Report on the measurement of the magnetic field at the KAGRA site

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Detector Characterization

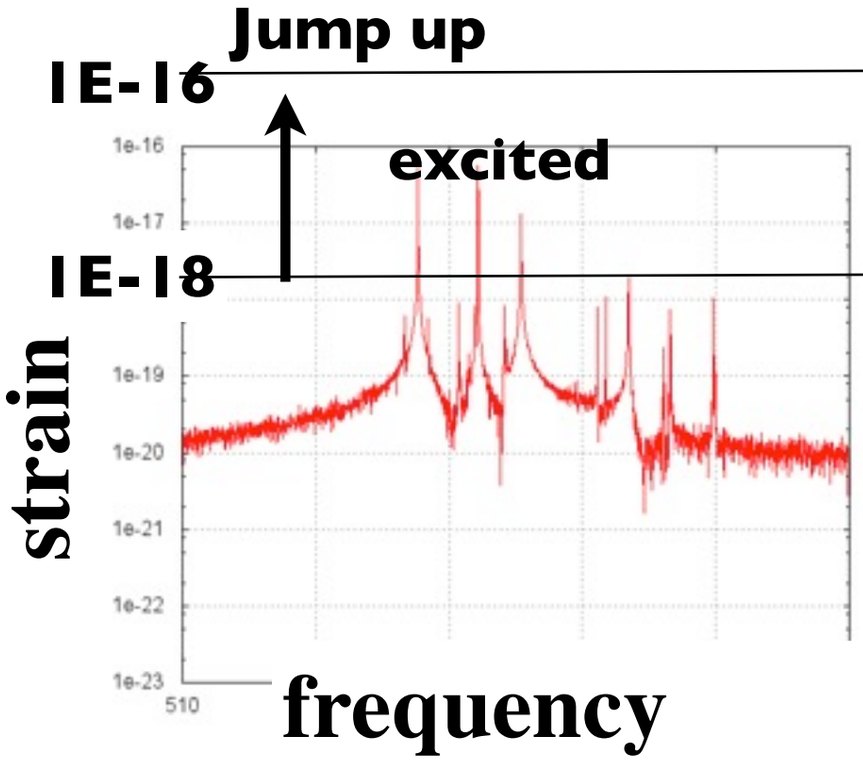
- **Diagnostics system to know detector conditions, environmental noise, helping for improvement detector operation.**

- **Evaluation of data quality**

- **Distribution of the data quality information to collaborators.**

- **Veto analysis. Results are used for to obtain higher-quality scientific results.**

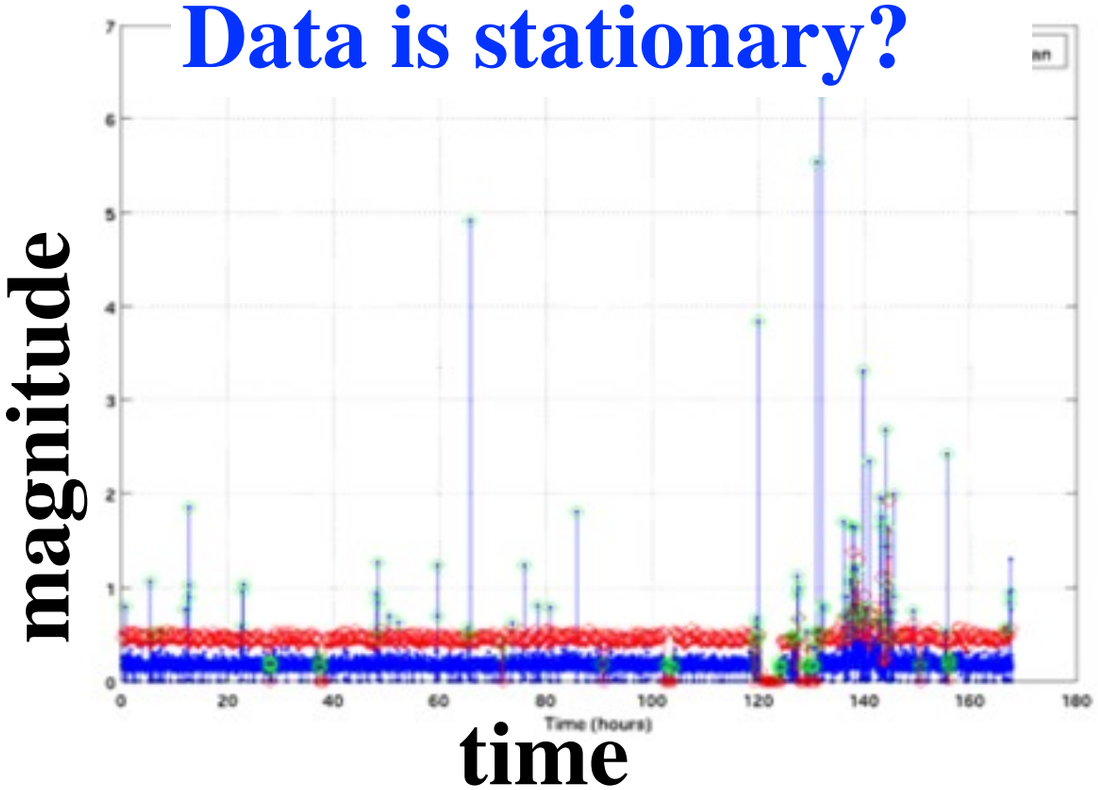
Characterization of a detector output

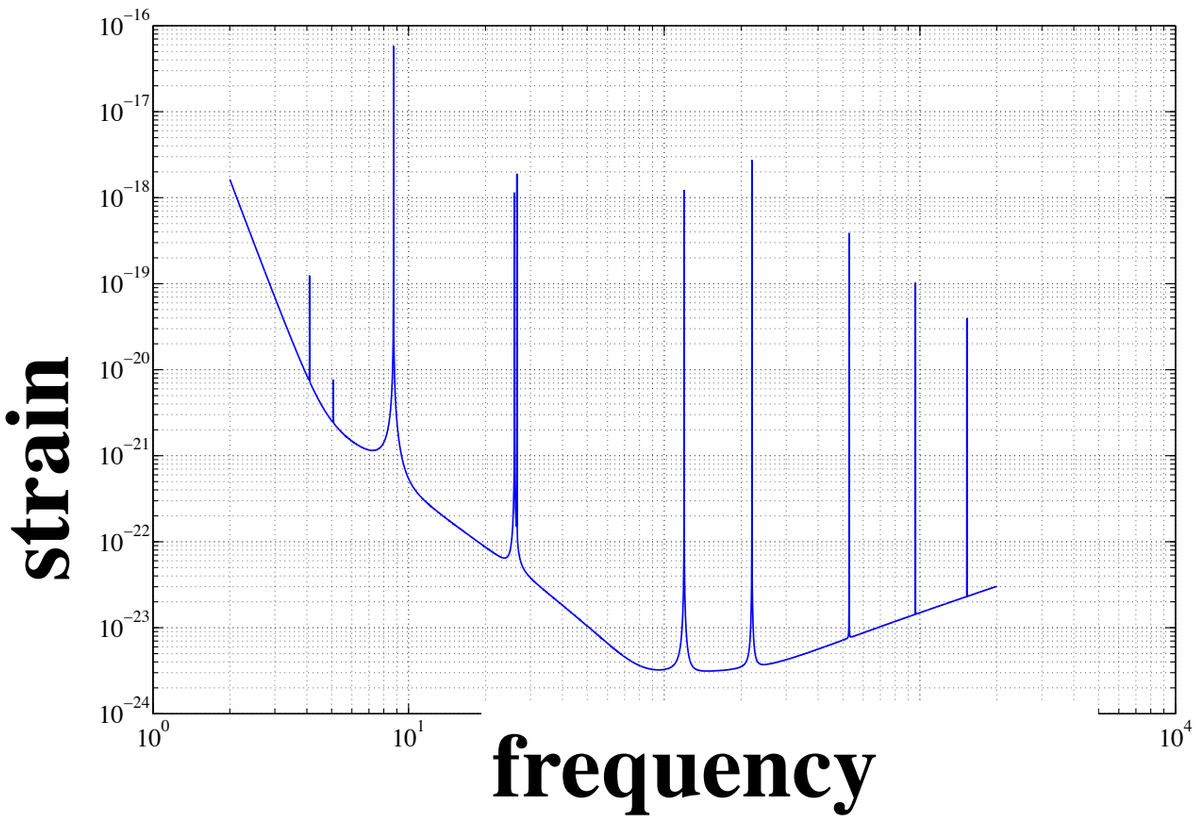


What about violin modes with ultra high Q ?

Data is sensitive as expected?

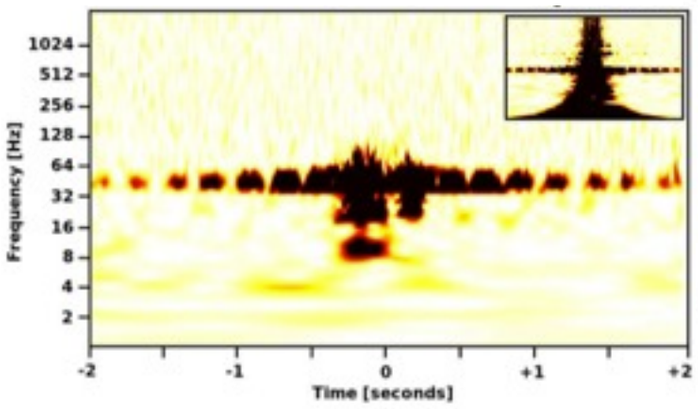
Data is stationary?



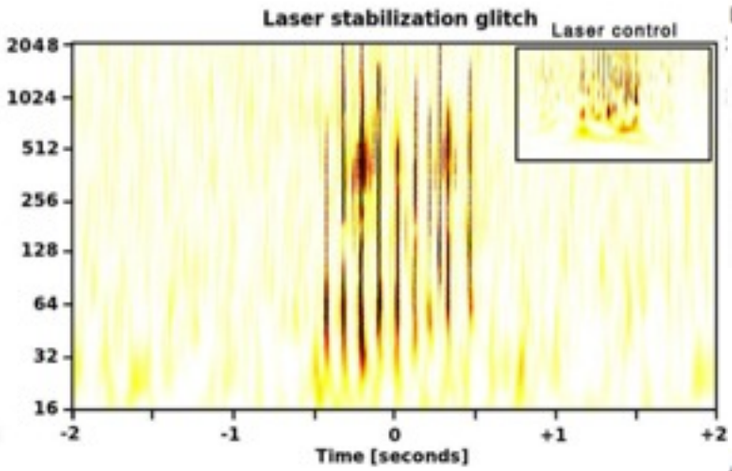


Characterization of burst-like noise (called glitch)

