ADVANCED VIRGO

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Advanced Virgo Project Leader

for the Virgo Collaboration and EGO

20 Febbraio 2017
Advanced Virgo Dedication

ADVANCED VIRGO

- Advanced Virgo (AdV): upgrade of the Virgo interferometric detector
- Partecipated by France and Italy (former founders of Virgo), The Netherlands, Poland, Hungary, Spain
- Funding approved in Dec 2009 (21.8 ME + Nikhef in kind contribution)
- Goal: be part of the international network of 2nd generation detectors
- Short-term goal: join the O2 run in 2017

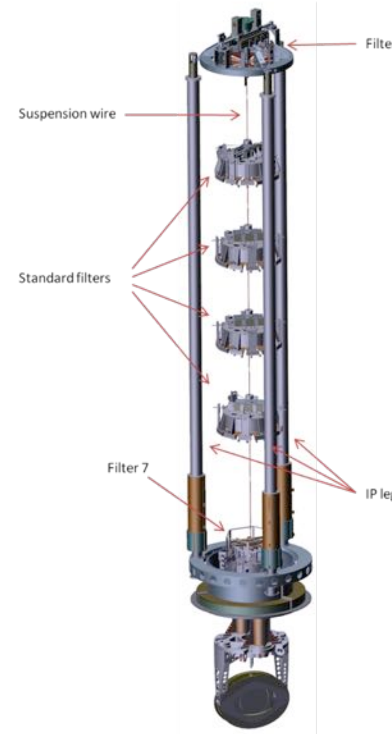
6 European countries
20 labs, ~250 authors

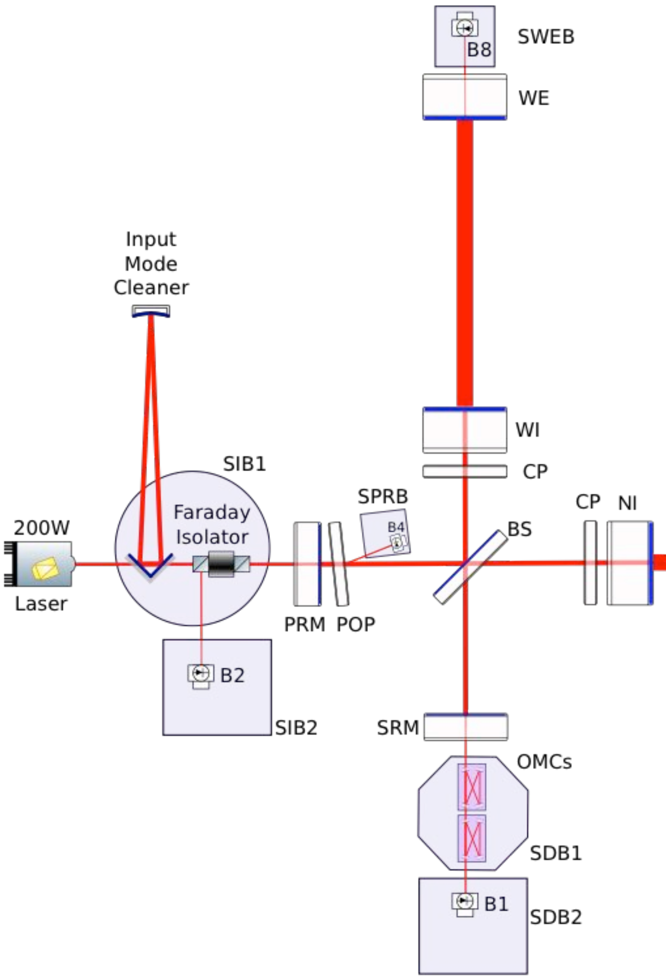
APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata
INFN Trento-Padova
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW(Poland)
RADBOUD Uni. Nijmegen
RMKI Budapest
Univ. of Valencia

ADV DETECTOR DESIGN

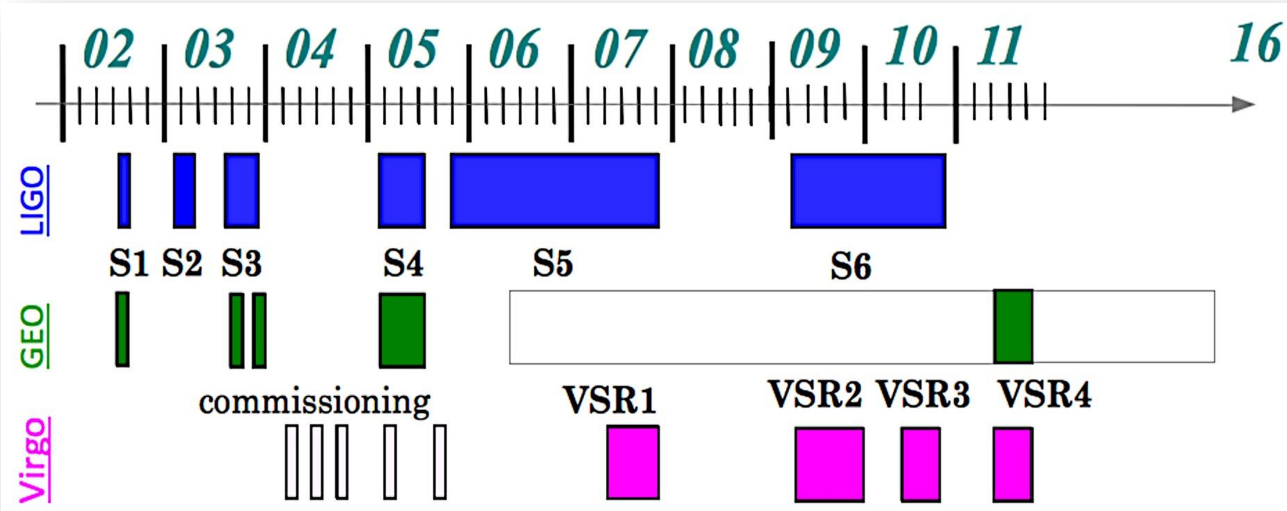
- MAIN CHANGES wrt Virgo
  - larger beam
  - heavier mirrors
  - higher quality optics
  - thermal control of aberrations
  - stray light control
  - improved vacuum
  - *200W laser*
  - *signal recycling*

