Report from the suspension meeting in Boston

Two new facts in Sources and Suspensions

Sources

B.H. with final mass 30 solar masses oscillate at 15 Hz
With high signal levels

(**f = 460/M**) M in solar masses

Suspensions

The use of ribbon mirror suspensions will reduce pendulum thermal noise by an order of magnitude.

thermal noise wall will come below 10 Hz at the base

It is now possible to take advantage of low frequency advanced suspensions.

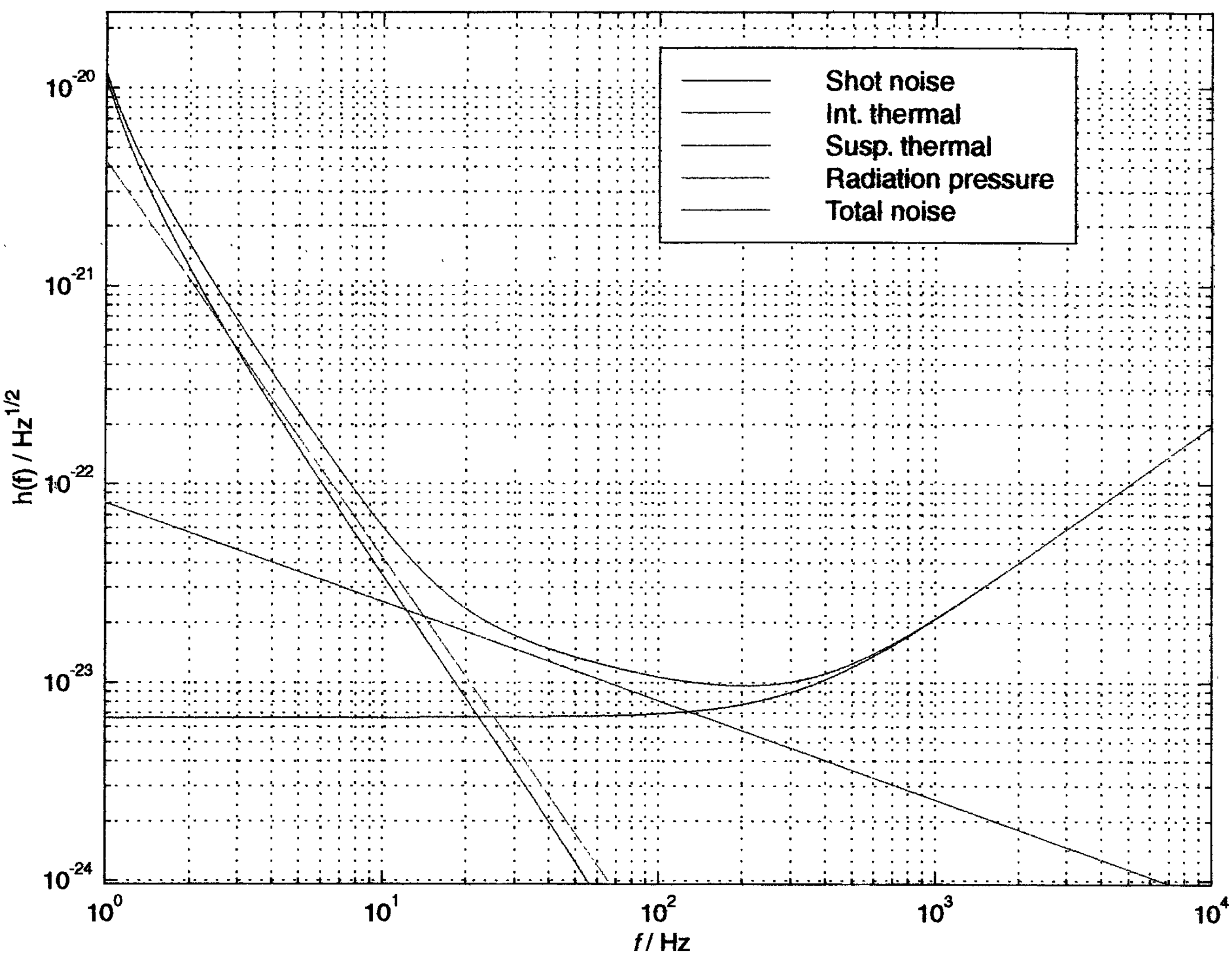
The limiting factor will be photon pressure noise

Long term Needs
- 30 Kg masses
- lower laser power

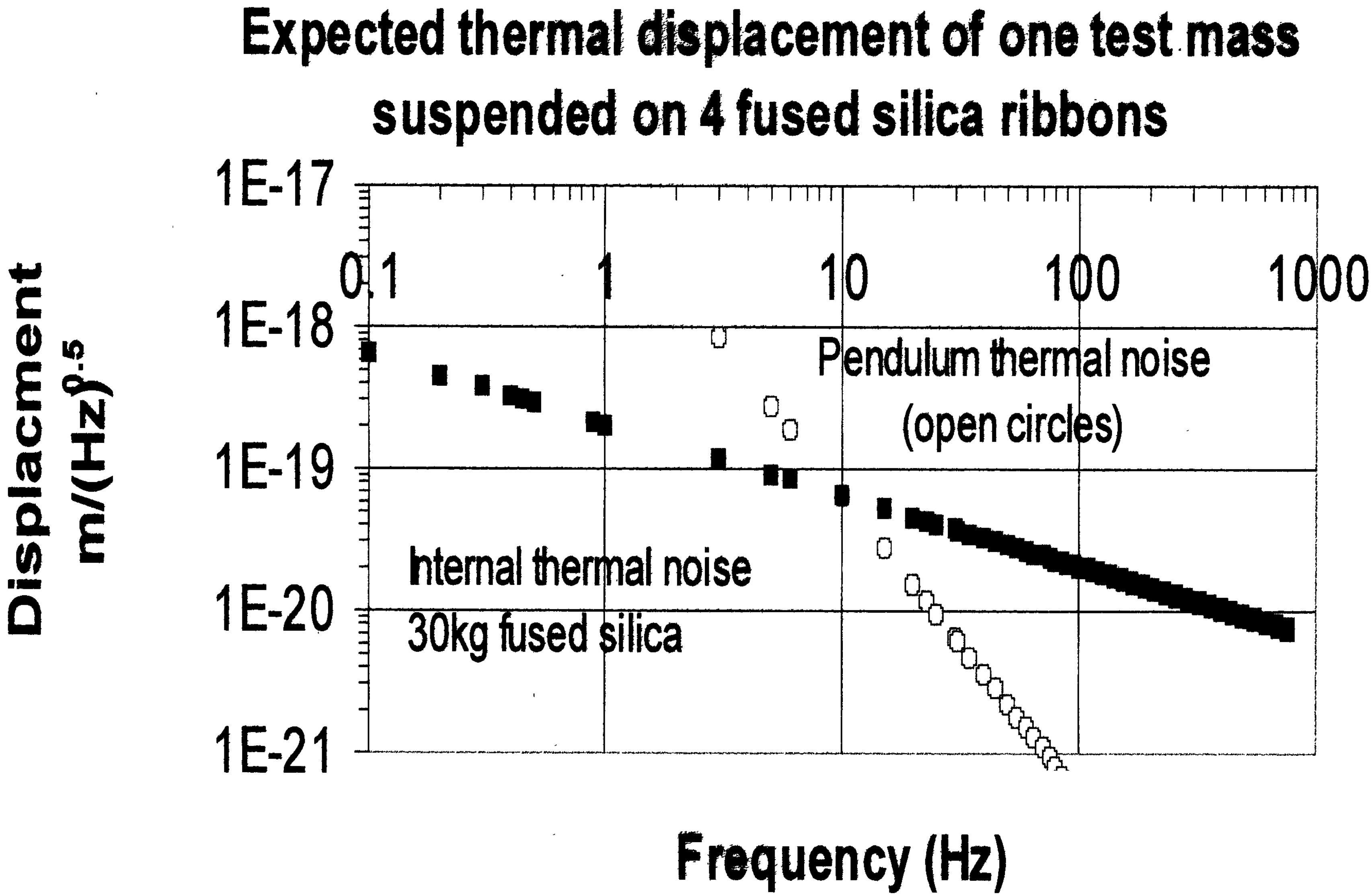
Physics suggest twin interferometers in each pipe
1) low power, low frequency
2) high power, high frequency

LIGO-G990057-00-D

R. De Salvo



Shot noise
Int. thermal
Susp. thermal
Radiation pressure
Total noise
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
h(f) / Hz$^{1/2}$
10^0
10^1
10^2
10^3
10^4
f / Hz


Expected thermal displacement of one test mass suspended on 4 fused silica ribbons
1E-17
1E-18
1E-19
1E-20
1E-21
0.1
1
10
100
1000
Displacment m/(Hz)^0.5
Pendulum thermal noise (open circles)
Internal thermal noise 30kg fused silica
Frequency (Hz)

PROBLEMS AND REMARKS

Ribbons have preliminary measurement giving sufficient performance despite other reports of surface losses on quartz.

Performance might even improve if the surface loss problems were solved.

Vertical thermal noise could be a problem limiting the ribbon potential if not properly addressed.

Also proposed auxiliary interferometer to stabilize suspensions (R. Drever)

Suspension development period
from now to 2006

Shut downs in 2004 and 2006

Final suspension system possible
only with final masses in 2006

Unlikely to get best masses in 2004

If possible to have final Seismic Isolation System,
best to install in 2004 to break it in early on
would use suspension and mirror of the day.

Not advisable to make multiple radical changes in a single shot.

Need to greatly reduce
shut down time
from present 18 man years of stack assembly.

