

Intensity ramp-up: 2011 experience and pushing it in 2012?

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LHC Beam Operation Workshop

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Thanks to : rMPP members, et al

- Recap of intensity ramp-up(s) in 2011
- Limitations, risks and mitigations
- rMPP role and response
- 1380 b in 3 weeks?

- Finished year 2010 with 368b and 150ns
- New ramp up in 2011 for new bunch spacing 75 ns, beta squeeze to 1.5m, e-clouds expected at some stage, many other changes
- Agreed plan before first TS and 1.38TeV run:
 - Complete MPS tests, loss maps, ... with ≤ 3 b
 - Start luminosity operation with 3 bunches per beam (get experience with the full operational procedures from injection to stable beams)
 - Intensity ramp-up (8 b, 32 b, 64 b, 136 b, 200 b)
 - Baseline is three fills per step, in total 20h of Stable Beams
 - rMPP might propose to reduce the number of fills or the total number of hours for a step, if everything goes very smooth

Note: Focused on proton runs, not discussing beam commissioning period

Intensity Ramp up in 2011

Note: Showing always max intensity achieved during the day

	Jan			Feb					Close ring	Re-commissioning with beam	Mar			Intermediate energy run
Wk	52	1	2	3	4	5	6	7	8	9	10	11	12	
Mo		3	10	17	24	31	7	14	21	28	7	14	21	
Tu												8 b	200 b	
We												32 b		
Th		Technical stop			Hardware commissioning						1 st collision @ 3.5TeV			
Fr														
Sa	1							1 st circ. beam		Nom, bunch @ 3.5TeV		64 b		
Su											Stable Beams 3 nom b	136 b		

- First stable beams with 3b on Sunday 13th March
- Finished last MPS tests + wrestling a bit with noisy tune signals and QFB
- First attempt of 32b failed due to problem with GMT (wrong timestamps on events)
- 2 days of investigations, correction and validation
- Very smooth ramp up to 200b with batches of 3 consecutive fills from 18th – 22nd (1 intensity step /day)

