Vibration Budget For SuperB

XVII SuperB Workshop and Kick-off Meeting
Elba
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Vibration Issues

- Vibration requirements
  - Effect on luminosity
  - Vibration sensitivity, esp. of IR
  - Proposed vibration budget
- Expected vibrations and their effects
  - Ground motion at LNF
  - Expected vibration of arc quads
  - Expected vibration of IR cryostat
- General site requirements

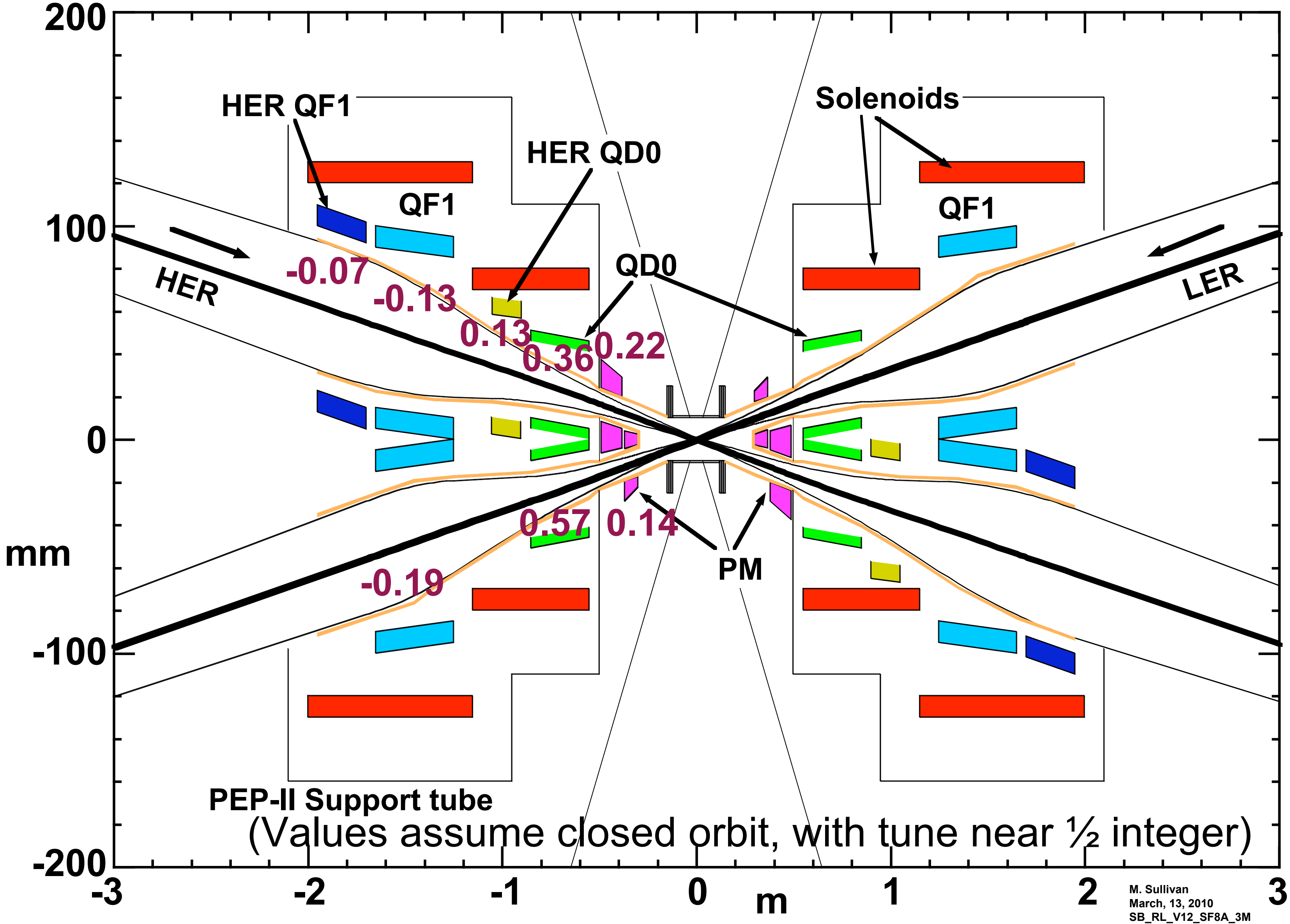
New from Previous SuperB Meetings

- PAC2011 paper (THP069)
  - Investigated final focus quads
  - Updated to latest lattice (v12)
  - Re-analyzed X and Y’ sensitivities
- Generated general site vibration specs

Allowed Differential Beam Displacement at IP

- Y position has very tight tolerance:
  - 8 nm relative beam displacement at IP reduces luminosity by 1%
- Other dimensions much looser:
  - Y angle: 200 urad relative displacement at IP reduces luminosity by 1%
  - X position: 2 um relative displacement at IP reduces luminosity by 1%

Vibration Transfer Functions of IR Components



(Values assume closed orbit, with tune near ½ integer)

Shared Quads in Cryostat are Highly Beneficial

- HER and LER IR magnets in shared cryostat move together
- Both beams move same direction and nearly same amount at IP due to cryostat motion
- Relative displacement reduced by ~100x!
- But: sensitive to cryostat rotation (torsion)
  - Tends to move magnets and beams in **opposite** directions
  - Need to control torsional vibrations

Cryostat Motion

Cryostat motion at end	Cryostat to IP xfer fn
Transverse offset in y	~ 0.002
Linear tilt in y	~ -0.002
Quadratic deflection in y	~ 0.007
Rigid rotation along z	~ 0.01 m/rad
Torsional rotation along z	~ 0.014 m/rad

- Coupled linear motion in cryostat should cancel ~99% of effect of single QD0 motion
  - Sounds very optimistic
  - Assume worst case ~5x worse: (transfer fn ~ 0.035 instead of ~0.007)
- Rotational motion needs to be limited
  - Avoid building torques into IR magnet support system

