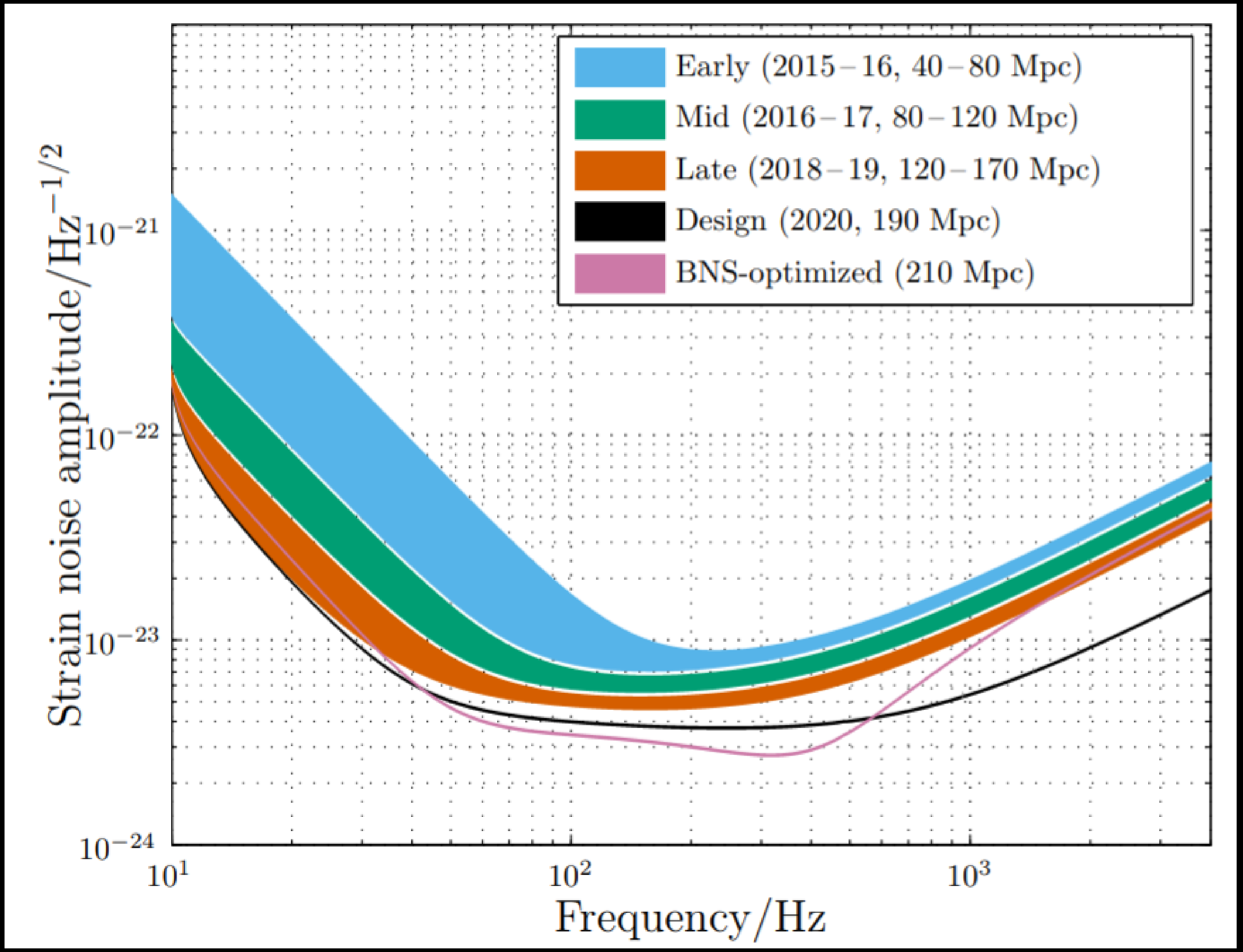
Status of LIGO detectors

Sheila Dwyer for the LSC

G1800941



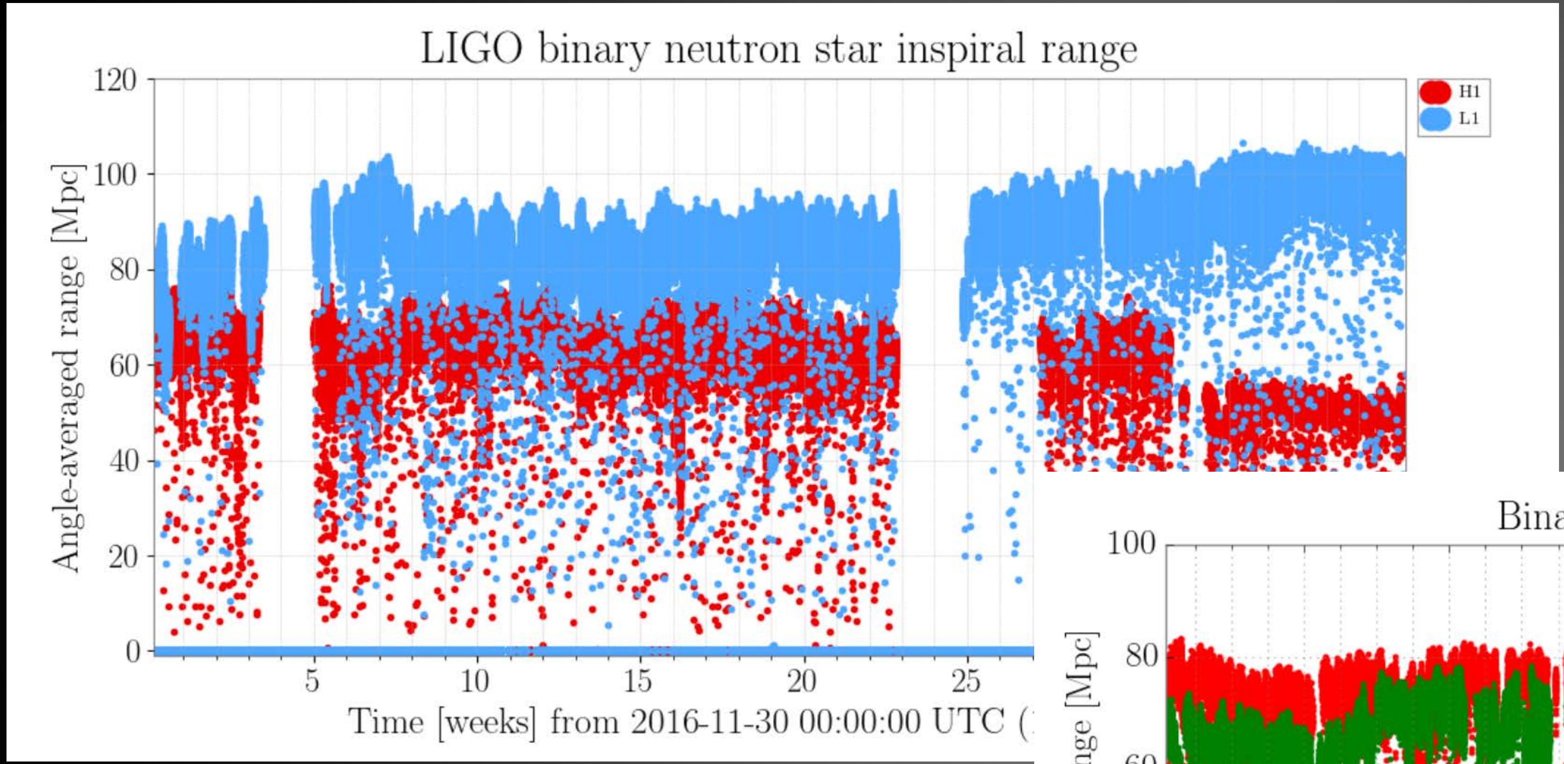
Observing plan

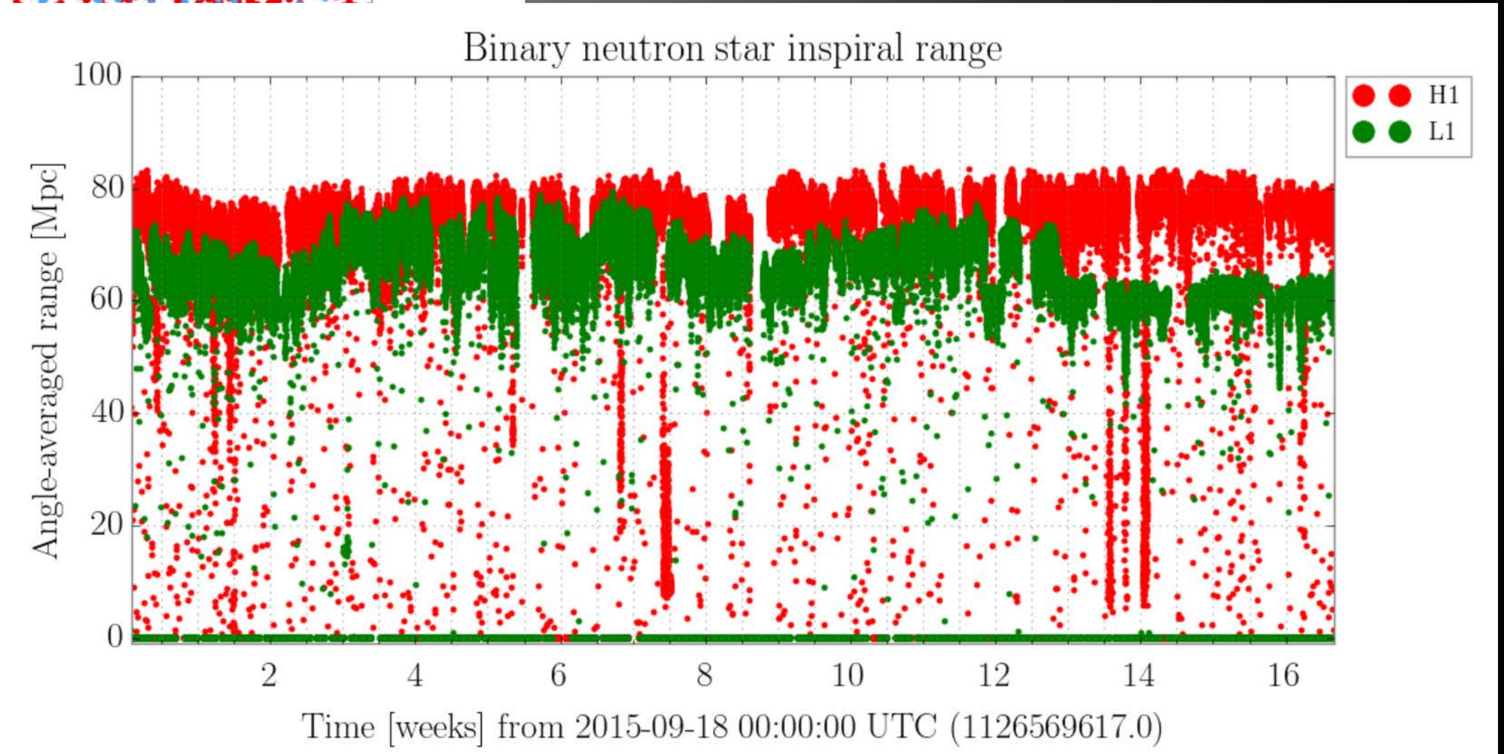
Successful first observing run in 2015 and second run late 2016-2017

