BabyIAXO

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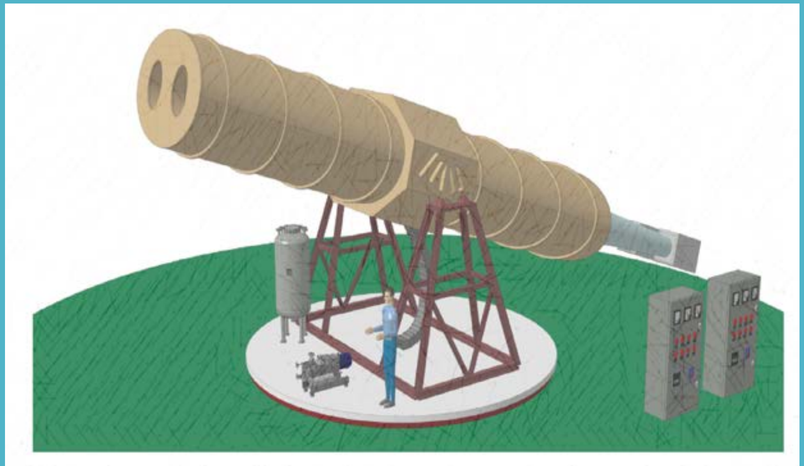
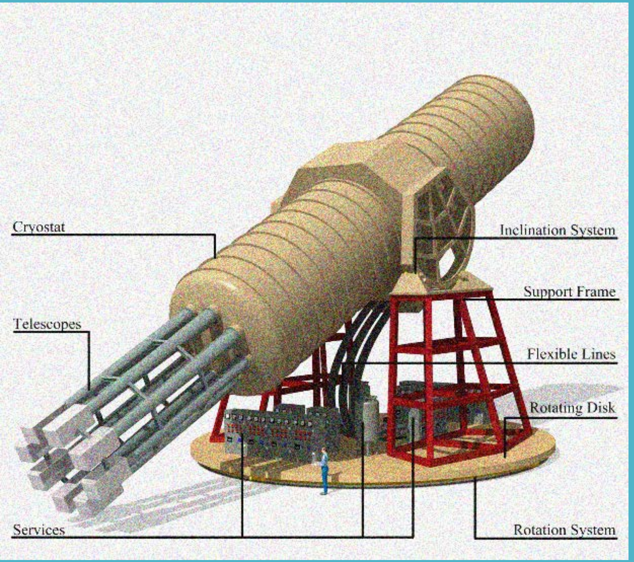




Axions and ALPs

- ✓ Axions are the most elegant solution to the Strong CP problem: (why QCD does not seem to break the CP symmetry)
  - pseudoscalar particles, neutral, practically stable
  - phenomenology driven by the scale f_a , m_a and g_{ai} correlated
- ✓ Candidates for both cold and hot dark matter
- ✓ Axion-like particles (ALPs) or WISPs (Weakly Interacting Slim Particles) share the axion phenomenology but m_{ALP} and g_{ALPi} not correlated
- ✓ Axions and ALPs are predicted by many extensions of the standard model
- ✓ String theory predicts axions/ALPs with detectable parameters
- ✓ Axions in astrophysics:
  - produced in the core of stars can drain energy from them and alter their lifetime
  - decay to two γ may produce lines in the emission from places like the galactic centre.
  - Hints for axion/ALPs?
    - transparency of the Universe to UHE gammas
    - stars cooling anomaly $\rightarrow$ point to few meV axions
    - …

Relevant axion/ALPs parameter space at reach of current and near-future experiments

Axion Searching techniques

Most of the searches are based on the axion-to-photon conversion

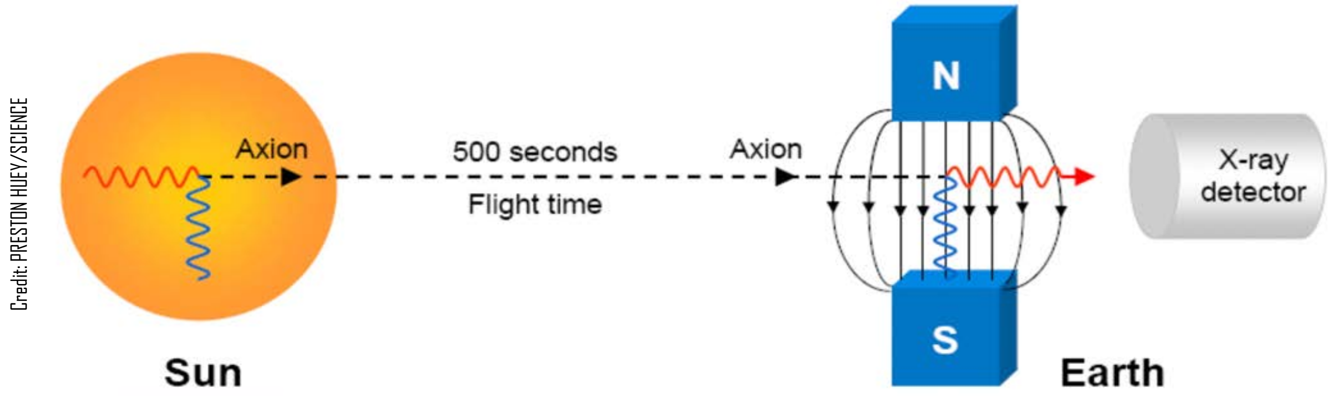
Present in practically every model $\mathcal{L}_{a\gamma} = g_{a\gamma}\, \mathbf{E} \cdot \mathbf{B}\, a$

Source	Experiments	Model & Cosmology dependency	Technology
Lab axions	ALPS, OSQAR, CROWS, 5th force exps,…	Very low	New ideas, Active R&D,…
Relic axions	ADMX, HAYSTAC, CASPEr, CULTASK, CAST-CAPP, MADMAX, RADES, QUAX, …	High	
Solar axions	SUMICO, CAST, IAXO	Low	Ready for large scale experiment

Helioscopes

Three generations of helioscopes

Brookhaven, Lazarus et al. PRL 69 (1992) 2333
SUMICO, Inoue et al. PLB 668 (2008) 93
CAST, Nature Physics 13 (2017) 584-590

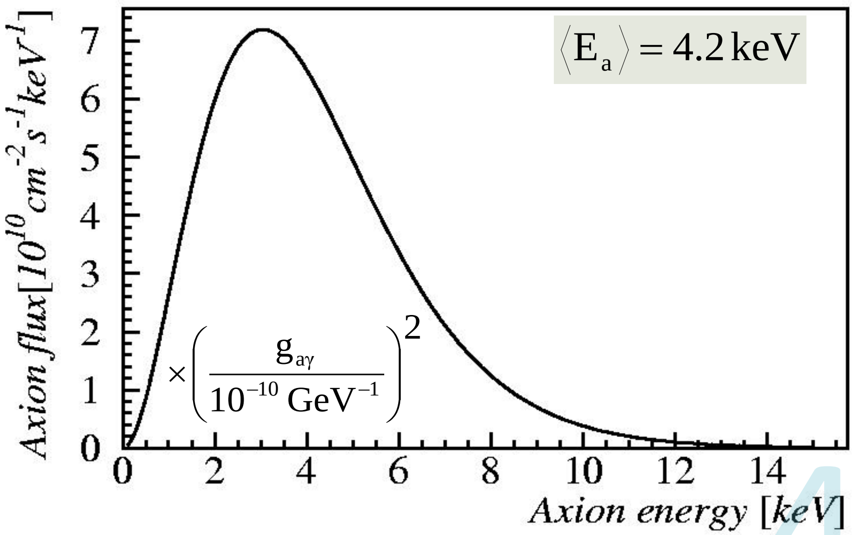


Signal: excess of x-rays during alignment over background

Production: Primakoff effect
Thermal photons interacting with solar nuclei produce Axions

