Axion Physics in PPCC: IAXO

1ST MEETING ARAGÓN - COMUNIDAD VALENCIANA OF THE ASTRO-HEP COMPLEMENTARY PLANS

GLORIA LUZÓN (CAPA) ON BEHALF OF IAXO-ZARAGOZA

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Subprojects in LA5

LA5.1	**Integration of the ultra-low background detection line of the axion helioscope BabyIAXO**, and study of the extension of the physics case to the detection of Dark matter axions (RADES)	**UNIZAR-ITA**
LA5.2	Implementation of improvements in energy threshold and noise background of the experiment TREX-DM for the search of low mass WIMPs at the LSC	UNIZAR-ITA
LA5.3	ANAIS+: improvements in the sensitivity of ANAIS-112 using automatic learning and a new experimental approach	UNIZAR

Milestone H5.1.1 – Prototype detection line, and shielding built and in operation

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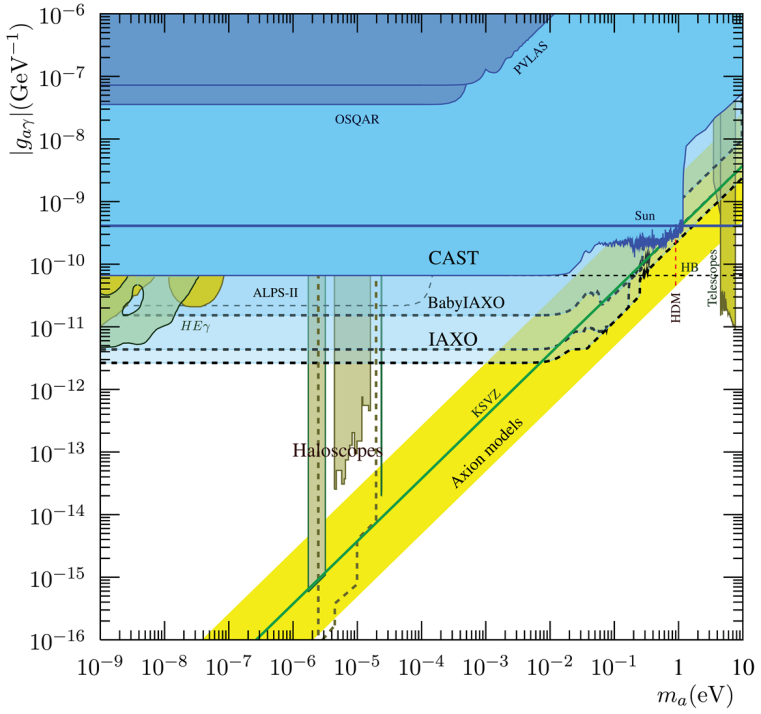
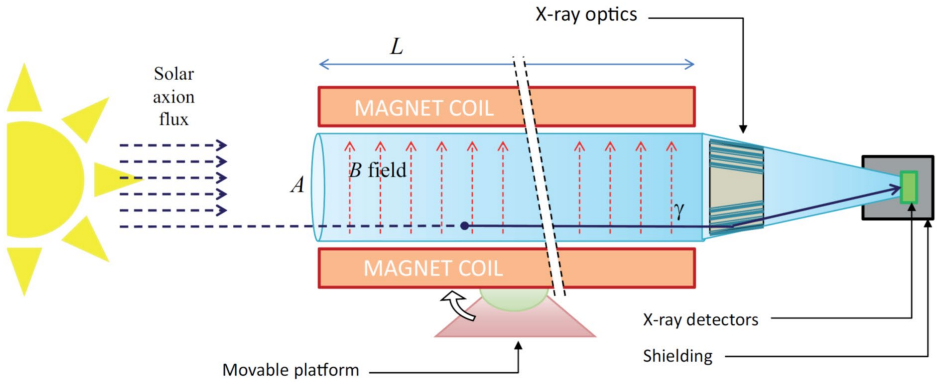
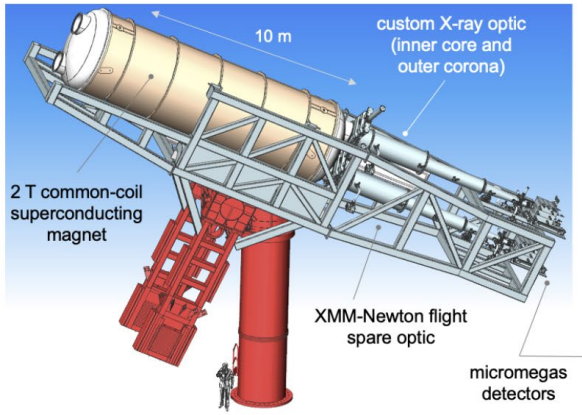
International Axion Observatory

A fourth-generation axion helioscope

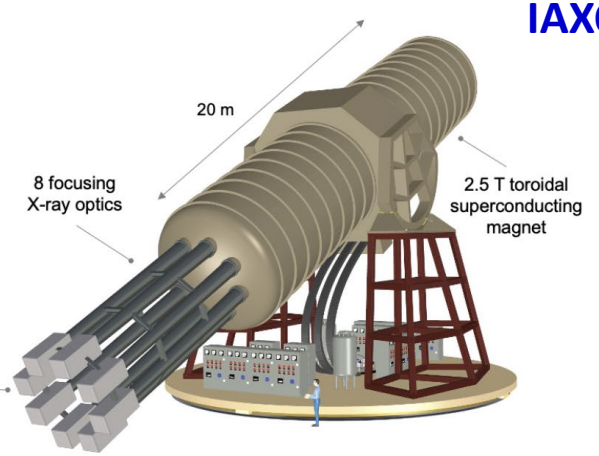




BabyIAXO



IAXO



Collaboration created in 2017: ~100 scientists from 21 institutes, 4 Spanish (CAPA, CEFCA, ICCUB, UPCT)

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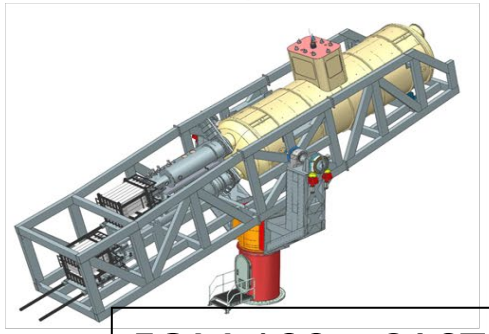
Helioscope generations

