LHC Commissioning in 2008

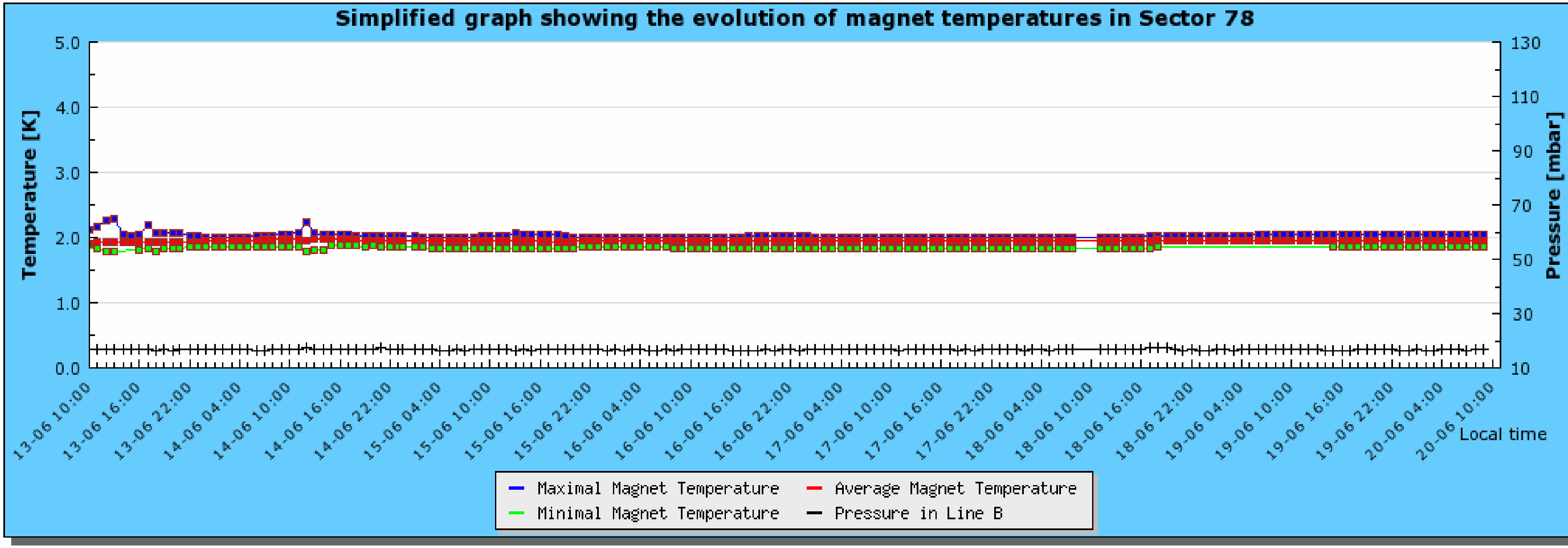
Mike Lamont AB/OP

Schedule slides c/o Lyn Evans (MAC 14/6/07)

Status: Installation & equipment commissioning

- Procurement problems of remaining components (DFBs, collimators) now settled
- Good progress of installation and interconnection work, proceeding at high pace in tunnel
- Numerous non-conformities intercepted by QA program, but resulting in added work and time
- Technical solutions found for inner triplet problems, but repair of already installed magnets will induce significant delays
- Commissioning of first sectors can proceed by isolating faulty triplets, but will have to be re-done with repaired triplets (needing additional warm-up/cooldown cycles)
- First sector cooled down to nominal temperature and operated with superfluid helium; teething problems with cold compressor operation have now been fixed.
- Power tests now proceeding.

