# Atmospheric Newtonian Noise (NN)

## Infrasound NN

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Donatella Fiorucci[a], Jan Harms[b], Matteo Barsuglia[a]

[a]Astroparticule et Cosmologie (APC)
[b]Università degli Studi di Urbino 'Carlo Bo'

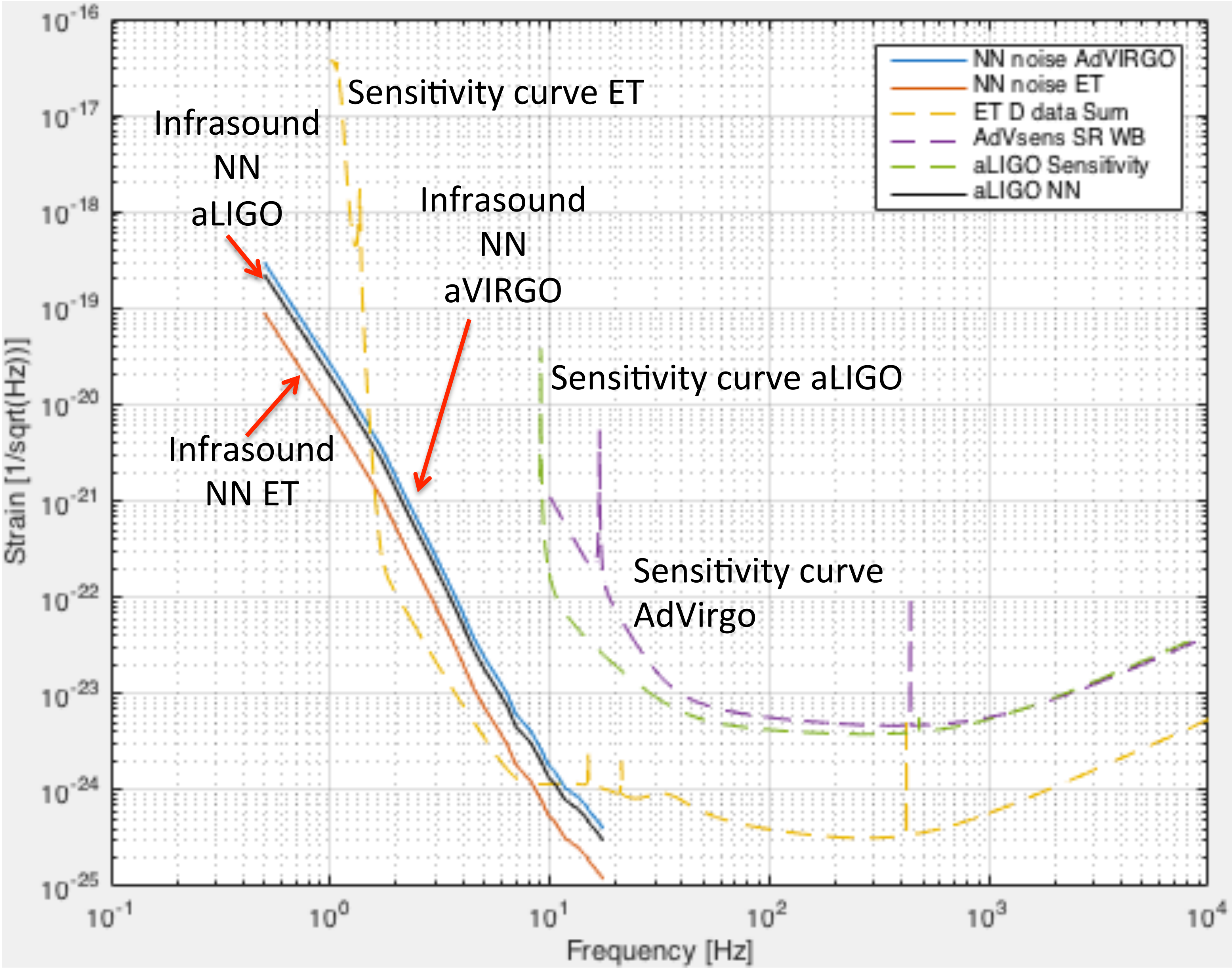
# Atmospheric sources of Newtonian Noise

- Atmospheric weak pressure waves (small $\delta p/p$)
- Atmospheric temperature perturbations
- Atmospheric shockwaves
- High-speed massive objects moving near the interferometer

# Why modeling infrasound NN?

| | | |
|---|---|---|
| aLIGO, AdVirgo, KAGRA | → | Frequency range ≈ 10Hz – 30Hz |
| Einstein Telescope (ET) | → | Frequency range ≈ 1Hz – 30Hz |
| Torsion bar antennae and other low frequency detectors (i.e. TOBA, TORPEDO, atom interferometers ...) | → | Frequency range ≈ 10 mHz-1Hz |

