Installation of additional BLMs and replacement of 6 SEMs in the collimation region

B.Salvachua and C.Zamantzas (SY-BI-BL)

Input from the BLMTWG

15 Dec 2023 - Machine Protection Panel Meeting

Introduction

During **2023 proton run, losses in IR7 during injection** were dumping the beam with **236b injection trains and only in Beam 1**.

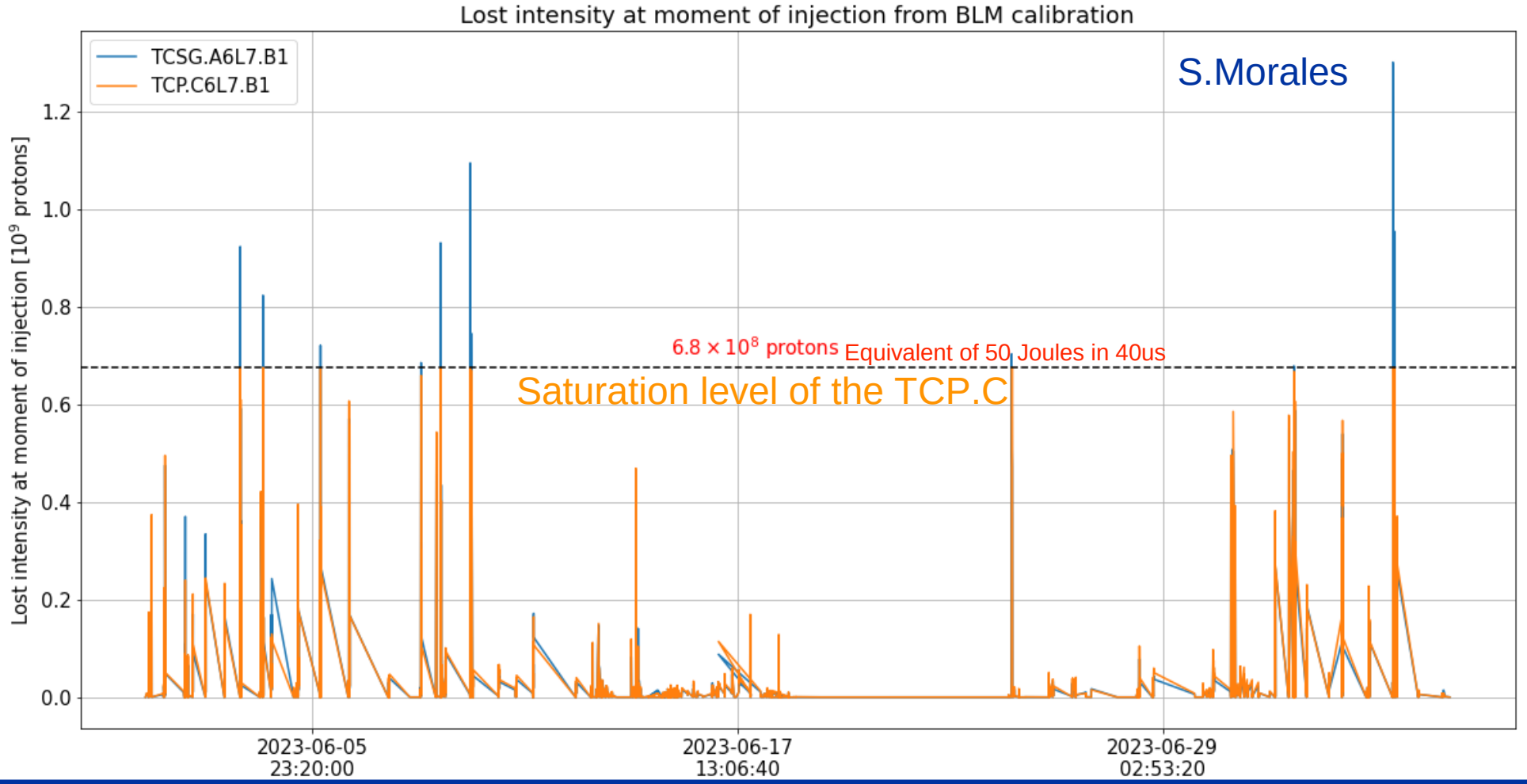
These are **fast losses** in RS01 (40us) reaching the BLM **maximum electronics limit of 23 Gy/s** at the **primary horizontal and skew collimators**.

See follow-up at:

- JAPW 2023:
  - Session 2 (5th Dec 2023): https://indico.cern.ch/event/1337597/sessions/515527/#20231205
  - Session 5 (6th Dec 2023): https://indico.cern.ch/event/1337597/sessions/515567/#20231206
- BLMTWG (27th Nov 2023): https://indico.cern.ch/event/1350470/
- LBOC (20th Jun 2023): https://indico.cern.ch/event/1291758/

How many protons impact the primary collimator?

Estimation of protons at 450 GeV impacting the primary collimators during saturation by calibrating another BLM downstream that does not saturate.



