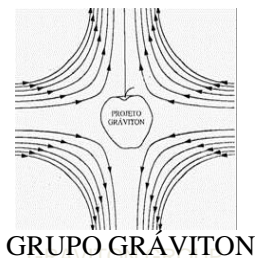


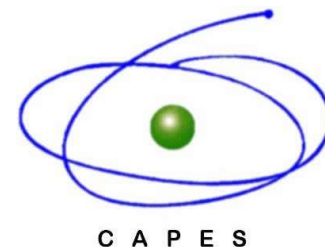
# TRANSDUTORES PARA O DETECTOR SCHENBERG

## ISOLAMENTO VERTICAL DO *MNP* PARA O DETECTOR *LIGO*

Elvis Camilo Ferreira (Doutorado)  
Orientador: Dr. Odylio Denys de Aguiar  
Workshop DAS, 04 de maio de 2016.



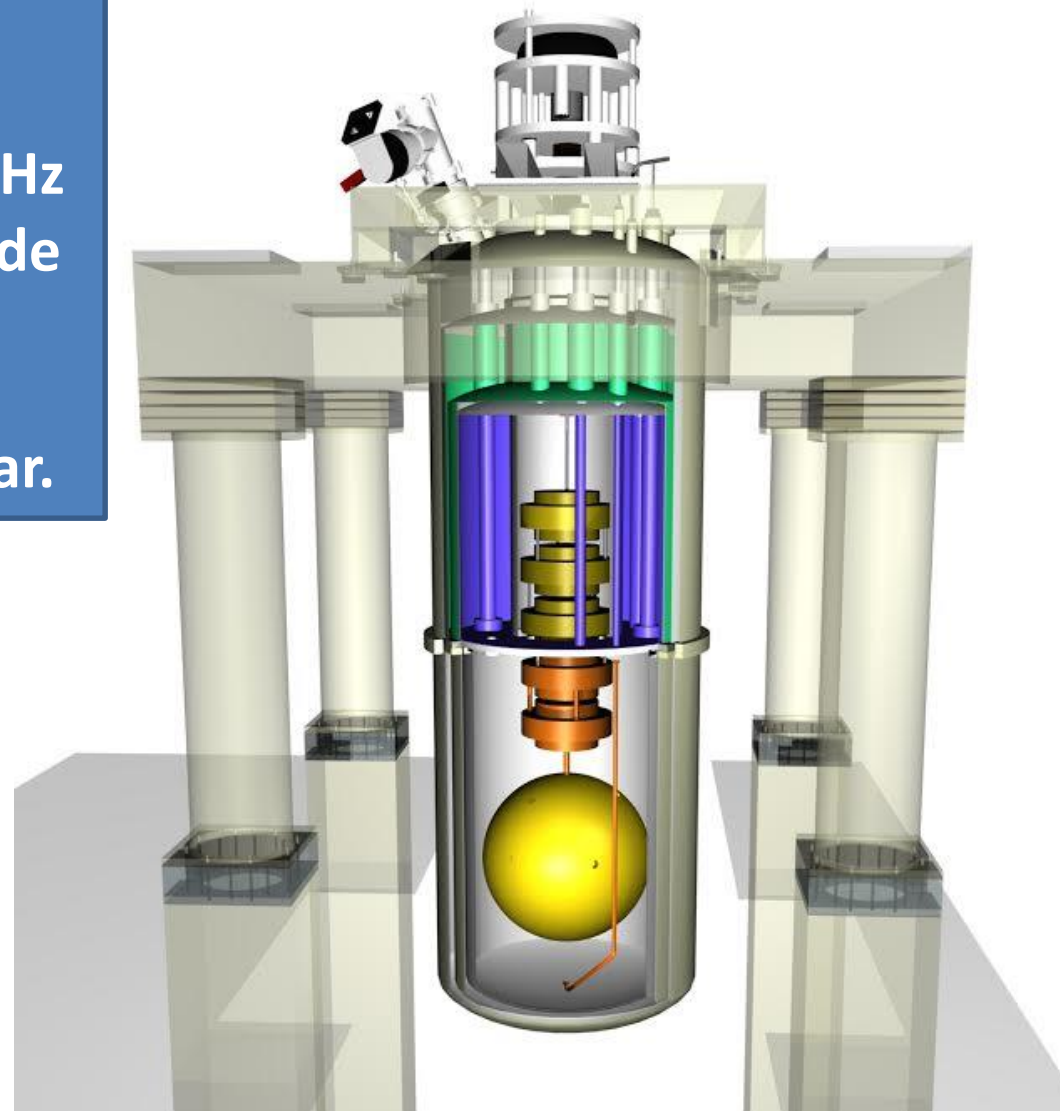
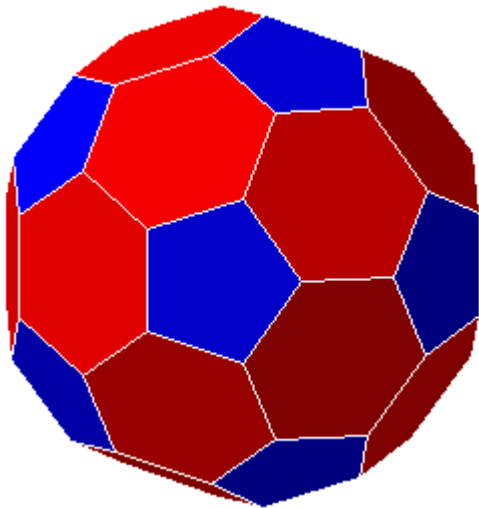
LIGO  
Scientific  
Collaboration

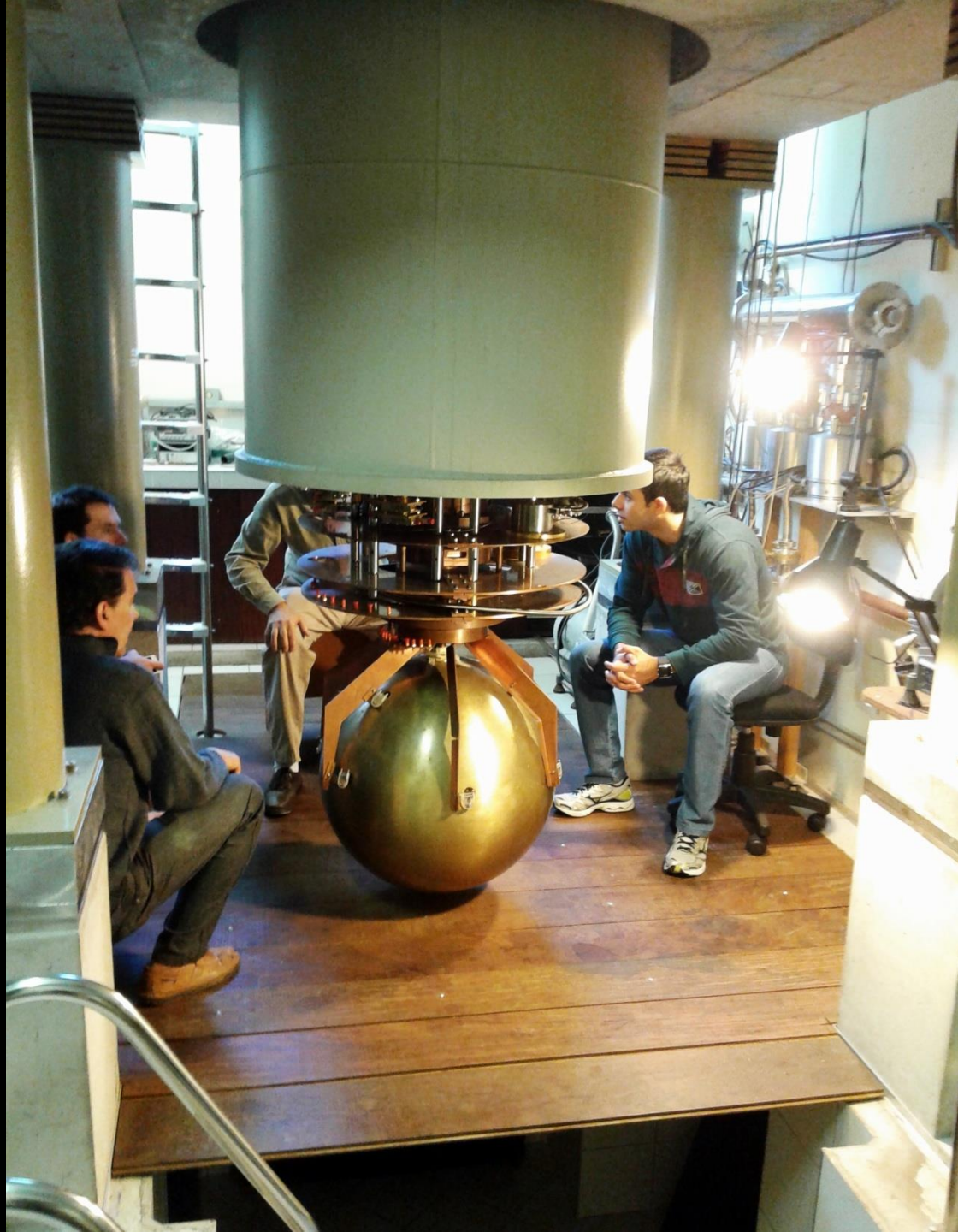


**Cu-Al(6%) , 1150 kg e 65 cm de diâmetro;**

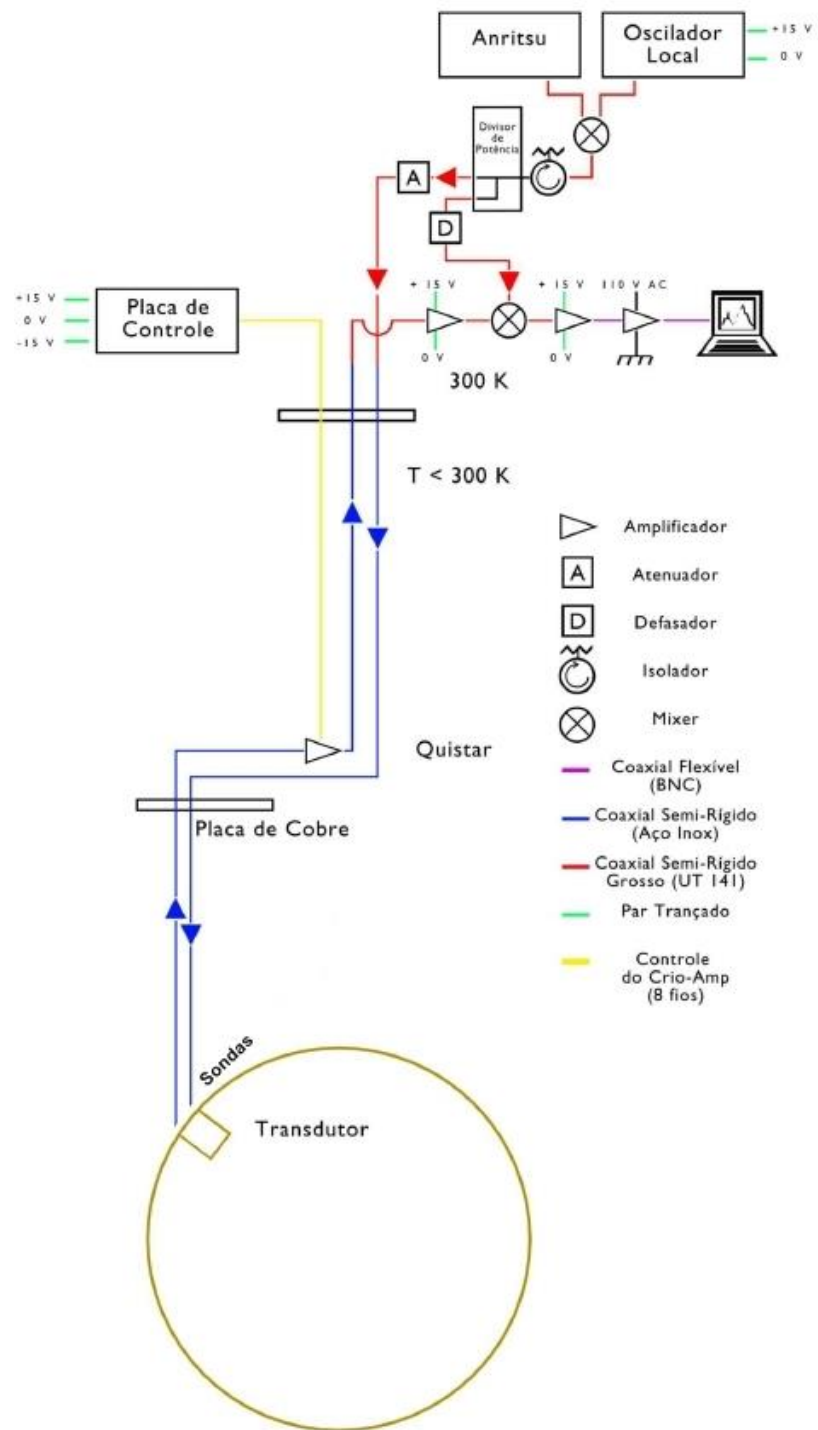
**Maior sensibilidade em 3,2 kHz nos 5 modos quadrupolares de massa efetiva 287 kg;**

