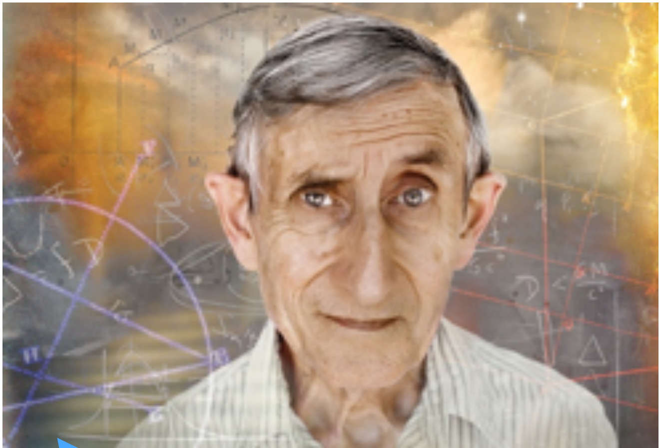
Future GW Detectors

Rana Adhikari (Caltech), David McClelland (ANU)

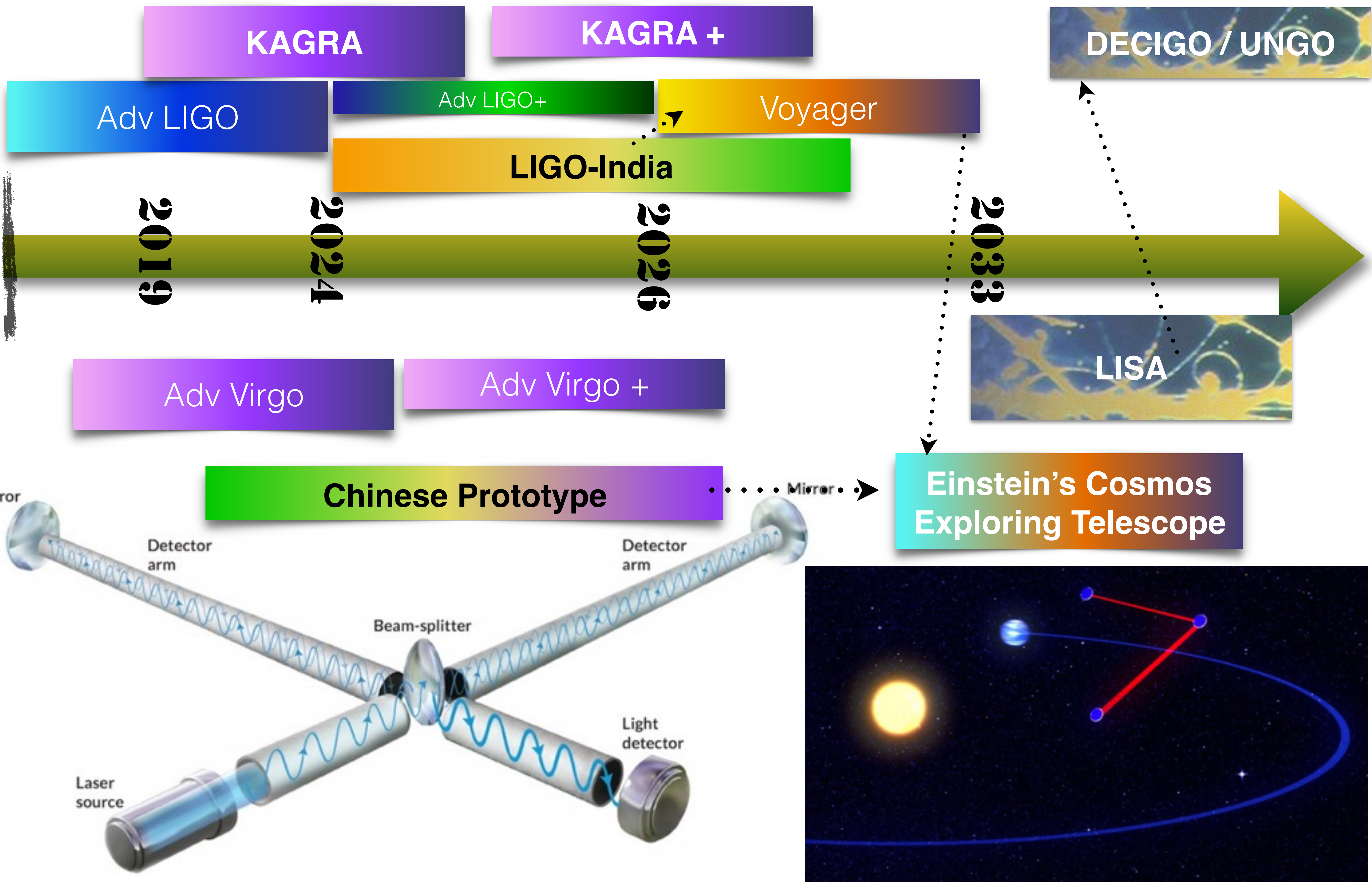
IUCAA GW Detector Workshop, Aug-2016



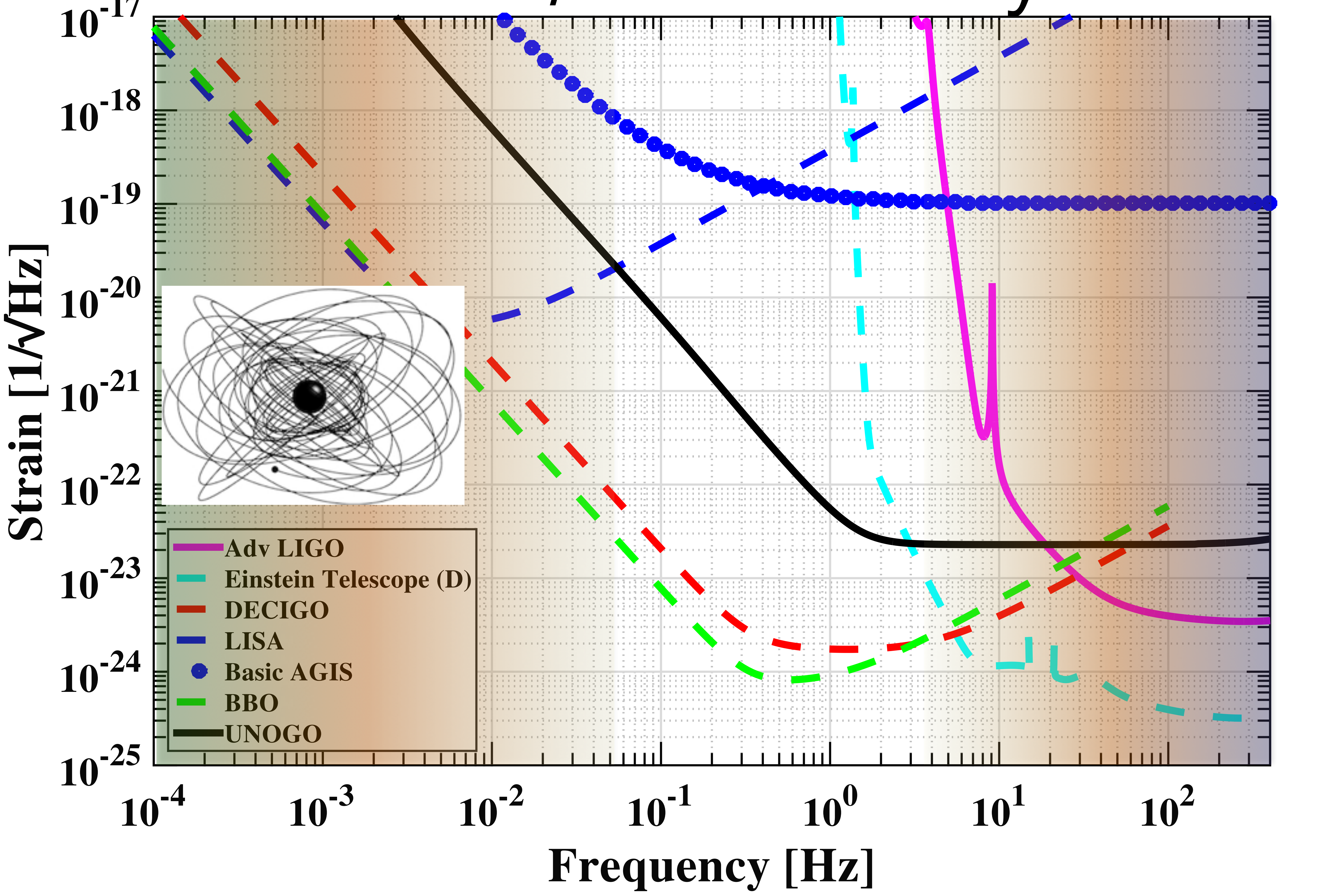
Past Detectors

- The Earth (Dyson, Dicke, Weiss, Harms)
- **Pulsar Timing** (Detweiler, Estabrook)
- The Moon (Paik)
- Resonant Bars (Weber, …)
- **Laser Interferometers**
- HF GWs (Birmingham)

