

Reports on GWADW2026 & IDM2026

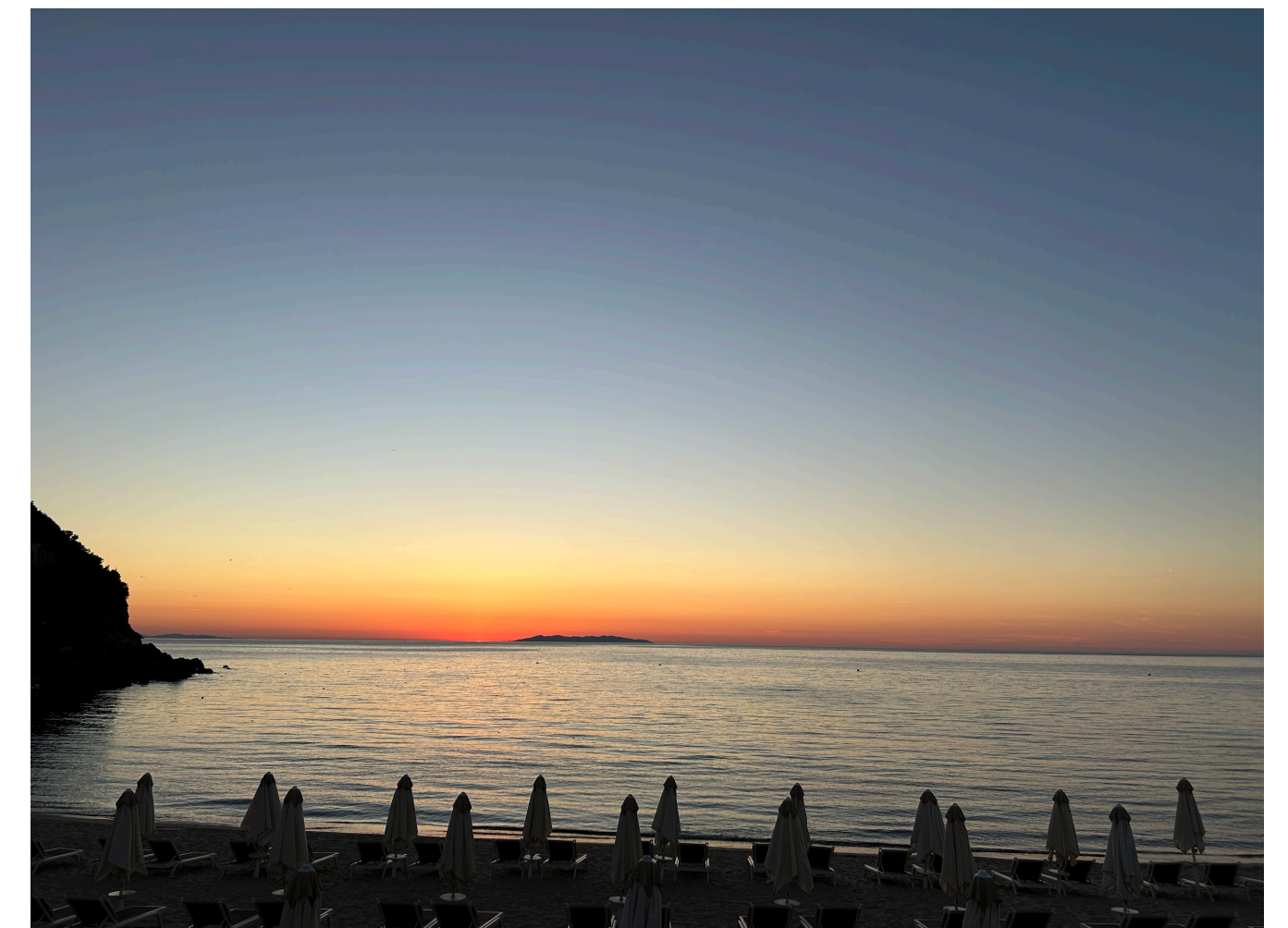
Hinata Takidera (D3)

Department of Physics, The University of Tokyo

Ando-Michimura Group Seminar, July 3rd, 2026

GWADW2026 (Gravitational-Wave Advanced Detector Workshop)

- One of the main opportunities worldwide to present the work on detectors leaving, as is tradition, ample space for informal discussions
- May 17th - 23rd, 2026
- Hotel Hermitage, La Biodola, Isola d'Elba, Italy

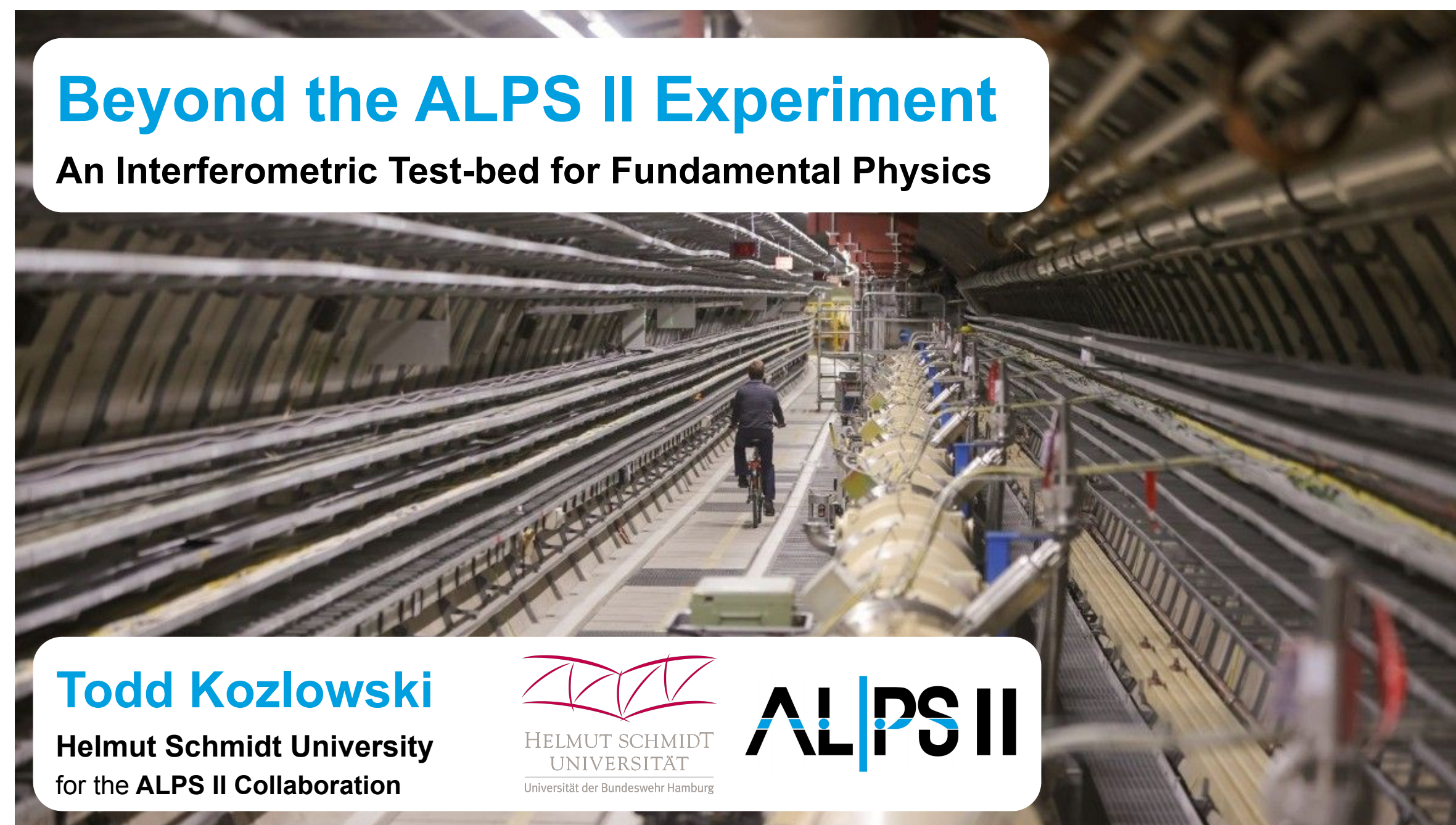


- There were only plenary sessions, so I did not have to worry about which talks to listen to
 - 3G detectors (Einstein Telescope and Cosmic Explorer)
 - Coating
 - Squeezing
- Many Japanese participants

Talk about ALPS II experiment

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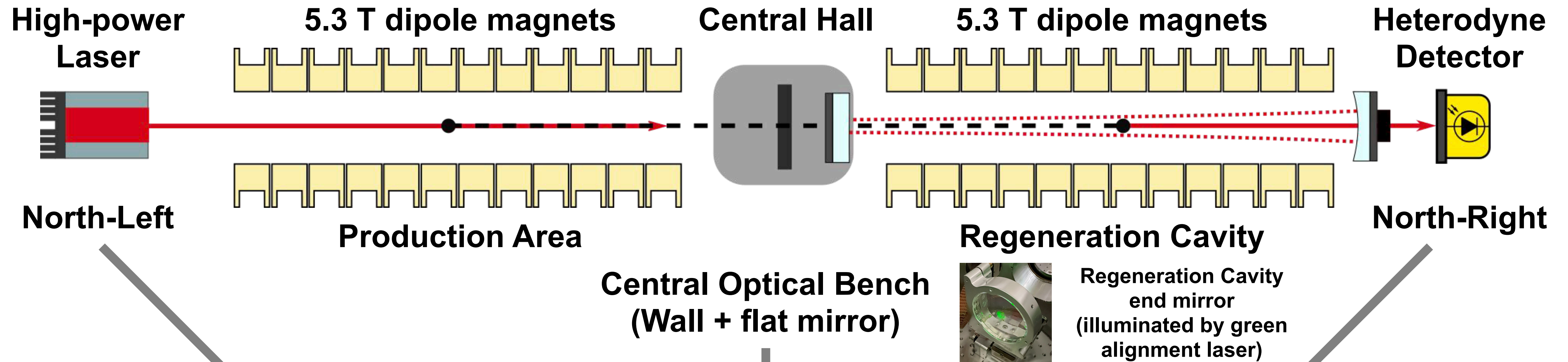
- Session: Exploring New Directions (before me)
- ALPS II (Any Light Particle Search II)
 - First results of light particle searches
 - Vacuum Magnetic Birefringence (VMB)
 - Dark matter and high frequency gravitational waves



[Slides](#)

ALPS II setup for first run

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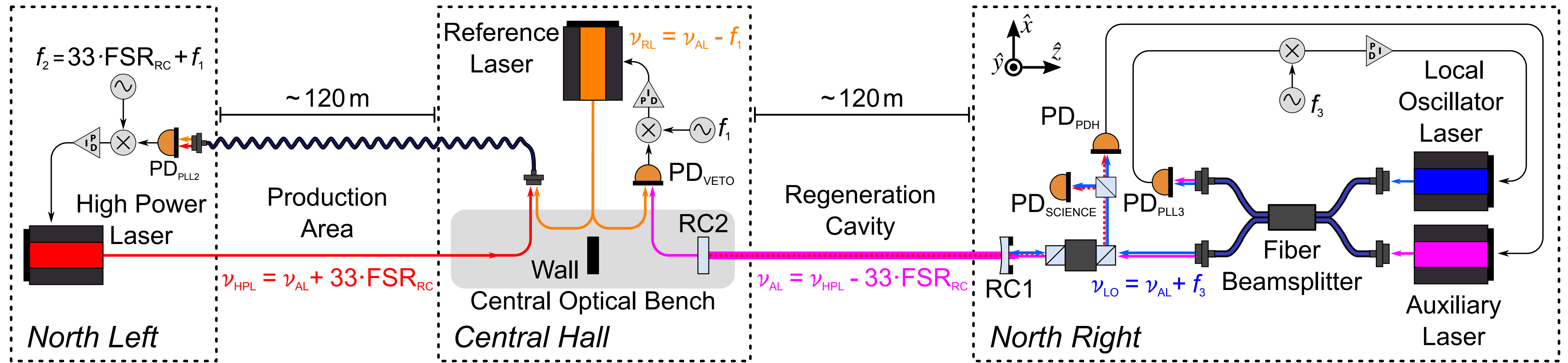
- High power laser system
- From neoLASE / AEI
 - Stable operation at 40 W of 1064 nm light



- Regeneration cavity
- Half-confocal, 122 meter-long FP inside 51 mm beam pipe
 - Cavity storage time: 7.2 ms (44 Hz linewidth)

ALPS II setup for first run

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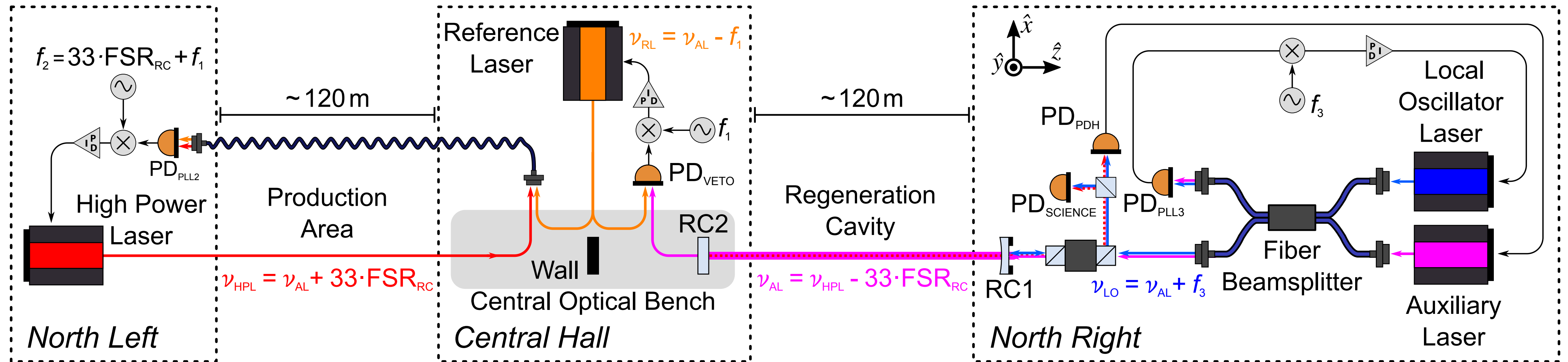


A.D. Spector *et al.*, arXiv:2601.18684.

