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Grenoble Axion Haloscopes

The Grenoble Axion Haloscope project

(T. Grenet, Néel Institute)

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Brief reminder: cavity haloscopes

Sikivie Phys. Rev. D 32, 2988 (1985)

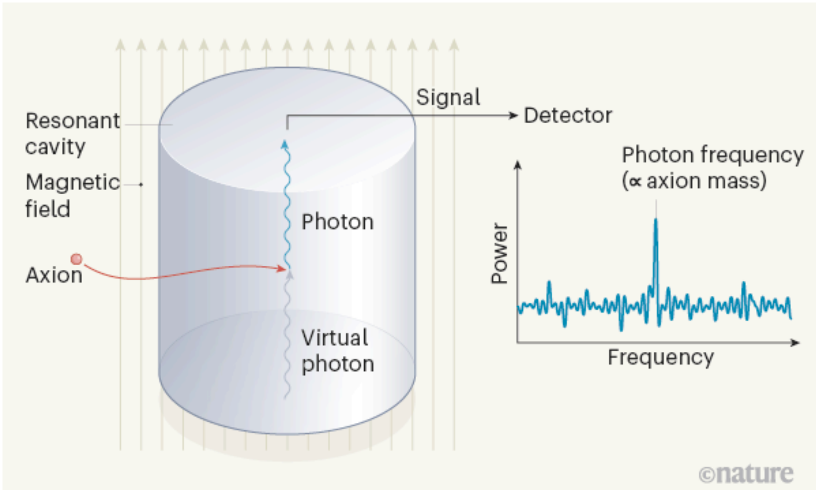
Axion electrodynamics :

$$\nabla \cdot \mathbf{E} = g_{a\gamma\gamma} \mathbf{B} \cdot \nabla a$$

$$\nabla \times \mathbf{B} - \partial_t \mathbf{E} = g_{a\gamma\gamma} \left(\mathbf{E} \times \nabla a - \mathbf{B} \partial_t a \right)$$

$$\nabla \times \mathbf{E} + \partial_t \mathbf{B} = 0$$

$$\nabla \cdot \mathbf{B} = 0$$



Picture from I. G. Irastorza, *Nature* **590**, 226-227 (2021)

Resonant conversion to RF photon in a strong magnetic field :

$$P = 2{,}67.10^{-25} (Watt) \left(\frac{g_\gamma}{0.97} \right)^2 \left(\frac{\rho_a}{0.45 GeV / cm^3} \right) \left(\frac{\beta / (1+\beta)^2}{2/9} \right) \left(\frac{C}{0.5} \right) \left(\frac{B_0}{10T} \right)^2 \left(\frac{f}{1GHz} \right) \left(\frac{V_{ol}}{1L} \right) \left(\frac{Q_L}{10^4} \right) \qquad (Q_L << Q_a)$$

$$1GHz = 4{,}13 \mu eV$$

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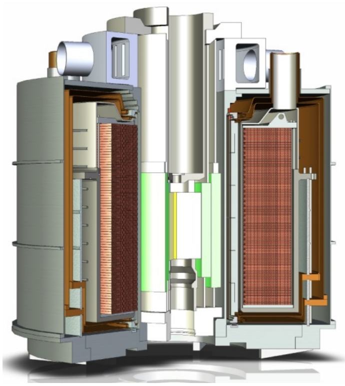
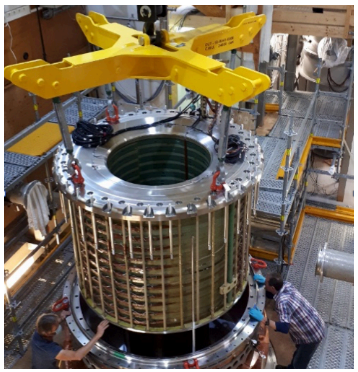
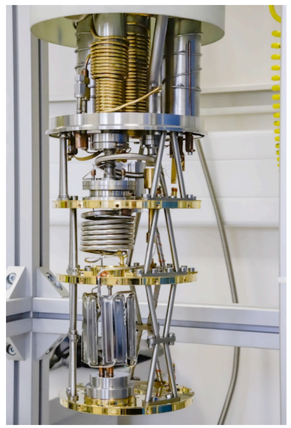
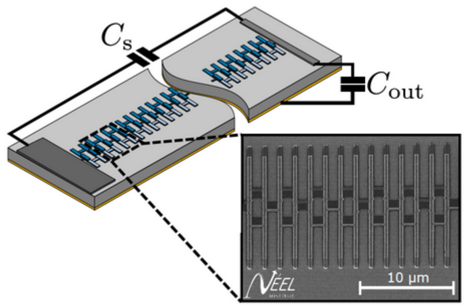
$$SNR \propto \frac{CB_0{}^2 V_{ol} f Q_{eff}}{k_B T_{noise}}\sqrt{\frac{t}{\Delta f}}$$









A near quantum limited Josephson Parametric Amplifier, based on superconducting metamaterials.

