



Injection losses vs Operational Availability

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LHC Injection constraints



High beam quality required: transverse and longitudinal Depending on LHC + whole injector chain

- o Minimize satellites from injectors
- o Minimize unbunched beam at location of next injection
- o Transfer line collimators at the end of line \rightarrow cross-talk with LHC BLMs
 - Keep bunches short
 - Remove beam tails \rightarrow scraping
 - Keep trajectory stable at TCDIs



- o Keep injection oscillations small
 - Below 2 mm for aperture and maximum damper performance (interlock at 1.5 1.75 mm)
- o Minimize time spent at injection
- o Keep injection safe \rightarrow inject first intermediate, steer with intermediate



LHC Injection status



- o Injecting routinely 144 bunches, 50 ns
 - Small emittances
- o Can inject 3.5 μm emittances with 4.5 σ TCDIs
 - Similar loss levels as nominal 50 ns

Result: MD 1 – Injection Quality

- o Can inject 288 bunches, 25 ns, without problem!
 - Slightly smaller bunch intensity than nominal, slightly smaller emittance



- o Set up transfer line collimators once during the run 2011
 - End of February/ beginning of March
 - One trajectory reference for the whole year





o Average bunch intensity 1.45e+11. Record bunch intensity 2011. Fill 2222.

INJECTION SEQUENCER v0.1.08												
o ▼ RBA: Ihcop												
······	50ns 1380b 1331 0 1320 144bpi12ini											
Injection schemes		INJECTION RING1							NJECTION RING2			
Filter	load >>	RFBucket	NbrBnche	s BnchSpac[I	ns] PS btchs	BnchInt[E9]	RFBucket	NbrBnches	BnchSpac[ns] P	S btchs	Bnchint[E9]	
GRP : 50ns 👻		<mark> </mark> 651					61 651				100	
50ns_1092b+1small_1042_35_10 🔺		4121					4121				100	
50ns_1092b+1small_1042_35_10											100	
50ns_1093b+1small_1042_35_10	Scheme active										100	
50ns_109b_85_69_72_24bpi6inj	when loaded										100	
50ns_109b_91_12_90_12bpi10inj	— Allows online										100	
50ns_1104b+1small_1042_35_10	buck modif						18411				100	
50ns_1200b_36x3bpi_13inj_scrub =											100	
50ns_1236b+1small_1180_37_11											100	
50ns_1380b+1small_1318_39_12		27351									100	
50ns_1380b_1331_0_1320_144bp	Display	30821	144	100	4	100	30821	144	100 4		100	
50ns_13b_BPMtest_12bpi	circ bu conf											
50ns_144b_qtest_bpi12inj												
50ns_205b_169_24_168_24bpi10i-												
50ns_228b+1small_214_12_180_:												
50ns_264b+1small_250_25_216_:	Clear						i					
50ns_264b_249_0_240_36bpi8inj	active											
50ns_28inj_12bpi		INJECTION_SUCCESS_IQC_WARNING					INJECTION_SUCCESS					
50ns_301b_283_4_288_24bpi10in	Disable inj trims	OVERINI	Start		Sten	STOP	OVERINI	Start		Sten	STOP	
50ns_336b+1small_322_12_288_1			Juli		Step	3101		Start		Step	3101	
50ns_336b+1small_322_12_288_		BunchConf autoCl Loop					BunchConf autoCl Loop					
5005_3360+15mail_322_14_288_		🕑 Enable inj cleaning		DB/BQM check		4 check	🗹 Enable inj cleaning		DB/BQM check		check	
Refrech list		Clear b	ch conf	RESET IN	l] se	t Bu int	Clear b	ch conf	RESET INJ	set l	Bu int	
check reservation						Reque	st ISA master	shin				
	cwo-ccc-d4lc							SP9		nastershin		
Take the reservation						Remov	e LSA master	ship				
set onem.												
18:14:38 : IQC_RESULT BEAM1 >>> WARNING, BEAM INJECTED WITH HIGH LOSSES NORM INJ B1 Beam injected! BQMs: Injected 144 bunches(1380 bunches circulating). BLM analysis was bad.								UNLATCH	B1 LAT	CH STATUS B1		
NORM INJ B2 18:12:03 : IQC_RESULT BEAM2 >>> INJECTION OK Beam injected! BQMs: Injected 144 bunches(1380 bunches circulating).							UNLATCH	B2 LAT	CH STATUS B2			
18:14:39 - INJECTION RING 1 : IQC analysis OK												

o Very good injection quality







- o Beam quality not stable
 - Emittances and tail population especially (different booster rings,...)
 - We know we can take these variations if we are well-centered in the TCDIs

- o Transfer line trajectories too unstable in the horizontal plane
 - Drifts
 - Supercycle dependence
 - Large shot-by-shot variations







Dumps due to injection losses



o Number of dumps due to injection losses since middle of July



14 dumps for beam 1

6 dumps for beam 2

o Try to avoid dumps, start steering before we reach dump level



Steering frequency:

Beginning of year: ~ once a week September: every 2 – 3 fills Now: every couple of days

Steering mainly triggered by losses



How much time is lost?



o Filling (excluding switch between intermediate and nominal): 30 minutes

- o Time lost with steering: ~ 30 min to 2 h
 - Need to take average over several shots

Not easy to steer – compromise between small injection oscillations and small offsets at TCDIs





Summary



- o We are injecting 144 bunches routinely and mostly very cleanly!!
- o The reproducibility of the LHC beams and transfer line stability is however still NOT good enough
- o Together with the tight constraints from losses, machine protection and injection oscillations, injection is still the least predictable part of the LHC nominal cycle.
- o Injection tuning is required several times a week \rightarrow time lost probably still acceptable with current turn-around time but not in the long run.

From the 8:30 meeting

 TI2 may benefit from Generally injection every second fill 								
Problems encountered wi	th tin	🔊 Tra	ansfer Line Issue: (Dscillati	ions			
Cryo PLC problem Vacuum pump in IP4		<i></i>						
 Injection tuning 	→	10.5 h	16:15 Injecting for physics –	15 Injecting for physics – SPS some problems set				
Controls network	→	8.5 h	some injection losses in the	LHC				
Collimator controls	→	5 h	5:52h injection beam 1					
Access system	→	4 h	ontimising heam narame	tors				
BPM interlock limits	→	1.5 h	opunusing beam paramet	opunitisting beam parameters				
□ Total:		66.5 h	strong losses at SPS / Tra	insferline				









50ns_1380b+1small_1318_39_1296_144bpi													
INJECTION RING1						INJECTION RING2							
RFBucket	NbrBnches	s BnchSpac[n	s] PS btch	s Bnchint[E 9]	RFBucket	NbrBnches	s BnchSp	ac[ns] PS b	tchs	Bnchint[E9]		
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						4481					100		
						8121					100		
							144	50	4		100		
							144	50	4		100		
						16941					100		
							144	50	4		100		
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							leeu	o wit	h etaa	rina	тірц		
			1550		13166	ing							
INJECTION_SUCCESS													
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BunchConf autoCl Loop						BunchConf autoCl Loop							
Enable inj cleaning DB/BQM check					Enable inj cleaning DB/BQM check					ieck			
Clear bch conf RES		RESET IN	l	set Bu int		Clear bch conf		RESET INJ		set Bu int			