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The LHC Machine Startup and Operational Schedule from a WLCG Service Viewpoint

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- The LHC machine
 - commissioning schedule
 - operation schedule(based on material from Roger Bailey, AB-OP)
- Impact on the WLCG Service schedule
 - interventions and upgrades
 - reliable services during LHC running

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LHC Machine Schedule

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PSS Main Installation Targets

- Cryogenics lines finished well before end of 2006 ✓
- Last magnets tests through SM18 before end of 2006 ✓
 - Activity continues in 2007 for spares
- Sector 7-8 cold before end of 2006 *in progress!*
- Last magnet lowered March 2007
- Vacuum closed August 2007
- Engineering run in 2007

- Power tests on magnet circuits
 - Sectors 78, 81, 45 fully hardware commissioned
 - Cycled to 7.2TeV with full protection systems
 - 7-8 8-1 kept on standby below 80K after HWC
 - 4-5 kept at nominal operating temperature after HWC
 - Sectors 34, 56, 67 hardware commissioned for 450GeV
 - Cycled to ~1TeV with limited protection systems
 - Kept at nominal operating temperature after HWC
 - Sector 23, 12 hardware commissioned for 450GeV just in time
- All special function equipment to be tested to 450GeV and more
 - Transfer lines, Injection systems, Extraction systems
 - RF, BI, Collimators
 - RP systems, MP systems (users)
- Vacuum closed end August 2007
- Global test of Access Control System October 2007
- Engineering run in 2007

PSS But..

- During the pressure test of Sector 8-1 (25th November) the heat exchanger tube in the inner triplet failed at 9 bar differential pressure
- A repair procedure is being validated and will have to be implemented on all 24 quadrupoles (18 are already installed)
- Priority: Inner triplet quadrupoles in 5L and 5R to be repaired in time for Sectors 4-5 and 5-6 cooldown. Others afterwards
- Consequences
 - Planning will have to change
 - Sector 8-1 will be cooled down and commissioned after 4-5
 - Sector 8-1 will be commissioned only to 450GeV in 2007
 - 450GeV run in 2007 is still the target
 - More time needed for commissioning hardware to high energy in 2008

Machine is closed (Aug 2007)



Minimum hardware commissioning



Nov/Dec 2007: Beam operation with collisions at 450 GeV



Full hardware commissioning and installation of some delayed equipment for 7 TeV (e.g. some collimators)



