98th Meeting of the SPSC

28/09/2010

CAST 2010 Status Report

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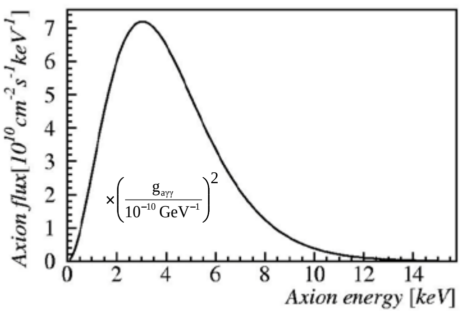
On behalf of the
CAST Collaboration

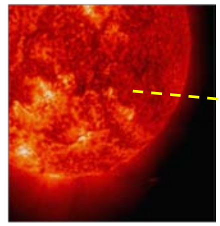
Outline

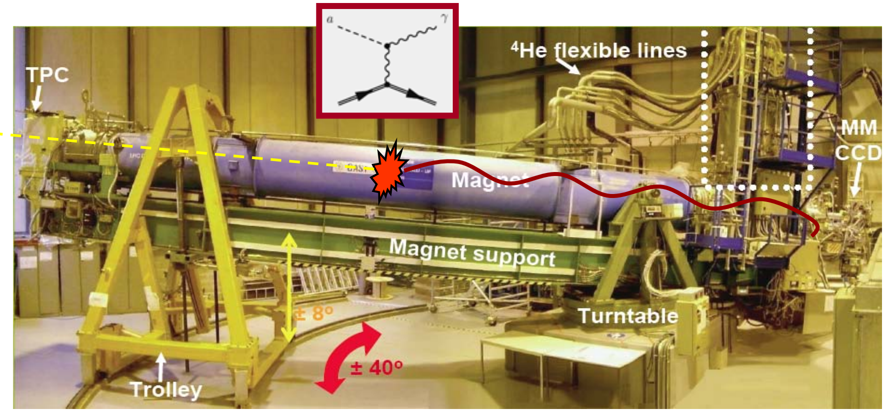
- CAST physics
- Data taking & shutdown in 2009 – 2010
- Detectors
- The ^{3}He System
- 2008 preliminary analysis results
- Request for running in 2011
- Conclusions

CAST Physics

The 10 years of CAST!!!







CAST is using a decommissioned prototype superconducting LHC dipole magnet to detect solar axions:

Operation at T=1.8 K, I=13,000A.

B=9T, L=9.26m.

- Solar tracking: ~3 hours/day

- Signal: X-Ray excess during tracking at **1-10 keV** region
- *CAST phase II ➔ different pressure setting(s) in every tracking*. Each setting is a new experiment!
  - expect **0.3 events/hour** for $g_{a\gamma\gamma} = 10^{-10}$ GeV^{-1} and A = 14.5 cm^2

CAST, Physics program

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

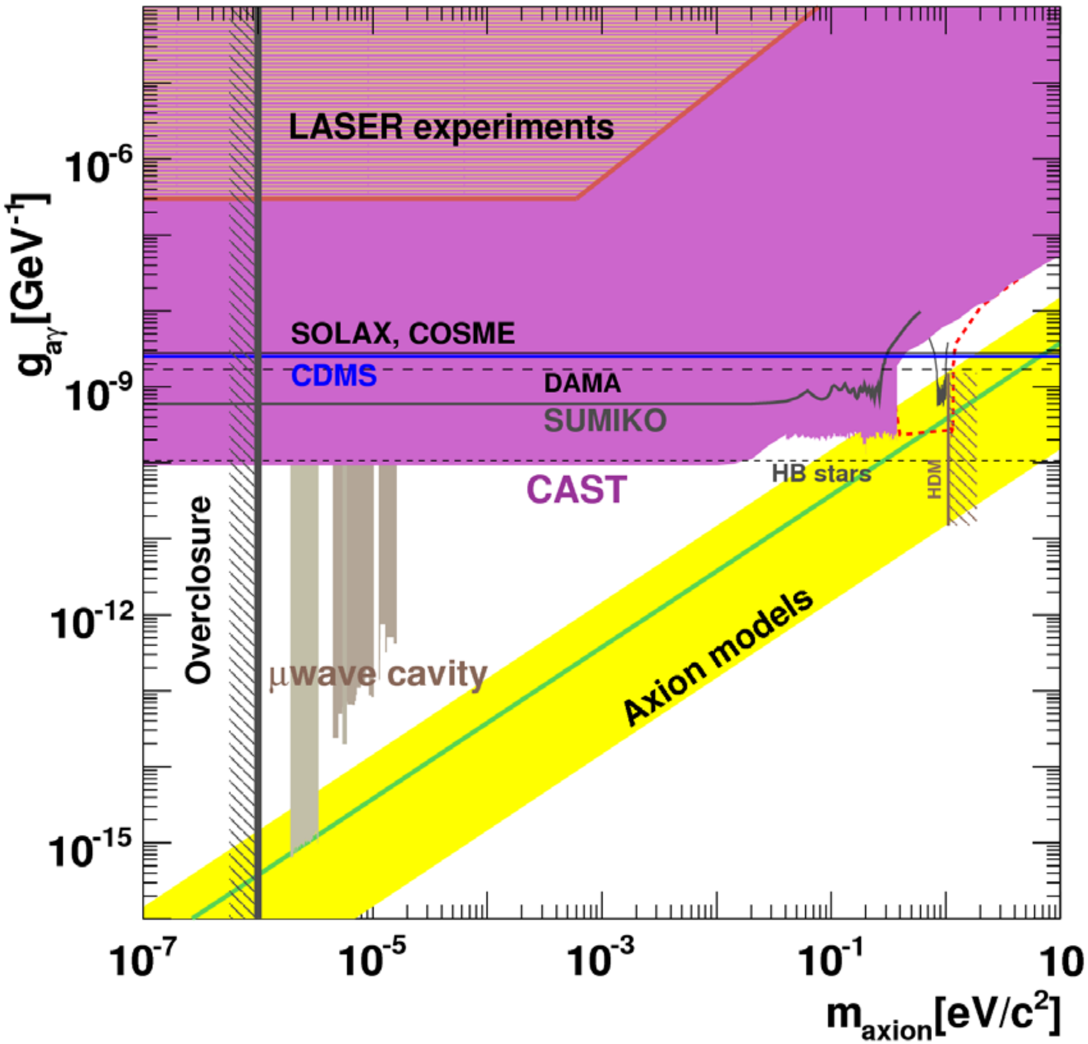
2) *CAST Phase II:* ^{4}He run, *completed* (2005–2006)
$0.02\ eV < m_a < 0.39\ eV$