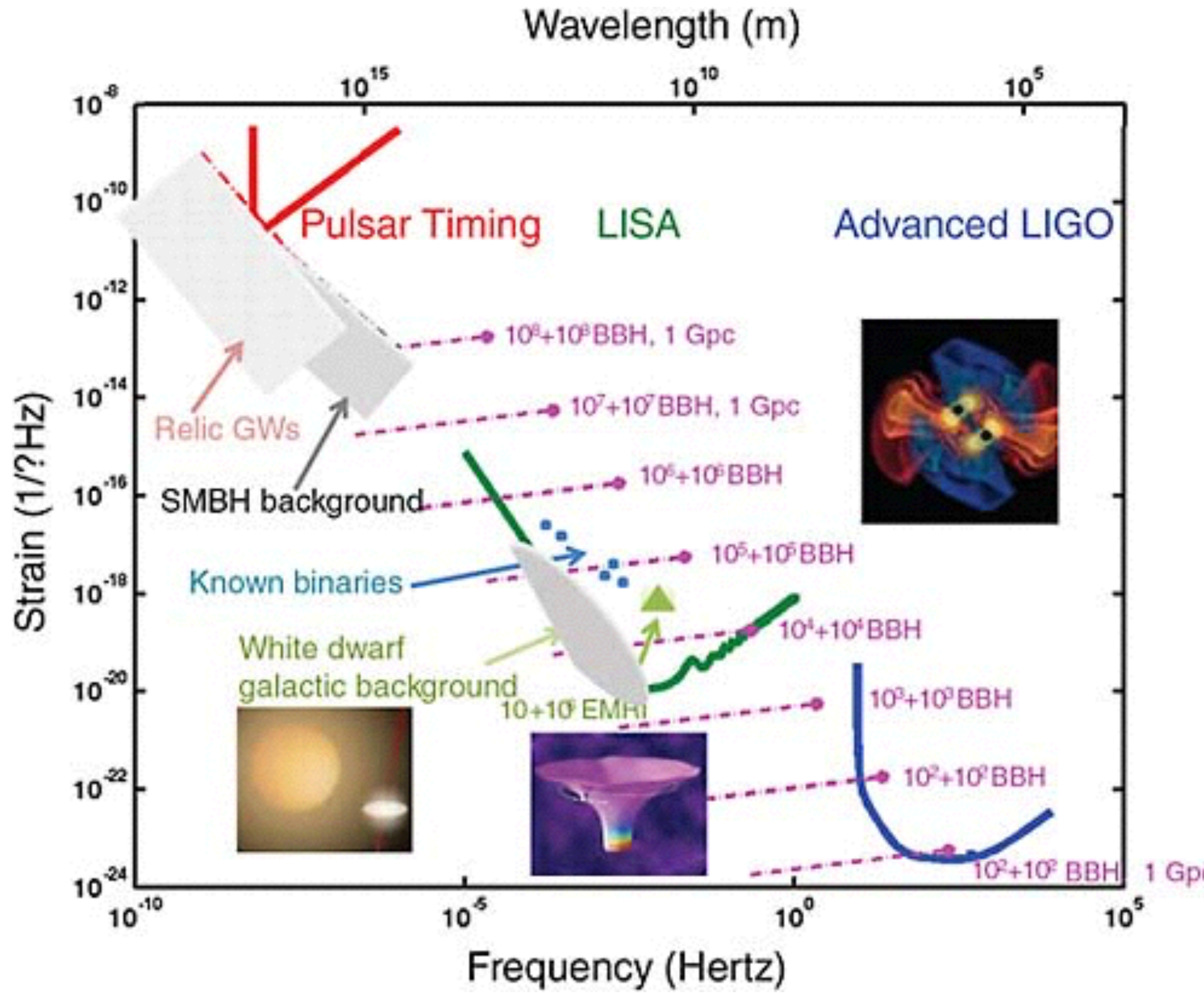
Future Detectors



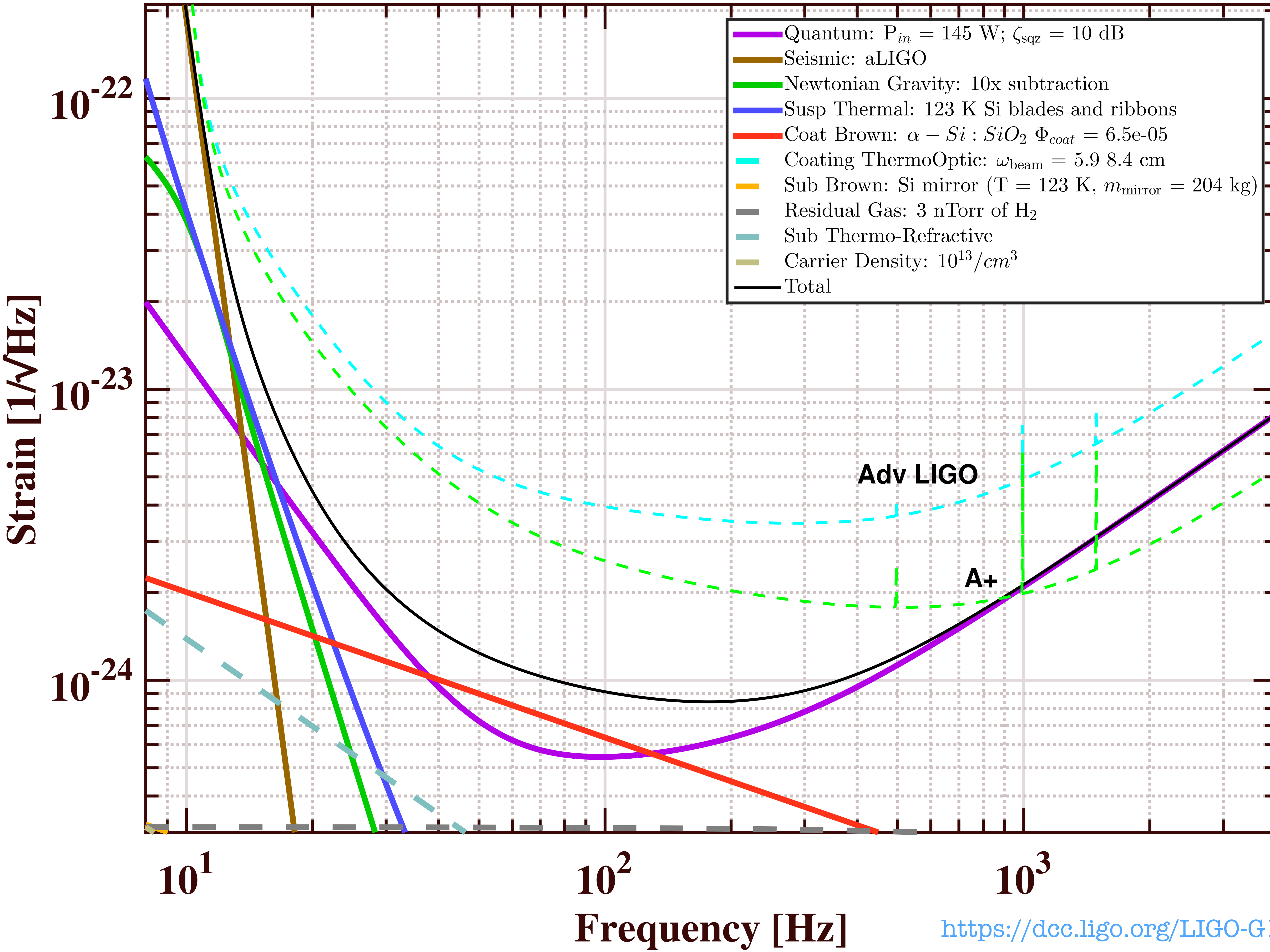
Noise / Sensitivity



Scientific Reach



Voyager Status

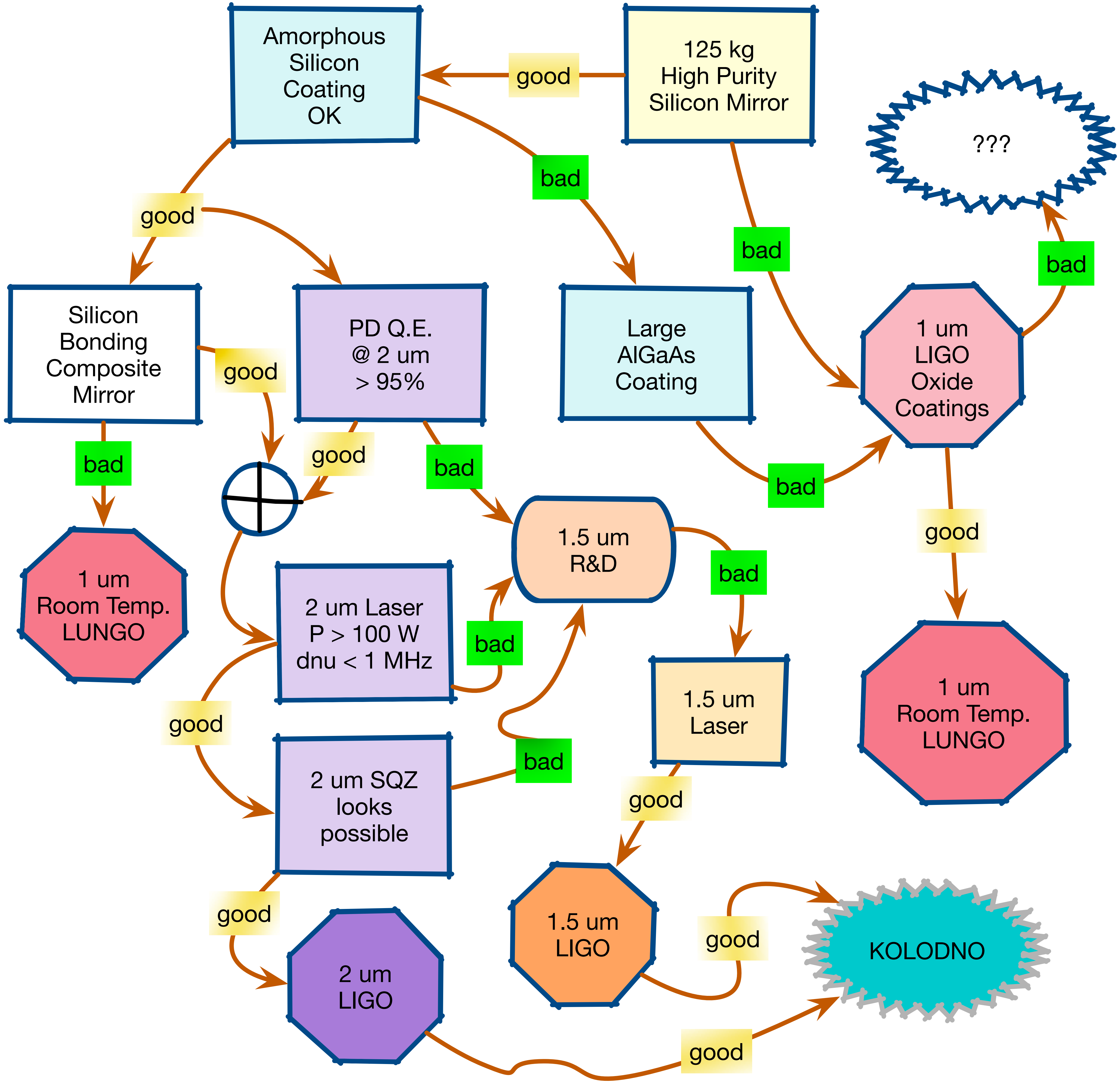


https://dcc.ligo.org/LIGO-G1601461

Sub-Systems

- Silicon Mirrors: 140-**200 kg**, mCZ
- Coatings: a-Si/SiO_2 or others
- *Wavelength Choice: 1.55 - 2.1 microns*
- Cryogenics: 123 K, radiative cooling (steady state)
- Lasers (~2 micron): P_{PRM} ~ 140 W, P_{ARM} ~ 3 MW
- Thermal Compensation: Silica compensation plates only (CO2 lasers, no ring heaters)
- Photodiode Quantum Efficiency: 80 -> 99% for 2 micron

