Thermal noise reduction : impact on the infrastructure

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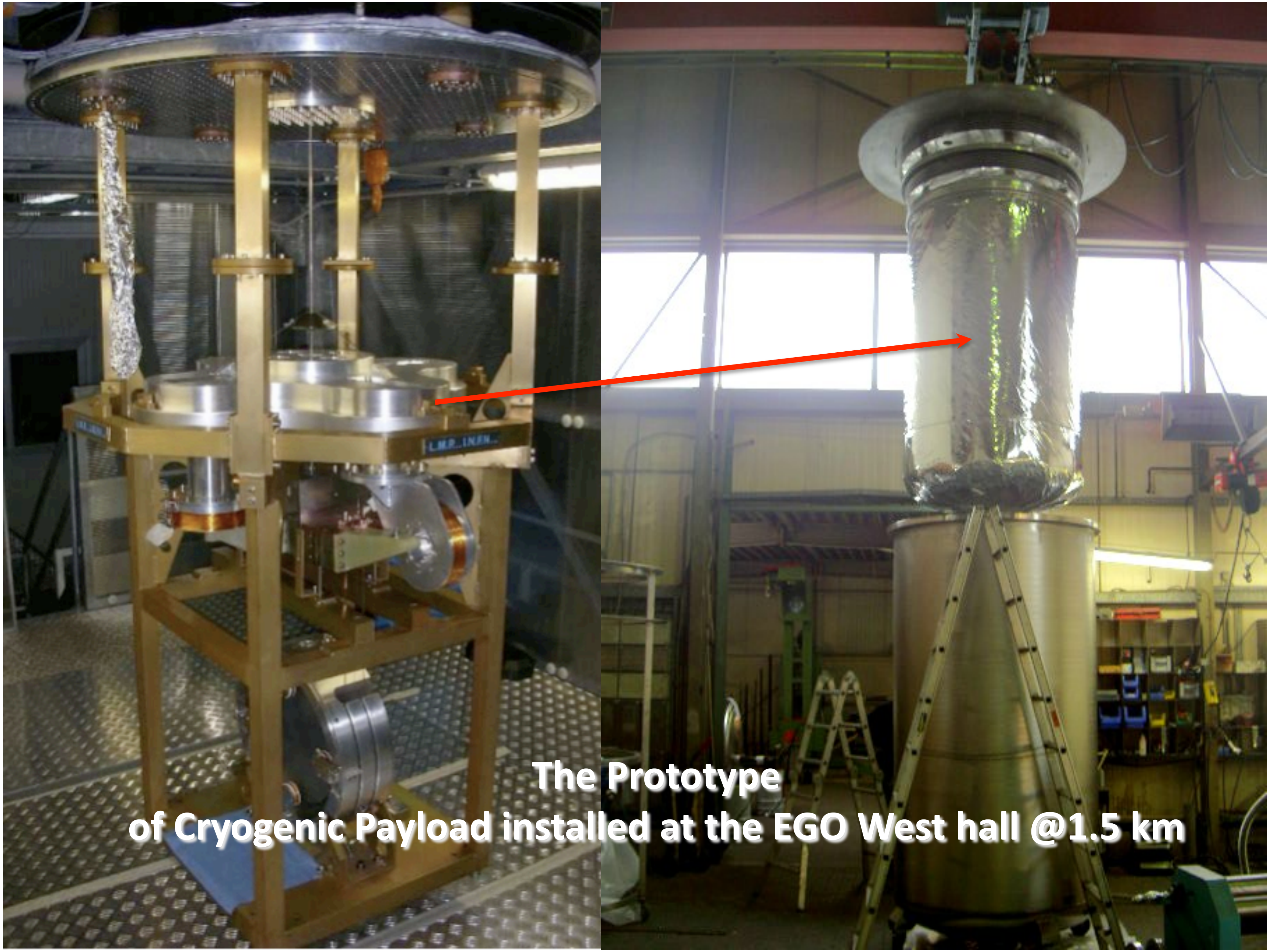
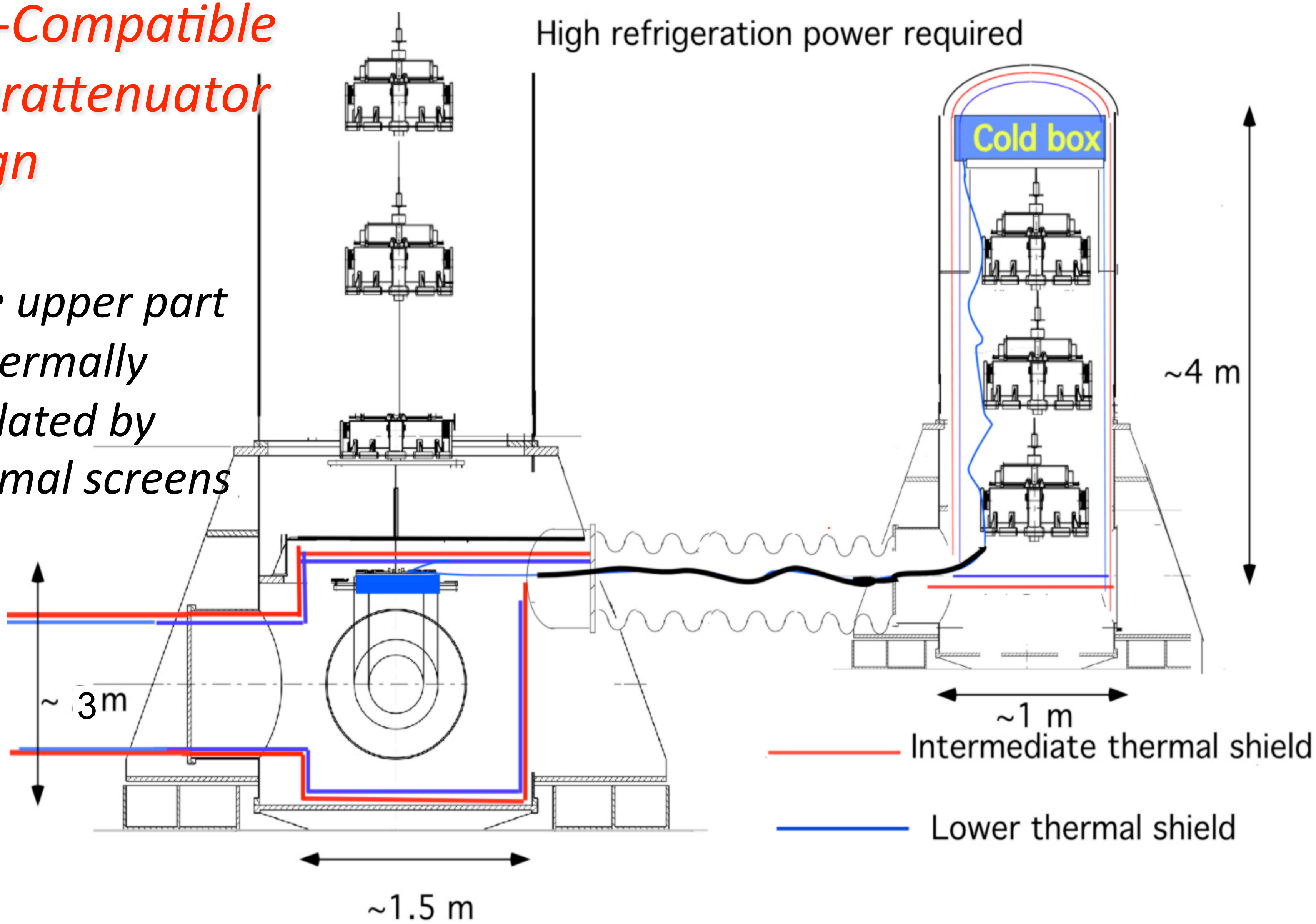


