International Axion Observatory (IAXO) status and prospects

Biljana Lakić

Rudjer Bošković Institute, Zagreb, Croatia

for the

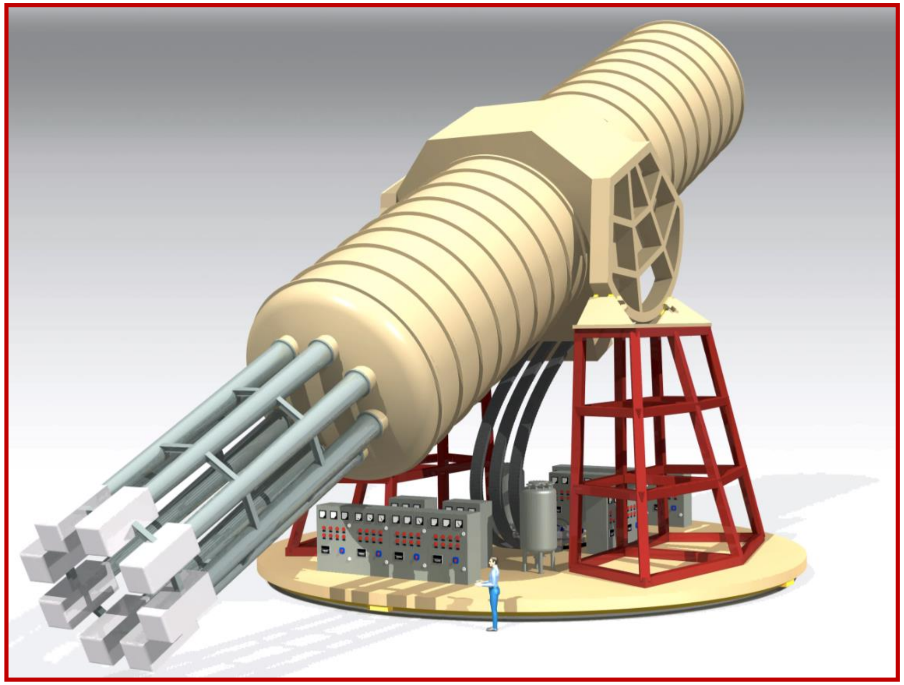
IAXO Collaboration

TAUP 2017— XV International Conference on Topics in Astroparticle and Underground Physics, 24 – 28 July, Sudbury, Canada

IAXO: International AXion Observatory

Outline:

- Axions and ALPs
- Experimental searches
- The IAXO project
  - Physics
  - Conceptual design
  - BabyIAXO
- Sensitivity prospects
- Status of the project



Letter of Intent to the CERN SPS Committee (CERN-SPS-2013-022)

Conceptual Design of the International Axion Observatory (JINST 9 (2014) T05002).

Axions and ALPs: Motivation

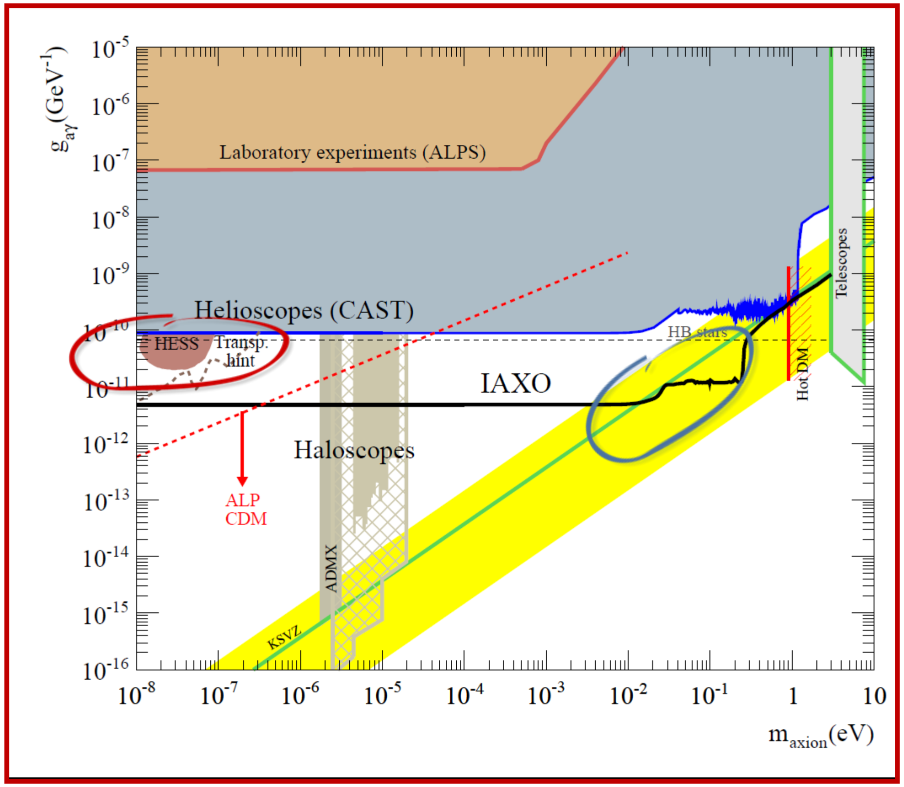
Axions solve **the strong CP problem** of the standard model

