Micromegas as Low Background x-ray detectors in axion searches: CAST & IAXO

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On behalf of U. de Zaragoza
RD51 Collaboration Meeting - 29th October 2014 - Kolkata

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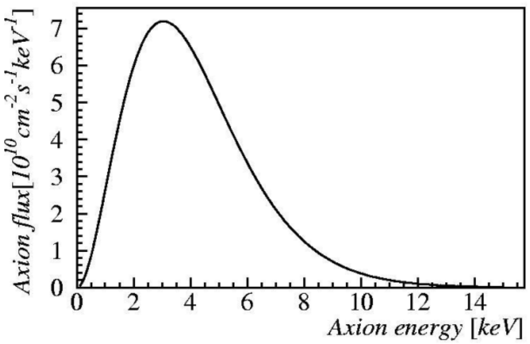
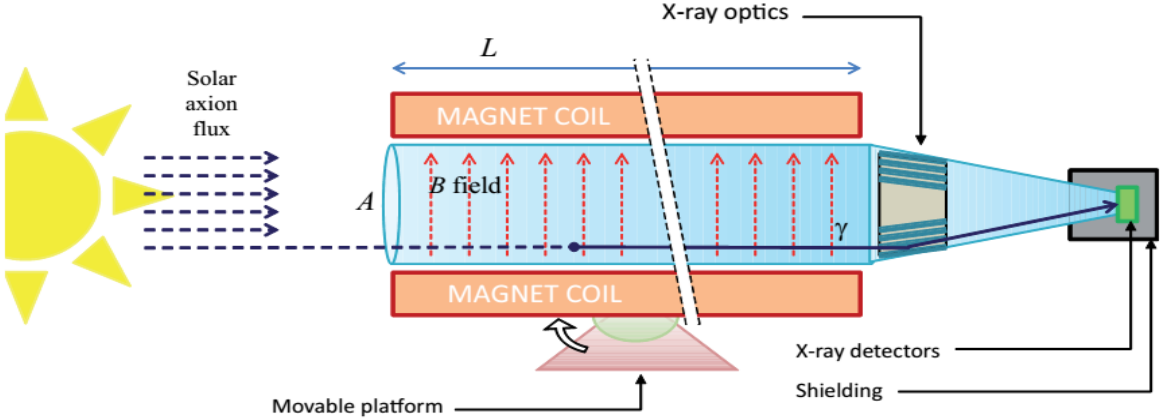
Outline

- Axion helioscopes: CAST & IAXO
- Micromegas in CAST.
- Background level and background model.
- Prospects: background reduction and lowering the enegy threshold
- Conclusions.

Axion detection by an helioscope



Serpico & Raffelt, JCAP04 (2007) 010



Production: *Primakoff effect.* Thermal photons interacting with solar nuclei produce axions.

Detection: *inverse Primakoff* (Sikivie 1983) Axions in a magnetic field convert to photons. Expected x-ray excess when the magnet points to the Sun.

Axions are the most elegant solution to the Strong CP problem (why QCD does not seem to break the CP symmetry):

- Axion-like particles (ALPs) are predicted by many extensions of the Standard Model.
- Candidates for both cold and hot dark matter.
- Predicted in many extensions of the Standard Model, relevant parameter space at reach of current or near future experiments.

CAST: CERN Axion Solar Telescope

Description of CAST:

- Decommissioned prototype LHC dipole magnet.
- Length = 9.3 m. Field = 9 T.
- Range of movement: 80º horizontally and ± 8º vertically.
- Solar tracking possible during sunrise and sunset (2 x 1.5 h per day).

Detectors since 2010:

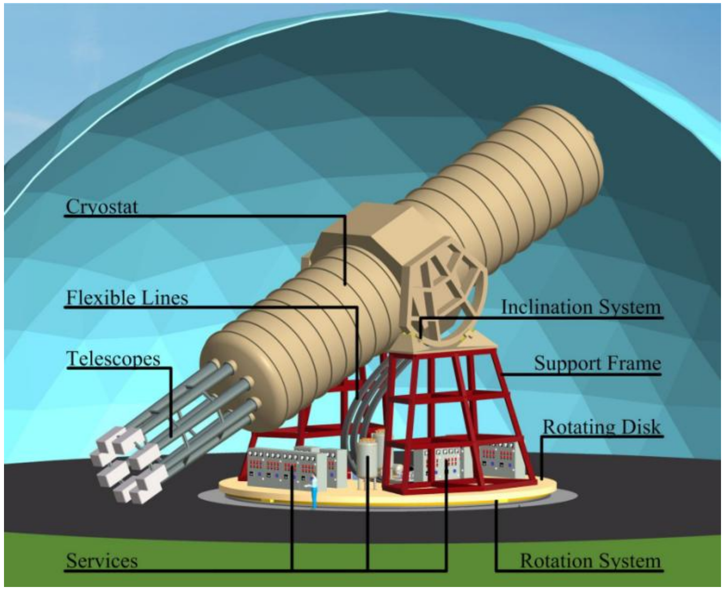
- Sunrise: x-ray focusing device + CCD, and Micromegas microbulk.
- Sunset: 2 Micromegas microbulk detectors.

Detector figure of merit

$$f_{DO} = \frac{\varepsilon_d \varepsilon_o}{\sqrt{ba}}$$

X-ray detectors

IAXO: International AXion Observatory



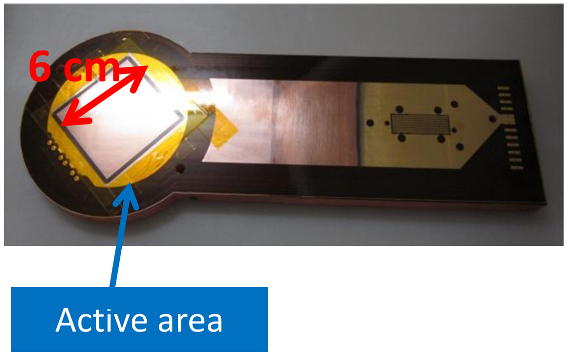
- New generation of axion helioscope.
- 4 orders of magnitude better in S/N wrt CAST, i.e. 1-2 orders in $g_{a\gamma}$.
- New features: toroidal magnet, dedicated optics, low background detectors.
- CAST can explore a big part of the axion model region in next decade.
- Positive recommendations from SPSC.
- More details: IAXO-CDR (**2014 JINST 9 T05002**) & NGAH (**JCAP 06 (2011) 013**).

Several preparatory activities in parallel for the Technical Design Report (TDR):

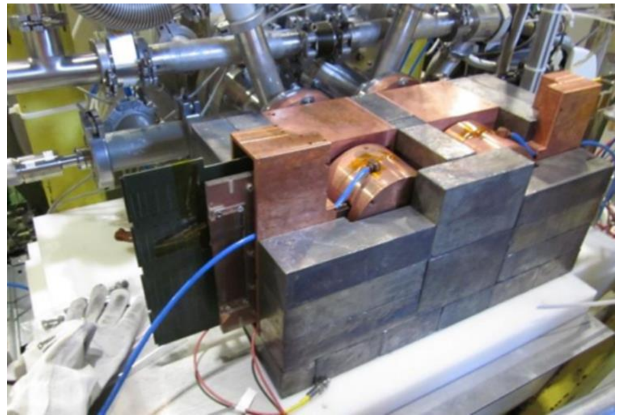
- **IAXO-T0**: a demonstration coil.
- **IAXO-X0**: a prototype x-ray optics.
- **IAXO-DO**: a low background detector.
- **Pathfinder**: a small optics & detector at CAST. The same techniques as for IAXO.

Micromegas in CAST

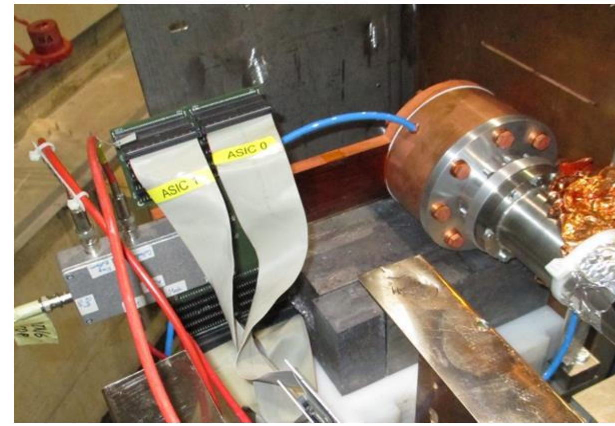
The goal is to develop efficient x-ray detectors with low background and energy threshold.



Readout plane



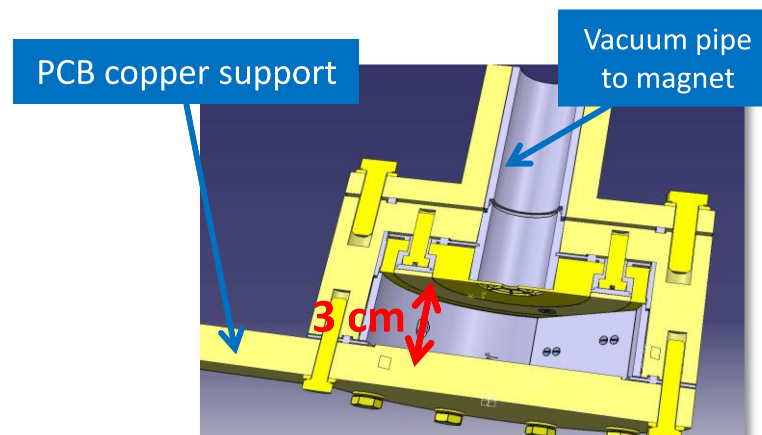
CAST Micromegas at Sunset



CAST Micromegas at Sunrise

CAST-MMFeatures

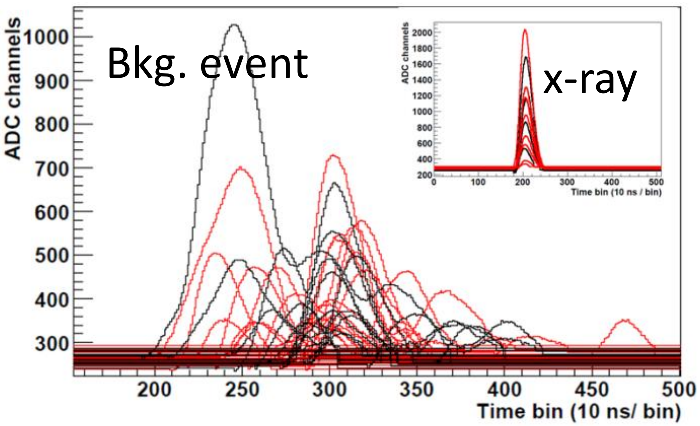
- Active area: 6x6 cm (120x120 strips).
- Gas: Ar+iC_2H_4 at 1.4 bar.
- Conversion/Drift region: 3 cm (100 V/cm) .
- Amplification gap: 50 µm (10^4 V/cm).
- X-ray window: 4 µm aluminized mylar.
- Radiopure materials: copper, kapton, teflon.

