Vibration Requirements and Expectations For SuperB

XV Super-B General Meeting
Caltech
15 Dec 2010

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Vibration Issues

- Vibration requirements
  - Beam sensitivity to misalignments
  - Proposed vibration budget
  - Beam feedback system
- Expected vibrations and effects
  - Ground motion at LNF
  - Expected vibration of arc quads
  - Expected vibration of IR cryostat

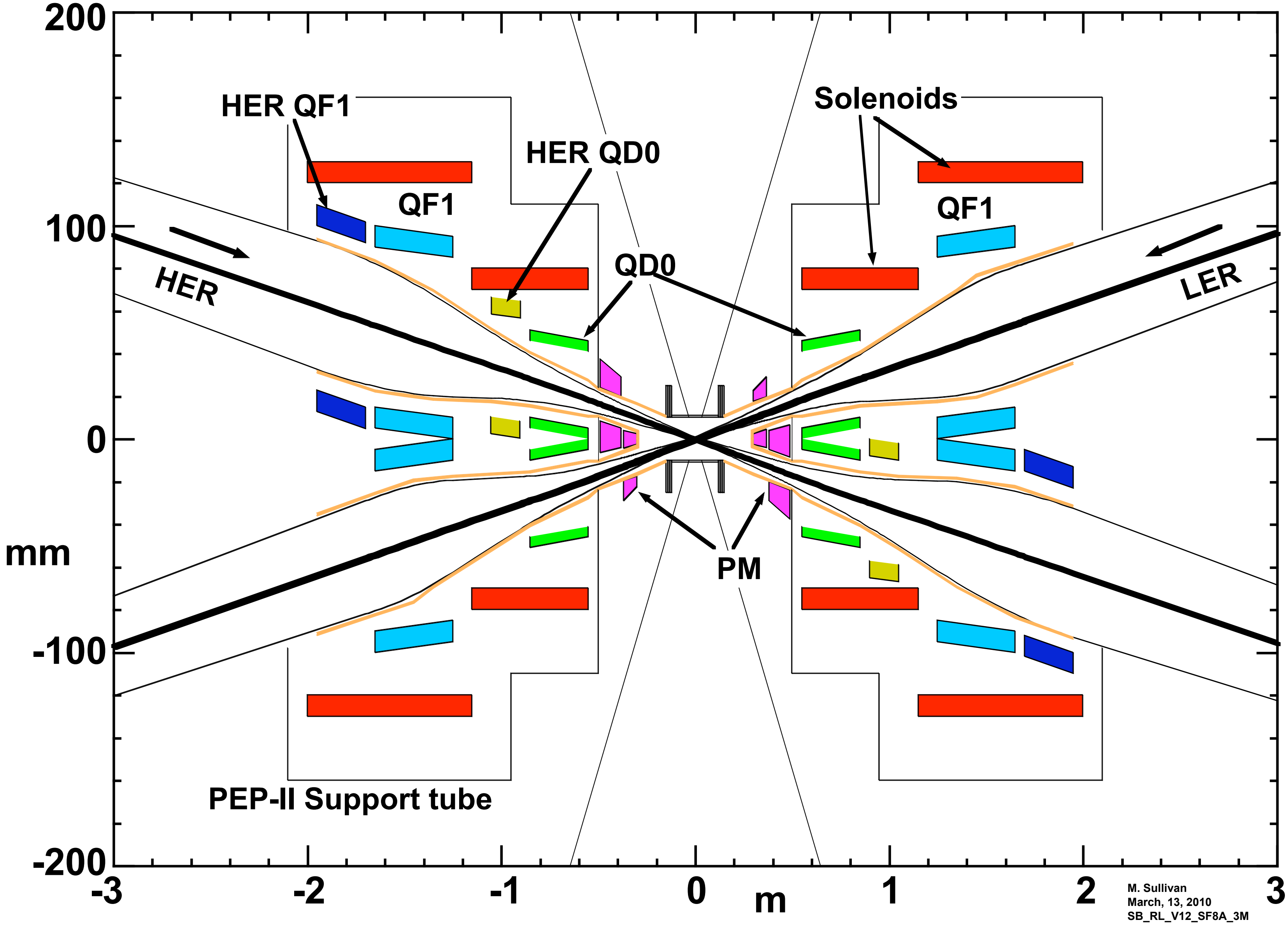
SLAC NATIONAL ACCELERATOR LABORATORY

Allowed Displacement at IP

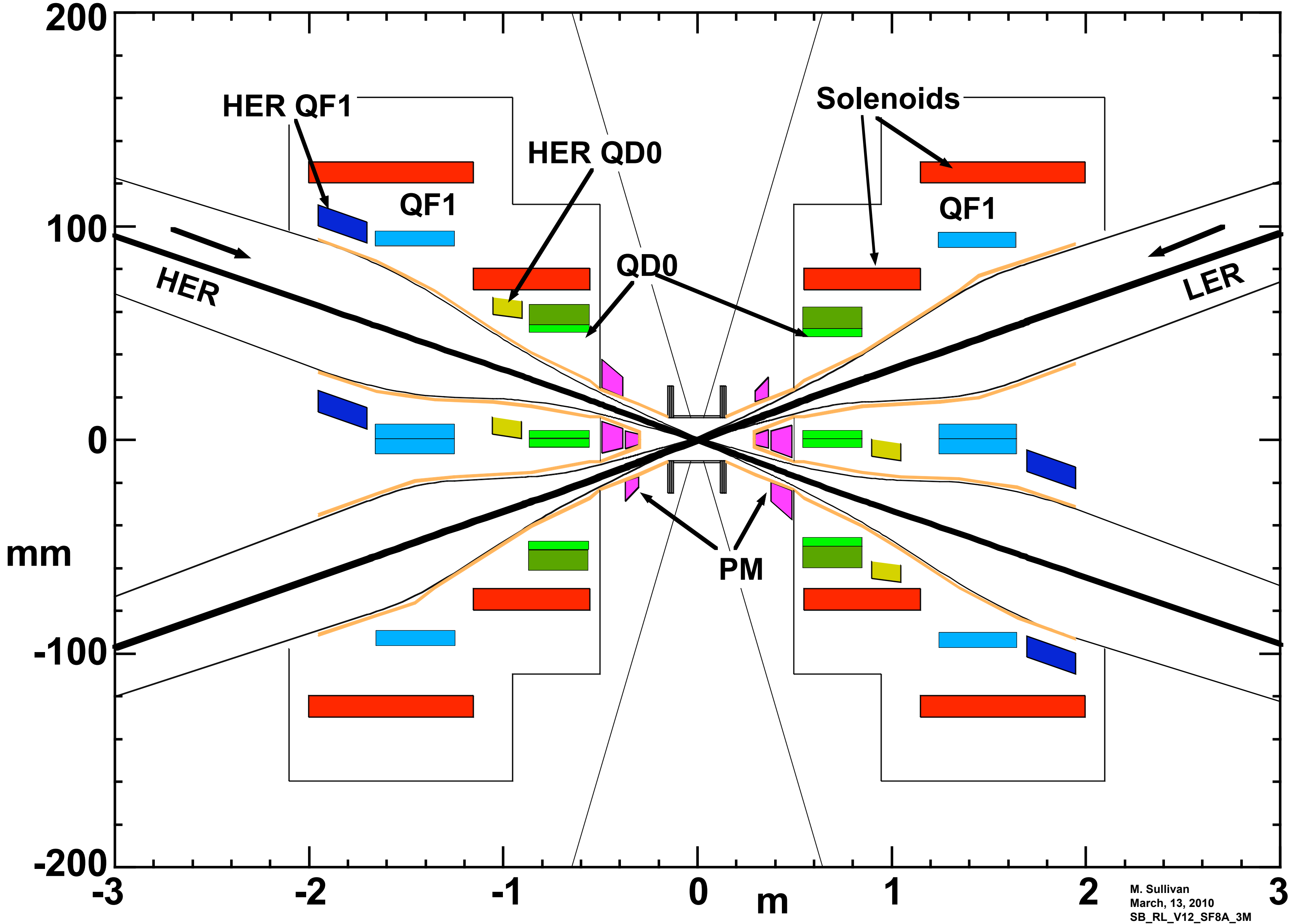
SuperB

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

Vanadium Permendur "Russian" IR Design



Air Core "Italian" IR Design



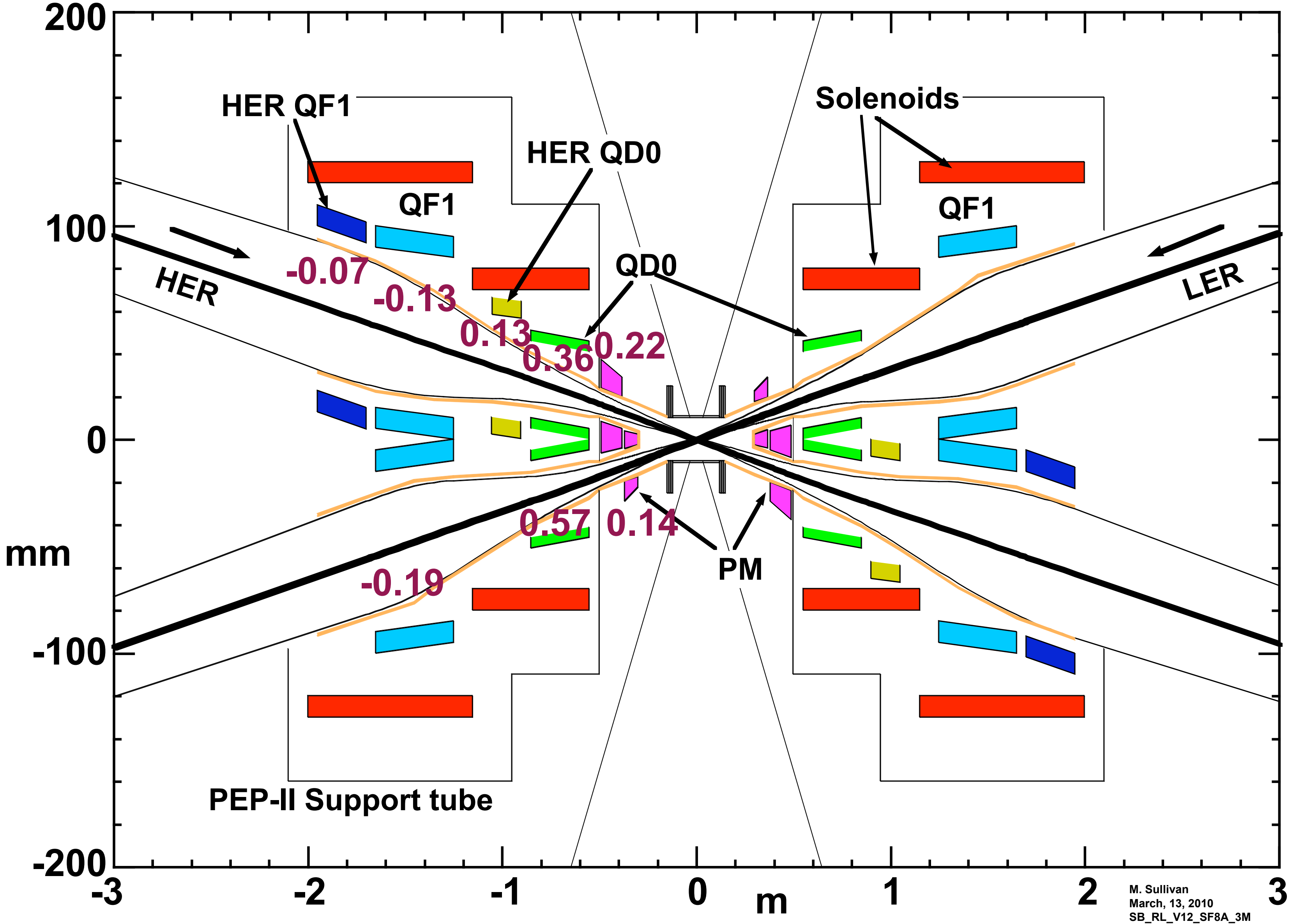
Quadrupole to IP Transfer Function

Quadrupole motion in Y	Vibration transfer fn
QD0	~ 0.35
QF1	~ -0.07
All Arc Quads (RMS sum, one ring)	< 0.03

- Collisions very sensitive to QD0 vertical motion
  - ~ 5x less sensitive to QF1 motion (and opposite sign)
  - Y angle and X position: > 100x less sensitive than Y position