Draft Whitepaper: https://dcc.ligo.org/LIGO-T1400226



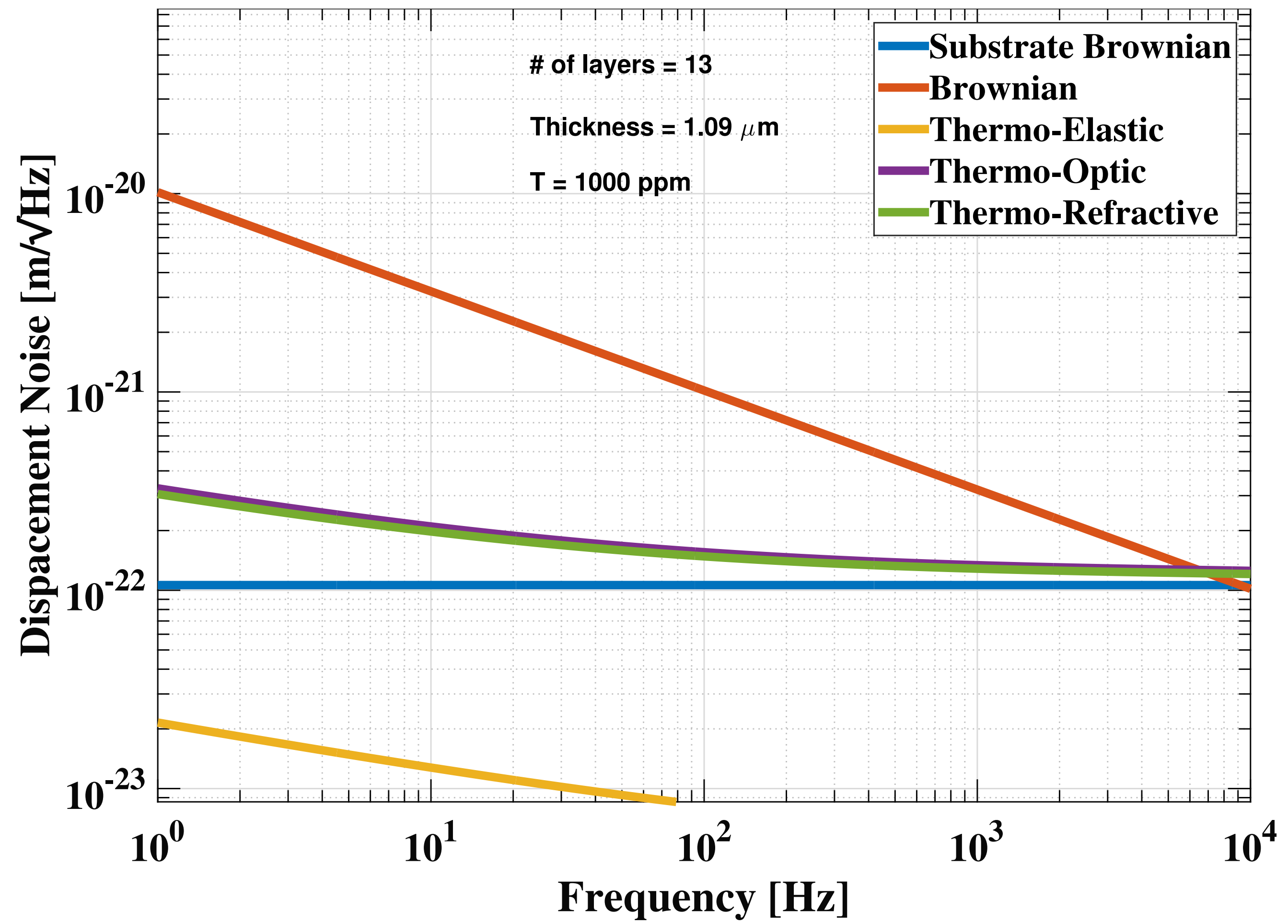
Evans,
Barsotti,
Adhikari
Nov 2015

200 kg Silicon Mirror

- P_{abs} < 5 W (goal); P_{coat} = alpha*3MW; P_{sub} = d_thick*alpha*P_{BS} (1W ~> 10 ppm/cm)
- 3 ppm/cm (FZ): FZ max diameter ~ 20 cm
- mCZ can get 10-20 kOhm in wafers after high T annealing (to trap oxygen)
- samples acquired, absorption measurements in progress (< 2 ppm)
- make 45 cm diameter mCZ
- how to sequence all of the annealing? Different processes for substrates, coatings.

Coatings

- a-Si / SiO_2 baseline
- Pohl, Hellman data
- Glasgow IBS results
- Evidence of high T deposition leading to low friction due to high surface mobility*
- may be good for room temp also
- high T deposition with IBS this year
- lower absorption (1-5-2 microns) (J. Steinlechner, S. Reid)

