Realizing Cosmic Explorer 2 with Evolved LIGO A+ or Voyager Technology

Kevin Kuns
for the
Cosmic Explorer Project

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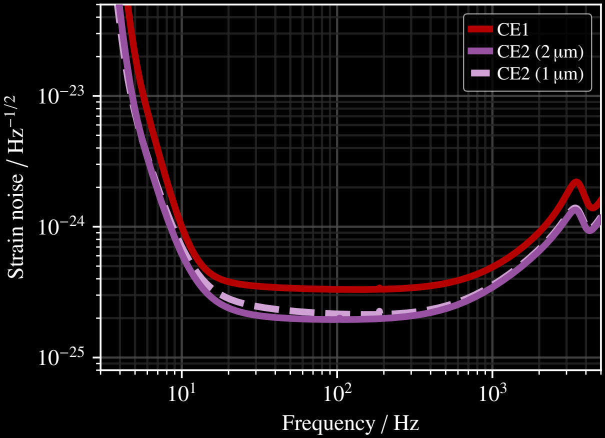
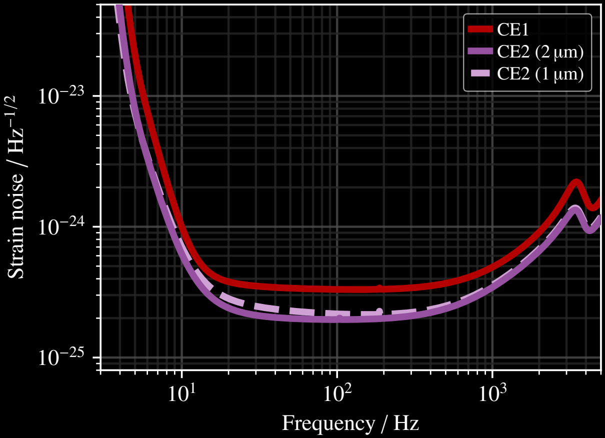
Cosmic Explorer



arXiv:2012.03608

Cosmic Explorer

- 40 km L-shaped surface facility



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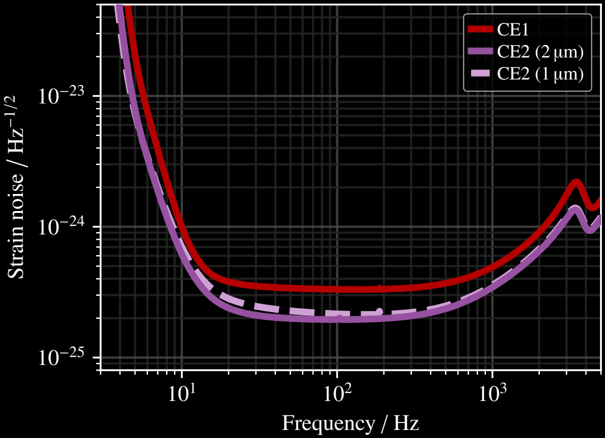

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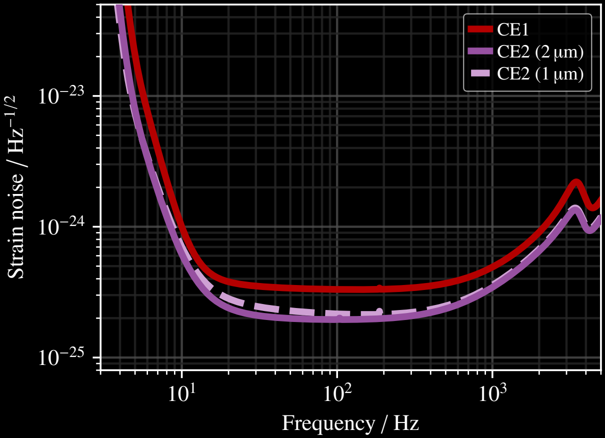

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COSMIC EXPLORER

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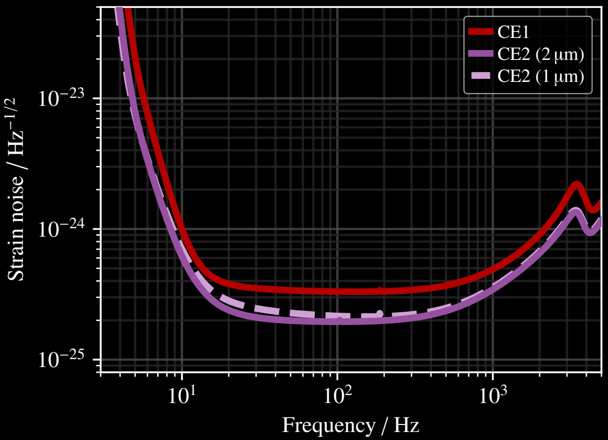

