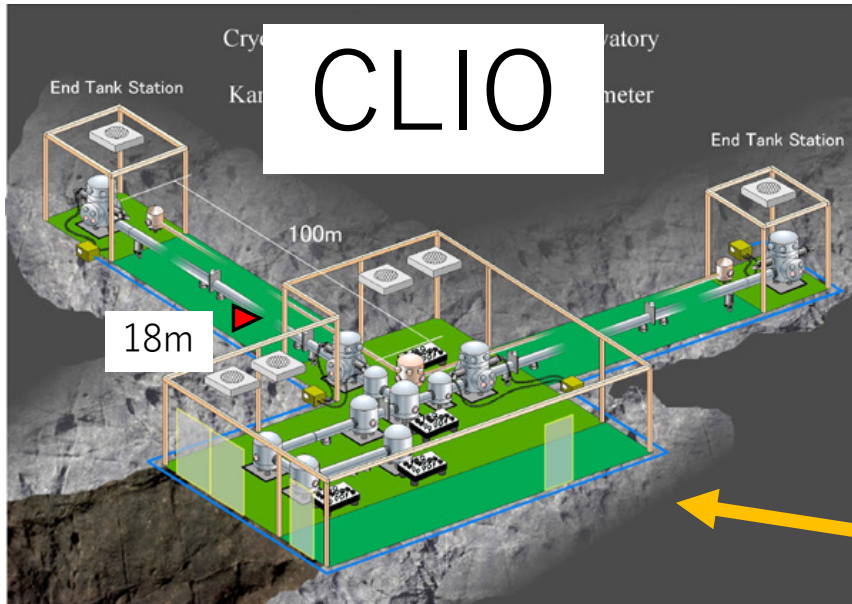


Schumann Resonance Measurement

Isamu Fukunaga (Osaka Metropolitan University)

2022-09-20 VK PEM meeting

Measurement Location

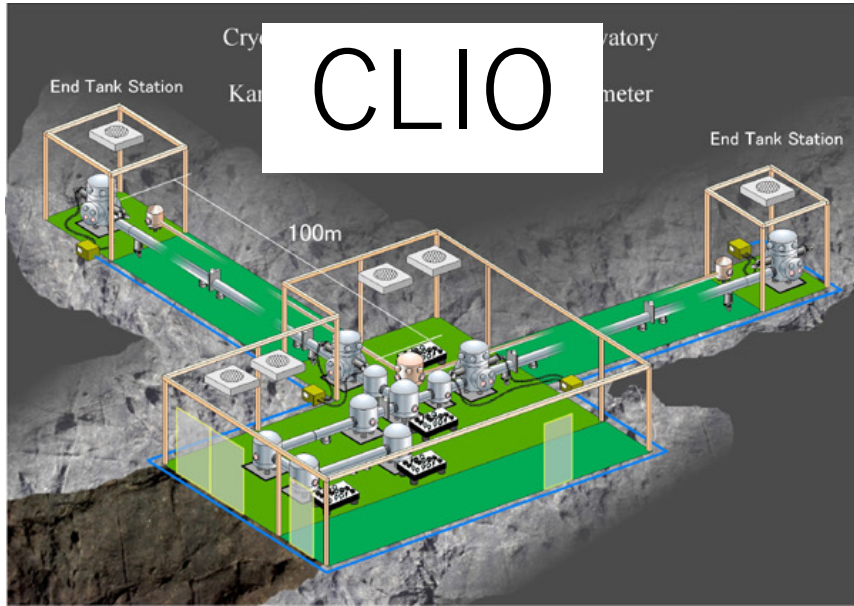


Location
PEM area
Yarm(30 m)
CLIO Yarm (18 m)
KAGRA Front room
Xarm(1500 m, 2440 m)
Outside



At the red triangular point, we took measurement around the beam duct.

Measurement Location



The directions of the measured magnetic field are aligned with the direction of the arm in each site.

Setup for Measurements

Scaling Dependent Performance Parameters						
Measuring range (μT)	± 60	± 70	± 100	± 250	± 500	± 1000
Scaling ($\text{mV}/\mu\text{T}$)	166	143	100	40	20	10
Scaling Temperature coefficient ppm/ $^{\circ}\text{C}$	± 15		± 20	± 100	± 100	± 200
Offset in zero field (nT)	± 5 (0.83mV)	± 5 (0.71mV)	± 5 (0.5mV)	± 12 (0.5mV)	± 25 (0.5mV)	± 50 (0.5mV)
Offset temperature coefficient (nT/ $^{\circ}\text{C}$)	± 0.3	± 0.3	± 0.3	± 0.5	± 1	± 1.8

Noise Floor : $6 pT_{rms}/\sqrt{Hz}$

→ Cannot measure ground level!
Schumann resonance



GRAPHTEC DATALOGGER midi LOGGER GL980

Bartington PSU: <https://www.bartington.com/products/data-acquisition-units/psu1/>

Measurement

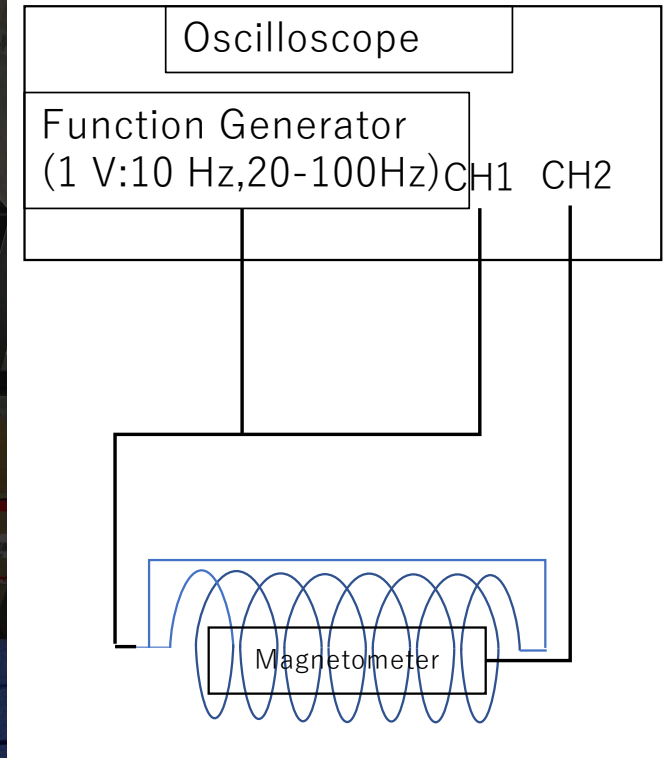
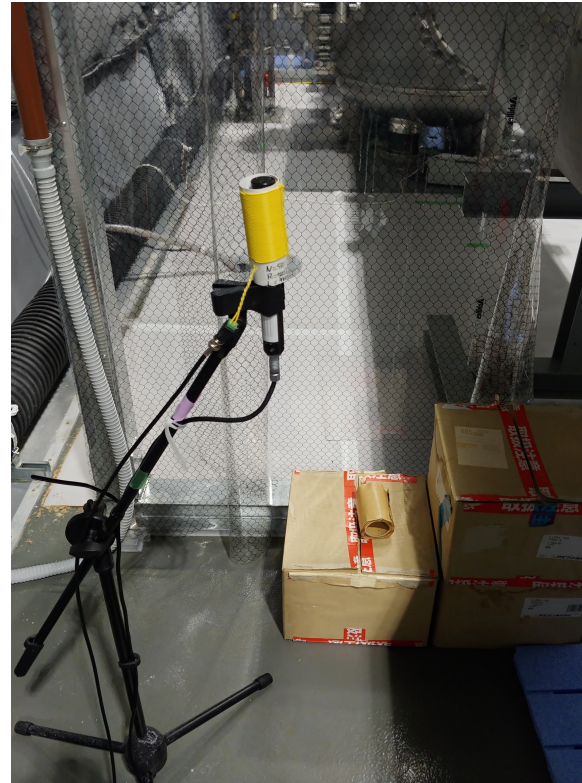
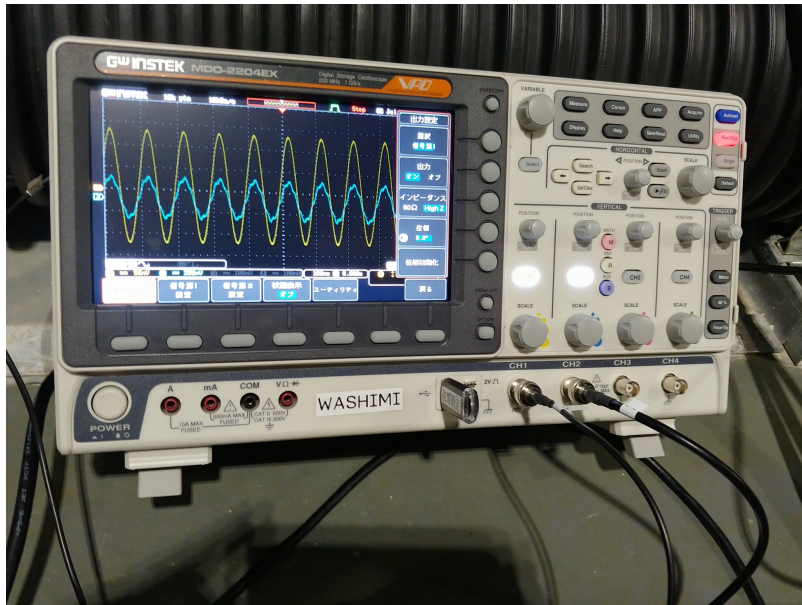


Yarm (30 m)



Xarm (2440 m) (using the battery)

Calibration



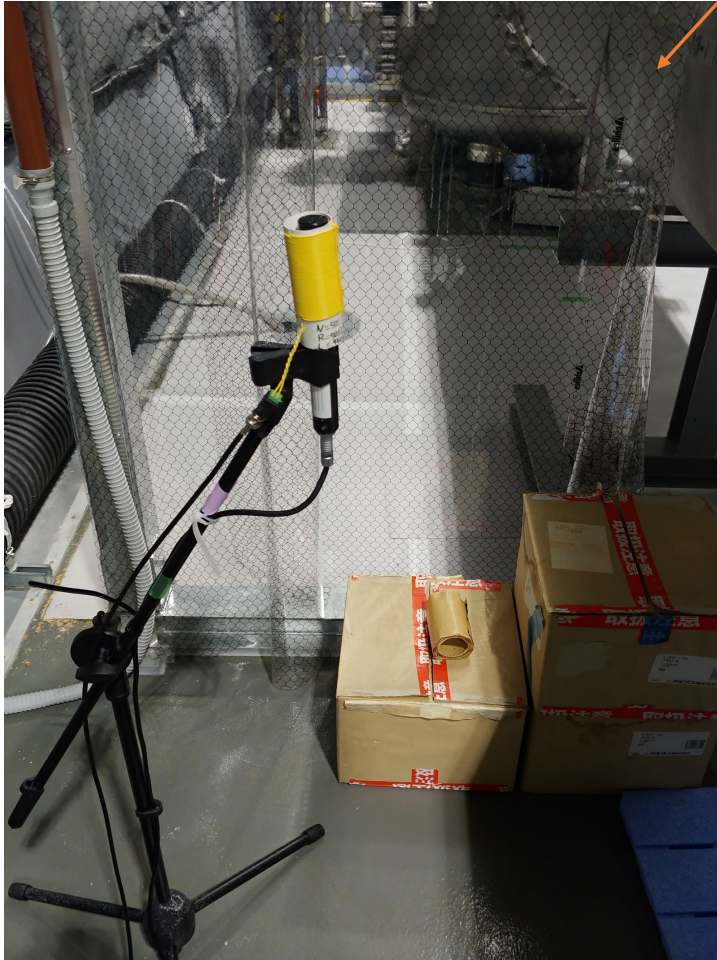
Investigate the response the magnetometer

