Technology WG activities: status and plans

Calatroni / Döbrich (CERN / MPP)

27.3.2024

Brief report from Technology Working Group

- **Experiments list and updates**
- **News from selected experiments**
- **Mini-workshops**

The PBC Technology Working Group

Mandate (highlights):

- …explore and evaluate **possible technological contributions of CERN** primarily to non-accelerator-related experimental physics initiatives and projects that may also be hosted elsewhere
- …**survey technologies** that could become relevant to CERN accelerator and non-accelerator projects
- …favour the **exchange of experience and expertise** in technological domains such as superconducting and normal conducting magnet and RF technology, cryogenics, optics, vacuum and surface technology
- …**support the development of new physics experiments** and detection methods like quantum sensing and new (accelerator and non-accelerator) experiment proposals

Objectives:

- Contribution to **advancing conceptual designs** where appropriate
- Identification and **promotion of synergies** with Quantum Sensing Initiatives at CERN and with other PBC Working Groups
- Documentation of identified and undertaken initiatives and benefits for the experimental community

All experiments & proposals linked with Tech WG

List from 2022 PBC Workshop

- ALPS-II -> axion search light-shining-through-wall with lasers -> DESY
- BabyIAXO -> axion search from the sun -> DESY
- VMB@CERN -> QED birefringence with lasers
- Grenoble Haloscope (GrAHal) -> axion search with RF cavities
- RADES/HTS -> axion search with HTS RF cavities
- DarkSide -> direct detection of WIMPS with liquid Ar TPC -> CERN REC
- Ptolemy -> Carbon NanoTubes for cosmological neutrino background
- STAX -> axion search light-shining-through-wall with RF cavities
- Advanced-KWISP -> search for Short Range Interactions
- New: Axion Heterodyne Detection -> axion search with two-mode RF cavities
- New: AION-100 @ CERN -> vertical atom interferometer

All experiments & proposals linked with Tech WG

Updated list after reaching out to all experiments

- ALPS-II (Joern Schaffran) -> axion search light-shining-through-wall with lasers
- BabyIAXO (Matthias Mentink, Igor Garcia Irastorza) -> axion search from the sun

- GrAHal (Pierre Pugnat) -> axion search with RF cavities
- RADES/HTS (Jessica Golm) -> axion search with HTS RF cavities
- Advanced-KWISP (Giovanni Cantatore) -> search for Short Range Interactions
- Axion Heterodyne Detection (TBC) -> axion search with two-mode RF cavities
- AION-100 @ CERN (Oliver Buchmuller, Richard Hobson) -> vertical atom interferometer

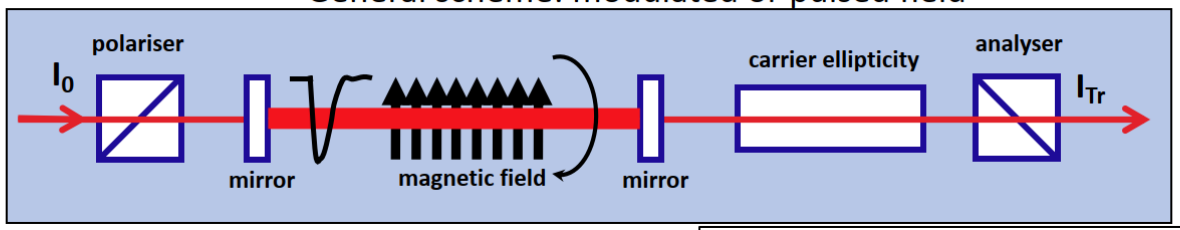
- NEW: FLASH (Claudio Gatti) - > axion search with RF cavities

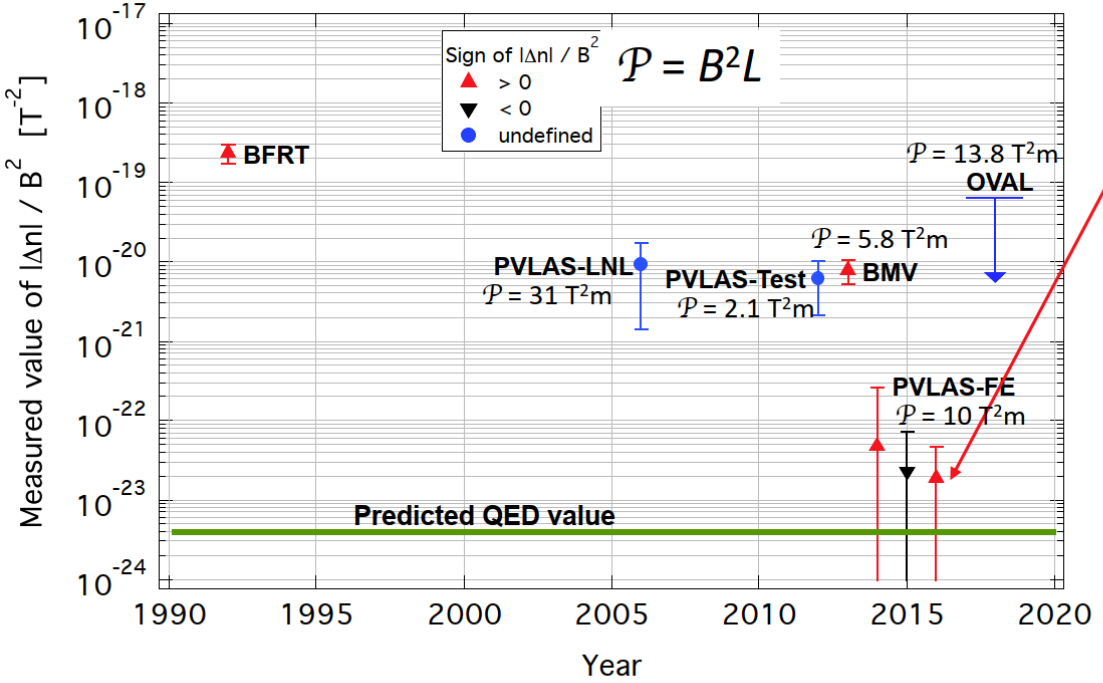
VMB@CERN status

Mostly taken from presentation of Guido Zavattini to SPSC and PBC Tech WG

State of the art
PVLAS @ Ferrara U.

General scheme: modulated or pulsed field





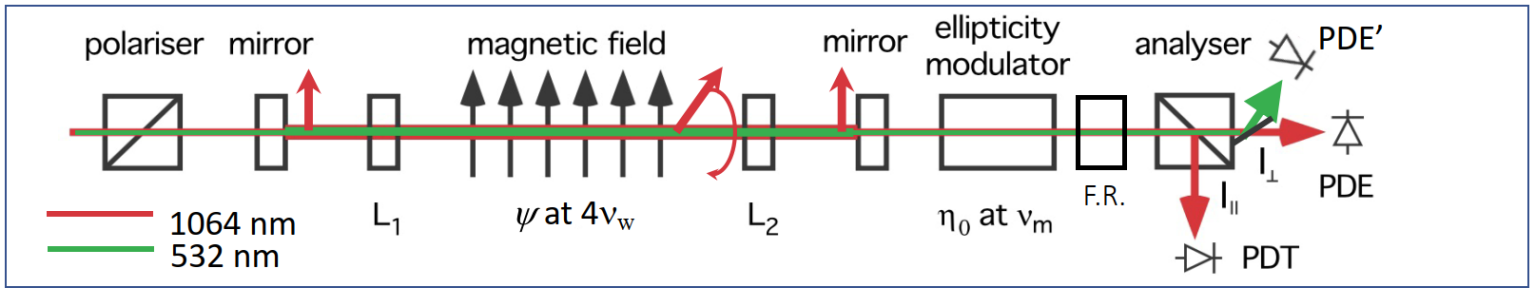
Physics Reports 871 (2020) 1–74

- The PVLAS - FE result remains the most sensitive measurement yet performed: $\Delta n/B^2 = (1.9 \pm 2.7)\cdot 10^{-23}$ T^{-2} with 2.5 T
- Permanent magnets allowed careful debugging of systematics: $B^2L = 10$ T^{2}m
- Optical path difference sensitivity: $S_{OPD} = 4\cdot 10^{-19}$m/√Hz @ ≈ 15 Hz
- Cavity amplification was $N \approx 4.5\cdot 10^5$
- Intrinsic thermal noise from the mirrors limited the sensitivity and the SNR
- Measured noise was x10 shot-noise

VMB@CERN status

Mostly taken from presentation of Guido Zavattini to SPSC and PBC Tech WG

Scheme: two co-rotating Half-Wave Plates inside the Fabry-Perot
Baseline scheme for VMB@CERN



LHC dipole field (B_{ext}^2 L ≈ 1000 T^2m) low-frequency modulation might help improving SNR (suppression of HWPs 4th harmonic)

$$\Psi(t) = \Psi_0 \sin 4\phi(t) + N\frac{\alpha_1(t)}{2}\sin 2\phi(t) + N\frac{\alpha_2(t)}{2}\sin[2\phi(t) + 2\Delta\phi(t)]$$

Signal @ $4\nu_w$

Spurious signals
Contain harmonics of ν_w

Relative rotation phase error
Degrades extinction

$\alpha_{1,2}$ are the phase errors from π of the two HWPs and $\phi(t)$ is their rotation angle

- ✓ Non resonant 532 nm beam (HWP -> FWP) allows independent positioning/orientation of the rotating HWPs to reduce 1st, 3rd and 4th harmonics
- ✓ Control the temperature of the wave-plates to reduce the dominating 2nd harmonic
- ✓ Demonstrated shot-noise sensitivity N ≈ 600 with two **NON-rotating** commercial HWPs inside the Fabry-Perot
- ✓ Demonstrated stable locking of the laser to the F.P. with the rotating HWPs @ 2.0 Hz with no active HWP control.
- ✗ Low frequency ellipticity noise with rotating HWPs but without the F.P. is due to input beam movement (≲ µrad) and to the rotation of the HWPs. ➔ **INPUT BEAM STABILIZATION IS NOT ENOUGH**

VMB@CERN status

Mostly taken from presentation of Guido Zavattini to SPSC and PBC Tech WG

- **Technical issues:**
  - We don’t know how to stabilize the beam to 1 nm/√Hz on each optical element in Ferrara on an isolated monolithic 4.8 m optical bench. How could this, in principle, be done in SM18 on the hall floor using twoseparate optical benches 20 m apart?
  - Is SM18 really adequate? Mechanical stability, thermal stability, cleanliness etc.
  - Extra noise, not associated to beam pointing noise, is induced by the rotating HWPs without the F.P. which we don’t know at present how to reduce
  - Dust on rotating HWPs generate intensity modulation. Is beam centering enough? Probably also modulates the polarisation generating more noise.

