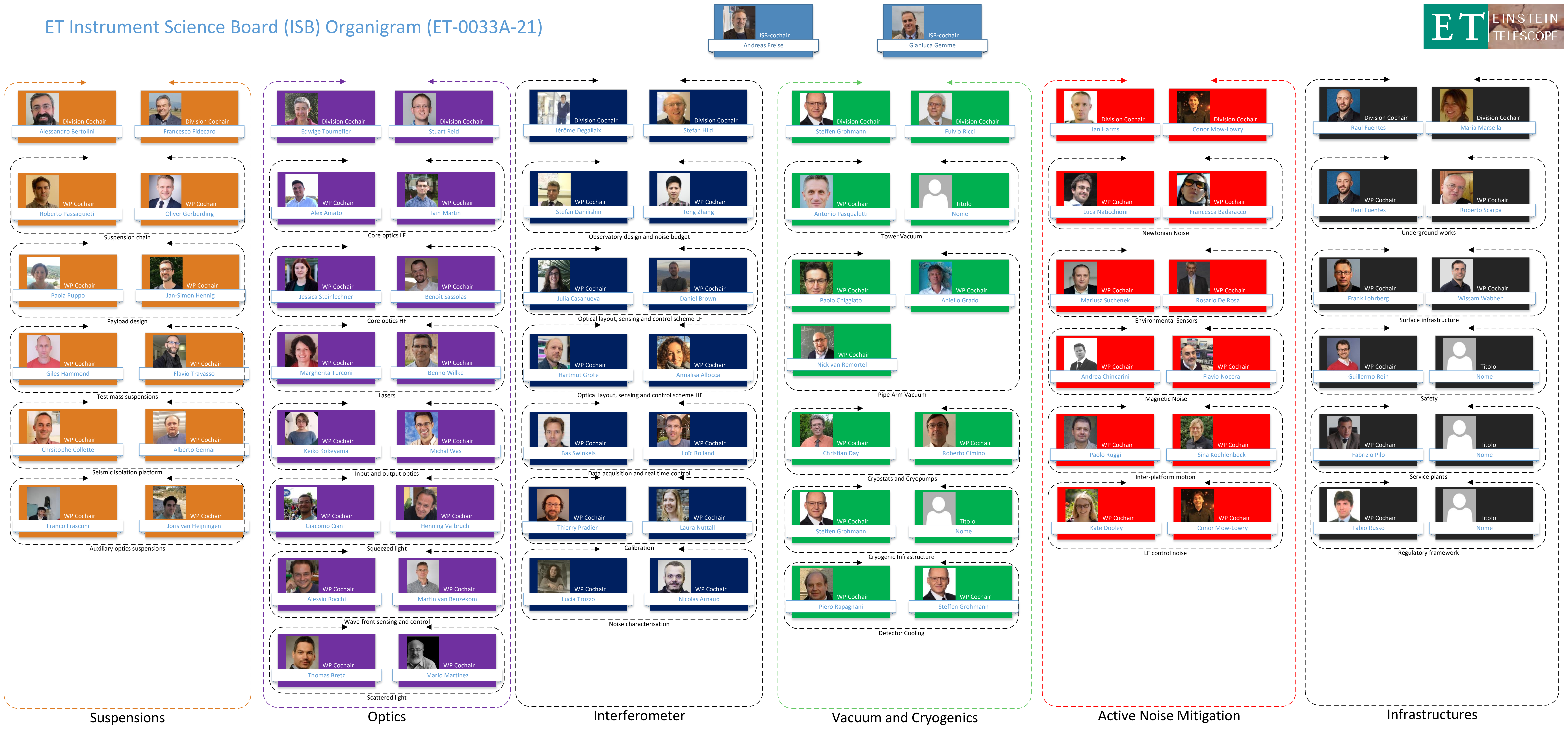
German ET Community Meeting
Mini-workshop on Mechanics, Cryogenics, Vacuum

