



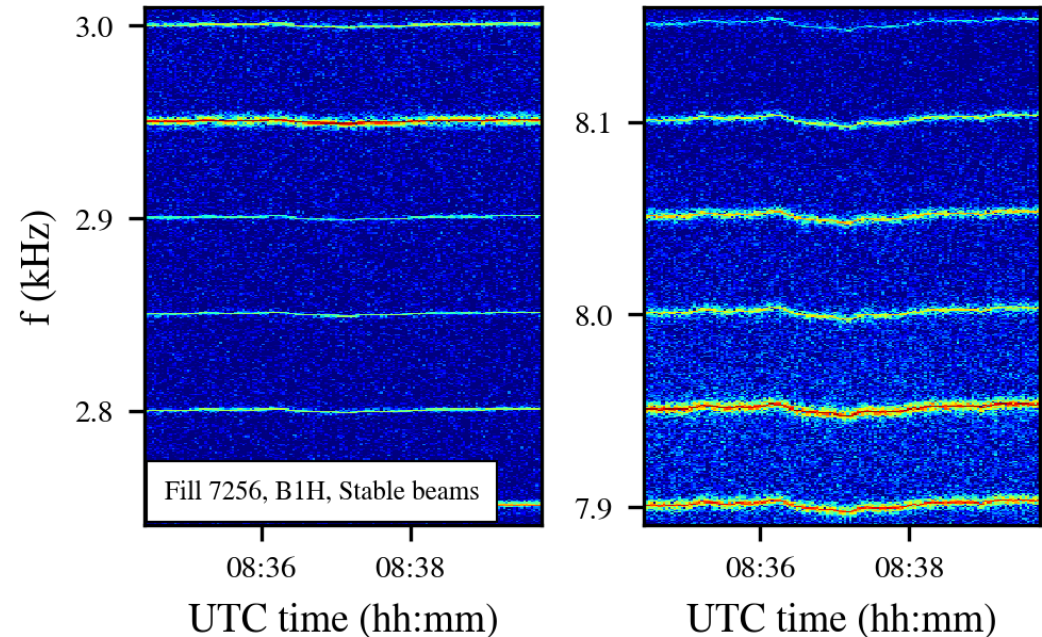
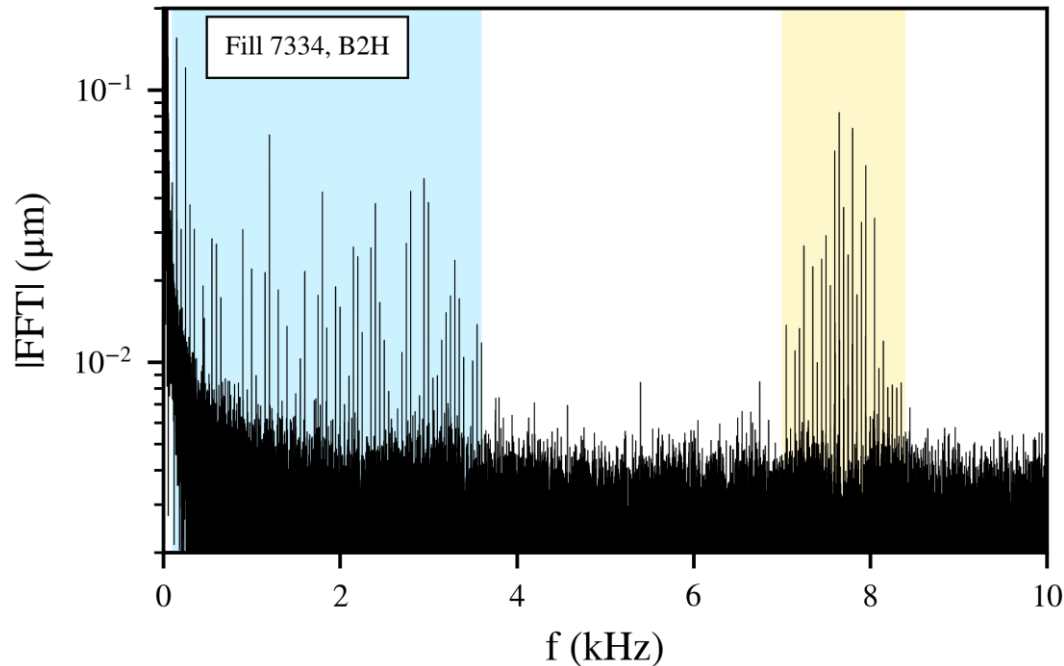
# MD6823: Evaluate impact of UPS noise on LHC beam spectrum

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# Motivation

LHC transverse spectrum features 50 Hz harmonics appearing in

- **low (0-3.6 kHz)** & **high (around 8 kHz)** frequency clusters, with frequencies fluctuating in time (due to stability of 50 Hz network frequency) as shown on spectrograms.
- Origin of low frequency → associated with main dipoles (see active filters in [Run 2 MDs](#)).
- Simulations indicate that **high frequency cluster** has an impact on beam lifetime → need to identify origin as first step to possible mitigation.

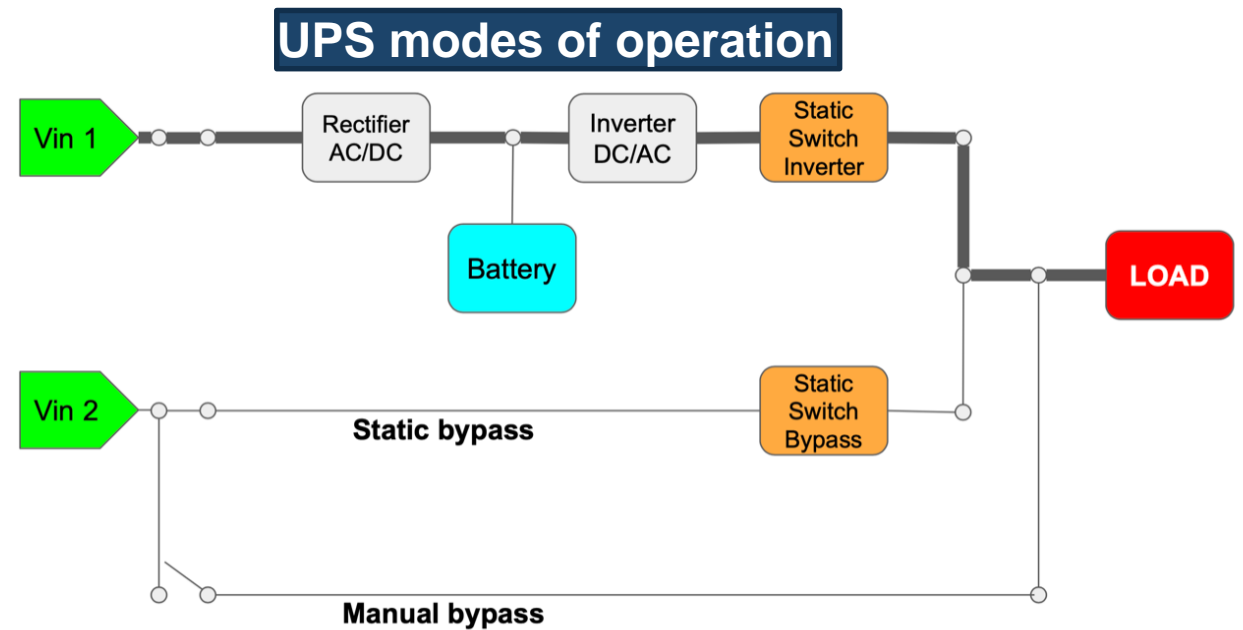
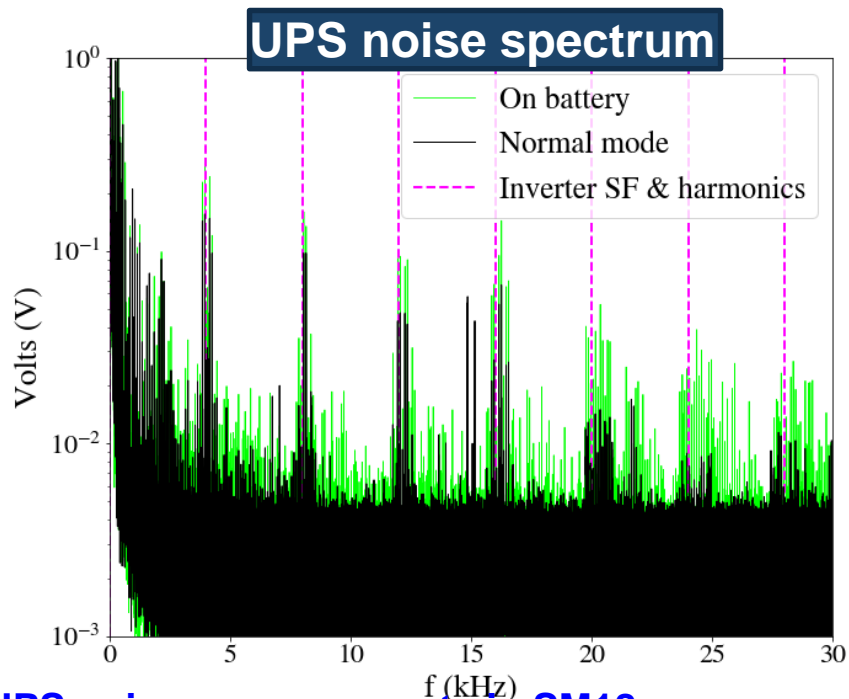


# MD6823 tried to address two questions

1. Can the UPS's connected to the ADT introduce an effect on the beam?
2. If yes, are these UPS's acting on the 8 kHz region?

# Few words on UPS voltage spectra

- Measurements of spare UPS in SM18 during LS2.
- UPS output voltage spectrum: 50 Hz harmonics around 4 and 8 kHz following network frequency fluctuation in time → similar to 50 Hz harmonics on the beam spectrum.
- UPS operation modes: nominal, on battery, static and manual bypass.



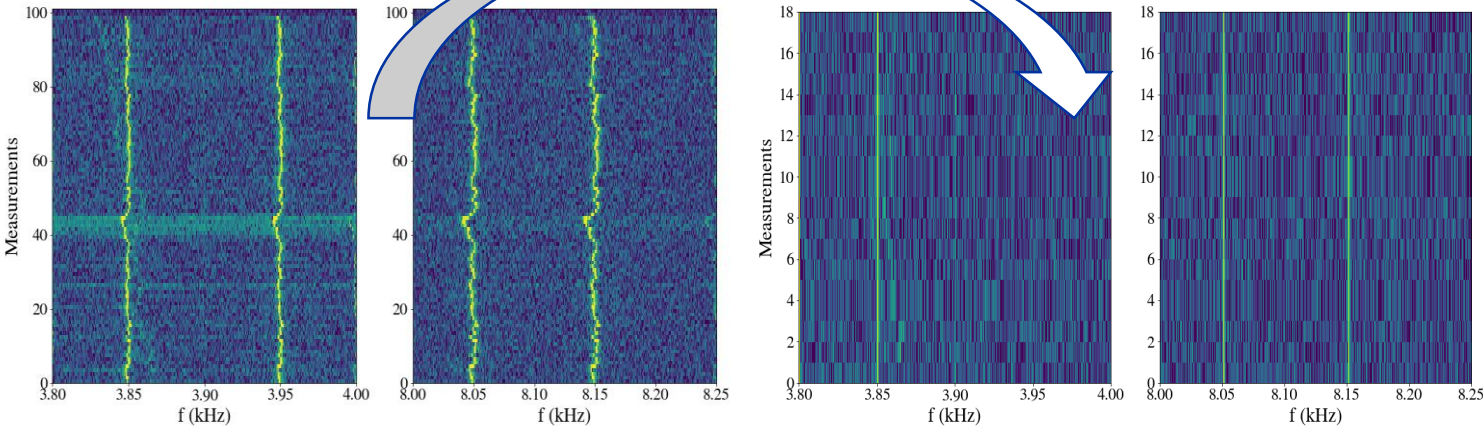
[Link for UPS noise measurements in SM18](#)



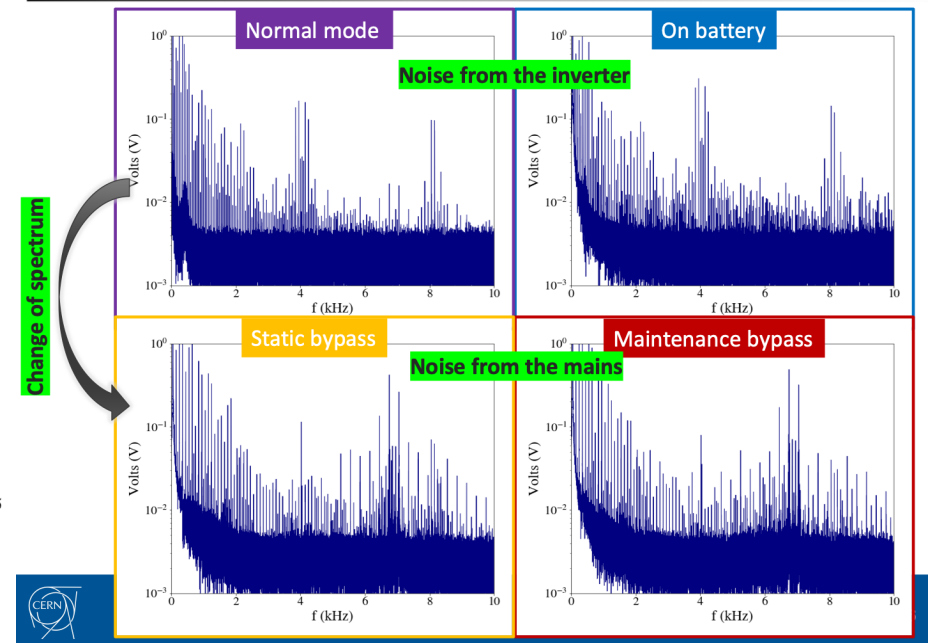
# Measurements in SM18

1. On battery with Vin1 and Vin2 disconnected: harmonics synchronized with internal clock, rather than mains, appear as fixed lines in the spectrograms (change that can be easily detected on beam spectrum).
2. Static & manual bypass: change of harmonics' amplitude (not easily detected on beam spectrum).

Nominal to battery mode



Spectra in all UPS modes



# MD overview

MD took place on 01/07/2022 15:05-22.05 (CET), Fills 7896 & 7897 [3 h lost due to PC fault]

**Filling scheme & beam conditions:** longitudinally equidistant bunches (first 6 pilots & then 4 nominals) at injection energy.

