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IQC refactoring status

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Acknowledgements: C. Bracco, W. Bartmann, L. Drosdal (PhD writeup)



IQC projects



- □ The OP IQC software consists of two distinct projects:
 - The IQC analysis (https://gitlab.cern.ch/acc-co/pm/iqc/pm-iqc-user/-/tree/master/lhc-iqc-analysis),
 - Part of the IQC server,
 - The data analysis should be entirely in this project.
 - The IQC display application (<u>https://gitlab.cern.ch/acc-co/pm/iqc/pm-iqc-user/-/tree/master/lhc-app-iqc</u>).
 - The display application used in the CCC on live data or in playback mode (historic events).
- Goal of LS2 work: clean up the code and ensure there is enough internal OP knowledge to adapt it to Run 3 (and to future needs).
 - The code <u>really</u> needs some cleaning.
 - Despite a lot of testing on the Run 2 data, some commissioning time with beam will be required.

Inject	tion Beam 1				Injection Be	eam 2	
-08-04 18:27:34.289: Beam i	njected! BQMs:	Injected 144 bur	nches(2555 bur	ches circulating).	MKI analysis gave	warnings.	
AM EXTR. INJ. KICKER	BEAM LOSS	RF BUCKETS	INJ.OSCILL	. TRANSFER L.	RF PHASE	SCRAPING	DBLM
-08-04 18:27:34.305: Beam	osses are withi	in thresholds.		*			
Monitor name	IQC re	ef (%) IQC	applied (%)	IQC applied	Max loss	Dump	Loss/Dump
BLMTI.04R8.B2E10_TDI.4R8.B2	20.	.0	10.00	2.3168	1.7761	23.1680	7.67%
BLMQI.03R8.B2E10_MQXA	20.	.0	10.00	0.3846	0.2777	3.8459	7.22%
BLMTI.04R8.B2E20_TDI.4R8.B2	20.	.0	10.00	2.3168	1.4229	23.1680	6.14%
BLMAI.04R8.B2E20_MBXB	20.	.0	10.00	2.3168	1.1524	23.1680	4.97%
BLMAI.04R8.B2E10_MBXB	20.	.0	10.00	0.2317	0.0914	2.3168	3.95%
BLMQI.03R8.B1I20_MQXA	20.	.0	10.00	0.3846	0.1355	3.8459	3.52%
BLMQI.03R8.B2E20_MQXA	20.	.0	10.00	0.3846	0.1225	3.8459	3.19%
BLMQI.07R8.B2E10_MQM	20.	.0	10.00	0.7715	0.1845	7.7149	2.39%
BLMTI.04L8.B2I10_TCLIA.4L8	20.	.0	10.00	2.3168	0.4796	23.1680	2.07%
BLMQI.02R8.B1I30_MQXB	20.	.0	10.00	0.3846	0.0760	3.8459	1.98%
BLMQI.02R8.B1I23_MQXB	20.	.0	10.00	0.3846	0.0731	3.8459	1.90%
BLMQI.02R8.B1I22_MQXB	20.	.0	10.00	0.3846	0.0596	3.8459	1.55%
2 ← Beam 2 2 2 280	+ + + + + + + + + + + + + + + + + + +	320	340	360	****		
280	300	320	340 Monitor In		380	4	00
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		Get LSA	references	et references			







- General code cleaning (in progress):
 - Proper user of loggers to improve diagnostics,
 - Fixing bugs,
 - A major one was present in the playback GUI (introduced with the diamond BLM module).
 - Moving step by step from ,FORTRAN/C in a JAVA shell' to proper object-oriented JAVA code,
 - Overall poor code structure, improved the worst cases.
 - Re-structuring of LSA IQC settings,
 - Moving hardcoded parameters to new LSA IQC settings,
- Trying to understand what the code actually does...





- For each module the testing on selected events was consolidate.
 - Analysis modules write local files,
 - Local files can be loaded into single module UI components (eg. BLMs or BPMs only).
 - Work ongoing.
- In the git path of the IQC analysis, file **INFO.md** is progressively filled with documentation.
 - Can be viewed in a web browser.