Hannover, 21.10.2022

Outline

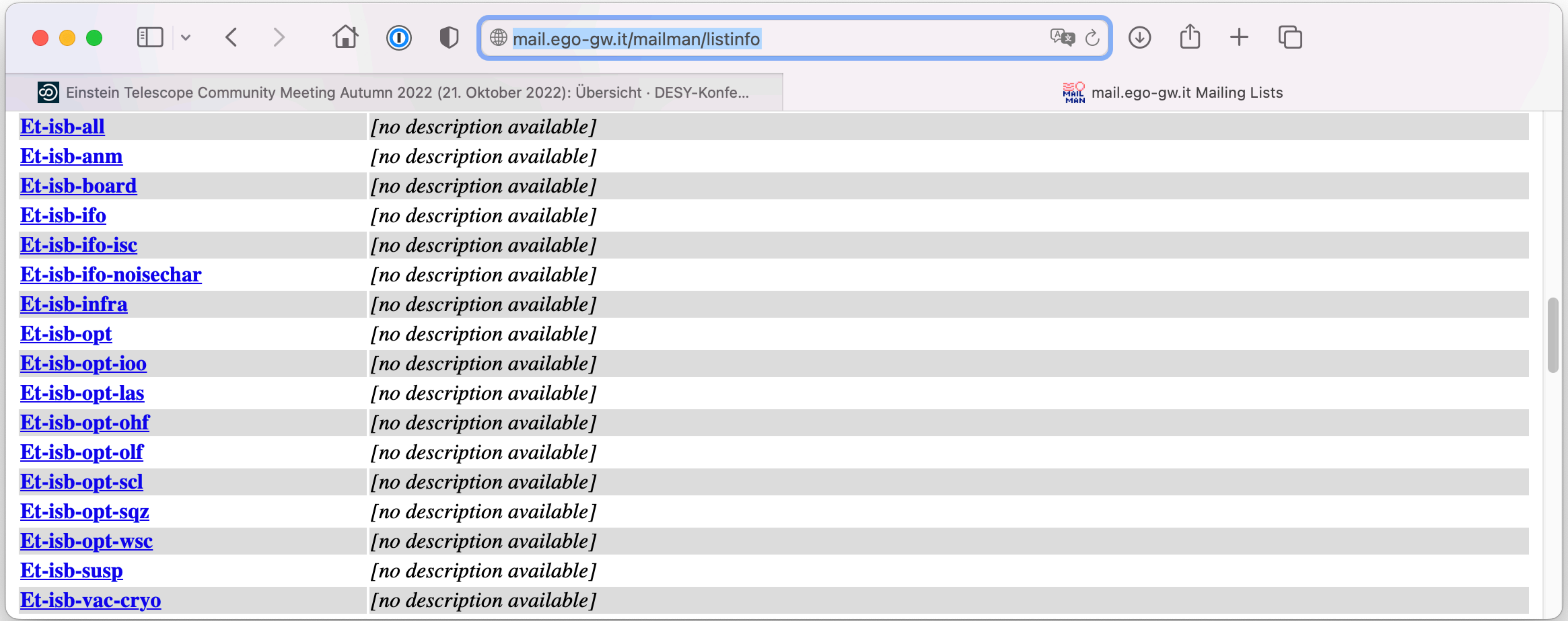
- Overview on ET-ISB organisation
- Status in vacuum and cryogenics
- Presentations of participants
- Discussion, synergies
- Summary

Instrument Science Board



Subscription to mailing lists

- Follow http://mail.ego-gw.it/mailman/listinfo



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Et-isb-ifo	*[no description available]*
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Et-isb-opt-sqz	*[no description available]*
Et-isb-opt-wsc	*[no description available]*
Et-isb-susp	*[no description available]*
Et-isb-vac-cryo	*[no description available]*

ET-ISB Div. IV: Vacuum and Cryogenics

Division chairs

- Fulvio Ricci, University of Rome, La Sapienza, Italy
- Steffen Grohmann, Karlsruhe Institute of Technology, Germany

Work packages

No	Work Package	Chairs	Institution	Country	Expertise
IV.1	Tower vacuum	Antonio Pasqualetti	EGO	IT/FR	VIRGO vacuum group leader
		t.b.d.			
IV.2	Pipe arm vacuum	Aniello Grado	INFN/INAF	IT	Senior GW detector expert
		Nick van Remortel	University of Antwerp	BE	
IV.3	Cryostats and cryopumps	Christian Day	KIT	DE	Senior expert Large Vacuum and Cryopumping Systems
		Roberto Cimino	INFN	IT	Senior expert surface lab
IV.4	Cryogenic infrastructure	Steffen Grohmann*	KIT	DE	Professor of refrigeration and cryogenics
		t.b.d.			
IV.5	Detector cooling	Piero Rapagnani	University of Rome, La Sapienza	IT	Senior expert cryogenics
		Steffen Grohmann*	KIT	DE	Professor of refrigeration and cryogenics

