Advanced Virgo

What are the challenges?

Niels van Bakel
on behalf of the Virgo collaboration

ICNFP 2015 - Crete - August 27th

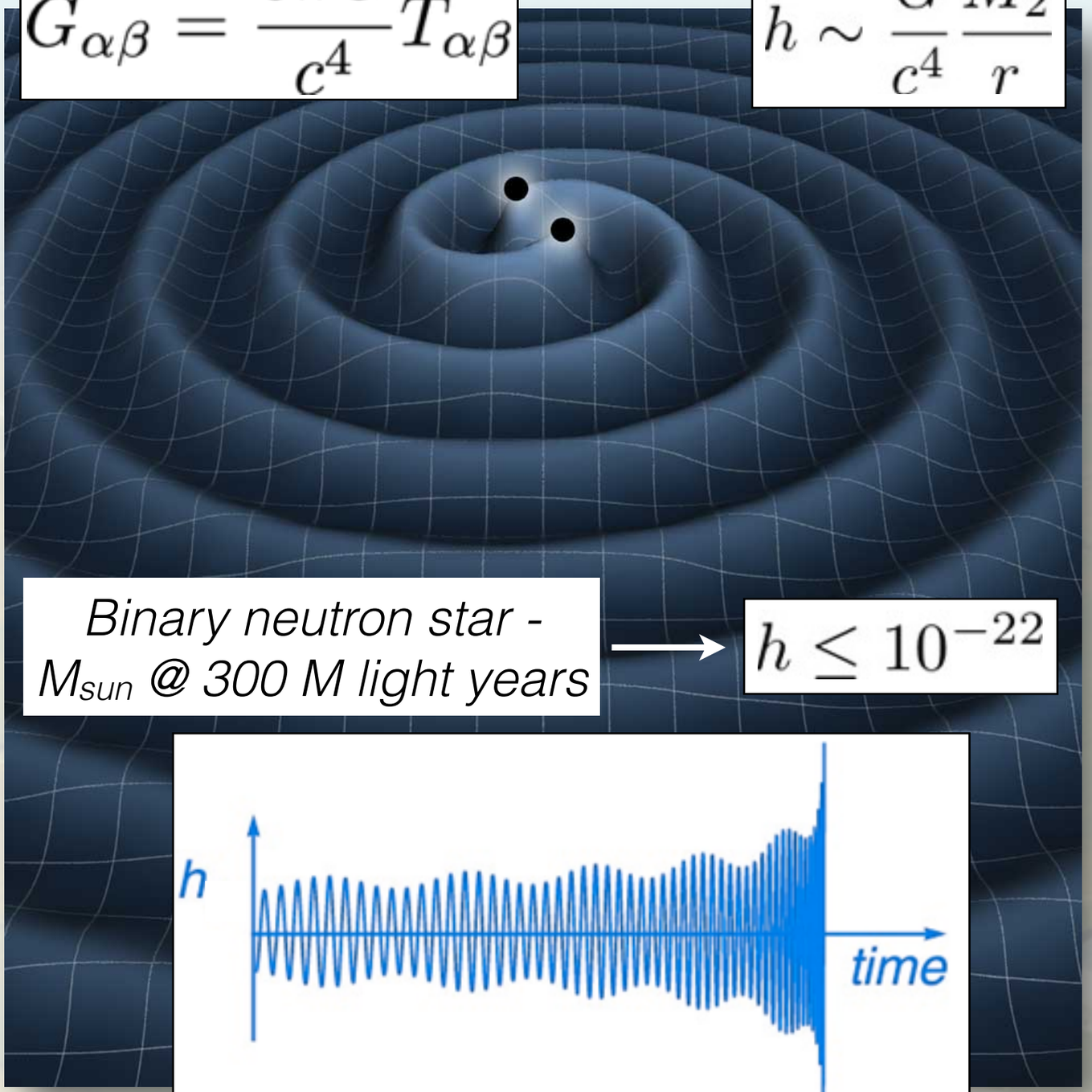
APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata

INFN Trento-Padova
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW(Poland)
RADBOUD Uni. Nijmegen
RMKI Budapest

Gravitational Waves

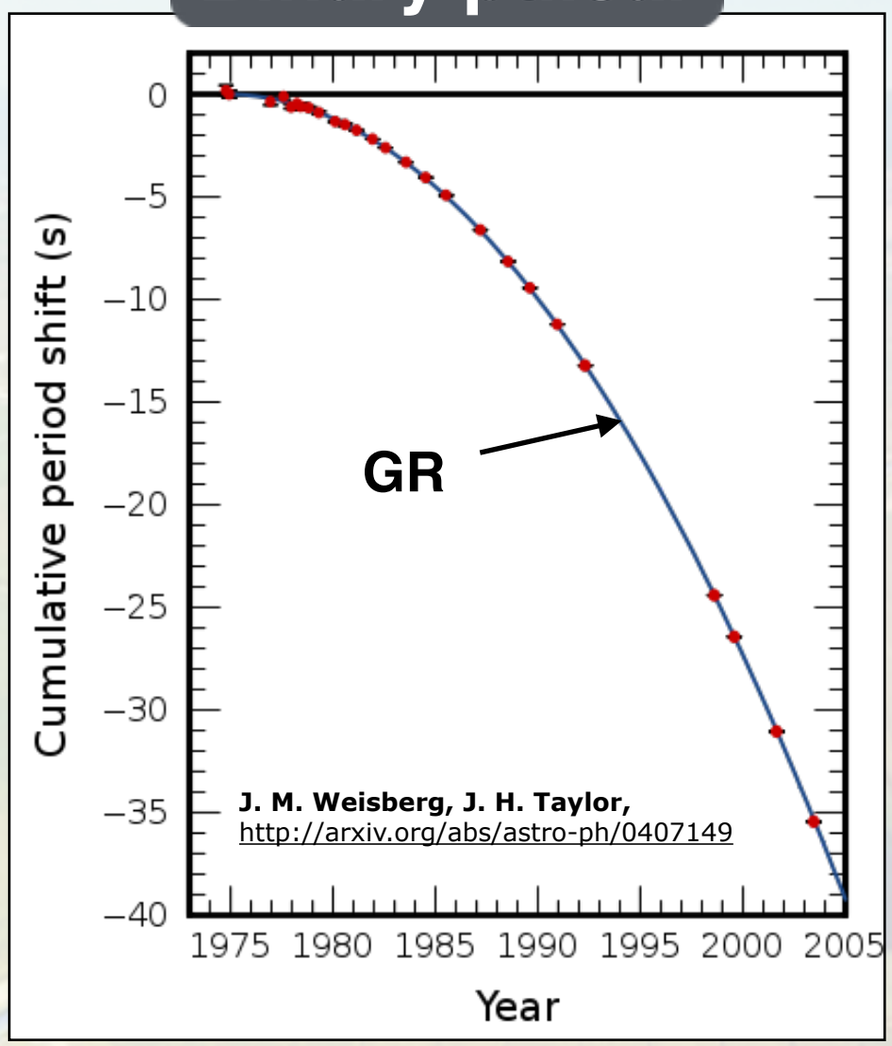
$$G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

$$h \sim \frac{G}{c^4} \frac{\ddot{M}_2}{r}$$

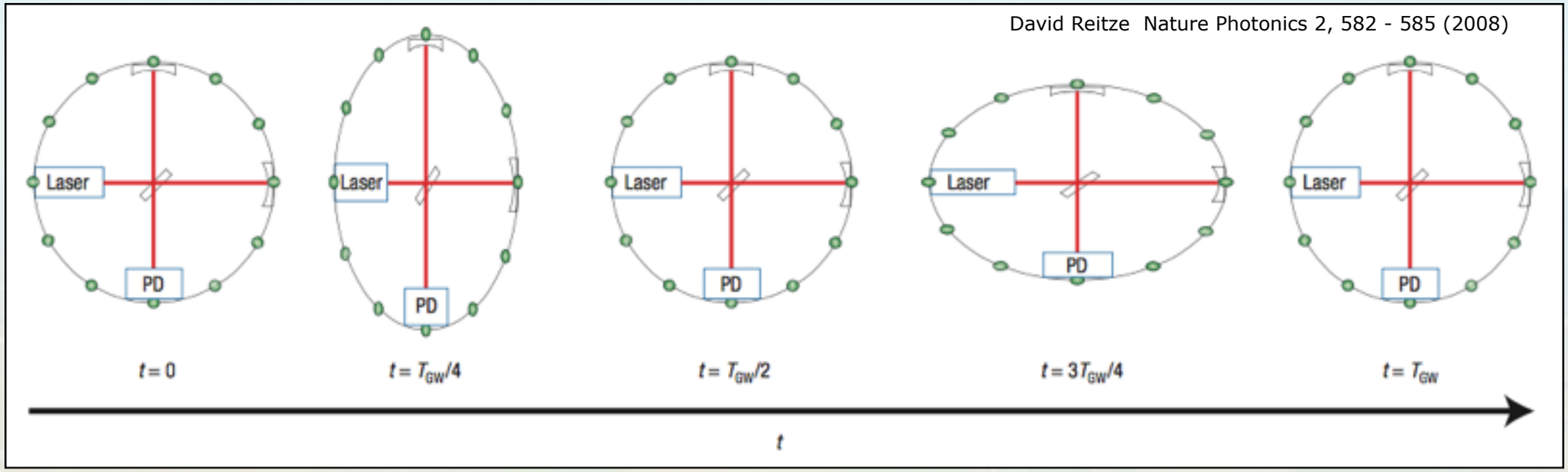


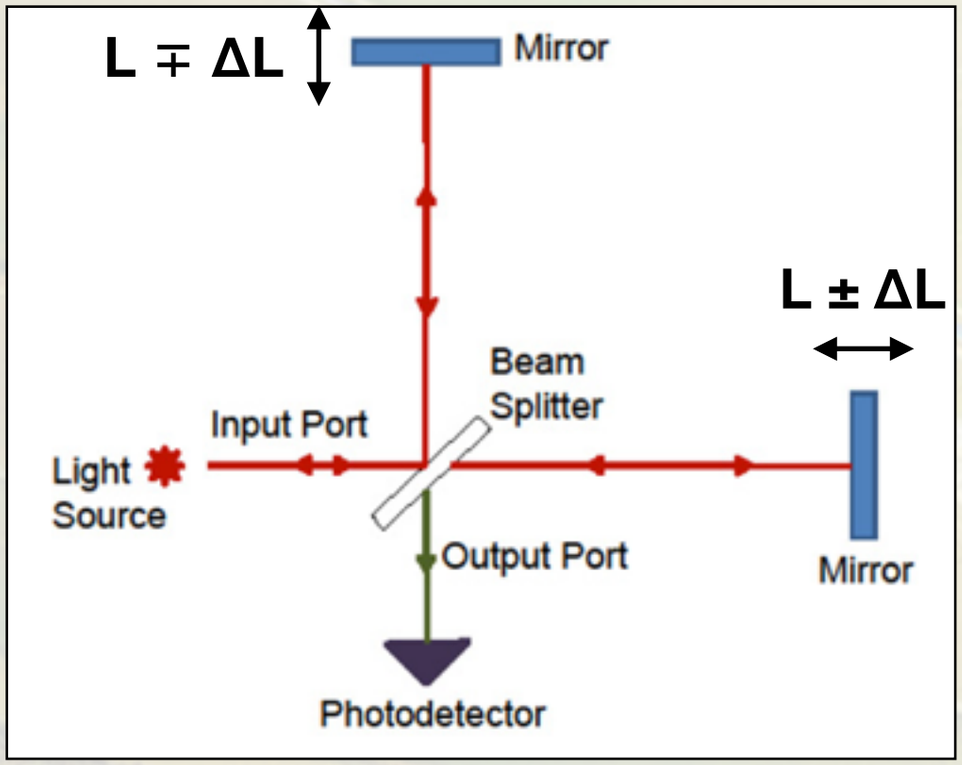
Binary neutron star - M_{sun} @ 300 M light years → $h \leq 10^{-22}$

Binary pulsar



How to detect?



