Status of Advanced LIGO

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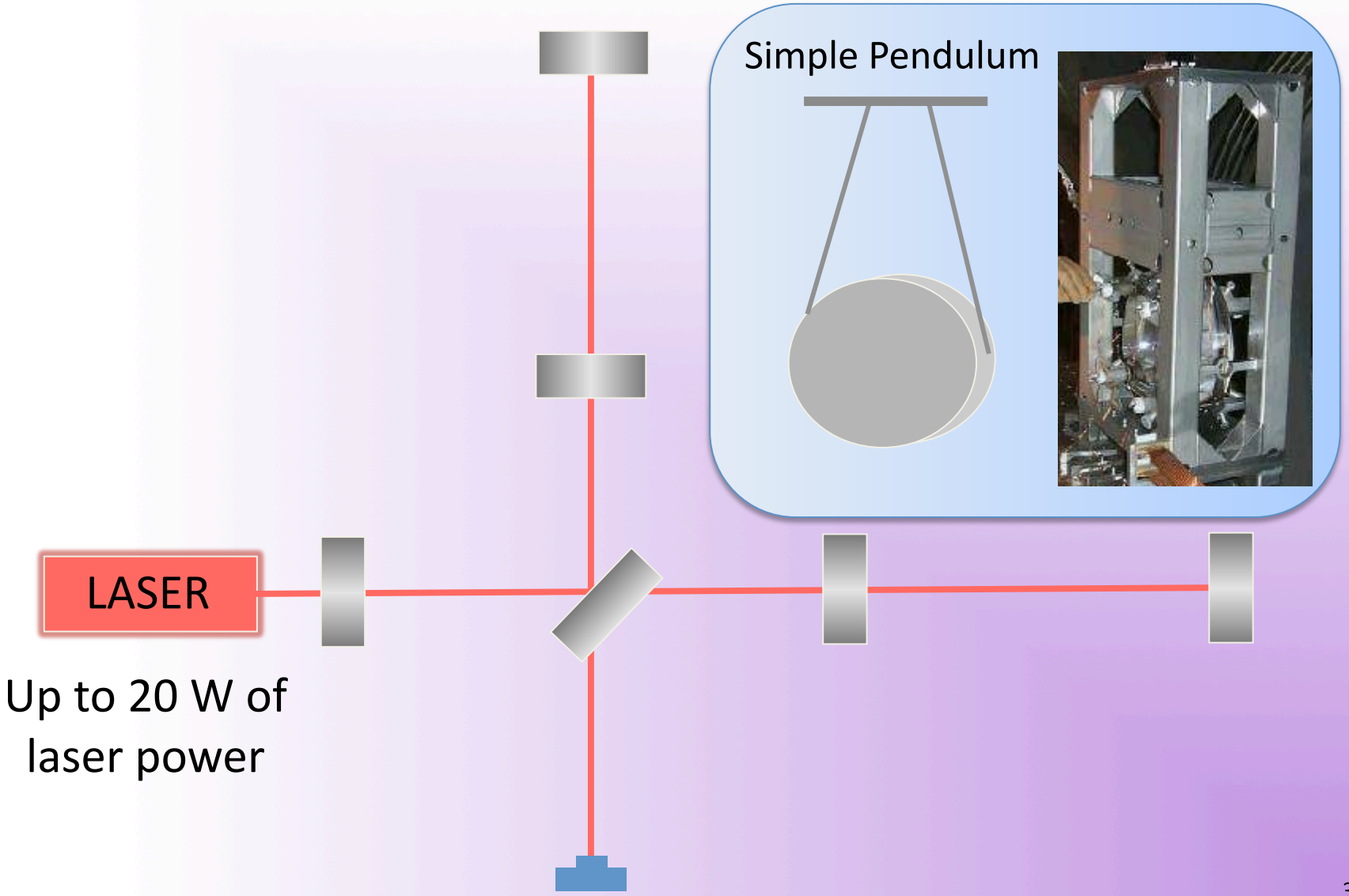
MIT-LIGO Laboratory

On behalf of the

LIGO Scientific Collaboration

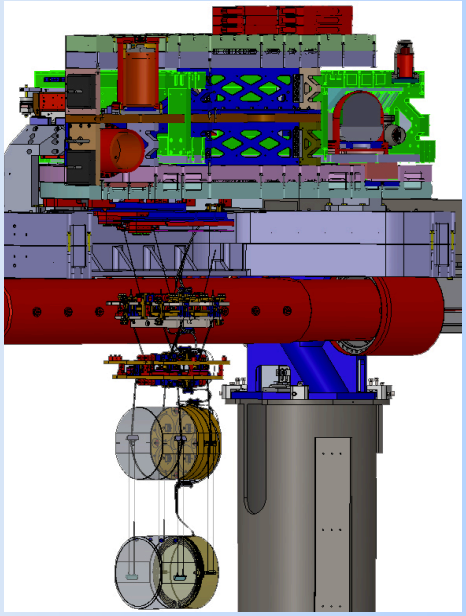
Hanford (WA) & Livingston (LA), 4 km arms

How LIGO looked like (2001-2010)

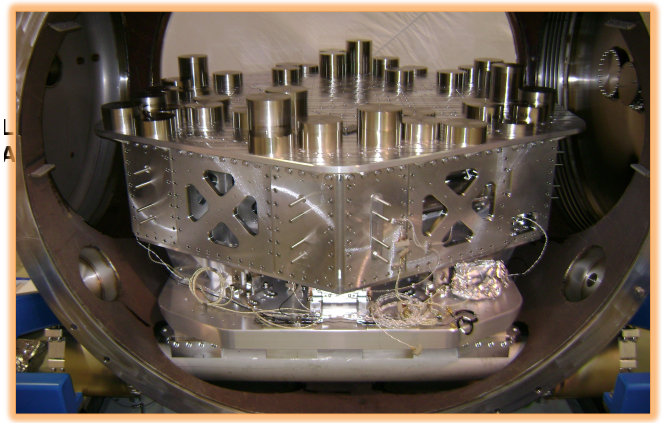


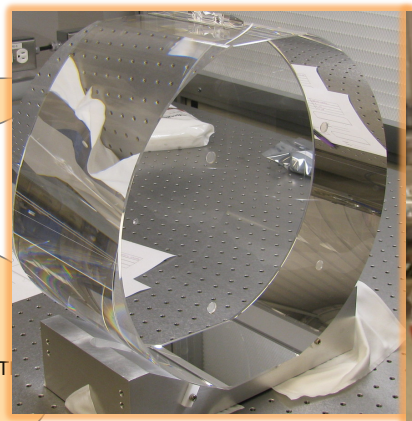
Advanced LIGO in a Nut Shell

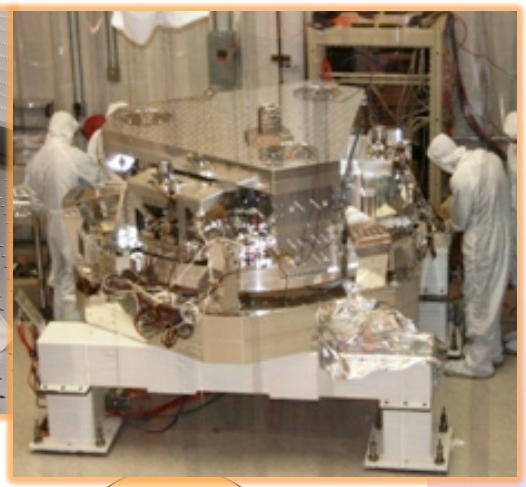
- ✧Larger mirrors
- ✧More laser power
- ✧Less seismic noise
- ✧Better optical layout

