Status of the studies on 50 Hz multiple noise

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WP2 04/09/2018

Overview

1. Observations
   - LBOC 2012:

   http://lhc-beam-operation-committee.web.cern.ch/lhc-beam-operation-committee/minutes/Meeting51-16_10_2012/workoutline.pdf
   - LMC 2015:

   https://indico.cern.ch/event/436679/contributions/1085928/attachments/1136594/1627012/LMC05082015_50Hz_04082015.pdf
   - Meeting with BI, RF, EPC:

   https://hackmd.web.cern.ch/s/Sy4F9l2zm
   - Beam-beam & Luminosity meeting:

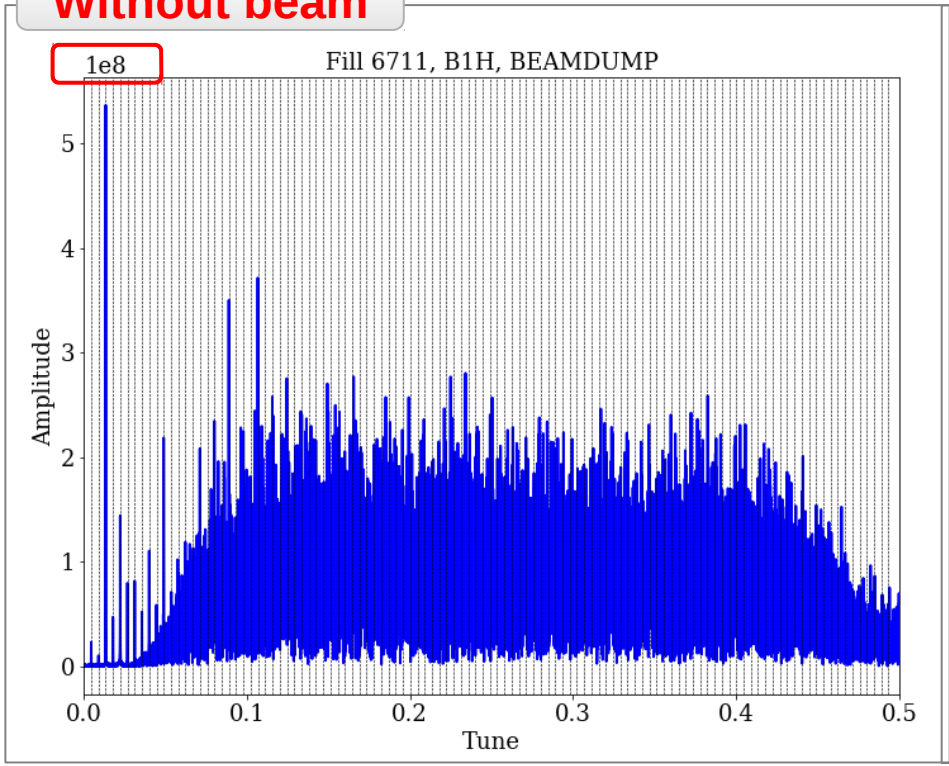
   https://indico.cern.ch/event/744642/
   - LBOC 2018:

   https://indico.cern.ch/event/747171/contributions/3095533/attachments/1698446/2734401/50Hz.pdf
   - Useful link:

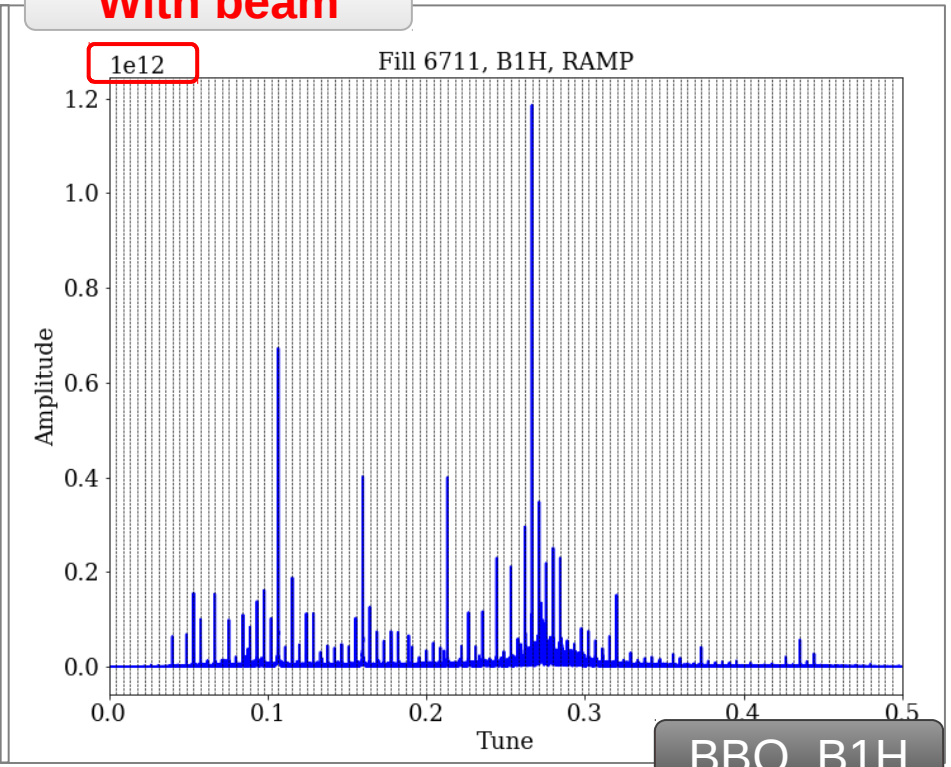
   https://hackmd.web.cern.ch/S9EQdOspQViyW9gDmTIpyg
2. Tests with the active filters of the main dipoles
3. Simulations: DA, FMAs & Lifetime

Observations: Visible only with beam

Without beam



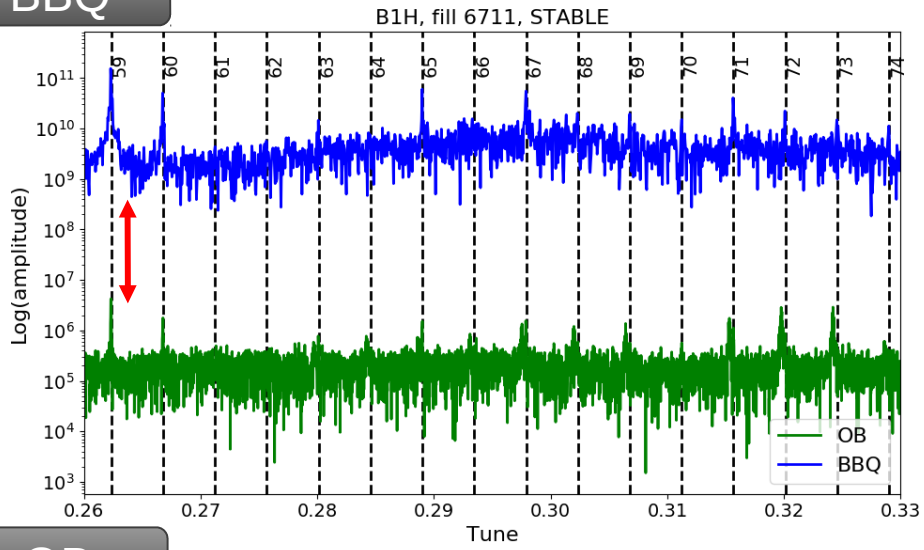
With beam



BBQ, B1H

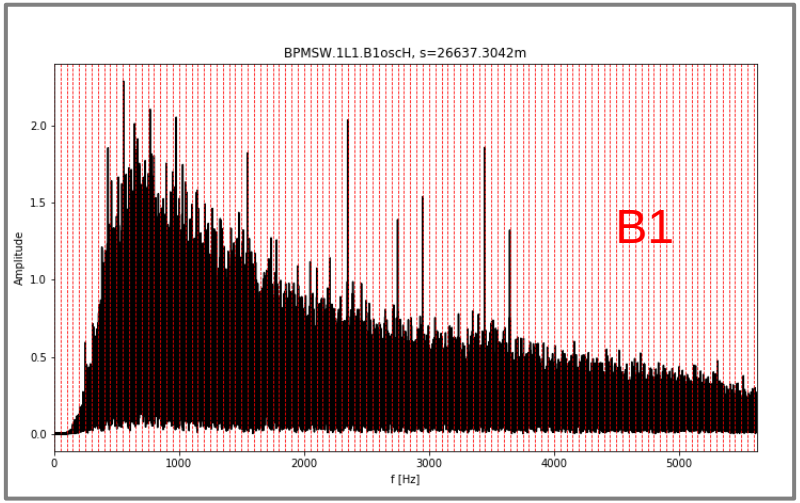
Observations: Consistent between instruments

