Application of bi-spectral techniques to Virgo Data

G. Vedovato

Padova Trento Group

Summary

- When & Why ?
- What is the Bicoherence ?
- The Bicoherence Tool
- The Virgo Data Set
- The Virgo Bicoherence
- Next Steps

When & Why

- When : non Gaussian noise, non-linear response… , non stationary noise…
- Why : because of bilinear couplings of noise sources / signal disturbances.
- Consider a physical process, which puts out the value of the product of two signals at two different frequencies

$$s_1 = a_1 \sin(2\pi f_1 t + \phi_1) \qquad s_2 = a_2 \sin(2\pi f_2 t + \phi_2)$$

- The output signal will then be

$$S = s_1 + s_2 + k\, s_1 s_2$$

- where **k** is a coupling factor which in general could be frequency dependent. As we can expect, there will be two additional frequencies at $f_1 - f_2$, $f_1 + f_2$

What is the bicoherence ?

- The bicoherence is a normalized form of the bispectrum :

$$S_{3x}(f_1, f_2) = \left\langle \tilde{X}(f_1)\, \tilde{X}(f_2)\, \tilde{X}^*(f_1 + f_2) \right\rangle$$

- and is defined as

$$b(f_1, f_2) = \frac{S_{3x}(f_1, f_2)}{\sqrt{S_{xx}(f_1) S_{xx}(f_2) S_{xx}(f_1 + f_2)}}$$

- where X_k , X_l *and* X_m are the Fourier components of the signal at the frequencies ***k***, ***l*** and ***m=l+k***, If the signal at ***m=l+k*** arises due to the product of the signal at ***k*** and ***l***, then for the phase of the numerator

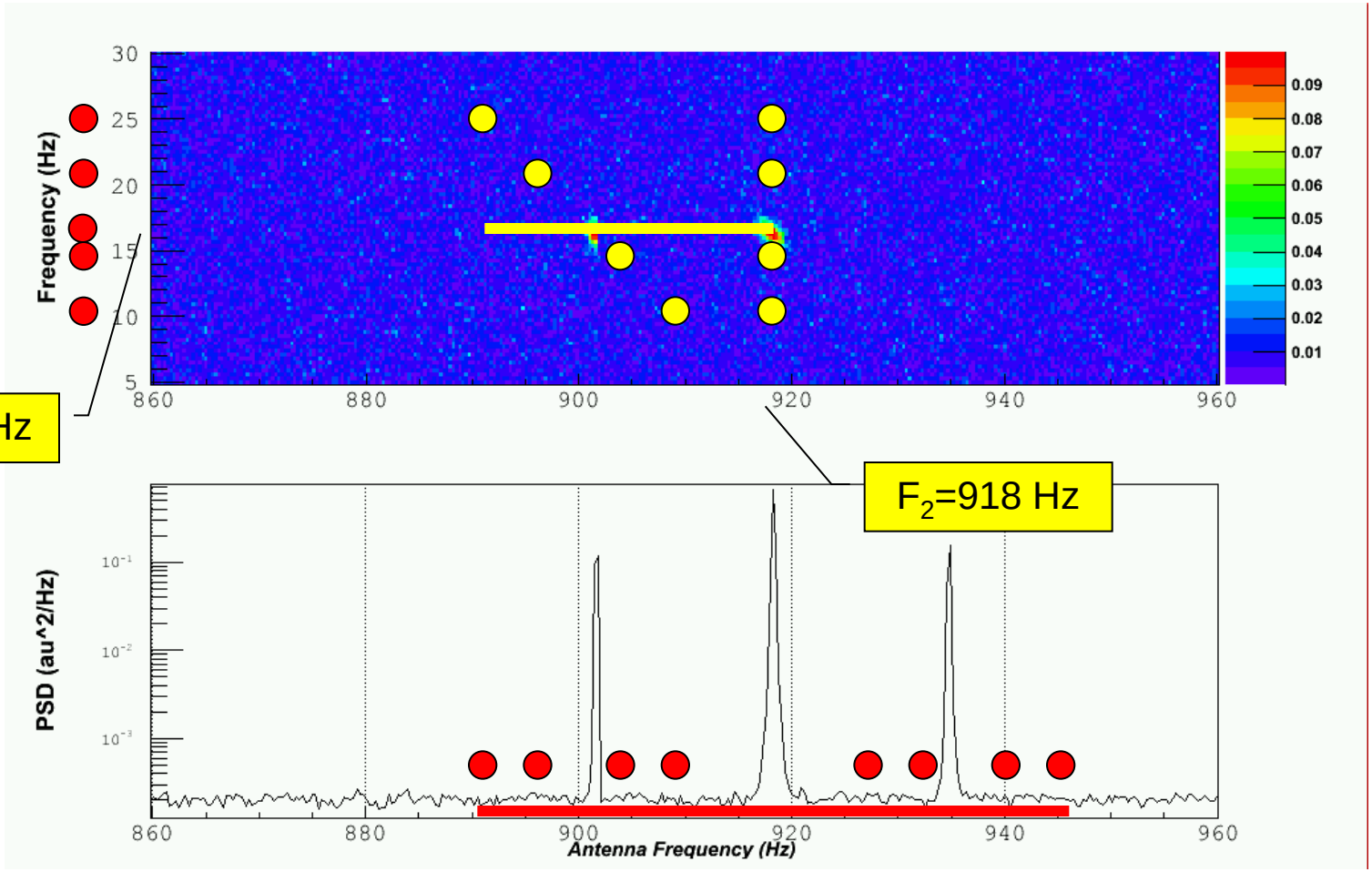
$$e^{i\phi_1} e^{i\phi_2} e^{-i(\phi_1+\phi_2)}$$