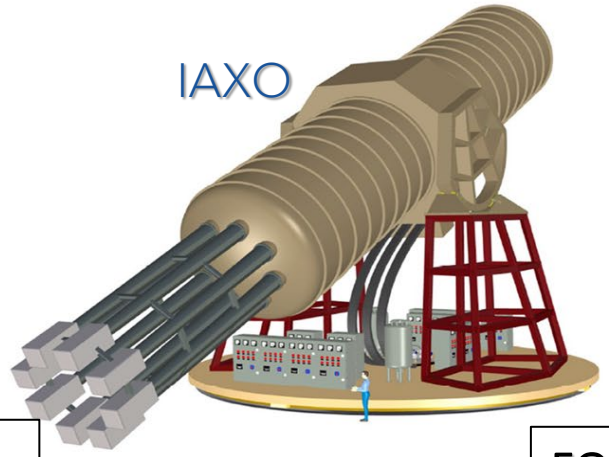
CAST
CERN Axion Solar Telescope

BabyIAXO



FOM 100 x CAST

IAXO



FOM 10.000 x CAST

- Currently under construction at DESY
- Test and improve all systems. Risk mitigation for full IAXO
- **Magnet**: 2 bores of Ø= 70 cm, L = 10 m, B = 3-4 T
  - test design options of final IAXO magnet
- **Dedicated x-ray optics** 0.2 cm^2 focal spot
- **Detection** lines representative of final ones
  - Micromegas baseline

- **Toroidal magnet:** 8 bores of Ø=60 cm, L = 20 m, B = 5.4 T
- **Dedicated x-ray optics:** 0.2 cm^2 focal spot
- **Tracking system:**
  - based on CTA
  - 50% Sun-tracking time
- **8 detection lines**

Abeln, A., et al. "Conceptual design of BabyIAXO, the intermediate stage towards the International Axion Observatory." *Journal of High Energy Physics* 2021.5 (2021): 1-80.

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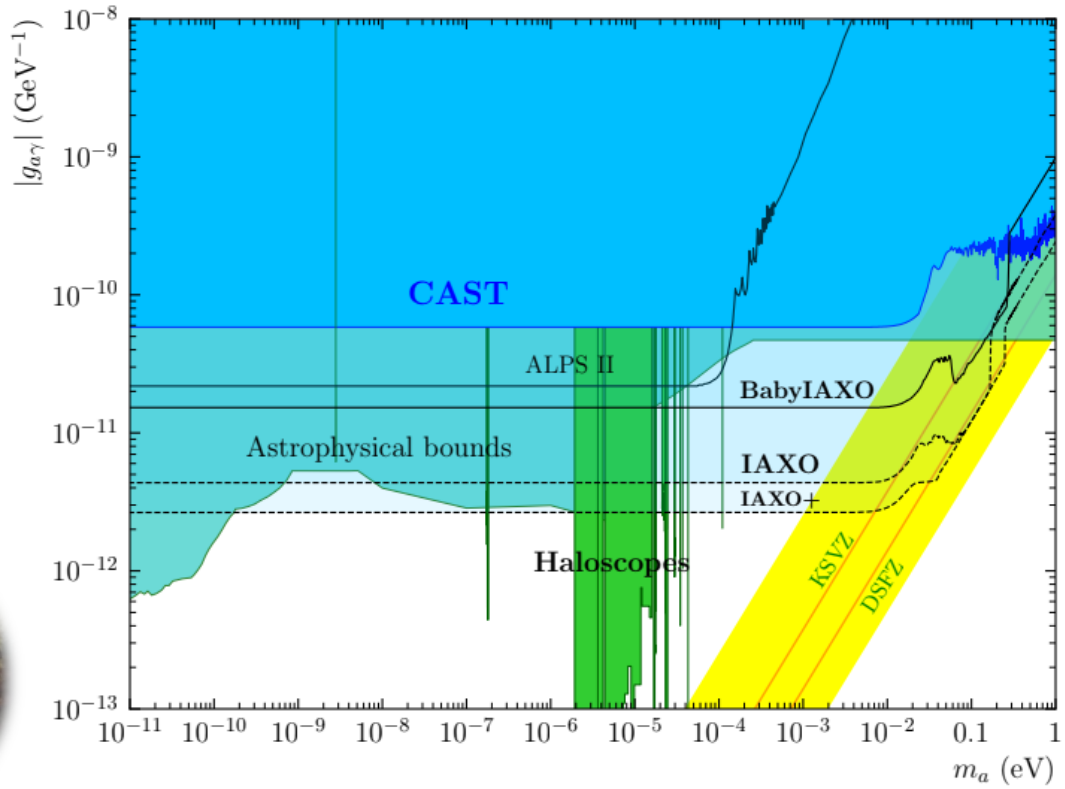
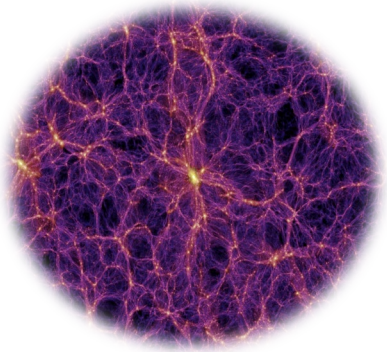
Sensitivity and physics potential

Sensitivity prospects: $g_{a\gamma}$- m_a



Further physics potential

Non-primakoff solar axions



DM axions: haloscope setups in (Baby)IAXO

Axions from close-by Supernovae

Physics studies in PPCC

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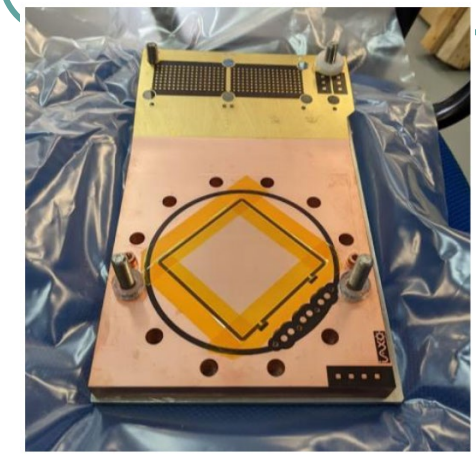
X-ray detector requirements

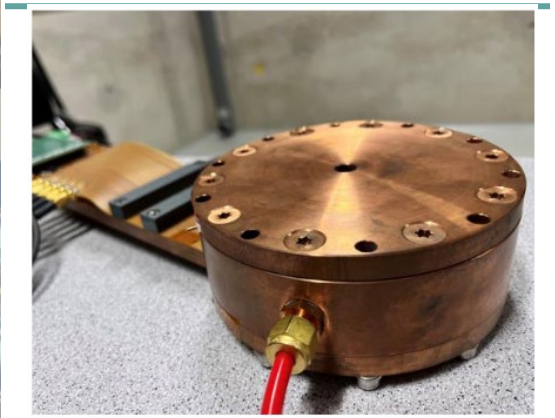
- High X-ray detection efficiency in the ROI (0-10 keV)
- Ultra low background levels:
  - 10^{-7} c/keV/cm^2/s (BabyIAXO)
  - 10^{-8} c/keV/cm^2/s (IAXO)

IDEALLY

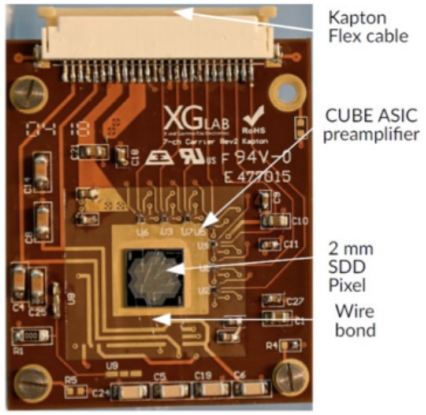
- Low energy threshold (100 eV)
- Good energy resolution