* Interim until replacement becomes available

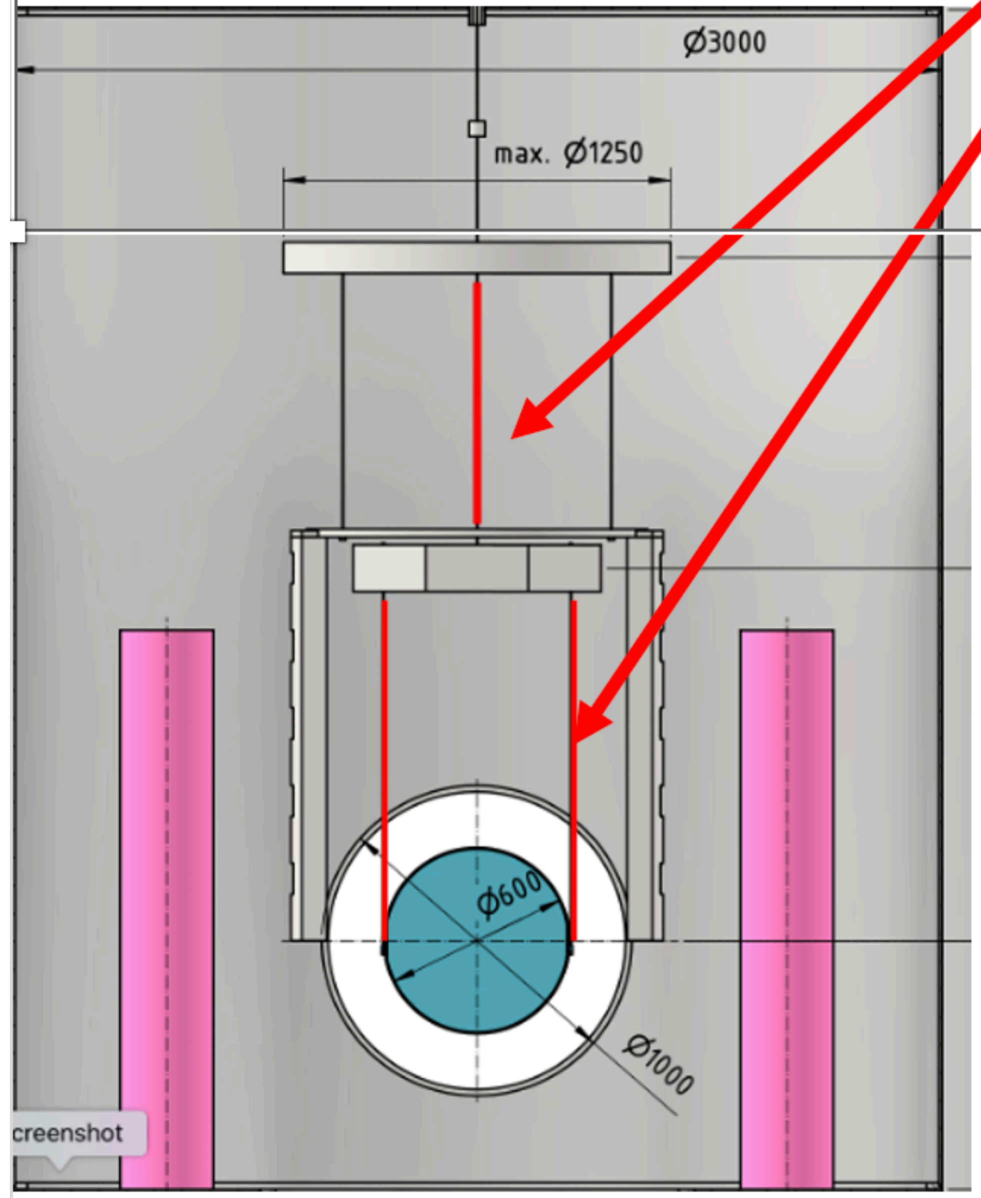
Handled by INFN/NIKHEF-CERN Agreement

Status of Vacuum and Cryogenics

- Recent status report: https://apps.et-gw.eu/tds/ql/?c=16423
- Contents
  - Tower vacuum
  - ET-LF cryostat, geometrical constraints
  - Concepts of cryopumps
  - Cryogenic infrastructure requirements
  - Two options for ET-LF payload design and cooling
    - Suspension thermal noise
    - Cool-down
    - Steady-state operation

First possible cooling configuration (to be tested)

1) using a high-conductivity material also for the marionette suspension, providing low mechanical losses thanks to the very high Q of crystalline materials (silicon or sapphire), and reaching the platform via soft heat links.