# Why modeling infrasound NN?

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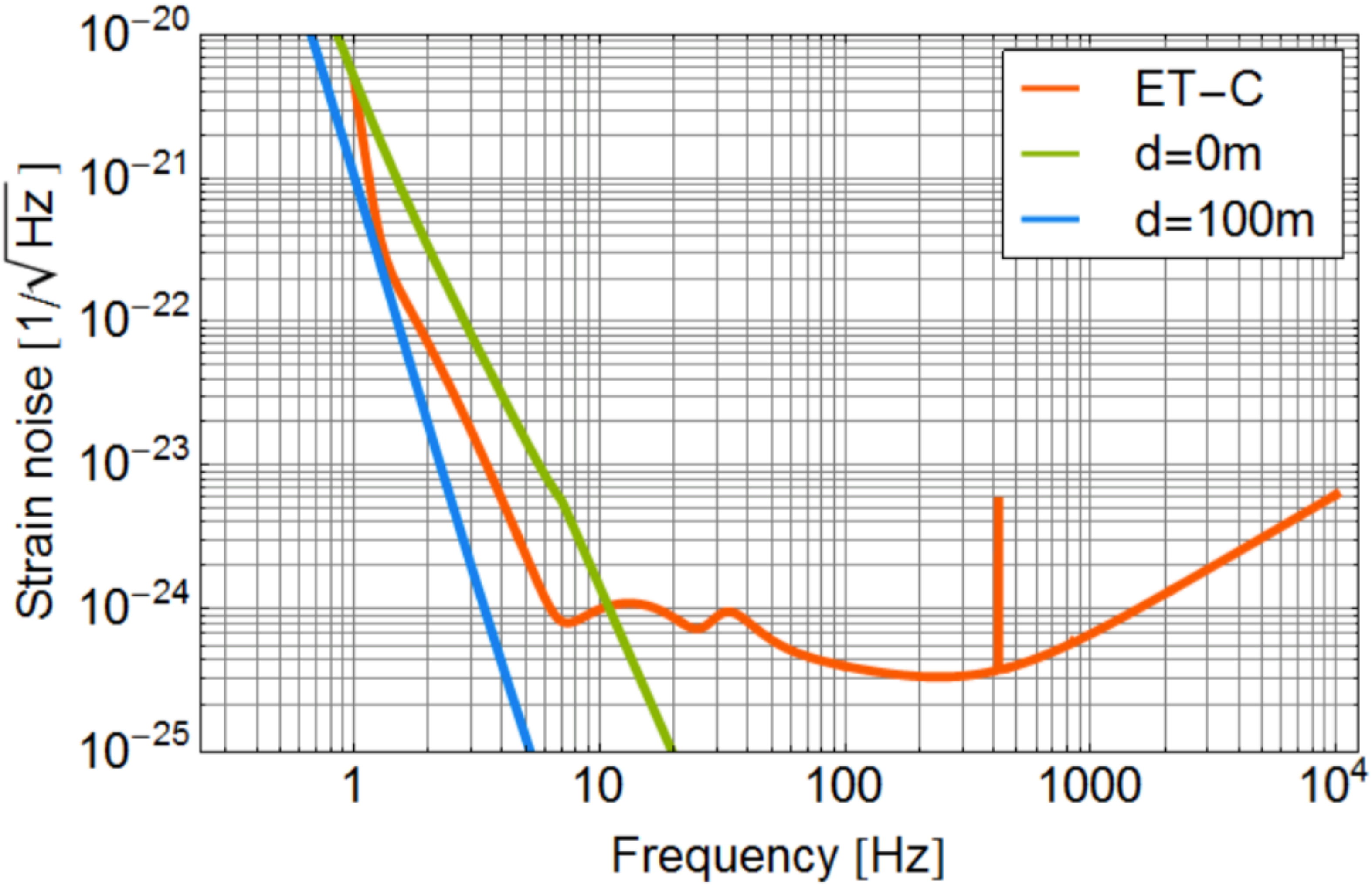
* Infrasound NN estimates obtained by using Creighton's model, see CQG. **25** (2008) 125011

