LHC operation and objectives for 2010/2011

Mike Lamont

Rough outline

- Introduction
- Outline operational sequence
- Mechanics
  - sequencer, procedure
  - software
  - settings
- Key systems
  - collimation, beam dump, RF..
- Machine protection
- Brief overview of beam through the sequence
  - losses, emittance, lifetimes, optics

Commissioning recap

- Magnetically and optically well understood
  - Excellent agreement with model and machine
- Magnetically reproducible
  - Important because it means optics and thus set-up remains valid from fill to fill
- Aperture clear and as expected
- Excellent performance from instrumentation and controls
- Key systems performing well
  - Injection
  - Beam dump
  - Collimation
  - Machine protection

Commissioning recap

- Ramp and squeeze
  - In general under control
- Inject, ramp and squeeze multiple bunches and bring them into stable beams.
- Keep them there
  - Maximum fill length – a remarkable 30 hours
- And do it again
- Routinely over-inject nominal bunch intensities and ramp them to 3.5 TeV, squeeze them, bring them into collisions and deliver stable beams.

A remarkably successful initial commissioning period

which is still ongoing… [NB]

Operational modes

- Physics production
- Machine development
  - End of fill MD [potentially with unsafe beam]
  - Dedicated commissioning periods
  - Ad hoc inter-fill system commissioning
  - Validation runs – loss maps, dumps with beam in abort gap
- Access/interventions as required
- Technical stops
  - 4 days every 6 weeks
  - 2 months over Christmas

Might question the rigour with which we pass between these modes

Comments

- Haven't fully come out of commissioning mode yet.
- In proton physics Operations crew drive the machine through the full cycle…
- … punctuate regular operations with periods of dedicated beam commissioning system commissioning
- "Collegiate atmosphere". Still considerable presence in control room of sub-system experts tracking up, improving, tweaking. Some of this is passive, some can impact beam.
  - Beam instrumentation, Beam transfer, Feedbacks etc…
  - "I'm just going to make a transparent change to the voltage ramp" YESTERDAY
- Other teams also present intermittently
- Controls/software improvements/bug fixes still common
- Relaxed attitude to testing

Organization

- Operations
  - 6 highly skilled machine coordinators who pair up and take 1 out 3 weeks
  - 8 engineers-in-charge who run the show in the CCC while on shift
  - 7 operators – experienced (LEP) individuals
- Restricted Machine Protection Panel
  - ~10 cross system experts
  - Weigh the odds, set intensity envelope
- Physics coordinator
  - Italian with eyes firmly fixed on 1 fb^{-1}
- LHC commissioning working group
  - Discussions of a technical nature
- LMC
  - Decisions

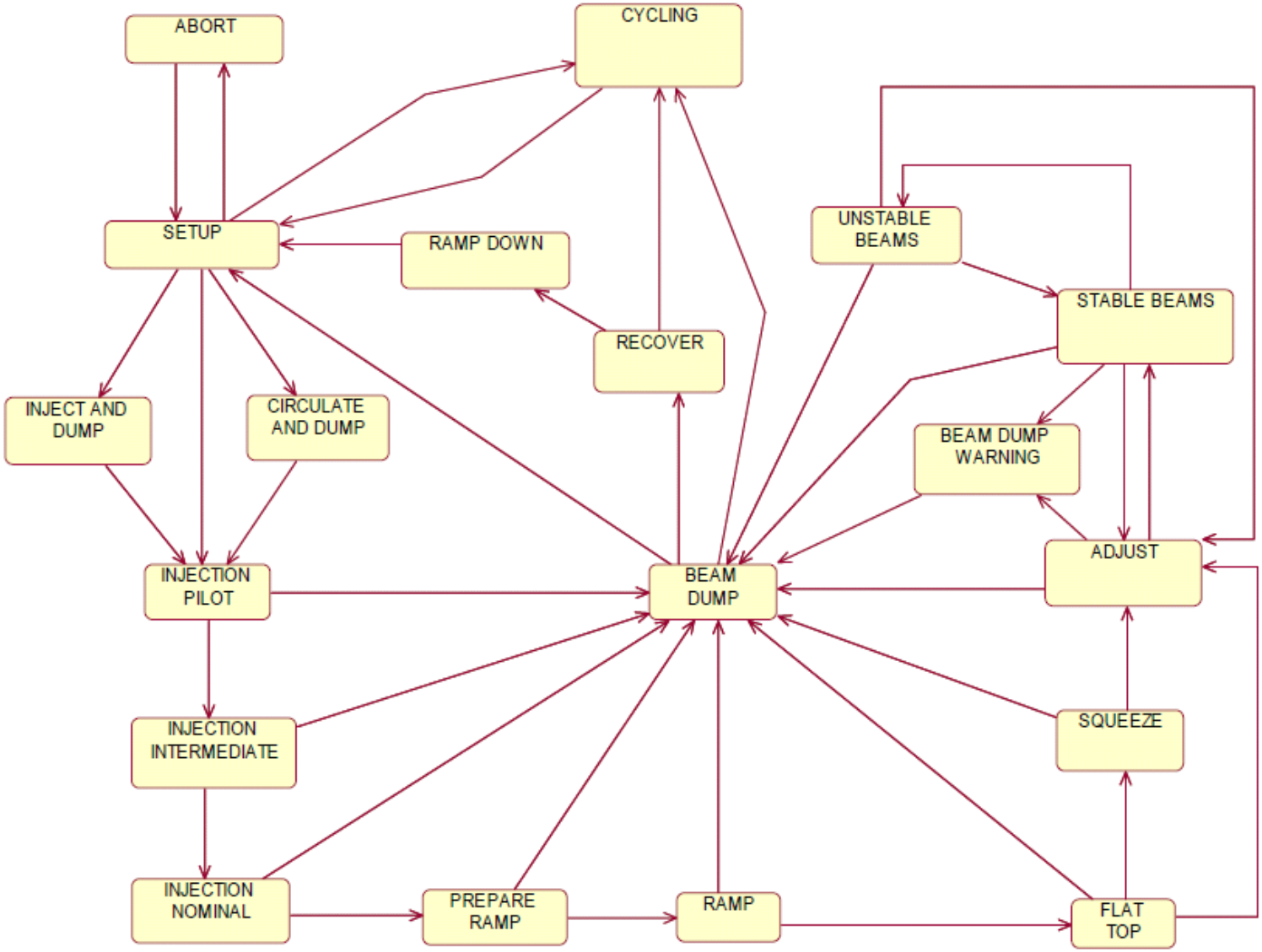
The sequence

PROTON PHYSICS

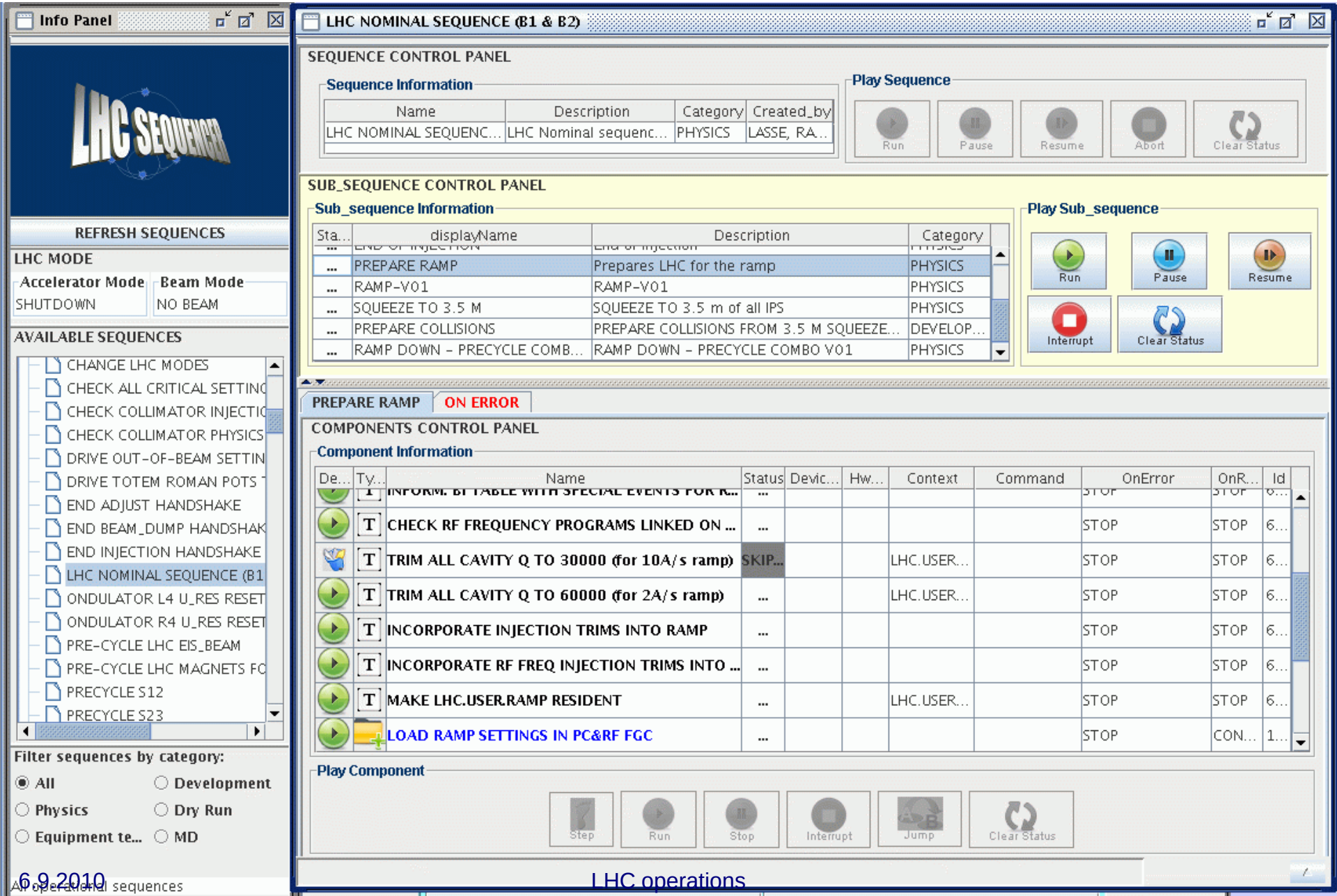
- Bread and butter mode of operation
- In which is concentrated high intensity
- Task by task breakdown of everything that needs to be done to drive LHC through the nominal operational cycle

Nominal cycle

Globally the machine state is fairly well described by machine mode/beam mode combination