- BUT, shared quads tend to cancel the effect
  - HER and LER sensitivities very similar
  - If shared quad is moved, both beams will be shifted same direction at IP
- (Values assume closed orbit, with tune near ½ integer)

Corrected from Bertsche, IX SuperB General Meeting (June 2009, Perugia)

Transfer Functions of IR Components



Cryostat Motion

Cryostat motion at end	Cryostat to IP transfer function
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 ~98% of effect of single QD0 motion!
  - Sounds very optimistic
  - Assume worst case ~5x worse: ~90% reduction (transfer fn ~ 0.035)
- Rotational motion needs to be limited
  - Avoid building torques into IR magnet support system
  - Allow no more than ~ 0.2 μrad rotation

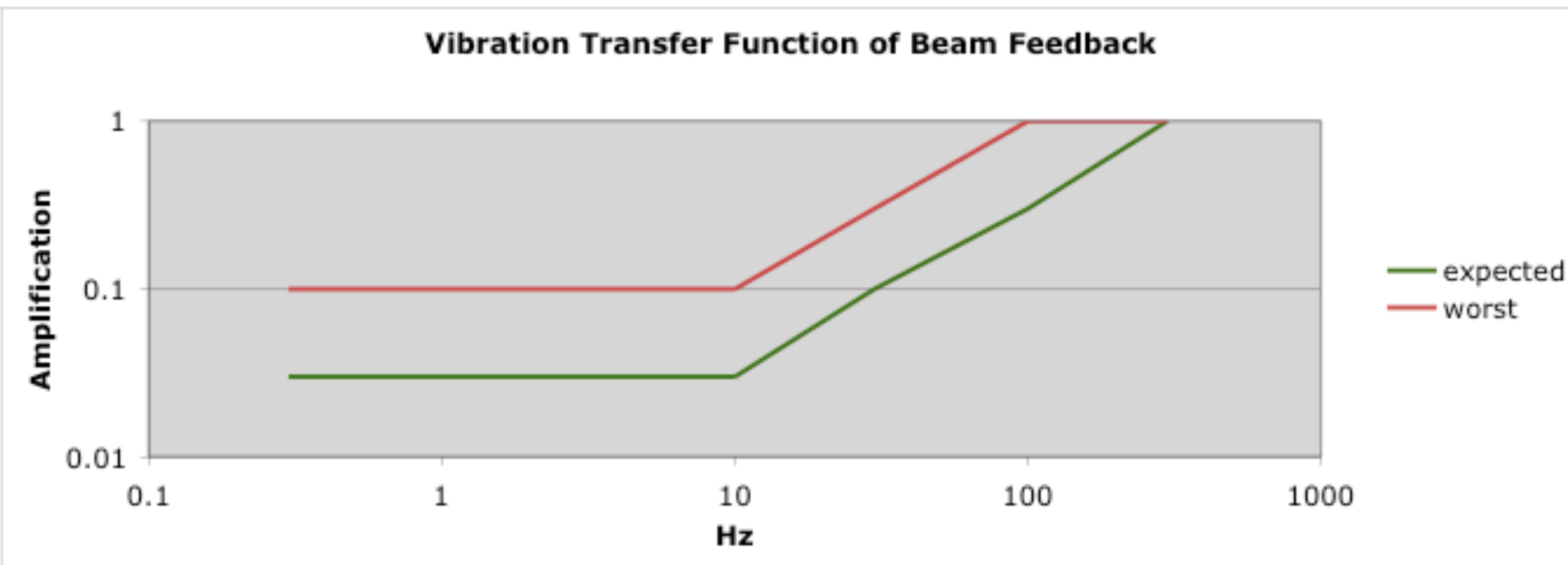
Proposed Vibration Budget

Element	RMS motion	Xfer Fn	IP displacement	
			no feedback	with feedback
Cryostat linear	< 1 μm	< 0.035	< 35 nm	< 3.5 nm
Cryostat rotation	< 2 μrad	0.014 m/rad	< 30 nm	< 3 nm
Arc quads	< 1 μm	0.03	< 30 nm	< 3 nm
Total (two rings)			< 78 nm	< 7.8 nm

