BCCM – experience from the 2023 run and strategy for the 2024 operation

240th Machine Protection Panel meeting, 17/11/23

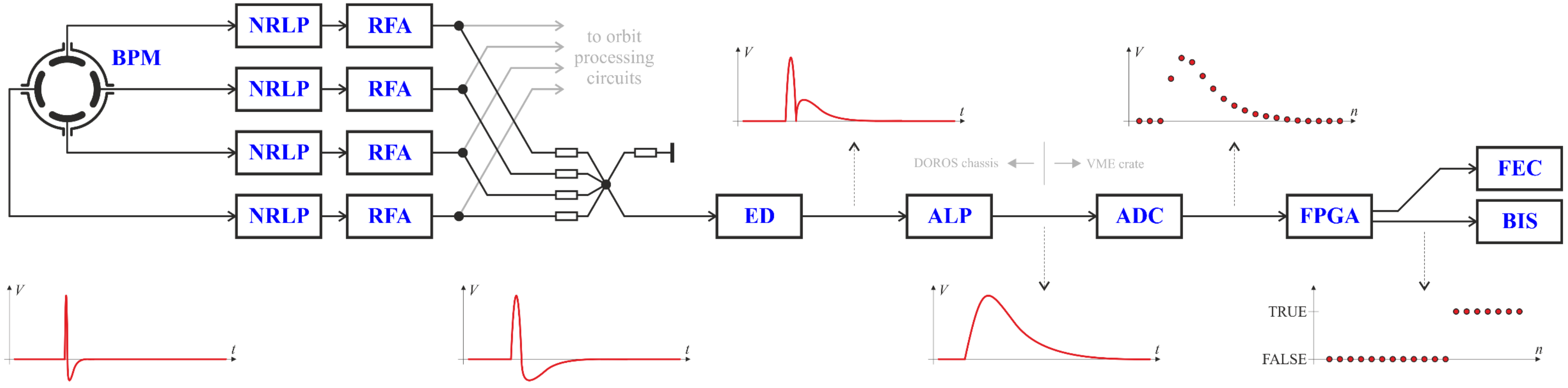
Marek Gasior, Tom Levens

SY-BI-IQ

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)

- BCCM uses BPM signals with the position dependence removed by summing the electrode signals
- Analog processing to make the signals as slow as possible, allowing digitization with the highest possible resolution: low-pass filtering, amplification, envelope detection + rectification + again filtering
- Digitization: 16-bit, 40 MHz beam-synchronous sampling, 1T period = 3564 ADC clocks
- 1T “raw intensity” is ADC sample sum above a “beam presence threshold” minus “no beam offset”
- 1T “raw dI/dt signal” is a difference of the 1T raw integrals from two consecutive turns
- “Raw dI/dt signals” in the other five integration windows are the running sums of 1T “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 constant “BCCM/BCT scaling factor”
- The absolute dump thresholds in elementary charges are translated into “raw dump thresholds” using the same “BCCM/BCT scaling factor”