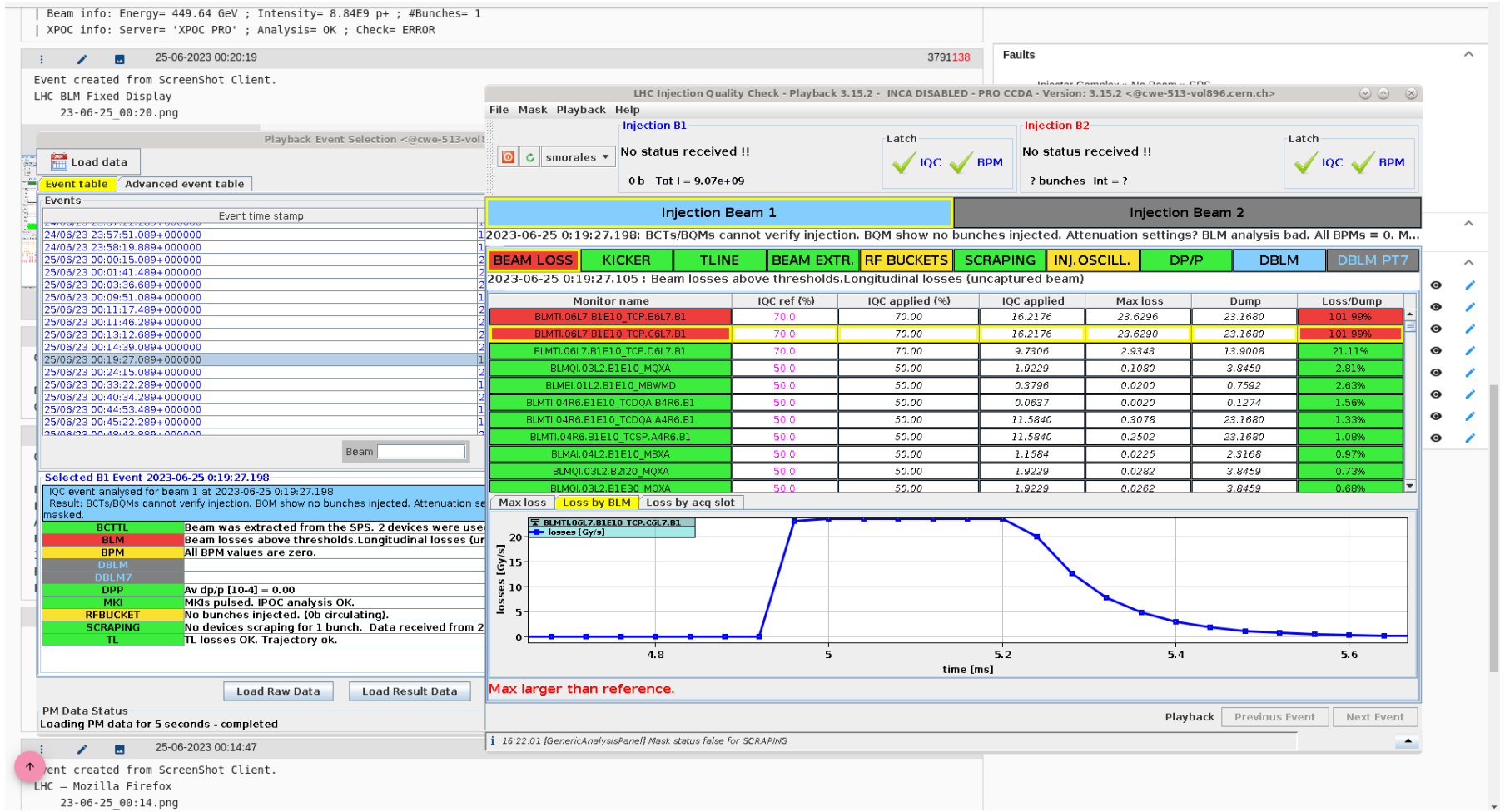
RS01 6.8e8 p in 40 us or 8e-4% train

For the injections that made it:
RS09: 4e10 p in 1.3 s or 0.1% train
0.1% of train

RS12: 8e11 p in 83 s or 2% train

How many protons impact the primary collimator?

This estimate of saturation around a pilot is confirmed by a test on 23 June.



Can the losses be reduced? Studies on-going…

Can the BLM signal be reduced?

Can the BLM signal be reduced?

- ***Displace the Ionisation chamber in order to capture less shower.***
  - We would need at least a factor of 2 reduction for the primaries, then other BLMs will be limiting.
  - Need Fluka estimates of the optimal new position —> A.Lechner (outcome before Xmas)
  - We could install during EYETS additional IC next to the present one and move the interlock functionality to these one after confirming the new signal factors.
- Are there other options?
  - Blindable system was not designed for Point 7 - not trivial option for the short-term.
  - LICs: offer about a factor 14 of signal reduction, stability and linearity for the particular monitors will need to be assed. *Plan for new LIC-type detector is being discussed - not before LS3*

Installation of additional IC - 6L7

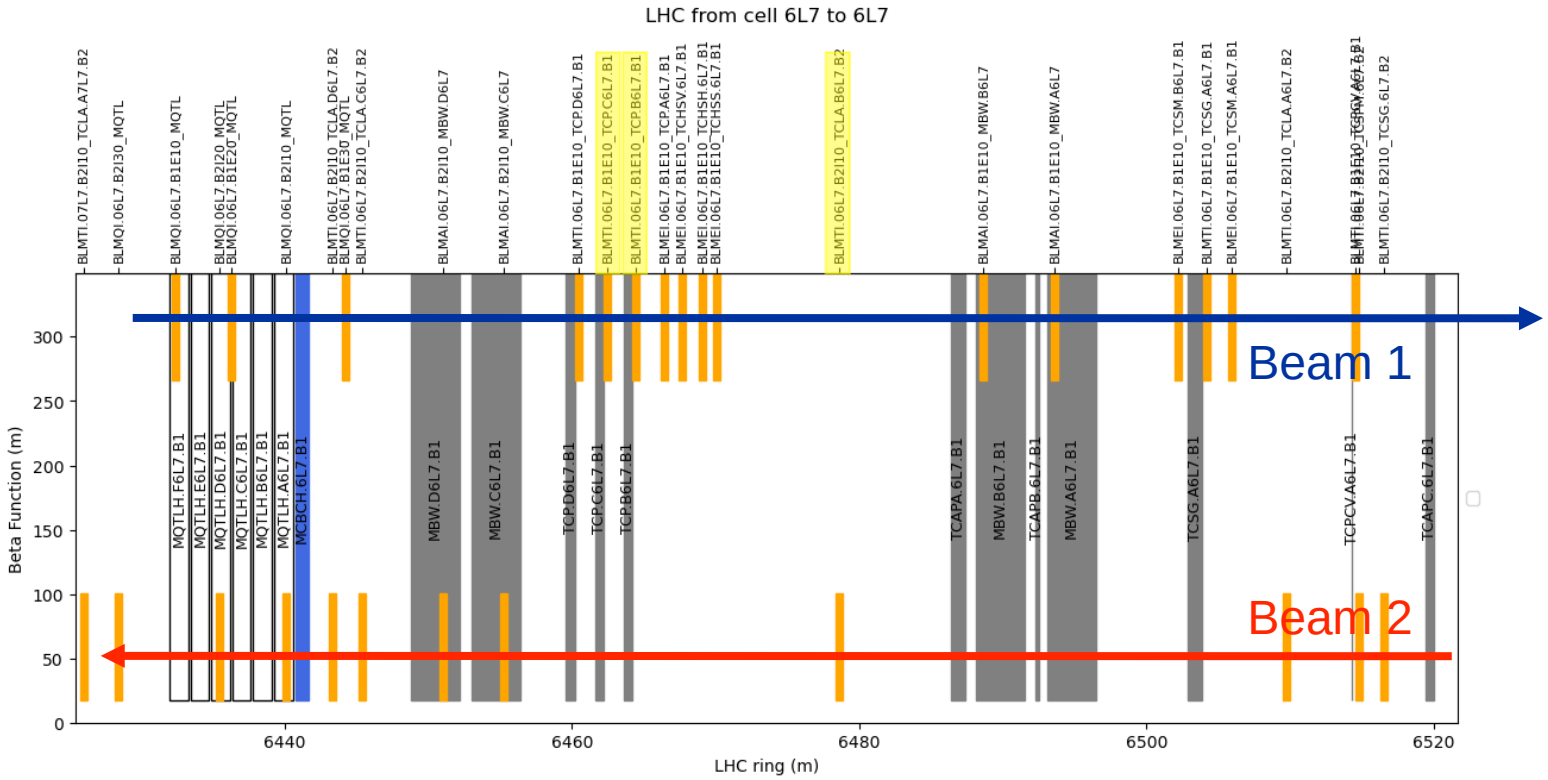
List of BLMs close to saturation during injections of Beam 1.