2018/19



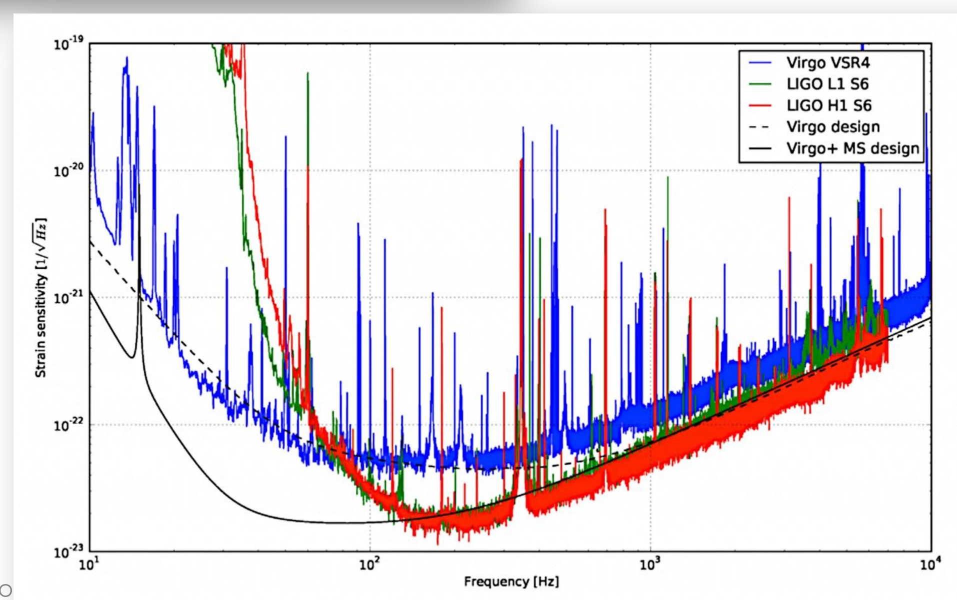


1st GENERATION

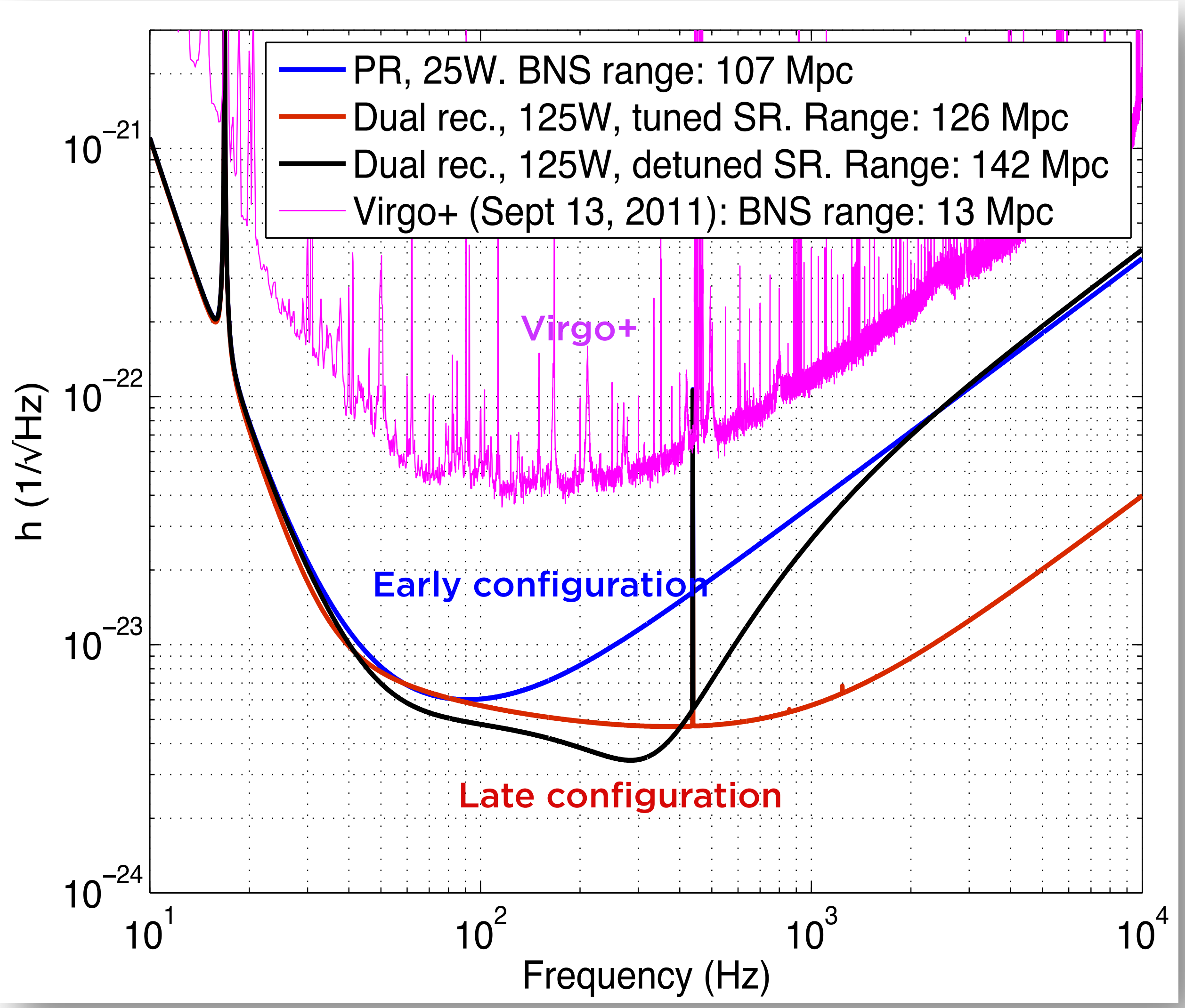


DATA TAKING SLOTS
FOR LIGO, GEO, VIRGO

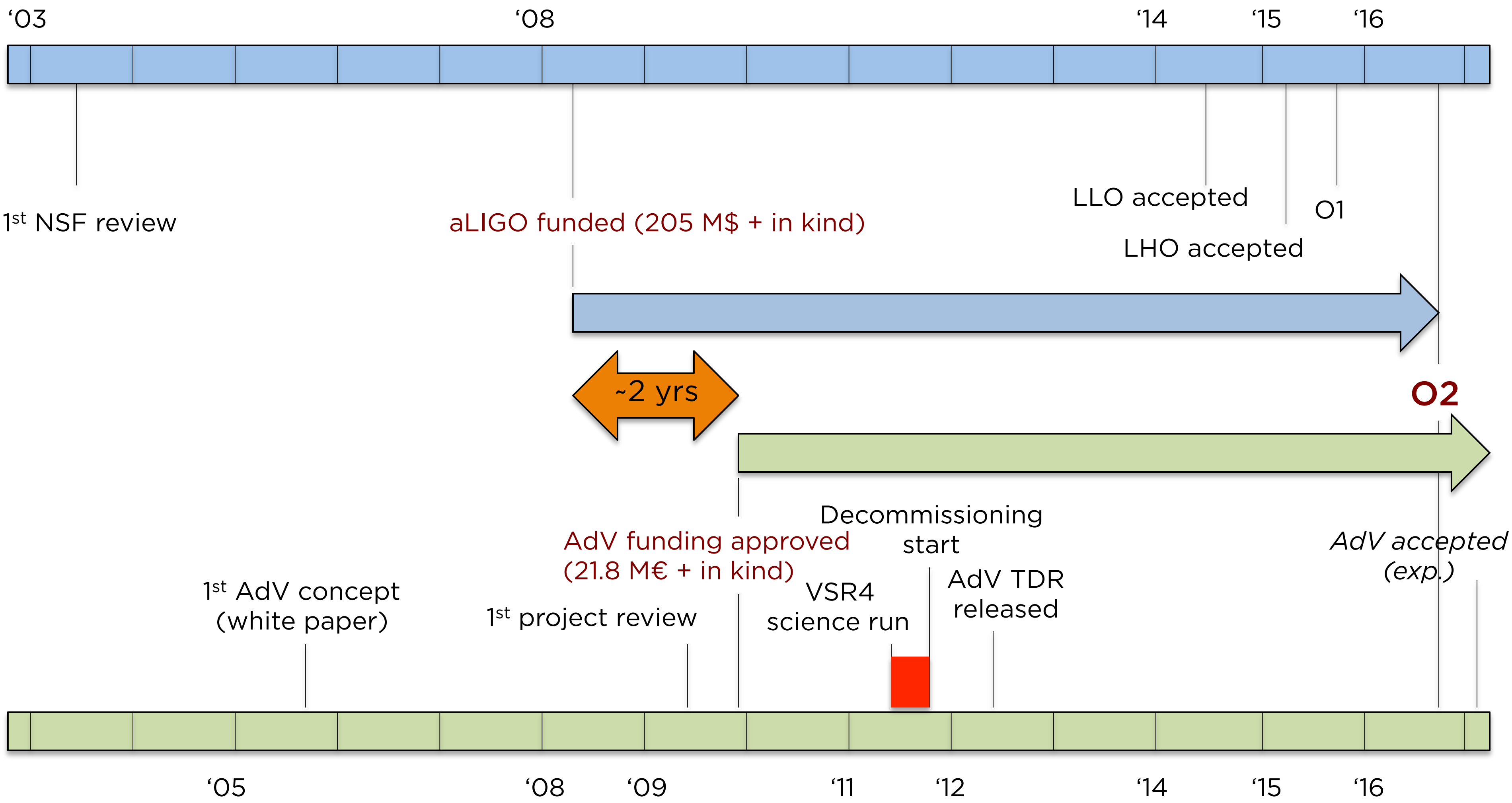
BEST SENSITIVITY FOR
LIGO, VIRGO



SENSITIVITY TARGETS



Advanced LIGO vs VIRGO TIMELINES

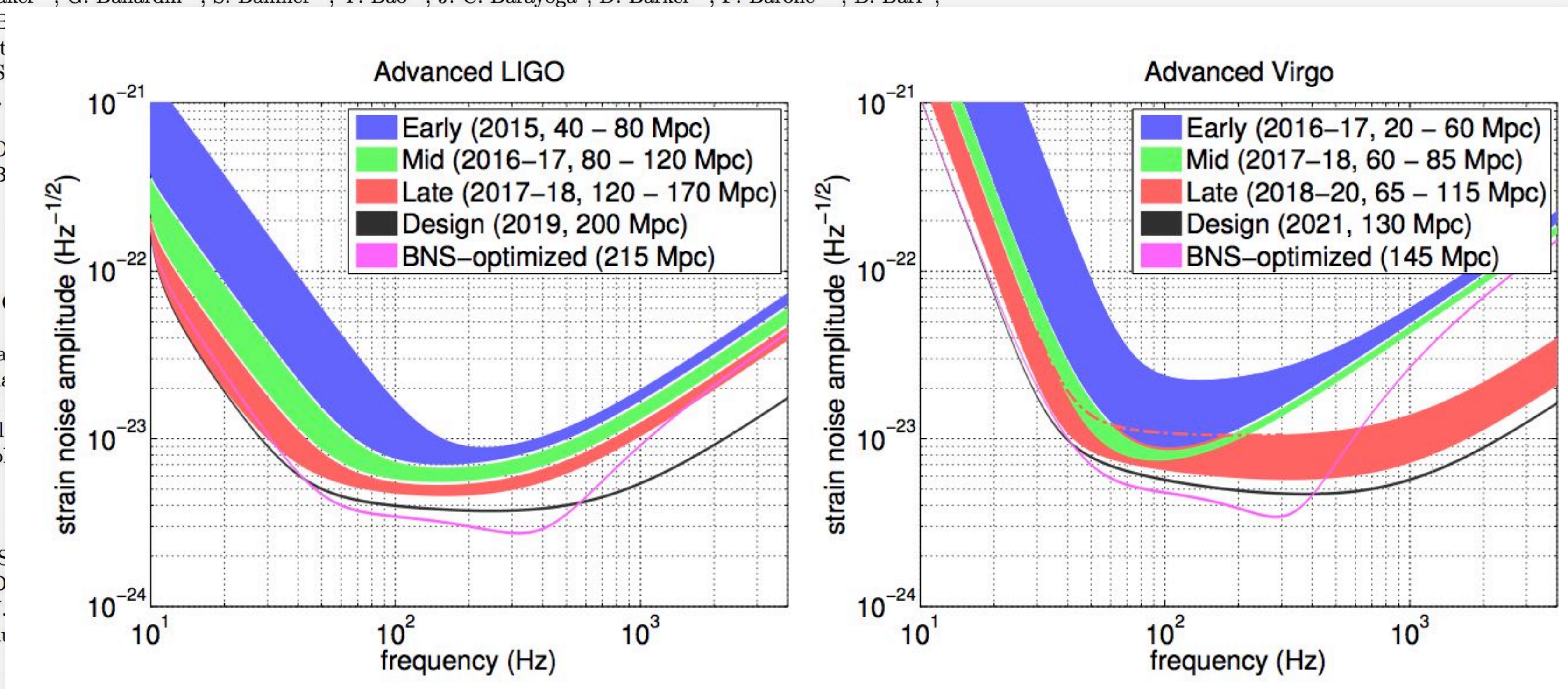


OBSERVING SCENARIO

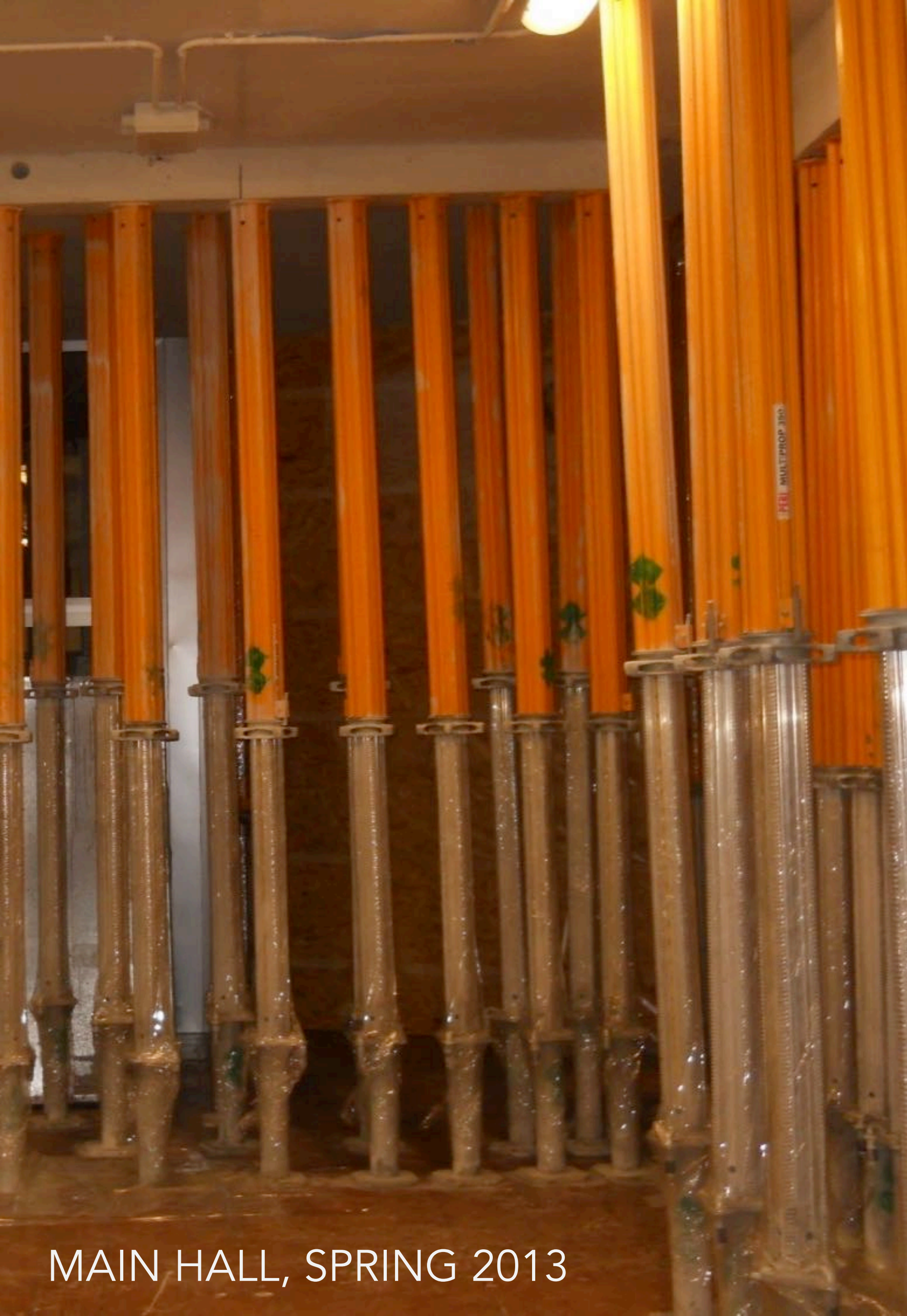
Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories

J. Aasi[1], J. Abadie[1], B. P. Abbott[1], R. Abbott[1], T. D. Abbott[2], M. Abernathy[3], T. Accadia[4],
F. Acernese[5ac], C. Adams[6], T. Adams[7], P. Addesso[8], R. X. Adhikari[1], C. Affeldt[9,10], M. Agathos[11a],
O. D. Aguiar[12], P. Ajith[1], B. Allen[9,13,10], A. Allocca[14ac], E. Amador Ceron[13], D. Amariutei[15],
S. B. Anderson[1], W. G. Anderson[13], K. Arai[1], M. C. Araya[1], C. Arceneaux[16], S. Ast[9,10], S. M. Aston[6],
P. Astone[17a], D. Atkinson[18], P. Aufmuth[10,9], C. Aulbert[9,10], L. Austin[1], B. E. Aylott[19], S. Babak[20],
P. Baker[21], G. Ballardin[22], S. Ballmer[23], Y. Bao[15], J. C. Barayoga[1], D. Barker[18], F. Barone[5ac], B. Barr[3],
L. B
J. Bat
A. S
P. T.
M.
C
R. B
C
M. Ca
S. Cha
H.
F. Cl
A. Co
S
M. D
W.
S. Dh
J. C.
S. S. Eikenberry[15], G. Endrőczi[59], R. Engel[1], R. Essick[24], T. Etzel[1], K. Evans[3], M. Evans[24], T. Evans[6]