VMB@CERN status

Mostly taken from presentation of Guido Zavattini to SPSC and PBC Tech WG

- **Remaining work**
  - 2023 is the last R&D year financed by INFN. References to our LoI to SPSC
  - initiative paper: (https://cds.cern.ch/record/2649744/files/SPSC-I-249.pdf)
  - In 2022 our results led us to write a Conceptual Design Report for the INFN - CSN2.

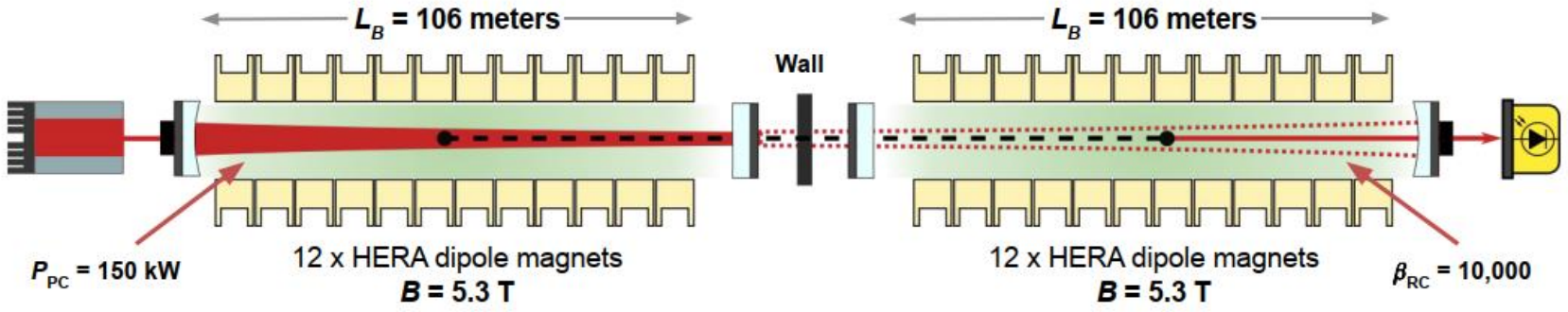
  ✕ In early 2023 we aimed at submitting a proposal to the SPSC at CERN. We also aimed at presenting a proposal to INFN

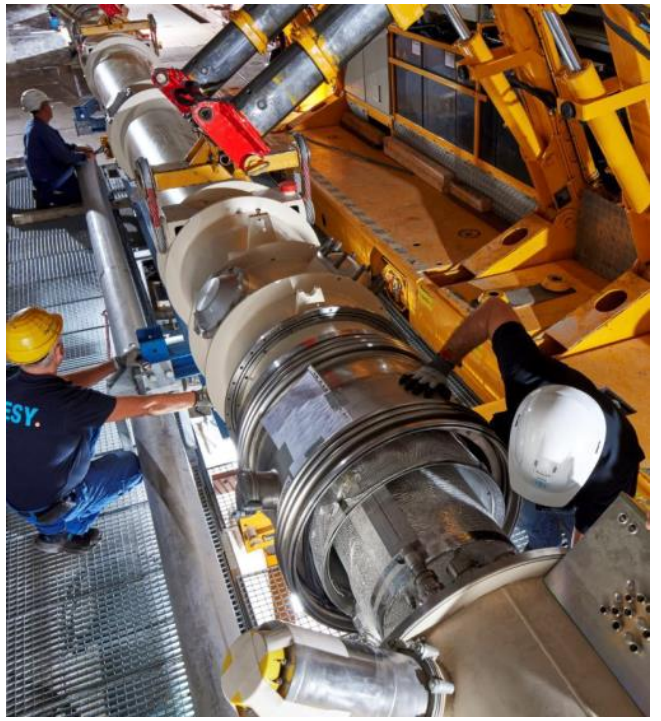
  - During 2023
    - Implement alignment and temperature feedbacks on rotating wave plates
    - Possibility to rotate at ≈ 10 Hz (?)
    - Install F.P. low finesse cavity (mirrors will arrive in May)
  - Presented this status report to INFN on April 17th
  - Report these findings to SPSC in May.

  ✕ Due to these studies and related results, we are postponing a proposal for VMB@CERN to SPSC until further notice.

Some updates: ALPS-II

- **ALPS-II, now data-taking in DESY**
- **Axion search light-shining-through-wall with lasers (“successor” to OSQAR)**





DESY News 27 October 2022

ALPS II achieves world record

"Dark-matter experiment at DESY manages to store laser light in-between two mirrors for the longest time ever"

"DESY's very own dark-matter experiment ALPS II – for "Any Light Particle Search" – hasn't even started up yet, but is already breaking world records. The team, whose experiment sits in the tunnel of the former HERA accelerator and uses upcycled HERA magnets to (hopefully) send light through a wall, has managed to store laser light for 6.75 milliseconds. "We believe this a **world record for the longest amount of time laser light spends circulating between two mirrors**," says ALPS II researcher Todd Kozlowski, PhD student of the University of Florida.. …"

DESY. UHF-GW Workshop @ CERN | ALPS II & BabyIAXO | 6 Dec. 2023 | Axel Lindner

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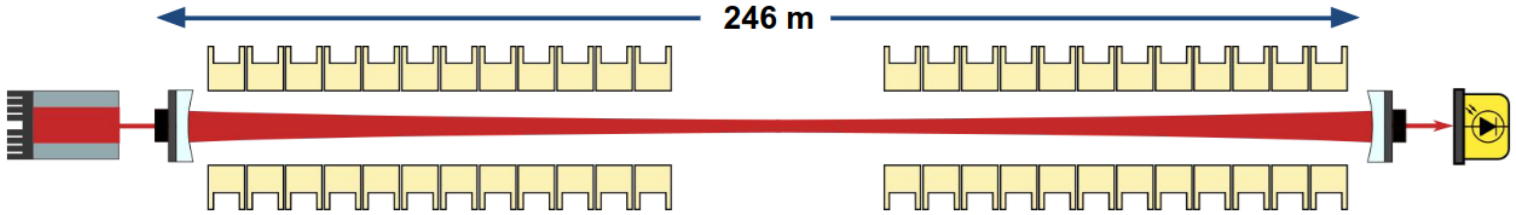
ALPS-II and VMB

Mostly taken from presentation of Todd Kozlowski @Technology WG meeting in June

VMB Effect and Magnitude

- prediction of QED: in a magnetic field, the vacuum acts like a birefringent medium

$$\Delta n^{(\mathrm{VMB})} = n_{\parallel}^{(\mathrm{VMB})} - n_{\perp}^{(\mathrm{VMB})} = 3A_e B_{\mathrm{ext}}^2$$



- scale of the effect in **ALPS II** (B^2 = 28 T^2, L = 212m, λ = 1064nm, N ~ 10,000)

B_{ext}^2 L ≈ 6000 T^2m
for VMB@CERN with one LHC dipole it was ≈ 1000 T^2m

$$\Delta L \sim 2.1 \times 10^{-20}\mathrm{m}$$

$$\Gamma(L) = 3.159 \times 10^{-9} \left(\frac{B_{\mathrm{ext}}}{5\mathrm{T}}\right)^2 \left(\frac{\mathcal{F}}{40,000}\right) \left(\frac{L}{212\mathrm{m}}\right) \quad \mathrm{radian}$$

Some updates: BabyIAXO

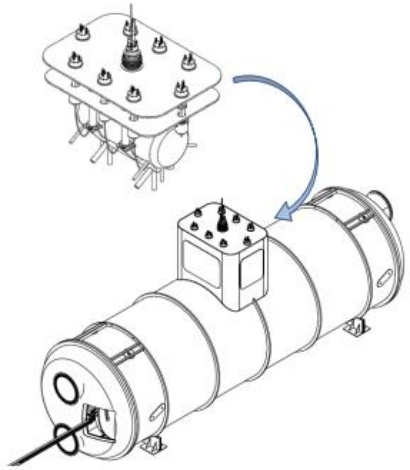
- BabyIAXO, now under construction
- Axion helioscope + option as halosc

BabyIAXO

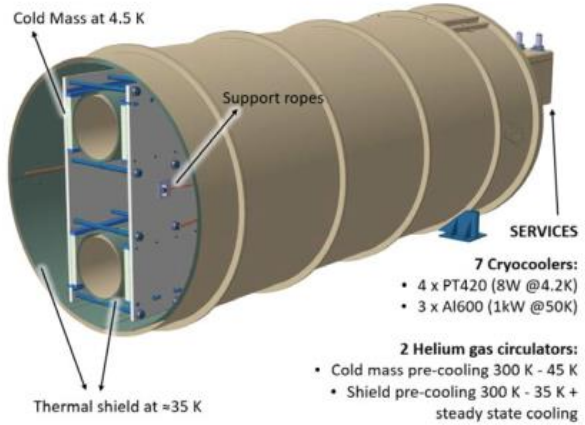
Solar Axion Searches

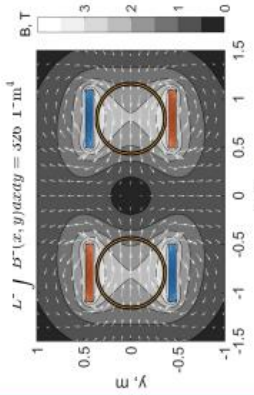
- ✓ BabyIAXO magnet to be operated at T ≤ 5 K featuring Nb-Ti-based superconducting coils with about 2 T in the bore
  - Nb-Ti is most affordable superconductor
  - It is also mechanically ductile and robust
  - Well studied work-horse conductor for most existing superconducting magnets

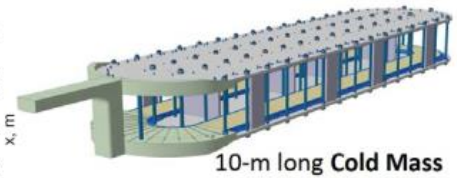
Contract for cable development recently signed



BabyIAXO magnet







Baby IAXO

Magnet design and quench studies performed within PBC.

