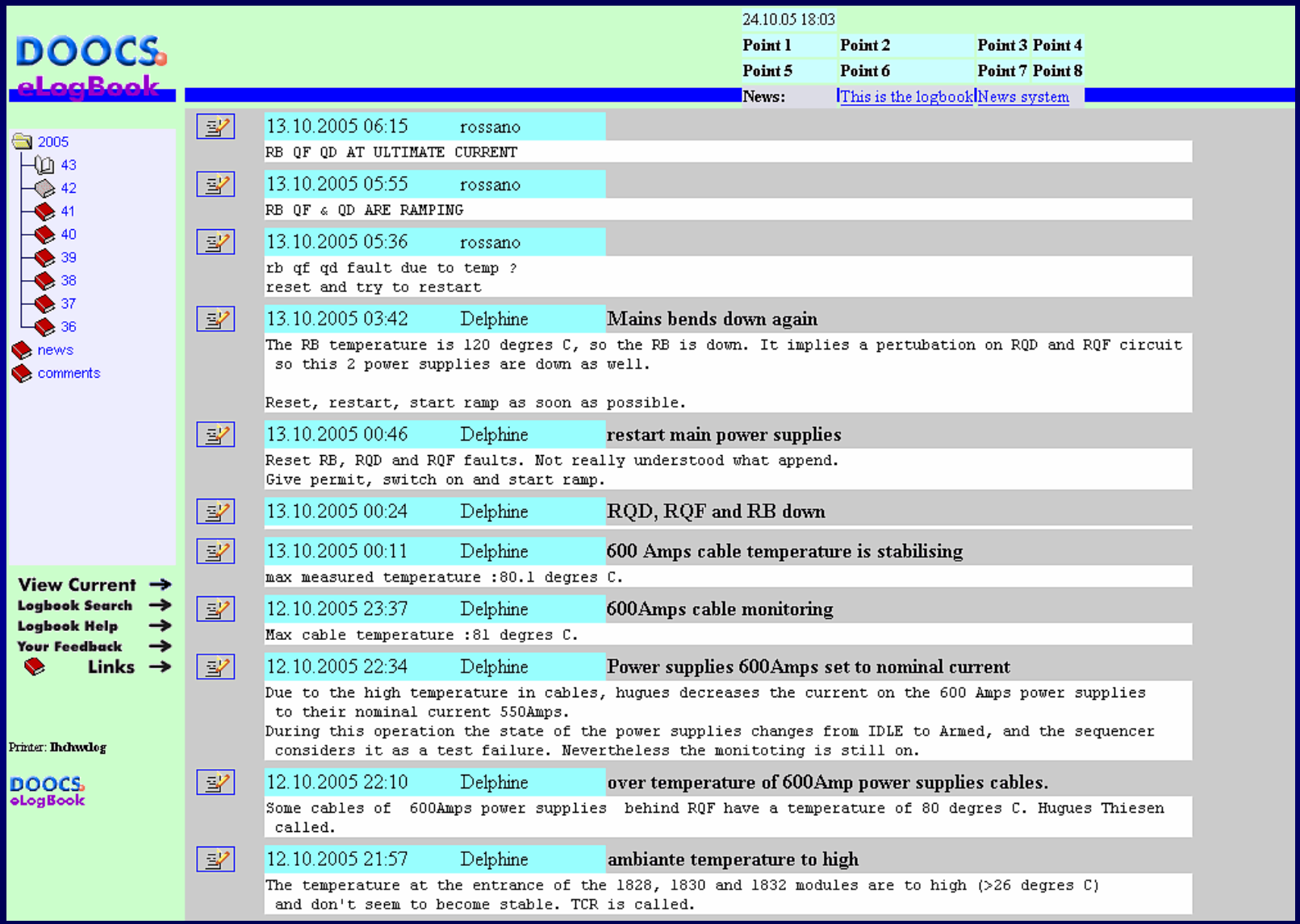
LHC commissioning

Mike Lamont
AB-OP

10th November 2005

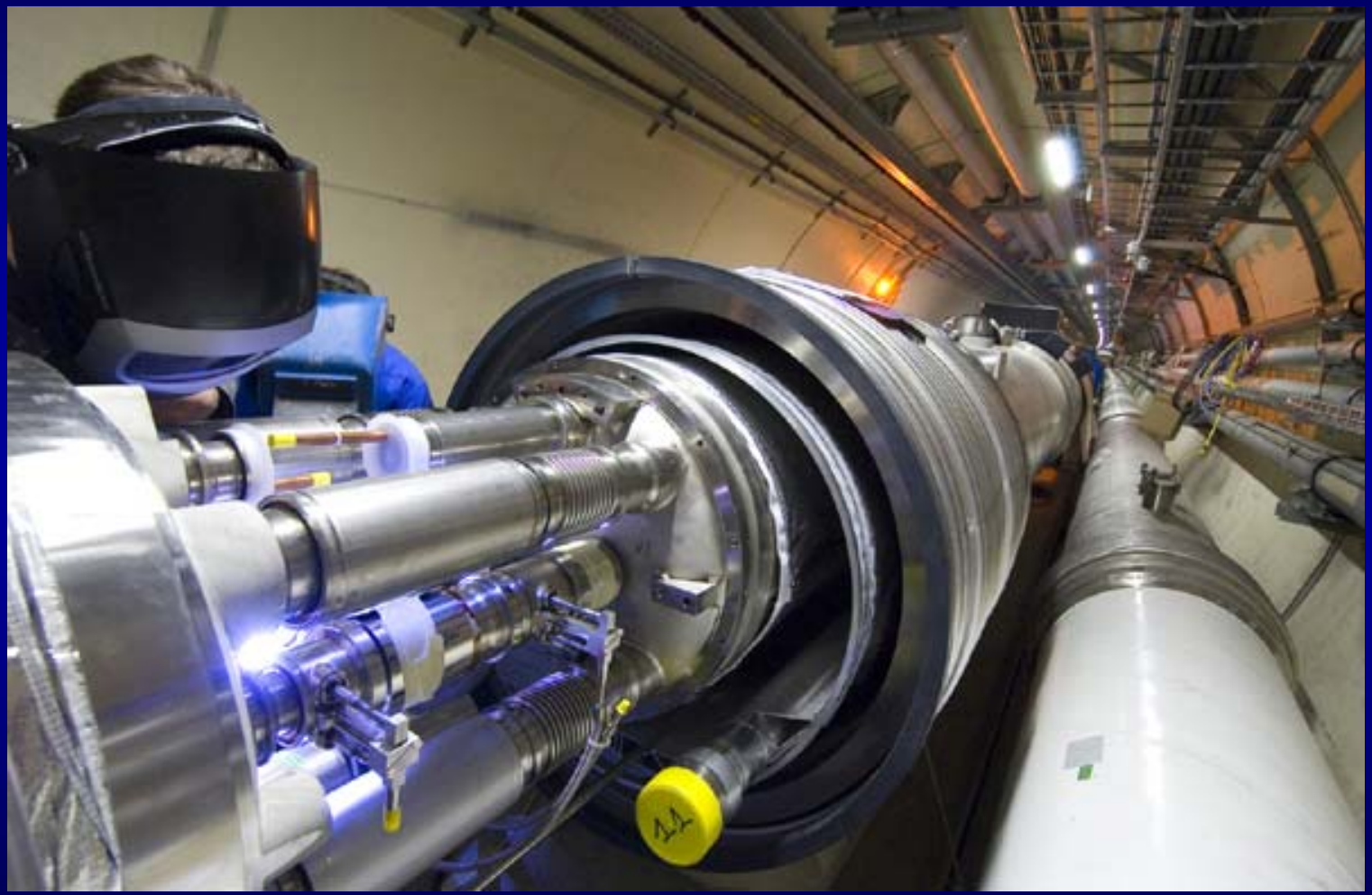
Short circuit tests


DOOCS
eLogBook
24.10.05 18:03
Point 1
Point 2
Point 3
Point 4
Point 5
Point 6
Point 7
Point 8
News:
This is the logbook
News system
2005
43
42
41
40
39
38
37
36
news
comments
View Current
Logbook Search
Logbook Help
Your Feedback
Links
Printer: lhdhwdog
DOOCS
eLogBook
13.10.2005 06:15 rossano
RB QF QD AT ULTIMATE CURRENT
13.10.2005 05:55 rossano
RB QF & QD ARE RAMPING
13.10.2005 05:36 rossano
rb qf qd fault due to temp ?
reset and try to restart
13.10.2005 03:42 Delphine
Mains bends down again
The RB temperature is 120 degres C, so the RB is down. It implies a pertubation on RQD and RQF circuit so this 2 power supplies are down as well.
Reset, restart, start ramp as soon as possible.
13.10.2005 00:46 Delphine
restart main power supplies
Reset RB, RQD and RQF faults. Not really understood what append.
Give permit, switch on and start ramp.
13.10.2005 00:24 Delphine
RQD, RQF and RB down
13.10.2005 00:11 Delphine
600 Amps cable temperature is stabilising
max measured temperature :80.1 degres C.
12.10.2005 23:37 Delphine
600Amps cable monitoring
Max cable temperature :81 degres C.
12.10.2005 22:34 Delphine
Power supplies 600Amps set to nominal current
Due to the high temperature in cables, hugues decreases the current on the 600 Amps power supplies to their nominal current 550Amps.
During this operation the state of the power supplies changes from IDLE to Armed, and the sequencer considers it as a test failure. Nevertheless the monitoting is still on.
12.10.2005 22:10 Delphine
over temperature of 600Amp power supplies cables.
Some cables of 600Amps power supplies behind RQF have a temperature of 80 degres C. Hugues Thiesen called.
12.10.2005 21:57 Delphine
ambiante temperature to high
The temperature at the entrance of the 1828, 1830 and 1832 modules are to high (>26 degres C) and don't seem to become stable. TCR is called.