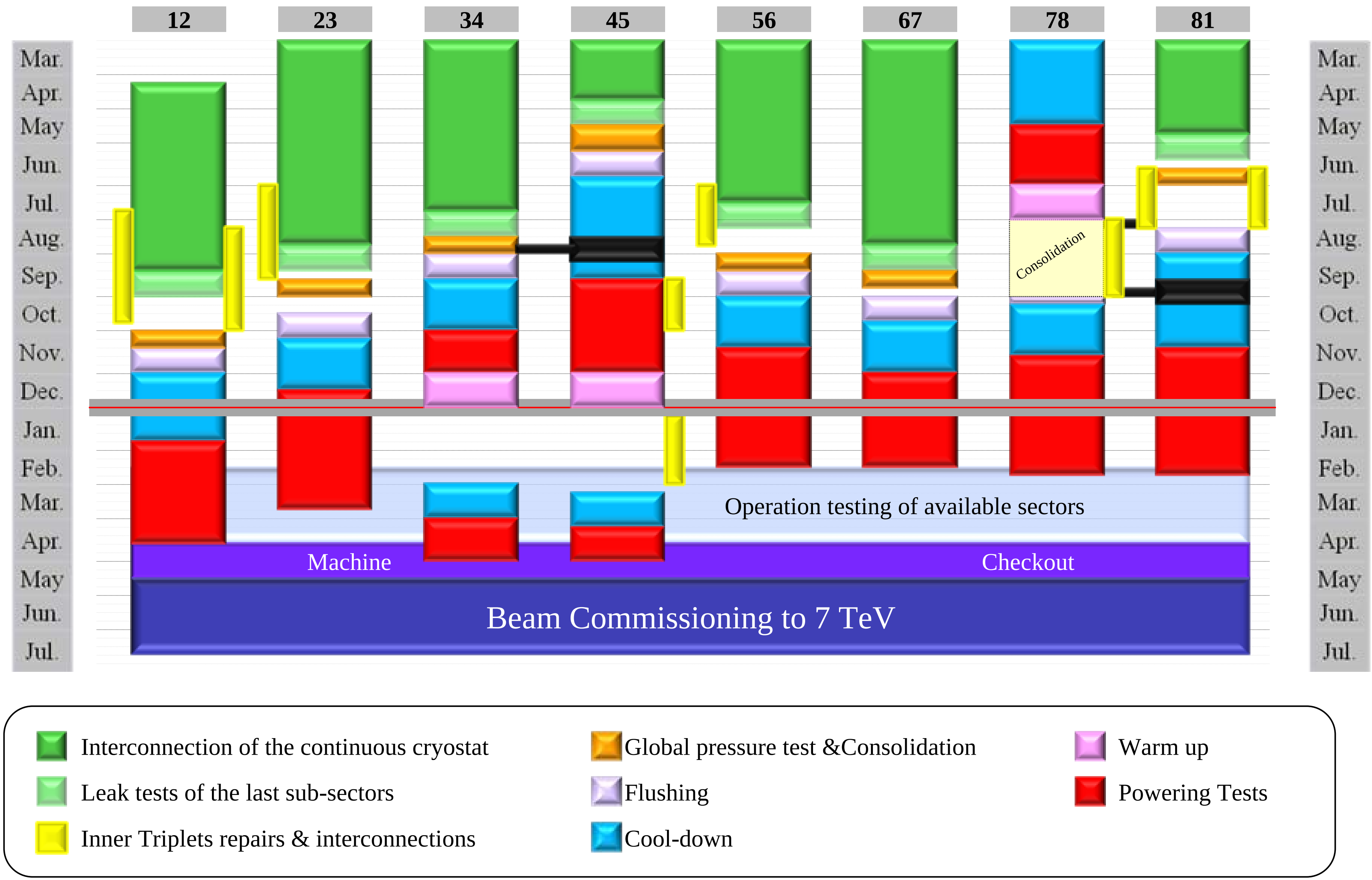
Sector 78



Should power the main de-focusing quadrupole circuit today.

End hardware commissioning 6th July for warm-up

Schedule

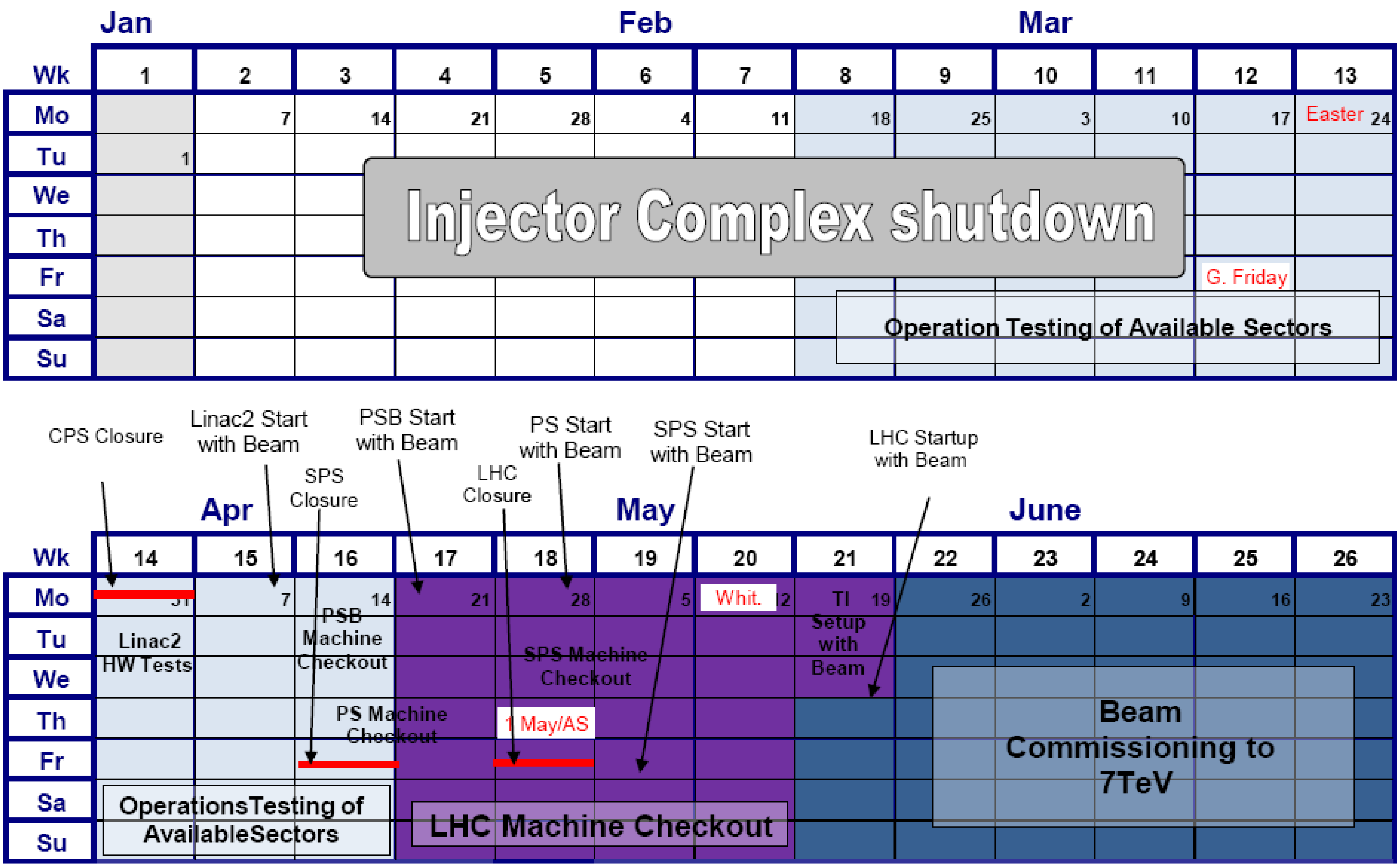


12
23
34
45
56
67
78
81
Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May Jun. Jul.
Consolidation
Operation testing of available sectors
Machine
Checkout
Beam Commissioning to 7 TeV
Interconnection of the continuous cryostat
Leak tests of the last sub-sectors
Inner Triplets repairs & interconnections
Global pressure test &Consolidation
Flushing
Cool-down
Warm up
Powering Tests

