European Organization for Nuclear Research

STABILIZATION FOR LHC INNER TRIPLETS

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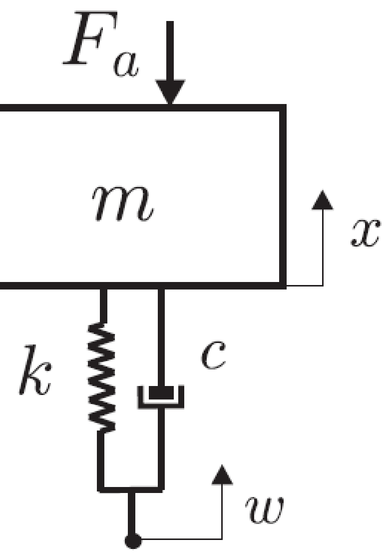
Outline

- Vibration Control (Stef Janssens)
  - Passive Isolation
  - Active isolation CLIC
  - Commercial system
  - Conclusion

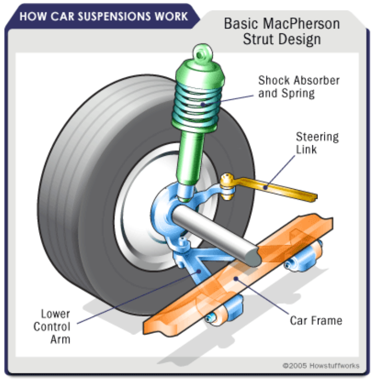
Passive Isolation Strategies

Spring mass system



Term	Sym.	Unit
mass	m	[kg]
stiffness	k	[N/m]
Damping	c	[N/(m/s)]
Induced force	Fa	[N]
Ground vibrations	w	[m]
Quadrupole vibrations	x	[m]

$$M\ddot{x} + c(\dot{x} - \dot{w}) + k(x - w) = F_a$$

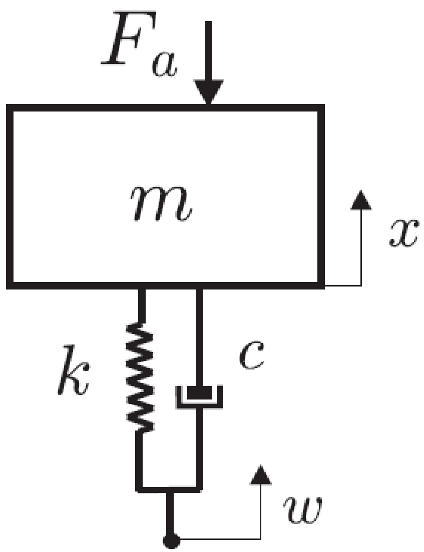


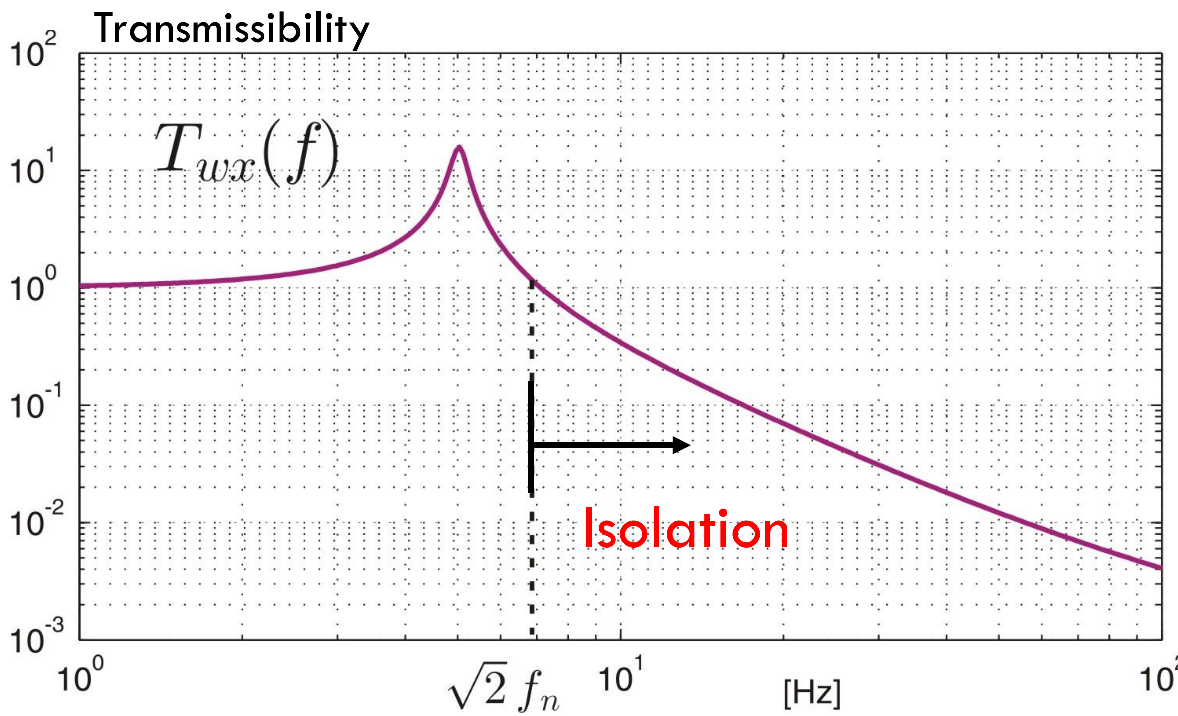
Term	Physical meaning	Symbol	Unit
Transmissibility	x/w	T_{wx}	[-]
Compliance	x/Fa	T_{Fax}	[m/N]