- pseudoscalar particles, neutral, practically stable

Axion-like particles (ALPs) are predicted by many extensions of the standard model, notably **string theory**.

IAXO sensitivity region (for axion – photon coupling) encompasses:

- part of the region relevant for QCD axions
- part of the region relevant for cold and hot dark matter
- region relevant for ALPs & inflation
- some unexplained astrophysical observations:
  - transparency of the Universe to UHE gammas
  - anomalous cooling of stars



IAXO in the axion landscape

Experimental techniques based on the axion(ALP) – photon coupling:

Laser experiments:

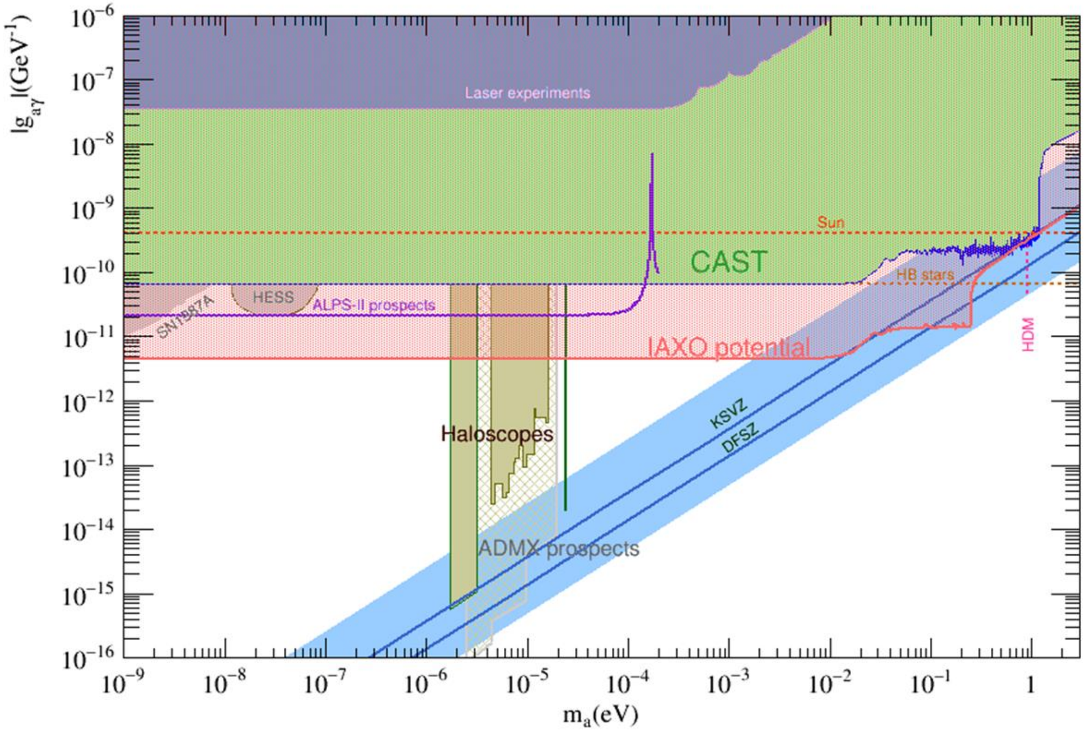
- search for ALPs in "light shining through a wall" laboratory experiments (ALPS, OSQAR, PVLAS, ARIADNE …)

Haloscopes:

- search for relic dark matter axions (ADMX, CAPP, Casper, HAYSTACK, MADMAX,…

Helioscopes:

- search for solar axions and ALPs (SUMICO, **CAST**, **IAXO**)