# Why modeling infrasound NN?

## ET Infrasound Newtonian Noise for different detector depths, d.

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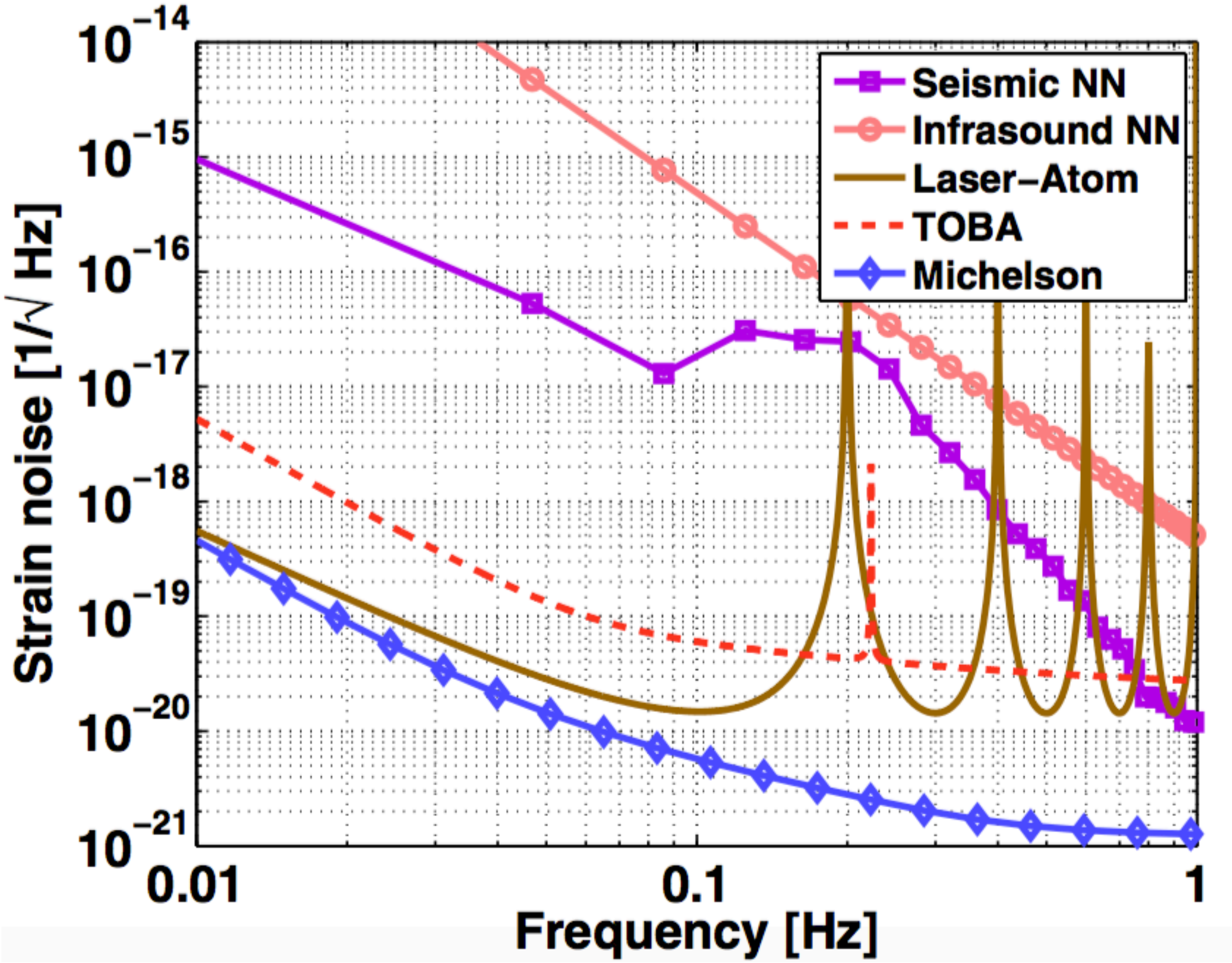
# Why modeling infrasound NN?

**Infrasound NN in low frequency detectors for GW and earthquakes (TOBA, TORPEDO, atom interferometers)**

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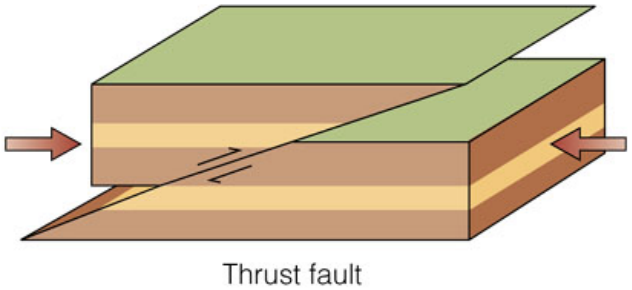
* J. Harms at al, Low-frequency terrestrial gravitational-wave detectors

# E-GRAAL (Earthquake GRAvity Alerts) Project

Earthquake

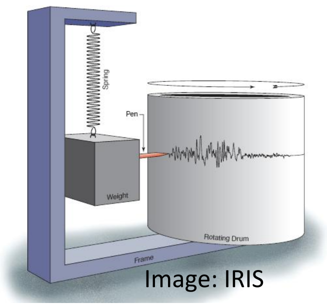


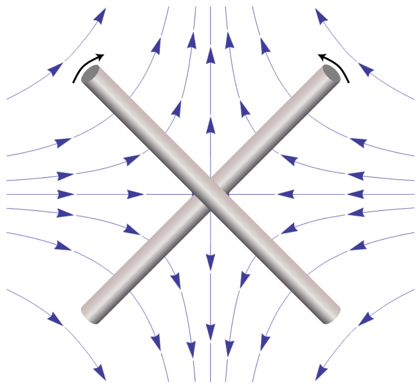

**E-GRAAL** (Earthquake GRavity ALerts): Feasibilty study of a new earthquake early warning system based on prompt gravity perturbations from earthquakes

p-waves
(a few km/s)

