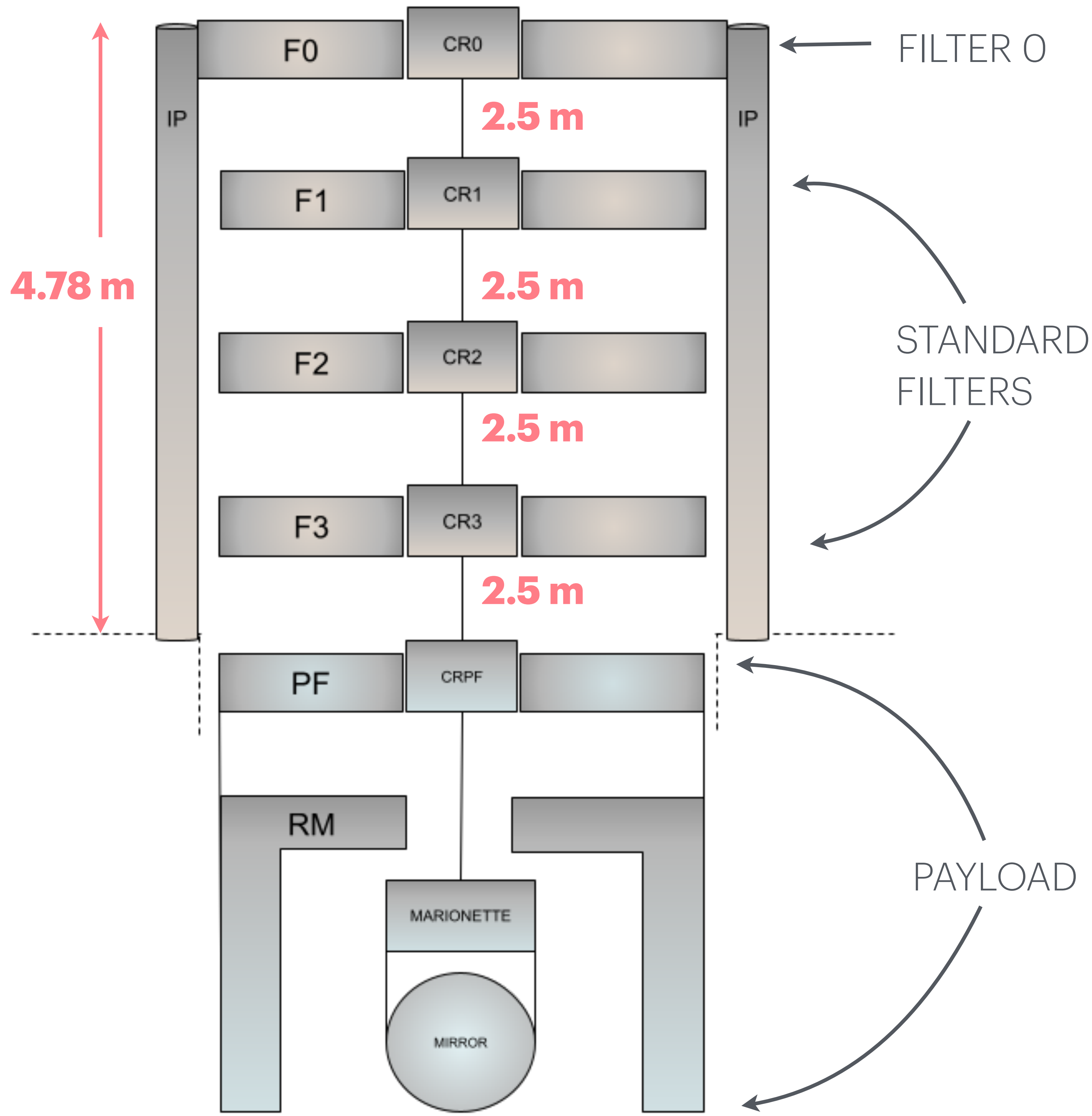
ET-LF Test Masses Superattenuator for the Double Cavern

Lucia T., Francesca S, Paolo R., Manuel P., Leonardo L., Giovanni L.

III Workshop on ET-LF TM Tower Integration
La Biodola 28/9-1/10/2025

Single-cavern Configuration



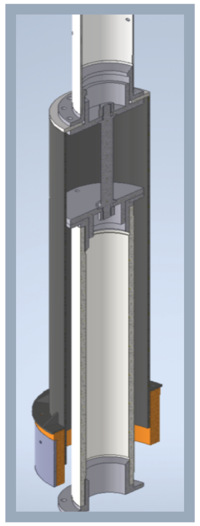
IP

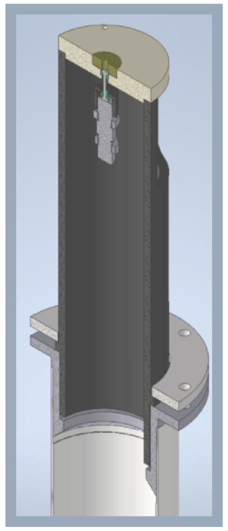
Rationale: keep the leg length and vary the free parameters (inner and outer pipe diameter)

- Preserve the AdV+ performance on:
  - Compression displacement due to the suspension load
  - Bending stiffness
  - Spurious (flexural) eigenfrequency of the pipe
  - Safety factor of the structure with respect to buckling
- Increase the IP radius to guarantee the same clearances between filters and IP legs

Radius (m)	Leg			Joint		
	Material	Diameter (mm)	Length (m)	Material	Thickness (mm)	Length (cm)
0.9	Al	170/180	4.78	Mar	35.7	23.6

Wire			Counterweight			
Material	Thickness (mm)	Length (cm)	Mass (kg)	I_x (kg·m^2)	I_y (kg·m^2)	I_z (kg·m^2)
Mar	3.	2.5	33.	3.7	0.7	3.7





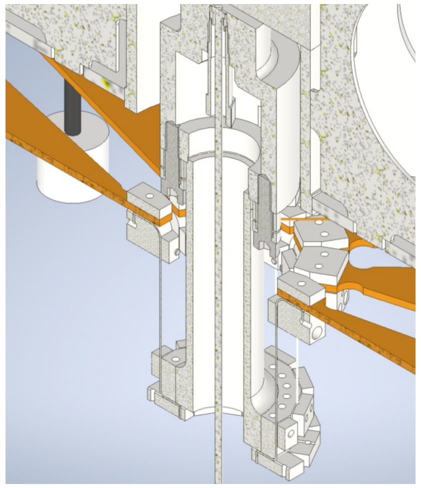
Filters

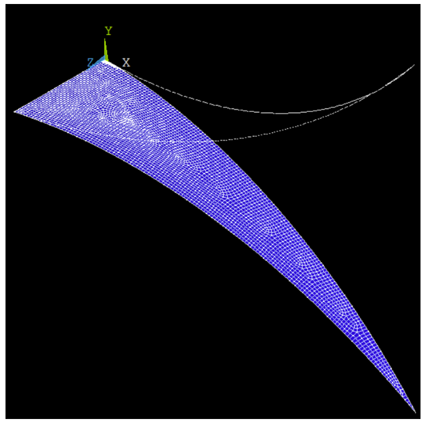
Rationale: maintain vertical tuning frequency

