Measurements to Characterise Stray Magnetic Fields for CLIC

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Contents

Stray Field Sources

Stray Field Sources

- Natural sources:
  - Stray fields from non-man-made objects.

- Stray fields from man-made objects:
  - Environmental sources:
    - Equipment in the vicinity of CLIC, but not an element of CLIC.
  - Technical sources:
    - Elements of CLIC.

Natural Sources

- E.g. geomagnetic storms, lightning, etc.
  - B. Heilig, et al., “Natural sources of geomagnetic field variations”. http://cds.cern.ch/record/2643499.
- Typically have low frequencies (< 1 Hz).
  - Mitigated effectively with a beam-based feedback.
- Natural sources above 1 Hz:

Phenomenon	**Typical Amplitude**	**Frequency Range**	**Typical Occurrence**
Schumann Resonances	3 pT	Hz	Continuous
Ionospheric Alfven Resonator	1 pT	Hz	> 1 per week
Pc1 Pulsations	0.1 nT	Hz	< 1 per year
‘Regional’ Lightning (<1000 km)	0.25 nT	Hz-MHz	Daily
‘Local’ Lightning (<10 km)	1 nT	Hz-MHz	> 1 per month

Natural Sources

- E.g. geomagnetic storms, lightning, etc.
  - B. Heilig, et al., “Natural sources of geomagnetic field variations”. http://cds.cern.ch/record/2643499.
- Typically have low frequencies (< 1 Hz).
  - Mitigated effectively with a beam-based feedback.

- Should not pose a danger to CLIC.

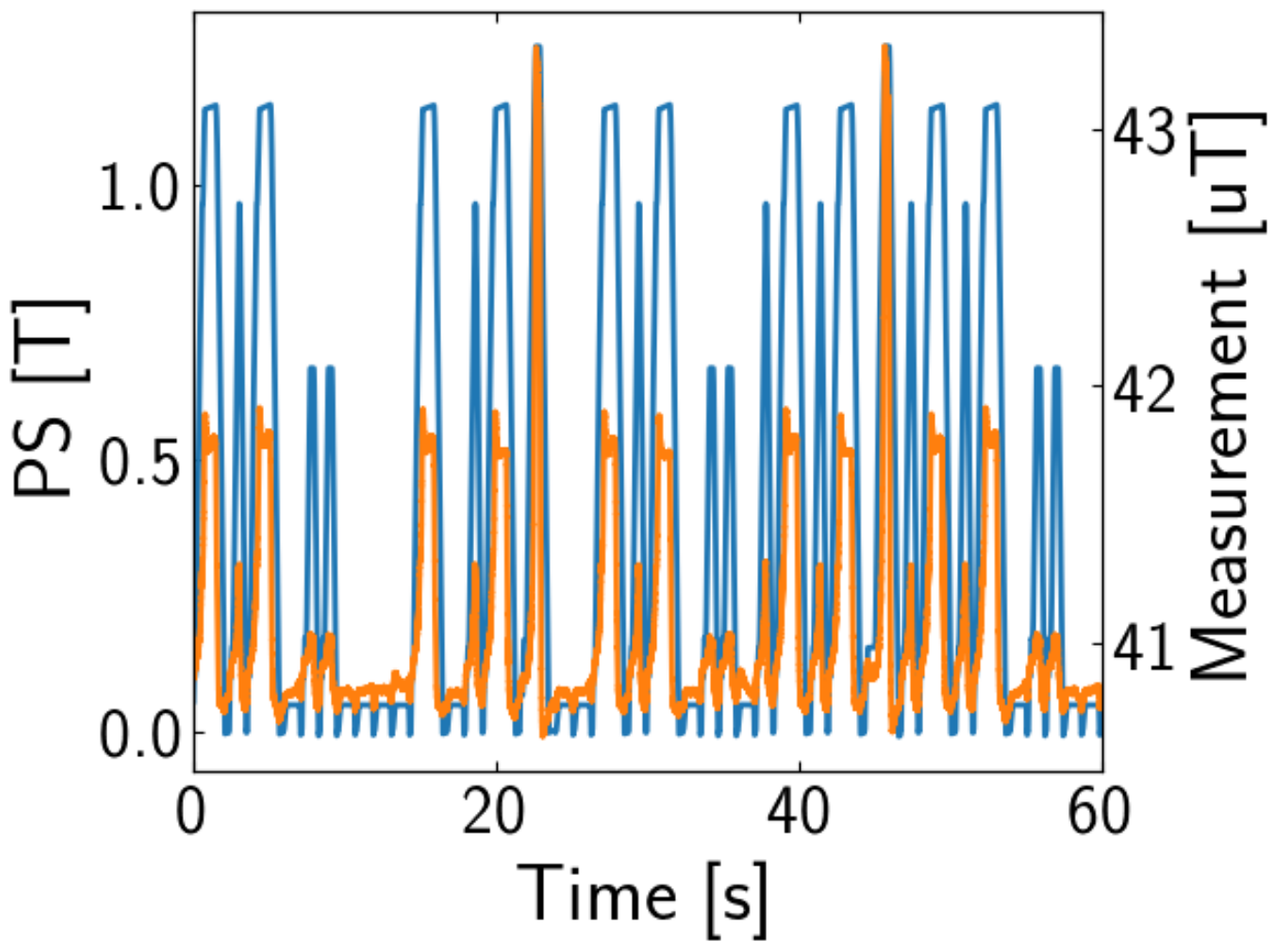
Environmental Sources

- Electrical grid:
  - Largest contribution in most measurements.
  - At 50 Hz, 100 Hz, 150 Hz, etc.

- Repetition frequency of the CLIC beam is 50 Hz.
  - 50 Hz, 100 Hz, 150 Hz, etc. appear static to the beam.

Environmental Sources

- Other running accelerators:
  - The Proton Synchrotron:

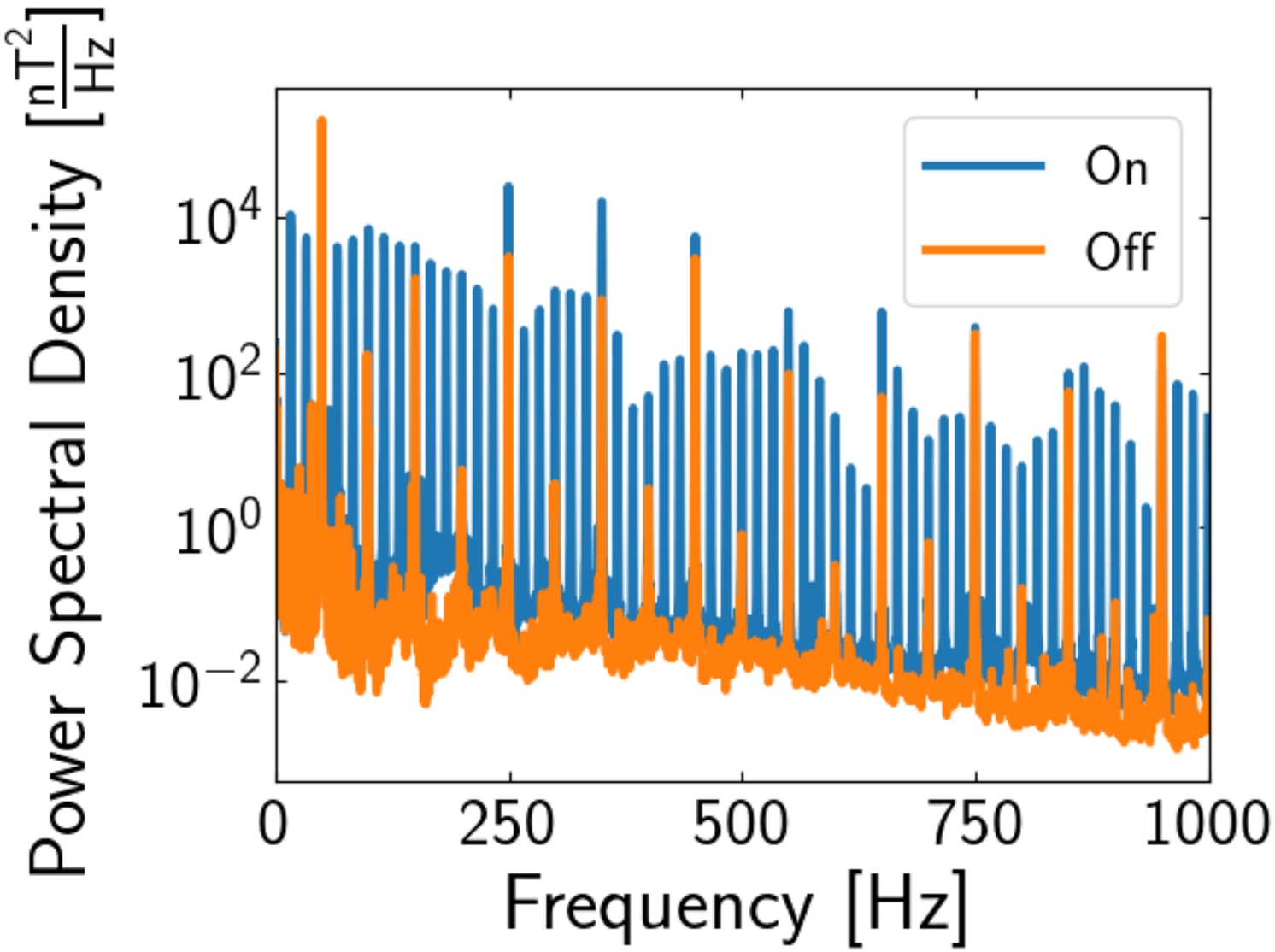


Technical Sources

- Technical sources include:
  - RF systems
  - Magnets
  - Power supplies
  - Cables
  - Vacuum pumps, motors, fans, etc.

