# Measurement of Schumann Resonance

Sho Atsuta, Nelson Christensen, Michael Coughlin, Rosario Derosa, Irene Fiori, Mark Golkowski, Melissa Guidry, Jan harms, Kazuhiro Hayama, Yuu Kataoka, Jerzy Kubisz, Andrzej Kulakm, Janusz Mlynarczyk, Tsutomu Ogawa, Federico Paoletti, Tristan Shoemaker, Kentaro Somiya, Eric Thrane

2016 08 26th F2F meetings at Toyama university

# Contents

- Calibration
- Result of Measurement
- Data quality
- Conclusion & Future Works

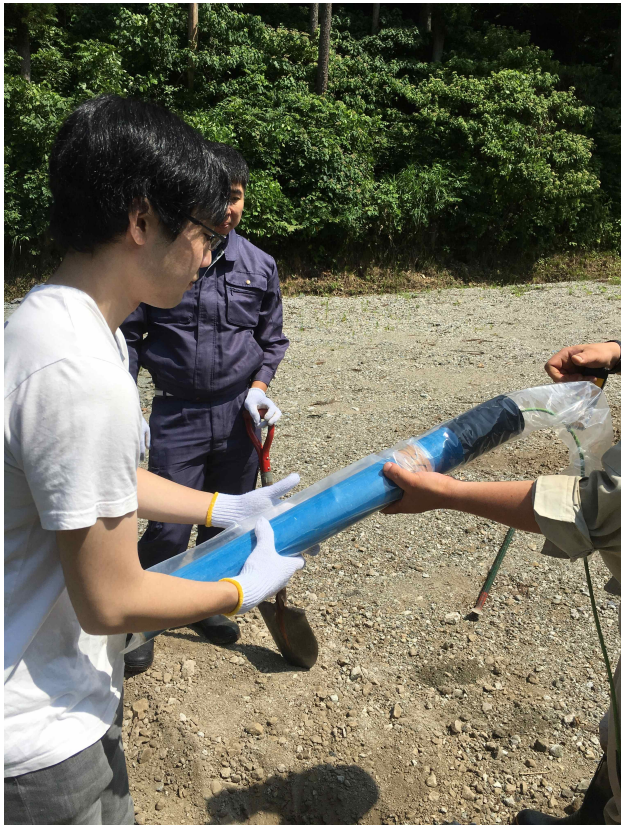
# Contents

- Calibration
- Result of Measurement
- Data quality
- Conclusion & Future Works

# Calibration

We used six magnetometers and two loggers and each equipment has filters

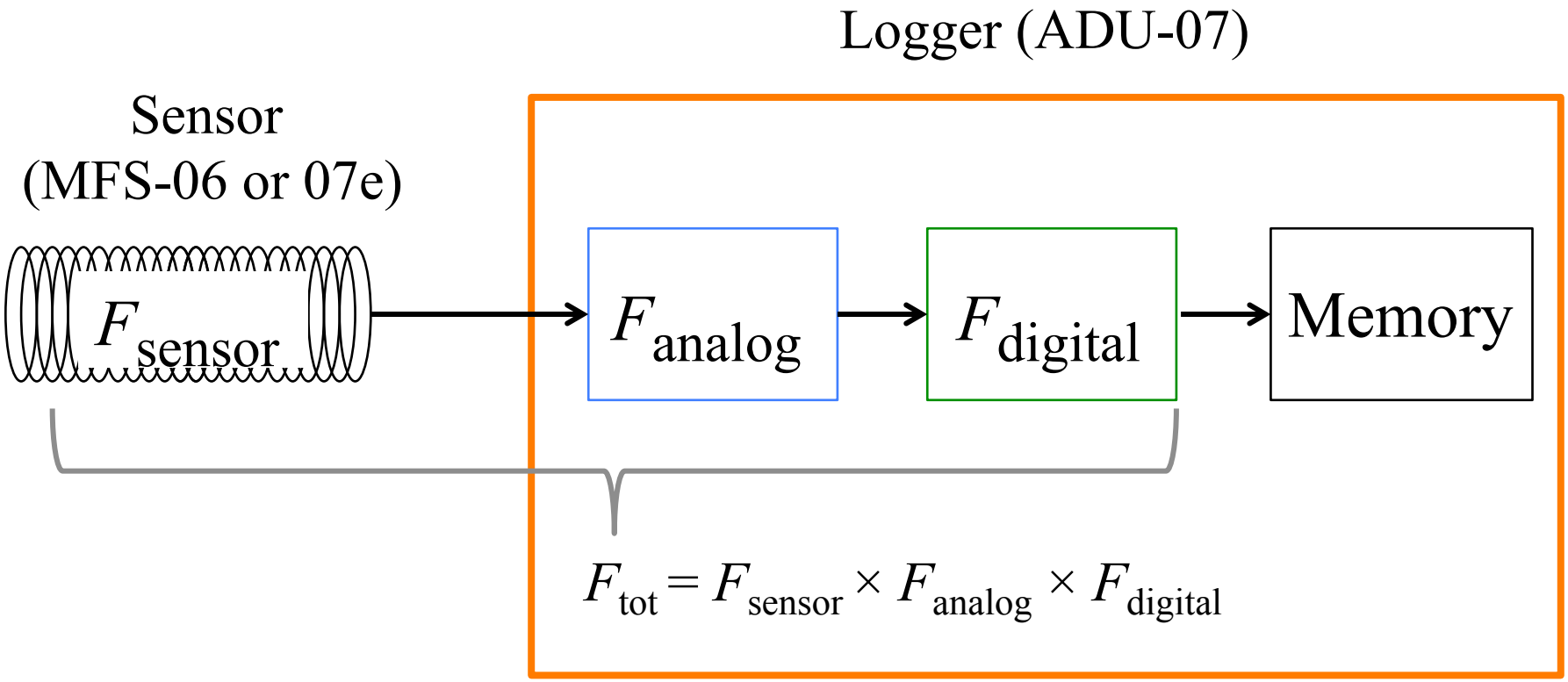
MFS-06 or 07e ( metronix )



ADU-07 ( metronix )


MFS-06,07e and ADU-07: under joint usage by ERI

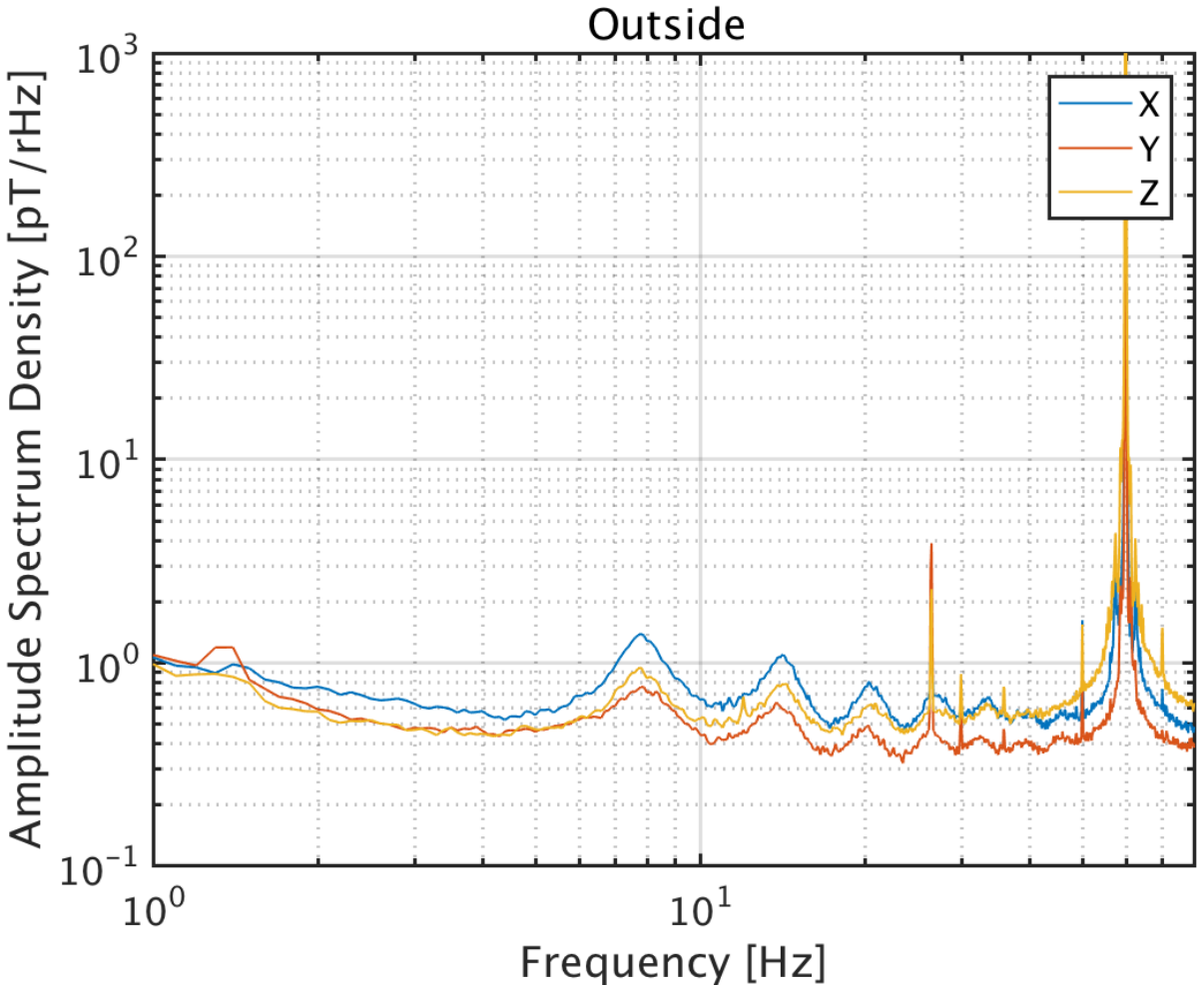
# Calibration




$$X_{cal} = 1/F_{tot} \times X_{raw}$$

Plus, down sampling the data from 1024Hz to 250Hz to follow Virgo format

# After calibration




**Direction rules**

- NS -> X
- EW -> Y
- Vertical -> Z

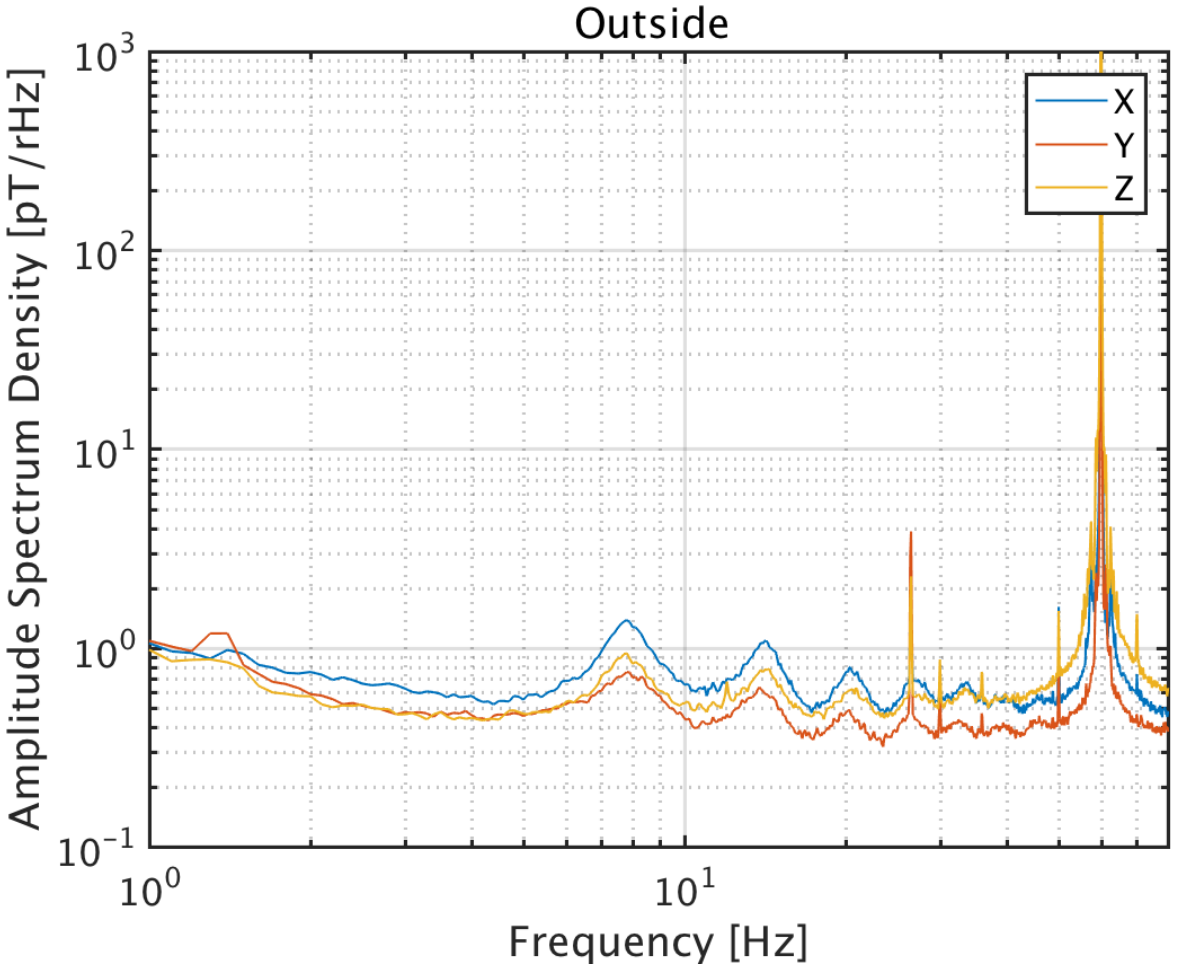
# Contents

- Calibration
- **Result of Measurement**
- Data quality
- Conclusion & Future Works

