SUMMARY

Organizers: Matteo Barsuglia , Marica Branchesi , Barbara Patricelli

Irina Dvorkin -Prospects for populations of CBC

BBH and BNS: mass distribution and merger rate evolution

BHs in the lower mass gap? Implications for SN explosion mechanism?

BHs in the upper mass gap? Dynamical channel?

EM counterparts for intermediate black hole mergers?

Third generation detectors: PBH, POPIII BHs, IMBHs

Simone Mastrogiovanni - Prospects for cosmology

Bright sirens, dark sirens, spectral sirens

One year of Virgo_nEXT could be able to solve the Hubble constant tension

Massimo Vaglio - Prospects for fundamental physics and ECO

Quantum BHs, Boson Stars, Fuzzballs

GW tests: inspiral-merger, ring-down

Ulyana Dupletsa – Science for different ET designs

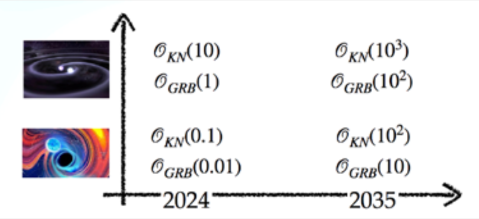
Triangle10 km remarkable performance with respect to 2G

2L-15 km-45º improves by a factor of 2-3 detections and PE

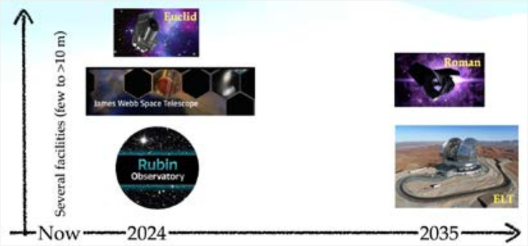
Low frequency sensitivity crucial for accessing the early Universe and pre-merger alerts

Giancarlo Ghirlanda – What EM facilities we have, will have, wish to have

Rates



Nir/Optica instruments



Radio arrays

High-energy satellites (example monolithic mission vs satellites)

THESEUS-XGIS	0.002 - 10	3×10^{-8}	0.16	< 15 arcmin	10^{+5}_{-4}	$63^{+13}_{-13}\%$	15^{+6}_{-4}	$94^{+6}_{-7}\%$
HERMES	0.05 - 0.3	0.2(*)	1.0	1 deg	84^{+42}_{-30}	$61^{+10}_{-11}\%$	139^{+54}_{-36}	$94^{+6}_{-6}\%$

Golam Shaifullah and Delphine Perrodin – PTA

array of MSPs, large work to identify PTA noise sources and to analyze the data

All PTAs see a common, uncorrelated signal consistent with GW background

Sources to be detected: SMBHBs and cosmological

Future large improvement with SKA

(MeerKAT and FAST already in operation)

Panel : Scientific objectives of different GW projects, the R&D needed, difficulties and opportunities

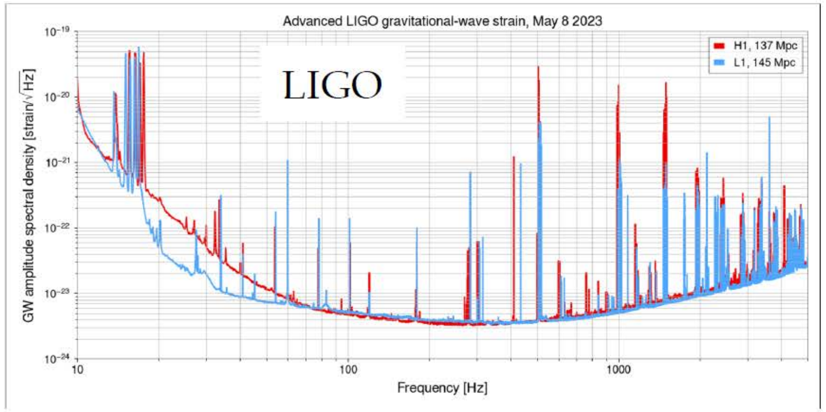
GWADW
Elba 2023

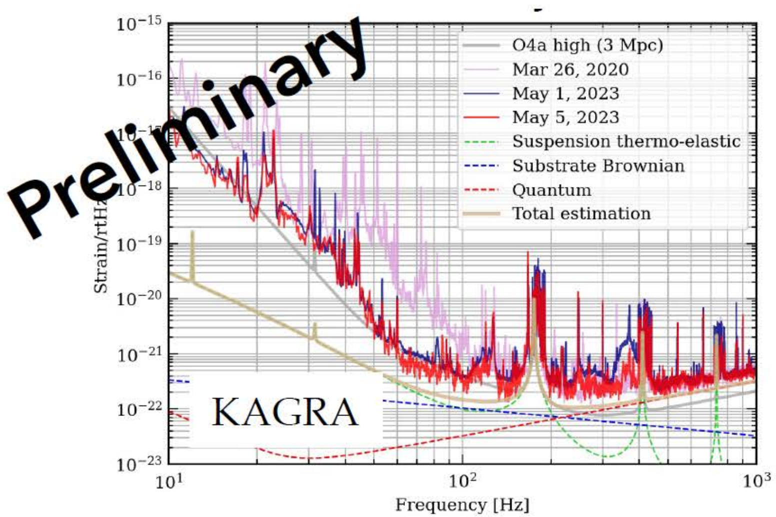
Rana Adhikari (Voyager), Stefan Ballmer (CE), Lisa Barsotti (A#), Viviana Fafone (VnEXT), Harald Lück (ET), Kentaro Somiya (KAGRA+ ad beyond), Bram Slagmolen (NEMO)

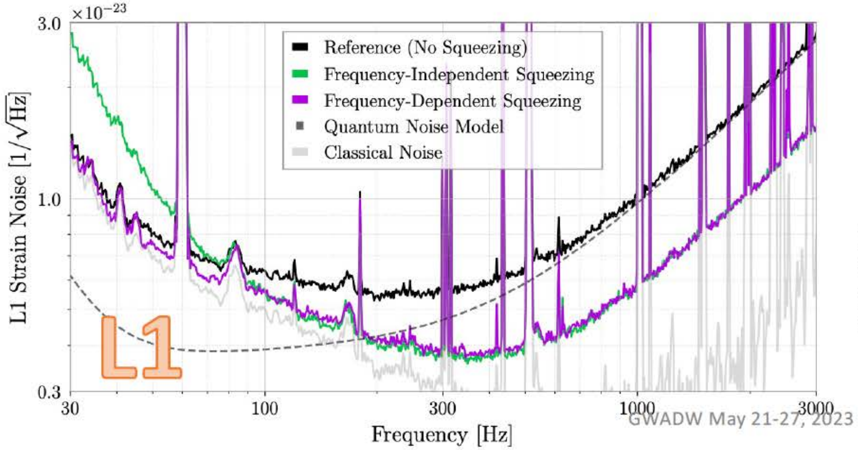
* What are the challenges in achieving the main scientific goals in the coming years?
* What lessons have been learned and what mistakes should be avoided when transitioning from the present generation to building the next upgrades or next generation of detectors?
* What challenges are involved in scaling up the detectors to the next generation (both from engineering and organizational point of view), and how these challenges can be effectively addressed?
* How an international collaboration and coordination can play a role in the development and operation of next-generation gravitational-wave detectors?
* In addition to detecting gravitational waves, what other scientific objectives (i.e. quantum mechanics, geophysics) or research fields can be explored or used with the next-generation detectors (i.e. machine learning, AI in general)?

O4 Status

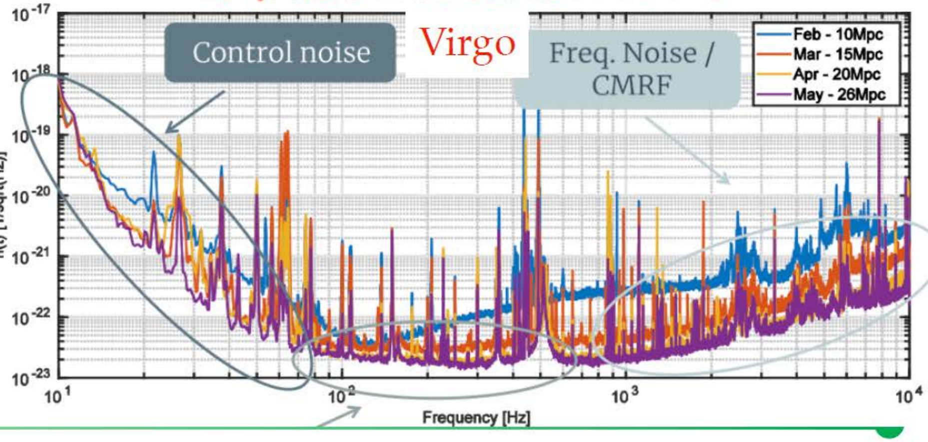
LIGO, Virgo, KAGRA have all had challenges in preparing for O4, but have also all had ***significant successes***.







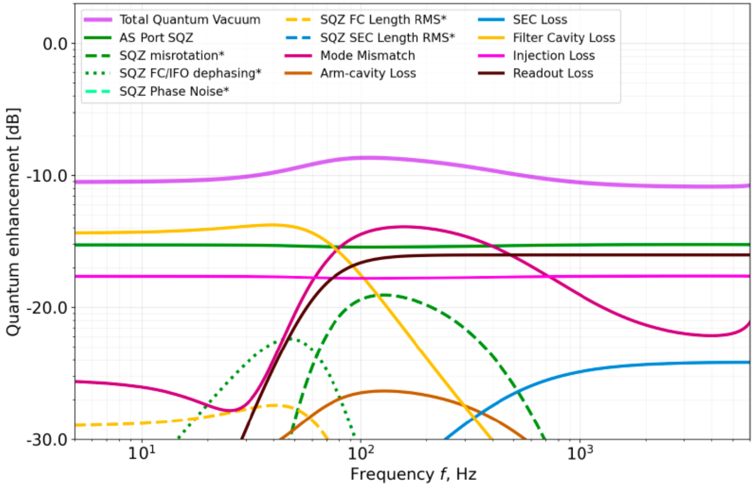
IMPROVING SENSITIVITY



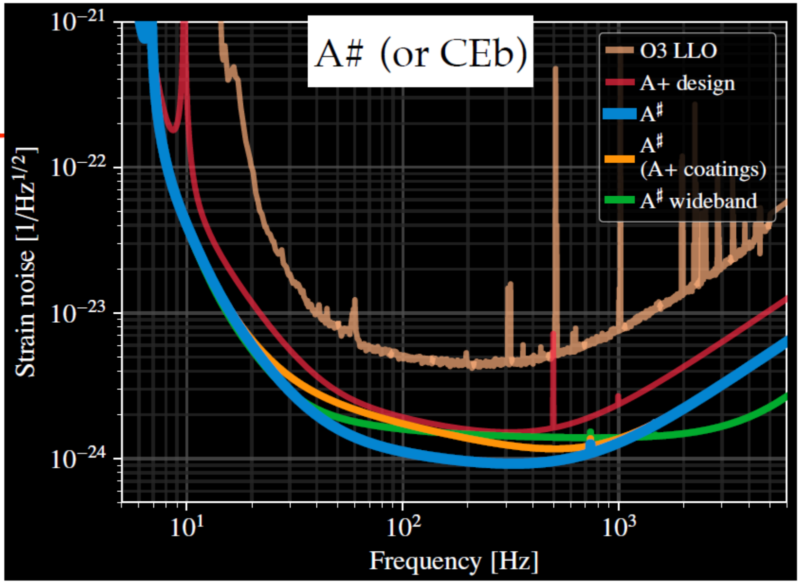
O5 and Post-O5

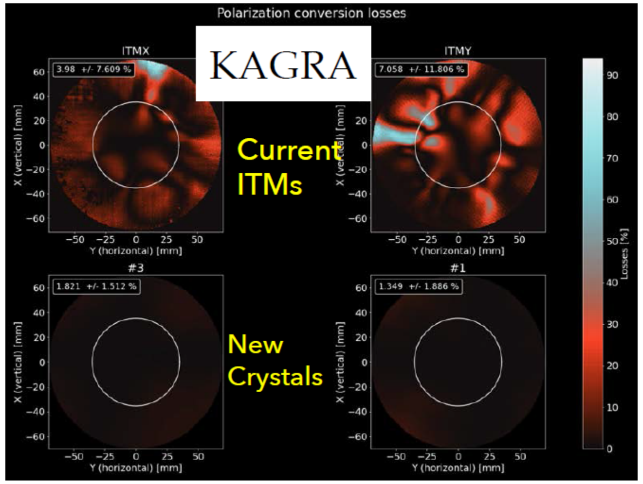
LIGO, Virgo, KAGRA all have exciting paths forward for O5, and beyond!