Both can be referred to as transfer functions

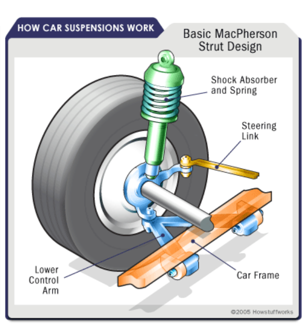
Passive Isolation Strategies

Passive Isolation





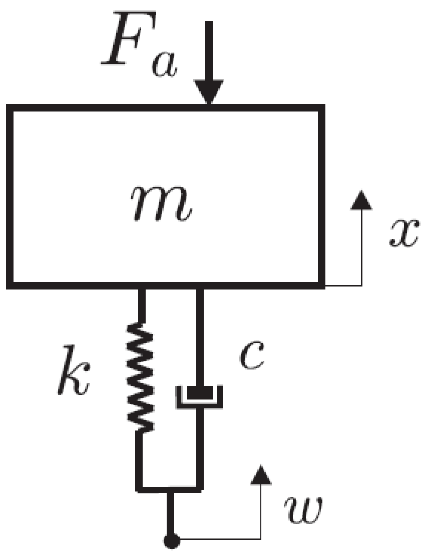
Car suspension

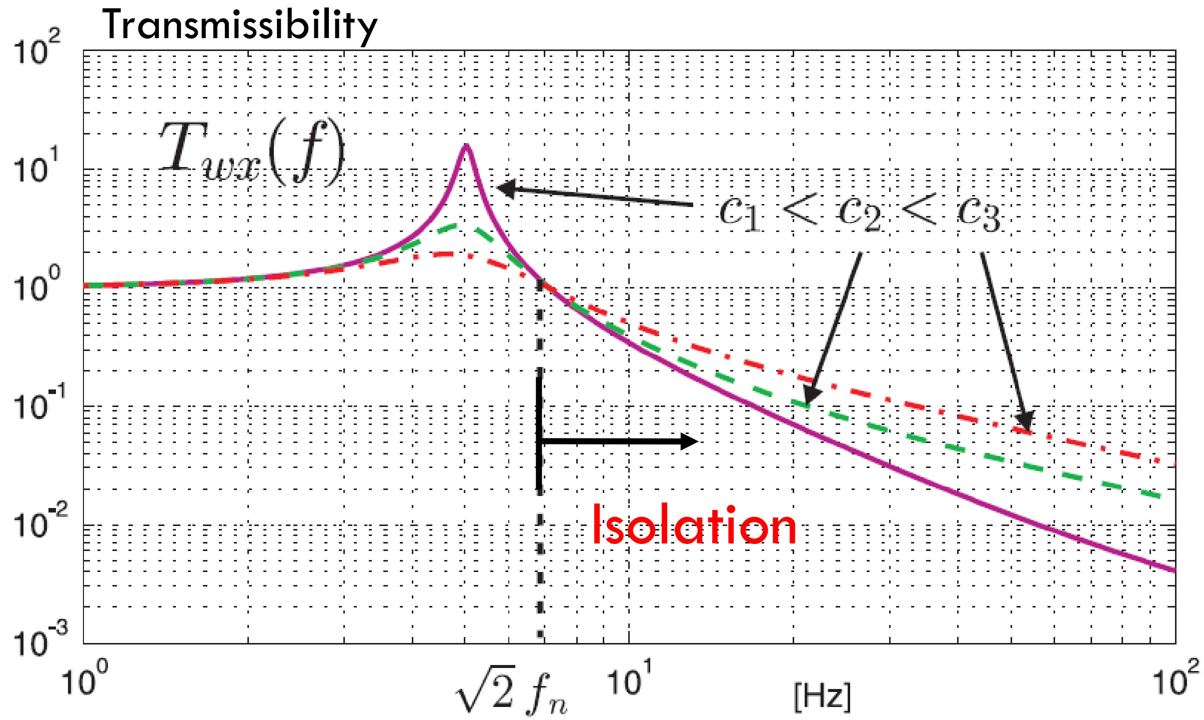


Vibration reduction:
Payload ↔ ground

Passive Isolation Strategies

Passive Isolation

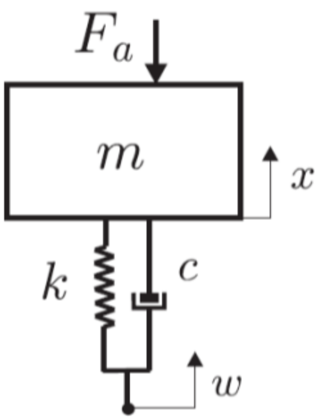


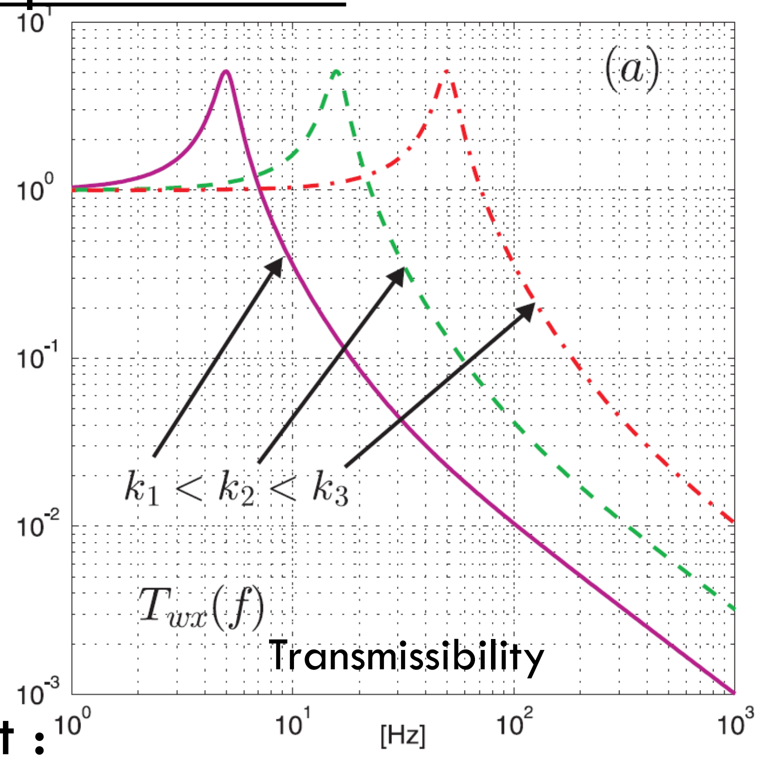


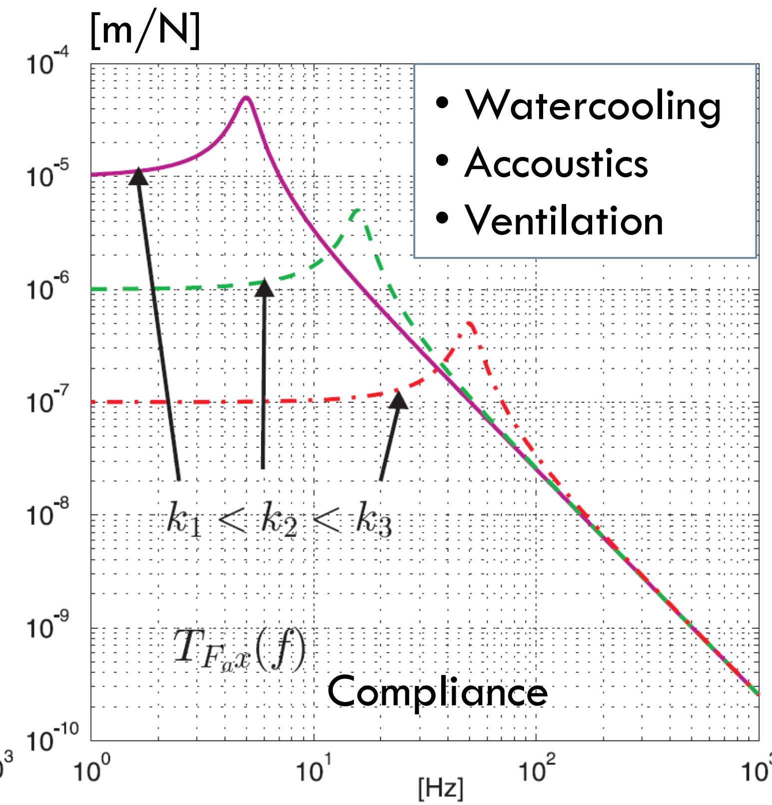
➔ Trade off between magnification at resonance and isolation

