INITIAL RESULTS FROM THE LHC MULTI-BAND INSTABILITY MONITOR

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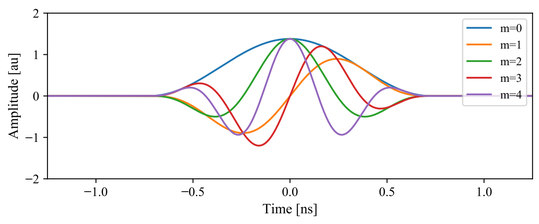
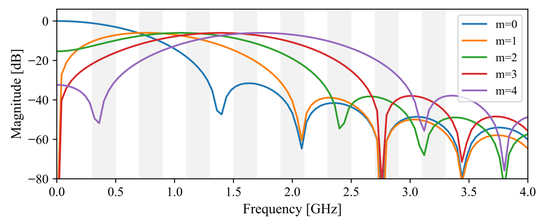
ABSTRACT

Intra-bunch transverse instabilities are routinely measured in the LHC using a "Head-Tail Monitor" based on sampling a wide-band BPM with a high-speed digitiser. However, these measurements are limited by the dynamic range and short record length possible with typical commercial oscilloscopes. This paper will present the initial results from the LHC Multi-Band Instability Monitor, a new technique developed to provide information on the beam stability with a high dynamic range using frequency domain analysis of the transverse beam spectrum.

CONCEPT

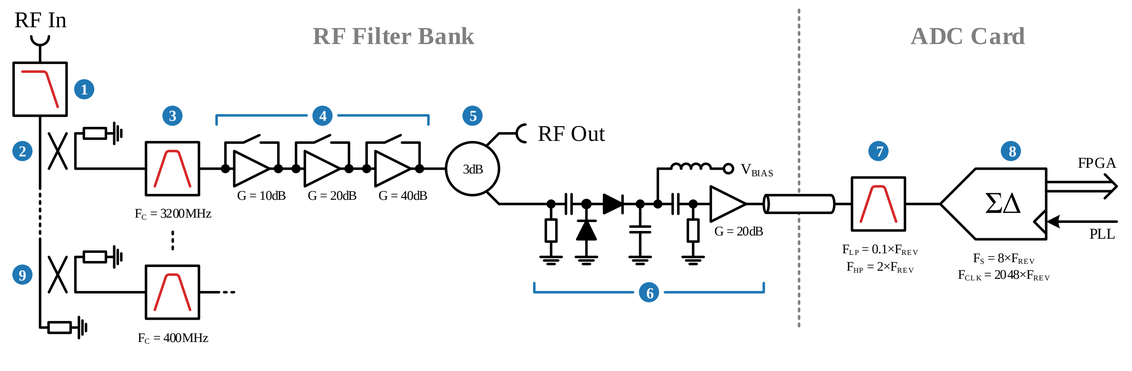
- LHC instability diagnostics limited by dynamic range of high speed digitisers
- As instability mode increases, a shift in spectral power to higher frequencies is expected
- Can measure this shift by sampling different frequency bands and acquiring in parallel
- Each band has limited bandwidth so can be sampled at a higher resolution than the full signal





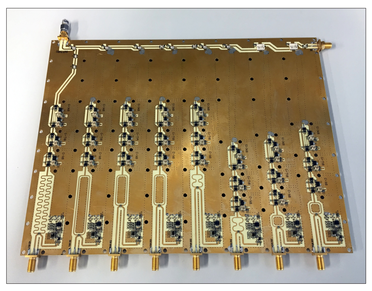
MIM RF FRONT-END

- RF band-pass filter bank selects eight frequency components from 400 MHz to 3.2 GHz
- Detection with high-sensitivity diode detectors, similar to those employed in BBQ system
- Sampled with high-resolution 24-bit ADCs

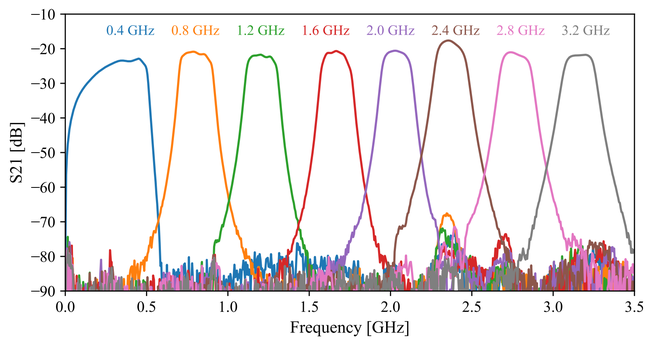


❶ Image suppression low-pass
❷ Directional coupler (first band)
❸ RF band-pass filter
❹ RF programmable gain amplifier
❺ 3 dB Wilkinson divider
❻ Diode detector
❼ Baseband filter
❽ 24-bit ADC
❾ Directional coupler (last band)