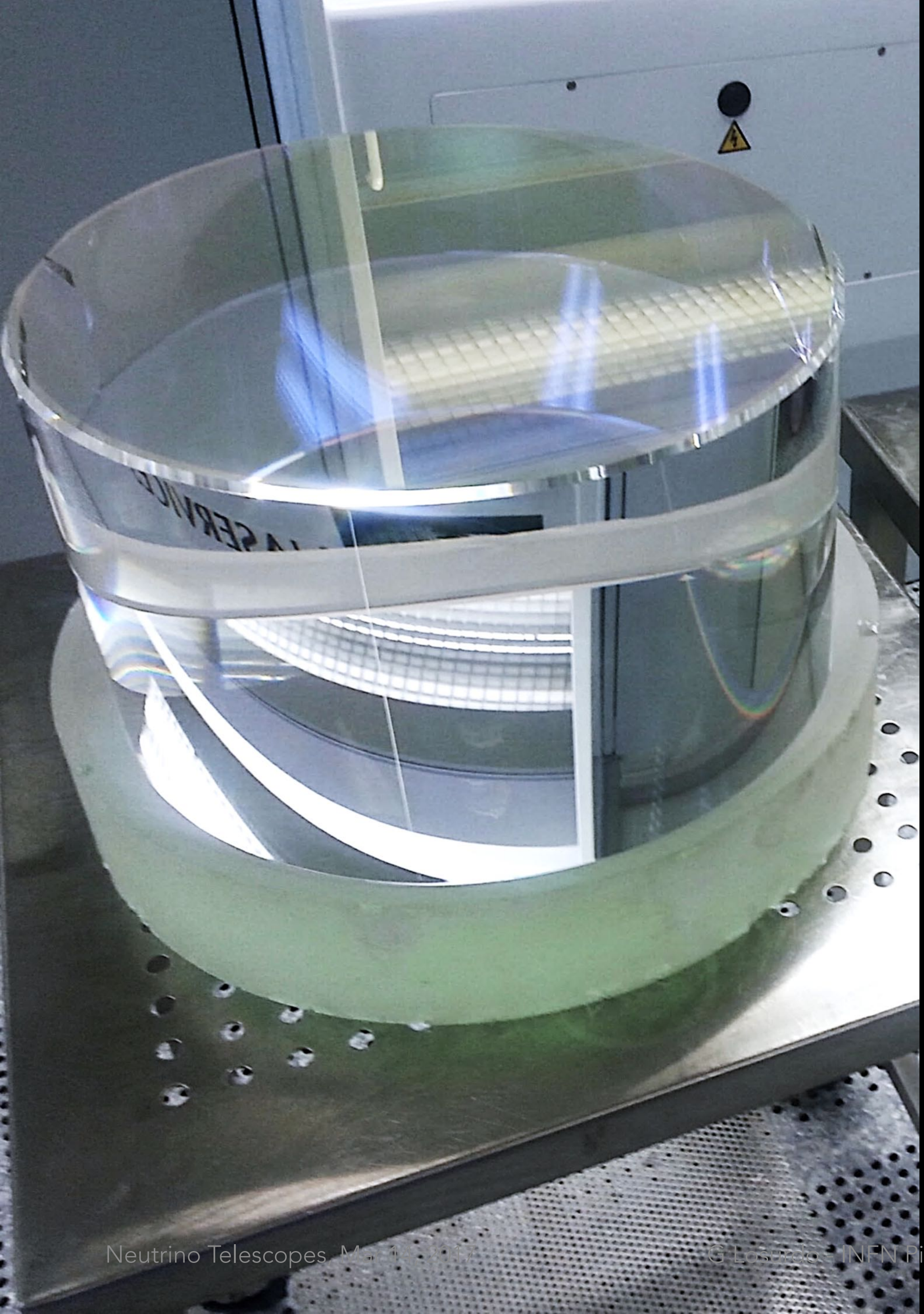
arXiv:1304.0670v1 [gr-qc] 2 Apr 2013



WHAT WE HAVE DONE



MAIN HALL, SPRING 2013



EXTREME MIRROR TECHNOLOGY:

- Low losses
- Low absorption
- Low scattering

FEATURES:

- 42 kg, 35 cm ⃠, 20 cm thick
- Flatness < 0.5 nm rms
- Micro-roughness: 0.1 nm rms
- Optical absorption < 0.5 ppm

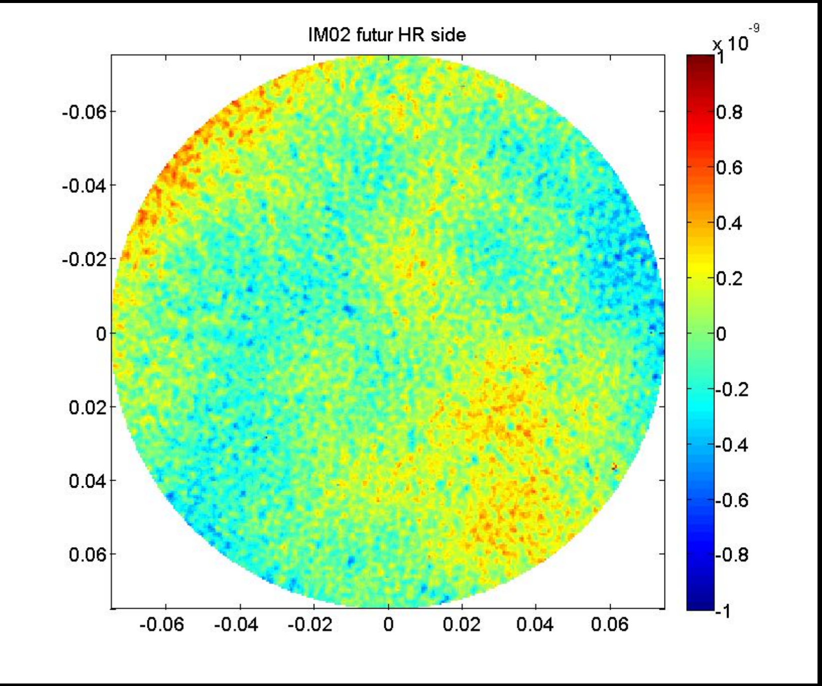
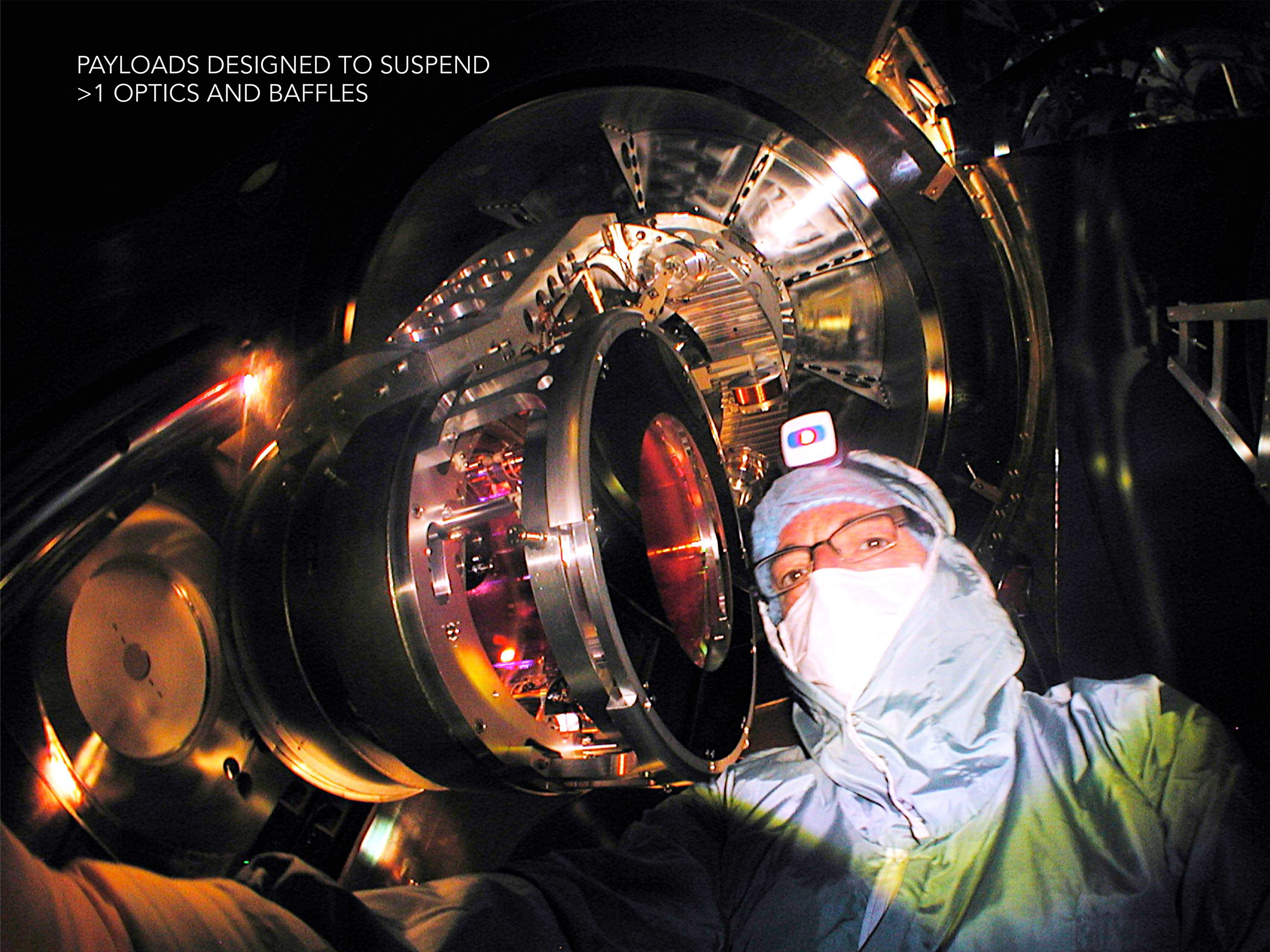
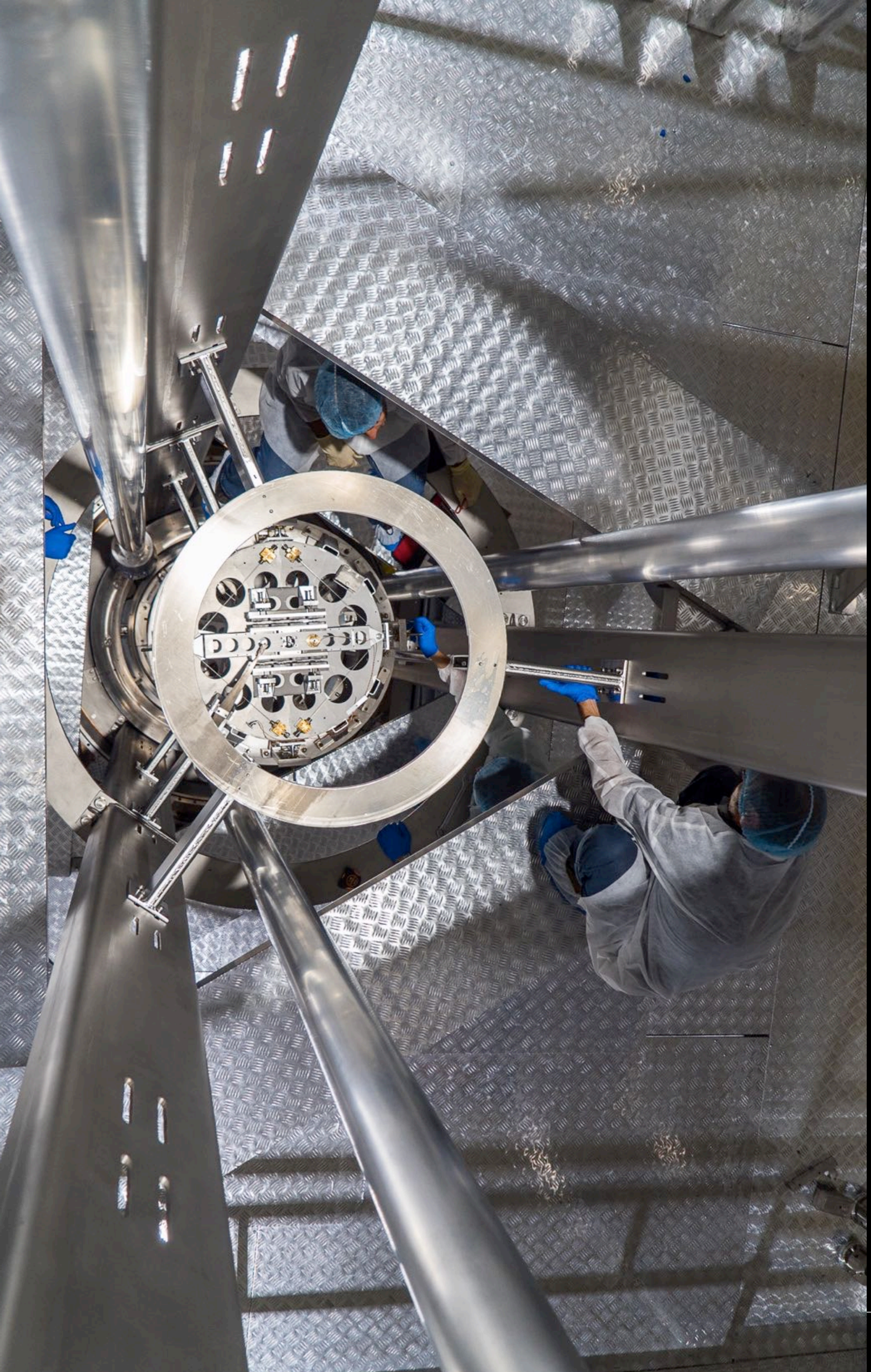
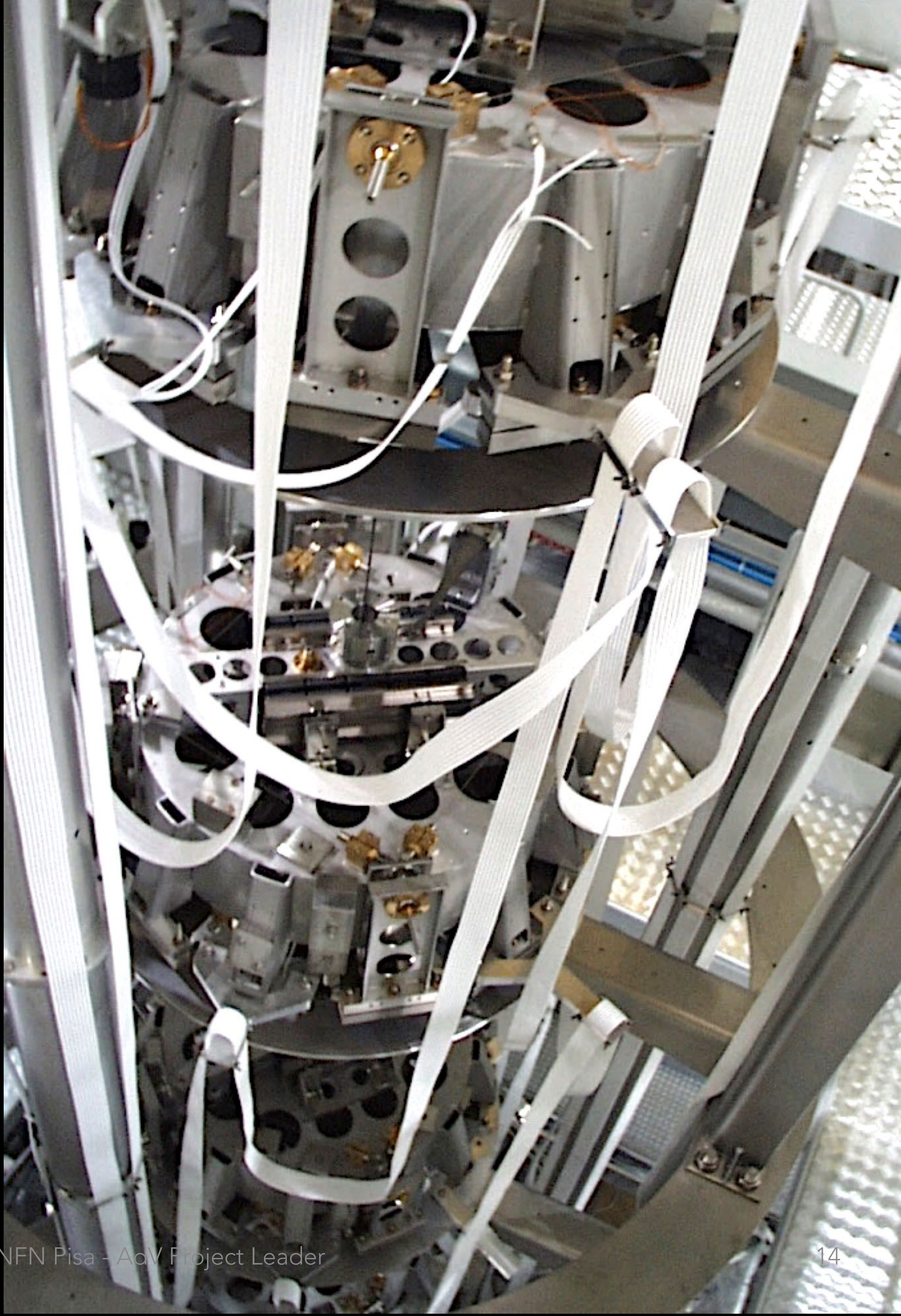