Proposed Vibration Budget

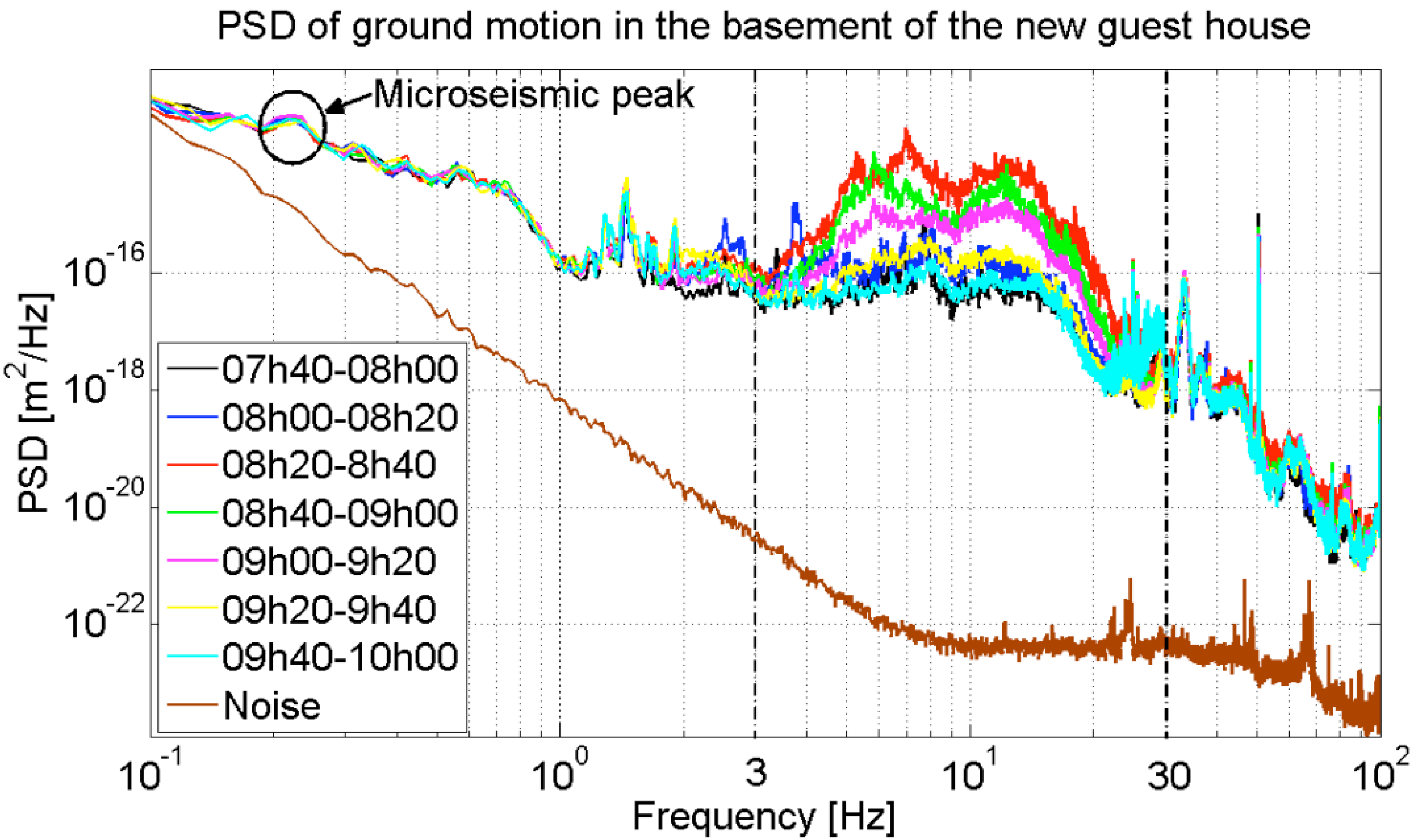
Element	RMS motion per element	Xfer Fn (RMS sum, both rings)	RMS differential displacement @ IP	
			no feedback	with feedback
Cryostat linear	< 800 nm	< 0.05	< 40 nm	< 4 nm
Cryostat rotation	< 2 urad	0.02 m/rad	< 40 nm	< 4 nm
Final focus quads, excluding IR	< 200 nm	< 0.2	< 40 nm	< 4 nm
Arc quads	< 200 nm	< 0.14	< 30 nm	< 3 nm
Total (two rings)			< 75 nm	< 7.5 nm

- Budget applies to integrated vertical RMS motion > 1 Hz
- Can allow 1.4x larger motion in arcs, if necessary
- Beam feedback: assumes >10x reduction of motion at IP, needs > ±400 nm (5x RMS) dynamic range

X and Y' Considerations

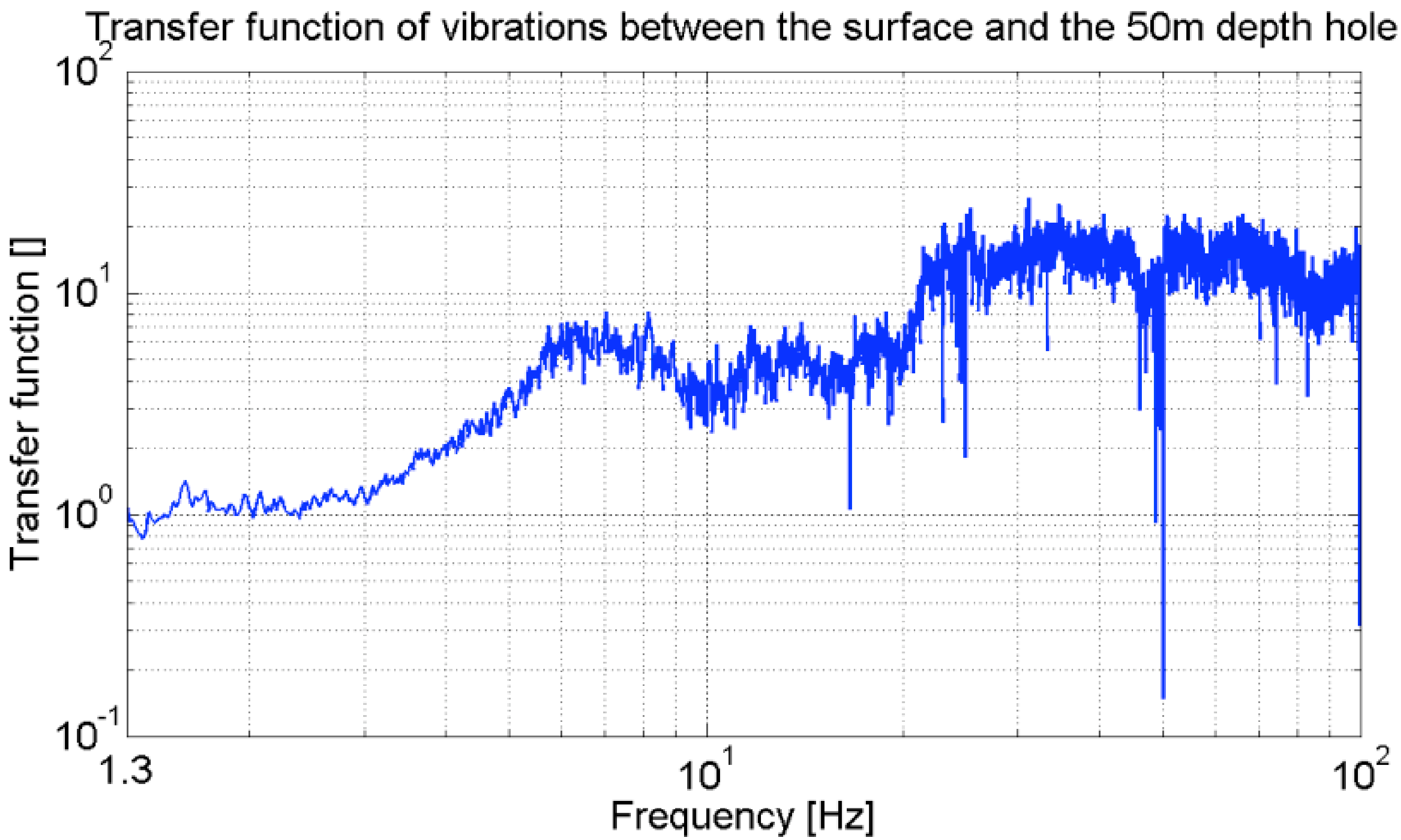
- Horizontal
  - Excitation usually less than vertical (~1/3?)
  - Horizontal vibration transfer functions up to 15x larger than vertical (arc quads are worst contributor)
  - Horizontal vibration tolerance 250x vertical
- Vertical angle (Y')
  - Arc quads are worst contributor
  - Vertical angle effects ~8x less significant to luminosity than vertical position