Gravitational
field change

Seismic signal



# Gravity perturbations from Infrasound NN

Plane pressure wave → δp/p <<1, frequency *f*, sound speed c

↓

Adiabatic density change δρ/ρ = δp/γp, γ=1.4

↓

Gravitational acceleration caused by the waves, along its direction of propagation

$$g_z(t) = G\int z\frac{\delta\rho(t)}{r^3}dV$$

$$\tilde{h}(f) = (2\pi f)^{-2}\tilde{g}(f)/L$$ → Spectral density= $S_h(|f|) = \langle \tilde{h}(f)\tilde{h}(f')^* \rangle$

Interferometer arm length

Average over the plane wave modes contributing to the noise

# Issues on Infrasound NN

$$g_z(t)^{*} = \int \frac{Gz\delta\rho}{r^3}\, dV = \frac{G\rho c}{\gamma p f} \cos(\theta) \underbrace{C(2\pi f r_{\min}/c)}_{2} \underbrace{\delta p(t + 1/4f)}_{1}$$

Angle between the wave propagation direction and the interferometer arm

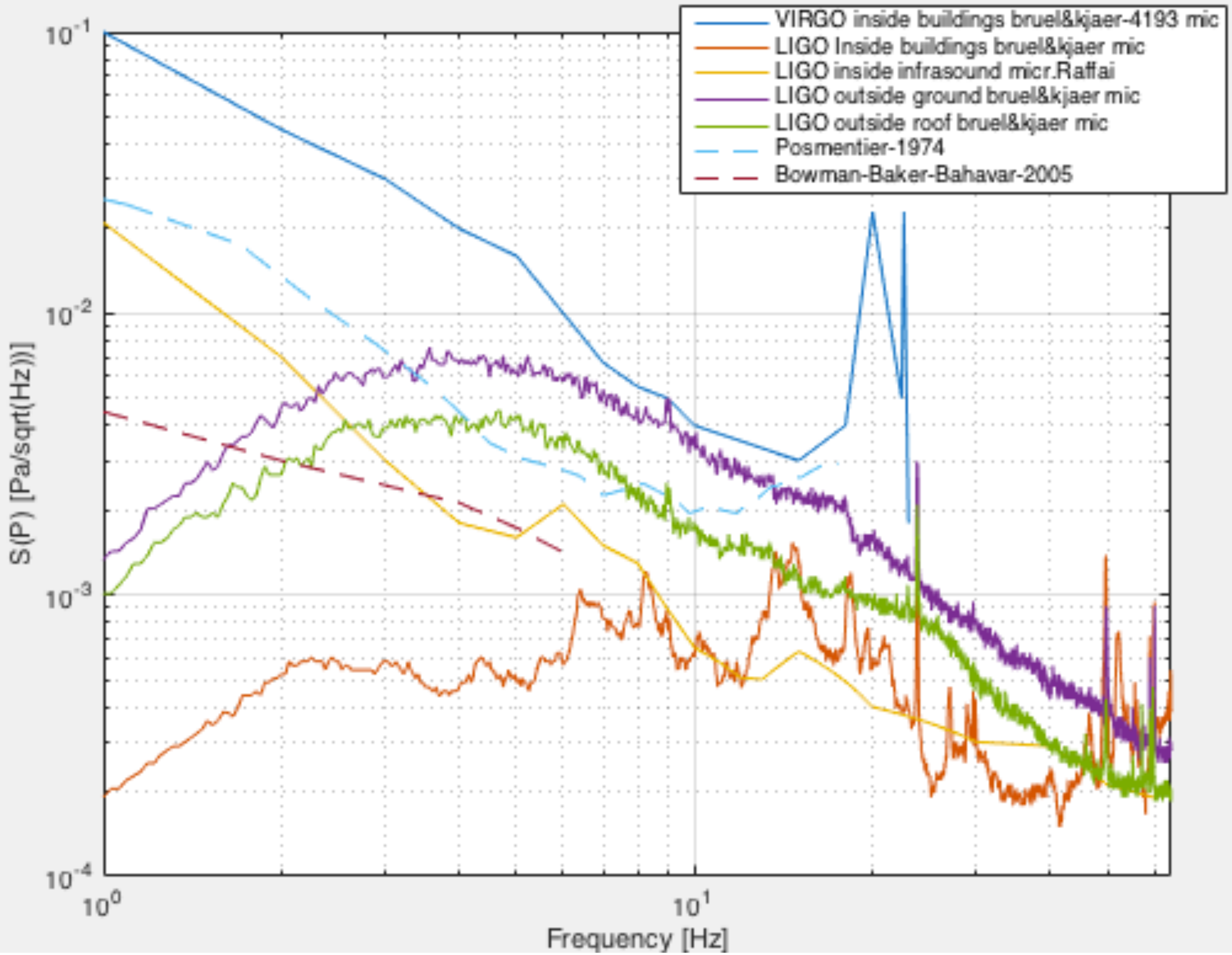
**1)** Measurement of pressure fluctuations at infrasound frequencies →