^{3}He run, commissioning in Nov 2007
data taking started in Mar 2008
approved until Dec 2010
$0.39\ eV < m_a < \sim 1.20\ eV$

3) *Low energy axions* (2007 – 2010) in parallel with the main program
$m_a \sim$ few eV

13th April 2010: CAST 10th anniversary

CAST published physics results



CAST experimental limit dominates in most of the favored (cosmology/astrophysics) parameter space

For m_a < 0.02 eV:

$g_{a\gamma} \leq 0.88 \quad 10^{-10}$ GeV^{-1}

JCAP04(2007)010, CAST Collaboration

PRL (2005) 94, 121301, CAST Collaboration

For m_a < 0.39 eV typical upper limit:

$g_{a\gamma} \leq 2.2 \quad 10^{-10}$ GeV^{-1}

JCAP 0902:008,2009, 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)

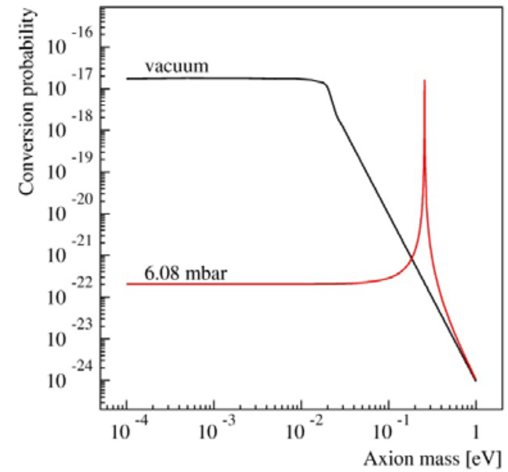
Low Energy (visible) Axions: Data taking with a PMT (arXiv:0809.4581)

Extending sensitivity to higher axion masses…

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

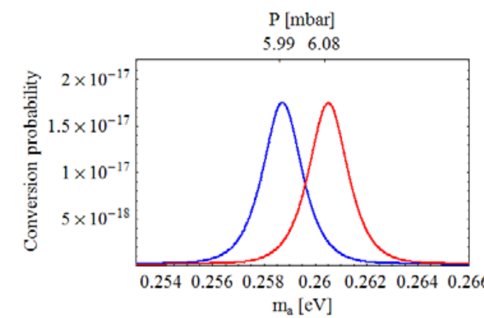


Coherence condition: $qL < \pi$, $|q|=\dfrac{m_a^2}{2E}$

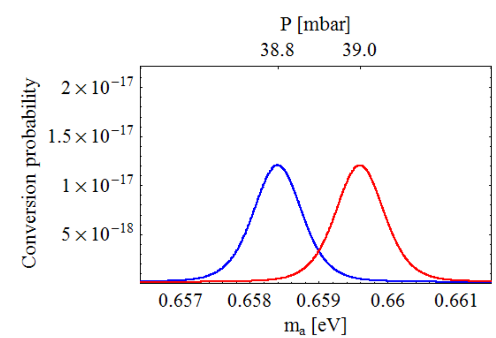
For CAST phase I conditions (vacuum), **coherence is lost for m_a > 0.02 eV**.