Filter bank PCB



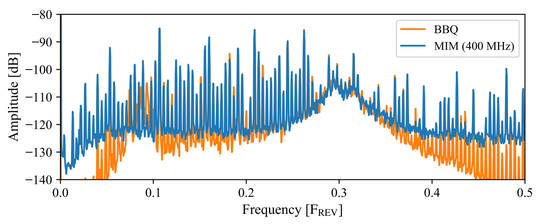
Measured response of each band

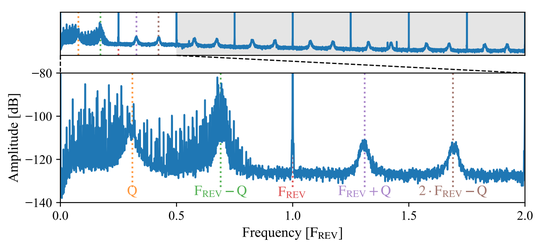


MIM ACQUISITION SYSTEM

- Stand alone 2U chassis
- Two RF front-ends per chassis
- Sixteen 24-bit 4 MSPS ADC channels
- PLL generates 2048×F_{REV} ADC clock from beam-synchronous 3564×F_{REV} clock
- Xilinx Zynq 7030 FPGA
- Integrated ARM processor running Linux allows control and acquisition over Ethernet

RESULTS - TUNE MEASUREMENTS



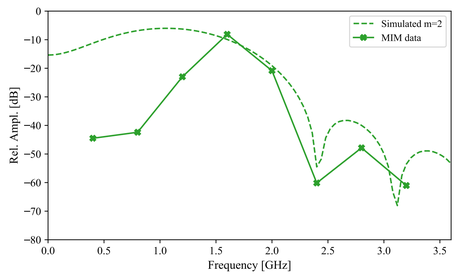


- Comparison with BBQ shows similar sensitivity for full machine
- 50 Hz lines seen on the BBQ also seen on MIM with similar amplitudes
- Cause of these lines not understood and currently being investigated
- MIM has higher sampling rate and wider input bandwidth than BBQ
- Looking at extended spectrum confirms that these lines are limited to base-band
- Above 8 kHz the spectrum much cleaner
- Possibility to modify BBQ system to look at F_{REV} + Q being studied