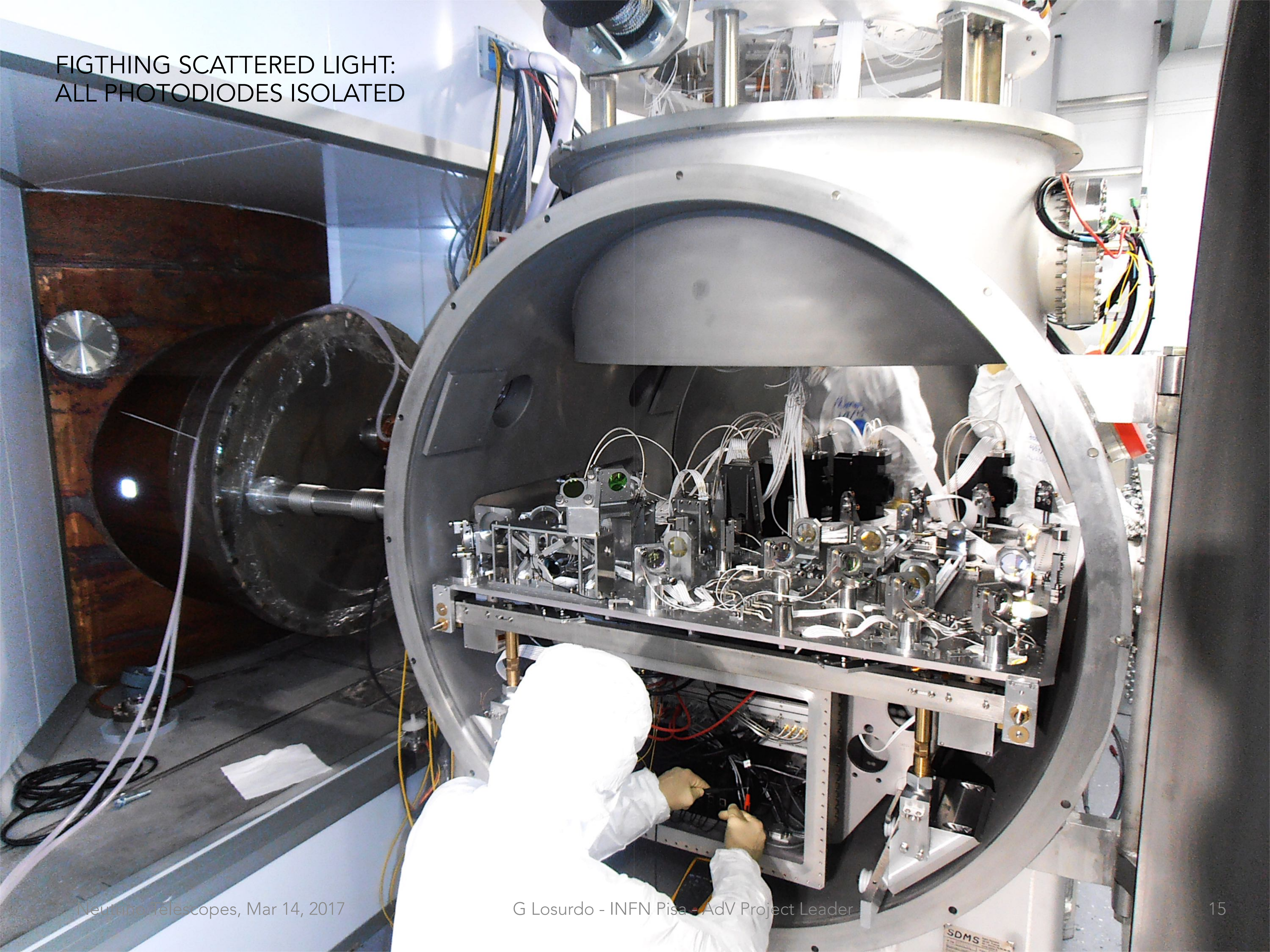

FOTO: MAURIZIO PERCIBALLI _mirror_without_first_contact_11-11-2015


PAYLOADS DESIGNED TO SUSPEND
>1 OPTICS AND BAFFLES

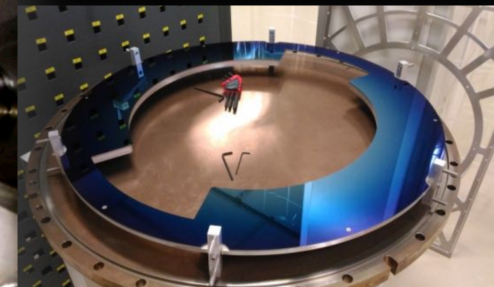
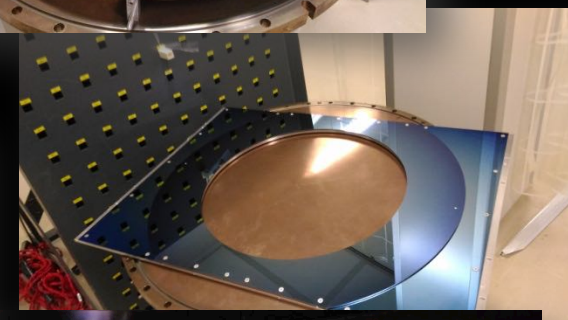


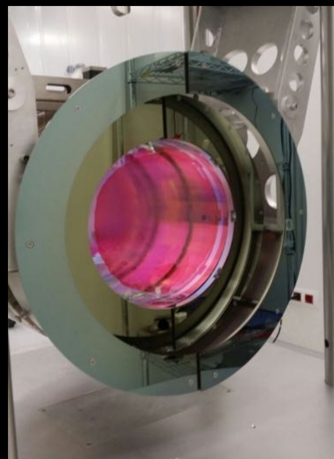
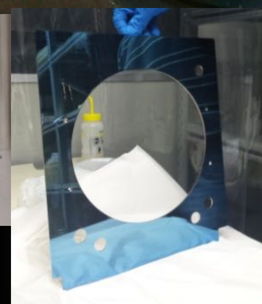


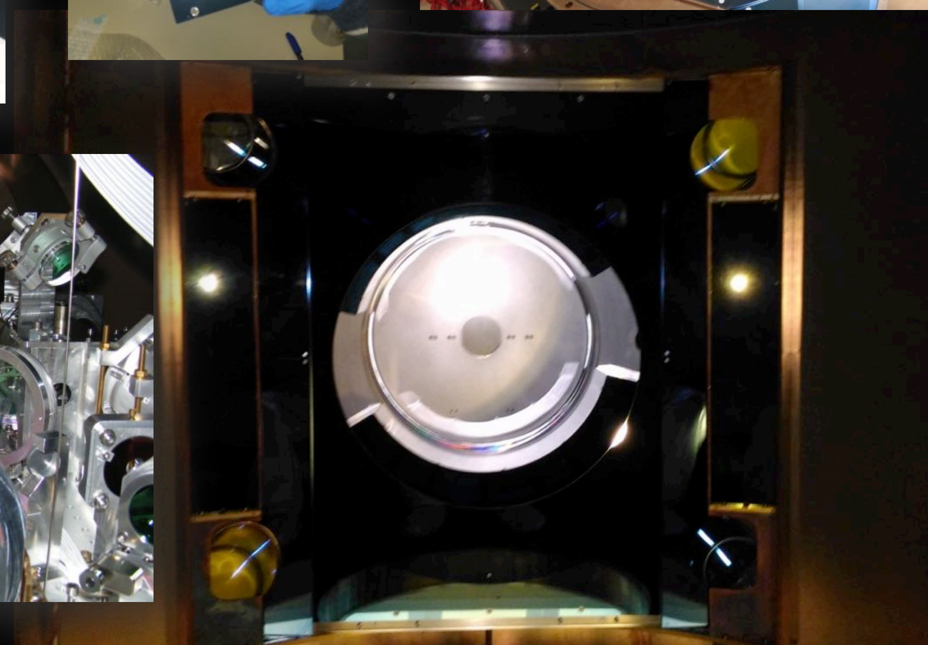
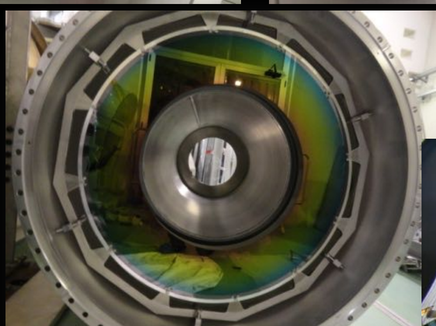
FIGTHING SCATTERED LIGHT: ALL PHOTODIODES ISOLATED