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



- New discovery potential for each density (pressure) setting

For P~50 mbar Δm_a ~ 10^{-3} eV

Data taking & shutdown in 2009 - 2010

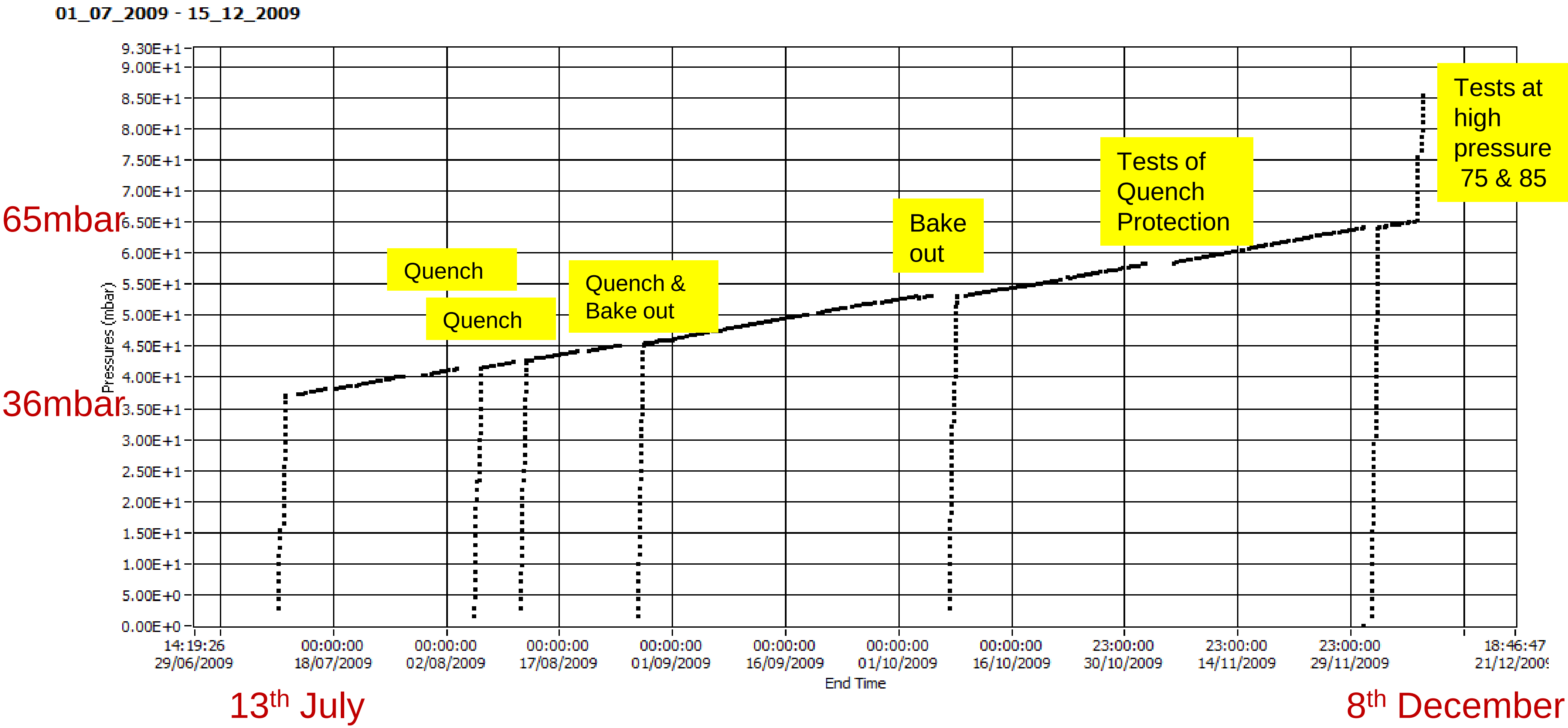
Smooth run in 2009

Extended winter shutdown & ^{3}He incident

Major interruption during 2010 run

Data taking 2009

	Calendar days	Tracking days	Settings covered	Mass Range [eV/c²]	Data taking efficiency	Comments
Projection SPSC 2009	*158*	*115*	*231*	*0.64-0.85*	*75 %*	*125 settings covered up to the SPSC*
Actual numbers	**149**	**124**	**247**	**0.64-0.85**	**83 %**	**247 settings @ 1.4dP**



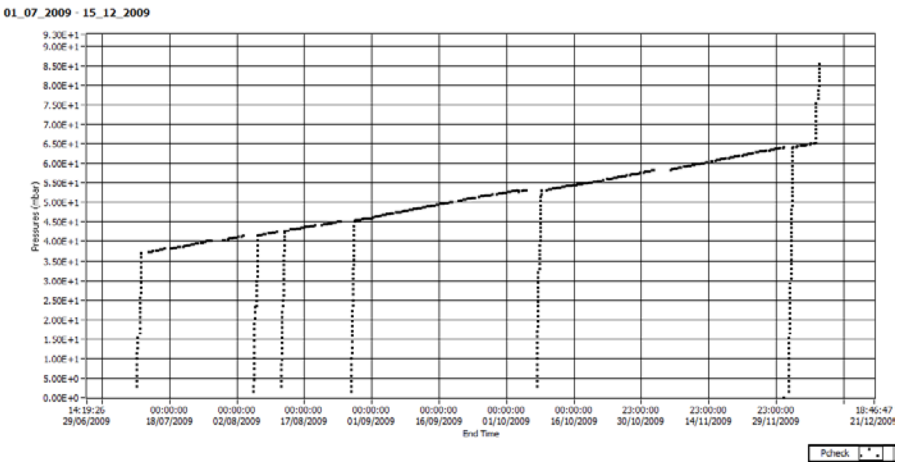
Data taking 2009

Data taking period: 13 July - 08 December.

- 247 settings covered with step size of 1.4dP (dP is the nominal pressure setting ~0.1 mbar).
- Data taking efficiency 83%.
- Mass range covered: 0.64 – 0.85 eV/c^2.

Few data taking breaks:

- October 5th–8th planned stoppage of 3-4 days
  - Cold windows **bake-out** @ 200K.
  - **Add ^3He to the storage volume** to reach ~85 mbar @ 1.8K in 2009.
  - **regeneration/cleaning of the cold-trap and filters** in ^3He system.
- Stoppage in November (3rd-5th): aftermath of the famous bird & the baguette story.
  - The short circuit of the LHC machine 18kV power supply at PA8 occurred in the switchyard directly opposite the CAST zone.
  - The power cut stopped the **LHC & CAST cryogenics** and the **CAST power converter** (13kA).
  - The **CAST magnet did not quench**! *Unusual for the Quench Protection System (QPS)* , which triggers with perturbations on power converter when running at 13kA.
  - Several days to **verify that the QPS is OK**.
- Quench which triggered the ^3He gas recovery safety system on the 2nd December.
  - The quench was **caused by power cut in SR8** which caused the quench heaters to discharge into the magnet.
  - ^3He gas was recovered by the system and refilled into the cold bore in order to complete the 2009 run.
- Test fillings to 75 and then 85 mbar
  - tests of **conditions to be experienced in 2010** and also to execute a single morning tracking data taking run at each pressure.



The ^3He incident

While recovering the gas from the cold bore at the end of the 2009 run, an **over-pressurization event** occurred in the ^3He system resulting in:

- **losing part of the ^3He gas**
- **damaging the ^3He primary pump**

The loss did not jeopardise CAST's ability to reach 120mbar @ 1.8K but this event had a large consequence on the subsequent shutdown schedule

The 2009 – 2010 shutdown

^{3}He system:

- Extensive work was done on ***reviewing the ^{3}He system and its interlocks***, ***repairs and installation of modifications*** following the recommendations of the review

Cryogenics:

- Delayed start of cool down
- Problems with the Roots pump and its primary pump
- Extensive tests and intervention on June-July (5 weeks stop)

Power converter:

- Magnet electrical insulation tests
- Magnet Power Converter improvements
- Magnet and Quench Protection System (QPS)

Routine actions / interventions:

- Tracking system / slow control
- Vacuum
- Survey GRID
- Sun Filming

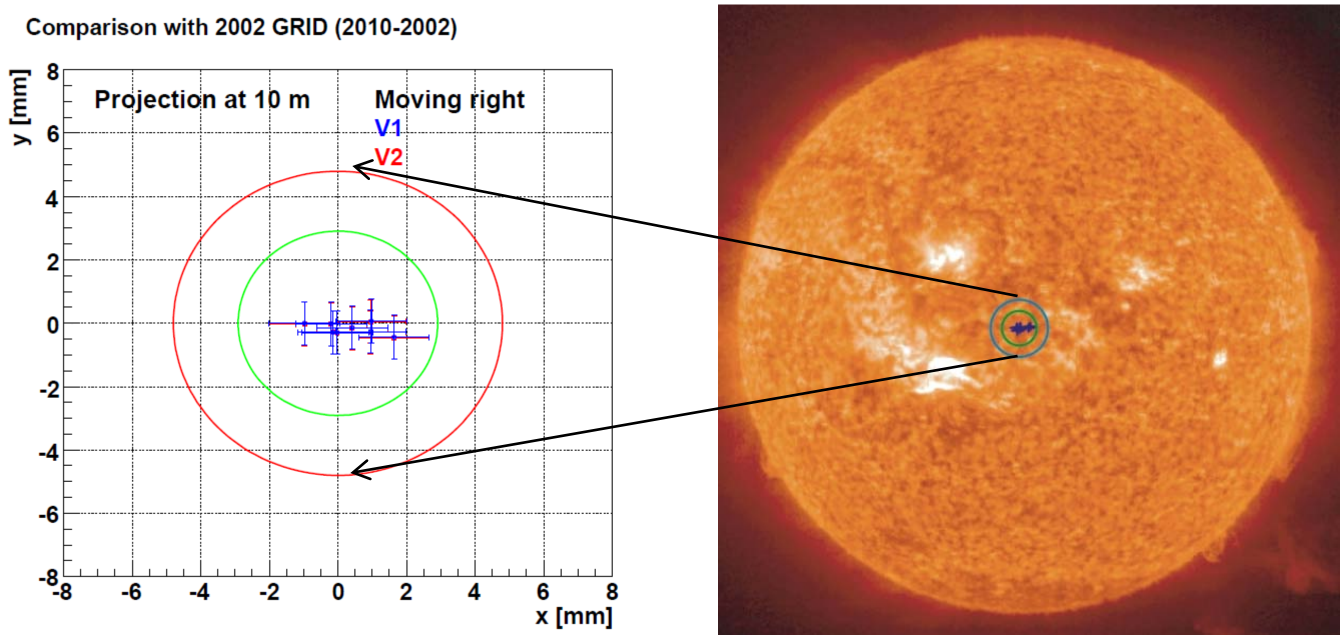
Grid 2010

Periodical check (by CERN surveyors group) of the correspondence between:

H/V Motor Encoders (Magnet orientation)	↔	Grid points (Reference coordinates)

Most recent measurement in March 2010 showed:

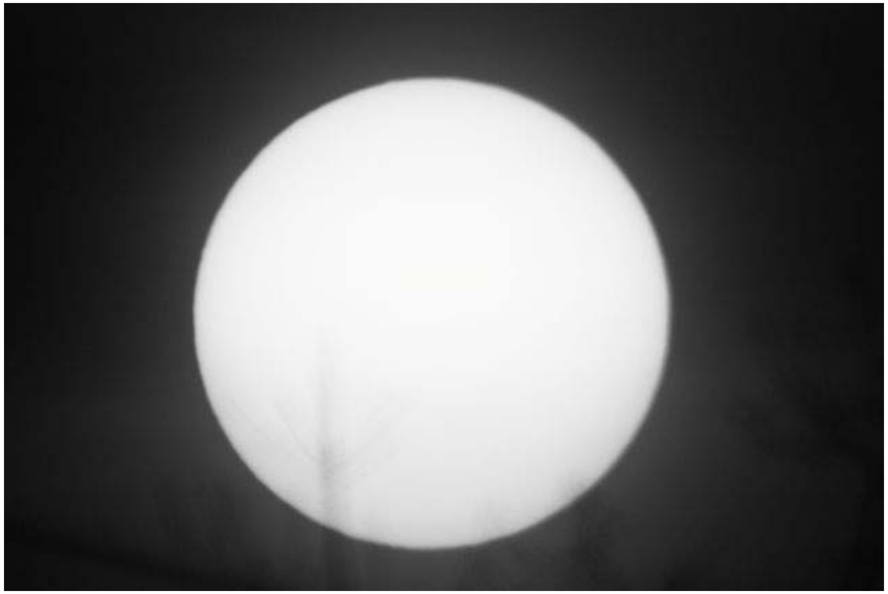
- ✓ System practically *unchanged from 2009*
- ✓ Static correspondence within the required precision (1arcmin)



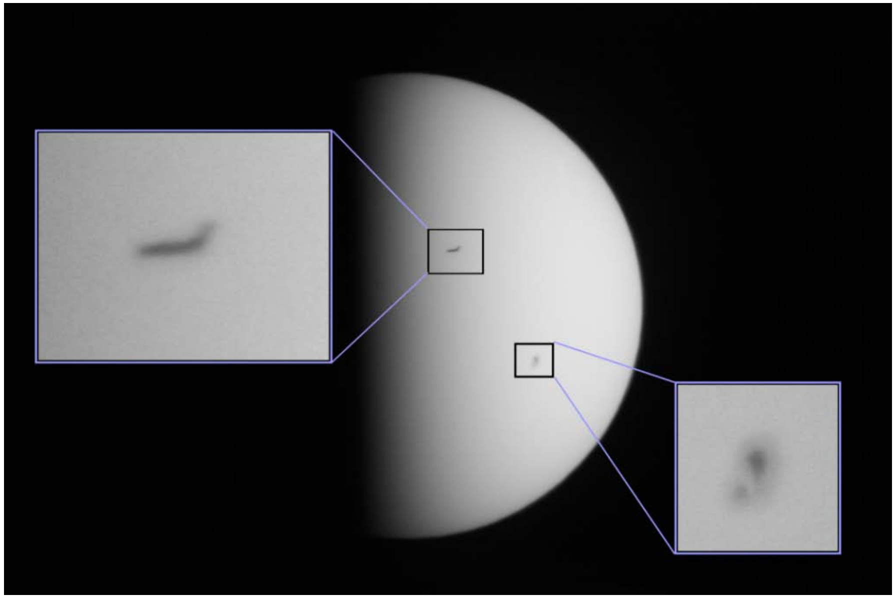
Sun Filming

- **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 (March/September)**
- **Trieste System with upgraded camera / objective**
- **Enhanced precision** (Sun radius 1139±2 pixels / alignment ±25 pixels)!

