Solar Axion Searches, and the next generation Helioscopes

Javier Galan (University of Zaragoza)

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

17st/February/2021
Seminar at the Particle Physics Group
University of Birmingham (UK) - Online

Outline

Centro de Astropartículas y Física de Altas Energías Universidad Zaragoza

- Axion motivation, past and present axion helioscope searches.
- The next generation of axion helioscopes.
- Design and construction of BabyIAXO.

- Exploiting state-of-the-art TPC-technology for axion searches.

Axion search motivation

AXION

Most elegant solution to the strong CP problem of the SM.

Astrophysical hints for axion/ALPs:

- Universe transparency to UHE gammas.
- Anomalous cooling of WDs, and HB stars.
- Sun phenomenology: Solar corona, flares.

Axions are a potential candidate to DM without being an adhoc solution.

Still little experimental effort when compared to WIMPs

Relevant axion/ALP parameter space at reach for next generation experiments.

Axion-like particles predicted by many extensions of the SM (e.g. string theory).

Axion search motivation

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

Most elegant solution to the strong CP problem of the SM.

Astrophysical hints for axion/ALPs:

- Universe transparency to UHE gammas.
- Anomalous cooling of WDs, and HB stars.
- Sun phenomenology: Solar corona, flares.

Axions are a potential candidate to DM without being an adhoc solution.

AXION

The axion is a very attractive particle from a theoretical perspective because it addresses problems in

Particle Physics

Astrophysics

and Cosmology

at once.

Axion experimental techniques

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

Due to its interaction with light it is a very attractive particle from the experimental point of view.
Many ideas leading to different detection techniques.

Axion detection technique	Experiments	Model and cosmology dependency	Technology
Haloscope	ADMX, HAYSATC, CASPer, CULTASK, CAST-CAPP, MADMAX, ORGAN, RADES, QUAX, …	High	New ideas emerging, Active R&D going on, …
Laser/Interferometry	ALPS, OSQAR, CROWS, ARIADNE	Very Low	Ready for large scale experiment
Helioscope	SUMICO, CAST, (NuSTAR), IAXO & baby-IAXO	Low	Ready for large scale experiment

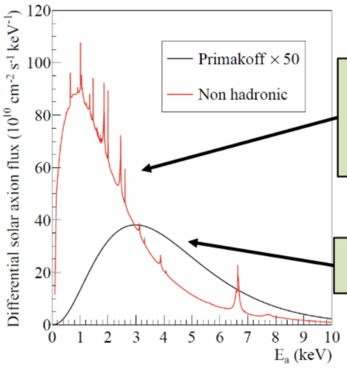
Helioscope technique does not require axions to be a dominant component of dark matter.

Solar Axion detection principle

Axion helioscope idea was first proposed by P. Sikivie *Sikivie PRL 51:1415 (1983)*

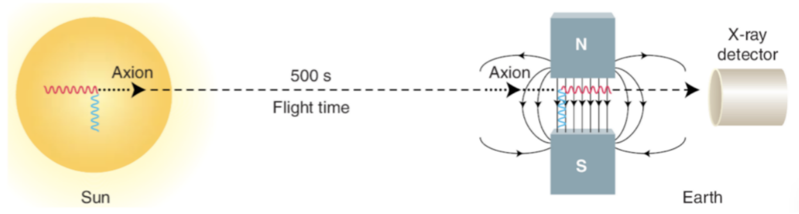
- Blackbody photons (keV) in solar core are converted into axions in the dense stellar plasma.

- Reconversions of axions into x-ray photons possible in strong laboratory magnetic field



Non-hadronic "ABC" Solar axion flux at Earth *JCAP 1312 008* (only if axion couples to electron)

Standard Primakoff spectrum



Idea refined by K. van Bibber, Raffelt et al. by using buffer gas to restore coherence over long magnetic field

Van Bibber et al. Phys.Rev. D 39:2089 (1989)

Helioscope generations

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

1990-2020

Today we are living in the 3rd helioscope generation

<u>1st generation:</u> helioscope: Brookhaven

- Just a few hours of data
- Lazarus et at. PRL 69 (92)

<u>2nd generation</u>: Tokyo Helioscope (SUMICO)

- 2.3 m long, 4 T magnet

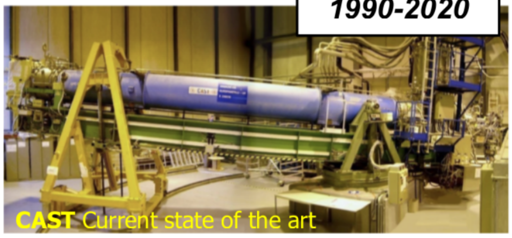
<u>3rd generation</u>: CERN Axion Solar Telescope (CAST)

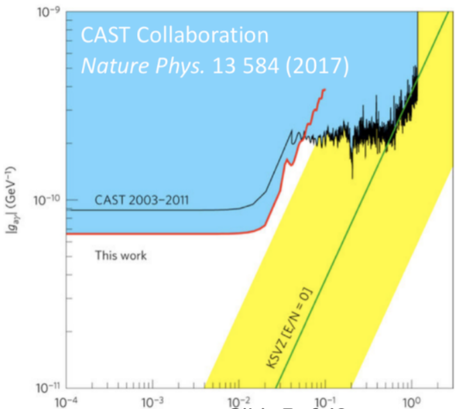
- Most sensitive axion helioscope to date (10 m, 9 T) - No axions detected yet

- Best experimental limit on axion-photon coupling over broad axion mass range

$$g_{a\gamma} < 0.66 \times 10^{-10}\ \mathrm{GeV}^{-1}\ (95\%\ \mathrm{C.L.})$$

- Latest CAST results have been provided by IAXO-pathfinder.





Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

Studies pointed to great potential to enhance axion-photon coupling sensitivy by building a new dedicated helioscope

JCAP 1106, 013 (2011)

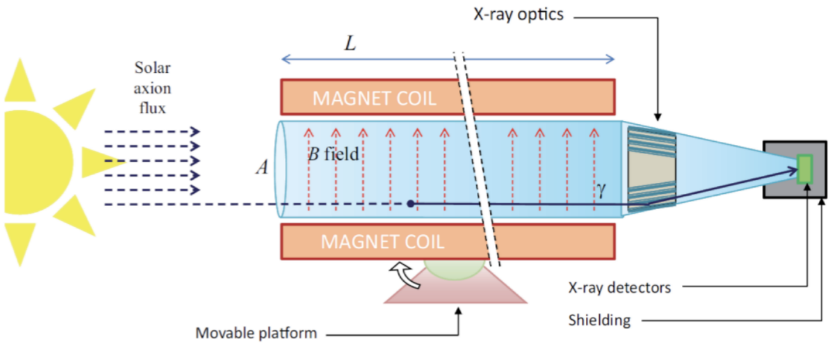
Sensitivity to g_{ag} coupling.

IAXO Figure Of Merit (FOM).

A factor 10,000 to 20,000 improvement over CAST.

2011

Enhanced axion helioscope prospects by increasing each of the helioscope components



$$g_{a\gamma}^4 \propto \underbrace{(BL)^{-2} A^{-1}}_{\text{magnet}} \times \underbrace{t^{-1/2}}_{\text{exposure}} \times \underbrace{s^{1/2}\varepsilon_0^{-1}}_{\text{optics}} \times \underbrace{b^{1/2}\varepsilon^{-1}}_{\text{detectors}}$$

magnet: B = magnetic field, L = magnet length, A = cross-sectional area

exposure: t = time

optics: s = spot size, ε_0 = efficiency

detectors: b = background, ε = efficiency

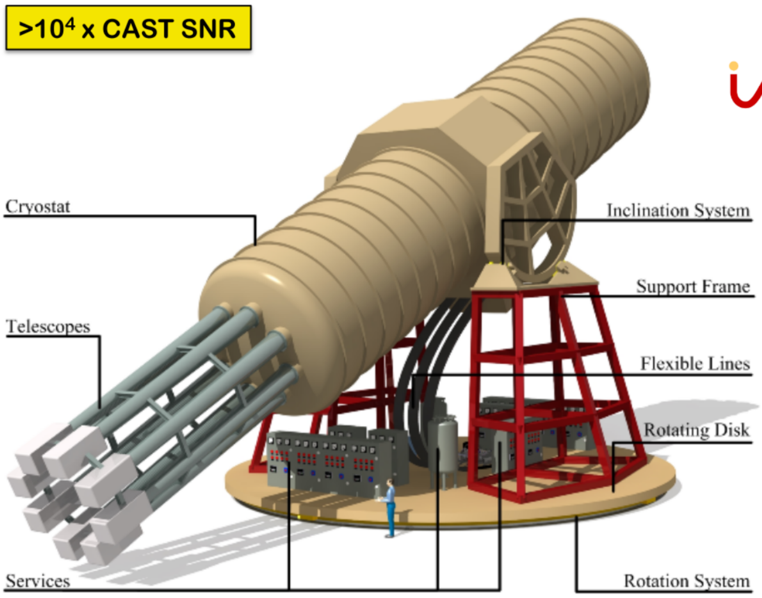
Conceptual Design

- **Large toroidal 8-coil magnet** ***L* =~20 m**
- **8 bores: 600 mm diameter each**
- **8 x-ray telescopes + 8 detection systems**
- **Rotating platform with services**

Armengaud et al.
JINST 9 T05002 (2014)