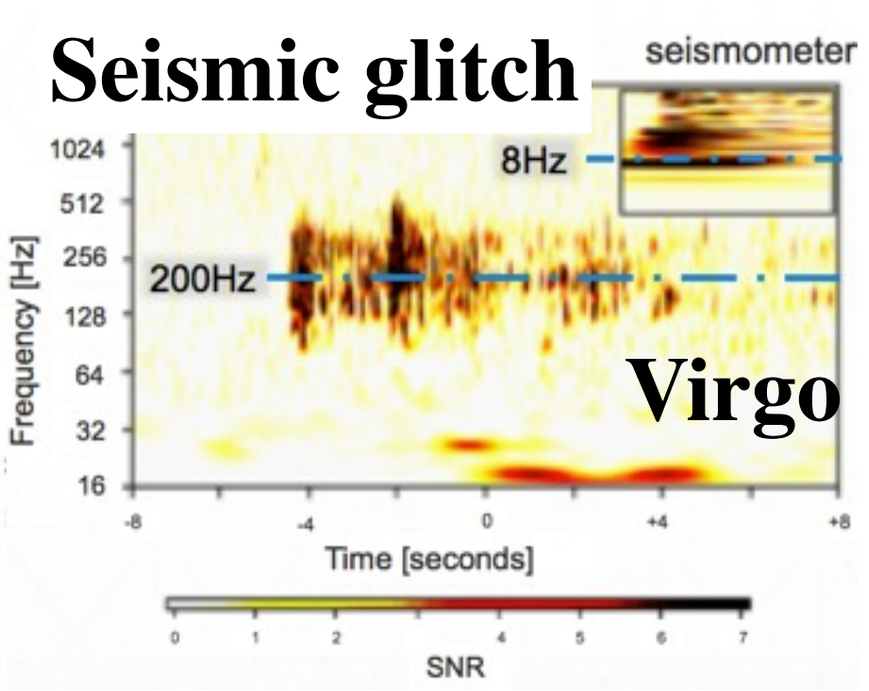
Magnetic glitch

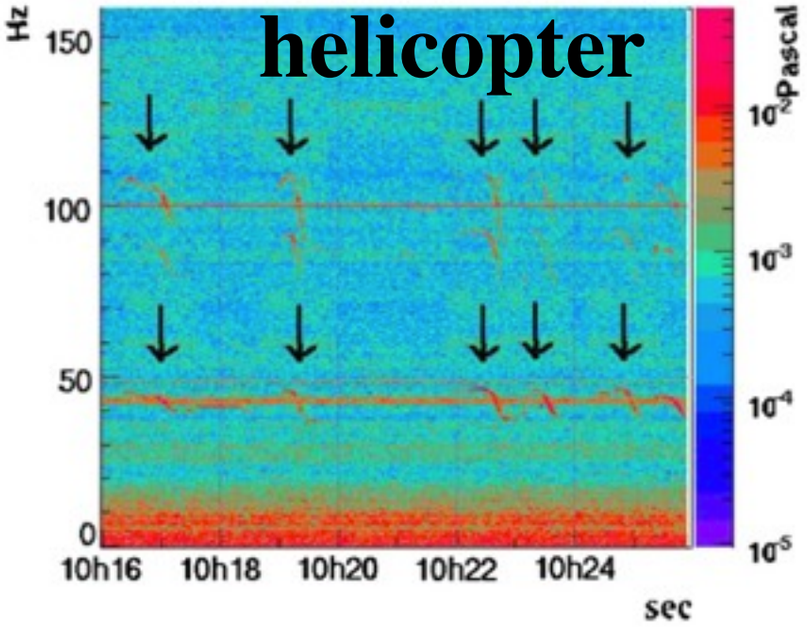


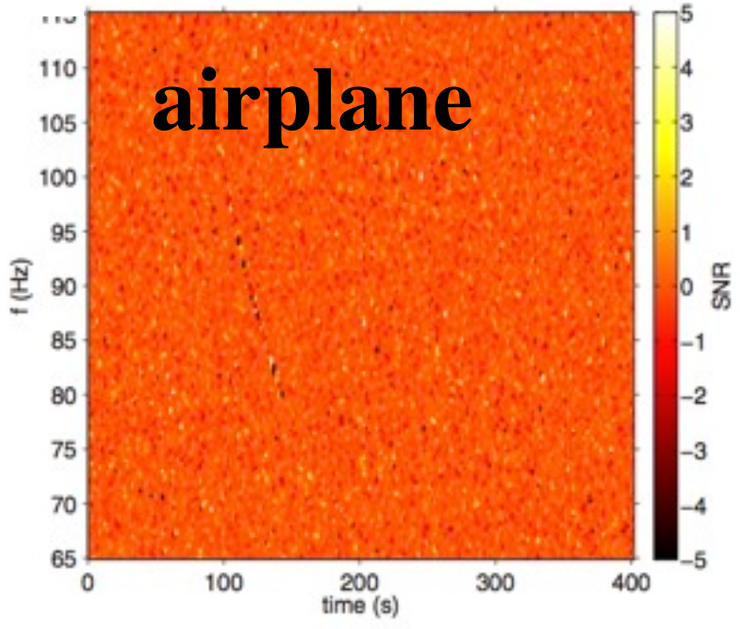
Laser stabilization



Seismic glitch



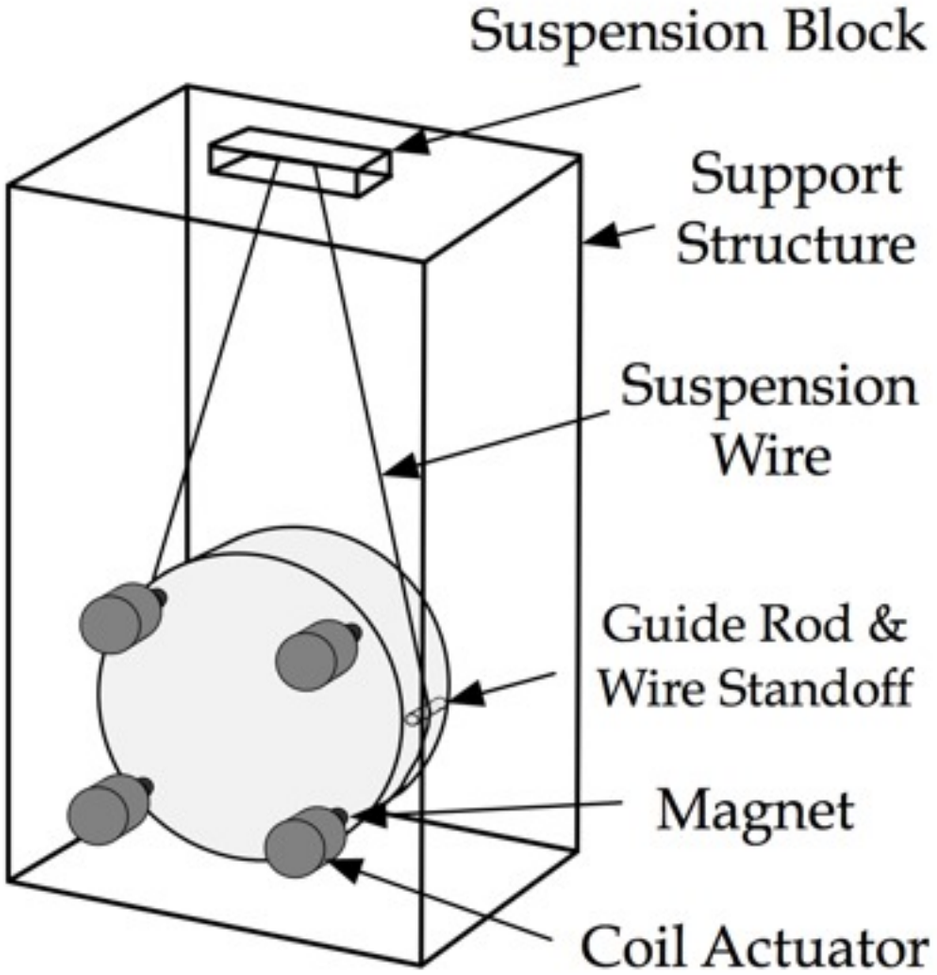




And so on ...

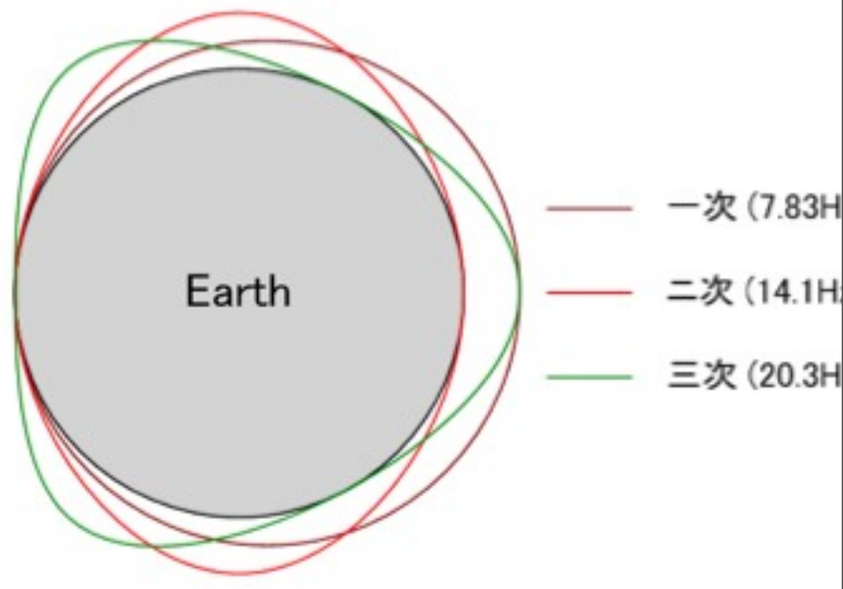
Effect of the magnetic field to KAGRA

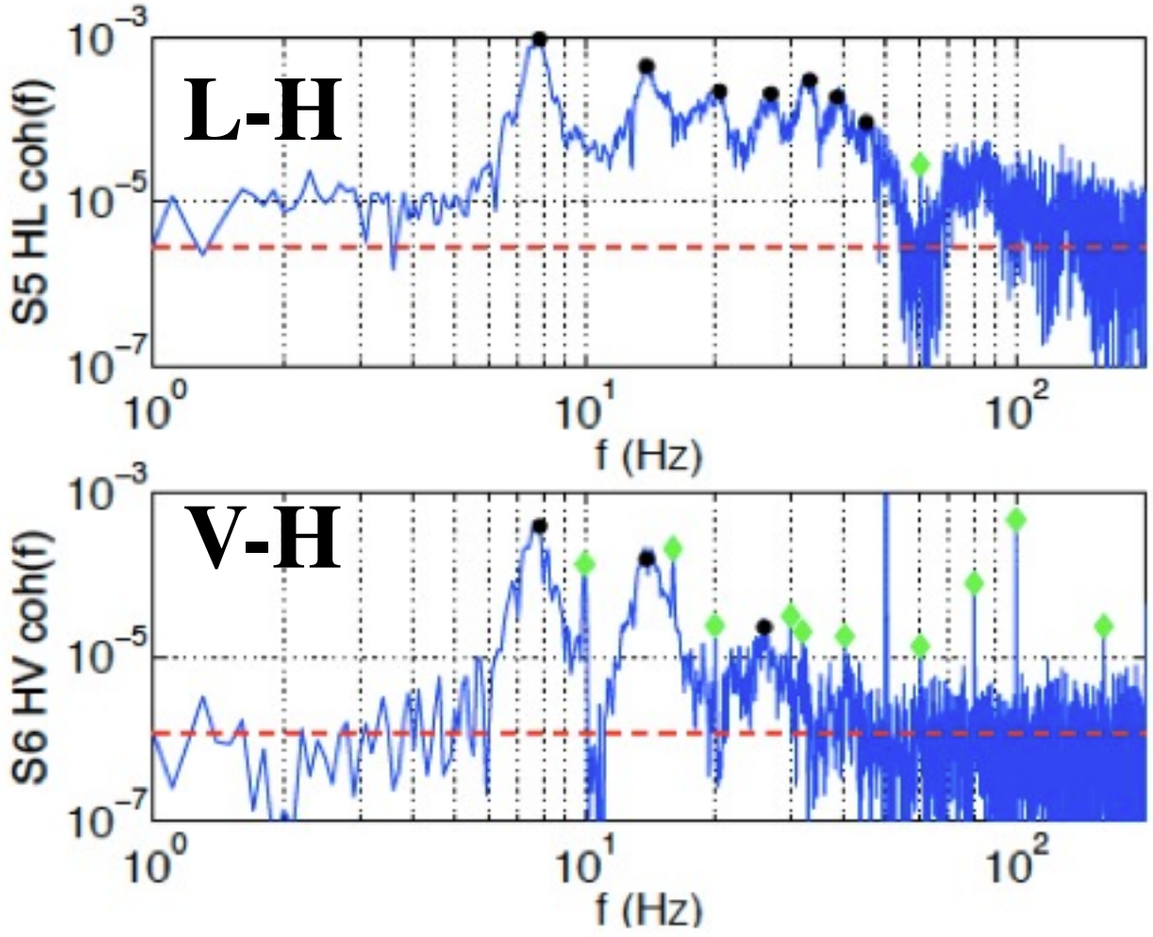
- **KAGRA's mirror will be controlled by Magnet-Coil actuator.**
- **The Magnet-Coil actuator is affected by the environmental magnetic field.**
- **What size of the magnets can we use without serious influence from the magnetic field?**
- **How is the magnetic field at the KAGRA site?**