Virgo_nEXT goal quantum noise reduction



Parameter	O5	Initial post-O5	VnEXT
Injected squeezing	12 dB	12 dB	15 dB
injection losses	6.5%	5.5%	1.8%
FC losses	30 ppm	30 ppm	20 ppm
Readout losses	6%	4.5%	2.5 %
Arm-cavity roundtrip losses	75 ppm	75 ppm	75 ppm
Signal extraction cavity (SEC) roundtrip losses	1000 ppm	1000 ppm	500 ppm
Phase noise	25 mrad	15 mrad	10 mrad
Mismatching squeezing - filter cavity	0.5%	0.5%	0.25%
Mismatching squeezing - interferometer	2%	1%	0.5%
Measured squeezing at high-frequency	**5.5 dB**	**7.5 dB**	**10.5 dB**





Third generation infrastructures

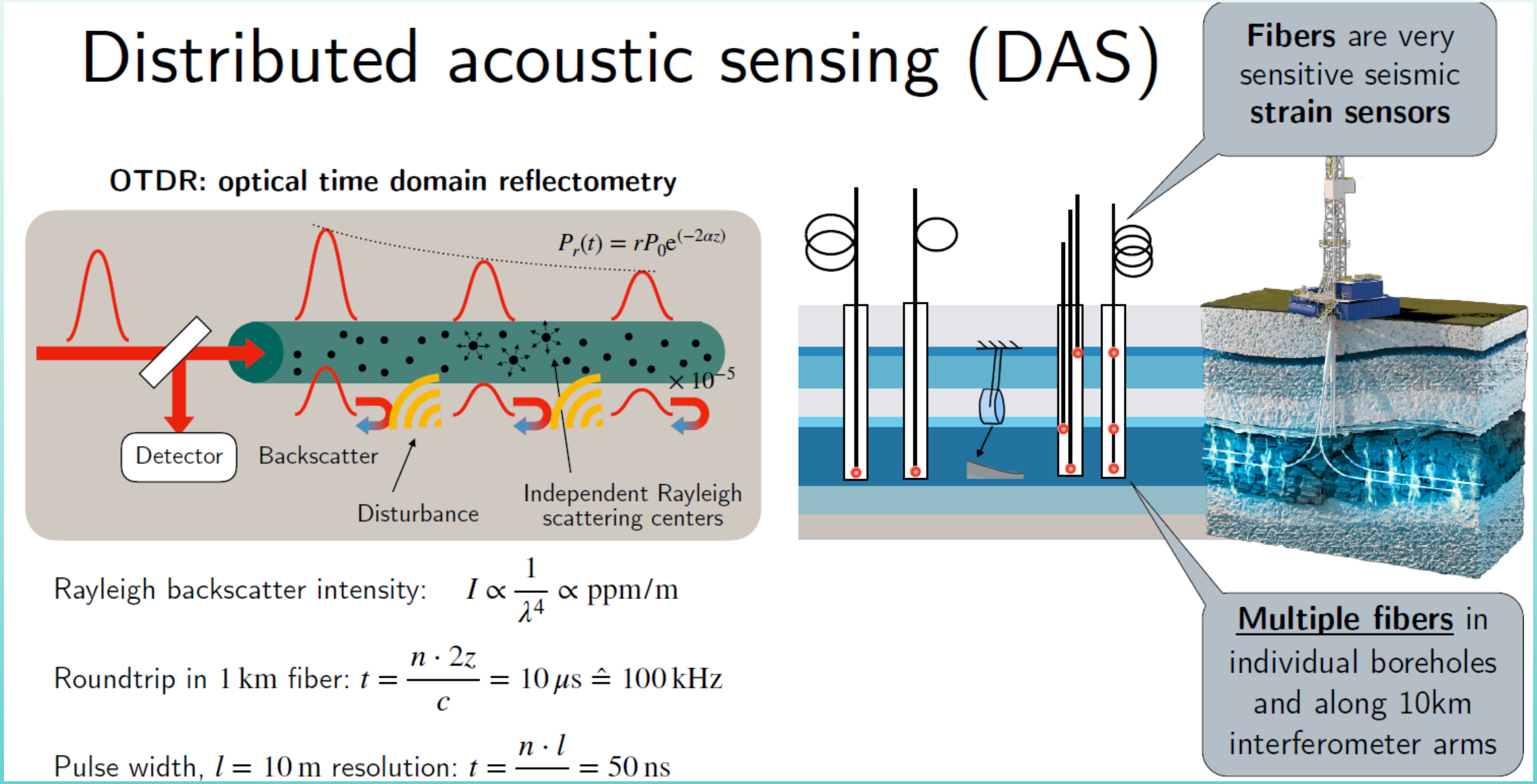
- Vladimir Bossilkov: A review of parametric instabilities and discussion of why the longer arms, higher power, and larger test masses of next generation detectors will make the PIs more challenging
- Craig Cahillane: Discussion of a new frequency stabilization scheme for CE necessary due to its longer arms
- Lucia Trozzo: Description of a prototype nested inverted pendulum for ET suspensions to reduce the height of the traditional superattenuator
- Satoshi Tanioka: Update on AlGaAs coatings including measurements of mechanical loss at cryogenic temperatures and discussion of dichroic AlGaAs mirrors necessary for new lock acquisition scheme
- Rana Adhikari: Update on Voyager including idea to detect 2 μm light with higher quantum efficiency by first upconverting it to 1 μm light
- Marc Andrés Carcasona: Analysis of scattered light in ET and a baffle design that will satisfy scattered light noise requirements

Site characterization

Reduction of Newtonian Noise

(1)How to measure seismic motion ? -> Fiber sensors

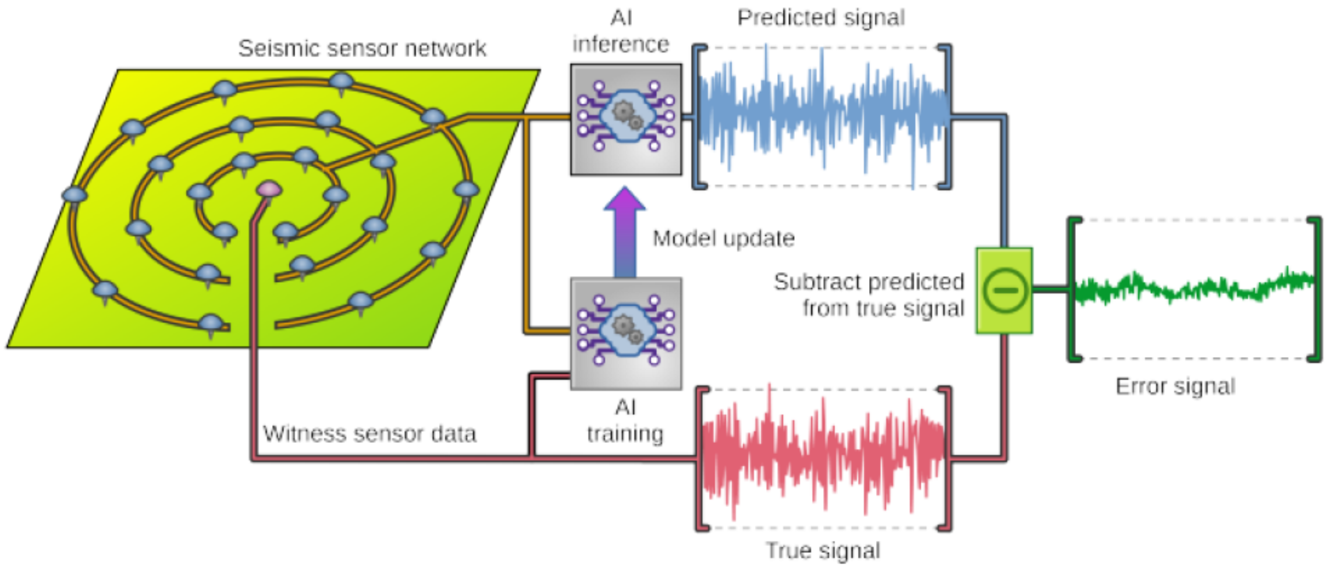
(Katharina Isleif1 (isleifk@hsu-hh.de))



Site characterization

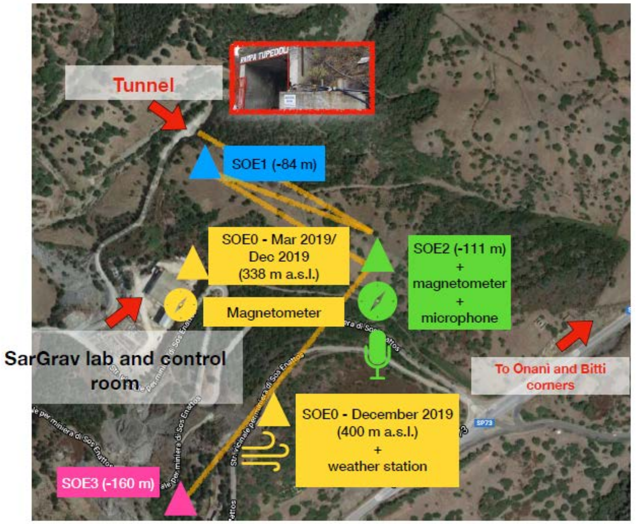
Reduction of Newtonian Noise
(2)How to derive Newtonian noise from seismic motion ?
-> Neural network (Henk Jan Bulten),

- Neural network: attempt to solve this problem by weighing/combining the full dataset (non-linear) – this approach may succeed if there is a way to train the network. (thesis work Vincent van Beveren, submitted to GQC)



Site characterization

Report from Sardinia (Luca Naticchioni, Matteo Di Giovanni)



The Onanì corner

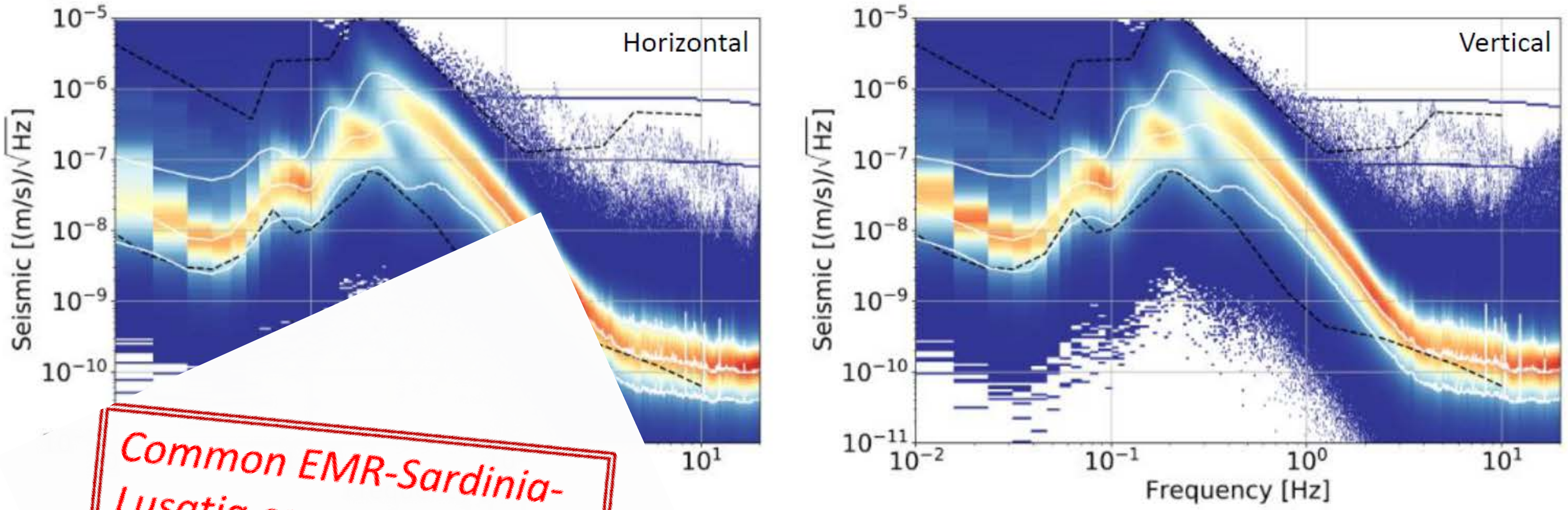
The Bitti corner

Site characterization

Report from Sardinia (Luca Naticchioni, Matteo Di Giovanni)

