450 GeV Calibration Run

Mike Lamont

22/6/06

450 GeV – Calibration Run

- **Fastest Safe Path to low intensity collisions**
  - **Commission essential safety systems**
  - **Commission essential beam instrumentation**
  - **Commission essential hardware systems**
  - **Perform measurements to check:**
    - Polarities
    - Aperture
    - Field characteristics
- **Skip non-essential**
  - **Mop up in interleafed MD**
- **Could also do in MD:**
  - **First part of ramp (to 1.1 TeV)**
  - **Get a handle on reproducibility etc.**
- **Could also do parasitically:**
  - **Commission beam instrumentation (PLL etc.)**

Handover from HWC

- Interlocks, compatibility tests, protection tests
- Power Converters:
  - protection, calibration, ramp tests performed
- Circuits commissioned to around 1.1 TeV equivalent
  - ~ 1900 A in main bends, ~16% nominal

Followed by curtailed machine checkout

Magnets

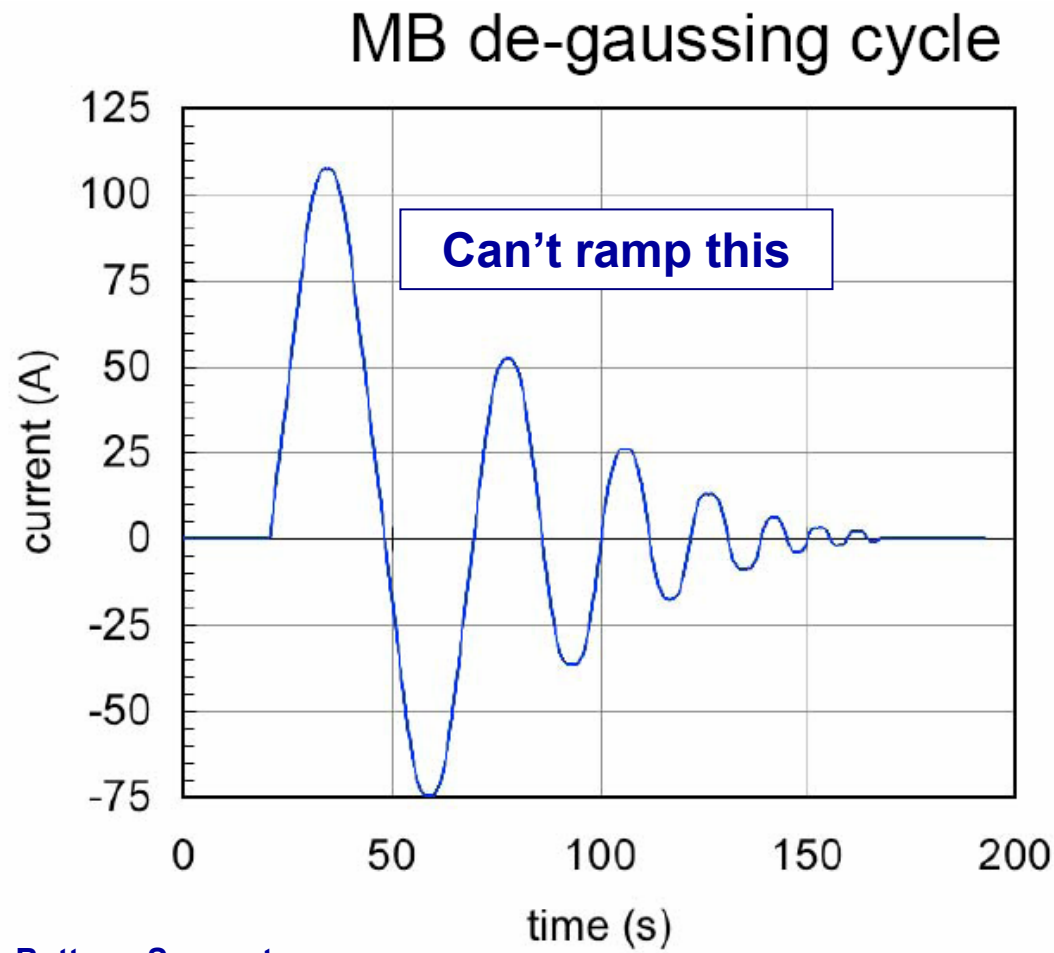
Need limited cycling capabilities in order to reset magnetic history

- **Need to be able to cycle main bends, quads, sextupoles to ~16% of nominal [1.1 TeV equivalent]**
- **Similarly need to be able to cycle insertion quads, separation dipoles etc. to ~20% of nominal**
- **Would expect correction circuits ≤ b3 to fully commissioned to full current:**
  - **This includes all orbit correctors.**
  - **Coulde make do with 10-20% of Imax if really necessary.**

