Irfu - CEA Saclay
Institut de recherche sur les lois fondamentales de l'Univers

107th Meeting of the SPSC

23/10/2012

Status & plans of the CAST experiment

Thomas Papaevangelou
CEA Saclay
On behalf of the
CAST Collaboration

Outline

Introduction - CAST physics

Status report

- Shutdown in 2011 – 2012
  - ✓ Buffer gas
  - ✓ CFD
  - ✓ GRID – tracking
  - ✓ Filming
- Datataking 2012
- Detector performance
- Analysis status

Request for running in 2013-2014

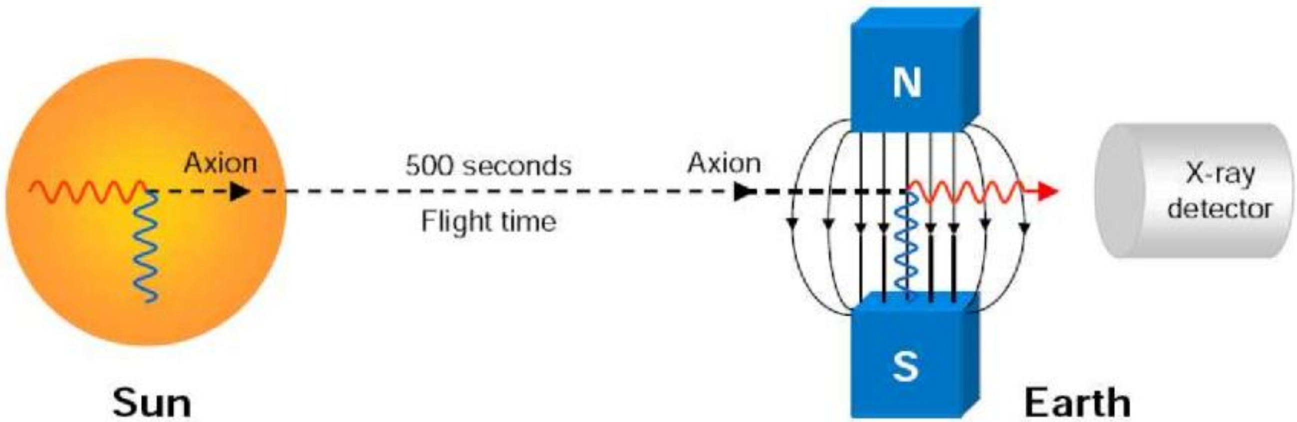
- Physics
  - ✓ Axions/ALPs
  - ✓ Sub-keV WISPs – Chameleons
- Detectors
- Request to CERN

Conclusions

CAST Physics

The "à la Sikivie" helioscope

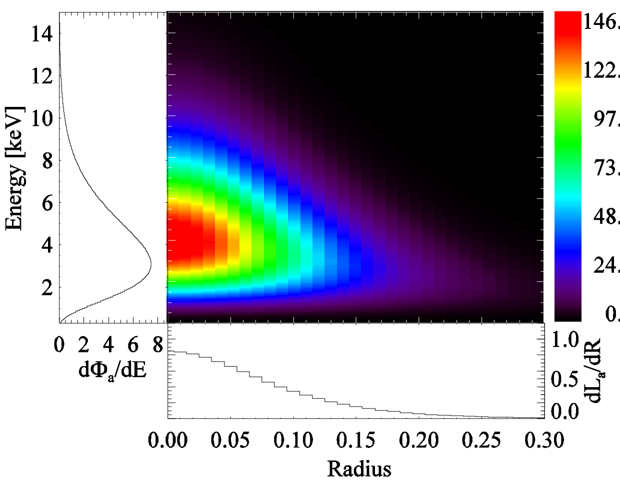
Axions would be **produced in the Sun's core** and re-converted **to X-rays** inside an **intense magnetic field**. *P. Sikivie, Phys. Rev. Lett. 51, 1415-1417 (1983)*



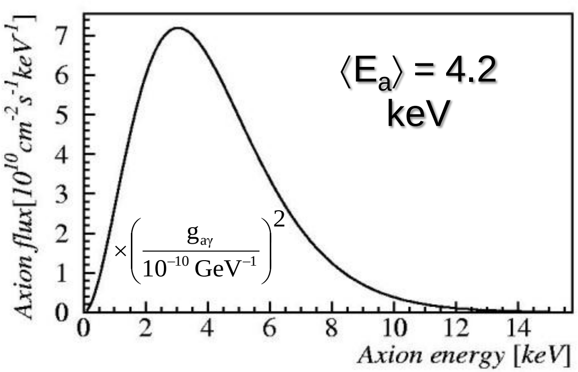
Expected number of photons:

$$N_\gamma = \Phi_a \cdot A \cdot P_{a\to\gamma}$$

Solar axion luminosity



Axion flux on earth



Expected signal

X-Ray excess during solar alignment at 1-10 keV region

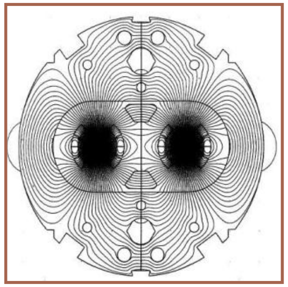
CAST sensitivity per detector

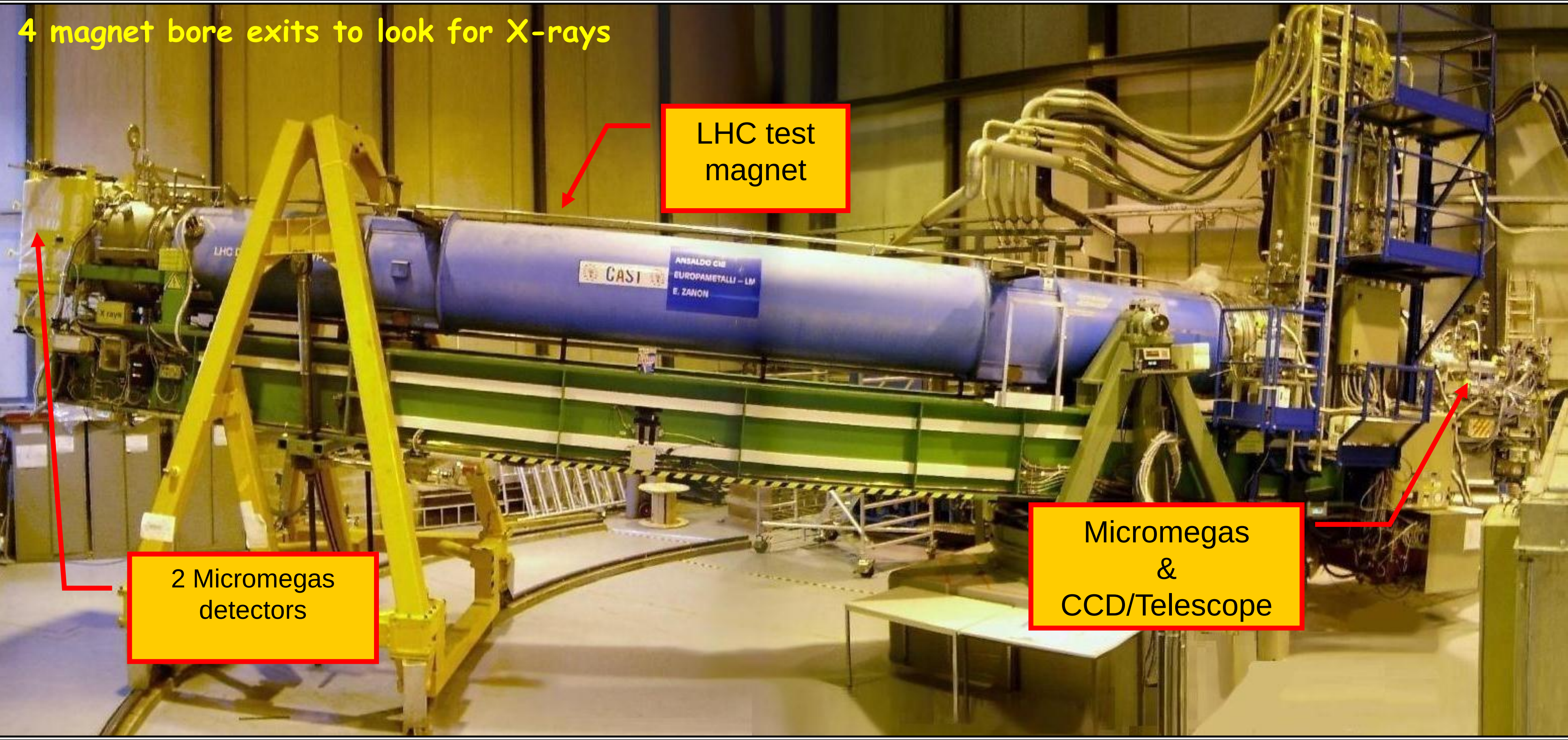
0.3 counts/hour for $g_{a\gamma\gamma} = 10^{-10}$ GeV^{-1} and $A = 14.5$ cm^2

CAST

CAST is using a prototype superconducting LHC dipole magnet able to track the Sun for about 1.5 hours during Sunrise and Sunset.

Operation at T=1.8 K, I=13,000A, B≈9T, L=9.26m



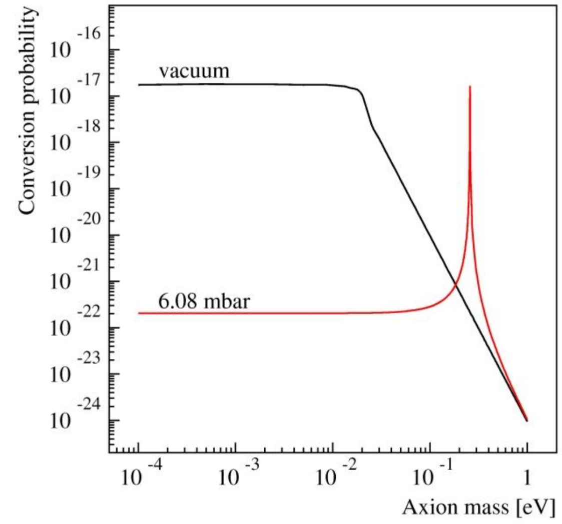


CAST Sensitivity

Axion to photon conversion probability:

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

Vacuum:
Γ=0, m_γ=0



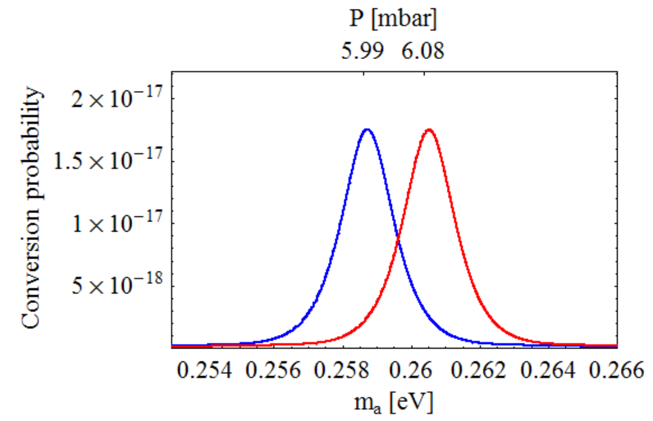
Coherence condition: *qL < π ,* $|q| = \frac{m_a^2}{2E}$

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

With the presence of a **buffer gas** it can be **restored** for a narrow mass range:

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

with $m_\gamma = \sqrt{\frac{4\pi\alpha N_e}{m_e}} \approx 28.9\sqrt{\frac{Z}{A}\rho} \quad eV$



- New discovery potential for each density (pressure) setting

Physics Program & main results

Proposal approved by CERN **(13th April 2000)**

Commissioning **(2002)**

CAST Phase I: **vacuum operation (2003 - 2004)**
completed

CAST Phase II: **(2005–2011)**

^{4}He run, (2005–2006) ***completed***

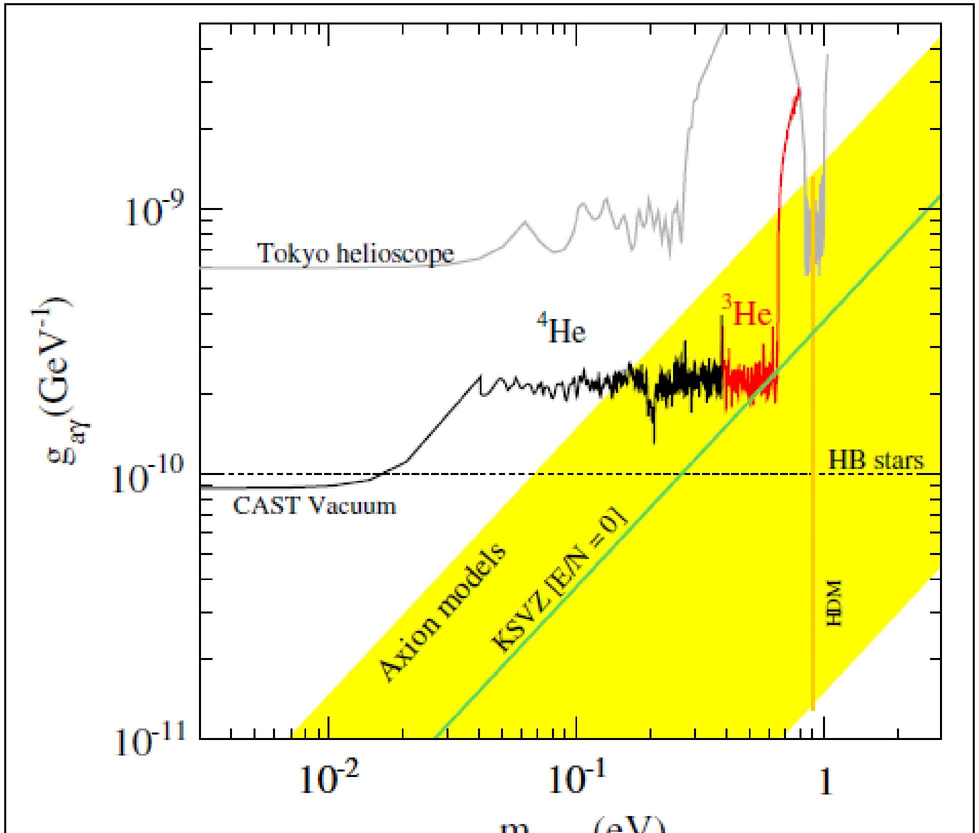
0.02 eV < m_a < 0.39 eV

^{3}He run (2007-2011) ***completed***
ongoing analysis

0.39 eV <m_a<~1.20 eV

^{4}He run, (2012) ***completed***

0.39 eV < m_a < 0.42 eV



PRL (**2011**) 107, 261302

2013-2014: Proposal to SPSC for ***Start of 3rd CAST phase,***
solar axions & chameleons