A quick glance at the measurements

PPSD - P2 borehole seismometer



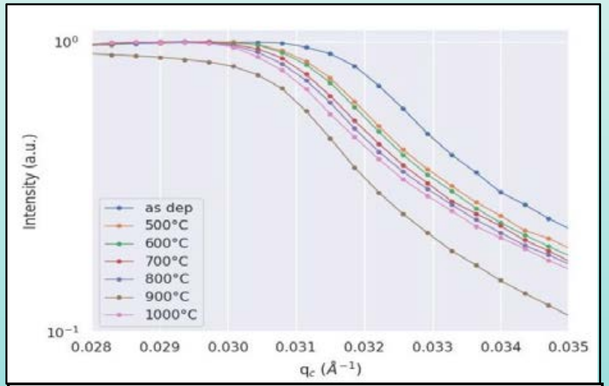
Common EMR-Sardinia-Lusatia comparison paper in preparation

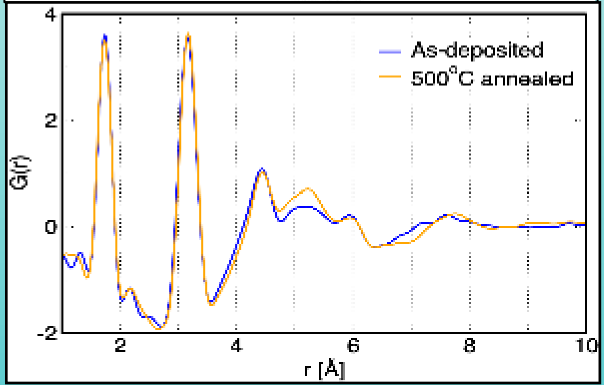
V… …ometimes even **below** the Peterson's **New Low Noise Model**!

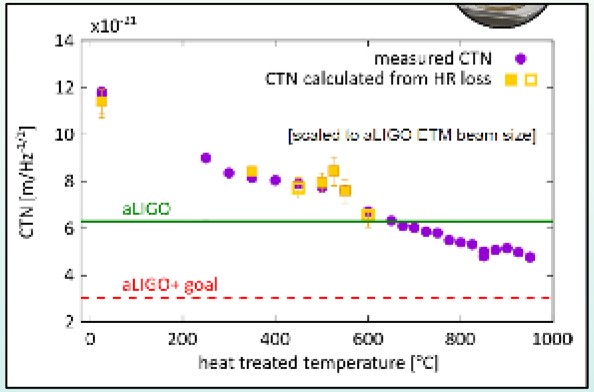
CTN – session

E. Cesarini and J.Steinlechner

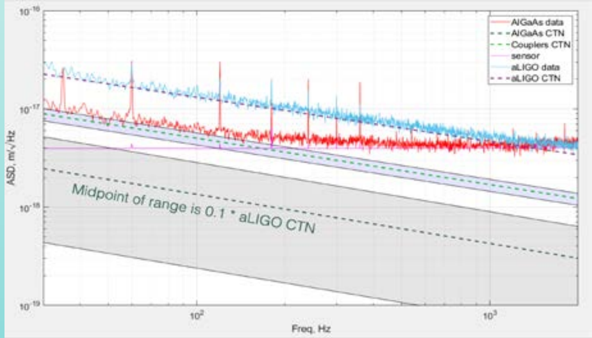
Experimental characterization and **Modeling** of the amorphous film **structure** → hints on deposition and thermal treatment **(Laura and Kiran)**





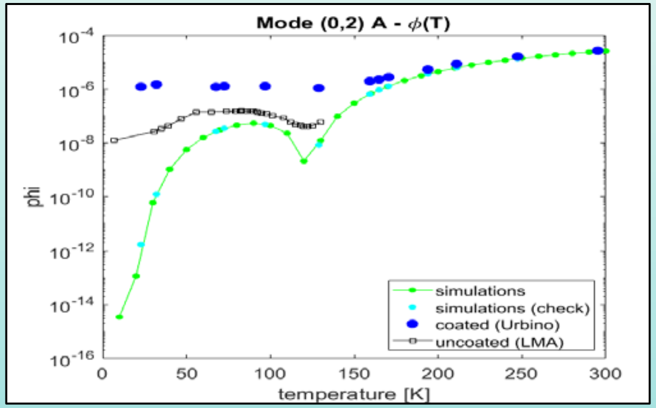


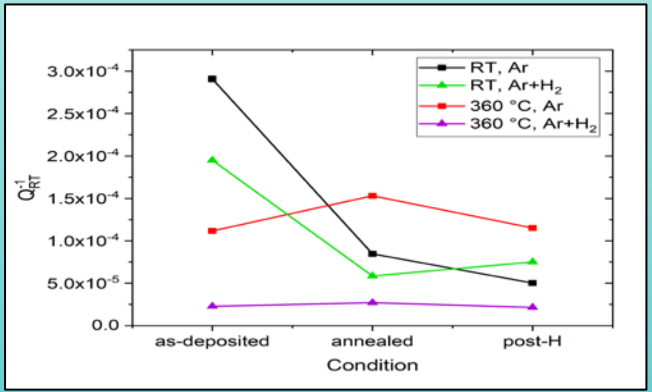
Last news on **Titania-Silica** coating that need to be taken into account for near future upgrades **(Greame)**



State of the art of **AlGaAS/GaAs crystalline coating** for Post O5 application → investement needed. **(Steve)**

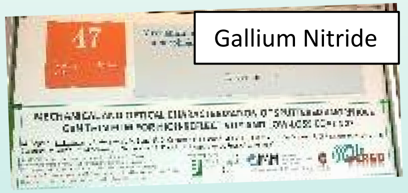
New materials (fluorides) and **innovative treatment** (hydrogenation) for future cryogenic application **(Federica and Frances)**

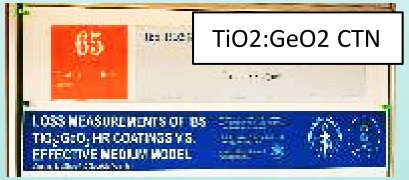


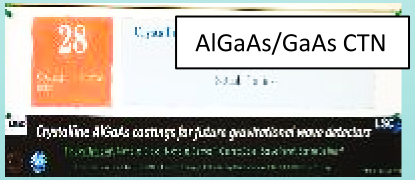


Poster session

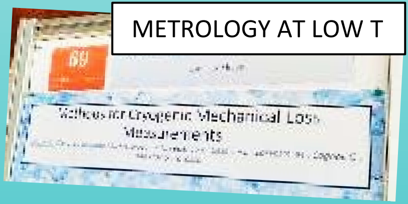

Crystallization Ta2O5


Gallium Nitride


TiO2:GeO2 CTN


AlGaAs/GaAs CTN


MULTI-SPATIAL MODE


METROLOGY AT LOW T

Moon and Space: Summary

- LISA (Oliver Gerberding)
  - Moving forward
  - Timeline: Adoption (2024), Flight acceptance review (2034), Launch (2036)
- DECIGO (Seiji Kawamura)
  - DECIGO: design parameters being updated for PGW
  - SILVIA: study for mission definition underway
- LGWA (Jan Harms)
  - White paper: ongoing
  - Various study ongoing
- Toolset for Adjustable Picometer – Stable Interferometers (Marcel Beck)
  - Experiment ongoing for LISA
- Sub-femtoWatt laser phase tracking (Callum Sambridge)
  - Experiment ongoing for “LISA and beyond”

High Frequency Detection

GWADW Elba 2023

A Gravitational Wave Detector for Post-Merger Neutron Stars: Beyond the Quantum Loss Limit of Michelson Fabry–P\'e
Teng Zhang

Detecting high frequency (10-100KHz) gravitational waves with levitated micro disks *Dr george winstone*
Hotel Hermitage, La Biodola, Isola d'Elba 11:15 - 11:40

Bulk Acoustic Wave cavities for high-frequency gravitational wave antennas *Tommaso Tabarelli De Fatis et al.*
Hotel Hermitage, La Biodola, Isola d'Elba 11:40 - 12:05

Superfluid Helium for Detecting Dark Matter & Gravitational Waves *Glen Harris*
Hotel Hermitage, La Biodola, Isola d'Elba 12:05 - 12:20

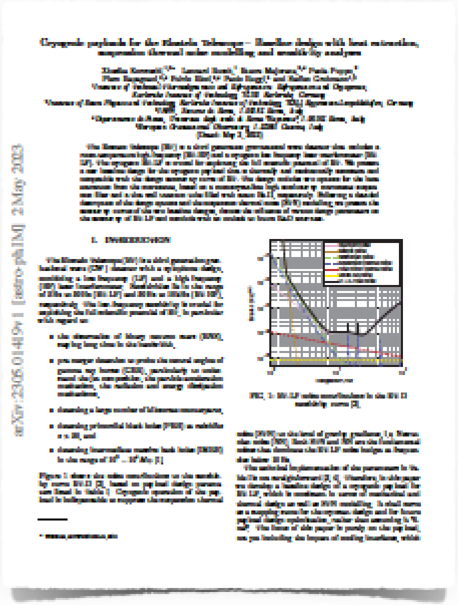
High Frequency detection discussion *Hartmut Grote et al.*
Hotel Hermitage, La Biodola, Isola d'Elba 12:20 - 12:30

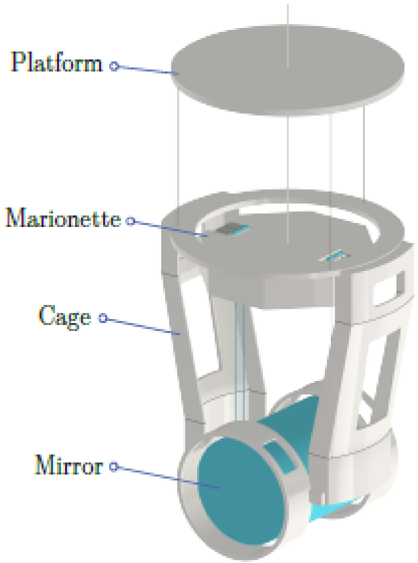
Cryogenic

Summary for ET-LF cryogenic and vacuum (Steffen Grohmann)

Baseline design of ET-LF cryogenic payloads

- **New reference paper**
  - Link: https://arxiv.org/abs/2305.01419



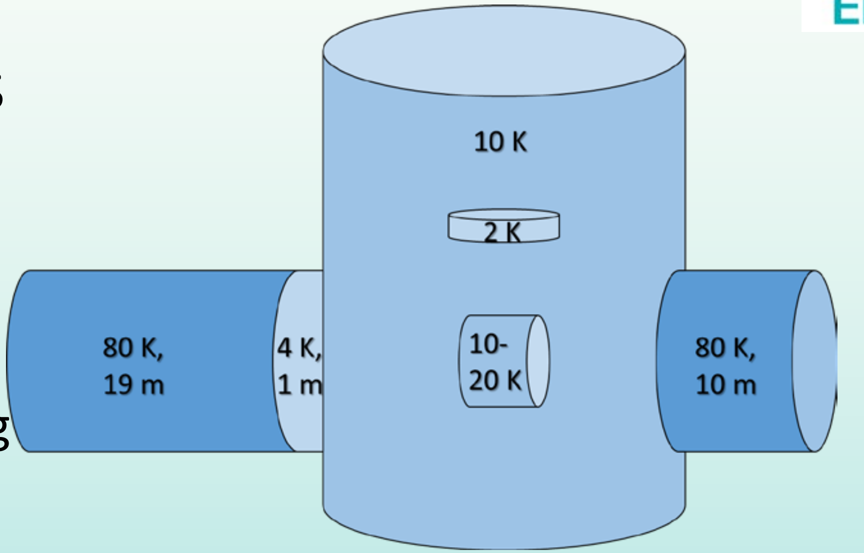


- **Objectives**
  - **Consistent** design study in terms of
    - **Mechanical** design
    - **Thermal** design
    - **STN** modelling
  - Compete description of the **STN model**, including collection of available material data
  - **Stepping stone** for future design optimisation(s)
  - Reference for **cryostat design** (dimensions)

Cryogenic

Design and simulation (cryogenic, vacuum) for ET of ET pathfinder (Katharina Battes, Henk Jan Bulten)

Results



Source 1:

- cryopump 80 K for water trapping sufficient
- 10 km beam pipe conditions via low outgassing (instead of high pumping speed)

Source 2:

- conducta … ing in upper tower needed to reduce
- flow accordıng …
- more options will be studied (e.g. special water …

→ Developed pumping concept fulfils all gas related requirements, but thermal loads on the cryogenic mirror have to be addresssed.