Sequencer


Info Panel
LHC SEQUENCER
REFRESH SEQUENCES
LHC MODE
Accelerator Mode
SHUTDOWN
Beam Mode
NO BEAM
AVAILABLE SEQUENCES
CHANGE LHC MODES
CHECK ALL CRITICAL SETTING
CHECK COLLIMATOR INJECTIO
CHECK COLLIMATOR PHYSICS
DRIVE OUT-OF-BEAM SETTIN
DRIVE TOTEM ROMAN POTS
END ADJUST HANDSHAKE
END BEAM_DUMP HANDSHAK
END INJECTION HANDSHAKE
LHC NOMINAL SEQUENCE (B1
ONDULATOR L4 U_RES RESET
ONDULATOR R4 U_RES RESET
PRE-CYCLE LHC EIS_BEAM
PRE-CYCLE LHC MAGNETS FC
PRECYCLE S12
PRECYCLE S23
Filter sequences by category:
All
Development
Physics
Dry Run
Equipment te...
MD
All operational sequences
LHC NOMINAL SEQUENCE (B1 & B2)
SEQUENCE CONTROL PANEL
Sequence Information
Name
Description
Category
Created_by
LHC NOMINAL SEQUENC...
LHC Nominal sequenc...
PHYSICS
LASSE, RA...
Play Sequence
Run
Pause
Resume
Abort
Clear Status
SUB_SEQUENCE CONTROL PANEL
Sub_sequence Information
Sta...
displayName
Description
Category
PREPARE RAMP
Prepares LHC for the ramp
PHYSICS
RAMP-V01
RAMP-V01
PHYSICS
SQUEEZE TO 3.5 M
SQUEEZE TO 3.5 m of all IPS
PHYSICS
PREPARE COLLISIONS
PREPARE COLLISIONS FROM 3.5 M SQUEEZE...
DEVELOP...
RAMP DOWN - PRECYCLE COMB...
RAMP DOWN - PRECYCLE COMBO V01
PHYSICS
Play Sub_sequence
Run
Pause
Resume
Interrupt
Clear Status
PREPARE RAMP
ON ERROR
COMPONENTS CONTROL PANEL
Component Information
De...
Ty...
Name
Status
Devic...
Hw...
Context
Command
OnError
OnR...
Id
CHECK RF FREQUENCY PROGRAMS LINKED ON ...
STOP
TRIM ALL CAVITY Q TO 30000 (for 10A/s ramp)
SKIP...
LHC.USER...
TRIM ALL CAVITY Q TO 60000 (for 2A/s ramp)
INCORPORATE INJECTION TRIMS INTO RAMP
INCORPORATE RF FREQ INJECTION TRIMS INTO ...
MAKE LHC.USER.RAMP RESIDENT
LOAD RAMP SETTINGS IN PC&RF FGC
CON...
Play Component
Step
Run
Stop
Interrupt
Jump
Clear Status

& 6 pages of procedure

Over-injection

- **ADT phase shift to injection** (if not already done before)

- Ask injectors to switch to LHC INDIV and to **copy over transfer line settings**
- Check that the SPS has longitudinal emittance blow up on and at the nominal settings: (0.6eV.s which corresponds to a bunch length of ~1.6ns)
- Mask BLMs in 2 and 8 (masking is still required)
- Change **BPM sensitivity** through YASP (LOW for nominal bunches, HIGH for probe and bunch intensities below 3-4 x 10^{10})
- Change **BQM attenuation**: three buttons available: pilot, intermediate (indiv up to some 10^10), nominal (10^11)
- Change beam mode to INJECTION PHYSICS BEAM
- **ADT**:
  - **CHECK with the ADT application in the CCM that the ADT system is switched on, i.e. "RF ON". If it is off, in level 1 or level 2, switch it to "RF ON".**
    - *The gain of the feedback is controlled by 8 FGC functions. These have to be correctly started at the ramp and set back to the injection value. Pending further studies the injection values are -20 dB except for the vertical beam 2 plane where -24 dB is programmed. During the ramp the gain is linearly increased to -3 dB except vertical beam 2 which ramps to -7 dB. Beta functions at vertical beam 2 are higher so a lower gain is used.*
  - **VERIFY in the working sets (RF-LHC:ADT) that the damper off and on are enabled for the four timing cards in question, i.e. eight knobs to verify, Damper H/V B1/B2 On/Off, all enabled**; if they are disabled then this has the effect that the action of the corresponding HX.ADTSTART-CT and HX.ADTSTOP-CT on the damper on/off switch located inside the damper lowlevel system is masked.
    - *The timing delay is not really important, this is an expert setting to be used if RF teams make local observations synchronised with the On or OFF command.*
    - *The damper system is currently configured to close the loop automatically on turn 3 after injection. In fact the beam in signal opens the feedback loop, then an internal turns counter starts and will close the feedback loop at turn 3. This delay allows for filter transients that will not be put onto the beam.*
    - *The damper feedback loop can be opened ("switched off") by sending a timing event, HX.ADTSTOP-CT; it can be switched on again if wanted, using the HX.ADTSTART-CT event. The Beam_in signal will briefly open the loop (if it was closed) and activate the turns counter to issue the ON on turn 3 (see point 4 above).*
  - **OBSERVE with the fixed display "Injection oscillations what happens**. Currently the damper is configured to not act on the pilot, you should see flat lines. For the nominal bunch a damped oscillation should be seen.
- Clear "circ bunch config" in Injection sequencer, and then request injection
- For these injections, make sure that "Circ bunch confing autoClear" in unticked in the Injection Sequencer, or else the circulating bunch configuration will only contain the latest injection per beam.
- Bunch positions can be verified through LHC BQM display (LHC Control -> Beam Measurements -> Beam Quality Monitor)
- Measure emittance H&V of both beams with the wire scanner
  - Parameters to be used for the wire scan, both beams both plane: Gain:1300V, filter T_1_PER_CENT for B1 H/V and B2 H, filter T_10_PER_CENT for B2 V

Pre-cycle

Aim: reproducible magnetic machine

- Coming back from recovery
  - Full pre-cycle of all magnetic circuits
    - Main dipoles, quadrupoles to 6 kA
    - “de-Gauss” corrector circuits
    - IPQs, IPDs, ITs to around 3.5 TeV level
- After stable beams
  - Rampdown/precycle combination
    - All main circuits from 3.5 TeV/3.5 m to below injection current
    - “de-Gauss” corrector circuits

Largely successful

Pre-flight checks etc

- Beam dump XPOC
- Check critical settings
  - beam dump - various, injection kicker, BETS, IPOC, abort gap, SMP energy limits, collimators
  - BLM
- BLM sanity checks
- BIS pre-operational checks
- BI checks
- Injection kickers conditioning
- Load collimator and protection devices energy thresholds
- Set thresholds for roman pots

Pre-injection

- Set power converters, RF, ADT to injection level
- Condition injection kickers
- Injection handshake with experiments
- Collimators to parking
- RF-LBDS frequency link check
- RF beam control resynch
- Resynchronize to SPS if needed
- Ask the SPS to check beam parameters
- load BI defaults and tune viewer injection settings
- check frequency lock

Injection – general

Complex dance of hardware, timing, RF, interlocks etc.

- Transfer lines in good shape after big effort.
- Re-phasing, synchronization & transfer & capture
- Inject pilot, measure and correct
- Over-inject witness pilot with nominal bunches
- Injection process controls semi-automatically by injection sequencer
- Beam quality check in SPS
  - vetos extraction
- Injection quality check in LHC
  - inhibits further injection, latches, easily unlatched

Full program of beam based checks performed: injection protection (TDI etc), transfer line collimators, TDI positioning, aperture, kicker waveform etc. have been performed.

Injection 1/2

- Collimators are set to injection positions
- Arm LBDS
- Change accelerator mode to PROTON PHYSICS.
- Change beam mode to INJECTION PROBE
- Set BQM attenuation to probe
- Increment fill number
- Inject 1 bunch for beam 1 and beam 2
- Measure and correct RF injection phase
- Verify Injection synchro error :
- Correct orbit with respect to reference**
  - "450 GeV collimator setup, separation is ON, low int." (for 2-3x1010) ,
  - "450 GeV collimator setup, separation is ON, high int." (for 8-10x1010)

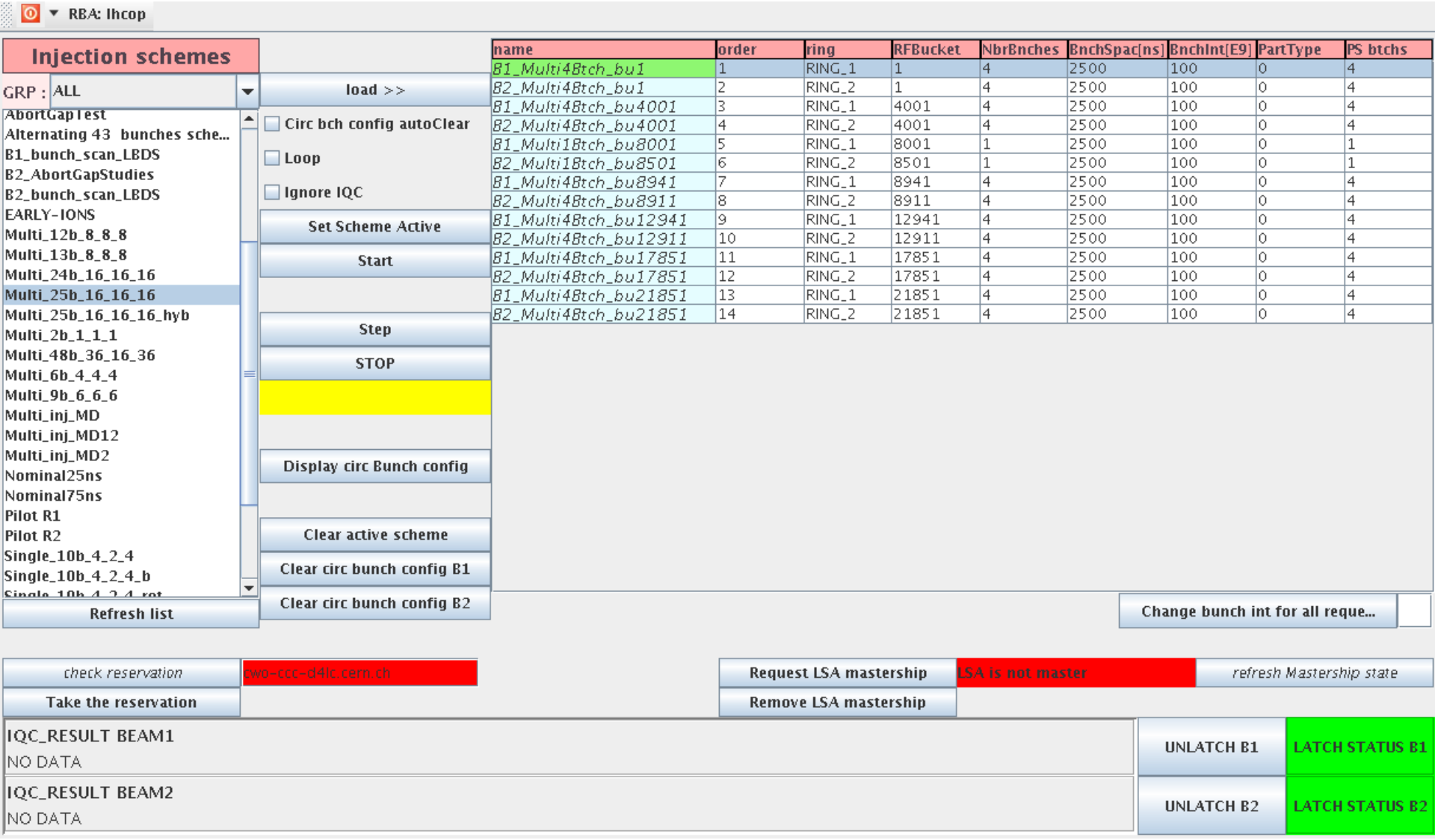
Injection 2/2

- Verify Injection oscillations
- Measure and set fractional tunes to 0.28/0.31
- Measure and set chromaticity to ~4, 4
- Dump and re-inject if you have done corrections of the synchro error, injection phase or injection oscillations to check your trims