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COSMIC EXPLORER

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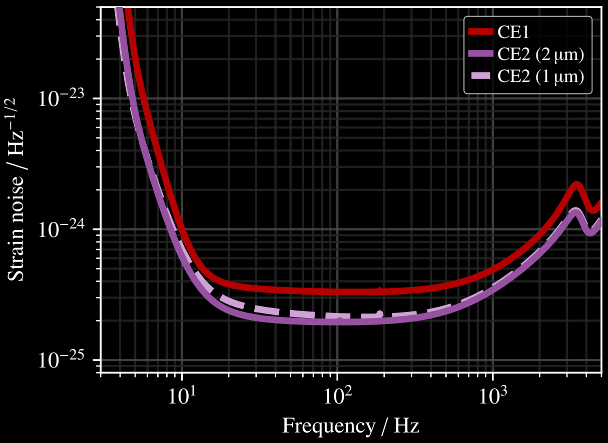

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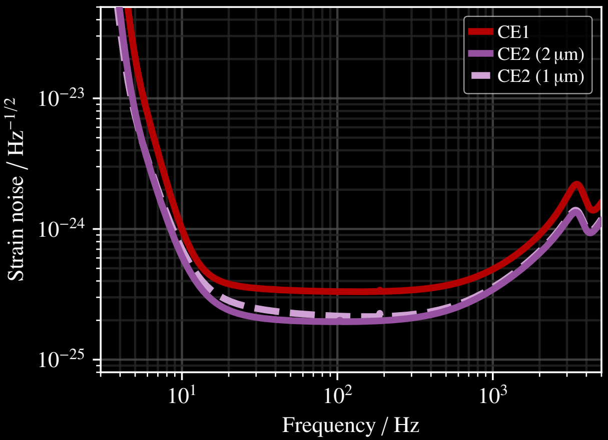

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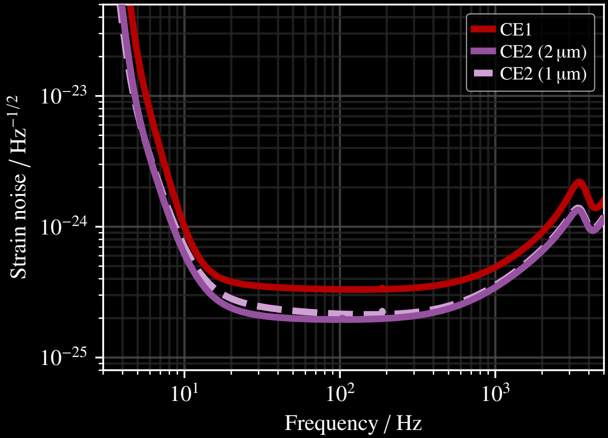

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- Facility can support future detectors

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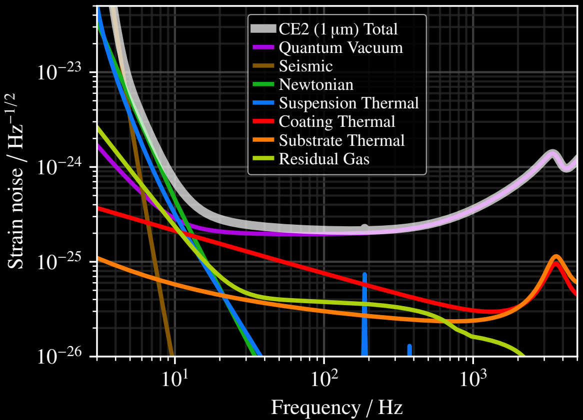
Cosmic Explorer 2