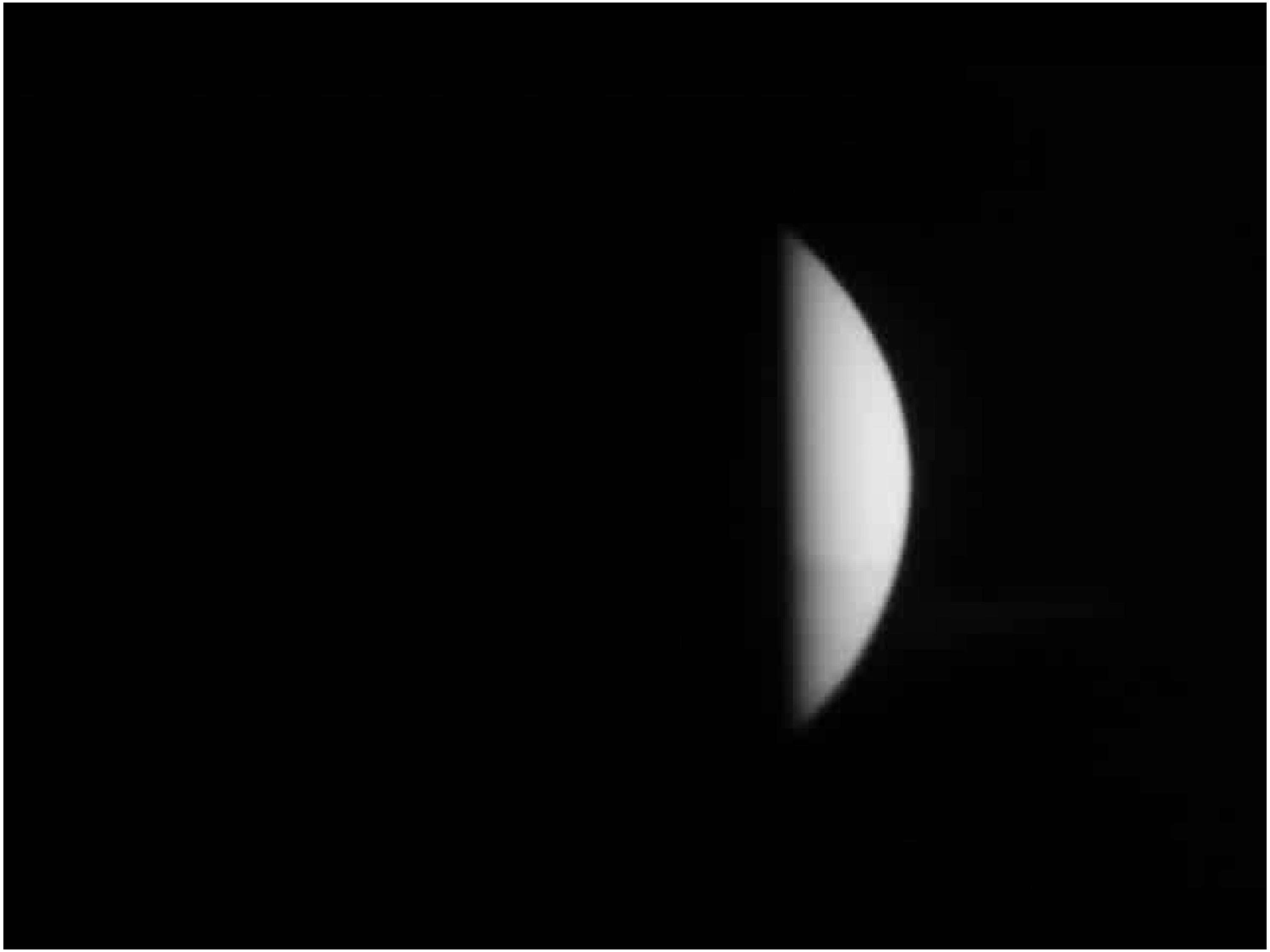
March



September



Solar filming

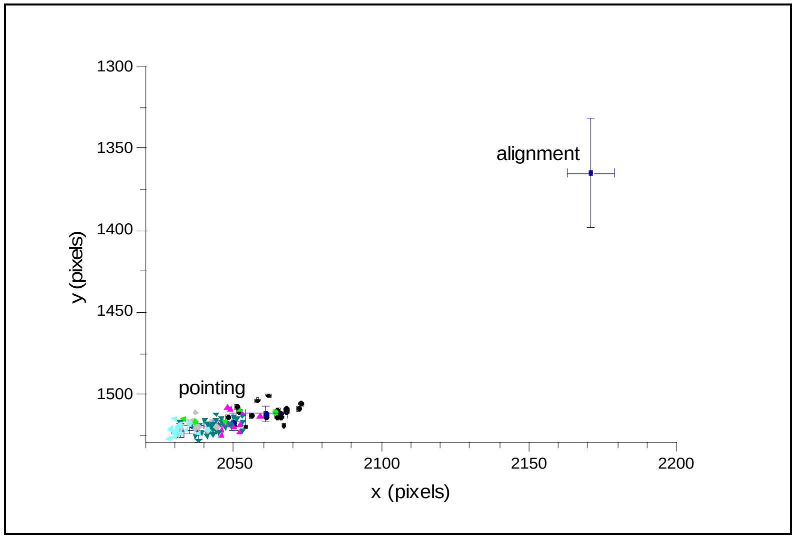


September 2010

Sun filming

Both filmings show that CAST magnet points slightly ahead from solar center (less than 7 sec)

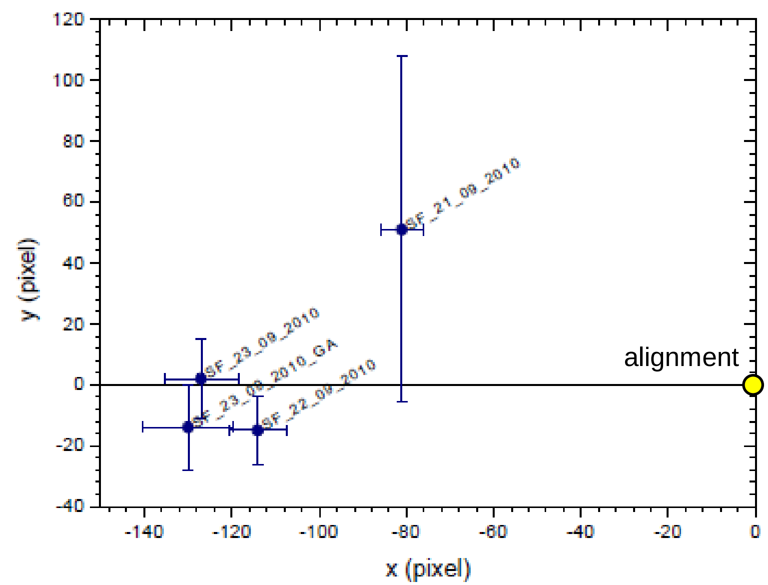
- Difference compatible with CAST acceptance
- No problem for the 3 MM detectors
- Might imply 2-3 pixel correction for CCD spot center
- Under investigation