Blades

- Dimensions and clamping length must be increased
- FEM–based simulation
  - **total length 58 cm** (to be compared with 38 cm of AdV+)
  - including a **10 cm clamping length** at the body of the filter (to be compared with 3 cm in AdV+)
  - **23 cm blade base** (to be compared with 18 cm in AdV+) to keep same vertex angle
  - Thickness:

Filter 0	Filter 1	Filter 2	Filter 3
6.0 mm	5.0 mm	4.0 mm	3.5 mm



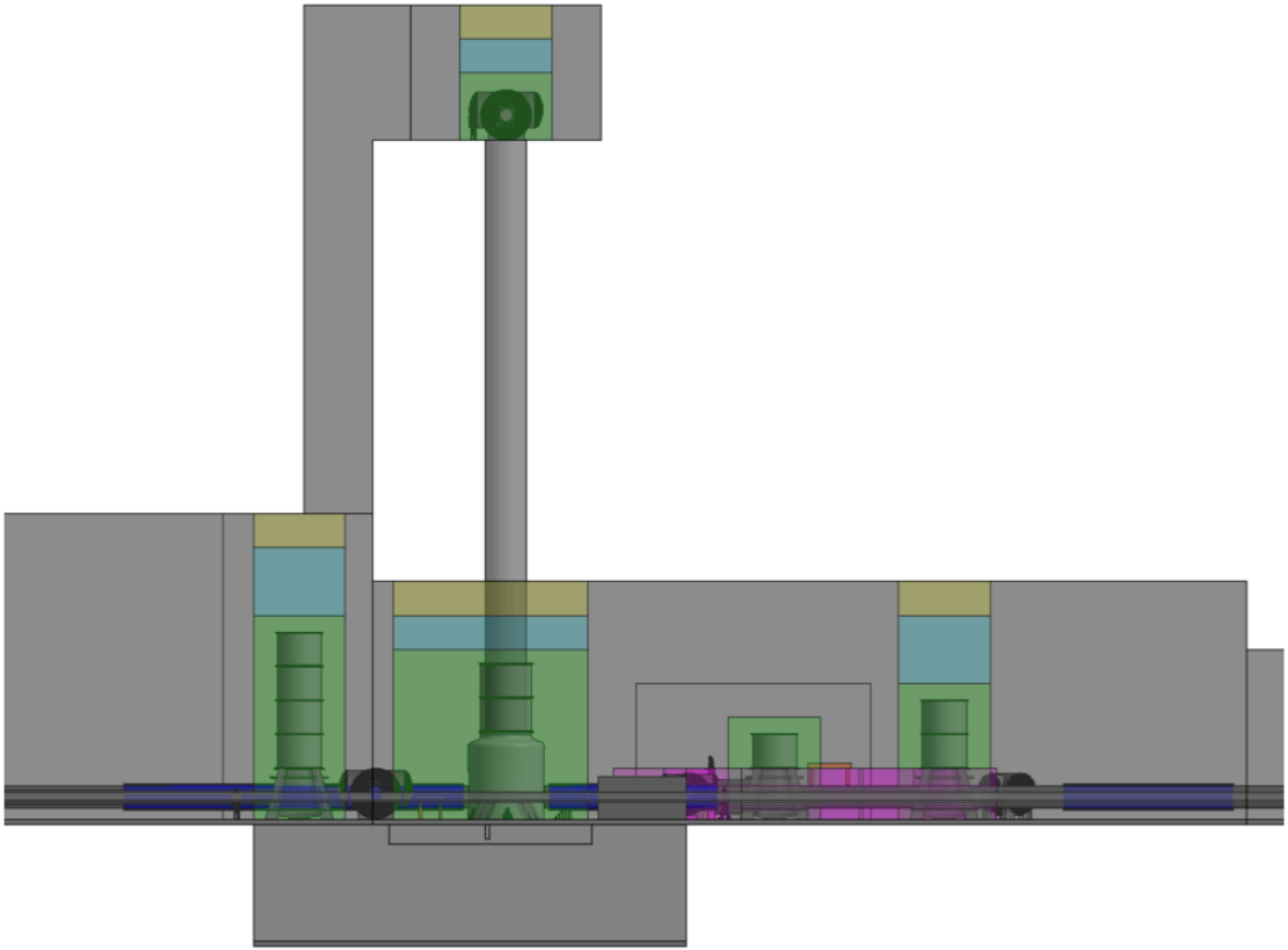


Filters

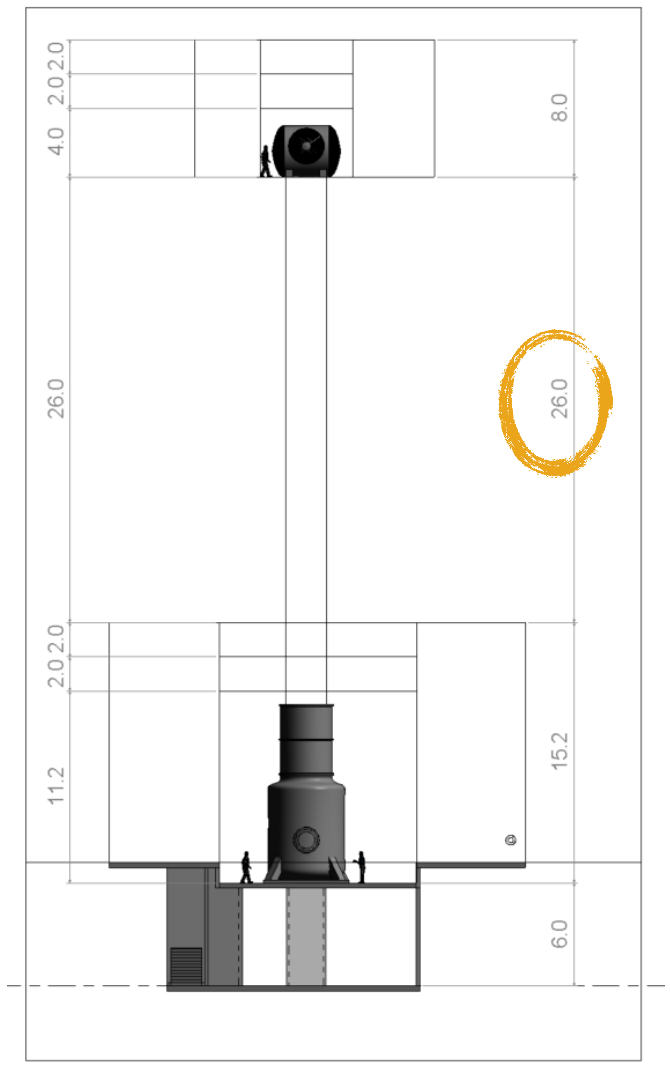
- Dimensions increase to allocate longer blades
  - **Filter Diameter 125 cm** (to be compared with 86 cm of AdV+)
- Masses:

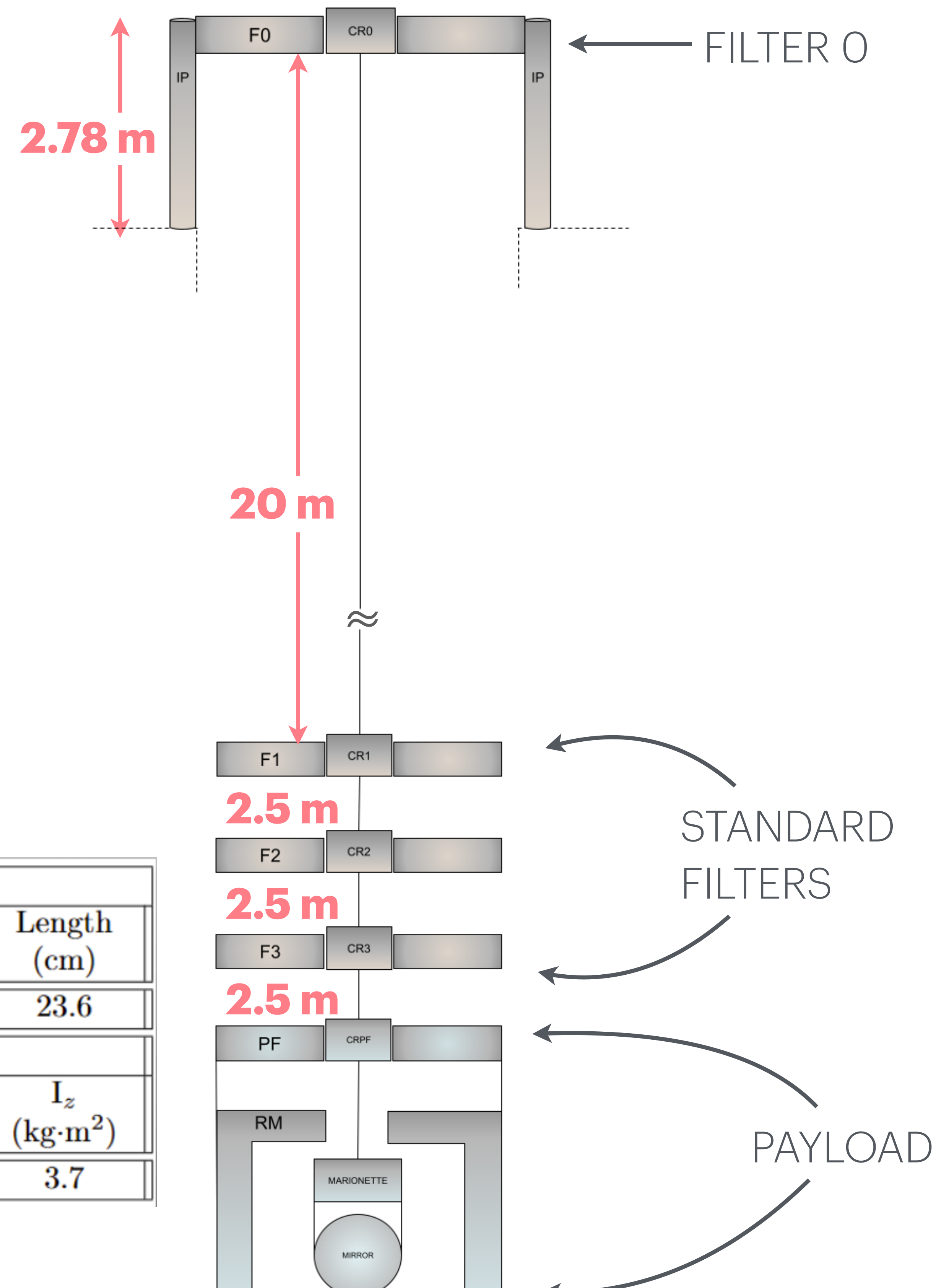
Body	Mass (kg)
Filter 3 (F3)	367.
Filter 2 (F2)	514.
Filter 1 (F1)	726.
Filter 0 (F0)	1013.

