Reading Seminar:
Towards a first design of a Newtonian-noise cancellation system for Advanced LIGO
arXiv:1606.01716

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KAGRA DetChar Group

References

- Jennifer Clair Driggers Ph.D thesis at California Institute of Technology (2015)
  - http://thesis.library.caltech.edu/8998/

- Jan Harms, Living Rev. Relativity 18, 3 (2015).

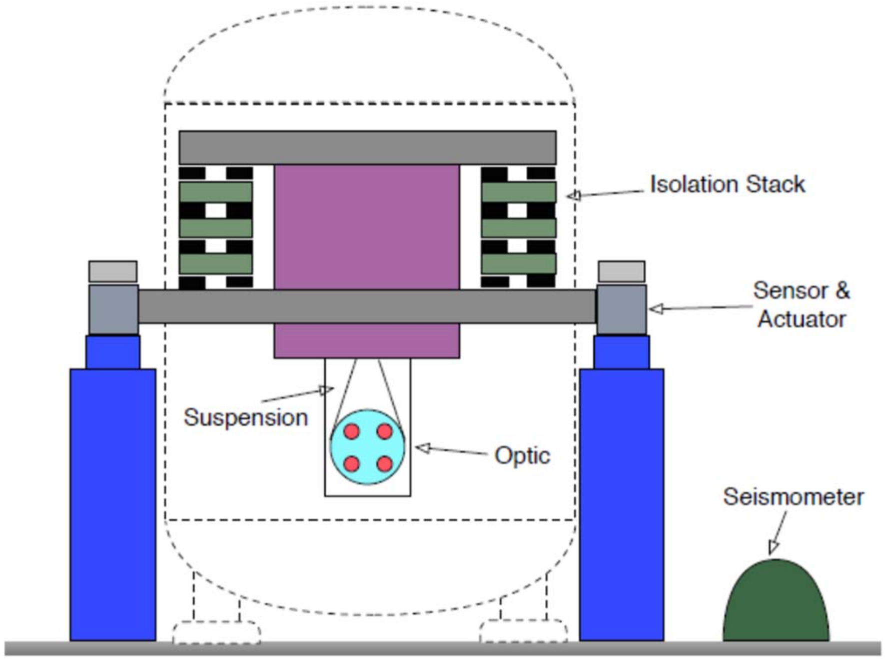
- LIGO-T1100237-v1-H
  - Results of Phase 1 Newtonian Noise Measurements at the LIGO Sites, February-March 2011

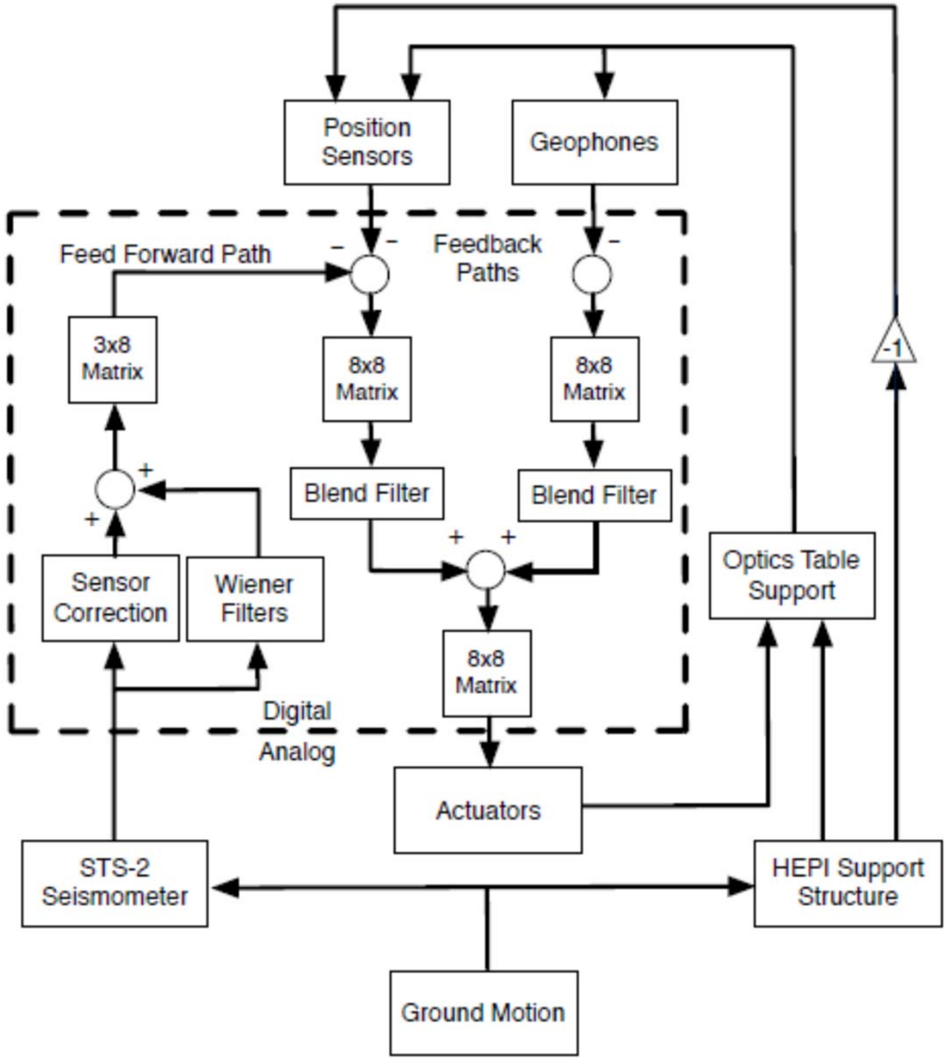
- LIGO-G1200540-v1
  - "Measured" Newtonian Noise: Implications for Advanced Detectors

- J. C. Driggers, J. Harms, and R. X. Adhikari, Phys. Rev. D 86, 102001 (2002). Optimization of Arrays of Sensor

LIGO situation

- Global seismic motion cancellation system was implemented on O6 run at iLIGO.