**E também o modo monopolar.**



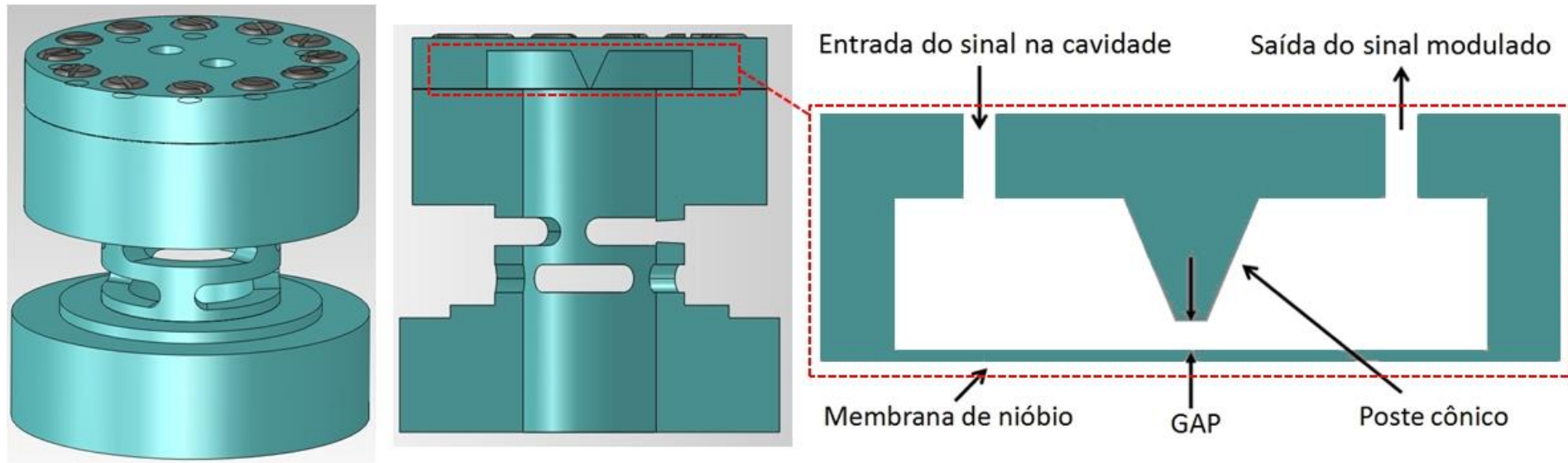


# Sistema de detecção



- Os transdutores ressonantes paramétricos são acoplado à antena.





Ganho em amplitude  $\sim 10^4$ .

Ressonância membrana: 3,2 kHz.

Meta: ressonância elétrica da cavidade em 9,44 GHz.

*Gap* de 3 microns.

# DESENVOLVIMENTO DOS TRANSDUTORES

## Torno mecânico



desgaste com retífica



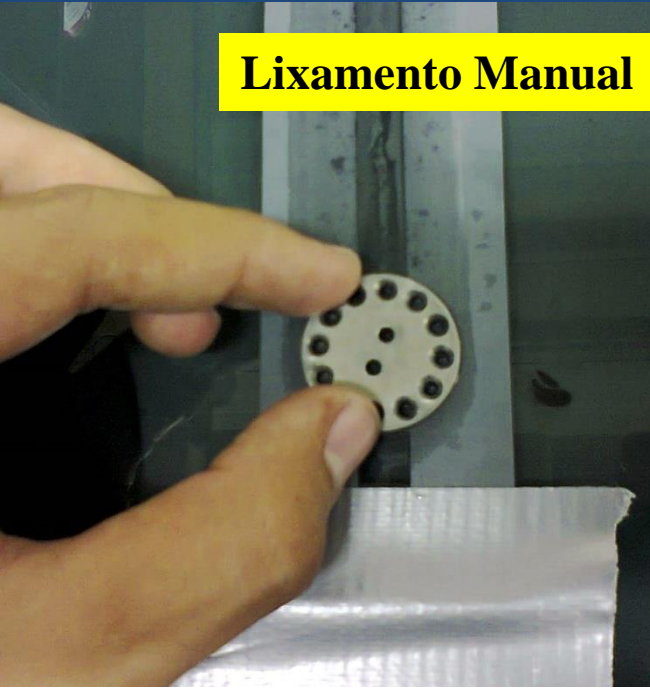
lixamento no torno mecânico



Resultado: *gaps* eram ~100 microns e se tornaram 10-20 microns

# DESENVOLVIMENTO DOS TRANSDUTORES

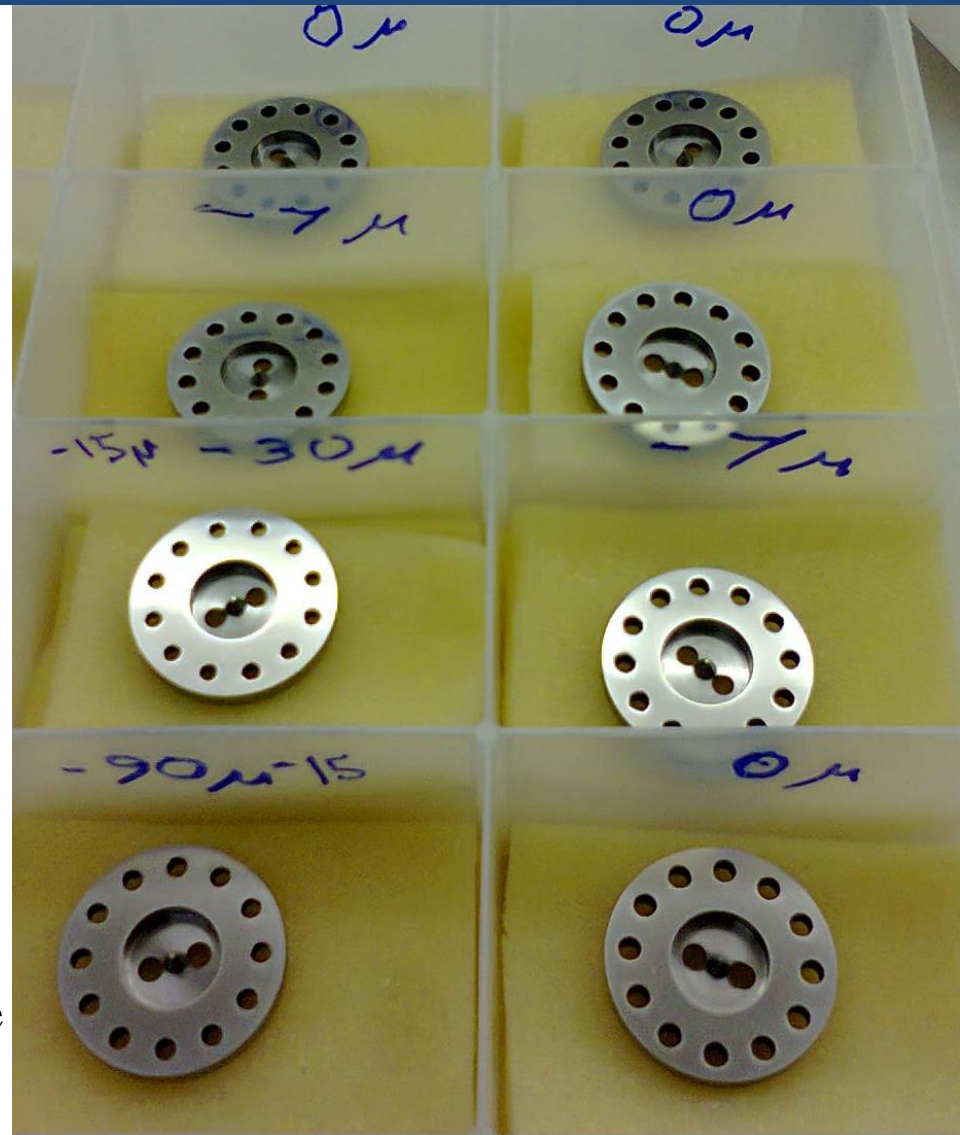
## Lixamento Manual



Irregularidades no procedimento anterior  
→ Lixamento manual.

Lixas 600, 1200 e 2000.

As amostras obtiveram um ótimo acabamento e os *gaps* se reduziram para a ordem de grandeza esperada.