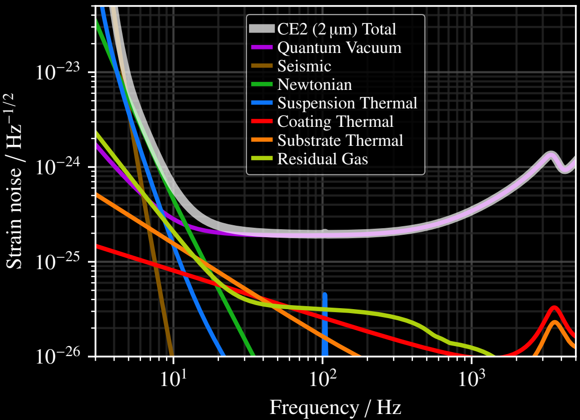
LIGO A+ Technology



1 μm laser

Room-temperature fused-silica optics

Voyager Technology

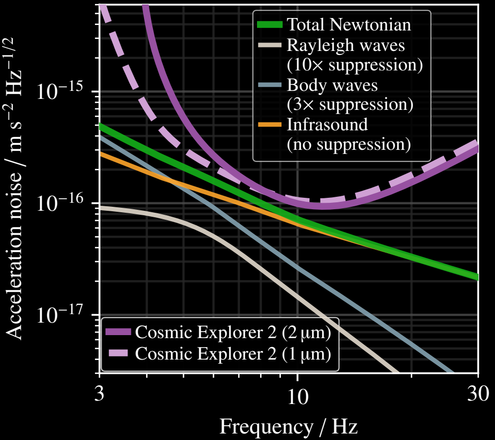


2 μm laser

Cryogenic silicon optics

Facility upgrades result in similar sensitivities for both designs

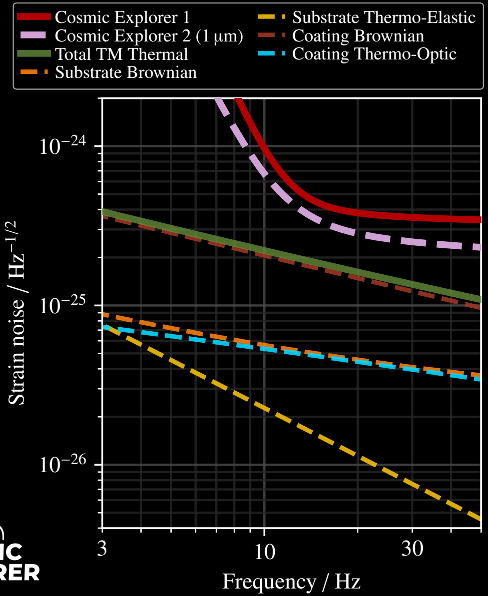
Newtonian noise

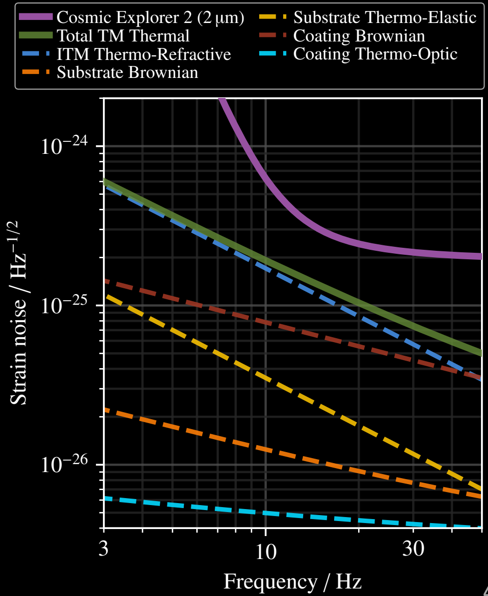


- Suppression techniques are facility upgrades common to both technologies resulting in the same Newtonian noise for both
- Seismometer array subtraction
- Excavation underneath test masses
- Berms, trenches, and seismic metamaterials

