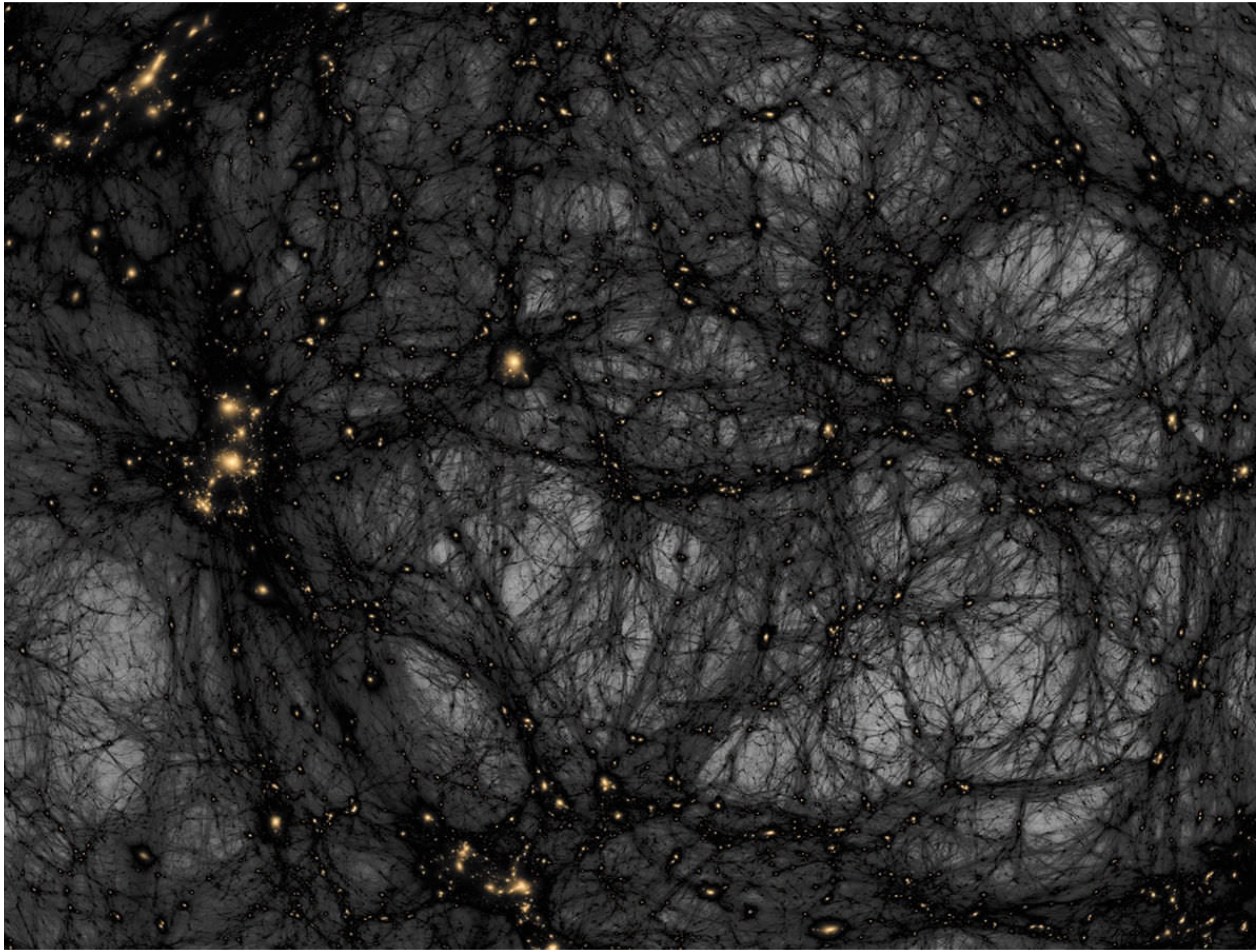


SEARCH FOR AXION DARK MATTER

CLAUDIO GATTI LNF-INFN

Outline

- Axion Properties
- Experiments
  - Laboratory Searches
  - Solar Axions
  - Axion Dark Matter Searches
- The QUAX Experiment
- The FLASH Experiment

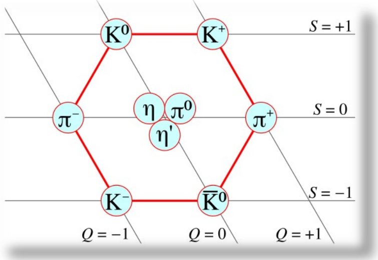
Axion Properties

Axions

U(1)$_A$ problem

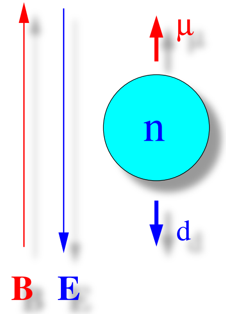
$$M_{\eta'} = 958 \text{ MeV} \gg M_\eta$$

S.Weinberg U(1) problem PRD 11 (1975)



Strong CP problem

$$\mathcal{L}^{\not{CP}}_{QCD} = \theta_{QCD} \frac{\alpha_s}{8\pi} G^a_{\mu\nu} \tilde{G}^{\mu\nu}_a$$



Phys Rev Lett 82, n.5 (1999) p.904

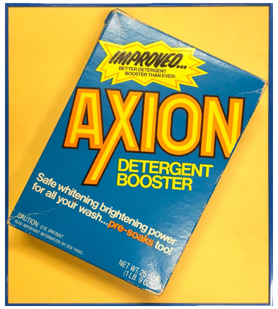
$$d_n < 2.9 \times 10^{-26} e \text{ cm}$$

$$\theta < 10^{-10}$$

R.D.Peccei and H.R.Quinn, Phys. Rev. Lett. 38, 1440 (1977); Phys. Rev. D 16, 1791 (1977).
S. Weinberg, Phys. Rev. Lett. 40, 223 (1978).
F. Wilczek, Phys. Rev. Lett. 40, 279 (1978).

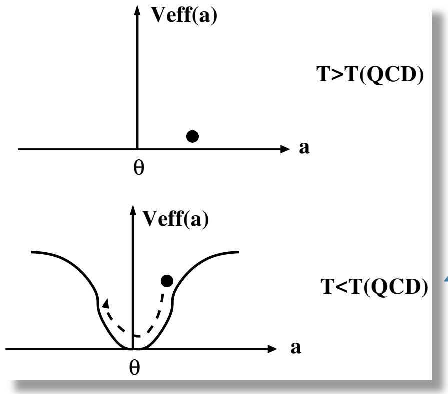
Axions

$$\mathcal{L}^{\not{CP}}_{QCD} = \left(\theta - \frac{a}{f_a}\right) \frac{\alpha_s}{8\pi} G^a_{\mu\nu} \tilde{G}^{\mu\nu}_a$$



Axion Dark Matter

Misalignment mechanism



Axion Mass

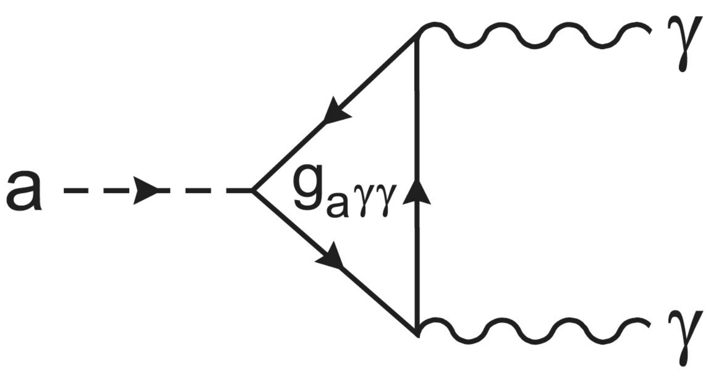
$$m_a = 5.70(7)\left(\frac{10^{12}GeV}{f_a}\right)\mu eV \simeq \frac{m_\pi f_\pi}{f_a}$$

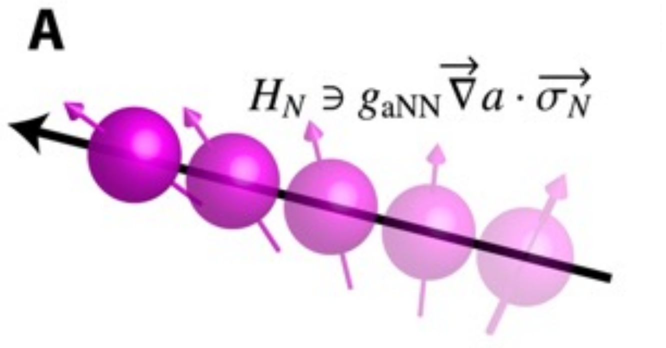
f_a PQ breaking energy scale

If $f_a \sim f_{ew} = 100$ GeV , as in original PQ model, then $m_a \sim 100$ keV and $BR(K^+ \rightarrow \pi^+ a) \sim 10^{-5}$
NA62 measurement $BR(K^+ \rightarrow \pi^+ X^0) < 5\times 10^{-11}$

Asztalos et al. Ann. Rev. Nucl. Part. Sci. 56 2006

Axion Interaction with Matter





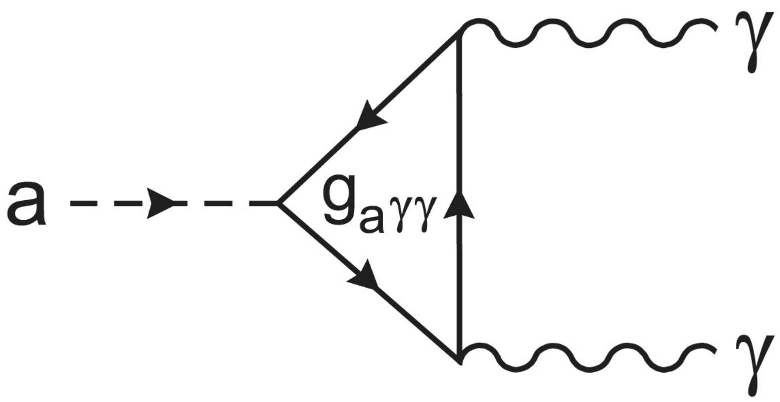
$$\mathcal{L} = i\frac{g_d}{2} a \left(\bar{N}\sigma_{\mu\nu}\gamma^5 N\right) F^{\mu\nu} + i\frac{g_{aNN}}{2m_N}\partial_\mu a \left(\bar{N}\gamma^\mu\gamma^5 N\right) + i\frac{g_{aee}}{2m_e}\partial_\mu a \left(\bar{e}\gamma^\mu\gamma^5 e\right) + g_{a\gamma\gamma} a E\cdot B$$

Casper Electric Experiment (time-varying EDM)

Casper Wind Experiment

Quax-ae Experiment

Helioscopes
Haloscopes
LSW



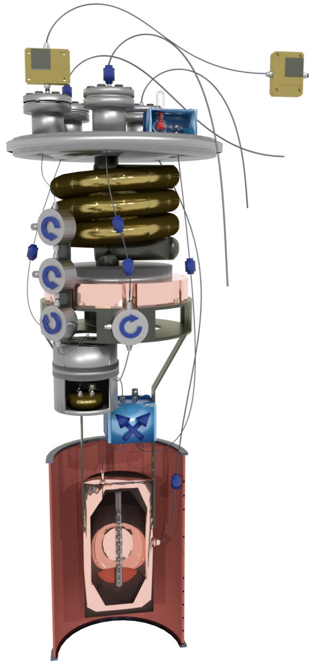
Light axion are stable particles

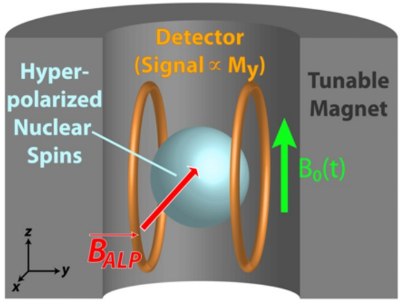
$$\Gamma_{a\to\gamma\gamma} = \frac{g_{a\gamma\gamma}^2 m_a^3}{64\pi} = 1.1 \times 10^{-24} s^{-1} \left(\frac{m_a}{eV}\right)^5$$

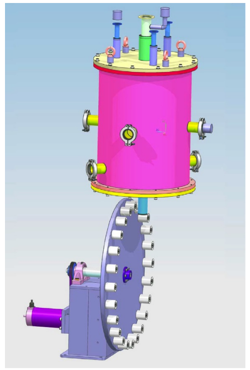
$$g_{a\gamma\gamma} = \frac{\alpha_{em}}{2\pi f_a}\left(\frac{E}{N} - 1.92(4)\right)$$

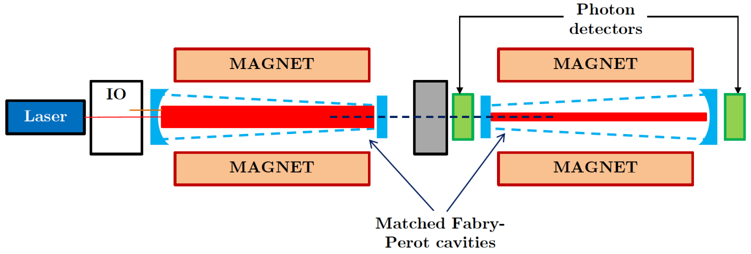
The effective coupling is model dependent:
E/N=0 KSVZ model
E/N=8/3 DSFZ model

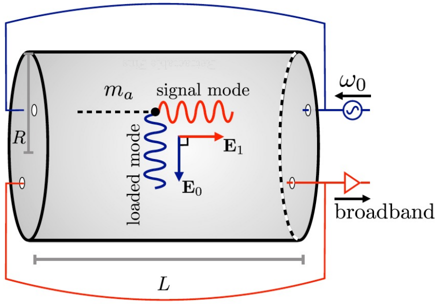
Axion Lifetime



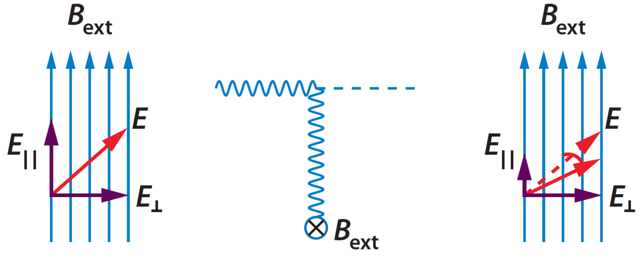


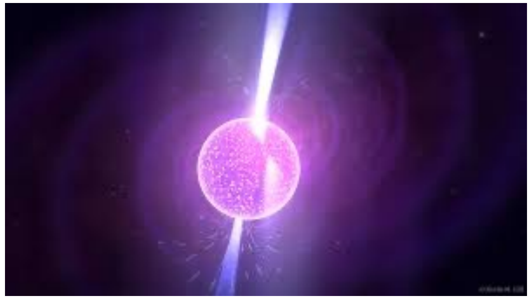


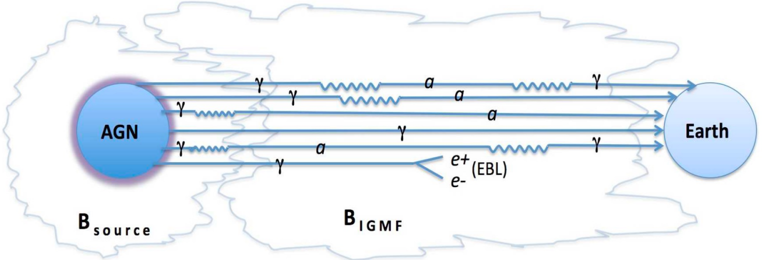


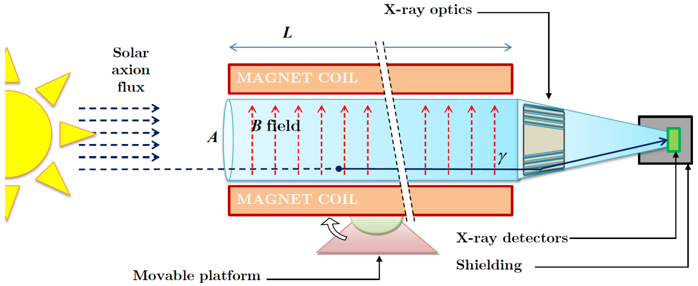


EXPERIMENTS







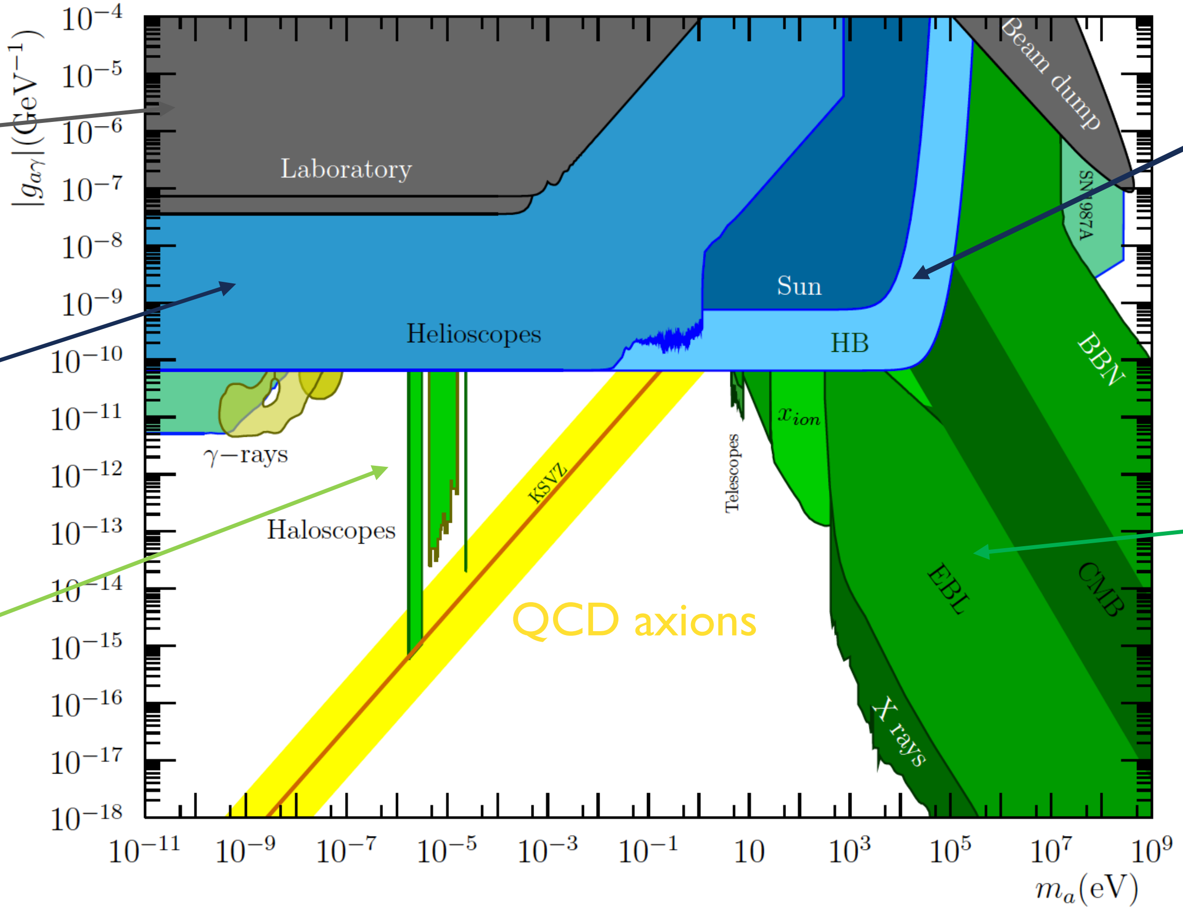


Limits

Laboratory experiments

Detection of axions from the Sun (Helioscopes)

DM axion detection (Haloscopes)

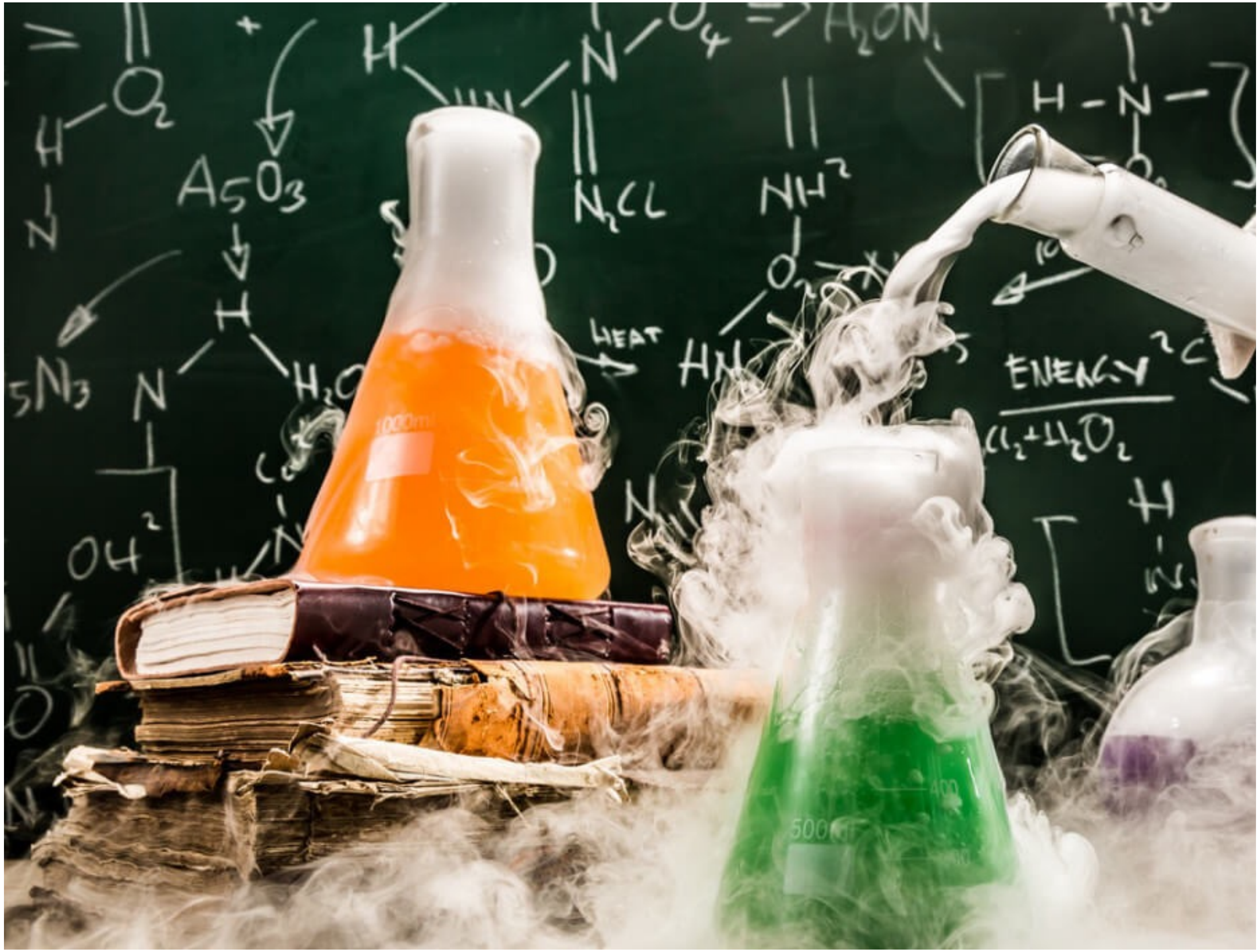


Stellar physics:
Primakoff process in stars $\gamma\, Ze \rightarrow a\, Ze$.
Constraints on stellar lifetime or energy-loss rates: Sun, HB.