EVENT_TIMESTAMP INT [1e11] SB [h] DUMP CAUSE COMMENT

EVENT_TIMESTAMP	INT [1e11]	SB [h]	DUMP CAUSE	COMMENT	
13-MAR-11 03.11.59	1	0	MPS test	Asynch dump test after squeeze	MPS tests + Loss maps
13-MAR-11 05.24.54	1	0	MPS test	Asynch dump test at collision settings	
13-MAR-11 08.11.28	Pilot	0	MPS test	Off momentum loss map	
13-MAR-11 01.33.56	Pilot	0	EOF	Programmed dump from 1.38TeV	
14-MAR-11 01.15.09	3	7.17	EOF	Programmed dump of beam 2 as part of end of fill study.	
14-MAR-11 01.41.46	3	0	MPS test	Async dump test at collision settings. Only beam 1. End of fill study.	
14-MAR-11 03.23.40	3	0	EOF	Programmed dump at flattop - realised beam 1 was not in correct bucket.	
14-MAR-11 07.19.03	3	2.1	Water	Electrical instability tripped warm magnet PCs	
14-MAR-11 04.05.27	3	5.28	MPS test	Dump of B1 Prior to loss maps for B2	
14-MAR-11 04.44.19	0	0	MPS test	Dump with RF off	
14-MAR-11 05.29.18	0	0	MPS test	Test PM for BLM team	
14-MAR-11 05.35.15	0	0	MPS test	Test PM for BLM team	
14-MAR-11 06.04.21	0	0	MPS test	Test PM for BLM team	
15-MAR-11 04.53.58	3	2.91	LBDS	Generator problem on MKD-M	
15-MAR-11 02.30.01	3	0	Orbit	2 RQTs trip. B2H tune signal noisy	
15-MAR-11 11.34.33	3	0	Orbit	Trip of trim quad due to increasing corrections of tune feedback on B2H	
16-MAR-11 08.31.45	3	6.37	EOF	End of fill	
16-MAR-11 12.16.43	8	0	EOF	Standard dump after ramp and squeeze test.	
16-MAR-11 08.43.01	32	0	FB 1	Problem with timing system (timing event distribution sometimes gets wrongly time-tagged).	MTG problem
17-MAR-11 04.00.04	0	0	EOF	Dump of pilot bunch at collision settings after checking ramp after switching to System B of master timing gateway.	
17-MAR-11 06.10.09	2	0	Coll Sys	TCTH.4L5.B1 had a position interlock at the first step of the squeeze.	
17-MAR-11 10.55.00	0	0	MPS test	Collimator test at end of fill (without beam)	
17-MAR-11 12.16.16	0	0	EOF	Collimator test at end of fill (without beam)	
17-MAR-11 08.36.41	2	0	Coll ad	SIS: TCDQ-TCS retraction, TCS gap interlocks with constant collimators	
18-MAR-11 12.11.21	2	0	Orbit	Testing the collision BP with nominal bunches at 1.38TeV. ... Losses on TCTVB.4R2 Dump was OK	
18-MAR-11 04.40.58	0	0	EOF	Programmed dump at 1.38TeV with 3 pilots in Dump OK	
18-MAR-11 07.39.08	0	0	FB 1	Trip of RQTF circuits following large trims of tune feedback (jumping between fake tune lines)	
18-MAR-11 11.18.12	1	0	FB 1	Trip of RQTF circuits following large trims of tune feedback (jumping between fake tune lines)	
18-MAR-11 09.05.44	32	6.01	EOF	Clean dump at end of fill 1634	32b -> 200b
18-MAR-11 11.35.11	32	0.1	PC	RF interlock, but caused by problem with FGC that got two many event at the same time	
19-MAR-11 10.37.44	32	6.01	EOF	Clean dump at end of fill 1636	
19-MAR-11 08.00.18	64	6.69	EOF	Clean dump at end of fill 1637	
20-MAR-11 05.49.56	64	7.08	Cryo	S81: Cryogenics lost for MSR8	
20-MAR-11 06.01.15	64	6.33	EOF	Clean dump at end of fill 1639	
21-MAR-11 06.04.23	136	8.55	EOF	Clean dump at end of fill 1640	
21-MAR-11 09.45.59	136	6.54	EOF	Clean dump at end of fill 1642	
22-MAR-11 06.09.12	136	5.96	EOF	Clean dump at end of fill 1644	
23-MAR-11 06.12.15	200	8.95	EOF	Programmed dump at the end of 200b physics fill	
23-MAR-11 09.32.07	200	0.228	Water	RQTL11.R6B1 got a water fault due to a faulty interconnection piece	

	Scrubbing run		physics program											
	Apr		May						June					
Wk	13	14	15	16	17	18	19	20	21	22	23	24	25	
Mo		96 b	1020 b		Easter							Whit		
Tu		50ns inj												
We		408 b												
Th		HTS cable inversion								Ascension				
Fr				G. Friday		MD				1st May comp.				
Sa	Transfo	588 b												
Su	UJ76	800 b			1st May									

- Recovery from TS interrupted by transformer problem in UJ76
- First scrubbing with 96 b and 75ns, followed by injection setup for 50ns
- Quickly got up to 400b
- Stopped powering for 2 days for CL quench and HTS cable verification
- Increasing in steps of 200b, mainly due to potential damage to RF components
 - Extracted power by HOM dampers \sim Intensity²
 - Qext set to 20000 to limit max induced voltage <1.2MV

Intensity Ramp up continued...