will average out to a nonzero value and hence the bispectrum will be nonzero

Example

F_1=16.5 Hz, F_2=918 Hz

F_2-F_1=901.5 Hz, F_2+F_1=934.5 Hz



The Bicoherence Tool

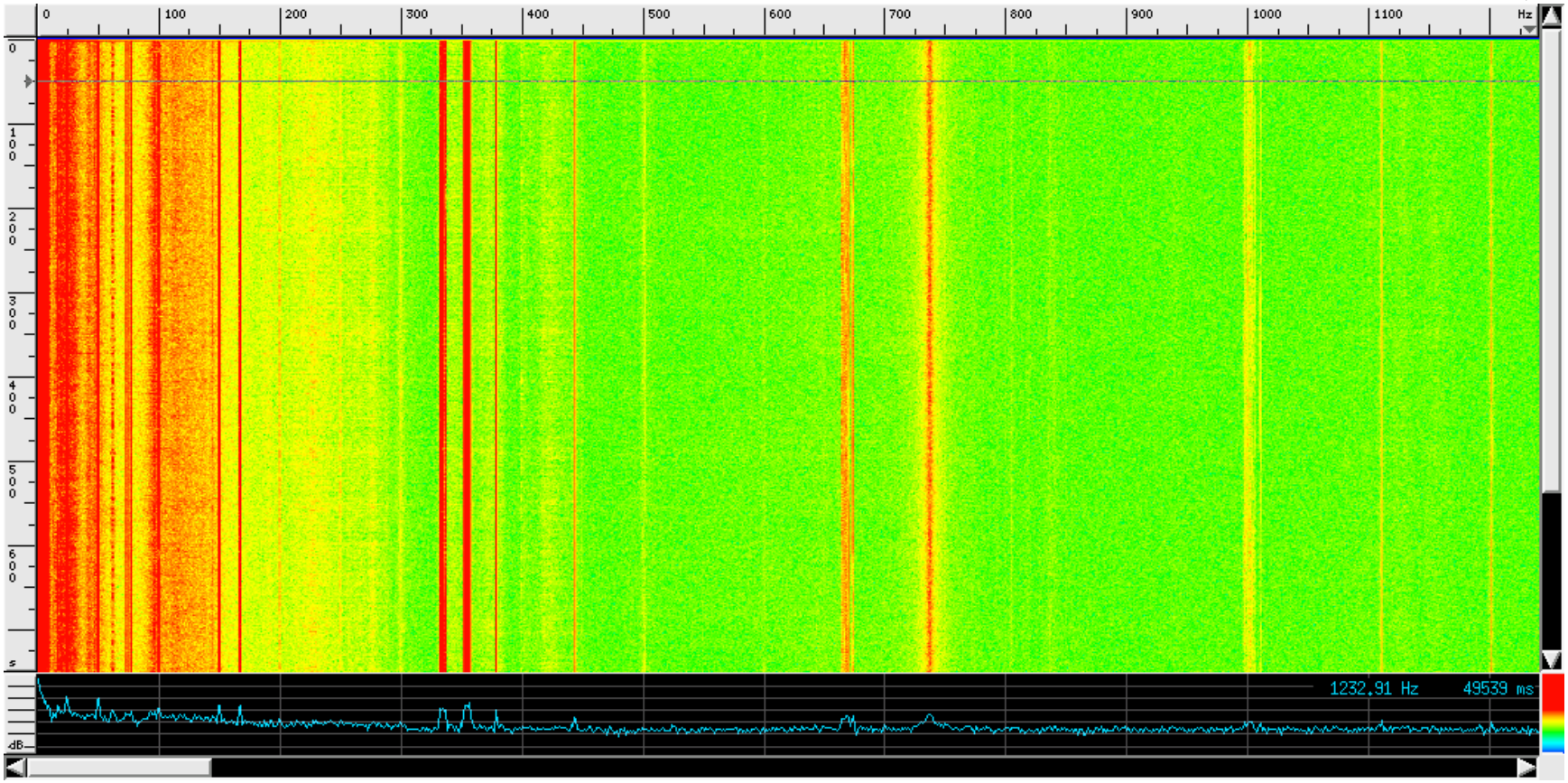
- Our bicoherence tool is embedded in the AURIGA Data Analysis, which works in the ROOT framework, reads frame format data files, includes some LAL libraries…
- It has been extremely useful in AURIGA to identify the “bad” low frequency resonances to design the additional suspension stage
- The analysis reported in this talk has been implemented with a ROOT macro
- Performances : Intel Xeon CPU 3.4GHz
  - Sample Rate : 20KHz
  - Analyzed Frequency Area : 5Hz x 50Hz
  - Frequency Resolution : 0.03125 Hz
  - # average : 250
  - Speed : 44x (8000 sec of data analyzed in 186 sec)

Virgo Data Set

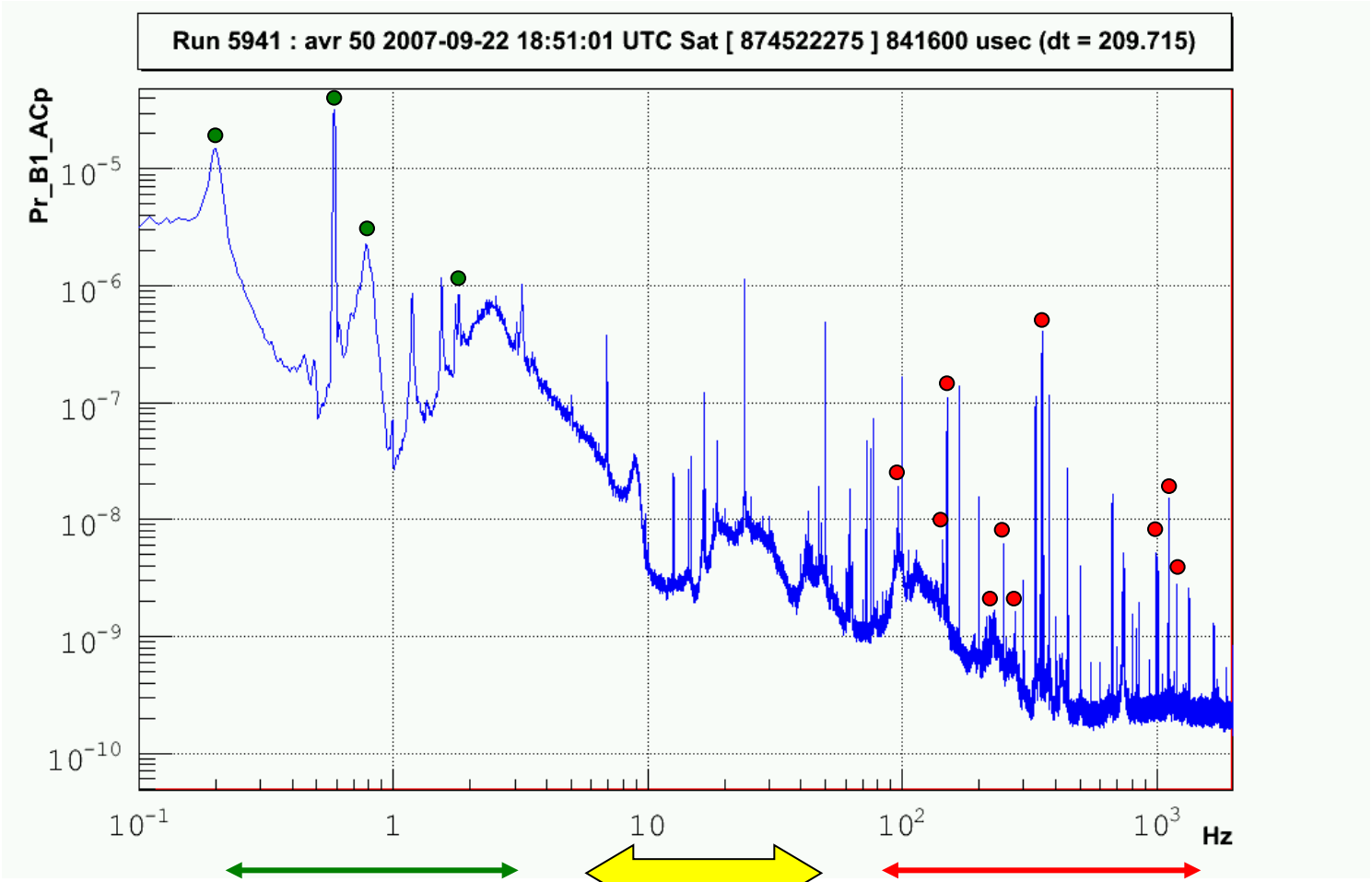
Run 5941 : Channel : V1:Pr_B1_ACp : 2007-09-22 17:00:00