# Result of measurement

- Check Point

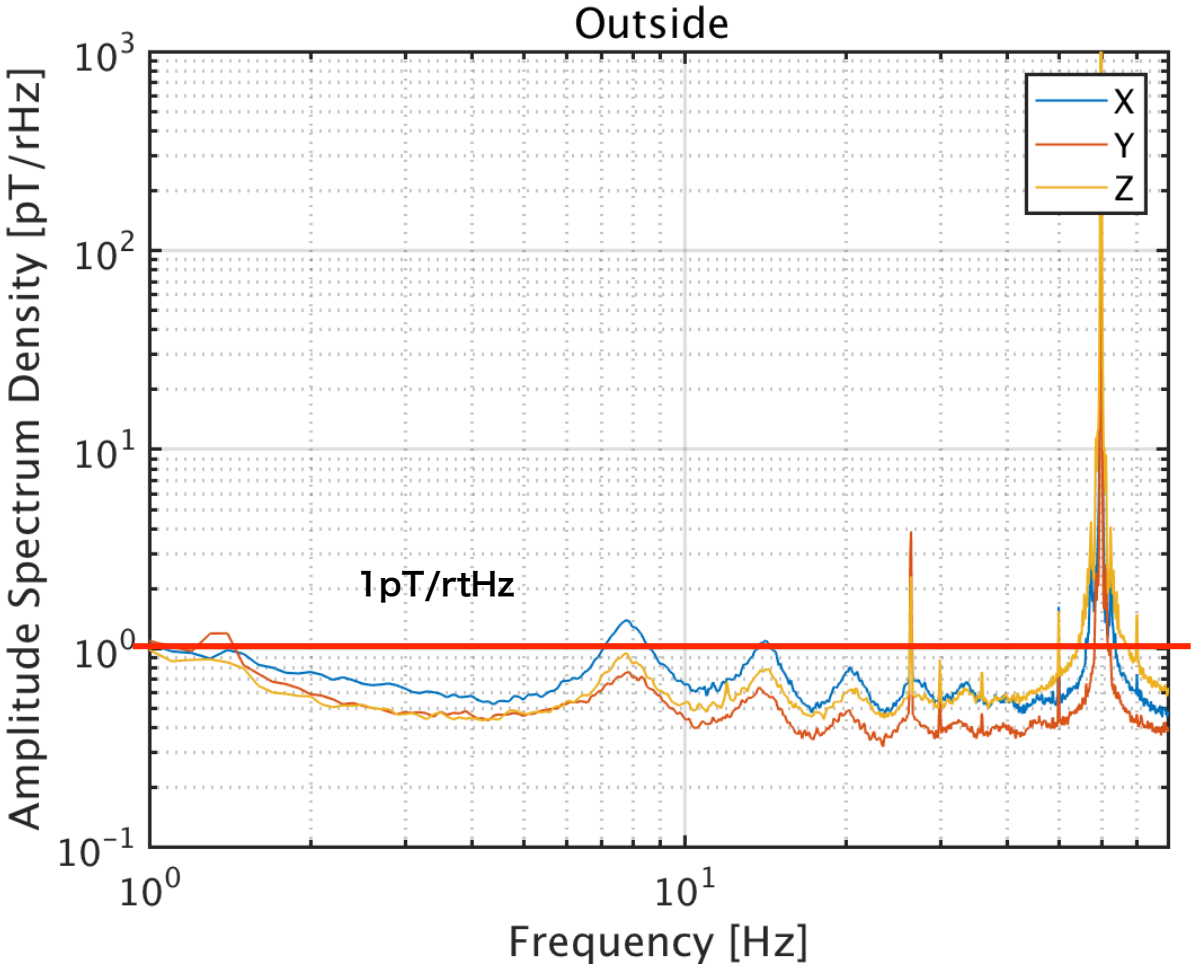
1. Amplitude
2. Frequency



# Result of measurement

- Check Point

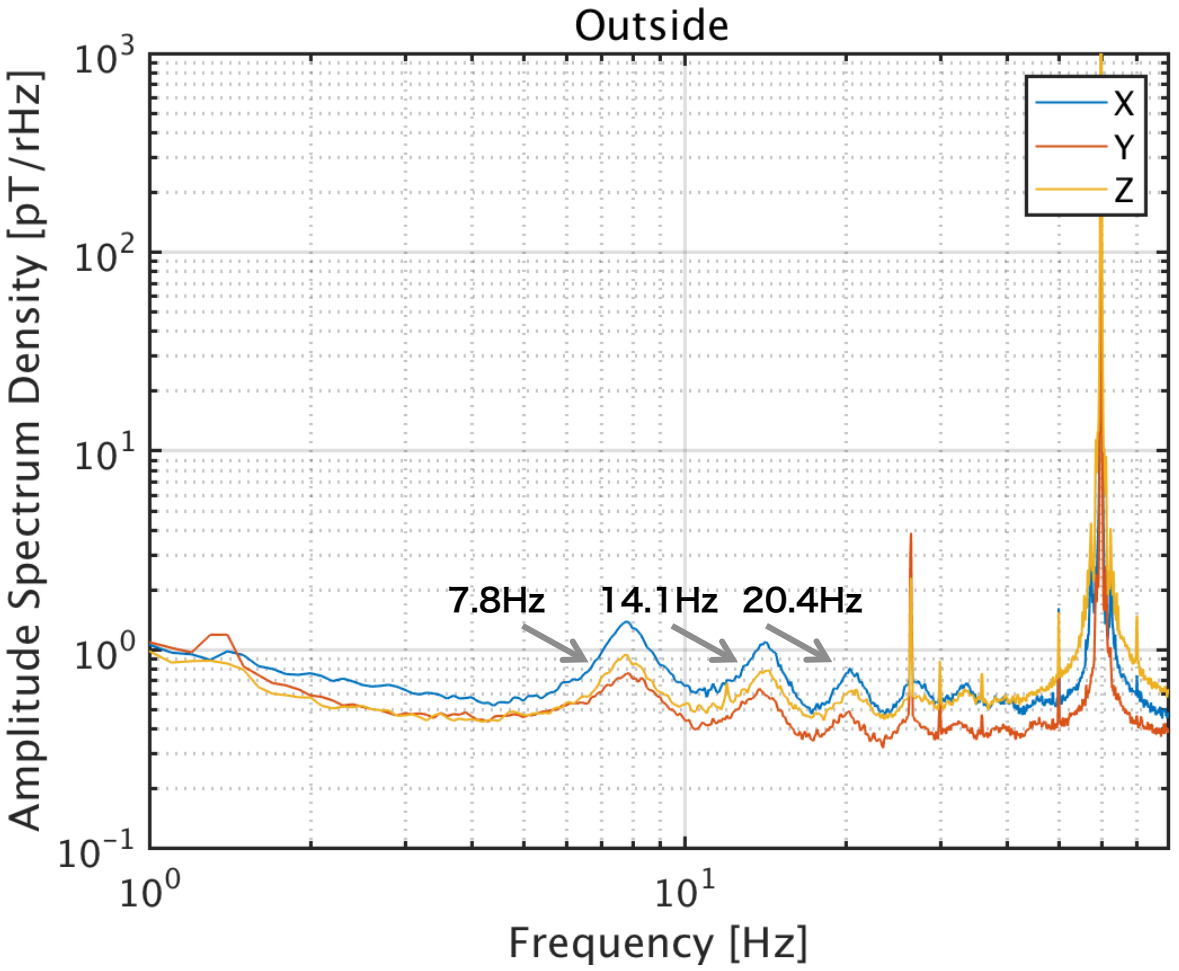
1. Amplitude
2. Frequency



# Result of measurement

- **Check Point**

1. Amplitude
2. **Frequency**




Measurement was consistent with the prior study [1] !!