BBQ



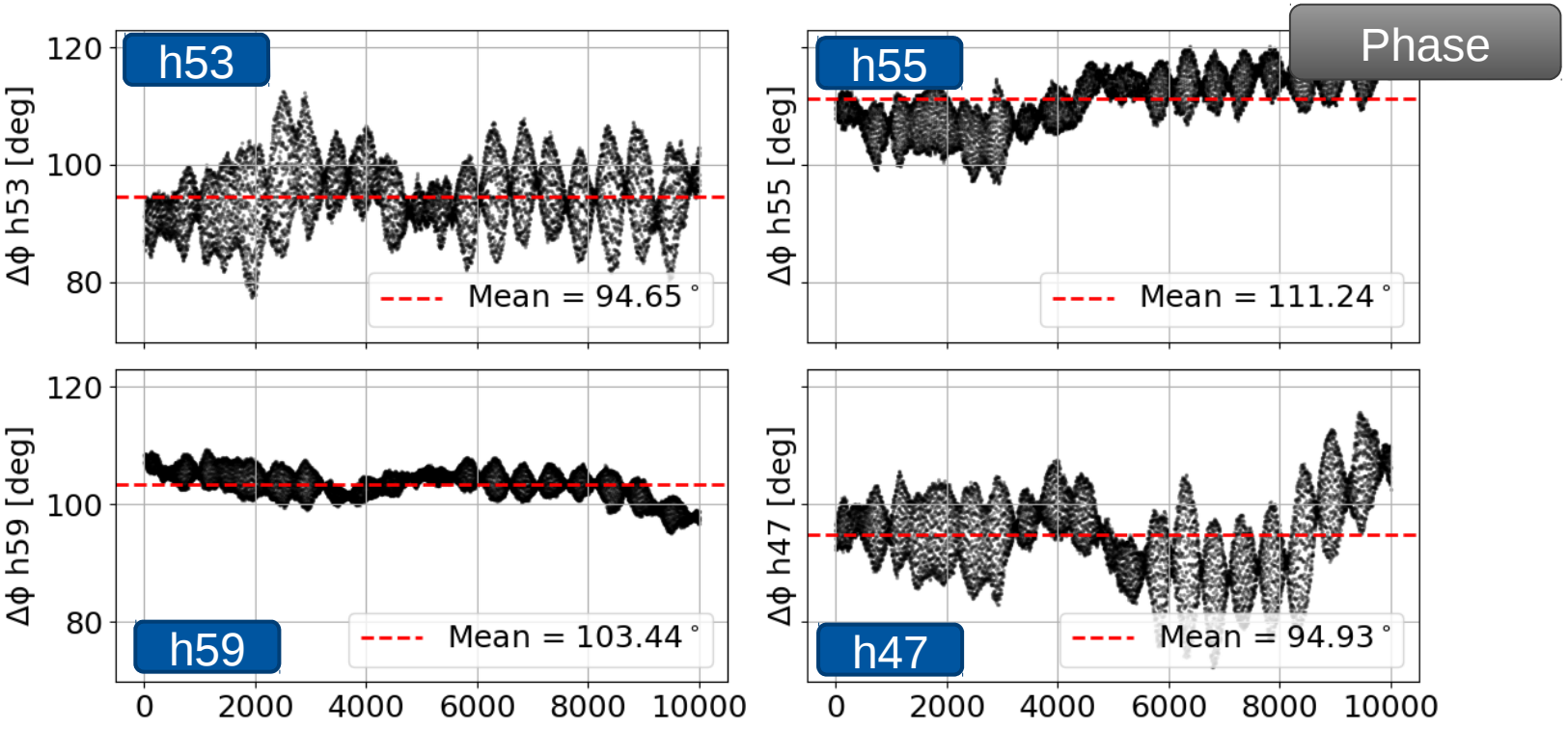
OB

DOROS

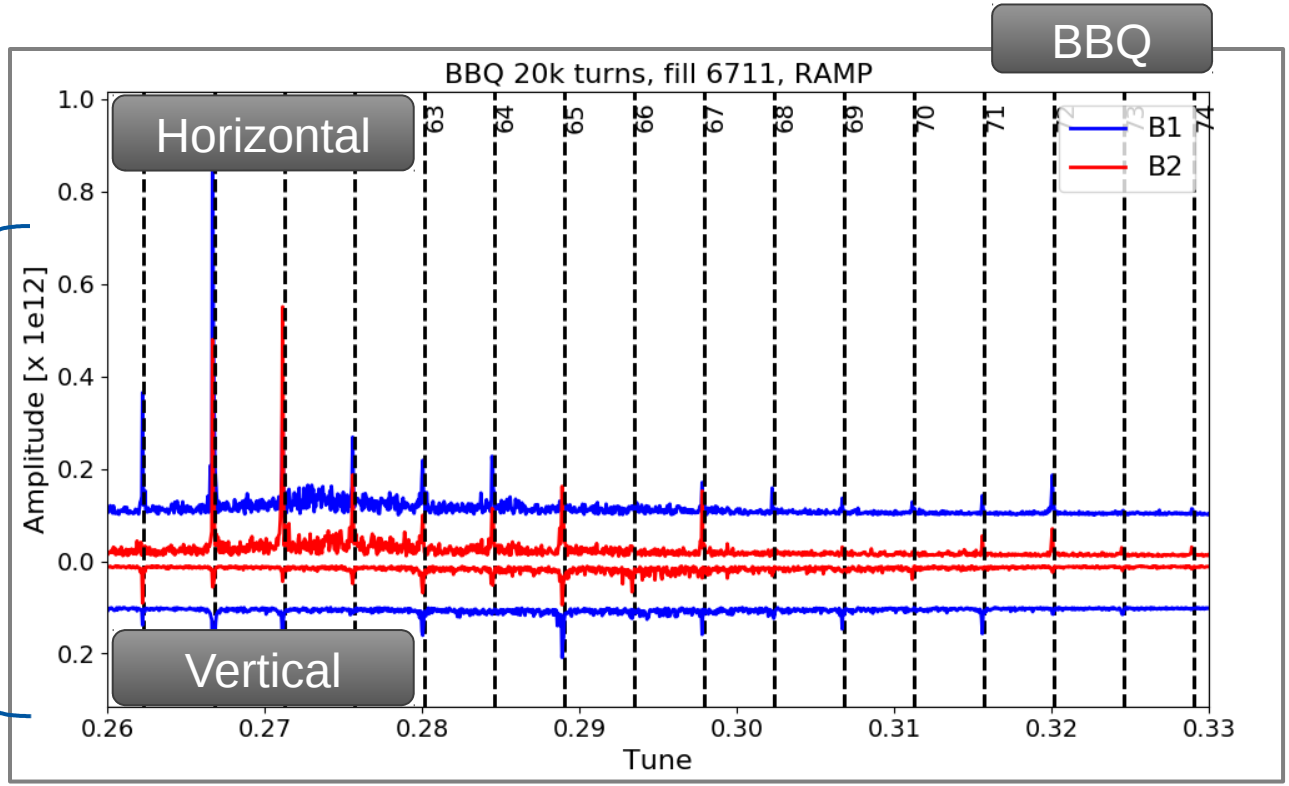


Observations: They follow the betatronic phase advance

- OB PU Q7 & Q9



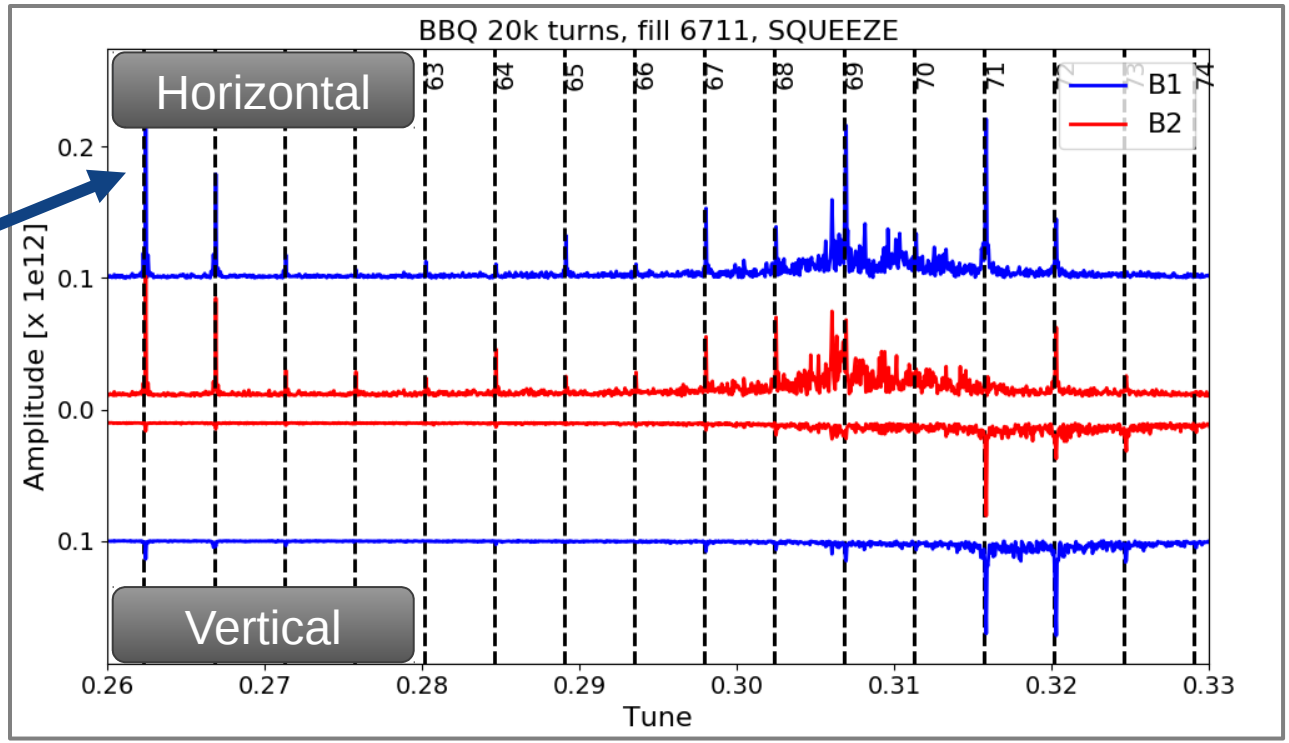
Observations: Mostly on H plane



Same harmonics B1 & B2, H &V

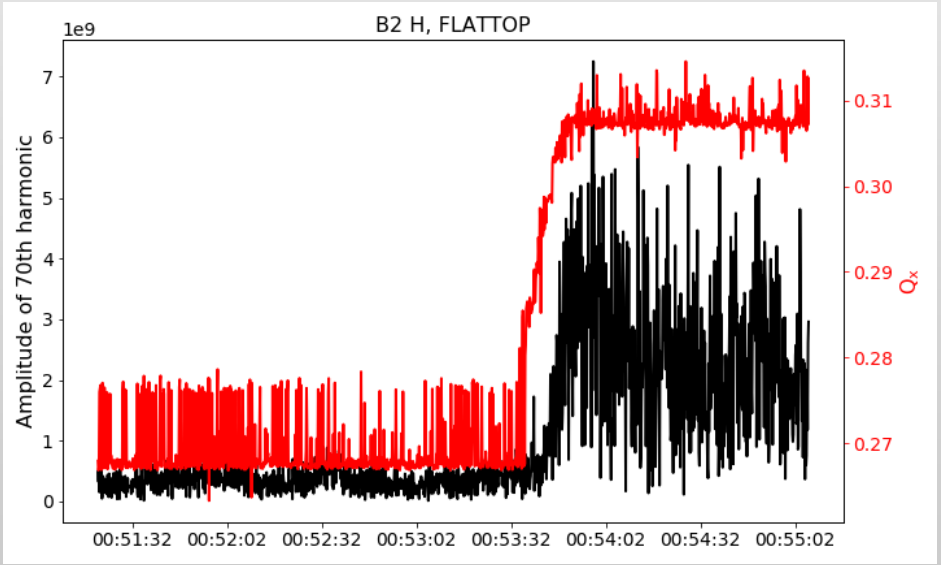
Observations: Their amplitude varies with the tune

Main harmonics during RAMP



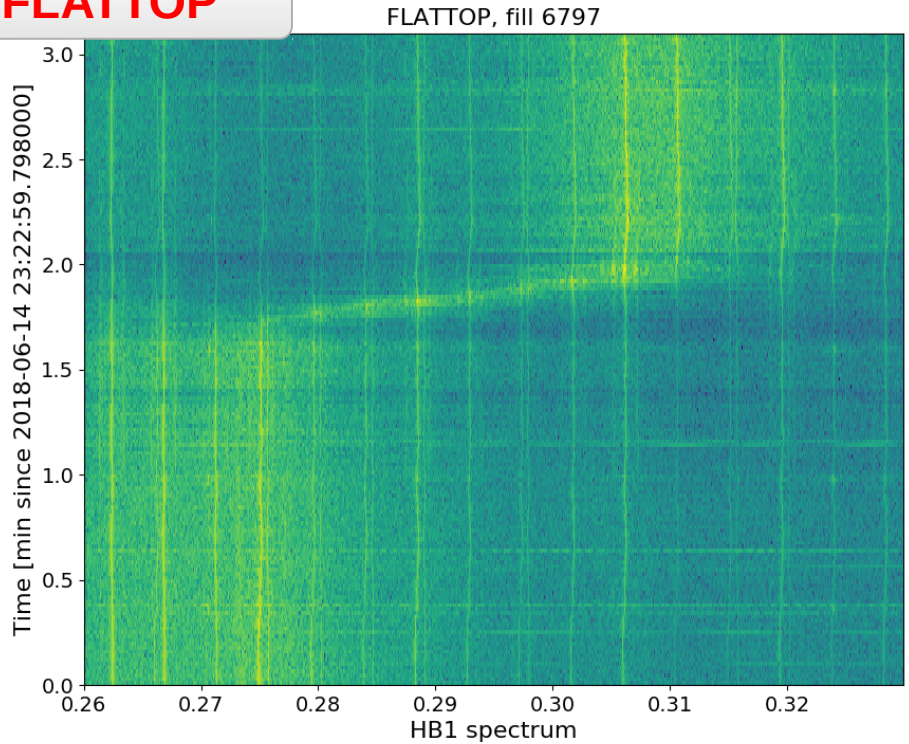
Observations: Their amplitude varies with the tune

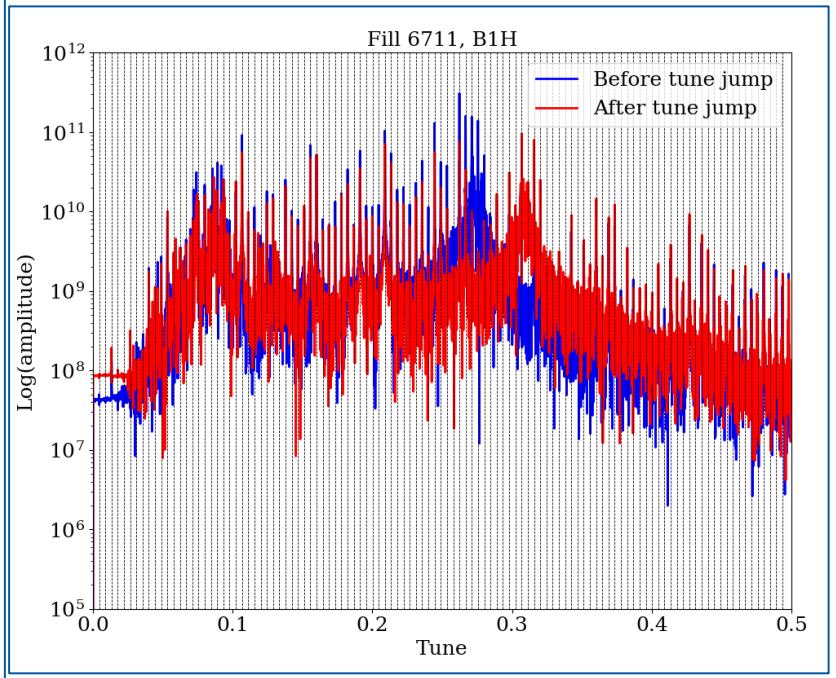
Amplitude evolution of 70th harmonic during tune jump



Observations: Not a tune modulation

FLATTOP





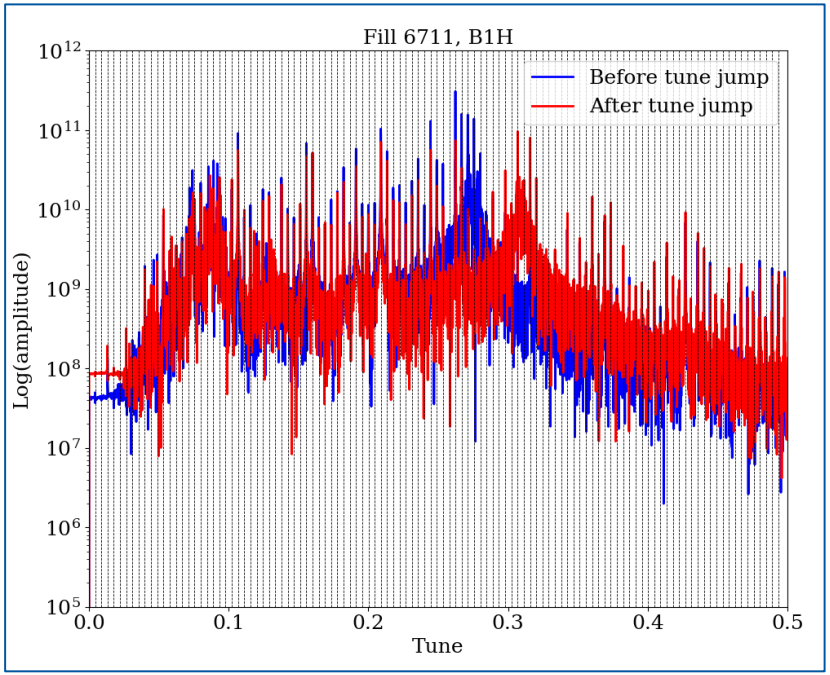
Observations: ”Forest” of 50Hz

Table 1: LHC Power Converter types

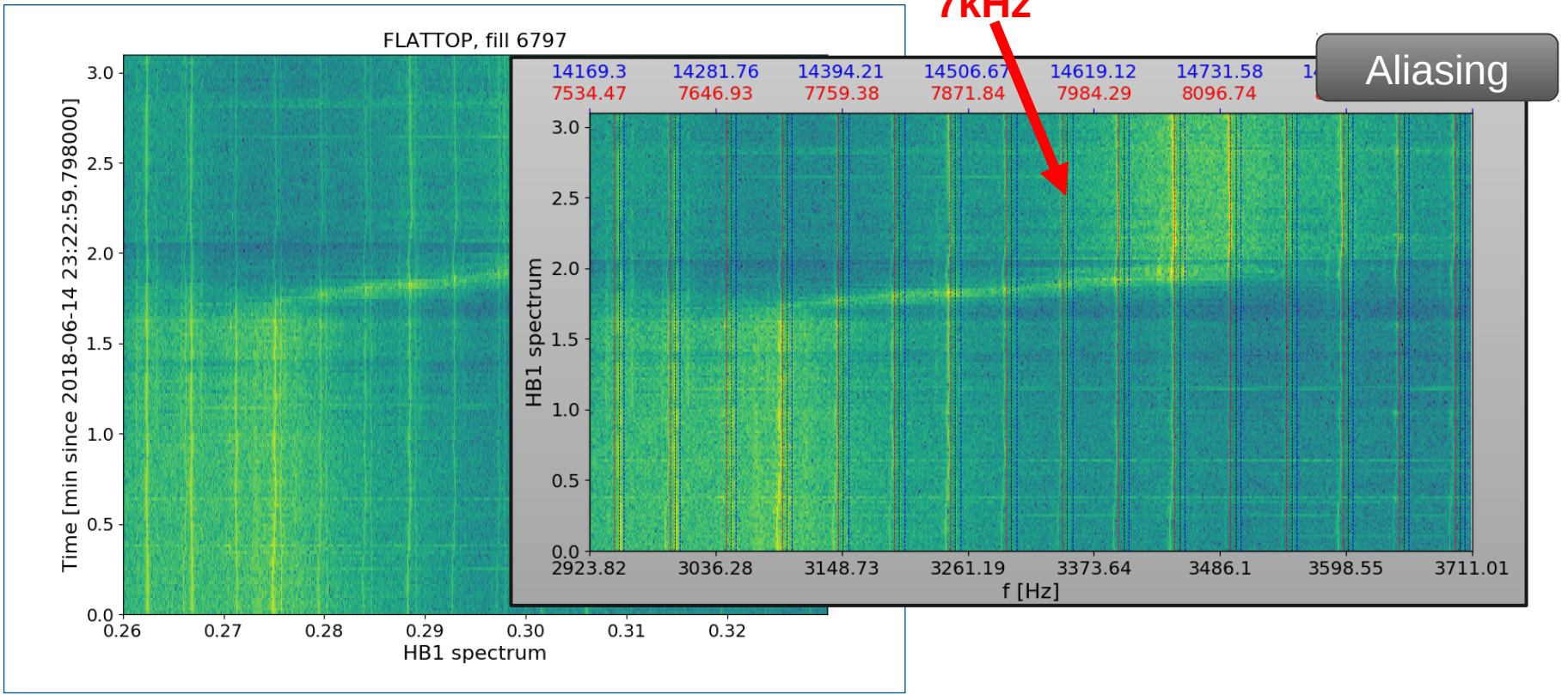
PC type	Qty	Switch Type	½ hour stability	Area
MB [13kA/±190V]	8	SCR	3 ppm	U
MQ [13kA/18V]	16	SM	3 ppm	U
Inner Triplet [5..7kA/8V]	16	SM	5 ppm	U
IPD and IPQ [4..6kA/8V]	174	SM	5 ppm	U
600A type 1 [±0.6kA/±10V]	400	SM	10 ppm	U
600A type 2 [±0.6kA/±40V]	37	SM	10 ppm	U
120A [±120A/±10V]	290	SM	50 ppm	U
Orbit correctors [±60A/±8V]	752	SM	50 ppm	U
Warm magnets [1kA/450..950V]	16	SCR	20 ppm	S