$>10^4$ x CAST SNR

2014



IAXO Pathfinder @CAST supports the testing of new systems, R&D for IAXO

2014-15

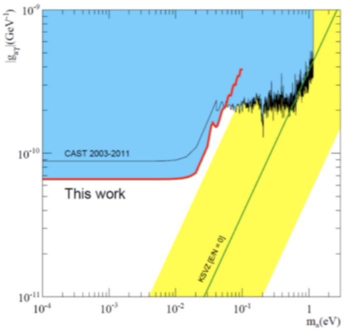
Sensitivity increase for CAST

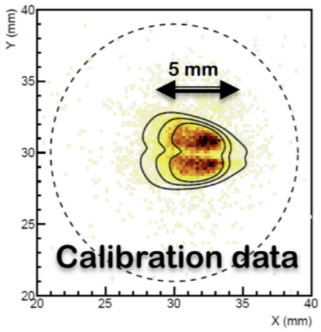
and

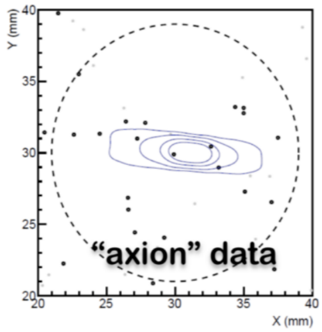
Testbench for IAXO

- § Small x-ray optics
- • Fabricated purposely using thermally-formed glass substrates (NuSTAR-like)
- § Micromegas low background detector with recirculated Xenon gas
- • Applied lessons learned from R&D: compactness, better shielding, radiopurity,…
- § Data acquisition at CAST (2014/15)
- • Background level ~ 0.003 counts/hour

Anastassopoulos et al. Nature Phys. 13 (2017) 584-590







IAXO Collaboration was officially born in 2017

The International Axion Observatory

- Johannes Gutenberg University of Mainz (Germany)
- University of Cape Town (South Africa)
- Moscow Institute of Physics and Technology (Russia)
- Instituto de Microelectronica de Barcelona, CSIC (Spain)
- Lawrence Livermore National Laboratory (United States)
- Centro de Estudios de Física del Cosmos de Aragón (Spain)
- Institut de Ciències del Cosmos, Barcelona (Spain)
- Universidad de Zaragoza (Spain)
- Physikalisches Institut der Universitaet Bonn (Germany)
- Petersburg Nuclear Physics Institute (Russia)
- Irfu/CEA Saclay (France)
- CERN (Switzerland)
- Rudjer Bošković Institute, Zagreb (Croatia)
- Heidelberg University (Germany)
- Barry University (United States)
- Institute for Nuclear Research of the Russian Academy of Sciences (Russia)
- Istituto Nazionale di Astrofisica (Italy)
- DESY (Germany)
- University of Siegen (Germany)
- MIT's Laboratory of Nuclear Science (United States)


12th IAXO Collaboration Meeting in memory of Biljana Lakic
Loredana Gastaldo

BabyIAXO

2019

BabyIAXO = Intermediate experimental stage before IAXO

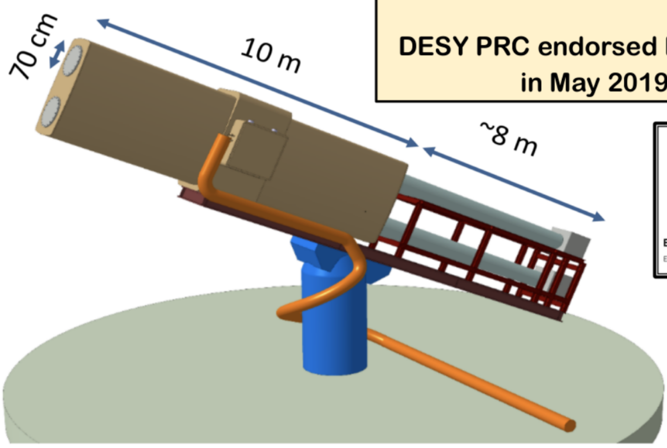
§ Performance verification for IAXO and significant science return simultaneously

§ Conceptual design finished (Presented to DESY Oct 2018)

§ Two bores of dimensions similar to final IAXO bores

Aperture/diameter [m]	2 x 0.7
Magnetic field length [m]	10
Average field intensity [T]	~2-3
Peak field [T]	4.1

~100 x CAST in terms of $B^2L^2A\ t$



ERC advanced grant by I. Irastorza to support the development of BabyIAXO and enhance future IAXO prospects.

DESY PRC endorsed BabyIAXO in May 2019

ERC-AvG 2017 IAXO+

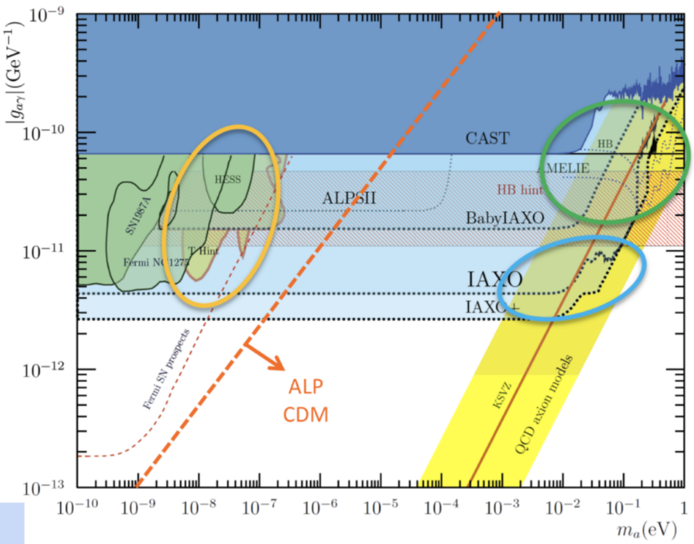
IAXO will probe large parts of QCD axion model space (KSVZ, DFSZ) including viable DM models

"ALP miracle" region: ALPs solving both DM & inflation
Daido et al. 2017 arXiv:1710.11107

Large fraction of the axion & ALP models invoked in the "stellar cooling anomaly" (*gae* particularly interesting for this)

IAXO will fully explore ALP models invoked to solve the "transparency hint"

IAXO will also be able to probe large parameter space for CDM ALPs



Baby-IAXO: 10 x MFOMCAST + optics and detector from conservative scenario of LoI

IAXO: > 300 x MFOMCAST +optics and detector improvements

IAXO+: Enhanced scenario with x 10 (x4) higher FOM (MFOM) with respect LoI

E. Armengaud et al., JCAP (2019) 06 047

BabyIAXO status

- Formal BabyIAXO proposal to DESY approved last year.
  - Site for BabyIAXO chosen: one of underground HERA halls at DESY
- Construction costs mostly secured (critical point passed):
  - ERC, but also ANR (France), BMBF (Germany), AEI (Spain), LLNL LDRD, etc…
  - DESY fully committed: 3.1 M€ “host” investments approved.
  - CERN involved in magnet design & construction
  - Very important in-kind contributions: SC cable from INR, platform from DESY (refurbished CTA mount)
- Construction phase just started. Expected commissioning by 2023

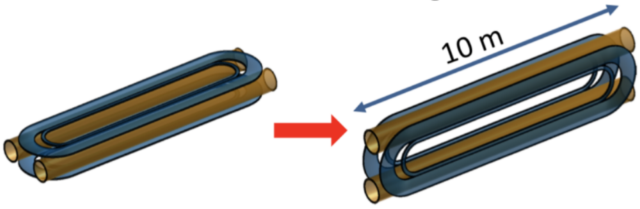
- Outcome from ESPP(*) very positive for axions. Search for axions explicitly mentioned (and even the DESY axion program mentioned in the deliberation document)

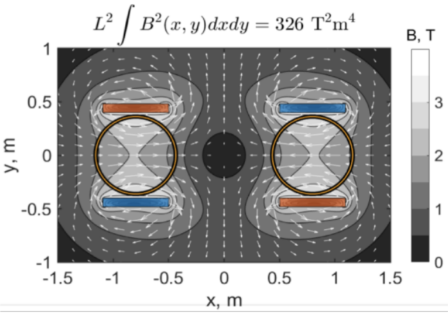
(*) European Strategy for Particle Physics

BabyIAXO Project tentative timeline

		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029+
	Design											
	Construction											
	Commissioning											
Data taking	Vacuum phase											
	Upgrade to gas											
	Gas phase											
	Beyond-baseline											
IAXO	Design											
	Construction					Tentative						

BabyIAXO magnet : "Common coil" configuration chosen.
Minimal construction risk with existing infrastructure

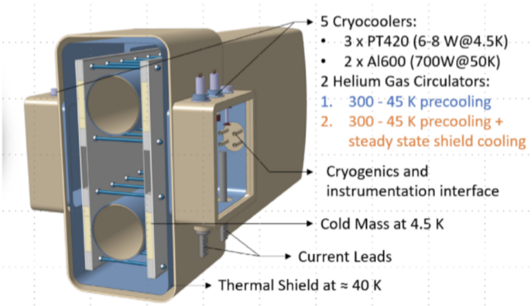




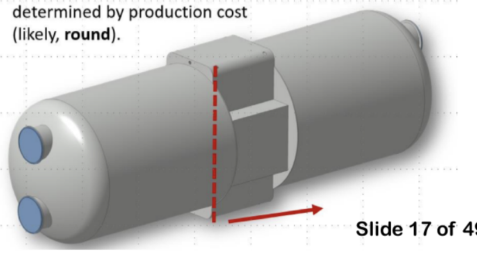
Much larger aperture magnet compared to CAST.