# Result of measurement

- **Compare Inside with Outside**

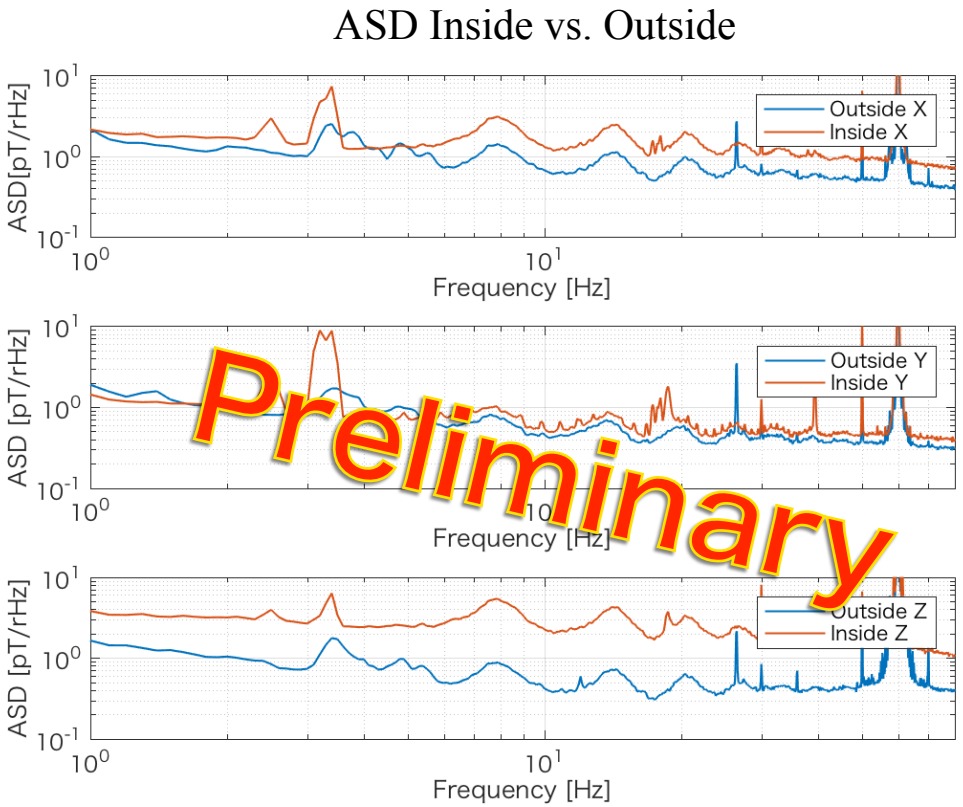
- **Result**

Magnetic field inside the tunnel

**is larger than outside**

- **Reason**

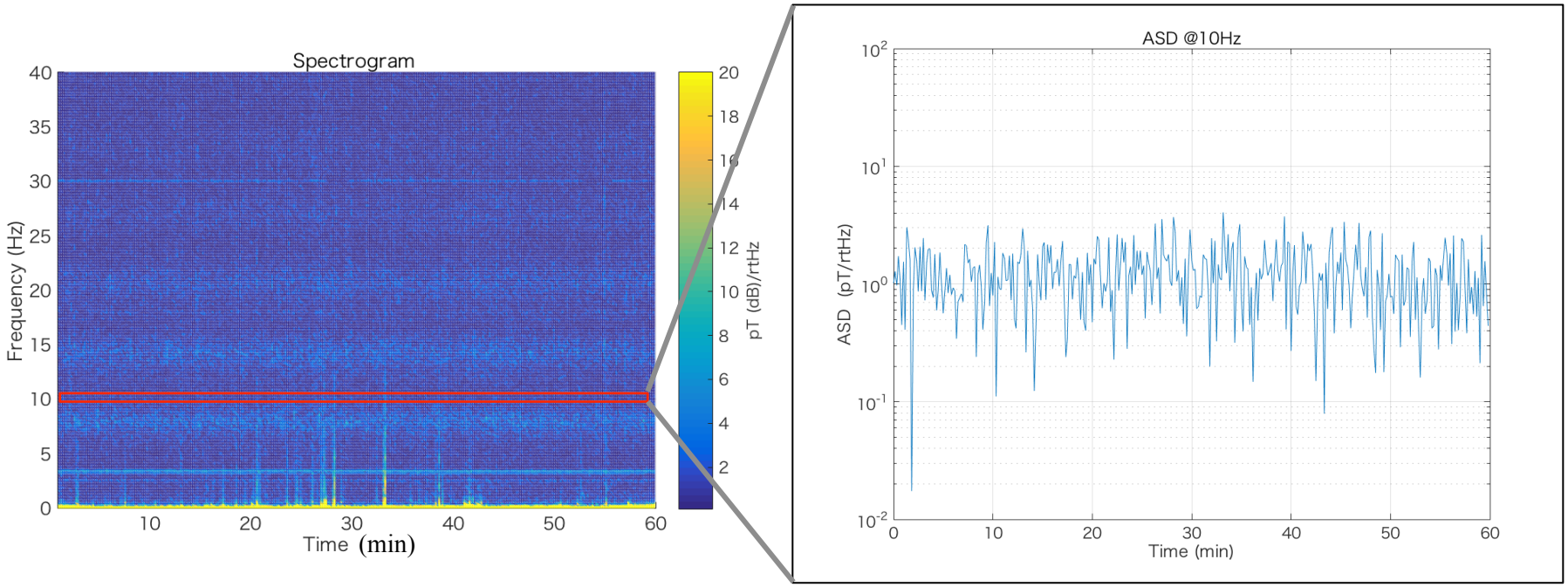
**?????????**



# Result of measurement

- **Spectrogram**

spectrogram of X direction outside the tunnel

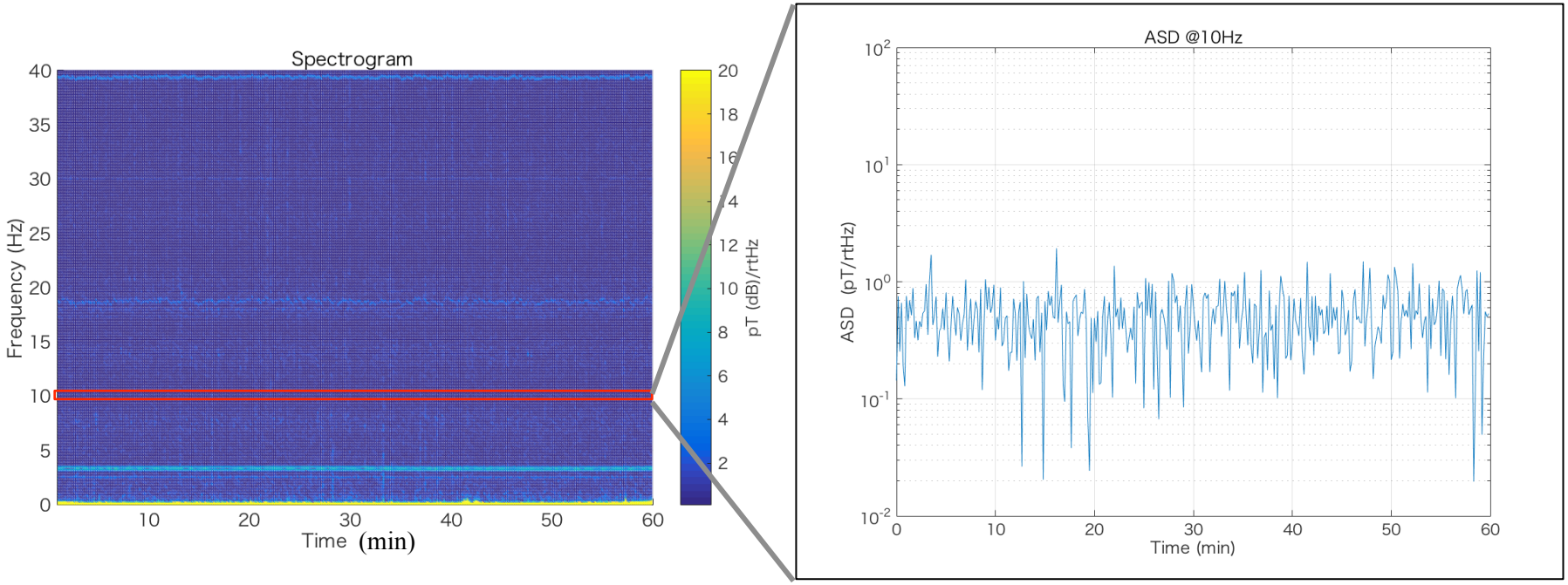



$Fs = 250\mathrm{Hz}, T_{\mathrm{FFT}} = 10\mathrm{s}$

# Result of measurement

## ■ Spectrogram

spectrogram of Y direction outside the tunnel

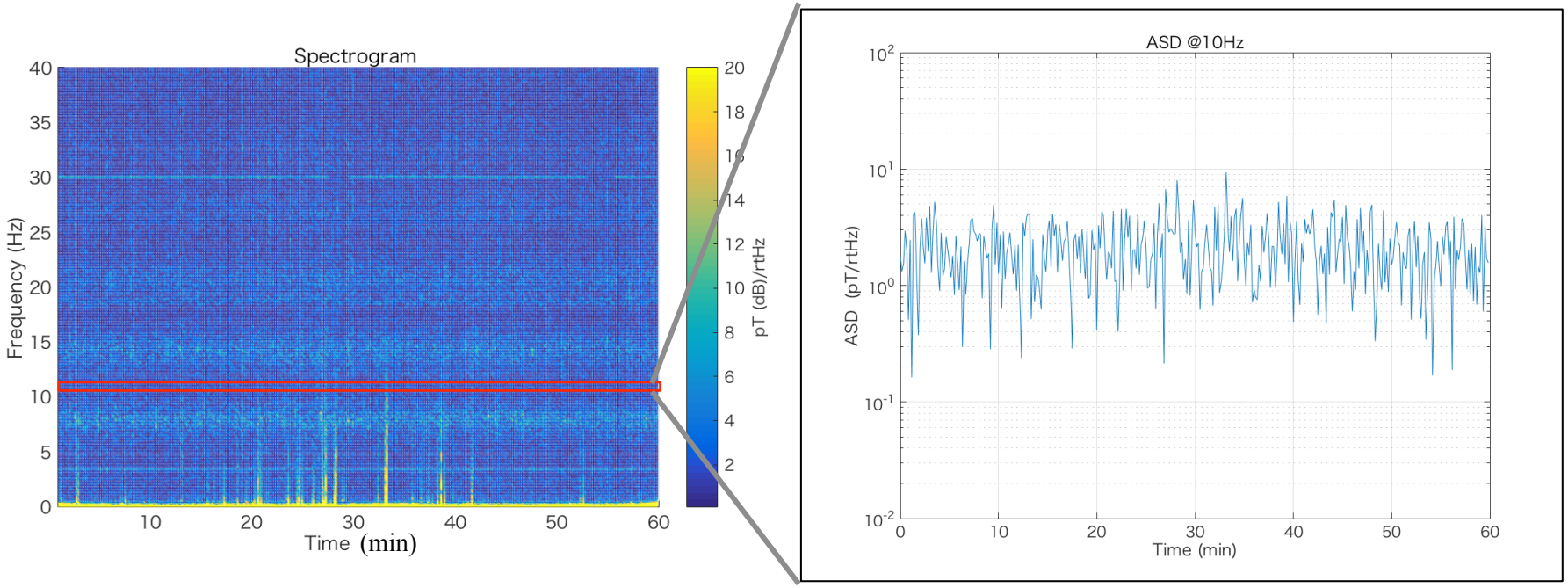



$Fs = 250\mathrm{Hz}, T_{\mathrm{FFT}} = 10\mathrm{s}$

# Result of measurement

- **Spectrogram**

spectrogram of Z direction outside the tunnel

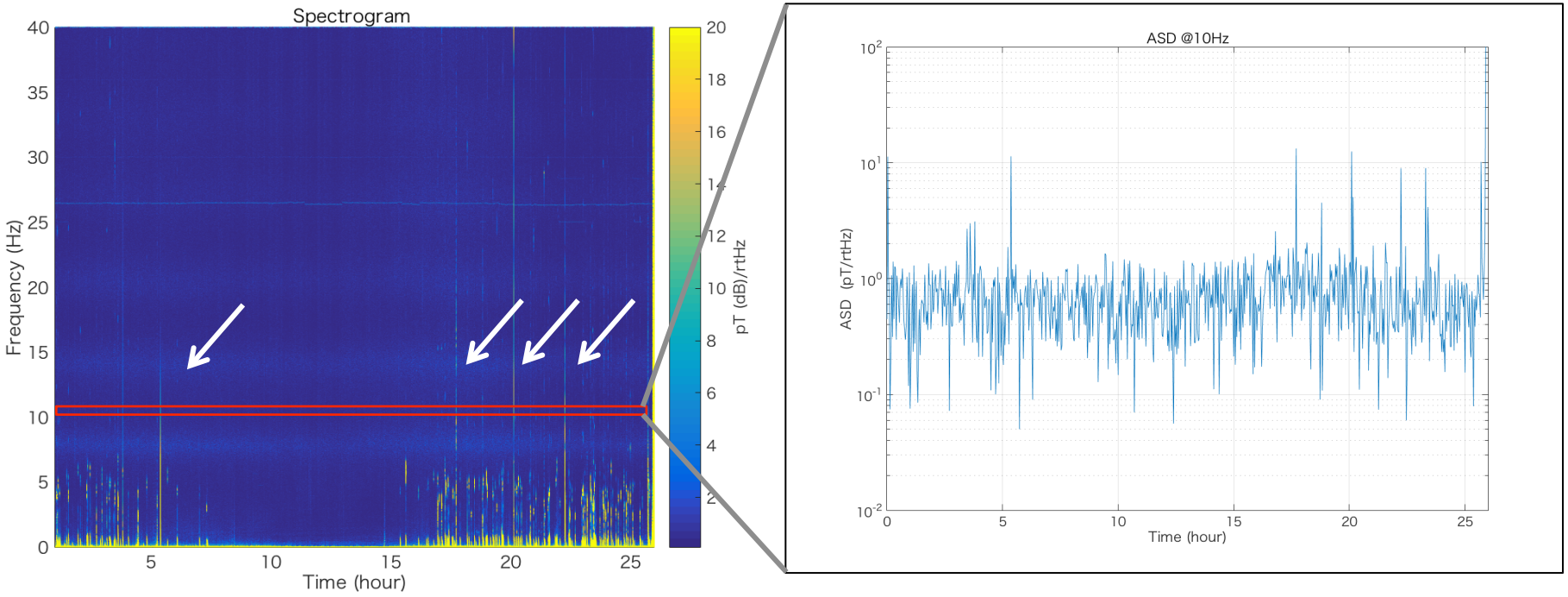



$Fs = 250\mathrm{Hz}, T_{\mathrm{FFT}} = 10\mathrm{s}$

# Result of measurement

## ■ Spectrogram

spectrogram of X direction outside the tunnel



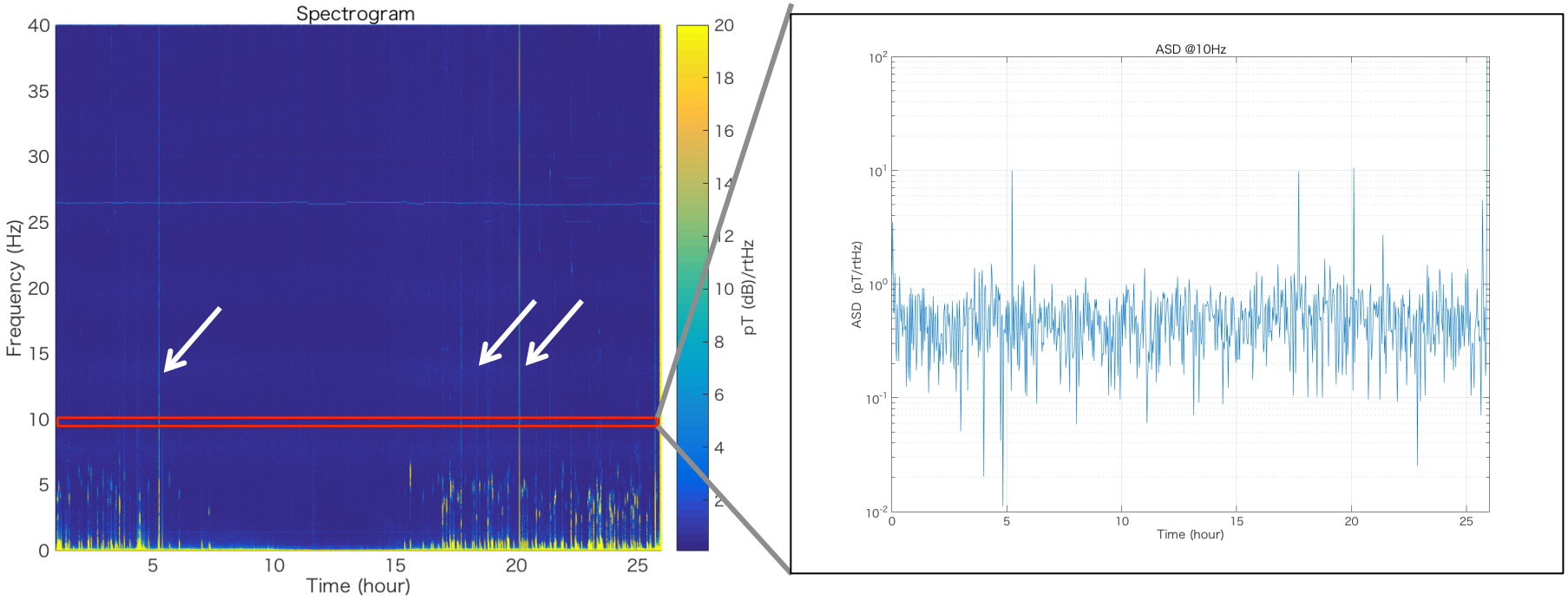

$Fs = 100\mathrm{Hz},\ T_{\mathrm{FFT}} = 120\mathrm{s}$

Some glitches caused by human activity were detected !

# Result of measurement

## ■ Spectrogram

spectrogram of Y direction outside the tunnel