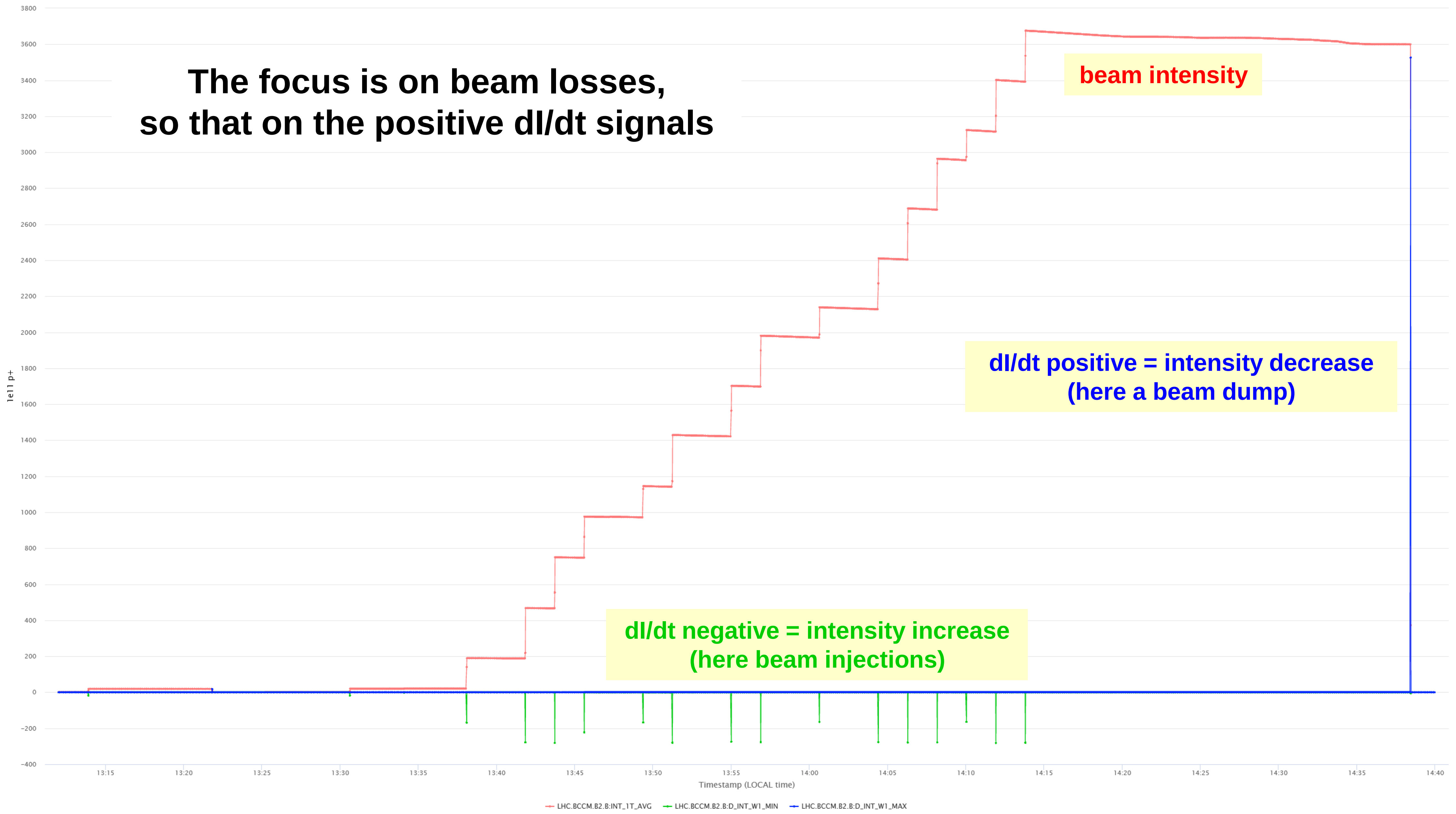
Window [turn]	1	4	16	64	225	1125
< 0.5	6	6	6	6	6	10
≥ 0.5	3	3	3	3	5	10
Energy [TeV]	Losses [1e11]					

Changes for the 2023 startup and during the run

- RF filtering changed for the startup to decrease the sensitivity to the longitudinal RF blow-up
- The hardware of the operational systems have not changed since the 2023 startup
- Installation of the R&D system C
  - It does not have any BIS interface
  - It is meant to be used only by the experts to optimise the system hardware, firmware and software
  - If any important improvements were found, they could be propagated to the operational systems whenever convenient
- Upgrades of the FPGA code, last one in May
- Upgrades of the FESA code, last one in May
- System settings optimisation, last change in June