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Key expertise at CNRS-Grenoble for High magnetic fields, Extreme Low Temperatures, Quantum Detectors and Theory

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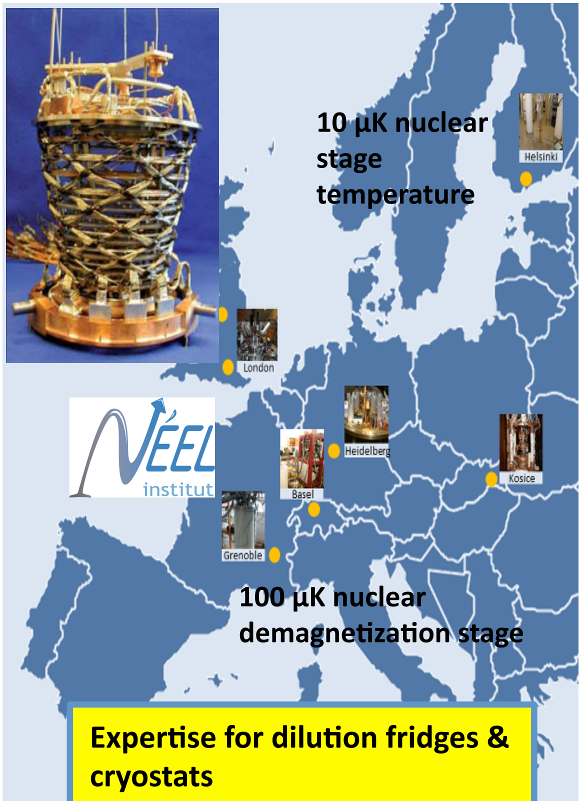
EMFL European Magnetic Field Laboratory
LNCMI

43+T Grenoble Modular Hybrid Magnet

NÉEL institut

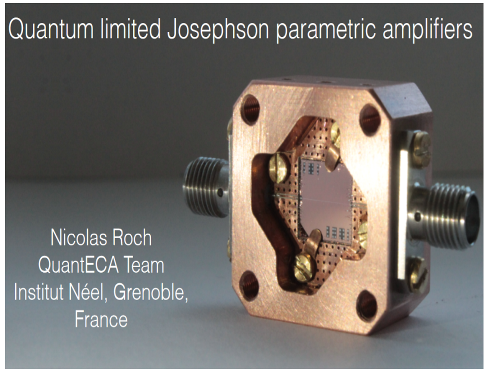
European Microkelvin Platform

20 leading ultralow temperature physics & technology Institutes in Europe including 7 submilliK facilities



Expertise for dilution fridges & cryostats (Planck, Edelweiss, CUT, SuperCDMS …)

JPA Achievements



LPSC Grenoble

Theory group :

- Beyond the SM Physics
- Cosmology, BHs, Q. Grav.

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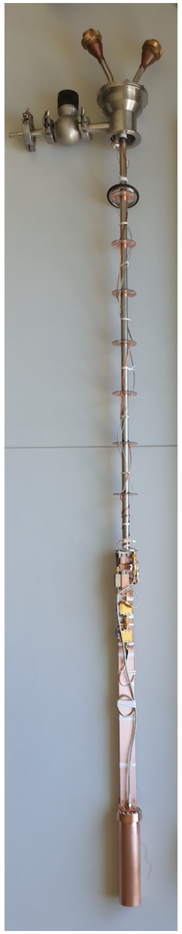
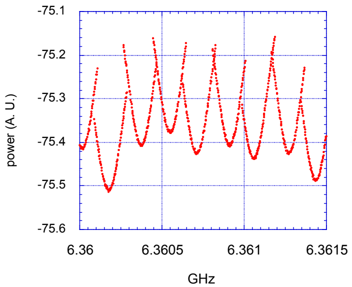
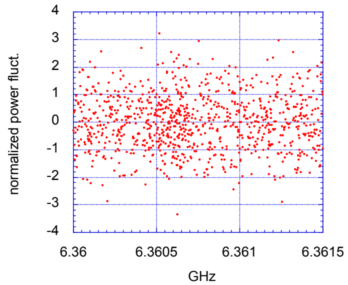
Starting to play : GrAHal 1st Measurement Run