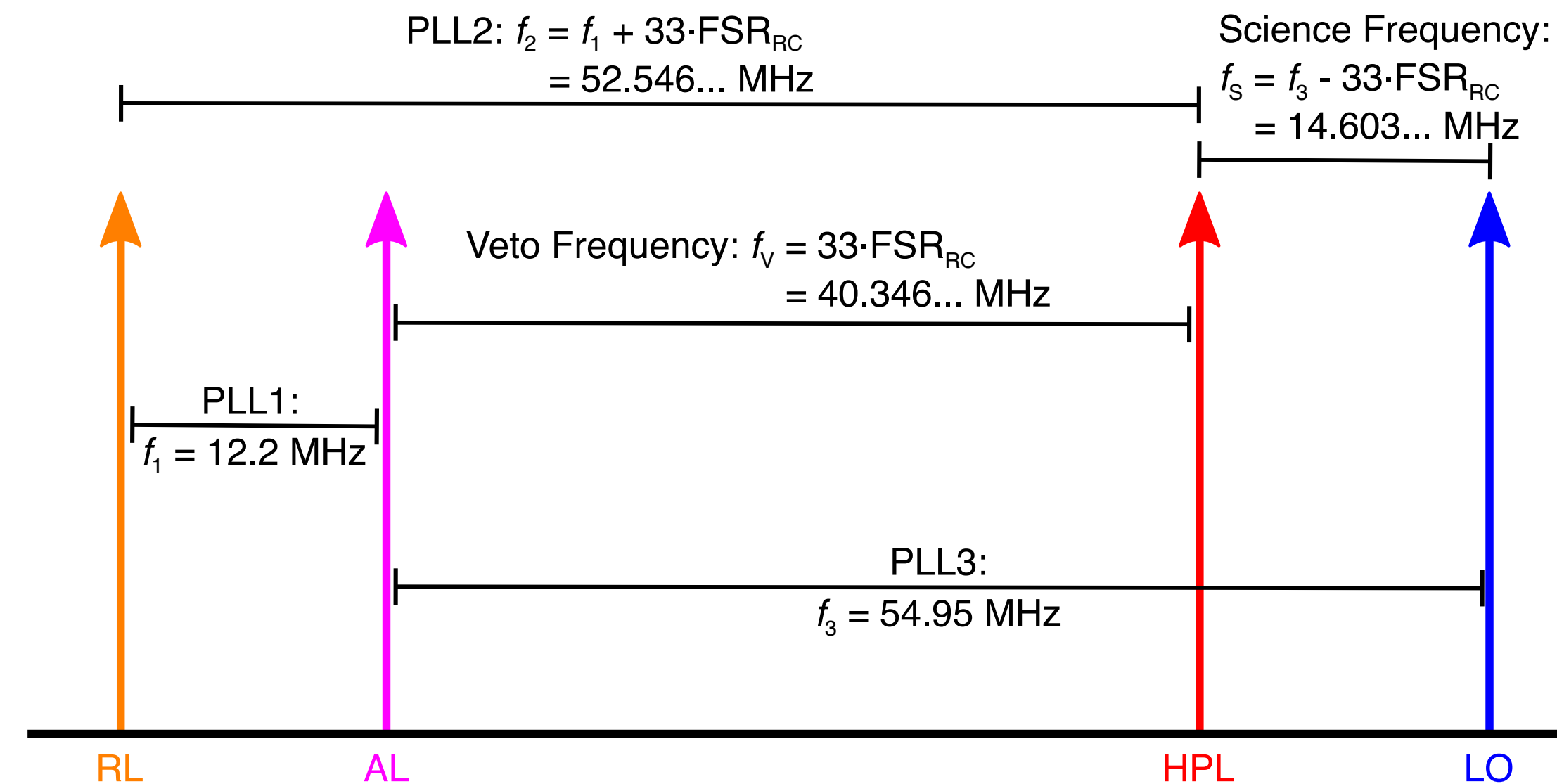
- ① Auxiliary laser is resonant in the regeneration cavity
- ② Reference laser is phase-locked using transmitted light of the auxiliary laser
- ③ High power laser is phase-locked to the reference laser
- ④ Local oscillator laser is phase-locked to the auxiliary laser
- ⑤ Obtain beat note between the high power laser derived signal regenerated after a wall and local oscillator (heterodyne detection)

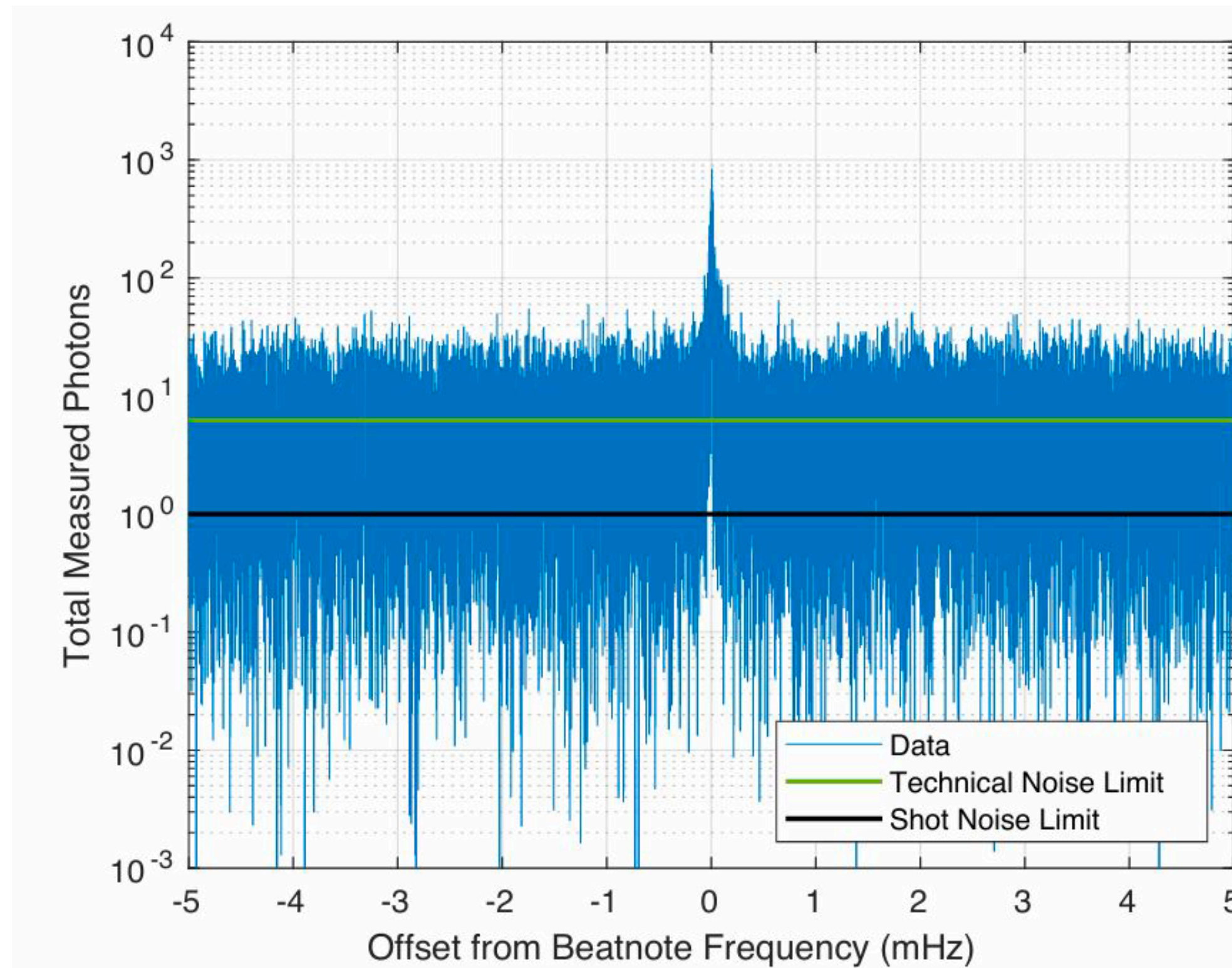
ALPS II setup for first run

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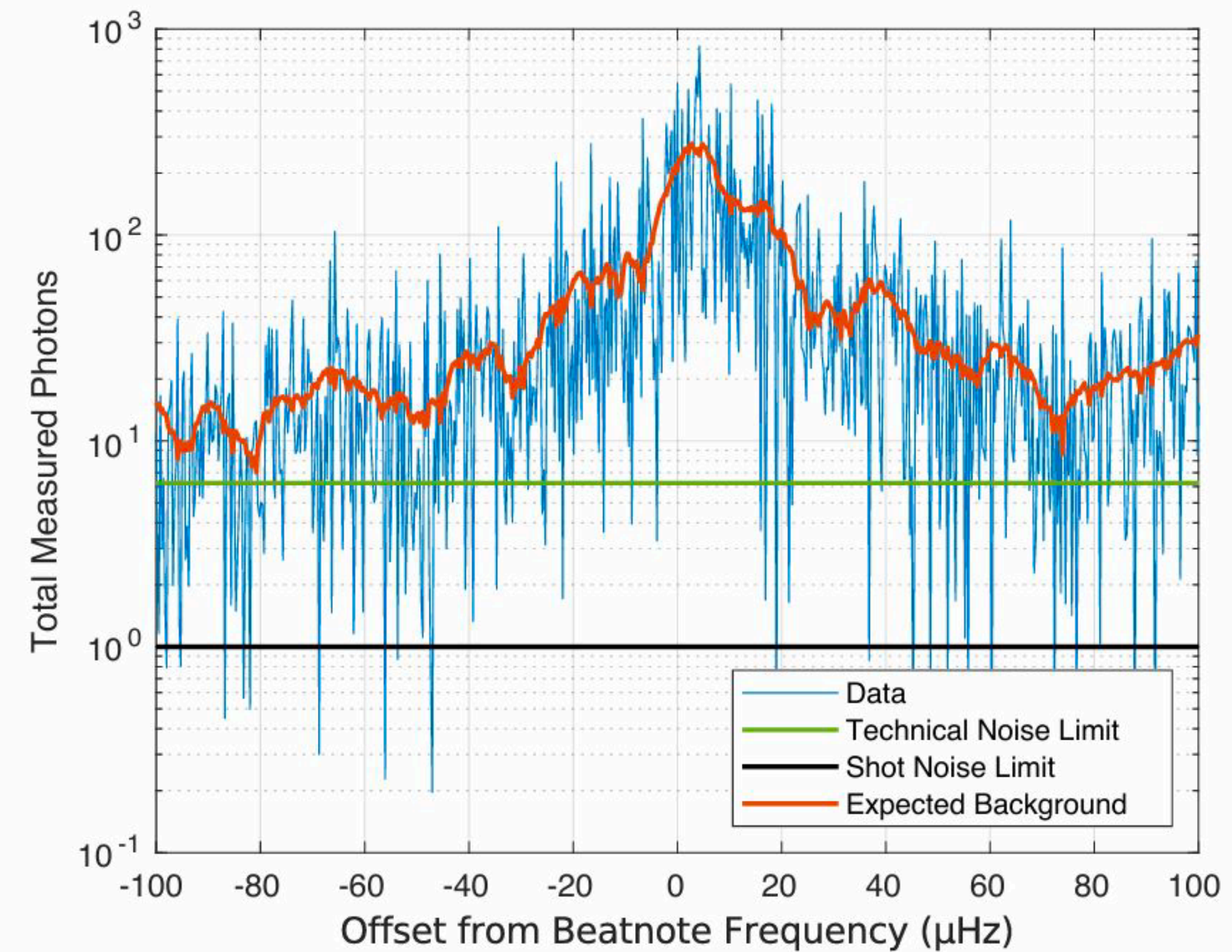


A.D. Spector *et al.*, arXiv:2601.18684.