Presently, effect of quenches (eddy current stresses) on objects inside magnet bores are underway within PBC.

GrAHal status

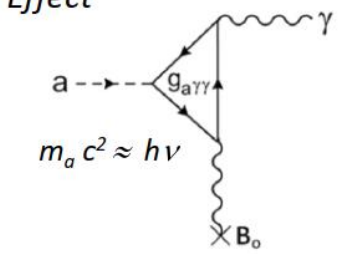
Mostly taken from presentation of Pierre Pugnat for CERN REC Committee and Tech WG

GrAHal - CAPP

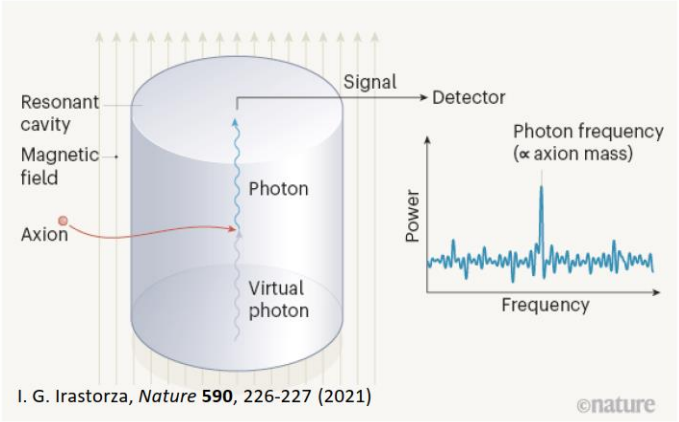
Grenoble Axion Haloscopes

& BabyGrAHal

Inverse Primakoff Effect



Sikivie's haloscope, i.e. with RF cavity



Theory Group

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European Magnetic Field Laboratory

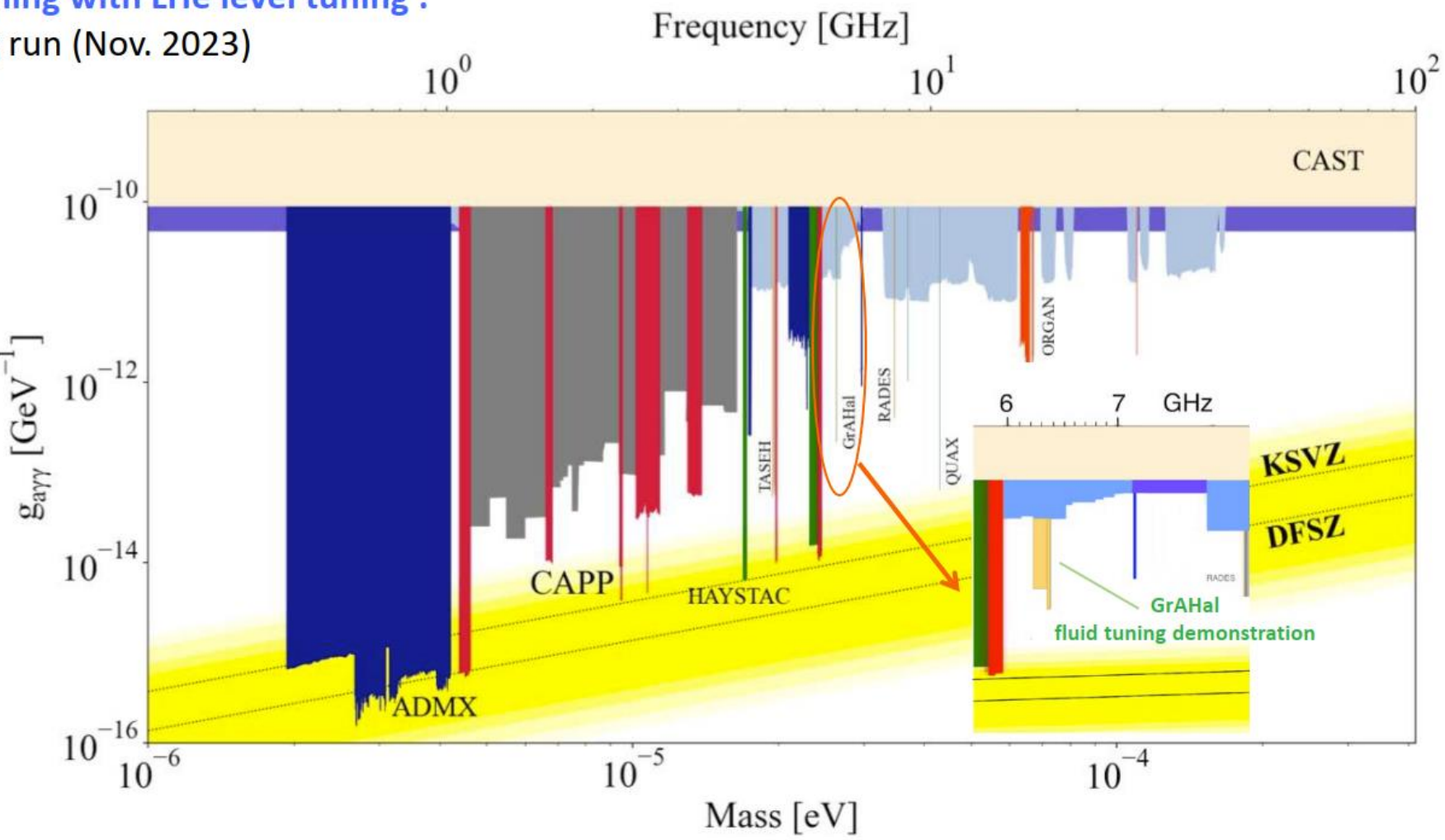
P. Pugnat, LNCMI-Grenoble/CNRS, EMFL

GrAHal status

Mostly taken from presentation of Pierre Pugnat for CERN REC Committee and Tech WG

R&D + running with LHe level tuning :

- Ongoing run (Nov. 2023)



GrAHal status

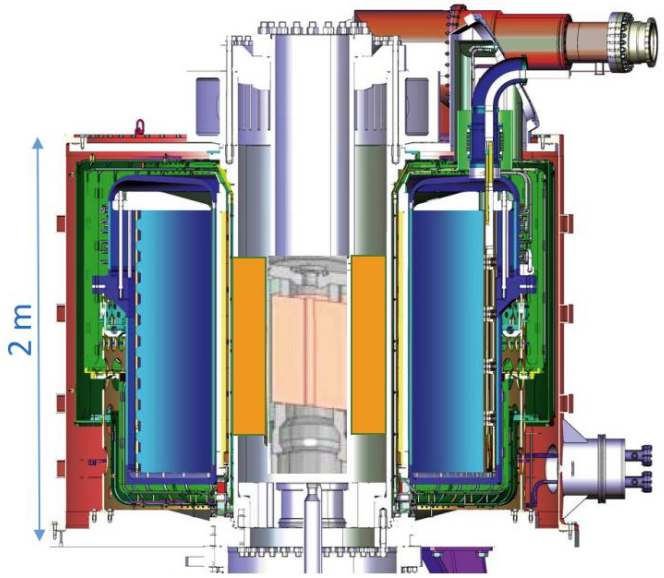
Mostly taken from presentation of Pierre Pugnat for CERN REC Committee and Tech WG

Next steps, approved by ANR (Agence Nationale pour la Recherche) for the run of GrAHal @ 43 T & 11.5 GHz
(before 31st December 2024 – funding for operation at 24 MW secured…)
Within available 4.4 K LHe Cryostat @ LNCMI

LNCMI

Grenoble Hybride in the commissioning phase, operation foresees in 2024

Field	Warm dia.	RF-cavity dia.	Freq. TM010	Axion mass
43 T	34 mm	20 mm	11.5 GHz	47.2 μeV
40 T	50 mm	34 mm	6.76 GHz	27.8 μeV
27 T	170 mm	86 mm	2.67 GHz	11 μeV
17.5 T	375 mm	291 mm	0.79 GHz	3.2 μeV
9.5 T	812 mm	700 mm	0.33 GHz	1.4 μeV



GrAHal status

Mostly taken from presentation of Pierre Pugnat for CERN REC Committee and Tech WG

GrAHal-QUAX for 7-10 GHz (dielectric RF cavity)

Field	Warm dia.	RF-cavity dia.
27 T	170 mm	86 mm
17.5 T	375 mm	291 mm

Collaboration with C. Braggio et al. (INFN and Univ. Padova)
"Search for Galactic Axions with high-Q Dielectric Cavity" Phys. Rev. D 106, 052007 (2022); Phys. Rev. Applied **17**, 054013 (2022)

Use of the TM030 mode,
$Q_{loaded} \sim 300\,000$

- First test with High Q Dielectric cavities + Dilution Fridge (30 mK, 0.7 l) + 14 T + TWPA
- R&D on photon counters for better SNR

GrAHal-CAPP for 200-600 MHz (thin Cu RF cavity)

Field	Warm dia.	RF-cavity dia.	Freq. TM010	Axion mass
9.5 T	812 mm	700 mm	0.33 GHz	1.4 μeV

Thin* Cu RF-cavity
- Made by CAPP/IBS, KAIST, Daejeon, South Korea, W. Chung, O. Kwon, Y. K. Semertzidis (arXiv:2210.10961, accepted, PRL)

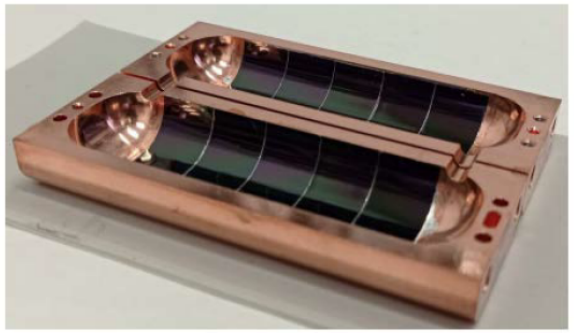
*Ex. of 0.5 mm thickness Cu cavity made by CAPP, need to be enlarge to 1 mm