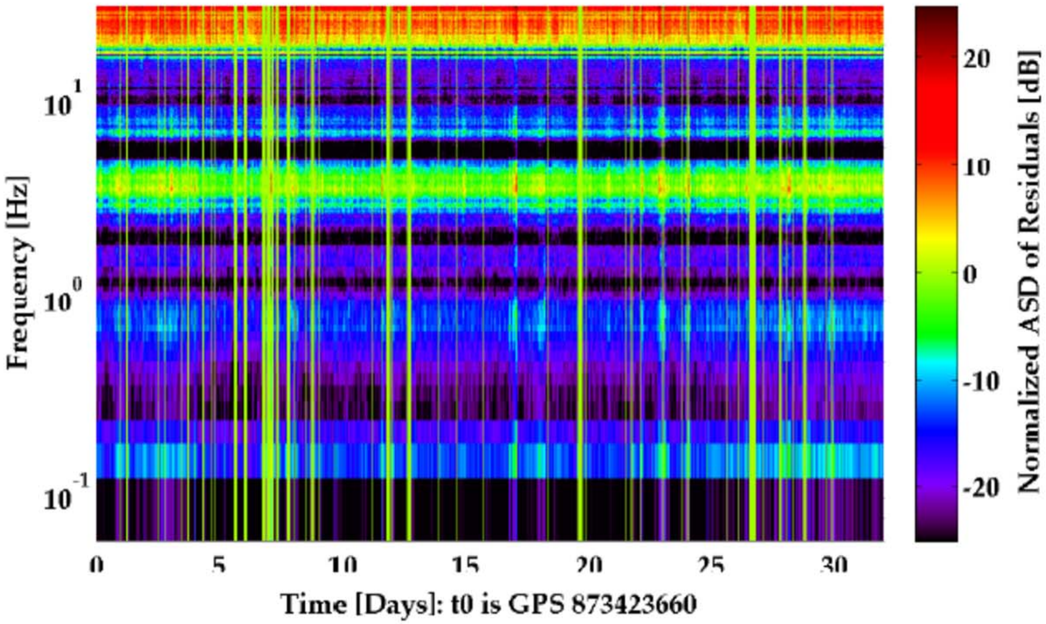


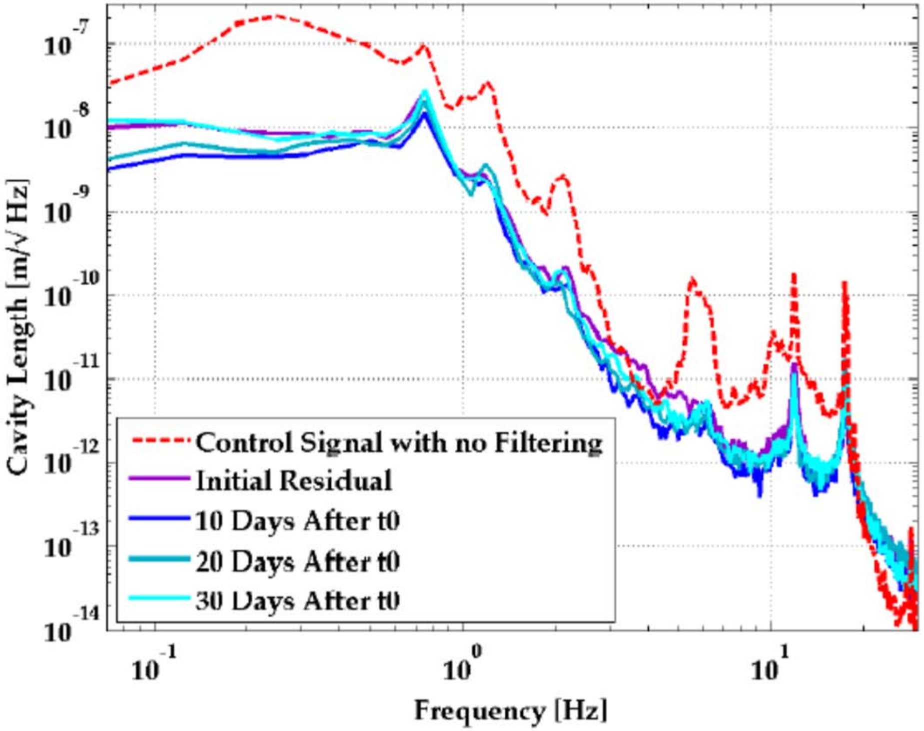


Streckeisen STS-2
Broadband Sensor at LLO

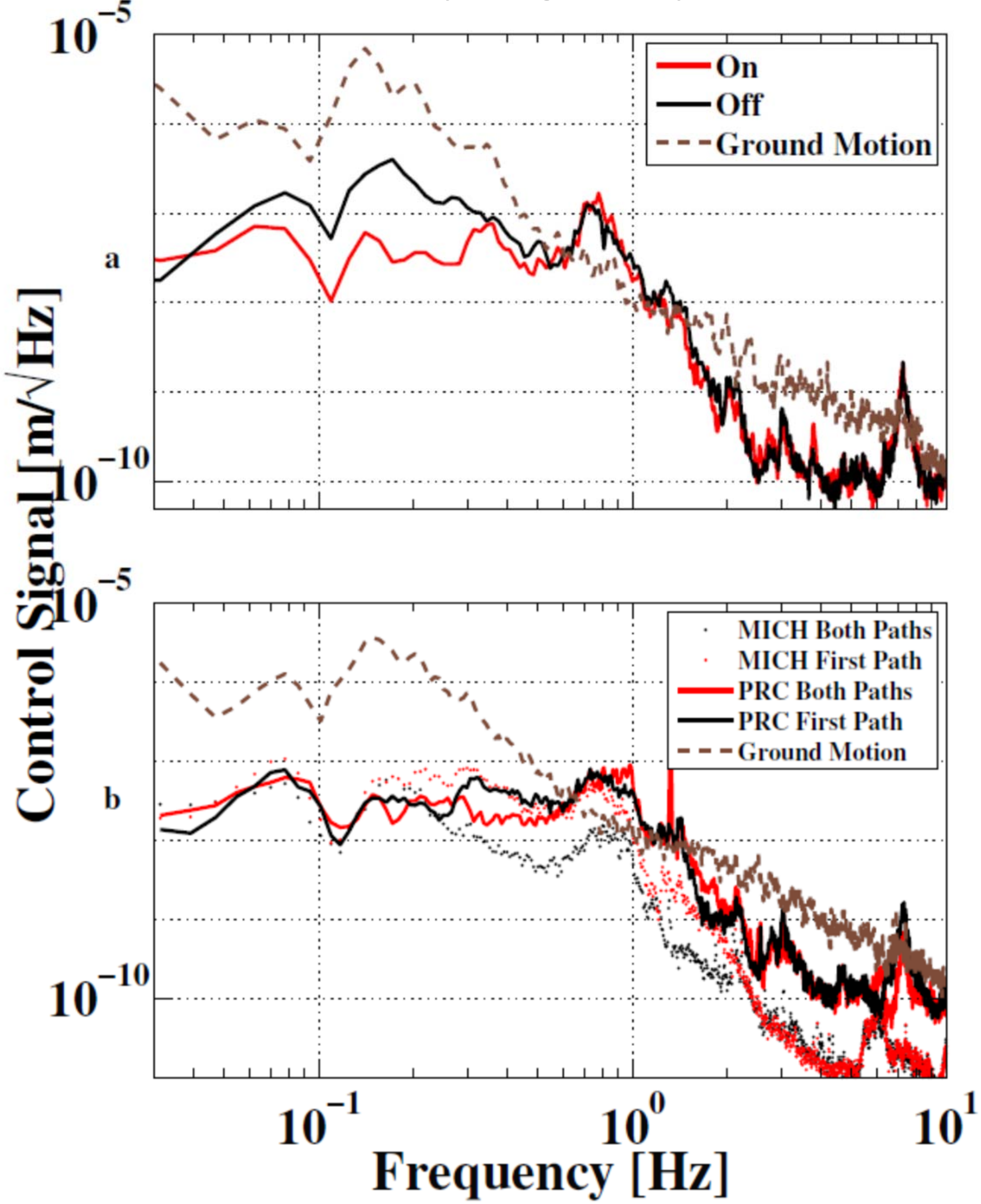
Geotech GS-13 at LHO

Wiener filter construction





Power recycling cavity at LLO



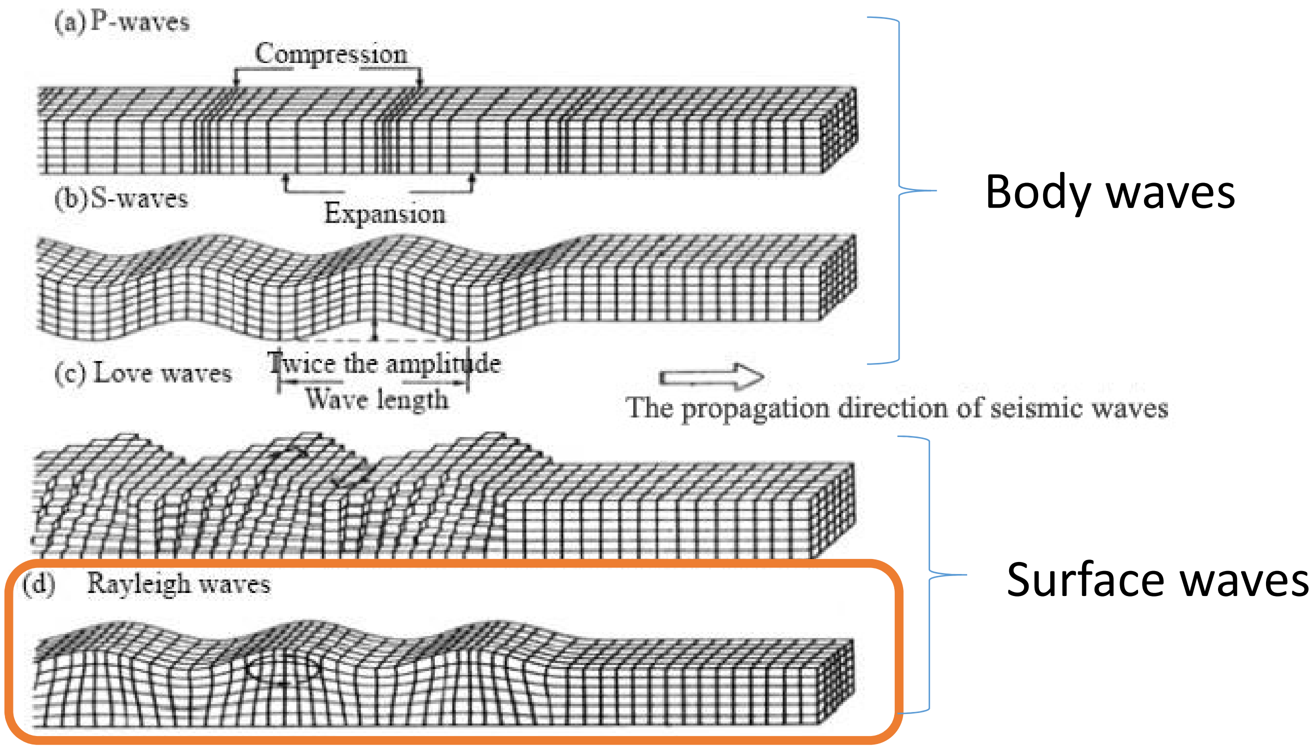