Double Cavern layout



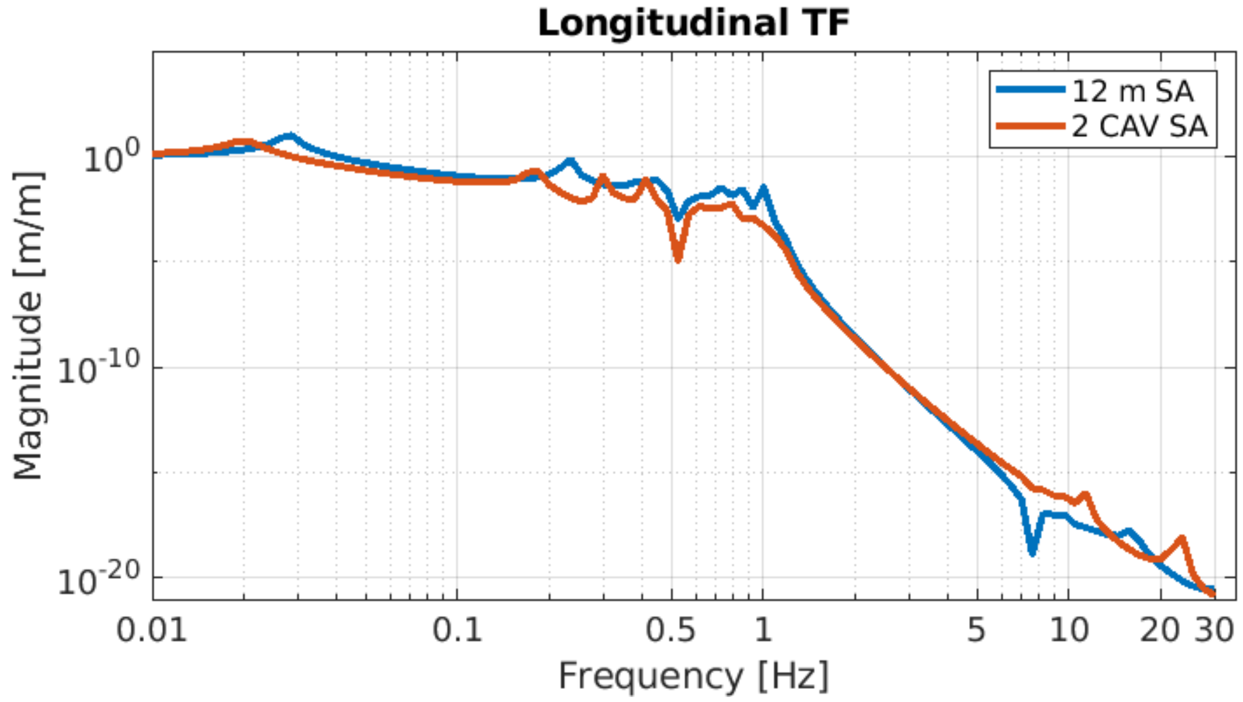
Configuration for a Double Cavern

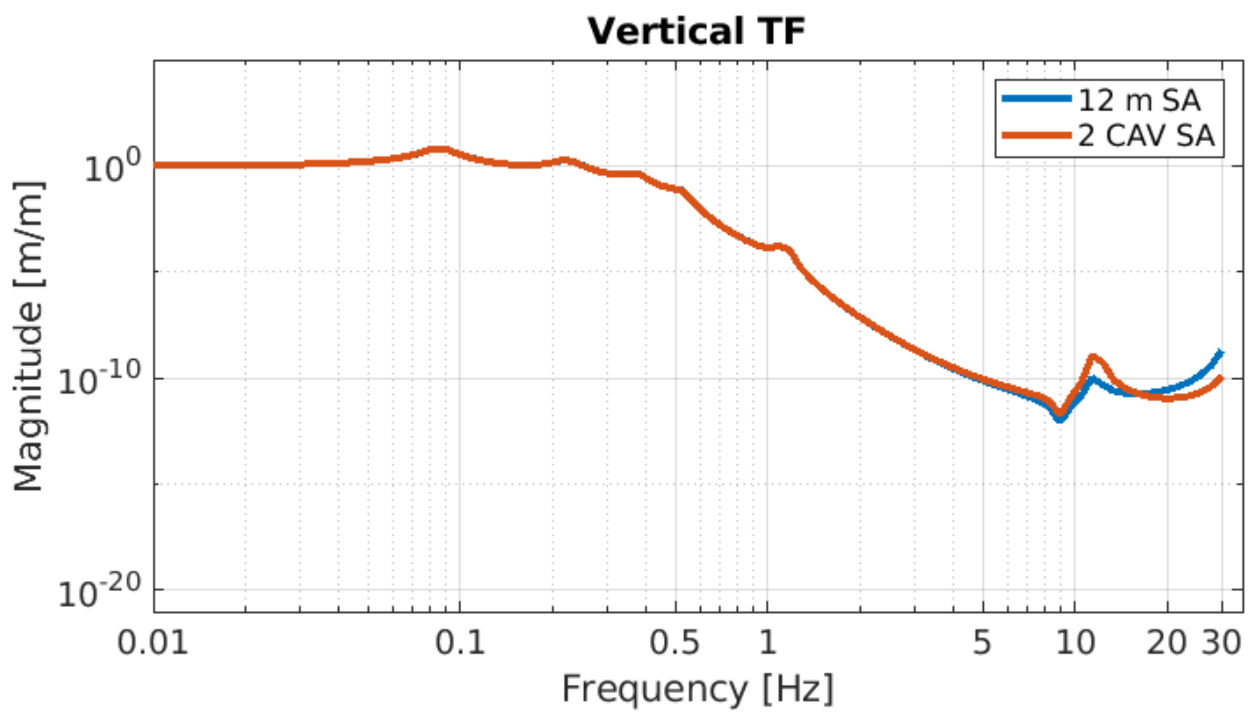


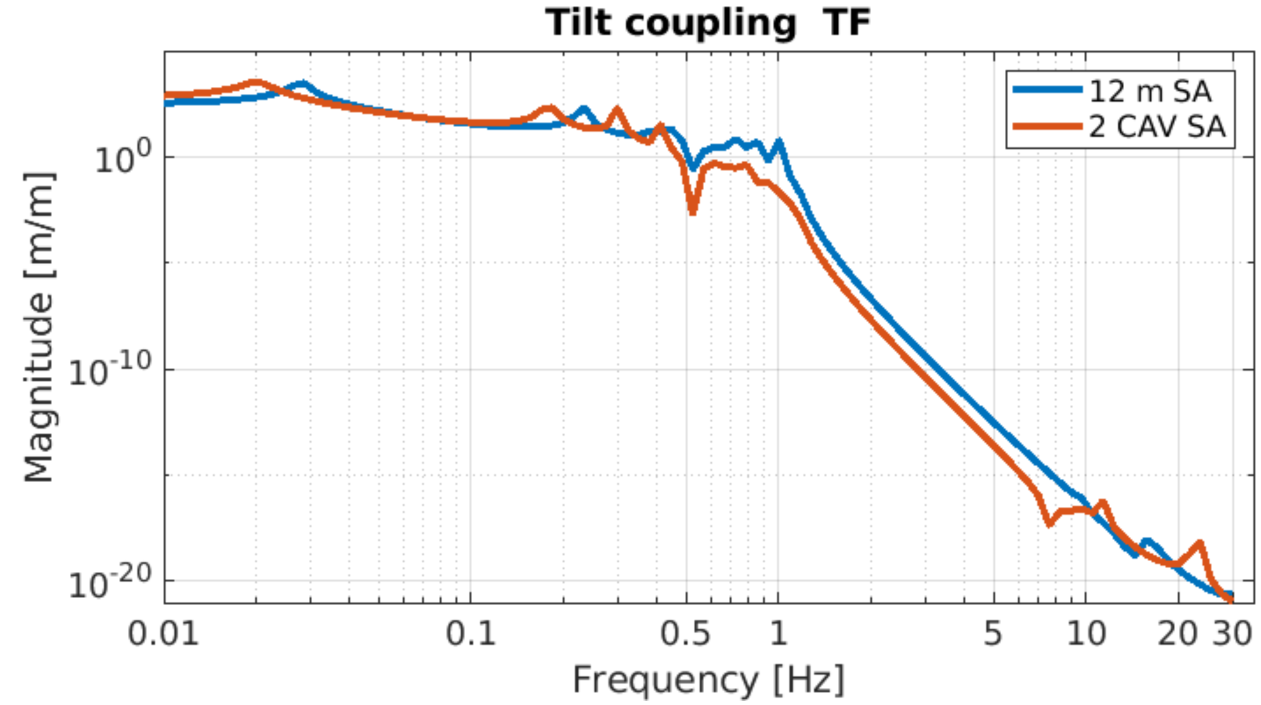


Radius (m)	Leg			Joint		
	Material	Diameter (mm)	Length (m)	Material	Thickness (mm)	Length (cm)
0.9	Al	170/180	2.78	Mar	30.5	23.6
Wire			Counterweight			
Material	Thickness (mm)	Length (cm)	Mass (kg)	I_x (kg·m^2)	I_y (kg·m^2)	I_z (kg·m^2)
Mar	3.	2.5	33.	3.7	0.7	3.7