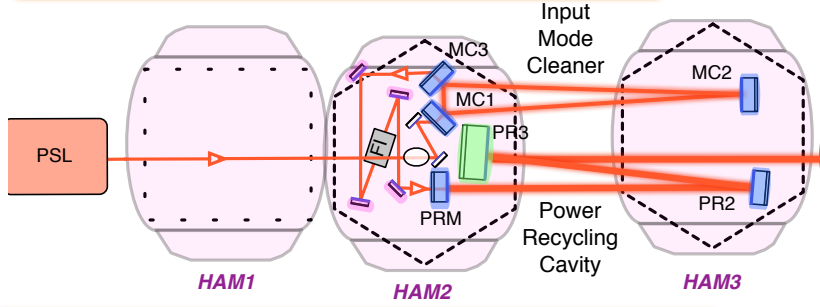


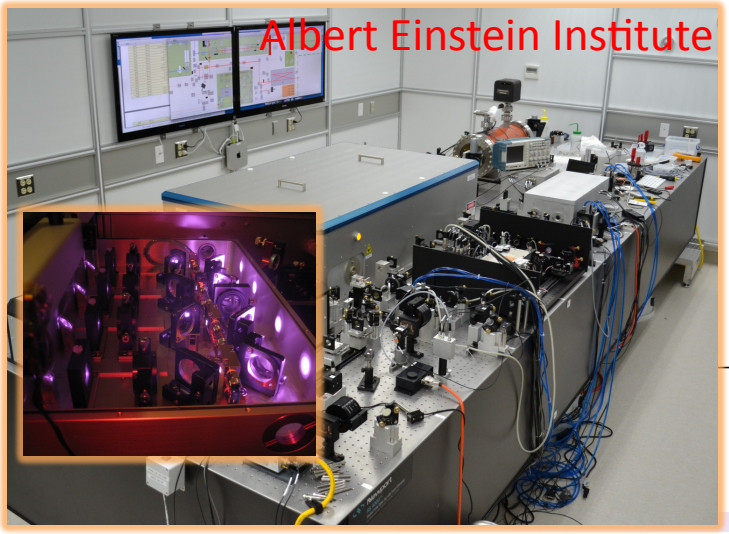
Advanced LIGO

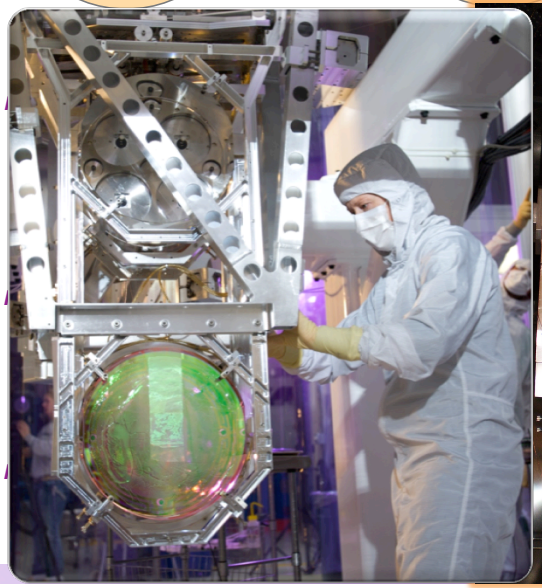


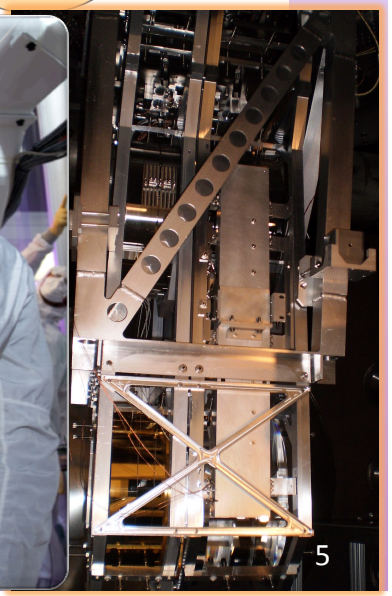




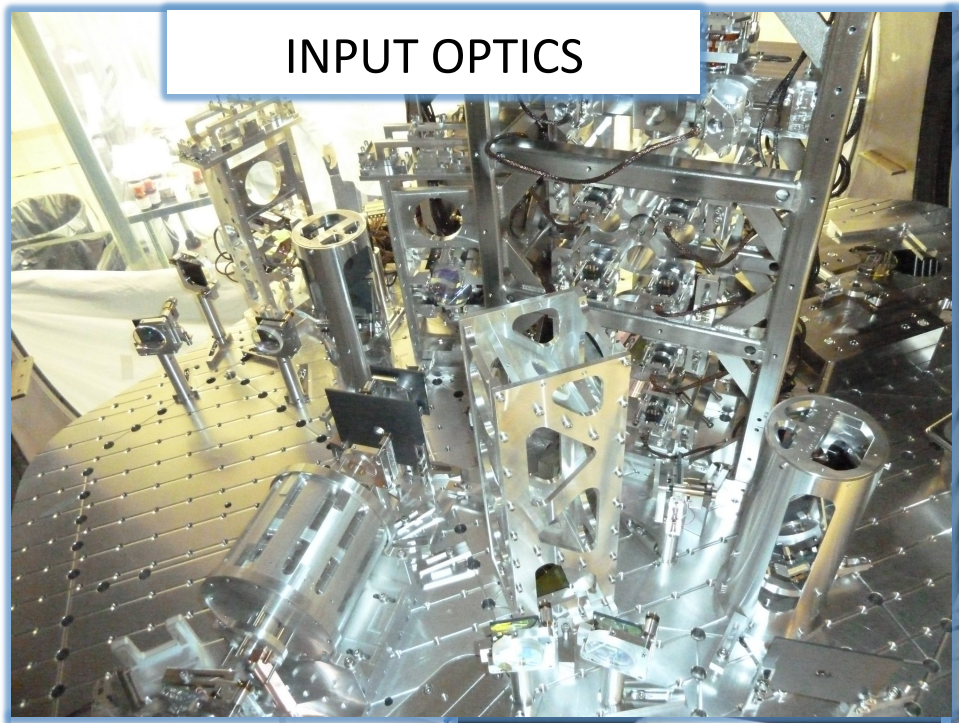


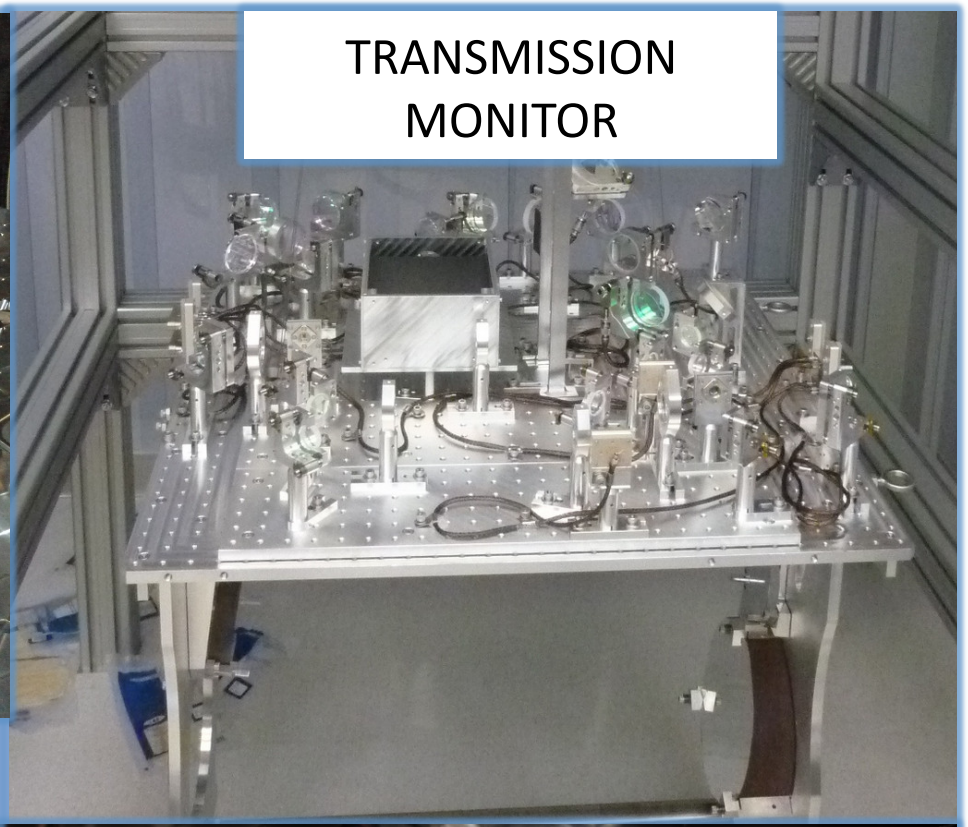


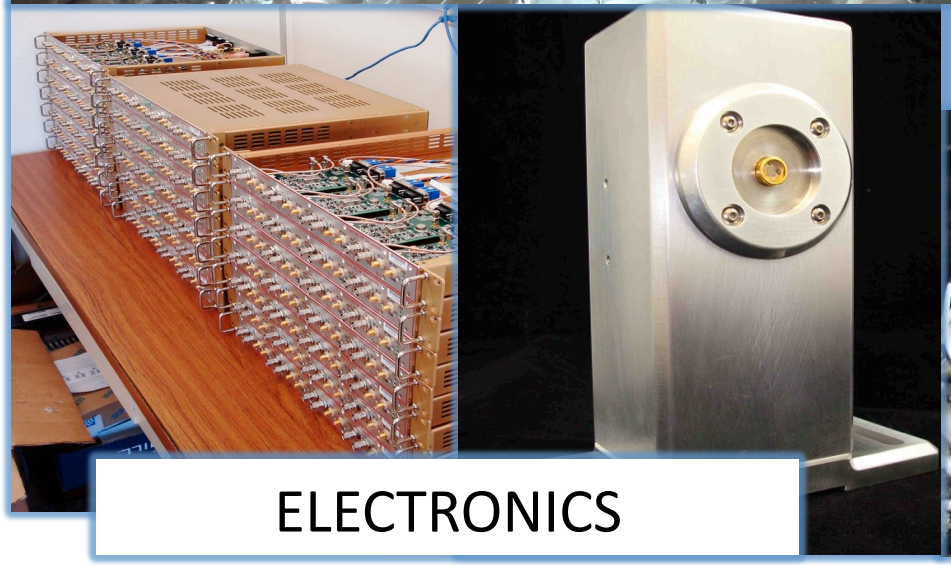


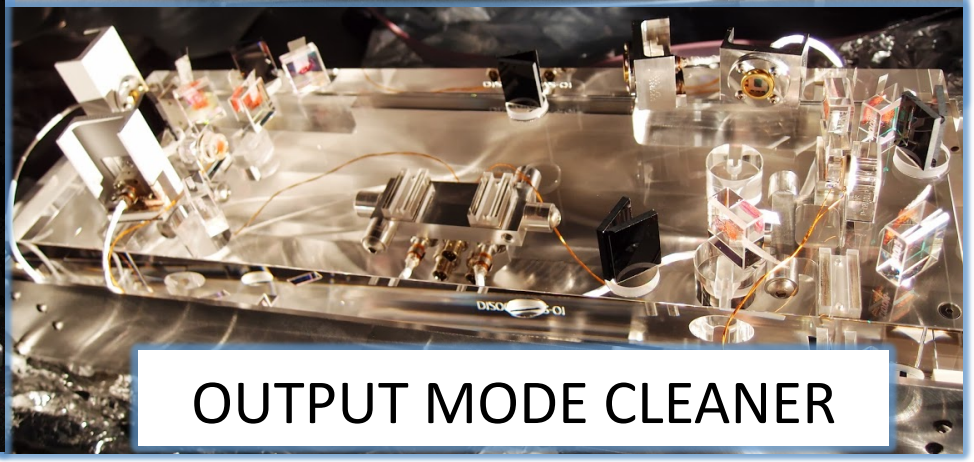


“EVERYTHING is better in Advanced LIGO!”

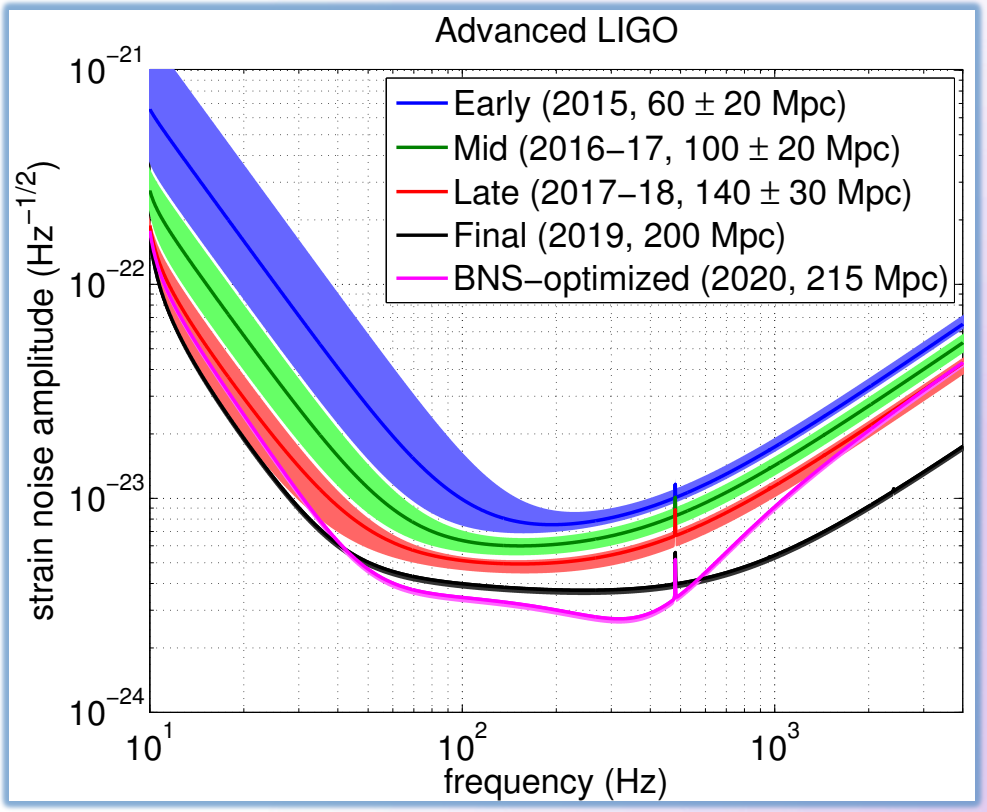








GOAL: reach a scientifically interesting sensitivity as soon as possible



http://arxiv.org/abs/1304.0670

TENTATIVE TIMELINE:

- Complete integration by 2014 (interferometer "locked")
- "Early" Science Run in 2015 (~60 Mpc)
- Within a factor of 2 of design sensitivity by 2016 (~100 Mpc)

Detection Rates

Epoch	Estimated Run Duration	$E_{GW} = 10^{-2} M_\odot c^2$ Burst Range (Mpc)		BNS Range (Mpc)		Number of BNS Detections	% BNS Localized within	
		LIGO	Virgo	LIGO	Virgo		$5\,\mathrm{deg}^2$	$20\,\mathrm{deg}^2$
2015	3 months	40 – 60	–	40 – 80	–	0.0004 – 3	–	–
2016–17	6 months	60 – 75	20 – 40	80 – 120	20 – 60	0.006 – 20	2	5 – 12
2017–18	9 months	75 – 90	40 – 50	120 – 170	60 – 85	0.04 – 100	1 – 2	10 – 12
2019+	(per year)	105	40 – 80	200	65 – 130	0.2 – 200	3 – 8	8 – 28
2022+ (India)	(per year)	105	80	200	130	0.4 – 400	17	48

Neutron Star Binaries:

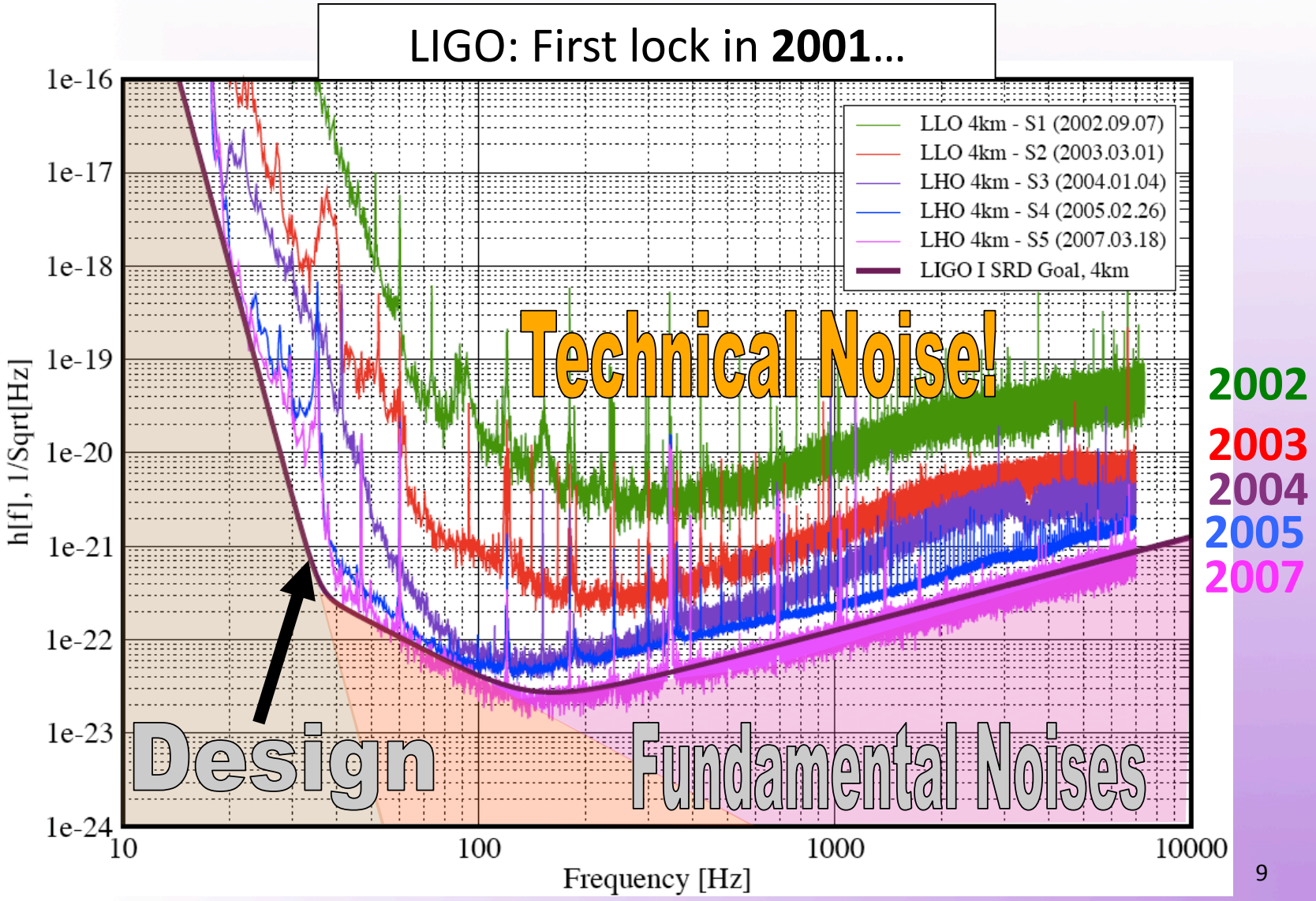
Initial LIGO: ~15 Mpc → rate ~1/50years

Advanced LIGO: ~ 200 Mpc *"Realistic rate" ~ 40/year*

Class. Quant. Grav. **27**, 173001 (2010)

http://arxiv.org/abs/1304.0670

It took longer the first time..



…but this time will be different!

Advanced LIGO Installation and Commissioning Strategy:

- ✧Extensive “standalone” testing before installation
- ✧Installation of “new” things as soon as possible
- ✧Configurations of increased complexity
- ✧Parallel effort between Hanford and Livingston
- ✧Better design and engineering informed by LIGO, more experienced staff

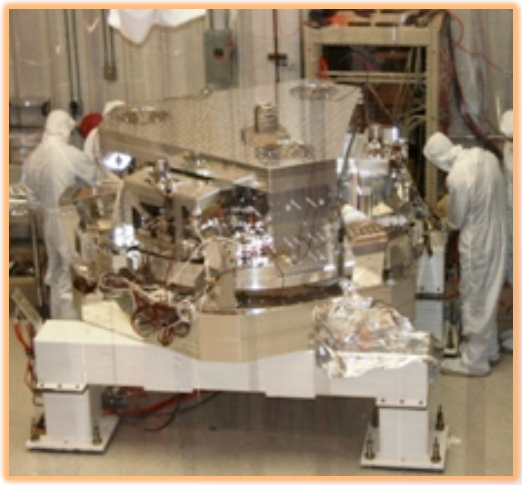
Results are already visible:

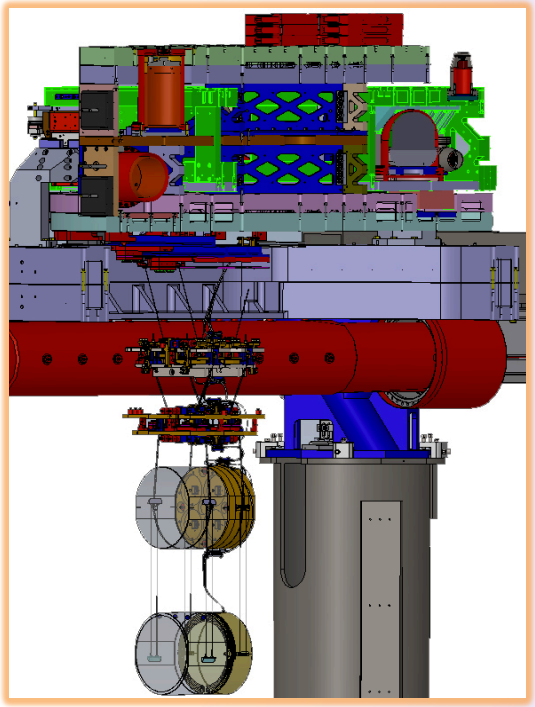
It took 4 months to lock the input mode cleaner cavity in LIGO,
it took less than 1 week in Advanced LIGO (the first time at Livingston),
more like 1 day at Hanford

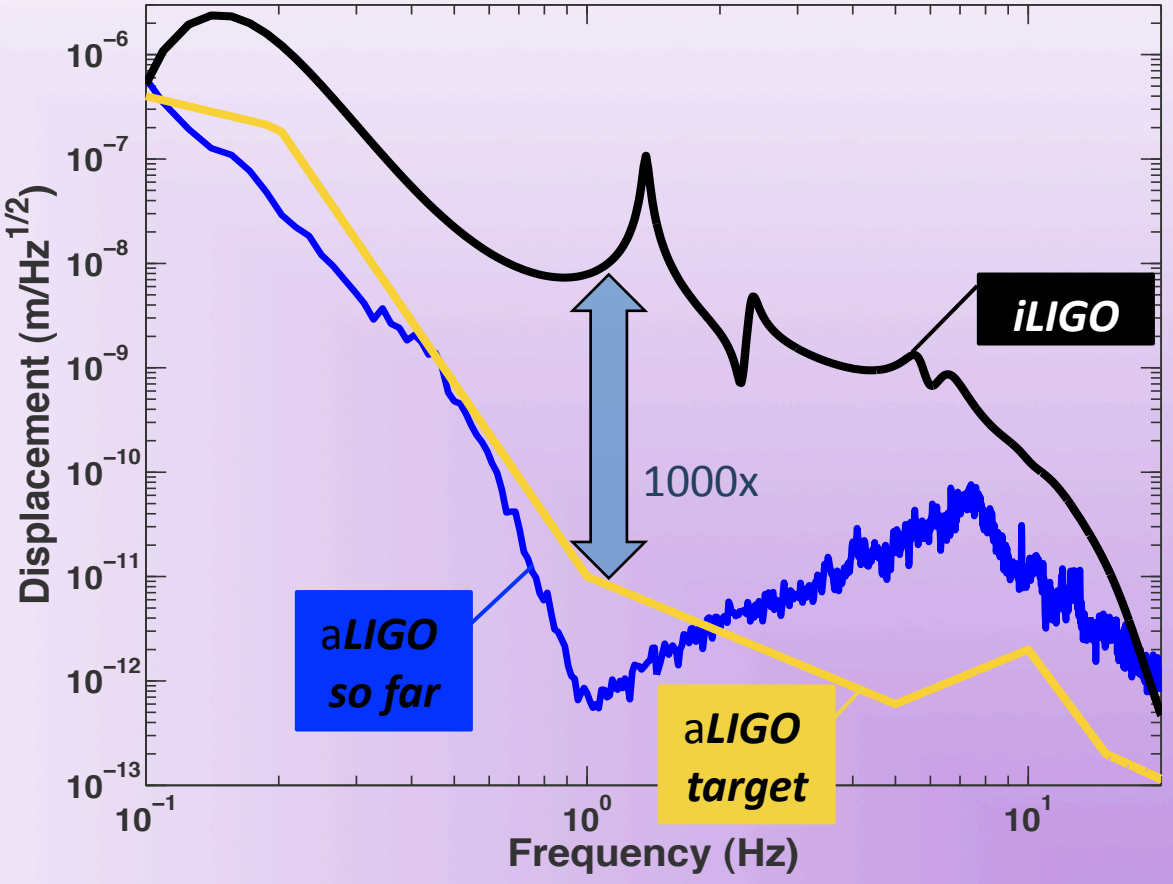
“Half Interferometer” in progress @ Hanford (now one arm, in the fall the other)