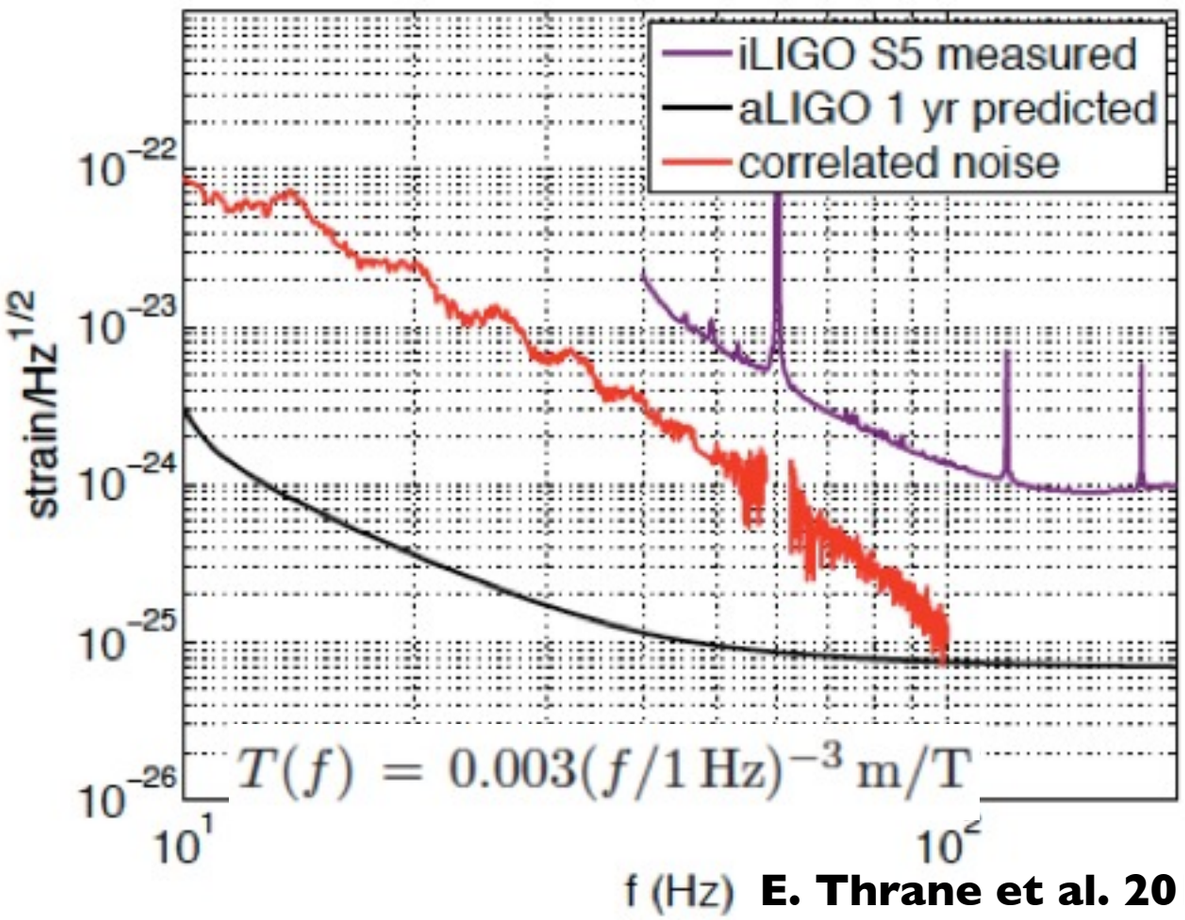


Globally Correlated Magnetic Noise

- **Schumann resonance**
  Resonance of the ionosphere due to discharge of thunders, solar wind,...
  - **Very weak (0.5-1E-12T/rHz) (Earth's:1E-5T**
  - **Long coherent length ~1000km**
  - **Correlation appears by 1year integration**







E. Thrane et al. 2013

Globally correlated magnetic noise

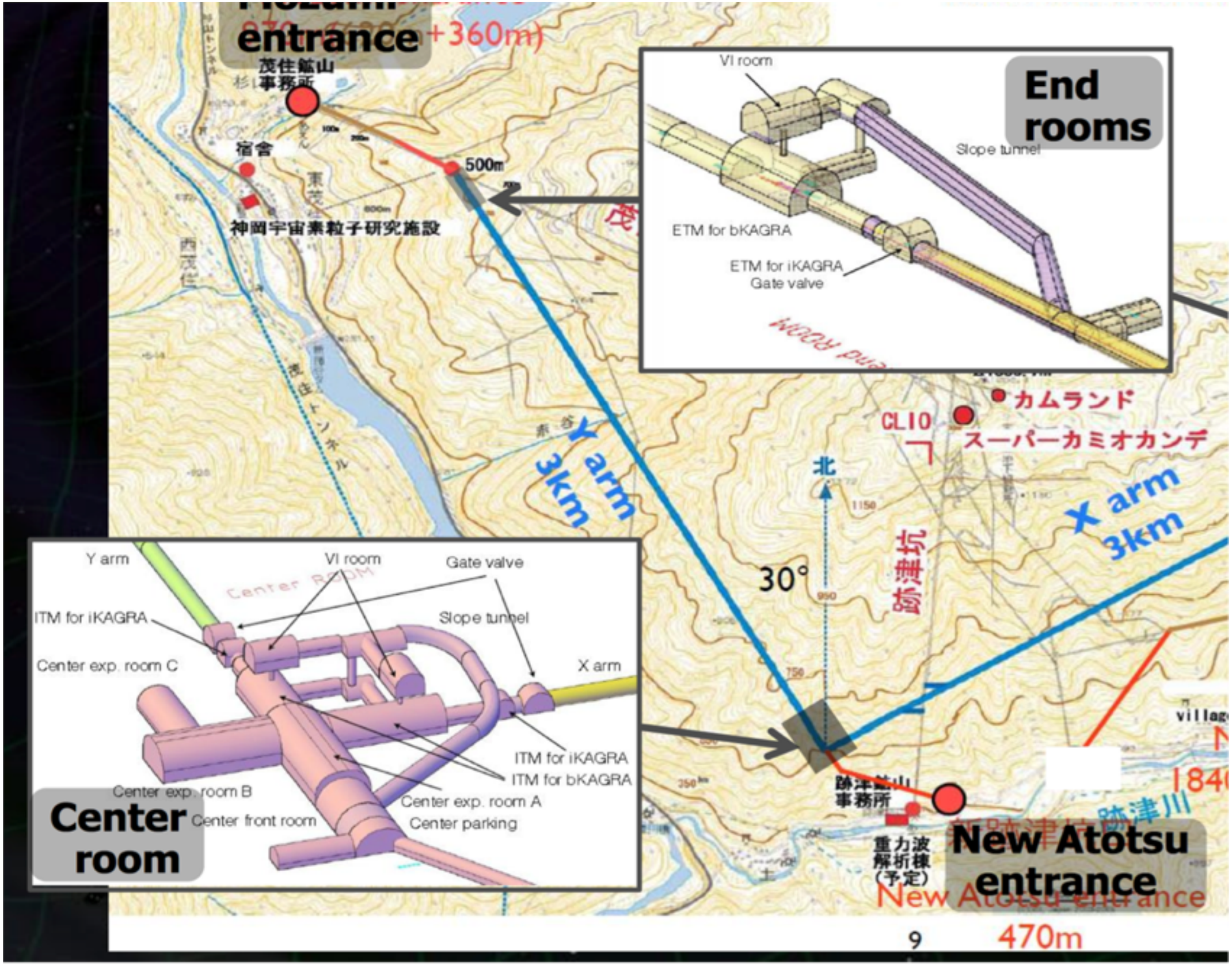
- **Impact on sensitivity to GW**
  - **stochastic : GWB sensitivity is limited at the level of correlated magnetic noise**
  - **Burst : coincident false events increase and have to put large SNR threshold for the detection**
- **What about KAGRA's case?**
  - **Under the mountain is good?**

Our motivation of the measurement

- How is the magnetic field?
- How is the non-stationarity of the magnetic field?
- How about difference between outside and inside the mountain?

