First experience with beam regarding the reduced sensitivity of the newly installed BLMs + BLM Latency results

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22 March 2024 - 245th Machine Protection Panel Meeting (LHC & Injectors)

Introduction

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

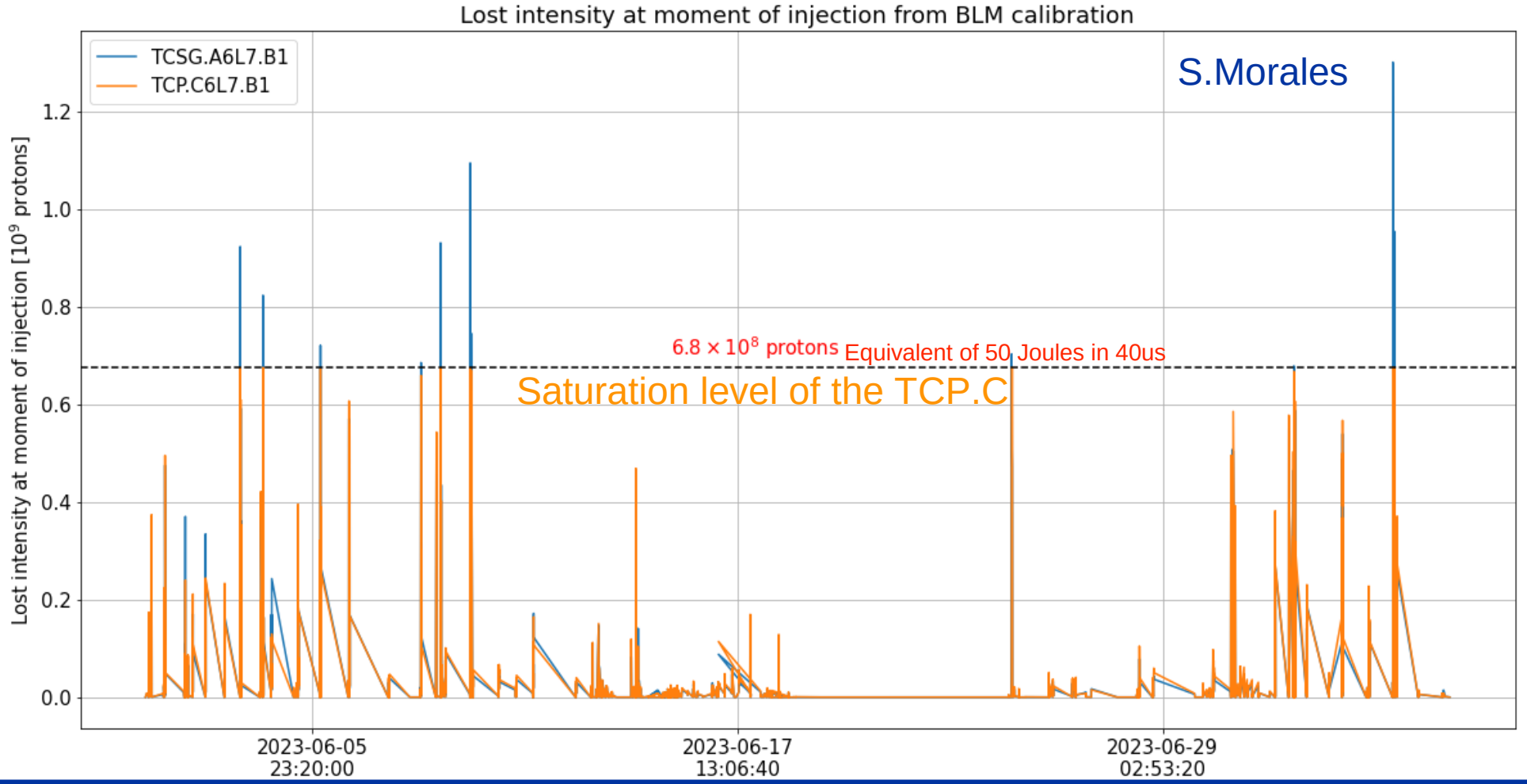
These are **fast losses** in RS01 (40us) reaching the BLM **maximum electronics limit of 23 Gy/s** at the **primary horizontal and skew collimators**.

Since then there were a series of follow-up meetings and actions:

- 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/
- MPP (15th Dec 2023): https://indico.cern.ch/event/1356938/
- BLMTWG (23rd Feb 2024): https://indico.cern.ch/event/1385086/

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

Although the losses are not a concern for Machine Protection, the solution might be.

BLM signals during injection of Beam 1

These are the measured BLM signals during one of the injections with high losses in IR7.

Max. Signal RS01 (Gy/s)	IC BLM name	IC BLM dcum (m)
1.7	BLMTI.06L7.B1E10_TCP.D6L7.B1	19789.80
23.6	BLMTI.06L7.B1E10_TCP.C6L7.B1	19791.80
23.5	BLMTI.06L7.B1E10_TCP.B6L7.B1	19793.80
20.8	BLMTI.06L7.B2I10_TCLA.B6L7.B2	19807.98
13.7	BLMAI.06L7.B1E10_MBW.B6L7	19818.01
8.7	BLMTI.06L7.B2I10_TCLA.A6L7.B2	19839.12

In order to study what would be the strategy for LS3, we have proposed:

1. The installation of transversally displaced Ionization Chambers (IC) in order to reduce its response and eventually move the interlock functionality to these new IC.

2. The replacement of SEM detectors by Little Ionization Chambers (LIC) in the 6L7 area.

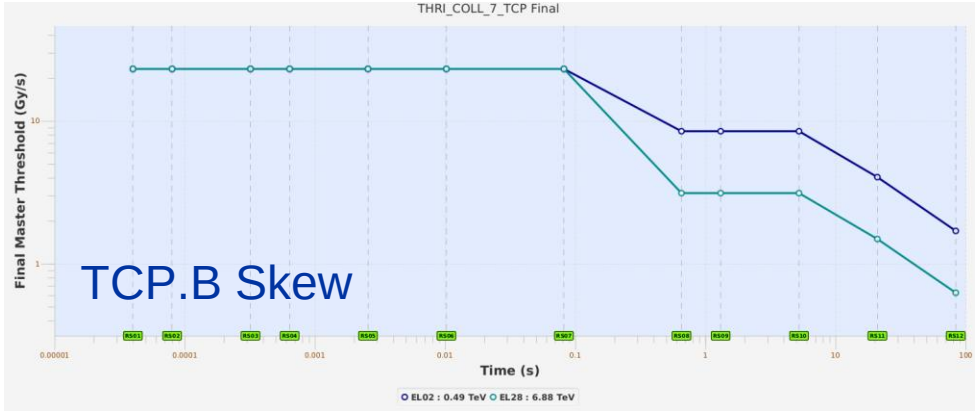
BLM type	Conversion Gy/BLMbit	Ratio to IC
IC	3.62×10^{-9}	1
LIC	5.07×10^{-8}	14
SEM	2.53×10^{-4}	69890