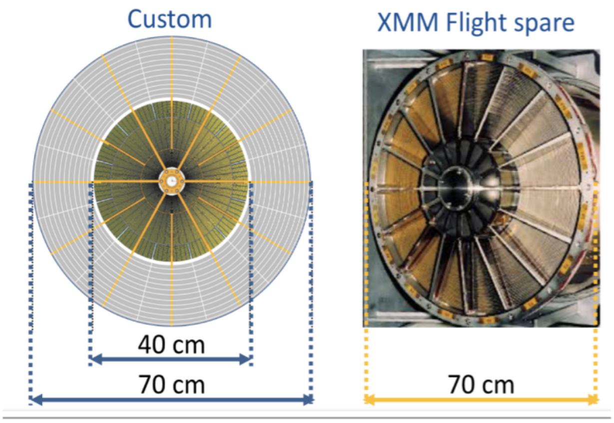
Magnetic profile not uniform, is not a requirement for axion searches, as opposed to accelerator physics.

Magnet conception & design moving towards construction design.



* shape of cryostat **end-caps** will be determined by production cost (likely, **round**).





baby-IAXO will use:

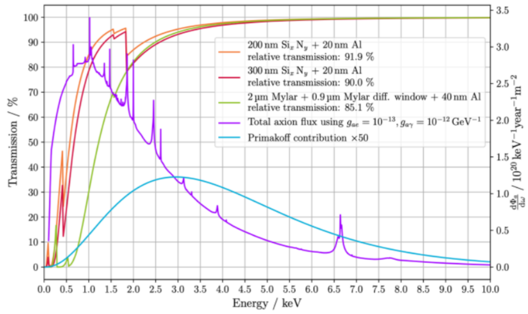
- One custom IAXO optic (multilayer-coated, segmented- glass Wolter-I) to be built.
- and one existing flight spare XMM telescope from ESA.

– Minimal risk to the project
  a. On one hand, XMM optics specs very close to IAXO optics design
  b. On the other, we gain experience on the production of segmented-glass optics for future IAXO (8 optics needed)

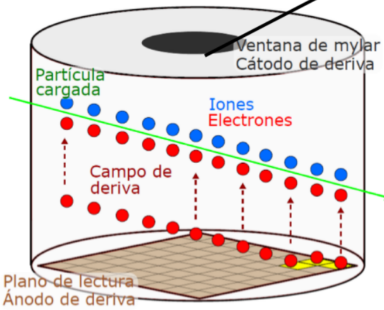
Micromegas detectors for BabyIAXO

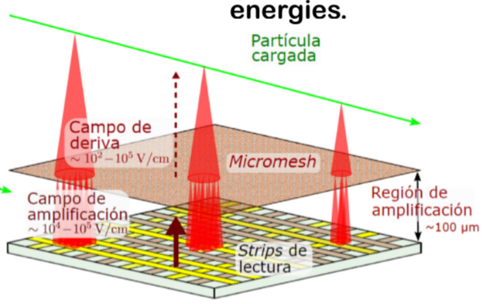
Micromegas based TPC exploiting particle identification for background reduction.

Spatial resolution ~ 100um.

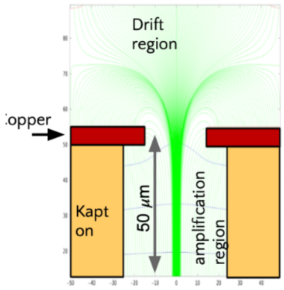


Thin mylar window to assure máximum x-ray transparency at low energies.





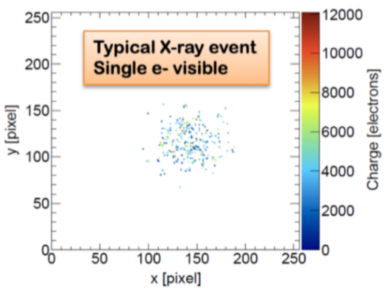
Microbulk detection principle

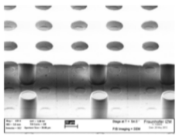


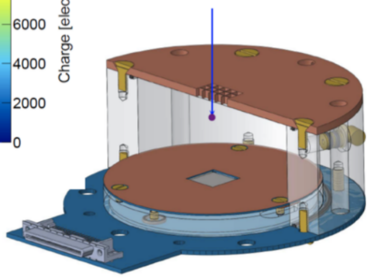
Built with radiopure materials (copper and kapton) + low mass budget

GridPix detectors (U. Bonn):

- Micromegas on top of a CMOS chip (Timepix)
- Very low threshold (tens of eV)
- Tested in CAST

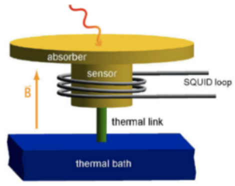


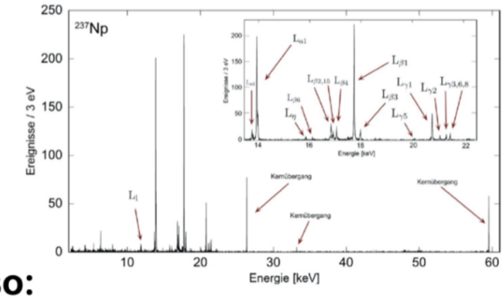




MMC detectors (U. Heidelberg):

- Extremely low threshold and energy resolution (~eV scale)
- Low background capabilities under study





Also:

- Transition Edge Sensors (TES)
- Silicon Drift Detectors (SDD)

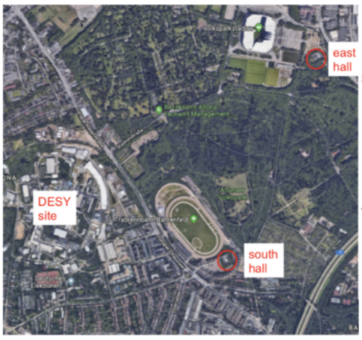
BabyIAXO @ DESY

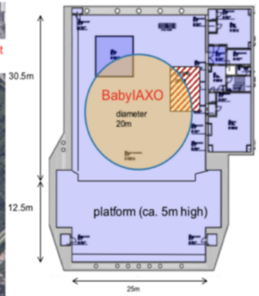
- Preparations for the installation of BabyIAXO @ DESY HERA South

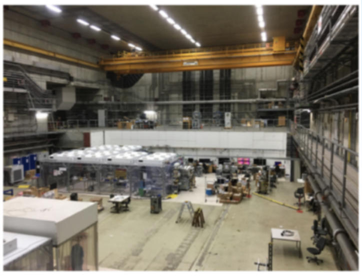
- Infrastructure at DESY & good expertise very well suited to host IAXO

- CTA MST prototype, support and drive system already being installed for BabyIAXO

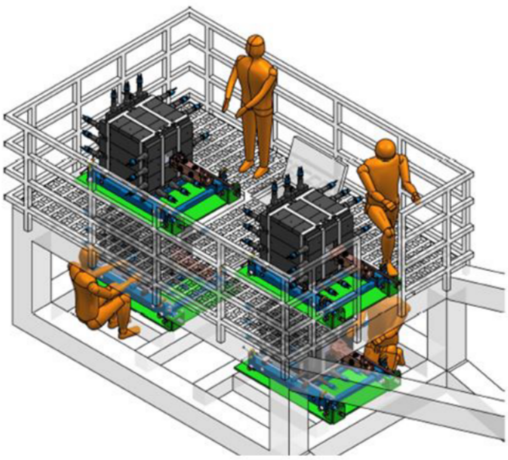
BabyIAXO Sun Tracking capabilities ~ 18 hours per day.

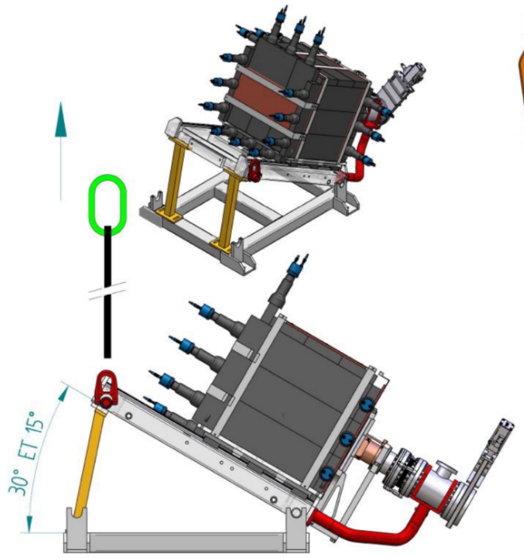


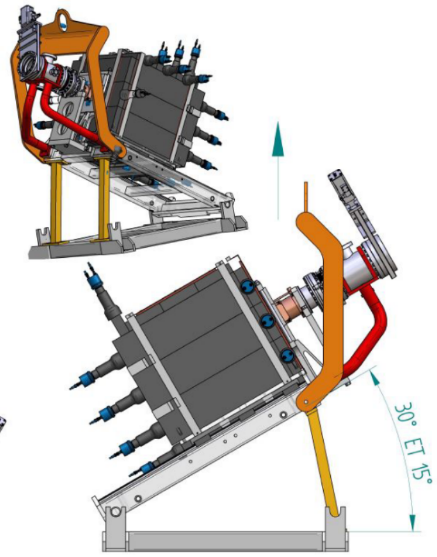


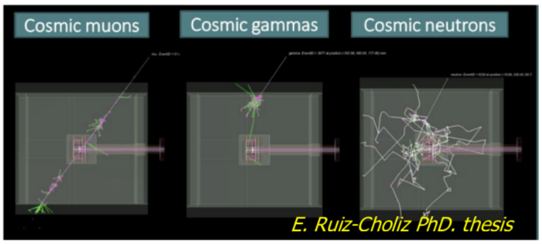


Mechanical studies ongoing.
Detector platform design ready!