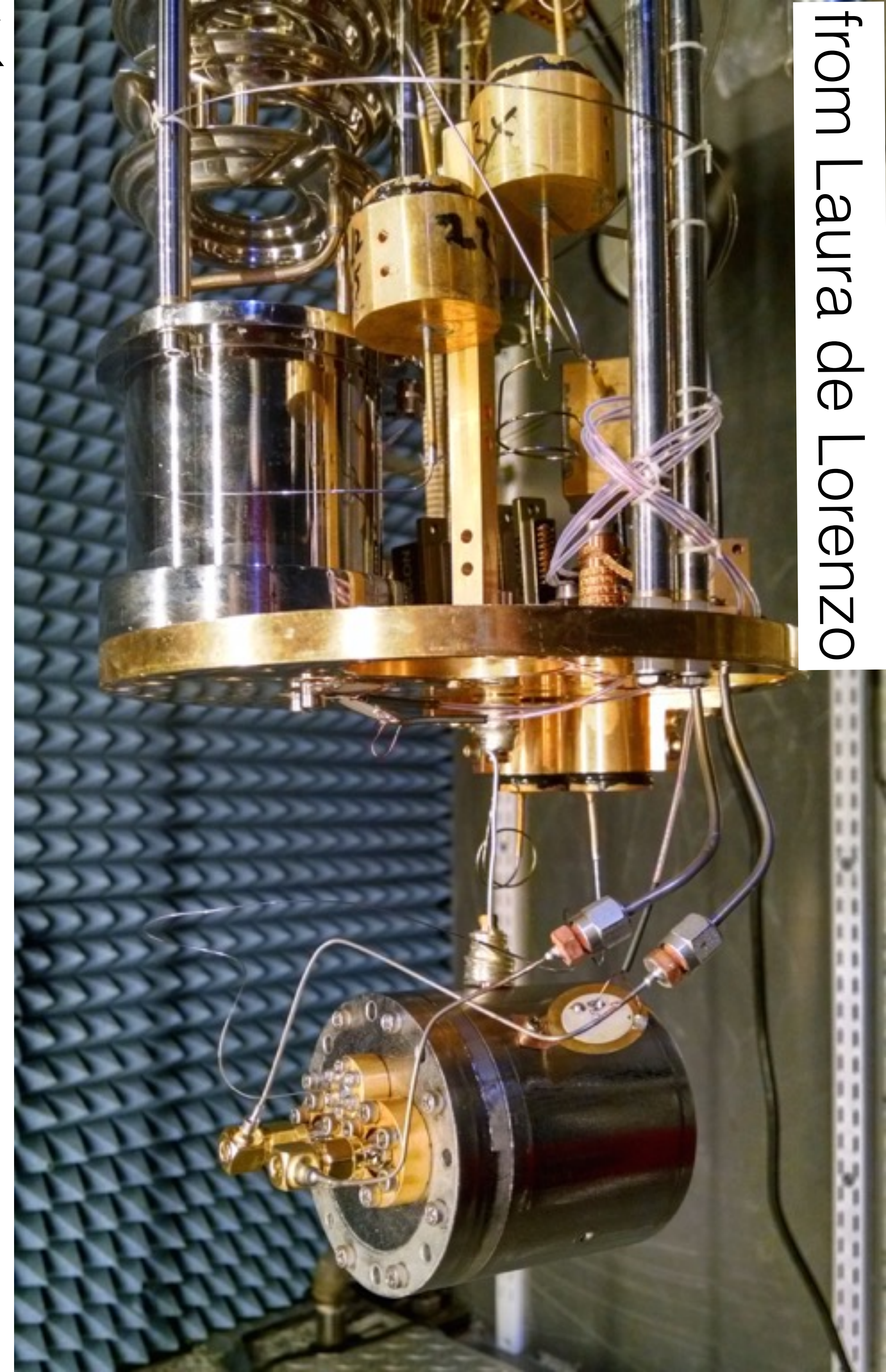


*Physics Today (Jan 2016): http://arxiv.org/abs/1512.03540

serious Cryogenics

4 cm Niobium cavity
filled with Superfluid ^{4}He
Q ~ 100 million

1 K



30 mK

from Laura de Lorenzo

Cryogenics

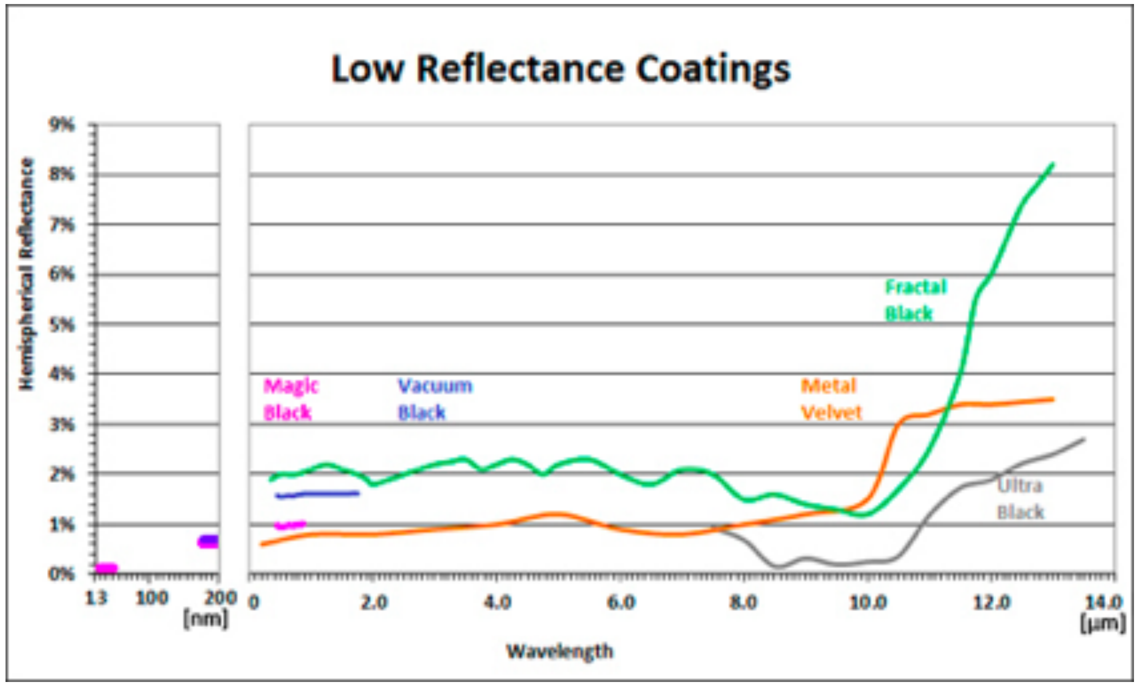
- No serious issues here; this is **NOT** like CERN or KAGRA
- ~10 W heat extraction capability in steady state
- Prelim mech drawing & backscatter analysis done (Stanford/CIT engineers).
- Vibration from cryogenics no worse than existing cryo traps.
- How to do initial cool down? Heat switches?