Ground Motion at LNF



From Bolzon et al, XI SuperB General Meeting (Dec 2009, Frascati) and IPAC10 (Kyoto, Japan)

Vibration Attenuation with Depth



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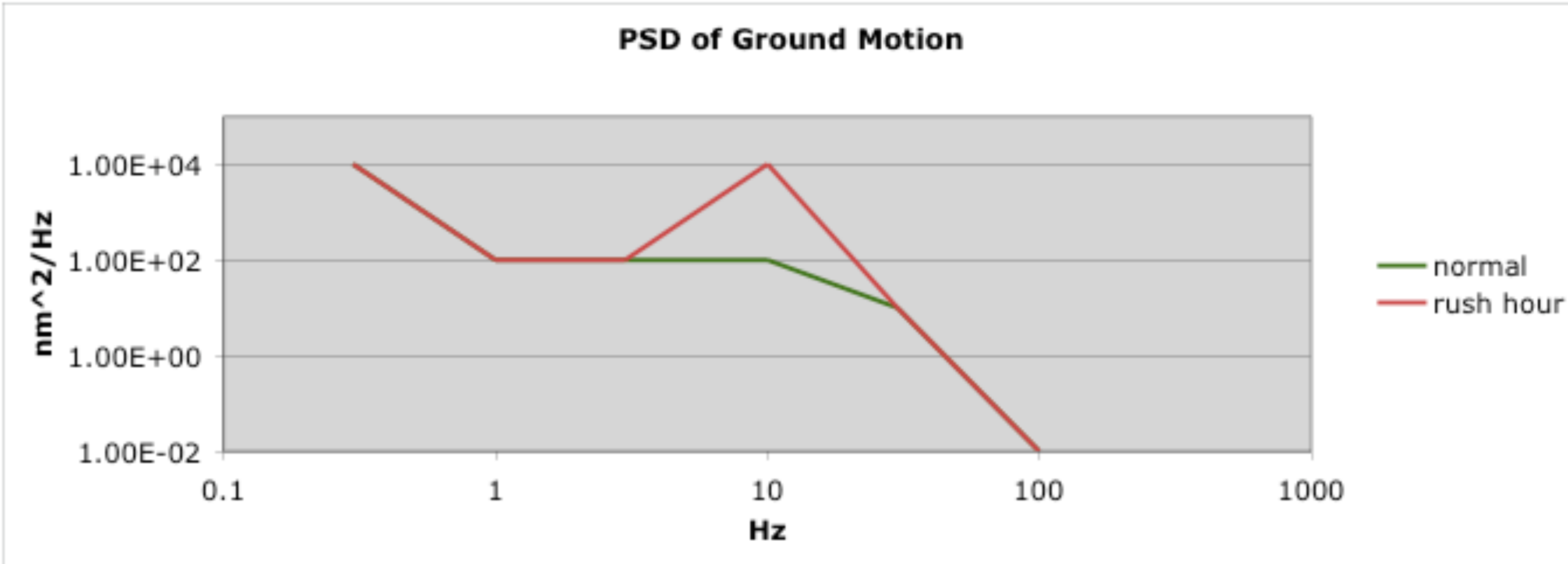
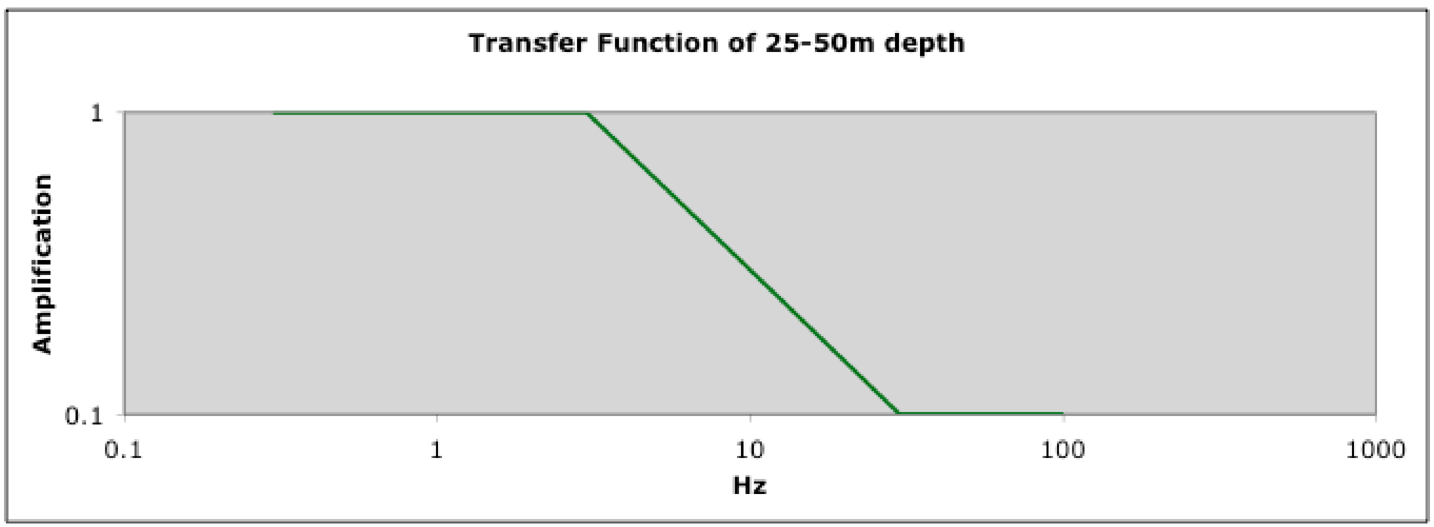
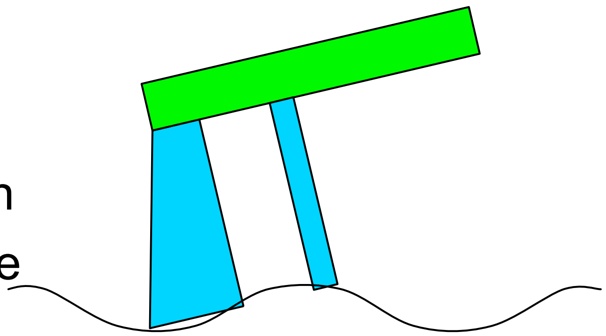
Idealizations For Error Budget