Passive Isolation Strategies

Effect of support stiffness



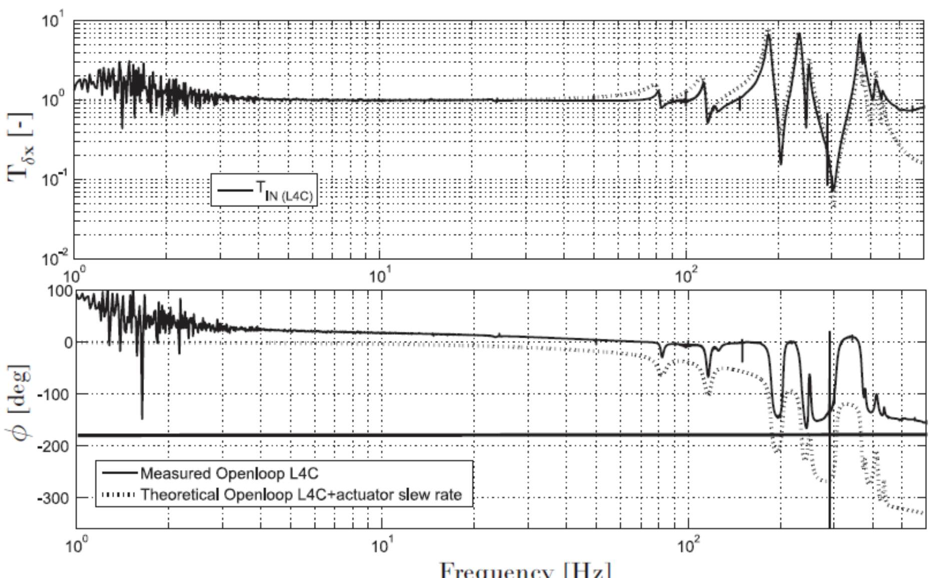


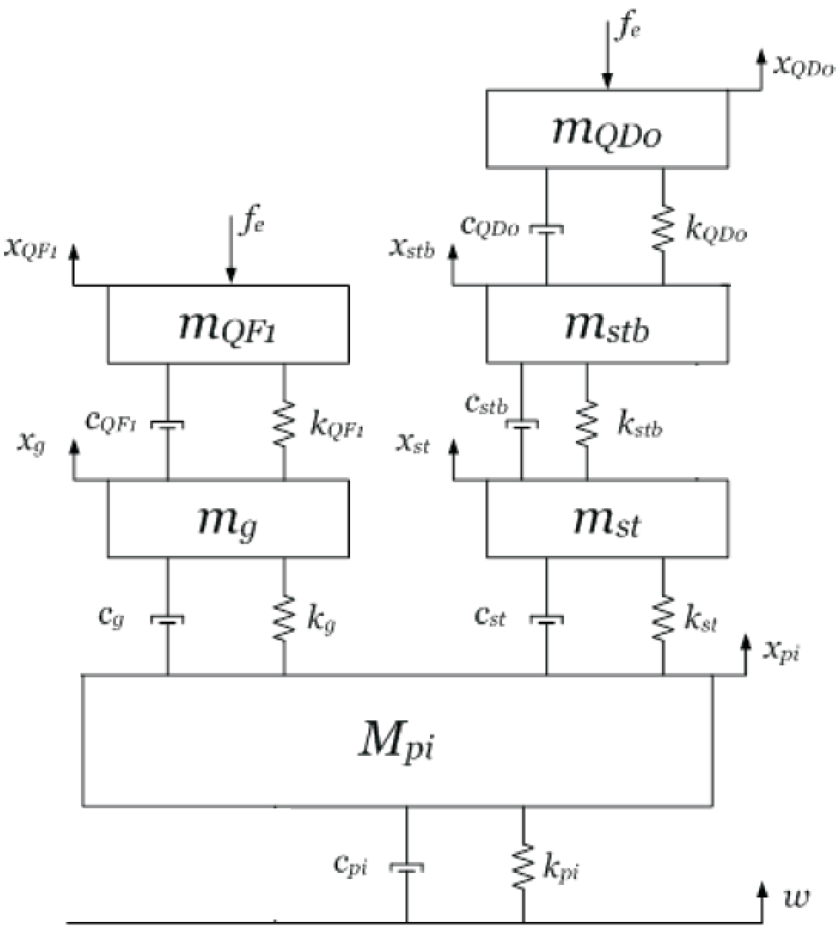


Soft support :

- Improves the isolation
- Make the payload more sensitive to external forces Fa
- Difficult alignment (adding of helium, connections,…)

Effect of support stiffness



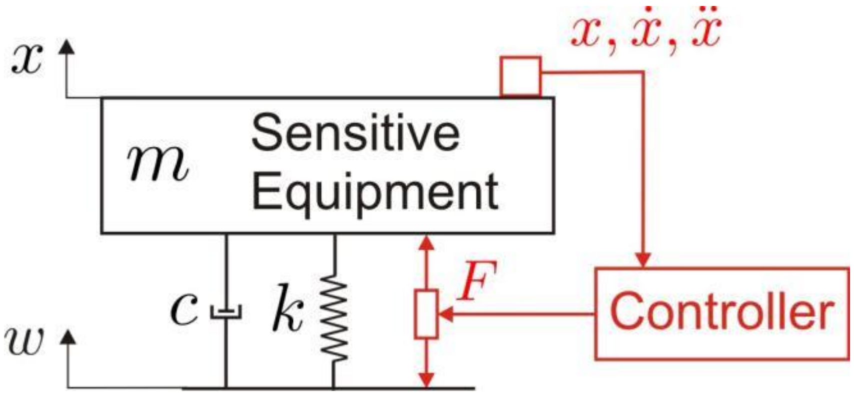


Reality:

- Many resonances
- Little passive isolation
- Possible uncoherence between magnets