COSMIC EXPLORER

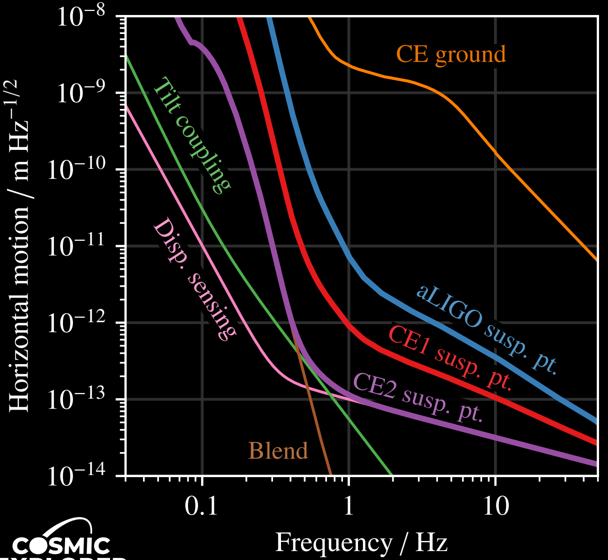
Test mass thermal noise





COSMIC EXPLORER

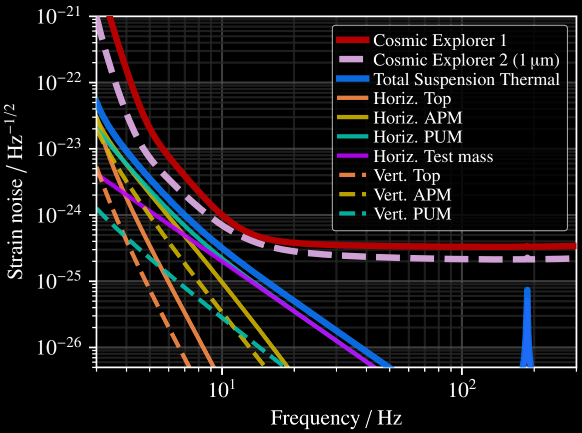
Seismic noise and inertial isolation

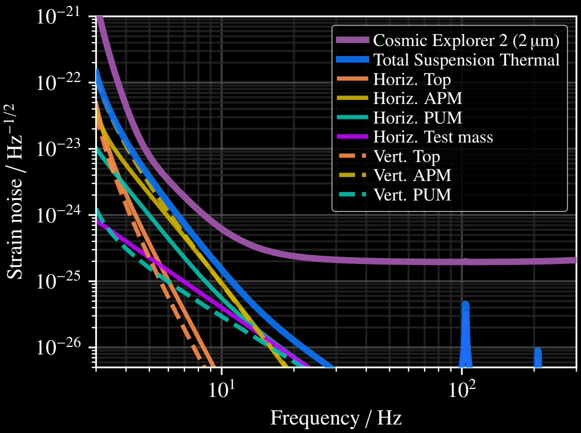


- Both detector technologies have similar seismic noise
- Both technologies use suspensions with final stage blade springs to reduce vertical resonances: Sebastien's talk
- CE2 target requires 100× improvement over aLIGO inertial isolation performance at 1 Hz
- Several novel isolator ideas: Mow-Lowry & Martynov, van Heijningen, …

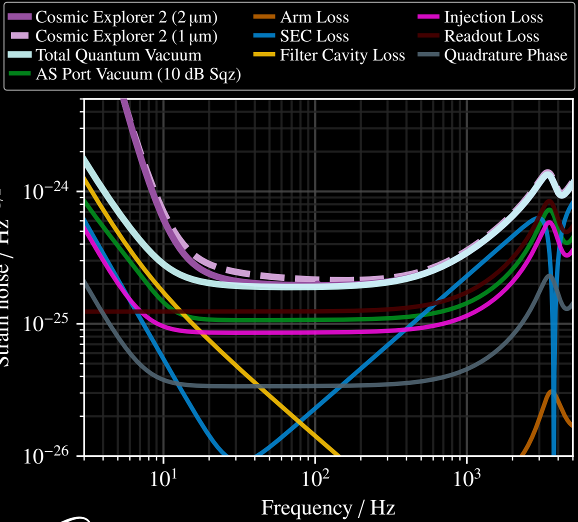
COSMIC EXPLORER

Suspension thermal noise



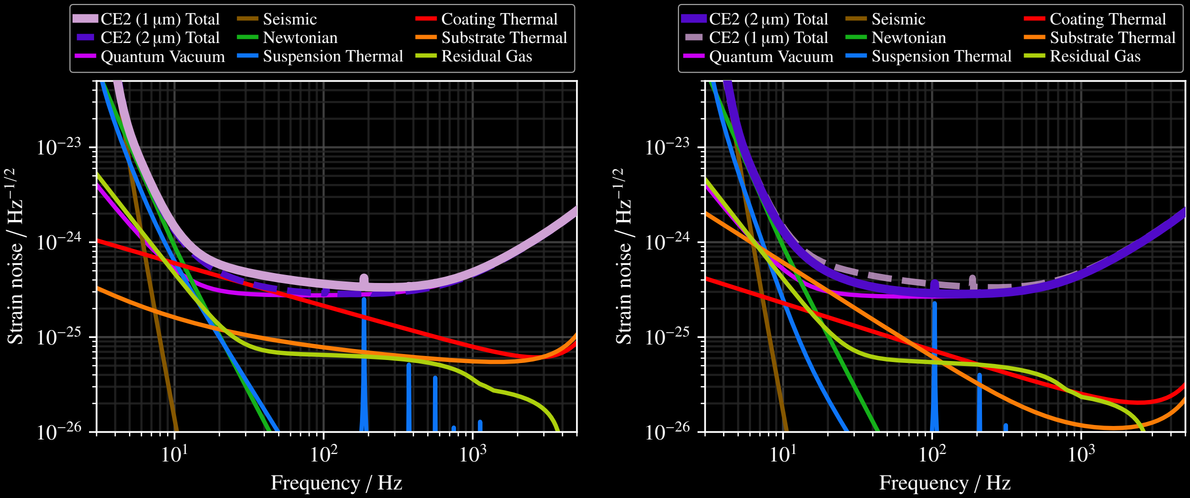


Quantum noise



- Same quantum noise for both technologies
- Shot noise $\propto \sqrt{\lambda / P_{\mathrm{arm}}}$
  - $P_{\mathrm{arm}} = 1.5\,\mathrm{MW}$ for $\lambda = 1\,\mu\mathrm{m}$
  - $P_{\mathrm{arm}} = 3\,\mathrm{MW}$ for $\lambda = 2\,\mu\mathrm{m}$
- 10 dB frequency dependent squeezing for both technologies
- 500 ppm SEC loss limits HF sensitivity