LHC commissioning for 7 TeV physics



LHC High Energy Operation 2

PSS Engineering run in 2007

Installation
Hardware Commissioning

Hardware
Commissioning
450GeV

Engineering Run
450GeV

Machine checkout
450GeV

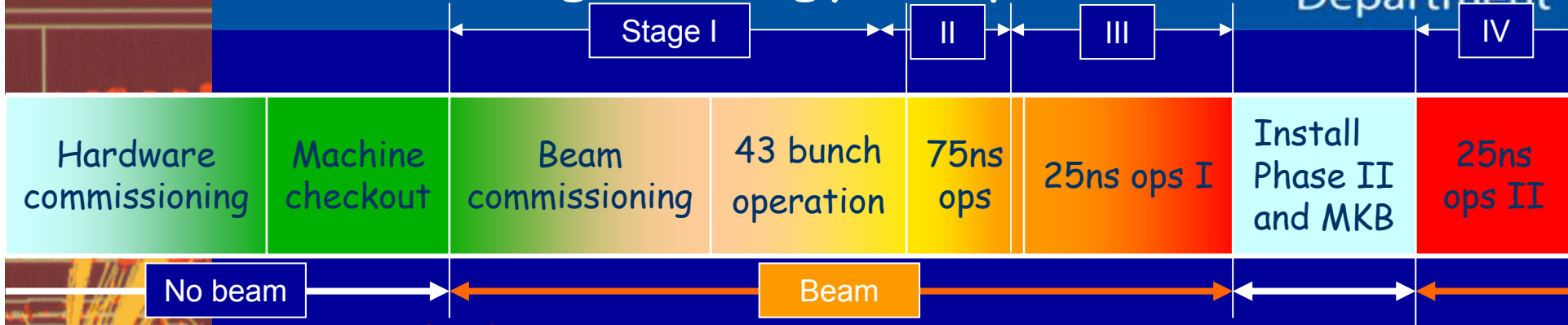
Beam commissioning
450GeV

Collisions 450GeV
Ramp
commissioning

- **Aims:**

- Commission essential safety systems
- Commission essential beam instrumentation
- Commission essential hardware systems
- Perform beam based measurements to check:
 - Polarities
 - Aperture
 - Field characteristics
- Establish stable two beam operations
- Provide collisions
- Interleave with further machine development, in particular, the ramp

PSS Commissioning strategy for protons



- **Pilot physics run**
 - First collisions
 - 43/156 bunches per beam, no crossing angle, no squeeze, moderate intensities
 - Push performance
 - Performance limit $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ (event pileup)
- **75ns operation**
 - Establish multi-bunch operation, moderate intensities
 - Relaxed machine parameters (squeeze and crossing angle)
 - Push squeeze and crossing angle on
 - Performance limit $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ (event pileup)
- **25ns operation I**
 - Nominal crossing angle
 - Push squeeze
 - Increase intensity to 50% nominal
 - Performance limit $2 \cdot 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- **25ns operation II**
 - Push towards nominal performance

Minimise

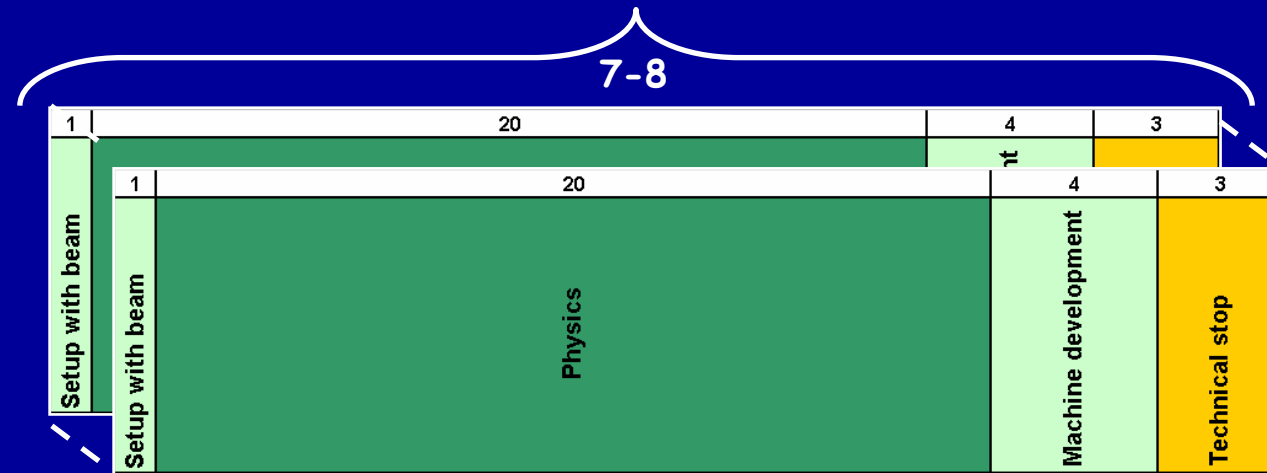
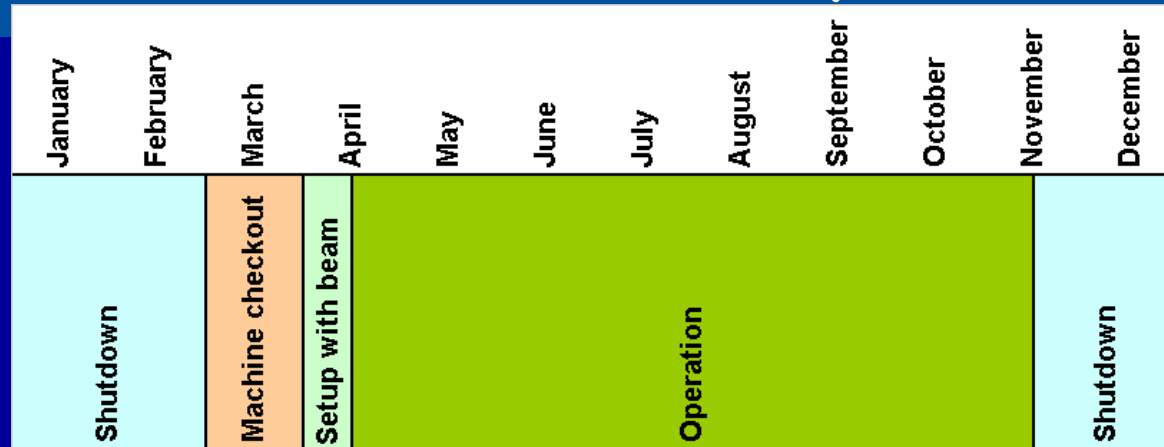
- Complexity
- Beam power
- Losses (β^*)
- Pileup