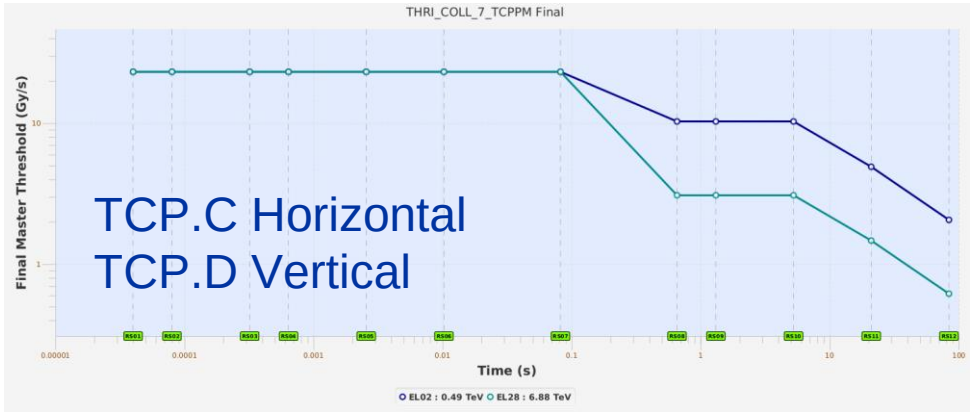
The SEM provide a response that is too low, while for the LIC the response is expected to be 14 times lower.

To be mentioned, that we need a response of about 100 times lower at the TCPs in order to completely avoid saturation.

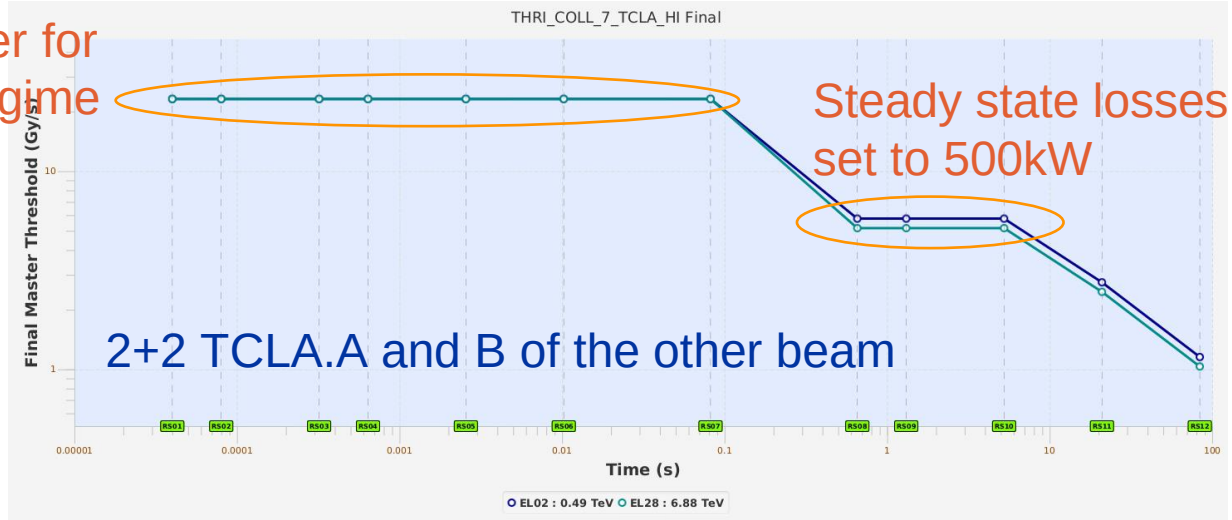
BLM Thresholds for collimators

The BLM saturation of short running sums occurs in several locations and could affects all energies (not only injection). Many other collimation families are also affected by saturation but these families more heavily.





Tolerate higher beam power for shorter period - different regime 125 kJ



Curves are based on measured data taking into account the BLM response and expected energy depositions confirmed by simulations.

They correspond to the maximum allowed BLM signal.

New IC BLM installation in 6L7

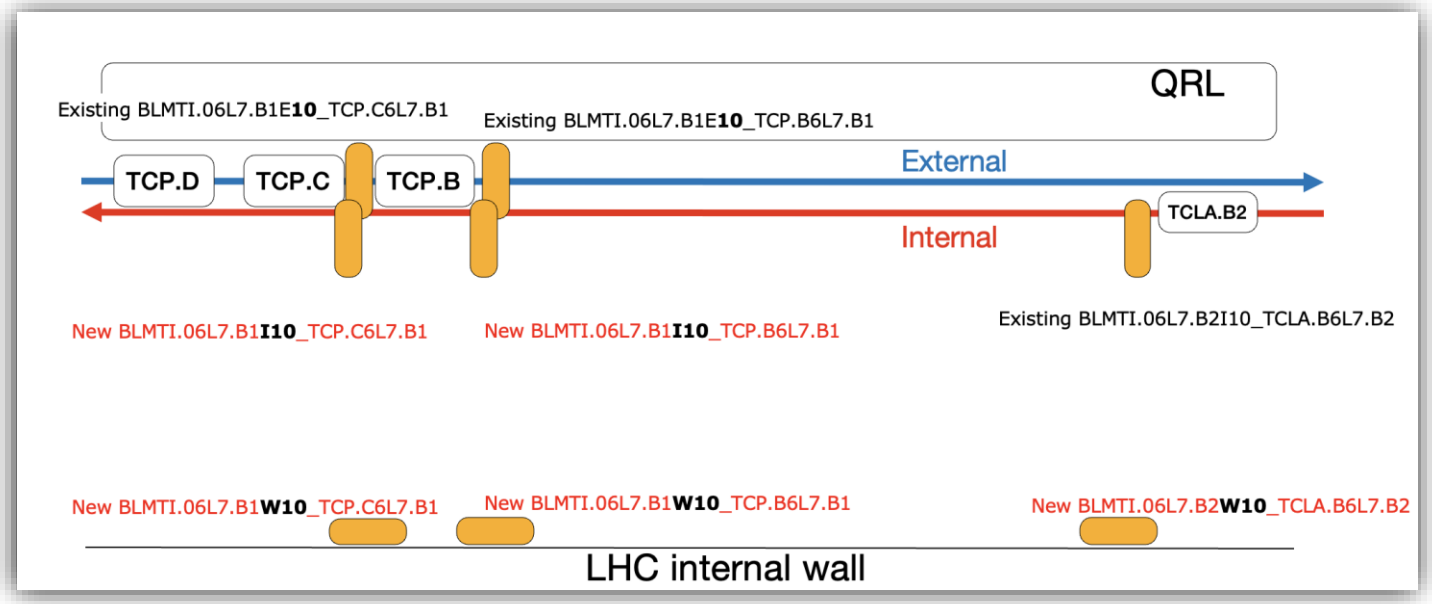
Over EYETS we have proceed with the installation of 5 additional Ionisation chambers in 6L7 and the replacement of 10 SEM detectors at the collimators by LICs:

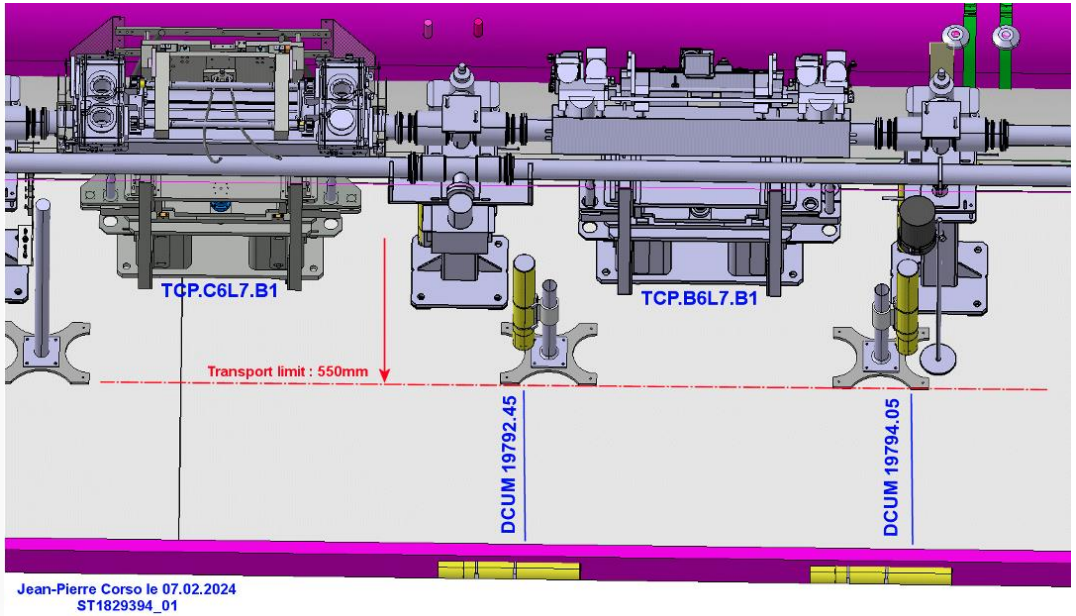
LHC-BLM-EC-0019, Addition of BLM detectors and replacement of several SEM by LIC

2 IC BLM in position about I3 for the TCP.C and TCP.B —> 60% response expected TCP.C and 96% at TCP.B from FLUKA (https://indico.cern.ch/event/1371132/)

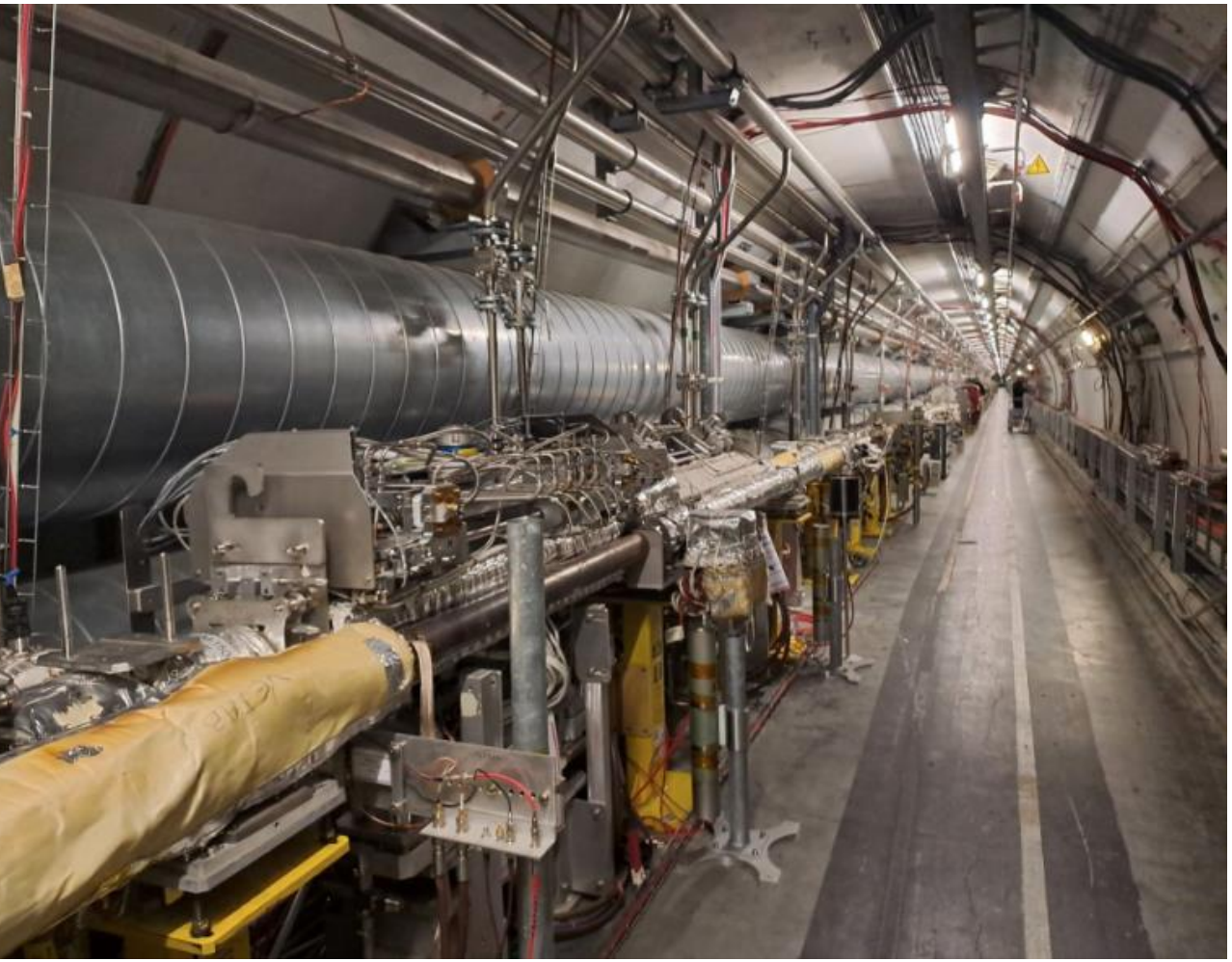
3 IC BLM installed in the tunnel passage WALL, about 2 m transversal displacement from the beam pipe for TCP.C, TCP.B and TCLA.B

10 LIC BLM replacing 10 SEM BLM, at the same location



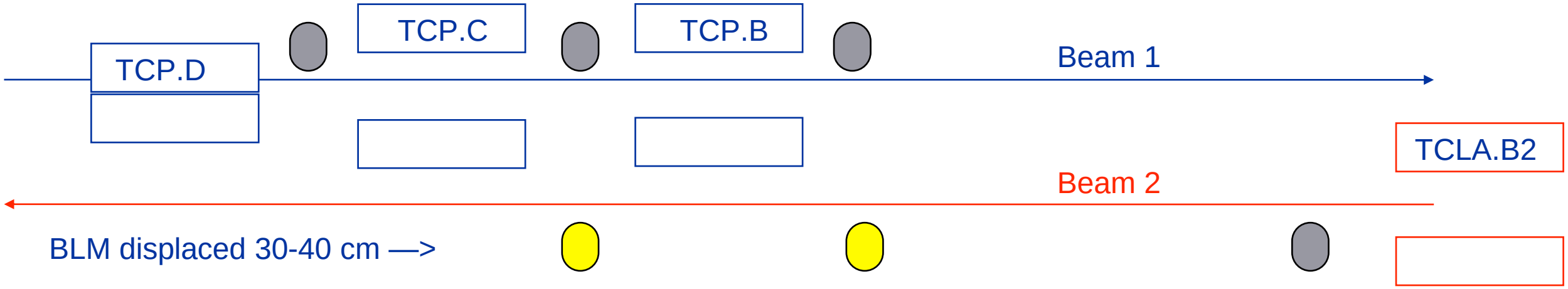


Installation pictures



Test at injection - 11th March

Thanks to OP for taking the data!
Injecting a pilot beam about 8.8e9 p
(test repeated 3 times per collimator)