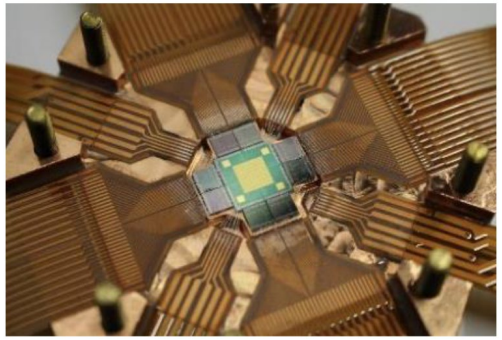
Microbulk Micromegas TPC
(U. Zaragoza and CEA-Saclay)



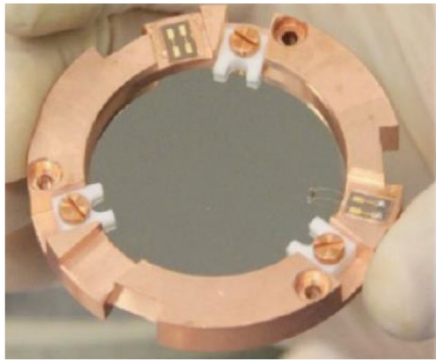
GridPix TPC
(U. Bonn)



SDD: Silicon Drift Detectors
(Technical U. Munich)



MMC: Metallic Magnetic Calorimeters
(U. Heildeberg and CEA-Saclay)



TES: Transition Edge Sensors
(U. Zaragoza-INMA ICMAB-CSIC IJCLab)

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Goals in PPCC

1. **Construction of the X-ray detection lines of the experiment based on Micromegas detectors**, according to the results obtained from the prototypes built so far, and their integration into the overall structure of the experiment.

2**. Implementation of new strategies to reduce the background of the Micromegas detectors for BabyIAXO**, based on the results obtained with the IAXOD0 and D1 prototypes (the latter at the LSC), including:

a) Increase in the efficiency of the active shielding, with the implementation of new veto concepts for cosmic events.

b) Electromagnetic study and characterization at the LSC of the site of the IAXO-D1 prototype.

c) Analysis of the electrical/electronic architecture of the data acquisition (DAQ) and control system; implications and improvements for electromagnetic noise reduction according to EMI/EMC criteria.

d) Implementation of a new, more radiopure acquisition electronics system.

e) Implementation of an in-situ calibration system based on X-ray fluorescence generation using a UV lamp.

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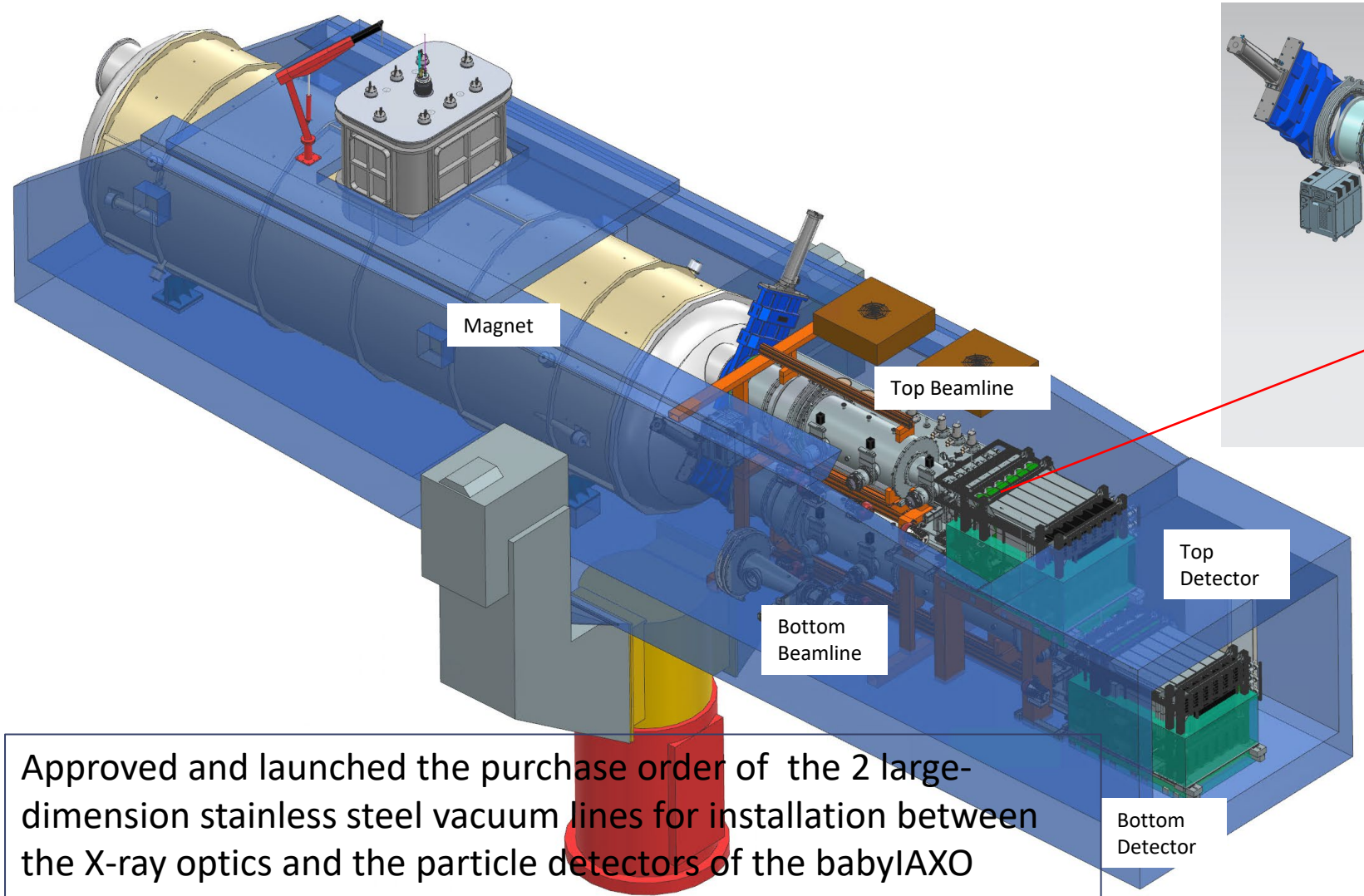
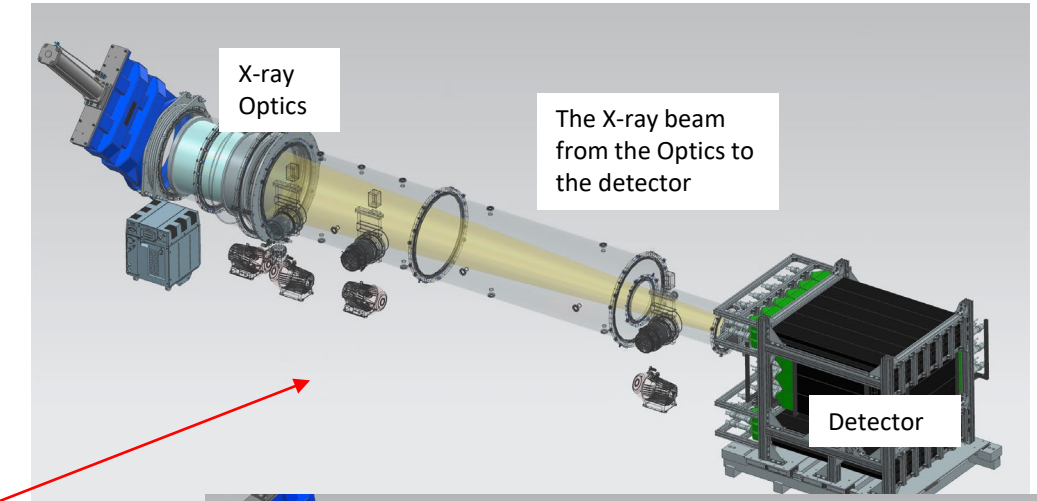
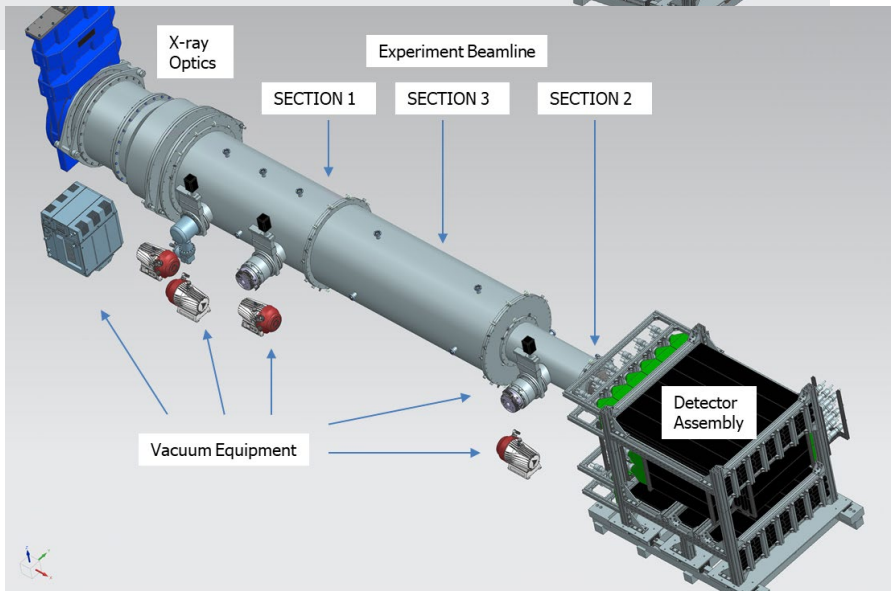
H1-The beamlines at BabyIAXO Experiment