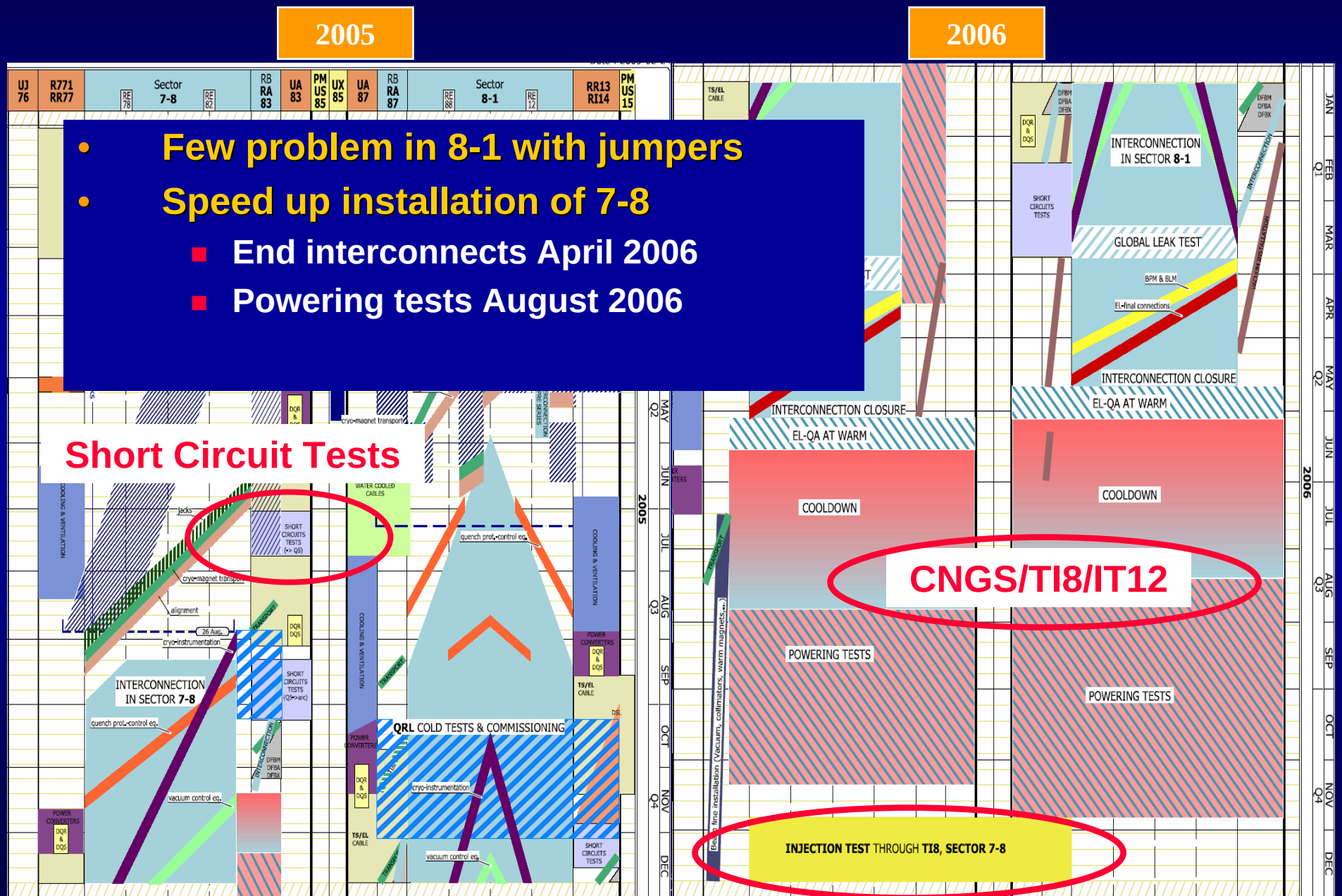
QRL

Dipoles

Interconnects

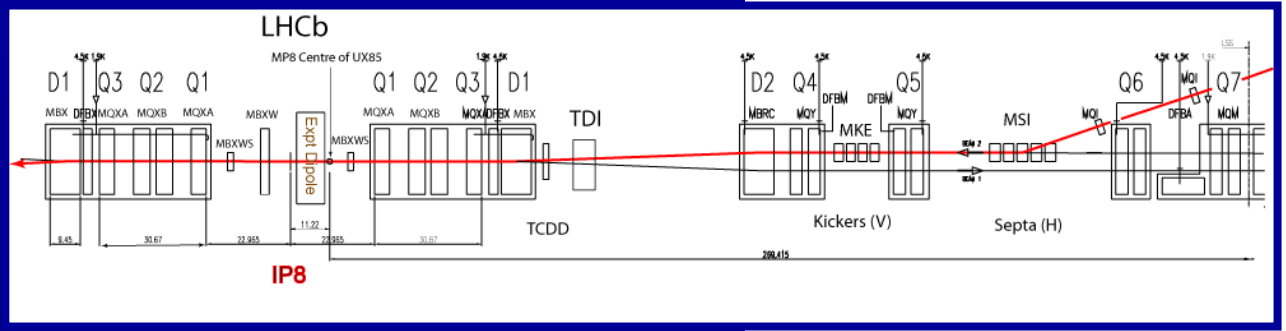


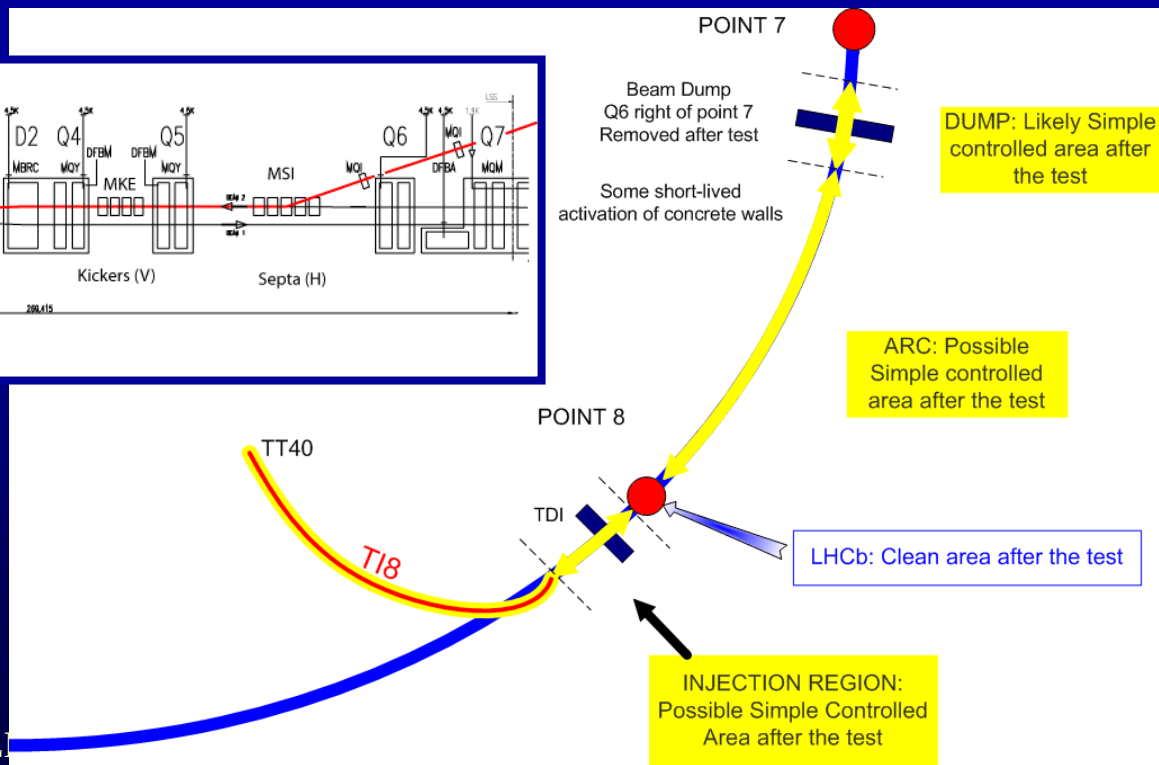
Detailed planning for 7-8 and 8-1



Sector Test

- Rigorous check of ongoing installation and hardware commissioning
- Pre-commission essential acquisition and correction procedures.
  - Commission injection system
  - Commission Beam Loss Monitor system
  - Commission trajectory acquisition and correction.
  - Linear optics checks:
  - Mechanical aperture checks.
  - Field quality checks.
  - Test the controls and correction procedures
- Hardware exposure to beam will allow first reality checks of assumptions of quench limits etc.