D. C. Brotherton *et al.*, arXiv:2512.14110.

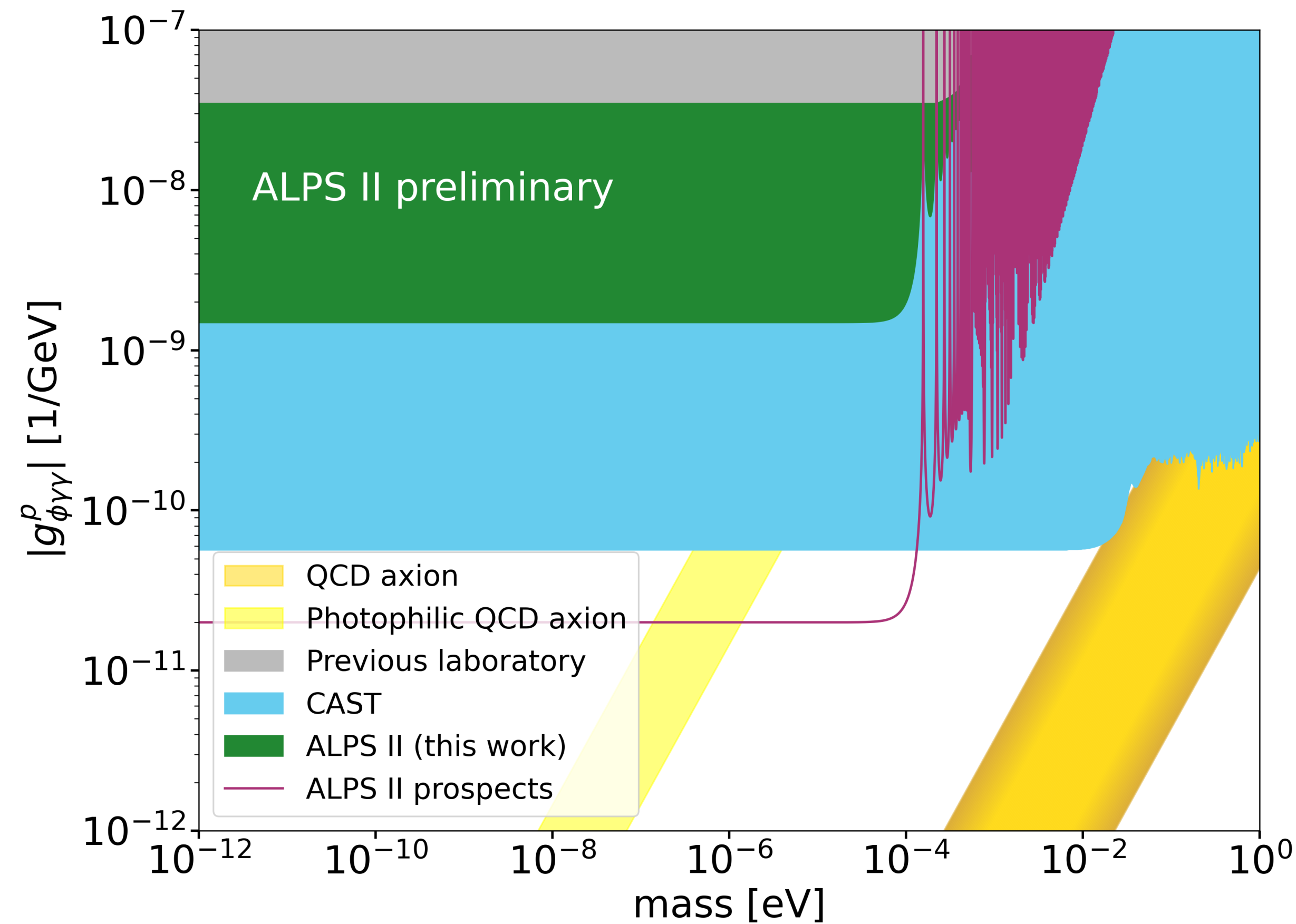


A.D. Spector *et al.*, arXiv:2601.18684.

- Total measured photons around the heterodyne frequency
- Observation time: 580,000 s (~ 6.7 days) for injected laser light polarized parallel to the magnetic dipole field
- No beyond the standard model physics signal present

Limits on pseudoscalar bosons

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$$|g_{\phi\gamma\gamma}^p| < 1.5 \times 10^{-9} \text{ GeV}^{-1} \text{ for } m_a < 0.1 \text{ meV (95\% C.L.)}$$

- Axion Dark-Matter Birefringent Cavity (ADBC) experiment has already finished
- Joscha Heinze, the first author of Laser-Interferometric Detector for Axions (LIDA) experiment, has moved to another institution, it is unclear whether the project has been handed over to someone else or completely halted
- DANCE might be the only active tabletop experiment using a ring cavity

- Title: Sensitivity improvement of Dark matter Axion search with riNg Cavity Experiment (DANCE)
 - Simultaneous resonance with a critical couple cavity
 - Latest sensitivity
- I feel like I went into too much detail of the experiment, so the audience's reaction was a bit flat
- I got one question
 - About how to adjust cavity non-planarity

IDM2026 (16th International Workshop on the Identification of Dark Matter 2026)

- Goal: to present a comprehensive overview of the status of dark matter searches, covering theoretical and experimental perspectives across theories, candidates, and detection strategies
- June 1st - 5th, 2026
- Paraninfo, University of Zaragoza, Zaragoza, Spain
- Hold once every 2 years



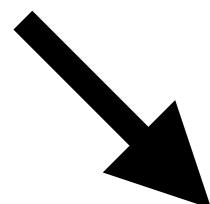
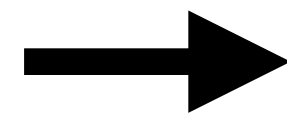
Venue of IDM2026

13



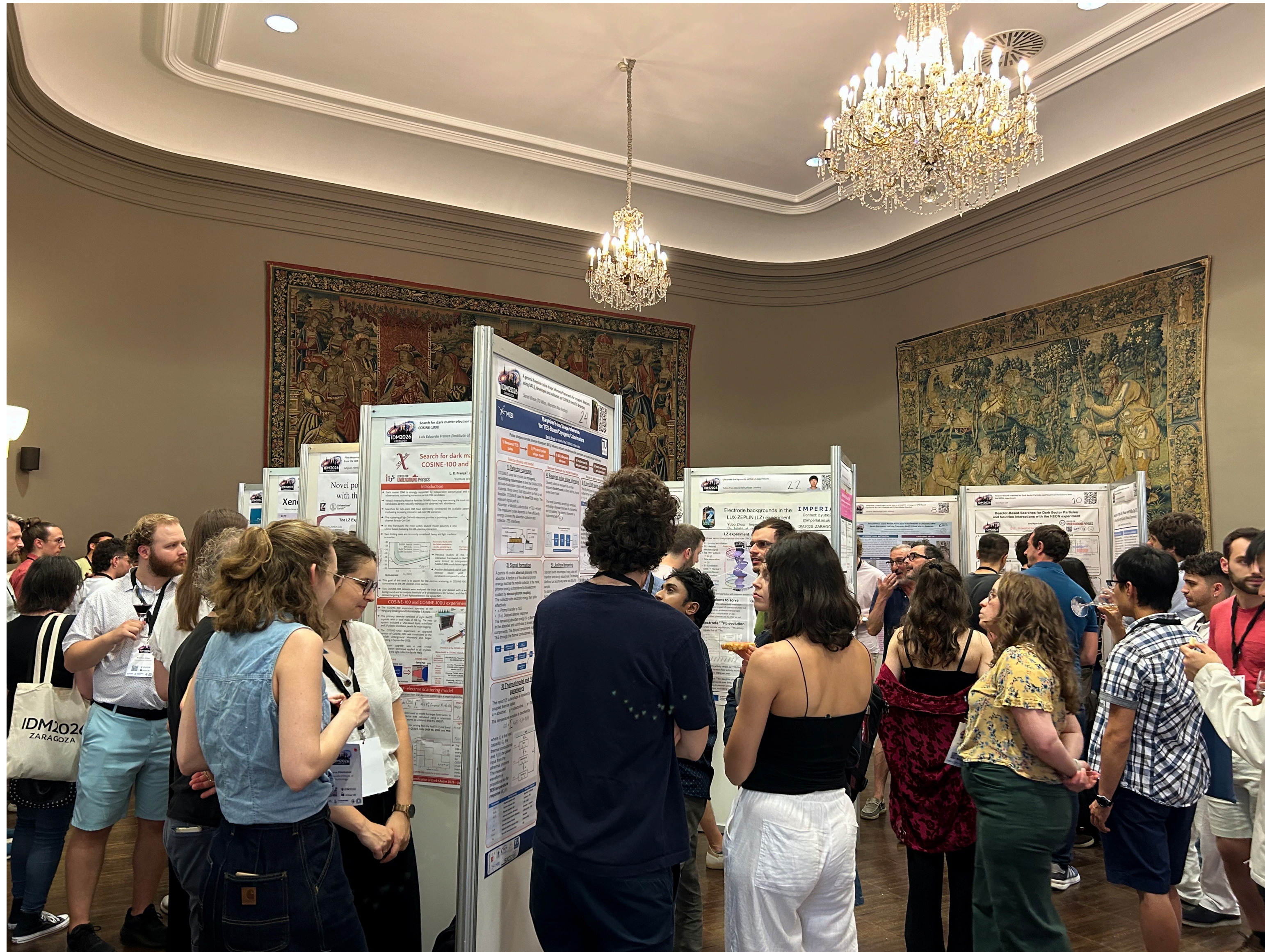
Venue of IDM2026 (entrance & talk)

14



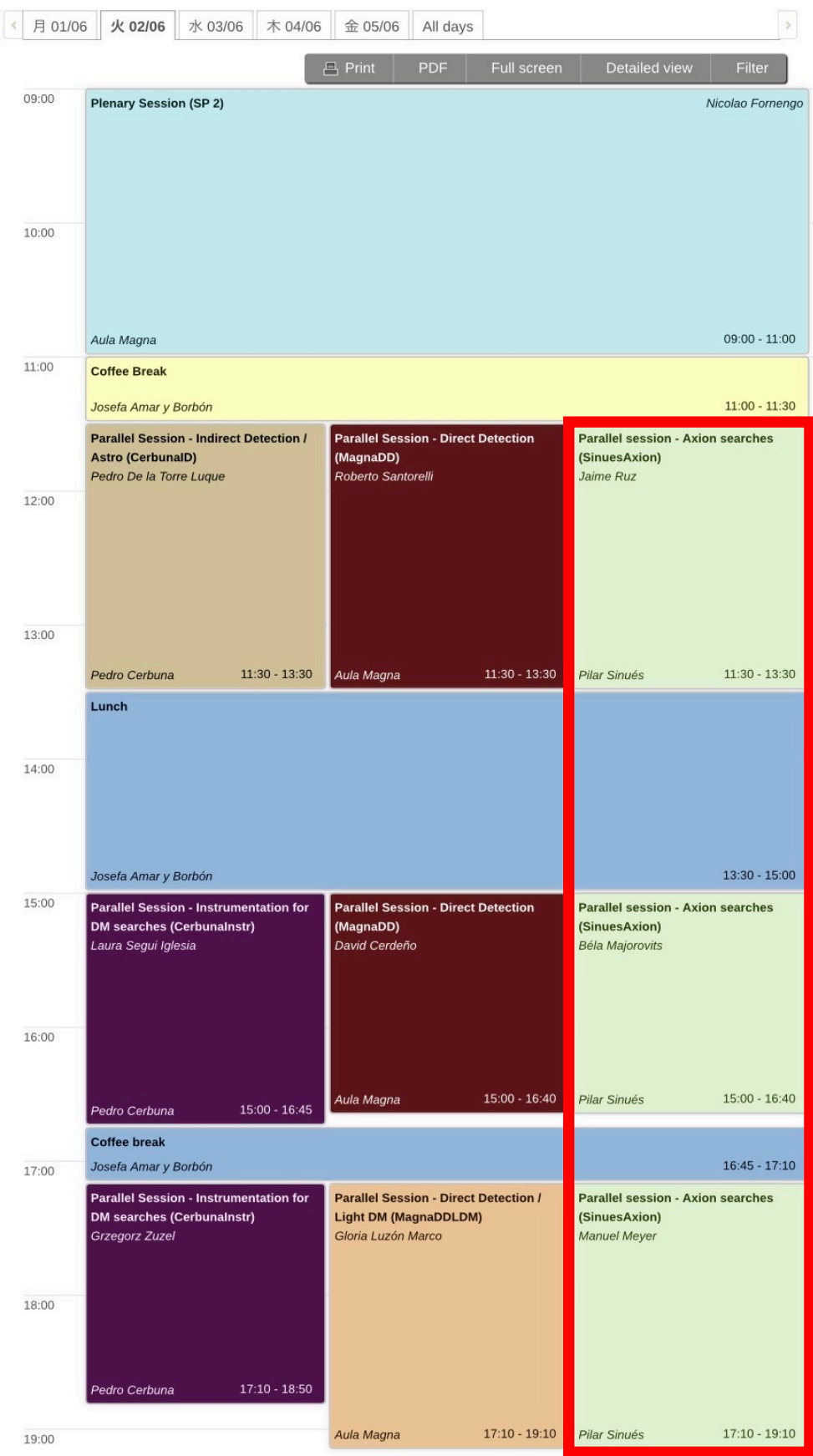
Venue of IDM2026 (poster)

