Analysis of the BCCM functionality

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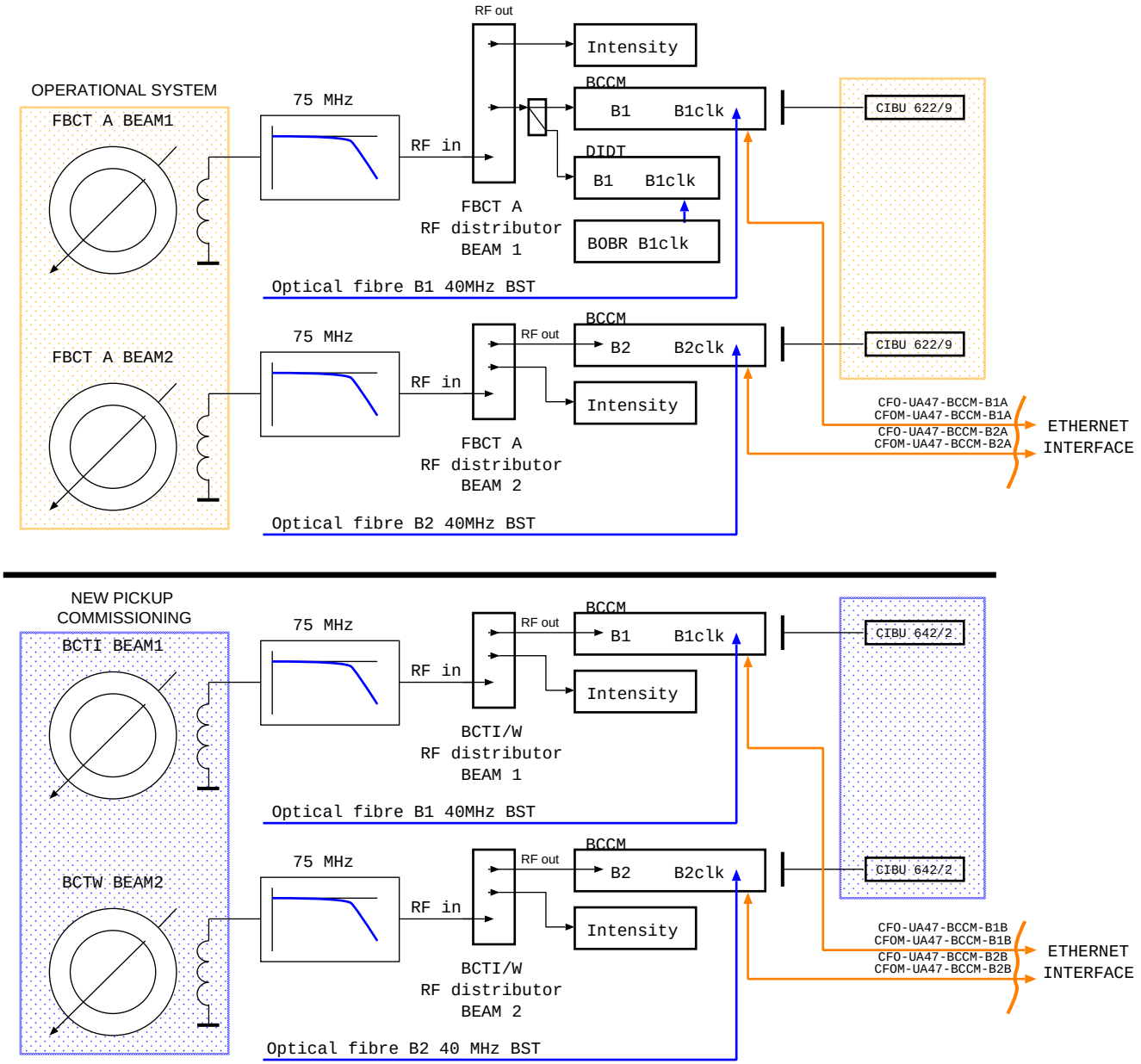
Analysis presented

- System status
- The ADC dynamic range reuse
- MD of bunch position for FBCT/BCTI/BCTW
- How the threshold is setup
- Analysis of the physics run
- Analysis of the scrubbing run
- Conclusions

Installation overview



Performed checks

- Signal amplitudes verification $\rightarrow$ assure that all 4 BCCM systems receive the beam signal of approximately of the same amplitude
- ADC dynamic range verification: $\approx 1.35 \times 10^{11}$ charges per bunch use 55% of the ADC dynamic range $\rightarrow$ full scale measurements of 2.5×10^{11} ch/b are possible
- Occasionally BST bunch and turn clock missing, related to BST restarts.
- Network errors observed, causing temporary BCCM disconnects. 10 disconnects observed in 1.5 month time observation period not affecting the protective function of the equipment.
- System running with current FW for more than 1.5 month without service interruption

MD - Common notes

- FBCTs are known to be bunch position and length dependent. Recent MD measurements show a change of 0.3 to 0.7 %mm^{-1} depending of plane [1].
- BCTI (Integrating Current Transformer, Bergoz) and BCTW (Wall Current Transformer, CERN) were measured in this MD:
  - BCTI $<$ 0.01 - 0.02%mm^{-1}
  - BCTW $<$ 0.001%mm^{-1}

How these imperfections affect the BCCM measurements?

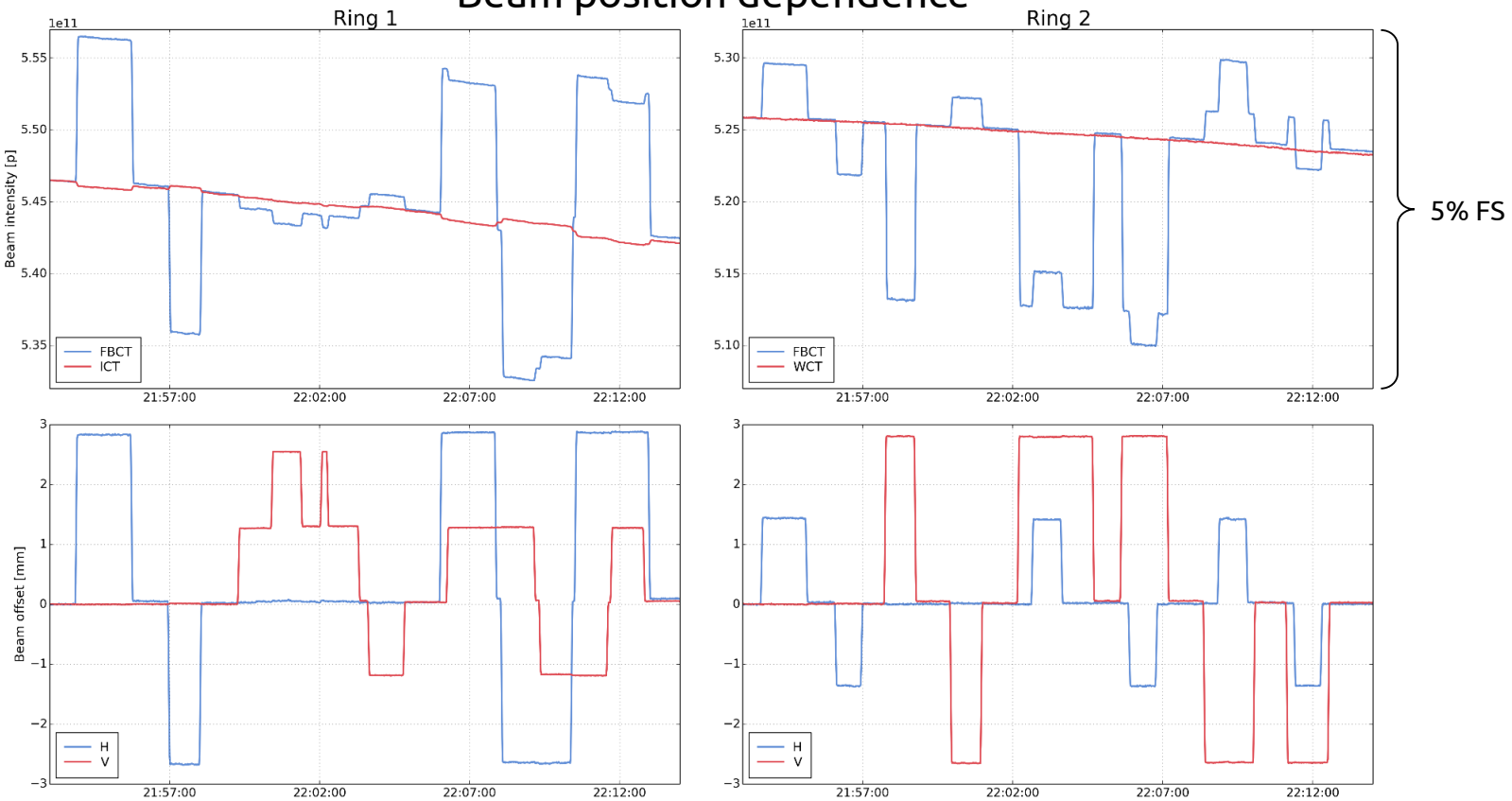
[1] Credit M. Krupa et al., LHC MD398

Bunch position MD

LHC MD398: Verification of the dependence of the BCTF measurements on beam position and bunch length (20/07/2015)