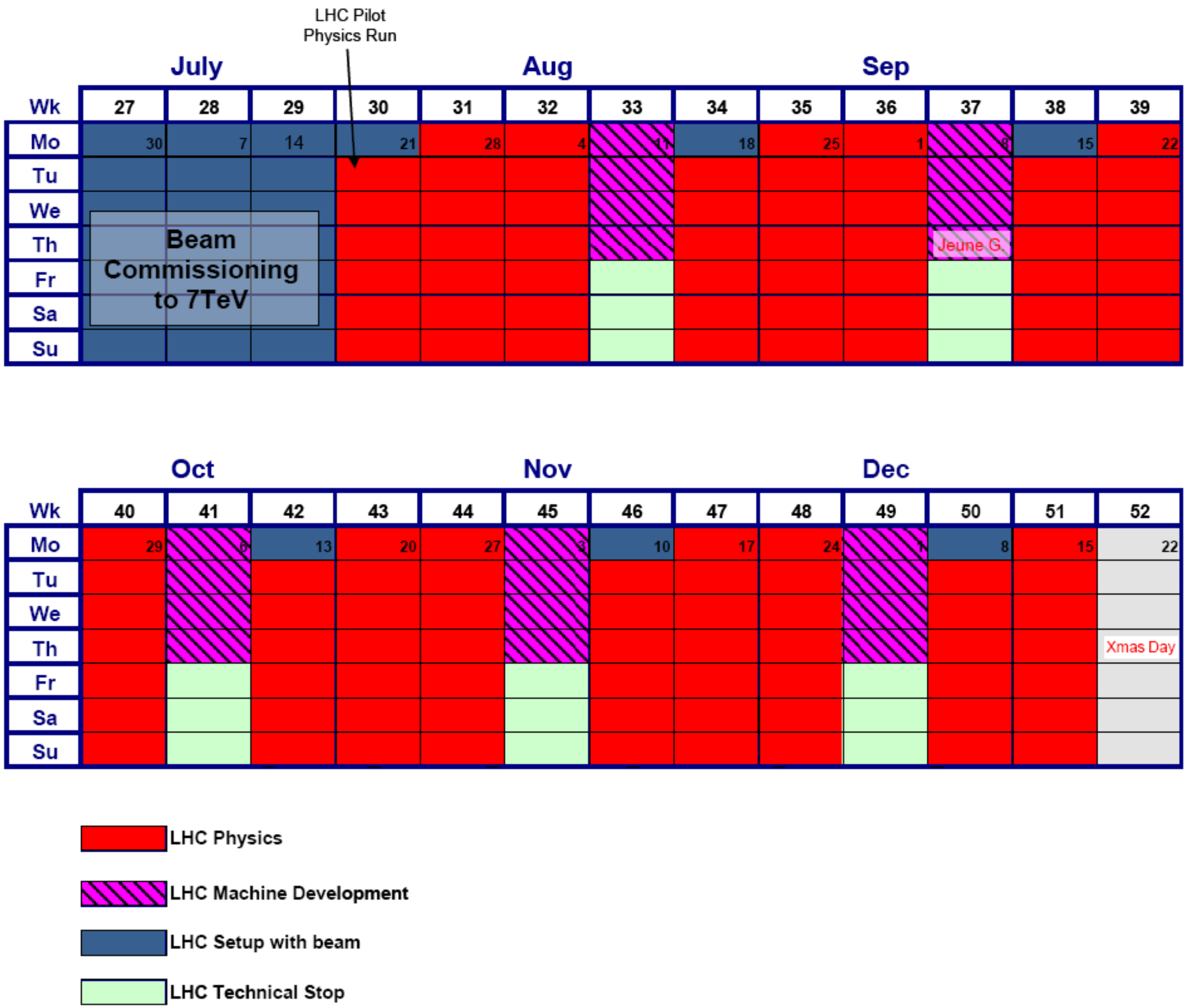
General co-ordination schedule - Milestones

	Pressure test	Cool-down		Powering tests	
Sector 12	27-28 Oct. 07	03 Dec. 07	25 Jan. 08	28 Jan.08	18 Apr.08
Sector 23	15 -16 Sep.07	05 Nov. 07	14 Dec.07	17 Dec. 07	21 Mar. 08
Sector 34	11-12 Aug. 07	17 Sep. 07	26 Oct. 07	29 Oct. 07	30 Nov. 07
		03 Mar. 08	28 Mar. 08	31 Mar. 08	02 May 08
Sector 45	Done	25 Jun. 07	14 Sep. 07	17 Sep. 07	30 Nov. 07
		10 Mar. 08	04 Apr. 08	07 Apr. 08	02 May 08
Sector 56	18 - 19 Aug. 07	01 Oct. 07	09 Nov. 07	12 Nov. 07	15 Feb.08
Sector 67	25-26 Sep. 07	22 Oct. 07	30 Nov. 07	03 Dec. 07	15 Feb.08
Sector 78	Done	Done		Started	29 Jun. 07
		08 Oct. 07	16 Nov. 07	19 Nov. 07	22 Feb. 08
Sector 81	16-17 Jun. 07	27 Aug. 07	09 Nov. 07	12 Nov. 07	22 Feb. 08

