



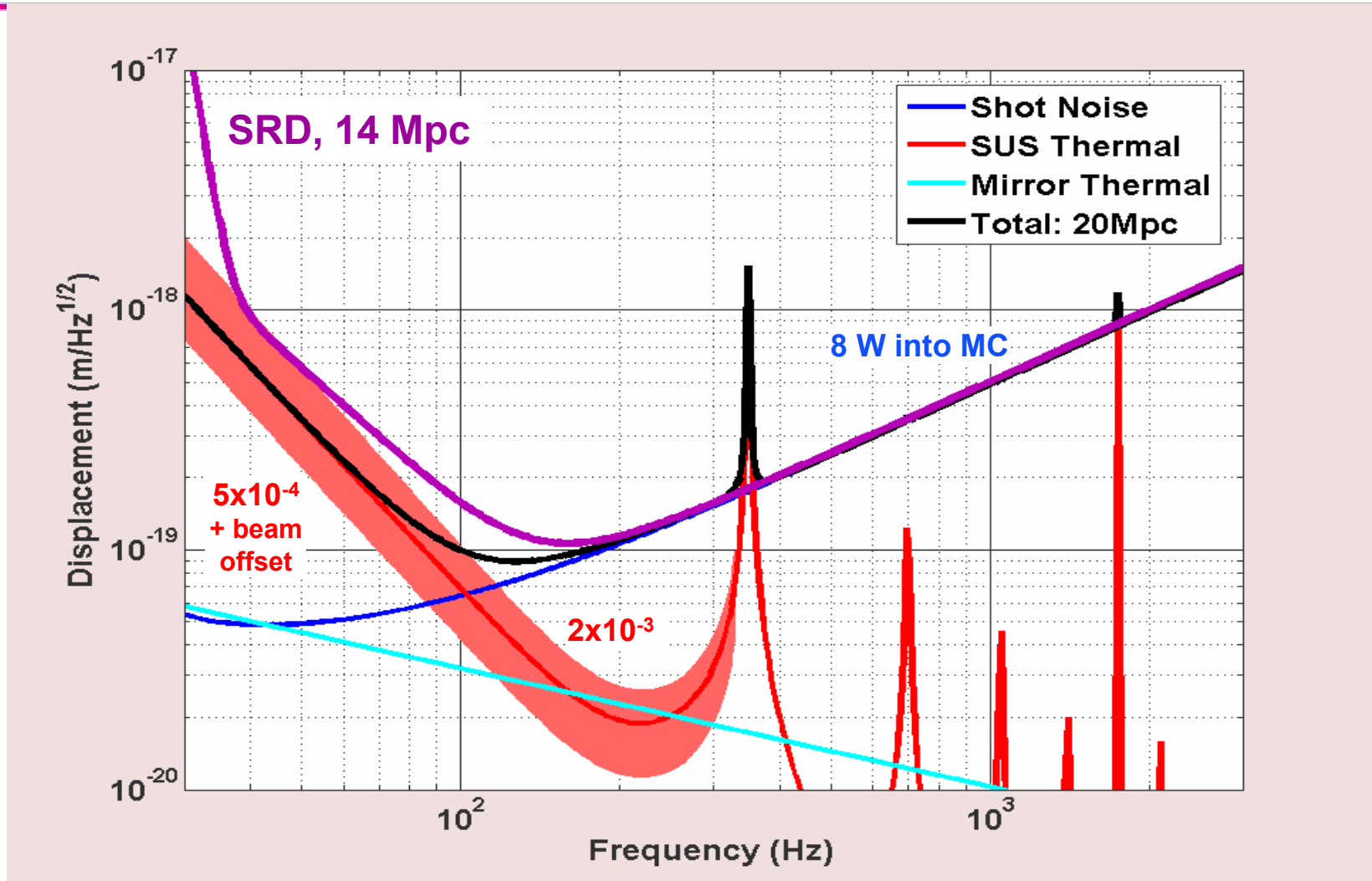
Initial LIGO improvements & Advanced LIGO

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PAC Meeting
LLO, 18 May 2005

General considerations

- ❑ Any upgrade must account for time to install and fully commission it, plus time for running!
- ❑ Plan should favor technologies, techniques, subsystems that are part of Advanced LIGO
- ❑ Plan should consider contingency options for potential AdLIGO delays
- ❑ Initial LIGO components/features that are not candidates for upgrade
 - Core Optics (except possible spare replacements)
 - Isolation stacks
 - IFO beam path (e.g., no suspension change that moves the optic)