Calibration by measuring magnet field by the coil with the magnetometer

Coil for calibration
 Radius : 2 cm
 Number of turns : 50
 Length : 7.2 cm
 Resistance : 50 Ω
 Inductance : 46 μ H

Calibration

Beam Duct (Yarm)

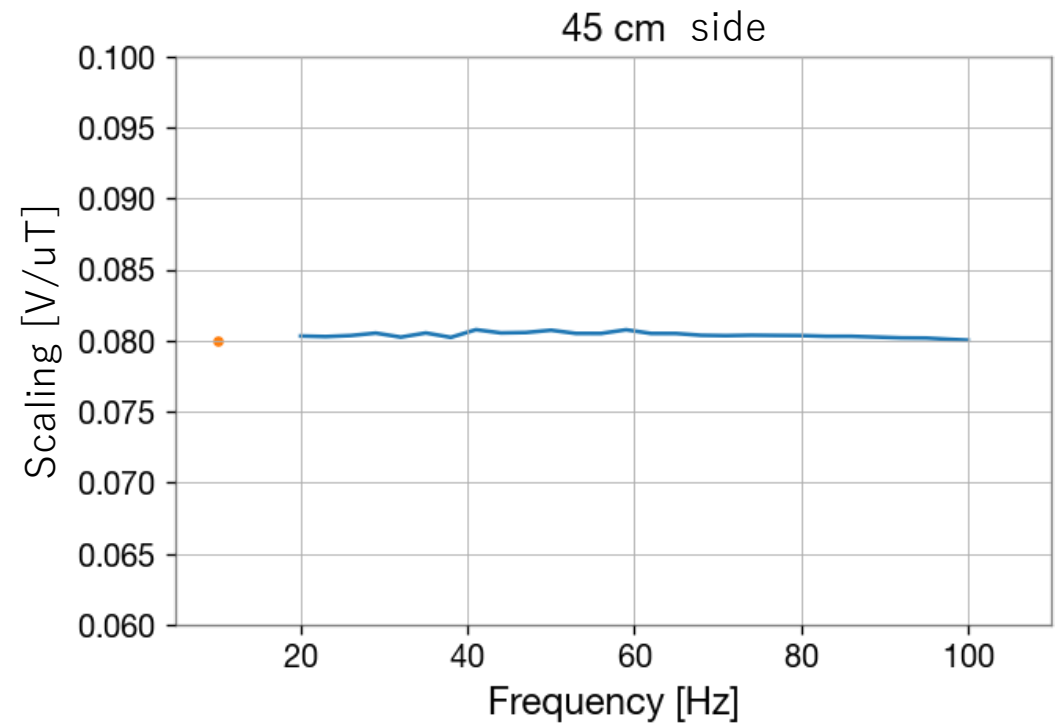
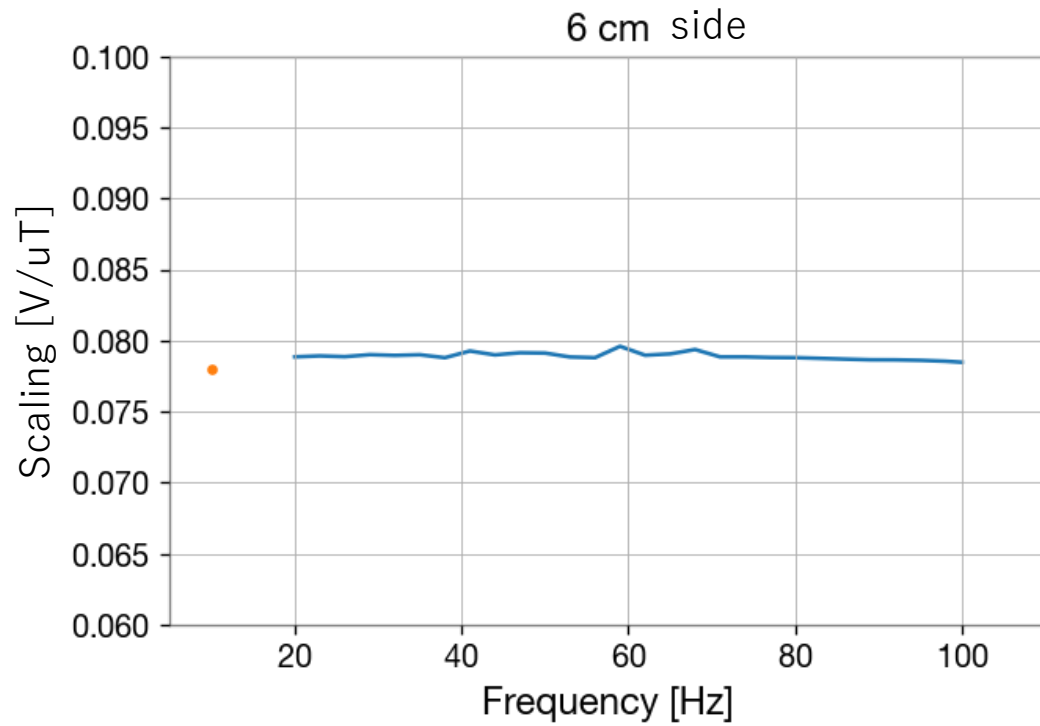


45 cm



6 cm

Calibration



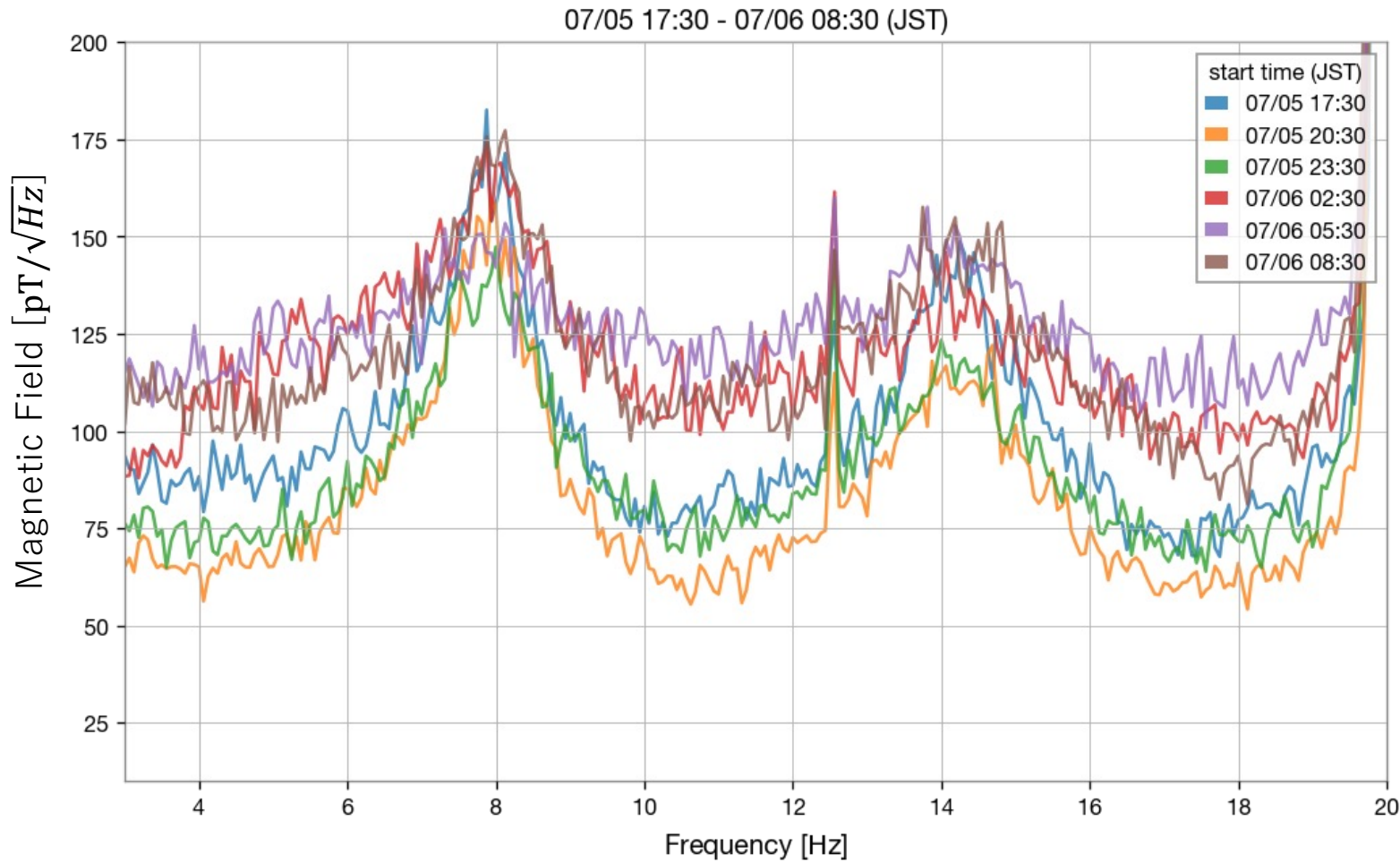
The transfer function of the magnetometer does not vary significantly with distance from the duct.