Low energy ALPs (2007 – 2011) in parallel with the main program **~ few eV range**

Physics Program & main results

Proposal approved by CERN **(13th April 2000)**

Commissioning **(2002)**

CAST Phase I: **vacuum operation (2003 - 2004)**
completed

CAST Phase II: **(2005–2011)**

^{4}He run, (2005–2006) ***completed***

0.02 eV < m_a < 0.39 eV

^{3}He run (2007-2011) ***completed***
ongoing analysis

0.39 eV <m_a<~1.20 eV

^{4}He run, (2012) ***completed***

0.39 eV < m_a < 0.42 eV

2013-2014: Proposal to SPSC for ***Start of 3rd CAST phase, solar axions & chameleons***

Low energy ALPs (2007 – 2011) in parallel with the main program **~ few eV range**

For m_a < 0.02 eV:

$$g_{a\gamma} < 0.88 \times 10^{-10}\ GeV^{-1}$$

JCAP04(**2007**)010, CAST Collaboration

PRL (**2005**) 94, 121301, CAST Collaboration

For m_a < 0.39 eV typical upper limit:

$$g_{a\gamma} < 2.2 \times 10^{-10}\ GeV^{-1}$$

JCAP 0902:008,**2009**, CAST Collaboration

For 0.39 <m_a < 0.64 eV typical limit:

$$g_{a\gamma} < 2.1 \times 10^{-10}\ GeV^{-1}$$

PRL (**2011**) 107, 261302, CAST Collaboration

CAST byproducts:

High Energy Axions: Data taking with a HE calorimeter (JCAP 1003:032,2010)

14.4 keV Axions: TPC data (JCAP 0912:002,2009)

Low Energy (visible) Axions: Data taking with a PMT/APD. (arXiv:0809.4581)

2012 upgrades & run

2011 – 2012 shutdown

Upgrades to CAST Magnet

- Replacement of magnet power cables
- Wheel bearings and central pivot bearings
- Replacement of magnet chariot lifting Jacks
- Movement tests, tracking tests, GRID

Cryogenics:

- New oil pump and proximity pipework primary pump
- Replacement & revision of damaged gearbox

^{3}He extraction:

- System designed, constructed and tested in collaboration between CAST, the CERN Cryolab and LLNL.
- Extraction by
  - ✓ liquefying the gas in pressurization volume @ 2 K
  - ✓ evaporation and pressurization into the LLNL transport cylinder
- Shipped back to LLNL

Buffer gas system:

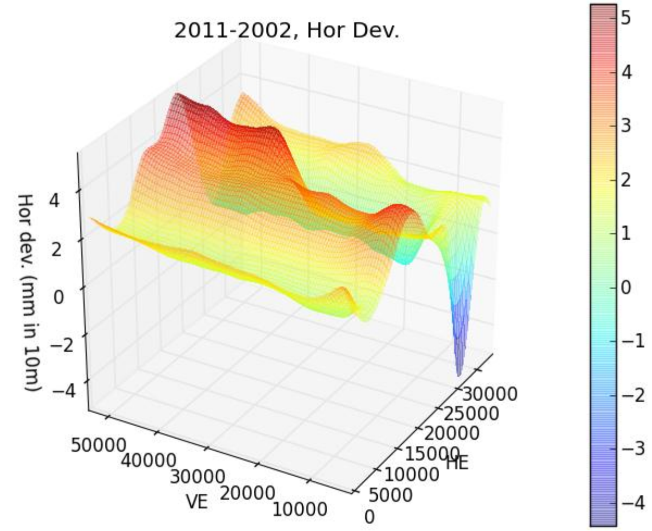
- The existing ^{3}He system was used, filled with ^{4}He

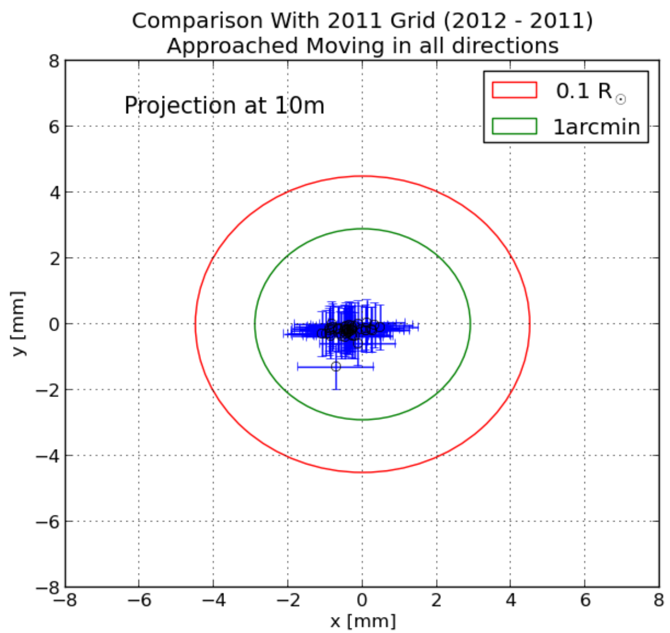
GRID measurements

GRID measurements are performed to establish a connection between the angle space and encoder space

- Up to 2011, the **2002 grid** was used to define movement of the magnet.
- Changes in magnet movement system ➔ *deviation of real movement from 2002 GRID*
- 2011 November: full GRID measurements
- 2012 June:
  - ✓ new GRID implemented into tracking software
  - ✓ GRID measurements to check consistency
- New GRID increased our accuracy:
  from maximum error 4-5 mm in 10 m
  to 1 mm in 10 m

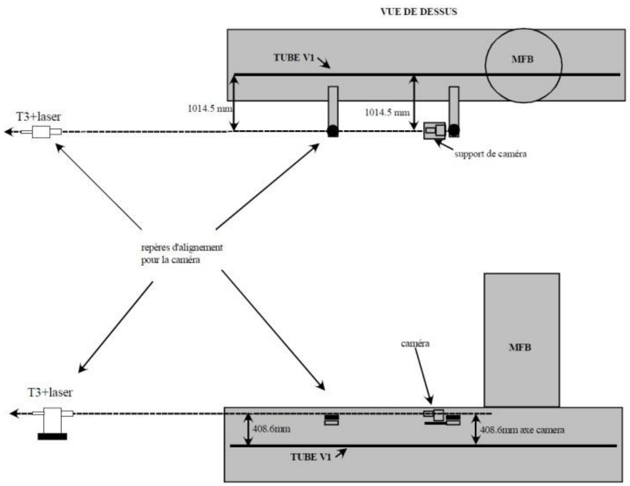
- *A new full grid will be done in 2012 shutdown to crosscheck the 2011 grid, and replace if necessary.*



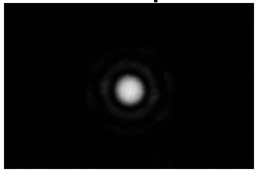


Sun filming 2012

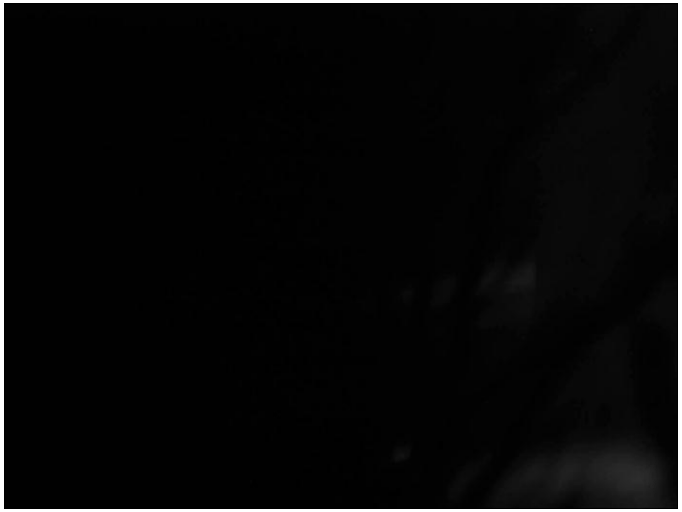
- **Direct optical check** (tracking the sun applying a correction for optical refraction)
- Camera aligned with laser beam parallel to CAST cold bore 1 axis (X-ray telescope)
- Twice per year, ~10 days (March/September)
  - ! Weather conditions
- Analysis of images



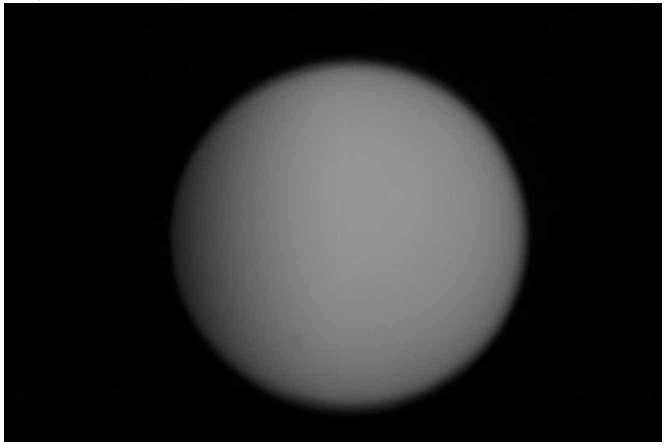
Laser spot



March 2012



September 2012



Sun filming 2012 results

September 2012 filming:

- ✓ 1.2mm/10m ahead
- ✓ 1.7mm/10m above

the center of the Sun.

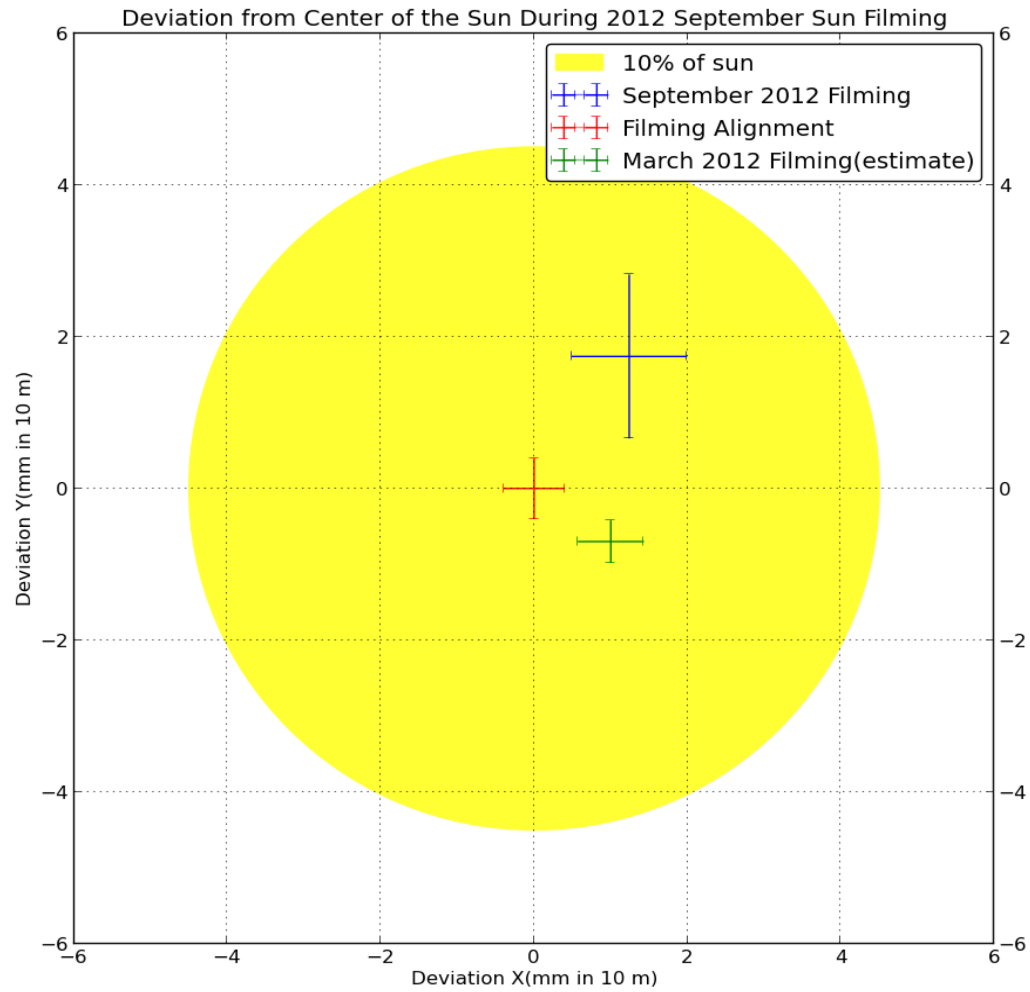
March 2012 filming:

- ✓ 1.0mm/10m ahead
- ✓ 0.7mm/10m below

the center of the Sun.

