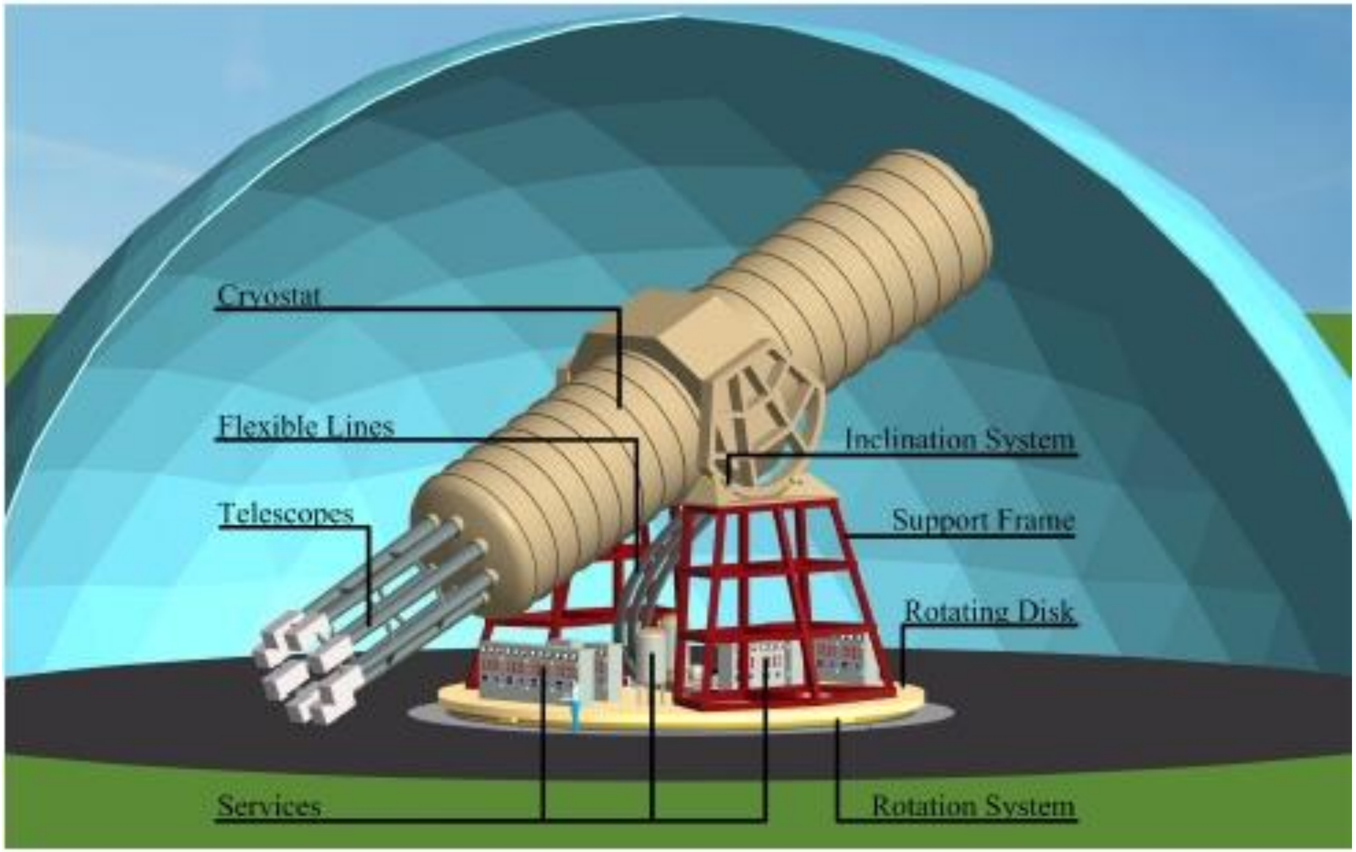
The IAXO (*I*nternational ***Ax***ion ***O***bservatory) Helioscope



Esther Ferrer Ribas, IRFU/SEDI
on behalf of the IAXO Collaboration

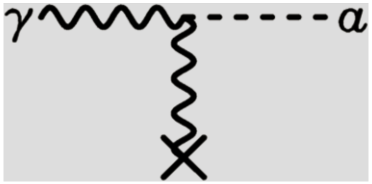
Irfu
Institut de recherche sur les lois fondamentales de l'Univers

7th Symposium on Large TPCs for Low Energy Rare Events, APC, 15-17 December 2014

Axion motivations and properties

- **Most elegant solution to the strong CP problem**
- Neutral Pseudoscalar
- Pratically stable
- Very low mass
- Very low cross-section
- Coupling to photons
- Possible dark matter candidates

$$m_a \simeq 0.6 \text{ eV} \frac{10^7 \text{GeV}}{f_a}$$



$$L_{a\gamma} = g_{a\gamma}(\vec{E} \cdot \vec{B})a$$

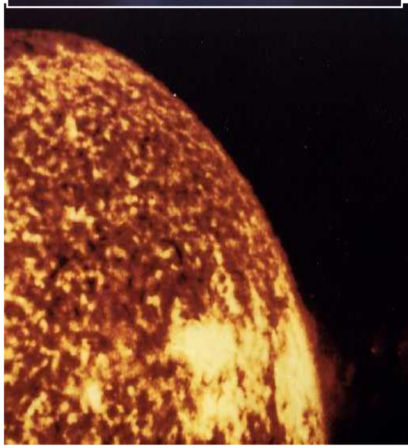
$$g_{a\gamma} \propto 1/f_a$$

$$g_{a\gamma} \propto m_a$$

Axion searches

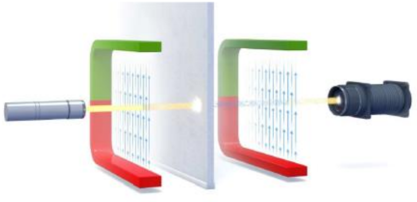
- Relic Axions
  - Axions that are part of galactic dark matter halo:
    - Axion Haloscopes (ADMX)

Direct detection searches for axion dark matter, Gray Rybka *et al*, 2014 *Physics of the Dark Universe* **4**