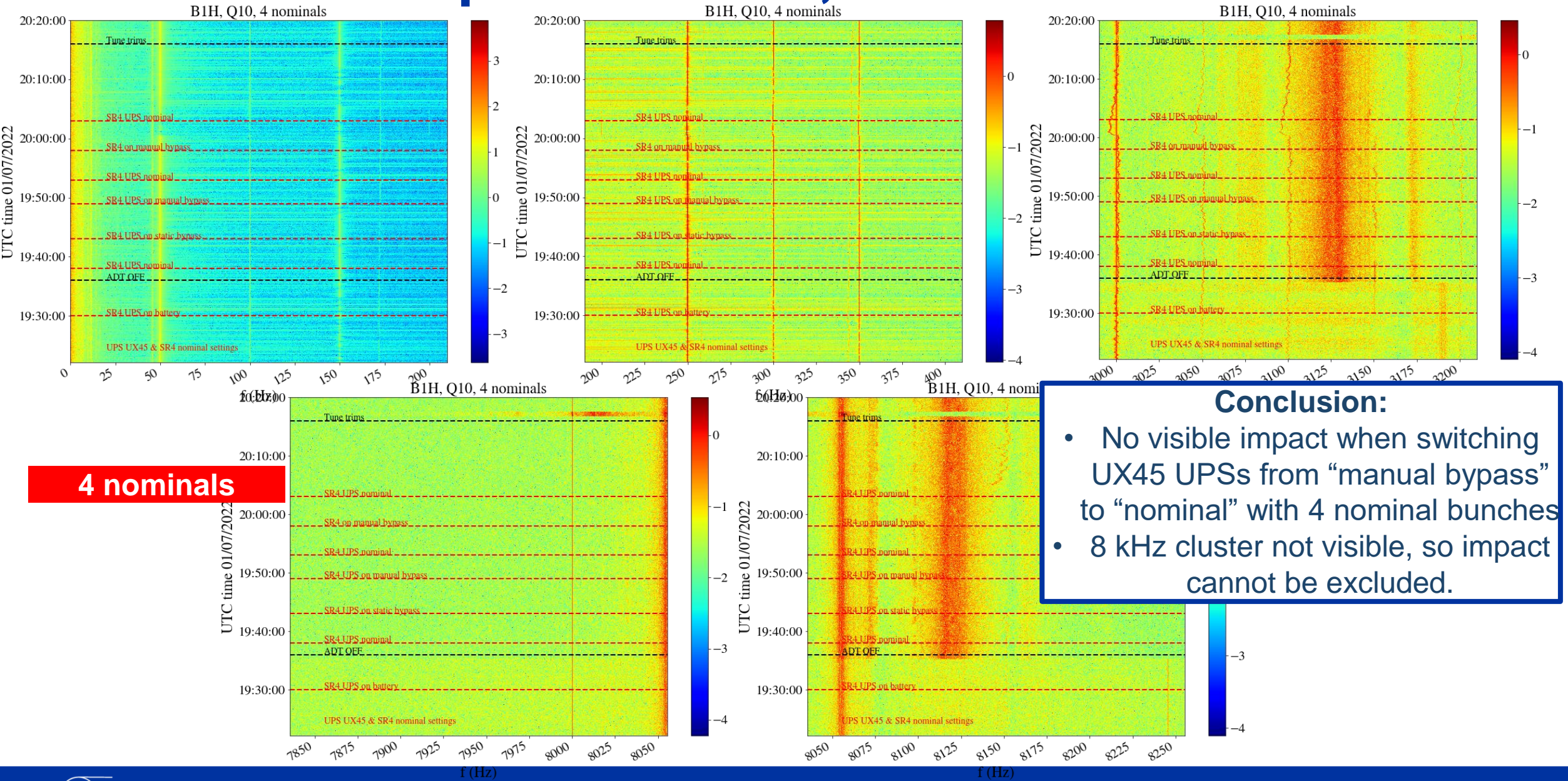
**Tools for observation of beam spectrum:** continuous ADTObsBox circular buffer.

## UPS modifications from EN/EL:

1. EBS11/4R in SR4 (**no access needed**) switched from “nominal” configuration to “**battery**”, “**static bypass**”, “**manual bypass**” and back to “nominal”.
  - UPS connected to (H. Timko): ADT, LHC beam control (RF frequency generation, beam phase loop, synchronisation etc.), longitudinal diagnostics in SR4 (APWL, beam spectra, longitudinal ObsBox)
2. EZS1/45X and EZS11/45X (in cascade) in UX45 (**access needed**) switched from “**nominal**” **configuration to “manual bypass”** and then back to “nominal”. Not possible to switch to “battery mode” without remote control.
  - UPS connected to (H. Timko): ADT, racks for klystrons, LLRF crates for cavity control and longitudinal diagnostics in UX45.

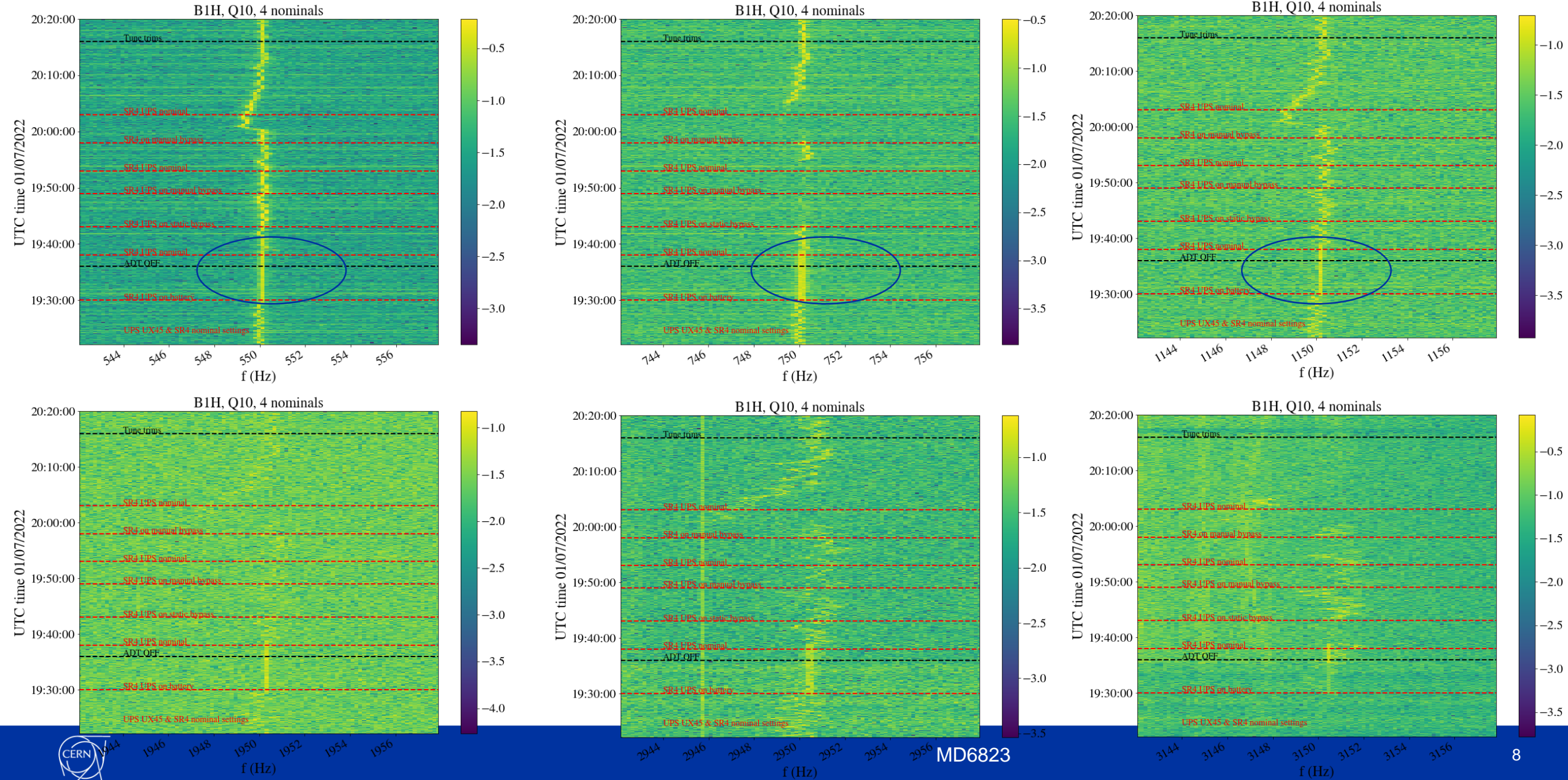


# ADTObsBox spectra in MD, UPS in SR4 tests



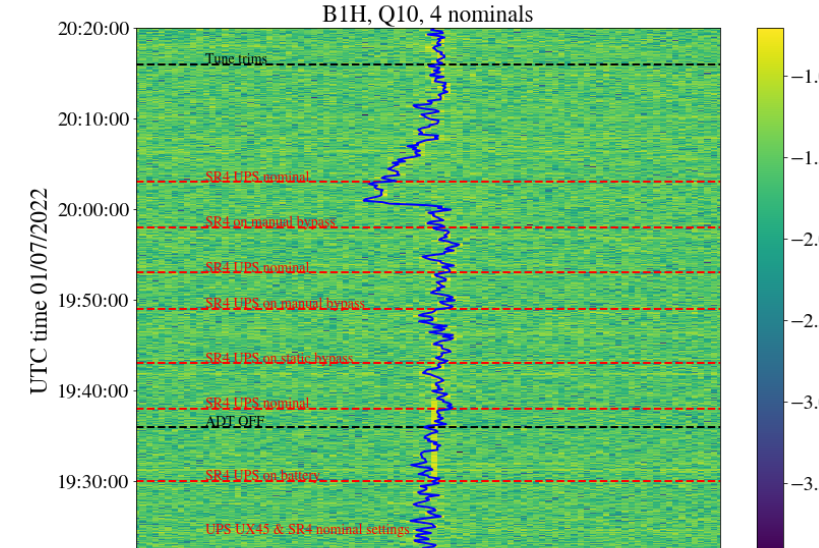
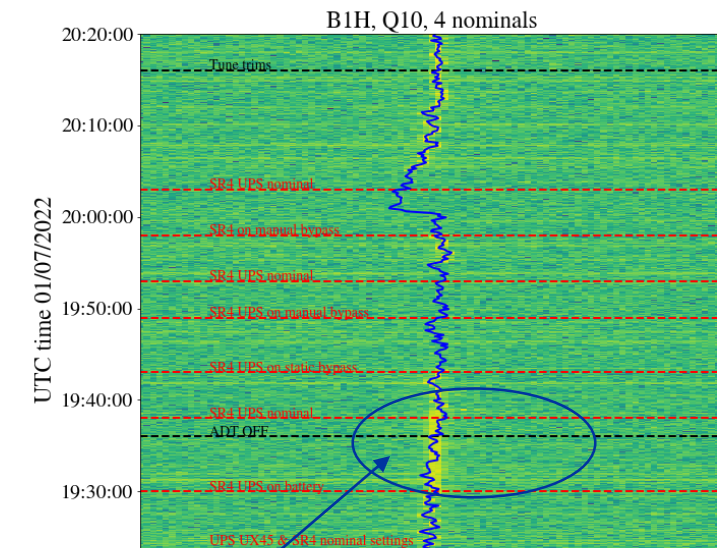
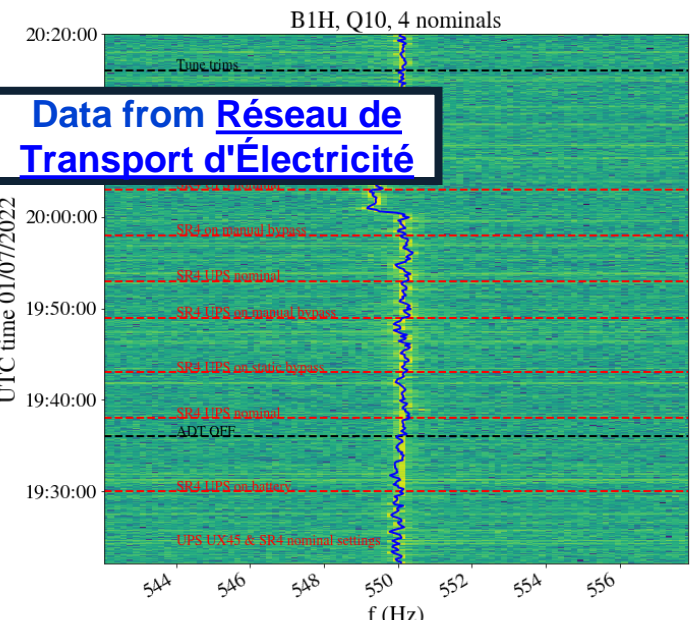


# ADTObsBox spectra in MD, UPS in SR4 tests



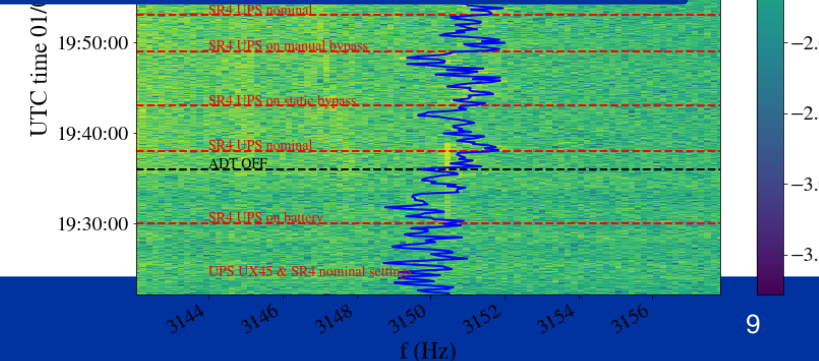
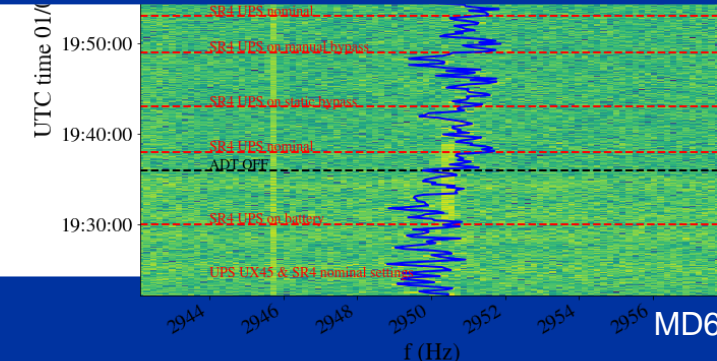
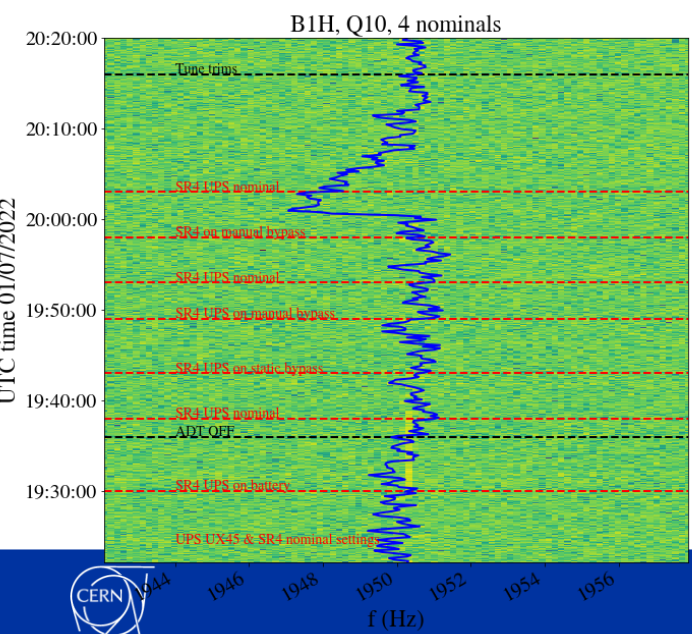


