## LHC INJECTION LOSSES AND NEED FOR SUNGLASSES?

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MPP, 9<sup>th</sup> October 2015

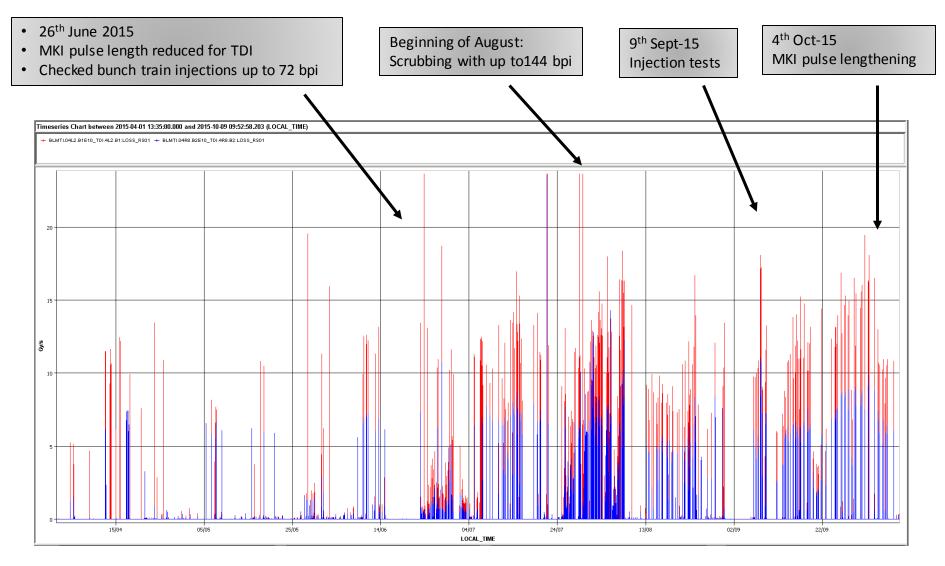
### Outline

- Types of injection losses
- Recap of longitudinal losses from LIBD on 29<sup>th</sup> Sept. 2015
- MKI pulse lengthening
- Transverse losses
- Doublets
- Mitigations of longitudinal losses
- Conclusions

## Types of injection losses

▼ RBA: carlier		Beam 1: 🧹		Beam 2: 💊			
	Injection	Beam 1			Injectio	n Beam 2	
015-09-09 20:5 1:09.085	: Beam inject	ed! BQMs: Injected 1	.44 bunches(589	bunches circulating	). BLM analysis w	as bad.	
EAM EXTRACTION INJECT	ION KICKER	BEAM LOSS	RF BUCKETS	INJ.OSCILLATIONS	TRANSFER LINE	RF PHASE	SCRAPING
015-09-09 20:5 1:09.10:	1: Beam losse	s above thresholds.		ппп		И	л
Monitor nam	e	Max loss	IQC appli	ed IQC r	ef Dump	threshold	Ratio to dump
BLMTI.04L2.B1E10_TDI.	4L2.B1	17.4173	2.3000	4.6		3.1680	75.18%
BLMTI.04L2.B1E20_TDI.	4L2.B1	7.2260	2.3150	4.63	2	3.1680	31.19%
BLMQI.03L2.B1E10_M	QXA	0.9616	0.2300	0.46		3.8459	25.00%
BLMQI.03L2.B2I20_M	QXA	0.6648	0.2300	0.46		3.8459	17.29%
BLMTI.04R2.B2E10_TCTP	V.4R2.B2	0.7489	0.4650	0.93		4.6336	16.16%
BLMEI.04L2.B1E10_M	BXA	0.3694	2.3150	4.63		2.3168	15.95%
BLMQI.02L2.B2I30_M	QXB	0.4807	0.2300	0.46		3.8459	12.50%
BLMTI.04R2.B1I10_TCL	IA.4R2	2.1574	2.3150	4.63	2	3.1680	9.31%
RI MOLOGI 2.R1F20 M Max plot Per slot Per BLM	OXA	0.33.95		<b>6</b>			8.83%
	TCDI she	wer	· · · · · · · · · · · · · · · · · · ·	es from satellit			· · · · · · · · · · · · · · · · · · ·
					mina J. I		
	160	180	200	220	240	260	280
0.001				220 monitors	240	260	280
0.001		3.62E-9		monitors	240	260 find:	280