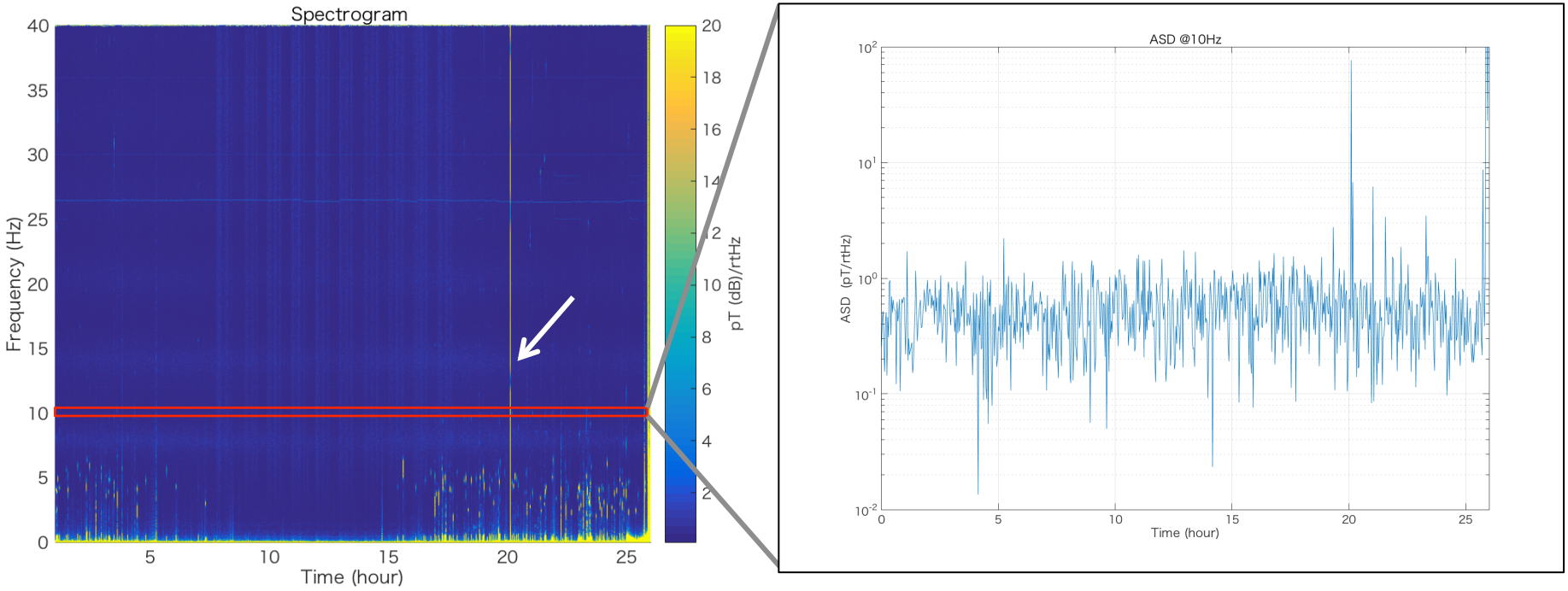

$Fs = 100\mathrm{Hz},\ T_{\mathrm{FFT}} = 120\mathrm{s}$

Some glitches caused by human activity were detected !

# Result of measurement

## ■ Spectrogram

spectrogram of Z direction outside the tunnel



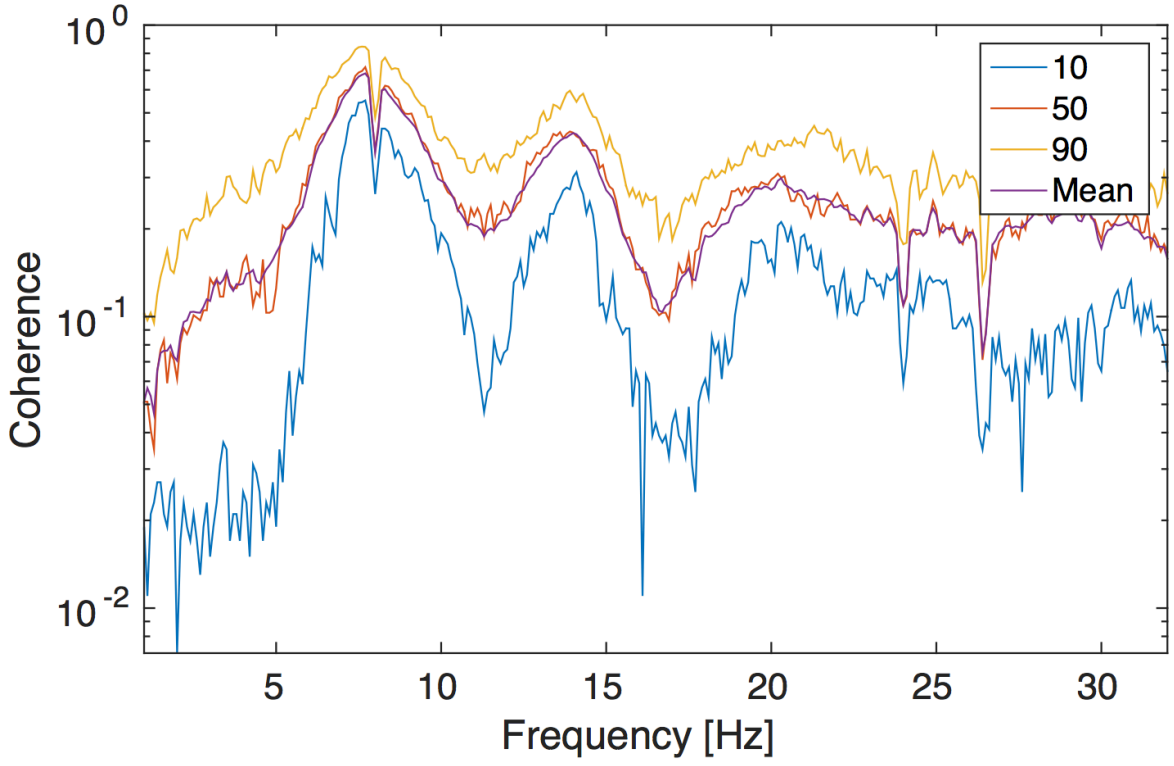

$Fs = 100\mathrm{Hz},\ T_{\mathrm{FFT}} = 120\mathrm{s}$

Some glitches caused by human activity were detected !

# Result of measurement

- **Compare KAGRA with Virgo**

Virgo team calculated the coherence between KAGRA site with Virgo site



# Result of measurement

From the result of measurement :

1. Amplitude of magnetic field was few pT
2. However amplitude of magnetic field inside the tunnel was larger than outside of the tunnel
3. Some glitches caused by human activity were measured
4. Coherence of KAGRA site and Virgo site were good

# Contents

- Calibration
- Result of Measurement
- **Data quality**
- Conclusion & Future Works

# Data Quality

- We focus on the Gaussianity because it determines the performance of Wiener filter

To evaluate the data quality we used 3 values :

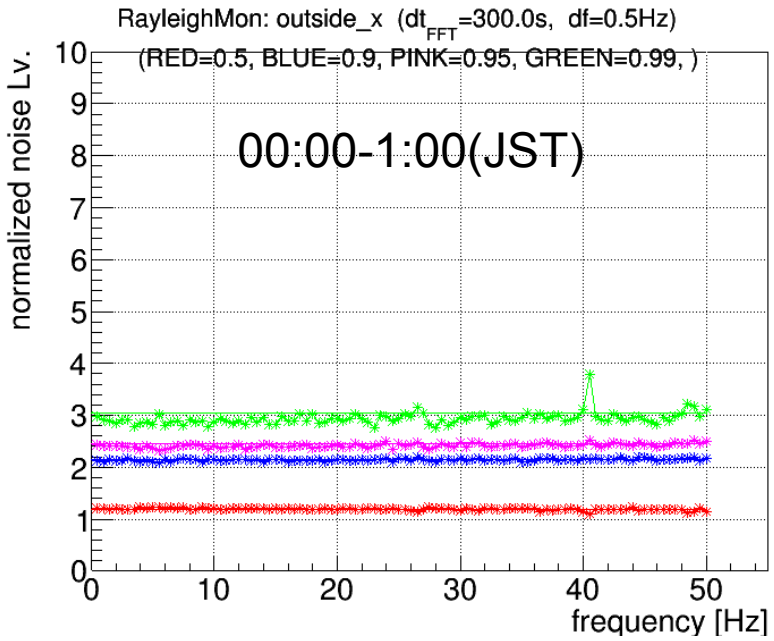
1. Rayleigh Monitor
2. Spectrogram-histogram
3. Line-Tracking