BLM on the passage WALL —>

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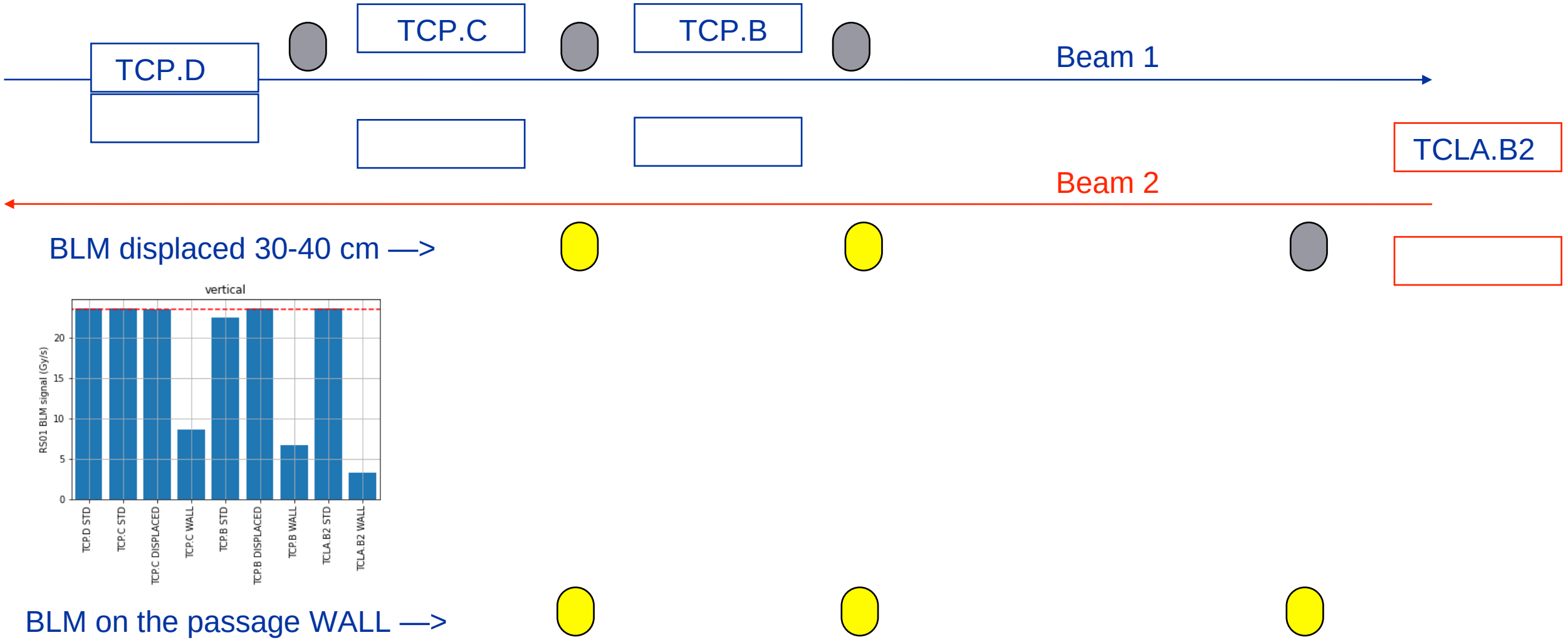

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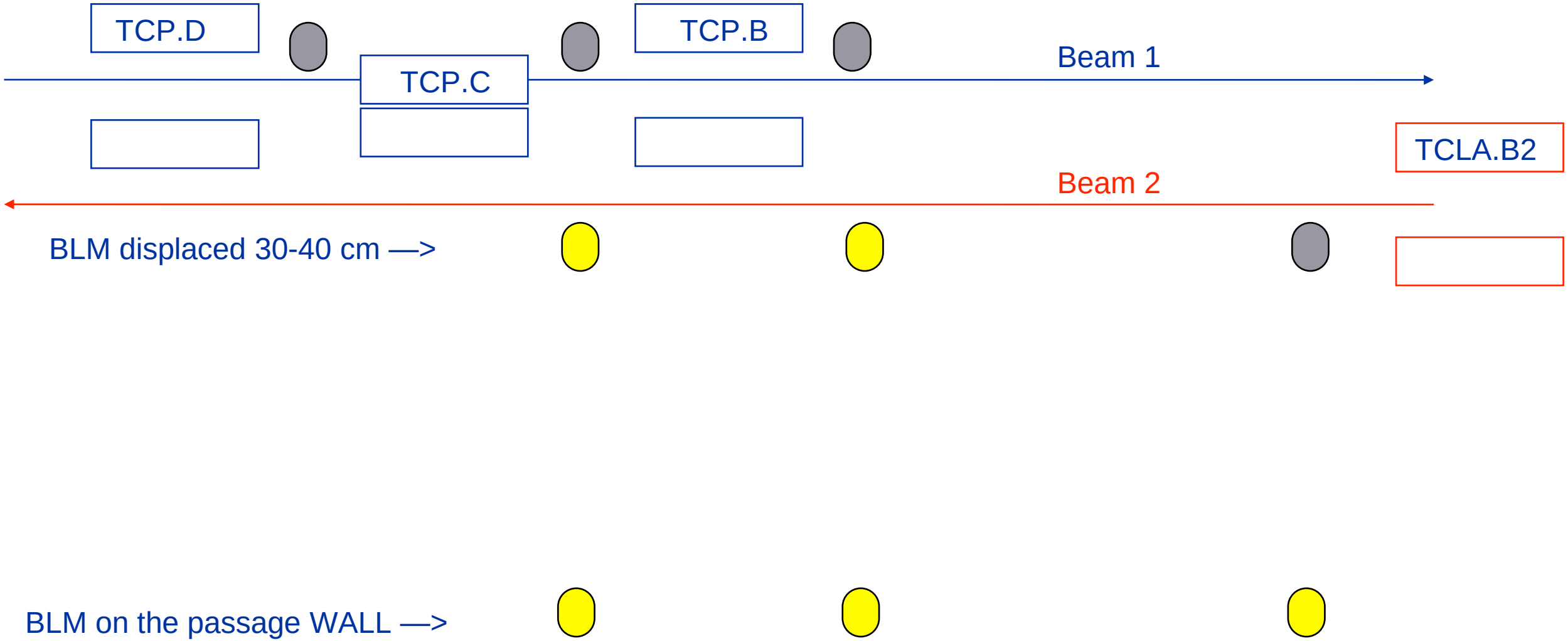