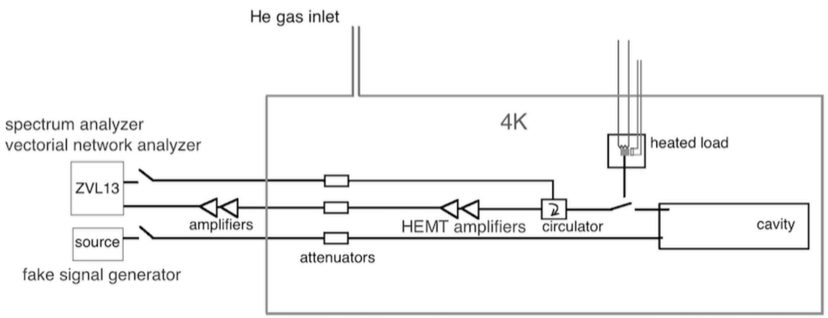


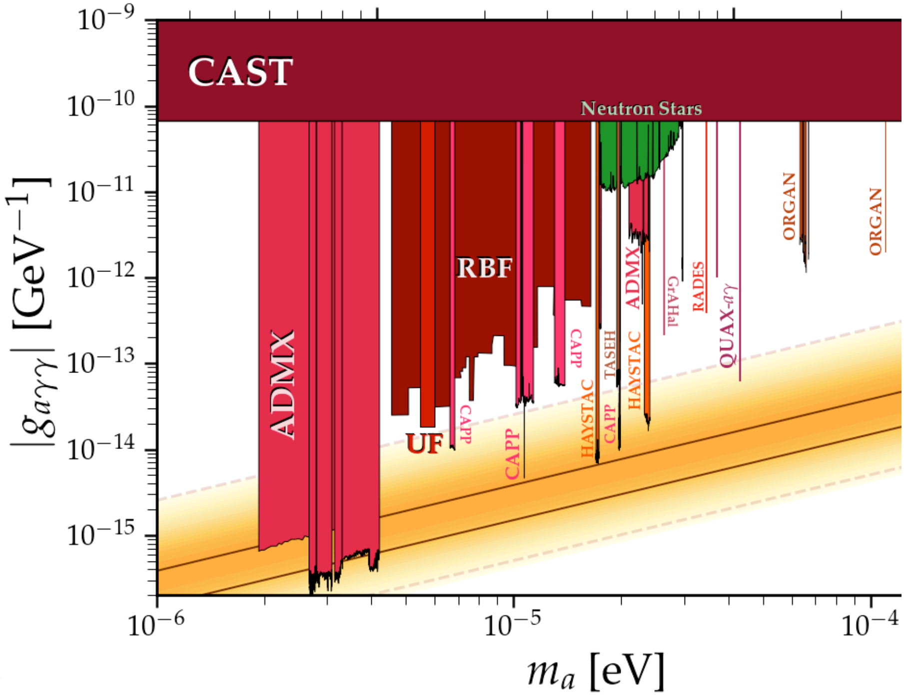
He tuning steps



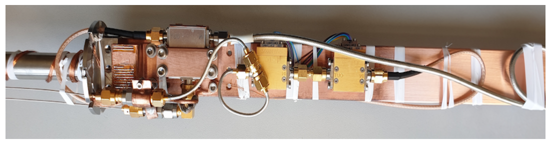
Power noise

14 T @ 4 K, He gas tuning
≈ 20 KSVZ exclusion over 20 MHz below 6.375 GHz (*i.e.* 26.37 µeV)





arXiv:2110.14406 , full data to be published



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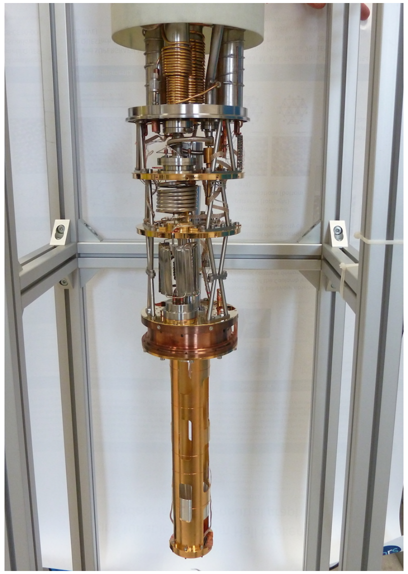
ANR funding (826 k€), october 2022 → sept. 2026