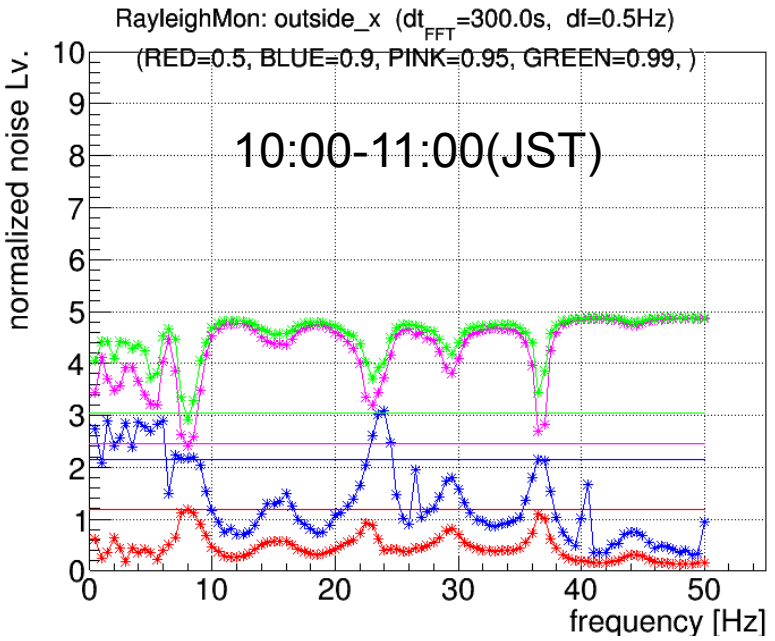
We used **HasKAL** to evaluate the Data Quality
Links: https://github.com/gw-analysis/detector-characterization

# Data Quality

## ■ Rayleigh Monitor

Rayleigh Monitor calculates deviation of the detector noise from Gaussian distribution



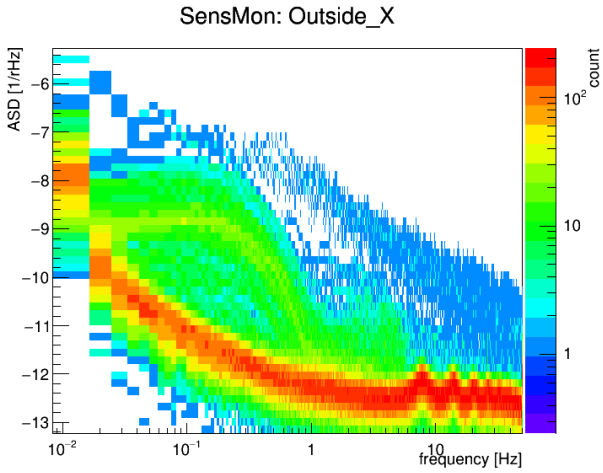



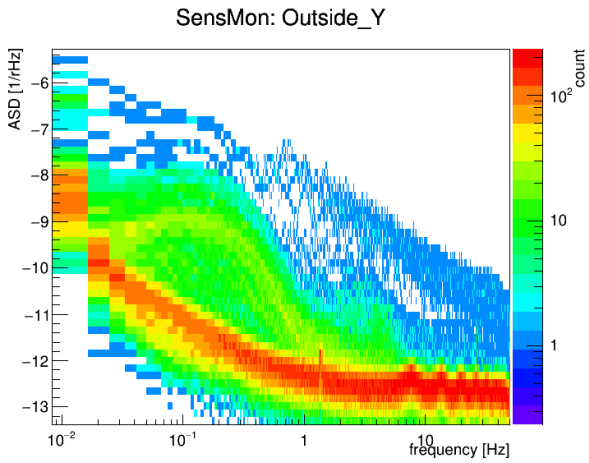

Even in the daytime, deviation of the detector noise from Gaussian distribution is not so large

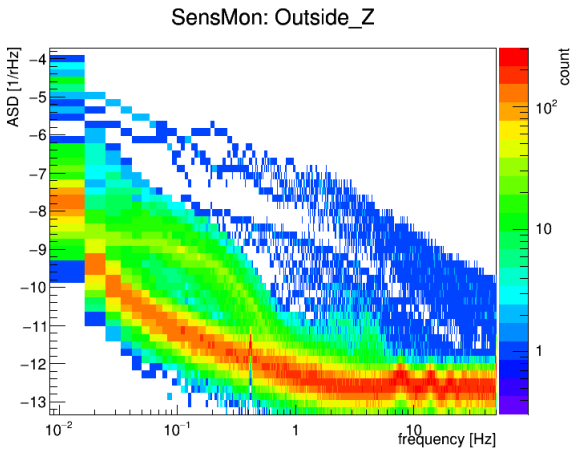
# Data Quality

## ■ Spectrogram - Histogram

- Calculate Spectrogram-Histogram from 26 hours data (Outside of tunnel)
- $T_{FFT}$ = 120s, Fs = 100Hz



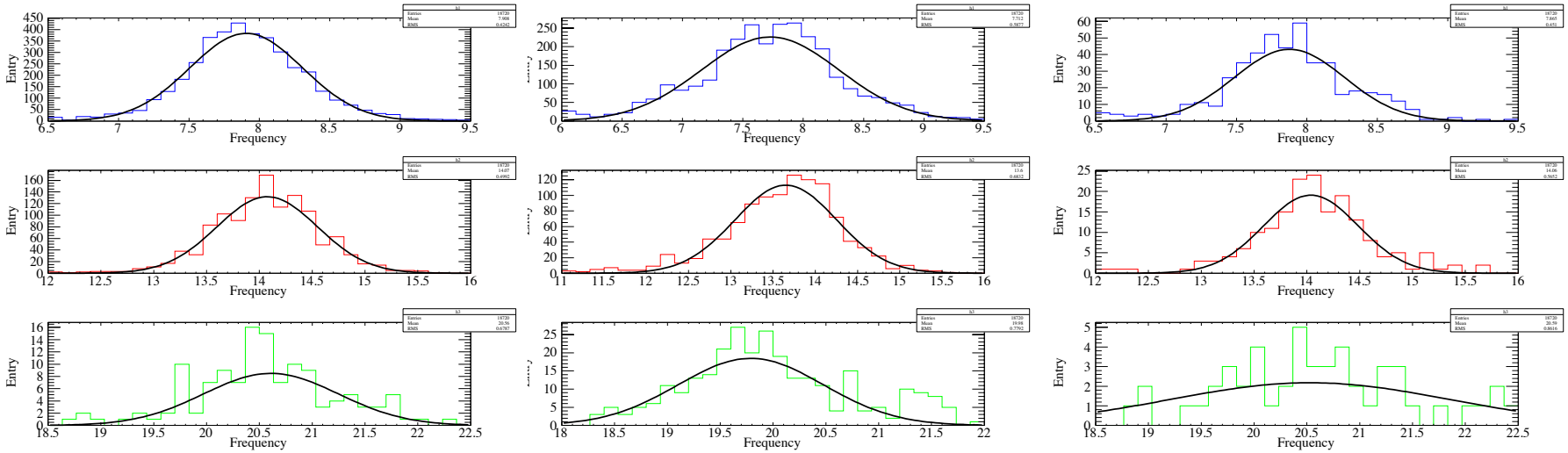

- More than 90% signals concentrates the mean value of spectrum

➡ Measurement is good

# Data Quality

- **Line-Tracking (calculated by Ueno-san)**

Tracking the resonant **frequency** of schumann resonance( 1st 2nd 3rd )




We concluded the fluctuation of the resonant frequency showed Gaussian distribution

# Contents

- Calibration
- Result of Measurement
- Data quality
- **Conclusion & Future Works**

# Conclusion & Future works

We concluded :

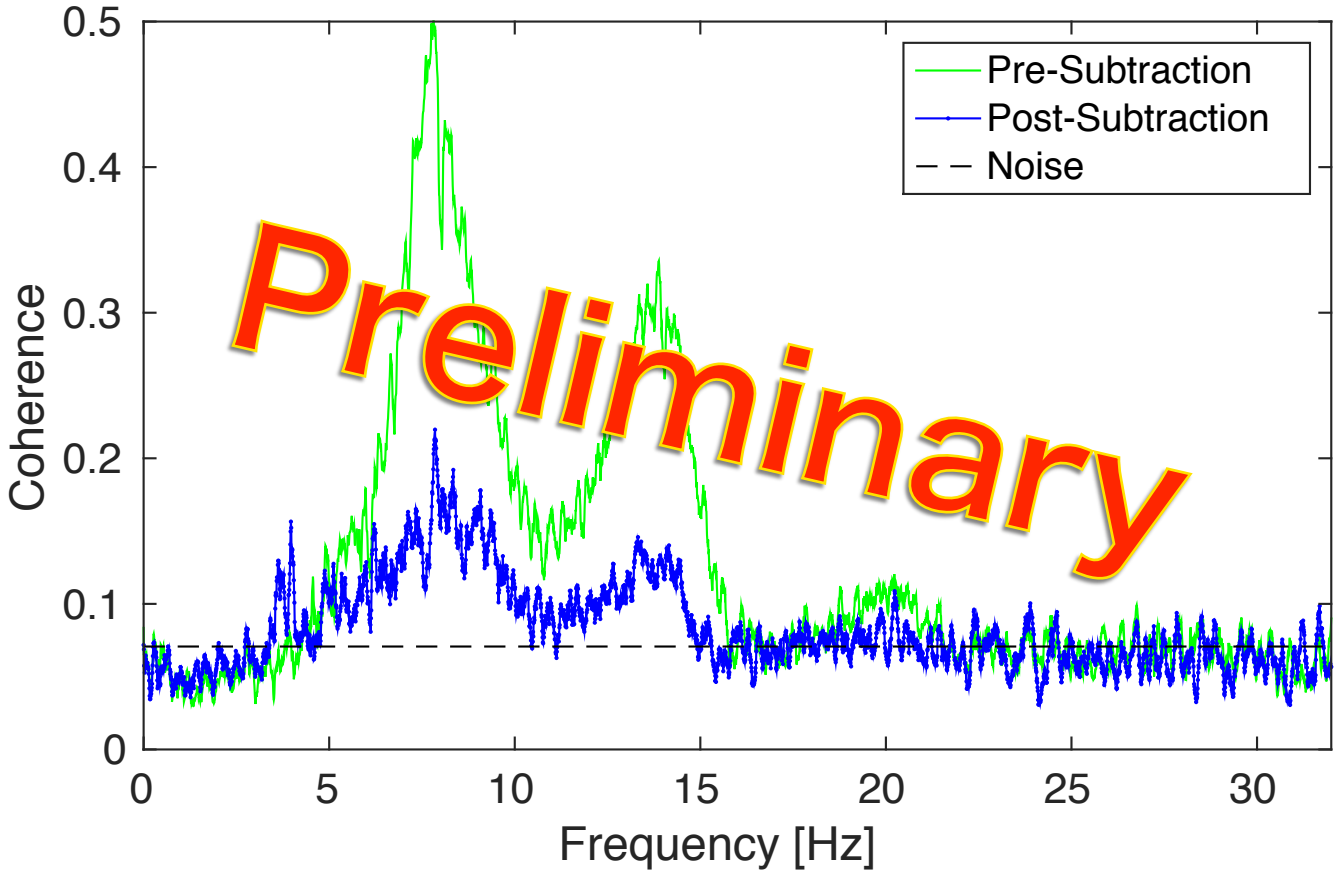
1. Measurement and calibration were successful 
2. Data quality was enough to make a Wiener filter 
3. Magnetic field inside the tunnel was larger than outside but we could not understand the true reason. ? 