Aims of the measurement at each location

1. Yarm(30 m) : Time variation and Direction
2. Xarm(1500 m,2440 m) : Distance dependence in the arm direction
3. CLIO(18 m) : Dependence on beam duct length and Mt. Ikenoyama environment
4. Xarm(2440 m)、 Front Room : Distance dependence from beam duct

Time Dependence of ASD

measurement10
Yarm(30 m) Bottom 6cm



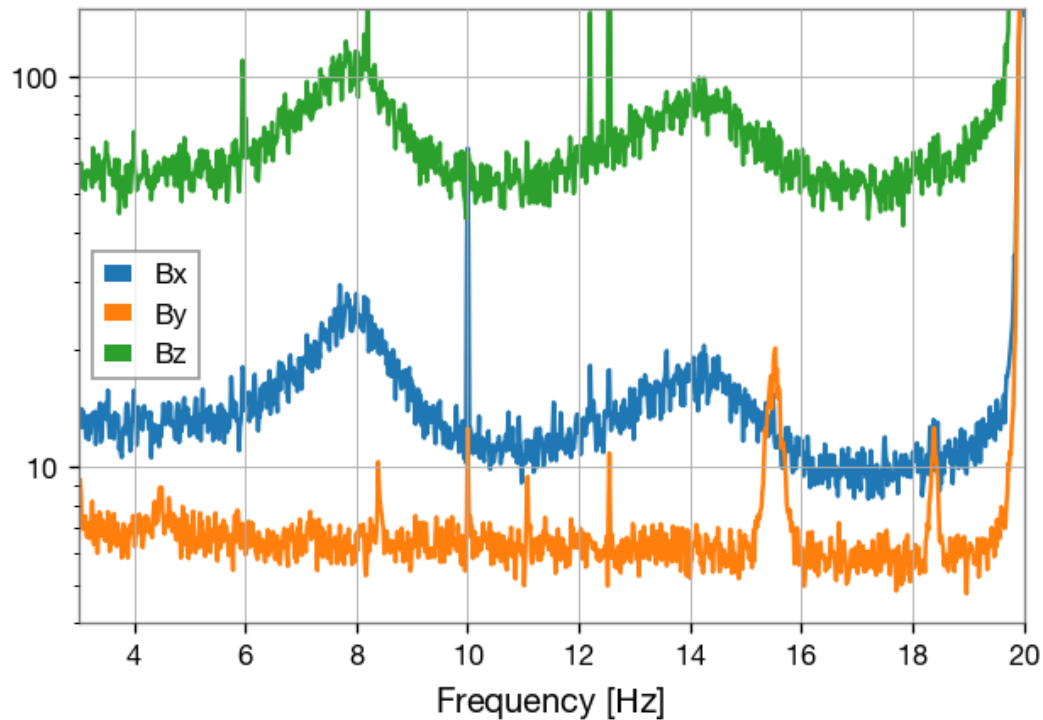
The Schumann resonance seems to be about 100 times higher than ground level $1 \text{ pT}/\sqrt{\text{Hz}}$.

Stable within about 20%.

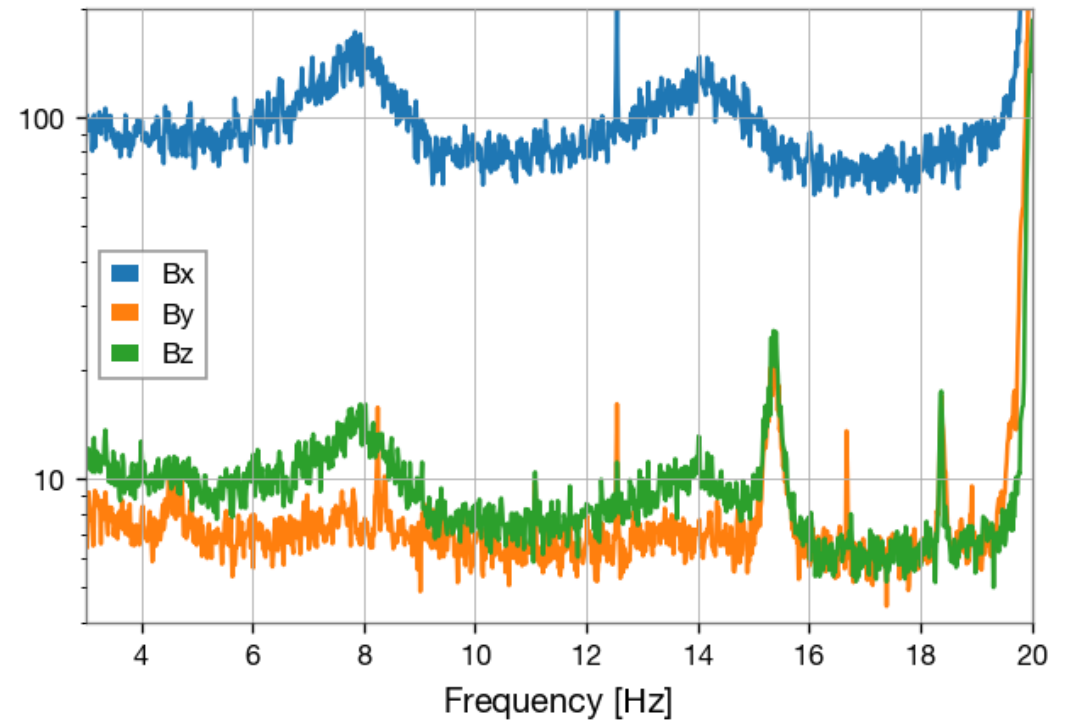
Direction of Magnet Field around Beam Duct

Yarm(30 m)

side 6cm

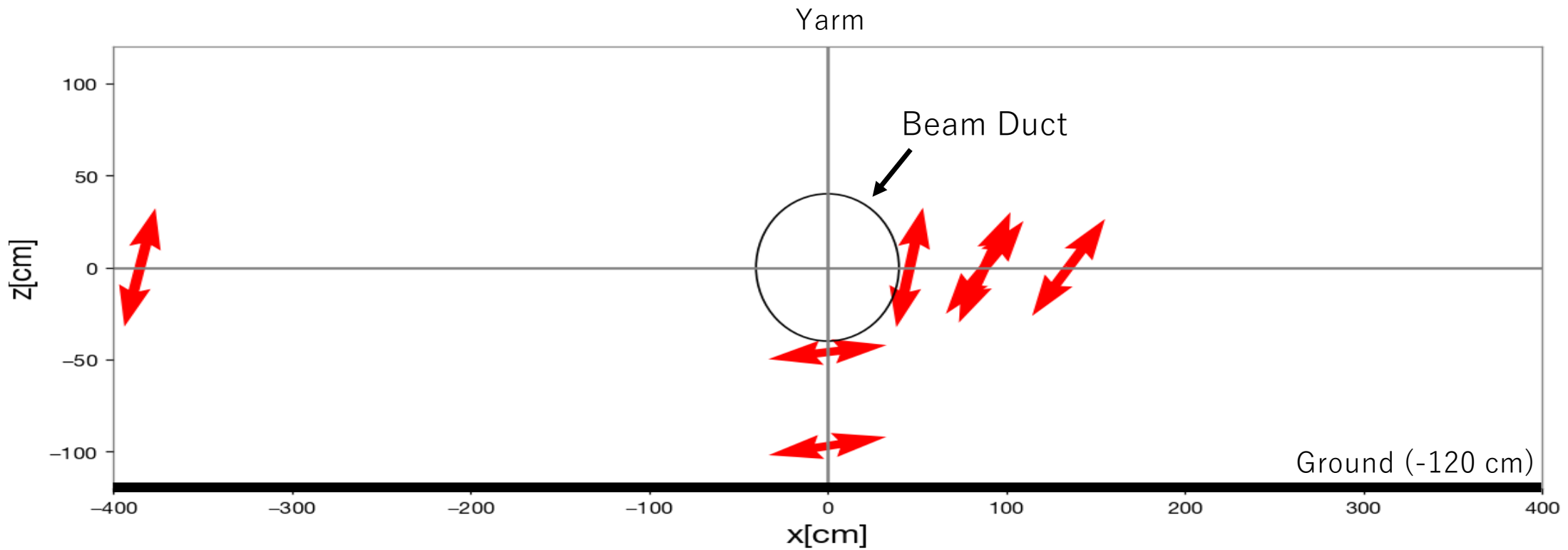


bottom 6cm



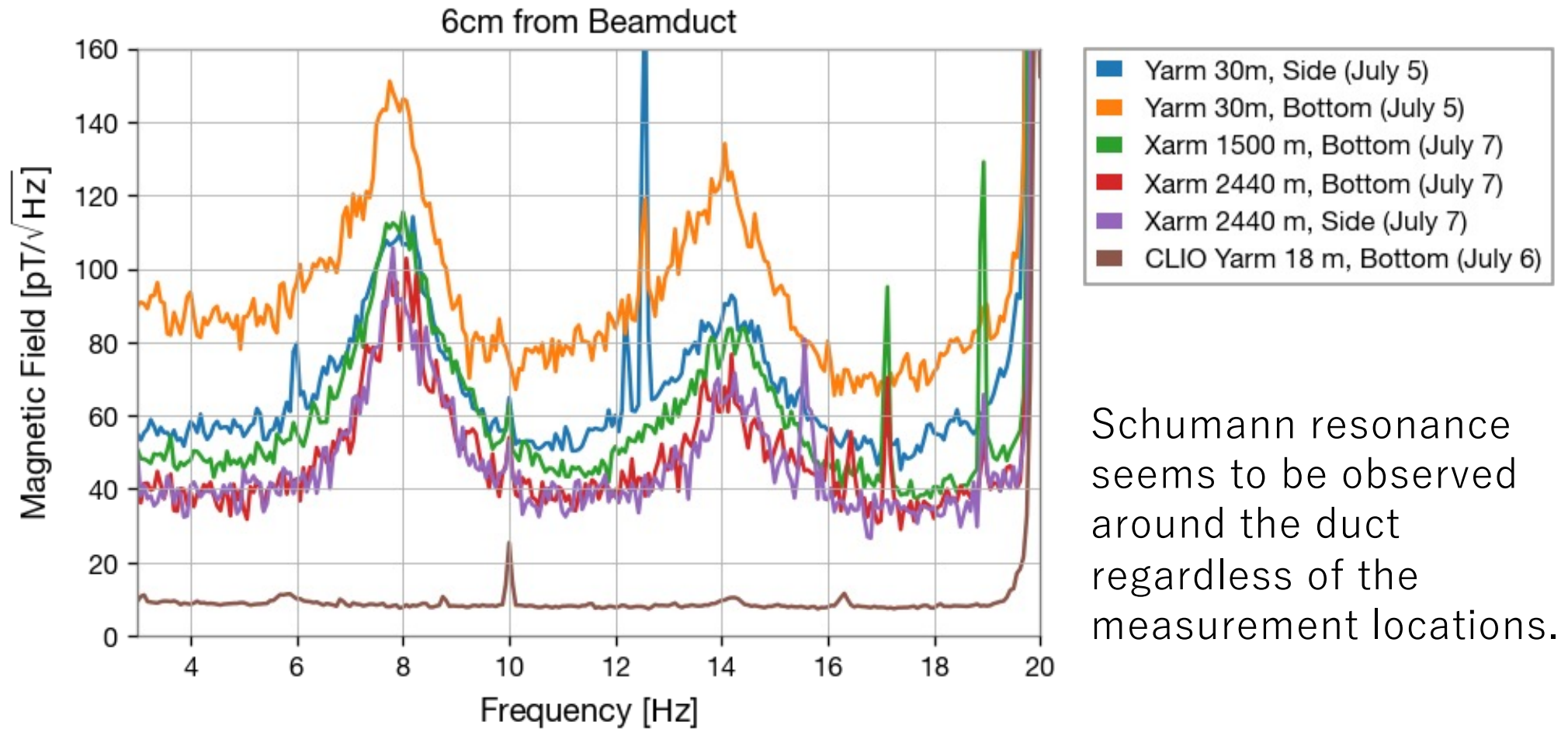
The magnetic fields in the y-direction were smaller than noise floor of the magnetometer.