GrAHal status

Mostly taken from presentation of Pierre Pugnat for CERN REC Committee and Tech WG

Expected support from CERN

- **To profit from CERN expertise** for the development of (large) RF-cavities (0.2-12 GHz) including the tuning mechanism
  - ► In contact with S. Calatroni, W. Wuensch, W. Venturini-Delsolaro, and F. Caspers (retired)
- Within a synergy with RADES studies, built high-Q HF haloscope, *i.e.* above 10 GHz
  - ► R&D including Tests of HTS RF-cavity in high field (> 12 T)

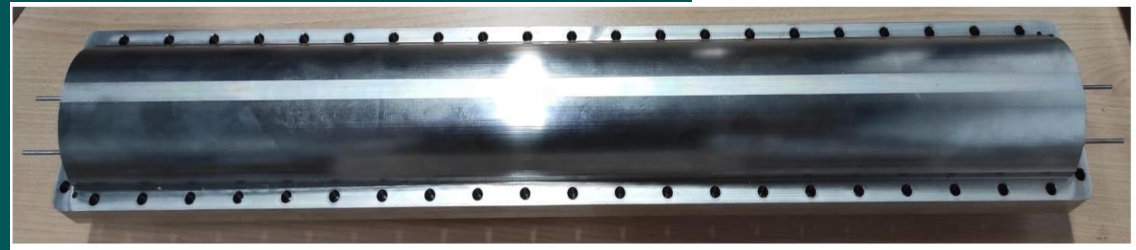


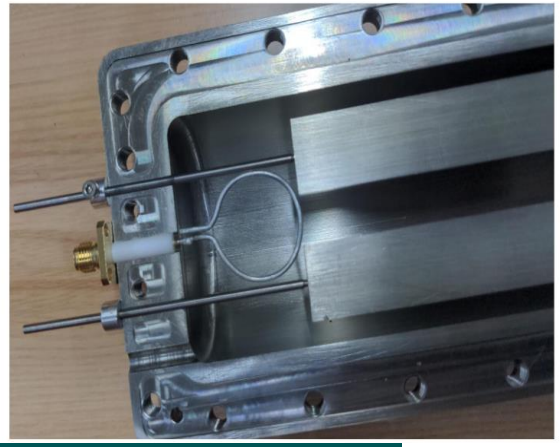
HTS tape cavity by ICMAB (G. Telles, N. Lamas, X. Granados, T. Puig, J. Gutierrez)
Courtesy S. Calatroni and J. Golm (CERN)

News from RADES

- RADES (Relic Axion Dark matter Exploratory Set-up): R&D effort with long-term idea to operate babyIAXO (also) as a haloscope
- However RADES activities independent of babyIAXO:
  Many different R&D directions
- One R&D partially supported by PBC:
  HTS cavity studies (Jessica Golm)
- R&D also starting towards Single Photon detection

Prototype to test tuning concept

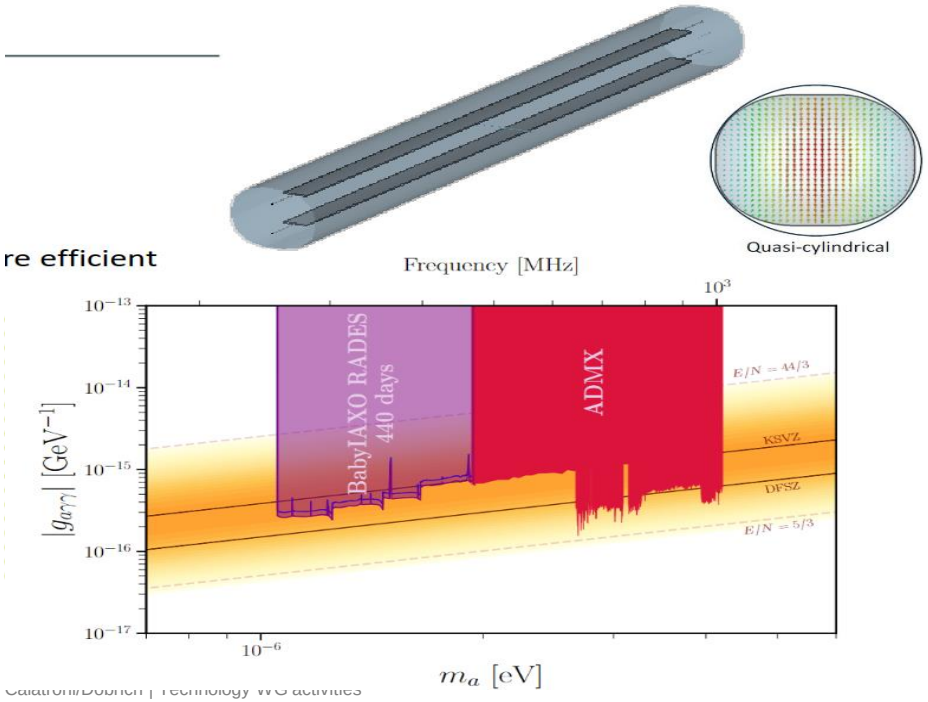




A loop able to rotate is under construction.

News from RADES

- Published concept for a haloscope option for babyIAXO



RESEARCH ARTICLE Ann. Phys. (Berlin) 2023, 2300326 2300326 (1 of 23)
annalen der physik
www.ann-phys.org

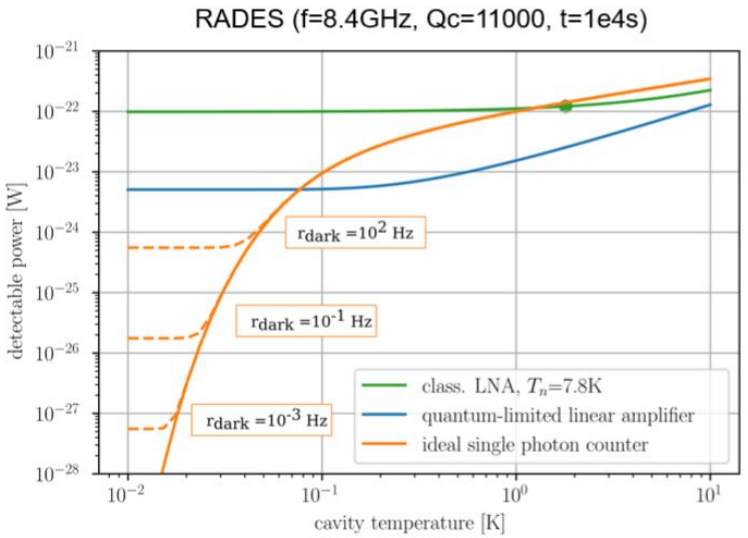
A Proposal for a Low-Frequency Axion Search in the 1–2 μeV Range and Below with the BabyIAXO Magnet

Saiyd Ahyoune, Alejandro Álvarez Melcón, Sergio Arguedas Cuendis, Sergio Calatroni, Cristian Cogollos, Jack Devlin, Alejandro Díaz-Morcillo, David Díez-Ibáñez, Babette Döbrich, Javier Galindo, Juan Daniel Gallego, Jose María García-Barceló, Benito Gimeno, Jessica Golm, Yikun Gu, Louis Herwig, Igor Garcia Irastorza, Antonio Jose Lozano-Guerrero, Chloé Malbrunot, Jordi Miralda-Escudé, Juan Monzó-Cabrera, Pablo Navarro, Jose Ramón Navarro-Madrid, Javier Redondo, José Reina-Valero, Kristof Schmieden, Tim Schneemann, Marc Siodlaczek, Stefan Ulmer, and Walter Wuensch*

Proposal also contains BASE-like concept for search of ultra-light ALPS (0.1-1000 neV)
-> Devlin/Ulmer

News from RADES

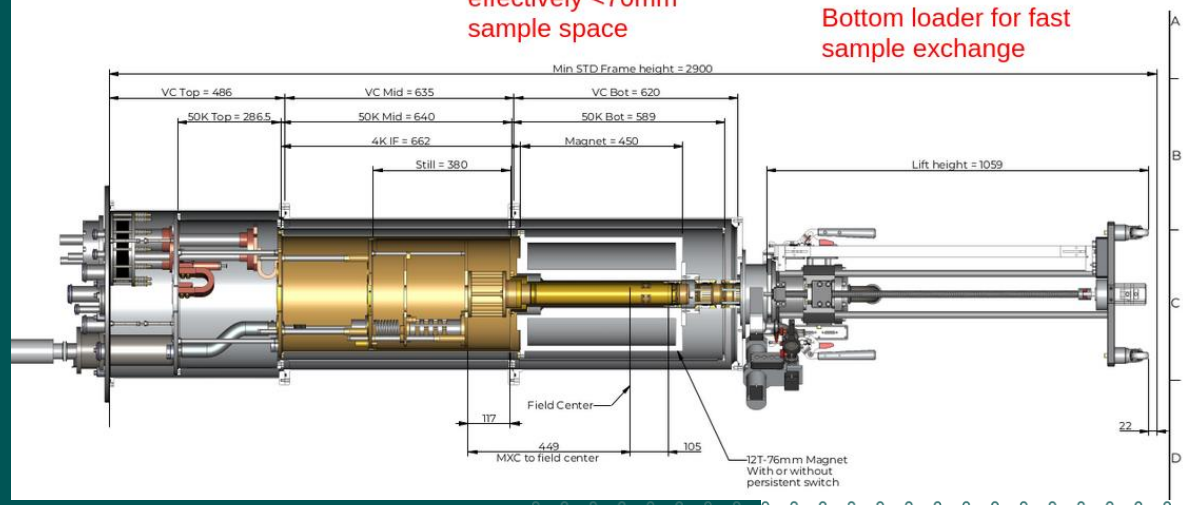
- Studying different R&D strains for SPD, ultimate handle to improve sensitivity (shown in plot)
- Ordered a dil-fridge incl magnet for the group, to arrive ~ mid 2024 at MPI