Optimise

- N
- k_b
- β^*



PSS Breakdown of a normal year



~ 140-160 days for physics per year
 Not forgetting ion and TOTEM operation
 Leaves ~ 100-120 days for proton luminosity running
 ? Efficiency for physics 50% ?
 ~ 1200 h or ~ 4 10^6 s of proton luminosity running / year

Every year there will be a long shutdown (3-4 months)

At the end of every shutdown

- Close the machine personnel access system
- Get all equipment ready for beam (machine checkout, ~ 3-4 weeks)
- Get machine ready for operation (setup with beam, 2-3 weeks)

During periods of operation

- Need regular technical stops (3 days every month)
 - Interventions need careful but flexible planning
- Get machine ready for operation (1 day)
- Machine development (around 15% during first years)
- Operations for physics
- Access as required for unscheduled stops

P2008 draft schedule

3 month++ shutdown (no beam)

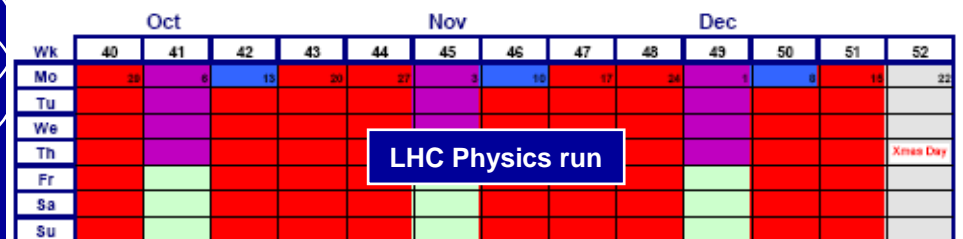
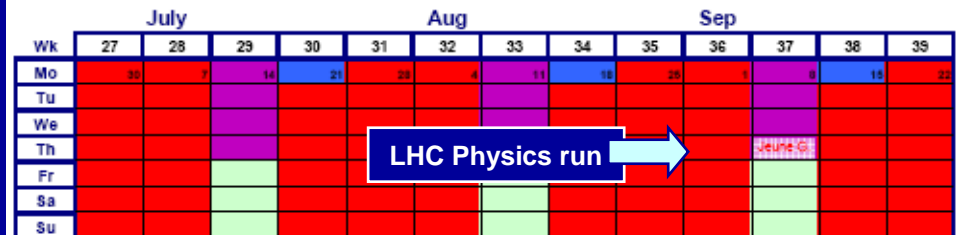
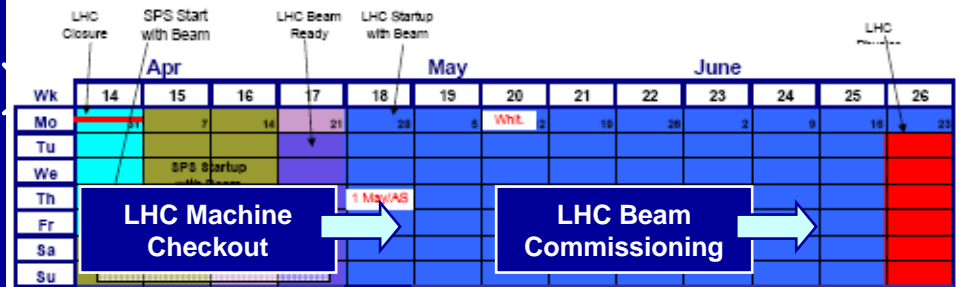
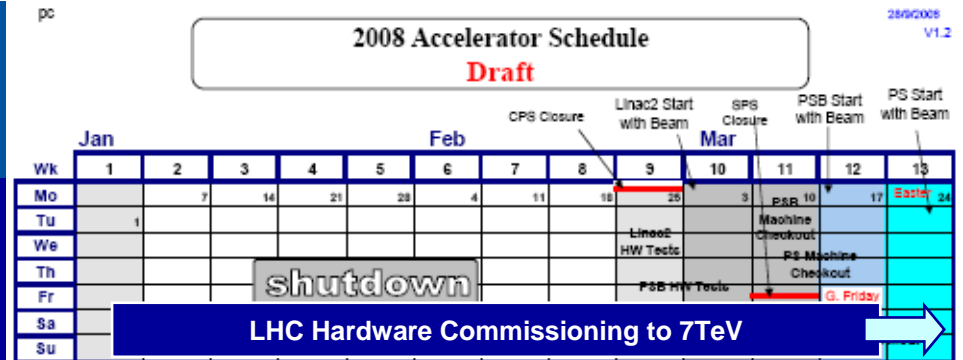
4 weeks checkout (no beam)
8 weeks beam commissioning