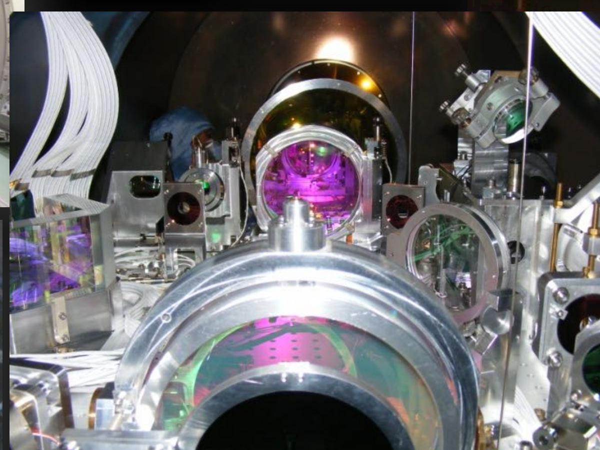


FIGTHING SCATTERED LIGHT: EXTENSIVE BAFFLING

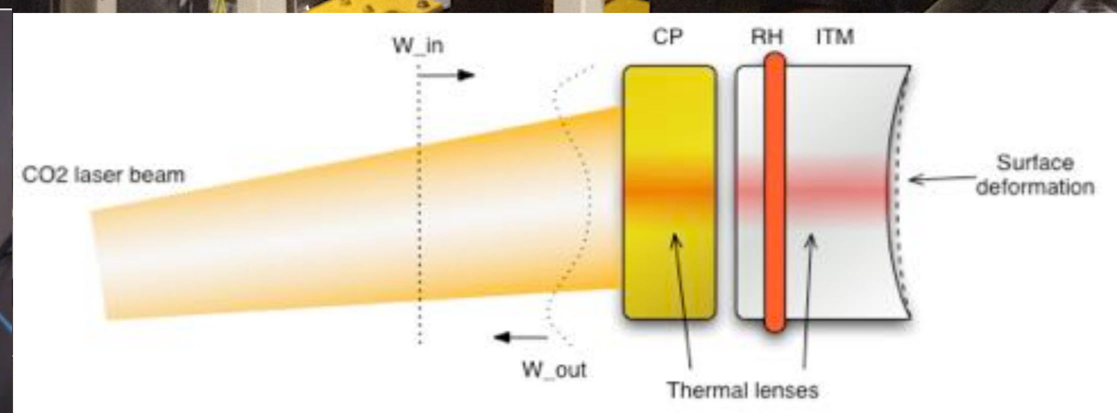




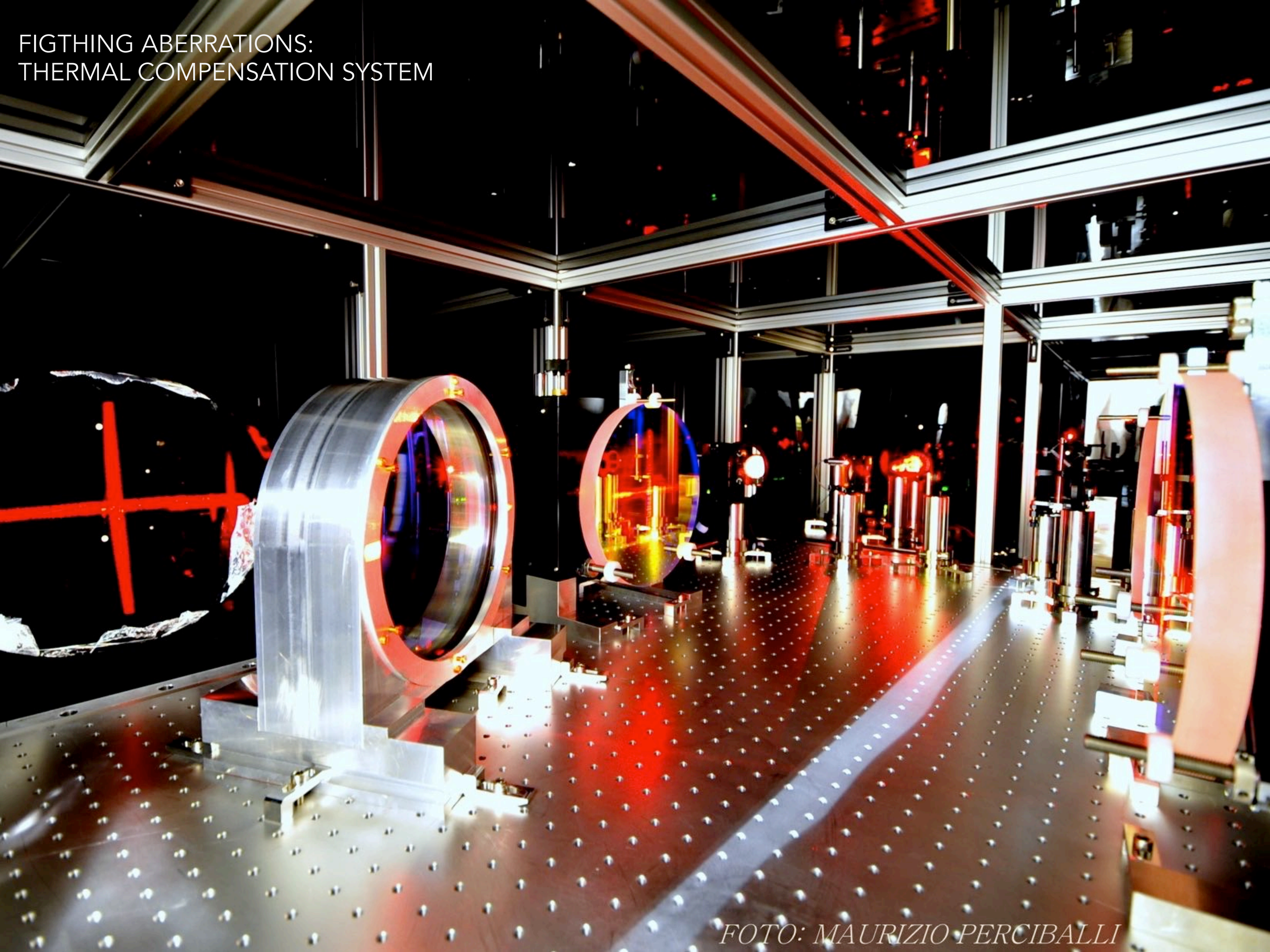





FIGTHING ABERRATIONS: THERMAL COMPENSATION SYSTEM

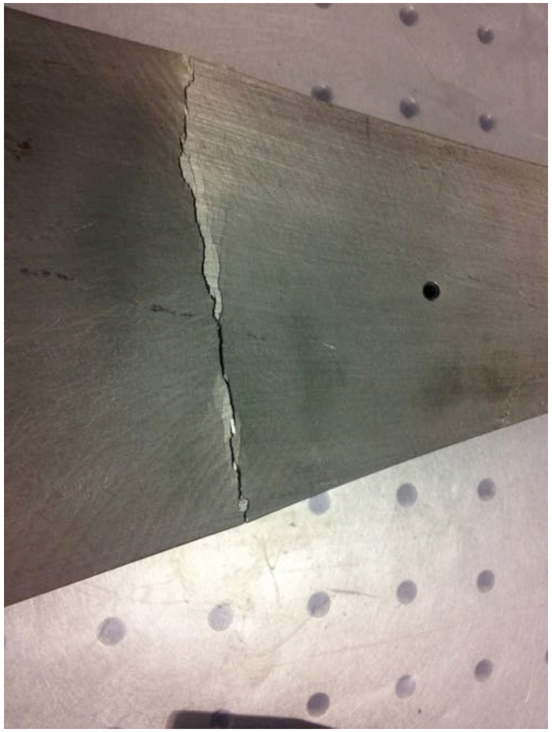


FIGTHING ABERRATIONS:
THERMAL COMPENSATION SYSTEM



IMPROVING THE VACUUM LEVEL: CRYOLINKS

- Integration completed ON BUDGET on Aug ’16
- Two major issues encountered during the construction