Detection: (Sikivie '83) Inverse Primakoff
axion interacting with a very strong magnetic field converts to a photon

Differential axion flux on Earth



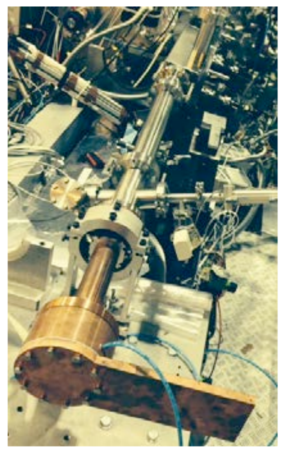
Expected number of Photons

$$N_\gamma = \int \frac{d\Phi_a}{dE_a} \cdot P_{a\rightarrow\gamma} \cdot S \cdot t \cdot dE_a$$

CERN Axion Solar Telescope

Decommissioned prototype LHC dipole magnet
Spare ABRIXAS telescope

XRT+mM
XRT+Ingrid



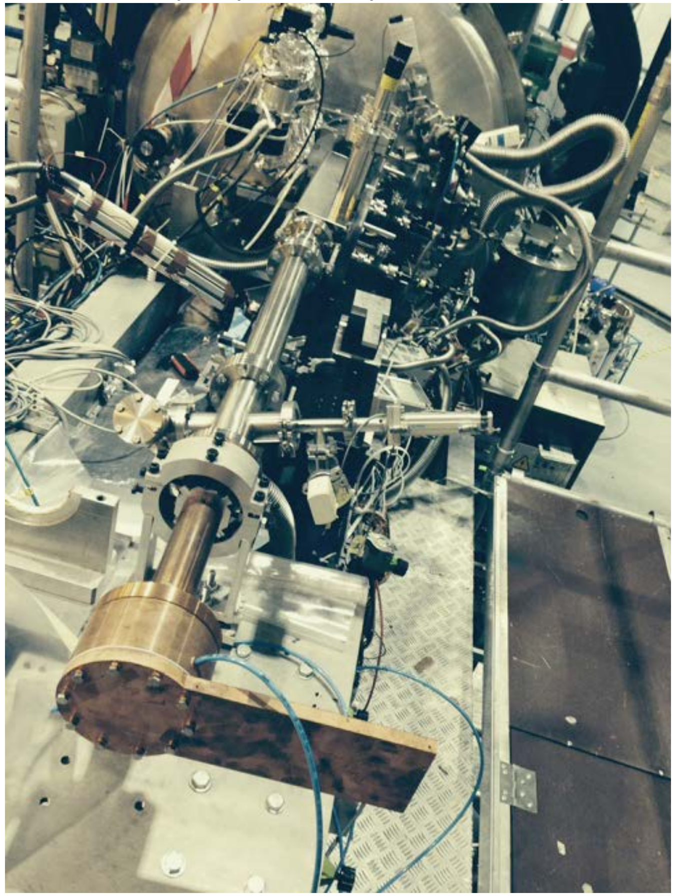
Two low-bkg mM (sunset)

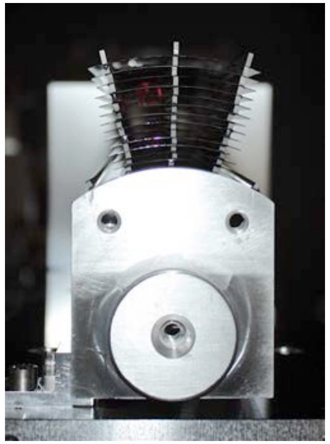
Magnetic Field B=9T
Length (field) L=9.26m
Rotating platform
Vertical : ±8°, Horizontal: ±40°
2x90min solar tracking/day

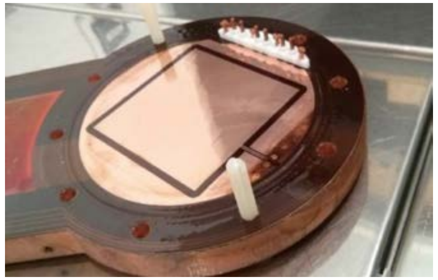
Latest CAST result (IAXO pathfinder)

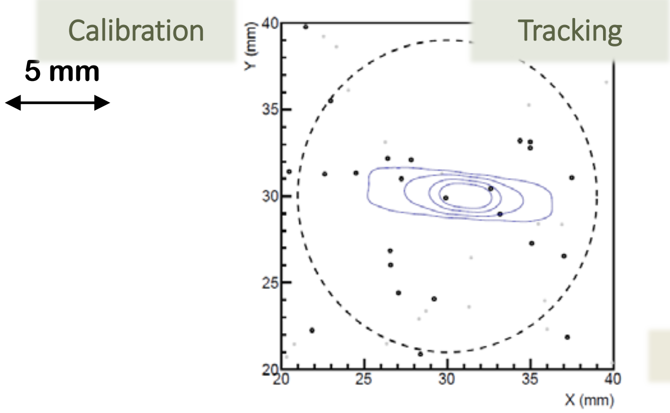
The most stringent limit on $g_{a\gamma}$ for $m_a < 0.02 eV$ (helioscopes)

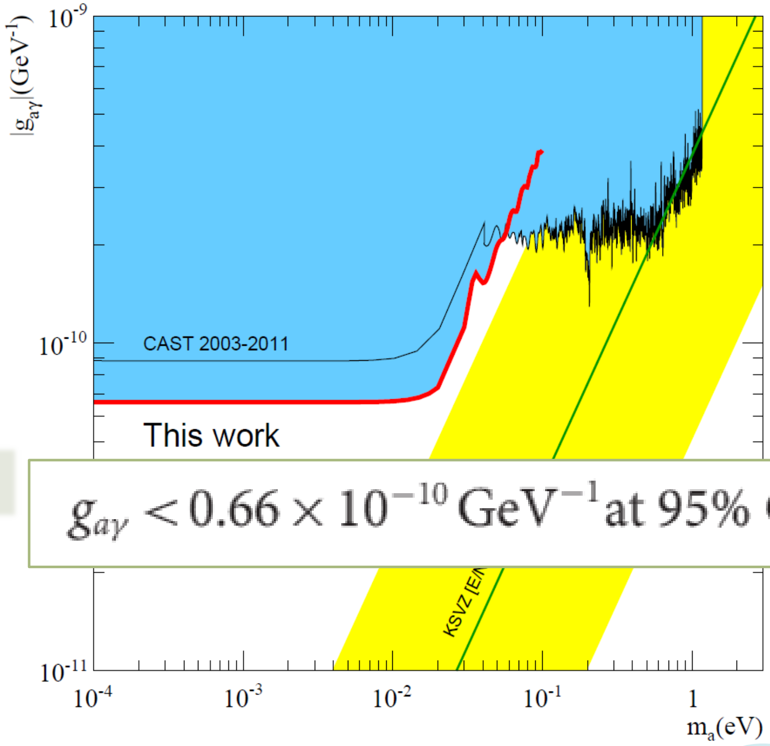
X-ray optics specifically built for axions, low-bkg mM at the focal point