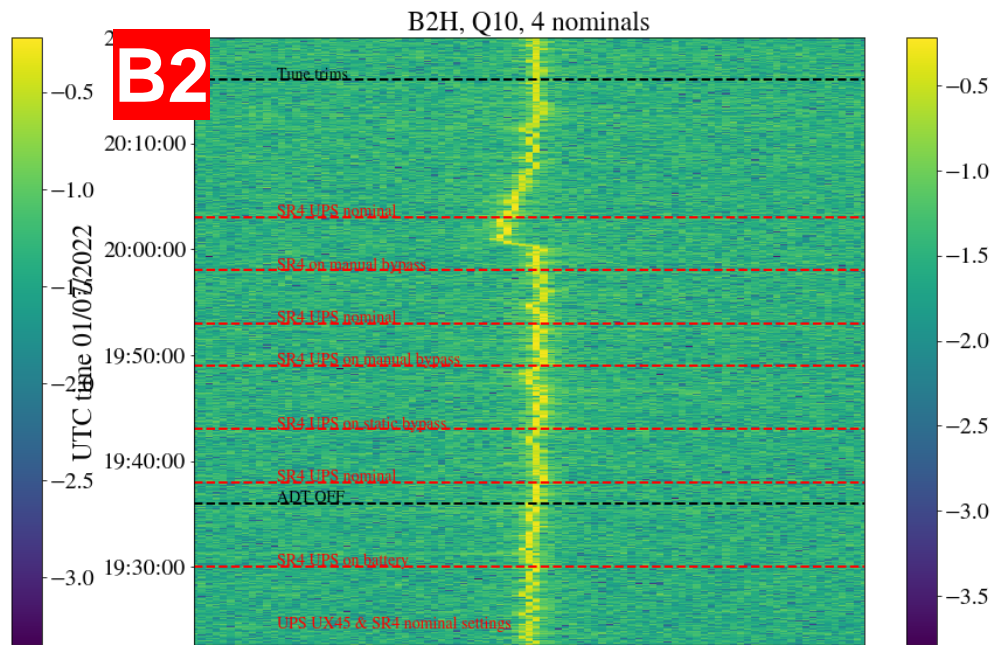
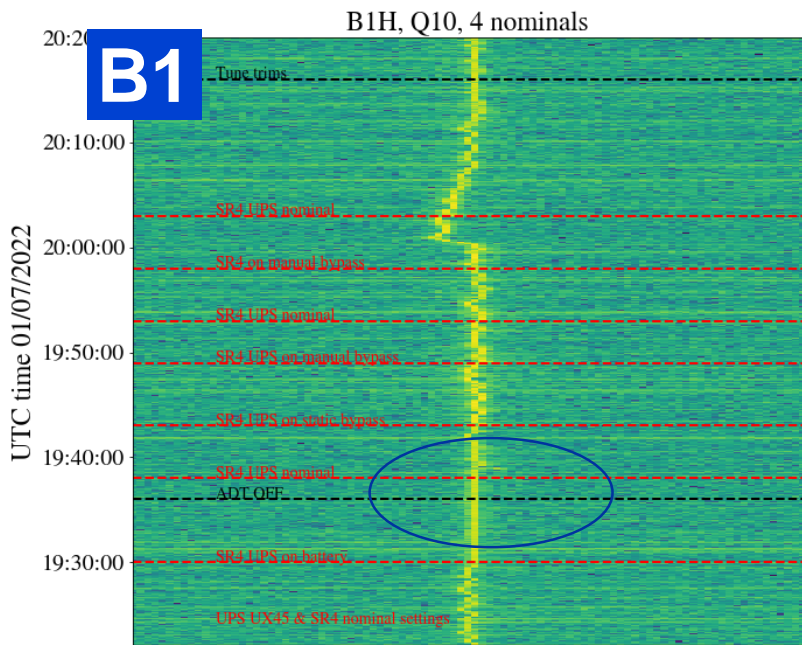
# ADTObsBox spectra in MD, UPS in SR4 tests



## Conclusion:

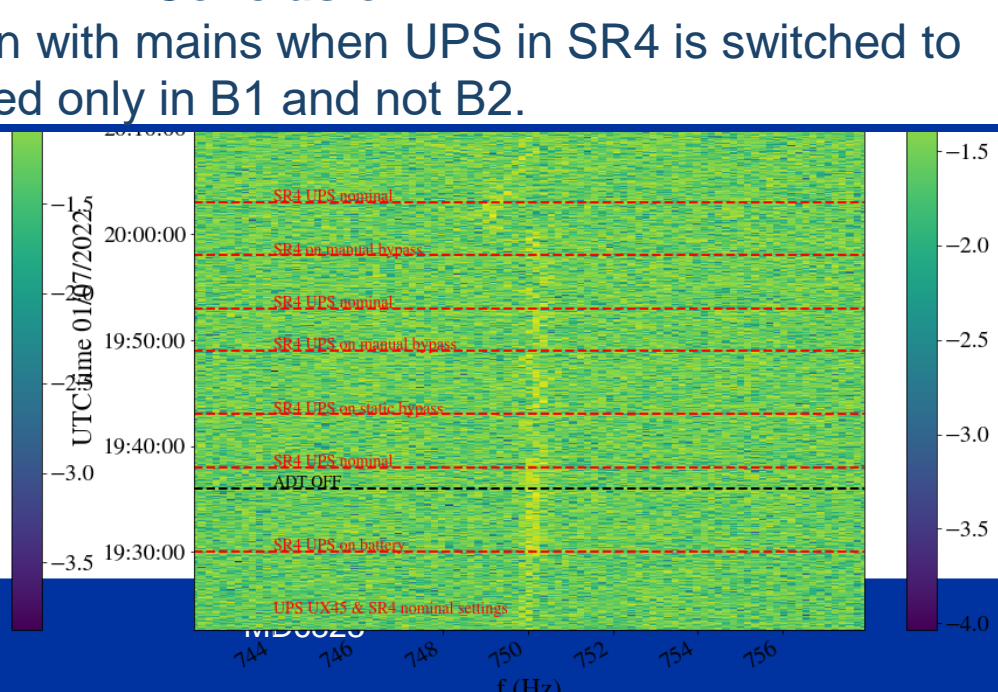
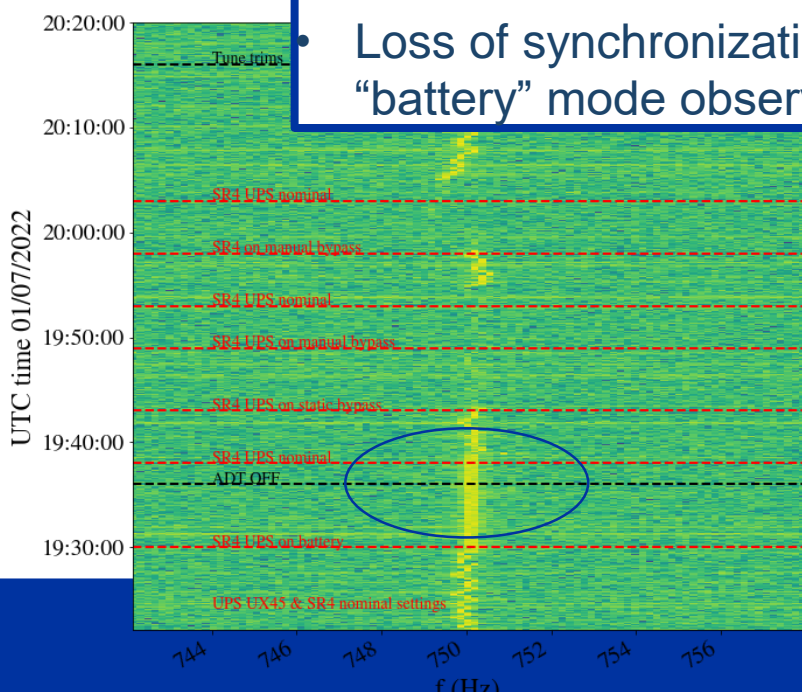
- Clear loss of synchronization with mains when UPS in SR4 is switched to “battery” mode for some harmonics on the beam spectrum (e.g. 550, 750, 1150, 1950, 2950, 3150 Hz).
- 8 kHz cluster not visible so impact from SR4 UPS cannot be excluded.





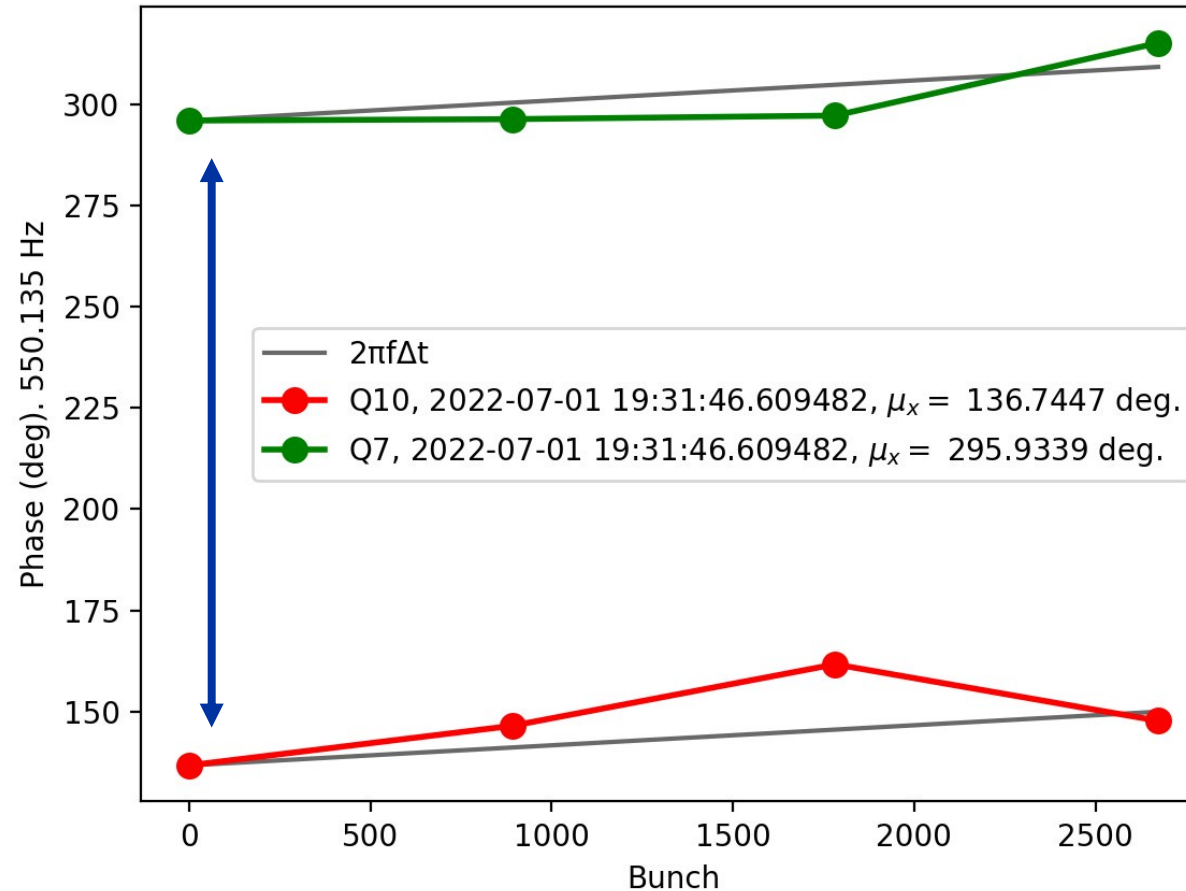
**Conclusion:**

- Loss of synchronization with mains when UPS in SR4 is switched to “battery” mode observed only in B1 and not B2.





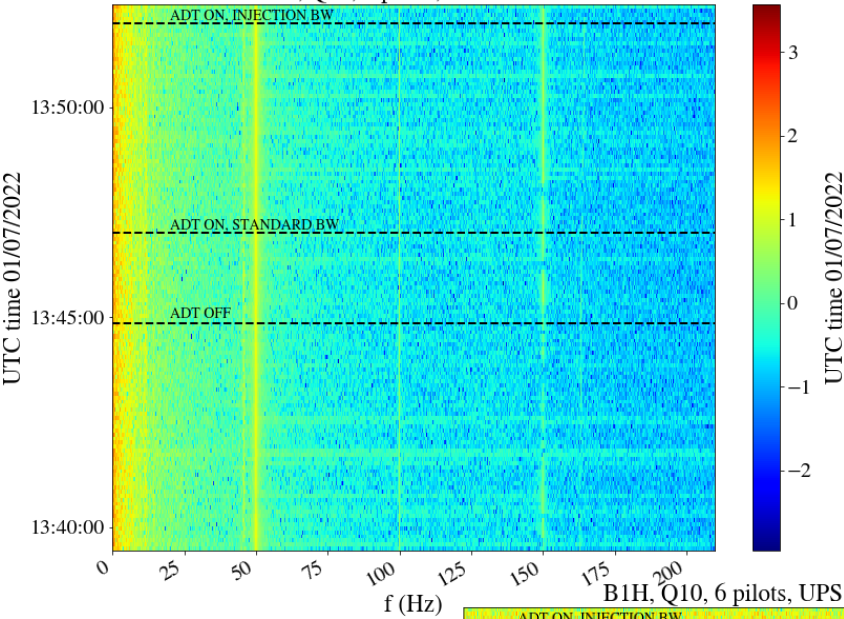
# Is it an instrumental effect or a real beam oscillation?



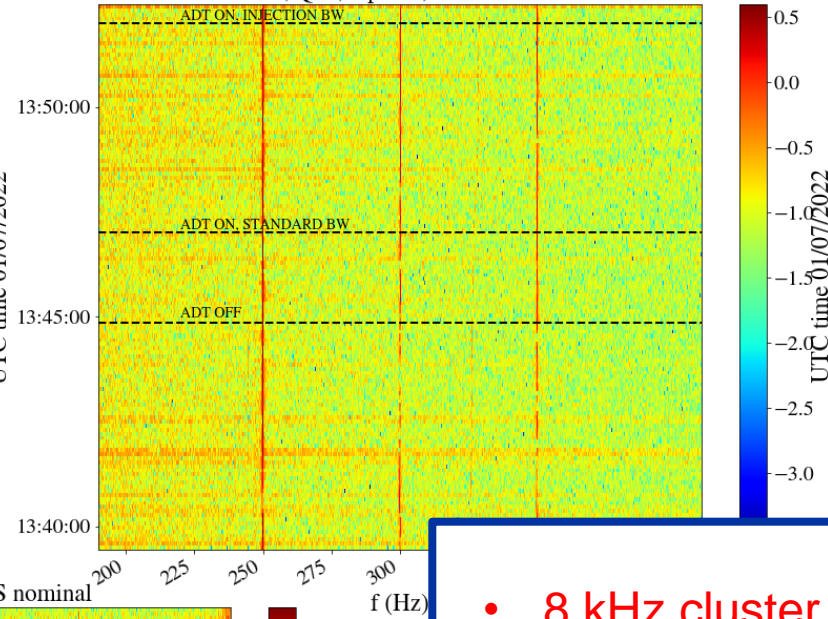
The observed phase is NOT compatible with the B1 betatron phase.  
We think it is instrumental.