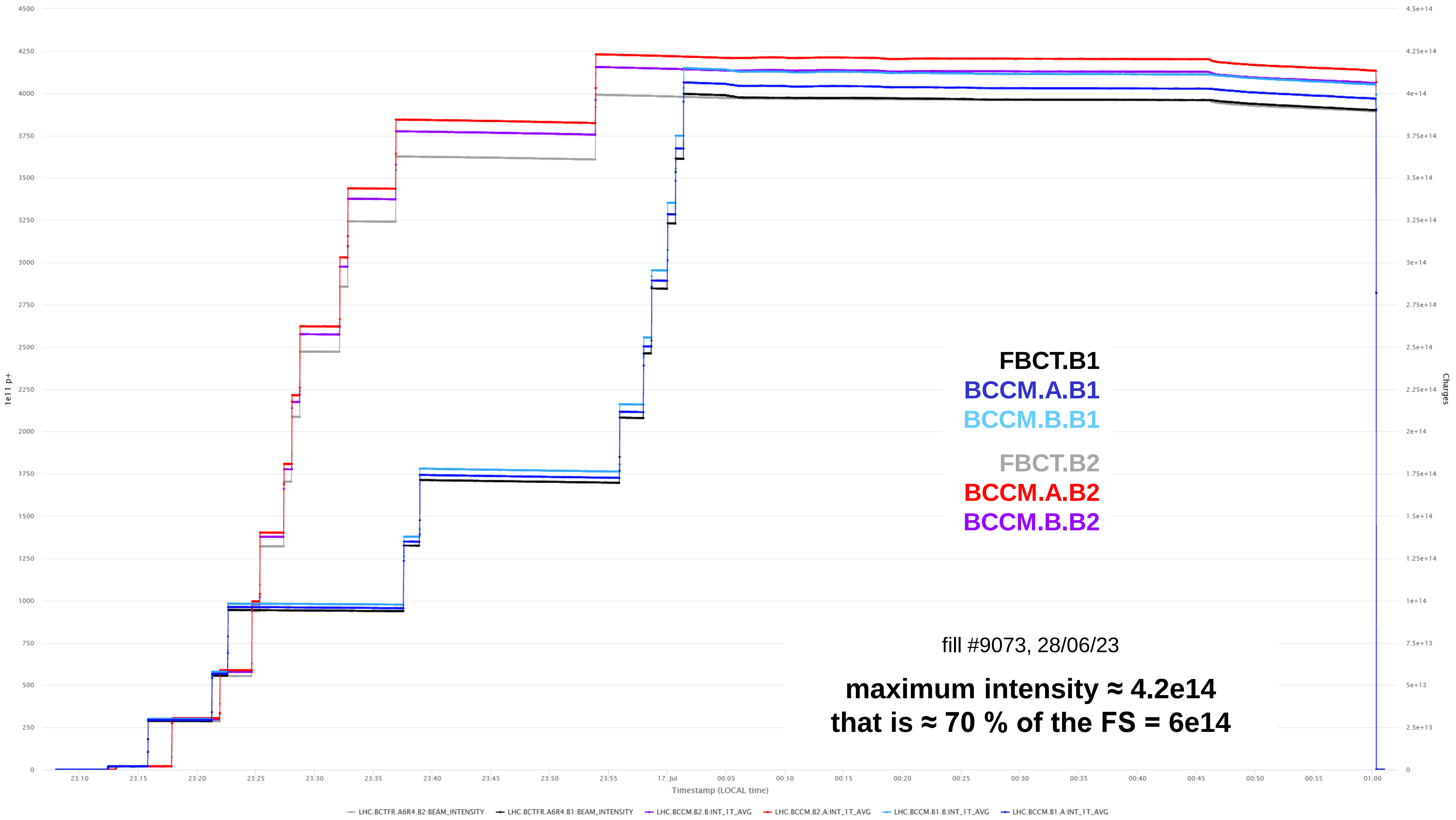
- **The operational systems A and B have been operated without any changes since June**