The Prototype
of Cryogenic Payload installed at the EGO West hall @1.5 km

Design of the cooling system

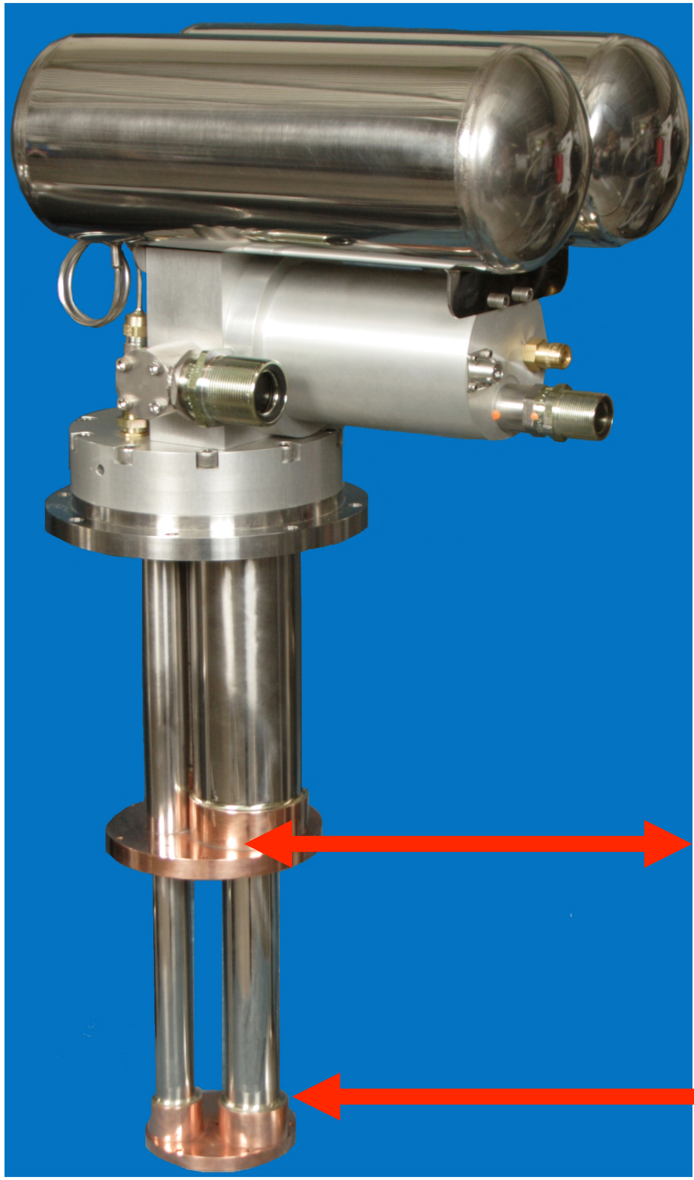
Cryo-Compatible Superattenuator design

- *The upper part is thermally insulated by thermal screens*

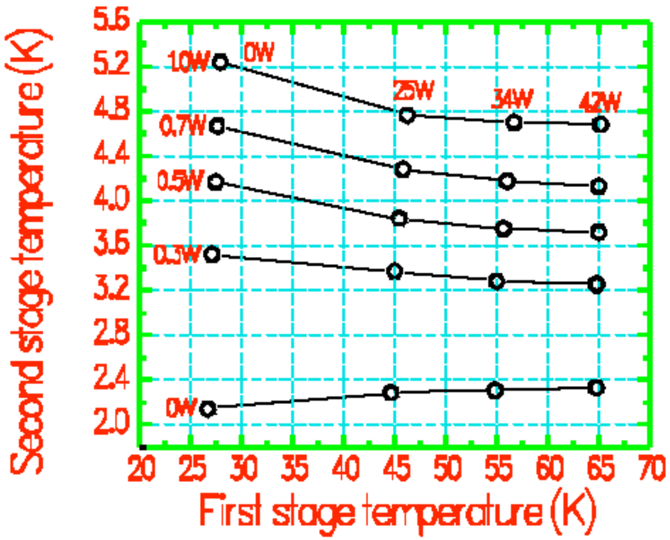


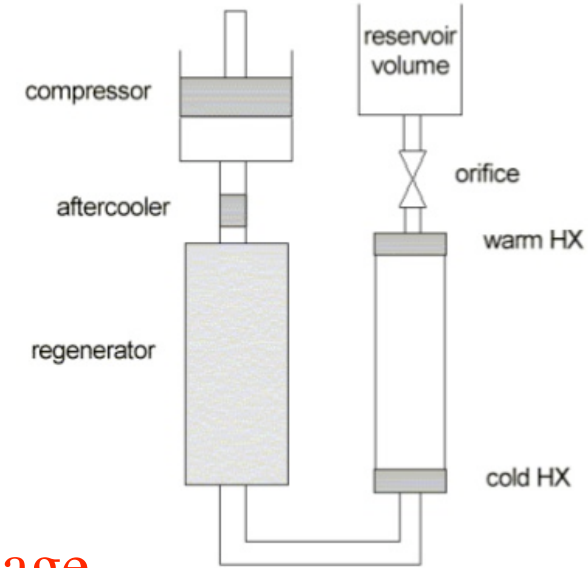
The Pulse Tube Cryo generator

An example: CryoMec PT 410 ➔ 0.83W at 4 K and 38W at 45 K; absorption power 8kW



High pressure lines
Lenght up to 30 m





A typical helium compressor

Compressor unit, RW 6000-1 891 44
Operating pressure in the high-pressure circuit@50 Hz, 22±1 bar
Electrical power drawn at 50 Hz kW 6.1 – 6.9
Coolant consumption at 25°C inlet temperature 5 l/min
Max. coolant flow rate 10 l/min

