

LHC INJECTION

W. Bartmann, M.J. Barnes, C. Bracco, F. Burkart, E. Carlier,
B. Goddard, V. Kain, R. Steerenberg, L. Stoel, F. Velotti, C. Wiesner, C. Xu

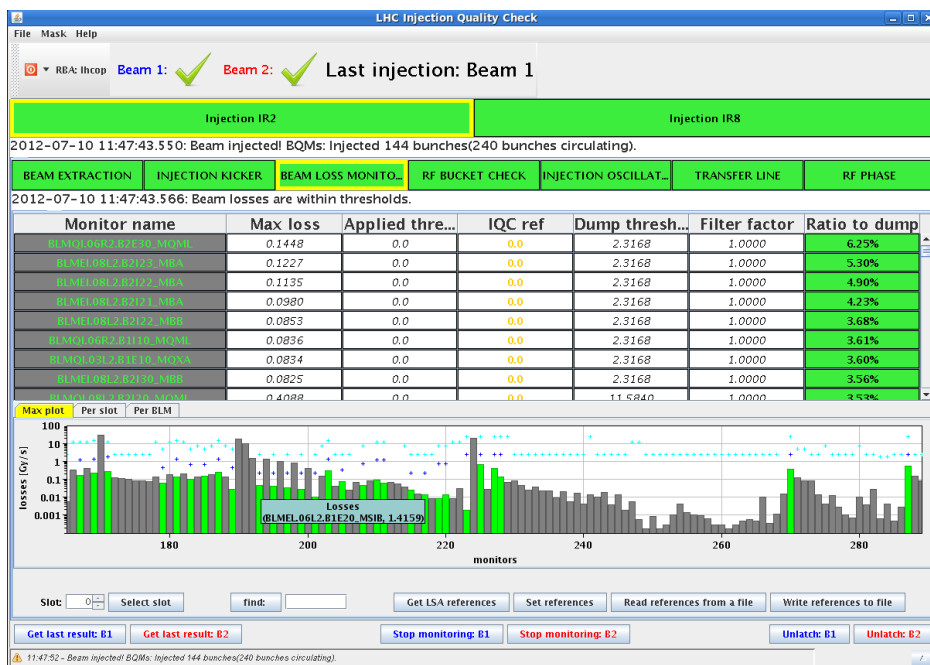
7th Evian workshop 13th - 15th Dec. 2016

Outline

- Injection loss analysis
 - Run1 vs Run2
 - Transverse vs. longitudinal
 - Protons vs. ions
 - Diamonds
 - New IQC thresholds
- Injection process – how to improve?
- Suggested batch spacings for MKP/MKI for 2017

Injection losses from run 1 to run 2

Run 1: 144 bpi, 25 ns, 2012

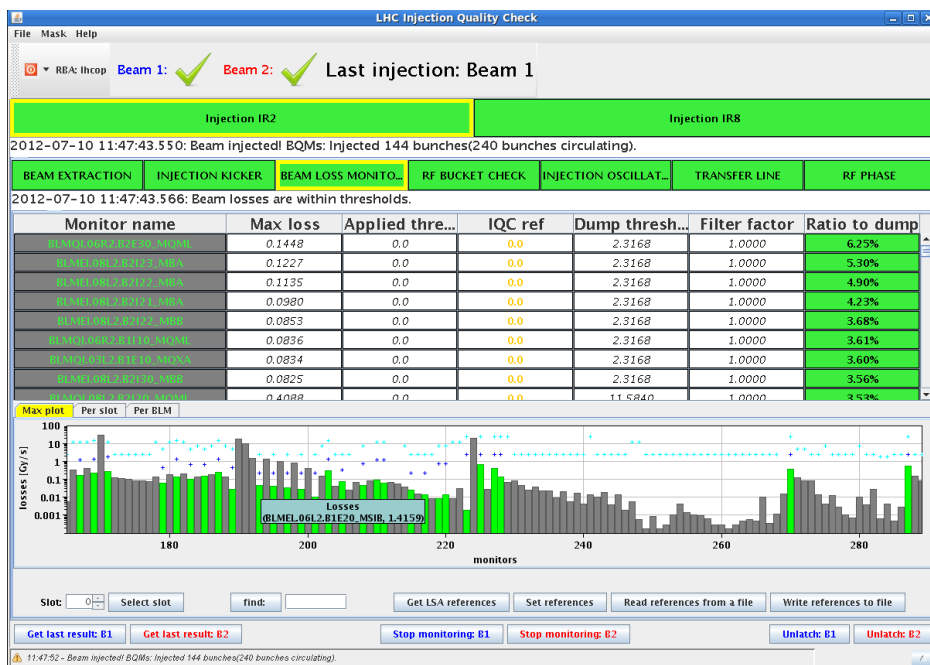


Dominated by TL shower

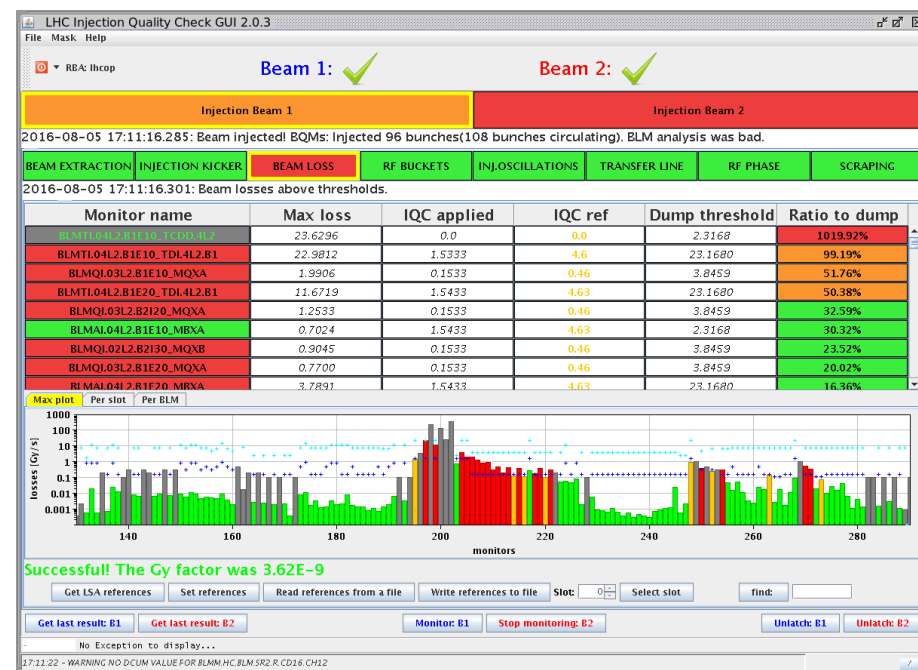
Injection losses from run 1 to run 2

Run 1: 144 bpi, 25 ns, 2012

Run 2, 96 bunches

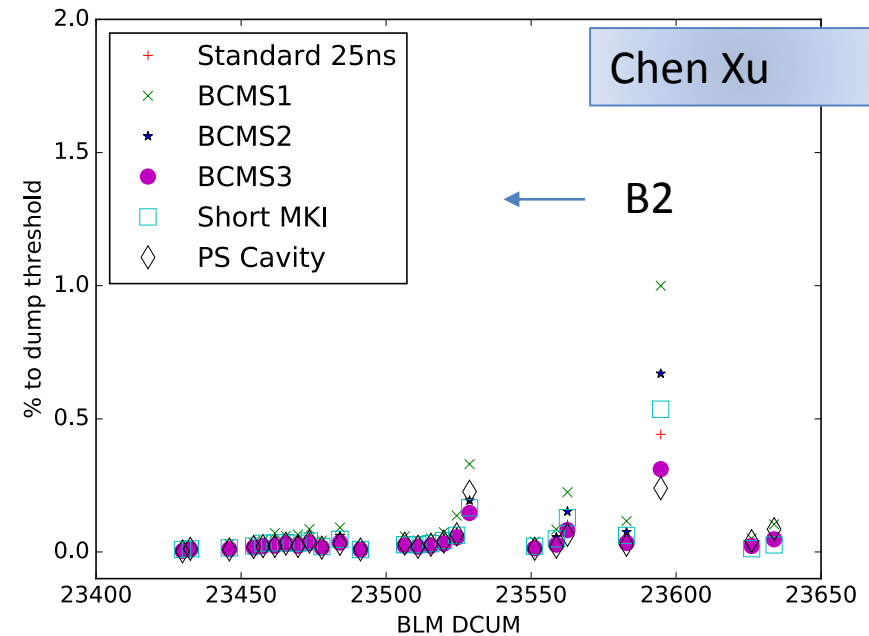
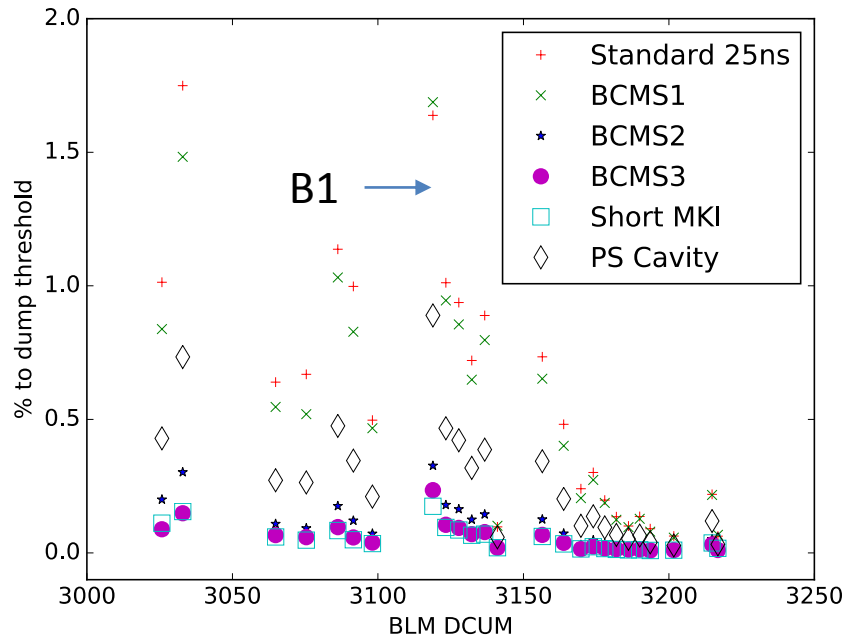