BE/BI: M. Gasior, M. Krupa, L. Soby. T. Lefevre BE/OP: R. Alemany Fernandez, M. Pojer

Beam position dependence



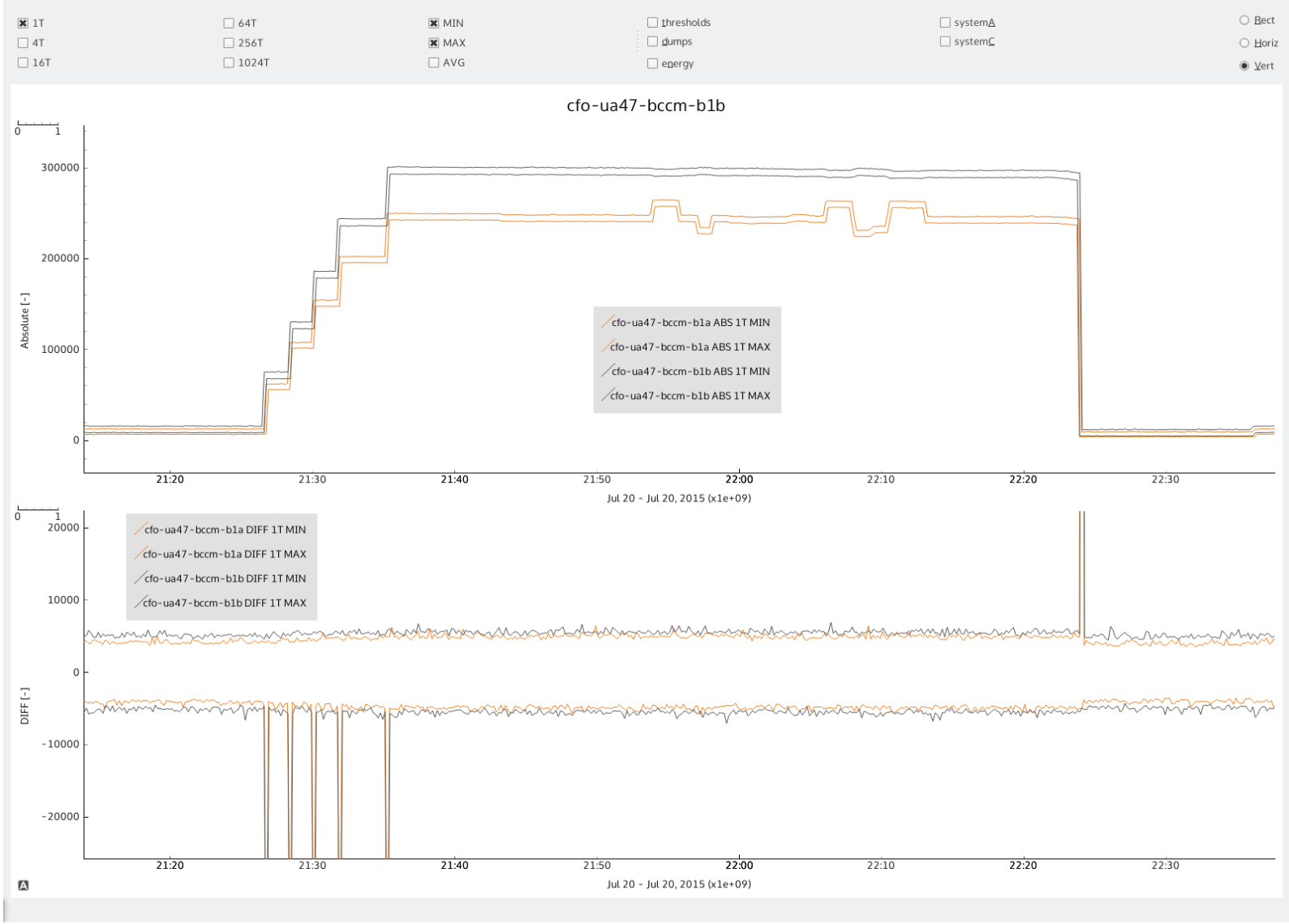
FBCT
$\Delta I/I \approx (3\text{-}7)E\text{-}3 \cdot mm^{-1}$

ICT
$\Delta I/I \approx (1\text{-}2)E\text{-}4 \cdot mm^{-1}$

WCT
$\Delta I/I < 1E\text{-}5 \cdot mm^{-1}$

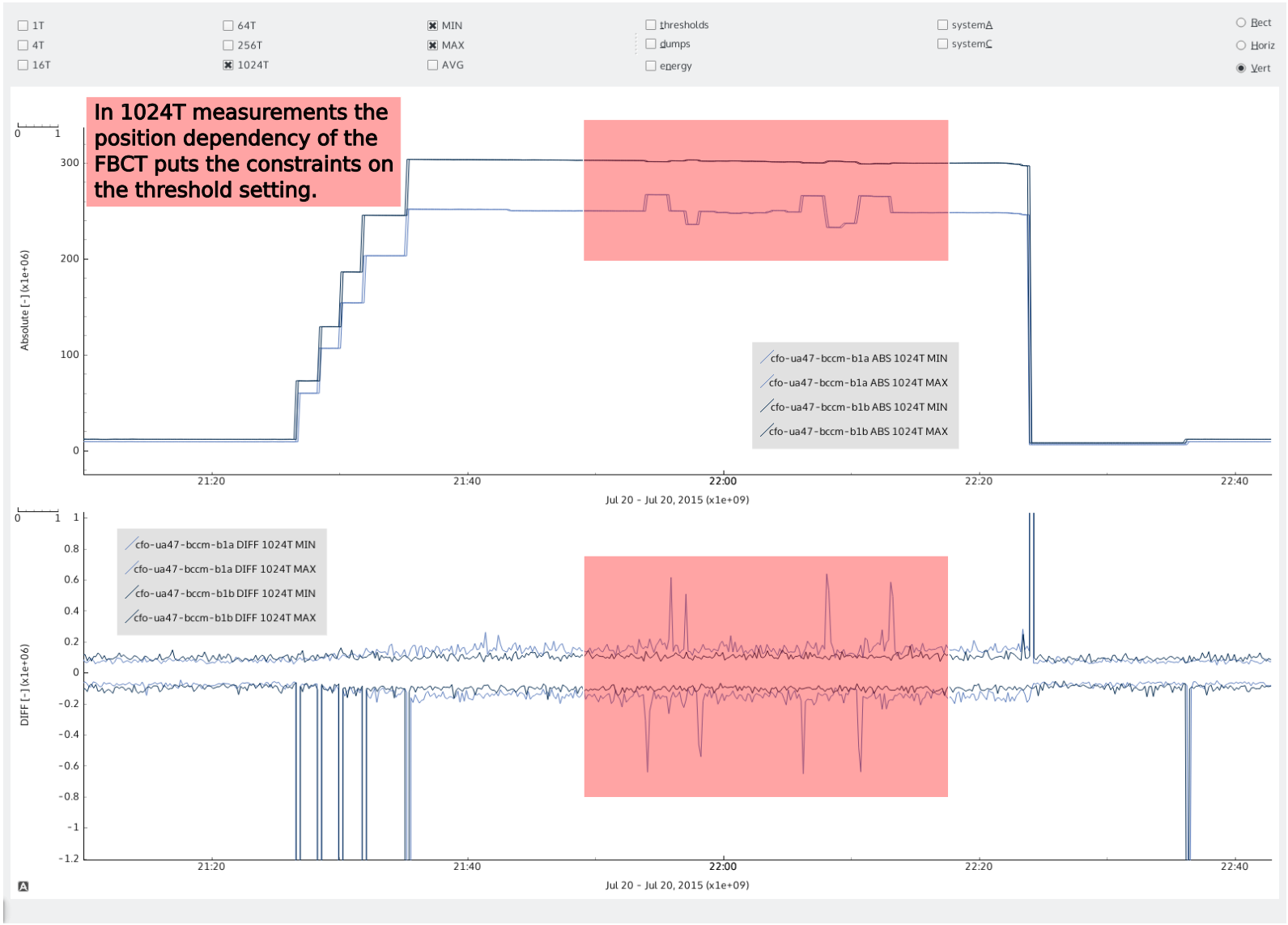
FBCT and BCTI wrt bunch position

1 turn moving averager window:

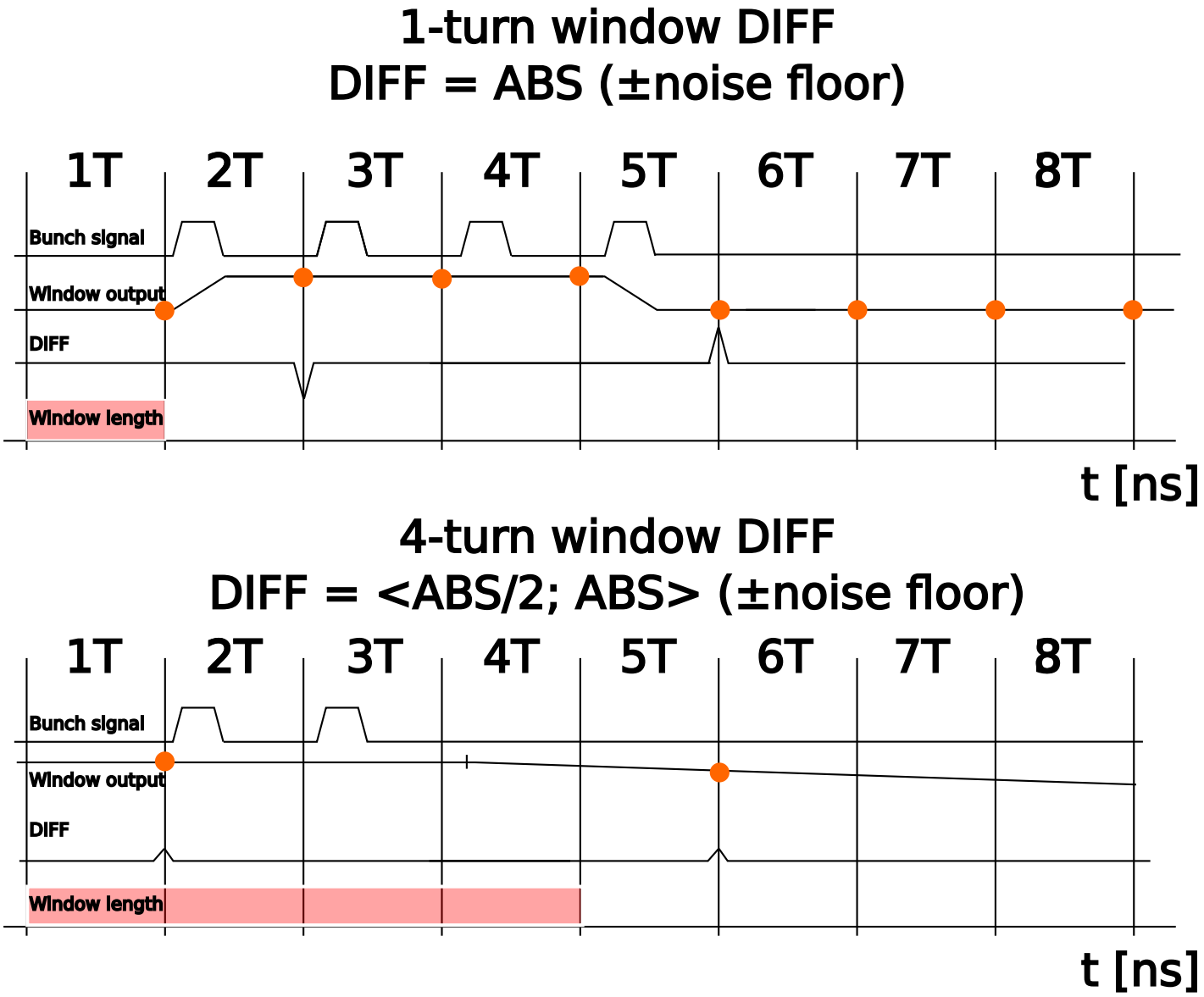


FBCT and BCTI wrt bunch position

1024 turn moving averager window:

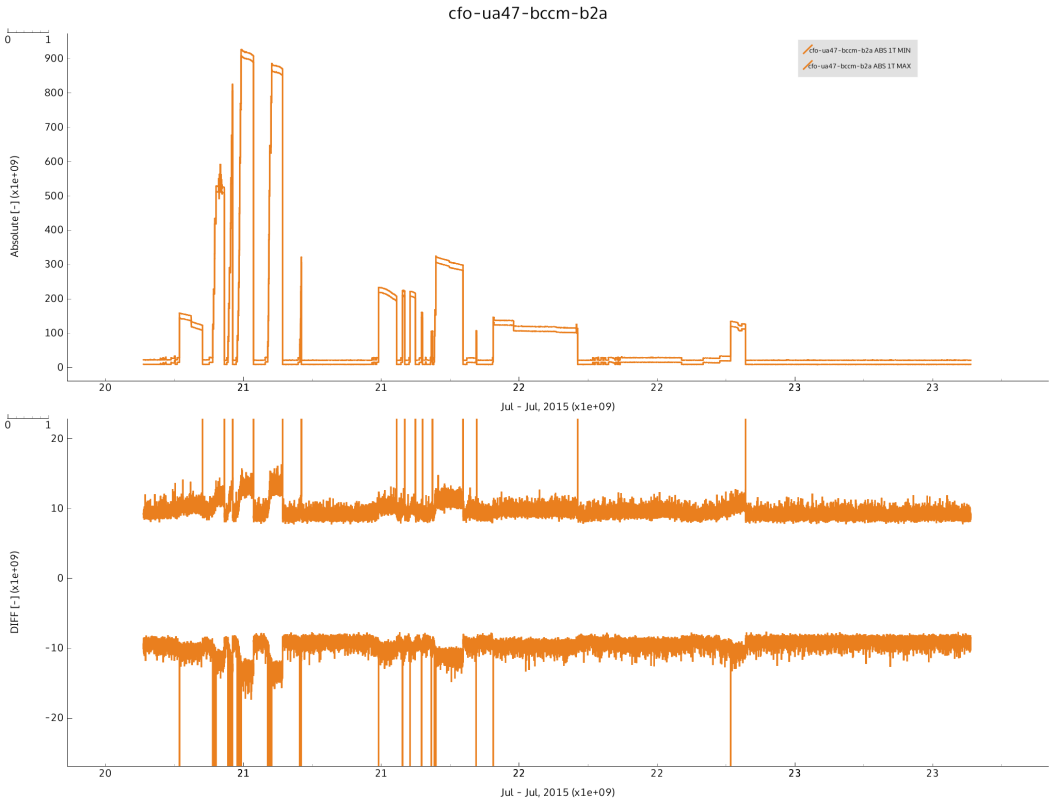


How the threshold is setup



Setting the threshold - 1T explanation

- On a single turn the value of DIFF should be a replica of ABS, taking into account the noise figures:



- for 1T window the noise is non-negligible, amplitude $\pm 1 \times 10^{10}$ ch/b.