Over injection

- Change beam mode to: INJECTION PHYSICS BEAM
- Ask injectors to switch to LHC INDIV for single bunch injection or LHC2 for multi bunch injection and to copy over transfer line settings if trims have been done.
- Check that the SPS has longitudinal emittance blow up on and at the nominal settings: (0.6eV.s which corresponds to a bunch length of ~1.6ns)
- Mask BLMs in 2 and 8 (masking is still required)
- Change BPM sensitivity through YASP (LOW for nominal bunches, HIGH for probe and bunch intensities below 3-4 x 1010)
- Change BQM attenuation: three buttons available: pilot, intermediate (indiv up to some 10^10), nominal (10^11)

Injection sequencer



Injection - nominal

- Change beam mode to INJECTION PHYSICS BEAM
- Clear "circ bunch config" in Injection sequencer, and then request injection
- For these injections, make sure that "Circ bunch confing autoClear" in unticked in the Injection Sequencer, or else the circulating bunch configuration will only contain the latest injection per beam.
- Bunch positions can be verified through LHC BQM display
- Measure emittance H&V of both beams with the wire scanner

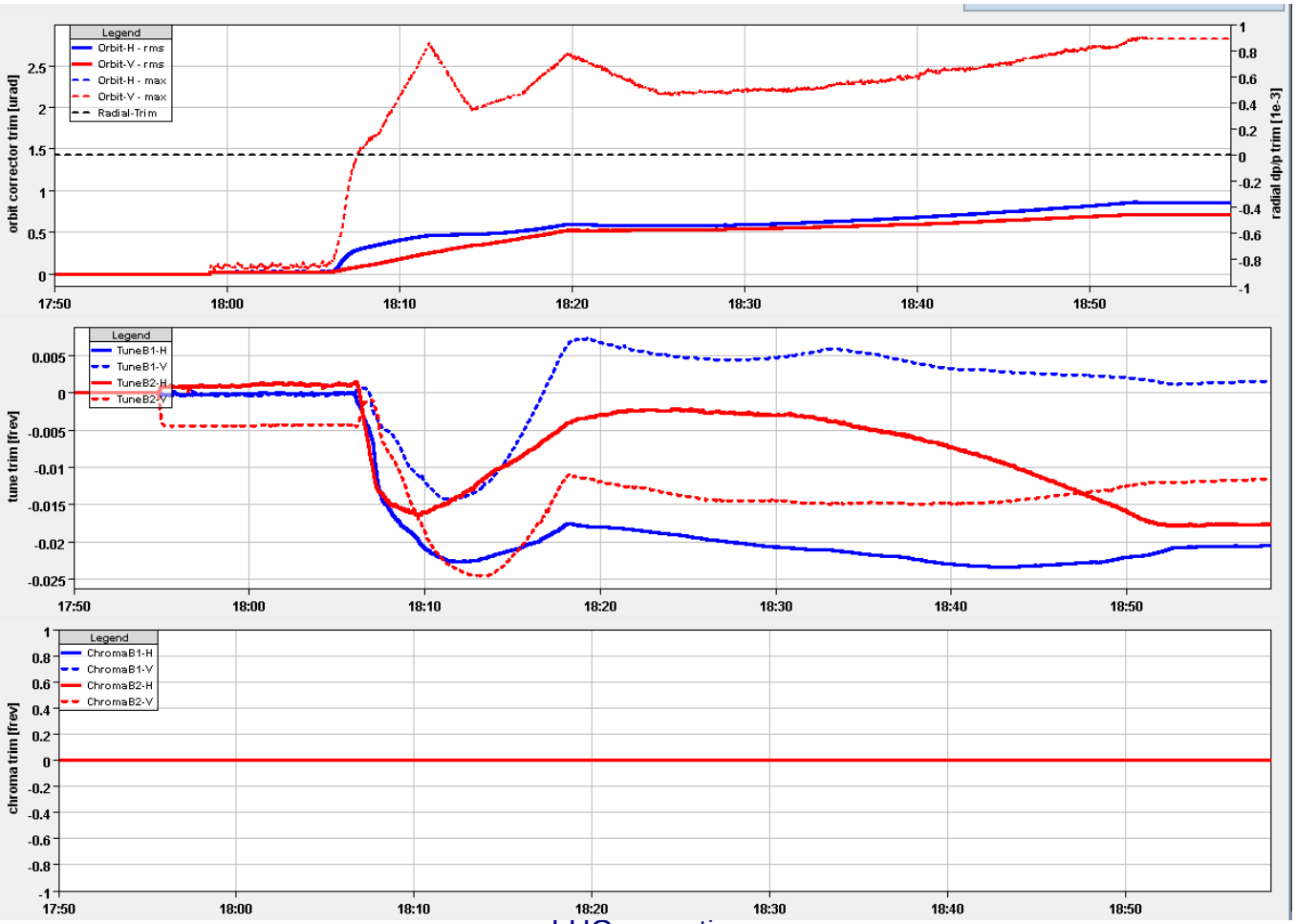
Ramp

- 450 GeV – 3500 GeV
  - 17 minutes
  - Parabolic – exponential – linear – parabolic to minimize effects of snapback and duration
  - Snapback correction pre-programmed for b2,b3,b4,b5,a2,a3 based on FIDEL predictions for full decay
- Preloaded functions to power converters, collimators, RF
  - ramp initiated with timing event
- Tune and orbit feedback considered mandatory
- Transverse feedback on
- Fill-to-fill feed-forward performed intermittently

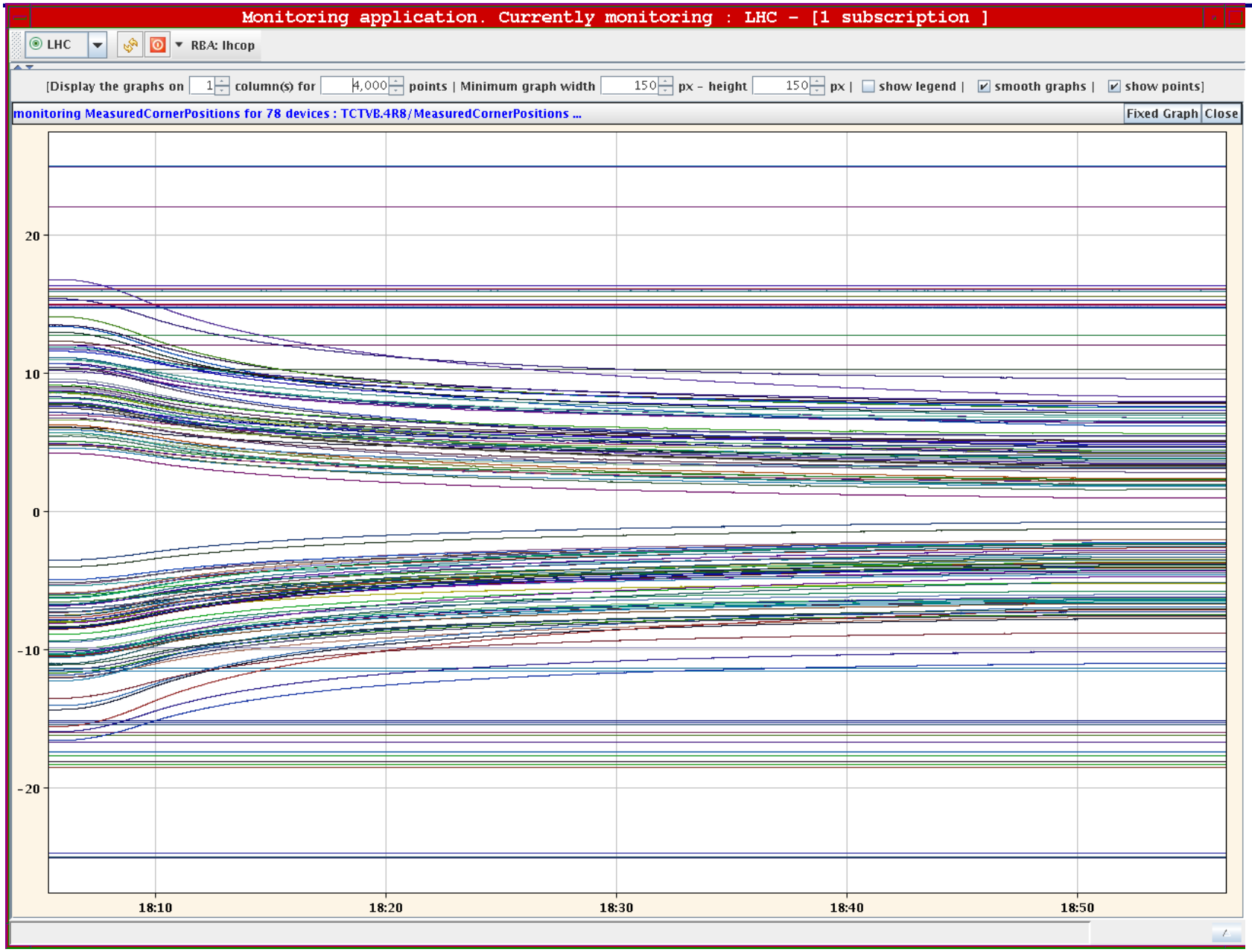
Ramp

Remarkably smooth so far

Feedbacks – mission critical and in general working very well - have had some issues – damping to robustness



Ramp - collimators



Flat top – prepare for squeeze

- Go to FLAT TOP mode
- Turn off the Transverse feedback
- Switch Tune FB OFF
- Stop the orbit feedback
- Turn off continuous chromaticity measurement (if switched on for the ramp)
- Measure and correct chromaticity (dp/p 0.2 per mille) and tune.
- Check that the coupling is <0.005 otherwise correct it with COUPLING KNOB -> LHCBEAMn/CMINUS_IM.IP1 and LHCBEAMn/CMINUS_RE.IP1

decay observed but not handled rigorously

Flat top – prepare for squeeze

- Re-measure and correct orbit
  - wrt "Reference for collimation at 3.5 TeV separated", (SEPARATED-3.5TeV-HIGH_INT in REF catalog).
- Correct radial position
- Start orbit acquisition/saving with a YASP
- Start the beta * monitoring tool
- Open windows of tune viewers (H: 0.295 - 0.315 ; V: 0.315 - 0.325)
- trim the TUNE-FB reference for tune feedback to collision tunes with the continuous tune viewer application
- go in FB/Trim tab, enter the right values (64.31 and 59.32) and press H&V button