Current upgrades to reach target range of 120 Mpc for NS-NS inspirals for observations starting early in 2019

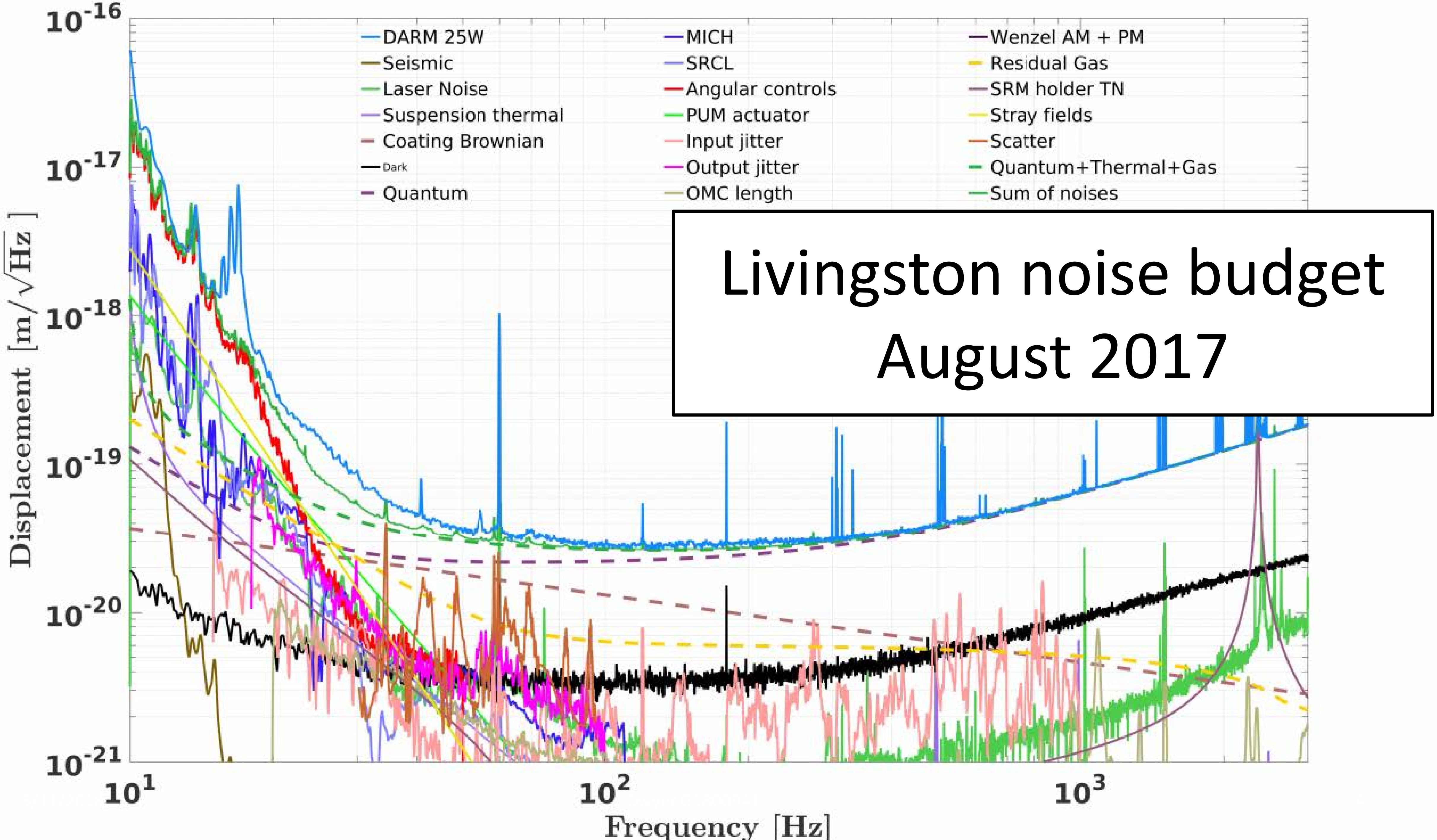
Living Rev Relativ (2018) 21:3
DOI:10.1007/s41114-018-0012-9

First and second observing runs

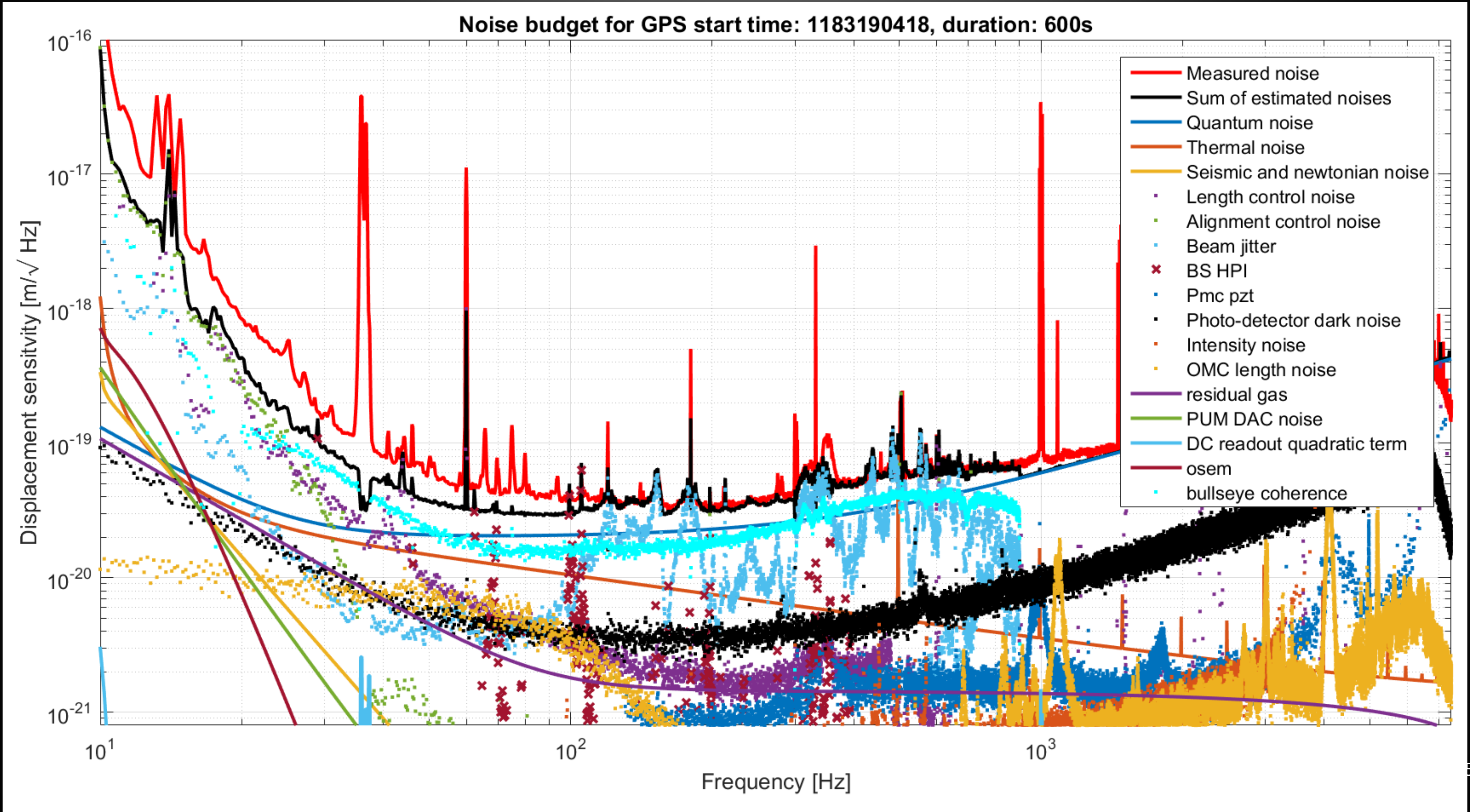




Offline noise subtraction gives a 20% improvement in range for Hanford during O2


Livingston noise budget
August 2017
DARM 25W
Seismic
Laser Noise
Suspension thermal
Coating Brownian
Dark
Quantum
MICH
SRCL
Angular controls
PUM actuator
Input jitter
Output jitter
OMC length
Wenzel AM + PM
Residual Gas
SRM holder TN
Stray fields
Scatter
Quantum+Thermal+Gas
Sum of noises
Displacement [m/√Hz]
Frequency [Hz]
10-16
10-17
10-18
10-19
10-20
10-21
101
102
103

Hanford noise budget early July 2017

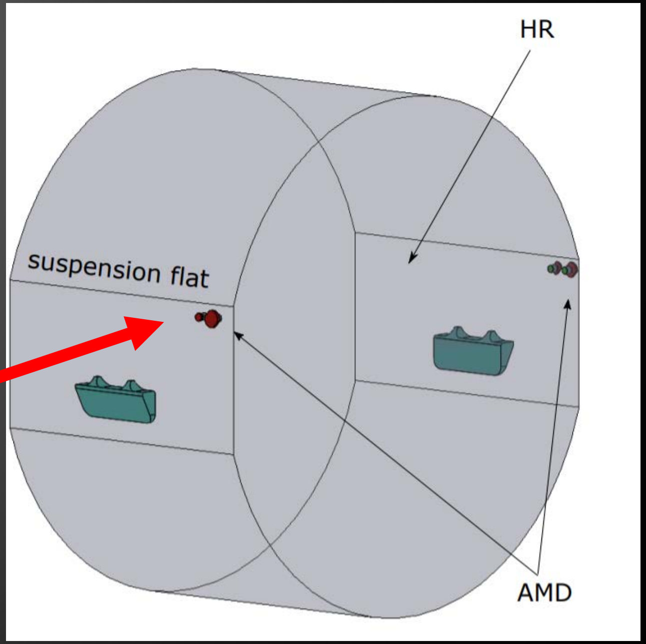


What are we doing now?

