BCCM strategy for 2023

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SY-BI-IQ

BCCM (dI/dt) system

- The system is based on BPM signals shared with the standard BPM system (passive RF splitters)
- The beam position dependence is removed by summing the four electrode signals
- Analog operations to make the signals as slow as possible, allowing digitization with the highest possible resolution: low-pass filtering, amplification, envelope detection + rectification + level shifting, low pass filtering
- Digitization: 16-bit, 40 MHz beam-synchronous sampling, one revolution period is exactly 3564 ADC clocks
- One turn “raw intensity” is a sum of ADC samples above a “beam presence threshold” minus “no beam offset”
- One turn “raw dI/dt signal” is a difference of the one turn raw integrals from two consecutive turns
- “Raw dI/dt signals” in the other five windows are calculated as running sums of the one-turn “raw dI/dt signals”
- Every turn each of the “raw dI/dt signals” are compared to its corresponding raw dump threshold level and potential beam dump triggers are generated. All real-time calculations are done in the FPGA in an integer arithmetic.
- The BCCM absolute intensities are calculated by scaling the “raw BCCM intensities” using a “BCCM/BCT scaling factor”. The factor is a constant for each system and is obtained by matching the BCCM intensity to the corresponding BCT readings.
- The absolute dump thresholds in elementary charges are translated into “raw dump thresholds” using the same “BCCM/BCT scaling factor”

Window [turn]	1	4	16	64	225	1125
< 0.5	6	6	6	6	6	**10** (6)
≥ 0.5	3	3	3	3	**5** (2)	**10** (0.5)
Energy [TeV]			**Losses [1e11]**			

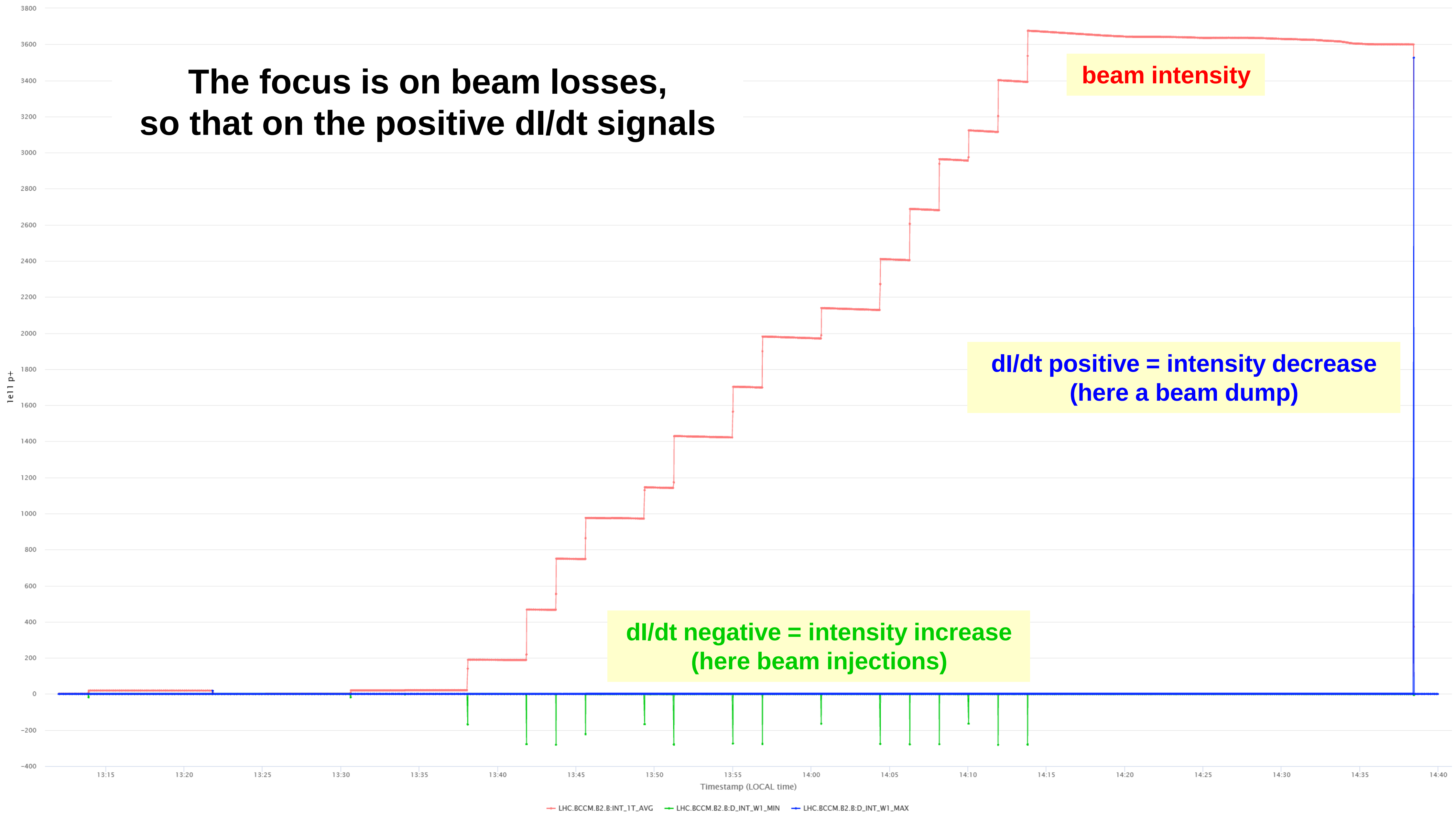
As presented on 21/10/22: Conclusions and options to investigate

