



How long do we stay at injection?



Time spent at injection = beam mode INJECTION PROBE BEAM+ INJECTION PHYSICS BEAM +PREPARE RAMP We consider only fills that have reached stable beam (discard all the special run and MDs) Source is Timber and the accelerator performance and statistic page https://acc-stats.web.cern.ch/ Where is the time lost, Can it be improved?

- ➢Injectors and beam set-up time
- ➢ Filling schemes
- ➤Transfer line steering
- ➢Injection quality check
- ➤ Measurements at injection
- ➤Limitations

Injectors supercycle length

- For protons, the SPS supercycle length could be optimized to reduce the injection time.
 - Supercycles: up to 1mins
 - Nominal LHC proton cycle: 21.6s

Fully dedicated supercycle not possible:

- Time needed between 2 SPS consecutive cycles for continuous injection
 - Interleaved injection: 3-4 seconds (next request after injection event)
 - One beam at a time: 10s (next request after the IQC analysis)
- > LHC cryo limitation requires to inject slowly and with pauses
- In this situation, dedicated supercyle would penalize too much the north area physic

May be reconsidered next run

- If the cryo is stable and we inject continuously
- If we manage fast setting up and fast injection
- If we continue to do most of the steering while filling

Advantage for the SPS users:

LHC cycle in the supercycle = bad fixed target beam quality and less duty cycle for them With fast dedicated LHC filling they could even gain beam time.

Injectors beam setting-up time

152h downtime assigned to no beam from injector

28 h assigned to injector setting-up in 2015



Injectors beam setting-up time

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28 h assigned to injector setting-up

- Many LHC beams in 2015
- At least 3 types of beam per filling, 3 beams to check and optimized before each filling period
- TIDV dump intensity interlock slow down the setting-up (will get worse with 288 bunches)
- Many clients in SPS for MDs, not always compatible with LHC beam preparation
 Can be improved by a better synchronisation of LHC and SPS planning

Sometime too short notice for new requests
 Can be improved by a better communication and anticipation from the coordinators

SPS Beam Quality

Several parameters are checked before extraction to guarantee that the injected beam has the requested parameters and the rephasing is OK

Bunch length, bunch pattern, satellites, bunch peak spread etc...

L SPS Beam Quality Monitor -	SPS.USER.LHC25N	S (INCA)															1313	∓ ₀ [⊭]	ď
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Expected Beam Pattern		Results																	
SPS LHC		SPS Mas	tership					550	Numbe	n 18						2015.0	5.04	00:45:	51
	***	Status	Data G	raphs	Oth. Gra	phs	Inj. Graj	phs E	xtr. Graj	hs 5	at. and	Osc. Gra	aphs	Doublets	Ra	aw Wave			
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Number of Bunches per Batch:	72	00:4	LHC25NS	SPS	Enab	Ok	Ok	1.796	0.037	0.293	0.015	2724	0.165	72	Ok	Ok	0k	Ok Exp	p
	**	00:4	LHC25NS	SPS	Enab	OK	Ok	1.837	0.042	0.288	0.015	2664	0.156	72	OK	0k	0k	OK Eq	ρ
	AA	00:4	LHC25NS	SPS	Enab	Ok	Ok	1.754	0.031	0.285	0.013	2624	0.165	72	Ok	OK	OK	Ok Exp	ρ
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	•	00:4	LHC25NS	SPS	Enab	Ok	Ok	1.864	0.041	0.279	0.016	2591	0.166	72	Ok	Ok	0k	Ok Eg	p
Barrada Barrada an	AAAA	00:4	LHC25NS	SPS	Enab	Ok	OK	1.854	0.038	0.289	0.023	2679	0.236	72	Ok	OK	OK	Ok Exp	p
Eatch Spacing:	U ns	00:3	LHC25NS	SPS	Enab	OK	Ok	1.825	0.040	0.285	0.015	2611	0.177	72	OK	OK	OK	OK Exp	p
		00:3	LHC25NS	SPS	Enab	Ok	OK	1.838	0.036	0.289	0.014	2000	0.160	72	OK	OK	OK	Ok Exp	p
i inj t	ucket Selector Calc	00:3	LHC25NS	SIS	Enab	OK	OK	1.774	0.038	0.291	0.014	2662	0.166	72	OK	OK	OK	OK Exp	p
	A A	00:3	LHC25NS	SPS CDC	Enab	Error	OK	1.838	0.047	0.285	0.014	2033	0.159	72	OK	Error B	C T C C	OK EX	,3
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	**	00.3	LHC25N5	5P5	Enab	Ok	OK	1.847	0.055	0.201	0.014	2533	0.165	72	OK	Ok	Ok		200
	1 11	00:3	LHC25NS	SPS	Enab	Ok	Ok	1.801	0.047	0.289	0.012	2633	0.171	72	Ok	Ok	Ok	OK EX	p
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		00:3	LHC25NS	SPS	Enab	OK	Ok	1.804	0.037	0.285	0.013	2622	0.158	72	OK	0k	OK	OK Ex	D
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> SPS beam quality monitor dumps (statistics for 25ns protons)

- > 15% for 12 bunches or pilots and Indiv
- > 20% of the nominal beam requests.