$$A_{face} = \pi(0.45/2)^2$$

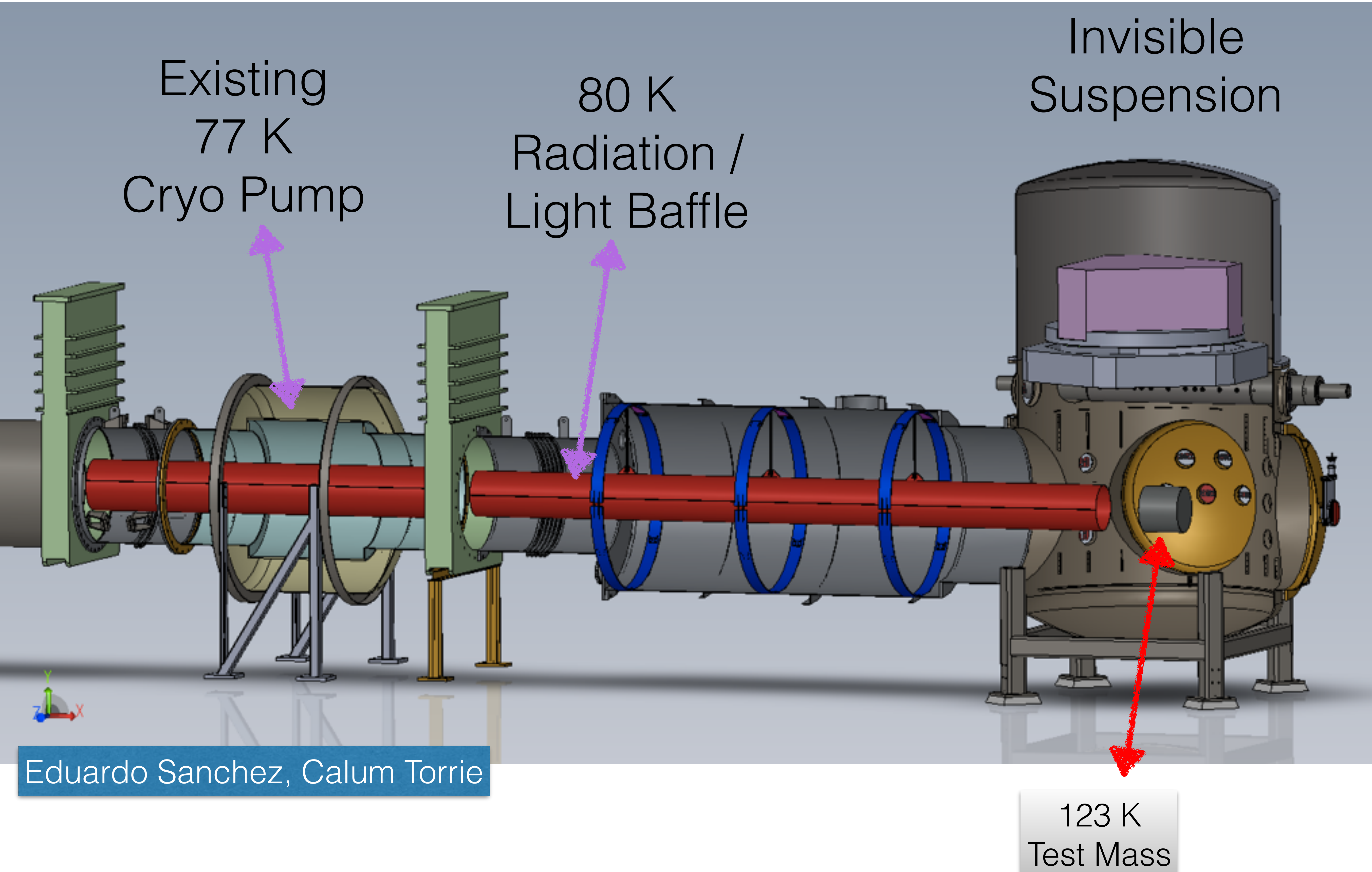
$$A_{barrel} = 2\pi(0.45/2)0.5$$

$$P = \sigma(123^4 - 80^4)(2A_{face} + A_{barrel})$$

Surrey Nanosystems

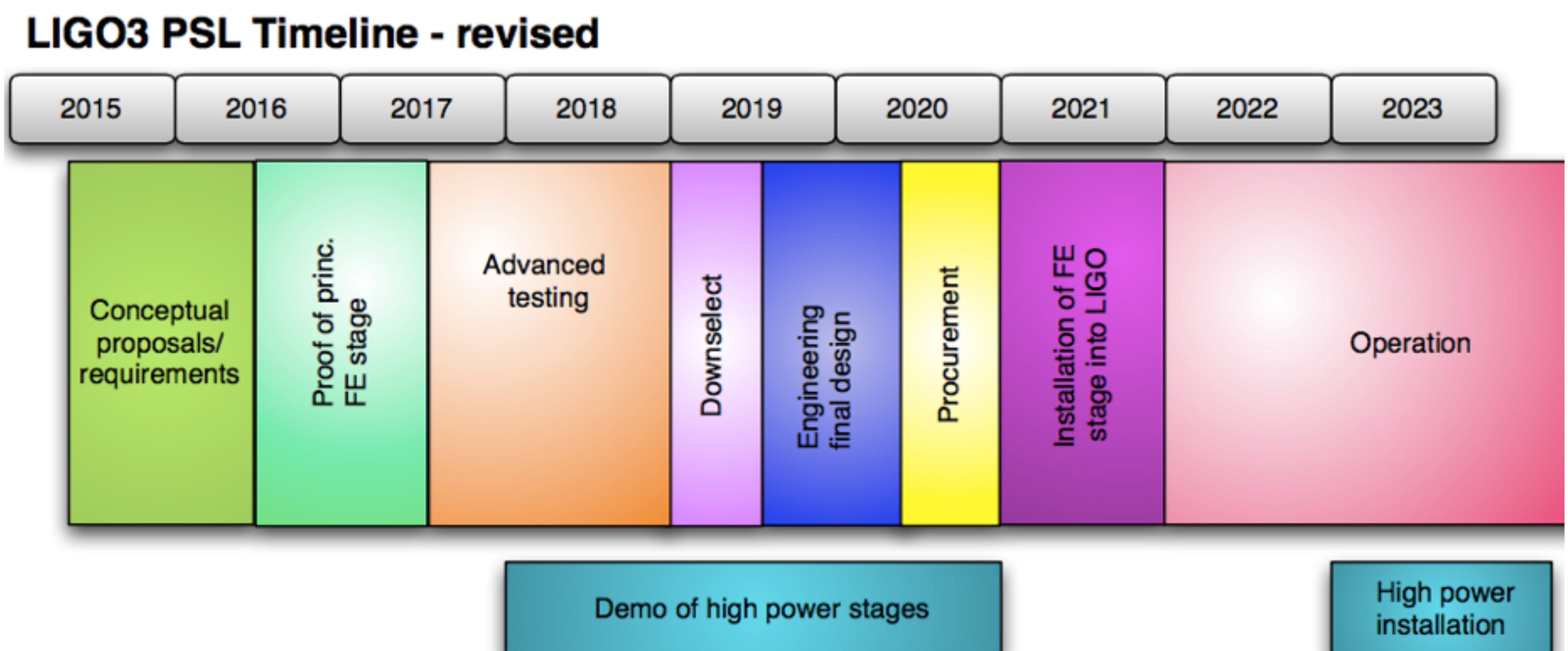


Acktar Black


Existing
77 K
Cryo Pump
80 K
Radiation /
Light Baffle
Invisible
Suspension
123 K
Test Mass
Eduardo Sanchez, Calum Torrie