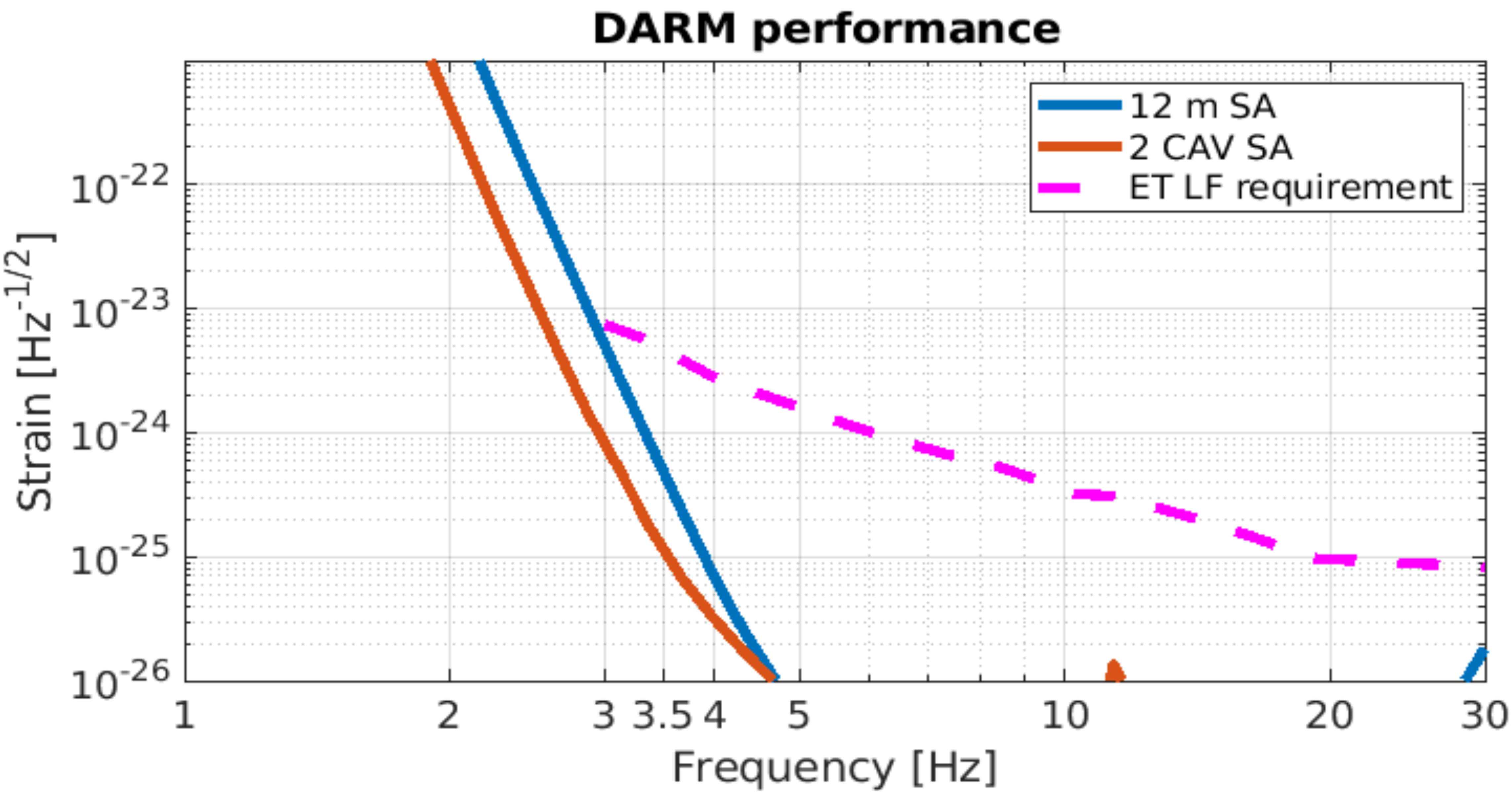
Transfer functions







DARM



DARM performance
12 m SA
2 CAV SA
ET LF requirement
Strain [Hz$^{-1/2}$]
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
1
2
3 3.5 4
5
10
20
30
Frequency [Hz]