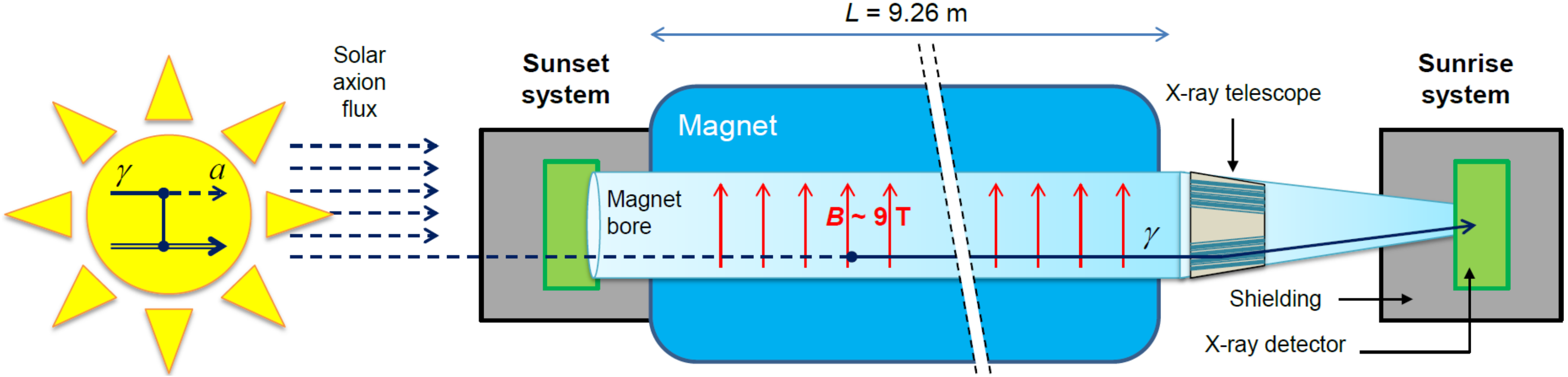


$$g_{a\gamma} < 0.66 \times 10^{-10}\, GeV^{-1} \text{at } 95\% \text{ CL}$$

CAST Nature Physics 13 (2017) 584-590

Enhanced Helioscope

Enhanced helioscope
JCAP 06 (2011) 013



magnet · optics

$$g_{a\gamma}^4 \sim B^2 L^2 A \quad \varepsilon_d b^{-1/2} \quad \varepsilon_o \alpha^{-1/2} \quad \varepsilon_t^{-1/2} t^{-1/2}$$

detectors · time

$B \cong 2.5T$
$L = 20m$
$A \cong 2.3m^2$

$t \cong 12h/day$

$\alpha \cong 8 \times 0.2\ cm^2$

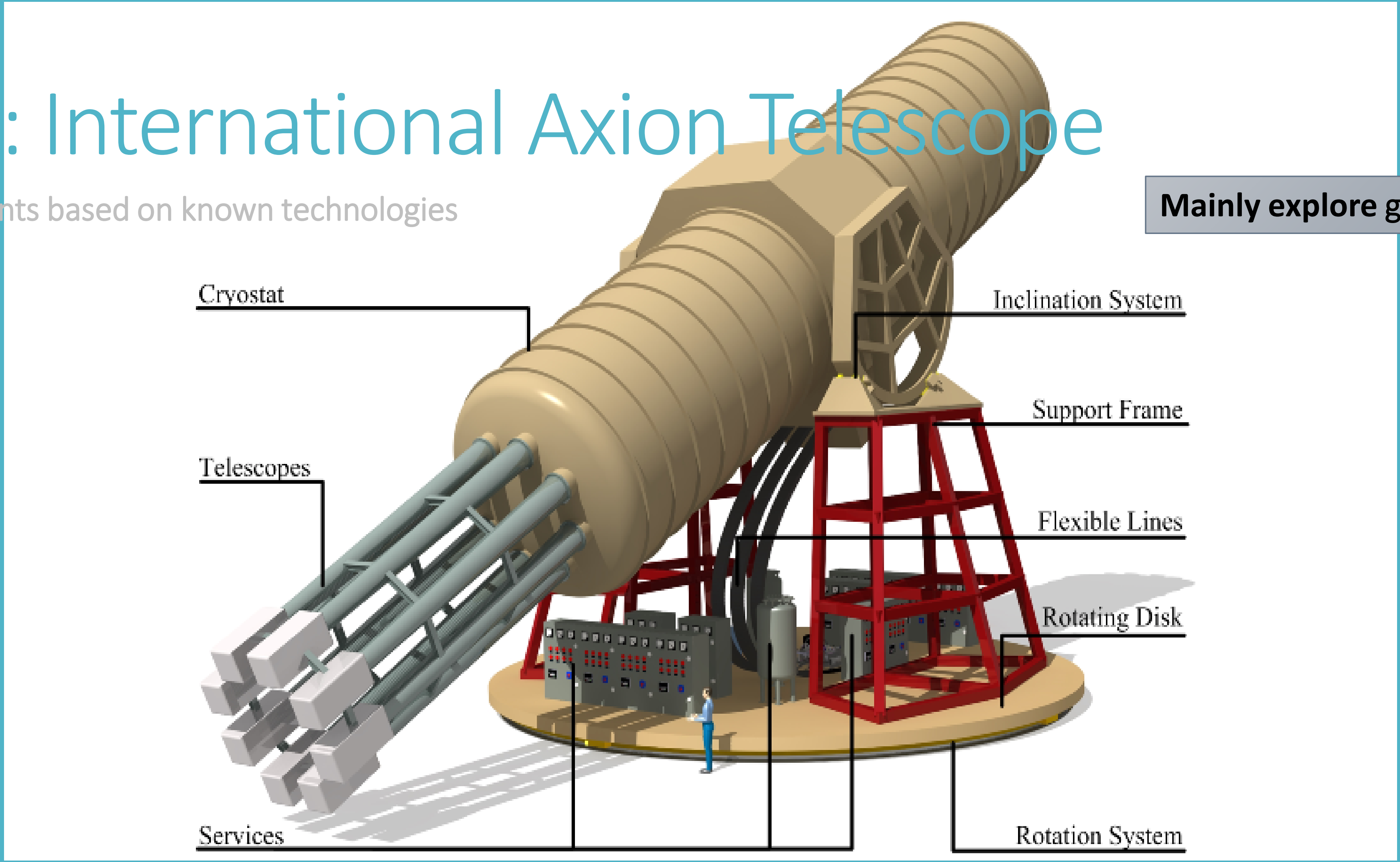
$b < 10^{-7} c\ keV^{-1} cm^{-2} s^{-1}$