Cancellation system was well worked.

Newtonian Noise?

- Test mass fluctuation due to the gravity perturbation
  - By seismic motion
  - By air

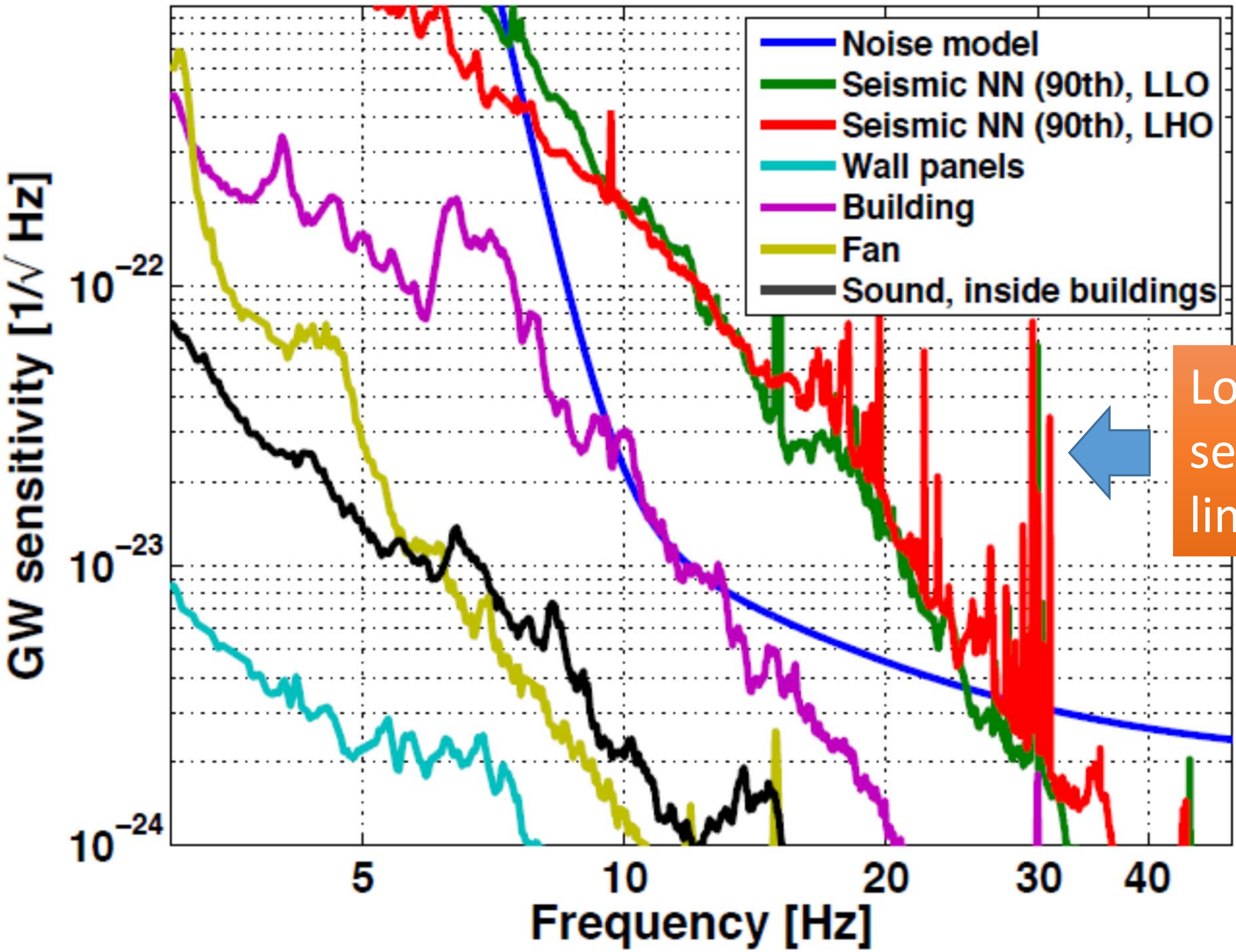
  etc. (= change of the mass)

Newtonian noise by seismic motion can be classified.