The KAGRA site

Location of the measurement



Location of the measurement

Magnetometer

- Mag649

made by Bartington instruments

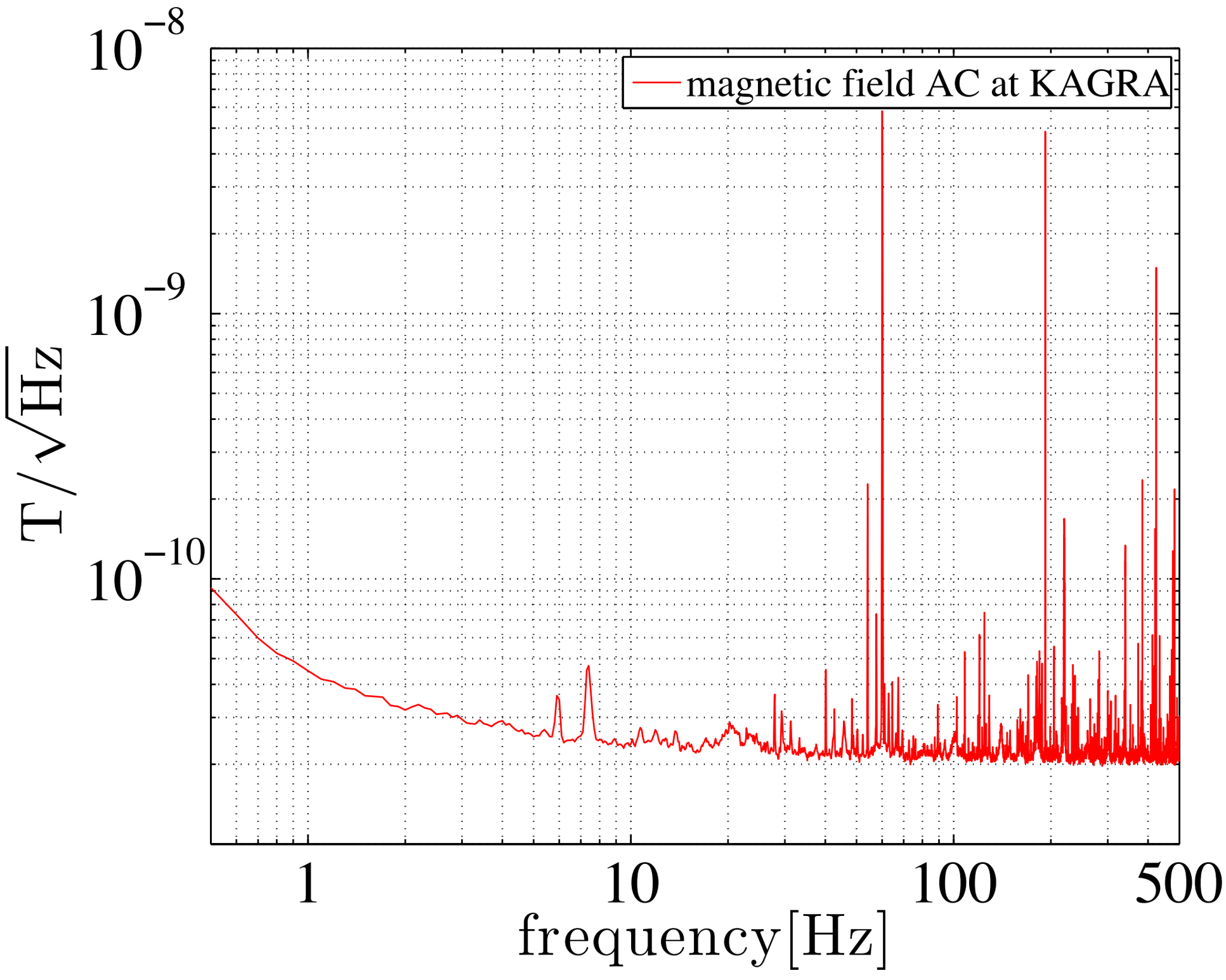
Fluxgate magnetometer

Main spec

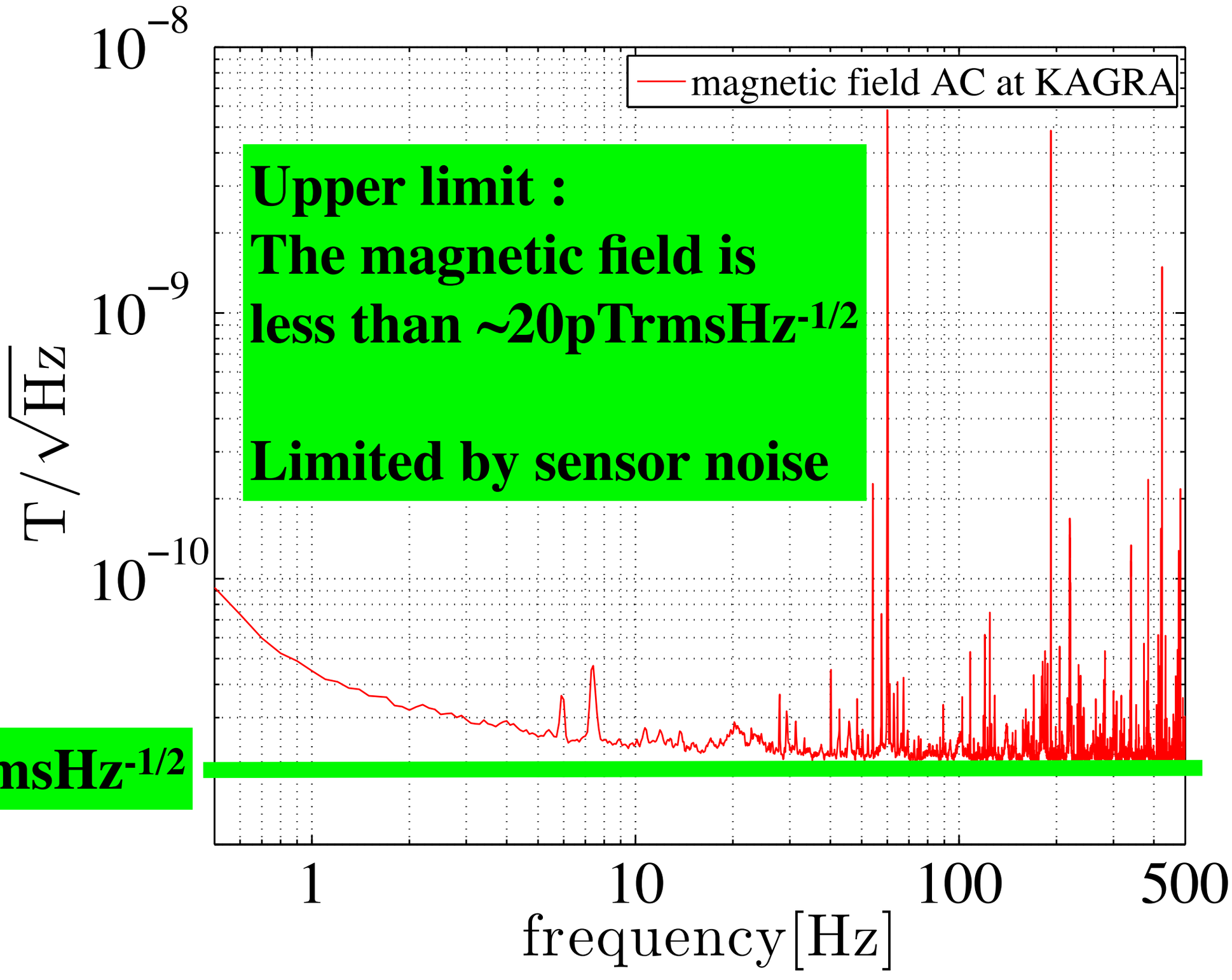
- Number of axis:3(x,y,z)
- Range:±60μT
- Bandwidth at -3dB:<1kHz
- standard noise:
  between 10 and 20 pTrms

External magnetic field change is about ~1pT/√Hz
→we could see “upper limit”

Spectrum of the Magnetic Field



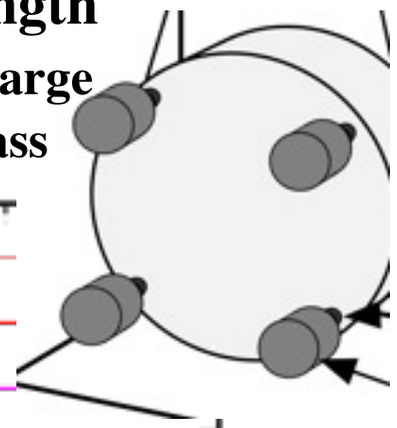
Spectrum of the Magnetic Field

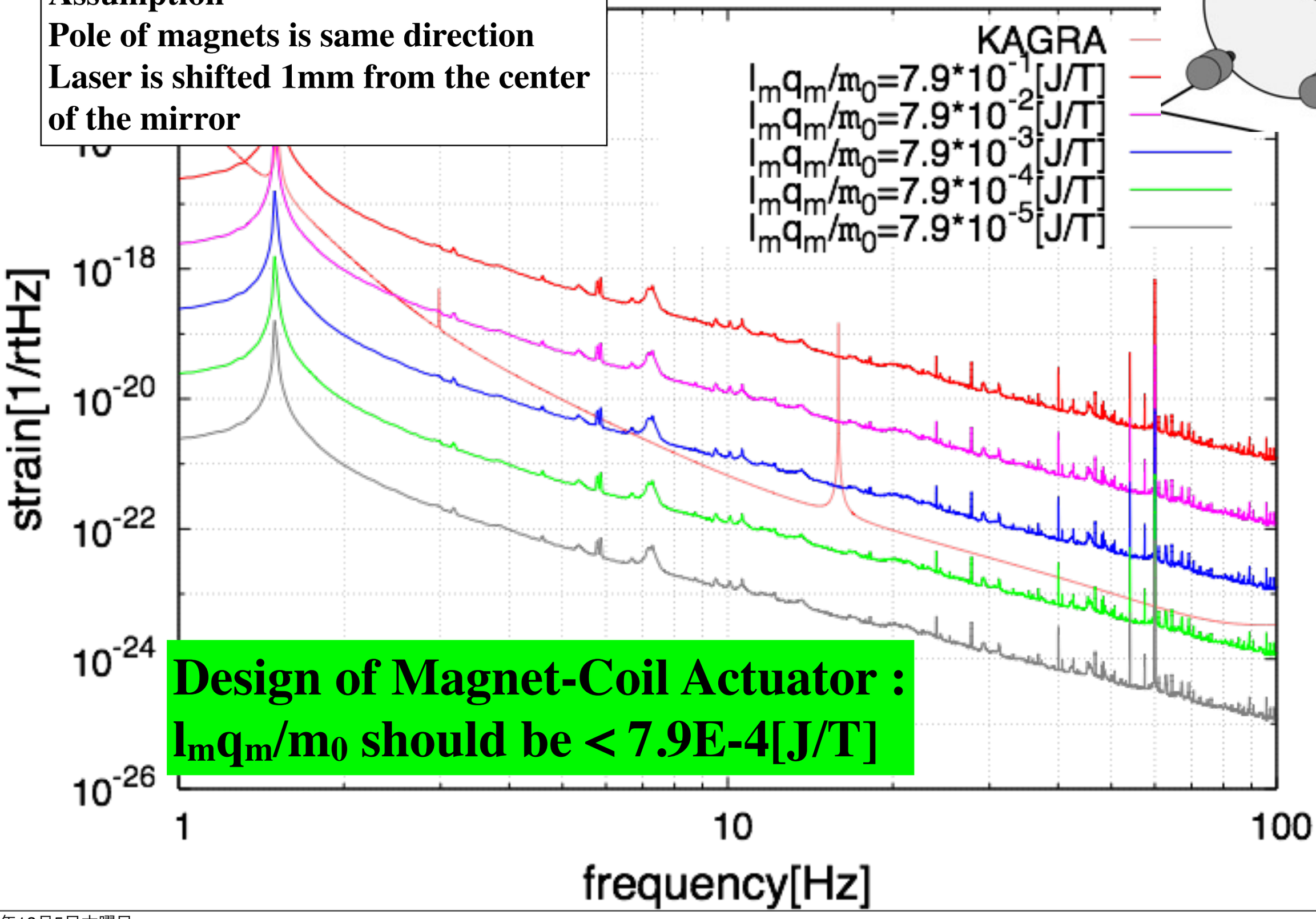


Strain-equivalent spectrum

Assumption
Pole of magnets is same direction
Laser is shifted 1mm from the center of the mirror