	CAST	IAXO
f.o.m.	1	2-6 x 10^4

IAXO: International Axion Telescope

All developments based on known technologies

Mainly explore $g_{a\gamma}$ and g_{ae}



Magnet structure length: ~25m
Magnet structure diameter: ~5m
Total mass ~ 250ton

8 bores with 60cm diameter
8 focusing devices
8 low-background x-ray detectors

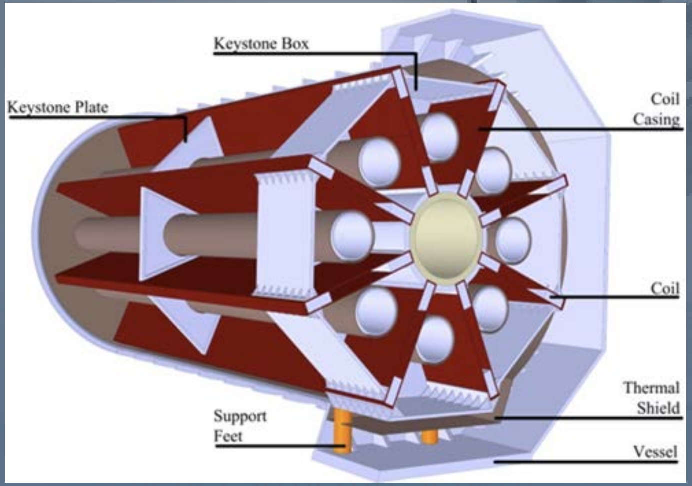
Rotating platform following the Sun for 12h a day

IAXO: International Axion Observatory

All developments based on known technologies

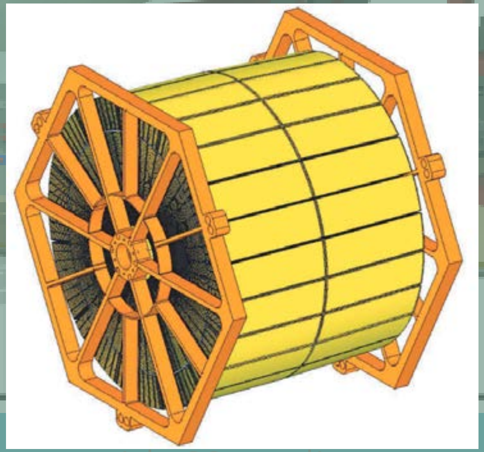
IAXO magnet

- Superconducting “detector” magnet.
- Toroidal geometry (8 coils) (ATLAS)
- CERN+CEA expertise
- 8 bores / 20 m long / 60 cm Ø per bore



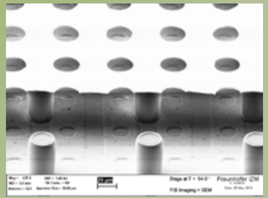
IAXO telescopes

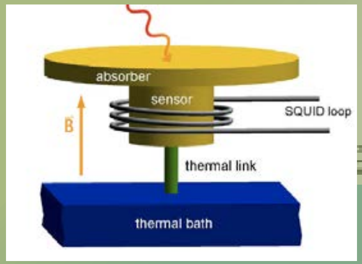
- Slumped glass, multilayers tech., cost-effective for large areas
- Based on NuSTAR developments
- LLNL+DTU+MIT+INAF expertise
- Focal length ~5 m, 60-70% efficiency

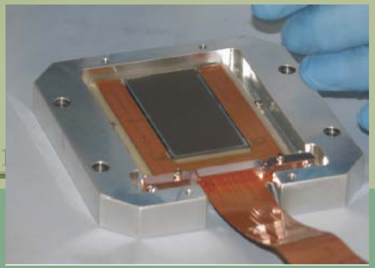


IAXO detectors

- Micromegas gaseous detectors
- Zaragoza + CEA (+ others) expertise
- Also considered: GridPix, MMCs, CCDs







Total mass ~ 250ton

8 bores with 60cm diameter
8 focusing devices
8 low-background x-ray detectors

following the Sun for
12h a day

IAXO: International Axion Observatory

All developments based on known technologies

An all-purpose axion observatory:

- ✓ non-hadronic axions
- ✓ WISPs
- ✓ non-standard axions
- ✓ relic axions

Magnet structure length: ~25m
Magnet structure diameter: ~5m
Total mass ~ 250ton

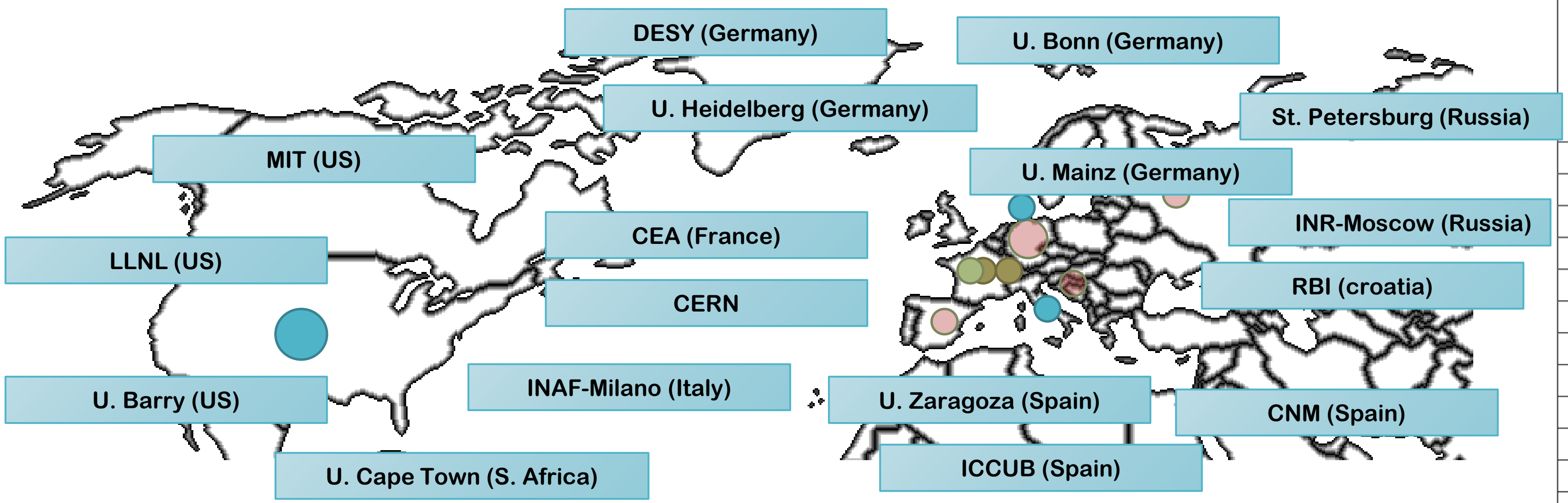
8 bores with 60cm diameter
8 focusing devices
8 low-background x-ray detectors

Rotating platform following the Sun for 12h a day

IAXO Collaboration

17 institutions from Germany, Spain, USA, France, Russia, Croatia, S. Africa, CERN.