Approved and launched the purchase order of the 2 large-dimension stainless steel vacuum lines for installation between the X-ray optics and the particle detectors of the babyIAXO Experiment –> To be delivered by the end of the 2025

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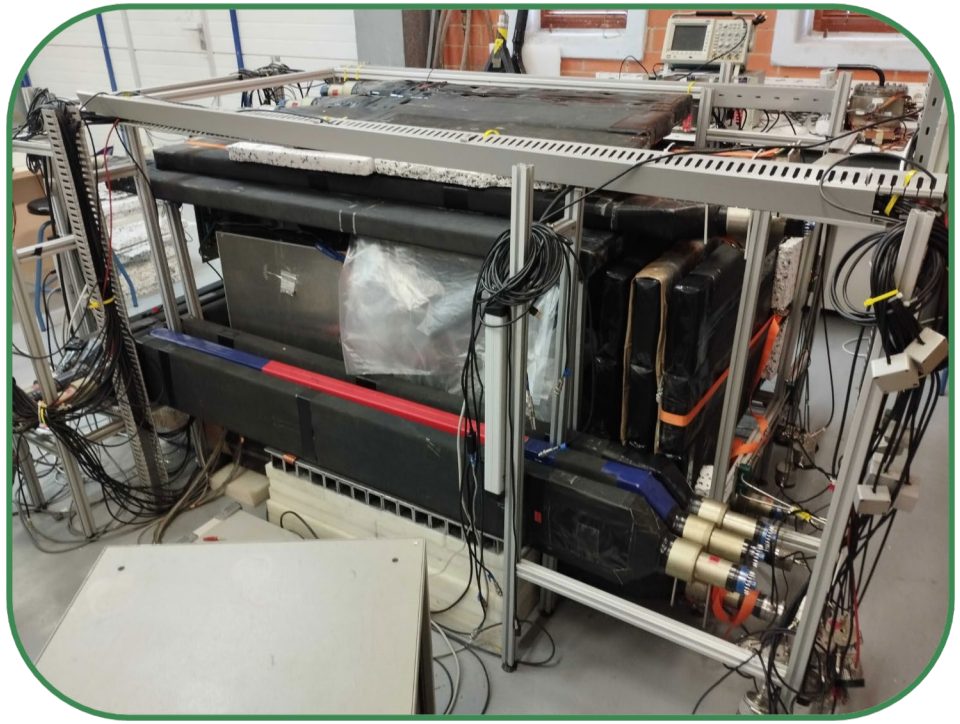
Background reduction: Micromegas prototypes

Zaragoza

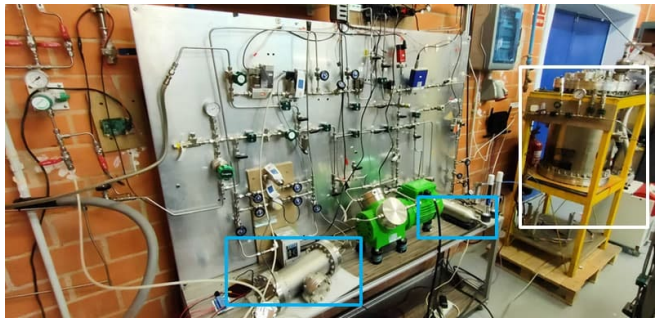
Surface level

Laboratorio Subterráneo de Canfranc

- Effect of multi-layer veto system to tag cosmogenic neutrons (in addition to muons)
- 20cm lead+vetoes



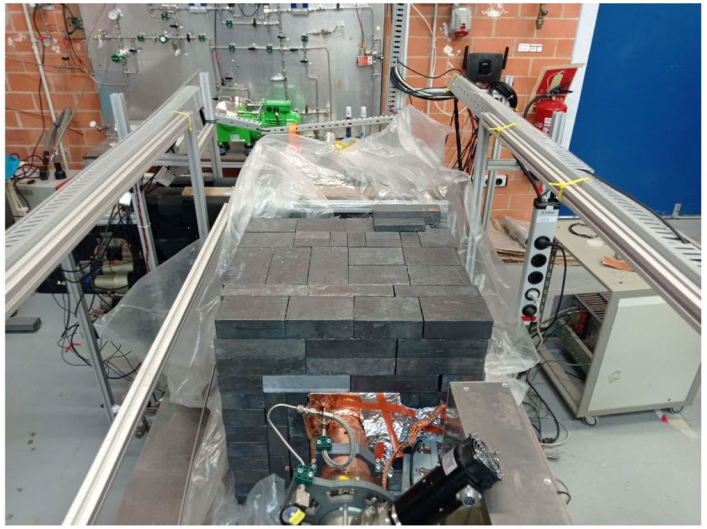
- Cosmic muon flux reduced by a factor 10^4: instrinsic detector background
- Test of different gas mixtures : Ar or Xe/Ne
- 20 cm lead
- Buffer gas to reduce Rn contamination