Noise scalings with arm length: a 20 km CE2



Fixed bandwidth $T_{\mathrm{sem}} \propto 1/L$

Spotsize $w \propto \sqrt{L}$ for constant cavity geometry

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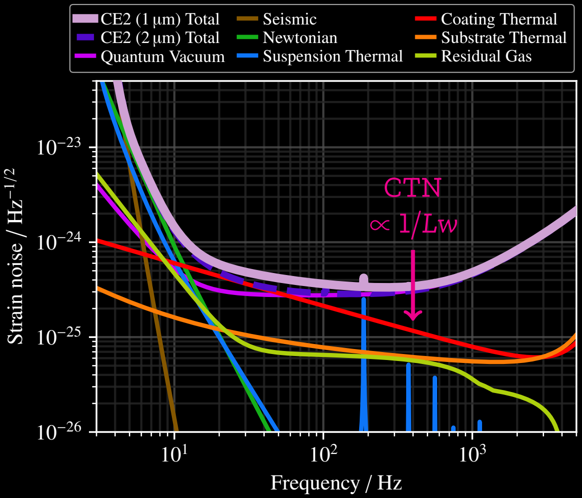

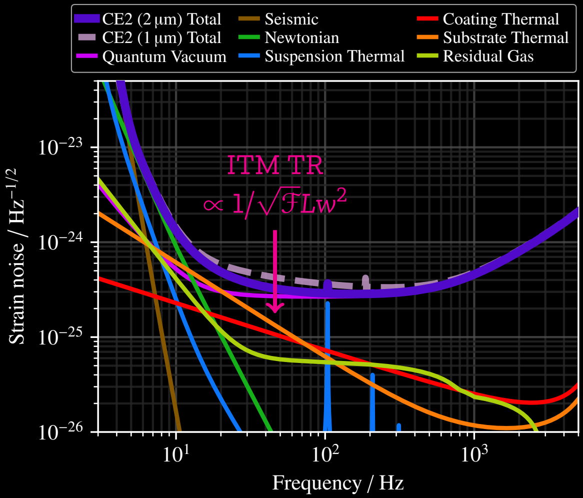

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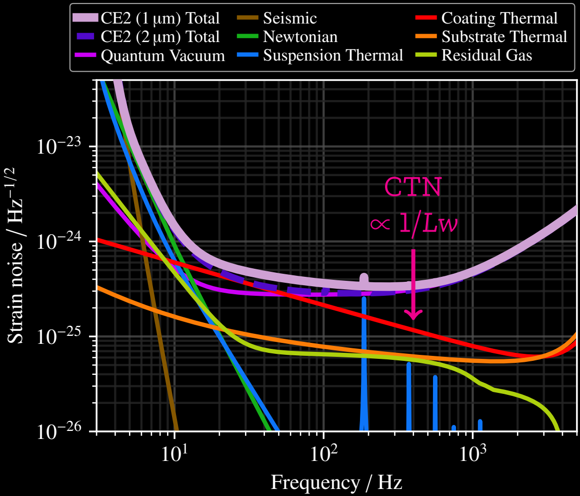

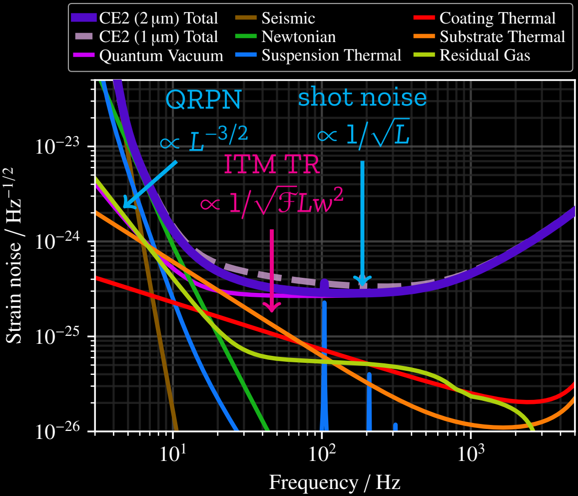

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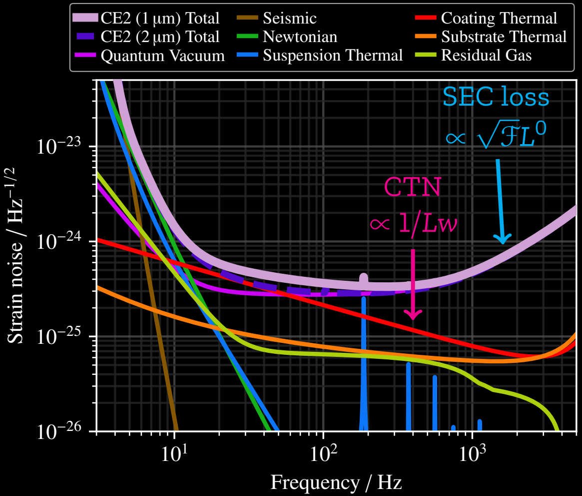