Cannot afford to keep idle a very large investment

Cannot afford to remain blind for long times

Development targets
for mirror and intermediate masses
in triple pendulum

NO MAGNETS or Q spoiling appendages ON MIRROR

Mirror drive
electrostatic drive,
preferentially used only during locking
(shut down in operation
to avoid noise coupling to standing forces)
photon drive
during data taking

Intermediate mass drive
electrostatic drive
(photon drive if ultra low r.m.s. residual motion achieved by full active isolation on inverted pendulum suspensions)

Top mass drive
magnet/coil drive

Requirements for
Advanced Seismic Attenuation and Mirror Suspensions

1) Very low r.m.s. residual motion
   => to allow low force mirror controls
      => enable better mirror quality factors
         => better thermal noise performance

2) Seismic wall below 10 Hz
   => allow observation of new classes of sources.
      => enable low r.m.s. residual motion

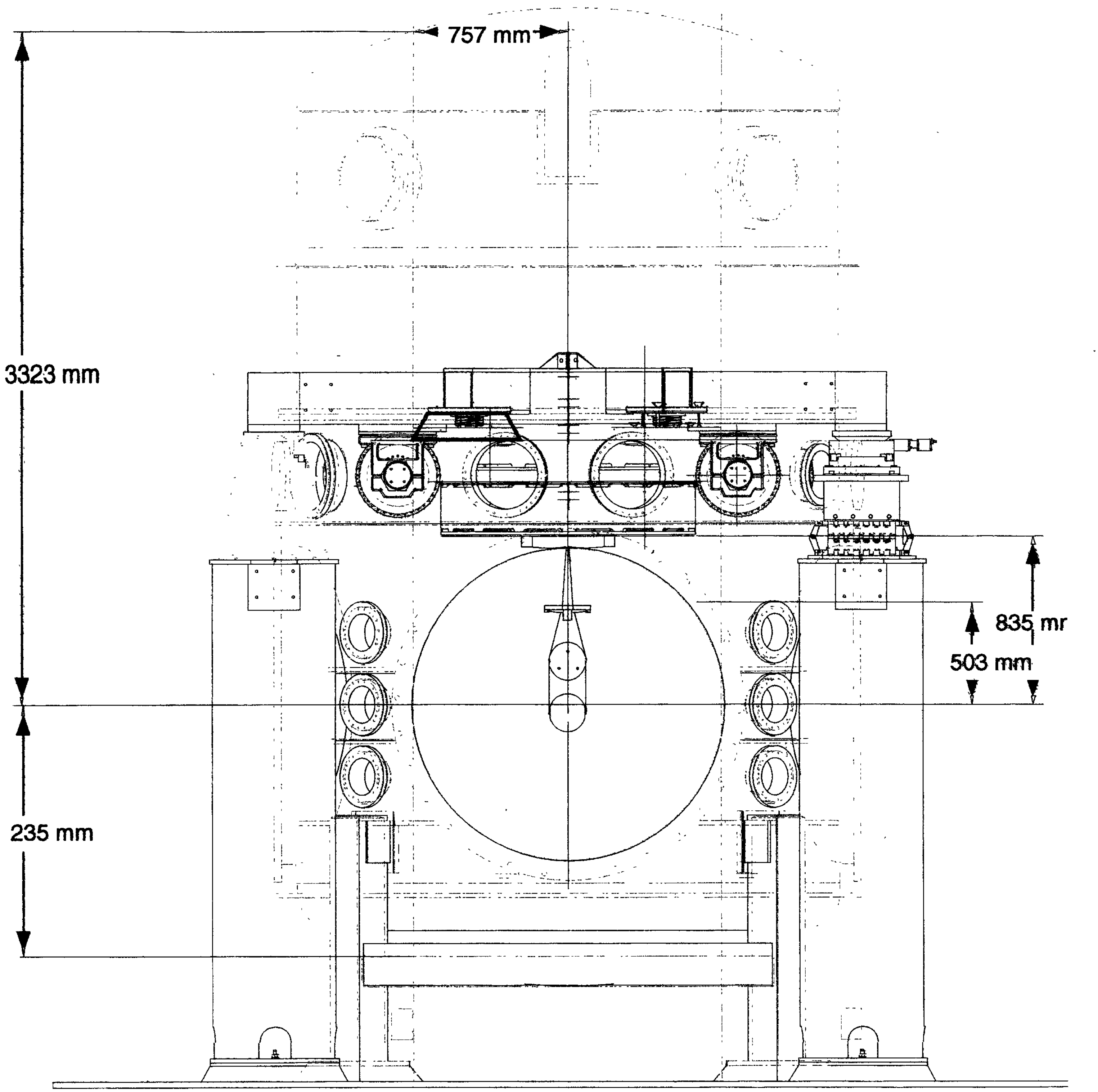
   => keep technical noise sources in check
      up-conversion and/or leakage mechanisms.

Three Seismic isolation options envisaged

1) 20 Hz basic solution.
   Use old down tube mechanics raised 30 cm to accommodate GEO triple pendulum, basically keep Hytec stacks. Active isolation on the piers.
   Just enough vertical space for present GEO triple pendulum.
   Should reach the 20 Hz level.

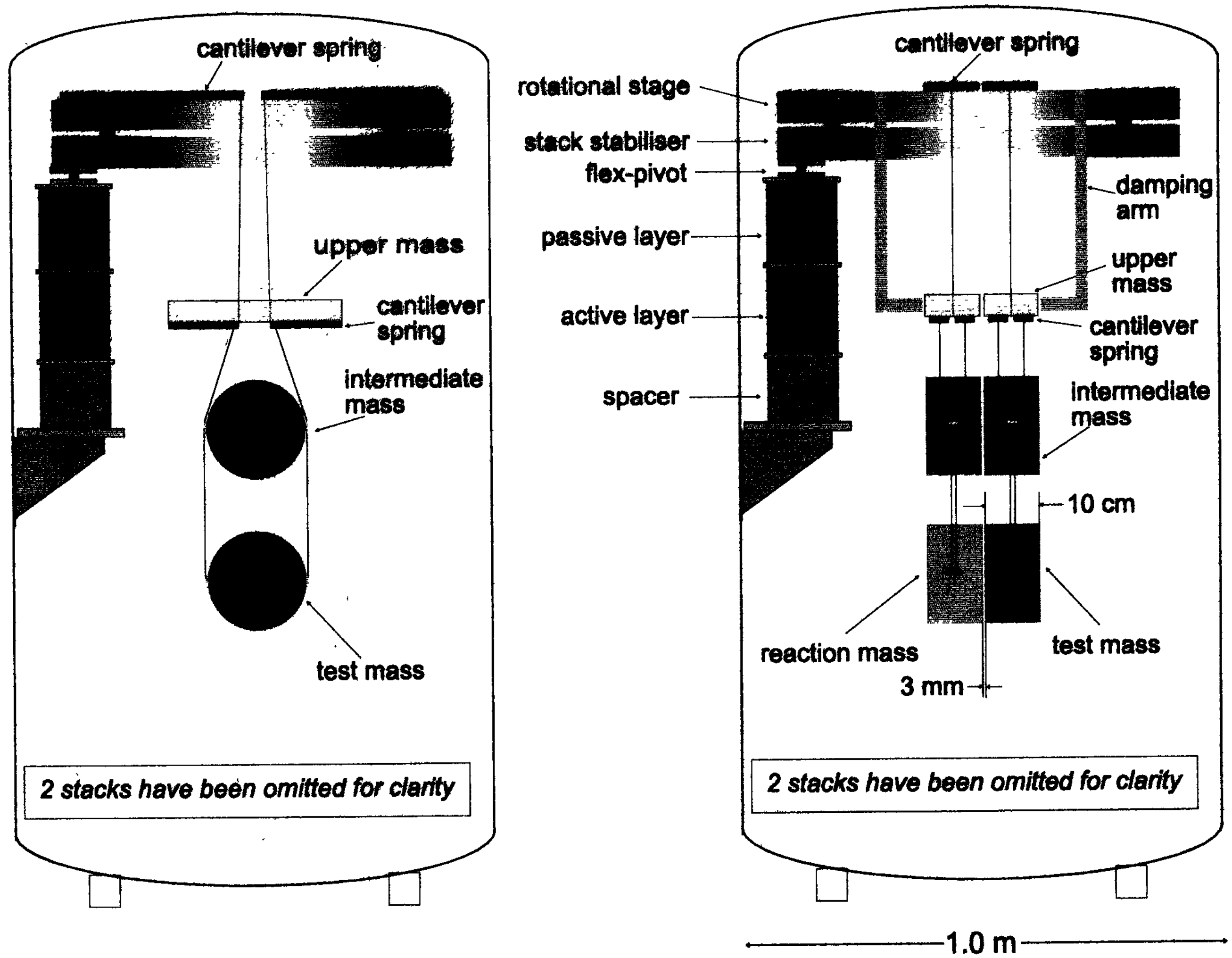
2) 10 Hz Active Seismic Isolation.
   Hytec geometry with 2 active nested loops.
   Uses present mechanics.
   If need to accommodate one passive layer of GAS filters, will need new down tube but still inside present vacuum envelope.
   If stretched will allow modified triple pendulum

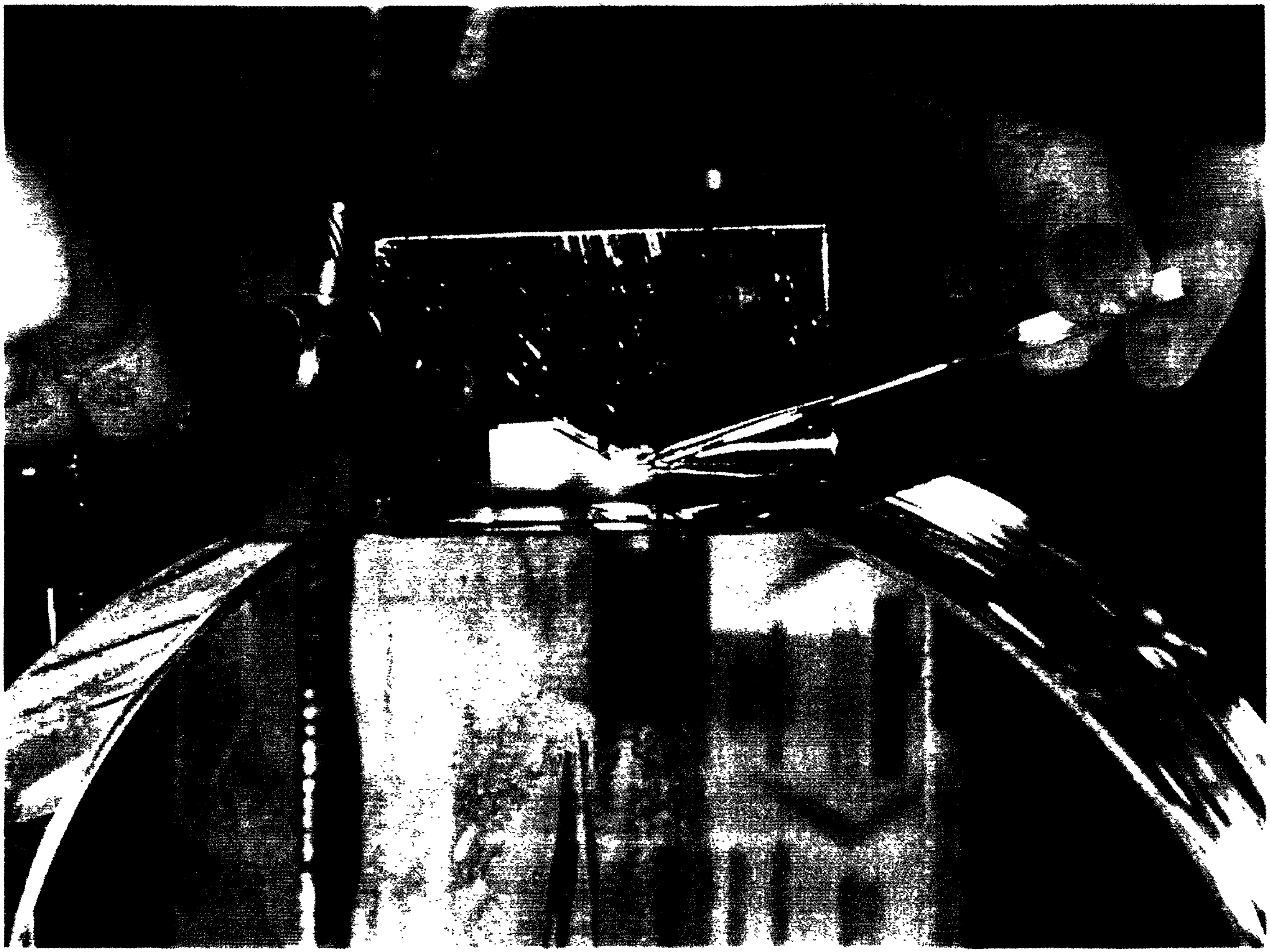
3) Inverted pendulum and ULF GAS filters operated in active inertial damping followed by multiple passive GAS filters and modified stretched GEO triple pendulum.
   Need vacuum envelope extension.
   Brute force approach, basically reaches goal passively (with inertial modal damping) with active seismic isolation used only to boost performances.
   Will give overkill capability, lower frequency wall, active reserve
   Will enable quietest mirror drives
   Allow stretched triple pendulum
   Plenty of payload capability

