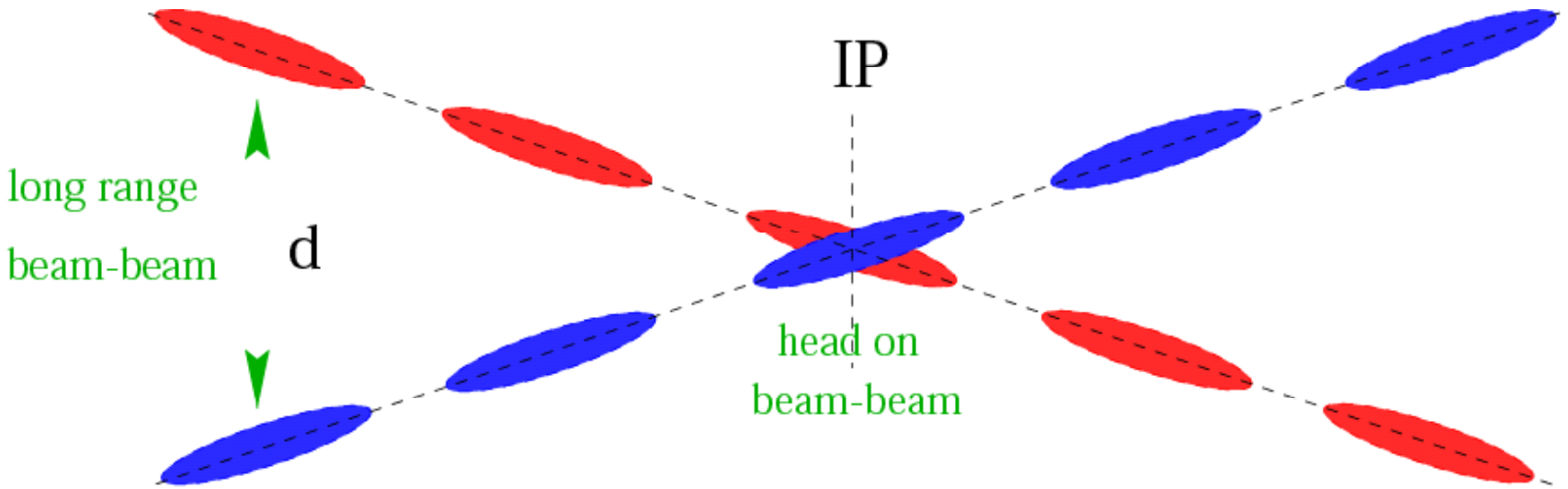
2808 bunches, 1.15 10^{11} protons per bunch

Through a very cold, very dark, very small hole...

Machine Protection is critical…

R.Schmidt and J.Uythoven June 2009 LHC Point 6.
Discussion on how the Beam Dump System reliability could be improved

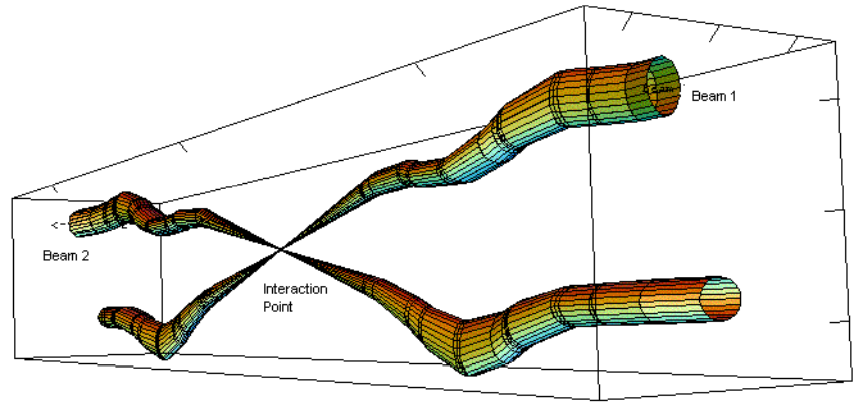
Beam - Crossing angle



With 2808 bunches per beam work with a crossing angle to avoid parasitic collisions.

