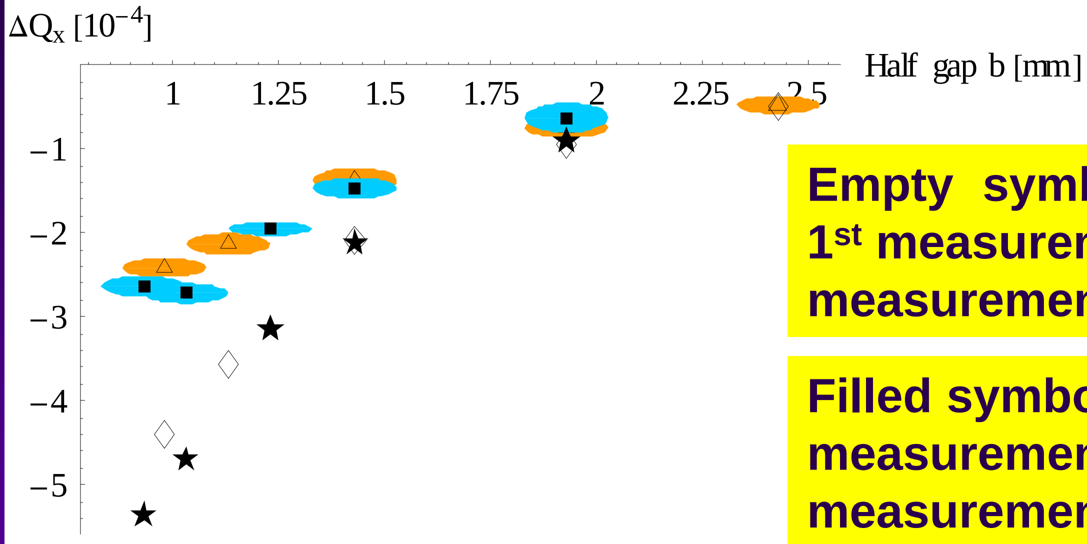
SPS (HORIZONTAL) PROTOTYPE OF THE LHC COLLIMATOR : LINEAR THEORY VS MEASUREMENTS (II)

E. Métral

- **Update of the comparison using $\rho_C = 10\,\mu\Omega\mathrm{m}$ instead of $\rho_C = 14\,\mu\Omega\mathrm{m}$ before (value given by Ralph Assmann at the RLC meeting of 01/04/05) for M.Gasior's measurements**
- **Comparison with the "classical thick-wall" formula**
- **Theory vs. measurements from F.Caspers&T.Kroyer (data sent on 13/04/05)**

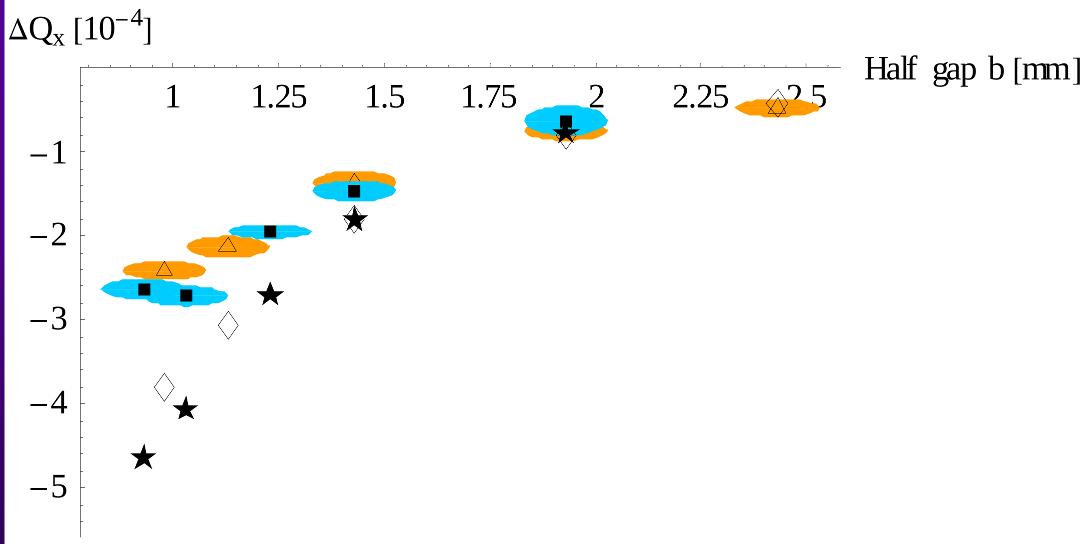
$\rho_C = 14\ \mu\Omega m$



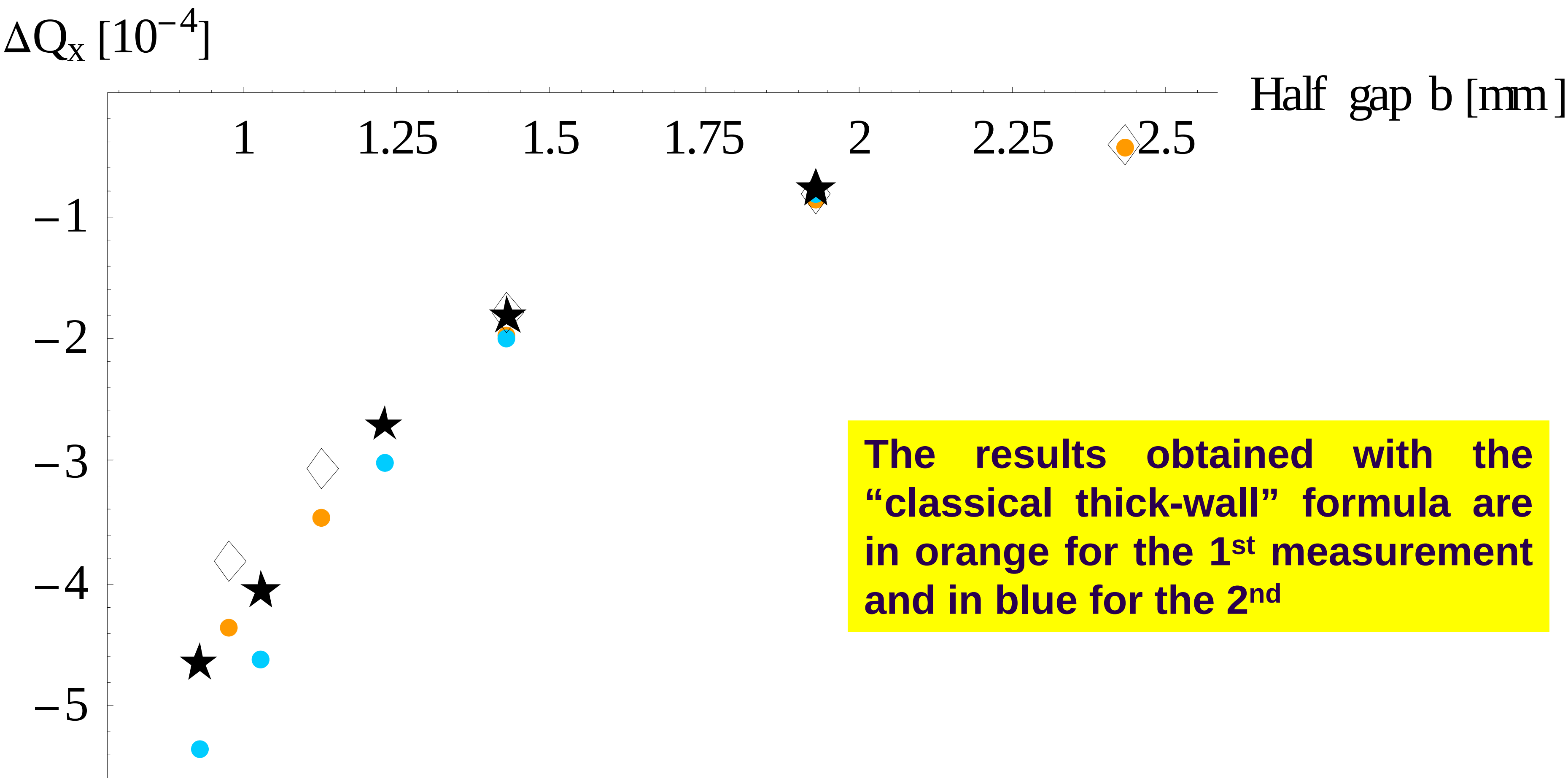
Empty symbols are for the 1st measurement (error in the measurements is in orange)

Filled symbols are for the 2nd measurement (error in the measurements is in blue)

$\rho_C = 10\ \mu\Omega m$



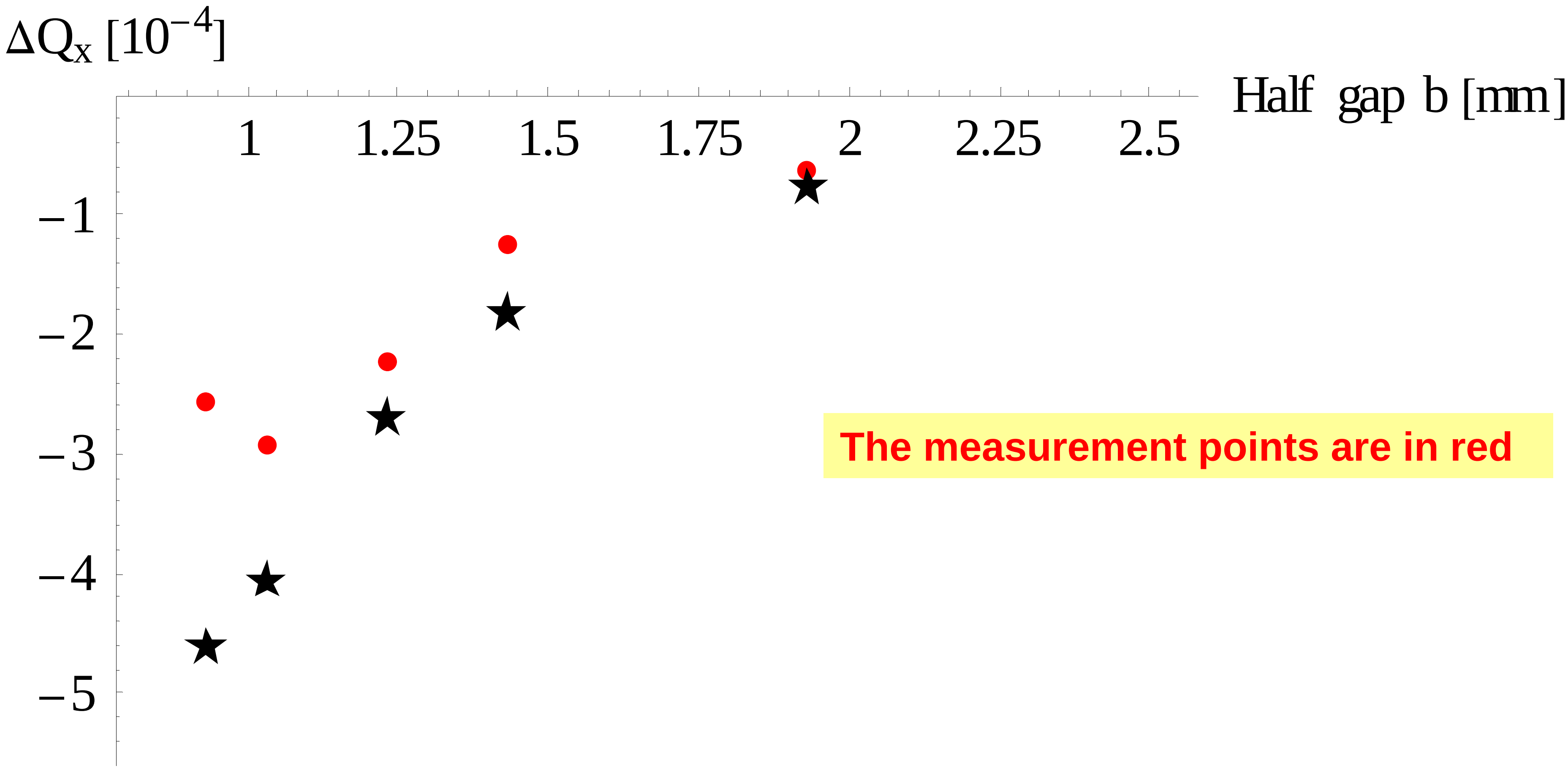
COMPARISON WITH THE "CLASSICAL THICK-WALL" FORMULA



The results obtained with the "classical thick-wall" formula are in orange for the 1st measurement and in blue for the 2nd

