A+ FOR LIGO

GariLynn Billingsley

On Behalf of

LIGO Laboratory

Advanced LIGO UK Group

Oz-Grav ANU, Oz-Grav UA

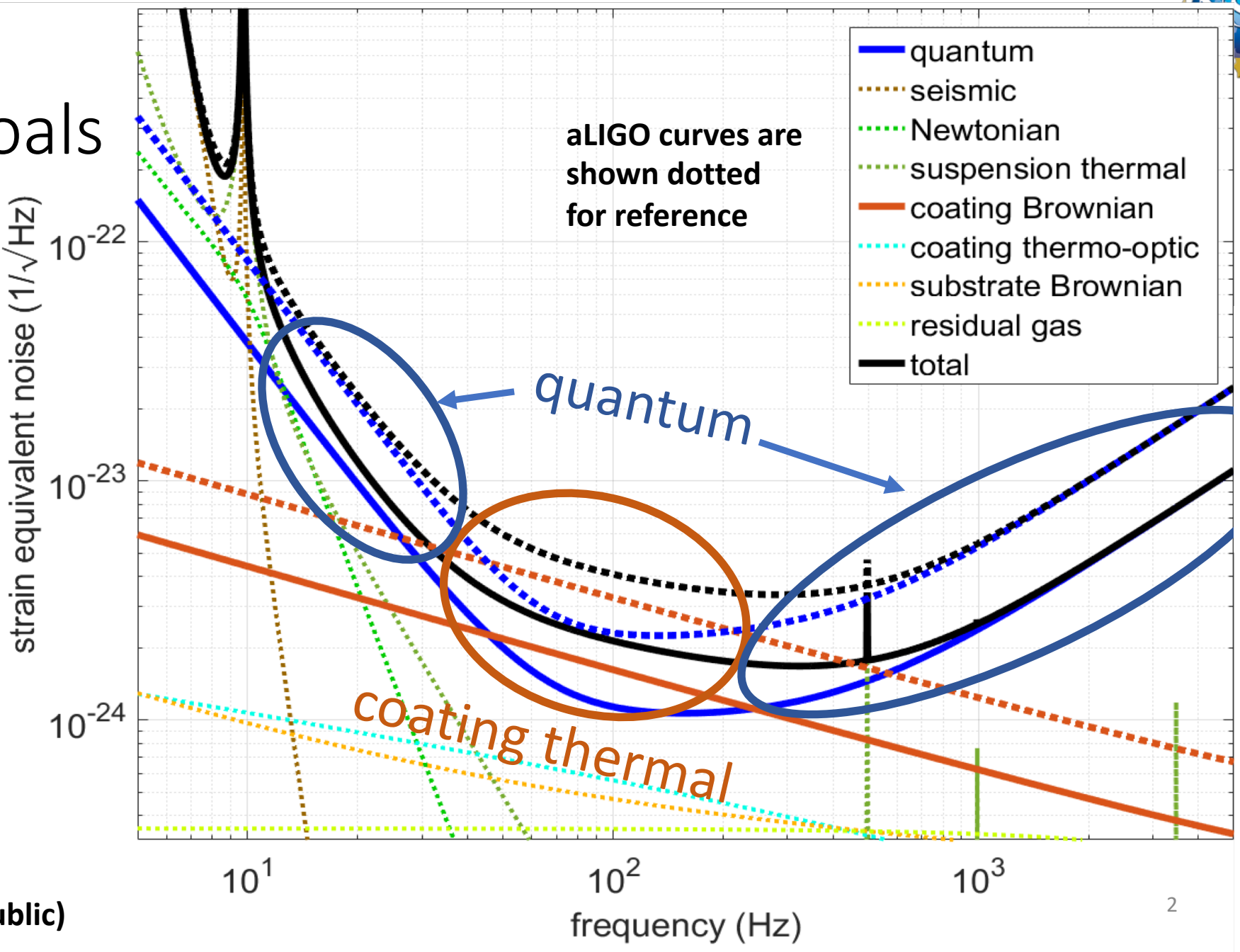
LVC 21 March 2019

LIGO-G1900666-v1

Performance goals

observing range improvement

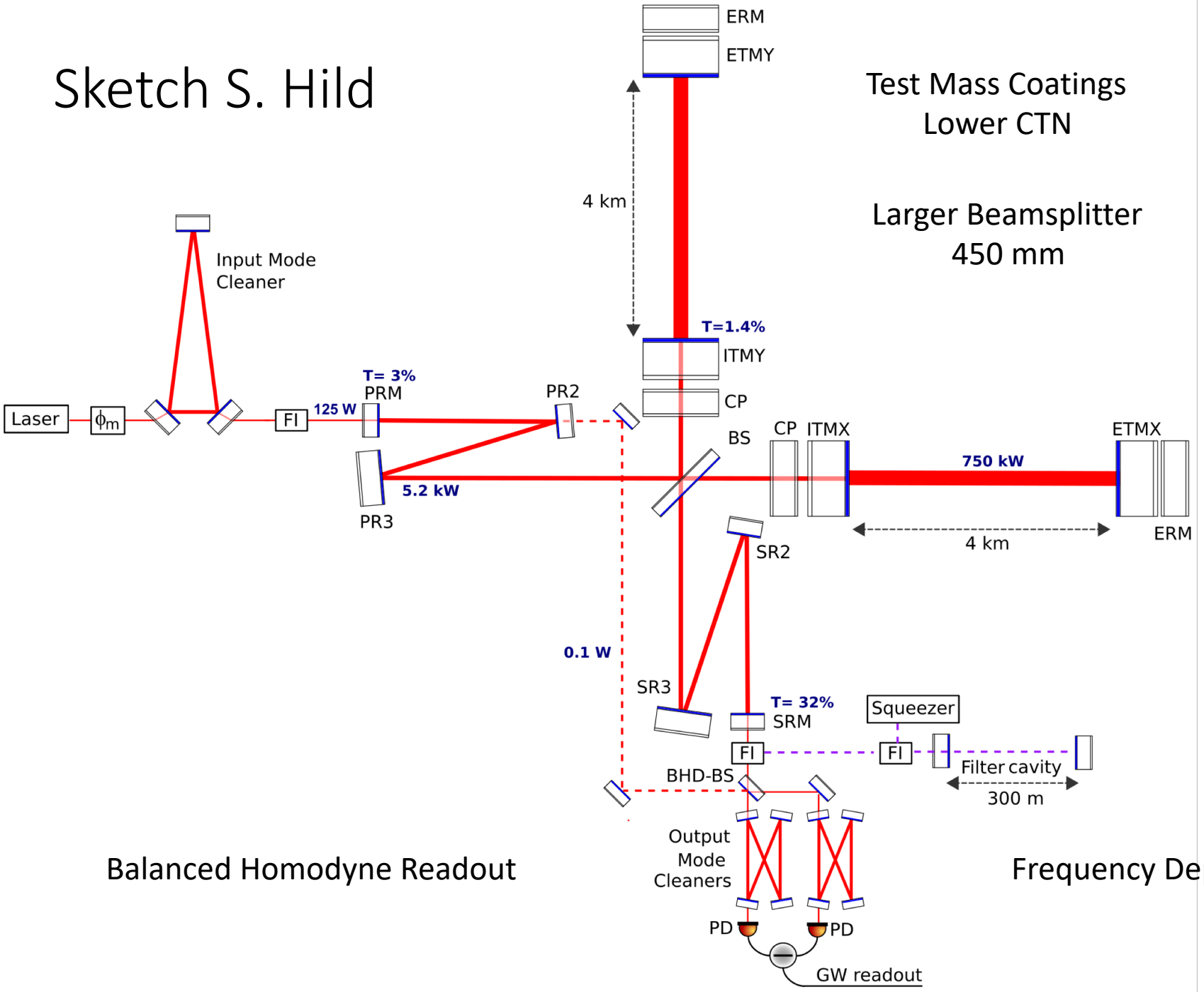
- NS:NS 1.4 M⊙
  - 173 Mpc
  - -> **325** Mpc
- BH:BH 30 M⊙
  - 1606 Mpc
  - -> **2563** Mpc