Squeeze

- From 11-10-11-10 to 3.5 m all points
  - (over squeezed in Alice)
- Collisions tunes (.31/.32)
- Tune feedback on
- Orbit feedback on [interaction regions disabled]
- Tune, Q', coupling, orbit, optics corrections
- Squeeze in two stages
  - Stop in middle to set tertiary collimators to 3.5 m values

Relatively smooth – occasional soft lifetime dips

Collide

- Beams brought into collisions at same time via functions which collapse the separation bumps (~100 s)
  - fine IP positioning included – Alice to ~3.8 sigma separation
  - orbit, tune feedback off
  - transverse feedback on, octupoles on
  - nominal tunes
- Tertiary collimators to stable beam positions after bump collapse from sequencer
- Move to stable beams if lifetime, losses, luminosities look reasonable
- Luminosity optimization
  - Powerful application – allows movement of beams at IP, and as a result the tertiary collimators
- Stable beams – very stable

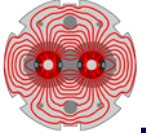
Operations above 1 MJ

- Case 1: Loss of beam due to procedural error or sub-system failure
  - in principle caught by BIS – very extensively tested - positive experience so far
- Case 2: Putting the machine in a dangerous state so that if something does go wrong it is not properly protected
  - Collimation, protection devices in wrong positions, orbit at collimators,
  - Local orbit bumps, optics errors
- These can be:
  - genuine mistakes
  - incomplete sequence execution
  - complacency and/or a gung ho attitude
  - experts messing around when they shouldn't
  - equipment failures or glitches
  - …

Case 2, sub clause a

- The collimators and protection devices must be in position at all times
- The hierarchy must be respected
- The collimators and protection devices are positioned with respect to the closed orbit
- Therefore the closed orbit must be in tolerance at all times. This includes the ramp and squeeze.
  - Orbit feedback becomes mandatory
  - Interlocks on beam positions

- If these rules are not respected something will get broken eventually



CONTROLS

LSA (LHC Software Architecture)

- Standard architecure for high level software
- Middle tier designed to provide services to allow effective accelerator control. Technology now well established.
- Data model & business layer are common for all accelerators
- Database design and implementation well established

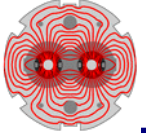
- 21st century version control and release mechanism
- Some unit testing, limited device based test environment
- No rigorous testing on machine of new releases

LSA Core 1

- Optics & Magnet model
  - Machine layout, device configuration
  - Optics, Twiss
  - Transfer functions, harmonic errors etc.
  - On-line model
- Settings generation
  - Settings span full parameter space
- Settings management & trim
  - Management of settings for all parameters through fullcycle
  - Coherent modifications
  - History of changes and rollback.

[LSA] Core 2

- Hardware exploitation
  - Equipment control/settings
    - Power Converters, RF, Collimators, Kickers, Beam Dump etc.
  - Equipment monitoring
- Run control
  - Hypercycle: pre-cycle, injection, ramp and squeeze
  - Sequencer, Mode etc.
- Timing
  - Timing events, event tables, telegrams, Safe Beam Parameters, injection requests…
  - RF: Bucket selection, pre-pulses
  - BST
  - Triggered measurement acquisition…



Standard services

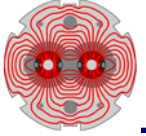
- Security
  - Role Based Access Control (RBAC)
    - Restrict access to accelerator devices
    - Developed in the framework of the LAFS collaboration
  - Management of Machine Critical Settings (MCS)
- Post mortem
- Logging
- Fixed displays
- Communication with experiments
- Software Interlocks
- Daemons
- Measurement facilities

Services - Hardware

	Application	XPOC	Analog Acquisition	Alarms	SIS	MCS	PM	Timing	RBAC
INJECTION KICKERS	X	X	X	X		X	X	X	X
BEAM DUMP	X	X	X	X		X	X	X	X
POWER CONVERTERS	XX			X	X		X	X	X
COLLIMATORS	X			X	X	X	X	X	X
RF	XX		X	X	X		X	X	X
TRANVERSE FB	X		X	X			X	X	X
MAGNETS	XX			X			X		
MKQA etc	X			X	X		X	X	X
WARM MAGNETS	X			X	X		X	X	X
RADIATION MONITORS				X			X		
SPECTROMETERS				X	X		X	X	

Services - Instrumentation

	Priority	Conc	Settings	State	Logging	PM	SIS	MCS	Application	FDisplay	Daemon
BPM [D,I]	1	X			X	X			XX	X	
BLM	1	X	X		X	X		X	XX	X	
BCT [DC, FD, FR]	1				X	X				X	
BTV	1		X	X	X		X		X	X	
Rest Gas [BGI]	3		X	X	X		X		X		
Sync. Rad [BSRA]	1		X	X	X		X		X		X
Wire Scanners [BWS]	2		X		X		X		X		X
Luminosity [BRA,S,G]	1				X				X	X	X
Tune [BQBBQ]	1		X	X	X	X			XX		
Tune [BQHT]	2				X				X		
AGM [BSRA]	2				X				X	X	
Schottky [BQS]	2				X				X		X
BST [BOB]	1										