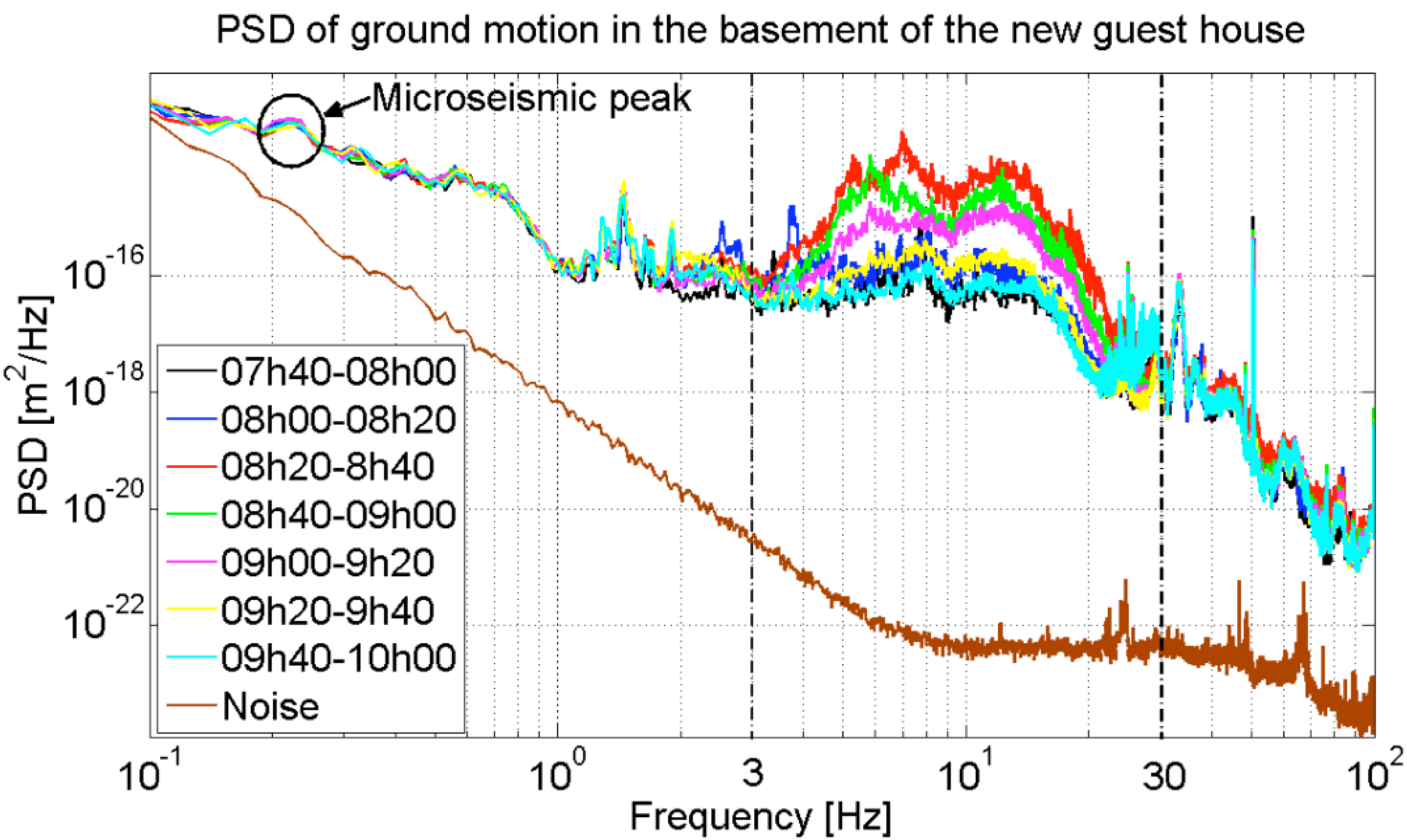
- Assumes beam feedback achieves > 10x reduction of motion at IP
  - If motion is kept 10x smaller, may not need beam feedback
- Budget applies to integrated RMS motion > 1 Hz
- This budget will keep relative motion < 8 nm, and lumi loss < 1%

Active Beam Feedback

- Fast dither system
  - Presented by Bertsche at VIII SuperB General Meeting (Feb 2009, Orsay), PAC09 (May 2009, Vancouver)
- Fast IP feedback system
  - Presented by Drago at VIII SuperB General Meeting (Feb 2009, Orsay)
- Need >100 Hz bandwidth, >10x vibration reduction at LF