Sketch S. Hild

Test Mass Coatings
Lower CTN

Larger Beamsplitter
450 mm



Balanced Homodyne Readout

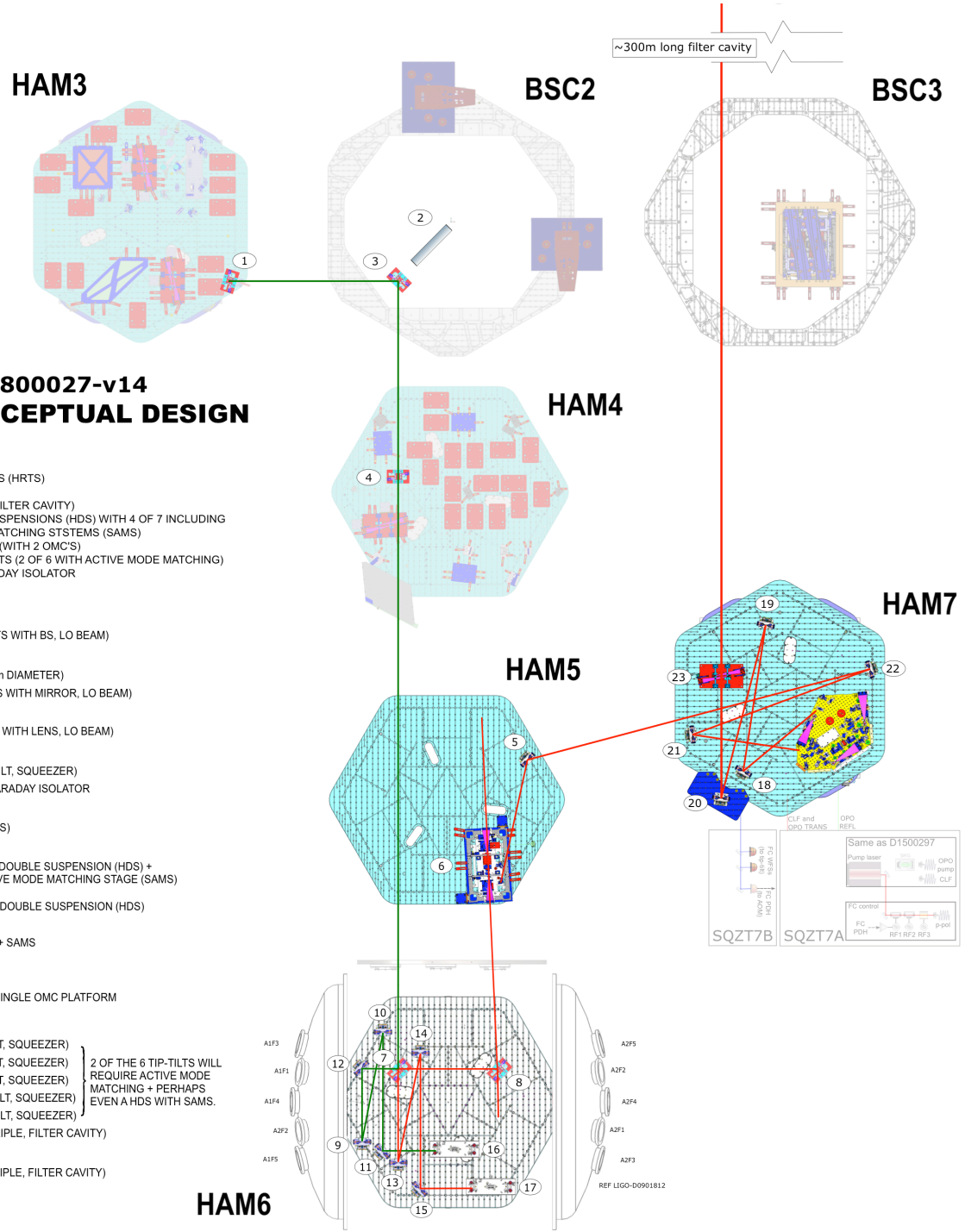
Frequency Dependent Squeezing

A+ Cartoon

+Y

+X

UK/US breakout see
LIGO-G1900646



LIGO-D1800027-v14

A+ CONCEPTUAL DESIGN

OPTICS/SITE SUMMARY:

5X SIMPLER TRIPLES (HRTS)
1X LARGER BS
2X HSTS TRIPLES (FILTER CAVITY)
7X HAM DOUBLE SUSPENSIONS (HDS) WITH 4 OF 7 INCLUDING ACTIVE MODE MATCHING STSTEMS (SAMS)
1X OMC PLATFORM (WITH 2 OMC'S)
6X EXISTING TIP-TILTS (2 OF 6 WITH ACTIVE MODE MATCHING)
1X LOW LOSS FARADAY ISOLATOR

DETAILS:

HAM3
1. BHDBS1 (HRTS WITH BS, LO BEAM)

BSC2
2. BS (BS 450mm DIAMETER)
3. BHDM1 (HRTS WITH MIRROR, LO BEAM)