15

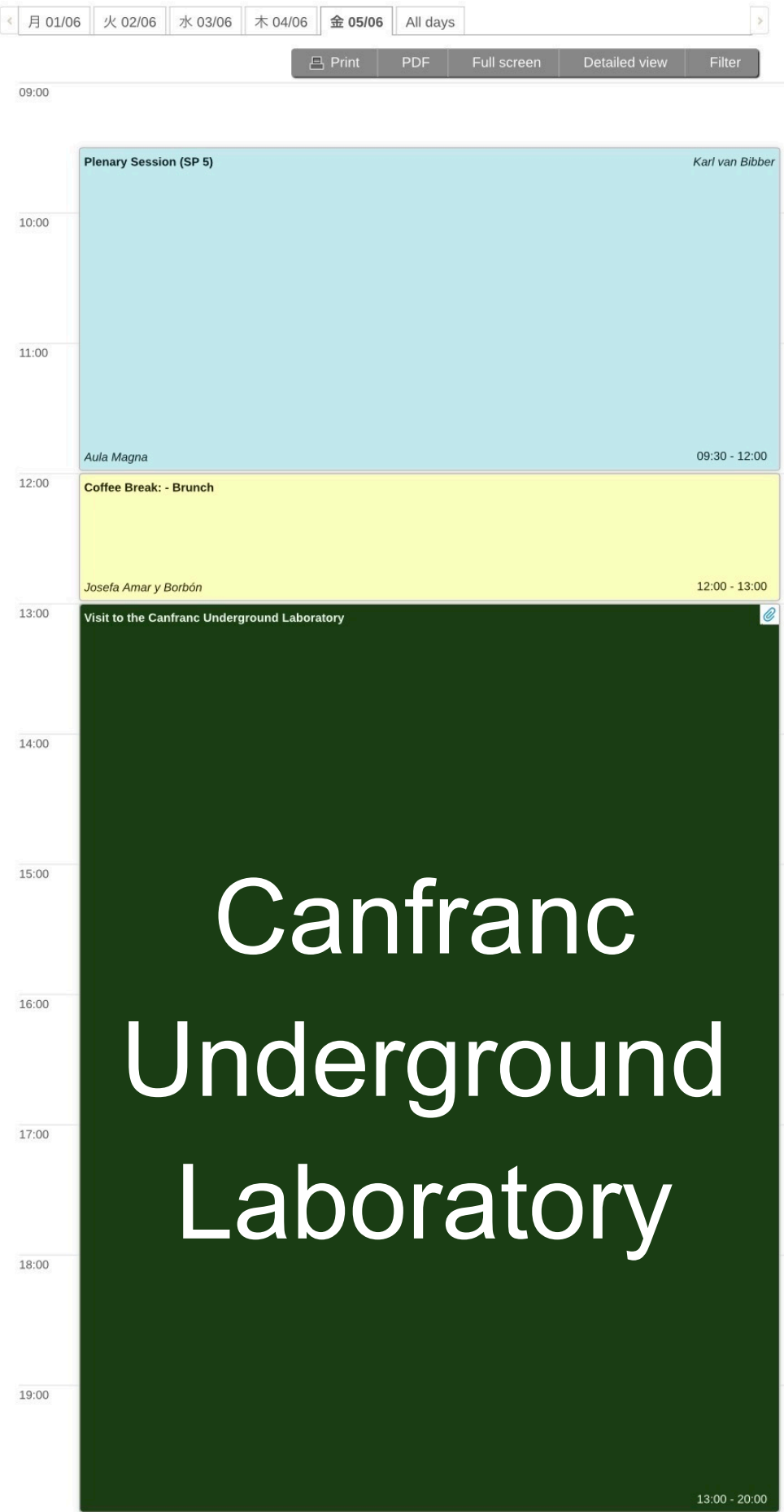
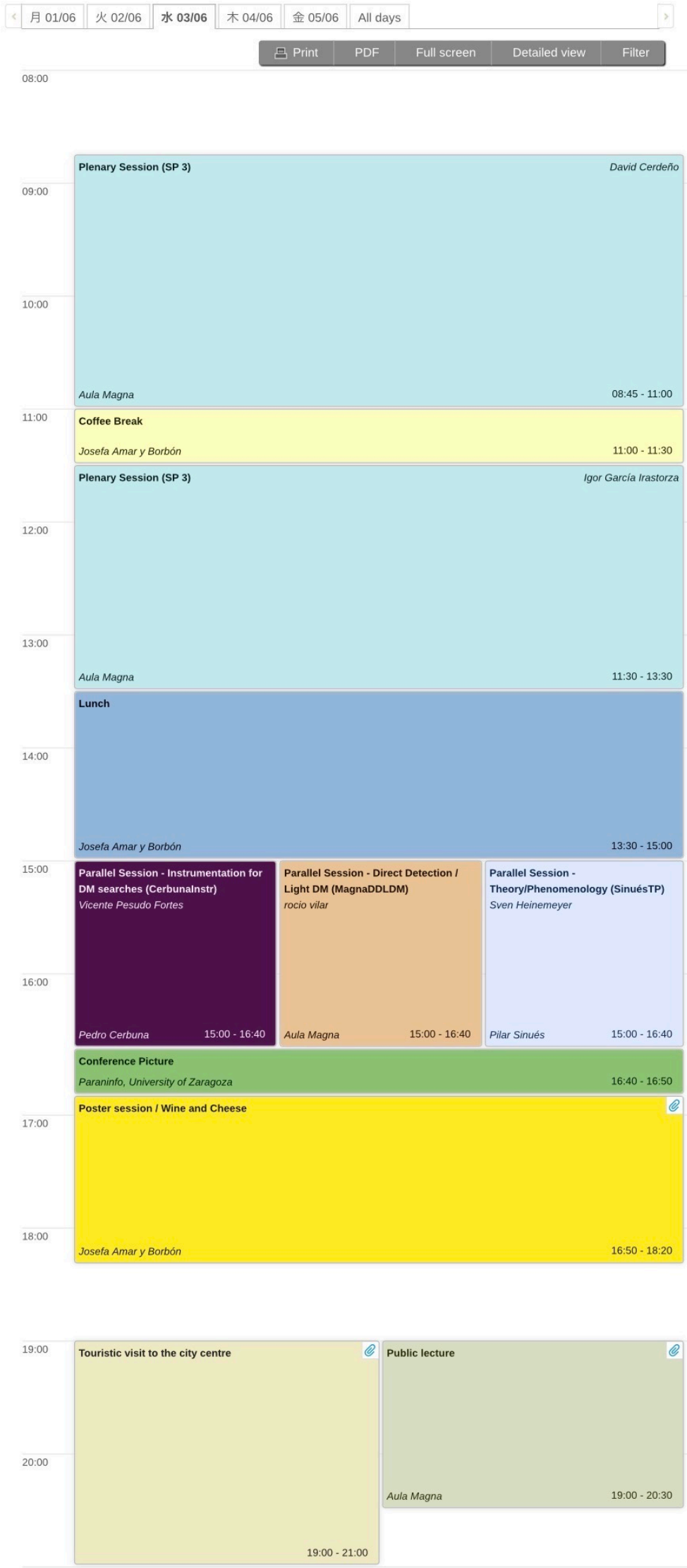


Wine & Cheese

Timetable



Axion searches



Canfranc
Underground
Laboratory

- Many of the talks and posters focused on proposing new techniques and reporting commissioning progress
- Since IDM covers dark matter searches over a broad mass range, each mass region requires different experimental techniques, which makes it difficult to fully understand every approach
- Only two Japanese participants, including me
- A few people who attended IDM2024 remembered me

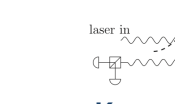
Searching for Ultralight Dark Matter with MOLeQuTE : a Massive Optically Levitated Quantum Tabletop Experiment *

Louis Hamaide – Johannes Gutenberg Universität Mainz

Novel mechanical quantum sensors

- **Mechanical quantum sensors (MQS)** are (e.g. macroscopic) quantum harmonic oscillators whose motion is readout by an external field (optical/ electric/magnetic) and whose noises are limited by **quantum fluctuations** of this field
- Both harmonic oscillators and ULDM have high Q making MQS good at detecting oscillating ULDM forces on resonance
- Recent new sensor concepts use the external field for trapping **AND** reading out the motions, but their noises & applications required further study:

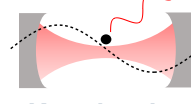
Cavity (old):



Key advantage

Sensor resonant frequency is tunable to scan for ULDM (or GWs!).

Tweezer (new):



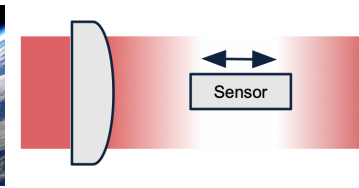
Key disadvantage

Noise no longer tunable independently of frequency

- New key insight: **larger optically trapped sensors perform better** IF larger than optical wavelength (geometric optics rather than Rayleigh regime)

Several future directions (preliminary)

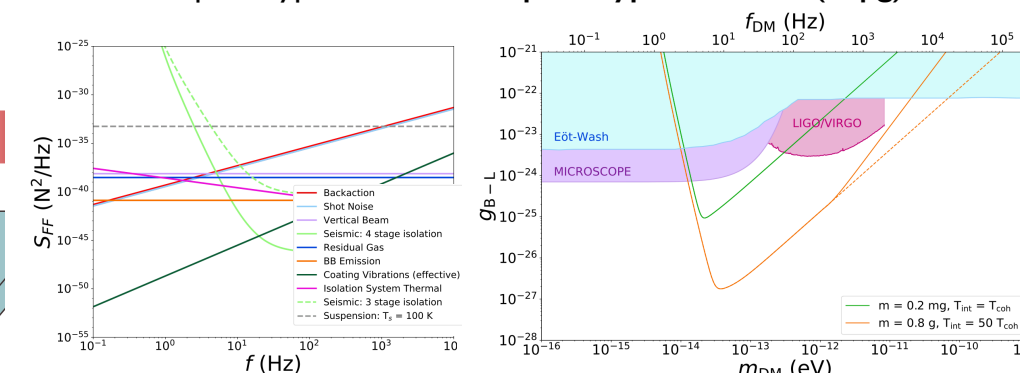
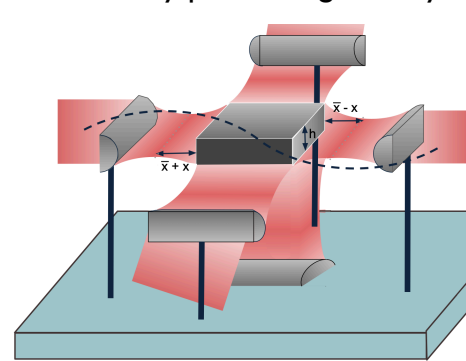
- MOLeQuTE reaches the 'Standard Quantum Limit' (SQL) by balancing large photon statistics ('shot noise') with minimal excitation of sensor motion ('backaction'). Generically optically trapped sensors only achieve off-resonance SQL. **Engineered optical beams** can easily improve this, leading to $>10^2$ improvements of sensitivity



- Seismic noise limits our sensitivity at low ULDM mass/frequency → **MOLeQuBE: compact (cubesat) space mission** is both an **affordable** solution ($<1M€$) and provides access to probing new parameter space for low mass (sub-Hz) dark matter
- Searching new parameter space of **DM self-interactions** via **bosenovae** signals (bursts) in miniclusters
- **Axion searches:** new fermion+EDM coupling parameter space using electric/magnetic fields and spin-polarized materials

State-of-the-art ULDM detection with MOLeQuTE

- We propose **MOLeQuTE** : first macroscopic O(mg-g) optically levitated sensor in the geometric optics regime where **optical noises** $\propto \text{mass}^{1/2}$ while **signal** $\propto \text{mass}$, leading to $\times 10^5$ improvement compared to levitated nanoparticles. Our key limitation is the large optical powers required at large mass and/or high frequencies
- MOLeQuTE traps and reads off the sensor's motion between the foci of two **opposing optical beams** in each direction. We avoid melting from optical absorption with to a **large aspect ratio** (thin plate shape) which provides more surface area to **cool via blackbody radiation**
- We will search for **scalar** (e.g. dilatons/moduli) or **gauge vector** (e.g. from B-L conserving dark U(1)) ultralight dark matter coupling which produce oscillating forces near the ULDM Compton frequency
- Full theoretical study of **systematic noises and stability** performed in 2025, showing quantum limit of noise achievable at 100K and a seismic damping system
- Currently performing stability simulations and prototype fabrication → **prototype levitation (10 μ g) late 2026**