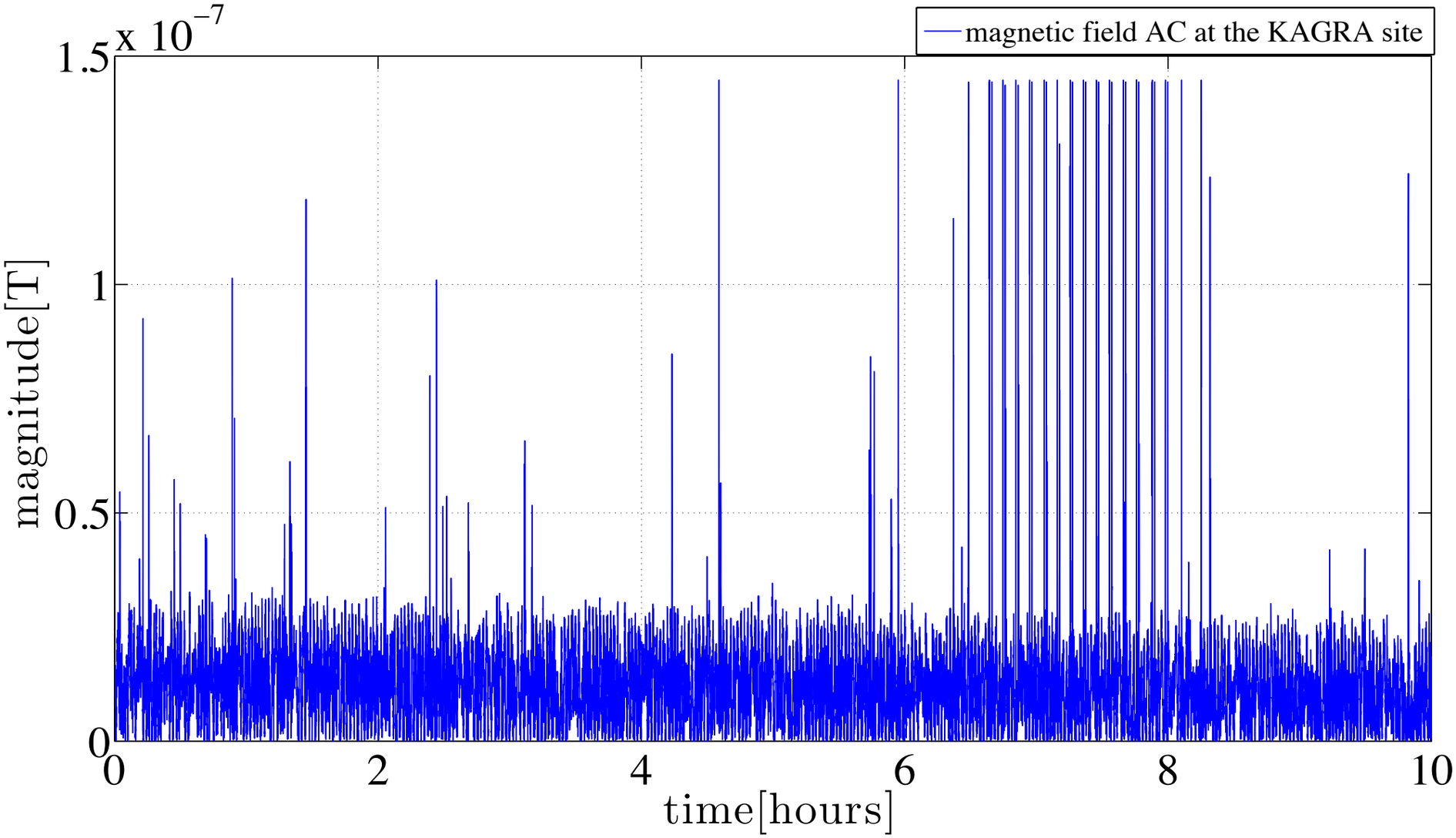
lm: length
q_m : charge
m0: mass





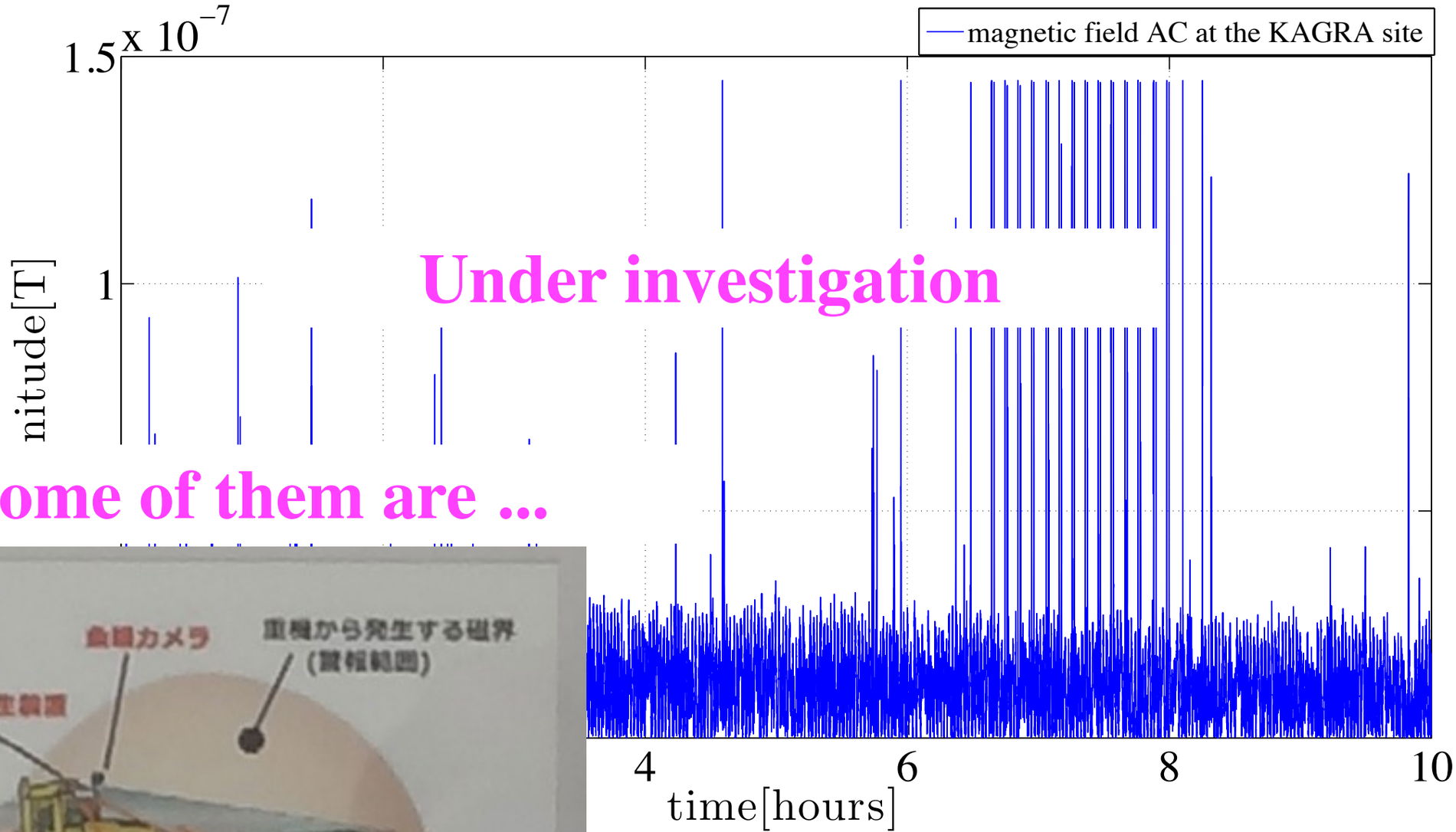
Design of Magnet-Coil Actuator : $l_m q_m/m_0$ should be < 7.9E-4[J/T]

Glitches



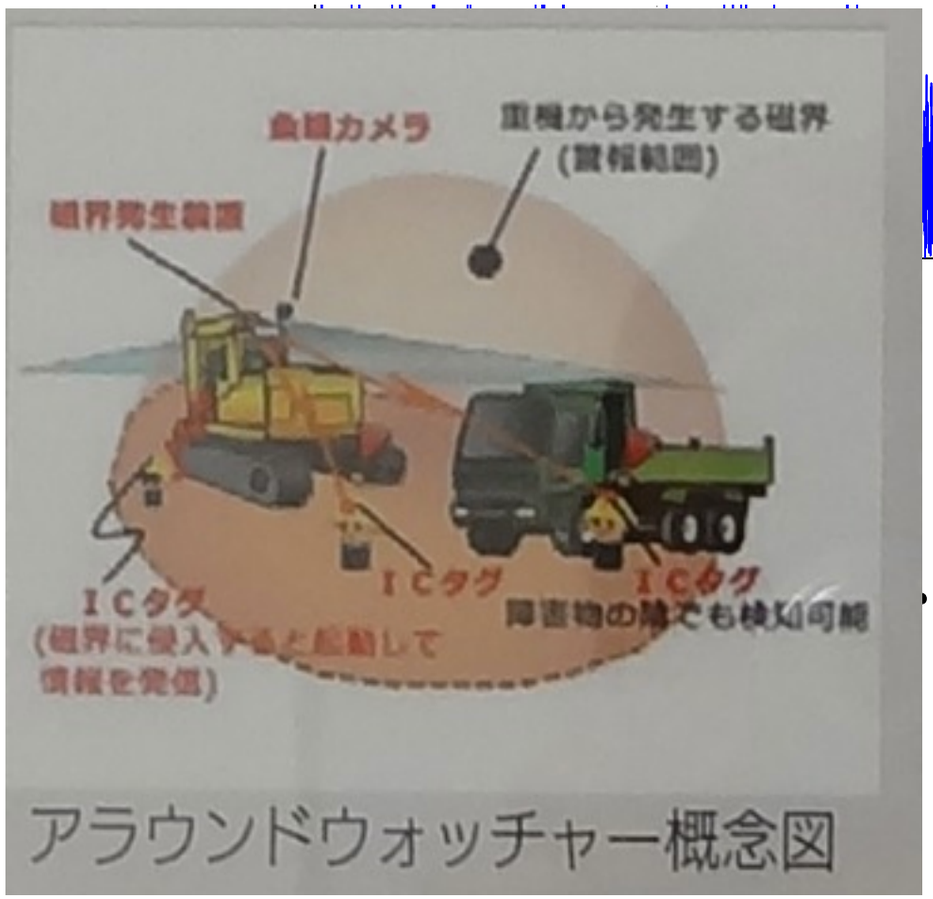
- **4.5 glitch events per hour.**

Glitches



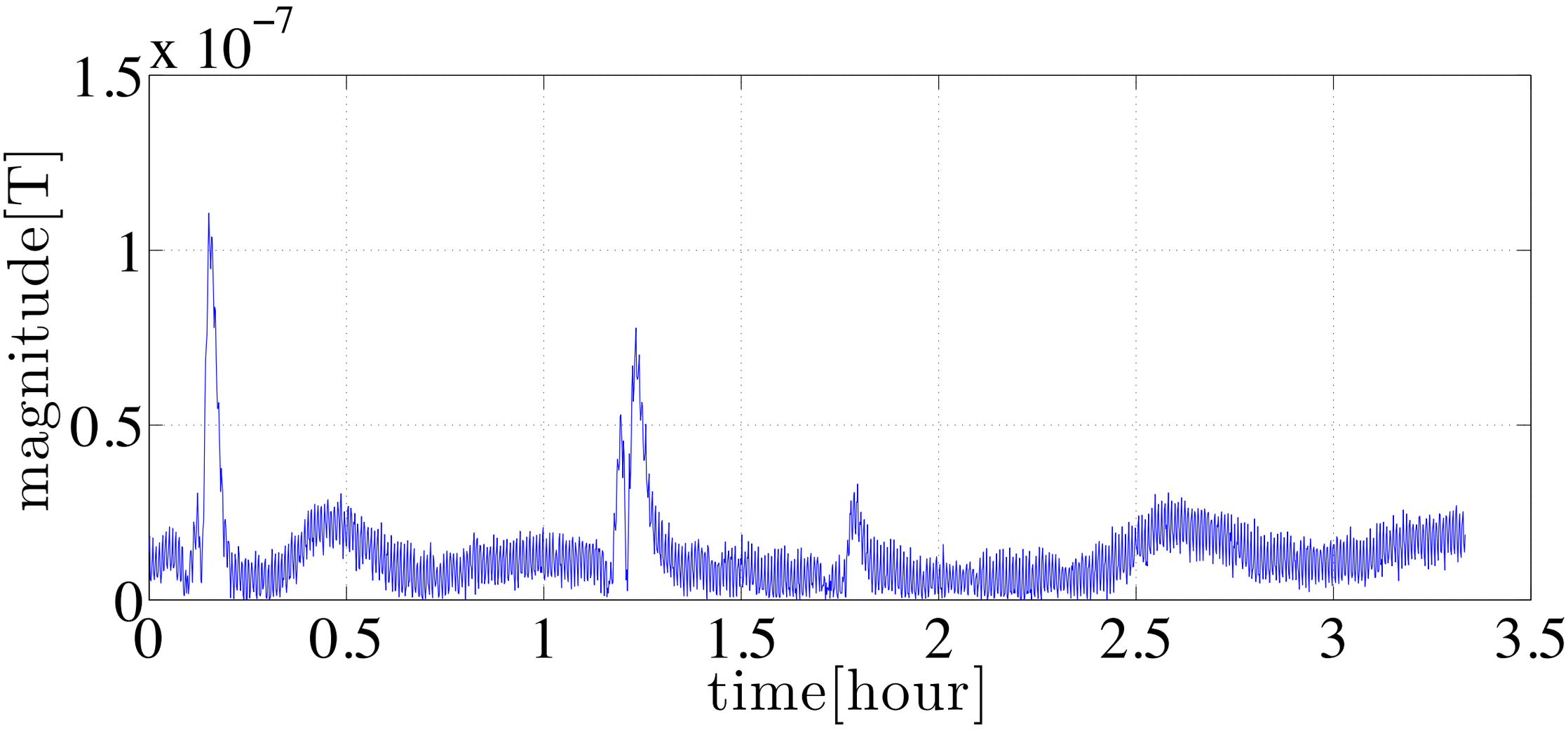
Under investigation

Some of them are ...



hour.

Glitches

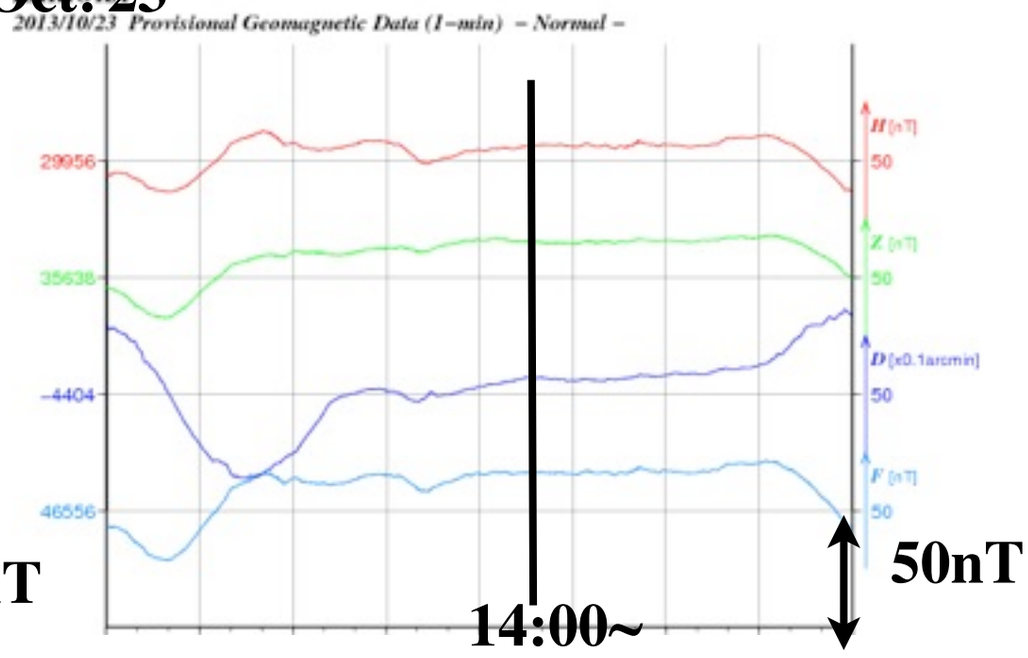


- **4.5 glitch events per hour.**
- **SNR is higher than 5, may appear in obs. band.**