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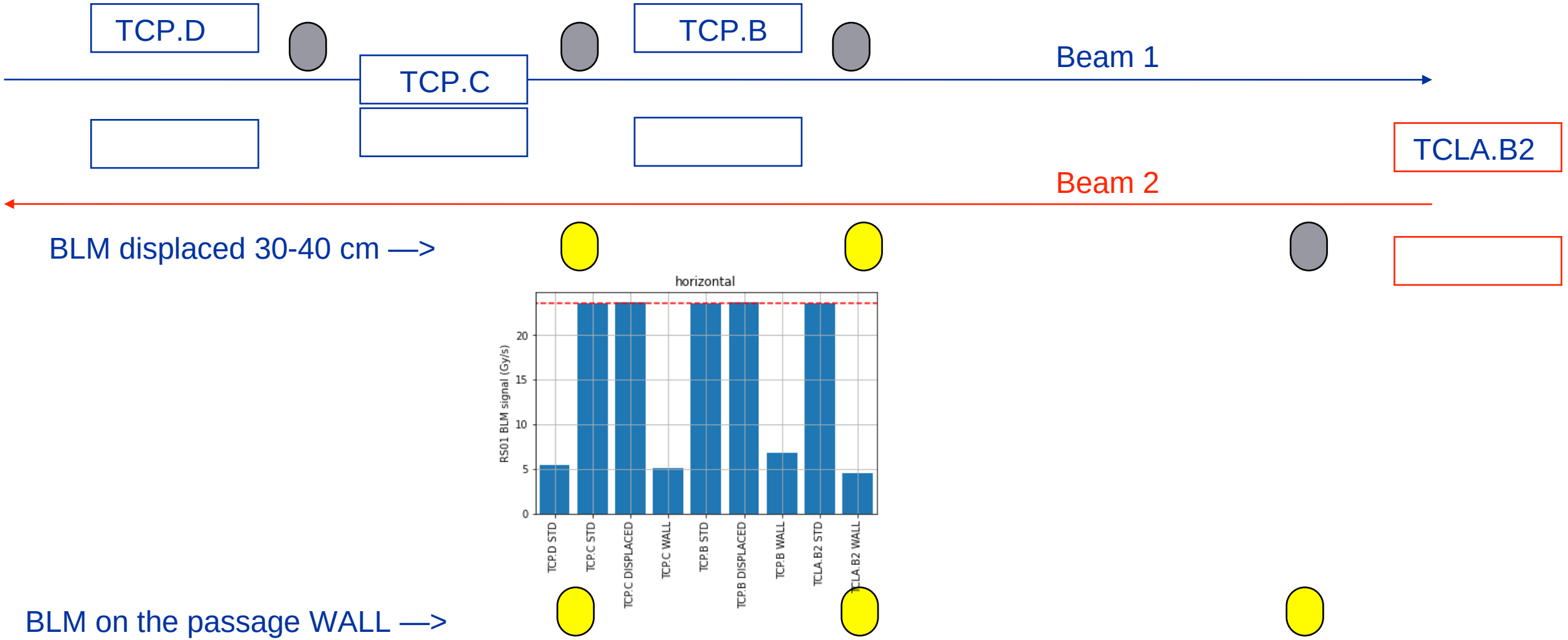

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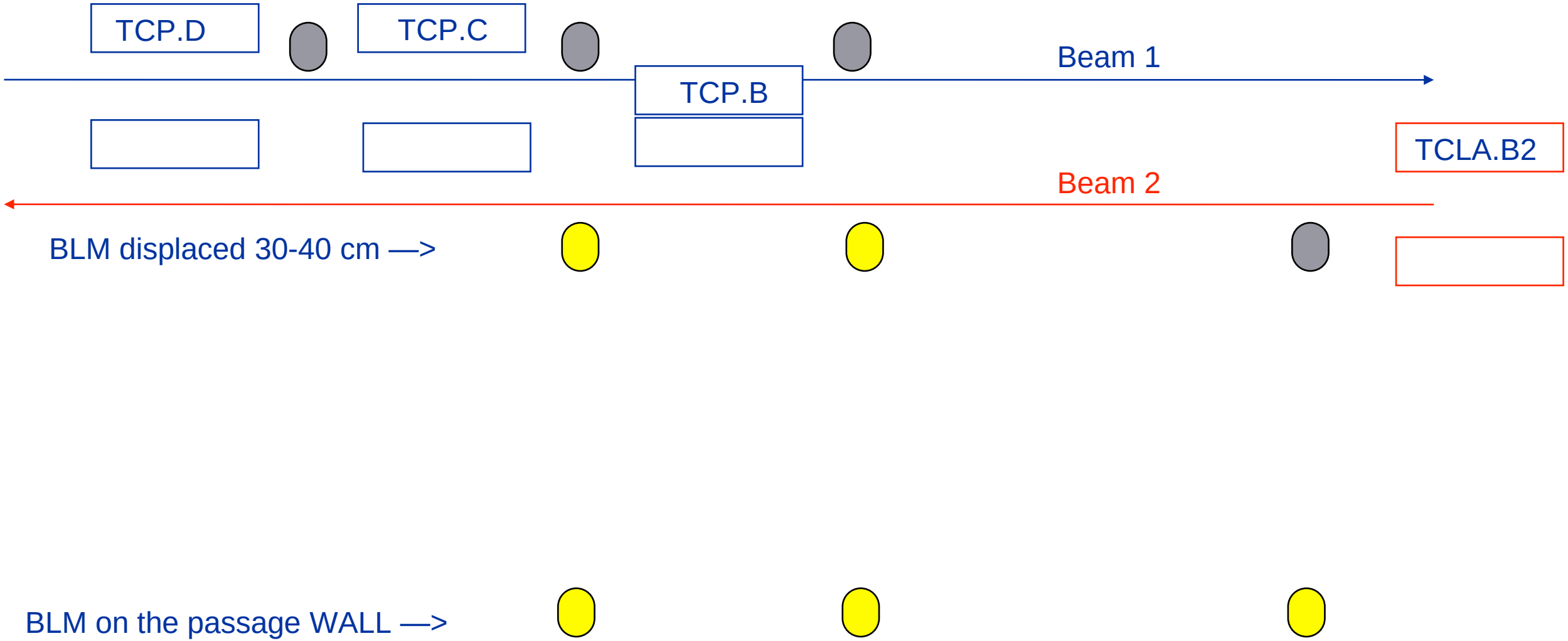