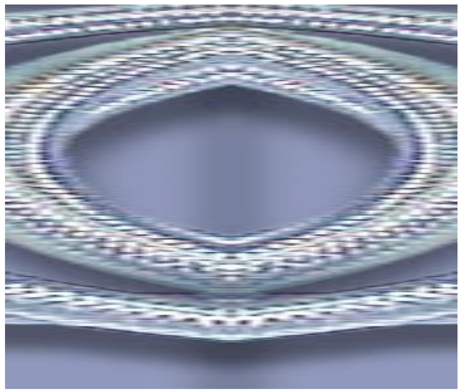
Dimensions 450x445x445 mm
Weight kg 105

Noise level @1 m dB(A) 78 - 80

For a silent model as **COOLPAK 6000/6200 MD** (less powerful)
Noise level @1 m distance 53 dB(A)

High pressure helium flexible lines: maximum length provided 30 m

Pump frequency 1 Hz - Vibration transmitted along the tube
Active cancellation is needed



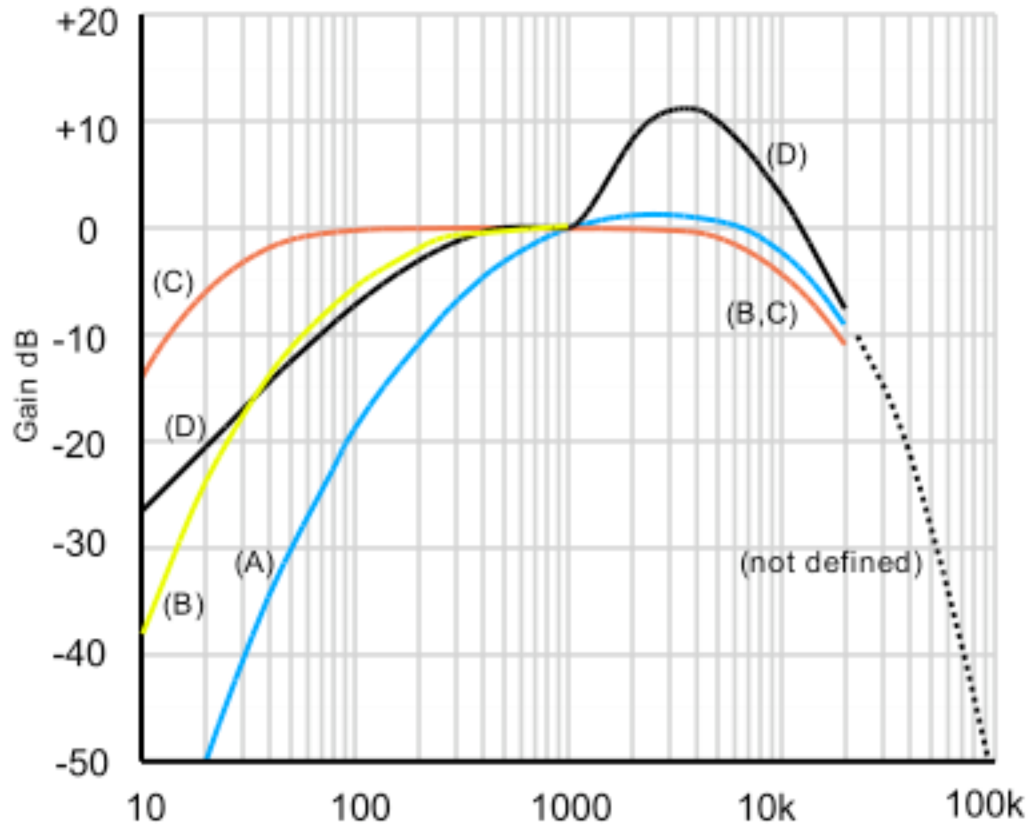
Standard scale for the Sound Noise

Source:
Handbook of Noise Measurement,
General Radio Company

dBA	*Source*
140	*Engine exhaust – no muffler @ 1 m*
130	*50 HPSiren @ 30 m.*
120	*Jet takeoff @ 60 m*
110	*Riveting machine*
100	*Large Diesel Engine @ 3 m*
90	*Train @ 6 m*
80	*Inside a sports car @ 100 km/h*
70	*Inside a luxury car @ 100 km/h*

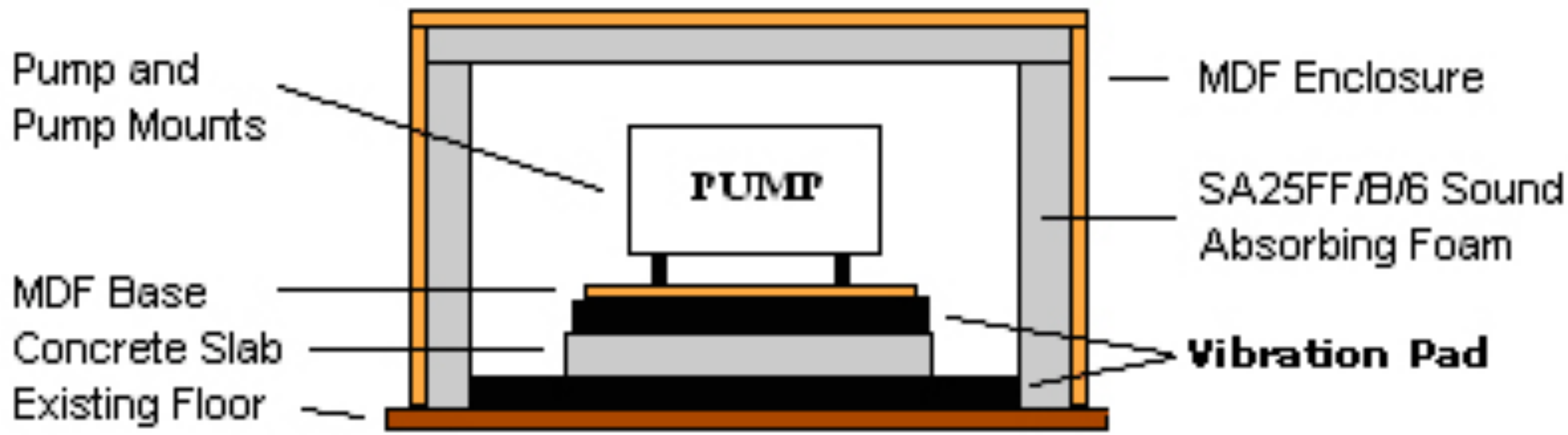
dBA	*Source*
60	*Large store or office*
50	*Average residence*
40	*Soft whisper*
30	*Quiet office on Saturday*
20	*Mouse walking across a wood floor*
0	*Threshold of hearing for a young person* (2×10^{-5} Pa) *or a mosquito flying @ 3 m*