Frequency : 0-1250 Hz

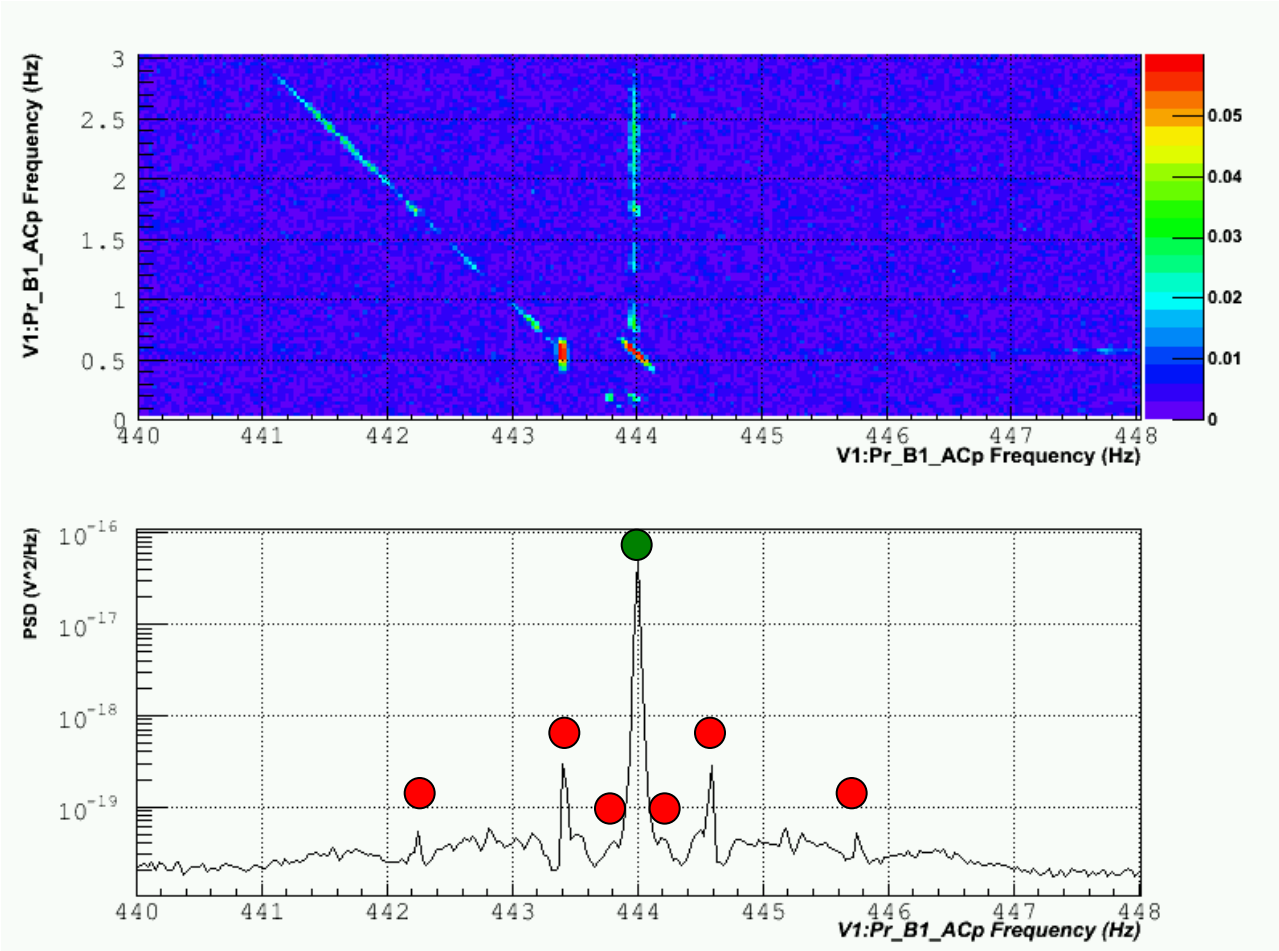
Time : 0-700 sec



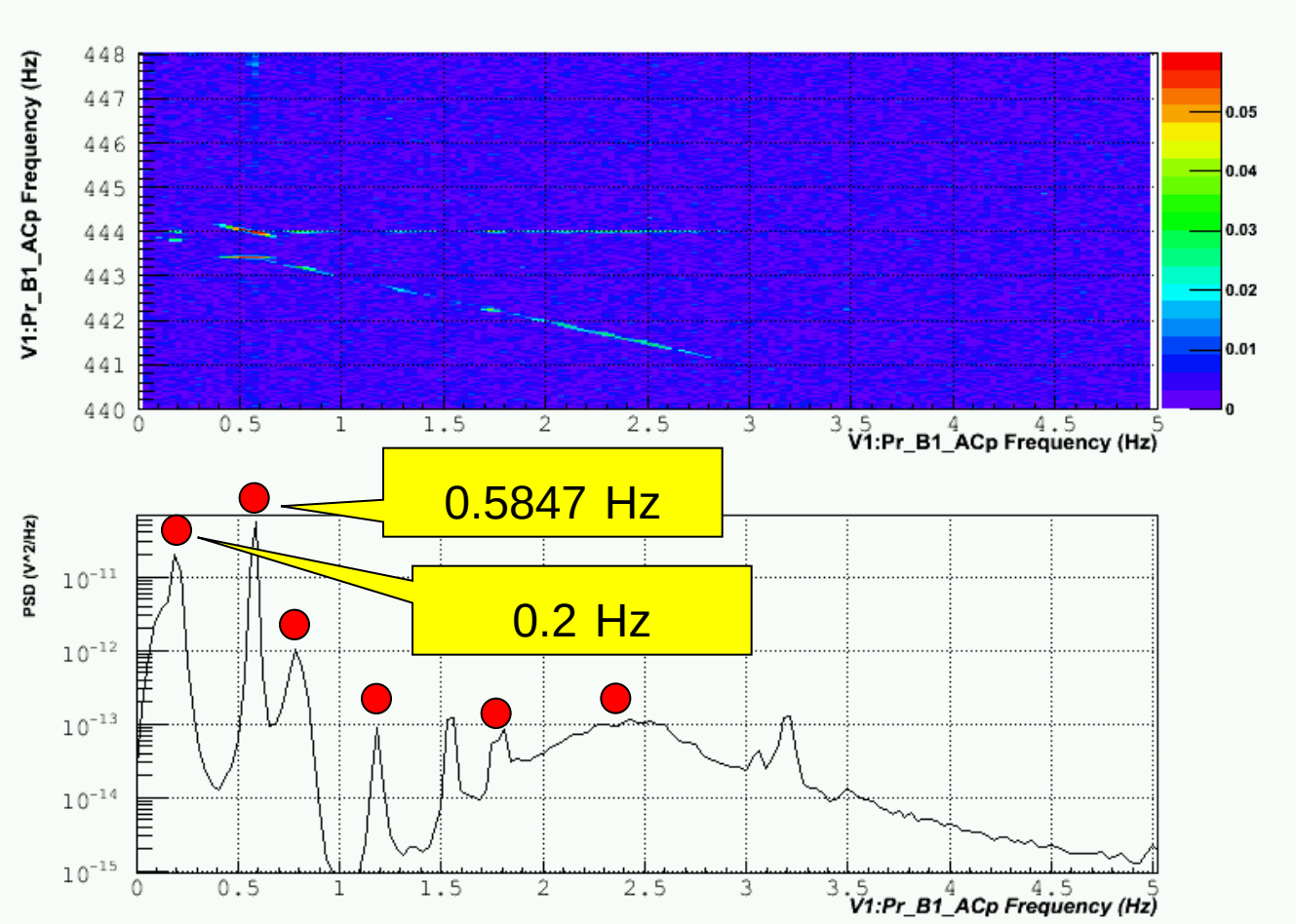
Bilinear Coupling in Virgo



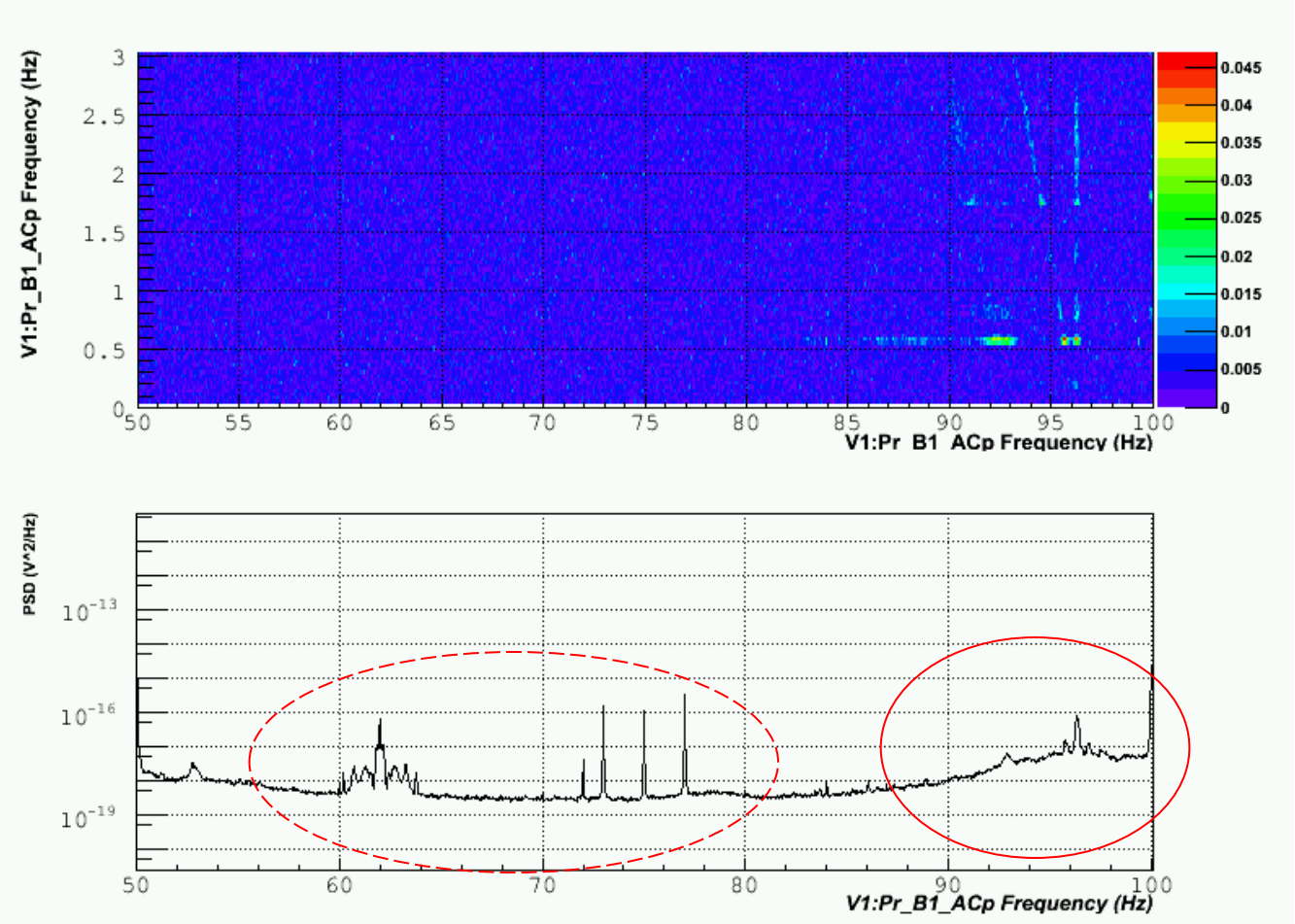