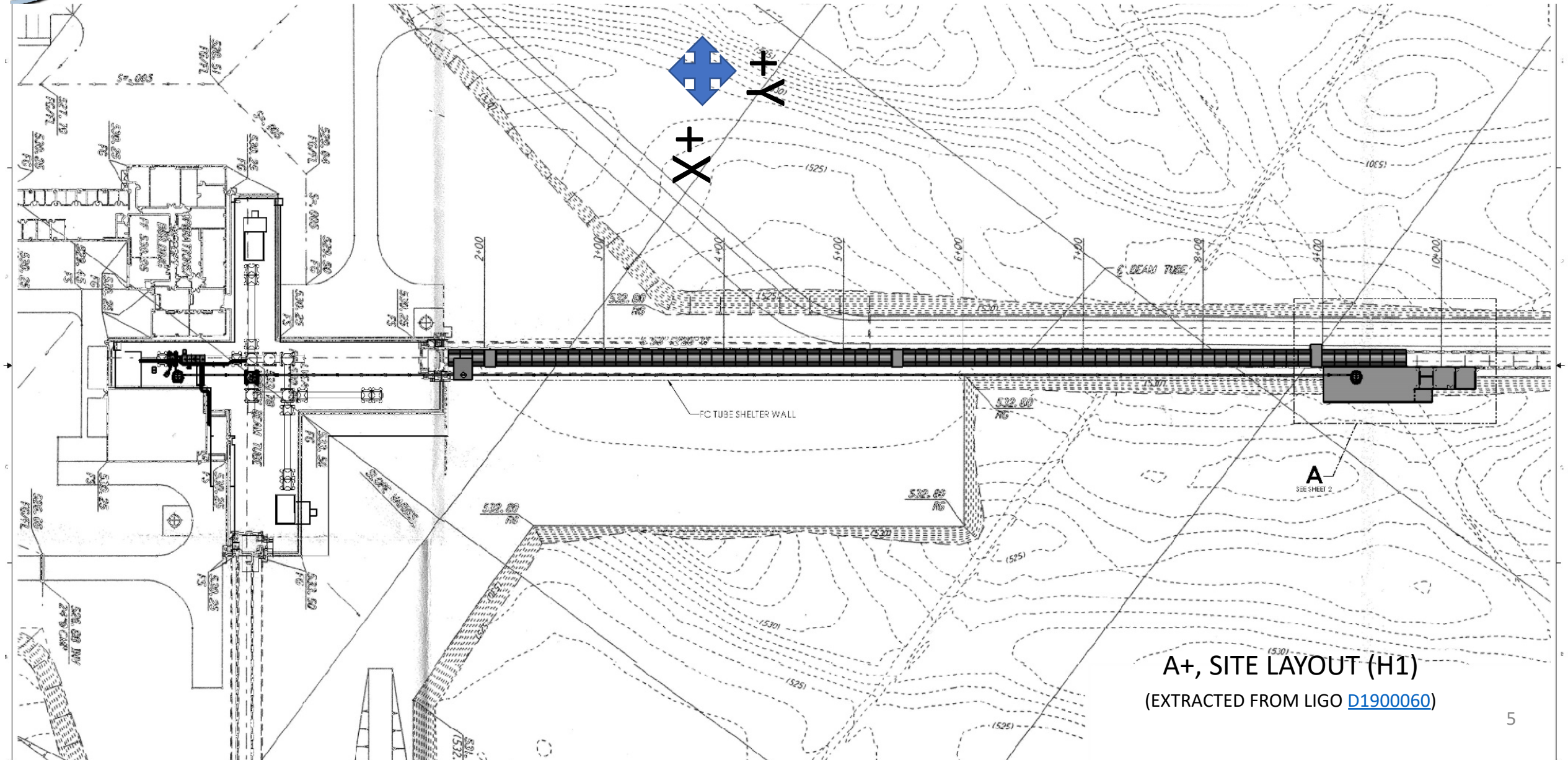
HAM4
4. BHDL1 (HRTS WITH LENS, LO BEAM)

HAM5
5. SQZR3 (TIP-TILT, SQUEEZER)
6. LOW LOSS FARADAY ISOLATOR

HAM6
7. BHDBS2 (HRTS)
8. OM0 (HRTS)
9. OMA1 } HAM DOUBLE SUSPENSION (HDS) +
10. OMA2 } ACTIVE MODE MATCHING STAGE (SAMS)
11. OMA3 } HAM DOUBLE SUSPENSION (HDS)
12. OMAS }
13. OMB1 } HDS + SAMS
14. OMB2 }
15. OMB3 (HDS)
16. OMCA } ON SINGLE OMC PLATFORM
17. OMCB }

HAM7/9
18. FCR1 (TIP-TILT, SQUEEZER)
19. FCR2 (TIP-TILT, SQUEEZER)
20. FCR3 (TIP-TILT, SQUEEZER) } 2 OF THE 6 TIP-TILTS WILL REQUIRE ACTIVE MODE MATCHING + PERHAPS EVEN A HDS WITH SAMS.
21. SQZR1 (TIP-TILT, SQUEEZER)
22. SQZR2 (TIP-TILT, SQUEEZER)
23. FC1 (HSTS TRIPLE, FILTER CAVITY)

HAM8/10
24. FC2 (HSTS TRIPLE, FILTER CAVITY)



A+, SITE LAYOUT (H1)

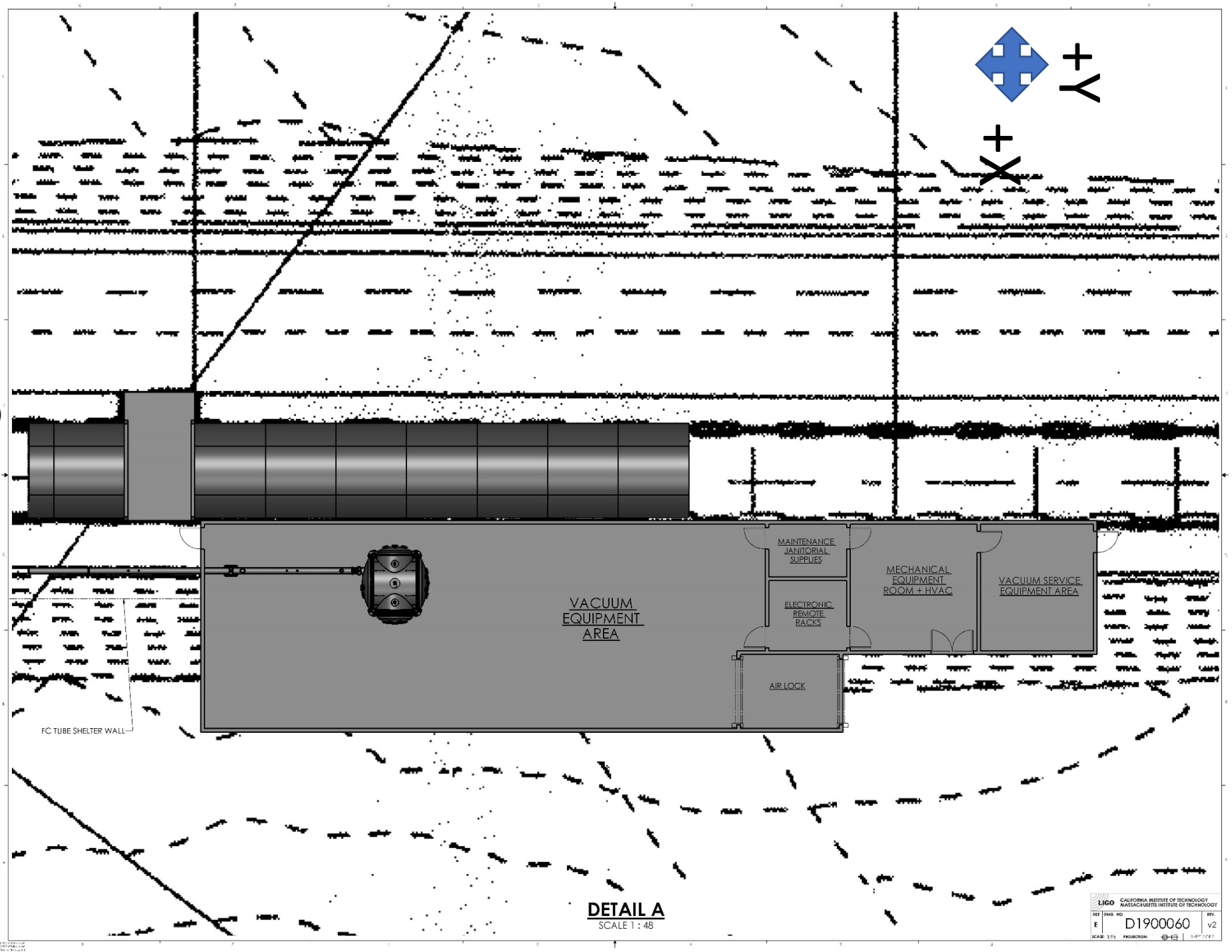
(EXTRACTED FROM LIGO D1900060)