2008 LHC Accelerator schedule



2008 LHC Accelerator schedule

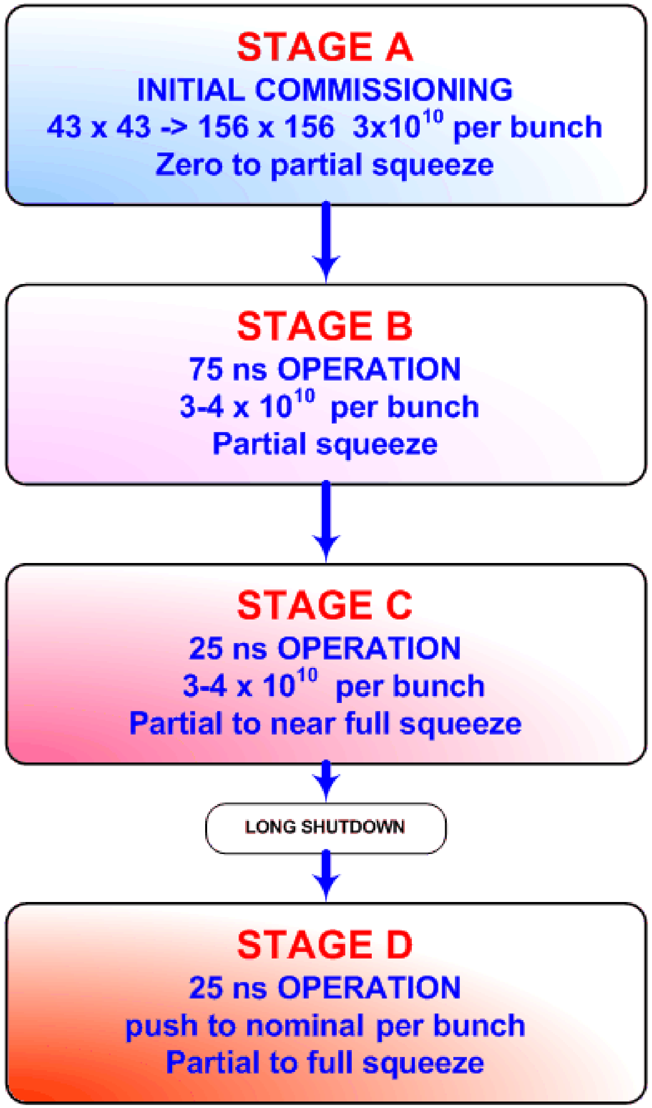


General Schedule

- Engineering run originally foreseen at end 2007 now precluded by delays in installation and equipment commissioning.
- 450 GeV operation now part of normal setting up procedure for beam commissioning to high-energy
- General schedule being reassessed, accounting for inner triplet repairs and their impact on sector commissioning
  - **All technical systems commissioned to 7 TeV operation, and machine closed April 2008**
  - **Beam commissioning starts May 2008**
  - **First collisions at 14 TeV com July 2008**
  - **Pilot run pushed to 156 bunches for reaching 10^{32} $cm^{-2}s^{-1}$ by end 2008**
- No provision in success-oriented schedule for major mishaps, e.g. additional warm-up/cool-down of sector

Commissioning Plans

Commissioning stages



- Establish colliding beams as quickly as possible
- Safely
- Without compromising further progress

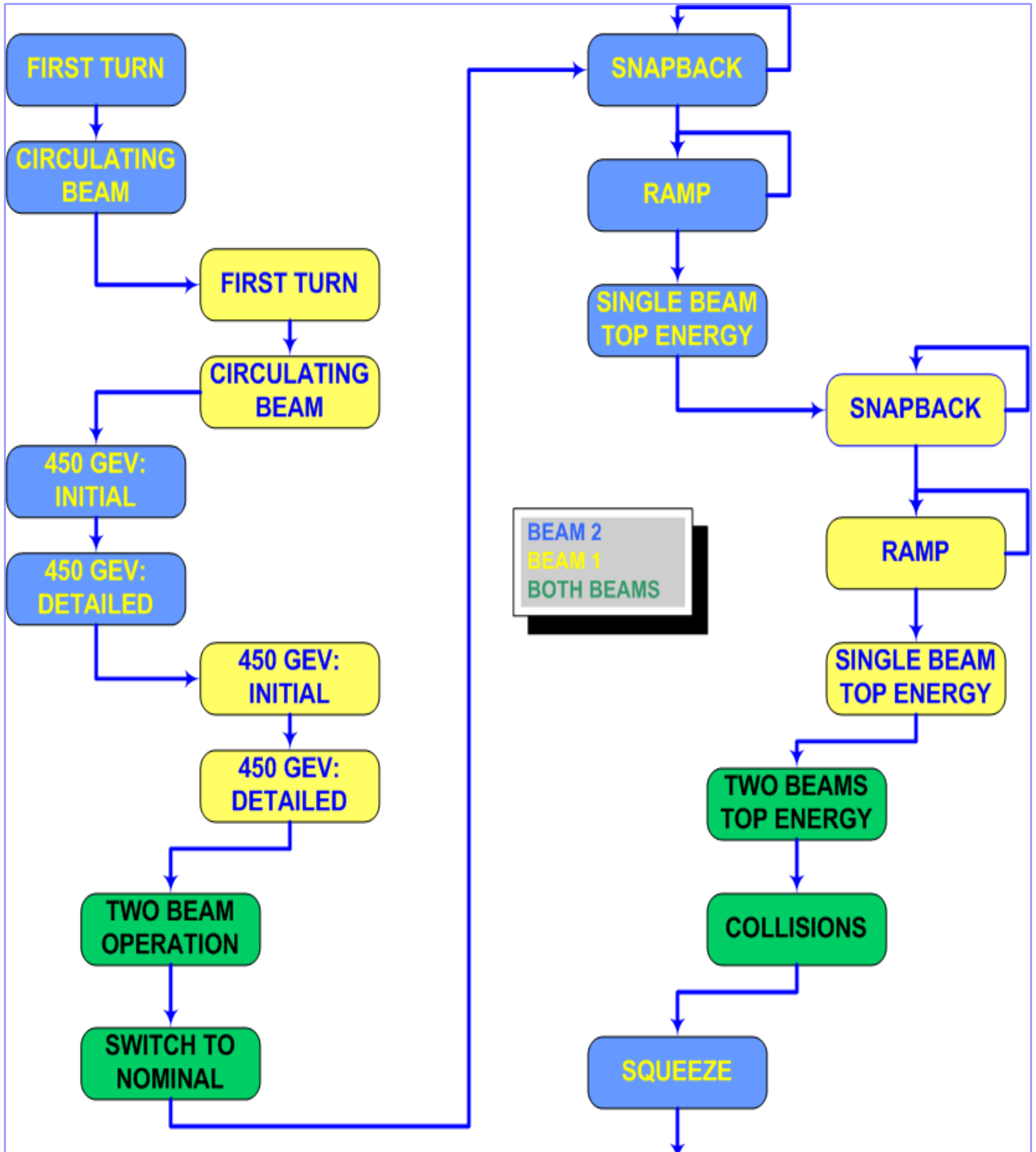
- Initial optics:
  - β^*= 11 m in IR 1 & 5
  - β^*= 10 m in IR 2 & 8
- Crossing angles off
  - 1, 12, 43, 156 bunches per beam
  - No parasitic encounters - no long range beam-beam
  - Larger aperture in IRs