R&D program to understand the nature of the background and identify dominant components.

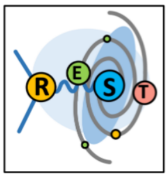
Many years of expertise developed at Univ. of Zaragoza.

MonteCarlo
+
experimental data

Set-up optimization.

Combining

active + passive shielding

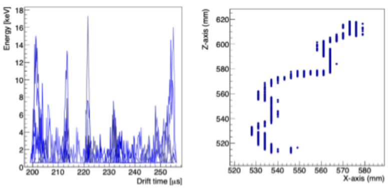


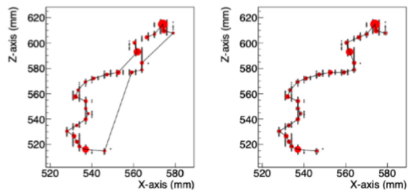
Studies based on RESTSoft (Rare Event Searches with TPCs) Framework for data analysis and Geant4 MonteCarlo simulation.

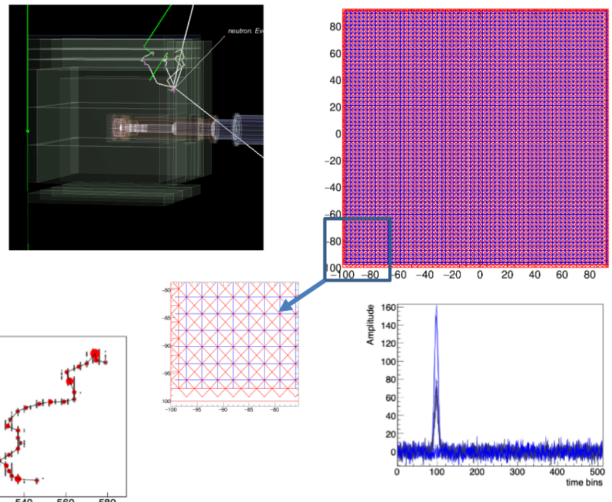
REST-for-Physics II

REST-for-Physics is a ROOT based framework strongly used and developed by U. Zaragoza for Rare Event searches.

- **Data analysis**
- **Detector response simulation**
- **Raw signal processing, conditioning, FFT, etc.**
- **Event reconstruction, clustering, track pattern identification.**
- **Event visualization, plotting and browsing tools.**
- **Geant4 simulations**







The project is reaching maturity, and it is used in the context of different experiments: CAST, PandaX-III, TREX-DM, and IAXO.
It is also strongly supporting academic activity.

REST-for-Physics

Garfield++

ROOT Data Analysis Framework

GEANT4 A simulation toolkit

GitLab

zenodo

GitHub

https://github.com/rest-for-physics

First oficial public reléase. V2.3.4

DOI 10.5281/zenodo.4528986

IAXO@DESY

CAST@CERN

PandaX-III@JinPing

TREXDM@LSC

Universitat de Barcelona

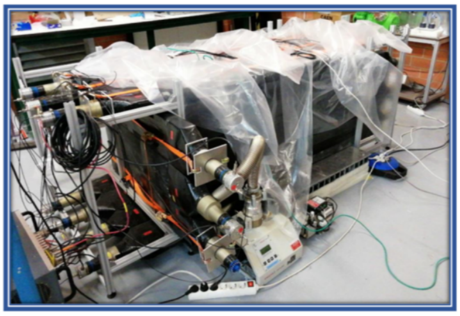
CEA Saclay (France)

SJTU (China)

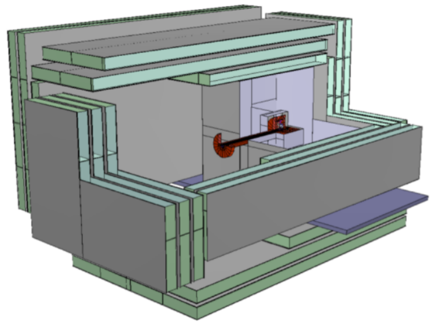
Universidad Zaragoza

Active VETO studies at IAXO-Lab

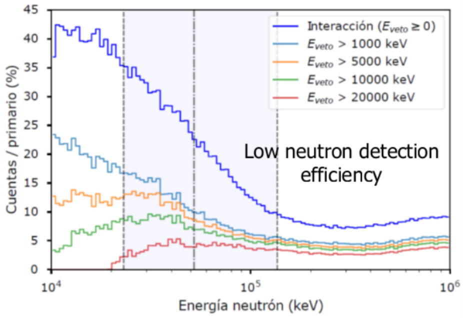
IAXO-D0 Geometry installed at dedicated IAXO-Lab @ U. Zaragoza



- **Plastic dims: 1500/850 x 200 x 50 mm.**
- **3 Layer, 3-4 plastics per layer.**
- **Already taking data.**
- **Neutron veto (stacked scint + Cd) not finished yet.**
- **Simulated neutron tagging efficiency (~75% - 90%). R&D on-going.**



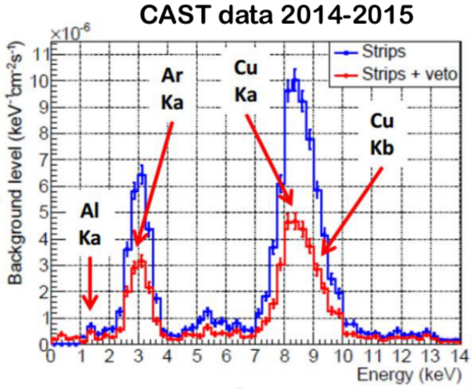
5cm Scintillator neutron efficiency



Montecarlo studies show that muon induced background is strongly reduced by using standard VETOs.

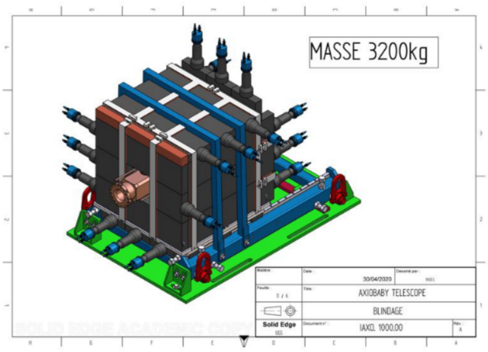
However, new strategies are needed to identify neutrons

CAST data 2014-2015



Including active VETOs in CAST data taking run has shown a considerable reduction in background.

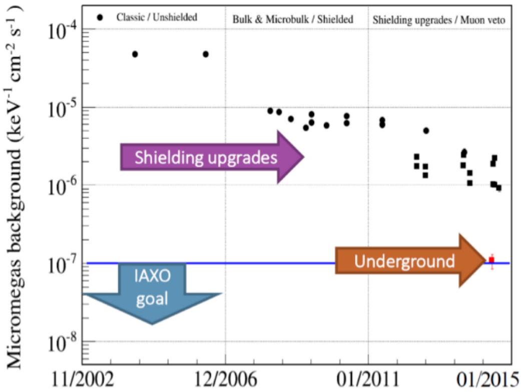
New design!
Full 4-PI coverage.
Improvement from an ad-hoc design respect to CAST



IAXO detectors testbench at LSC

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

Historical background improvements

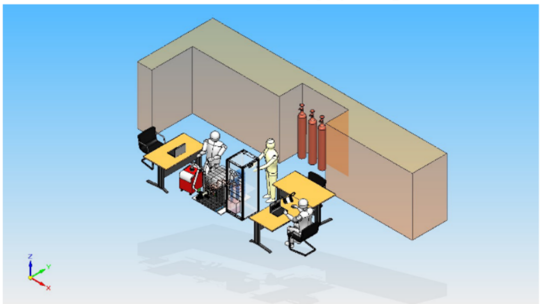


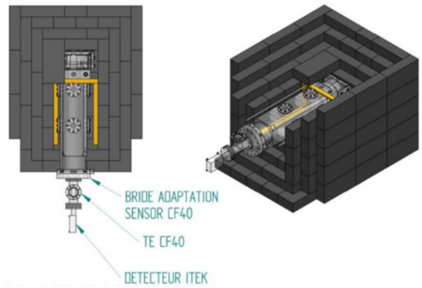
Underground studies show potential to continue background reduction

Recent proposal to install a research facility for BabyIAXO at the Canfranc Underground Laboratory (LSC).

To assess background of different detector technologies in similar conditions.

Parallel radioassay program





Different set-ups to understand the backgrounds nature, characterize VETOs efficiency, and assess the achievable background levels.

A deep review on axion theory, axion hints and the physics reach of the future IAXO helioscope was recently published.

Physics potential of the International Axion Observatory (IAXO)

E. Armengaud,[a] D. Attie,[a] S. Basso,[b] P. Brun,[a] N. Bykovskiy,[c] J. M. Carmona,[d] J. F. Castel,[d] S. Cebrián,[d] M. Cicoli,[e,f] M. Civitani, [b] C. Cogollos,[g] J. P. Conlon,[h] D. Costa,[g] T. Dafni,[d] R. Daido,[i] A.V. Derbin,[j] M. A. Descalle,[k] K. Desch,[l] I.S. Dratchnev,[j] B. Döbrich,[c] A. Dudarev,[c] E. Ferrer-Ribas,[a] I. Fleck,[m] J. Galán,[d] G. Galanti,[b] L. Garrido,[g] D. Gascon,[g] L. Gastaldo,[n] C. Germani,[g] G. Ghisellini,[b] M. Giannotti,[o] I. Giomataris,[a] S. Gninenko,[p] N. Golubev,[p] R. Graciani,[g]

Important reference for axion searches.