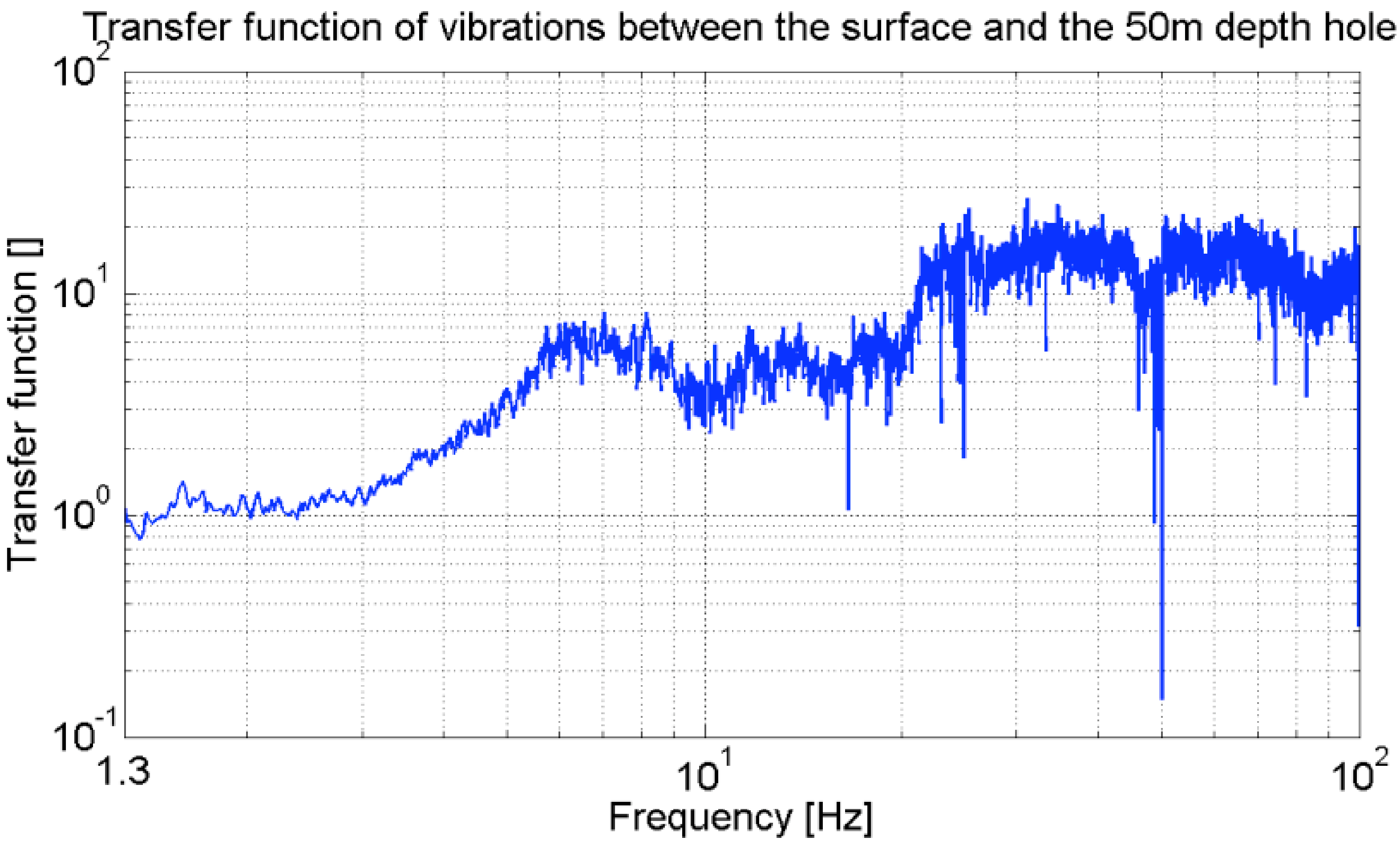


Ground Motion at LNF



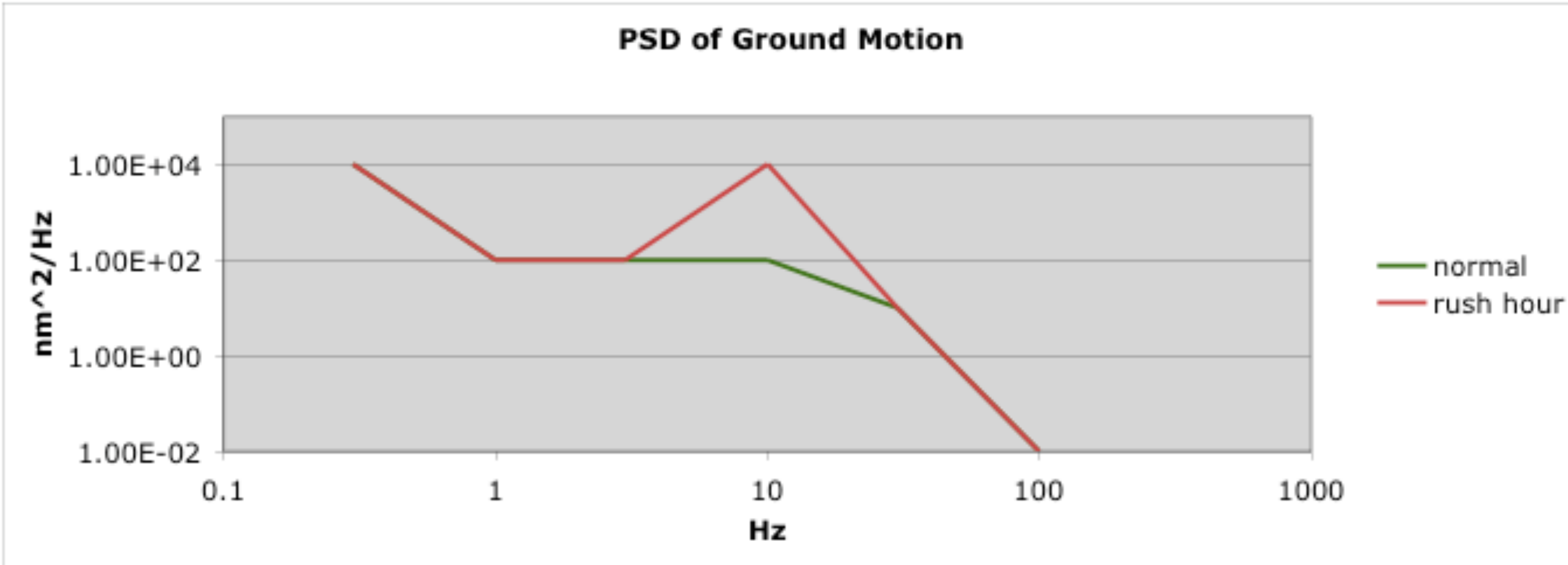
From Bolzon et al, XI SuperB General Meeting (Dec 2009, Frascati) and IPAC10 (Kyoto, Japan)