Cosmology:
No DM $a \rightarrow \gamma\gamma$ decays seen in the visible region from galaxies with telecopes. Similar searches with X-rays and extragalactic background light (EBL) or H ionization.

Ringwald et al. PDG 2017

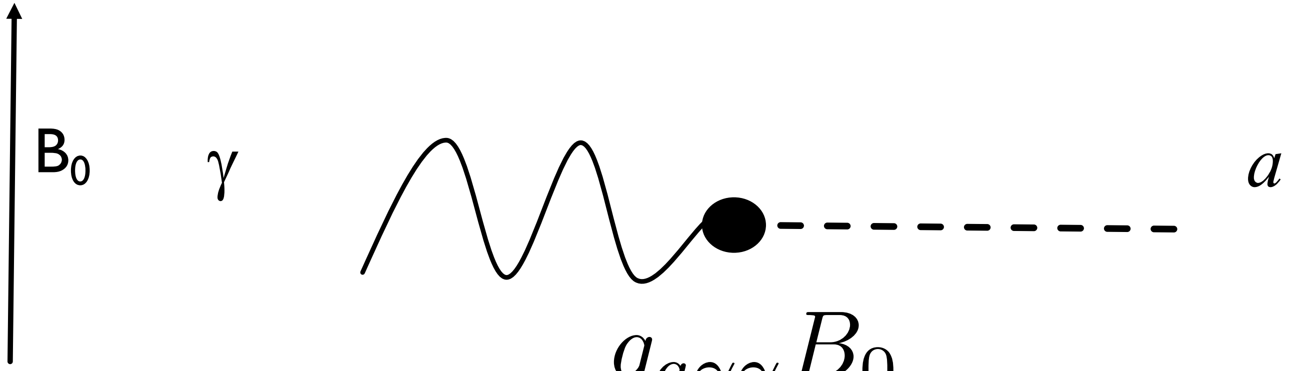
Irastorza Redondo arxiv:1801.08127



LABORATORY EXPERIMENTS

Photon Conversion in a Magnetic Field

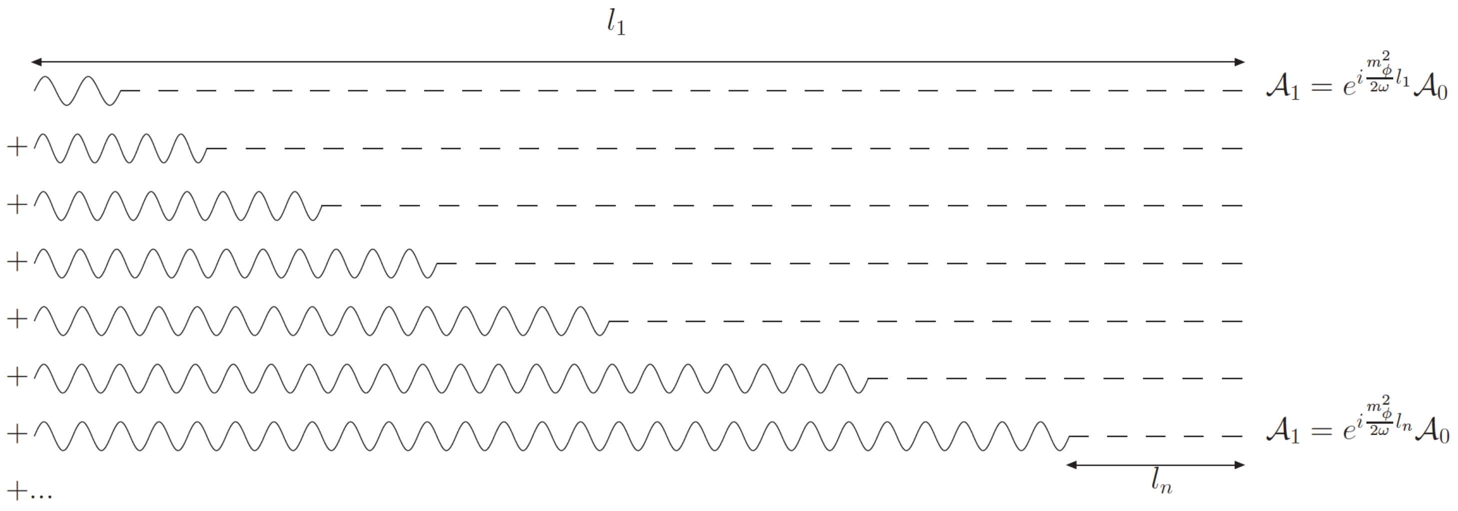
$$\mathcal{L} = g_{a\gamma\gamma} a E \cdot B$$



$$i\frac{g_{a\gamma\gamma}B_0}{2}$$

Redondo Ringwald arxiv:1011.3741

Coherent Axion Production



Coherence condition

$$m_a \ll \sqrt{\frac{4\omega}{L}}$$

$$\mathcal{A}(\gamma \to a) = i\int_0^L dz \frac{g_{a\gamma\gamma}B_0}{2} e^{i(k_a - k_\gamma)z} = i\int_0^L dz \frac{g_{a\gamma\gamma}B_0}{2} e^{i\frac{m_a^2}{2\omega}z}$$

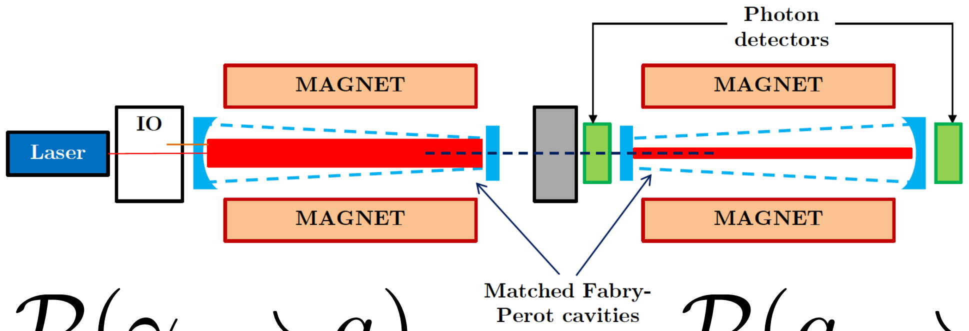
$$k_a - k_\gamma = \sqrt{\omega^2 - m_a^2} - \omega \simeq \frac{m_a^2}{2\omega}$$

Conversion probability

$$\mathcal{P}(\gamma \to a) = |\mathcal{A}|^2 = 4\frac{g_{a\gamma\gamma}^2 B_0^2 \omega^2}{m_a^4} \sin^2\left(\frac{m_a^2 L}{4\omega}\right)$$

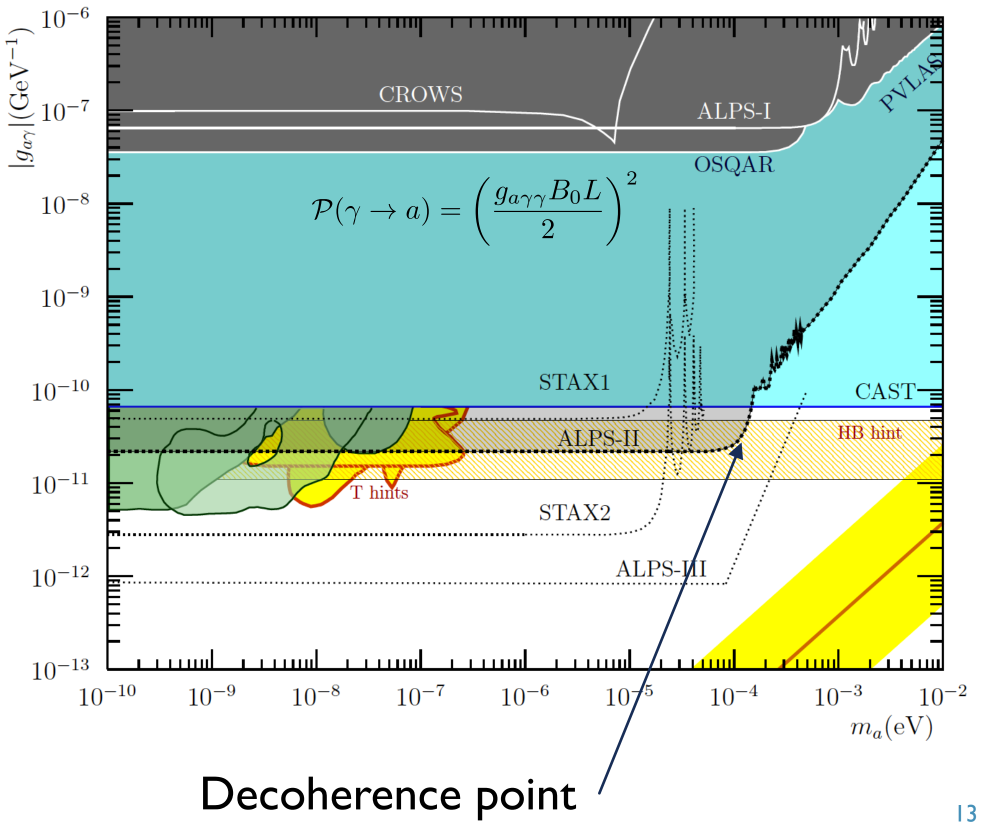
Redondo Ringwald arxiv:1011.3741

Light-shining-through Wall Experiments

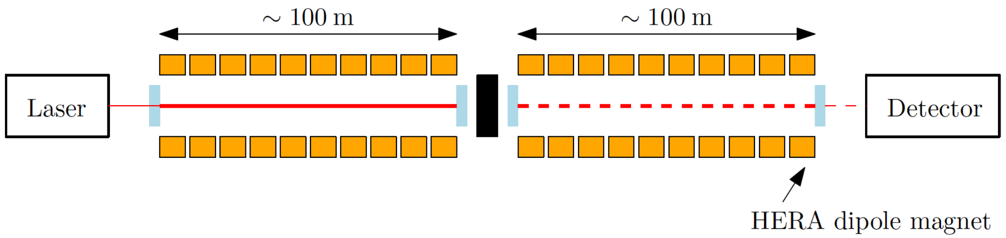


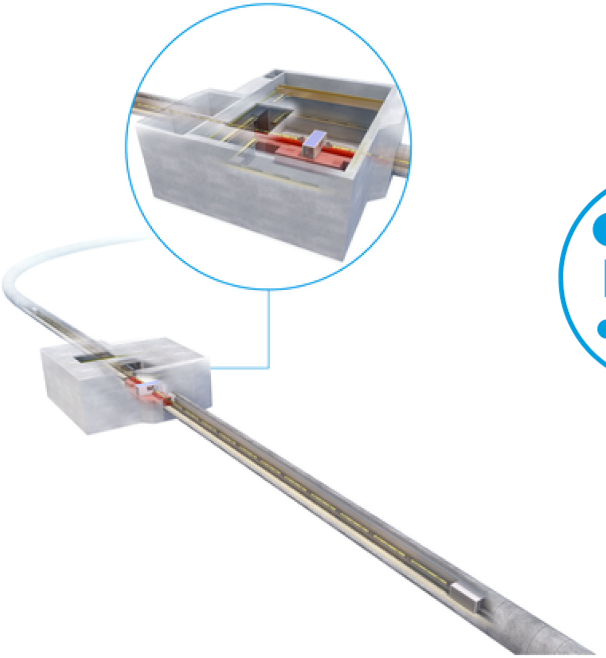
$$\mathcal{P}(\gamma \to a) \qquad \mathcal{P}(a \to \gamma)$$

Experiment	status	B(T)	L(m)	P(W)	$G_{a\gamma\gamma}$ (GeV^{-1})
ALPS-I	done	5	4.3	4	5×10^{-8}
OSQAR	done	9	14.3	18.5	3.5×10^{-8}
ALPS-II	ongoing	5	100	30	2×10^{-11}

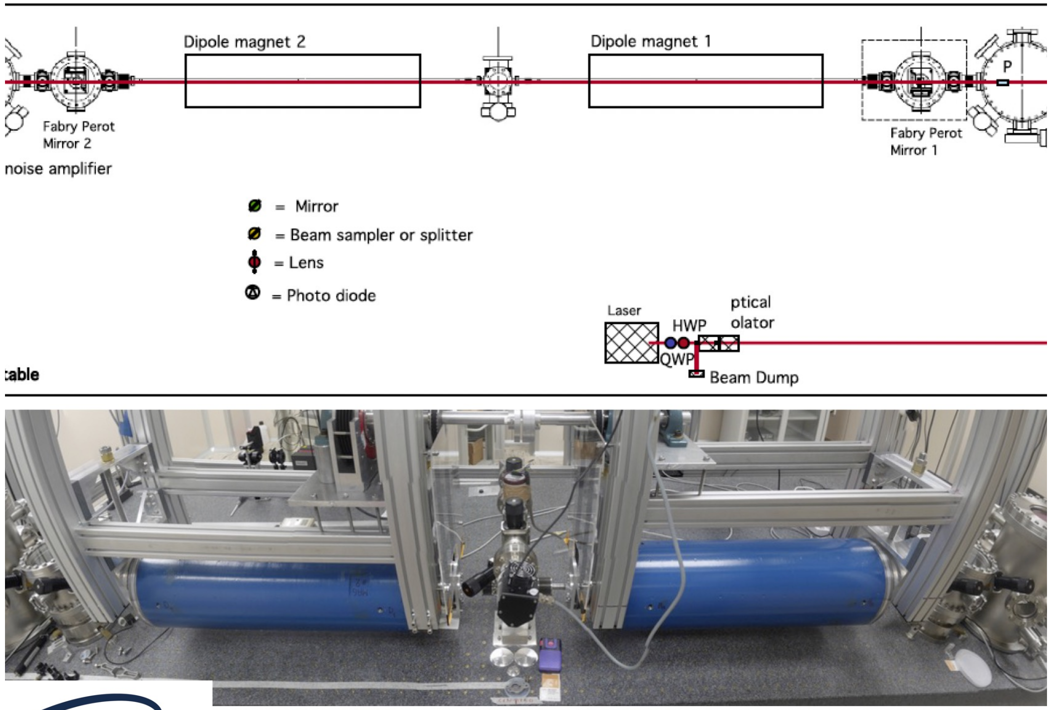


ALPS-II





Polarization Experiments - PVLAS



- PVLAS aims at the direct measurement of the small polarisation changes undergone by a linearly polarised laser beam traversing a dipole magnetic field in vacuum.

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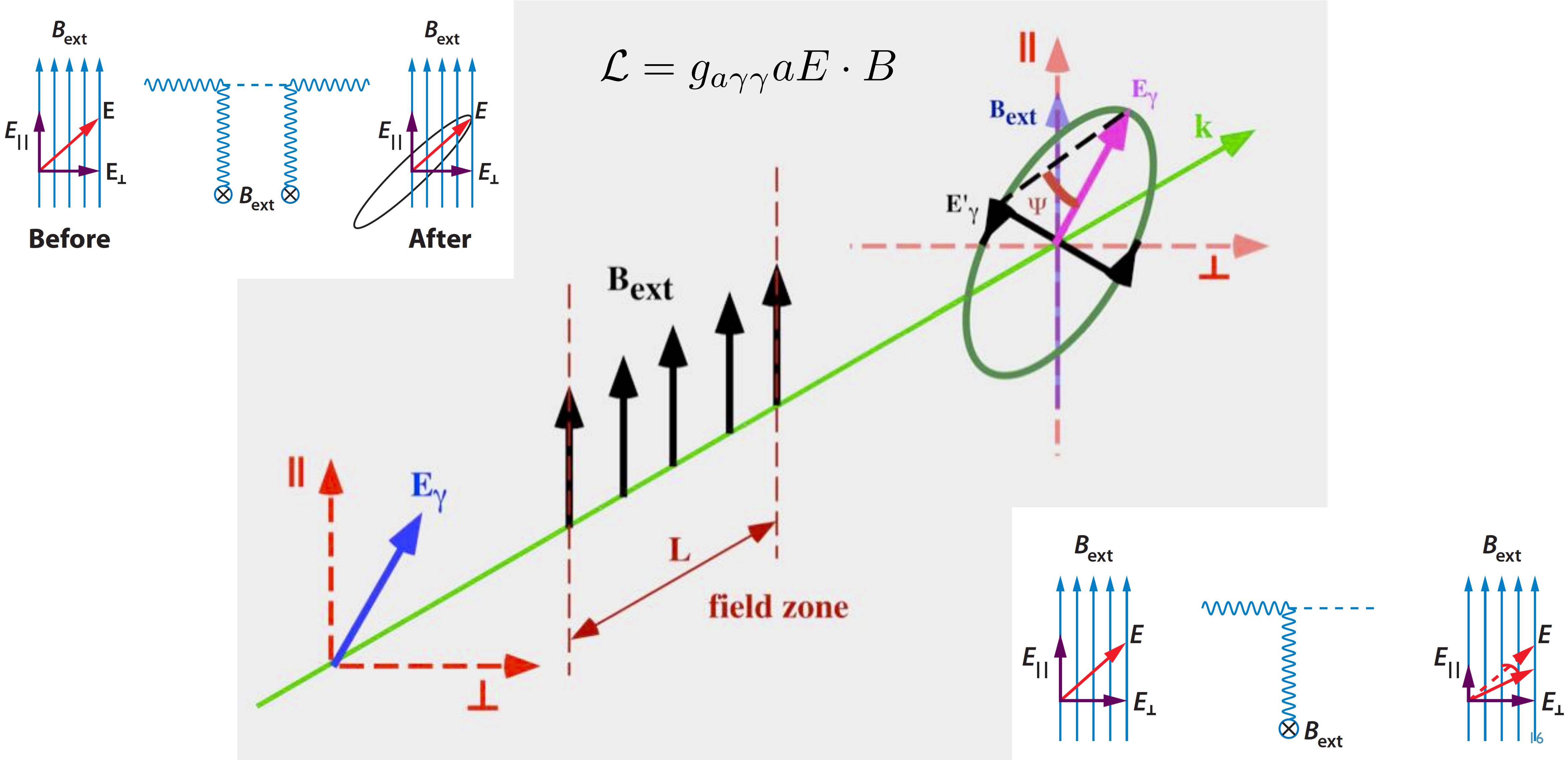
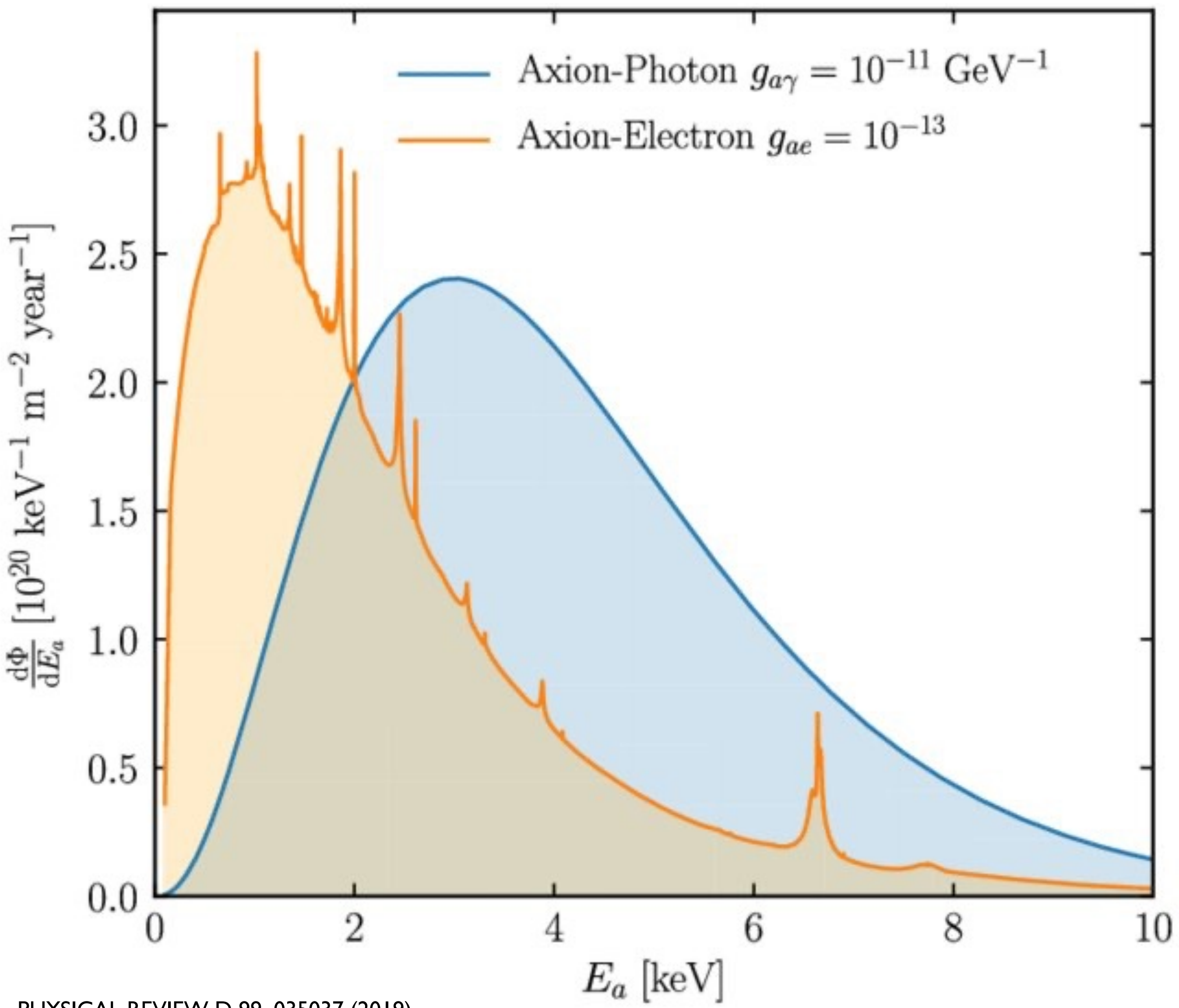
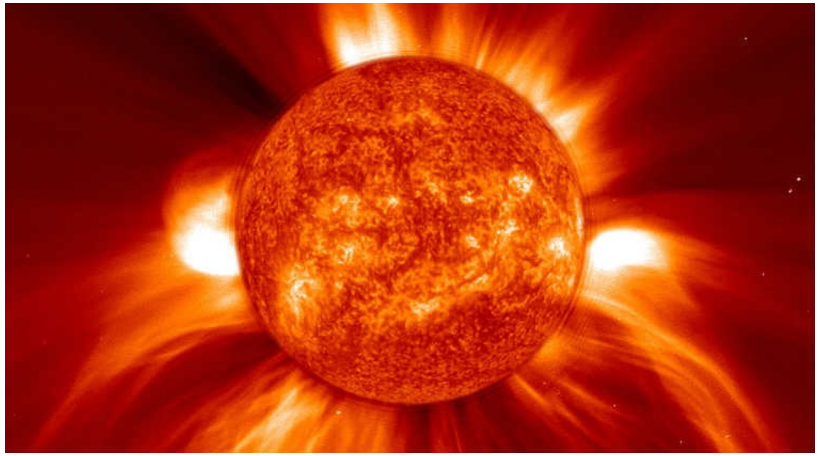
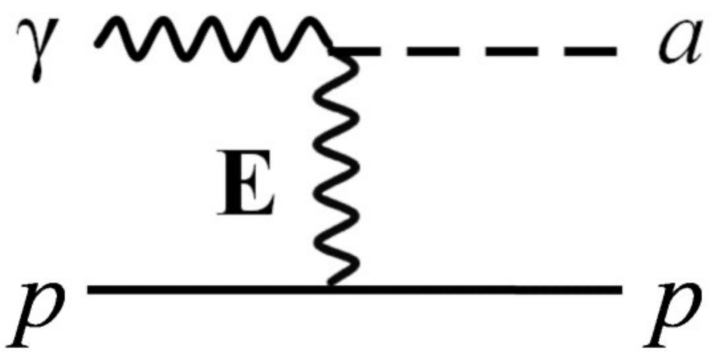