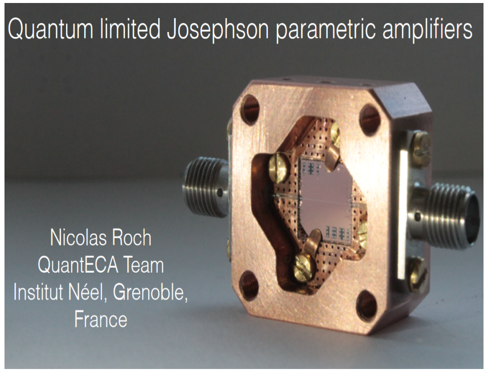
Dilution Fridge

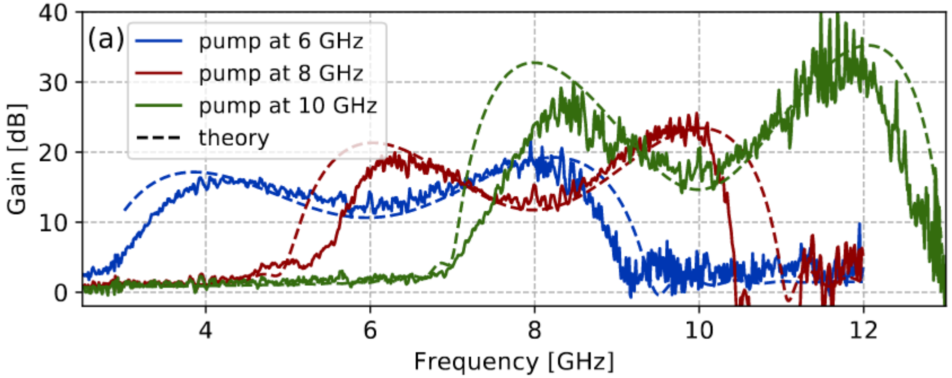


(T<30 mK, ø=77mm)
in
14 T magnet

Collab. B. Sacépé

TWPA amplifiers (N. Roch group, Neel Institute)





$1GHz = 4{,}13 \mu eV$

A. Ranadive et al., Nat. Com. **13**, 1737 (2022)

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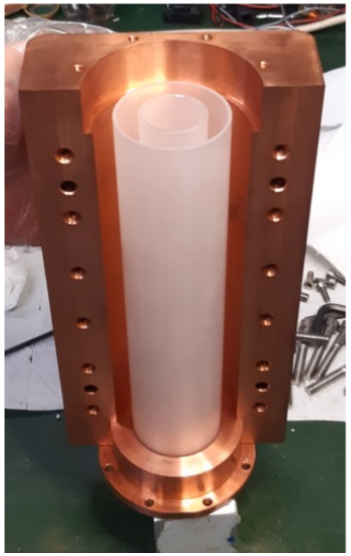
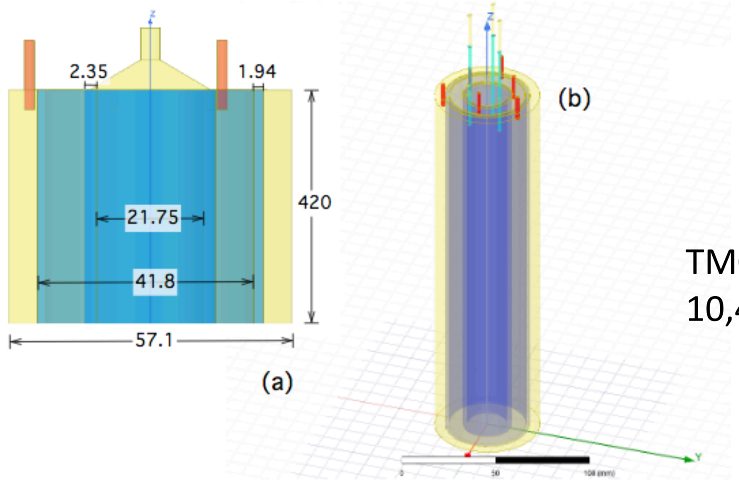
GrAHal / QUAX collaboration (C. Braggio et coll.) :





TM030
10,4 GHz

R. Di Vora et al., Phys. Rev. Applied **17**, 054013

* High Q dielectric cavities in dilution fridge (30mK, 0.7L) + 14T + TWPA
→ towards KSVZ sensitivity