	Scrubbing run		physics program													
	Apr		May						June							
Wk	13	14	15	16	17	18	19	20	21	22	23	24	25			
Mo	28	4	11	18	Easter	2	9	16	23	30	6	13	20			
Tu			3 b													
We			48 b													
Th			228 b	480 b						Ascension						
Fr				G. Friday		MD				1st May comp.						
Sa			336 b													
Su					1st May											

- Standard recovery after TS (and scrubbing): 1 test ramp with pilots (no stable beams) and 1 fill with Single_2b_1_1_1_wp (~1h stable beams + loss maps) + asynch dump
- Switching to 50ns: 1 fill of 48, then usual 3 fills/20h for 228b and 336b
 - Needed 8 fills for both steps to obtain 20h ('usual' mixed bag of problems with water cooling, Cryo, controls, PC trip, El Net ... + mini UFO near ALICE)
- First 3 fills for 480b gave >20h stable beams, no step due to Easter WE
 - Discovered 2nd bug in MTG watchdog (energy value jump to FFFF every 20 days)
 - First trip on slow beam loss due to vacuum spike to 1E-6 in IR8 during 9th fill

Intensity Ramp up continued...

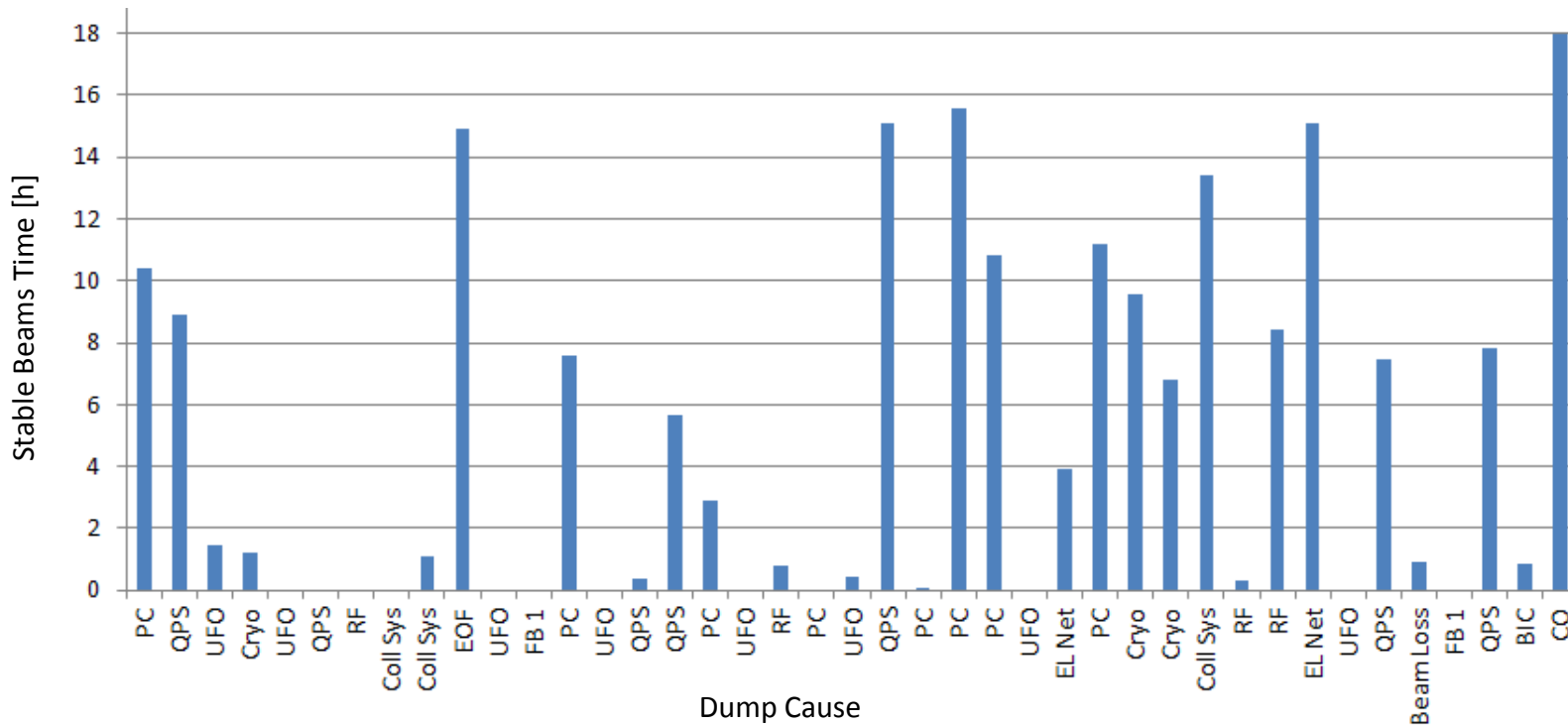
	Scrubbing run		physics program													
	Apr				May					June						
Wk	13	14	15	16	17	18	19	20	21	22	23	24	25			
Mo	28	4	11	18	Easter	2	9	16	23	30	6	Whit	13	20		
Tu			3 b													
We			48 b		624 b											
Th			228 b	480 b						Ascension						
Fr				G. Friday		MD				1st May comp.						
Sa			336 b													
Su					768b											