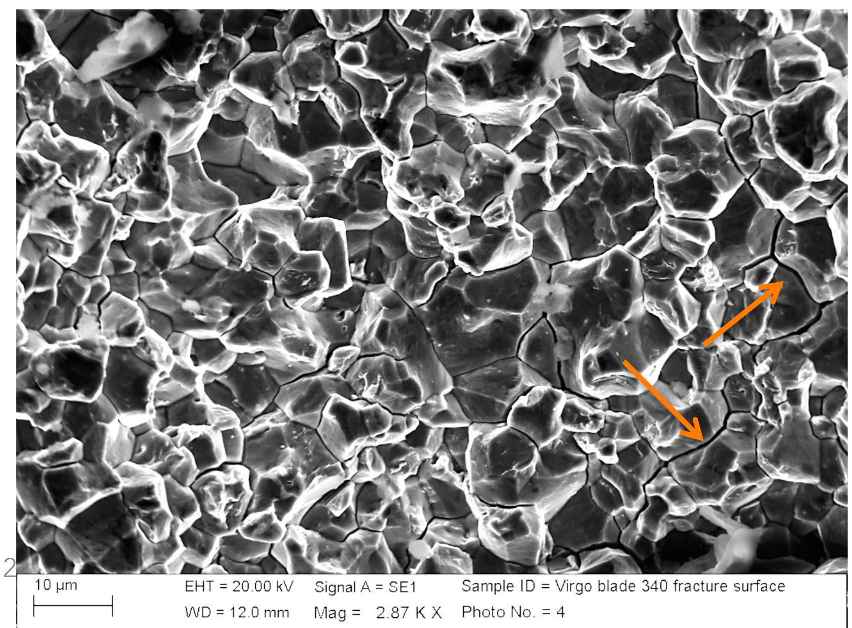


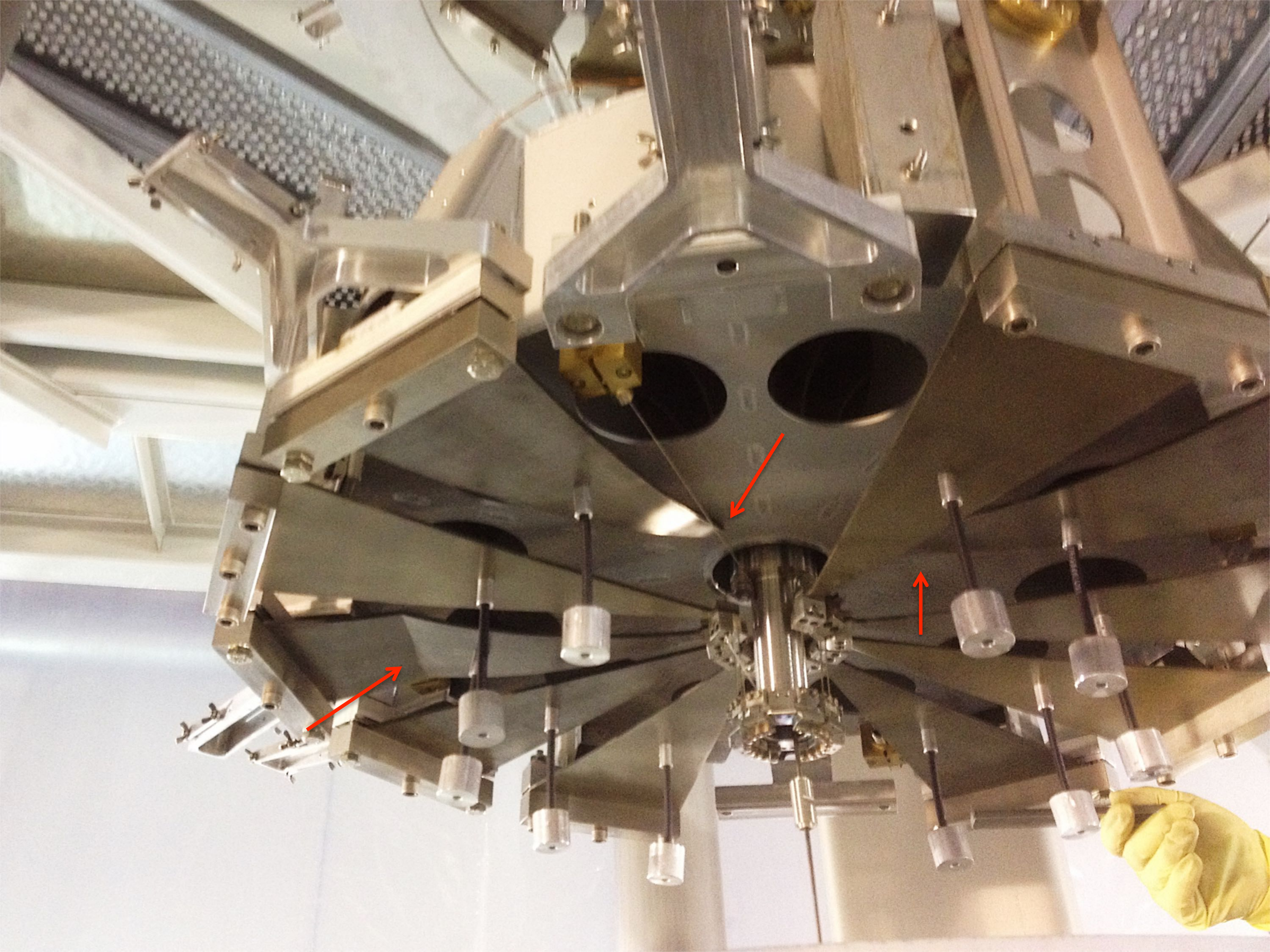
BROKEN SUPERATTENUATOR BLADES

BROKEN MONOLITHIC SUSPENSIONS

BLADES

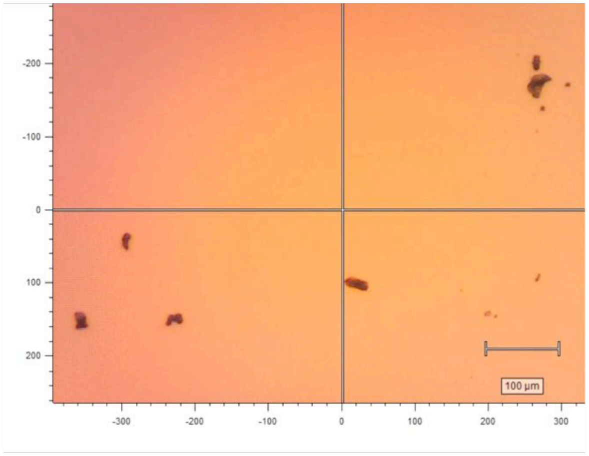
- System for vertical vibration isolation. Made of a special steel (maraging) studied to prevent creep. In use since ~15 years
- 13 blades broken (out of ~350)
- Cause identified: hydrogen embrittlement (due to excess H concentration in the bulk)
- Risk mitigation: all the blades showing possible defects in the protective Ni coating have been replaced (40% of the total)

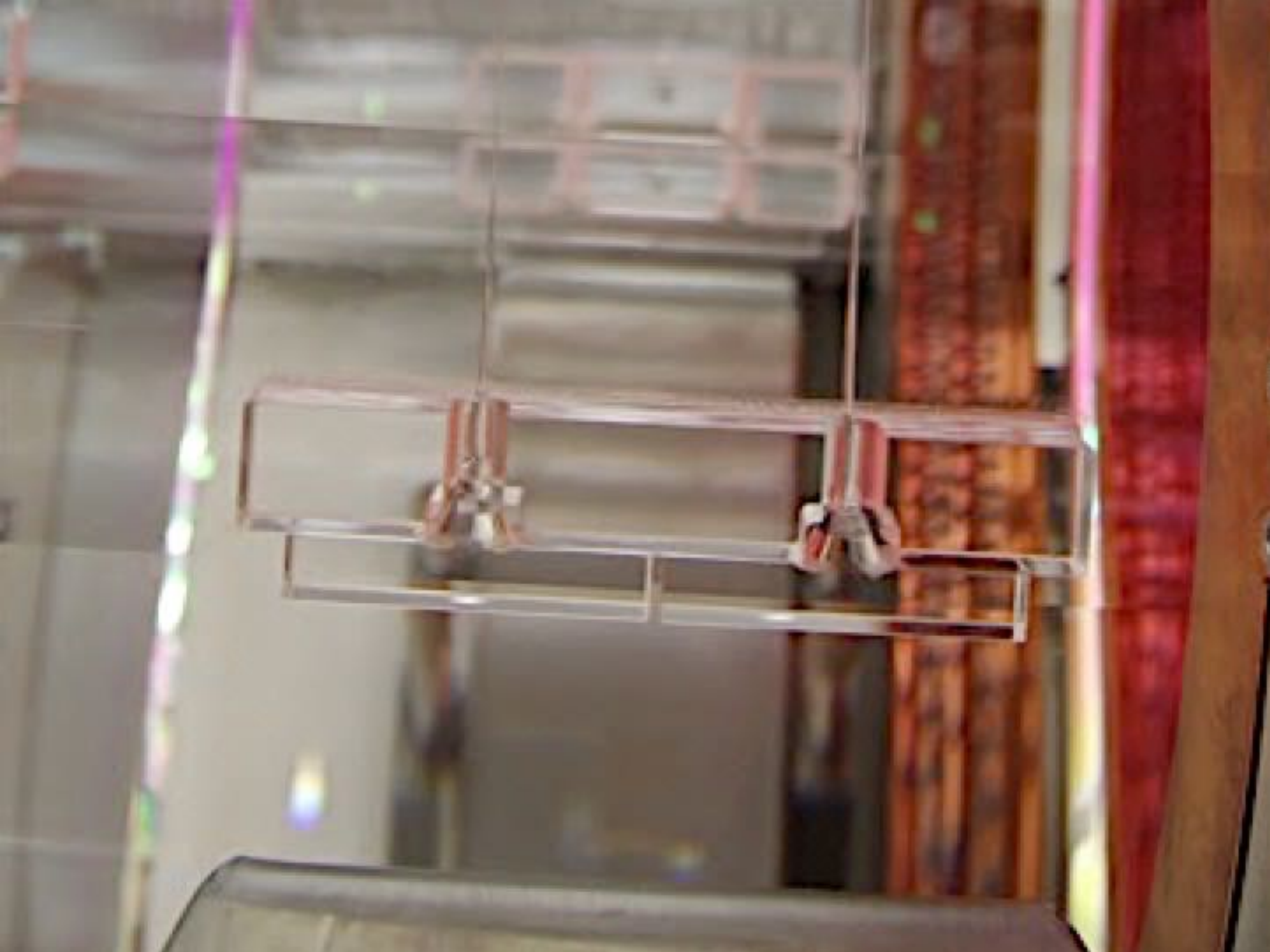




MONOLITHIC SUSPENSIONS

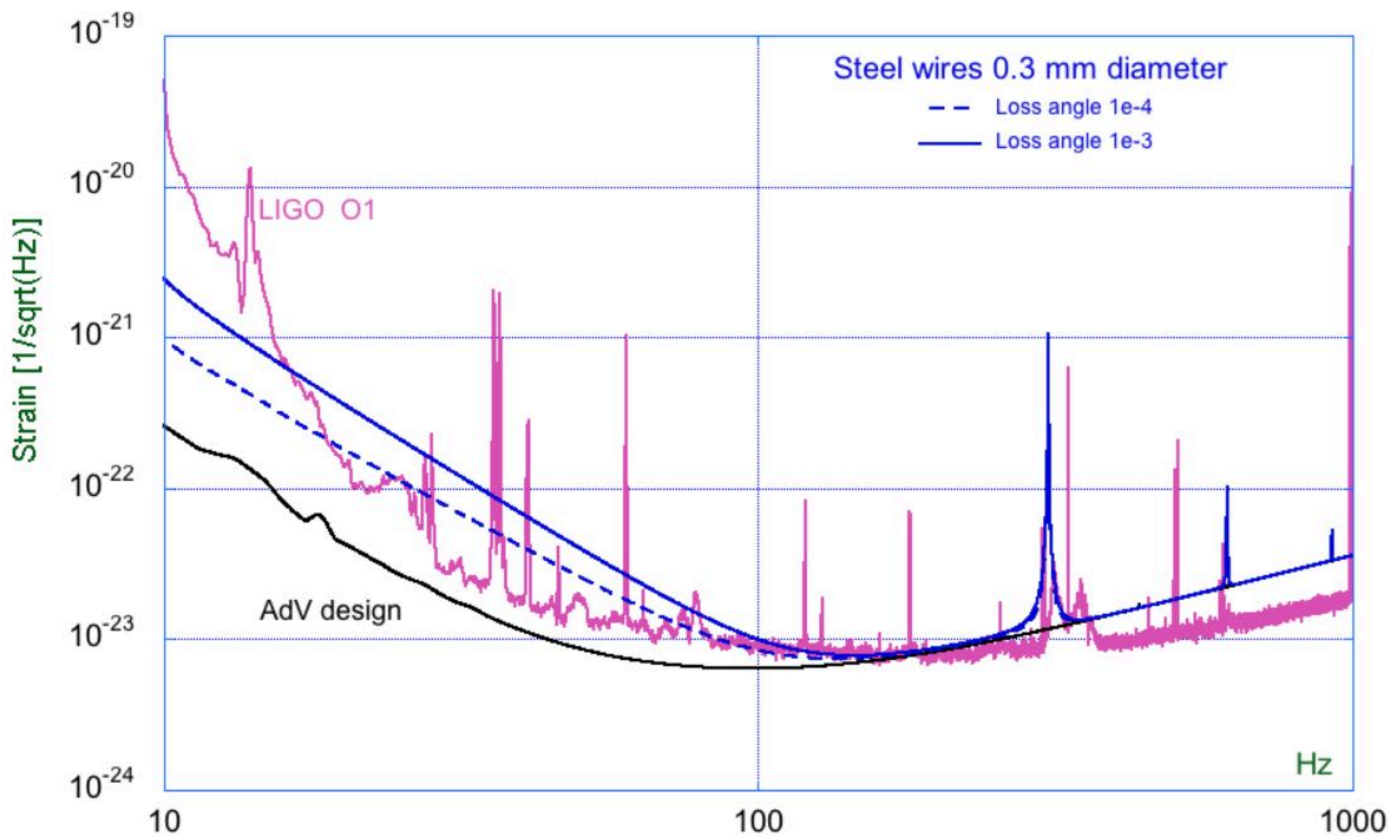
- AdV test masses to be suspended with thin fused silica fibers to reduce suspension thermal noise
- Technology already used successfully by Virgo in 2011
- In AdV: several failures, when mirrors in vacuum
- Multi-front investigation done (materials, design, procedures, …). Eventually, culprit found (fall 2016): contamination generated in the scroll pumps
- Meanwhile, test masses had been suspended with steel wires in order not to stop the commissioning (at the cost of losing some sensitivity at low frequencies)