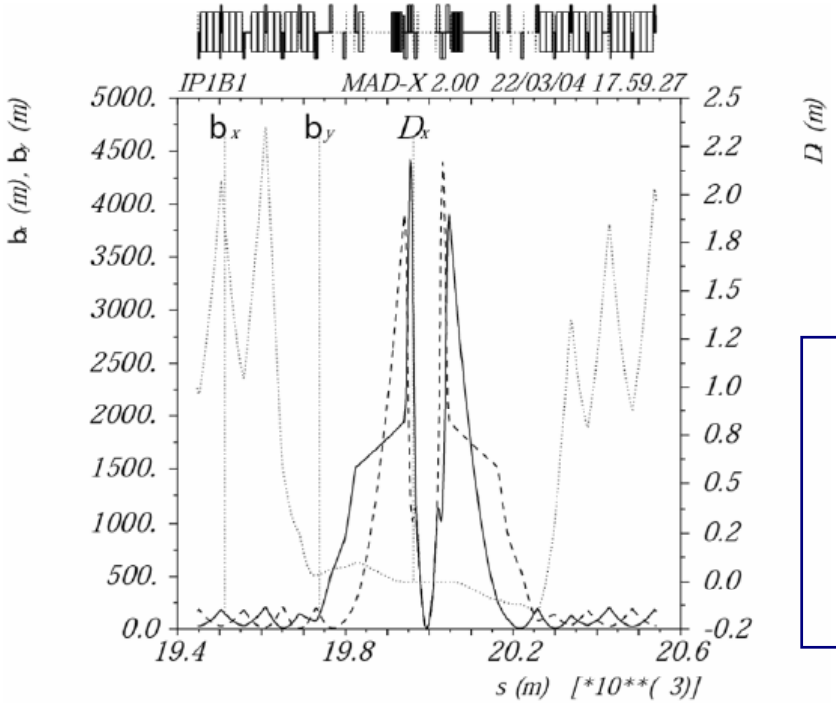
Can leave the crossing angle off with up to 156 bunches per beam

Beam - Squeeze



Relative beam sizes around IP1 (Atlas) in collision

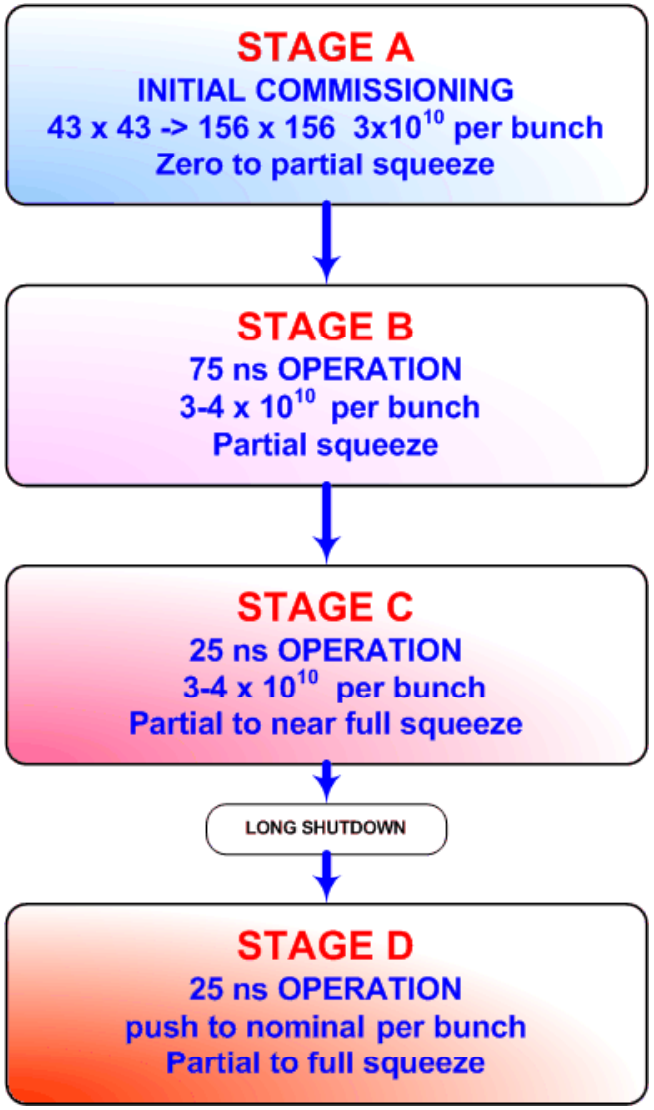
beta*	Beam size at IP (μm)
17	92
11	74
9	67
5	50
1	22
0.55	17



Small beam in the IP → big beams in the inner triplets → reduced aperture

Therefore inject & ramp (& collide initially) with bigger beam sizes at IP.