Full test of the new “Arm Length Stabilization” system: auxiliary green laser to stabilize the arm cavity length

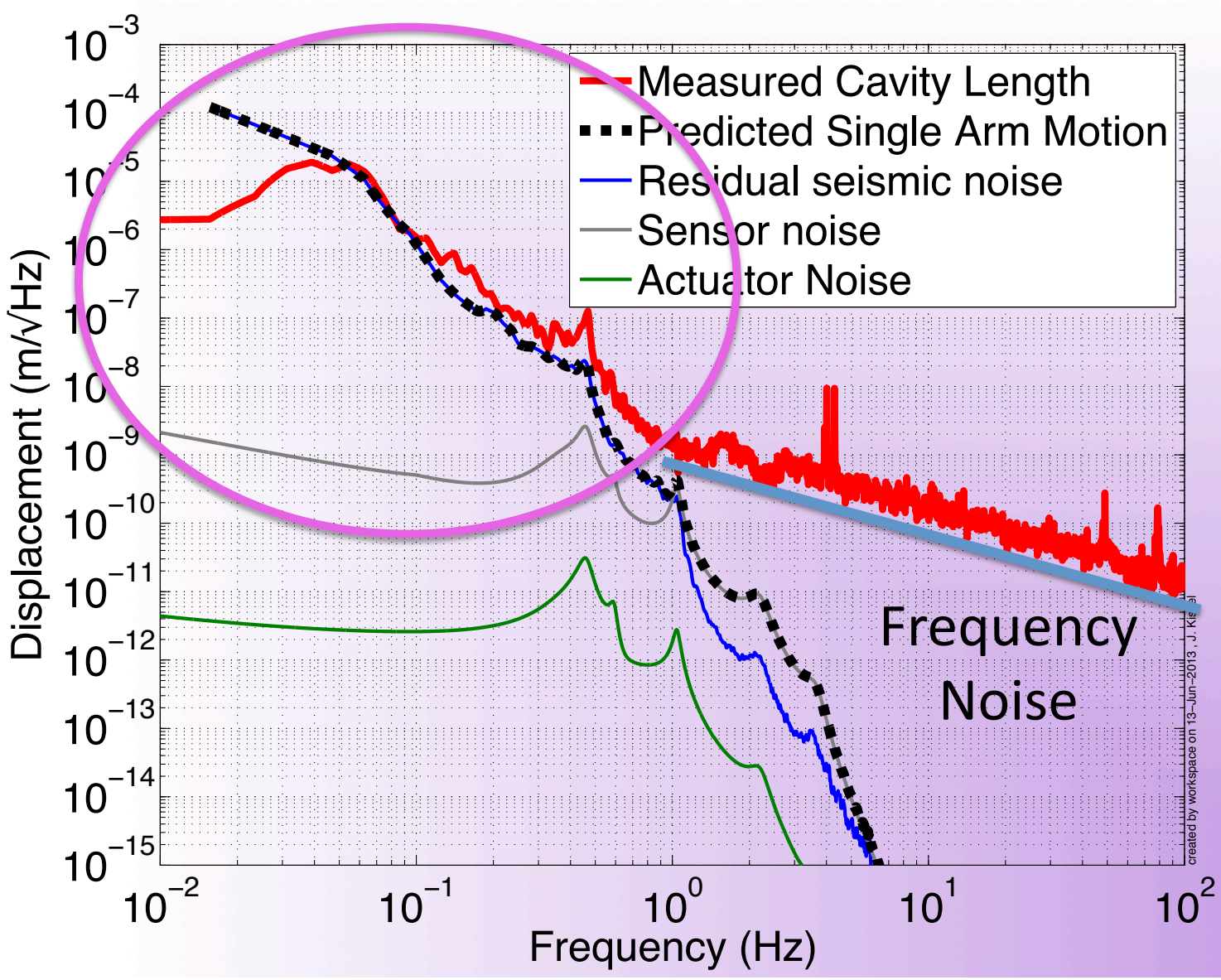
Seismic isolation performance





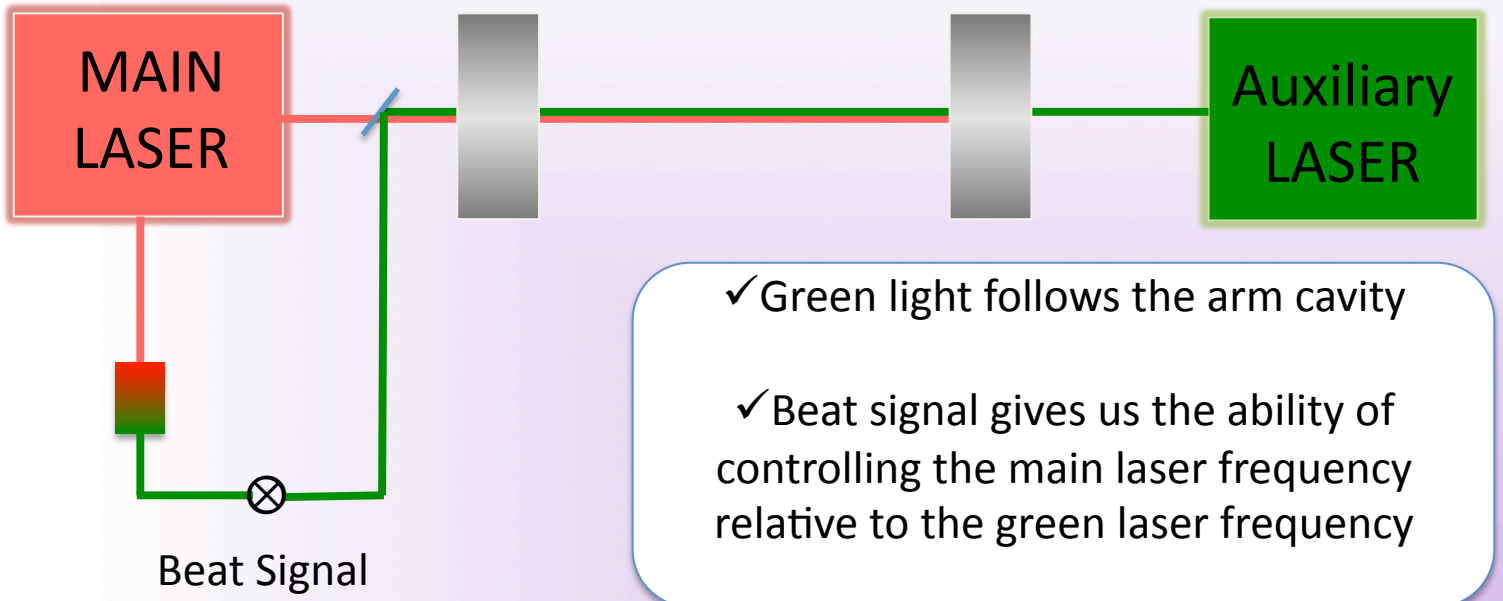


Cavity motion in good agreement with model (Jeff Kissel, MIT)