Direction of Magnet Field around Beam Duct

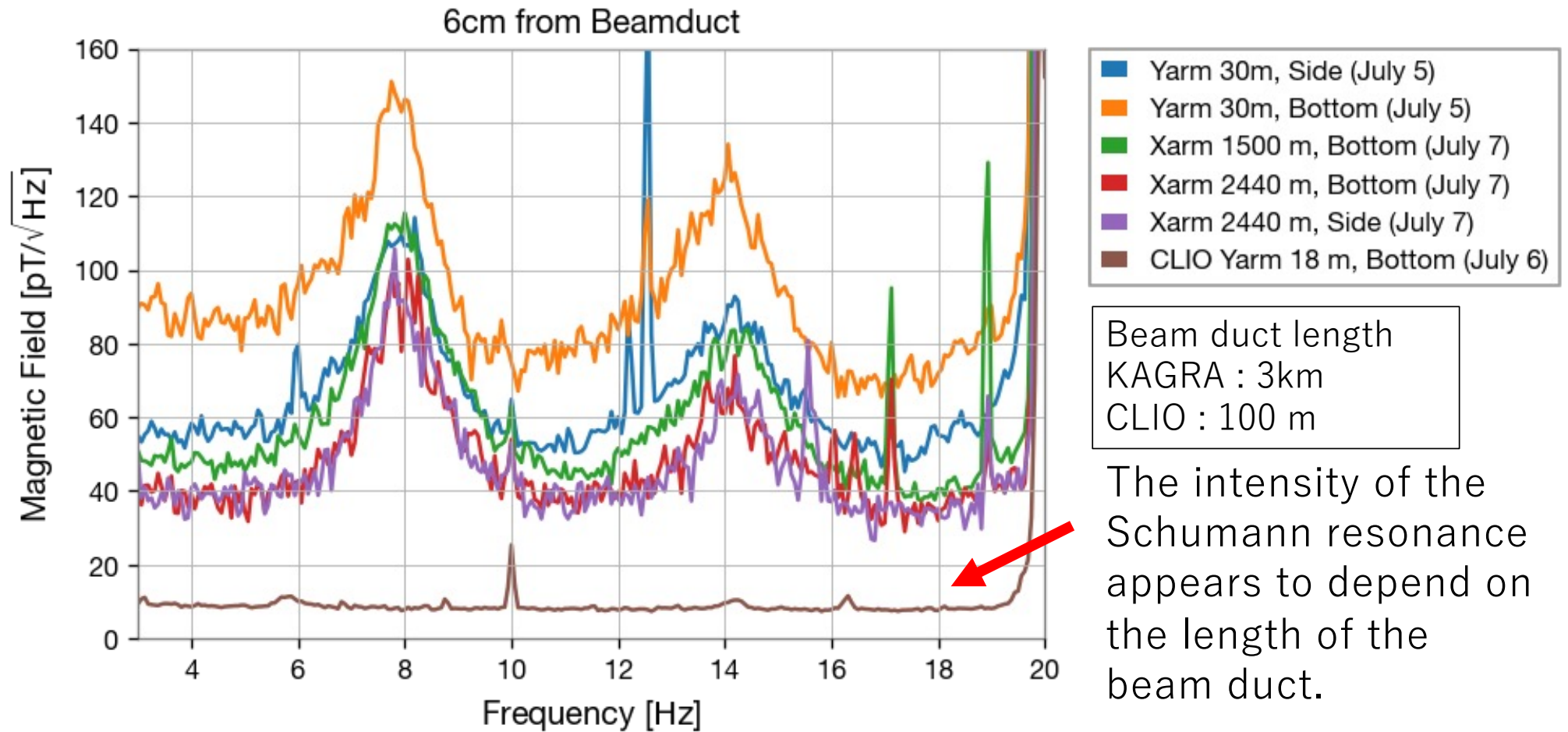


The direction of the magnetic field is the direction around the beam duct.

ASD Comparison (6 cm from Beam Duct)



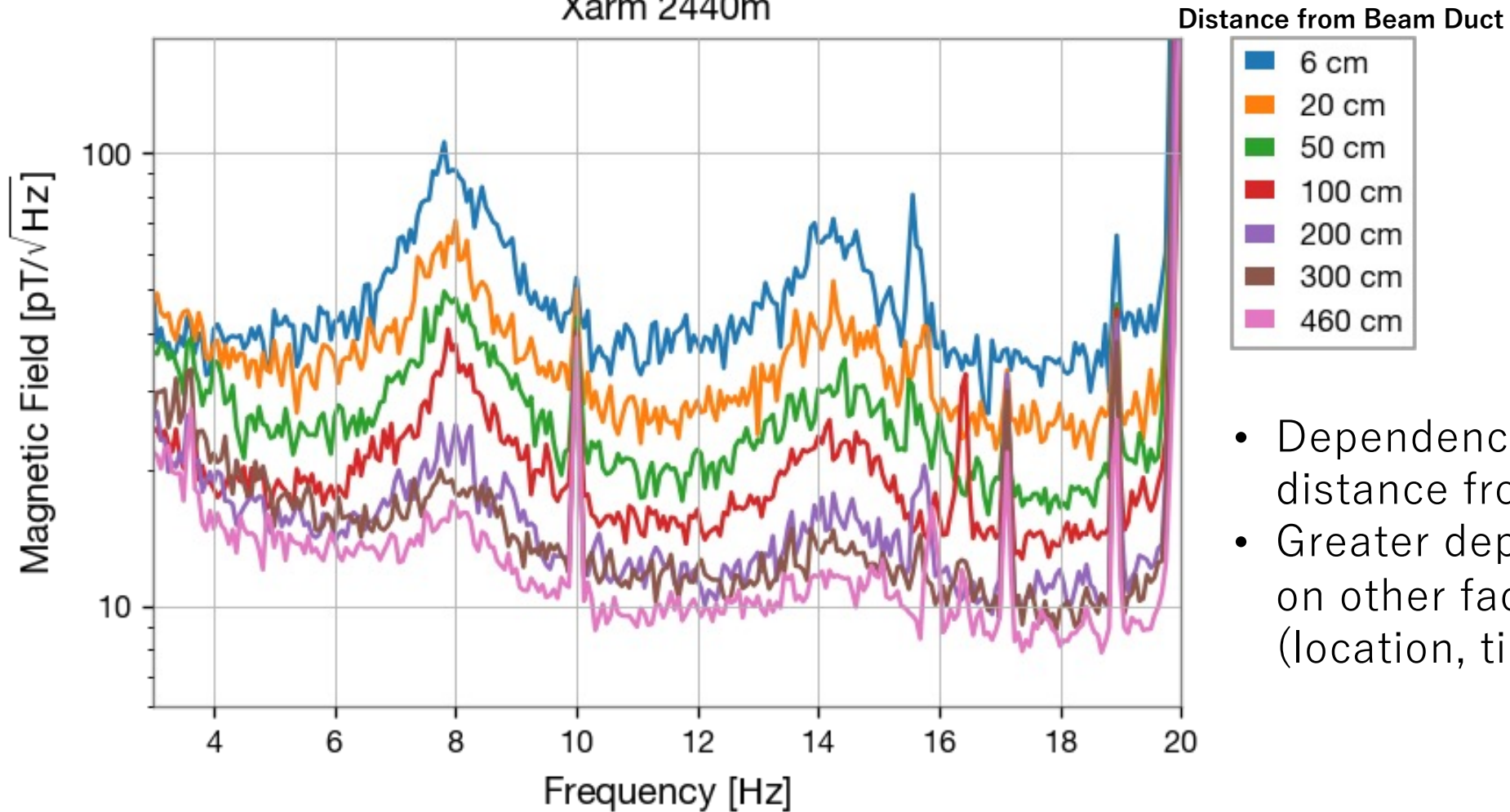
ASD Comparison (6 cm from Beam Duct)



ASD Comparison

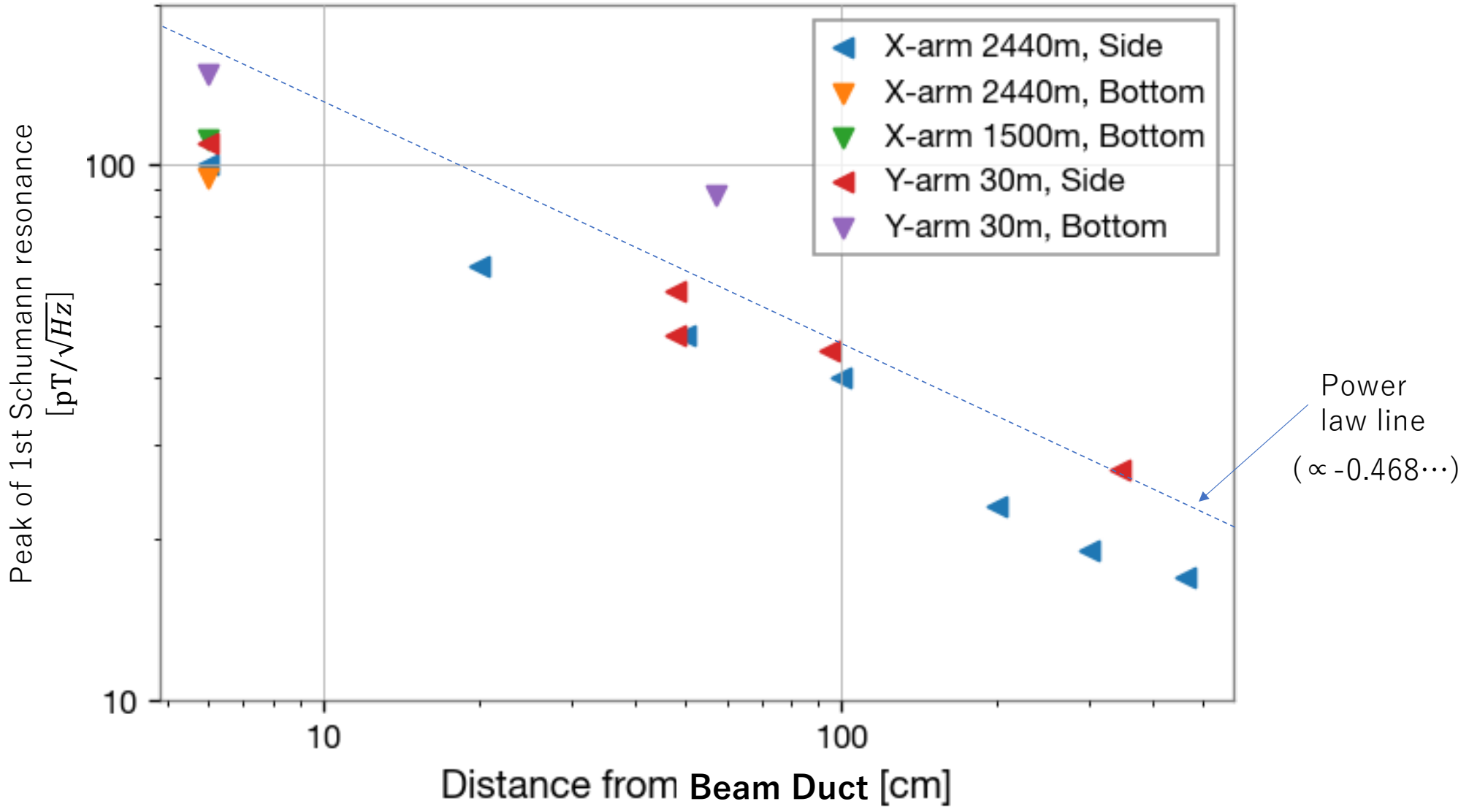
(Distance Variation from Beam Duct) (2440 m)

Xarm 2440m



- Dependence on distance from duct
- Greater dependence on other factors (location, time, ...)