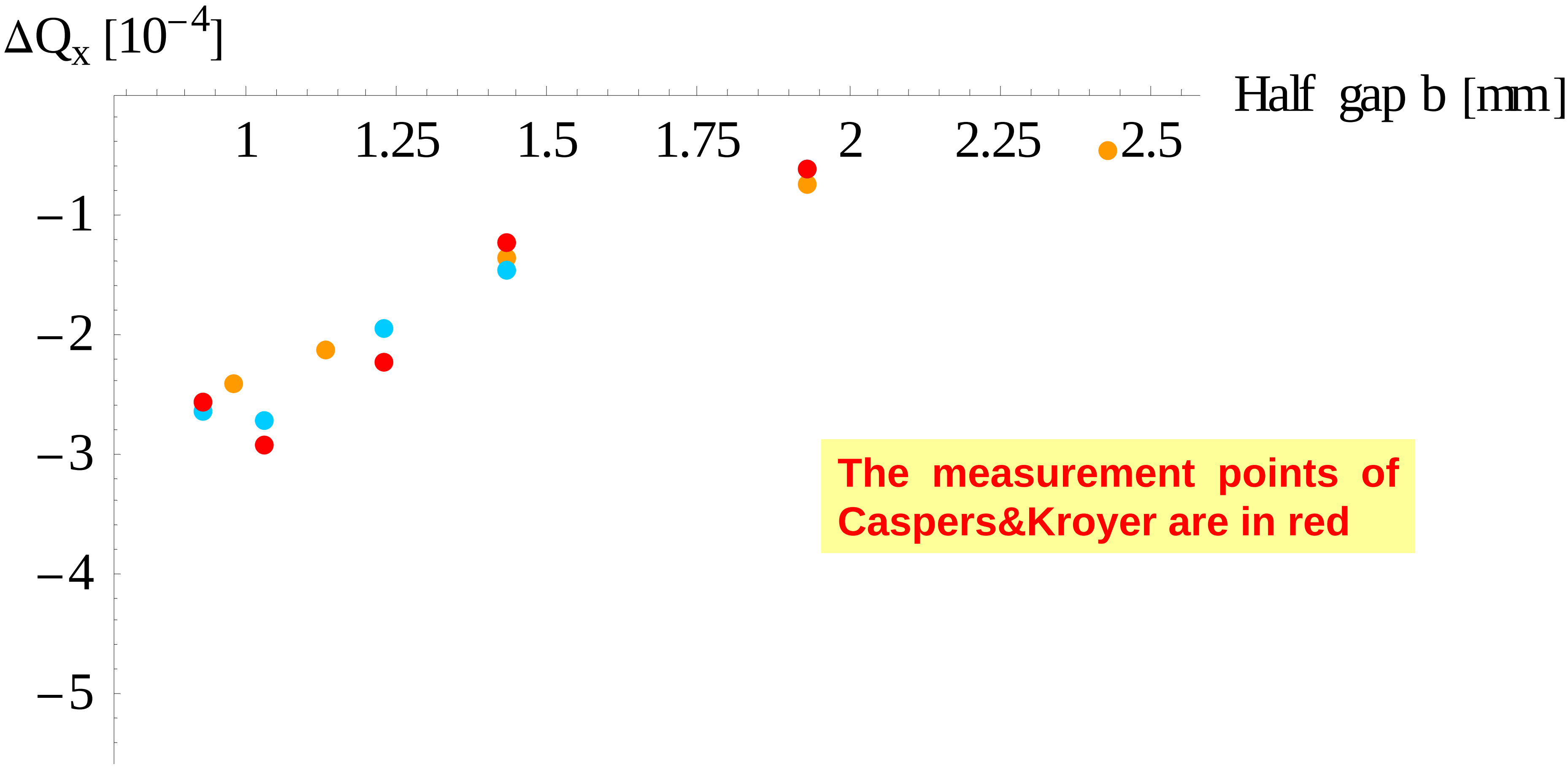
$\rho_C = 10\ \mu\Omega\text{m}$

THEORY VS. MEASUREMENTS FROM CASPERS&KROYER



$\rho_C = 10 \ \mu\Omega\mathrm{m}$

MEASUREMENTS FROM GASIOR AND CASPERS&KROYER



The measurement points of Caspers&Kroyer are in red

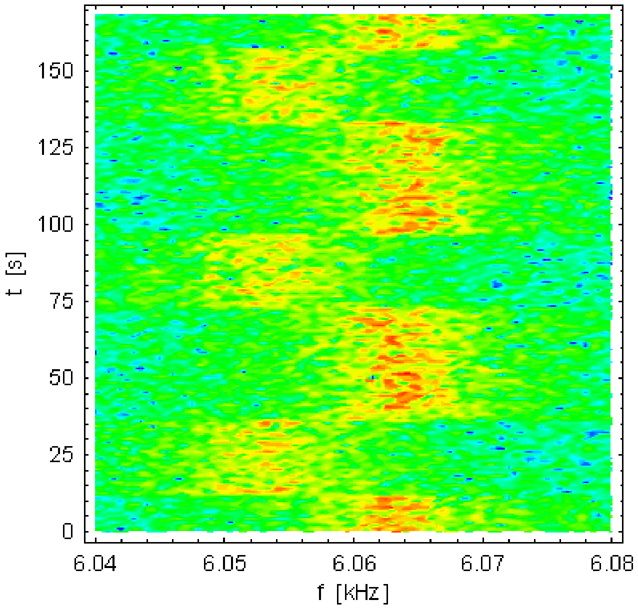
APPENDIX 1 : Details on M.Gasior's measurements

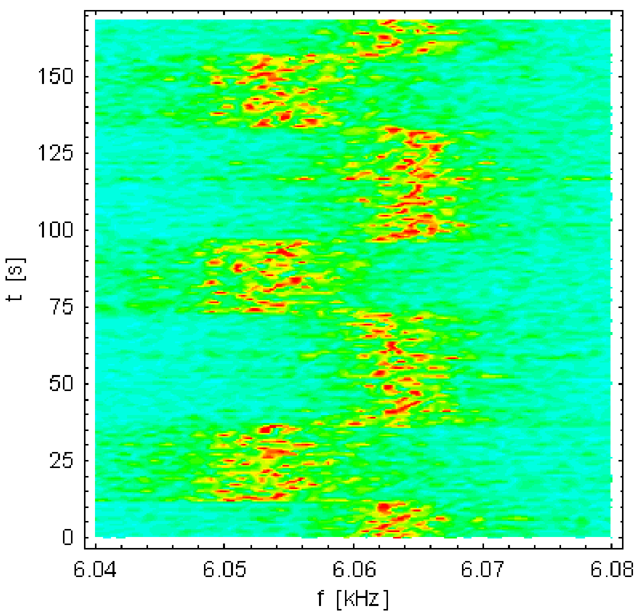
Collimator MDs #2
(11-12/10/04)

Results from the
Base-Band Q (BBQ) Measurement

M. Gasior, R. Jones, CERN-AB-BDI

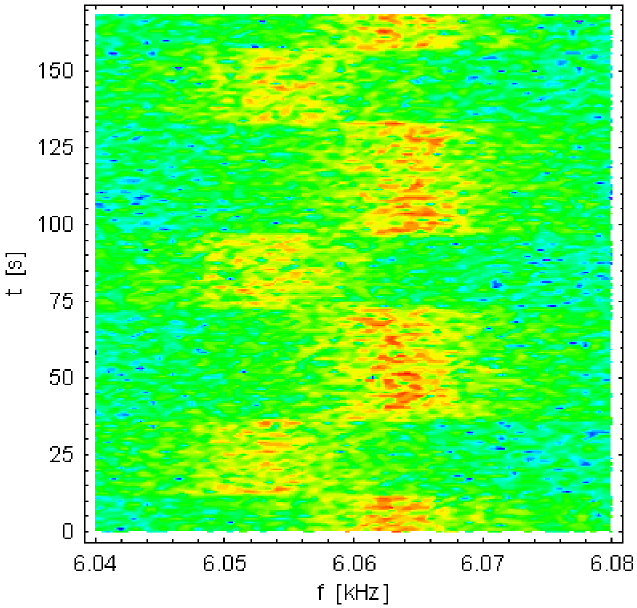
Data analysis example – the story

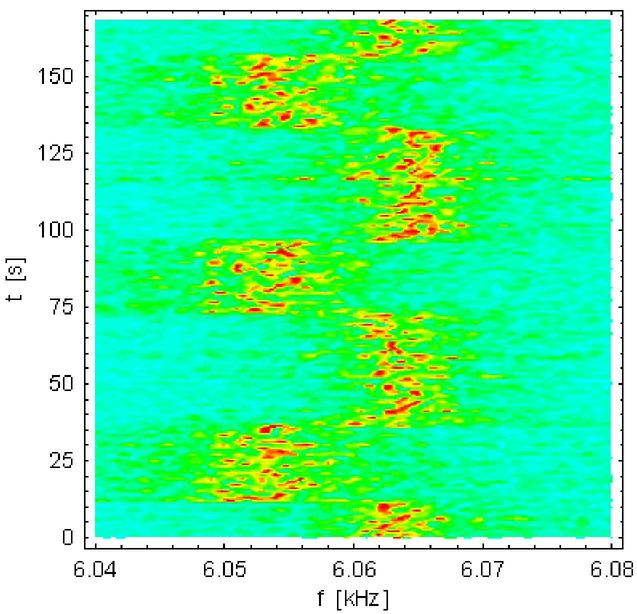


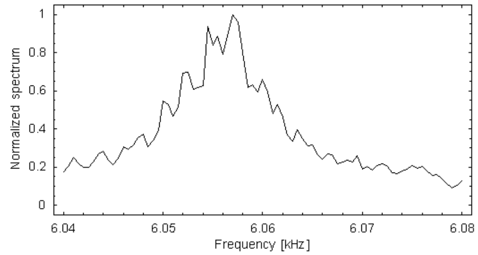


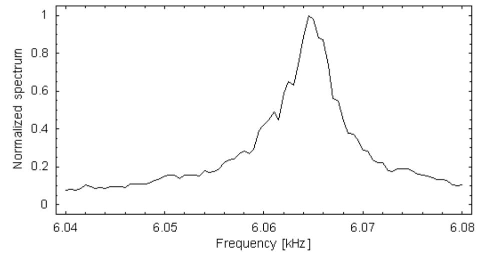
- The top picture shows spectra from the measurement at 4:40 (gap of 1.96 mm) with log color scaling. The bottom one – with linear color scaling.
- BBQ signal samples were acquired with a 24-bit sound card at the rate of 48 kS/s (16-bit samples stored).
- Each spectrum segment is calculated from 96000 Hanning windowed samples, i.e. the record is 2 s long, giving FFT bin spacing of 0.5 Hz. Two adjacent data segments overlap by 50%, so there is one spectrum segment per second. These parameters are a compromise between the frequency and time resolution required by the measurements.
- The next slide shows an example of the procedure discussed here.
- "Collimator in" and "collimator out" spectra are grouped by calculating an RMS sum. For the discussed measurement this gives three "in" and two "out" spectra.
- For each RMS summed spectra it is evaluated an RMS center of gravity of the main distribution, within a few Hz bandwidth to not take into account the distribution tails. In this way there are produced five frequency numbers.
- Out of these 5 numbers there are calculated 4 frequency differences.
- Out of these differences there are calculated a mean and a standard deviation.
- The mean is considered as the frequency change due the collimator movement and the standard deviation is considered as the measurement error estimate.
- The procedure is used to calculate 5 frequency changes for each of two measurement series. For more difficult cases it is taken longer time record at the expense of much longer PC processing time.
- Lengths of the records are limited either by capabilities of my PC (Pentium 2.8 GHz, 512 MB of RAM, Windows XP, Mathematica 4.1) or the measurement length, if it is shorter than some 3 minutes.
- Note that the achieved resolution is a consequence of a very long observation time. For a 150 s record one stores some 7 millions of samples, corresponding to some 6.5 millions of turns. This is possible only with a continuous beam excitation, self-excitation in this case.

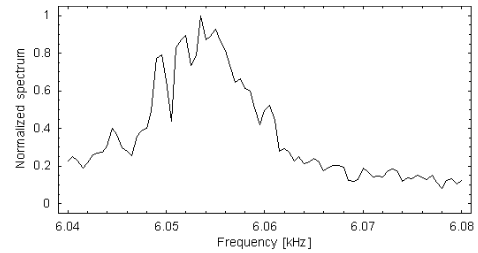
Data analysis example – the plots and numbers

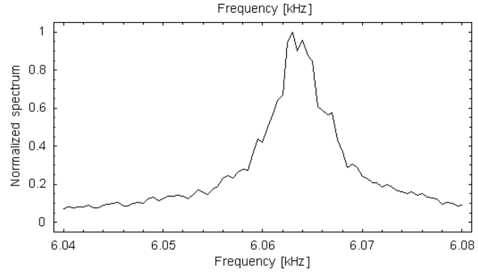


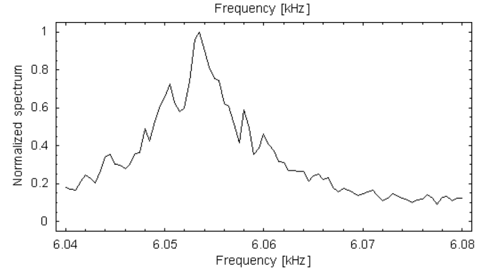












f [Hz]	Δ*f* [Hz]
6053.43	
	10.16
6063.59	
	9.80
6053.80	
	10.88
6064.68	
	10.71
6053.97	

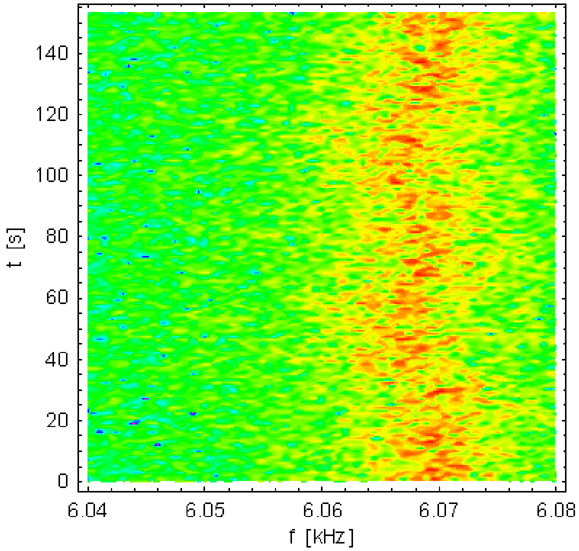
mean
10.4 Hz
$2.4\times10^{-4} f_r$

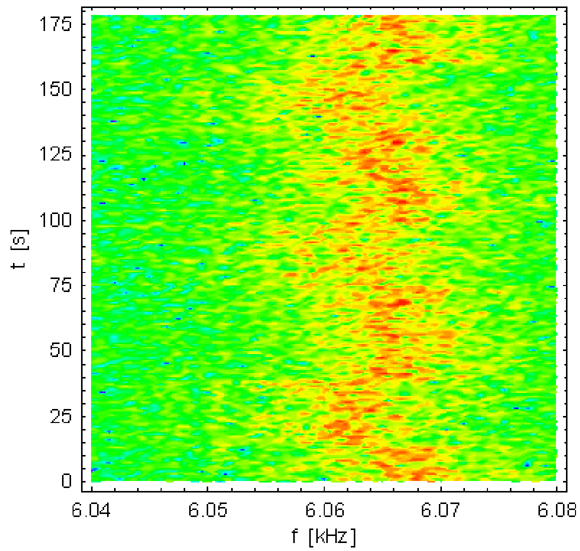
std. dev.
0.5 Hz
$1.2\times10^{-5} f_r$

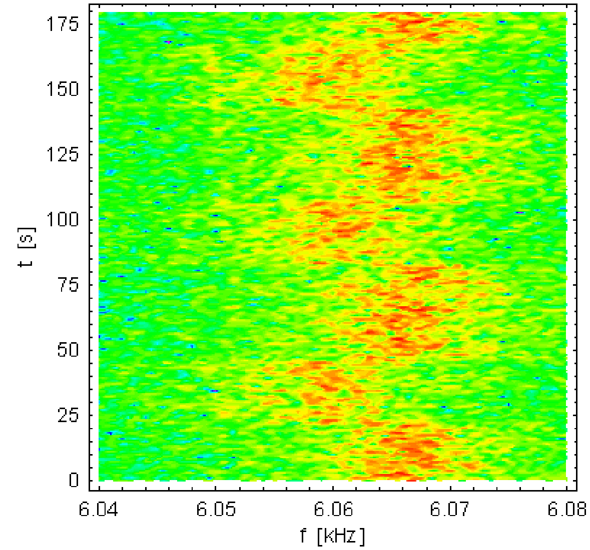
Spectra from all measurements – the story