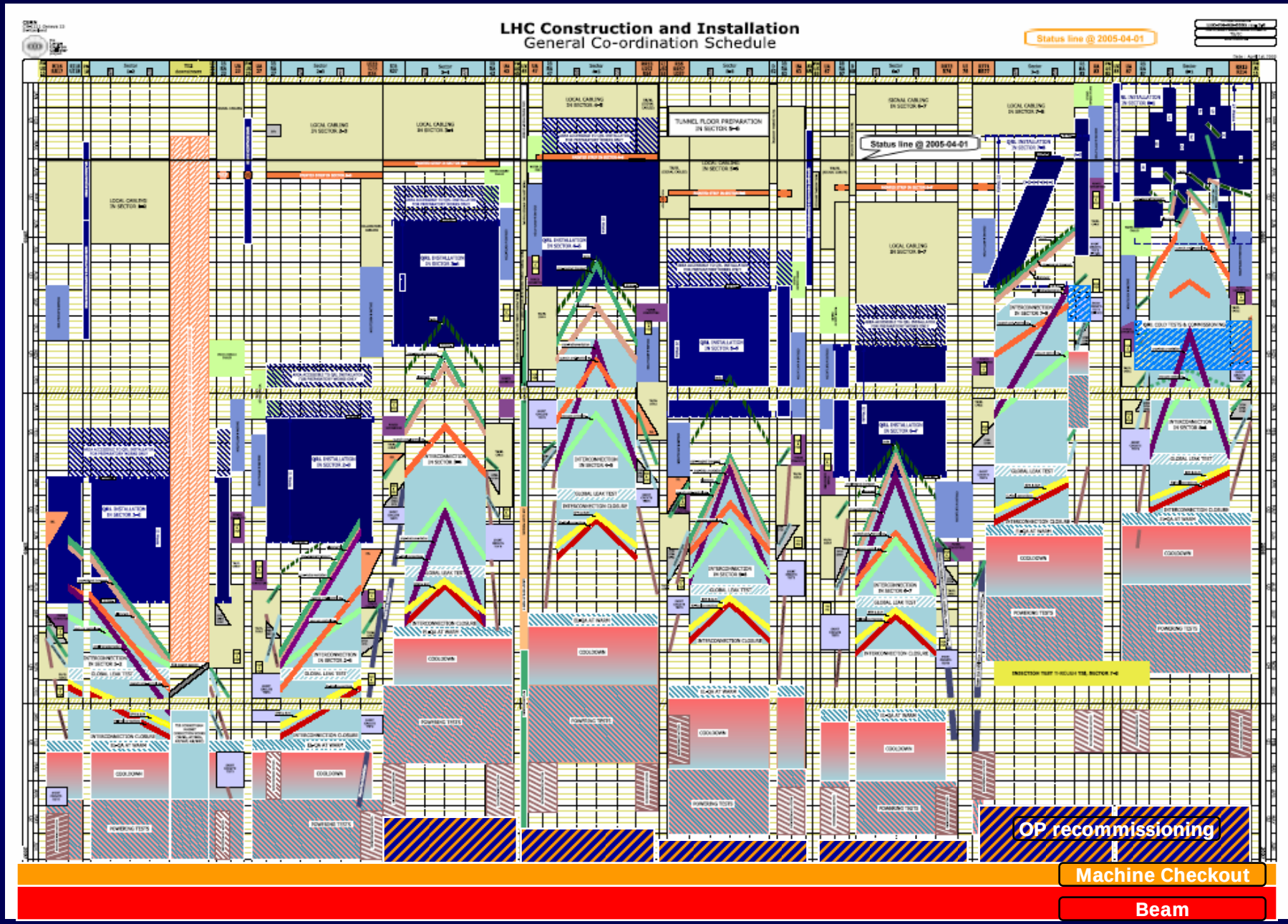




3 weeks Nov-Dec 2006

Sector Test – Tests with beam

Test	Priority	Duration [hours]	Intensity	Number of shots	Integrated Intensity	Comments
End TI8, Injection Steering, commission screens, IBMS, timing	1	24	5.00E+09	500	2.50E+12	TDI in, protecting LHCb
Trajectory acquistion commissioning, trajectory correction, threading, check energy matching	1	24	5.00E+09	500	2.50E+12	To beam dump
Linear Optics from kick/trajectory, coupling, BPM polarity checks, corrector polarity checks	1	12	1.00E+10	400	4.00E+12	
Commission & calibrate BLM system	1	24	5.00E+09	500	2.50E+12	First to TDI
Aperture limits, acceptance	1	24	5.00E+09	1000	5.00E+12	Pi bumps, BLMs, BCT
Momentum aperture	1	6	5.00E+09	100	5.00E+11	Move energy of SPS beam
Commission normal cycle - recheck dispersion, optics, aperture	1	24	5.00E+09	300	1.50E+12	Cycle & wait
Effects of magnetic cycle, variations during decay, reproducibility	1	24	5.00E+09	300	1.50E+12	10 cycles
IR bumps, aperture, seperation, crossing angle bumps [LHCb?]	2	6	5.00E+09	100	5.00E+11	Careful in LHCb
Energy offset versus time on FB	2	12	5.00E+09	100	5.00E+11	Cycle & repeat
Field errors	2	6	3.00E+10	100	3.00E+12	Collect data, off-line analysis
Multi-bunch injection - determination of quench level	2	12	2.00E+11	10	2.00E+12	10 quenches (maximum - start with pilot and work slowly up…)