Setting the threshold - other windows

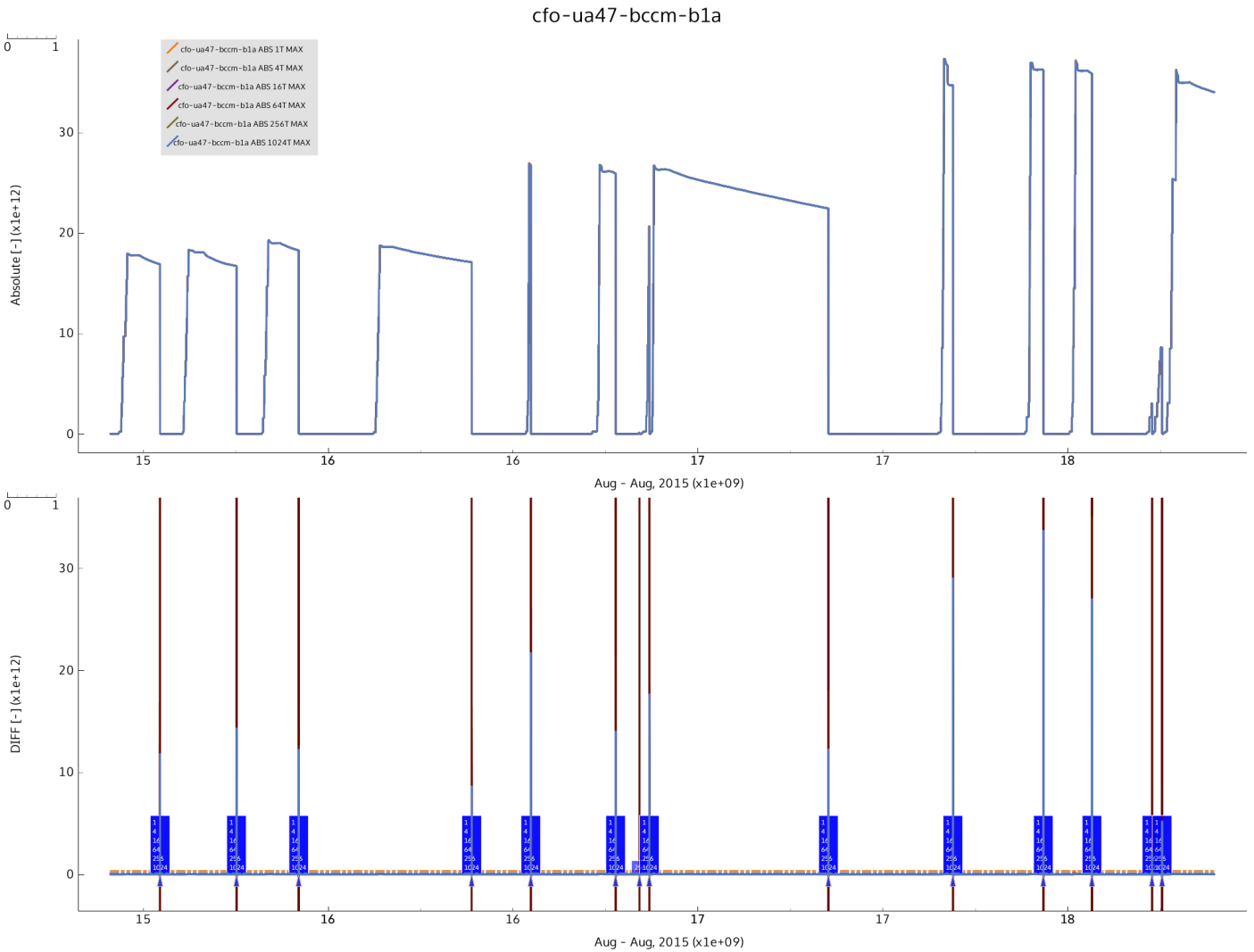
- On other windows, the DIFF value can be anywhere between half and max ABS, as well taking into account the noise floor, which increases uncertainty.

What does that mean?

- If we want to setup the threshold to e.g. 3×10^{11} lost in single turn:
  - for the 1T window, with 1×10^{10} noise amplitude we have to set the threshold to (3×10^{11}) - $2\cdot(1\times10^{10})$ to have a 100% certainty to catch 3×10^{11} and 'some' certainty to catch 2.8×10^{11}
  - for all other windows, e.g. for 4 turn window - the DIFF for 3×10^{11} (per-turn) can be anywhere between 1.5×10^{11} to 3×10^{11}, again including the noise, which is however in higher turn window-lengths less dominant ($4T = \approx 5\times10^{9}$). So to catch 3×10^{11} with $>99\%$ probability the threshold has to be set roughly to 1.5×10^{11}.

Analysis of the physics run

Physics - quiet background, 'injection losses':



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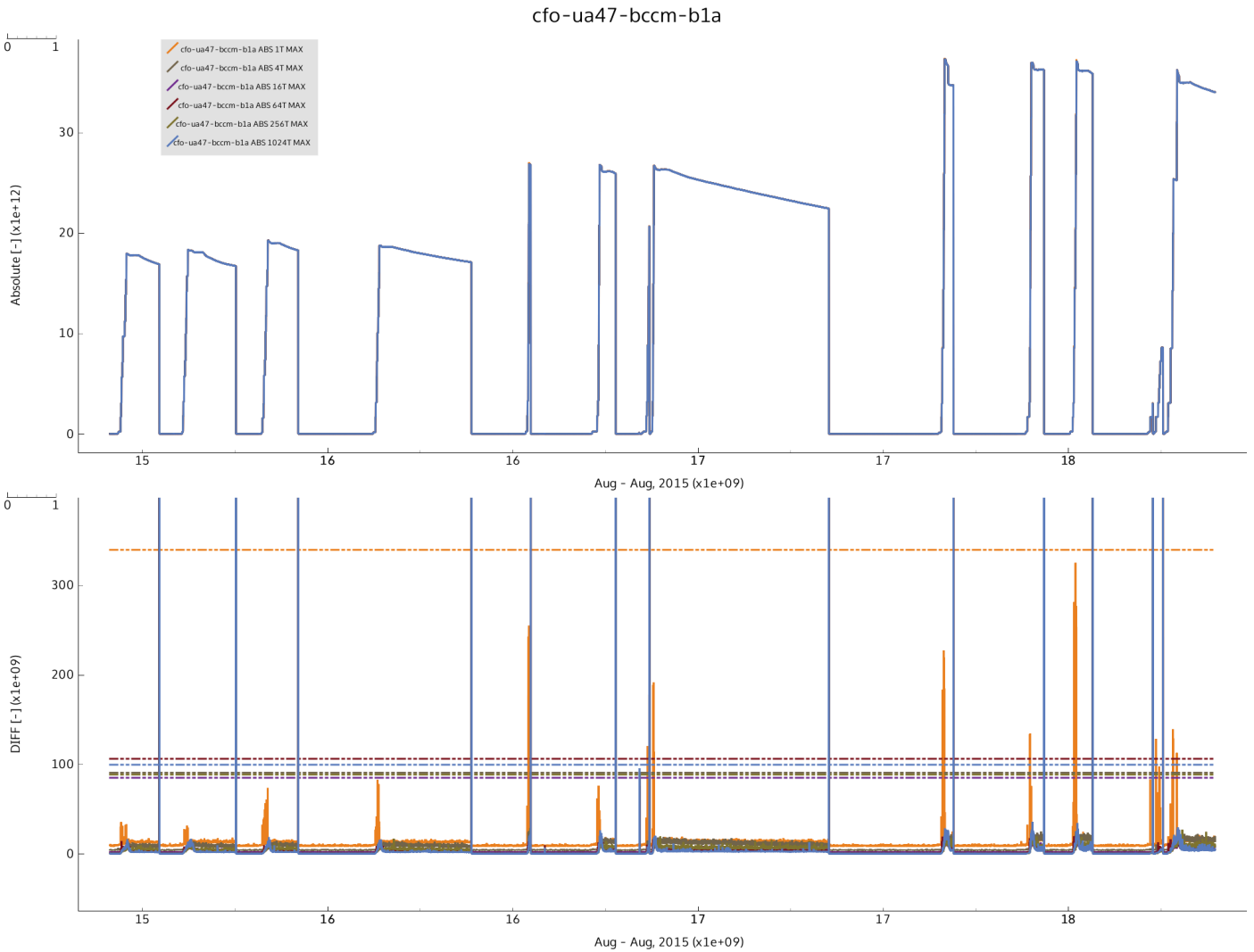
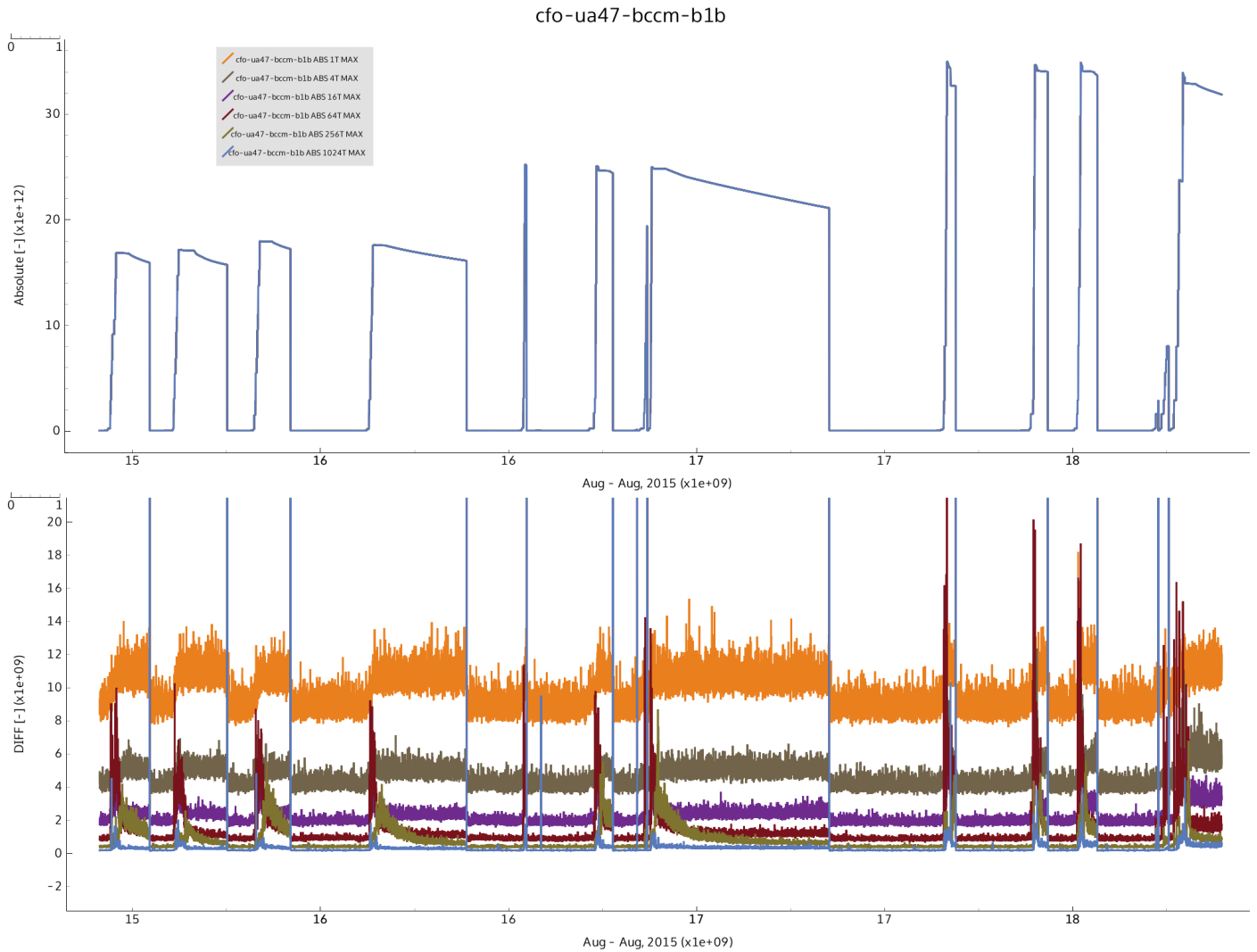