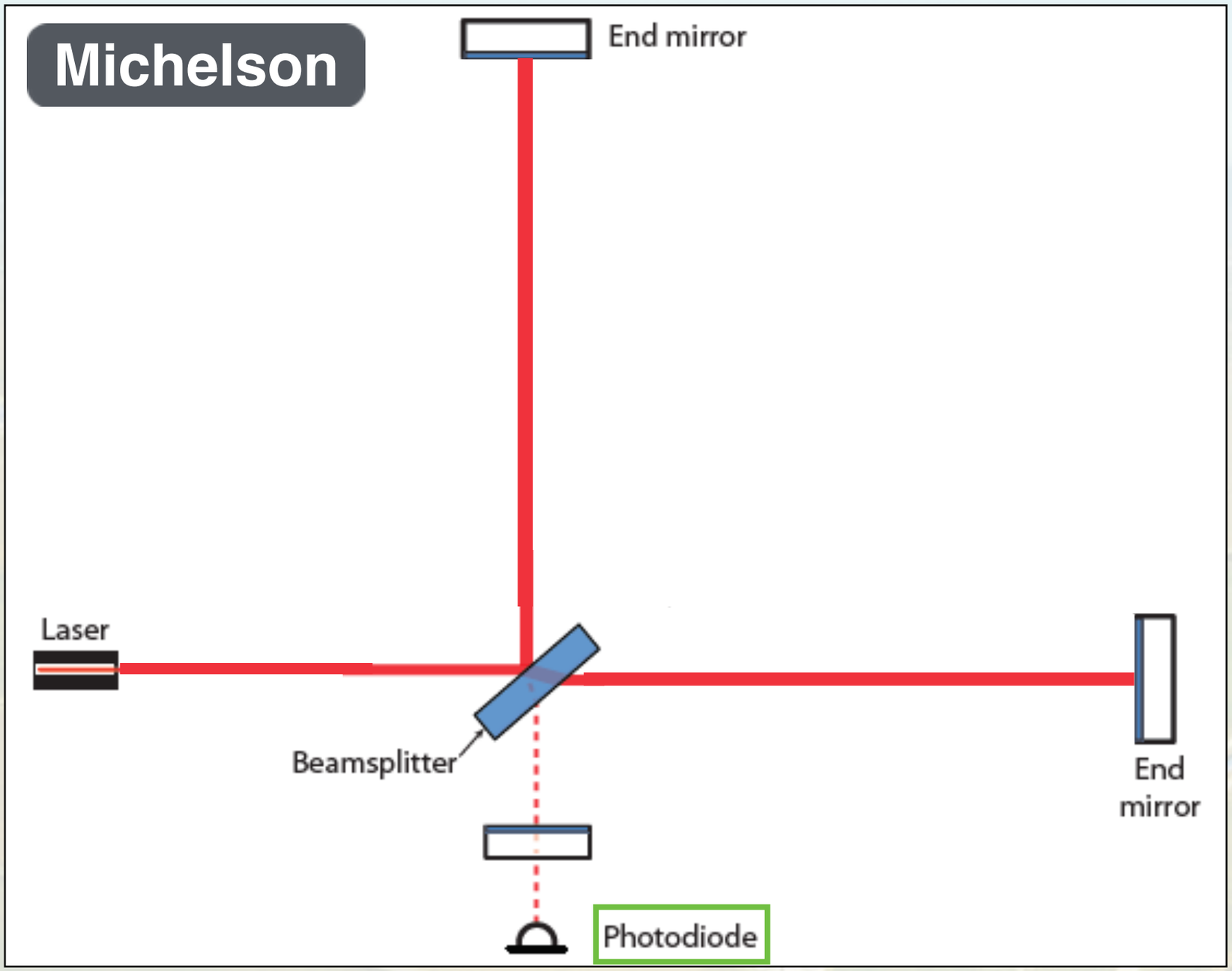


$$h(t) = \frac{\Delta L}{L} \approx 10^{-22}$$

Long arms & Low noise

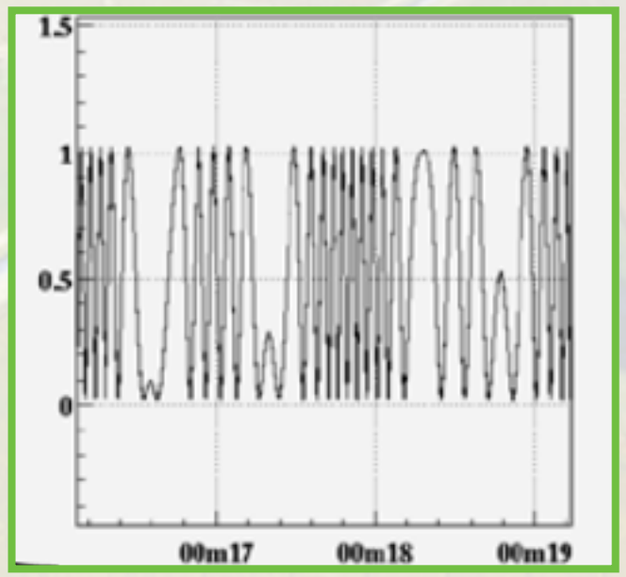
$\Delta L \approx 10^{-19}$ m

Interferometer

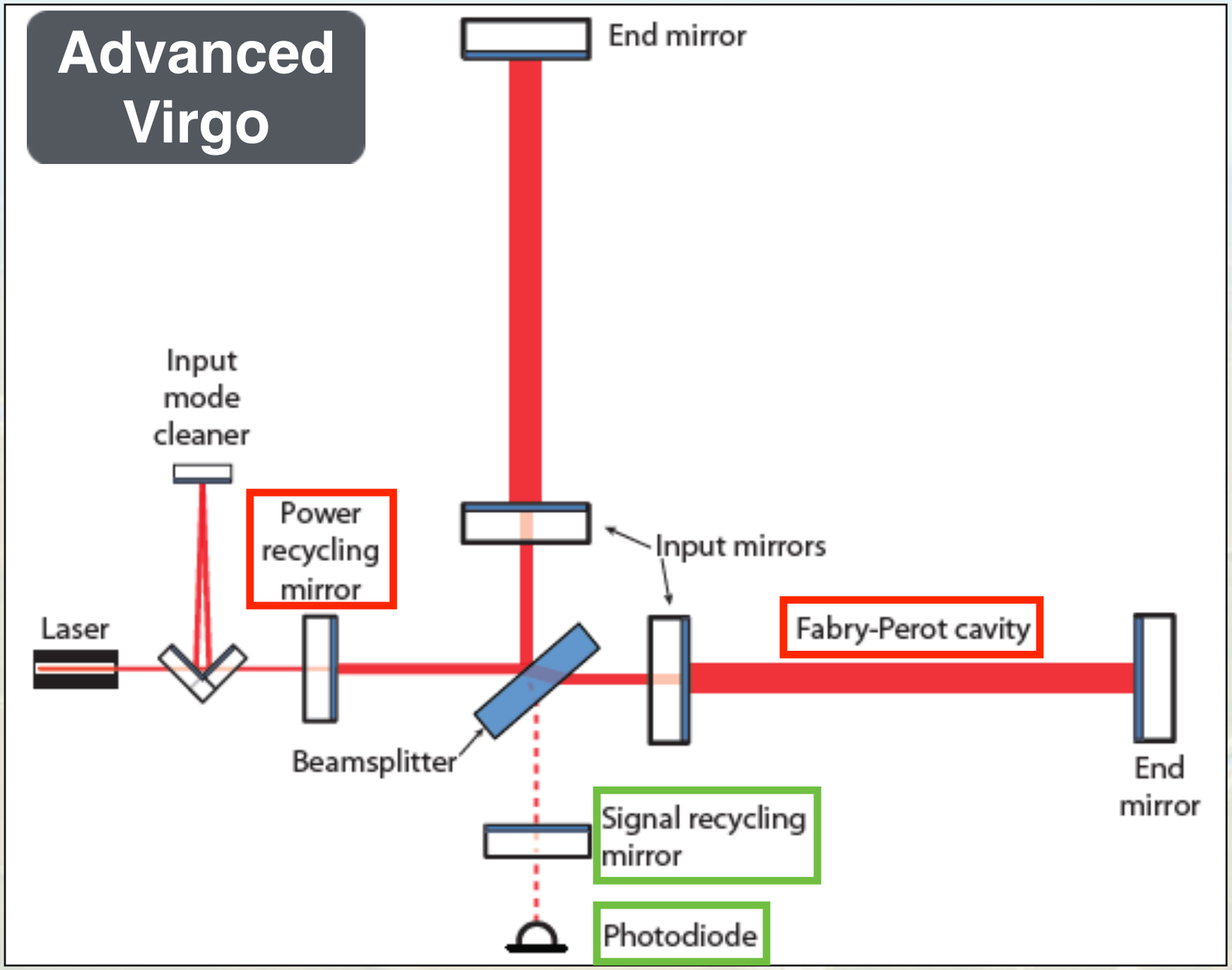


Improve factor
10^{12}

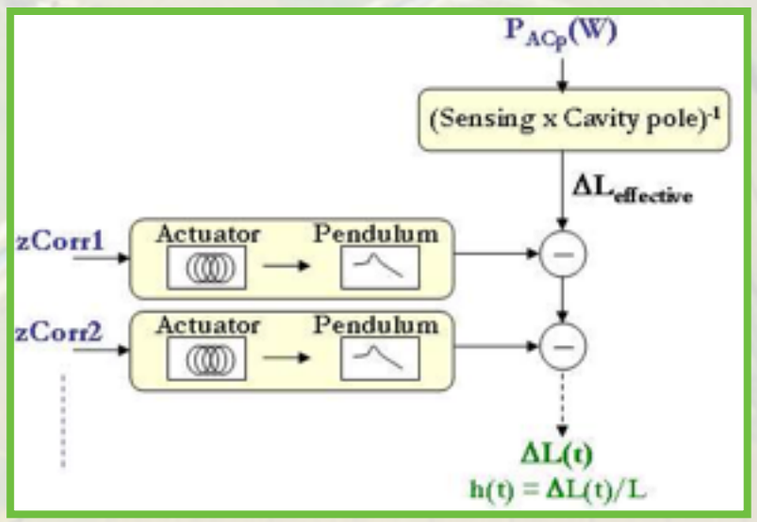
$$h_{\mathrm{sn}}(f) \sim \frac{\lambda}{4\pi}\frac{1}{L}\sqrt{\frac{\bar{h}\omega}{P}}$$