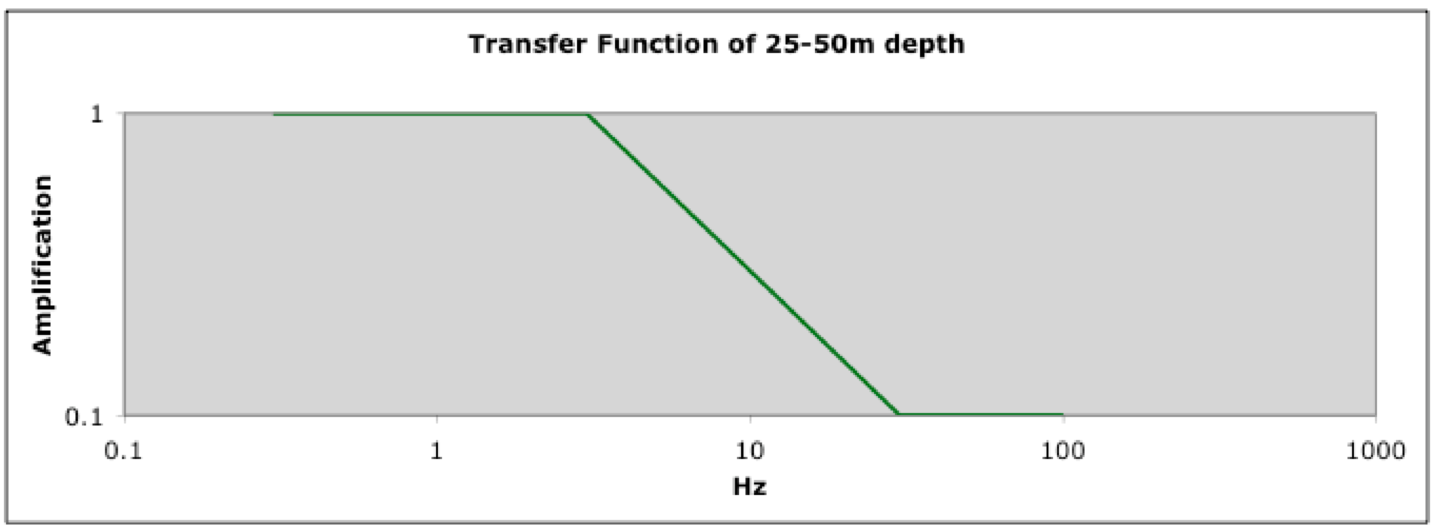
Vibration Attenuation with Depth



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

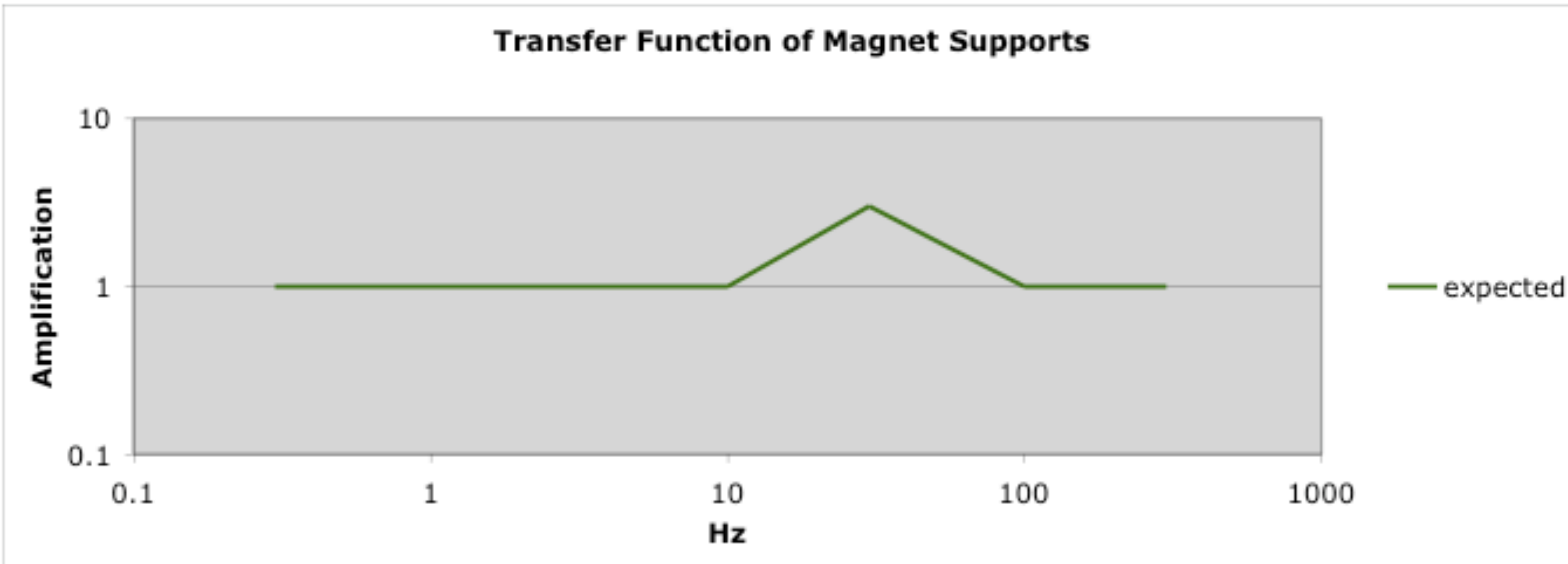
Idealizations For Error Budget



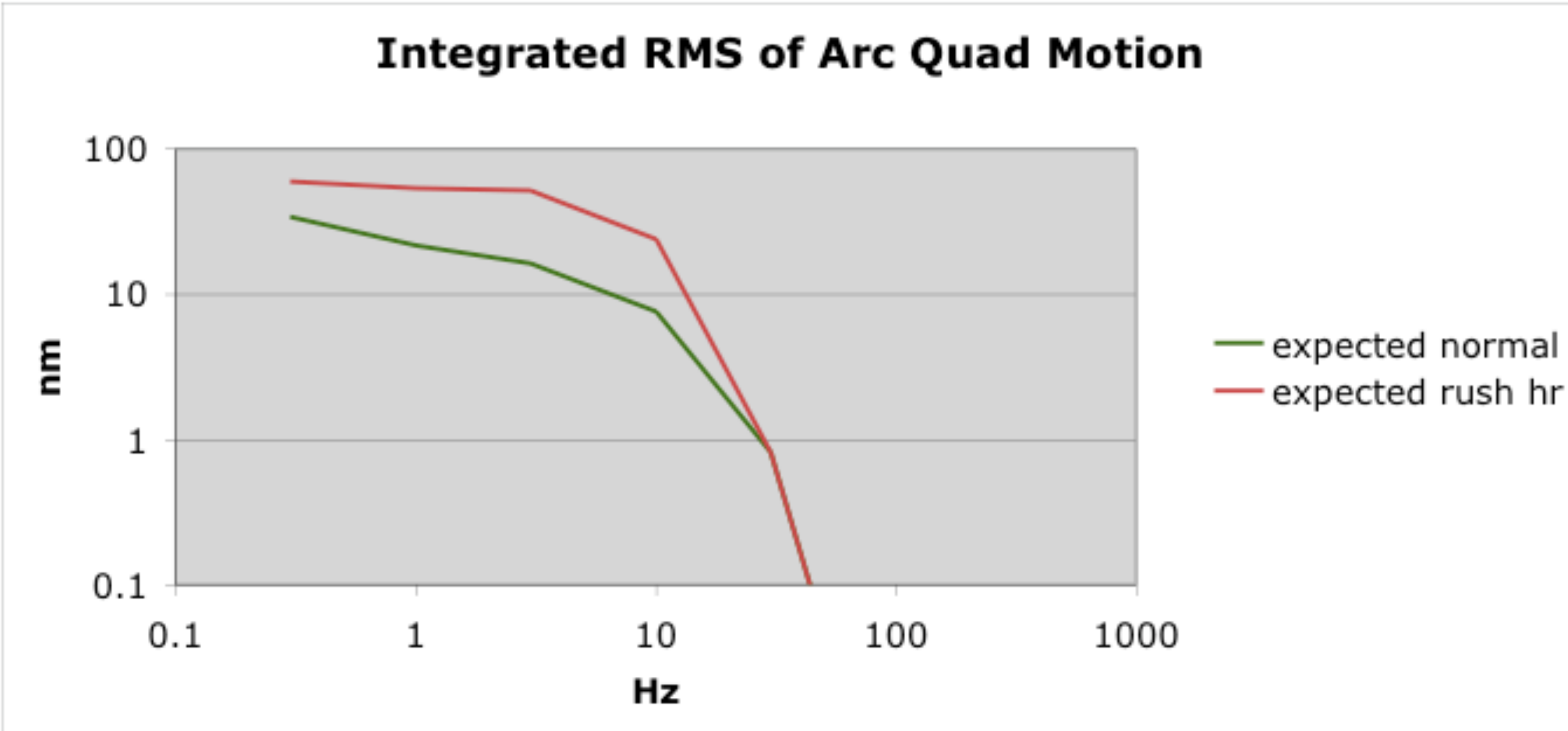


Vibration Amplification of Magnet Supports

- Magnet supports may amplify vibrations slightly in 10-100 Hz range
- This should be small (< 3x)

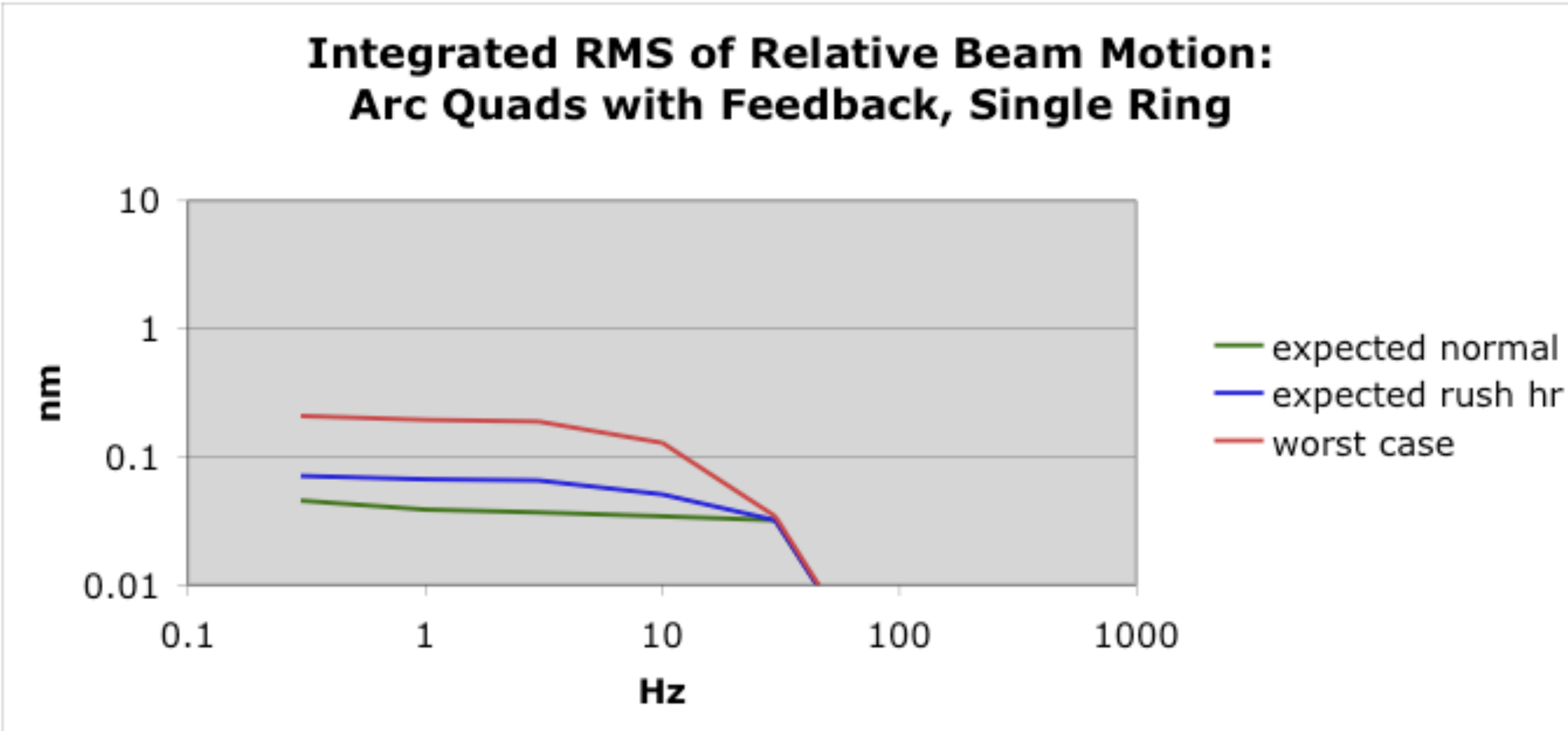


Arc Quad Motion



- Includes ground motion and quad supports
- Arc quads should easily meet error budget of < 1 μm motion
- Magnet supports could amplify ground motion by 10x more and still meet budget

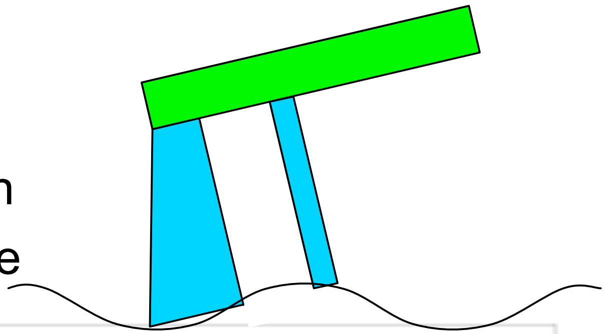
IP Motion Due to Arc Quads, With Feedback