Most likely layout

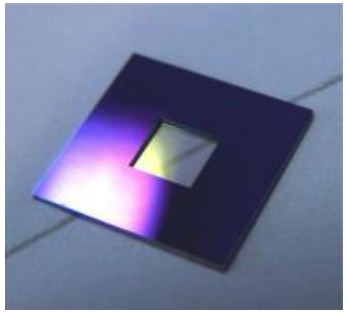
12T solenoid with effectively <70mm sample space

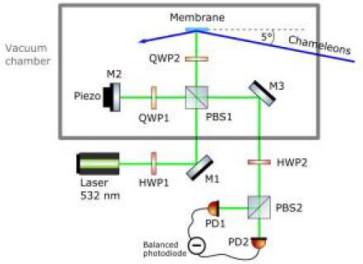
Bottom loader for fast sample exchange



Possible technologies: nano-TES, QBIT

A-KWISP status





- **Dark matter sensors based on room-temperature membranes, read-out by a Michelson interferometer**
- **Three sensor-network, one in Rijeka (Croatia) operating, two in Trieste and Camerino (Italy) under construction**
- **Temperature measurement and control system being finalized, soon implemented on all three sensors.**
- **CERN ideal place for further expanding the network of sensors, and studying technological development for bringing the membranes to cryogenic temperatures**
- **Giovanni Cantatore aims at presenting ideas and status (and possible requests for support to PBC) towards the end 2024**

Axion Heterodyne detection status

Mostly taken from presentation of R.-T. D'Agnolo and S. Ellis at PBC meetings

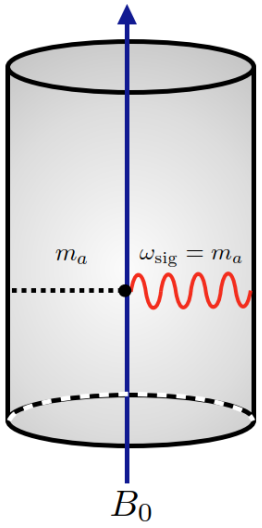
Talk by Raffaele-Tito D'Agnolo this afternoon

Resonant Approaches

Static-field Haloscope:

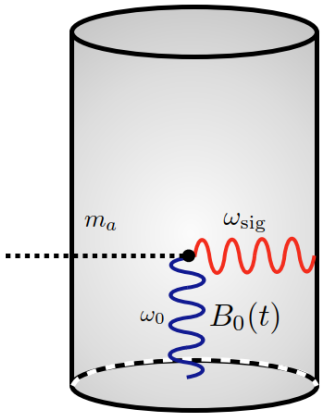
e.g. ADMX

$\omega_{\rm sig} = m_a \sim V^{-1/3}$



Heterodyne Resonator:

$\omega_{\rm sig} \sim \omega_0 \pm m_a \sim V^{-1/3}$



JHEP 07 (2020) 088, hep-ph/1912.11048

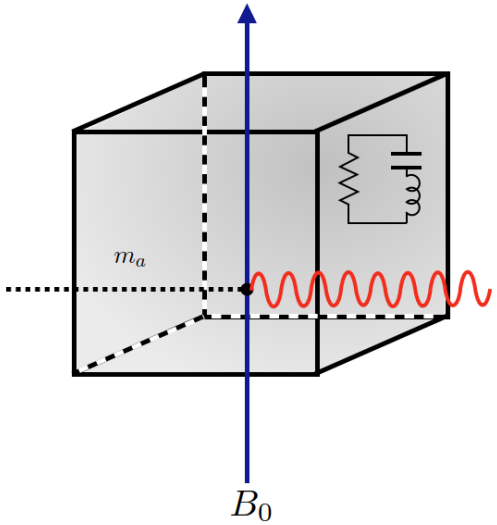
A. Berlin, R. T. D'Agnolo, SARE, P. Schuster, N. Toro, C. Nantista, J. Neilson, S. Tantawi, K. Zhou

Also: R. Lasenby hep-ph/1912.11467

LC Resonator:

e.g. DM Radio

$\omega_{\rm sig} = m_a = \omega_{\rm LC}$



Axion Heterodyne detection status

- **Presented to PBC management in 2021**
  - Experiment based on superconducting cavities of high performance
  - Concept **received high praise**, but some **preliminary experiments** were deemed necessary (intermodulation levels in standard RF measurement chain)
  - SRF section in RF group interested, but **no much progress** since

  - **SLAC has received** an LDRD **grant** for a preliminary design (corrugated HE11 cavity)
  - During investigation they moved for $$$ reasons from a SC prototype to **NC prototype**

  - **FNAL** is also building a **bulk niobium SC cavity** tailored for this purpose
  - They made preliminary background signal measurements on an existing cavity https://arxiv.org/abs/2207.11346 a bit inconclusive for the time being

Axion Heterodyne detection status

- **CERN QTI v2.0 approved by Management and Council for the period 2024-2028**

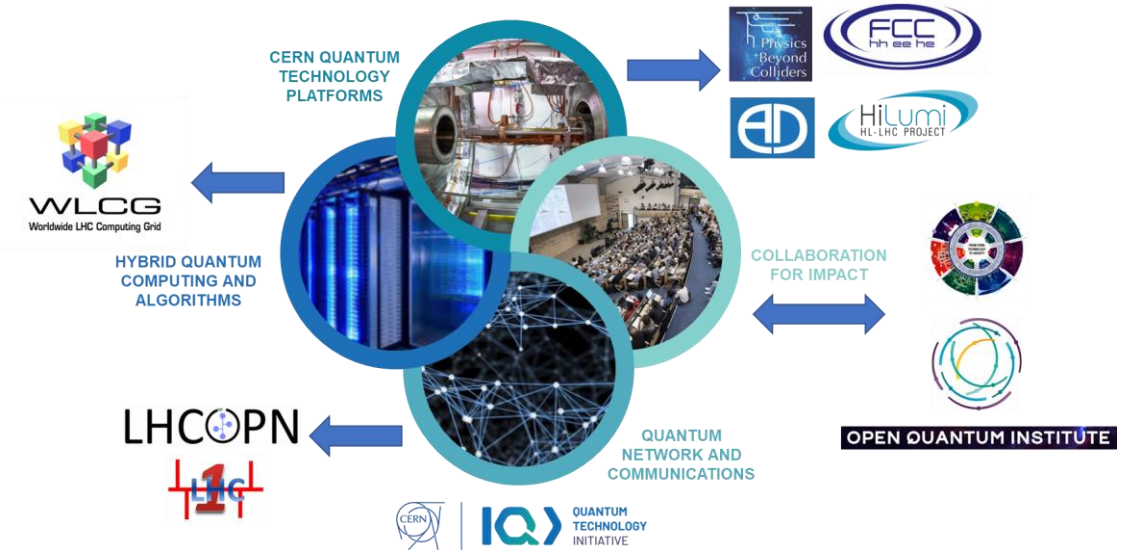
Centre of Competence: Quantum Platforms Demonstrators

Activities

- Exotic atoms and ions as qubits and Dark Matter sensors
- Atomic and nuclear clocks as sensors for new, feeble interactions
- Cryogenics and RF cavities for axion and Gravitational Wave searches
- Development and characterisation of (prototype) multi-qubit systems with superconducting cavities, ion traps and isotopes
- Quantum sensors for millicharged particles and for HEP
- Quantum data acquisition

Expected impact

- Accelerate the development and adoption of quantum technology and classic "enabling" technologies based on unique, existing facilities and technologies at CERN
- Establish visible, efficient mechanisms for impactful co-development and knowledge sharing
- Work with labs and companies to further exploit the technologies beyond CERN (many expression of interest from companies to work with and learn from CERN)



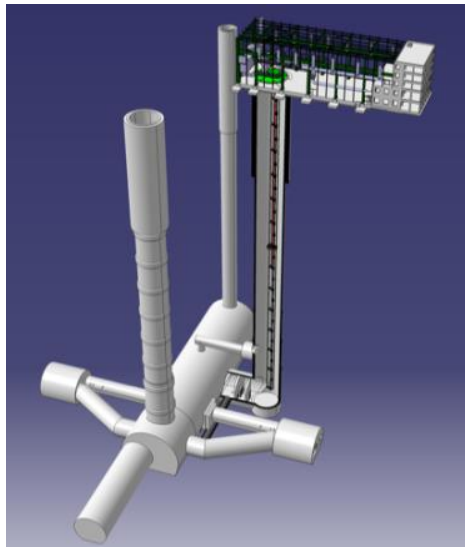
A. Di Meglio, S. Vallecorsa, M. Doser

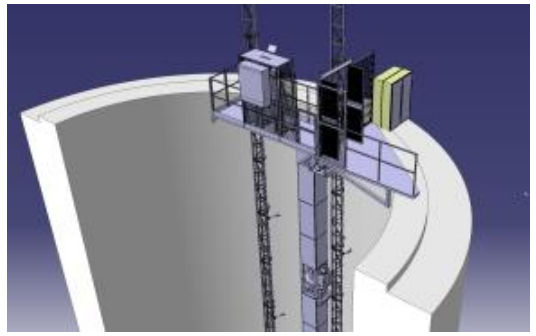
Axion Heterodyne detection status

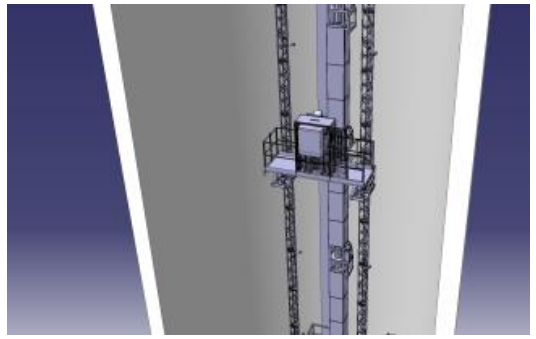
- **Dedicated Staff and Fellows both in TE and SY departments, and funds for investments have been allocated by QTI**
  - **Staff (5y)** in SY/RF, for supervision of cavity design and measurements
  - **Staff (5y)** in TE/CRG, for design and construction of sub-K cryogenics
  - **GRAD (3y)** in TE/VSC for cavity surface treatments
  - **Allocated funds** in SY/RF for cavity fabrication and in TE/CRG for cryogenics
- **PBC management agreed to contribute one GRAD (3y) for cavity design**
- **Program is in synergy with PBC <-> ideal platform for quantum sensing technologies**