Technical Sources

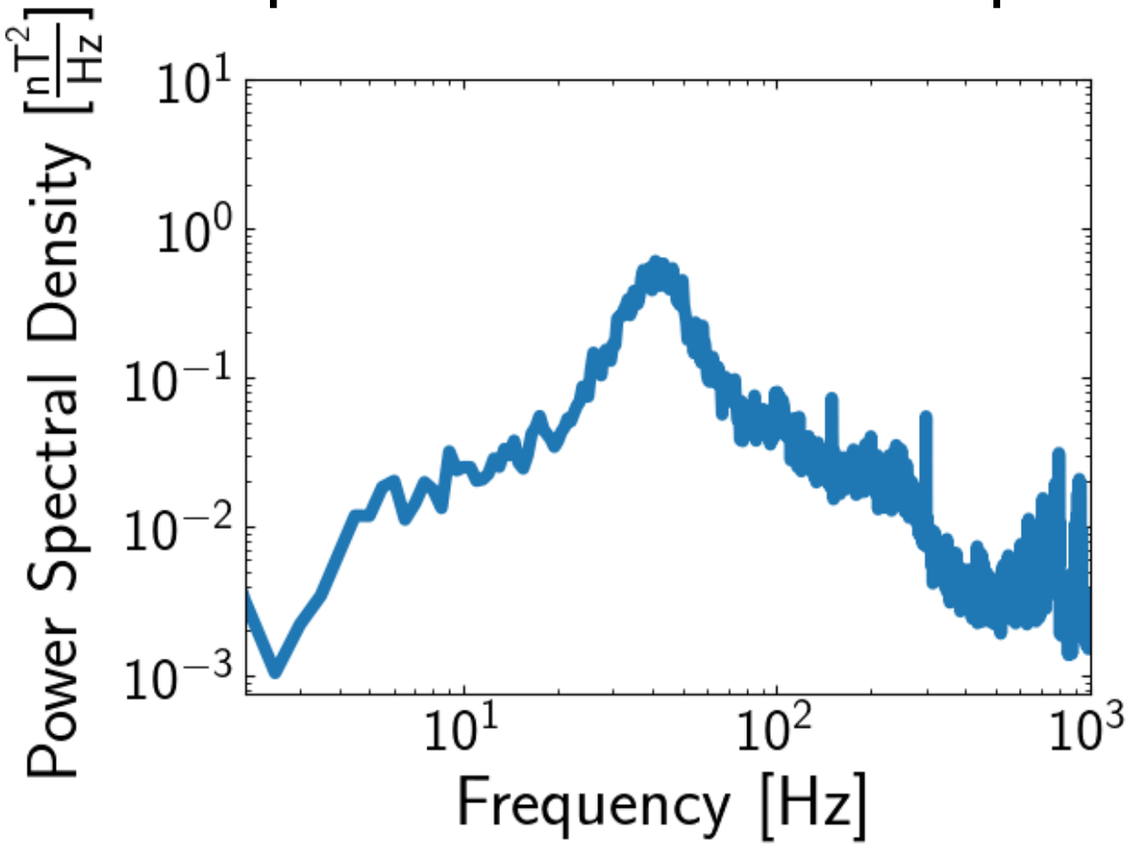
- RF systems:
  - XBOX3 test stand:

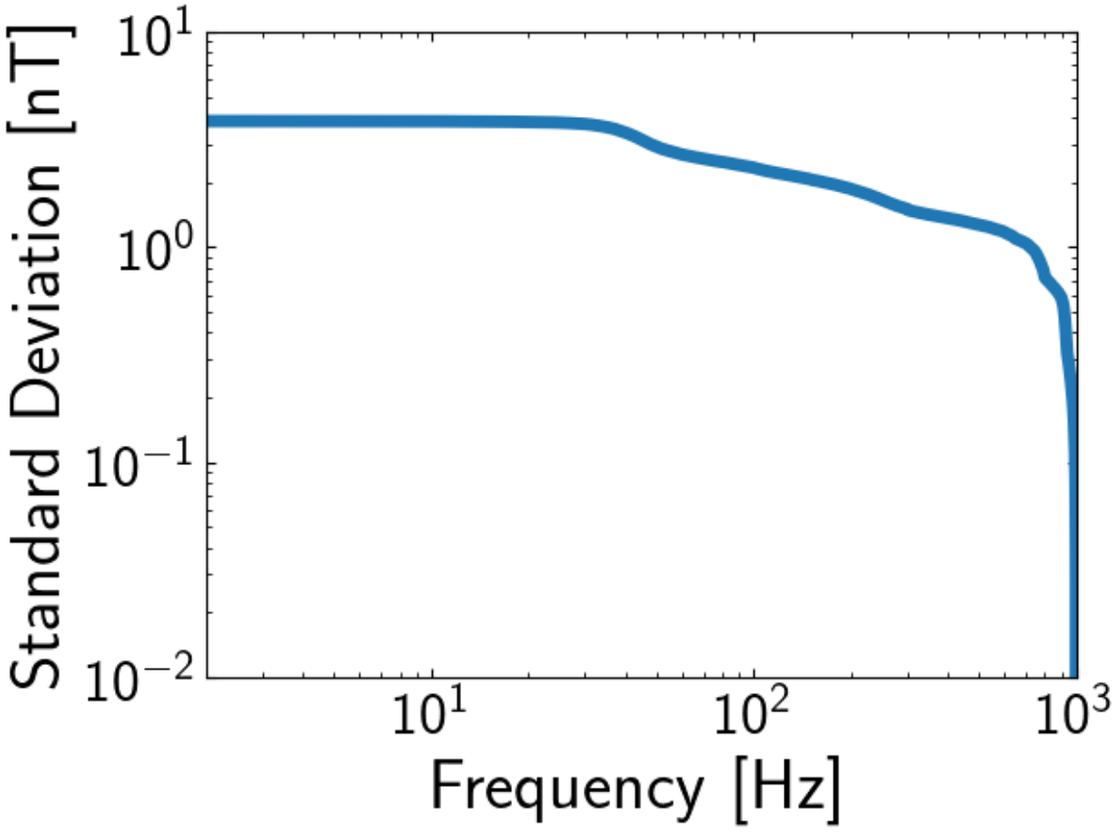


- Klystron repetition rate was set to 16.7 Hz.
- Stray fields are from recharging of modulators.
- Will be at 50 Hz in CLIC.
  - Won't affect the beam.

Technical Sources

- Magnets:
  - Fringe field of a CLIC quadrupole magnet was measured.
  - Specification for ML quadrupoles is $\Delta B/B = 10^{-4}$.

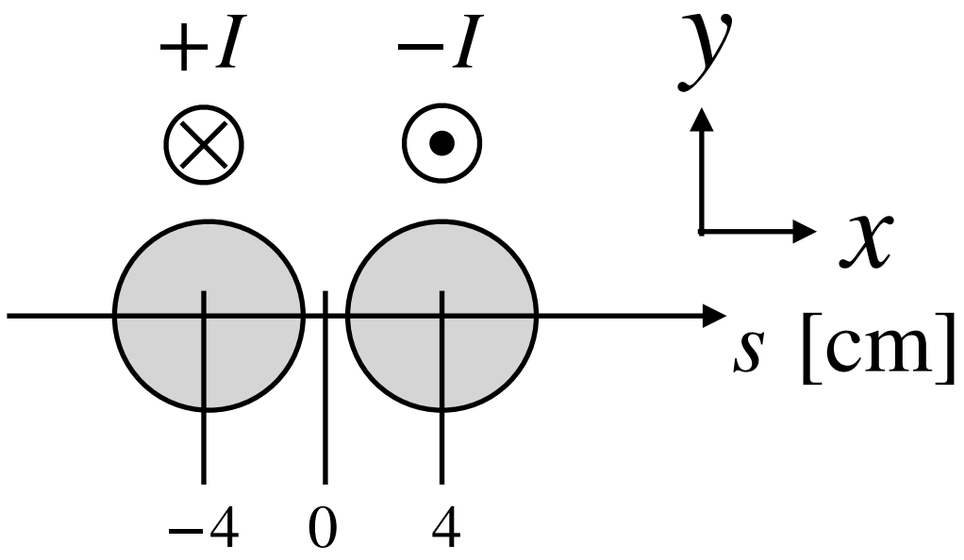


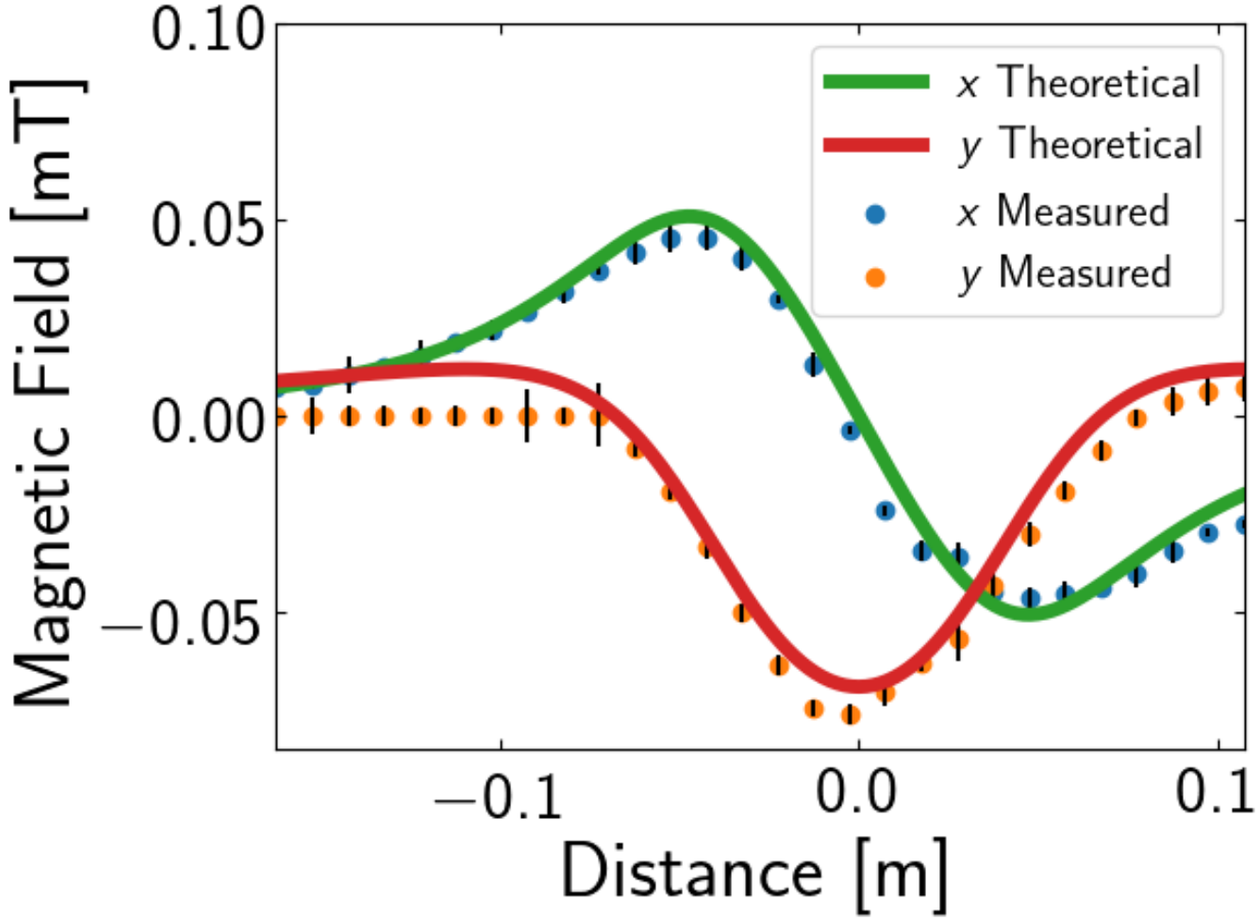


- Measured ripple: $\Delta B/B = 1.07 \times 10^{-4}$.