BCCM (– dI/dt) polarity convention

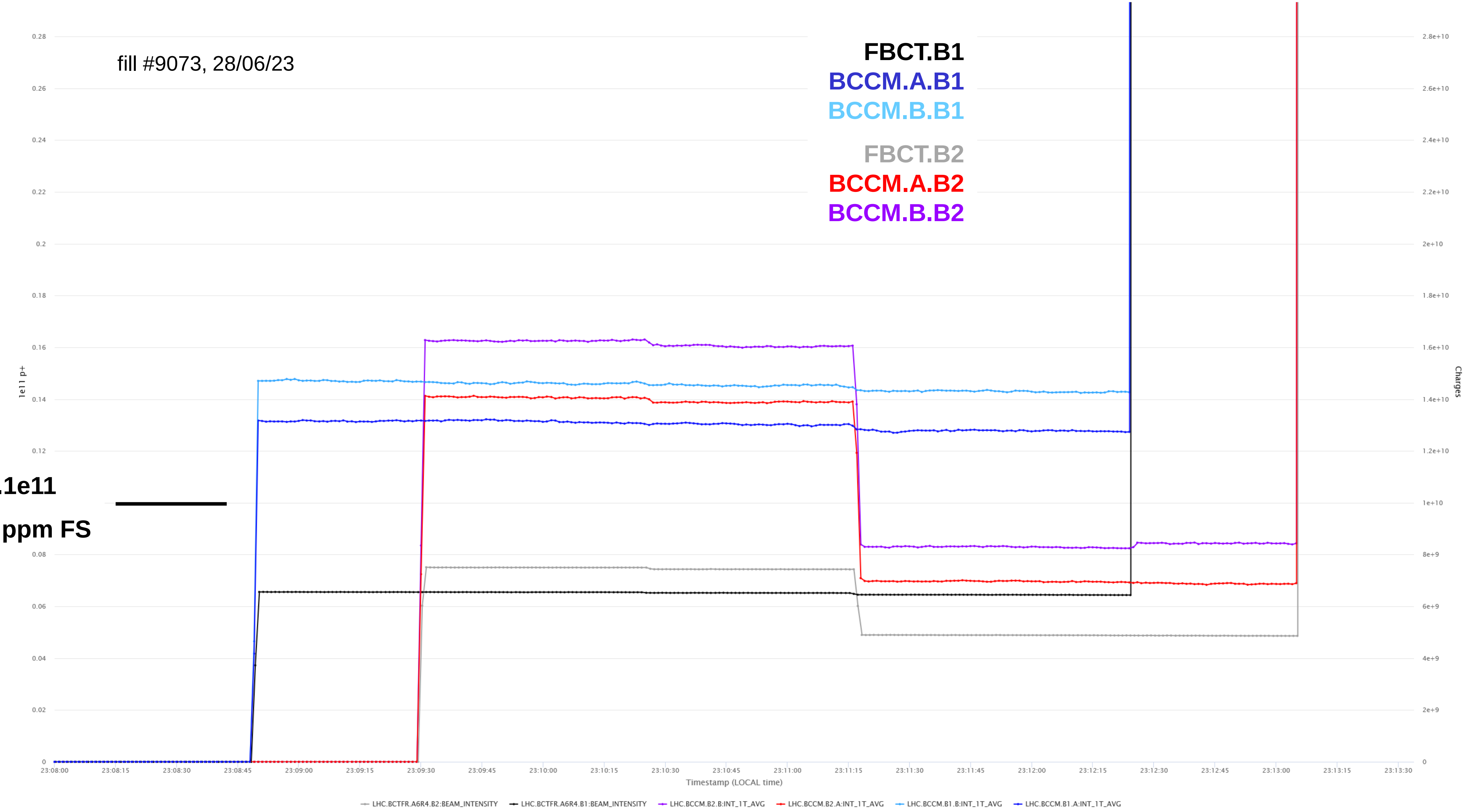


Weaknesses: overestimation of the beam intensity

**70 %
FS**



Overestimation of the beam intensity for single bunches