Low field

- **Some insertion quadrupoles (including inner triplets) at low field**
  - **Therefore low field quality**
  - **Tracking in progress (Massimo Giovannozzi)**
  - **Might need the triplet correctors to improve the field quality of the low-beta quadrupoles at injection**
  - **Similarly MCDO might be useful**

De-Gauss cycle – short cut



Bottura, Sammut

Commission on De-Gauss

First collisions

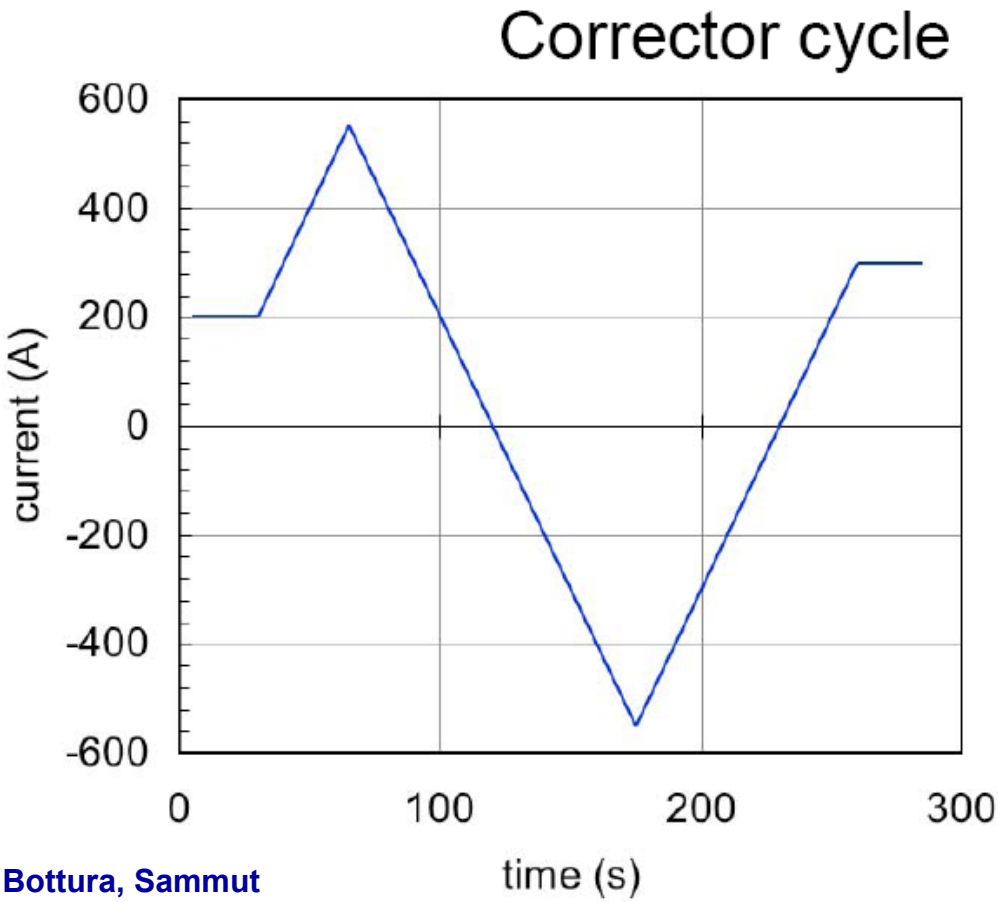
↓

HWC 450 GeV++

↓

Commission on nominal

Collisions & ramp



Bottura, Sammut

Standard cleansing and setting cycle:
The pre-cycle:
- resets persistent current effects
- insures no hysteresis crossing at new setting

Required Circuits

Main dipoles	MB
Separation dipoles (warm & cold)	MBRB MBRC MBRS MBW MBXW
Spectrometer compensation	MBXWH MBXWS MBXWT
Orbit correctors	MCBH MCBV MCBY MCBX MCBC
Sextupole spool	MCS
Lattice Quad	MQ
Insertion quads	MQM MQMC MQML
Lattice skew	MQS
Tuning quads	MQT
Dispersion suppressors quads	MQTL MQTLI
Twin aperture warm quads	MQWB
Inner triplets	MQXA MQXB
Wide aperture insertion quads	MQY
Lattice sextupole	MS

Circuits not immediately needed

Essentially can skip higher order correction… checks in progress

Decapole spool correctors	MCD
Octupole spool correctors	MCO
Skew Octupole - triplet	MCOSX
Skew sextupole - triplet	MCSSX
Sextupole corrector – triplet	MCSX
Dodecapole Spool - triplet	MCBXA
Lattice Octupole	MO
Skew quadrupole - triplet	MQSX
Arc skew sextupoles	MSS