- Switch to 624 b after Easter WE
 - 6 fills for >20 hours
 - 1st fill dumped by beam losses following vacuum spike in IR8
 - 4th fill due to a vacuum spike in IR2
- 4 more fills with 768 b for ~8 hours of SB before MD period
 - 1st UFO near injection kicker MKI2
 - SEU on collimation system
 - False QPS trigger
 - UPS failure in IR5

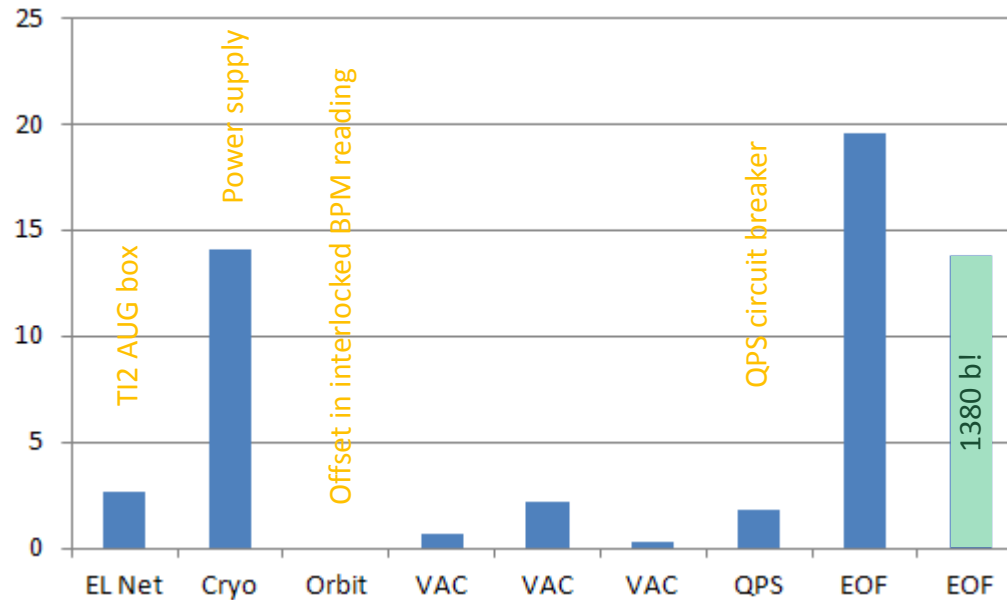
Intensity Ramp up to 1380 b

	Apr		May						June				
Wk	13	14	15	16	17	18	19	20	21	22	23	24	25
Mo	28	4	11	18	Easter	2	9	EDF glitch	23	30	6	Whit	20
Tu			3 b					228 b					
We			48 b		624 b			480 b					
Th			228 b	480 b			Quench HTS			Ascension			
Fr				G. Friday		MD	RD3.LR4	768 b		1st May comp.			1236 b
Sa			336 b				AUG						
Su					768b		T12	912 b	1092 b				

- Without problems back to 480b, in parallel setting up for 144b injection
- Completion of 20h SB for 768b with next 4 fills (again 1 vacuum problem in IR8)
- Difficult step to 912 b, 13 fills in total
 - Main problem with spurious RF main coupler interlock (arc detection)
 - Very fast UFO in Q28L8, rise time 0.2ms
- Even more difficulties with 1092 b, total of 41 fills!