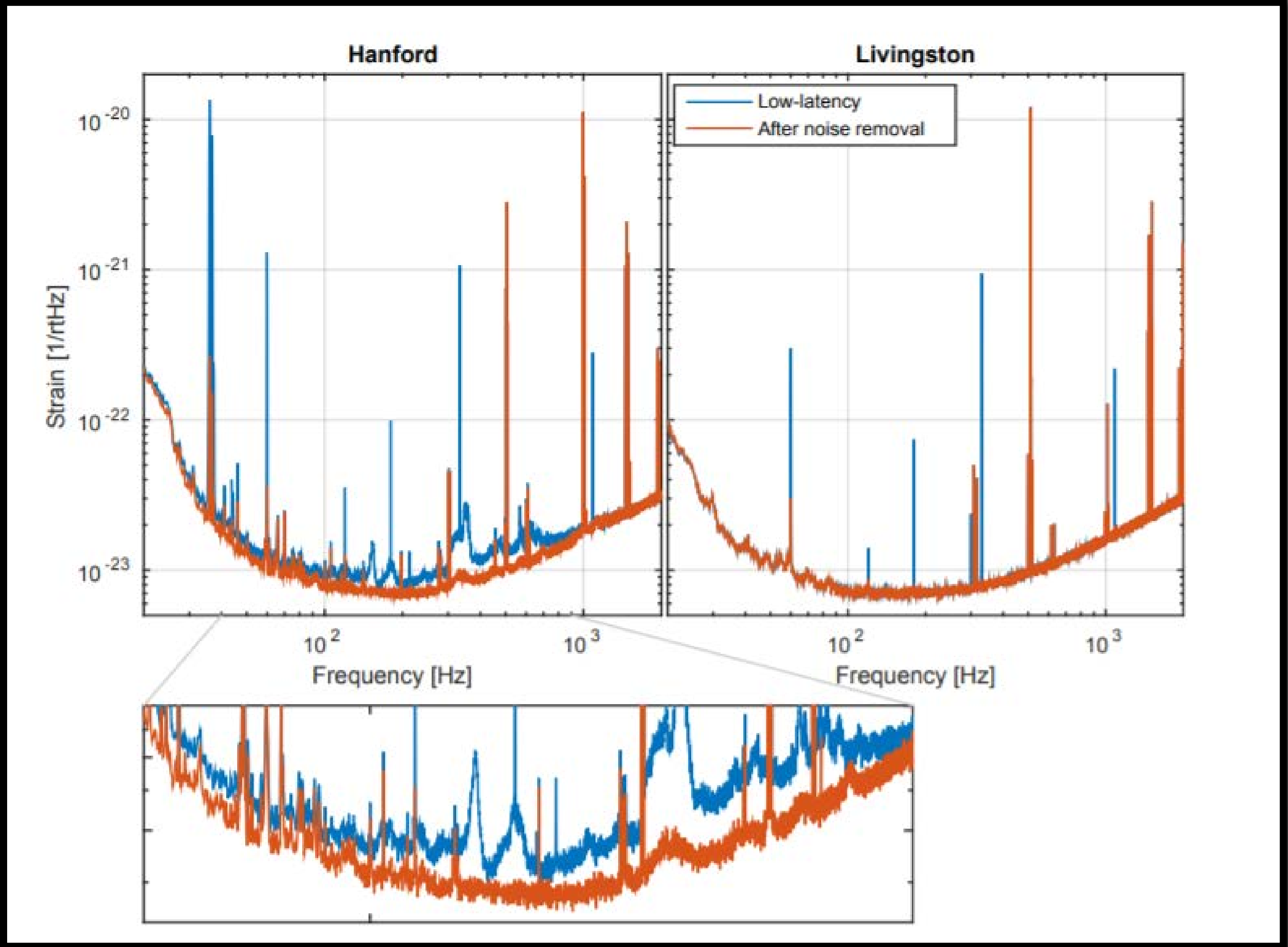
- Using lessons learned from second observing run commissioning
  - Hanford attempted high power operations
  - Livingston concentrated on low frequency noise
- In the midst of a major hardware upgrade at both LIGO sites
  - High power
  - Laser noise
  - Squeezing
  - Signal recycling mirror change
  - Stray light control
  - Electric field sensors
  - Test mass replacements

High power stability and control

- See controls session tomorrow from 4 to 5:30
- Both sites have now operated with ~40W input power (150-200kW circulating power)
  - New radiation pressure instability seen at both sites
  - Thermal compensation
  - Parametric instabilities
    - Active damping tried
    - Acoustic mode dampers now being installed



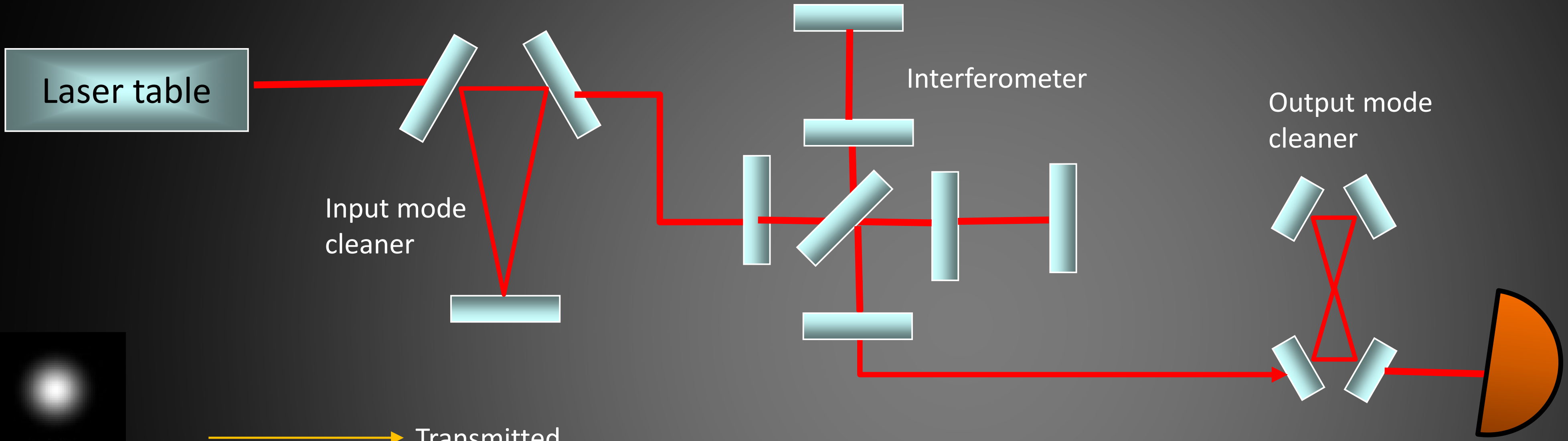
High power at Hanford : Laser jitter

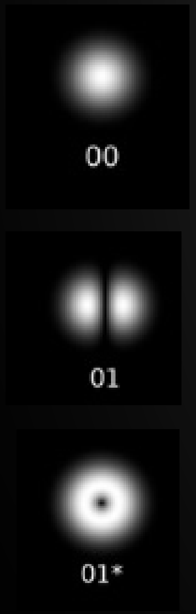


Jitter subtraction gives a 20% improvement in range for Hanford during O2

J Driggers et al P1700260

Higher order mode coupling to gravitational wave signal





Transmitted

Only 00 modes detected

Angular jitter (water cooling, acoustic noise)

Beam size jitter (High power oscillator)

Attenuated

Converted to 00 mode by misalignment and mode mismatch in interferometer

Mitigation strategies:
1) Reduce amplitude of higher order modes (high power laser change)
2) Reduce couplings to 00 mode in interferometer (test mass replacement)

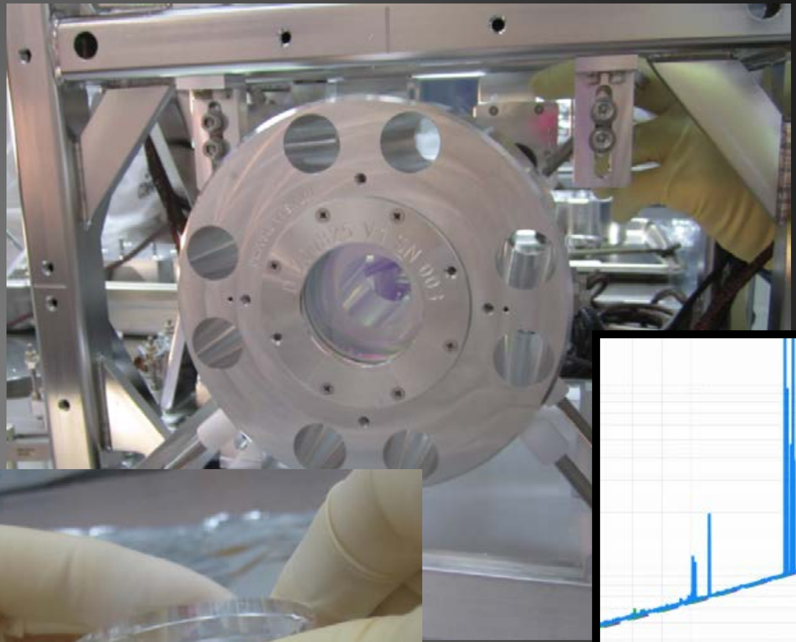
Hanford test mass spot absorber

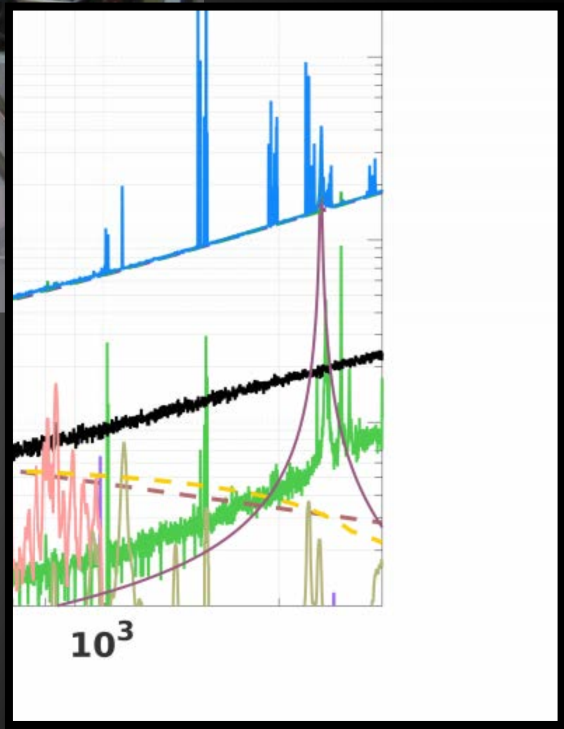
- Anomalous absorption spot found on one Hanford input test mass
- May have been responsible for increased jitter coupling
- This test mass has now been replaced