Dominated by TL shower



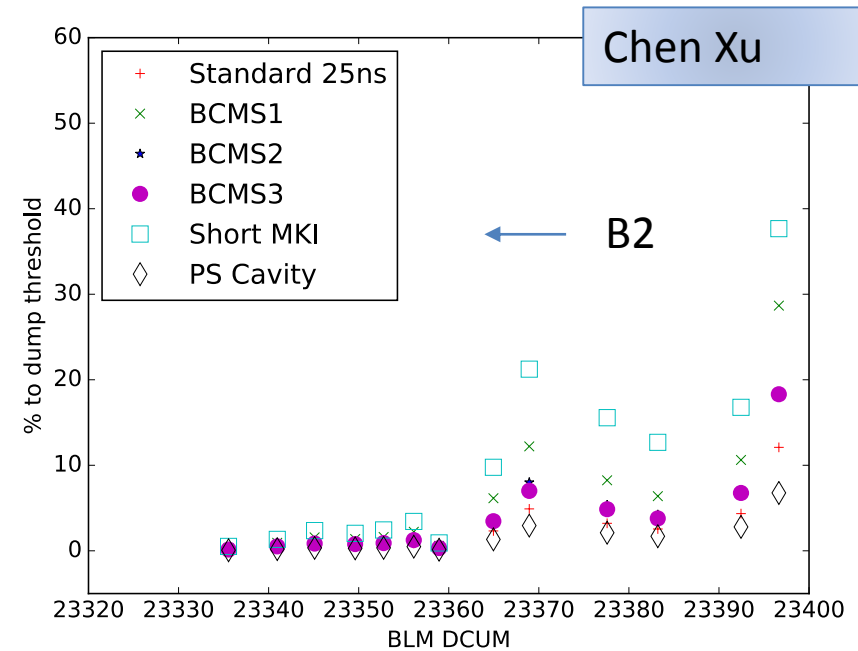
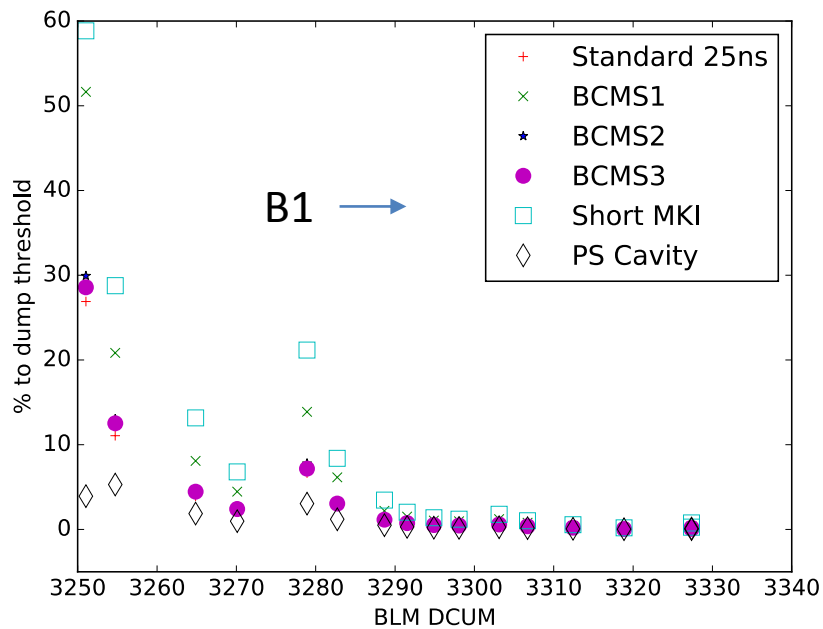
Dominated by longitudinal losses

Transverse inj. losses (until Sept) – Median



- Transverse losses within 2% of dump threshold
- Better line stability and straightforward steering in Run 2 wrt Run 1
- B1/B2 differences seen due to different TCDI to BLM geometries
- **No issue foreseen with 288 b**

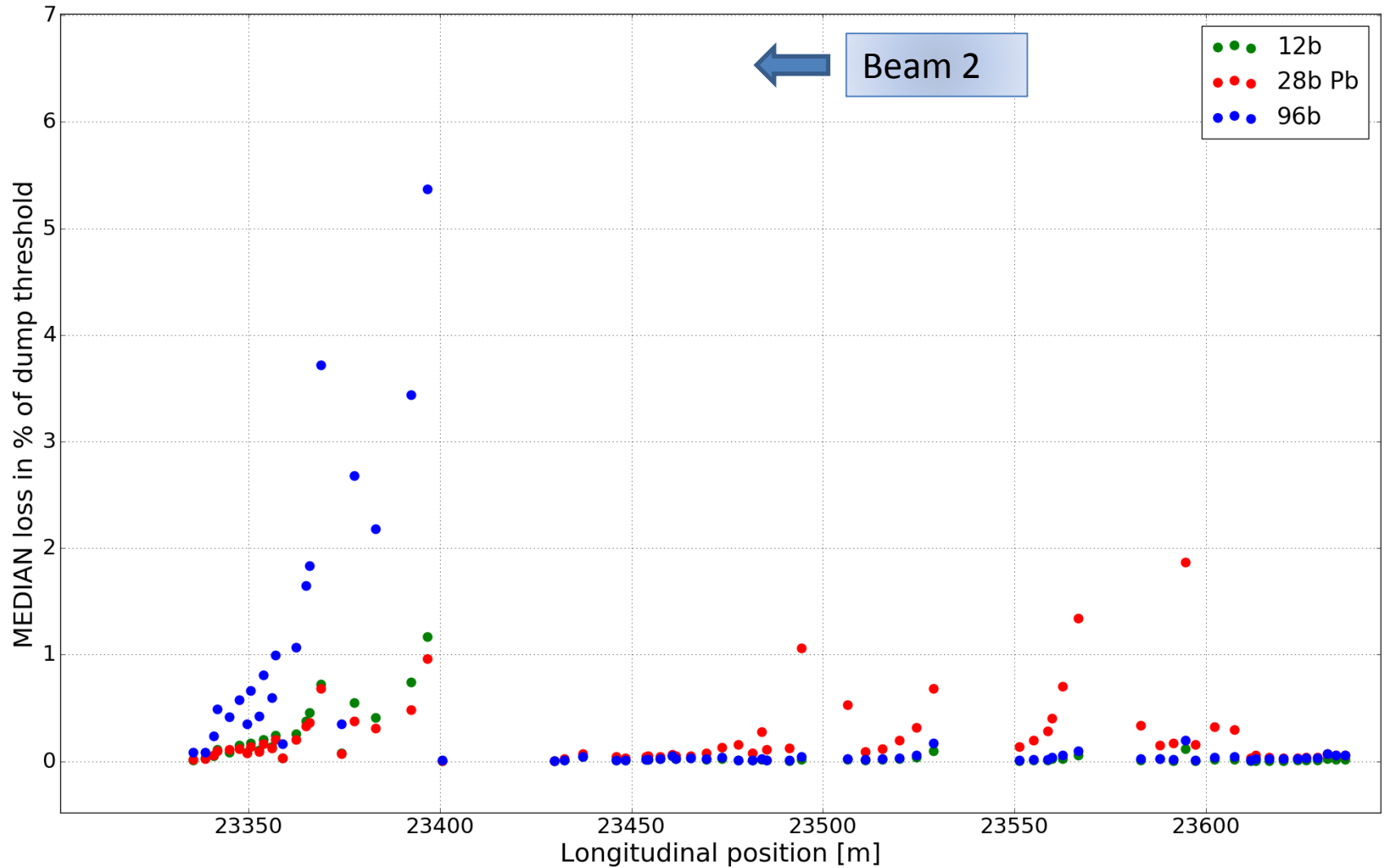
Longitudinal inj. losses (until Sept) – Median