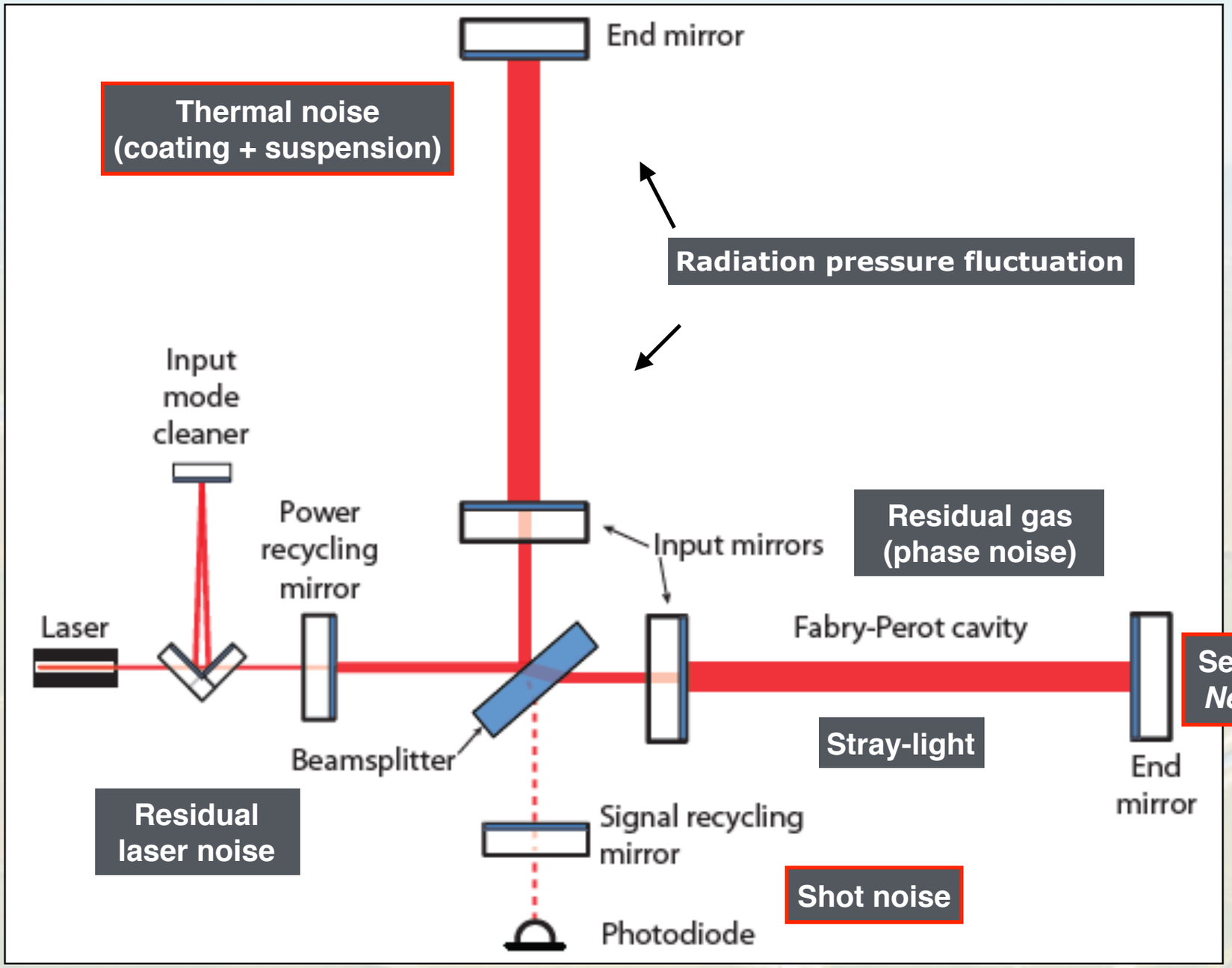
Interferometer++



$$h_{\mathrm{sn}}(f) \sim \frac{\lambda}{4\pi}\frac{1}{L}\sqrt{\frac{\bar{h}\omega}{P}}$$



Noise



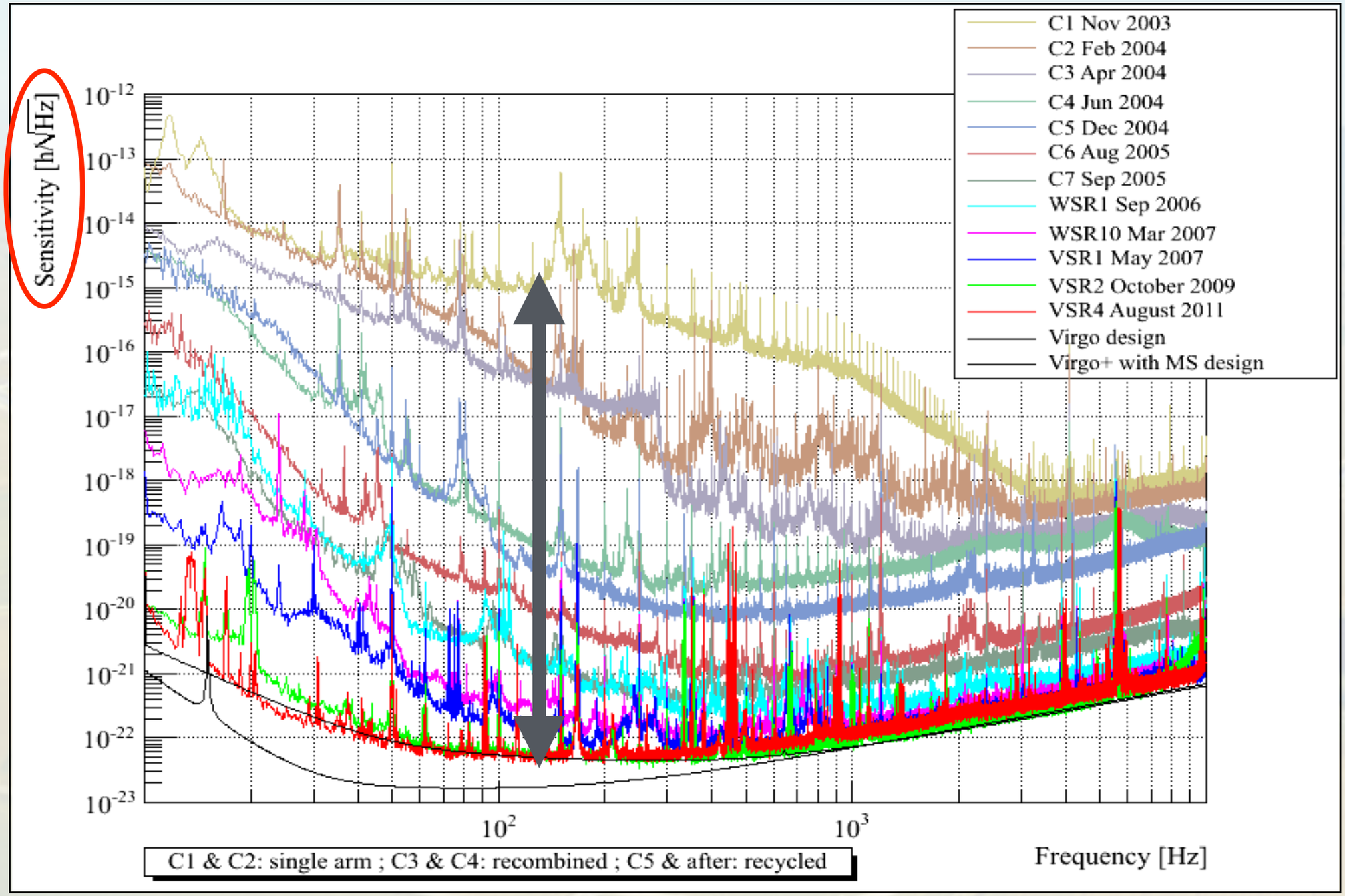
Noise sources:

- Effect mirror position
- Limit ΔL measurement

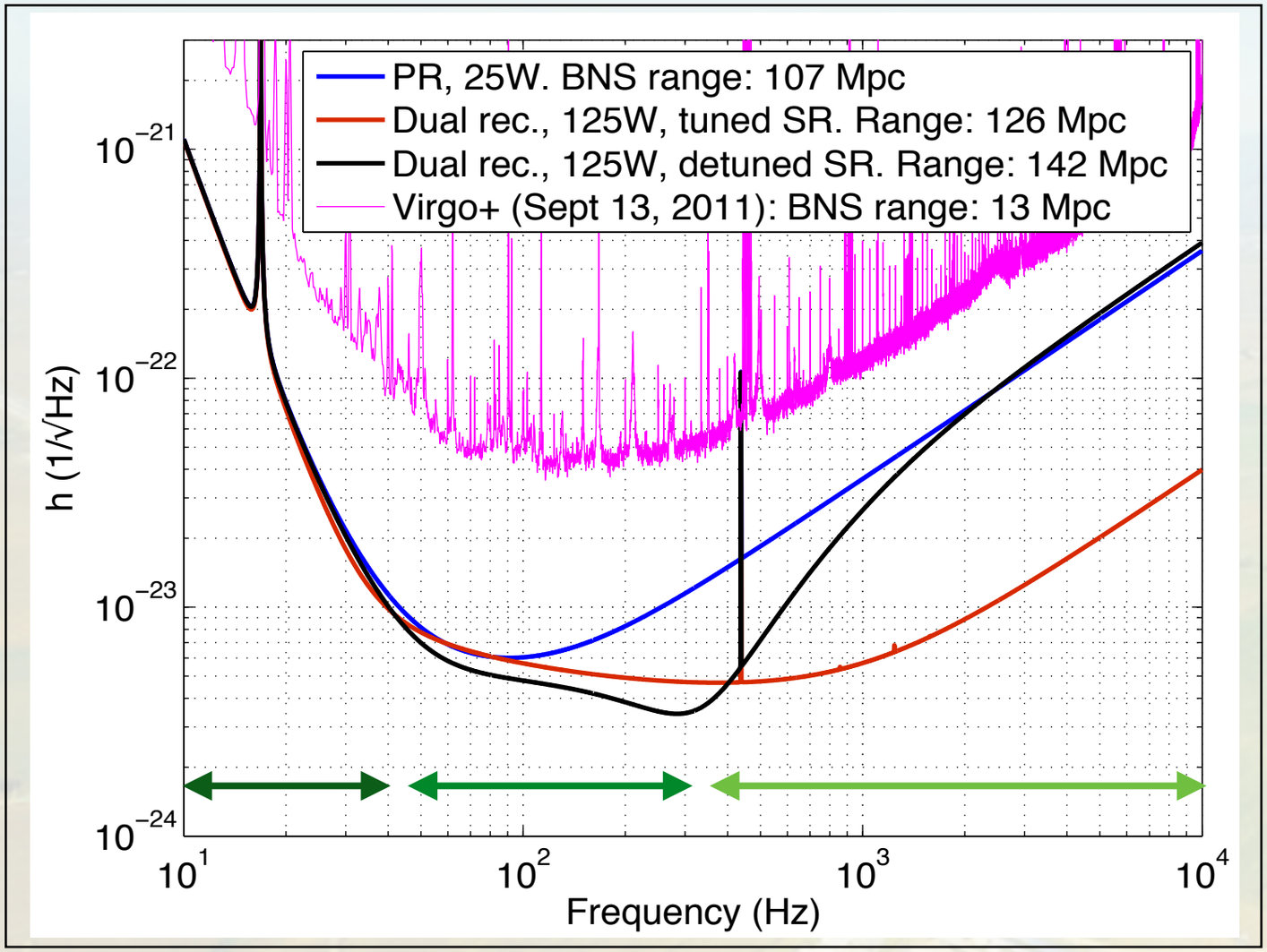
Ground motion at 10 Hz

$$10^{-9}\ \mathrm{m}/\sqrt{\mathrm{Hz}} \Rightarrow 10^{10}$$

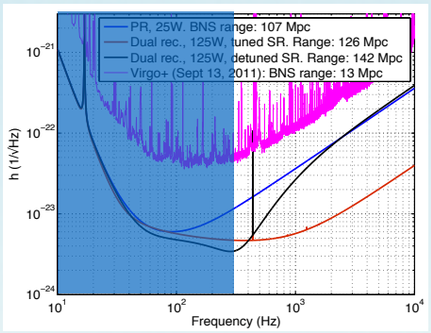
What we achieved!