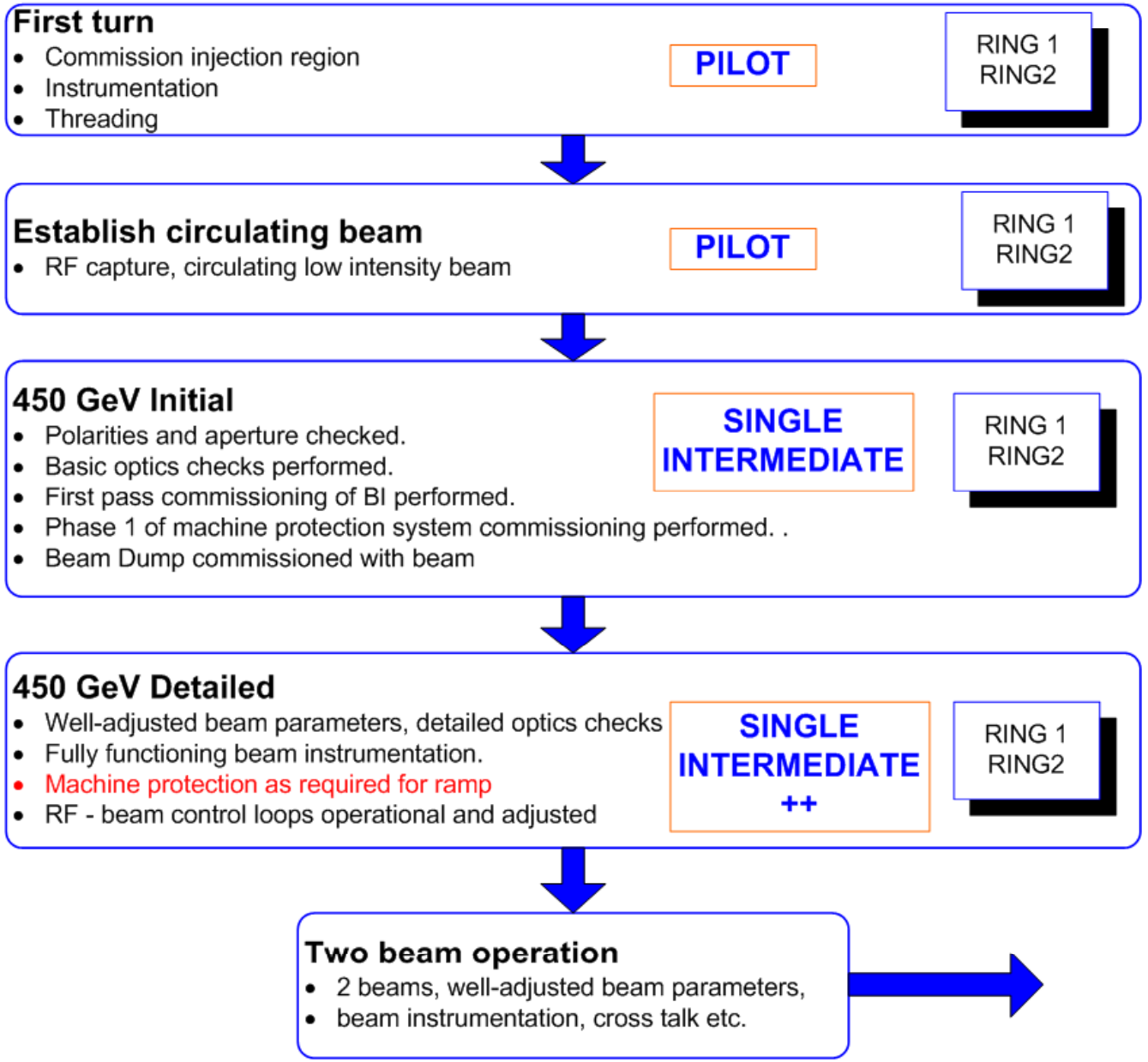
Commissioning stages



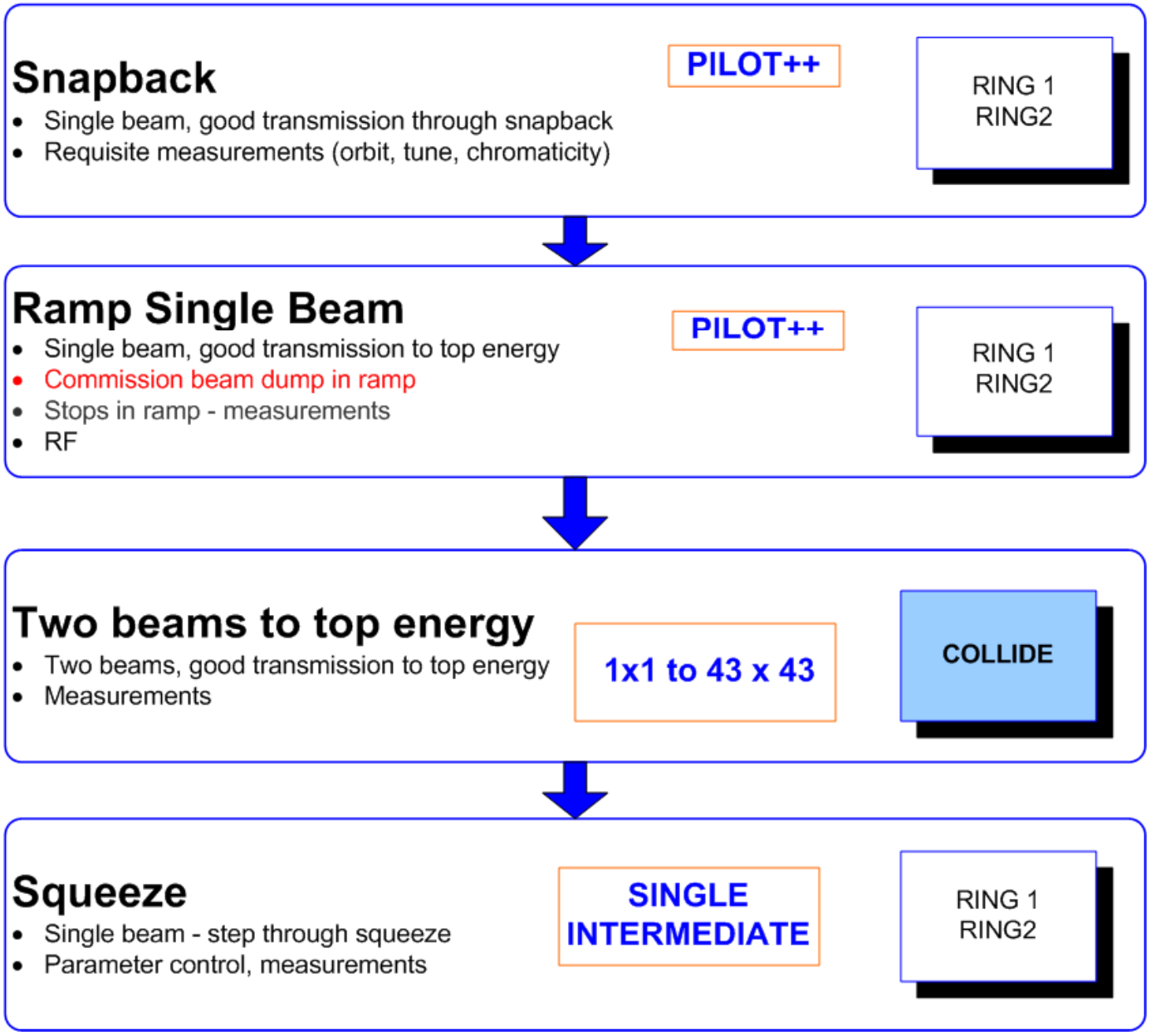
Safely establish colliding beams as quickly as possible

- Initial optics:
  - β*= 11 m in IR 1 & 5
  - β*= 10 m in IR 2 & 8
- Crossing angles off
  - Low bunch intensity
  - 1, 12, 43, 156 bunches per beam
  - No parasitic encounters - no long range beam-beam
  - Larger aperture in IRs