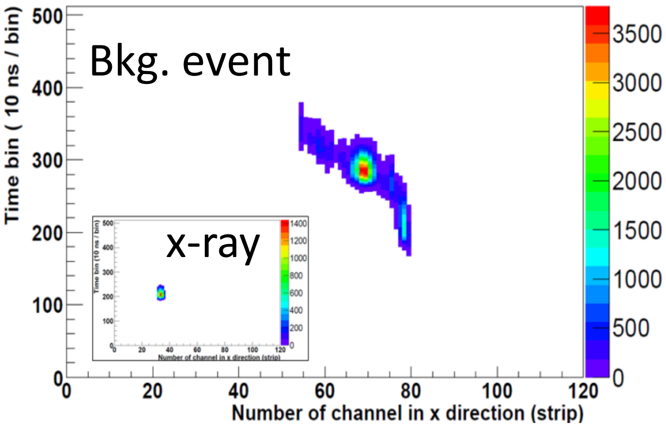


TPC schematics

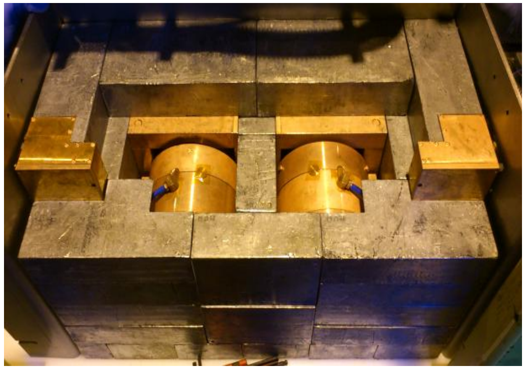
Why are they used in axion searches?

- High power to discriminate x-rays signals from other type of events. Event topology.
- Intrinsically radiopure, very low radioactivity budget ***(Astr. Part. 34 (2011) 354*).**
- Shielding techniques from low background experiments are also applied.

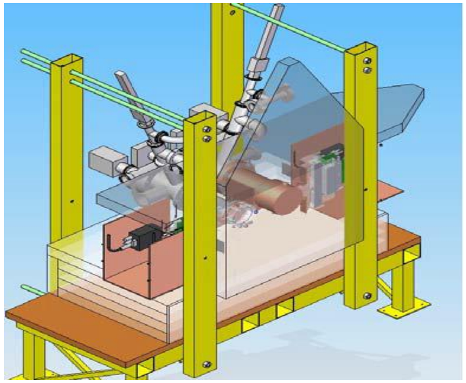




X-ray (punctual energy depositions.) vs. Background events



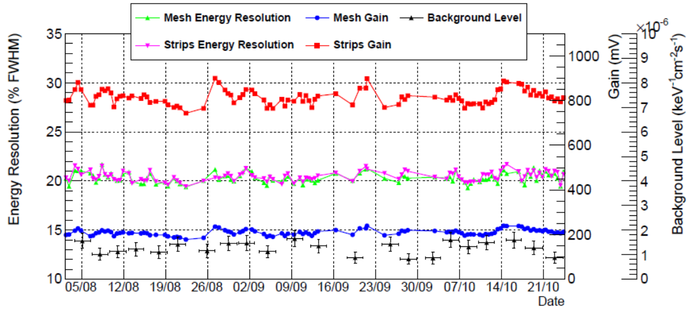
Passive shielding : lead & copper



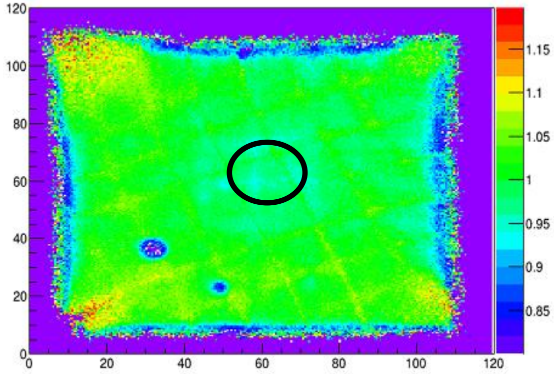
Active shielding: muon vetos.

Why are they used in axion searches?

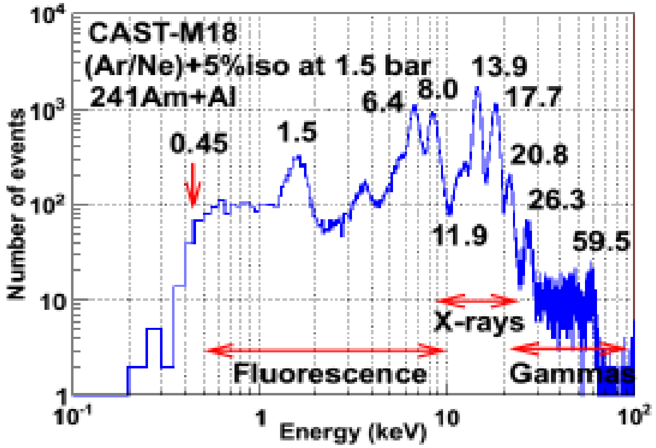
- Gain uniformity.
- Consolidated fabrication (***JINST 5 (2010) P02001, JINST 7 (2012) P04007***).
- Good energy resolution (12% FWHM at 5.9 keV)
- Stable over long running periods.



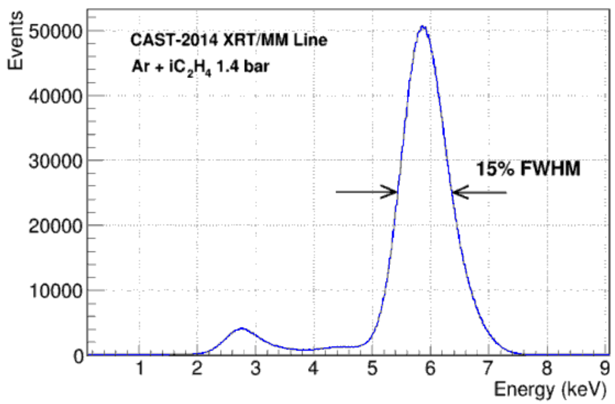
Long term stability



Uniformity of gain

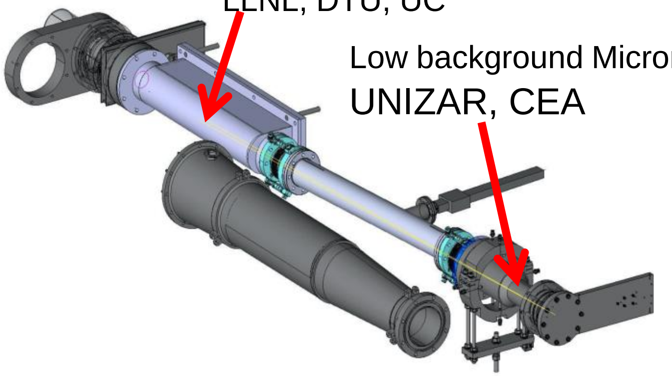


Energy threshold



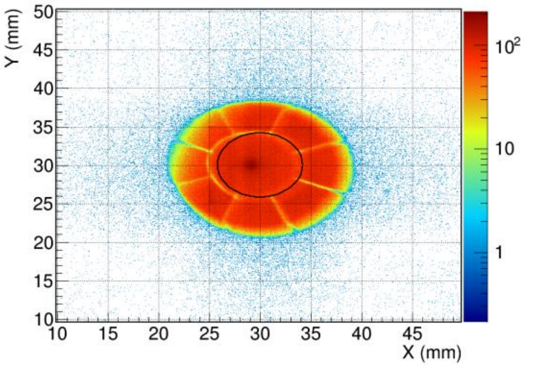
Enegy resolution

Micromegas + X-ray Telescope at CAST 2014

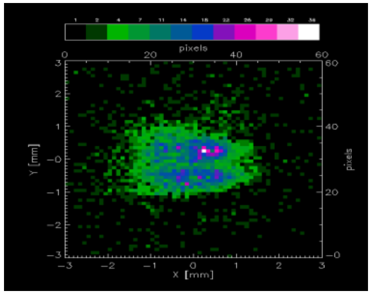


X-ray telescope (XRT), specifically designed and built for CAST.

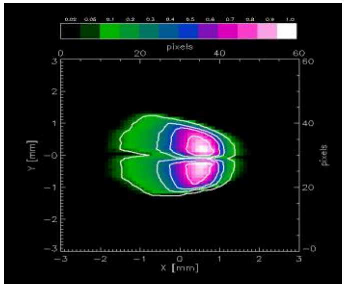
Window + strongback cathode.



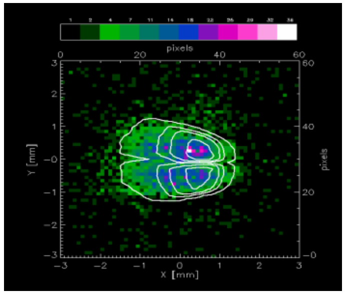
Micromegas Intensity map: ^{55}Fe calibration.



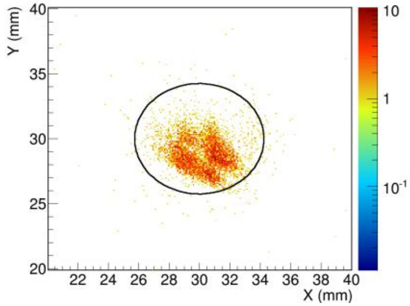
Micromegas



Simulation



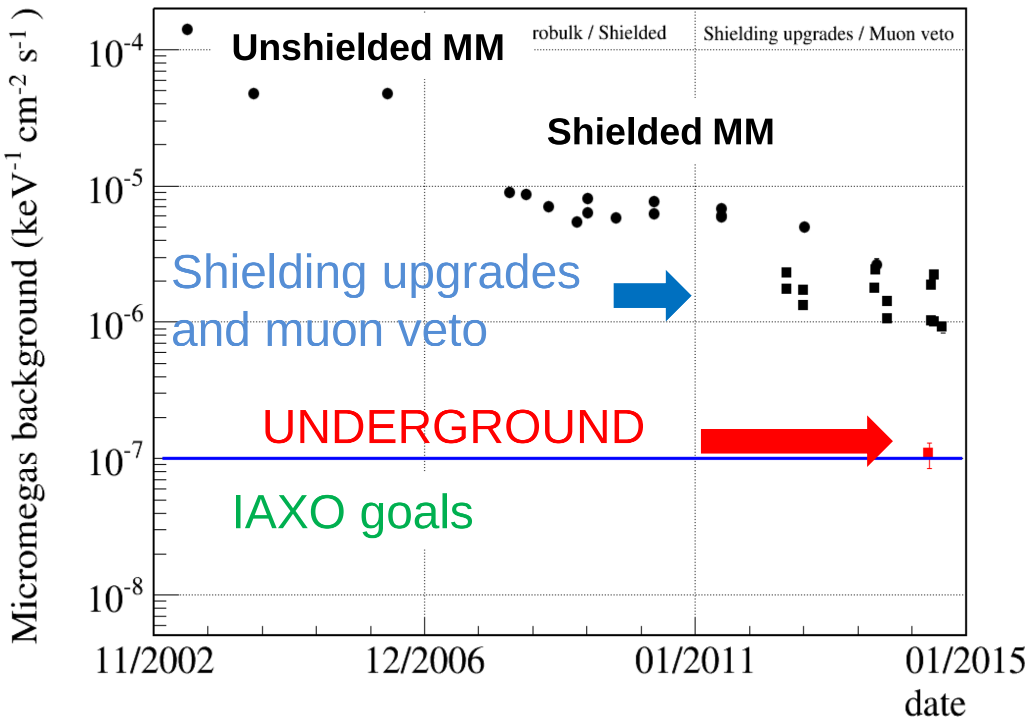
Simulation & Micromegas data over-plotted



Micromegas intensity map of x-ray source through the optics.

- XRT installed + commissioned in August 2014.
- Big milestone for CAST → best SNR ratio.
- X-rays from an x-ray source in the other side of magnet (13 m away) and focused by the XRT on the Micromegas detector.