Initial LIGO fundamental noises



See also Rana Adhikari's thesis

Astrophysical impact of a modest improvement

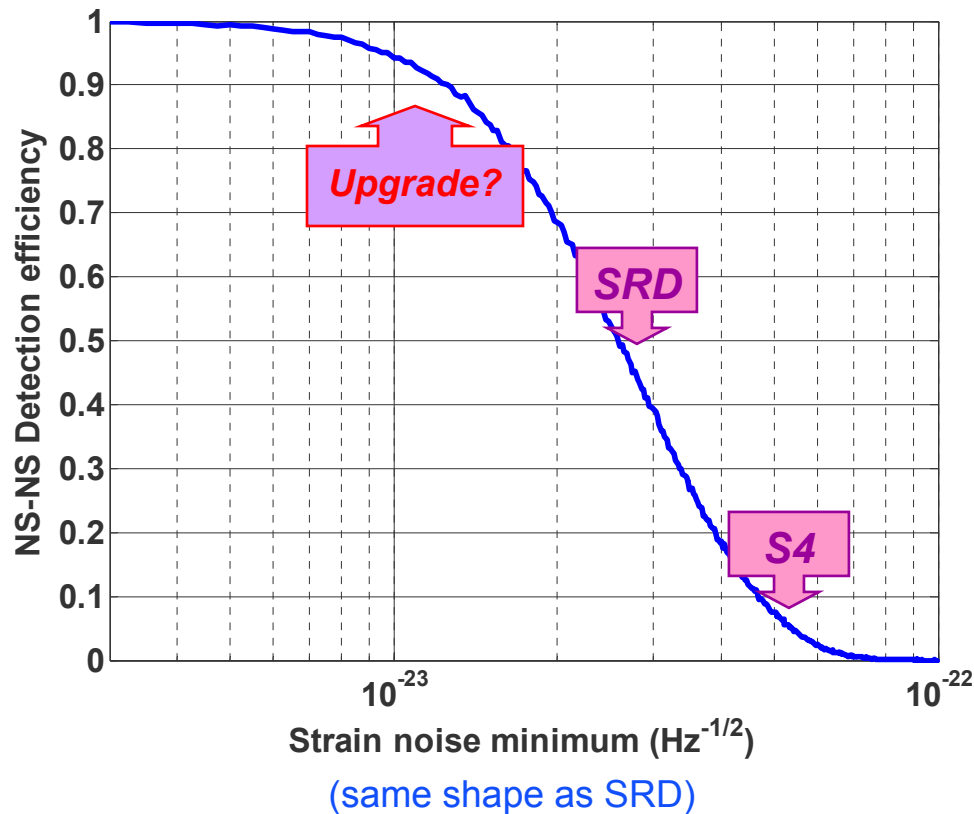
- How does the number of surveyed galaxies increase as the sensitivity is improved?

From astro-ph/0402091, Nutzman et al., "Gravitational Waves from Extragalactic Inspiring Binaries: Selection Effects and Expected Detection Rates"