- How to perform the measures
- Where to take the measures

**2)** Effect of the building housing the test mass → further analysis needed

* CQG. **25** (2008) 125011

# Pressure Fluctuations

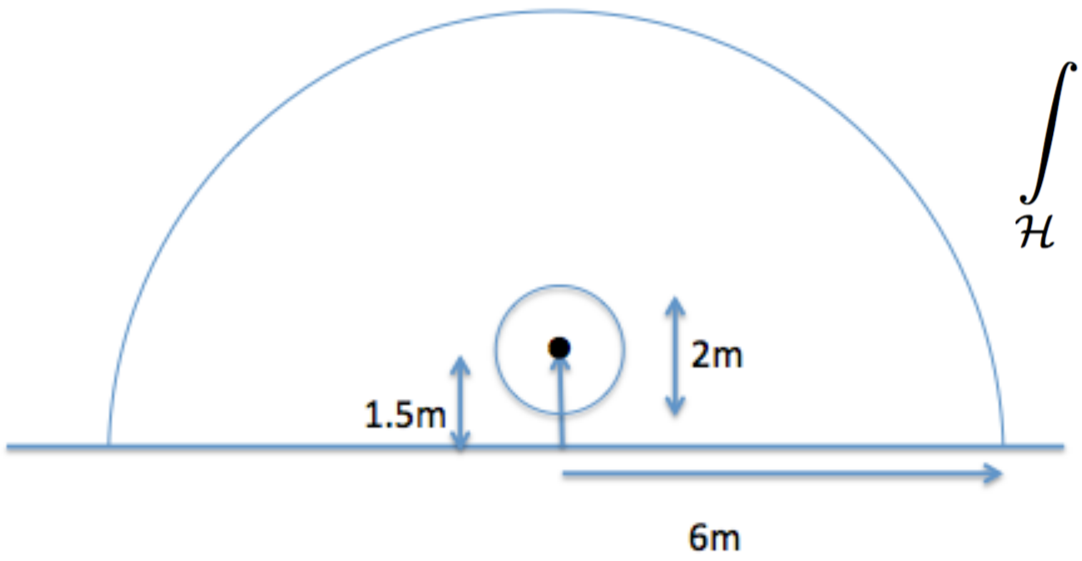



Need for data in the sub-Hz frequency range

# Building effect modeling

**Considered geometry**: **hemispheric building**, 6m radius, centered at xo=0m,yo=0m,zo=0m

**spheric vacuum