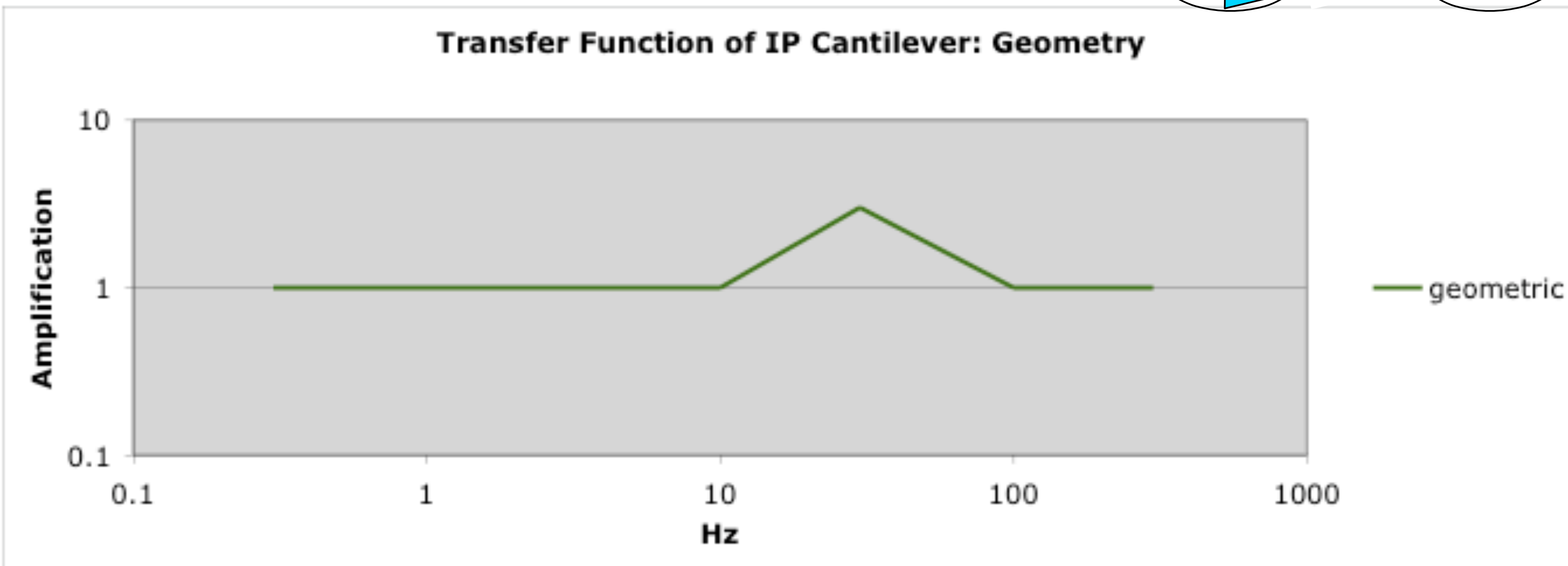


- Includes ground motion and quad supports
- Arc quads should easily meet error contribution of < 3 nm at IP
- Magnet supports could amplify motion by 10x more and still meet budget

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

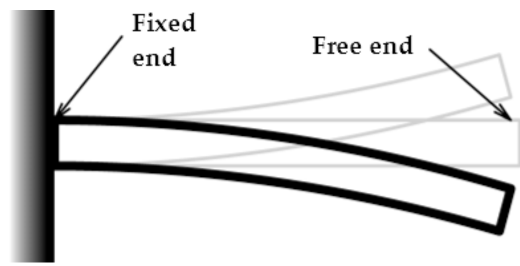


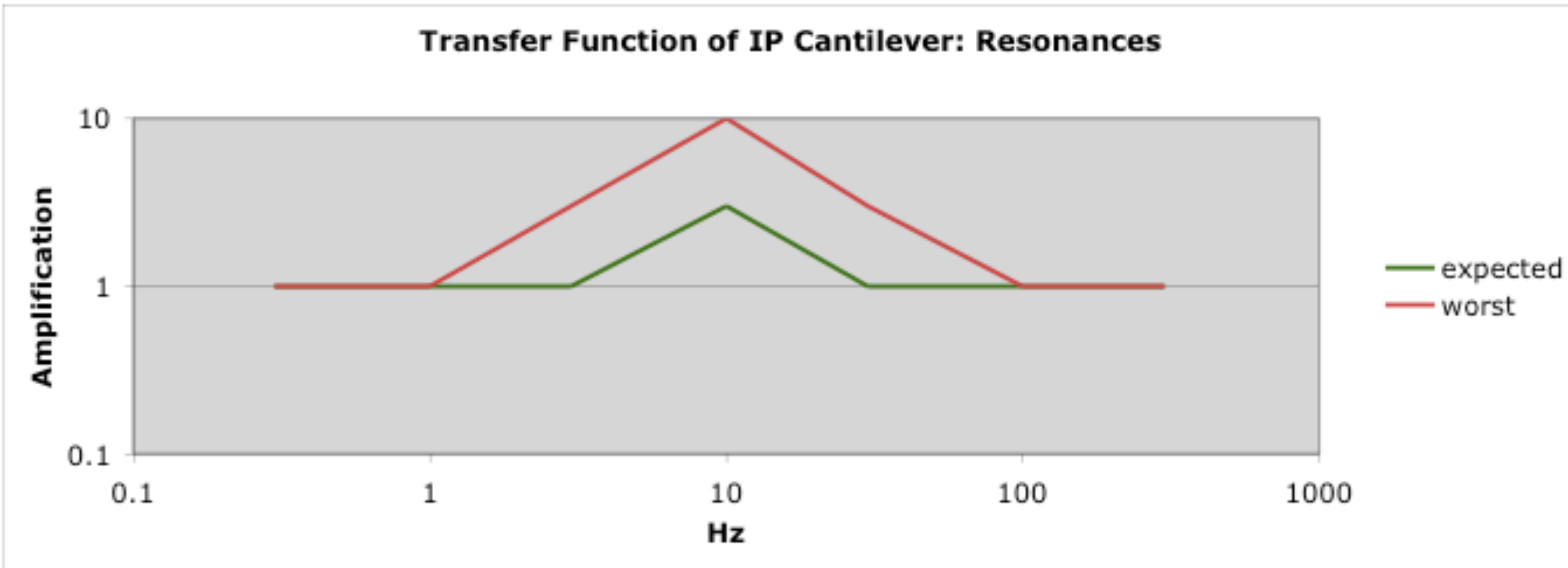


- Assumes:
  - Ground vibration wave velocity 100-200m/s
  - Cantilever ~ 2 m
  - Base 1-2 m