E. Armengaud et al., JCAP (2019) 06 047

All details on BabyIAXO can be found at a recent preprint (publication pending at JHEP)

Conceptual Design of BabyIAXO, the intermediate stage towards the International Axion Observatory

IAXO collaboration

A. Abeln[1], K. Altenmüller[2], S. Arguedas Cuendis[3], E. Armengaud[4], D. Attié[4], S. Aune[4], S. Basso[5], L. Bergé[6], B. Biasuzzi[4], P. T. C. Borges De Sousa[3], P. Brun[4], N. Bykovskiy[3], D. Calvet[4], J. M. Carmona[2], J. F. Castel[2], S. Cebrián[2], V. Chernov[7,8], F. E. Christensen[9], M.M. Civitani[5], C. Cogollos[10,11], T. Dafní[2], A. Derbin[12], K. Desch[13], D. Díez[2], M. Dinter[21], B. Döbrich[3], I. Drachnev[12],

https://arxiv.org/abs/2010.12076

Helioscope seminal papers

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

1983

VOLUME 51, NUMBER 16 — PHYSICAL REVIEW LETTERS — 17 OCTOBER 1983

Experimental Tests of the "Invisible" Axion

P. Sikivie
Physics Department, University of Florida, Gainesville, Florida 32611
(Received 13 July 1983)

1989

THIRD SERIES, VOLUME 39, NUMBER 8 — 15 APRIL 1989

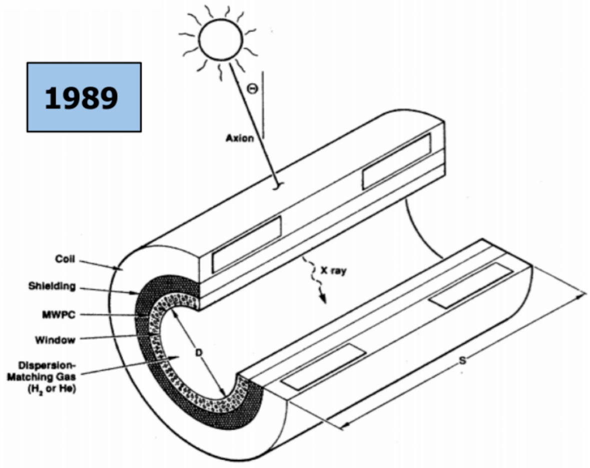
Design for a practical laboratory detector for solar axions

K. van Bibber
Physics Department, Lawrence Livermore National Laboratory, University of California, Livermore, California 94550

P. M. McIntyre
Physics Department, Texas A&M University, College Station, Texas 77843

D. E. Morris
Physics Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

G. G. Raffelt
*Institute for Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, University of California, Livermore, California 94550
and Astronomy Department, University of California, Berkeley, California 94720*
(Received 19 September 1988)



Pioneering helioscope ideas were stationary

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

VOLUME 69, NUMBER 16 PHYSICAL REVIEW LETTERS 19 OCTOBER 1992

Search for Solar Axions

D. M. Lazarus and G. C. Smith
Brookhaven National Laboratory, Upton, New York 11973

R. Cameron,[a] A. C. Melissinos, G. Ruoso,[b] and Y. K. Semertzidis[c]
Department of Physics and Astronomy, University of Rochester, Rochester, New York 14627

F. A. Nezrick
Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, Illinois 60510
(Received 22 May 1992)

1992

First helioscope

A helioscope "a la Sikivie".
Taking data when magnet pipe is on the Sun field of view.
$g_{ag} < 3.6 \times 10^{-9}$ GeV^{-1} for $m_a < 30$meV
Also running using low pressure buffer gas

Experimental Search for Solar Axions via Coherent Primakoff Conversion in a Germanium Spectrometer

F. T. Avignone III,[1] D. Abriola,[2] R. L. Brodzinski,[3] J. I. Collar,[4] R. J. Creswick,[1] D. E. DiGregorio,[2] H. A. Farach,[1] A. O. Gattone,[2] C. K. Guérard,[1,2] F. Hasenbalg,[2] H. Huck,[2] H. S. Miley,[3] A. Morales,[5] J. Morales,[5] S. Nussinov,[6] A. Ortiz de Solórzano,[5] J. H. Reeves,[3] J. A. Villar,[5] and K. Zioutas[7]

(SOLAX Collaboration)

[1]*Department of Physics and Astronomy, University of South Carolina, Columbia, South Carolina 29208*
[2]*Department of Physics, TANDAR Laboratory, C.N.E.A., Buenos Aires, Argentina*
[3]*Pacific Northwest National Laboratory, Richland, Washington 99352*
[4]*CERN, CH-1211 Geneva, 23 Switzerland*
[5]*Laboratorio de Física Nuclear y Altas Energias, Universidad de Zaragoza, Zaragoza, Spain*
[6]*Department of Physics, Tel Aviv University, Tel Aviv, Israel*
[7]*Department of Physics, University of Thessaloniki, GR54006 Thessaloniki, Greece*
(Received 17 June 1998)

1997

First Underground helioscopes

COSME, SOLAX, CDMS, DAMA
Crystal solid detectors. Exploiting interatomic fields.
These experiments gave similar upper limits for the axion-photon coupling

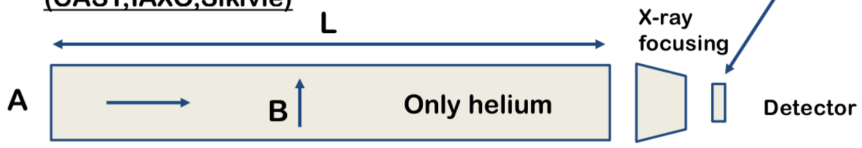
$g_{ag} < 1.7\text{-}2.7 \times 10^{-9}$ GeV^{-1} $m_a < 1$keV

Two helioscope techniques for axion detection

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

Photons detected at the end of magnet bore

Helioscope - Photon transmission (CAST,IAXO,Sikivie)

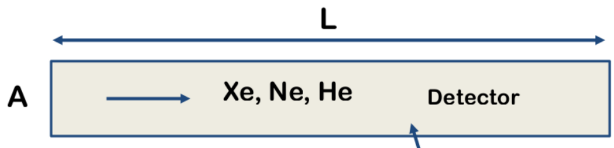


Number of photons found at a distance L

$$P_\gamma = \frac{(B/2M)^2}{q^2 + \Gamma^2/4}\left[1 + e^{-\Gamma L} - 2e^{-\Gamma L/2}\cos(qL)\right]$$

Helioscope - Photon absorption
(Never exploited before!)

Starts to be competitive for higher masses ~eV



Photons detected inside the magnetic volume

Number of photons absorbed along a distance L

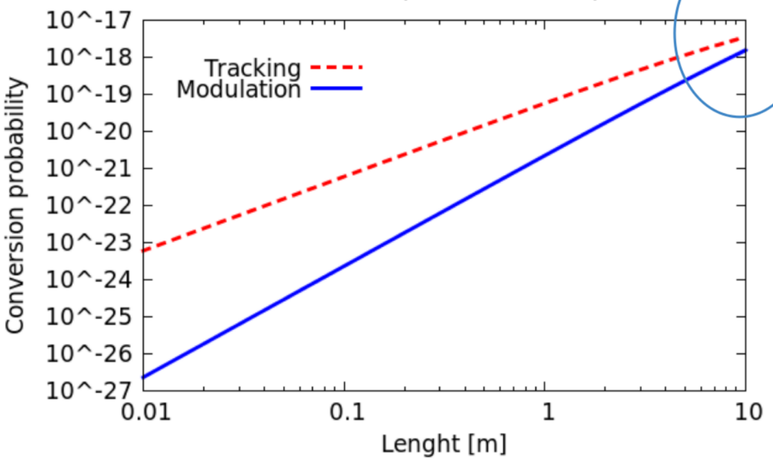
$$P_\gamma = \frac{(B/2M)^2}{q^2 + \Gamma^2/4}\Gamma L$$

Absorbed or transmitted photon component

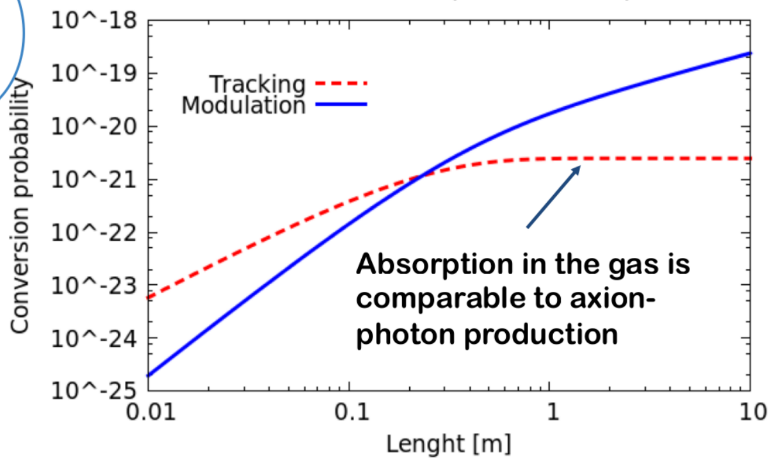
Corresponding to latest CAST pressure settings

Pressures at enviroment temperature …

Helium at 10 bar (ma ~ 0.85 eV)



Xenon at 100 mbar (ma ~ 0.4 eV)