# ADTObsBox spectra in MD: Reference spectrum

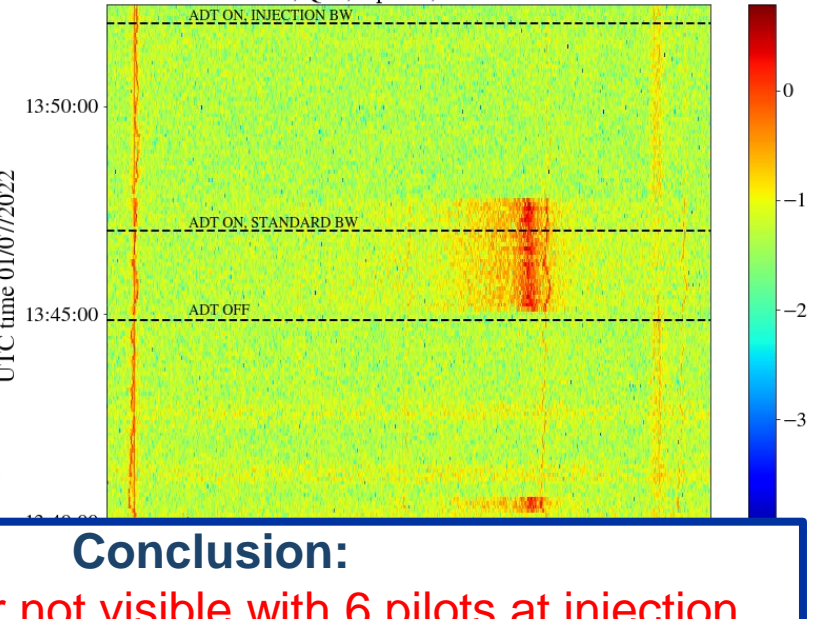
B1H, Q10, 6 pilots, UPS nominal



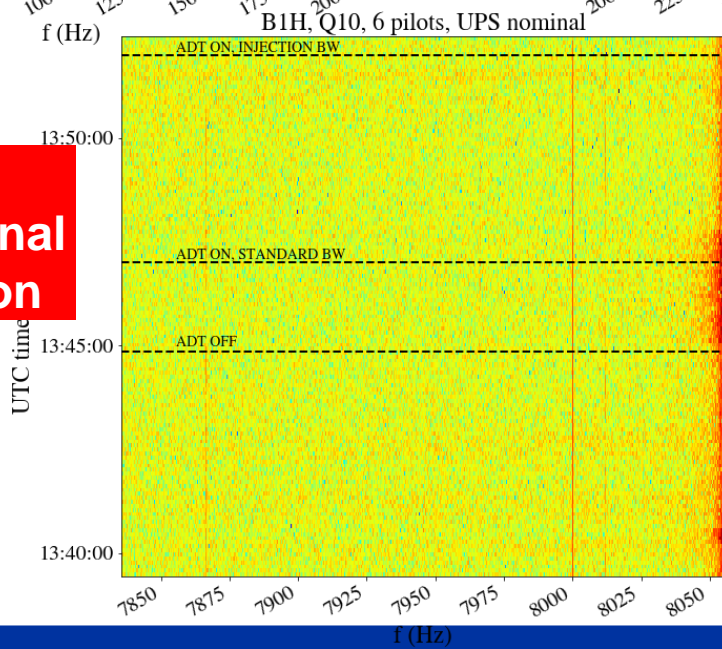
B1H, Q10, 6 pilots, UPS nominal



B1H, Q10, 6 pilots, UPS nominal

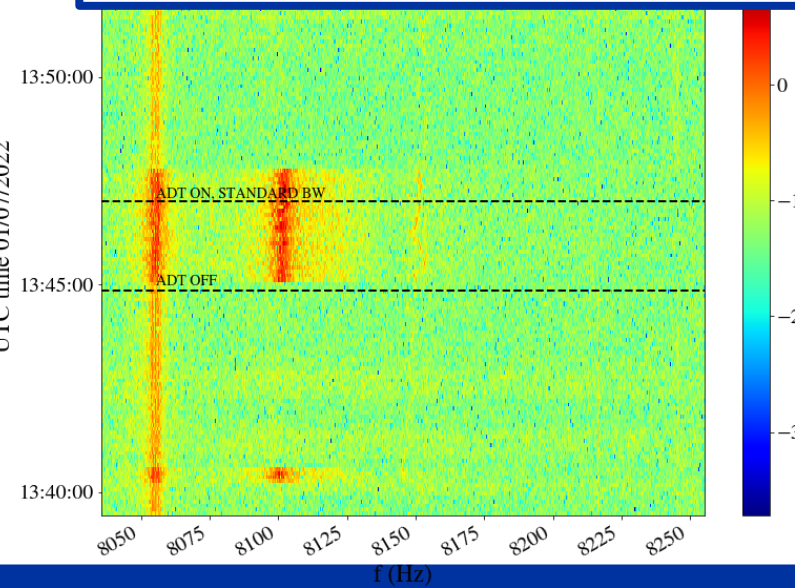


**6 pilots  
UPS to nominal  
configuration**



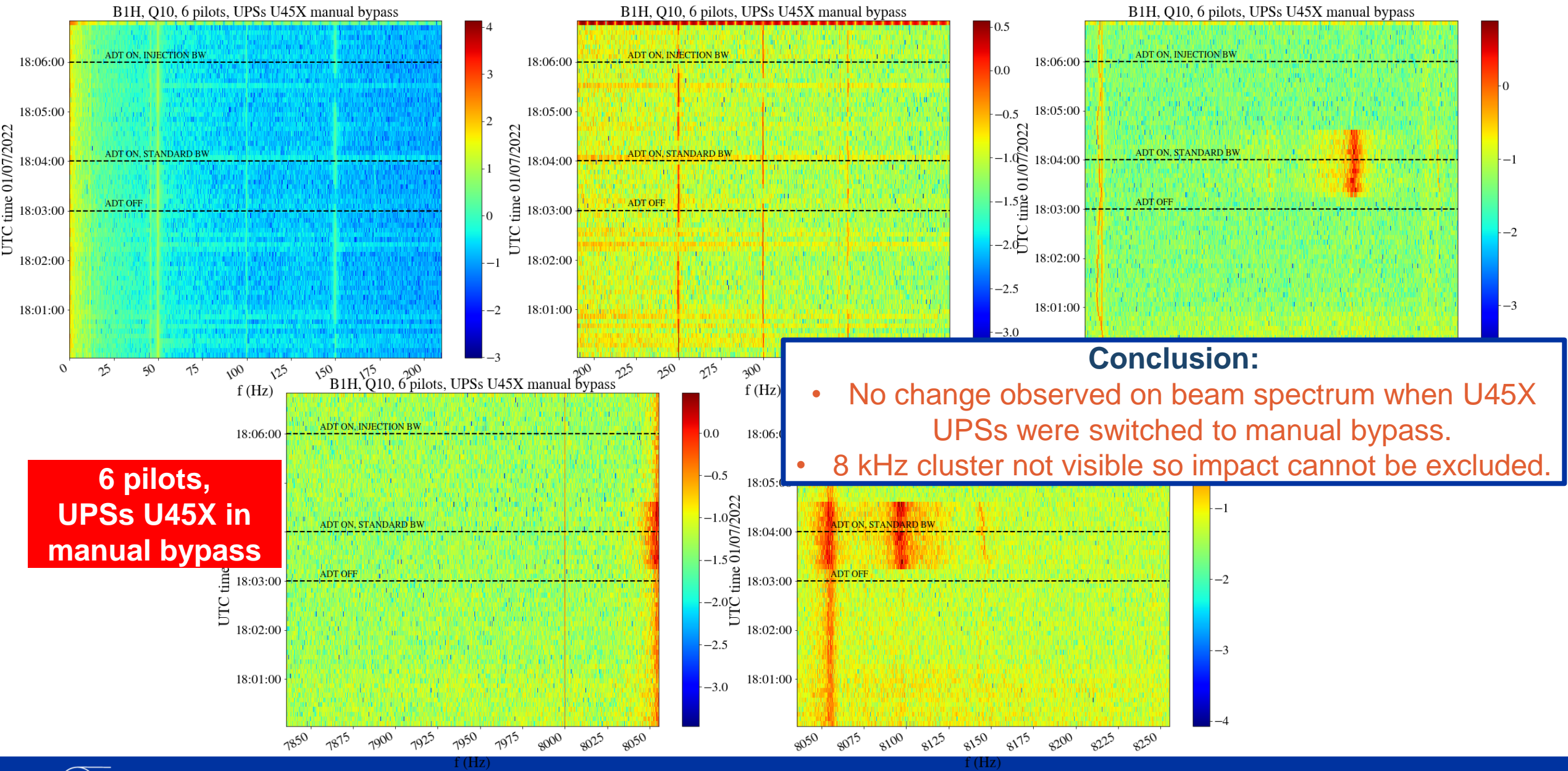
**Conclusion:**

- 8 kHz cluster not visible with 6 pilots at injection.

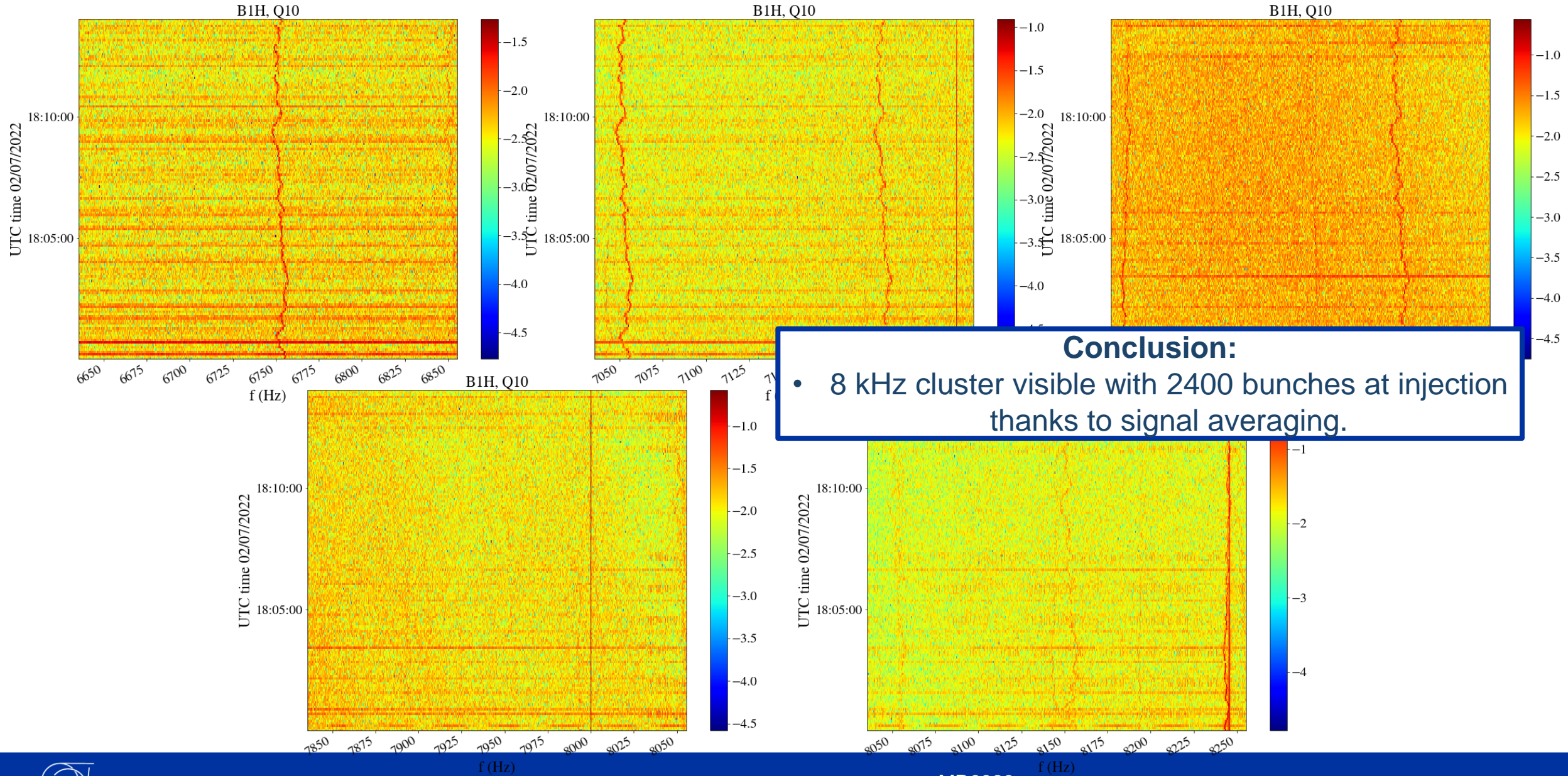




# ADTobsBox spectra in MD: U45X UPSs in manual bypass



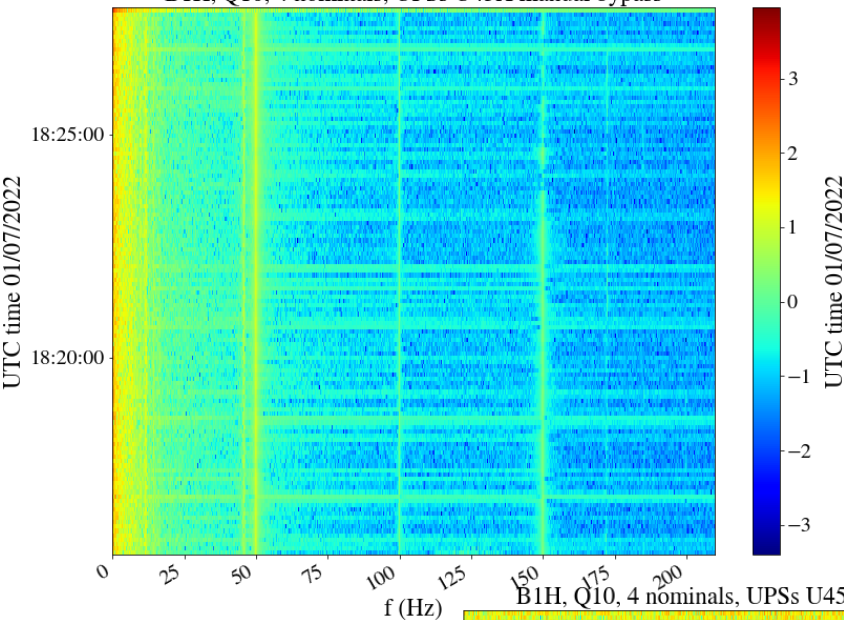
# ADTObsBox spectra, 02/07/2022 ~2400 bunches