Photo: G Billingsley

Signal recycling (extraction) mirror replacement

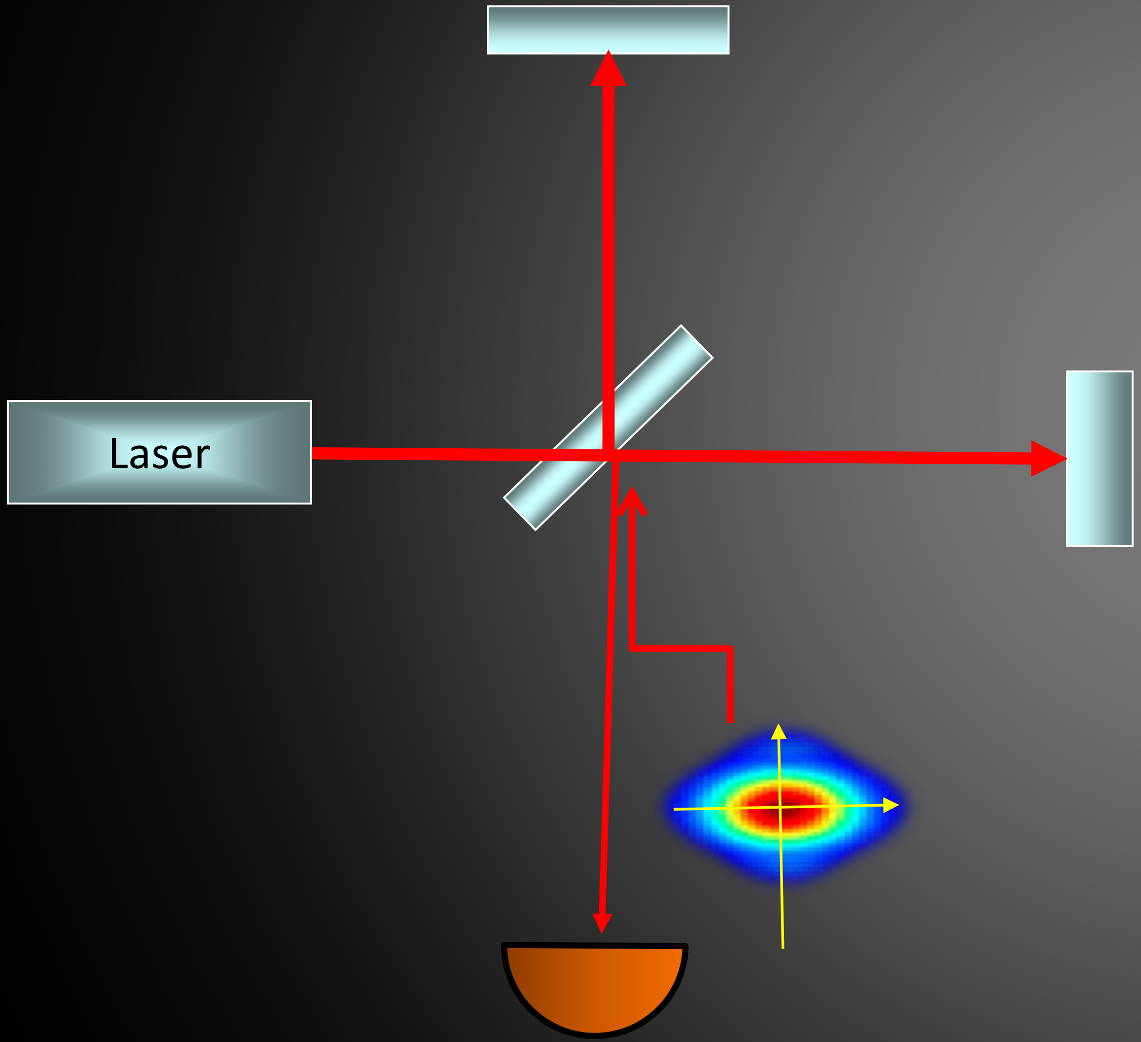
- First signal recycling mirror used a composite mass to allow for quick changes of reflectivity
- Thermal noise at 3.3kHz from PEEK screw used in composite mass
- SRM replaced with a full optic
- Transmission changed from 37% to 32.3%, moving DARM cavity pole from 350/380 Hz to 450 Hz





Photos: D Sellers M Hetize LHO alog 27530

Squeezing!



Squeezers now installed at both sites

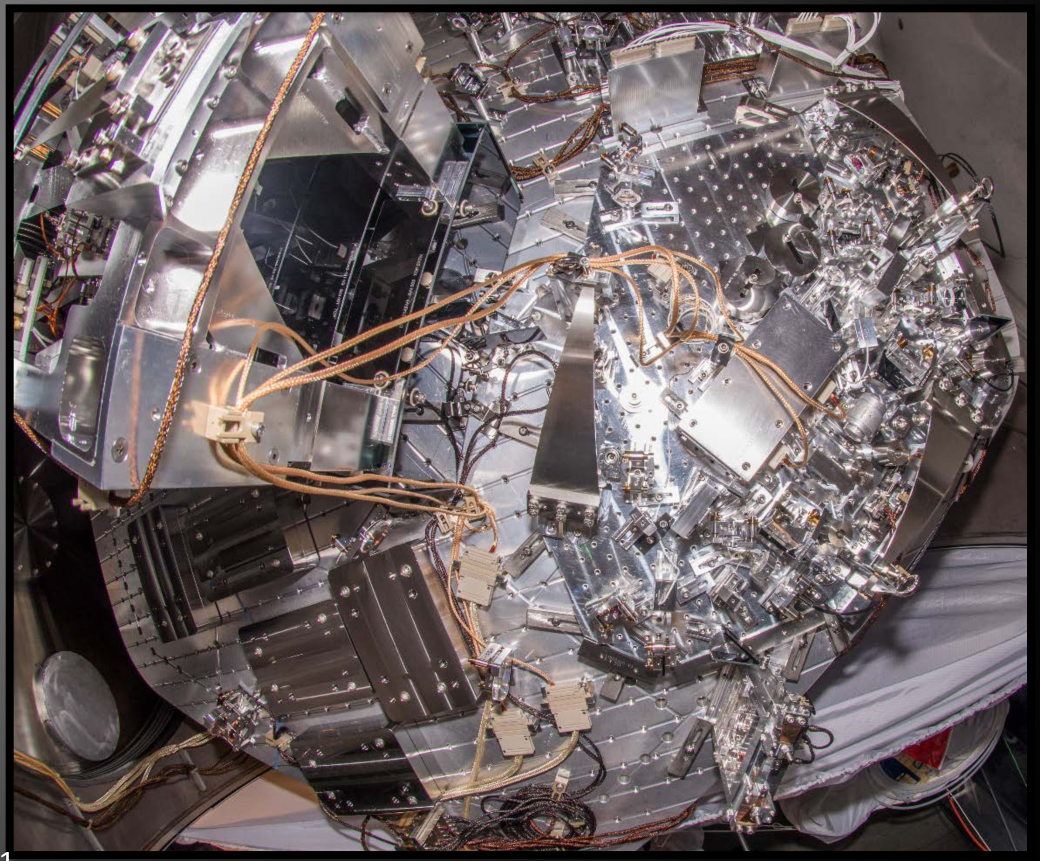
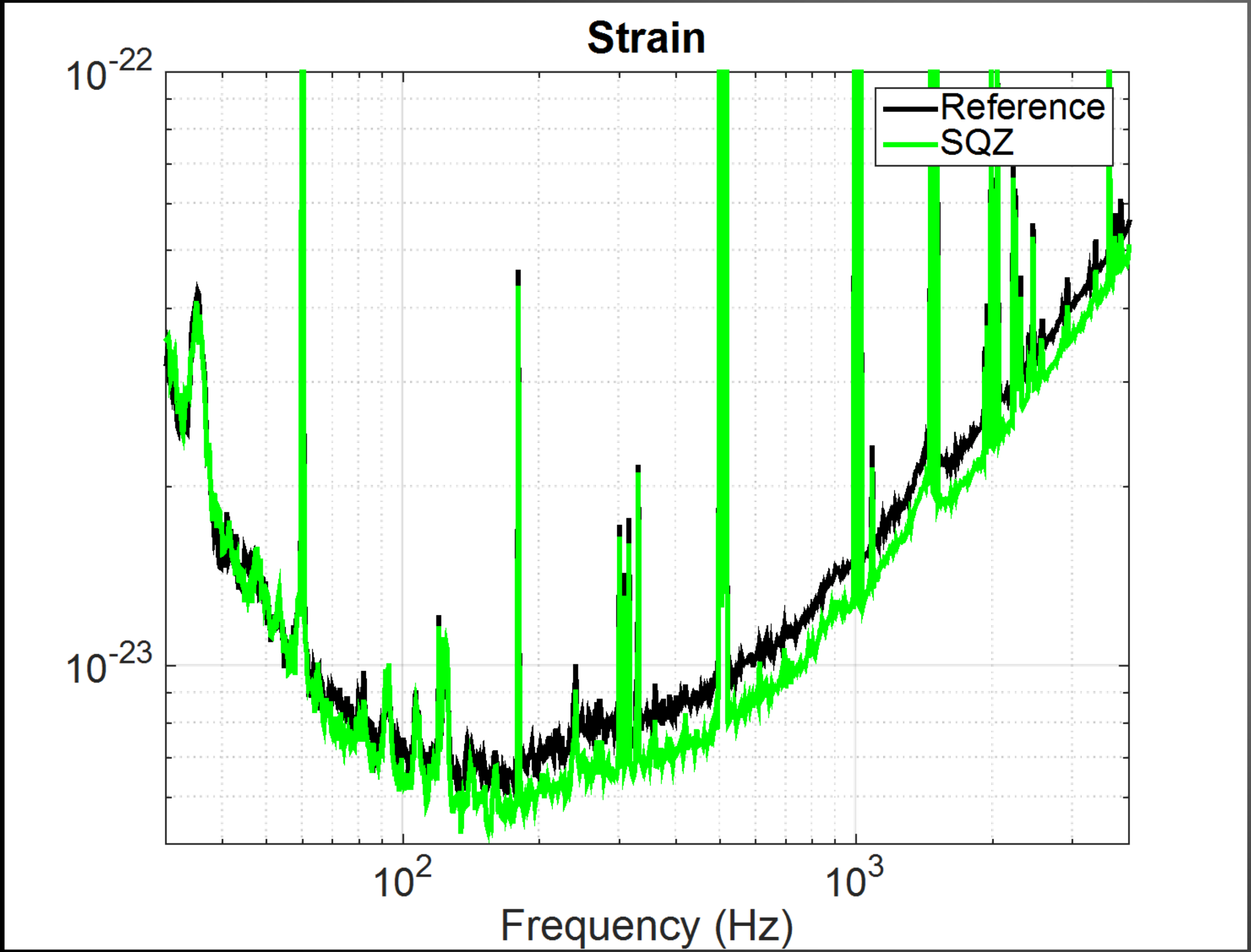