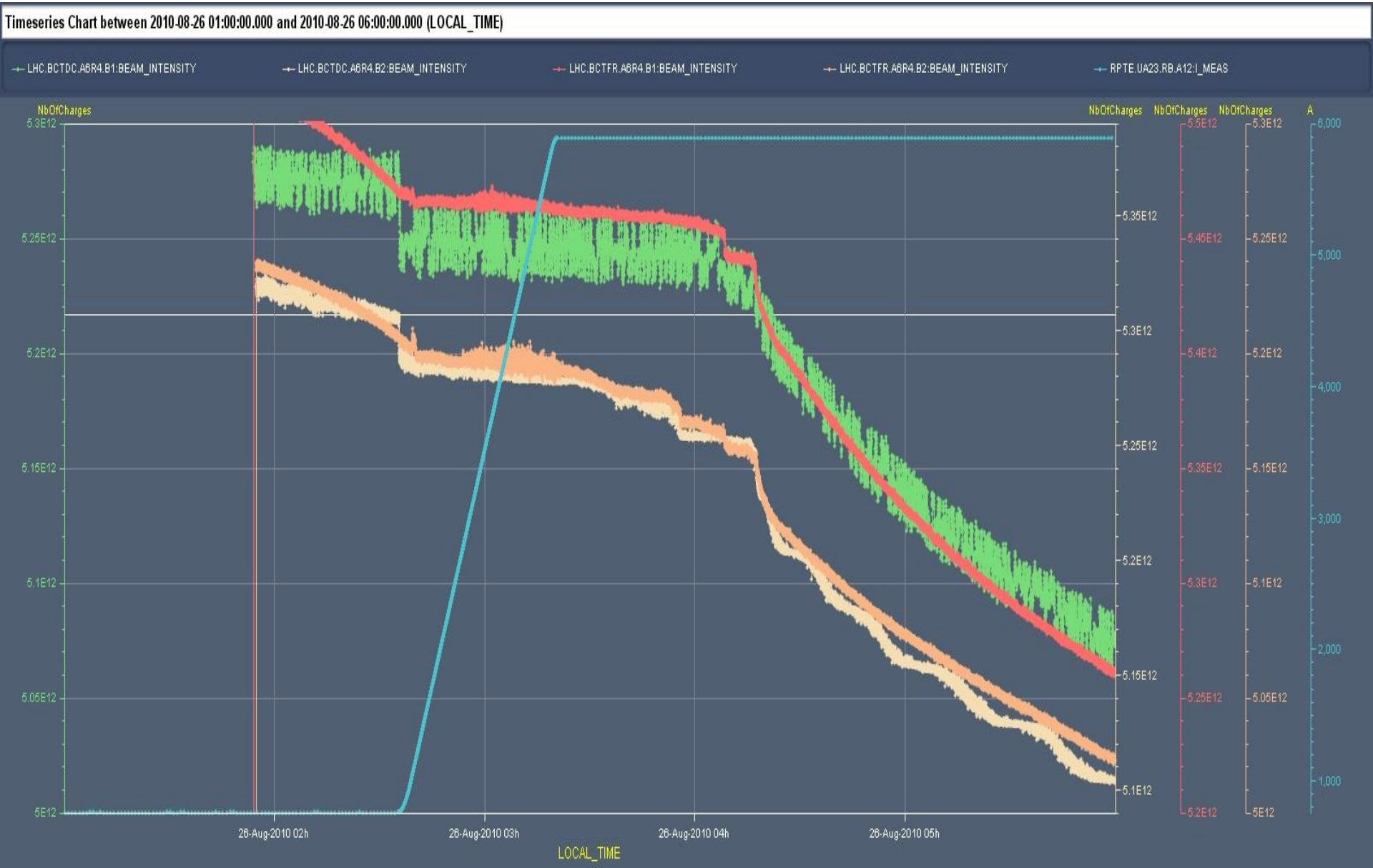
BEAM THROUGH THE CYCLE

Nominal cycle – hot spots – 2008 guess

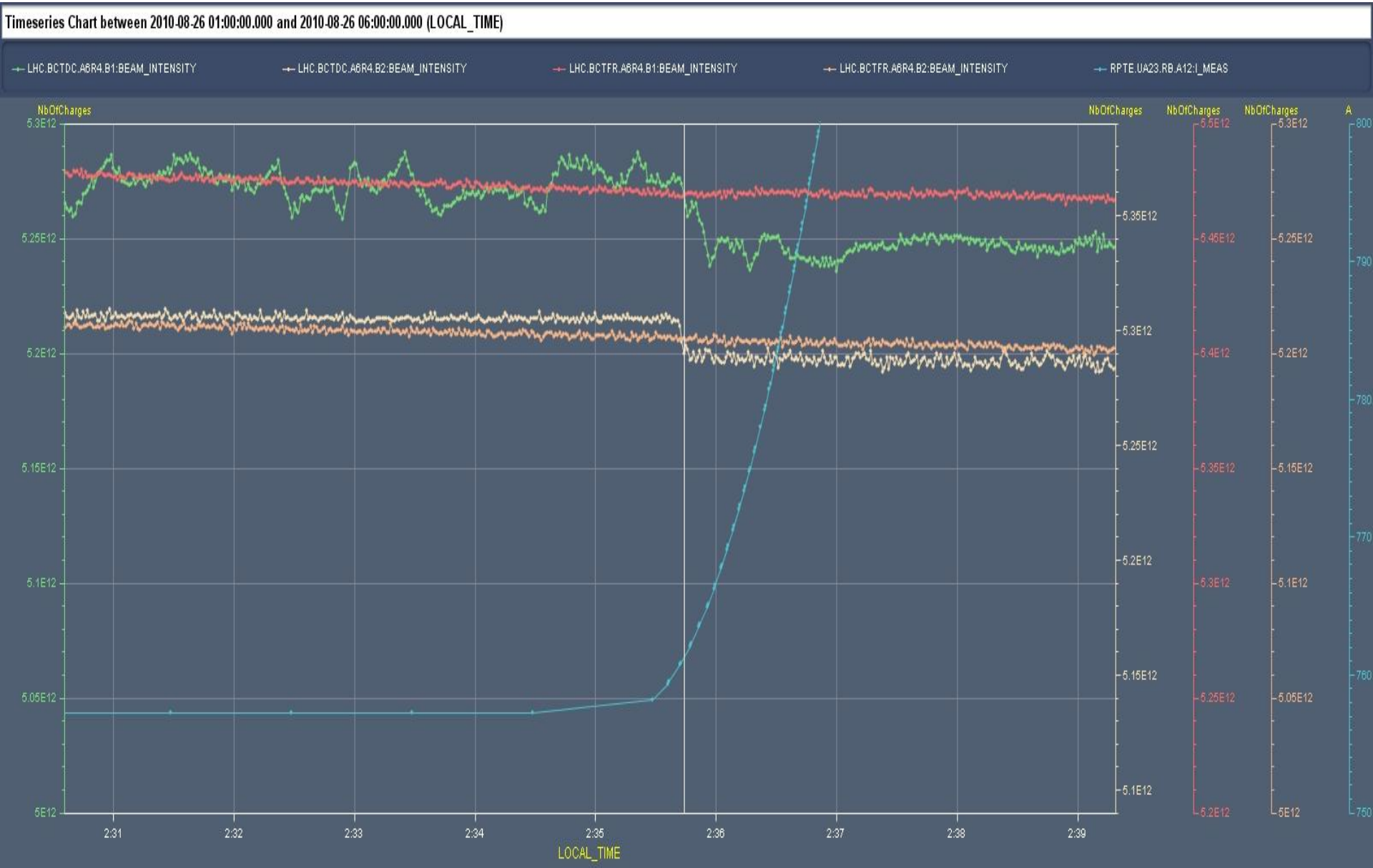
Injection	Losses at injection: injection oscillations, RF capture
Injection plateau	Big beams, lower dynamic aperture, full buckets, un-captured beam, long range beam-beam, crossing angles, persistent current decay Won't be pretty. 10 hours lifetime will be good
Start ramp	Un-captured beam lost immediately we start the ramp (~5% total) Snapback: chromaticity, tunes all over the place
Ramp	Things should calm down, assume 10 hour lifetime
Squeeze	Tunes, chromaticity, collimator, TCDQ adjustments – expect some lifetime dips
Collide	Beam finding, background optimization (?)
Physics	Collisions, beam-gas, halo production etc.
Adjust	Squeezing IR2, roman pot adjustment
Dump	Should be squeaky clean, very occasion pre-fire…

Beam current during fill 25/08/2010

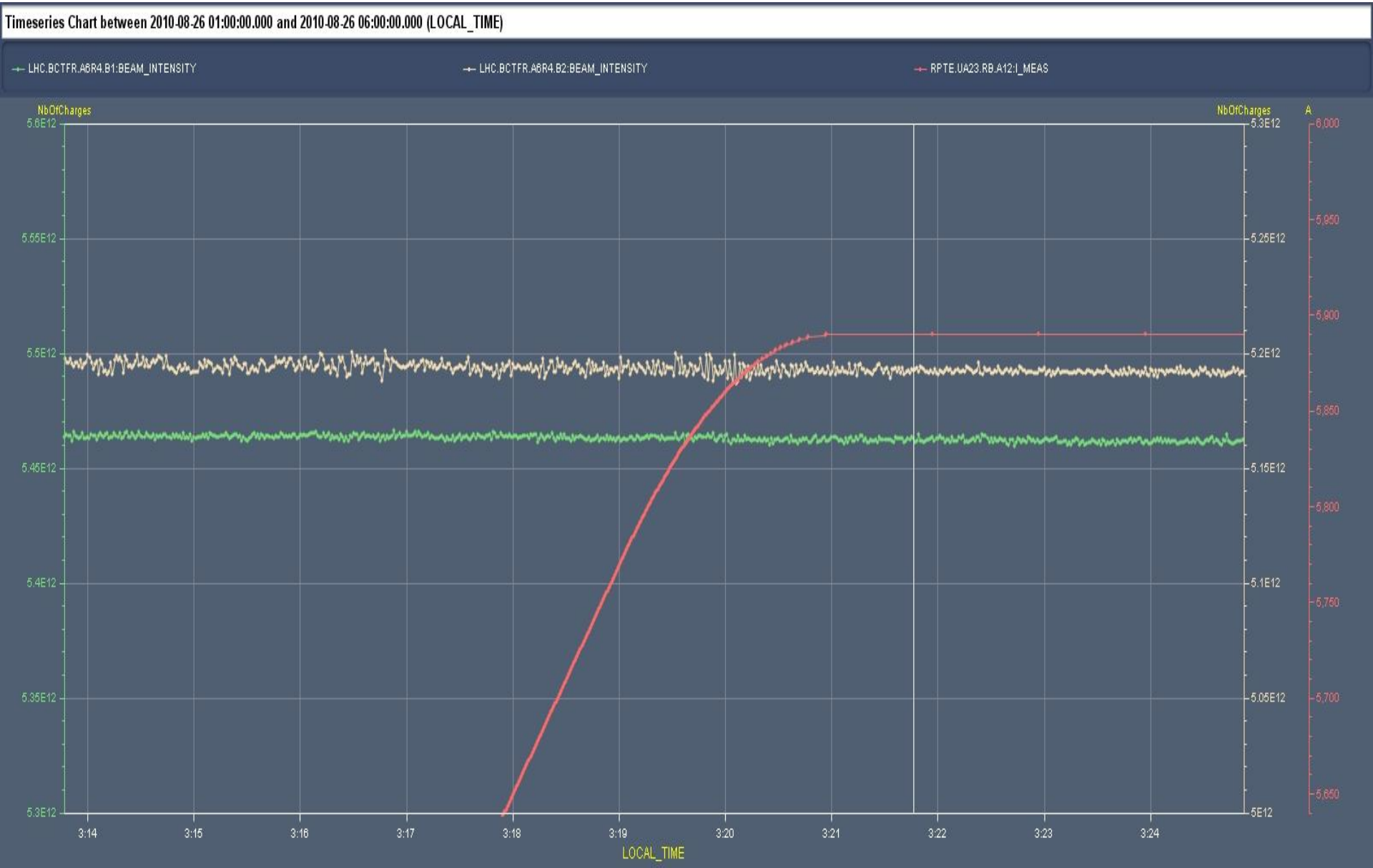
Beam current FBCT / DBCT



Beam current during start ramp 25/08/2010



Beam current during round off 25/08/2010

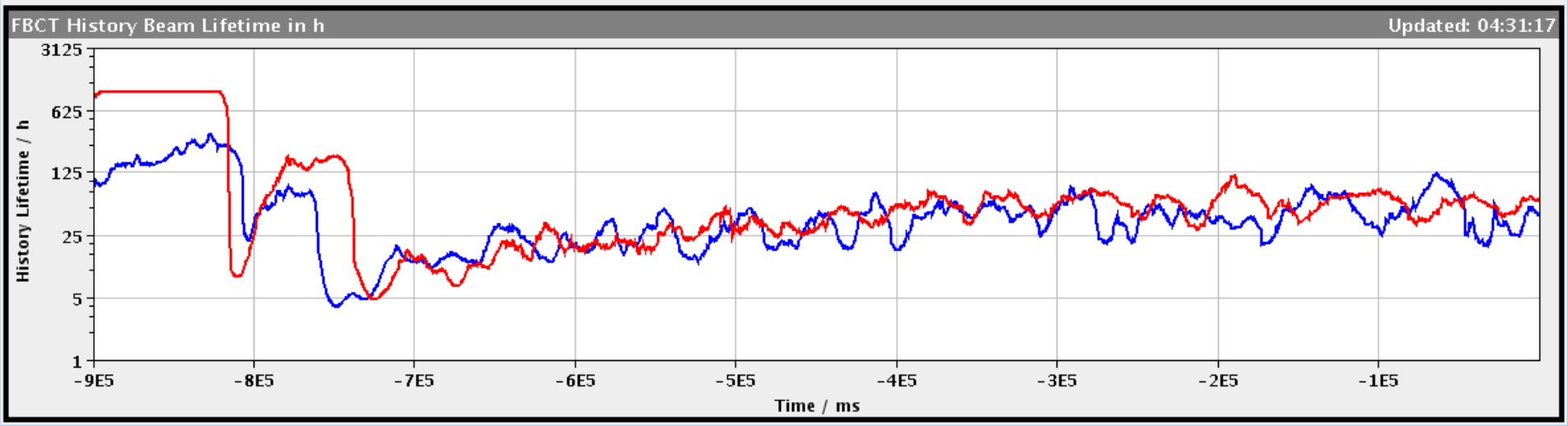


New Record Lumi

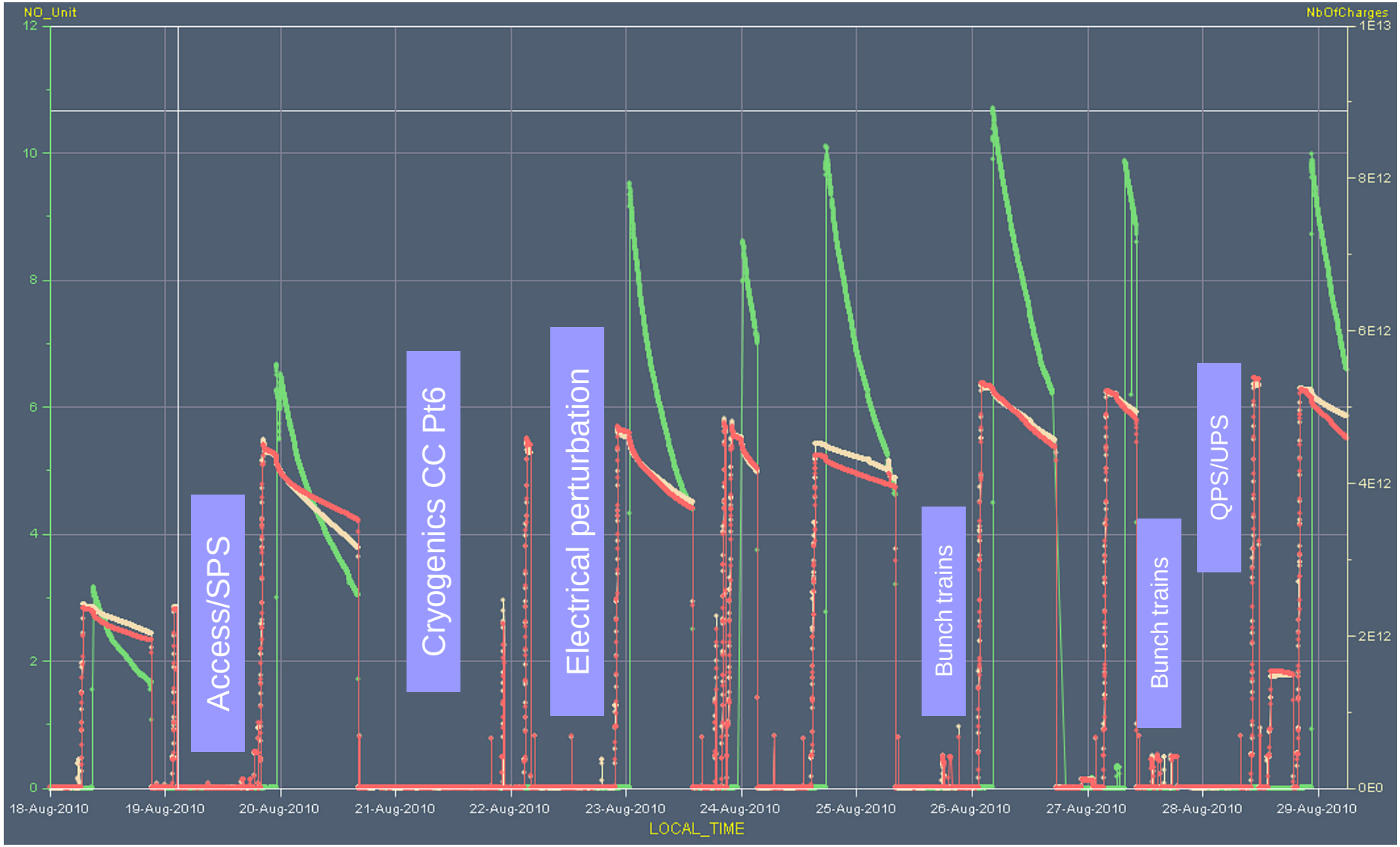
26-Aug-2010 04:24:46 Fill #: 1303 Energy: 3500 GeV I(B1): 5.51e+12 I(B2): 5.23e+12