chamber** of radius 1m , centered at xo=0m,yo=0m,zo=1.5m

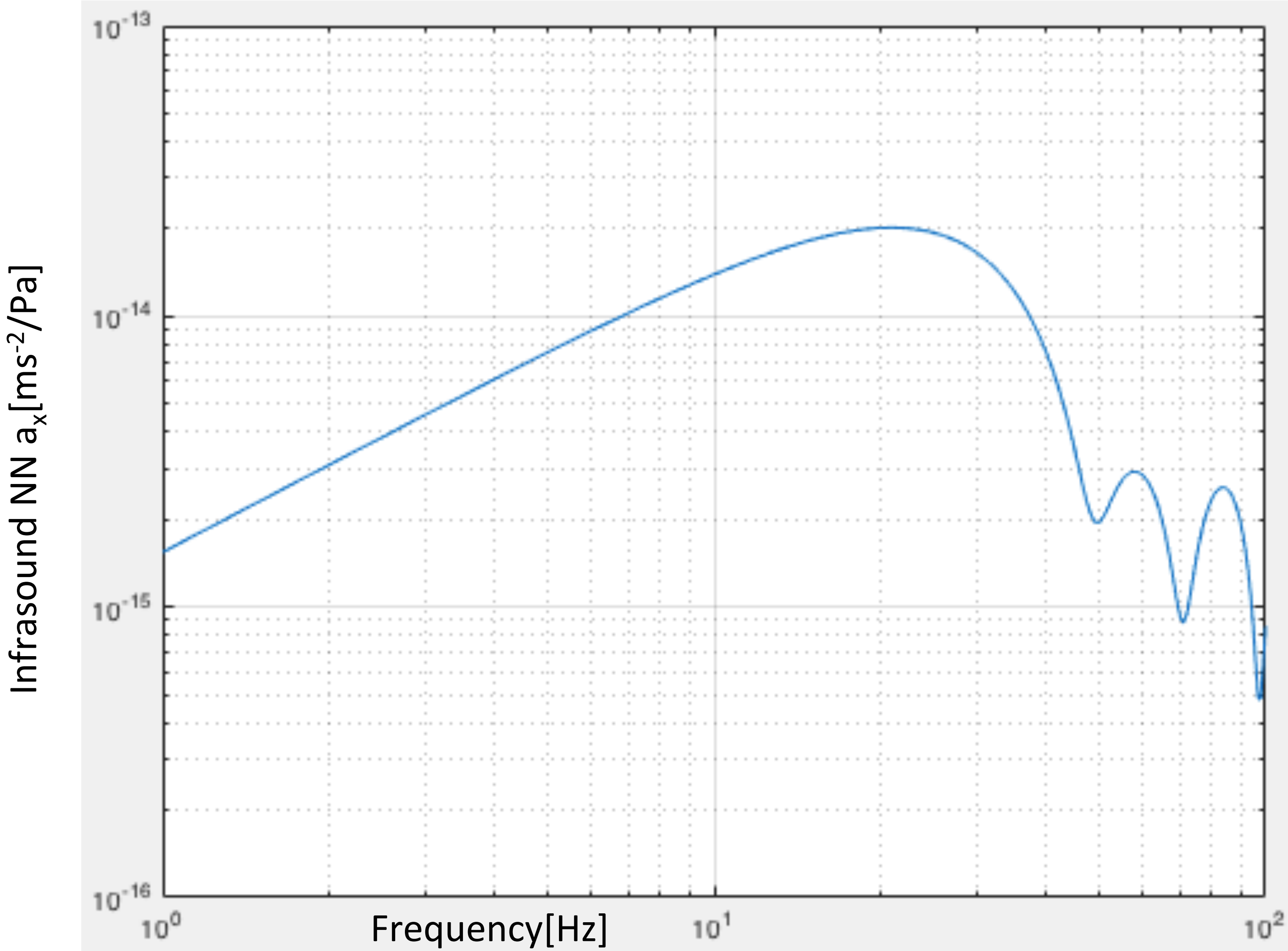



$$\int_{\mathcal{H}} \mathrm{d}V \, \frac{(\mathrm{e}^{-\mathrm{i}k_z z} + \mathrm{e}^{\mathrm{i}k_z z})\mathrm{e}^{-\mathrm{i}\vec{k}_\varrho \cdot \vec{\varrho}}}{(\varrho^2 + (z - z_0)^2)^{1/2}}$$ *

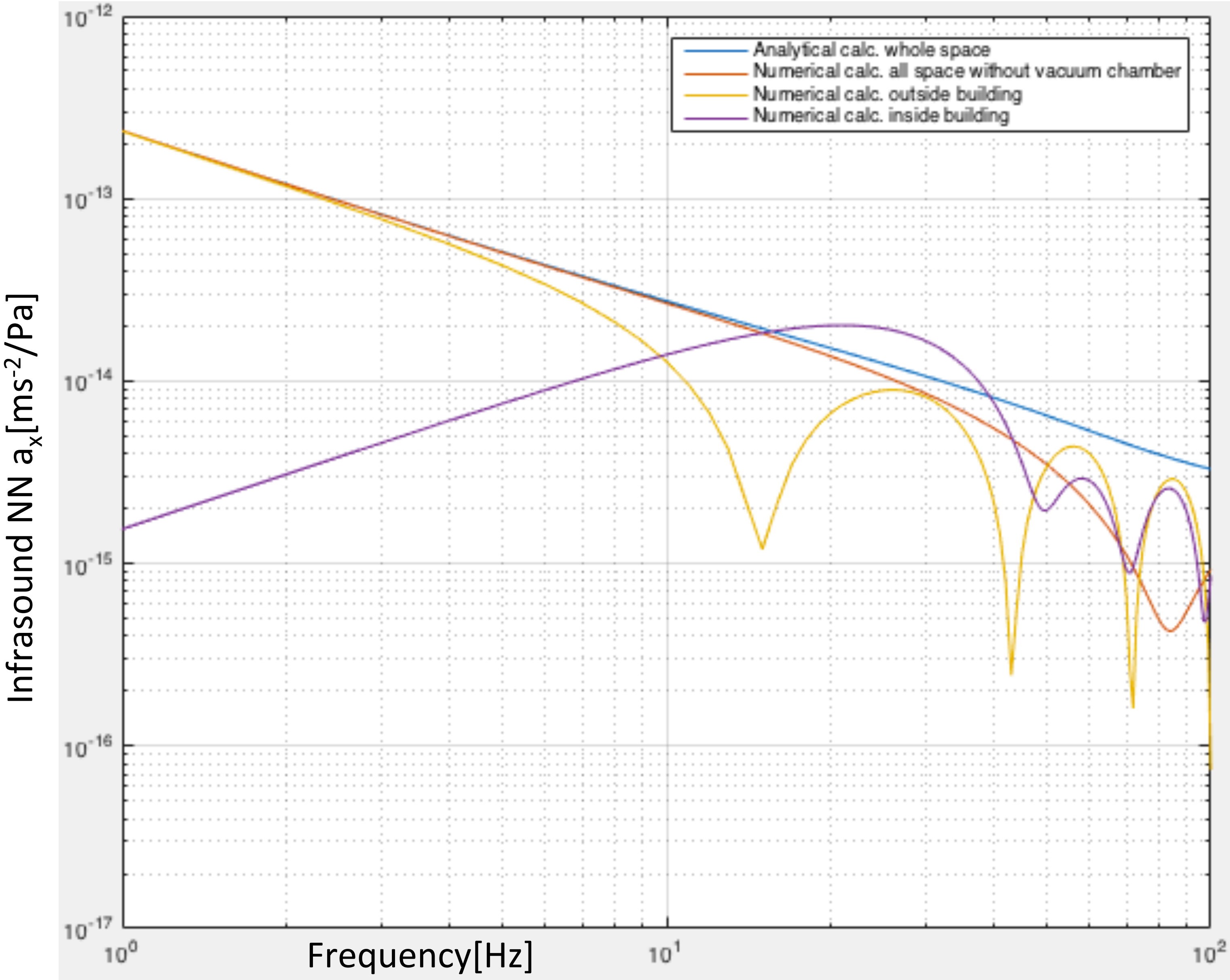
To be calculated to find the infrasound NN gravitational acceleration