Photo: M Tse

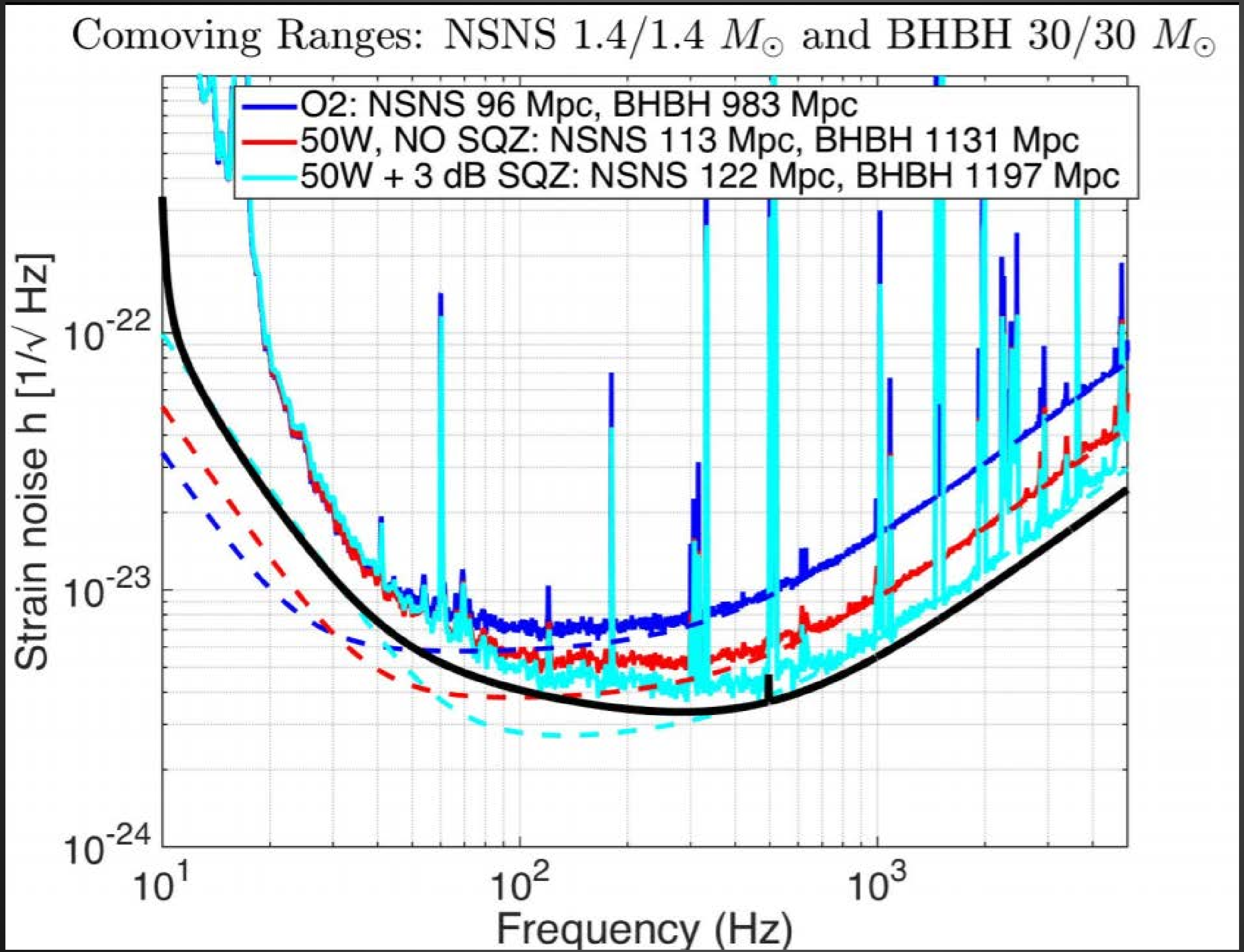
Squeezing preliminary results



- Early results from Livingston
- Around 1 dB of squeezing measured
- Goal is to 3dB of squeezing (40% shot noise reduction)

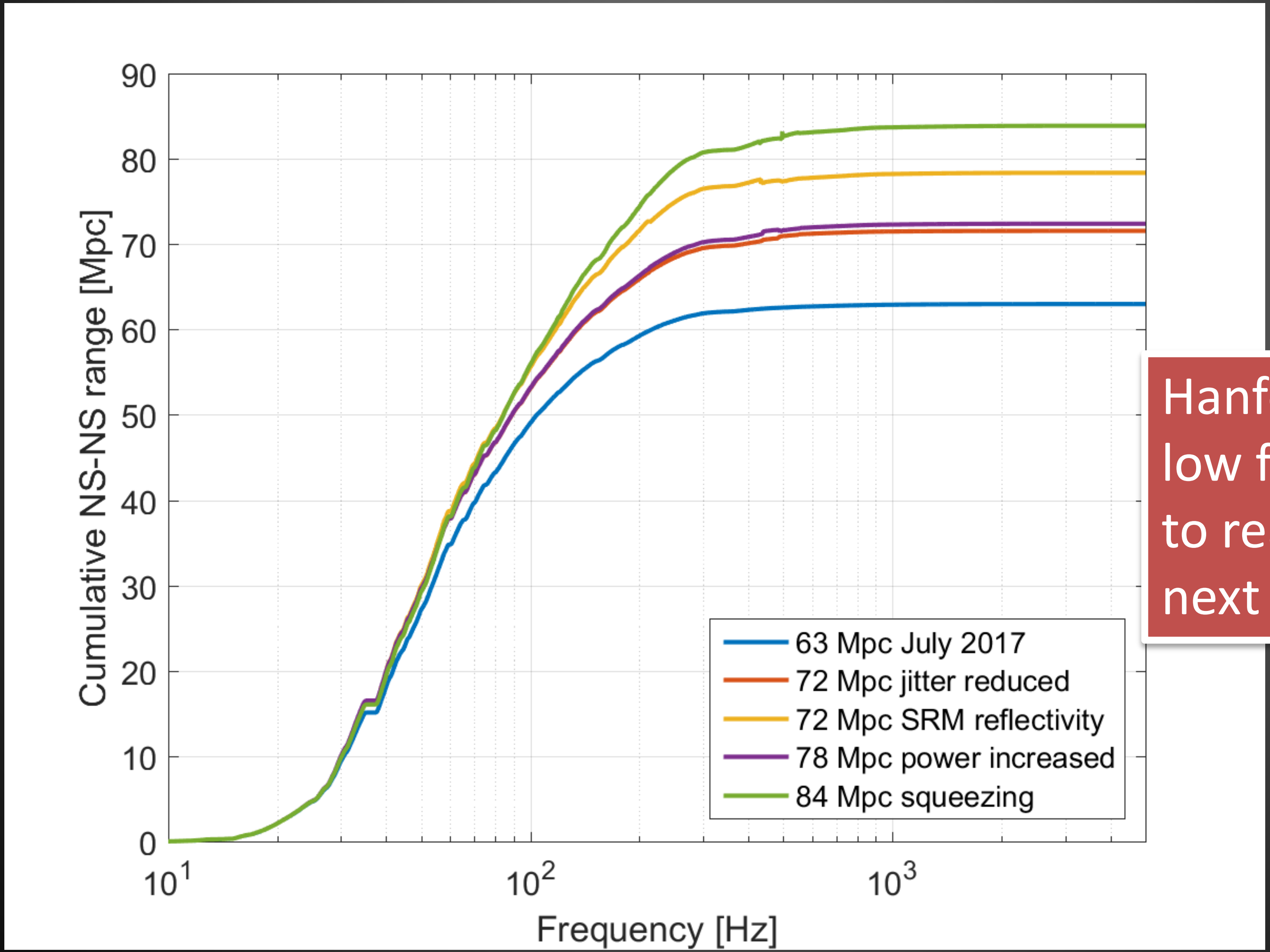
Plot: L Barsotti

Projection of noise improvements from high power and squeezing: Livingston 120 Mpc



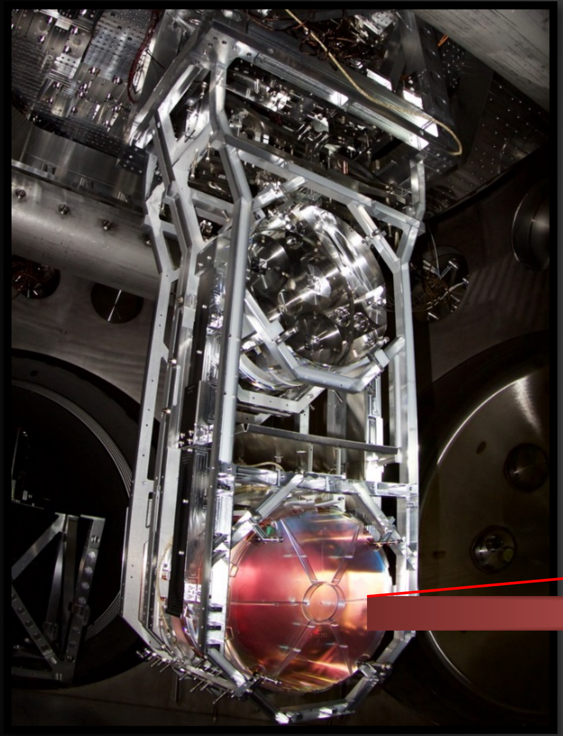
L Barsotti

Projection of noise improvements from high power and squeezing: Hanford



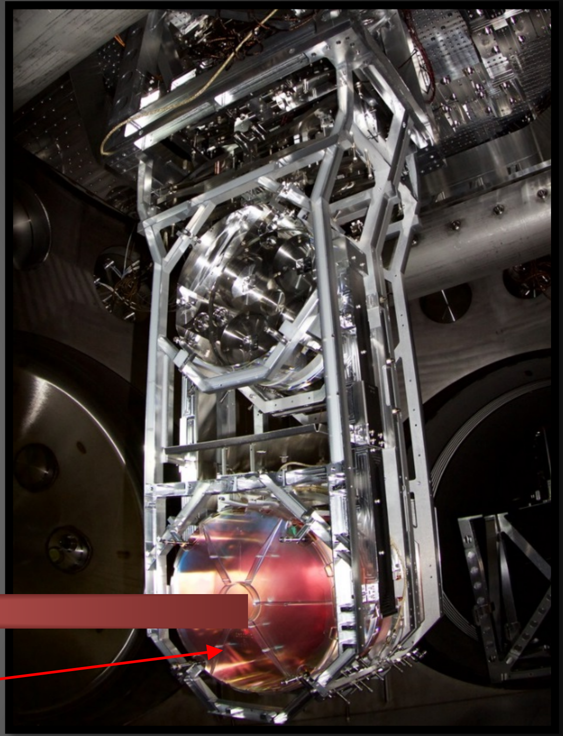
Hanford needs to improve low frequency noise in order to reach sensitivity goal for next observing run

Scattered light



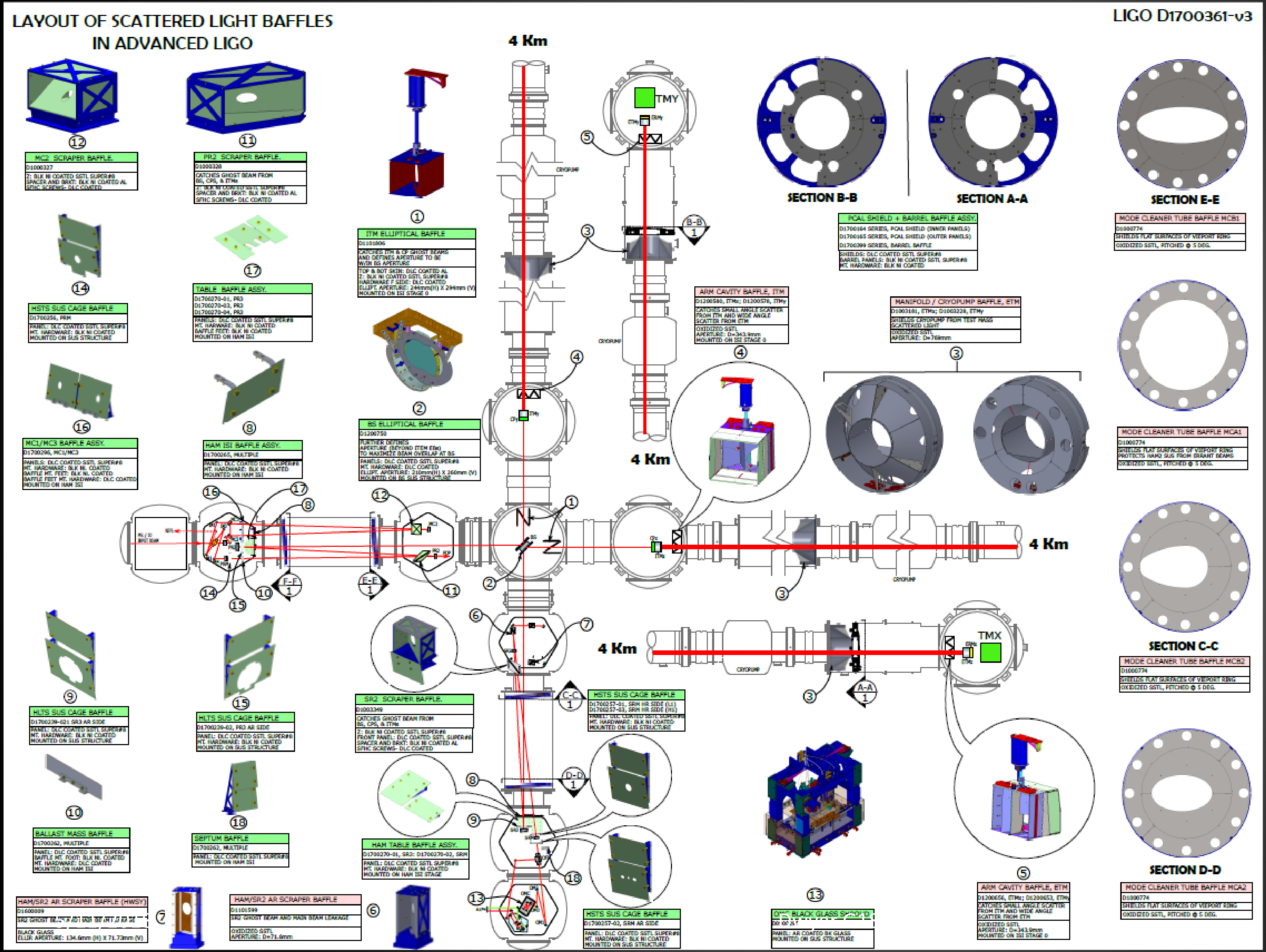
Mitigation strategies:
1) Reduce amplitude of light in spurious path
2) Reduce motion of scattering objects