In the future :

1. Make the wiener filter
2. Evaluate the performance of the filter
3. Understand the difference between inside and outside of tunnel

# Status

Virgo team calculated the wiener filter and checked the performance



# Acknowledgement

This study were supported many people and especially ,

- **Koh Ueno**
- **Takahiro Yamamoto**
- **Yutaka Shikano**

**Thank you very much!!**

# Data

We have three magnetic filed data :

Measured at Shin-Atotsu (2016/07/21 05:00:00 ~ 2016/07/22 07:00:00 GMT )

Measured at Shin-Atotsu (2016/07/21 10:00:00 ~ 2016/07/22 06:00:00 GMT)

Measured inside KAGRA (2016/07/21 07:30:00 ~ 2016/07/21 08:30:00 GMT)

# Bibliography

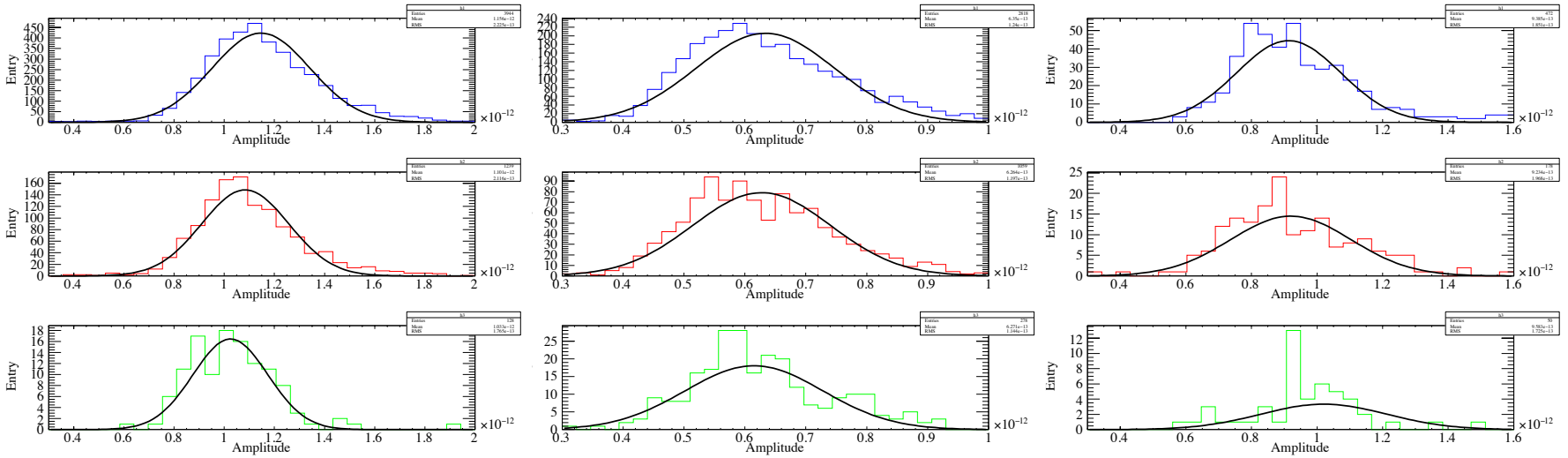
[1] Schumann Resonance for Tyros (Nickolaenko and Hayakawa)

# Supplementary slides

# Data Quality

- **Line-Tracking (calculated by Ueno-san)**

Tracking the **Amplitude** of schumann resonance( 1st 2nd 3rd )