L.Maiani, R. Petronzio, E. Zavattini, Phys. Lett B, Vol. 175, no.3 1986



PHYSICAL REVIEW D 99, 035037 (2019)



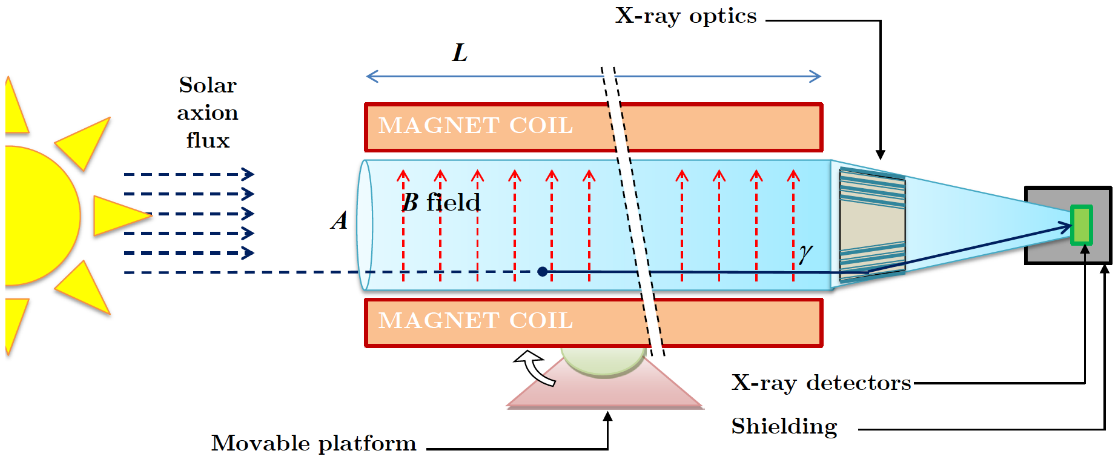


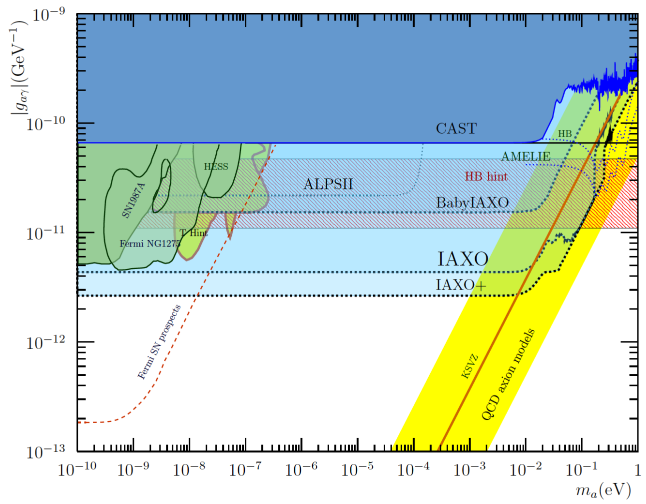
Helioscopes

$$\mathcal{P}(\gamma \to a)$$

$$\mathcal{P}(a \to \gamma)$$

Axion produced in the core of the Sun from Primakoff conversion with typical energy few keV.





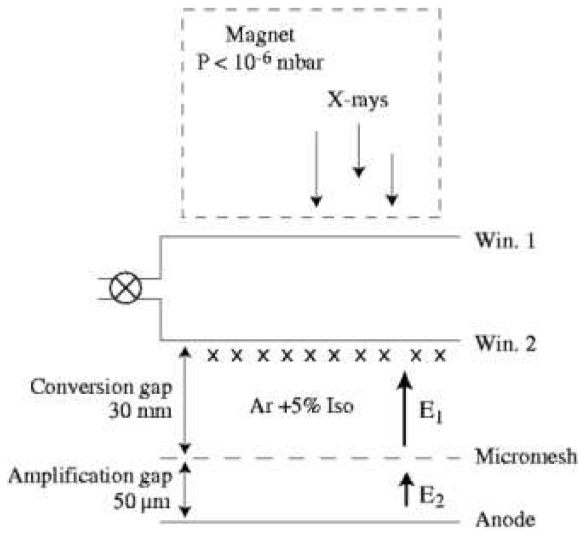
Experiment	status	B(T)	L(m)	A(cm²)	$G_{a\gamma\gamma}$ (GeV^{-1})
BNL	done	2.2	1.8	130	36×10^{-10}
SUMICO	done	4	2.5	18	6×10^{-10}
CAST	done	9	9.3	30	6.6×10^{-11}
IAXO	In design	2.5	22	2.3×10^{4}	4×10^{-12}

$$\mathcal{P}(a \to \gamma) = \left(\frac{g_{a\gamma\gamma} B_0 L}{2}\right)^2$$

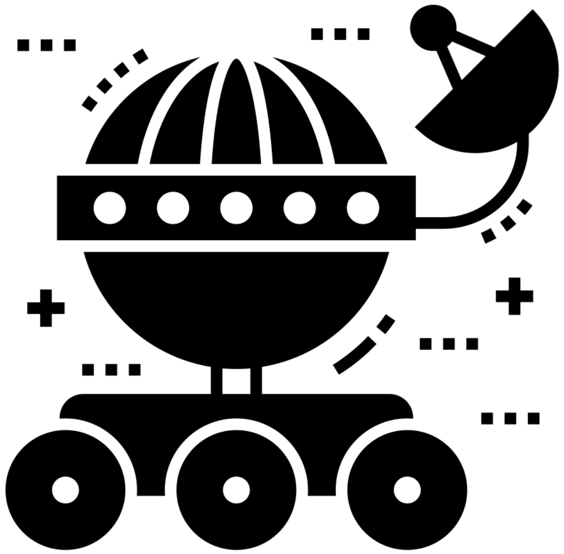
Sikivie Phys. Rev. D 32,11 (1985)

CAST - CERN Axion Solar Telescope

Micromegas low-background X-ray detector built with radiopure material. 10^{-3} counts/h



Giomataris et al arXiv:physics/0702190



SEARCH FOR AXION DARK MATTER

AXION DM

Local Dark Matter density

$$\rho \simeq 0.3GeV/cm^3$$

Axion density

$$n_a \simeq 3 \times 10^{12} \left(\frac{100\mu eV}{m_a}\right) 1/\text{cm}^3$$

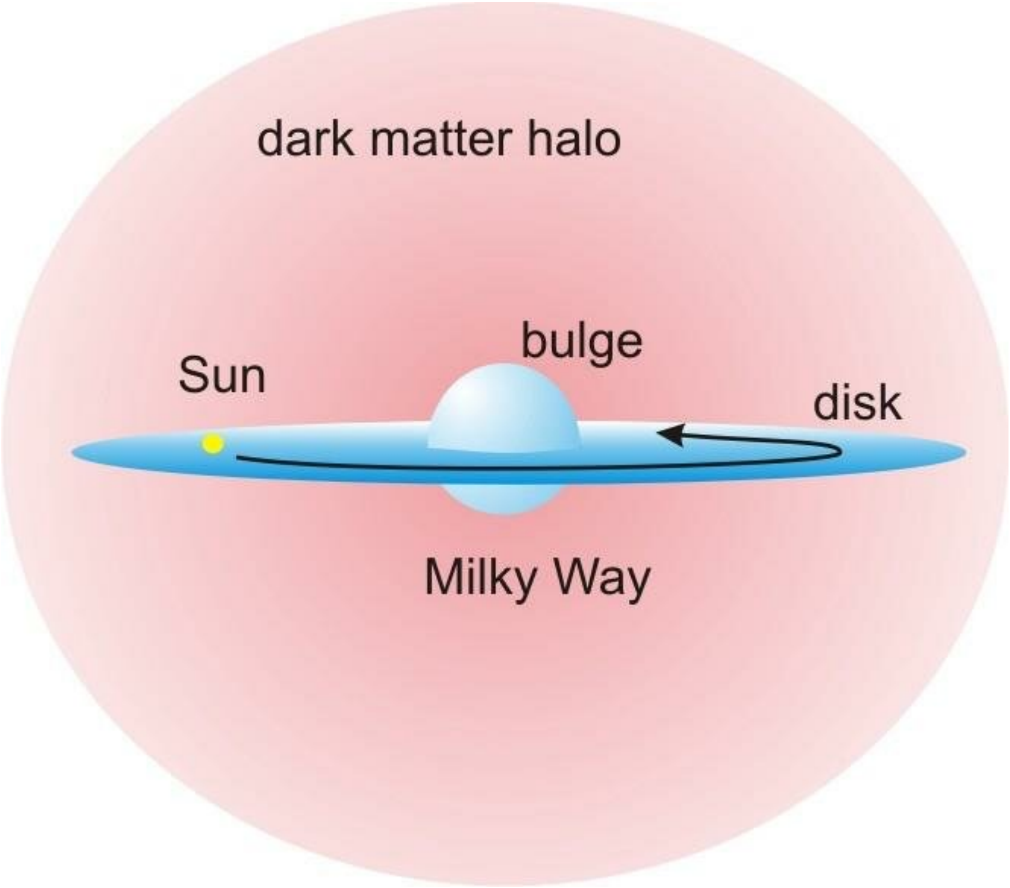
Axion-Earth relative speed

$$\beta_a \sim 10^{-3}$$

Axion as a classical field

$$a = a_0 \cos\left(\omega t - kx\right) \qquad a_0 = \sqrt{\frac{2\rho_{DM}}{m_a^2}}$$

$$\hbar\omega \simeq m_a c^2$$

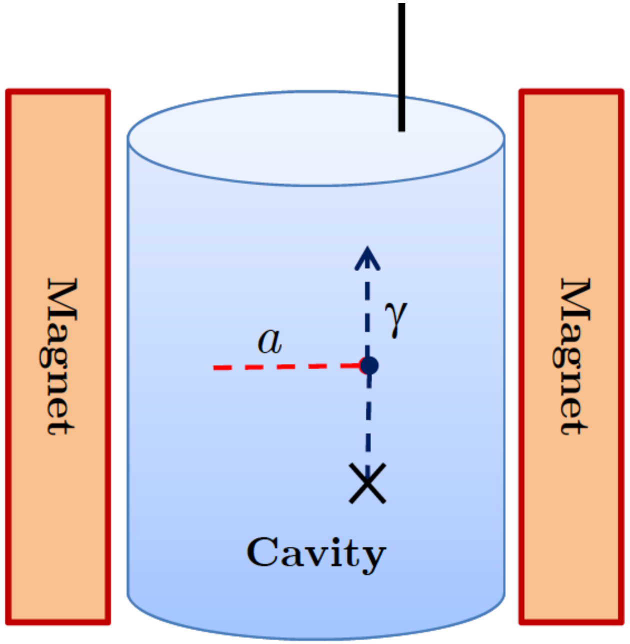


Sikivie's Haloscope

$$\nabla^2 E - \partial_t^2 E = -g_{a\gamma\gamma} B_0 \partial_t^2 a$$

Solving the equation inside a cylindrical resonant cavity, the signal power is

$$P_{\text{sig}} = \left(g_\gamma^2 \frac{\alpha^2}{\pi^2} \frac{\hbar^3 c^3 \rho_a}{\Lambda^4} \right) \times \left(\frac{\beta}{1+\beta} \omega_c \frac{1}{\mu_0} B_0^2 V C_{mnl} Q_L \right)$$



β antenna coupling to cavity

V cavity volume

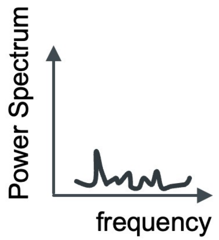
C_{mnl} mode dependent factor about 0.6 for TM010

Q_L cavity "loaded" quality factor

Sikivie Phys. Rev. D 32,11 (1985)

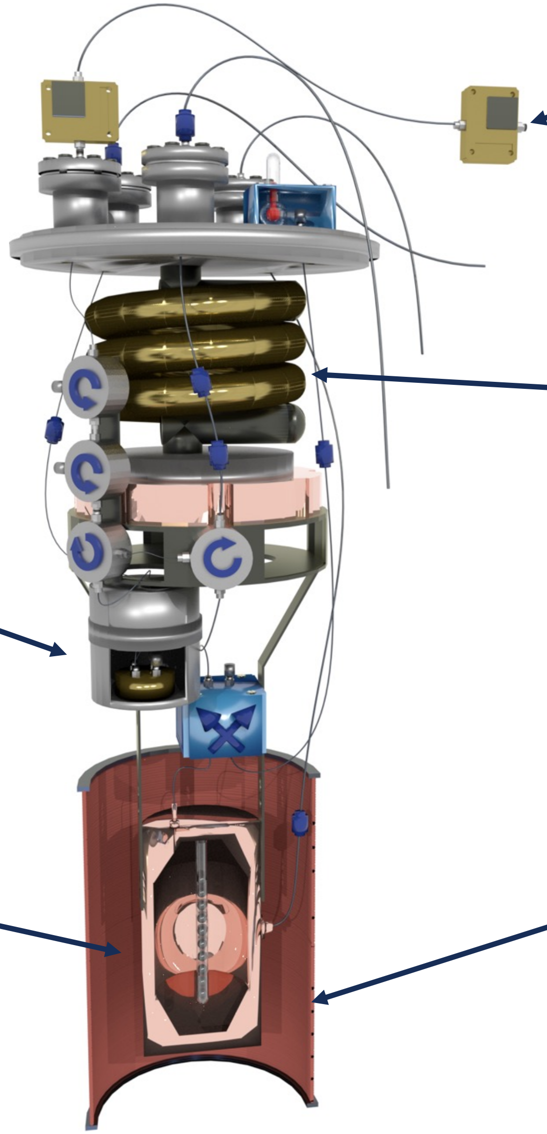
State of Art Sikivie's Haloscope

Room Temperature Amplifiers



Dilution Refrigeretor T<100 mK

Cryogenic Amplifier (noise at SQL)



Scan rate

$$\frac{df}{dt} \propto \frac{B^4 V^2 Q_L}{T_{sys}^2}$$

Resonant cavity

SC magnet (~10 T)

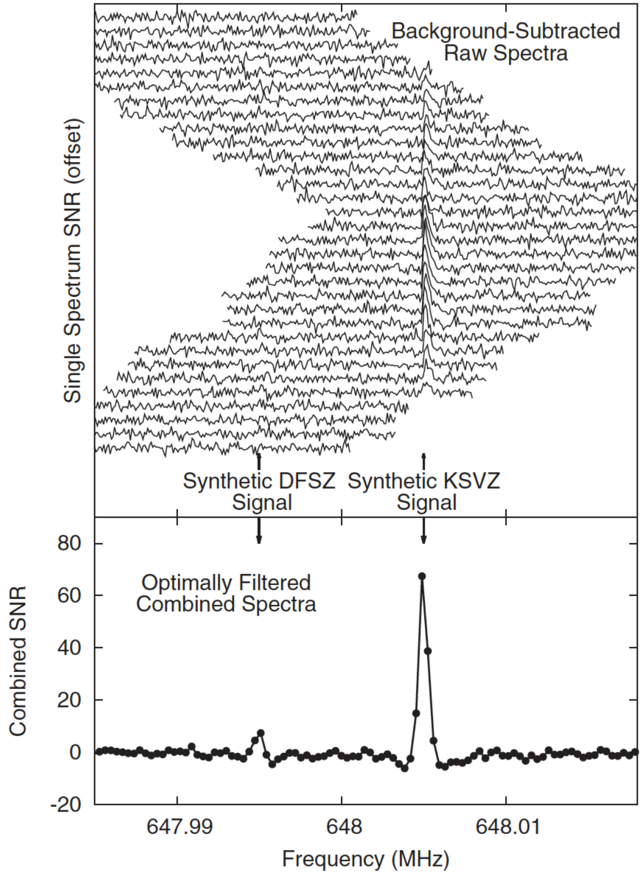
Sikivie Phys. Rev. D 32,11 (1985)

Signal Sensitivity

$$P_{noise} = k_B T \Delta\nu \simeq 1.4 \times 10^{-23}\ \mathrm{JK}^{-1} \times 4\ \mathrm{K} \times 10^4\ \mathrm{Hz} \sim 6 \times 10^{-19}\mathrm{W}$$

$$SNR = \frac{P_{\rm sig}}{k_B T_{sys}} \sqrt{\frac{\tau}{\Delta\nu_a}}$$

τ integration time
$\Delta\nu_a$ axion bandwidth
$T_{sys} = T + T_{noise}$



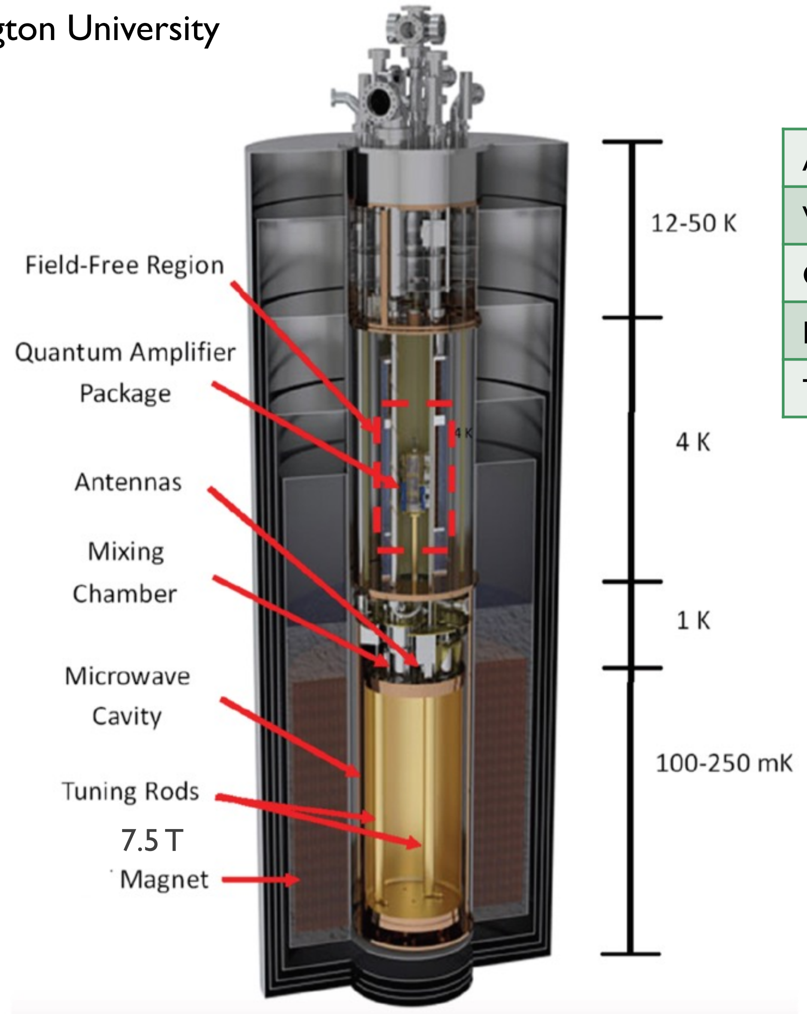
Typical signal power 10^{-22} W

Average on several samples for a time (SNR=1):