Know-how covering broadly IAXO needs:



Institution	Superconducting magnets	X-ray optics	Detector & electronics	Axion phenomenology	Low background techniques	General infrastructures & engineering
Barry U. (USA)				x		
Irfu/CEA-Saclay (France)	x		x	x	x	x
U. Cape Town (S. Africa)				x		
ICCUB Barcelona (Spain)			x			
LLNL (USA)		x		x		
St. Petersburg NPI (Russia)				x		
Heidelberg U. (Germany)			x		x	
U. of Zaragoza (Spain)			x	x	x	
MIT (USA)		x				
INR Moscow (Russia)	x			x		
RBI Zagreb (Croatia)				x		
U. Bonn (Germany)			x			
CNM-IMB Barcelona (Spain)			x			
JGU Mainz (Germany)			x			
INAF - Brera (Italy)		x				
DESY (Germany)				x	x	x
CERN (Switzerland)	x					x

Baby IAXO: A full experimental stage

- Two bores of dimensions similar to final IAXO bores detection lines representative of final ones.
- Test & improve all systems.
- Risk mitigation for full IAXO

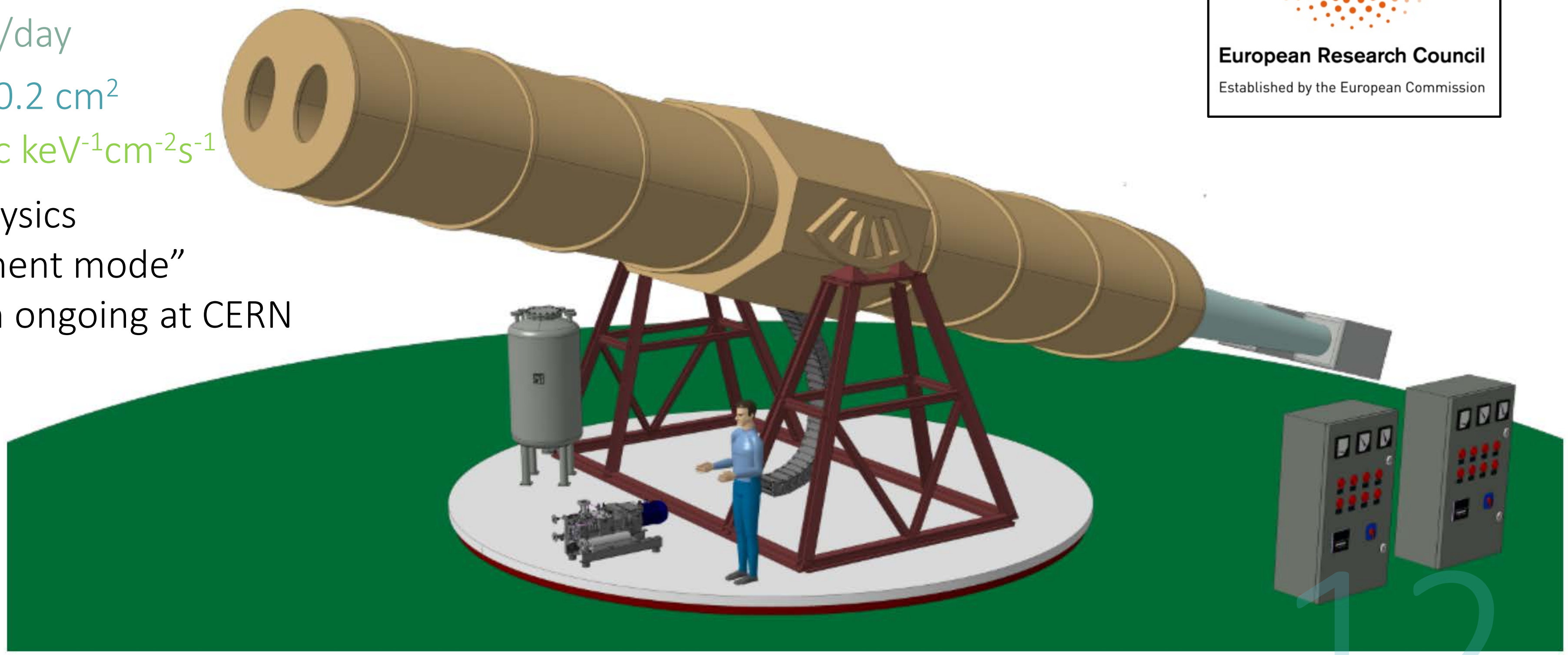
$B \cong 2.5T$
$L = 10m$
$A \cong 2x0.4m^2$

$t \cong 12h/day$
$\alpha \cong 2 \times 0.2\ cm^2$
$b \sim 10^{-7} c\ keV^{-1}cm^{-2}s^{-1}$

- Will produce relevant physics
- Move earlier to “experiment mode”
- Magnet Technical Design ongoing at CERN