(corrected for the 2011-2002 GRID difference)

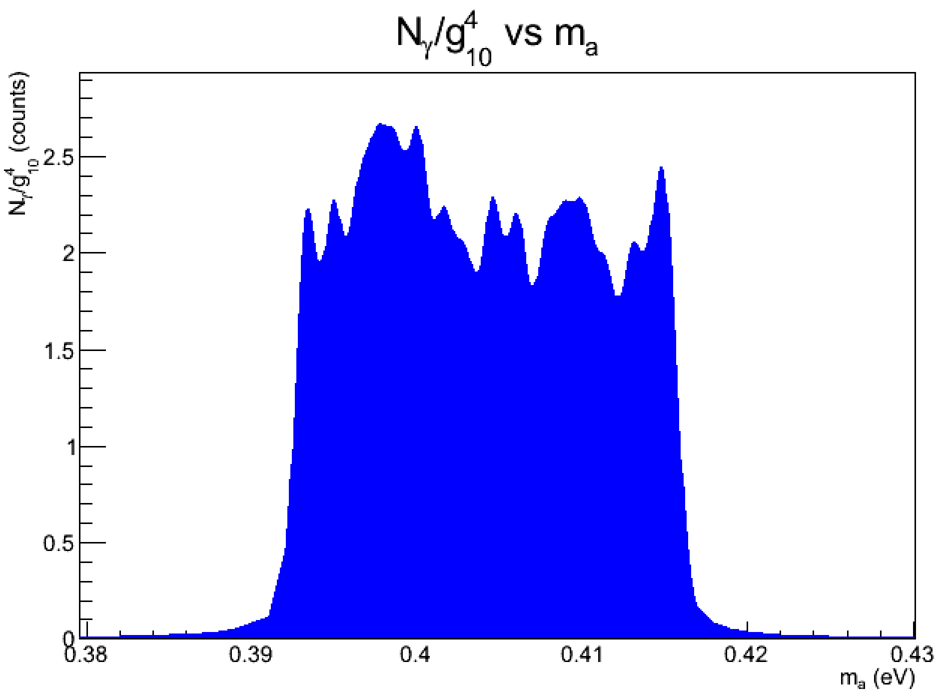
Sun filming precision similar to GRID precision !!!



Data taking 2012

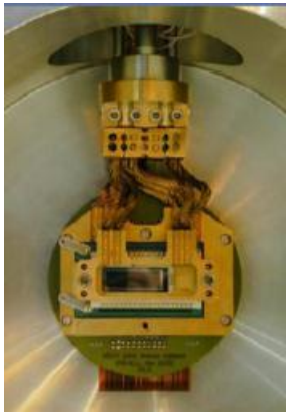
Goal: Revisit, with **improved sensitivity** and **longer exposures**, a narrow part of a theoretically motivated range of axion masses around 0.4 eV using ^{4}**He** as a buffer gas.

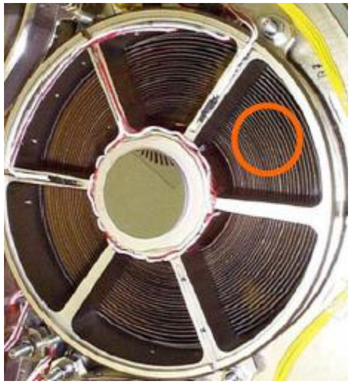
- Data taking period: **22nd June - 7th October**
- Pressure range: 13.9 – 15.5 mbar @ 1.8 K (axion masses: 0.39 – 0.42 eV)
- Measurement time ~ 5 solar trackings per detector & per pressure setting
- 17 settings covered as scheduled (pressure step size 0.1 mbar)
- *Overall data taking efficiency: 79%*
- 2 additional weeks to revisit a density setting with statistical excess.

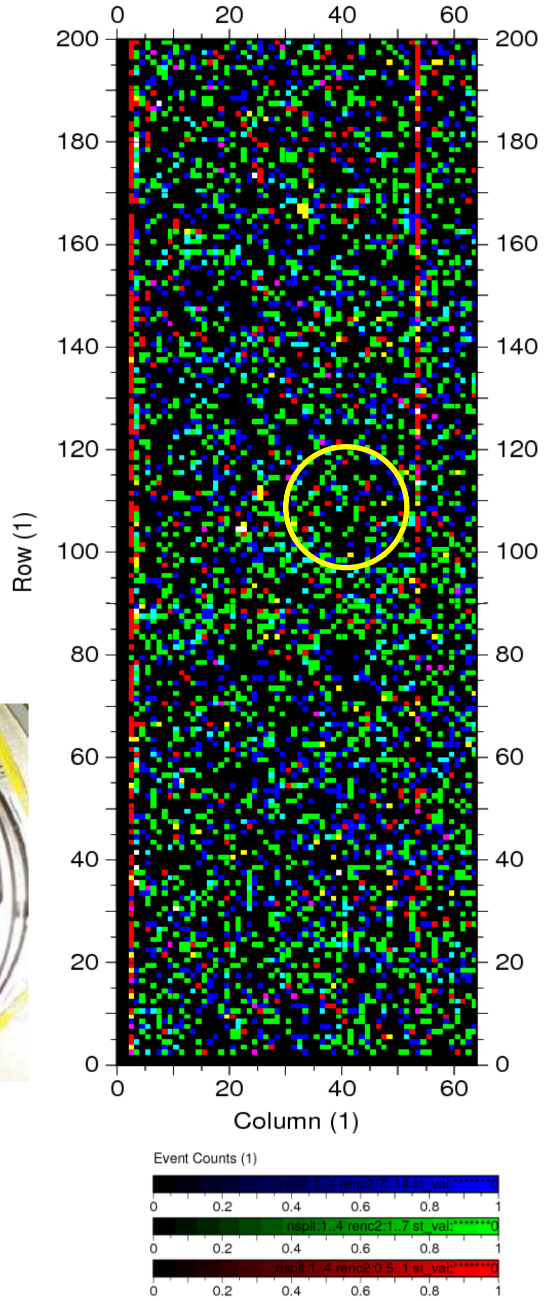


CCD + X-ray telescope

- No major changes to the system compared to 2011
- Reliable operation of CCD during 2012 (84 trackings - efficiency 92%)
- 3 additional noisy pixels on the CCD: removed by analysis
- Alignment of telescope and detector has been checked before the current run
- Long term stability of the detector is good (checked with ^{55}Fe calibration source)
- 123.2 hours of axion sensitive time (first 82 trackings)
- Rates:
  - ✓ $8.2 \times 10^{-5}\ s^{-1}\ keV^{-1}\ cm^{-2}$ (whole chip)
  - ✓ $8.9 \times 10^{-5}\ s^{-1}\ keV^{-1}\ cm^{-2}$ (signal region)
  - ✓ 22 events in the signal region
- **~ 0.3 counts / tracking**

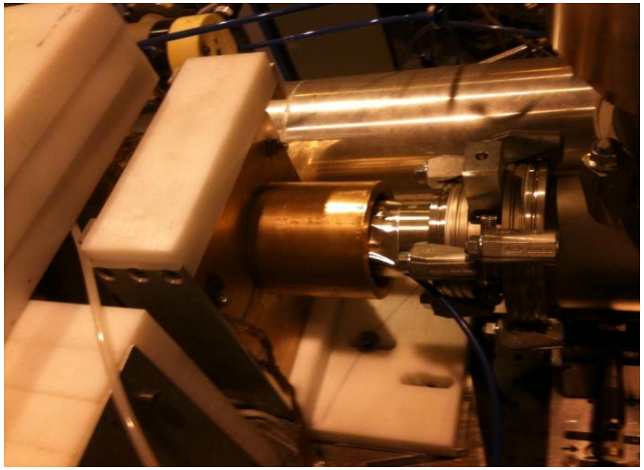




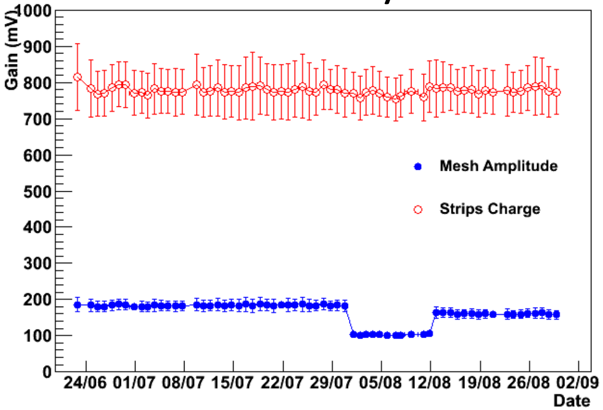


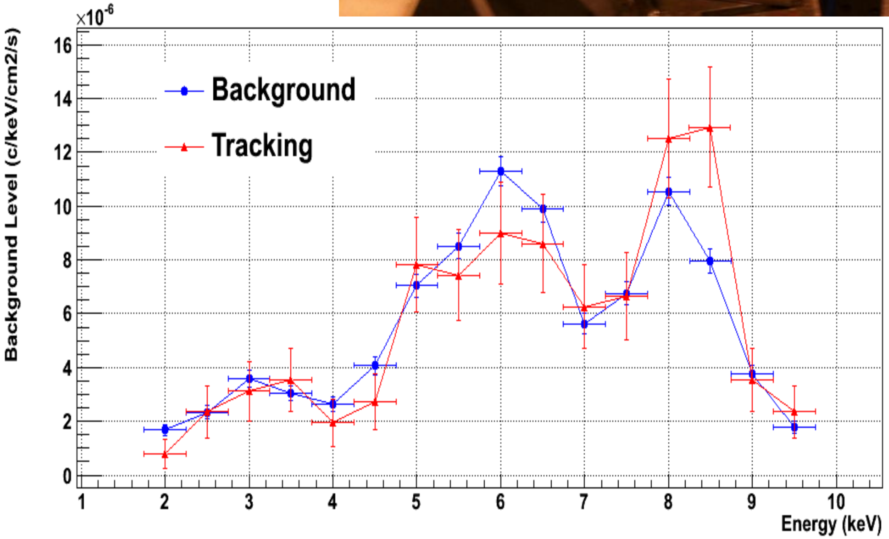
Sunrise Micromegas

- No major modifications compared to 2011
- Reliable operation
  (89 trackings - efficiency 96%)
- Stable & good performance
- **~ 2 counts / tracking**

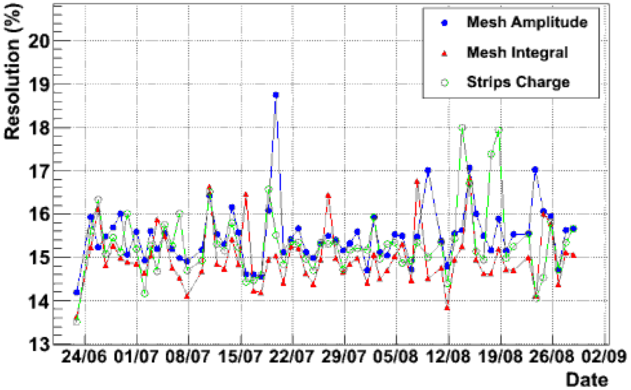


Gain stability





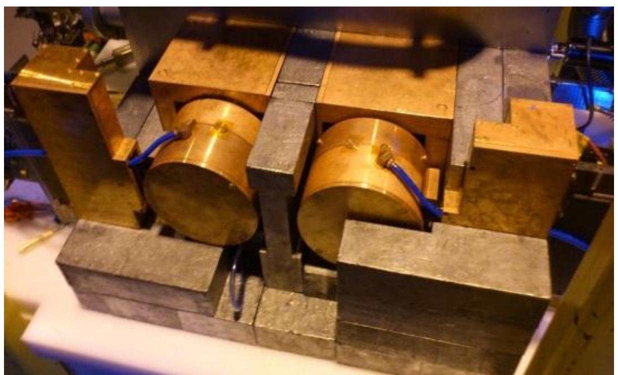
Energy resolution



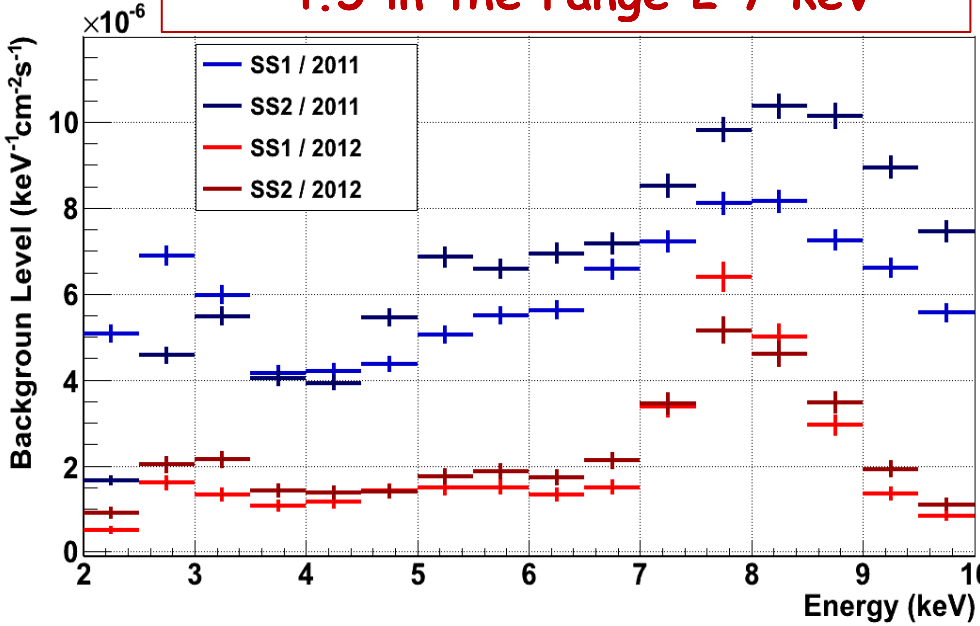
Background time (hours)	Tracking time (hours)	Background rate [2-7] keV ($\times 10^{-6}$ $keV^{-1}cm^{-2}s^{-1}$)	Tracking rate [2-7] keV ($\times 10^{-6}$ $keV^{-1}cm^{-2}s^{-1}$)
1540	102	5.0 ± 0.1	4.4 ± 0.4

Sunset Micromegas

- Installation of new detectors (tested in the CAST detector lab)
- Upgrade of detector shielding
  - ✓ 1 cm Copper shielding
  - ✓ Copper window strongback
  - ✓ Copper interface-to-magnet-tubes + Teflon coating
  - ✓ 10 cm lead
  - ✓ Muon veto