- During the 2022 run the four BCCM systems have been evolving quite a bit and have been continuously tested
- The hardware and FESA are “almost final” and very reliable
- Operational extensive data logging implemented, including continuous turn-by-turn logging of the most important data and on-demand 73-turn snapshots of the 40 MHz raw ADC samples (currently stored also every beam dump)
- The residual bunch length dependence of the BPM signals is the only known problem with the current implementation of the system. The problem shows up during beam injections, **the RF longitudinal blow-up** and beam instabilities.
- The new dump threshold levels for the two longest integration windows help a lot to fulfil all the system specifications
- New lengths of the two longest integration windows are being tested. To be decided whether they are helping enough
- A 1st order low-pass filter compensating the 1st order high-pass characteristic of the BPM reduces the bunch length dependence. Unfortunately, the low-pass causes issues with the “stability of the signal baseline”.

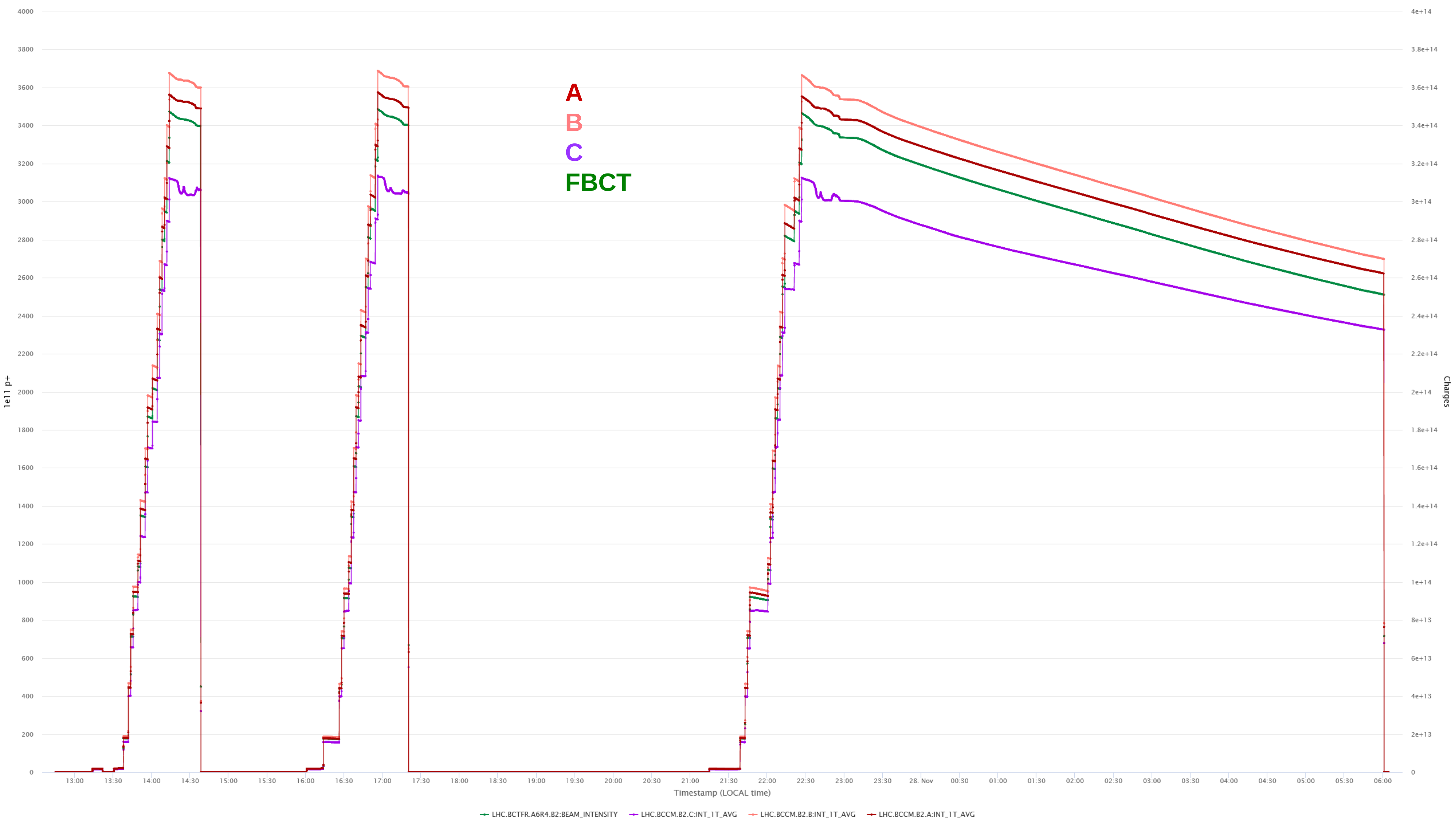
Options to investigate:

- A less aggressive 1st order low-pass, with the hope to improve the “stability of the signal baseline”
- FBCTs with the flat frequency characteristic as the beam signal source

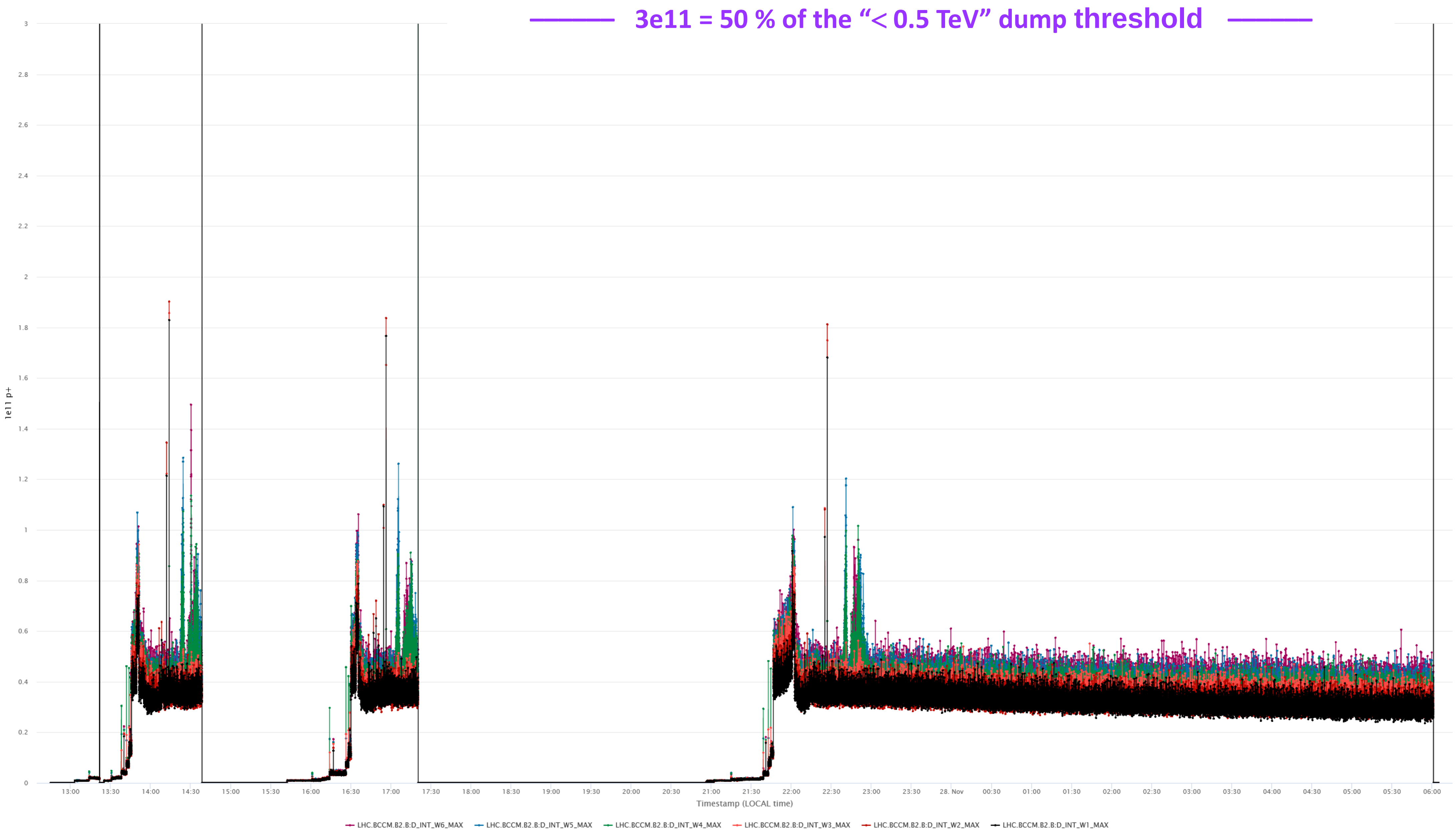
BCCM (– dI/dt) polarity convention



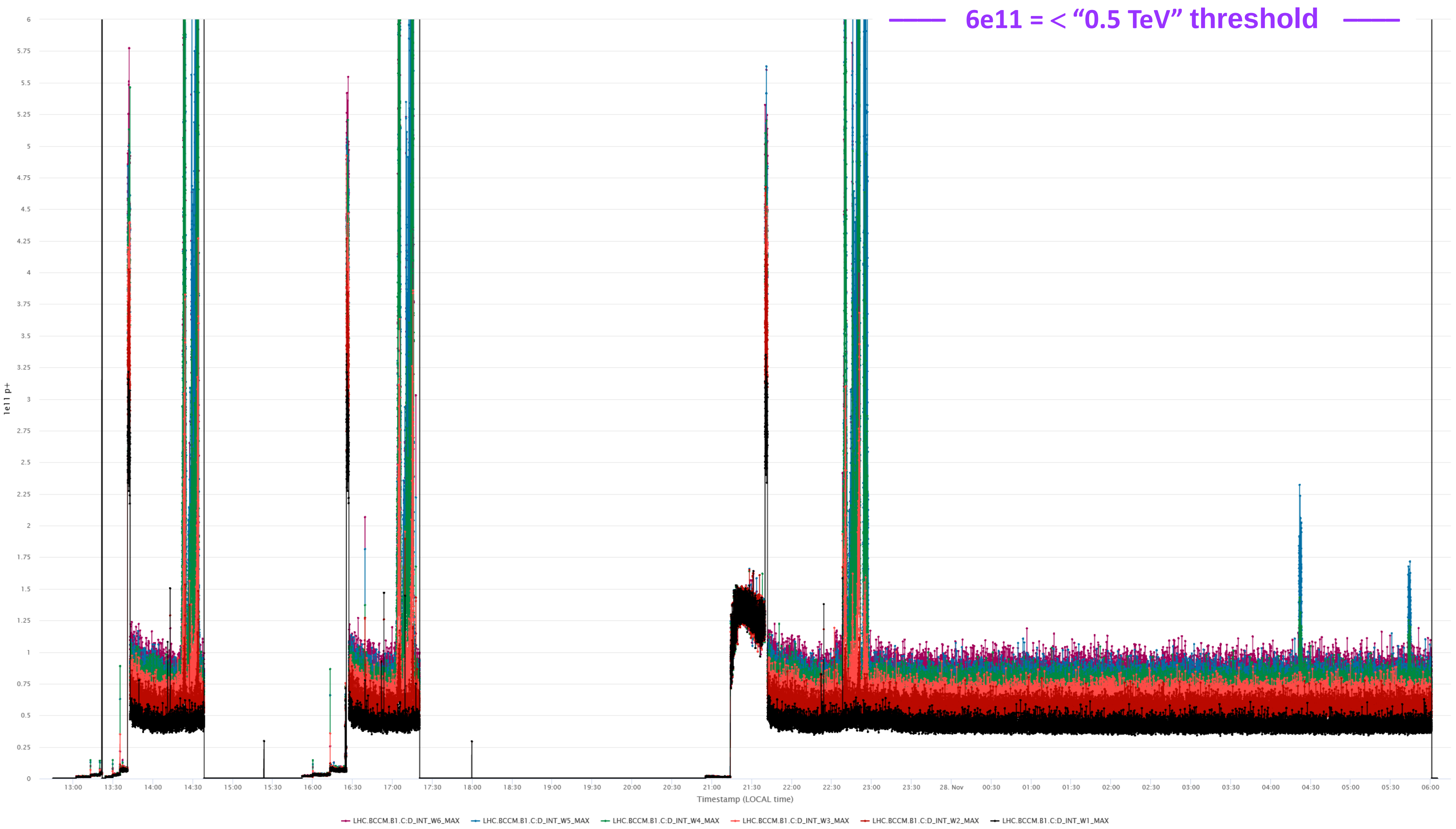
Performance at the end of the 2022 run – systems A, B, C + FBCT



The 2022 filtering winner: dI/dt 1-s maxima for top intensities ≈3400e11



BCCM system C based on FBCT signals had very bad performance



BCCM development system C

- Once systems A and B become operational, their state becomes frozen
- To carry on with optimisations, we need a development system, which is initially a copy of the operational systems, and can be modified easily
- The development system C will not have any connections to the interlock system
- If significant improvements were achieved on system C, they could be propagated to the operational systems during YETS. The improvements should be important enough to justify the system recommissioning

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LHC

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ENGINEERING CHANGE REQUEST

Installing A BCCM Development System During YETS 2022-2023

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

A new Beam Charge Change Monitor (BCCM) development system will be installed during YETS 2022-2023. The development system will be used only for BCCM performance optimisation with beam, while the existing BCCM redundant system will be commissioned to operate in the LHC machine protection system.

SUMMARY OF THE ACTIONS TO BE UNDERTAKEN:

- Split electrode signals of BPMs BPMYA.5L4.B1 and BPMYB.5L4.B2.
- Install a development BCCM system in rack BY08 in UA43.
  The development system will not be connected to the LHC machine protection system nor be used for any operational purposes.