Phase A: Beam

- Start with Pilot Beam:
  - Single bunch, 5 to 10 x 10^9 protons
- Intermediate single:
  - 3 to 4 x 10^{10} ppb
- 4 bunches etc. pushing towards…
- 43 (and possibly 156) bunches
  - 3 to 4 x 10^{10} ppb **(3.1 mA - 2 MJ)**

- Good for Instrumentation (bunch spacing), RF, vacuum…
- Relatively safe beam
  - Reduced demands on beam dump system, Collimation & Machine protection

Stage A: Commissioning Phases



Have to commission:

Hardware: RF, beam Dump, Collimators, Kickers etc

Instrumentation: BPMs, BLMs, BCT, Beam size, luminosity etc.

Controls

Machine Protection

Measure optics, energy, aperture etc. etc. etc.

Procedures: Injection, snapback, ramp, squeeze, recover etc.

Details available…

Beam commissioning to 7 TeV collisions

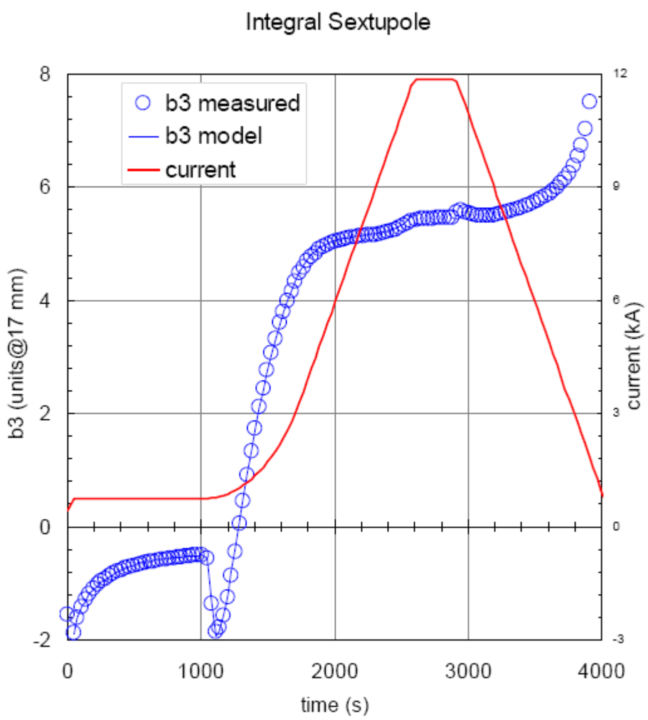
		Rings	Total [days]
1	**Injection and first turn**	**2**	**4**
2	**Circulating beam**	**2**	**3**
3	**450 GeV - initial**	**2**	**4**
4	**450 GeV - detailed**	**2**	**5**
5	**450 GeV - two beams**	**1**	**1**
6	**Snapback - single beam**	**2**	**3**
7	**Ramp - single beam**	**2**	**6**
8	**Ramp - both 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
- Approx 2 months elapsed time
  - Given optimistic machine availability
- Continued commissioning thereafter
  - Increased intensity
  - Squeeze

Stage A: Ramp

- Start of the ramp could be messy
  - Persistent currents (main contribution – dipoles) decay on the injection plateau
  - Potentially big shifts in chromaticity, tune, momentum…
  - “Snapback” at start of ramp (timescale ~ 1 minute)
    - large parameter shifts have to corrected



- Learn with low beam currents
- Collimators have to protect arc aperture (~7.5 σ)
- Experiments are un-squeezed – plenty of aperture in IRs

(Unless any weak magnets show up – expect to go to 7 TeV)

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	18	10^{10}	10^{27}	Low
43 x 43	18	3×10^{10}	3.8×10^{29}	0.05
43 x 43	4	3×10^{10}	1.7×10^{30}	0.21
43 x 43	2	4×10^{10}	6.1×10^{30}	0.76
156 x 156	4	4×10^{10}	1.1×10^{31}	0.38
156 x 156	4	9×10^{10}	5.6×10^{31}	1.9
156 x 156	2	9×10^{10}	1.1×10^{32}	3.9

Stage B – 75ns

- Parameter tolerances:
  - Tightened up. Optics/beta beating under control
- Commission crossing angles.
  - Injection, ramp and 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 needs to be mastered.
- Bunch train bunch-to-bunch variations, implications for beam instrumentation.
- Emittance conservation through the cycle