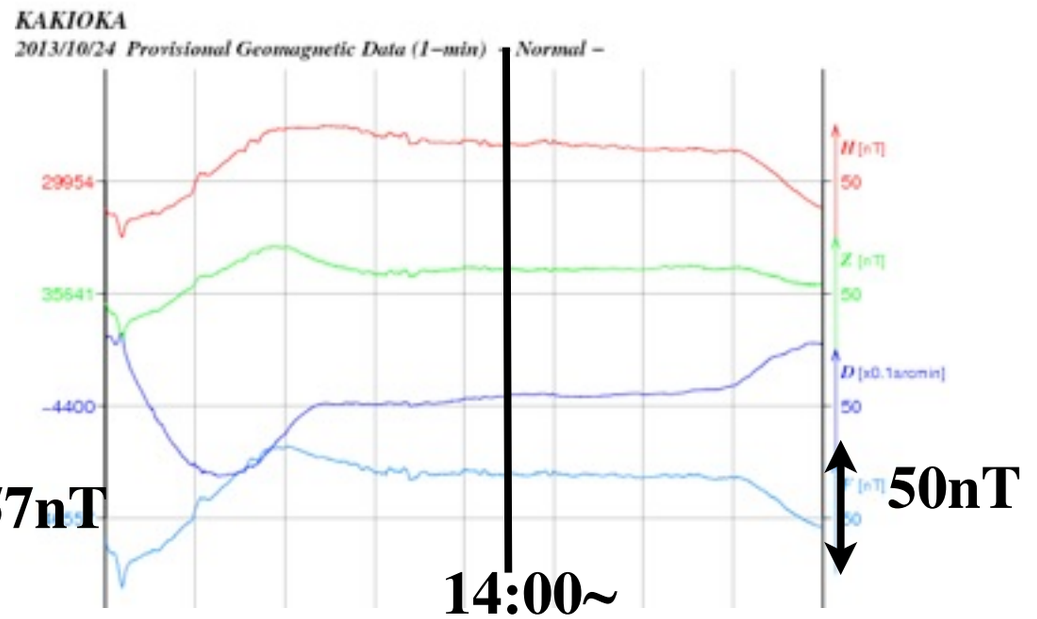
Difference of inside/outside of the Kamioka mine

- Unfortunately one magnetometer was not working.
- We measured DC component at the KAGRA site on 23.
- We measured DC component outside the KAGRA site on 24.
- The geomagnetic variation on 23,24 at 14:00 were within 10nT(< 0.001%)

Oct. 23

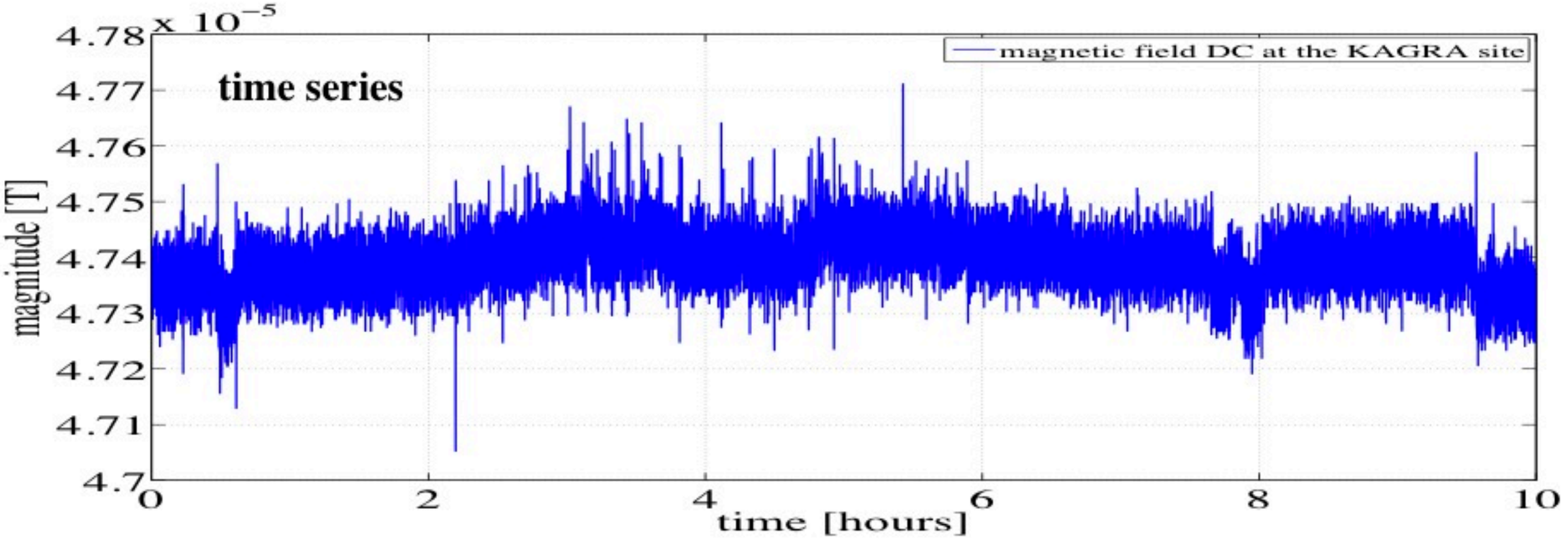


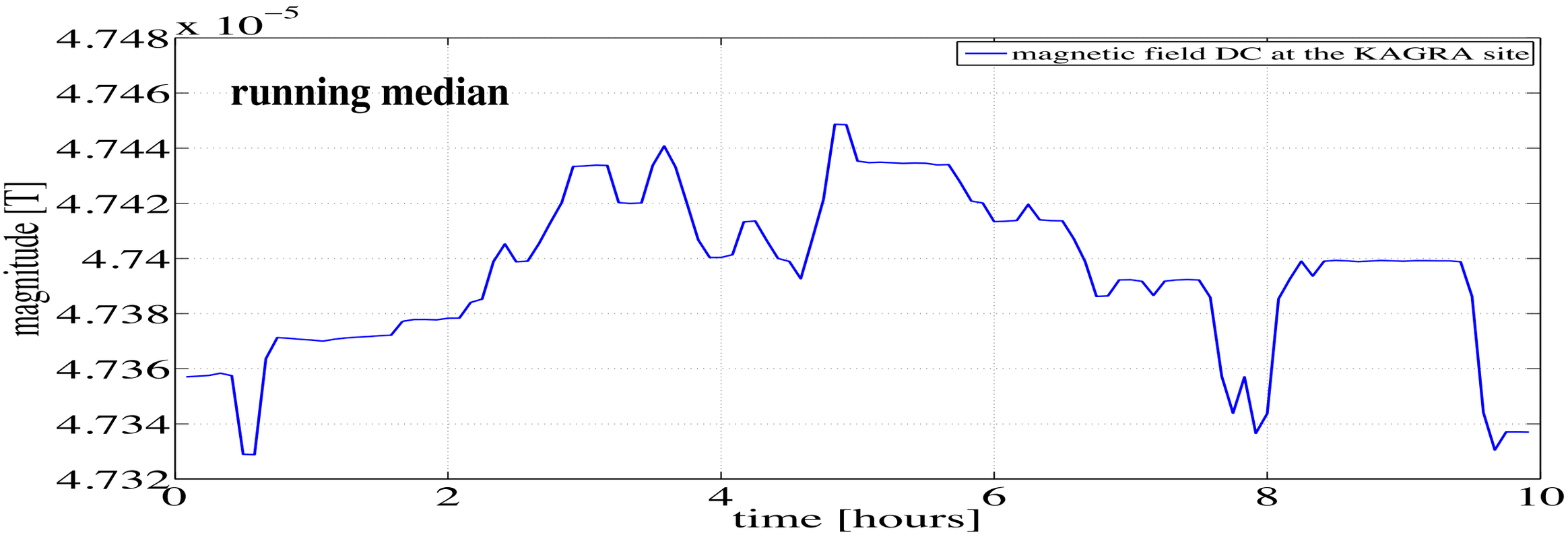
Oct. 24



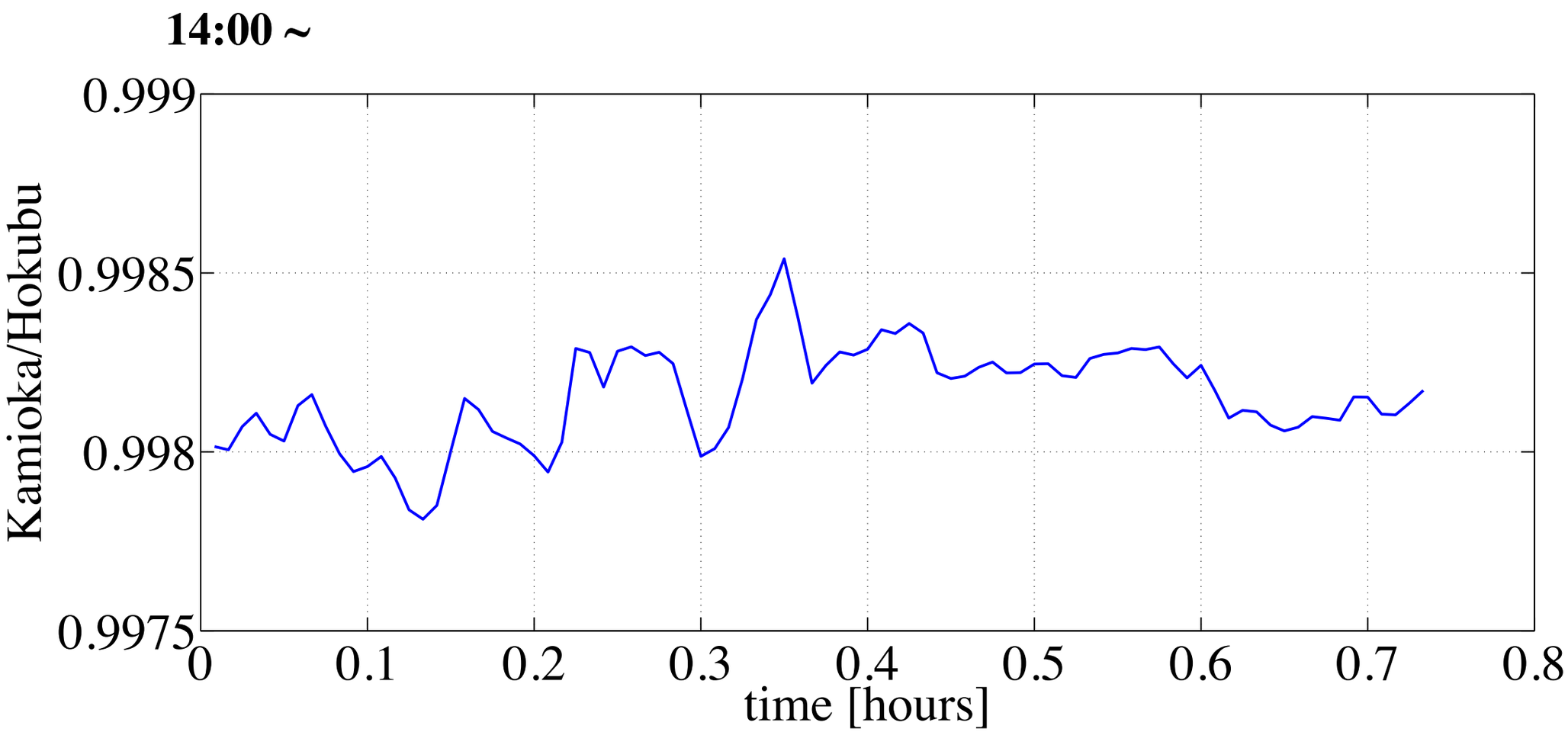
Geomagnetic variation

DC component of the magnetic field





Ratio KAGRA/Hokubu



- **The magnetic field at the Kamioka site is ~0.2% smaller than the outside.**

Summary

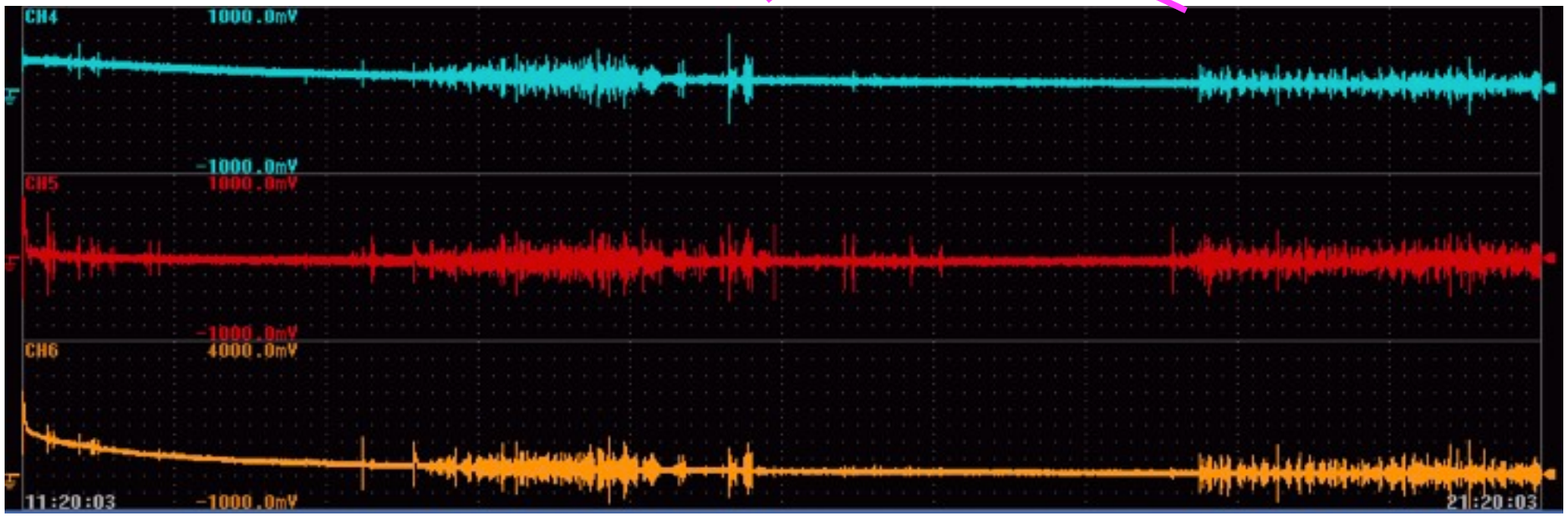
- How is the magnetic field?
  - We see the upper limit of the magnetic field at the KAGRA sited is ~ 20pTrms/rHz which is sensor noise.
  - Not dominated by unexpected magnetic fields.
  - Need more sensitive measurement, upper limit.
- How is the non-stationarity of the magnetic field?
  - A few events per hour, maybe magnetic flare.
  - Need investigation of origin, taking longer data.
- How about difference between outside and inside the mountain?
  - The DC component at the KAGRA site is ~0.2% smaller than the outside.
  - Need measurement of AC components!