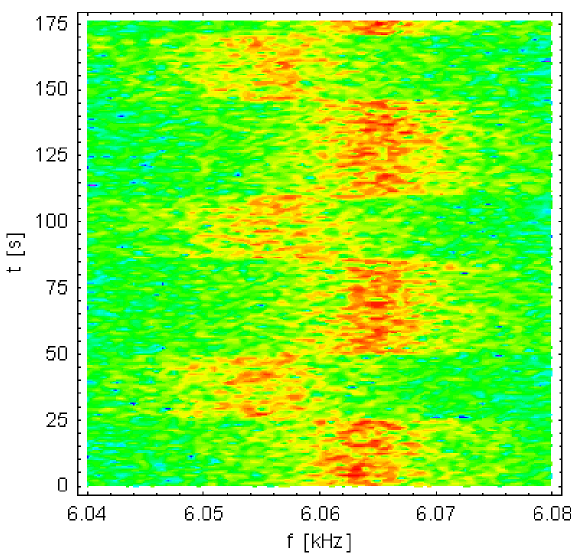
- On the following two slides (#5 and #6) you have spectra for all 5 measurements for both series. The specified time is supposed to be the measurement "middle".
- I recalculated all spectra (this is the new thing with respect to what I have shown already) to have the same frequency band for each series. Also now I always calculate RMS values, instead of normal averaging which I was using in the past. This RMS method gives slightly worse standard deviations for the results, but better spectra shapes and it is more mathematically correct.
- Since all spectra for each series are plotted for the same frequency band (always 40 Hz), you can see two effects: 1. The "collimator out" frequency slowly drifts. For the first series it drifts by some 8 Hz within one hour and for the second series, by some 6 Hz within half an hour. Most of the drift happened when the collimator was cycling to small gaps. The drift is likely to be caused by the decreasing beam current. 2. The second effect is that when the collimator is cycling to small gaps, the tune distribution is narrower – the tune peak wonders less, is less jittery. I am trying to visualize this on the slide #7.
- On the plot of slide #7 you see also the spectra from the measurement at 4h40. You see RMS summed spectra for the whole record, RMS summed spectra for the collimator in and out, and all three curves on one plot. It is seen that betatron oscillations for the collimator out have larger amplitudes and the distribution is narrower. Before you start drawing any deep conclusions, you should see similar plots for a few more measurements (slide #8).
- On the 3D plot in slide #7 you see linear scale spectra for the measurement of 4:40. Note that the oscillations are composed of short bursts popping up every now and then.
- On slide #8 you see "collimator in" and "collimator out" RMS summed spectra for the 3 last measurements for each series, i.e. the ones with smaller collimator gaps. The change in the distribution width is not systematic, it is evident only for the measurement of 4:40.
- On the slide #9 you have the final plot with error bars. For the collimator gap I assumed 50 um errors everywhere and the gap values I obtained a long time ago. You can ask collimator guys for recent exact numbers and their tolerances.
- It looks like for two measurement series the curves are slightly separated, at least on the measurement beginnings. Due to beam current decay (and maybe the bunch length drifting) the two curves bends towards smaller frequency shifts. This should not be a problem, since you can get the beam current and the bunch length at the very moment of each measurement. Well, since each measurement takes some 3 minutes, you have to assume that within this time the machine conditions do not change. This may be not true for the beam current with small collimator gaps, that is for the last measurements in each series.
- On Slide #10 you have a table with the numbers I calculated.

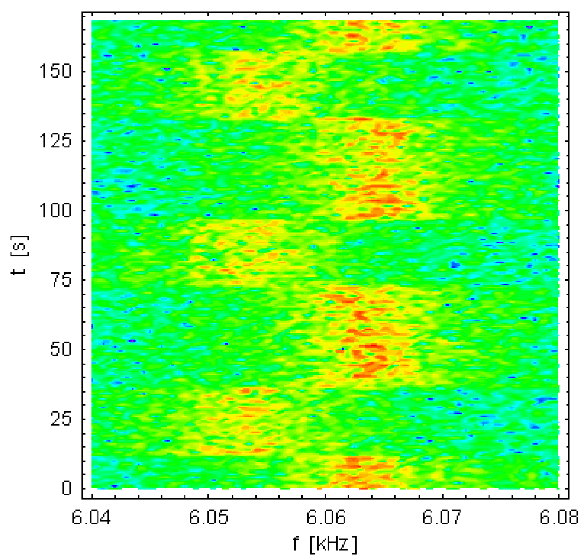
Spectra from measurements 3:30 – 4:45







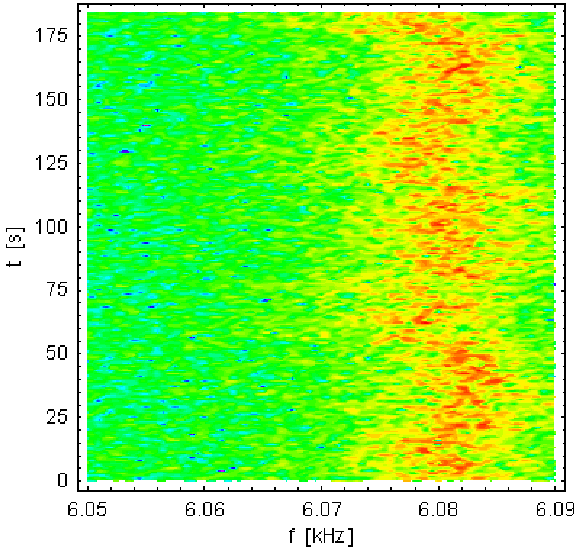


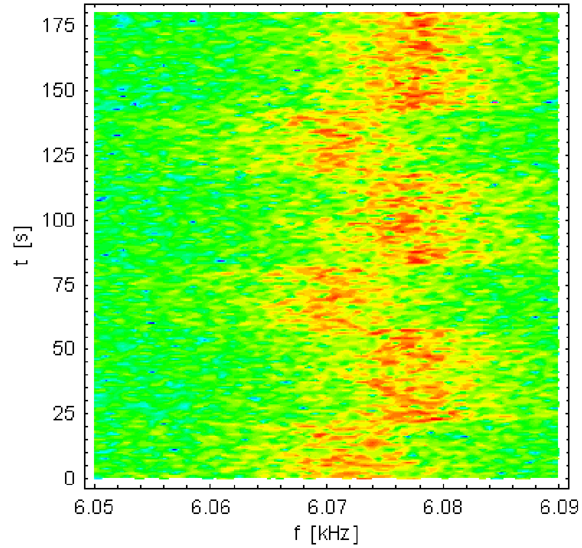


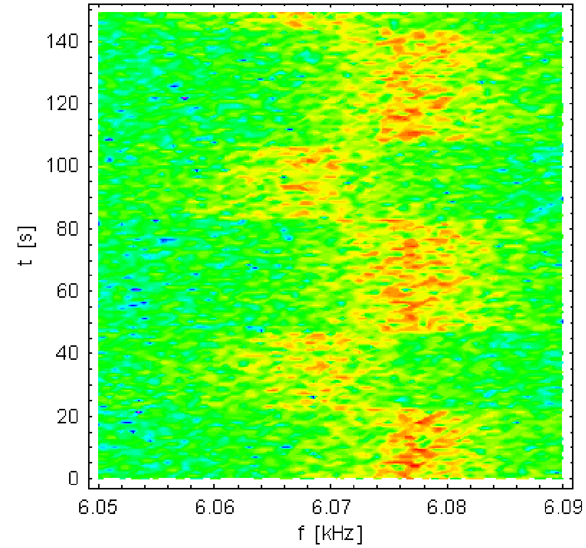
Collimator gap @ time

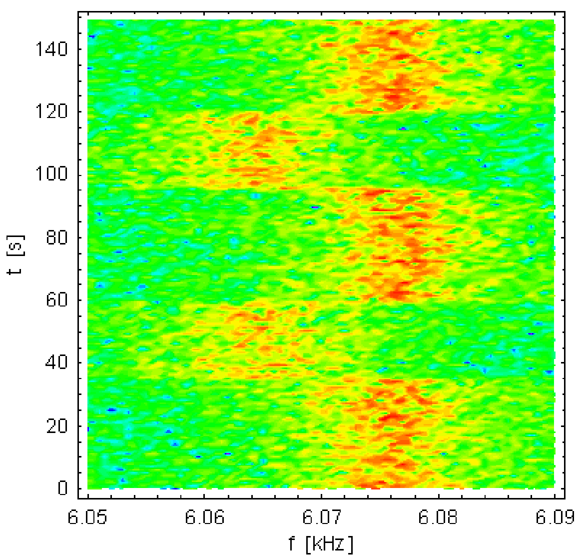
- 4.86 mm @ 3:36
- 3.86 mm @ 3:45
- 2.86 mm @ 4:01
- 2.26 mm @ 4:22
- 1.96 mm @ 4:40