1. Switching frequencies: 25kHz, 50-200kHz

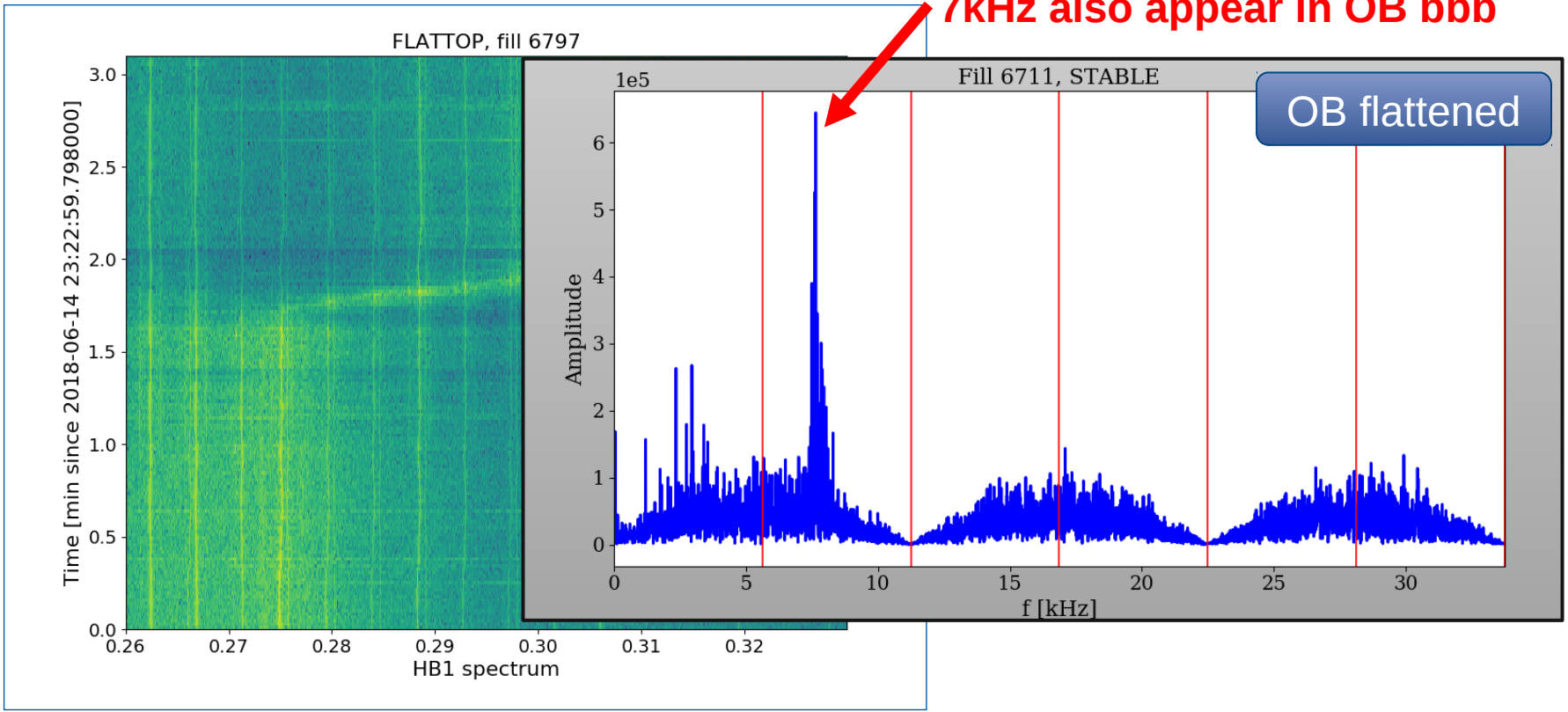
2. “Forest” indicates SCR



Observations: “Triplets” due to aliasing



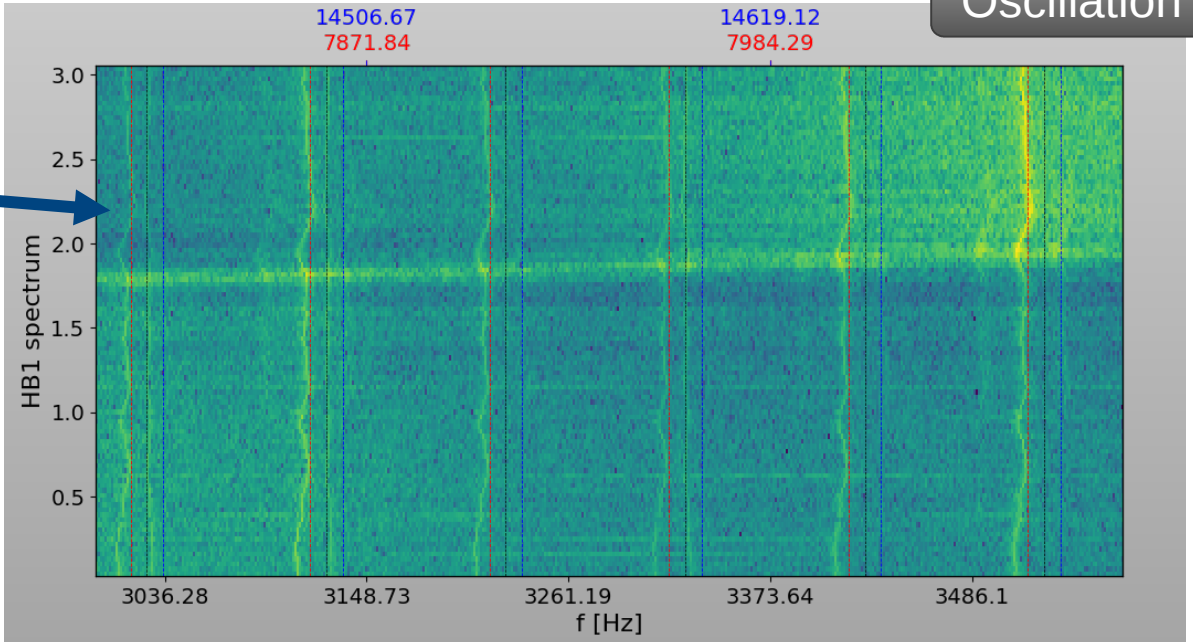
Observations: “Triplets” due to aliasing



Observations: “Jittering”

Oscillation

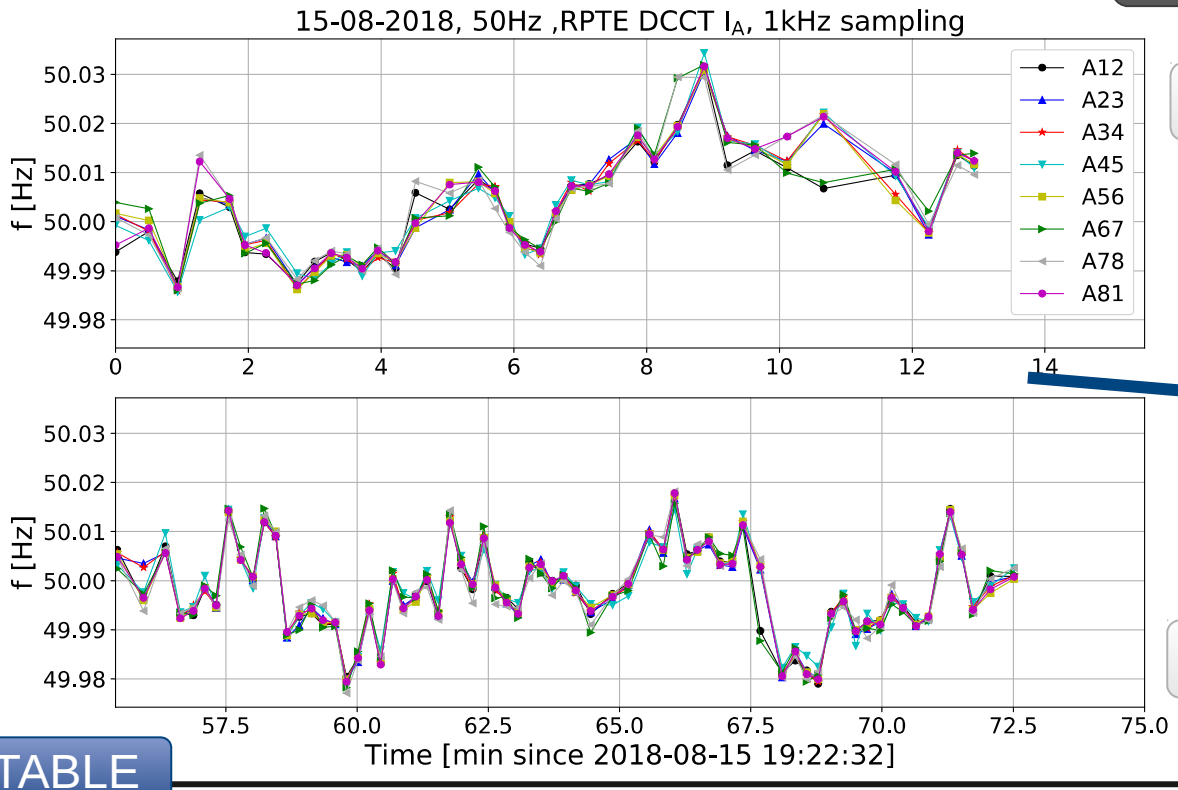
Can this be correlated with the mains? (0.1Hz for 50)*



*http://wwwhome.cs.utwente.nl/~ptdeboer/misc/mains.html

Observations: “Jittering” & DCCTs

1kHz sampling DCCTs



1st set

Frequency evolution of 50Hz from the DCCTs. Is it correlated with the beam spectrum?