* arxiv.org/abs/2512.00166, accepted in PRR

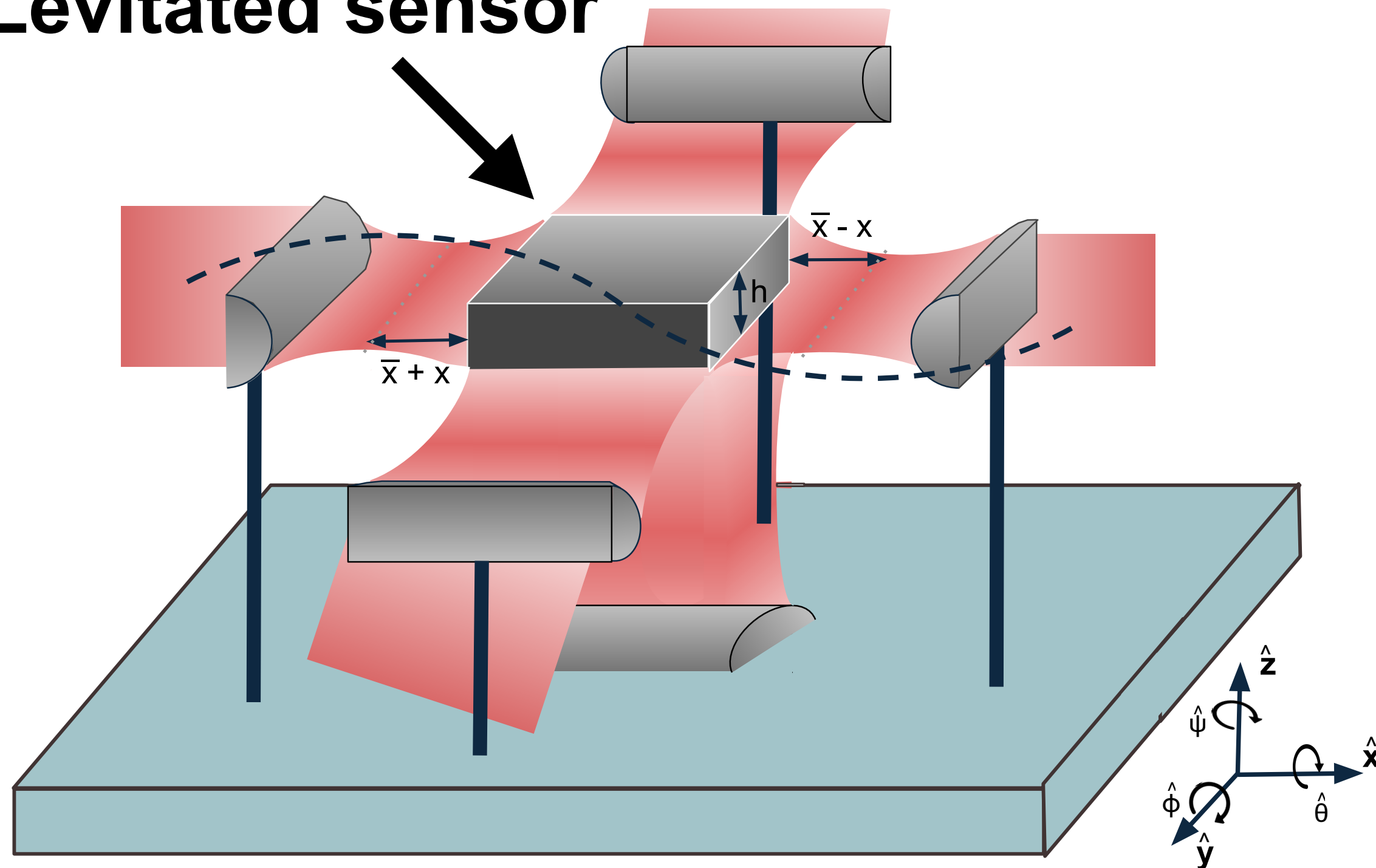


Alexander von
HUMBOLDT
STIFTUNG

- Based on “Searching for Ultralight Dark Matter with MOLeQuTE: a Massive Optically Levitated Quantum Tabletop Experiment” submitted by arXiv:2512.00166, accepted in Physical Review Research
 - New, tunable, optically trapped sensor specifically designed to detect forces on macroscopic objects
 - Sensor resonant frequency is tunable to scan for ultralight dark matter (ULDM)
 - Sensitivity projections and the optimization of quantum noise for B-L dark matter search
- Further discussion is needed

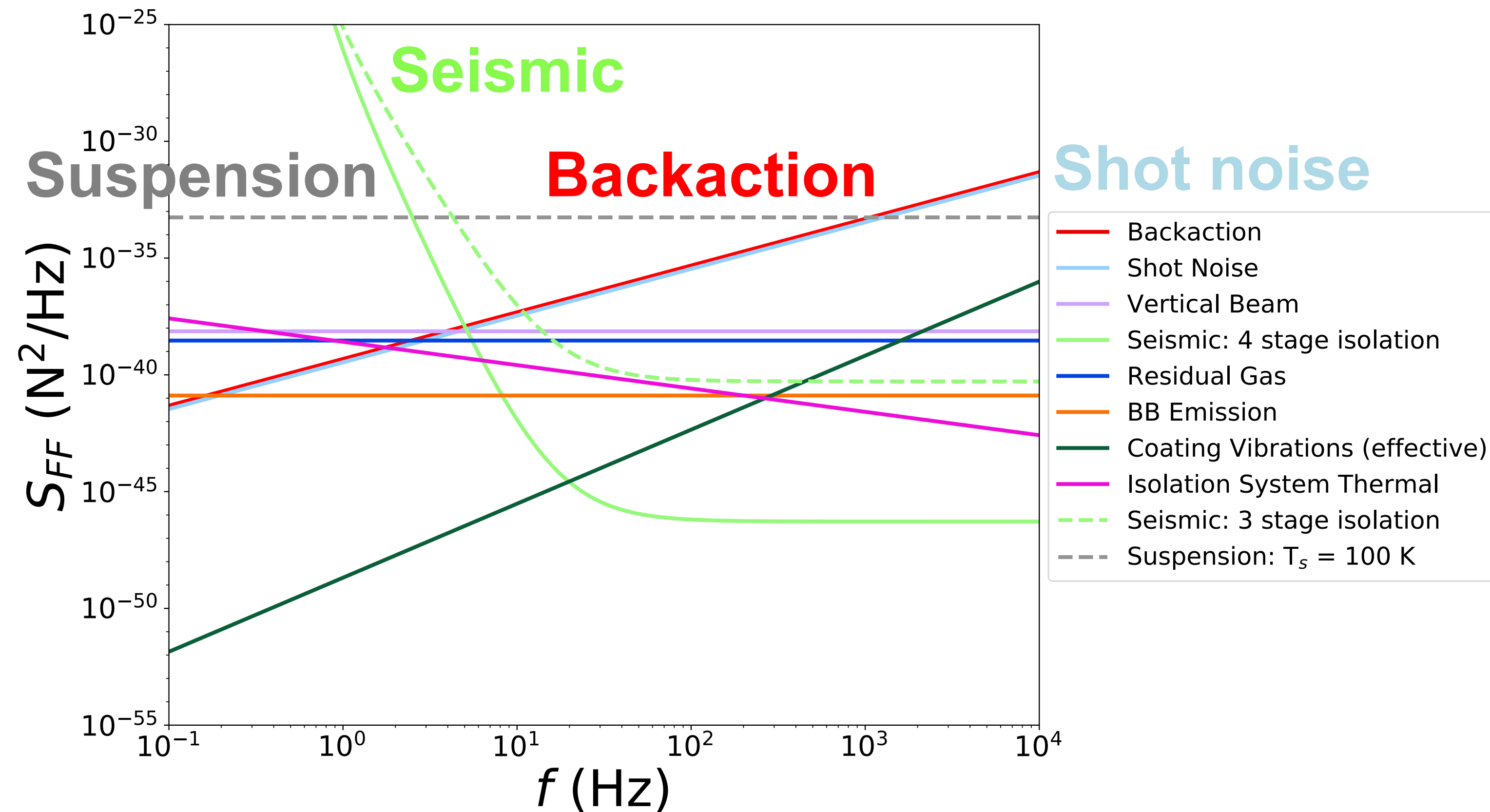
Poster

Levitated sensor

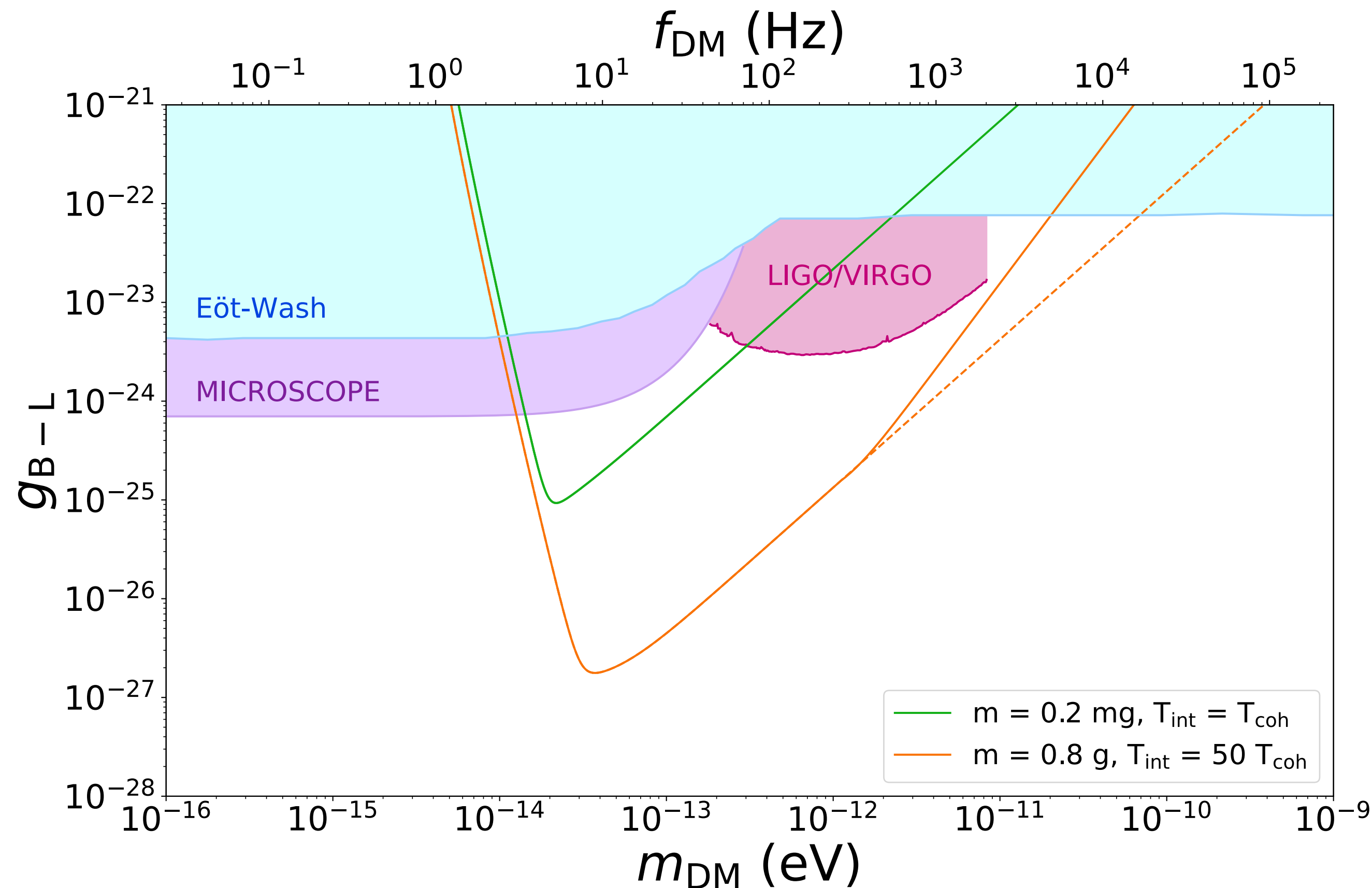


- First macroscopic $O(\text{mg-g})$ optically levitated sensor in the geometric optics regime
- ➔ The sensor is trapped between the foci of two opposing optical beams in each direction, allowing its motion to be measured
- Search for ULDM coupling which produce oscillating forces near the ULDM Compton frequency

MOLeQuTE reaches the standard quantum limit (SQL) by balancing shot noise (large photon statistics) with backaction (minimal excitation of sensor motion)

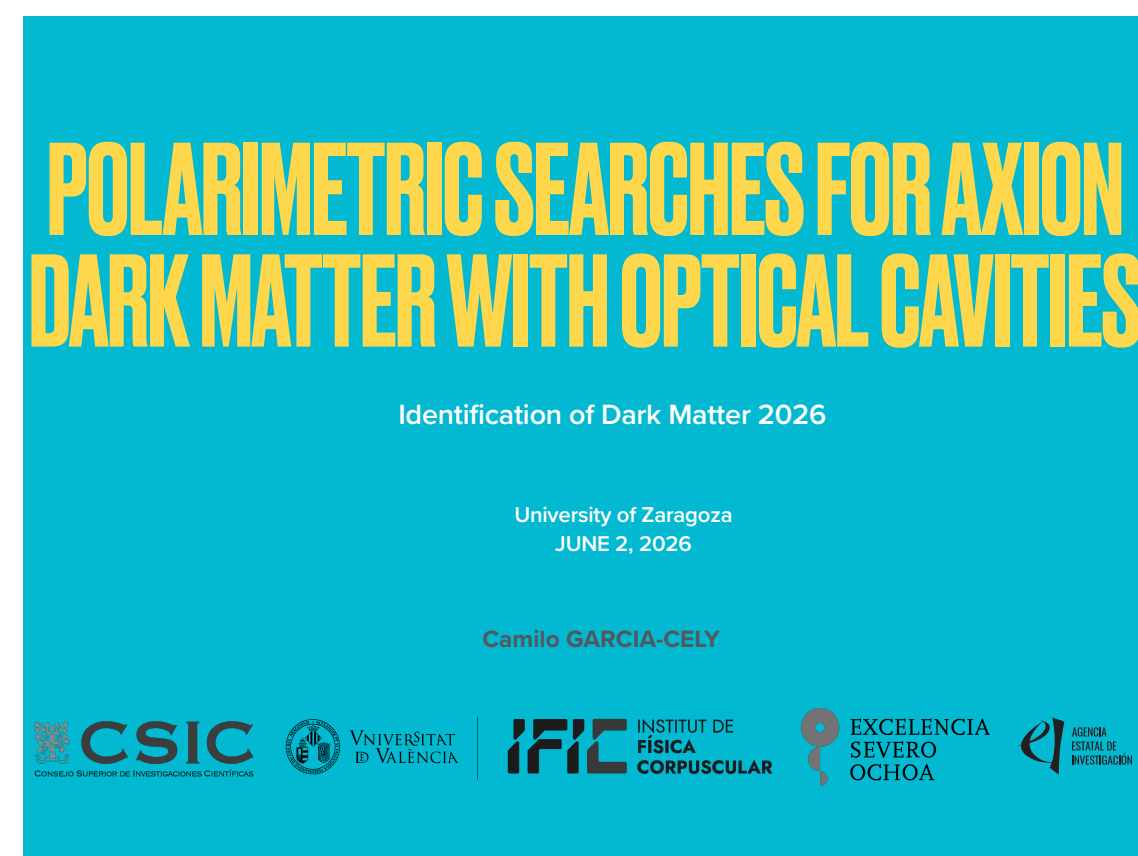


- Full theoretical study of systematic noises and stability
- ➡ Quantum limit of noise achievable at 100 K and a seismic damping system
- Levitation is preferable to suspension