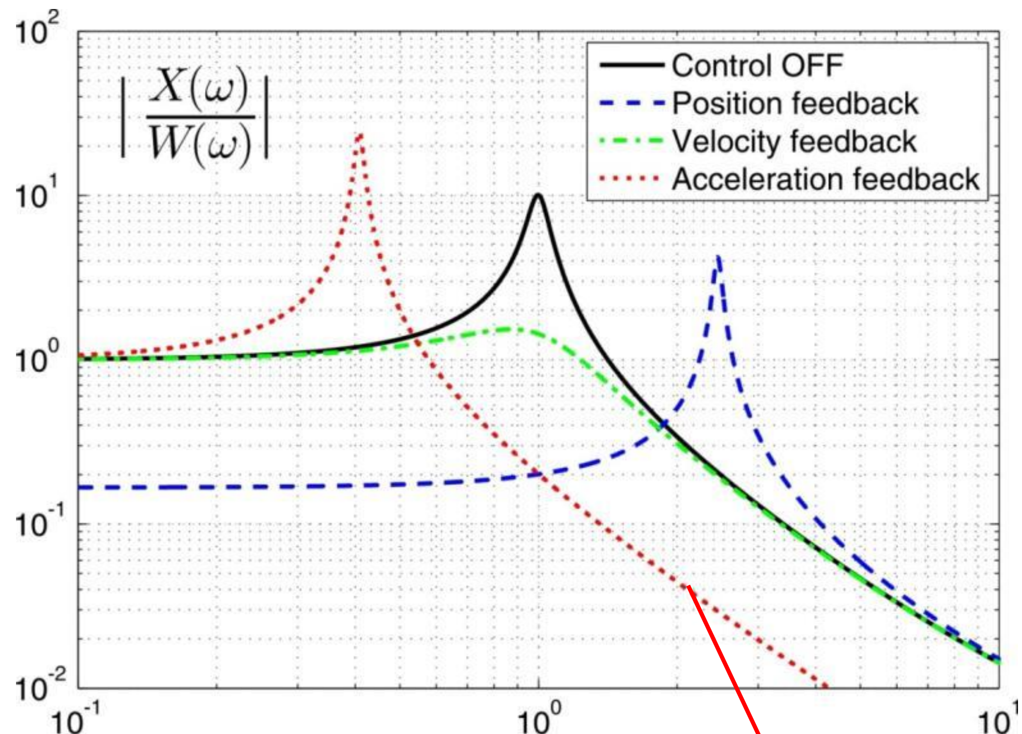
Active Isolation Strategies

Feedback control principle



$$F(t) = k_d x + k_v \dot{x} + k_a \ddot{x}$$

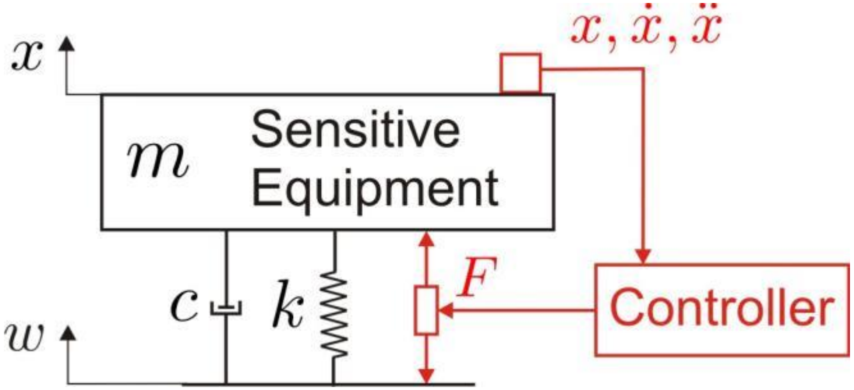
$$\frac{X(s)}{W(s)} = \frac{cs+k}{(m+k_a)s^2+(c+k_v)s+(k+k_d)}$$



Add virtual mass

Active Isolation Strategies

Feedback control principle



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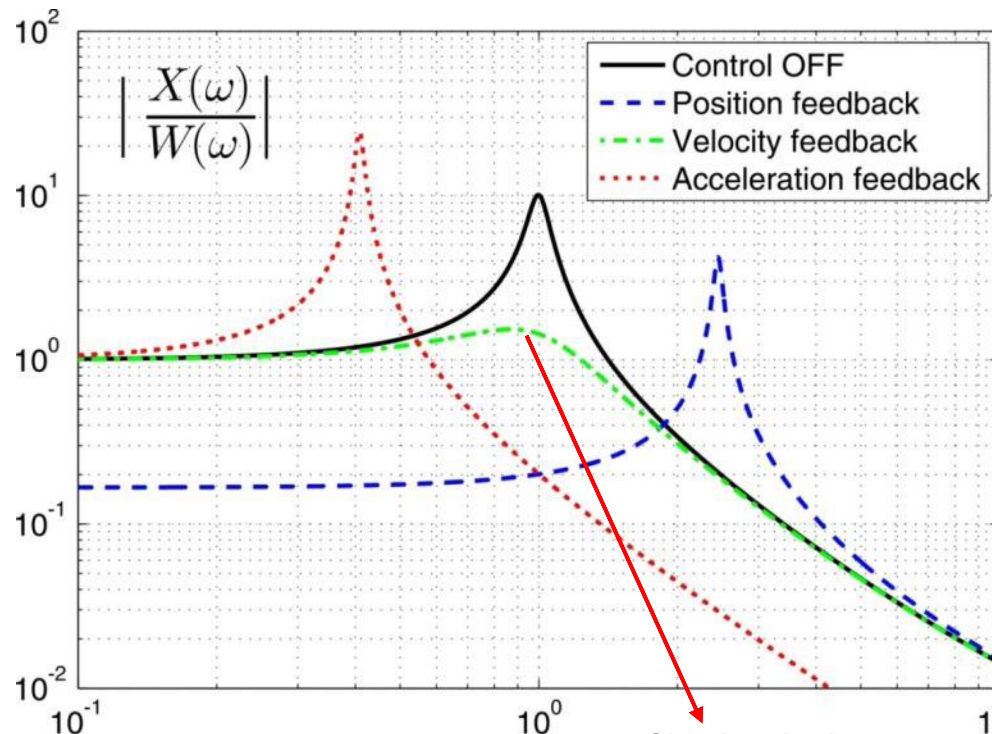
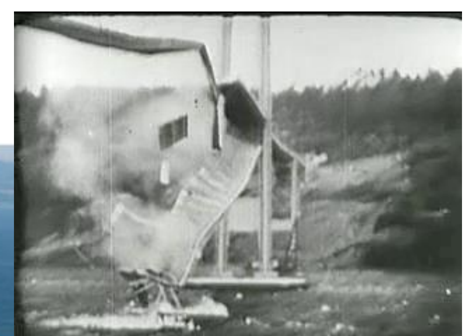