Background reduction by factor ~4.5 in the range 2–7 keV



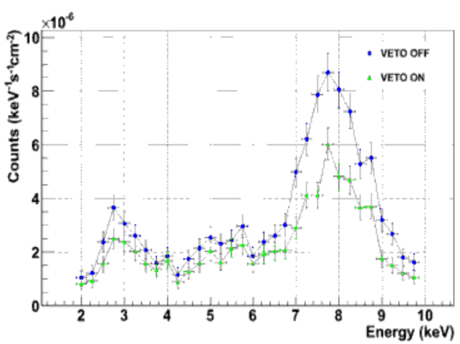
Detector / Year	Background [2-7] keV ($\times 10^{-6}$ keV^{-1}cm^{-2}s^{-1})	Tracking [2-7] keV ($\times 10^{-6}$ keV^{-1}cm^{-2}s^{-1})	FOM_{DET}
Sunset 1 / 2012	**1.29 ± 0.07**	**1.1 ± 0.2**	**506**
Sunset 2 / 2012	**1.69 ± 0.07**	**1.9 ± 0.3**	**442**
Sunset 1 /2011	*5.97 ± 0.11*	*6.6 ± 0.6*	*235*
Sunset 2 /2011	*6.83 ± 0.11*	*7.5 ± 0.6*	*201*

Sunset Micromegas

- Reliable operation (91 trackings - efficiency > 99%)
- Stable & good performance
- **MM1 ~ 0.5 counts / tracking**
- **MM2 ~ 0.7 counts / tracking**

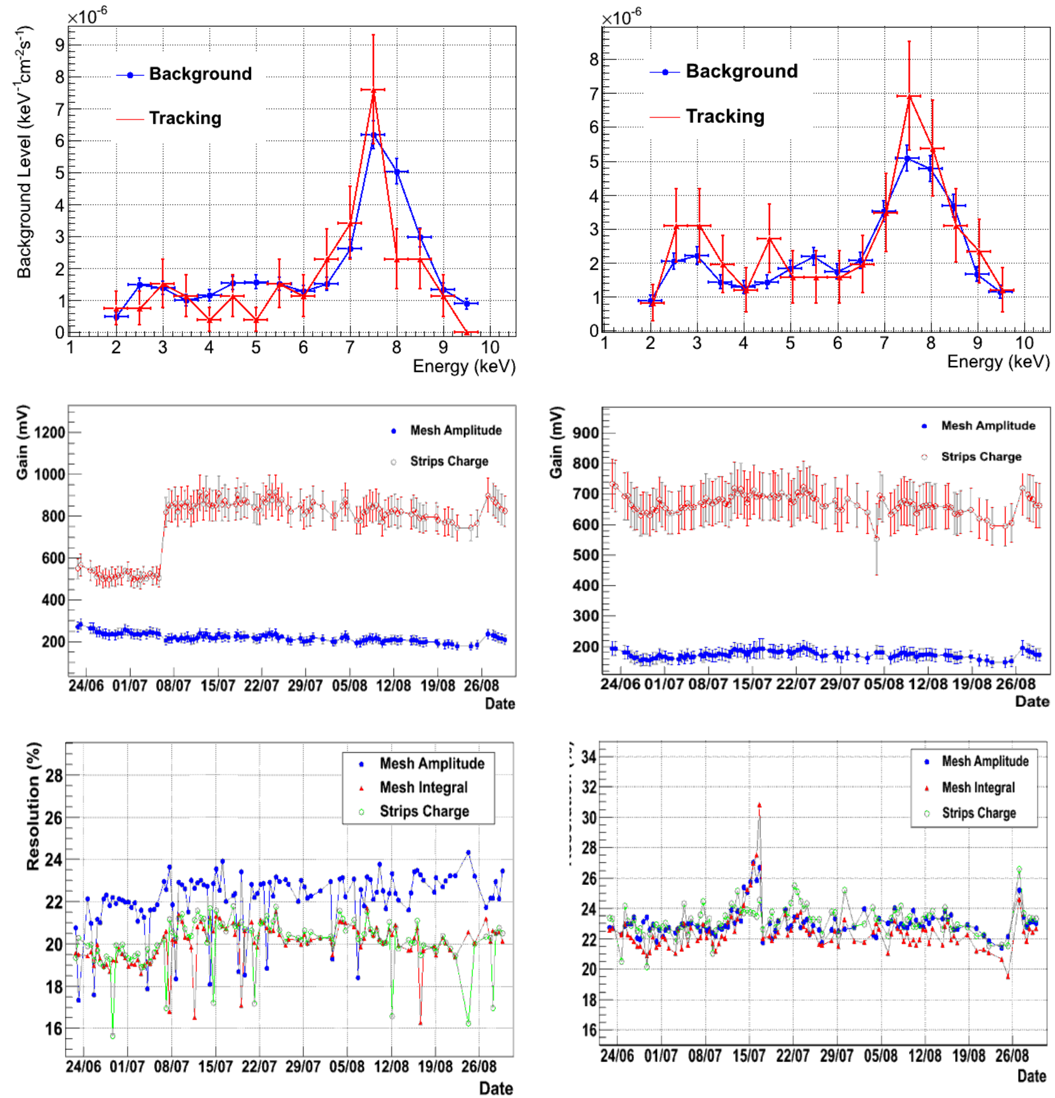
- Background reduction by factor ~4.5 in the range 2–7 keV
  - ✓ Elimination of fluorescence lines from stainless steel parts (Fe,Cr)
  - ✓ Muon veto ➔ reduction 30%
- Improvement of figure of merit:

$$\epsilon/\sqrt{b} \sim 2.2$$



MM 1

MM 2



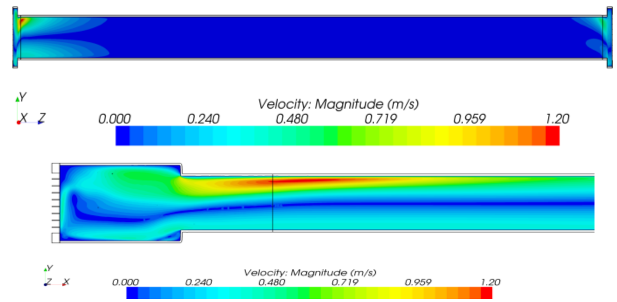
Working with a buffer gas

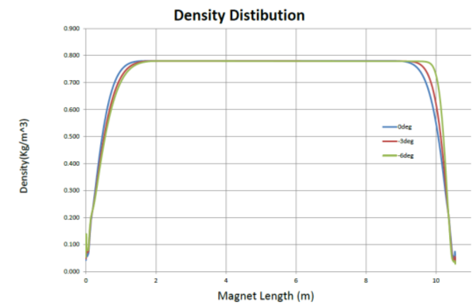
- Precise knowledge and/or **reproducibility** of each pressure setting is essential
- Gas **density homogeneity** along the magnet bore during tracking is critical
  - ✓ **Superfluid** ^{4}He @ 1.8 ➔ **temperature stability** along the cold bore
  - ✓ Hydrostatic pressure effects are not critical
  - × parts of the magnet bores, outside the magnetic field region, in higher temperatures. **Variations during tracking, depended on the buffer gas density**

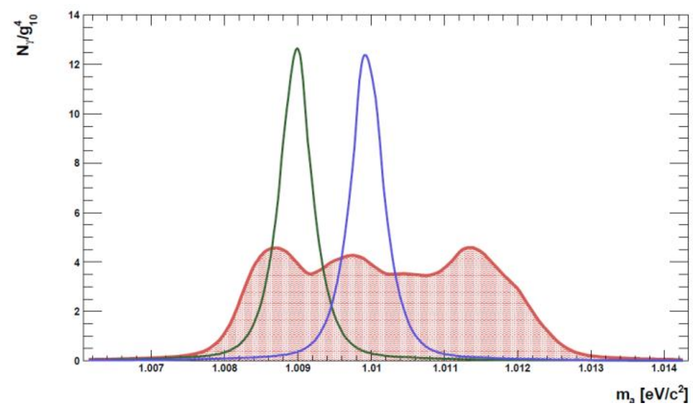
To face that situation we:

- Precise **measurement of the amount of gas** injected into the cold bores
- Installed **temperature and pressure sensors** at **several** points
- ***Computational Fluid Dynamics Simulation*** with the **sensors' data as boundary conditions**

Variation of gas density during tracking ➔ m_a scanning!





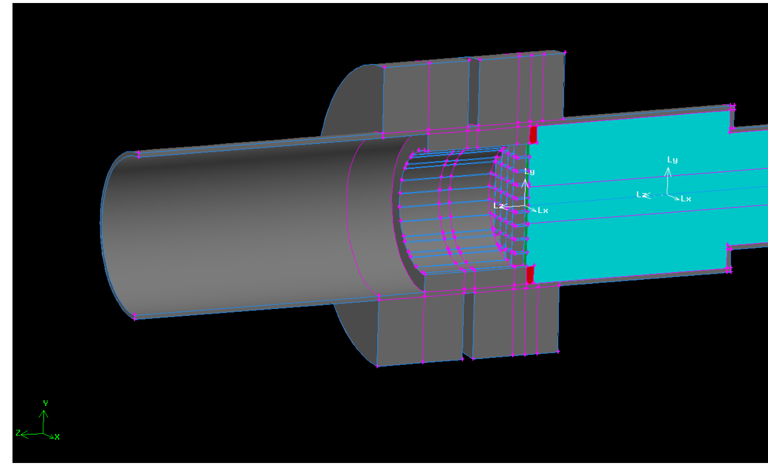


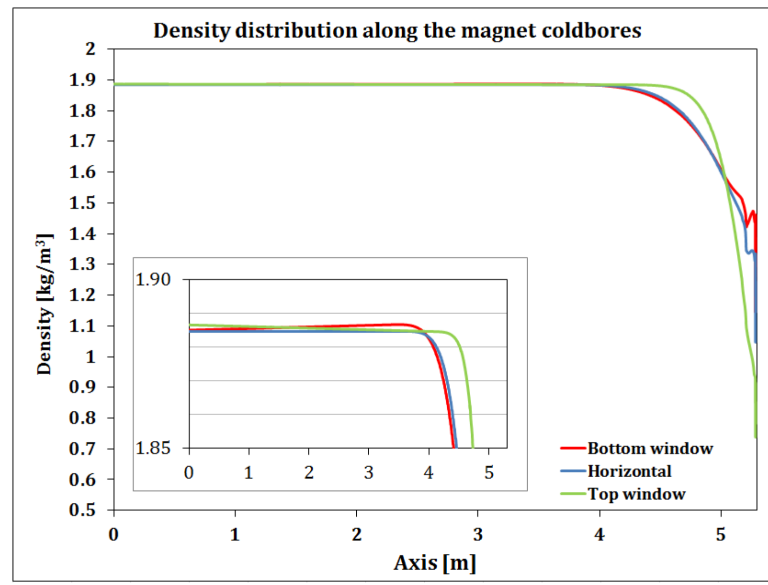
CFD simulations

CAST is performing computational fluid dynamics (CFD) simulations with the help of the CERN CFD team (EN/CV).

- CFD simulations ➔ a great tool to describe:
  - ✓ the density distribution across the cold bore
  - ✓ horizontal & tilted
- A new set of simulations to study individual thermodynamic phenomena:
  - ✓ hydrostatics
  - ✓ effects due to the magnet operating temperature variations
  - ✓ convection
- Different scenarios representing various vertical angles during solar tracking:
  - ✓ demonstrated the overall measured pressure variation
  - ✓ revealed an underestimation of the change in convective heat transfer during magnet tilting
  - ✓ very sensitive to the precise position of temperature probes
- A new set of simulations underway
  - ✓ more realistic description of the heat exchange paths
  - ✓ integrate the uncertainty of the probe positions
  - ✓ describe in greater detail the full geometry

Study is currently underway





Analysis status – ^{3}He data

Data taken in 2008 (published) covered axion mass interval: $0.39 \leq m_a \leq 0.64$ eV

Data taken during 2009 – 2011 covered axion mass interval: $0.64 \leq m_a \leq 1.18$ eV

Data analysis of ^{3}He data performed in a similar manner as in the published ^{4}He results published

✓ *Lower detector backgrounds*

× *Lower exposure times per m_a*

Exclusion plot includes:

✓ 2008 data (all detectors)

✓ Sunrise MM 2009, 2010, 2011

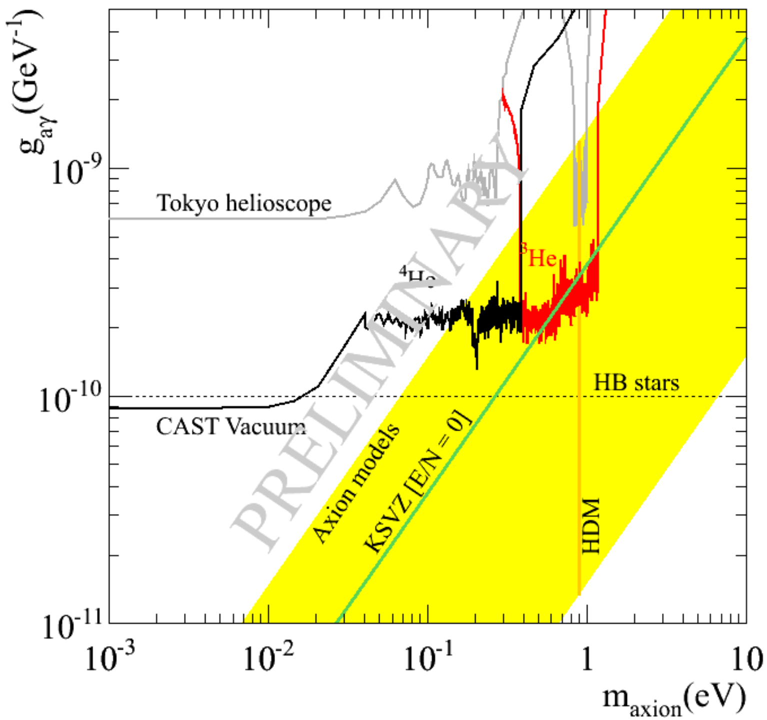
✓ Sunset MM *2009, 2010*, 2011

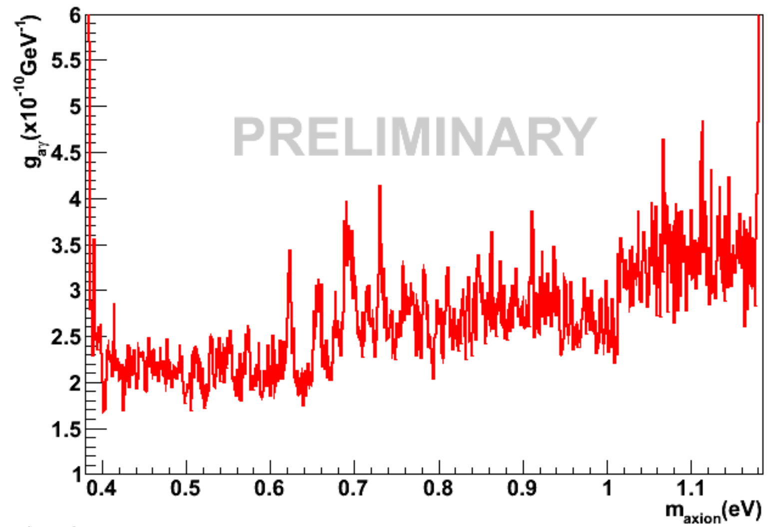
✓ X-Ray telescope 2010 (gaps)