Source 3:

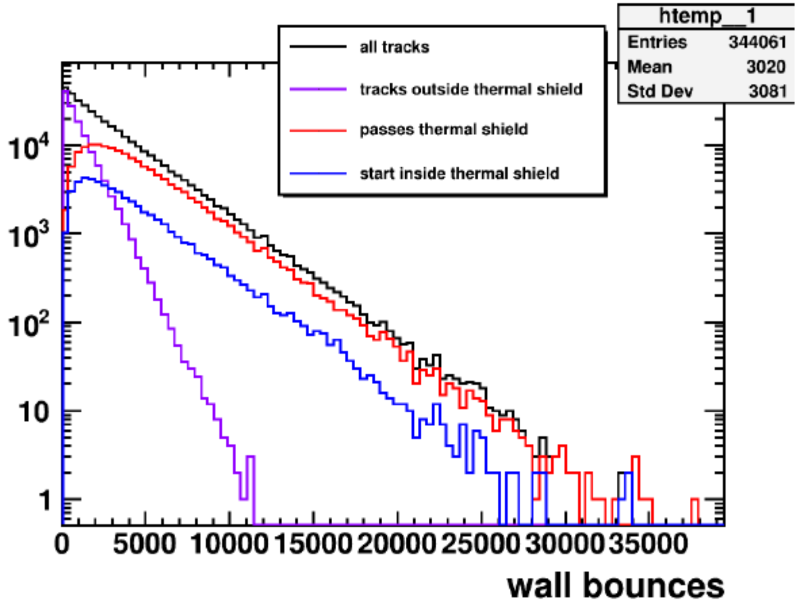
- cryopump section for hydrogen needed, additional to water pumping main section

→ Pressures around mirror - H_2: $3 \cdot 10^{-13}$ mbar, H_2O: $1 \cdot 10^{-14}$ mbar, water ice build-up ~2 years for 1 ML

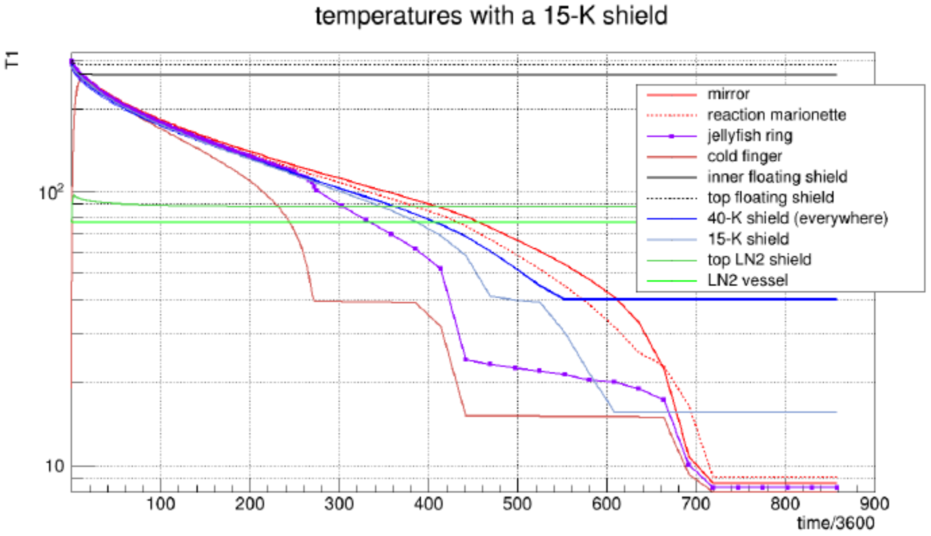
Cryogenic

Design and simulation (cryogenic, vacuum) for ET of ET pathfinder (Katharina Battes, Henk Jan Bulten)

Modeling – ETpathfinder setup



Example of raytrace results: one ETpathfinder tower with shields, mirror, marionette, baffles and reaction mass has been modeled. The number of hits per track before reaching the turbopump is plotted for different start positions – 10 billion tracks calculated in ~ 4 hours (using 12 threads on an iCore7)



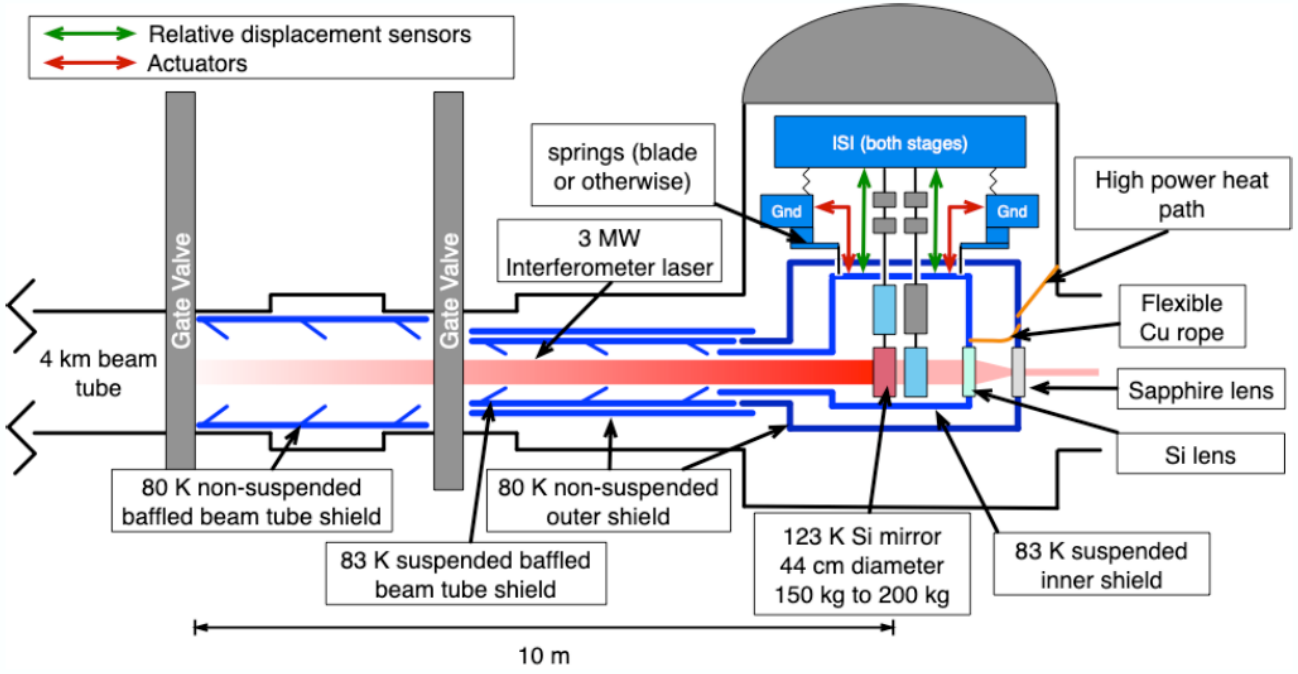
Cool-down of the mirrors in about 1 month – using liquid Nitrogen cooling for the LN2 shield, 30W cooling power for the 40K shield until T=40K, then 3W sorption cooling power, 1.5W cooling power at a 15-K screen (not shown in drawings, and 0.1 W cooling power at cold finger.

About 400 elements are needed to describe the system, the heat transfer between each pair of elements is solved in each time step. (5 days CPU on an iCore7)

Cryogenic

Design and simulation (cryogenic, vacuum) for Voyager and Mariner (Radhika Bhatt)

Voyager Cryogenics

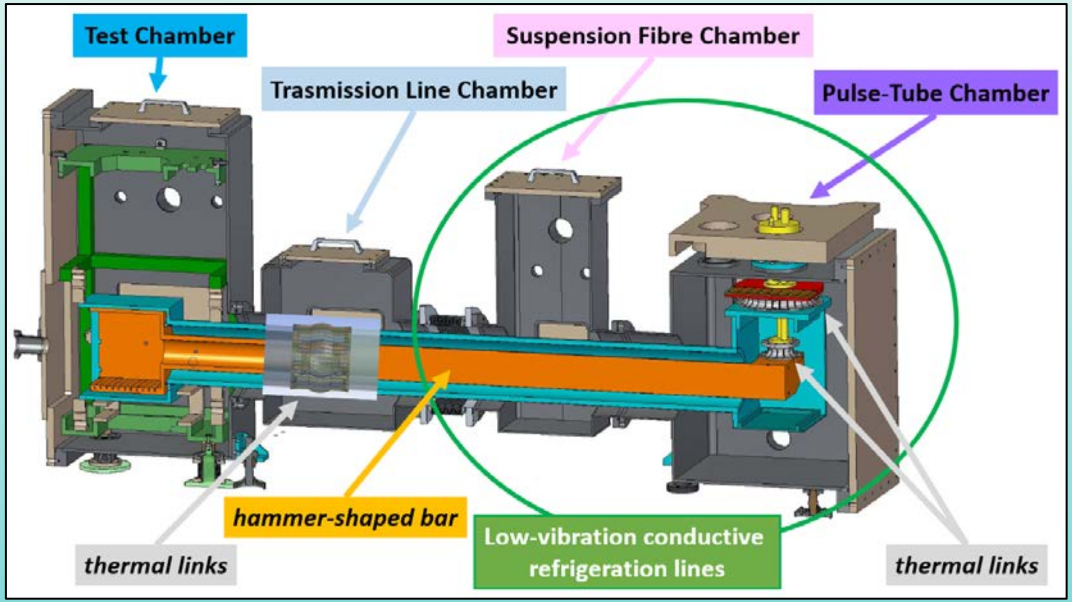


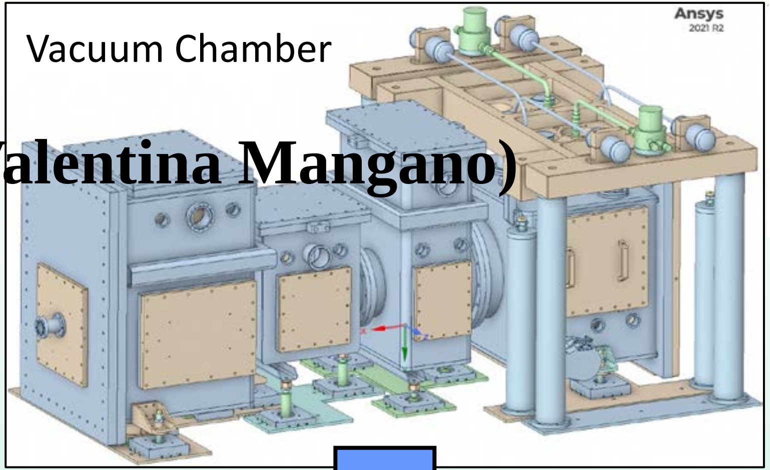
Voyager ETM chamber design, from Voyager White Paper