ERC-AvG 2017 IAXO+

erc
European Research Council
Established by the European Commission

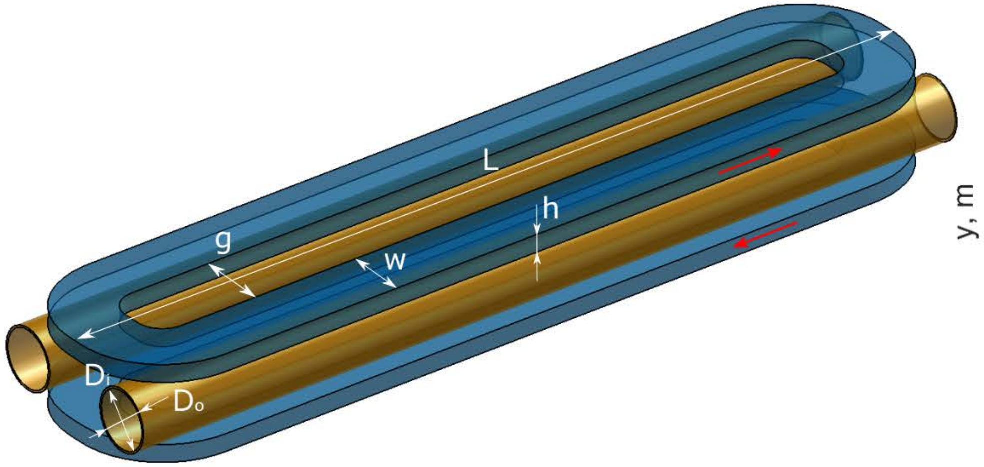


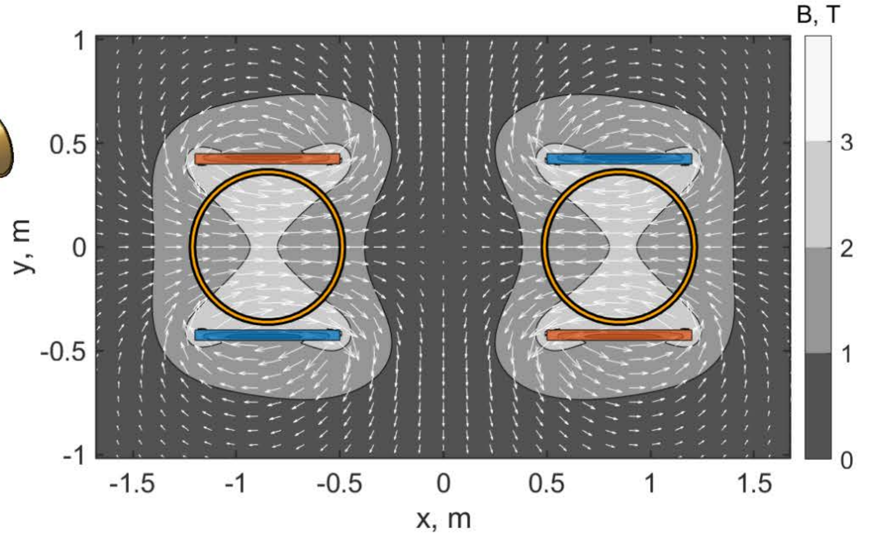
BabyIAXO Magnet

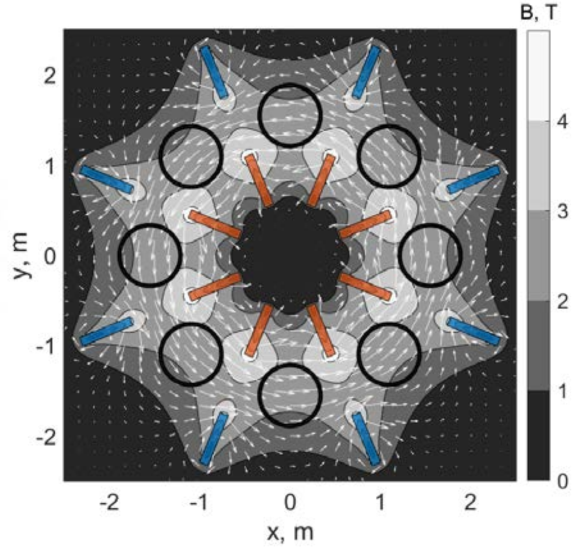
A lot of R&D ongoing the last few years

"Common coil" configuration chosen

- Minimal construction risk: move to construction asap
- Cost-effective: Best use of existing infrastructure (tooling) at CERN







BabyIAXO Optics

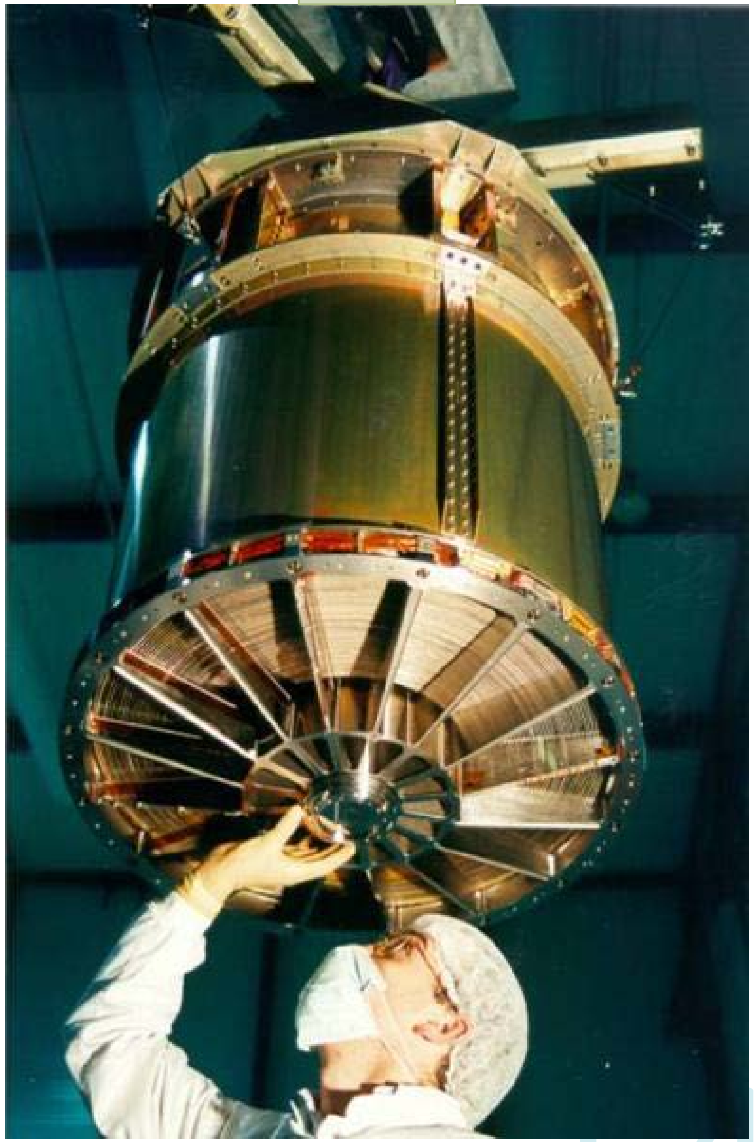
Baseline option:

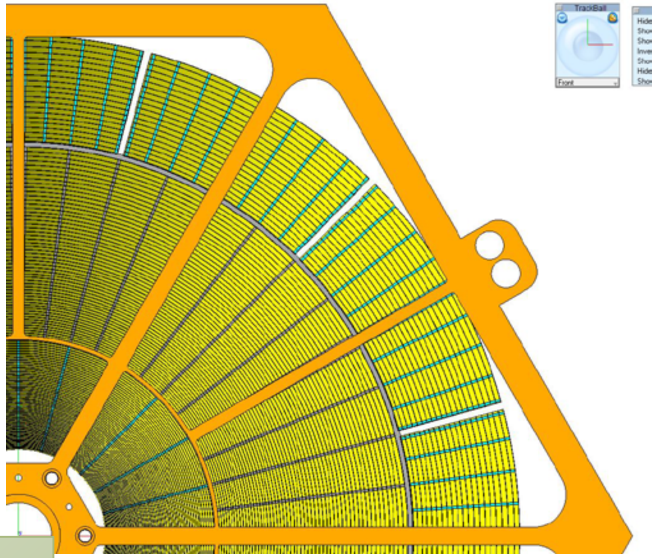
- Segmented-glass and flight spare XMM optics (ESA)

Minimal risk to the project

- Risk reduction for final IAXO segmented-glass optics
- XMM optics specs very close to IAXO optics design