End

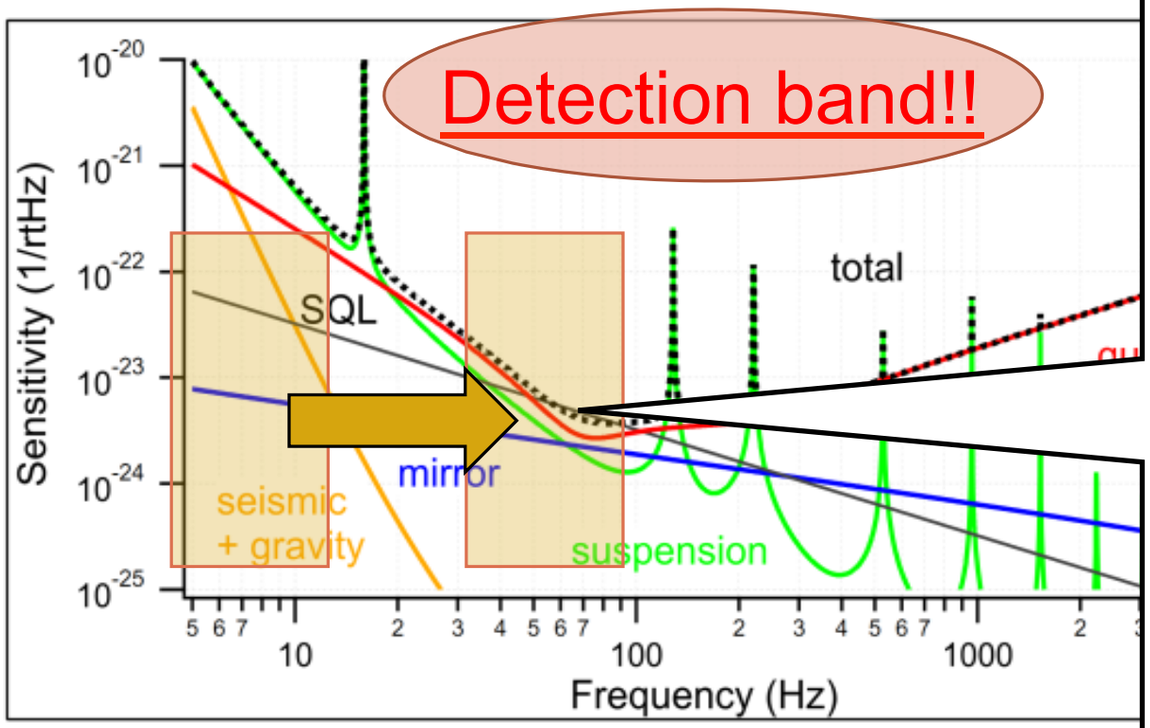
トンネルサイクルタイム表　（　アーム）

断面パターン；　X：CII　Y：CII　　掘削ピッチ；　4m　　平成25年10月23日水曜日

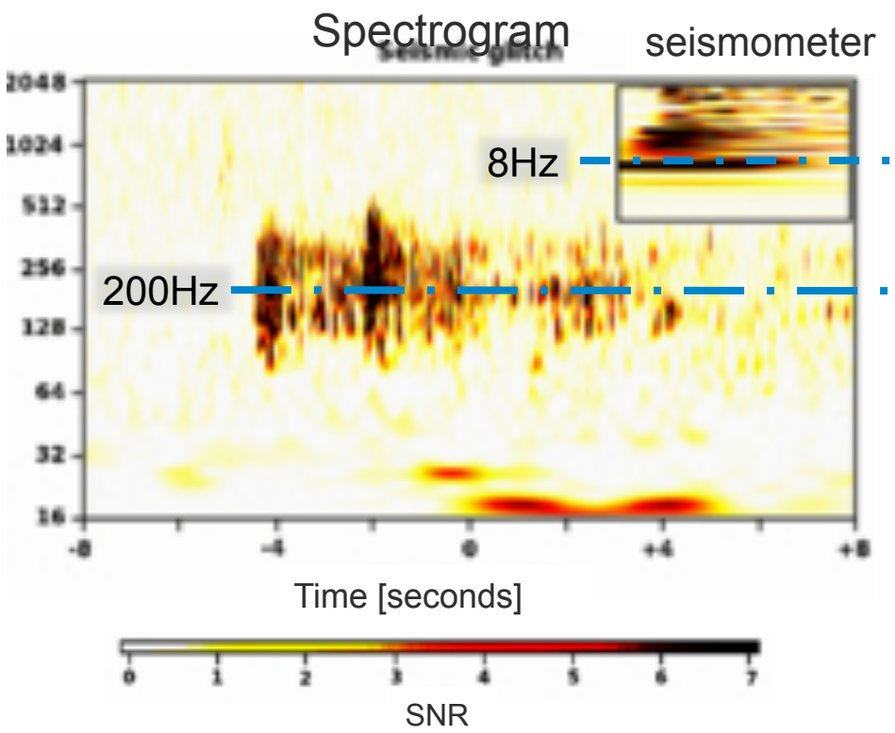
工種	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5
ミーティング・KYK																							
準備工																							
掘削（穿孔）																							
掘削（装薬・発破）																							
ズリ出し・コソク																							
二次吹付																							
食事																							
																坑外へズリ運搬							
中央排水・横断排水掘削																							
中央排水・横断排水敷設																							
中央排水・横断排水埋戻																							
床盤コンクリート打設																							
片付け																							
風管・メッセン張り																							
給排水管延長				ダンプ方向 ワイヤー																			
機械修理・故障等		—		—								吹付機パンク											



Seismic glitch



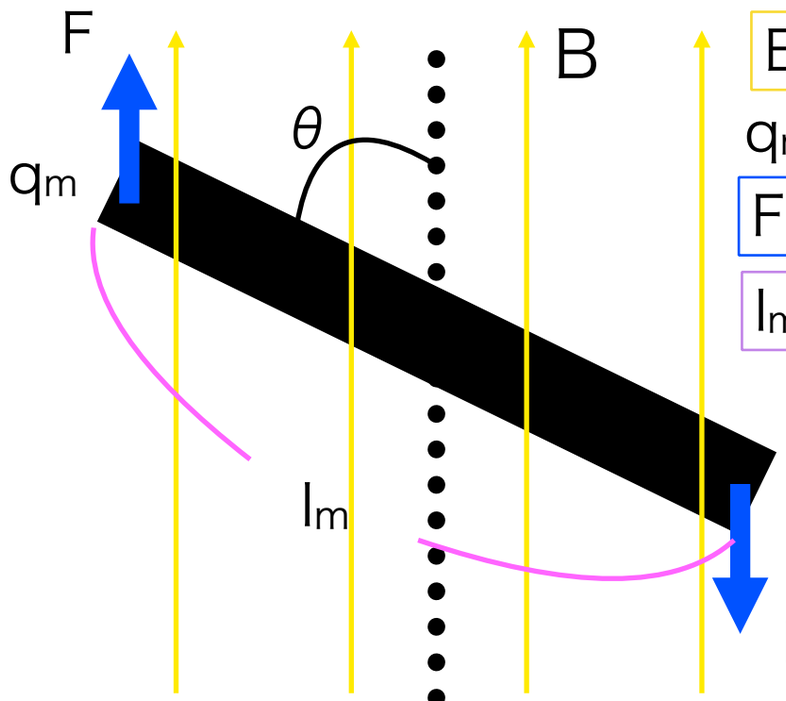
Sensitivity curve of KAGRA



- **Seismic bursts excite bench motion's resonance.** **< 10 Hz**
- **Bench motion's resonance induce scattered light noise** **> 200Hz**

Moving mirror(upper limit)

Magnet feels “Torque”



B:magnetic field

q_m:Magnetic charge

F:Magnetic force

l_m:Magnet length

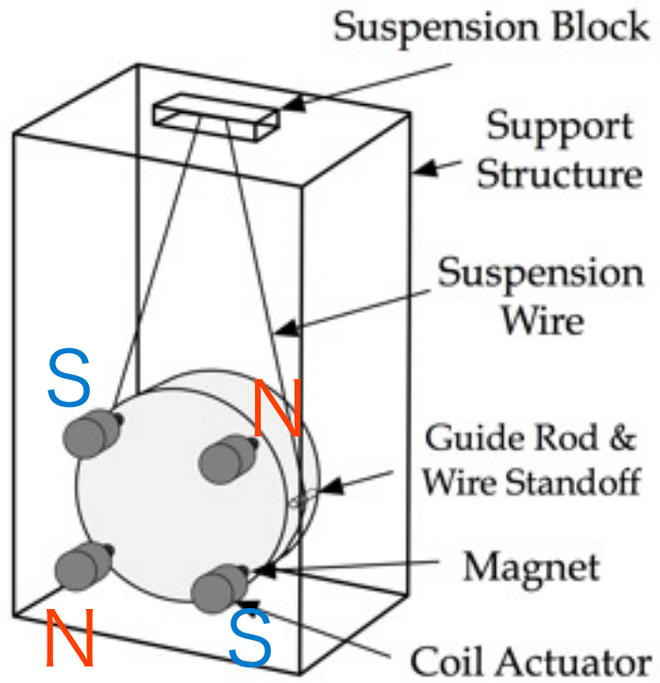
$$F = \frac{q_m}{\mu_0} B$$

$$\mathbf{N} = \mathbf{r} \times \mathbf{F}$$

The number of magnet : 4

$$N = 4 \frac{q_m}{\mu_0} l_m B \sin\theta$$

In upper limit, $\sin\theta \sim 1$



EOM of rotation

$$I \frac{\partial^2 \phi}{\partial t^2} = -k\phi + 4 \frac{q_m l_m}{\mu_0} B$$

↓ Fourier transformation and Simplify

$$|\tilde{\phi}| = \frac{q_m l_m}{I \pi^2 \mu_0} \frac{1}{f^2 - f_{res}^2} |\tilde{B}|$$

I : moment of inertia　$L = I\omega$: angular momentum

ω : angular velocity　k : coefficient of resilience of mirror

$$f_{res} = \frac{1}{2\pi} \sqrt{\frac{k}{I}}$$

Ono

Moving mirror(upper limit)