Why important?

From noise budget in Feb. and Mar. 2011

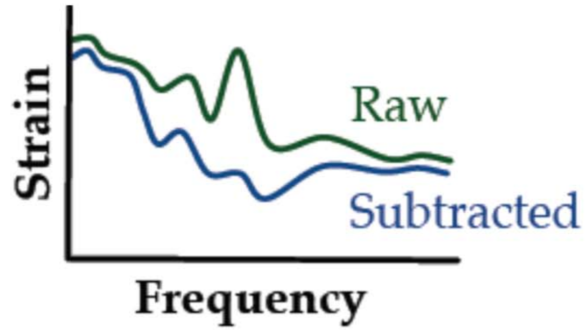


Low-frequency sensitivity is limited.

How to ?

- Define the subtraction factor at the single frequency.
- The subtraction factor is changed by
  - Number of sensors
  - Sensor layout
  - Array size

$$\sqrt{R} = \sqrt{\frac{S_{NN_{Sub}}}{S_{NN_{Raw}}}}$$



From the Rayleigh model, the correlation function is given by

$$C(\delta a_x; \vec{\rho}_0, \omega) = (2\pi G \rho_0 \gamma(\nu))^2 \int\int \frac{\mathrm{d}^2 k}{(2\pi)^2}\frac{\mathrm{d}^2 k'}{(2\pi)^2} S(\xi_z; \vec{k}, \vec{k}', \omega) \frac{k_x}{k}\frac{k'_x}{k'} \mathrm{e}^{-hk}\mathrm{e}^{-hk'}\mathrm{e}^{\mathrm{i}\vec{\varrho}_0\cdot(\vec{k}-\vec{k}')},$$

$$C(\delta a_x; \vec{\varrho}_0, \omega) = (G\rho_0\gamma(\nu))^2 \int\int \mathrm{d}^2\varrho\,\mathrm{d}^2\varrho' C(\xi_z; \vec{\varrho}, \vec{\varrho}', \omega)\mathcal{K}(\vec{\varrho}, \vec{\varrho}_0)\mathcal{K}(\vec{\varrho}', \vec{\varrho}_0),$$

$$C(\xi_z, \delta a_x; \vec{\varrho}_0, \vec{\varrho}, \omega) = -2\pi\mathrm{i}G\rho_0\gamma(\nu) \int\int \frac{\mathrm{d}^2 k}{(2\pi)^2}\frac{\mathrm{d}^2 k'}{(2\pi)^2} S(\xi_z; \vec{k}, \vec{k}', \omega)\frac{k_x}{k}\mathrm{e}^{-hk}\mathrm{e}^{\mathrm{i}(\vec{\varrho}_0\cdot\vec{k}-\vec{\varrho}\cdot\vec{k}')},$$

$$S(\xi_z; \vec{k}, \vec{k}', \omega) \equiv \int\int \mathrm{d}^2\varrho\,\mathrm{d}^2\varrho' C(\xi_z; \vec{\varrho}, \vec{\varrho}', \omega)\mathrm{e}^{-\mathrm{i}(\vec{\varrho}\cdot\vec{k}-\vec{\varrho}'\cdot\vec{k}')}$$

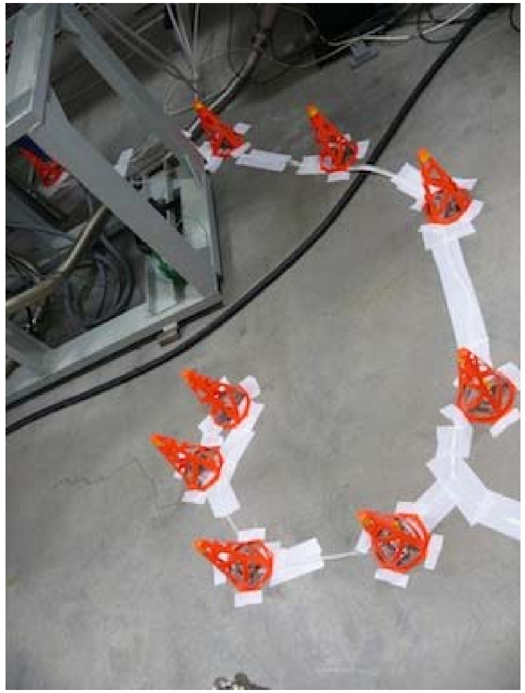
$$C(\xi_z, \delta a_x; \vec{\varrho}_0, \vec{\varrho}, \omega) = G\rho_0\gamma(\nu)\int \mathrm{d}^2\varrho' C(\xi_z; \vec{\varrho}, \vec{\varrho}', \omega)\mathcal{K}(\vec{\varrho}', \vec{\varrho}_0).$$

$$\mathcal{K}(\vec{\varrho}_1, \vec{\varrho}_2) \equiv \frac{x_1 - x_2}{(h^2 + |\vec{\varrho}_1 - \vec{\varrho}_2|^2)^{3/2}}.$$