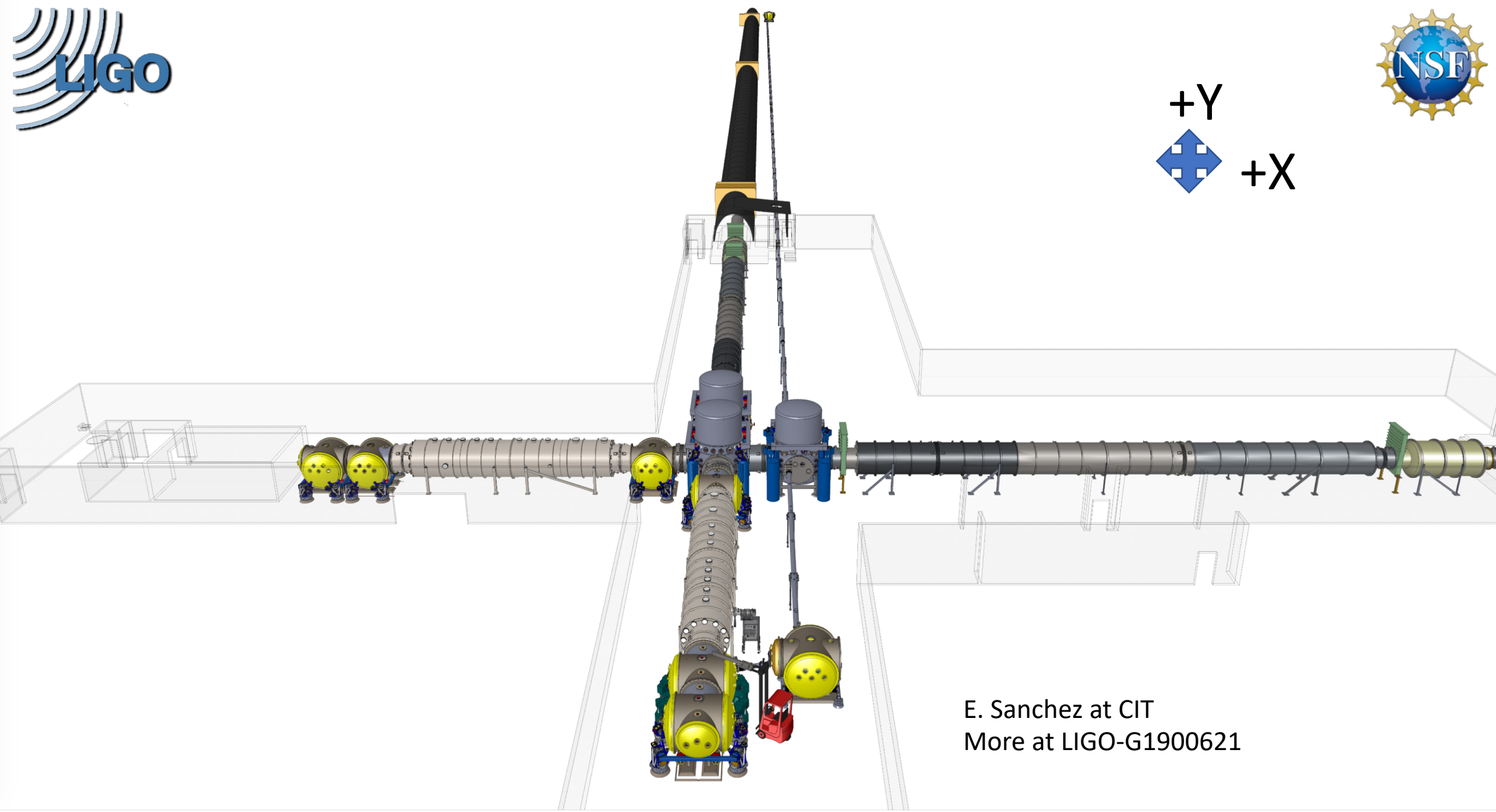
A+ Filter Cavity End Station Building Sites