Micromegas Background evolution at CAST



JINST 9 (2014) P01001:
Low background x-ray detection with Micromegas for axion research

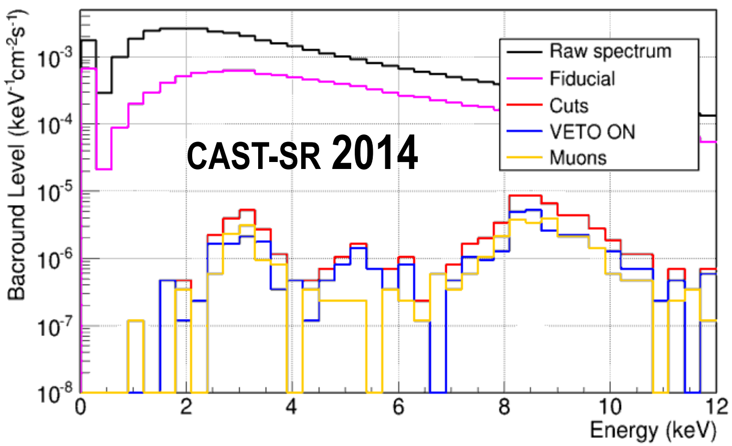
JINST 8 (2013) C12042
X-ray detection with Micromegas with background levels below 10^{-6} keV^{-1}cm^{-2}s^{-1}

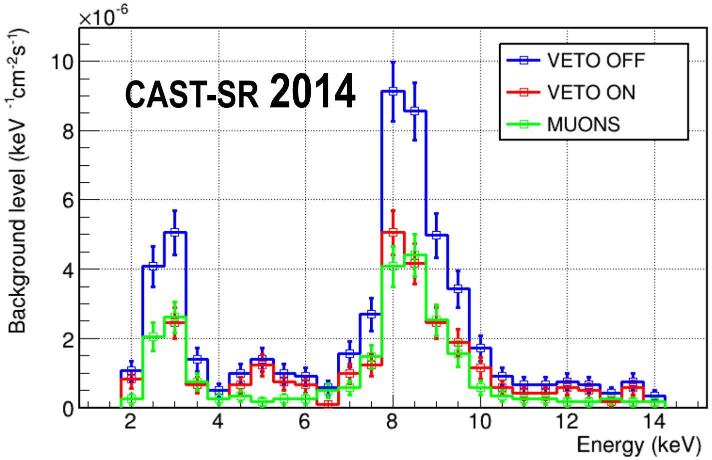
- Underground level: 10^{-7} keV^{-2}cm^{-2} s^{-1}, almost at required IAXO levels.
- XRT+ MM line in CAST-2014 for the first time below 10^{-6} keV^{-2}cm^{-2} s^{-1}. Setup easy to improve → further background reductions expected.
- Application of low background techniques → more than 2 orders of magnitude improvement in background over the years .

Background level at CAST in 2014

XRT/MM Line: below 10^{-6} $keV^{-2}cm^{-2}s^{-1}$ → $(0{,}86 \pm 0.06)\cdot 10^{-6}$ in 670 hours.

SUNSET Detectors CAST-2014: $(1{,}00 \pm 0{,}06)\cdot 10^{-6}$ and $(0{,}99 \pm 0{,}06)\cdot 10^{-6}$ in 1317 hours.





- Background spectrum characteristic of an 8 keV x-ray (copper k_α) + escape peak (5 keV) + 3 keV (argon k_α).
- A background reduction requires the identification of the origin of these dominant events.

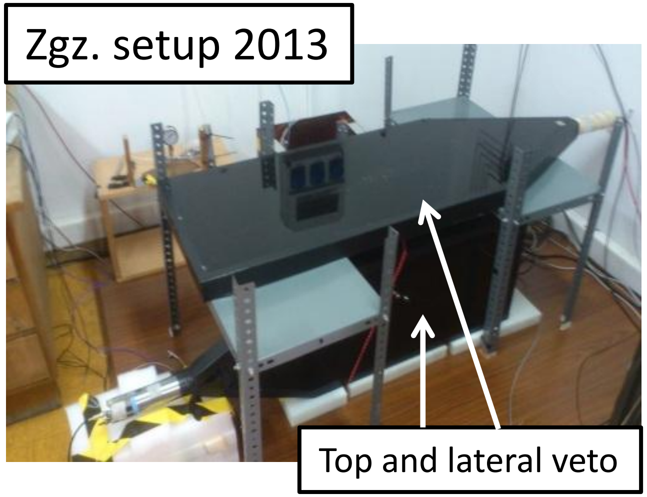
Current Background Model based on:

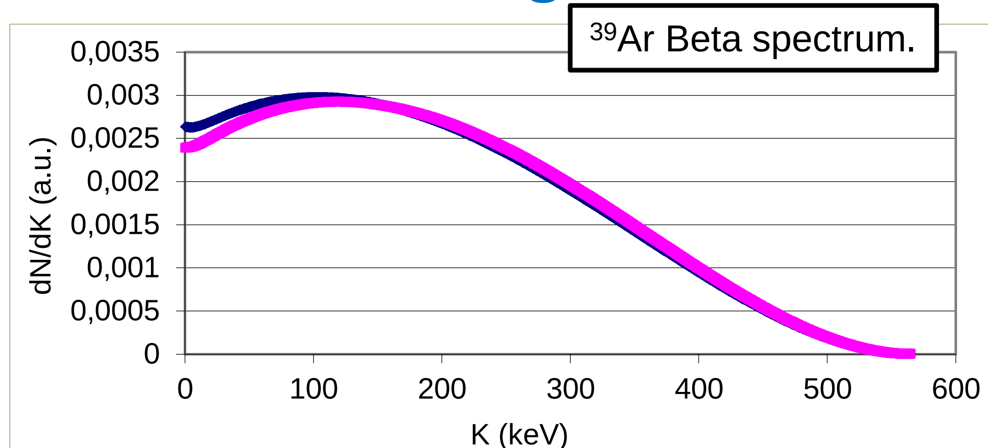
- In situ measurements at CAST.
- Surface tests at Zaragoza (Spain).
- Canfranc Underground Laboratory: CAST-MM replica.
- Geant4 Montecarlo simulations of CAST-MM.

Contribution	Technique	Background Level in 2-7 keV (counts $keV^{-2}cm^{-2}s^{-1}$)	
Gamma flux	Lead shielding	~ 7×10^{-5}	Contributions eliminated
Radon	N_2 flux	~ 8×10^{-7}	
Muons	Active veto	$2 \times 10^{-6} \rightarrow 7 \times 10^{-7}$	Dominant contributions
CAST-LSC Lower limit	^{39}Ar radio-activity ?? components activity ?? Neutrons ?? Cosmic ativation ?? ….	1×10^{-7}	

- R&D activity to reduce the dominant contributions to background (**main IAXO-Micromegas TDR activity**).

IAXO-Micromegas R&D on background





Expected rate in CAST-Micromegas:
Integrated rate : 6×10^{-6} cm^{-2} s^{-1}.
Rate in [2-7] keV: 2×10^{-8} $keV^{-1}cm^{-2}$ s^{-1}. (no secondaries included)

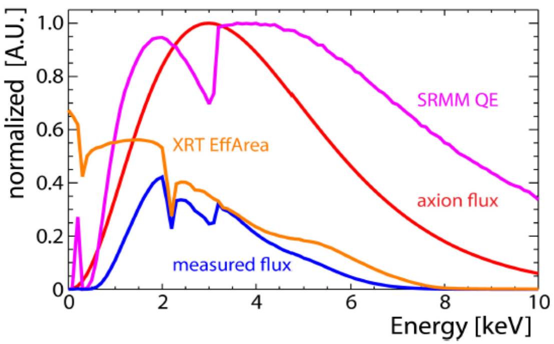
SURFACE → achieve (at least) underground lower limits.

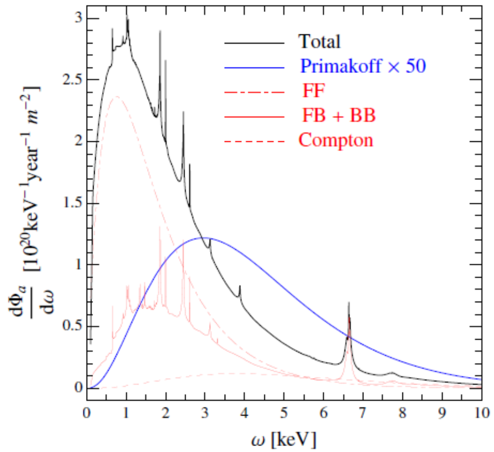
- Build a first prototype of a Micromegas detection line as would be in IAXO.
- Better (thicker) lead shielding with less openings.
- 4π muon veto.
- Where? Zaragoza. When? 2014-2016.

UNDERGROUND → pushing lower limits

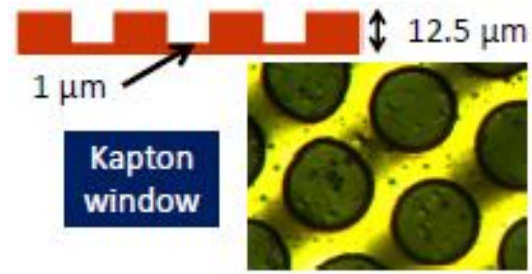
- **Gas change**: Argon → Xenon/Neon? **No ^{39}Ar radio-activity**. No 5 keV and 3 keV fluorescence peaks.
- **Detectors size**: larger detector → double cluster identification.
- Thicker lead shielding: 10 →15 cm.
- **Neutron shielding:** polyethylene.

Lowering the enegy threshold





J. Redondo, JCAP 12 (2013) 008
K. Barth et al, JCAP 05 (2013) 010



- **Motivation:** with the XRT efficiency, big part of the axion flux is expected below 2 keV.
- In non-hadronic axion models, the Sun produces axion by BCA processes. The axion flux peaks at sub-keV energies.

- **R&D in this line**
  - thinner x-ray windows windows.
  - auto-trigger electronics (AGET) S. Anvar et al, NSS/MIC/RTSD IEEE 2011
  - new gas mixtures with higher gain (Neon?).
  - resistive microbulk.
  - Calibrations at lower energies.

CONCLUSIONS

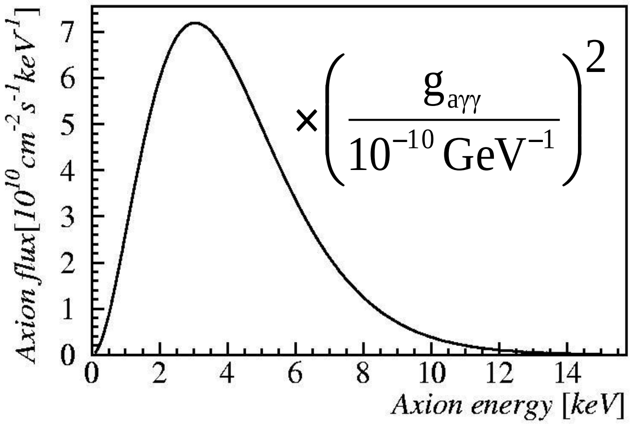
- Micromegas: excellent option for x-ray detection in axion physics.
- CAST-2014 LLNL XRT + MM succesfully installed → IAXO optics+detector pathfinder system.
- In CAST, 2 orders of magnitude of background reduction over the years, currently slightly below 10^{-6} $keV^{-2}cm^{-2}s^{-1}$.
- IAXO bacground goal: below 10^{-7} $keV^{-2}cm^{-2}s^{-1}$.
- Clear strategy for background reduction in surface and background tests.
- Sub-kev axion physics → R&D lines to lower the energy threshold.