Backup

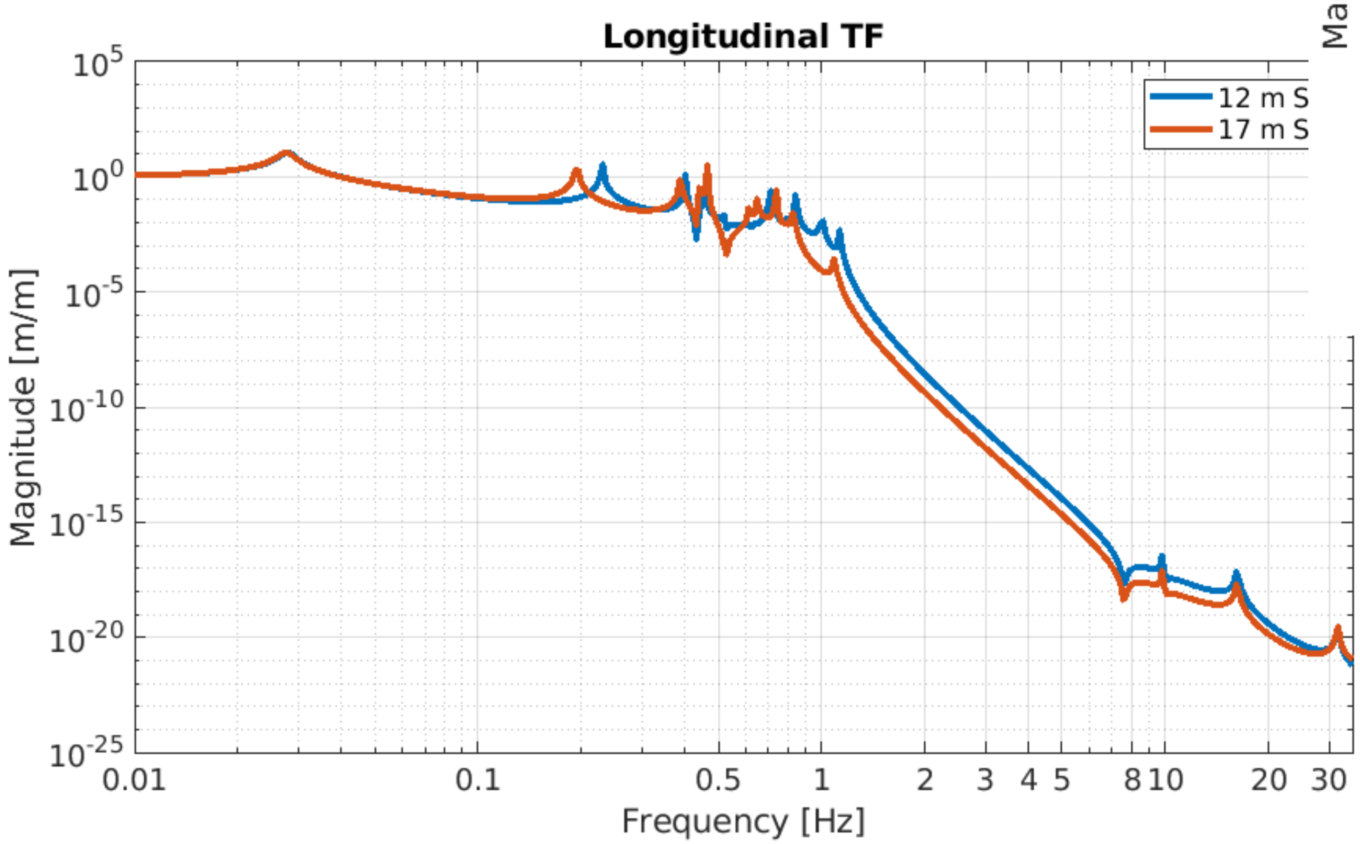
Superattenuator Basic Principles

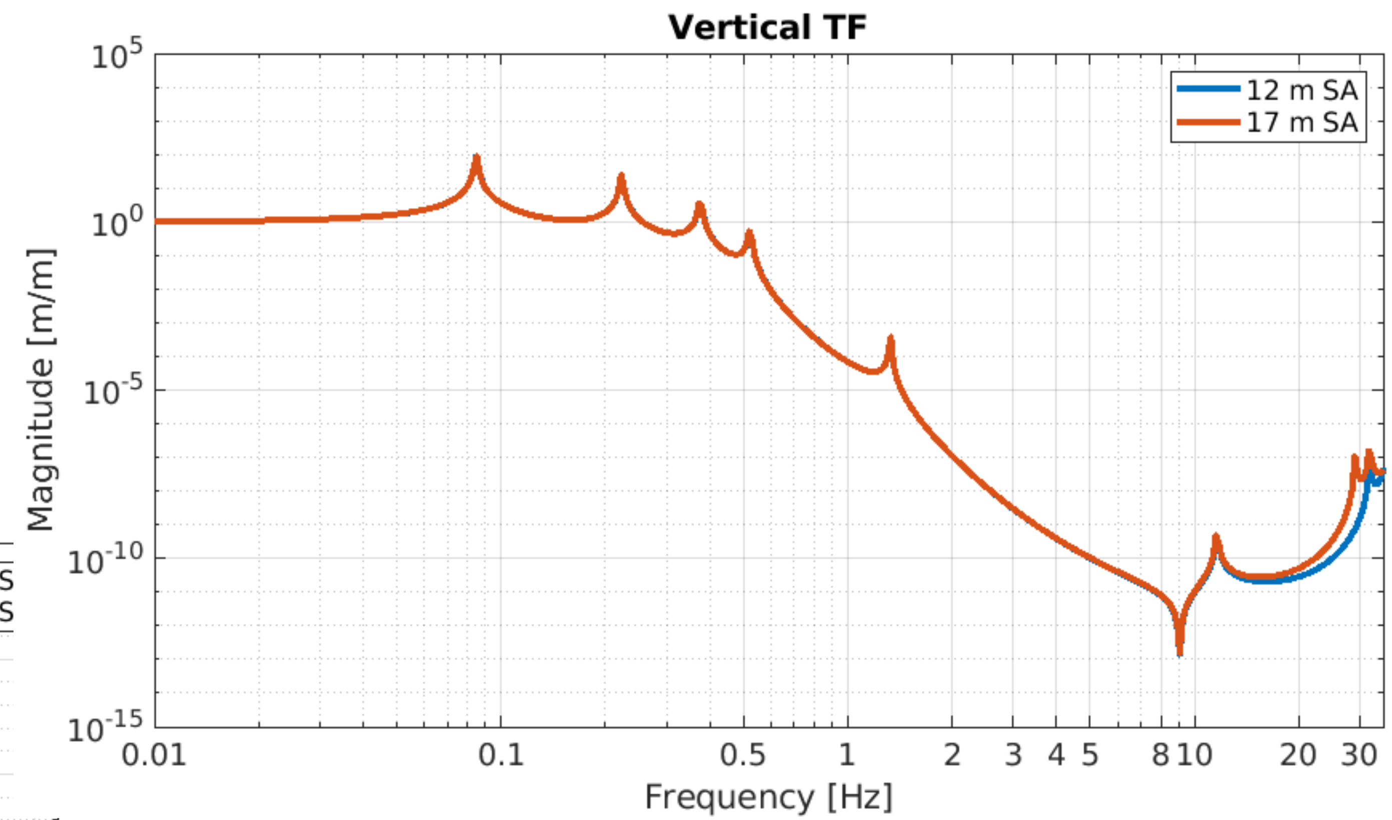
Combination of well-established principles to achieve high-performance attenuation

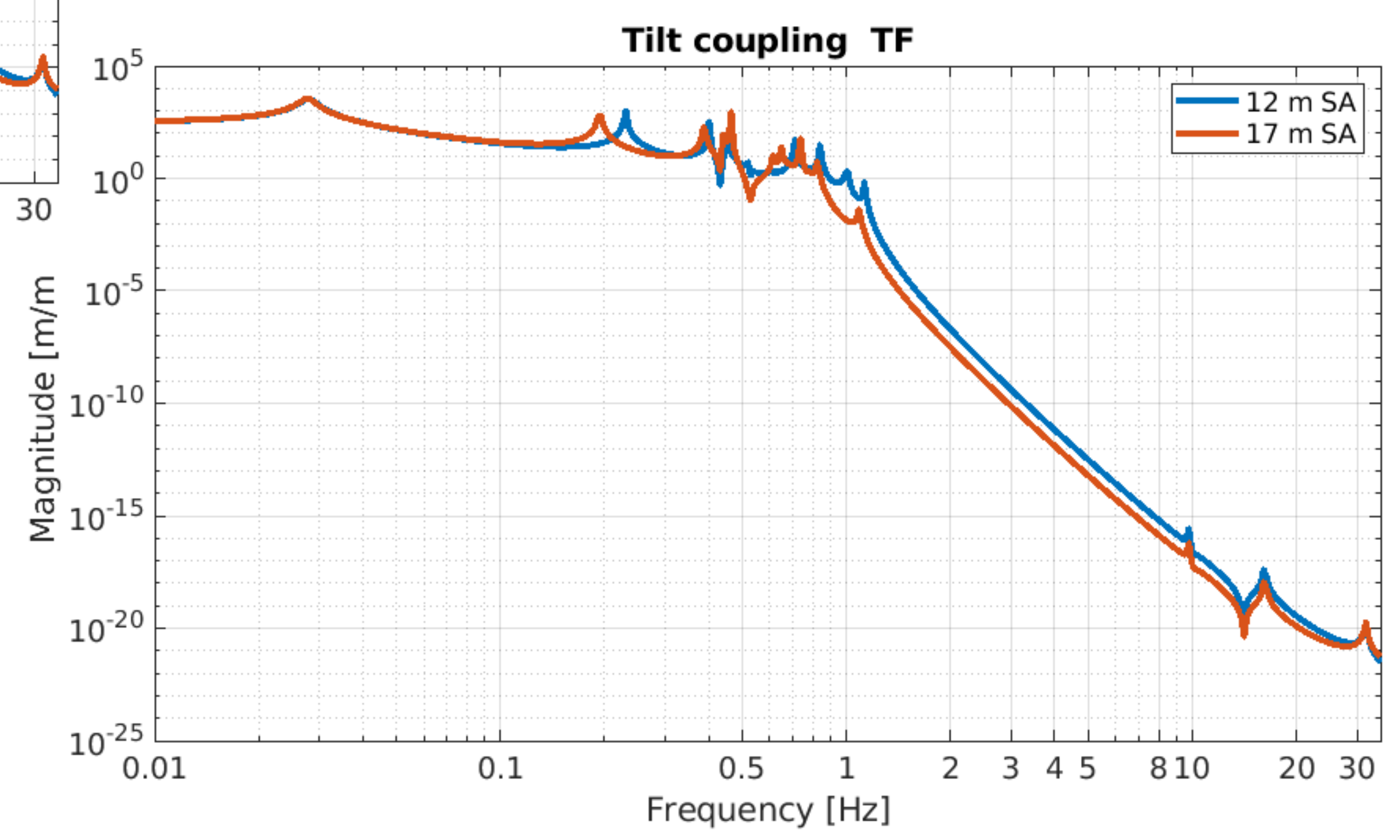
- Inverted Pendulum
  - a first isolation stage
  - effective support for **heavy loads**
  - precise positioning with **minimal control forces**
- Filters with cantilever blades
  - effective seismic attenuation in the vertical direction
  - small return torque to rotations around the horizontal axis -> **low tilt frequency**
- Magnetic Antisprings
  - reduce overall vertical stiffness -> confine vertical modes below highest frequency of hor
  - **vacuum compatibility**
  - **contactless** action on the filter