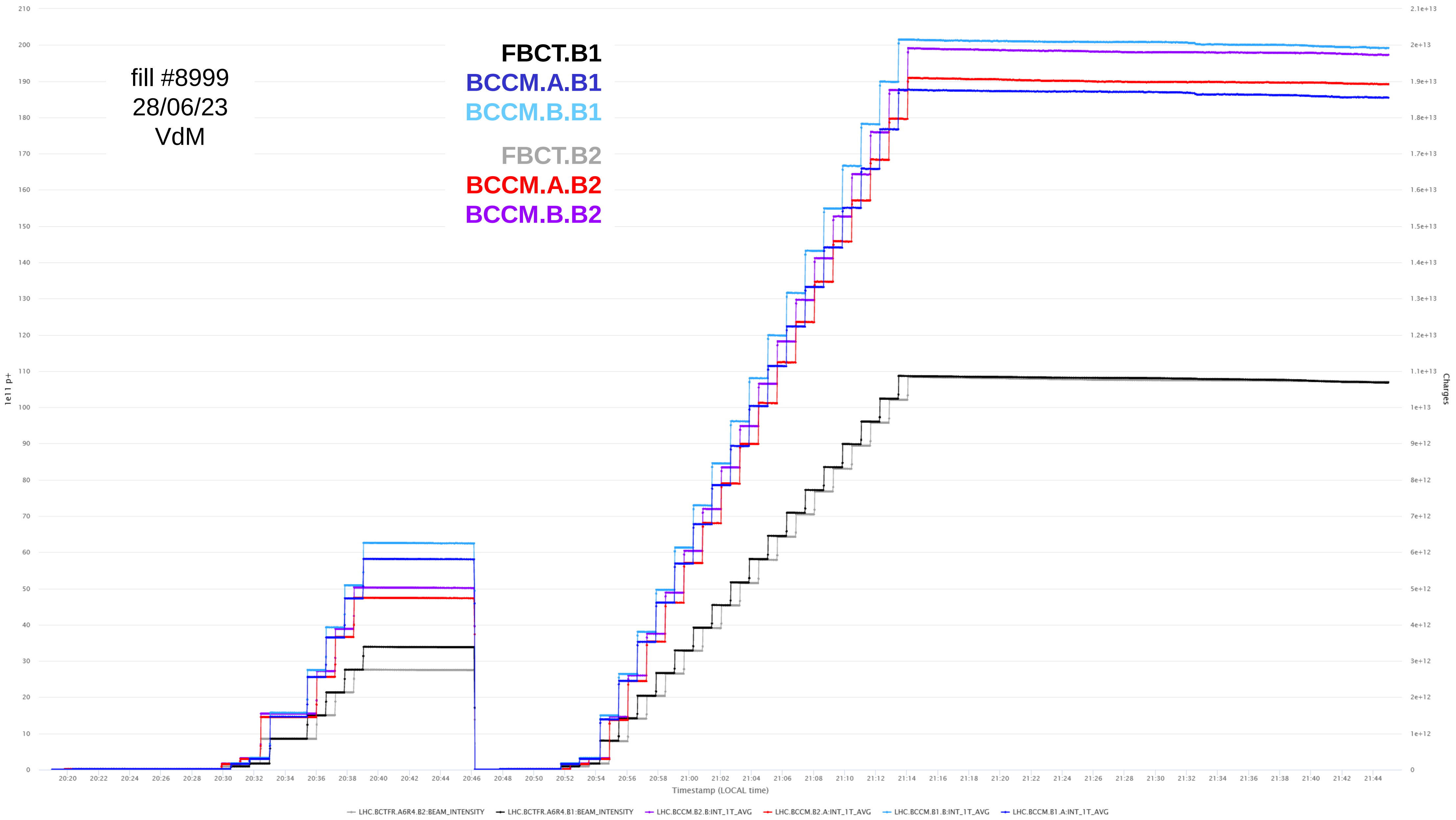


0.1e11

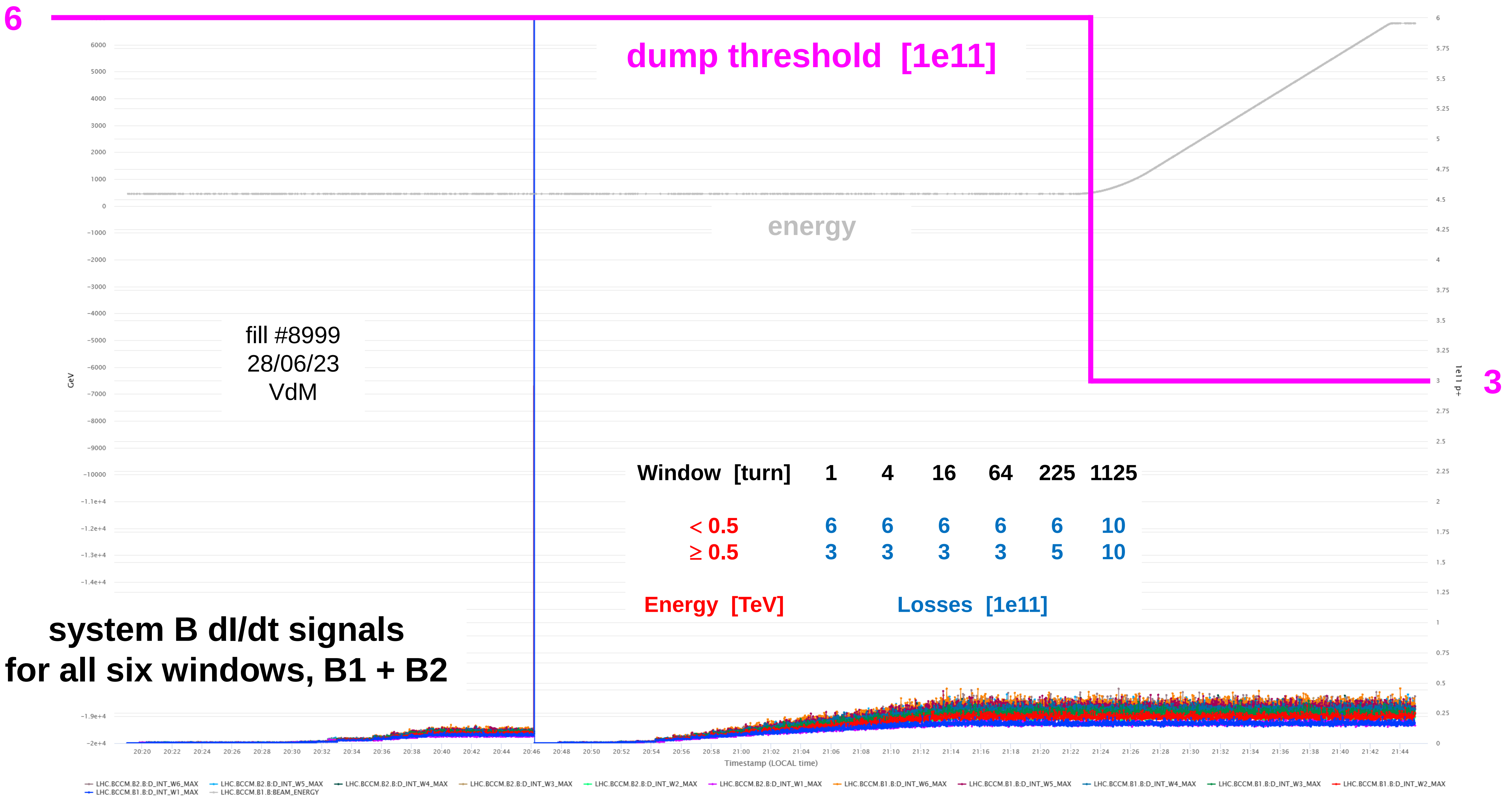
≈ 17 ppm FS

Overestimation of the beam intensity for single bunches