Injection protection studies - TDI/TCLI/TCDI	3	6	5.00E+09	800	4.00E+12	TDI in - mainly on to TCDI
TDI	3	6	5.00E+09	800	4.00E+12	On to TDI
TOTAL		210		5510	2.35E+13	On to TED
DAYS		8.8			6.50E+12	On to TDI
					4.00E+12	On to TCDI


LHC Construction and Installation
General Co-ordination Schedule
Status line @ 2005-04-01
Status line @ 2005-04-01
OP recommissioning
Machine Checkout
Beam

Objectives

Commissioning the LHC with beam - Stage One

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

Take two moderate intensity multi-bunch beams to high energy and collide them.

Stage 1

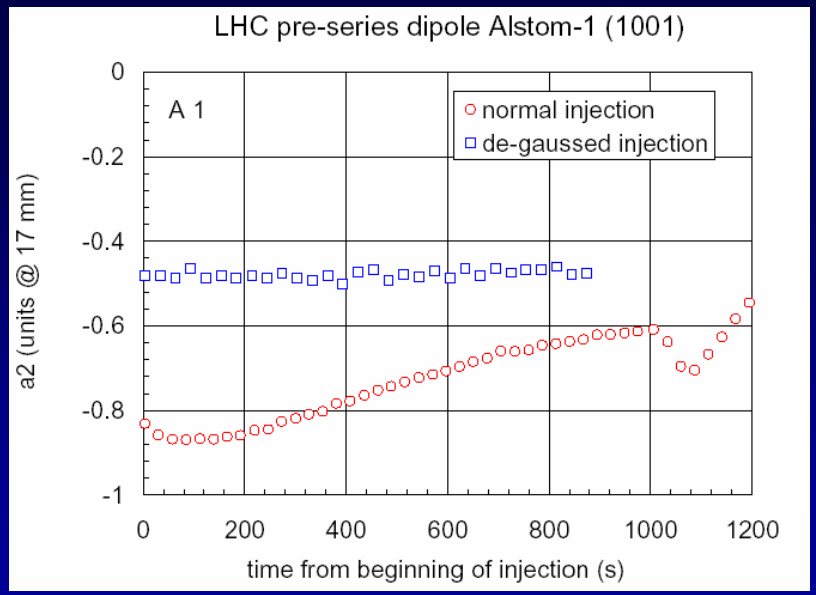
43 on 43 with 3 to 4 x 10^{10} ppb to 7 TeV

- **No parasitic encounters**
  - No crossing angle
  - No long range beam
  - Larger aperture
- **Instrumentation**
- **Good beam for RF, Vacuum…**
- **Lower energy densities**
  - Reduced demands on beam dump system
  - Collimation
  - Machine protection
- **Luminosity**
  - 10^{30} $cm^{-2}s^{-1}$ at 18 m
  - 2 x 10^{31} $cm^{-2}s^{-1}$ at 1 m

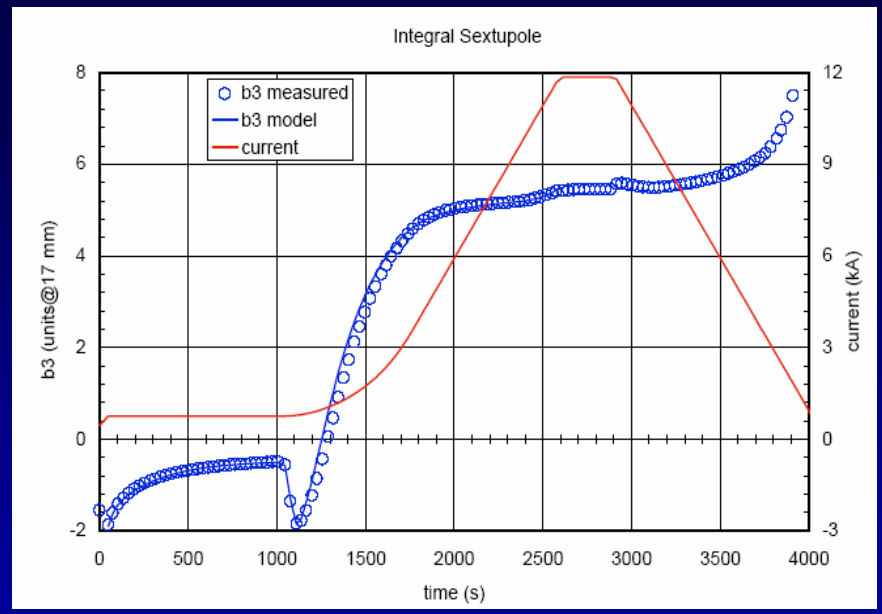
Beam

- **Pilot Beam:**
  - **Single bunch, 5 to 10 x 10^9 protons**
  - **Possibly reduced emittance**
- **Intermediate single:**
  - **3 to 4 x 10^{10} ppb**
- **4 bunches etc. pushing towards…**
- **43 (to 156) bunches**
  - **3 to 4 x 10^{10} ppb**