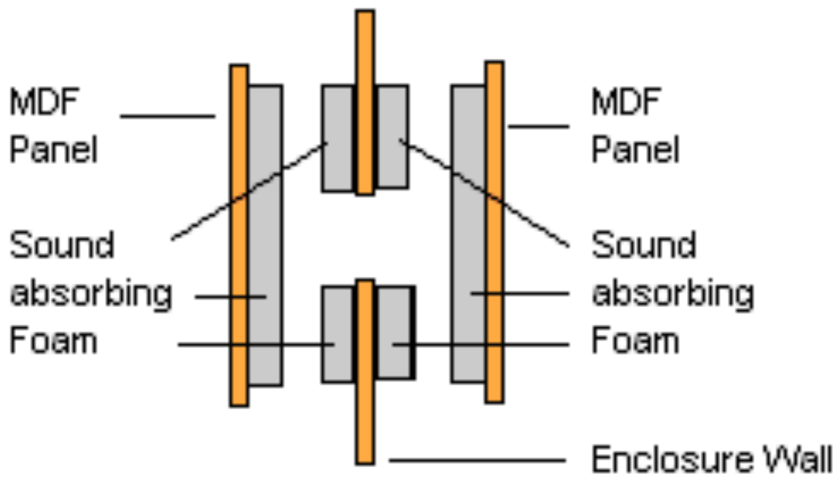
Filter applied to get dBA



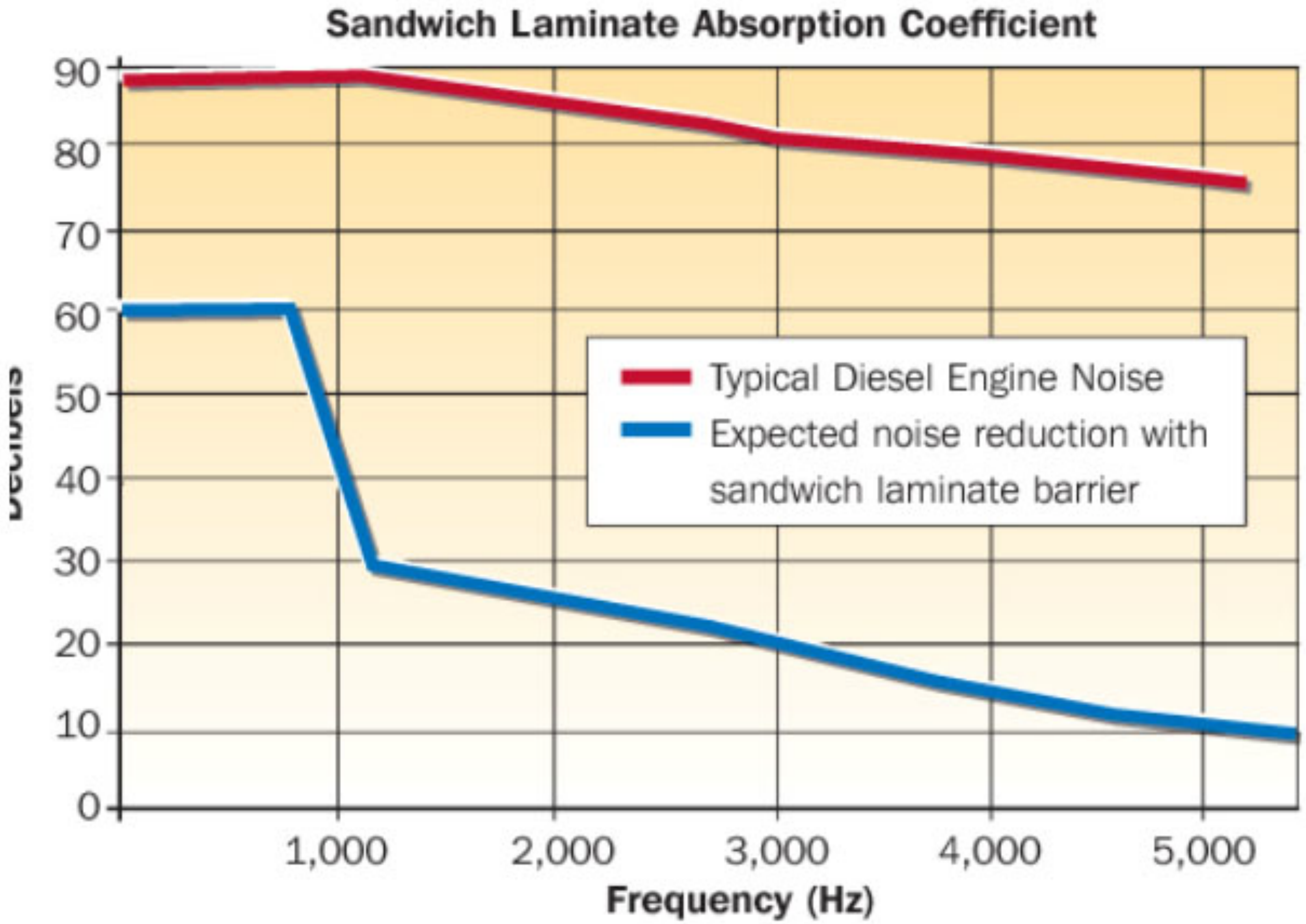
A-weighting (blue), B (yellow), C (red), and D-weighting (blk)

The standard mounting





Insulation material : Foam Laminate (SA25FF/B/6)



Nominal Thickness:
32mm

Foam Density:
27-30 kg/m^3

Effective airborne absorption for small cavities and enclosures.

Toward a reference solution?