March

Difference between pointing (solar center from images) and alignment (axes of V1 magnet bore) from all images taken during one filming is:

~120 pixels horizontal
~140 pixels vertical,
(~11% of the solar radius)



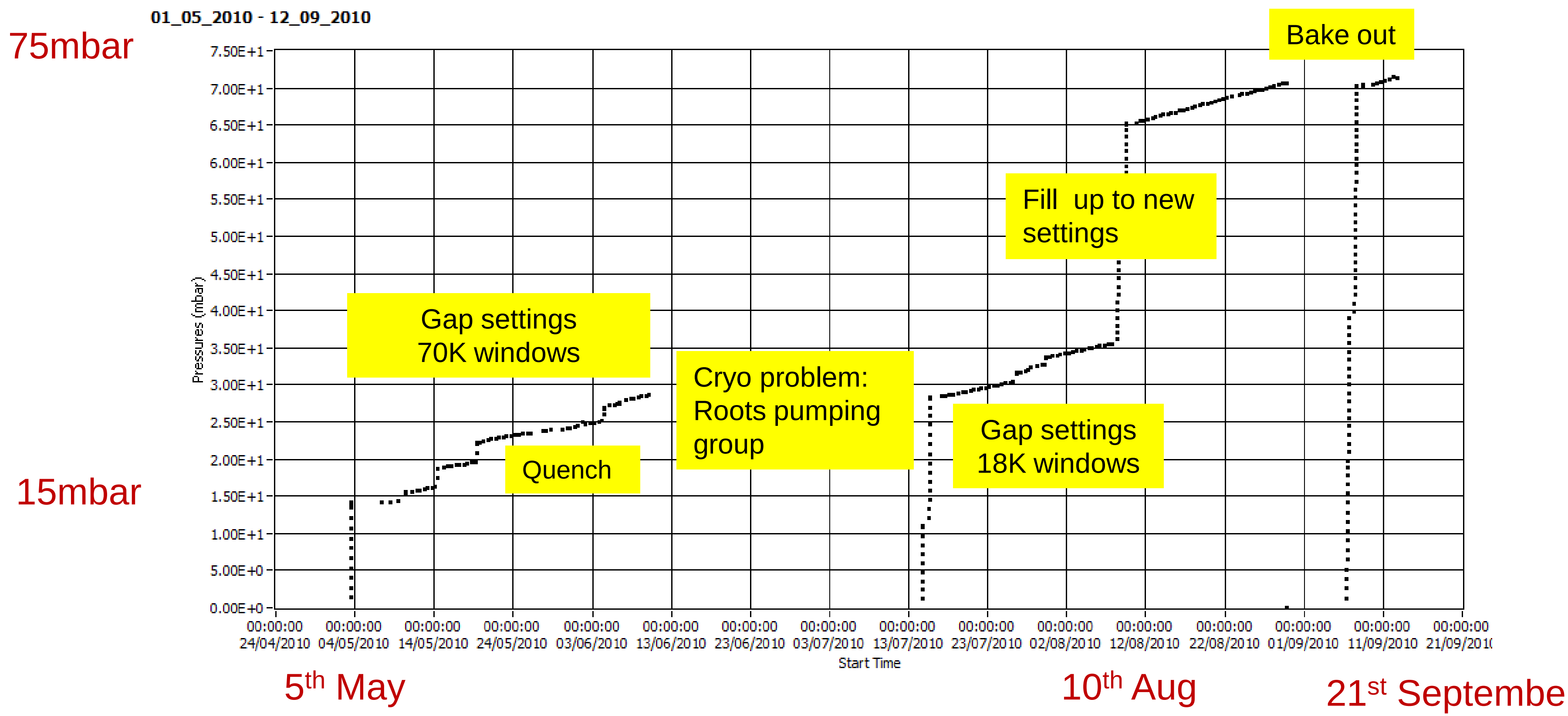
September

Difference is:

~120 pixels horizontal
~10 pixels vertical,

Data taking 2010

	Calendar days	Tracking days	Settings covered	Mass Range [eV/c²]	Data taking efficiency	Comments
Measured	*58*	*53*	*105*	*0.39-0.65*	*[90.5 %]*	*Missing 105 settings 2008*
Projection 2010	**118**	**~81**	**~162**	**0.85-0.99**	**~70 %**	**40+122 settings @ 1.4dP**



Data taking 2010

Delayed start of data taking in 2010 because of extended shutdown period

- 2010 data taking started on 05 May 2010
  - improved Micromegas detectors and suppressed EMC pickup noise from the movement system
  - ^{3}He system much better interlock- protected and understood
  - ^{3}He quench protection system had been reviewed and upgraded for the high density part of the scan
- First part dedicated to **cover missing density settings** (^{3}He leak in 2008)
  - Each missing gap extended to have overlap of 2-3 settings with settings already covered
  - → 105 "missing" density settings were covered in the period 05 May to 07 August (efficiency 90.5%)
    (^{3}He leak, window temperature changes\` , protocol triggered)
- **New density settings** on 10 August (65.1 mbar, 0.85 eV/c^2)
  - From 10 August to 10 September 2010, 40 new settings were covered (efficiency 65%)
- 5-week data taking gap due to the cryogenic pump problems
- **Minimal other perturbations to the experiment:**
  - ✓ Modifications to the power converter controls
  - ✓ Policy of ramping down the field after the sunrise tracking each weekday
  - ✓ Very steady infrastructure conditions required for stable LHC running

- **Data taking until ~1st December**

➔ Expect to reach ~87 mbar (**m_a=0.99 eV/c^2**), step 1.4dP, efficiency ~70%
  - ^{3}He System tests
  - LHC shutdown @ 7th December

➔ *To reach desired target of 1.16 eV/c^2, further running in 2011 will be needed*

Detectors

Smooth & very stable operation

"Finally 4 equally performing detectors"