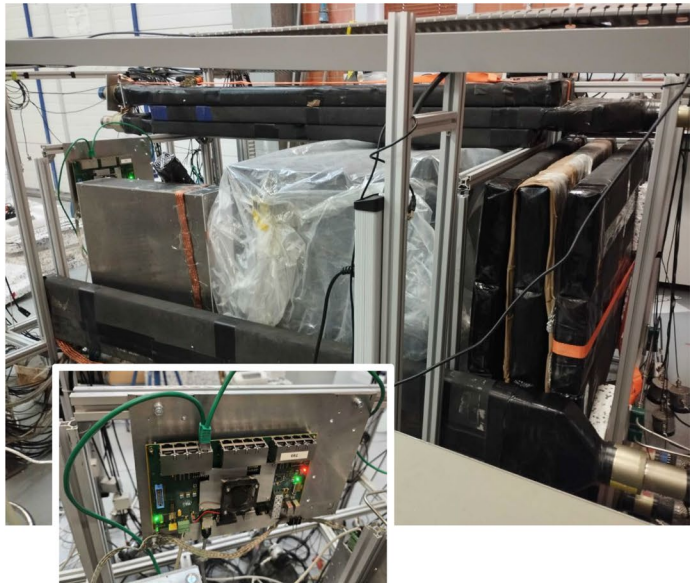


IAXO-D1@IAXOLAB

Passive shielding (lead): 20 cm

Active shielding: partially mounted+ TCM (Trigger Clock Module) to synchronize MM– veto triggers installed





%Ar+2%Isobutane with passive shielding: [3-4]x10^{-6}c/keV/cm2/s

IAXO-D0 After veto cuts (8.56 ± 1.22) × 10^{-7} c/keV/cm2/s

K. Altenmuller et al., Background discrimination with a Micromegas detector prototype and veto system for BabyIAXO, Front. in Phys. 12 (2024) 1384415 [2403.06316]

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IAXO-D1 at the LSC: background status

Argon background level [1-2] x 10^{-7} counts/keV·cm²·s

- Lowest background level achieved with this technology underground

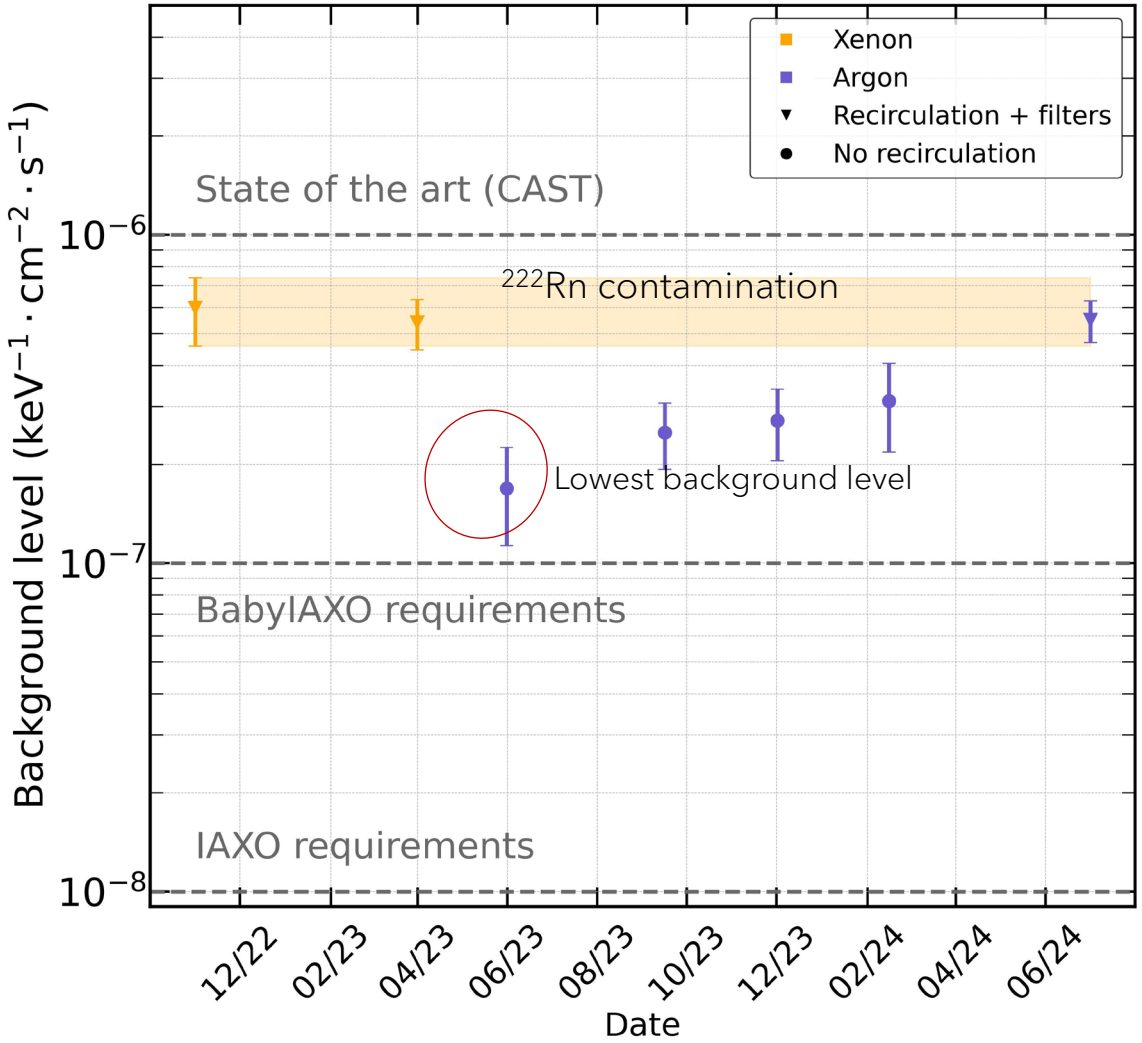
Xenon background level [5-6] x 10^{-7} counts/keV·cm²·s

- Not compatible with previous measurements in Ar+Iso at the LSC

^{222}Rn contamination from filters

Altenmüller, K., et al. 2021 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC). IEEE, 2021.