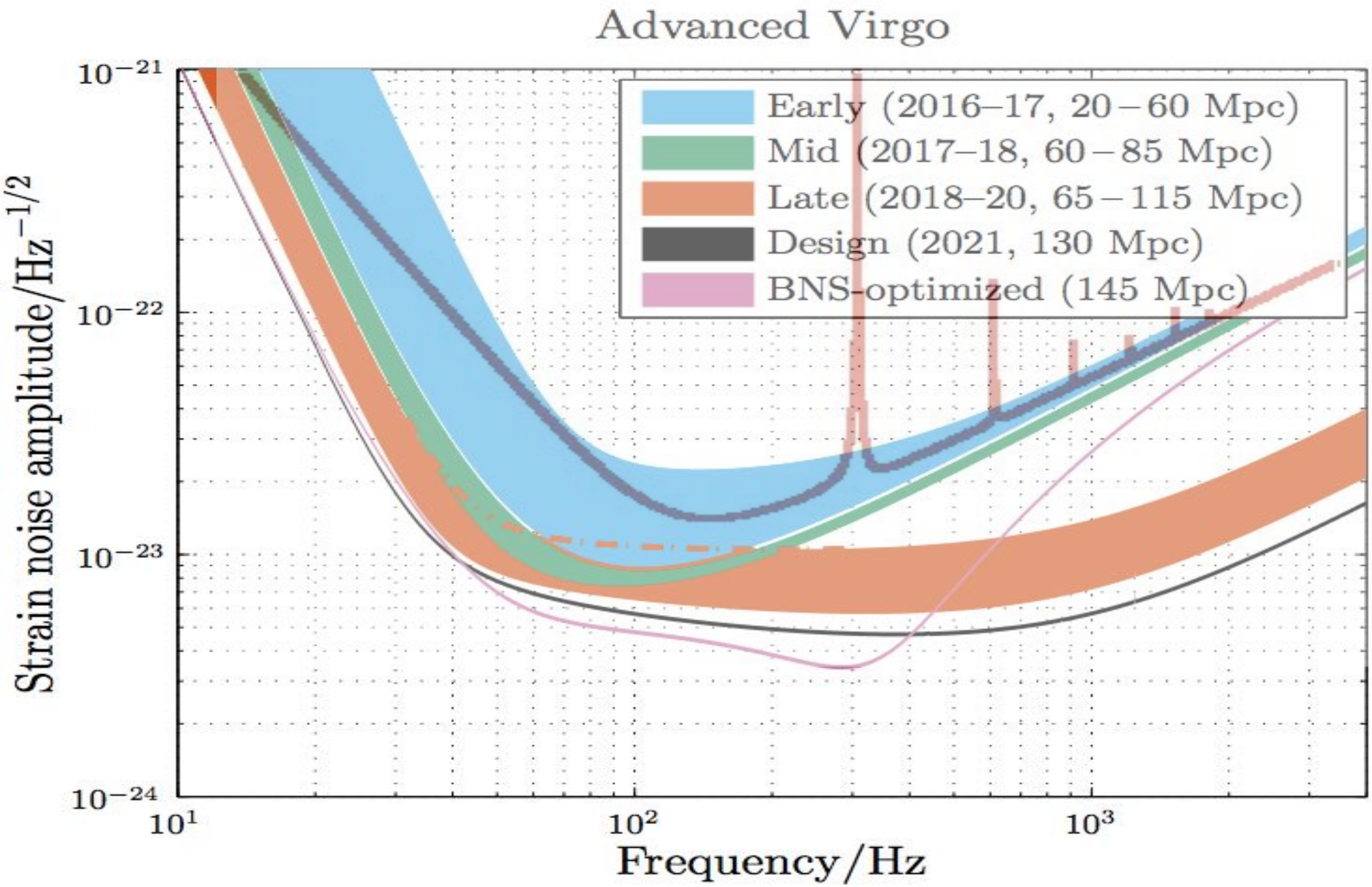


TEST MASSES SUSPENDED
WITH STEEL WIRES

TARGET O2 SENSITIVITY



Inspiral range (Mpc), steel wires on 4 TM, ϕ = 1e-3	
BNS	45
BBH	202



Advanced Virgo
Early (2016–17, 20 − 60 Mpc)
Mid (2017–18, 60 − 85 Mpc)
Late (2018–20, 65 − 115 Mpc)
Design (2021, 130 Mpc)
BNS-optimized (145 Mpc)
Strain noise amplitude/Hz$^{-1/2}$
Frequency/Hz
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{1}
10^{2}
10^{3}

WHAT WE ARE DOING

COMMISSIONING MILESTONES

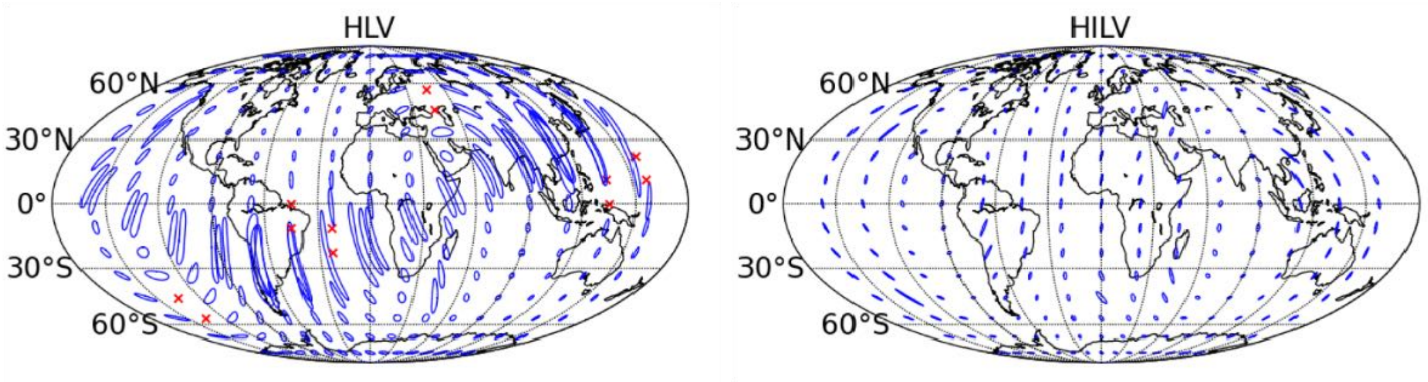
1	STABLE LOCK AT HALF FRINGE		ACHIEVED DEC 30th
2	STABLE LOCK AT DARK FRINGE		ACHIEVED MAR 3rd
3	LOW NOISE STABLE CONFIGURATION	Final alignment, OMC lock, lock on B1, low noise actuation. 1st noise budget	
4	SCIENCE MODE	Full automation, final calibration, more DET benches in vacuum - Sensitivity target	

A few more months of work before starting to run. Goal: join LIGO in O2 in summer.

IT'S JUST THE BEGINNING…

Slide from E Katsavounidis,
LIGO-G1700321,
this session

Localization with a detector network



LIGO and Virgo Collaborations: Living Rev. Relativity 19, (2016)

Significant improvements expected

aLIGO in 2015-2016: 100's of square degrees
aLIGO+Virgo in 2019: 10's of square degrees
aLIGO+Virgo+IndLIGO in 2022: few square degrees

36

AdV: WHAT NEXT?

- Goal for the next decade: maximize the scientific output of AdV
  - Maximize data taking
  - Minimize downtime

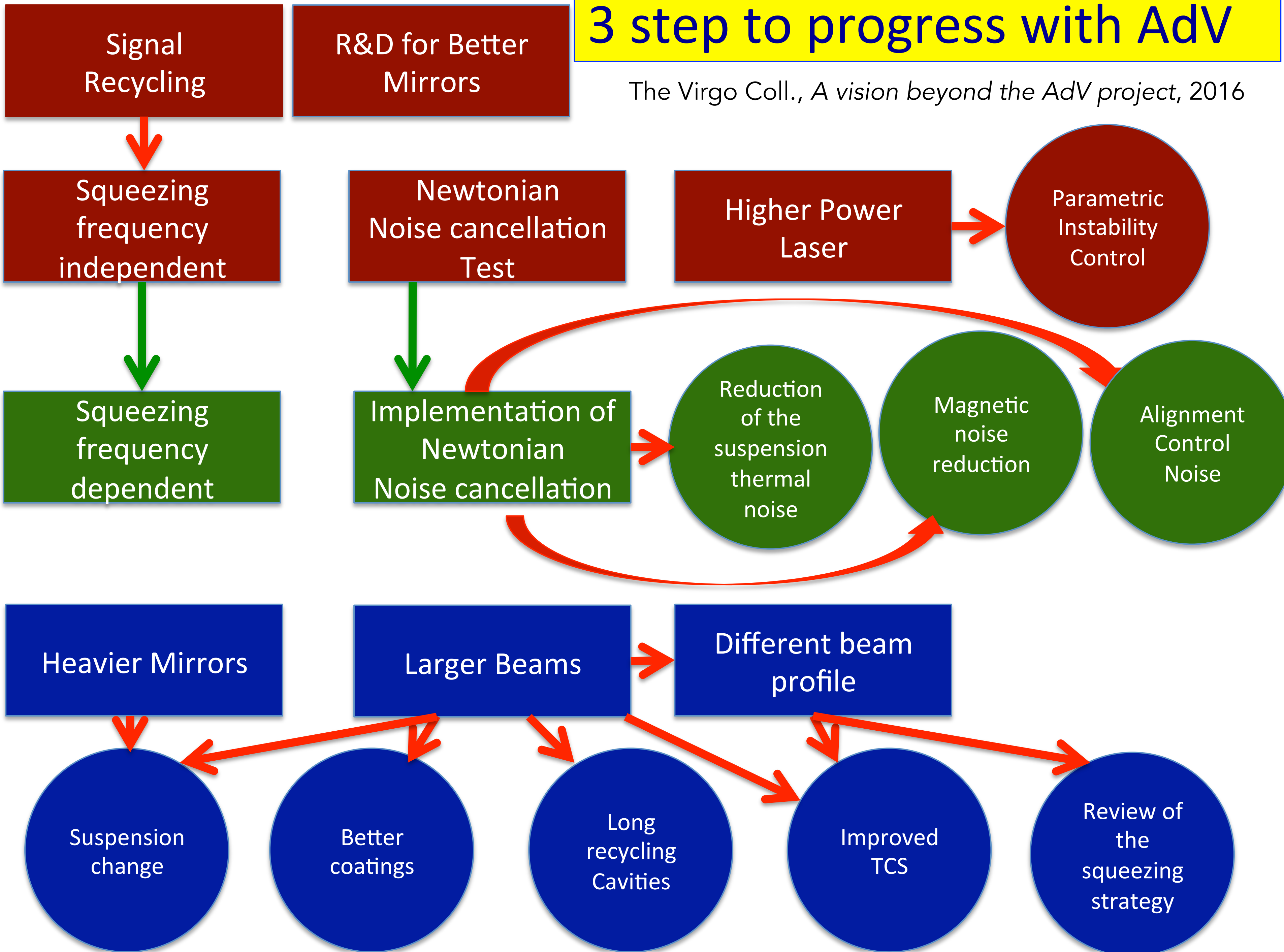
- PHASE 1 (2017-18):
  First run, *priority upgrades*

- PHASE 2 (2018-2022):
  pushing toward the nominal sensitivity of AdV

- PHASE 3 (>2022):
  Actions to further enhance the AdV sensitivity, exploiting the limits of the present infrastructure and useful in view of a new 3G infrastructure

3 step to progress with AdV

The Virgo Coll., *A vision beyond the AdV project*, 2016



PLANS

- Run in O2, then…
- MAIN PRIORITY: re-install monolithic suspensions
- NEXT PRIORITIES:
  - implementation of signal recycling
  - increase of laser power
  - installation of squeezing

already funded within AdV

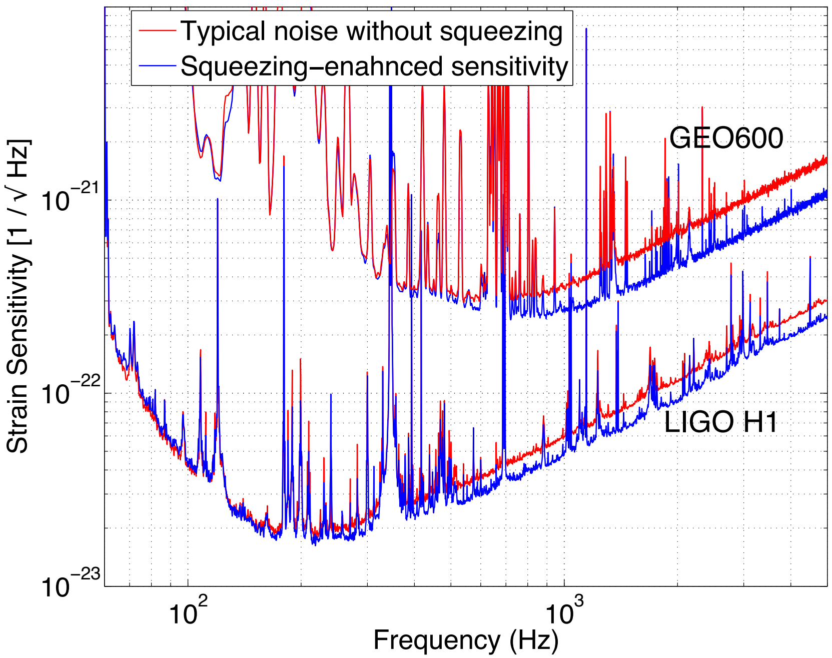
squeezer in kind from AEI Hannover

- Longer term upgrades (depending on new funding)