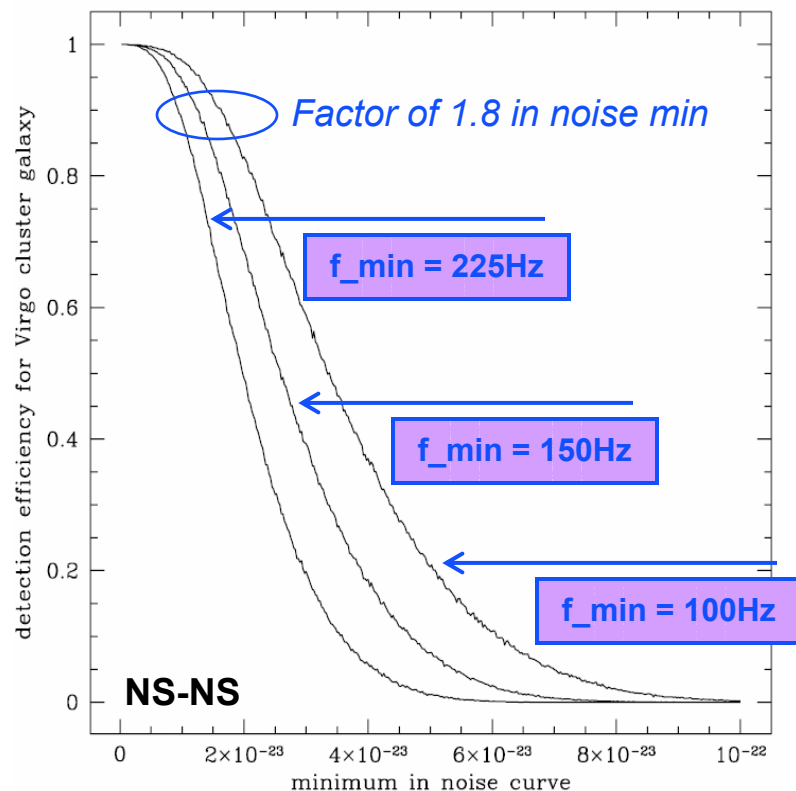


Sensitivity to Virgo cluster

Effect of reducing noise floor:



Effect of reducing min freq:



Data courtesy of Philip Nutzman

Detection rate estimates

Assuming factor of 6 increase in surveyed volume:

<i>Source</i>	<i>Initial LIGO</i>	<i>Improved</i>
NS-NS	~1 / 3000 yrs to ~1 / 3 yrs	~1 / 500 yrs to ~2 / yr
NS-BH	~1 / 5000 yrs to ~1 / 3 yrs	~1 / 800 yrs to ~2 / yr
BH-BH	~1 / 250 yrs to ~2 / yr	~1 / 40 yrs to ~12 / yr

Suspension options

- ❑ Find that current wire suspensions operate at wire-loss limit
 - Optimize with beam position shift (1 cm down from center)
- ❑ Find that current wire suspensions have excess loss
 - Design new clamping systems for the ends

Factor of 2-3 lower noise than SRD at 100 Hz

Beyond current wire suspensions: more than 3x below SRD

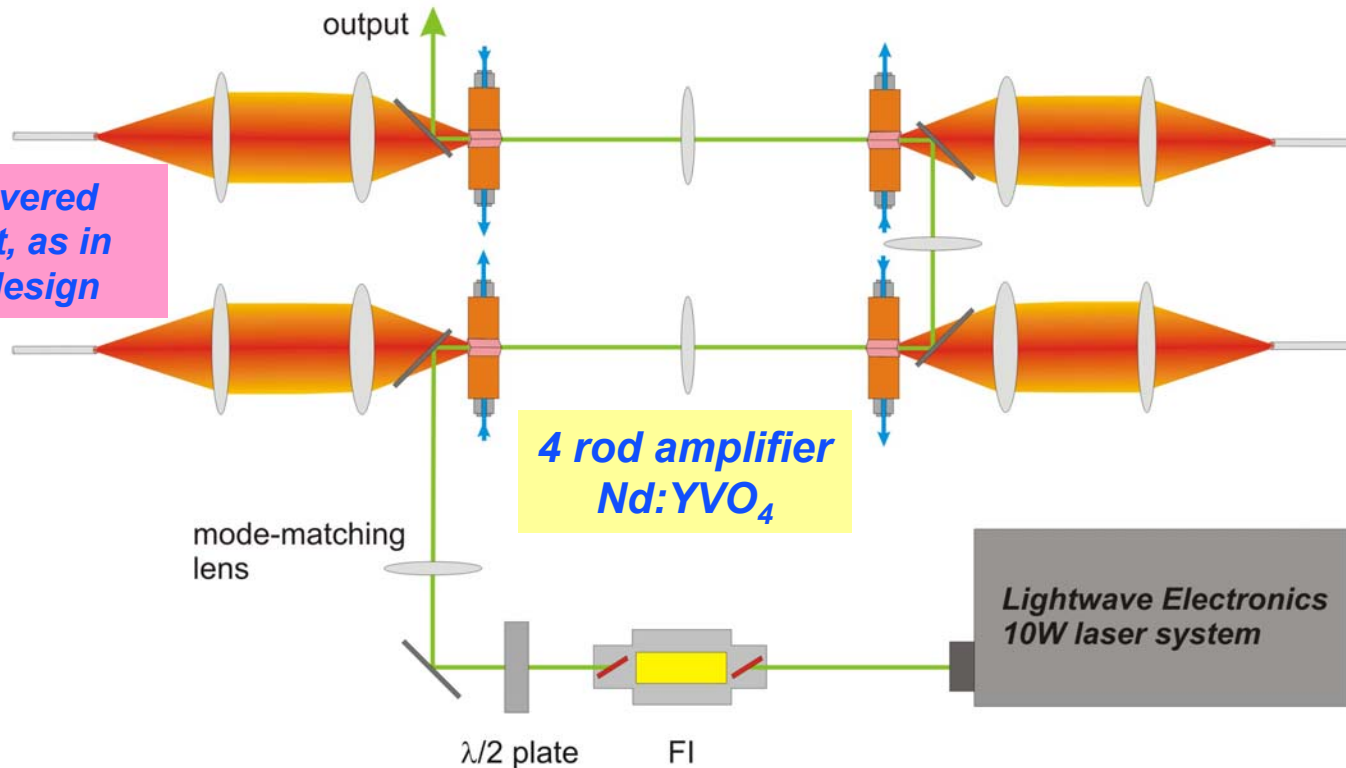
- ❑ Two wire loops
- ❑ Low-loss flexures
- ❑ Cradle for optic, suspended by silica fibers
 - See G020241 & G020242