1. Low gain run with Xe confirmed Rn contamination
2. Ar recirculating: compatible background level



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HENSA collaboration

A. Quero
presentation@CPAN XVI
Madrid 2024

- Collaboration with the dark matter search experiment (Baby) IAXO (March - 2024)

  https://gifna.unizar.es/iaxo/

- Neutrons above **~20 MeV** contribute to the interest region of their detectors

Outdoor measurement: HENSA + IAXO team

- **Objective:** Characterization of the neutron **background spectrum** and the **moderation effect** of their laboratory in quiet solar conditions

(Baby) IAXO laboratory measurement

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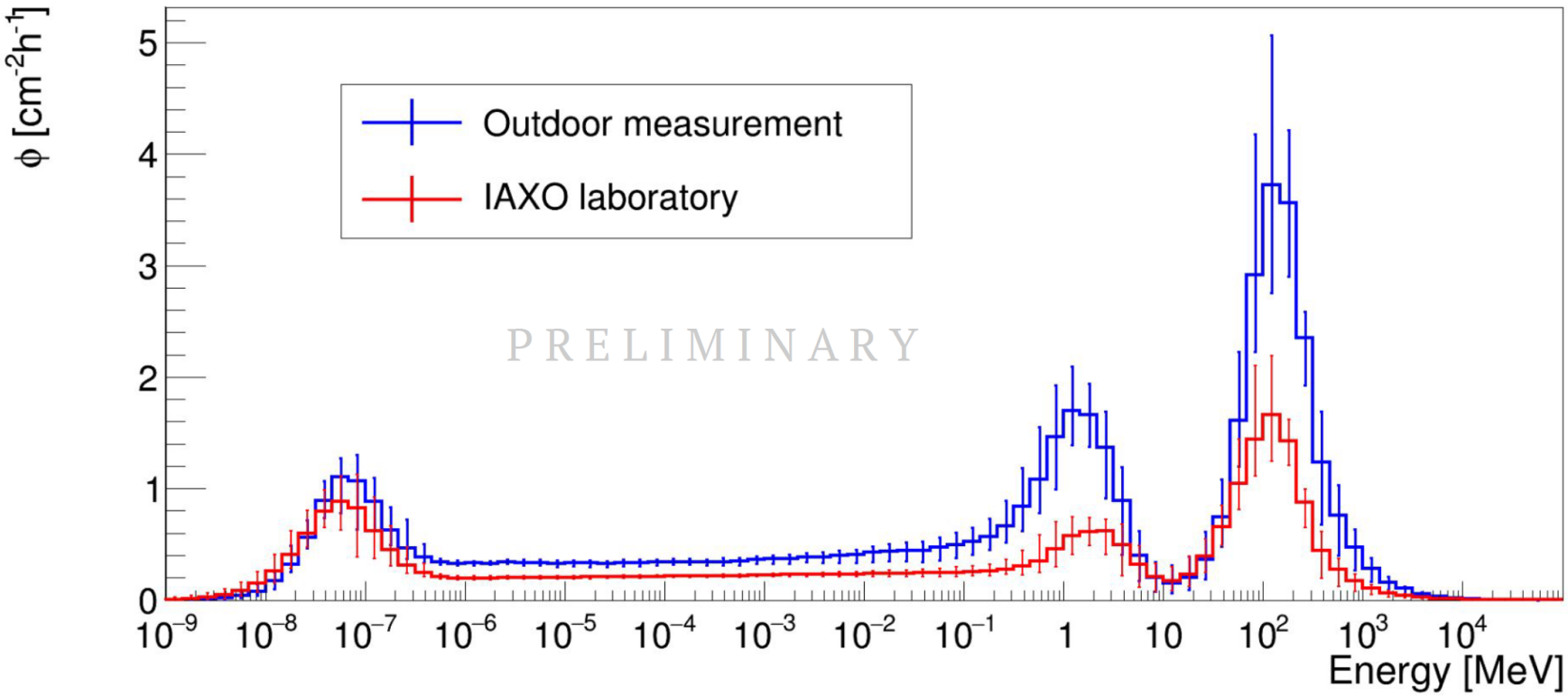
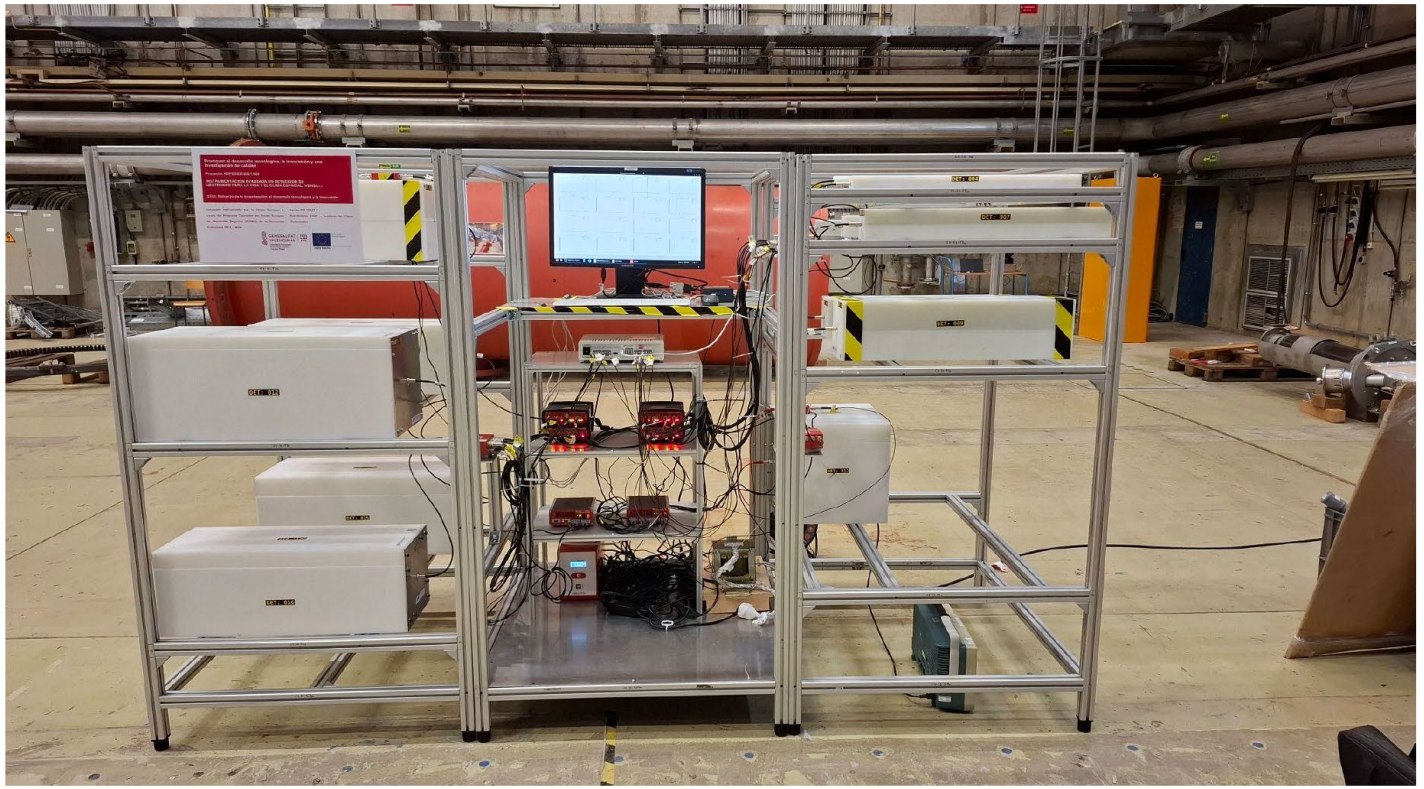
- Unfolding with the "POU" code that we are developing.
- Reduction of ~50% on the evaporation and high energy components of the spectrum.
- The thermal component is almost constant.
- Next step: DESY, Germany.