2.1 Gy/s BLMTI.06L7.B1E10_TCP.D6L7.B1 6460.21 m
23.6 Gy/s BLMTI.06L7.B1E10_TCP.C6L7.B1 6462.21 m
23.6 Gy/s BLMTI.06L7.B1E10_TCP.B6L7.B1 6464.21 m
20.6 Gy/s BLMTI.06L7.B2I10_TCLA.B6L7.B2 6478.39 m
13.6 Gy/s BLMAI.06L7.B1E10_MBW.B6L7 6488.41 m
1.94 Gy/s BLMAI.06L7.B1E10_MBW.A6L7 6493.35 m

Installation of 3-4 additional IC at: the two BLMs in TCP.Horizontal and TCP.Skew and the BLM at the TCLA of the other beam and MBW.

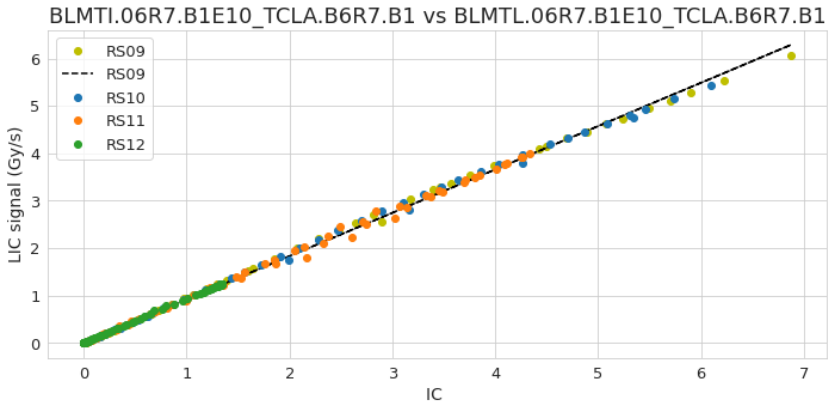
Slots identified, final location to be defined after:

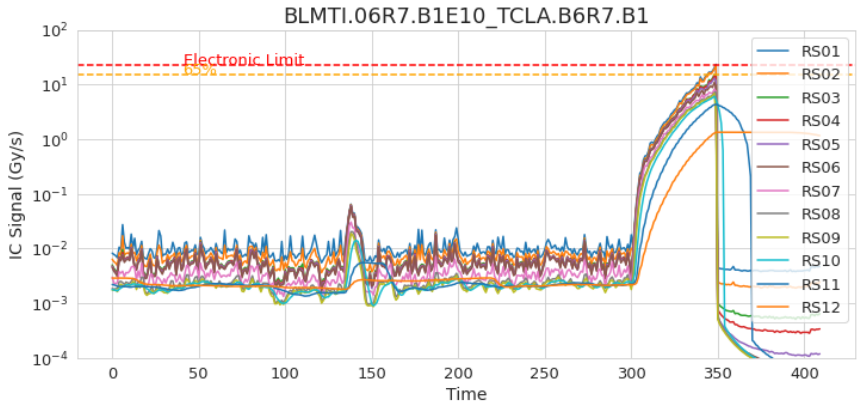
- FLUKA estimates (before Xmas)
- Inspection and integration (January)

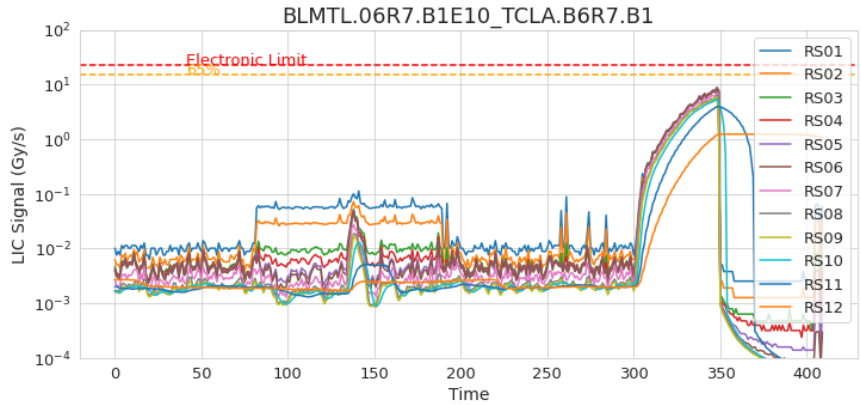


Usage of LIC detectors

- ***Interlock during injection or for fast losses on the LIC is a possibility, however this is only possible in LS3.***
  - Stability of the LICs need to be assessed.
  - SEM in IR7 would need to be replaced by LICs as soon as possible to gather this data.







Replacement of SEMs by LICs

Propose to replace initially 7+3 SEM detectors by LIC for Beam 1 (Beam 2 are already populated with LICs)

BLMTS.06L7.B1E10_TCP.D6L7.B1
BLMTS.06L7.B1E10_TCP.C6L7.B1
BLMTS.06L7.B1E10_TCP.B6L7.B1
BLMTS.06L7.B2I10_TCLA.B6L7.B2
BLMAS.06L7.B1E10_MBW.B6L7
BLMAS.06L7.B1E10_MBW.A6L7

Expect
LIC ~ 14 times lower sensitivity
SEM ~ 7e4 times lower sensitivity

	Conversion Gy/BLMbit	Ratio to IC
IC	3.62E-09	1
SEM	2.53E-04	69890
LIC	5.07E-08	14