LHO study

Measurement:
April – November, 2012

LHO Y-end station



Wilcoxon Research
731-207

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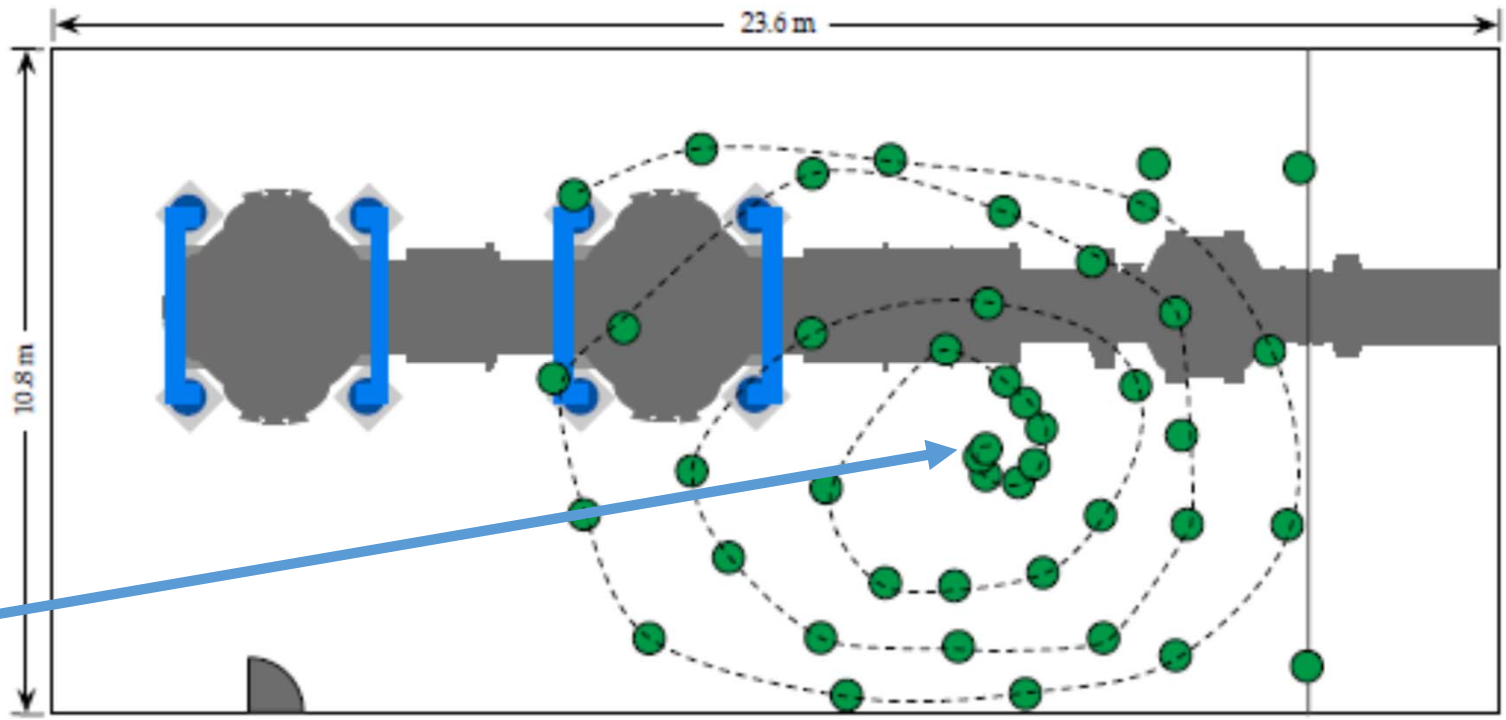
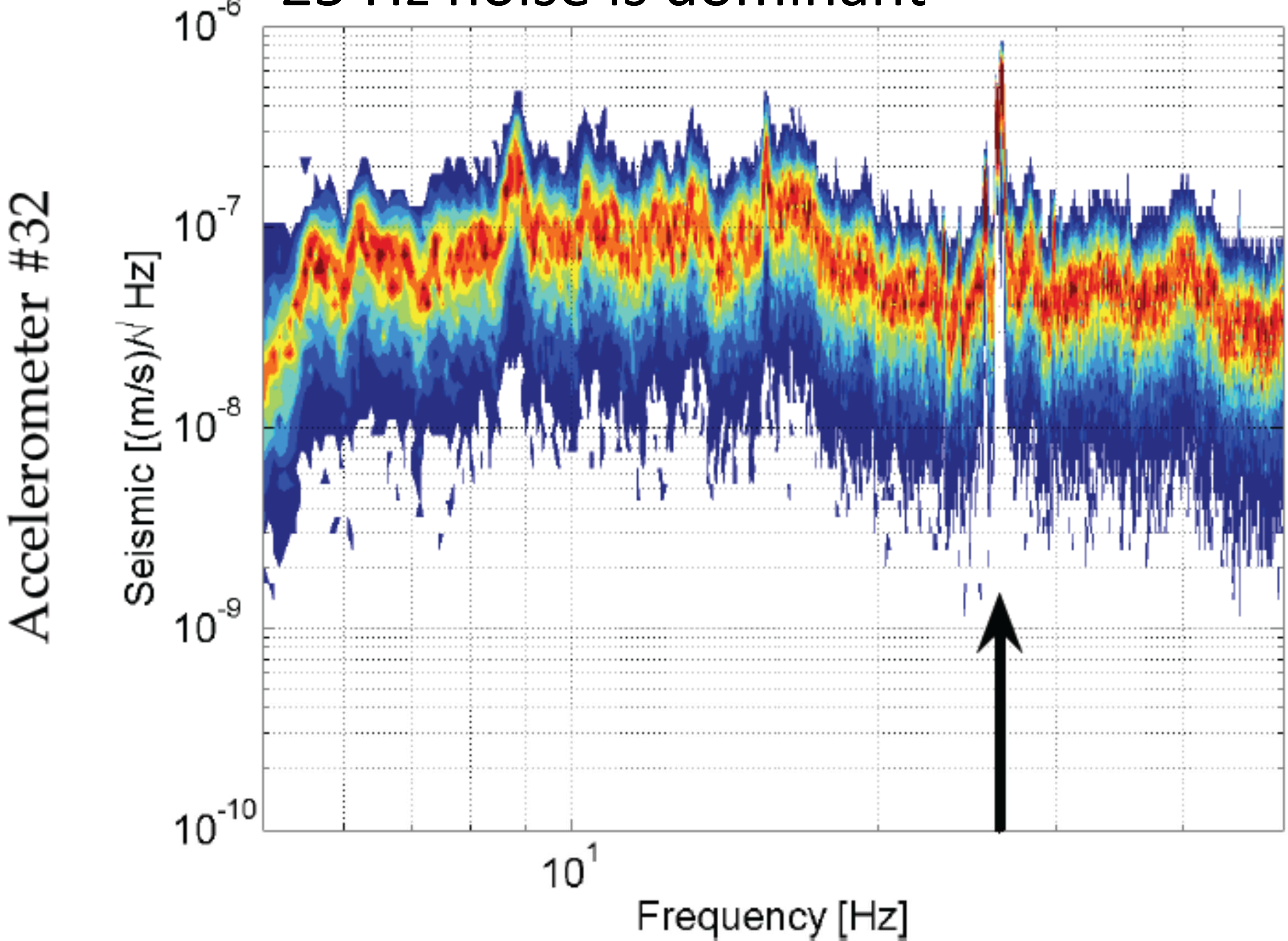
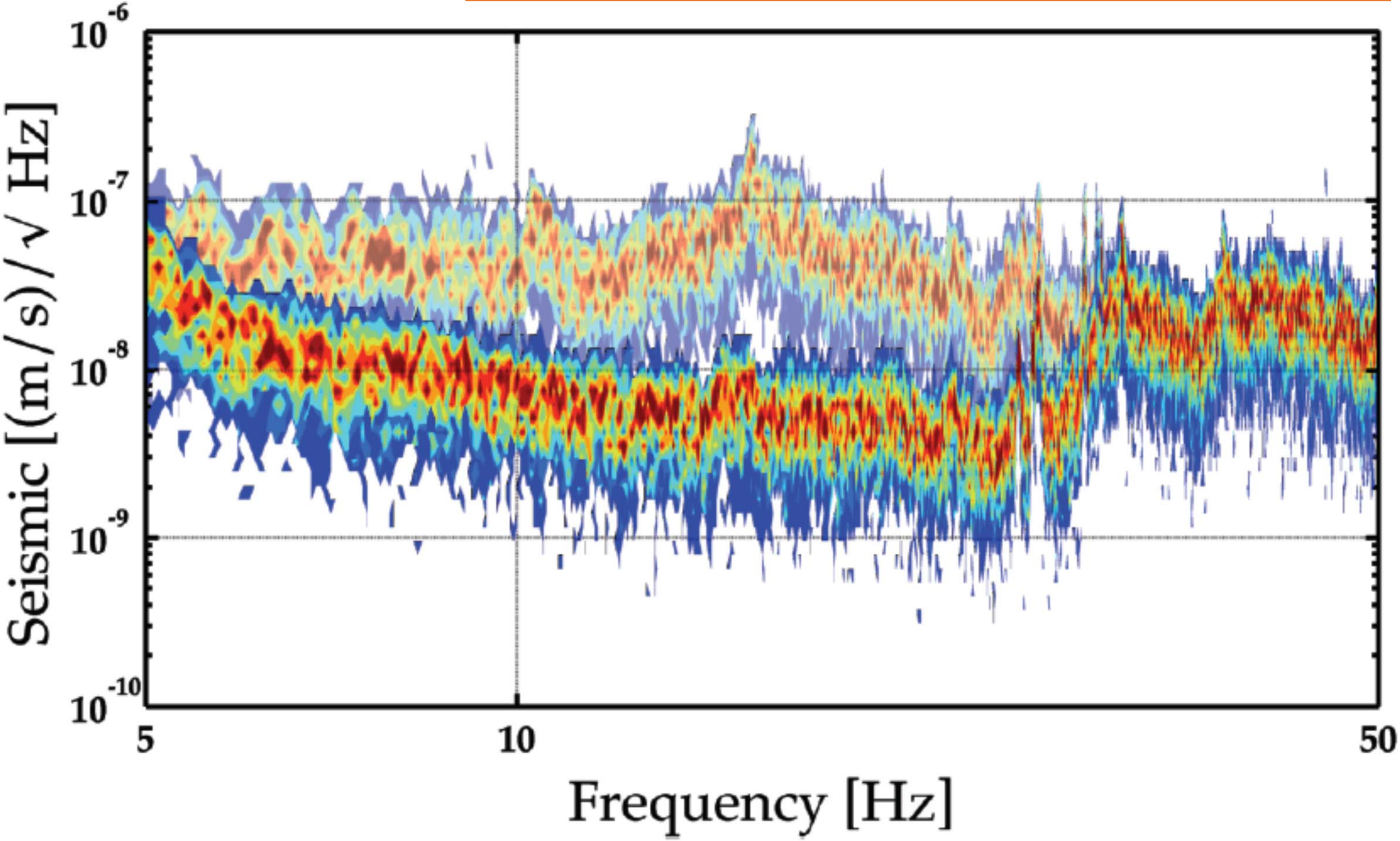