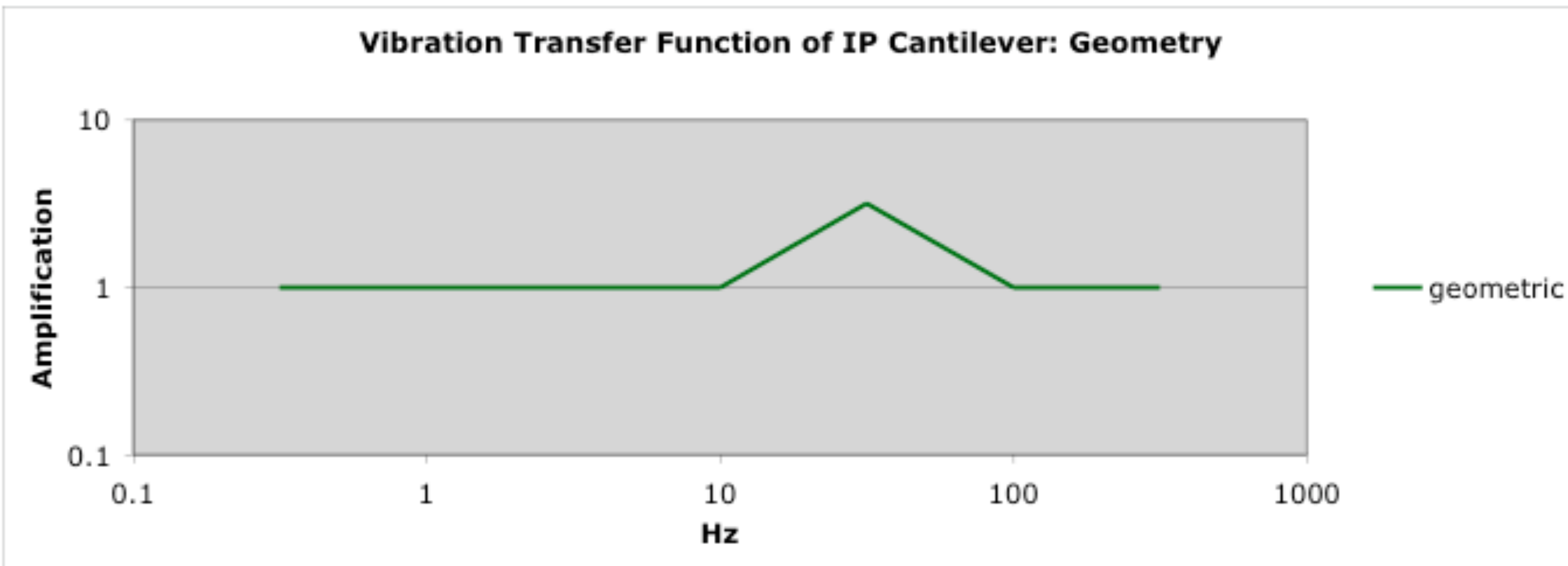




Vibration Amplification of IR

- Even a rigid cantilever will geometrically amplify ground motion
  - Increases with freq due to y-angle of ground motion
  - Decreases when wavelength shrinks to size of base

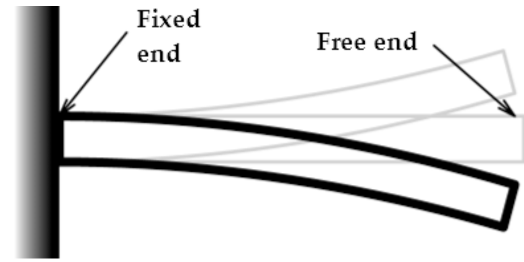


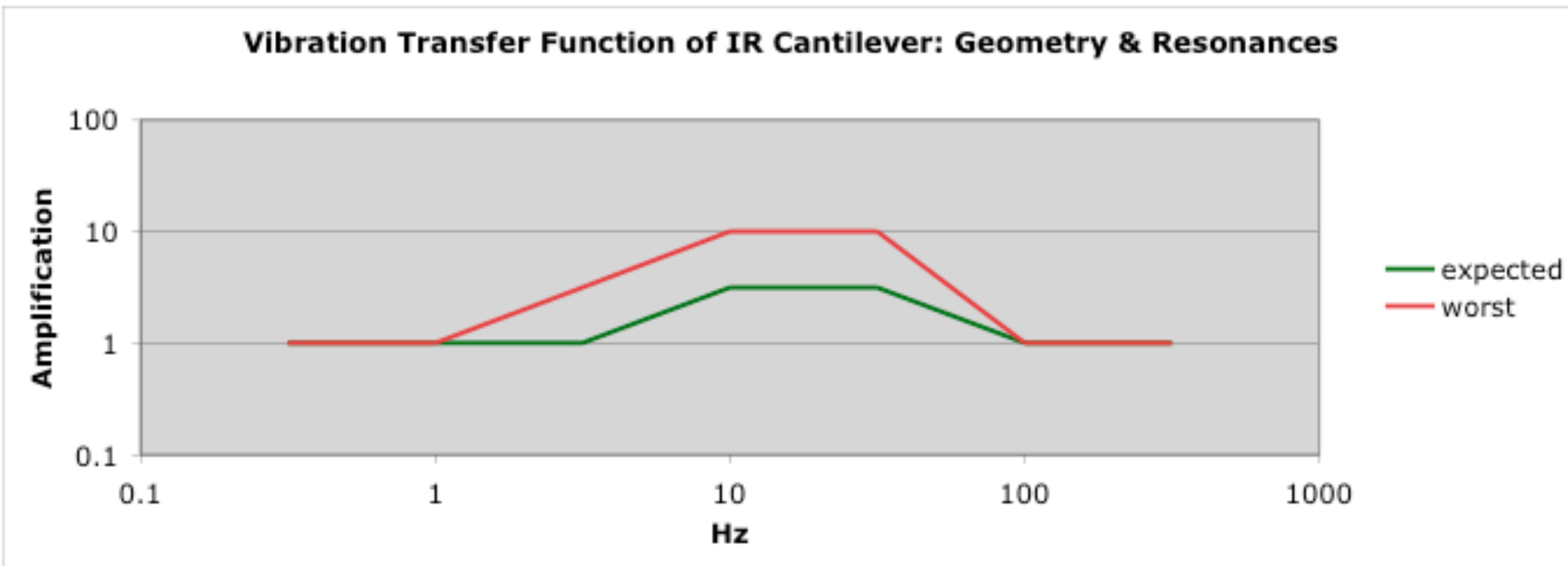


- Assumes:
  - Ground vibration wave velocity 100-200m/s
  - Cantilever ~ 2 m
  - Base 1-2 m