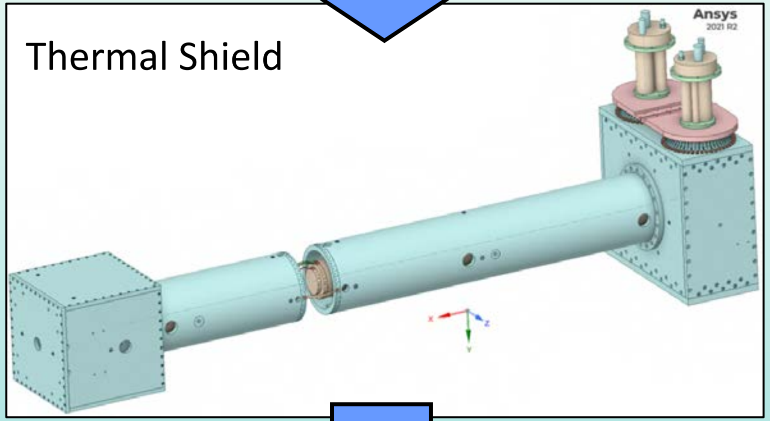
- Si mirrors
- 2 layers of radiative shielding
- Conductively cooled via heat extraction path
- Shields extend into beam tube
- Radiative cooling of test mass (TM) from inner shield (IS)
- Quasi-monolithic suspension: cold Si blade springs and Si ribbons

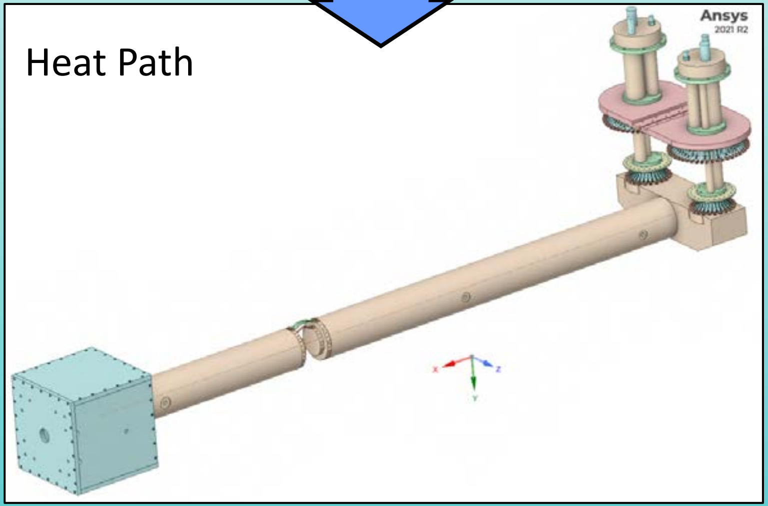
Cryogenic

Cryostat at Rome for ET (Marco Ricci,Valentina Mangano)









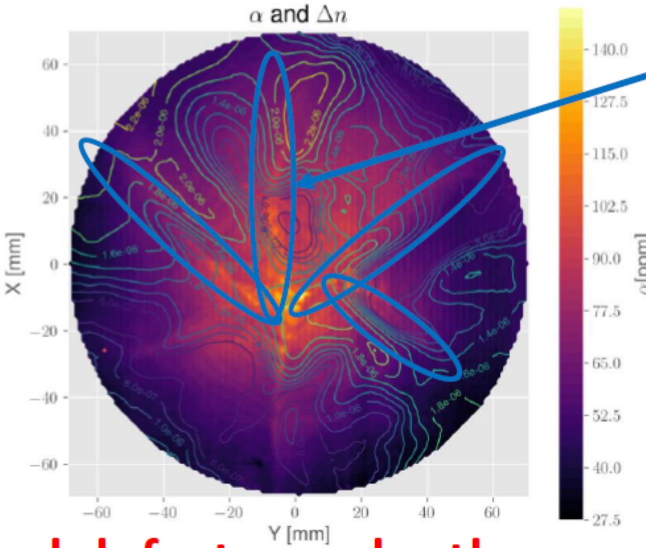
Cryogenic

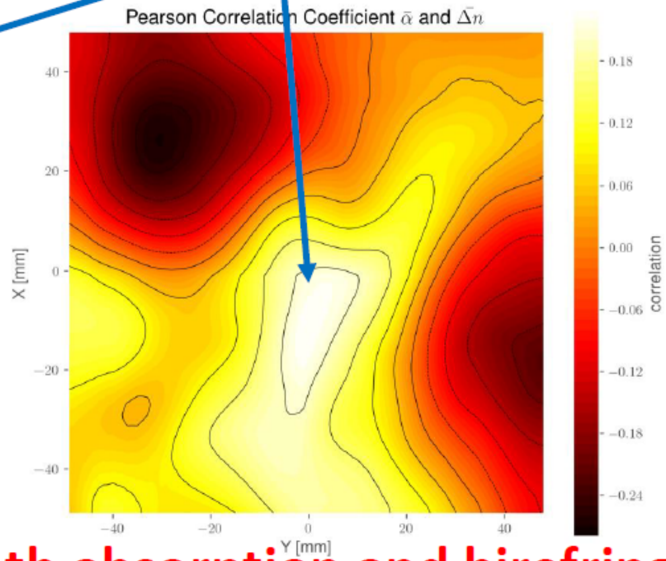
Cooled mirror

Birefringence and absorption spatial correlation

Δn_{RMS} is within original specs

Correlation between absorption and internal stress leading to birefringence





Structural defects can be the cause of both absorption and birefringence*

*Paper submitted to Scientific Reports.

Thermal effects summary 1/2

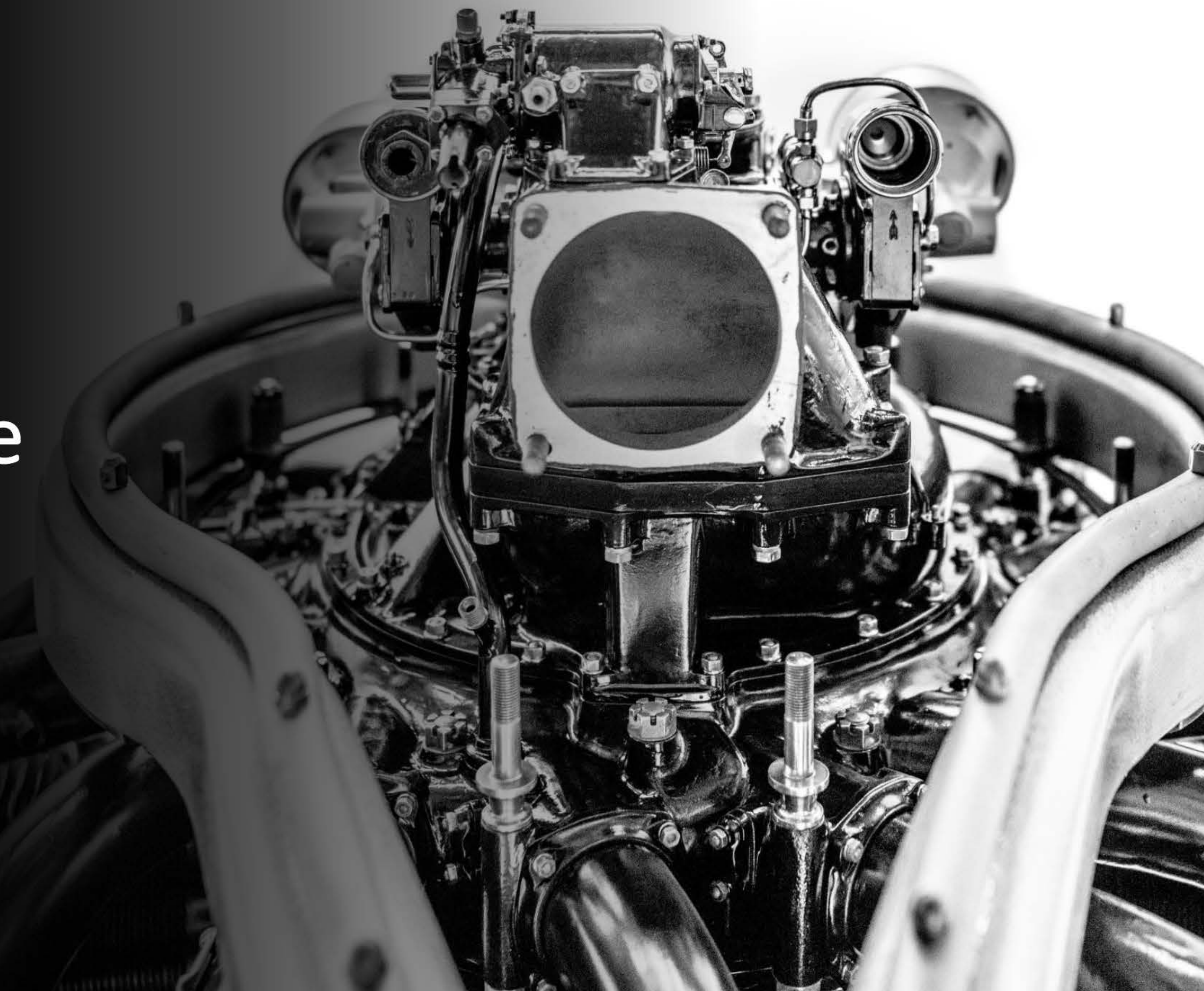
- TCS in Advanced Virgo (M. Lorenzini)
  - Several lessons learned from O3 and O4 commissioning and activities in test facility;
  - Identified a number of upgrades for O5;
  - Clear FOMs from ITF channels must be identified;
- Directly measuring mode-mismatch in coupled cavities (A. W. Goodwin-Jones)
  - Simulations show that this is possible;
  - Actual measurement performed at LLO;
  - Table-top experiment do refine technique;
- Mitigation of point absorbers (M. Cifaldi)
  - Point absorbers measured in the Virgo ITMs (indirect evidence of PAs on ETMs);
  - Reported case of point absorbers cleaned from West ITM;
  - Actuator based on single heating element and binary mask ready to be installed (waiting for NE venting);
- Mode-mismatch in Advanced Virgo (R. Cabrita)
  - Phase camera can be used to measure mode-mismatch between recycling and arm cavities;
  - Measurements interpreted after coupled simulation activity;
  - Results in line with FSR scans.