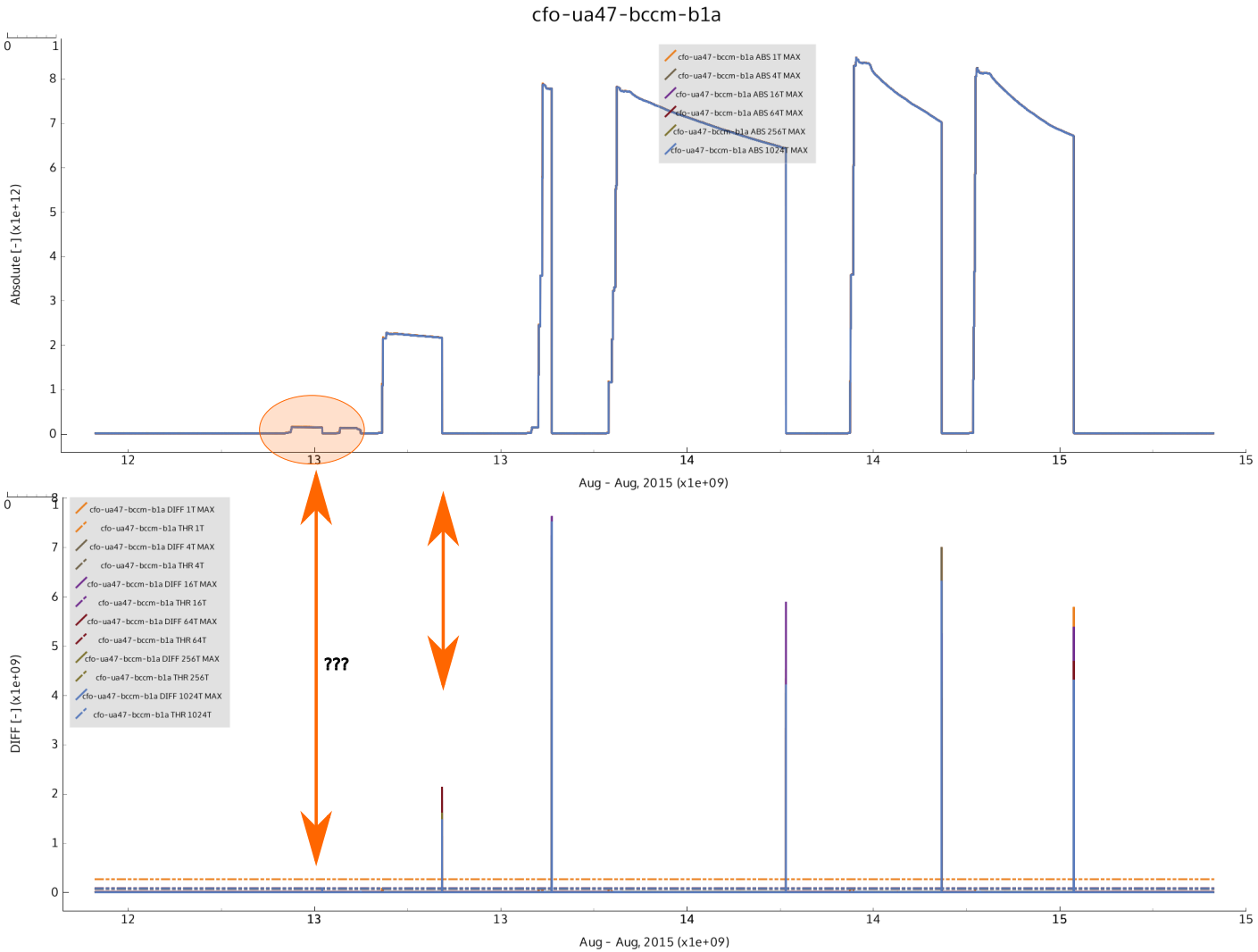
For comparison: BCTI of the same run

Physics - quiet background, 'injection losses':



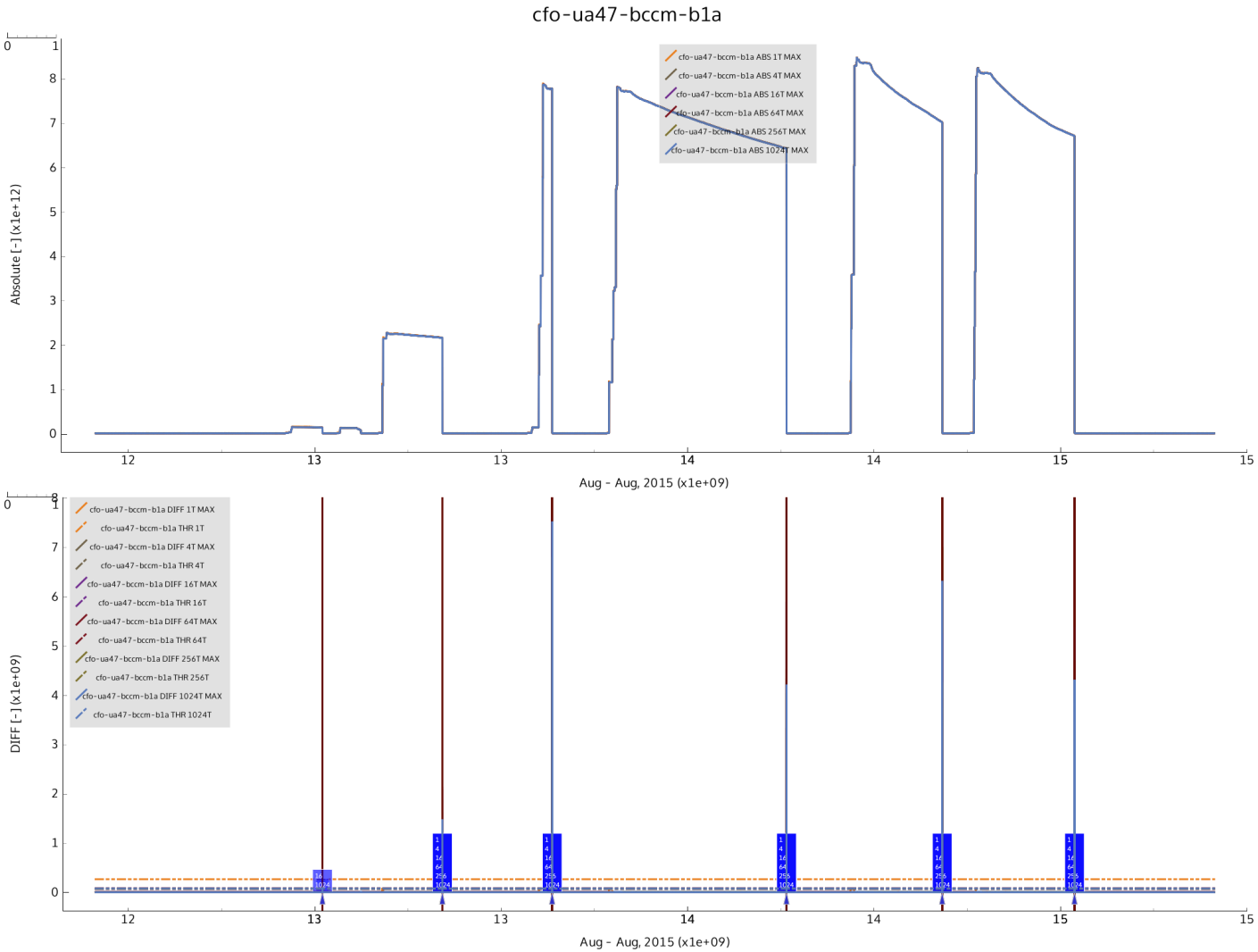
Into the details (1) - DIFF values

- With 'large signals' the DIFF calculus fits with the prediction, what about low-intensity beams?