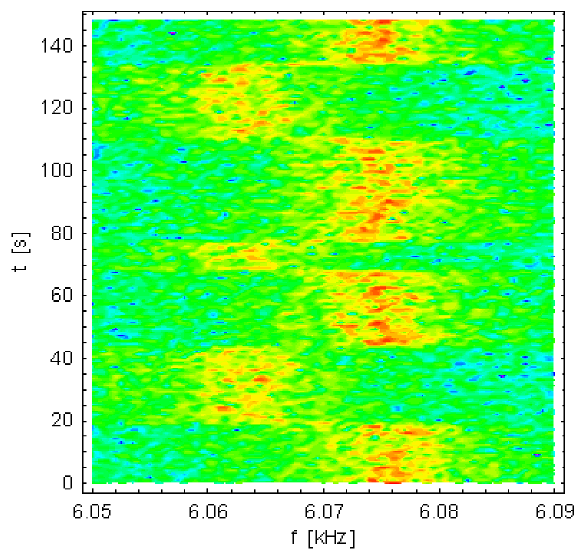
Spectra from measurements 5:30 – 6:05







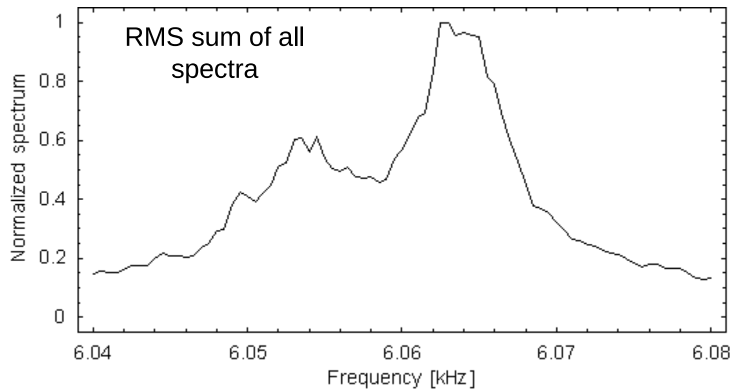


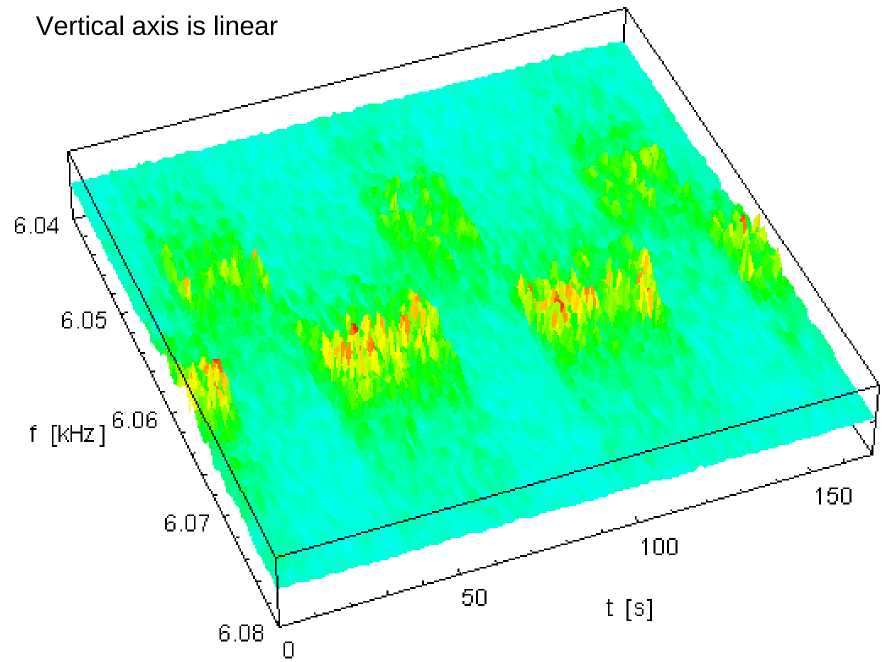


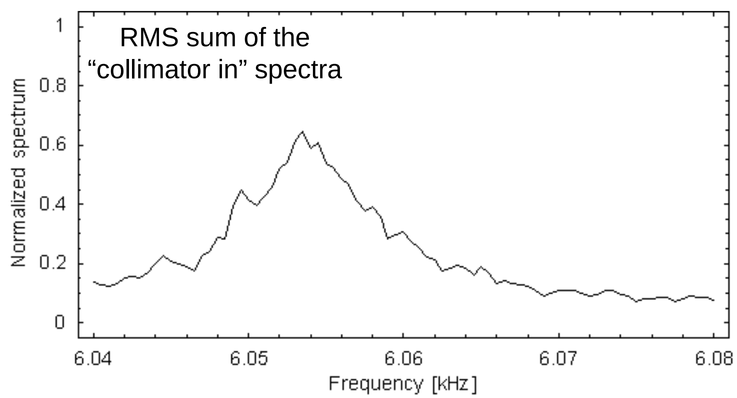
Collimator gap @ time

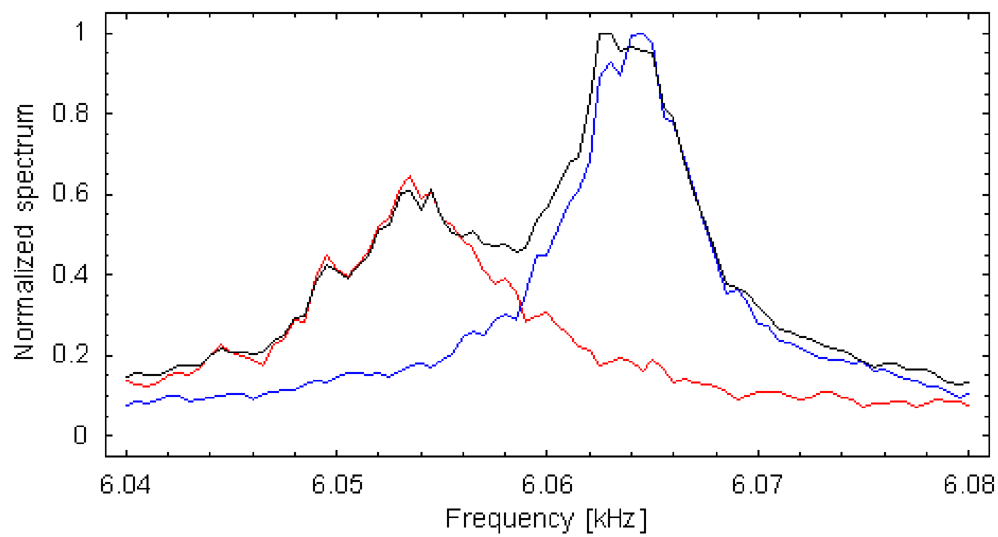
- 3.86 mm @ 5:30
- 2.86 mm @ 5:38
- 2.46 mm @ 5:46
- 2.06 mm @ 5:53
- 1.86 mm @ 6:05