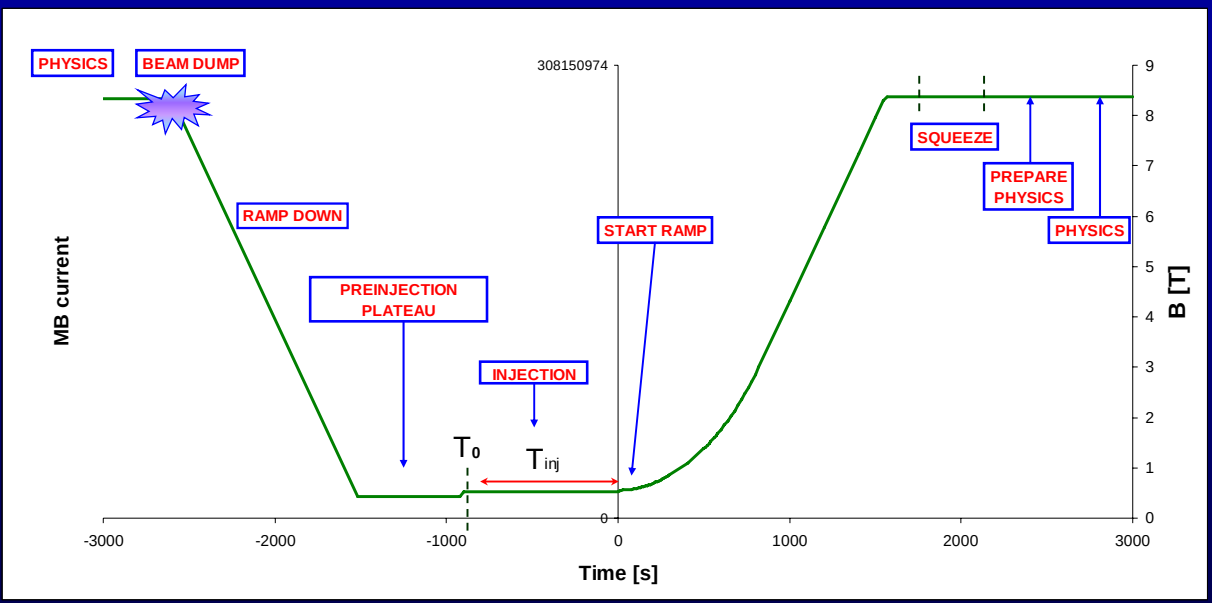
Will stepping up & down in intensity/number of bunches through the phases

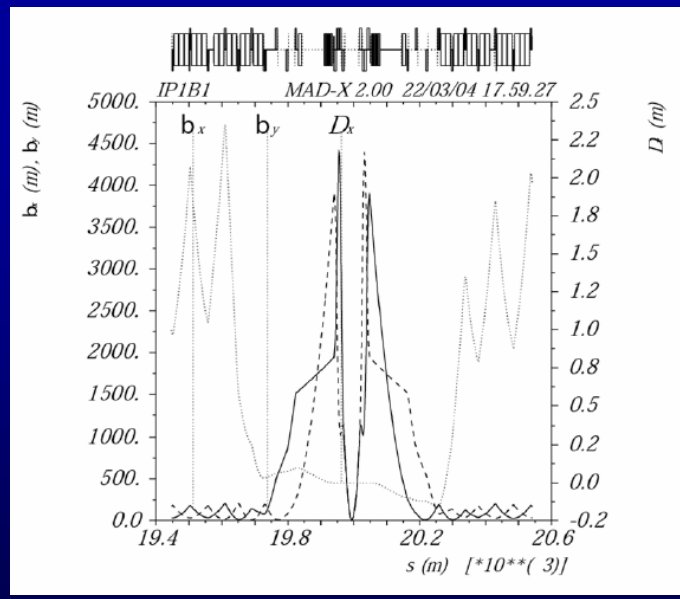


De-Gauss



Snapback

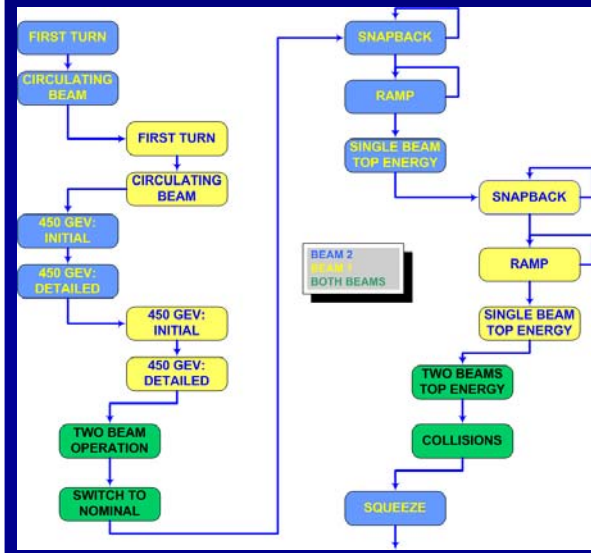




Squeeze

PLANNING

1	Injection
2	First turn
3	Circulating beam
4	450 GeV: initial commissioning
5	450 GeV: detailed measurements
6	450 GeV: 2 beams
7	Nominal cycle
8	Snapback – single beam
9	Ramp – single beam
10	Single beam to physics energy
11	Two beams to physics energy
12	Physics
13	Commission squeeze
14	Physics partially squeezed