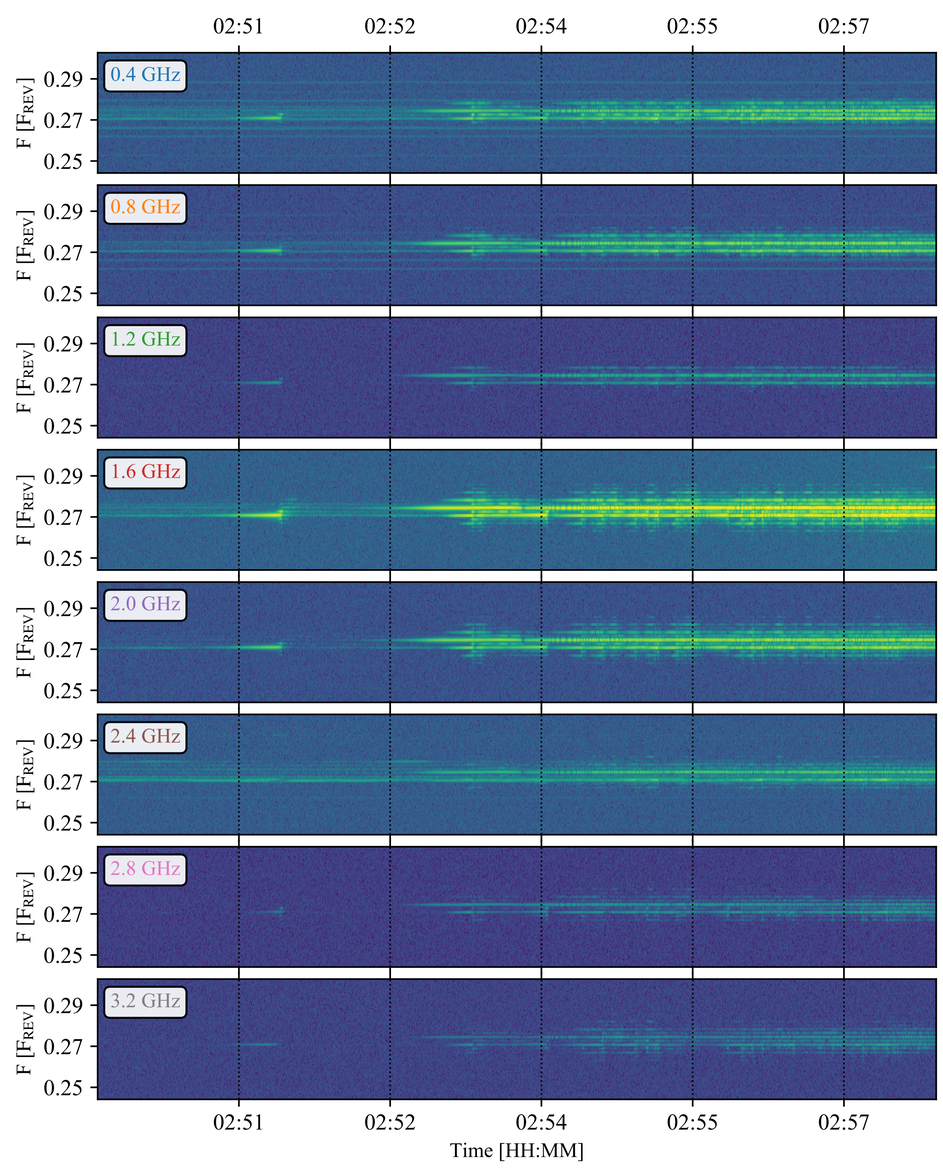
RESULTS - INSTABILITY MEASUREMENTS

- Instabilities recorded during a machine development session on 3rd December 2017
- At flat-top energy the octupole strength was lowered until bunches became unstable
- At 02:51 one bunch becomes unstable, seen as m=2 by the Head-Tail Monitor
- Clear signature recorded by the MIM and reconstruction matches prediction for m=2
- After 02:52 many bunches become unstable, change in F_{REV} peak amplitude indicates bunch shape distortion

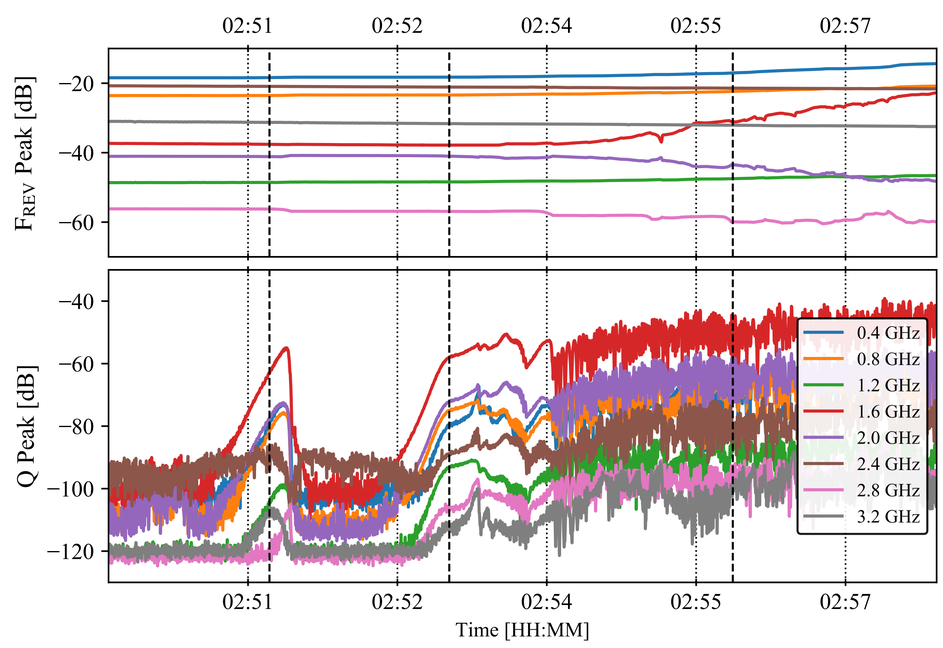
Reconstructed spectrum from MIM



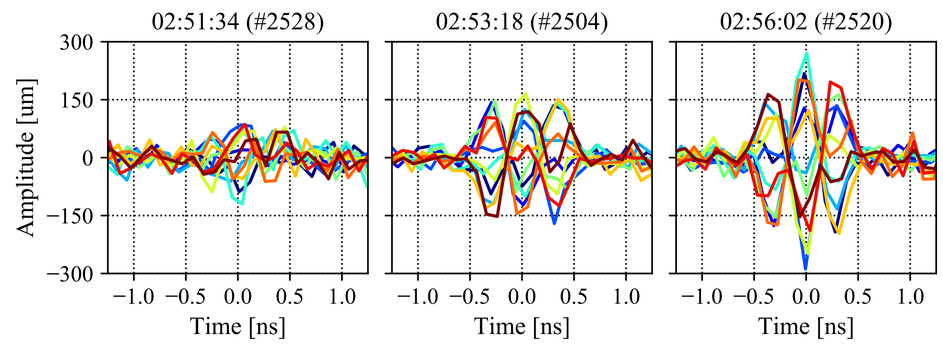
MIM Band Spectrograms



F_{REV} and Tune Peak Amplitudes



Head-Tail Measurements



CONCLUSION

- New monitor developed for the LHC, measuring beam spectrum in bands from 0.4 to 3.2 GHz
- Sensitivity for tune measurements with a full machine shown to be similar to the BBQ
- Initial results taken during machine development sessions show clear signatures of intra bunch motion and higher sensitivity than the Head-Tail Monitors
- Future work to focus on developing a system for real-time identification of the mode for instabilities that occur during normal machine operation

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