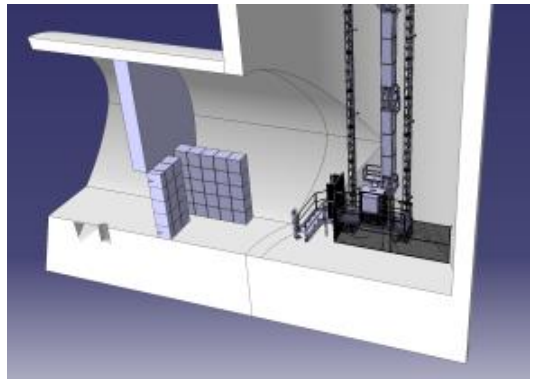
AION-100 @ CERN status

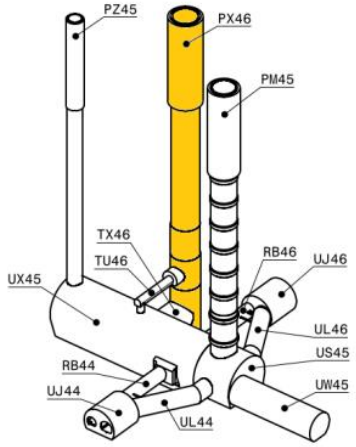
Mostly taken from my presentations and feasibility study report https://arxiv.org/abs/2304.00614











CERN-PBC Report-2023-002

A Long-Baseline Atom Interferometer at CERN: Conceptual Feasibility Study

G. Arduini[1,], L. Badurina[2], K. Balazs[1], C. Baynham[3], O. Buchmueller[3,4,*], M. Buzio[1], S. Calatroni[1,*], J.-P. Corso[1], J. Ellis[1,2,*], Ch. Gaignant[1], M. Guinchard[1], T. Hakulinen[1], R. Hobson[3], A. Infantino[1], D. Lafarge[1], R. Langlois[1], C. Marcel[1], J. Mitchell[5], M. Parodi[1], M. Pentella[1], D. Valuch[1], H. Vincke[1]*

Talk by Oliver Buchmuller this morning

AION-100 @ CERN status

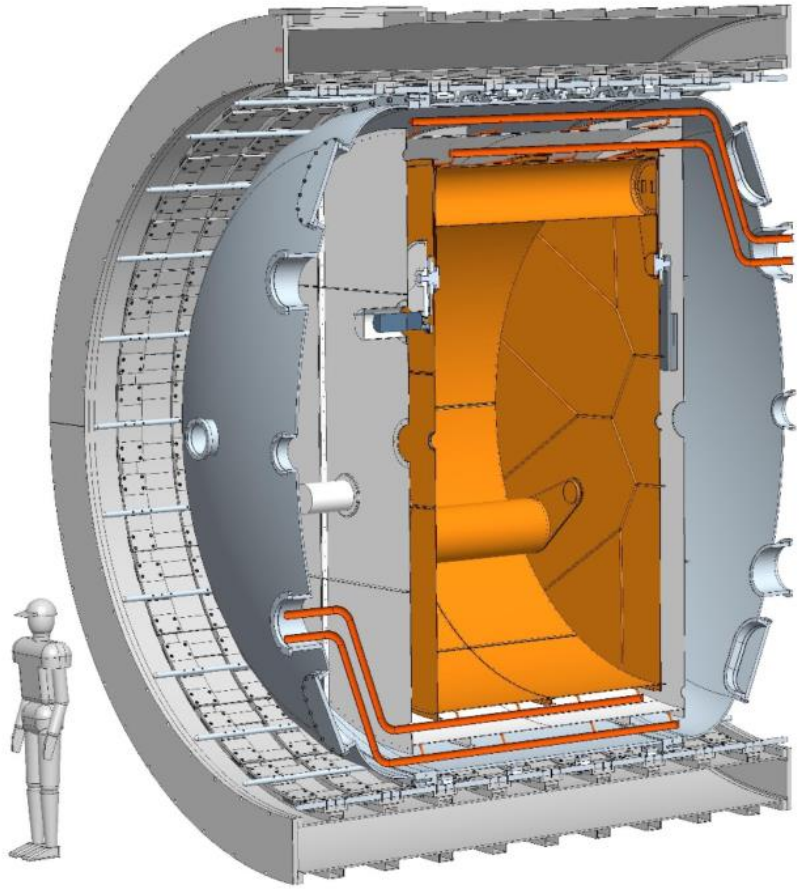
- **Conceptual feasibility study** for AION-100 like vertical atom interferometer at LHC point 4 https://arxiv.org/abs/2304.00614
- **Presented** at Terrestrial Very-Long-Baseline Atom Interferometry Workshop https://indico.cern.ch/event/1208783/
- "**Community Roadmap**" (workshop summary) document is prepared, accepted for publication in AVS Quantum Science, arXiv:2310.08183
- Discussed with **CERN management** (Mike Lamont), who **agreed to support the formation of a "Proto-Collaboration"**. Memorandum of Cooperation being finalized by CERN legal service.
- Will be presented and discussed at 2nd Terrestrial Very-Long-Baseline Atom Interferometry Workshop https://indico.cern.ch/event/1369392/ (**Next week**)
- Future (ideal) step: if a Collaboration is formed, CERN management must be requested to **prepare site during LS3 for subsequent installation of an experiment**.

New entry: FLASH

Talk by Claudio Gatti this morning

FLASH
Finuda magnet
for Light Axion
SearcH

Galactic axion search at 100 MHz
(0.5-1.5 μeV)



~~Mini~~-workshops

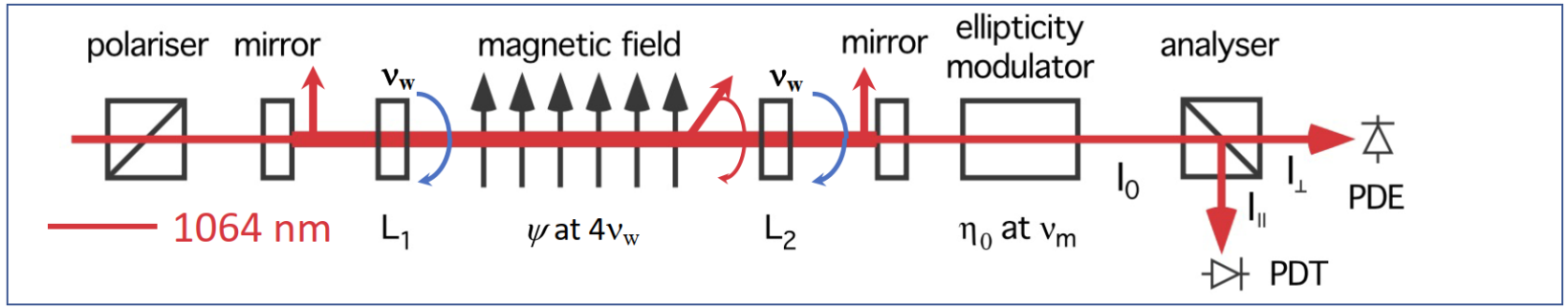
- Tech WG aims at **supporting initiatives in the PBC** requiring CERN expertise in technology
- The **mix of technologies** considered is **very varied**: magnets, optics, coatings…
- The technology WG mini-workshop series is aimed at providing users with an overview of possibilities/expertise at CERN and – in turn – providing CERN with an overview of ideas “out there”
- The first four workshops were well received:
  - 1st PBC technology mini workshop: superconducting RF
  - 2nd PBC technology mini workshop: lasers & optics
  - 3rd PBC technology mini workshop: vacuum, coating and surface technologies
  - 4th PBC technology mini workshop: cryogenics technologies
- **Last workshop was >1 year ago**: we were absorbed by other activities and organization of future workshops lagged behind
- **Date for new workshop is fixed 26.9.2024: (Superconducting) magnet technologies, measurements and shielding, in presence at CERN Building 30**
- Initially foreseen as remote-only in June, but was re-scheduled upon request of several speakers to have it in-presence
- Next workshops (hopefully at shorter interval)
  - Mechanical, design and fabrication technologies
  - PBC meets QTI

home.cern

VMB status

Mostly taken from presentation of Guido Zavattini to SPSC and PBC Tech WG

Scheme: two co-rotating half-wave plates *inside* the F.P.



$$\Psi(t) = \Psi_0 \sin 4\phi(t) + N\frac{\alpha_1(t)}{2}\sin 2\phi(t) + N\frac{\alpha_2(t)}{2}\sin[2\phi(t) + 2\Delta\phi(t)]$$

Signal @ $4\nu_w$

Spurious signals
Contain harmonics of ν_w

Relative rotation phase error
Degrades extinction

$\alpha_{1,2}$ are the phase errors from π of the two HWPs and $\phi(t)$ is their rotation angle

Allows the use of (quasi) static superconducting fields with $B_{ext}^2 L \approx 1000\ T^2m$ (LHC dipole)

Eur. Phys. J. C (2016) 76:294

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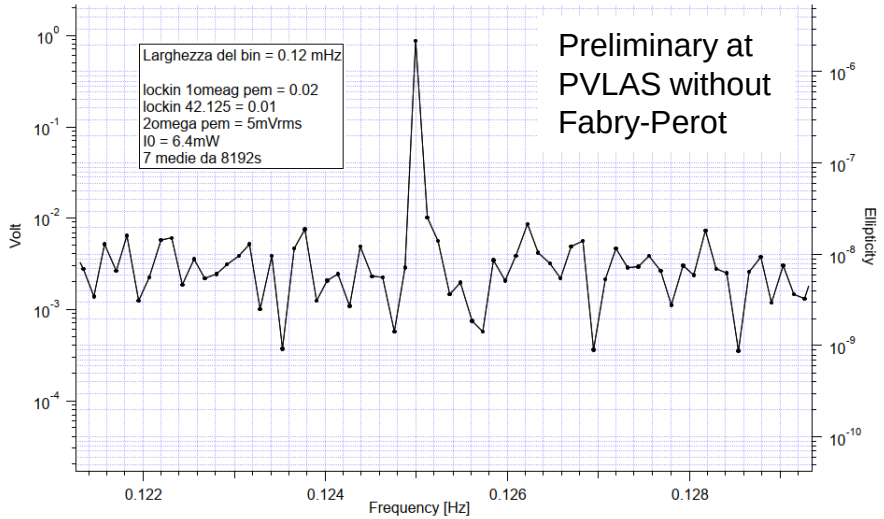
VMB status

Mostly taken from presentation of Guido Zavattini to SPSC and PBC Tech WG

Separate 4th harmonic spurious from VMB signal

- Modulate the magnetic field (slowly) to separate the unavoidable 4th harmonic generated by the rotating HWPs from a true birefringence. VMB signal remains far from the low frequency intrinsic noise.
- How fast can the LHC dipole be ramped? How narrow is the systematic signal at $4\nu_w$?