2) Scatters off of less well isolated objects (baffles)



1) Light scatters out of main interferometer beam (Anti reflection coatings, imperfections in optics)

3) Light re-enters interferometer creating spurious interferometer

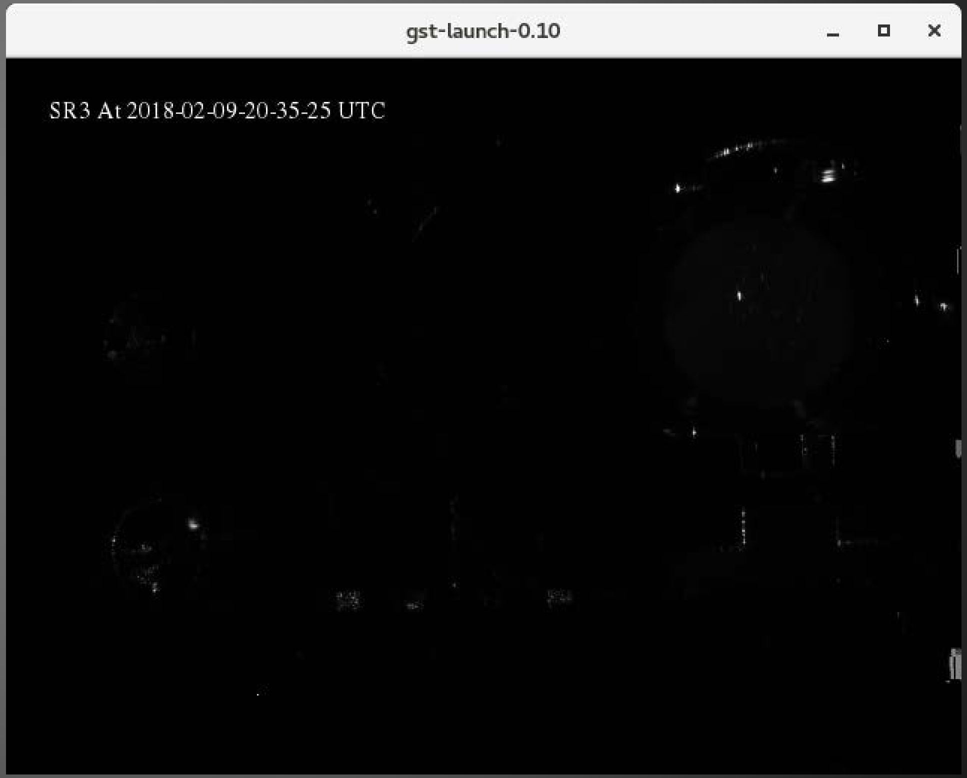


Stray light control:

- Removing some baffles which caused noise
- Adding new baffles
- Modifying some baffles

Reducing scattered light with baffles

Posted by Valera Frolov to LLO aLog (#28312)

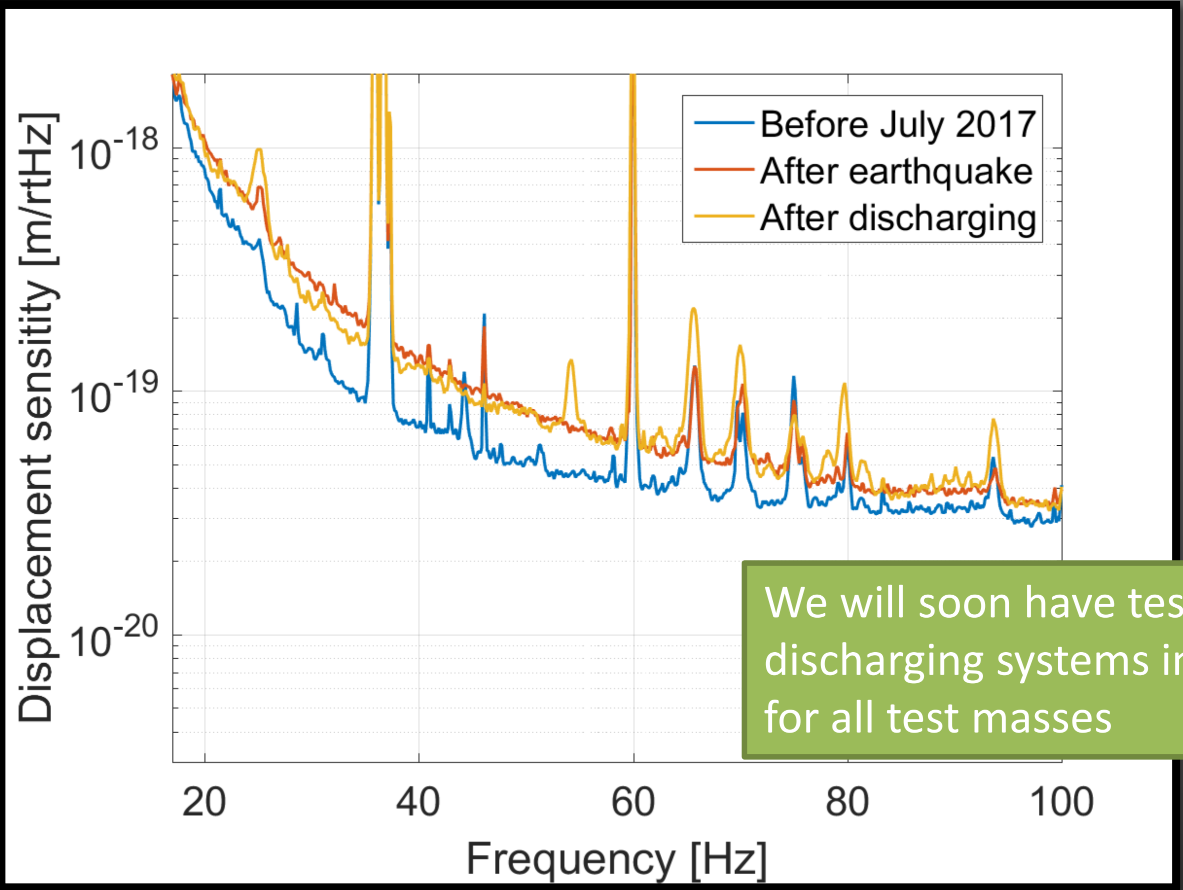


Posted by Alena Ananyeva to LLO aLog (#36113)

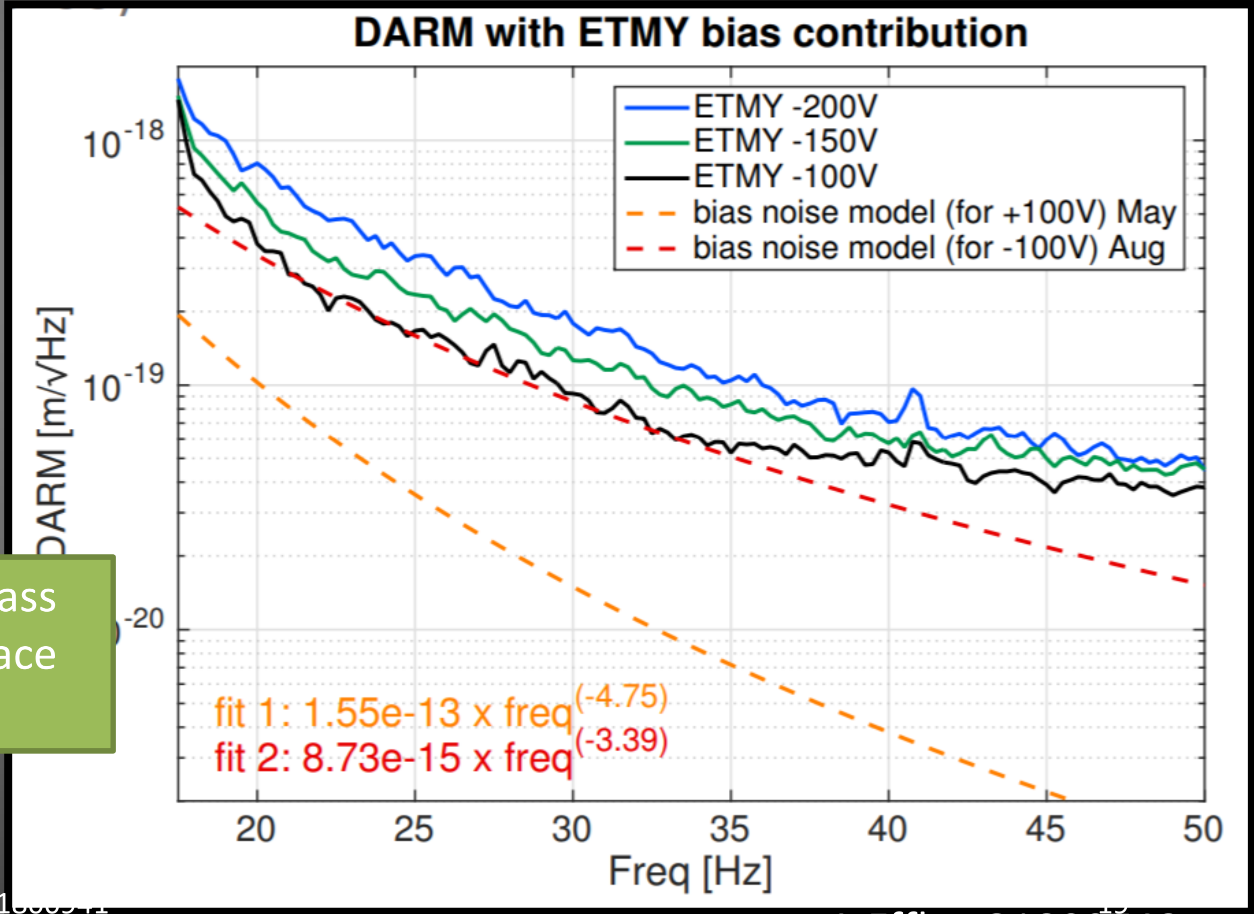
Slide courtesy C Austin

Charge on optics and noisy electric fields

Large earthquake added charge to Hanford test masses



Noise dependence on static electric fields around test mass at Livingston



We will soon have test mass discharging systems in place for all test masses

A Effler G1800748

Electric Field Meters

Sensor for stray electric fields will be installed in one end chamber at each site