Stage A: commissioning phases



Stage A: commissioning phases



Beam Commissioning to 7 TeV Collisions

		Rings	Total [days]
1	**Injection and first turn**	**2**	**4**
2	**Circulating beam**	**2**	**3**
3	**450 GeV - initial**	**2**	**4**
4	**450 GeV - detailed**	**2**	**5**
5	**450 GeV - two beams**	**1**	**1**
6	**Snapback - single beam**	**2**	**3**
7	**Ramp - single beam**	**2**	**6**
8	**Ramp - both beams**	**1**	**2**
9	7 TeV - setup for physics	**1**	**2**
10	Physics un-squeezed	**1**	**-**
	TOTAL TO FIRST COLLISIONS		**30**
11	Commission squeeze	**2**	**6**
12	Increase Intensity	**2**	**6**
13	Set-up physics - partially squeezed.	**1**	**2**
14	Pilot physics run		

Stage A: First Collisions

- Approx 30 days of beam time to establish first collisions
  - Un-squeezed
  - Low intensity
  - **Optimistic!**
- Approx 2 months elapsed time
  - Given reasonably optimistic machine availability
- Continued commissioning thereafter
  - Increased intensity
  - Squeeze

RHIC 2000:
- First beam April 3rd
- First successful ramp: June 1st
- First collisions June 12th

Stage A - Luminosities

- 1 to N to 43 to 156 bunches per beam
- N bunches displaced in one beam for LHCb
- Pushing gradually one or all of:
  - Bunches per beam
  - Squeeze
  - Bunch intensity

IP 1 & 5

Bunches	β^*	I_b	Luminosity	Event rate
1 x 1	11	10^{10}	~10^{27}	Low
43 x 43	11	3 x 10^{10}	6 x 10^{29}	0.05
43 x 43	4	3 x 10^{10}	1.7 x 10^{30}	0.21
43 x 43	2	4 x 10^{10}	6.1 x 10^{30}	0.76
156 x 156	4	4 x 10^{10}	1.1 x 10^{31}	0.38
156 x 156	4	9 x 10^{10}	5.6 x10^{31}	1.9
156 x 156	2	9 x 10^{10}	1.1 x10^{32}	3.9

Pilot physics – the first month

- Interleaved physics and commissioning
- Push number of bunches, intensity, squeeze…
  - 156 x 156
  - 3 x 10^{10} protons per bunch
  - $\beta^* = 2$ m.
- Peak luminosity: ~1.2 x 10^{31}
- Integrated: few pb^{-1}

Pushing the bunch intensities with 156x156 with reasonable operational efficiency another month would see 30-40 pb^{-1}

Acceptable exit condition for 2008

Stage B – 75ns

- Up to 936 bunches
- Parameter tolerances:
  - Tightened up. Optics/beta beating under control
  - Emittance conservation through the cycle
- Commission crossing angles.
  - Injection, ramp and partial squeeze
  - Long range beam-beam, effect on dynamic aperture,
- Need for feedback
  - Orbit plus adequate control of tune and chromaticity through snapback.
- Lifetime and background optimization in physics
  - with a crossing angle and reduced aperture

Plus Machine Protection with increased intensity

Won't happen overnight

Stage B - Luminosities

β^*	I_b	Luminosity	Event rate	% Total I	Per month [pb^{-1}]
4	**4×10^{10}**	**5.6×10^{31}**	**0.32**	**0.12**	**40**
2	**4×10^{10}**	**1.1×10^{32}**	**0.64**	**0.12**	**100**
2	**6×10^{10}**	**2.5×10^{32}**	**1.1**	**0.17**	**220**
2	**8×10^{10}**	**4.5×10^{32}**	**2.6**	**0.23**	**400**