- Mirror material: silicon
- Mirror dimensions:
  - 45 – 50 cm diameter
  - 30 cm thickness
  - 110 -120 kg mass

- Payload total mass ~ 3 - 4 x mirror mass

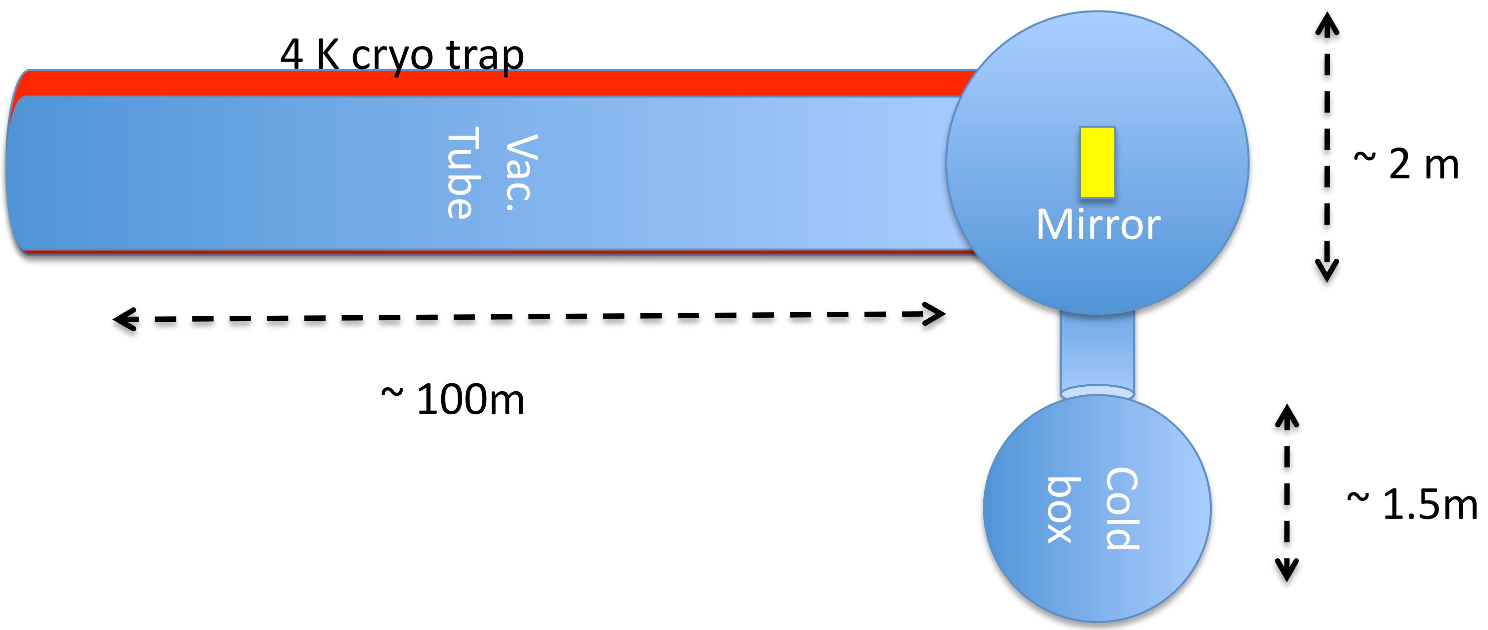
A guess about the surface needed for hosting a test mass

For each test mass we need 2 towers and 2 cryostats :

Assuming a mirror of t~300 mm ϕ~ 450 mm (400 is available already but soon we can hope in silicon slabs of 450 mm in diameter)
m~ 110kg

The test mass is hosted in an inner cylindrical vacuum chamber
ϕ~ 1.5 m   h ~ 4 m ➔ external crystat ϕ~ 2 m   h ~ 4.5 m

Cold element tower which includes filters   ϕ~ 1.5 m   h ~ 4.5 m



How many compressors for each tower ?

- Vacuum tube: 4 K thermal shield (ϕ ~1.2 m , L_{N2}~ 100 m*, but we need also a second shorter shield at 4 K*)

using 75 layers of super insulation (s.u.)

Heat load @77K ~ 600 W ➔ 10 compressors
(including redundancy)

- Lower section of the Tower: 4 K thermal shield (ϕ ~2 m , L~ 4 m + 25 layers s.u.) + 77 K thermal shield (ϕ ~2.05 m , L~ 4.05 m + 75 lay s.u.)