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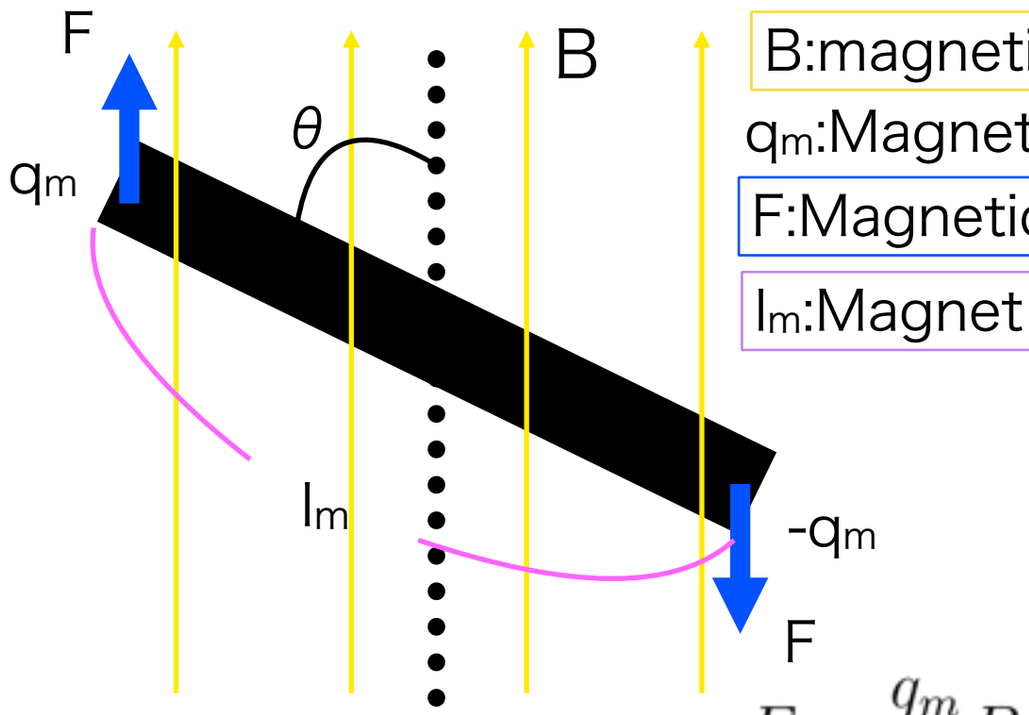

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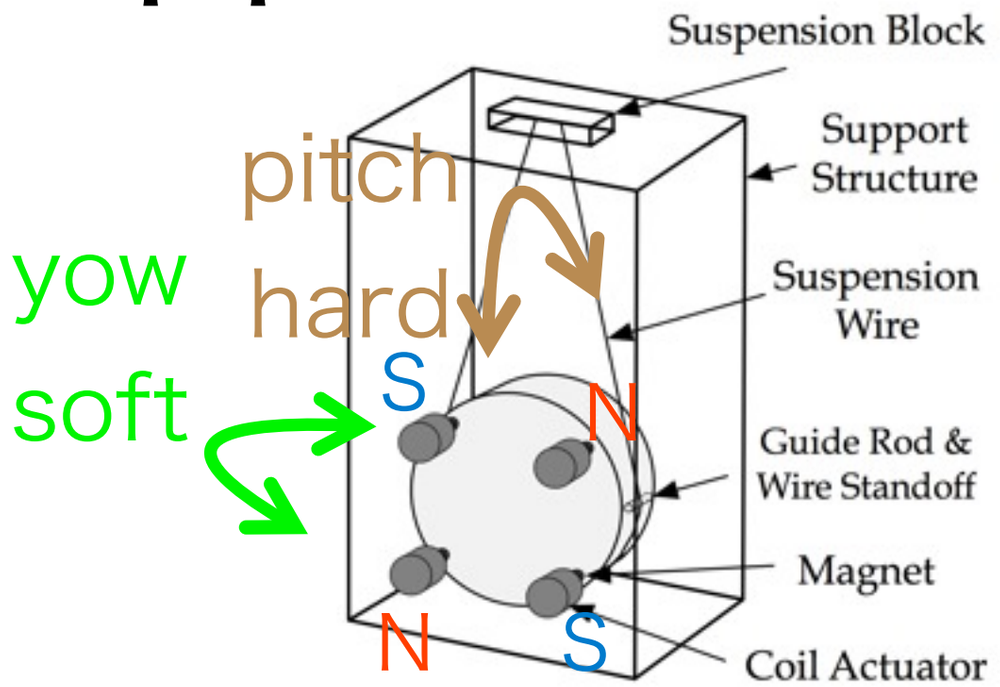

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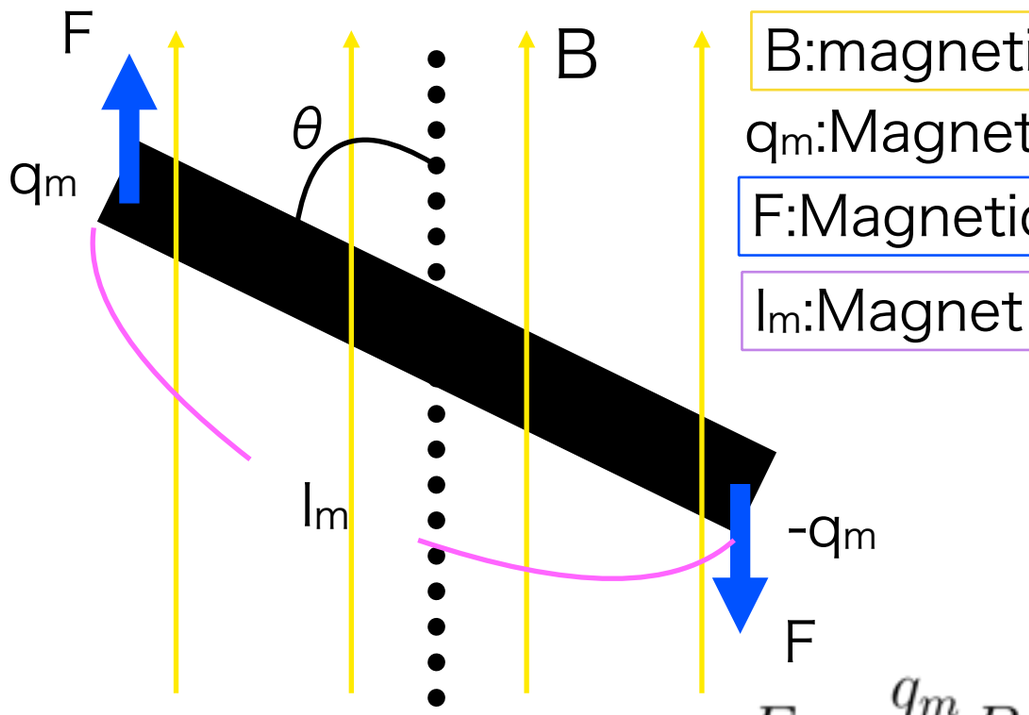

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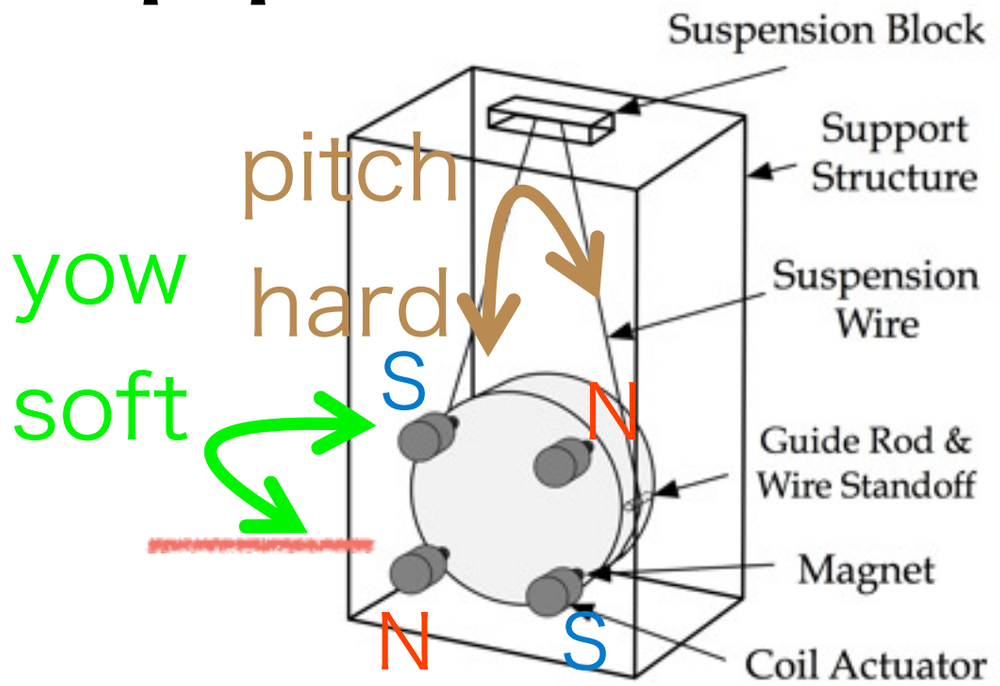

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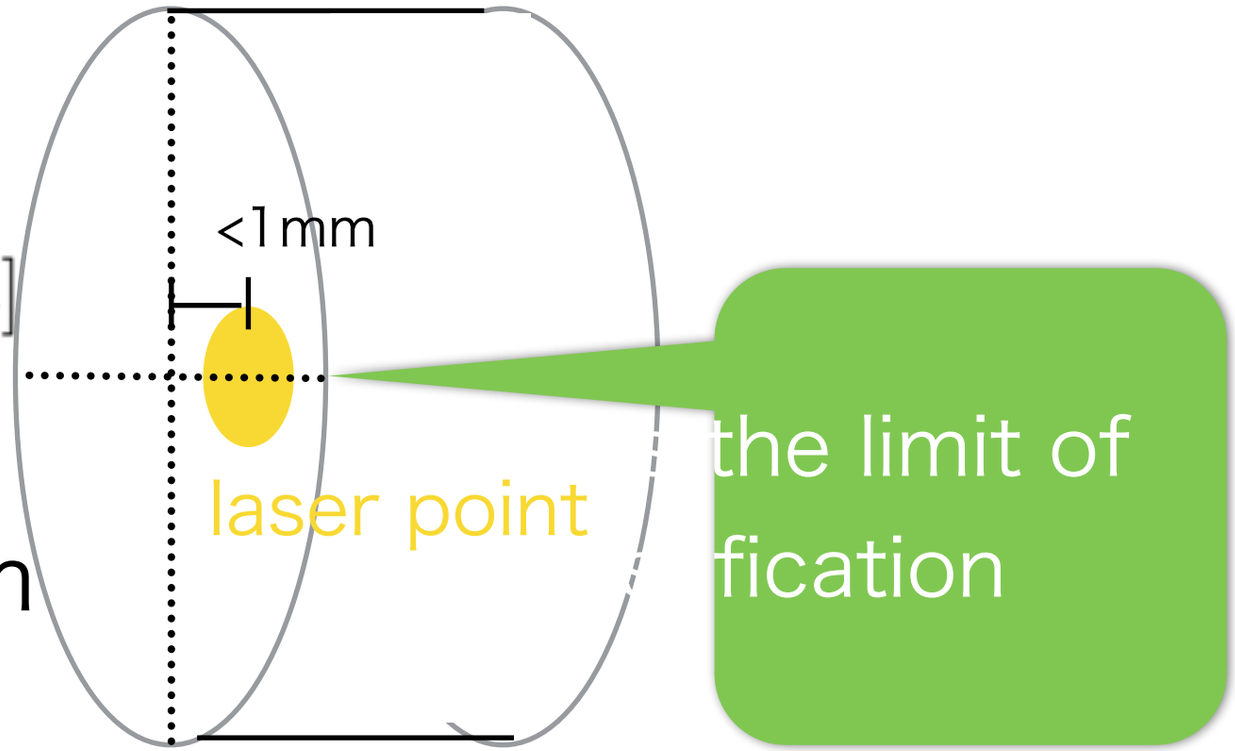
Ono

How much does the magnetic field affect for sensitivity?

Displacement of optical path length is $10^{-3}\phi[m]$



the limit of fication

Optical path length:3000m

the number of mirror:4

$$h_{\text{magnetic noise}} = \frac{2}{3}10^{-6}\frac{q_m l_m}{I\pi^2\mu_0}\frac{1}{f^2 - f_{res}^2}|\tilde{B}|\ [1/\sqrt{\text{Hz}}]$$

Ono

How much does the magnetic

vity?

Disp

We need this information.

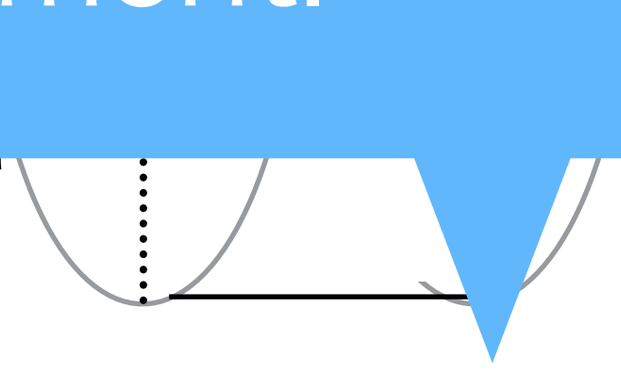
→measurement.

the limit of

fication

Optical path length:3000m

the number of mirror:4



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Ono