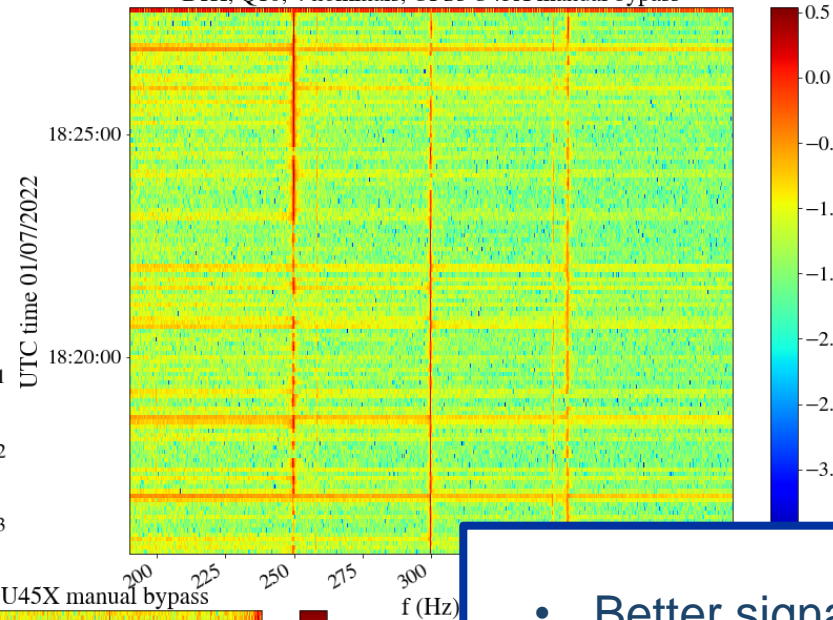


# ADTObsBox spectra in MD with 4 nominals

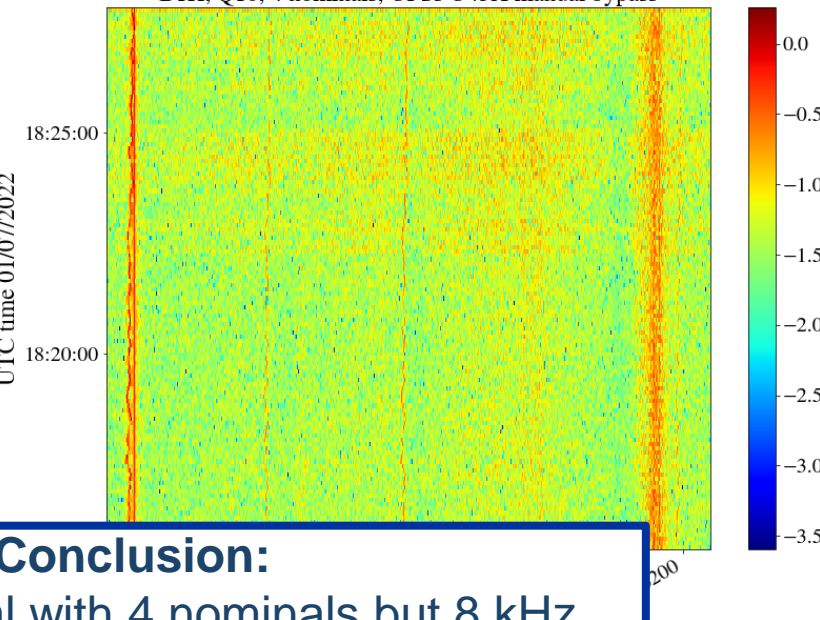
B1H, Q10, 4 nominals, UPSs U45X manual bypass



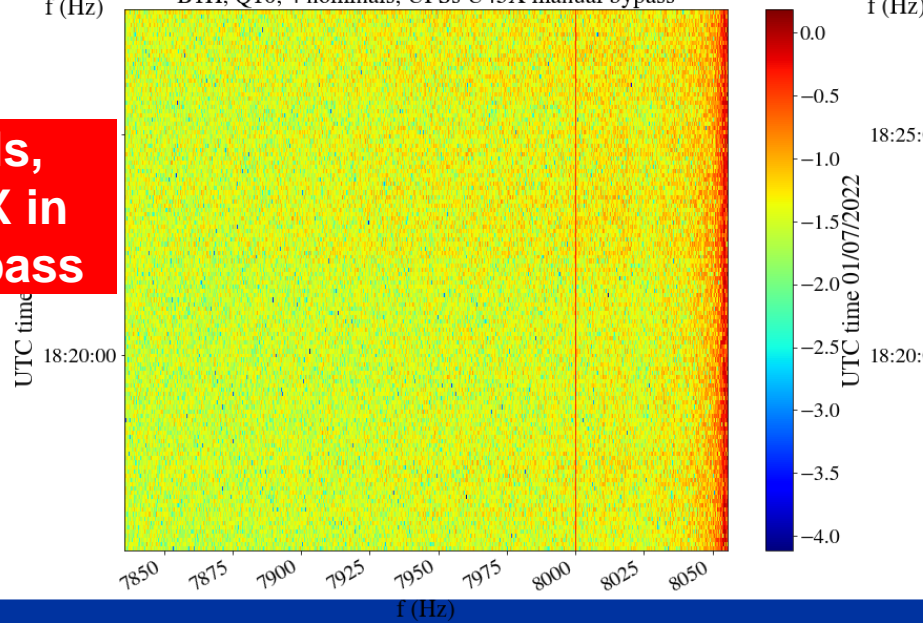
B1H, Q10, 4 nominals, UPSs U45X manual bypass



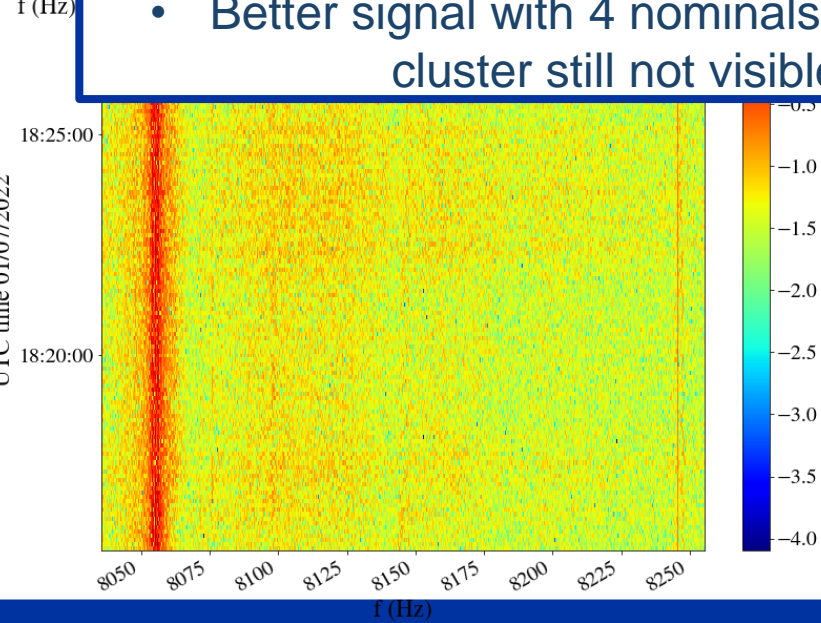
B1H, Q10, 4 nominals, UPSs U45X manual bypass



B1H, Q10, 4 nominals, UPSs U45X manual bypass



B1H, Q10, 4 nominals, UPSs U45X manual bypass



**Conclusion:**

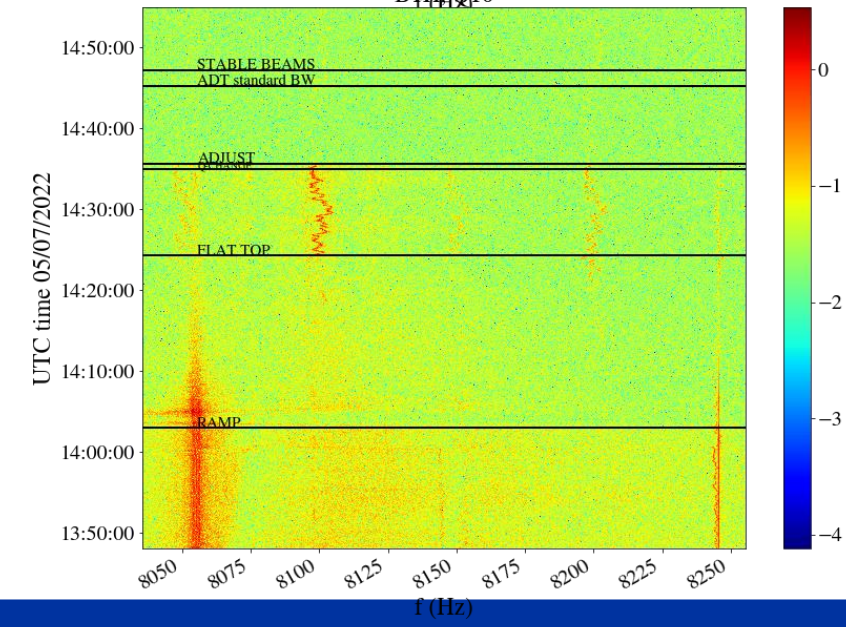
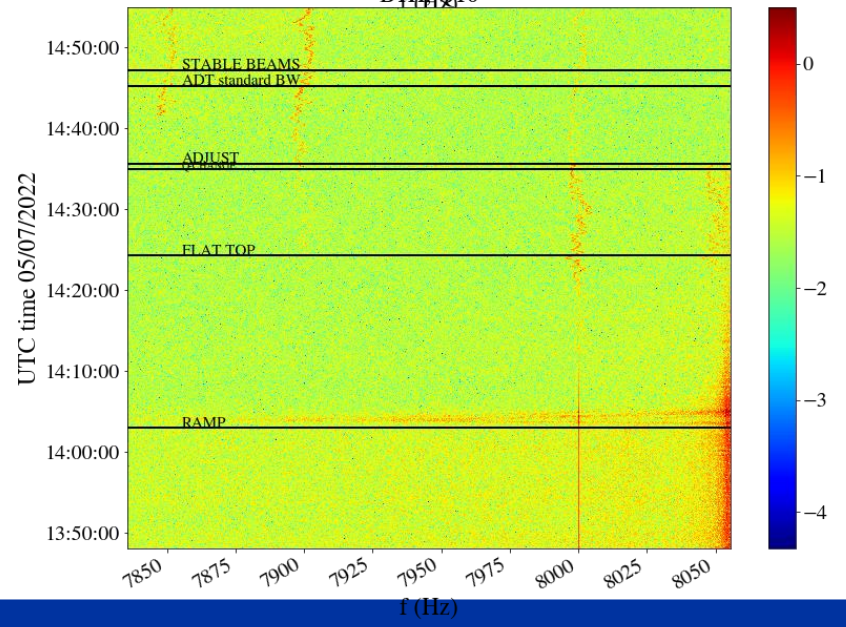
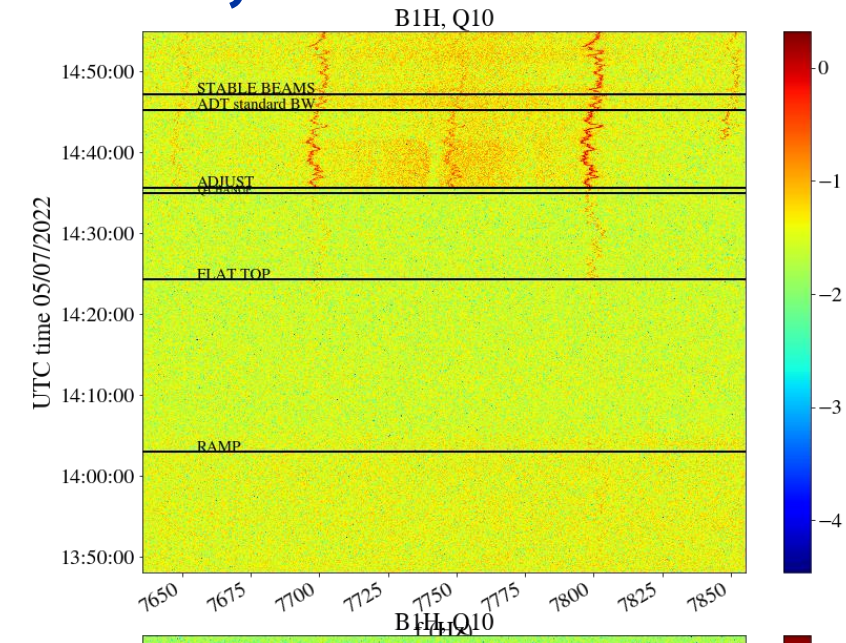
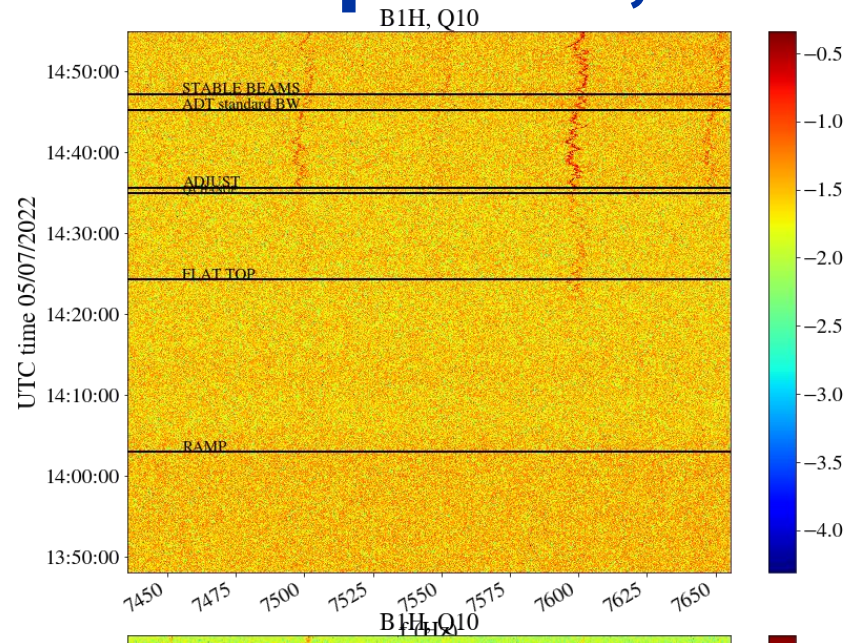
- Better signal with 4 nominals but 8 kHz cluster still not visible.