Vibration Amplification of IR

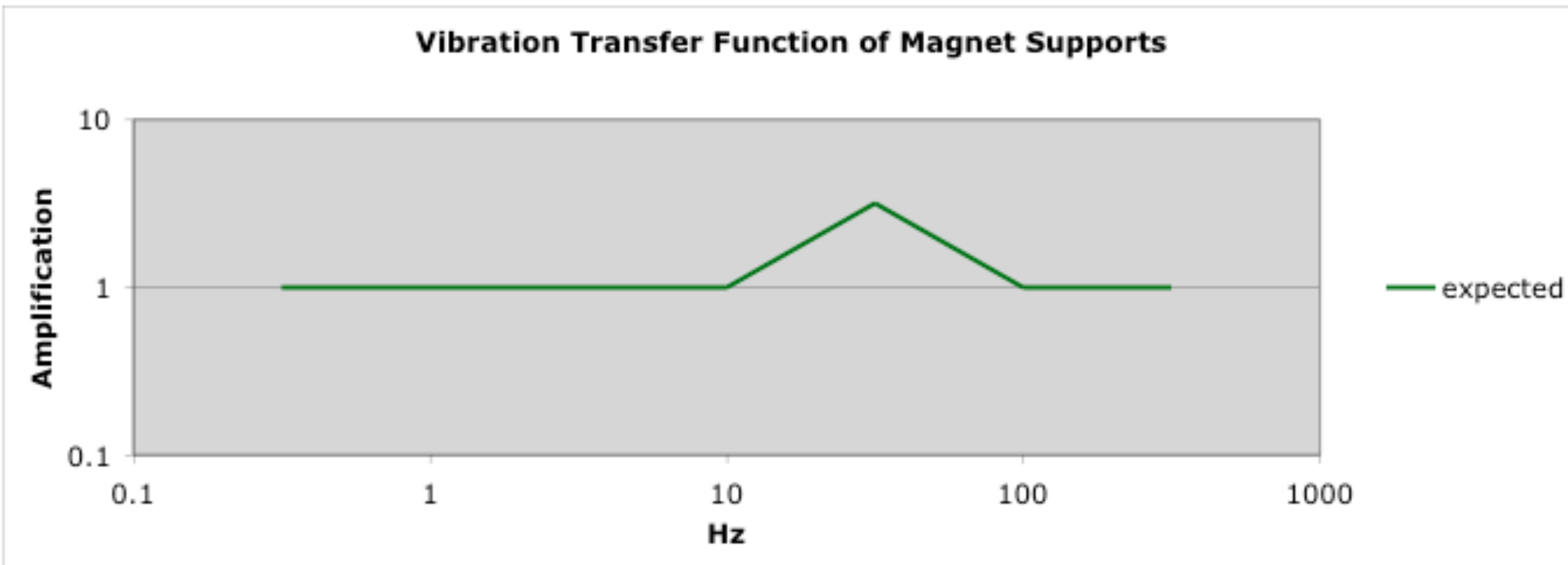
- Cantilever will also have resonances 3-30 Hz
  - Damp; push freqs as high as possible





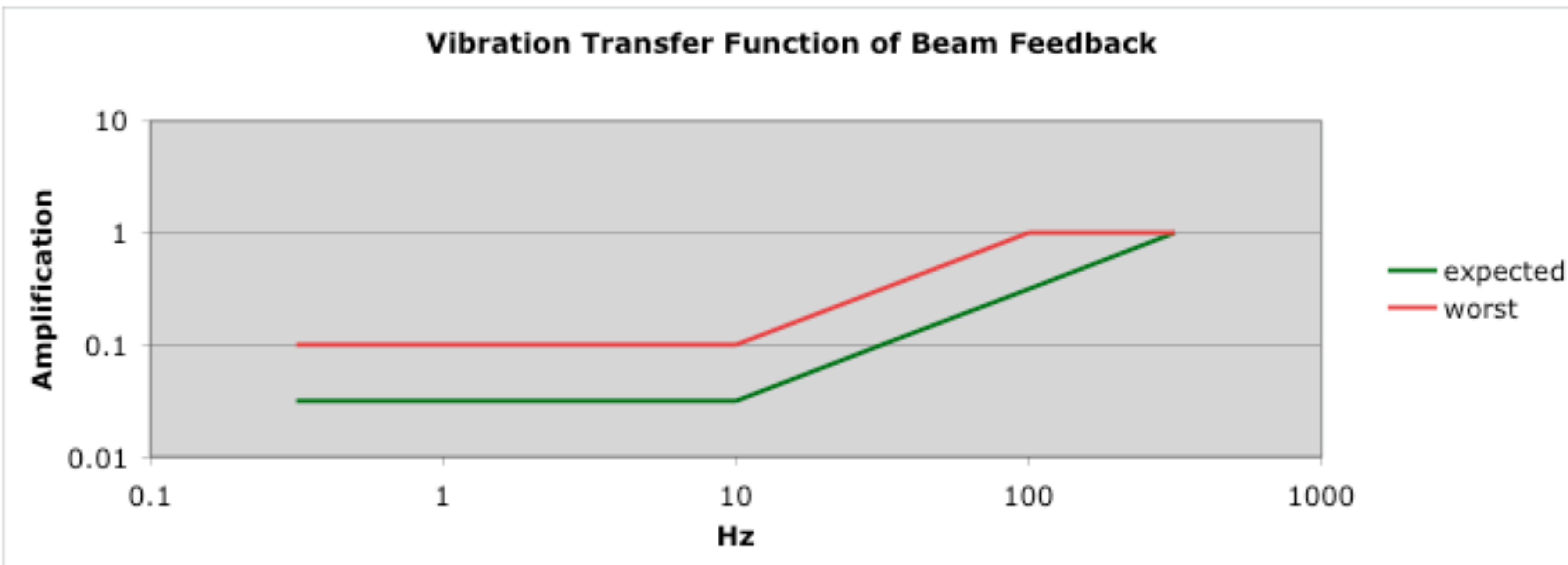
Vibration Amplification of Magnet Supports

- Magnet supports expected to slightly amplify ground motion between 10-100 Hz
- Applies to all arc quads and final focus quads except for quads in cantilevered IP cryostat