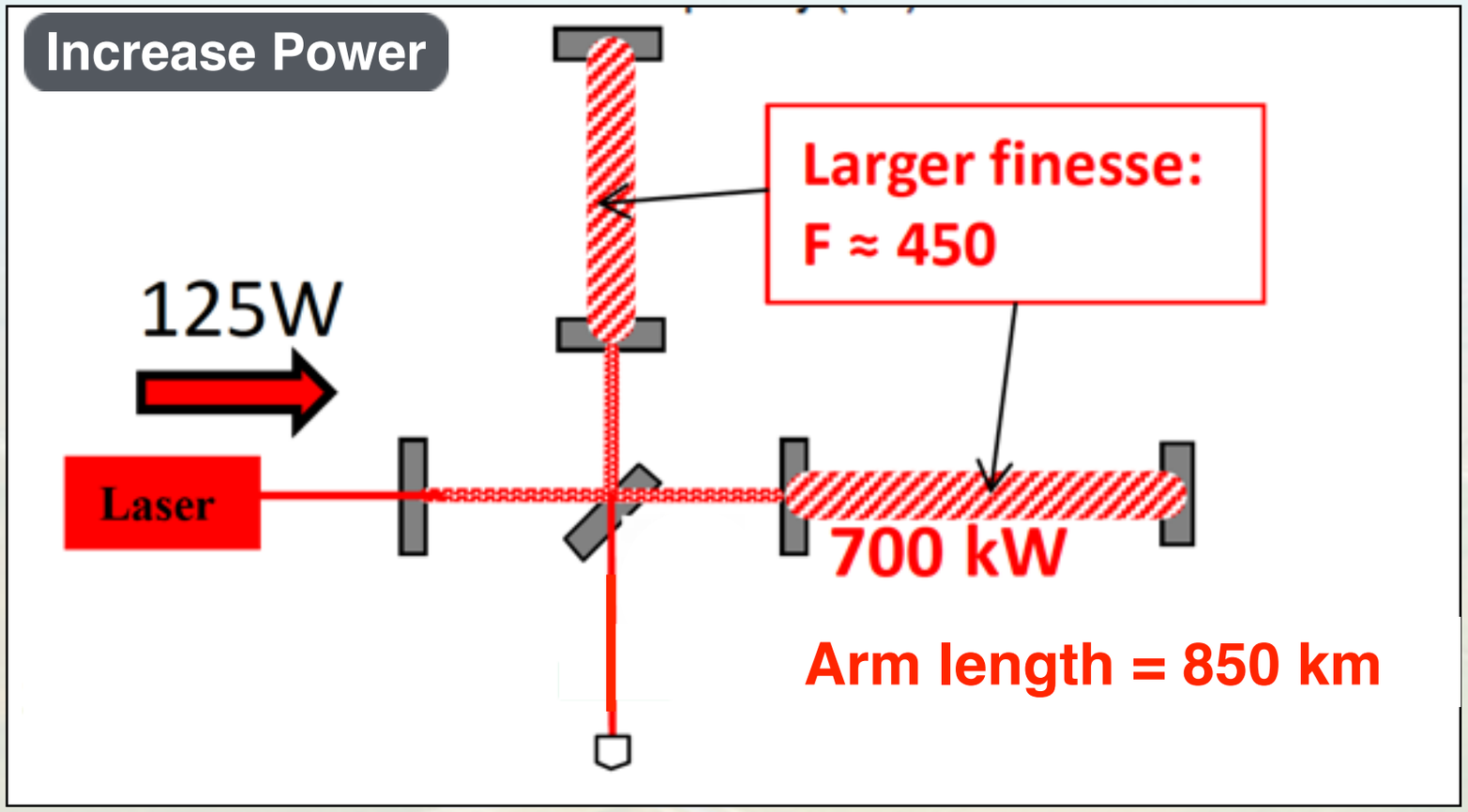
Advanced Virgo

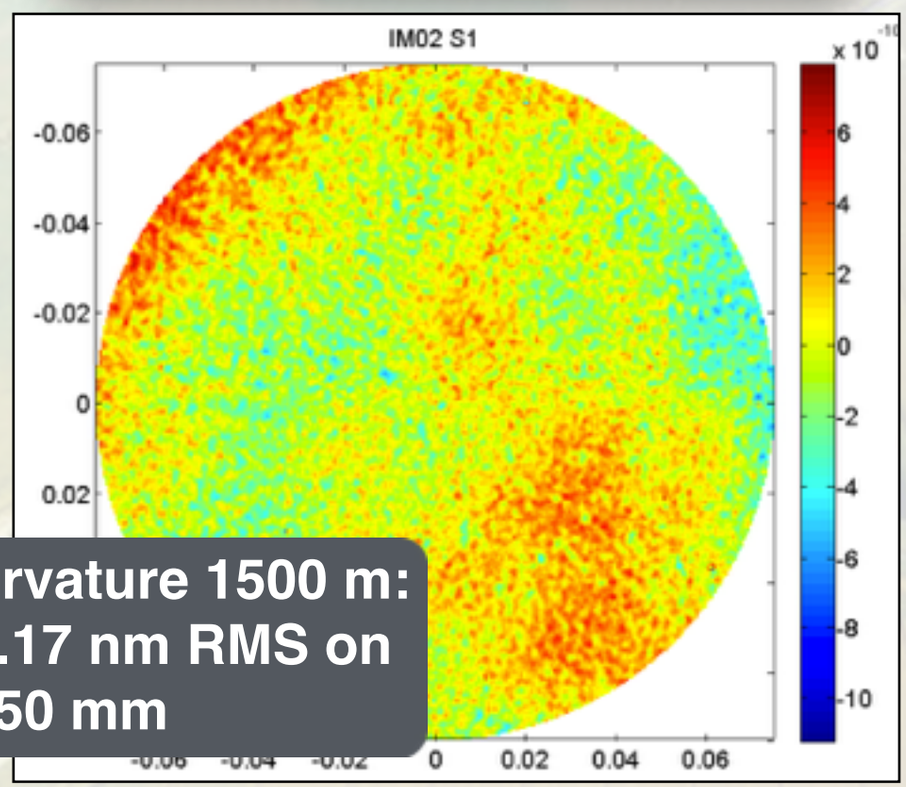


- **High-freq (>300 Hz):**
  - ✓Laser shot noise
    - ➡ Increase laser power
- **Mid-freq (40-300 Hz):**
  - ✓Thermal noise
    - ➡ Improve mirrors
- **Low-freq (<40 Hz):**
  - ✓Seismic noise
    - ➡ Vibration isolation



Shot noise

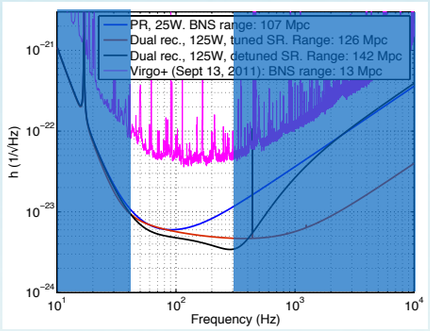




Requires:

- Powerful laser
- High quality optics
- Thermal compensation systems

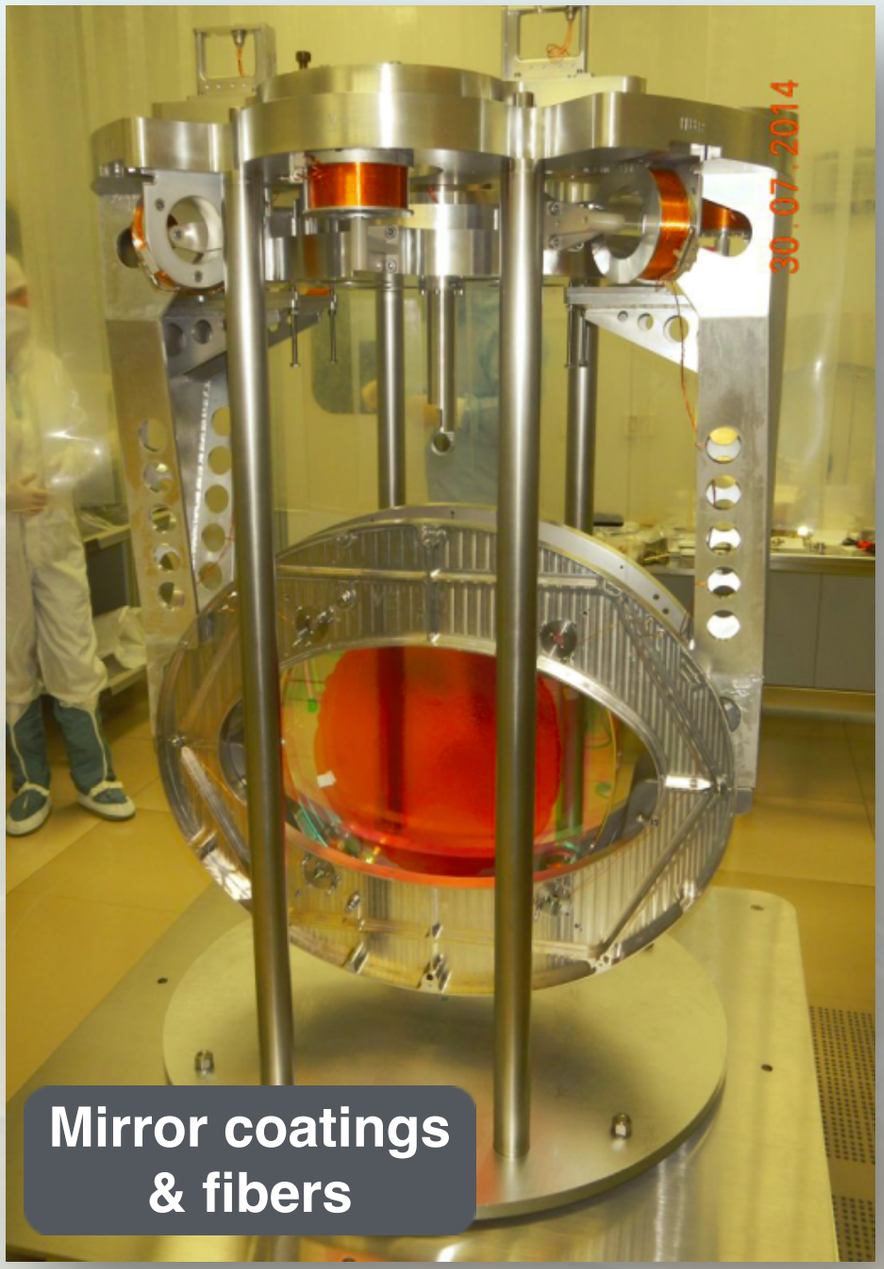
Radius of curvature 1500 m: measured 0.17 nm RMS on ∅150 mm