# Building effect modeling

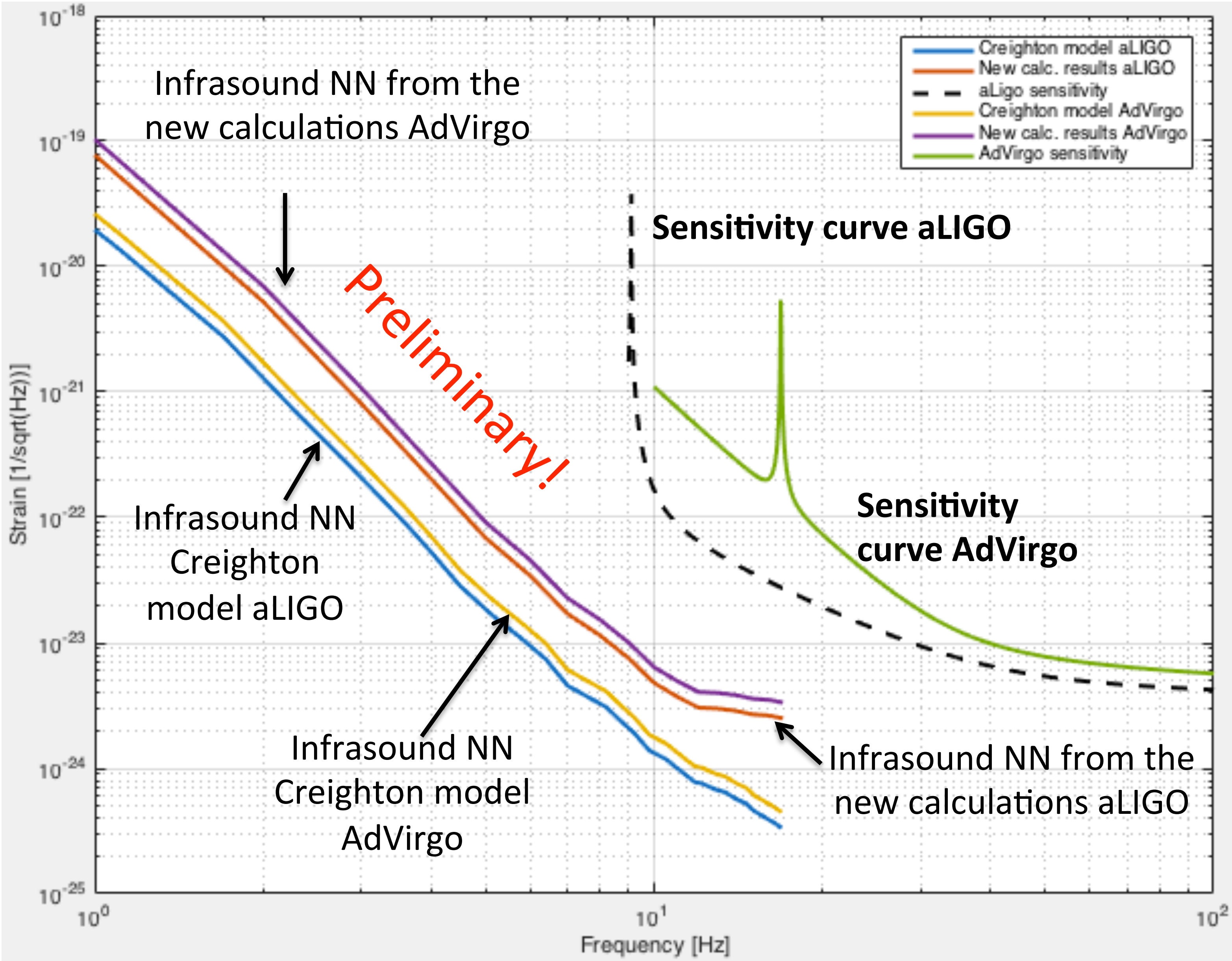
**Inside building, numerical integration, average over 60 acoustic wave directions**