"Arm Length Stabilization" System

in collaboration with the Australian National University



✓Green light follows the arm cavity

✓Beat signal gives us the ability of controlling the main laser frequency relative to the green laser frequency

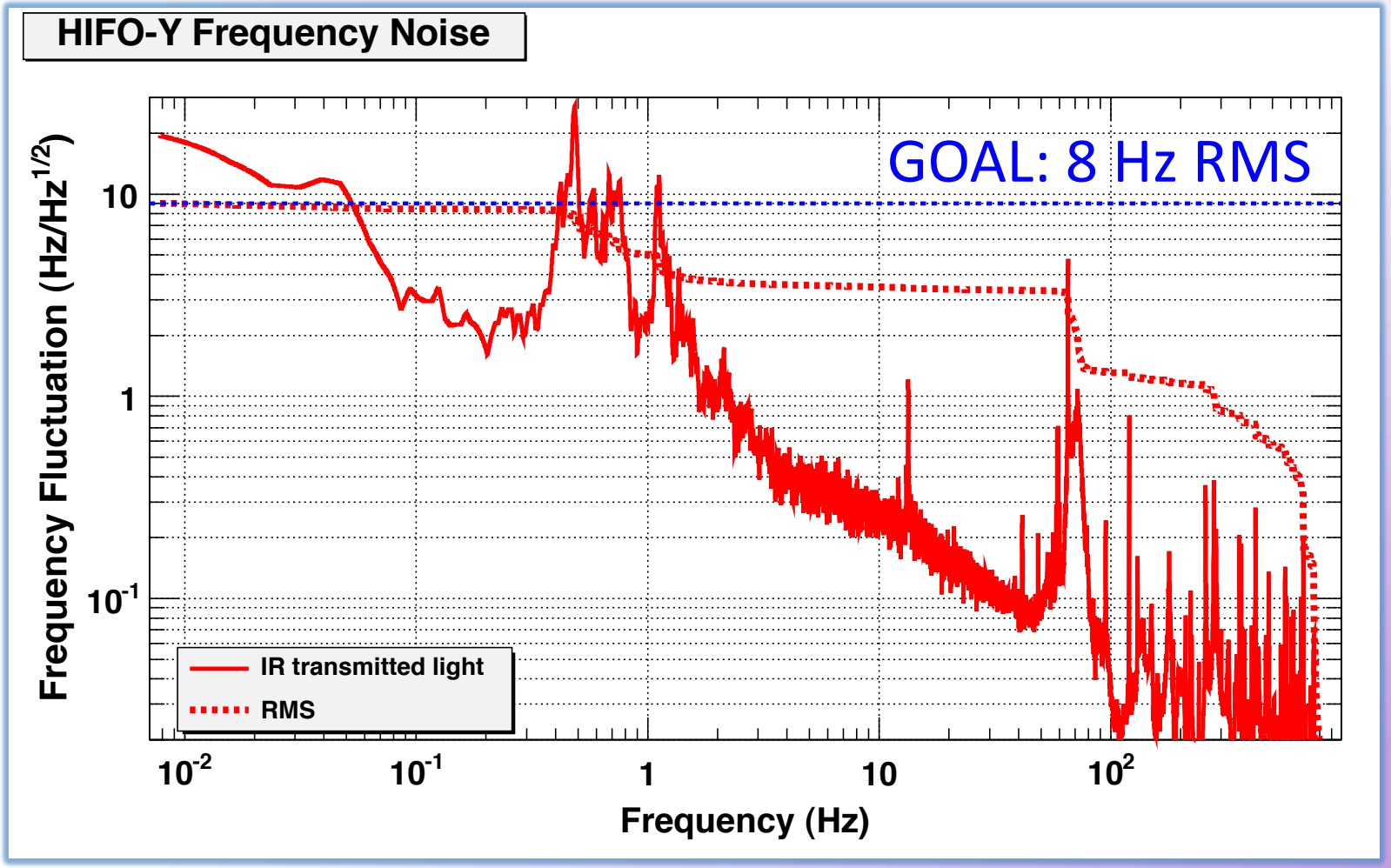
Green light won't be used in "science mode" but it will help us to bring the interferometer on its working point reliably

C3: Tuesday, 17:18 - 17:36 **Adam Mullavey (LIGO Livingston)**

The Arm Length Stabilization System for Advanced LIGO Lock Acquisition

“Arm Length Stabilization” System

Frequency fluctuations of main laser light is already “good enough”
(1/10 of the cavity linewidth), “noise hunting” still in progress



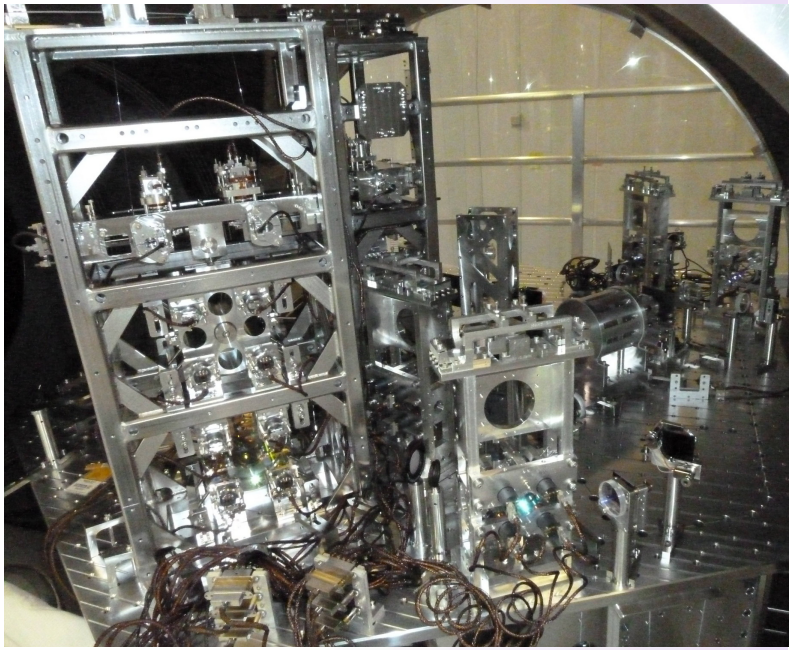
Corner Interferometer in progress @ Livingston (Dual Recycled Michelson Interferometer)

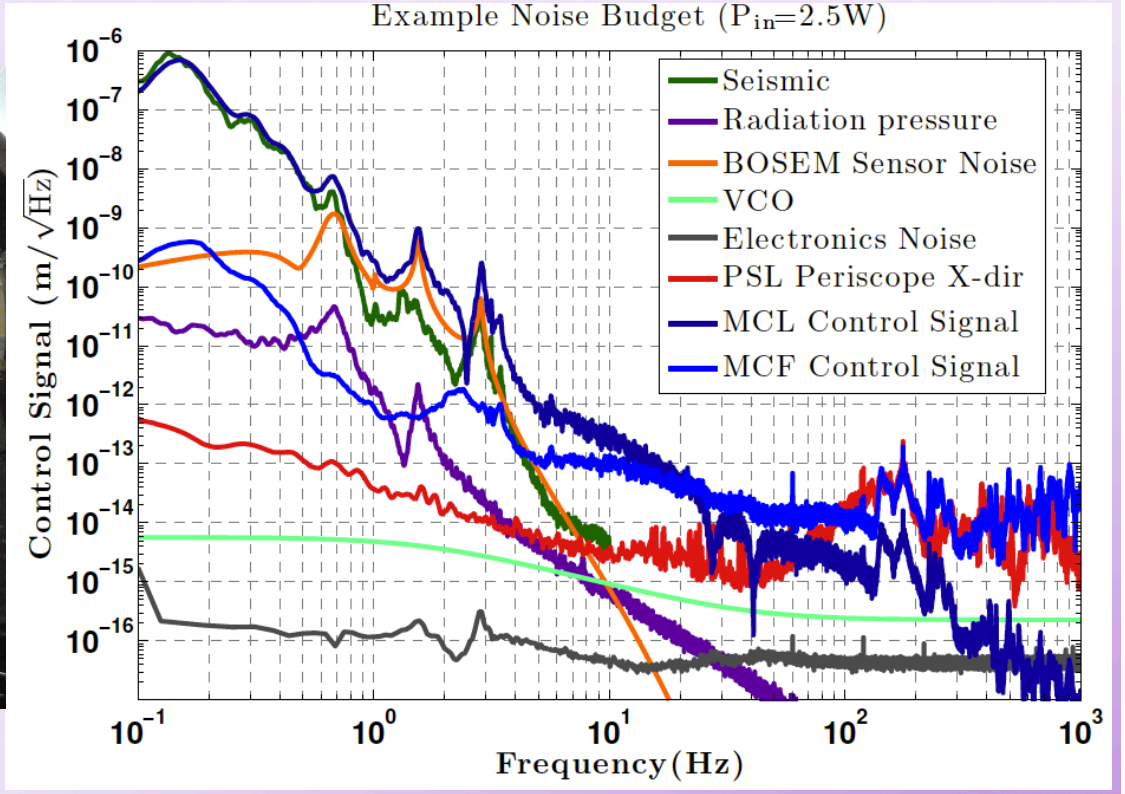
✓ Lock of the central part of the interferometer ("everything except the arms")