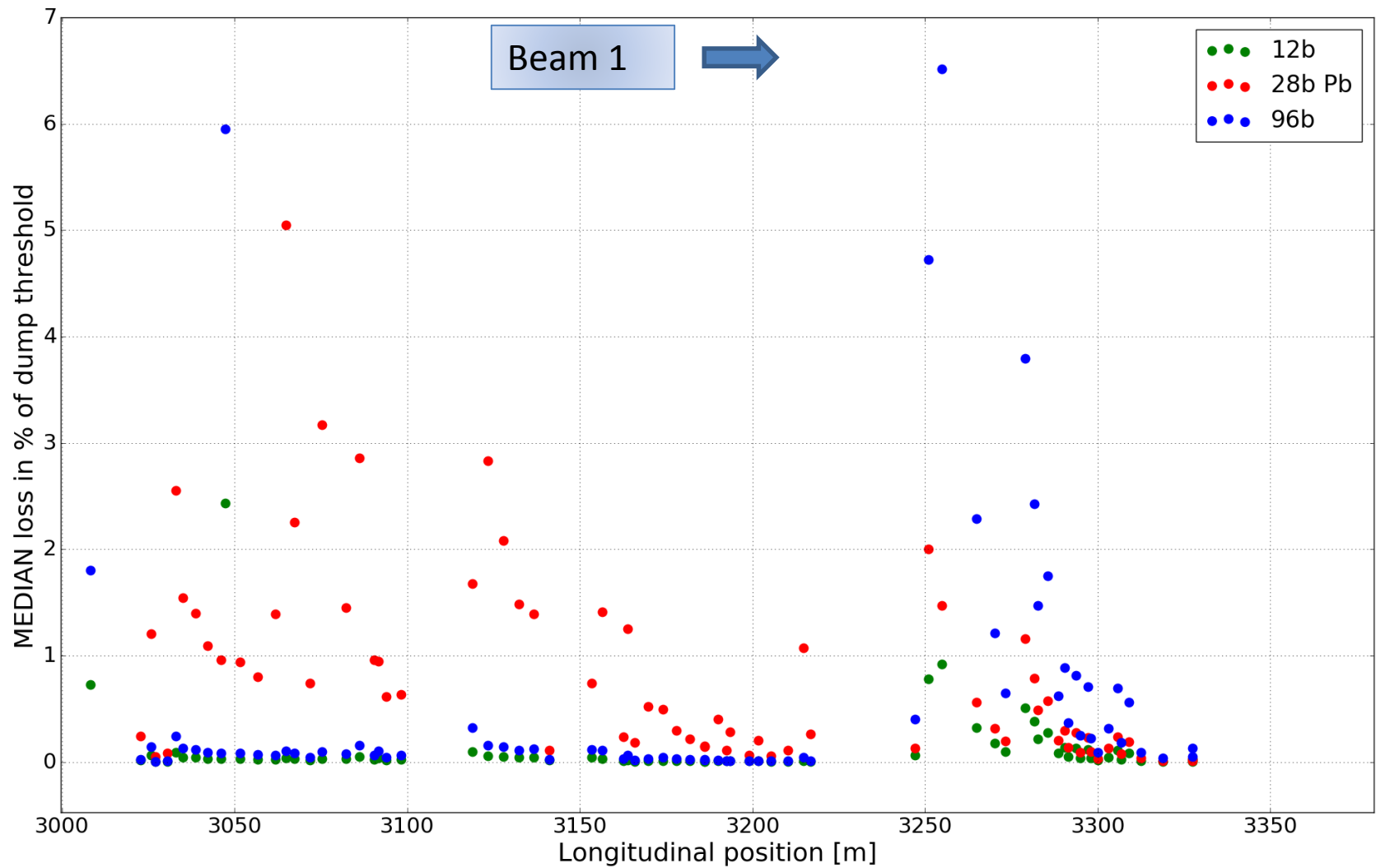
Chen Xu

- Longitudinal losses mainly dependent on beam type/configuration
- Reduction of factor 10 when switching on 2nd 40 MHz cavity at PS extraction

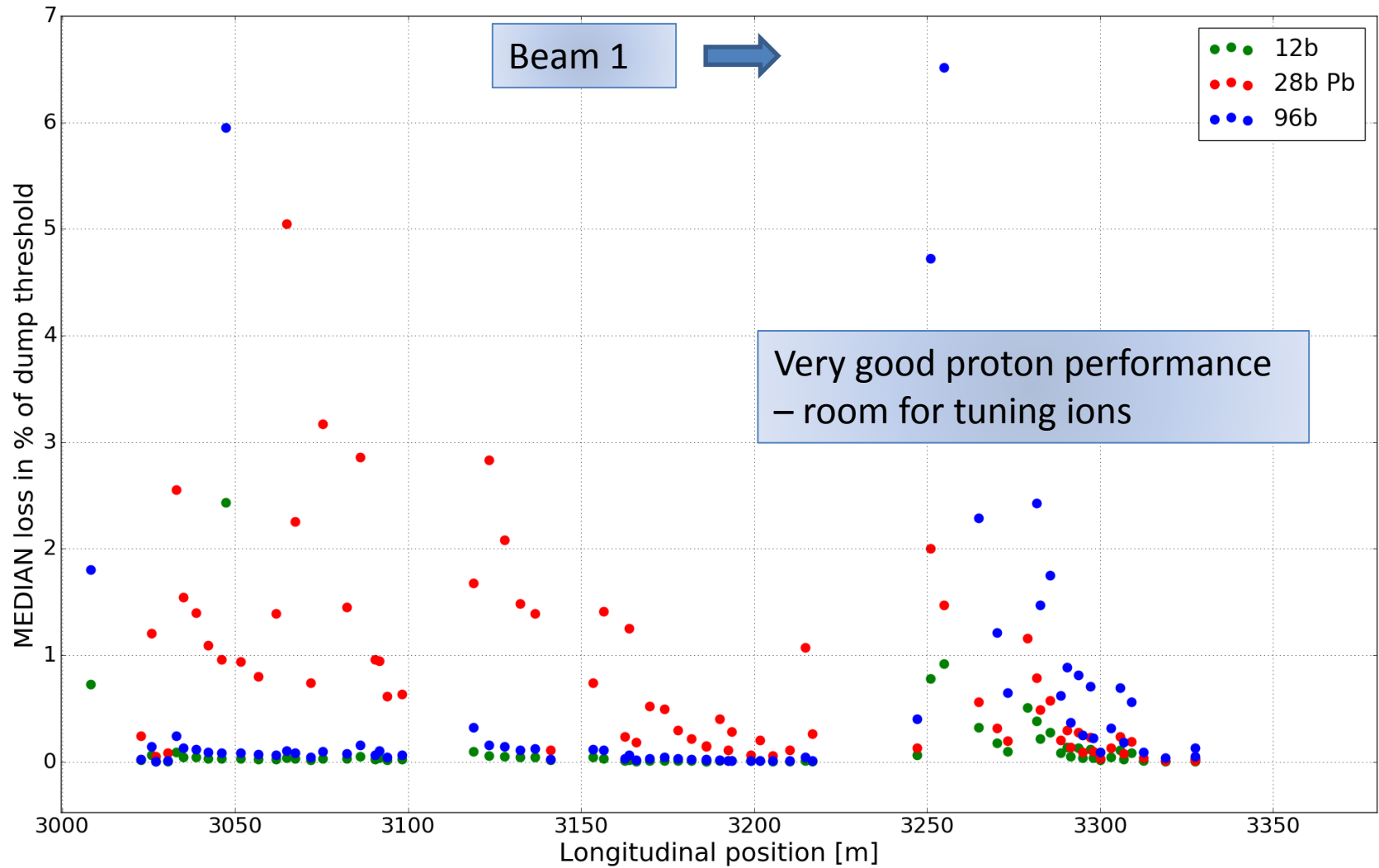
Sept – Dec 2016



Sept – Dec 2016



Sept – Dec 2016



Injection losses in operation

19:09:59 - -----
19:09:59 - Warning on: BLMTI.04L2.B1E20_TDI.4L2.B1, integration time: 320 us, losses = 7.010515E00, threshold = 2.316800E01, ratio = 30%
19:09:59 - Warning on: BLMTI.04L2.B1E20_TDI.4L2.B1, integration time: 80 us, losses = 7.063027E00, threshold = 2.316800E01, ratio = 30%
19:09:59 - Warning on: BLMTI.04L2.B1E20_TDI.4L2.B1, integration time: 40 us, losses = 7.075742E00, threshold = 2.316800E01, ratio = 31%
19:09:59 - Warning on: BLMTI.04L2.B1E10_TDI.4L2.B1, integration time: 2560 us, losses = 1.065407E01, threshold = 2.316800E01, ratio = 46%
19:09:59 - Warning on: BLMTI.04L2.B1E10_TDI.4L2.B1, integration time: 640 us, losses = 1.342958E01, threshold = 2.316800E01, ratio = 58%
19:09:59 - Warning on: BLMTI.04L2.B1E10_TDI.4L2.B1, integration time: 320 us, losses = 1.390080E01, threshold = 2.316800E01, ratio = 60%
19:09:59 - Warning on: BLMTI.04L2.B1E10_TDI.4L2.B1, integration time: 80 us, losses = 1.416791E01, threshold = 2.316800E01, ratio = 61%
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Injection losses in operation - IQC