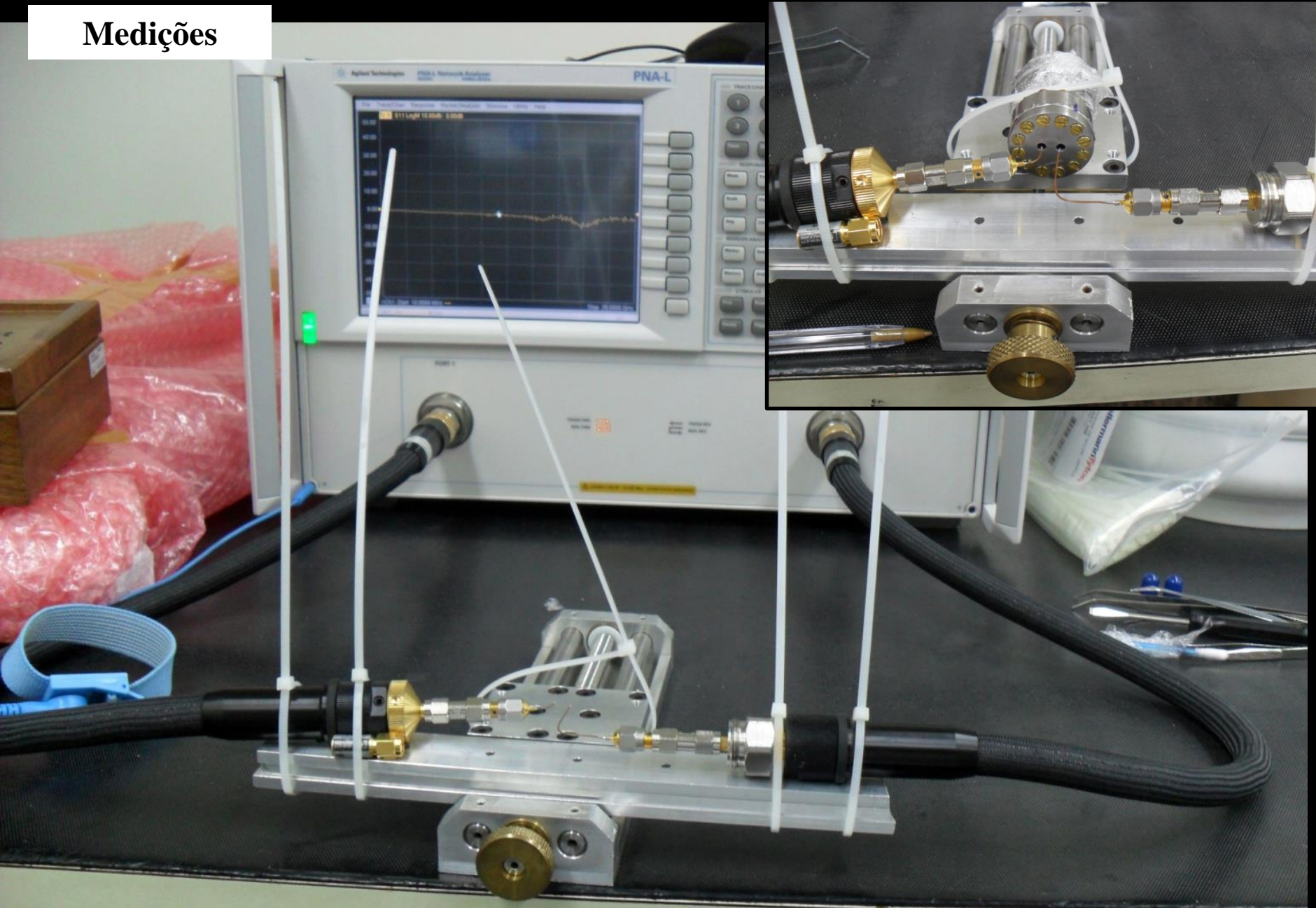
# DESENVOLVIMENTO DOS TRANSDUTORES

## Montagem das cavidades



# DESENVOLVIMENTO DOS TRANSDUTORES

## Medições



Amostra	$f_0^{\text{cav}}$ [GHz]				
	Etapa 1	Etapa 2	Etapa 3	Etapa 4	Etapa 5
1	12,76	12,88	<b>9,52</b>	<b>9,52</b>	<b>9,52</b>
2	12,44	12,32	<b>9,52</b>	<b>9,52</b>	<b>9,52</b>
3	13,40	13,88	13,36	13,16	12,76
4	10,96	10,92	<b>9,88</b>	<b>9,88</b>	<b>9,88</b>
5	13,12	13,28	13,00	12,76	12,64
6	12,64	13,20	12,36	12,00	11,74
7	<b>9,76</b>	<b>9,76</b>	<b>9,76</b>	<b>9,76</b>	<b>9,76</b>
8	11,28	11,28	10,60	10,08	<b>9,48</b>

Amostra	$f_0^{\text{cav}}$ [GHz]			
	Etapa 6	Etapa 7	Etapa 8	Etapa 9
1	<b>9,52</b>	<b>9,52</b>	<b>9,52</b>	<b>9,52</b>
2	<b>9,52</b>	<b>9,52</b>	<b>9,52</b>	<b>9,52</b>
3	12,72	12,32	12,06	11,08
4	<b>9,88</b>	<b>9,88</b>	<b>9,88</b>	<b>9,88</b>
5	12,08	11,92	11,56	10,54
6	(nenhum pico)	12,52	12,20	12,13
7	<b>9,76</b>	<b>9,76</b>	<b>9,76</b>	<b>9,76</b>
8	<b>9,48</b>	<b>9,48</b>	<b>9,48</b>	<b>9,48</b>

RECEIVED: August 13, 2014

REVISED: November 22, 2014

ACCEPTED: January 7, 2015

PUBLISHED: March 3, 2015

# High sensitivity niobium parametric transducer for the Mario Schenberg gravitational wave detector

---

L.A.N. de Paula,<sup>a,b,1</sup> E.C. Ferreira,<sup>c</sup> N.C. Carvalho<sup>d</sup> and O.D. Aguiar<sup>c</sup>

<sup>a</sup>*Physics Department, Technological Institute of Aeronautics – ITA,  
Praça Marechal-do-Ar Eduardo Gomes 50, São José dos Campos, Brazil*

<sup>b</sup>*Department of Mechanics and Material Physics, University of São Paulo – USP,  
Rua do Matão 187, São Paulo, Brazil*

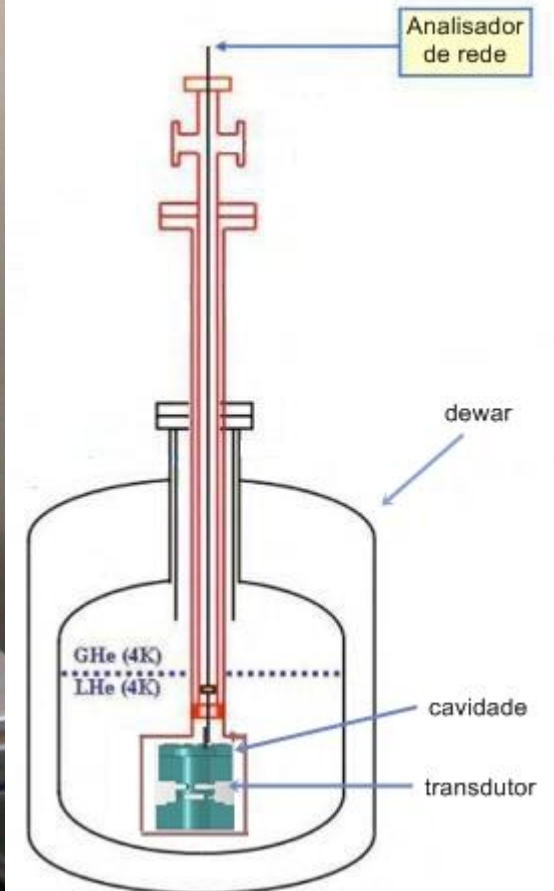
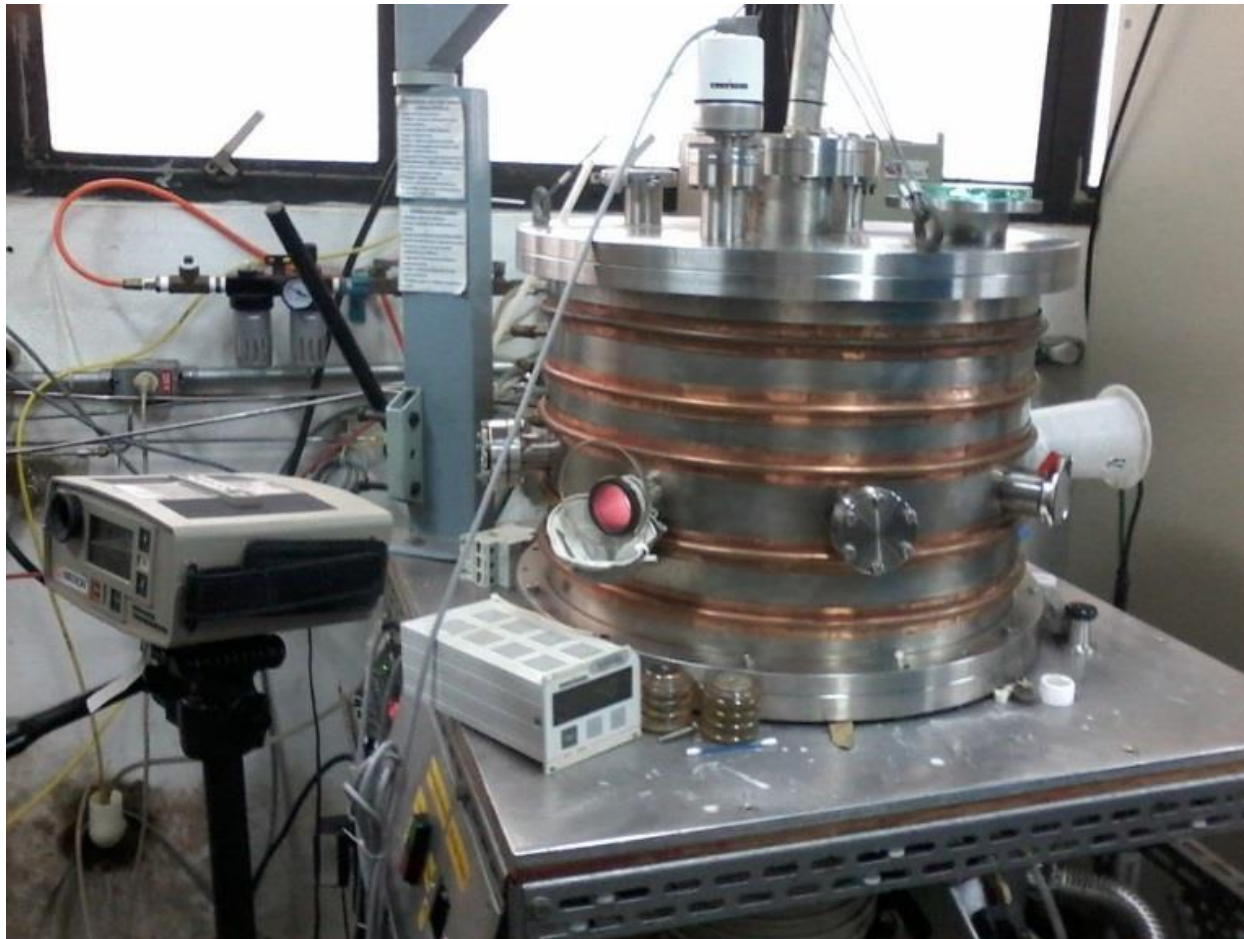
<sup>c</sup>*Astrophysics Division, National Institute for Space Research – INPE,  
Av. dos Astronautas 1758, São José dos Campos, Brazil*

<sup>d</sup>*School of Physics, University of Western Australia – UWA,  
35 Stirling Hwy, 6009 Crawley, Western Australia, Australia*