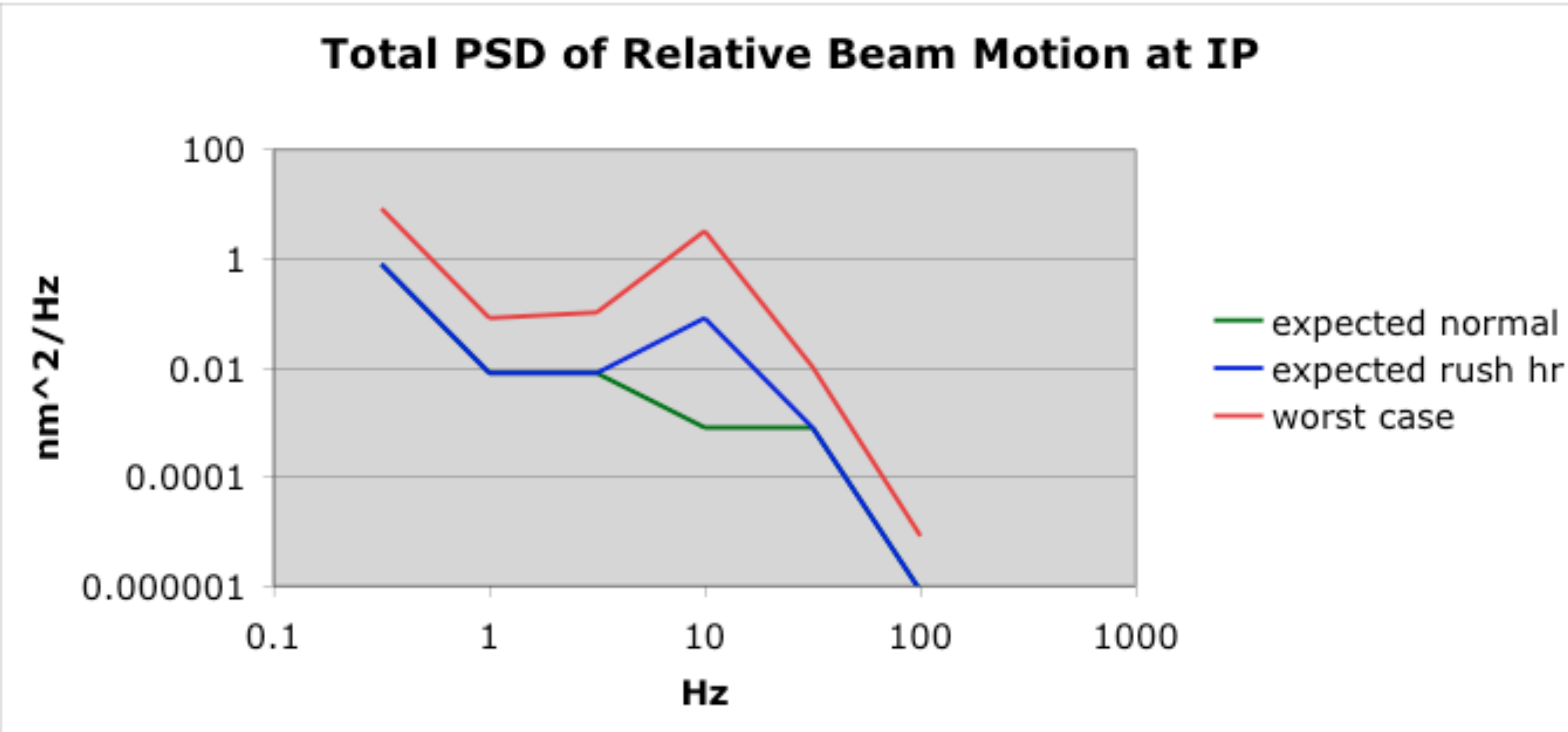


Active Beam Feedback

- Need >100 Hz bandwidth, >10x vibration reduction at LF, >±400 nm dynamic range V (and >±5 um H)
- Fast dither system
  - Proposed by Bertsche et al, PAC09 we6pfp053 (2 um x 25 um dynamic range)
- Fast IP feedback system
  - Proposed by Drago et al