✓ First configuration with interesting sensitivity

The Input Mode Cleaner

C3: Tuesday, 17:00 - 17:18 **Chris Mueller (University of Florida)**
[Characterization of the Input Optics for the Advanced LIGO Detectors]



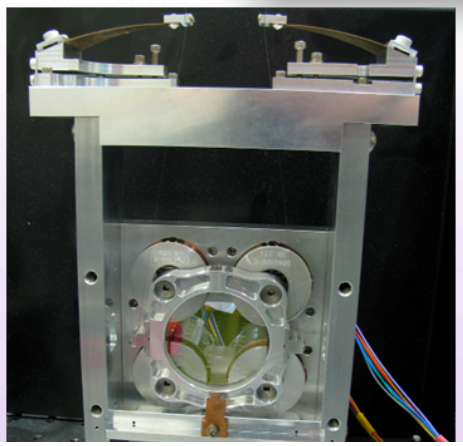


To be updated with new plot from Chris

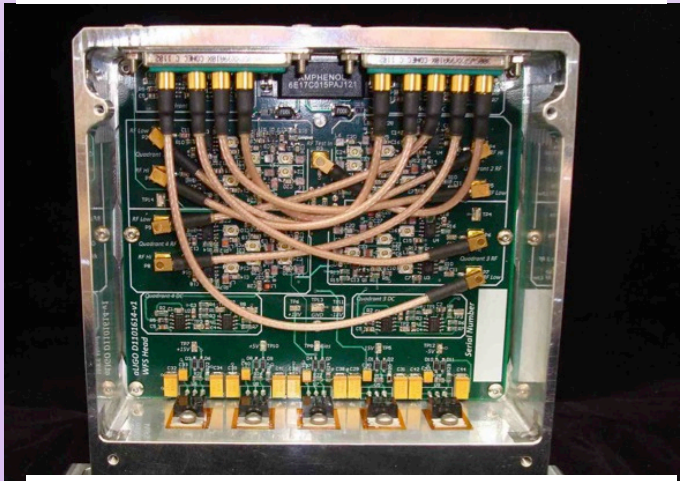
Dual Recycled Michelson Interferometer

(Almost) everything installed, integration started

Output mode cleaner installation
(more pictures from Zach)

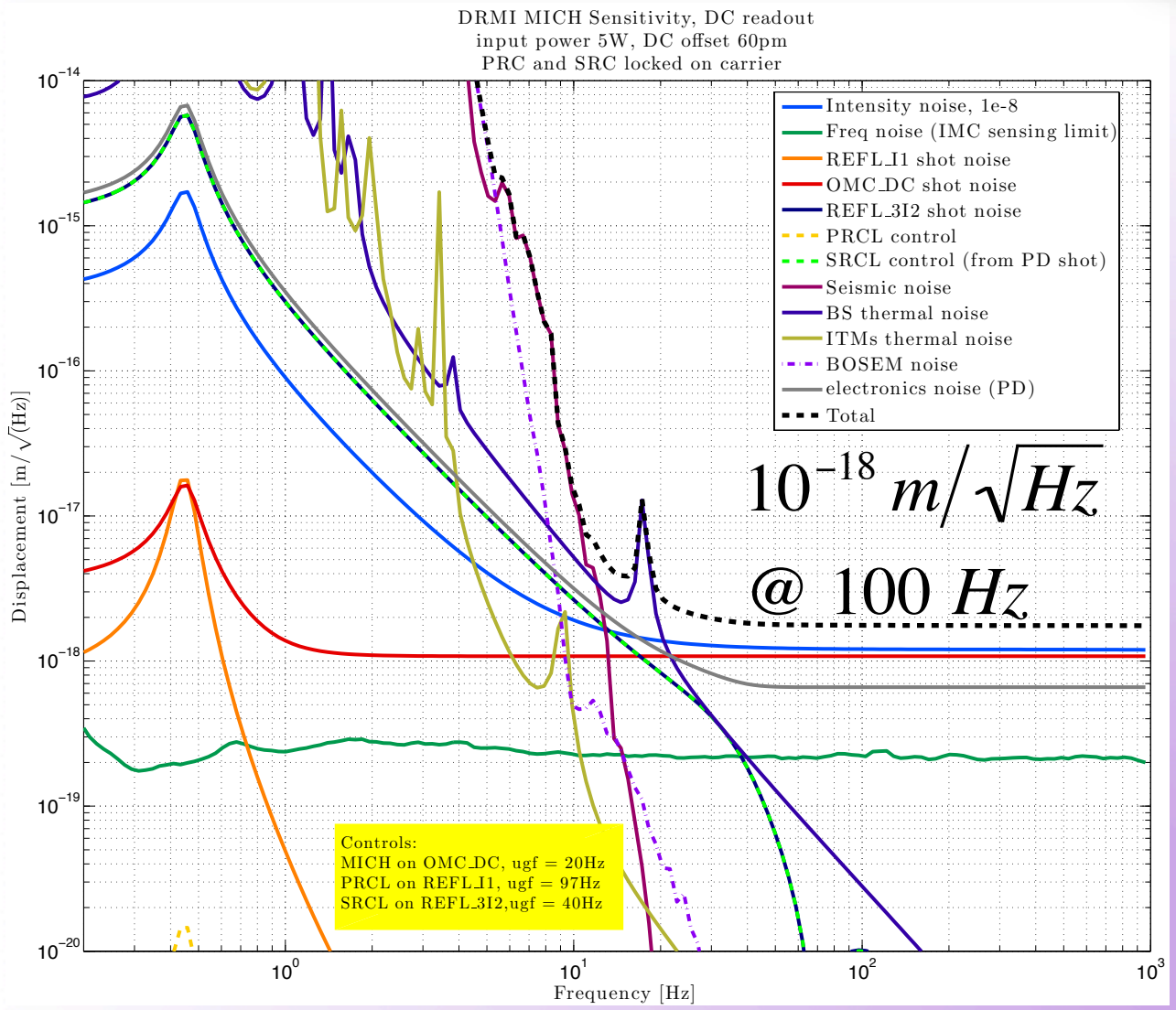


Small suspensions for steering the beam into the OMC (ANU)