	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	NOT READY	STANDBY	PHYSICS
Instantaneous Lumi (ub.s)^-1	10.456	0.138	10.719	8.882
BRAN Luminosity (ub.s)^-1	9.573	0.137	7.914	7.327
Fill Lumiosity (nb)^-1	2.0	0.0	2.0	1.7
BKGD 1	0.018	0.019	20.644	0.197
BKGD 2	16.000	0.290	0.002	4.773
BKGD 3	5.000	0.008	0.003	0.106

LHCb VELO Position OUT Gap: 58.0 mm | STABLE BEAMS | TOTEM: STANDBY



Last two weeks



25b | ← 48b → | ← 50b →

W34

Peak luminosity – stable beams	1.03 x 10^{31} $cm^{-2}s^{-1}$
Average luminosity – stable beams	7.08 x 10^{30} $cm^{-2}s^{-1}$
Total stable beam time	67.6 hours (40.2%)
Delivered luminosity	1724 nb^{-1}
Luminosity lifetime	~25 hours

Hübner factor ≈ 0.29

Including some dedicated bunch train commissioning

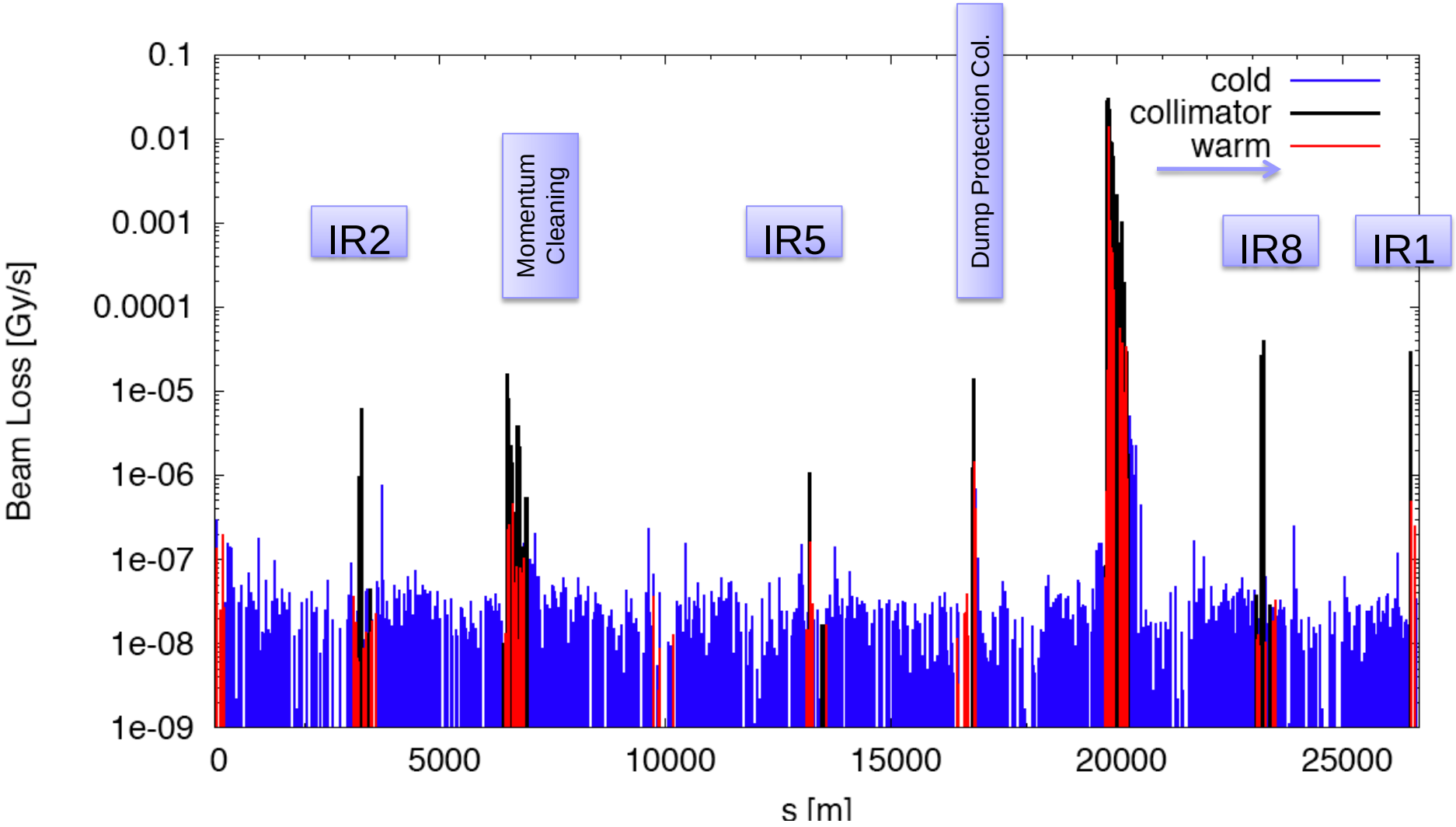
	Availability	Physics
W33	47.3%	22%
W34	~85%	40.2%

- **Remarkable machine availability**: impressive performance of cryogenics, QPS, converters, RF, instrumentation, collimators, injectors…
- **Very effective** use of available time

Lumi numbers courtesy Atlas

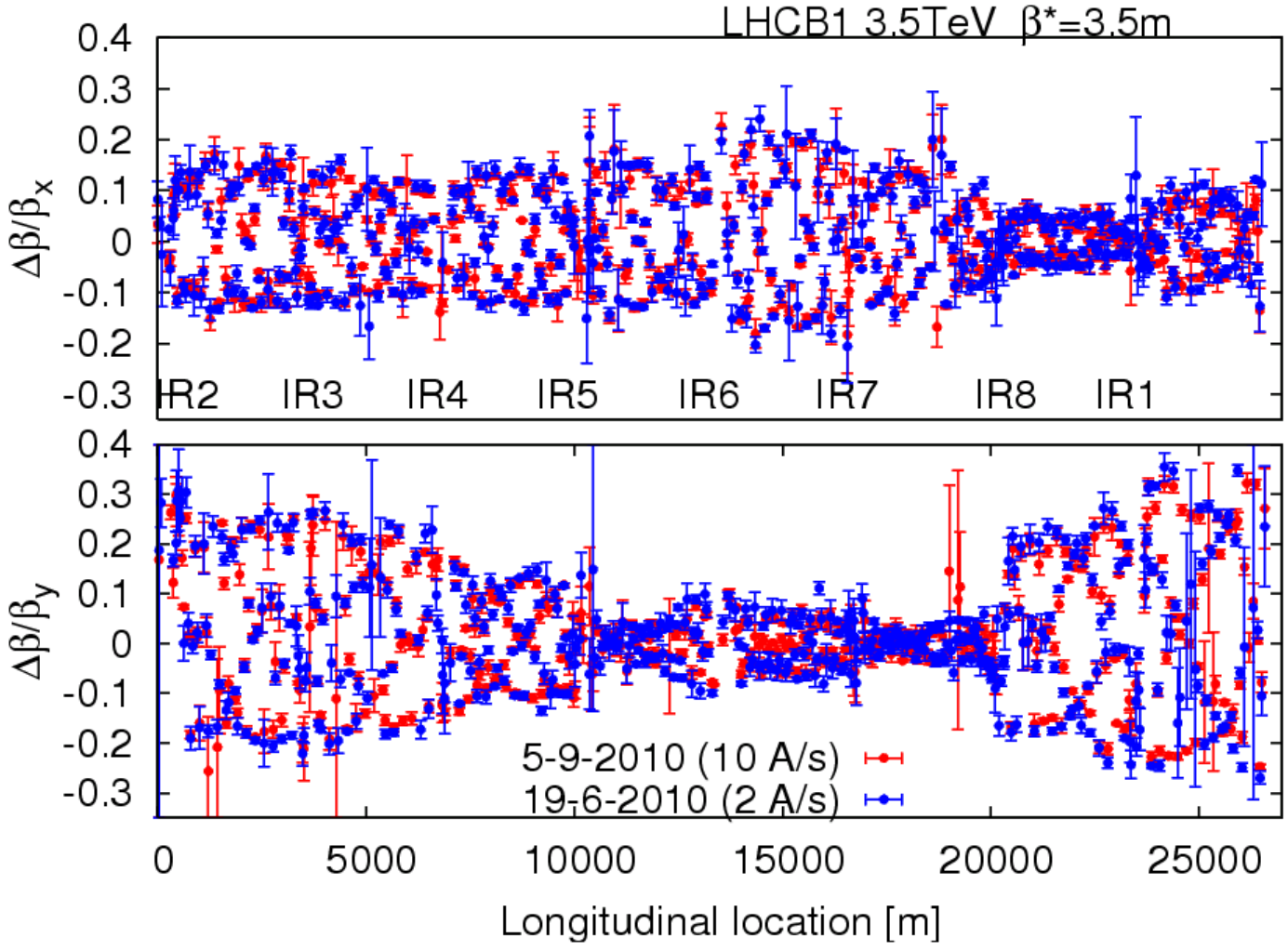
Measured Cleaning at 3.5 TeV

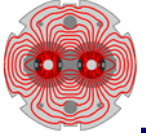
(beam1, vertical beam loss, intermediate settings)