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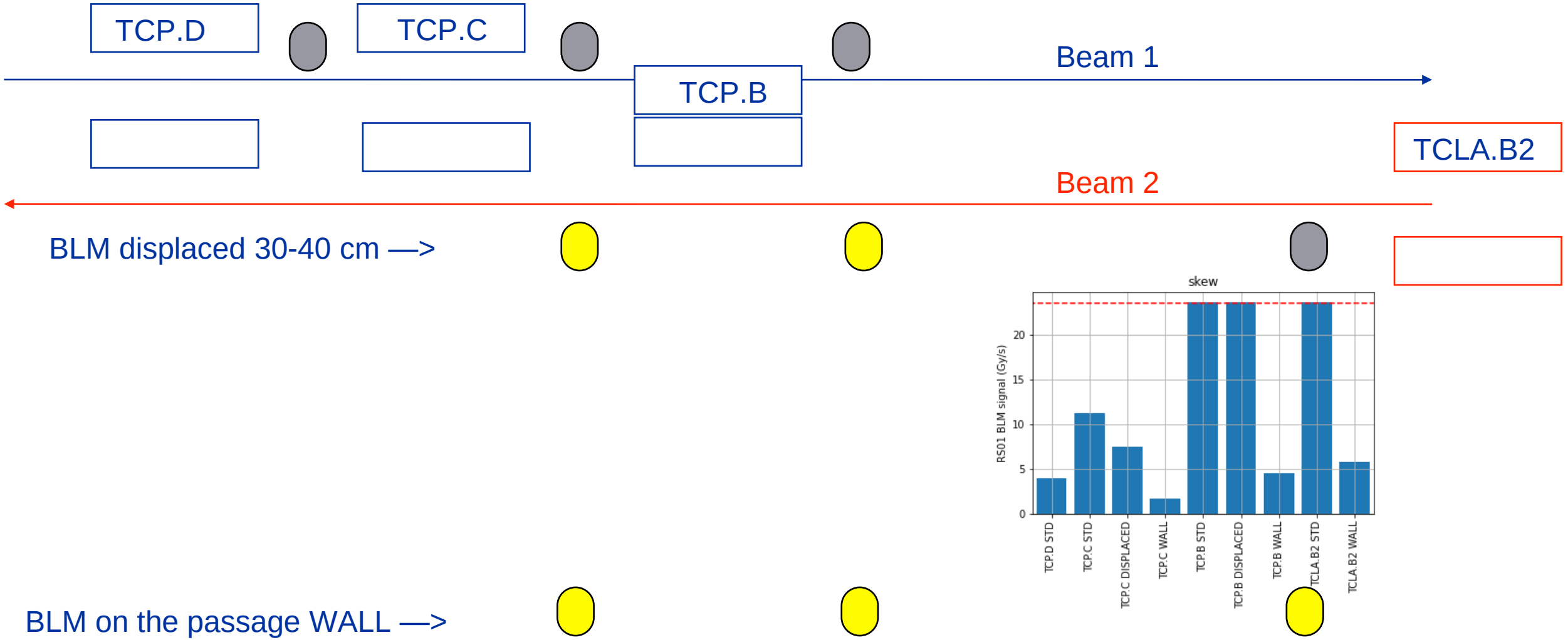
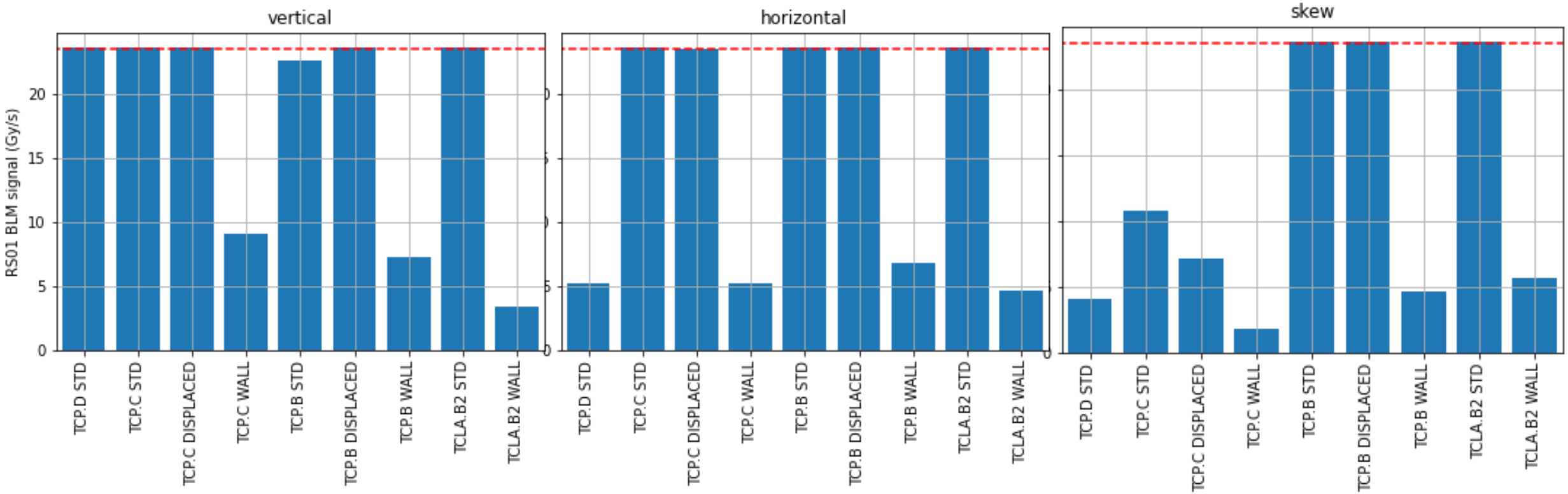


Summary of test at injection - 11th March

The IC BLM displaced by 40 cm do not show any significant improvement, with 8.8e9 p we observed saturation.

The IC BLM on the WALL they show at injection lower response, if we use these BLMs the new limits on the injection will be:

- For Horizontal: loss saturation above **3.0e10 p first rom TCP.B WALL**
- For Skew: loss saturation above **3.4e10 p first from TCLA.B2 WALL**



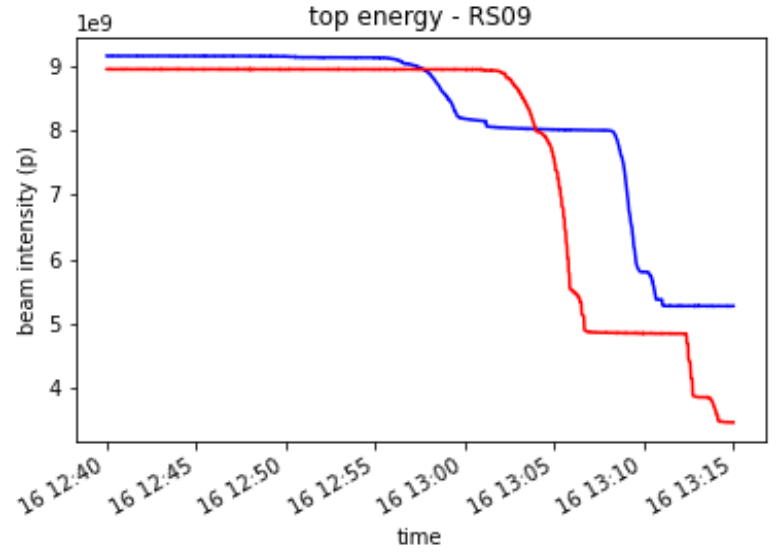
Test at top energy - 16th March

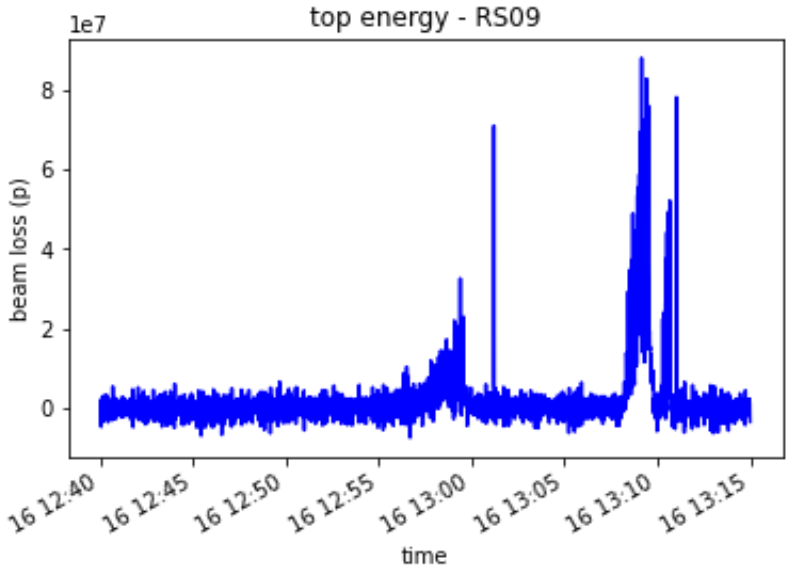
Collimation scraping tests were done at top energy on Saturday 16th March to study the onset of signal on the new BLMs.