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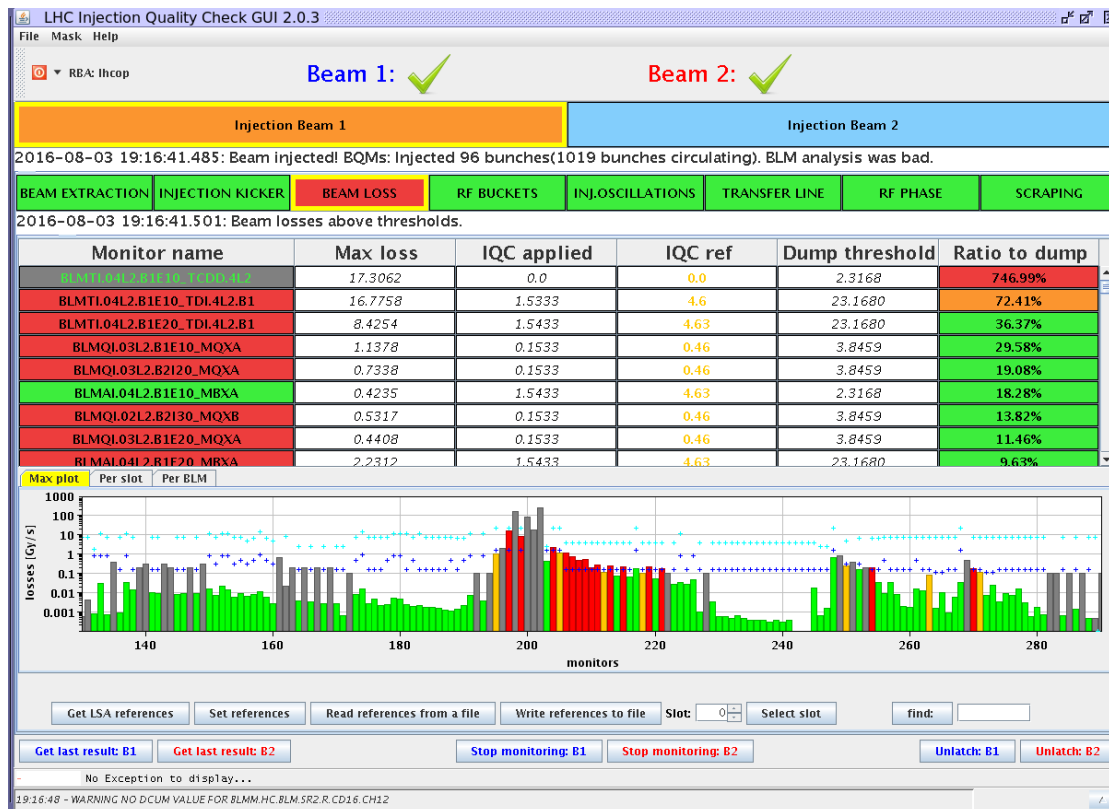
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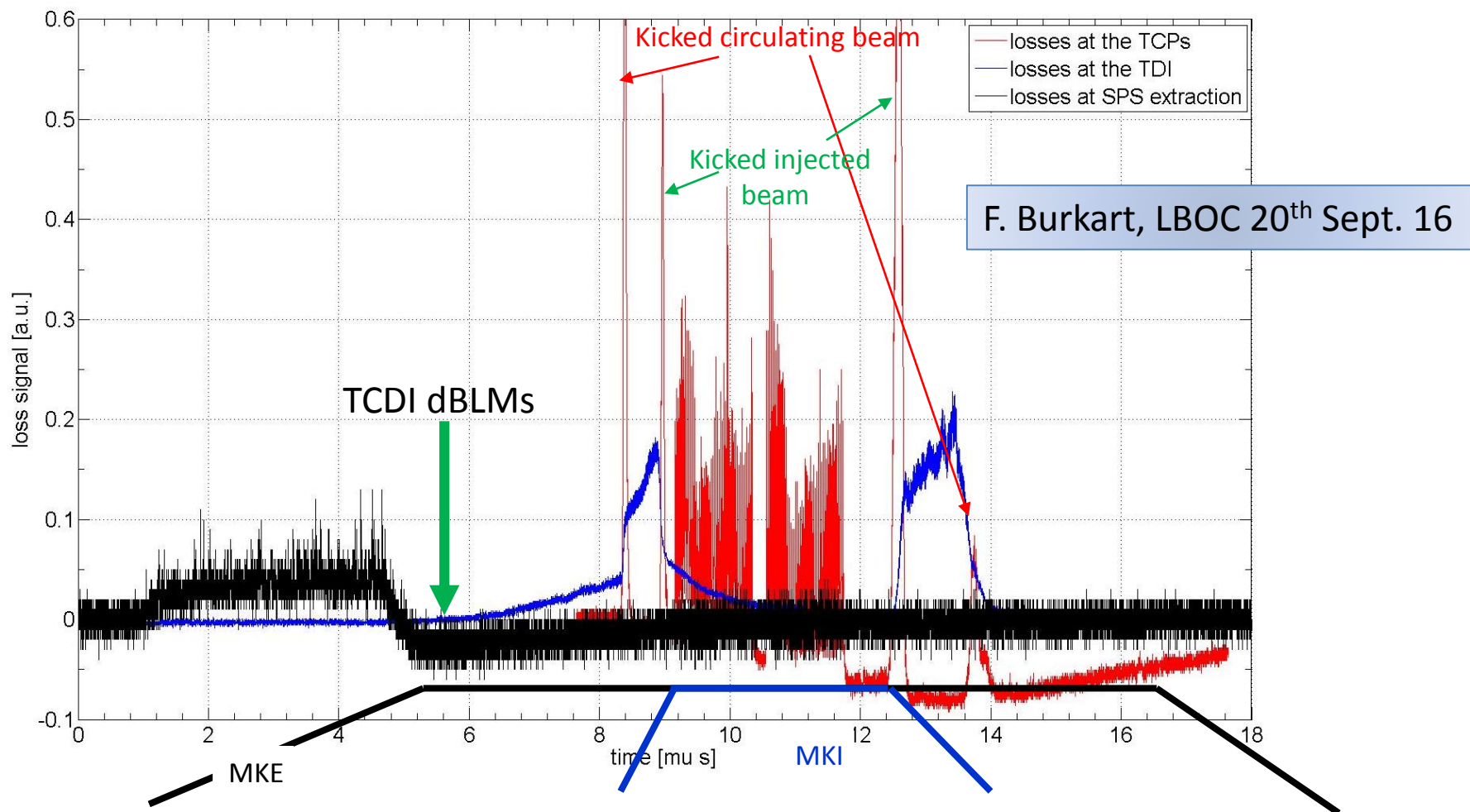
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Make IQC more useful for operation - thresholds

- Simplify internal thresholds which define the colour code
- Transverse losses scale relatively well with injected intensity
 - Ok as it is, enough margin for 288 b and 4.5 sig TCDI settings
- Longitudinal losses are much more dependent on beam type (Standard vs BCMS, 12b) and equipment configuration (PS cavities for bunch rotation, MKI flattop length) than number of bunches injected
 - TDI:
 - Loss < 30% - green
 - Loss between 30% and 50% - orange
 - Loss > 50% - red
 - MQX:
 - Loss < 10% - green
 - Loss between 10% and 25% - orange
 - Loss > 25% - red

Make IQC more useful for operation – include diamonds



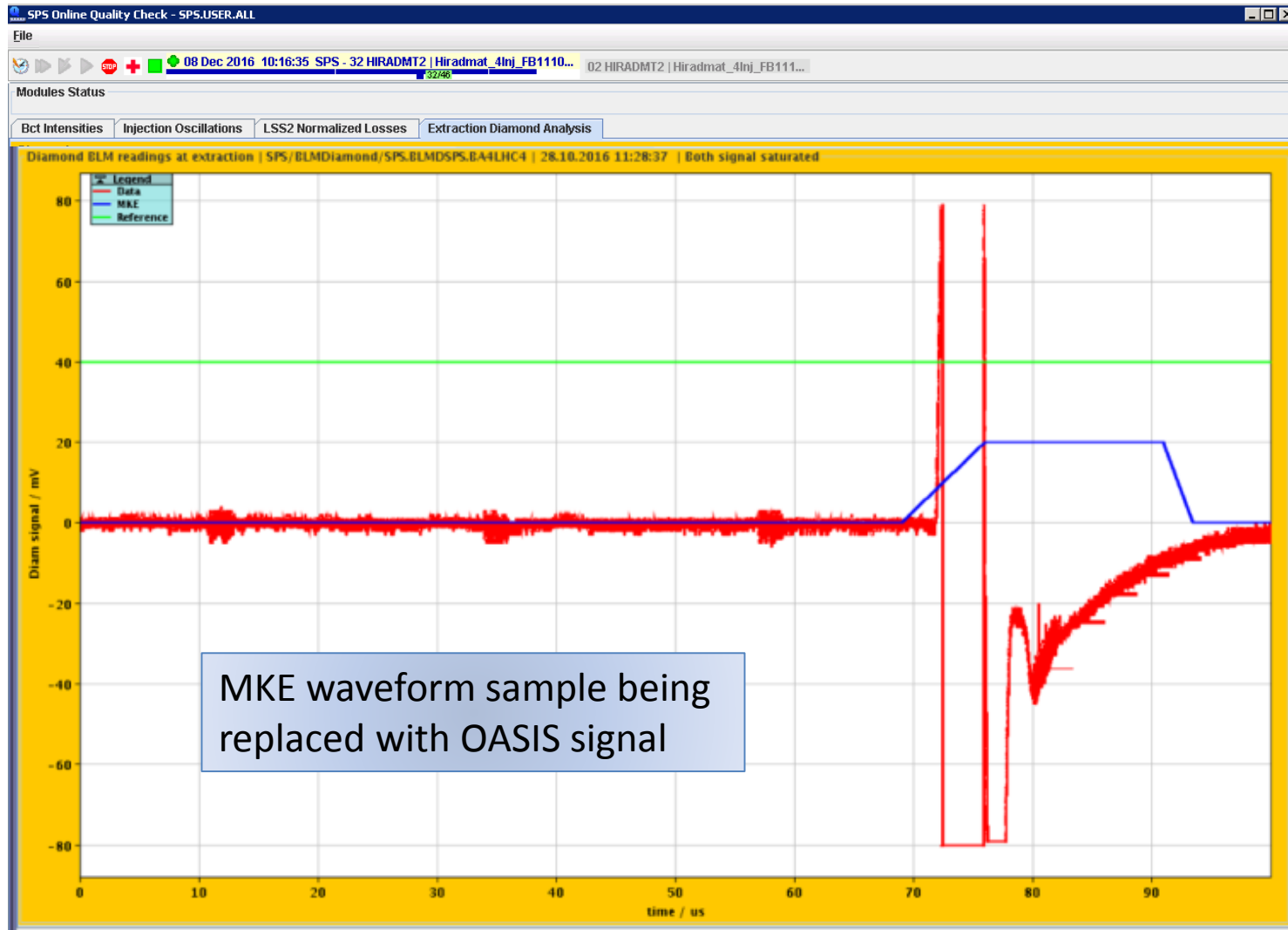
Overview dBLMs around LHC

F. Burkart, LBOC 20th Sept. 16

	Position	Responsible HW	Contact	Read-out	Data stored
SPS extraction	TPSG	BE-BI-BL	TE-ABT	Scope + FESA	PM
Transfer lines	TCDIh	BE-BI-BL	TE-ABT	Scope + FESA	PM
LHC injection	TDI	BE-BI-BL	TE-ABT	Scope + FESA	PM
Collimation	TCP	BE-BI-BL	BE-BI (data taking), TE-ABT (@ injection) and TE-MPE (@ flat top)	ROSY + Scope	BE-BI server, EOS
Crystal collimation	Crystal	BE-BI-BL	Collimation	ROSY	MD only
Abort gap population	BGI	BE-BI-BL	TE-MPE	ROSY	-
LHC extraction	TCDQ	BE-BI-BL	TE-MPE	Scope	locally

* Many more: LINAC4, PS extraction, HiRadMat, SPS slow extraction TT20, etc....