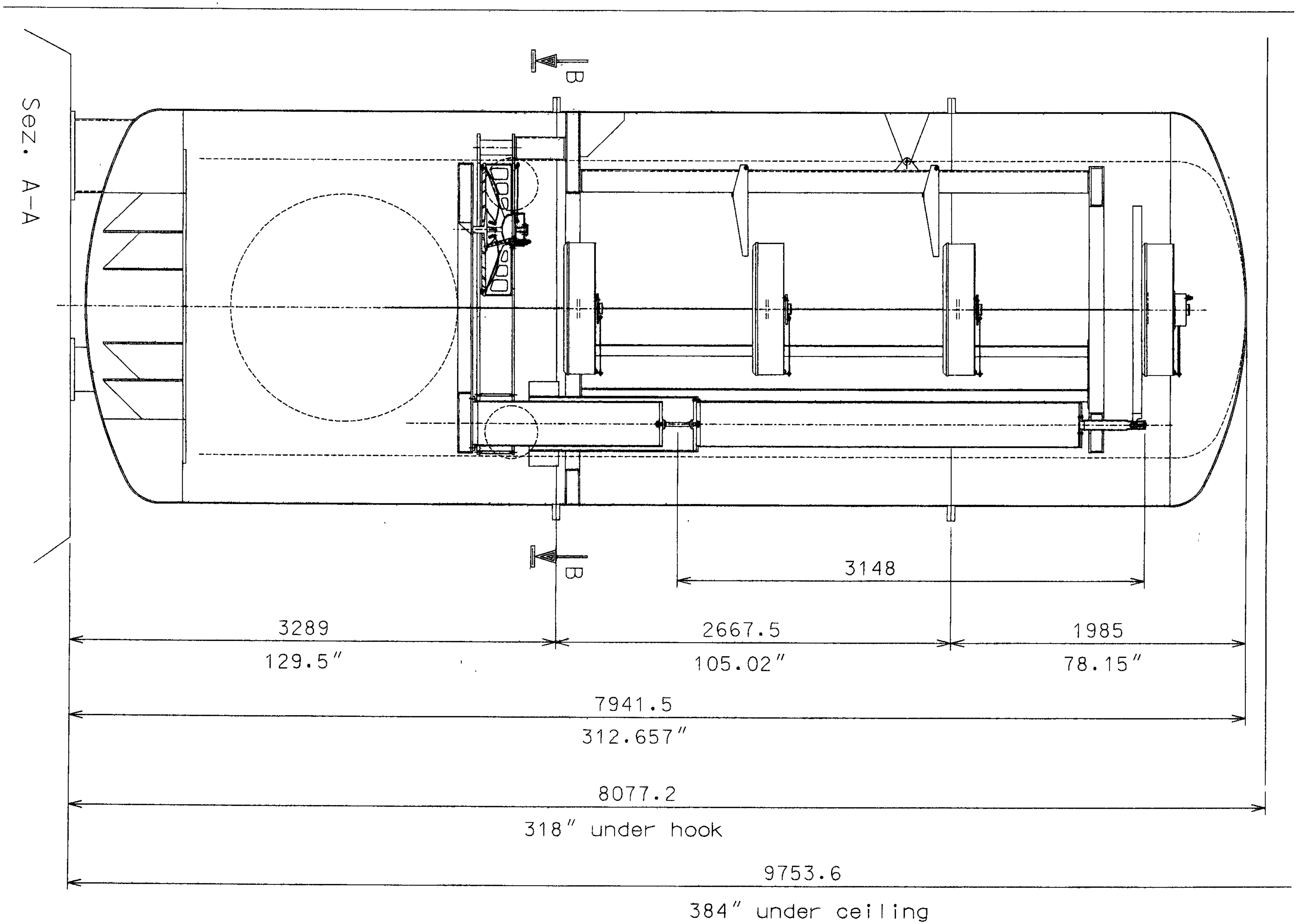


757 mm
3323 mm
835 mr
503 mm
235 mm

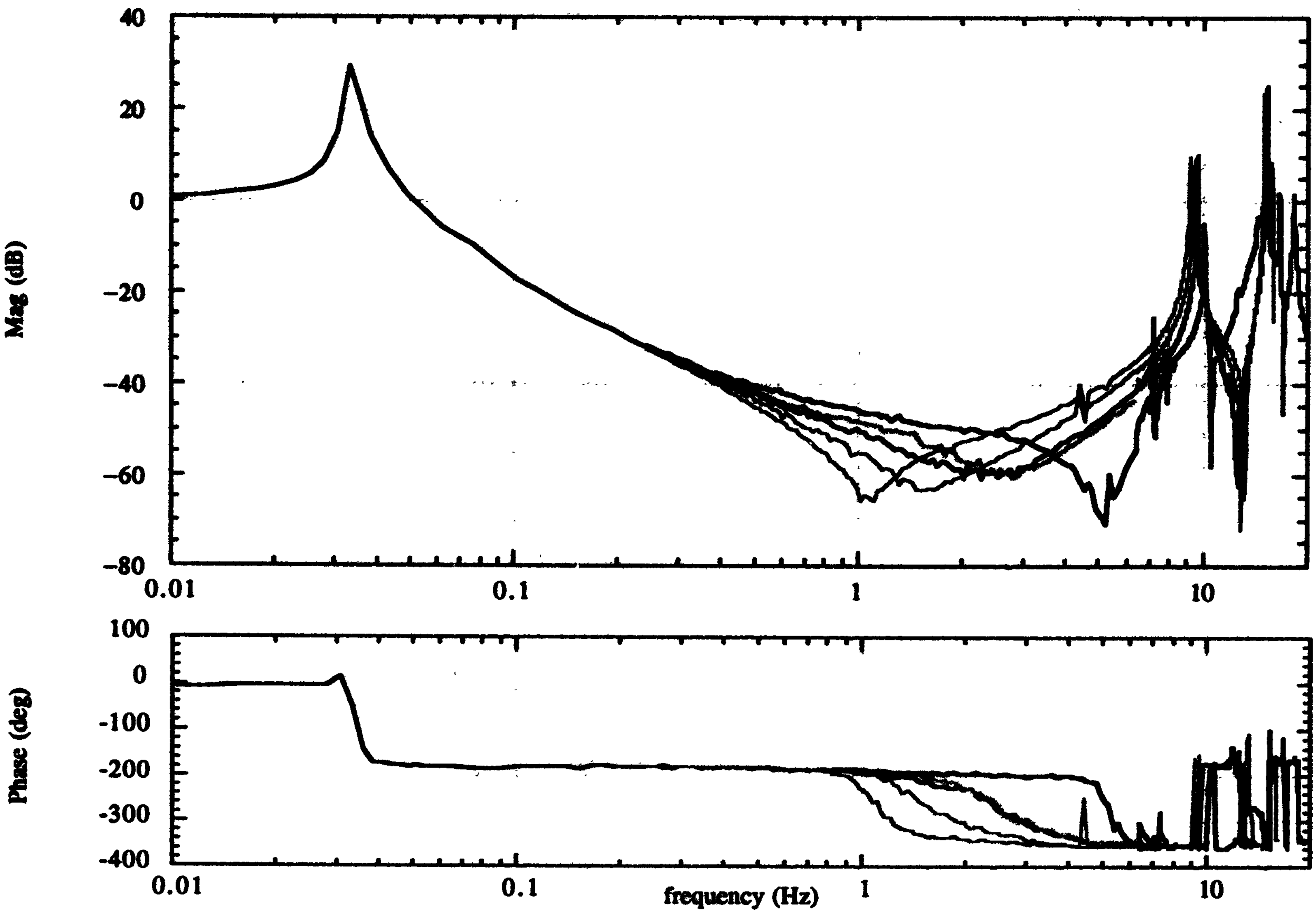
GEO 600 main suspension



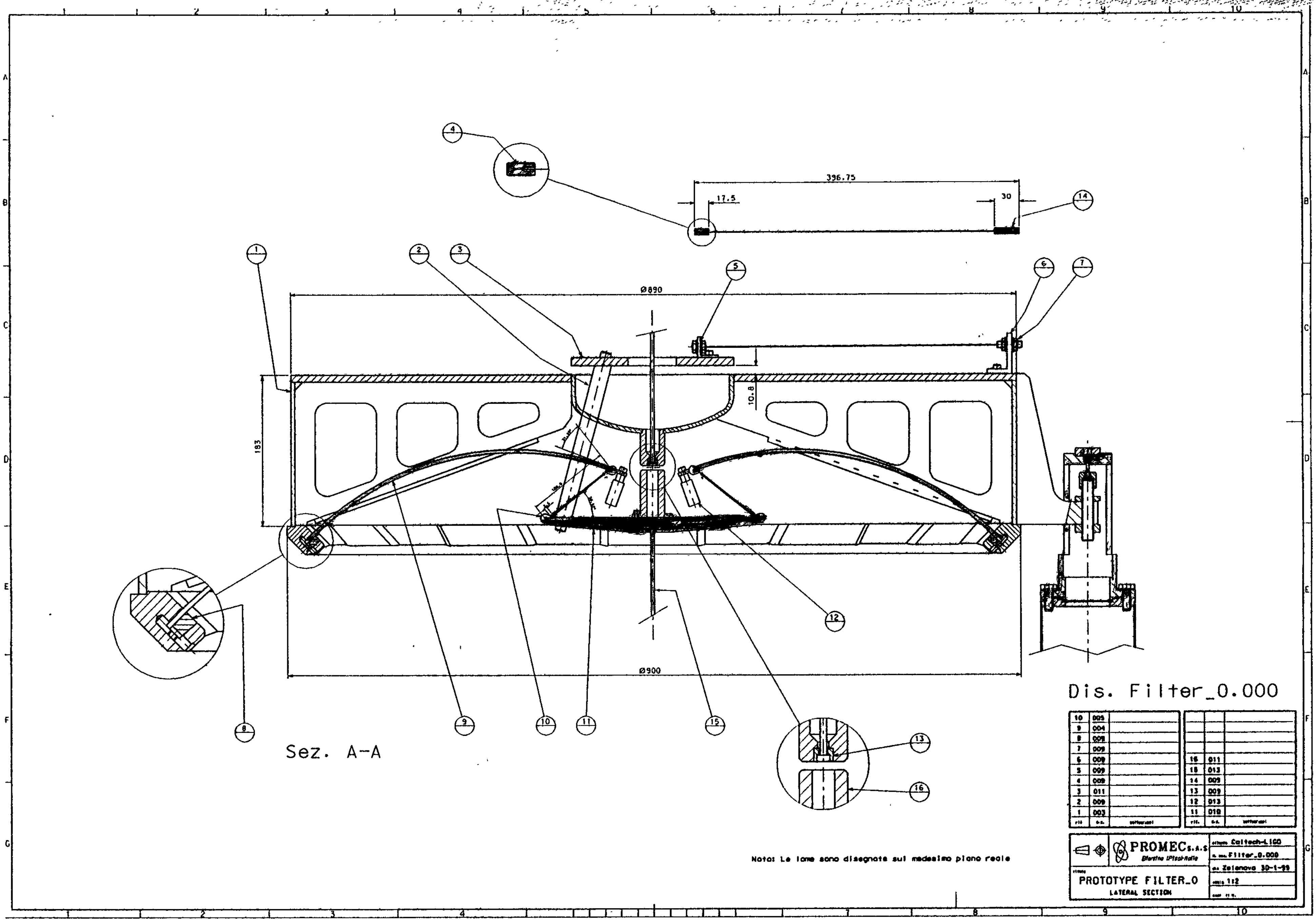



Sez. A-A
B
B
3148
3289
129.5"
2667.5
105.02"
1985
78.15"
7941.5
312.657"
8077.2
318" under hook
9753.6
384" under ceiling

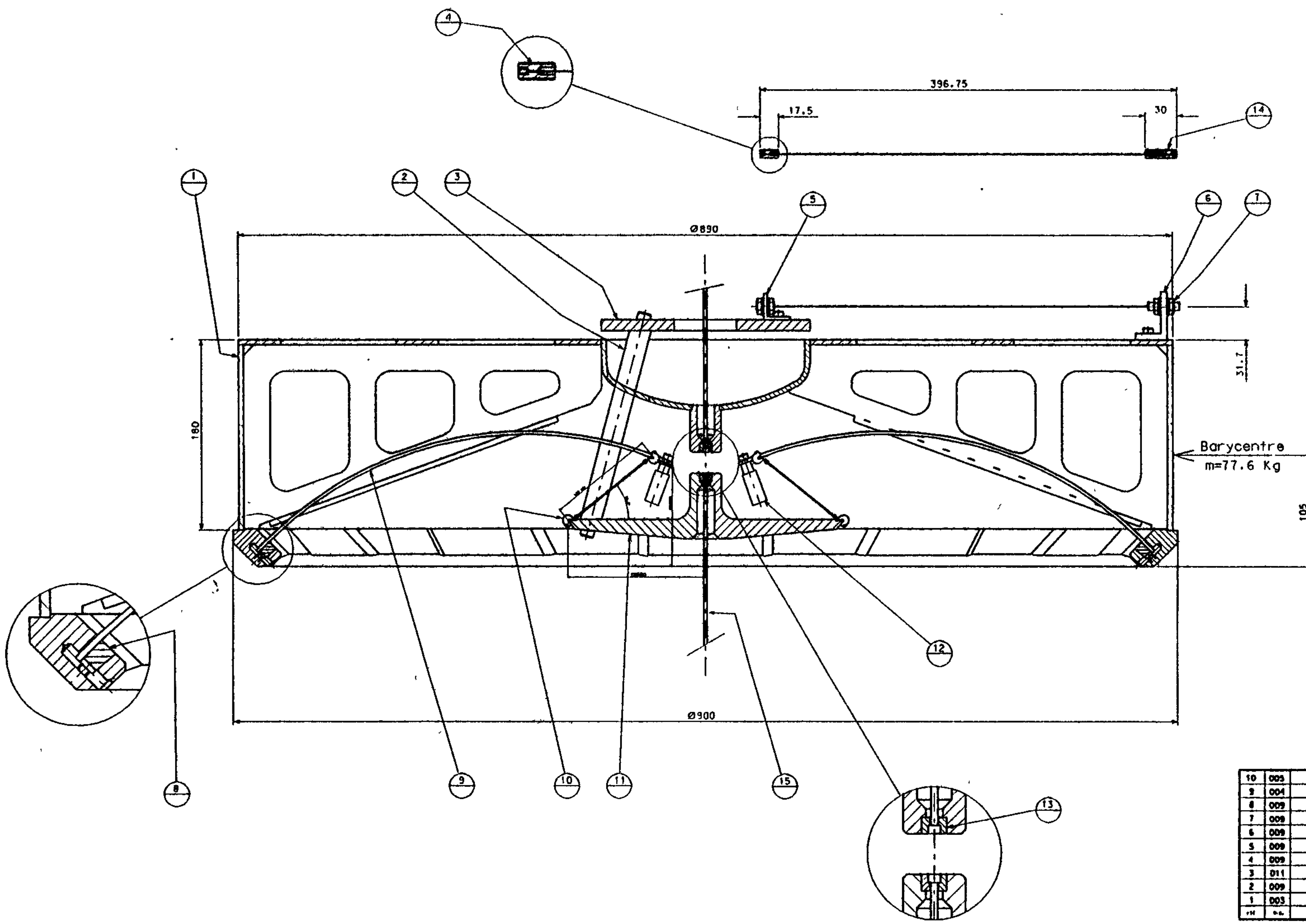
Inverted Pendulum Transfer Function



Giovanni Losurdo - Scuola Normale Superiore & INFN



396.75
17.5
30
Ø890
10.8
183
Ø900
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Sez. A-A
Nota: Le lame sono disegnate sul medesimo piano reale
Dis. Filter_0.000
10 005
9 004
8 009
7 009
6 009
5 009
4 009
3 011
2 009
1 003
16 011
15 013
14 009
13 009
12 013
11 010
PROMEC S.A.S
Caltech-LIGO
Filter_0.000
Zelenova 30-1-99
1:2
PROTOTYPE FILTER_0
LATERAL SECTION



10	005				
9	004				
8	009				
7	009				
6	009				
5	009		15	013	
4	009		14	009	
3	011		13	009	
2	009		12	013	
1	003		11	010	