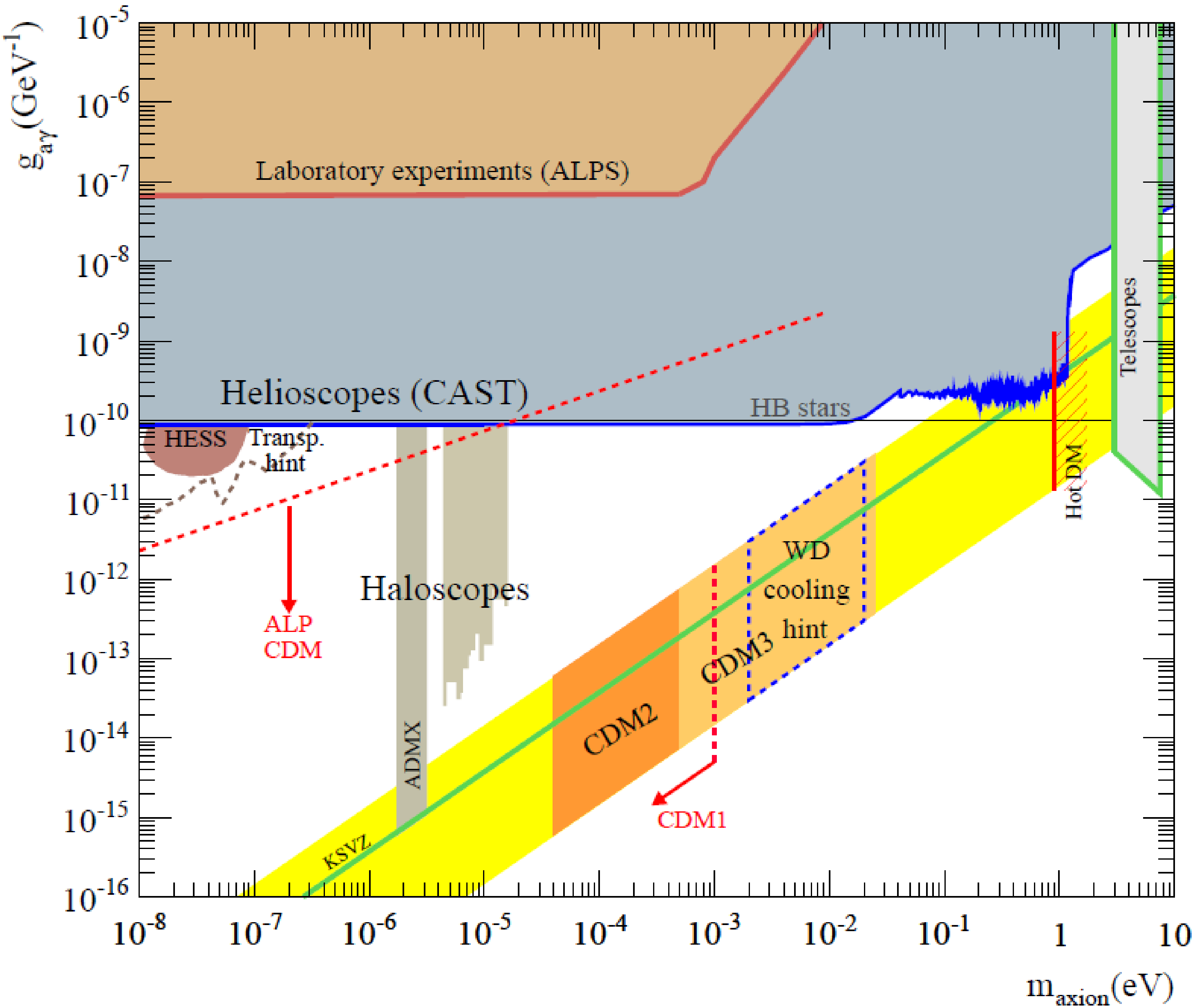
- Solar Axions
  - Emitted by the solar core.
    - Axion Helioscopes (CAST → IAXO)

- Axions in the laboratory
    - “Light shinning through wall” experiments (ALPS)