Technical Sources

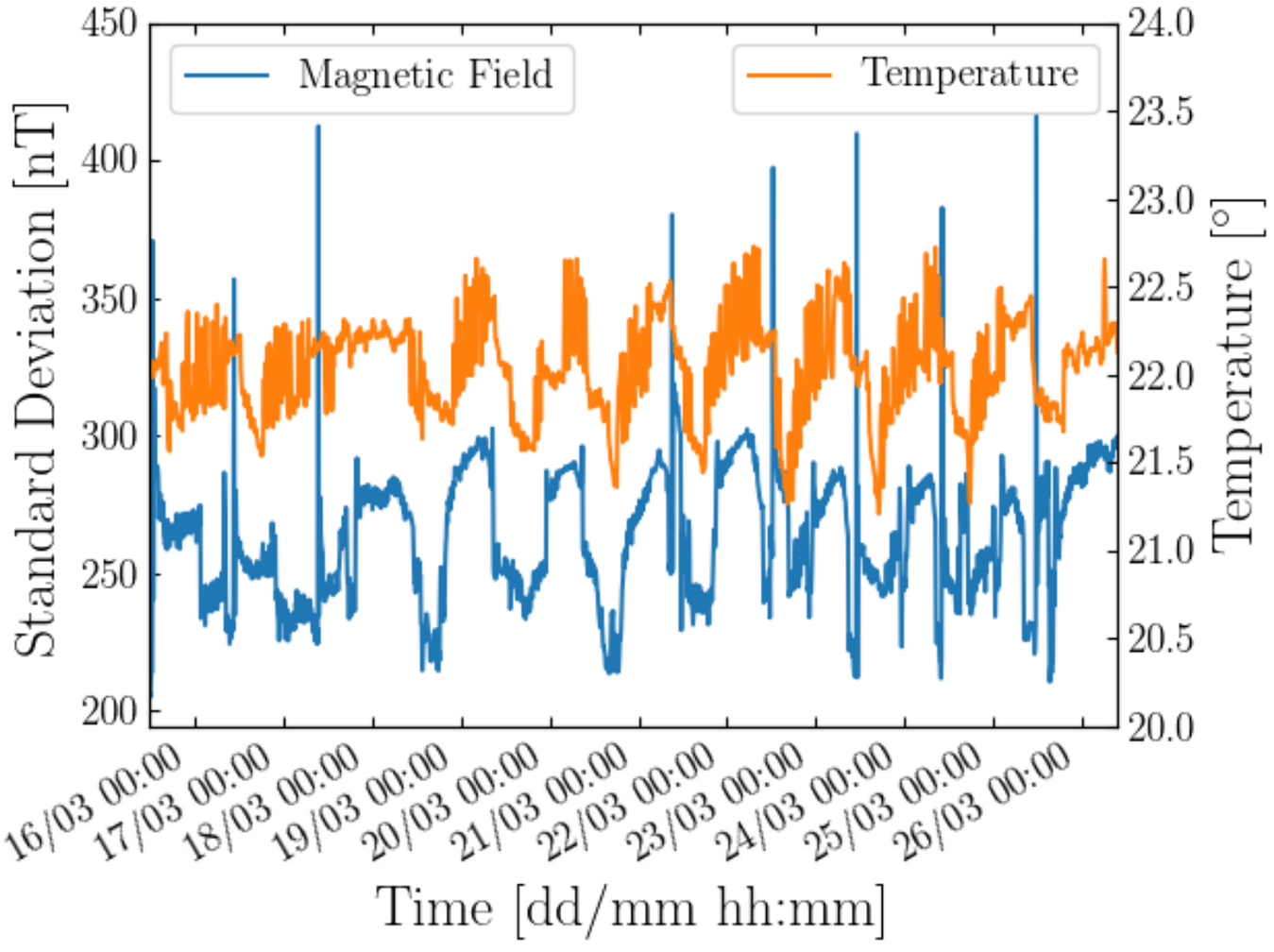
- Cables:
  - Often arranged in pairs or twisted to minimise magnetic field.
  - Measured the magnetic field from a power cable to a magnet.
  - 20 A was running through the cables.





Technical Sources

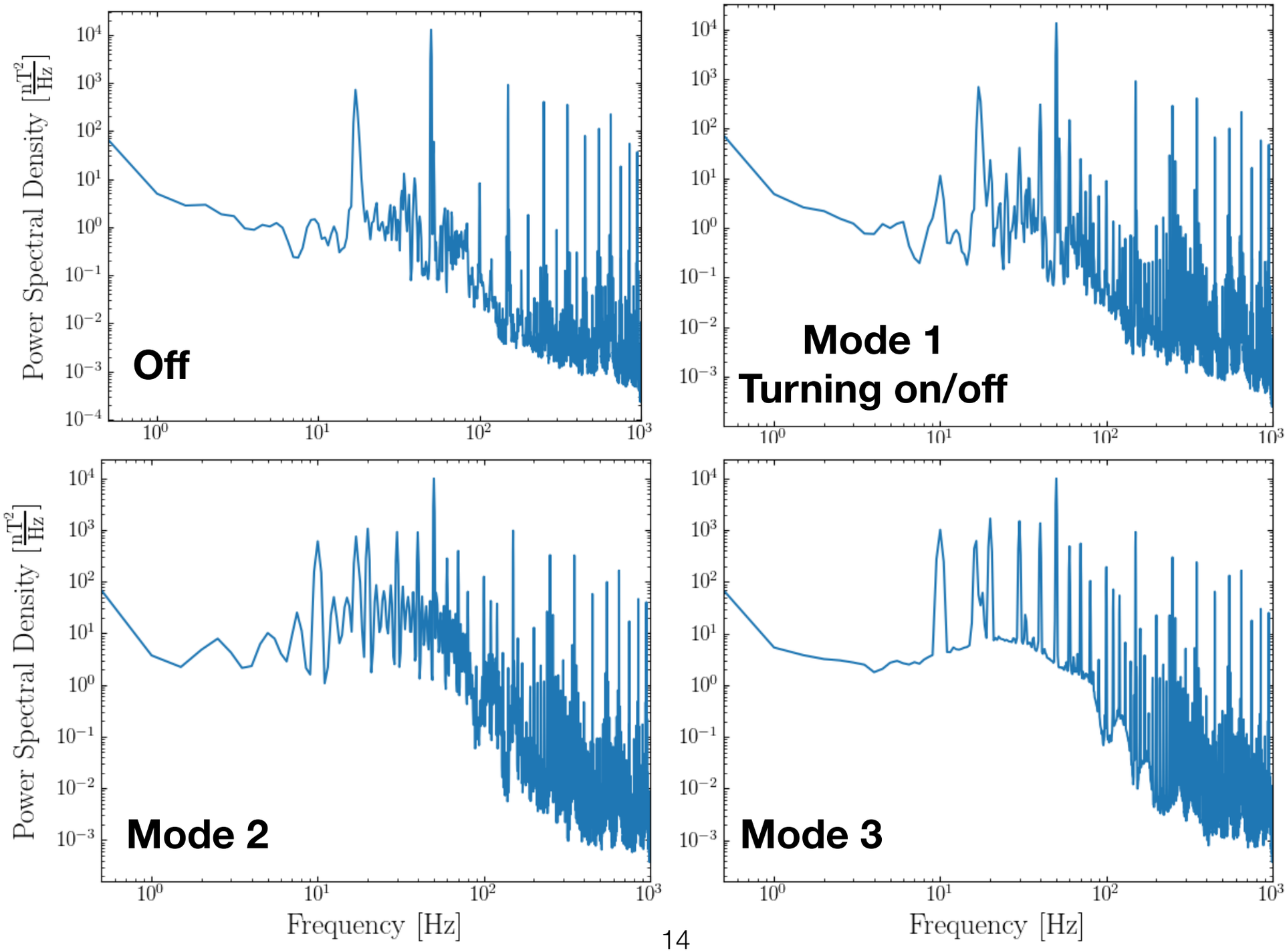
- Ventilation systems:
  - A long term measurement was performed near the ventilation system in CLEAR:



- Magnetic field varies with temperature of the CLEAR beamline!

Technical Sources

- Different modes of the ventilation system:



Accelerator Environments

Accelerator Environments

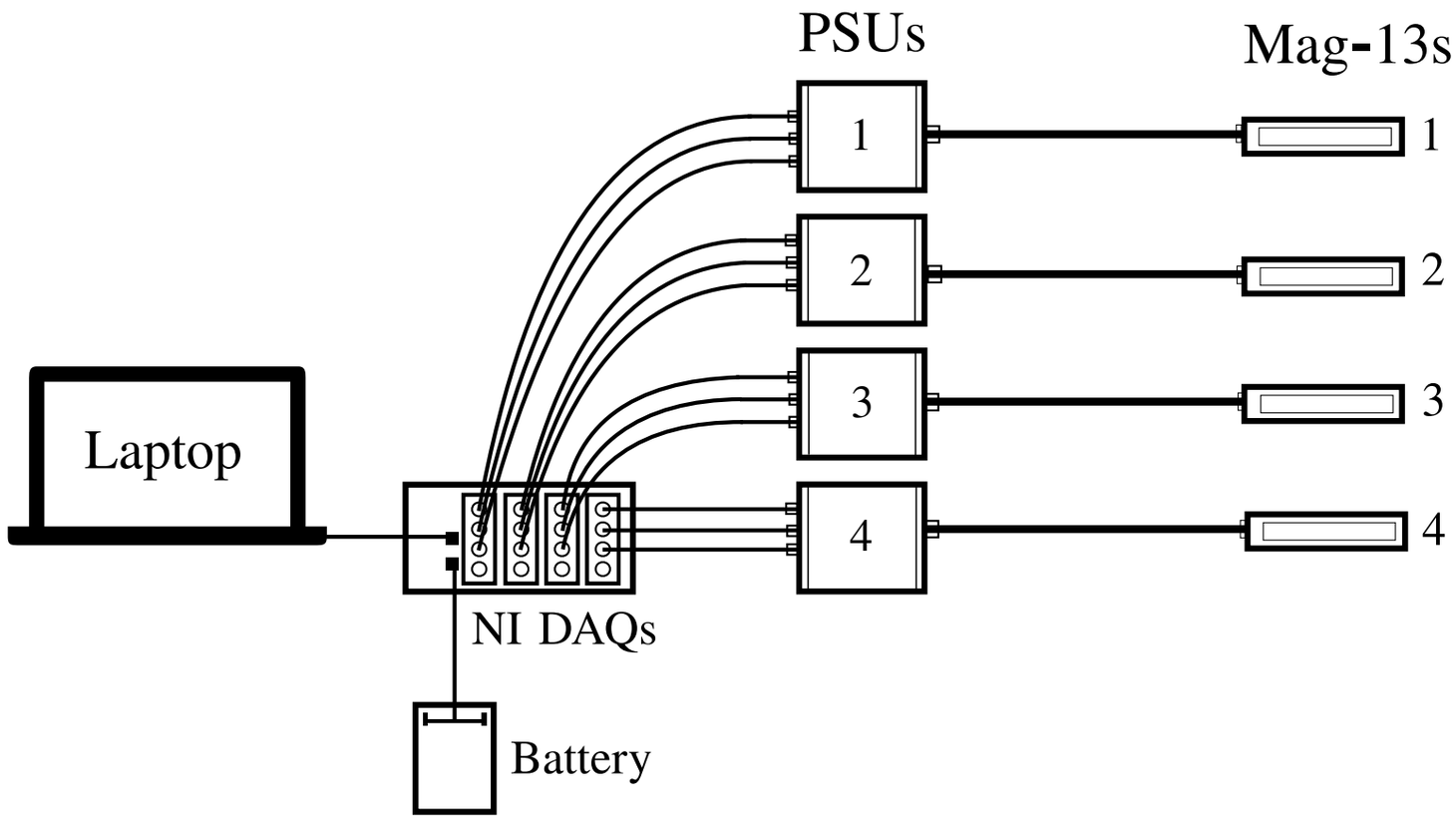
- Ambient magnetic field was measured underground in the LHC tunnel.

- Measurements were in a ‘noisy’ environment containing stray fields from all sources: natural, environmental and technical sources.

- No beam and no RF.

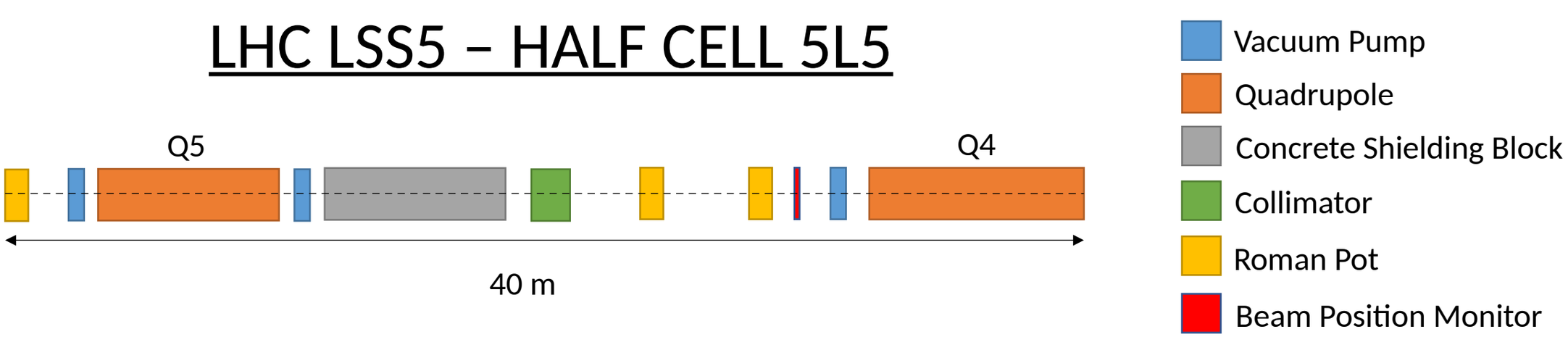
Measurement Setup

- A set of 4 Mag-13 sensors produced by Bartington Instruments was used.
  - Frequency range: DC-3 kHz
  - Noise at 1 Hz: 7 pT/√Hz
- With 4 ±0.5 V 24-bit National Instruments DAQ (NI 9238).

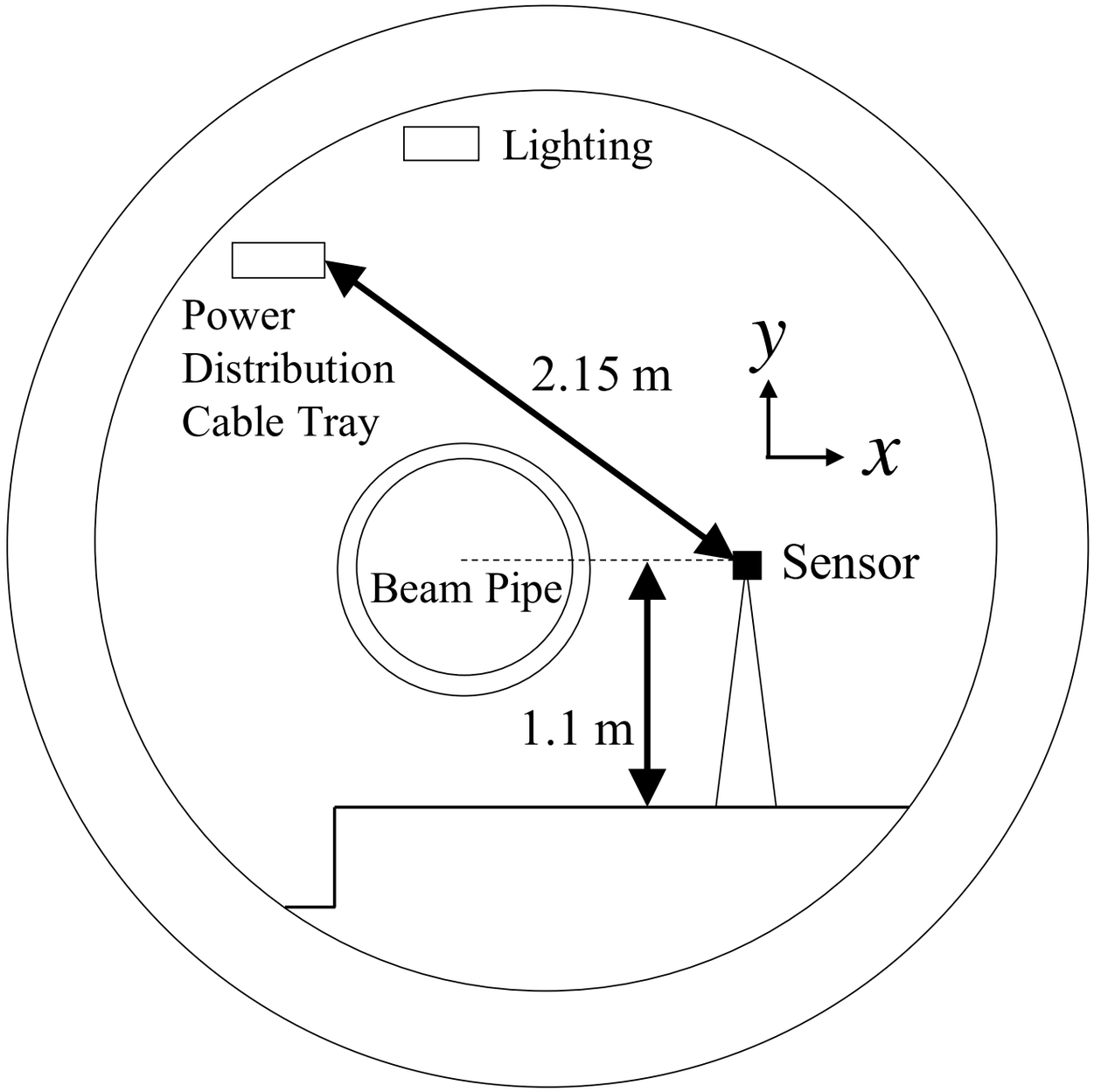


The LHC Point 5

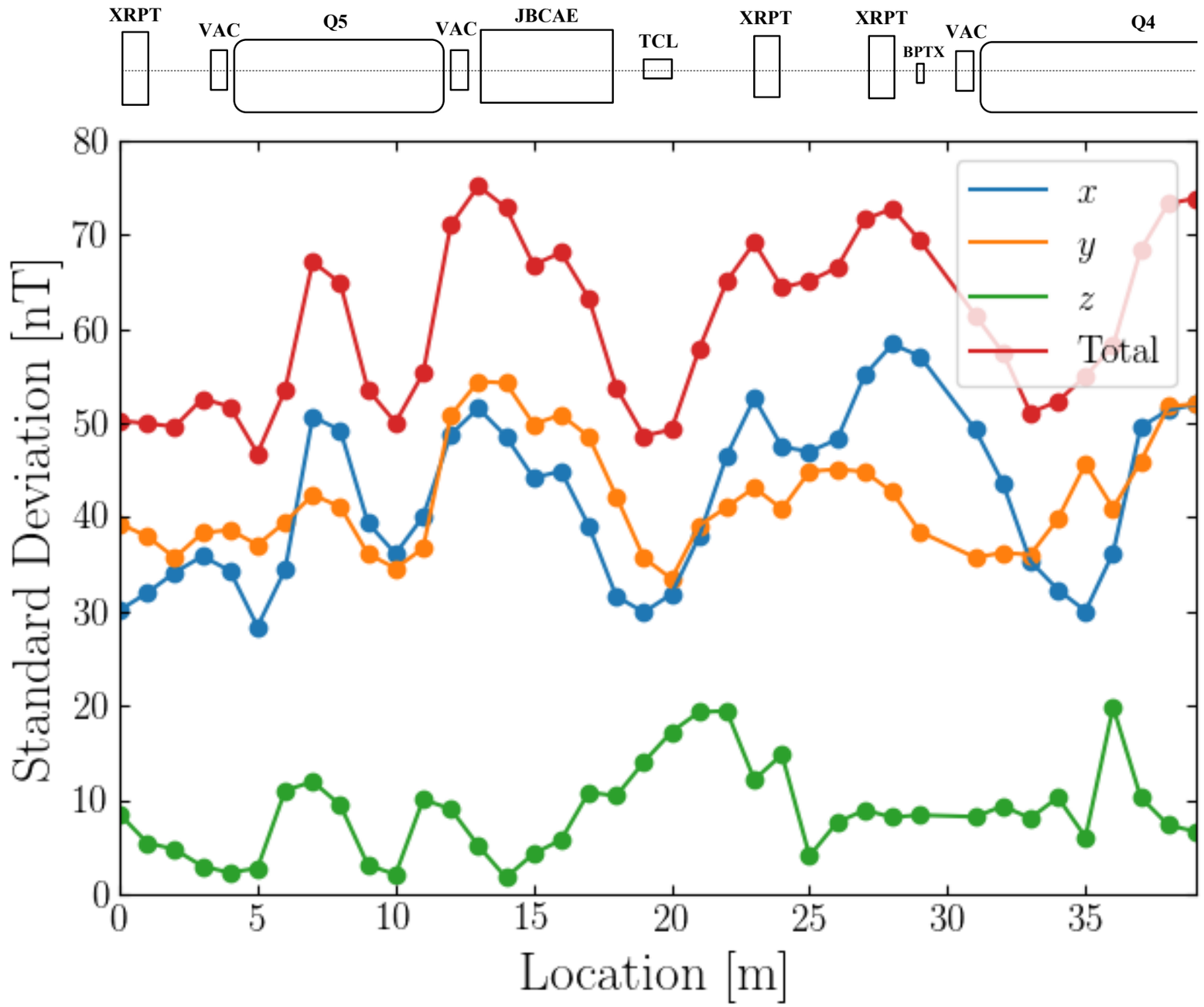
- Measurements performed on 29/04/19 at point 5 (near CMS).
- A 40 m section of the LHC beamline was surveyed:



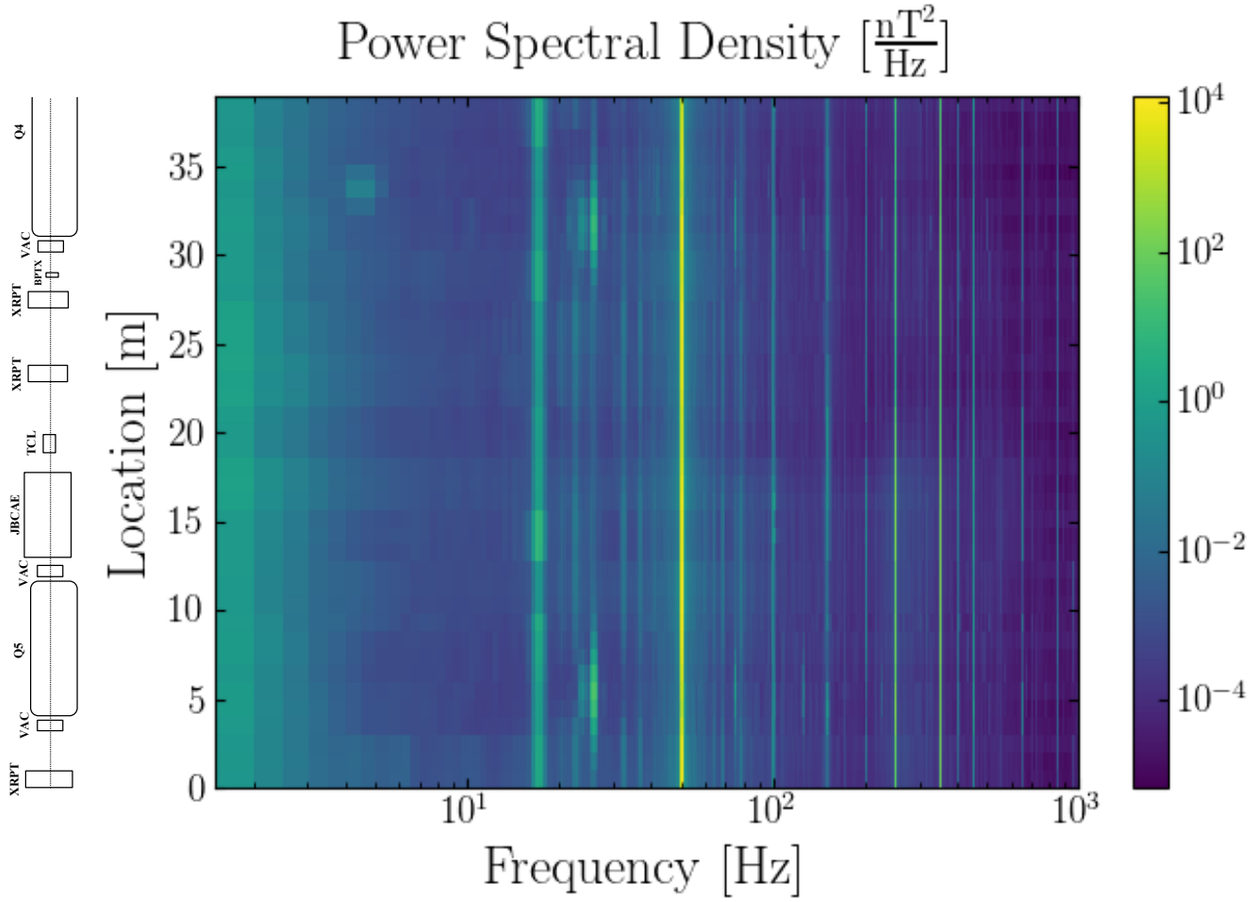
Measurement Geometry



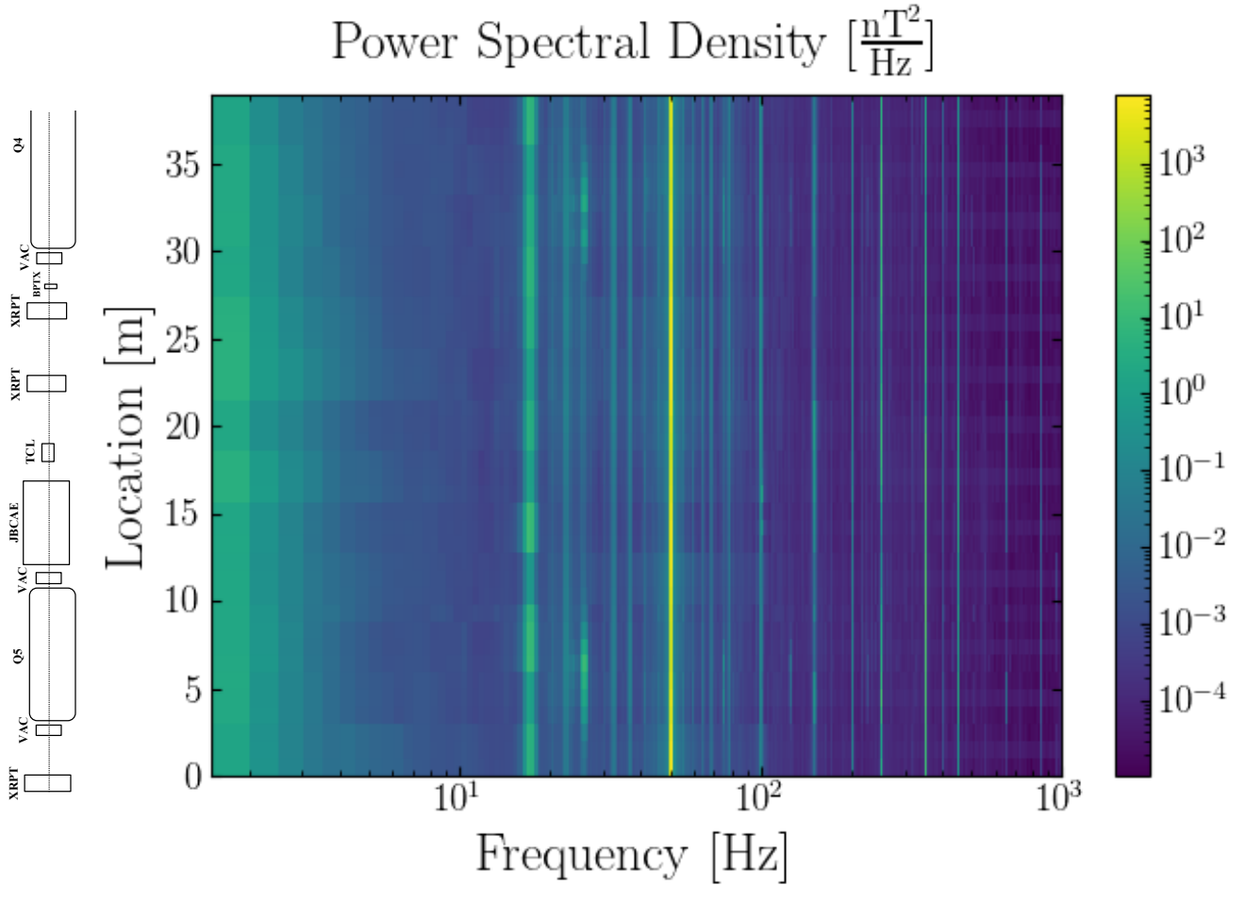
Standard Deviation



PSD

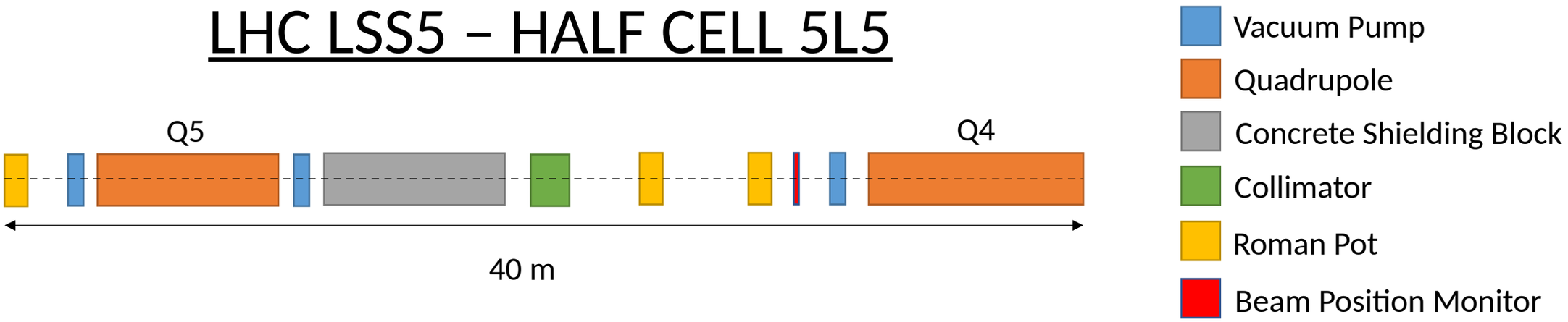


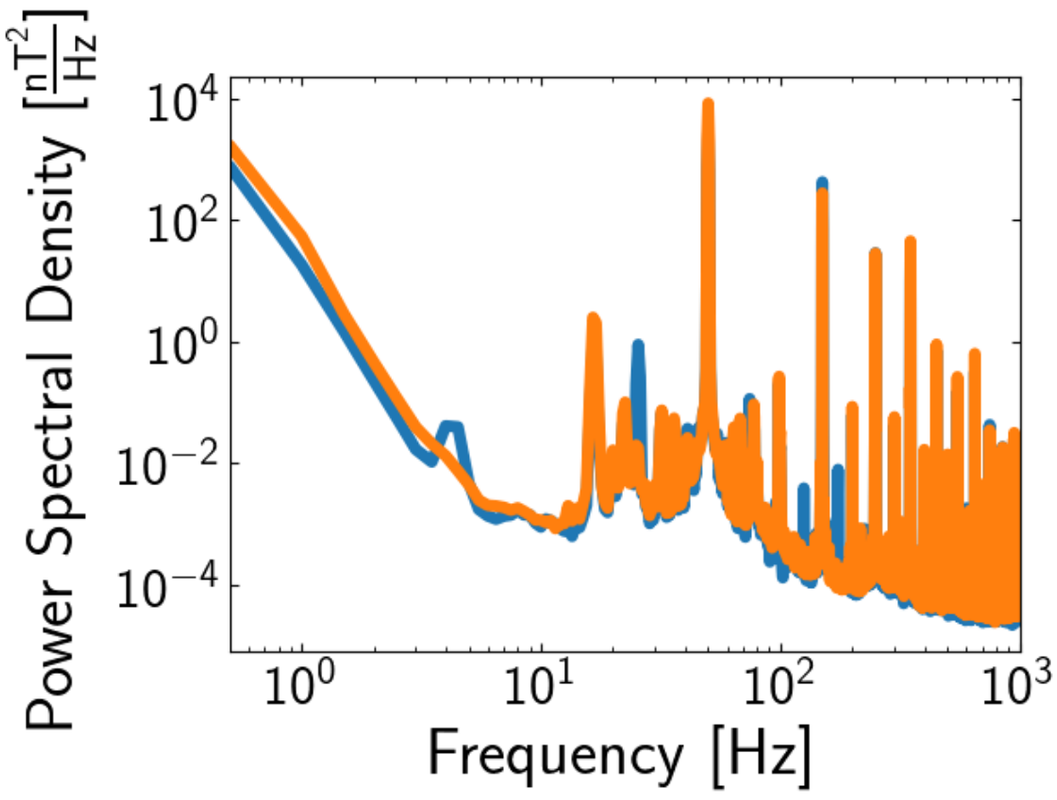
x-component