Would expect all circuits for 34 45 78 81

Machine Configuration

Optics:

- **Inject into 6 m. IPs 1 & 5; 10 m. IPs 2 & 8**
  - **round beam optics, the minimum beta* allowed for aperture is 6 m**
  - **for flat beam optics beta*_x/y=6/3.7m in IR1 and beta*_x/y=3.7/6m**
  - **limit from aperture considerations**

Stephane Fartoukh

- **Crossing angles off (up to 156 bunches per beam)**
- **Would have to shift bunches for LHCb**

No powering limitation were observed in the sense that all quadrupole gradients are in between 3% of nominal and nom./16 (so the foreseen hardware commissioning up to 1.2 TeV is fully sufficient).

Performance

Bunch Current	No Bunches	Total current	Luminosity IR1 & 5 [$cm^{-2}s^{-1}$]
1 e10	1	1 e10	1.9 e26
4 e10	43	1.7 e12	1.3 e29
4 e10	156	6.2 e12	4.8 e29
1 e11	156	1.6 e13	3 e30*

***120K events per sec**

Machine Protection

- BIS plus SBF and BPF
- PIC
- LBDS connected to BIS
- User input:
  - Collimators, TCDQ, TDI, injection kickers, PIC, FCDM, BLMs, experiments, access, vacuum…
- BEM
- Software interlocks

Should be commissioned and tested without beam as far as possible

Clearly less critical during initial phases but must be commissioned and tested with beam before pushing the intensity

Parallelism

- **Opportunities for parallelism, parasitic development**
  - **Injection region of beam 1 with ongoing commissioning of ring 2.**
  - **Parasitic beam instrumentation commissioning:**
    - transverse beam profiles, beam loss monitors, orbit acquisition, BCT lifetime.
  - **Collimators: ring 2/ring 1, momentum/betatron cleaning.**
  - **RF: ring 1/ring 2. Could imagine RF working on beam 2, BI on ring 1 etc.**
  - **Orthogonal scans etc.**

Phases

	Phase
1	First turn
2	Establish circulating beam
3	450 GeV – initial
4a	450 GeV - consolidation
4b	450 GeV – system commissioning
5a	Two beam operations
5b	Collisions
6	Increase intensity

First Turn

Commissioning for 7 TeV

450 GeV

Team	Sub-phase	Total Time both rings	Priority	450 GeV Collisions
BT/OP	Commission TI8 & TI2 end transfer line, Commission injection region: kickers, septa, check aperture, instrumentation, beam to TDI.	24	1	Essential
OP/BI	Commission trajectory acquisition and correction, thread beam - first turn, energy matching	48	1	Essential
BI	Commission Beam Loss Monitor system phase 1	12	1	Parasitic
OP/AP	Orbit response, kicks, trajectory, BPM and corrector polarity checks	24	1	Essential
OP	Initial aperture checks	16	1	Leave
OP	Momentum aperture	6	1	Leave
COL	Setting up of injection machine protection	12	2	Leave
		6 days		**4 days**

Circulating beam

	Sub-phase	Total Time both rings	Priority	450 GeV Collisions
OP/AP	Adjust chromaticity, close trajectory, establish multiple turns, obtain closed orbit	24	1	Essential
OP/RF	Energy matching and correction, B-sps, f-lhc, B-lhc - both rings, RF capture	32	1	Essential
OP/AP	Measure integer tunes, fractional tunes, phase advance per turn	16	1	Essential
		3 days		**3 days**

450 GeV - initial

Team	Sub-phase	Total Time both rings	Priority	450 GeV Collisions
RF	Beam control loops (Phase, Synchro, Radial). Tuner loop, RF Feedback loop. Synchronisation	24	1	Essential
OP/AP	Test control and correction (corrector polarities, cabling, control system, software, procedures …). Measure & correct orbit.	16	1	Essential
OP/BI	Commission transverse diagnostics - tune measurement [FFT]. Measure and adjust tunes, chromaticity, and coupling.	16	1	Essential
OP/AP	Linear optics checks: check orbit versus kick, phase advance, BPM and corrector polarity.	24	1	MD
BI	Commission beam loss monitors - acquisition, display etc. No connection to BIC for the moment.	12	1	Parasitic
BT	Commission beam dump - phase 1	24	1	Essential
BI	Commission BCTs: lifetime measurement	-	1	Parasitic
MPS	Commission beam interlock system with beam - phase 1. BIC to dump with beam. Test.	8	1	Essential
		5 days		**3 days**