View toward LVEA

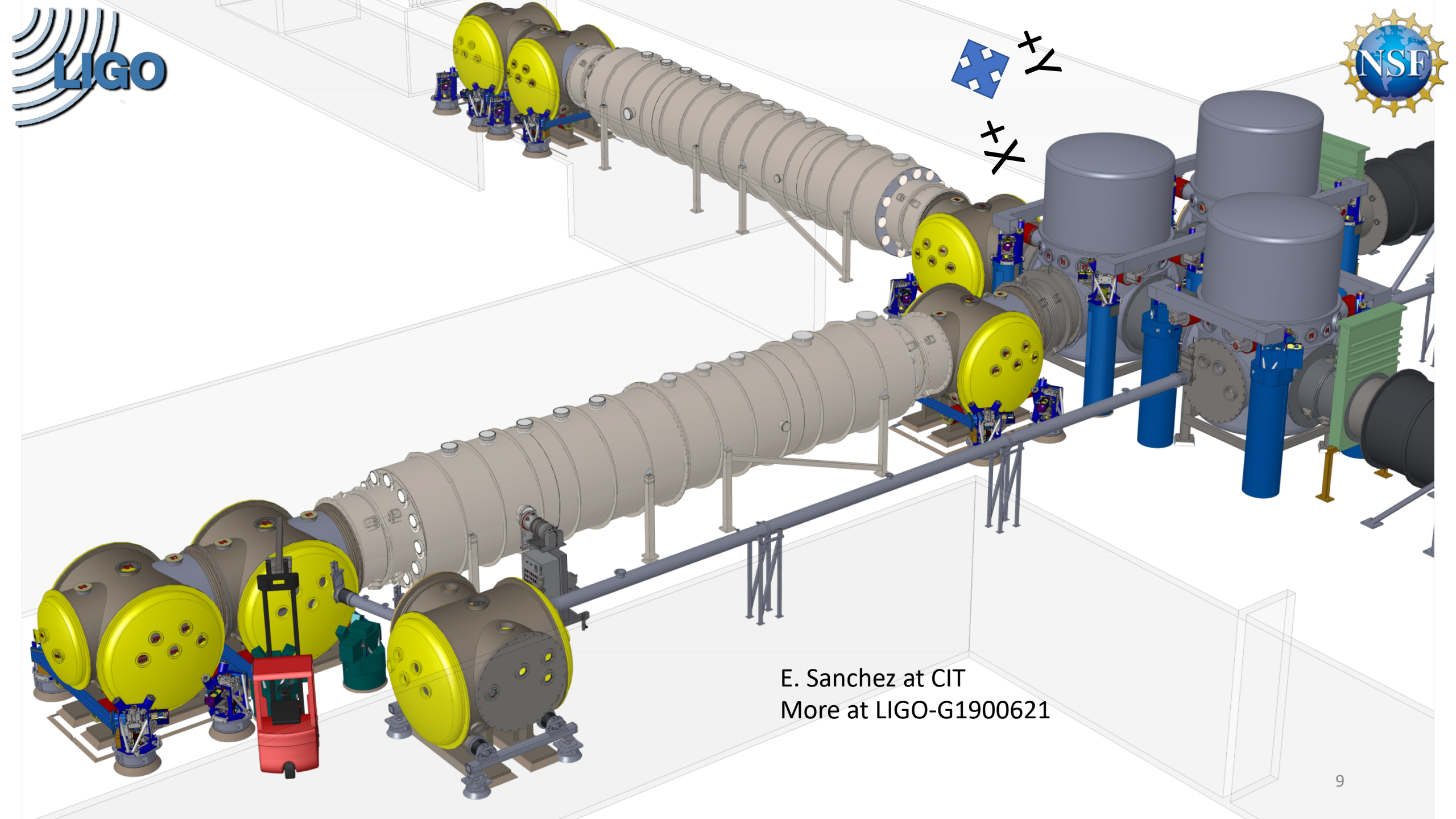
A+, SITE LAYOUT (H1): END STATION

(EXTRACTED FROM LIGO D1900060)





E. Sanchez at CIT
More at LIGO-G1900621



E. Sanchez at CIT
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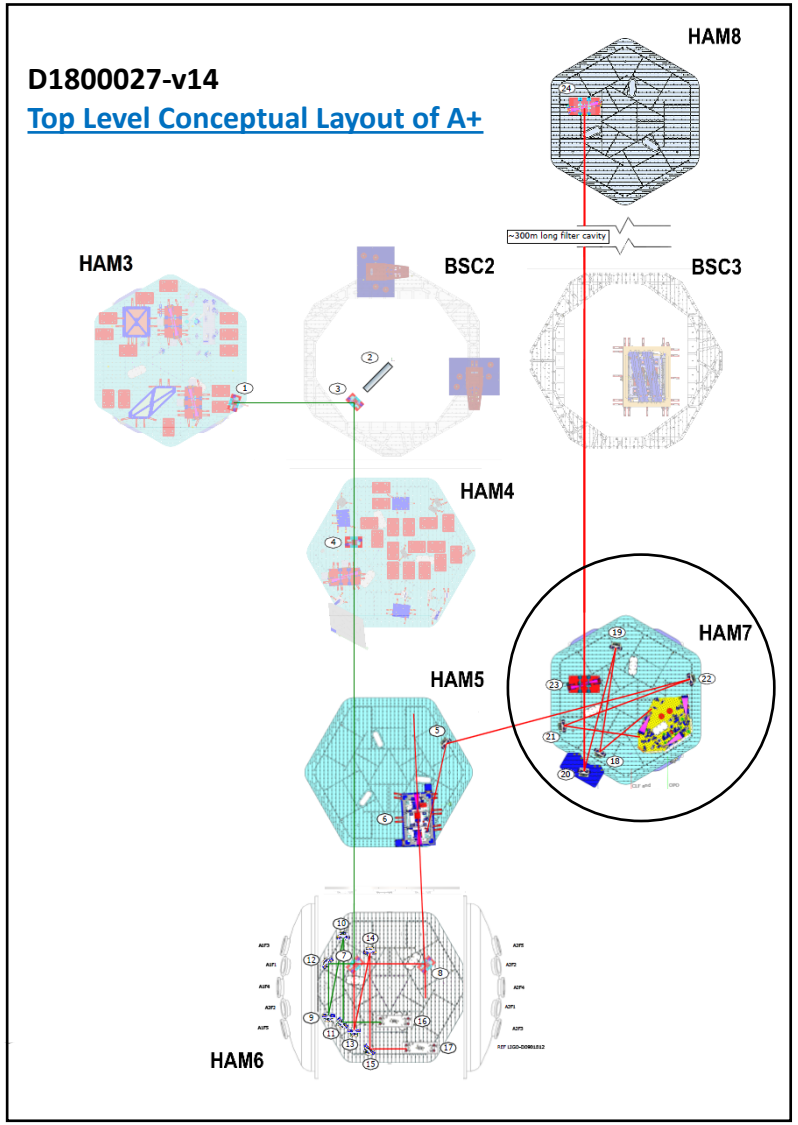
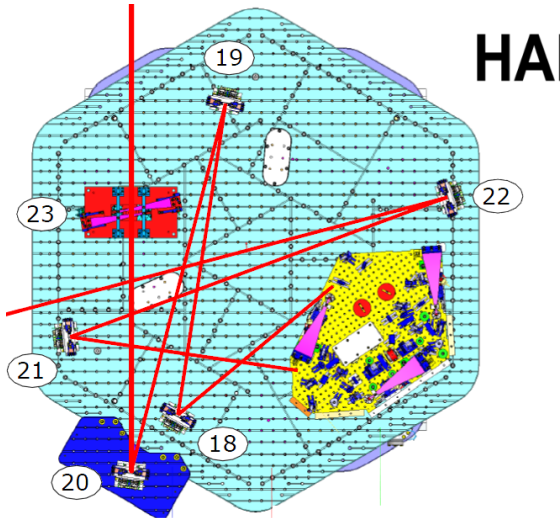
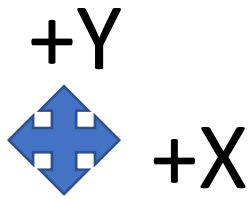
HAM Double Suspension (aka SAMS)