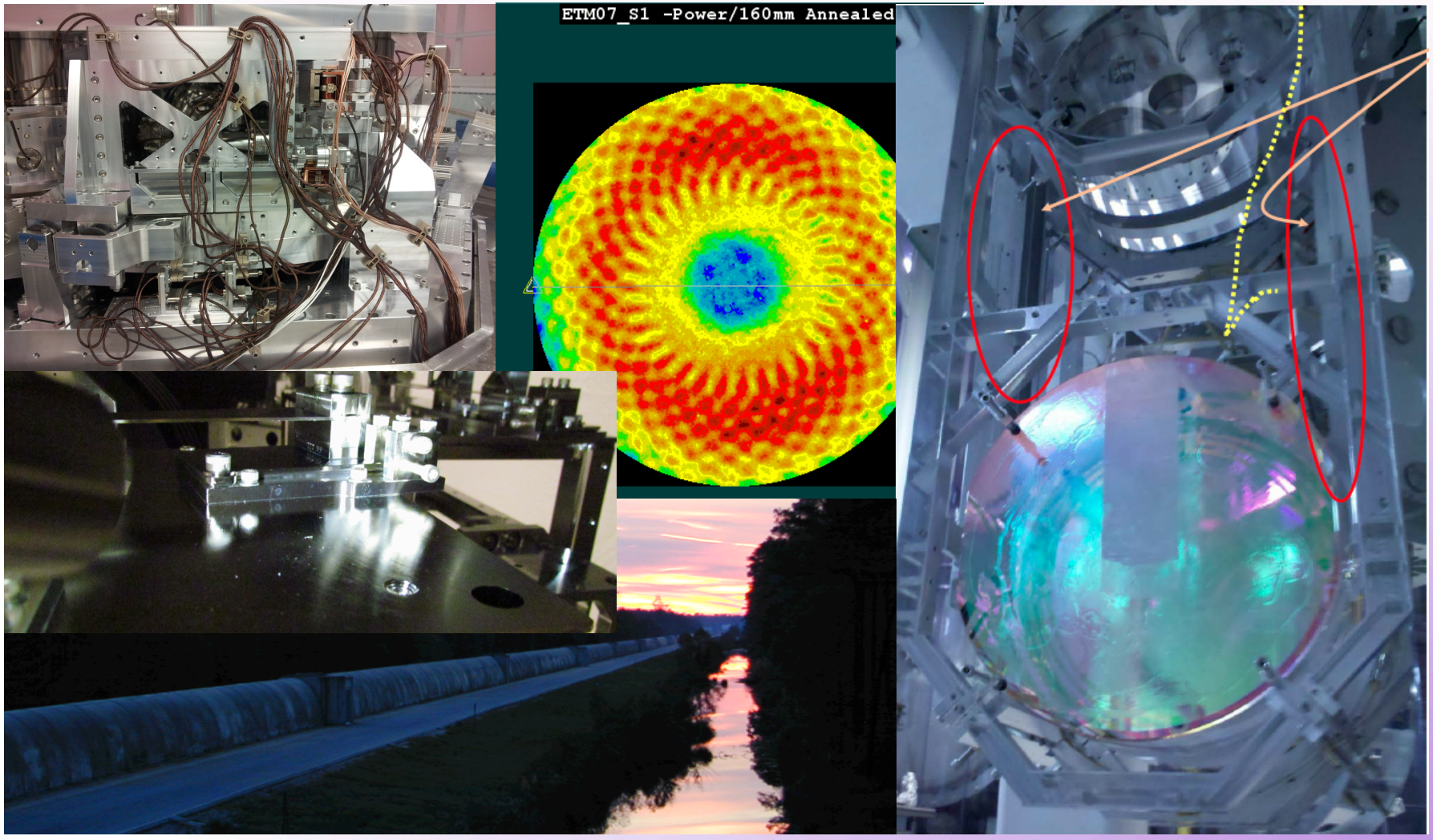


RF Wave Front Sensors
(for in vacuum use)

DRMI Noise Budget Model
(Anamaria Effler, LSU-LIGO Livingston)



Bumps in the road, but no showstoppers



Outlook

- ✧ Within a couple of months:
  - ✓ each “type” of chamber will have been populated at least at one of the two sites
  - ✓ main steps of lock acquisition sequence will have been tested full locking in progress at the Caltech 40m prototype
- ✧ “Second-site” testing to follow
  (DRMI @ LHO, Arms @ LLO)
- ✧ Full Interferometer Lock:
  - ✓ Starting February 2014 @ LLO
  - ✓ Starting May 2014 @ LHO
- ✧ On track for Advanced LIGO “acceptance” target
  - ✓ “2 hours of lock”, end of 2014

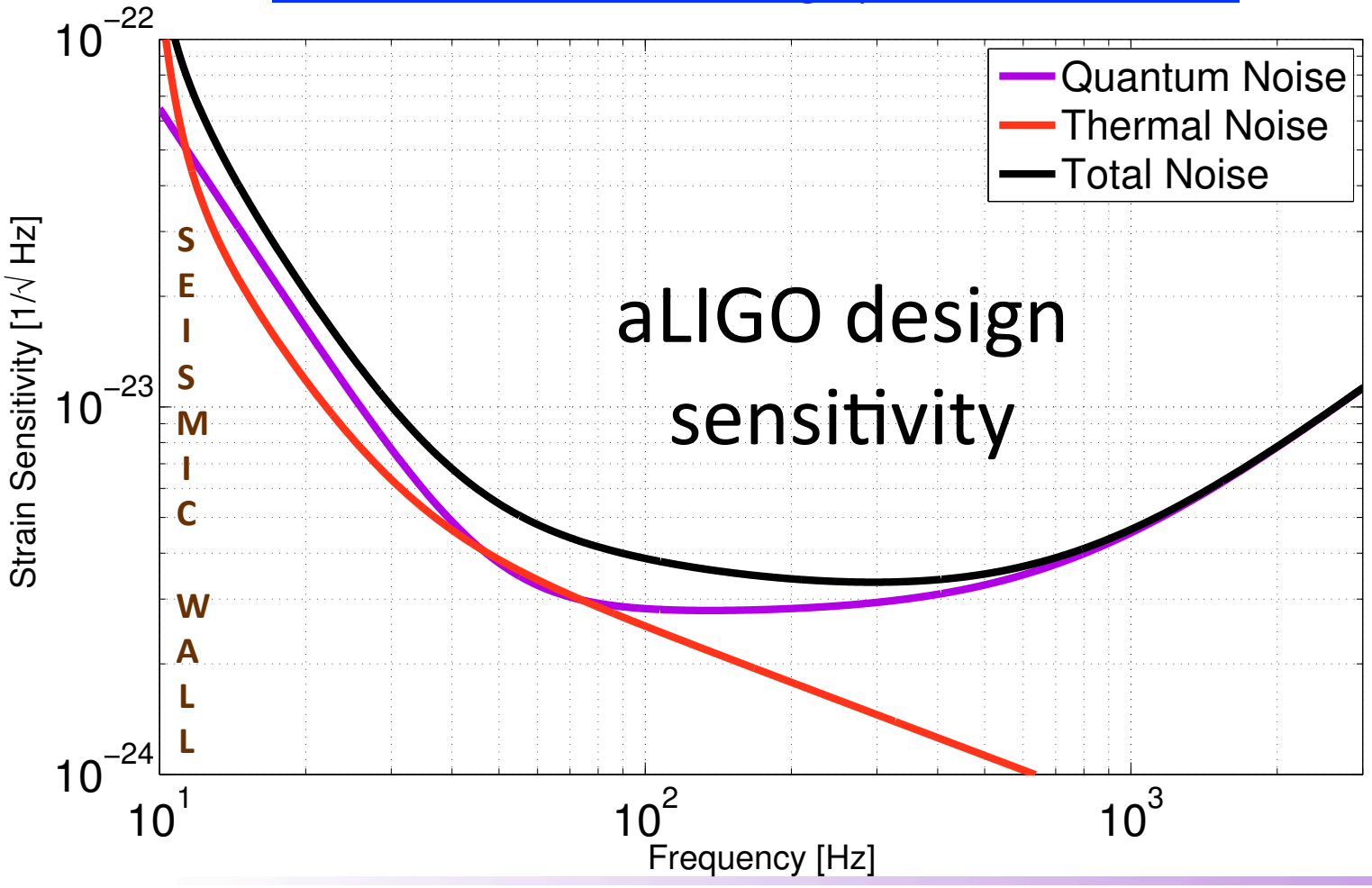
The Message

- Main goal of Advanced LIGO is to reach a scientifically interesting sensitivity as soon as possible (~ 60 Mpc@2015, ~100 Mpc@2016)
- Installation and commissioning strategy designed with this goal in mind
- So far so good!

By the way, is Advanced LIGO the best that we can do?

C3: Tuesday, 17:54 - 18:12 Sheila Dwyer

Quantum noise reduction using squeezed states in LIGO



Spare slides

What we call “commissioning”: from installation to **science** data

Understand and fix an entanglement of noise coupling mechanisms

Example from Enhanced LIGO