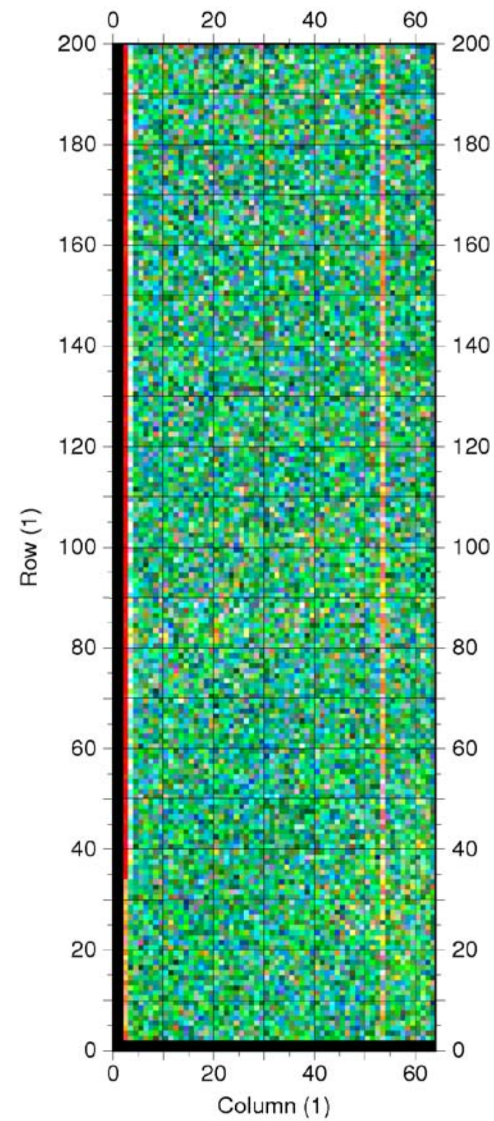
X-Ray telescope status

- ✓ Smooth operation
- ✓ No major problems
- ✓ 99% efficiency

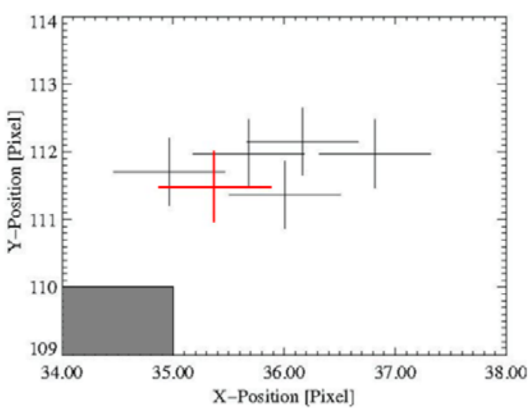
Background [h]	5434
Mean rate (1-7 keV) [cts keV^{-1}cm^{-2}s^{-1}]	~8×10^{-5}
Counts/half tracking (in spot, 9.4mm^2)	0.124

Year	Dates	Nr. of days	Live time	Axion sensitive
2009	13-07 -> 10-12	115	19564106 sec 326068 min 5434 hours 226.4 days	1023057 sec 17050 min 284.2 hours 11.85 days
2010	06-05 -> 29-08	74		

Accumulated hitmap



Alignment check



Results X-ray Spot

Reference Position June 2009

$x = 35.4 \quad y = 111.5$

EDMS Doc ID 1021585

Measurement December 2009

$x = 35.0 \quad y = 111.7$

$x = 36.8 \quad y = 111.9$

$x = 36.2 \quad y = 112.5$

$x = 35.7 \quad y = 112.0$

$x = 36.0 \quad y = 111.4$

Alignment is stable within the tolerance of 1 pixel !

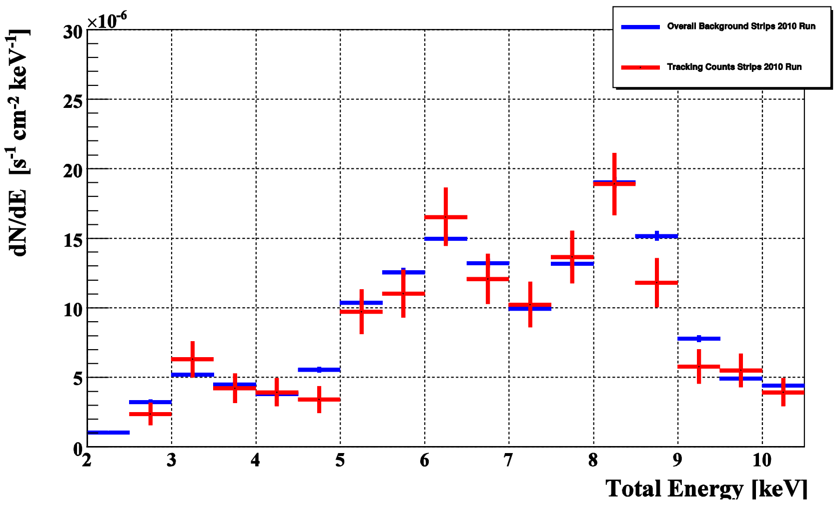
Sunrise Micromegas

Sunrise Micromegas in 2009.

	Tracking	Background
Time (h)	198	3393
Counts	262	5269
Mean Rate (2-7 keV) ($c\ keV^{-1} cm^{-2} s^{-1}$)	$(4.84 \pm 0.31) \times 10^{-6}$	$(5.49 \pm 0.07) \times 10^{-6}$

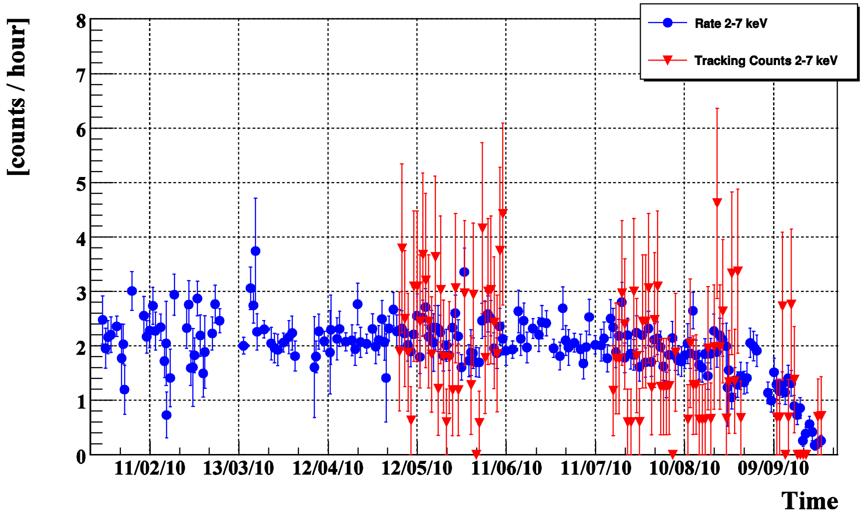
Sunrise Micromegas in 2010
(up to the 8th of September)