Thank you

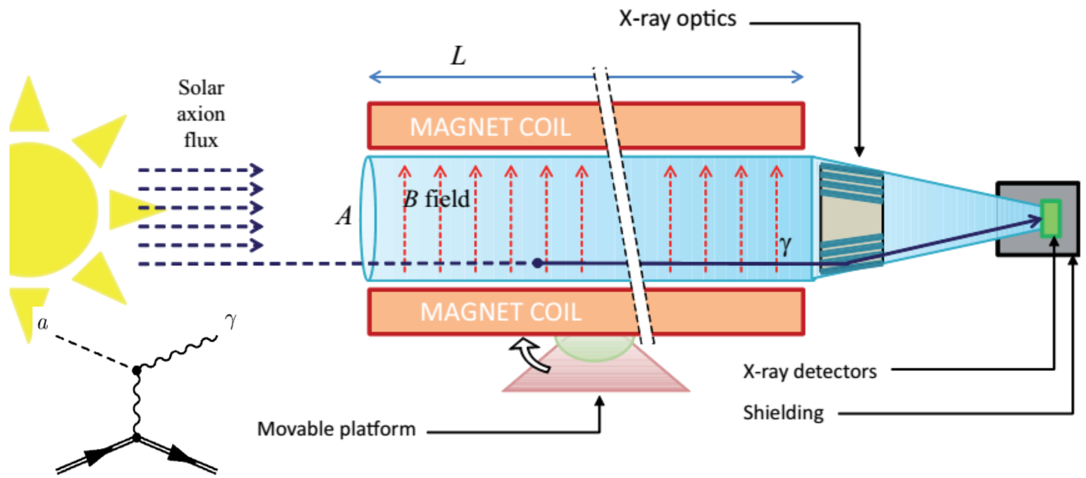
Axions

- 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.
- Candidates for both cold and hot dark matter.
- Axion-like particles (ALPs) are predicted by many extensions of the Standard Model
- Relevant axion/Axion-Like Particles parameter space at reach of current and near-future experiments
- New theory scenarios: string theory predicts axions/ALPs with detectable parameters
- Astrophysical hints for axion/ALPs?
    - transparency of the Universe to UHE gammas $\rightarrow$ very light ALPs
    - white dwarf cooling anomaly $\rightarrow$ few meV axions

Axion detection by an helioscope



Serpico & Raffelt, JCAP04 (2007) 010



Production: *Primakoff effect.*
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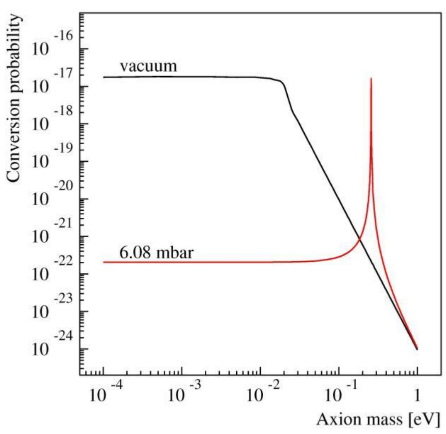
Detection: *inverse Primakoff* (Sikivie 1983)
Axions in a magnetic field convert to photons.
Expected x-ray excess when the magnet points to the Sun.

- Conversion probability depends on medium.
- In vacuum coherence is lost for $m_a > 0.02$ eV.
- In the presence of a buffer gas, the coherence can be restored for a narrow mass range.



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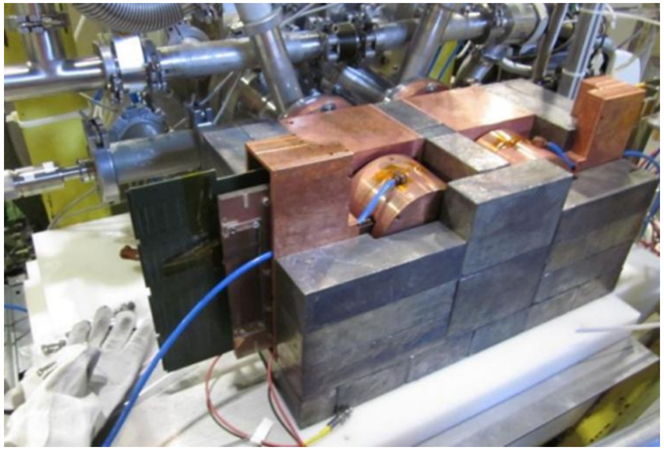
Detectors since 2010:

- Sunrise: x-ray focusing device + CCD (SDD in 2013, Ingrid in 2014) / Micromegas.
- Sunset: 2 Micromegas detectors.

CAST detectors



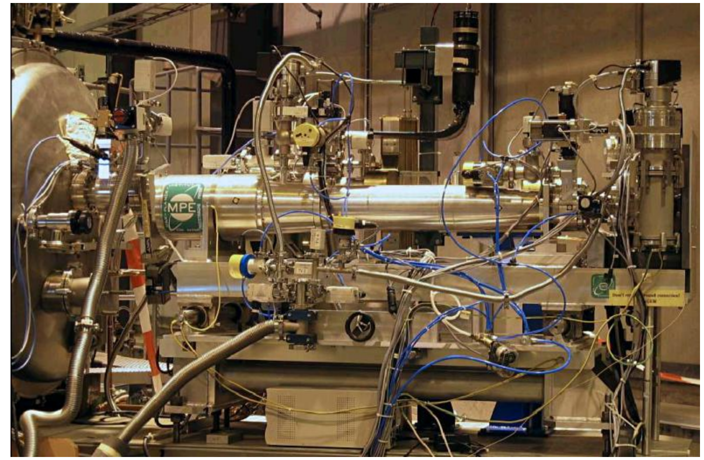
CAST-Micromegas at Sunset

Micromegas microbulk detectors

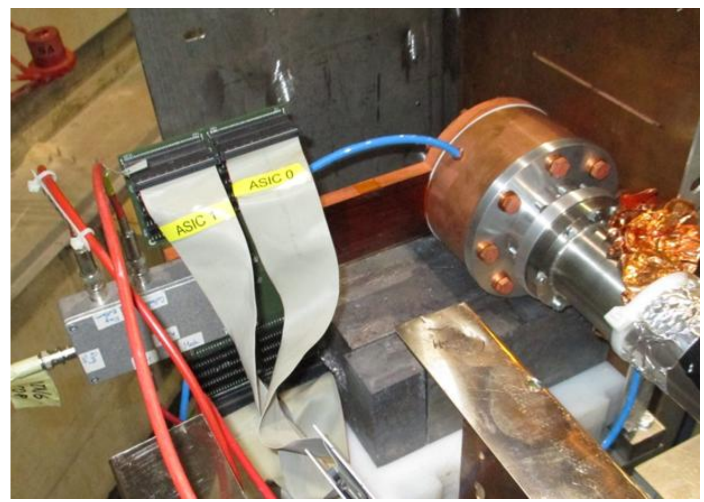
- High power to discriminate x-rays.
- Intrinsic radiopure.
- Shielding techniques applied.
- **JINST 9 (2014) P01001.**

X-ray telescope + CCD

- Telescope: prototype of ABRIXAS mission.
- CCD: Excellent spatial & energy resolution. SN~150 due to simultaneous measurement.
- **New J. Phys. 9 (2007) 169.**



X-ray telescope + CCD



CAST-Micromegas at Sunrise

CAST Physics Program

1) CAST Phase I, Vacuum

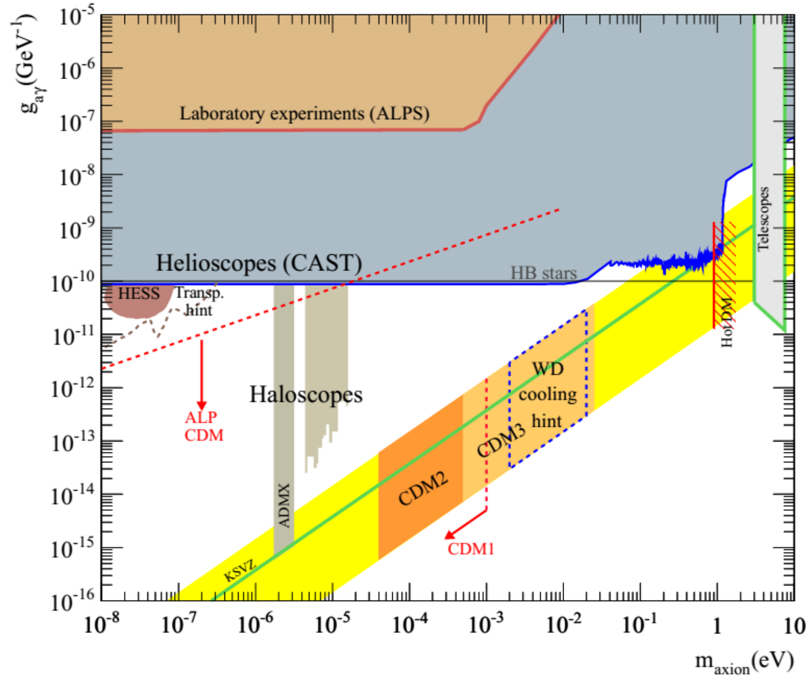
- $m_a < 0.02$ eV
- **$g_{a\gamma\gamma} \lesssim 0.88 \times 10^{-10}$ GeV^{-1}**
- **PRL94 (2005) 121301** & **JCAP04(2007)020.**

2) CAST Phase II, ^{4}He

- P < 13.4 mbar (1.8K), 160 steps
- 0.02 eV < m_a < 0.39 eV
- **$g_{a\gamma\gamma} \lesssim 2.2 \times 10^{-10}$ GeV^{-1}**
- **JCAP02 (2009) 008**.

3) CAST Phase II, ^{3}He

- P < 120 mbar (1.8K), 160 steps
- 0.39 eV < m_a < 1.17 eV
- **$g_{a\gamma\gamma} \lesssim 3.3 \times 10^{-10}$ GeV^{-1}**
- **PRL 107 (2011) 261302** & **PRL 112 (2014) 091302**



Parallel searches:

- HE axions: **JCAP 1003 (2010) 032**.
- 11.4 keV axions from M1 transitions: **JCAP 0912 (2009) 002**.
- LE (visible) axions: **arXiv:0809.4581**.
- Constrains on axion-electron coupling: **JCAP 1305 (2013) 010**

CAST: latest results & current activites

Latest results:

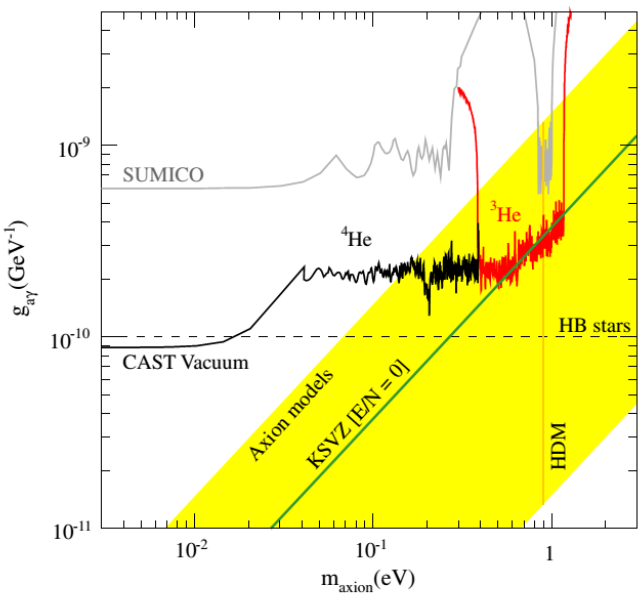
- ^{3}He phase results recently published: PRL 112 (2014) 091302 (only mM).
- Axion mass 0.64 – 1.17 eV excluded down to **~3.3 × 10^{-10} GeV^{-1}**.
- Paper on the simulation of gas dynamics inside the magnet in preparation.