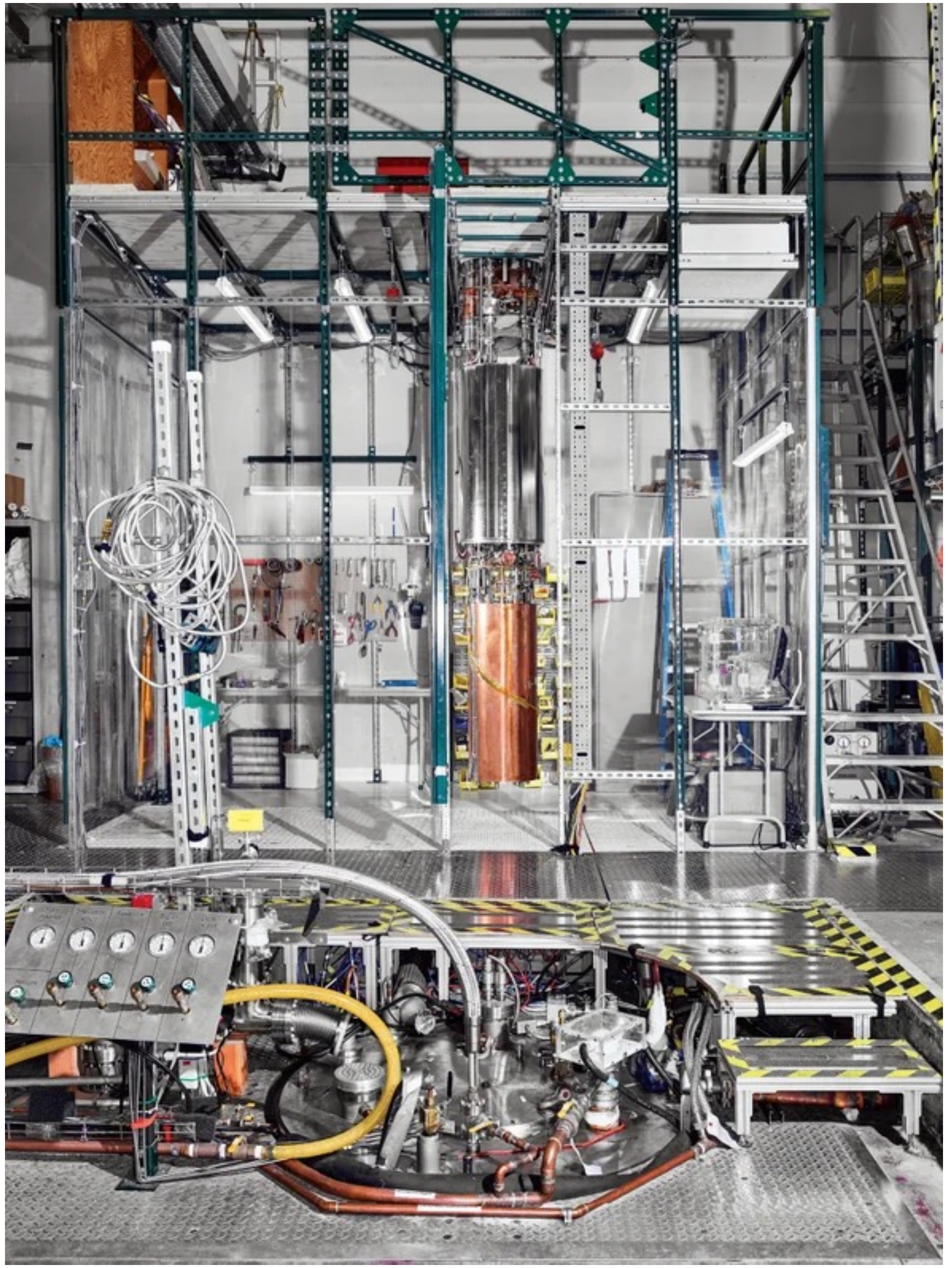
$$\tau \sim 10^8 \tau_a$$

ADMX – Axion Dark Matter Experiment

Washington University

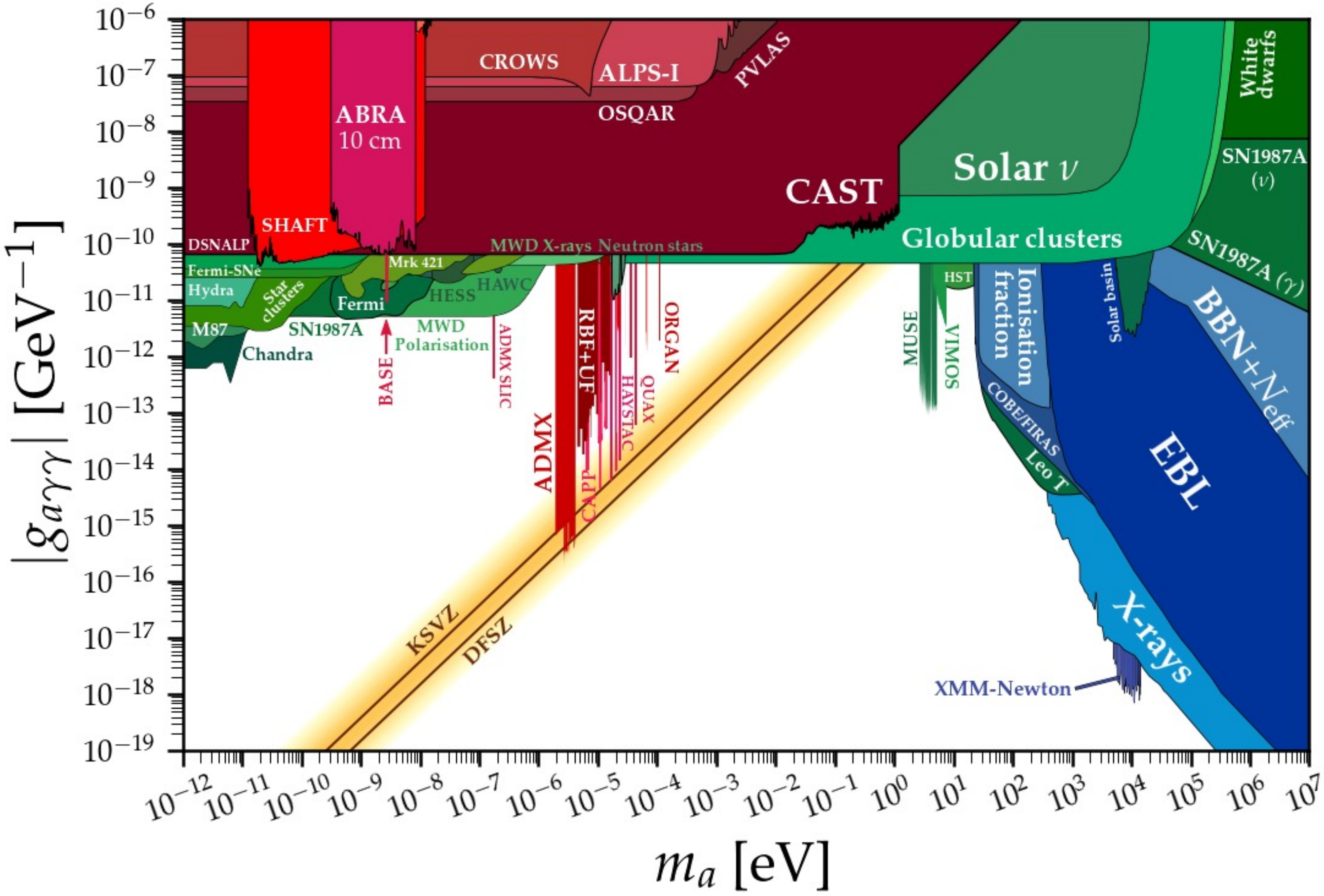


ADMX	800 MHz
Volume	136 L
Q_0	200,000
B	7.5 T
T_{noise}	600 mK



PHYSICAL REVIEW LETTERS 120, 151301 (2018)

Axion DM Searches Now



QUAX

INFN PADOVA
Istituto Nazionale di Fisica Nucleare
Sezione di Padova

TIFPA
Trento Institute for Fundamental Physics and Applications

INFN Gruppo Collegato di Salerno
Sezione di Napoli
Istituto Nazionale di Fisica Nucleare

UNIVERSITY OF BIRMINGHAM

NÉEL institut

SQMS

SUPERGALAX

Laboratori Nazionali di Legnaro (LNL)

Laboratori Nazionali di Frascati (LNF)

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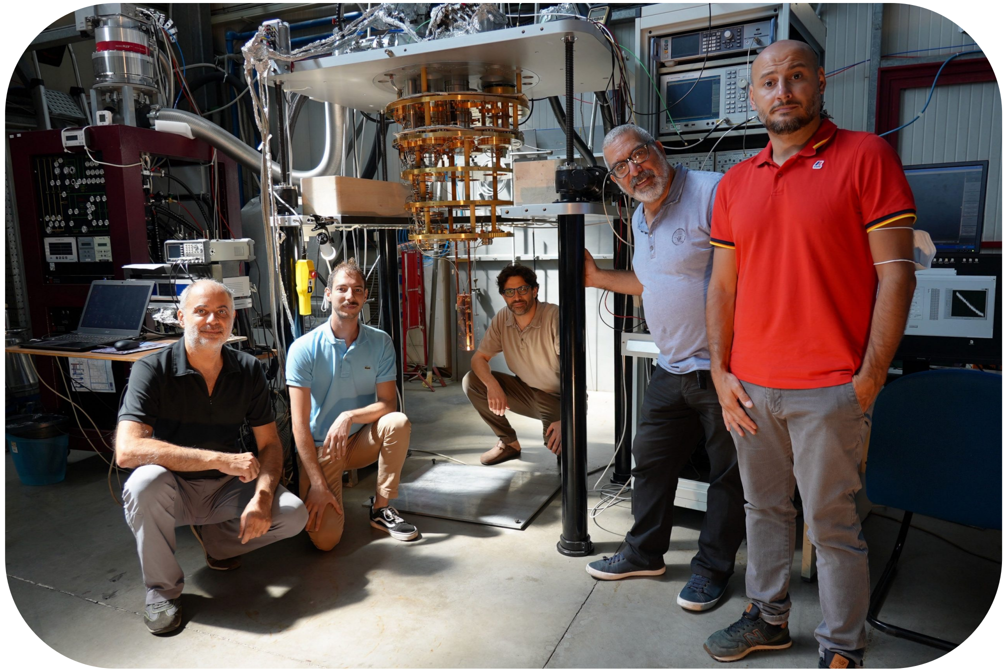
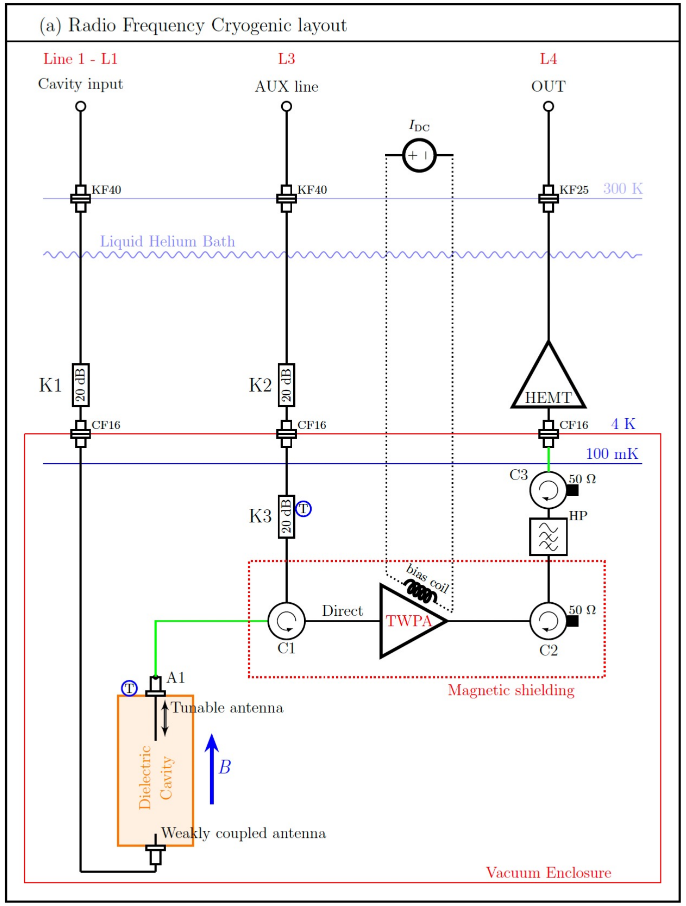
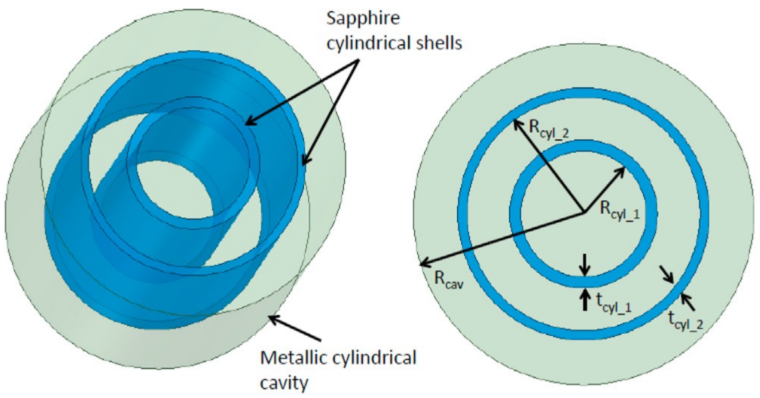


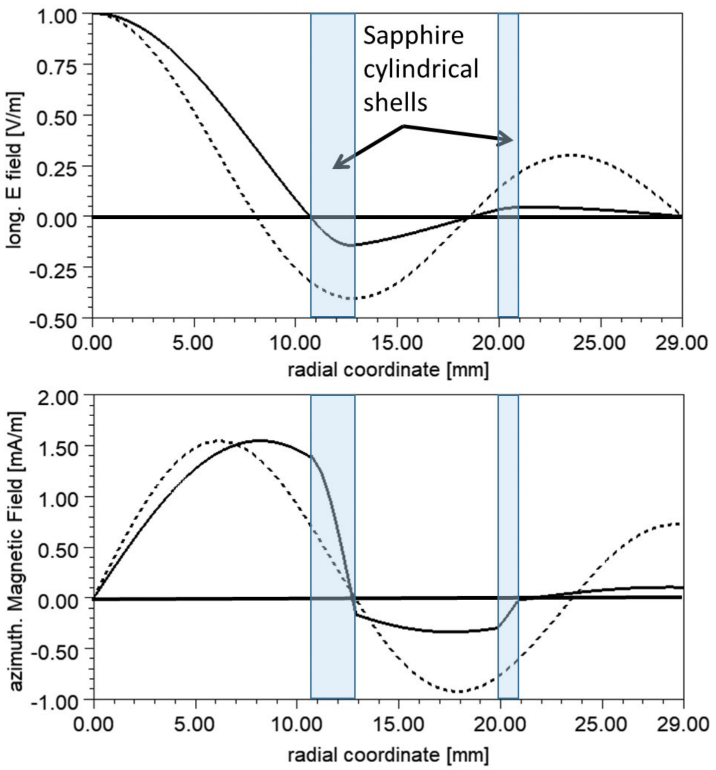
The LNL Haloscope



- B=8 T
- Dilution Refrigerator
- Tcavity 110 mK
- TWPA
- T_{noise}=2 K
- Dielectric Cavity
- Sapphire tuner
- Q=2.5×10^5
- VC_{030}=0.034 L

Search for galactic axions with a traveling wave parametric amplifier
PHYSICAL REVIEW D 108, 062005, arXiv:2304.7505 (2023)

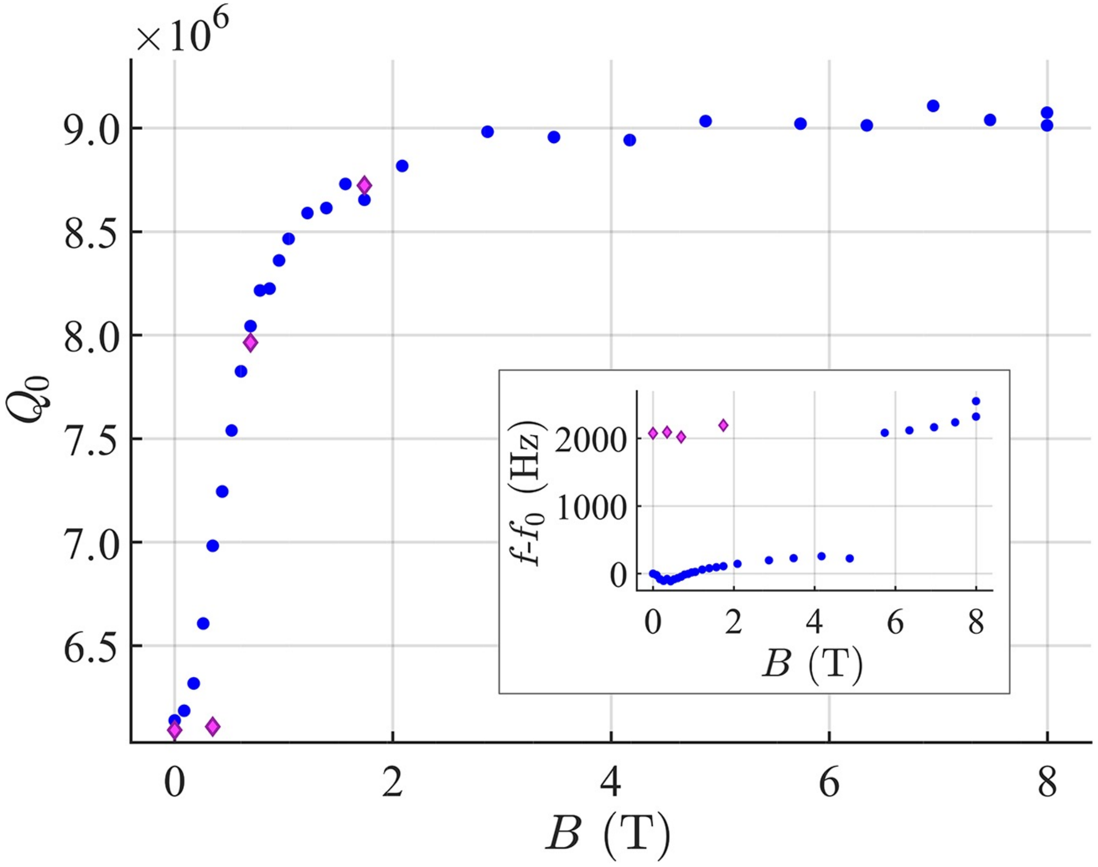


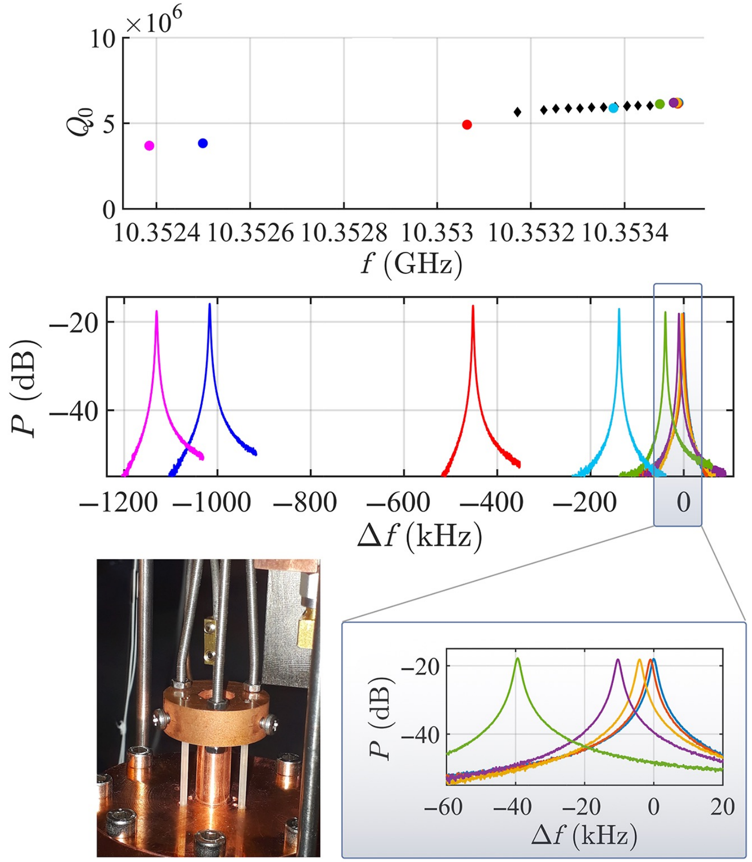


High Quality Factor Resonator with Hollow Dielectric Cylinders

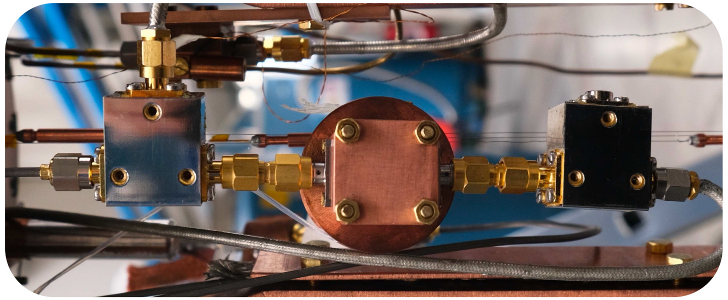
- Nuclear Inst. and Methods in Physics Research, A 985 (2021) 164641

High-Q Microwave Dielectric Resonator for Axion Dark-Matter Haloscopes PHYSICAL REVIEW APPLIED 17, 054013 (2022)





Reversed Kerr TWPA

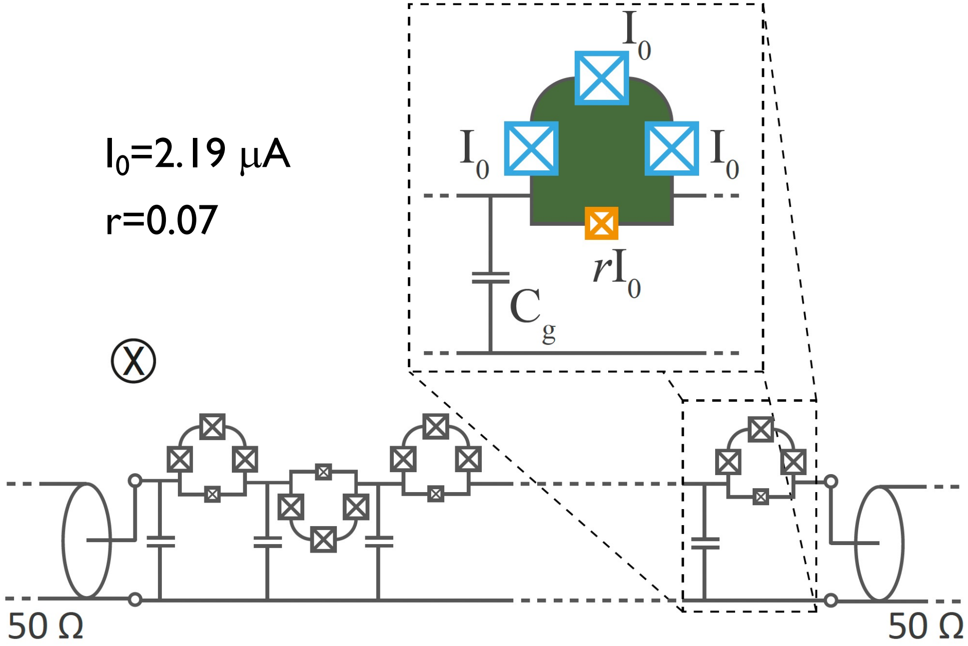


6 mm transmission line composed by 700 cells made of superconducting nonlinear asymmetric inductive elements (SNAIL)