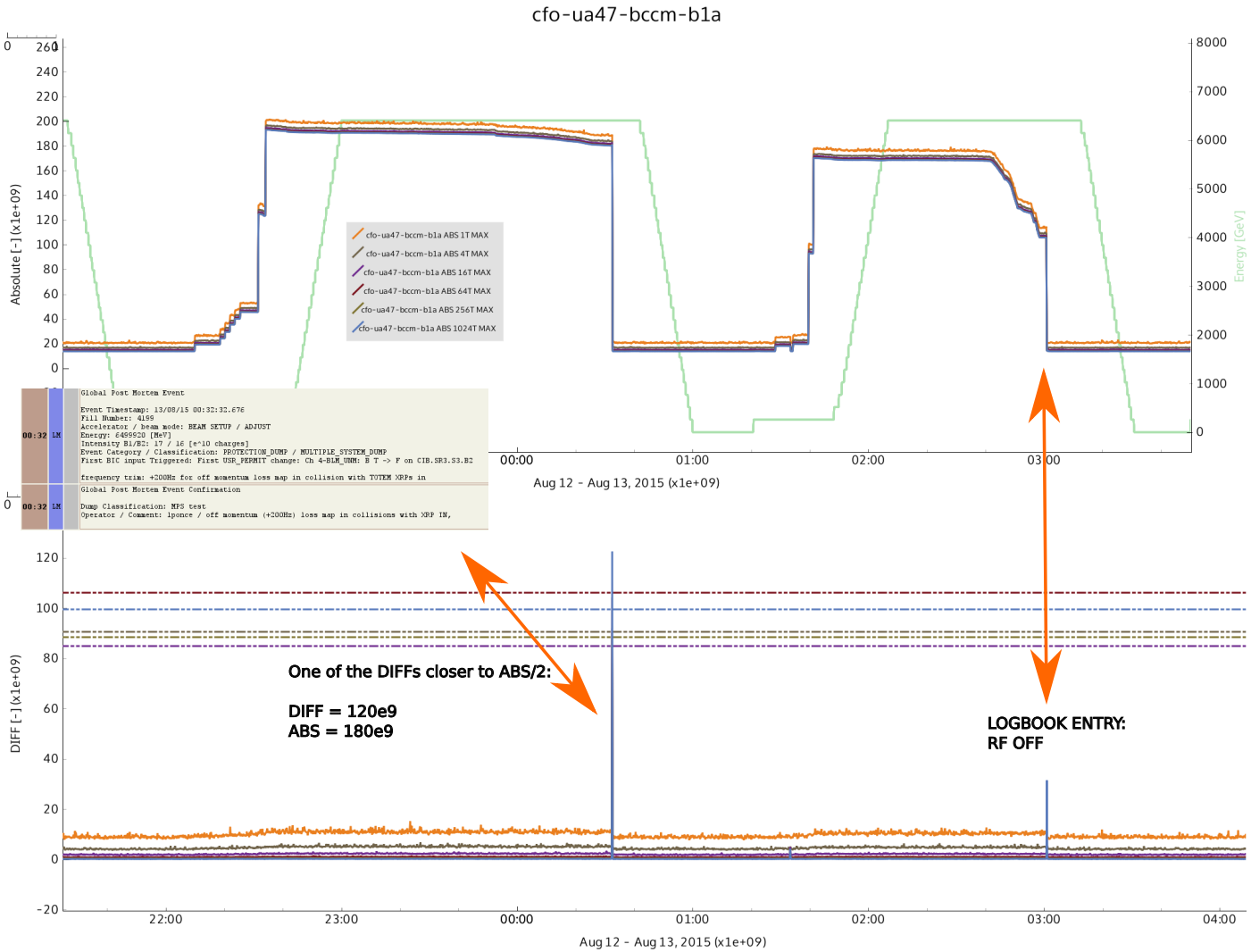
Into the details (2) - DIFF values

- With 'large signals' the DIFF calculus fits with the prediction, what about low-intensity beams?



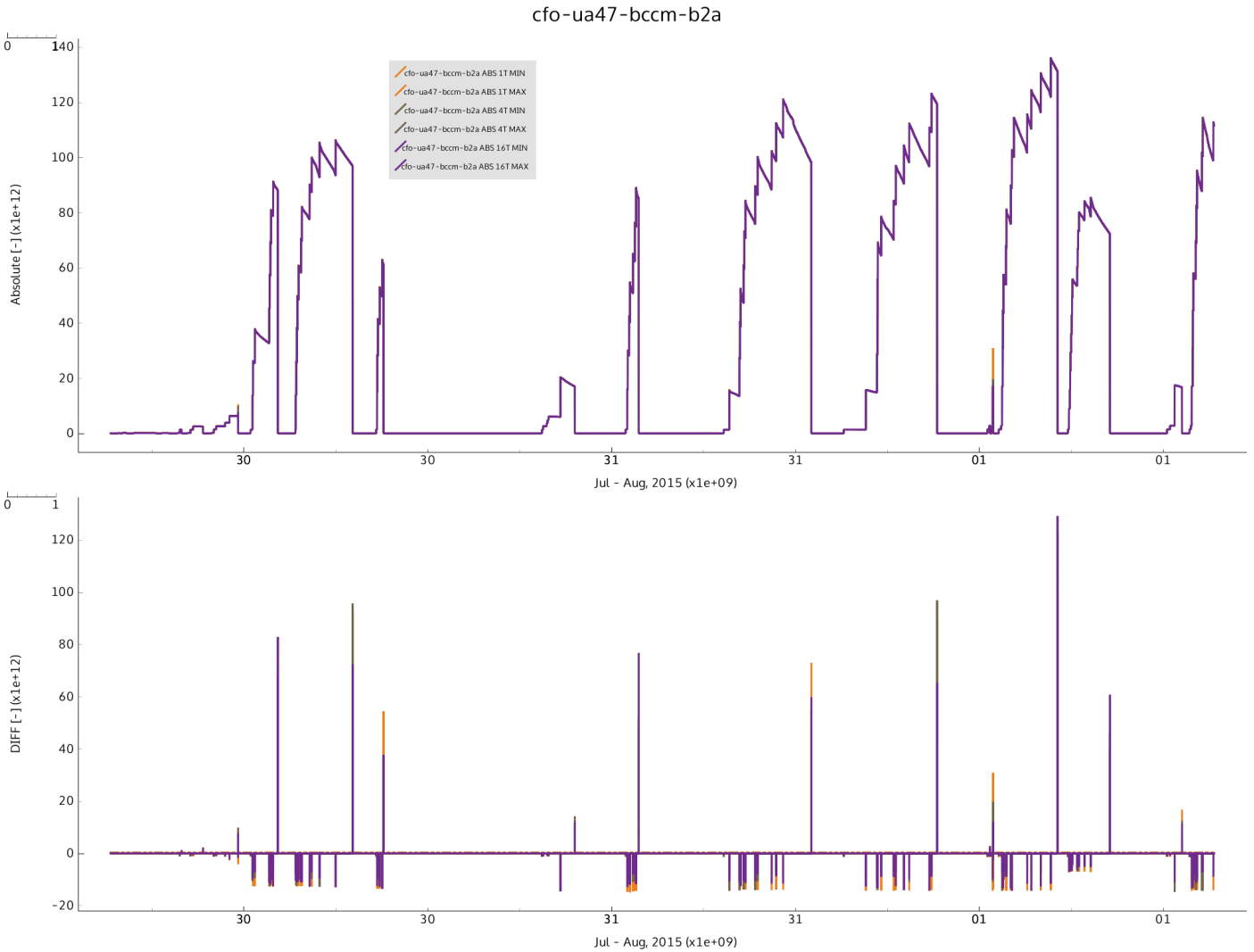
Into the details (3) - DIFF values

- With 'large signals' the DIFF calculus fits with the prediction, what about low-intensity beams?