Bicoherence @ 444 Hz



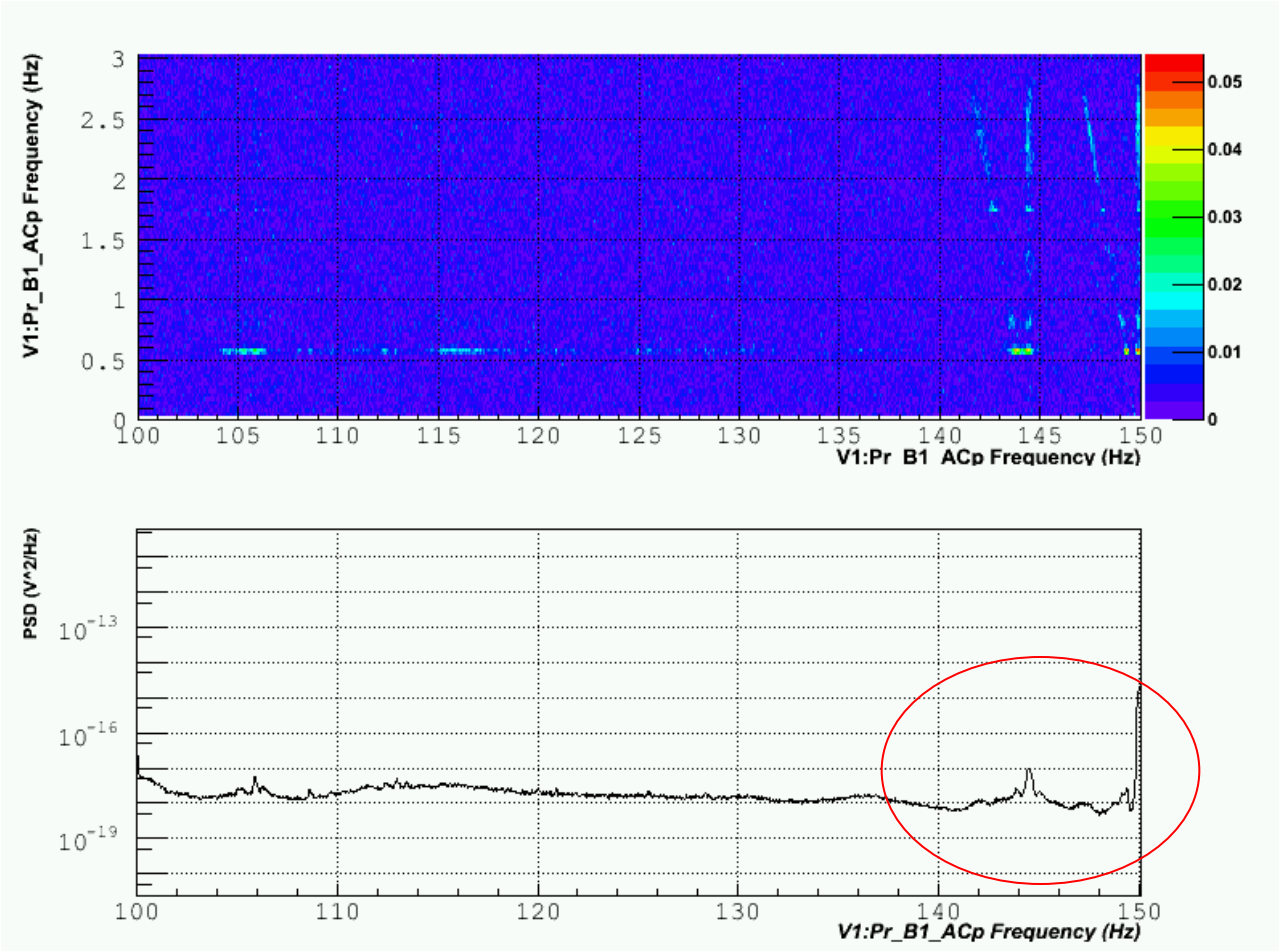
Bicoherence @ 444 Hz



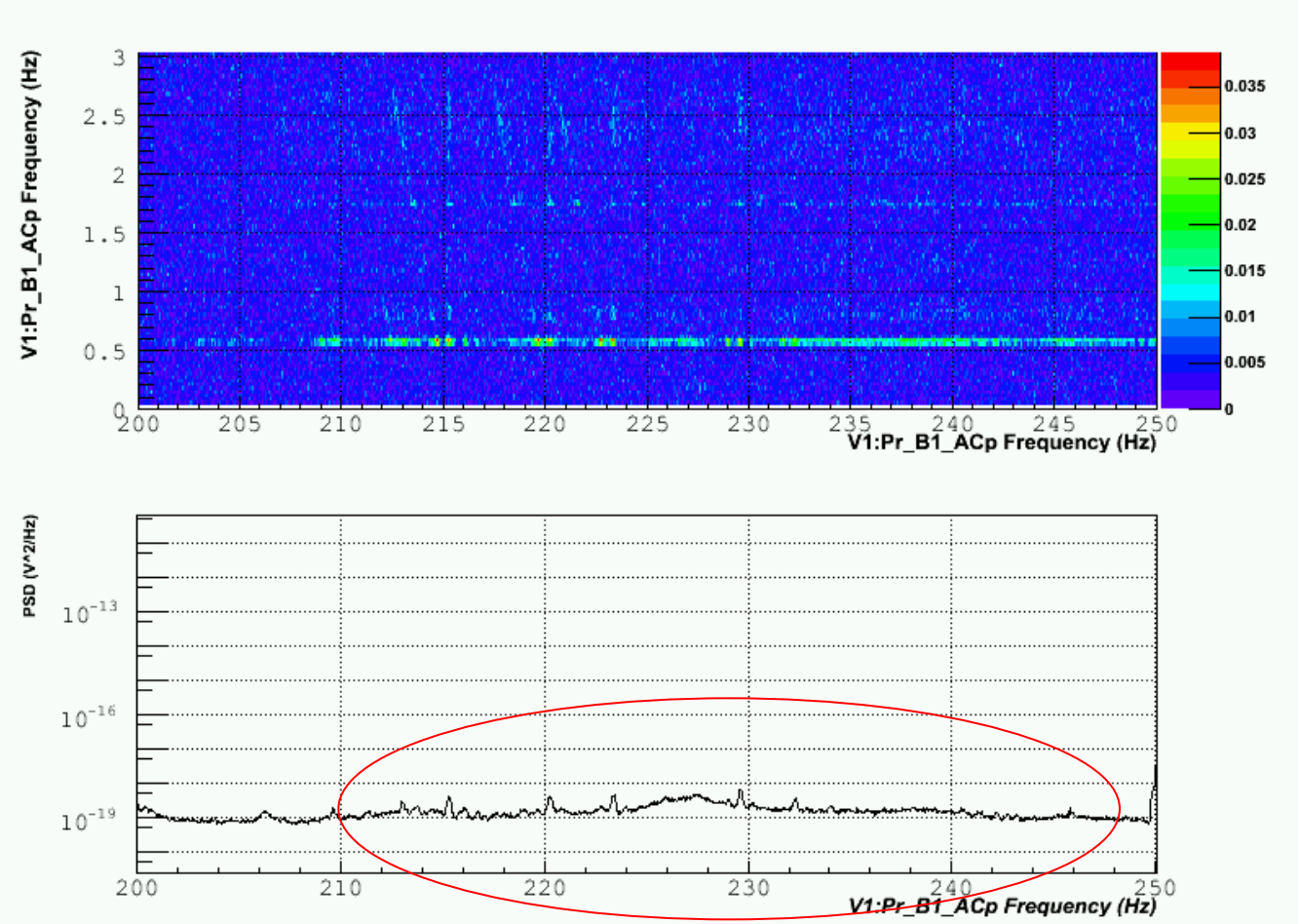
Bicoherence @ 50-100 Hz x 0-3 Hz