➢ Analysis to be completed

➢ Finalize CFDs

➢ ***CAST is first helioscope to have crossed the KSVZ line***



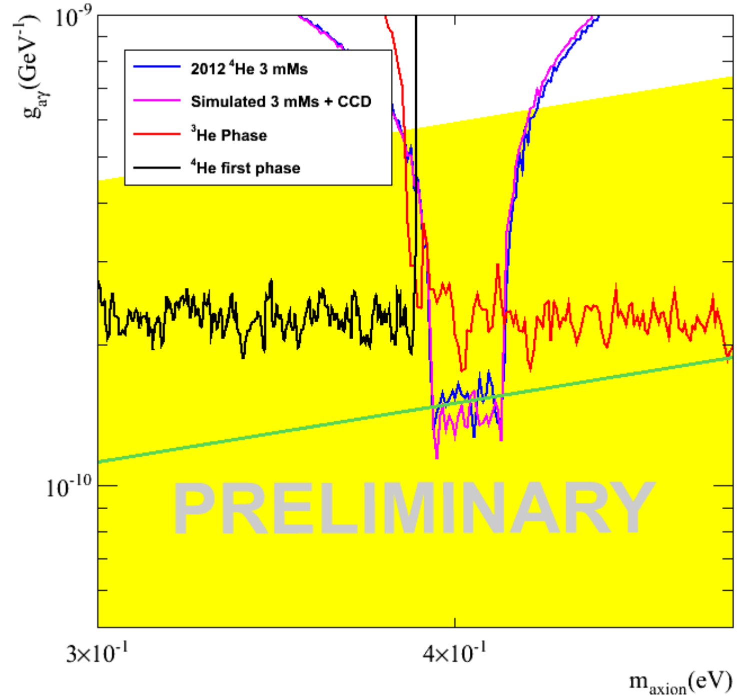


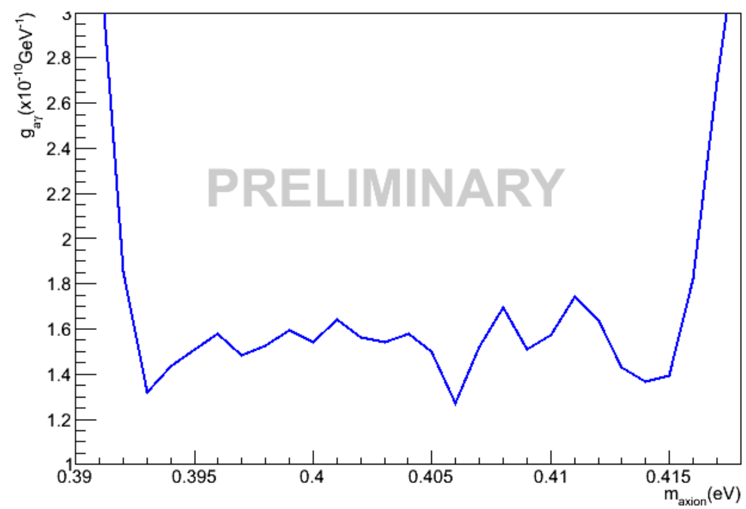
Analysis status – ^{4}He data

- Datataking period: 22nd June - 7th October (axion masses: 0.39 – 0.42 eV)
- ~ 5 solar trackings per detector & per pressure setting (17 settings covered)

➔ Improved Sunset Micromegas background

- Analysis in a similar manner like ^{3}He data
- Preliminary results from 3 out of 4 detectors
- No signal excess in all 4 detectors

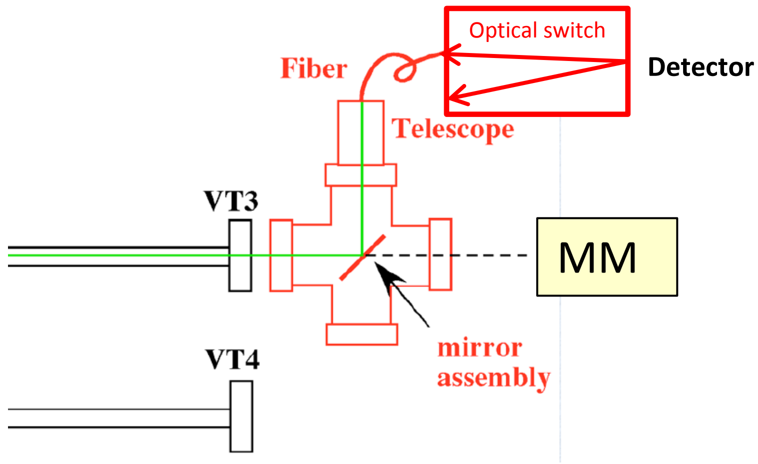




BaRBE detector

Since 2010, fifth line searching in visible range, e.g. **paraphotons**:
Transparent mirror to X-rays on the Sunrise Micromegas line to deflect **visible photons** by 90° towards the **PMT** through an **optical switch**

BaRBE mostly sensitive at E_γ=2.5 – 3.5 eV



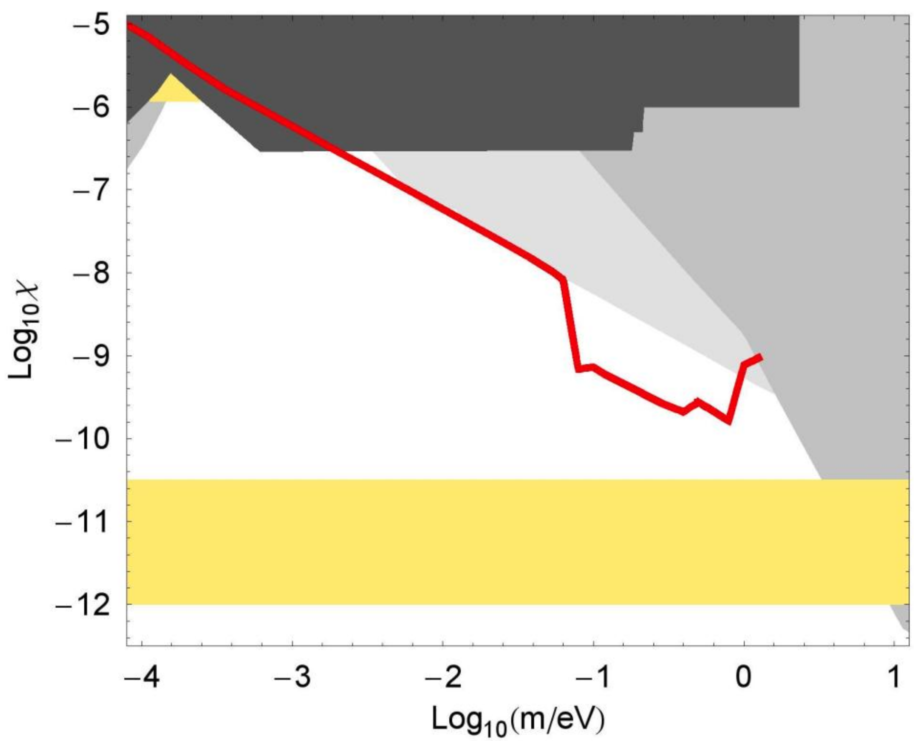
May 2012 increase the angular field of view:

1.5 mrad ➔ 7 mrad,

(Sun angular diameter ~ 9 mrad)

2×10⁶ s background data &

185000 s solar tracking data



Differential rates:

DDCR (background) = (10±2) mHz @ 2σ

DDCR (solar tracking) = (10 ± 9) mHz @ 2σ

Prospects: TES

CAST constraint on axion – electron coupling

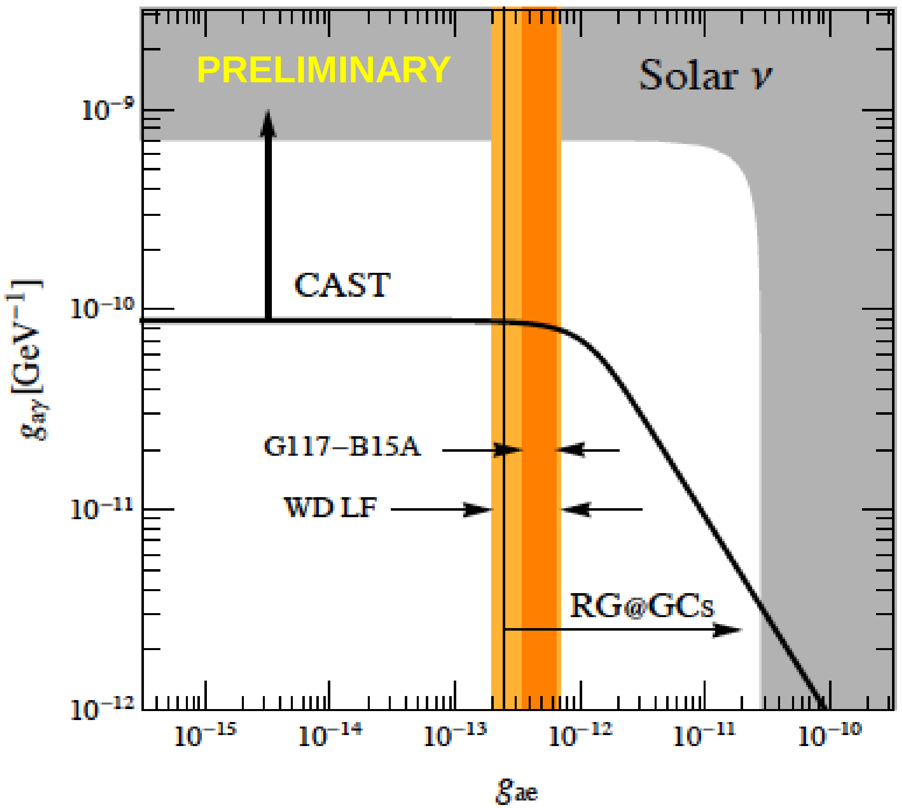
CAST has mainly focused on hadronic (KSVZ) axions:

- **no** coupling of axions to electrons at tree level
- dominant production process in the Sun is the Primakoff process
  $\gamma + Z \rightarrow a + Z$ (two-photon coupling)

Non-hadronic (DFSZ) axions:

- coupling of axions to electrons at tree level
- additional axion-production channels in stars:
  - ✓ electron – nucleus and electron – electron bremsstrahlung
    ($e + Z \rightarrow e + Z + a$, $e + e \rightarrow e + e + a$)
  - ✓ Compton process ($\gamma + e \rightarrow e + a$)
  - ✓ axio – recombination ($e + I \rightarrow I^- + a$)
- astrophysical constraint (evolution of red giants): $g_{ae} \leq 2.5 \times 10^{-13}$
- couplings of $g_{ae} \leq$ few 10^{-13} might explain the anomaly in the cooling of white dwarfs (WD)
- corresponding axion mass is $m_a \sim$ meV $\Rightarrow$ other interesting phenomenological implications in the context of astrophysics and cosmology

CAST constraint on axion – electron coupling



Preliminary limits on the product of the axion – electron & axion – photon coupling constants for **$m_a \leq 0.02$ eV** using CAST phase I data (vacuum phase):

$g_{ae} \times g_{a\gamma} \leq 0.9 \times 10^{-22}$ GeV^{-1} at 95% CL

Request for running in 2013 - 2014

Physics motivation: Solar Axions/ALPs

- The limit obtained in the CAST vacuum phase, $g_{a\gamma} < 8.8 \times 10^{-11}\ GeV^{-1}$ for $m_a < 0.02\ eV$, is the first helioscope limit surpassing the astrophysical bound $g_{a\gamma} < 10^{-10}\ GeV^{-1}$, and entering previously unexplored ALP parameter space.
- ALPs (or more generically WISPs) are light (pseudo)scalars that weakly couple to two photons ($g_{a\gamma}$ and m_a are independent from each other).
- The possibility of pushing CAST vacuum limit to lower $g_{a\gamma}$ values is motivated, both theoretically and observationally:
  - ✓ ALPs often appear in **extensions of the standard model** as pseudo Nambu-Goldstone bosons of new symmetries broken at high energy.
  - ✓ **String theory** also predicts not just one ALP, but in most cases a rich spectrum of them (including the axion itself) ⇒ specially motivated is the region of the ALP parameter space corresponding to the first orders of magnitude just beyond the current CAST bound in $g_{a\gamma}$.
  - ✓ ALPs are **dark matter** candidates. The range of ALP parameters possibly solving the DM problem includes part of the region that an improved CAST vacuum run could probe.
  - ✓ Some unexplained **astrophysical observations** may indicate the effects of an ALP. One such case is the excessive transparency of the intergalactic medium to very high energy photons. Required ALP parameters are not far beyond the CAST limit.