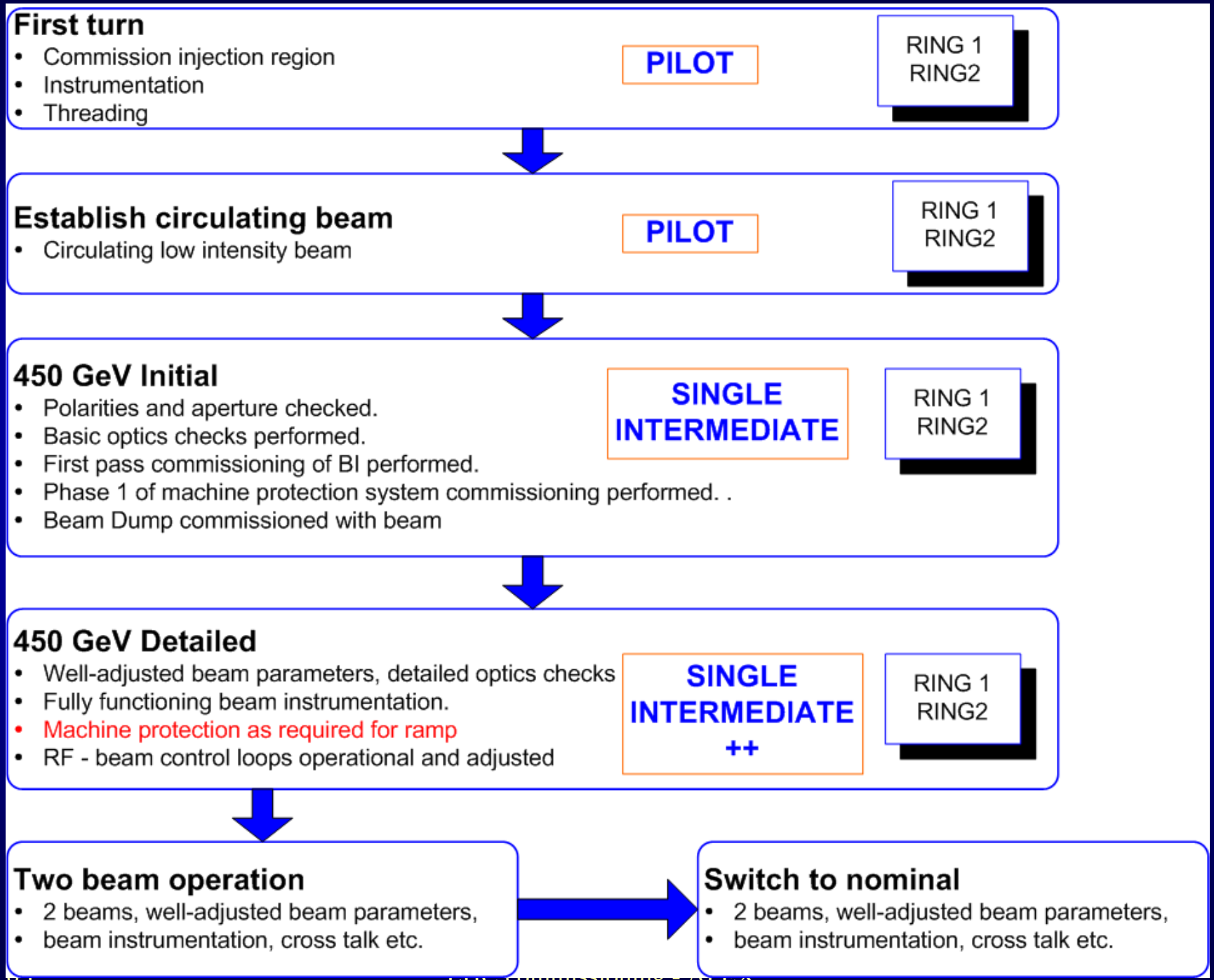
Pilot++

At each phase:

- Equipment commissioning with beam
- Instrumentation commissioning
- Checks with beam
  - BPM Polarity, corrector polarity, BPM response
- Machine protection
- Beam measurements
  - beam parameter adjustment, energy, linear optics checks, aperture etc. etc.

to the levels required.

Looking for an efficient commissioning path to get us to the above objectives


First turn
• Commission injection region
• Instrumentation
• Threading
PILOT
RING 1
RING2
Establish circulating beam
• Circulating low intensity beam
PILOT
RING 1
RING2
450 GeV Initial
• Polarities and aperture checked.
• Basic optics checks performed.
• First pass commissioning of BI performed.
• Phase 1 of machine protection system commissioning performed. .
• Beam Dump commissioned with beam
SINGLE
INTERMEDIATE
RING 1
RING2
450 GeV Detailed
• Well-adjusted beam parameters, detailed optics checks
• Fully functioning beam instrumentation.
• Machine protection as required for ramp
• RF - beam control loops operational and adjusted
SINGLE
INTERMEDIATE
++
RING 1
RING2
Two beam operation
• 2 beams, well-adjusted beam parameters,
• beam instrumentation, cross talk etc.
Switch to nominal
• 2 beams, well-adjusted beam parameters,
• beam instrumentation, cross talk etc.

Snapback

- Single beam, good transmission through snapback
- Requisite measurements (orbit, tune, chromaticity)

PILOT++

RING 1
RING2

Ramp Single Beam

- Single beam, good transmission to top energy
- Commission beam dump in ramp
- Stops in ramp - measurements
- RF

PILOT++

RING 1
RING2

Two beams to top energy

- Two beams, good transmission to top energy
- Measurements

43 x 43

COLLIDE

Squeeze

- Single beam - step through squeeze
- Parameter control, measurements

SINGLE
INTERMEDIATE

RING 1
RING2

Stage 1 - How long?

	Phase	R1/2	Time [days]	
	Injection	2	1	2
1	First turn	2	3	6
2	Circulating beam	2	3	6
3	450 GeV: initial commissioning	2	4	8
4	450 GeV: detailed measurements	2	4	8
5	450 GeV: 2 beams	1	2	2
6	Nominal cycle	1	5	5
7	Snapback – single beam	2	3	6
8	Ramp – single beam	2	4	8
9	Single beam to physics energy	2	2	4
10	Two beams to physics energy	1	3	3
11	Physics	1	2	2
12	Commission squeeze	2	4	
13	Physics partially squeezed	1		
	TOTAL TIME (WITH BEAM)			*60*

Stage 1 - Luminosities

- 43 to 156 bunches per beam
- N bunches displaced in one beam for LHCb
- Push one or all of:
  - To 156 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

10 pb^{-1} during pilot run

STAGE 1
INITIAL COMMISSIONING
43 x 43 -> 156 x 156 $3x10^{10}$ per bunch
Zero to Partial squeeze