Diamonds in SPS online monitoring app

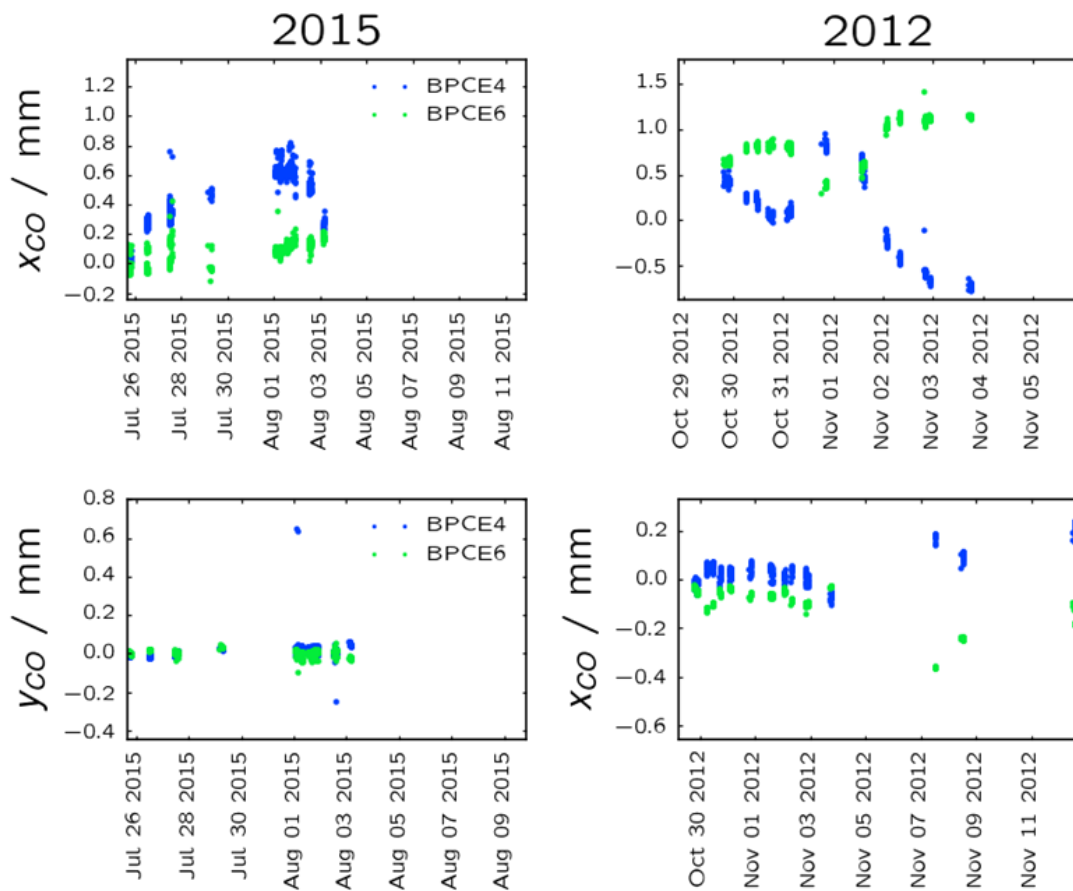


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- **Injection process – how to improve?**
- Suggested batch spacings for MKP/MKI for 2017

Injection process

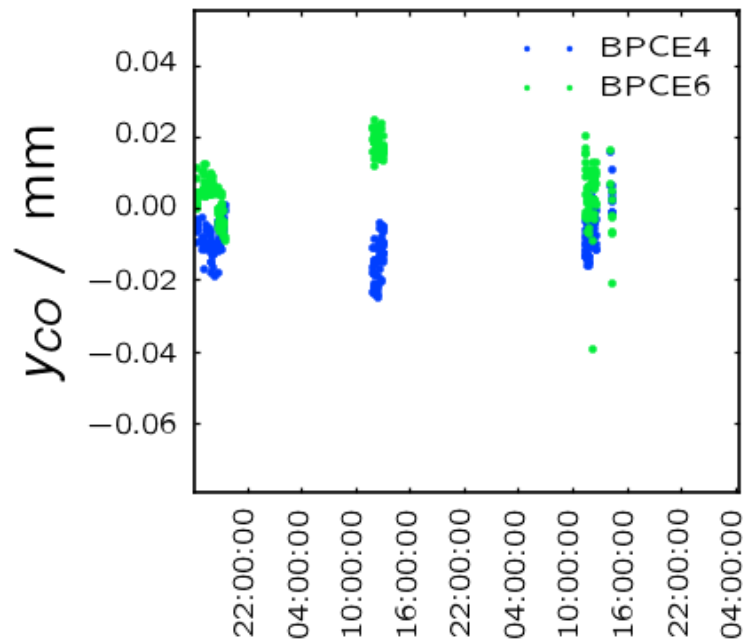
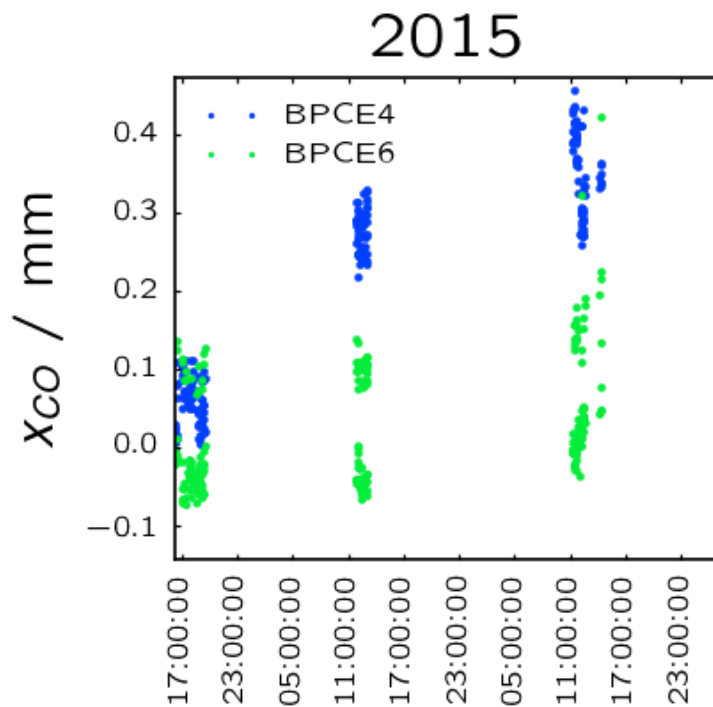
- Not clearly distinct in availability chart but usually a big contributor of idle time
- Related to stability of injectors?



Injection process

- Not clearly distinct in availability chart but usually a big contributor of idle time
- Related to stability of injectors?

Injectors well stable over several hours!



Injection process

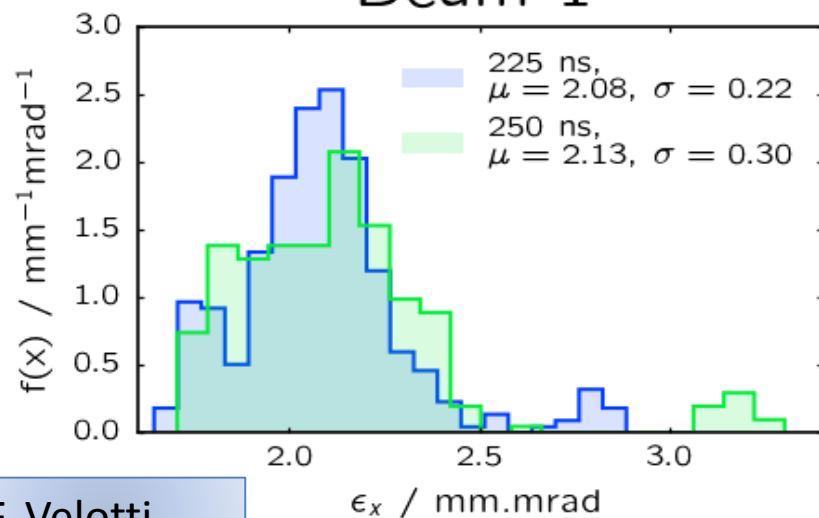
- Aim to minimize waiting time at LHC injection for beam
- Ideal would be automatic preparation of LHC beam in injectors as soon as LHC starts ramp down
- Could fall back to prepared supercycle for LHC filling
 - Some disadvantages like maintenance of several supercycle templates
- Should not impact other physics program like for dedicated LHC filling cycle
- Impact on MD program in injectors only if LHC is not ready to take beam as planned
- Daily tuning of LHC beams in injectors is very valuable and lead to impressive beam quality at SPS extraction – increased monitoring of beam quality is ongoing, e.g. SPS online monitoring tool with injection oscillations, intensity, diamond loss data and also foreseen for the PS complex → should help for automatization of LHC beam preparation