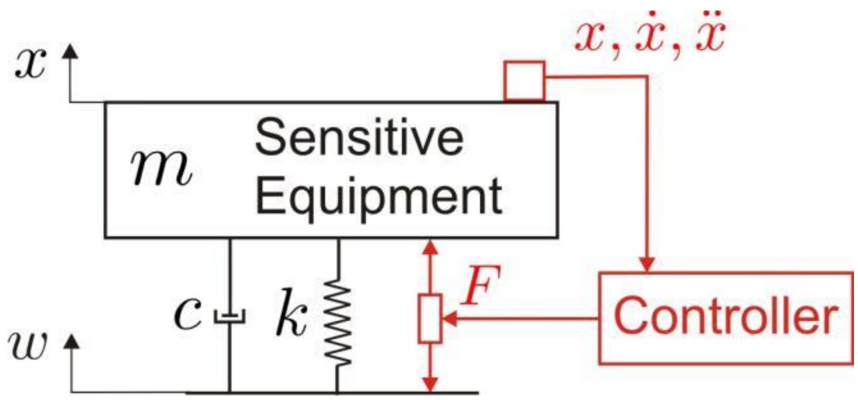
Sky-hook damper

(D.C. Karnopp, 1969)



Active Isolation Strategies

Feedback control principle



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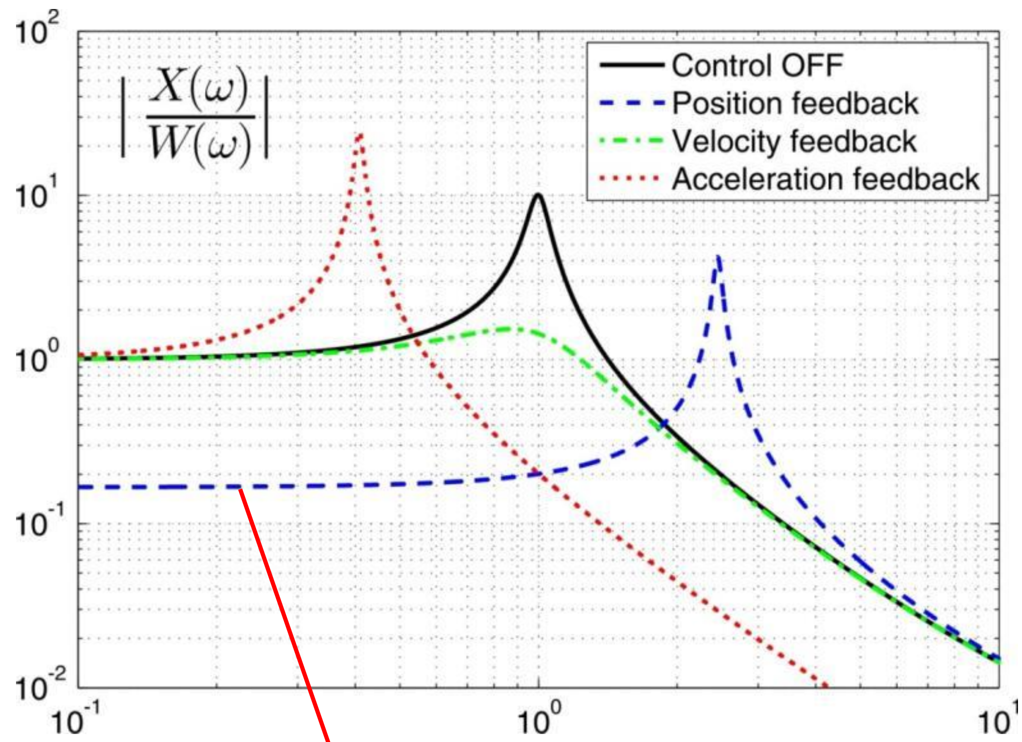


Position feedback would be great !

➔ How to do it ?

Practical application

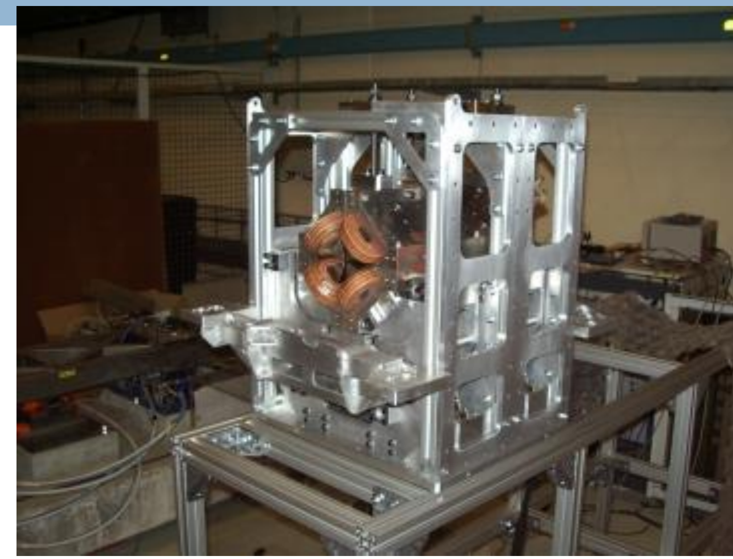
CLIC stabilisation

- 100 kg-400 kg magnets
- Piezo actuators
- Max. ~50 kg/actuator

Piezo actuator

- PI 225.1
- K=480 N/µm (114 N/µm with joints)
- A=0.01 m^2
- Force capacity push = 12500 N
- Force capacity pull = 2000 N
- Shear force max. = 255 N

4 actuators:
15 000 kg => 20 Hz =>~237 N/µm ok
Max. stress 50 Mpa
Stress=29 Mpa very High