25 Hz noise is dominant



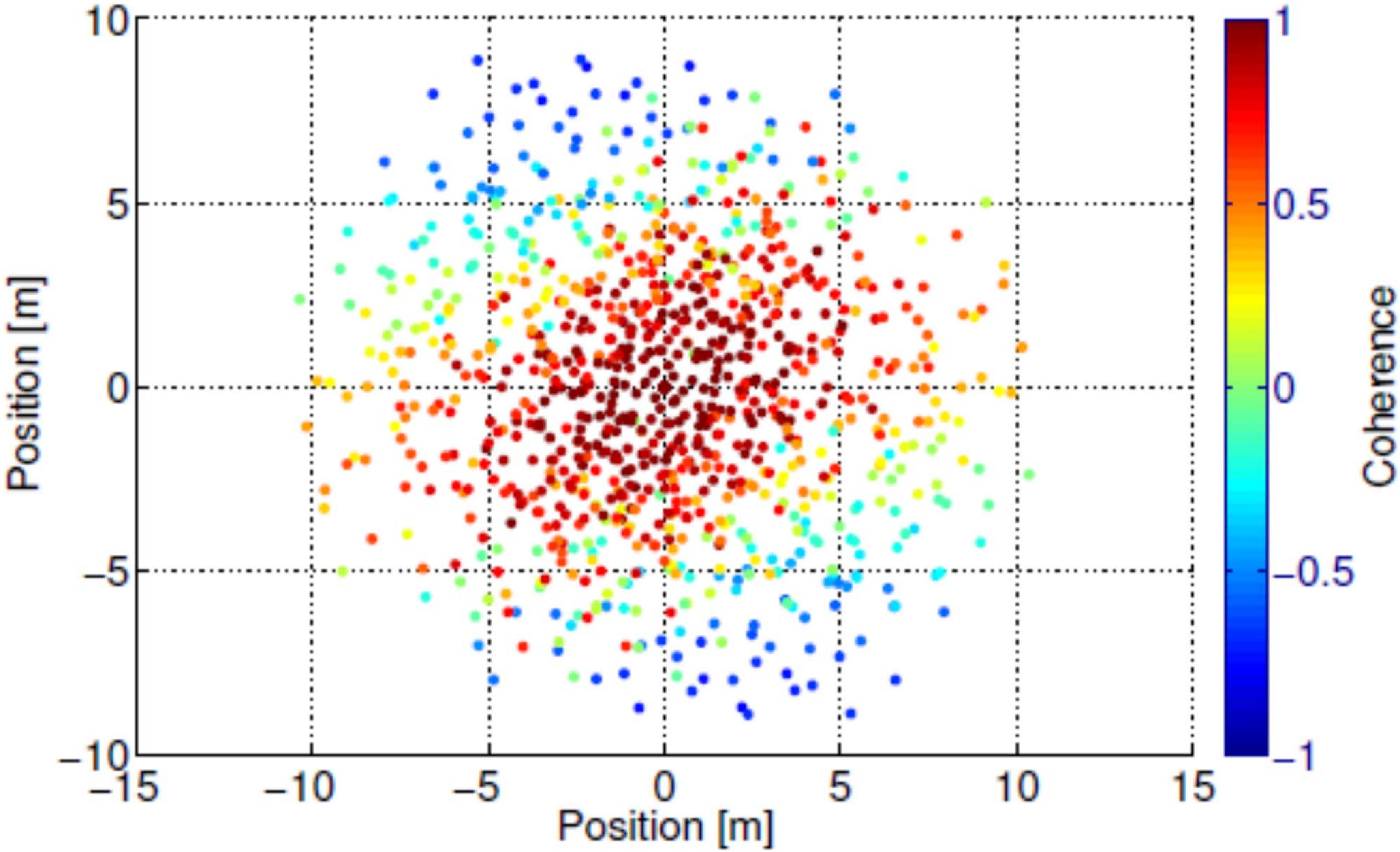
Filter check

Subtract seismic noise from one sensor (#44), using surrounding sensors



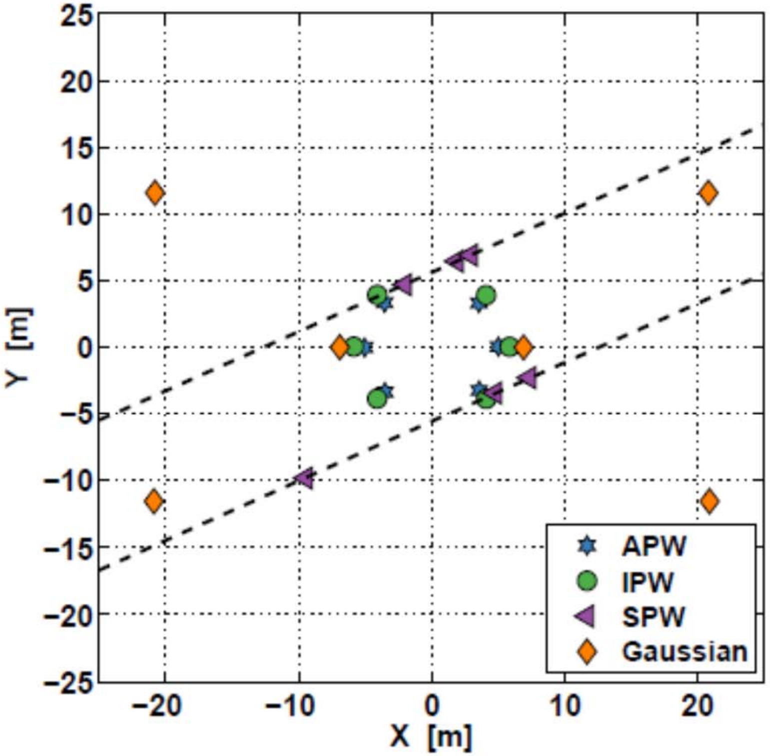
Coherence at 15 Hz

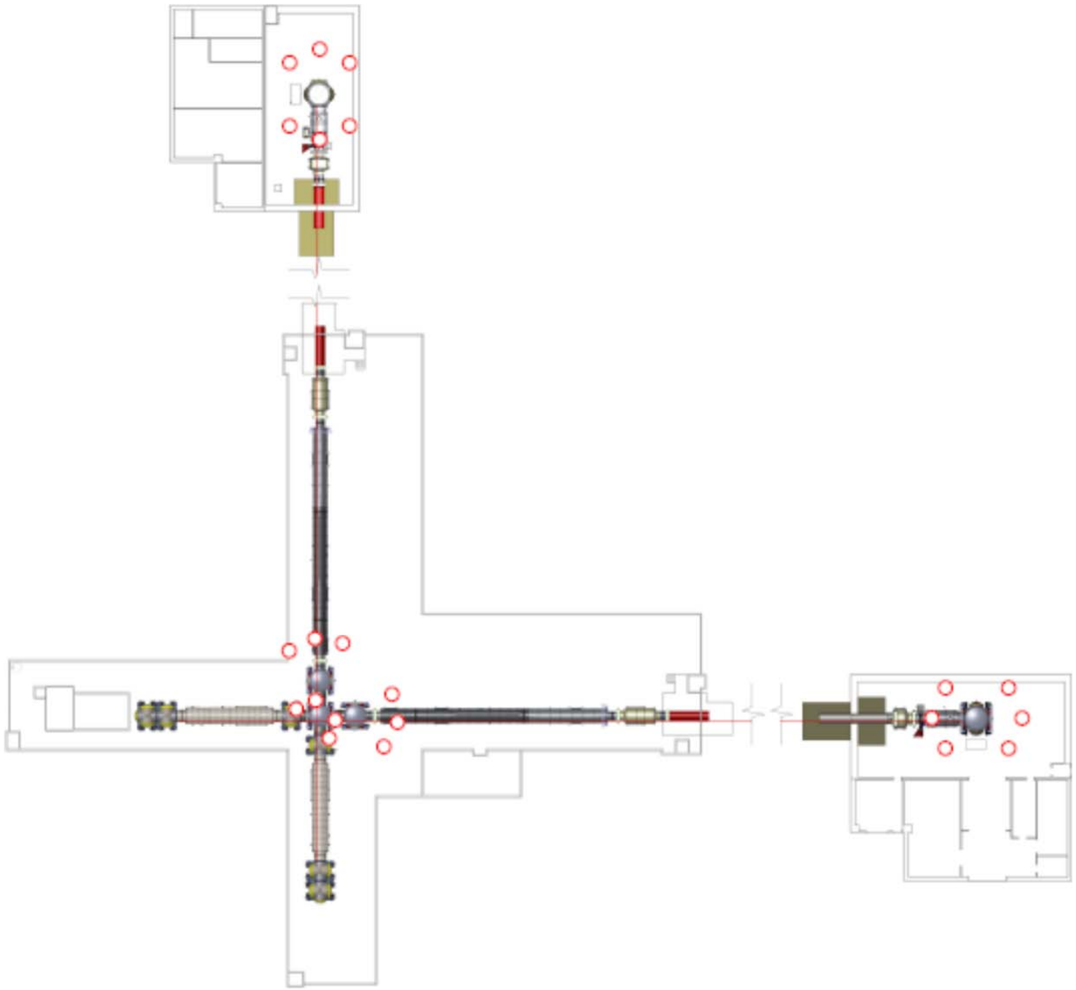
Why to choose this parameter?