Proposal to replace:
- 7 SEM near the TCPs and
- 3 SEM near the TCLA & MBW

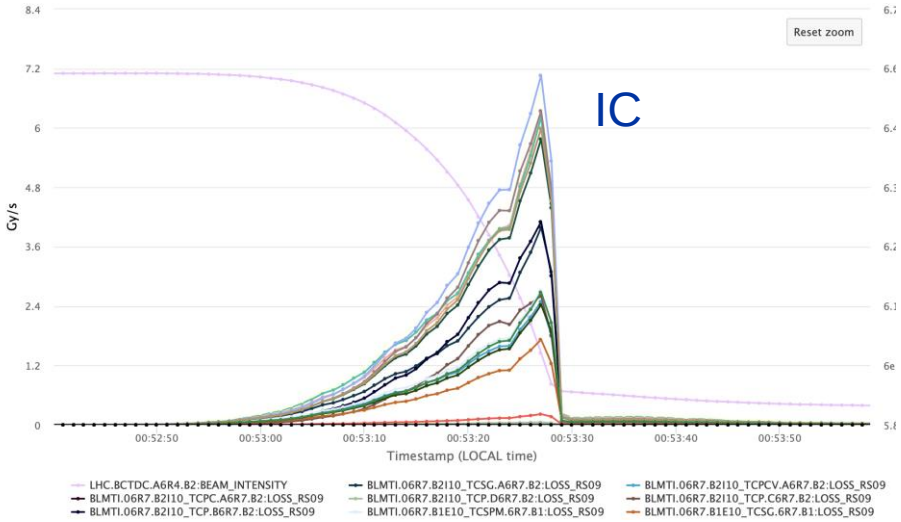
Reminder: SEMs are NOT interlocked

MONITOR_EXP_NAME	ACTION	DCUM	MONITOR_EXP_NAME	ACTION	DCUM
BLMTI.06L7.B1E10_TCP.D6L7.B1		19790.05	BLMTS.06L7.B2I10_TCLA.B6L7.B2	Replace with LIC	1980836
BLMTI.06L7.B1E10_TCP.C6L7.B1		19792.05	BLMAS.06L7.B1E10_MBW.B6L7	Replace with LIC	1981874
BLMTI.06L7.B1E10_TCP.B6L7.B1		1979405	BLMAS.06L7.B1E10_MBW.A6L7	Replace with LIC	1982367
BLMEI.06L7.B1E10_TCP.A6L7.B1		1979605	BLMM.HC.BLM.SR7.C.CD06.CH04		
BLMEI.06L7.B1E10_TCHSV.6L7.B1		1979725	BLMM.HC.BLM.SR7.C.CD06.CH05		
BLMEI.06L7.B1E10_TCHSH.6L7.B1		1979871	BLMM.HC.BLM.SR7.C.CD06.CH06		
BLMEI.06L7.B1E10_TCHSS.6L7.B1		1979965	BLMM.HC.BLM.SR7.C.CD06.CH07		
BLMM.HC.BLM.SR7.C.CD07.CH08	Add new IC at TCP.C6L7.B1		BLMM.HC.BLM.SR7.C.CD06.CH08		
BLMTS.06L7.B1E10_TCP.D6L7.B1	Replace with LIC	1979018	BLMTI.06L7.B2I10_TCLA.B6L7.B2		1980823
BLMTS.06L7.B1E10_TCP.C6L7.B1	Replace with LIC	1979218	BLMAI.06L7.B1E10_MBW.B6L7		1981826
BLMTS.06L7.B1E10_TCP.B6L7.B1	Replace with LIC	1979418	BLMAI.06L7.B1E10_MBW.A6L7		1982319
BLMES.06L7.B1E10_TCP.A6L7.B1	Replace with LIC	1979618	BLMM.HC.BLM.SR7.C.CD06.CH12	Add new IC at TCLA.B6L7.B2 region	
BLMES.06L7.B1E10_TCHSV.6L7.B1	Replace with LIC	1979738	BLMM.HC.BLM.SR7.C.CD06.CH13	Add new IC at MBW.B6L7 region	
BLMES.06L7.B1E10_TCHSH.6L7.B1	Replace with LIC	1979858	BLMM.HC.BLM.SR7.C.CD06.CH14		
BLMES.06L7.B1E10_TCHSS.6L7.B1	Replace with LIC	1979978	BLMM.HC.BLM.SR7.C.CD06.CH15		
BLMM.HC.BLM.SR7.C.CD07.CH16	Add new IC at TCP.B6L7.B1		BLMM.HC.BLM.SR7.C.CD06.CH16		

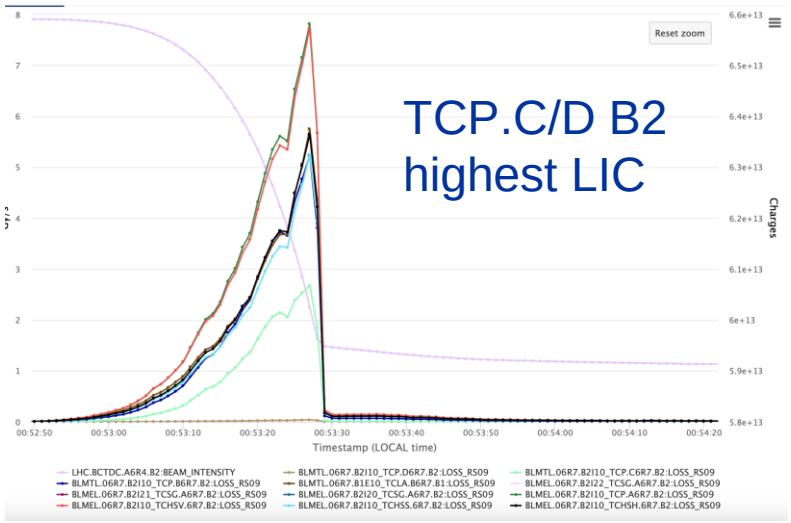
Summary

- Saturation of BLMs in the primary collimators could be a limitation for 2024 run.
- A mitigation needs to be in place during EYETS:
  - Adding new IC in a location with reduced signal. Measure and confirm reduction factors during beam commissioning. Agree with MPP or rMPP moving the interlock to the new monitors.
  - Replacing SEM by LIC at 7+3 locations to study linearity and stability for possibly interlocking on LIC in LS3.