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LSA IQC settings



- Many LSA settings for IQC based on virtual FESA classes and devices.
 - Removed obsolete settings,
 - Added new settings for SPS scrapper and diamond BLMs,
 - Made critical all settings that ,should be critical'.
 - Some settings were only partly critical (for example for B1 and not B2 etc),
 - Some looked like work intiated but never completed.
- Reorganized the LSA IQC systems.
 - All system names = ,IQC xxxx'.
 - They are now all next to each other in the settings management app list.

<u><u></u></u>	LSA Applicatio	ons s	Suite (v 13.9.0)
ile <u>Applications</u> <u>S</u> earch			
🚸 🖲 LHC 🗕 🕒 BP 🗶 🛷 🏇 🐻	🧿 🖒 jwenning 🔻		
	Jwenning		
Settings Management × Device Groups Co	onfiguration $ imes$		
Source			
Beam Process	Parameter Group	-	Parameter Type
DISCRETE_LHCRING_ADTDSPU_BW_STANDAF	IQC BLM REF	_	IQC.BPM.THRESHOLDS/BadBunchAcce
_NON_MULTIPLEXED_LHC			IQC.BPM.THRESHOLDS/BadPpmAccept
ADT-TEST_V1	IQC BPM REF		IQC.BPM.THRESHOLDS/MaxHor
BetaStarLevelling-SQUEEZE-6.5TeV-ATS-30	IQC BPM TRANSFER		
BetaStarLevelling-SQUEEZE-6.5TeV-ATS-30	IQC GENERAL		IQC.BPM.THRESHOLDS/MaxVer
BetaStarLevelling-SQUEEZE-6.5TeV-ATS-30 =	IQC MKI ABORTGAP		IQC.BPM.THRESHOLDS/P2PHor
BetaStarLevelling-SQUEEZE-6.5TeV-ATS-30	IQC MKI REF		IQC.BPM.THRESHOLDS/P2PVer
CollimatorBP-Parking	IQC PHASEERR REF		IQC.BPM.THRESHOLDS/RmsHor
DISCRETE_LHCRING_ADTBPOS_HIGH			IQC.BPM.THRESHOLDS/RmsVer
DISCRETE_LHCRING_ADTBPOS_NOMINAL			IQC.BPM.TL.REF/TrajectoryBpmRef
DISCRETE_LHCRING_ADTBPOS_PILOT			IQC.DiamondBLM/Settings
DISCRETE_LHCRING_ADTDSPU_BW_ENHANCE			IQC.MKI.ABORTGAP/AbortGapBegin
DISCRETE_LHCRING_ADT_FLATTOP			IQC.MKI.ABORTGAP/AbortGapEnd
DISCRETE_LHCRING_ADT_INJECTION			
DISCRETE_LHCRING_INJ_KICKER_EXTEND			IQC.MKI/MaxDelay
DISCRETE_LHCRING_INJ_KICKER_INTRM			IQC.MKI/MaxFalltime
DISCRETE_LHCRING_INJ_KICKER_V1			IQC.MKI/MaxLength
DummyBPforOFB_HalfIntegerTune_V1			IQC.MKI/MaxMAX
InjectionProtection_BP_2014@0_[START]			IQC.MKI/MaxRisetime
InjectionTrim_V1			IQC.MKI/MaxStrength
LHC-SIS-REF-INJ-6.37TeV-ATS-Ion-2018_\			IQC.MKI/MinDelay
LHC-SIS-REF-PHYSICS-6.37TeV-50cm-240			IQC.MKI/MinFalltime
LHC-SIS-REF-PHYSICS-6.5TeV-30cm-120s-			IOC.MKI/MinLength
LHC-SIS-REF-RAMP-SQUEEZE-6.37TeV-ATS			
LHC-SIS-REF-RAMP_PPLP-SQUEEZE-6.5TeV-			IQC.MKI/MinMAX
LHC-SIS-Ref-INJ-6.5TeV-ATS-1m-2017_V1			IQC.MKI/MinRisetime
LHC-SIS-Ref-INJ-DESQUEEZE-19m-2016			IQC.MKI/MinStrength
LHC-SIS-Ref-PHYSICS-6.5TeV-19-24m-20			IQC.PHASERR.ANALYSIS/InjectionThre
LHC-SIS-Ref-RAMP-DESQUEEZE-19m-2010			IQC.SCRAPER/Settings
PC_INTERLOCK_REF-PHYSICS-6.37TeV-50cm			LHC_BLM/LossType
PC_INTERLOCK_REF-PHYSICS-6.37TeV-50cm			LHC_BLM/ReferencePercentage
PC_INTERLOCK_REF-PHYSICS-6.37TeV-50cm			,
PC_INTERLOCK_REF-PHYSICS-6.37TeV-50cm			
PC_INTERLOCK_REF-PHYSICS-6.5TeV-19-24			
PC_INTERLOCK_REF-PHYSICS-6.5TeV-19-24			
PC_INTERLOCK_REF-PHYSICS-6.5TeV-30cm PC_INTERLOCK_REF-QCHANGE-6.37TeV-Ior			
	Select All		Select All
		1	
Filter	IQC		Filter