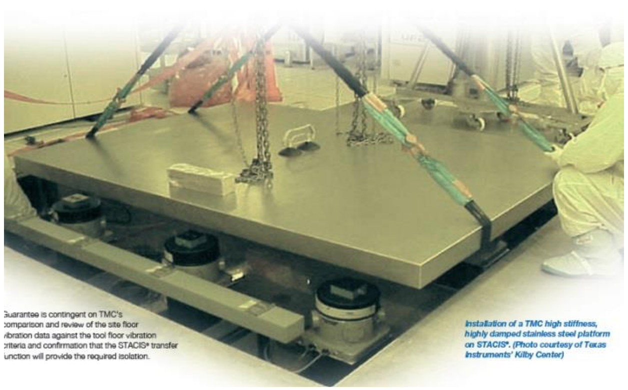
Complex guidance system needed
=>Very difficult and costly
=> Side loads (vacuum, pressure test,…)
=> Develop collocated sensor/actuator
=> Big project!

Actuators that can take the load:
(Pneumatic, Hydraulic)
=> No sub micron resolution

Commercial possibility

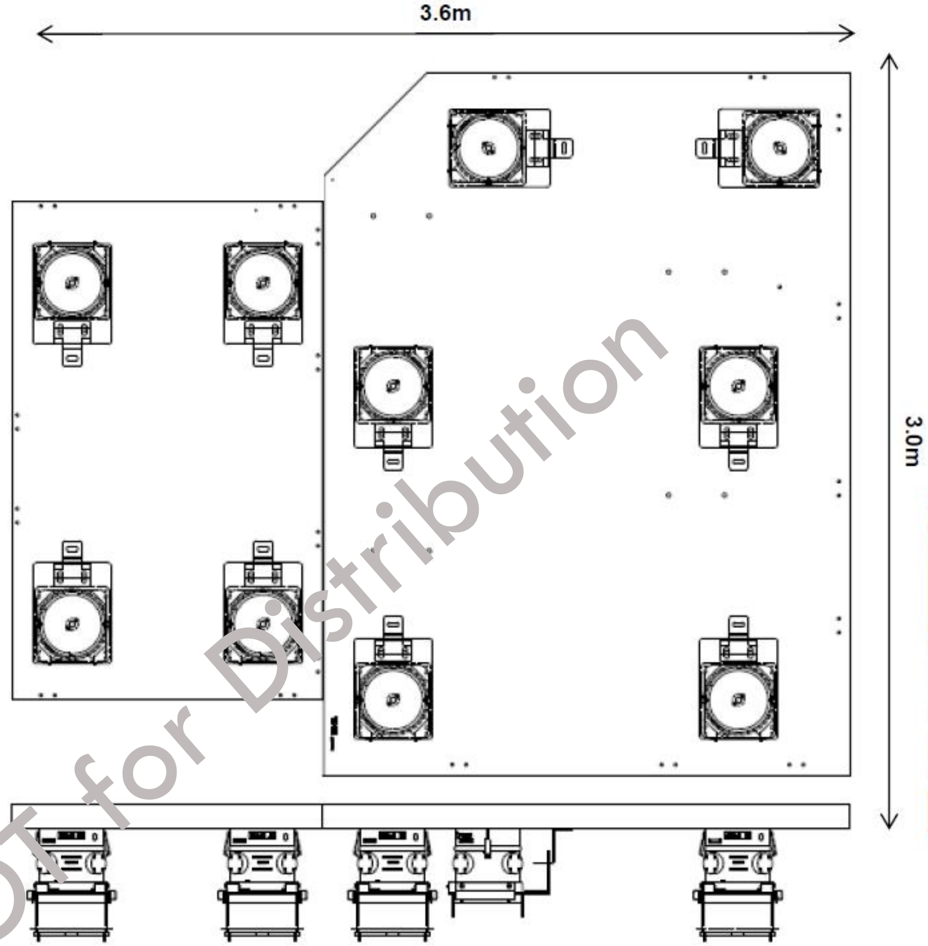
- TMC STACIS vibration isolation feet
  - Six d.o.f. vibration isolation
  - Piezo actuator+elastomer
  - Geophone collocated

  - Range 12 µm
  - Payload mass 182-2048 kg
  - Isolation bandwidth 0.6-150 Hz
  - ~20-25k US Dollar/foot



Commercial possibility: example

TMC STACIS vibration isolation feet



10-Mount STACIS System, supporting steel laminate platform for a Semiconductor Laser Inspection tool.