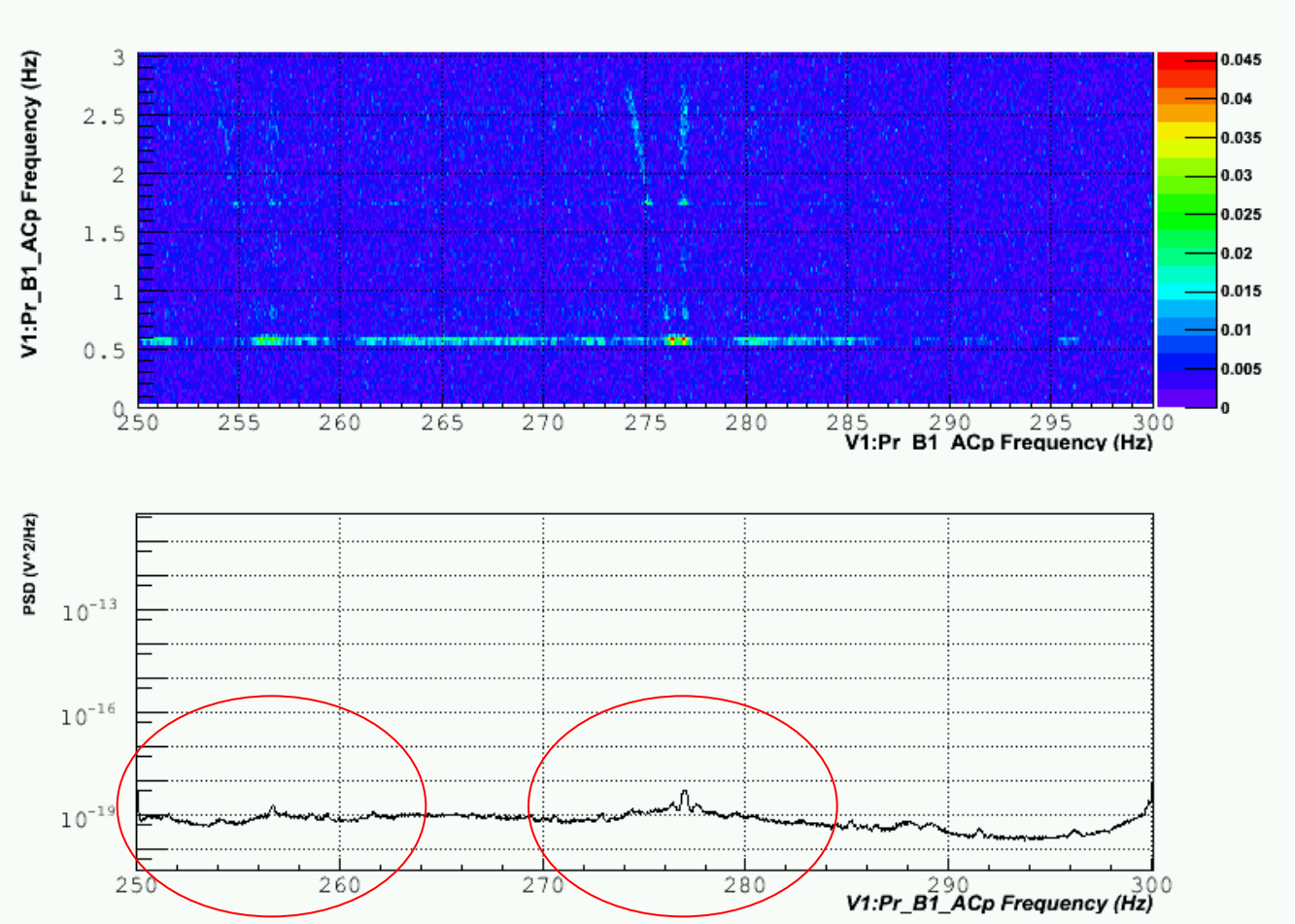
Bicoherence @ 100-150 Hz x 0-3 Hz



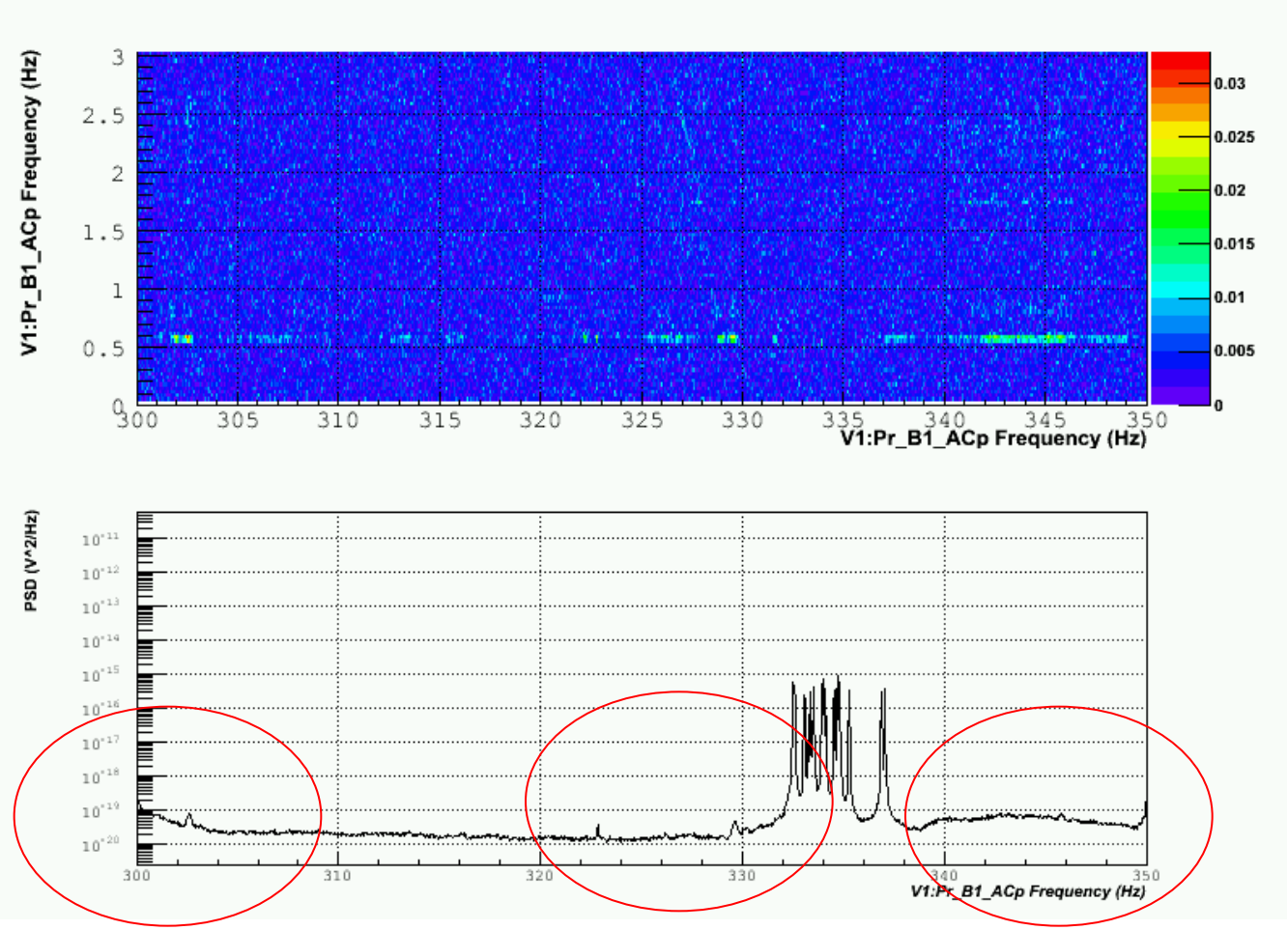
Bicoherence @ 200-250 Hz x 0-3 Hz



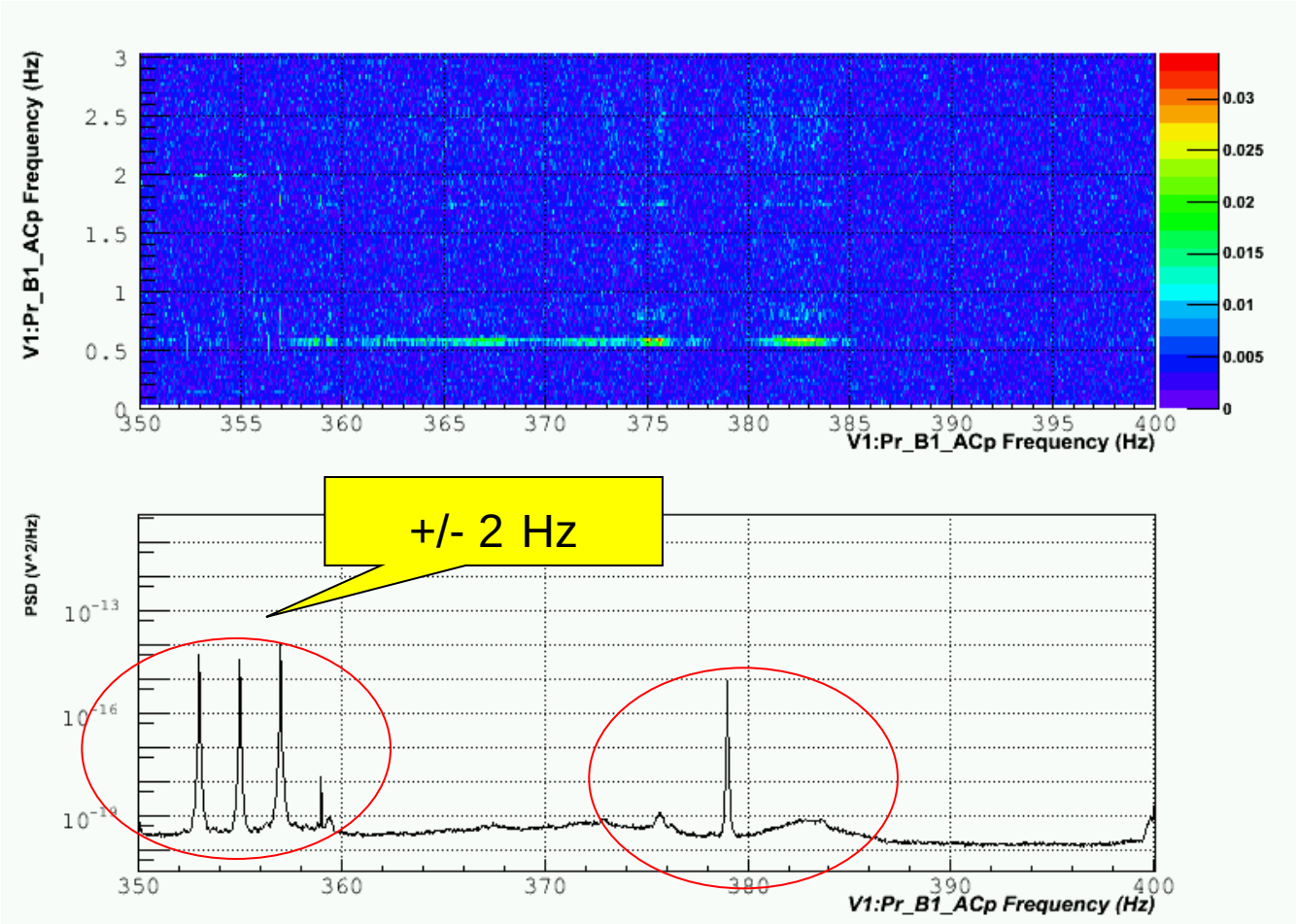