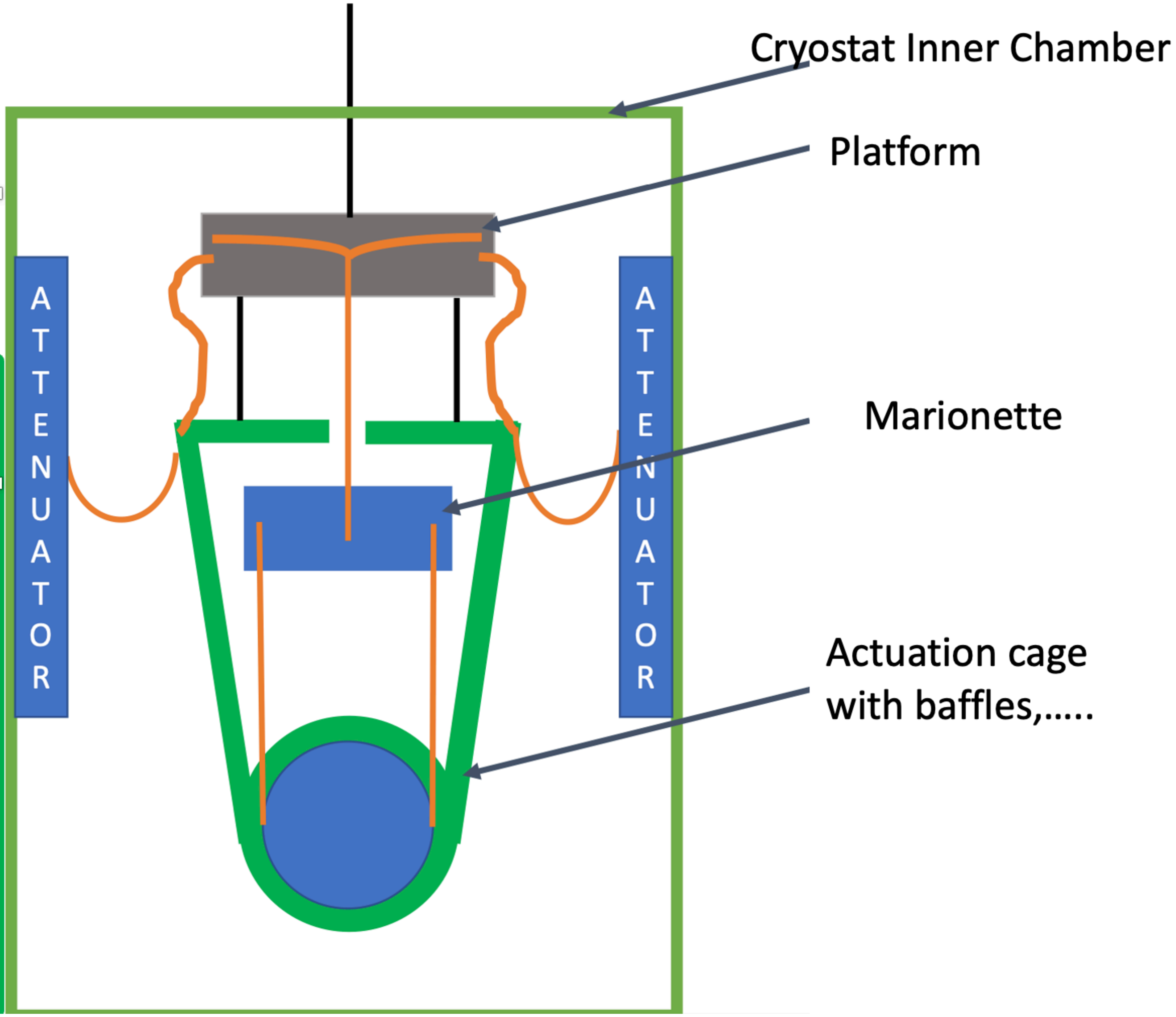


Double pendulum Cryostat Platform (PF) with Blades

Platform with blades for vertical attenuation

Heat links on the screen

Screen connected to PF with 3 wires (for angular control)



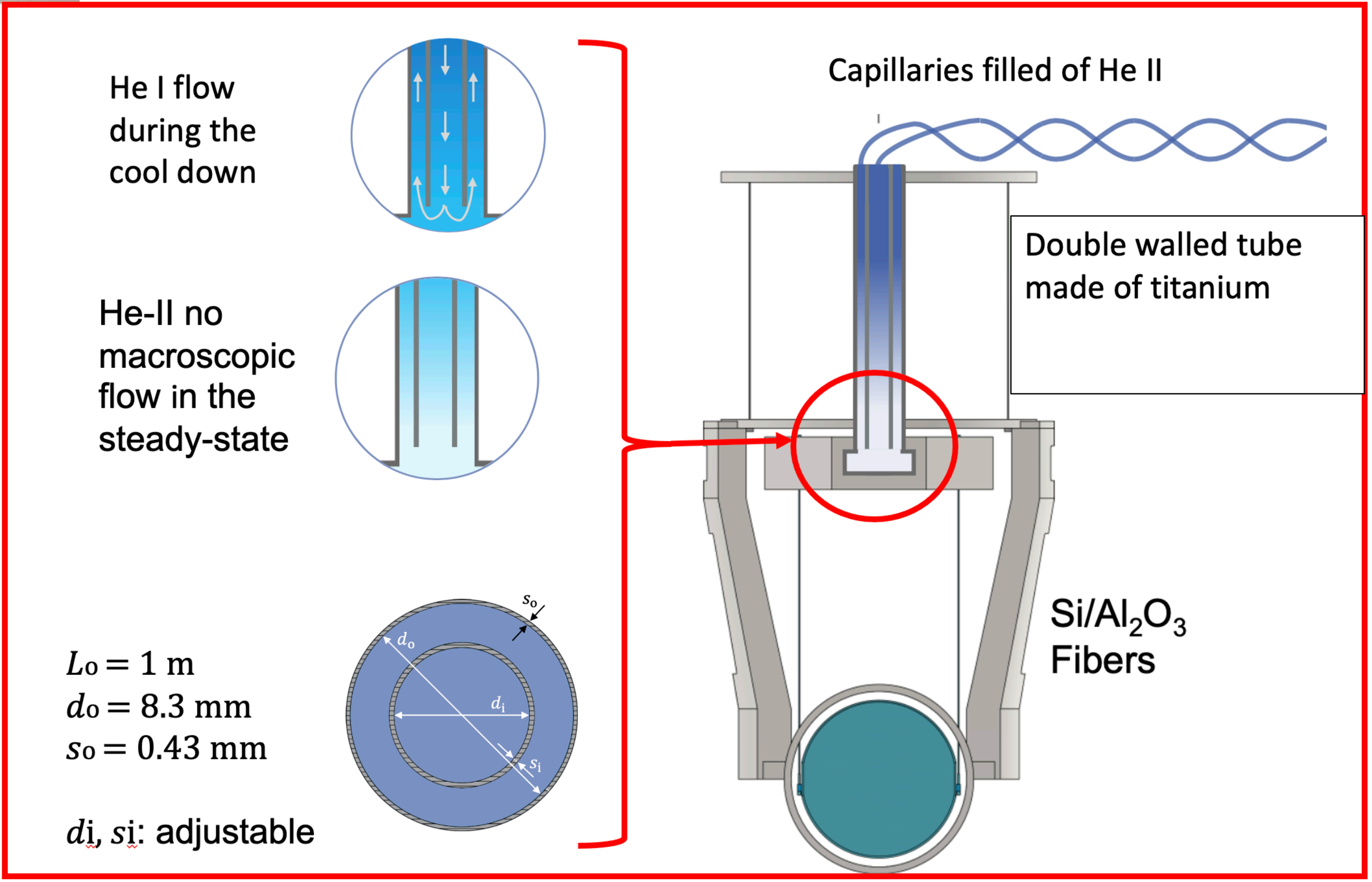
Second possible cooling configuration (to be tested)

Take advantage of quantum properties of He II

He-II fills the marionette suspension tube made of titanium, (relatively high quality factor @2 K)

Marionette@ ~2 K

He-II reaches the platform via a set of supply capillaries.