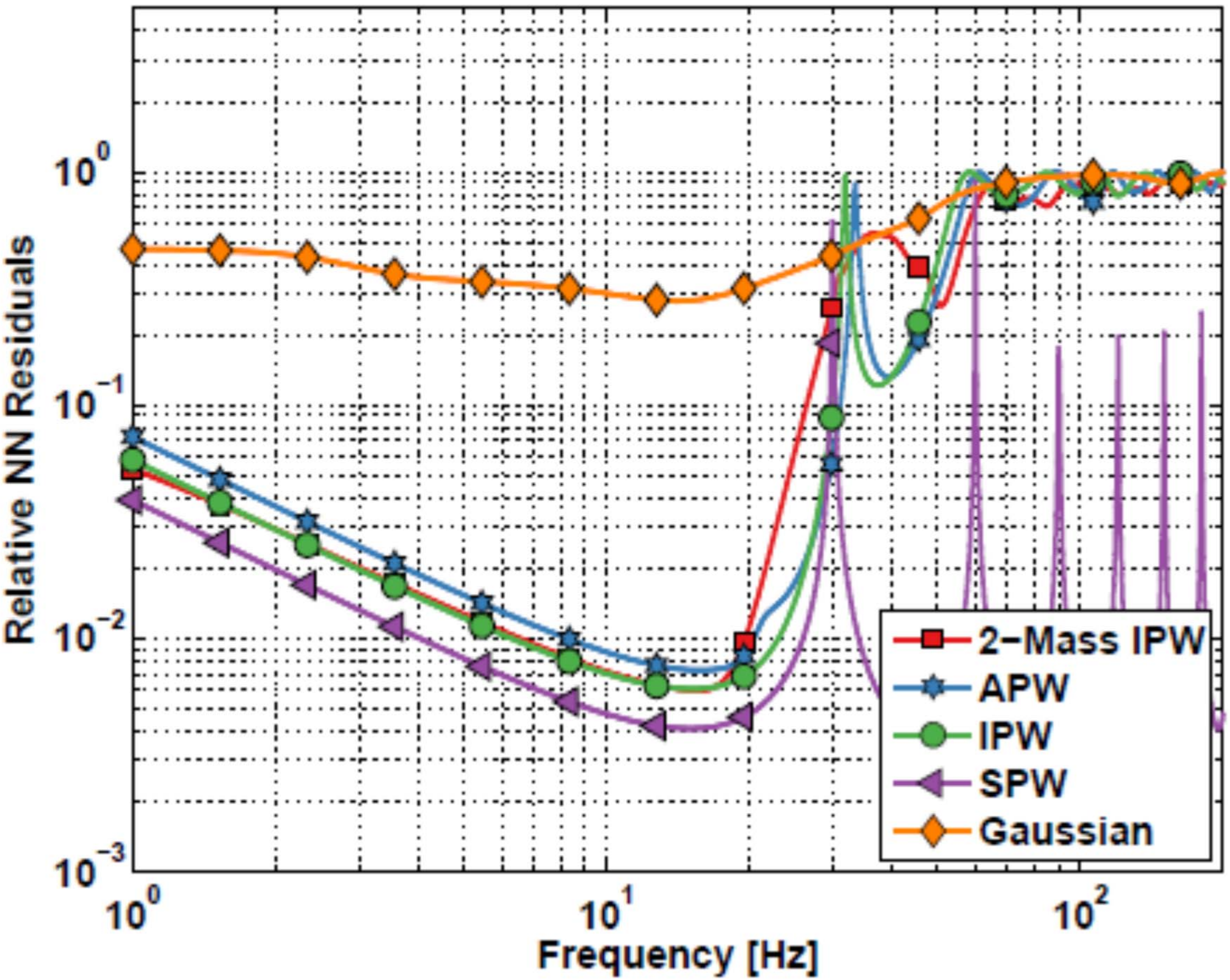
Optimized sensor position

APW: anisotropic plane-wave
IPW: isotropic plane-wave
SPW: single plane-wave
Gaussian: isotropic Gaussian

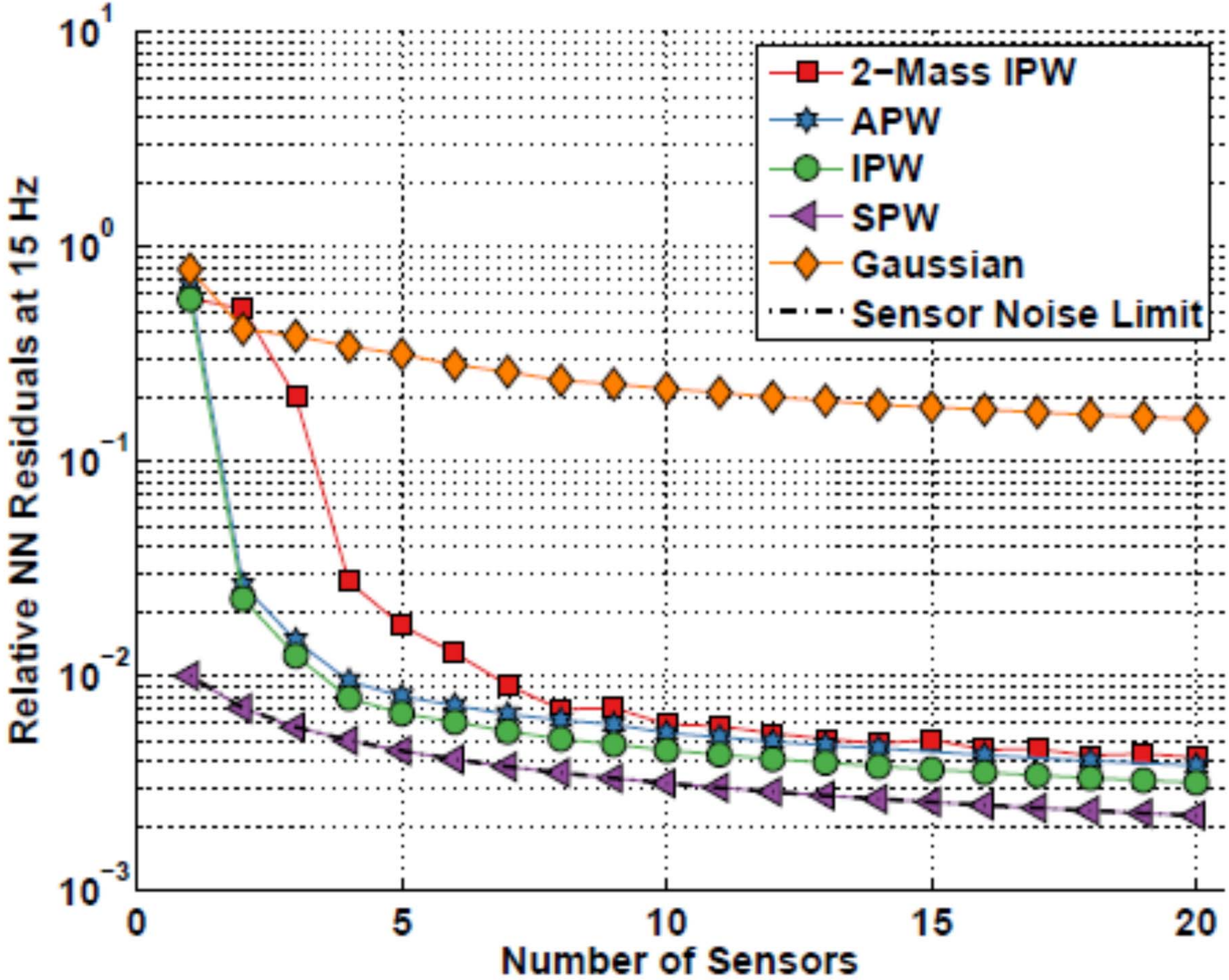




Estimated subtraction



15 Hz subtraction



Conclusion

- Sensor layout optimization at 15 Hz to subtract the Newtonian noise was done.
- Cancellation system (not written the details) may use the similar system of the seismic cancellation system.

- Yutaka does not understand
  - Why 15 Hz optimization? Where 25 Hz noise?
  - Adaptive filter system is needed?
  - Cancellation system is well worked?