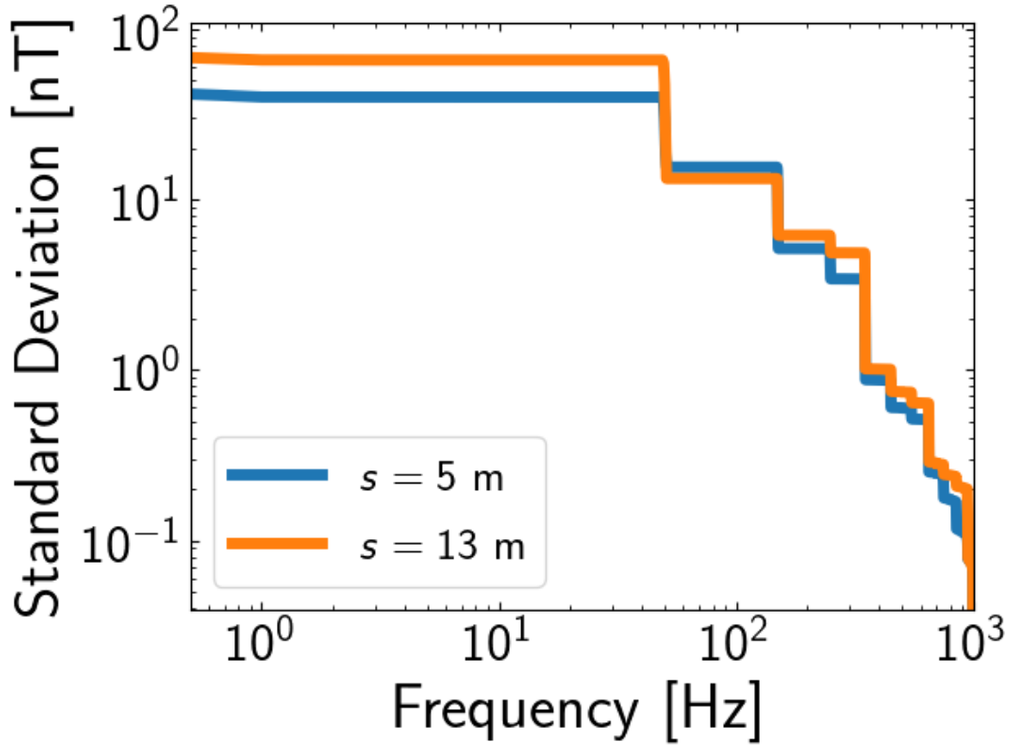


y-component

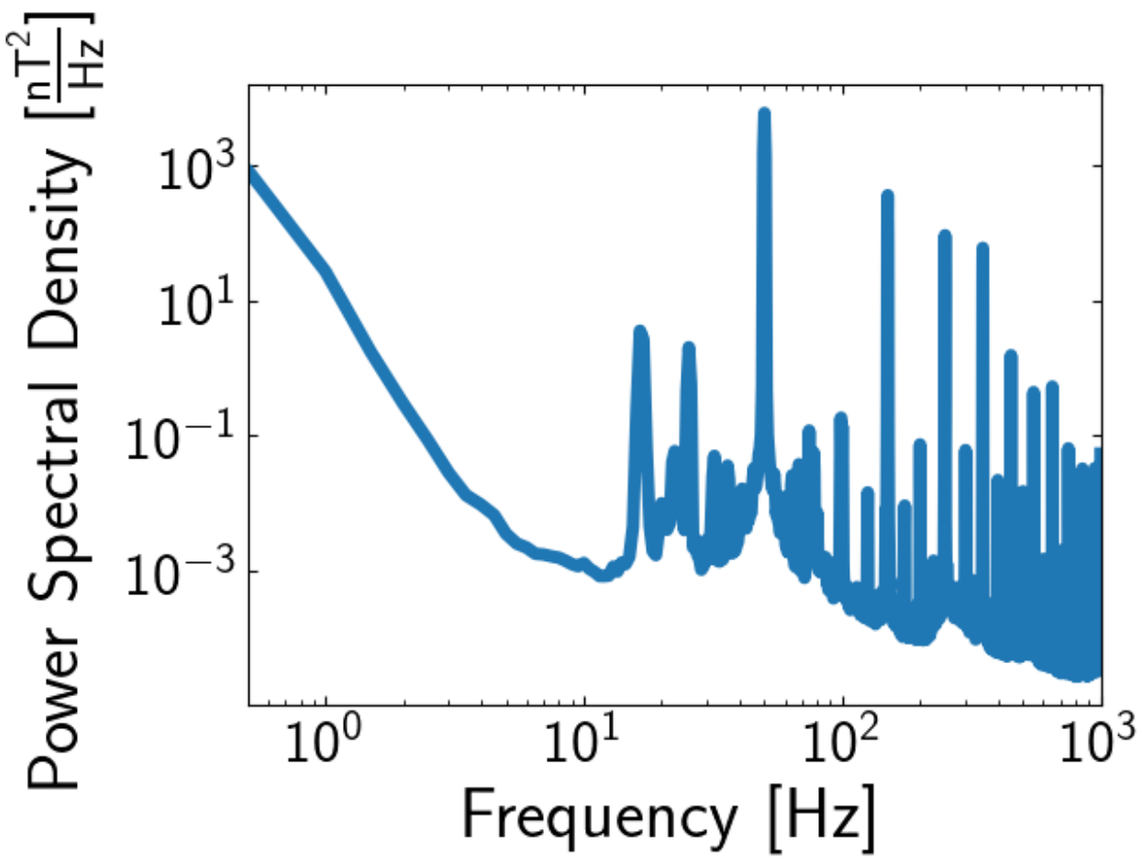
Smallest and Largest PSD

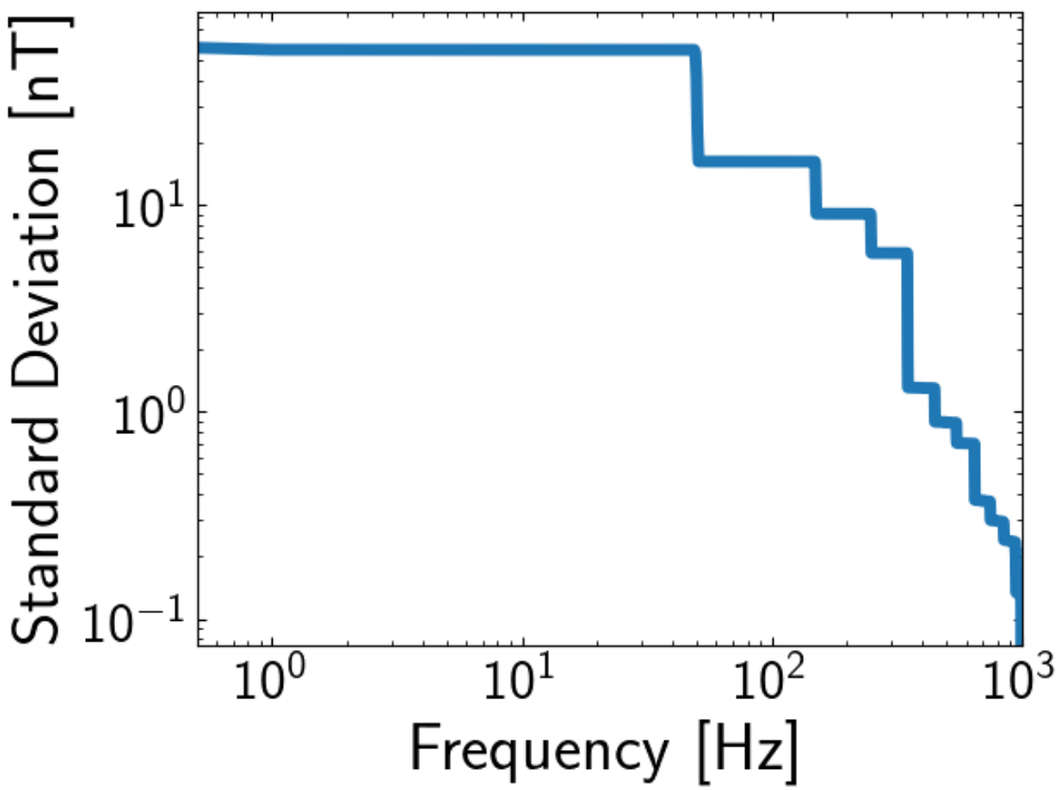






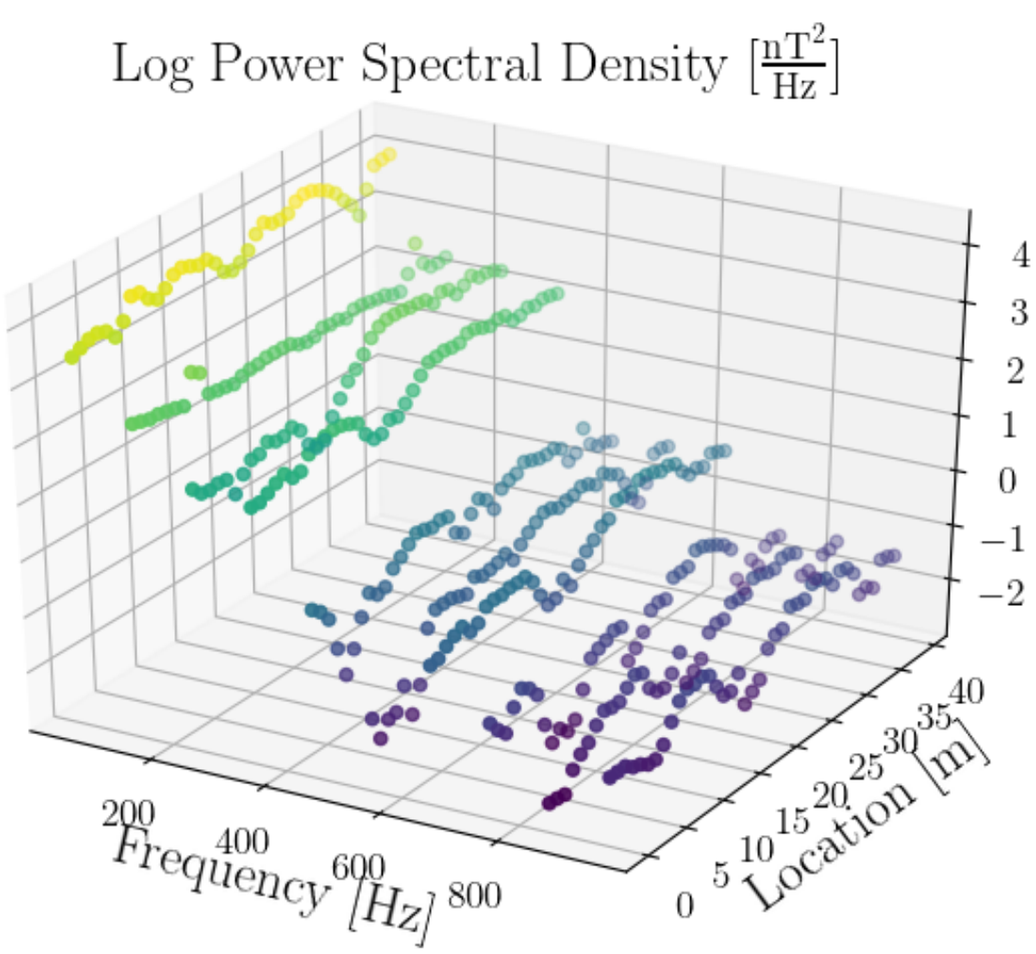
Average PSD