# OTIMIZAÇÃO DO Q ELÉTRICO DAS CAVIDADES

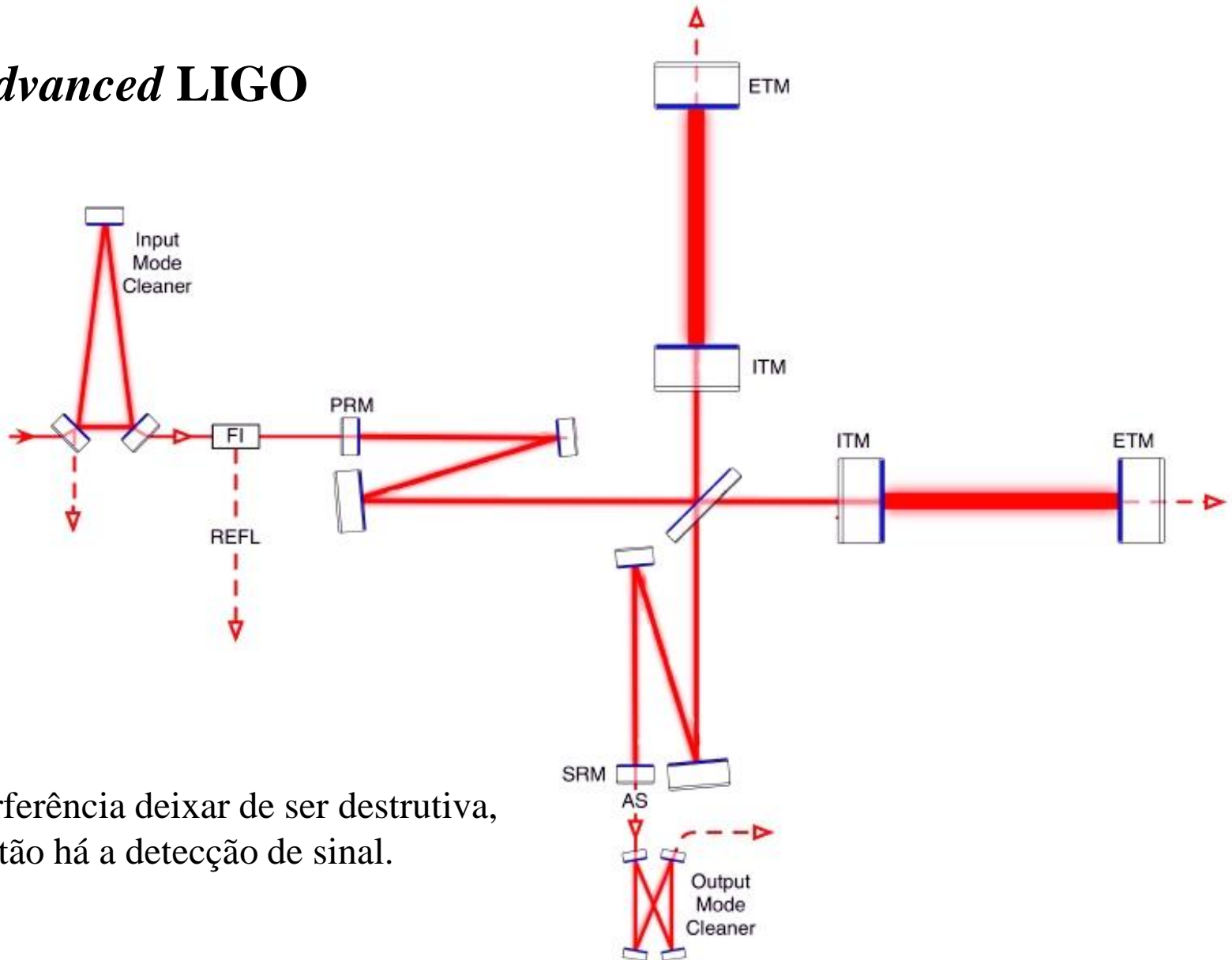


# OTIMIZAÇÃO DO Q ELÉTRICO DAS CAVIDADES



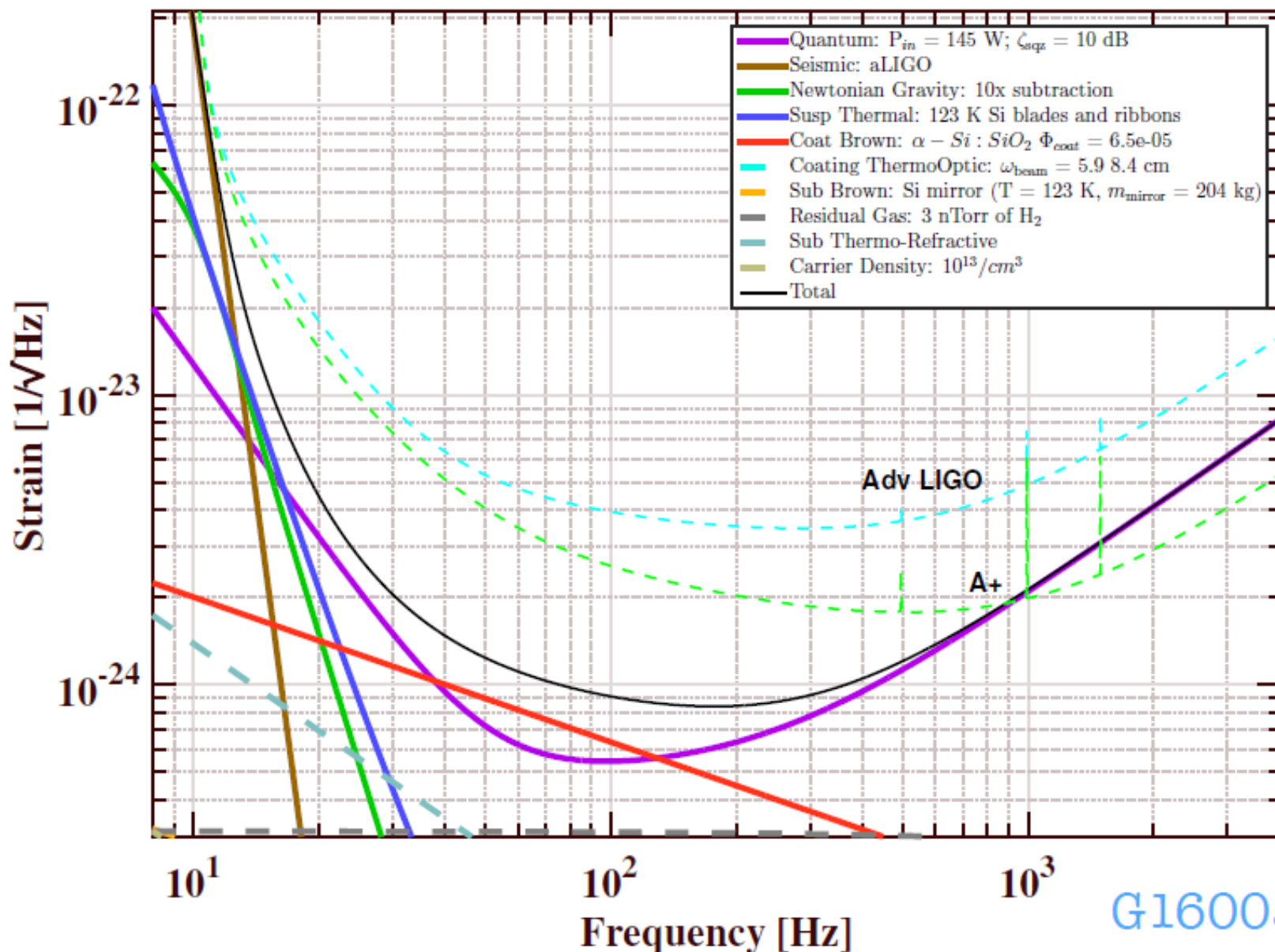
# DETECTOR INTERFEROMÉTRICO

## *Advanced LIGO*

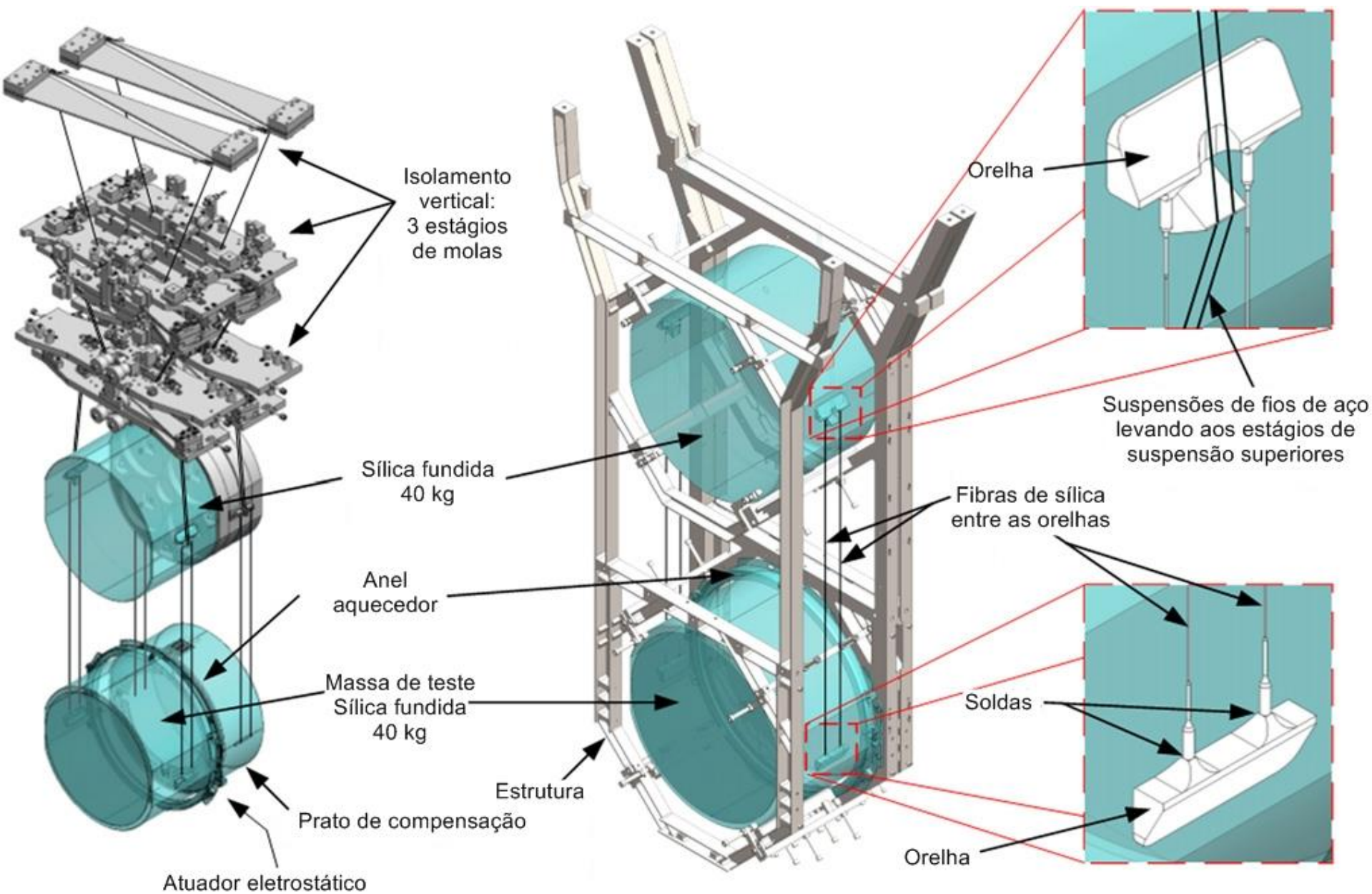


Se a interferência deixar de ser destrutiva,  
então há a detecção de sinal.