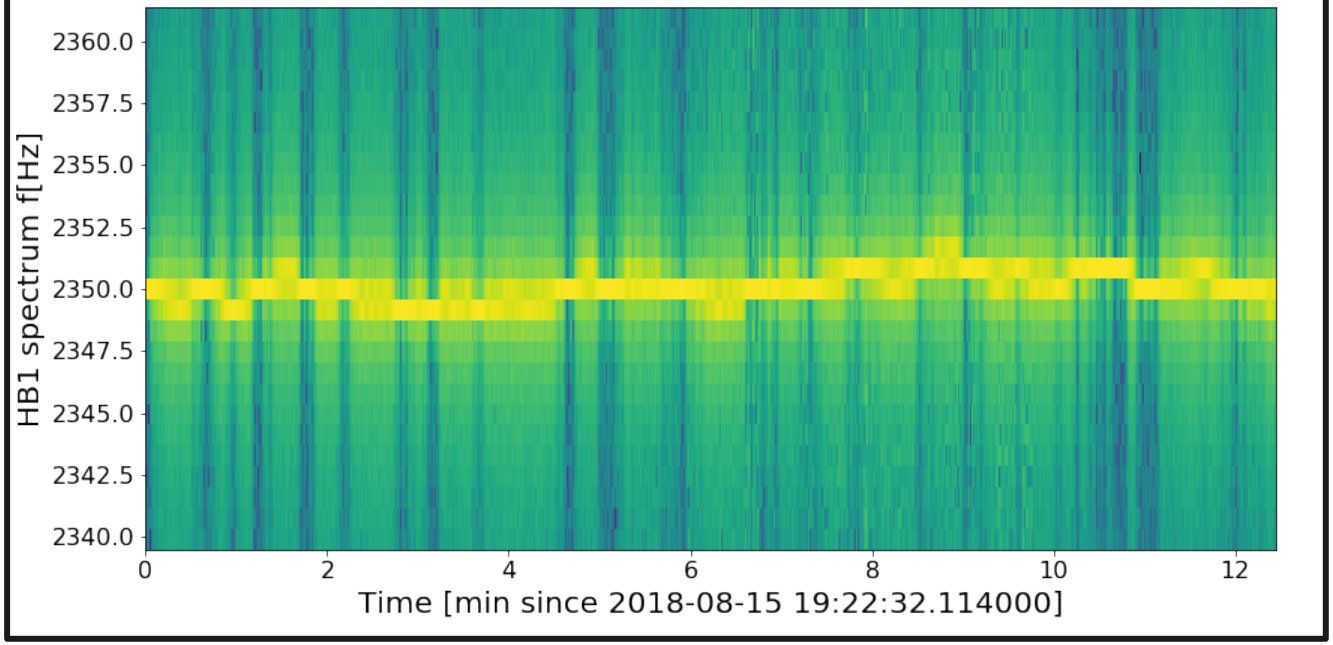
2nd set

STABLE

Observations: “Jittering” & DCCTs

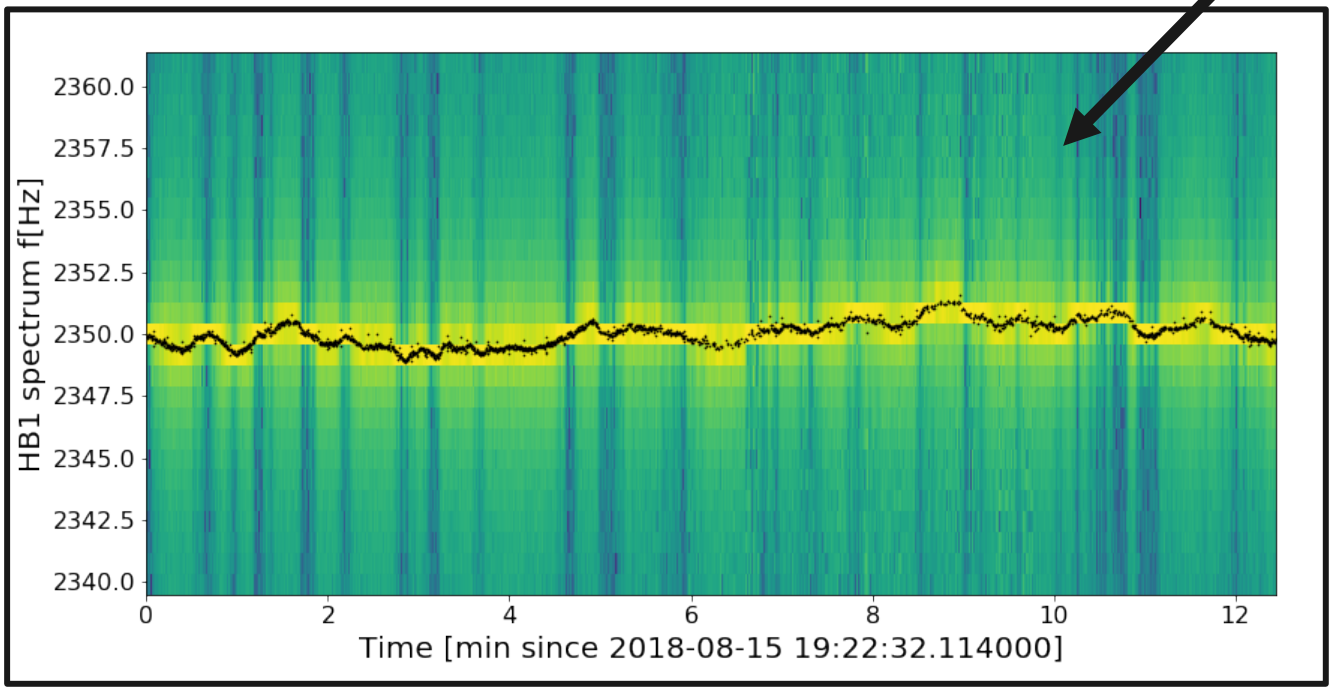
h47

STABLE, B1H



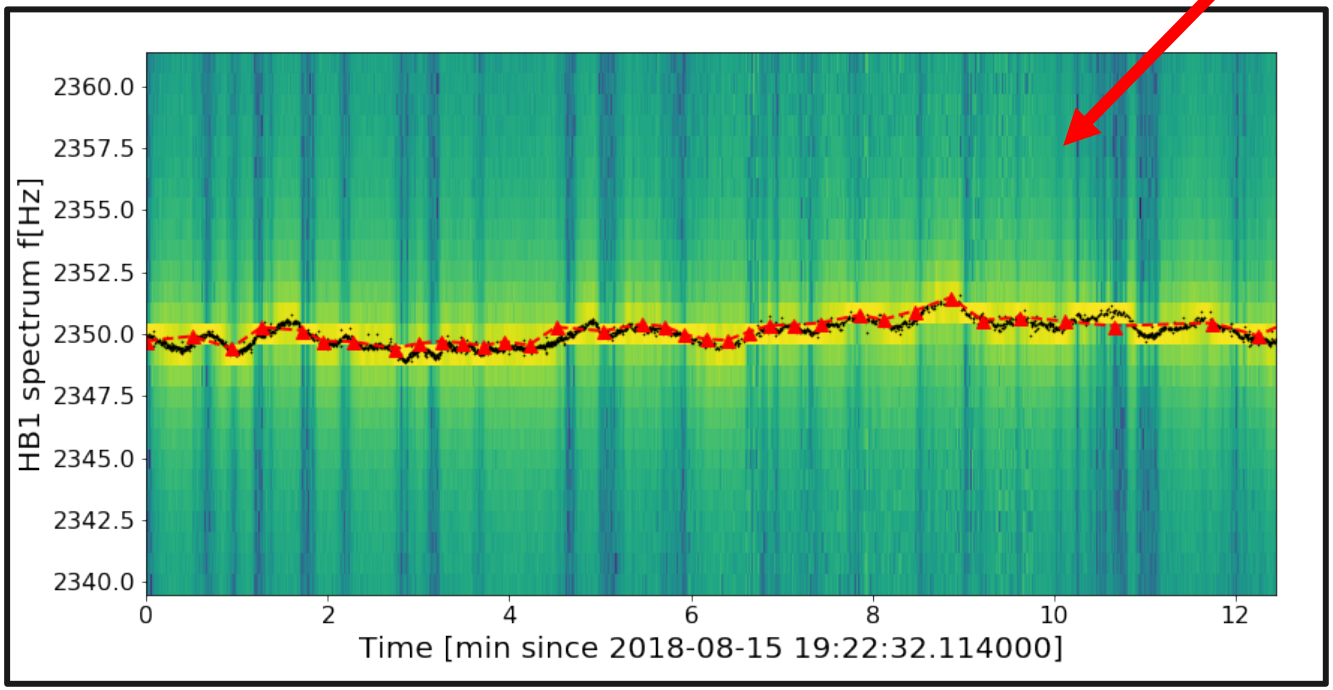
Observations: “Jittering” & DCCTs

Follow frequency with NAFF



Observations: “Jittering” & DCCTs

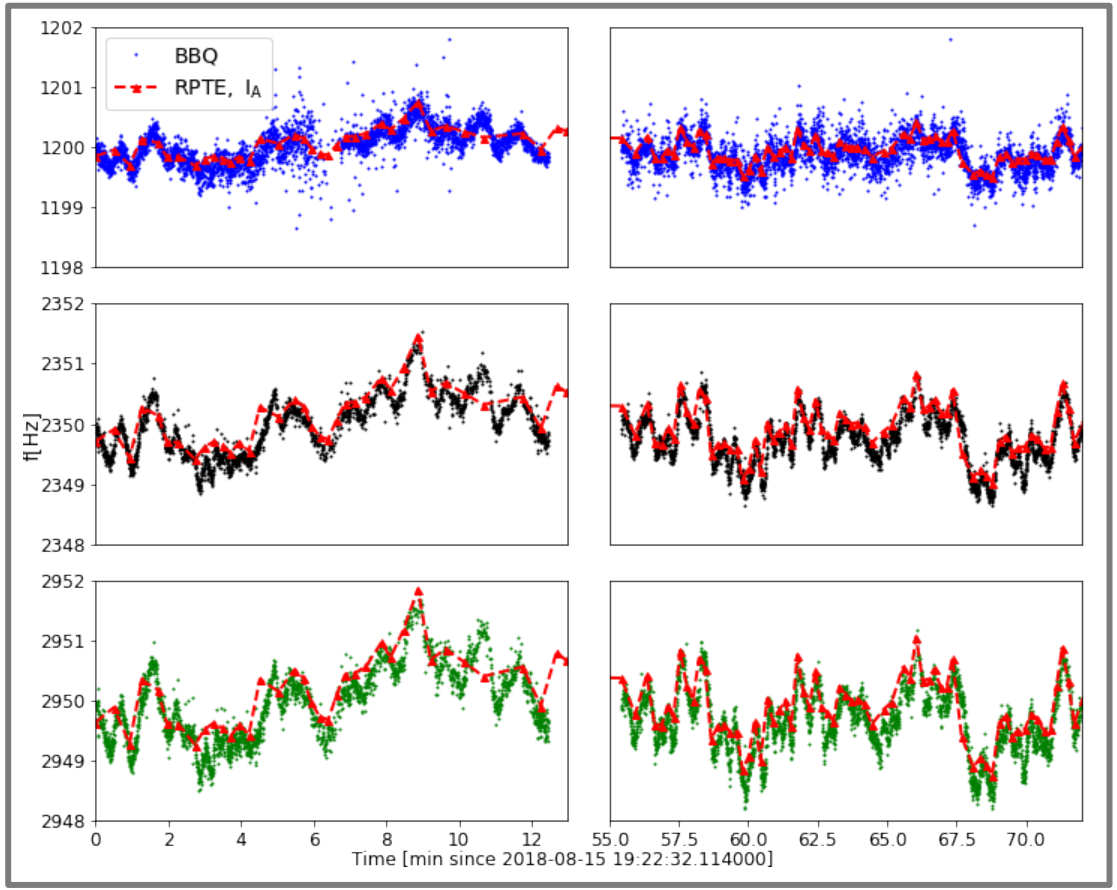
DCCT 50Hz evolution x 47 (2350/50)



DCCT 50Hz evolution x 24

DCCT 50Hz evolution x 47

DCCT 50Hz evolution x 59

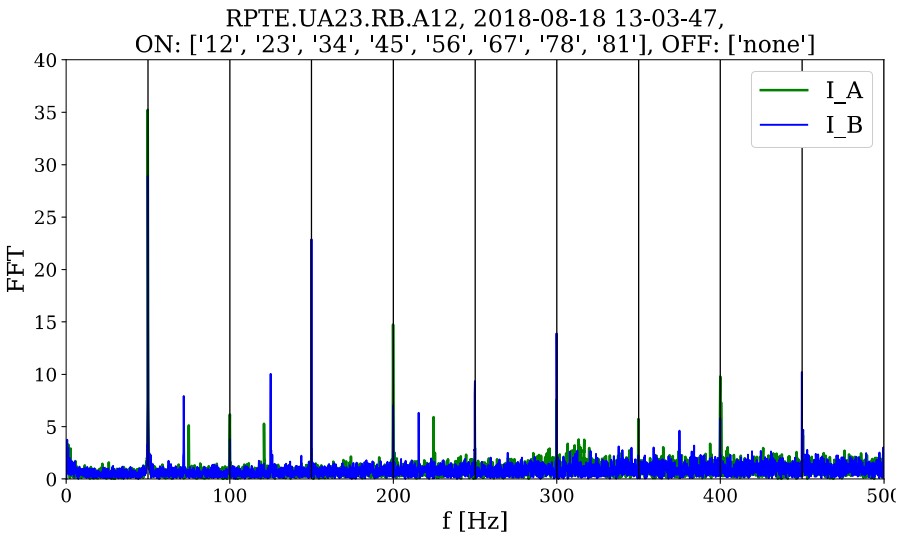


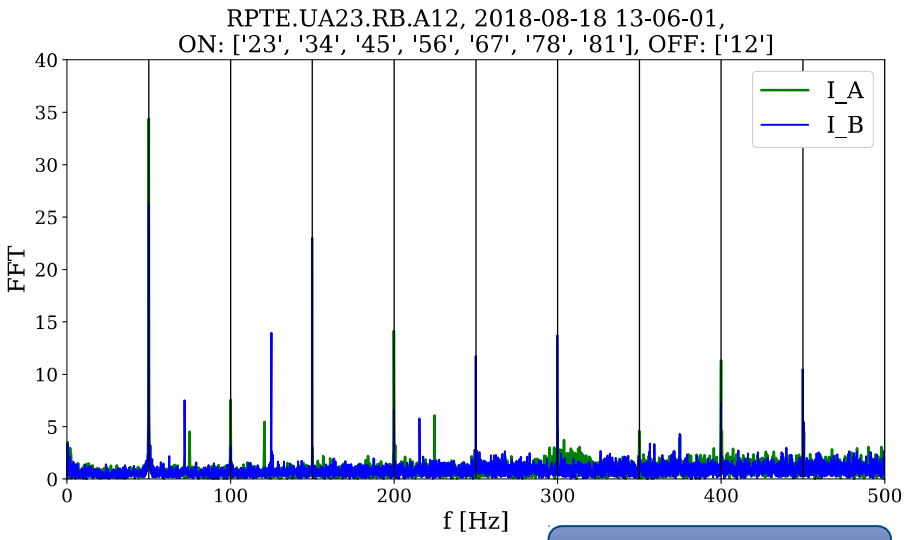
1. Same oscillation between all DCCTs
2. Same oscillation between DCCTs and beam
   - Mains

Active filters at EOF

DCCTs spectrum before/after switching OFF S12

No significant difference observed



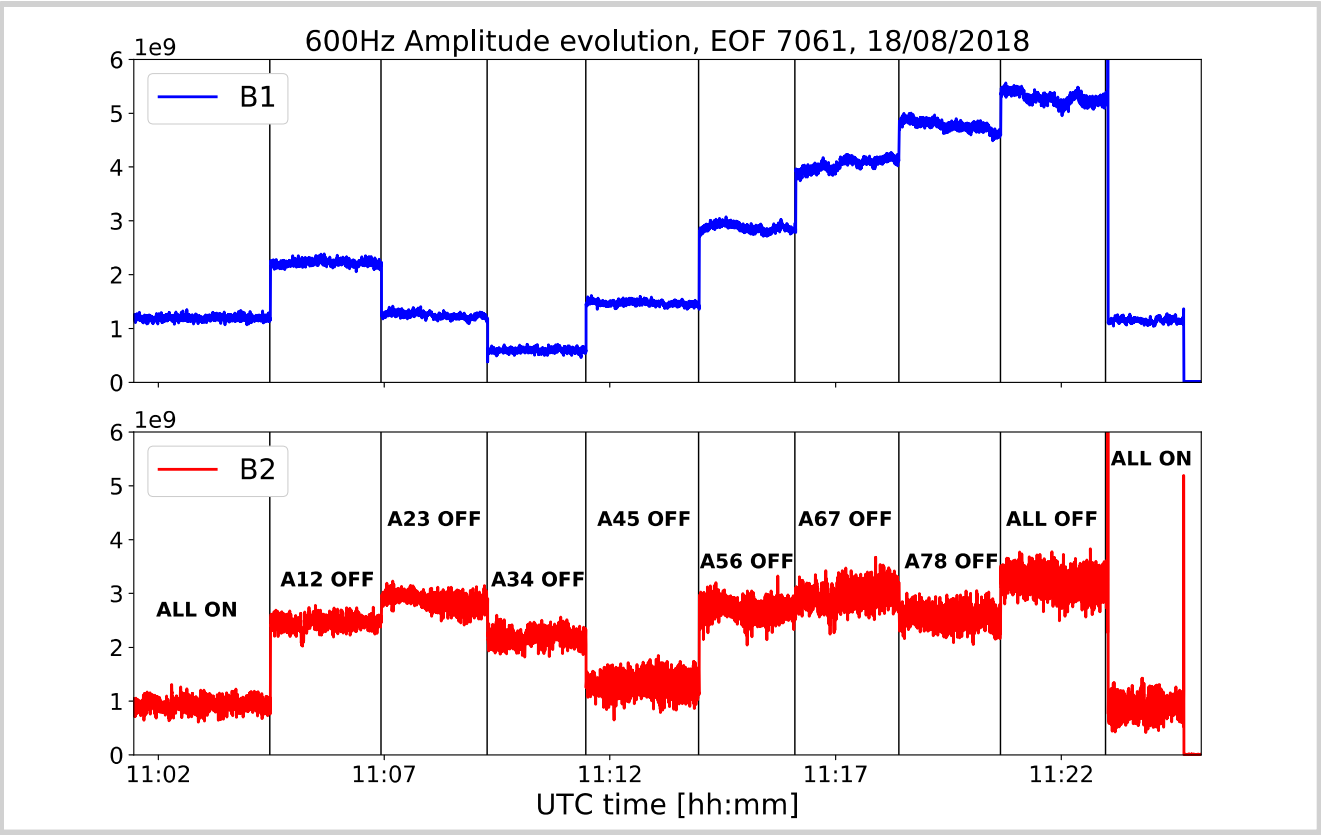


Fill 7061

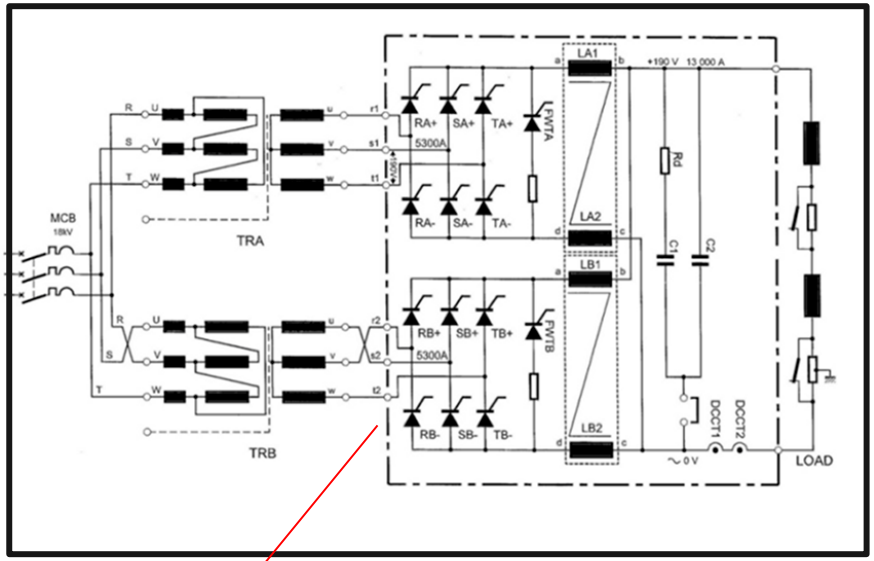
Active filters at EOF

Amplitude evolution of 600Hz

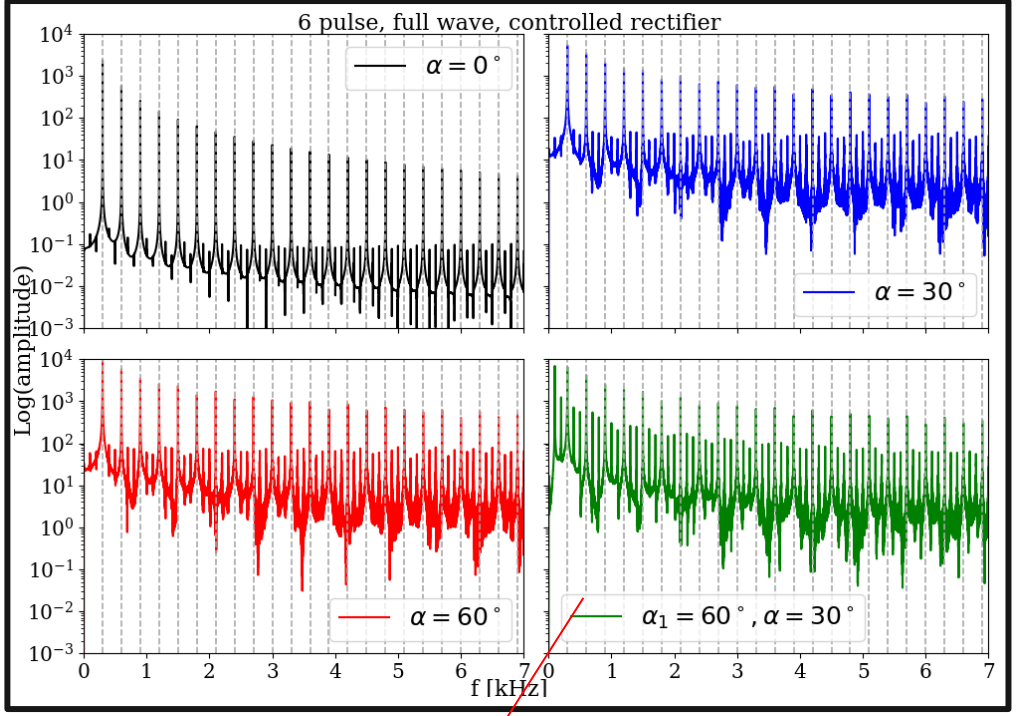
We are expecting an impact in 600Hz from SCR



Active filters at EOF



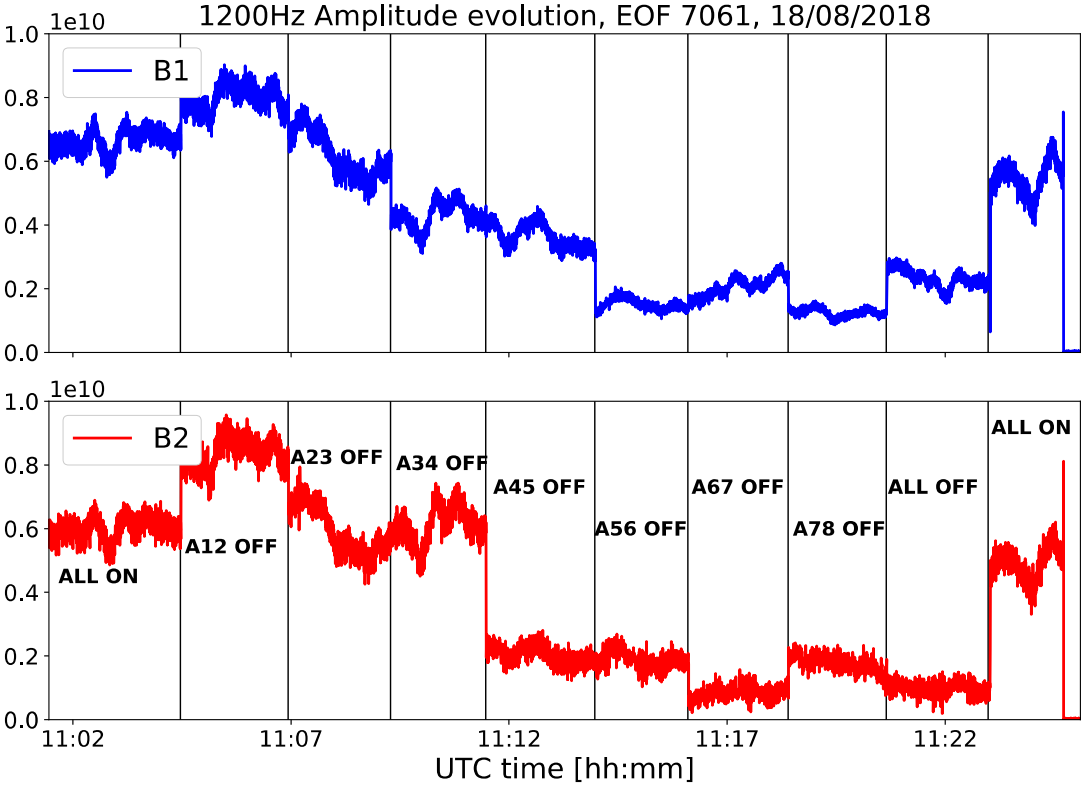
2 x 3 phase, full wave, 6 pulse controlled rectifiers