26 weeks physics run (protons)

- 20 days physics
- 4 days MD
- 3 days technical stop

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LHC Sched



- LHC Physics
- LHC Machine Development
- LHC Setup with beam
- LHC Technical Stop

- Expect to spend as much time out of physics as in
 - Ramp down, cycle, injection, ramp, squeeze, prepare
 - Faults, access, other problems
- Will be aiming to
 - Fix faults, give access, solve problems, fill, ramp, squeeze by day
 - Provide colliding beams for physics overnight
 - Averaging a 10h fill per day would be good (40% efficiency for physics)

(10^6 seconds @ $\langle L \rangle$ of $10^{33} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 1 \text{ fb}^{-1}$)

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WLCG Service Issues

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- Longer and less frequent MD/technical machine stops (1 week/month)
 - Stable beam conditions are expected during **weekends and nights**
 - Expect a significant impact on the experiment online process
 - Understand with the experiments what the impact is on the **offline and Grid processing**
 - Need for piquet / 24x7 services (cf MoU)
 - Will clearly be very strong pressure to process data at Tier0 and Tier1 sites (if not also Tier2s...) asap!
- Address with the experiments expected access pattern changes during the LHC running cycles

- When to schedule major interventions
 - Long interventions: machine shut-down periods
 - Machine room moves, air conditioning maintenance etc.
 - Short interventions: MD/technical stop weeks
 - Security, s/w, m/w and h/w upgrades
 - Critical interventions during data taking:
 - Site responsibility
- In all cases approved WLCG procedures for announcing interventions must be followed!!
- See attachment to agenda page

PSS Some Obvious No-nos...

- ☺ Going on holiday all August so that the complete site is down
 - ☺ Scheduling major downtimes - 'long term interventions' (e.g. air conditioning maintenance, machine room moves) during data taking
 - ☺ Scheduling 'short term' interventions (such as O/S, DB, M/W patches) in the middle of data taking - wait for next stop
 - ☺ Not responding to service problems overnight / weekends - MoU targets!!!
- Obviously many sites have non-HEP / non-LHC constraints which may conflict with this...

- Aims for 2007
 - Commission 450GeV machine
 - Multiple bunches (43) circulating in each ring
 - Single beam lifetimes ~ 30h
 - Injection optics ($\beta^* = 11$ m in IR 1 & 5, $\beta^* = 10$ m in IR 2 & 8)
 - No squeeze
 - No crossing angle
 - Collisions
 - Secondary aims
 - Commission ramp to 1TeV
 - Commission crossing angle
 - Commission 75ns beams
- Aims for 2008
 - Commission high energy operation
 - Aim for 7TeV (magnets will decide)
 - 43 /156 bunch running
 - No squeeze to start
 - Then commission partial squeeze (aim for 2m)
 - 75ns running
 - 25ns running
 - High $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ is in reach
 - ~100 days for physics, efficiency at 40%?