# Voyager Status

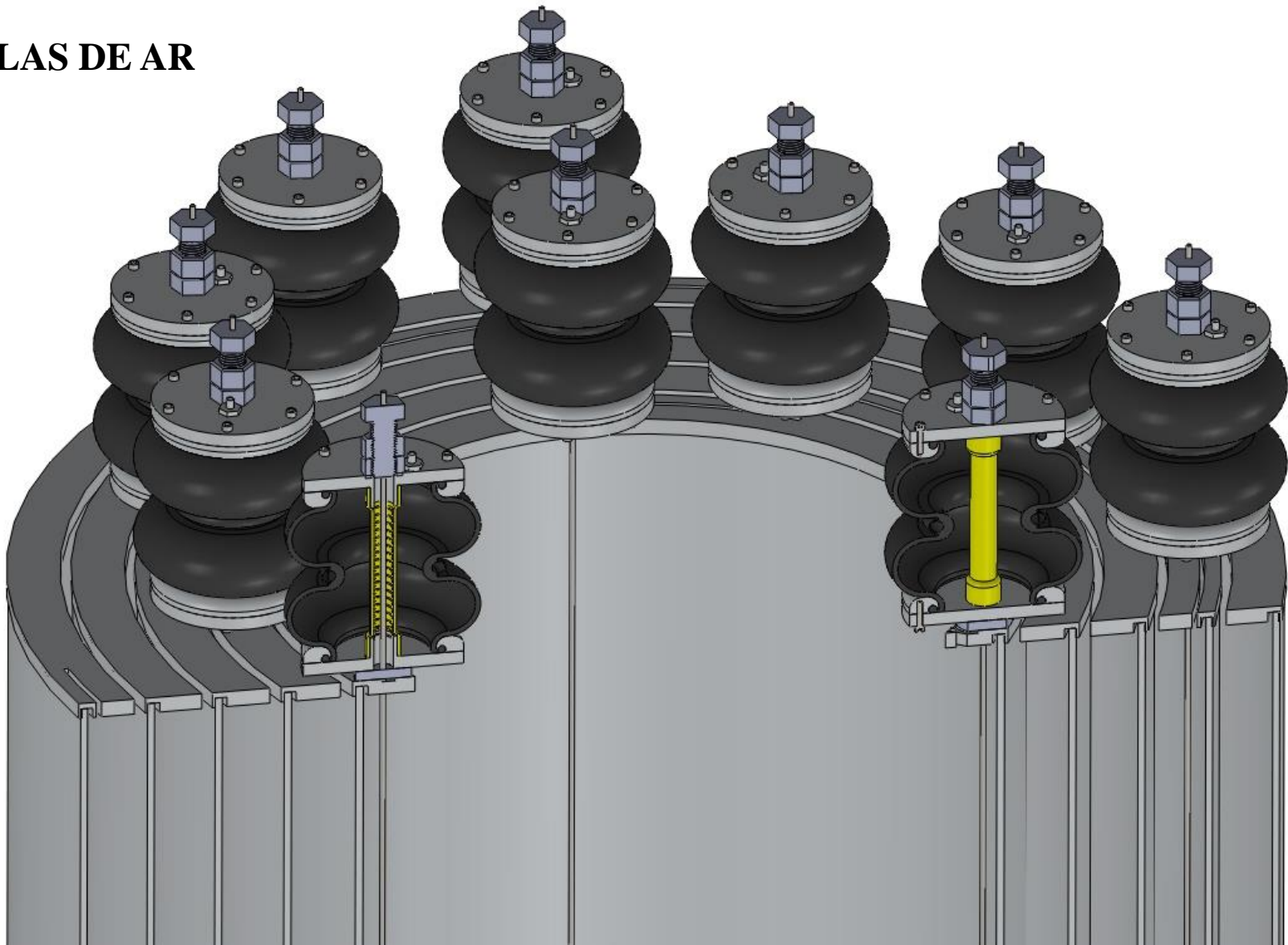






# ISOLAMENTO VERTICAL DO MNP

## MOLAS DE AR





O MNP tem 30 graus de liberdade:

5 graus acoplados na direção Z (vertical);

5 acoplados na direção de rotação em torno do eixo Z;

5 na direção X (horizontal) acoplados com 5 na direção de rotação em torno de Y (também horizontal);

5 na direção Y acoplados com 5 na direção de rotação em torno de X.

Em Z:

$$m_{(i)}\ddot{z}_{(i)} = -k_{z(i)}(z_{(i)} - z_{(i-1)}) + k_{z(i+1)}(z_{(i+1)} - z_{(i)}) \\ -c_{z(i)}(\dot{z}_{(i)} - \dot{z}_{(i-1)}) + c_{z(i+1)}(\dot{z}_{(i+1)} - \dot{z}_{(i)})$$

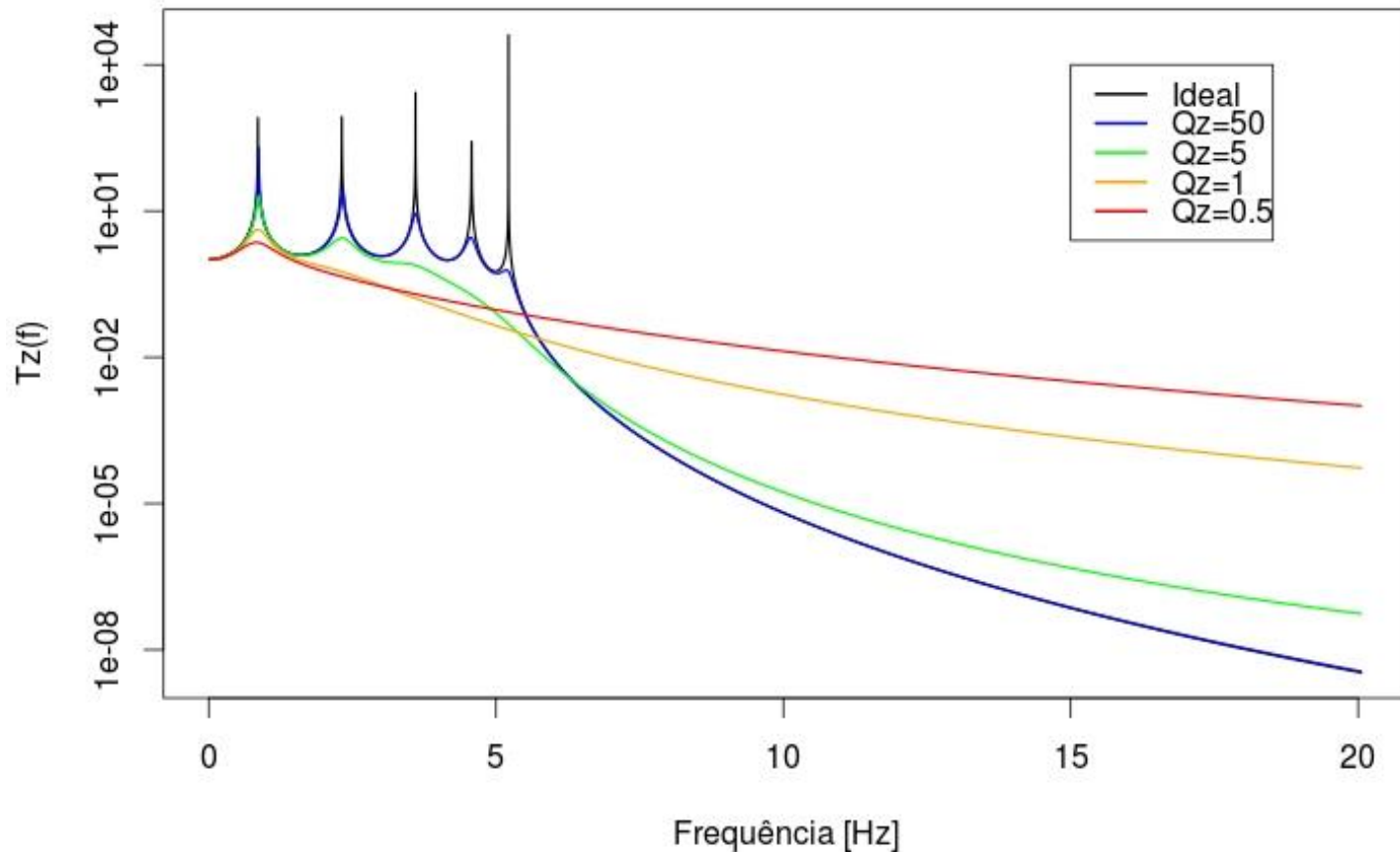
$$c_{z(i)} = \sqrt{m_{(i)}k_{z(i)}/Q_z}$$

tomando

$$T_z(\omega) = \left| \frac{z_5}{z_0} \right|$$

geramos:

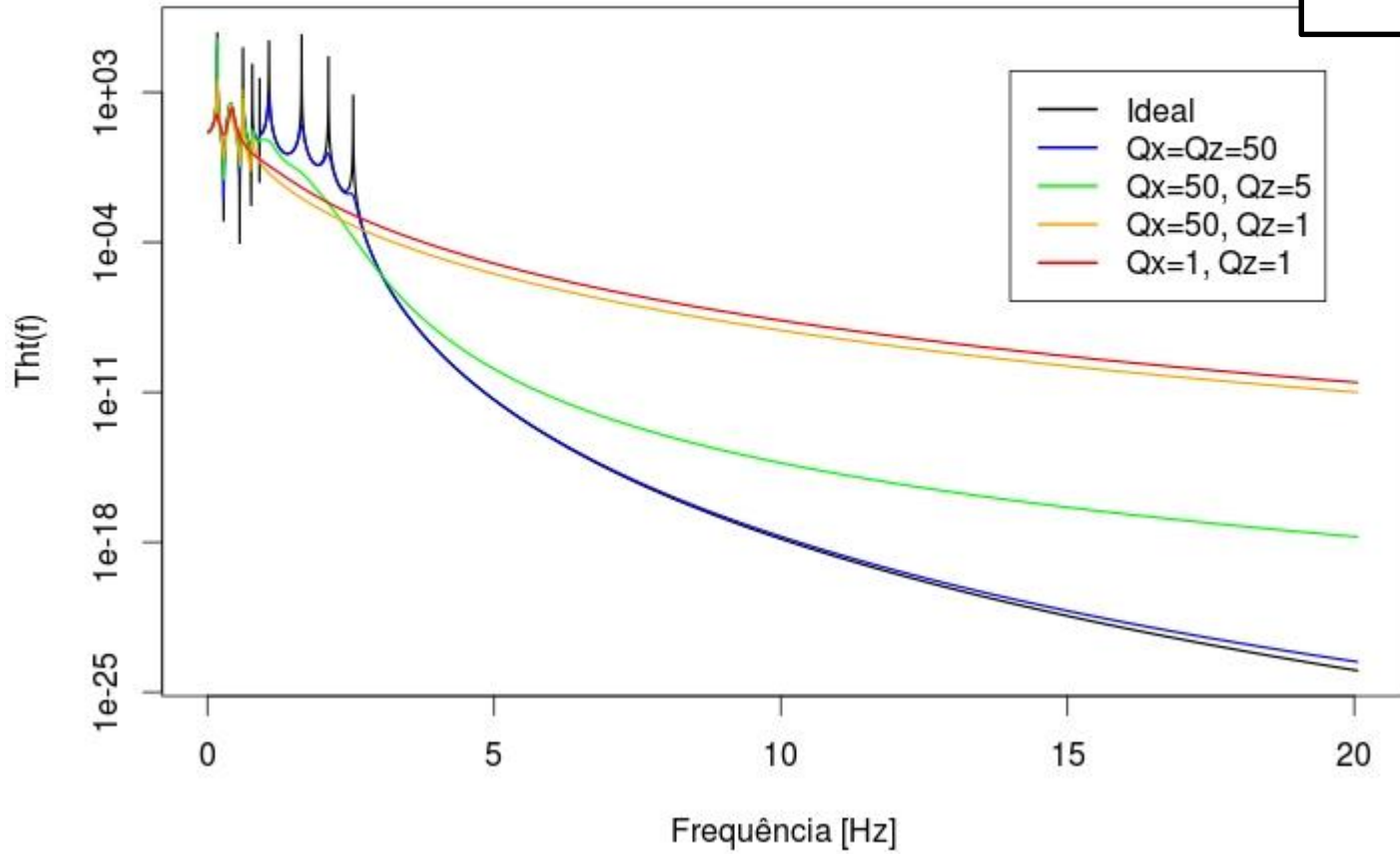
**Função de transferência vertical (z)**