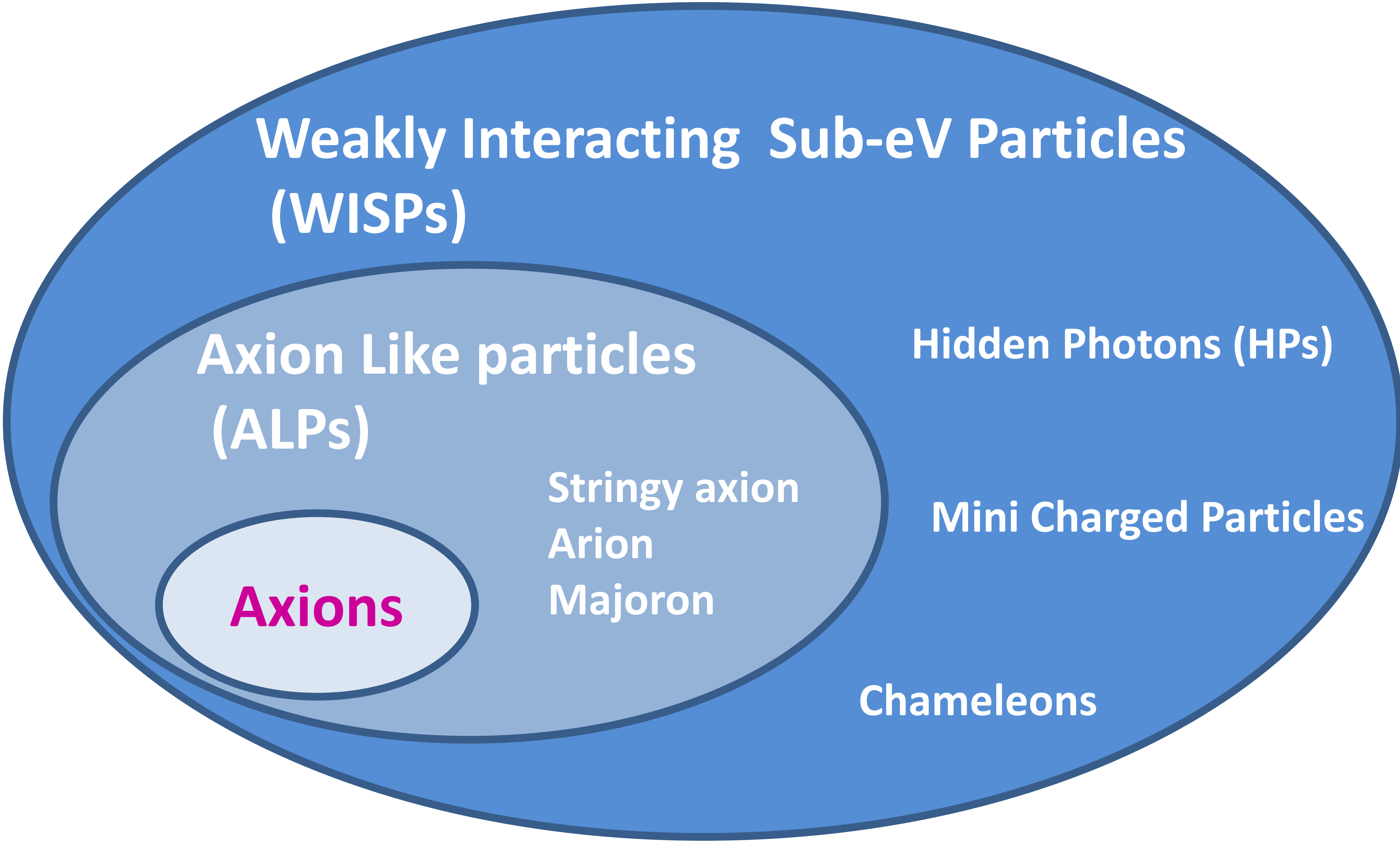


Any light particle search II — Technical Design Report R Bähre *et al* 2013 *JINST* **8** T09001

Bounds: experimental, astrophysical, cosmological



The WISPs zoo



$g_{a\gamma}$ and m_a are two independent "phenomenological" parameters

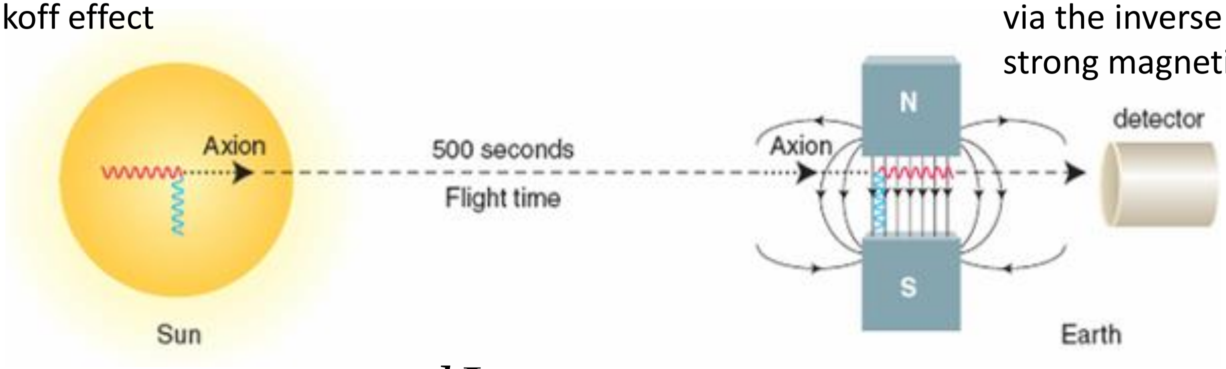
Helioscope physics

Production in the Sun

Conversion of thermal photons into axions via Primakoff effect in the solar core

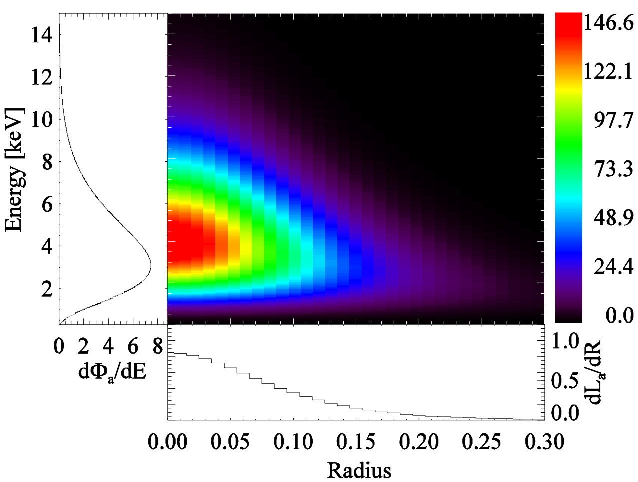
Detection in CAST

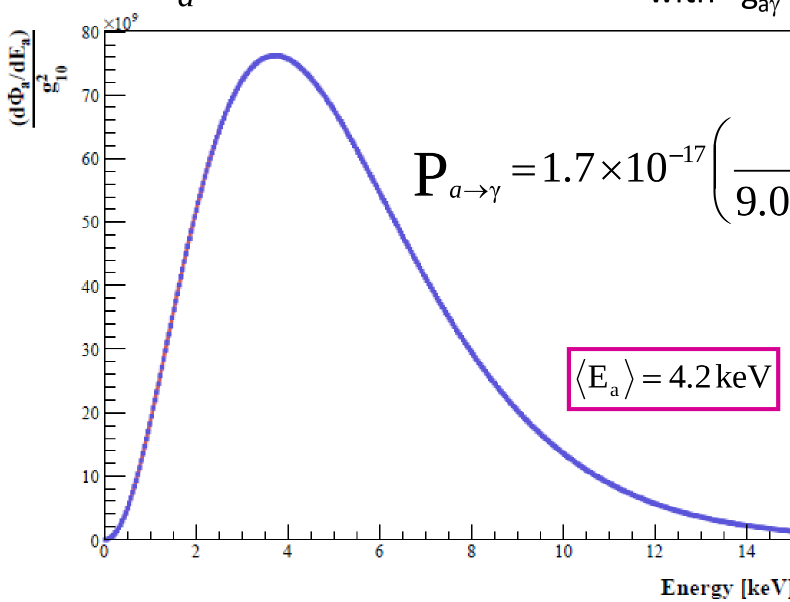
Conversion of axions into photons via the inverse Primakoff effect in a strong magnetic field



Expected number of photons: $$N_\gamma = \int \frac{d\Phi_a}{dE_a} \cdot P_{a\to\gamma} \cdot S \cdot t \cdot dE_a$$ ≈0.3 evts/hour