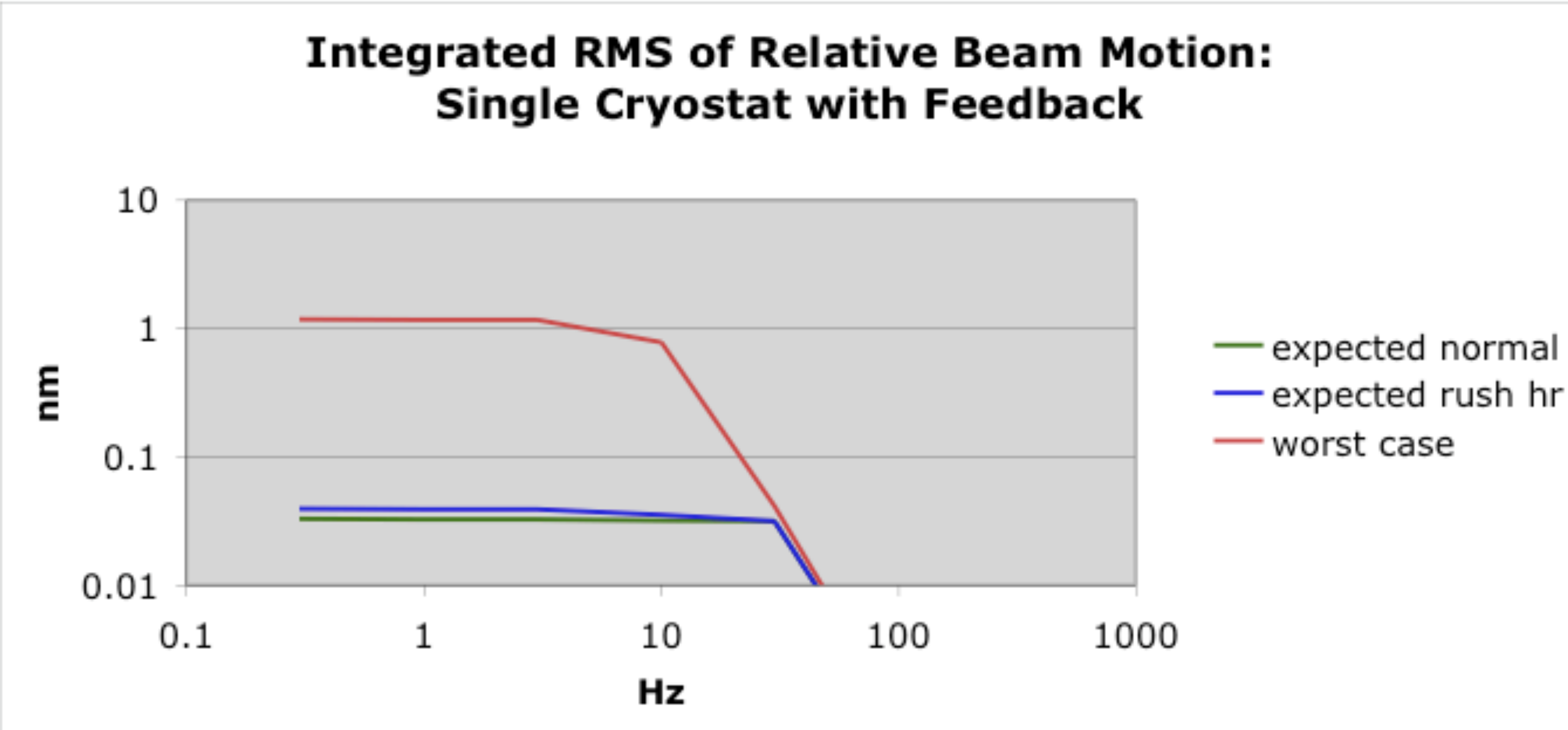
Vibration Amplification of IR

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



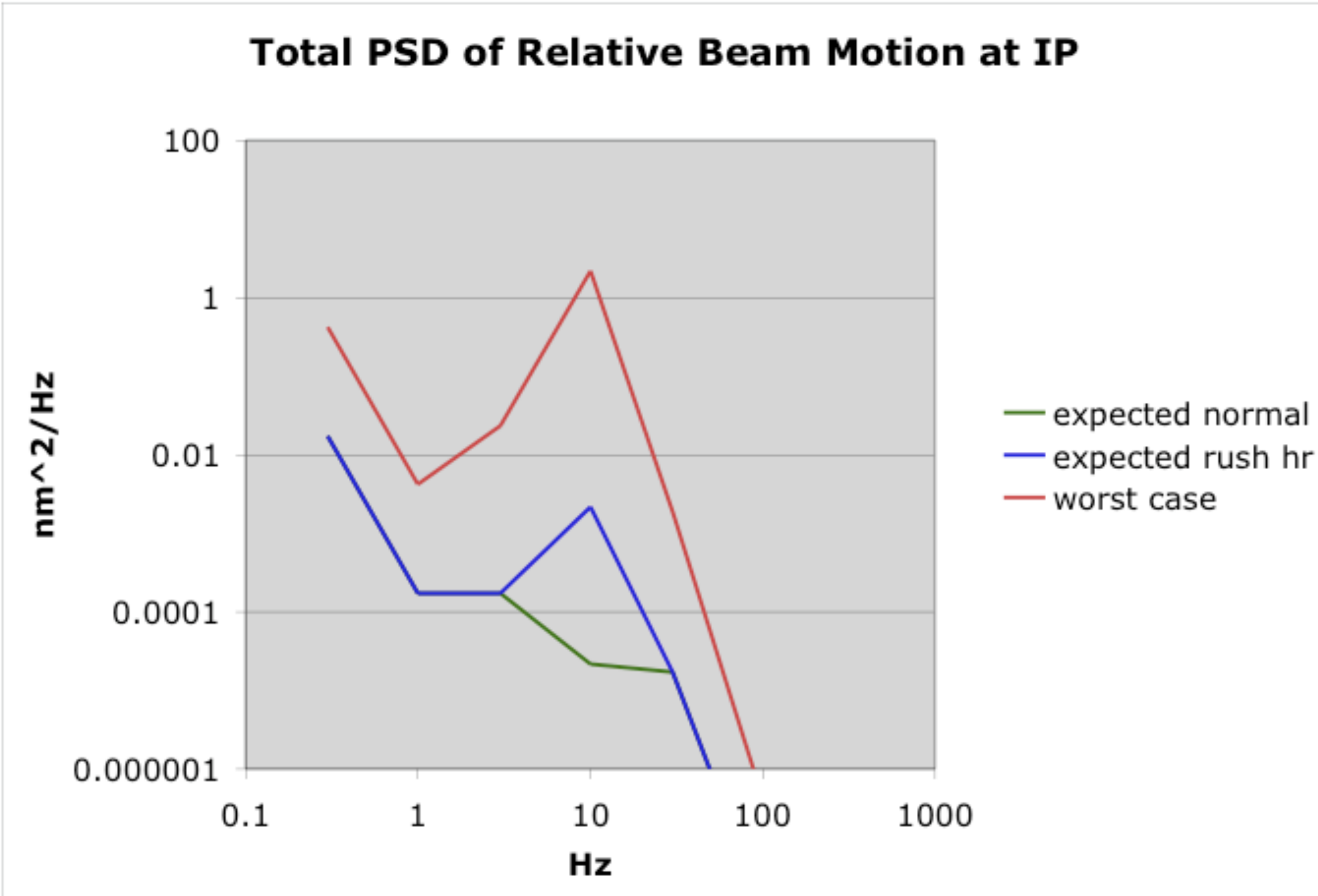


IP Motion Due to Cryostat, with Feedback



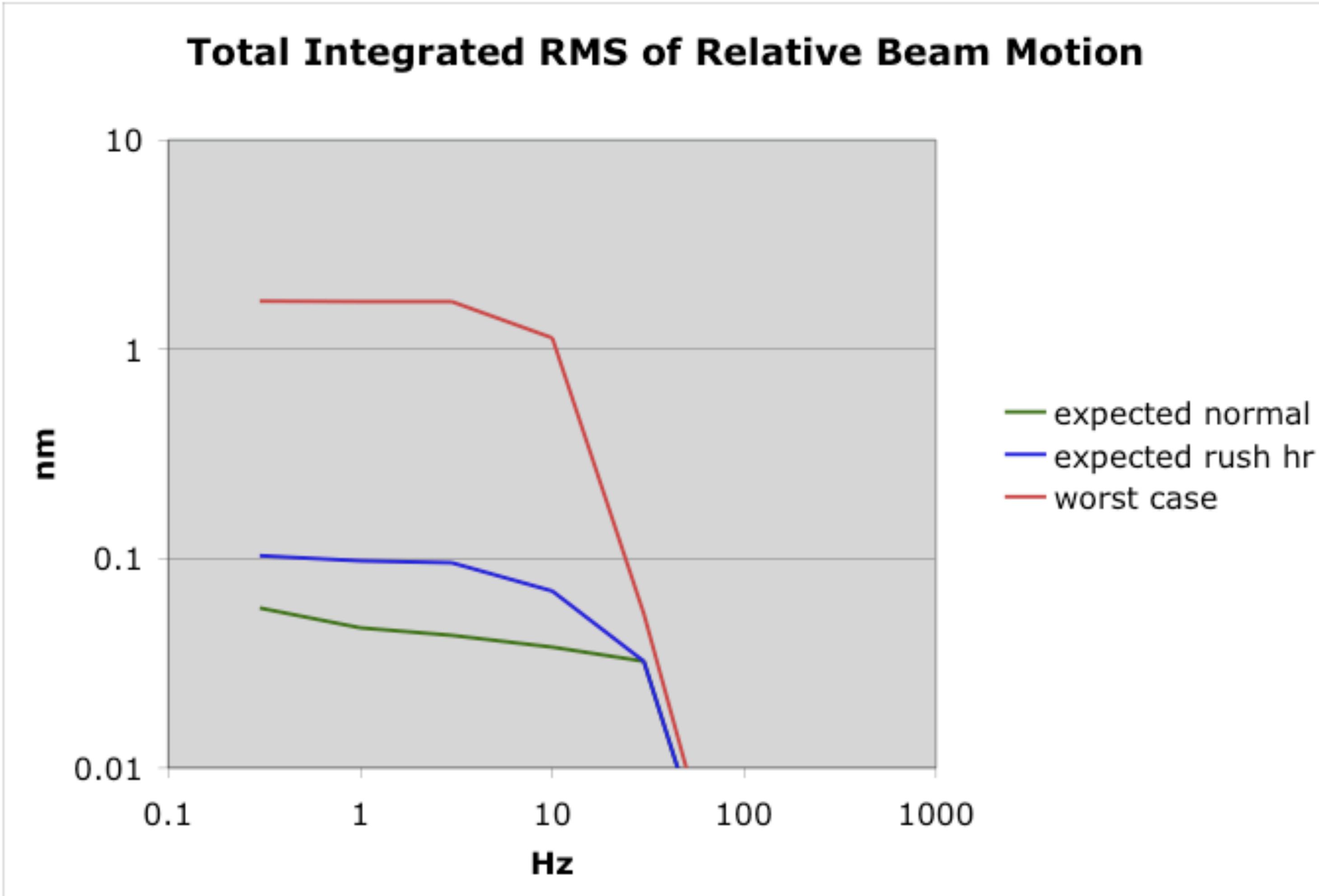
- Includes ground motion, cantilever geometry, cantilever resonances, and transfer function to IP displacement
- "Worst case" includes 5x worse deflection sensitivity of cryostat
- Cantilever should meet error contribution of < 3 nm motion at IP
- Worst case *common mode* motion at IP should be < 150 nm