Physics motivation: Solar Axions/ALPs

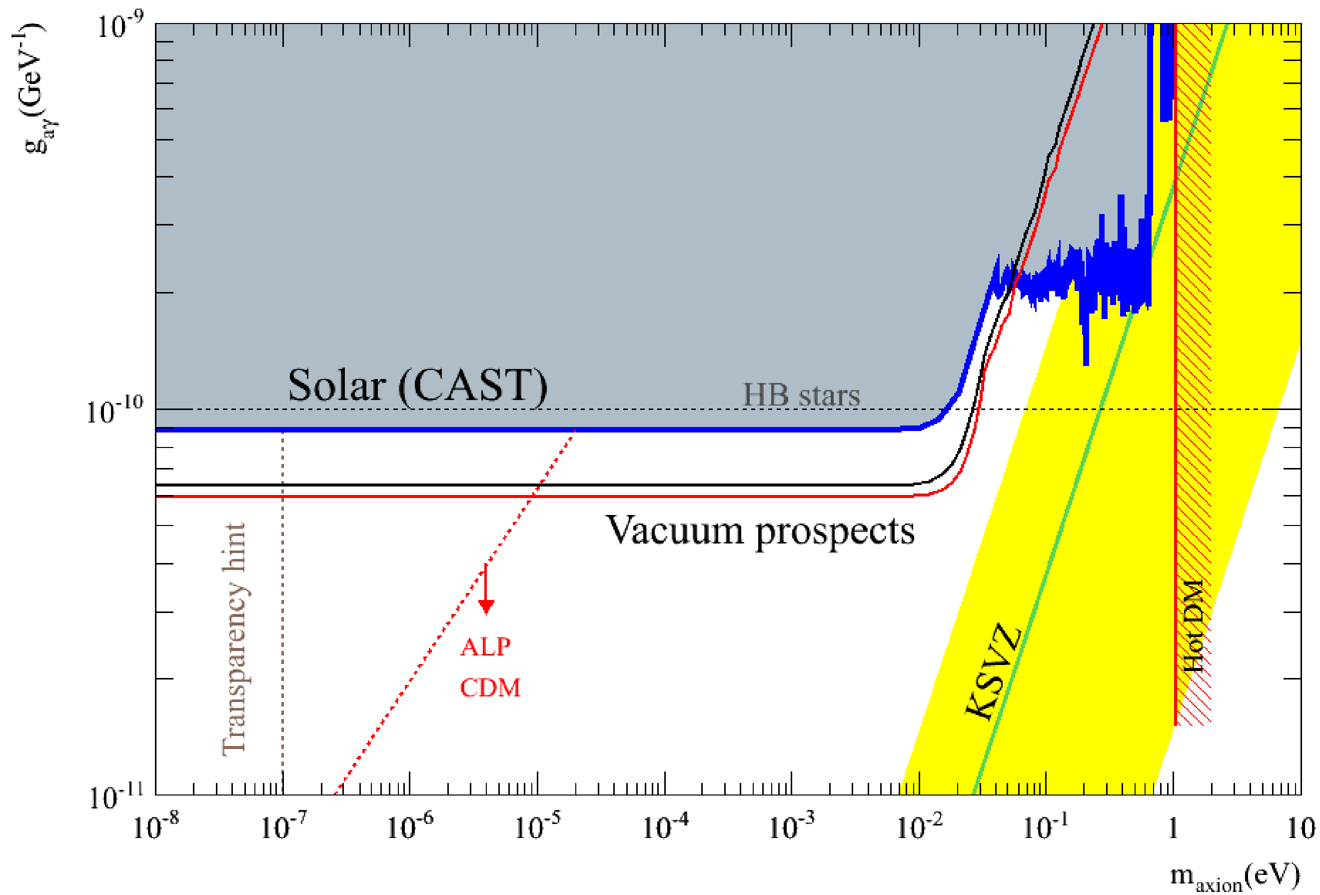
Two of the innovations in which CAST success has relied:

- X-ray focalization to increase the signal-to-noise ratio
  - ✓ CAST has used the recycled ABRIXAS X-ray optics with the CCD
  - ✓ **One new X-ray optics adapted to the CAST geometry is to be installed in the Micromegas sunrise line (for the 2013 – 2014 data taking)** ⇒ increased sensitivity of the experiment + test the technological options for the next generation axion helioscope (IAXO proposal currently in preparation)

- Low background techniques to reduce the detector backgrounds
  - ✓ The sustained development of the detectors towards lower backgrounds during the whole CAST's lifetime
  - ✓ The latest generation of sunset Micromegas detectors achieved a level of about 1.5×10^{-6} counts keV^{-1} cm^{-2} s^{-1}, a **factor 4.5 better** that last year's detectors and an accumulated **factor of more than 100 better** than in 2002
  - ✓ **A new detector and shielding system for 2013 – 2014 run will be installed in the sunrise Micromegas line, at the focal spot of the new X-ray optics**
  - ✓ **An upgrade** of the muon veto scintillator in the sunset side is planned ⇒ the background down to levels below 1×10^{-6} counts keV^{-1} cm^{-2} s^{-1}

These improvements allow us to consider revisiting the vacuum configuration of CAST with improved sensitivity with respect current CAST limit.

Physics motivation: Solar Axions/ALPs



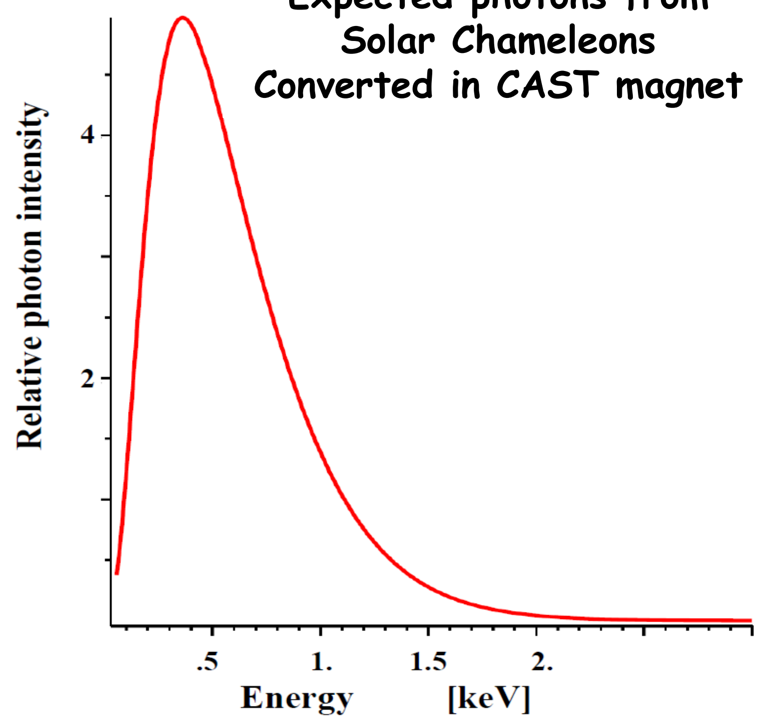
Expected sensitivity with the setup proposed in vacuum conditions 9 calendar months assuming 75% data taking efficiency. Two assumptions for the Micromegas background: 1.5×10^{-6} (black line) and 8×10^{-7} counts keV^{-1} cm^{-2} s^{-1} (red line)

Physics motivation: the sub keV range

Solar Chameleons

- Chameleons are **Dark Energy** candidates to explain the accelerated expansion of the Universe
- Chameleon **mass depends on the ambient energy density**
- Chameleon particles can be created by the **Primakoff effect** in a strong magnetic field. This can happen in the tachocline of the Sun.
- The chameleons created inside the Sun eventually reach the Earth where they are energetic enough to penetrate into the CAST experiment. **Like axions**, they can then be back-converted to X-ray photons
- In vacuum, CAST observations lead to better detection sensitivity of solar chameleons

Expected photons from Solar Chameleons Converted in CAST magnet



axion helioscope = chameleon helioscope @ LE!!

Sub-keV detector threshold+vacuum

+ axion – electron coupling

Solar Paraphotons: Hidden Sector particles (Theoretically motivated)

kinetic mixing with thermal photons:

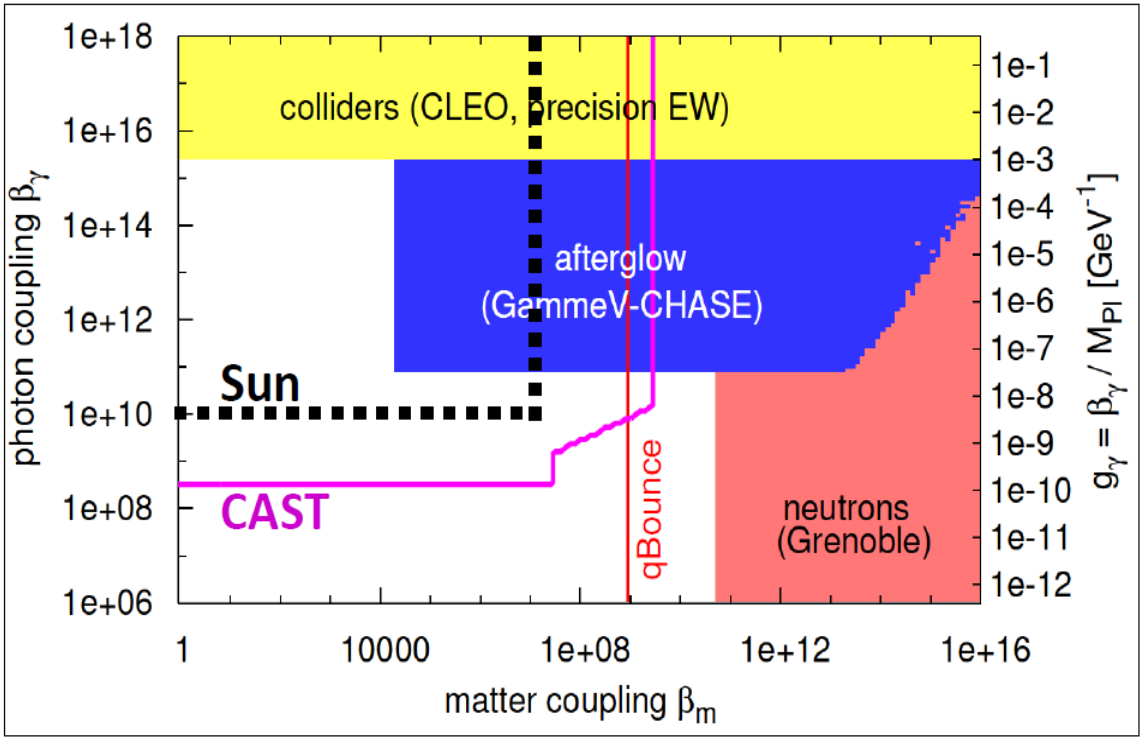
$\gamma \leftrightarrow \gamma'$ oscillations

→ **NO magnetic field!** → NO cold bores needed

Physics motivation: the sub keV range

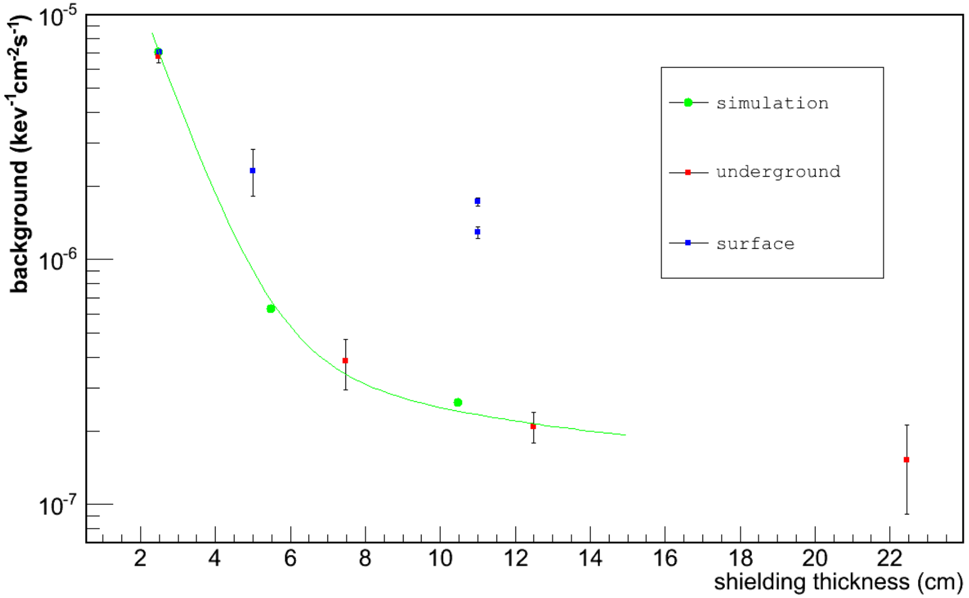
Solar Chameleons prospects

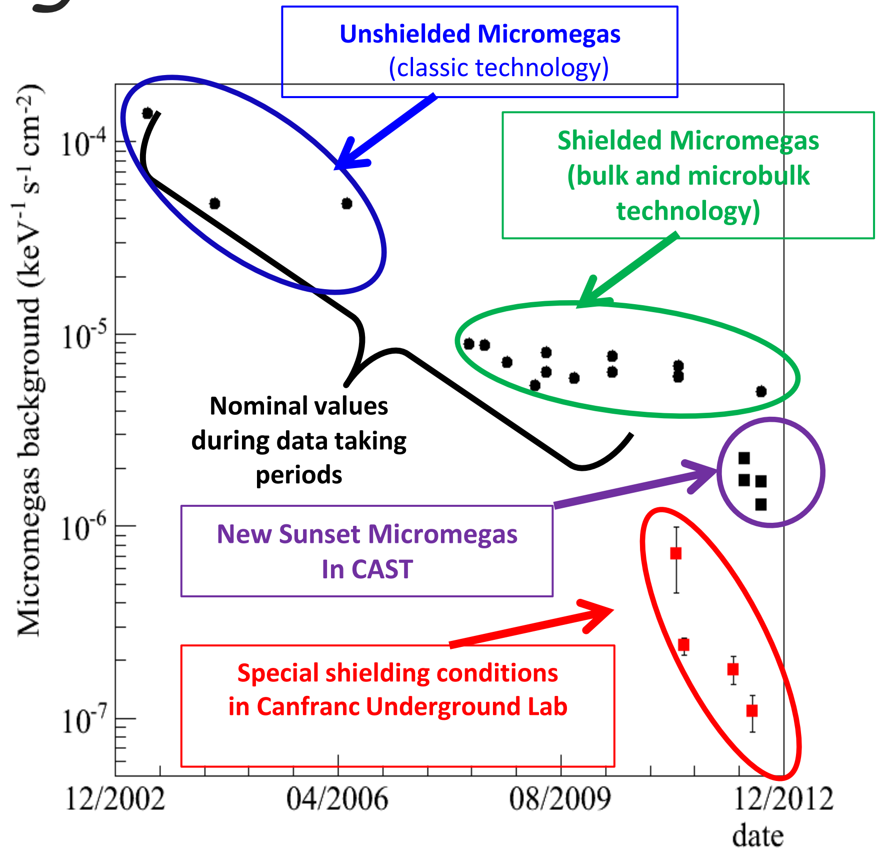
- Maximum sensitivity expected to be reached with CAST assuming
  2 events / 100 min
  being sensitive to the whole solar chameleon spectrum:
  $\beta_\gamma = 3.13\times10^8$
- Corresponding solar chameleon luminosity CAST could detect is
  $\sim 4\times10^{-4}\ L_{solar}$
  associated chameleon-to-photon conversion probability
  $P_{ch\rightarrow\gamma} = 3.9\times10^{-17}$
- Experimentally derived limits exclude a chameleon matter coupling of $\beta_m > 10^9$
- maximum allowed solar chameleon luminosity (0.1 L_{solar}) ➔ "Sun" dashed



Upgrades: ULB Micromegas

- Thorough tests in Canfranc Underground Laboratory
- Performance of new Sunset detectors with upgraded shielding + muon veto
- ➔ New design for sunrise Micromegas aiming for background level of ~8×10^{-7} $s^{-1}keV^{-1}cm^{-2}$





ULB background (<10^{-6} $s^{-1}keV^{-1}cm^{-2}$) is achievable in CAST!