Outline

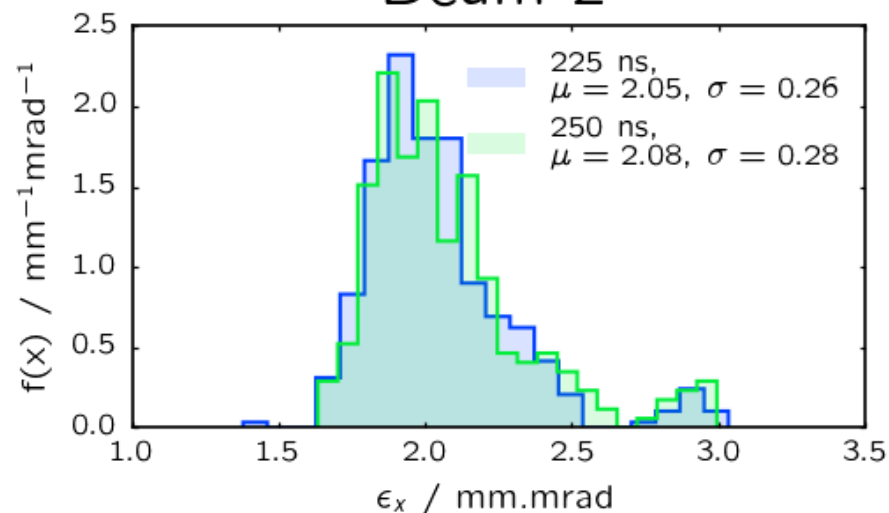
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- **Suggested batch spacings for MKP/MKI for 2017**

MKP: 250 ns vs 225 ns batch spacing

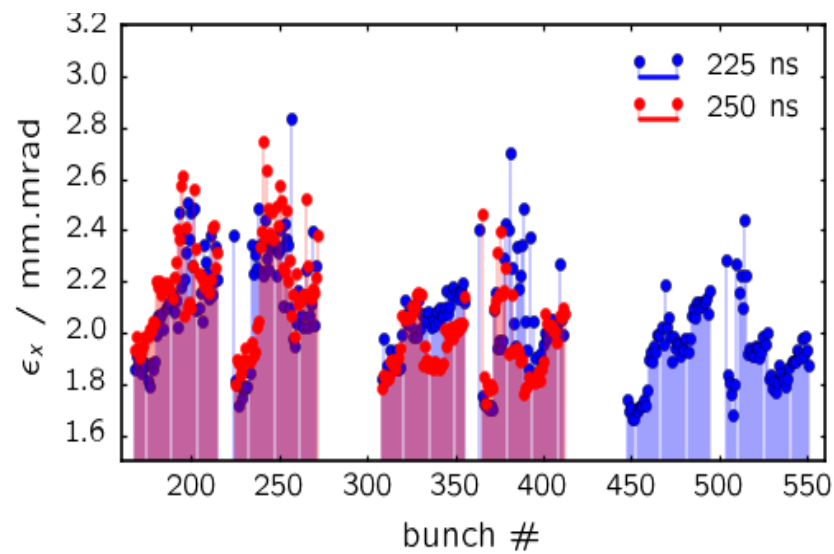
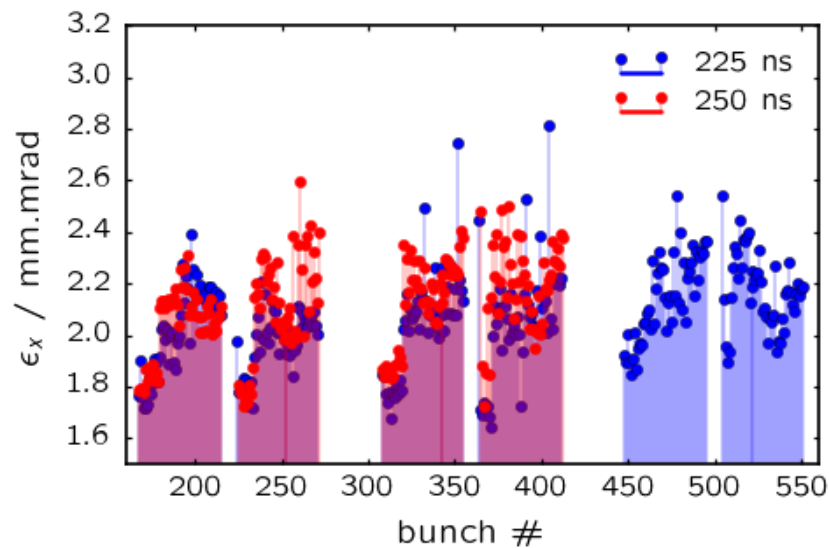
Beam 1