Total Beam Displacement at IP



- Includes ground motion, arc quad vibration, and cryostat vibration, but NOT cryostat rotation

Total Beam Displacement at IP

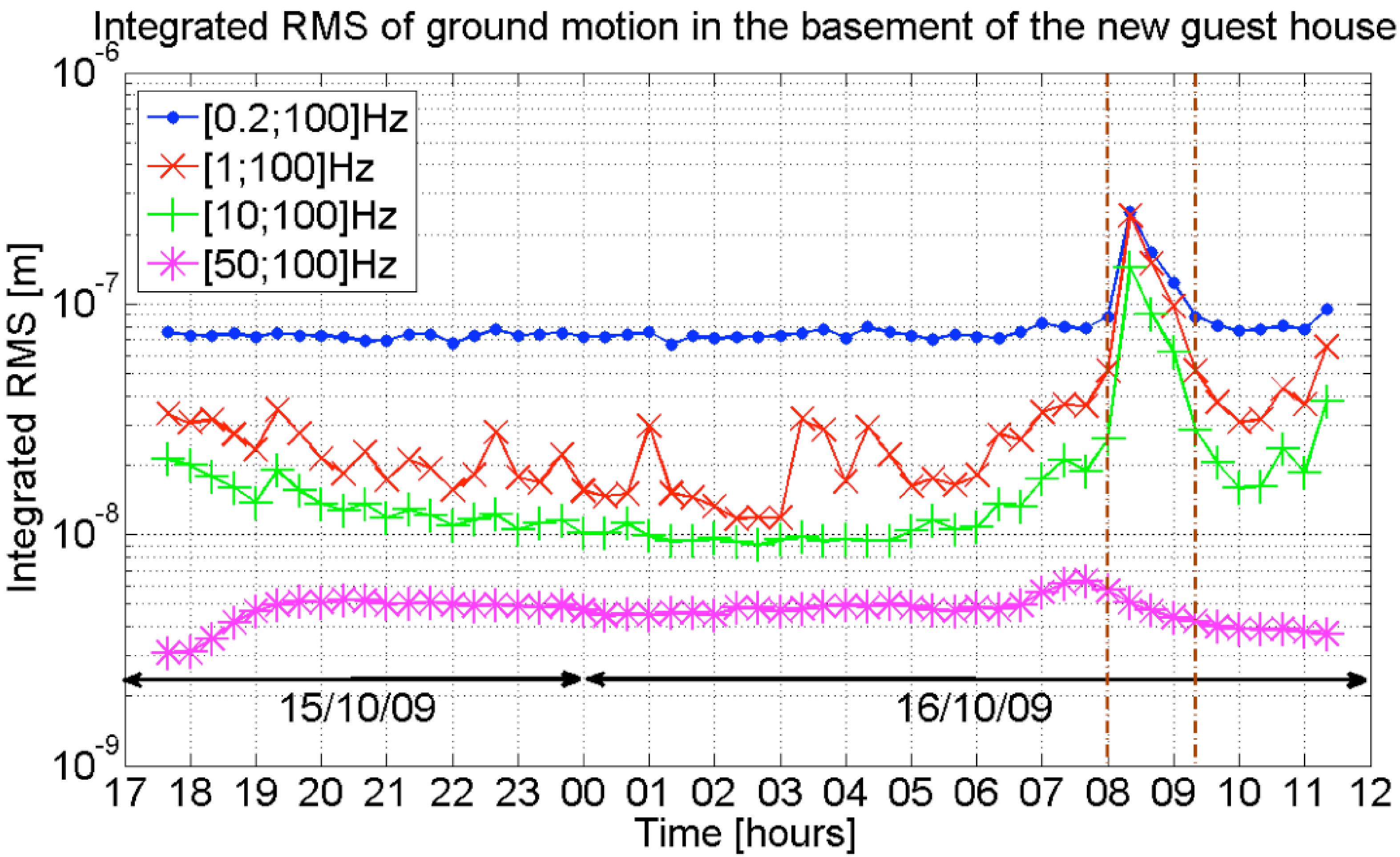


- Includes ground motion, arc quad vibration, and cryostat vibration, but NOT cryostat rotation
- Need < 8nm for < 1% loss of luminosity

Summary

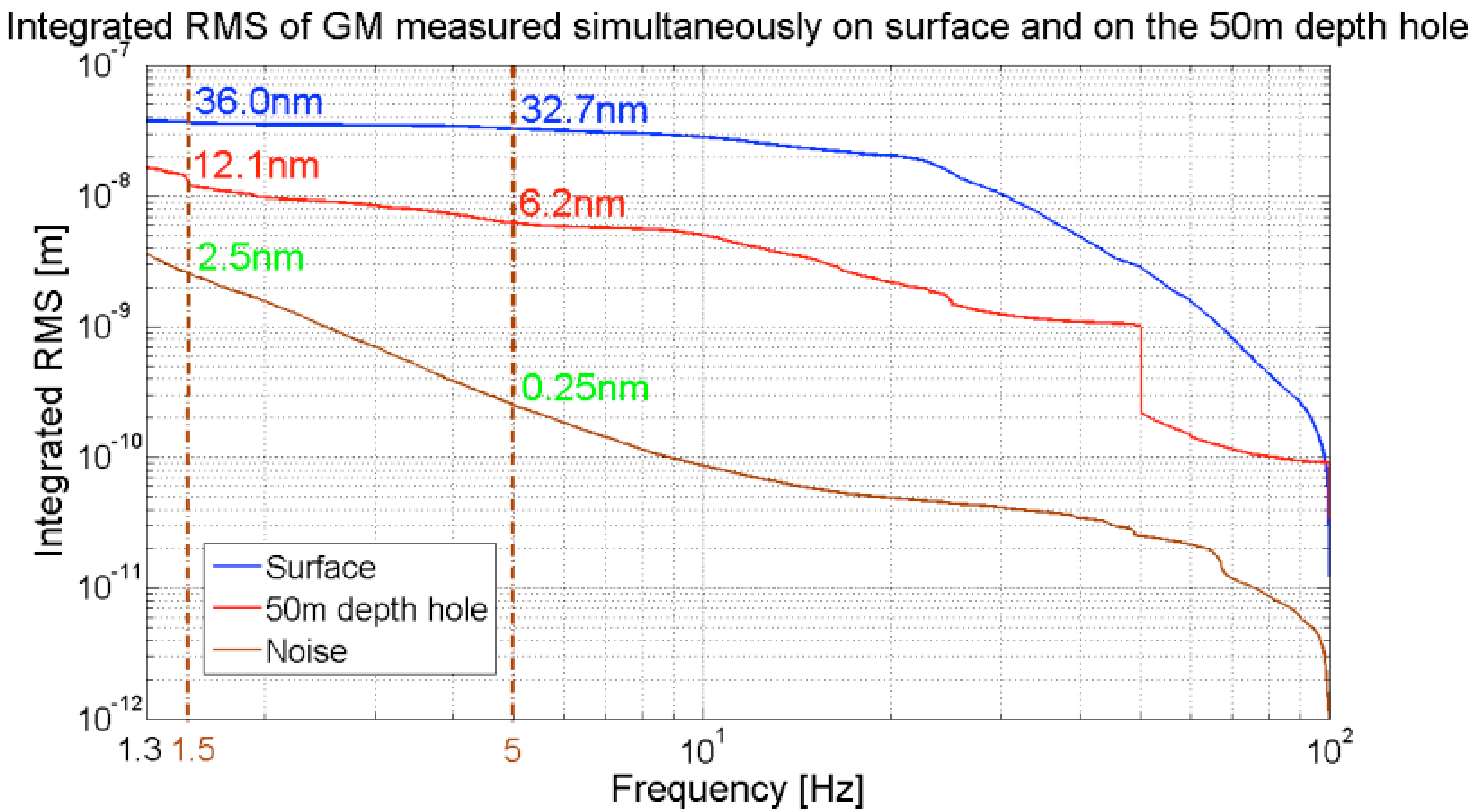
- Must keep quad motion below 1 μm
  - Cantilevered cryostat should be designed for low vibration
    - Damp resonances and push > 10 Hz
    - Support cryostat on both sides of detector door
- Must keep cryostat rotation below 2 μrad
  - Avoid building torques into magnet supports
- Beam feedback should extend to > 100Hz, provide > 10x vibration reduction at LF
  - But we may not even need beam feedback during quiet parts of day
- Vibration should not be a problem for SuperB at LNF, even at rush hour

Ground Motion Data



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

Vibration Variation with Depth



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