Bicoherence @ 250-300 Hz x 0-3 Hz



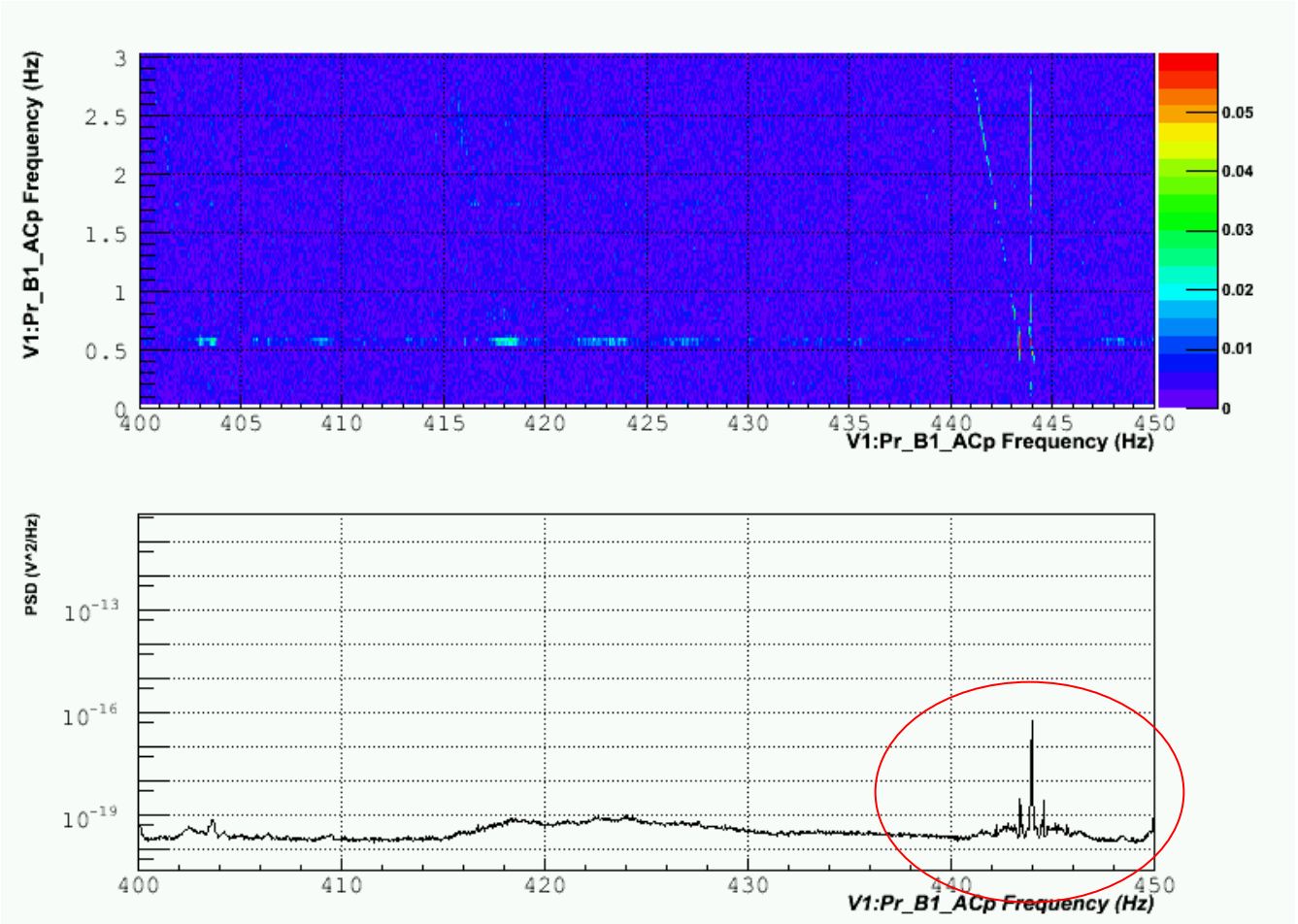
Bicoherence @ 300-350 Hz x 0-3 Hz



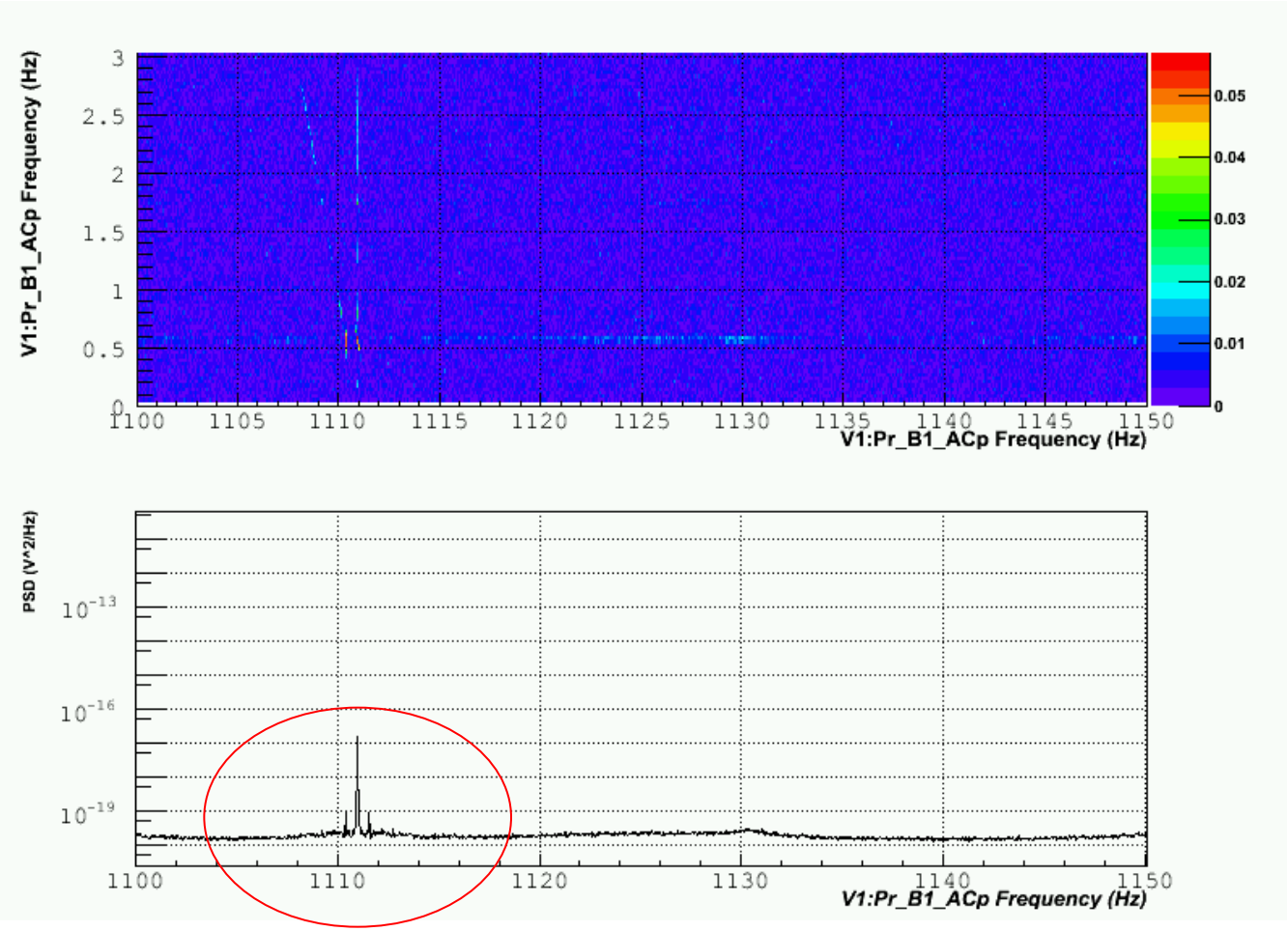
Bicoherence @ 350-400 Hz x 0-3 Hz