Playback



IQC/MKI/MKI RES B2

- The playback event selection menu was actually broken since 2018 when the diamond BLMs were added the link between dBLMs and playback problems (reported by TE-ABT) was not recognised.
- Important code changes in playback logic and UI to make it more user friendly and the code more readable.
 - UI repaired, _
 - Panel does not close automatically when data is loaded.
 - Easier to browse through multiple events.
 - Inspection of raw and result IQC data by clicking on the table entries (for debugging).

System

Source

/ersion

Qualifier

Encoding

Event stam

Analysis flag:

PMData

- 🗂 Parameters

Arrays 1D

int - attenuation

🗋 short - attnNomina

🗋 short - attnPilot

Short - attnintermediate

lass

RF_BUCKET_IQC

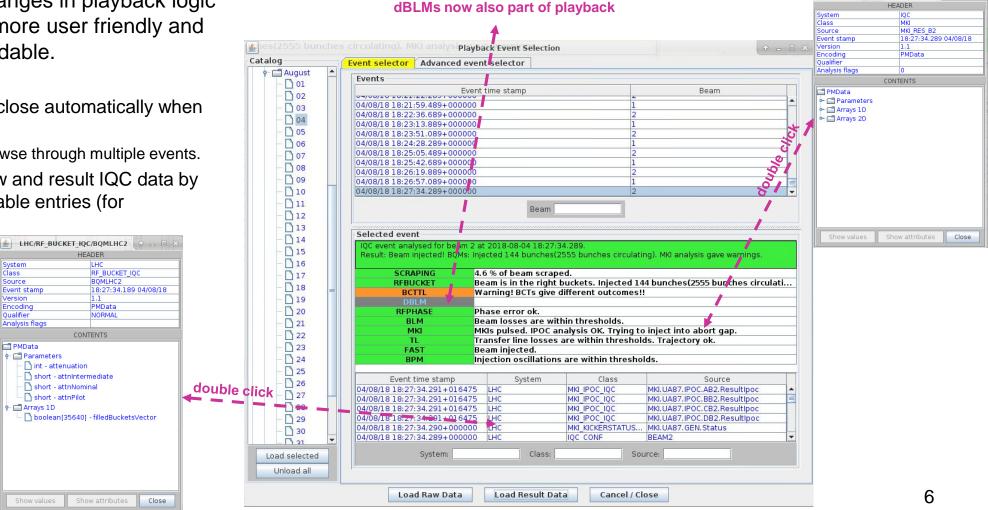
BOMLHC2

PMData

NORMAL

CONTENTS

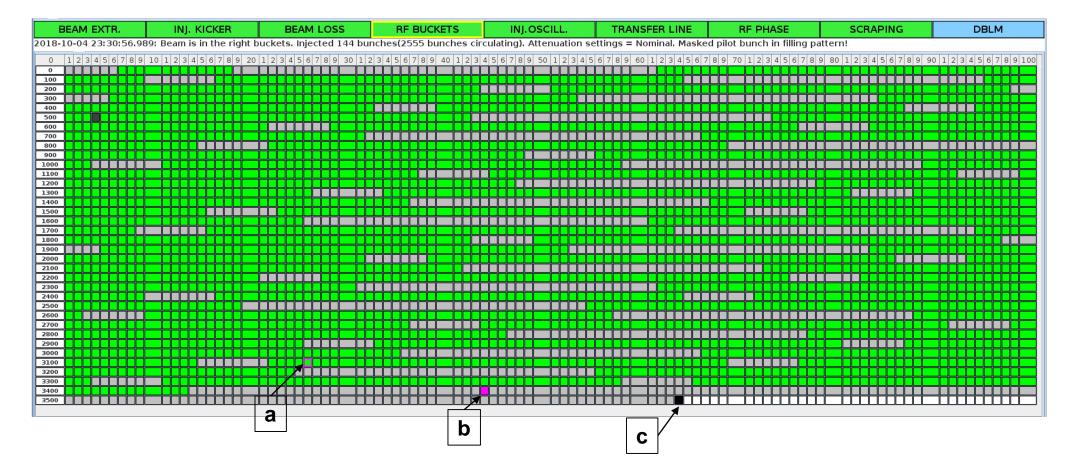
boolean[35640] - filledBucketsVector







- □ Analysis code messy restructuring to be continued.
- □ The display was updated as it was incomprehensible to me (to identify a bunch).
 - Each row has now 100 bunch slots, the decade (10, 20, 30 etc) columns made wider to ease navigation.
 - Added markers for: last allowed bucket for injection request (a), start of abort gap (b), end of abort gap/machine (c).
 - Last allowed bucket part of MKI analysis, value was wrong for most of Run 2...