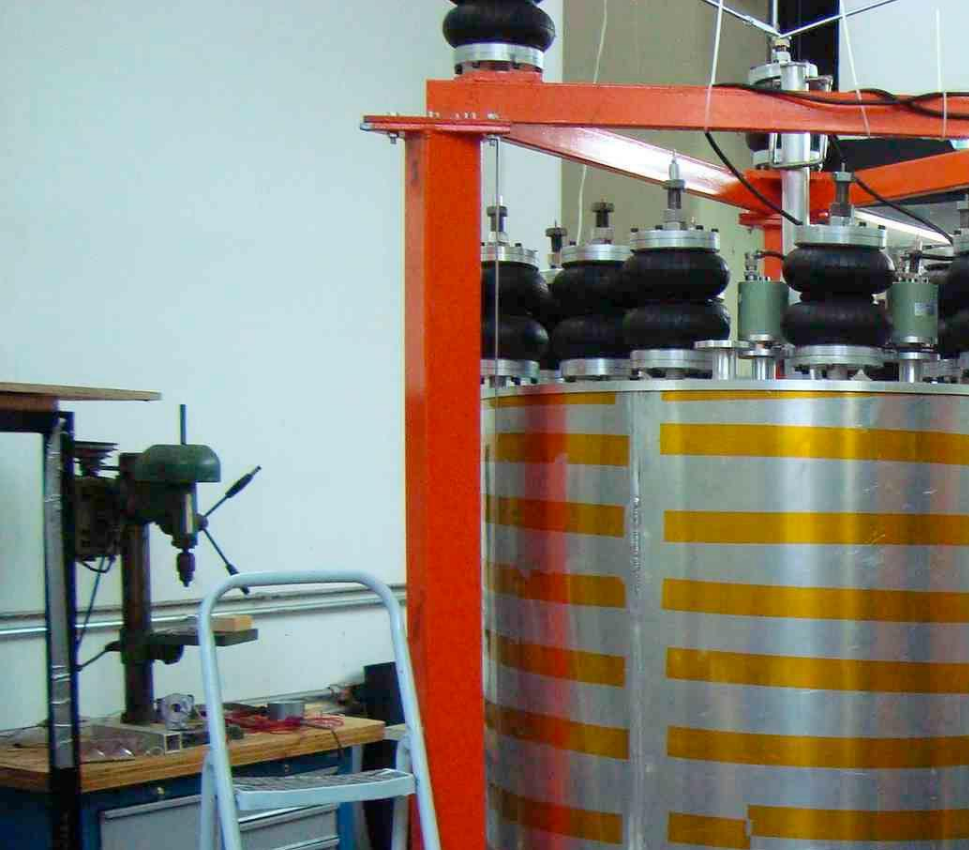
valor da função de transferência vertical para  $Q_z \geq 50$  é  $T_z \leq 6,5 \times 10^{-6}$

### Função de transferência Horizontal-Tilting

$$T_{HT}(\omega) = \left| \frac{x_5 - \frac{h}{2}\theta_5}{x_0 + \frac{h}{2}\theta_0} \right|$$