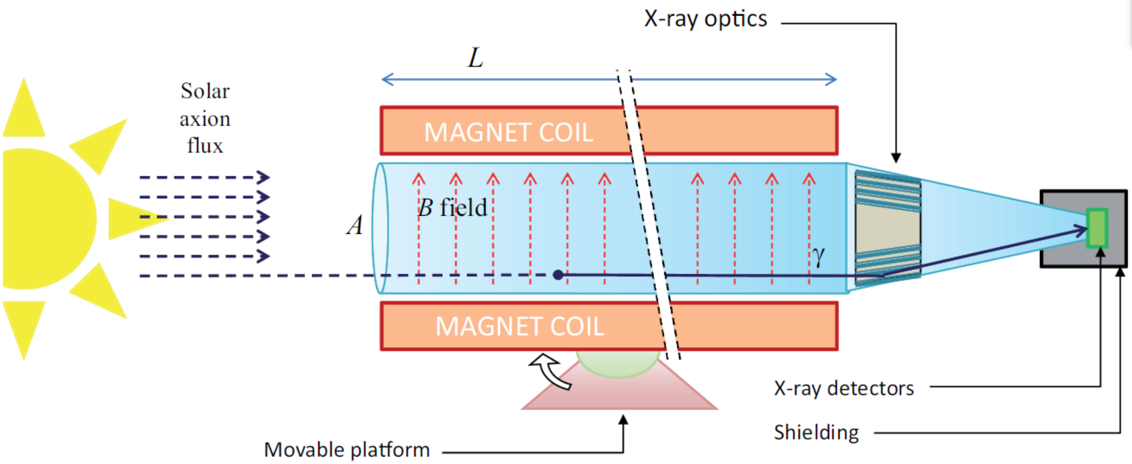
Helioscopes:

- do not rely on axions being the dominant DM component
- large complementarity with other techniques
- technology mature enough for a large scale experiment (IAXO)

Talk by G. Carosi

IAXO Physics

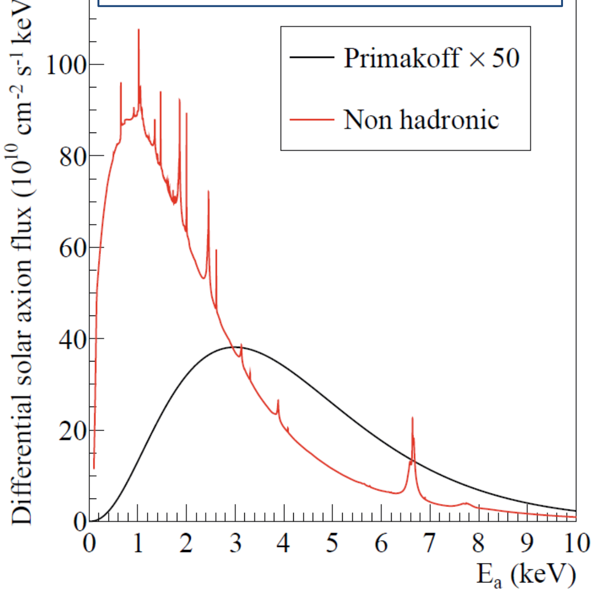
Axion helioscope concept
P. Sikivie, Phys. Rev. Lett 51, 1983
+ K. van Bibber et al., Phys.Rev. D39, (1989) (use of buffer gas)



photons convert into axions via Primakoff process in the solar plasma

axions convert into photons in a strong transverse magnetic field

Differential axion flux:



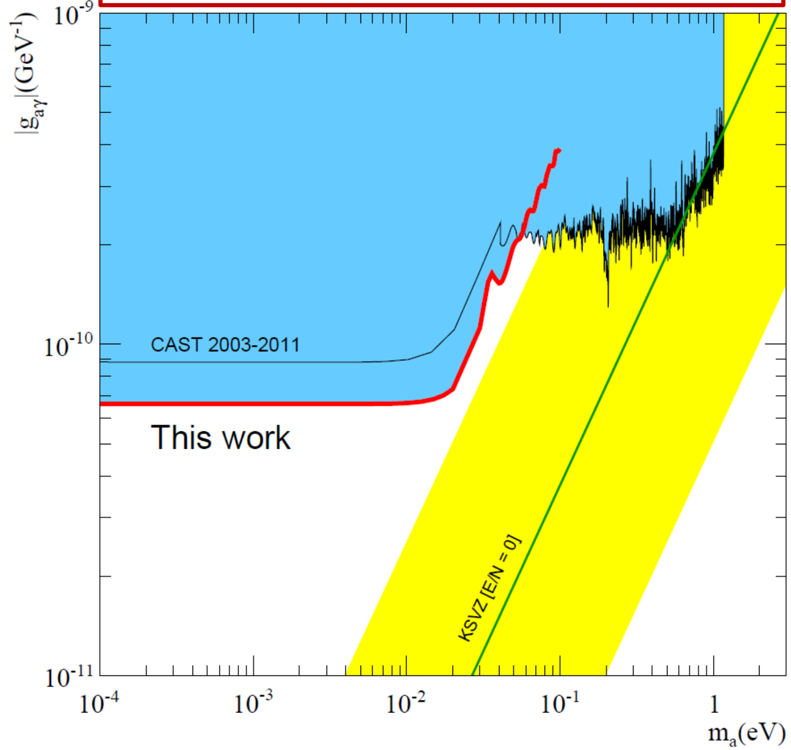
Expected number of photons:

$$N_\gamma = \int \frac{d\Phi_a}{dE_a} P_{a\to\gamma}\, S\, t\, dE_a \quad \propto \quad g_{a\gamma}^4$$

$$P_{a\to\gamma} = \left(\frac{g_{a\gamma} B}{q}\right)^2 \sin^2\left(\frac{qL}{2}\right) \qquad q = \frac{m_a^2}{2E}$$

IAXO Physics

Nature Phys. 13 (2017) 584-590



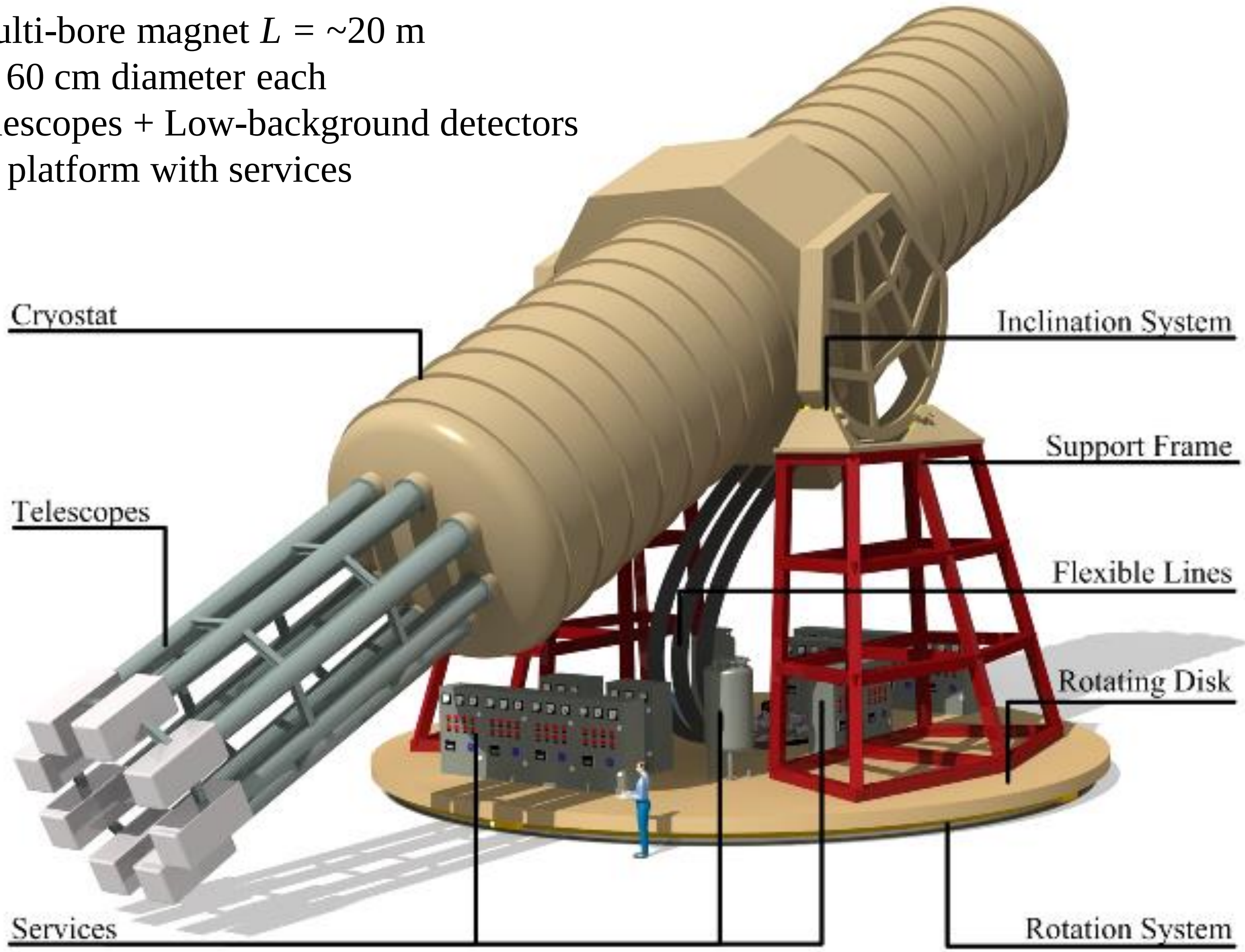
- **CAST** is currently the most sensitive axion helioscope
- No signal over background observed so far
- The best experimental limit on $g_{a\gamma}$ over a broad range of axion masses:
  $g_{a\gamma} < 0.66 \times 10^{-10}$ GeV^{-1} at 95% C.L.
- Result enabled by the IAXO pathfinder system: X-ray optics specifically built for axions & low background Micromegas detector