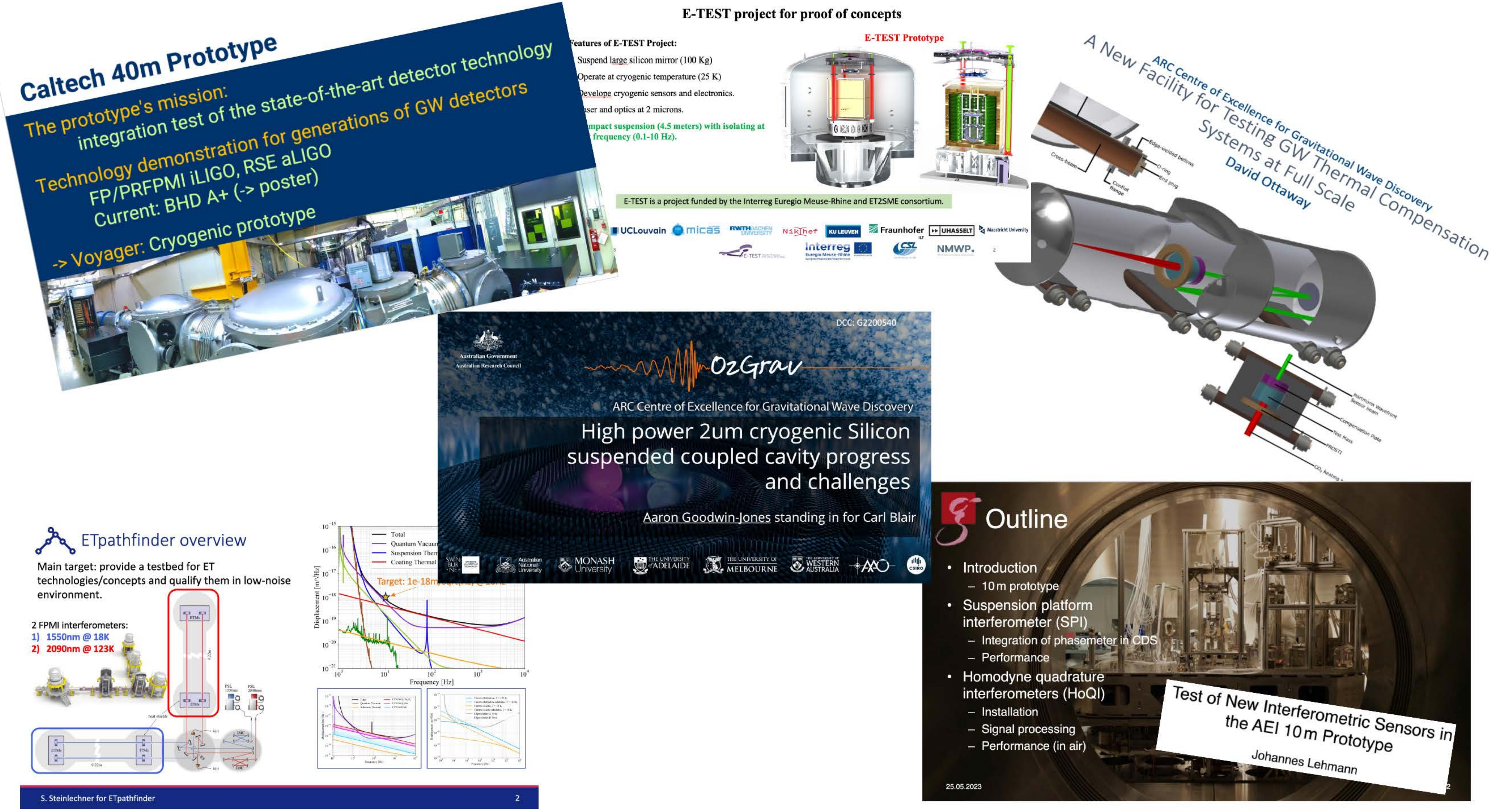
Thermal effects summary 2/2

- Simulating marginally stable cavities in Advanced Virgo (A. Green)
  - Finesse used to model effects of imperfections on some relevant ITF observables (like DARM OLTF);
  - Imperfections affect error signals, and produce offsets;
  - Results from simulations and commissioning being used for the optical design of upcoming Virgo upgrades;
- $A^{\#}$ thermal modelling (A. Brooks)
  - TCS in post-O5 era is going to be challenging (more stringent requirements);
  - Intense modelling ongoing coupling FEA and optical simulations, including tolerancing studies;
  - Work-in-progress, but solutions meeting requirements are coming out;
- Next generation Gravitational Wave Simulation package (H. Yamamoto)
  - Many simulation packages around, non is doing everything;
  - Need something like HEP GEANT4, user friendly (or transparent);
  - Trans-Collaboration effort needed.

Current Prototype

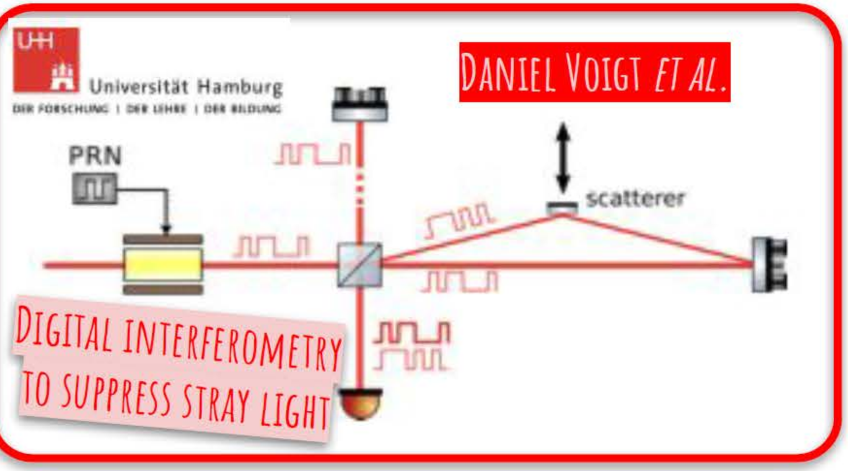
(Thu, Koji Arai, Sebastian Steinlechner, Bram Slagmolen)

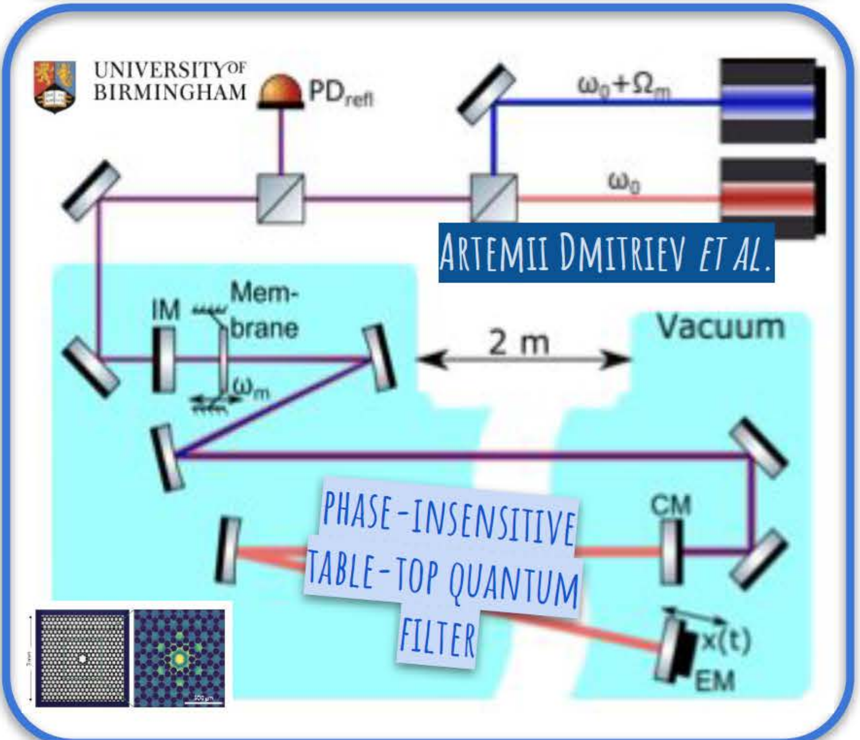


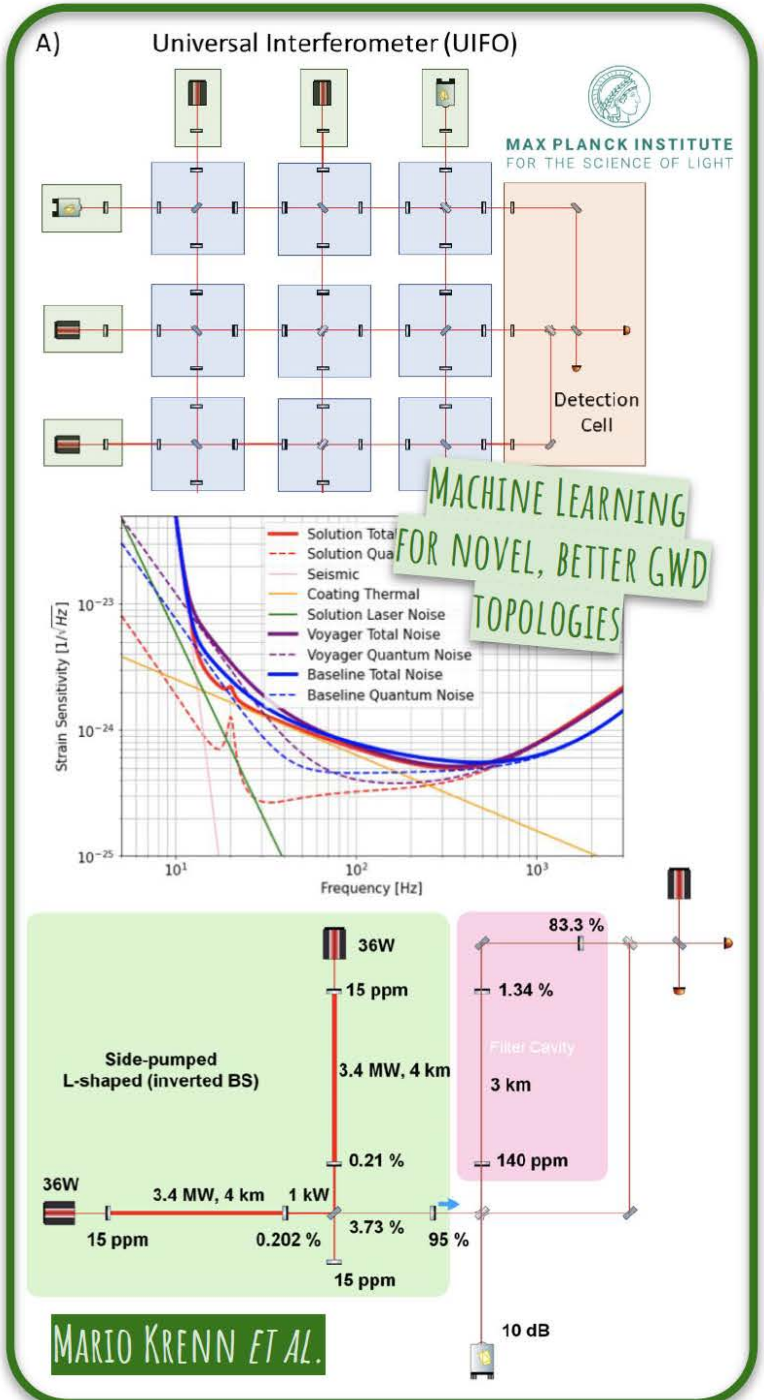

Caltech 40m Prototype
The prototype's mission:
integration test of the state-of-the-art detector technology
Technology demonstration for generations of GW detectors
FP/PRFPMI iLIGO, RSE aLIGO
Current: BHD A+ (-> poster)
-> Voyager: Cryogenic prototype
E-TEST project for proof of concepts
Features of E-TEST Project:
Suspend large silicon mirror (100 Kg)
Operate at cryogenic temperature (25 K)
Develope cryogenic sensors and electronics.
aser and optics at 2 microns.
mpact suspension (4.5 meters) with isolating at
frequency (0.1-10 Hz).
E-TEST Prototype
E-TEST is a project funded by the Interreg Euregio Meuse-Rhine and ET2SME consortium.
UCLouvain
micas
Nikhef
KU LEUVEN
Fraunhofer
UHASSELT
Maastricht University
Interreg
NMWP.
A New Facility for Testing GW Thermal Compensation Systems at Full Scale
ARC Centre of Excellence for Gravitational Wave Discovery
David Ottaway
Edge-welded bellows
O-ring
End plug
Cross-beam
Conflat flange
Hartmann Wavefront Sensor beam
Compensation Plate
Test Mass
FROSTI
CO2 heating
DCC: G2200540
Australian Government
Australian Research Council
OzGrav
ARC Centre of Excellence for Gravitational Wave Discovery
High power 2um cryogenic Silicon suspended coupled cavity progress and challenges
Aaron Goodwin-Jones standing in for Carl Blair
Australian National University
MONASH University
THE UNIVERSITY of ADELAIDE
THE UNIVERSITY OF MELBOURNE
THE UNIVERSITY OF WESTERN AUSTRALIA
AAO
CSIRO
ETpathfinder overview
Main target: provide a testbed for ET technologies/concepts and qualify them in low-noise environment.
2 FPMI interferometers:
1) 1550nm @ 18K
2) 2090nm @ 123K
9.22m
Total
Quantum Vacuum
Suspension Thermal
Coating Thermal
Target: 1e-18m
Displacement [m/√Hz]
Frequency [Hz]
S. Steinlechner for ETpathfinder
2
Outline
Introduction
– 10 m prototype
Suspension platform interferometer (SPI)
– Integration of phasemeter in CDS
– Performance
Homodyne quadrature interferometers (HoQI)
– Installation
– Signal processing
– Performance (in air)
25.05.2023
Test of New Interferometric Sensors in the AEI 10 m Prototype
Johannes Lehmann