PROMEC S.A.S

Bientina (Pisa) Italia

Caltech-LIGO

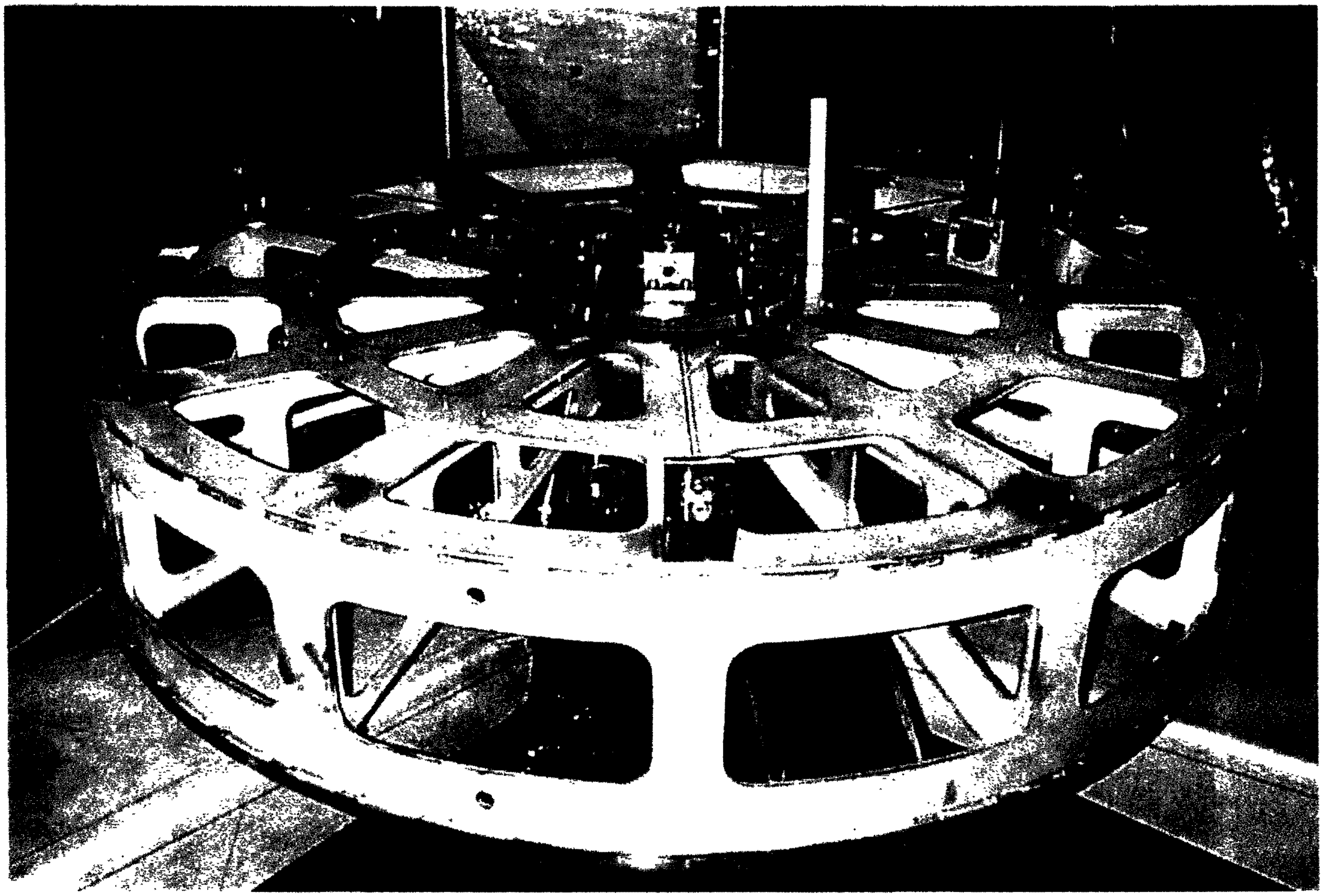
Filter.000

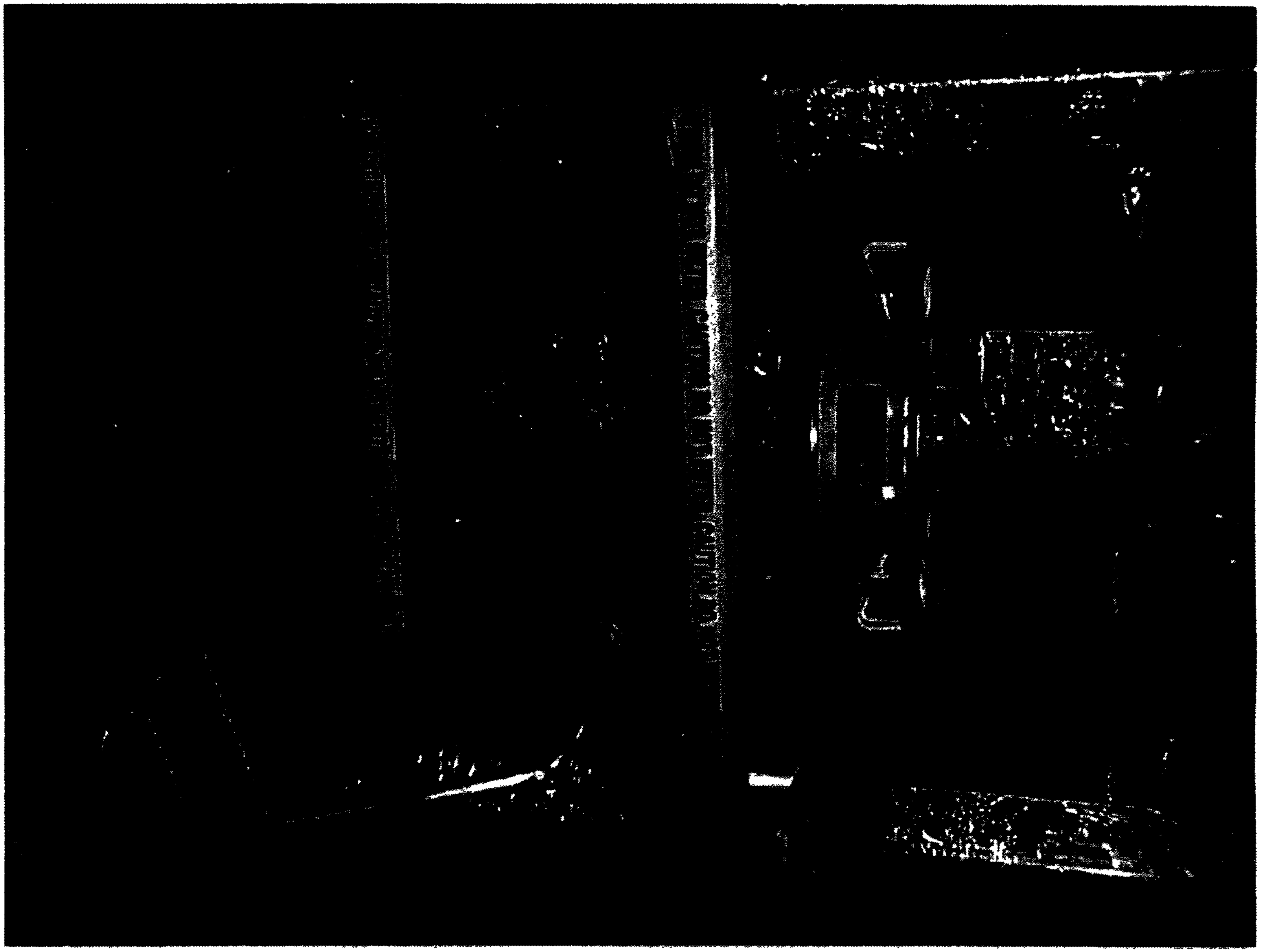
Zelenova 30-9-98

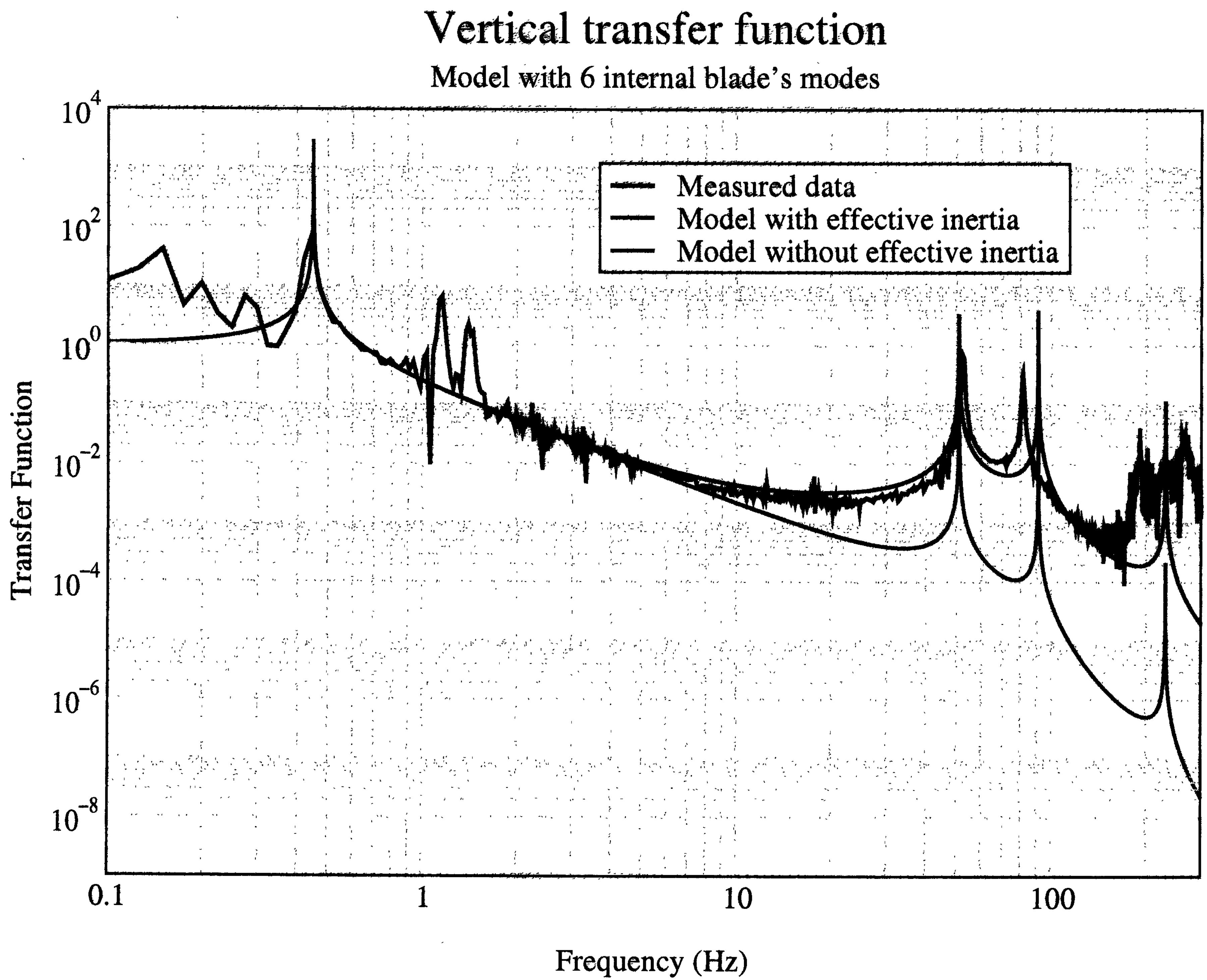
scale 1:2

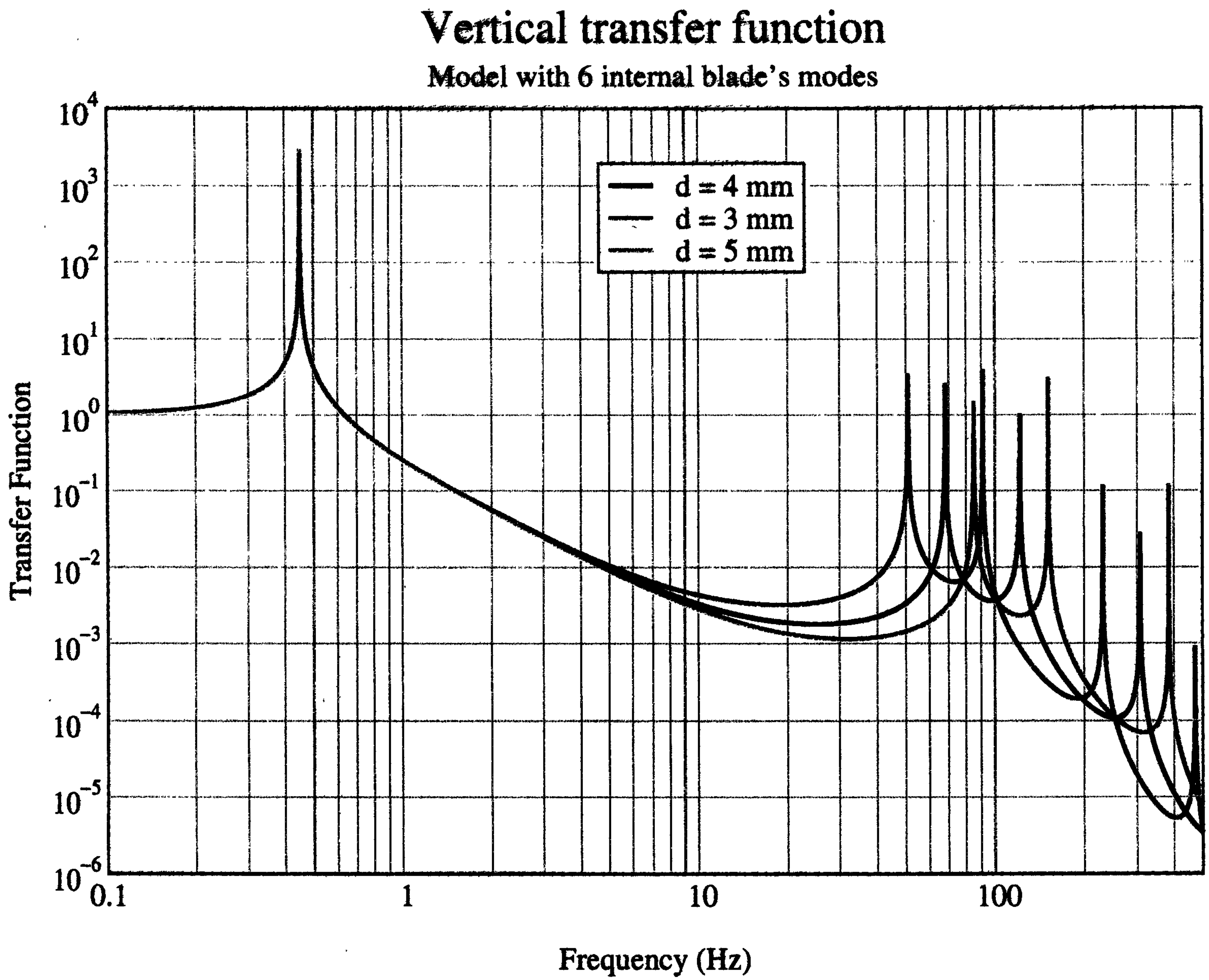
PROTOTYPE FILTER

LATERAL VIEW






Vertical transfer function
Model with 6 internal blade's modes
Measured data
Model with effective inertia
Model without effective inertia
Transfer Function
Frequency (Hz)
10^4
10^2
10^0
10^-2
10^-4
10^-6
10^-8
0.1
1
10
100