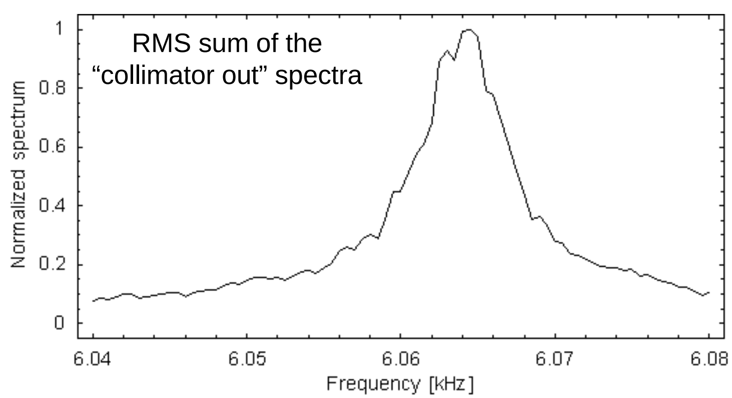
Spectra from the measurement of 4:40



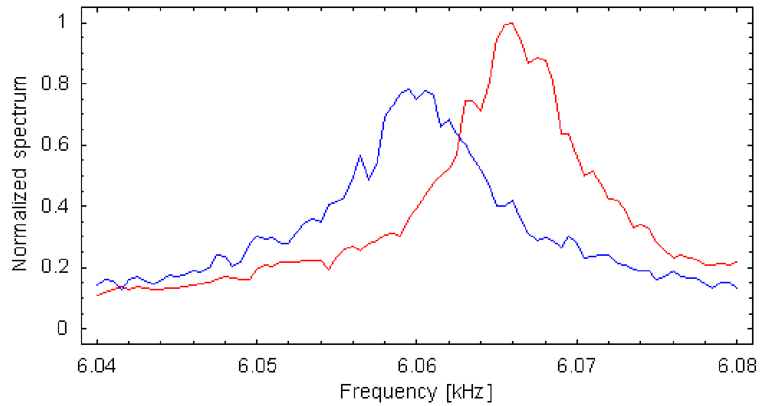






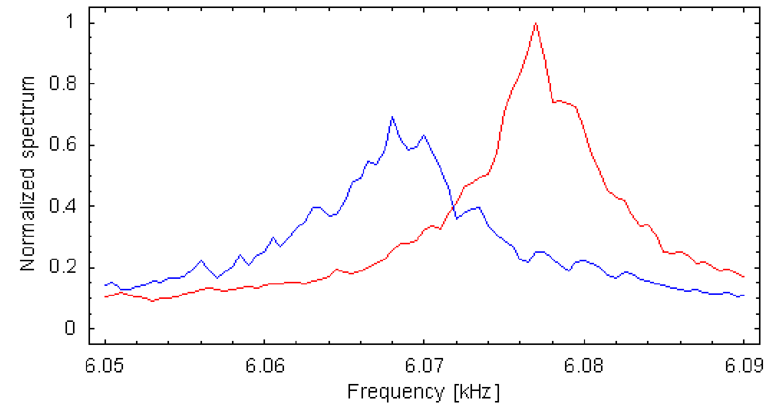


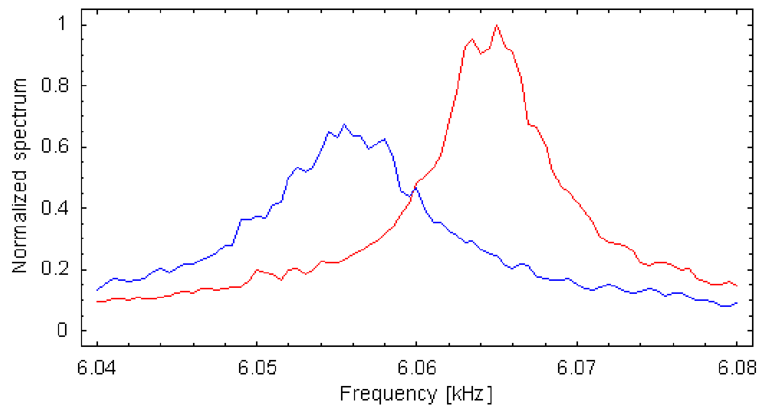
"In" and "out" spectra



4:01

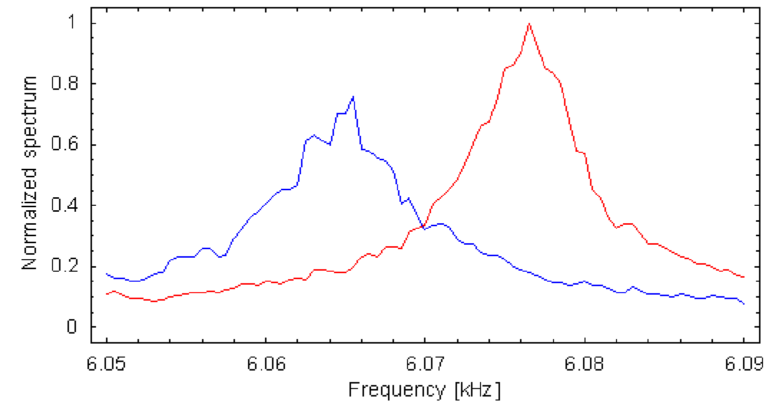
5:46

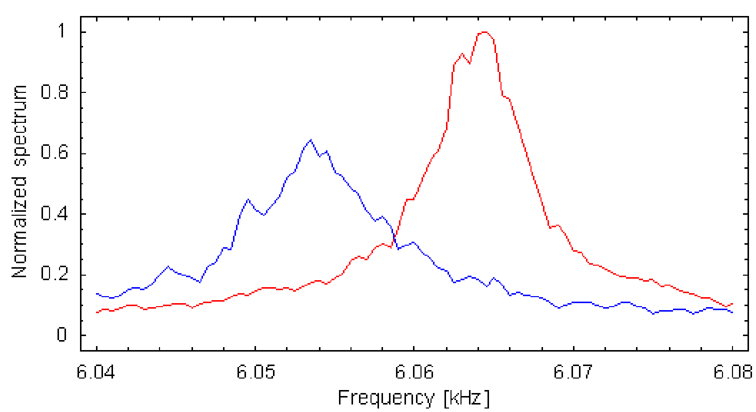




4:22

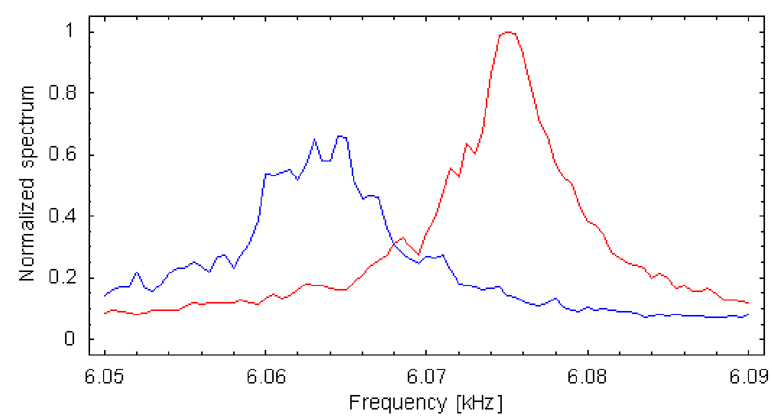
5:53



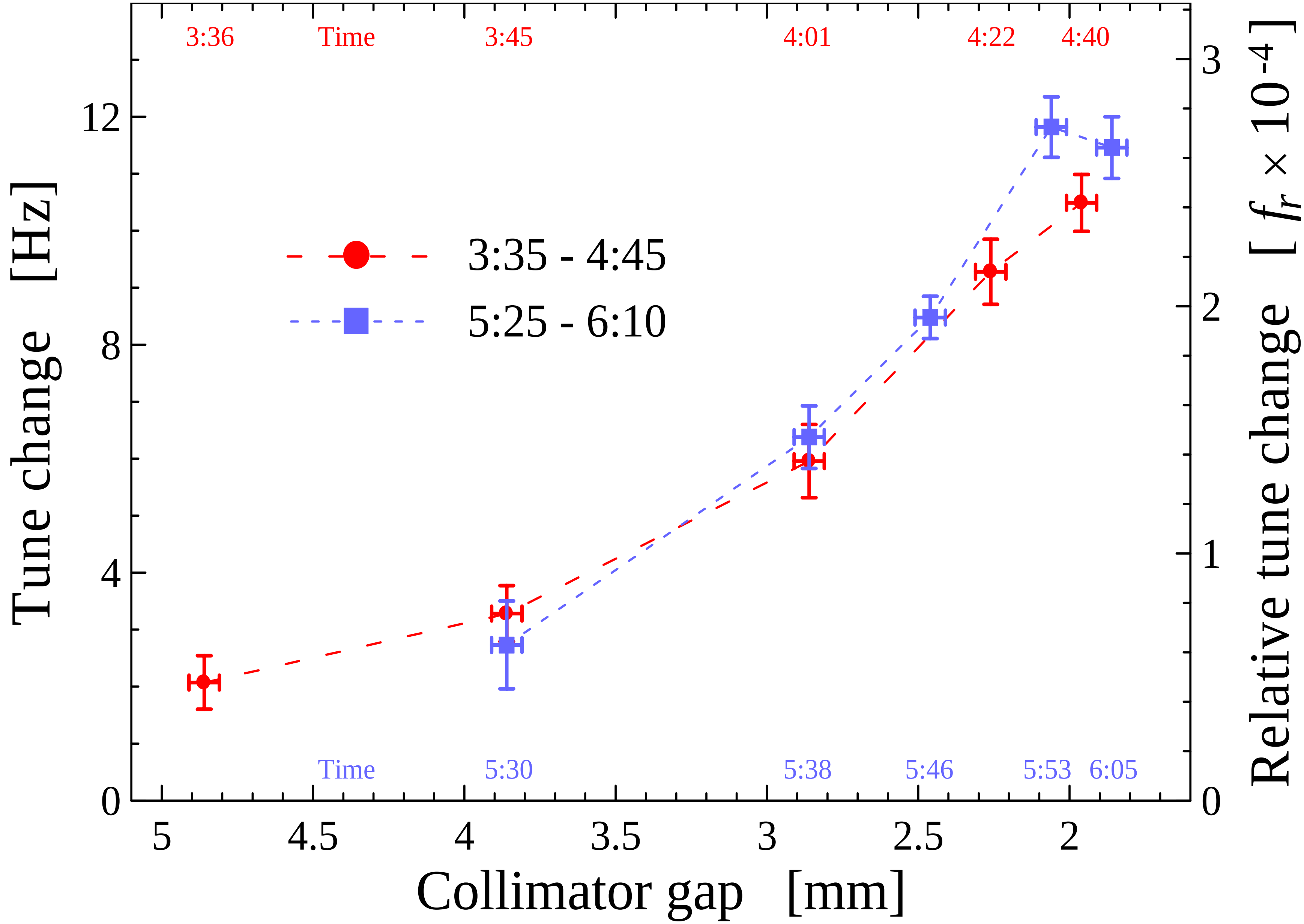


4:40

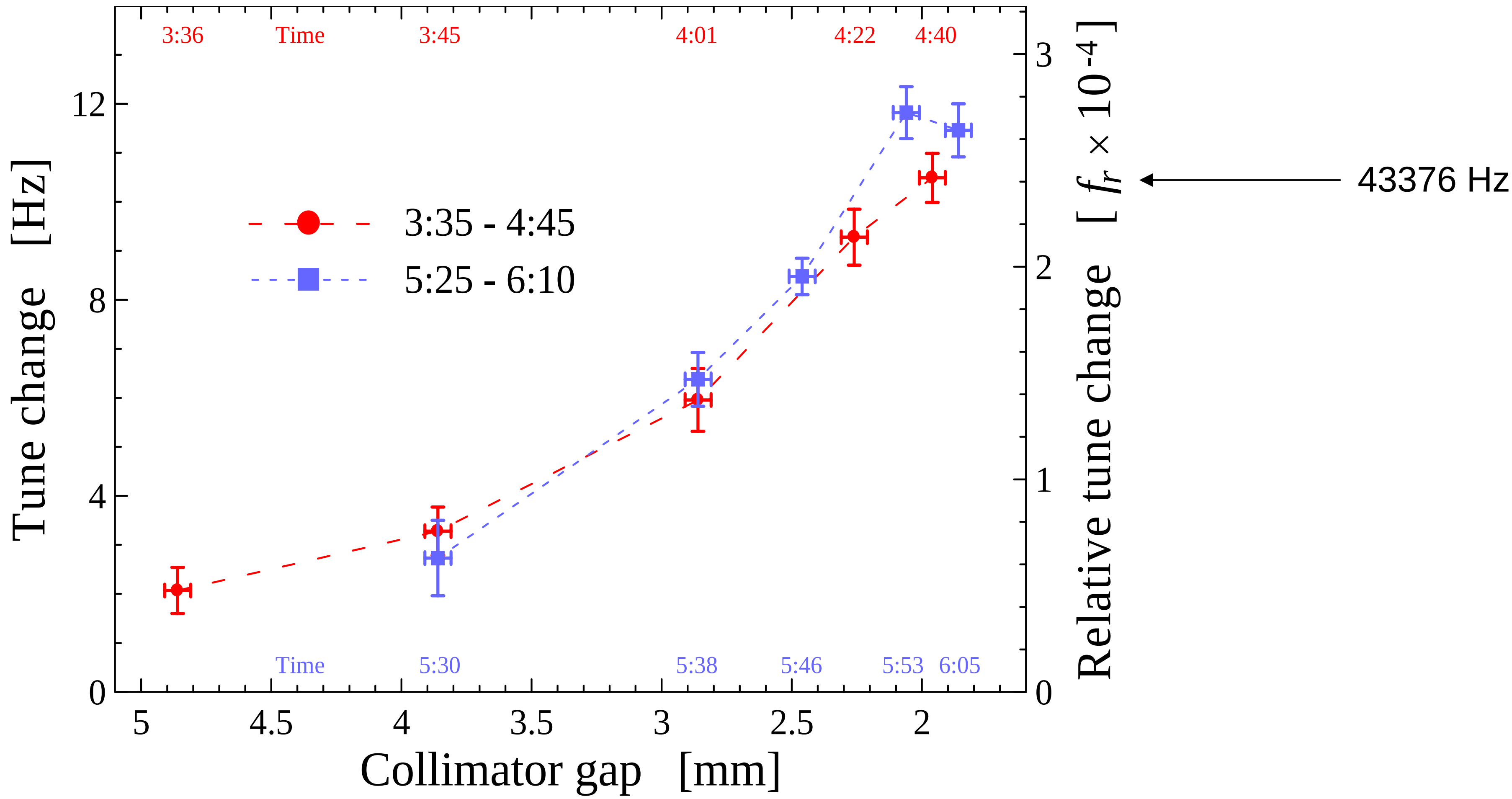
6:05



The final plot



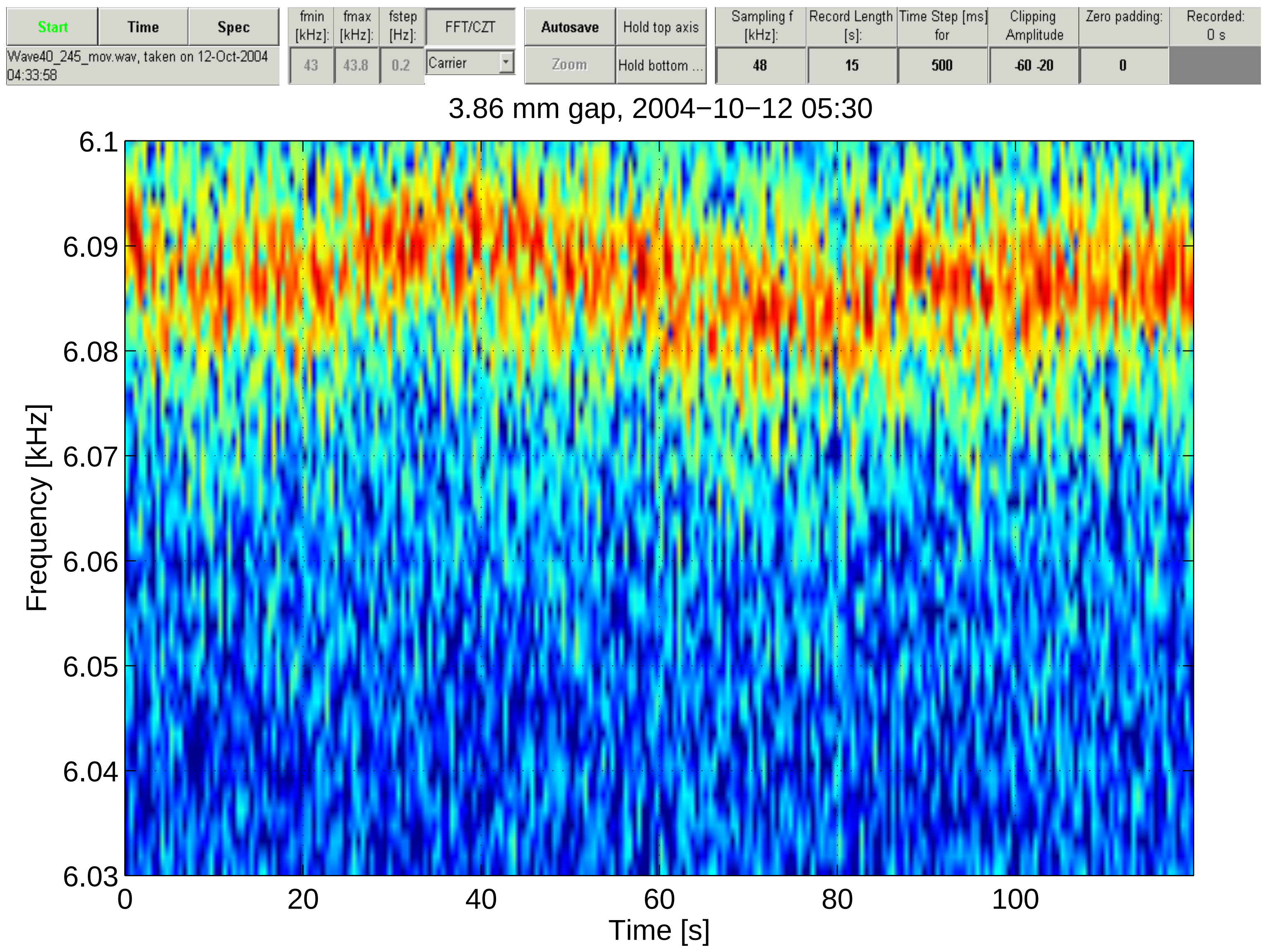
The result table

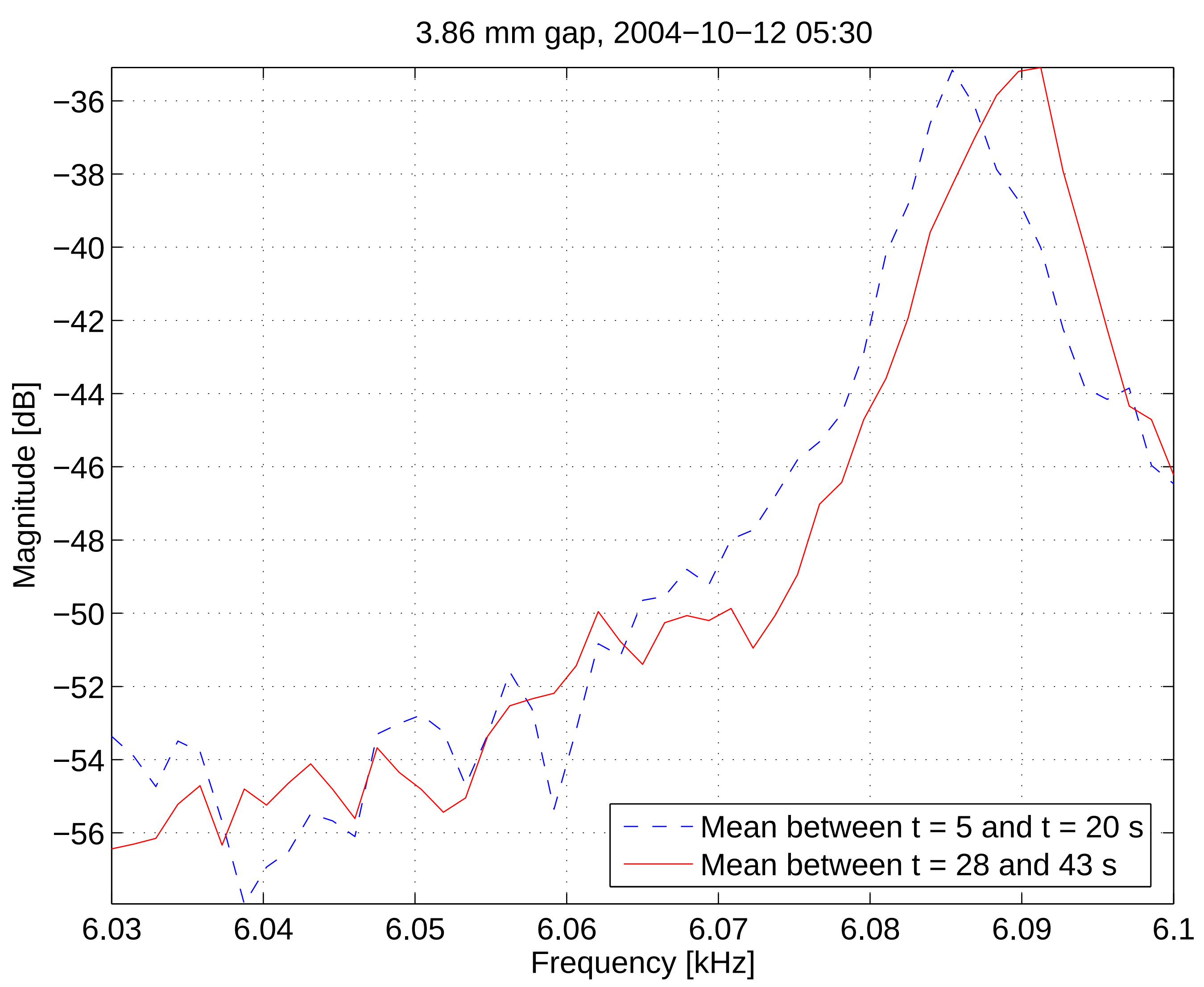


time	gap [mm]	err [mm]	dq [Hz]	err [Hz]
03:35:42	4.86	0.05	2.07	0.47
03:45:28	3.86	0.05	3.28	0.49
04:01:57	2.86	0.05	5.96	0.64
04:21:49	2.26	0.05	9.28	0.57
04:39:44	1.96	0.05	10.49	0.50

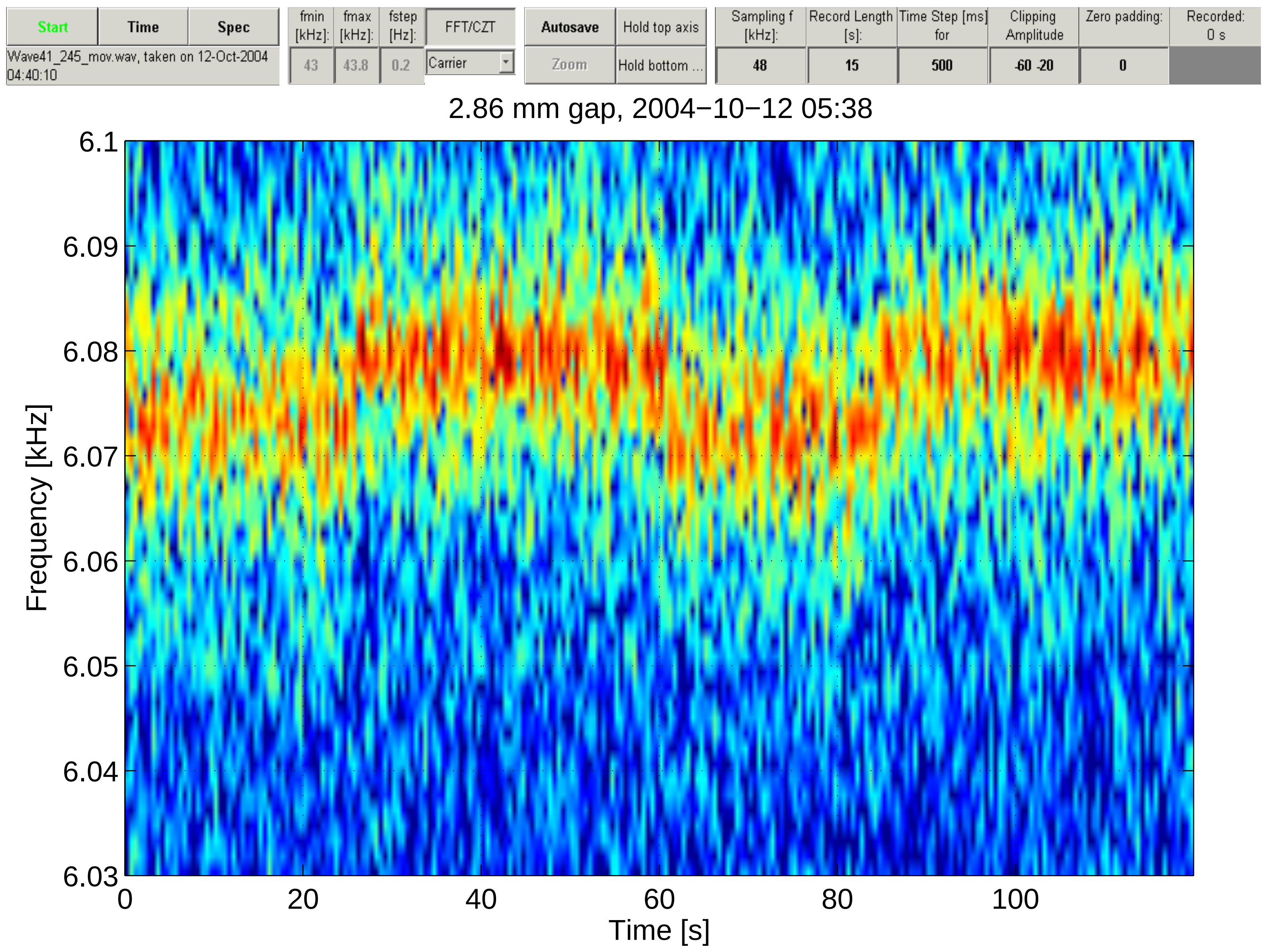
time	gap [mm]	err [mm]	dq [Hz]	err [Hz]
05:29:56	3.86	0.05	2.73	0.77
05:37:34	2.86	0.05	6.38	0.549
05:45:51	2.46	0.05	8.48	0.37
05:53:19	2.06	0.05	11.82	0.53
06:04:37	1.86	0.05	11.46	0.54