- Initial problems to keep the fills, mainly because of increasing UFOs and R2E problems
 - series of BLM threshold changes early June (Q6L2, MKI2/8, TCTH IR2/IR8, MQY, TCTVB.4L8,.... described in LHC-BLM-ECR-0016, LHC-BLM-ECR-0021,...)
 - Increase of Vacuum thresholds + continued deployment of QPS R2E mitigations
- For reasons of integrated lumi, even step back to 912 b was considered at this point
- Eventually did ~ 200 hours of stable beams @ 1092 b

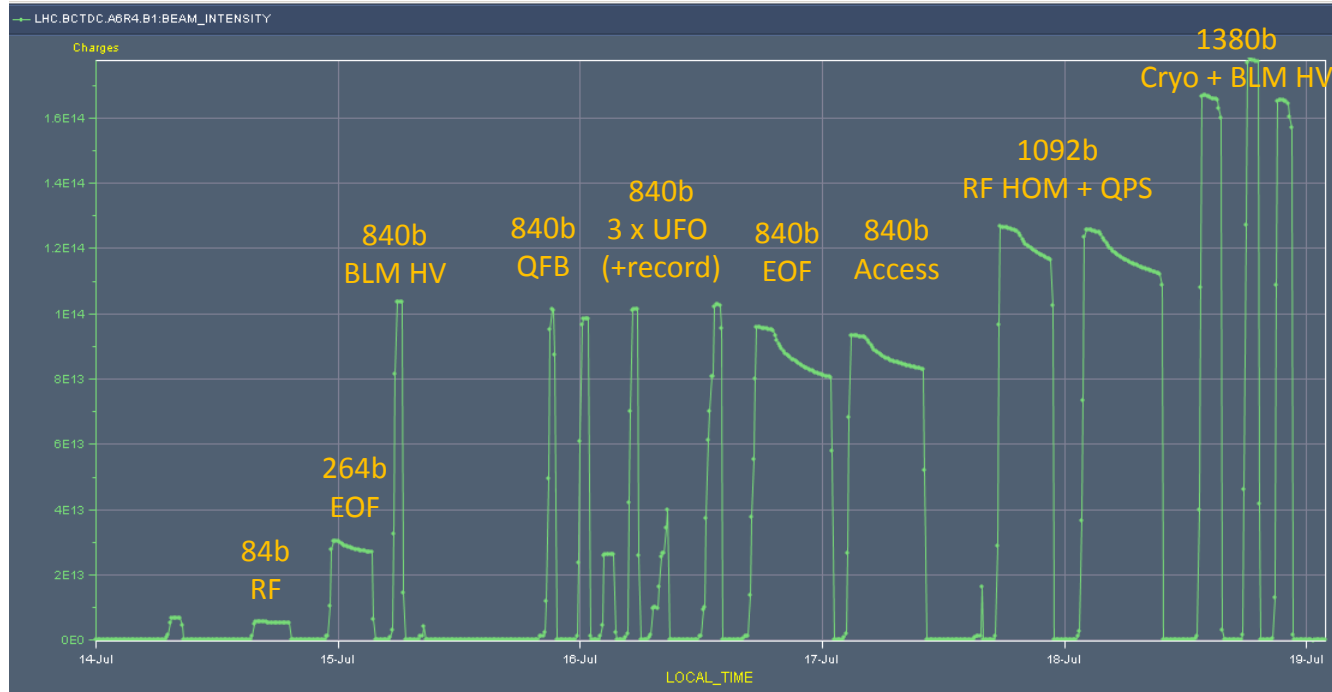


- Reasonable start with 1236 b due to previous long plateau at 1092 b
- 3 consecutive B2 vacuum interlocks in IR4 + valves closing
 - vacuum interlock threshold increased from $4E-7$ to $2E-6$ for VVGH.1174.5R4.R