(b)

I_0=2.19 μA

r=0.07



Pump

Signal

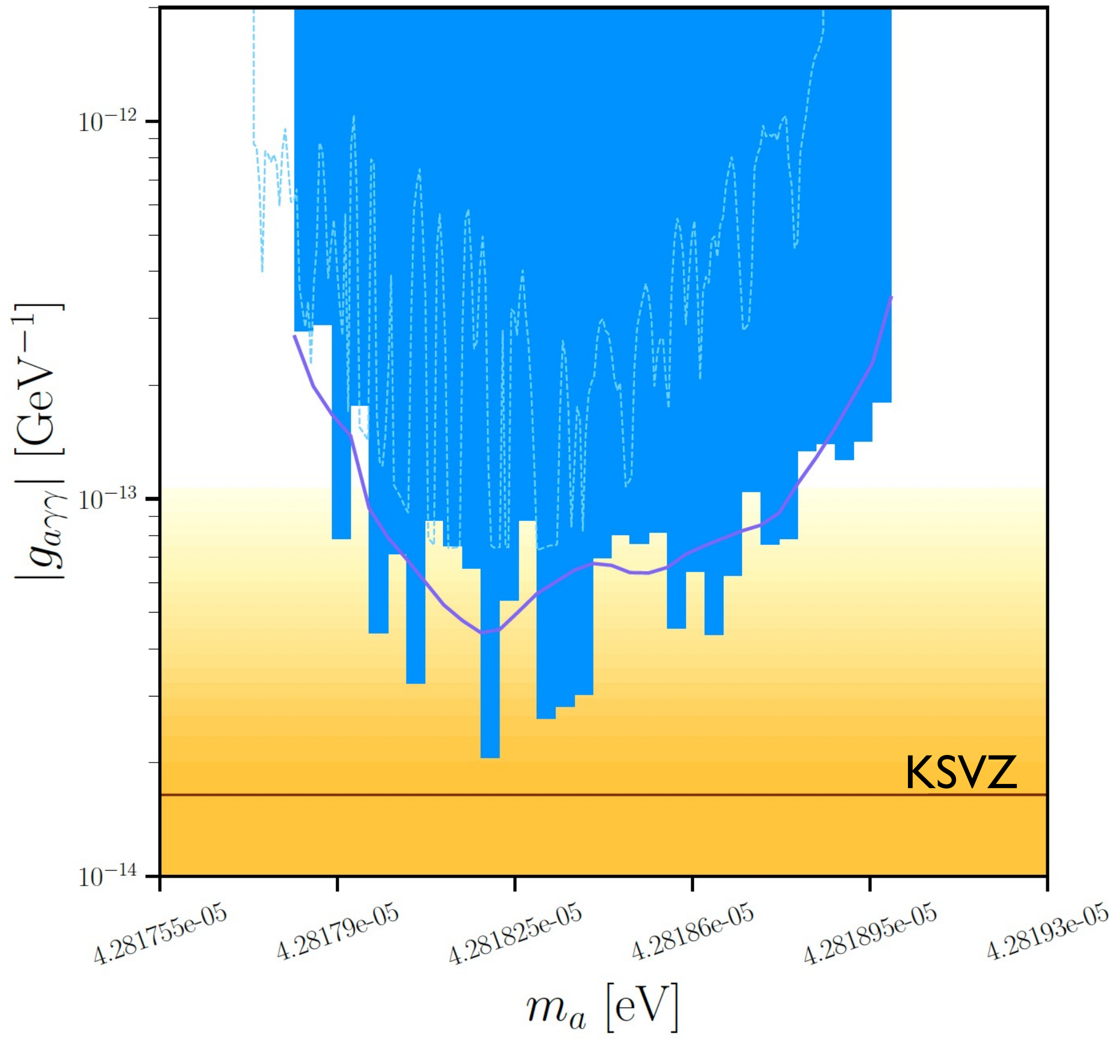
$$\varphi(z,t) = \frac{1}{2}\left[A_p(z)e^{i(k_p z - \omega_p t)} + A_s(z)e^{i(k_s z - \omega_s t)} + A_i(z)e^{i(k_i z - \omega_i t)} + \text{c.c.}\right],$$

Idler

$$\omega_s + \omega_i = 2\omega_p$$

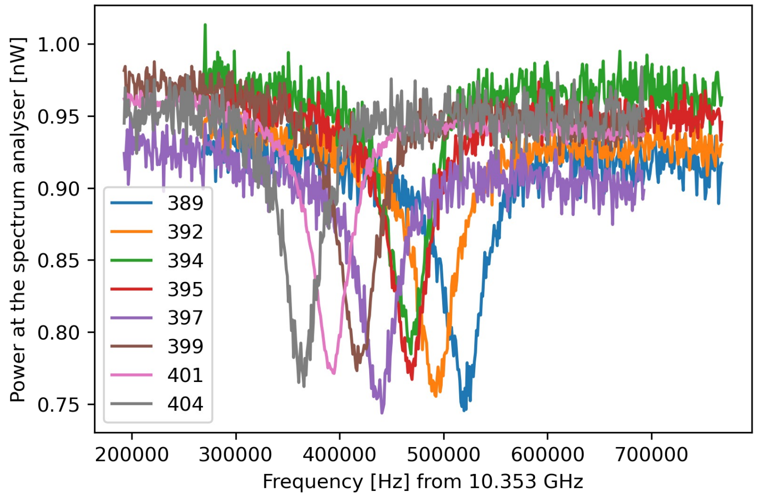
A. Ranadive et al. Kerr reversal in josephson meta-material and traveling wave parametric amplification. Nature Communications, 13(1):1737, Apr 2022.

Result of LNL Axion Search in 2022



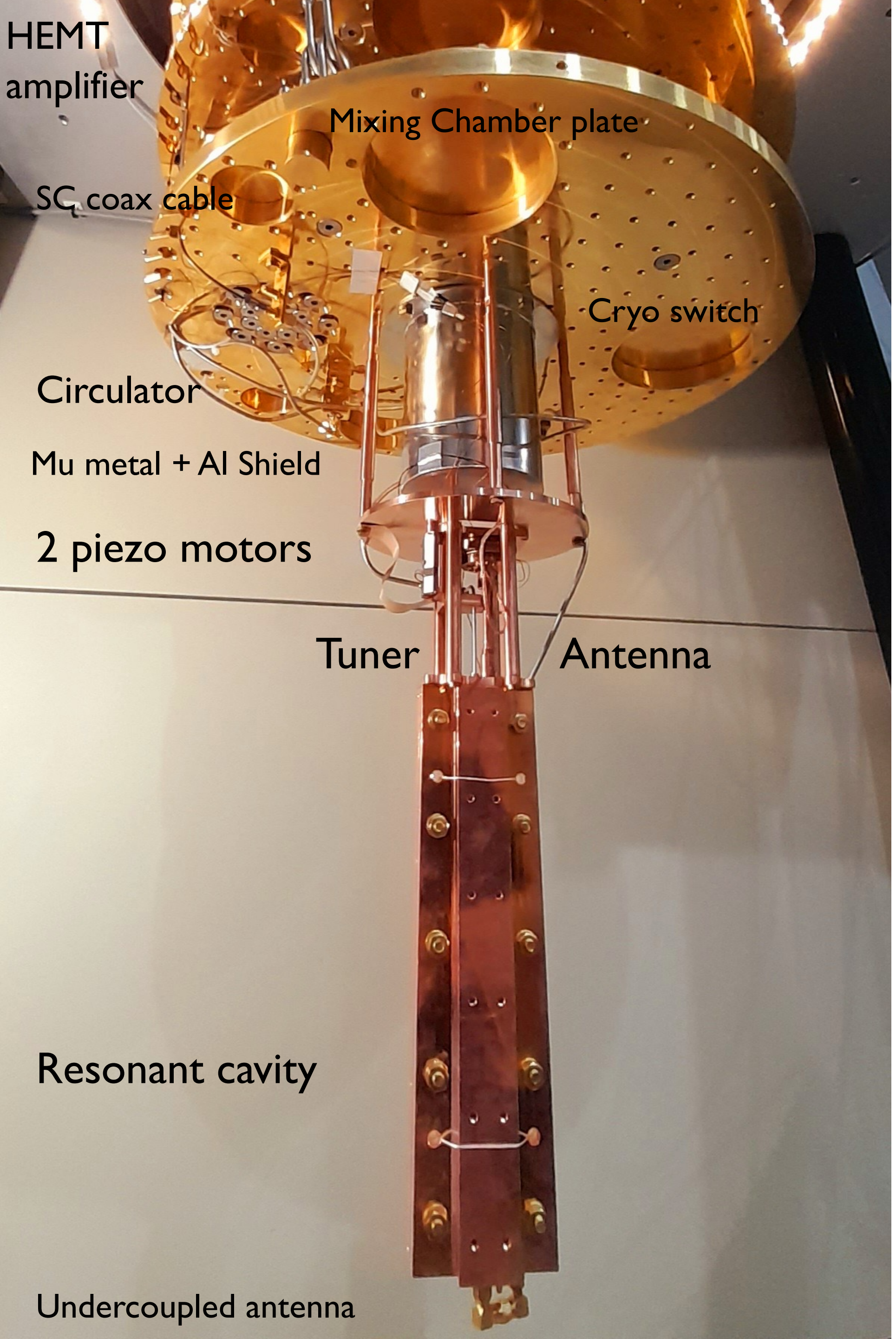
Search for galactic axions with a traveling wave parametric amplifier
PHYSICAL REVIEW D 108, 062005, arXiv:2304.7505 (2023)

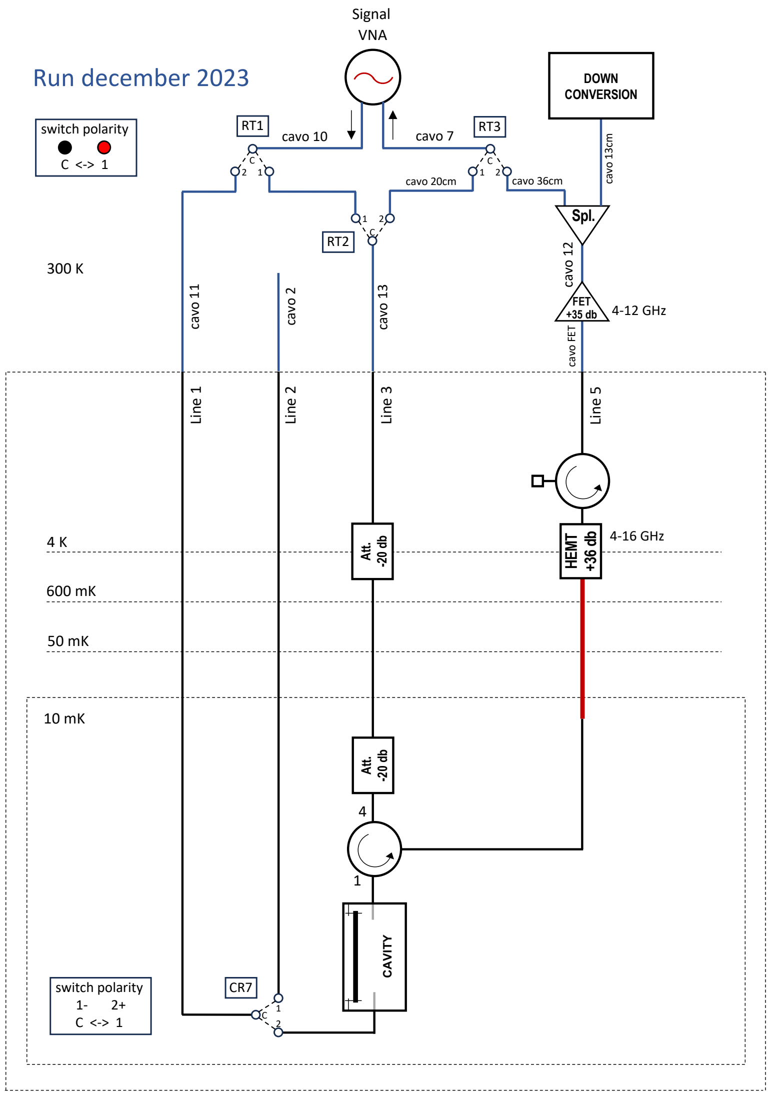
RUN n	$\nu_c - 10.353$ GHz (Hz)	Cavity Q_L	β	Ref Peak (a.u.)
389	522 600	230 000	21.6	179
392	494 100	240 000	23.8	185
394	468 800	245 000	24.2	186
395	468 800	245 000	24.2	187
397	439 800	245 000	22.7	175
399	418 500	245 000	22.6	191
401	393 100	250 000	22.5	186
404	365 400	255 000	23.5	193



Scanning rate:
About 10h Run → 0.3 MHz/day

The LNF Haloscope

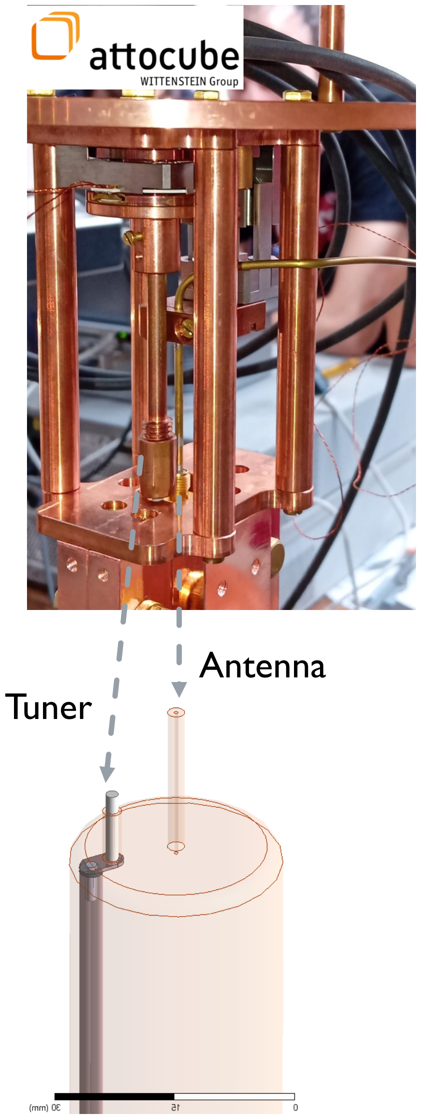


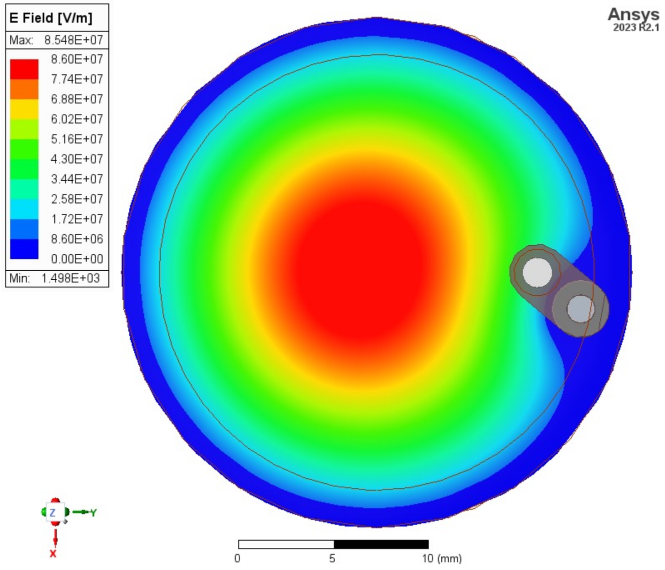


- Cavity temperature 30 mK
- Magnetic Field B=8 T
- Frequency 8.8 GHz
- Copper cavity Q_0=50,000 with tuner
- HEMT amplifier
- Tnoise 4K
- 2 weeks data taking
- 6 MHz scan