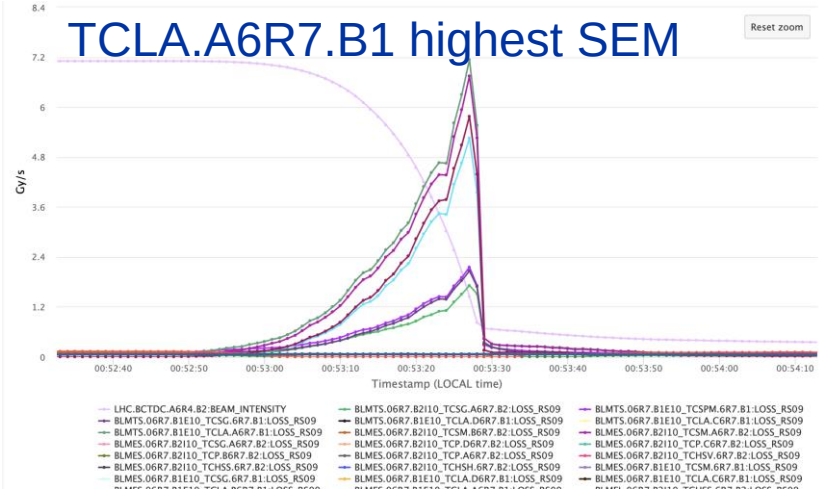
B2 Quench Test 2022



IC

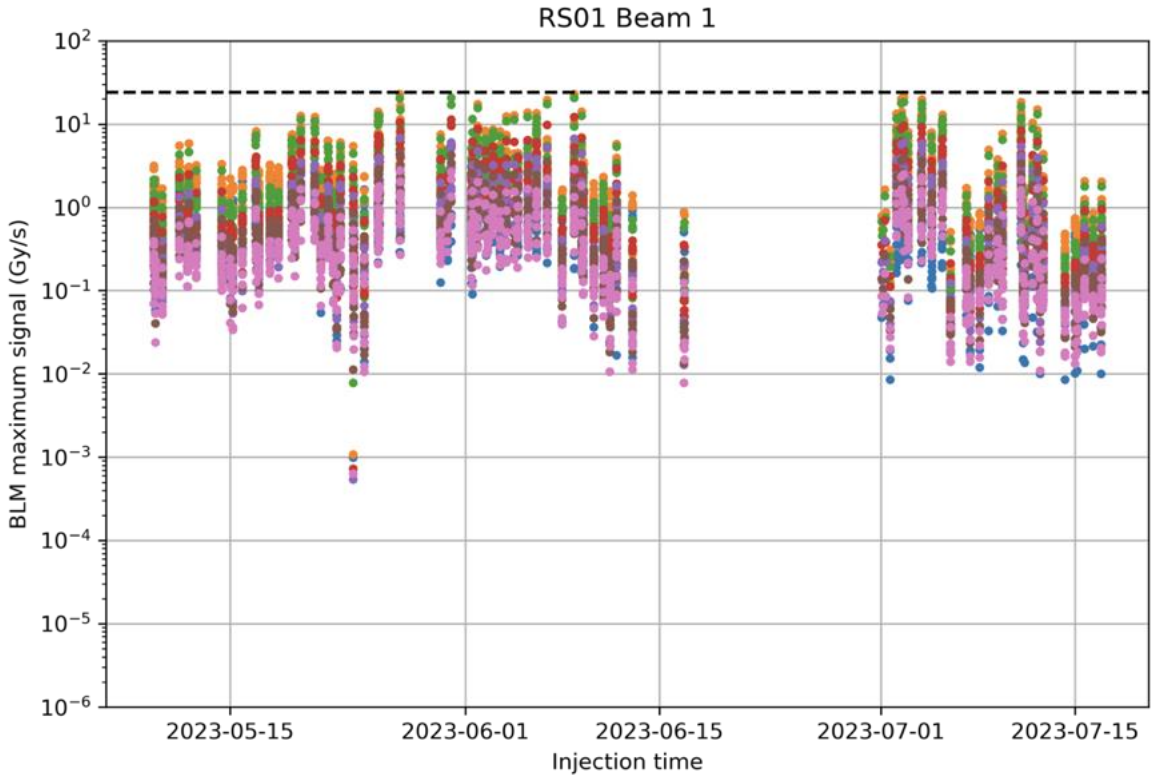


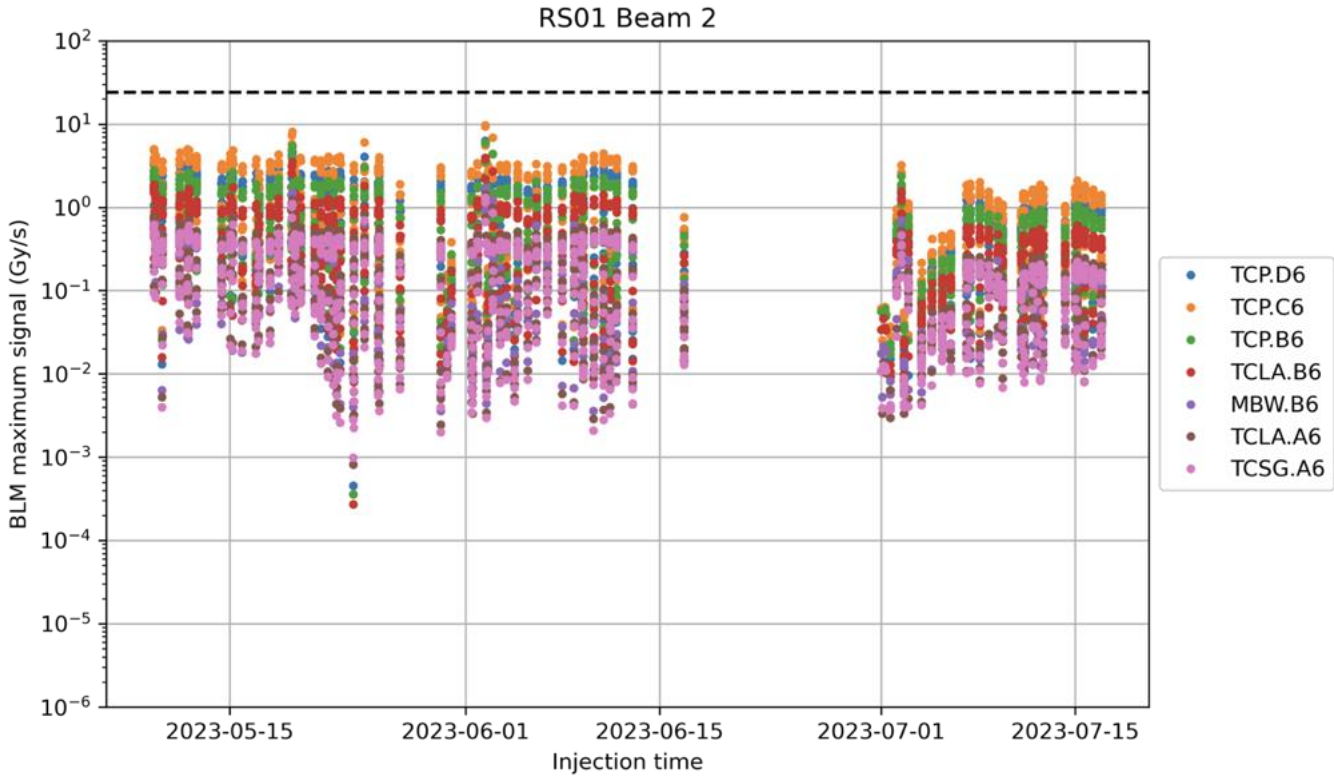
TCP.C/D B2
highest LIC



TCLA.A6R7.B1 highest SEM

Maximum Beam Loss during Injection



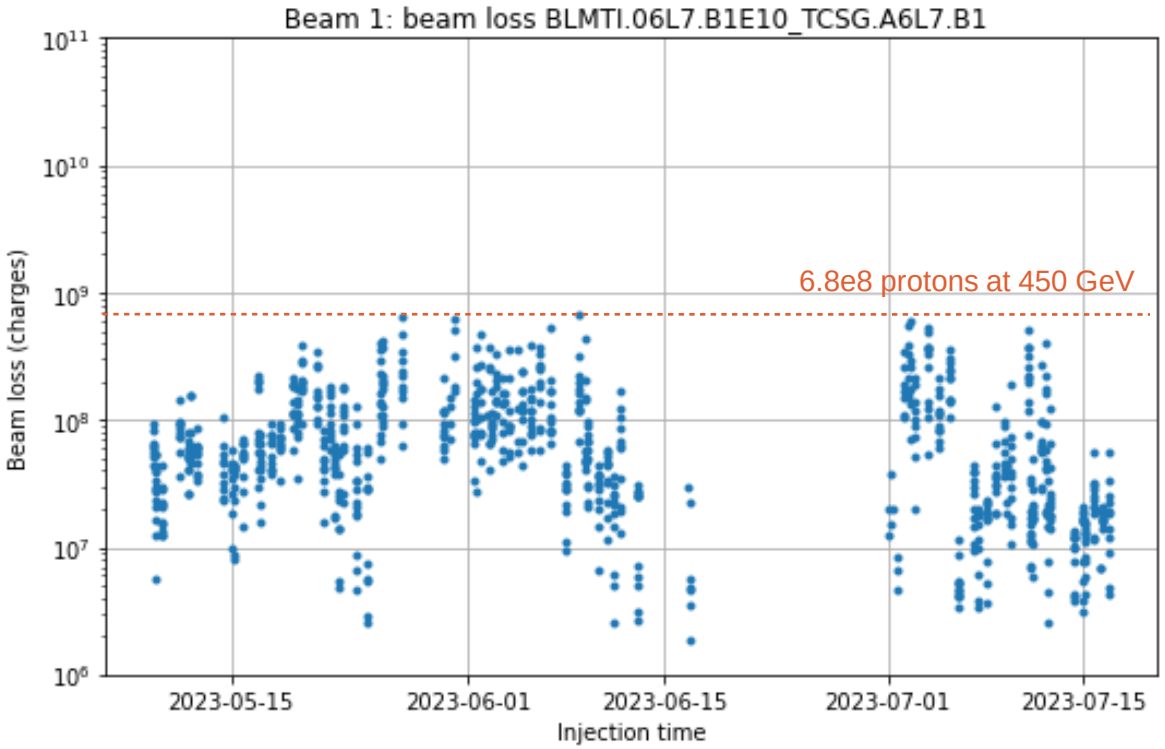


RS02 Beam 1

RS02 Beam 2