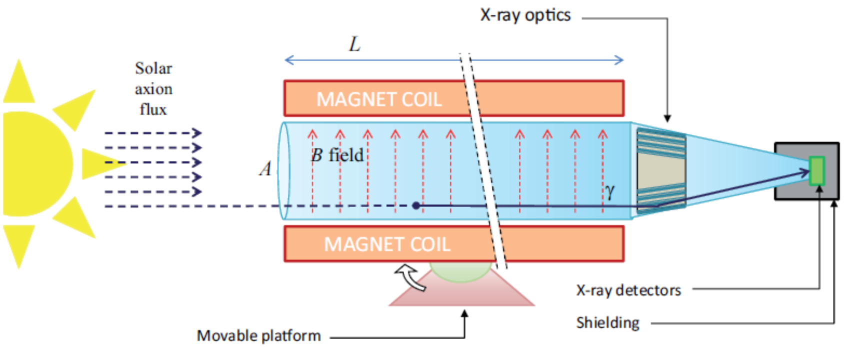
with $g_{a\gamma} = 10^{-10}\ \mathrm{GeV}^{-1}$ and $A = 14\ \mathrm{cm}^2$





$$P_{a\to\gamma} = 1.7\times10^{-17}\left(\frac{B\cdot L}{9.0\mathrm{T}\cdot 9.3\mathrm{m}}\right)^2\left(\frac{g_{a\gamma}}{10^{-10}\,\mathrm{GeV}^{-1}}\right)^2$$

IAXO concept



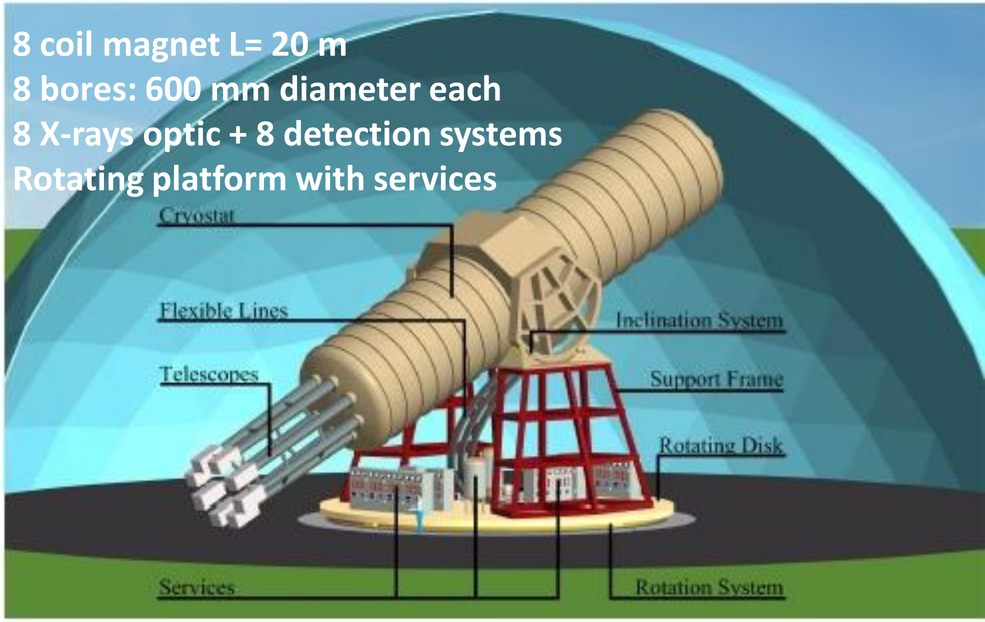
JCAP 06 (2011) 013

No technology challenge (built on CAST experience)

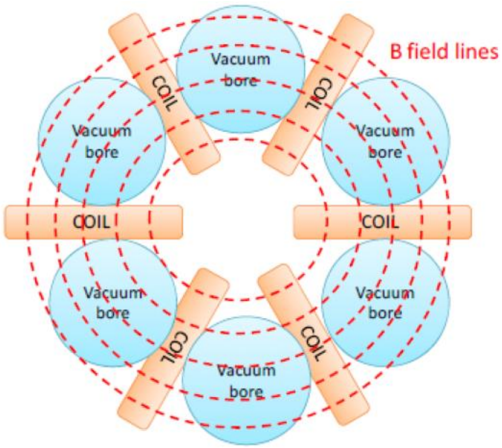
✓New dedicated superconducting magnet
✓Use of X-ray focalisation over ~m^2 area
✓Low background detectors (improve bck by 1-2 orders of magnitude)

Goal: in terms of signal to background ratio 4-5 orders of magnitude more sensitive in than CAST, which means sensitivity to axion-photon couplings down to a few ×10^{-12} GeV^{-1}

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

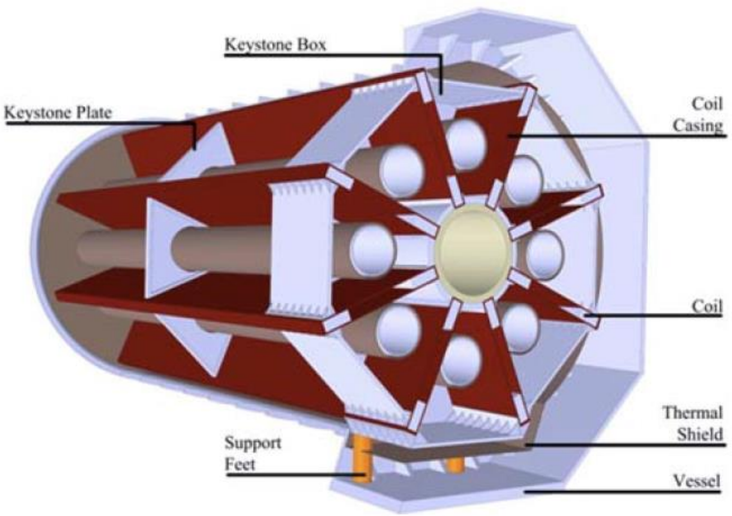


IAXO magnet



Optimised configuration: TOROIDAL with 8 bores
25 m long, 5 m diameter and a peak field of 5.4 T