**4 nominals,  
UPSs U45X in  
manual bypass**

# **Spectrograms 05/07/2022 (injection-Stable beams, 3 bunches)**



# ADTObsBox spectra, 05/07/2022, 3 bunches

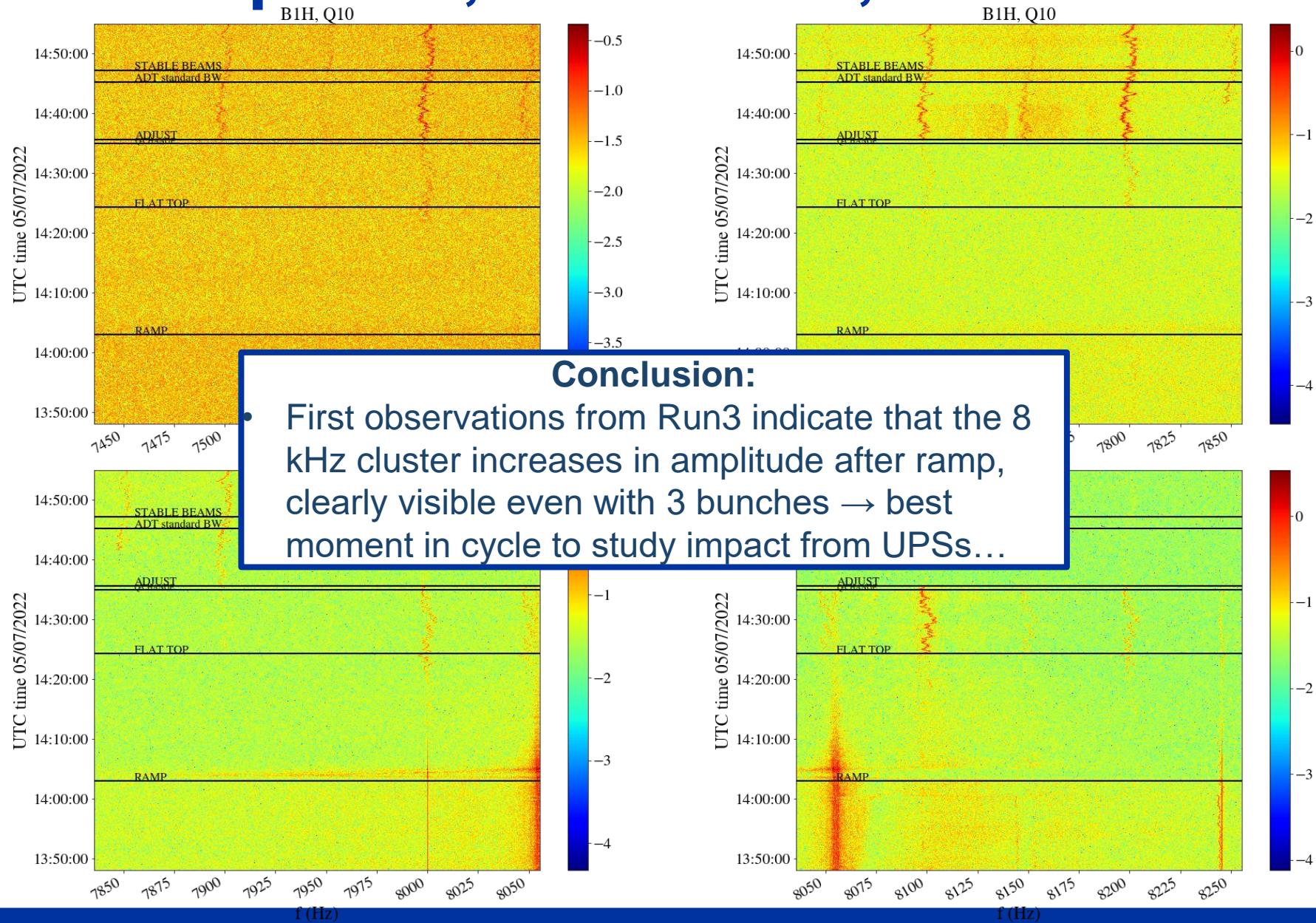


f (Hz)

f (Hz)



# ADTObsBox spectra, 05/07/2022, 3 bunches



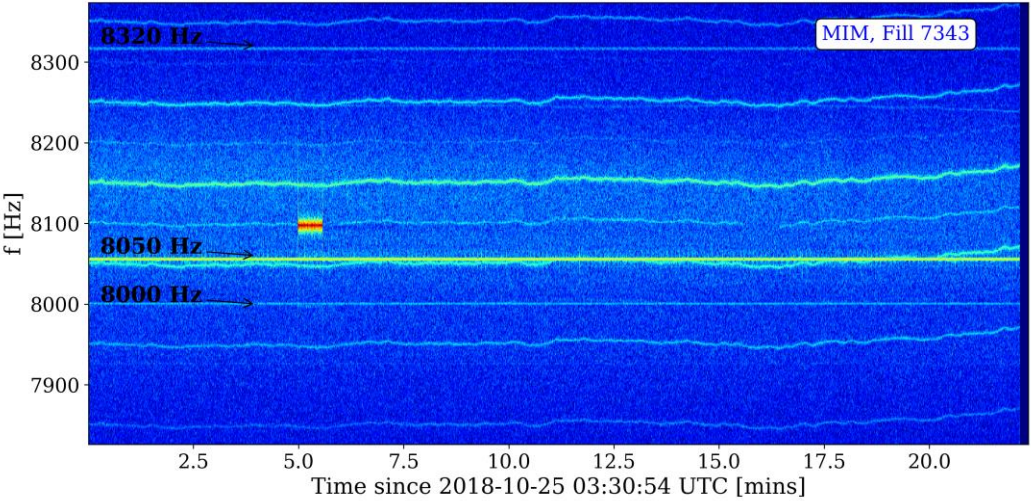
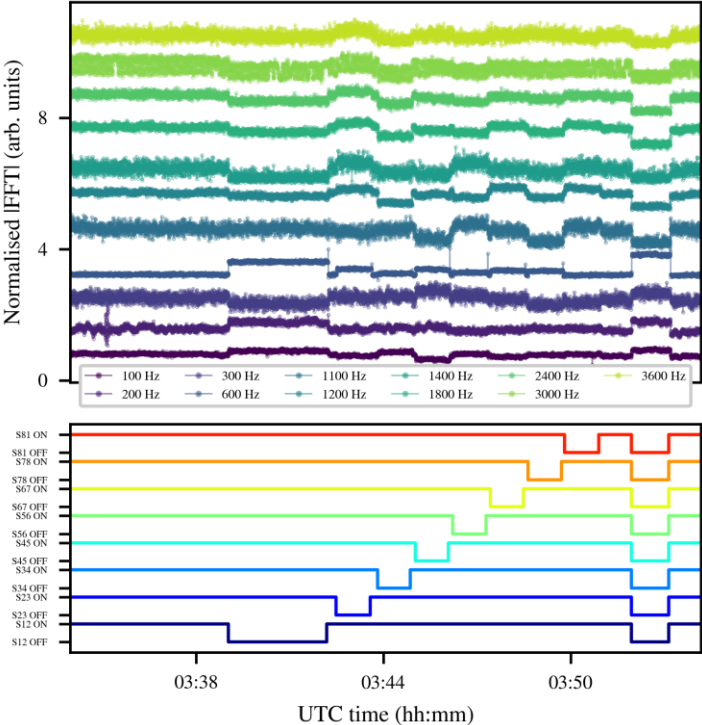
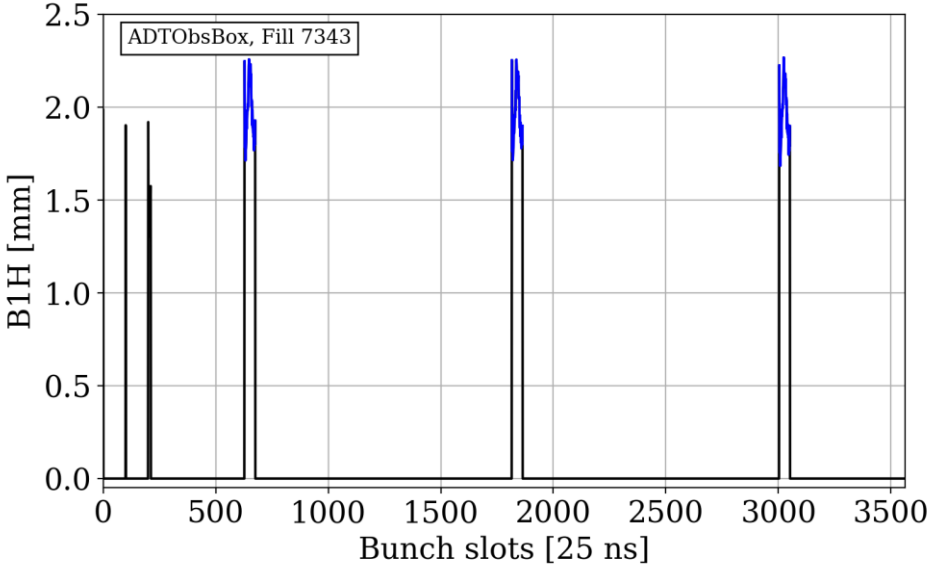
# Summary

- Collected important new insights concerning 50 Hz harmonics during the MD thanks to ADTObsBox continuous buffer combined with UPS tests:
  - As a first attempt, UPS tests performed at injection with low intensity beams.
- Can the UPS's connected to the ADT introduce an effect on the beam? **Impact from UPS in SR4 on a few low-order harmonics** (550, 750, 1150, 1950, 2050, 3150 Hz), **it is the first time that we observe a clear signature when UPS in SR4 is switched to battery mode, effect observed only on B1.**
- Are these UPS's acting on the 8 kHz region? **No clear impact of UPS in UX45 on any 50 Hz line, however 8 kHz cluster not observed during MD and thus UPS impact cannot be excluded.**
- 8 kHz cluster not visible during MD with a few bunches at injection:
  - ***Proposal: repeat “SR4 UPS on battery” after Ramp as an End of Fill MD when largest amplitudes of 8 kHz cluster are observed.***

# Backup



# Noise MD in Run 2



# UPS modes

**Normal mode:** ACin1 → Rectifier → Inverter → Load

- **Synchronized** to **bypass** (ACin2) through internal inverter PLL.

**On battery:** Battery → Inverter → Load

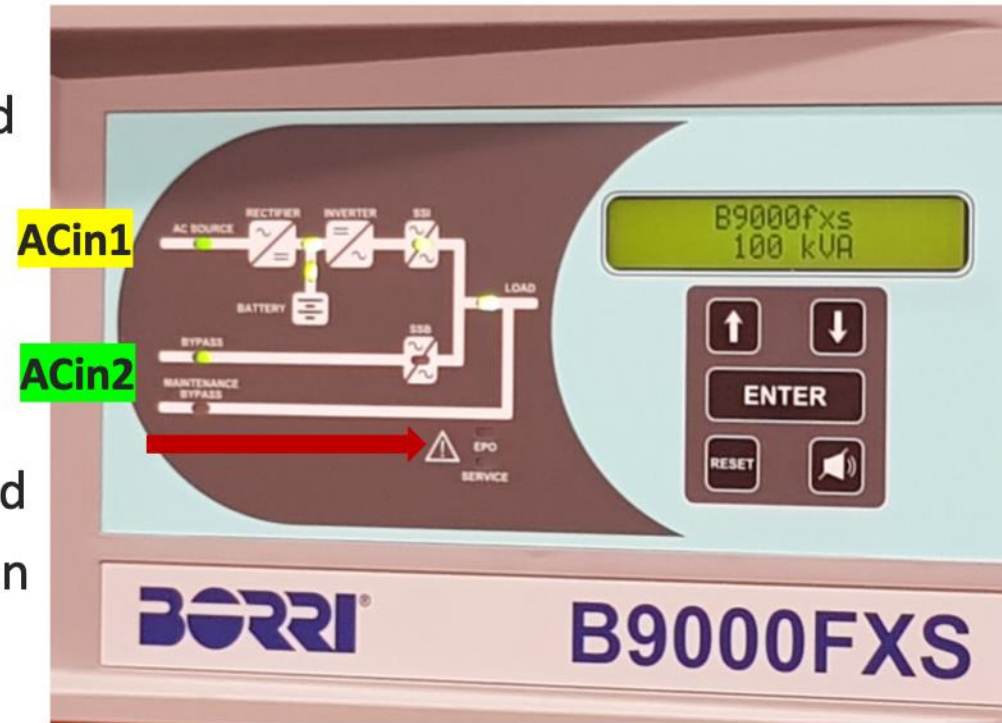
- In case of **power failure**.
- In our measurements, no synchronization with ACin1 and ACin2.

**Static bypass:** ACin2 → Switch → Load

- Switches **automatically** to maintain power continuity in case of **inverter failure**.

**Maintenance bypass:** ACin2 → Load

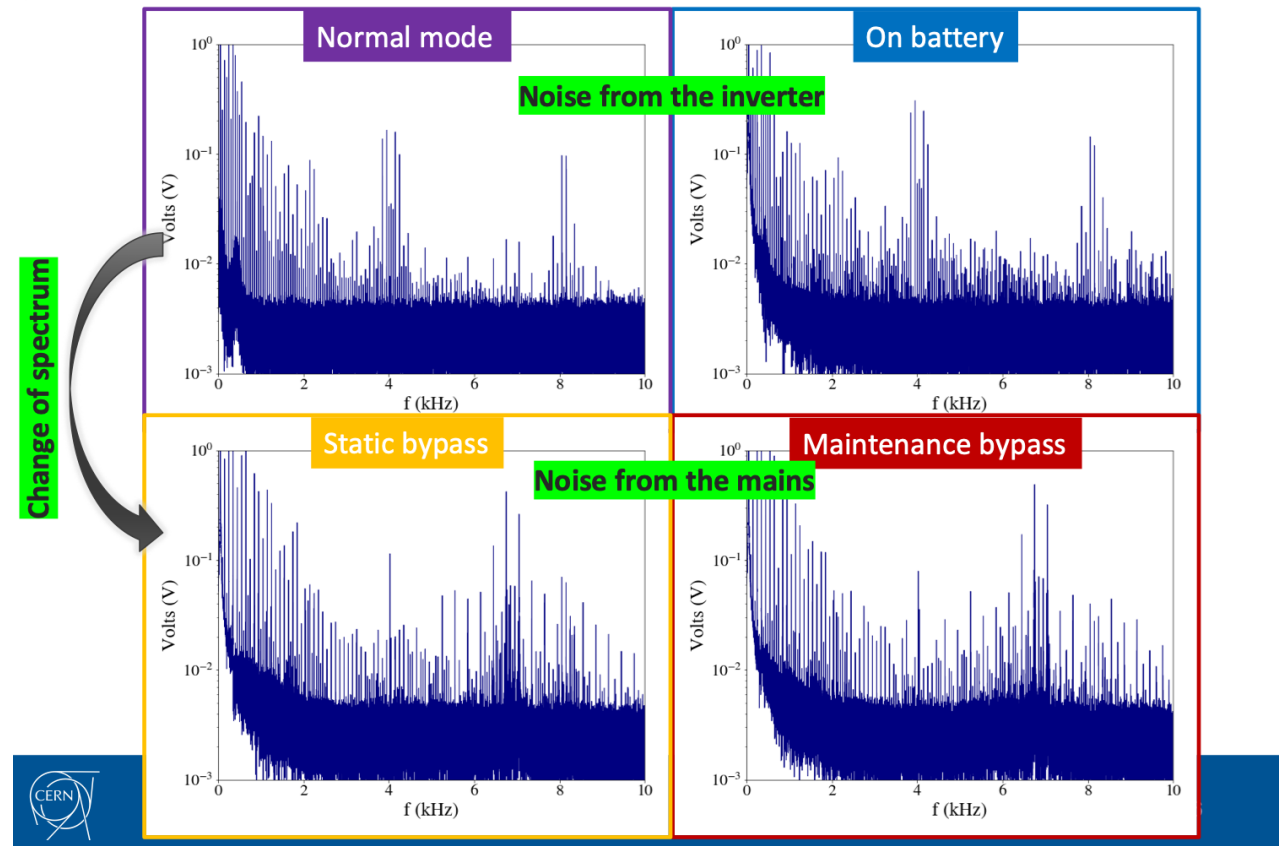
- **Manual** action required.