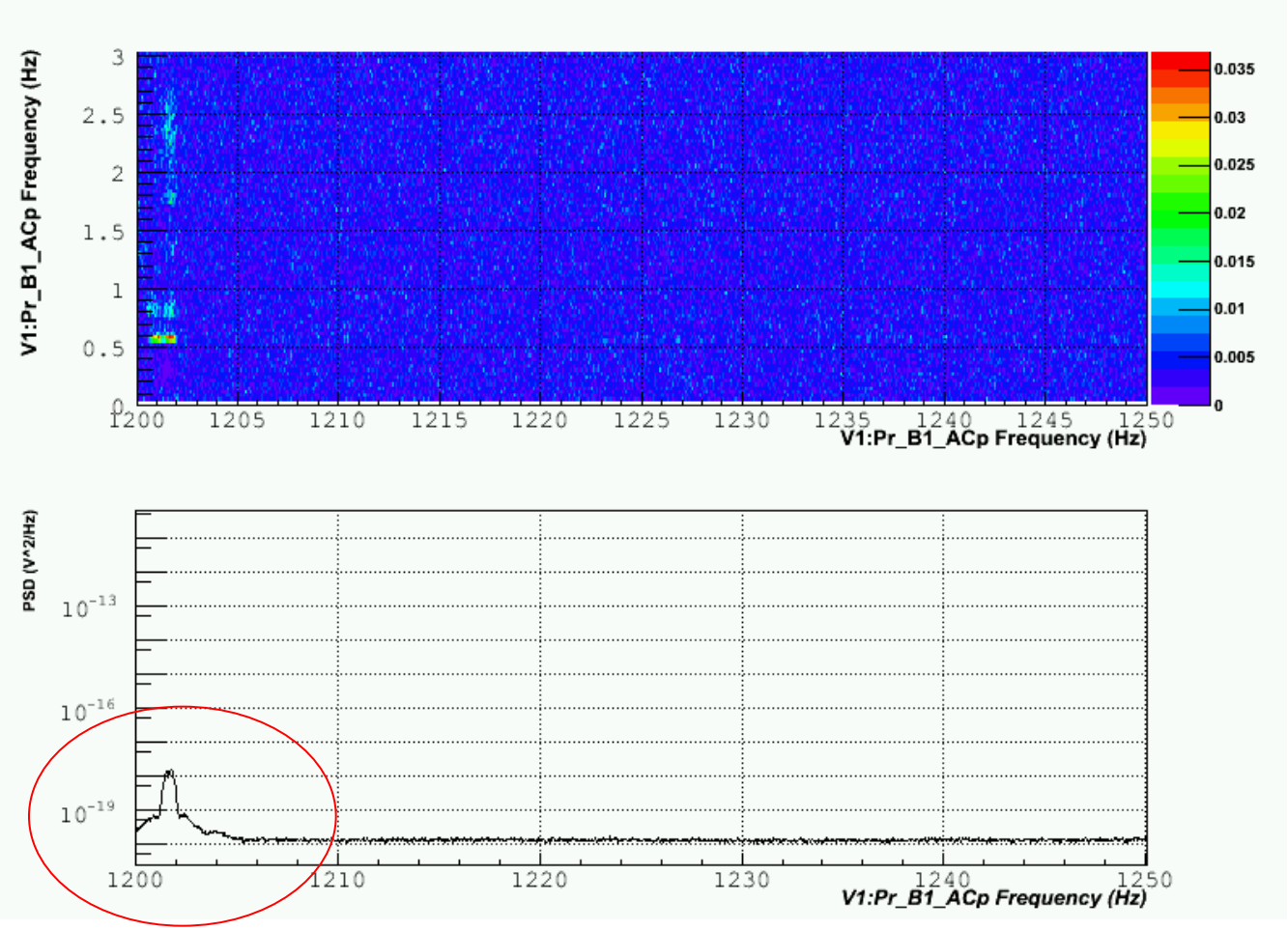
Bicoherence @ 400-450 Hz x 0-3 Hz



Bicoherence @ 1000-1150 Hz x 0-3 Hz



Bicoherence @ 1200-1250 Hz x 0-3 Hz



Next Steps

- Feedback from HW Virgo peoples
- Analysis of data set with different setup
  - Comparisons could highlight the origin of the non linearities
- Implementation of an offline tool under ROOT framework (? if useful)