## TDI losses since start of beam commissioning

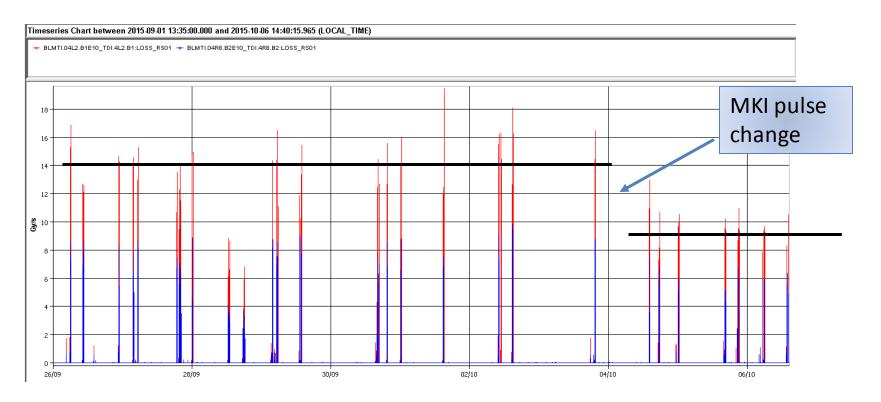


# Recap on longitudinal losses from LIBD, 29<sup>th</sup> Sept. 2015

- B1 144 b injections reached 30-60% of dump threshold on the TDI
- B2 around 10 25%
- Factor 25 higher compared to run 1
- Reasonable operational margin should not exceed ~20%
- B1/B2 difference due to different SPS extraction kicker rise times (1 vs 7 us)
- LHC injection gap cleaning successfully setup on Sept. 9<sup>th</sup>, 2015 reduces losses from a few percent to below a percent

### Extension of MKI pulse length

- Lengthening of MKI pulse length to allow for alternative LHC beam production types on 4<sup>th</sup> October 2015
- 100 ns longer flattop after batch end brings ~30% reduction of TDI losses for both beams (14 Gy/s → 9 Gy/s for B1 and 9 Gy/s → 4 Gy/s for B2)



#### Transverse losses

- Experience with 144 b train injections
- Usual 'hot' spots:
  - P2: Q8, Q5, MSI, Q6
  - P8: Q7, Q5, MSI
- In normal conditions stay below 0.5 1 Gy/s
- RS01 thresholds at injection at MQMLs around 7-11 Gy/s

#### • Q5

- Q5L2 threshold 13.9 Gy/s while Q5R8 threshold 0.83 Gy/s according to small filter reduction (~17)
- Loss signals show rather a factor 2 higher for Q5R8
- Q5R8 has IC+SF ?? Do we have this filter really in?
- Q5L2 has IC
- Expect increase for 288 b, but should still allow efficient operation
- Mitigations
  - Steering the lines
  - Scraping in the SPS

BEAM EXTRACTION	INJECTION KICKER	BEAM LOSS	RF BUCK
2015-08-03 19:09:03.1	01: Beam losses abov	e thresholds.	
Monito	name	Max loss	IQC
BLMQI.05R8.	32E10 MQY	0.3601	
BLMTI.06R7.B1E1	_TCLA.B6R7.B1	1.7176	
BLMTI.06R7.B2I1	D_TCP.B6R7.B2	1.0347	
BLMQI.07R8.E	2E10_MQM	0.6989	
BLMTI.06R7.B1E1	D_TCLA.A6R7.B1	0.4925	
BLMTI.06R7.B2I1	D_TCP.C6R7.82	0.4644	
BLMTI.04R8.B2E	10_TDI.4R8.B2	1.1244	
BLMTI.06R7.B2I10	_TCSG.A6R7.B2	0.3796	
BLMTI.05R7.B1E10	_TCSG.B5R7.B1	0.3244	
Max plot Per slot Per 0.35 0.3 0.35 0.35 0.25 0.55 0.5 0 0 0 0 0 0 0 0 0 0 0 0 0	BLM 22E10 MQY		