- □ Analysis code messy restructuring to be continued.
 - Fixed / re-activated the check for injection into the abort gap. IQC only catches it once it happened, but still good to sound an alarm !
 - Some GUI font optimization

BEAM EXTR.		NJ. KICKER		BEAM LO		RF BUC		INJ.OS	CILL.	TRAI	NSFER LINE	1	RF PHASE		SCRAPIN	G	DBLM	
18-10-04 23:30:5																		
device name	d MIN	delay [us]	d MAX	I MIN	length [us]	I MAX	s MIN	strength [kA]		m MIN	max1[kA]	m MAX	r MIN	rise time [us]		f MIN	fall time [us]	fМ
MKI.UA87.IPOC.AB2 MKI.UA87.IPOC.BB2	79.900	79.984	80.000	4.455	4.613	4.755	4.790	4.835	4.890	4.810	4.851	4.910	0.640	0.664	0.700	1.375	1.404	1.4
MKI.UA87.IPOC.BB2	79.910	79.977 79.948	80.010 80.000	4.565 4.495	4.725 4.653	4.865 4.795	4.760 4.825	4.808 4.848	4.860 4.925	4.780 4.850	4.827 4.865	4.880 4.950	0.640	0.663	0.700	1.375 1.375	1.397 1.392	1.4
MKI.UA87.IPOC.DB2	79,920	79.940	80.020	4,455	4.605	4.755	4.825	4.900	4.925	4.850	4.916	4.950	0.640	0.668	0.700	1.375	1.401	1.4
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o	0	Abort	Gap limits		31262	- -		time	e [us]		,	Next	bucket	check : 32	551	>		





- □ The error message for injecting into abort gap was there, but the module status was good !
- The status will be bad again in such a situation in Run 3: we will have to add the update of the IQC settings in the procedure to update abort gap keeper limits...