Width of spurious peak: ≈ 0.12 mHz con SNR ≈ 300



LHC dipole modulation frequency (7 mHz) must be >> than width of spurious peak

Modulating an LHC dipole magnet at a few mHz could be a solution

EPJC 82 (2022) 159

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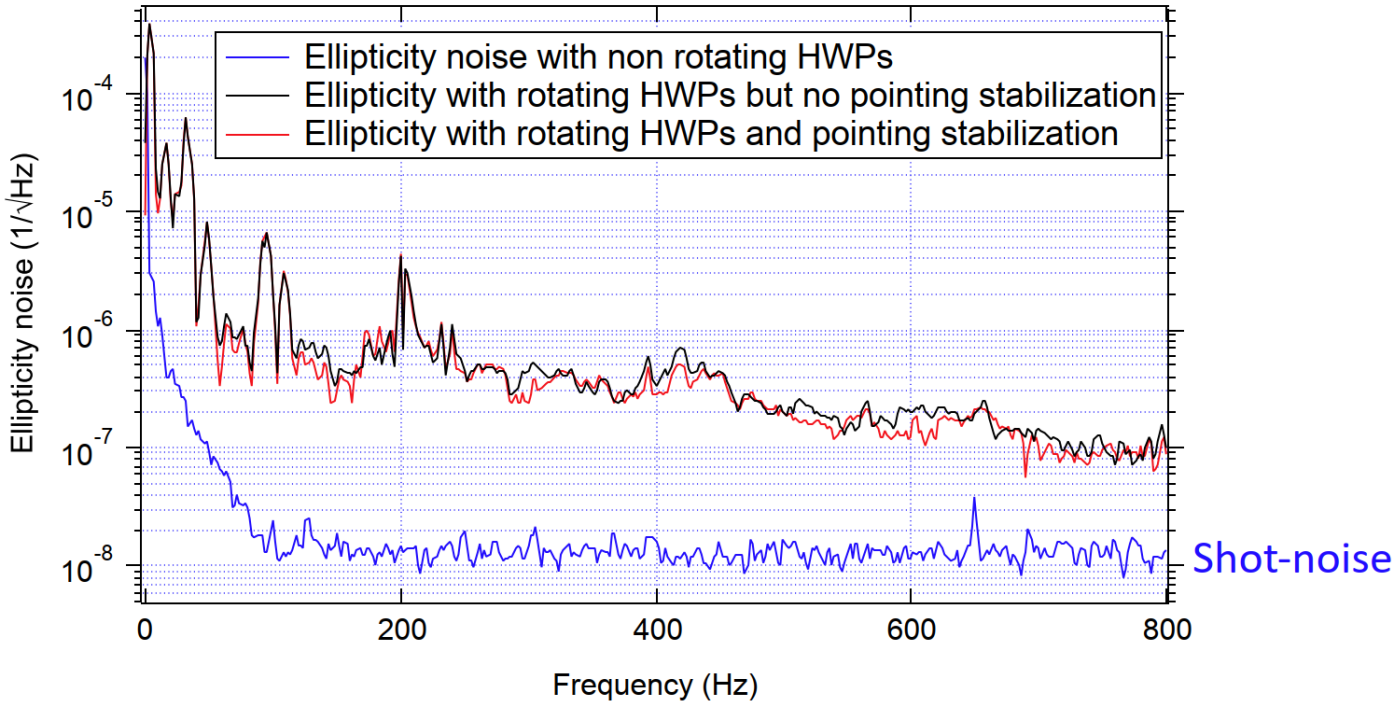
VMB status

Mostly taken from presentation of Guido Zavattini to SPSC and PBC Tech WG

Wideband ellipticity noise with rotating HWPs

Co-rotating HWPs at 2 Hz with stepper motors Vs. non rotating HWPs



There is a wideband ellipticity noise generated by the rotation of the HWPs.

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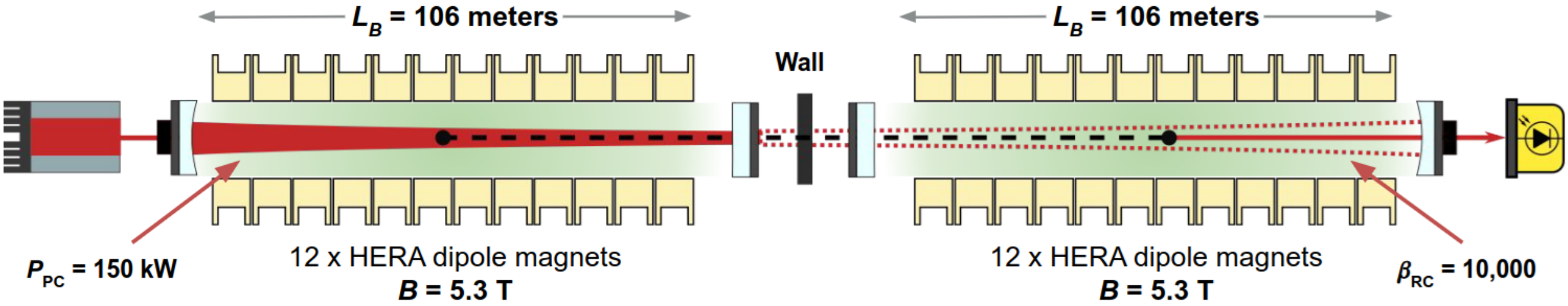
News from ALPS-II

Mostly taken from presentation of Todd Kozlowski @Technology WG meeting in June



$$n_{\text{signal}} \approx n_{\text{PC}} \beta_{\text{RC}} \frac{\eta}{16} (g_{a\gamma\gamma} BL)^4$$

For the ALPS II design parameters:

$$n_{\text{signal}} \approx \frac{1 \text{ photon}}{37 \text{ hours}} \cdot \left(\frac{P_{\text{PC}}}{150 \text{ kW}}\right)\left(\frac{\beta_{\text{RC}}}{10{,}000}\right)\left(\frac{\eta}{0.9}\right)\left(\frac{g_{a\gamma\gamma}}{2\times10^{-11} \text{ GeV}^{-1}}\right)^4\left(\frac{B}{5.3 \text{ T}}\right)^4\left(\frac{L}{106 \text{ m}}\right)^4$$

News from ALPS-II

Mostly taken from presentation of Todd Kozlowski @Technology WG meeting in June 2023

> 35 W of stable 1064 nm laser light injected through the Production Area

Optics on COB must be pre-aligned before insertion into vacuum

Heterodyne Interferometry:
measurement of the interference beat-note between an ultra-weak signal field and a strong local oscillator on a shot-noise-limited photodetector

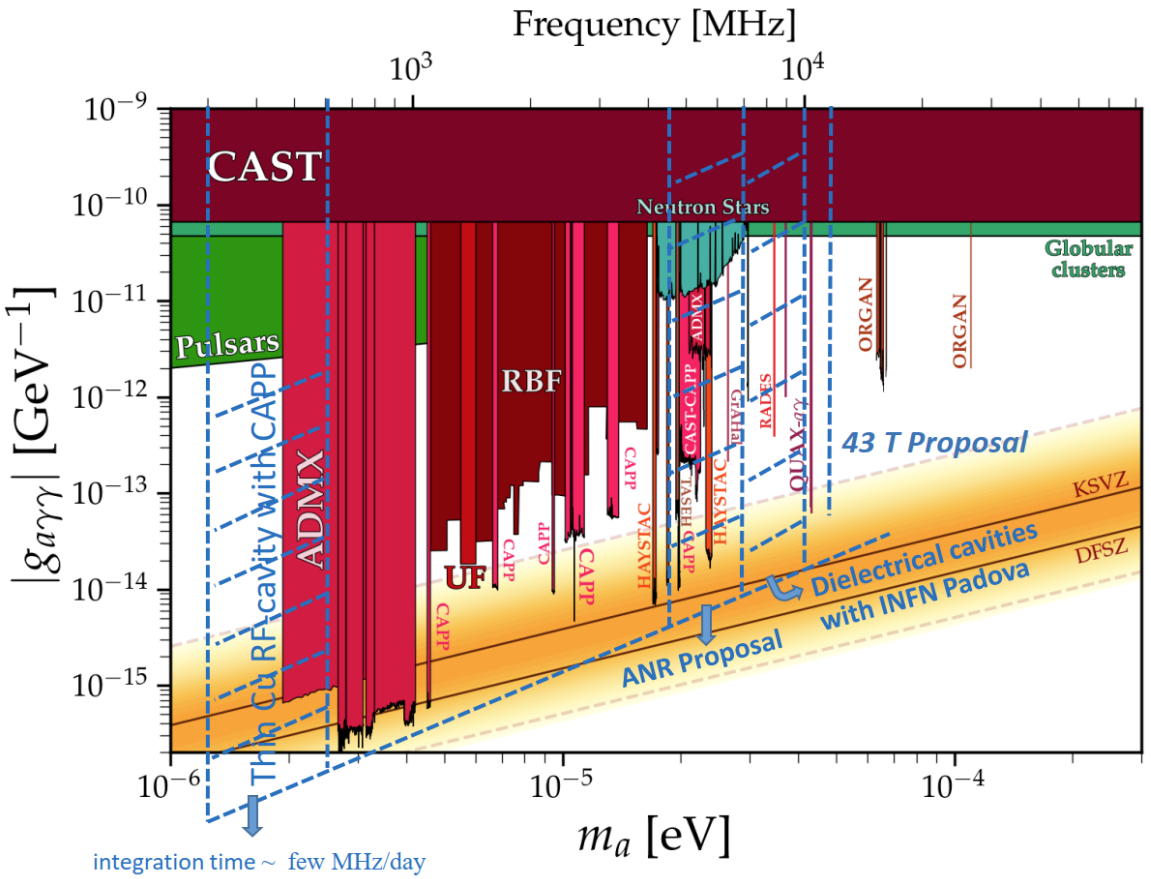
News from ALPS-II

Mostly taken from presentation of Todd Kozlowski @Technology WG meeting in June

- ALPS-II started smooth data taking (except when Metallica plays in nearby concert venue)
- Different concepts for future VMB measurement under study
- The ALPS II experiment, with its 24 HERA dipole magnets (B2 L = 6000) can produce the largest magnitude VMB effect of any contemporary experiment
- VMB will not be implemented into the ALPS II program until after all experimental goals achieved - outlook 3-4 years

GrAHal status

Mostly taken from presentation of Pierre Pugnat for CERN REC Committee



Some Updates: DarkSide-20K

- **DarkSide, under construction at INFN-LNGS, formal collaboration with CERN**
- **Direct detection of WIMPS with liquid Ar TPC**

Collaboration with the Neutrino Platform on the Atmospheric Argon cryostat.