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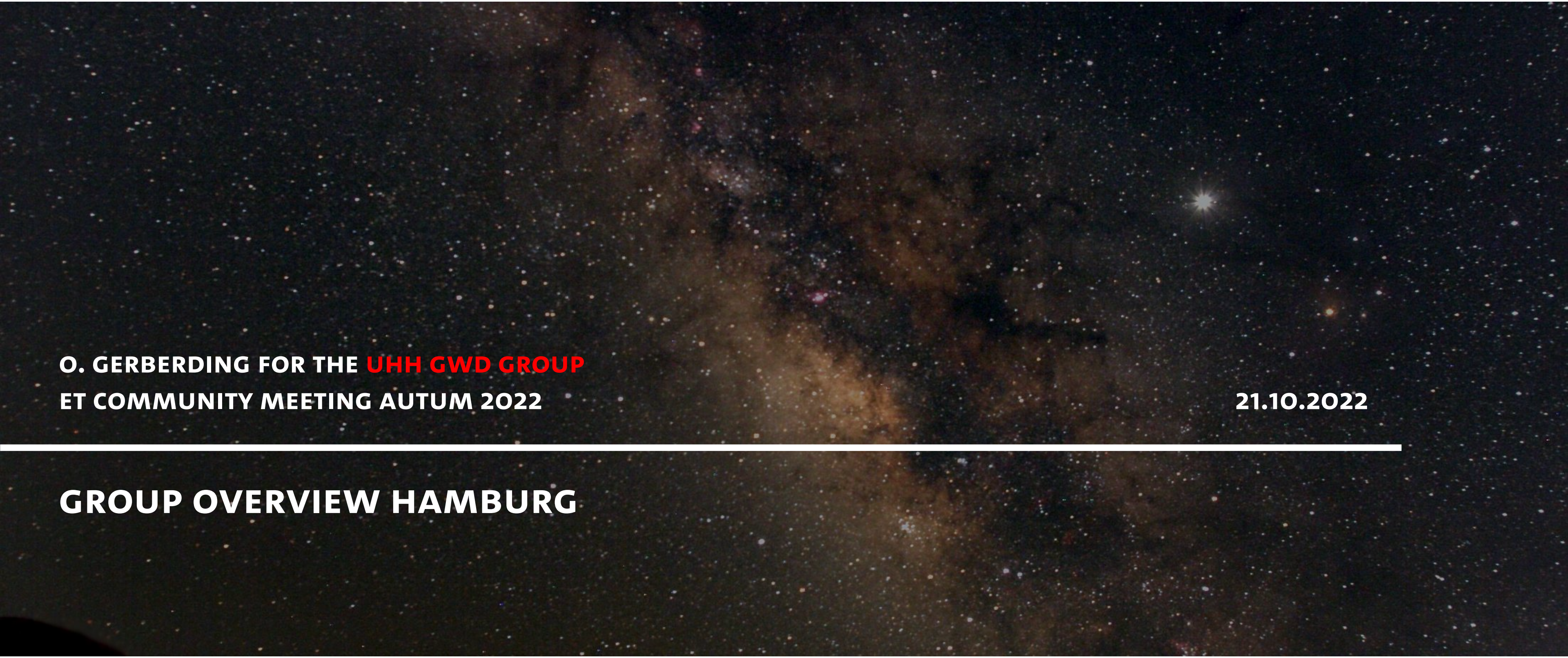
GRAVITATIONAL WAVE DETECTION

CLUSTER OF EXCELLENCE QUANTUM UNIVERSE



O. GERBERDING FOR THE UHH GWD GROUP

ET COMMUNITY MEETING AUTUM 2022

21.10.2022

GROUP OVERVIEW HAMBURG

CREDIT: THE MILKY WAY GALAXY BY DEREK ROWLEY

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THE HAMBURG GWD GROUP AT INSTITUTE OF EXPERIMENTAL PHYSICS

André L. | Daniel V. | Marcel B. | Christian D.-F. | Oliver G. | Artem B. | Tobias E. | Shreevathsa C.S. | Meenakshi M. | Leander G. | Wanda V.