Beam 2 losses are kept under control along all the year
Different pattern Beam 1 vs Beam 2 (horizontal/skew)
Last period at around 5th July and 10th July visible improvement of beam losses

Maximum Calibrated Beam Loss during Injection



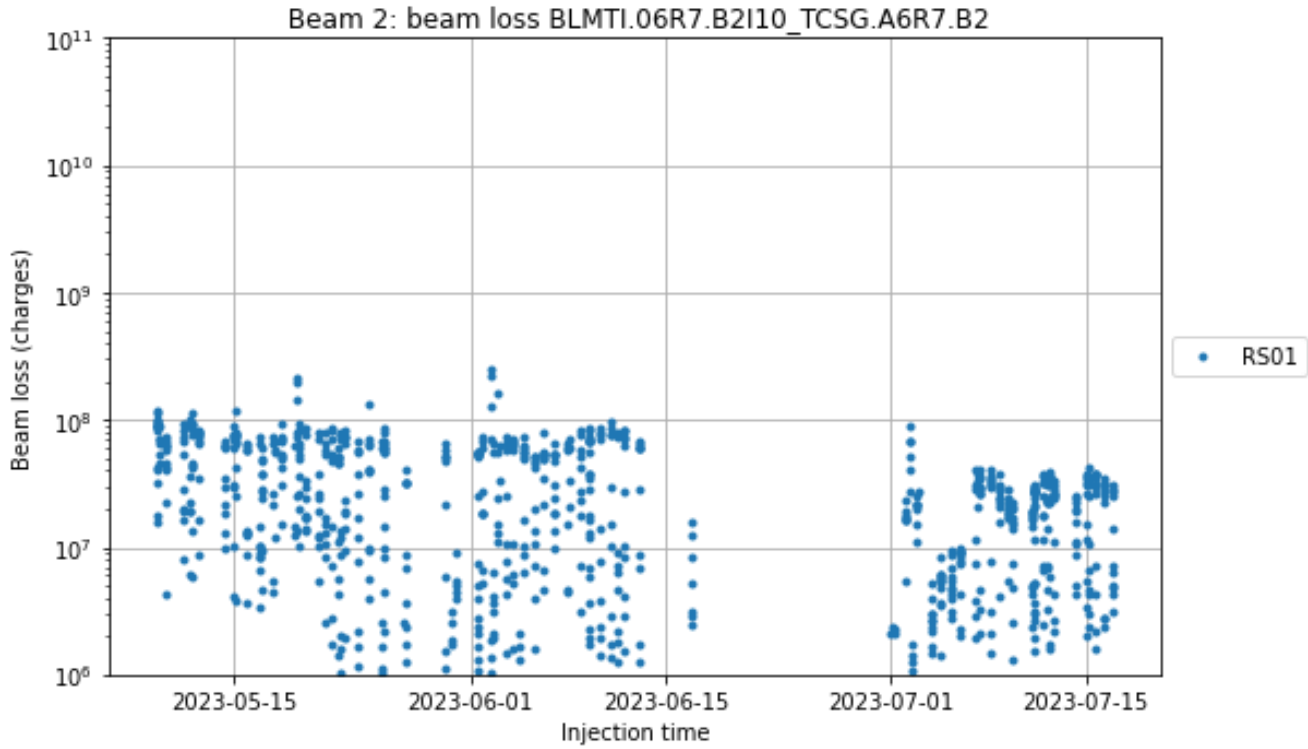
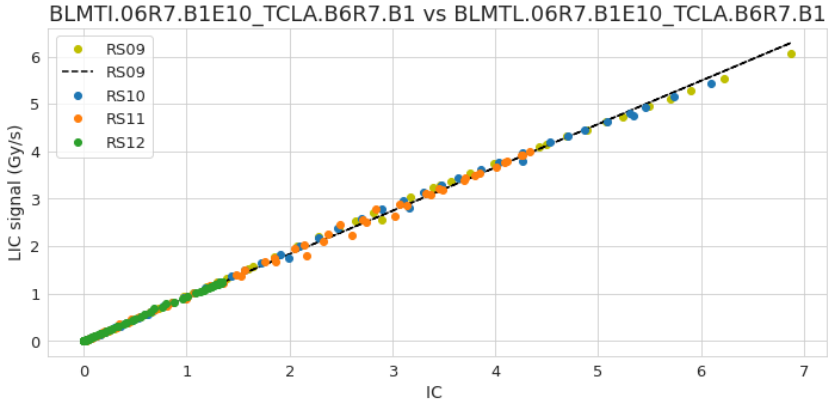
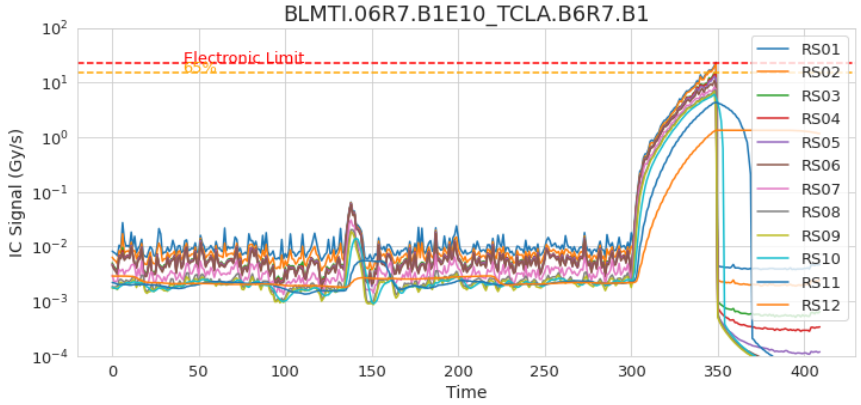