Up to 12 Double Suspension for A+

First units possibly installed for O4

HDS Main functionalities:

- **Seismic isolation (2 stages)**
- **DC tip-tilt steering**
- **Dither for alignment signals (2kHz tip-tilt)**
- **Mode matching (Mirror curvature control**

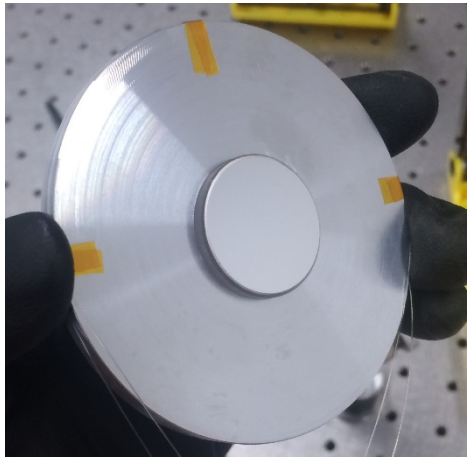
Huy Tuong Cao, Sebastian Ng, Daniel Brown, Peter Veitch at **University of Adelaide**

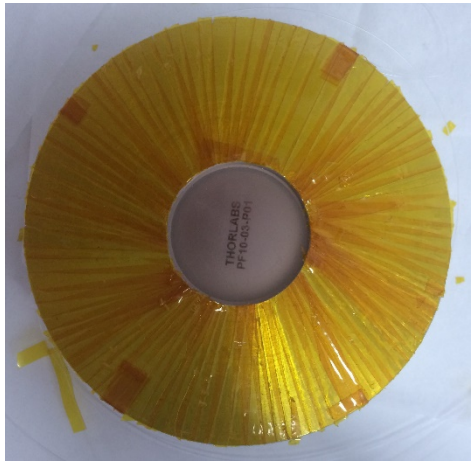
Minkyun Noh, Peter Fritschel, Fabrice Matichard at **MIT**

Calum Torrie, Dennis Coyne, Aidan Brooks at **Caltech**

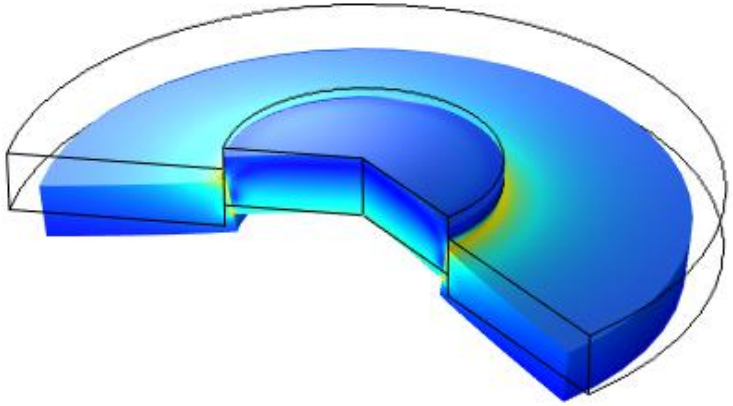
Compression Fit Mirror (CFM) - Cao Huy-Tuong, Sebastian Ng, Peter Veicht

The University of Adelaide





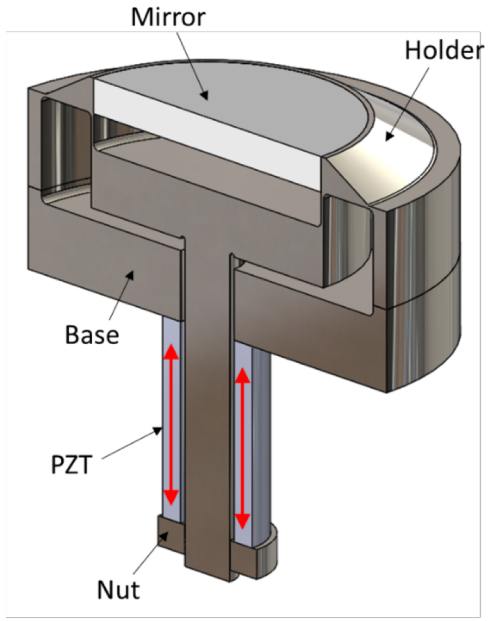
- Thermal expansion allows assembly and provides actuation
- Demonstrated low higher order aberration
- No adhesive
- Requires optimization of geometry
- Curvature actuation: up to ~ 3 mD / degree C

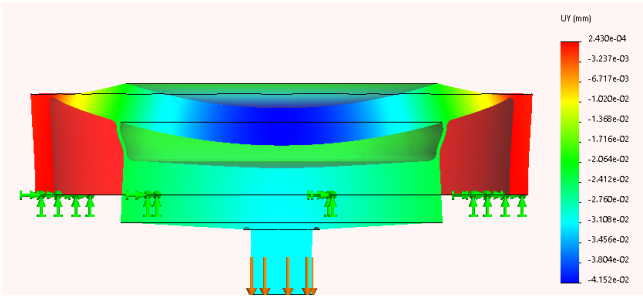


LIGO-E1900044: SAMS-Compression fit mirror A+ Stress and deformation optimization

LIGO-E1900073: SAMS - Thermal adaptive optics geometry parameter optimization

Piezo flexure mechanism designed by Minkyun Noh





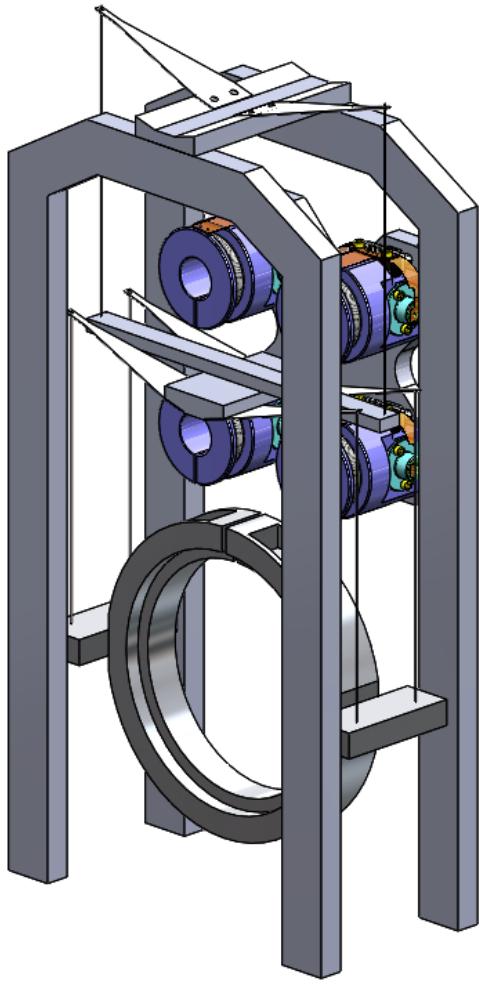
Compression fit inspired by Adelaide's concepts

Flexure Mechanism designed to translate axial displacement into moment on the barrel of the mirror.