Total System Capacity = 20400 kg

STACIS Isolators supporting a Steel Laminate Platform in a Raised Floor

Commercial possibility: Effect

TMC STACIS vibration isolation feet

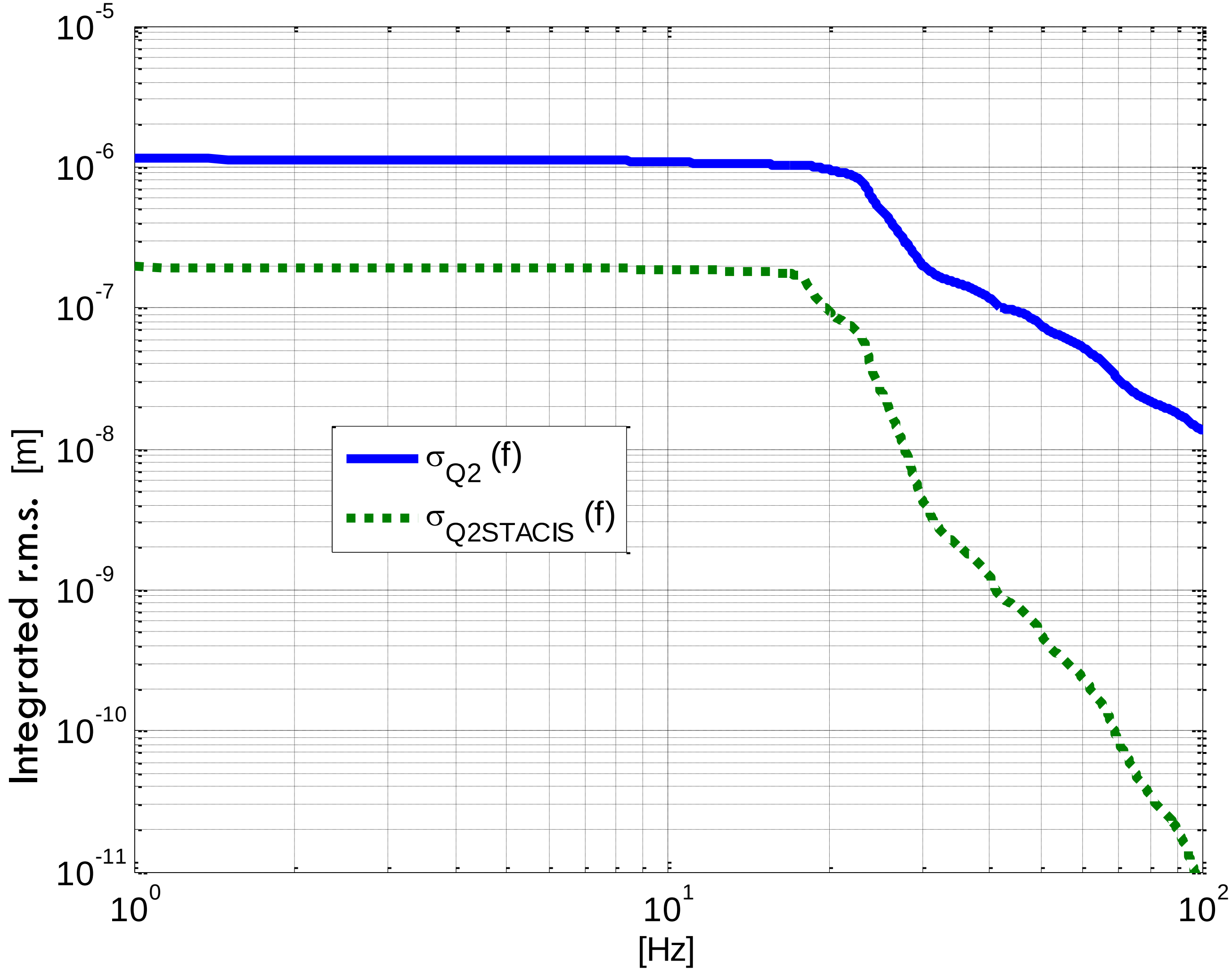
Active Control:

=>Reduction factor 5 <20Hz

Active Control + Passive

=>Reduction of factor
10-100>20 Hz

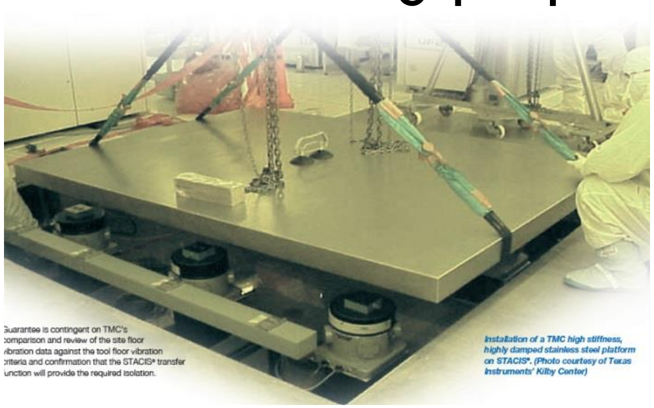
Sufficient?



Commercial possibility

- TMC STACIS vibration isolation feet possible issues
  - Radiation (elastomer, electronics?)
  - Will range be enough (12 μm)?
  - Will large sideways forces be a problem?
  - Can feet be placed on existing alignment stage?
  - Uncorrelated motion with rest of accelerator

=> Still big project



Conclusion

- Passive Isolation exists
  - => Not robust against external forces (helium, interconnections,…)
  - => Difficult to perform alignment
  - => Multiple resonances reduce performance
- CLIC stabilisation system is very sensitive to shear forces
  - => Needs complex and costly guidance system
  - => Develop Sensor actuator pair
  - => Big project!
- Commercial solution exists
  - => Large lateral forces might be a problem
  - => Not Accelerator ready => Big project
  - =>20-25 k US Dollar per foot

Commercial possibility

TMC STACIS vibration isolation feet

9-Mount STACIS System, supporting Optical Tables at the Max-Planck Institute in Heidelberg, Germany

Total System Capacity = 18500kg

This eight-piece CleanTop® Optical Table System is installed at the Max Planck Institute in Heidelberg, Germany. The system may be configured as one entire assembly or smaller assemblies of one or more table units. The entire system is installed on a STACIS® Active Piezoelectric Vibration Cancellation System.