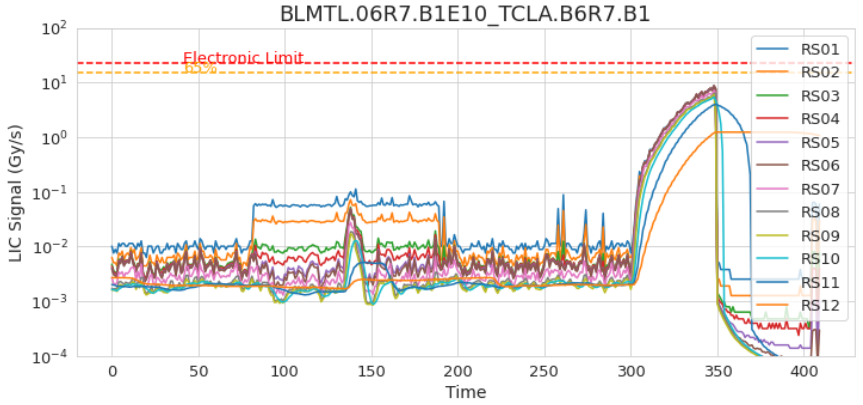
Table 2.3: New damage limits for losses in the collimator system.

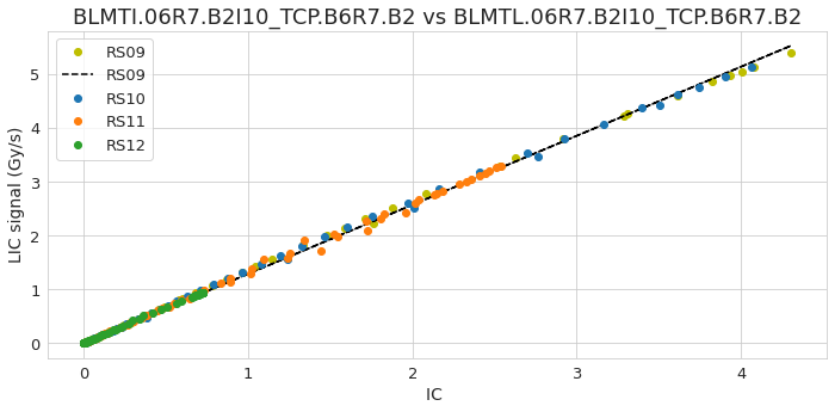
Running Sum	Time Scale	Maximum Values	Max. Nb. Protons at 7 TeV	Max. Nb. Protons at 450 GeV
RS01 – RS06	40 μs – 0.01 s	125 kJ	1.1×10^{11} p	17.3×10^{11} p
RS07	0.08 s	500 kJ	4.5×10^{11} p	69.3×10^{11} p
RS08	0.6 s	500 kJ (833 kW)	4.5×10^{11} p	69.3×10^{11} p
RS09	1.3 s	500 kW	5.8×10^{11} p	90.2×10^{11} p
RS10	5.2 s	500 kW	23.2×10^{11} p	360.6×10^{11} p
RS11	20.9 s	5000 kJ	44.6×10^{11} p	693.6×10^{11} p
RS12	83 s	100 kW	74.0×10^{11} p	1151.3×10^{11} p

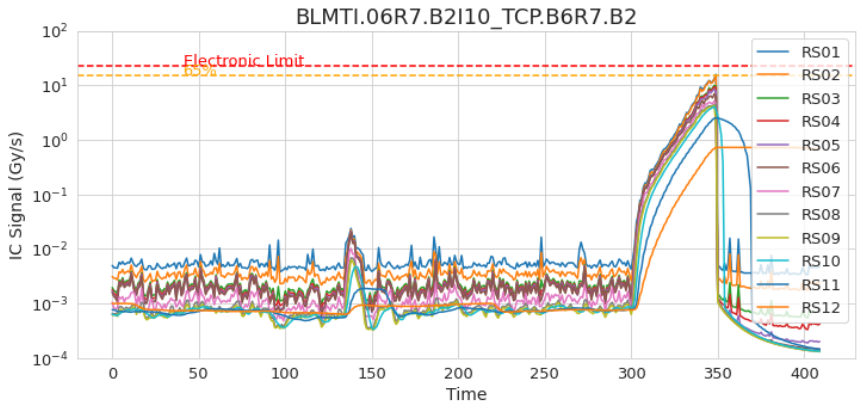
IC vs LIC

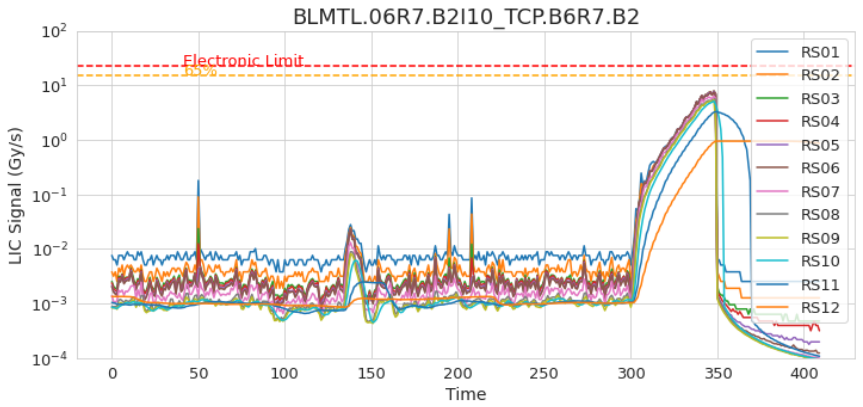

BLMTI.06R7.B1E10_TCLA.B6R7.B1 vs BLMTL.06R7.B1E10_TCLA.B6R7.B1
RS09
RS09
RS10
RS11
RS12
LIC signal (Gy/s)
IC


BLMTI.06R7.B1E10_TCLA.B6R7.B1
Electronic Limit
95%
RS01
RS02
RS03
RS04
RS05
RS06
RS07
RS08
RS09
RS10
RS11
RS12
IC Signal (Gy/s)
Time