This is for 6 pulse. For 12 pulse we are expecting 600Hz multiples

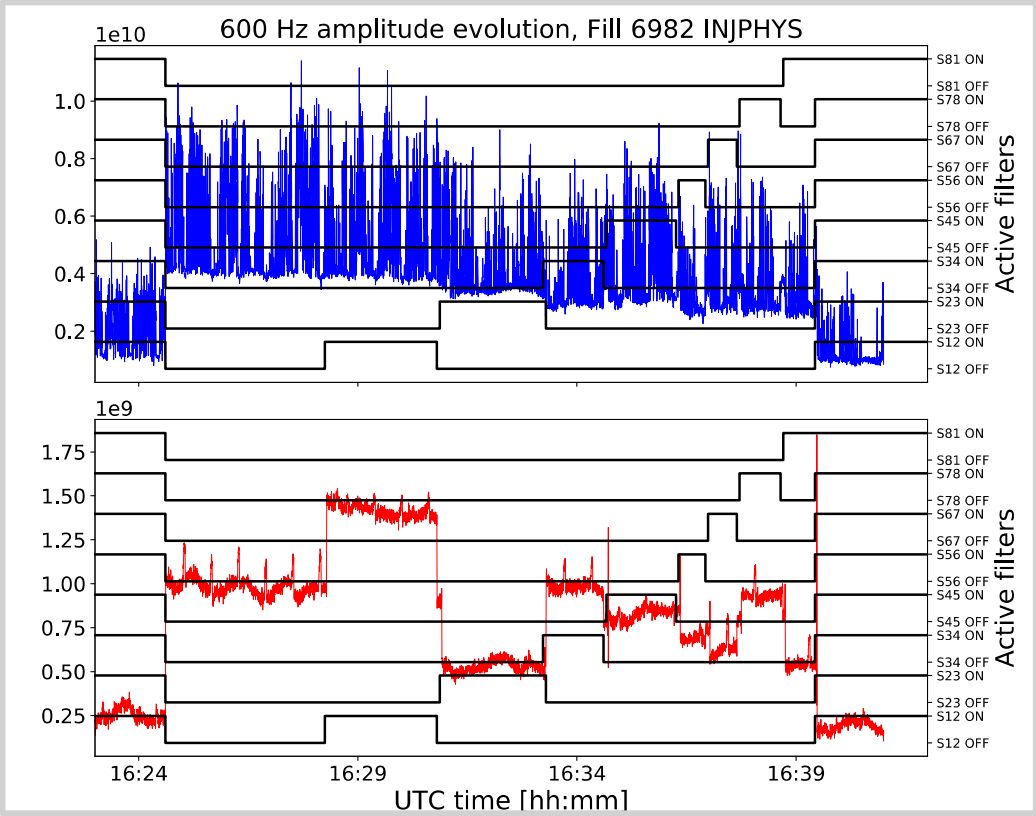
Active filters at EOF

Similar evolution for all multiples of 600Hz

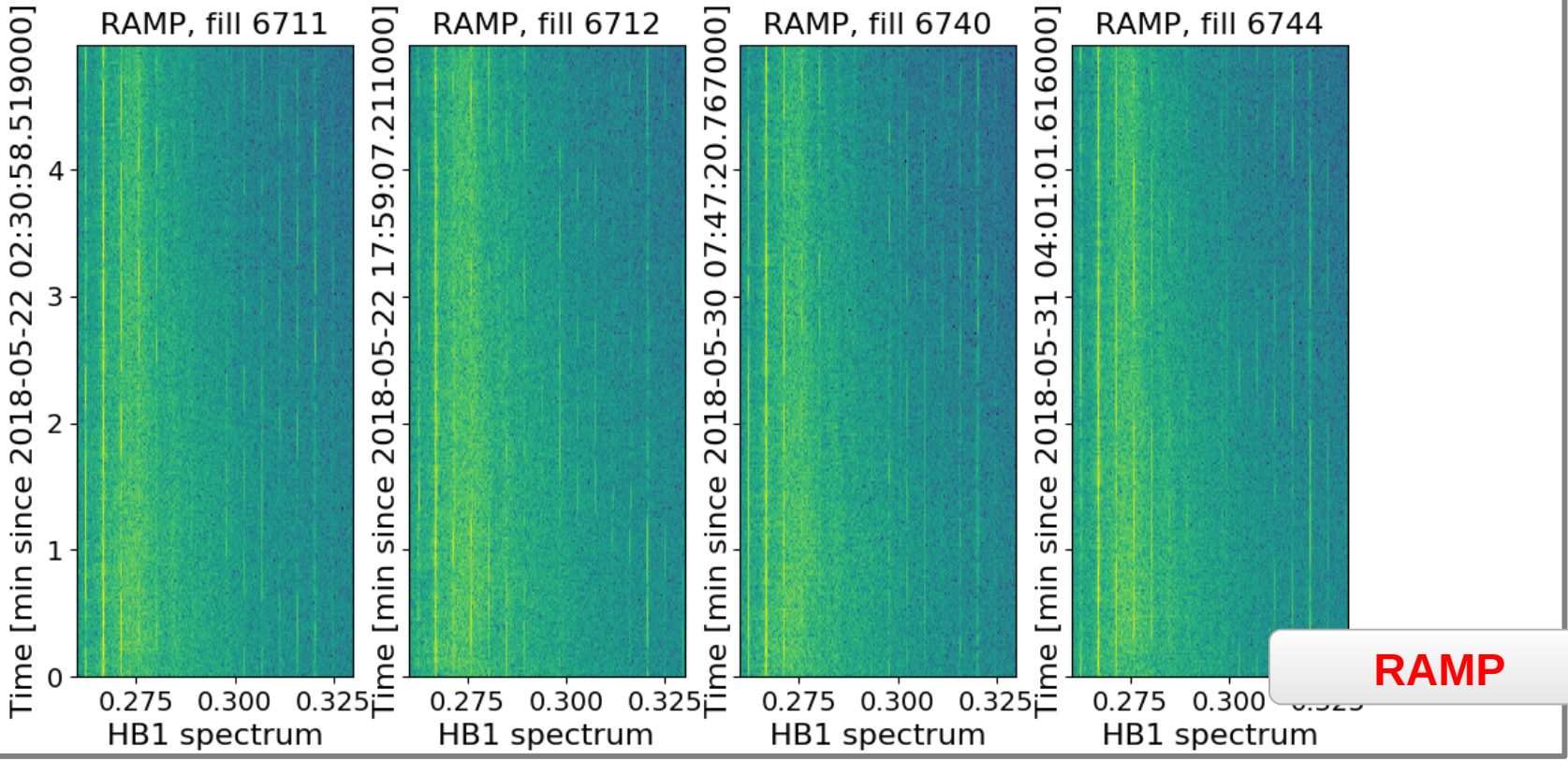


Active filters at INJPHYS

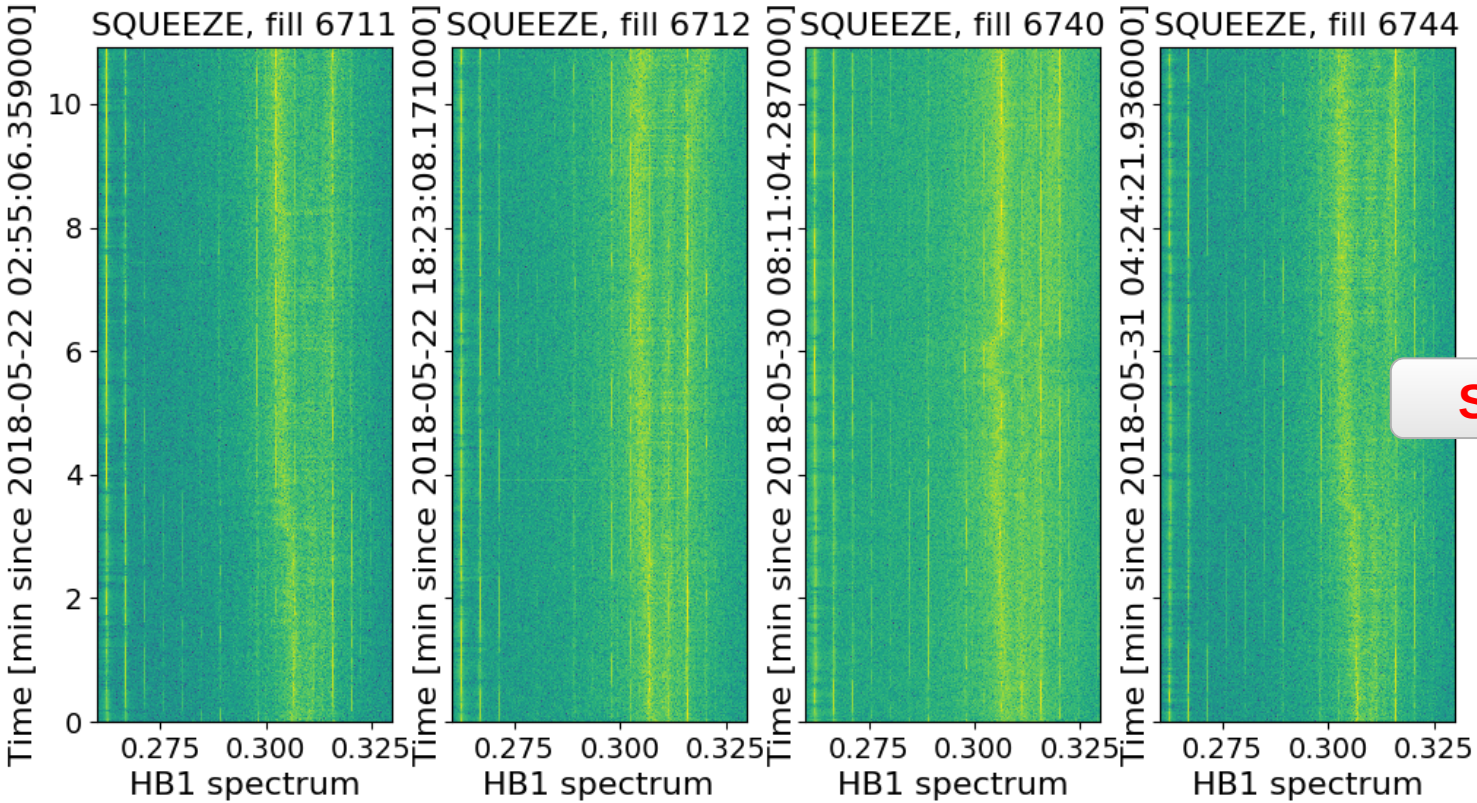
Also at INJPHYS test, same behavior observed



Observations: No attenuation during RAMP



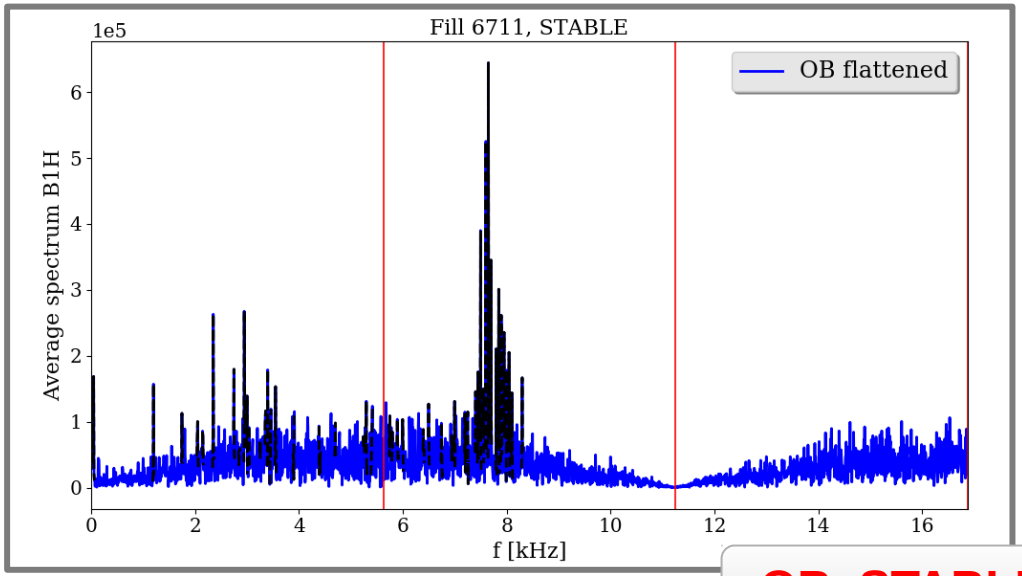
Observations: No change during SQUEEZE



Simulations-LHC

PRELIMINARY

- We don’t really know the source
  - Convert in μm the largest 50Hz harmonics from the OB

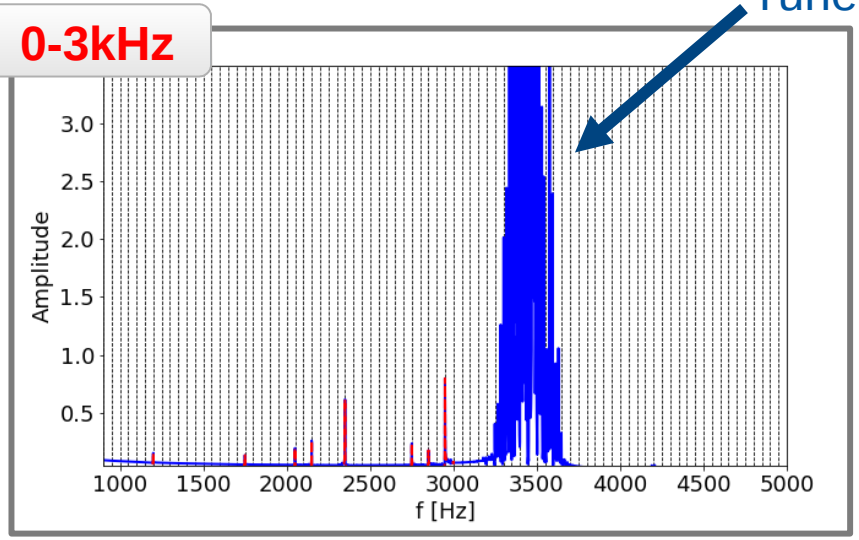


OB, STABLE

Simulations-LHC

- We don’t really know the source
- Convert in μm the largest 50Hz harmonics from the OB
- Install a dipolar ripple in BPMCS.7L4.B1 (Q7 OB PU) and dump tbt at the same location
- Adapt the strengths so that we get an equivalent spectrum in amplitude in simulations
- Split studies: I. up to 3kHz

0-3kHz



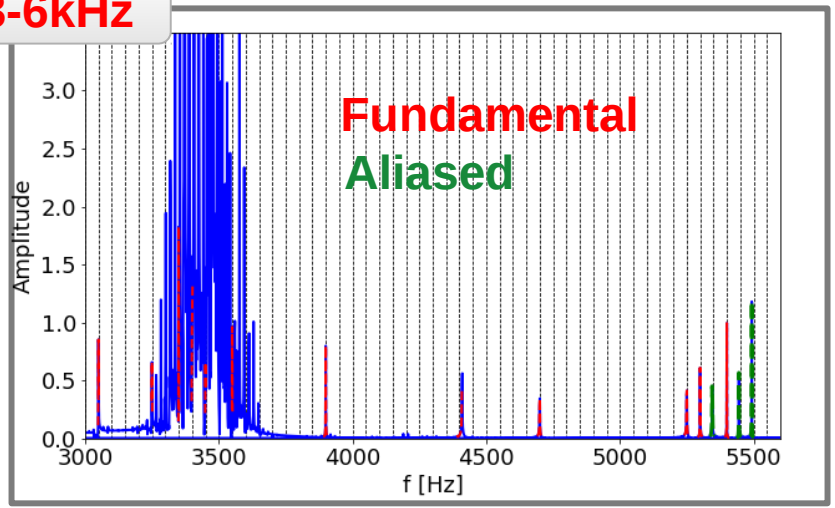
f[Hz]	OB[μm]	Sim [μm]
2950	0.269	0.26
2350	0.227	0.22
2750	0.169	0.15
2050	0.147	0.15
1750	0.118	0.11
1200	0.118	0.11
2150	0.118	0.11
2850	0.117	0.11
50	0.114	0.11