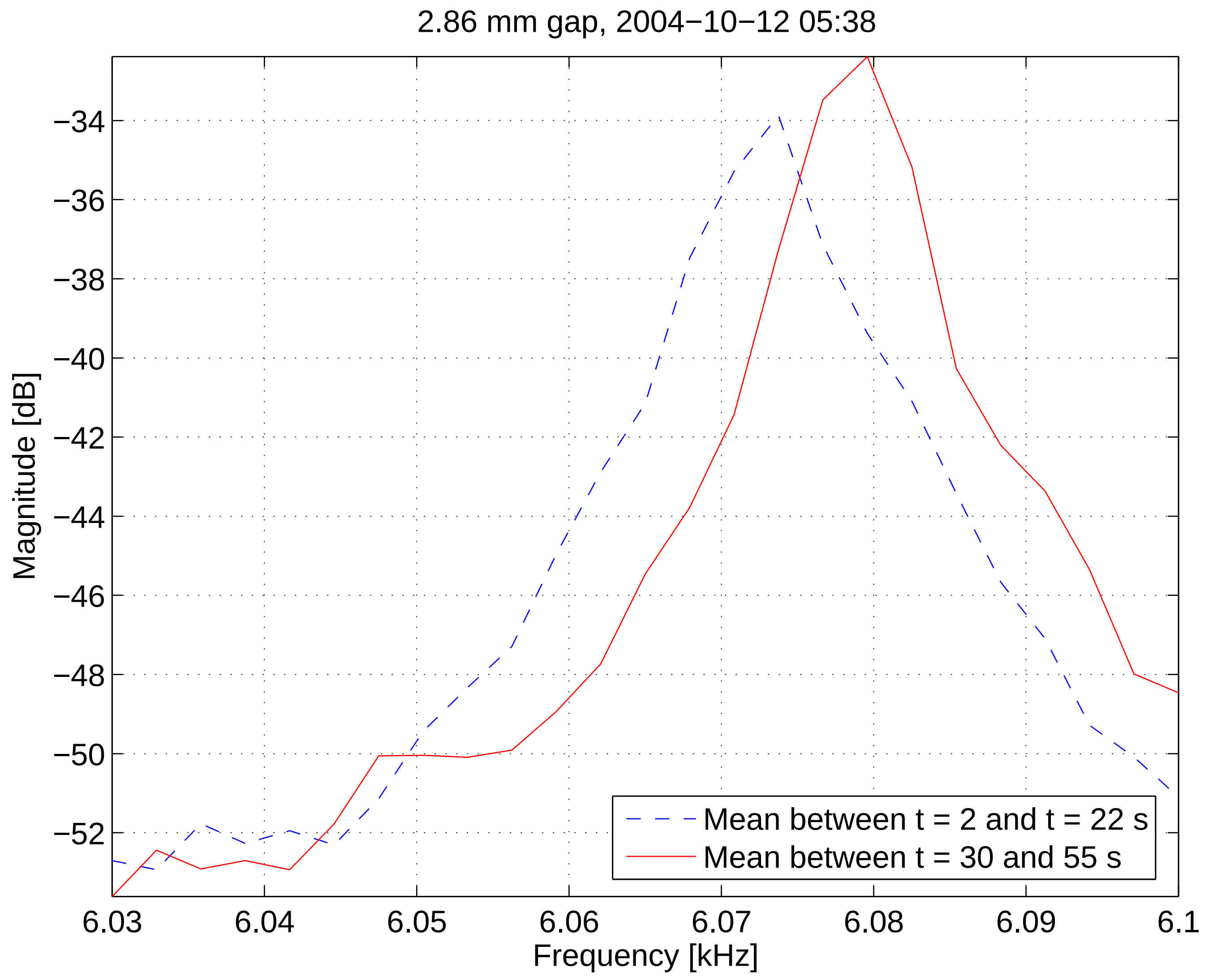
APPENDIX 2 : Details on F.Caspers&T.Kroyer's measurements

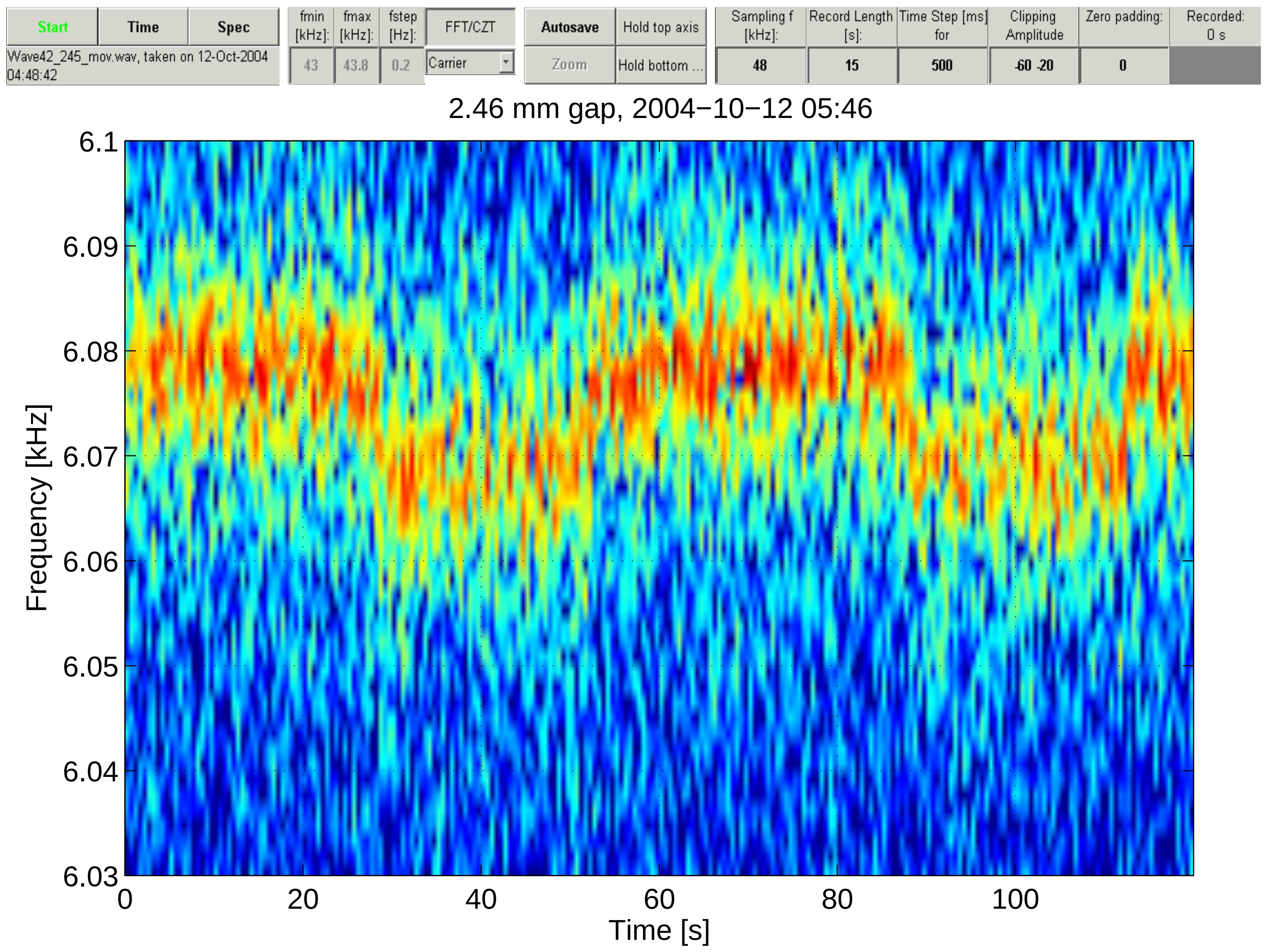

Start
Time
Spec
Wave40_245_mov.wav, taken on 12-Oct-2004 04:33:58
fmin [kHz]:
43
fmax [kHz]:
43.8
fstep [Hz]:
0.2
FFT/CZT
Carrier
Autosave
Zoom
Hold top axis
Hold bottom ...
Sampling f [kHz]:
48
Record Length [s]:
15
Time Step [ms] for
500
Clipping Amplitude
-60 -20
Zero padding:
0
Recorded: 0 s
3.86 mm gap, 2004−10−12 05:30
Frequency [kHz]
6.1
6.09
6.08
6.07
6.06
6.05
6.04
6.03
0
20
40
60
80
100
Time [s]