Optics

- Stunningly stable





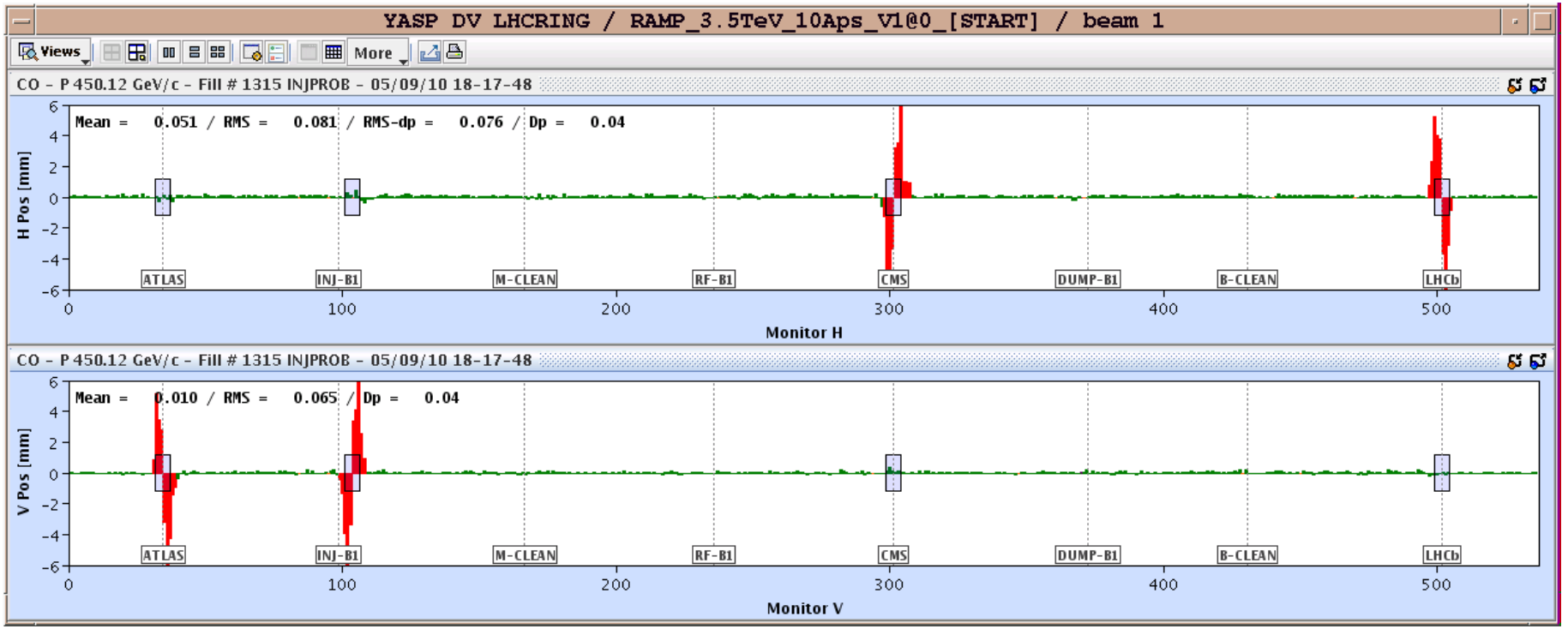
2010

2010 – main aims

- Clear priority to lay the foundations for 2011 and delivery of 1 fb^{-1}
- Have performed a safe, phased increase in intensity with validation and a running period at each step
- Gained solid operational experience of [not faultlessly] injecting, ramping, squeezing and establishing stable beams
- Need to finish commissioning of some critical sub-systems
  - E.g. Abort gap monitoring, abort gap cleaning, transverse damper
- Aimed for steady running at or around 1 MJ over the summer…

Bunch trains

- Next up



through the cycle

Ramp, squeeze and collide – high intensity

- 1 nominal bunch
- Reference orbit nailed
- Adjust collimators and dump protection at flat-top
  - setup for momentum cleaning of beam 2
- Qualify collimation and protection with loss maps at 3.5 TeV before squeeze. Asynchronous dump test
- Re-establish reference orbit at 3.5 TeV after squeeze.
- Perform required re-setup of ring collimators (depends on orbit changes).
- Qualify collimation and protection with loss maps at 3.5 TeV after squeeze. Asynchronous dump test.

High intensity bunch trains

- Push through 4, 12, 24 bunches per beam
- Monitor & adjust
  - ADT
  - Longitudinal blow-up
  - RF
  - Feedbacks
- First stable beams: 3x4

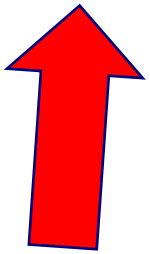
Brennan Goddard, Malika Meddahi

STEPS	# bunches/beam	# SPS bunch trains	# SPS bunches/train	# bunches/injection	# injections	E/inj [MJ]	I/inj (e12)	E/total (MJ @ 3.5 TeV)
A	48	1	4	4	12	0.03	0.4	2.69
	48	1	8	8	6	0.06	0.8	2.69
	96	1	8	8	12	0.06	0.8	5.38
	96	1	12	12	8	0.09	1.2	5.38
	144	1	12	12	12	0.09	1.2	8.06
B	144	2	12	24	6	0.17	2.4	8.06
	192	2	12	24	8	0.17	2.4	10.75
	240	2	12	24	10	0.17	2.4	13.44
	288	2	12	24	12	0.17	2.4	16.13
	336	2	12	24	14	0.17	2.4	18.82
C	396	3	12	36	11	0.26	3.6	22.18

An older estimate

Table 2: Projected intensity increases and associated performance in 2010 with around nominal bunch intensity (1.1×10^{11}). All numbers approximate.

N_b	N_c	I_{tot}	Energy per beam [MJ]	Peak Luminosity [$cm^{-2}s^{-1}$]	Days	Int. Lumi [pb^{-1}]	Approx. date
3	1	3×10^{11}	0.2	2.5×10^{29}	5	0.03	W4 June
4	2	4×10^{11}	0.2	5.1×10^{29}	5	0.07	W1 July
8	4	8×10^{11}	0.4	1.0×10^{30}	5	0.13	W2 July
20	10	2×10^{12}	1.1	2.5×10^{30}	10	0.6	W3/4 July
24	16	2.4×10^{12}	1.5	4.9×10^{30}	20	1.7	August
48	32	4.8×10^{12}	3.0	9.8×10^{30}	10	1.7	September
96	96	9.6×10^{12}	5.9	2.9×10^{31}	10	5.1	September
144	144	1.4×10^{13}	8.9	4.4×10^{31}	10	7.6	October
192	192	1.9×10^{13}	11.8	5.9×10^{31}	10	10.1	October
240	240	2.4×10^{13}	14.8	7.3×10^{31}	10	12.7	November

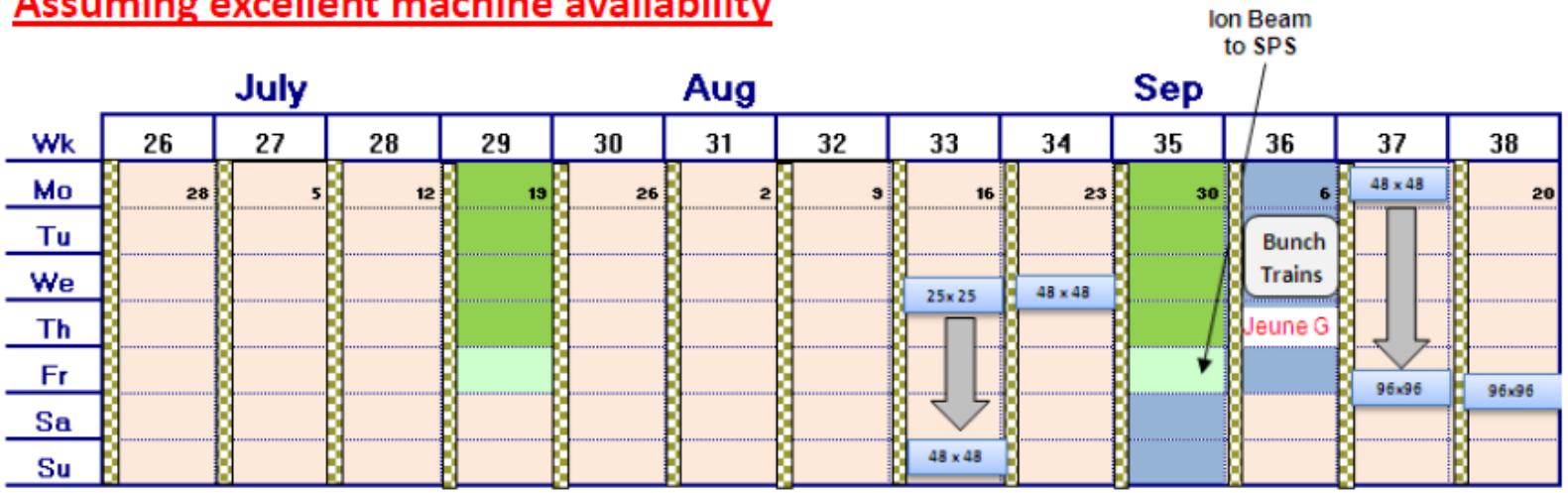


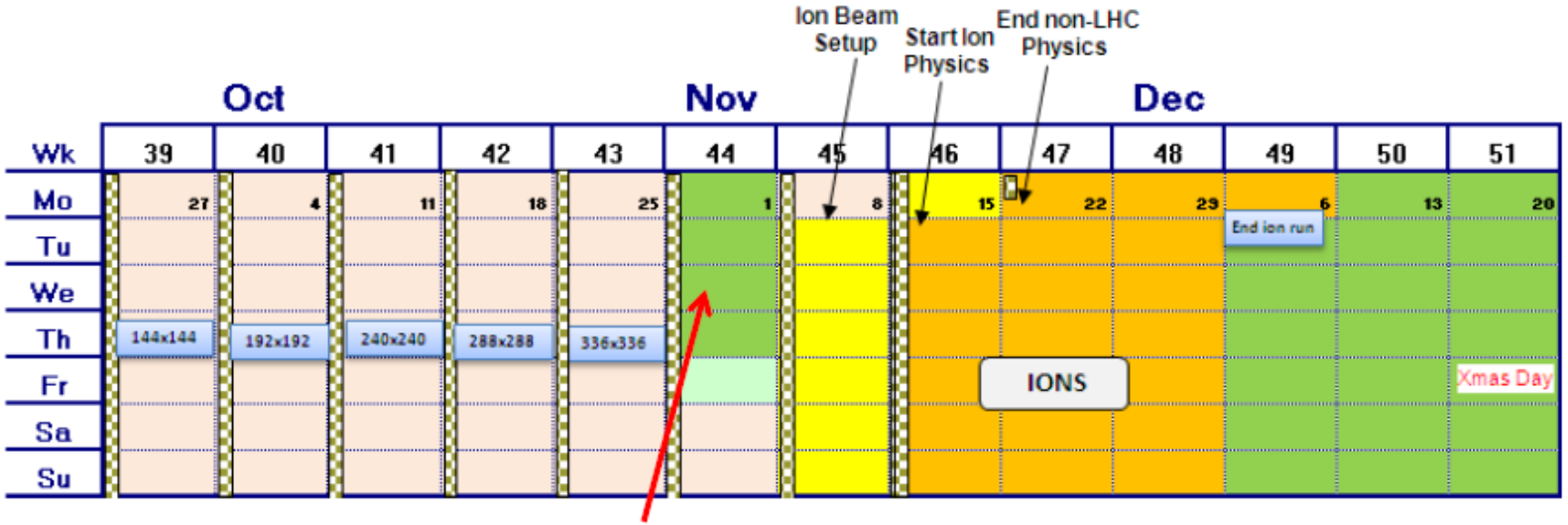
Target of some aggressive programming

Schedule

Very AGGRESSIVE schedule!