- LHC commissioning / running schedule for 2007 and 2008 confirmed
- **We must now operate in full service mode**
 - Scheduling and announcing interventions
 - Responding to service problems in a timely manner
 - Providing reliable, stable services in general
- **The experiments' "Dress Rehearsals" are the last opportunity to verify that everything is in place and functioning as required!**
- Services and procedures need to be in place some 2 months prior to start date of Dress Rehearsals
 - i.e. Q2 2007 for Q3 start

PSS Parameter evolution and rates

$$L = \frac{N^2 k_b f \gamma}{4\pi \epsilon_n \beta^*} F$$

$$\text{Eventrate / Cross} = \frac{L \sigma_{TOT}}{k_b f}$$

All values for nominal emittance, 7TeV and 10m β^* in points 2 and 8

Parameters			Beam levels		Rates in 1 and 5		Rates in 2 (and 8)	
k_b	N	β^* 1,5 (m)	$I_{\text{beam proton}}$	E_{beam} (MJ)	Luminosity ($\text{cm}^{-2}\text{s}^{-1}$)	Events/crossing	Luminosity ($\text{cm}^{-2}\text{s}^{-1}$)	Events/crossing
43	$4 \cdot 10^{10}$	11	$1.7 \cdot 10^{12}$	2	$1.1 \cdot 10^{30}$	$\ll 1$	$1.2 \cdot 10^{30}$	0.15
43	$4 \cdot 10^{10}$	2	$1.7 \cdot 10^{12}$	2	$6.1 \cdot 10^{30}$	0.76	$1.2 \cdot 10^{30}$	0.15
156	$4 \cdot 10^{10}$	2	$6.2 \cdot 10^{12}$	7	$2.2 \cdot 10^{31}$	0.76	$4.4 \cdot 10^{30}$	0.15
156	$9 \cdot 10^{10}$	2	$1.4 \cdot 10^{13}$	16	$1.1 \cdot 10^{32}$	3.9	$2.2 \cdot 10^{31}$	0.77
936	$4 \cdot 10^{10}$	11	$3.7 \cdot 10^{13}$	42	$2.4 \cdot 10^{31}$	$\ll 1$	$2.6 \cdot 10^{31}$	0.15
936	$4 \cdot 10^{10}$	2	$3.7 \cdot 10^{13}$	42	$1.3 \cdot 10^{32}$	0.73	$2.6 \cdot 10^{31}$	0.15
936	$6 \cdot 10^{10}$	2	$5.6 \cdot 10^{13}$	63	$2.9 \cdot 10^{32}$	1.6	$6.0 \cdot 10^{31}$	0.34
936	$9 \cdot 10^{10}$	1	$8.4 \cdot 10^{13}$	94	$1.2 \cdot 10^{33}$	7	$1.3 \cdot 10^{32}$	0.76
2808	$4 \cdot 10^{10}$	11	$1.1 \cdot 10^{14}$	126	$7.2 \cdot 10^{31}$	$\ll 1$	$7.9 \cdot 10^{31}$	0.15
2808	$4 \cdot 10^{10}$	2	$1.1 \cdot 10^{14}$	126	$3.8 \cdot 10^{32}$	0.72	$7.9 \cdot 10^{31}$	0.15
2808	$5 \cdot 10^{10}$	1	$1.4 \cdot 10^{14}$	157	$1.1 \cdot 10^{33}$	2.1	$1.2 \cdot 10^{32}$	0.24
2808	$5 \cdot 10^{10}$	0.55	$1.4 \cdot 10^{14}$	157	$1.9 \cdot 10^{33}$	3.6	$1.2 \cdot 10^{32}$	0.24