Property		*Value*
Cryostat dimensions:	Overall length (m)	25
	Outer diameter (m)	5.2
	Cryostat volume (m^3)	$\sim$ 530
Toroid size:	Inner radius, R_{in} (m)	1.0
	Outer radius, R_{out} (m)	2.0
	Inner axial length (m)	21.0
	Outer axial length (m)	21.8
Mass:	Conductor (tons)	65
	Cold Mass (tons)	130
	Cryostat (tons)	35
	Total assembly (tons)	$\sim$ 250
Coils:	Number of racetrack coils	8
	Winding pack width (mm)	384
	Winding pack height (mm)	144
	Turns/coil	180
	Nominal current, I_{op} (kA)	12.0
	Stored energy, E (MJ)	500
	Inductance (H)	6.9
	Peak magnetic field, B_p (T)	5.4
	Average field in the bores (T)	2.5
Conductor:	Overall size (mm^2)	35 × 8
	Number of strands	40
	Strand diameter (mm)	1.3
	Critical current @ 5 T, I_c (kA)	58
	Operating temperature, T_{op} (K)	4.5
	Operational margin	40%
	Temperature margin @ 5.4 T (K)	1.9
Heat Load:	at 4.5 K (W)	$\sim$150
	at 60-80 K (kW)	$\sim$1.6



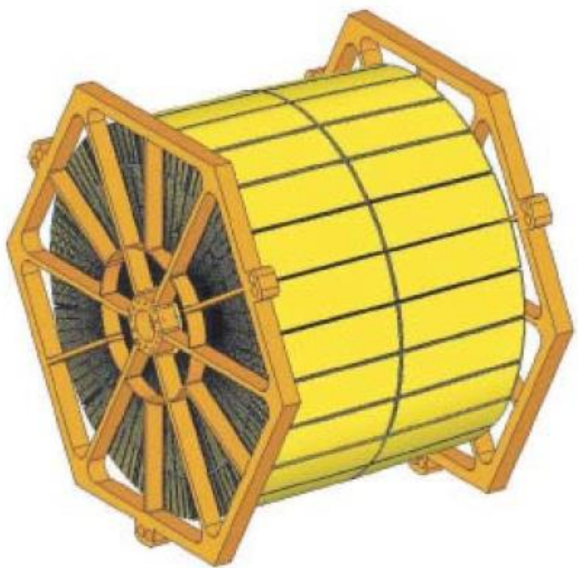
(ATLAS toroid 26 m long, 20 m diameter, peak field 3.9 T)

IAXO x-ray optics

Each bore equipped with an X-ray optics
8 systems of 600 mm diameter each

Specifications:

- Refined imaging not needed
- Need to cover large area (cost-effective)
- Good throughput (0.3-0.5)
- Small focal point (~1 cm^2)



Baseline : X-ray optics for NUSTAR satellite

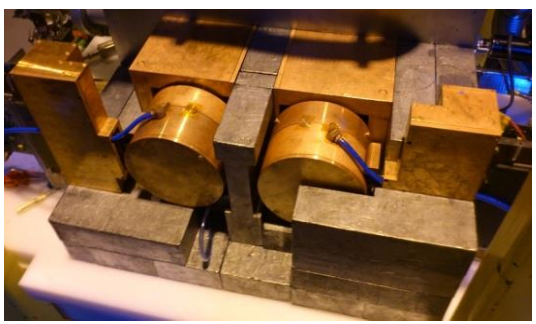
Telescopes	8
N, Layers (or shells) per telescope	123
Segments per telescope	2172
Geometric area of glass per telescope	0.38 m^2
Focal length	5.0 m
Inner radius	50 mm
Outer Radius	300 mm
Minimum graze angle	2.63 mrad
Maximum graze angle	15.0 mrad
Coatings	W/B_4C multilayers
Pass band	1 – 10 keV
IAXO Nominal, 50% EEF (HPD)	0.29 mrad
IAXO Enhanced, 50% EEF (HPD)	0.23 mrad
IAXO Nominal, 80% EEF	0.58 mrad
IAXO Enhanced, 90% EEF	0.58 mrad
FOV	2.9 mrad