Conversion probability as a function of the axion mass

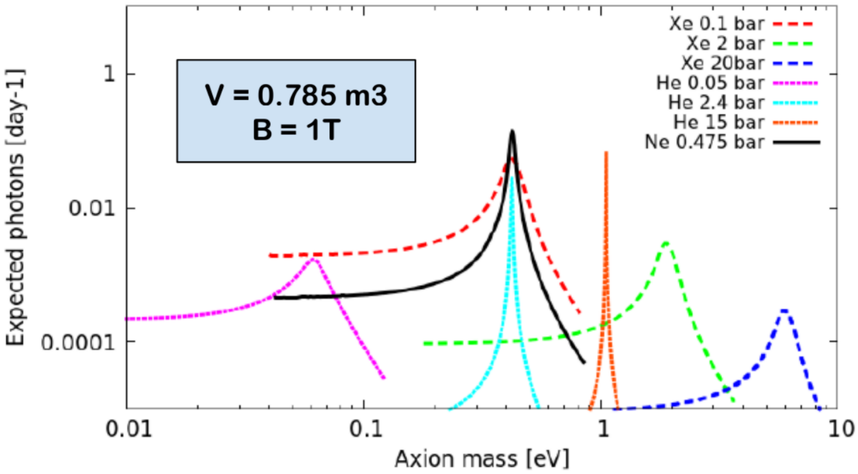
Helium	Neon	Argon	Xenon
100 mbar - 10 bar	20 mbar - 10 bar	4 mbar - 10 bar	4 mbar - 10 bar
86 meV - 0.86 eV	137 meV - 1.94 eV	51 meV - 2.57 eV	79 meV - 4.05 eV

Conversion probability resonances at different gases and mixtures

Effective axion mass related to gas conditions

$$m_\gamma^2 = 4\pi r_o (N_A / A m_u) \rho f_1$$

We are always interested to have a detector as largest as possible. But in the case of low Z gases this is critical.



A magnetic TPC for helioscope searches

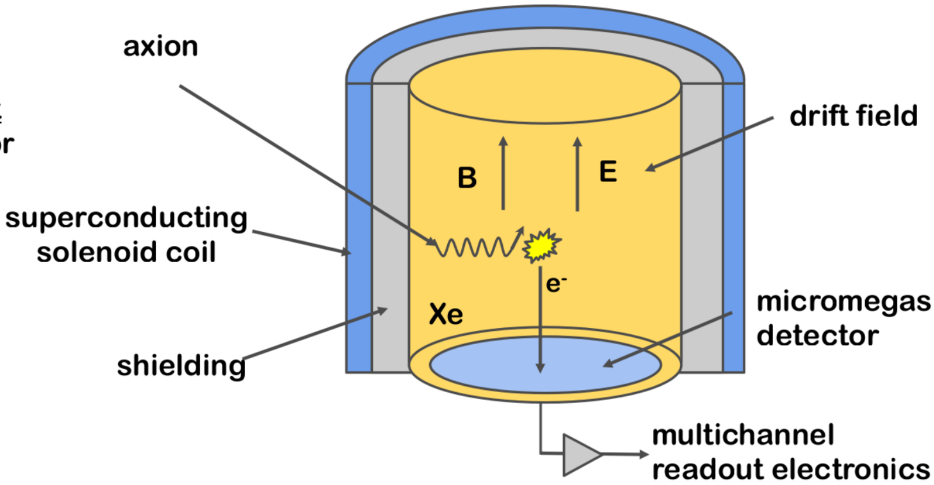
The transmitted photon component goes typically as L^2, thus a long pipe is usually the best suitable geometry.

However, for the axion-photon component absorbed is just proportional to L, thus (for high Γ) we can use any volume geometry

$$P_\gamma = \frac{(B/2M)^2}{q^2 + \Gamma^2/4} \Gamma L$$

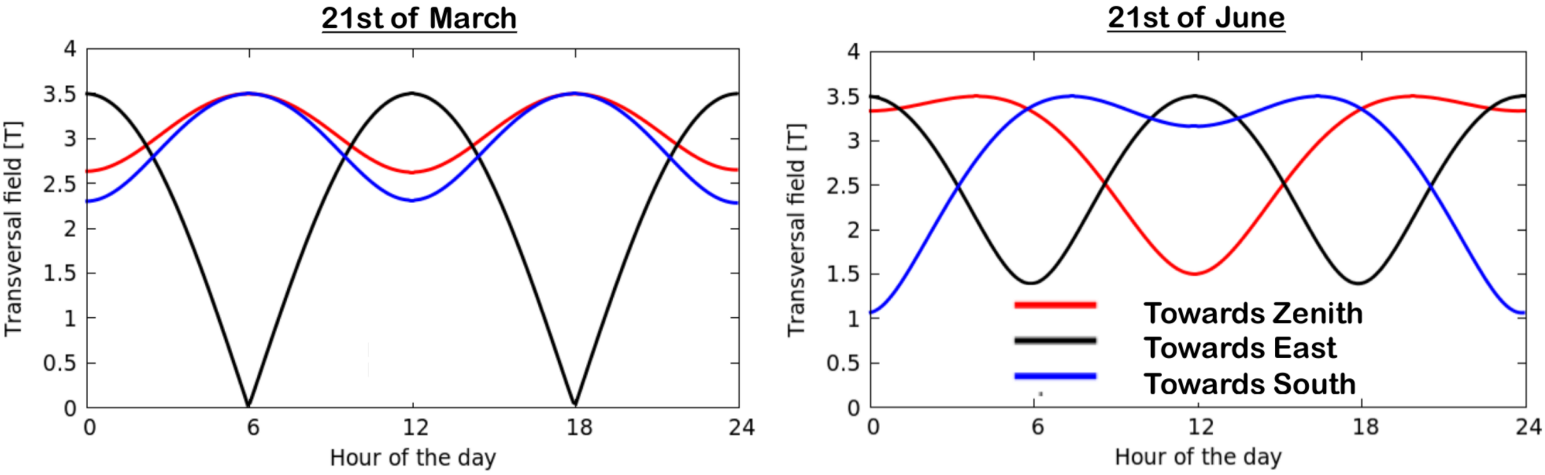
This technique is especially interesting if $\Gamma L >> 1$.
High Z gases

A possible conceptual TPC-magnet design

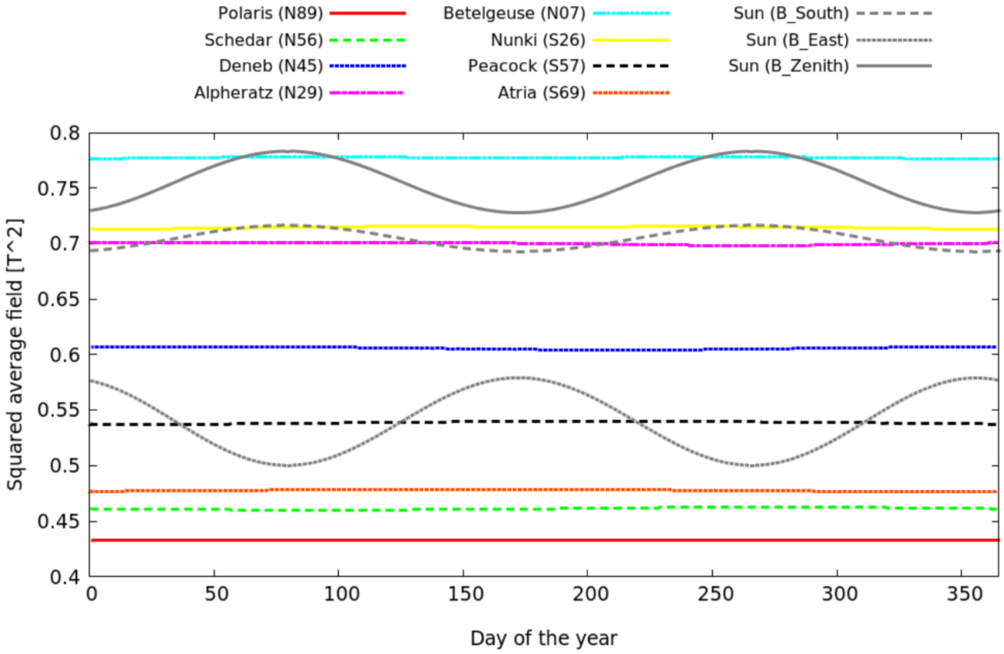


Daily modulation due to Earth rotation

The effective magnetic field for axion-photon conversion modulates.
Since, only the transversal field component contributes to the axion-photon oscillation.
to the axion propagation direction that changes along the day.



Annual solar axion modulation (daily averaged)



3 Different TPC magnetic field orientations are shown for Solar axions.

Effective field ~0.75 B^2 for a field perpendicular to the ground.
24h taking data = 18h tracking

Different sky positions are also shown. Negligible effect on annual modulation.

The Annual modulation pattern is exclusive of the Sun.