+ 2022 interns:
Octavio J Vega
Zoey Green
Lonnika Warda
Oza Passot

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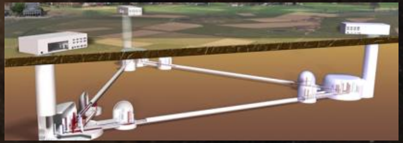
DLR

DFG
Deutsche Forschungsgemeinschaft

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

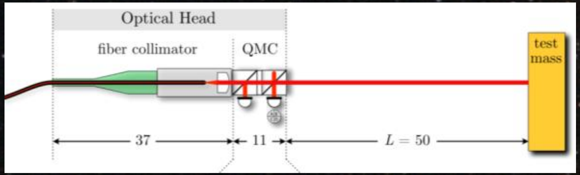


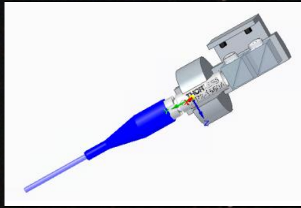
LSC LIGO Scientific Collaboration

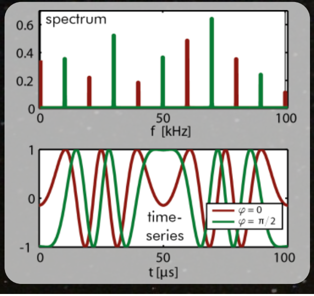
ET EINSTEIN TELESCOPE

LISA CONSORTIUM

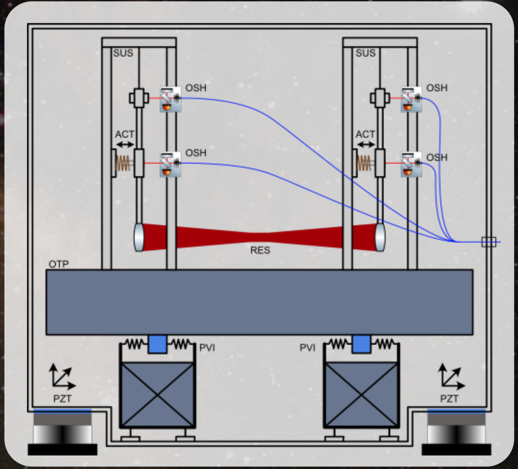
Compact interferometers for local test mass readout based on Deep Frequency Modulation Interferometry (DFMI)







Inertial test facility VATIGrav for testing local test mass readout, inertial sensors seismic isolation and control



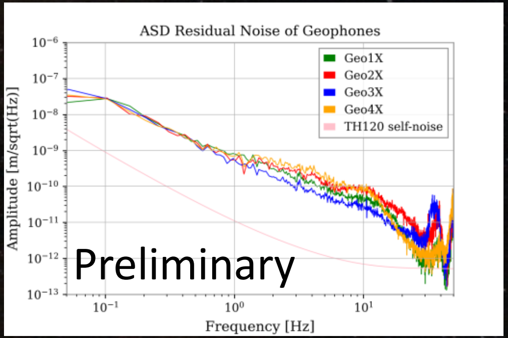
VATIGRAV – ACTIVE ISOLATION SELF-NOISE STUDY

Active isolation noise prediction experiment

- 4x STACIS isolators, each includes a 3-axis geophone
- 2x Trillium Horizon 120
- Goal: Measure and calibrate STACIS/geophone self-noise in m/sqrt(Hz) (not available from TMC)

Analysis

- Determine self-noise of geophones with huddle test, uncalibrated
- Use coherence of STACIS/geophones with TH120 to determine transfer function and to calibrate self-noise predictions (plot on the right)
- Analysis implemented in, and done via, SpicyPy (see Artem's Talk in CSWG, at 16:00 [G2201532])



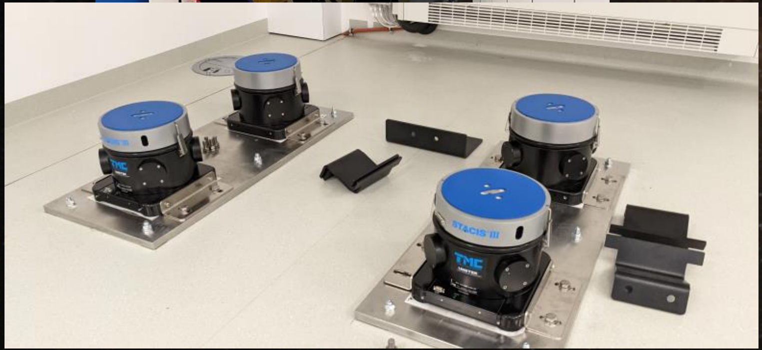
Ongoing work & next steps:

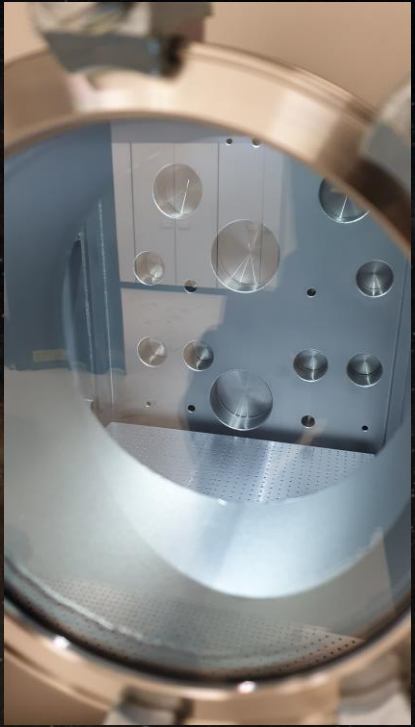
- Use ground-motion and control model to predict residual chamber motion
- Add passive isolator model to predict residual in-vacuum platform motion
- Extend to 6-DOF model and compare with device performance

VATI GRAV

PHOTOS

(FINALLY)