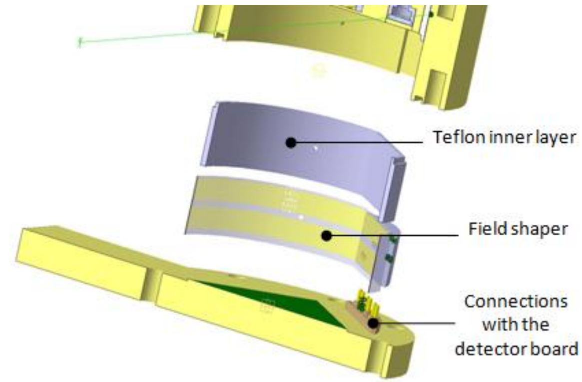
Upgrades: ULB Micromegas

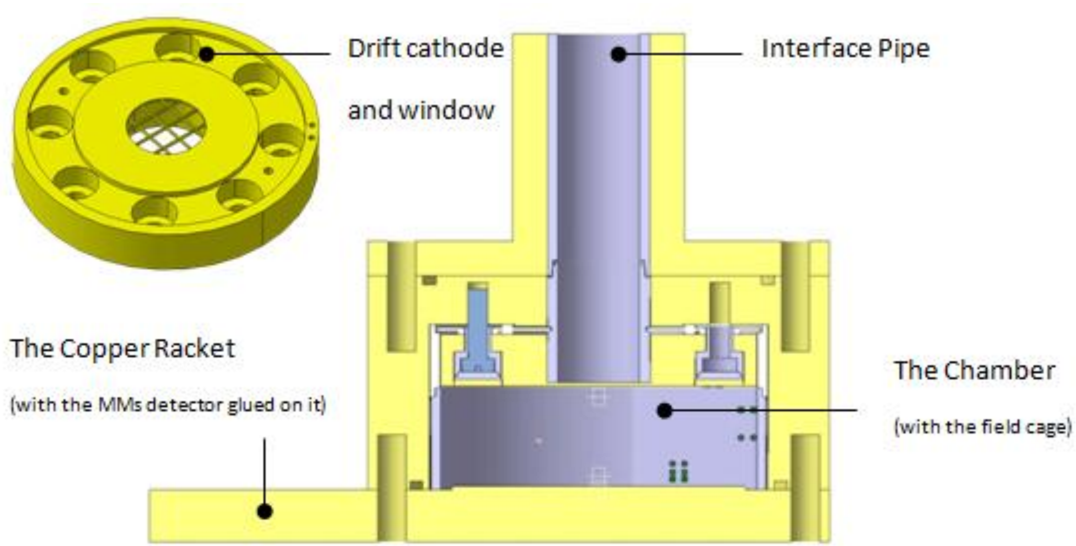
New sunrise Micromegas design:

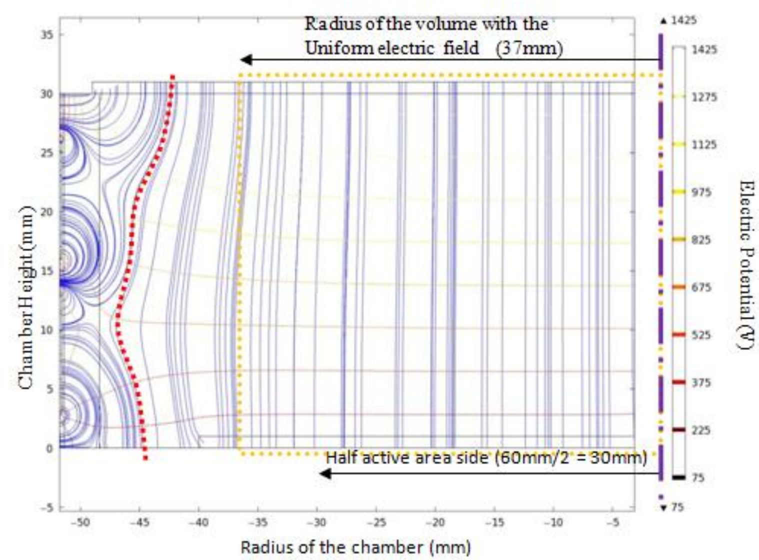
- ✓ Chamber body build in copper (shielding)
- ✓ Teflon to reduce 8 keV
- ✓ Copper interface tubes + Teflon
- ✓ Field degrader
- ✓ New analogue electronics (AFTER/GET)

+ X-ray optics

expecting **~1 count in the spot** for 9 months run



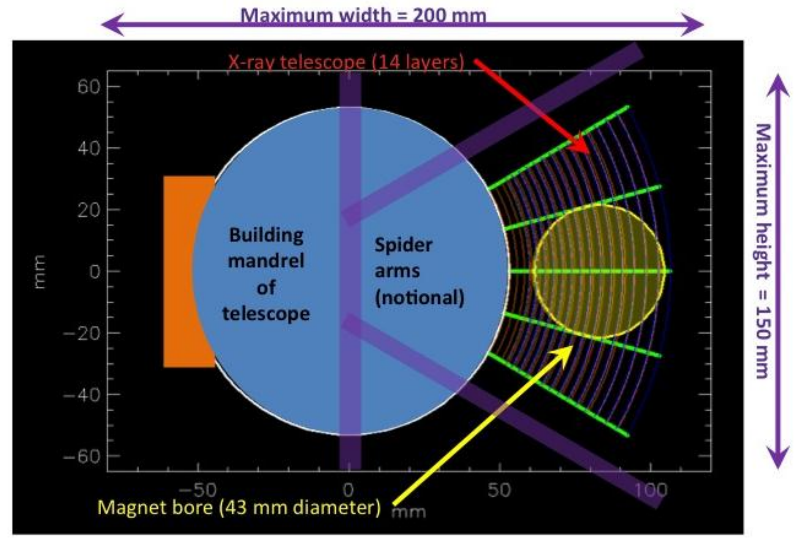




Design almost finalized, construction to start before the end of the year

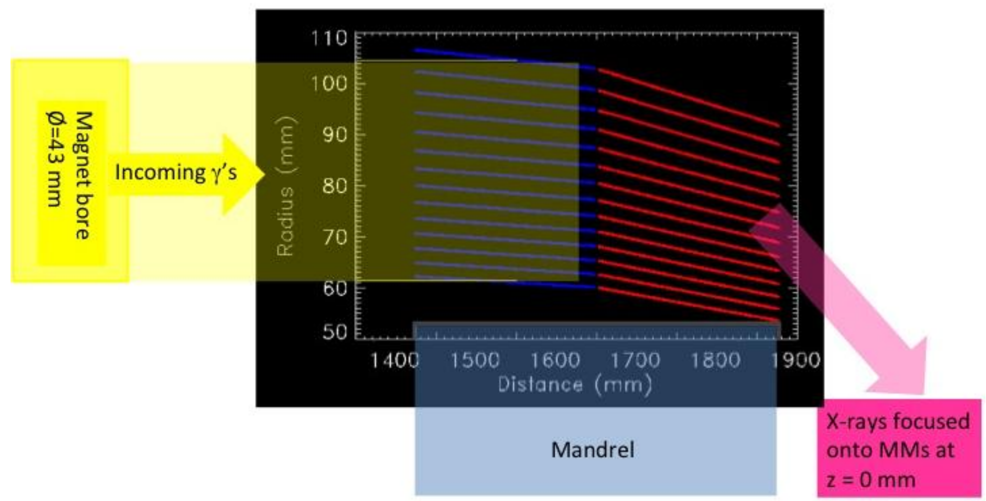
Upgrades: new X-ray optics

- Build a single optic to be coupled to a Micromegas detector on the existing Sunrise Micromegas line
  (Columbia University, the Danish Technical University-Space & LLNL)
- Similar properties to the ABRIXAS X-ray telescope
- "easy to build"
  - ✓ 15 nested shells
  - ✓ build 1/6th of a normal X-ray telescope (1 of 6 mirror sectors)
- Focal length ~1.5 m



Schedule

- ✓ Construct the optic in quarter 1 (Q1) 2013
- ✓ Calibration at the PANTER X-ray facility Q2
- ✓ Implementation and alignment in CAST in Q3
- ✓ Ready for science at CAST in Q4 of 2013

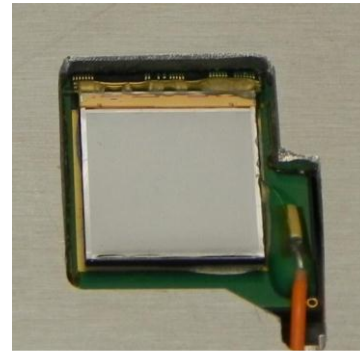


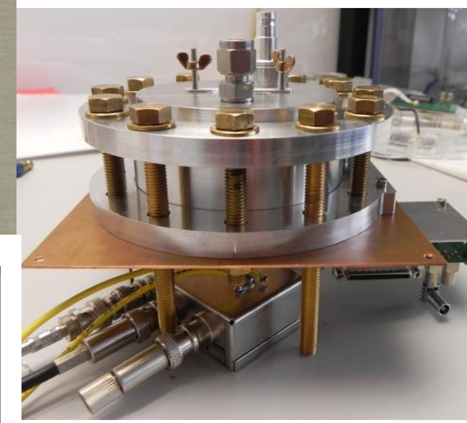
Upgrades: InGrid Micromegas

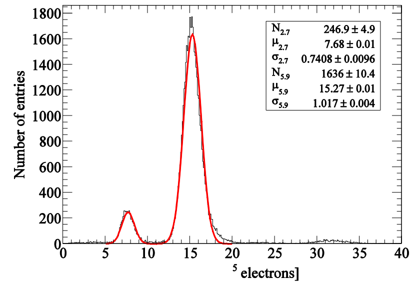
InGrid detector: a gas-amplification grid mounted onto a pixel-readout chip

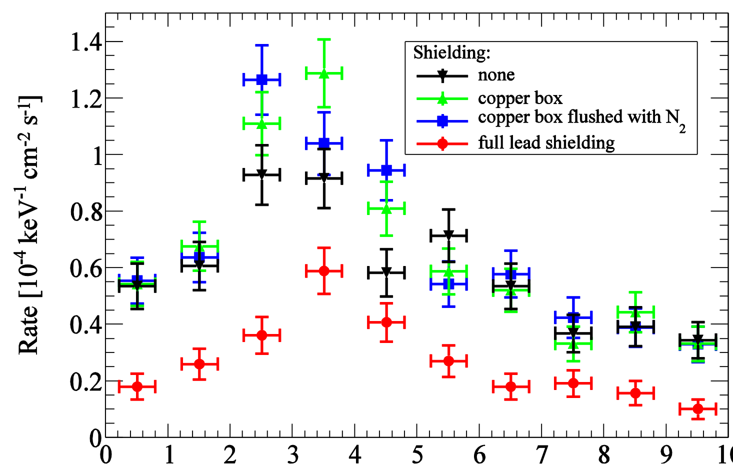
- Timepix, 2 cm², 55×55 μm2 pitch
- **Detect the primary electrons from X-rays with high (~100%) single-electron efficiency**
- capability to count the primary electrons (superb spatial resolution)
  - ✓ Photon clusters discriminated from non-photon background through analysis
- High single electron efficiency, ➔ **expected threshold well below 1 keV** *without performance degradation in higher energies*
- Simultaneous search for solar axions and lower energy particles, e.g. chameleons
- Detector fitting to CAST tubes constructed & successfully operated
  - ✓ Materials for low background
  - ✓ Shielding
- Measured background: 2.6×10^{-5} keV^{-1} s^{-1} cm^{-2}
- Optimization of entrance window ➔ determine the energy threshold

Tests in CAST detector lab: from december 2012









Request for 2013 - 2014

CAST aims at a significant increase of sensitivity to ALPs after upgrading part of the detector systems. The proposed baseline program includes **9 months of data taking during 2013-2014** with the **magnet bores under vacuum** and the following detectors:

Sunset detectors

- conservation of the current Sunset Micromegas system (upgrade the muon veto scintillator)

Sunrise detectors

- Replace the pn-CCD chip of the existing X-ray telescope system by the new shielded InGrid detector
- Replace the existing Sunrise Micromegas with a new detector and shielding system + new X-ray optic device

CAST very much appreciates the help and comprehension of the various technical service groups at CERN (EN-EL and EN-CV in particular) who have made special efforts to accommodate CAST requests.