### Doublets

#### • 72 b, no scraping, 43% on Q5

	Injectio	n Beam 1		Injection Beam 2				
015-08-03 19:27:05.4	85: Beam injected! E	Frrors in filled RFbucket	s, injected 72 bunche	es. BLM analysis was	bad. Check BPM dat	a! Bad scraping.		
BEAM EXTRACTION	INJECTION KICKER	BEAM LOSS	RF BUCKETS	INJ.OSCILLATIONS	TRANSFER LINE	RF PHASE	SCRAPING	
)15-08-03 19:27:05.5	501: Beam losses ab	ove thresholds.				Л	N.	
Monito	r name	Max loss	IQC applie	d IQC ı	ef Dump	threshold	Ratio to dump	
BLMQI.05R8.	B2E10_MQY	0.3550	0.1150	2.76		0.8300	42.78%	
BLMTI.06R7.B1E1	IO_TCLA.B6R7.B1	1.7945	0.0	0.0	İ	9.2672	19.36%	
BLMTI.06R7.B2I1	IO_TCP.B6R7.B2	1.0971	0.0	0.0	İ	9.2672	11.84%	
BLMTI.06R7.B2I1	IO_TCP.C6R7.B2	0.8950	0.0	0.0	Ì	9.2672	9.66%	
BLMQI.07R8.	B2E10_MQM	0.6409	0.0383	0.92	İ	7.7149	8.31%	
BLMTI.04R8.B2	E10_TDI.4R8.B2	1.4250	0.1917	4.6	2	23.1680	6.15%	
BLMTI.06R7.B2I1	I0_TCP.D6R7.B2	0.5298	0.0	0.0		9.2672	5.72%	
BLMTI.06R7.B1E10_TCLA.A6R7.B1		0.5056	0.0	0.0		9.2672	5.46%	
BLMQI.03R8.	B2E10_MQXA	0.1834	0.0192		.46 3.8459		4.77%	
ax plot Per slot Pe 100 10 10 10 10 ++++++ 0.1 0.01 260	+ + + + + + + + + + + + + + + + + + +	* * **********************************	+ + + + + + + + + + + + + + + + + + + +					
				monitors				
ax larger than r	reference. The G	y factor was 3.62E	-9					
Get LS	A references Set refe	erences Read references	from a file Write refe	erences to file Slot: 0	Select slot	find: %MQY		
				Playba	ck Previous Event	Replay event No	ext Event Show data dum	