Simulations-LHC

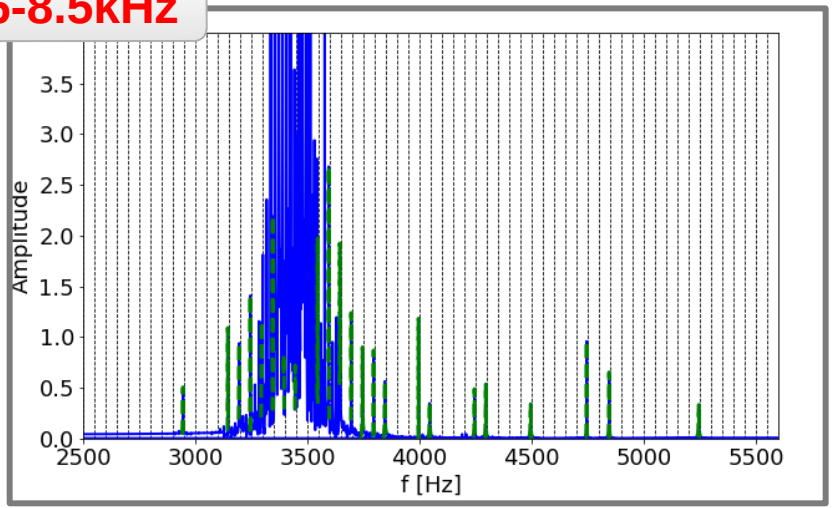
PRELIMINARY

- We don't really know the source
- Convert in μm the largest 50Hz harmonics from the OB
- Install a dipolar ripple in BPMCS.7L4.B1 (Q7 OB PU) and dump tbt at the same location
- Adapt the strengths so that we get an equivalent spectrum in amplitude in simulations
- Split studies: I. up to 3kHz II. 3-6kHz III. 6-8.5kHz IV. 0-8.5kHz

3-6kHz

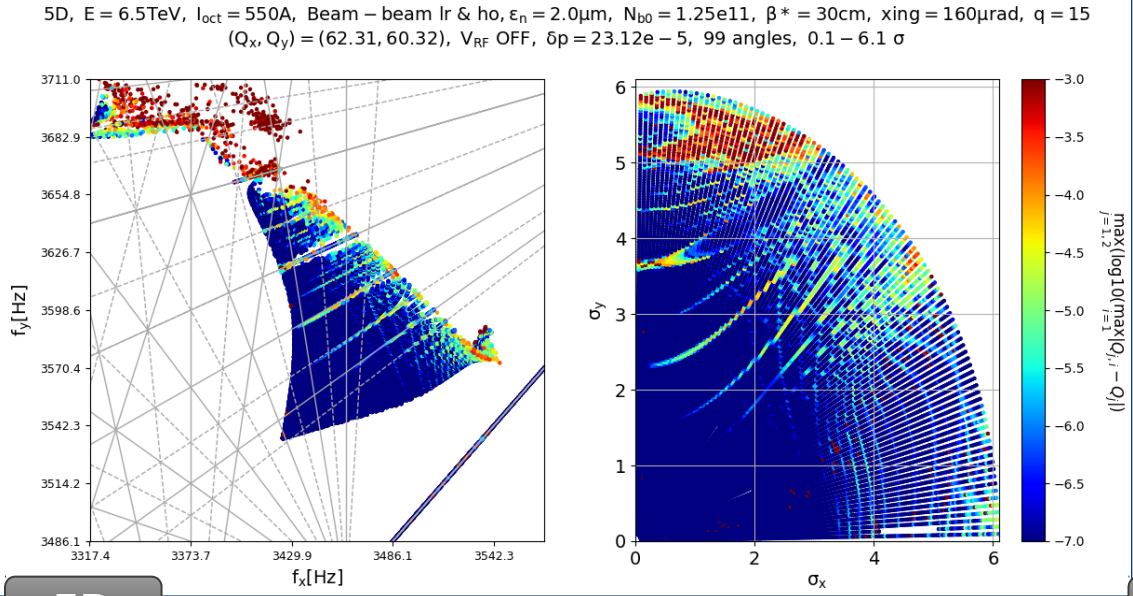


6-8.5kHz

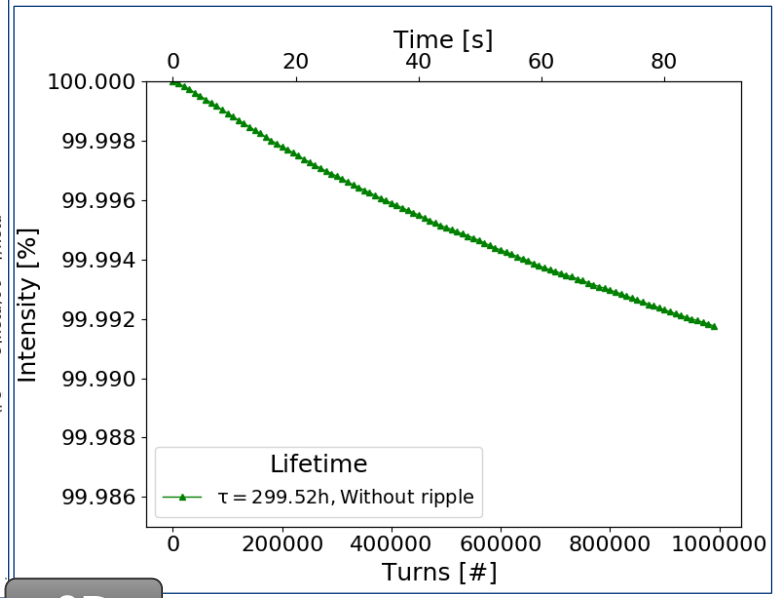


Simulations-LHC

Weighted distributions *



5D

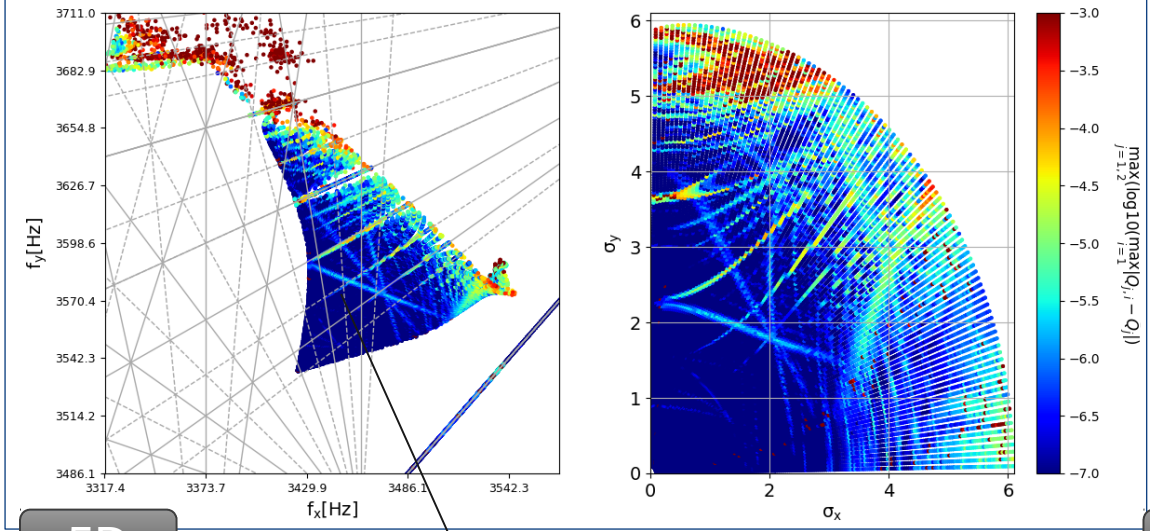


6D

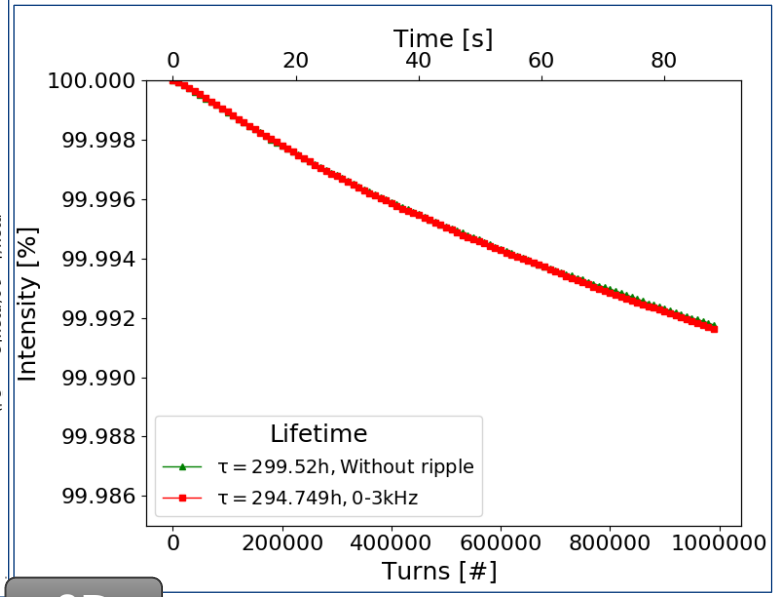
* https://indico.cern.ch/event/731934/contributions/3018038/attachments/1656342/2651603/weighted_distributions.pdf

Simulations-LHC

<3kHz



5D

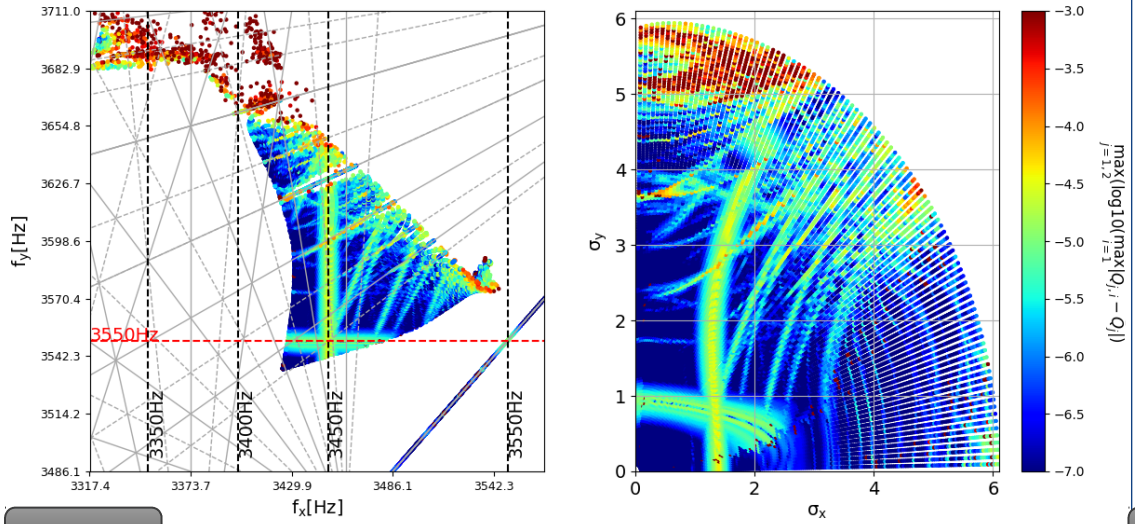


6D

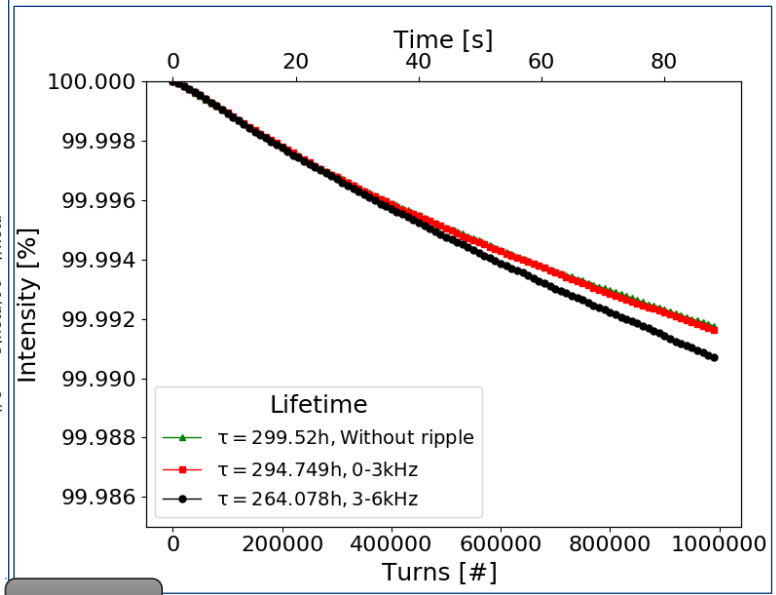
Sideband of modulation, but no significant impact