System status, the strategy and conclusions

- Systems A and B with the new filtering scheme are installed and are ready for the beam
- System C is still in the lab and is used for testing the newest FPGA and FESA codes.
  The system will be soon moved to UA43 and connected to the BPM signals.

- The system performance achieved at the end of the 2022 run should be enough to make the system operational.
  The system hardware and software worked very reliably.

- The 2023 intensity ramp-up will be used to optimise system settings and to check the system performance
- Once the system is proven to operate well with the full beam intensity, it can be commissioned for operation and its beam triggers unmasked. At this point also all critical system settings will become read-only.
- **This year we definitely should make the system operational**

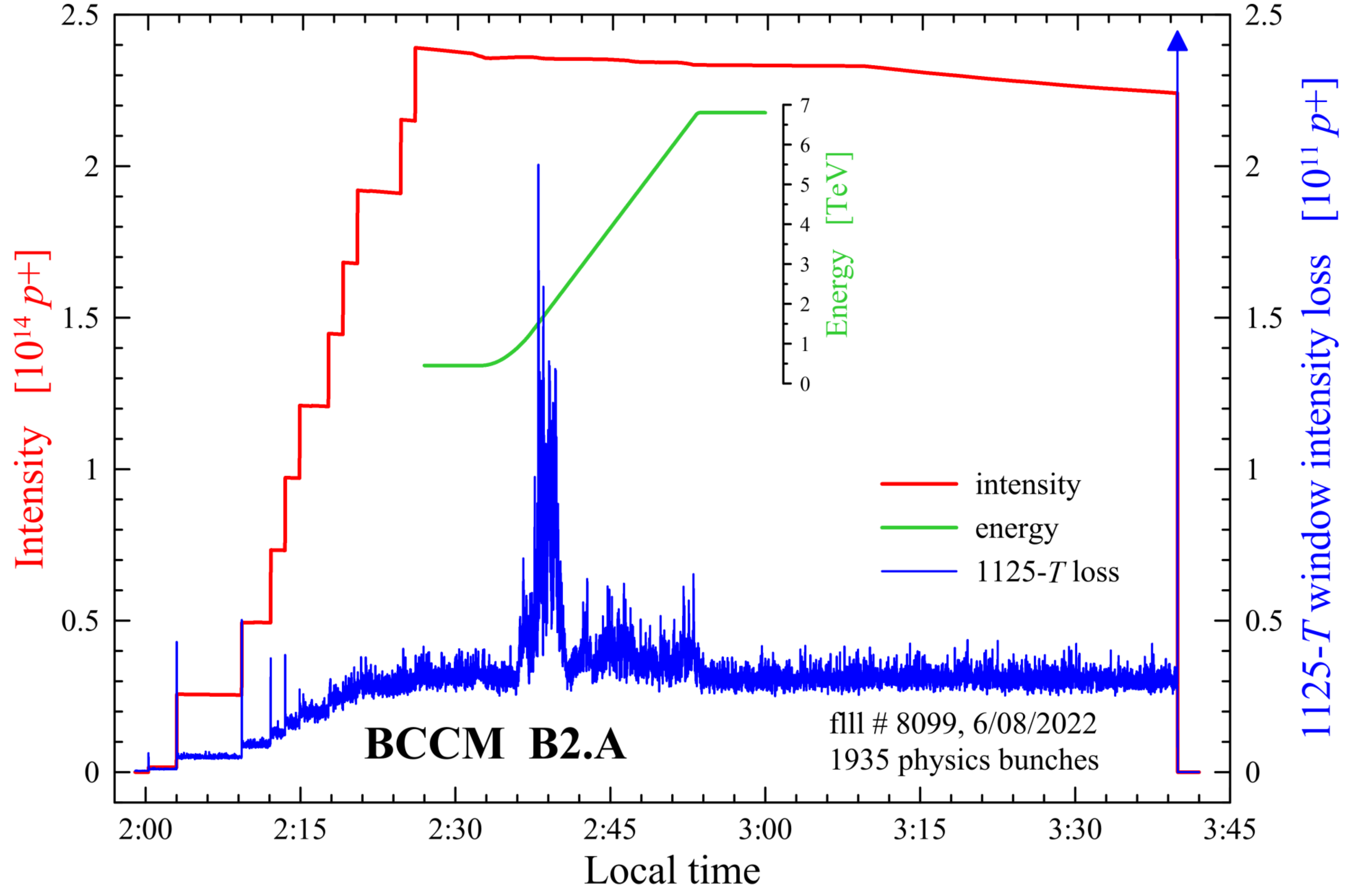
Plan B:

- If the system had not enough robustness for the RF longitudinal blow up for some window lengths, maybe the thresholds for such windows could be relaxed to make the system operating reliably
- A bit relaxed protection is better than no protection at all
- System C could be used to fight for the missing performance