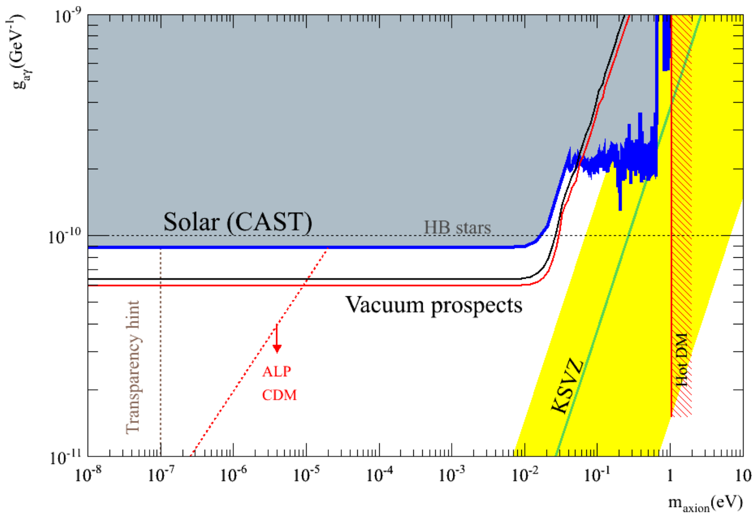
Current activities:

- Revisiting the vacuum phase with three high performance microbulk detectors.
- Seach of exotic physics (chameleons, paraphotons, low energy axions).

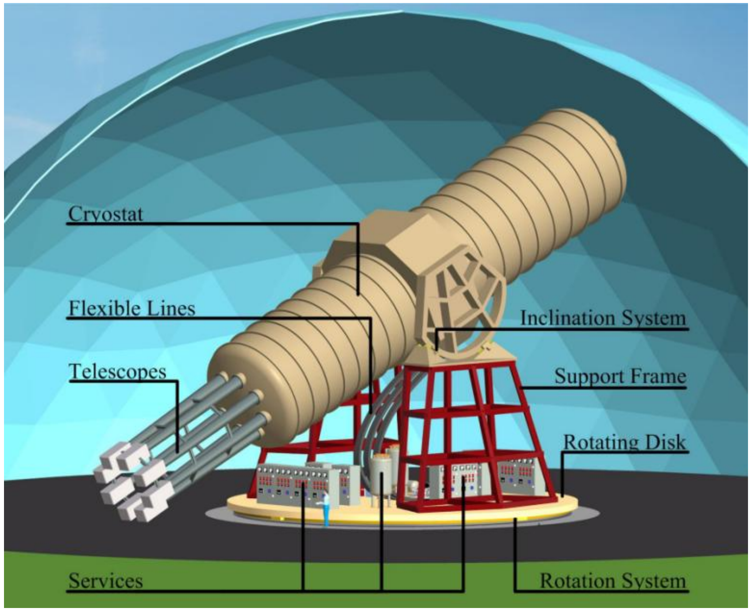
Detector updates:

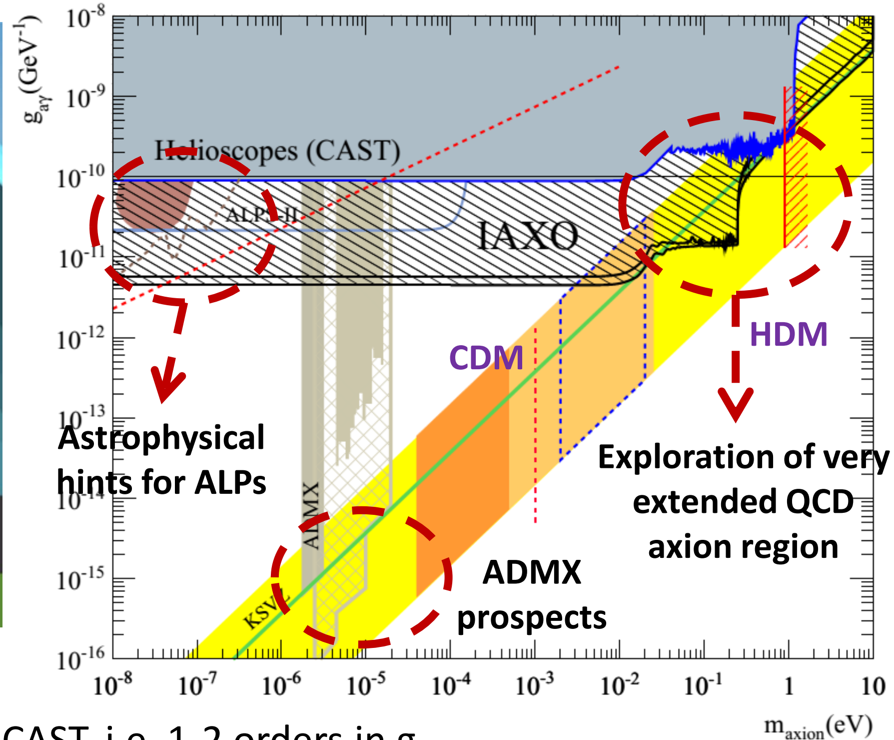
- An x-ray optics will increase the sensitivity of Sunrise detector.
- InGrid micromegas and Silicon Drift Detectors (SDD) are tested.





IAXO: International AXion Observatory





- New generation of axion helioscope.
- 4 orders of magnitude better in S/N wrt CAST, i.e. 1-2 orders in $g_{a\gamma}$.
- New features: toroidal magnet, dedicated optics, low background detectors.
- CAST & ADMX can explore a big part of the axion model region in next decade.
- Potential for new physics: white dwarfs, ALPs, low energy axions…
- Ideas under discussion to explore meV axions (resonant cavities, antenna dishes).
- More details: IAXO-CDR (**2014 JINST 9 T05002**) & NGAH (**JCAP 06 (2011) 013**).

Status of IAXO

- 90 signatures. 38 institutions. Enlarged community interested in IAXO physics.
- In International roadmaps of Europe (**ASPERA/APPEC, ESPP**) & US (**Snowmass**).
- Conceptual Design: **2014 JINST 9 T05002**.
- Letter of Intent presented at CERN-SPSC on 22th Oct 2013: **SPSC-2013-022**.
- Positive recommendations from SPSC.
- Preparation of a MoU to carry out TDR work. Search for new interested partners.
- Several preparatory activities in parallel for the Technical Design Report (TDR):
  - **IAXO-T0**: a demonstration coil.
  - **IAXO-X0**: a prototype x-ray optics.
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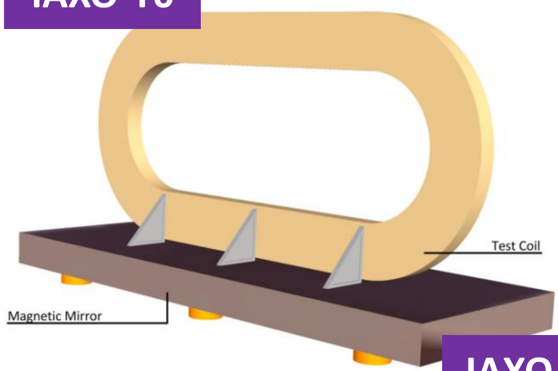
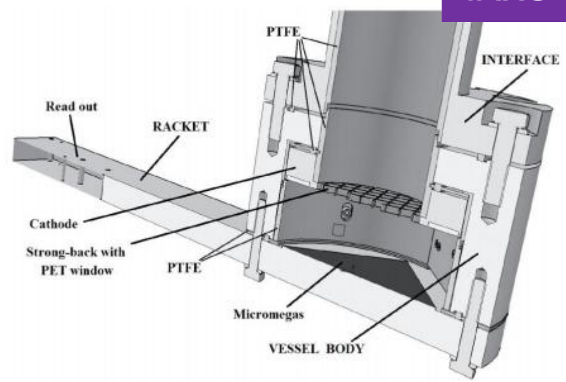
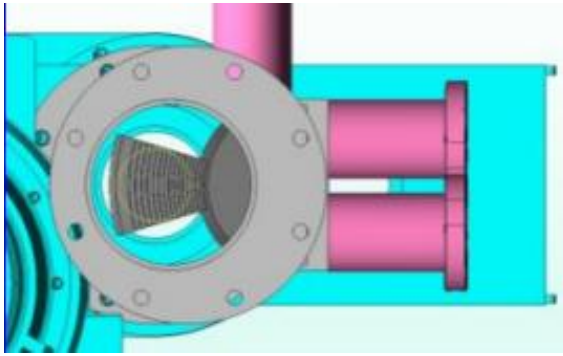
  - **Pathfinder**: a small optics & detector at CAST. The same techniques as for IAXO.

IAXO-T0



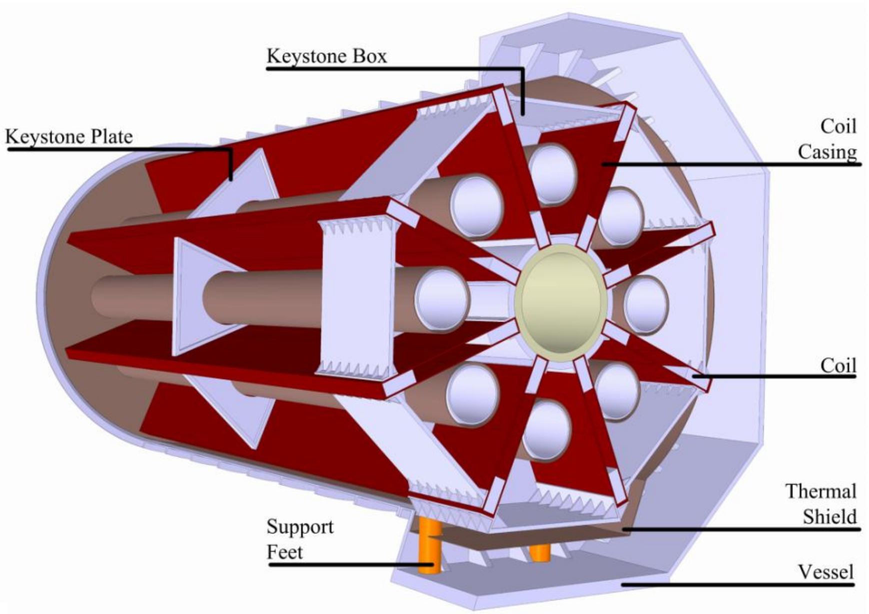
IAXO-XD

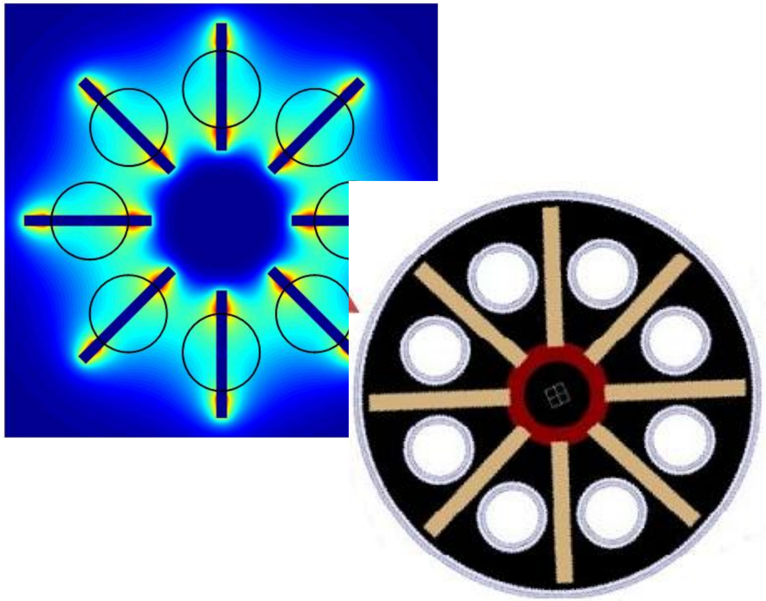




IAXO Magnet

- Large toroidal 8-coil magnet specifically built for axion physics.
- Many technical aspects studied and defined in the CDR.
- Magnetic length: 20 m.
- Bore diameter: 0.6 m.
- IAXO-T0 project to build a test coil.