# Measurements in SM18

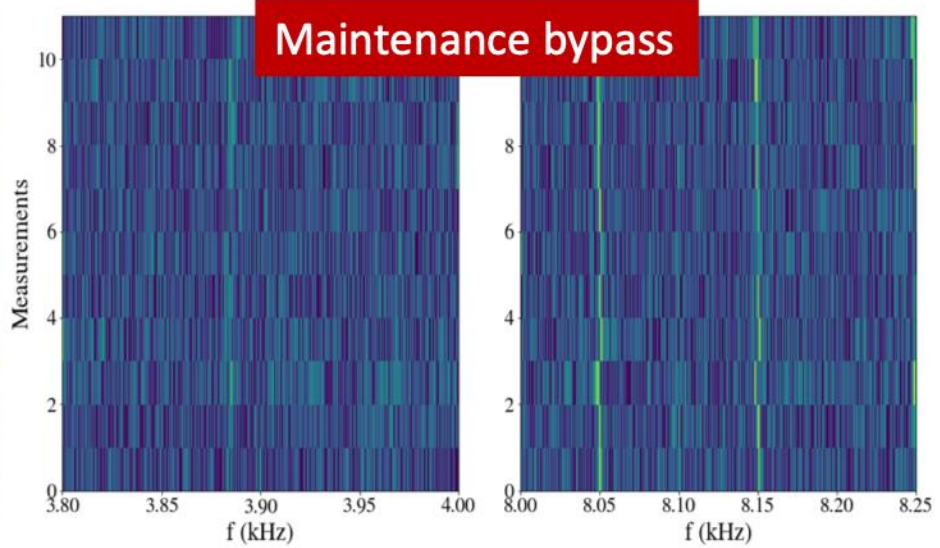
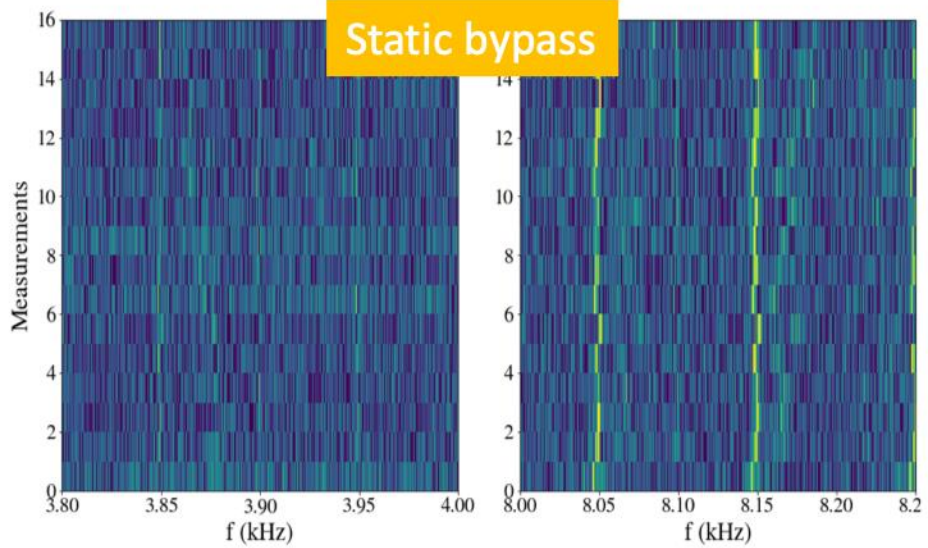
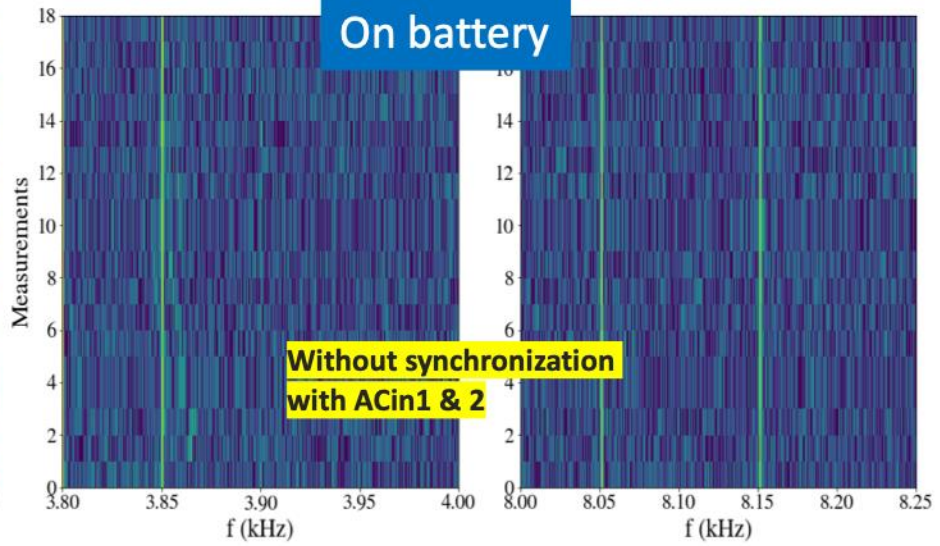
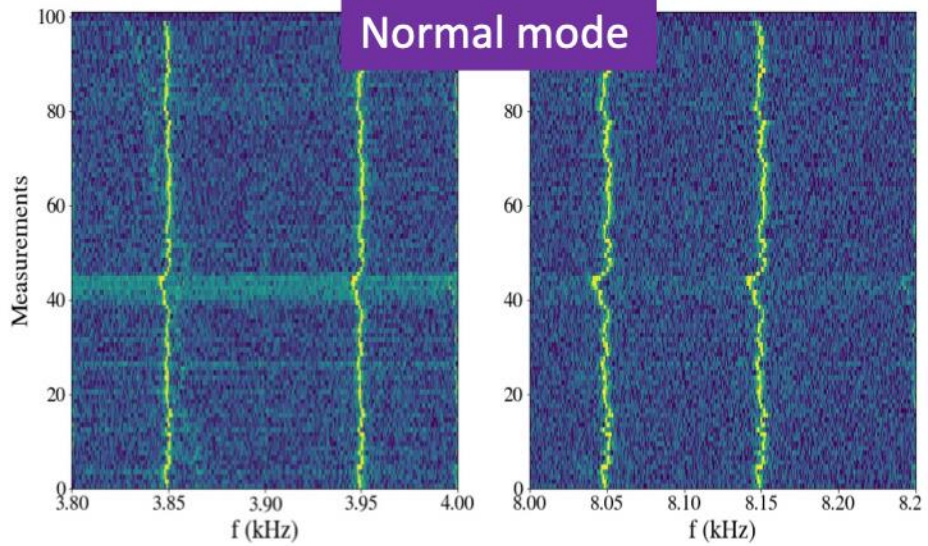
- Measurements of spare UPS in SM18 during LS2.
- UPS output voltage spectrum: 50 Hz harmonics around 4 and 8 kHz **following network frequency fluctuation in time** → similar to 50 Hz harmonics on the beam spectrum.
- UPS operation modes: **nominal, on battery, static and manual bypass.**
- Switching UPS operational modes leads to change in the UPS noise spectrum → **apply changes in UPS configuration during LHC operation with beam and observe beam spectrum.**

## Spectra in all UPS modes





# Spectrograms in all UPS modes

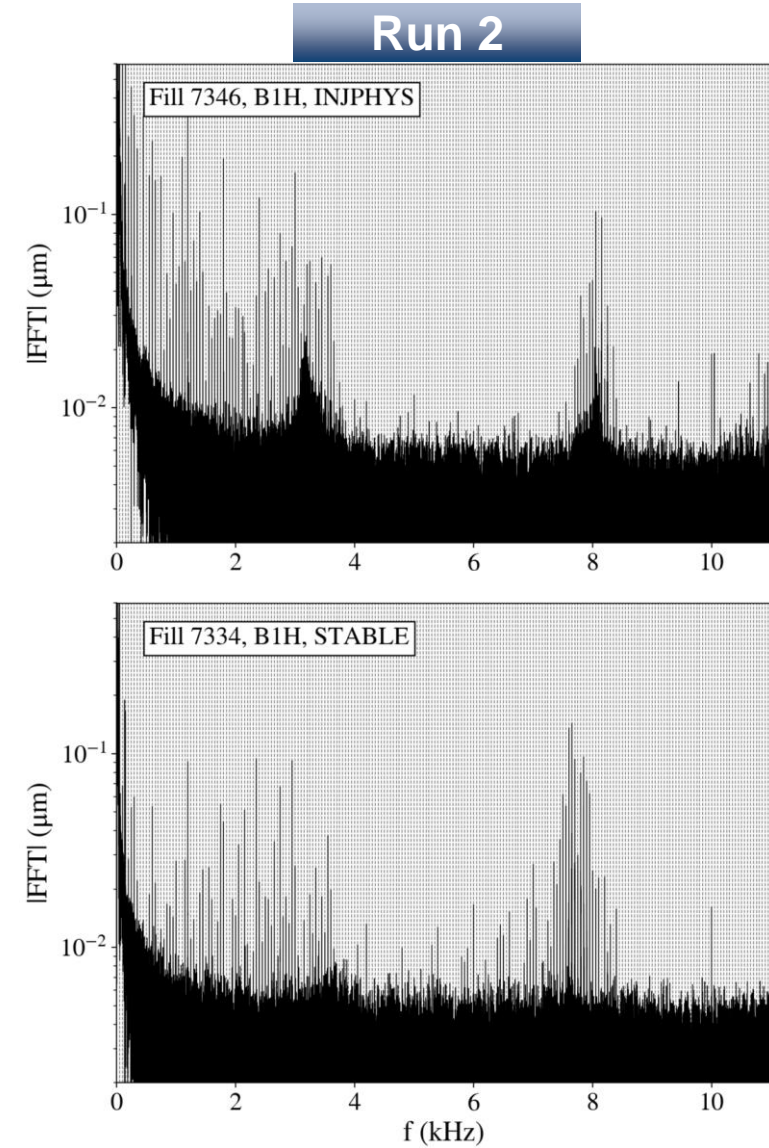
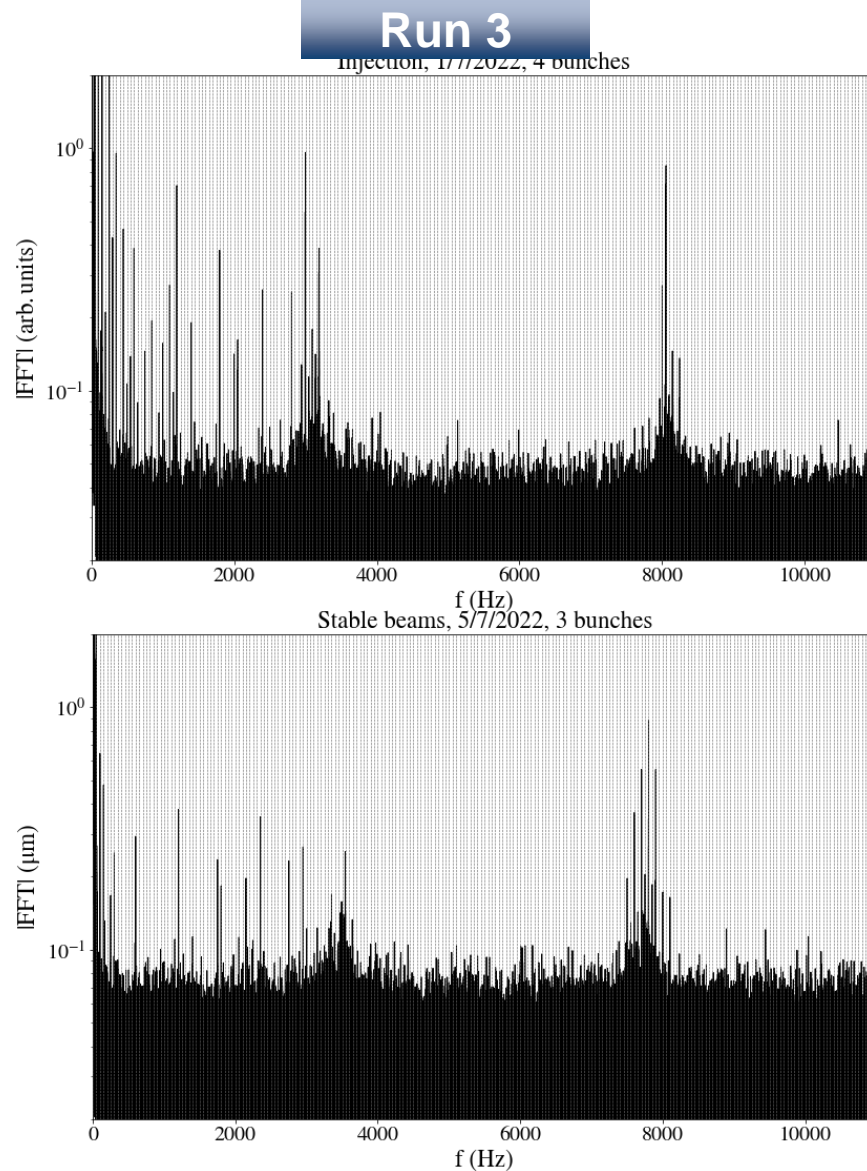


# ADTObsBox spectra

Note: arbitrary units, calibration not yet implemented

Injection

Stable beams



# MD overview

15:36 injection of **6 pilots**

15:44 ADT OFF

15:46 changed to standard ADT BW

15:52 changed to injection ADT BW

15:59 EN-EL access to **U45X** to switch 2 **UPSs** in **manual bypass**

20:00 injected **6 pilots** with injection ADT BW

20:04 changed to standard ADT BW

20:06 changed to injection ADT BW

20:15 injection of **4 nominal bunches**

20:27 Beam dump

20:30 EN-EL access to **U45X** to switch back 2 **UPSs** to nominal configuration