- Final fill before MD period with 1380 b, dumped by OP after 13.7 hours and $\sim 46\text{pb}^{-1}$

Intensity Ramp ups after TS

	July			Aug					Sep				
Wk	26	27	28	29	30	31	32	33	34	35	36	37	38
Mo	27	4	11	18	25	1	8	15	22	29	5	12	19
Tu	1380 b		Power Cut	1380 b									
We			Pilot										
Th			264 b								J. Genevois		
Fr			840 b										
Sa		Power Cut											
Su			1092 b										

Timeseries Chart between 2011-07-13 02:00:00.000 and 2011-07-19 01:59:59.000 (LOCAL_TIME) Timescaled with AVG every 10 MINUTE



1st re-ramp-up to 1380b after TS

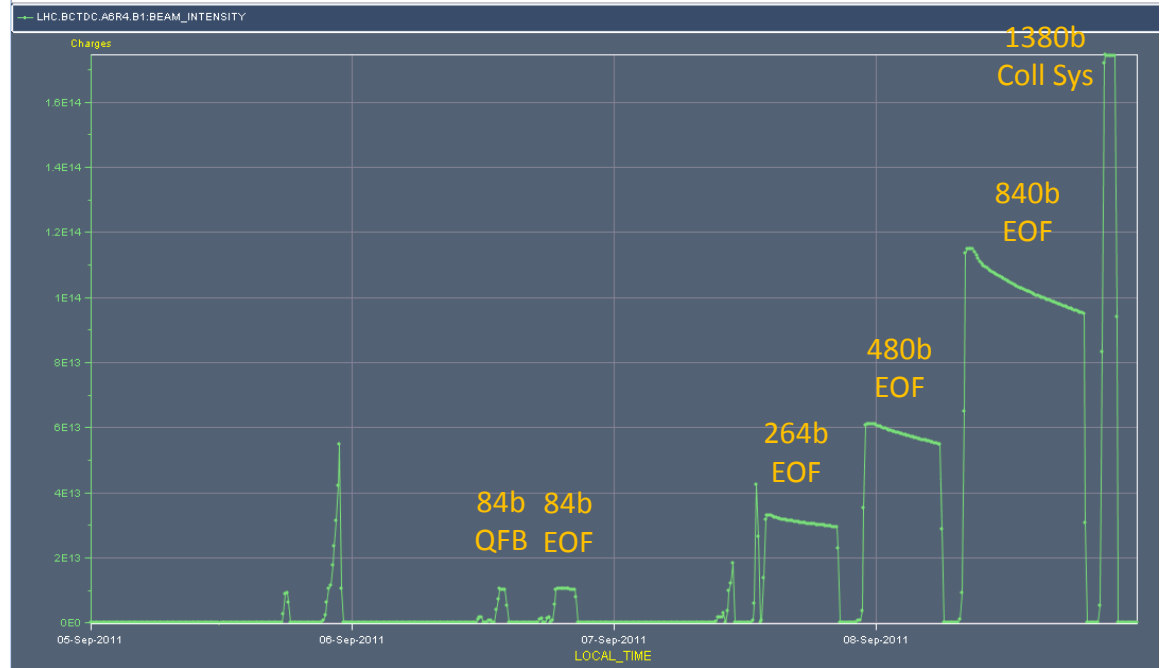
5 fills with 840b lost before SB, as after TS UFO rate increased around MKI in IR2

Could 480b fill have helped?