* R&D on photon counters for better SNR (C. Gatti's talk; N. Roch (Neel Institute))

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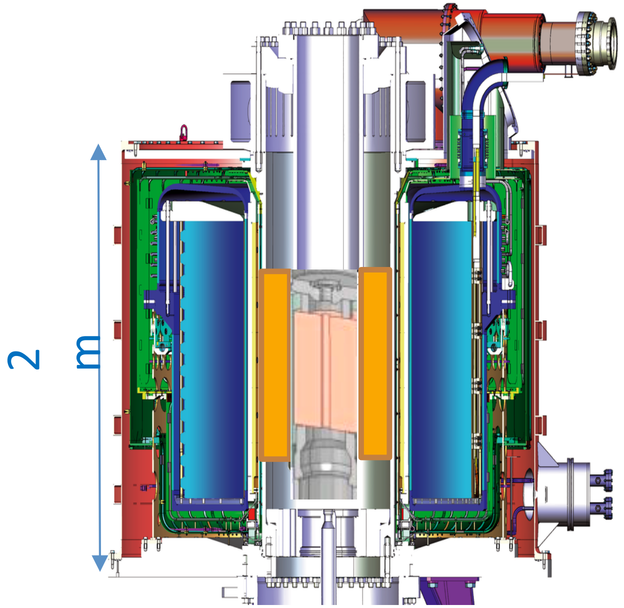
43+T Grenoble Modular Hybrid Magnet

LNCMI



Field	Warm dia.	RF-cavity dia.*	Frequency TM010	Height**
43 T	34 mm	20/12/8 mm	11-29 GHz	157 mm
40 T	50 mm	34/26/20 mm	5-11 GHz	157 mm
27 T	170 mm	86 mm	2.67 GHz	315 mm
17.5 T	375 mm	291 mm	0.79 GHz	484 mm
9 T	812 mm	675 mm	0.34 GHz	1400 mm

- modular magnet is adapted to different frequencies/cavity designs for axion (GW) searches

e.g. : - 27T / 86mm → QUAX dielectric cavity

- 9T/675mm SC outsert → { « low » frequency Sikivie cavity; « high » frequency metamaterial cavity }

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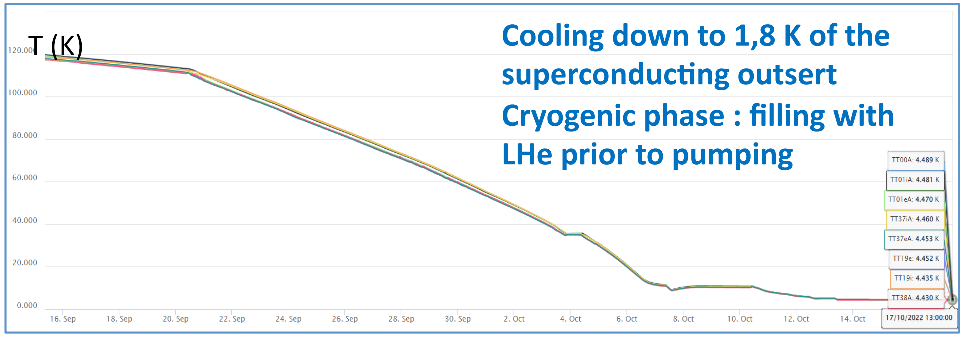
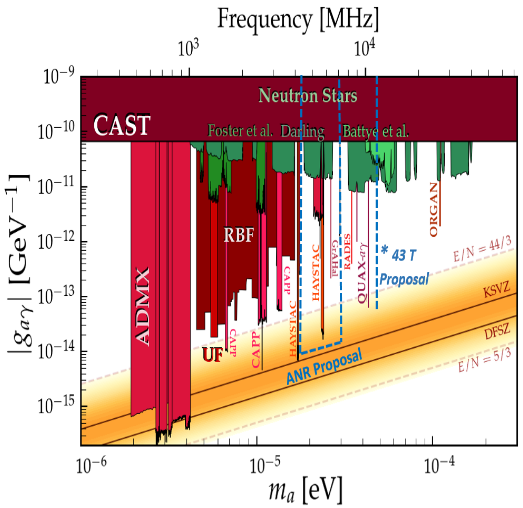
Magnet status :

* Commissioning started

* SC outsert transited october, 7

* 43 T commissioning 2023





- first haloscope test run @ 43T planned in 2023
- modular cryostat desing on-going

Note also FASUM project :

* 19 T / 150 mm
* 40 T / 34 mm } all SC

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Funding :

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