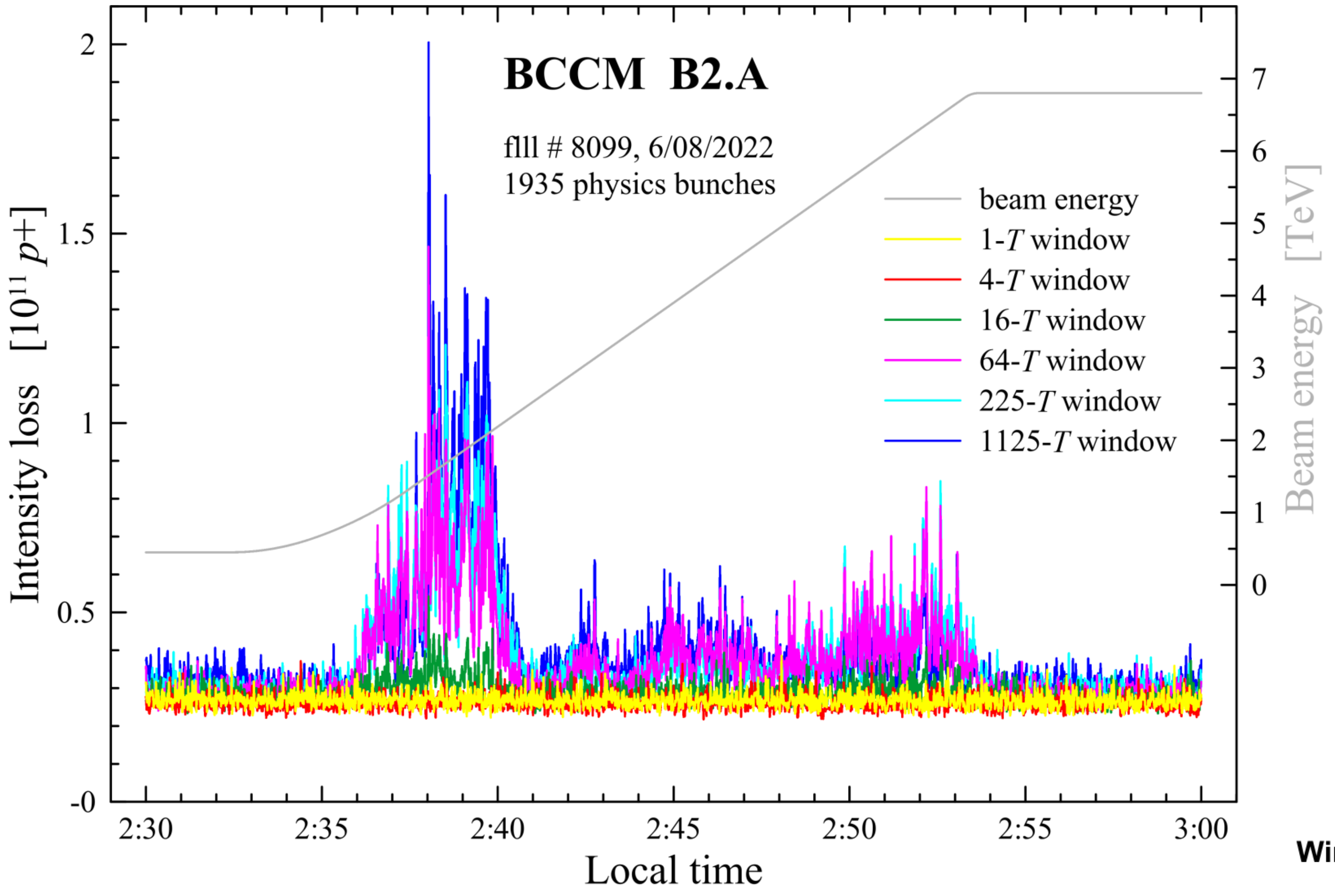
Window [turn]	1	4	16	64	225	1125
< 0.5	6	6	6	6	6	**10**
≥ 0.5	3	3	3	3	**5**	**10**
Energy [TeV]			**Losses [1e11]**			