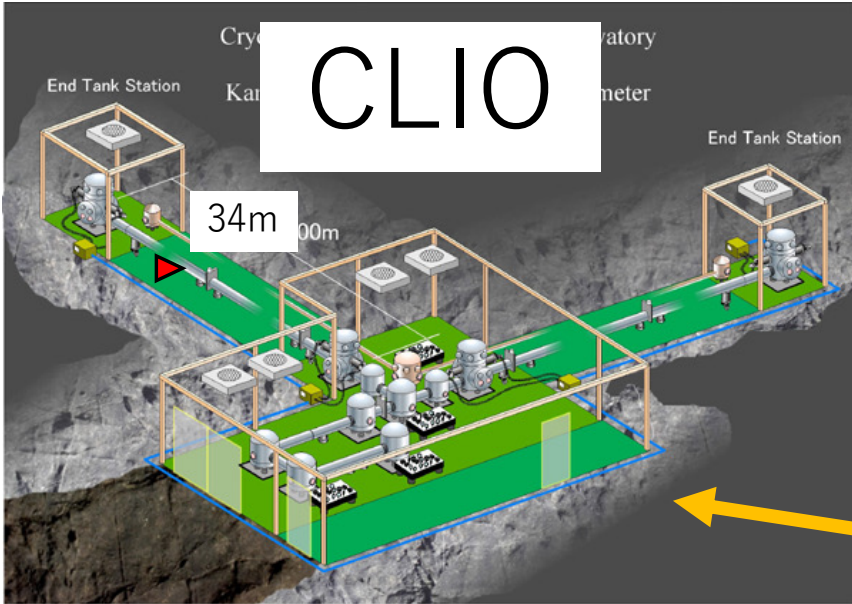
Summarize of 1st Measurement



Summarize of 1st Measurement

- We measured magnetic field at KAGRA and CLIO site.
- Schumann resonance has large dependence on distance from beam duct.
- The independence of the measurement location around the beam duct
- No clear Schumann resonance was observed at CLIO site and KAGRA front room.
- The magnetometer response did not change with distance from the beam duct.