For a 22 injections scheme, we loose around 4 mins

The thresholds for each parameter have to be the best compromise between efficiency of the injection and quality of injected beams.

Many filling schemes



~200 filling schemes have been used in 2015

- 48 for protons physics. (but almost as many created as spare or alternative and not used)
- > 7 for ions physics
- 44 used for scrubbing
- The rest for setting-up and MDs

Filling scheme's impact on injection duration

➢Number of injections not optimal

- Limitation to 144 bunches/ injection from the TDI instead of 288 nominal.
- For some fills : reduction of the number bunches/injection to reduce the e-cloud



Same number of bunches and collisions but the second one takes 16 mins more to inject

Filling scheme's impact on injection duration

Filling schemes have to be optimize to reduce the number of SPS cycle change.

Scheme	Name		25ns_1	86b_74_53	3_54_24b	pi7inj											
lnj schei	ne group	>	25ns								-						
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Collision	is in IP2		53	53													
Collision	is in IP5		74														
Collision	is in IP8		54														
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2001	12	12	25	1	INTR	3001	12	12	25	1	INTR						
8991	12	12	25	1	INTR	8991	12	12	25	1	INTR						
13451	1	1	0	1	NOM	13451	1	1	0	1	NOM						
17881	24	24	25	1	NOM	17881	24	24	25	1	NOM						
22391	1	1	0	1	NOM	22391	1	1	0	1	NOM						

Worse case: SPS supercycle changed 6 times

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Corrected for only 3 supercycles changes

Filling scheme that includes at least 3 intermediate beam injections allows steering while filling

							O shit		ation		****
RFBucket	Bu Tot	bu/btch	Spc/ns	PSbchs	Llevel	RFCal_	Urbit	corre	CUON	PShch	s I level
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3781	144	72	25	2	NOM	6001	144	72	25	2	NOM
6001	144	72	25	2	NOM	8221	144	72	25	2	NOM
8221	144	72	25	2	NOM	10501	144	72	25	2	NOM
40504	4.4.4	70	05	0	NOM	40704	1 4 4	70	05	0	NOM

Transfer line commissioning

> Establish the transfer line references with pilot

Procedure improved for the pilot trajectory to be more representative of the nominal :



Kickers delays changed for the MKEs and the MKIs so that the pilot is positioned at the middle of the waveform

In the SPS pilot on the nominal cycle for comparable magnetic history

Chiara Bracco

Transfer lines steering

The trajectory references were better than in 2012

Only 14 hours spent for dedicated steering during protons run.

50% of the steering were done while filling, thanks to appropriate filling schemes: several hours gained!

Shot by shot instabilities cured after LS1 hardware change at the SPS extraction septa to supress the current ripple.(Florian Burkart's talk)

> Almost no dump due to injection losses

- Optimization of the BLM thresholds
- Replacement of some BLMs by LICs (ionization chambers) , less sensitive, more margin
- but keep in mind that we were limited to 144b.

Injection Quality Check unreliable analysis

	Injection	Beam 1			Injection	Beam 2	
15-10-01 0:02:39.0	085: Beam injec	ted! BQMs: Injecte	d 12 bunches(13	bunches circulatir	ng). BLM analysis w	as bad.	
AM EXTRACTION INJE	CTION KICKER	BEAM LOSS	RF BUCKETS	INJ.OSCILLATIONS	TRANSFER LINE	RF PHASE	SCRAPING
15-10-01 0:02:39.	101: Beam loss	es above threshold	is.				
Monitor n	ame	Max loss	IQC appl	ied IQC	ref Dump	threshold	Ratio to dump
BLMTI.06R7.82110_T	CP.C6R7.B2	0.4717	0.0	0.0	9	2672	5.09%
BLMTL06R7.82110_T	CP.86R7.82	0.2818	0.0	0.0	9	2672	3.04%
BLMTI.06R7.82110_T	CP.DGR7.B2	0.2805	0.0	0.0	9	2672	3.03%
BLMTI.04R8.B2E10_	TDI.4R8.B2	0.5415	0.1917	4.6	23	.1680	2.34%
BLMQI.03R8.B2E1	0_MQXA	0.0799	0.0192	0.46	3	8459	2.08%
BLMTI.06R7.B1E10_T	CLA.B6R7.B1	0.1589	0.0	0.0	9	2672	1.71%
BLMTI.04L8.B1E10_T	CTPV.4L8.B1	0.0727	0.0388	0.93	4	6336	1.57%
BLMTI.04L8.B2110_	TCLIA4L8	0.3588	0.1929	4.63	23	.1680	1.55%
BLMEI.04R8.B2E2	0_MBXB	0.3438	0.1929	4.63	23	.1680	1.48%
BLMEI.04R8.B2E1	0_MBXB	0.0280	0.0192	0.46	2	3168	1.21%
BLMTI.04R8.B2E20_TDI.4R8.B2		0.2432	0.1929	4.63	23	.1680	1.05%
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260	280	300	320 n	340 Ionitors	360	3	80 4