In the forthcoming shutdown of CAST:

- ✓ interventions to the cryostat to convert from helium running to vacuum running
- ✓ to be completed before the start of LS1.
- ✓ every attempt has been made to avoid the likelihood of conflicts between LS1 infrastructure stoppages & future CAST setting up and running. *No apparent conflicts at present.*

CAST vacuum running:

- ✓ far more robust and flexible than the ^{3}He running
- ✓ easier to accommodate small interruptions

Request for 2013 - 2014

Cryogenics & Power Converter

M&O costs, running hours, electricity power costs (cryogenics and power converter), costs for the FSU contract for the power converter at a **similar level to the past years:**

			Actual values				Projected values		
Item	**Dept**	**Year**	2008	2009	2010	2011	**2012**	**2013**	**2014**
Cryogenics M&O	TE	(kCHF)	180	180	180	180	**180**	**180**	**180**
Cryogenics power		*(hours)*	*7000*	*4653*	*5660*	*2951*	*4805*	*4380*	*6570*
	TE	**(kCHF)**	193	128	156	81	**132**	**120**	**181**
Power Converter power		*(hours)*	*3527*	*2288*	*2079*	*797*	*1617*	*1445*	*2168*
	TE	**(kCHF)**	25	16	15	6	**12**	**10**	**16**
FSU maintenance			5	0	0				
	CAST	(kCHF)	0	5	5	5	5	5	5
Yearly TOTAL	CERN	**(kCHF)**	403	324	351	267	**324**	**311**	**376**

Manpower support

CAST requests from CERN continued **support at a similar level to the past years**

Conclusions

- After 10 years on the floor, **CAST achieved world class records**, even though no solar axion signal could be found as yet. CAST results have also been used in the field of the Hidden Sector ('paraphotons'), and therefore CAST appears in almost all related publication plots.
- With the envisaged upgraded and new detectors we can improve our own best records on axions and axion-like particles (WISPs).
- At the same time, CAST could enter a new territory within the sub-keV range, which could not be addressed before. CAST could search for low energy solar WISPs like the so called chameleons, expanding CAST's horizon into the dark energy sector.
- The expected new CAST results will be important input also for the IAXO proposal.
- *CAST's physics potential for the dark sector remains competitive in the forefront.*

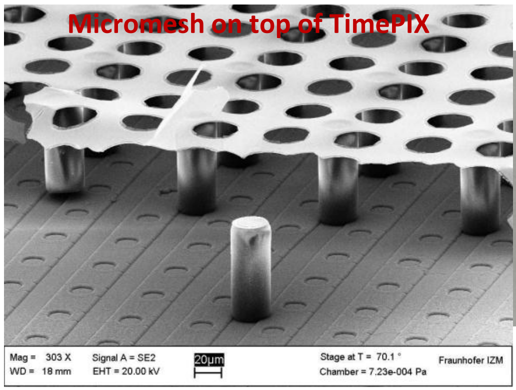
End

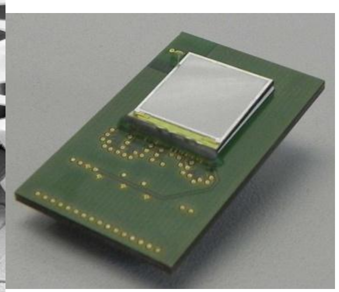
Backup slides

Operating in the sub-keV range

Low threshold detectors

InGrid: single electron detection!



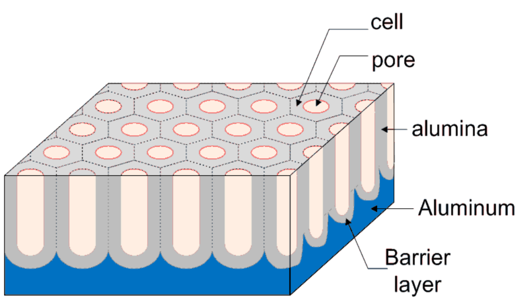


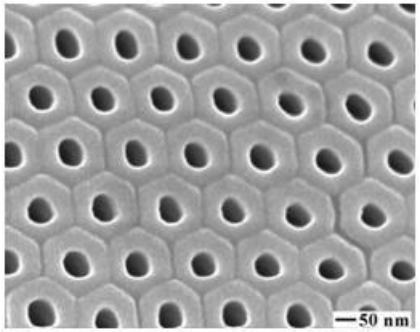
Micromegas + new electronics
Detectors optimized for Solar axions, however with analysis modification threshold of **500-600 eV** possible

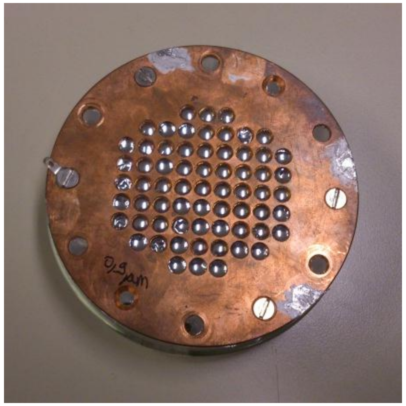
Sub-keV range is covered in "parasitic" mode

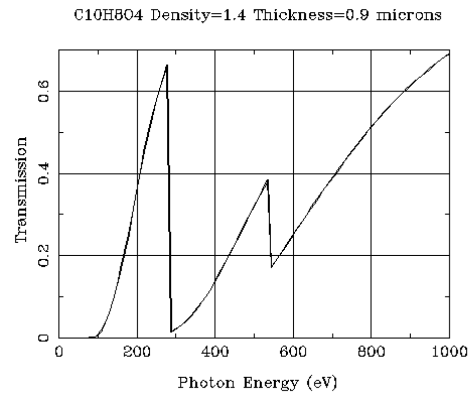
Transparent Windows

- ✓ Nanotube Porous aluminum membrane
  ➔ fraction of incident photons can be transmitted either directly or "channeled" through the pores
- ✓ Thin foil on strongback
- ✓ Commercial composite window







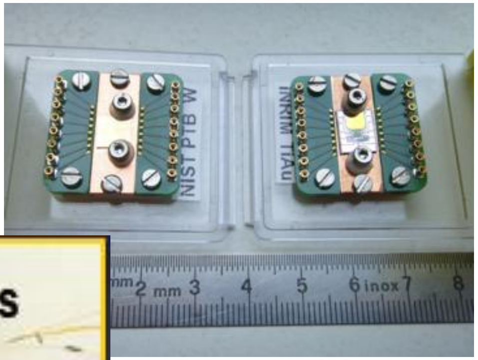


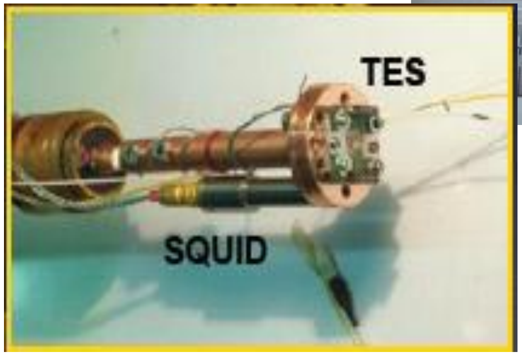
Upgrades: TES

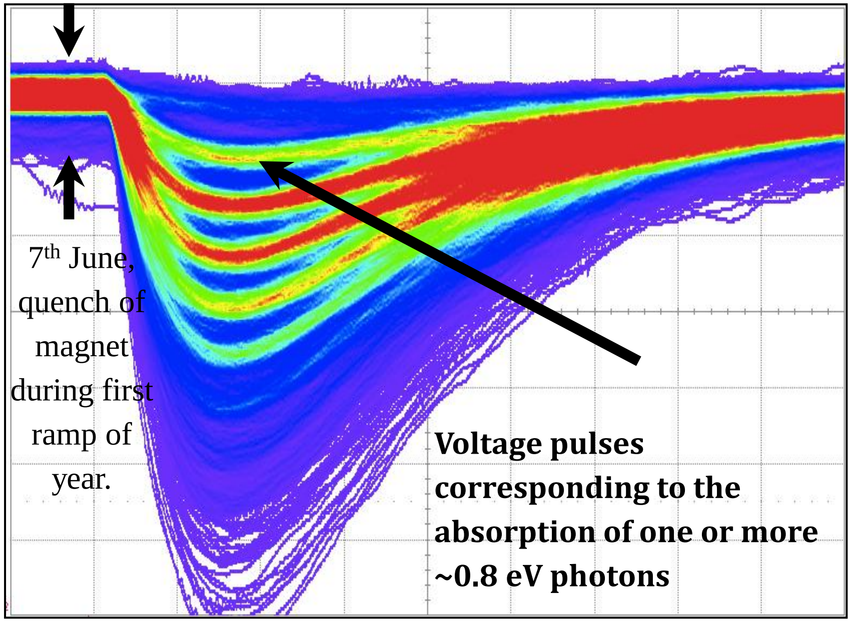
- 2012 main results on TES
  - ✓ detection of single 0.8 eV photons injected through an optical fiber (nofocussing)
  - ✓ DCR < 1 mHz over a period of the order of the hour
- 2013 perspectives
  - ✓ reduction of RF noise to reach DCR ~ 0.l mHz (*current setup ~ 10mHz*)
  - ✓ beam tests at CAST
  - ✓ new TES sensors sensitive at ~keV energies

Projected schedule:

- present -> 1st half of 2013
  - ✓ reduction of the noise of "visible" TES -> DCR down to 0.1 mHz
  - ✓ start production of "keV-TES"
- 2nd half of 2013
  - ✓ laboratory tests of "keV-TES"
  - ✓ beam tests at CAST (subject to acquisition of Ministry funds)







Request to CERN

Detailed manpower support request for 2013 and 2014

PH-DT Consultant *Mechanical engineer.*
Mechanical technician - support for the experimental apparatus
Electrical technician - support for Slow Control and interlocks.
Applied Fellow - completion of helium run; place it in a Standby state; Completion of the 3He CFD project; liaison with EN-CV.

TE-VSC Consultant *vacuum physicist/technician*

Aid with the intervention to change cold windows inside cryostat.

TE-EPC Support for the Power Converter (PC) operation and maintenance

TE-CRG Cryolab support: maintain ^{3}He, cold windows removal, Cryo sensors

Support for the operation of the magnet cryogenics and its ABB control system

TE-MPE Support for the Quench Protection rack

EN-ICE Support for the Power Converter controls system

BE-ABP General Survey work and support for the alignment of two X-ray telescopes

EN-MME Design and calculations support for upgrades and extra loading of MFB XRT platform. Design work for X-ray test beam laboratory.

TE-CV Support for demineralized water cooling system for 13kA cables and Power Converter.

Support for completion of ^{3}He CFD simulations

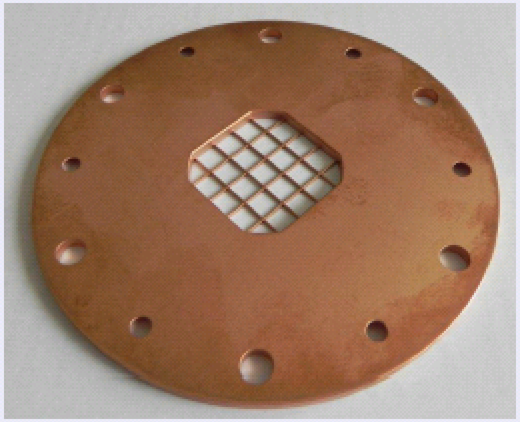
Request to CERN

Detailed program for 2012 and 2013

CAST 2012-2013 SCHEDULE	2012 Oct	2012 Nov	2012 Dec	2013 Jan	2013 Feb	2013 March	2013 April	2013 May	2013 June	2013 July	2013 Aug	2013 Sept	2013 Oct	2013 Nov	2013 Dec
End 4He data run (~ 10 october)	X														
Complementary measurements	XX														
End of Data taking ~ 20th October	XX														
CFD tests	X	X													
GRID *+ survey check of detectors and beam lines*		XX													
Remove SSMM		X													
Align XRT		XX													
Force warm magnet			XXX												
Install scaffolding			XX	X											
CRYO Maintenance & repair MFB bellows				XXX	XXXX										
Open cryostat				XX											
Insert windows				XX											
Close cryostat					XX										
Pump down and leak test cryostat and repaired valve					XX										
Remove detectors and XRT from Telescope platform					XX										
MPE-XRT test PANTER (1 week to be defined)						XXXX	XXXX								
Upgrade XRT platform						XXXX	XXXX								
Install XRT, detector and shielding supports							XX	XX							
Install MPE-XRT and pre align								XX	X						
Install LLNL- XRT and pre-align									XXX						
Cool down magnet									XXX						
Quench tests									X						
Align XRTs										XXXX					
Install SSMM and commission											XX				
GRID											XX				
Insert New GRID into tracking												X			
Data taking												XXX			
Sun Filming												XX			

InGrid based Detector - Progress

Sample strongback



Strongback & Window

- Received sample strongback
- 5 strongbacks will be produced
- 3 window types will be tested: $5\,\mu m$ Mylar, $2\,\mu m$ Mylar, commercial X-ray window (will be ordered soon)

Other parts

- Missing parts for detector clone (the one for CAST) are expected to be received from workshop end of October
- New adapter boards for new readout system are being designed

3^{rd} batch of IZM InGrids

Available InGrids

- Enough chips are available:
  Bonn received 2 gel packs (16 chips each)
- Some 'A'-grade chips are reserved for CAST detector

First results

- In Ar/iButane 95/5 Chips could be operated with up to $410\,\mathrm{V}$ without dieing
- At $410\,\mathrm{V}$ (estimated gas gain: $\sim 100\,\mathrm{k}$) frequent discharges can be observed
- But chips **DO NOT DIE** and are fully operable afterwards
- No chip was destroyed in Bonn during operation yet