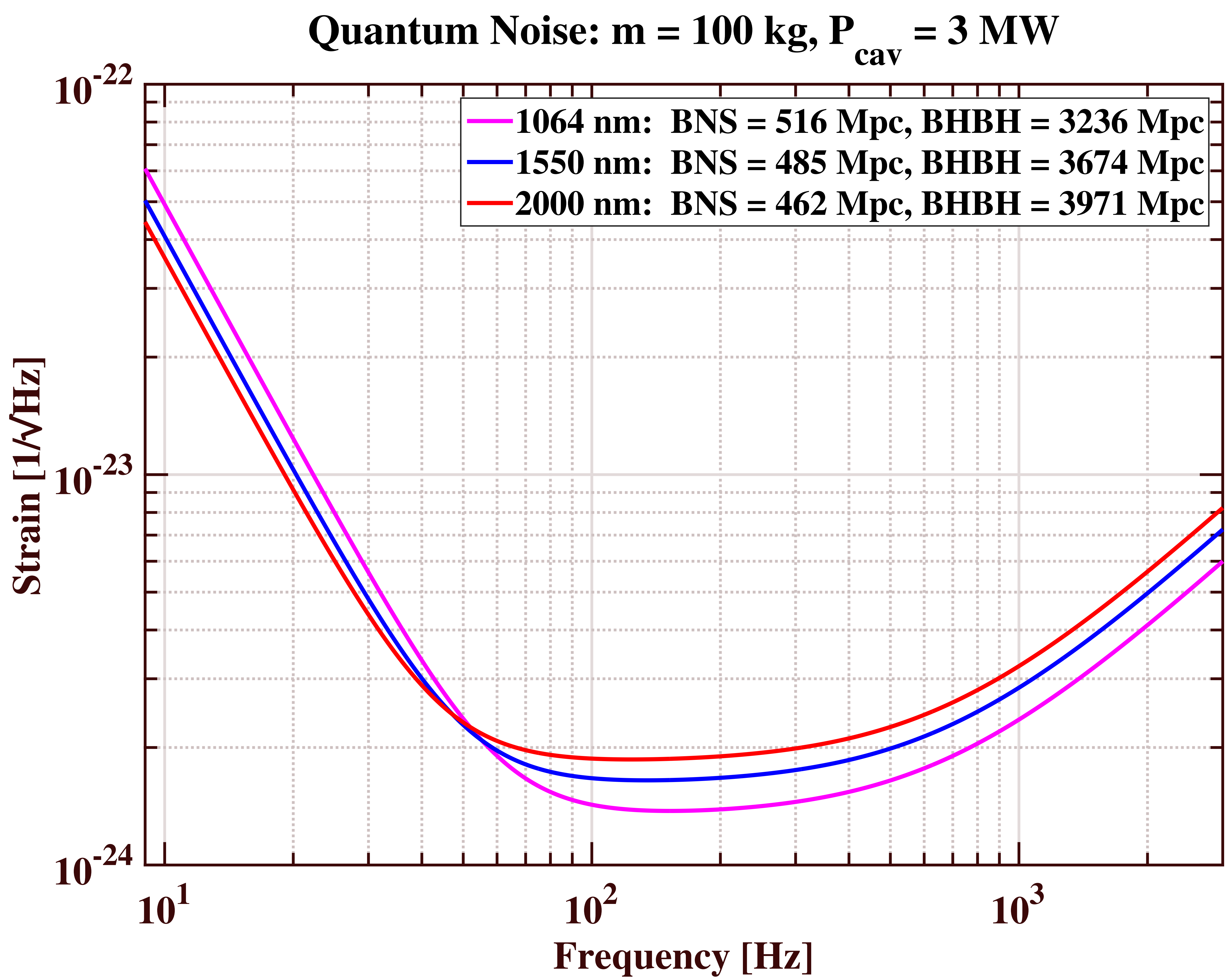
Lasers, TCS, PDs

- Tm:YAG, Ho:YAG commercial lasers exist (low power, low noise, or high power, high noise)
- Adelaide lasers (Veitch LVC talk)
- Testing at CIT this summer



Wavelength Choice

- We know and like 1064 nm. Lots of experience.
- Many new issues with 1.5-2.1 microns.
- ~200 W lasers feasible with 1.8-2.1 microns
- PD QE > 80% today. No showstoppers yet.
- Scatter loss decreases with wavelength; quantum noise improvement. Increases <u>ultimate</u> reach assuming we solve "*nuisance*" losses (FI, OMC, MM, PBS, clipping, alignment, viewports, etc.)


Quantum Noise: m = 100 kg, P cav = 3 MW
1064 nm: BNS = 516 Mpc, BHBH = 3236 Mpc
1550 nm: BNS = 485 Mpc, BHBH = 3674 Mpc
2000 nm: BNS = 462 Mpc, BHBH = 3971 Mpc
Strain [1/√Hz]
10^-22
10^-23
10^-24
10^1
10^2
10^3
Frequency [Hz]