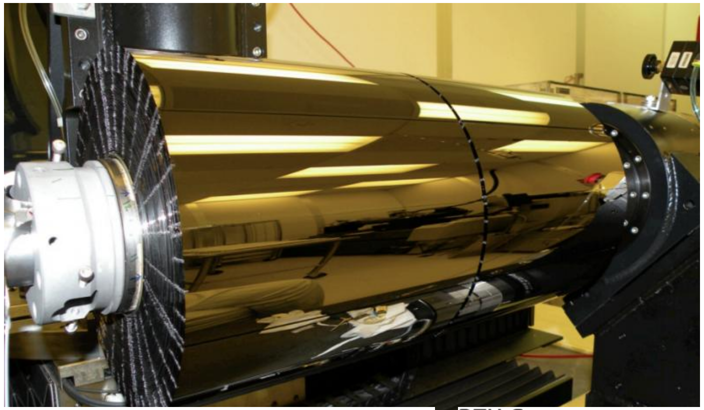


IAXO magnet concept presented in:

- IEEE Trans. Appl. Supercond. 23 (ASC 2012)
- Adv . Cryo. Eng. (CEC/ICMC 2013)
- IEEE Trans. Appl. Supercond. (MT 23)

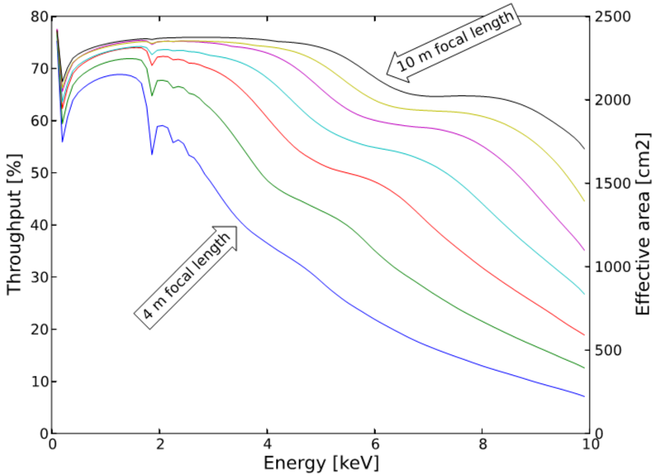
IAXO Optics

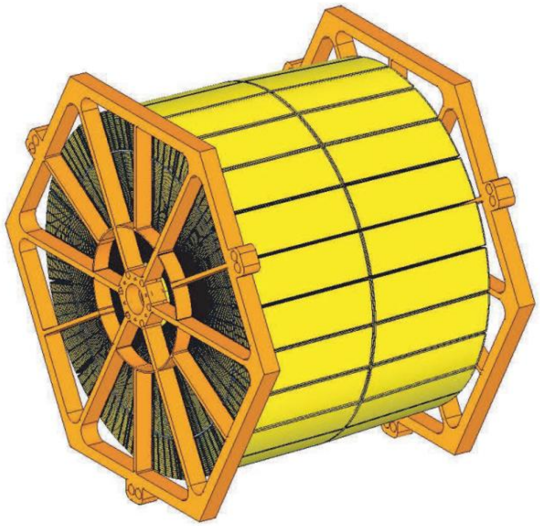
- Technique of choice: optics made of thin glass substrates coated to enhance reflectivity in the energy regions for axions. Used in NuSTAR/HEFT project.
- Optimization study to maximize the efficiency in the focussing power:
- Diameter: 600 mm. Focal length: 10 m.
- First realistic drawings made.
- New telescope for CAST in construction.



Lawrence Livermore National Laboratory

DTU Space
National Space Institute

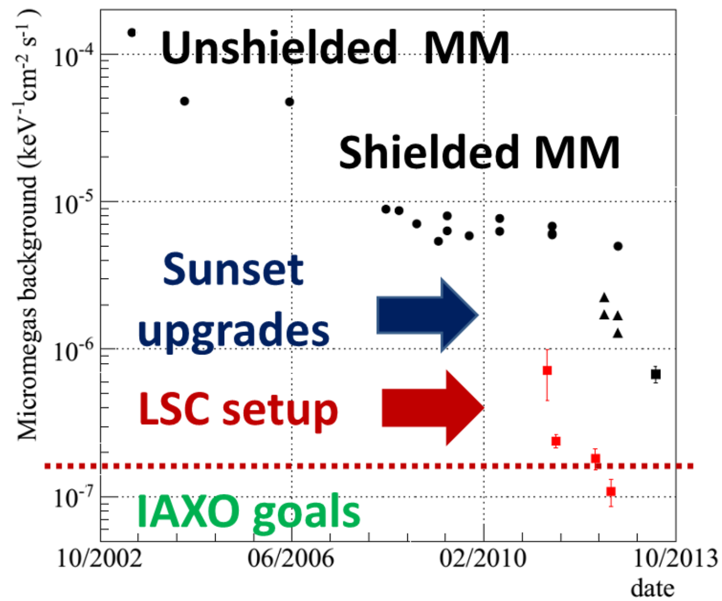




IAXO detector: Microbulk Micromegas

Why are they used in axion searches?

- High power to discriminate x-rays signals from other type of events.
- Intrinsic radiopure (*Astr . Part. 34 (2011) 354*).
- Consolidated manufacture (JINST 5 (2010) P02001, JINST 7 (2012) P04007).
- Shielding techniques from low background experiments can be also applied.



Status of Micromegas for IAXO

- Background levels below **10^{-6} s^{-1}keV^{-1}cm^{-2}** obtained **in CAST** for the first time (2013).
- Levels at **10^{-7} s^{-1}keV^{-1}cm^{-2} at LSC**.
- Roadmap to reach IAXO levels, based on
  - In-situ measurements at CAST.
  - Replica at Canfranc Laboratory (LSC).
  - Geant4 simulations of CAST-MM.

Contribution	Background level in 2-7 keV (counts s^{-1} keV^{-1} cm^{-2})	Technique
Gamma flux	~7 x 10^{-5}	Lead shielding
Muons	2 x 10^{-6} - > 6 x 10^{-7}	Active veto
Al cathode	(5.2 ± 1.2) x 10^{-7}	Cu cathode
Radon	~8 x 10^{-7}	N_2 flux
CAST-LSC lower limit	1.1 x 10^{-7}	Neutrons? Gas purity?

Summary

In the last 12 years, the **CAST experiment**

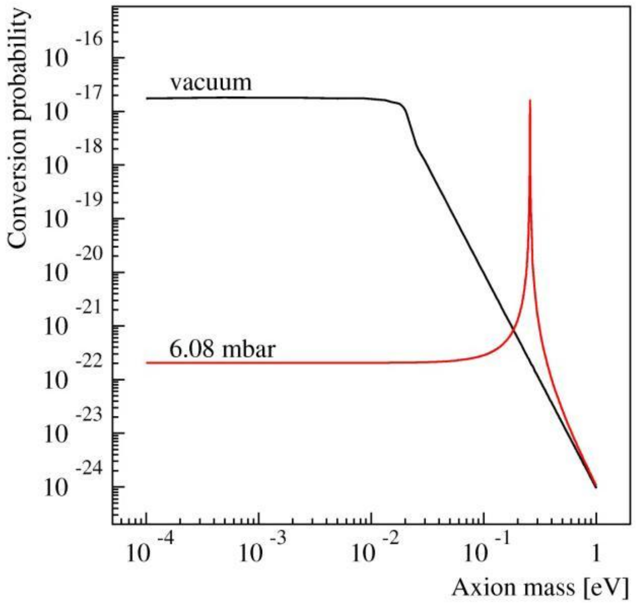
- has put the strictest limit on axion coupling for a wide range of masses and has gained extensive experience on Helioscope Axion Searches.
- has just published the first results of 3He phase (**PRL 112 (2014) 091302**): $\mathbf{g_{a\gamma\gamma} \lesssim 3.3 \times 10^{-10}\ GeV^{-1}}$ (95% CL) for $\mathbf{0.64\ eV < m_a < 1.17\ eV}$.
- is revisiting the vacuum phase to increase the sensitivity and explore other exotica like solar chamaleons, paraphotons, improve the LE setup.

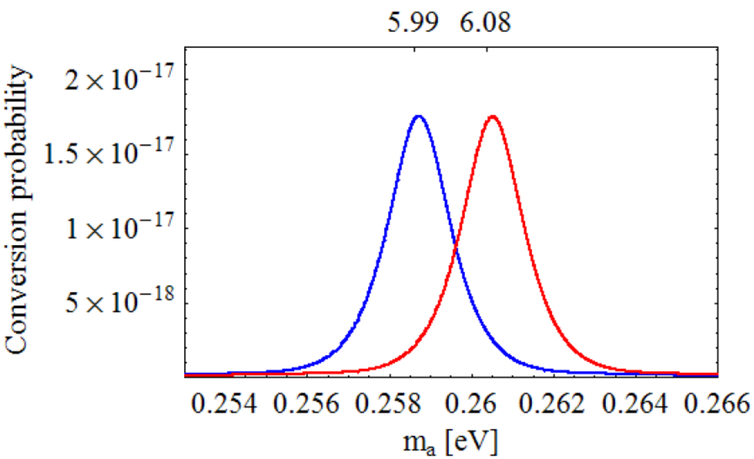
The future is the **International Axion Observatory (IAXO)** which

- will improve on CAST results more than one order of magnitude.
- will use a dedicated magnet, large area optics and low background detectors.
- can explore a big part of axion models in next decade together with ADMX.
- has published its LoI (**SPSC-2013-022**) & CDR (**2014 JINST 9 T05002**).
- develops several activities for the TDR: test coil, optics, detectors,…

Back-up slides

The detection probability





Axion to photon conversion probability

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

L = magnet lenght,
Γ = absorption coefficient

Coherence condition: $qL < \pi$, $|q| = \frac{m_a^2}{2E}$

For CAST phase I (vacuum), coherence is lost for $m_a > 0.02$ eV

With the presence of a buffer gas, the coherence can be restored for a narrow mass range

$$qL < \pi \Rightarrow \sqrt{m_\gamma^2 - \frac{2\pi E_a}{L}} < m_a < \sqrt{m_\gamma^2 + \frac{2\pi E_a}{L}}$$

Axion helioscope update: the status of CAST & IAXO, F.J. Iguaz et al.

Axion as Dark Matter candidate

- Axions are produced in the early Universe by a number of processes:
  - Axion realignment
  - Decay of axion strings
  - Decay of axion walls

→ **Non relativistic COLD AXIONS**

- Axion mass giving the right CDM density? Depends on cosmological assumptions:
  - "classical window": around 10^{-5}-10^{-3} eV
  - "anthropic window" ~ much lower masses possible
  - Other subdominant CDM / non standard scenarios

- Thermal production
  - Axion masses **ma > ~0.9 eV** gives densities too much in excess to be compatible with latest CMB.

Hannestad et al, JCAP 08 (2010) 001

→ **Relativistic HOT AXIONS**

What is the motivation of axions?

- Most compelling solution to the Strong CP problem of the SM.
- Axion-like particles (ALPs) predicted by many extensions of the Standard Model (like the string theory)
- Axions, like WIMPs, may solve the Dark Matter (DM) problem for free. (i.e. not an ad hoc solution to DM).
- Astrophysical hints for axion/ALPs?
  - Transparency of the Universe to UHE gammas.
  - White dwarfs anomalous cooling point to few meV axions
- Relevant axion/ALP parameter space at reach of current and near-future experiments
- Still too little experimental efforts devoted to axions when compared to WIMPs.