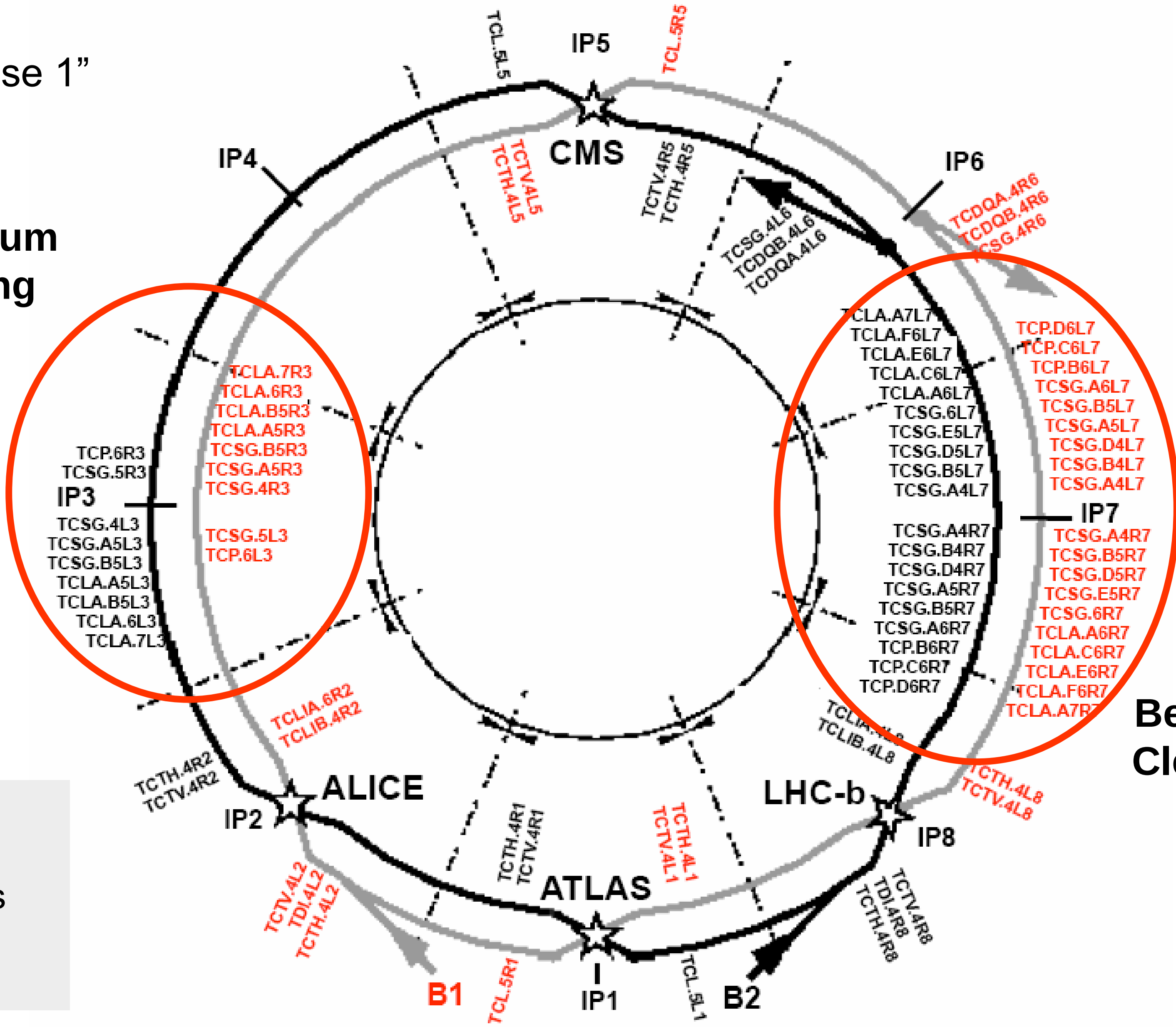
Plus Machine Protection with increased intensity

Won't happen overnight

Issues

Collimators - system overview

"Phase 1"



Momentum Cleaning

Betatron Cleaning

"Final" system:
Layout is 100% frozen!

Collimators - Functional Description

- Two-stage cleaning (**robust CFC primary and secondary collimators**).
- Catching the cleaning-induced showers (**Cu/W collimators**).
- Protecting the warm magnets against heat and radiation (**passive absorbers**).

- **Local cleaning and protection at triplets** (**Cu/W collimators**).
- Catching the p-p induced showers (**Cu collimators**).

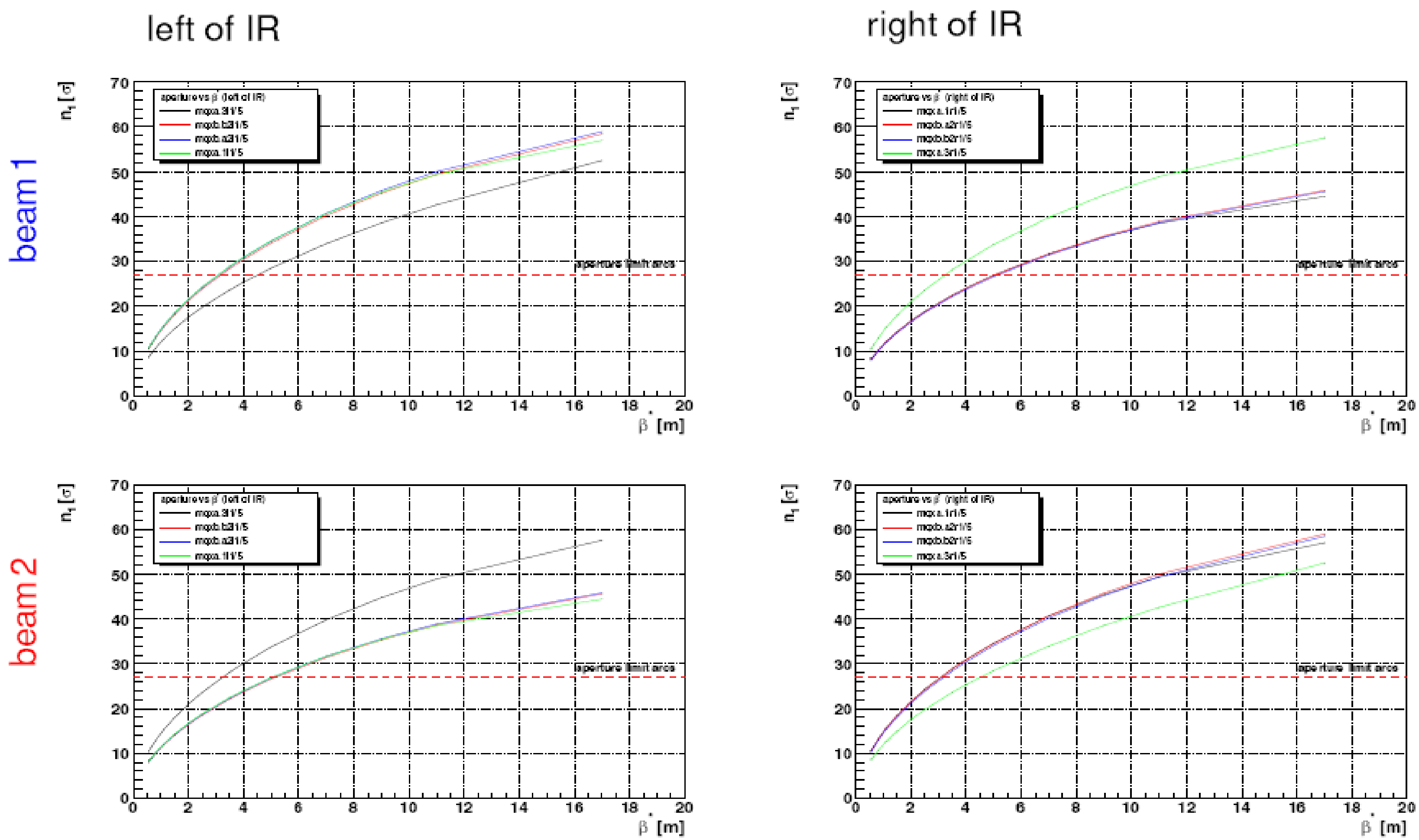
- Intercepting mis-injected beam (**TCDI, TDI, TCLI**).
- Intercepting dumped beam (**TCDQ, TCS.TCDQ**).
- Scraping and halo diagnostics (**primary collimators and thin scrapers**).