Assuming excellent machine availability





TS postponed from w42 to w43

Early Heavy Ion Run Parameters

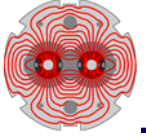
John Jowett

		Early (2010/11)	Nominal
√s per nucleon	TeV	2.76	5.5
Initial Luminosity (L_0)	$cm^{-2}s^{-1}$	1.25×10^{25}	10^{27}
Number of bunches		62	592
Bunch spacing	ns	1350	99.8
β^*	m	2	0.5
Pb ions/bunch		7×10^7	7×10^7
Transverse norm. emittance	μm	1.5	1.5
Luminosity half life (1,2,3 expts.)	h	τ_{IBS}=7-30	8, 4.5, 3

Initial interaction rate: 100 Hz (10 Hz central collisions b = 0 – 5 fm)

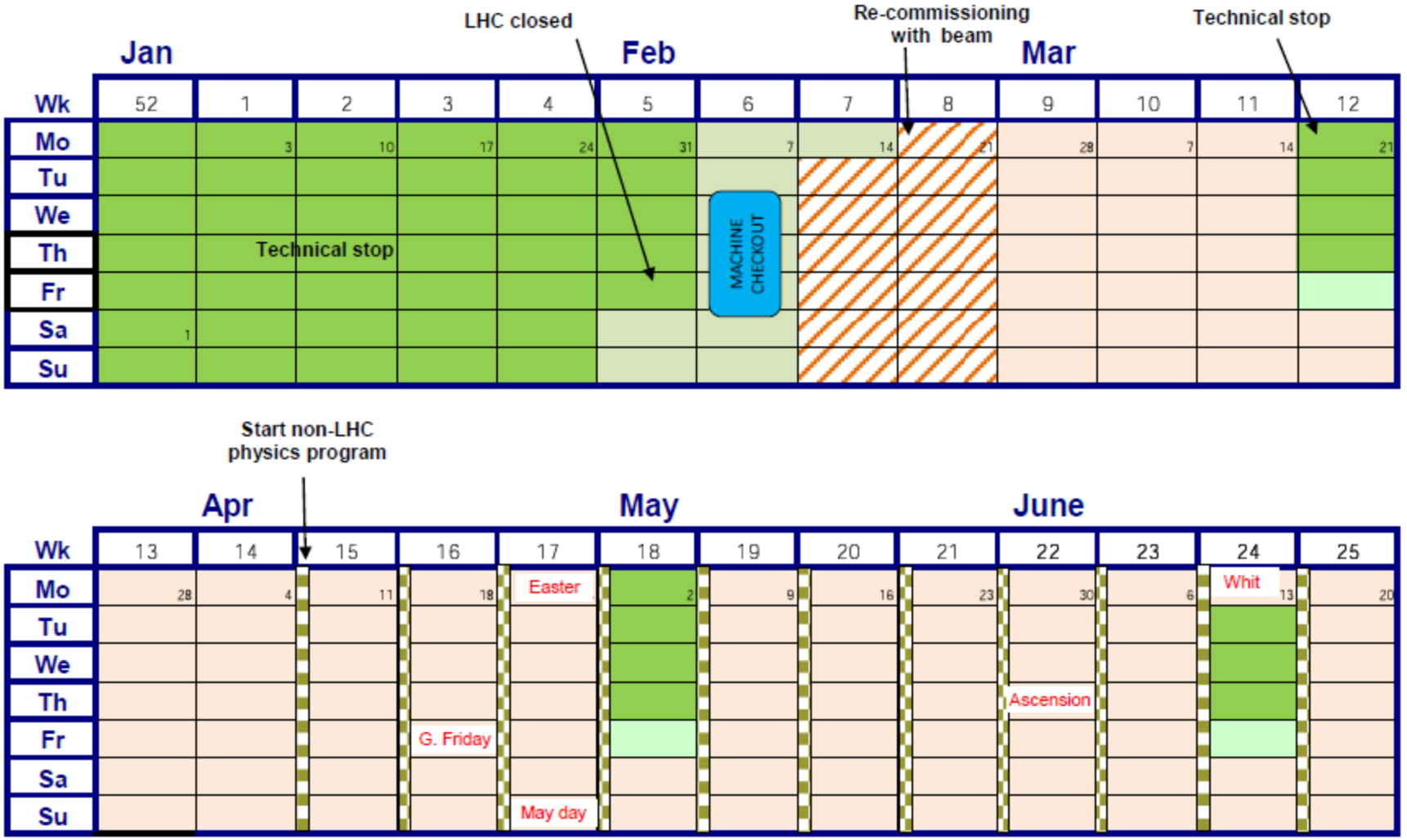
~10^8 interaction/10^6s (~1 month)

In two years: 2 x10^7 central collisions, integrated luminosity 25 □b^{-1}

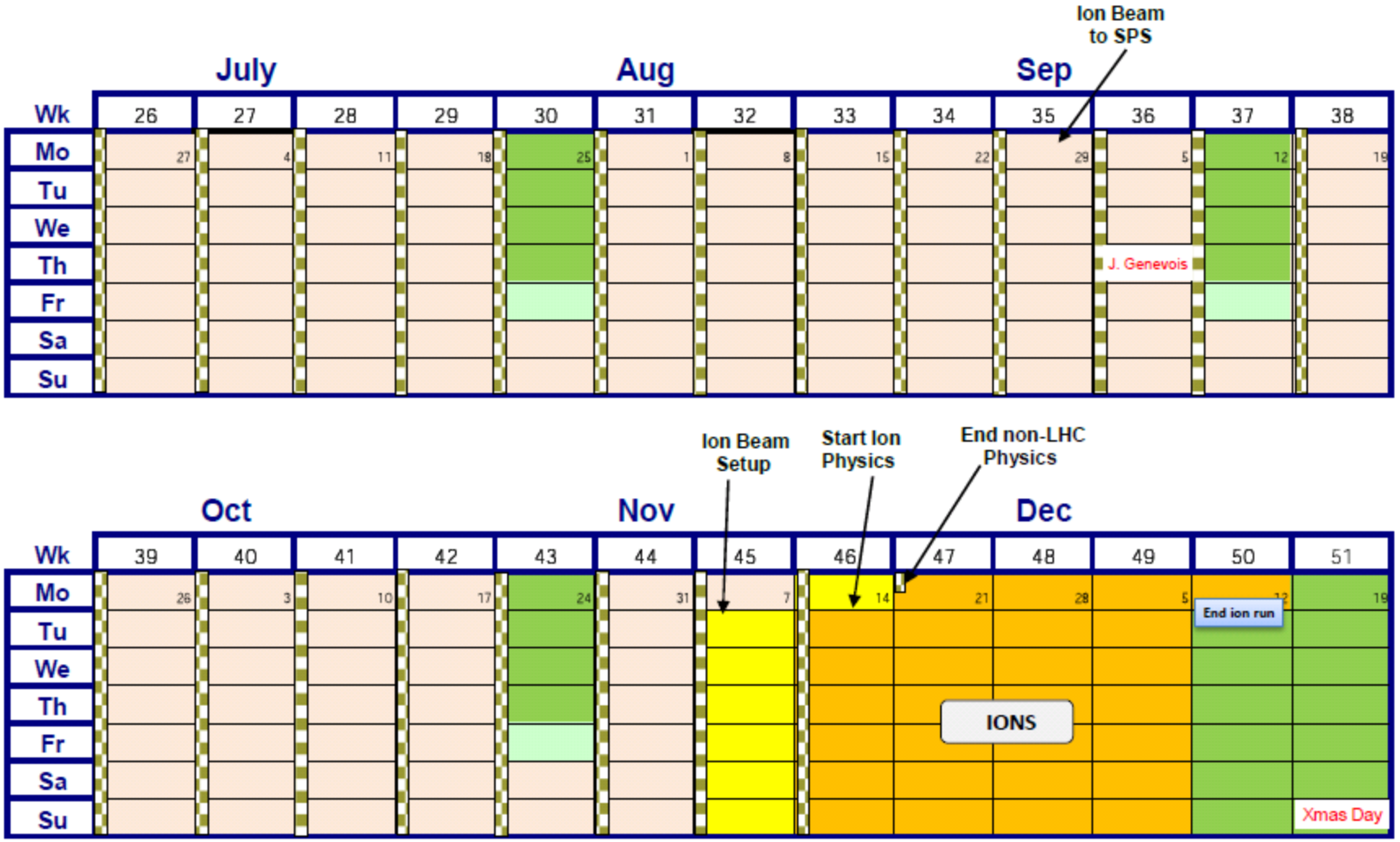


2011

2011 Q1&2


LHC closed
Re-commissioning with beam
Technical stop
Jan
Feb
Mar
Wk
52 1 2 3 4 5 6 7 8 9 10 11 12
Mo
Tu
We
Th
Fr
Sa
Su
Technical stop
MACHINE CHECKOUT
Start non-LHC physics program
Apr
May
June
13 14 15 16 17 18 19 20 21 22 23 24 25
Easter
Whit
Ascension
G. Friday
May day

2011 Q3&4


Ion Beam to SPS
July
Aug
Sep
Wk
26 27 28 29 30 31 32 33 34 35 36 37 38
Mo
Tu
We
Th
Fr
Sa
Su
J. Genevois
Ion Beam Setup
Start Ion Physics
End non-LHC Physics
Oct
Nov
Dec
Wk
39 40 41 42 43 44 45 46 47 48 49 50 51
Mo
Tu
We
Th
Fr
Sa
Su
End ion run
IONS
Xmas Day

2011 – 3.5 TeV

- Restart 4th February
- 9 months protons, 4 weeks ions
- Integrated luminosity target driven – 1 fb^{-1}
- Need to run flat out above 1e32 $cm^{-2}s^{-1}$

Table 4: Possible 2011 ball-park scenarios with 1.1×10^{11} protons per bunch.

N_b	β^* [m]	Energy per beam [MJ]	Peak Luminosity [$cm^{-2}s^{-1}$]	Int. Lumi per month [pb^{-1}]
432	3.5	27	1.3×10^{32}	61
432	2.5	27	1.8×10^{32}	85
796	3.5	49	2.4×10^{32}	113
796	2.5	49	3.4×10^{32}	157

Conclusions

- Very successful period of initial commissioning
  - 5 months since first collisions at 3.5 TeV
  - Commissioning is still ongoing…
- All key systems performing remarkably well – some hugely complex systems out there.
  - Some commissioning still required, issues still to address
- Performance with beam (losses, lifetimes, luminosity, emittance growth etc.) is very encouraging.
- Have bedded in the nominal cycle but it remains a complex procedure with a number of critical manual actions required – mistakes still very much possible
- We don't yet have a MJ culture.
- Aggressive planning for the rest of 2010
- Smooth running with 10s MJ in 2011 foreseen