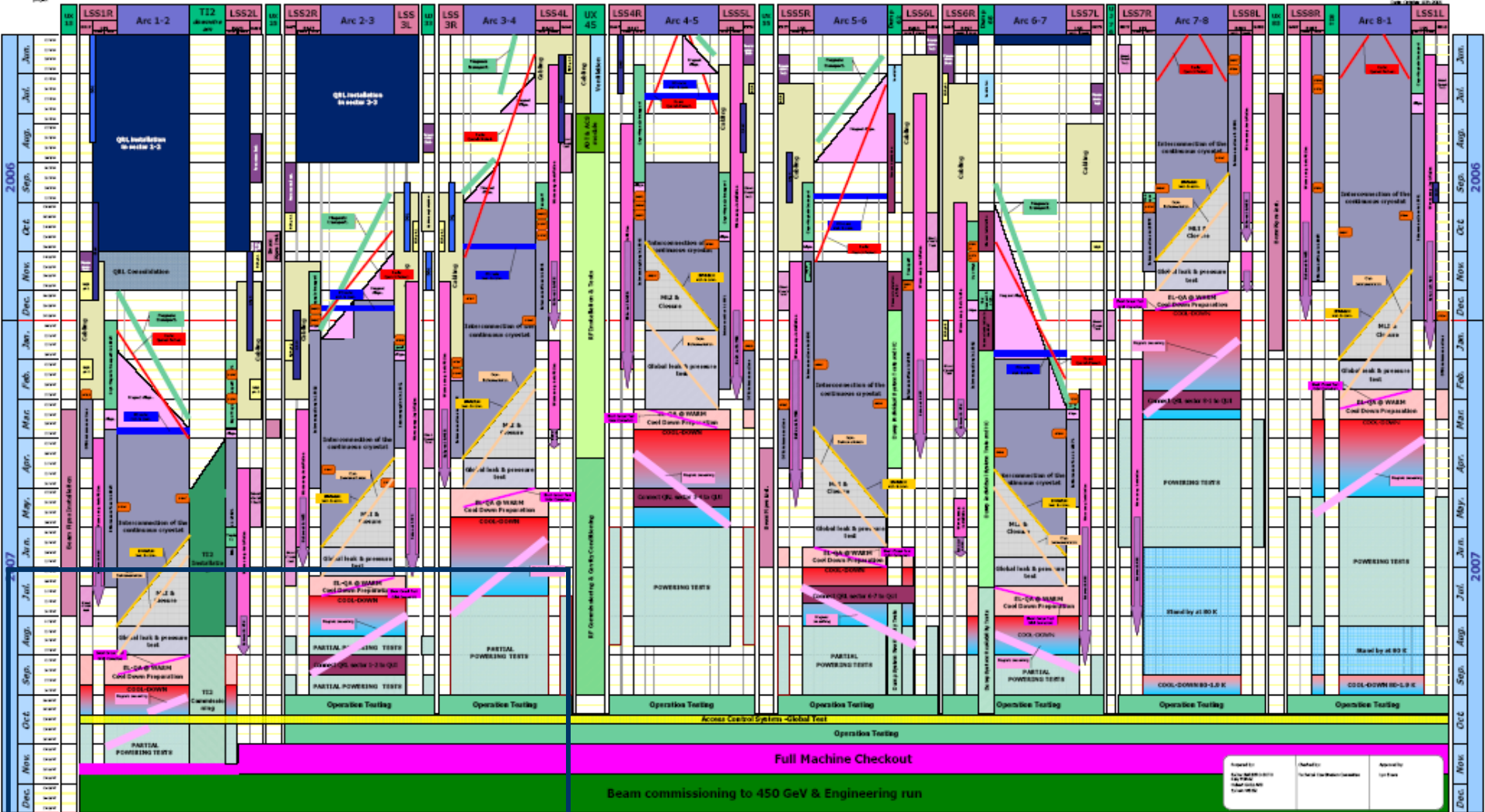


PSS Master Planning



LHC Construction and Installation General Co-ordination Schedule

Version: 1.0
LHC/IT-SS-0005.1 rev. 3.1
Title: New a table for construction
TS, IC
Date: 16/03/06
16/03/06



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PSS The end of 2007