Research needed: In-vacuum test suspension, to investigate violin mode Q's of current wire suspension, and potential variants

Power increase: 4x more laser power

Higher power laser

- Amplify current Lightwave Electronics laser with commercial amp
- Amplifier from Laser-Zentrum Hanover (LZH)



Input Optics to handle it

❑ New electro-optic modulators

- Thermal lensing in current modulators (LiNbO₃) would be too high
- Use modulators developed at UFI for Advanced LIGO
- RTP & RTA, 4 mm x 4 mm aperture, negligible thermal lensing at 100 W

❑ New in-vacuum Faraday isolator

- Current isolators produce beam drift, would lens too much at higher power
- Use AdLIGO Faraday isolator, developed at UFI
- Design uses birefringence & thermal lensing compensation; different polarizer type

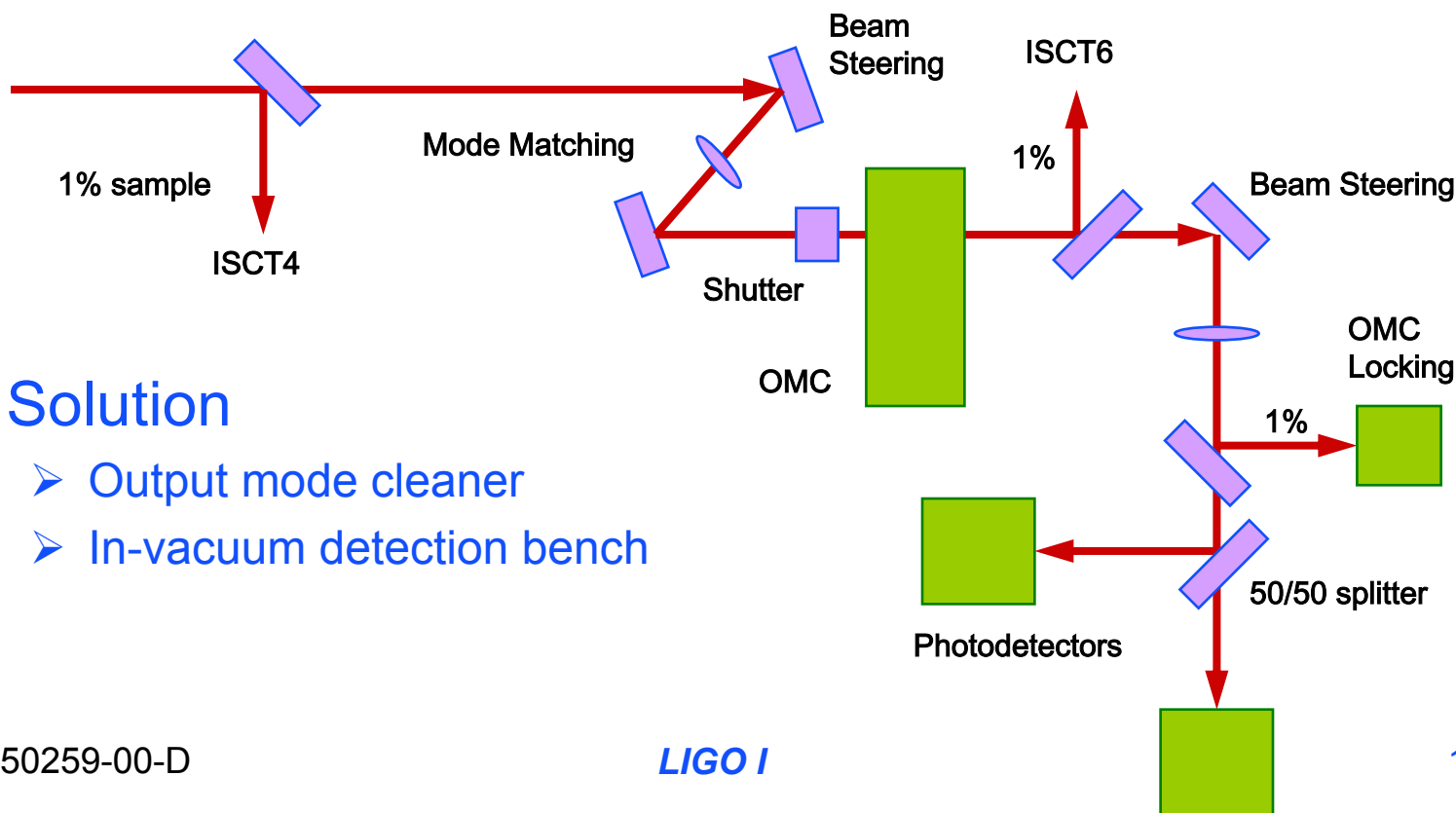
❑ Replace or clean mode cleaner optics ?