Example of IQC giving a warning because losses on the TDI at 2.34% of dump threshold!

- IQC analysis scales the losses to 288 bunches.
- At the TDI : mostly unbunched beam losses
- Scaling doesn't apply here, we get warning at almost every injection

Too many unjustified warnings or errors

Big risk to disregard real problems

Injection Quality Check unreliable analysis

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Several time per fill, IQC unable to know if beam is injected



Example of IQC not able to determine if beam was injected or not.

Analysis relies on 2 BCTs and the BQM

- Since modification during LS1, BQM post mortem less reliable.
- IQC gets "No beam injected" from BQM and "Beam injected" from BCTs and get confused
- Injection process stopped
- LHC operator has to check if beam is injected, unlatch the IQC and resume the injection requests
- The analysis result is not published

Injection Quality Check unreliable analysis

≻In 2015, IQC has lost its credit, and didn't fulfil its role

This could be improved for next run

- ➢ Review the BLM warning limits and apply an appropriate scaling.
- Give OP the possibility to control the warnings and error thresholds easily and anytime (like for SPS BQM)
- The LHC BQM have to be modified to give reliable PM data

The IQC analysis can be pushed farther to help understanding when steering is needed : correlate the beam position at the collimators with the beam losses and spot the critical beam positions.

Measurements at injection

➤Tune and chromaticity measurement:

- Transverse dampers new gain management : lower damper gain applied to the first 400 Buckets
- ➢Gives a constraint on the filling scheme to have beam in the first 400 buckets.

Q and Q' measurement much improved. (and time gained for the beam tuning)



Measurements at injection

➤Wire scanner:

- Measurement is too slow
 - Waiting for the high voltage ready
 - Takes ages to retrieved the filled buckets
 - No parallel measurement for B1 and B2
 - Good settings difficult to find and not stored
 - Intensity limitation forces the injection process to stop while we measure
- New application for wire scan is much better but still can be improved to get faster measurement.
- With a reliable BSRT, the necessity to measure each fill can be questioned.



Limitations

Cryogenics beam screen: necessary to stop injection process for a while to stabilize the temperature

- Almost 24h of downtime assigned
- Fine tuning of the parameters and reduction of the e-cloud by scrubbing improved a lot the situation at the end of the run
- More details on Cryogenics talk from Krzysztof BRODZINSKI

TDI.B2 vacuum

- 3h of downtime, 5 beam dumps at inj
- We had to inject B2 first and retract the TDI as soon as possible
- Both TDI will be replaced during the technical stop. (more details on Anton Lechner 's presentation on TDI)



MKI.B2 vacuum

- limiting the number of bunches per trains
- > 2244 bunches per beam possible only with trains of 36 bunches.
- How far can the vacuum threshold be relaxed?

Instability and blow-up at injection

- Instabilities and blow-up of the beam started to appear when bunch nbr > 1100
- No every fill, sometime on B1, sometime on B2.
- Beam had to be dumped several times (16 recorded in PM DB, sometime with the need to wait for cryo to stabilize)



- One problem identified and solved on the ADT, the gains optimized.
 We need a better ADT diagnostic at each injection to easily spot this kind of problems
- Higher octupoles an chromaticity necessary (15 both planes)
- > The cause of the instabilities is complex and not fully understood
- > More details on Lee Robert CARVER's presentation on instabilities

Conclusion

- Ramp, squeeze and rampdown time is driven by the functions settings (only small optimization can be done)
- Injection is the part of the turnover where we can really gain time
 - Optimize the SPS supercycle length
 - Improve the compatibility between LHC needs and SPS daily operation to allow more setting-up time before beam is requested
 - Optimize the filling schemes to reduce the number of SPS supercyle change, reduce the number of injections and allow for steering while filling.
 - > Optimize the time spent for beam measurement

Limitations appear when the number of bunches increases

- Beam instabilities: still needs to be understood better
- Cryogenics stability : where is the limit?
- ≻ Heat load

> Next run : injection of 288 bunches, more challenging.