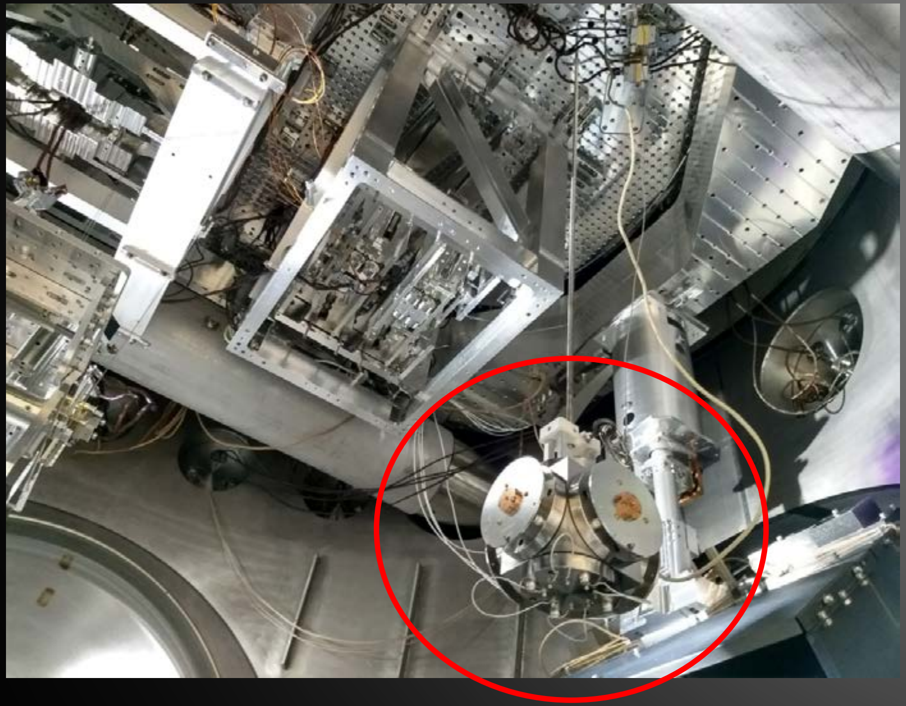
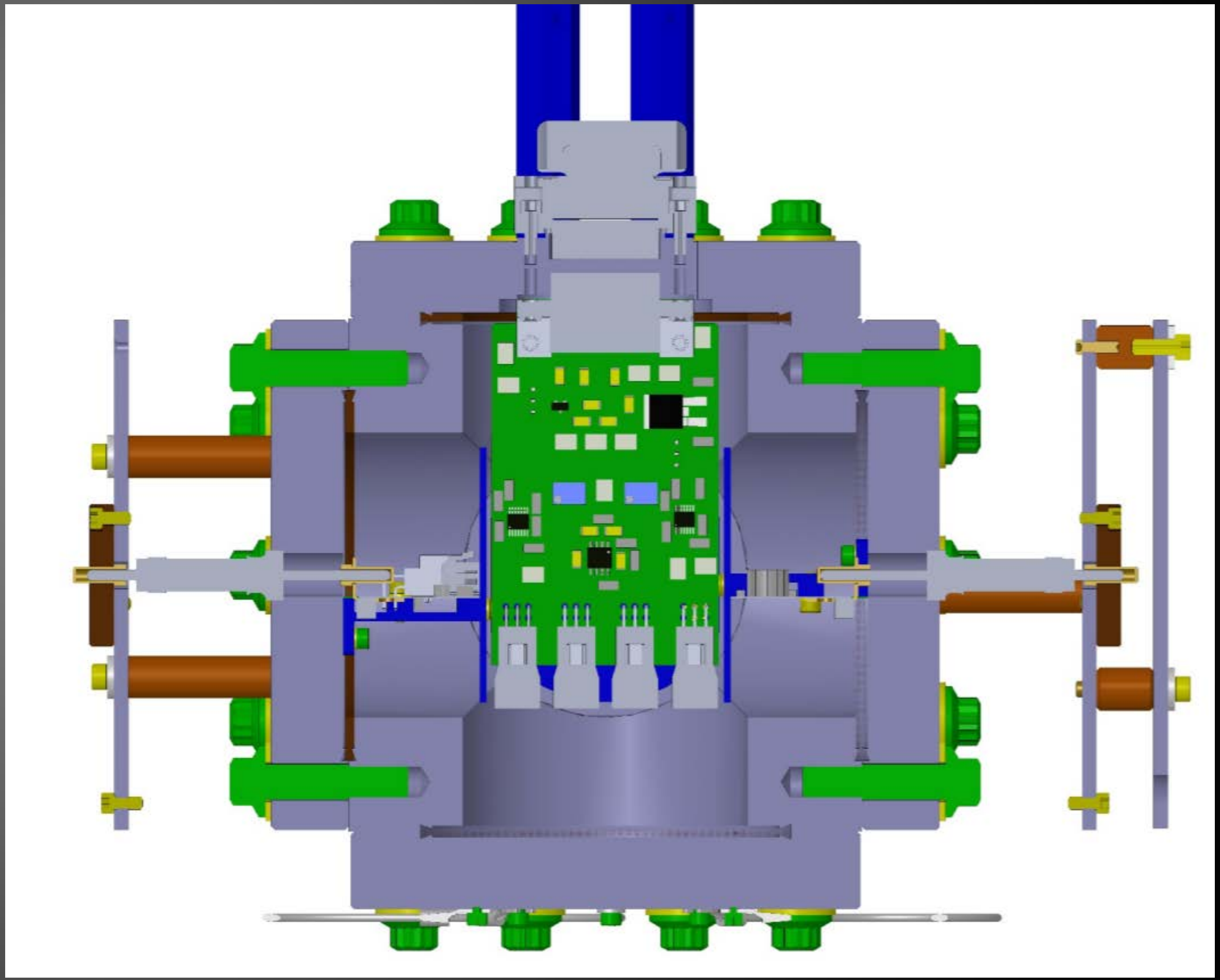


Photo: G Mansell C Cahillane

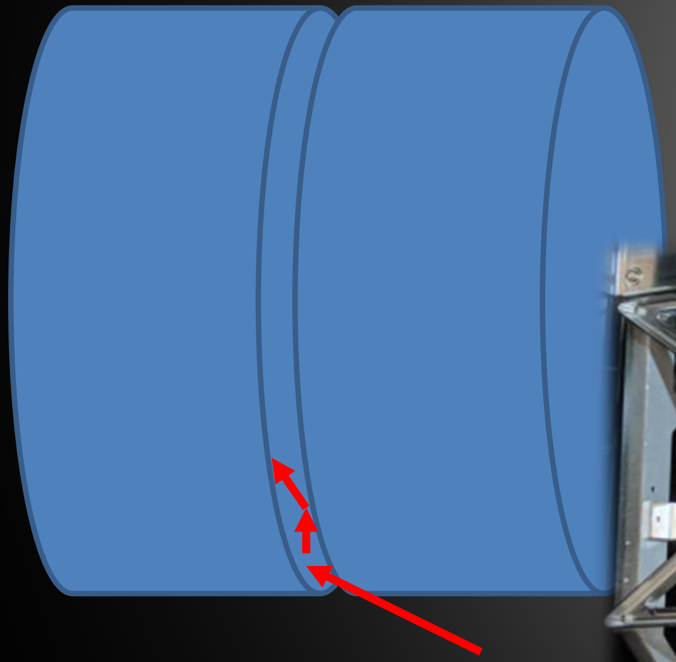


Design: G1800293

Squeezed film damping residual gas noise

Residual gas trapped between test mass and reaction mass makes a force noise (squeezed film damping)

Cutting a hole in the reaction mass should reduce squeezed film damping noise by almost a factor of 3



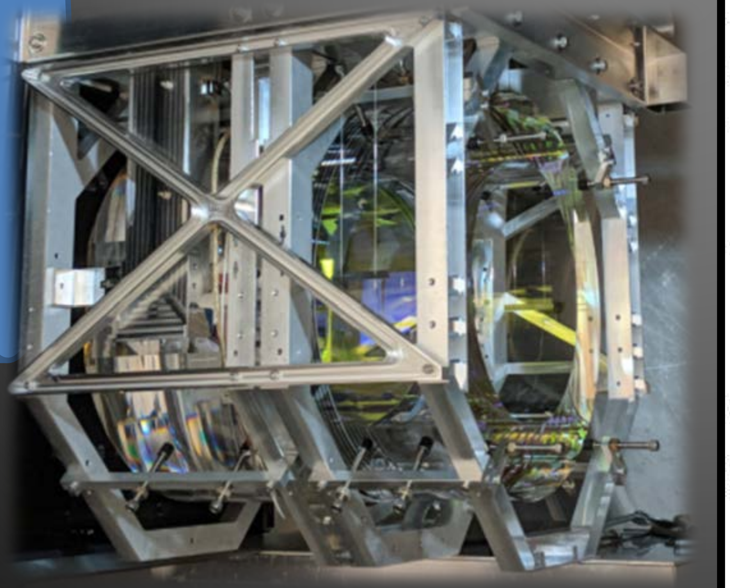
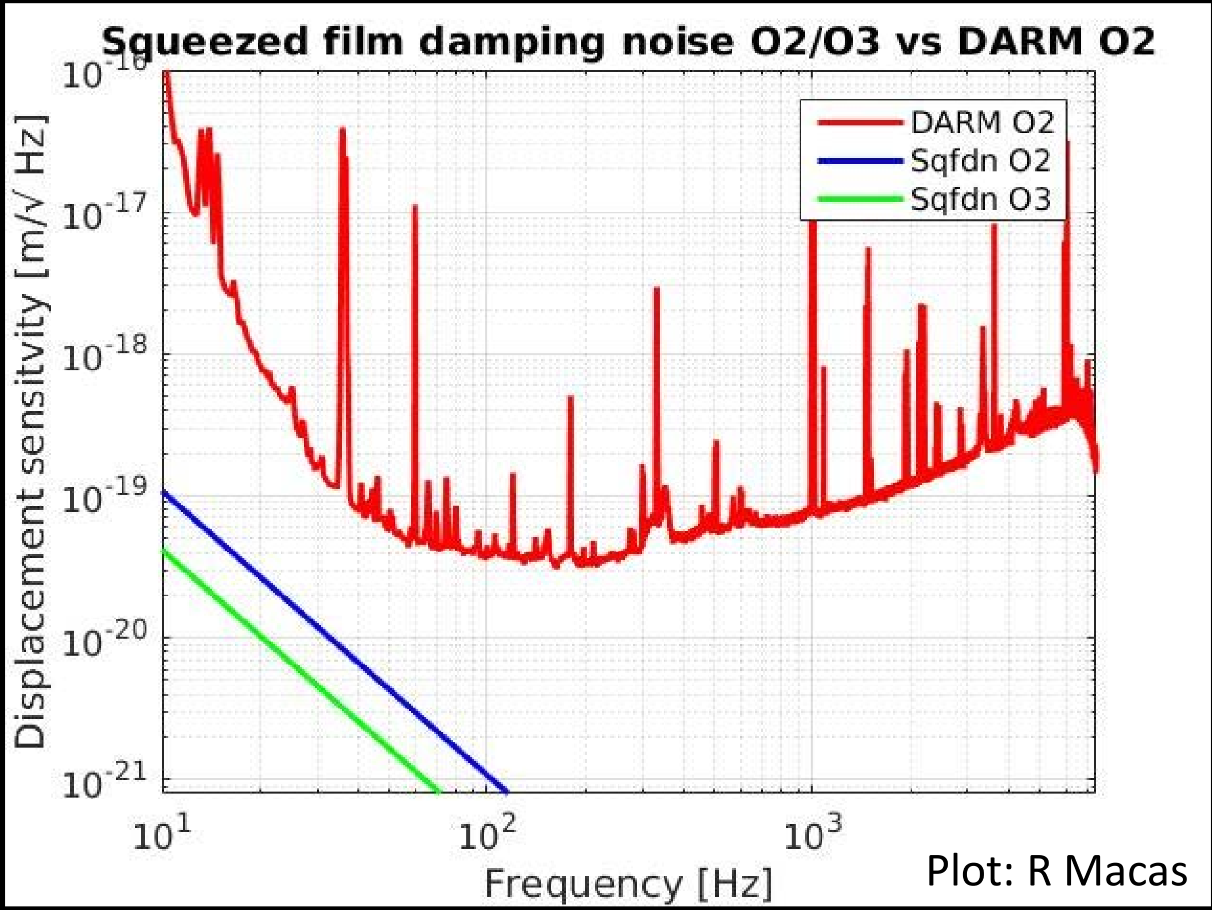