BLMTL.06R7.B1E10_TCLA.B6R7.B1
Electronic Limit
95%
RS01
RS02
RS03
RS04
RS05
RS06
RS07
RS08
RS09
RS10
RS11
RS12
LIC Signal (Gy/s)
Time


BLMTI.06R7.B2I10_TCP.B6R7.B2 vs BLMTL.06R7.B2I10_TCP.B6R7.B2
RS09
RS09
RS10
RS11
RS12
LIC signal (Gy/s)
IC


BLMTI.06R7.B2I10_TCP.B6R7.B2
Electronic Limit
95%
RS01
RS02
RS03
RS04
RS05
RS06
RS07
RS08
RS09
RS10
RS11
RS12
IC Signal (Gy/s)
Time


BLMTL.06R7.B2I10_TCP.B6R7.B2
Electronic Limit
95%
RS01
RS02
RS03
RS04
RS05
RS06
RS07
RS08
RS09
RS10
RS11
RS12
LIC Signal (Gy/s)
Time

For the ICs we can add two for the TCP (last two spare channels left):
We replace also the 7 SEM to LIC.

MONITOR_EXP_NAME	ACTION	DCUM	CRATE_CMW_NAME	DAB_IND	CHANNEL_INDEX	IS_CONNECTED_TO_BIS	IS_CABLE_CONNECTED
BLMTI.06L7.B1E10_TCP.D6L7.B1		19790.05	HC.BLM.SR7.C	7	1	1	1
BLMTI.06L7.B1E10_TCP.C6L7.B1		19792.05	HC.BLM.SR7.C	7	2	1	1
BLMTI.06L7.B1E10_TCP.B6L7.B1		1979405	HC.BLM.SR7.C	7	3	1	1
BLMEI.06L7.B1E10_TCP.A6L7.B1		1979605	HC.BLM.SR7.C	7	4	0	1
BLMEI.06L7.B1E10_TCHSV.6L7.B1		1979725	HC.BLM.SR7.C	7	5	0	1
BLMEI.06L7.B1E10_TCHSH.6L7.B1		1979871	HC.BLM.SR7.C	7	6	0	1
BLMEI.06L7.B1E10_TCHSS.6L7.B1		1979965	HC.BLM.SR7.C	7	7	0	1
BLMM.HC.BLM.SR7.C.CD07.CH08	Add new IC at TCP.C6L7.B1		HC.BLM.SR7.C	7	8	0	0
BLMTS.06L7.B1E10_TCP.D6L7.B1	Replace with LIC	1979018	HC.BLM.SR7.C	7	9	0	1
BLMTS.06L7.B1E10_TCP.C6L7.B1	Replace with LIC	1979218	HC.BLM.SR7.C	7	10	0	1
BLMTS.06L7.B1E10_TCP.B6L7.B1	Replace with LIC	1979418	HC.BLM.SR7.C	7	11	0	1
BLMES.06L7.B1E10_TCP.A6L7.B1	Replace with LIC	1979618	HC.BLM.SR7.C	7	12	0	1
BLMES.06L7.B1E10_TCHSV.6L7.B1	Replace with LIC	1979738	HC.BLM.SR7.C	7	13	0	1
BLMES.06L7.B1E10_TCHSH.6L7.B1	Replace with LIC	1979858	HC.BLM.SR7.C	7	14	0	1
BLMES.06L7.B1E10_TCHSS.6L7.B1	Replace with LIC	1979978	HC.BLM.SR7.C	7	15	0	1
BLMM.HC.BLM.SR7.C.CD07.CH16	Add new IC at TCP.B6L7.B1		HC.BLM.SR7.C	7	16	0	0

For the TCLA & MBW we can add also two new ICs but also change the 3 SEMs to LIC.

MONITOR_EXP_NAME	ACTION	DCUM	CRATE_CMW_NAME	DAB_INDEX	CHANNEL_INDEX	IS_CONNECTED_TO_BI	IS_CABLE_CONNECTE
BLMTS.06L7.B2I10_TCLA.B6L7.B2	Replace with LIC	1980836	HC.BLM.SR7.C	6	1	0	1
BLMAS.06L7.B1E10_MBW.B6L7	Replace with LIC	1981874	HC.BLM.SR7.C	6	2	0	1
BLMAS.06L7.B1E10_MBW.A6L7	Replace with LIC	1982367	HC.BLM.SR7.C	6	3	0	1
BLMM.HC.BLM.SR7.C.CD06.CH04			HC.BLM.SR7.C	6	4	0	0
BLMM.HC.BLM.SR7.C.CD06.CH05			HC.BLM.SR7.C	6	5	0	0
BLMM.HC.BLM.SR7.C.CD06.CH06			HC.BLM.SR7.C	6	6	0	0
BLMM.HC.BLM.SR7.C.CD06.CH07			HC.BLM.SR7.C	6	7	0	0
BLMM.HC.BLM.SR7.C.CD06.CH08			HC.BLM.SR7.C	6	8	0	0
BLMTI.06L7.B2I10_TCLA.B6L7.B2		1980823	HC.BLM.SR7.C	6	9	1	1
BLMAI.06L7.B1E10_MBW.B6L7		1981826	HC.BLM.SR7.C	6	10	1	1
BLMAI.06L7.B1E10_MBW.A6L7		1982319	HC.BLM.SR7.C	6	11	1	1
BLMM.HC.BLM.SR7.C.CD06.CH12	Add new IC at TCLA.B6L7.B2 region		HC.BLM.SR7.C	6	12	0	0
BLMM.HC.BLM.SR7.C.CD06.CH13	Add new IC at MBW.B6L7 region		HC.BLM.SR7.C	6	13	0	0
BLMM.HC.BLM.SR7.C.CD06.CH14			HC.BLM.SR7.C	6	14	0	0
BLMM.HC.BLM.SR7.C.CD06.CH15			HC.BLM.SR7.C	6	15	0	0
BLMM.HC.BLM.SR7.C.CD06.CH16			HC.BLM.SR7.C	6	16	0	0