CERN SPSC recommendations (Jan 2014)

*The Committee **recognizes 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 **encourage**s 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 r**ecommends** that the R&D for the TDR should be pursuit within **an MOU** involving all interested parties.*

IAXO in astroparticle roadmaps

- **ASPERA/APPEC Roadmap** acknowledges axion physics, CAST, and **recommends** progress towards IAXO.

> "...A CAST follow-up is discussed as part of CERN's physics landscape (new magnets, new cryogenic and X-ray devices). The Science Advisory Committee **supports** R&D on this follow up, as well as smaller ongoing activities on the search for axions and axion-like particles."

C. Spiering, ESPP Krakow

- Important community input in the **European Strategy for Particle Physics**
- Presence in the Briefing Book of the ESPP, which reflects also APPEC roadmap recommendations.
- **ESPP recommends CERN to follow APPEC recommendations.**
- Important effort in relation with US roadmapping (Snowmass, and P5 process). **Snowmass reports speak very favorably of axion physics and IAXO.**

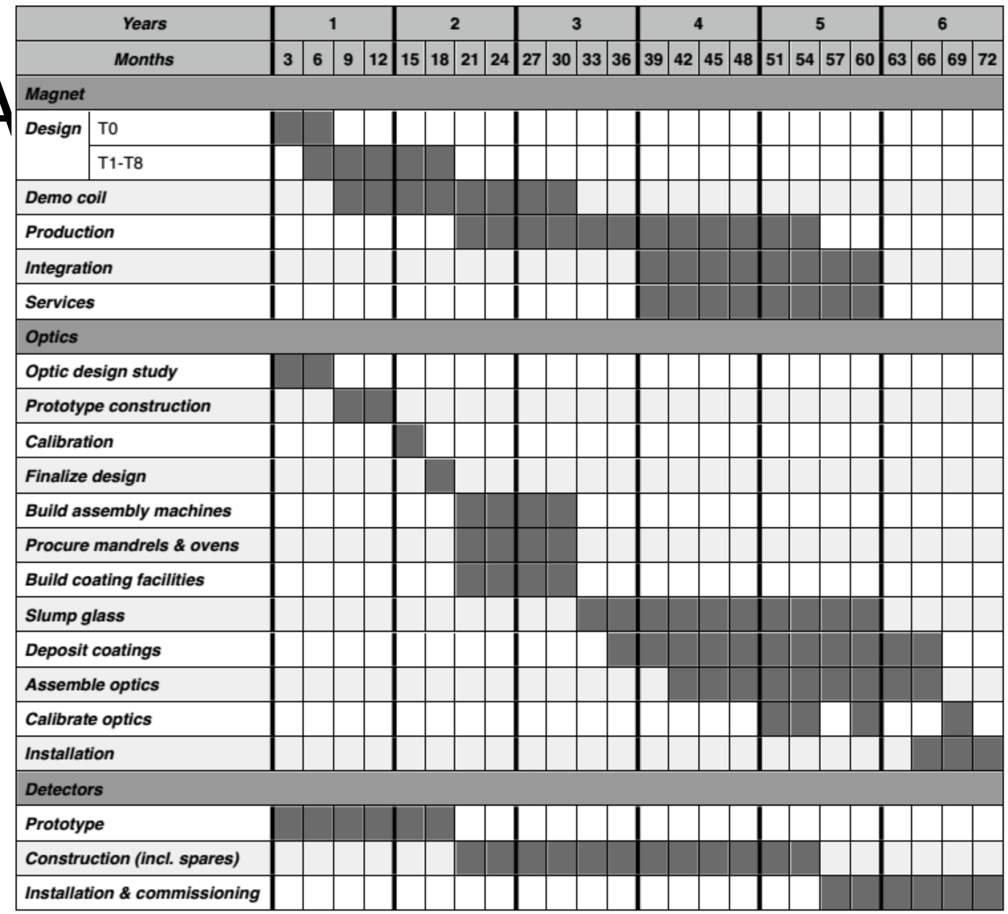
Signal-to-noise ratio of IAXO

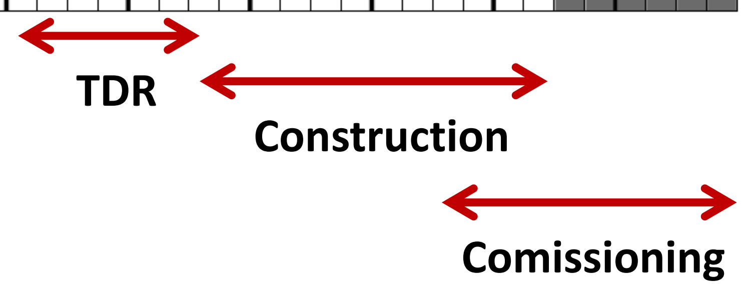
Parameter	Units	CAST-I	IAXO Nominal	IAXO Enhanced
B	T	9	2.5	2.5
L	m	9.26	20	20
A	m^2	2×0.0015	2.3	2.3
f^*_M		1	300	300
b	$\frac{10^{-5}\,c}{\mathrm{keV\,cm^2\,s}}$	~ 4	5×10^{-3}	10^{-3}
ϵ_d		0.5 – 0.9	0.7	0.8
ϵ_o		0.3	0.5	0.7
a	cm^2	0.15	8×0.2	8×0.15
f^*_{DO}		1	17	60
ϵ_t		0.12	0.5	0.5
t	year	~ 1	3	3
f^*_T		1	3.5	3.5
f^*		1	2×10^4	6×10^4

Table 3: Values of the relevant experimental parameters representative of IAXO, both the *nominal* and *enhanced* ones, based on the considerations explained in section 4. They are compared to the ones representing the CAST vacuum phase result (CAST-I) [59]. Numbers shown for the figures of merit (equation 11) are relative to CAST-I, i. e. $f^* = f/f_{\mathrm{CAST}}$, and are approximate.

Axion helioscope update: the status of CAST & IAXO, F.J. Iguaz et al.

IA





- TDR + preparatory activites: 1.5 years.
- Construction: 3.5 years.
- Integration & comissioning: 2.5 years.
- Total: **6 years**.

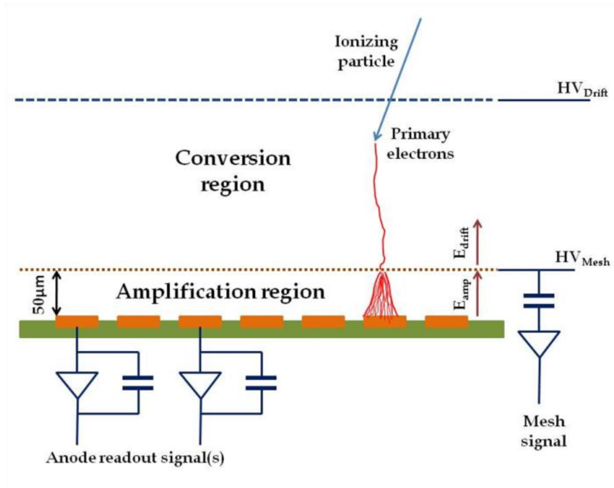
IAXO costs

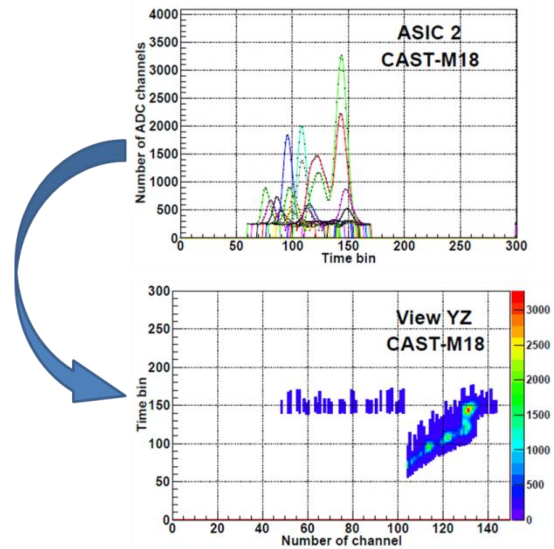
Item	Cost (MCHF)	Subtotals (MCHF)
Magnet		31.3
Eight coils based assembled toroid	28	
Magnet services	3.3	
Optics		16.0
Prototype Optic: Design, Fabrication, Calibration, Analysis	1.0	
IAXO telescopes (8 + 1 spare)	8.0	
Calibration	2.0	
Integration and alignment	5.0	
Detectors		5.8
Shielding & mechanics	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.

Laboratory engineering, maintenance & operation and physics exploitation not included

Micromegas for axion searches

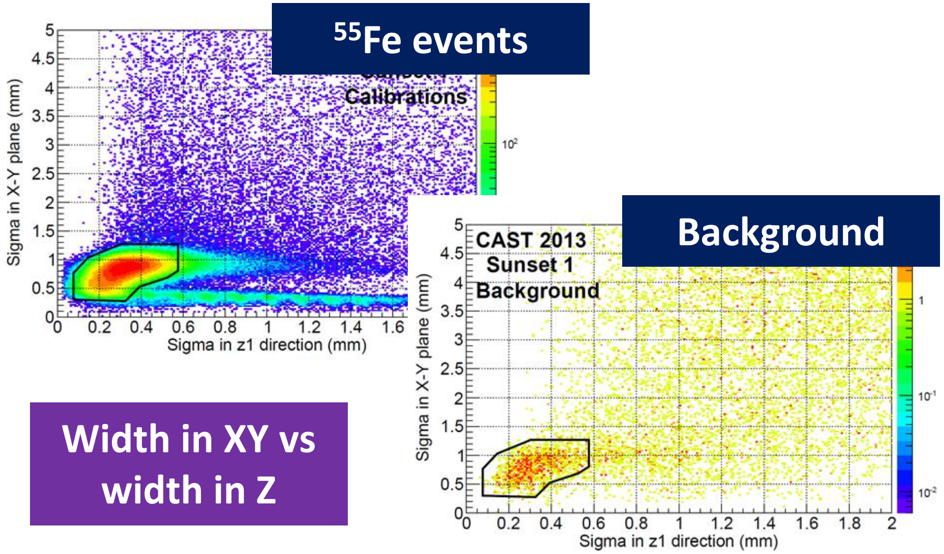




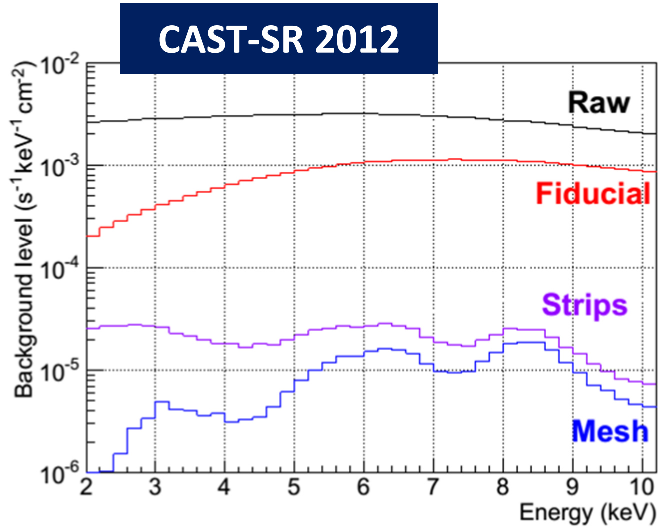
It is an amplification structure used as readout in a Time Projection Chamber (**Y. Giomataris, NIMA 376 (1996) 29**).