- **IAXO** is a new generation axion helioscope
- Goal: more than 4 orders of magnitude in signal-to-noise ratio with respect to CAST (more than 1 order of magnitude in sensitivity to $g_{a\gamma}$)
- Challenges:
  - New dedicated magnet
  - Extensive use of X-ray optics
  - Low background detectors

IAXO Conceptual design

Conceptual Design of the International Axion Observatory (JINST 9 (2014) T05002).

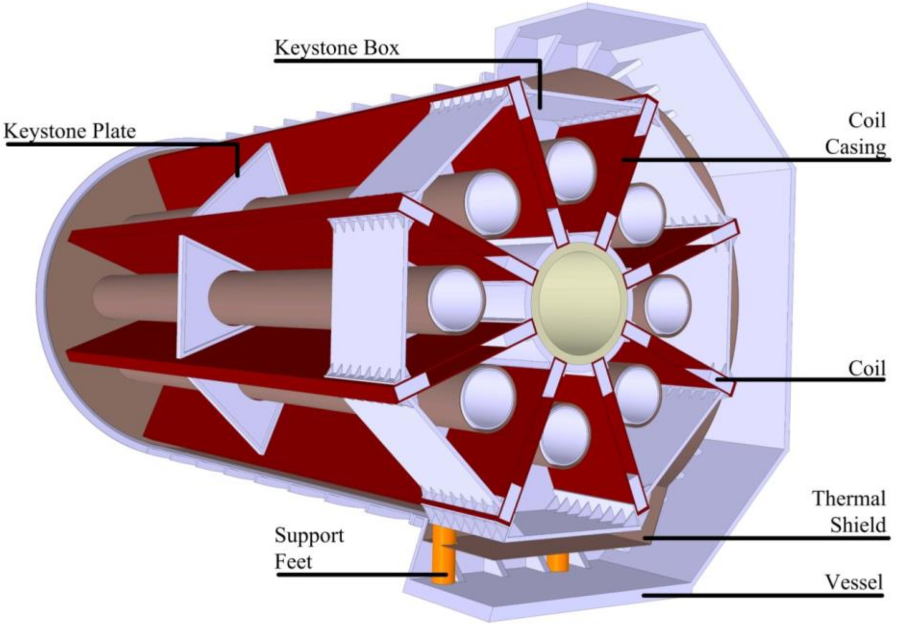
- Large multi-bore magnet *L* = ~20 m
- Bores: ~ 60 cm diameter each
- X-ray telescopes + Low-background detectors
- Rotating platform with services

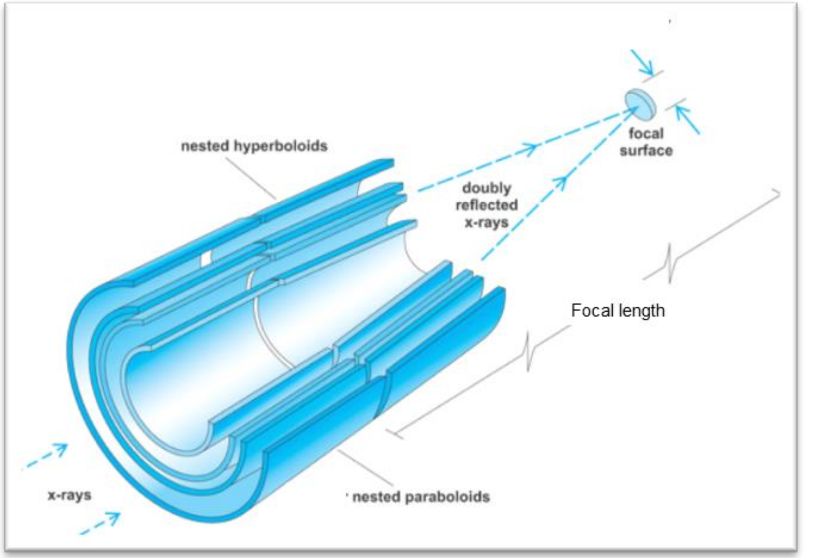


IAXO Conceptual design

IAXO Magnet:

- Toroidal geometry (8 coils)
- Based on ATLAS toroid technical solutions
- 8 bores / ~20 m long / ~60 cm Ø per bore
- 2.5 T magnetic field





IAXO Optics

- Slumped glass technology with multilayers
- Cost-effective to cover large areas
- Used by NASA for NuSTAR telescope
- Focal length 5 m

IAXO Conceptual design

IAXO detectors

Micromegas gaseous detector

- Long trajectory in CAST
- Continuous background reduction over the years
  - Radiopure components
  - Shielding
- IAXO pathfinder system in CAST 2014 – 15 run (background level **~0.003 counts/hour**)

InGRID detector

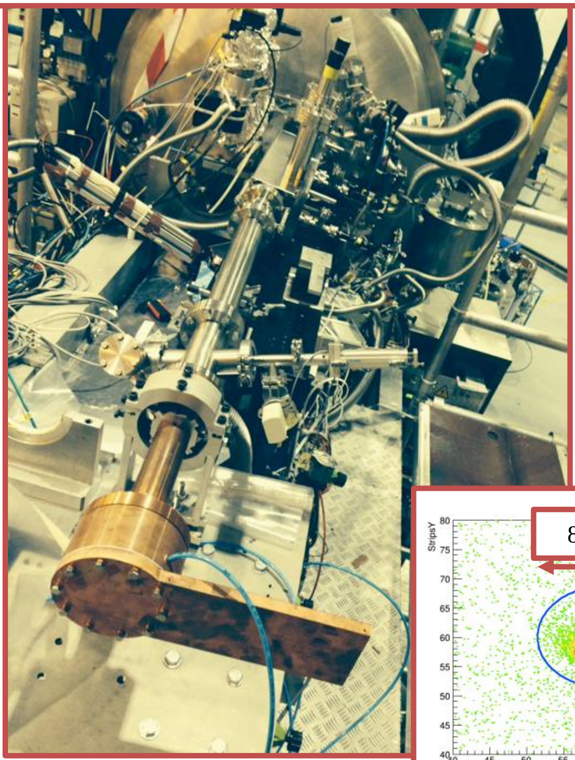
- Lower threshold

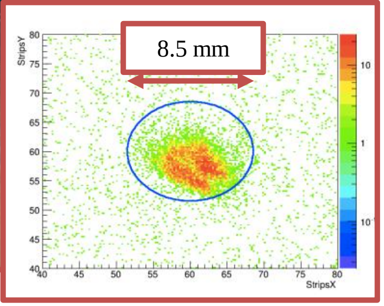
MMC (Magnetic Metallic Calorimeter)

- Very good energy resolution and threshold

… and more

Optics+detector IAXO pathfinder system





Calibration photons (source 14 m away) focused onto the Micromegas

BabyIAXO

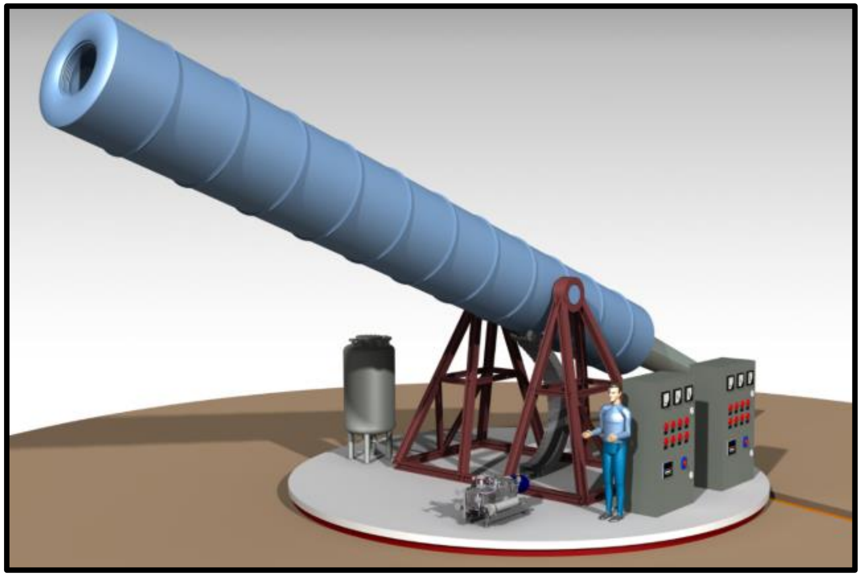
TDR baseline plans:

- Demonstration coil magnet (IAXO-T0)
- Prototype X-ray optics (IAXO-X0)
- Prototype low-background detector (IAXO-D0)

Extended TDR (**babyIAXO**/miniIAXO):

- Alternative magnet designs with higher risk
  $\rightarrow$ intermediate magnet prototype needed
- Test bench for optics and detectors
- One bore full diameter, half of the length
- Magnet FOM 10 × CAST $\rightarrow$ **Relevant physics at intermediate level**
- More staged access to funding
- Increased interest in the community

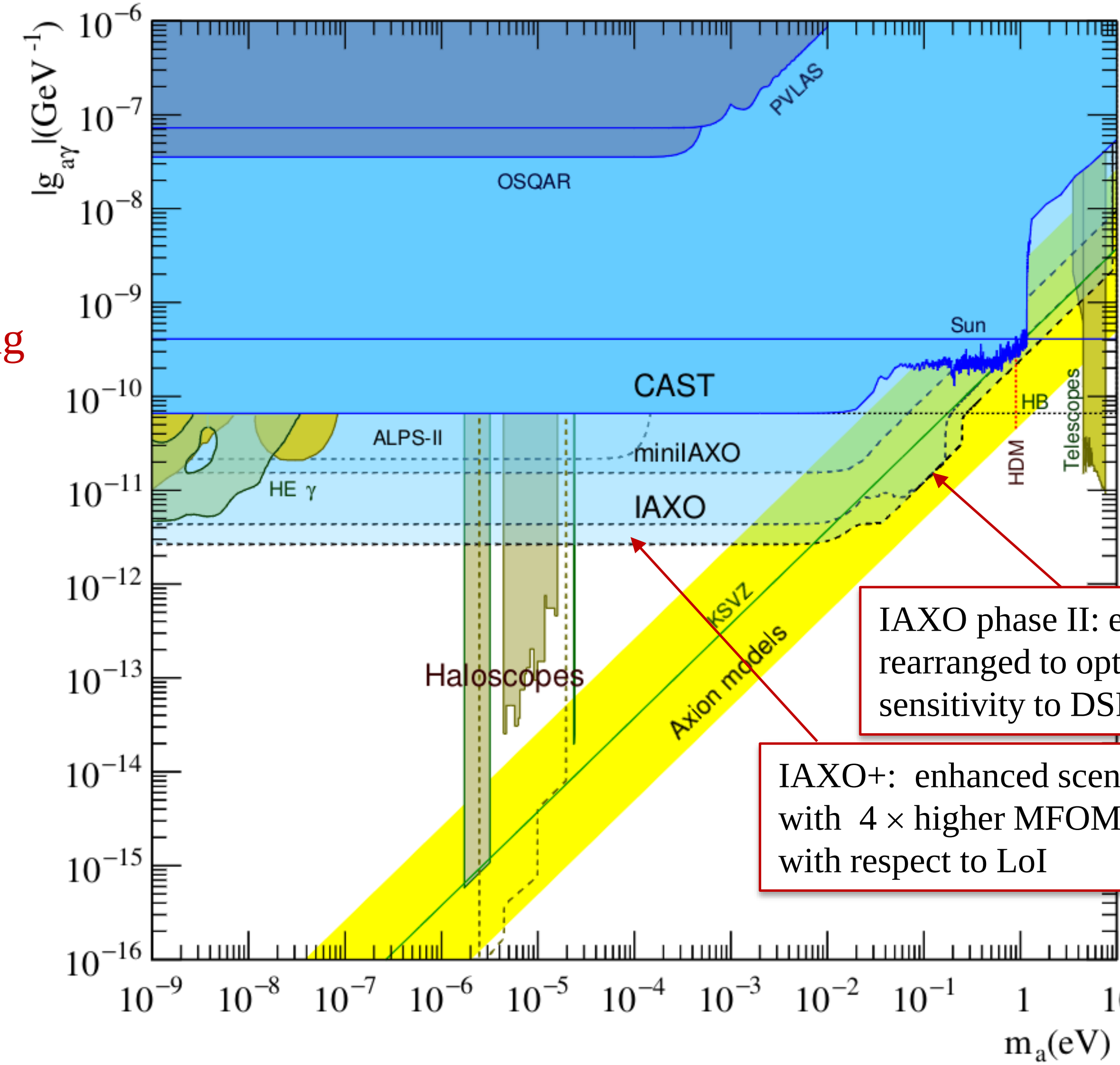
babyIAXO



Property	Value
Free bore [m]	0.6
Magnetic length [m]	10
Field in bore [T]	2.5
Stored energy [MJ]	27
Peak field [T]	4.1