Thermal noise

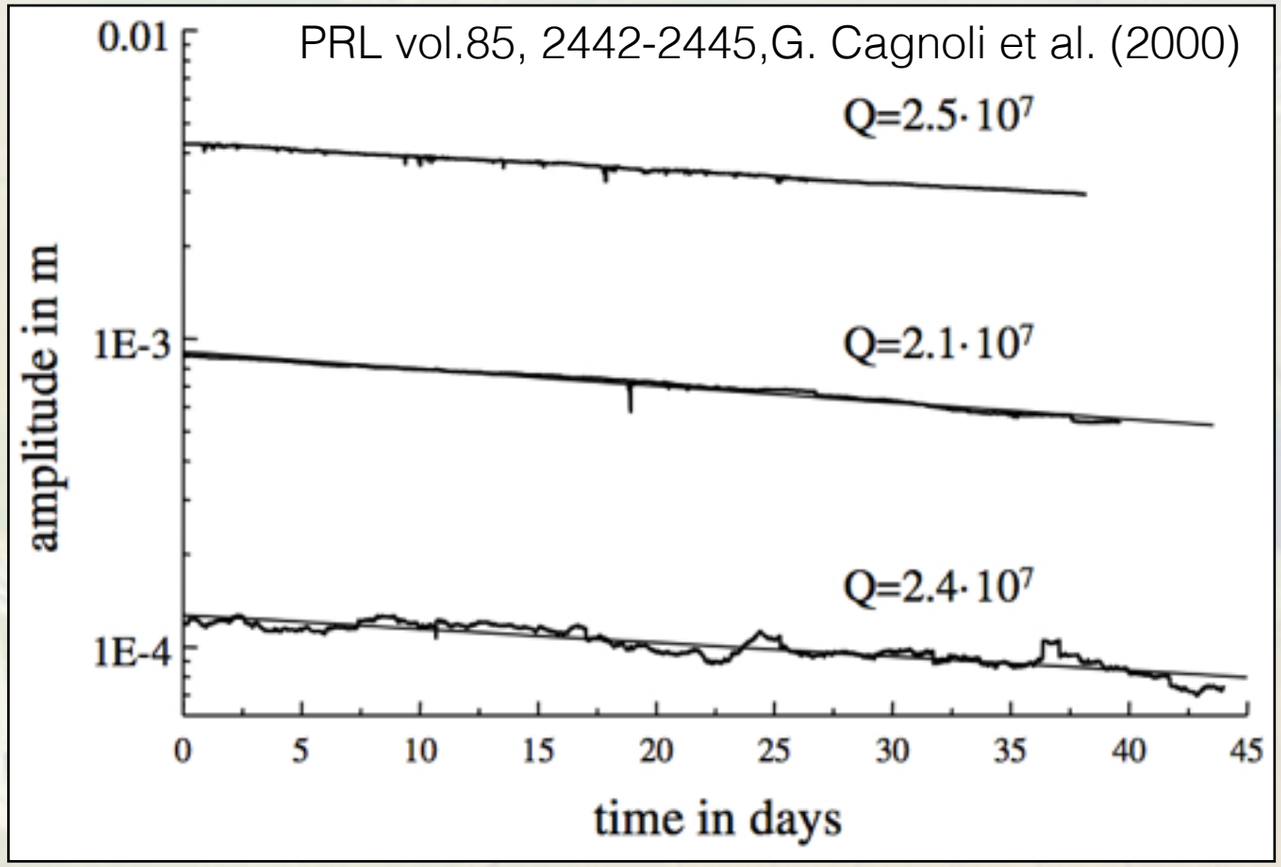
Requires:

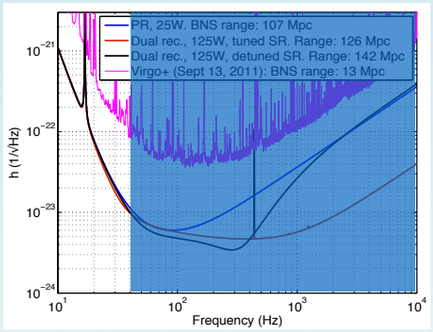
- Heavier test mass
- Larger beam
- Low loss coatings
- Different suspension material



Mirror coatings & fibers

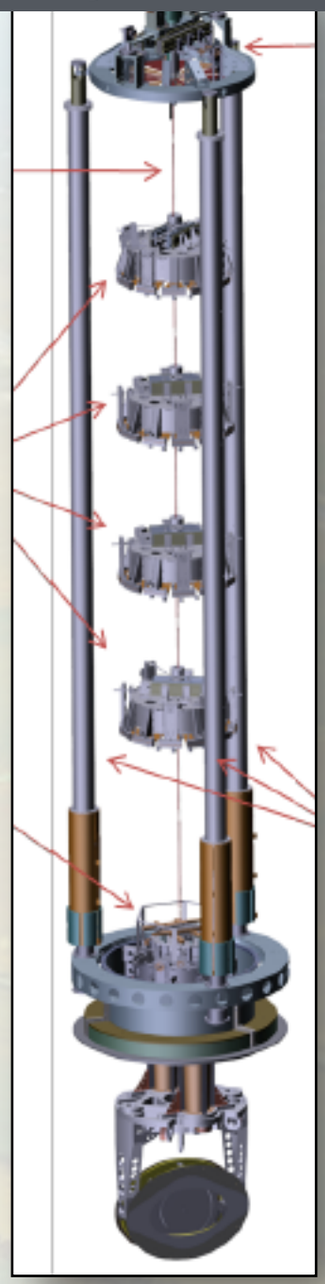
Suspended mass - fused silica wires





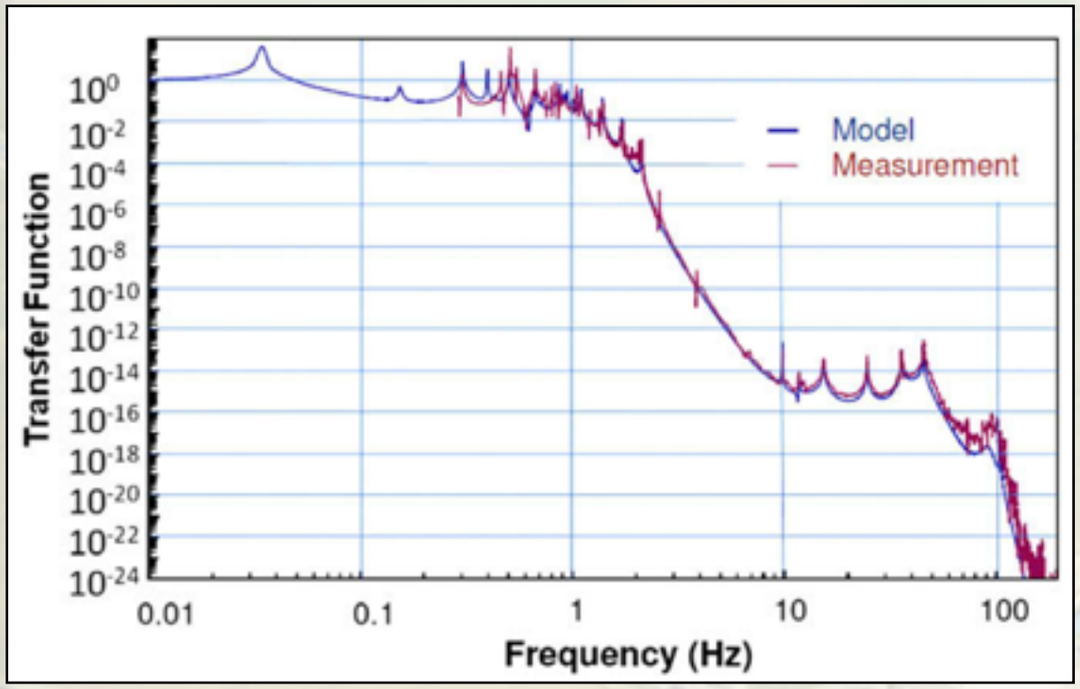
Seismic noise

Suspension systems

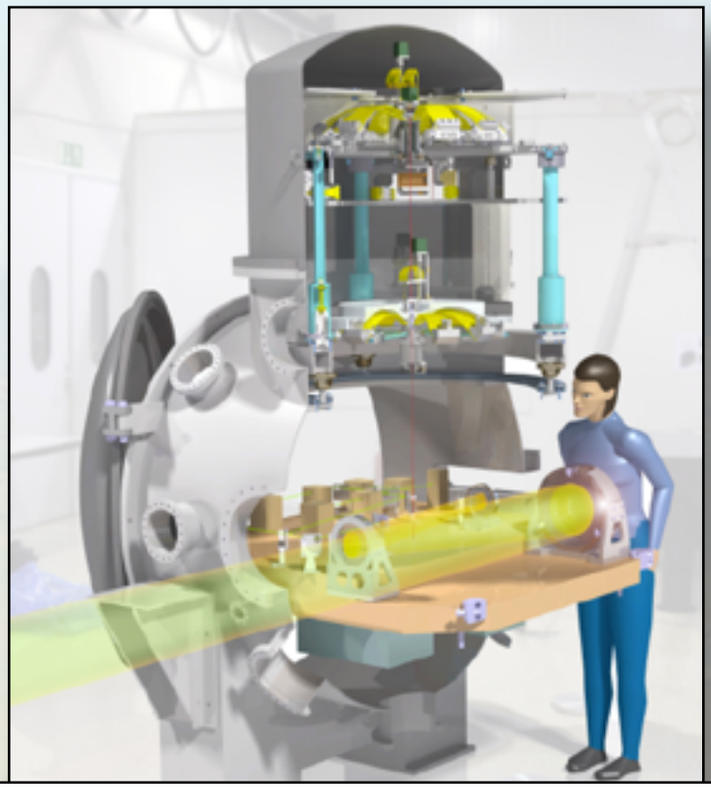


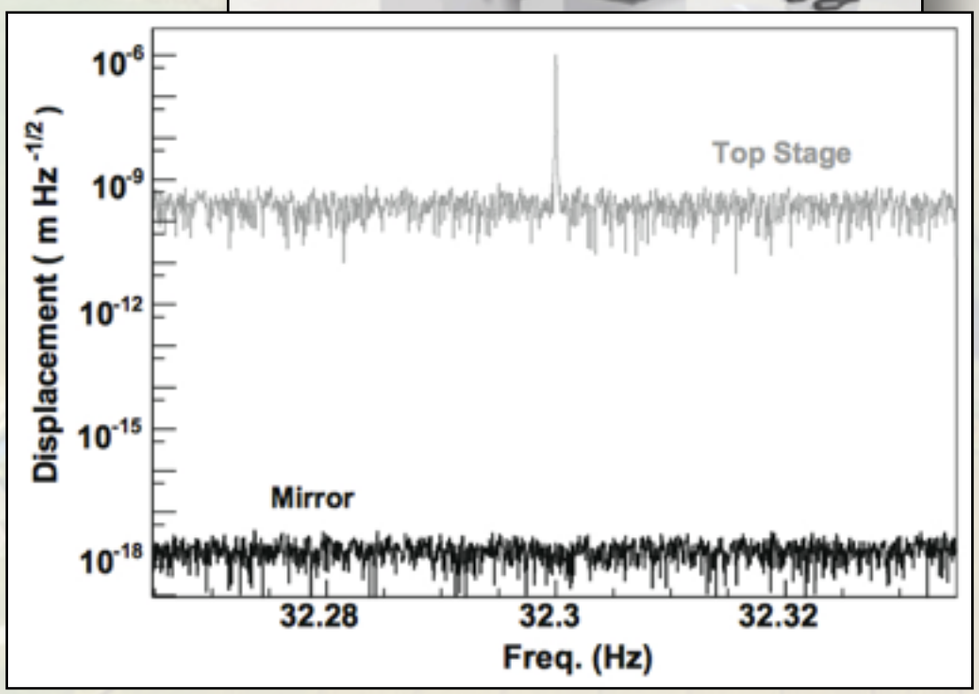
Requires:

- Extreme vibration isolation
- Suspended PD detection benches
- Shot noise limited sensors
- State-of-the-art actuators & controls