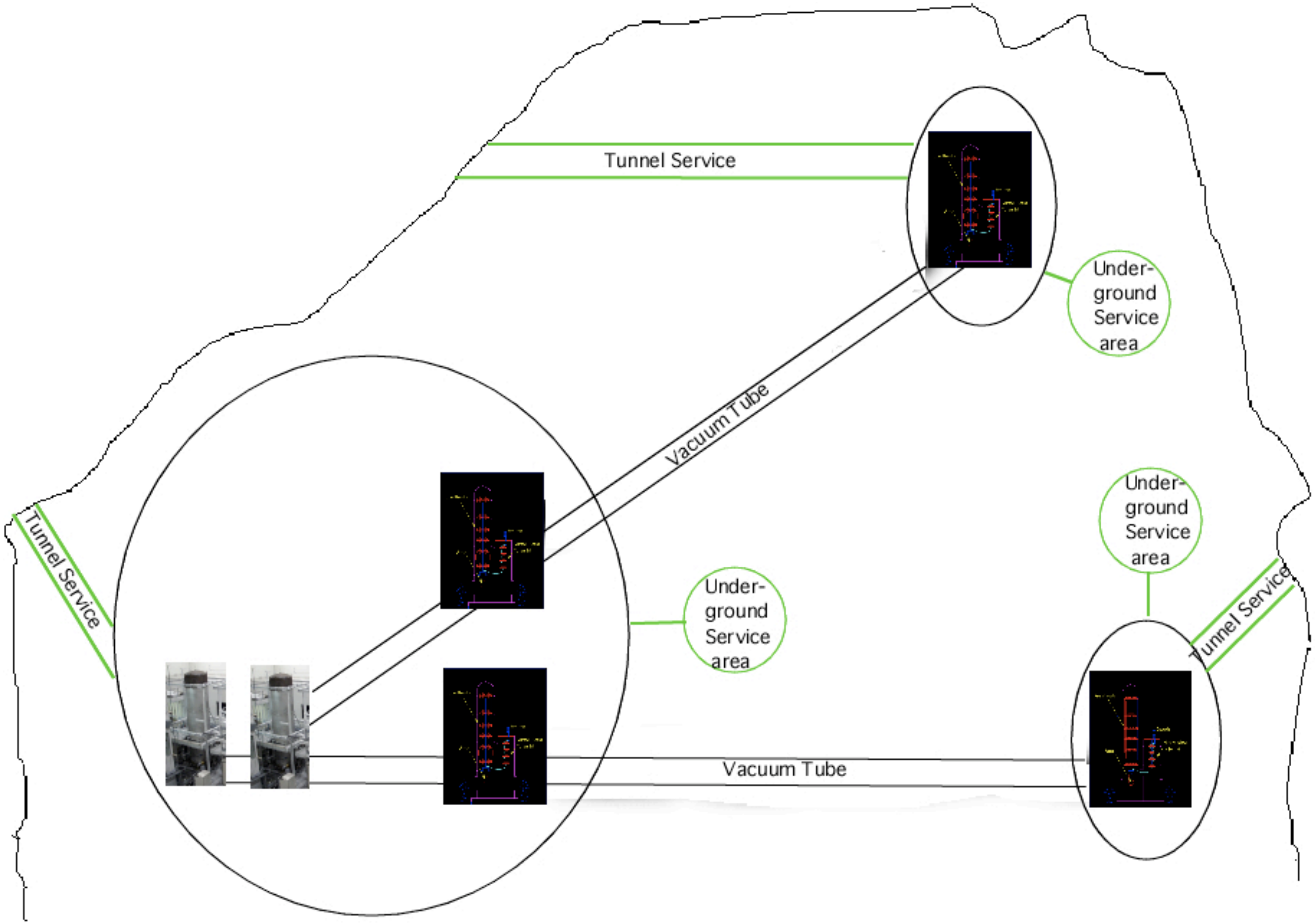
Heat load @77K ~ 60 W ➔

Heat load @ 4K ~ 2 W ➔ } 2 compressors

(including redundancy)

- For the auxiliary tower we have to add 2 more compressors

Cryogenic infrastructure requirement: auxiliary caverns for a full PT solution



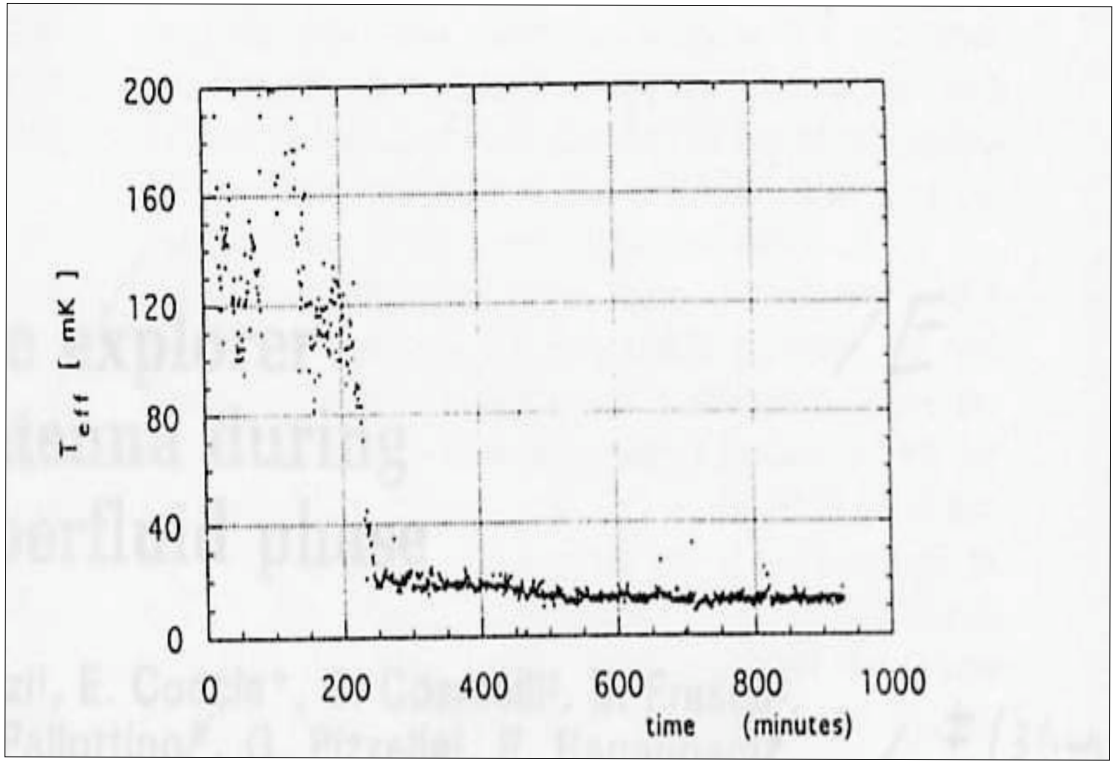
About cryo strategy

- Larger mirror ➔ larger vacuum tube ➔ longer cryo traps for reducing the radiation input
- 4 K Cryo traps are needed
- Cryo traps 50 /100 m long ➔ large total thermal input ➔ use of the cryofluids ?
- A hybrid solution should be studied also. The advantage is to have a system with a null evaporation rate.

The Helium II approach

- ➢Very high thermal conductivity
- ➢Very high specific heat
- ➢ Extremely low viscosity (Andronikashvili's effect)
- ➢Evaporation without bubbles

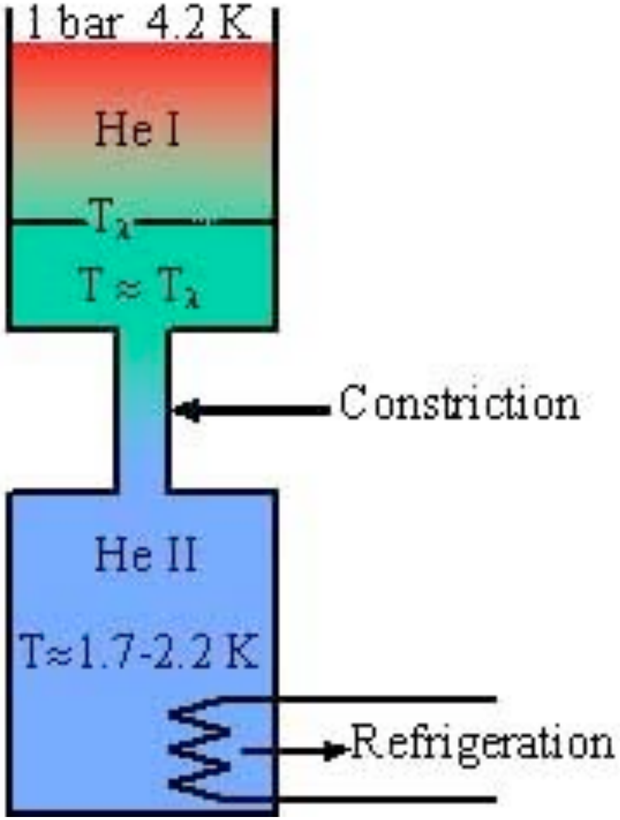
- ➢The most quiet and reliable approach for producing He II at atmospheric pressure
- ➢Massive use of the technique @ LHC