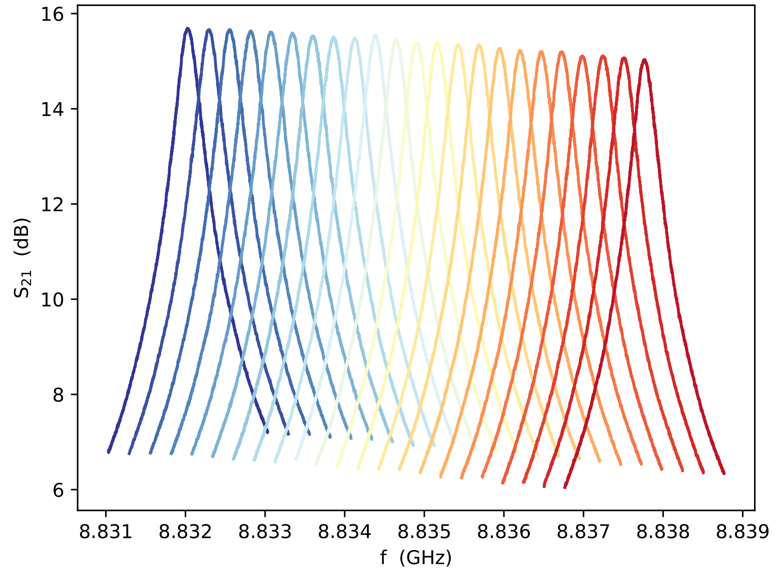
arXiv: arXiv:2404.19063

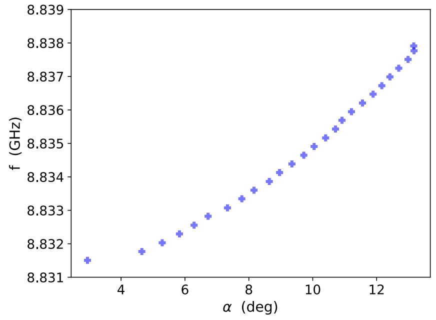
Cavity Tuning

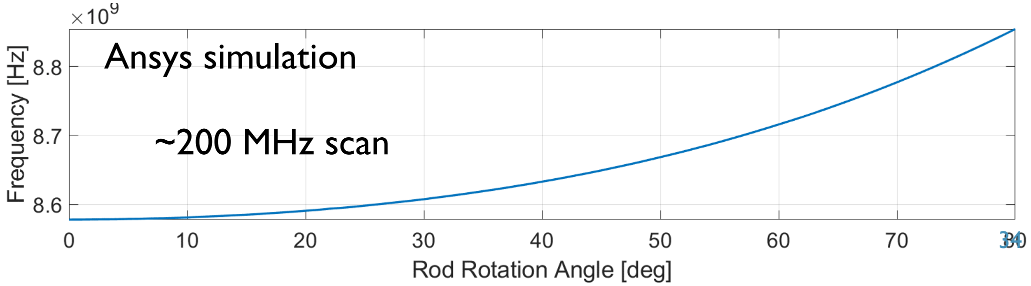




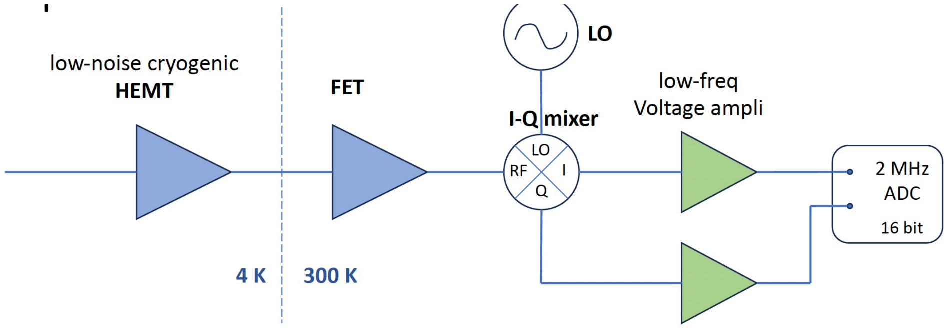
6 MHz of frequency scan







Acquisition Chain



$G^{HEMT} \simeq 37\ dB$

$T_n^{HEMT} \simeq 3\ K$

$G^{FET} \simeq 36\ dB$

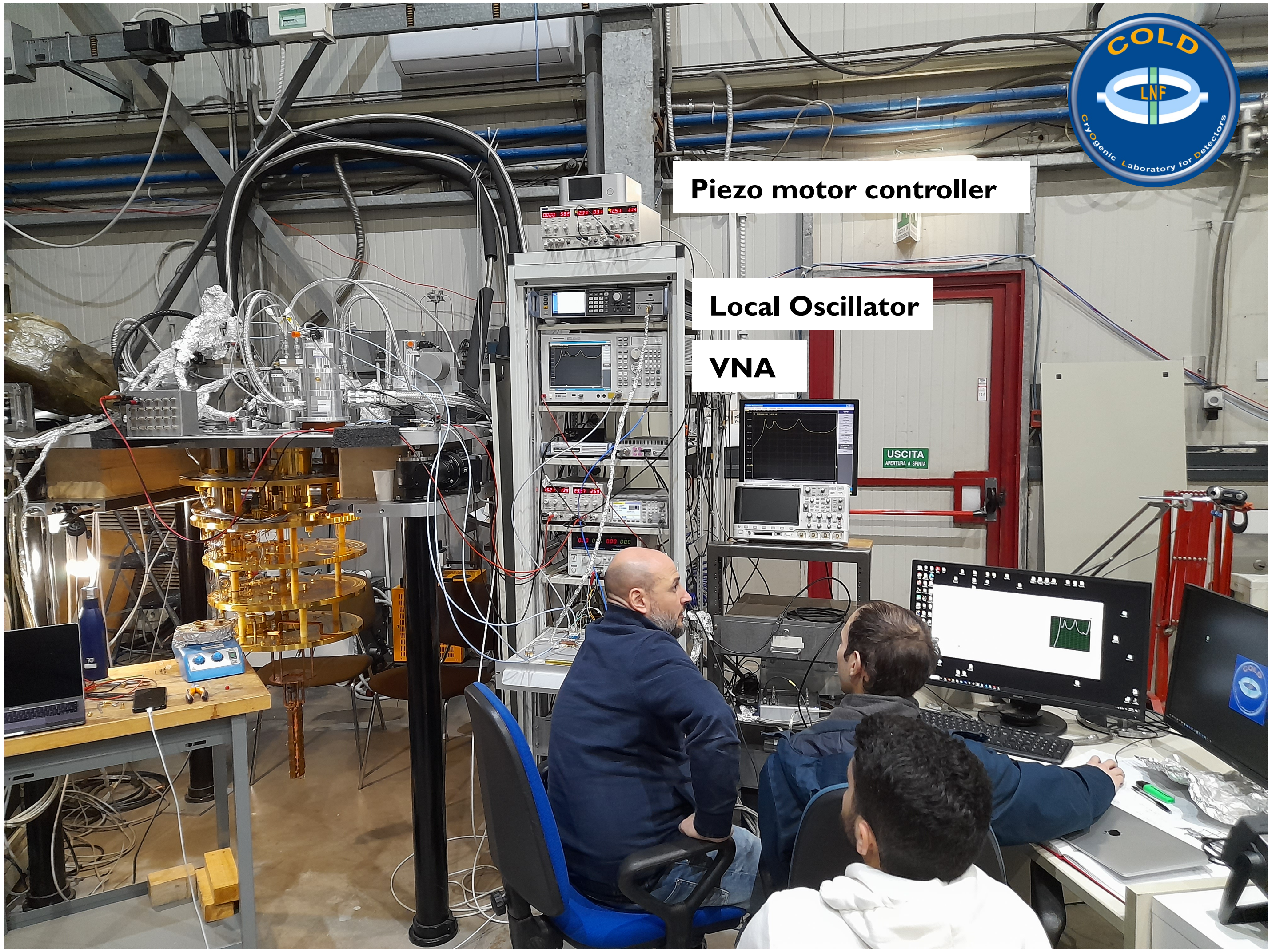
$T_n^{FET} \simeq 80\ K$

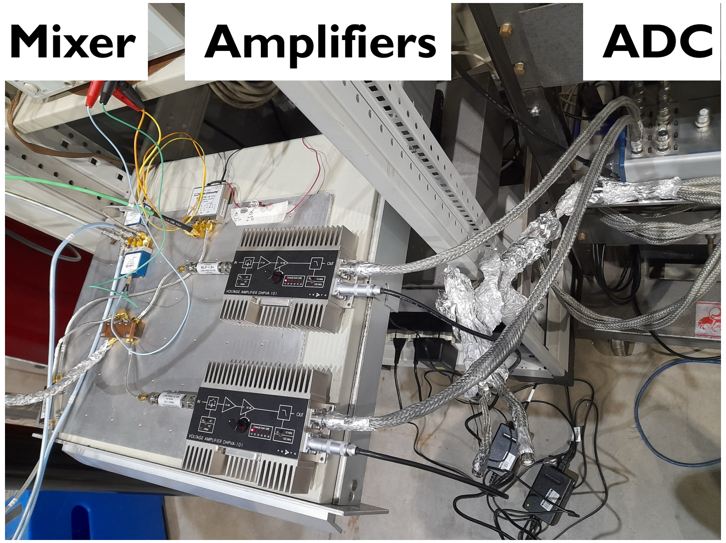
$G^{V} \simeq \times 1000$

$V_n = 2.3\ nV/\sqrt{Hz}$

Tot eff. Gain = 116 dB

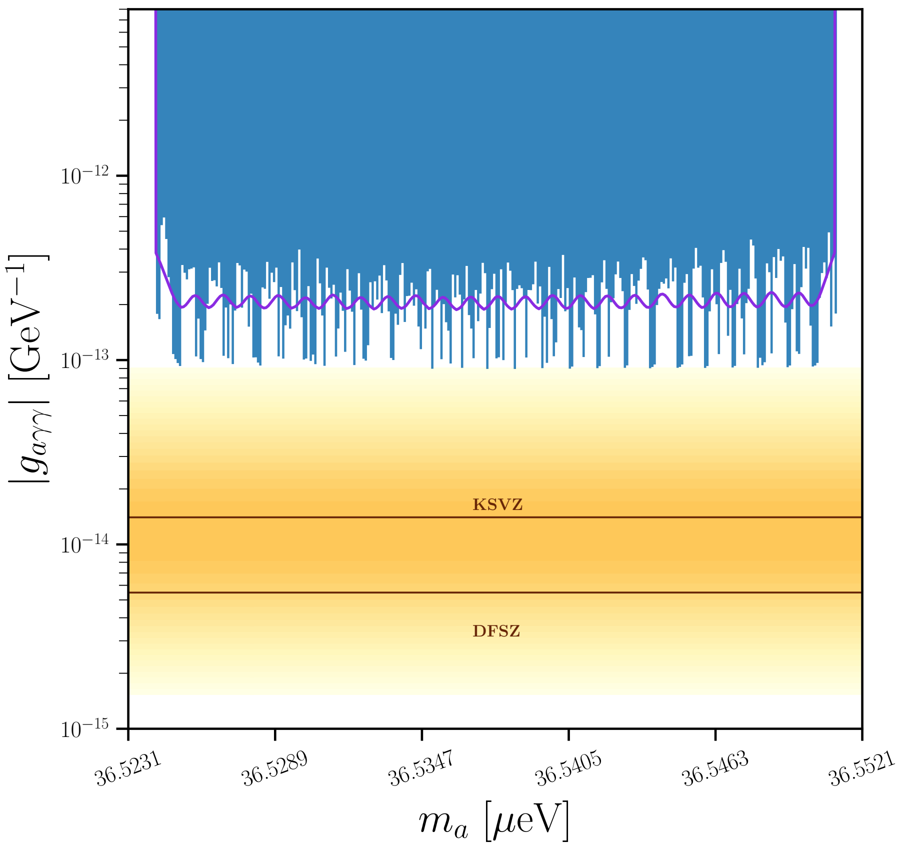
Noise Temp = 4.5 K





Result of LNF Axion Search in 2023

- 24 runs, 1 hour each, 250 kHz of frequency steps
- Average exclusion 90% c.l. about $g_{a\gamma\gamma} = 2\times10^{-13}\ GeV^{-1}$
- Preprint on arXiv: arXiv:2404.19063

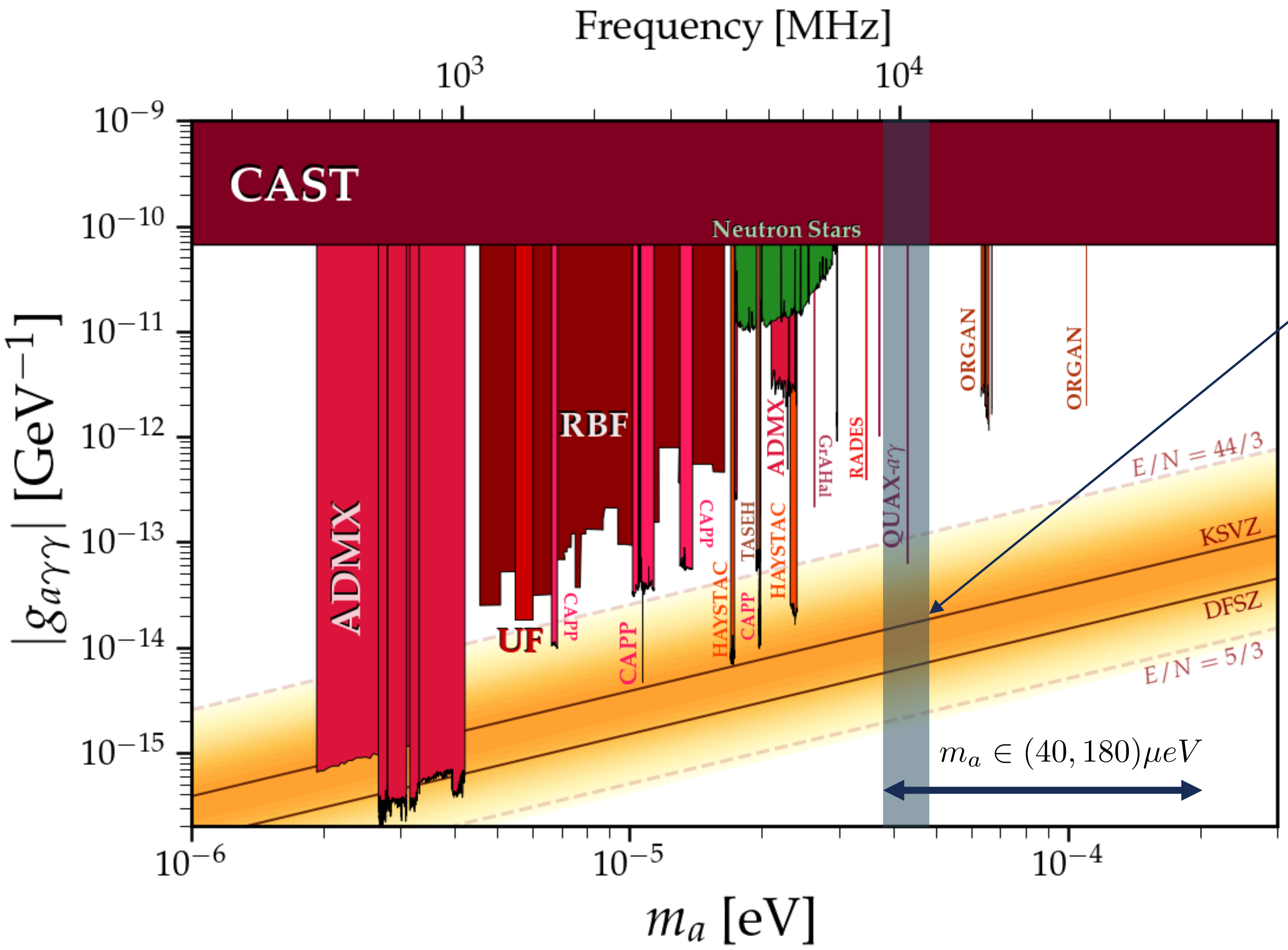


ν_c [GHz]	Q_L	β
8.83176900	32345	0.5206
8.83203080	32228	0.519
8.83229550	32273	0.5082
8.83255580	32332	0.5141
8.83282190	32387	0.5097
8.83307310	32401	0.5078
8.83334500	32300	0.5097
8.83360070	32503	0.5058
8.83386200	32540	0.5075
8.83412790	32752	0.5014
8.83438580	32573	0.5026
8.83464620	32904	0.5005
8.83490660	32957	0.4984
8.83516350	32863	0.4951
8.83542850	32872	0.4947
8.83568970	33326	0.4881
8.83594630	33051	0.489
8.83620570	33056	0.4894
8.83646975	33104	0.4857
8.83672330	33584	0.4823
8.83698660	33529	0.4803
8.83724500	33659	0.4823
8.83750860	33639	0.4793
8.83776640	33450	0.4793

QUAX LNF&LNL 2023-2025

LNF:
- Superconducting cavity $Q_0 > 2\times10^5$
- B=9T
- Multicavity

LNL:
- Dielectric cavity $Q_0 > 10^6$
- B=14T
- Single cavity



Next years with noise at Quantum Limit

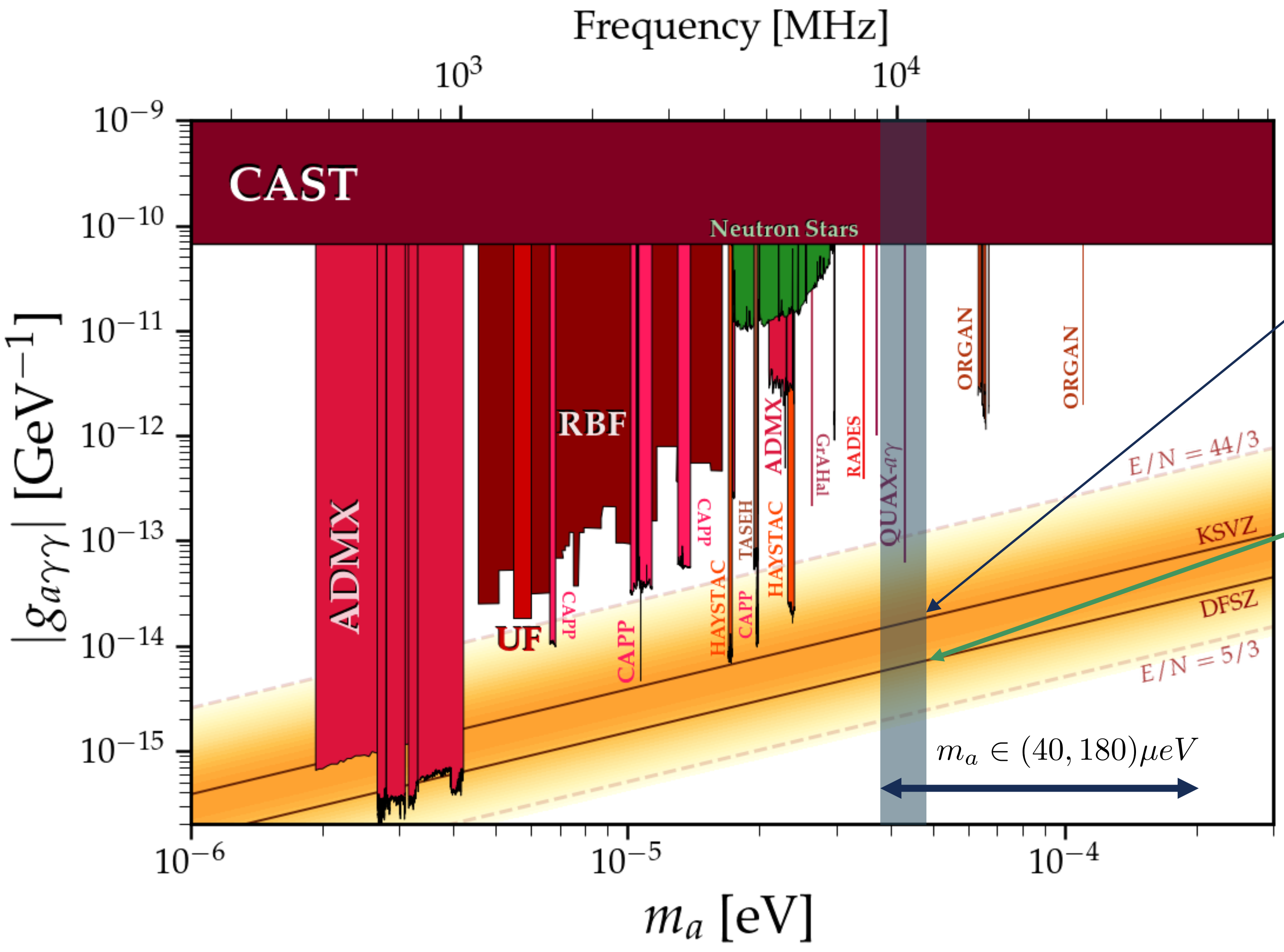
QUAX LNF&LNL 2023-2025

LNF:

- Superconducting cavity $Q_0 > 2\times10^5$
- B=9T
- Multicavity

LNL:

- Dielectric cavity $Q_0>10^6$
- B=14 T
- Single cavity



Next years with noise at Quantum Limit

Beyond Quantum Limit with photon counter (e.g. from Qub-IT R&D)

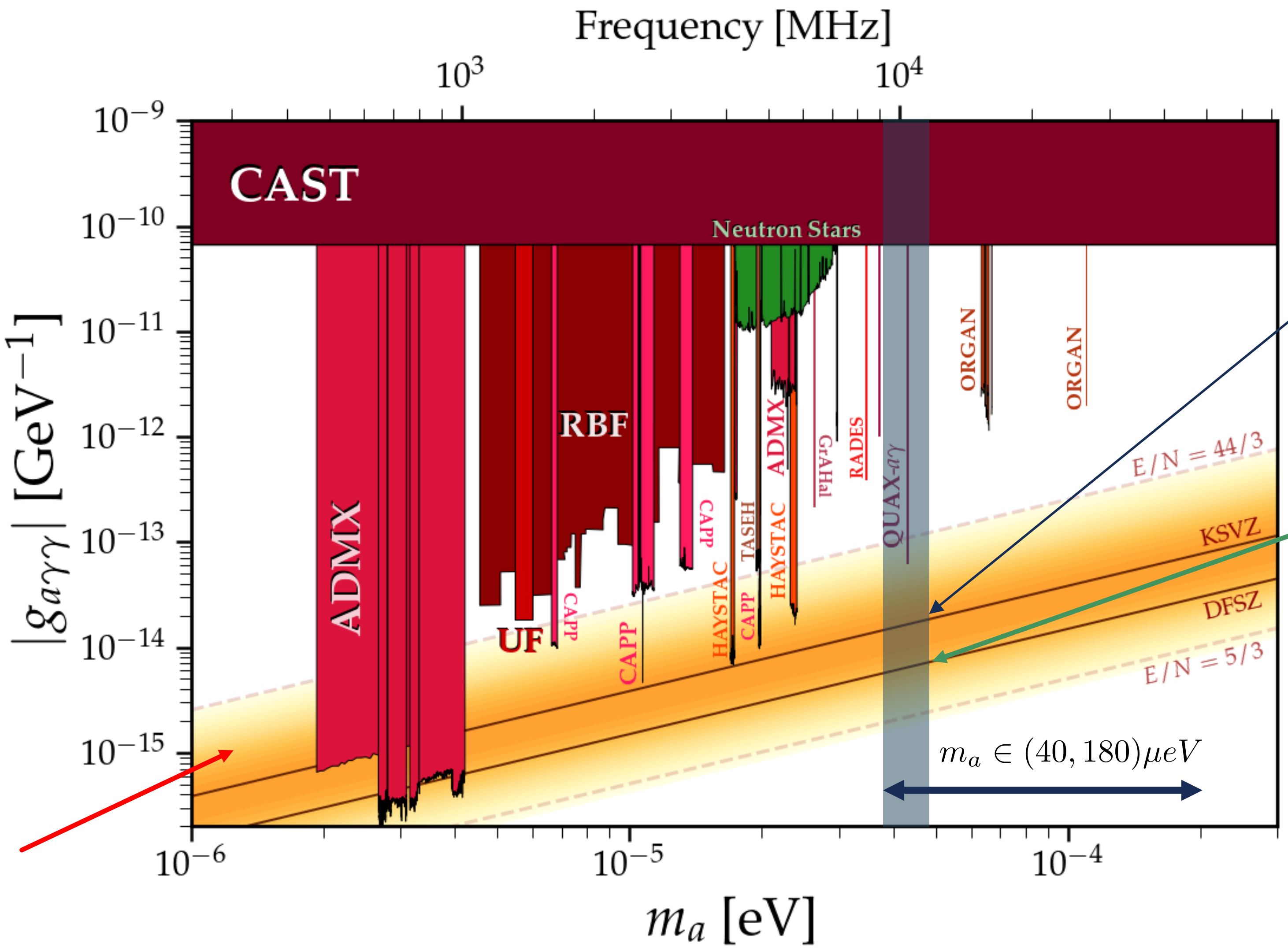
QUAX LNF&LNL 2023-2025

LNF:

- Superconducting cavity $Q_0 > 2\times10^5$
- B=9T
- Multicavity

LNL:

- Dielectric cavity $Q_0 > 10^6$
- B=14 T
- Single cavity



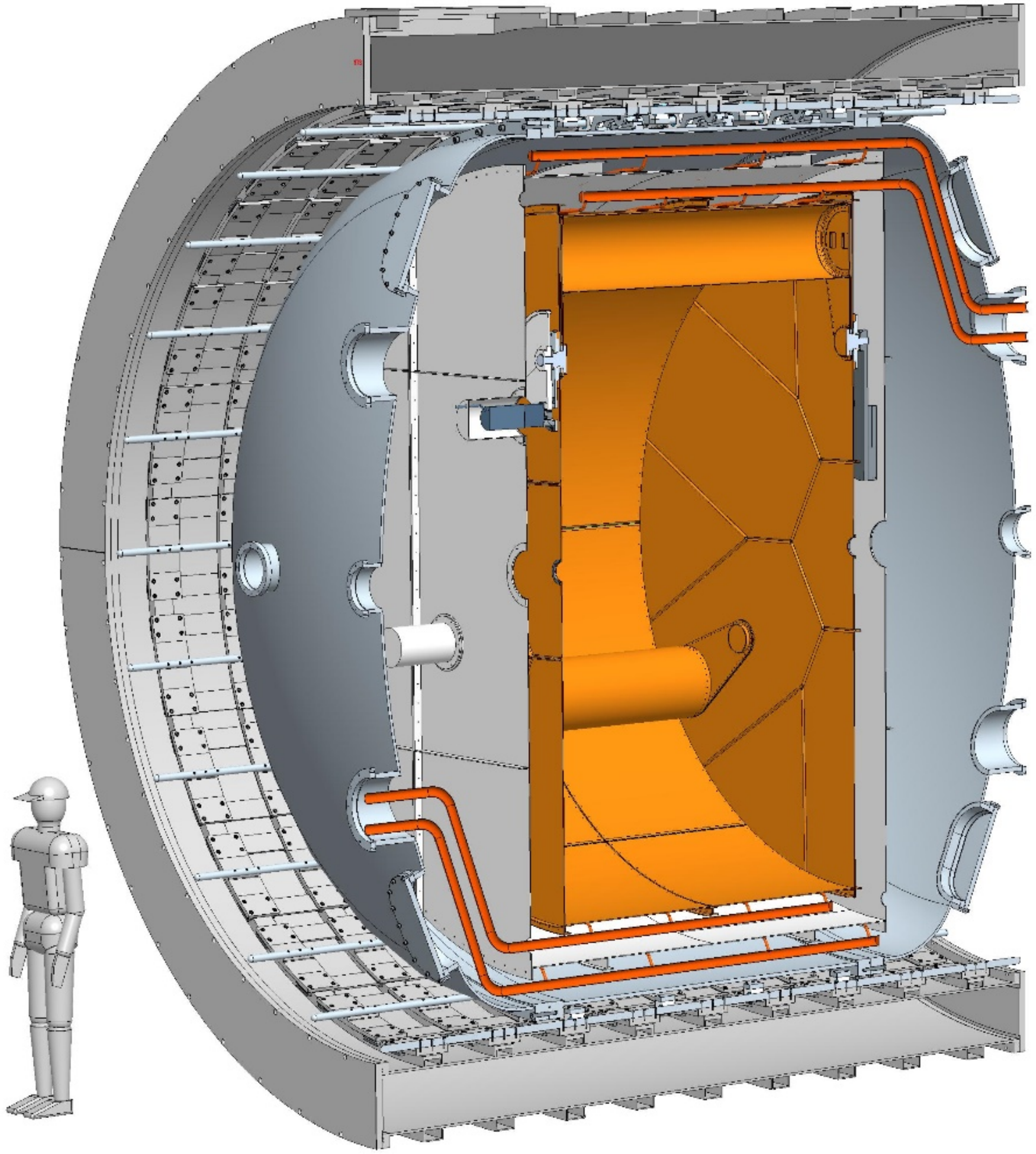
Next years with noise at Quantum Limit

Beyond Quantum Limit with photon counter (e.g. from Qub-IT R&D)

What about the low mass limit?