21:22 injection of **4 nominal bunches**

21:30 UPS SR4 **on battery**

21:36 ADT OFF

21:38 UPS SR4 **back to nominal**

21:43 UPS SR4 on **static bypass**

21:49 UPS SR4 on **manual bypass**

21:53 UPS SR4 back to **nominal**

21:58 UPS SR4 on **manual bypass**

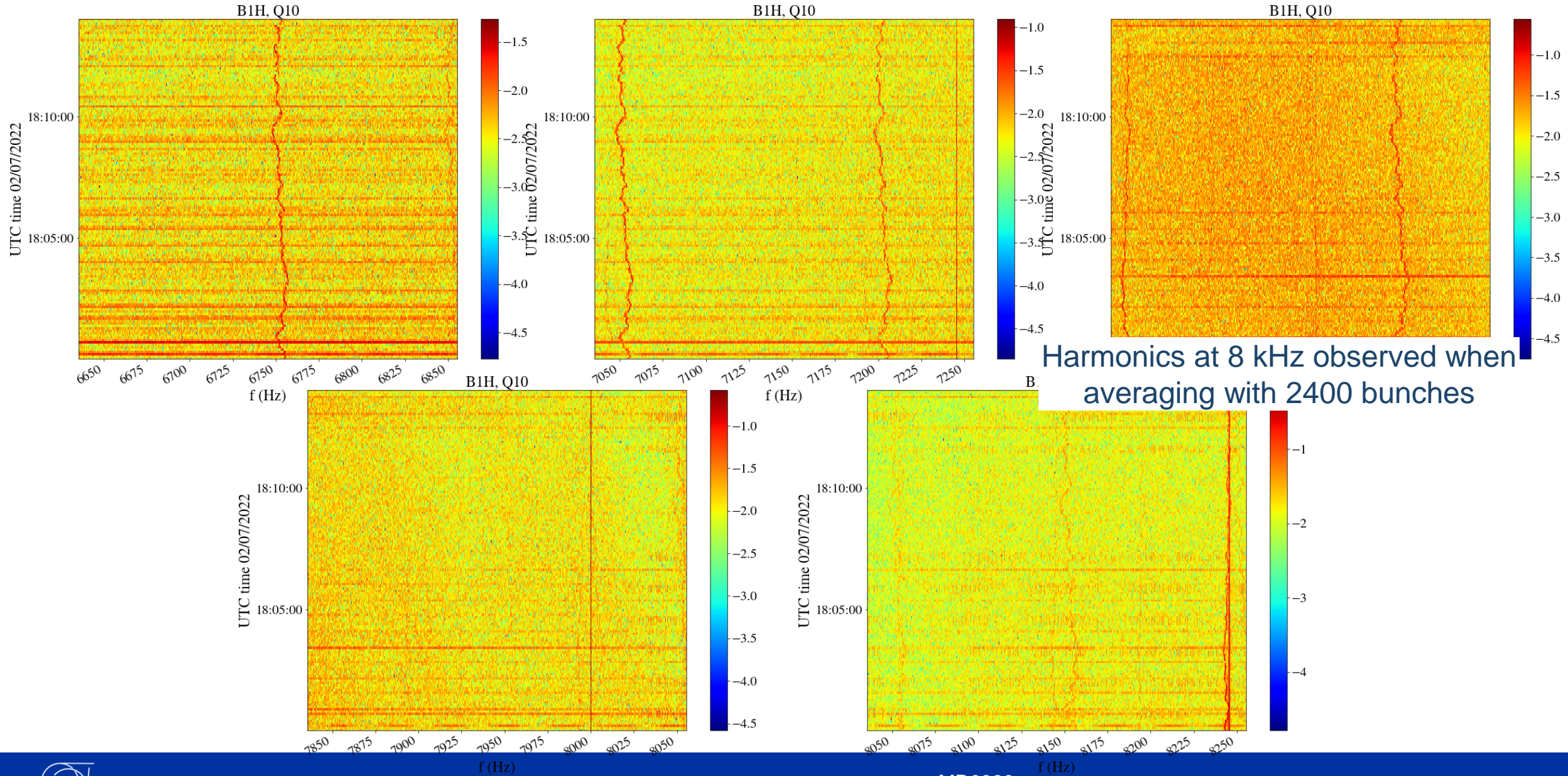
22:03 UPS SR4 **back to nominal**

22:16 Tune trims

22:20 Beam dump

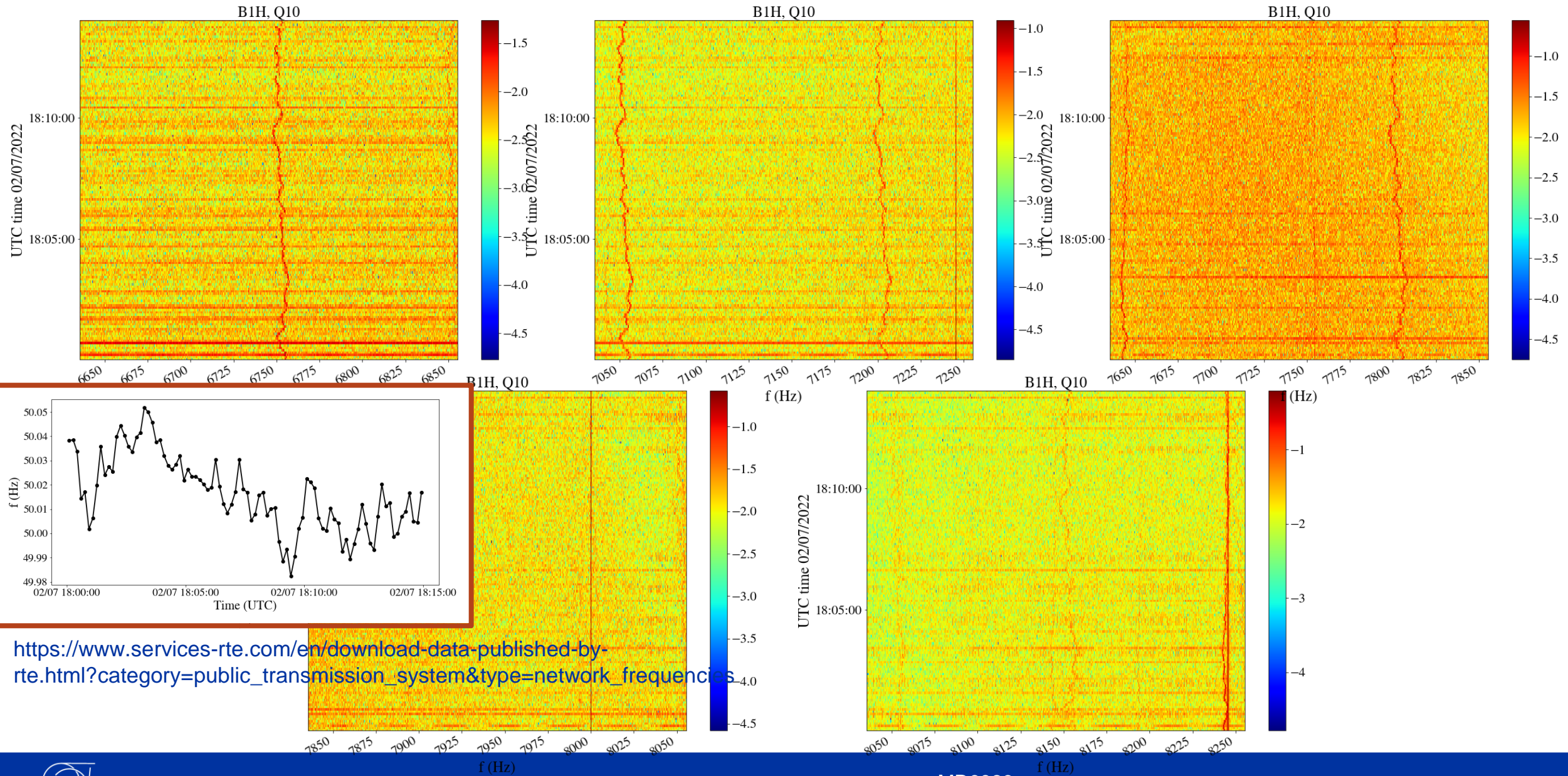


# ADTObsBox spectra, 02/07/2022 ~2400 bunches





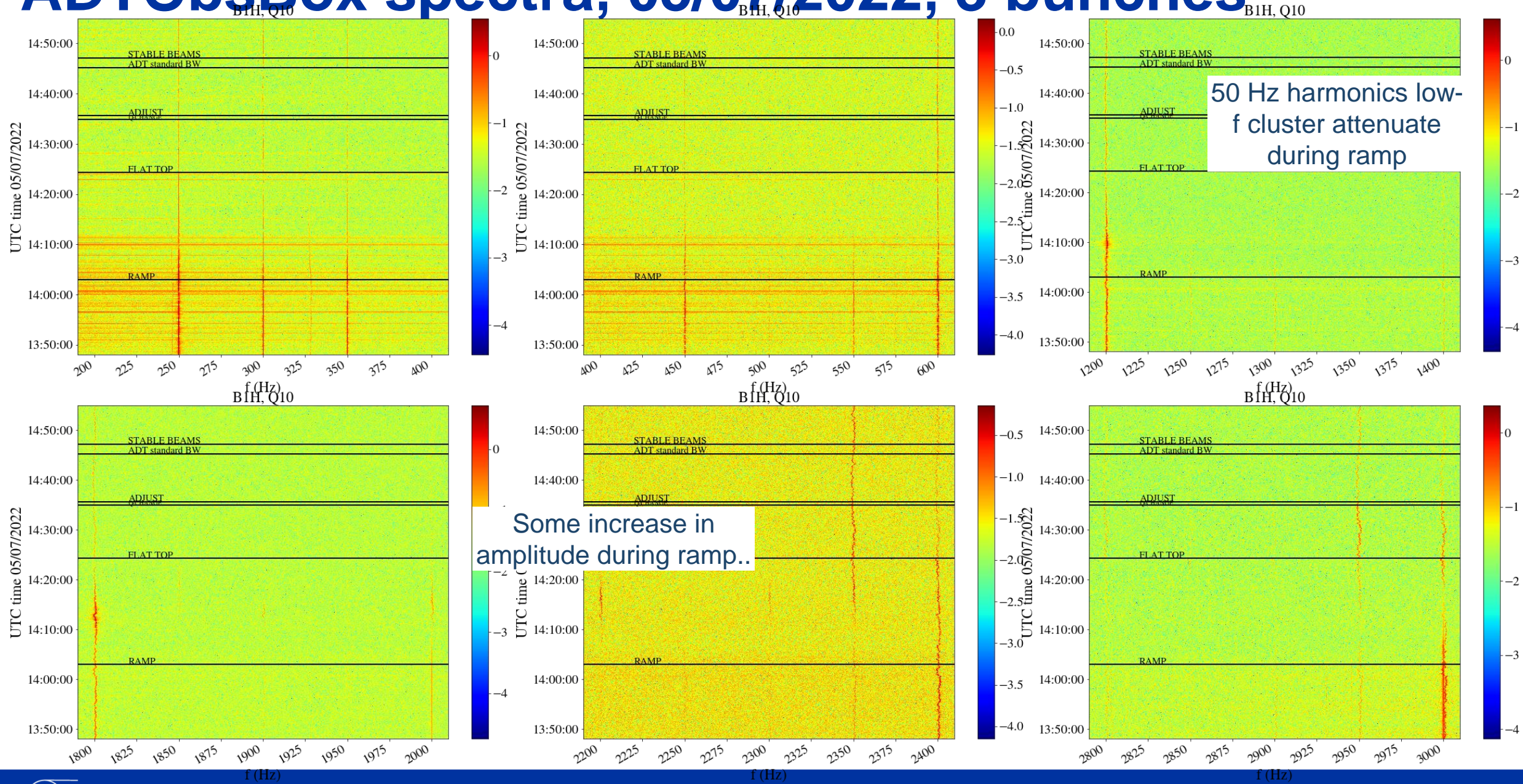
# ADTObsBox spectra, 02/07/2022 ~2400 bunches



[https://www.services-rte.com/en/download-data-published-by-rte.html?category=public\\_transmission\\_system&type=network\\_frequencies](https://www.services-rte.com/en/download-data-published-by-rte.html?category=public_transmission_system&type=network_frequencies)

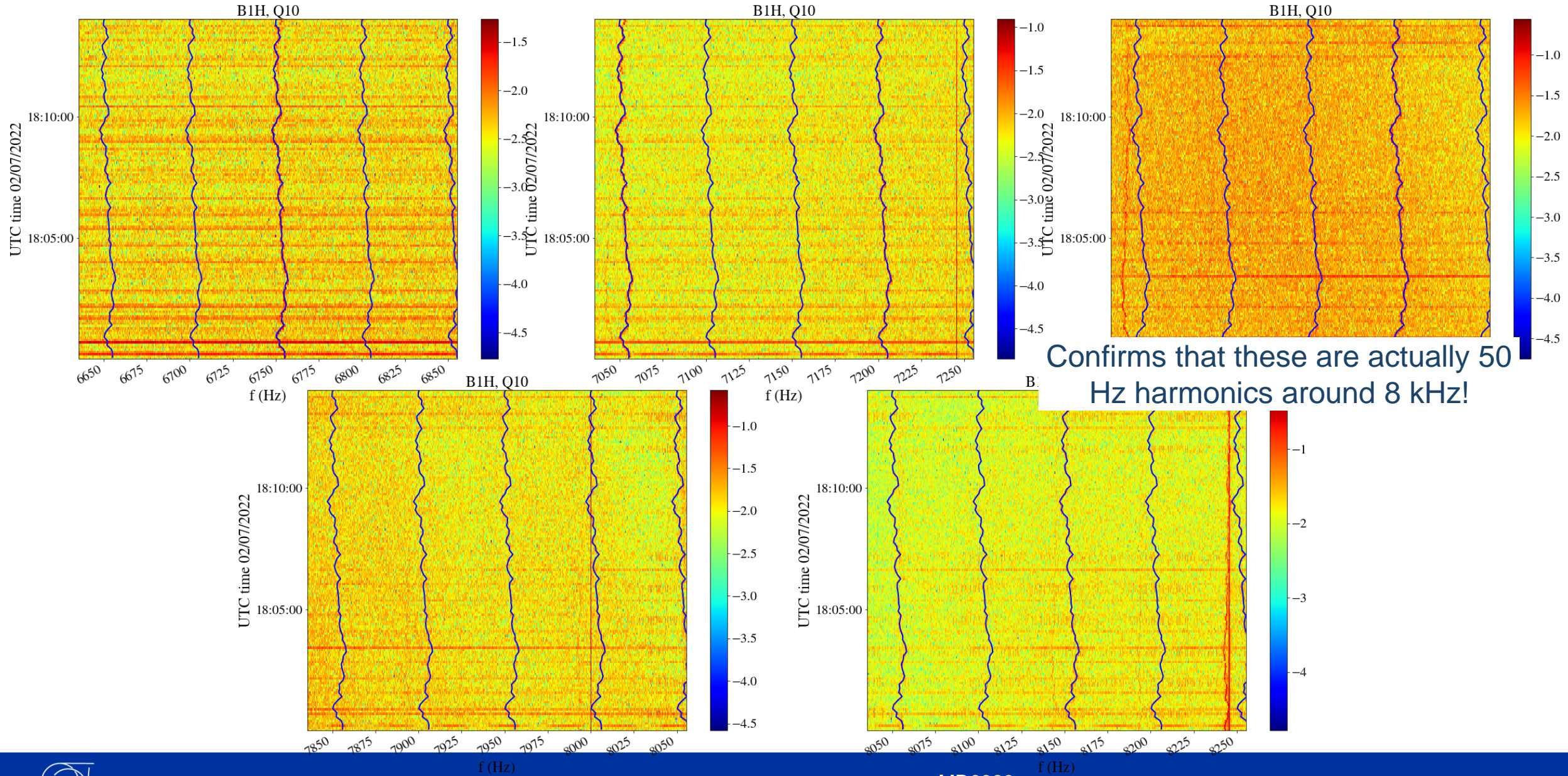


# ADT ObsBox spectra, 05/07/2022, 3 bunches





# ADTObsBox spectra, 02/07/2022 ~2400 bunches



Confirms that these are actually 50 Hz harmonics around 8 kHz!