SHUTDOWN

STAGE 2
75 ns OPERATION
3-4 x 10^{10} per bunch
Partial squeeze

STAGE 3
25 ns OPERATION
3-4 x 10^{10} per bunch
Partial to near full squeeze

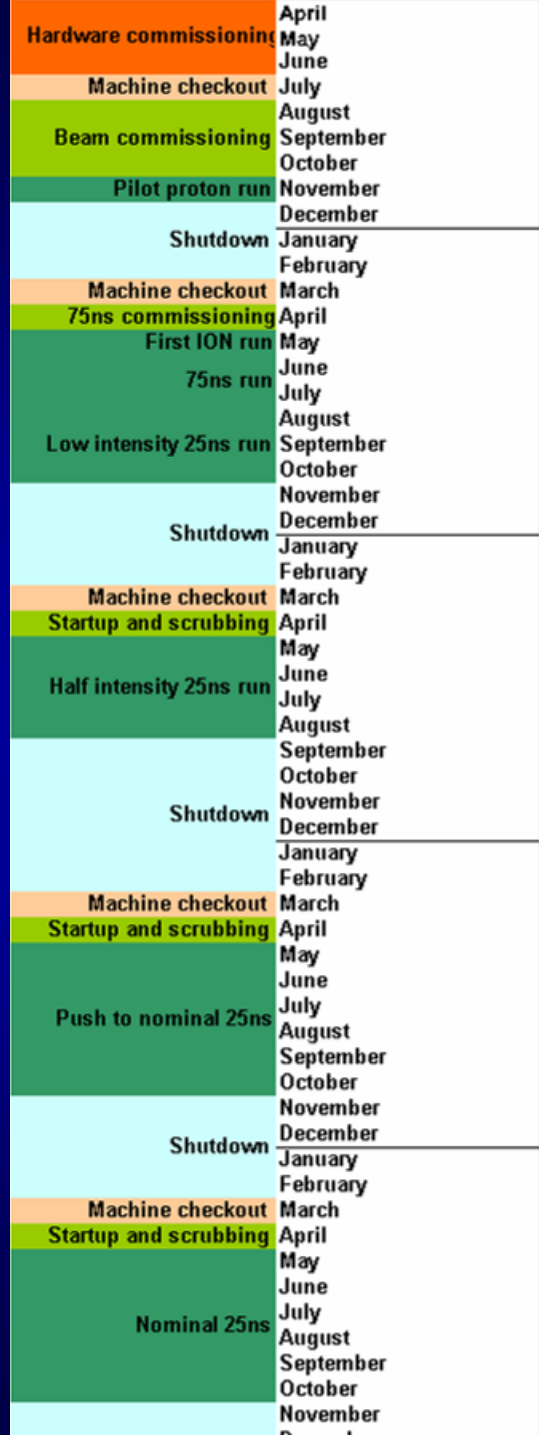
LONG SHUTDOWN

STAGE 4
25 ns OPERATION
push to nominal per bunch
Partial to full squeeze

Year one[+] operation:
Lower beam intensity/luminosity:
- Event pileup
- Electron cloud
- Phase 1 collimator impedance etc.
- Equipment restrictions

Relaxed squeeze, lower intensities, 75 ns. bunch spacing

Phase 2 Collimation
Full Beam Dump
Scrubbed



Stage 2 – 75ns

- **Parameter tolerances:**
  - will necessarily tightened up. Optics/beta beating under reasonable control (and measured)
- **Commission crossing angles. Re-commission ramp and squeeze**
- **Injection:**
  - 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**
  - has to be well under control & we have to be able to measure it. Associated BI has to be fully commissioned.
- **Squeeze**
  - only partially commissioned up to now, needs to be well mastered including the implications of crossing angle and long-range beam-beam.

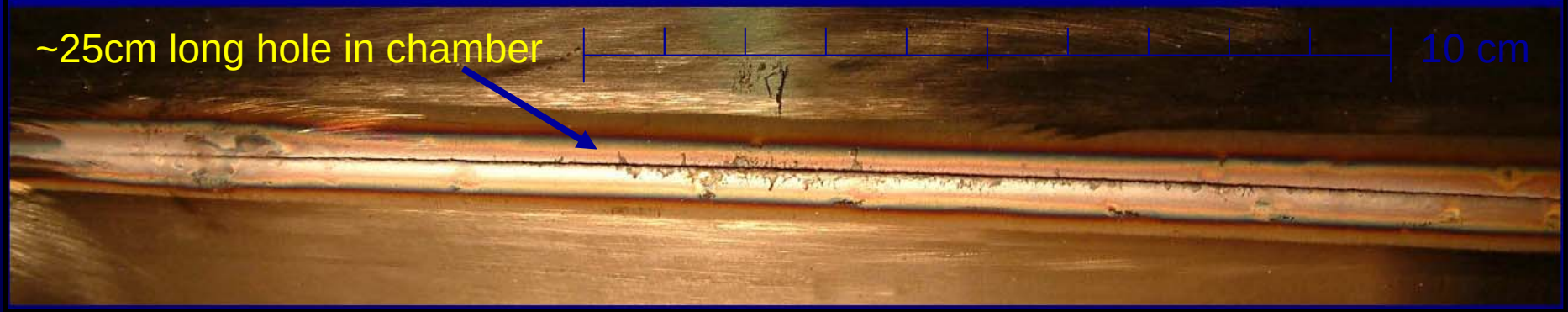
Plus Machine Protection etc

Give us a month…

Damage limit at 450 GeV:
1 full nominal batch » damage limit

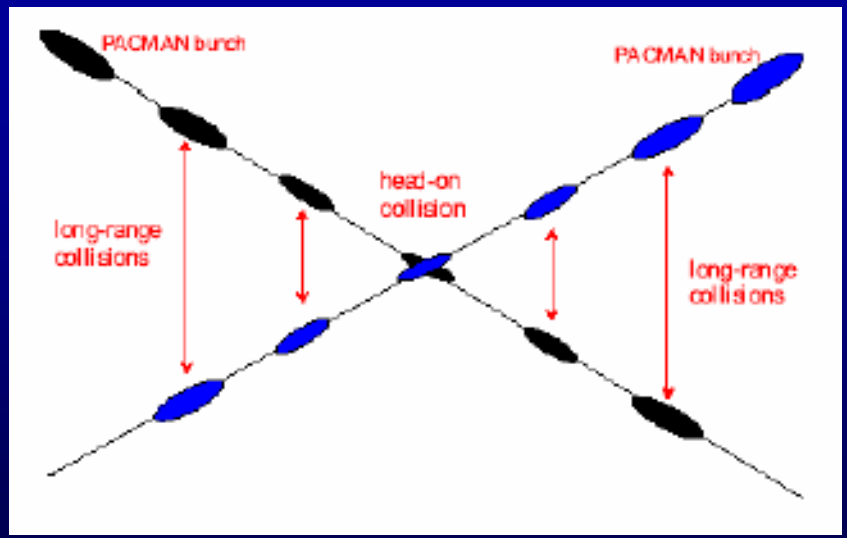
Verena Kain

25th of October: MSE trip during high intensity extraction. Damage of QTRF pipe and magnet.