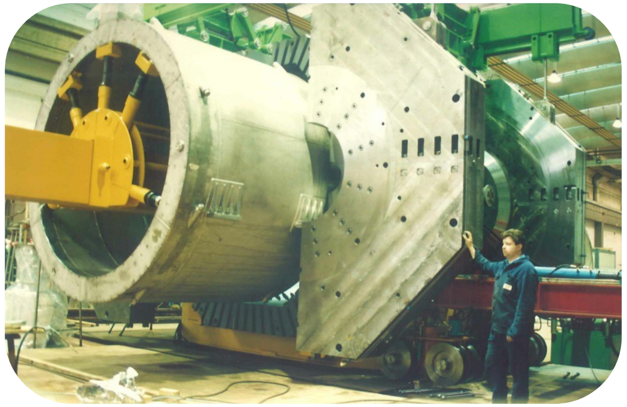
FLASH FINUDA MAGNET FOR LIGHT AXION SEARCH

GALACTIC AXION SEARCH AT 100 MHZ (0.5-1.5 μeV)

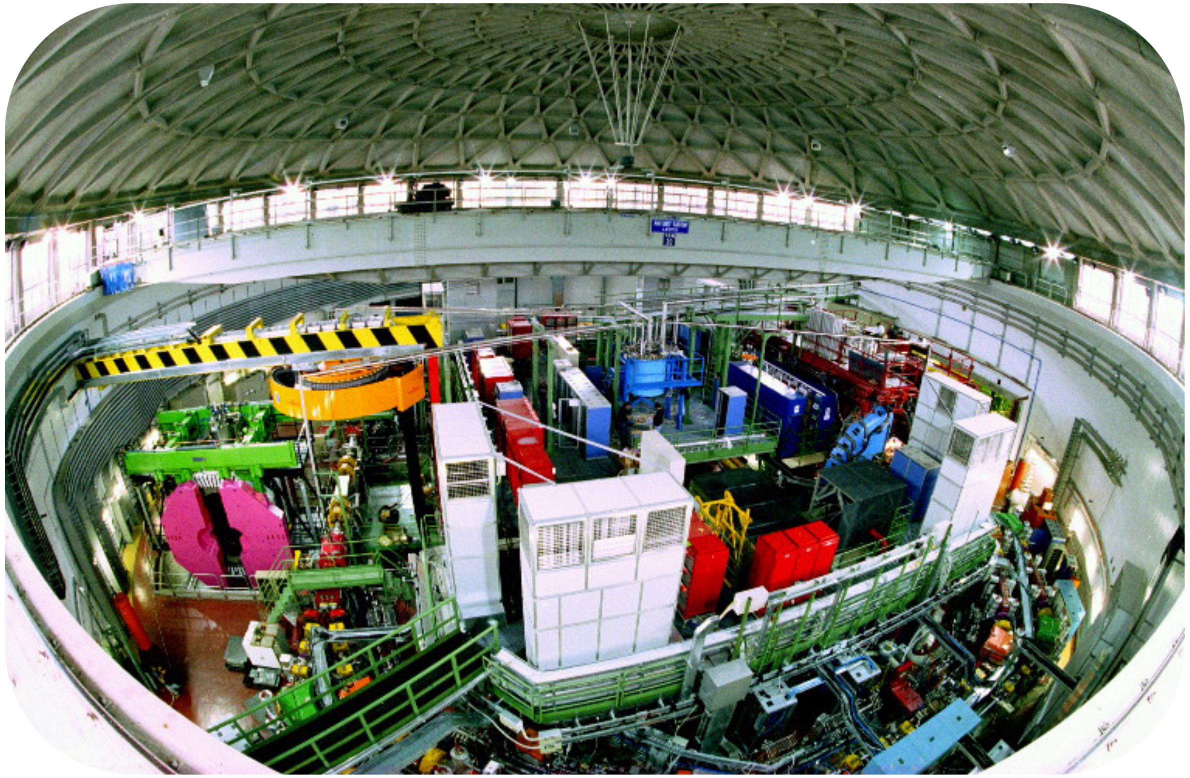


Large Superconducting Magnets at LNF

FINUDA→FLASH



B(T)	1.1
I(A)	2845
R(m)	1.4
L(m)	2.2



KLOE→KLASH

B(T)	0.6
I(A)	2300
R(m)	2.43
L(m)	4.4

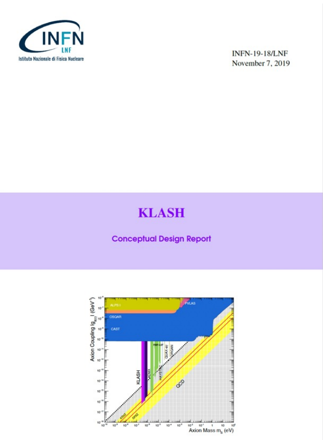

INFN LNF

Laboratori Nazionali di Frascati

INFN-18-09-LNF
September 18, 2018

The KLASH – Letter of Intent

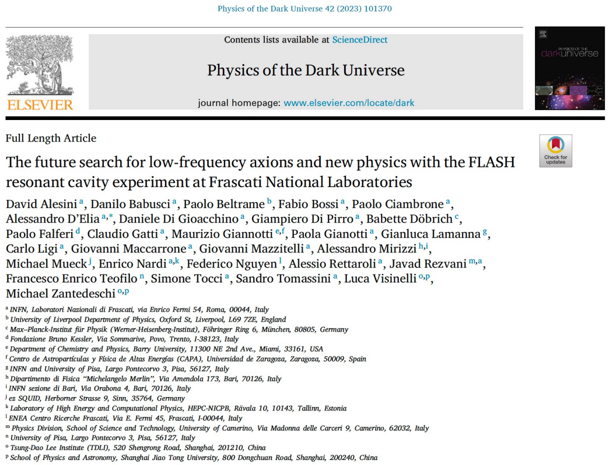
D.Alesini[1], D.Babusci[1], F.Bossi[1], P.Ciambrone[1], G.Corcella[1], D.Di Gioacchino[1], P.Falferi[2], C.Gatti[1], A.Ghigo[1], G.Lamanna[3], C.Ligi[1], G.Maccarrone[1], A.Mirizzi[4], D.Montanino[5], D.Moricciani[1], A.Mostacci[6], E.Nardi[1], A.Paoloni[1], L.Pellegrino[1], A.Rettaroli[1], R.Ricci[1], L.Sabbatini[1], S.Tocci[1].


INFN LNF

INFN-19-18/LNF
November 7, 2019

KLASH

Conceptual Design Report


Physics of the Dark Universe 42 (2023) 101370

Contents lists available at ScienceDirect

Physics of the Dark Universe

journal homepage: www.elsevier.com/locate/dark

ELSEVIER

Full Length Article

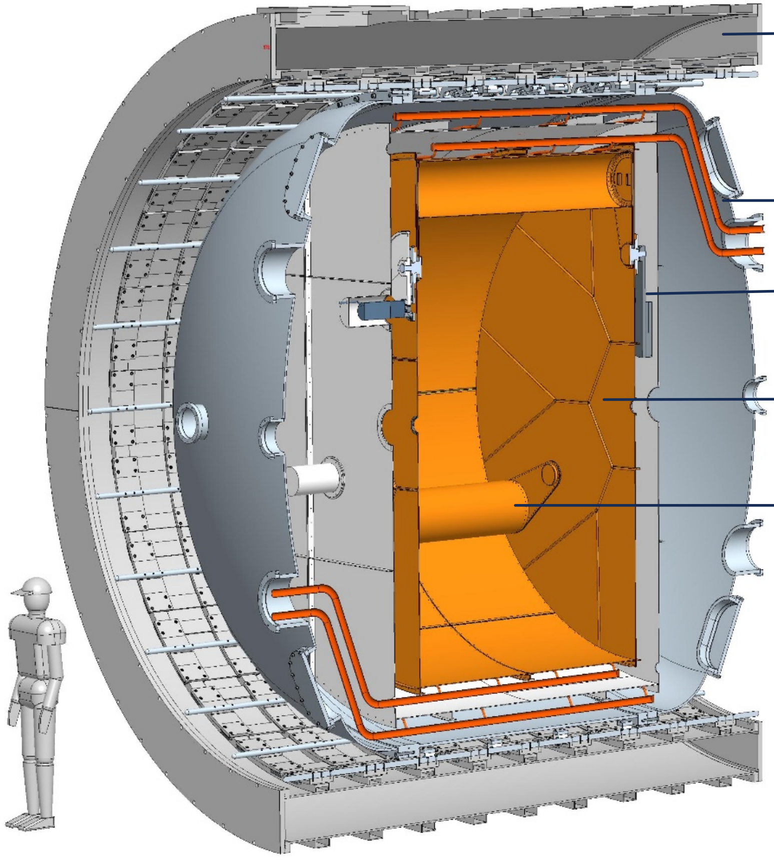
The future search for low-frequency axions and new physics with the FLASH resonant cavity experiment at Frascati National Laboratories

David Alesini [a], Danilo Babusci [a], Paolo Beltrame [b], Fabio Bossi [a], Paolo Ciambrone [a], Alessandro D'Elia [a,*], Daniele Di Gioacchino [a], Giampiero Di Pirro [a], Babette Döbrich [c], Paolo Falferi [d], Claudio Gatti [a], Maurizio Giannotti [e,f], Paola Gianotti [a], Gianluca Lamanna [g], Carlo Ligi [a], Giovanni Maccarrone [a], Giovanni Mazzitelli [a], Alessandro Mirizzi [h,i], Michael Mueck [j], Enrico Nardi [a,k], Federico Nguyen [l], Alessio Rettaroli [a], Javad Rezvani [m,a], Francesco Enrico Teofilo [n], Simone Tocci [a], Sandro Tomassini [a], Luca Visinelli [o,p], Michael Zantedeschi [o,p]

[a] INFN, Laboratori Nazionali di Frascati, via Enrico Fermi 54, Roma, 00044, Italy
[b] University of Liverpool Department of Physics, Oxford St, Liverpool, L69 7ZE, England
[c] Max–Planck-Institut für Physik (Werner-Heisenberg-Institut), Föhringer Ring 6, München, 80805, Germany
[d] Fondazione Bruno Kessler, Via Sommarive, Povo, Trento, I-38123, Italy
[e] Department of Chemistry and Physics, Barry University, 11300 NE 2nd Ave., Miami, 33161, USA
[f] Centro de Astropartículas y Física de Altas Energías (CAPA), Universidad de Zaragoza, Zaragoza, 50009, Spain
[g] INFN and University of Pisa, Largo Pontecorvo 3, Pisa, 56127, Italy
[h] Dipartimento di Fisica "Michelangelo Merlin", Via Amendola 173, Bari, 70126, Italy
[i] INFN sezione di Bari, Via Orabona 4, Bari, 70126, Italy
[j] ez SQUID, Herborner Strasse 9, Sinn, 35764, Germany
[k] Laboratory of High Energy and Computational Physics, HEPC-NICPB, Rävala 10, 10143, Tallinn, Estonia
[l] ENEA Centro Ricerche Frascati, Via E. Fermi 45, Frascati, I-00044, Italy
[m] Physics Division, School of Science and Technology, University of Camerino, Via Madonna delle Carceri 9, Camerino, 62032, Italy
[n] University of Pisa, Largo Pontecorvo 3, Pisa, 56127, Italy
[o] Tsung-Dao Lee Institute (TDLI), 520 Shengrong Road, Shanghai, 201210, China
[p] School of Physics and Astronomy, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai, 200240, China

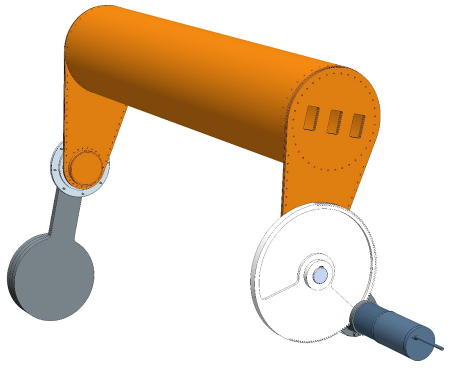
KLASH CDR arXiv:1911.02427
FLASH paper Phys. Dark Univ. 42 (2023)

THE F(K)LASH Cryostat and Resonant Cavity



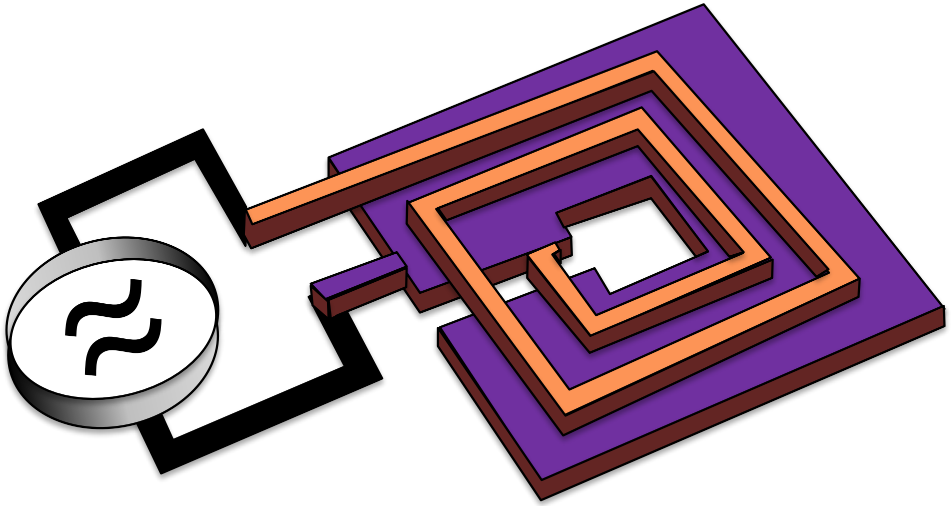
- KLOE/FINUDA Magnet
- Vacuum vessel made by a-magnetic stainless steel
- Shield in aluminum alloy, to be cooled to 70 K by gaseous Helium
- OFHC Cu resonant cavity, cooled to 4.6 K by saturated liquid Helium
- 3 OFHC Cu tuning bars mounted on eccentric cranks with reduction gearboxes

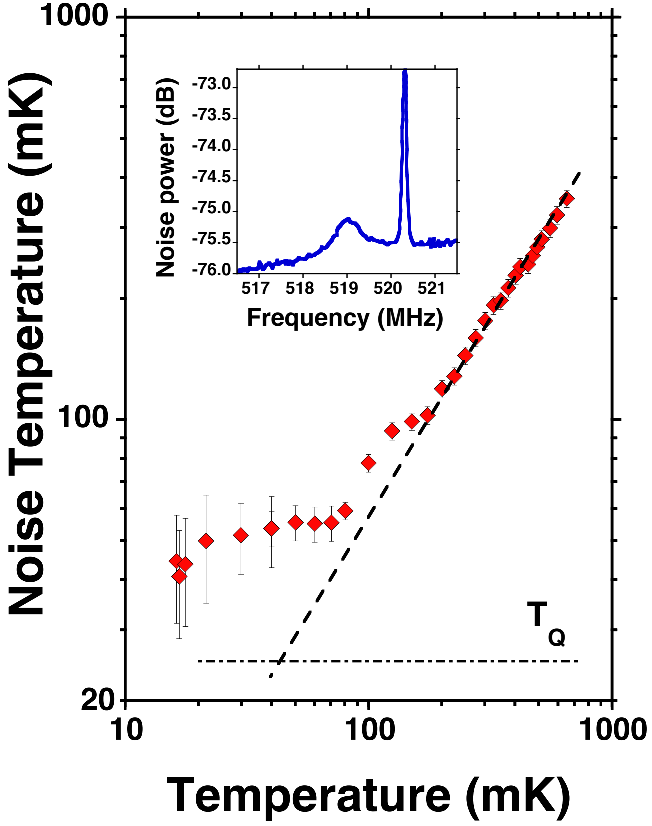
Design by FANTINI Sud Mechanical Div.



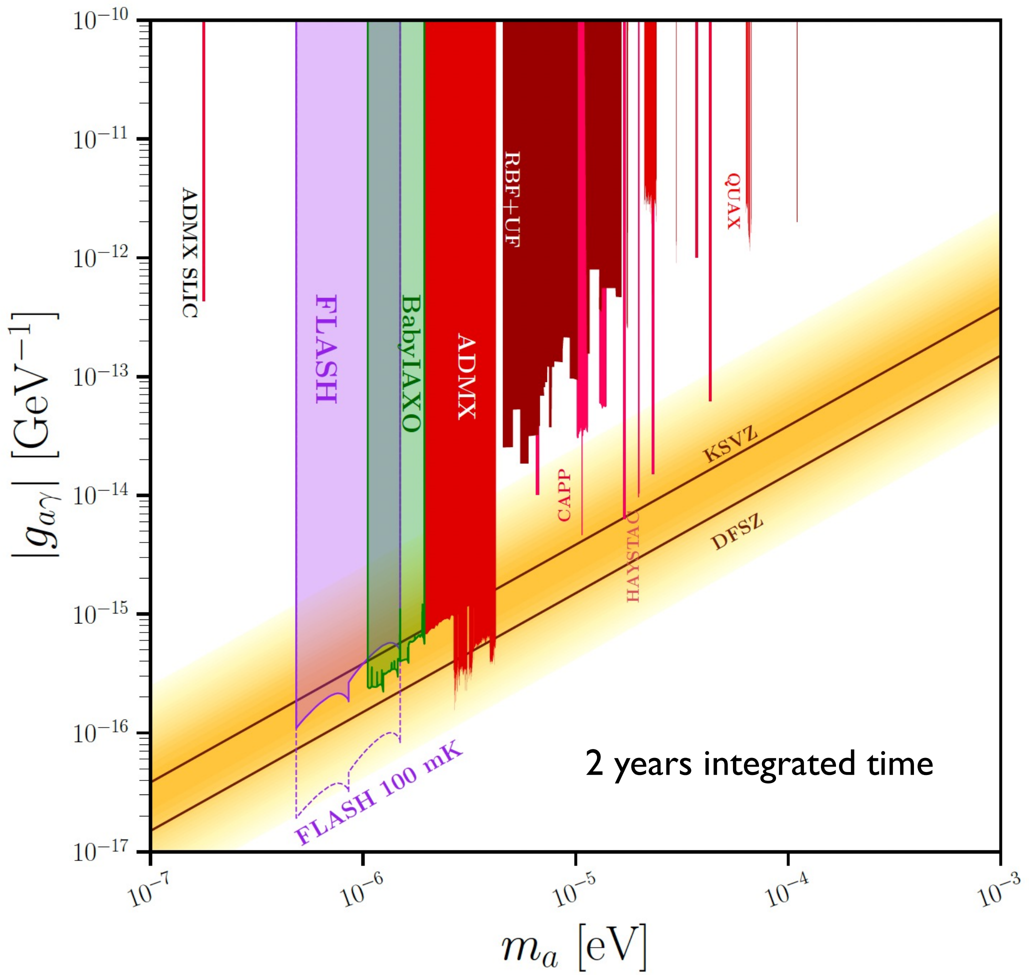
Signal Amplification

Microstrip SQUID amplifier provides large gain, low added noise and wide tunability.