#### • 48 b, 7.2% scraping, only longitudinal losses

Injection Beam 1 015-08-03 19:33:39.085: Beam injected! Errors in filled RFbuckets, injected 48 bunche				Injection Beam 2				
2015-08-03 19:33:39	.085: Beam injected! I	Errors in filled RFbuckets,	injected 48 bunche	s. BLM analysis was I	bad. Check BPM da	ata!		
BEAM EXTRACTION	INJECTION KICKER	BEAM LOSS	RF BUCKETS	INJ.OSCILLATIONS	TRANSFER LINE	RF PHASE	SCRAPING	
2015-08-03 19:33:39	.101: Beam losses at	ove thresholds.						
Monit	or name	Max loss	IQC applie	d IQC r	ef Dum	p threshold	Ratio to dump	
BLMTI.04R2.B2B	E10_TCTPV.4R2.B2	0.7280	0.0388	0.93	ĺ	4.6336	15.71%	
BLMTI.04L2.B	1E10_TDI.4L2.B1	2.2093	0.1917	4.6		23.1680	9.54%	
BLMTI.04R2.E	31110_TCLIA.4R2	2.2008	0.1929	4.63		23.1680	9.50%	
BLMEI.04R2	2.B1110_MBRC	0.6233	0.0192	0.46		6.9504	8.97%	
BLMTI.04R2.B2	E10_TCTPH.4R2.B2	0.5106	0.0388	0.93		6.9504	7.35%	
BLMTI.04L2.B	1E20_TDI.4L2.B1	0.9564	0.1929	4.63		23.1680	4.13%	
BLMQI.04R	2.B1I10_MQY	0.0933	0.0192	0.46		2.3168	4.03%	
BLMQI.03L2	B1E10_MQXA	0.1338	0.0192	0.46		3.8459	3.48%	
BLMQI.05R	2.B1I10_MQM	0.0507	0.0192	0.46		2.3168	2.19%	
Max plot Per slot F	Per BLM		+ + + ++	+		+	+	
10 (5) (5) (5) (5) (5) (5) (5) (5) (5) (5)	·····	· · · · · · · · · · · · · · · · · · ·			•••••••		···· ·································	
0.001	D 160	180	200	220	240	Losses QI.06R2.B1I10_MQML, 0 4 260	.0266) <b>2</b> 80	
Cuesesefull The	Cu footor upo 3	625.0		nonitors				
	e Gy factor was 3 SA references Set ref	erences Read references fr	om a file Write refe	rences to file Slot: 0	Select slot	find: %MQY	%	
				Playba	ck Previous Event	Replay event N	ext Event Show data dump	

# Possible mitigations of longitudinal losses

#### Losses from LHC unbunched beam

- Injection gap cleaning in LHC
- Was set up on 9<sup>th</sup> Sept-15
- Reduces losses on TDI from a few percent to below a percent
- Marginal gain compared to satellite loss level

#### Losses from satellites injected into LHC

- LHC
  - Increase MKI pulse length
    - Can be done immediately within TDI limits
    - Inject satellites close to the batch in a clean way into LHC
    - Possibility to clean them before next injection with injection gap cleaning
    - Should make the losses on ALICE/LHCb BCMs cleaner
    - TDI limit until exchange
    - 100 ns longer pulse gave ~30% reduction of losses on TDI
  - Sunglasses
    - Blind out dump trigger during injection
    - Hides the problem
    - Does not improve for ALICE/LHCb BCMs
- SPS
  - B2 losses will be similar to B1 after SPS MKE4 modifications in the coming YETS
  - Ramp program optimisation can be done immediately, but not a huge gain expected
  - Transverse damper to clean the machine around the batch longer term

• PS

• Optimisation of bunch length and extraction kicker flattop at extraction – already fairly optimised

#### Conclusion

- In recent operation longitudinal losses were dominant
  - There are short term (tweak bunch rotation in PS, longitudinal settings during ramp re-capture in SPS, increase MKI pulse length) and longterm (transverse damper in SPS) mitigation possibilities
  - Sunglasses are less preferred to mitigate longitudinal losses
- Transverse losses mainly due to TCDI shower from the outside at acceptable levels with up to 144 b trains
- Expect an increase with 288 b, but should still stay within limits that allow efficient operation
  - In case we go above levels of 20% dump threshold have the means of steering the lines and scraping in the SPS
  - No need for activating sunglasses in 2015/16 for normal operation
  - This comes in a big part from adding filters at critical monitors
  - Have to check Q5 where the loss/threshold ratio is a factor ~30 different, filter?
- In case doublets are needed, transverse (emittance increase) and longitudinal losses (production in the SPS) will be increased
  - When we first tested them the only way of injecting into LHC was by increasing the BLM master threshold!
  - Can heavily scrape in the SPS (factor 2-3 more than usual) to define a clear transverse beam edge and reduce the TCDI shower or blind out the dump trigger at injection
- Should test the sunglass functionality at the startup in 2016
- Which blind out length?
  - As long that the running sums of the blinded BLMs reach 50% of the dump threshold