Photo: J Kissel



Plot: R Macas

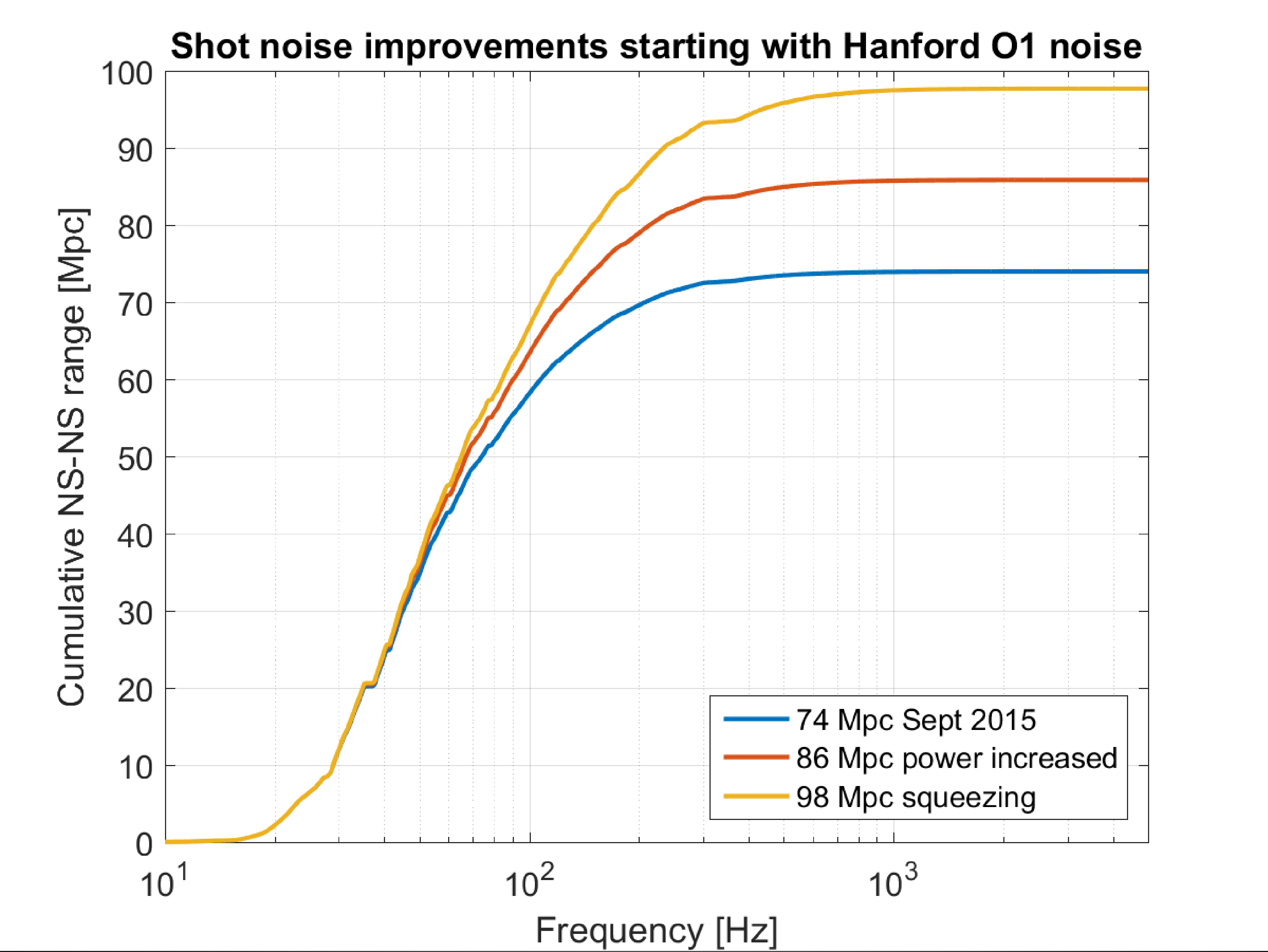
Summary of LIGO status

- Both LIGO sites finishing in vacuum work in the next couple of months
- Full locking at both sites in June/July
- Changes for high frequency sensitivity: increasing circulating power, squeezing
- Changes for low frequency: Stray light control, test mass discharging, electric field sensors, annular reaction masses
- For Livingston a clear path from O2 sensitivity to 120 Mpc goal, Hanford must improve low frequency noise to reach 120 Mpc

O3 plans

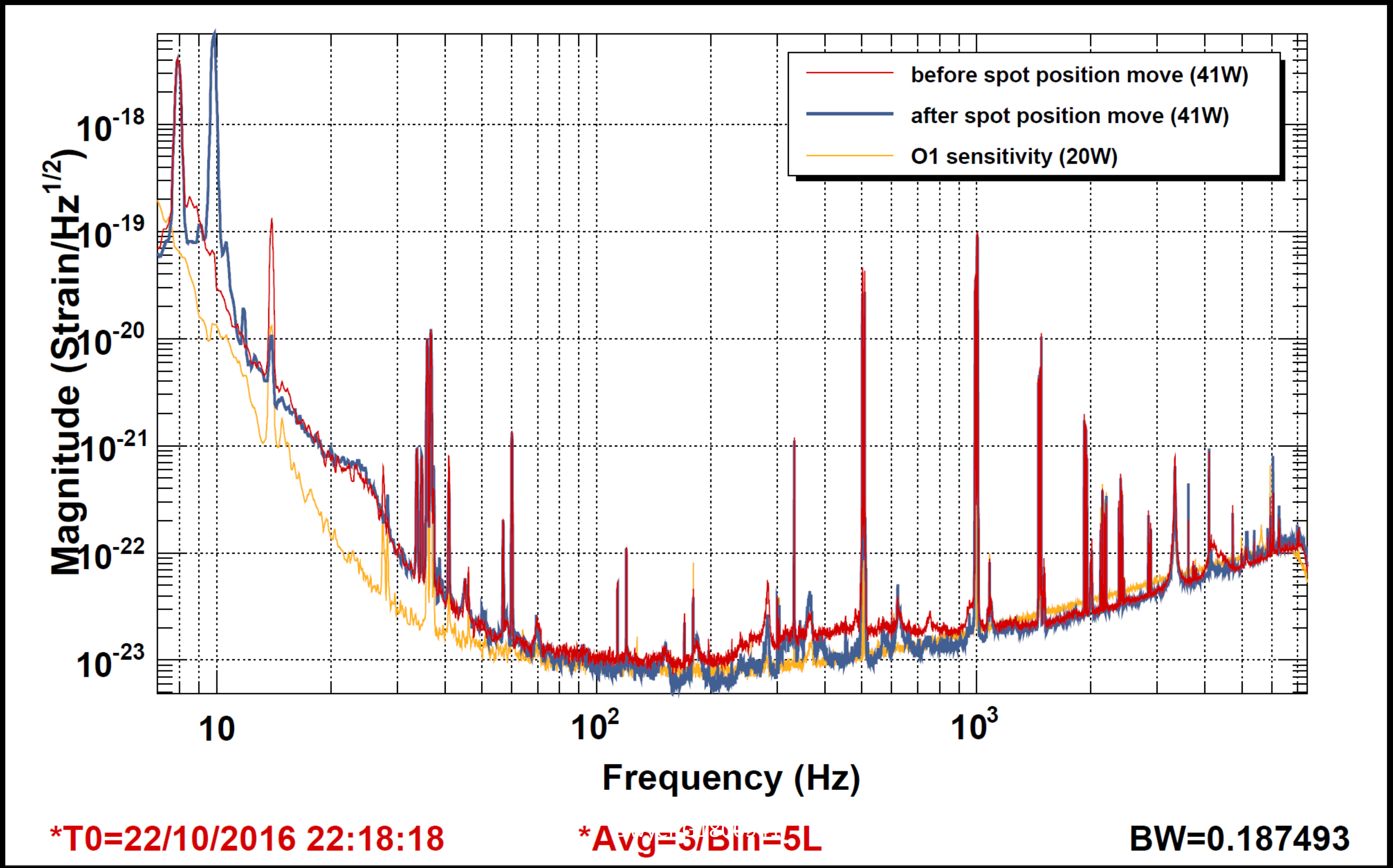
- The next observing run will start when both LIGO instruments are ready (performance goal of 120 Mpc or better)
- This is expected to be early 2019
- Alerts will be public, with latency of a few minutes
- Binary black hole detections should become routine

Extra slides



Shot noise improvements starting with Hanford O1 noise
Cumulative NS-NS range [Mpc]
100
90
80
70
60
50
40
30
20
10
0
10^1
10^2
10^3
Frequency [Hz]
74 Mpc Sept 2015
86 Mpc power increased
98 Mpc squeezing

Jitter with high power laser



Reduced input jitter from 70 W amplifier