Vertical transfer function
Model with 6 internal blade's modes
d = 4 mm
d = 3 mm
d = 5 mm
Transfer Function
Frequency (Hz)
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.1
1
10
100

Vertical Frequency Tuning

(Comparison with Magnetic Anti-Spring System)

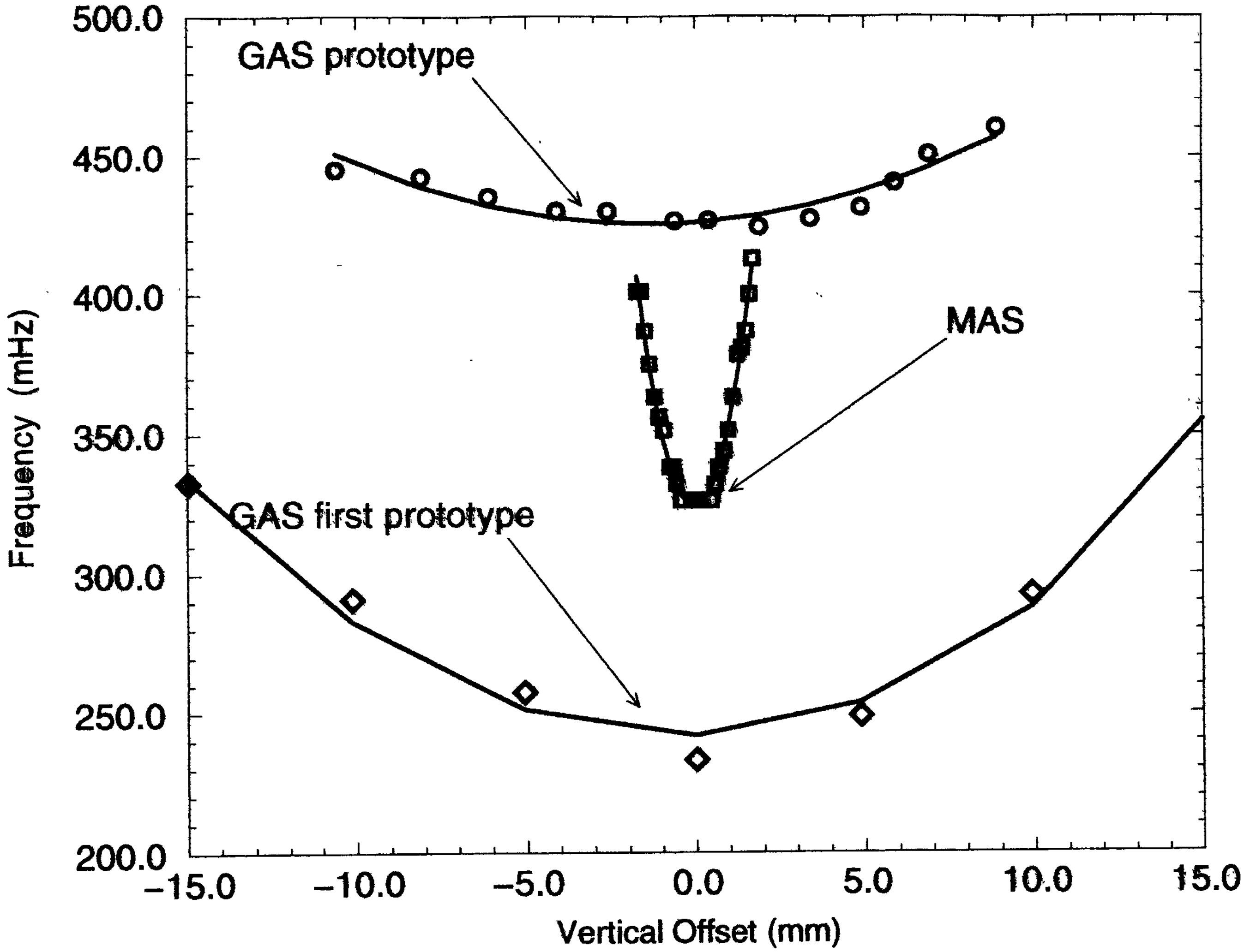
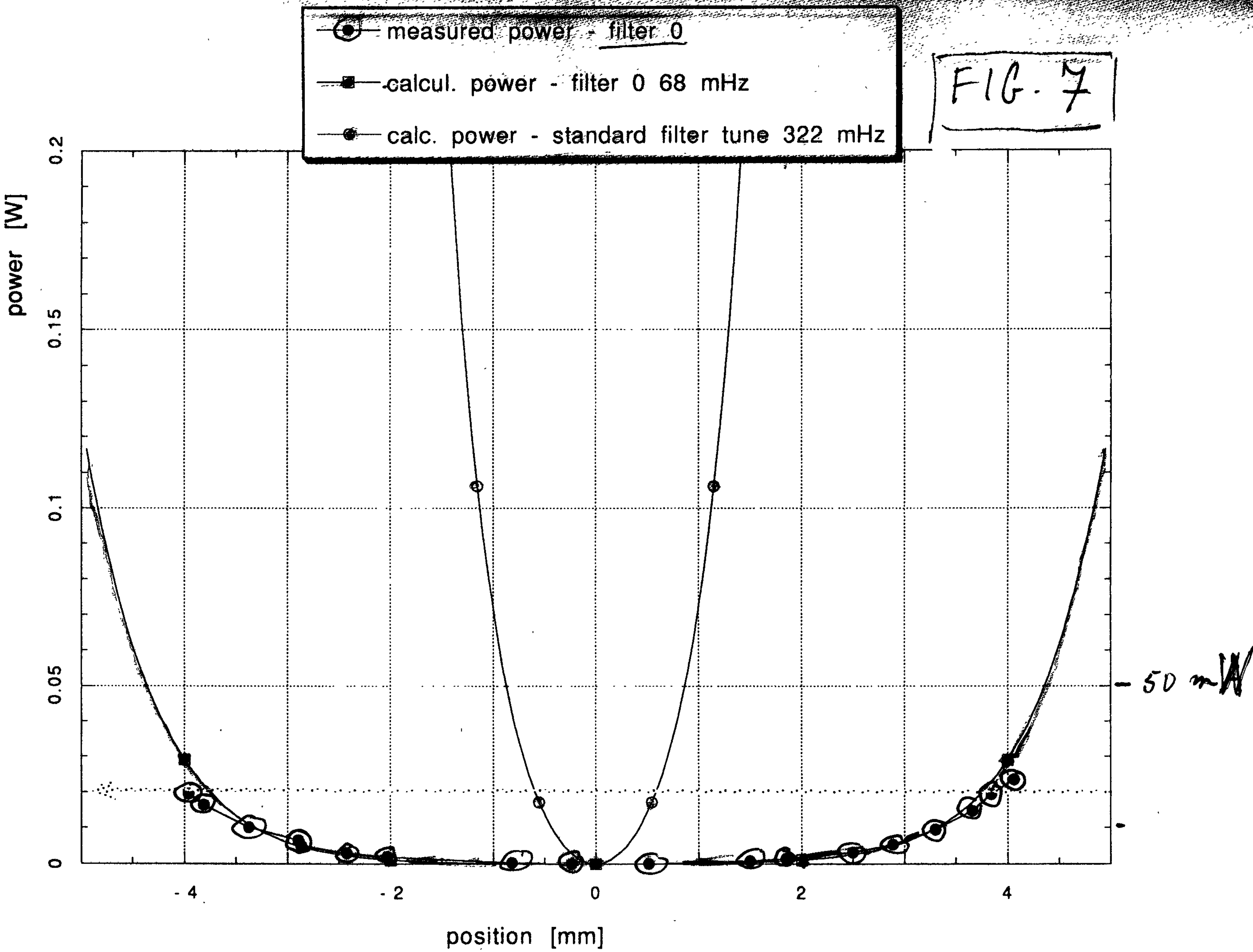


FIG. 7



measured power - filter 0
calcul. power - filter 0 68 mHz
calc. power - standard filter tune 322 mHz
power [W]
0.2
0.15
0.1
0.05
0
-4
-2
0
2
4
position [mm]
50 mW