Magnitude	[20 MeV, 1 GeV]	(1 GeV, 100 GeV]	Total
Indoor Fluence (cm^{-2}h{-1})	$8.2^{+0.8}_{-1.2}$	$0.15^{+0.09}_{-0.07}$	$26.8^{+0.5}_{-0.8}$
Outdoor Fluence (cm^{-2}h{-1})	$17.9^{+1.3}_{-2.3}$	$0.39^{+0.18}_{-0.13}$	$49^{+1.0}_{-1.5}$
Decrement (%)	-54.19	-61.54	-45.31

HENSA++ installation (Position 1 @HERA South)



DESY 2025

- Acquiring data since 23/05/2025
- Calibrated with AmBe & Cf-252 on 26/05/2025
- We miss Detector 10 (on shipment)
- We plan to move the setup to Position 2 on Wednesday

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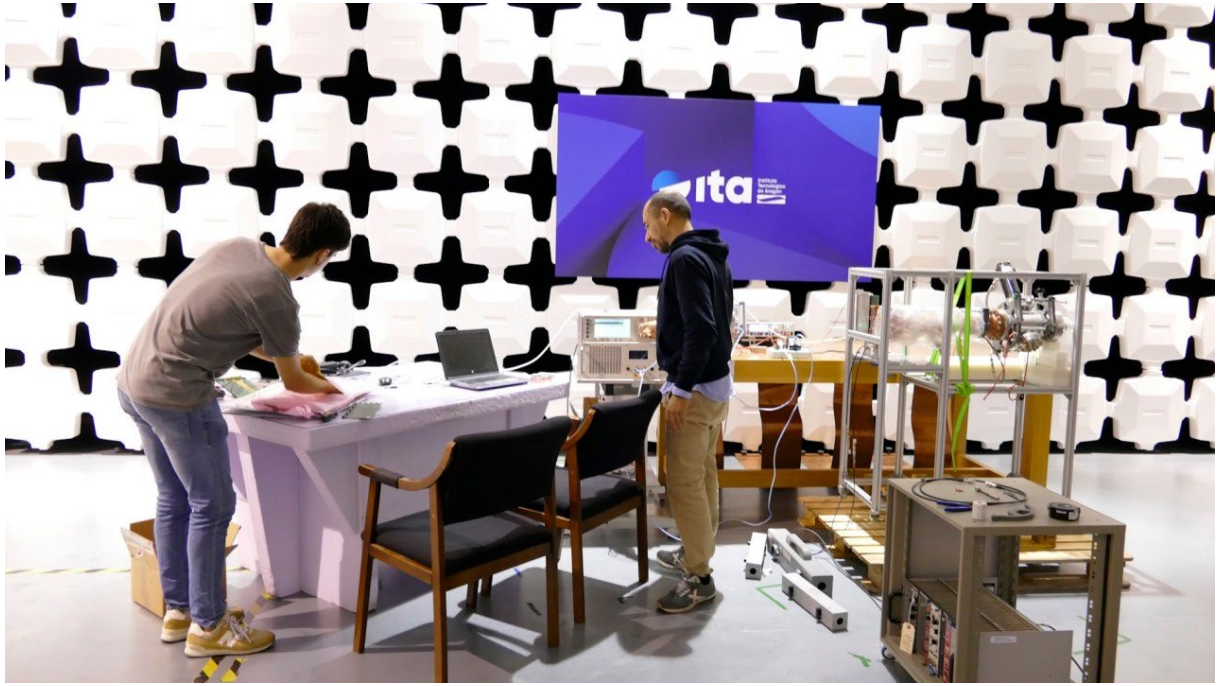
Noise Reduction

Analysis of the electrical/electronic architecture of the data acquisition (DAQ) and control system; implications and improvements for electromagnetic noise reduction according to EMI/EMC criteria

- Noise analyse of the IAXO-D1 detector

last month at ITA installations



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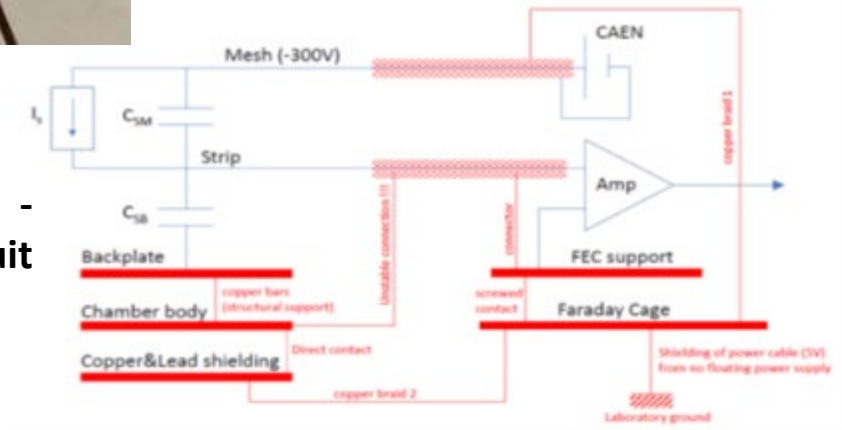
ITAINNOVA activities in L5

- Performance improvement studies in terms of connectivity, radiopurity and electromagnetic noise at infrastructure and system level;
  - Electromagnetic study and characterization at the LSC of the site where the IAXO experiment and TREX-DM (L2500) are relocated.
  - Analysis of the electrical/electronic architecture of the data acquisition (DAQ) and control system; implications and improvements for the reduction of electromagnetic noise according to EMI / EMC criteria.

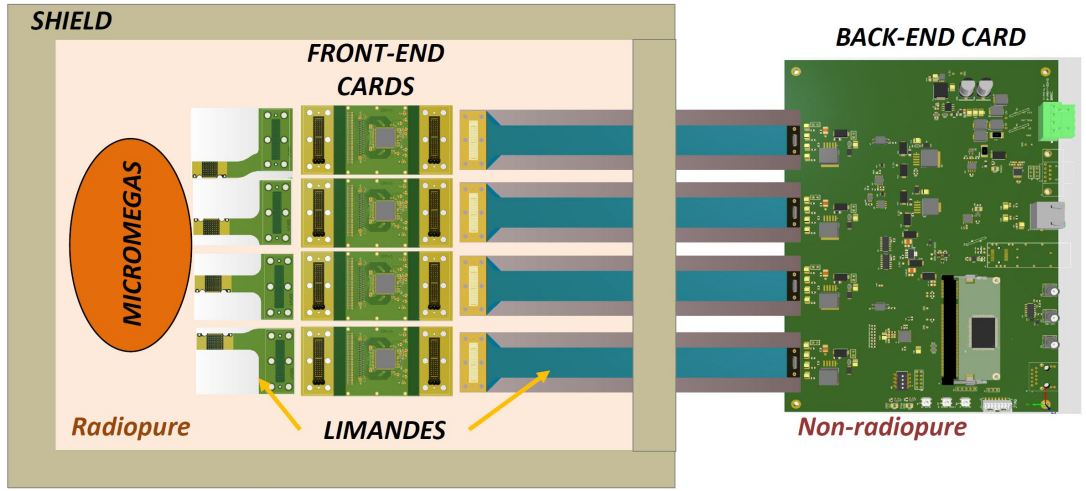
➢ **Several meetings and discussions have already taken place**