Beam 2



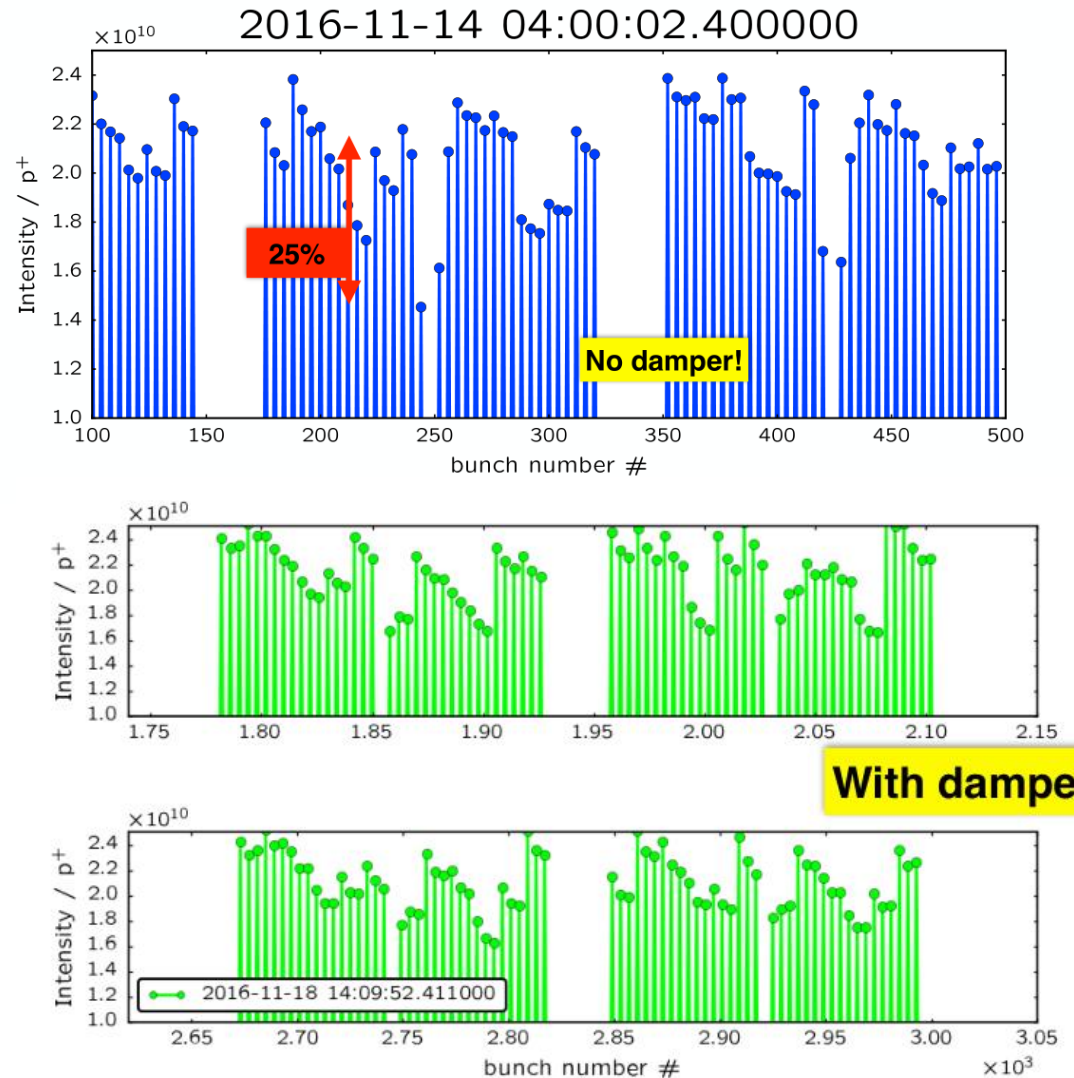
F. Velotti



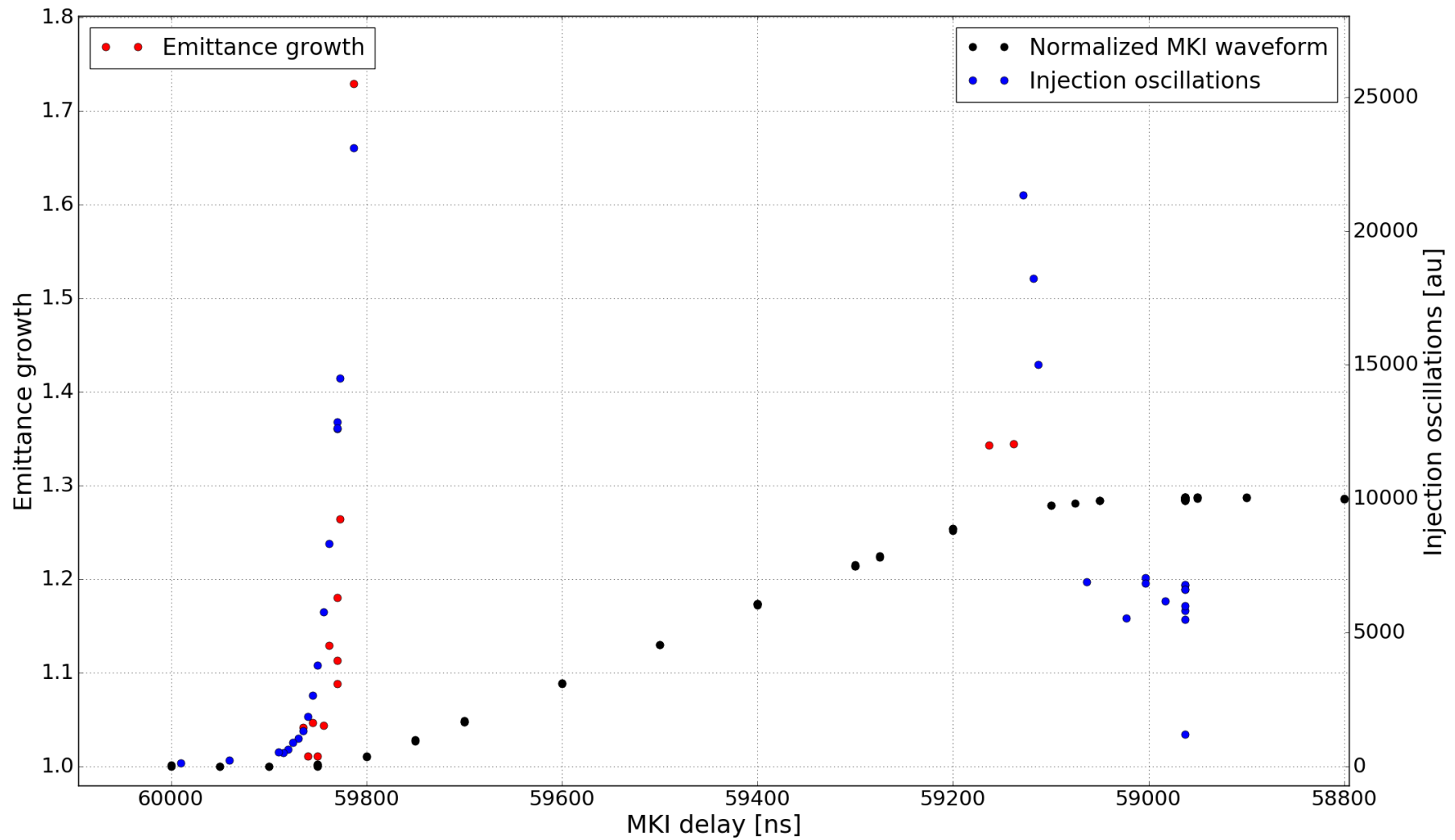
200 ns batch spacing SPS?

F. Velotti

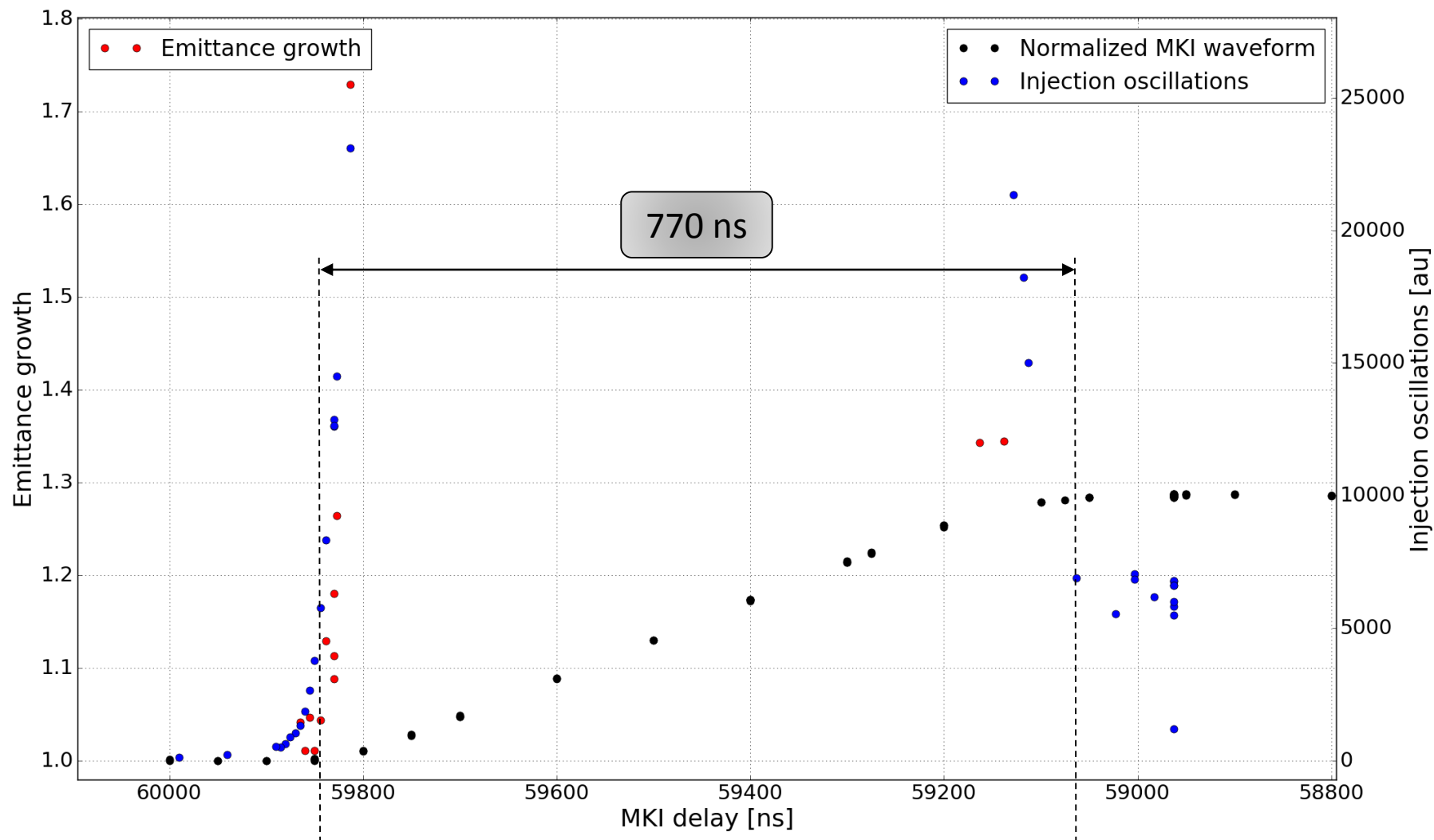
- Were running for weeks without damper in the SPS which was detrimental for beam quality of few bunches but accepted by LHC
- Can still see some effect with damper but much improved
- More sensitive to synchronisation drifts of injection kicker switches



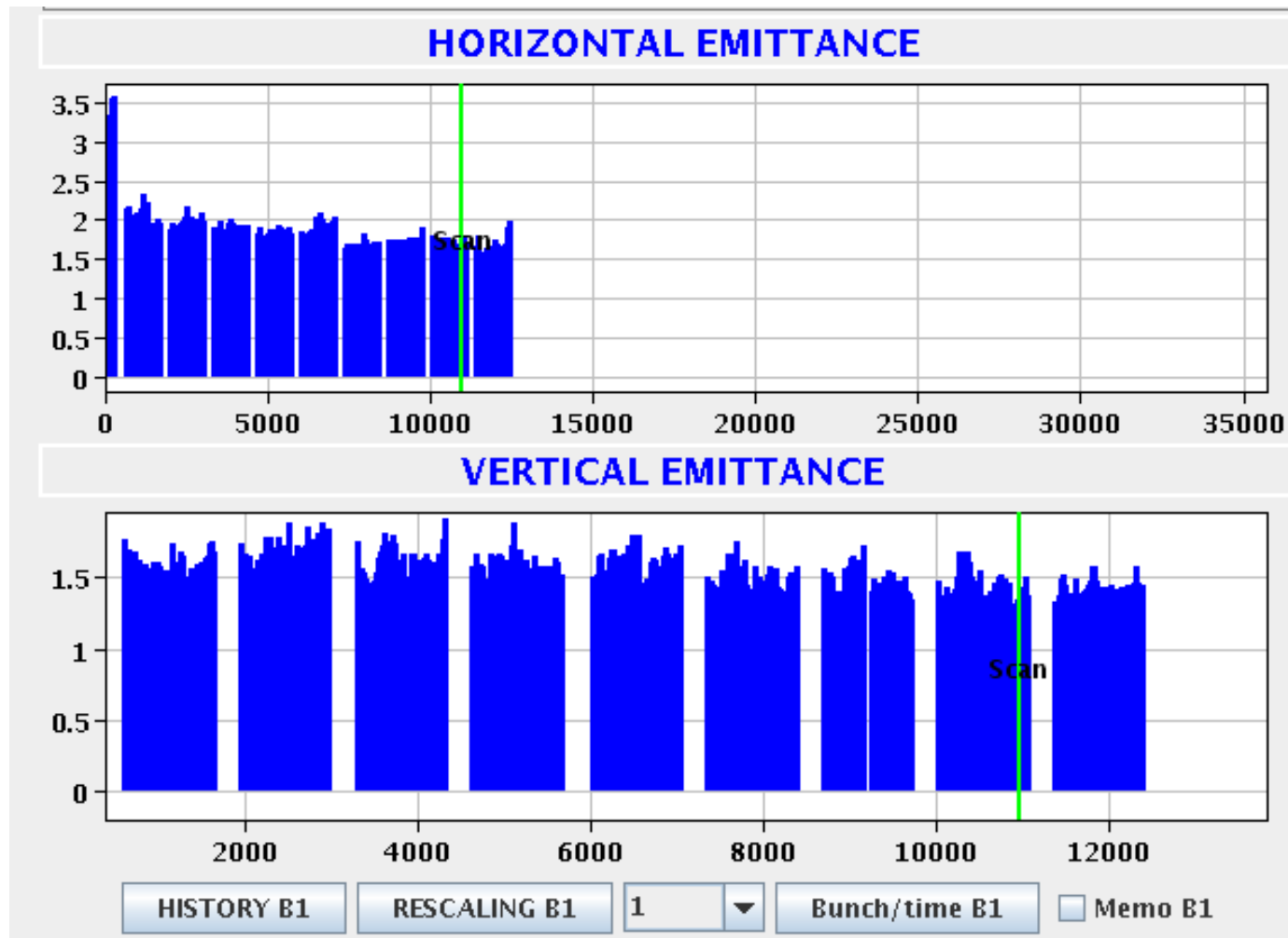
800 ns batch spacing LHC?