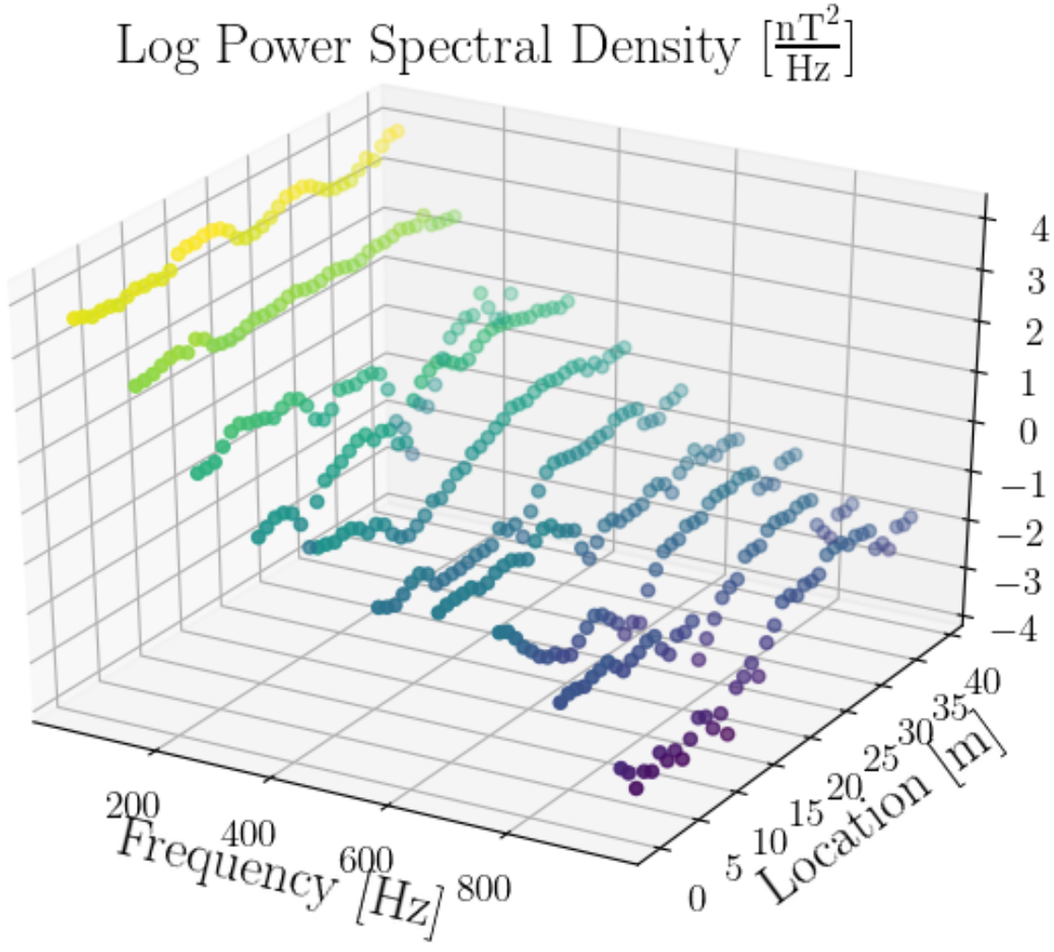


Largest contributions are odd harmonics of 50 Hz.

50 Hz Harmonics



x-component

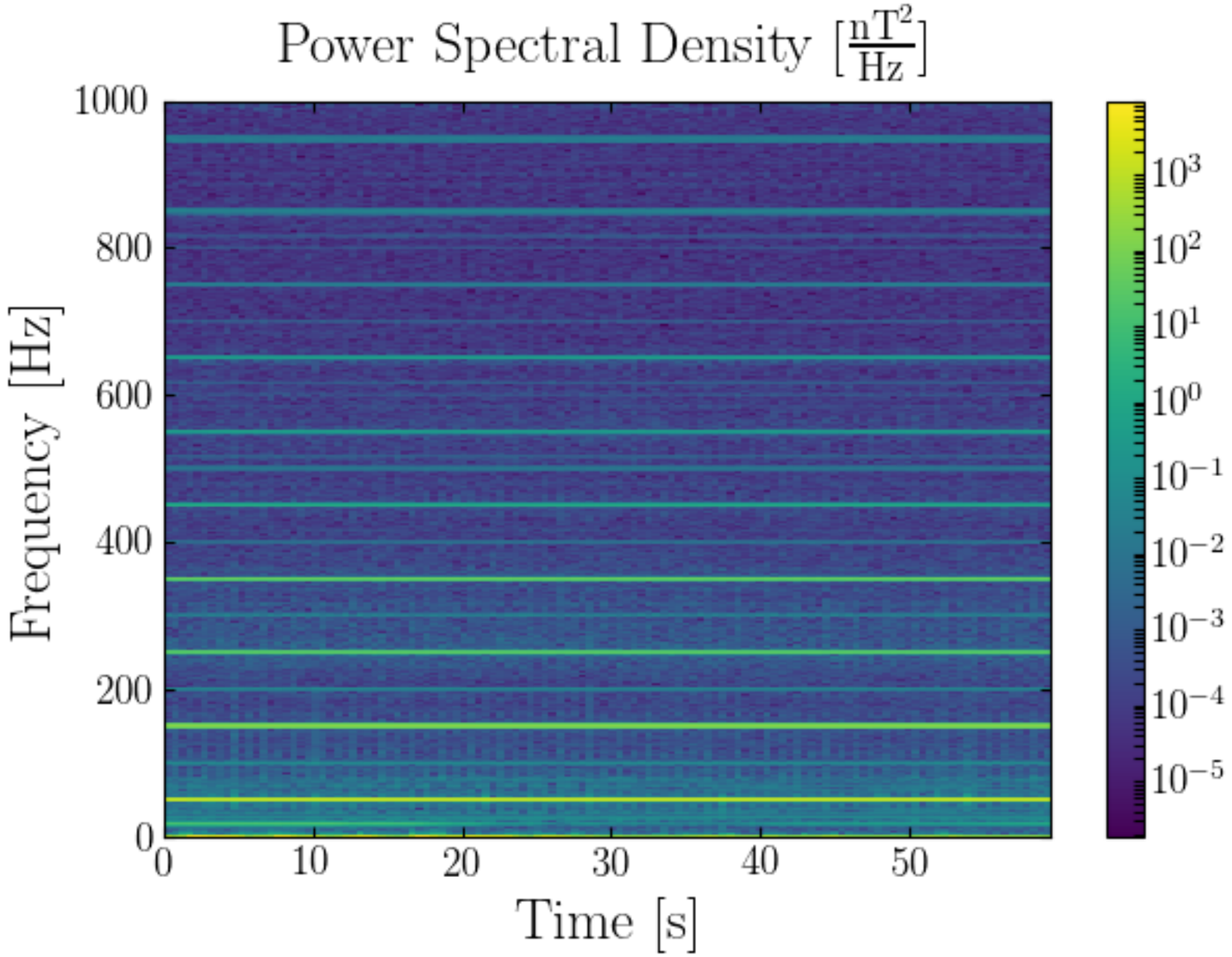


y-component

- Amplitude of the 50 Hz is ~50 nT.