Spare slides

BCCM operation – perturbations during the ramp



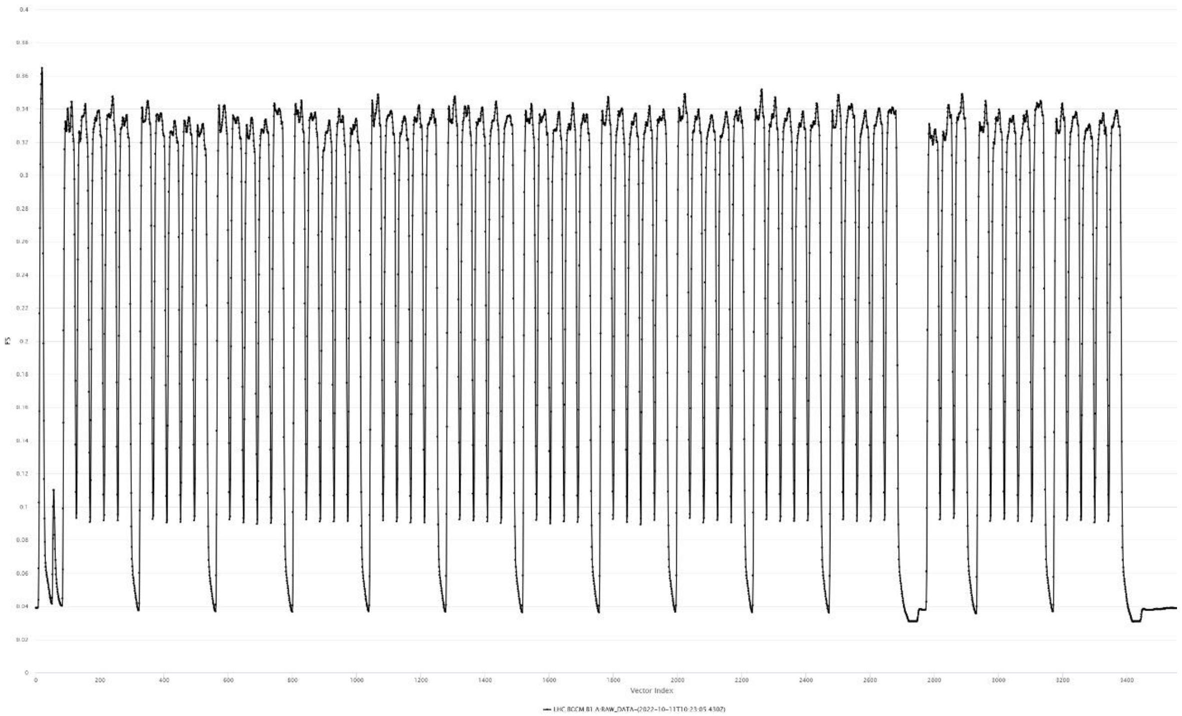
BCCM operation – perturbations during the ramp



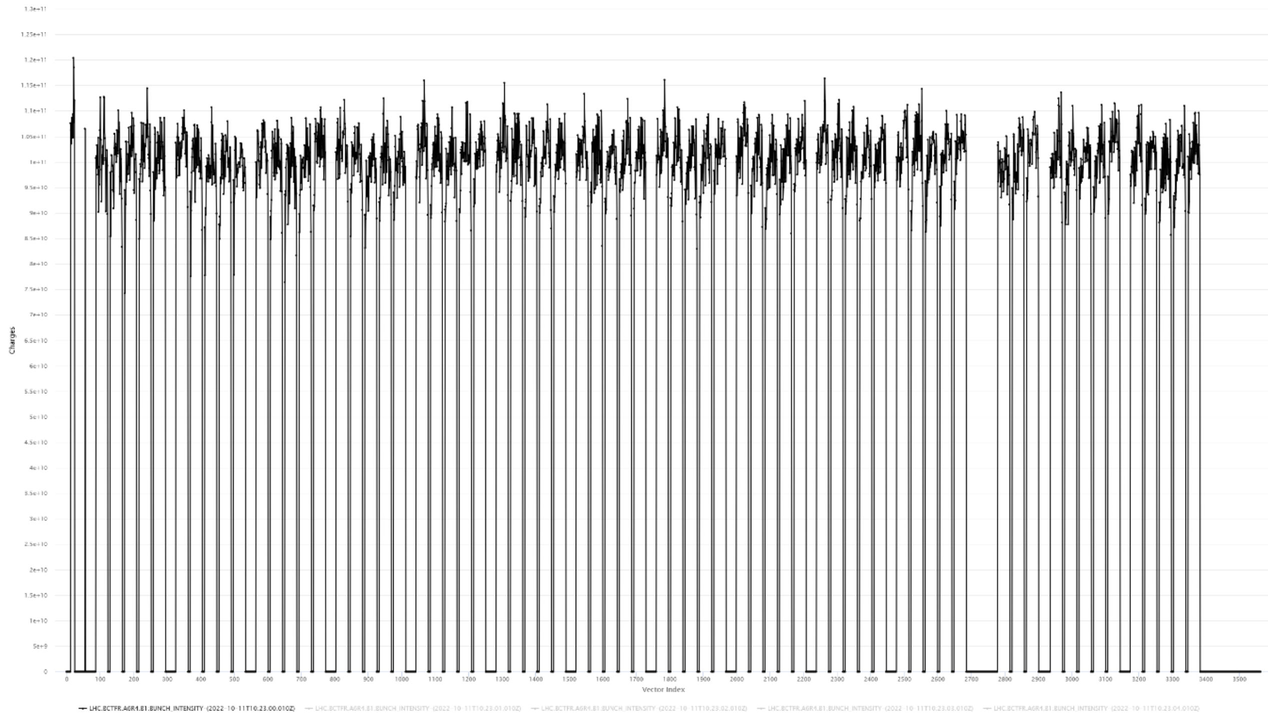
Window [turn]	1	4	16	64	225	1125
< 0.5	6	6	6	6	6	**10** (6)
≥ 0.5	3	3	3	3	**5** (2)	**10** (0.5)