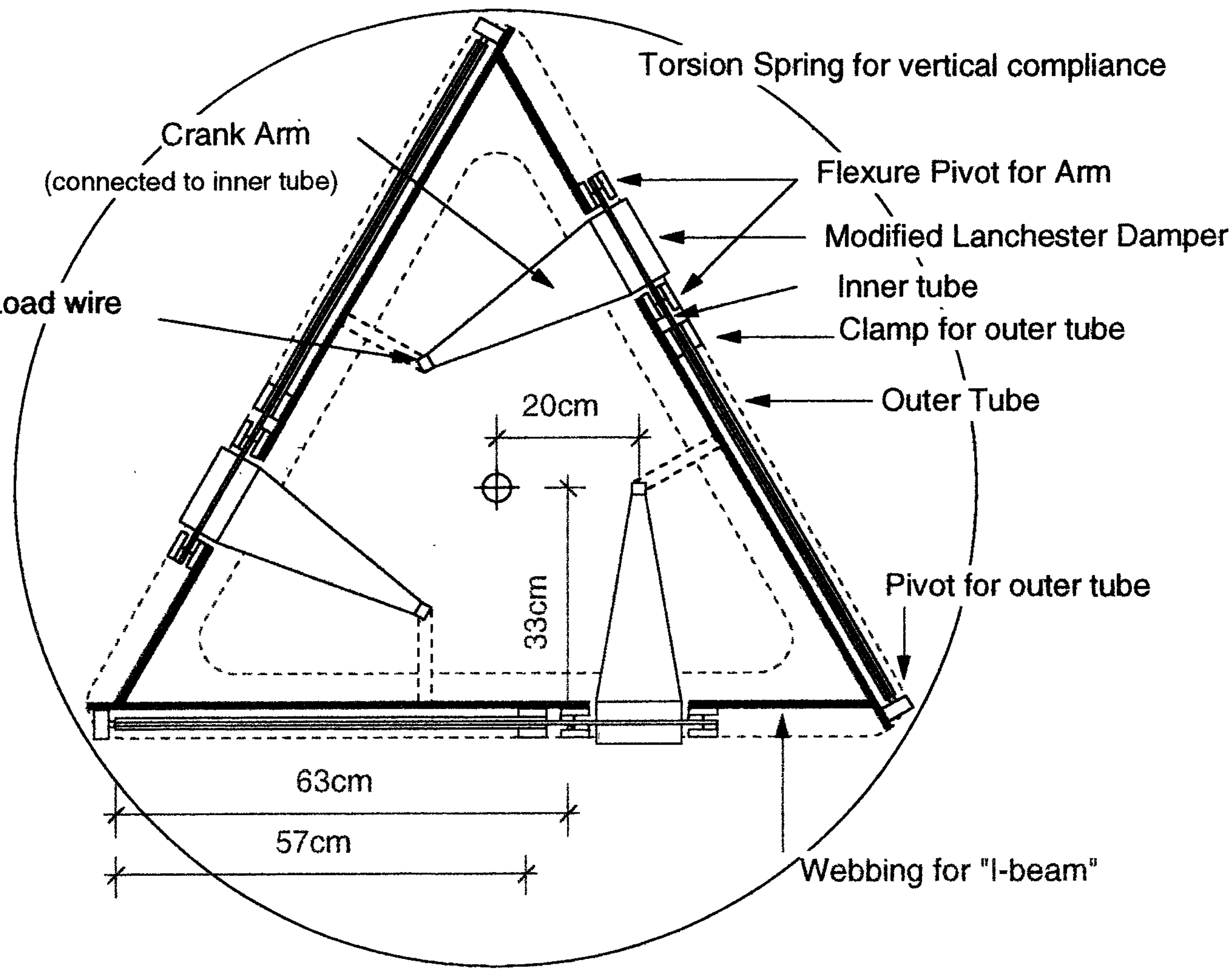
GAS filters thermal advantages

MAS	GAS	
19.3	1.6	mHz/K
400	40	µm/K

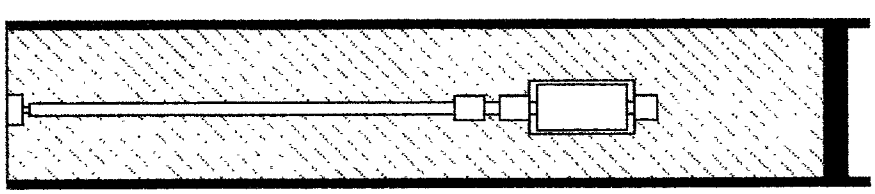
- 100 times less thermal sensitivity
- Wider mechanical dynamic range
  - No need for in-vacuum w.p. tuning
  - No need for load tuning mechanisms

Triangular Suspension Stage (L.S.4.)

Three vertical wires (~30 cm) for horizontal compliance



Section through midplane

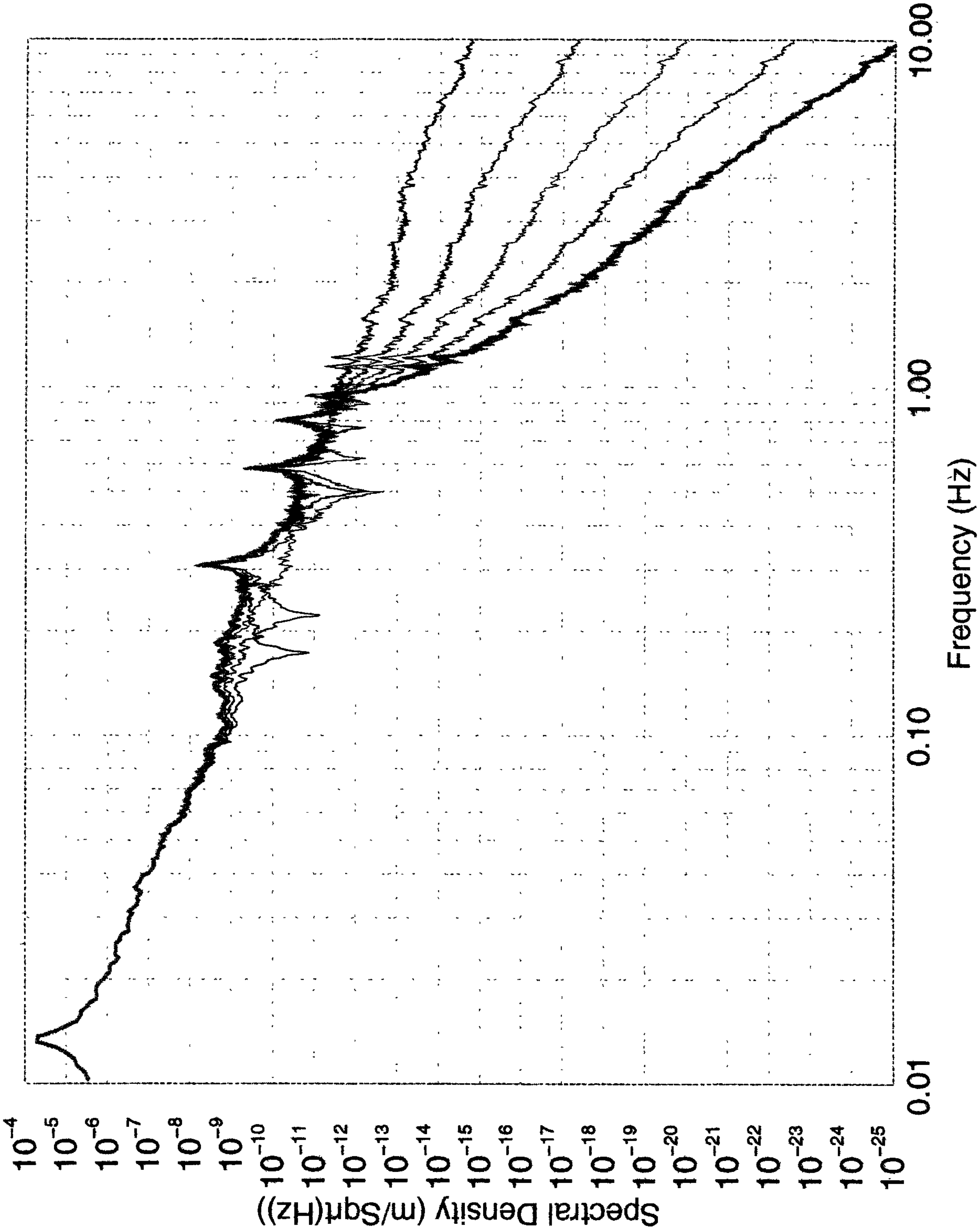


Side View

Filtered Seismic Noise LHO Site

Zoom in Horizontal Degree of Freedom

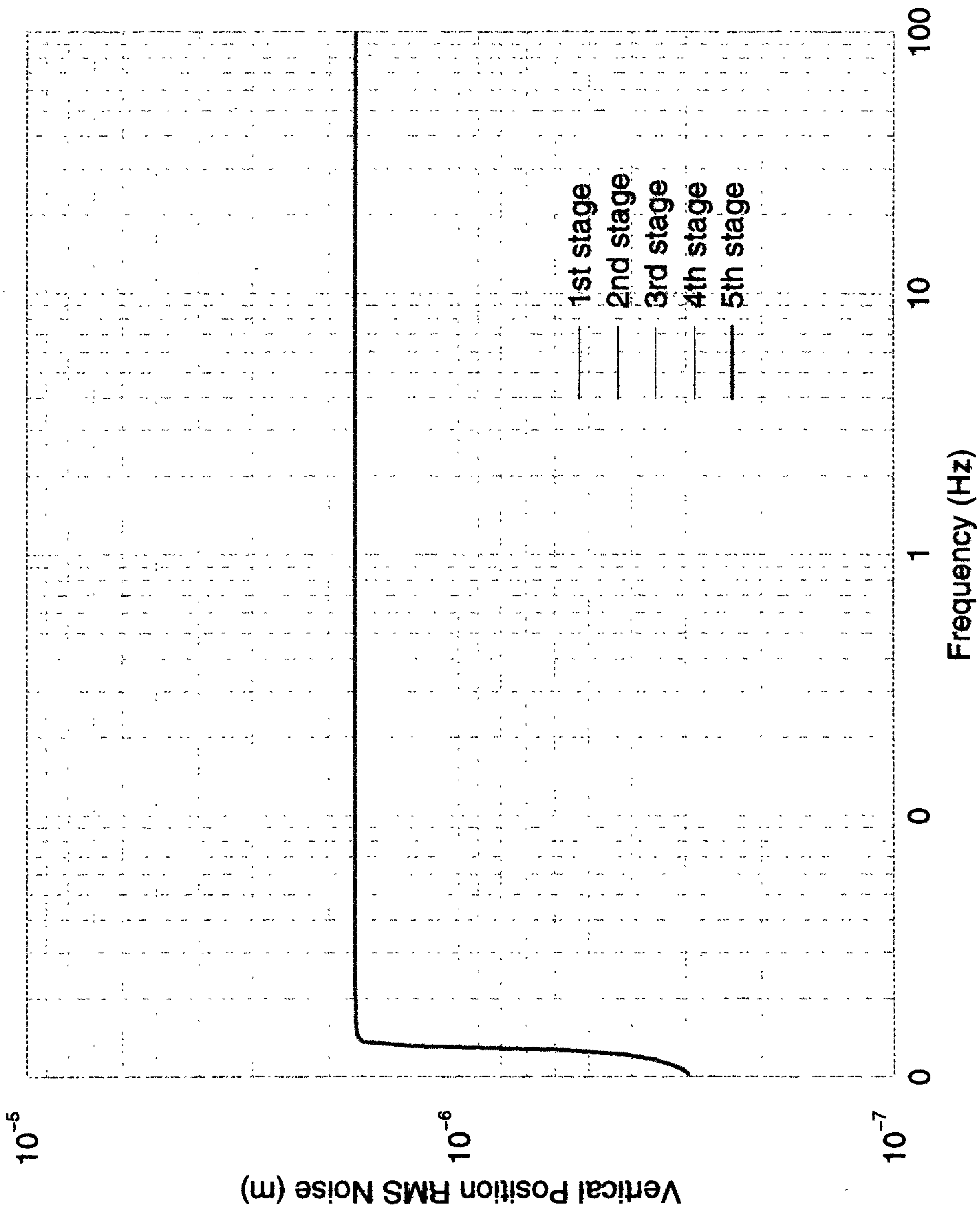
(Simplified model)