2nd Measurement Location



Location
CLIO Yarm (34 m)
Outside
Xend
Yend



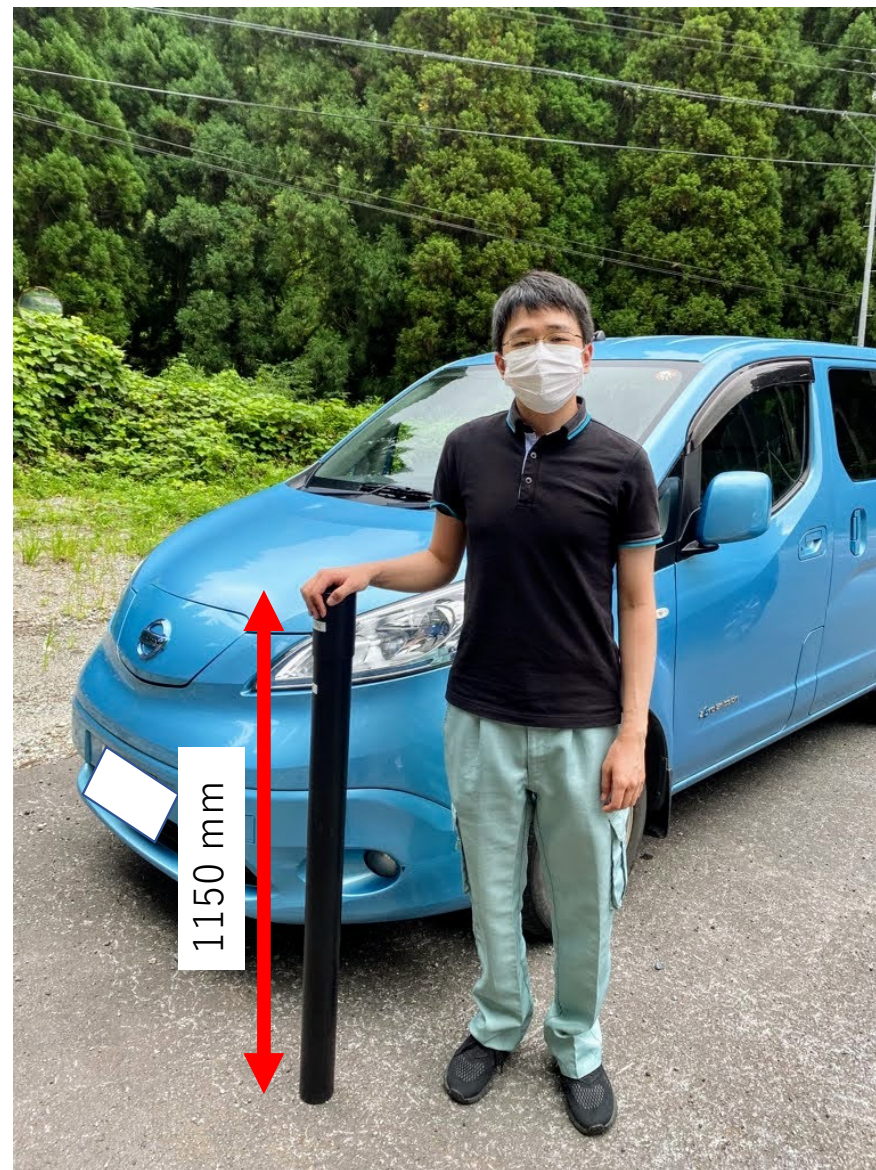
Setup for 2nd Measurement



ADU-08e

Magnetometer: MFS-06e

Noise Floor @1 Hz : $0.11 \text{ pT} / \sqrt{\text{Hz}}$



Outside Measurement

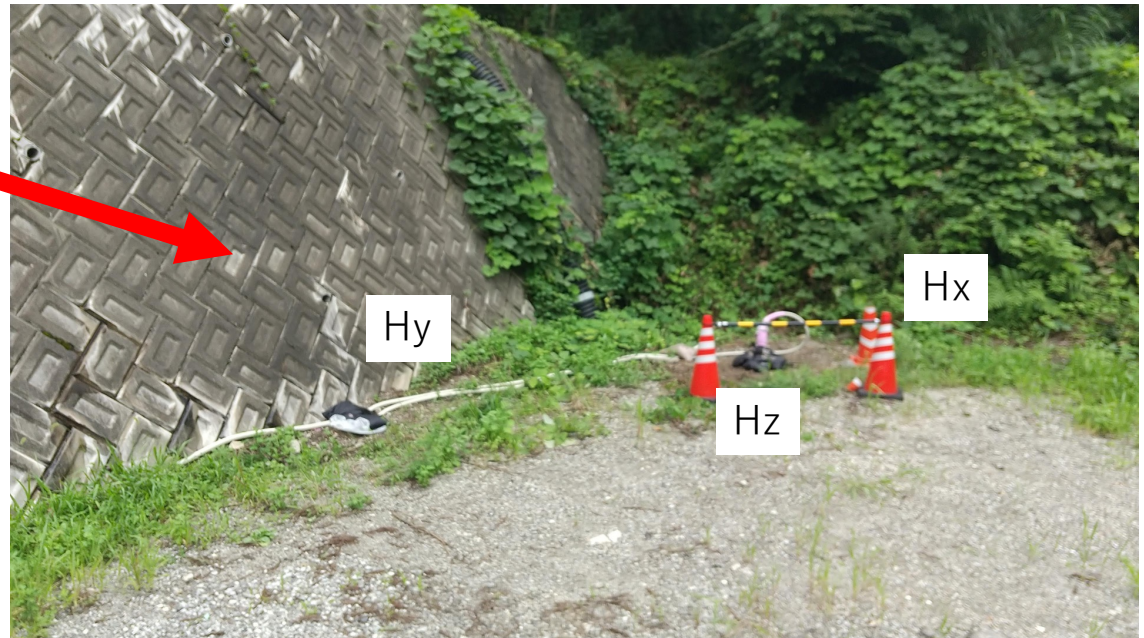


← View of the Measurement Point



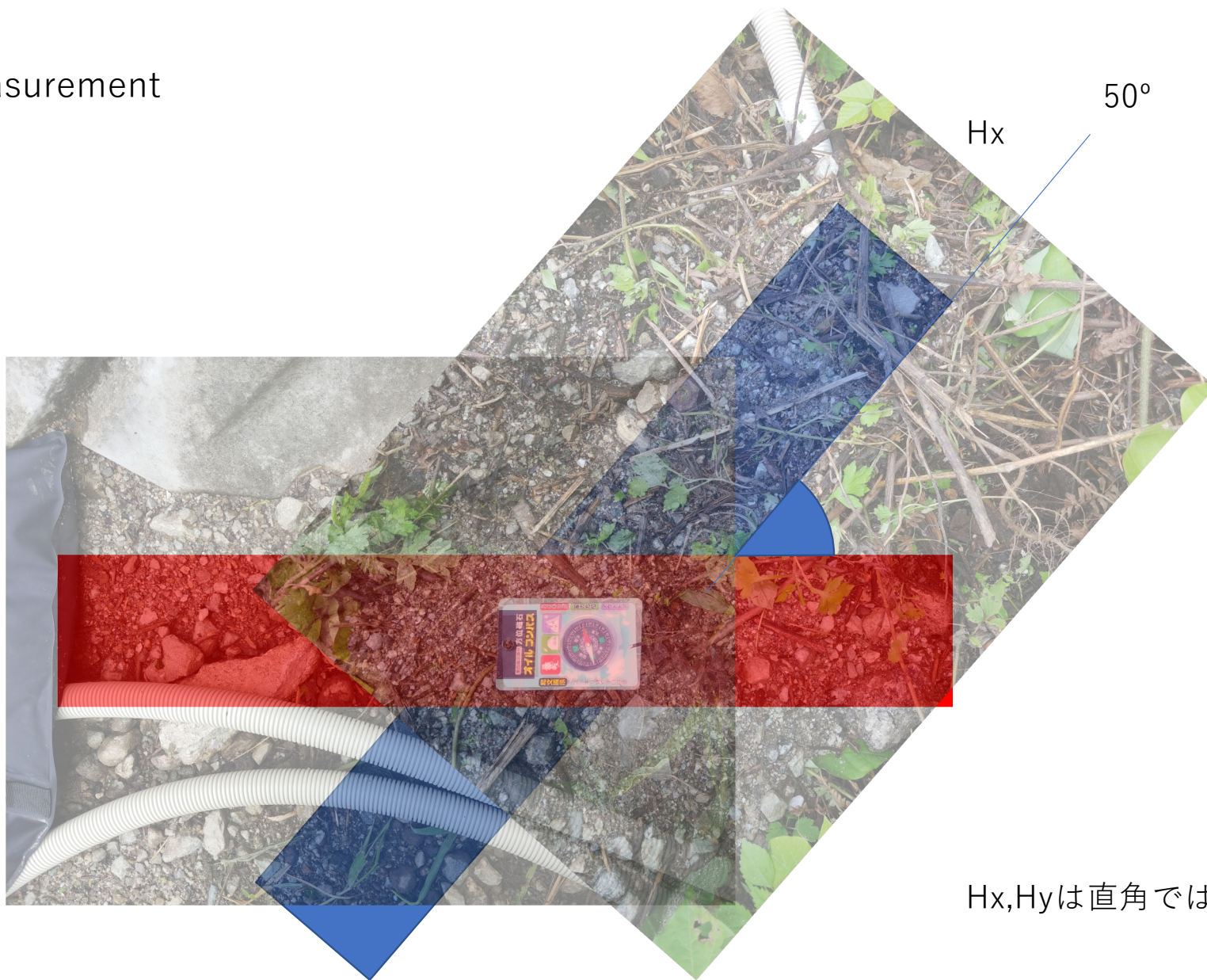
Outside Measurement

The orientation of the magnetometer has nothing to do with the direction of the KAGRA arm.



Vertical flux meter (Hz) buried 80 cm.

Outside Measurement



50°

Hx

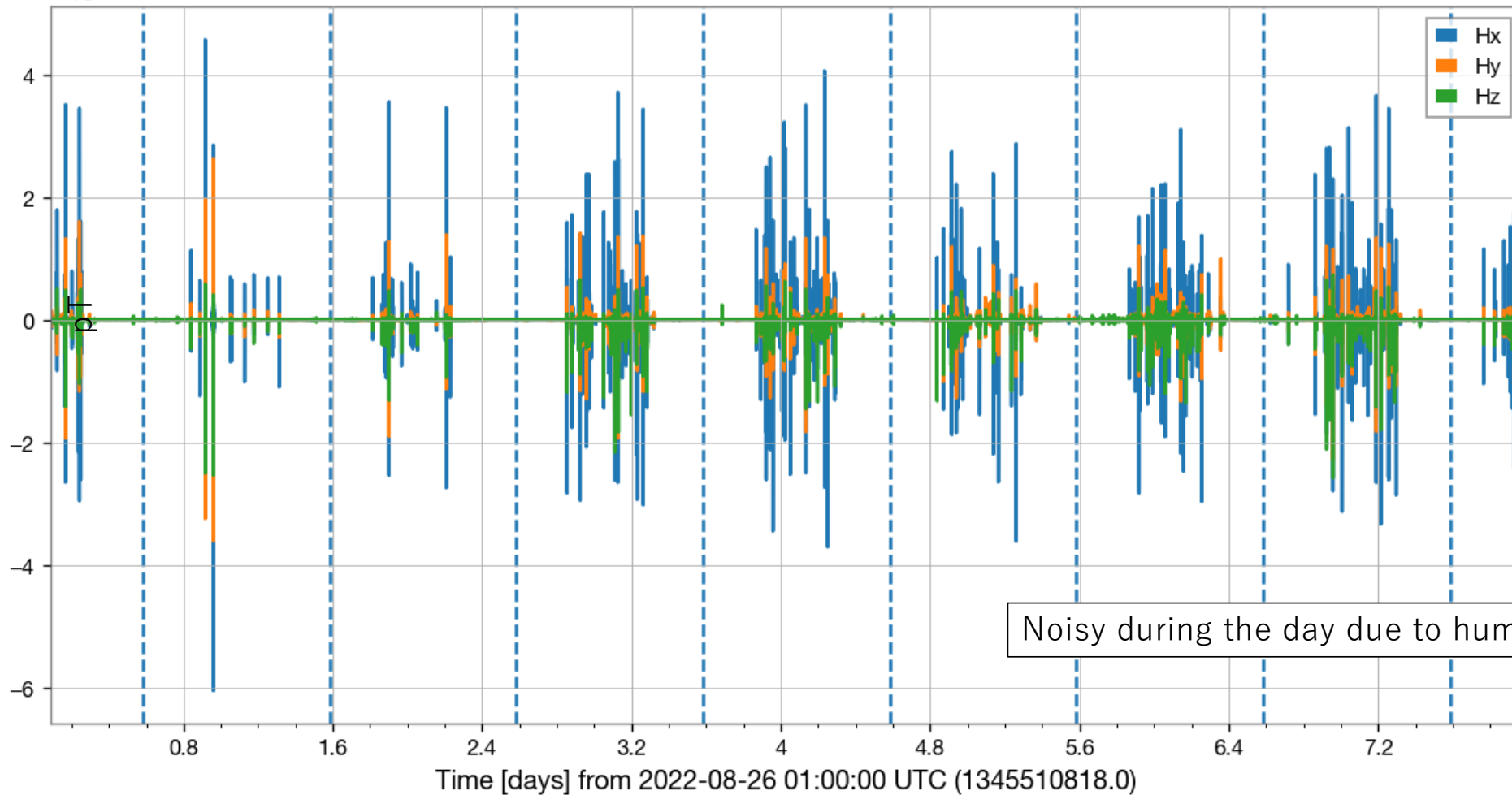
Hy

Hx,Hyは直角ではない

Outside Measurement

2022-8-26 3:09:43 - 9-3 0:16:31 (UTC)

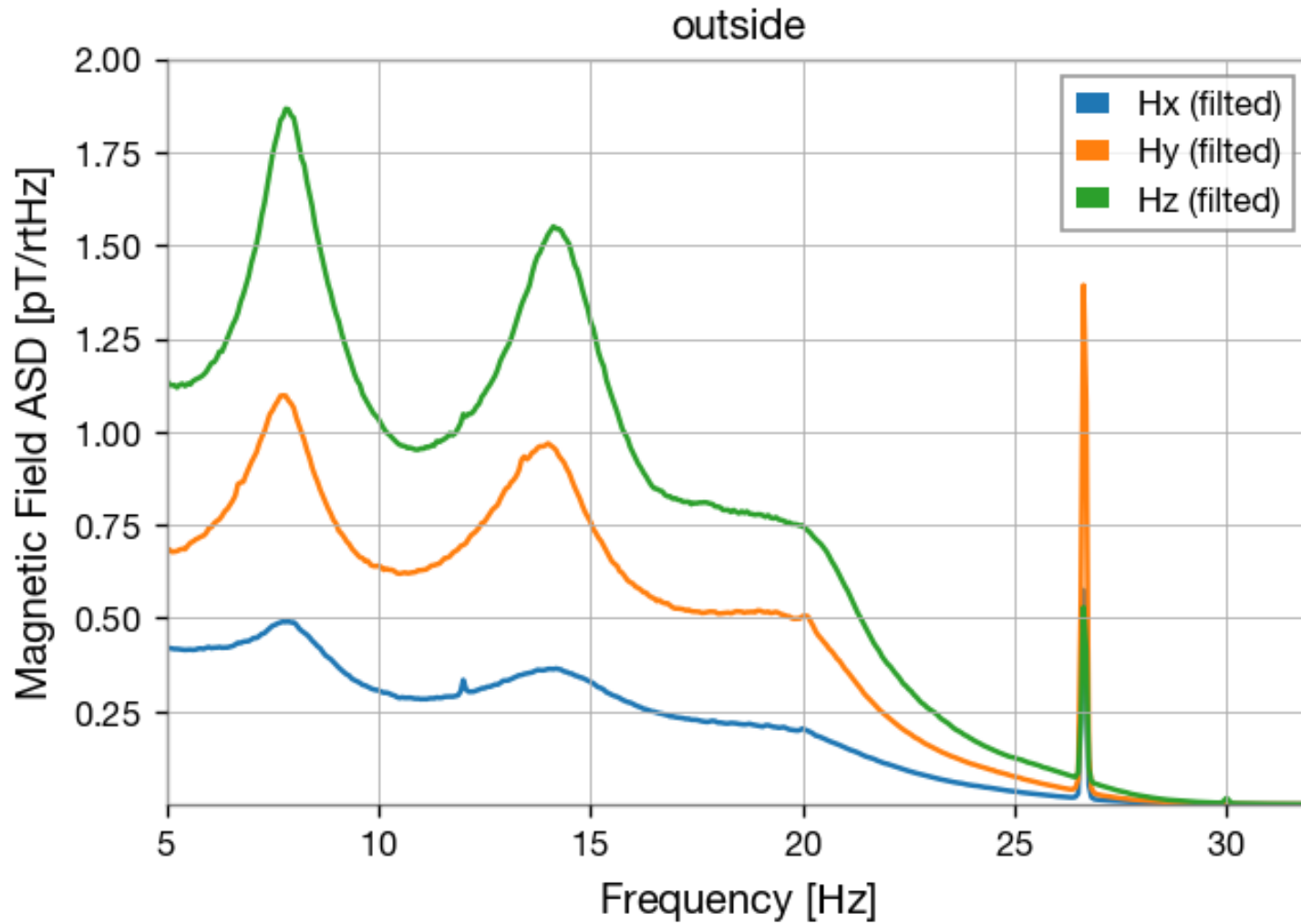
8/26 8/27 8/28 8/29 8/30 8/31 9/1 9/2 9/3 (JST)