- MC transmission only ~75%

Output mode cleaner to handle the output power

Basic motivations

- Quadruple the photodetectors: 4 \Rightarrow 16 !
- Acoustic noise: close to limiting sensitivity now (jitter on detection tables); H1-H2 stochastic sensitivity limited by it

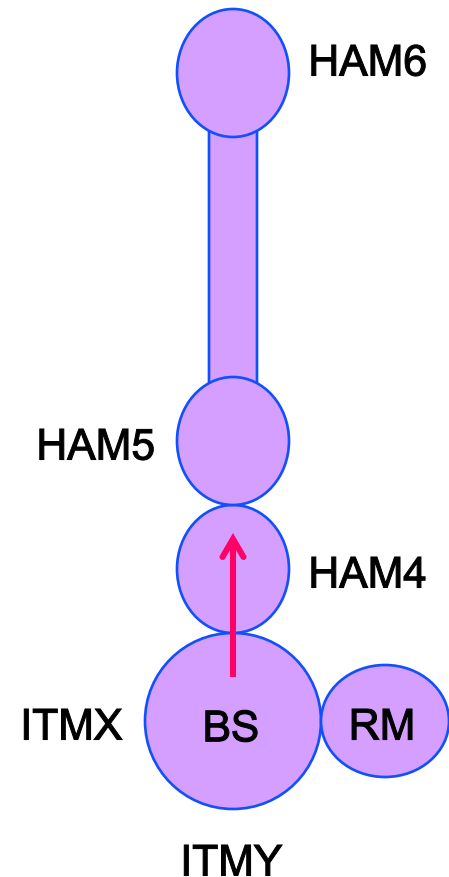


Solution

- Output mode cleaner
- In-vacuum detection bench

OMC design options

- ❑ Monolithic spacer cavity
 - Triangular or 4 mirror zig-zag
 - Low finesse
 - Sidebands pass on same FSR
 - Easier design, HAM5 or HAM6
 - Could test DC readout with a higher finesse version
- ❑ Suspended
 - Same design as input mode cleaner
 - High finesse
 - Sidebands pass on next over FSR
 - More complicated design, more expensive, HAM5 and HAM6
- ❑ Seismic isolation
 - Initial LIGO stack
 - Advanced LIGO HAM isolation



Thermal compensation

- ❑ Current thermal compensation system (TCS) on H1 compensates for 100 mW absorbed power

- Working to extend this with a higher power CO2 laser

- ❑ If optics absorb at their expected level

$$0.1 \text{ W} = (P_{bs} / 2)(4 \text{ ppm/cm} \times 20\text{cm} + 0.6 \text{ ppm} \times 130)$$