Energy [TeV] **Losses [1e11]**

25 ns data: BCCM vs FBCT



one turn of BCCM data



one turn of FBCT data

Updated dump threshold tables

Window [turn]	1	4	16	64	225	1125
< 0.5	6	6	6	6	6	**10** (6)
≥ 0.5	3	3	3	3	**5** (2)	**10** (0.5)

Energy [TeV] **Losses [1e11]**

Window [turn]	1	4	16	64	225	1125
< 0.5	1	1	1	1	1	**1.7** (1)
≥ 0.5	0.5	0.5	0.5	0.5	**0.8** (0.3)	**1.7** (0.08)

Energy [TeV] **Relative losses [‰] (FS = 6e14)**

BCCM (dI/dt) system

shared BPMs:

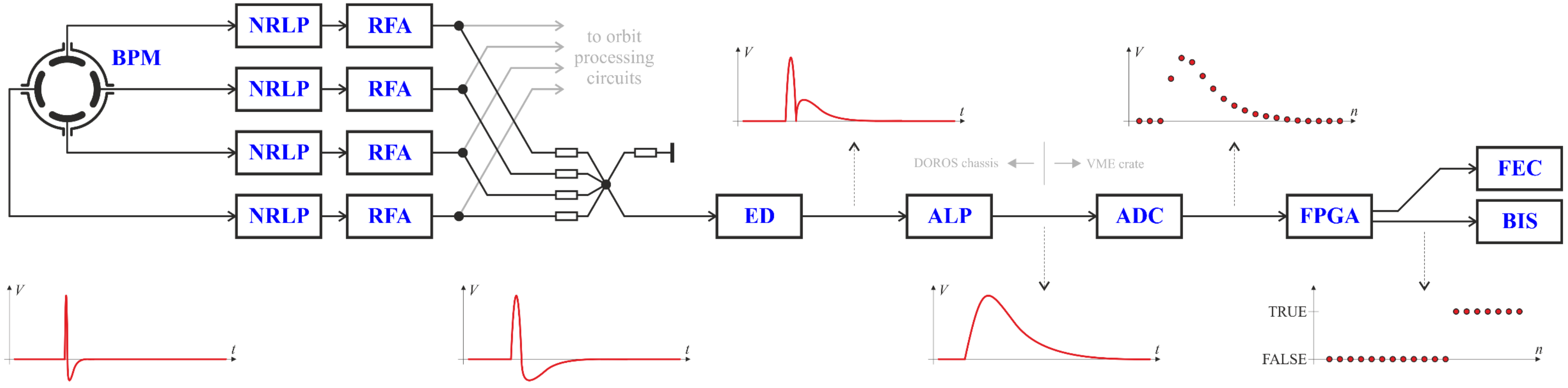
system A: BPMYA.5R4.B1+B2
system B: BPMYA.6R4.B1+B2

NRLP – Non-Reflective Low-Pass (≈ 80 MHz)

RFA – RF Amplifier

ED – Envelope Detector

ALP – Active Low-Pass (≈ 2 MHz)



- The system is based on BPM signals shared with the LHC beam position measurement system (passive RF splitters)
- The beam position dependence is removed by summing the four electrode signals
- Analog operations on the signals: low-pass filtering, amplification, envelope detection + rectification + level shifting, low pass filtering
- Digitization: 16-bit, 40 MHz sampling synchronous to the circulating beam (one revolution period is exactly 3564 ADC clocks).
  The 40 MHz ADC B1 and B2 clocks are derived from the 400 MHz RF frequencies received by optical fibers from the RF system.
- One turn “raw intensity” is a sum of ADC samples above a “beam presence threshold” minus “no beam offset”, selected from one turn 3564 samples
- One turn “raw dI/dt signal” is a difference of the one turn raw integrals from two consecutive turns
- “Raw dI/dt signals” in the five other integration windows are calculated as running sums of the one-turn “raw dI/dt signals”
- Every turn each of the “raw dI/dt signals” are compared to its corresponding raw dump threshold level and potential beam dump triggers are generated.
  All real-time calculations are done in the FPGA in an integer arithmetic.
- The BCCM absolute intensities in elementary charges are calculated by scaling the “raw intensities” using a “BCCM/BCT scaling factor”.
  The factor is a constant for each system and is obtained by matching the beam intensity evaluated by the BCCM to the corresponding BCT readings.
- The absolute dump thresholds in elementary charges are translated into “raw dump thresholds” using the same “BCCM/BCT scaling factor”.