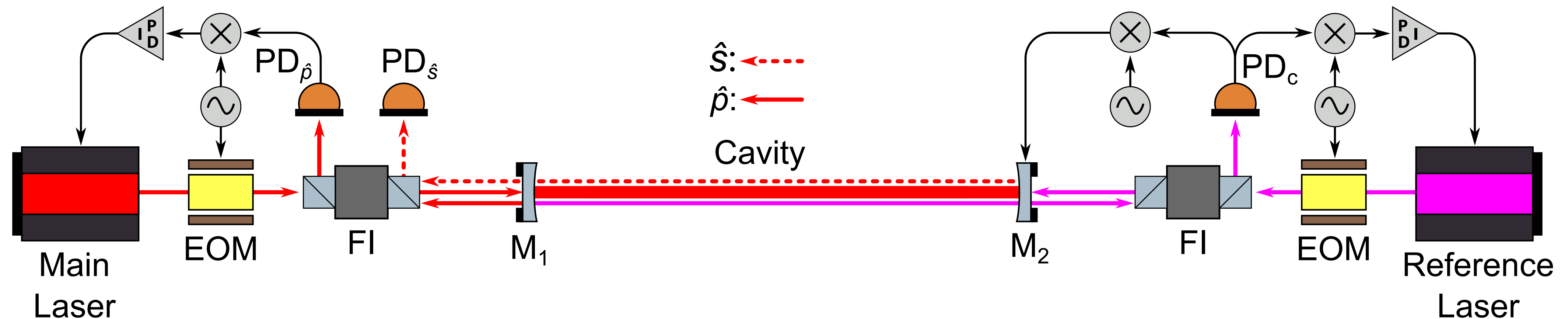


- Broadband B-L dark matter search by scanning the sensor resonant frequency
- Note that they ignore the small step-like behavior between each separate data-taking frequency bin

- Session: Axion searches (after me)
- Based on “Polarimetric searches for axion dark matter and high-frequency gravitational waves using optical cavities” published by Phys. Rev. D **112**, 023031 (2025)
 - Birefringence effects that occur as light propagates through axion dark matter or the background of a passing gravitational wave
 - Can be theoretically described by the unified formalism
- Plan to construct optical system at DESY, located in Hamburg, Germany

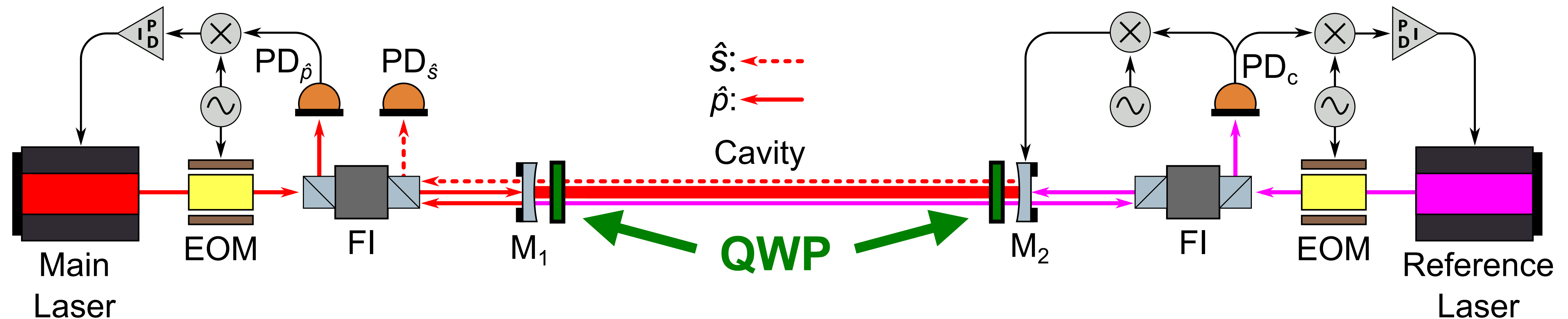


- Axion DM: rotation of linear polarization
- High-frequency GWs: polarization change (The light polarization changes, though the effect goes beyond a simple polarization rotation about the direction of motion)



QWP	l [m]	$P_{\max}$ [kW]	(t_1^2, t_2^2, ℓ^2) (ppm)	$\mathcal{F}$	$m_{\max}$ (eV)	τ_{storage} (ms)
No	245	150	(22, 2, 20)	1.4×10^5	4.2×10^{-8}	74.2
Yes	245	10	(1100, 100, 1000)	2.9×10^3	2.1×10^{-6}	1.48
No	20	50	(11, 1, 10)	2.9×10^5	2.6×10^{-7}	12.1
Yes	20	10	(1100, 100, 1000)	2.9×10^3	2.6×10^{-5}	0.121

- Carrier: p-polarization
- Signal sideband: s-polarization
- Obtain signal sideband at reflected PDs
- Introduce reference laser to stabilize M2 mirror by beating transmission of main laser

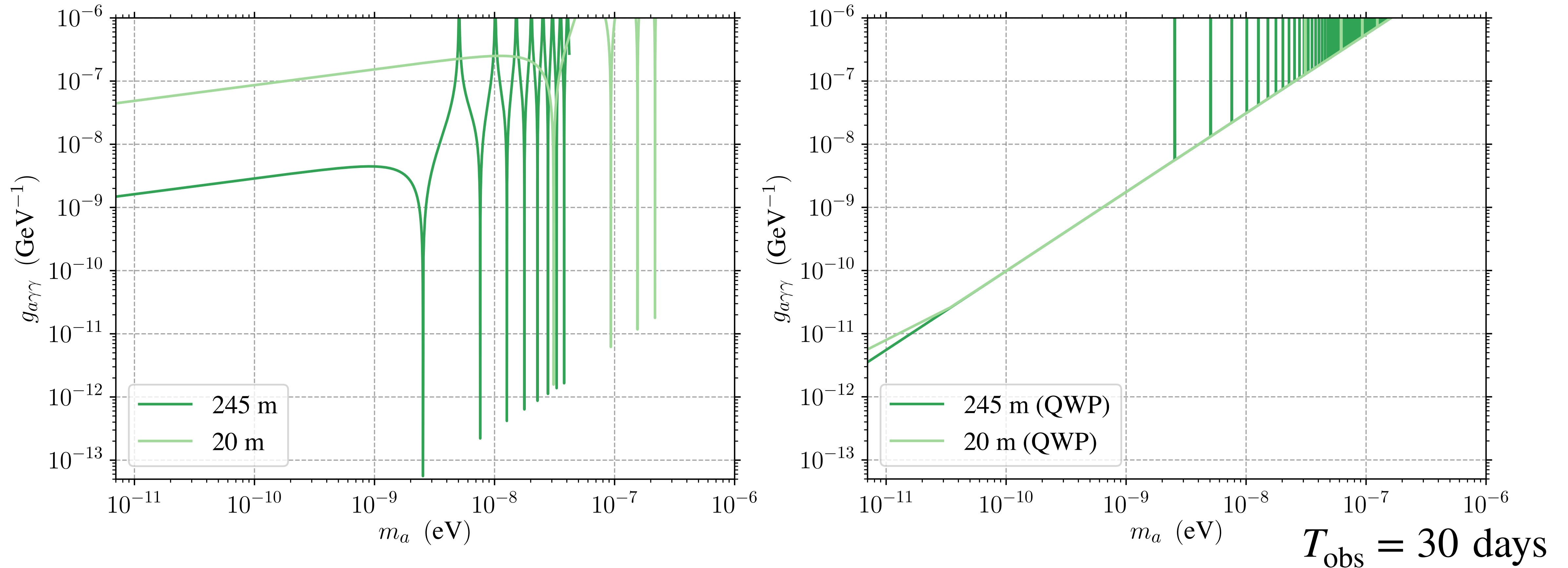


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- Carrier: p-polarization
- Signal sideband: s-polarization
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- Introduce reference laser to stabilize M2 mirror by beating transmission of main laser

Projected sensitivity to axion DM

25

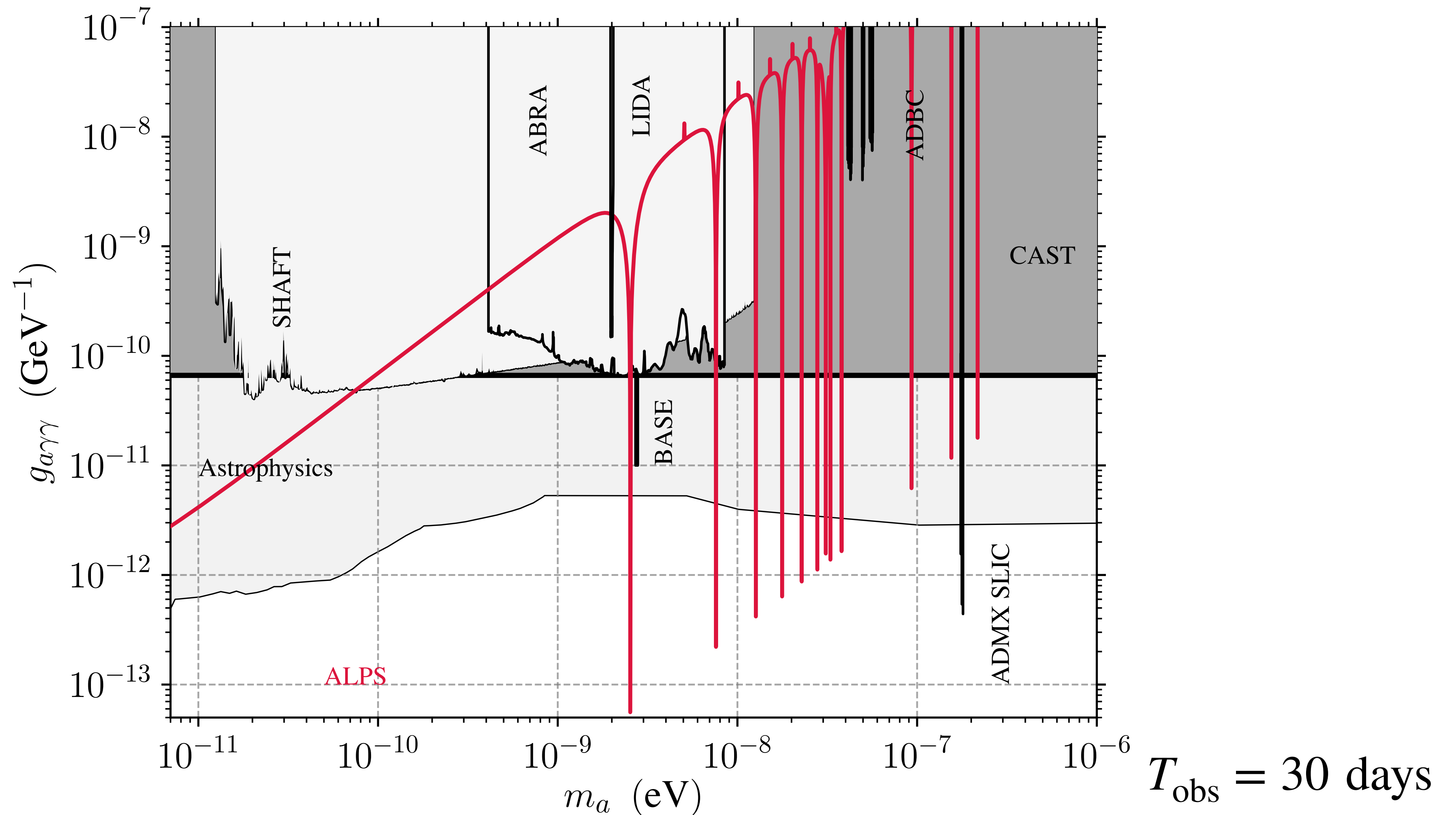


- Without QWPs (left): sensitive at odd multiples of the FSR
- With QWPs (right): sensitive to lower axion masses