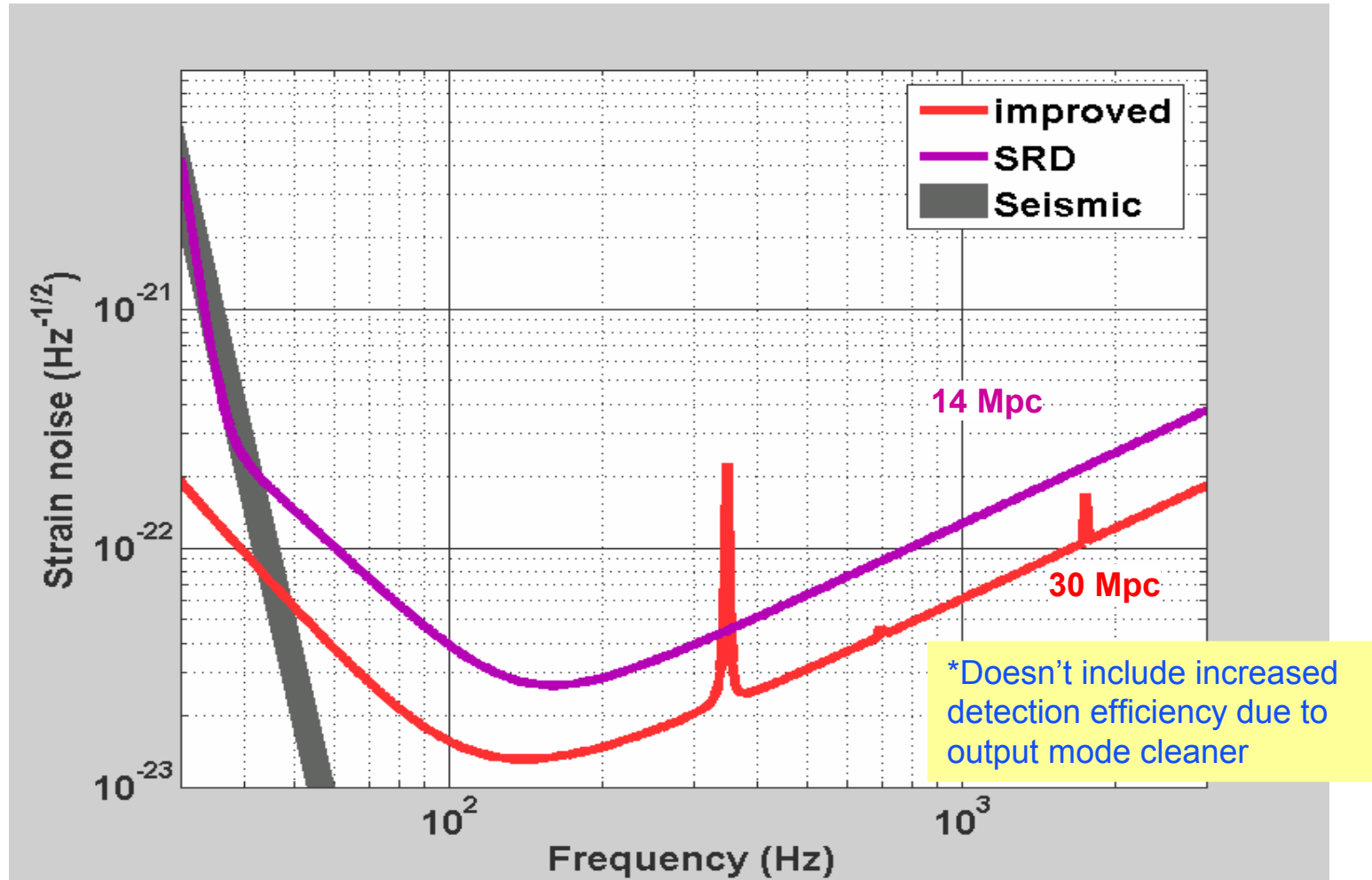
$$\Rightarrow P_{bs} = 1.3 \text{ kW}$$

- ❑ Initial LIGO estimate: $P_{bs} = 8\text{W} \times 0.65 \times 40 = 200 \text{ W}$:

- *factor of 6 headroom*

- ❑ Potential that extra-absorbant core optics would be replaced

4x more power* & good wire suspensions + beam offset



Other possibilities

□ Add PEPI to the LHO test masses

- Sensors (large part of cost) would be useable in AdLIGO
- Could help with up-conversion

□ Dealing with wind noise (both sites)

- Adding good tilt sensing to HEPI

□ Miscellaneous

- AdLIGO electronics improvements: lower noise ADCs; new architectures for controls and monitoring
- Detection table seismic isolation
- Acoustic mitigation at LHO