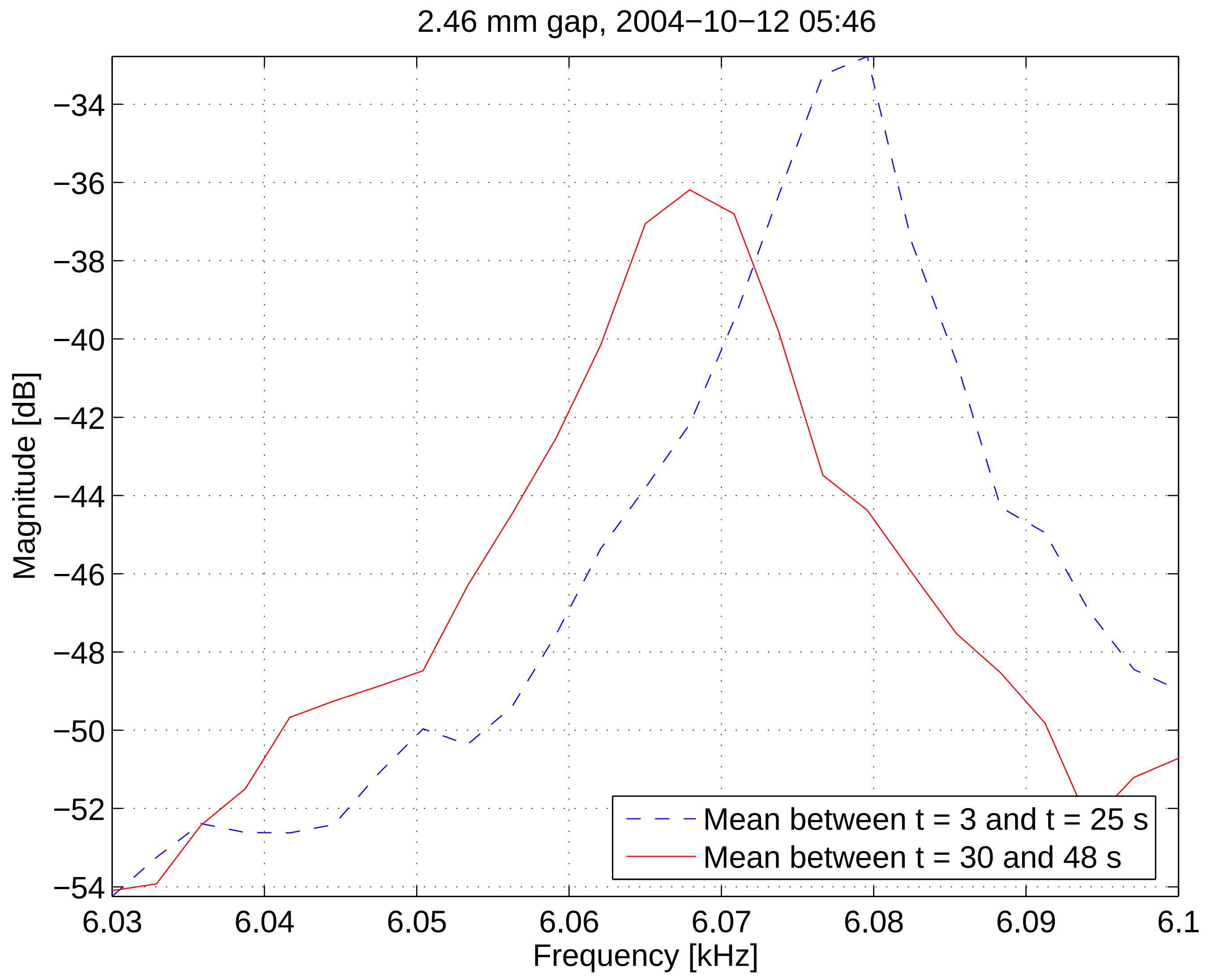


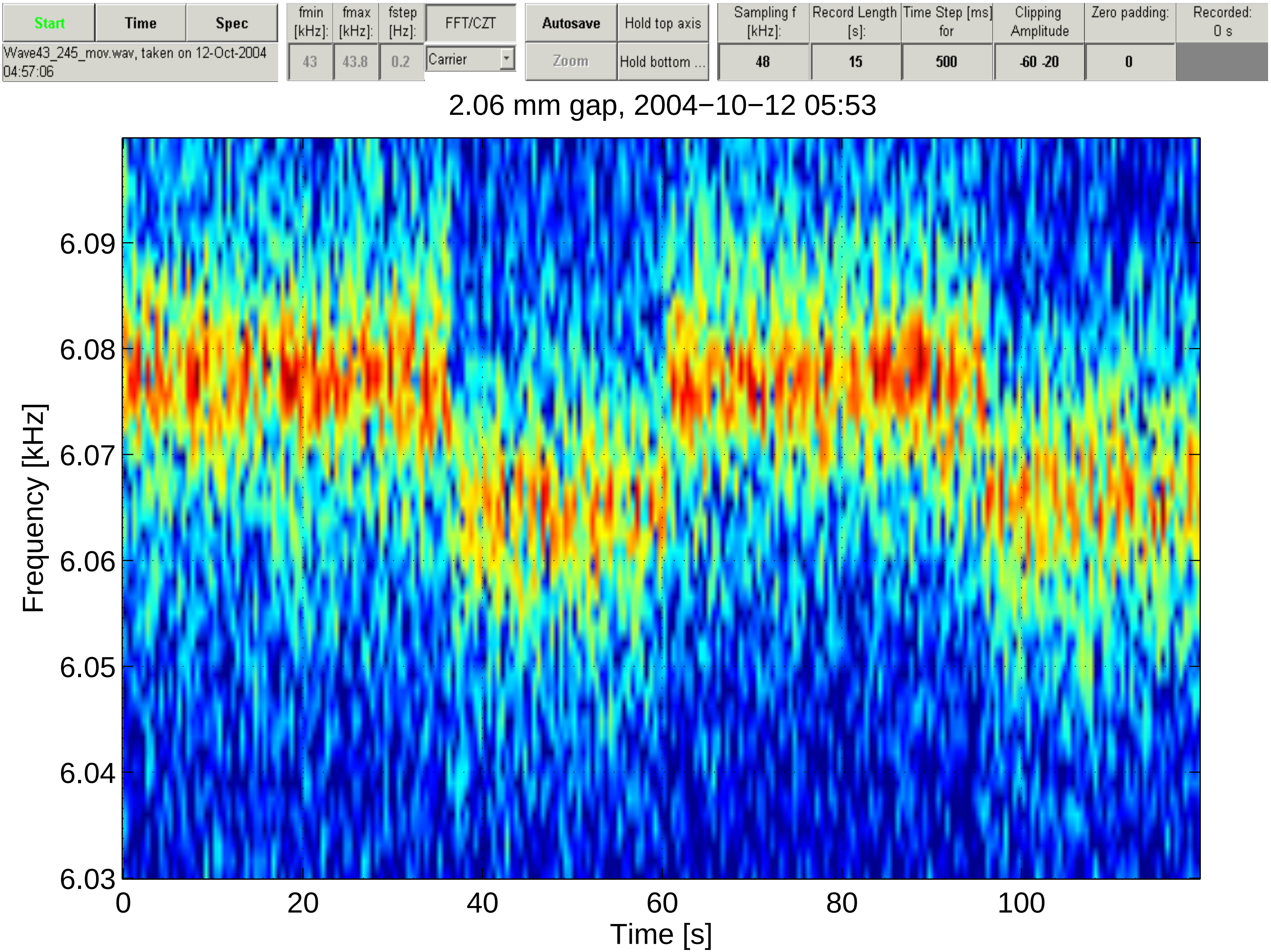
3.86 mm gap, 2004−10−12 05:30
Magnitude [dB]
Frequency [kHz]
−36
−38
−40
−42
−44
−46
−48
−50
−52
−54
−56
6.03
6.04
6.05
6.06
6.07
6.08
6.09
6.1
Mean between t = 5 and t = 20 s
Mean between t = 28 and 43 s


Start
Time
Spec
fmin [kHz]:
fmax [kHz]:
fstep [Hz]:
FFT/CZT
Autosave
Hold top axis
Sampling f [kHz]:
Record Length [s]:
Time Step [ms] for
Clipping Amplitude
Zero padding:
Recorded: 0 s
Wave41_245_mov.wav, taken on 12-Oct-2004 04:40:10
43
43.8
0.2
Carrier
Zoom
Hold bottom ...
48
15
500
-60 -20
0
2.86 mm gap, 2004−10−12 05:38
Frequency [kHz]
6.1
6.09
6.08
6.07
6.06
6.05
6.04
6.03
0
20
40
60
80
100
Time [s]

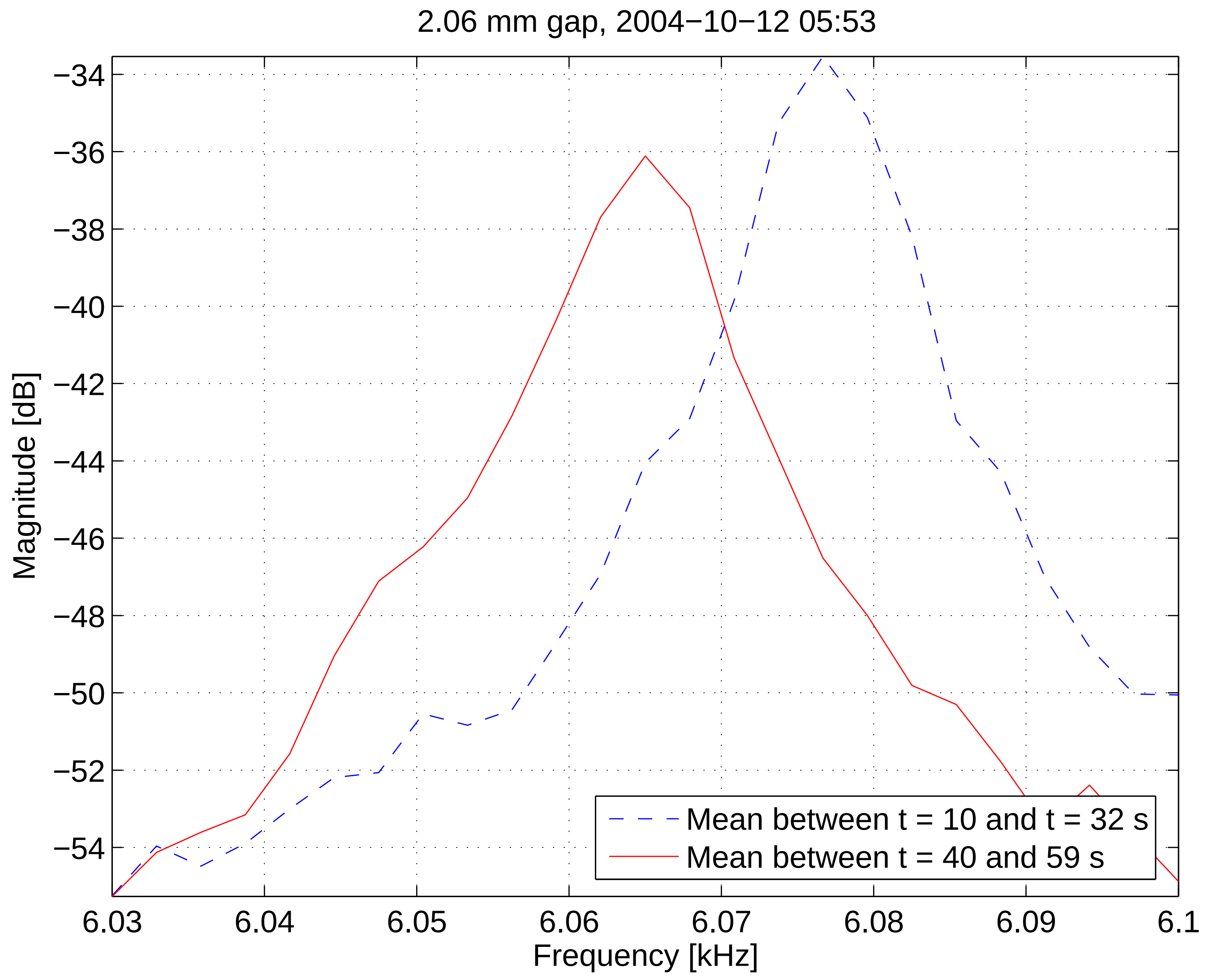

2.86 mm gap, 2004−10−12 05:38
Magnitude [dB]
−34
−36
−38
−40
−42
−44
−46
−48
−50
−52
6.03
6.04
6.05
6.06
6.07
6.08
6.09
6.1
Frequency [kHz]
Mean between t = 2 and t = 22 s
Mean between t = 30 and 55 s

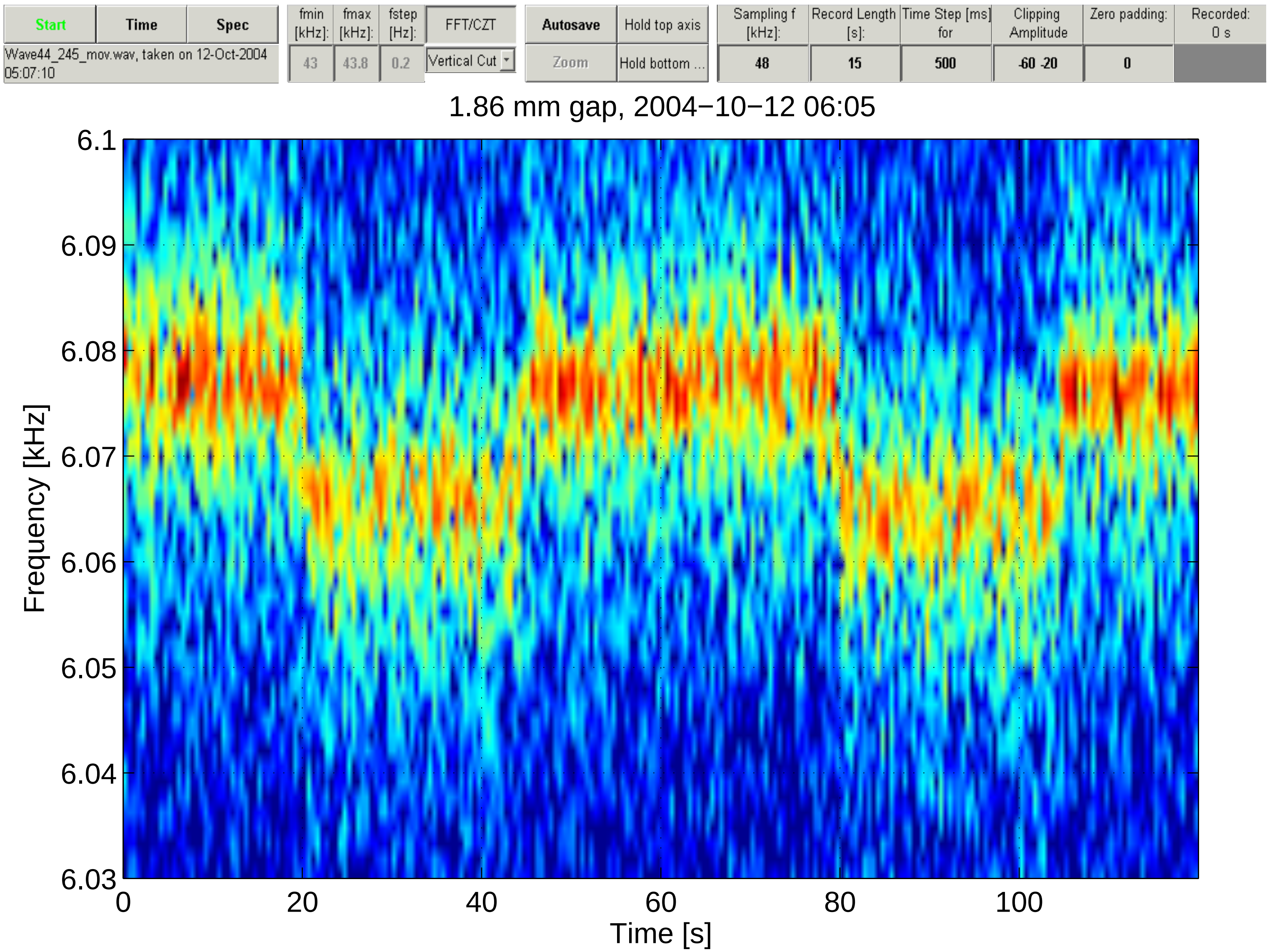

Start
Time
Spec
Wave42_245_mov.wav, taken on 12-Oct-2004 04:48:42
fmin [kHz]:
fmax [kHz]:
fstep [Hz]:
43
43.8
0.2
FFT/CZT
Carrier
Autosave
Hold top axis
Zoom
Hold bottom ...
Sampling f [kHz]:
48
Record Length [s]:
15
Time Step [ms] for
500
Clipping Amplitude
-60 -20
Zero padding:
0
Recorded: 0 s
2.46 mm gap, 2004−10−12 05:46
Frequency [kHz]
6.1
6.09
6.08
6.07
6.06
6.05
6.04
6.03
0
20
40
60
80
100
Time [s]