Thanks to OP to take the data!!

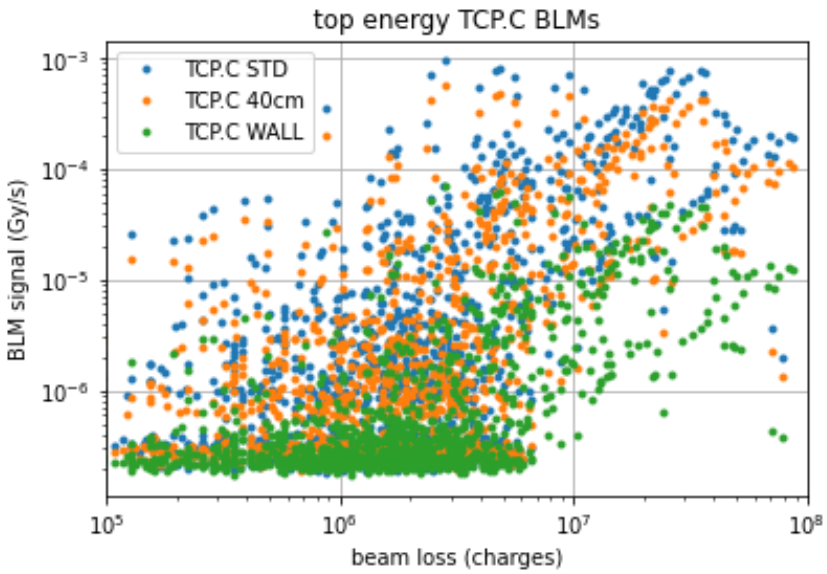
The final response for the creation of the BLM family thresholds should be calculated once the collimation hierarchy and alignment is well established.

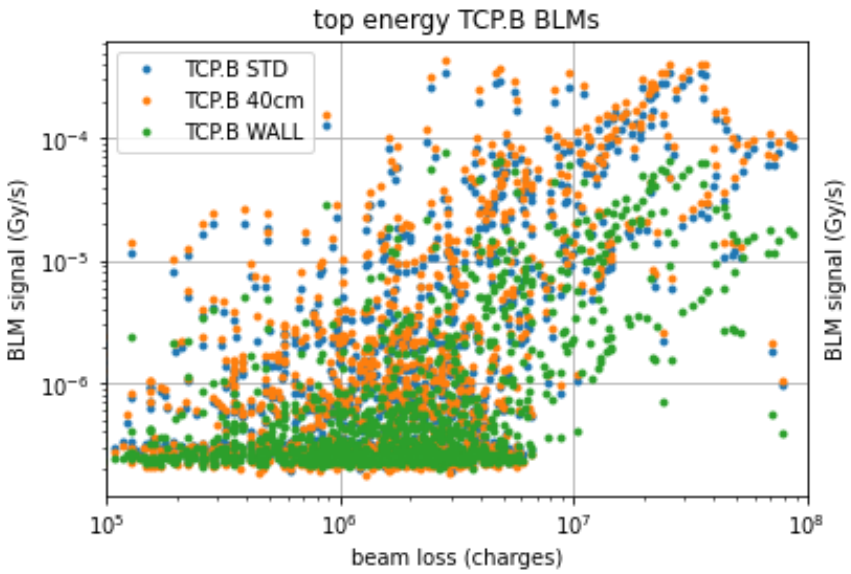
This test is not conclusive also because the scraping happened in more than one plane at the same time.