IAXO low background detectors

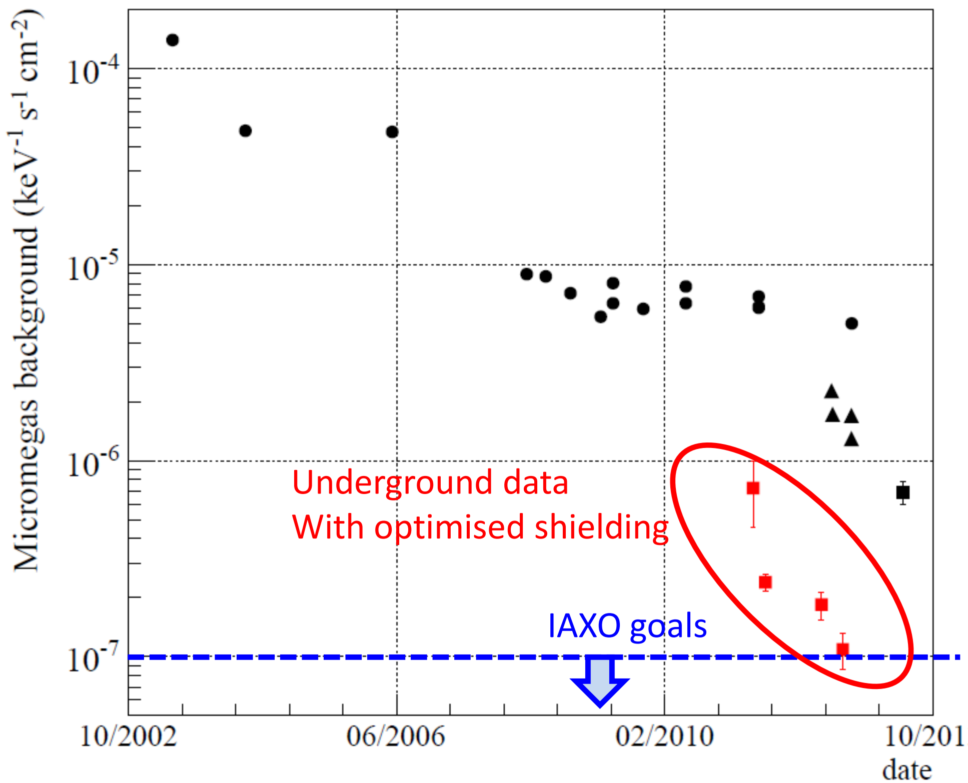
Baseline: Micromegas detectors

Goal: below 10^{-7} c/keV/s/cm^2

Key elements:
- Radiopure components
- Shielding
- Offline discrimination



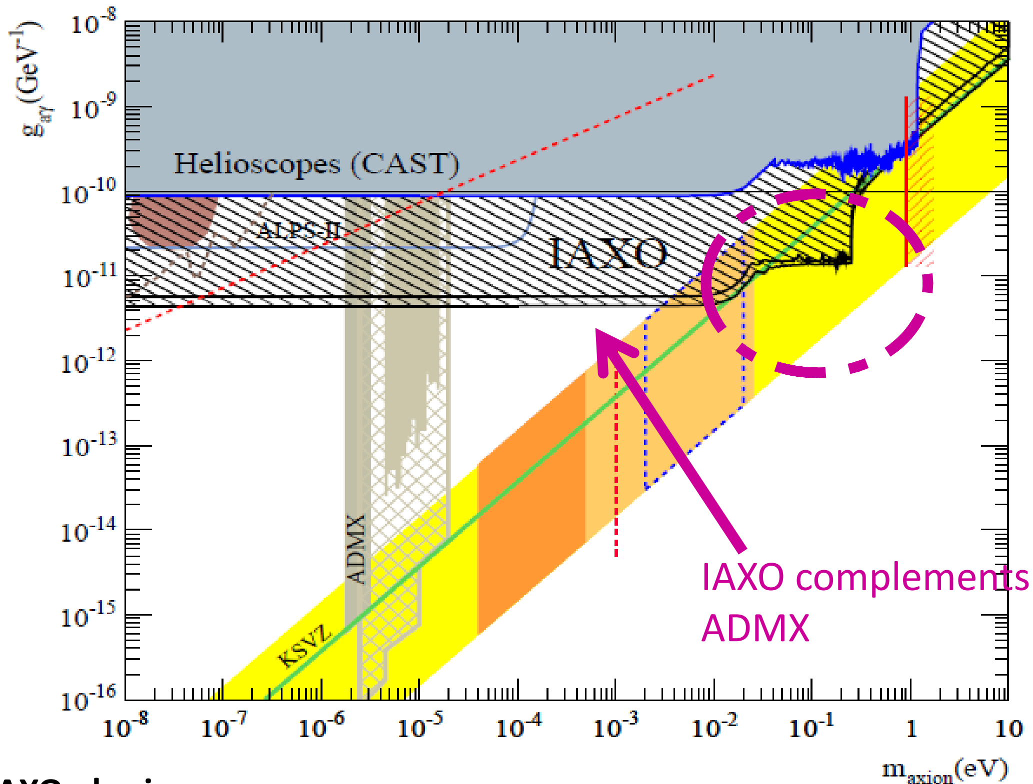
Evolution of Micromegas CAST background



Pathfinder system running in CAST:
last generation of Microbulk detectors + optimised shielding + Xray telescope

➔ CASTMM 2014 : 0.85 x 10^{-6} c/keV/s/cm^2 (*Javier G. Garza's* talk)

IAXO sensitivity prospects



Exploration of very extended QCD axion region

Additional IAXO physics cases:

IAXO would improve the sensitivity to BCA solar axion (g_{ae})

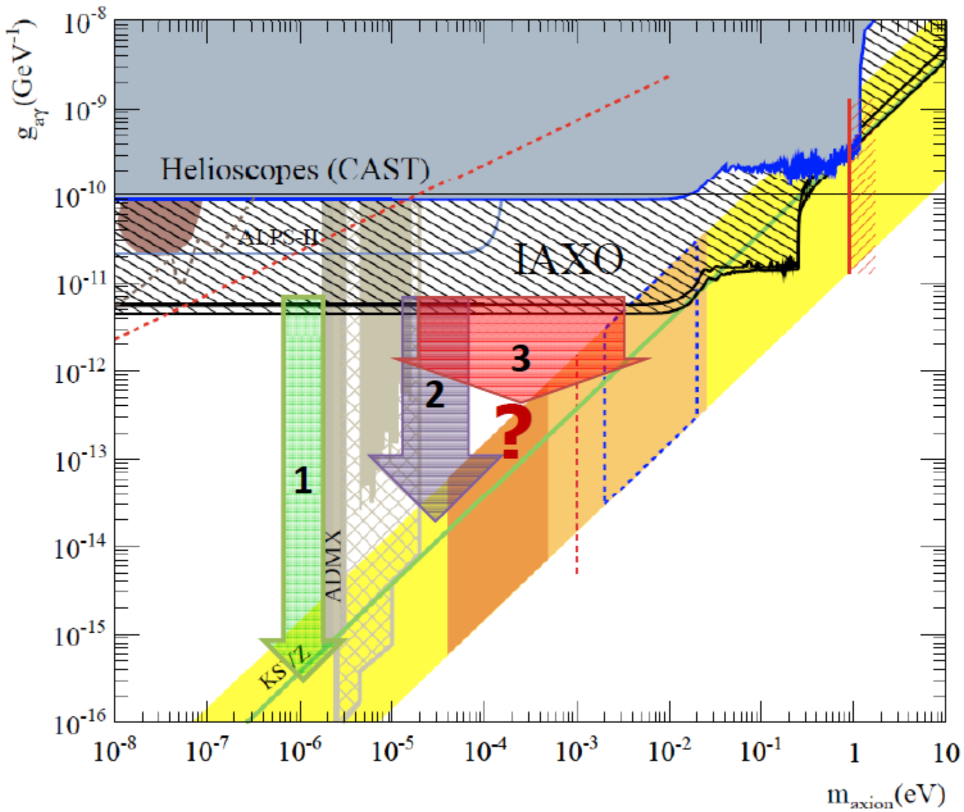
Sensitivity to other ALP or WISP models at the low energy frontier: paraphotons, chameleons…

Extend the sensitivity to dark matter halo axions by the use of microwave cavities or dish antennas

➔ **IAXO as a « generic axion/ALP facility »**

Additional IAXO physics cases

direct detection or relic axions/ALPs



- Promising as further pathways for IAXO beyond the helioscope baseline
- First indications that IAXO could improve or complement current limits at various axion/ALP mass ranges…
- **Caution**: preliminary studies still going on. Important know-how to be consolidated. Precise implementation in IAXO under study.