Simulations-LHC

3-6kHz



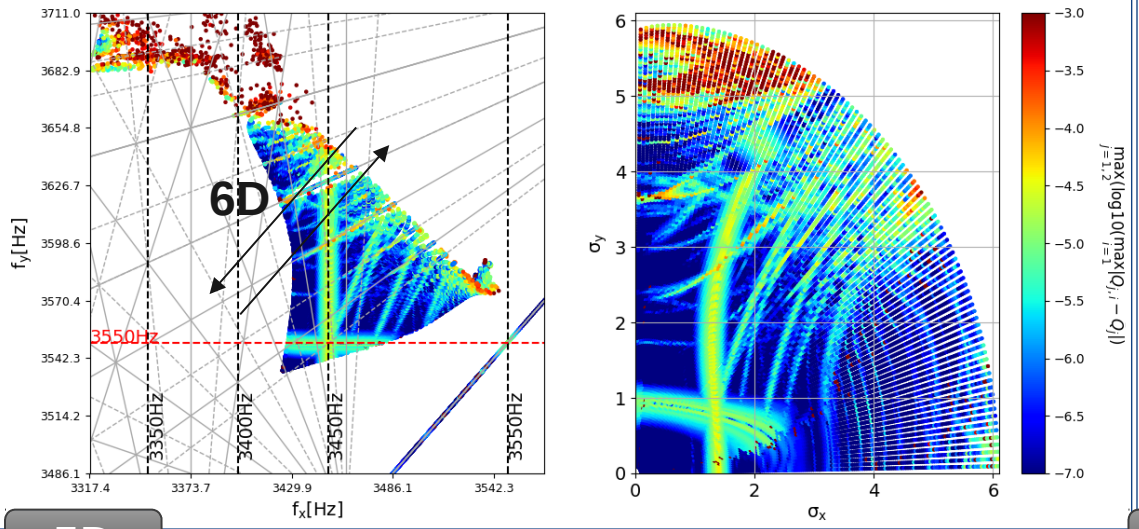
5D



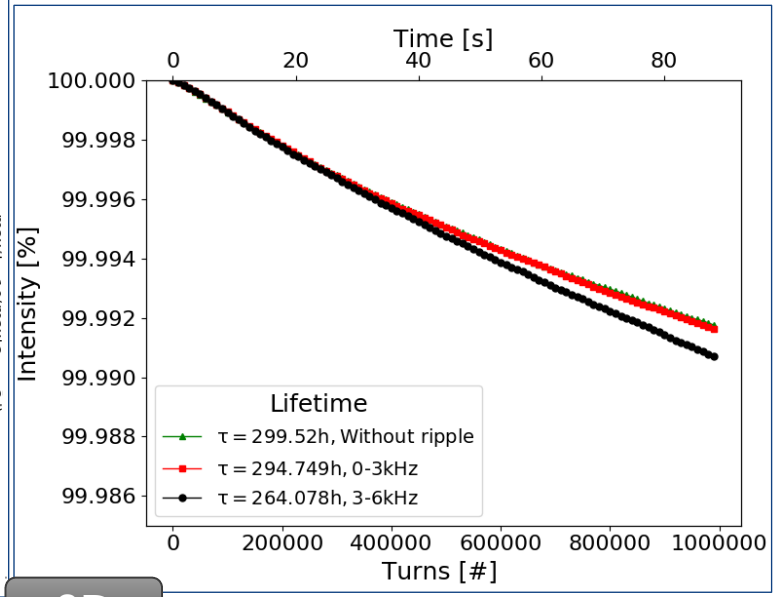
6D

Simulations-LHC

3-6kHz



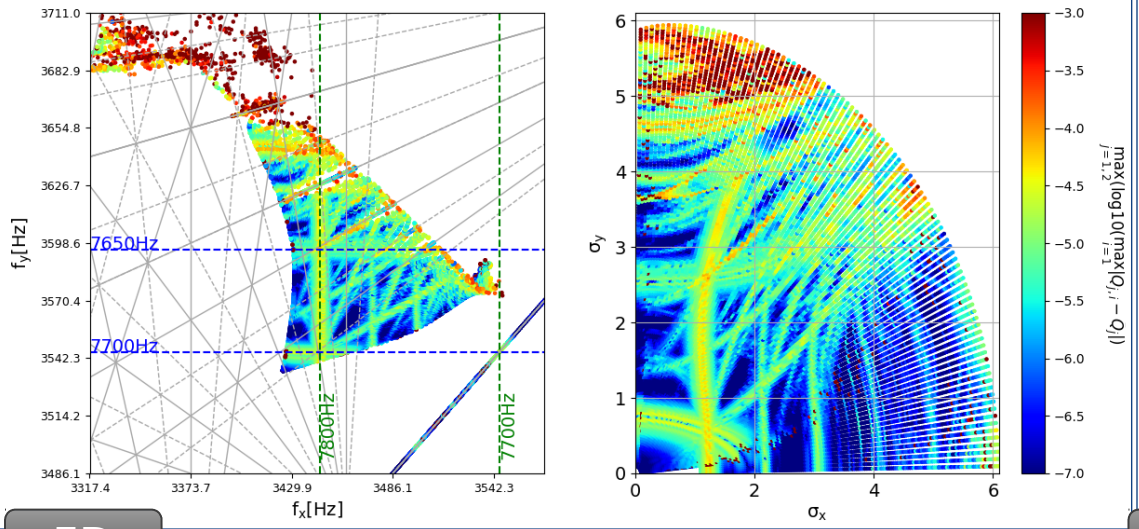
5D



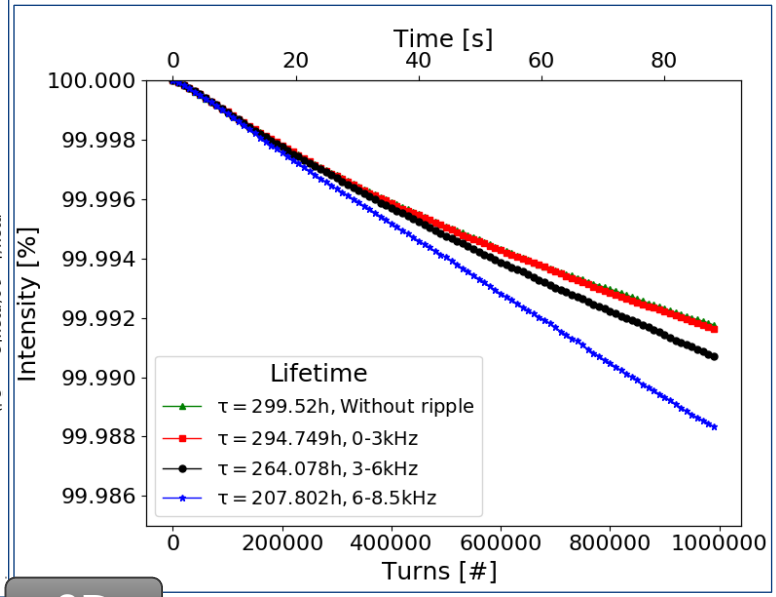
6D

Simulations-LHC

6-8.5kHz



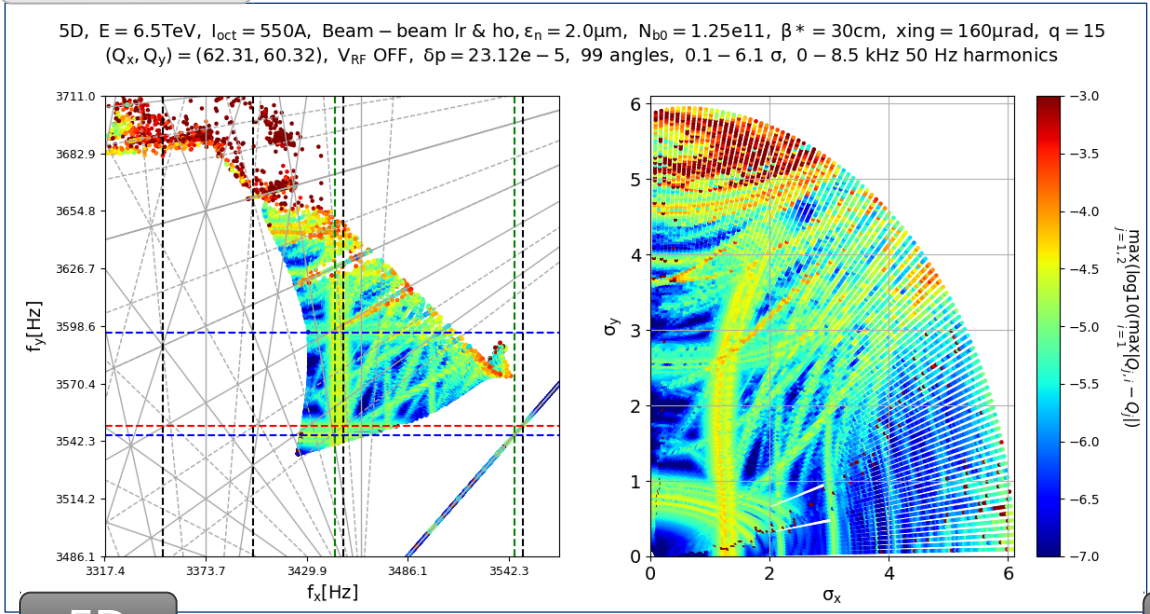
5D



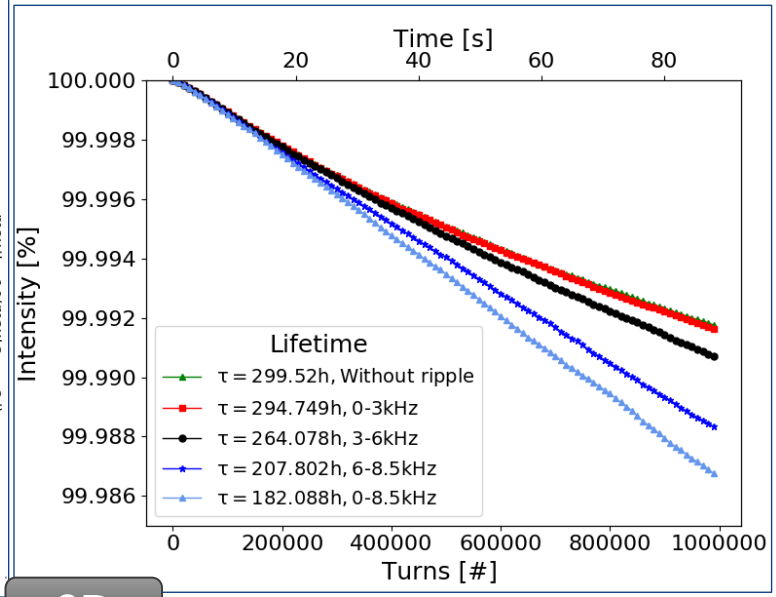
6D

Simulations-LHC

<8.5kHz



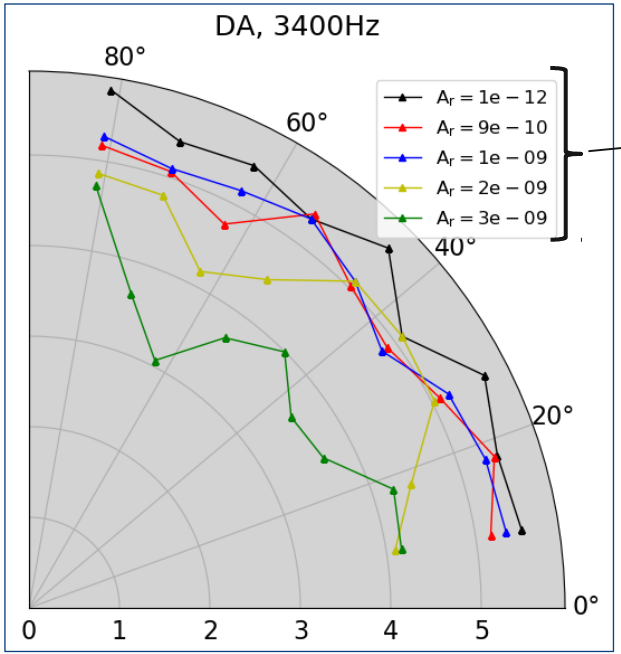
5D



6D

Simulations-LHC

PRELIMINARY



Relative

3400Hz	
Ar	**σ**
1e-12	0.000028
9e-10	0.025367
1e-9	0.028186
2e-9	0.056373
3e-9	0.084562

f [Hz]	Min DA<5σ	σ
3450	4.962	0.0015
3500	4.996	0.0018
3550	4.928	0.0032
7550	4.962	0.0021
7600	4.996	0.0085
7650	4.858	0.0103
7700	4.927	0.0020

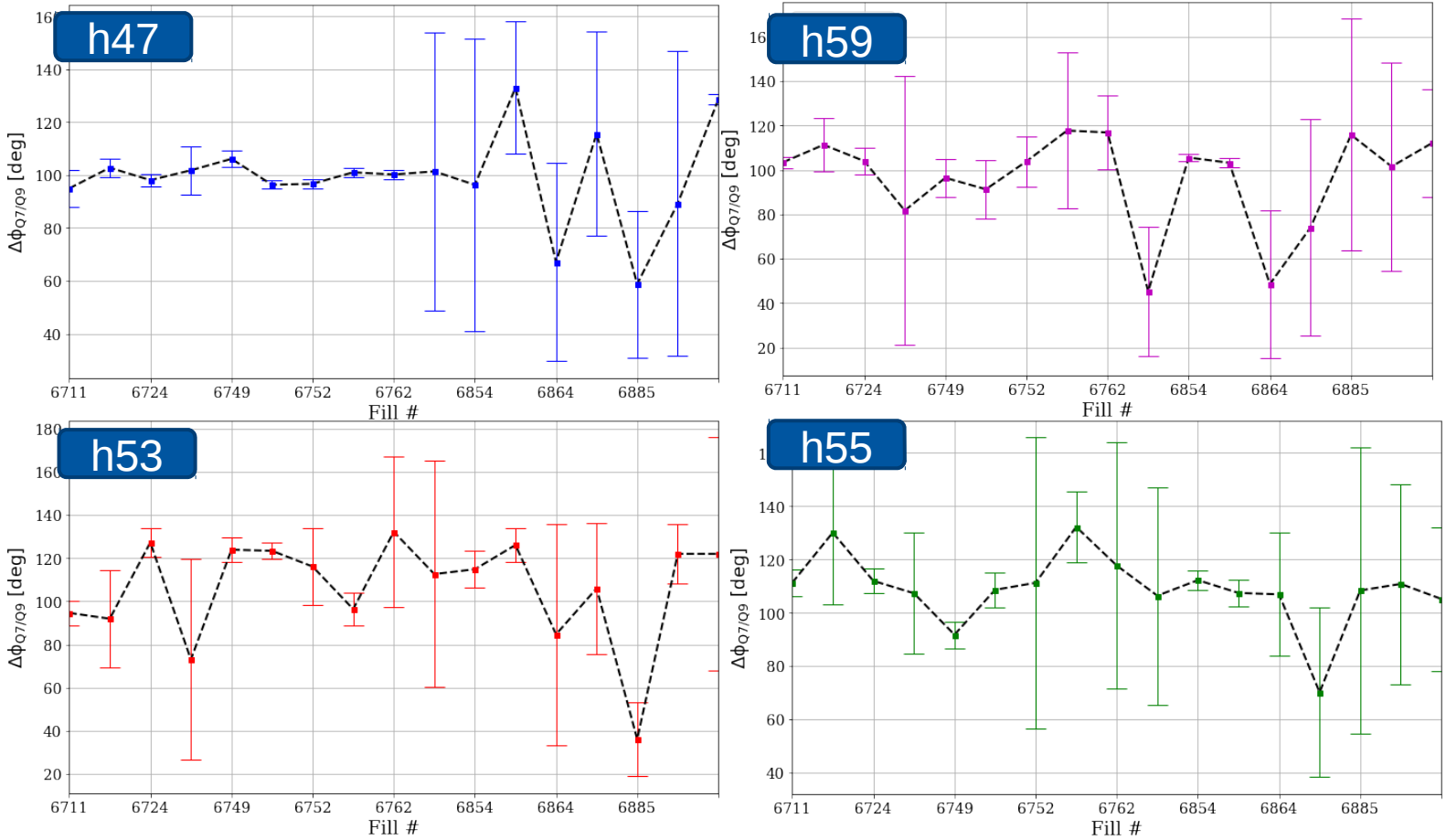
Conclusions:

- 50 Hz harmonics visible in OB & BBQ & DOROS
- Mostly in horizontal plane of both B1 & B2
- Correlation between the spectra of **both beams** and **both planes**
- No tune modulation, source is probably **dipolar**
- “Forest” of 50Hz indicates **SCR** and not SM
- No signs of attenuation during ramp
- No indication of change during squeeze
- Correlation with the DCCTs 50Hz evolution
- “Splitting” of the lines in the BBQ as a result of the aliasing
- Phase advance of 50 Hz harmonics compatible with betatronic phase advance
- Impact of active filters in multiples of 600Hz

To do:

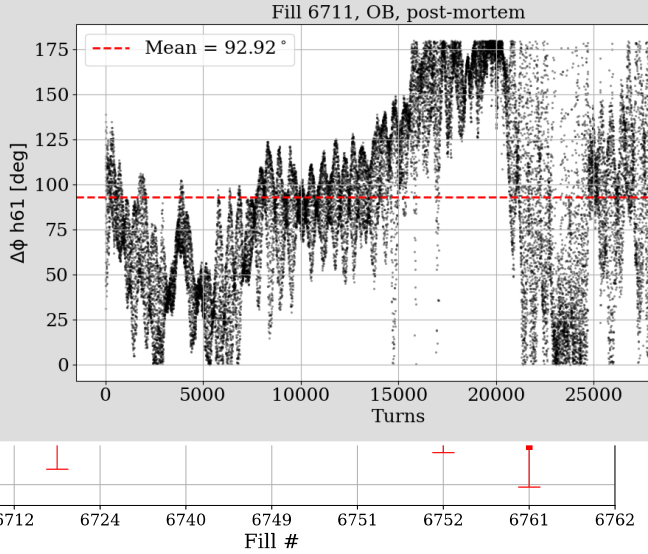
- Set tolerances for HL-LHC
- Fill by fill analysis
- Lock in correct bin (relative phase between B1, B2 & higher harmonics evolution)

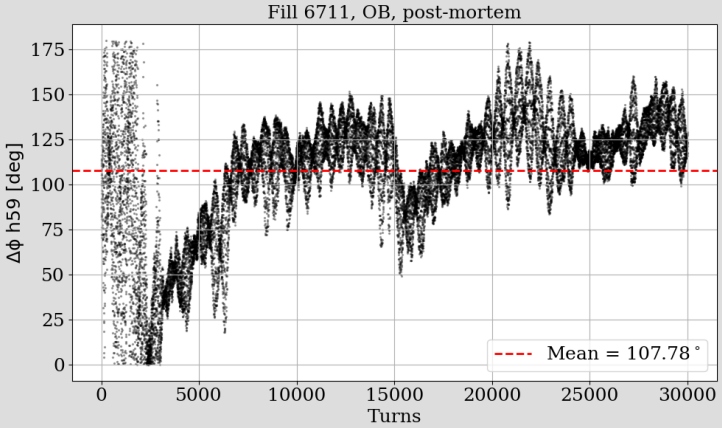
Backup

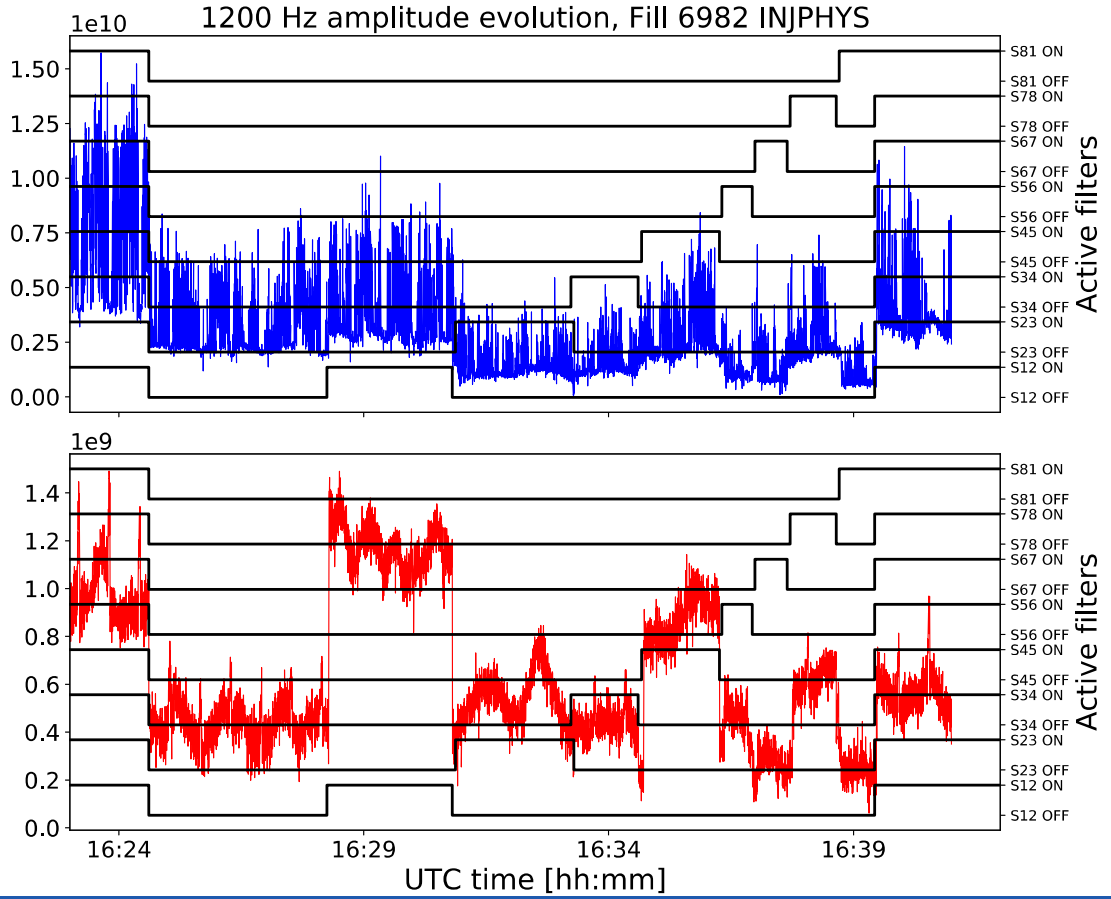

h47
h59
h53
h55
$\Delta\phi_{Q7/Q9}$ [deg]
Fill #
6711
6724
6749
6752
6762
6854
6864
6885