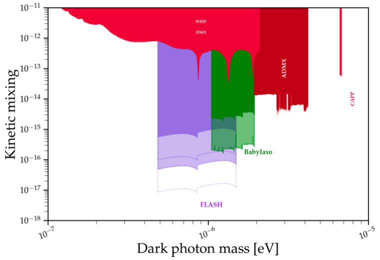


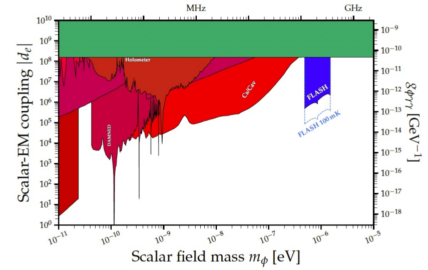


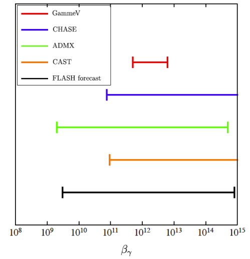
Sensitivity to AXIONS and ALPS



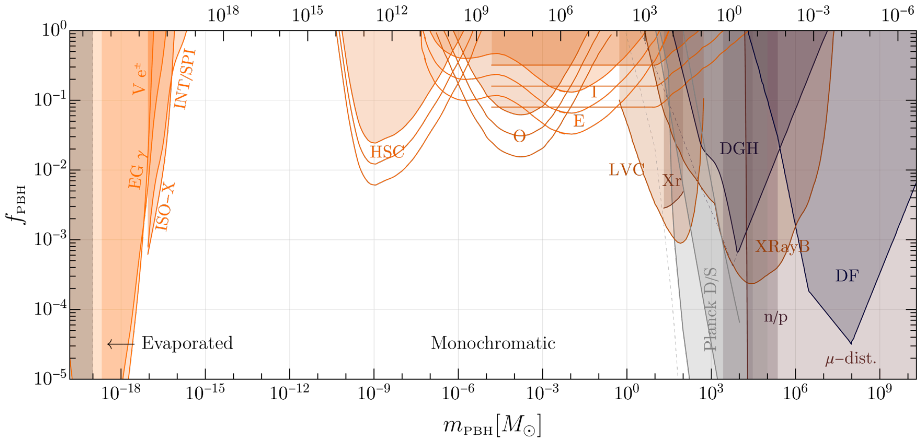
Parameter	Value
ν_c [MHz]	150
m_a [μeV]	0.62
$g_{a\gamma\gamma}^{\text{KSVZ}}$ [GeV^{-1}]	2.45×10^{-16}
Q_L	1.4×10^5
C_{010}	0.53
B_{max} [T]	1.1
β	2
τ [min]	5
T_{sys} [K]	4.9
P_{sig} [W]	0.9×10^{-22}
Scan rate [Hz s^{-1}]	8
m_a [μeV]	0.49 - 1.49
$g_{a\gamma\gamma}$ 90% c.l. [GeV^{-1}]	$(1.25 - 6.06) \times 10^{-16}$

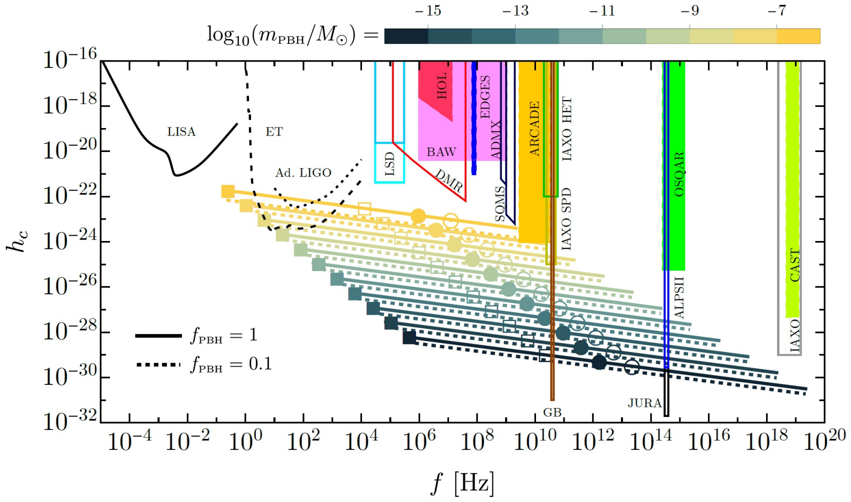


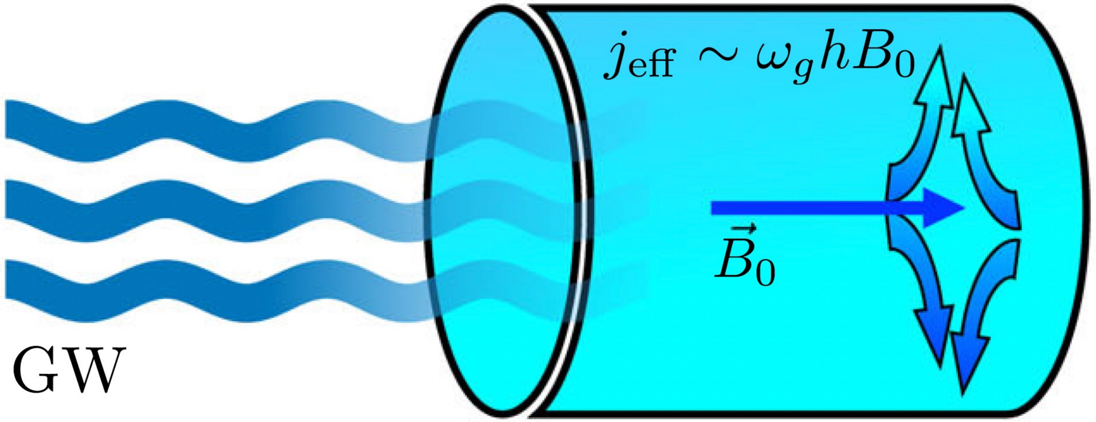




Light Primordial Black Hole Dark Matter with Ultra-high-frequency Gravitational Waves







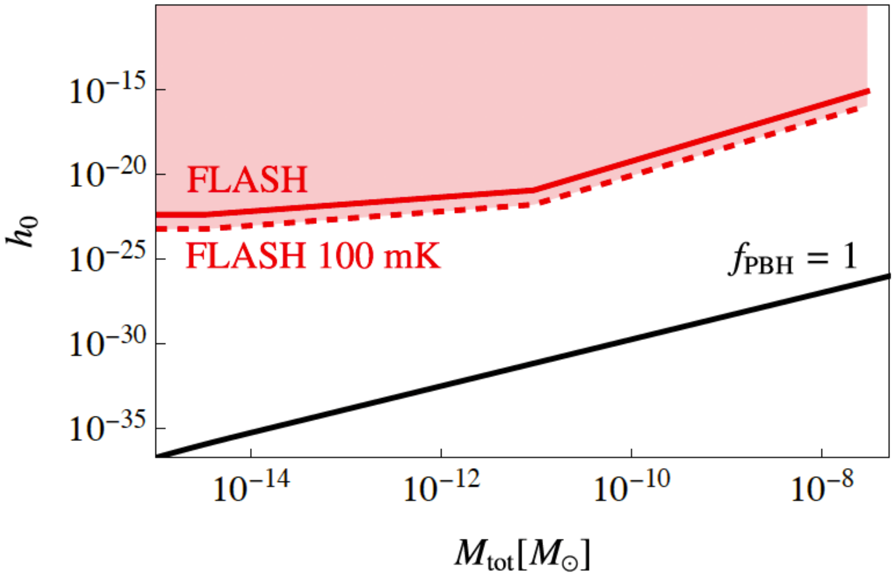
A. Berlin Phys. Rev. D 105, 116011

Franciolini Phys. Rev. D 106, 103520 2022

FLASH Sensitivity to HFGW

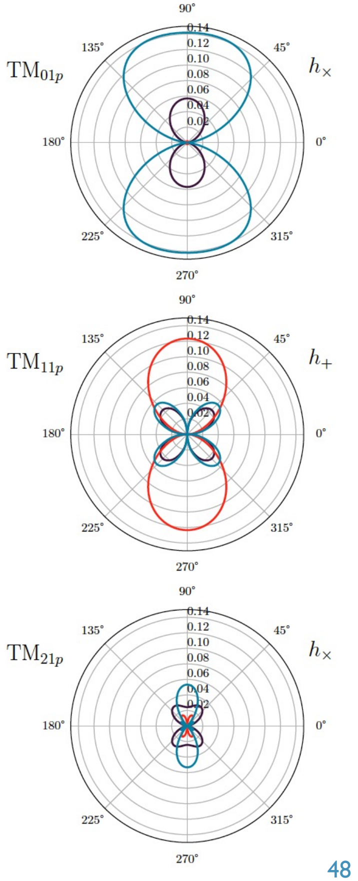
Sensitivity limited also by short duration time of the HFGW from PBHs. Gain 1 or 2 order of magnitudes wrt GHz cavities:

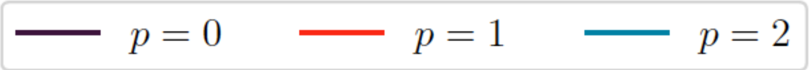
- Signal power scales as Radius^2
- Q factor effective as long as Ncycles~Q



$$t_{int} \simeq 2.72 \cdot 10^{-14}\ \mathrm{s} \times \left(\frac{M_c}{10^{-5} M_\odot}\right)^{-5/3} \left(\frac{\nu}{200\ \mathrm{MHz}}\right)^{-8/3} \left(\frac{10^6}{Q}\right)$$

Mode	Resonant Frequency [MHz]	Q factor (@4°K)
TM010	109.5	626e3
TM011	166.1	526e3
TM012	272.3	752e3
TM110	174.4	790e3
TM111	214.5	598e3
TM112	304.7	712e3
TM210	233.7	915e3
TM211	264.9	664e3
TM212	342.1	755e3

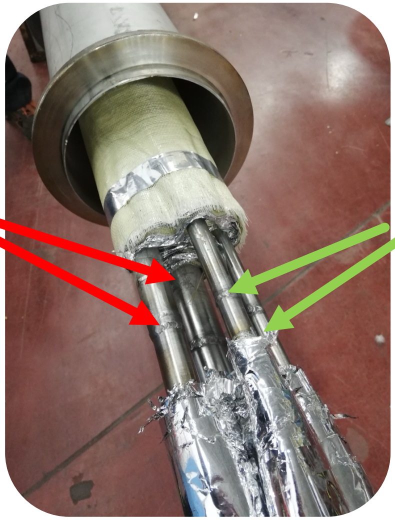




Synergistic with research with BAW detectors for HFGW!

Commissioning of the FINUDA Magnet - Last Operated in 2007!

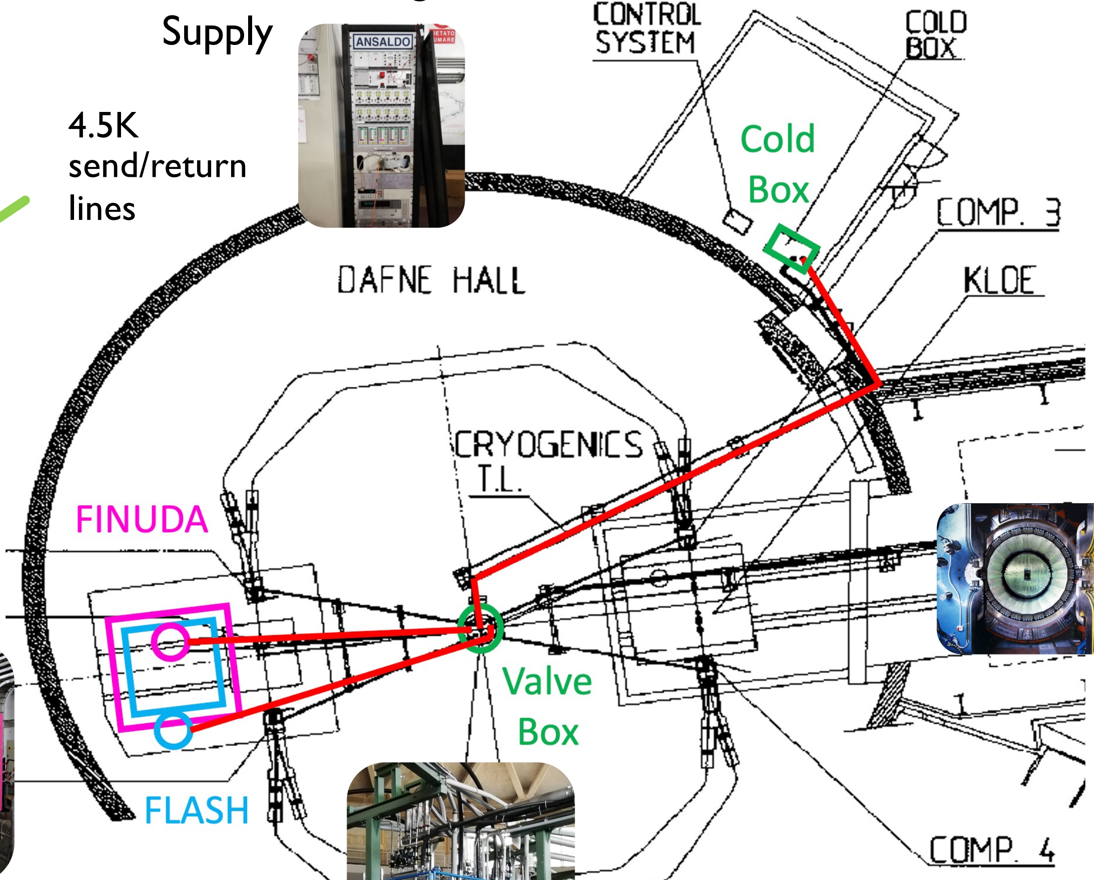
70K send/return lines

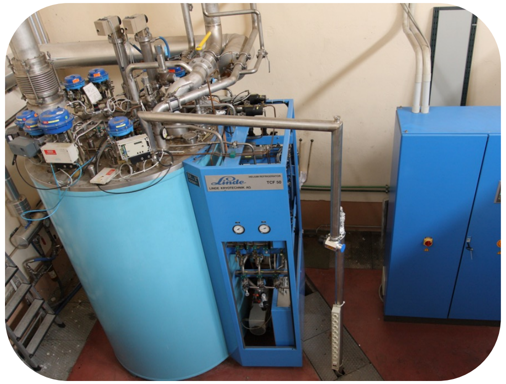


4.5K send/return lines

Reconnection of He transfer line

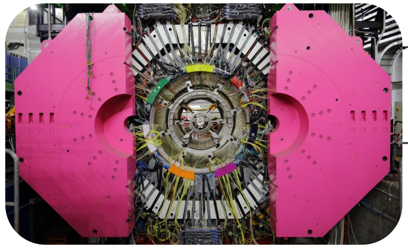
Control of Magnet Power Supply





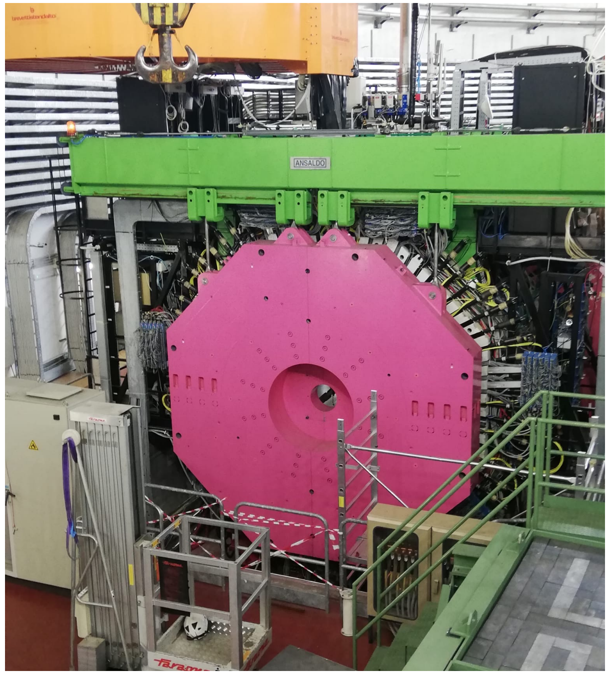
Cryogenic plant

KLOE

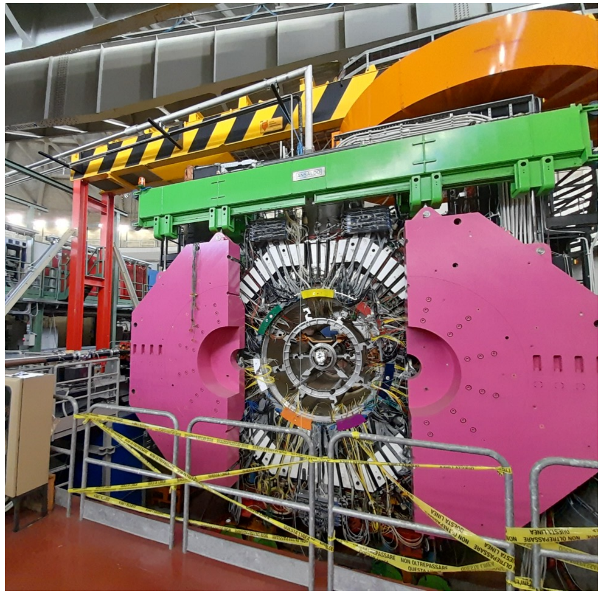


FINUDA/FLASH


LOXAM




VIETATO
FUMARE




CHIUSURA
BREAKER

Successful Test of the Finuda Magnet

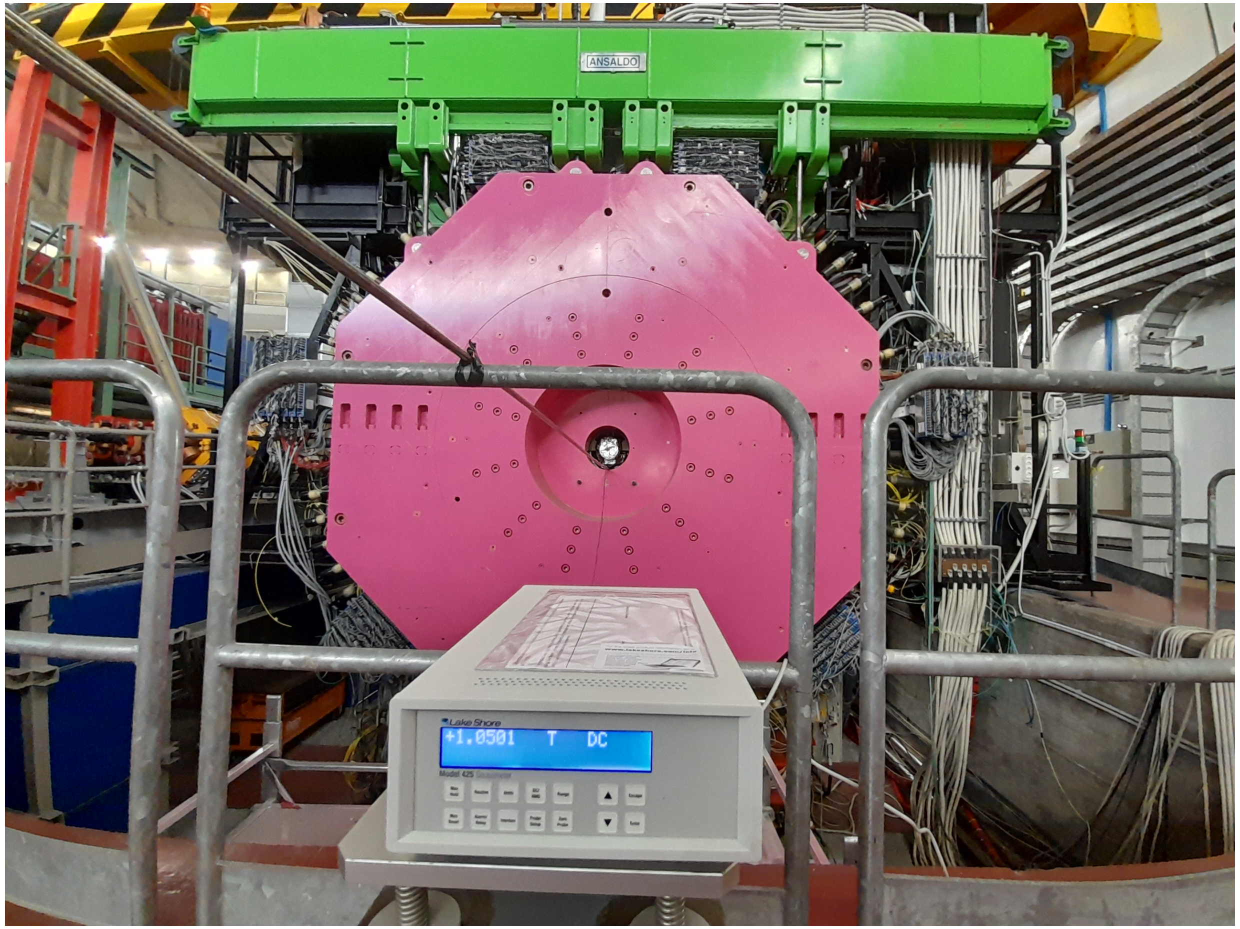
After a series of operations, the cryogenic plant was finally put back into operation. On Jan the 19th 2024, FINUDA was cooled down to 4 K and energized with a current of 2706 A, generating a magnetic field of 1.05 T.

Next steps:

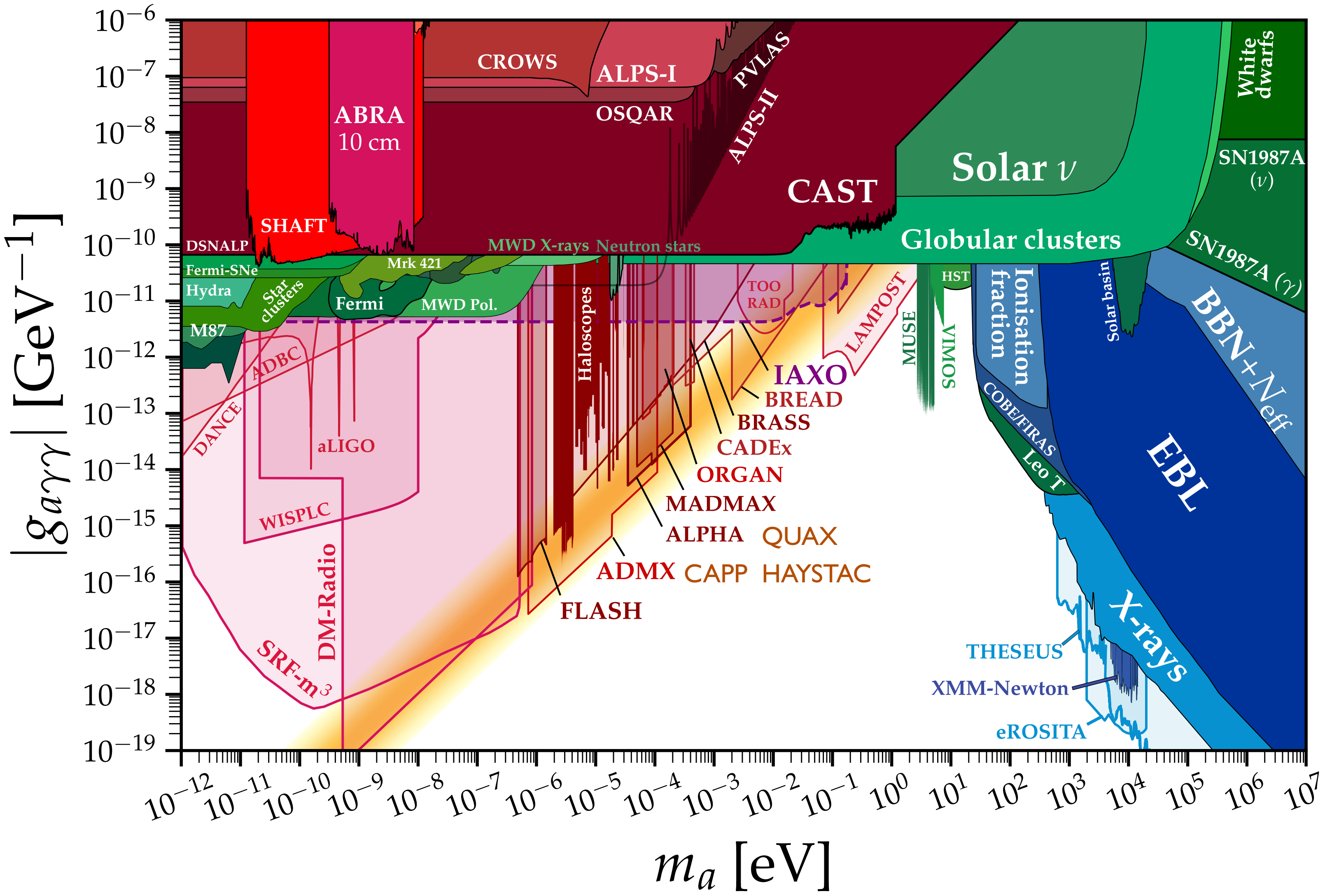
Prepare the Technical Design Report.

Set up the FLASH Collaboration:

Italy - Spain - Germany



Global Effort to Probe the Full QCD-Axion Band in the Next 10 Years



DARK SECTOR AT LNF