Tentative future prospects

Beyond current LoI scope

IAXO status of project

- 2011: First studies ***Irtastorza et al. JCAP (2011) 1106:013***
- ASPERA/APPEC Roadmap acknowledges axion physics, CAST and recommends progress towards IAXO (C. Spiering Krakow 2012)
- IAXO is also present in US roadmapping (Snowmass and P5 process) (december 2013)
- 2013: Conceptual Design: ***Armengaud et al. JINST 9 (2014) T05002***
- August 2013: Letter of Intent submitted to the **CERN SPSC [CERN-SPSC-2013-022]**
- January 2014: Recommendations of SPSC

SPSC Draft minutes [Jan 2014]

The Committee **recognises** the physics motivation of an International Axion Observatory as described in the Letter of Intent SPSC-I-242, and considers that the proposed setup makes appropriate use of state-of-the-art technologies i.e. magnets, x-ray optics and low-background detectors.
The Committee **encourages** the collaboration to take the next steps towards a **Technical Design Report**.
The Committee recommends that, in the process of preparing the TDR, the possibility to **extend the physics reach** with additional detectors compared to the baseline goal should be investigated. The collaboration should be further strengthened.
Considering the required funding, the SPSC **recommends** that the R&D for the TDR should be pursuit within an MOU involving all interested parties.

IAXO Collaboration

JINST

PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

RECEIVED: *January 15, 2014*
ACCEPTED: *February 17, 2014*
PUBLISHED: *May 12, 2014*

TECHNICAL REPORT

Conceptual design of the International Axion Observatory (IAXO)

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2014 JINST 9 T05002

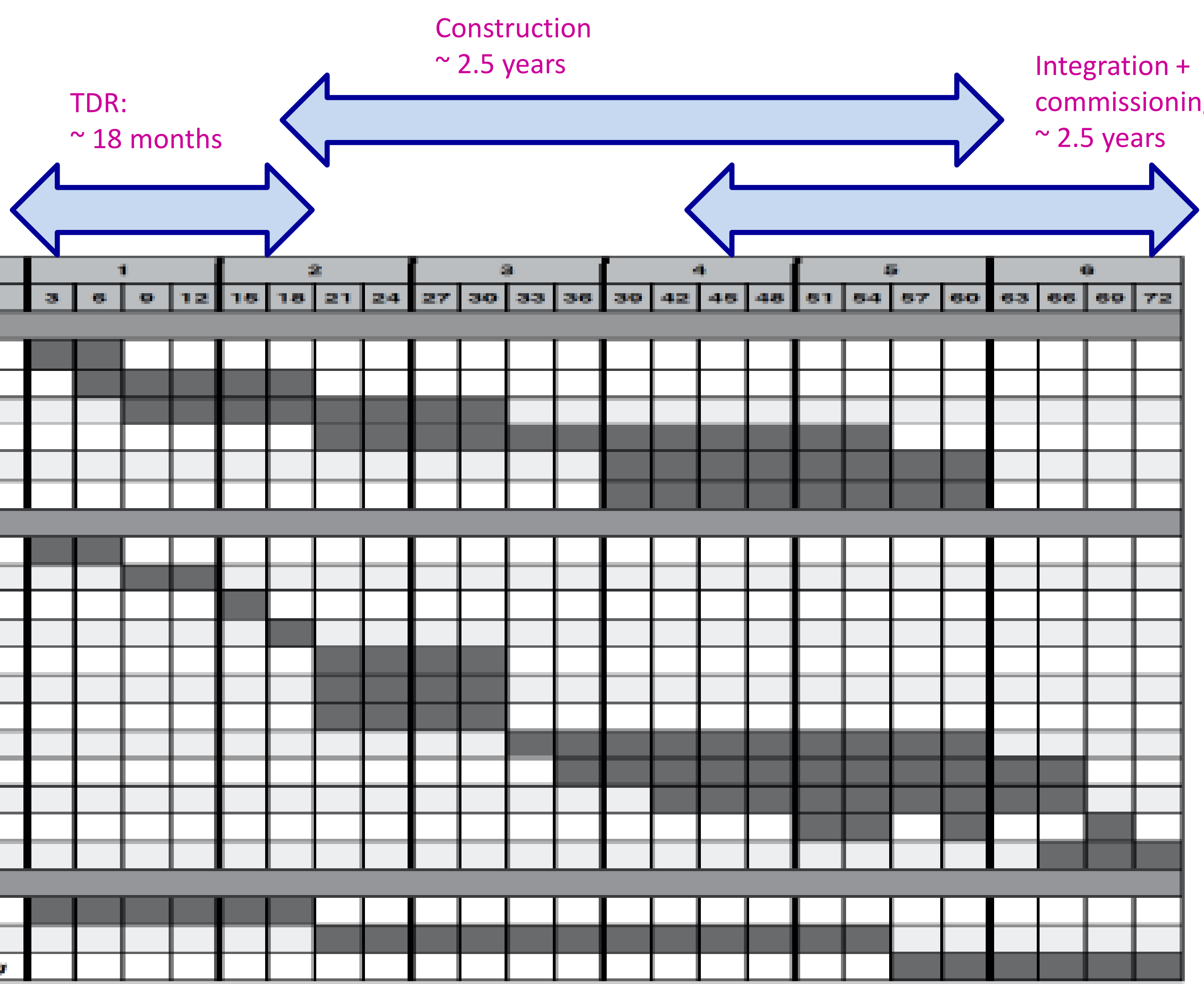
~80 authors

IAXO costs

Item	Cost (MCHF)	Subtotals (MCHF)
Magnet		31.3
Eight coils based assembled toroid	28	
Magnet services	3.3	
Optics		16.0
Prototype Optic: Design, Fabrication, Calibration, Analysis	1.0	
IAXO telescopes (8 + 1 spare)	8.0	
Calibration	2.0	
Integration and alignment	5.0	
Detectors		5.8
Shielding & mechanics	2.1	
Readouts, DAQ electronics & computing	0.8	
Calibration systems	1.5	
Gas & vacuum	1.4	
Dome, base, services building and integration		3.7
Sum		**56.8**

Table 5: Estimated costs of the IAXO setup: magnet, optics and detectors. It does not include laboratory engineering, as well as maintenance & operation and physics exploitation of the experiment.