Measurements

Team	Sub-phase	Total Time both rings	Priority	450 GeV Collisions
BT	Matching between TI8/TI2 and ring. Pilots.	8	2	Leave
AP/OP	Measure beta beating. Identify and correct local sources of phase advance errors.	16	1	Do
MA/OP	Check key transfer functions (separation dipoles etc.)	16	1	Later [MD]
AP/OP	Mechanical aperture checks. Bumps – check the aperture in the cold machine	16	1	Essential
OP/MA	Field quality checks. Check design fields, field harmonics, fields due to offsets between beam and magnet	16	1	$\leq$ b3
OP	Momentum aperture	8	2	Do
OP	IR bumps, check aperture in IRs	8	1	Leave
OP/AP	Reproducibility after cycling machine. Effect of magnetic cycle, reproducibility, field model	16	1	Leave
BI/AP	Quench levels and BLM response	24	2	Leave
		5 days		**1-2 days**

System commissioning

Team	Sub-phase	Total Time both rings	Priority	450 GeV Collisions
RF	Loop adjustment	8	1	Do
RF	Transverse damper	8	2	Leave
RF	Longitudinal feedback	8	1	Leave
BI	Transverse profile monitors	8	2	Parasitic
BI	Commission beam loss monitors - phase 2, calibration, thresholds. Commission the BLM's around the collimators. Link to BIC	16	1	Parasitic
BI	Tune - PLL	16	1	Do
OP	Closed orbit feedback	16	1	Do later
COL	Adjustment of collimators, orbit stabilization, test positioning procedures, beam loss monitors.	36	1	Essential for Intensity increase
BT	TDI. Position, angle, interlocks	8	1	Essential
BT	TCDQ orbit at 6, position, angle, interlocks	16	1	Essential
MPS	FMCM	4	1	Do
MPS	Test Safe LHC Parameters: Safe Beam Flag, Beam Presence Flag, Safe LHC mode, Safe Energy, Safe Squeezing Factor	8	1	Essential (plus parasitic)
		7 days		**2-3 days**

2 beam operation

Team	Sub-phase	Total Time	Priority	450 GeV Collisions
OP	SPS - switch rings - TI8/TI2 in parallel – LHC injection	8	1	Parasitic
OP/BT	Commission separation bumps. Closure of bumps. Check aperture. Check injection region.	16	1	Essential
OP/AP	Effect of bumps - dispersion, non-closure	8	2	Leave
BI	Beam parameters: Q split, Q' split, coupling, Beam instrumentation: BLMs, BPMs cross talk etc.	8	1	Do
OP	Control system: real-time feedback, orbit correction, orthogonality etc., energy matching - 2 rings	8	1	Do
		2 days		**1 day**

Colliding beams

Team	Sub-phase	Total Time	Priority
OP	Separation bump reduction, check interaction with orbit feedback: points 1,2,5 & 8. Establish collisions	4*8	Essential
BI	Commission luminosity monitors (v. low interaction rates)	8	Parasitic
COL	Collimation setup	-	Optimisation
OP	Commission spectrometer compensation (compensation at 450 GeV?). Bring solenoids on.	2*8	Essential
		2 days	**1-2 days**

Colliding

- **Beam size at IP ≈ 265 μm**
- **Should be able to find collision points with the BPMs**
- **Straining the limits of the luminosity monitors – at least initially**
- **Feedback from experiments**

Increase Intensity

Team	Sub-phase	Total Time	Priority
COL	Collimators: N1 = 6, N3= 30, NTCDQ = 10 moving towards N1 = 5.7, N2= 6.7, N3 = 30	3*8	MD
TDI	Move towards Ntdi = 6.8	2*8	MD
OP	Multi-batch injection	16	MD
RF	Longitudinal feedback	8	MD
			Spread

Time

	Phase	Beam time [days]
1	First turn	4
2	Establish circulating beam	3
3	450 GeV – initial	3
4a	450 GeV - consolidation	1-2
4b	450 GeV – system commissioning	2-3
5a	2 beam operations	1
5b	Collisions	1-2
		16 days

Given an operational efficiency of 60%, this gives an elapsed time of about 26 days.

Full commissioning

		Ring factor	Total Time [days] both rings
1	Injection and first turn	2	6
2	Circulating beam	2	3
3	450 GeV - initial	2	5
4	450 GeV - detailed	2	12
5	450 GeV - two beams	1	2
6	Snapback - single beam	2	4
7	Ramp - single beam	2	8
8	Ramp - both beams	1	3
9	7 TeV - setup for physics	1	2
10	Physics un-squeezed	1	-
	TOTAL to first collisions		47
11	Commission squeeze	2	6
12	Increase Intensity	2	6
13	Set-up physics - partially squeezed.	1	2
14	Pilot physics run		