Dynamic PSD

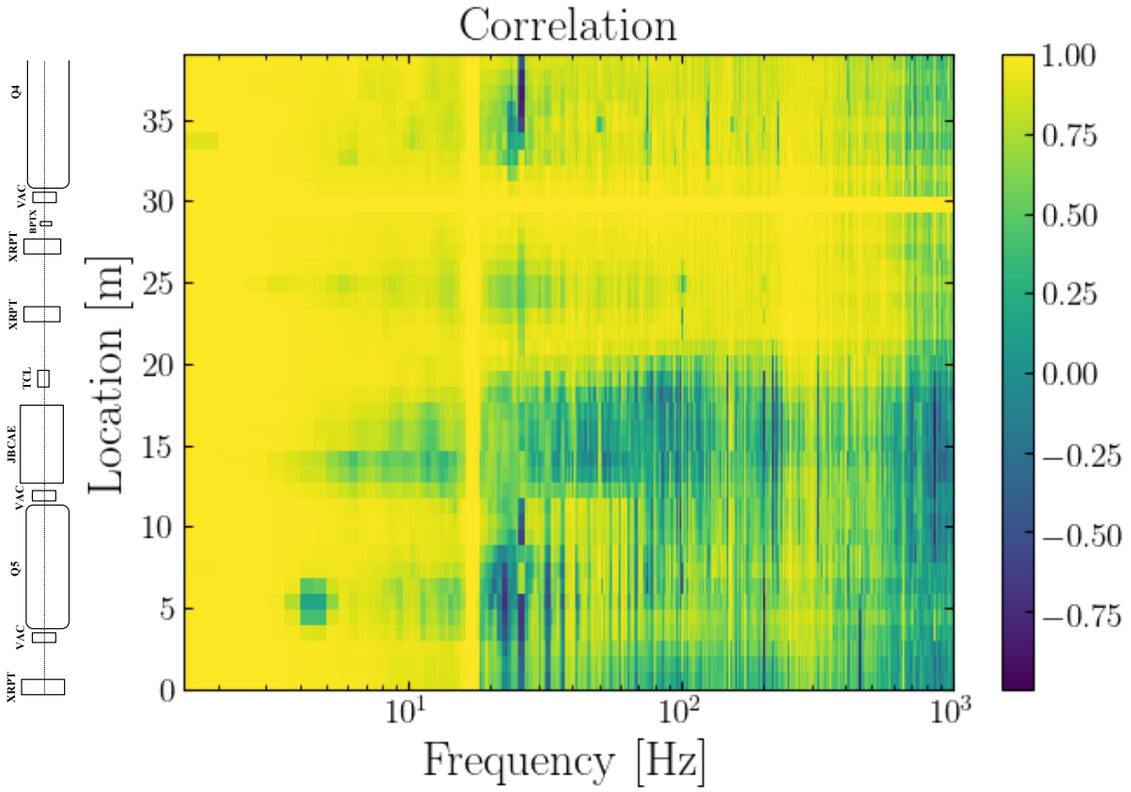
- PSD over a 1 minute measurement:



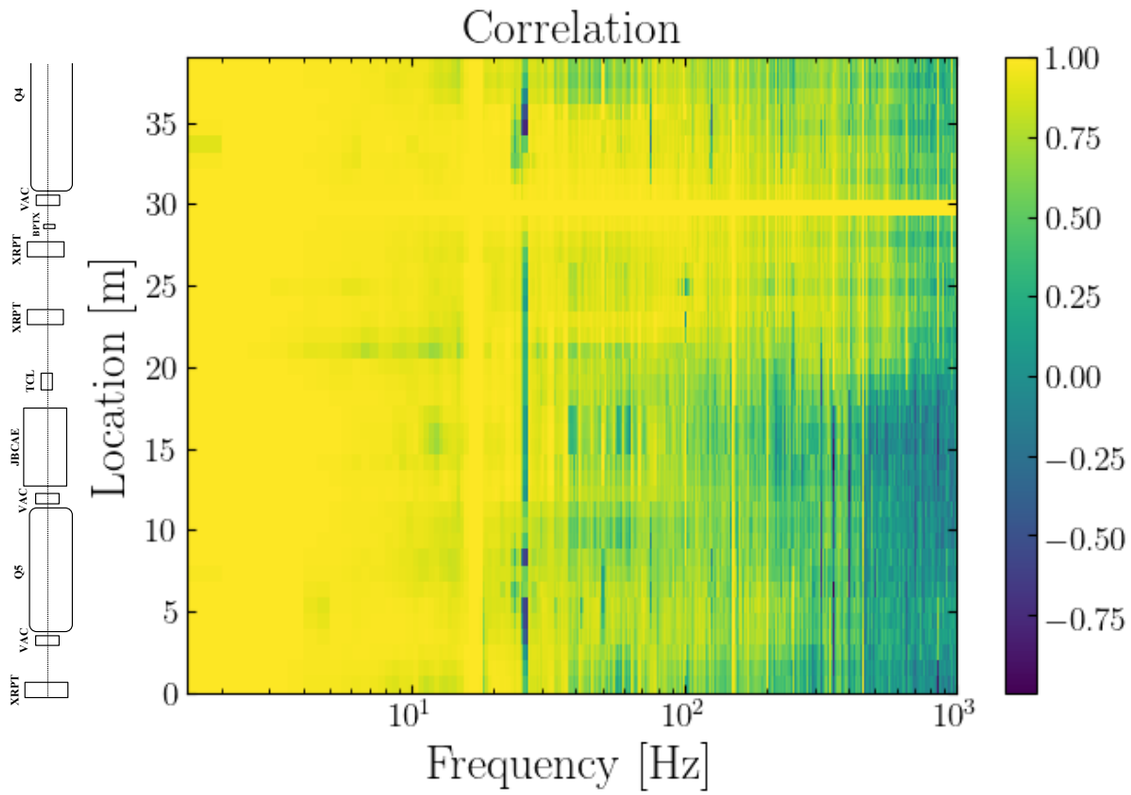
x-component

- Peaks appear to be stable.

Correlation



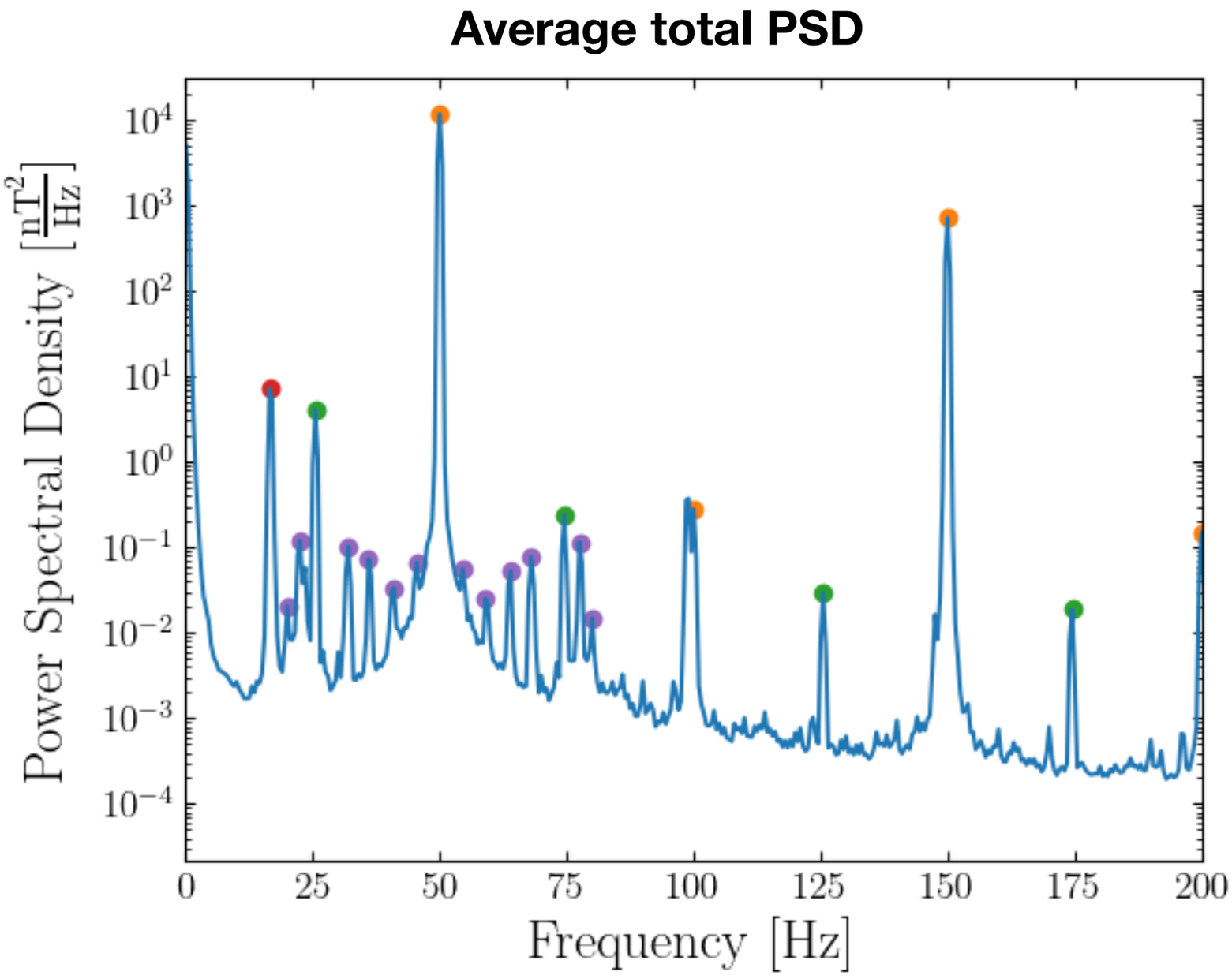
x-component



y-component

- Low frequencies appear to be very well correlated.
- High frequencies are less correlated.

Specific Peaks



- Most significant peaks are below 200 Hz.
- Peaks are symmetric around the 50 Hz.
  - From modulation.

Conclusions

- A wide variety of stray field sources have been surveyed:
  - Natural, environmental and technical.

- Natural sources should not pose a problem for CLIC.

- Modulation of 50 Hz results in peaks at dangerous frequencies for CLIC.

- Total magnetic field ~100 nT in the LHC tunnel.
  - Tolerances for CLIC at O(0.1 nT), for ILC at O(1 nT).
  - **Mitigation in another talk: “Sensitivity of CLIC and the ILC to Stray Magnetic Fields and Mitigation with Passive Shielding”.**