800 ns batch spacing LHC?



800/200 ns with trains



Conclusions

- Injection losses were dominated by satellites on TDI until improvement of PS-SPS transfer
- Last two months of proton run with very low losses
 - Median transverse < 1%
 - Median longitudinal < 7%
 - Maxima a factor 2-3 higher
- No issues expected with 288 b
- Ion run losses on the higher side in the transverse plane – would have needed some more tuning time
- Pure numbers in IQC indicated well the injected beam quality in run 2
 - Threshold simplification for IQC suggested based on loss scenarios
 - In a further step we also aim at reducing its visual overstimulation
- Diamonds should migrate from being only available for experts to IQC
 - Already working for SPS extraction
- Injection process fully automatized to minimize idle time at injection?
- 800/200 ns for MKI/MKP look promising and are suggested for 2017

Extra

Recent injections

LHC Injection Quality Check GUI 2.0.3
_ □ ×

File Mask Playback Help

⊙ ▾ RBA: wbartman

Injection Beam 1
Injection Beam 2

2016-09-06 10:34:47.485: BCTs/BQMs cannot verify injection. BQMs show no bunches injected.

BEAM EXTRACTION
INJECTION KICKER
BEAM LOSS
RF BUCKETS
INJ.OSCILLATIONS
TRANSFER LINE
RF PHASE
SCRAPING

2016-09-06 10:34:47.501: Beam losses are within thresholds.

Monitor name	Max loss	IQC applied	IQC ref	Dump threshold	Ratio to dump
BLMTI.04L2.B1E10_TDI.4L2	1.8283	0.0	0.0	2.3168	78.91%
BLMTI.04L2.B1E20_TDI.4L2.B1	1.2576	1.5433	4.63	23.1680	5.43%
BLMQI.08L2.B1E10_MQML	0.1046	0.7667	2.3	2.3168	4.52%
BLMTI.04L2.B1E10_TDI.4L2.B1	0.9473	1.5333	4.6	23.1680	4.09%
BLMQI.03L2.B1E10_MQXA	0.1157	0.1533	0.46	3.8459	3.01%
BLMQI.03L2.B2I20_MQXA	0.0799	0.1533	0.46	3.8459	2.08%
BLMAI.04L2.B1E10_MBXA	0.0433	1.5433	4.63	2.3168	1.87%
BLMQI.04L2.B1E10_MQML	0.1512	0.0	0.0	8.3405	1.81%
BLMQI.07L2.B1E10_MQM	0.0403	0.3067	0.92	2.3168	1.74%

Max plot

‘Transverse’ losses

‘Longitudinal’ losses

Max larger than 50% of reference. The Gy factor was 3.62E-9

Get LSA references
Set references
Read references from a file
Write references to file

Slot: 0
Select slot

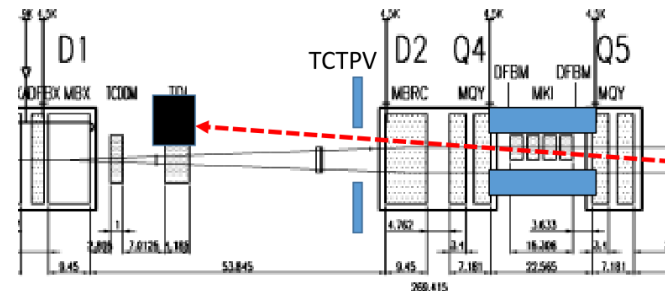
find: %TCP%

Playback
Previous Event
Replay event
Next Event
Show data dump

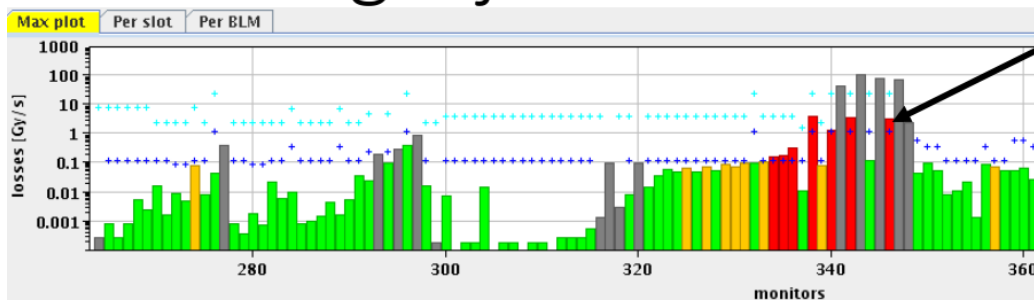
No Exception to display...

15:26:32 - WARNING NO DCUM VALUE FOR BLMM.HC.BLM.SR2.R.CD16.CH12

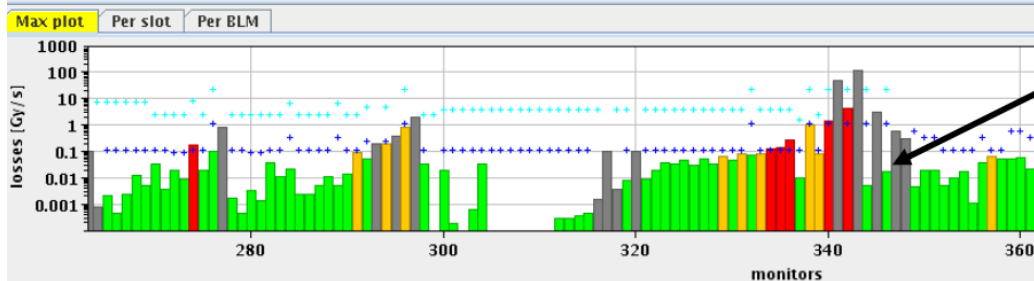
TCTPV issue



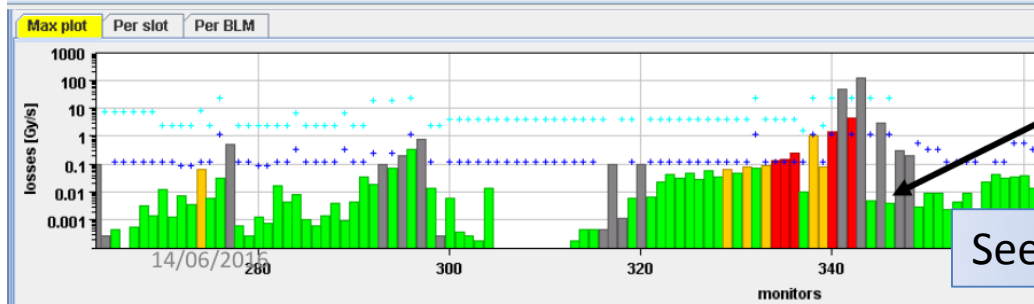
During injections of 72b:



TCTPV.4R8.B2 at ± 25 mm



TCTPV.4R8.B2 at ± 27.3 mm



TCTPV.4R8.B2 at ± 29 mm

See F. Burkart in [LIBD](#), 14th June 2016

LHC Injection Quality Check GUI 2.0.3

File Mask Playback Help

RBA: lhcop

Injection Beam 1
Injection Beam 2

2016-08-30 21:08:36.685: Beam injected! BQMs: Injected 12 bunches(12 bunches circulating). BLM analysis was bad.

BEAM EXTRACTION
INJECTION KICKER
BEAM LOSS
RF BUCKETS
INJ.OSCILLATIONS
TRANSFER LINE
RF PHASE
SCRAPING

2016-08-30 21:08:36.701: Beam losses above thresholds.

Monitor name	Max loss	IQC applied	IQC ref	Dump threshold	Ratio to dump
BLMQI.08L2.B1E10_MQML	0.6730	0.0958	2.3	2.3168	29.05%
BLMQI.08L2.B1E30_MQML					9.68%
BLMQI.07L2.B1E10_MQM					9.35%
BLMFL04L2.B1E10_TCDD-RL2					8.69%
BLMQI.07L2.B2I20_MQM					8.63%
BLMEI.06L2.B1E10_MSIB					6.85%
BLMQI.06L2.B1E10_MQML					5.13%
BLMQI.07L2.B2I10_MQM	0.2701	0.0367	2.32	3.4732	4.90%
BLMEI.06L2.B1E20_MSIB	0.1033	0.0192	0.46	2.3168	4.46%

High losses during injection
(wrong settings in SPS RF+ not enough scraping)

Max plot | Per slot | Per BLM

Get LSA references
Set references
Read references from a file
Write references to file
Slot:
Select slot
find:

Playback
Previous Event
Replay event
Next Event
Show data dump

- No Exception to display...

21:22:29 - WARNING NO DCUM VALUE FOR BLMM.HC.BLM.SR2.R.CD16.CH12