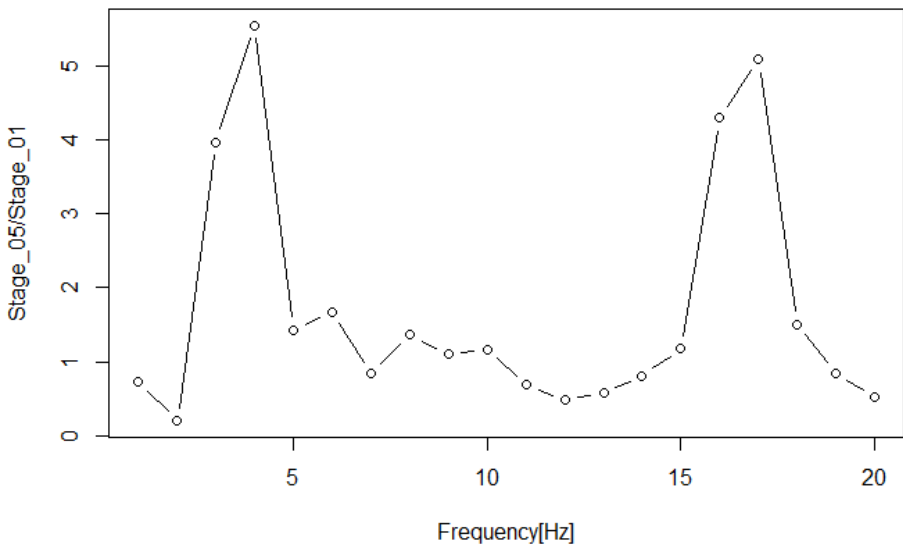


$T_{HT} \approx 1,8 \times 10^{-18}$  em 10 Hz, para  $Q_x = Q_z \geq 50$

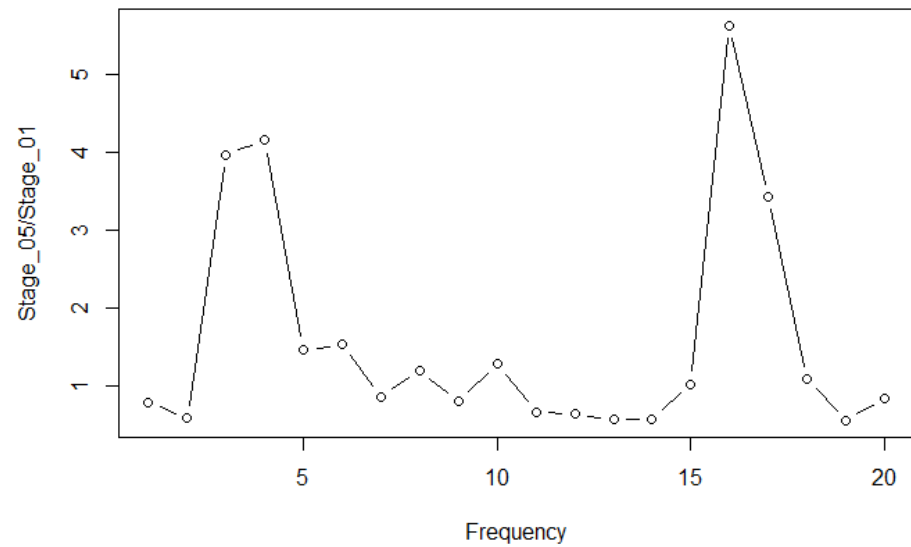


# MEDIDAS

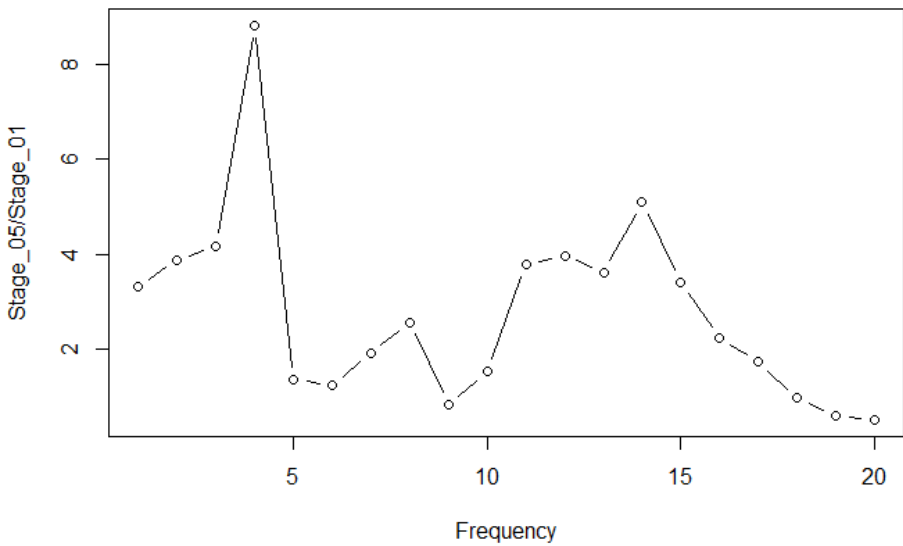
## Vertical



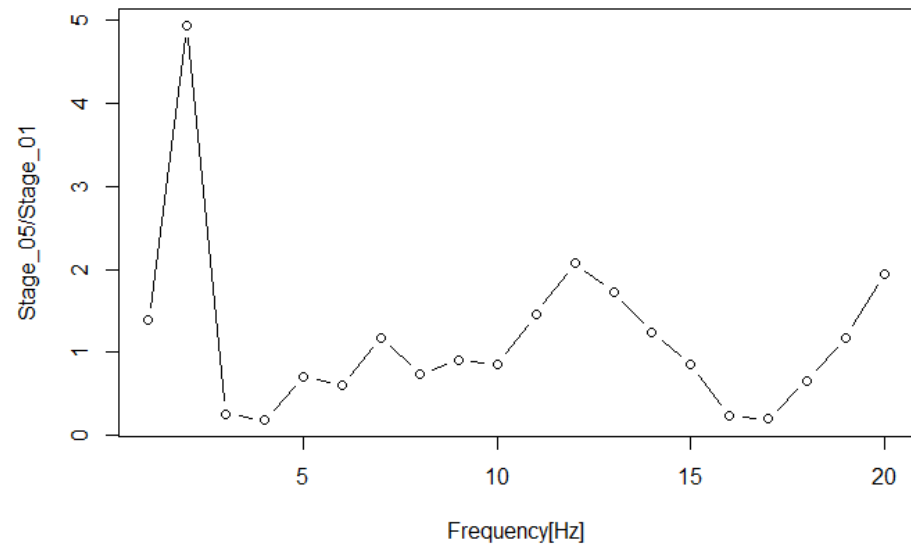
## Vertical



## Horizontal

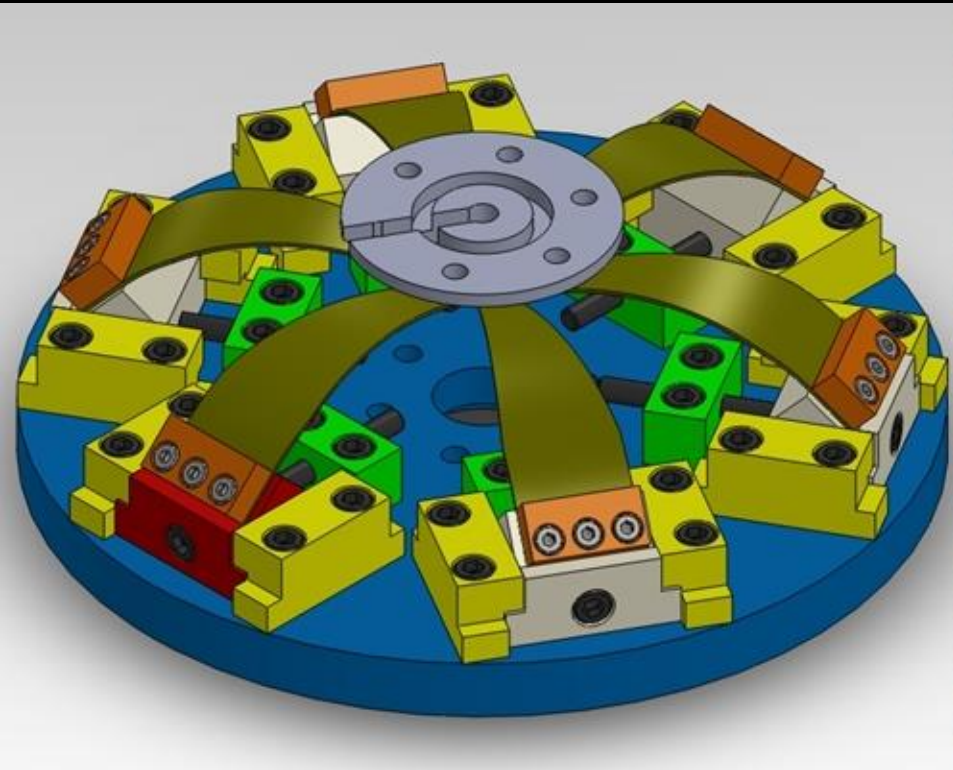


## Horizontal

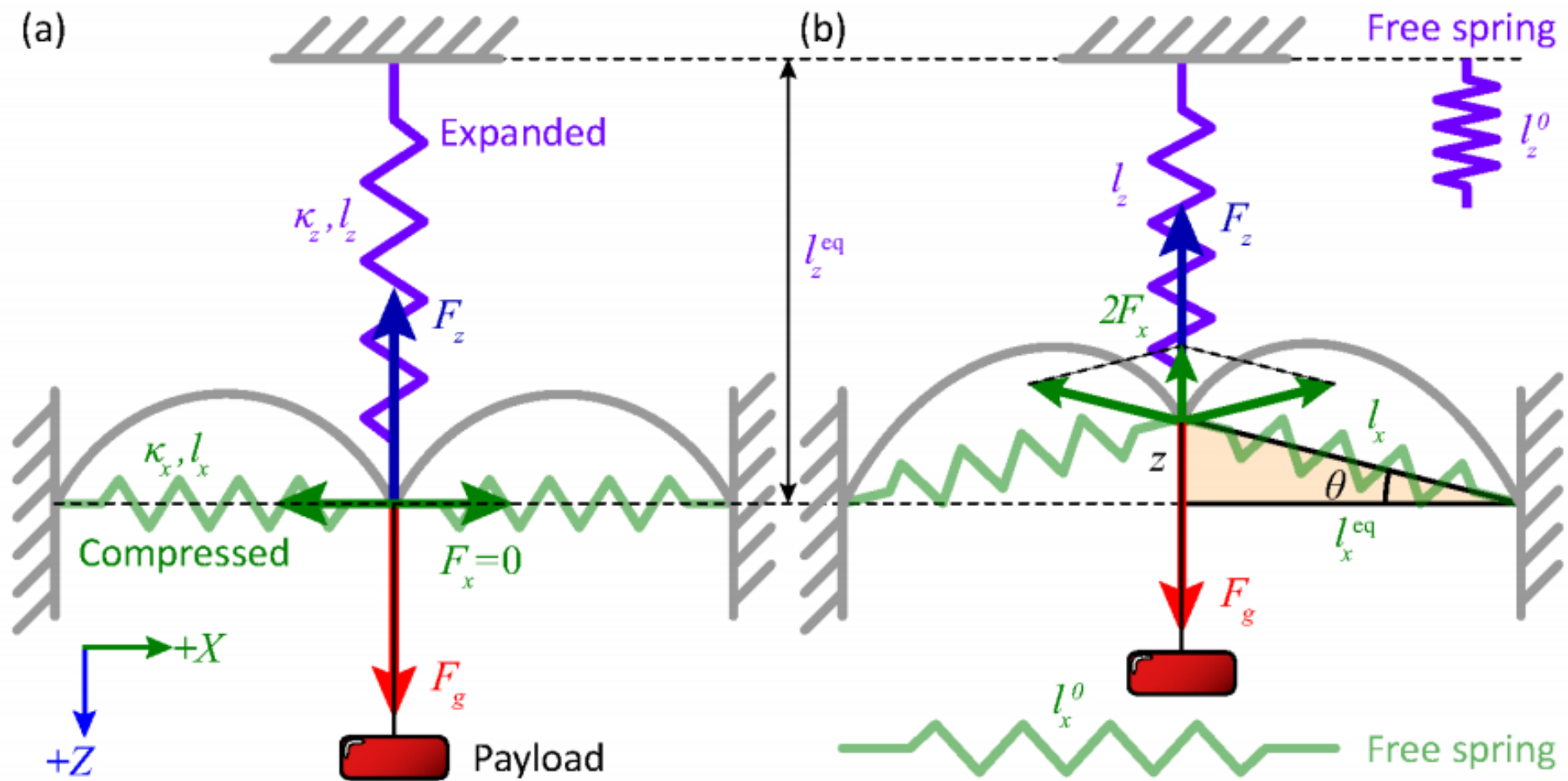




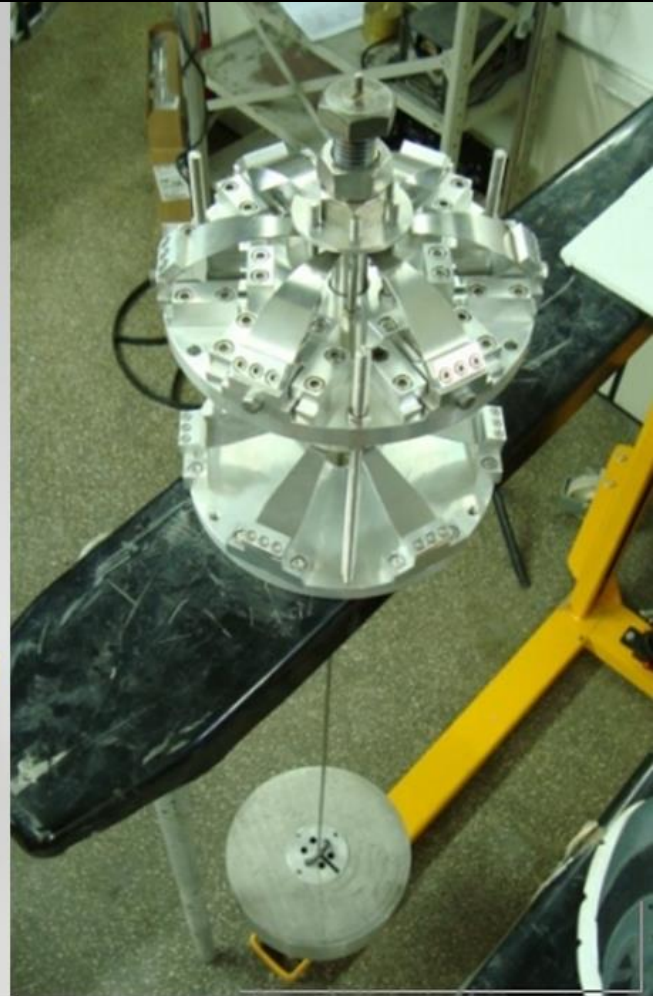
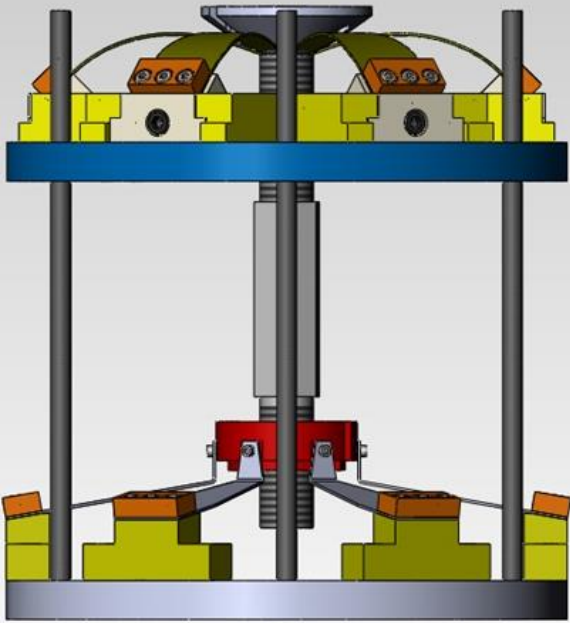
# *GEOMETRIC ANTI-SPRING*







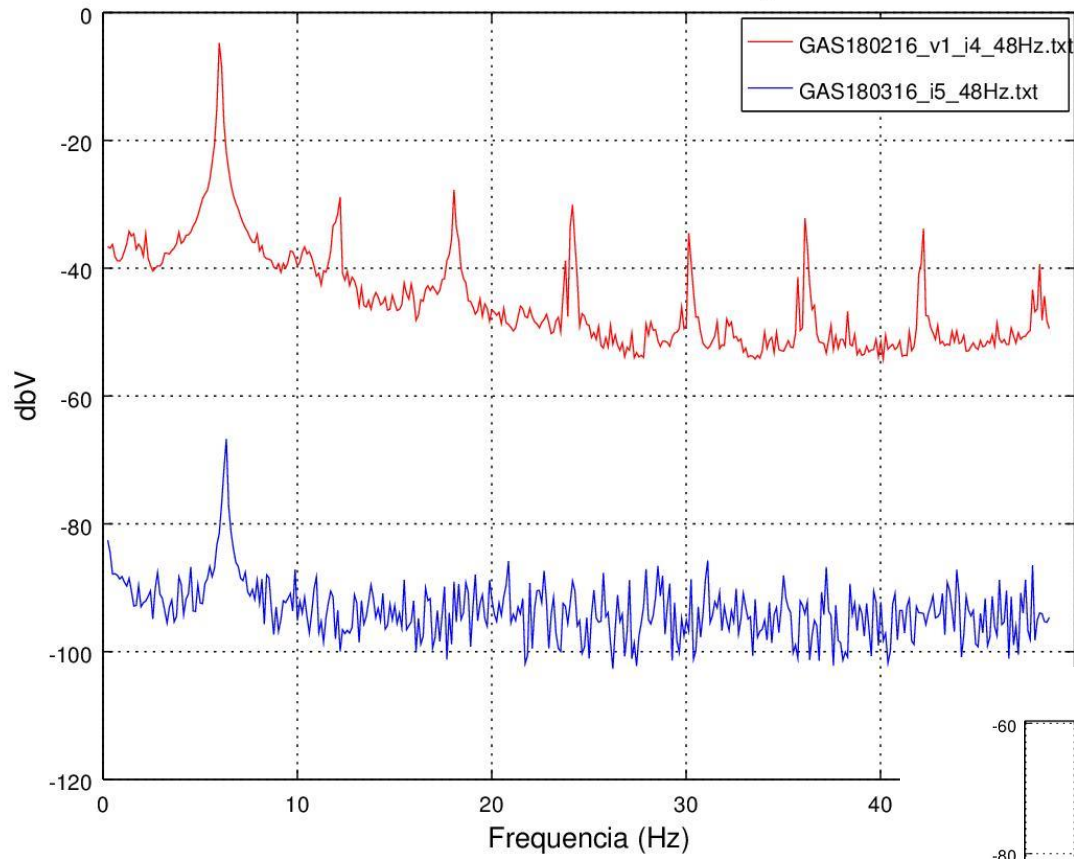
$$k_{\text{eff}} = k_z + k_x \left( \frac{l_x - l_x^0}{l_x} \right)$$