IAXO Sensitivity

Axion – photon coupling

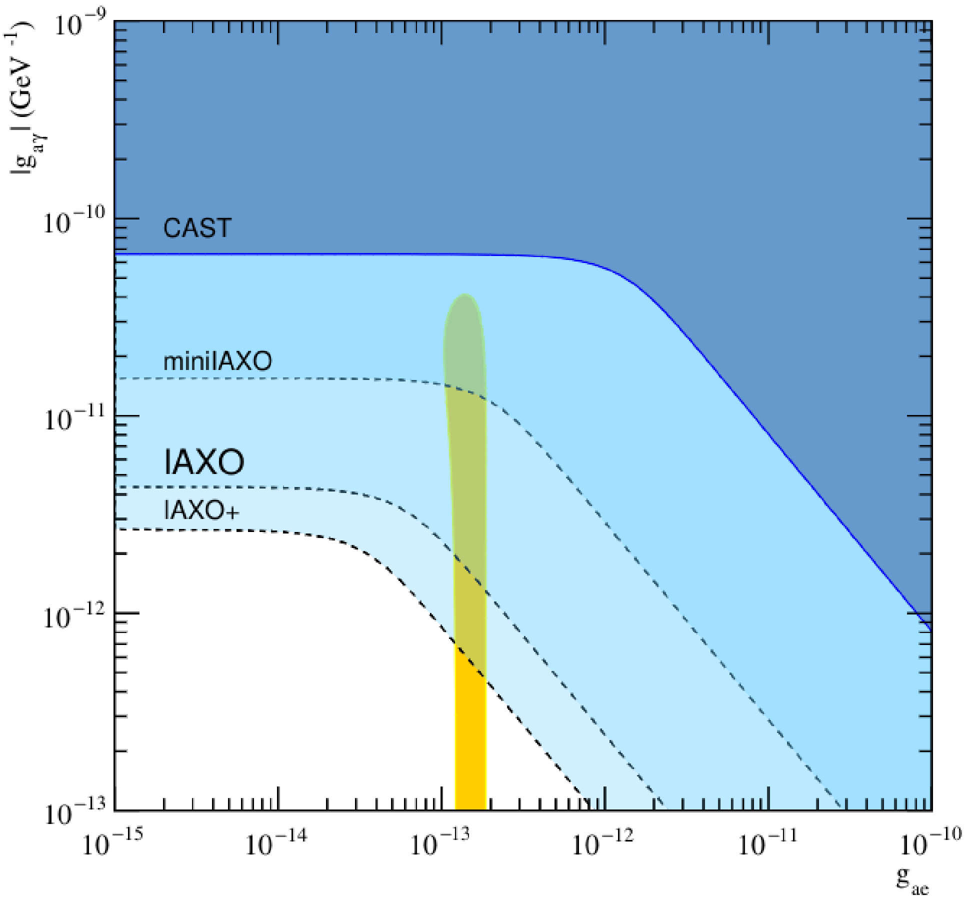


IAXO phase II: exposure rearranged to optimize sensitivity to DSFZ models

IAXO+: enhanced scenario with $4 \times$ higher MFOM with respect to LoI

IAXO Sensitivity

Axion – electron coupling



Additional physics cases:

- Relic axions: IAXO magnet with microwave cavities / RF antennas
- Search for other exotic particles: paraphotons, chameleons …
- … and more

IAXO Status & Conclusions

- IAXO is a new generation axion helioscope aiming to **improve CAST sensitivity to axion-photon coupling by more than one order of magnitude.** Additional physics cases include axion-electron coupling, relic axions, and more.

Status:

- In 2013 Conceptual Design completed
- In 2013 Letter of Intent submitted to the CERN SPSC: positive recommendations acknowledge physics case + encourage to proceed to TDR
- During 2014 – 2016 transition phase towards TDR: IAXO pathfinder system in CAST, coordinated funding applications …

Recently:

- BabyIAXO concept: intermediate experiment + enhancing final FOM of IAXO
- Formal constitution of the IAXO collaboration at a meeting in DESY on July 3 – 4:
  - Initial set of 17 institutions from over the world
  - Bylaws document approved (setting the rules and basic management bodies of the collaboration)
  - BabyIAXO to be presumably located at DESY