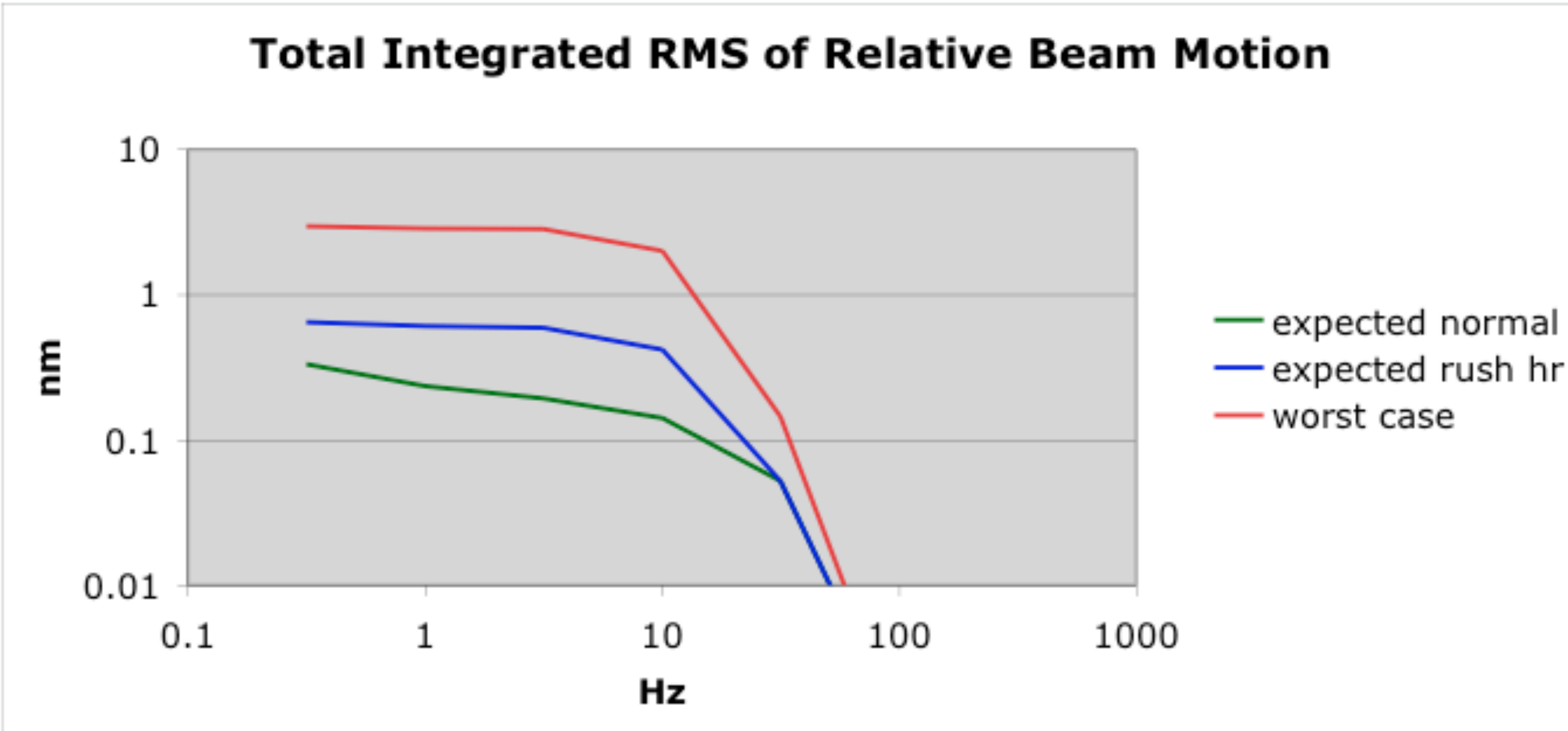


Total Beam Displacement at IP



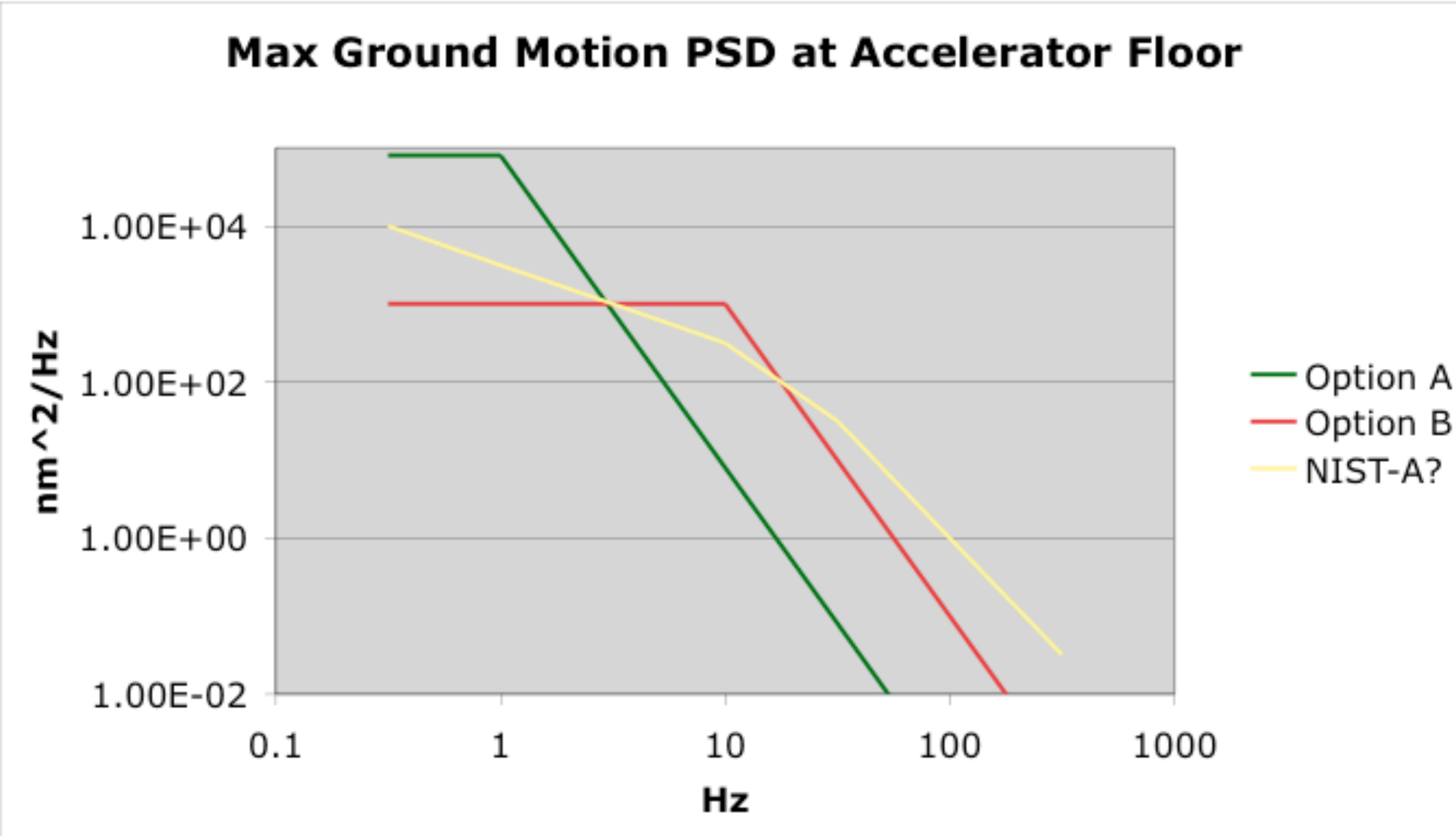
Assumes underground machine at LNF

Total Beam Displacement at IP



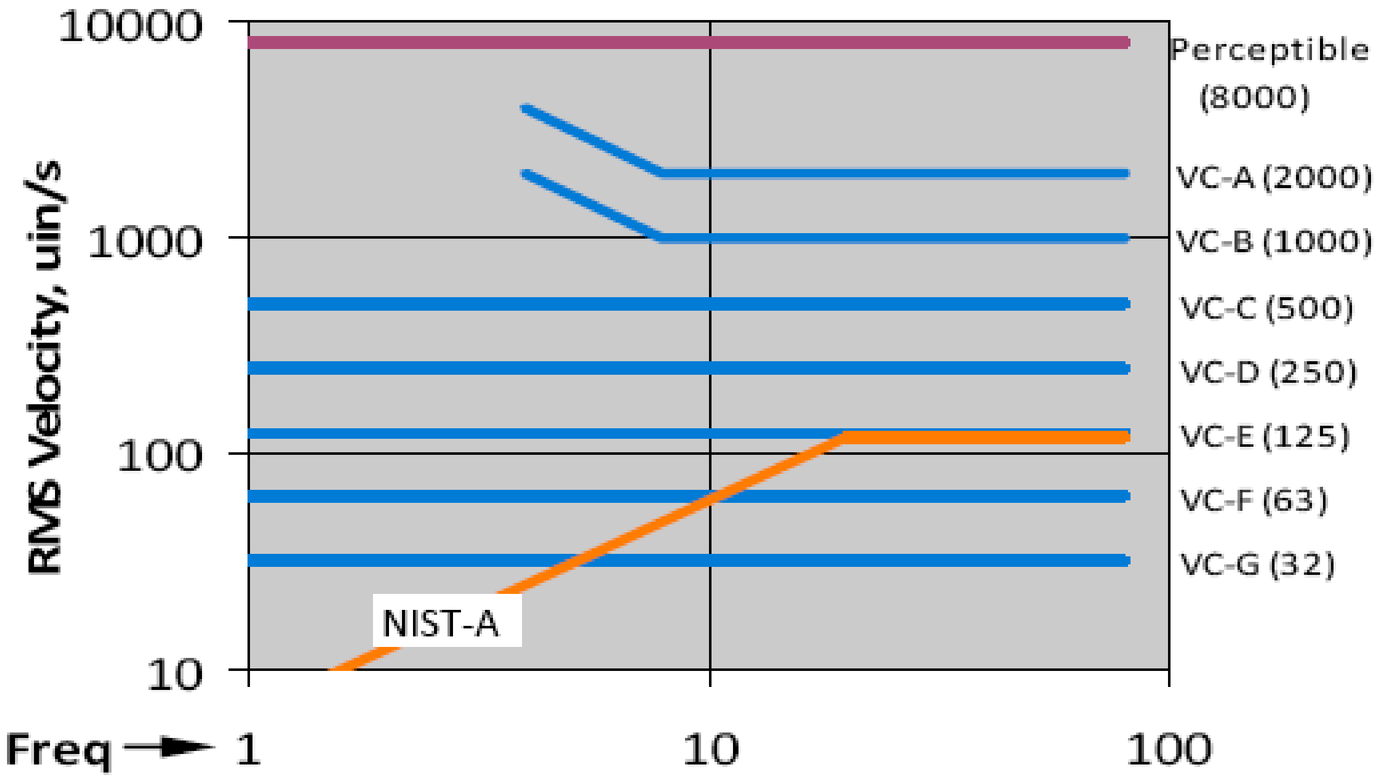
- Assumes underground machine at LNF
- ~4 nm worst case
- Need < 8 nm for < 1% loss of luminosity