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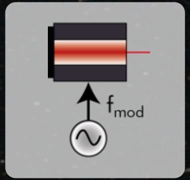
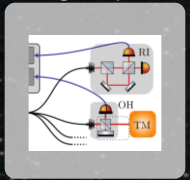
Deep-Frequency Modulation Interferometry (DFMI)

Laser modulation



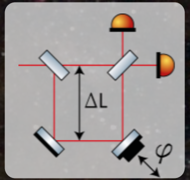
$$f(t) = f_0 + f_\Delta \cos(\omega_m t)$$
$$f_m = 1\,\mathrm{kHz}$$
$$f_\Delta = 3\,\mathrm{GHz}$$

Light split



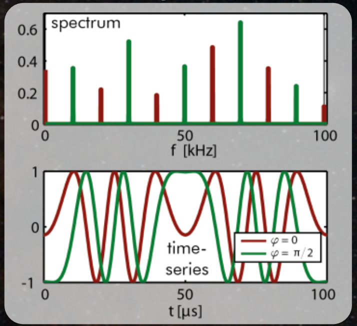
$$f_1(t) = f_2(t) = f_N(t)$$
$$f_R(t) \approx \mathrm{const} + f_\Delta(t)$$

Interferometer

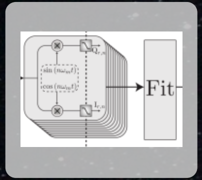


$$L_\Delta = 0.1\,\mathrm{m}$$
$$m = 2\pi \frac{L_\Delta}{c} f_\Delta \approx 7$$

Signal



Phasemeter



$$\hat{i}_{DC}, \hat{i}_{AC}, \hat{m}, \hat{\varphi}, \hat{\psi}$$

power, contrast, ranging, displacement

$$i(t) = i_{DC} + i_{AC} \cos(\varphi + m \cos(\omega_m t + \psi))$$

Main features:

- Signal is inherently non-linear and linearized by the phasemeter algorithm/estimator
- Each interferometer (optical head) has only one input beam and can be very compact
- Laser frequency noise is common mode (can be suppressed actively or in post-processing)
- Provides wide-range sensing of displacement & absolute ranging

O. Gerberding, Optics Express, 23, 11, (2015)
G. Heinzel et al., Optics Express, 18, 19, (2010)
K.-S. Isleif et al., Optics Express, 24, 2, (2016)

O. Gerberding & K.-S. Isleif, Sensors, 21(5), (2021)

COMPACT OPTICAL HEAD DEVELOPMENT

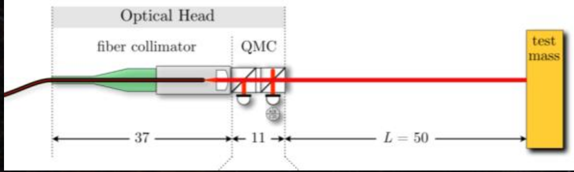
Design with low noise & large range

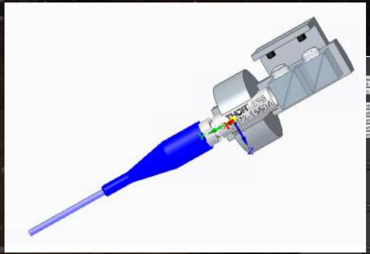
- polarization cleaning
- no fiber backscatter
- balanced detection
- ghost beam suppression via extended readout algorithms
- on-axis design can operate over and at various distances

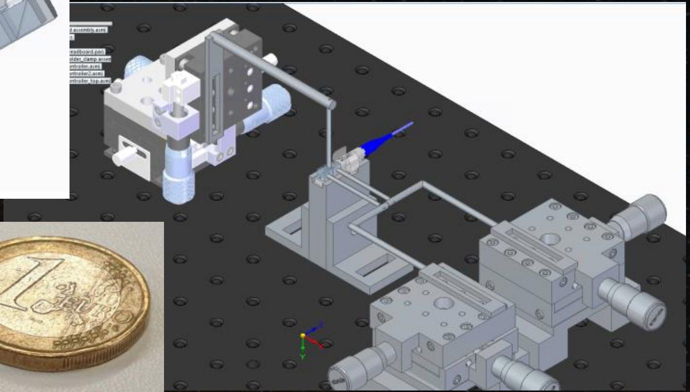
Status:

- Alignment jig is currently being designed, prototypes are being manufactured

See poster by Meenakshi, Wanda [LIGO G2201438]







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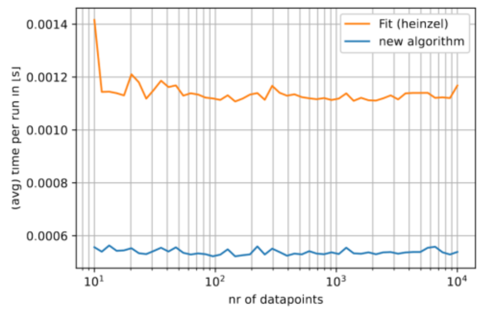
READOUT NOISE AND ALGORITHMS