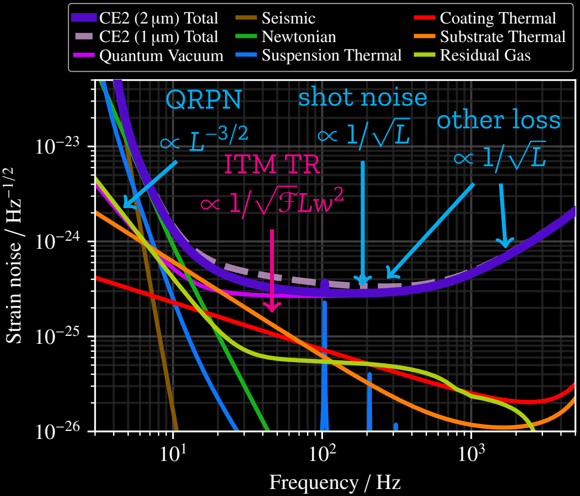

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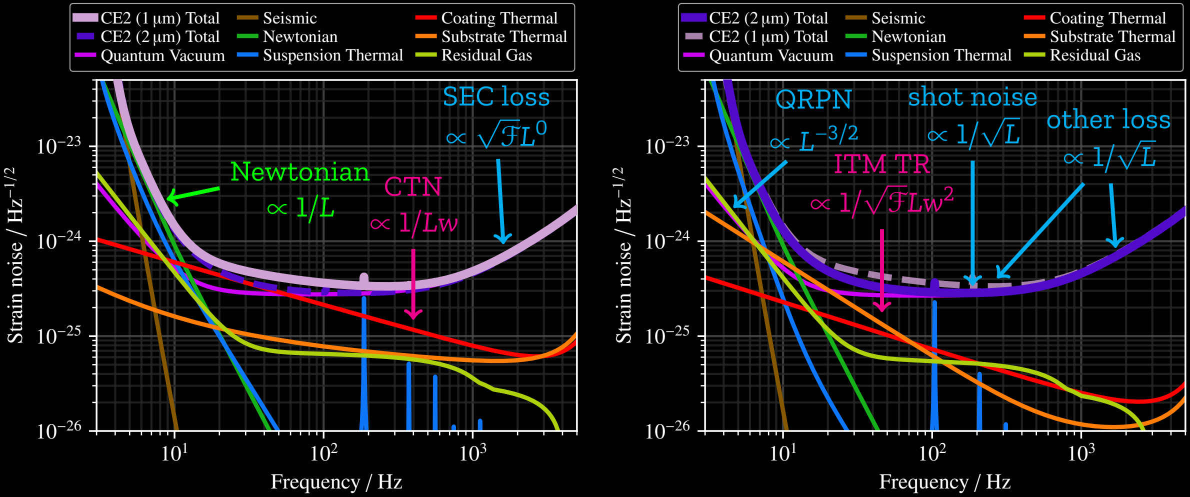

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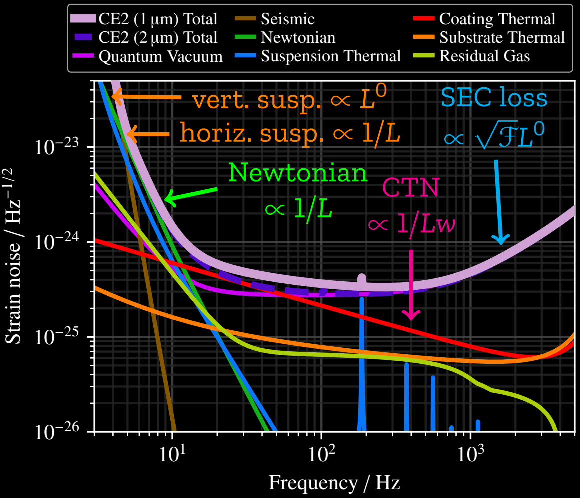