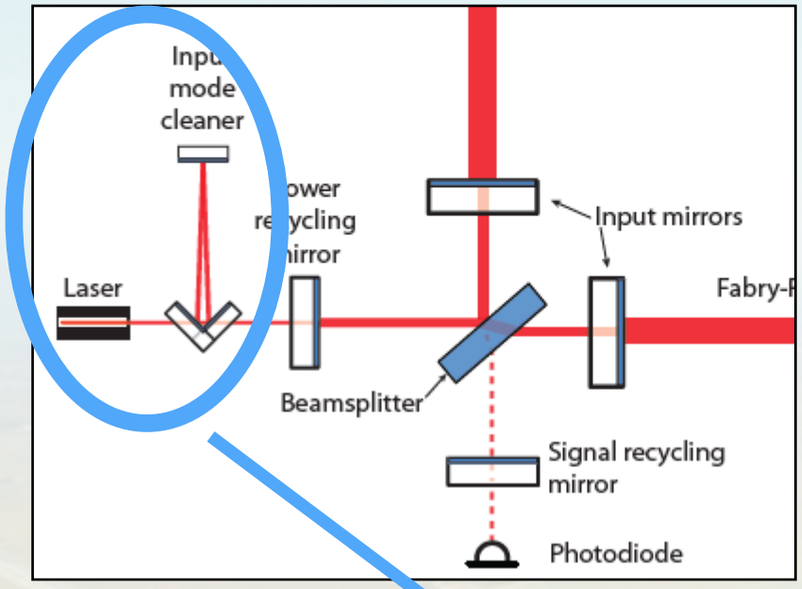


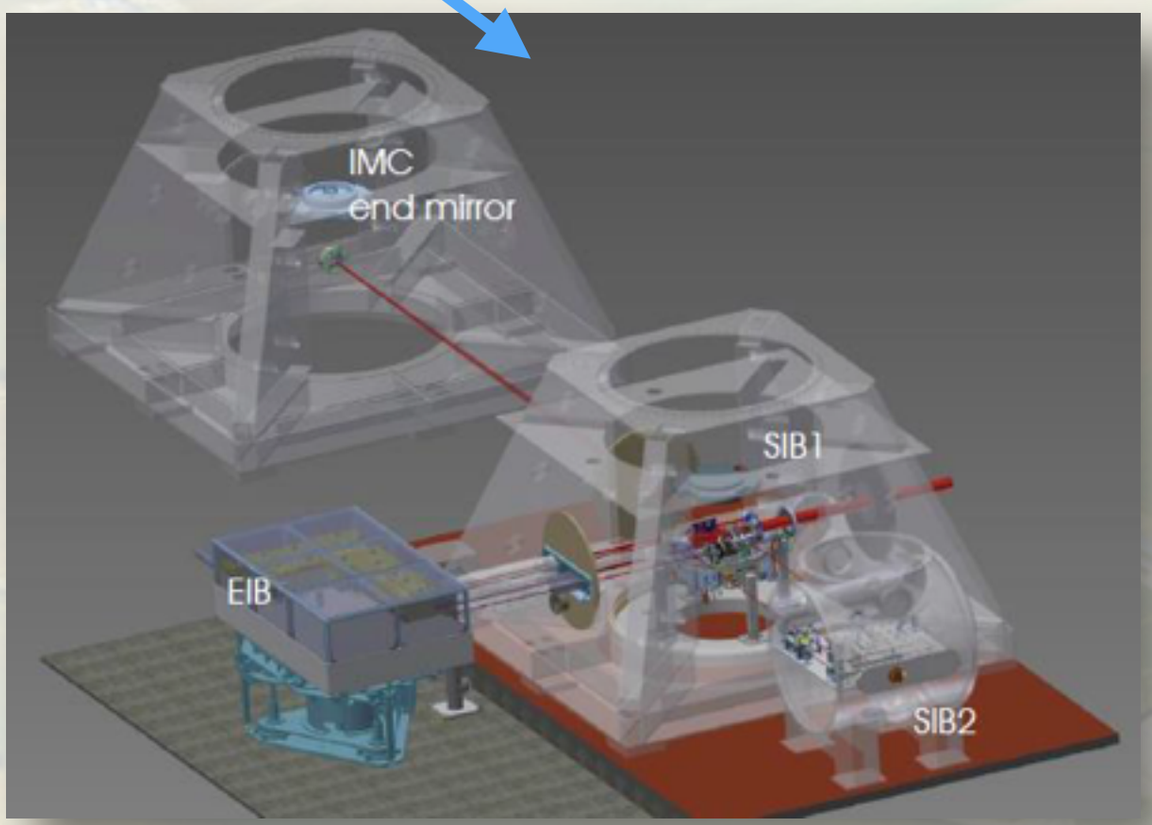
Astroparticle Physics 33 (2010), 182-189, F.Acernese et al.