Collimation - goals

- The plan is have almost all the 118 initial LHC collimators/absorbers of the phase 1 collimation system in place for the 2008 startup.
- Full passive protection & high cleaning efficiency (> 99.99%) will be there.
- Last collimators for installation ready in January 2008.
- Tertiary collimators will be installed in IP 1 & 5

Ralph Assmann

Flat Optics (IR5)

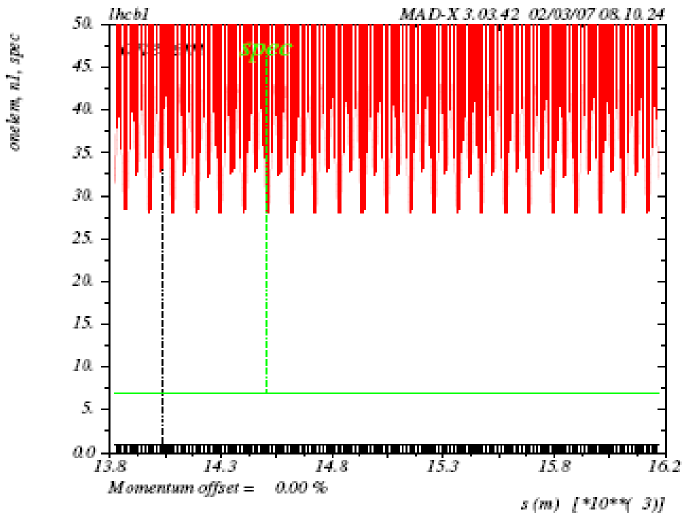


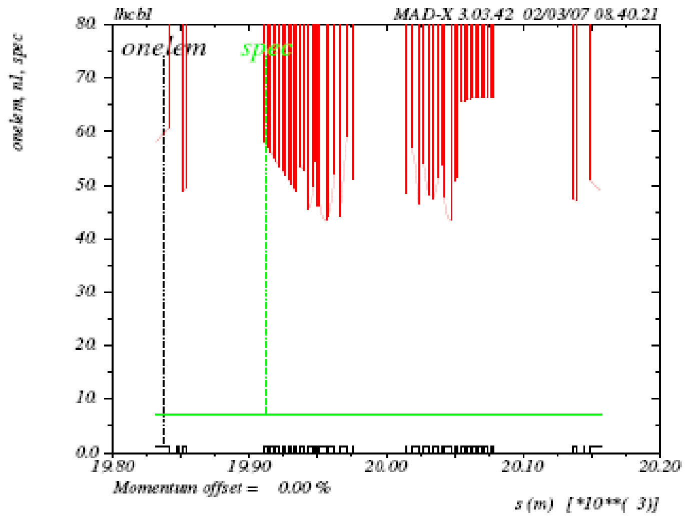
min. apeture: beam 1 $n_1 = 7.99\sigma$, beam 2 $n_1 = 7.99\sigma$

Th. Weiler, AB/ABP-LCU, CERN

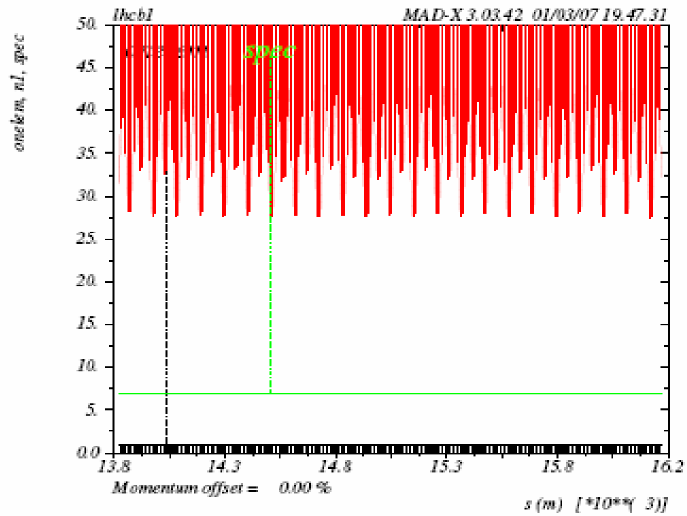
CWG-Meeting 20070423 – p.7/

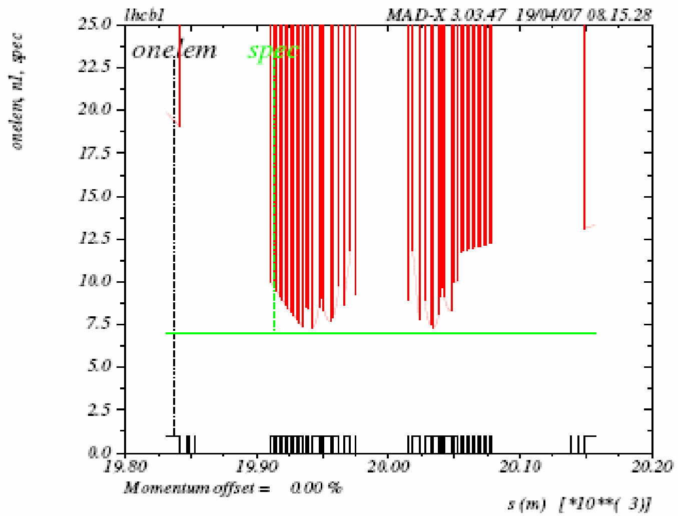
Aperture





Triplets only become potential aperture limits at around β* ≈ 5 m.