IAXO timeline



Conclusions and next steps

Axion searches→ strong physics case

Increasing experimental effort in the different axion searches strategies: solar axions, relic axions, laboratory axions…

CAST has been a very important milestone in axion research during the last decade

IAXO can probe deep into unexplored axion-ALP parameter space

IAXO could become next large project & a **generic axion facility with discovery protential in the next decade**

Need to continue with TDR & preparatory activities, formal endorsement & resources finding

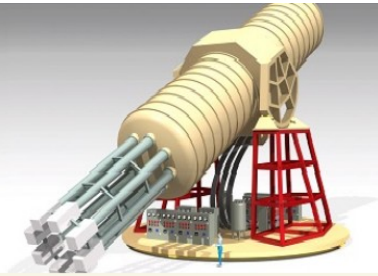
- Construction of demonstration coil IAXO-T0
- Construction of a prototype x-ray optics IAXO-X0
- Construction of a prototype low background detector IAXO-D0
- Refine and update physics case
- Feasability studies for IAXO-DM

Exciting work in front us: join us!

http://iaxo.web.cern.ch/iaxo/

IAXO

The International Axion Observatory



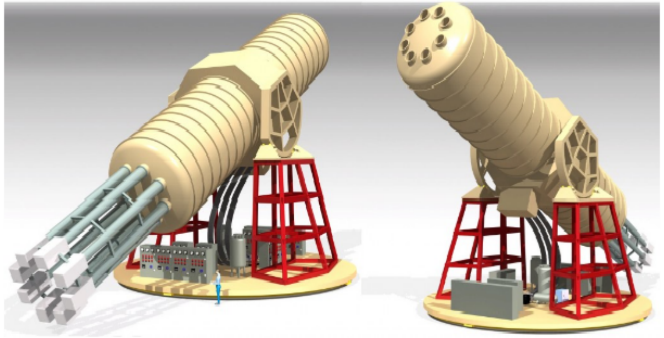
Home The Experiment Collaboration Publications and conferences Outreach News

Home

Welcome to the home page of the IAXO project!

The International Axion Observatory (IAXO) is a proposed fourth generation axion helio-scope. It aims at a sensitivity much improved with respect to past and current axion searches, with real discovery potential.

The conceptual design of the experiment has been finished and a Letter of Intent submit-ted to CERN. Recently, the SPSC has recognised the physics case of IAXO and has recom-mended to proceed with a Technical Design Report.



Views of the conceptual design of IAXO

Search ...

Recent Posts

- IAXO in the CERN Courier
- SPSC recommends IAXO
- Letter of Intent to CERN submitted

Categories

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- Outreach
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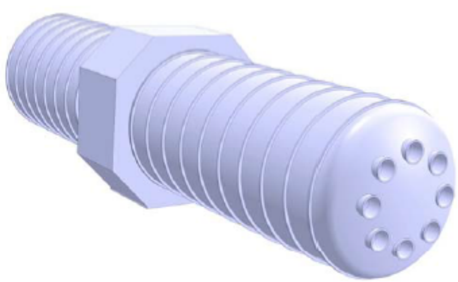
BACK UP

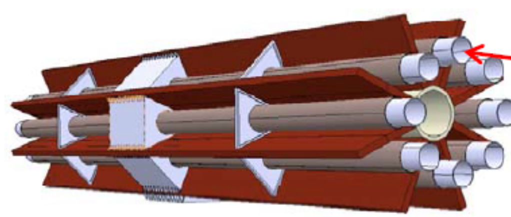
Axion DM detection – new ideas

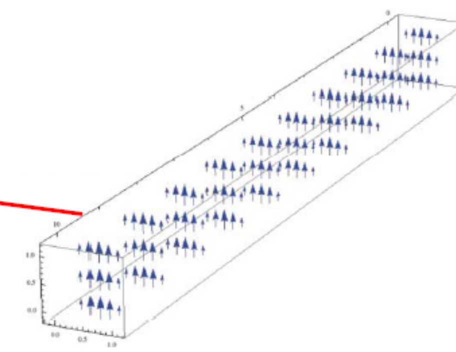
- Recent papers proposing new detection schemes. Very active field!
  - Precession of nuclear spins (CASPERs): PRD 84, 055013 (2011) and arXiv:1306.6089
  - Long thin cavities in dipole fields: PRD85 (2012) 035018
  - Directional effect in long thin cavities: JCAP 1210 (2012) 022
  - Dish antenna: JCAP 1304 (2013) 016
  - Directional effect in dish antenna: arXiv:1307.7181
  - LC circuit in B field: PRL 112, 131301 (2014)
  - Active resonators: arXiv:1403.6720
  - Cavitiy with wires: arXiv:1403.3121 (also old Sikivie paper)

IAXO-DM configurations?

- Prospects under study. Very motivated (encouraged by CERN SPSC)
- Needed new know-how (cavities, low noise microwave detectors…)
- Various possible arrangements in IAXO. Profit the huge magnetic volume available:
  1. Single large cavity tuned to low masses
  2. Thin long cavities tuned to mid-high masses. Possibility for directionality. Add several coherently?
  3. Dish antenna focusing photons to the center. Not tuned. Broadband search. Competitive at higher masses?







INFRADEV-DS : IAXOTDR

DEVELOPING NEW WORLD-CLASS RESEARCH INFRASTRUCTURES

H2020-INFRADEV-1-2014-1 Sub call of: H2020-INFRADEV-2014-2015

Opening Date	11-12-2013	**Deadline Date**	02-09-2014 17:00:00 (Brussels local time)
Budget	€95,000,000	**Main Pillar**	Excellent Science
Status	Closed	**OJ reference**	OJ C361, p. 9 of 11.12.2013

A total of 51 proposals were submitted in response to this call. The number of proposals for each topic is shown below.

- INFRADEV-1-2014 - Design studies: 39 proposals
- INFRADEV-4-2014-2015 - Implementation and operation of cross-cutting services and solutions for clusters of ESFRI and other relevant research infrastructure initiatives: 12 proposals

IAXOTDR
(technical annex)

Research and Innovation actions
Innovation actions

Call: INFRADEV-1-2014: Design Studies

Participant No *	Participant organisation name	Country
1 (Coordinator)	Universidad de Zaragoza (UNIZAR)	Spain
2	European Organization for Nuclear Research (CERN)	Switzerland
3	Commissariat à l'Energie Atomique (CEA)	France
4	Danish Technical University (DTU)	Denmark
5	Lawrence Livermore National Laboratory (LLNL)	US
6	University of Bonn (UBONN)	Germany