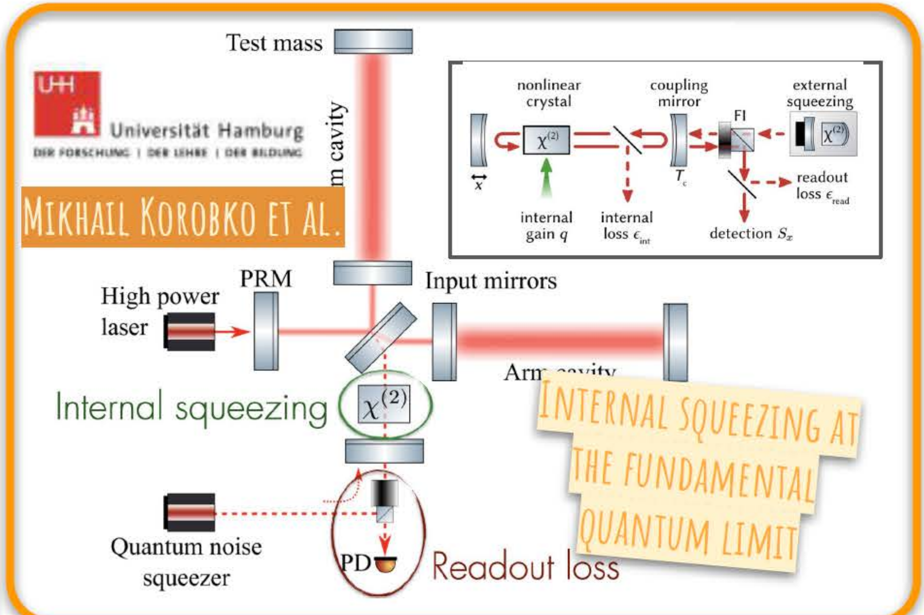
GWADW Elba 2023

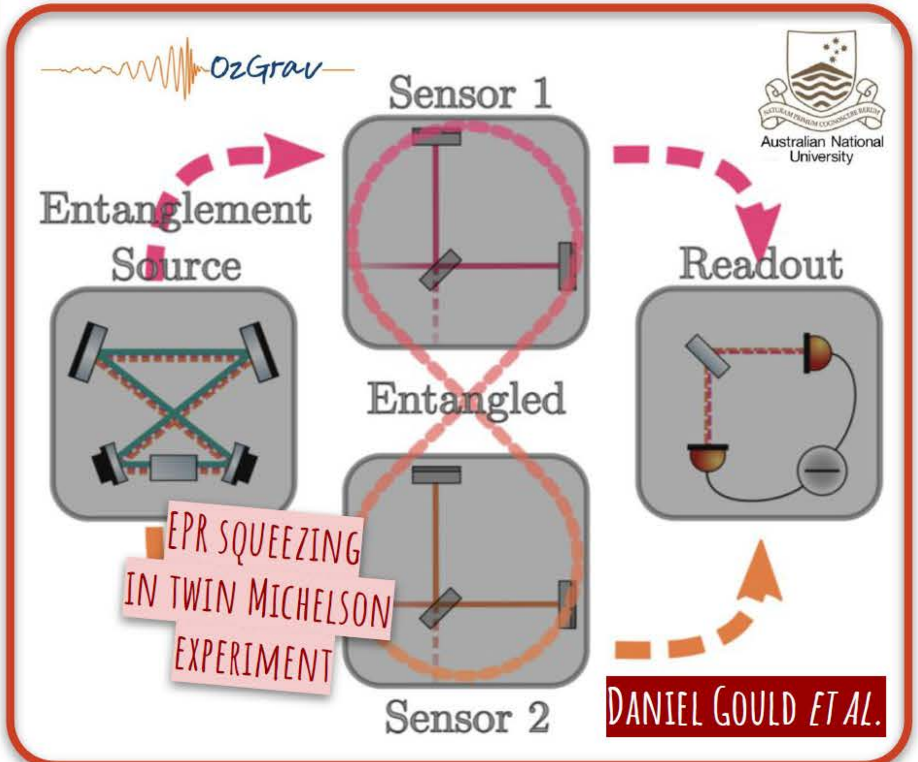
Ideas for Beyond 3G Era (Tue)











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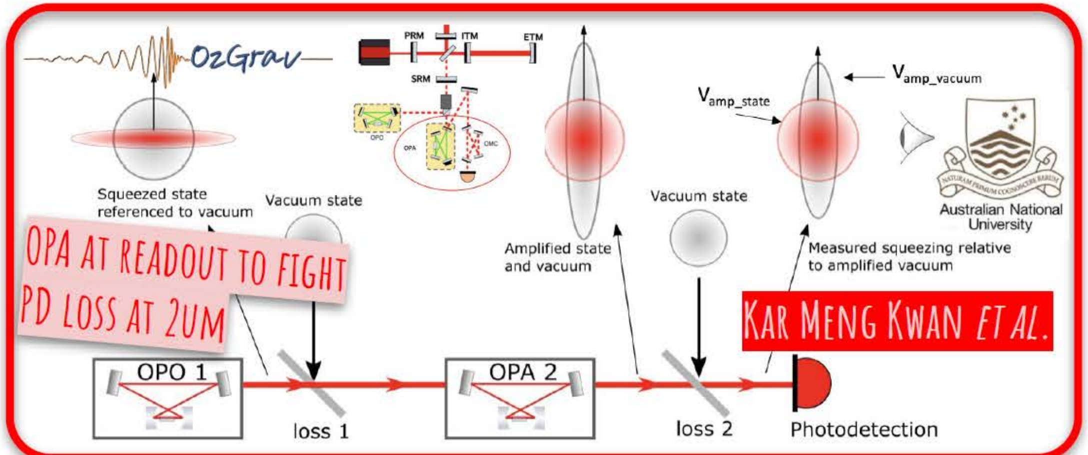
Ideas for Beyond 3G Era (Fri)

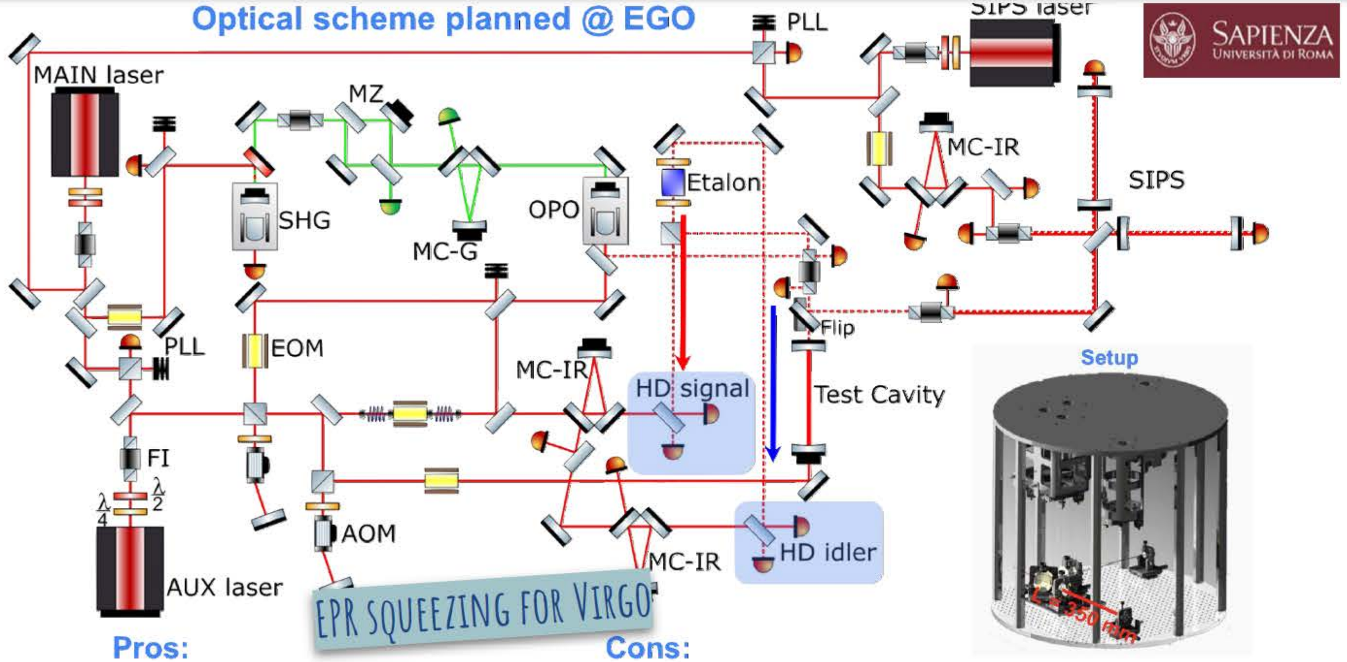
OPA at readout to fight PD loss at 2um

Kar Meng Kwan *et al.*



EPR squeezing for Virgo

Francesco De Marco *et al.*



Pros:

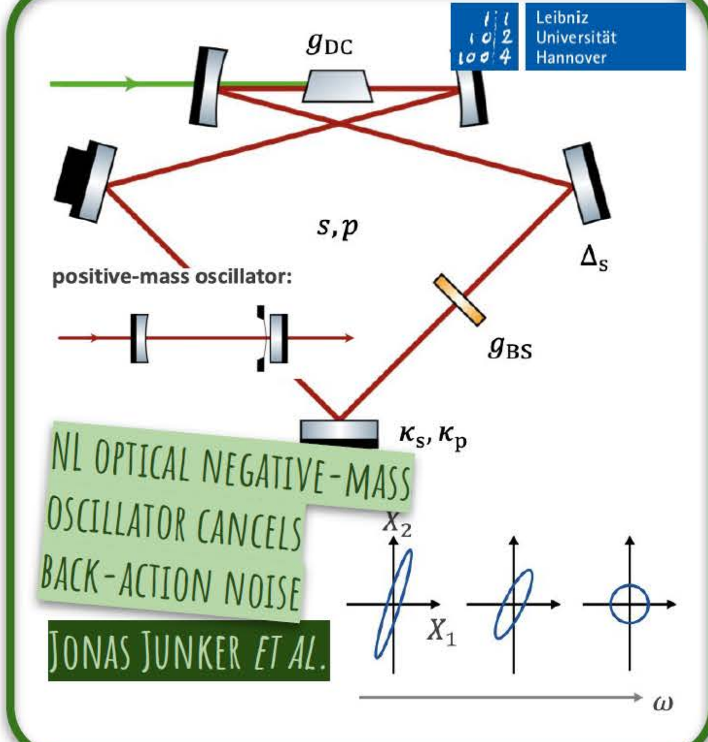
- More compact and cheaper
- More flexible vs SR
- Avoids FC optical losses

Cons:

- 2 squeezed beams to be handled
- 3 dB penalty w.r.t. optimal squeezing rotation ellipse

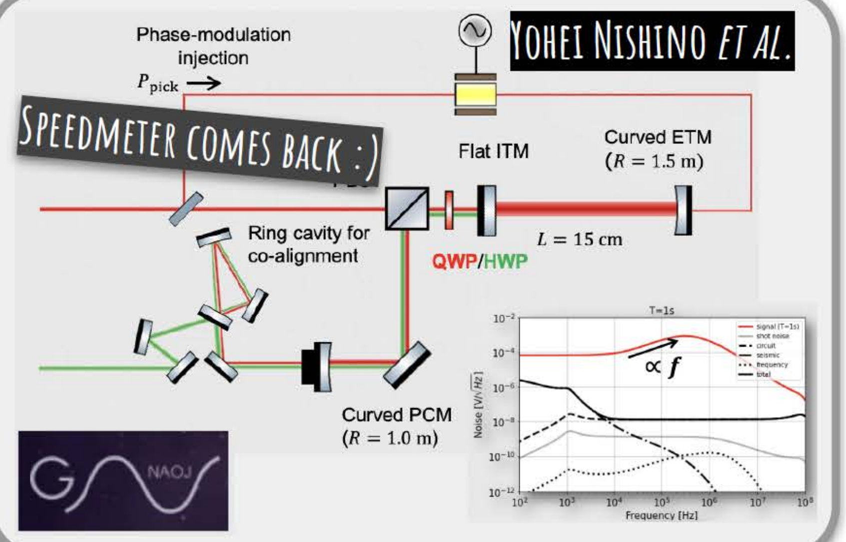
NL optical negative-mass oscillator cancels back-action noise

Jonas Junker *et al.*



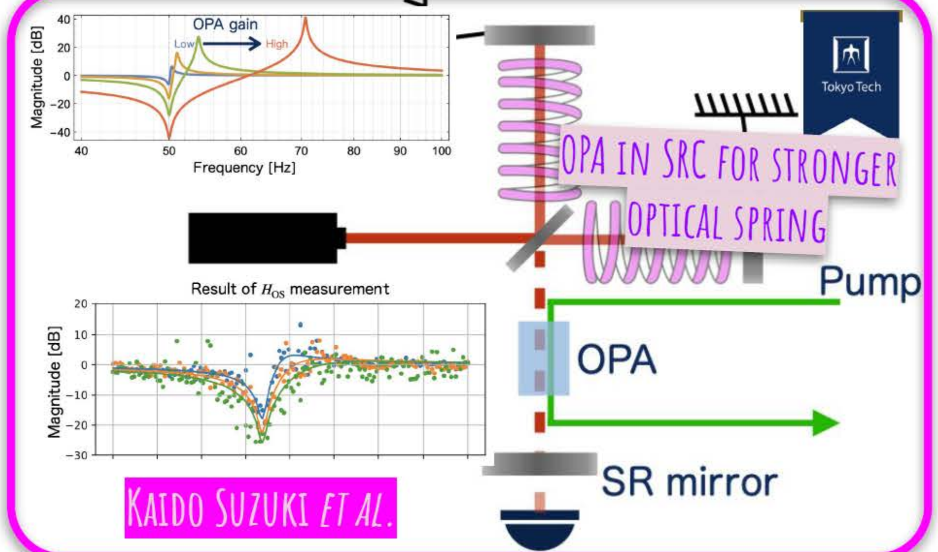
Speedmeter comes back :)

Yohei Nishino *et al.*



OPA in SRC for stronger optical spring

Kaido Suzuki *et al.*



LF noise and control (1st session)
how to beat the low frequency wall?