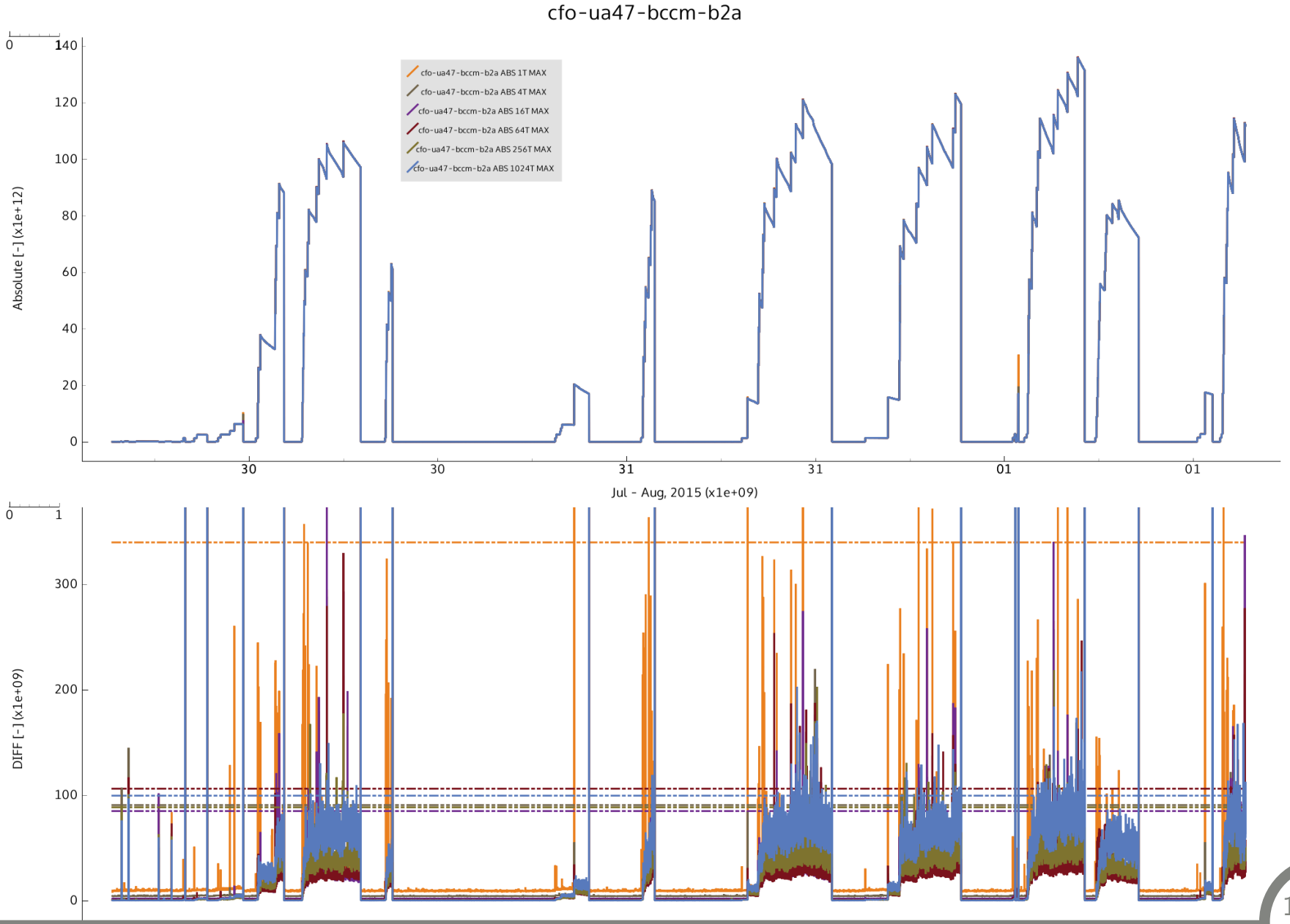


Analysis of the scrubbing run

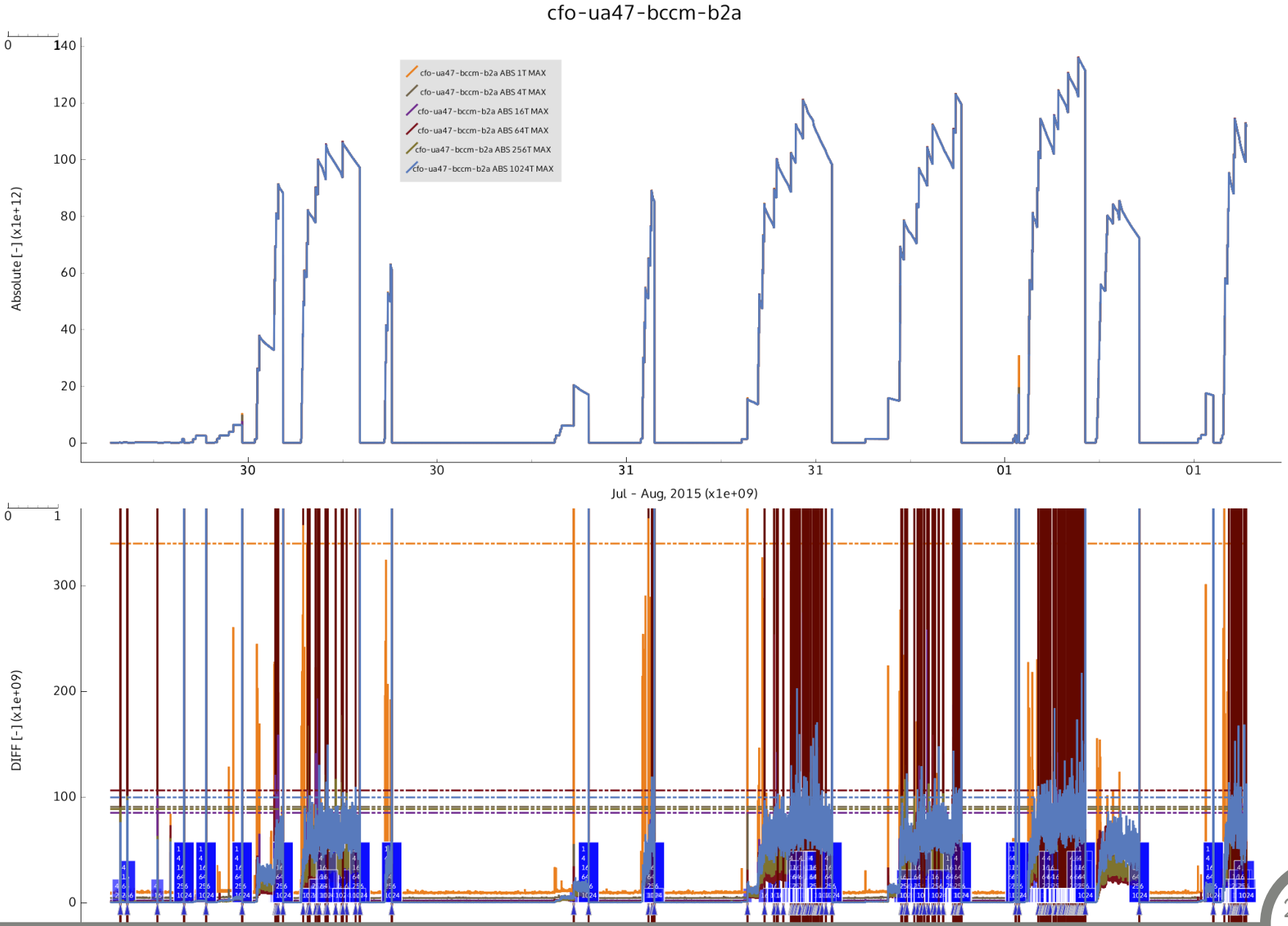
Scrubbing started on Saturday 25th July, finished $\approx$7th August.
Typical scrubbing run (single turn recalc):