AMELIE Search sensitivity prospects

1-year data taking
75 days per pressure setting

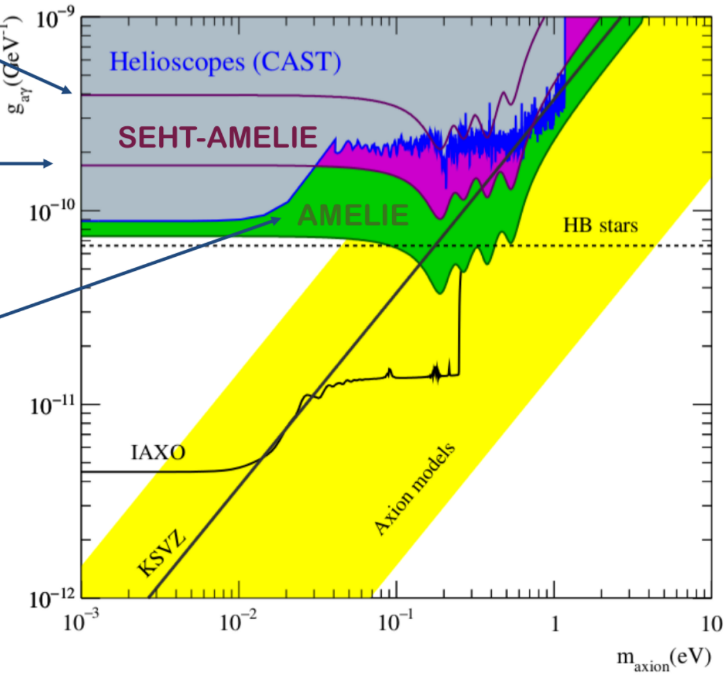
1000 cpd m^3 keV^{-1}

7.7 T^2 m^3

Level reachable underground 1 cpd m^3 keV^{-1}

10-year data taking program 0.1 cpd m^3 keV^{-1}

20 T^2m^3



Exploring 0.1–10 eV axions with a new helioscope concept

J. Galán[a], T. Dafni[a], E. Ferrer-Ribas[b], I. Giomataris[b], F.J. Iguaz[a], I.G. Irastorza[a], J.A. García[a], J.G. Garza[a], G. Luzon[a], T. Papaevangelou[b] Show full author list

Published 4 December 2015 • © 2015 IOP Publishing Ltd and Sissa Medialab srl
Journal of Cosmology and Astroparticle Physics, Volume 2015, December 2015

2.5T average field, R=30cm L=20m
1-IAXO magnet bore = 35 T^2m^3

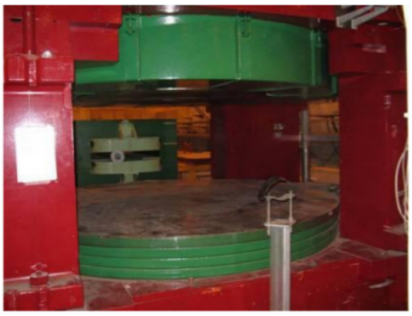
Existing magnet facilities

PC-MAG facility at DESY

"Portable" light weigth magnet.

(R=40cm L=1m)
1T solenoid magnet

(R=1.7m L=1.06m)
1.6 T magnet

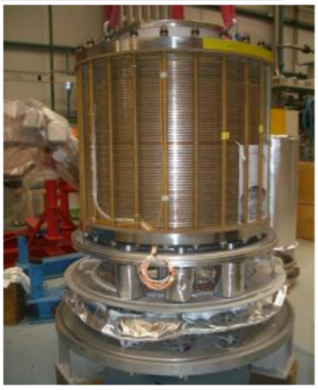


Goliath magnet at CERN

SEHT test station at CEA Saclay (France)

21 T^2m^3

+10cm shielding
8 T^2m^3



Advantages of using AMELIE technique

- An independent technique for solar axion searches competitive and complementary to running experiments.

- Full angular sensitivity (allows to observe the full solar disk + supernovae + ?) Not high accuracy alignment required.

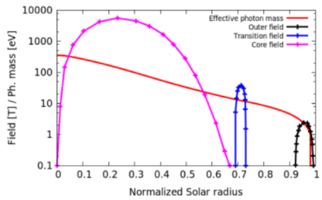
- For higher masses, improved gas density stability and broader axion mass coverage with a single setting. Longer data taking periods.

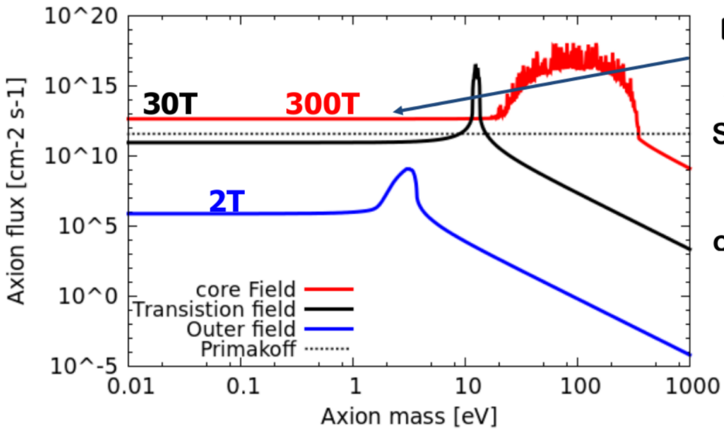
- Enables searches to very low energies (few ~200eV). Since detector and conversion volume are the same entity.

Full angular acceptance (4π)

S.Couvidat, S. Turck-Chieze, A. Kosovichev, APJ 599, 1434 (2003) → Magnetic fields

The Sun magnetic fields





In the core 3000T are still allowed without effect on Solar observables.

Calculation considering factor 10 reduction

300T

New solar axion flux components

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

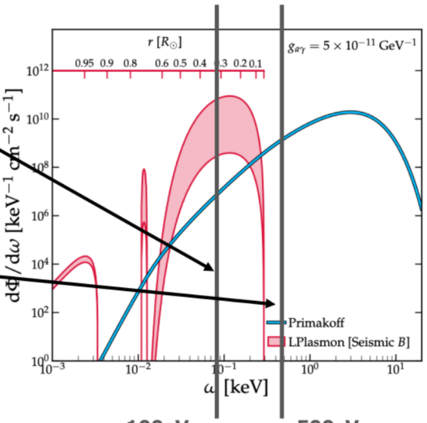
PHYSICAL REVIEW D **102**, 043019 (2020)

Axion helioscopes as solar magnetometers

Ciaran A. J. O'Hare,[1,*] Andrea Caputo,[2,†] Alexander J. Millar,[3,4,‡] and Edoardo Vitagliano[5,§]

Optimistic Gaseous TPC threshold: 100eV

Conservative Gaseous TPC threshold: 500eV

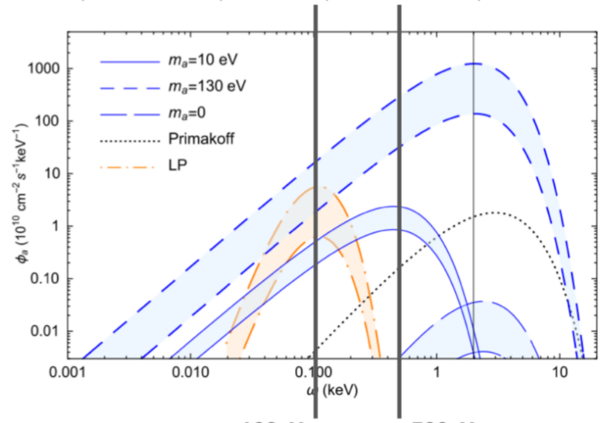


100eV **500eV**

PHYSICAL REVIEW D **102**, 123024 (2020)

Production of axionlike particles from photon conversions in large-scale solar magnetic fields

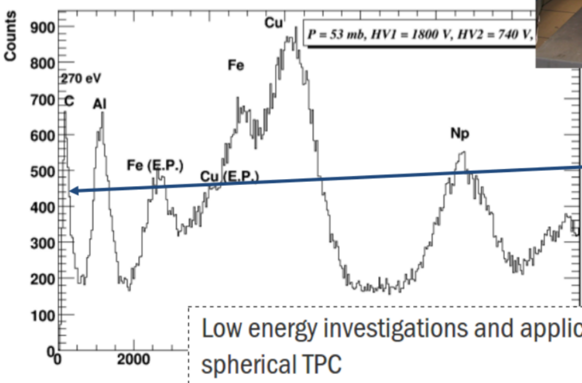
Ersilia Guarini,[1] Pierluca Carenza,[1,2] Javier Galán,[3] Maurizio Giannotti,[4] and Alessandro Mirizzi[1,2]



100eV **500eV**

Spherical TPCs for rare event searches

SEDINE spherical TPC running at LSM
Record background levels actually around 10 cpd/m³/keV



Ultra low energy threshold TPC 270 eV C peak

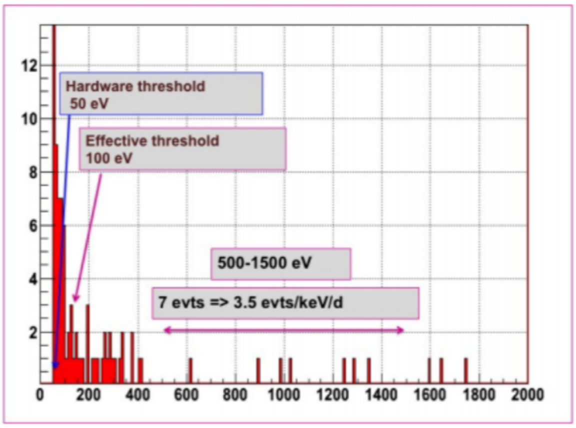
Low energy investigations and applications with the spherical TPC

E Bougamont[1], P Colas[1], J Derre[1], I Giomataris[1], G Gerbier[1], M Gros[1], P Magnier[1], X F Navick[1], P Salin[3], I Savvidis[2] Show full author list

Published under licence by IOP Publishing Ltd
Journal of Physics: Conference Series, Volume 309, Number 1

Simplest TPC, low intrinsic radiopurity.
Single channel
Field cage and vessel same entity

arXiv:1412.0161 [astro-ph.IM]