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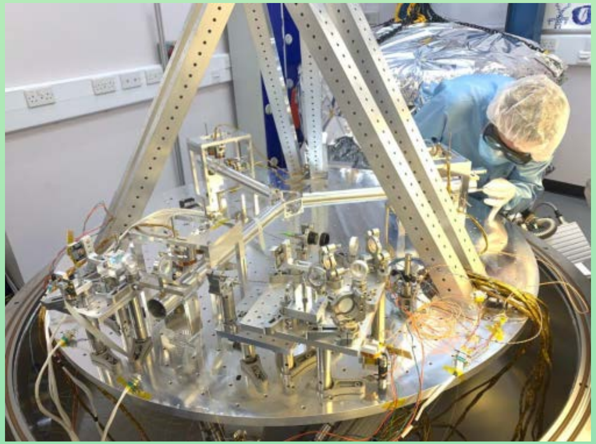
Suspension 6D inertial sensors

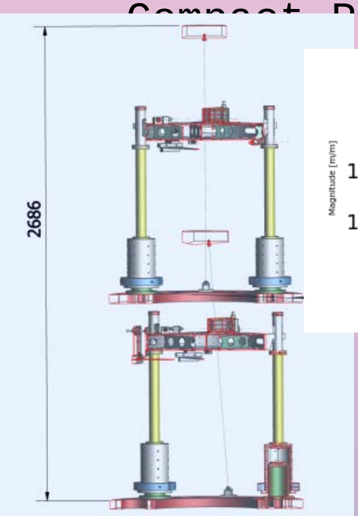


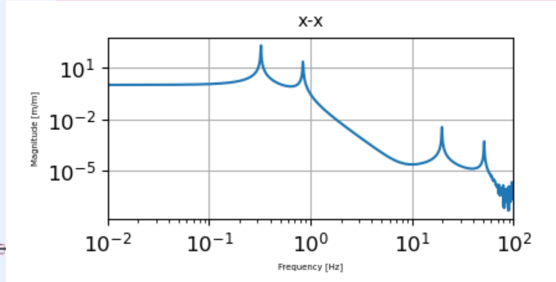
Jiri Smetana

platforms stabilization

Bram Slagmolen

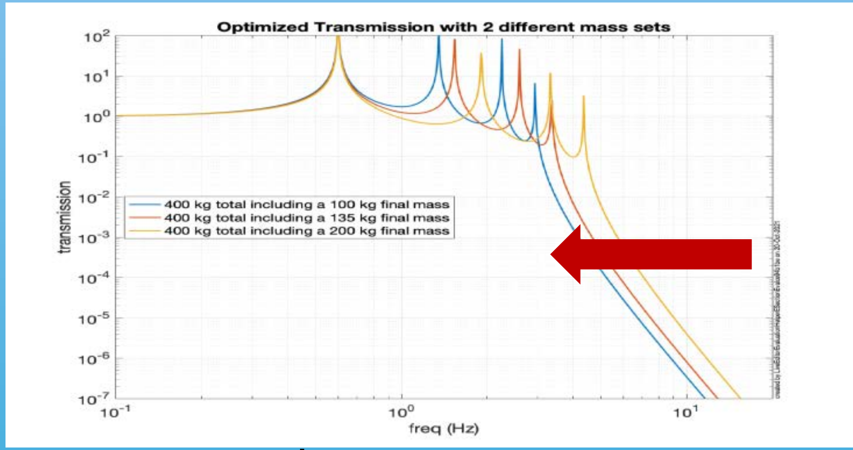
Compact PIP suspensions





Francesco Fidecaro

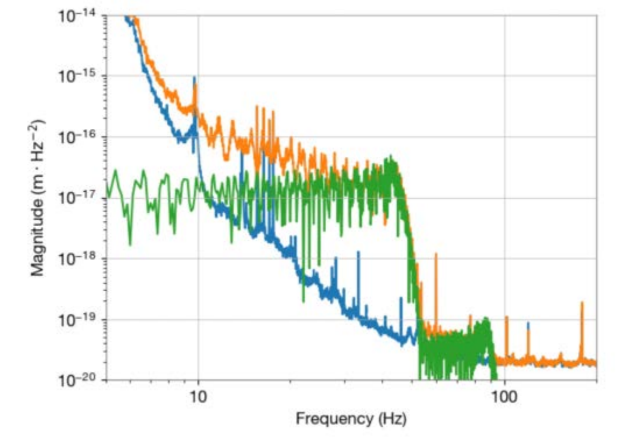
Large optics (100kg)



Brian Lantz

but, seismic and control noises are not the only offenders @ LF...

Scattered light



Eleonora Polini

M. Mantovani

Low Frequency

(Sensing + Control 1)

- Tackling difficult problems in low-frequency noise with a combination of studies of existing systems and development of new tools.
- There are now multiple technologies on the table for near-future seismic upgrades for both inertial and relative control.
- Most of the new approaches necessarily deal with noise in a MIMO way, to at least tackle the biggest cross-couplings at the design stage.

Low Frequency

(Sensing + Control 2)

- For future lower-frequency instruments, our modelling tools and noise projections are becoming more sophisticated.
- “Controls Noise” is approaching the stage where we can add some terms to GWINC-type design tools.
- Rotational inertial sensor technologies can now meaningfully characterize sites and potentially improve performance.
- We see advanced MIMO controls tools entering the observatories, a goal we spoke about many times at previous GWADWs.

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design to our main system.

Last year it was said that asc noise limits sensitivity more in ligo than in virgo, and it can be due to a better isolation system in virgo. On the other hand unstable recycling cavities are issues in virgo. Would everything be better if we have both the tower suspension and stable recycling cavities? (kagra has both though with cryogenic...)..

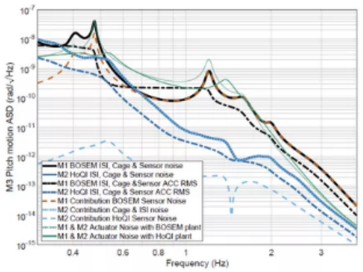
Better polishing for everything

Reduce the source of scattered light at the level of the mirrors by tightening the roughness specs

ML+out-of-loop sensors

The problem with the in-loop sensors is that in a complex system it is difficult to attribute their readings to any particular process, this is why out-of-loop sensors are so useful — they are just easier to understand. This extends to the simples sensors possible (seismometers on the floor, door sensors, fan on/off sensors, maybe even cameras etc.). The problem is that it required a lot of humanpower to install such a network and then implement models to search for the correlation between the "difficult" in-loop sensors and the "easy" out-of-loop ones, which was also hardly an exciting scientific problem, so it was difficult to find people to do it. But now we can do it easily with ML, and it is interesting so there will be people willing to do it. We just need to install a network of out-of-loop sensors and call the computer scientists. Then we'll be able to find correlations between the complicated ifo signals and simple sensors about what happens in the room.

Local Sensor RMS effect



MIMO control design techniques.

Point Absorber/Mirror Imperfections + DARM LSC/ASC Residual Motion → Excess unmodeled Length noise on output

Position dependant, frequency dependant contrast defect.

Feed-forward from facility sensors to isolation

Implement arrays of motion/rotation sensors in the buildings and feed forward to isolation systems via ML-identified MIMO xfer functions

Can you prove it will help DARM?

The coupling of things to DARM is often not well understood - it would be useful to have a way to make upgrade - even if it is just 'likely' to make an improvement. This is prevented by resource limits - so lets figure out how to get some additional resources (more commission team, better development facilities, more $$)

simulation of the control loops including the noise generators embedded in: where we are?

Are the residual MICH / SRCL couplings understood physically?

we believe BHD should help, but maybe it is not enough

ASC vs LSC

ASC noise improvements seem to end up being "move the UGF down" so we can just get it out of the band. This cannot be for LSC, but if feedforward fails, how can we mitigate?

the alignment of the PRC beam, so we need to reduce the latter with lower noise local damping.

Scattered light

We need to shield the vacuum chambers (BSC, at least) with baffles, so that there is no line of sight from the test masses to the chamber walls (baffles hanging from stage 2 of the ISI, e.g.)

A major issue

Driving noise (not only through mechanics, also new electronics !), sensor noise is also relevant, but the main topic in designing 3G detectors is driving noise as it impacts on the the overall mechanical design of suspensions and payloads

Random memo on the choice of suspension chains

It seems it would be inherently difficult to damp mechanical resonances in the complicated suspension chain itself without affecting the GW obs freq band, even forgetting about the global ASC loop; sometimes some of the remnant or "overlooked" mechanical resonances would be damped with the ASC loop, and that would make contamination at GW obs band as well. So the suspension should not be so complicated. If possible or feasible, I like the idea of vibration-isolation tables with nice inertial sensors and nice low noise actuators (displacement act. for DC ctrl, weak but speedy act for damping). For 10-km scale future ones, it might be required to consider tidal control with additional tidal interferometer(?). SPI would be also nice idea.

the necessary methods.

Heavy SUS as soon as possible

Do we really have to wait 2030 to upgrade the suspensions? Can't we do it sooner? Main benefit will be reduced control noise.

Continue to have sessions like this at future GWADWs.

Sense as many DoFs as possible.

If something is unsensed how can we find out what it's doing, and if it's limiting DARM.

Co-Design IFO/ITF systems to reduce scattering.

Design the ISC system/s, and optical paths with scattering as a fundamental issue - both small and wide angle scattering. This design should be from the ground up - not after the fact.

noise as early as possible.

Try to remove/suppress low frequency noise, at the earliest stage, and lowest frequency as possible.

Controls co-design of SUS, and ISI/SAT systems.

Simple to control SUS/PAY, and ISI/SAT systems will simplify commissioning, and clarify how auxiliary DoFs feed into DARM.

Excess Suspension Thermal Noise

Bond Losses on the mirrors coupling systems with the suspension wires.
Effects of defects on ears and anchors: violins quality factors can be used as diagnostics.

Bond losses at the level of the marionetta: still on the violins quality factors, but they can be disentangled from the bonding on mirrors, by comparisons on the mirror bulk quality factors.

Poster location

Poster sessions

GWADW Elba 2023

Social events

A few numbers

- 189 participants, 50 women, 139 men
- 37 early career scientists, 10 women, 27 men

- About 140 abstracts sorted by 30 conveners, 9 women, 21 men

- 89 speakers for 30 hours, 22 women, 67 men

- 64 posters listed, 40 printed on site, 3 hours dedicated to posters

- 14 children

Many people contributed

International Advisory Committee

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Scientific Organizing Committee

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- Marica Branchesi
- FF
- Shinji Miyoki
- Kentaro Somiya
- Gabriele Vajente

Without them, it would not happen

GWADW Elba 2023

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EE: Maurizio Garzella

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- Lorenzo Bellizzi
- FF
- Maria Antonietta Palaia
- Lucia Papalini
- Barbara Patricelli
- Massimiliano Razzano
- Michele Vacatello


See you next year
in Australia