Detail

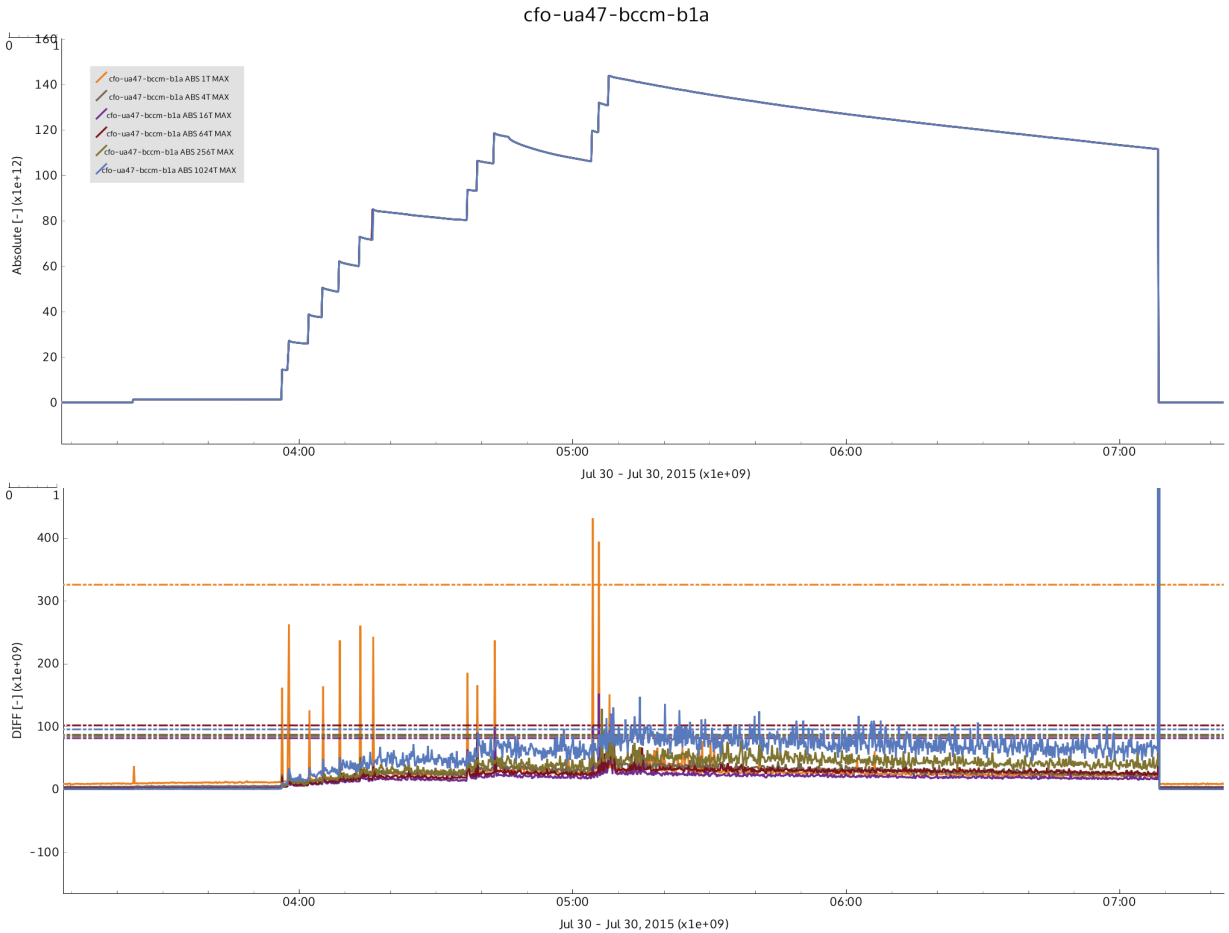

cfo-ua47-bccm-b2a
cfo-ua47-bccm-b2a ABS 1T MAX
cfo-ua47-bccm-b2a ABS 4T MAX
cfo-ua47-bccm-b2a ABS 16T MAX
cfo-ua47-bccm-b2a ABS 64T MAX
cfo-ua47-bccm-b2a ABS 256T MAX
cfo-ua47-bccm-b2a ABS 1024T MAX
Absolute [-] (x1e+12)
0
20
40
60
80
100
120
140
30
30
31
31
01
01
Jul - Aug, 2015 (x1e+09)
DIFF [-] (x1e+09)
0
100
200
300
1

Detail


cfo-ua47-bccm-b2a
cfo-ua47-bccm-b2a ABS 1T MAX
cfo-ua47-bccm-b2a ABS 4T MAX
cfo-ua47-bccm-b2a ABS 16T MAX
cfo-ua47-bccm-b2a ABS 64T MAX
cfo-ua47-bccm-b2a ABS 256T MAX
cfo-ua47-bccm-b2a ABS 1024T MAX
Absolute [-] (x1e+12)
0
20
40
60
80
100
120
140
30
30
31
31
01
01
Jul - Aug, 2015 (x1e+09)
DIFF [-] (x1e+09)
0
100
200
300

Into the details - Injection FBCT

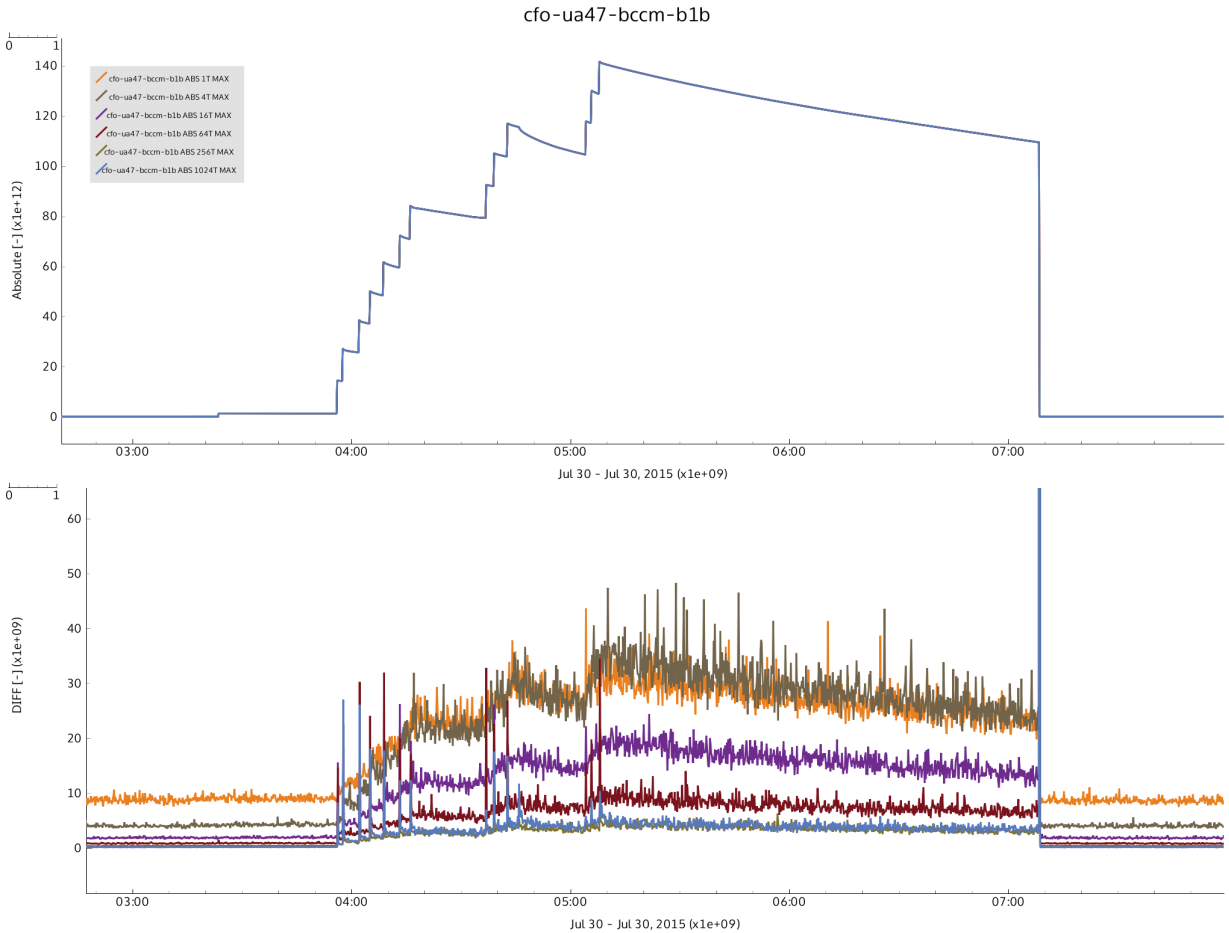
- Injection: FBCT detects 'injection losses':



But they are 'fake'. Neither BCTI nor BCTW connected to BCCMs detect them.

Into the details - Injection ICT

- Injection: FBCT detects 'injection losses':



But they are 'fake'. Neither BCTI nor BCTW connected to BCCMs detect them.

Conclusions

- I have 'just started' the analysis of the 1.5 month data capture
- So far no dump request without a reason.
- For scrubbing, there is a clear limitation in what kind of signal is obtained from FBCT:
  - FBCT signal change during injection, measured by 1T can easily artificially create losses of 5×10^{11} p/t
  - standard DIFF background during scrubbing requires at least 6×10^{11} p/t threshold
- For physics the currently used thresholds are satisfactory, again limited by behaviour at injection
- The BCCMs using BCTI and BCTW much improve the measurement quality $\rightarrow$ no injection peaks, more understandable/predictable behaviour.
- Detailed analysis of the DIFF signal amplitude behaviour is ongoing.

Proposal

- make the system alive
- change the thresholds to satisfy both physics and scrubbing:
  - single turn window to 1×10^{12} >99% detection probability of 2×10^{12}
  - all other windows 6×10^{11} >99% detection probability of 1.2×10^{12}, and not to cause spurious triggers during scrubbing on longer windows.
- Then, depending of performance we might lower the 1T for other than 450GeV