Vacuum

- Will start with warm vacuum chambers baked and NEG activated, both in the experimental region and in the LSS.
  - The static pressure after this is expected to be of order 10^{-11} mbar (as already achieved in ALICE).
- Cold sections will be simply cooled
- Followed by conditioning with beam:
  - **Dynamic vacuum:** increase beam current $\rightarrow$induced multipacting $\rightarrow$ lower secondary electron emissions.
  - Things get a bit worse.
- After conditioning things will improve.

Vacuum

	Stage 1	Stage 2	Nominal
Months of operation	4	7	7
Days of operation	100	175	175
Bunches	1/43/156	936/2808	2808
Protons/bunch	10^{10}-9 10^{10}	10^{10}-9 10^{10}	1.1 10^{10}
Protons	10^{10}-1.4 10^{13}	(3.7–9.8) 10^{13}	3.2 10^{14}
Current (mA)	0.02 - 25	70 - 80	582
Average current (mA)	8	140	582

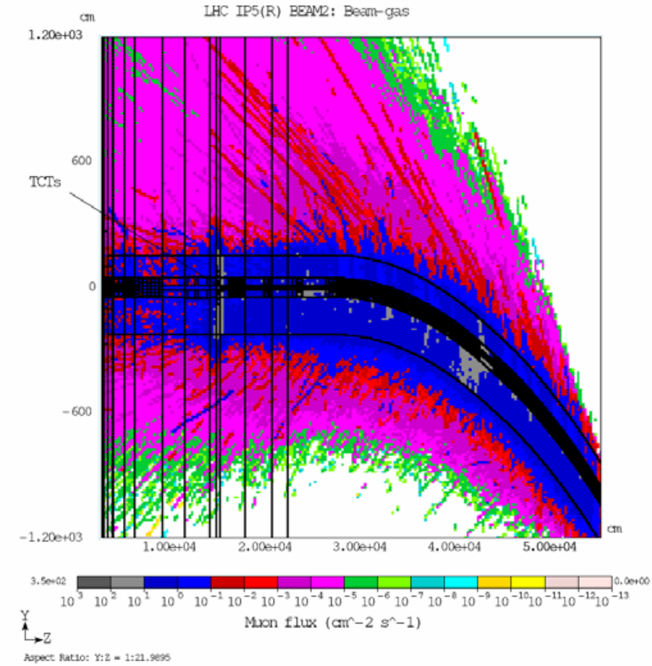
n_b	**43**	**156**	**2808**
Start-up	1.8×10^{12}	5.7×10^{12}	4.3×10^{13}
Nominal	4.2×10^{11}	6.3×10^{11}	5.3×10^{12}

Table 3: Average H_2 equivalent residual gas density, [mol/m^3] in the IR1 & 5 at the machine start-up and at nominal operation after the machine conditioning with the beam of different intensity.

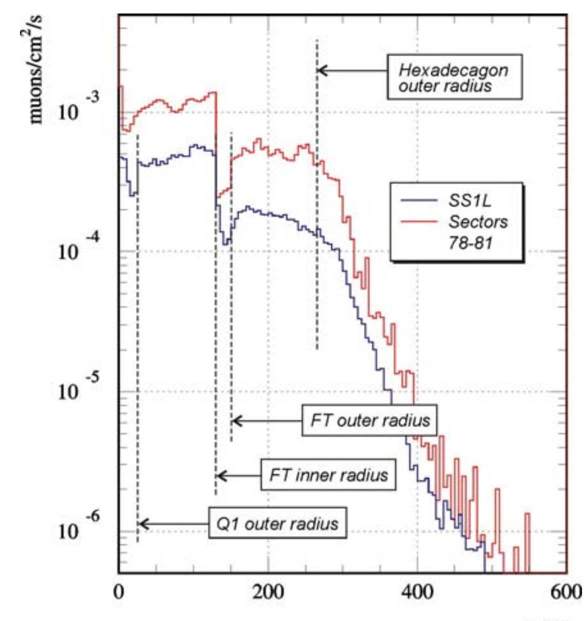
Residual gas density estimations in LHC Insertion Regions IR1 and IR5 and the experimental regions of ATLAS and CMS for different beam operations.
Adriana Rossi LPR 783

Background (briefly!)

Nikolai Mokhov



- Residual gas within experiments
  - Baked out etc. – low rates
- Residual gas in adjacent straight sections
  - See Adriana Rossi
- Gas pressure in adjacent cold sectors
  - Residual gas pressures expected in the cold arcs ≥ 20 times those in the cold sections of the LSS
  - Elastic scattering into IRs
  - Muons →
- Inefficiency of cleaning in IR7 & IR3
  - Tertiary halo on tertiary collimators
  - Not an issue initially



See: M. Huhtinen, V. Talanov, G. Corti, N. Mokhov et al

G. Corti, V. Talanov

Conclusions

- Beam commissioning
  - Should start May 2008
  - 2 months to get first collisions
  - First collisions - low intensity, un-squeezed.
  - We will be careful.

- Phase A
  - No crossing angle
  - Gradual increase in current - up to 156 bunches/beam
  - Pilot physics: un-squeezed to partial squeeze
  - $\leq 10^{32}$ $cm^{-2}s^{-1}$

- Collimation
  - Phase 1 scheme will be in place
  - Full and appropriate machine protection will be pursued.

http://cern.ch/lhccwg/