- 1 02	Event	time stamp		Beam	-
	04/08/18 18:21:59.489+000000		1		-
- 🗋 03	04/08/18 18:22:36.689+000000		2		-
- 🗋 04	04/08/18 18:23:13.889+000000		1		-11
- 05	04/08/18 18:23:51.089+000000		2		
- 106	04/08/18 18:24:28.289+000000		1		-
- 07	04/08/18 18:25:05.489+000000		2		
	04/08/18 18:25:42.689+000000		ī		
- 🗋 08	04/08/18 18:26:19.889+000000		2		
- 🗋 09	04/08/18 18:26:57.089+000000		1		
- 10	04/08/18 18:27:34.289+000000		2		-
- [] 11 - [] 12		Beam			
- 🗋 13	Selected event				
- 🗋 14	IQC event analysed for beam 2 at	+ 2010 00 04 10,27.24	200		
- 15	Result: Beam injected! BQMs: Inje	t 2018-08-04 18:27:34.	289. 55 hunchos circulatir	ad) MKI apalveis dava warpings	
- 16	Result: Beam injected: boms: inje	ected 144 bunches(25.	55 buricries circulati	ig). Micianalysis gave warnings.	
	and a second	5 av. (1			
D	SCRADING				
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- 🗋 17 - 🗋 18 📃	RFBUCKET Be	eam is in the right bu	ickets. Injected 14	4 bunches(2555 bunches circulati	i
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- 🗋 18 📃	RFBUCKET BE BCTTL W DBLM	eam is in the right bu	ickets. Injected 14		i
- ☐ 18	RFBUCKET BE BCTTL W DBLM RFPHASE PH	eam is in the right bu 'arning! BCTs give dif nase error ok.	ickets. Injected 14 ferent outcomes!!		i
- ☐ 18 = - ☐ 19 - ☐ 20 - ☐ 21	RFBUCKET BE BCTTL W DBLM RFPHASE PF BLM BE	eam is in the right bu 'arning! BCTs give dif nase error ok. eam losses are withi	ickets. Injected 14 ferent outcomes!! n thresholds.		i
- □ 18 = - □ 19 - □ 20 - □ 21 - □ 22	RFBUCKET Be BCTTL W DBLM RFPHASE PF BLM Be MKI MI	eam is in the right bu arning! BCTs give dif nase error ok. eam losses are withi KIs pulsed. IPOC ana	ickets. Injected 14 ferent outcomes!! n thresholds. Ivsis CK. Trving to	iniect into abort gap.	i
- ☐ 18 = - ☐ 19 - ☐ 20 - ☐ 21	RFBUCKET BE BCTTL W DBLM RFPHASE PF BLM BE MKI MI TL Tr	eam is in the right bu arning! BCTs give dif nase error ok. eam losses are withi KIs pulsed. IPOC ana ansfer line losses ar	ickets. Injected 14 ferent outcomes!! n thresholds. Ivsis CK. Trving to	iniect into abort gap.	i
- 0 18 ≡ - 0 19 - 0 20 - 0 21 - 0 22 - 0 23	RFBUCKET BE BCTTL W DBLM RFPHASE PH BLM BE MKI MI TL Tr FAST BE	eam is in the right bu 'arning! BCTs give dif nase error ok. eam losses are withi Kls pulsed. IPOC an ansfer line losses ar eam injected.	ickets. Injected 14 ferent outcomes!! n thresholds. lysis CK. Trying to e within threshold	niject into abort gap. ds. Traiectory ok	i
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- 18 ≡ - 19 - 20 - 21 - 22 - 23 - 24 - 25 - 26	RFBUCKET Be BCTTL W DBLM W RFPHASE PH BLM Be MKI MI TL Tr FAST Be BPM In Event time stamp	eam is in the right bu arning! BCTs give dif nase error ok. eam losses are within KIs pulsed. IPOC ana ansfer line losses ar eam injected. jection oscillations a System	ickets. Injected 14 ferent outcomes!! In thresholds. Iysis CK. Trying to re within threshol Ire within threshol	inject into abort gap. ds. Traiectory ok lds. Source	I
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SPS scraping



- Simple module and UI, overall OK except: the delay settings to identify H and V scrapping were hardcoded and unfortunately incorrect (for 2018).
 - Fine delay to be set with respect to scraper timing to identify the two scraper actions (H and V).
 - Hardcoded delay is now a setting in LSA to ease tuning.