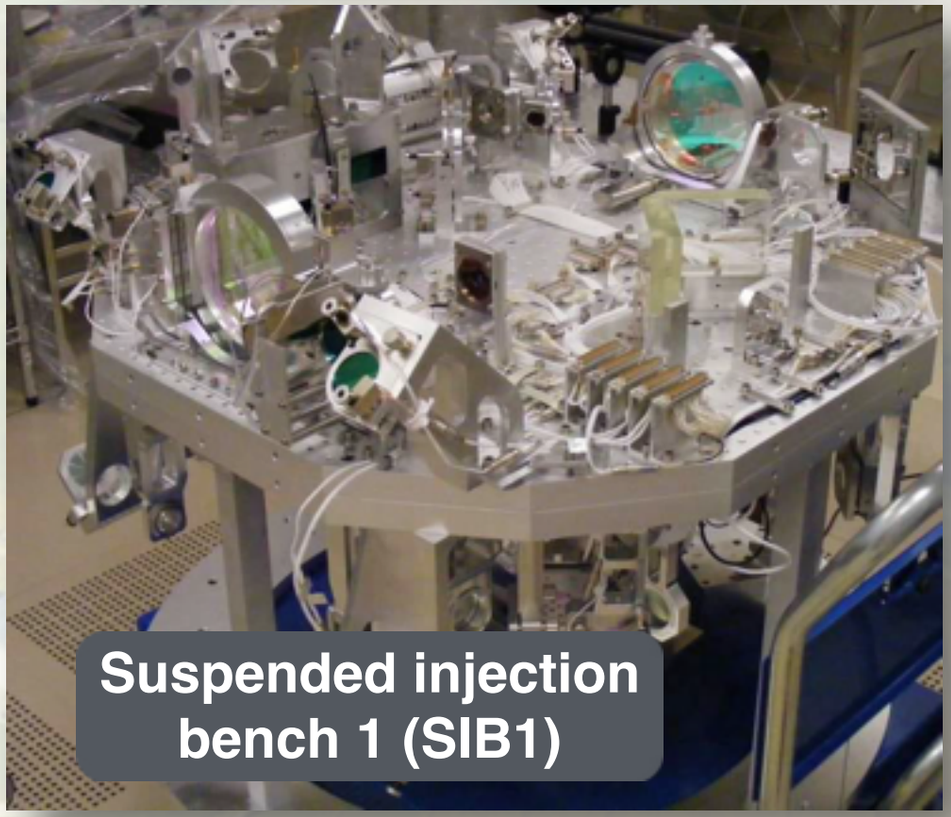




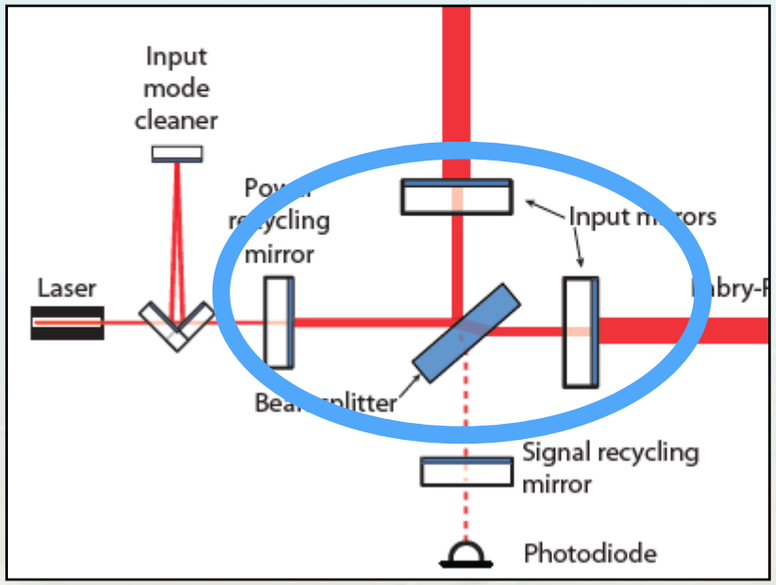
Construction

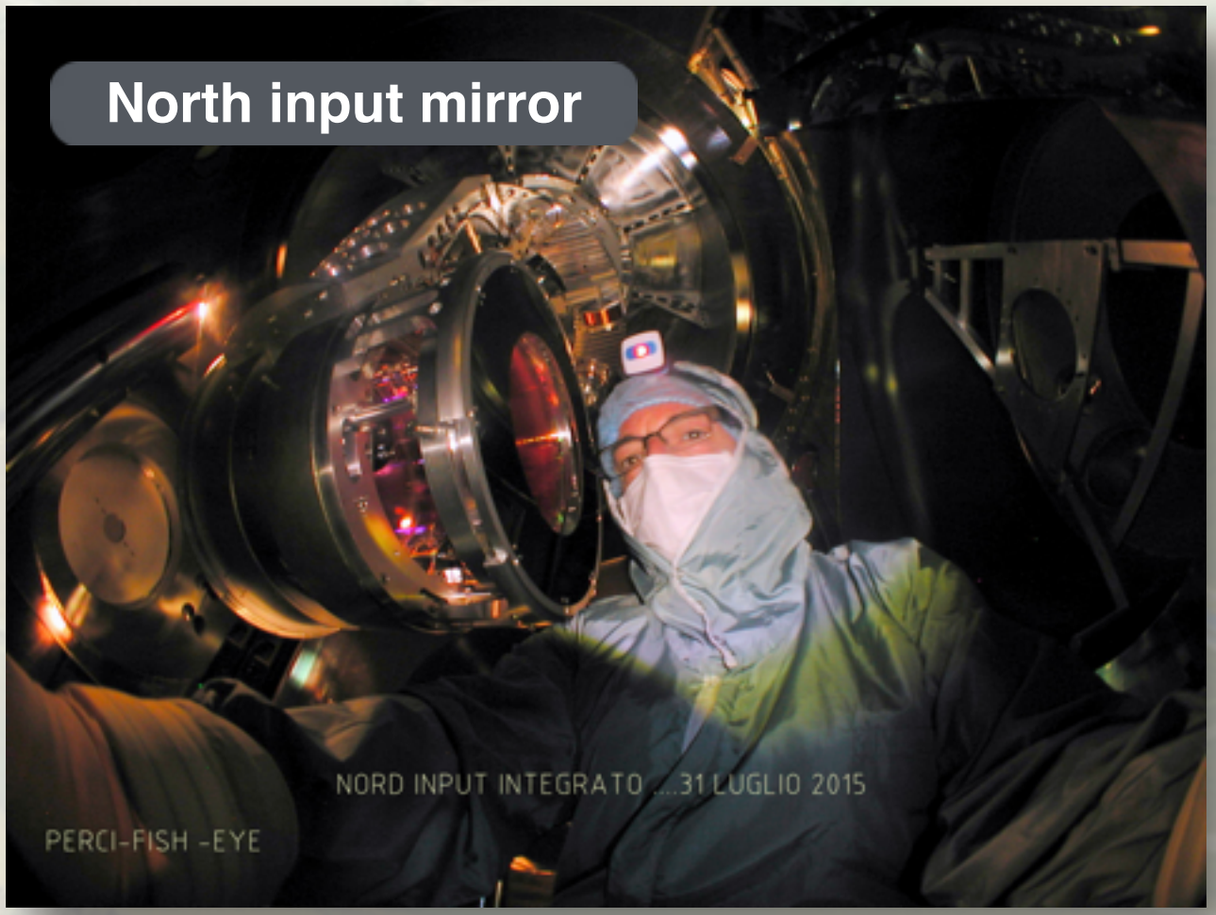


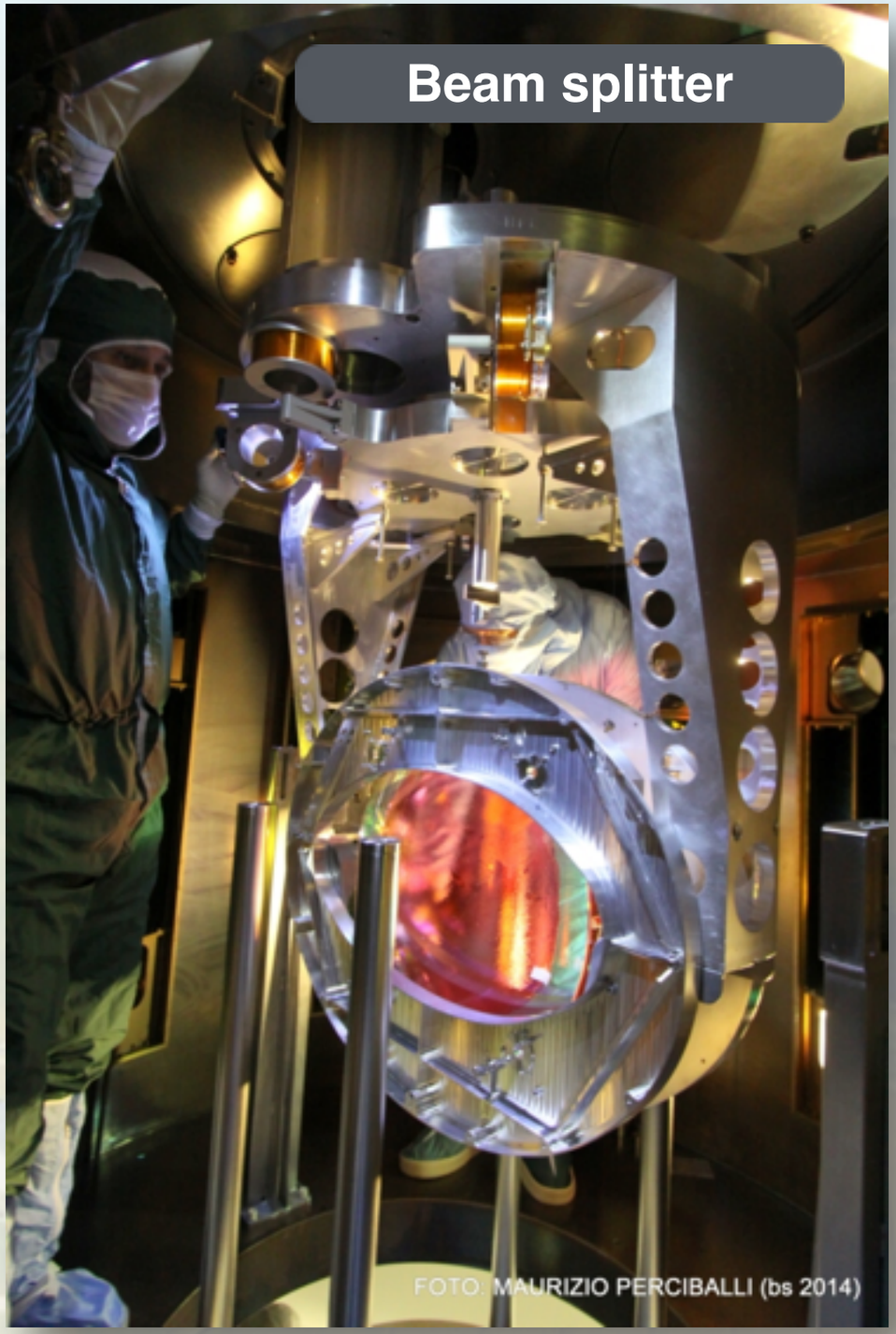




Construction

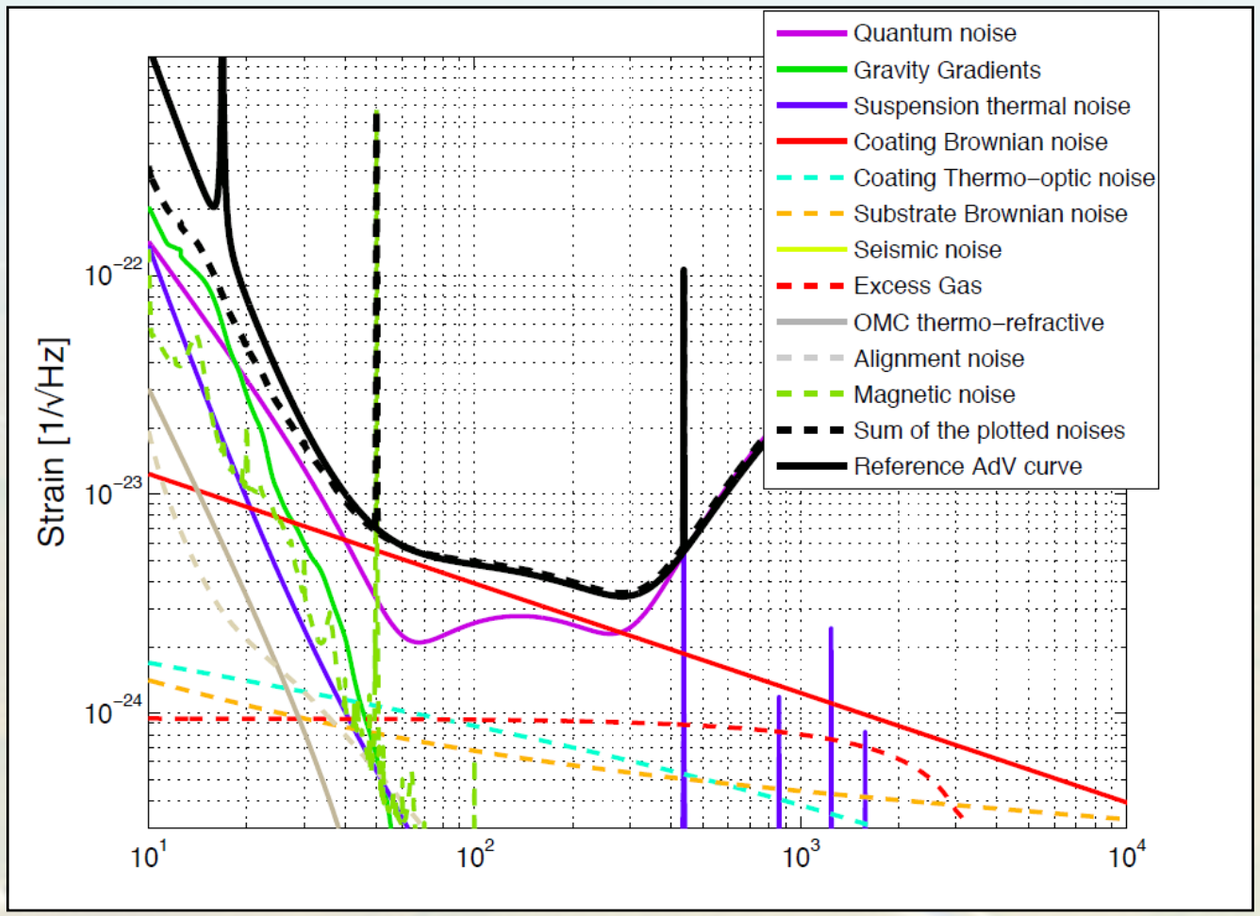


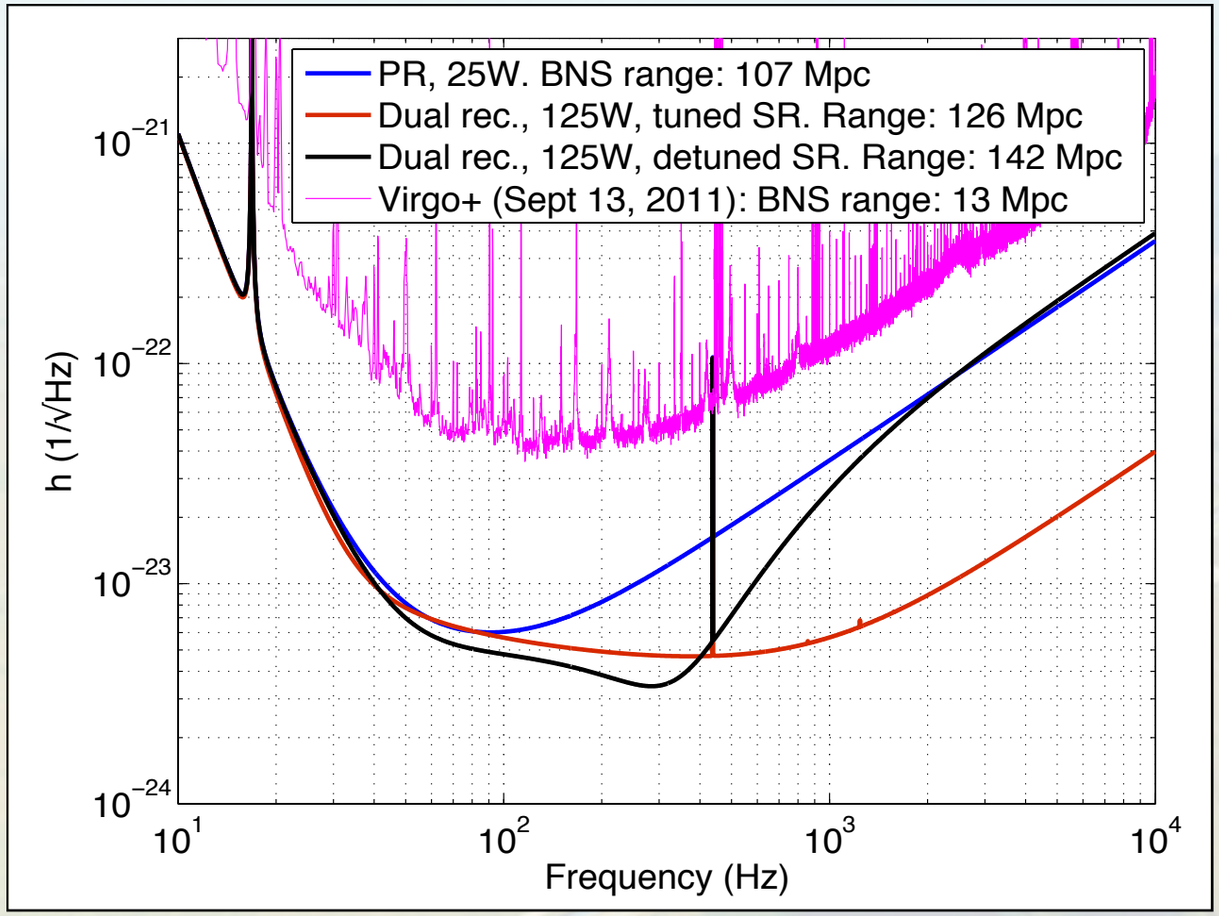




Commissioning

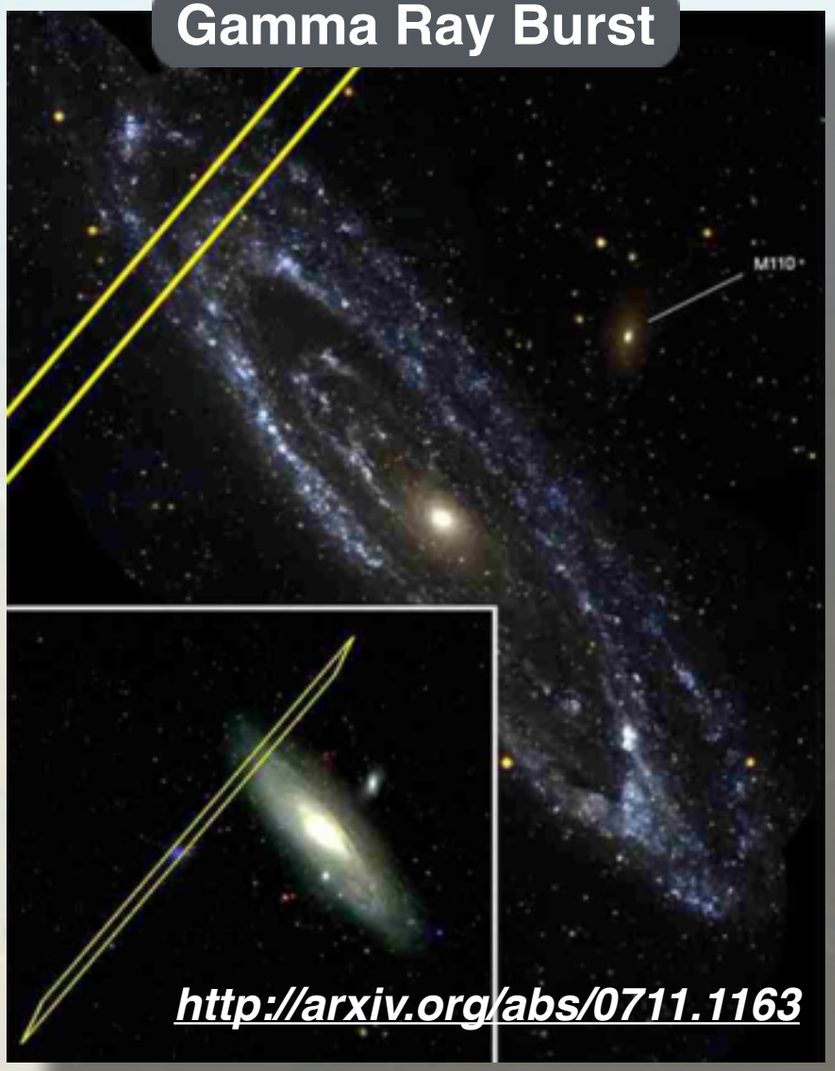
Early 2016





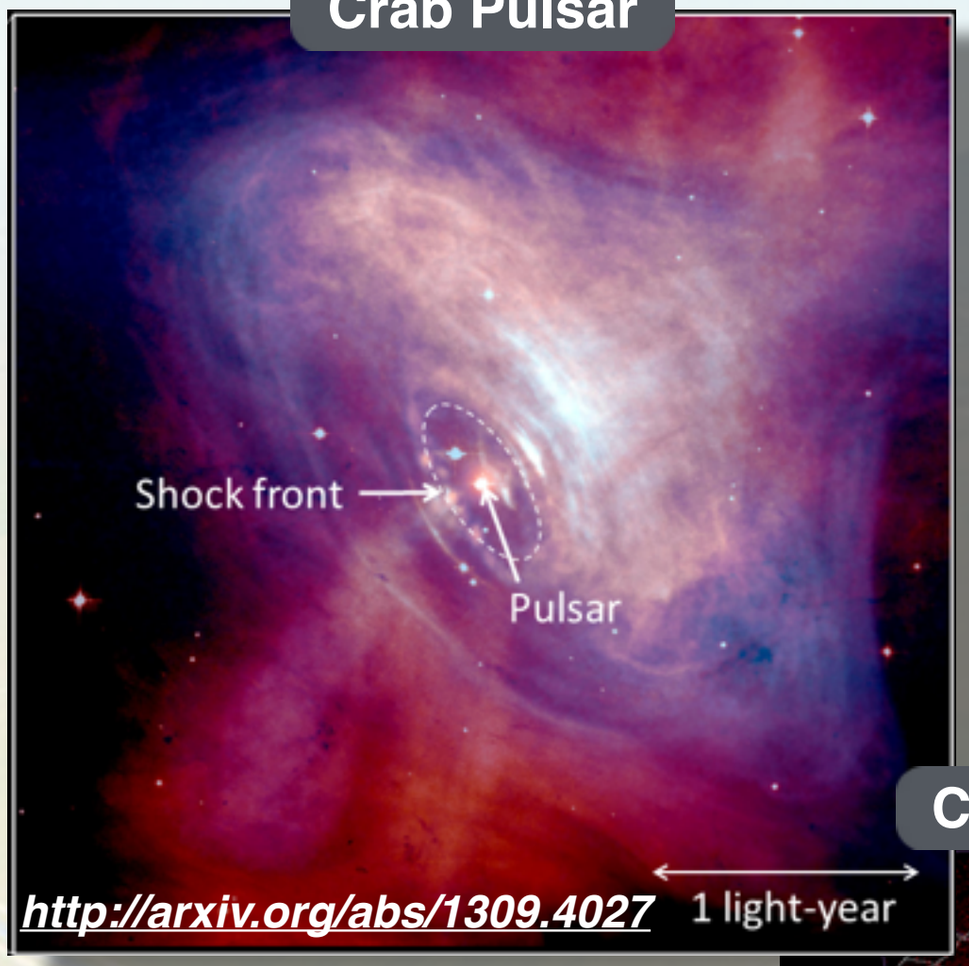
Ligo/Virgo results

Gamma Ray Burst