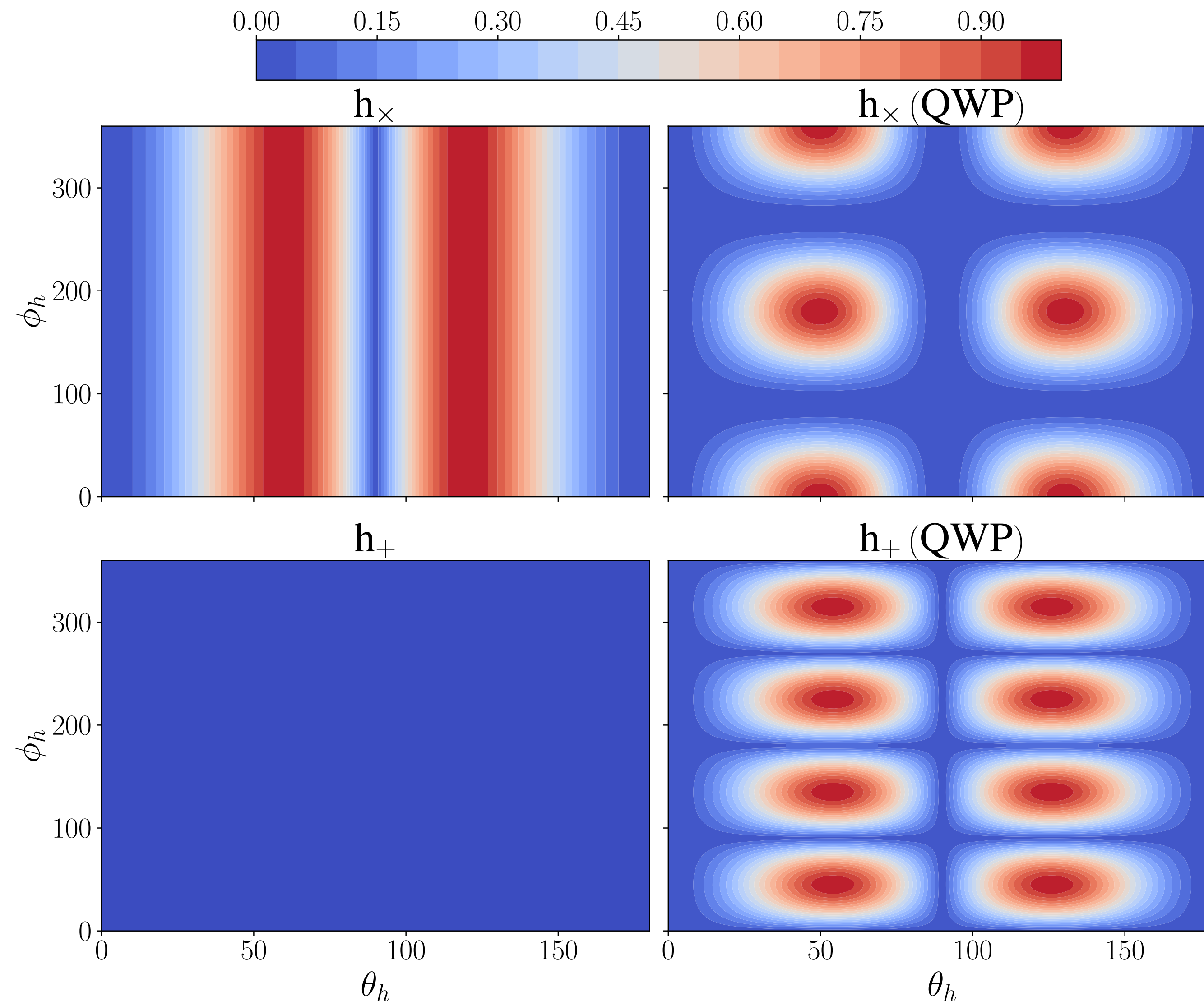
Combined projections to axion DM

26

Combined projections of the 20 m and 245 m cavities with and without QWPs



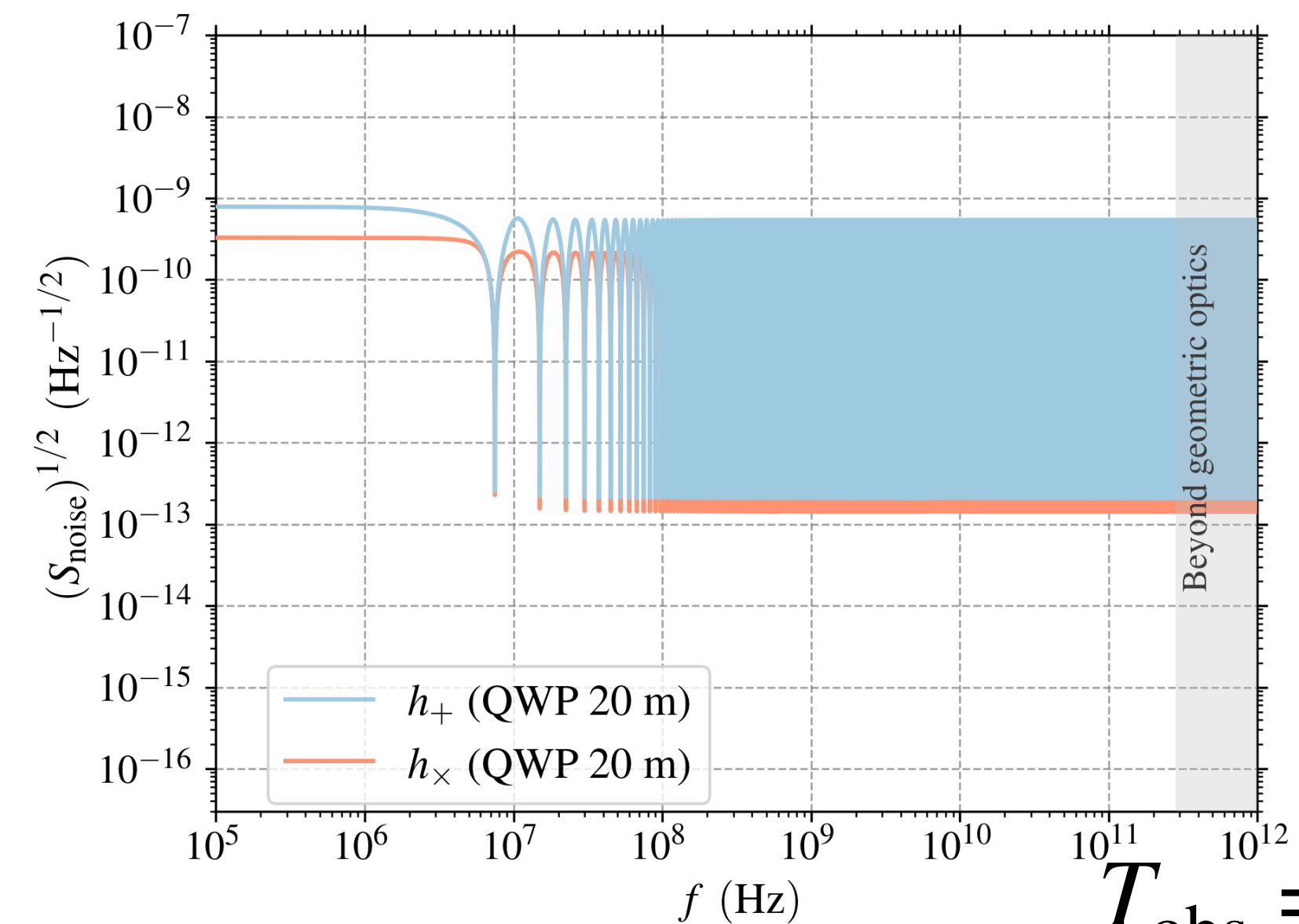
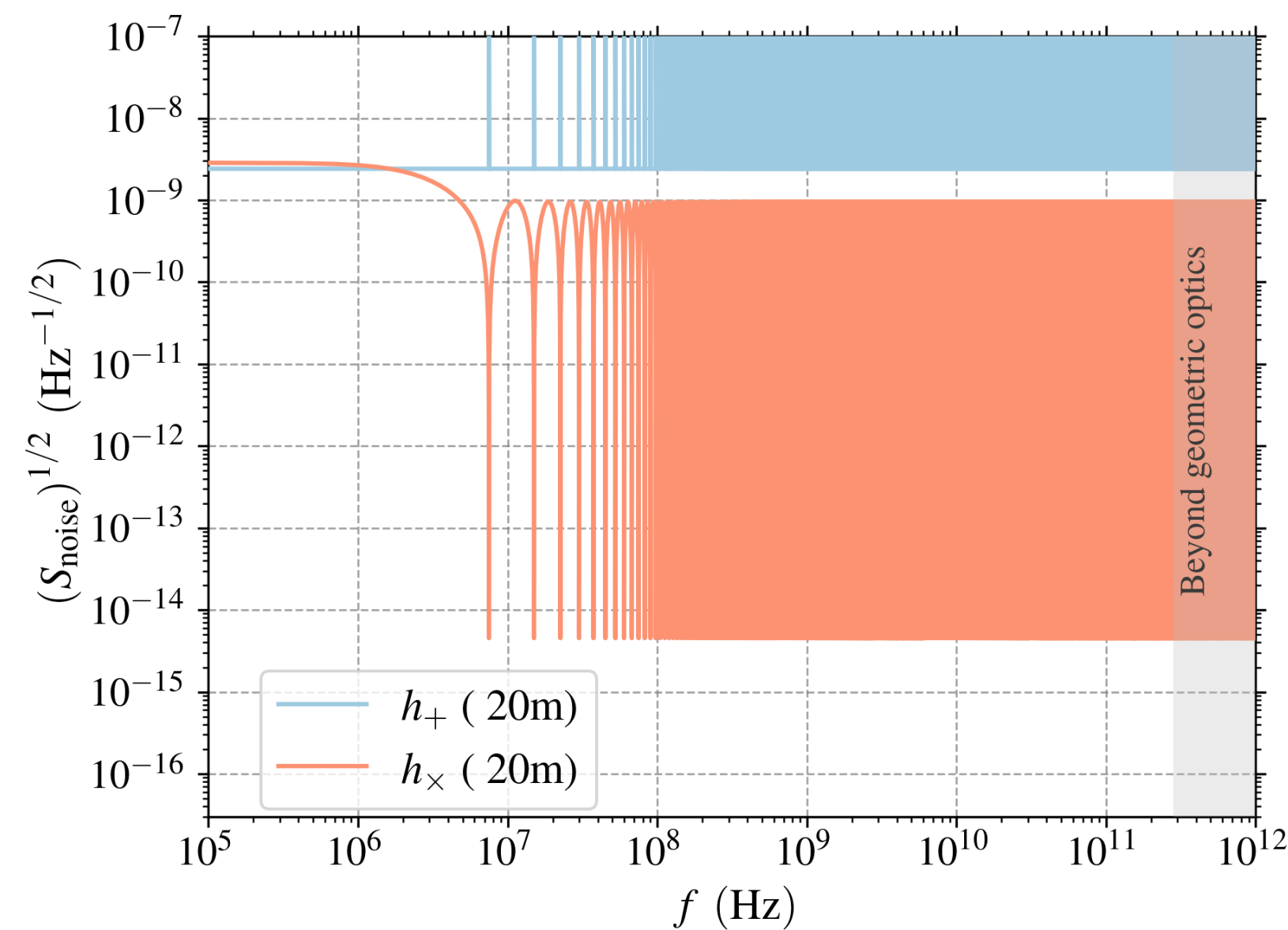
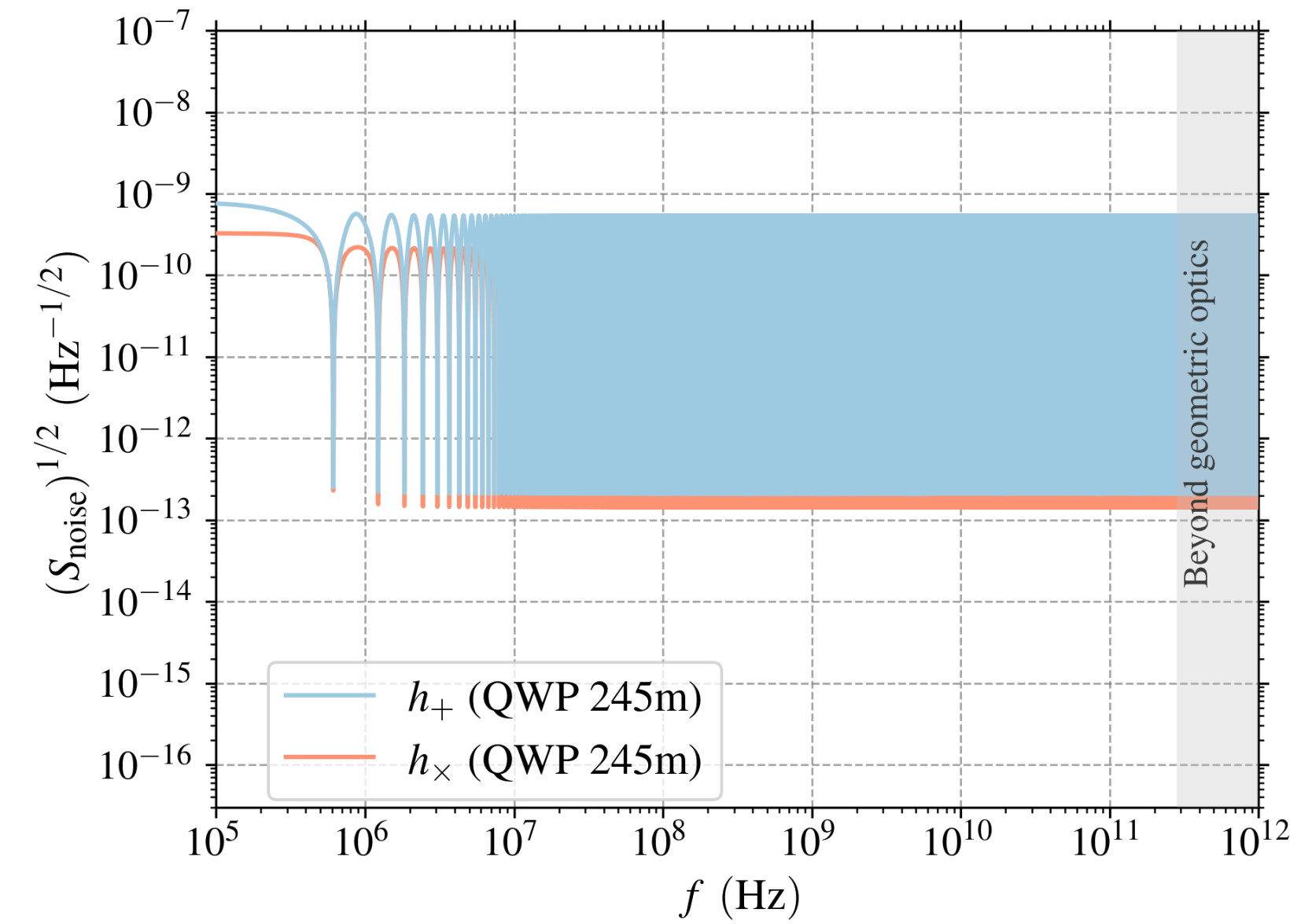
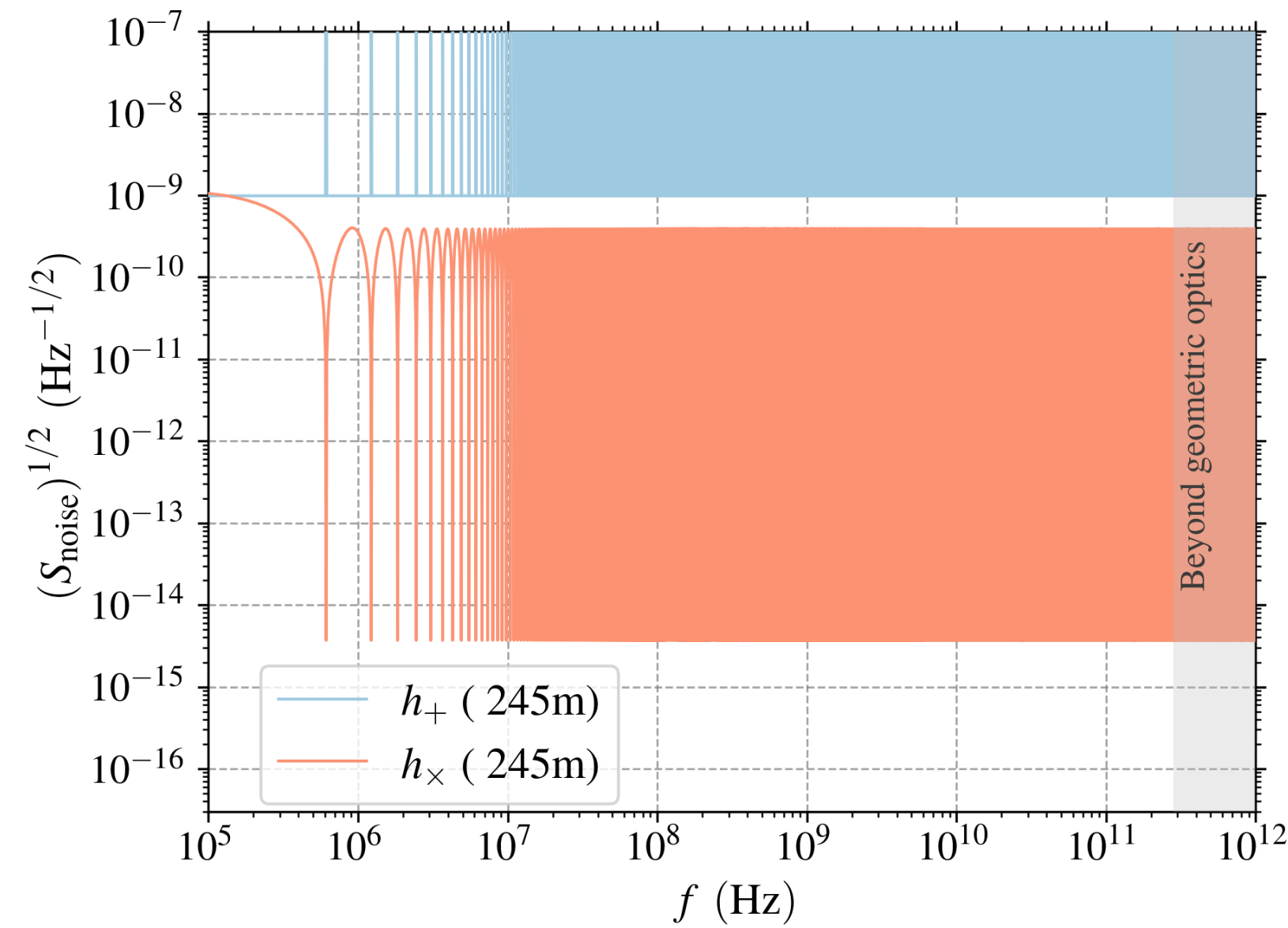
Antenna patterns of the response functions 27