General Tunnel Floor Specs



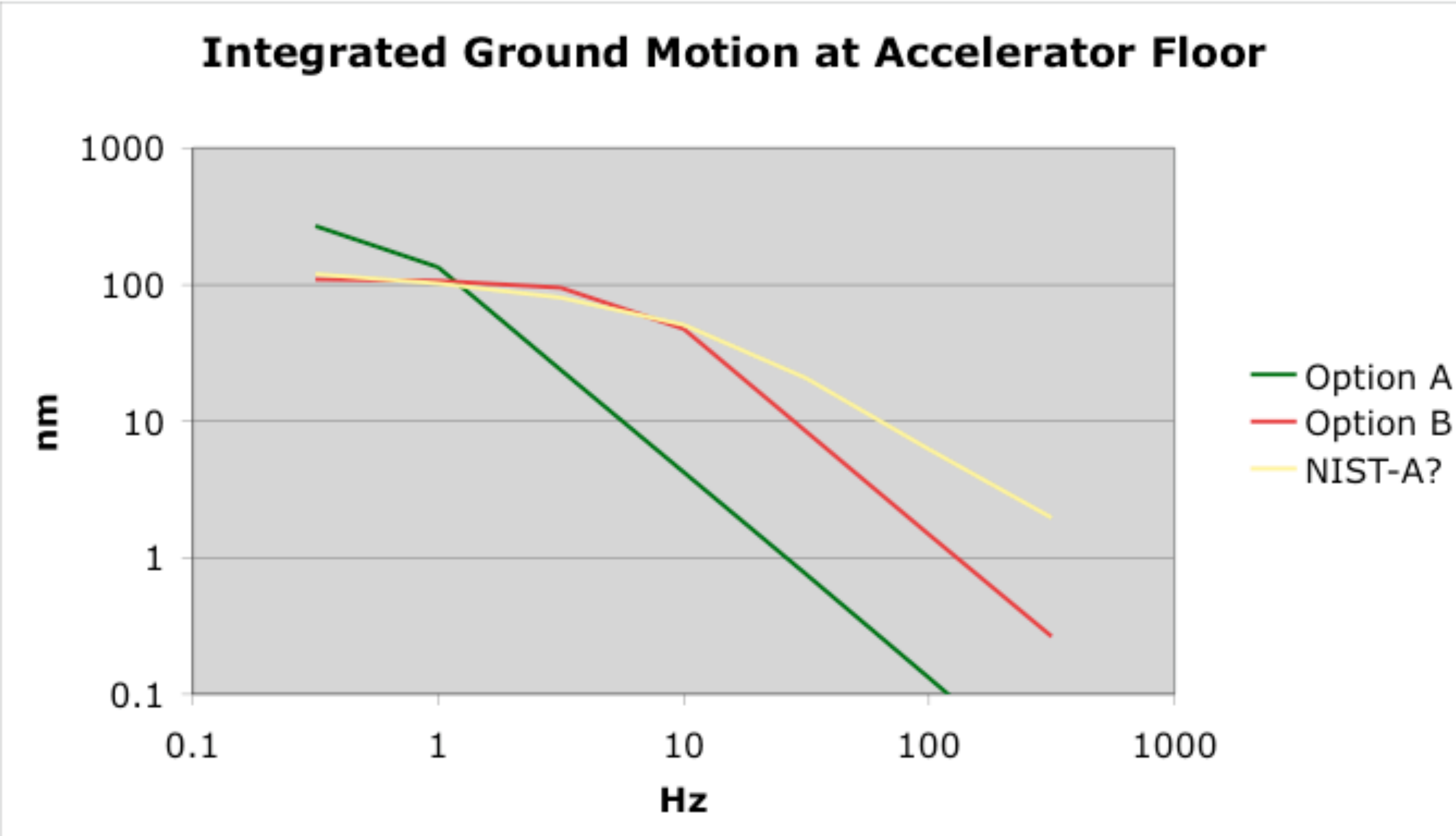
- Applicable to alternate locations or surface sites

Alternative Vibration Criteria from Architectural Acoustics



- From Byron Davis, “High End Vibration Criteria”, Vibro-Acoustic Consultants, San Francisco, CA
- NIST-A seems to be acceptable for tunnel floor

General Tunnel Floor Specs



- ~100 nm RMS ground motion integrated from 1Hz up

Peak-to-Peak Specs

- Peak-to-peak signal generally taken as 3x-8x the RMS (pure sine wave is 2.8x)
- Ground motion in arcs has margin: can be ~1.4x larger
- Suggested specs:
  - Dz <300 nm peak-to-peak in collider hall
  - Dz <300 nm peak-to-peak in final focus
  - Dz <500 nm peak-to-peak in arcs (tunnel)
  - Dx <1 um? peak-to-peak everywhere

Summary

- Cantilevered cryostat should be designed for low vibration
  - Damp resonances and push > 10 Hz
  - Support cryostat on both sides of detector door
  - Avoid building torques into magnet supports
- Beam feedback should extend to 100Hz, provide > 10x vibration reduction at LF, provide > ±400 nm dynamic range (vertical)
- Site vibration should meet specs on previous slides
- Given the above, vibration not expected to impact luminosity for SuperB