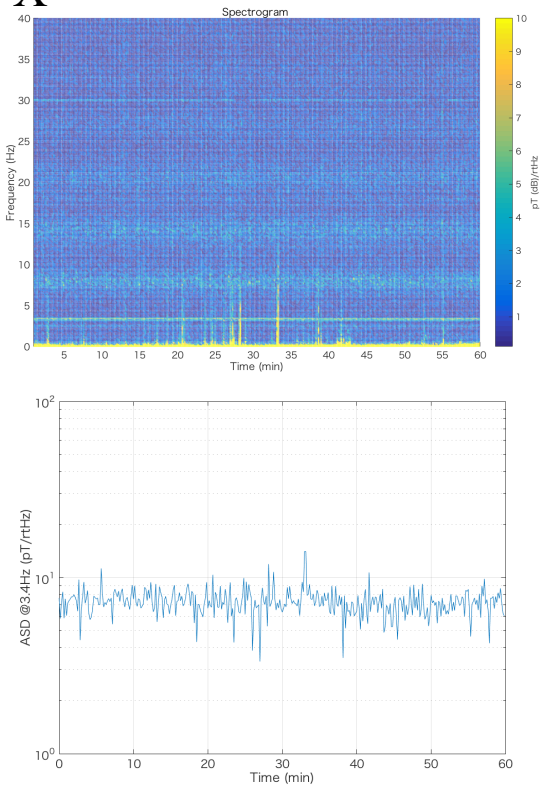

Fluctuation of resonant frequency showed square of $\chi^2$ distribution

# Data Quality

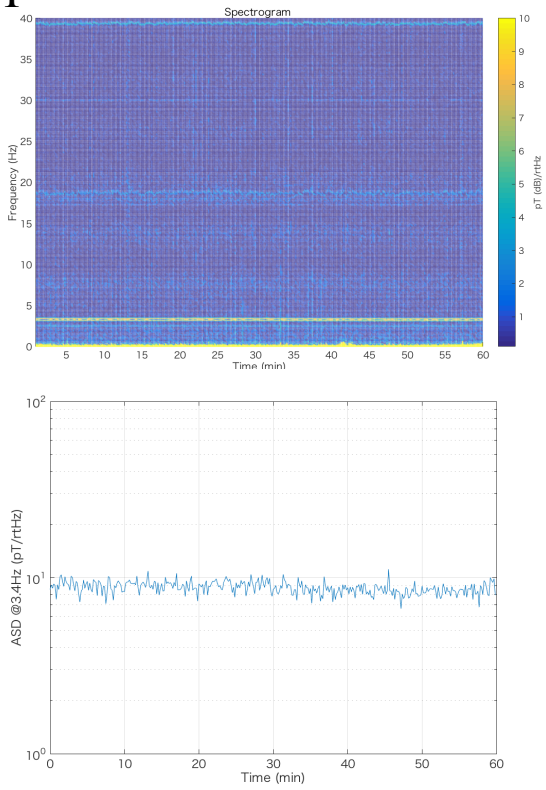
## ■ Spectrogram

Calculate the spectrogram inside the tunnel

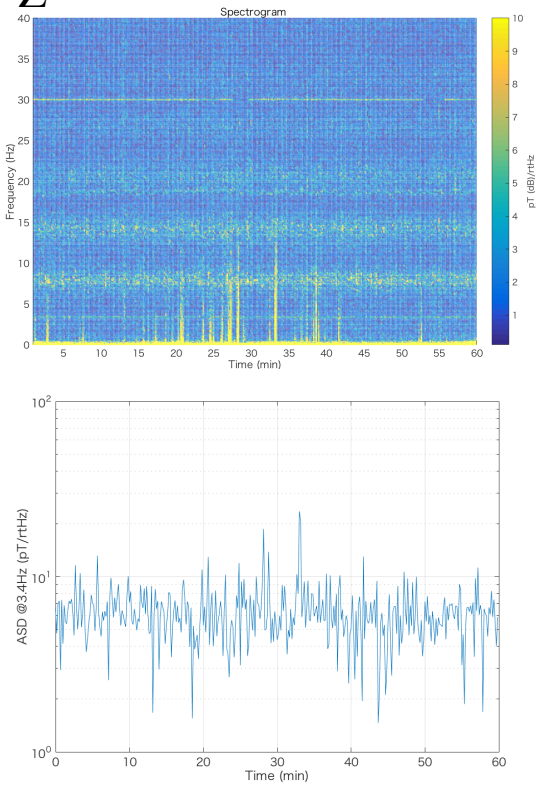
X




Y




Z

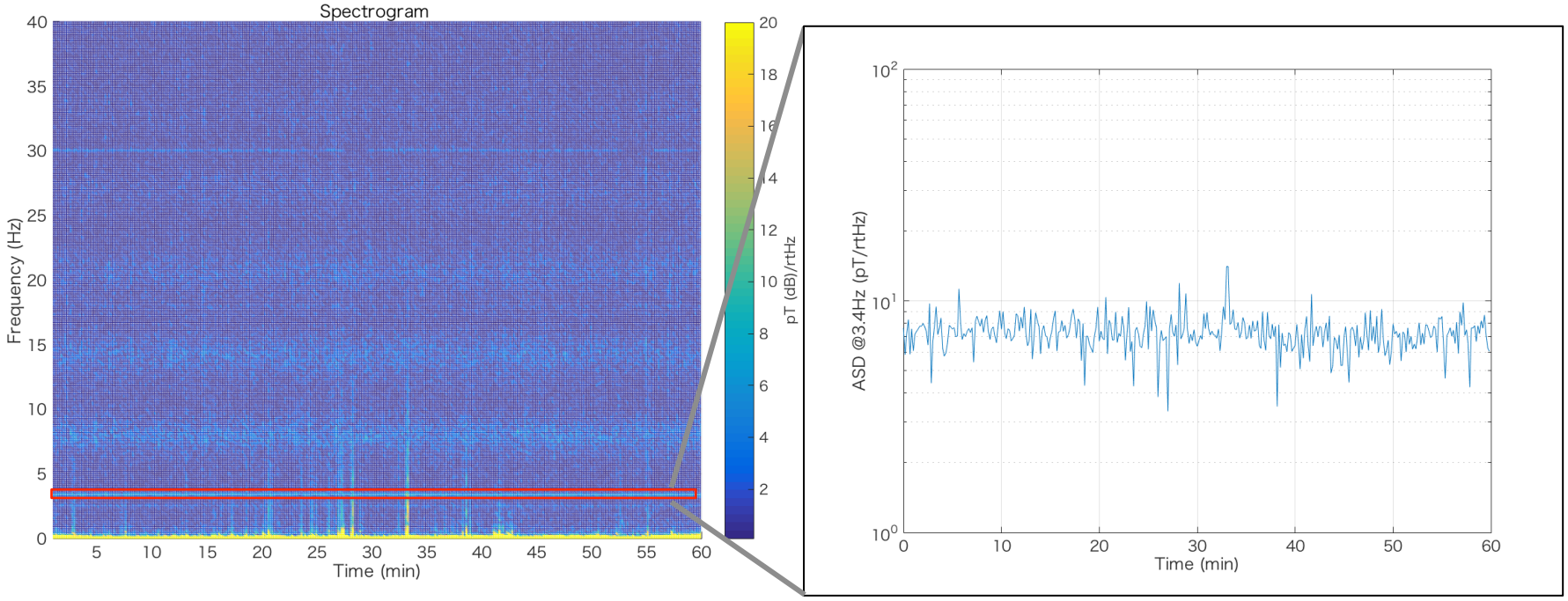



$Fs = 250\mathrm{Hz}, T_{\mathrm{FFT}} = 10\mathrm{s}$

# Data Quality

## ■ Spectrogram

Calculated the spectrogram of inside the tunnel

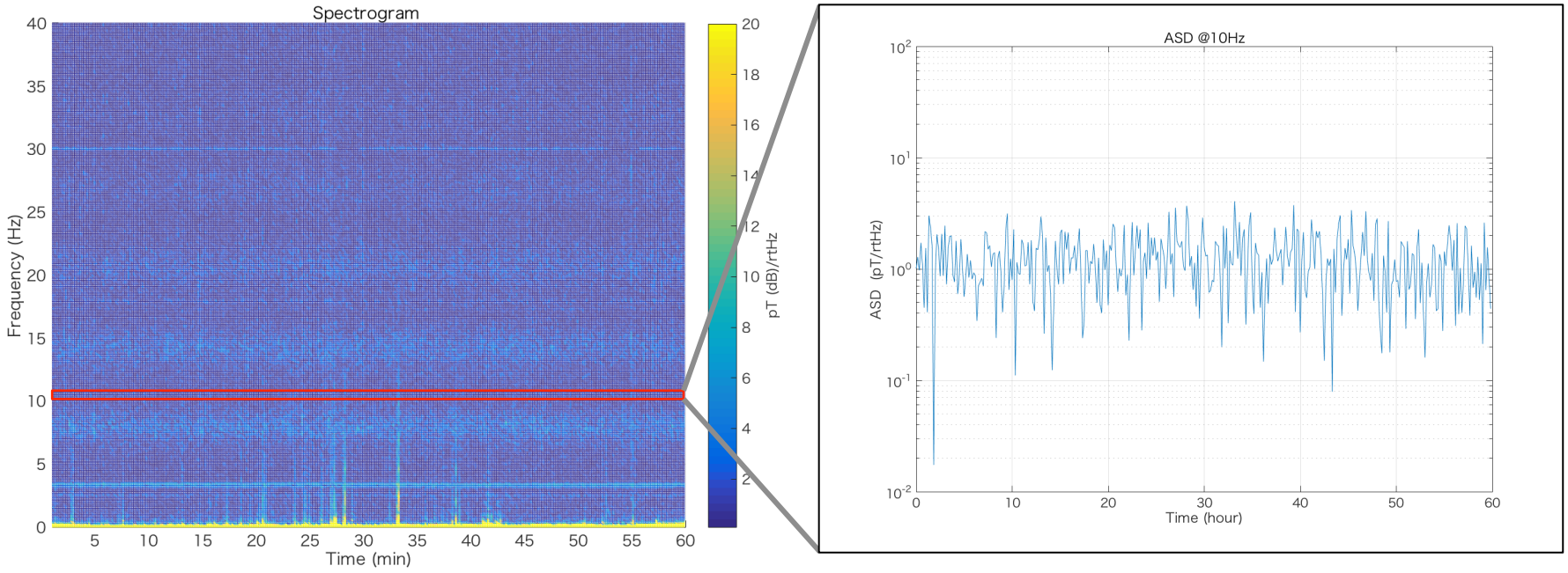



$$Fs = 250\mathrm{Hz}, T_{\mathrm{FFT}} = 10\mathrm{s}$$

# Data Quality

## ■ Spectrogram

Calculated the spectrogram of inside the tunnel

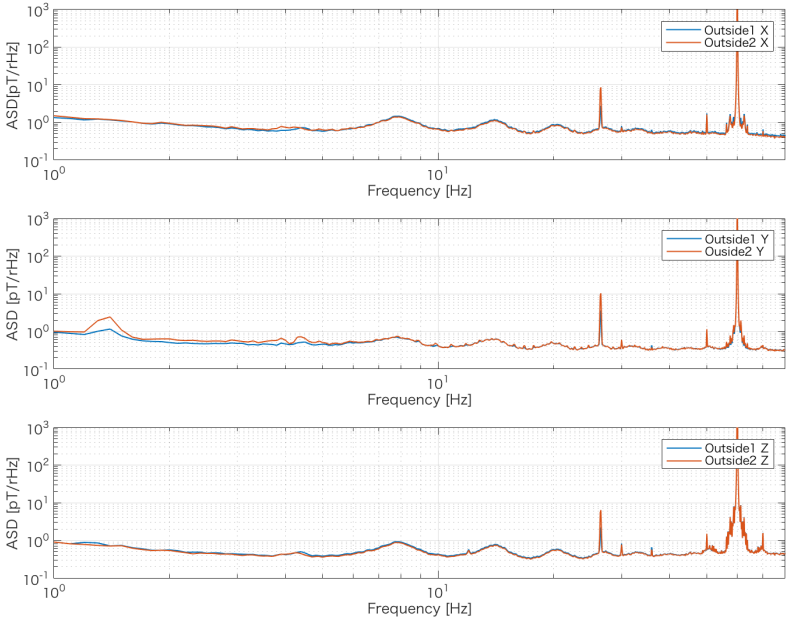


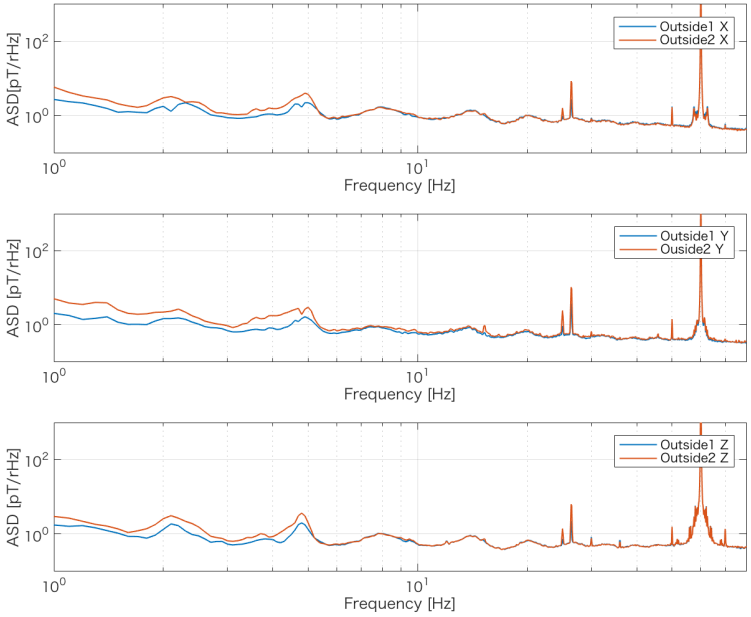

$$Fs = 250\mathrm{Hz}, T_{\mathrm{FFT}} = 10\mathrm{s}$$

# Data Quality

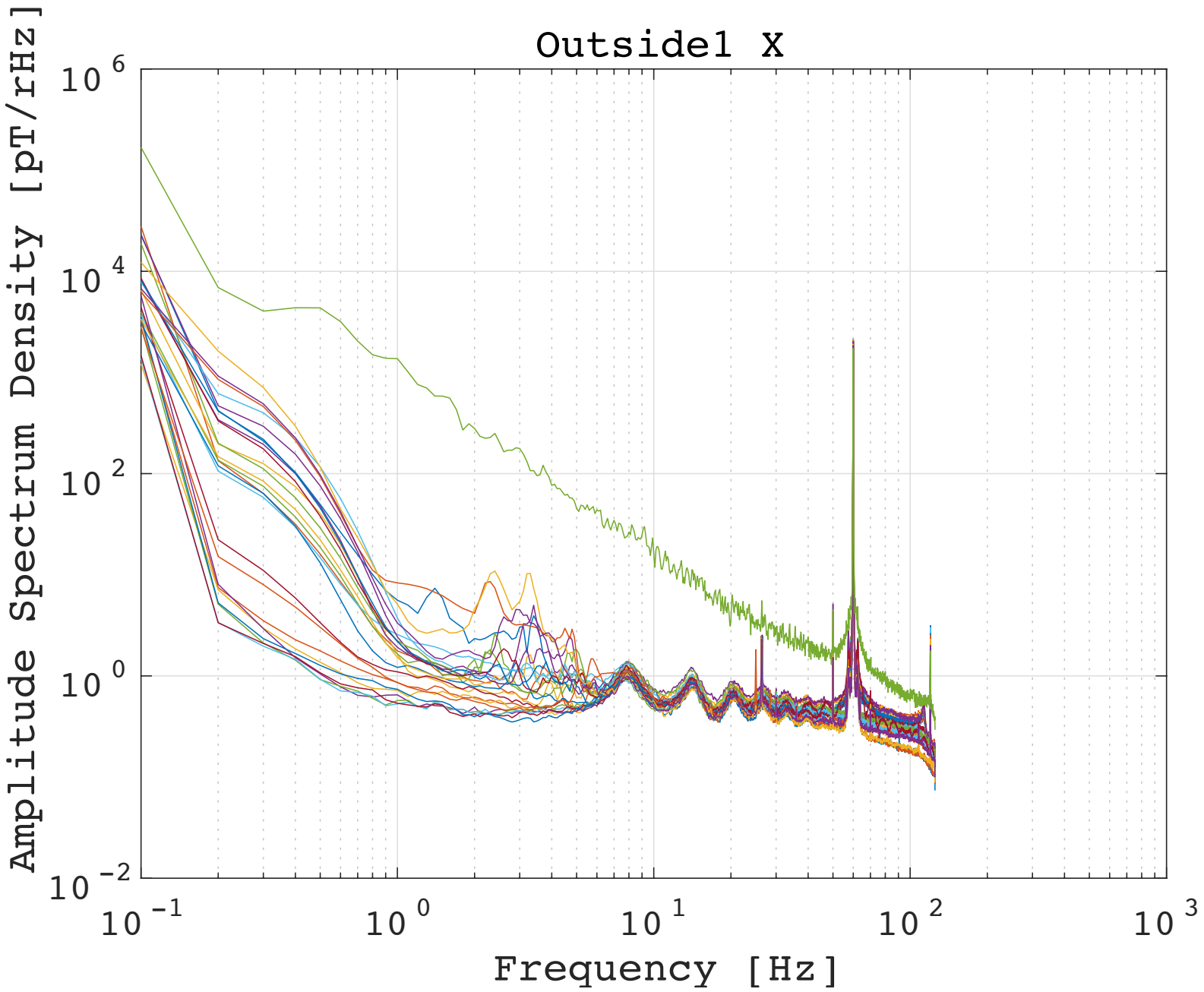
- **Outside1 vs Outside2**

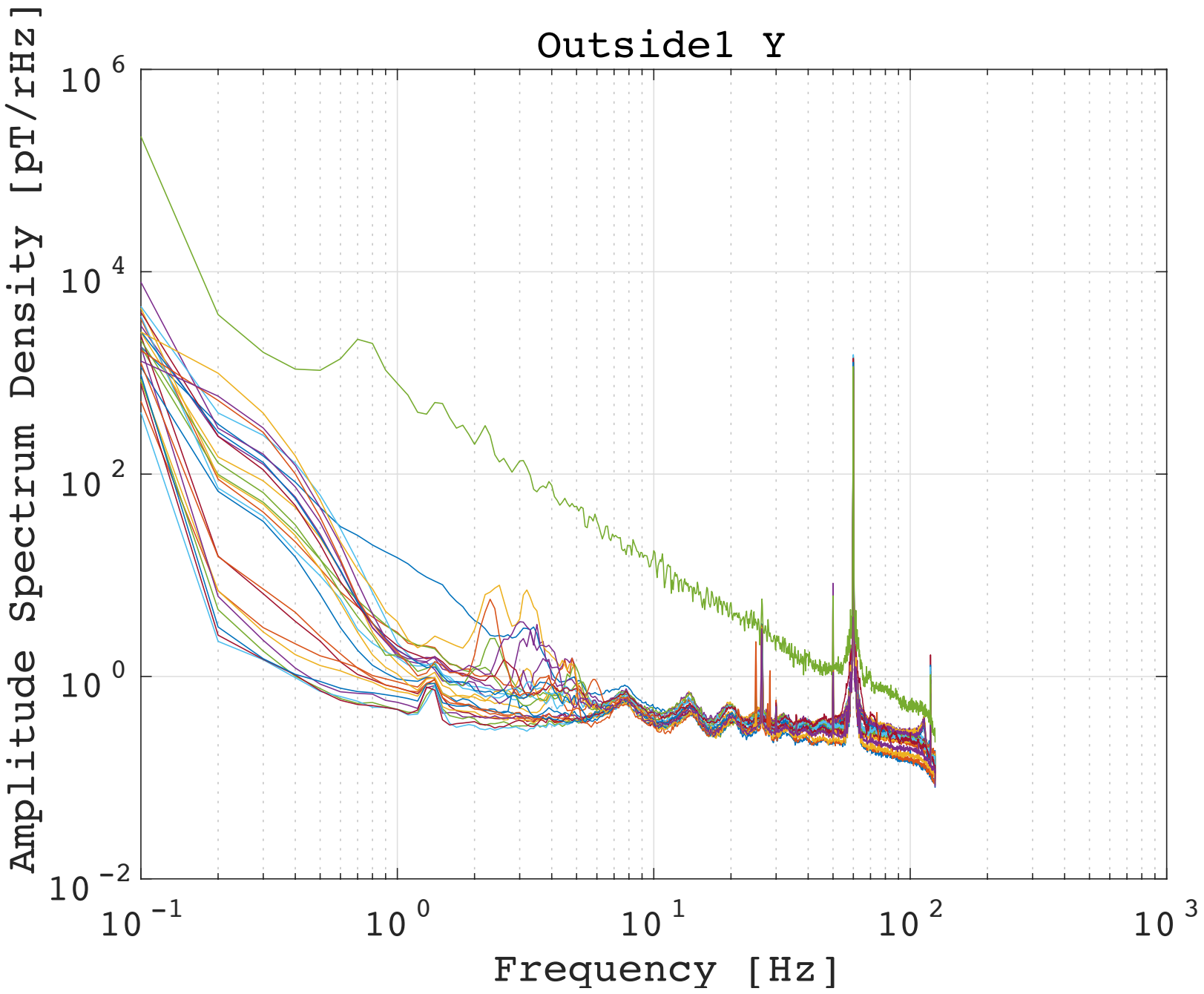
Almost same => Two detector were almost same