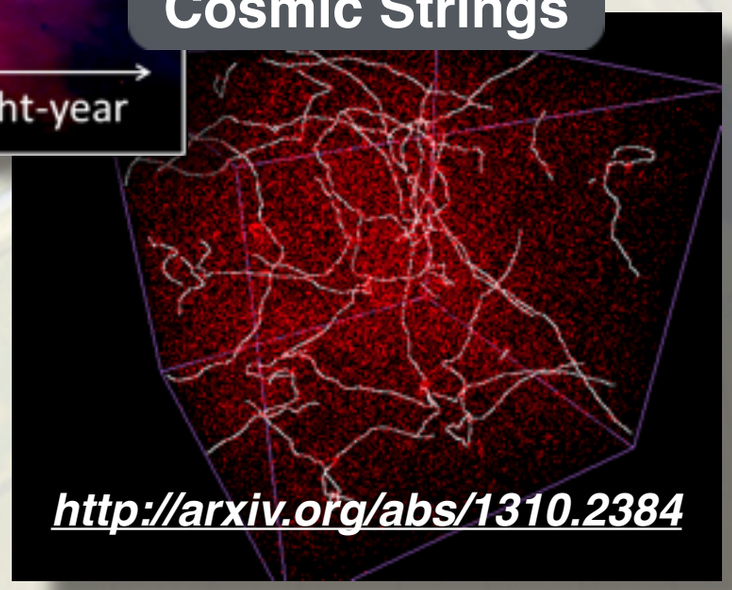
No GW - No merger in M31

Crab Pulsar



GW radiation ≤1% in ring down

Cosmic Strings

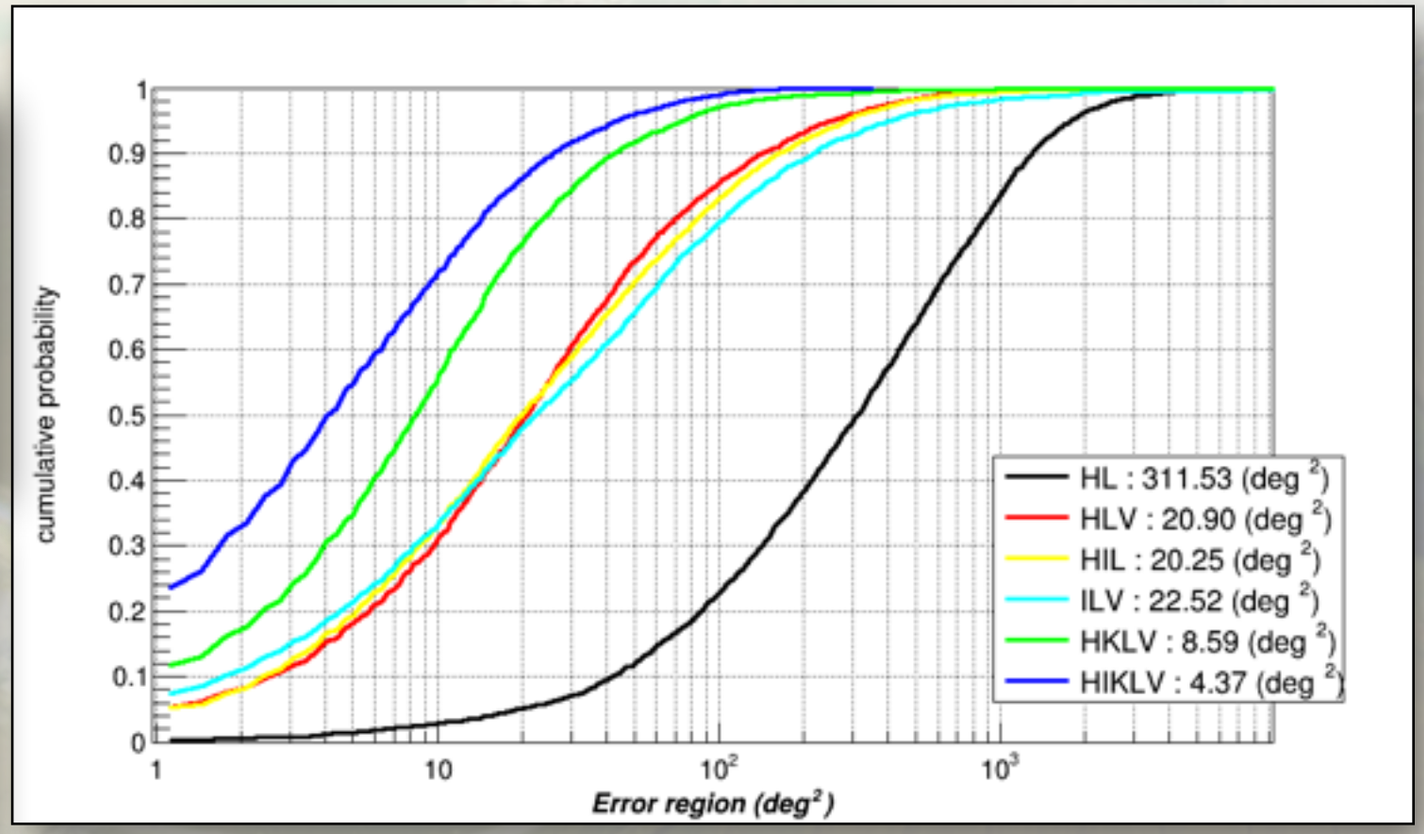


Parameter space

2016/18

Science runs

- Join Advanced LIGO second observation run in 2016
- Direct detection of gravitational waves
- Test General Relativity in strong-field, dynamical regime



To conclude

- What are the challenges?
- Advanced Virgo!
- Gravitational waves?
- New physics tool(s)…..