- Excellent energy resolution (**12% FWHM at 5.9 keV**).
- High power to discriminate x-rays signals from other type of events.
- Intrinsic radioupure (**S. Cebrian et al, Astr. Part. 34 (2011) 354**).
- Consolidated manufacture (**microbulk technique**) & stable in time (**S. Adriamonje et al., JINST 5 (2010) P02001**).

Micromegas for axion searches



Width in XY vs width in Z



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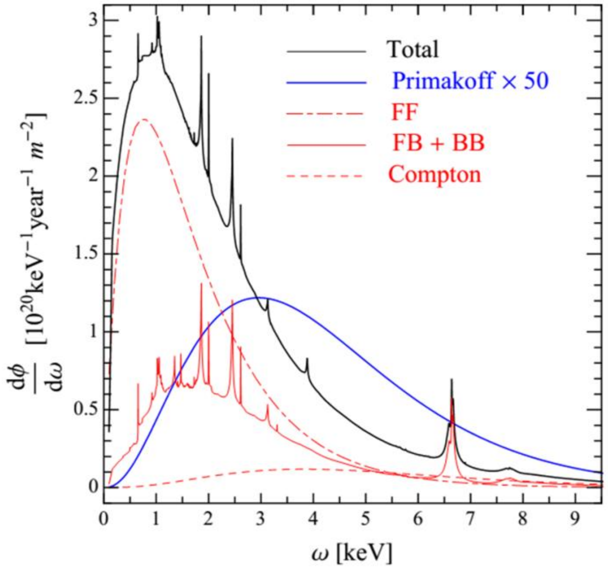
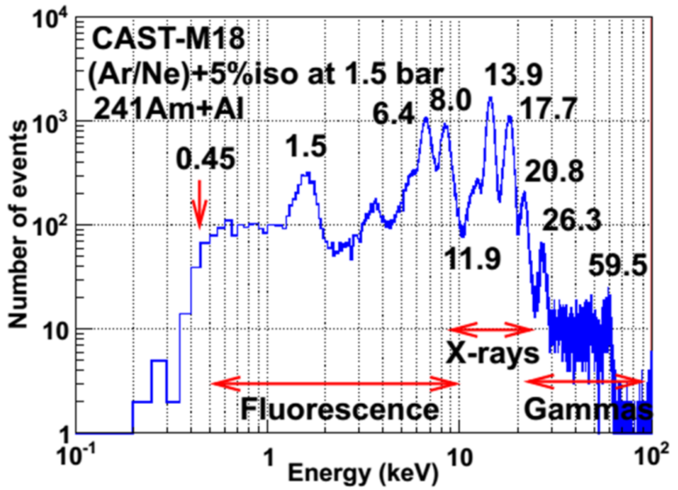
Lowering the energy threshold of CAST

Physics motivation:

- In non-hadronic axion models, the Sun produces axions by BCA processes.
- The expected axion flux peaks at sub-keV energies.



J. Redondo, *JCAP 12* (2013) 008
K. Barth et al, *JCAP* 05 (2013) 010



S. Aune et al, JINST *9* (2014) P01001

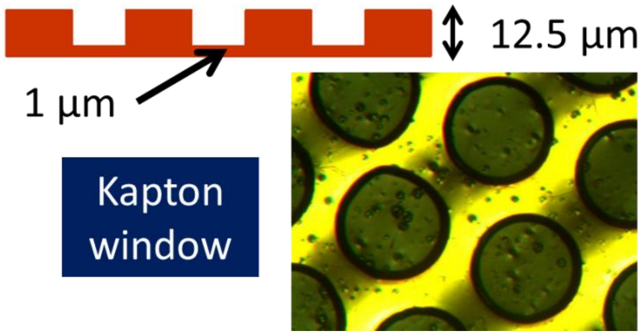
Is it feasible for x-ray detectors?

- Evident for CCD & SDD.
- To be verified by MM & Ingrid.

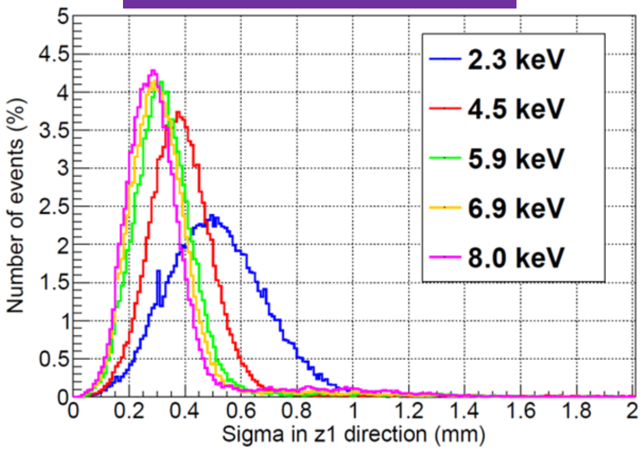
Lowering the energy threshold of CAST

R&D on this direction for Micromegas:

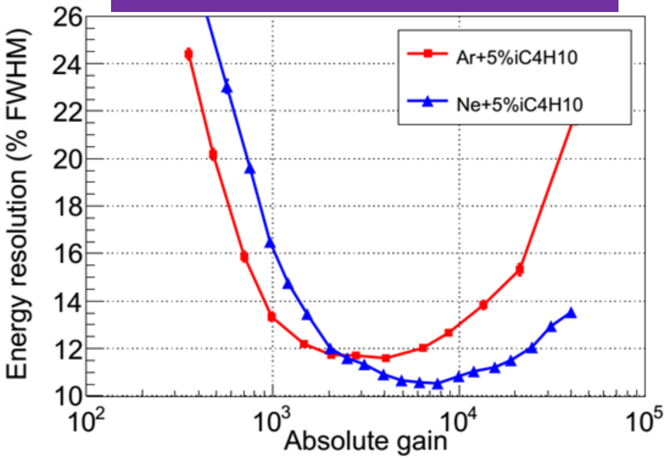
- New thin windows for CAST detectors.
- Autotrigger electronics **AGET.**
  (S. Anvar et al, NSS/MIC/RTSD IEEE 2011)
- New analysis based on x-rays calibrations.
- Neon-based mixture: higher gain
  (**F.J. Iguaz et al, JINST 7 (2012) P04007**).

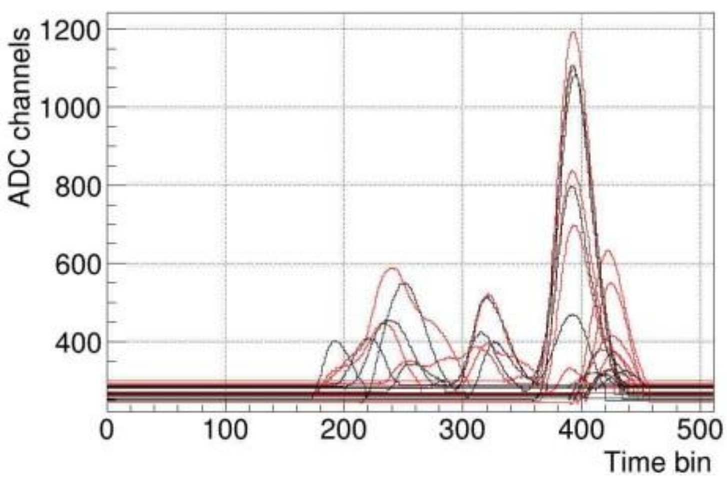


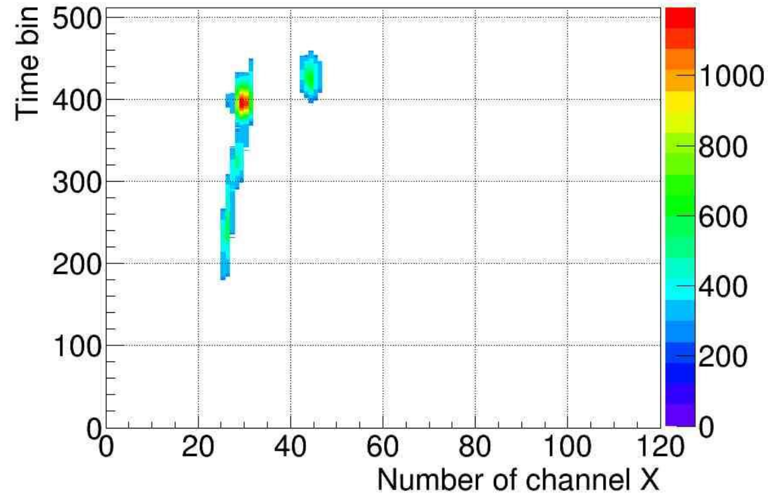
Cluster width in z

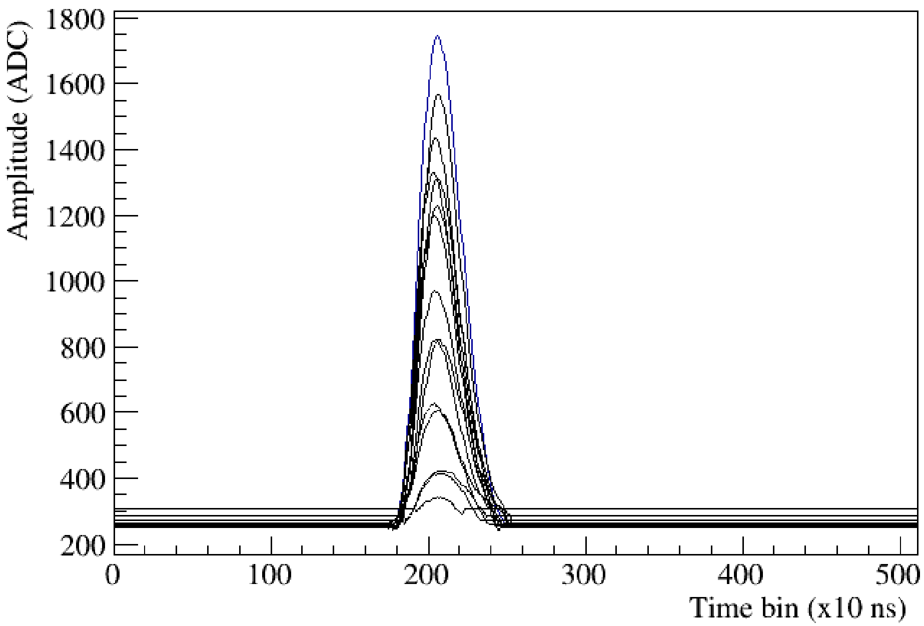


Energy resolution vs gain

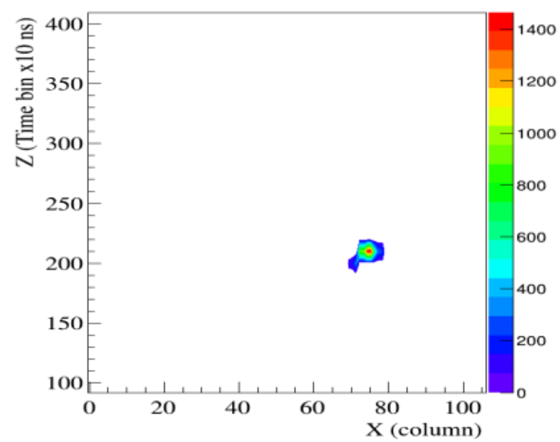



ADC channels
1200
1000
800
600
400
0
100
200
300
400
500
Time bin


Time bin
500
400
300
200
100
0
20
40
60
80
100
120
Number of channel X
1000
800
600
400
200


Amplitude (ADC)
1800
1600
1400
1200
1000
800
600
400
200
0
100
200
300
400
500
Time bin (x10 ns)

XZ view


Z (Time bin x10 ns)
400
350
300
250
200
150
100
0
20
40
60
80
100
X (column)
1400
1200
1000
800
600
400
200