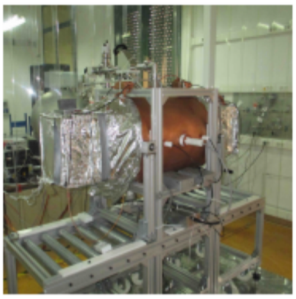
TREX-DM

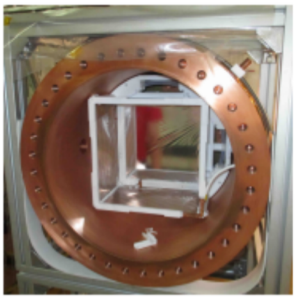
Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

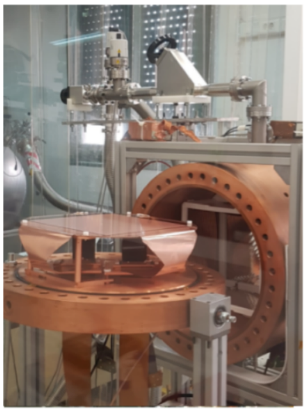
Gaseous time projection chambers for rare event detection: results from the T-REX project. II. Dark matter

I.G. Irastorza, F. Aznar, J. Castel, S. Cebrián, T. Dafni, J. Galán, J.A. Garcia, J.G. Garza, H. Gómez, D.C. Herrera Show full author list

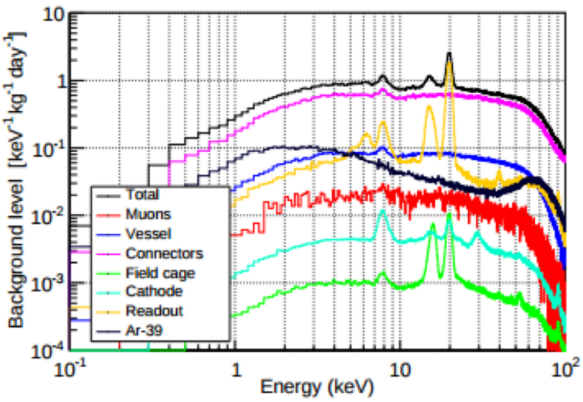
Published 19 January 2016 • © 2016 IOP Publishing Ltd and Sissa Medialab srl
Journal of Cosmology and Astroparticle Physics, Volume 2016, January 2016



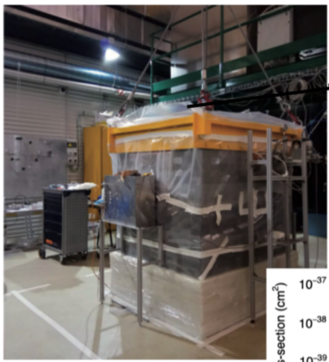




Simulated background considering the radiopurity of different detector components

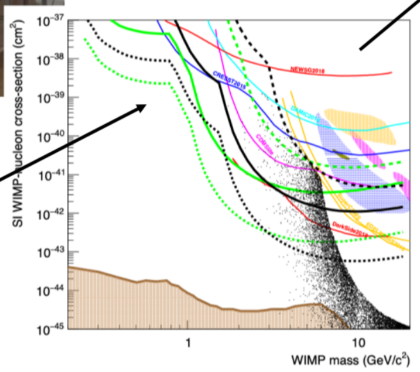


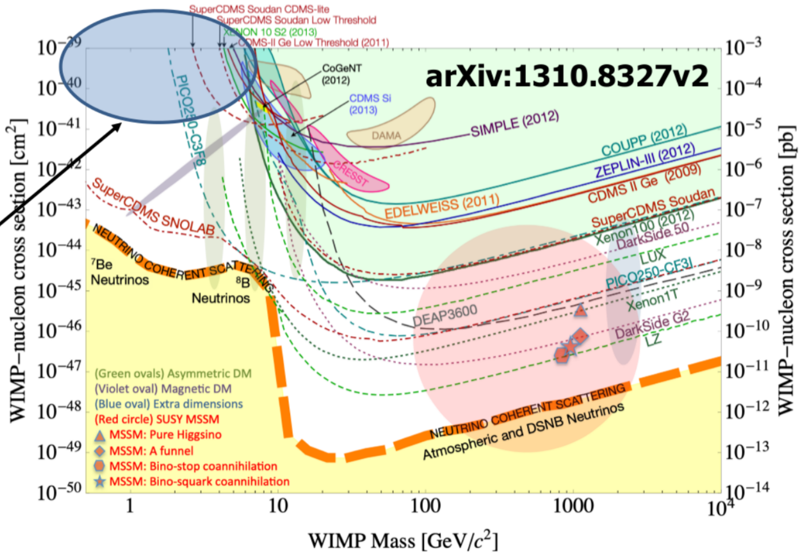
TREX-DM started commissioning phase



Very competitive and crowded WIMP search when compared to axions

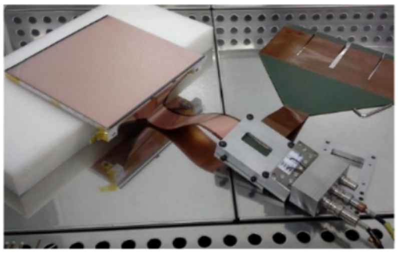
TREX-DM expected sensitivity





Large area low background detectors

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza



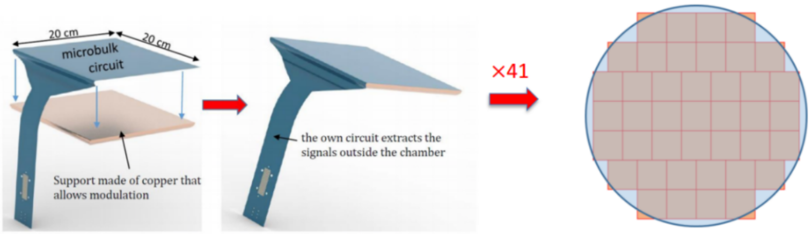
Microbulk technology is chosen because it is intrinsecally very clean from the radiopurity point of view.

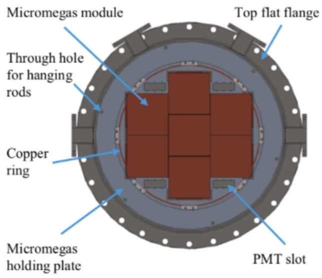
Th^{232} ~ 14 nBq/cm^2 and U^{238} ~ 45 nBq/cm^2

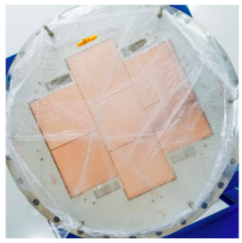
TREX-DM has tested the largest microbulk readout module/unit to date 25x25cm^2.

One solution is to tessellate independent modules.

H. Lin *et al* 2018 *JINST* **13** P06012



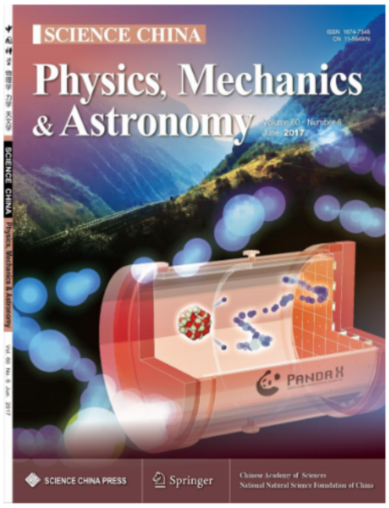




PandaX-III for neutrinoless double-beta decay

CDR published in 2017

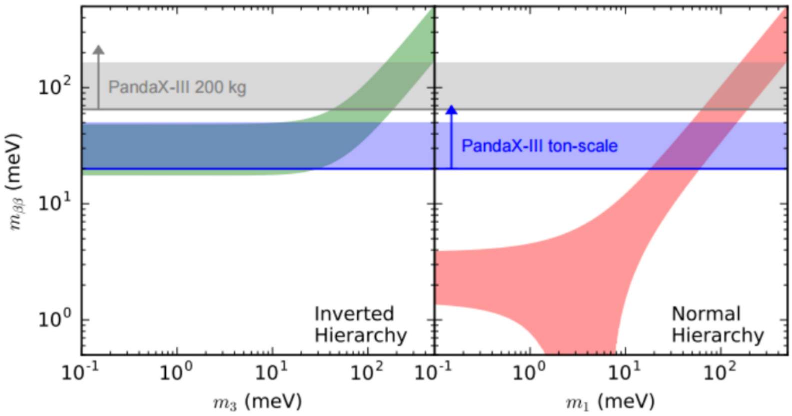
Sci.China Phys.Mech.Astron. 60 (2017) 6, 061011



Microbulk developments have also impact on neutrinoless double beta decay searches.

High pressure Xenon gas TPC

A lot of synergies with WIMP and axion searches.



Gargamellle bubble chamber

Gargamelle chamber (exposed at CERN) was crutial on the discovery of lepton and hadron neutral currents, and the understanding of electroweak theory.

Radius : 1m
Length : 4.8m
Field : 2T

$B^2V \sim 60\ T^2m^3$

The challenge today is to build Gargamelle a low background radiopure detector.

Conclusions

Centro de Astropartículas y Física de Altas Energías
Universidad Zaragoza

- The search for axions is very challenging experimentally but at the same point is very rich on the different approaches to detect them.

- Next generation axion helioscopes will cover interesting parameter space regions; astrophysical hints, theoretical models, etc.

- The state-of-the art developments on TPCs technologies for DM and NLDBD searches has a direct impact on future axion helioscope .