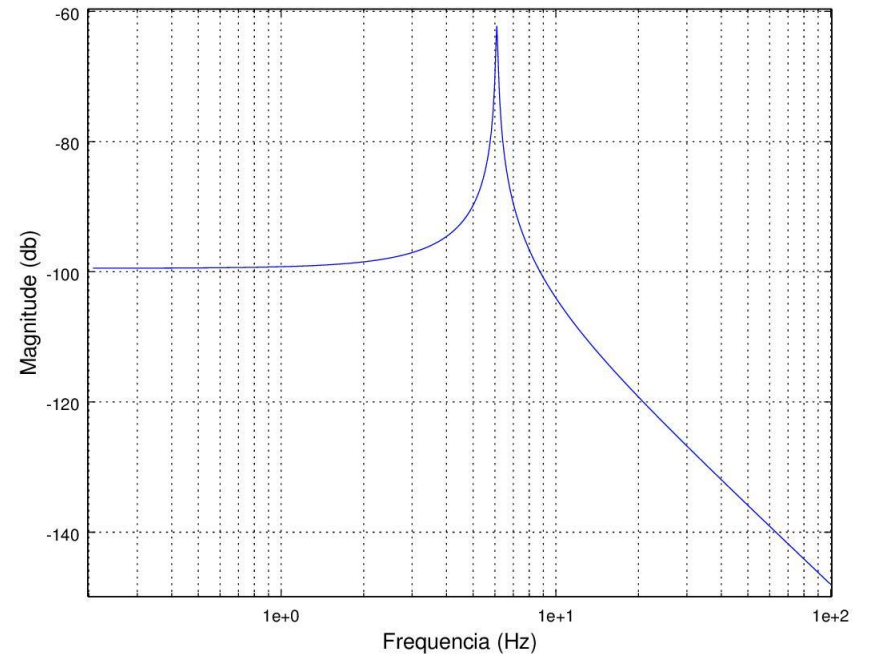
# MEDIÇÕES



Medidas de oscilacao da antimola geometrica



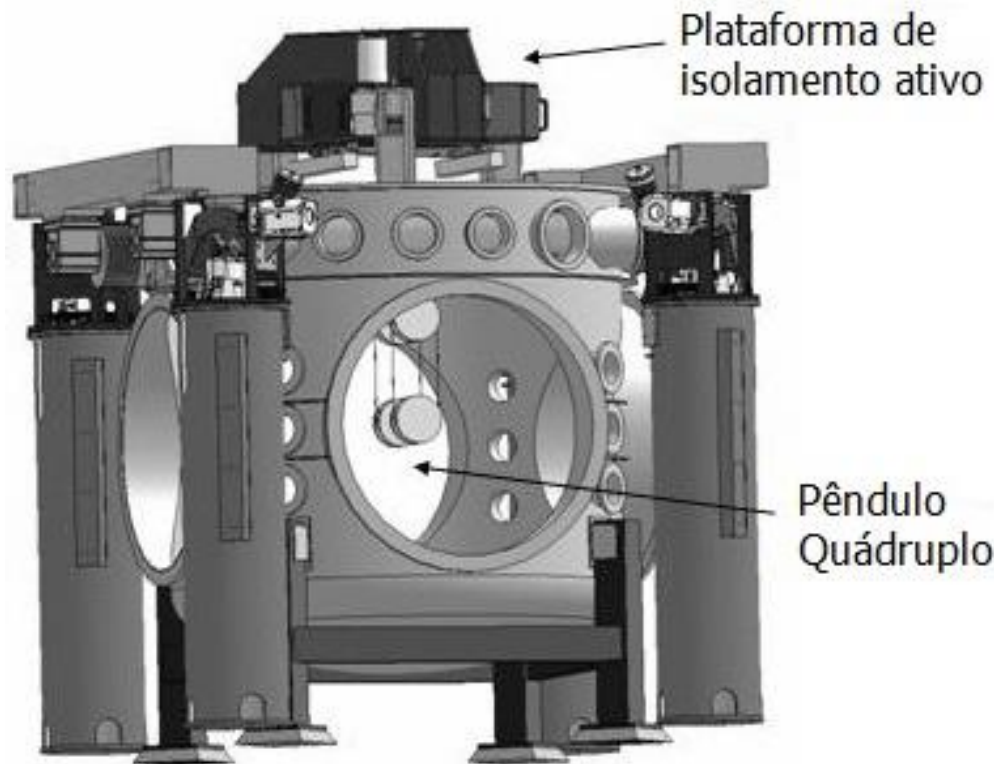
Funcao de transferencia da antimola geometrica



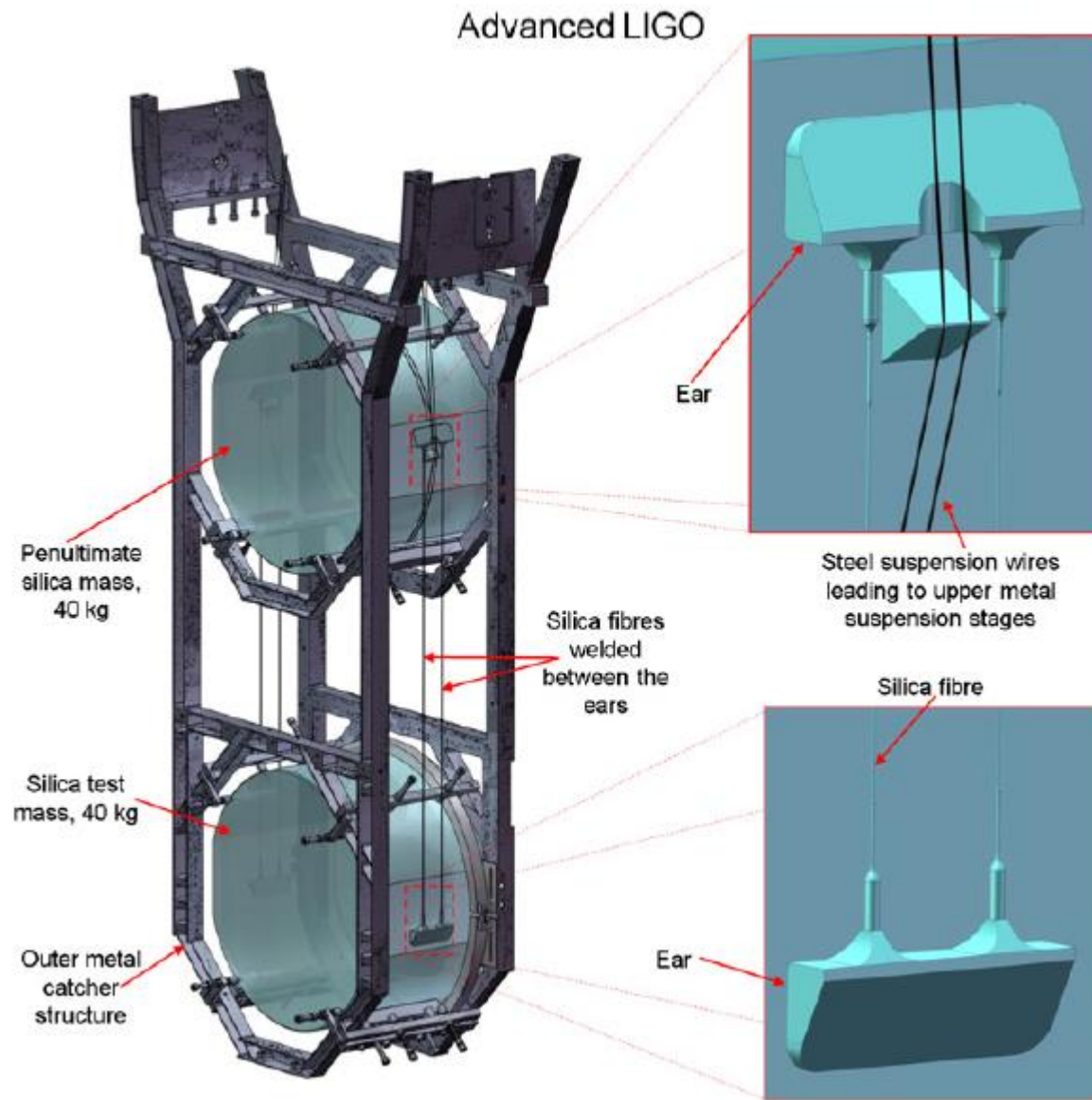
Obrigado!

# DETECTOR INTERFEROMÉTRICO

## Isolamento sísmico

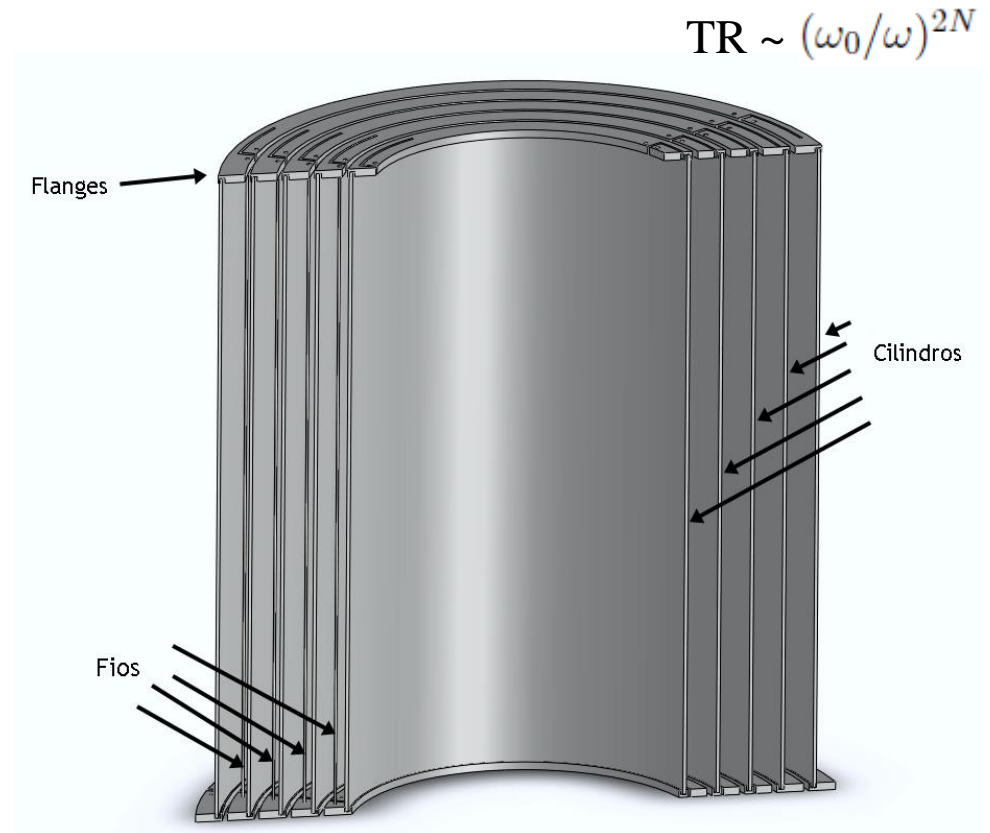






# DETECTOR INTERFEROMÉTRICO Sistema de Pêndulos Multi-Aninhados

Proposta do Multi-Nested Pendula (MNP): Isolamento adicional passivo em baixas frequências para o sistema de suspensão.



$$TR \sim (\omega_0/\omega)^{2N}$$

O movimento pendular é responsável pela atenuação de vibrações horizontais e os braços atuam como molas, atenuando as vibrações verticais.