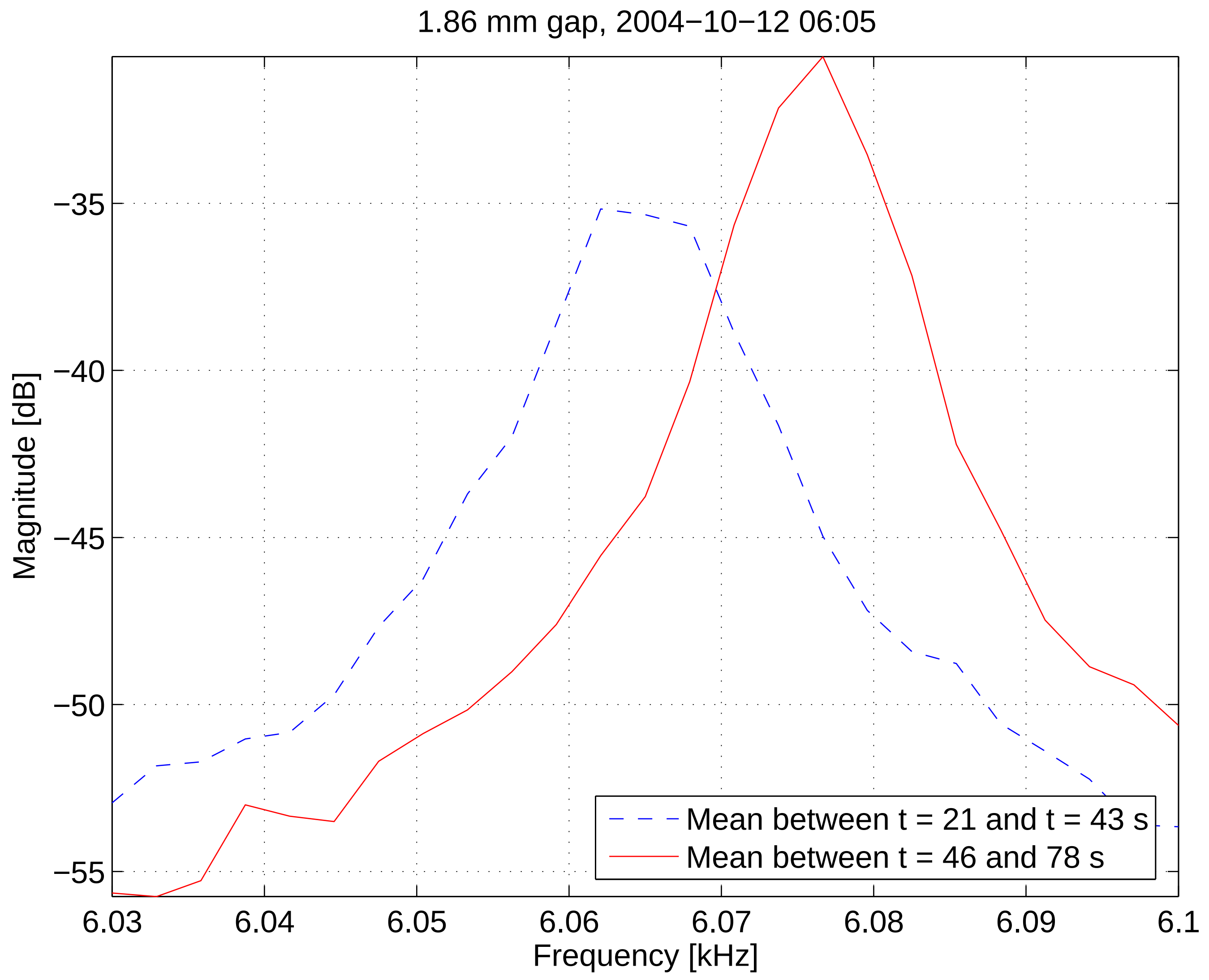

2.46 mm gap, 2004−10−12 05:46
Magnitude [dB]
Frequency [kHz]
−34
−36
−38
−40
−42
−44
−46
−48
−50
−52
−54
6.03
6.04
6.05
6.06
6.07
6.08
6.09
6.1
Mean between t = 3 and t = 25 s
Mean between t = 30 and 48 s

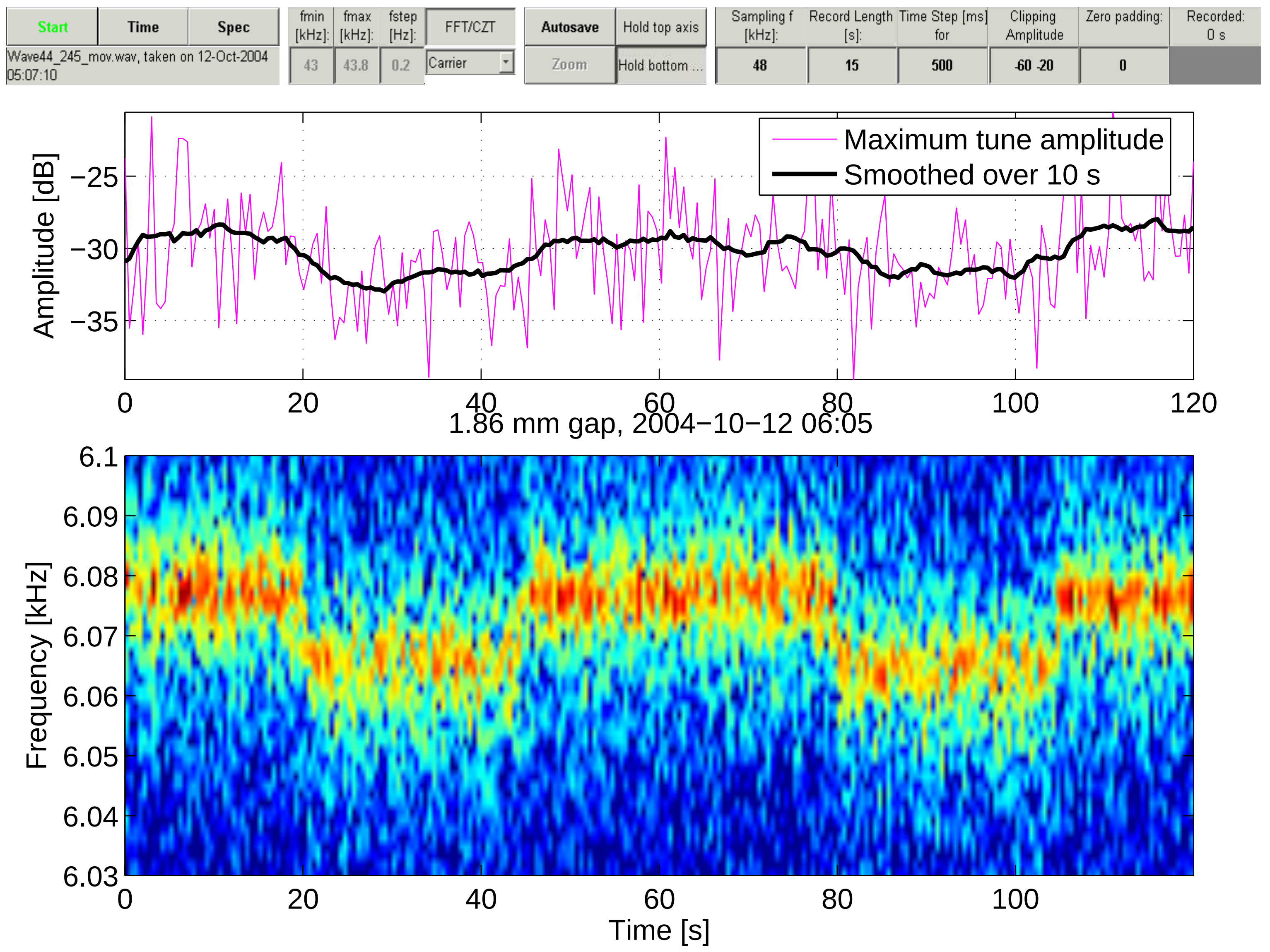


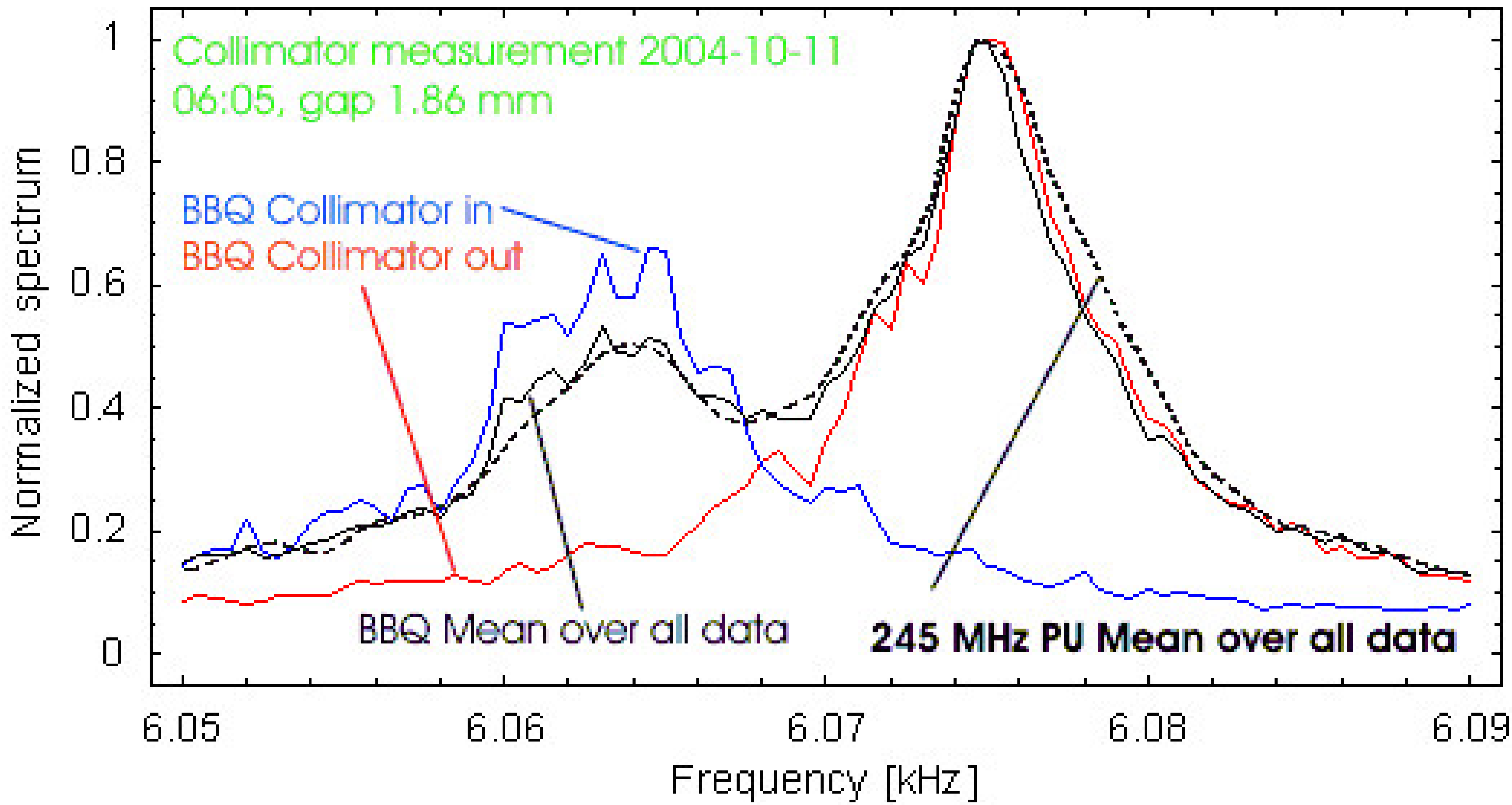
Start
Time
Spec
Wave43_245_mov.wav, taken on 12-Oct-2004 04:57:06
fmin [kHz]:
43
fmax [kHz]:
43.8
fstep [Hz]:
0.2
FFT/CZT
Carrier
Autosave
Zoom
Hold top axis
Hold bottom ...
Sampling f [kHz]:
48
Record Length [s]:
15
Time Step [ms] for
500
Clipping Amplitude
-60 -20
Zero padding:
0
Recorded: 0 s
2.06 mm gap, 2004−10−12 05:53
Frequency [kHz]
6.09
6.08
6.07
6.06
6.05
6.04
6.03
0
20
40
60
80
100
Time [s]


2.06 mm gap, 2004−10−12 05:53
Magnitude [dB]
Frequency [kHz]
−34
−36
−38
−40
−42
−44
−46
−48
−50
−52
−54
6.03
6.04
6.05
6.06
6.07
6.08
6.09
6.1
Mean between t = 10 and t = 32 s
Mean between t = 40 and 59 s


Start
Time
Spec
Wave44_245_mov.wav, taken on 12-Oct-2004 05:07:10
fmin [kHz]:
43
fmax [kHz]:
43.8
fstep [Hz]:
0.2
FFT/CZT
Vertical Cut
Autosave
Zoom
Hold top axis
Hold bottom ...
Sampling f [kHz]:
48
Record Length [s]:
15
Time Step [ms] for
500
Clipping Amplitude
-60 -20
Zero padding:
0
Recorded: 0 s
1.86 mm gap, 2004−10−12 06:05
Frequency [kHz]
6.1
6.09
6.08
6.07
6.06
6.05
6.04
6.03
0
20
40
60
80
100
Time [s]


1.86 mm gap, 2004−10−12 06:05
Magnitude [dB]
−35
−40
−45
−50
−55
6.03
6.04
6.05
6.06
6.07
6.08
6.09
6.1
Frequency [kHz]
Mean between t = 21 and t = 43 s
Mean between t = 46 and 78 s


Start
Time
Spec
fmin [kHz]:
fmax [kHz]:
fstep [Hz]:
FFT/CZT
Autosave
Hold top axis
Sampling f [kHz]:
Record Length [s]:
Time Step [ms] for
Clipping Amplitude
Zero padding:
Recorded: 0 s
Wave44_245_mov.wav, taken on 12-Oct-2004 05:07:10
43
43.8
0.2
Carrier
Zoom
Hold bottom ...
48
15
500
-60 -20
0
Maximum tune amplitude
Smoothed over 10 s
Amplitude [dB]
−25
−30
−35
0
20
40
60
80
100
120
1.86 mm gap, 2004−10−12 06:05
Frequency [kHz]
6.1
6.09
6.08
6.07
6.06
6.05
6.04
6.03
Time [s]


Collimator measurement 2004-10-11
06:05, gap 1.86 mm
BBQ Collimator in
BBQ Collimator out
BBQ Mean over all data
245 MHz PU Mean over all data
Normalized spectrum
0
0.2
0.4
0.6
0.8
1
6.05
6.06
6.07
6.08
6.09
Frequency [kHz]