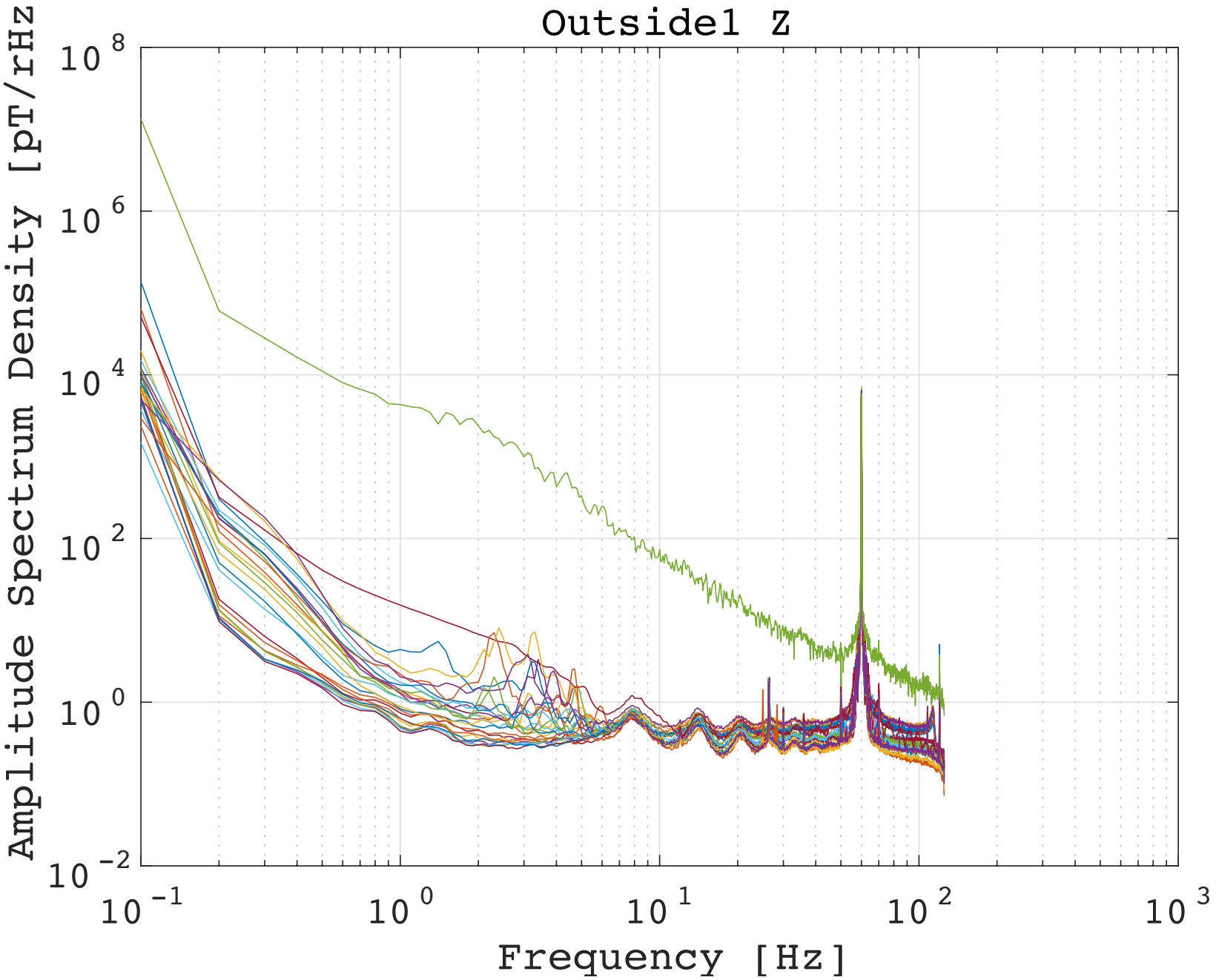


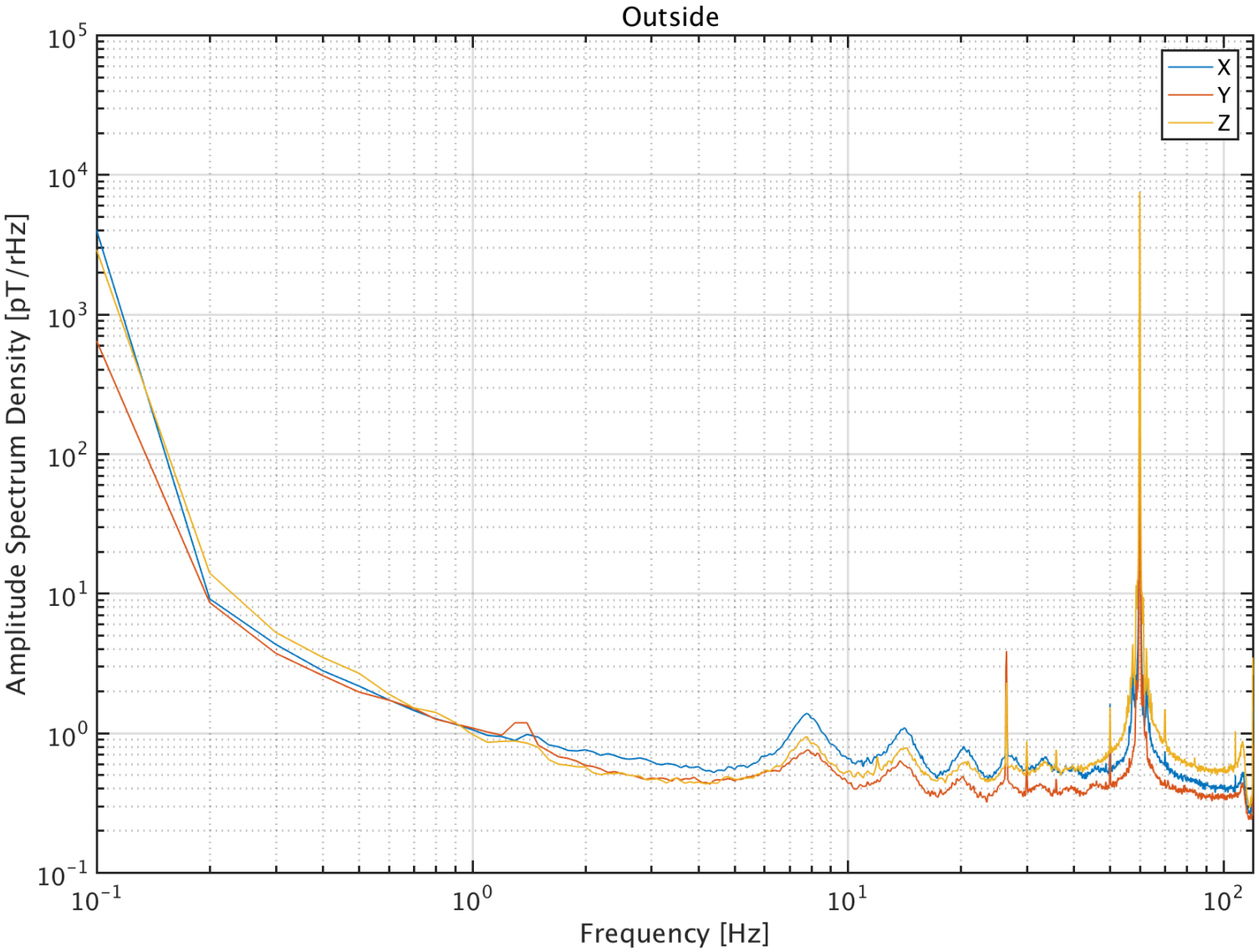



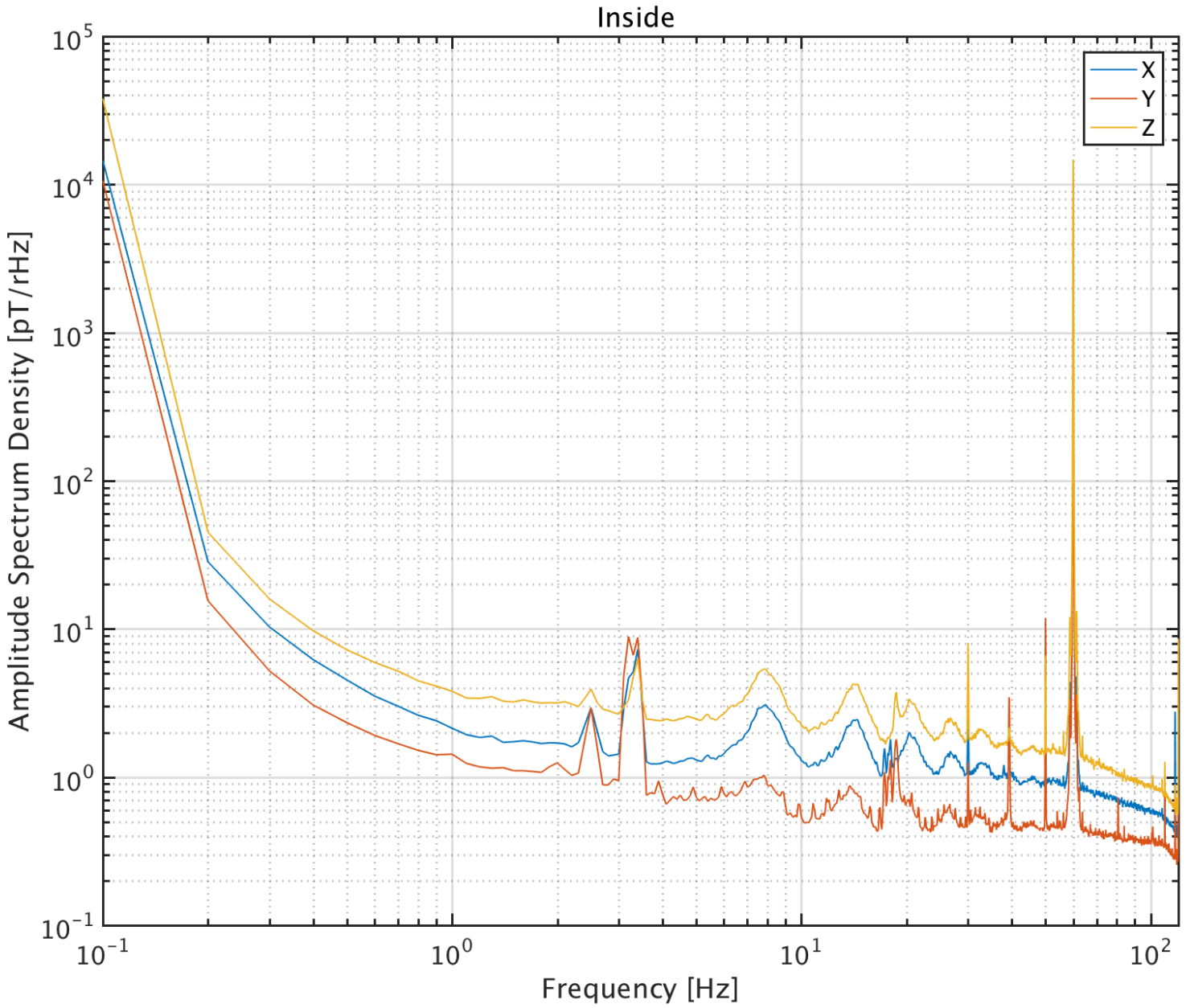
# Spectrum


Outside1 X
Amplitude Spectrum Density [pT/rHz]
10 6
10 4
10 2
10 0
10 -2
10 -1
10 0
10 1
10 2
10 3
Frequency [Hz]


Outside1 Y
Amplitude Spectrum Density [pT/rHz]
Frequency [Hz]
10^6
10^4
10^2
10^0
10^-2
10^-1
10^0
10^1
10^2
10^3


Outside1 Z
Amplitude Spectrum Density [pT/rHz]
Frequency [Hz]
10^8
10^6
10^4
10^2
10^0
10^-2
10^-1
10^0
10^1
10^2
10^3


Outside
X
Y
Z
Amplitude Spectrum Density [pT/rHz]
Frequency [Hz]
$10^{5}$
$10^{4}$
$10^{3}$
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$


Inside
X
Y
Z
Amplitude Spectrum Density [pT/rHz]
Frequency [Hz]
$10^{5}$
$10^{4}$
$10^{3}$
$10^{2}$
$10^{1}$
$10^{0}$
$10^{-1}$
$10^{-1}$
$10^{0}$
$10^{1}$
$10^{2}$