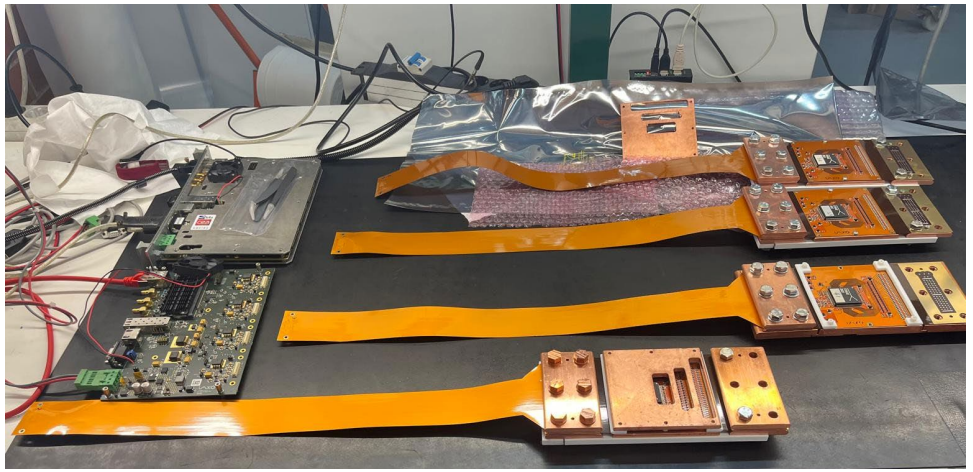
L2500 characterization at LSC – REF



DAQ IAXO - Signal circuit

Radiopure acquisition electronics system





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Front End, 4 cards with STAGE and limandes to conect to Back End

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Radiopure acquisition electronics system

1) Limandes Micromegas-FEC
   - Produced (at UNIZAR)
   - Under radiopurity measurement
2) FEC
   - 16 produced and assembled (Eonica)
   - FtF mechamics ready
   - To be tested
3) Limandes FEC-BEC
   - Produced (at UNIZAR)
   - Assembly started (UB)
4) BEC
   - Produced and assembled
   - FPGA programmed (15+1)
   - BIOS configured
   - DC levels tests passed
   - Link to FEC to be tested

12/03/2025

- Next steps
  - Soldering connectors on limandes
  - Testing
    - BEC with FEC
  - Design/produce BEC heat sink
    - Using FPGA sink + fan

E. Picatoste presentation 21th IAXO collaboration meeting March 2025

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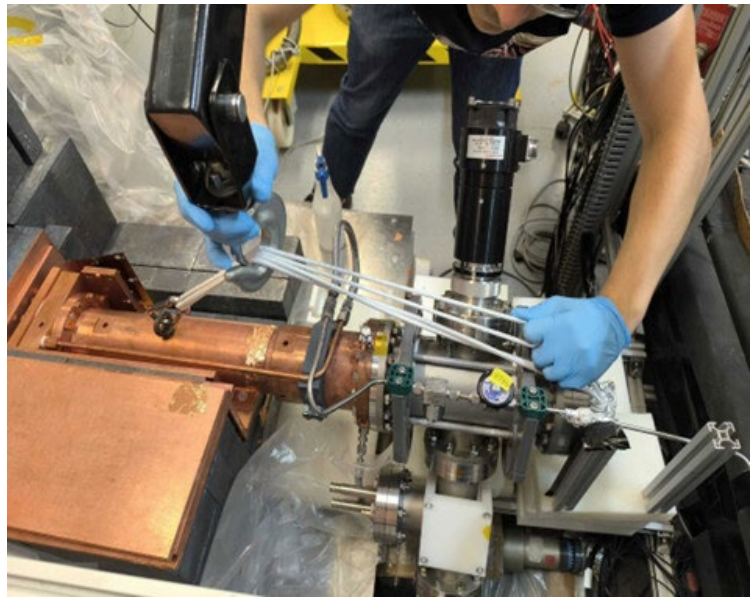
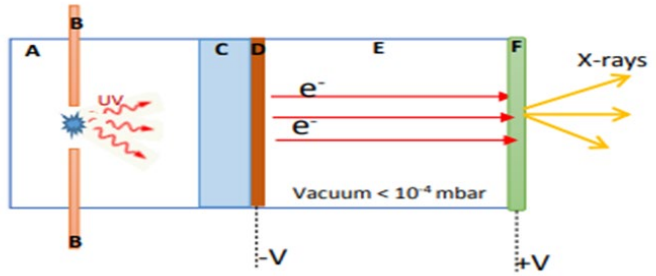
Calibration system based on X-ray fluorescence generation using a UV lamp.

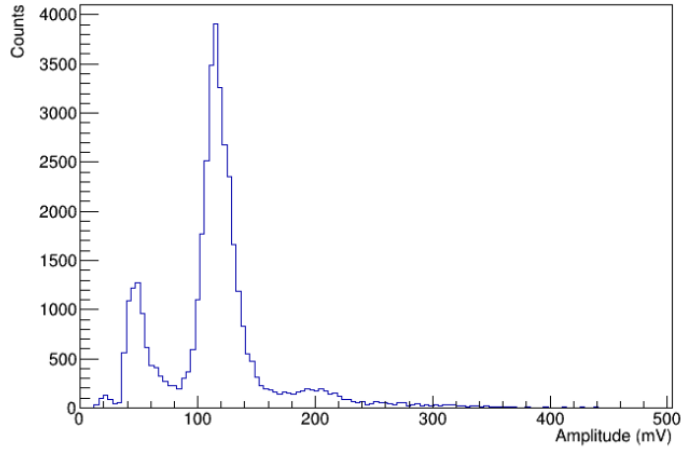
X-RAY GENERATOR





Filter combination:

- Ti target + 40 µm Ti filter →4.5 keV peak
- Cu target + 50 µm Ni filter →8 keV peak
- Small hole with 100 µm Al filter →1.5 keV peak



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Summary

- LA5.1 subproject **Integration of the ultra-low background detection line of the axion helioscope BabyIAXO**

Milestone H5.1.1 – Prototype detection line, and shielding built and in operation in progress

- Physics studies

- Prototype detection line designs and in construction to be delivered by the end of 2025

- Background reduction
  - **Internal background studies including filter emanation**
  - **Cosmic studies including HENSA campaigns at Zaragoza and DESY**
  - **Shielding design**
  - **Radiopure electronics**

- Noise reduction (ITA)

- lowering the threshold (electronics and calibration source)

- … a lot of work

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