XMM





Slumped-glass

BabyIAXO Detectors: Microbulk mM

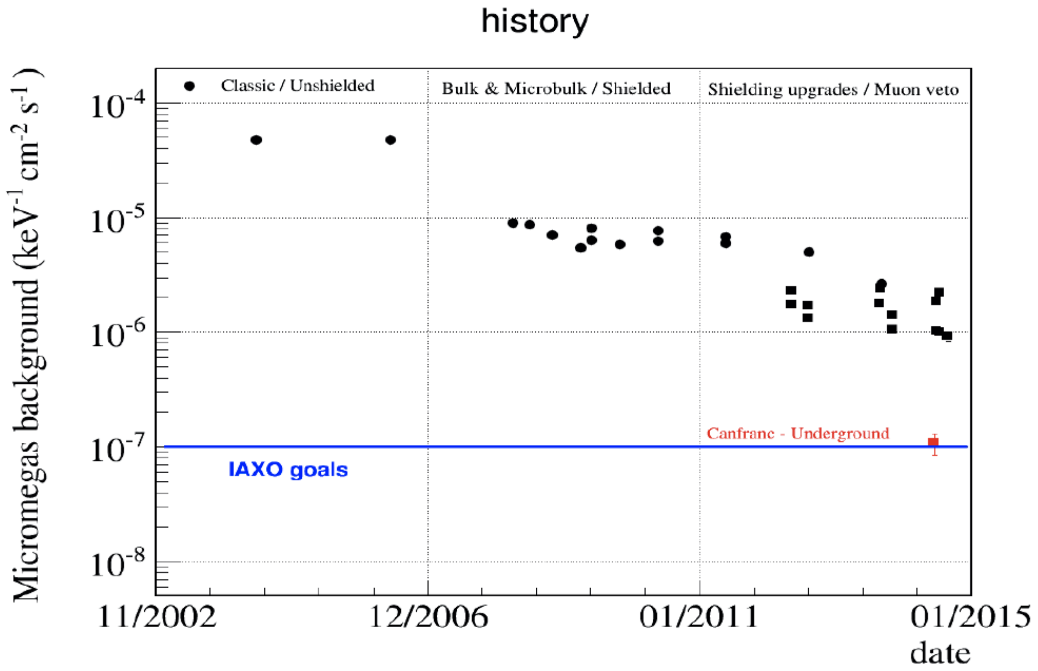
See next talk by E. Ruiz Choliz

IAXO background level goal: $10^{-7} – 10^{-8}$ c keV^{-1} cm^{-2} s^{-1}

Already demonstrated:

~8×10^{-7} c keV^{-1} cm^{-2} s^{-1} (CAST 2014)

10^{-7} c keV^{-1} cm^{-2} s^{-1} (underground @ LSC)



Very active R&D.

IAXO-D0 test-platform:

explore background sources and improve levels

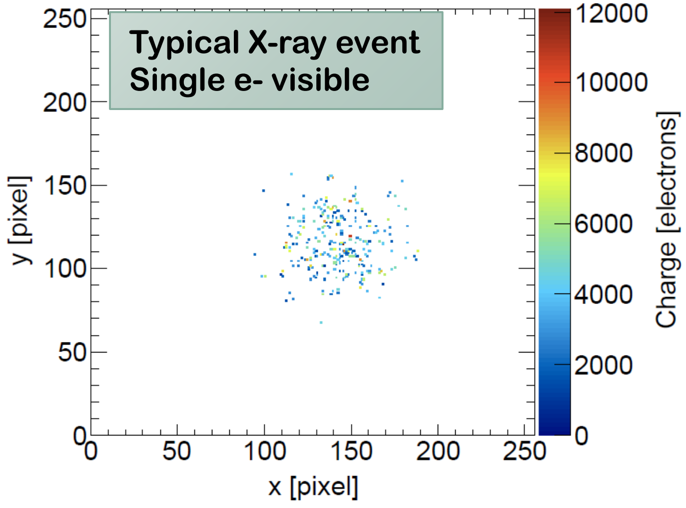
BabyIAXO Detectors: other technologies

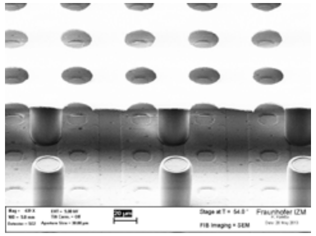
GRIDPIX DETECTORS (U. BONN):

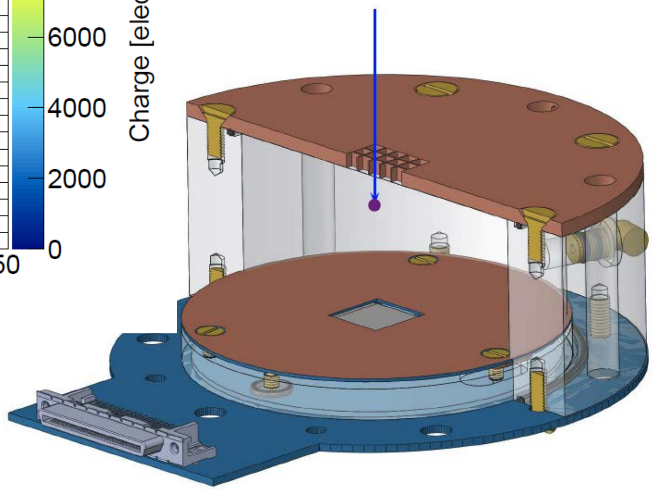
Micromegas on top of a CMOS chip (Timepix)

Very low threshold (tens of eV)

Tested in CAST



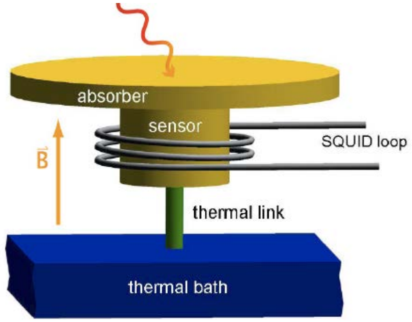


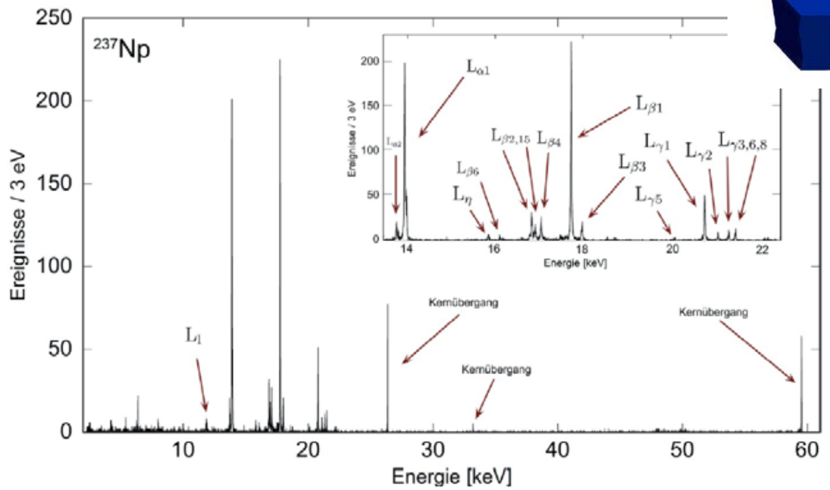


MMC DETECTORS (U. HEIDELBERG):