Noisy during the day due to human activity

Outside Measurement

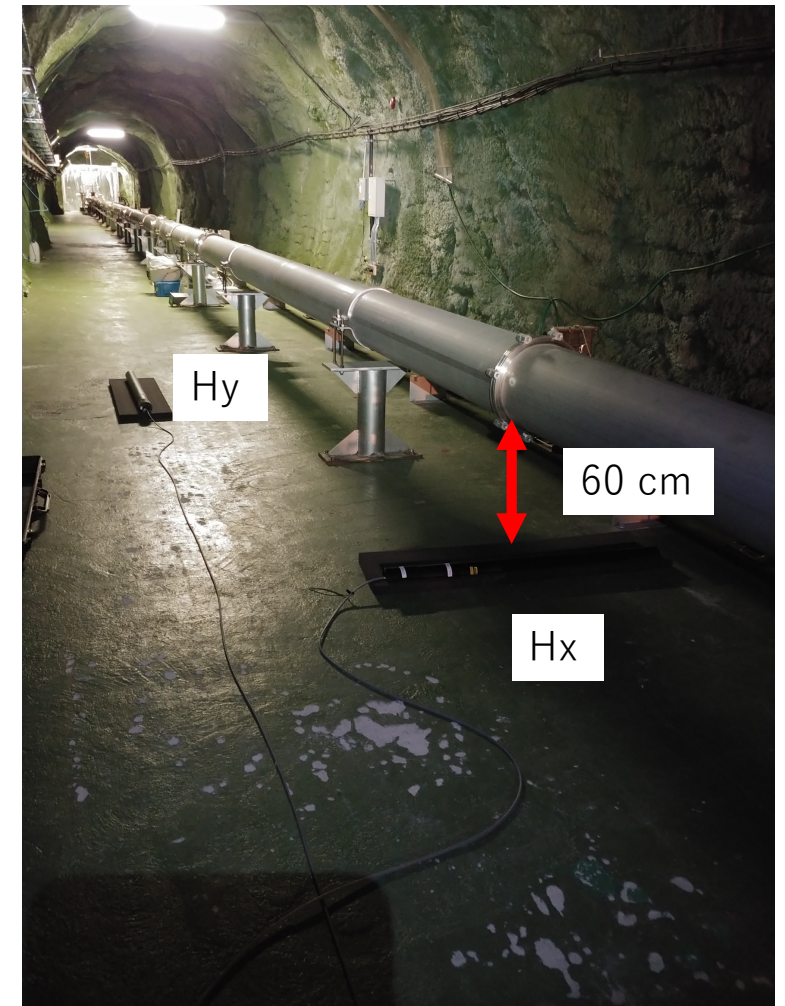
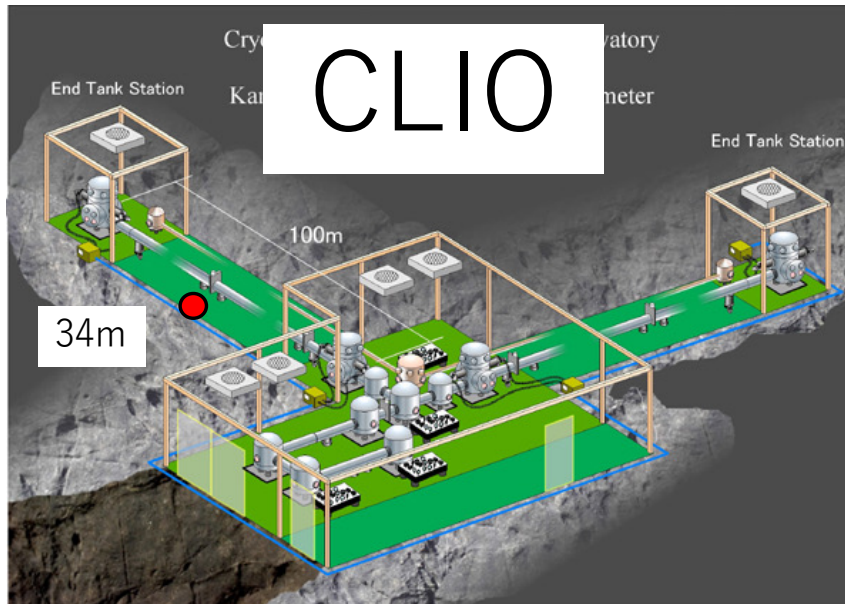
2022-8-26 3:09:43 - 8-31 9:09:43 (UTC)



Schumann resonance observed on vertical?

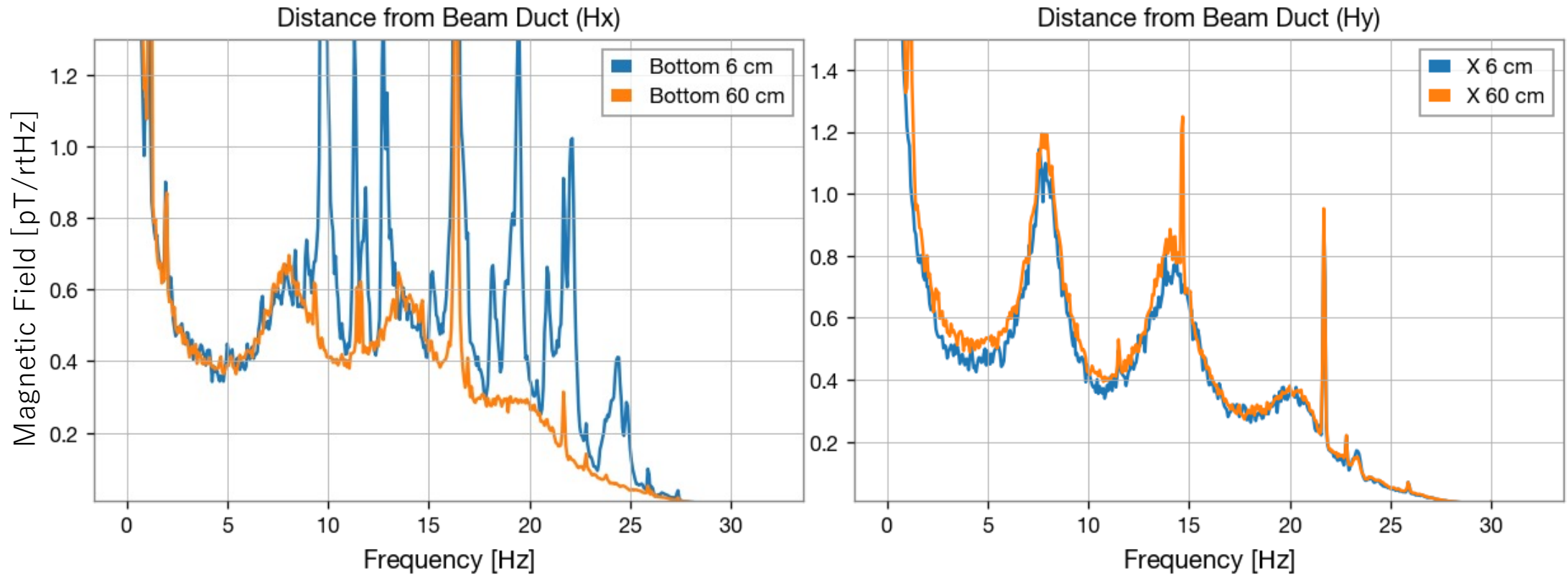
2nd Measurement at CLIO

- Measurement with more sensitive magnetometer than the previous one
- Two measurements were taken: in the case of the photo (60 cm from beam duct) and when only the flux meter in the X direction was close to the duct (18 cm).



CLIO Yarm

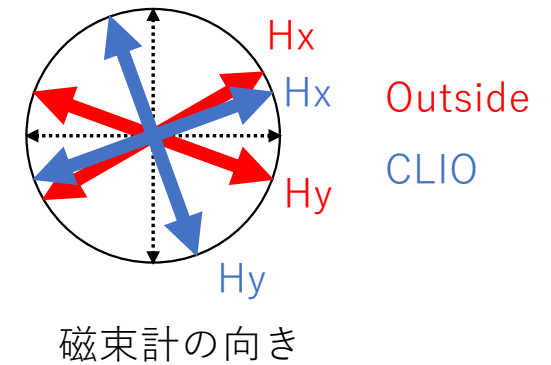
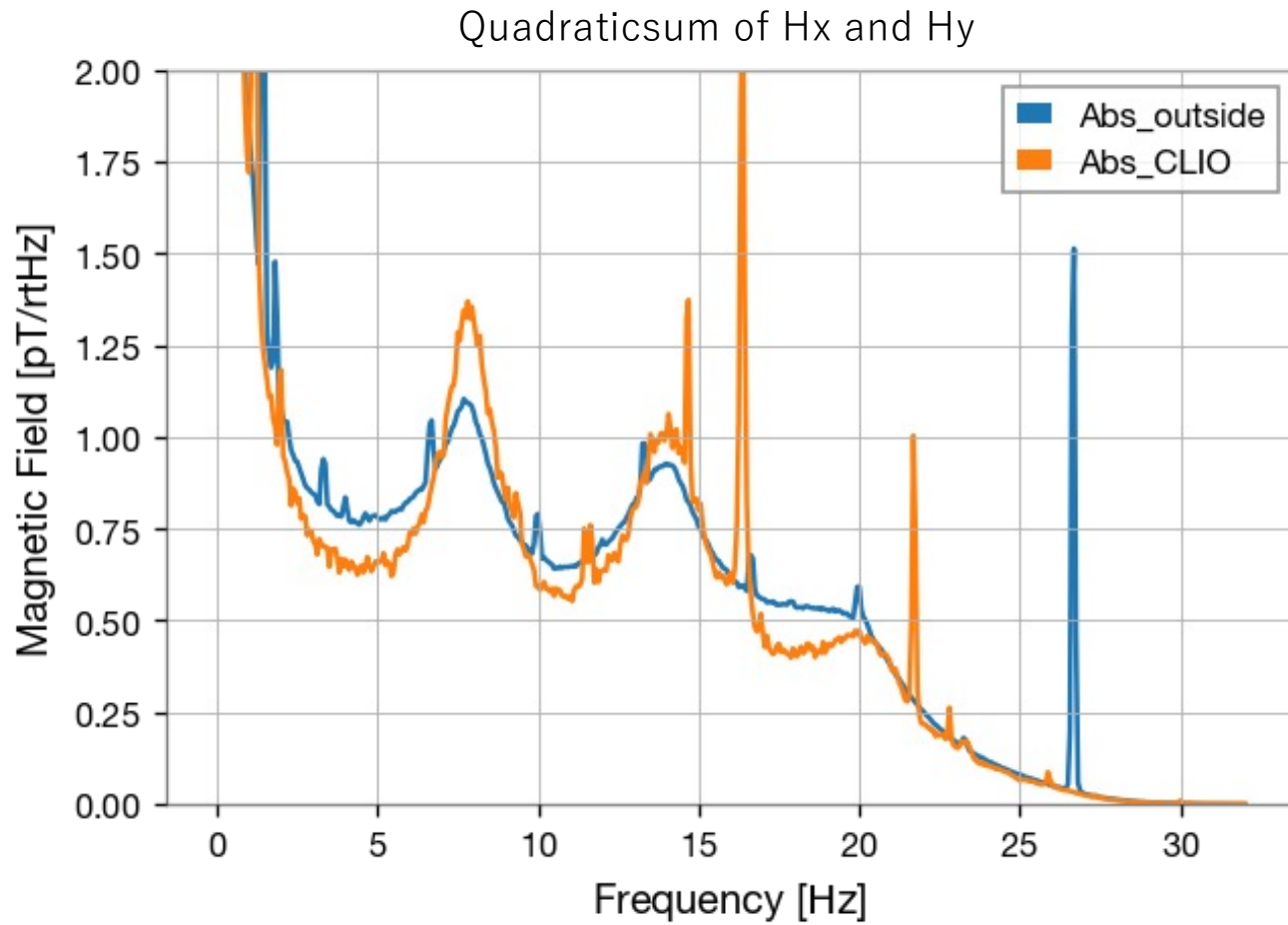
2nd Measurement at CLIO



No significant change in Schumann resonance when placed close to the arm.
No amplification due to the beam duct in CLIO?