Intensity Ramp ups after TS

	July				Aug				Sep				
Wk	26	27	28	29	30	31	32	33	34	35	36	37	38
Mo			Power Cut	1380 b							$\beta^* = 1m$		
Tu	1380 b										84 b		
We			Pilot								264/480 b		
Th			264 b								1380 b		
Fr			840 b										
Sa		Power Cut								Pilot			
Su			1092 b										

Timeseries Chart between 2011-09-05 00:00:00.000 and 2011-09-08 23:59:59.000 (LOCAL_TIME) Timescaled with AVG every 10 MINUTE



Rocket ramp-up

Sole premature dump with 84b

Fills of 84b, 264b, 480b, 840b and 1380b of ~ 6 hours each in SB

From 1st fill with 84b to first 1380b in ~ 2 days

- Majority of Machine protection tests done with SBF ≤ 3 nom bunches, requiring relatively little time during ramp-up
- Main driving factor was machine availability up to 768b, but time allowed to discover & clean up many teething problems at intensities $< 1380b$ (2xMTG, QFB, FGC current reading, arc detectors, ...)
- Initial steps to 912 b and 1092 b set off UFOs, vacuum activities and SEU
- Risk with faster intensity ramp up is not risk with machine protection, but effect of decreasing of efficiency
- Balanced approach to intensity increase allows for probing and resolving of upcoming issues while maintaining certain integrated luminosity

- Open and fruitful discussions between MPS representatives during ~ 15 meetings in 2011 to propose strategy of intensity ramp ups (EDMS)
- Very active during initial ramp-up, a bit less towards end of the run
- Proposals mostly followed, next intensity step approved through detailed checklists (almost 20 this year)
 - Standard checks + additional observations, non-conformities, comments, additional MPS checks,....
 - Filled by rMPP members almost real-time, often on WEs!

- For 2012
 - Formalise 'standard' ramp-up after TS
 - Closer follow-up during intensity cruise
 - Should we keep checklist only for initial ramp-up or also later?

Beam dump	Status	Who
Asynchronous dumps understood? Protection worked correctly?	NA	JU
Parasitic asynchronous dump data show no loss of protection 1)	OK	JU
No positioning errors on TCSG/TCOQ	OK	JU
No settings or thresholds mistakes/wrong sequences/unexplained faults on TCSG/TCOQ	OK	JU
No unexplained MKD, MKB kicker, TSU or BETS faults 2)	OK	JU
No potentially dangerous XPOC or IPOC failure on MKD or MKB	OK	JU
No unexplained synchronisation problem with TSU	OK	JU
Pressure and temperature rise in TDE block within tolerances 3)	OK	JU
Requalification passed OK at 450 GeV and 3.5 TeV with pilot in case of any important component exchange	OK	JU

Comments:

- 1) TCT/TCDO ratio 1.1e-4 for B2 and in 10-5 for B1.
- 2) BETS running with reduced margin after compensation pc exchange (will increase safety but possibly reduce availability).
- 3) Pressure change around 0.04 bar max, 0.1 max 1 degree.
- 4) Last 5 BLMs of TDE2 are disabled in XPOC. They were faulty on 08/06 and repaired on 10/06, but still labeled as "not connected" by the BLM team. For this reason they need to remain masked in the XPOC analysis, but the XPOC buffer can be read manually in case of any doubts. **BLMs enabled on 15/6, all ok.**
- 5) BTVD image was missing for a few dumps, but fixed by a camera reset.