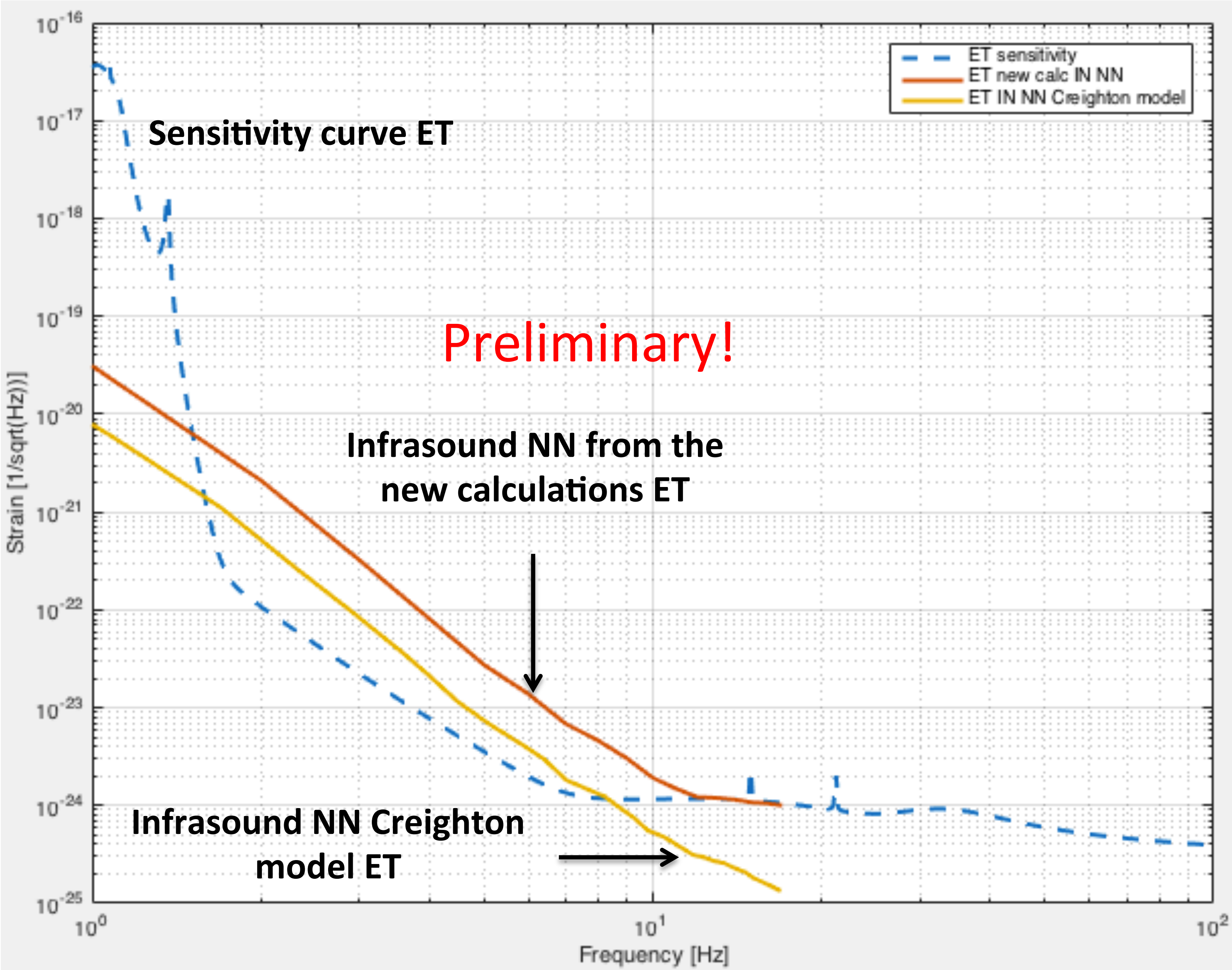
# Building effect modeling-Result Comparison/1



# Building effect modeling-Result Comparison/2



# Building effect modeling-Result Comparison/3



# Conclusions and Perspectives/1

## Pressure fluctuation measurements:

- Need for suitable sensor in the infrasound range
- Choise of meaningful microphone positions inside a gravitational wave (GW) detector
- Study of the pressure fluctuations role on sub-Hz GW detectors (e.g. TOBA, TORPEDO, atom interferometers,...)

## Building effects on the Infrasound NN:

- Infrasound NN inside the building is more important at higher frequencies
- Infrasound NN outside the building is more important at lower frequencies
- The new infrasound NN results for LIGO, VIRGO and ET confirm that the Infrasound NN does not limit the sensitivity of the first two detectors, but it is relevant for ET.
- Calculate the infrasound NN  for low frequency detectors (e.g. TORPEDO, TOBA, atom interferometers,...) used for GW detection and earthquakes.
- Make the calculations with new measurements of pressure fluctuation spectra

# Conclusions and Perspectives/2

- Atmospheric weak pressure waves (small $\delta p/p$)
- Atmospheric temperature perturbations
- Atmospheric shockwaves
- High-speed massive objects moving near the interferometer