BEAM EXTR.	INJ. KICKER	BEAM LOSS	RF BUCKETS	INJ.OSCILL.	TRANSFER L	RF PHASE	SCRAPING	DBLM	\backslash
8-08-04 18:2	7:34.289: 4.6 %	of beam scraped							
Device name	Status	Pos H [mm]	Pos V [mm]	Scr timing [ms]	H/V timing [ms]	Scr H %	Scr V %	Scr Tot %	$\mathbf{\lambda}$
BSHV.11760	IDLE - Stand By	-8.30	2.85	5000	5000	0.0	0.0	0.0	
3SHV.11772	Scraping H and V	-2.90	4.80	14700	14700	4.4	0.2	4.6	H scraping
					N				H scraping → V scraping
									21600-
600-									
100									1550-
400-									
1200				- Th	is timing w	vill he disn	laved in		1500
					is annig n		nayoa m		
000-						IIA Aires in			
.000					column	,H/V timin	gʻ		14600 14800 15000 15200 15400
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				(inc	column correct here.				14600 14800 15000 15200 15400
800-				(inc					14600 14800 15000 15200 15400 Timestamps
800-				(inc					In this case scraping H & V both around 2.2%, bu
800 - 600				(inc					14600 14800 15000 15200 15400 Timestamps
800 600 400				(inc					In this case scraping H & V both around 2.2%, bu old analysis claimed ~ only H scraping as the
800 - 600				(inc					In this case scraping H & V both around 2.2%, bu
800 - 600 - 400 - 200 -	2000	4000	6000	8000	correct here.			16000	In this case scraping H & V both around 2.2%, bu old analysis claimed ~ only H scraping as the timing for analysis was incorrect.
600	2000	4000	6000		correct here.	: old analys	sis result)	16000	In this case scraping H & V both around 2.2%, bu old analysis claimed ~ only H scraping as the

4.4

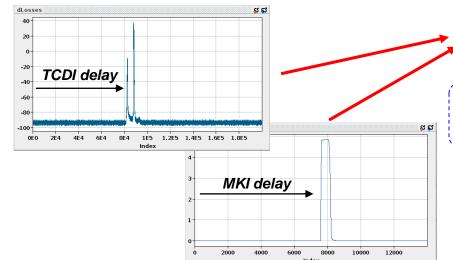
0.2

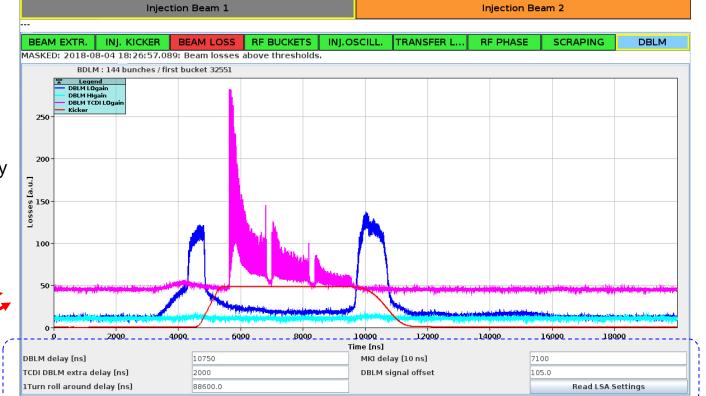


Diamond BLMs



- Diamond analysis only consists in re-aligning the dBLM and MKI data to overlap in the display.
 - This simple ,analysis' is actually performed in the GUI and not in the analysis which is not ideal...
- The raw data must be corrected for acquisition delays wrt triggers (beam dependent):
 - Fixed delay for MKI,
 - Fixed delay + first bucket *2.5 ns for dBLMs,
 - Extra offset for TCDI dBLMs,
 - Trigger ,roll-around' delay (when trigger jumps back by one turn) – missing so far, explained why some late injection did not show dBLM data.
- □ The delays were hardcoded, moved to LSA.