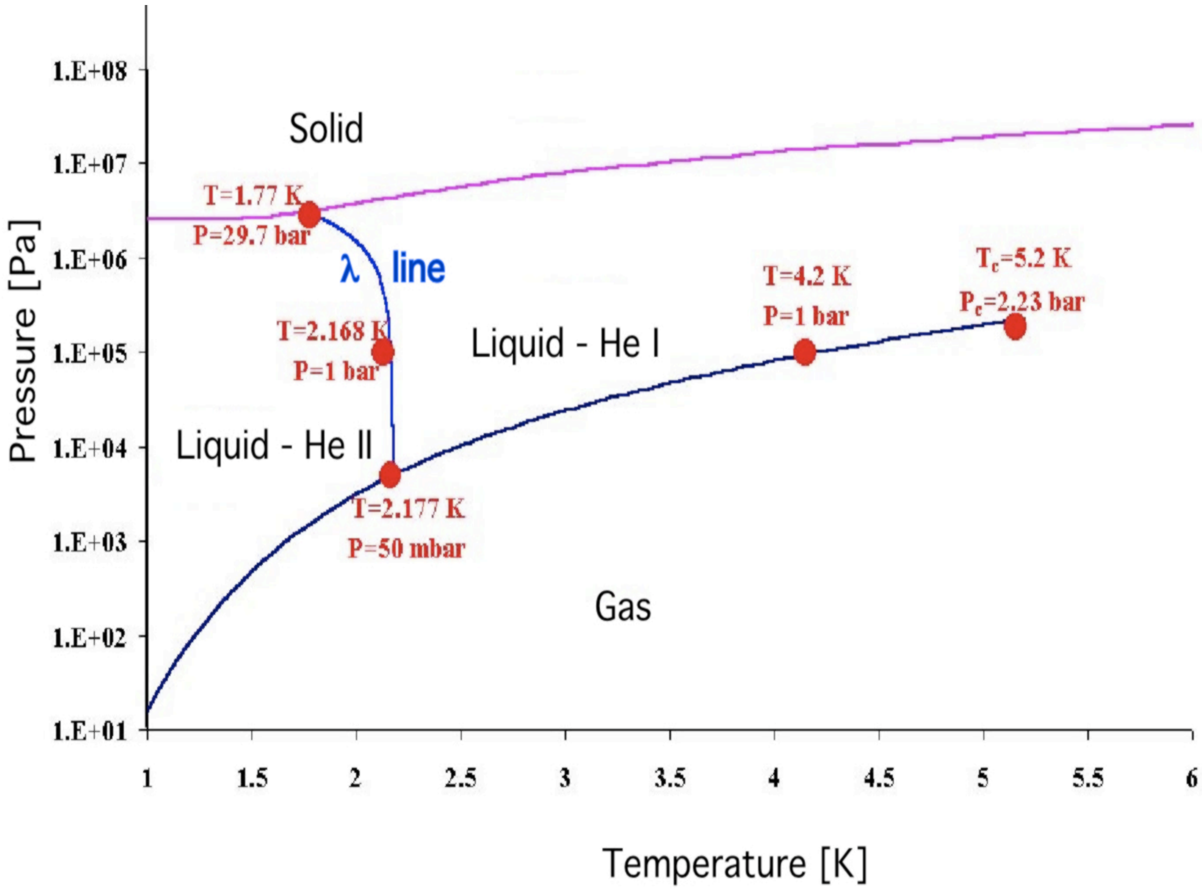


Output of GW antenna EXPLORER during the λ transition

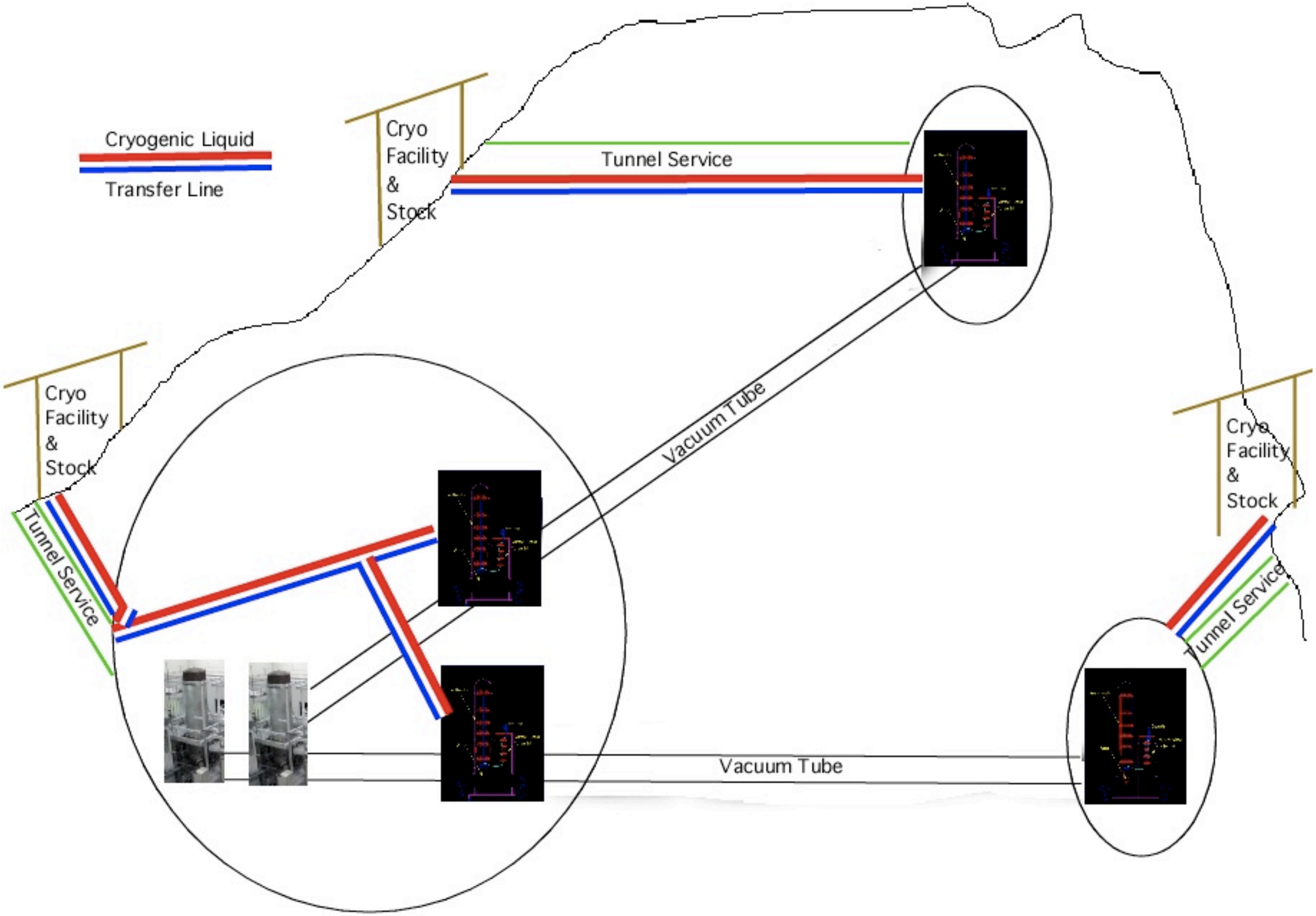
The He II approach:

the Claudet bath principle





Cryogenic Infracture Requirements
The superfluid Helium solution



Upper part suspension

- …..see the slides of Stefano Braccini and Franco Frasconi presented during the WG2 session

- If the low frequency cut-off of ET is 4 Hz the present VIRGO SA is already compliant with the ET specifications for the seismic noise attenuation

- In the case we assume a low frequency cut-off of ET is 1 Hz…………….

1) Inverted Pend. 40 mHz
2) 50 m tall mechanical filter chain

Courtesy of A. Giazotto

Assuming a

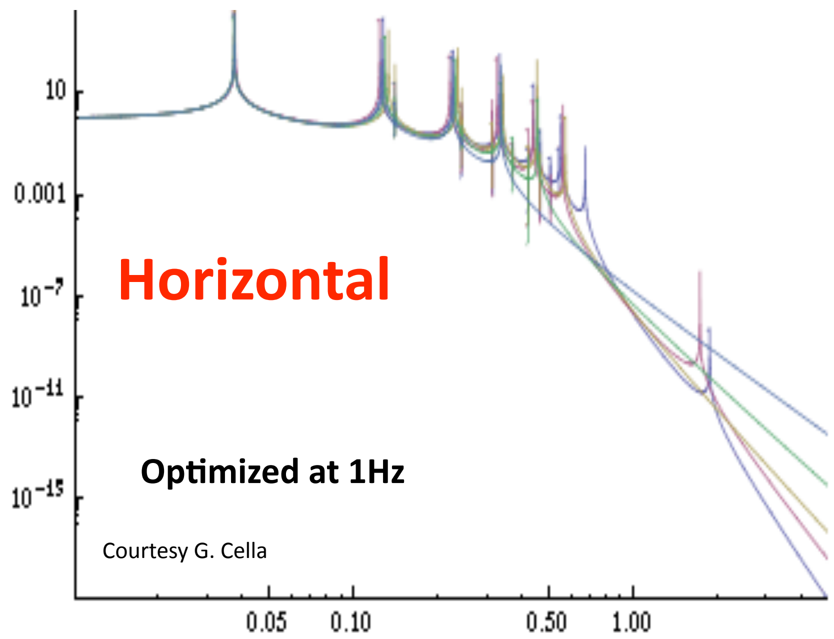
-seis. noise under. @1Hz 10^{-9} m $(Hz)^{-1/2}$,

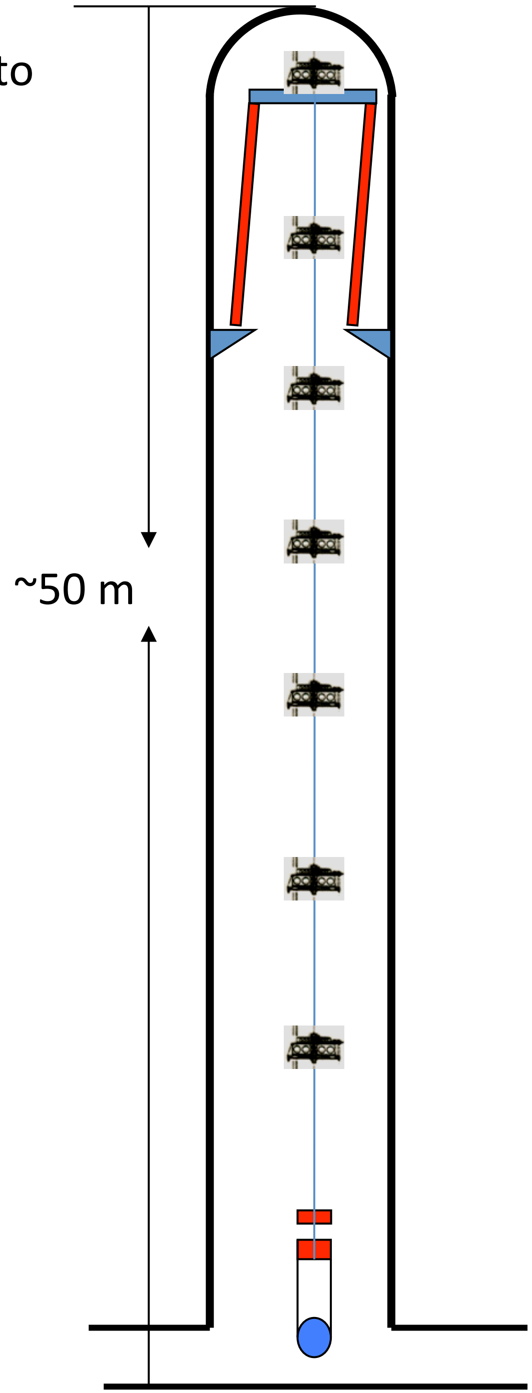
- TF opt. @1Hz

↓

h(1Hz) ~ 2.6 10^{-22} $(Hz)^{-1/2}$

N	1 Hz	2 Hz
{3,	1.6*10-7,	5.4*10-10}
{4,	4.8*10-8,	3.3*10-11}
{5,	2.6*10-8,	3.4*10-12}
{6,	2.3*10-8,	6.7*10-12}
{7,	2.1*10-8,	2.6*10-12}





No conclusion at present ! Further studies are needed

- PT solution
  - Increase the active damping efficiency
  - Increase the length of the high pressure lines
  - Increase the refrigeration power
- Superfluid helium solution

  - evaluation of the noise impact of the cryogenic facility

  - thermo acoustic insulation of the long transfer lines
- Suspension
  - effort to reduce the length of the SA chain in the case of 1 Hz freq. cut off