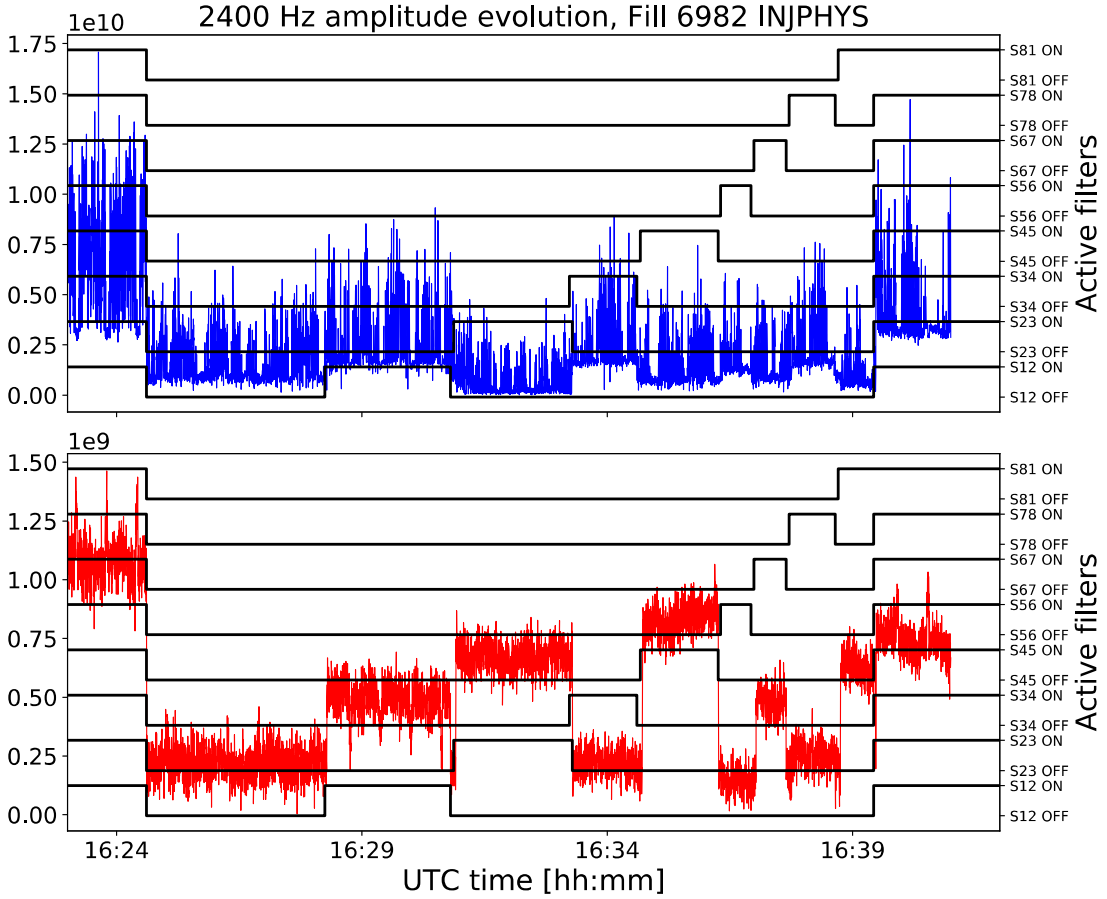
Note that:

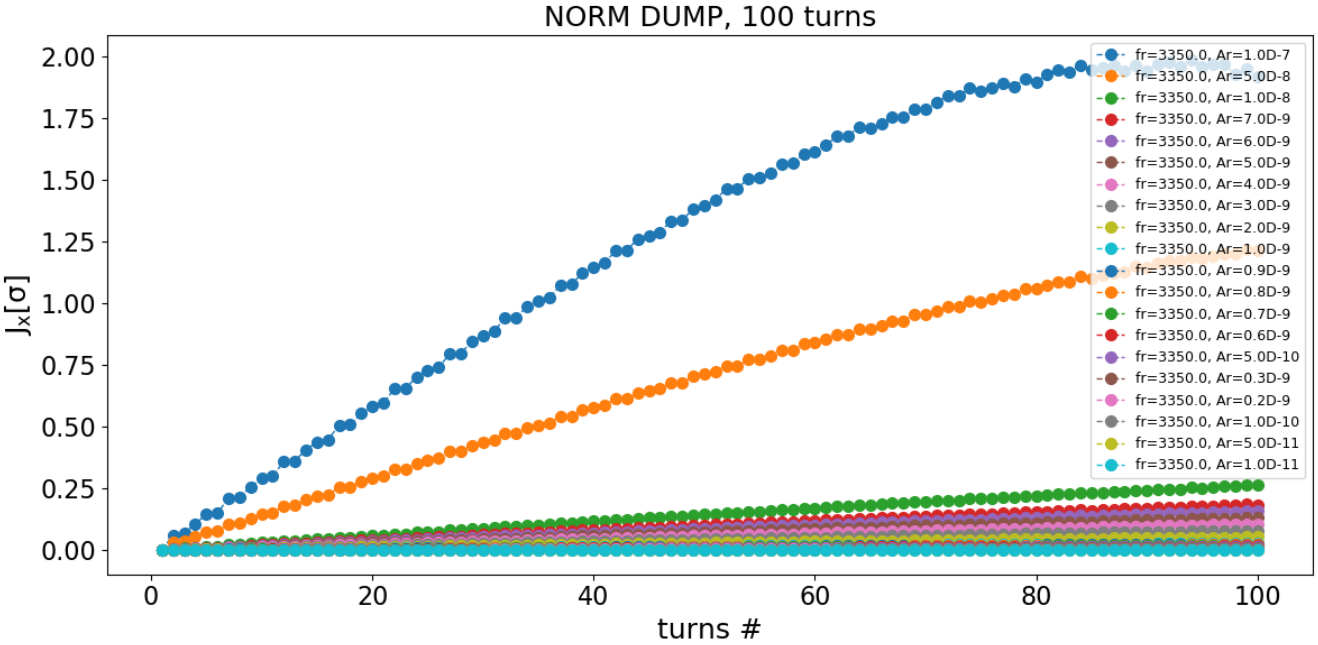
1. These are postmortem data
2. The harmonics oscillate while, during the analysis, we are locked in a bin

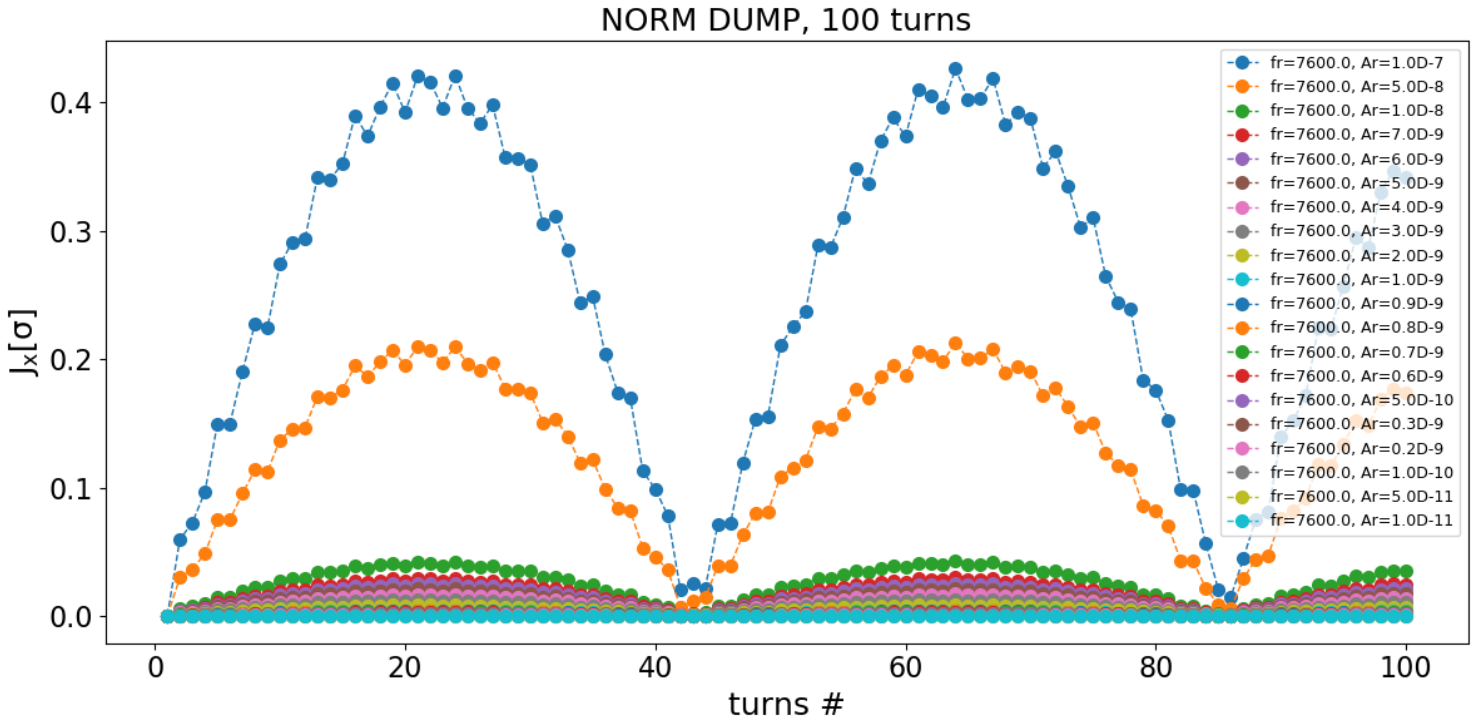


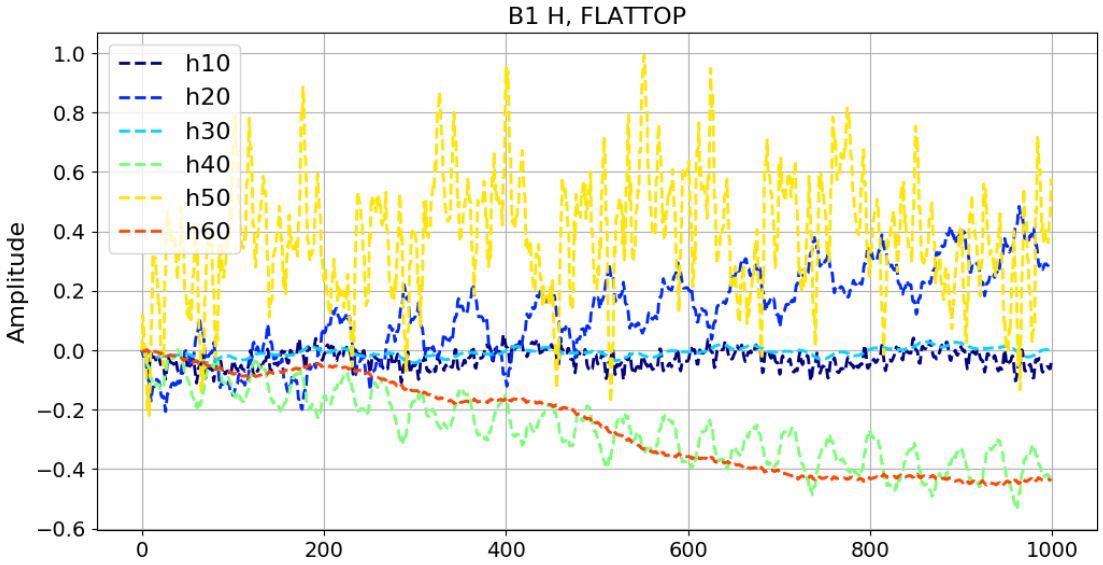



1200 Hz amplitude evolution, Fill 6982 INJPHYS
1e10
1.50
1.25
1.00
0.75
0.50
0.25
0.00
S81 ON
S81 OFF
S78 ON
S78 OFF
S67 ON
S67 OFF
S56 ON
S56 OFF
S45 ON
S45 OFF
S34 ON
S34 OFF
S23 ON
S23 OFF
S12 ON
S12 OFF
Active filters
1e9
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
16:24
16:29
16:34
16:39
UTC time [hh:mm]


2400 Hz amplitude evolution, Fill 6982 INJPHYS
1e10
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1e9
1.50
1.25
1.00
0.75
0.50
0.25
0.00
S81 ON
S81 OFF
S78 ON
S78 OFF
S67 ON
S67 OFF
S56 ON
S56 OFF
S45 ON
S45 OFF
S34 ON
S34 OFF
S23 ON
S23 OFF
S12 ON
S12 OFF
Active filters
16:24
16:29
16:34
16:39
UTC time [hh:mm]


NORM DUMP, 100 turns
$J_x[\sigma]$
turns #
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
0
20
40
60
80
100
fr=3350.0, Ar=1.0D-7
fr=3350.0, Ar=5.0D-8
fr=3350.0, Ar=1.0D-8
fr=3350.0, Ar=7.0D-9
fr=3350.0, Ar=6.0D-9
fr=3350.0, Ar=5.0D-9
fr=3350.0, Ar=4.0D-9
fr=3350.0, Ar=3.0D-9
fr=3350.0, Ar=2.0D-9
fr=3350.0, Ar=1.0D-9
fr=3350.0, Ar=0.9D-9
fr=3350.0, Ar=0.8D-9
fr=3350.0, Ar=0.7D-9
fr=3350.0, Ar=0.6D-9
fr=3350.0, Ar=5.0D-10
fr=3350.0, Ar=0.3D-9
fr=3350.0, Ar=0.2D-9
fr=3350.0, Ar=1.0D-10
fr=3350.0, Ar=5.0D-11
fr=3350.0, Ar=1.0D-11


NORM DUMP, 100 turns
$J_x[\sigma]$
turns #
0.0
0.1
0.2
0.3
0.4
0
20
40
60
80
100
fr=7600.0, Ar=1.0D-7
fr=7600.0, Ar=5.0D-8
fr=7600.0, Ar=1.0D-8
fr=7600.0, Ar=7.0D-9
fr=7600.0, Ar=6.0D-9
fr=7600.0, Ar=5.0D-9
fr=7600.0, Ar=4.0D-9
fr=7600.0, Ar=3.0D-9
fr=7600.0, Ar=2.0D-9
fr=7600.0, Ar=1.0D-9
fr=7600.0, Ar=0.9D-9
fr=7600.0, Ar=0.8D-9
fr=7600.0, Ar=0.7D-9
fr=7600.0, Ar=0.6D-9
fr=7600.0, Ar=5.0D-10
fr=7600.0, Ar=0.3D-9
fr=7600.0, Ar=0.2D-9
fr=7600.0, Ar=1.0D-10
fr=7600.0, Ar=5.0D-11
fr=7600.0, Ar=1.0D-11


B1 H, FLATTOP
h10
h20
h30
h40
h50
h60
Amplitude
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
0
200
400
600
800
1000