,analysis' settings (from LSA)

(can be edited in the GUI for tuning)



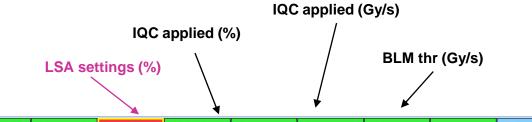




- □ The BLM analysis cleaning was already initiated in 2018, continued in LS2.
 - Code overhaul to ease changes,
 - Cleaning of the obsolete LSA settings, remaining:
 - Fraction of BLM threshold to use for IQC,
 - Flag to define if IQC threshold scales with # of bunches.
 - Completion of LSA settings,
 - Preparation for new BLMs (IR7 for B1, IR6 for B1+2).
 - LSA settings ready,
 - Changes to concentrator with CO.

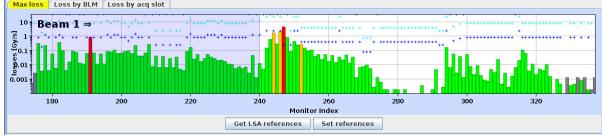
GUI changes.

- Table only contains BLMs used for IQC,
- More table columns to clarify what threshold is used,
- Some improvements in plots.
- Work in progress.



BEAM EXTR.	INJ. KICKER	BEAM LOSS	RF BUCKETS	INJ.OSCILL.	TRANSFER L	RF PHASE	SCRAPING	DBLM
2018-08-04 18:2	6:57.105: Beam	losses above thr	esholds.					

Monitor name	IQC ref (%)	IQC applied (%)	IQC applied	Max loss	Dump	Loss/Dump
BLMBI.08L2.B0T10_MBB-MBA_07L2	20.0	10.00	0.7715	0.8048	7.7149	10.43%
BLMTI.04L2.B1E20_TDI.4L2.B1	20.0	10.00	2.3168	2.2607	23.1680	9.76%
BLMTI.04L2.B1E10_TDI.4L2.B1	20.0	10.00	2.3168	1.7117	23.1680	7.39%
BLMQI.03L2.B1E10_MQXA	20.0	10.00	0.3846	0.2525	3.8459	6.57%
BLMQI.03L2.B2I20_MQXA	20.0	10.00	0.3846	0.1488	3.8459	3.87%
BLMBI.09L2.B0T10_MBB-MBA_08L2	20.0	10.00	0.7715	0.2959	7.7149	3.84%
BLMAI.04L2.B1E10_MBXA	20.0	10.00	0.2317	0.0828	2.3168	3.57%
BLMEI.06L2.B1E10_MSIB	20.0	10.00	0.8340	0.2677	8.3405	3.21%
BLMQI.08L2.B1E30_MQML	20.0	10.00	1.1584	0.3542	11.5840	3.06%
BLMQI.02L2.B2I30_MQXB	20.0	10.00	0.3846	0.1072	3.8459	2.79%
BLMQI.03L2.B1E20_MQXA	20.0	10.00	0.3846	0.0944	3.8459	2.45%
BLMQI.06L2.B1E10 MQML	20.0	10.00	0.4634	0.0921	4.6336	1.99%



J. Wenninger

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-2.5

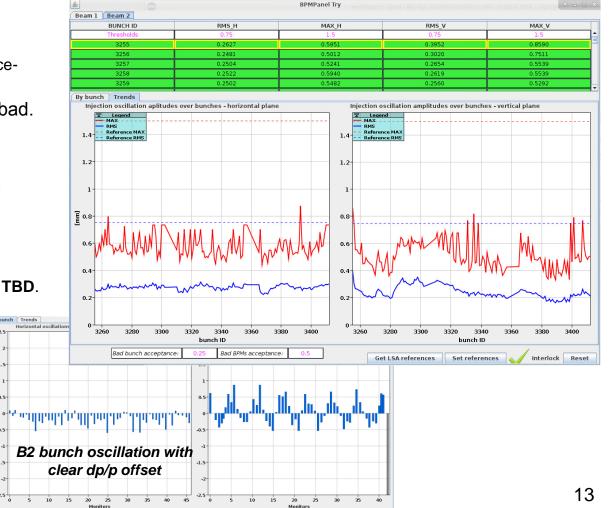


Analysis code refactoring into smaller classes –a nice

Improvements:

- Logic for H & V planes separated and simplified.
 - Before a bad H status would disqualify the V plane (and vice-• versa).
- Added the REMOVED OP' status bit to tag a BPM as bad.
 - Improved the rms/max results, eliminated some outliers. •
- On the plate:
 - Oscillation fits with hardcoded phase advances (!!), and without normalizing the positions with $\sqrt{\beta}$.
 - · Fits incorrect, and not used at all. Will be removed.
 - Fit the dp/p offset of injected beam. —
 - Requires LSA optics and improved oscillation fits etc. TBD. •
 - Reuse fits implemented in YASP. _
 - Could set a warning on dp/p offset.



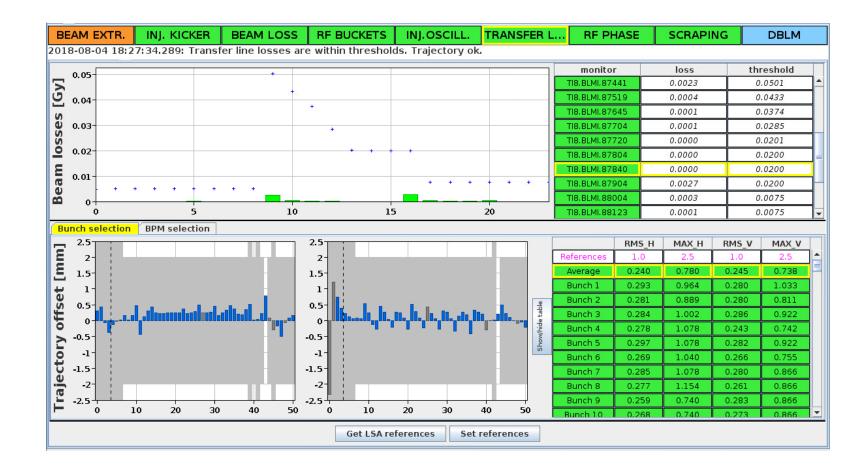




TL BLMs and BPMs



- A lot of code cleaning in the TL BPM part, BLM part ok as trivial (just get data and display).
 - Removed TL oscialltion fits with hardcoded phase advances which were anyhow not used.



5/11/2020



- □ IQC code analyzed, repaired and refactored.
 - A complete re-design could be worthwhile, not possible during LS2. But current consolidation will help in the future.
 Documentation setup within the SW project.
 - IQC settings cleaned and improved.
- GUI work in progress, playback UI fixed.
 - Propose to remove quasi-empty BCT UI \rightarrow replace by an overview UI.

Injection Beam 1	Injection Beam 2	Injection Beam 1	Injection Beam 2
BEAM EXTS. INJ. KICKER BEAM LOSS RF BUCKETS INLO 18-08-04 18-20:57.00% Beam was extracted from the SPS 2 devices w he extracted intensity was 1528.447 e+10	ore used in the analysis.	BEAM EXTR. NJ. NICKIR TEAM EXTR. NJ. OSCILL. TEAM EXTR. 2016-06-01 18:2057.00% Beam Was extracted from the SPS. 2 devices were used in the SPS	re analysis. ting). BLM analysis was bad. 144 bunches(2123 bunches circulati evices were used in the analysis. olds. Trajectory ok. nolds.

- Proposal to add a determination of dp/p at injection from the trajectory to complete the future RF determination from tomography.
- □ Changes of FESA classes (version, FESA2 →3 etc) to be carefully checked to maintain as much as possible backward compatibility.
- Currently the IQC code is no longer releasable because BE-CO removed the RDA2 libraries unilaterally and the PM/IQC framework still links the RDA2 libraries.