3.5 % FS

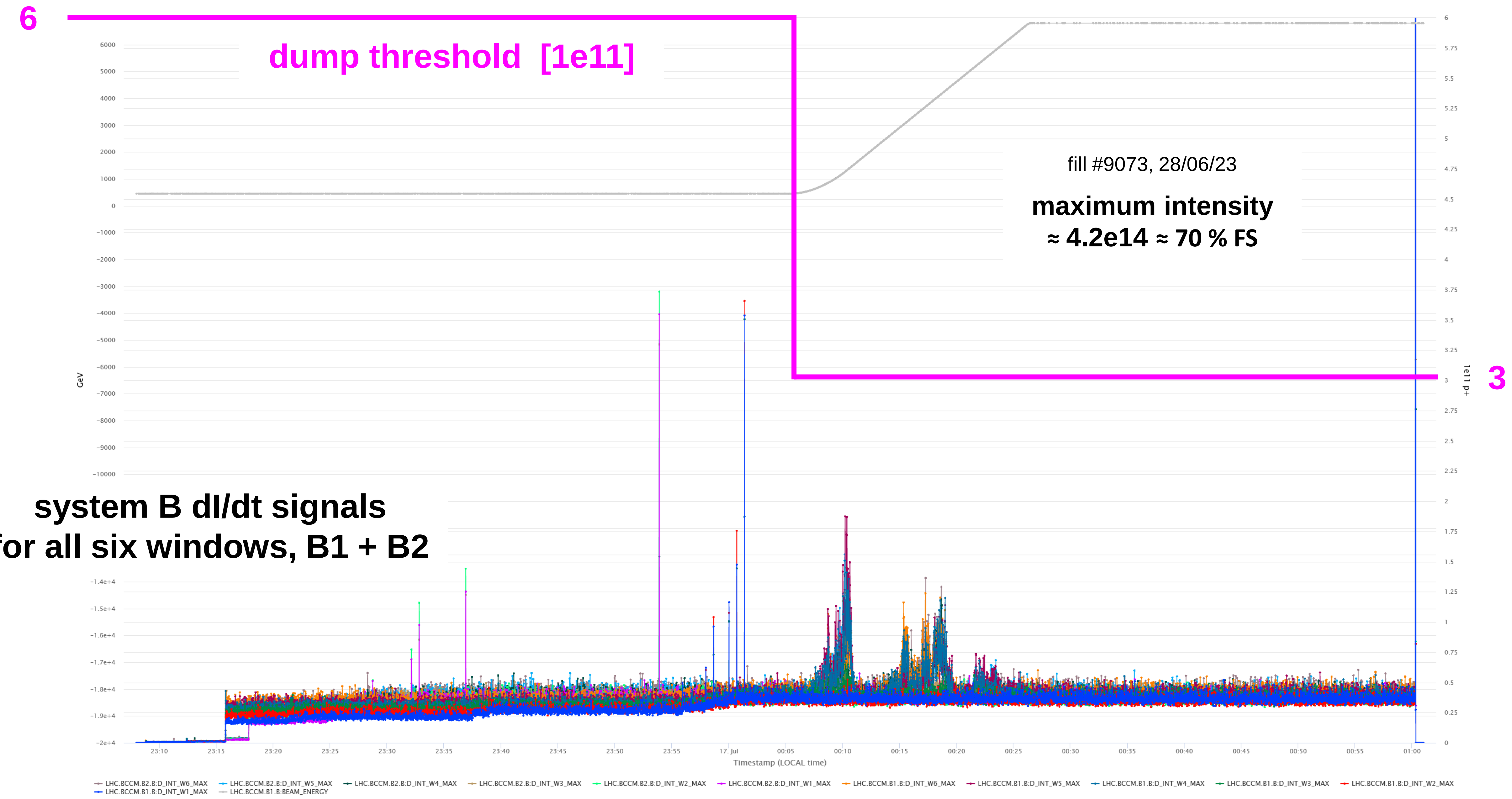


Overestimation of the beam intensity for single bunches



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]					