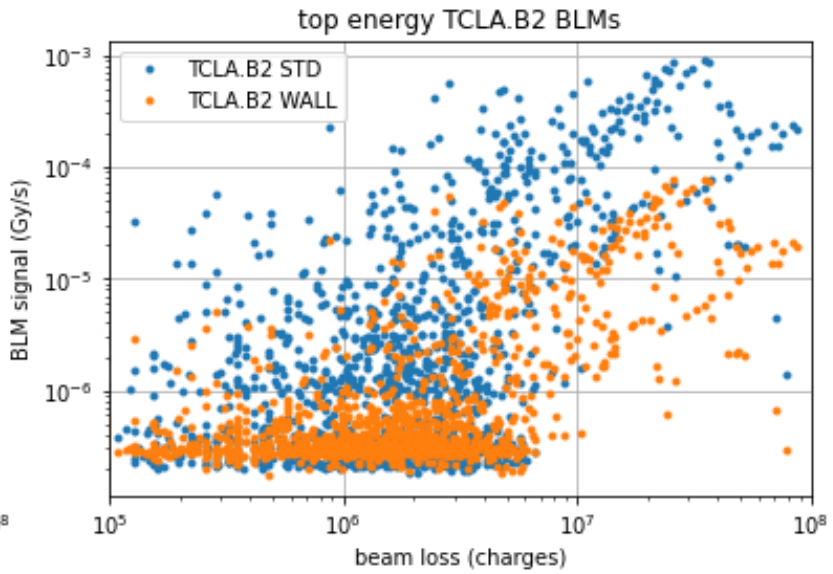




Sensitivity of BLM on the passage WALL - RS09





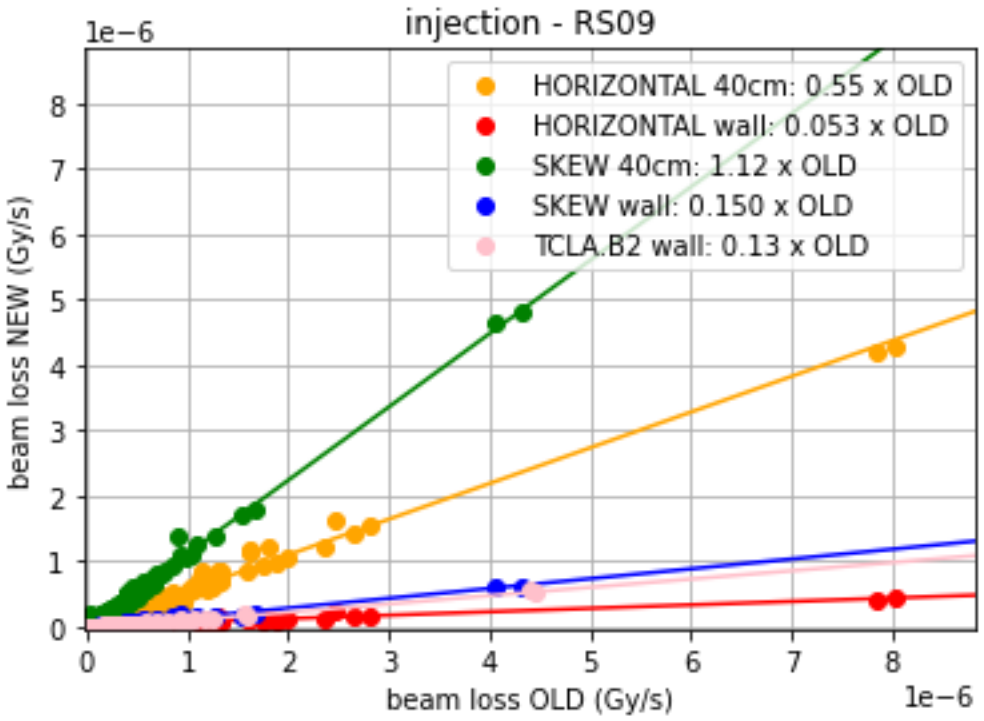


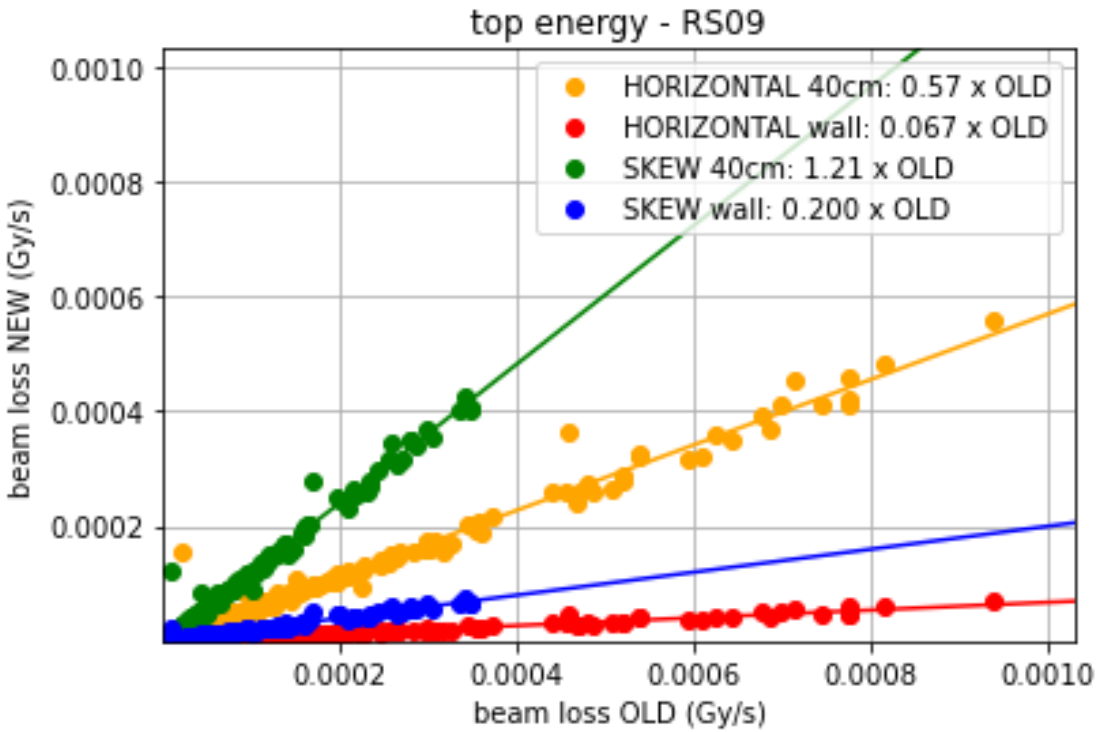
The scraping at very low intensity indicates that the BLM on the WALL can detect beam losses from direct impact at the collimator above 1e6-1e7 protons.

Factors between signals

The slope of these measurements could be used to estimate the expected response change.

Still final numbers will be calculated with the validation loss maps.





Thresholds strategy

BLM name 2023	Family 2023 (B1+B2)	Additional BLM 2024 for same protected element	Family 2024 (B1-wall)
BLMTI.06L7.B1E10_TCP.D6L7.B1 (external beam line)	THRI_COLL_7_TCPPM		
BLMTI.06L7.B1E10_TCP.C6L7.B1 (external beam line)	THRI_COLL_7_TCPPM	~~BLMTI.06L7.B1**I10**_TCP.C6L7.B1 (internal beam line)~~ BLMTI.06L7.B1**W10**_TCP.C6L7.B1 (internal wall)	THRI_COLL_7_TCPPM_WALL
~~BLMTI.06L7.B1E10_TCP.B6L7.B1 (external beam line)~~	THRI_COLL_7_TCP	~~BLMTI.06L7.B1**I10**_TCP.B6L7.B1 (internal beam line)~~ BLMTI.06L7.B1**W10**_TCP.B6L7.B1 (internal wall)	THRI_COLL_7_TCP_WALL
BLMTI.06L7.B2I10_TCLA.B6L7.B2 (internal beam line)	THRI_COLL_7_TCLA_HI	BLMTI.06L7.B2**W10**_TCLA.B6L7.B2 (internal wall)	THRI_COLL_7_TCLA_HI_WALL

Use the new BLMs on the WALL - this will provide more margin to the injection losses.

Notice that the BLM in the vertical collimator remains untouched - no limitation was observed in 2023.

New families will have the same collimation model but the response will be updated.

The signal of the LIC will be monitored along the Run to define the final strategy for the upgrade of the BLM system.

Conclusion

The usage of the IC BLM installed over EYETS on the passage wall seems to be the best option to mitigate the problem of the BLM signal saturation during injection.

They do not fully solve the problem but the provide more margin for injection losses:

- For Horizontal: loss saturation above **3.0e10 p first rom TCP.B WALL**
- For Skew: loss saturation above **3.4e10 p first from TCLA.B2 WALL**
- In 2023 the limit was found at 6.8e8 p

Further studies are need to finish the preparation of the threshold and to take a decision on the BLM upgrades in IP7.

BLM Latency test

Time between the injection and the BLM triggering the BIS when a collimator is closed to stop the beam.
Corrected latency is the same measurement but subtracting the time that takes to arrive to each Point.

13-03-2024 BLM Latency test in microseconds

IP	Latency B1	Latency B2	Corrected Latency B1	Corrected Latency B2
1	137	111	53.5	27.5
1	122	111	38.5	27.5
2	63	119	56.5	46.5
3	101	189	83.5	127.5
5	86	104	46.5	64.5
6	74	59	23.5	30.5
7	141	88	79.5	70.5
8	126	2407	53.5	2400.5

All Points are able to trigger a beam dump request in within 3 LHC turns (267us).

The outlier in IP8 for Beam 2 is an artefact. The collimator used has a BLM with a low pass filter, TCTPH.4R8.B2, and it took longer to trigger the dump. However, IP8 is validated with Beam 1.

Thanks to OP to take the data!
Dion Tzamarias for analysing it!

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