2009

- Commission and exploit 75 ns.
- Move to 25 ns

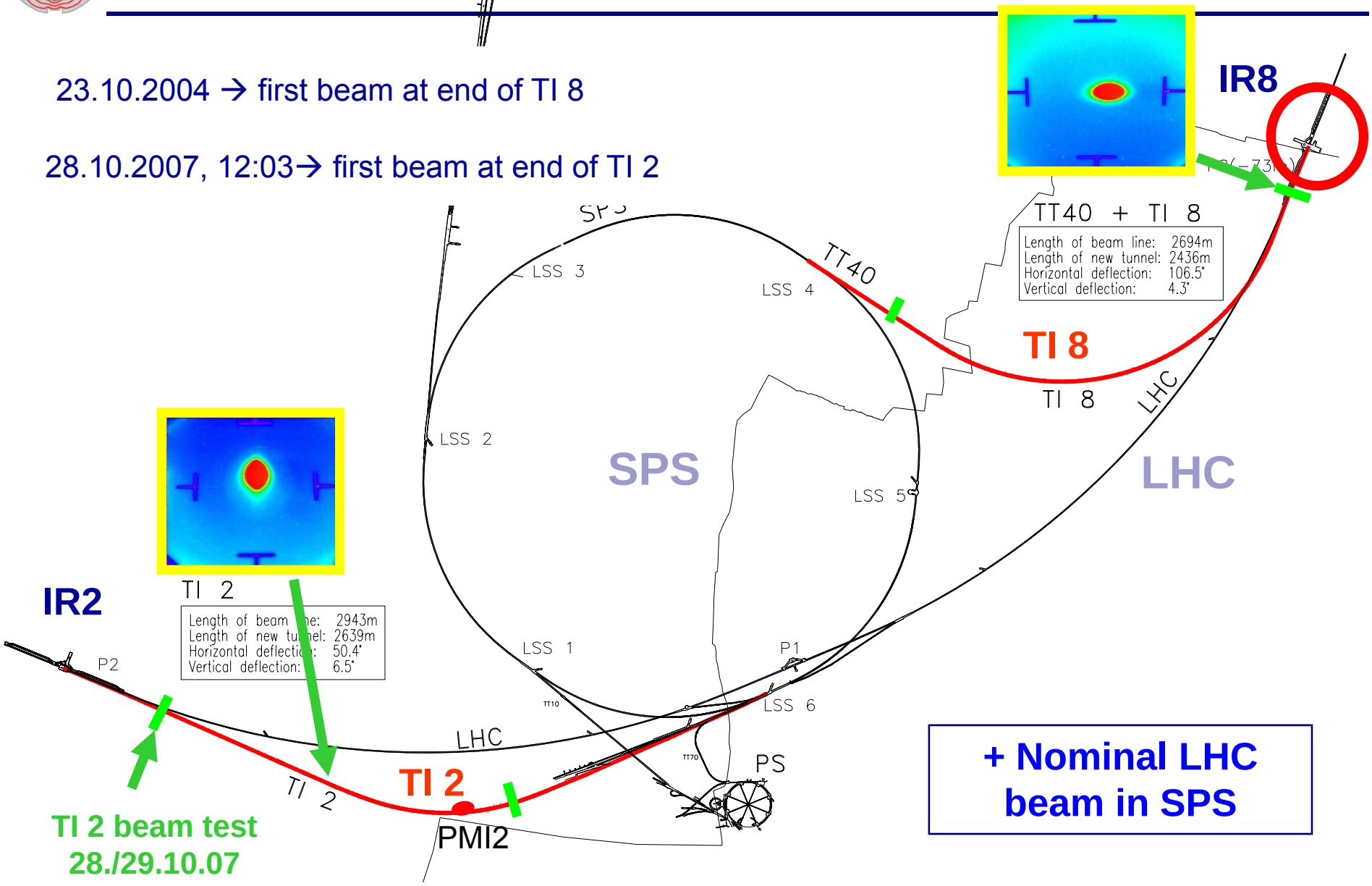
- Initial luminosity 8 x 10^{32} $cm^{-2}s^{-1}$ (say)
  - 2808 bunches, $\beta^* = 2$ m, 6 x 10^{10} protons per bunch
- Luminosity lifetime: 27 hours
- Fill length: 12 hours
- Turn around time: 5 hours
- 100 days of physics
- Operational efficiency 60%

Of the order 2-3 fb^{-1}

LHC transfer lines

23.10.2004 → first beam at end of TI 8

28.10.2007, 12:03→ first beam at end of TI 2



Courtesy of V. Mertens

Conclusions

- Priority is to get the machine cold and leak tight
- Machine should be cold in June 2008
  - Caveat: problems found at cold cost ~3 months to fix
- Take beam at 450 GeV before machine ready for 7 TeV
- First 7 TeV collisions 2+ months after first taking beam

Expectation management!

• The LHC is a huge, complex beast.

• Progress is good

• It will work

• BUT it is going to take time