Note: some items only relevant for increase injected intensity

Injection	Status	Who
Injection oscillations within tolerance for all injections 1)	OK	JU
No unexplained large beam loss on TCIDs 2)	OK	JU
No issues in injection procedure, settings or tolerances	OK	JU
Orbit in injection region in tolerance wrt reference (tolerance <0.5 mm)	OK	JU
Resetting of TL trajectories and TCIDs done when needed 1)	OK	JU
No increased rate of MKI flashovers	OK	JU
No increased rate of MKI switch errors or missings	OK	JU
No unexplained MKI vacuum or temperature activity 3)	OK	JU
No machine-protection related injection system hardware failures	OK	JU

Comments:

- 1) Some steering required for B1 to correct oscillation – were above IQC threshold, afterwards OK.
- 2) One injection from SPS without scraping, resulting in beam dump on BLMs
- 3) MKI temperature increased to 54 degrees, measurements during soft start did not show loss of magnet inductance and injection interlock moved up to 60 degrees. Temperature going up less steeply with longer bunches.
- 4) During injection, oscillations above threshold with T20, EQC "took the risk" to continue injecting 144b without dumping and correcting trajectory using 12b as is required by procedure. SIS/IQC interlocking should have prevented this – problem in the logic which resets the interlock if "no beam" is injected – needs to be fixed.
- 5) During week 24 more problems with injection oscillations in T12, most likely related to ripple on the

BLM
Internal test (sanity checks) results must be true
Rise time (10 to 90%) of fast losses must be larger than 200 us
No unexplained BLM check failures
Expected losses for the to be injected beam must be at least 30% threshold level
BLM system modification (ECRs) have to be agreed on, EDMS: not persons signature is needed
No nonconformities in the energy transmission to the BLM crates

Check list

Non-conform points: the inter resolution of the issue.

Magnet powering
No unexplained IPOC failure in P
No magnet quench after beam d
No unexplained quench of a mag
No unexplained abort of the pre
No problems with loss of QPS_0

Comments:

- 1) With present high intens a factor of up to 3-4 with
- 2) 11 out of the 18 fills wer RQTL11.R7B1, RCBX2.L radiation/noise related f version related to the tr release of the FGC SW.).
- 3) Numerous communicati (shown below), partially 29/05/2011 13:51:56:27; 31/05/2011 05:44:30:85; 01/06/2011 19:50:26:72; 03/06/2011 06:16:31:38; 05/06/2011 11:03:13:34; 06/06/2011 22:32:08:60; 09/06/2011 18:56:51:25; 09/06/2011 21:39:37:81;
- 4) Following the latest dum eventually was dumped by BLM as this critical type to that BIC configuration should be reviewed, and circuit types v operation configured to directly dump the beam through the upcoming technical stop (but could be done earlier if

Collimation
Valid betatron loss map done in las
Valid off-momentum loss map done
No observation of abnormal collima
No observation of abnormal passive
Collimators at agreed positions duri
Correct LSA positions, thresholds, li

Comments:

- 1) Loss maps at collision and injecti off-momentum loss maps 15./18.0 collimation team) before this inten momentum; Collision: B1 hor/year,
- 2) The occasionally higher losses in document, remained during running hierarchis preserved for high loss
- 3) Fills 1835 and 1865 were dumpex expert solved the problems by repli probably the problems were causee experts.
- 4) Fill 1831 was dumped due to a tel correlated to bunch length variator length from 1.2 to 1.25ns.

Main 'delay's of ramp-up in 2011 for understanding and mitigation of intensity related effects $\geq 912\text{b}$ (UFO, vacuum, SEUs,...)

Fast ramp-ups after TS show that quick(er) ramp up in 2012 depends on

- a) Good scrubbing
- b) Changes of machine parameters (E , β^* , bunch spacing,...)
- c) # of other system changes during X-mas stop (potential new 'features')

Assuming most likely scenario for 2012, 3 weeks for 1380b are within reach

Pushing too hard will at some point be counter-productive

Reduce to 7 steps in 2012, maintain 3 fills per step but vary SB time

3b for MPS

3 fills and 6 hours with 48b, 84b, 264b and 624b (OP cycle and teething pbms)

3 fills and 20 hours with 840b, 1092b, 1380b (lumi related problems)

In the end the machine will tell....

Thanks a lot for your attention



Stable Beams time over the year