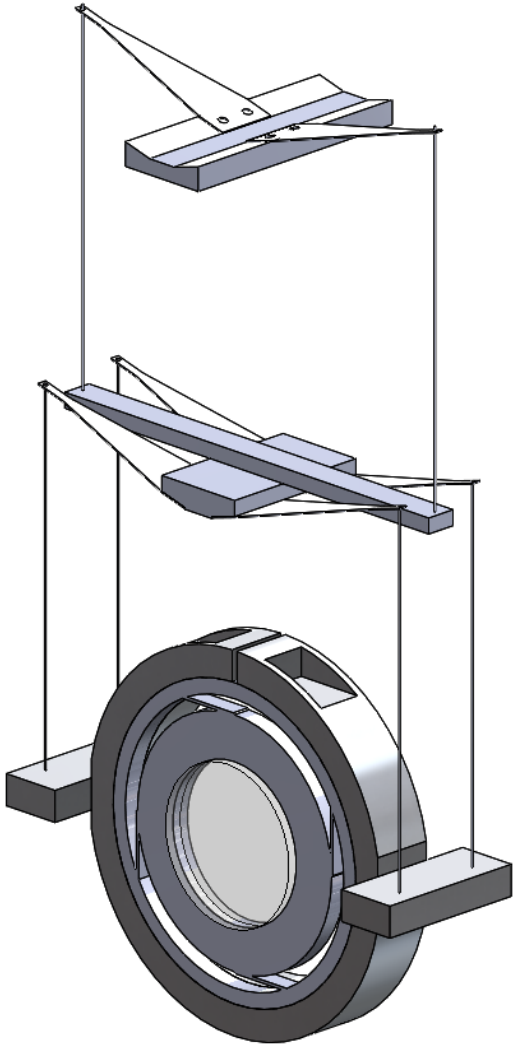
Pros	Cons
• High bandwidth • Adhesive-free • Standard mirror • Standard PZT	• PZT hysteresis • Sensing for closed-loop control • Flexure machining • Large inertia for dithering • PZT column resonance