RMS Seismic/Band LHO Site

Horizontal Degree of Freedom

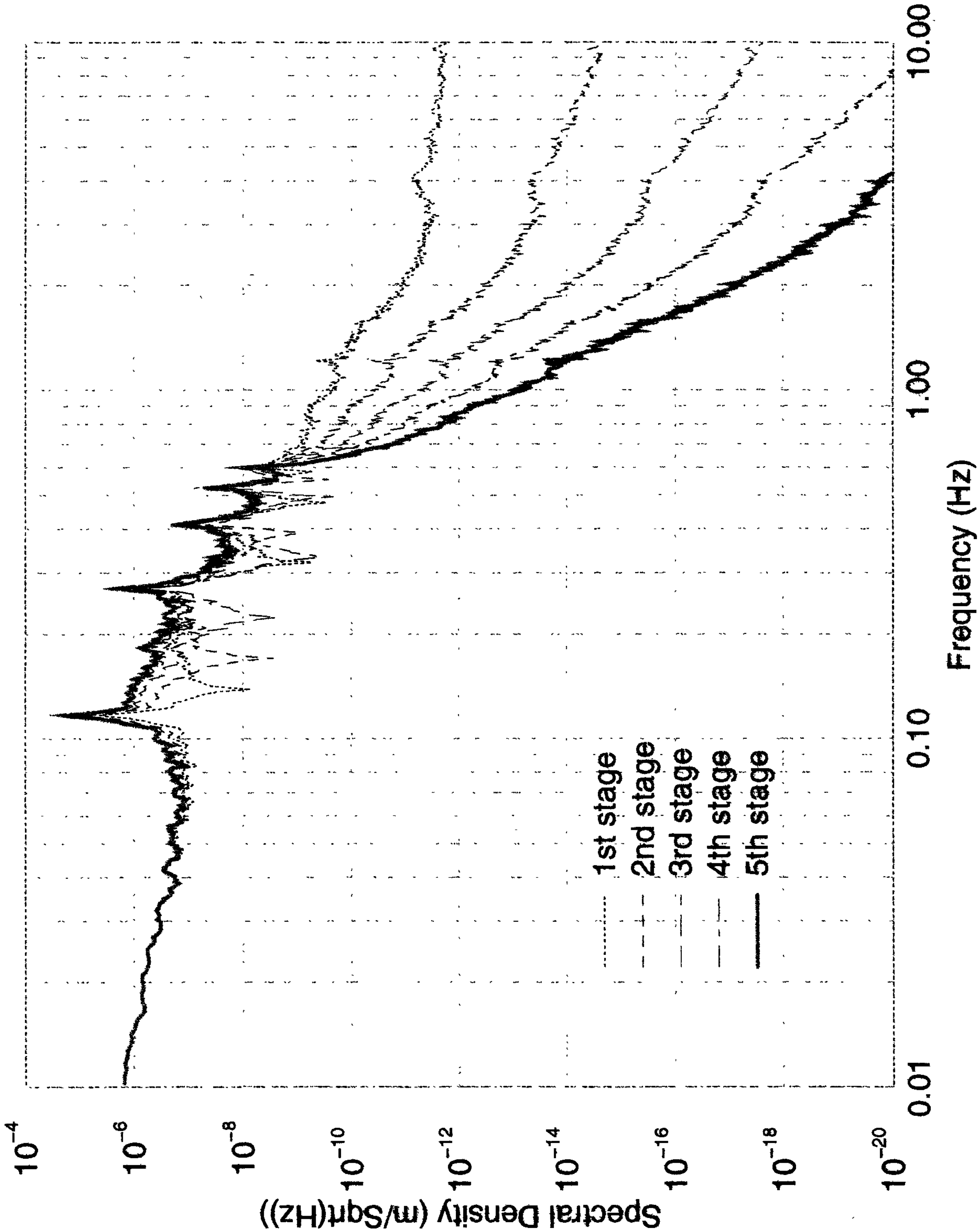
(Simplified model)



Filtered Seismic Noise LHO Site

Zoom in Vertical Degree of Freedom

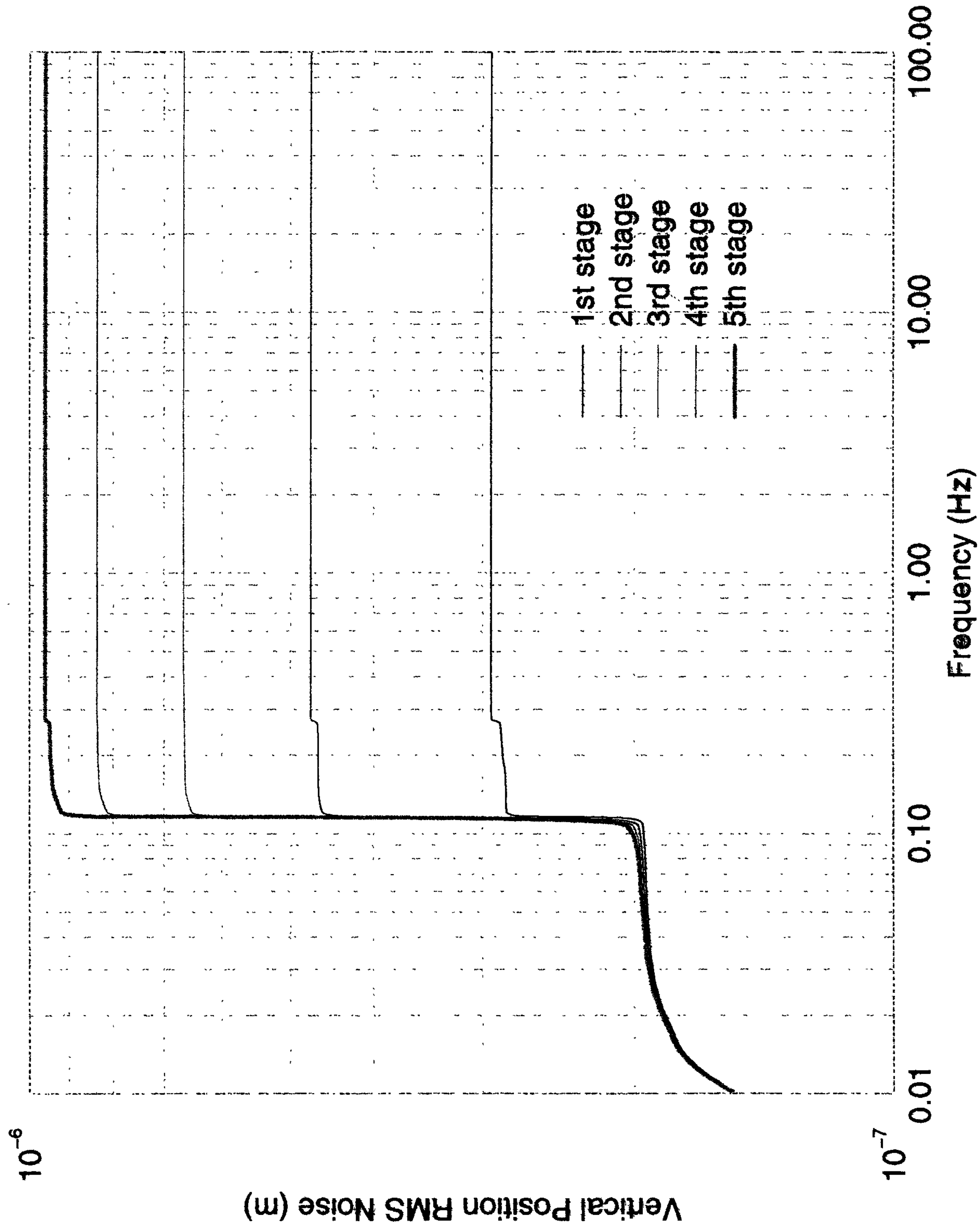
(Simplified model)



RMS Seismic/Band LHO Site

Vertical Degree of Freedom

(Simplified model)



Seismic Noise Reduction Estimation LHO Site

- Inertial damping of the peaks of the chain.
- Blades Internal modes not considered.
- No crosstalk considered.
- No wires resonances considered.
- No safety margin.

Degree Of Freedom	RMS Position Noise Free Chain (μm_{RMS})	RMS Position Noise Damped Chain (μm_{RMS})
Horizontal	$\sim 2 \cdot 10^{-6}$	$\sim \mathbf{4 \cdot 10^{-7}}$
Vertical	$\sim 1 \cdot 10^{-6}$	$\sim \mathbf{2 \cdot 10^{-7}}$

External and internal contributions

Glasgow will contribute in
Know how and materials to the
triple pendulum mass suspension system

Pisa University contributing with
simulations, a grad student, a postdoc, instruments and prototypes to the
accelerometer IP/GAS filter development

Tokyo University contributing with
a grad student.

Open to other institutions/collaborators

Also internal collaborations from LSU, Stanford etc.

Example alternate design to GAS filters (LSU)

It was stressed that tight collaboration with **Virgo** is absolutely necessary to maintain 2 interferometers up at all times.

Cannot afford another SN1987a debacle.

Questions and worries

will sapphire live up to its expectations

otherwise YAG , GGG, etc.

Will there be excess noise in quartz under stress?

Are (polycrystalline) mirror coatings going to kill the expected higher quality factors of future masses?