Outside Measurement

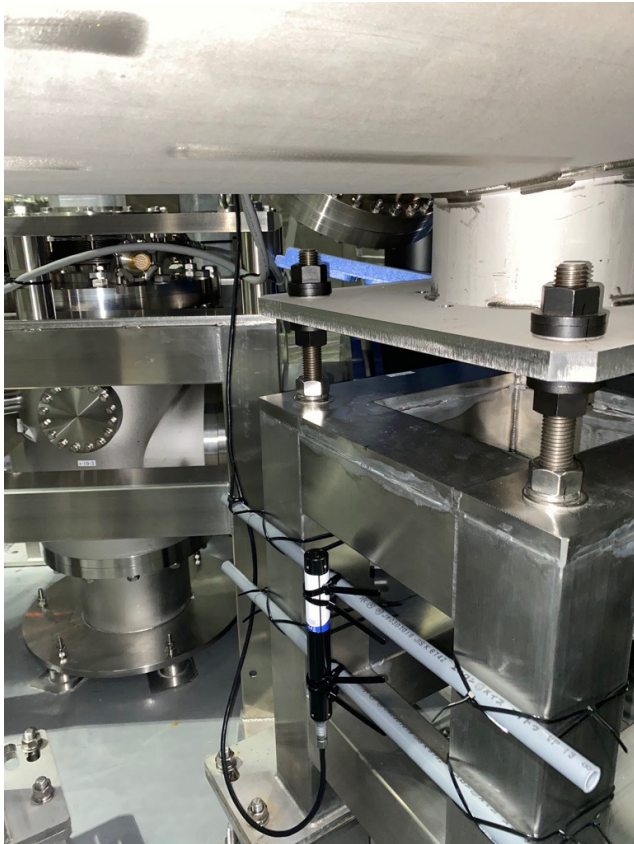
Comparison with outside data immediately prior to measurement at CLIO
(※ Not contemporaneous data)



Amplitude at CLIO is larger than outside.

Comparison of Magnetometer at Each End

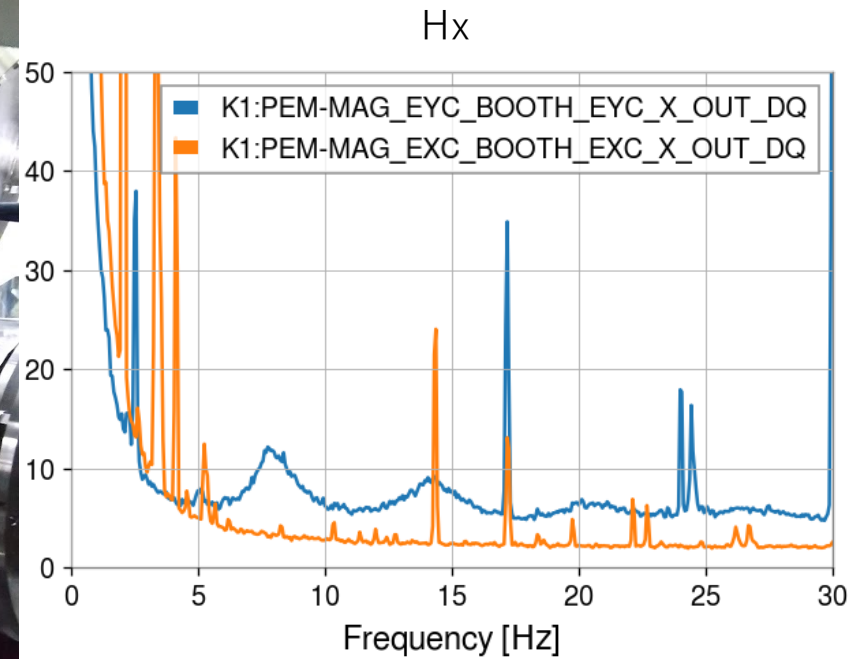
2022-8-25 23:59:32 - 8-26 1:57:58 (UTC)



Yend 35 cm



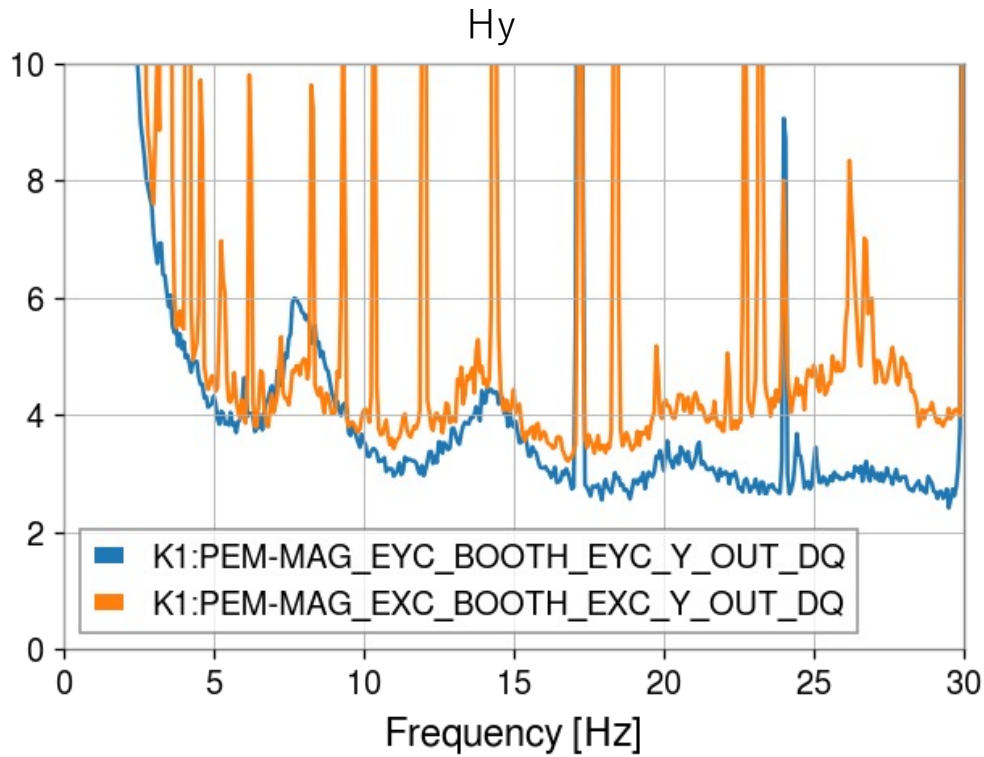
Xend 27 cm



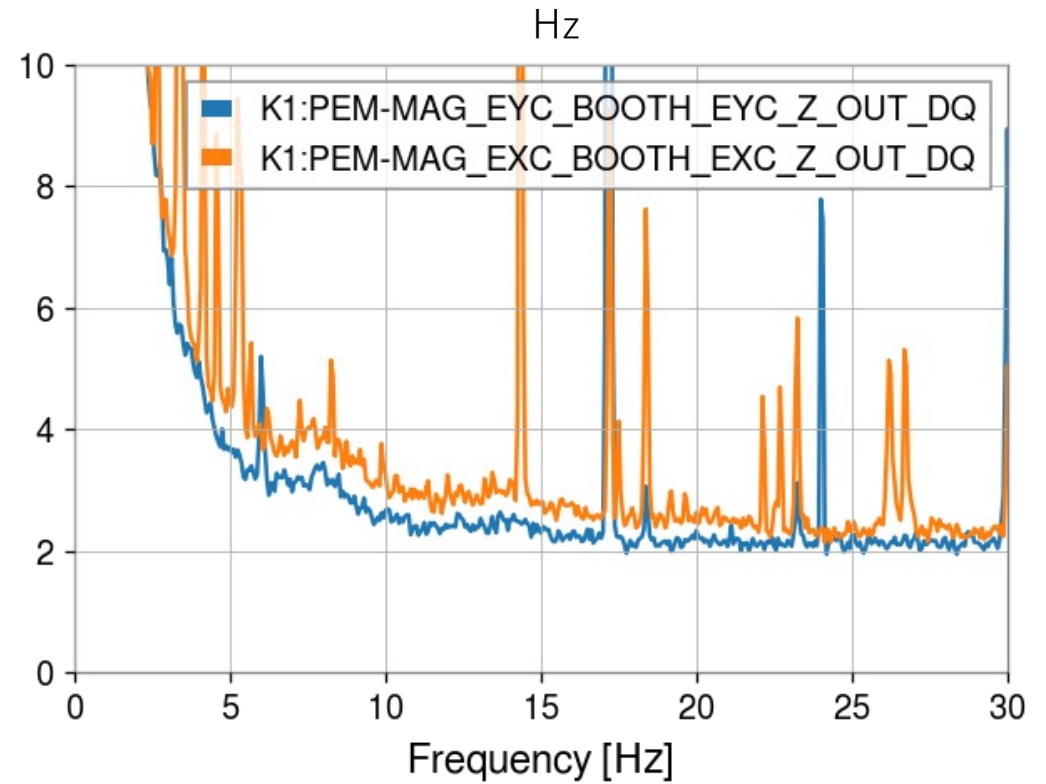
(Xend) No Schumann resonance
->Because Hx is aligned with the
direction of Xarm?

Comparison of Magnetometer at Each End

2022-8-25 23:59:32 - 8-26 1:57:58 (UTC)



(Yend) Despite Hy is aligned with the direction of Yarm, Schumann resonance was observed.



Amplitude at Xend was higher because the magnetometer is closer to the beam duct?

Summarize of 2nd Measurement

- We measured at CLIO site and outside of KAGRA.
- Schumann resonance was observed in outside ,but also as the vertical magnetic field.
- Amplitude of Schumann resonance at CLIO was ground level.
- We compared the magnetometers at each end.