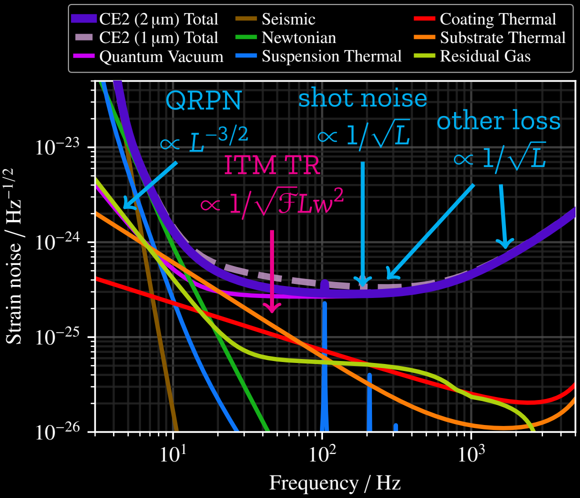

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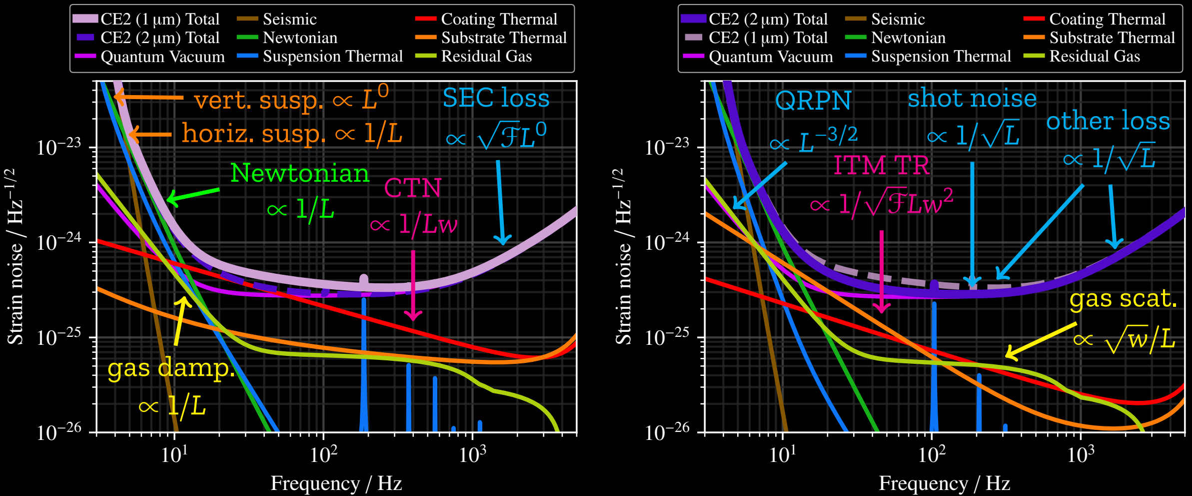

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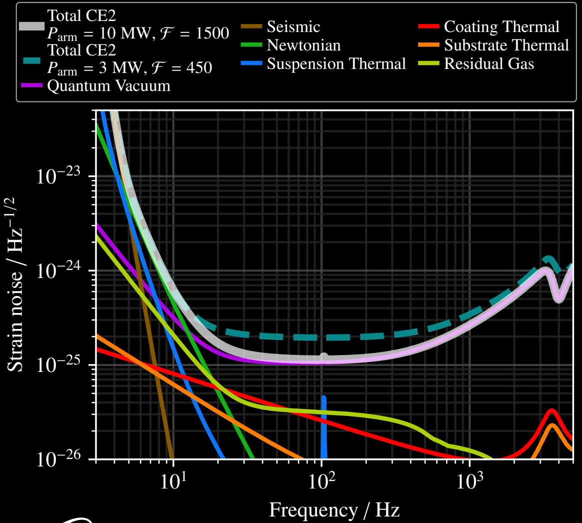
COSMIC EXPLORER

High power cryogenic silicon CE2



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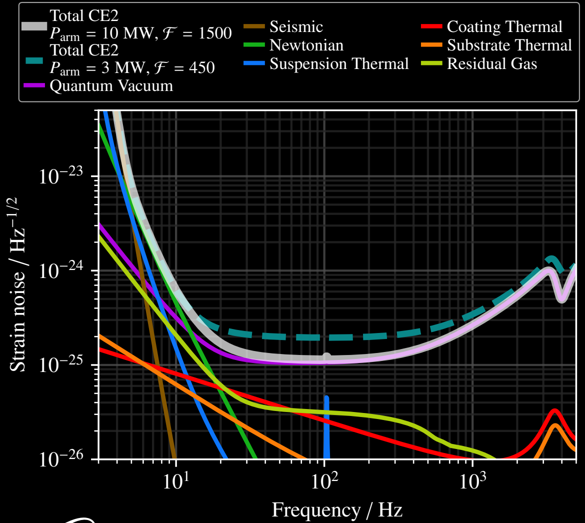