LIGO-E1900007: SAMS Development - Summary 4 - Piezo flexure mechanism

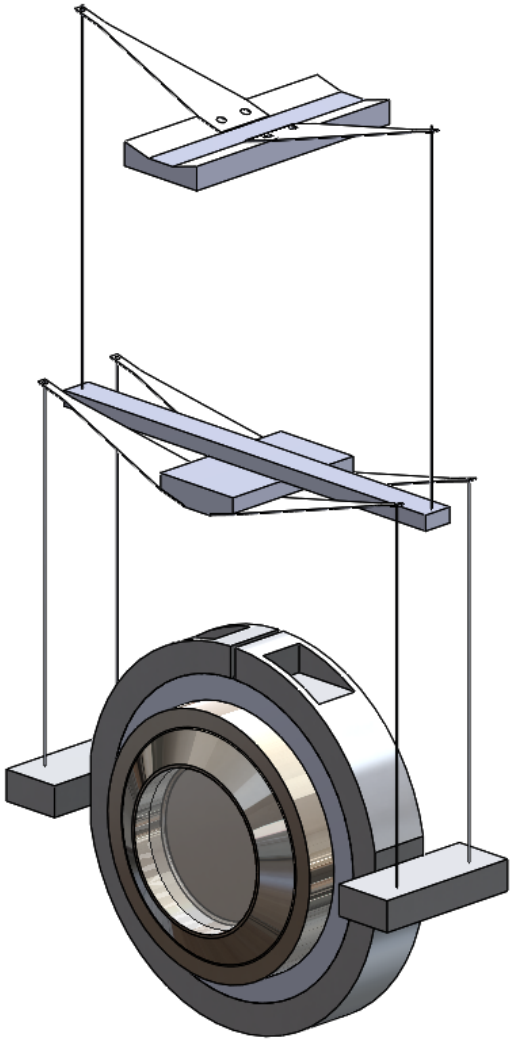
Suspension Concepts



Thermal Deformable Mirror



Piezo Deformable Mirror



LIGO-E1900056: SAMS - Suspension Interface

LIGO-E1900066: SAMS - Suspension Interface: Bracket Option

A+ Team

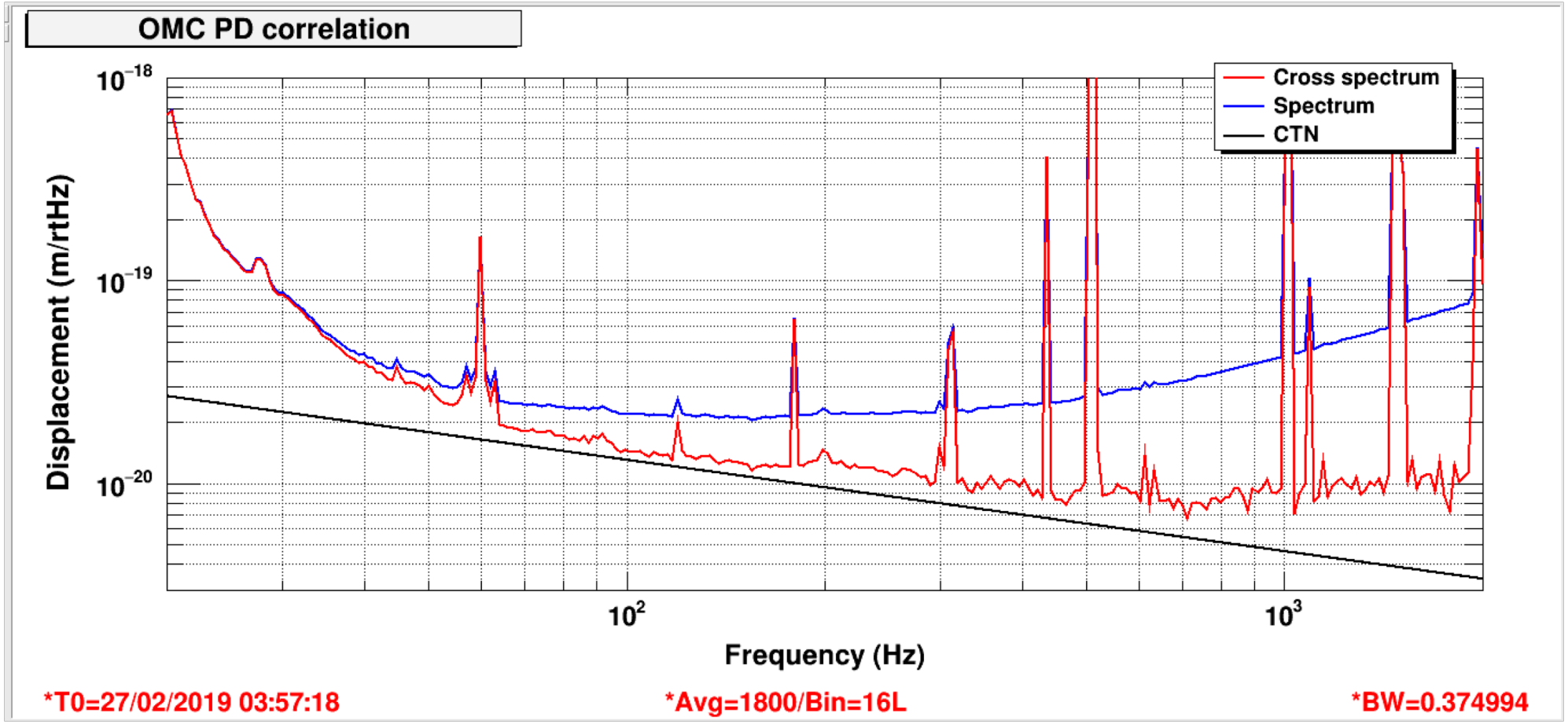
Name	Home	A+WBS/WP	A+ Project Subsystem/WP Title
D. Reitze	CIT	PM	PI
A. Lazzarini	CIT	PM	Co-PI
M. Zucker	MIT	PM, FAC	Co-Pi, Facilities
G. Billingsley	CIT	PM, COC	Project Lead Engineer, Optical Test
H. Hansen	LHO	PM	Business
C. Torrie	CIT	SYS	Systems Engineering
N. Robertson	CIT	SUS	Suspensions
K. Mason	MIT	SEI	Seismic Isolation
R. Abbott	CIT	CDS	Controls & Data Systems
C. Romel	LHO	VAC	Vacuum Systems
L. Barsotti	MIT	ISC	Interferometric Sensing & Controls
S. Rowan	GU	WP1	Test Mass Production/Coatings
K. Strain	GU	WP2/WP7	Beamsplitter Production and Project Management
J. O'Dell	RAL	WP3	Suspensions
C. Mow-Lowry	BU	WP4	Sensors and Actuators
S. Hild	GU+CU	WP5	Balanced Homodyne Readout
G. Hammond	GU	WP6	Suspension Upgrades

Project Summary

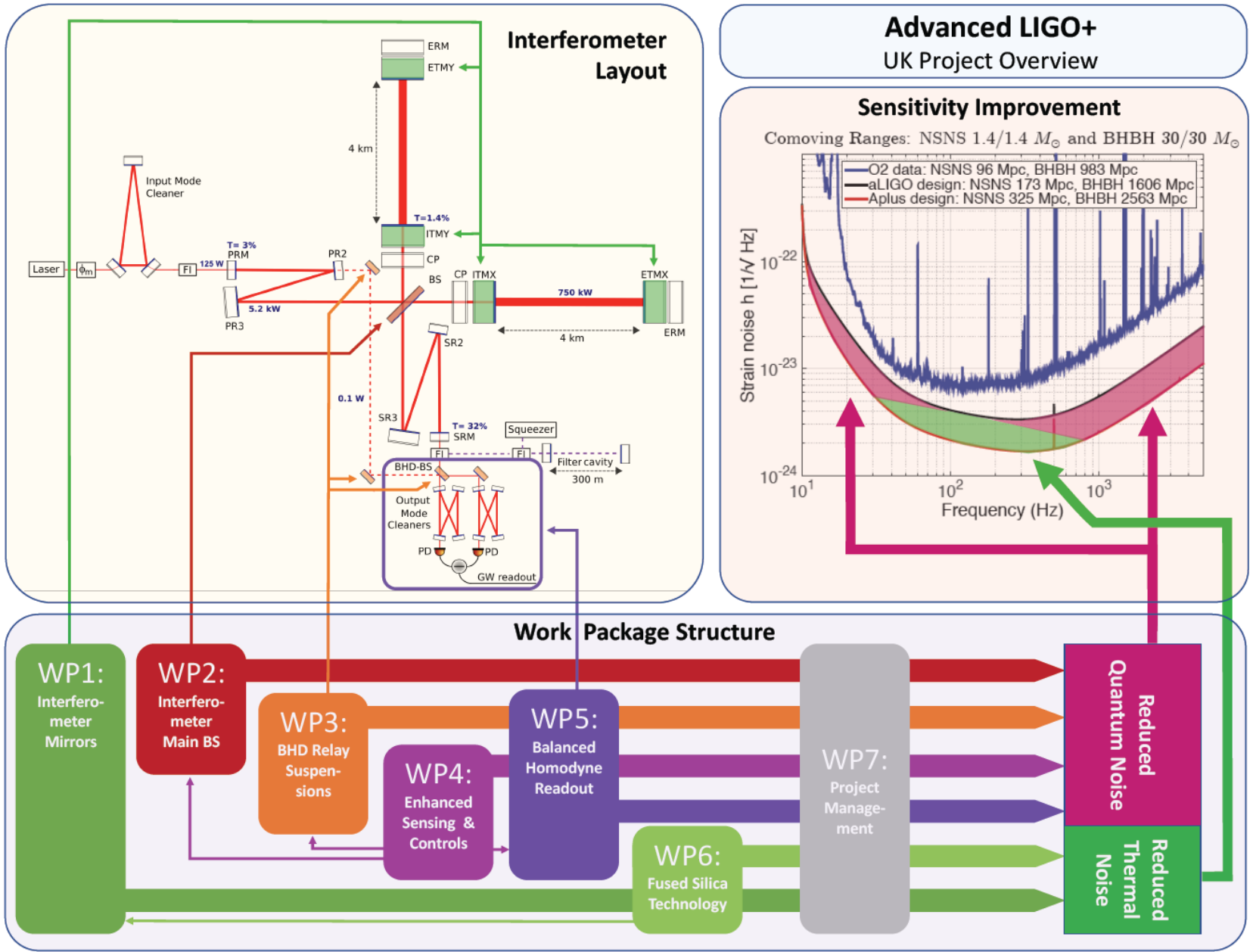
- PM infrastructure is in place
  - Resource-loaded schedule now under baseline review
  - WBS, cost accrual structures and interface definitions complete
- Early deliverables on track for pre-O4 integration
  - Facility Design Requirements complete and reviewed
  - Vacuum Design Requirements complete and reviewed, moving into procurement
  - Seismic isolation systems, fabrication underway
  - Low Loss Output Faraday Design Requirements complete, moving into procurement
- UK announcement in February 2019
  - Integrate deliverables into plan and move ahead together on all fronts

Extra Slides

LLO February 27, 2019



UK Work Package Overview



See also LIGO-G1900646