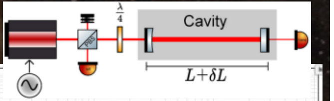
DFMI Readout algorithm

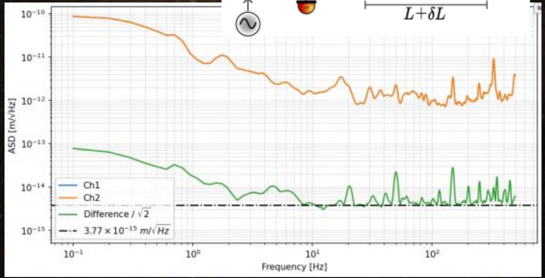
- Reduction of processing time via new, arithmetic algorithm
- Currently optimizing the dynamic range of the algorithm
- Work towards FPGA version (32 channels)

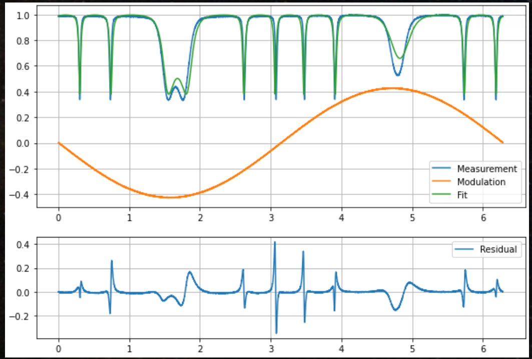


ReDFMI:

- Combine DFMI with cavities
- Readout via time-series fit (currently)
- Achieved a readout noise of 3fm/sqrt(Hz) in an optical zero measurement



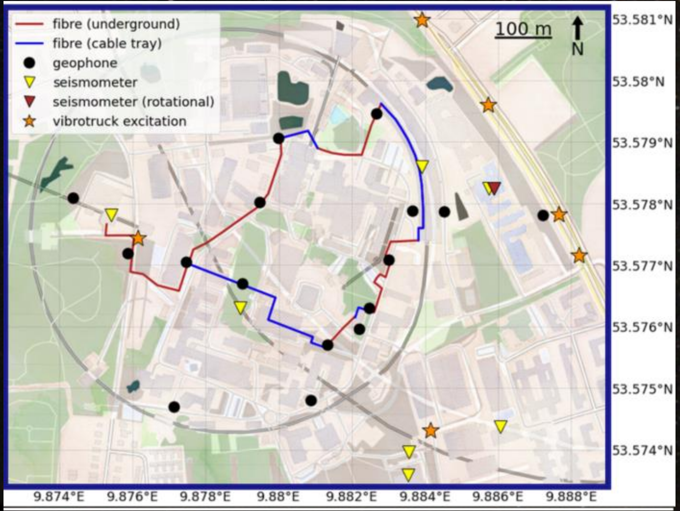


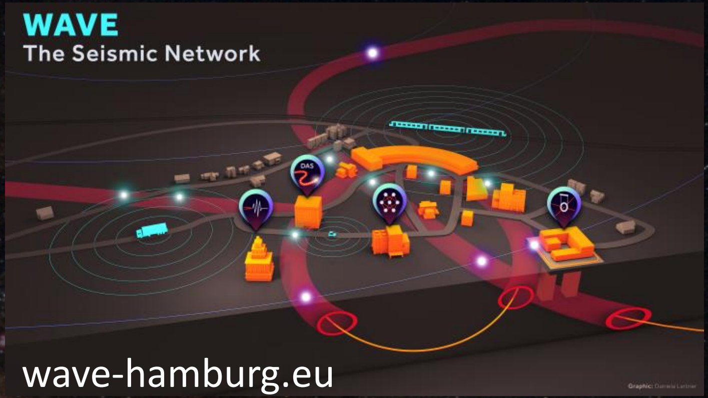


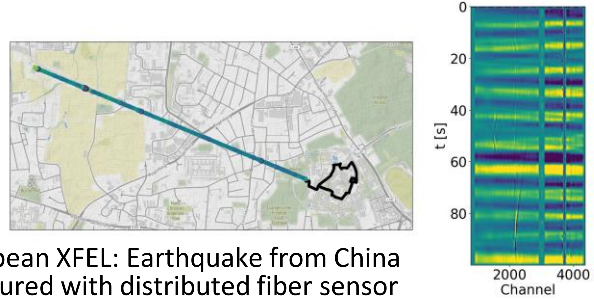
See poster by Tobias, Leander [LIGO G2201373]

SEISMIC NETWORK - WAVE

Distributed acoustic *fiber* sensing networks
Measurement campaign on DESY campus in May 2021
Goal: Prediction of seismic disturbances







European XFEL: Earthquake from China measured with distributed fiber sensor

UHH DESY. GFZ Helmholtz-Zentrum POTSDAM

Summary

- 4 groups present in the meeting
  - 2 Hamburg
  - 1 Hannover
  - 1 Karlsruhe
- Test facilities
  - Small scale (inertial facility commissioned in HH, He-II test cryostat planned in KA, cryo platform available in HH)
  - 10 m prototype in H (10 m interferometer, seismic isolation platform, vacuum pump testing, scattered light mitigation, sensor testing, quantum noise)
  - GEO600: inertial sensor testing, scattered light, ML for control, quantum noise
  - Seismic and sensor network for environmental noise in HH

Summary

- Compact interferometric sensors (HH)
  - 10 fm sensitivity
  - $10^{-2} \ldots 10^{2}$ Hz
  - Possible integration in He-II test environment (or other systems)
  - Test in the 10 m prototype or GEO600

- Sensor networks for noise reduction (HH)
  - Optical fiber sensing
  - Wireless accelerometers
  - Modelling