- Absorbed power in ITM's can't exceed radiative cooling power

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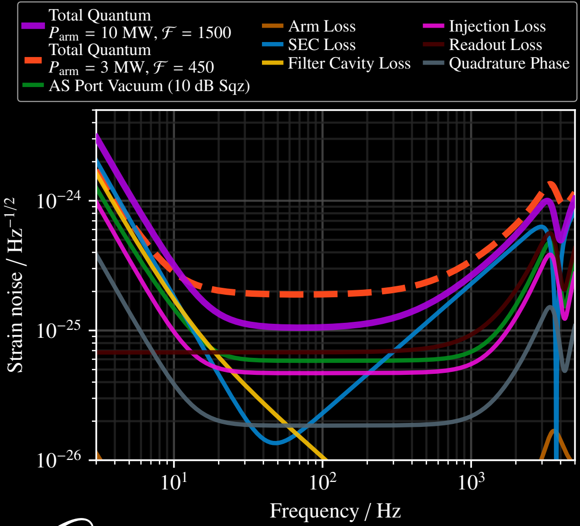

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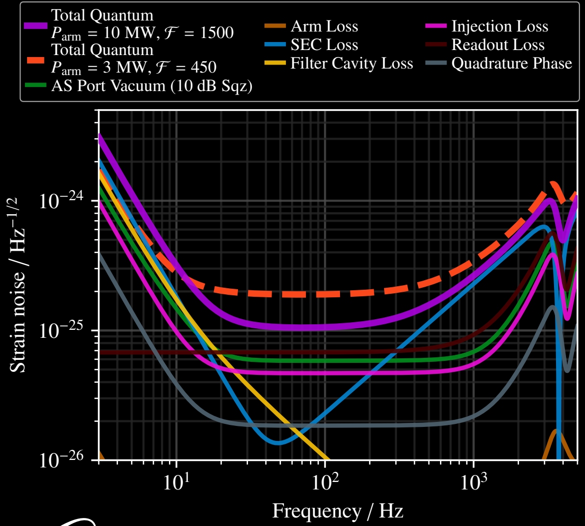

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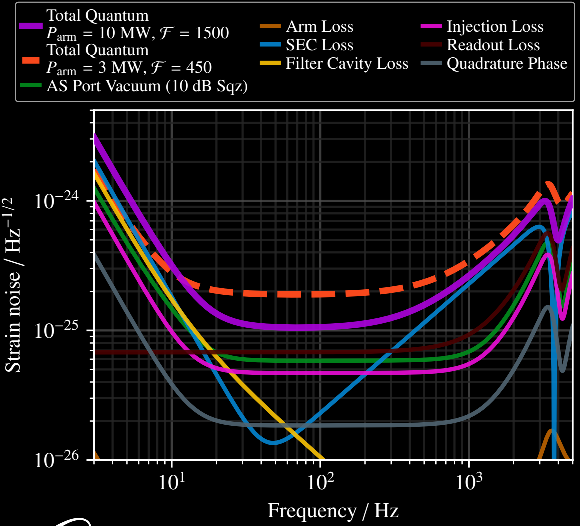

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- Thermal lensing, coating absorption, angular instabilities, PI's, …?

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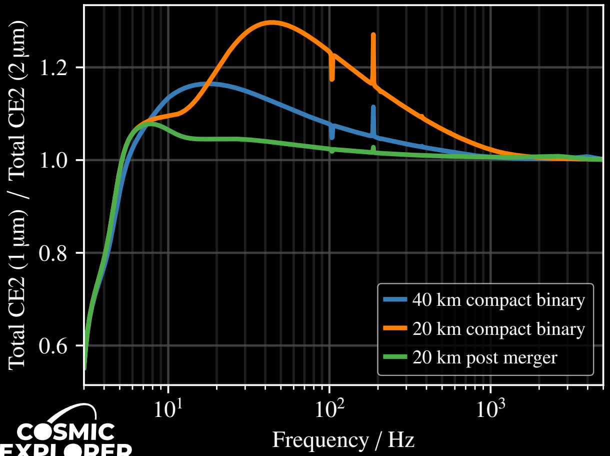
Summary

- CE2 can reach similar strain sensitivities using either evolved LIGO A+ or Voyager technology



- Risk mitigation in the event that significant challenges are discovered in one of the technologies
- However, many required R&D activities (Newtonian noise suppression, inertial isolation, …) are common to both realizations of CE2
- Many generations of detector technologies are expected to be used in the CE observatories
- Voyager technology has greater potential for increased arm powers in the future

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