- Normalized antenna patterns of the second cavity resonance, $f = 2f_{\text{FSR}} = c/l$
- Linear cavity becomes sensitive to both the plus and cross modes by using QWPs

Projected sensitivity to GWs

28



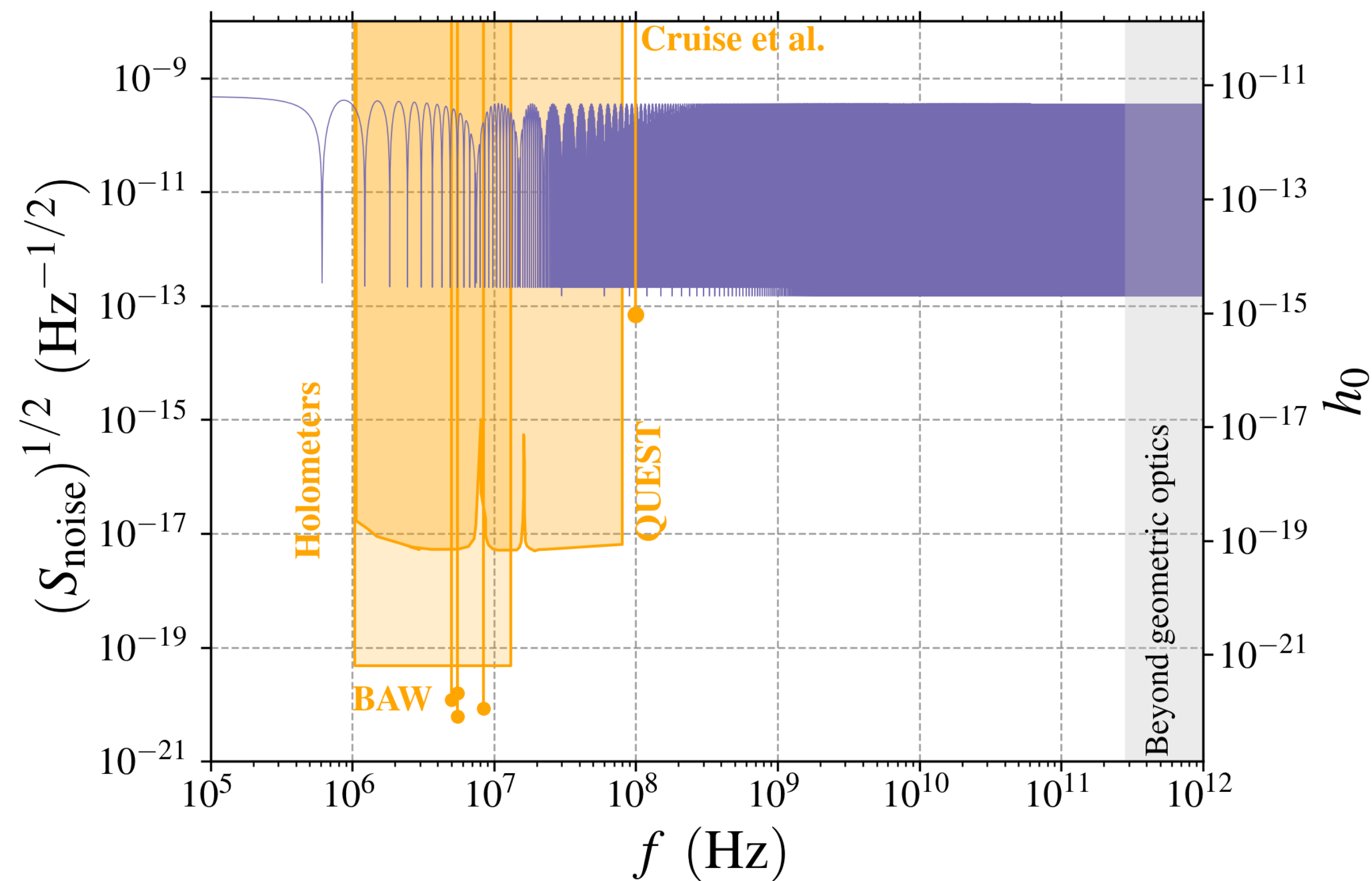
$T_{\text{obs}} = 1 \text{ year}, \tau = 1 \text{ s}$

Combined projections to GWs

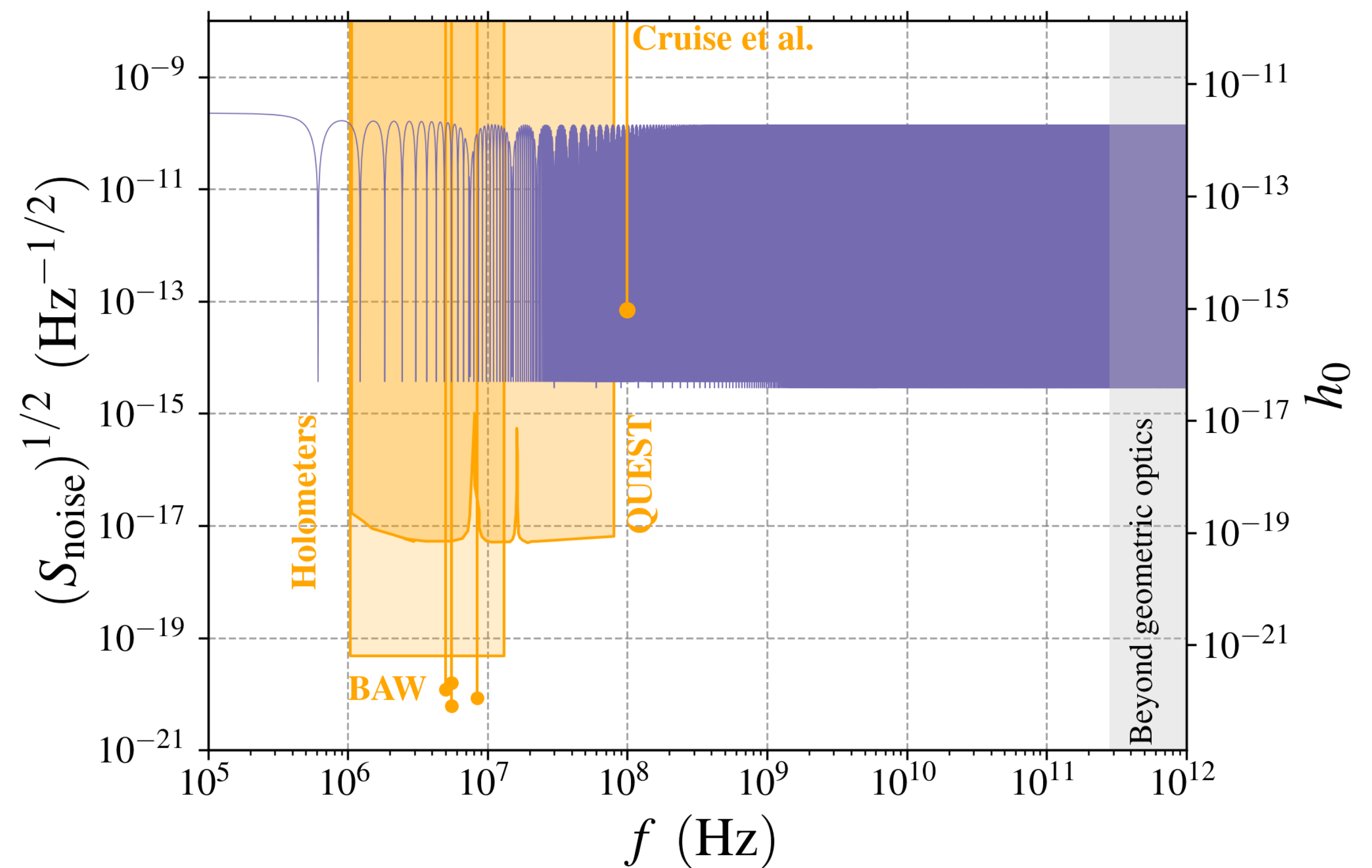
29

Combined projections of the 20 m and 245 m cavities with and without QWPs

Plus mode



Cross mode



$$T_{\text{obs}} = 1 \text{ year}, \tau = 1 \text{ s}$$

- Title: Dark matter Axion search with riNg Cavity Experiment (DANCE): Simultaneous resonance for sensitive broadband axion search
 - Simultaneous resonance with a critical couple cavity
 - Latest sensitivity
- I got two questions
 - Detail explanation about polarization rotation spectrum
 - Axion mass dependence of sensitivity
- A few people came up to me after my talk
 - Why not use a linear cavity?
 - About how polarization rotation occurs
 - Future prospects of DANCE

- I enjoyed discussing many researchers
- Attending two workshops in a short period of time was a valuable opportunity to improve my presentation skills
- “The important thing is not to stop questioning”