75 ns - performance

Bunches	β*	I_b	Luminosity	Events per crossing
936 x 936	10	4 ⑨ 10^{10}	2.3 ⑨ 10^{31}	0.13
936 x 936	4	4 ⑨ 10^{10}	5.6 ⑨ 10^{31}	0.32
936 x 936	2	4 ⑨ 10^{10}	1.1 ⑨ 10^{32}	0.64



Stage 3 – 25ns Luminosities

- Start with bunch intensities below electron cloud threshold [?!]
- Increase bunch intensities to beam dump & collimator limit
- Tune IP2 and IP8 to meet experimental needs

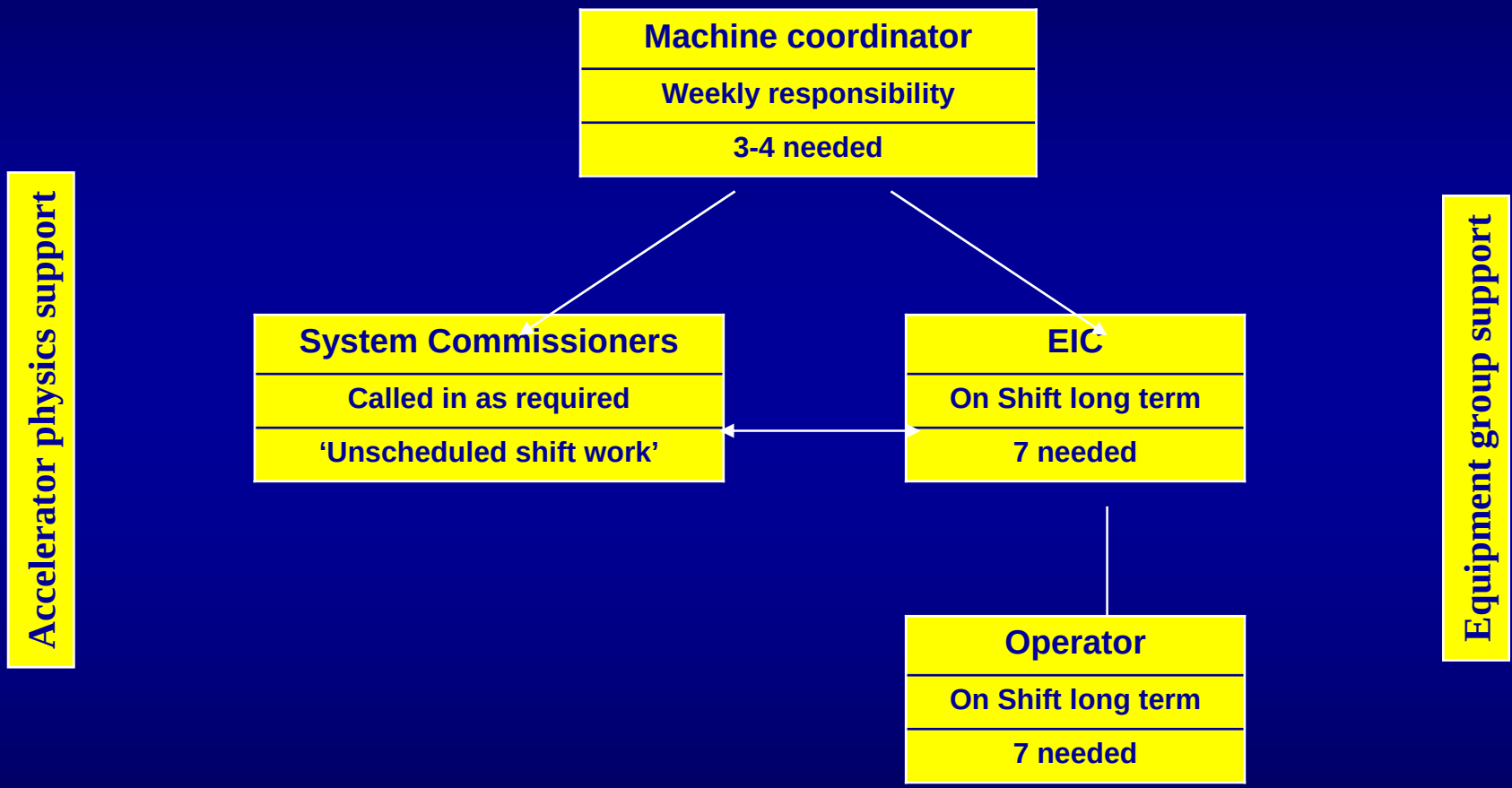
Number of bunches per beam	2808	2808	2808
β^* in IP 1, 2, 5, 8 (m)	0.55,10,0.55,10	0.55,10,0.55,10	0.55,10,0.55,10
Crossing Angle (μrad)	285	285	285
Bunch Intensity	$3\ 10^{10}$	$5\ 10^{10}$	$1.15\ 10^{11}$
Luminosity IP 1 & 5 ($cm^{-2}\ s^{-1}$)	$\sim 7\ 10^{32}$	$\sim 2\ 10^{33}$	10^{34}
Luminosity IP 2 & 8 ($cm^{-2}\ s^{-1}$)	$\sim 4\ 10^{31}$	$\sim 1\ 10^{32}$	$\sim 5\ 10^{32}$

Commissioning Org

- The overall picture is to have a central team of people driving the LHC beam commissioning, whose main thrust is to press on with the agreed program
- This team works 24/7, and hence is composed of shift workers and associated supervision
- This team must have considerable and effective support from both Accelerator Physics and Equipment Specialists. This support is a major enterprise, and will need to be organised effectively
- The people responsible for the various Accelerator Systems should be agreed now, and they should be involved in developing the details of the commissioning plan

System Commissioners !!

Commissioning organisation



Accelerator systems with beam

Team	Activity	Who (tbc)	LARP
Machine Protection	BIC commissioning	R. Schmidt B. Puccio J. Wenninger	XX
	Interface to BLMS		
	Interface to beam dump		
Beam Transfer	Extraction	V. Mertens, B. Goddard J. Uythoven V. Kain	
	Transfer Lines		
	Injection region commission		
	First turn		
	Absorbers		
	Beam Dump		
Power Converters	Sector to sector tracking	F. Bordry et al	
Collimation	Setting Optimisation	R. Assmann	X

Accelerator systems with beam

Team	Activity	Who (tbc)	LARP
Beam Instrumentation	Screens	X	
	BCT		
	BPMs etc	XX	
	BLM	XX	
	PLL	X	X
	Profile Monitors	X	
	Schottky	XXX	XX
	Luminosity monitors	XX	X
RF	Capture, phasing Longitudinal dynamics	TL,ES,TB X	
	Transverse feedback	WH	
CO [& OP]	RT feedback	JW, RS	X
	Post Mortem		

Accelerator systems with beam

Team	Activity	Who (tbc)	LARP
OP [& AP]	Filling efficiency	Bailey, Collier, Lamont, Wenninger et al	X
	Injection plateau optimisation		
	Snapback	XX	XX
	Ramp		
	Squeeze		
AP [& OP]	Optics	XXXXXX	
	Aperture	XXXX	
	Impedance	XXX	
	Lattice correctors	XX	
	Triplet correctors	XX	
	Lifetimes	XX	
	Separation & crossing angles	XX	
	Collisions	XX	XX
	Luminosity	XX	XX
	Ions	XXXX	

Conclusions

Commissioning with beam will be somewhat of a challenge

- **PREPARATION**
- **OBJECTIVES**
  - **Stage 1**
- **PLANNING**
  - **Before beam**
  - **Stage 1…**
- **LARP**
  - **Clear expectations & commitments**

- **http://cern.ch/lhc-injection-test**
- **http://cern.ch/lhc-commissioning**