Weaknesses: spurious dI/dt signals during injections and the ramp



Options for the 2024 run

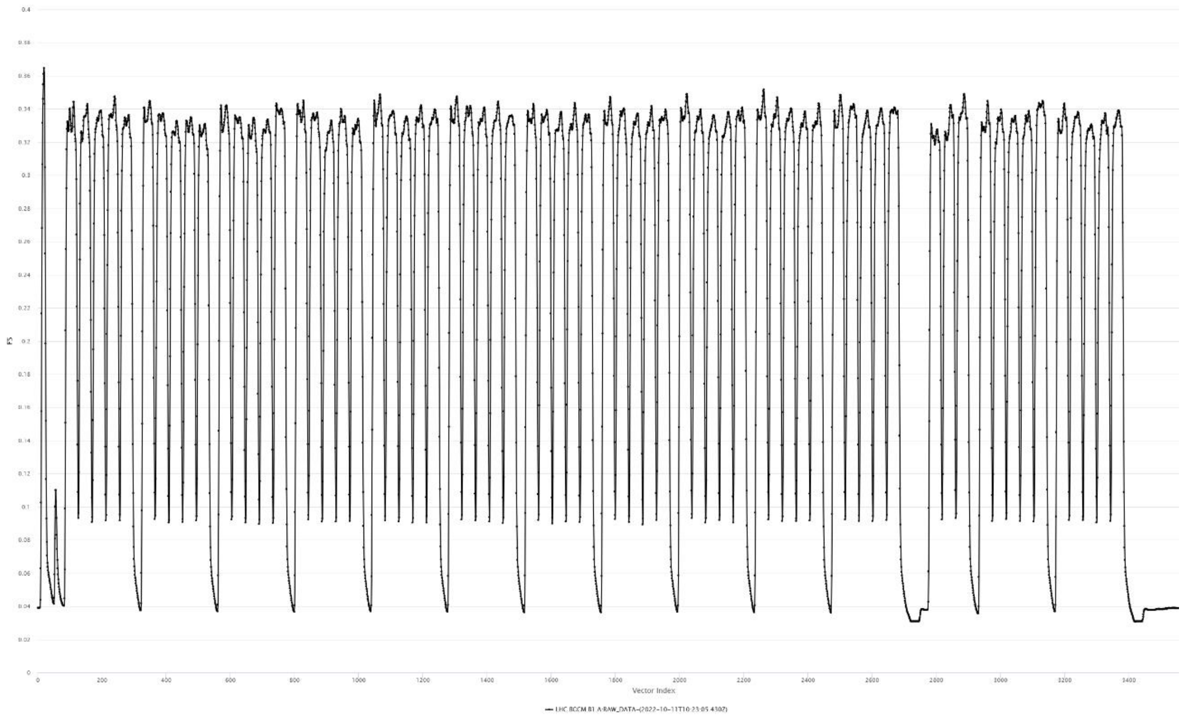
- Required updates for the startup: minor improvements in the post-mortem buffers
- Optional updates: new algorithms developed during the 2023 run for the FPGA processing to cope with the weaknesses

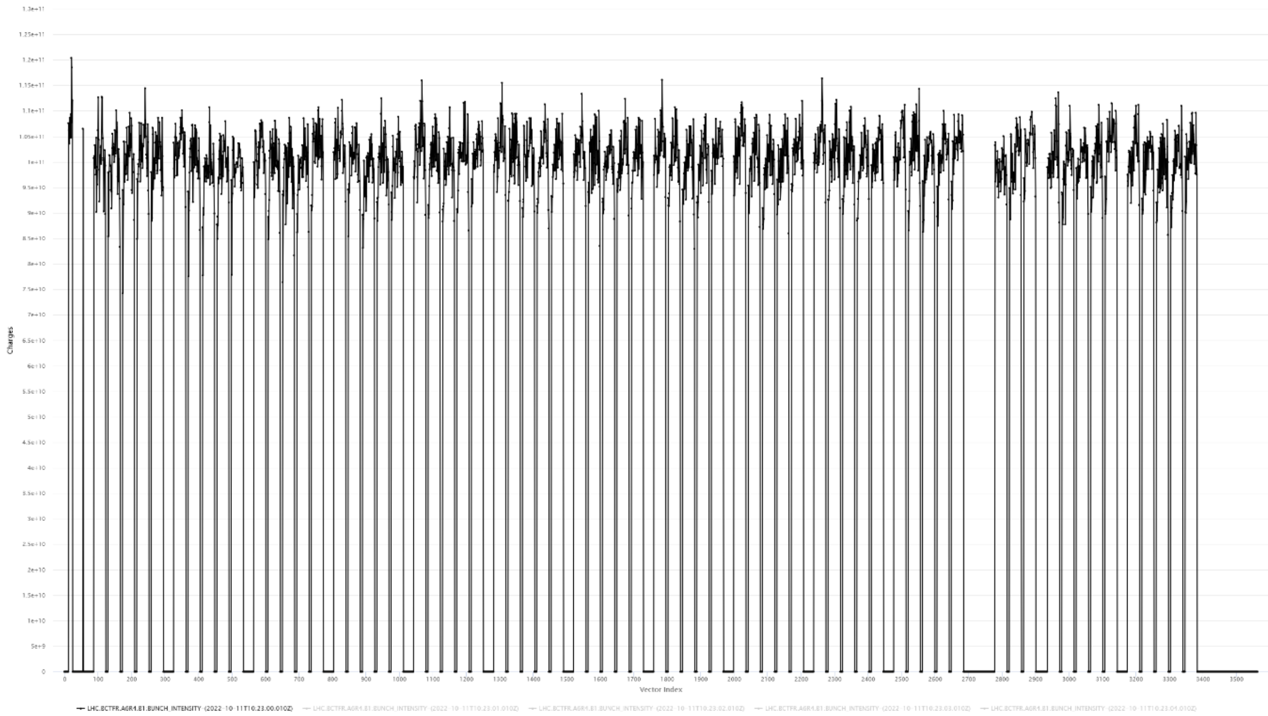
- Commissioning option 1 = “improvements first”:
  - Do both, the required and the optional updates
  - Optimise the processing and settings while waiting for the machine to operate with long batches and “important intensities”, which is something like 600e11 = 10 % of the system full scale
  - Enable the interlocks and commission the system with “the important intensities” according to the updated procedures