Transfer Functions

17 m vs. 12 m – Single Cavern

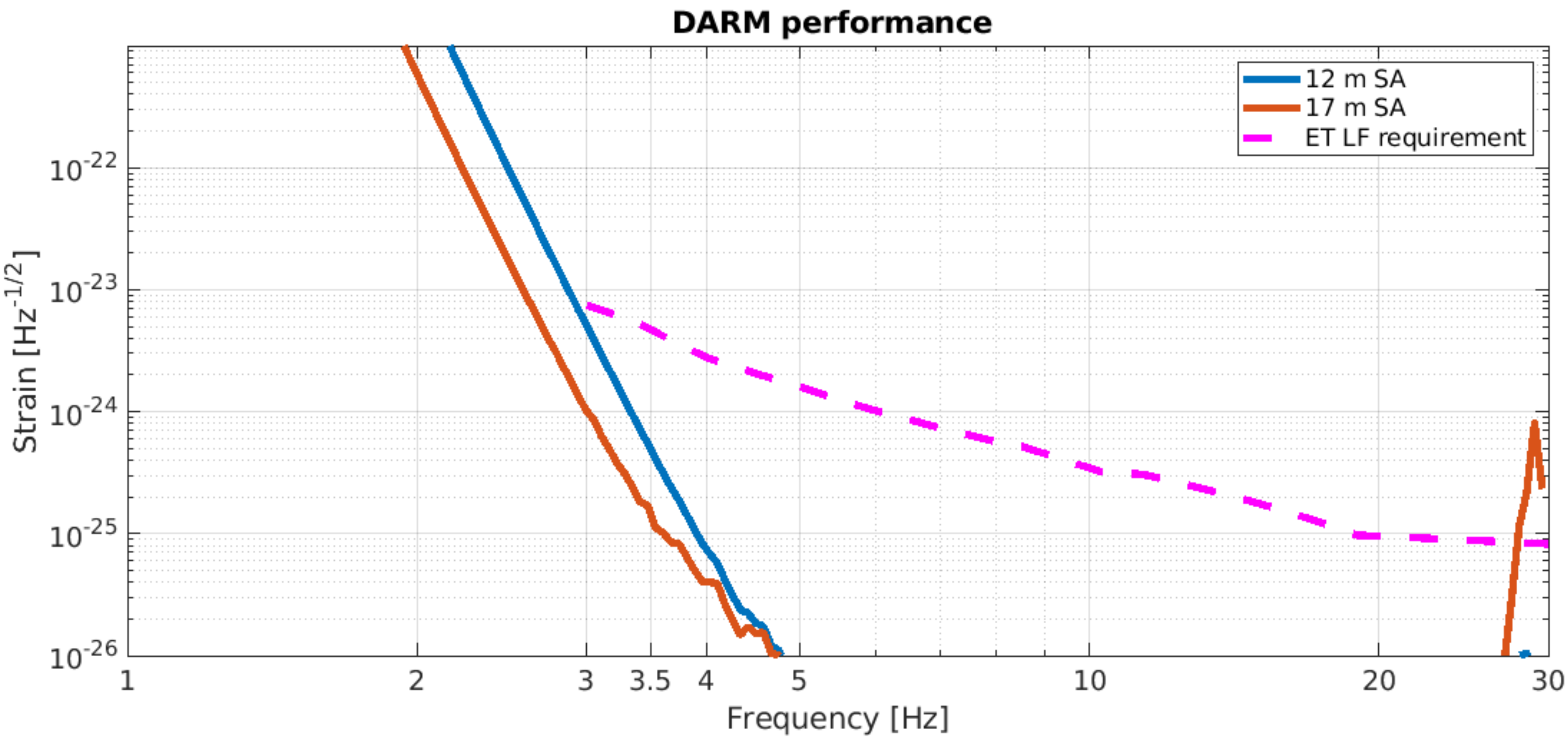






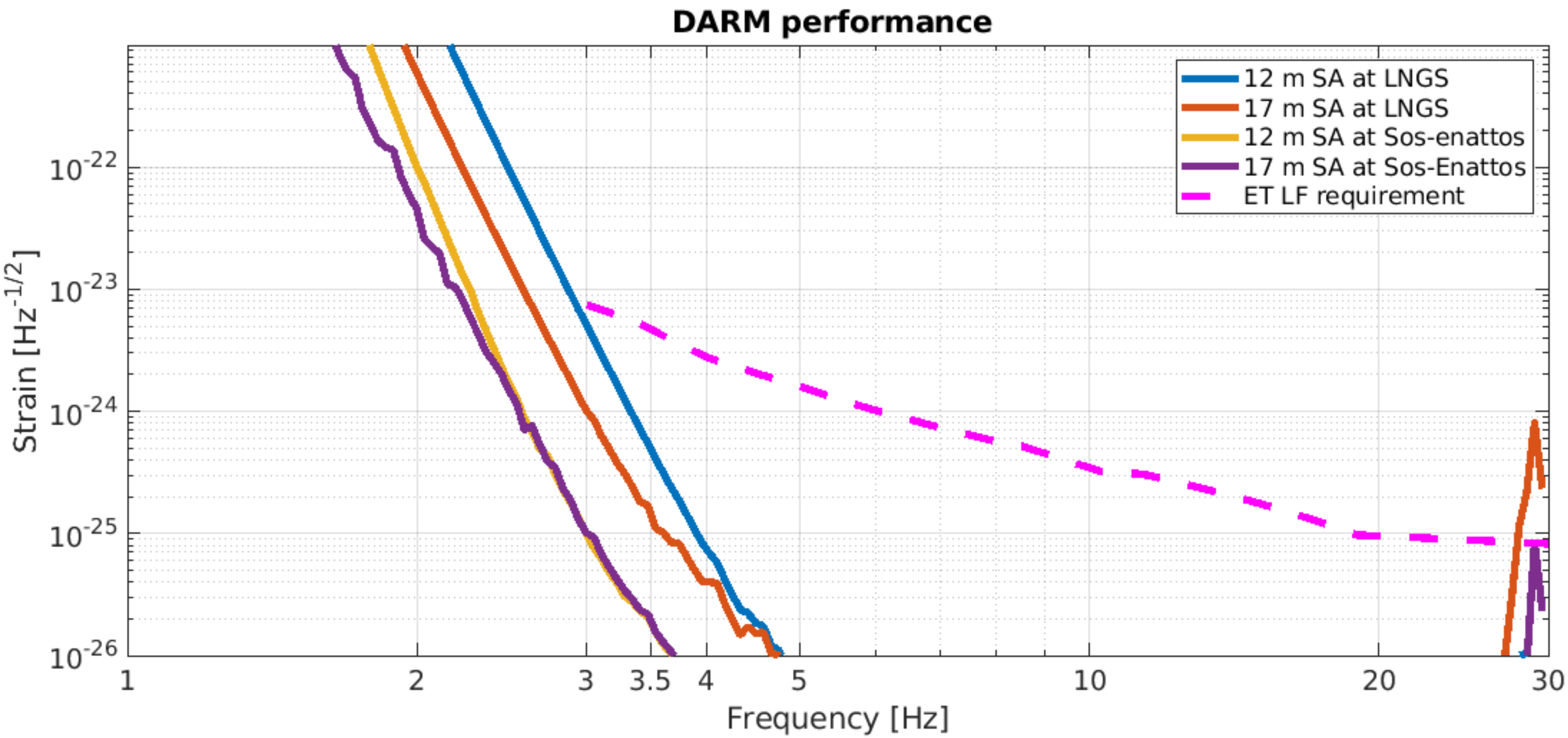
DARM

17 m vs. 12 m – Single Cavern - LNGS only

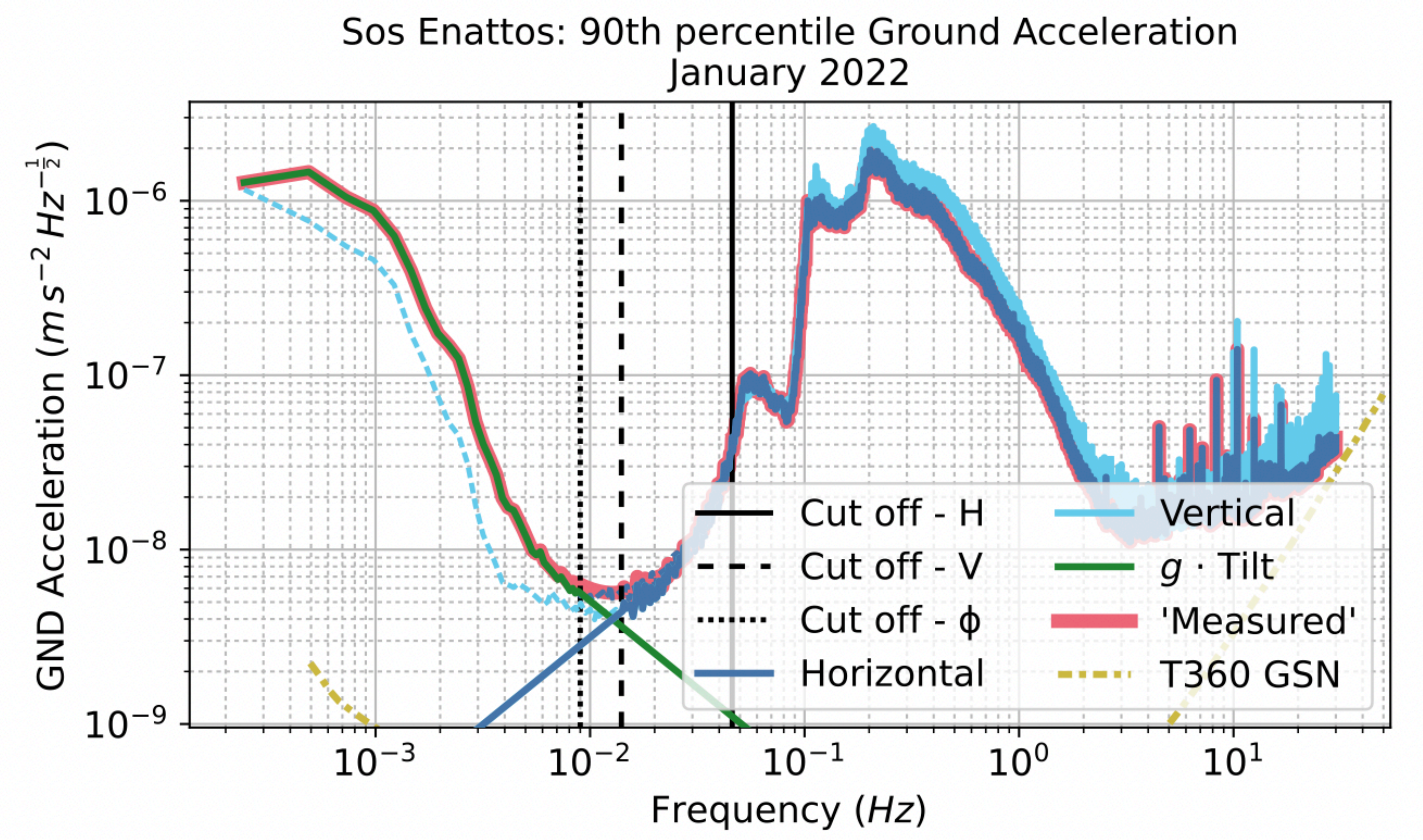


DARM

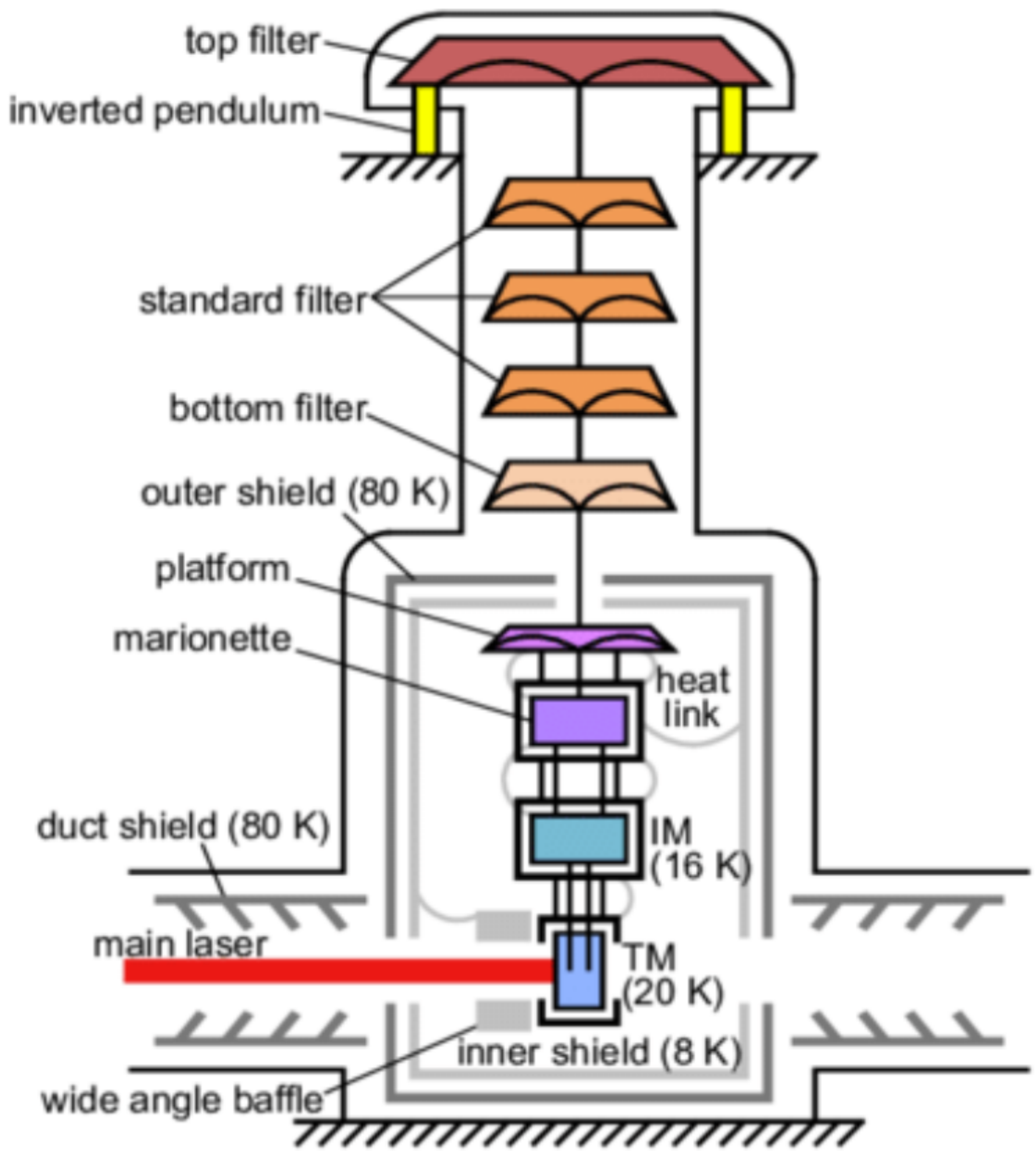
12 m vs. 17 m – Single Cavern - LNGS + Sos-Enattos



Seismic models



Kagra


top filter
inverted pendulum
standard filter
bottom filter
outer shield (80 K)
platform
marionette
heat link
duct shield (80 K)
IM (16 K)
main laser
TM (20 K)
inner shield (8 K)
wide angle baffle

Virgo Superattenuator

9-m tower nominal dimensions