Activities carried out at CERN under this collaborative agreement:

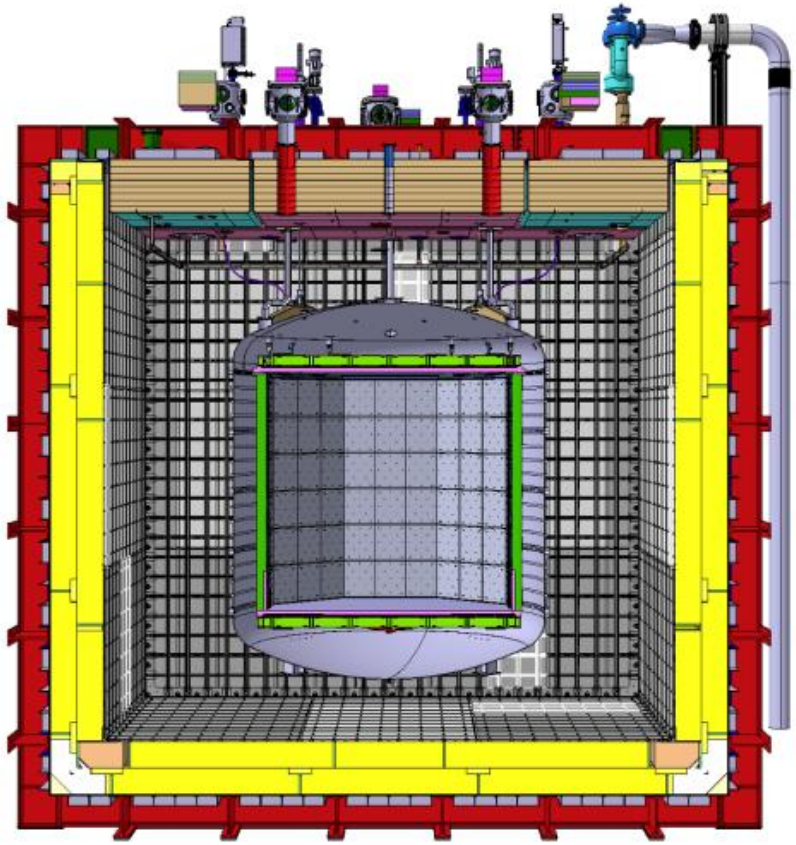
i. Design and engineering at CERN of detector integration in the hosting LNGS infrastructure (including safety considerations);

ii. Design and engineering of the necessary R&D components at CERN to validate the final cryostat design and integration within the final cryogenic infrastructure;

iii. Design and integration at CERN of the interfaces between the active TPC and the cryogenic infrastructure.

From: G. Fiorillo

The cryostat under construction in the Hall-C



Axion Heterodyne detection status

Mostly taken from presentation of R.-T. D'Agnolo and S. Ellis at PBC meetings

Oscillating background B-field: Radio-Frequency **up-conversion** approach

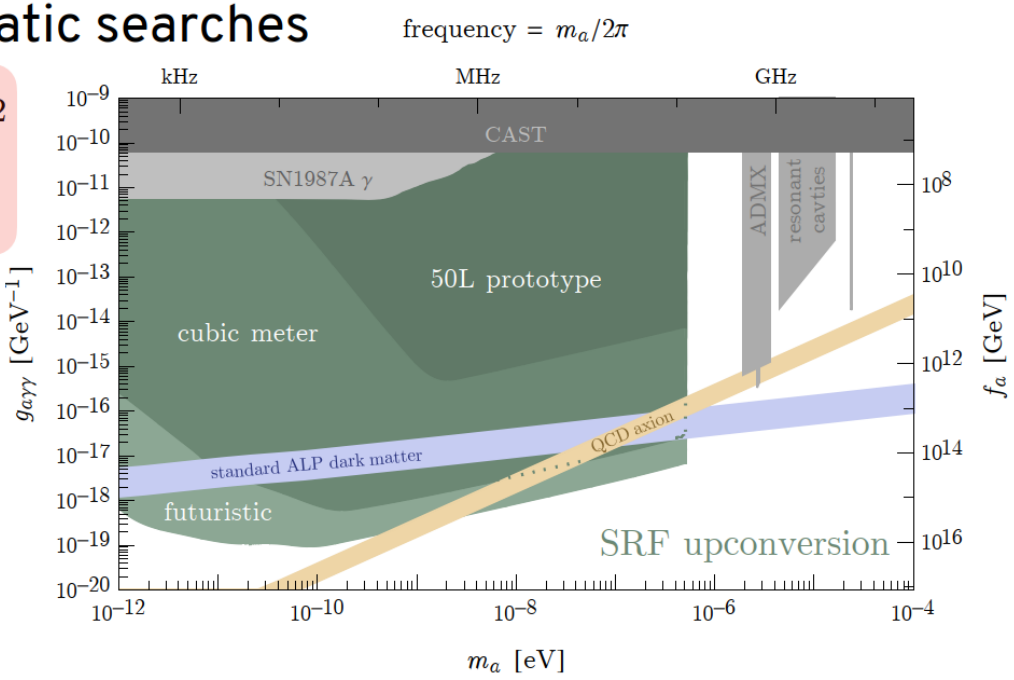
$$\omega_{\rm sig} = \omega_0 \pm m_a$$

Parametric gain for small axion masses vs. static searches

$$\frac{\rm SNR}{\rm SNR^{LC}} \sim \frac{\omega_0 \pm m_a}{m_a} \left(\frac{Q_{\rm int}}{Q_{\rm LC}}\right)^{1/2} \left(\frac{T_{\rm LC}}{T}\right)^{1/2} \left(\frac{B_0}{B_{\rm LC}}\right)^2$$

Prototype:

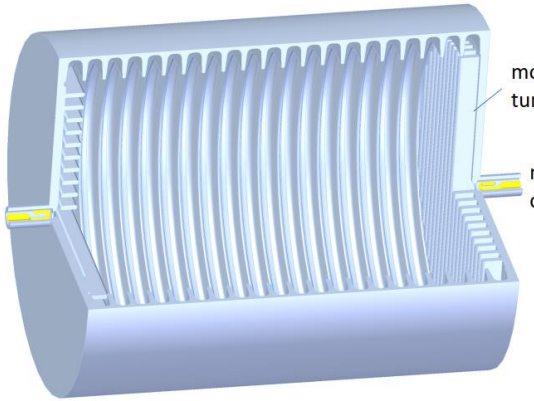
- **design underway @ SLAC, *PI* Sami Tantawi**
- **commissioned by FNAL SQMS:** *hep-ex/2207.11346*



Axion Heterodyne detection status

Mostly taken from presentation of R.-T. D'Agnolo and S. Ellis at PBC meetings

Axion Resonant Frequency Conversion



$$\eta \sim \frac{\int_V \vec{E}_0 \cdot \vec{B}_1}{\sqrt{\int_V |\vec{E}_0|^2 \int_V |\vec{B}_0|^2}} \sim 0.8$$

Proposed prototype

HE11 cavity @ SLAC

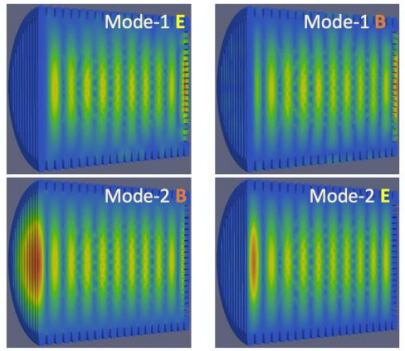
$\omega_0 \sim \omega_1 \sim \text{GHz}$

$Q_{\text{int}} \sim 10^9 \div 10^{13}$

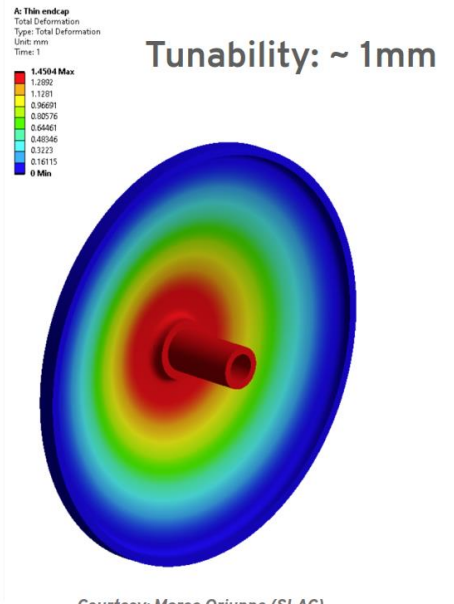
Courtesy: Zenghai Li (SLAC)

HE11 polatization-1 (E,B)

HE11 polatization-2 (B,E)



Tunability: ~ 1mm



Courtesy: Marco Oriunno (SLAC)

FNAL design https://arxiv.org/abs/2207.11346