- Commissioning option 2 = “safety first”:
  - Do only the required minor updates, which do not influence the system core functionality.
    The operational systems start in 2024 (almost) exactly in the 2023 configuration well tested with large intensities.
  - The optional updates are applied only for the R&D system C, where they are tested during the whole 2024 run
  - Enable the interlocks before the first injection and do a “progressive commissioning” with the increasing intensity
  - Do the final commissioning according to the updated procedures once the machine operates with “the important intensities”

Spare slides

25 ns data: BCCM vs FBCT





one turn of BCCM data | **one turn of FBCT data**

Dump threshold levels

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]					

Window [turn]	1	4	16	64	225	1125
< 0.5	1	1	1	1	1	1.7
≥ 0.5	0.5	0.5	0.5	0.5	0.8	1.7
Energy [TeV]	Relative losses [‰] (FS = 6e14)					

BCCM (dI/dt) system

shared BPMs:

system A: BPMYA.5R4.B1+B2
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NRLP – Non-Reflective Low-Pass (≈ 80 MHz)

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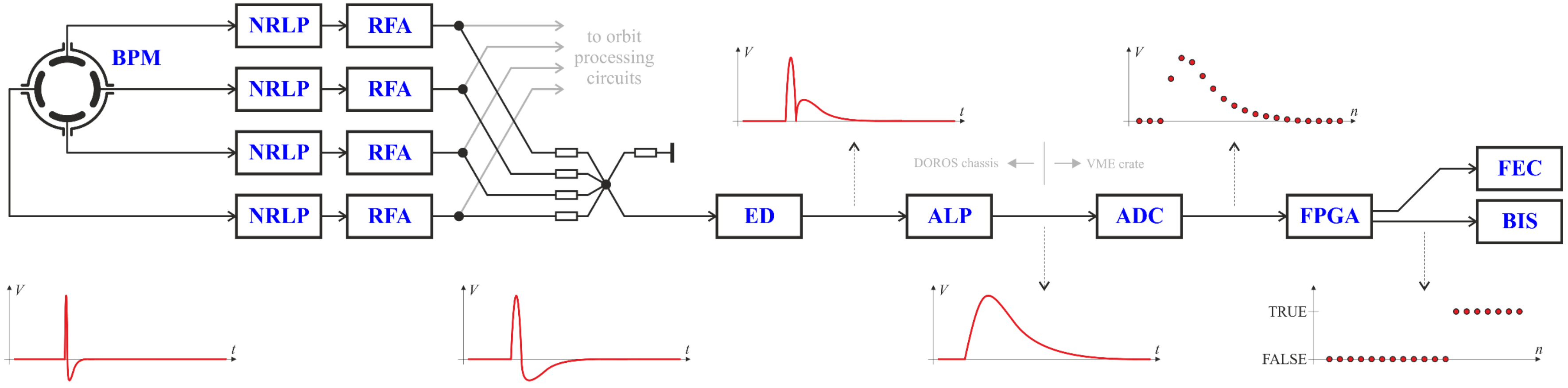

- The system is based on BPM signals shared with the LHC beam position measurement system (passive RF splitters)
- The beam position dependence is removed by summing the four electrode signals
- Analog operations on the signals: low-pass filtering, amplification, envelope detection + rectification + 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”.