Extremely low threshold and energy resolution (~eV scale)

Low background? under study





But also:

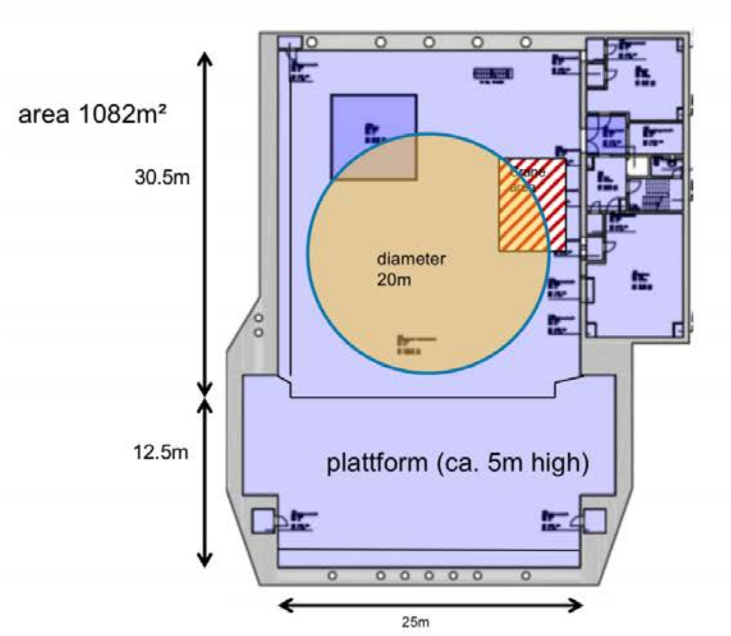
- Transition Edge Sensors (TES)
- Silicon Drift Detectors (SDD)

BabyIAXO @ DESY

HERA South hall: possible site for BabyIAXO

DESY infrastructure & expertise very well suited to IAXO

- telescope pointing structures
- magnets & cryogenics
- Project office



Sensitivity

BabyIAXO (in about 5years):

x10 magnet f.o.m.

discovery potential!

would cover an interesting part of the parameter space

IAXO (in about 10 years):

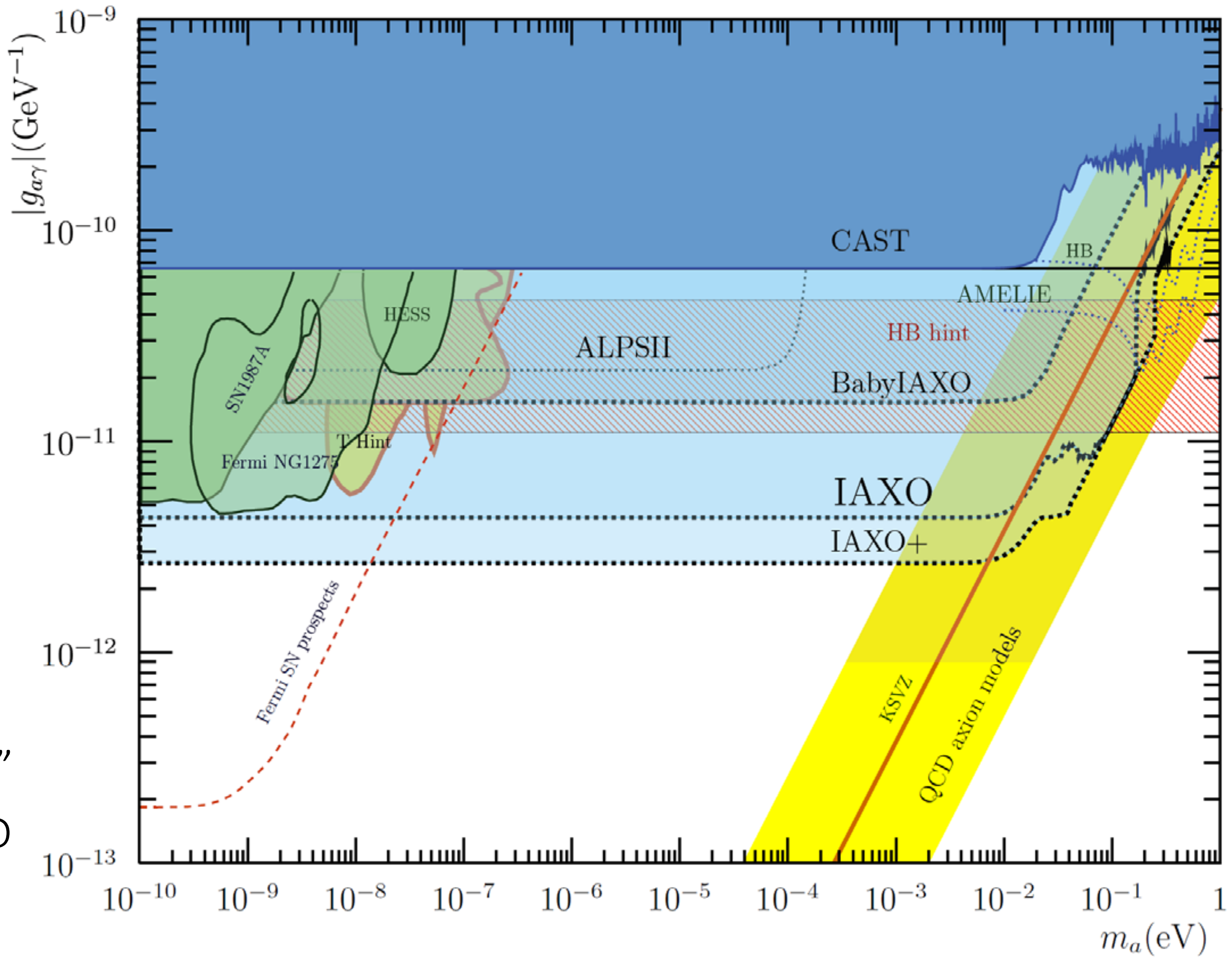
will fully explore ALP models

for the “transparency hint”

large fraction of ALP models

for the “stellar cooling anomaly”

will probe a good portion of the QCD axion parameter space



To take home

- ✓Axions (and ALPs) are at the spotlight for new physics
- ✓Enhanced helioscope studies since 2011 have led to the proposal of the
  International Axion Observatory
- ✓IAXO reviewed by CERN SPSC and part of the “Physics Beyond Colliders” process
- ✓Collaboration established in june 2017 (17 institutes and counting)
- ✓BabyIAXO: first stage to get things going with relevant physics potential within 5years.
  Magnet under design
  ERC funding in 2018
- ✓ Although baselines follow known technologies, a lot of R&D is ongoing in all fronts
- ✓ IAXO will have an impact on the parameter space, complemented by the other techniques