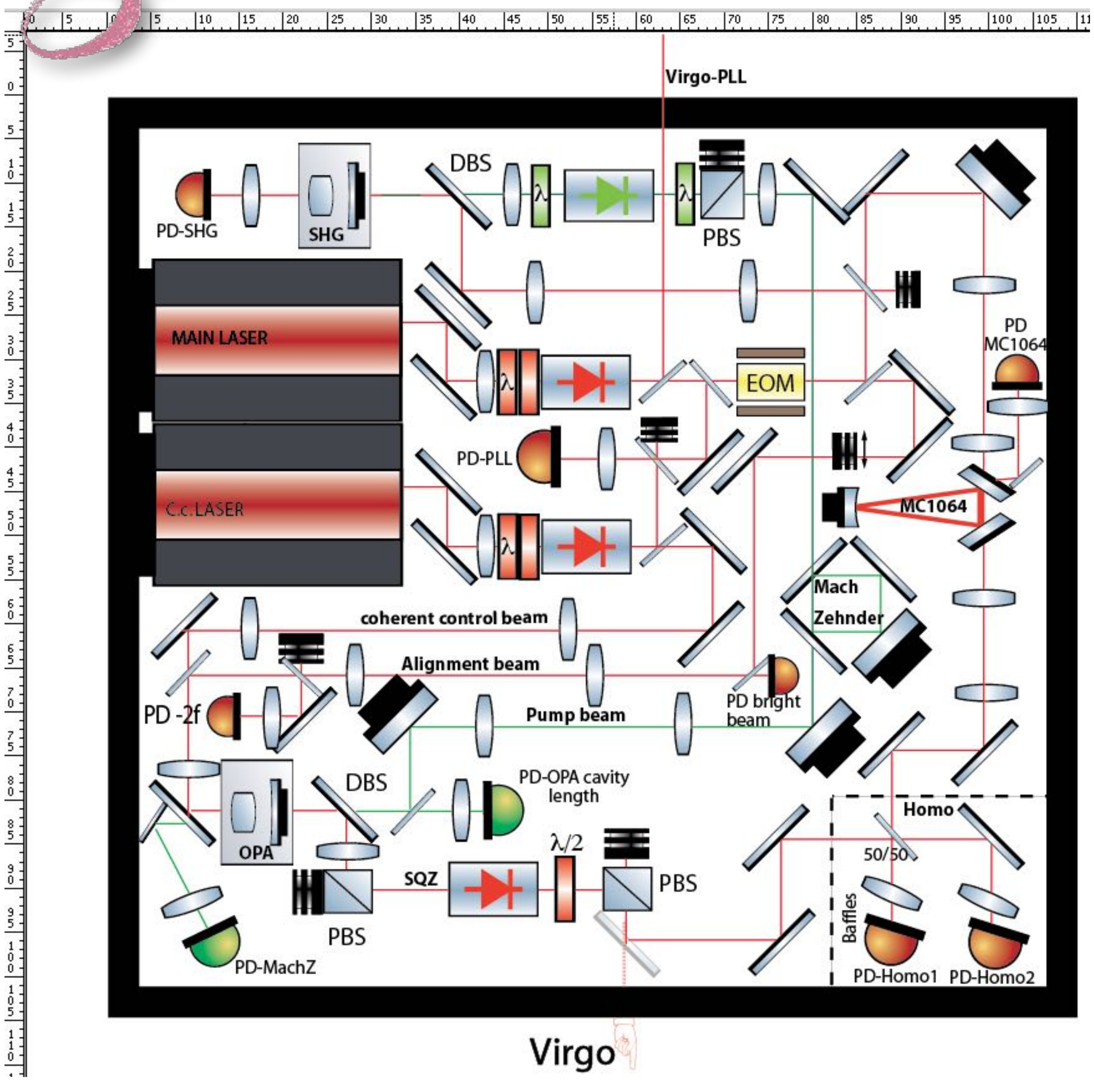
SQUEEZING

- Sensitivity eventually limited by quantum noise
  - shot noise (X_1), error on photon counting
  - radiation pressure noise (X_2): back-action noise caused by fluctuating number of photons hitting the mirrors
- Uncertainty relation: $\Delta X_1 \, \Delta X_2 \geq 1$
- But…we can reduce the uncertainty in one quadrature increasing it in the other
- This is done by a SQUEEZER. Already demonstrated on interferometers

LIGO Scient. Coll., Nature Physics, 2011
L Barsotti, LIGO-G1300420



New AEI Squeezer



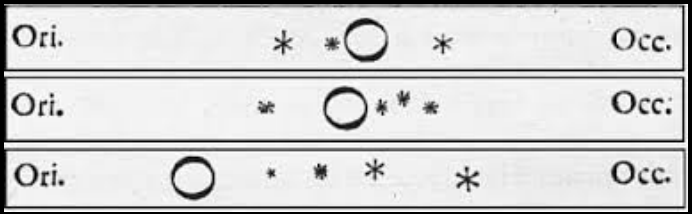
- 25% smaller compared to GEO-Squeezer
- 1,1m x 1,05m
- Less components but better performance
- Fully automated analog control

Onboard sub-components:

- 2 Lasers + PLL
- SHG
- 532nm Mach Zehnder
- 1064nm mode cleaner
- Homodyne detector
- Doubly resonant OPA

Offered as in kind contribution to Virgo. Collaboration for actual implementation started.

400 years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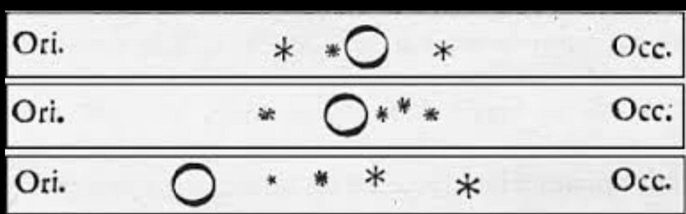
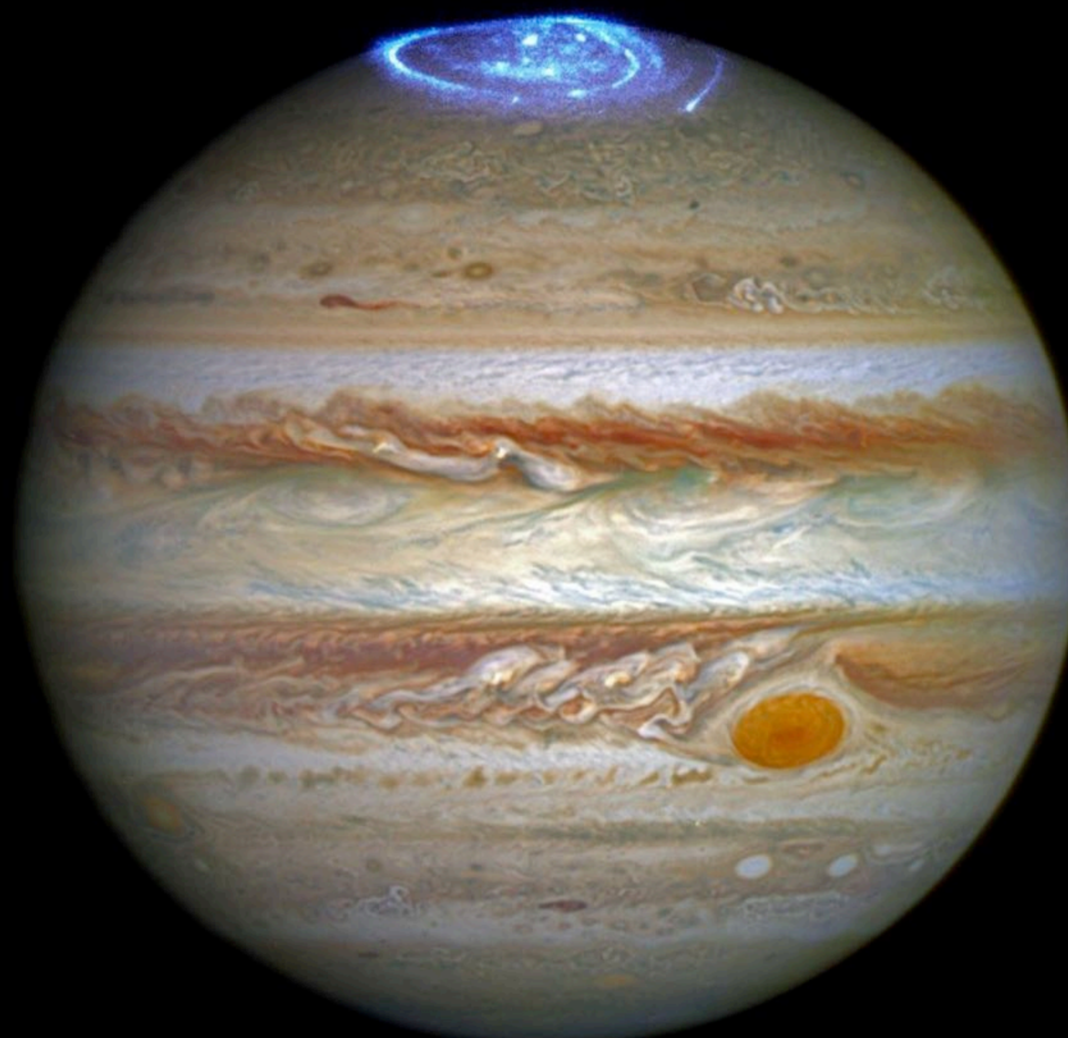
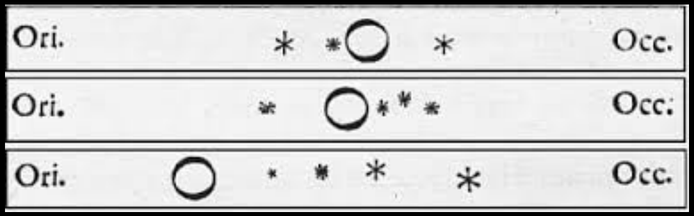




Credit: NASA/Hubble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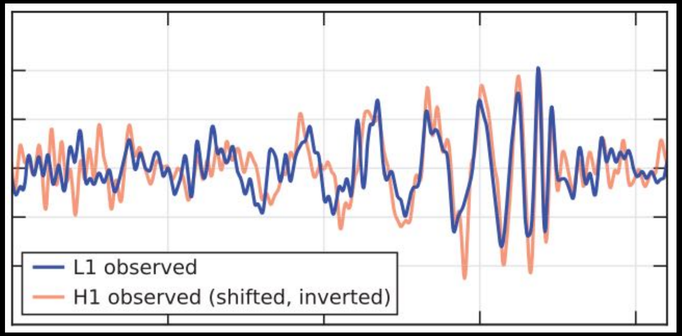
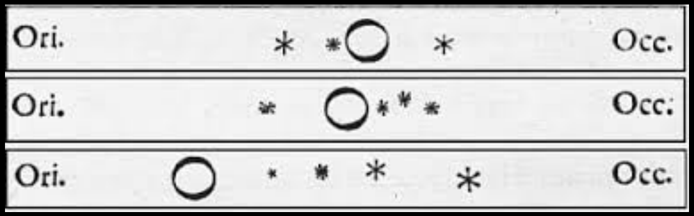

L1 observed
H1 observed (shifted, inverted)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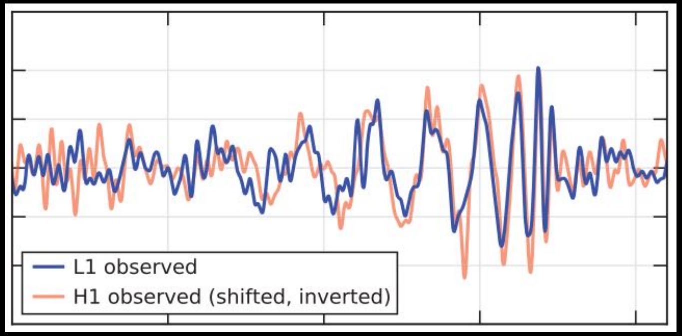
L1 observed
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