	Tracking	Background
Time (h)	120	5640
Counts	241	9561
Mean Rate (2-7 keV) ($c\ keV^{-1} cm^{-2} s^{-1}$)	$(7.32 \pm 0.47) \times 10^{-6}$	$(8.04 \pm 0.08) \times 10^{-6}$



Upgrades:

- New improved Faraday cage;
- Cabling work;
- ✓ Smooth operation
- ✓ No pickup EMC noise
- ✓ 99% efficiency



Sunset Micromegas

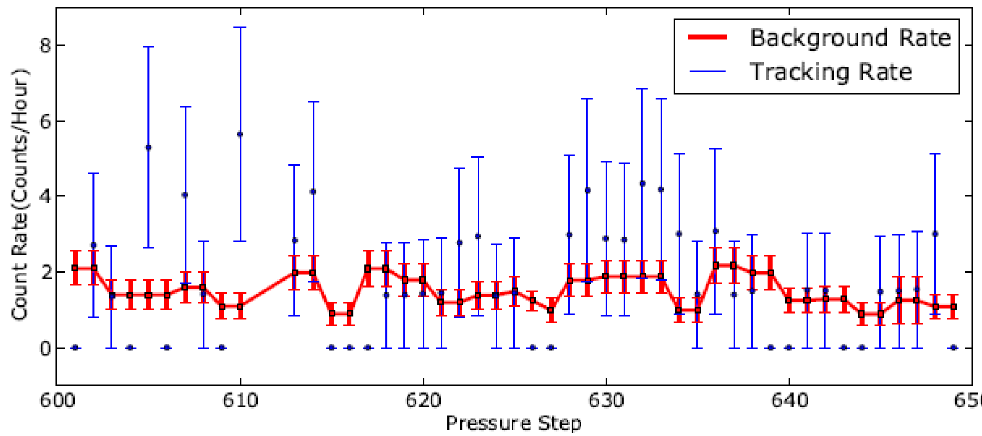
Sunset Micromegas in 2010
(up to the 8th of September)

SUNSET 1	Tracking	Background
Time (h)	105	2581
Counts	167	4095
Mean Rate (2-7 keV) ($c\ keV^{-1}cm^{-2}\ s^{-1}$)	$(6.04 \pm 0.47) \times 10^{-6}$	$(6.22 \pm 0.10) \times 10^{-6}$
SUNSET 2	Tracking	Background
Time (h)	104	2581
Counts	175	4877
Mean Rate (2-7 keV) ($c\ keV^{-1}cm^{-2}\ s^{-1}$)	$(6.38 \pm 0.49) \times 10^{-6}$	$(7.29 \pm 0.10) \times 10^{-6}$

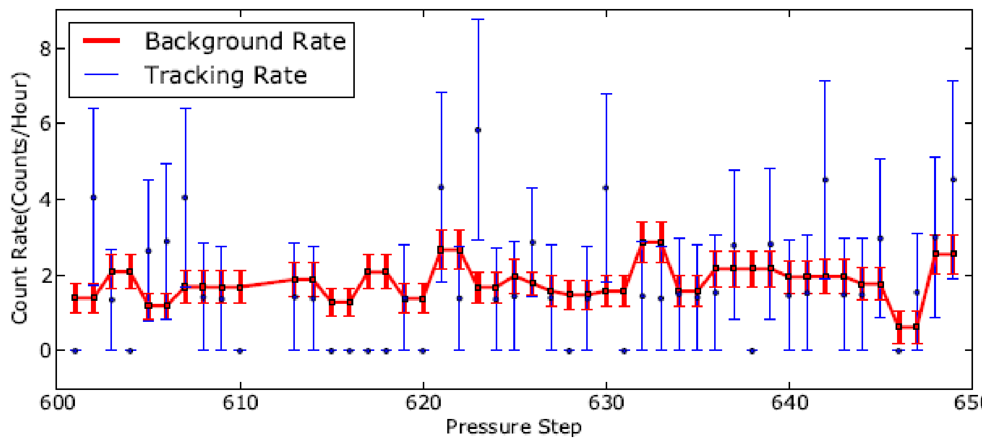
Upgrades:

- New source manipulators;
- Cabling work;
- ✓ Smooth operation
- ✓ No pickup EMC noise
- ✓ 99% efficiency

SSμM 1



SSμM 2



BaRBE status

Establishment of a "5th line":

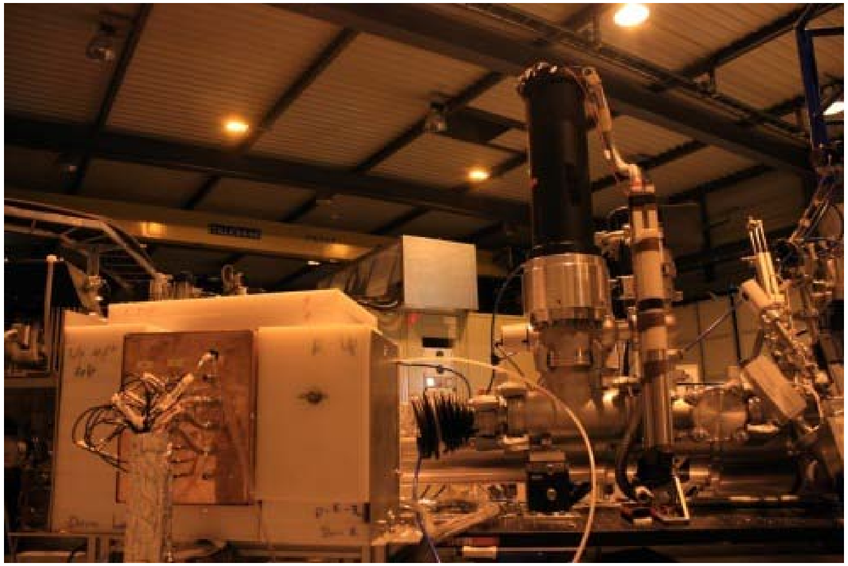
a 3.5 µm aluminized Mylar foil (transparent to X-rays) is placed on the sunrise micromegas line to deflect **visible photons** on an angle of 90°, towards the **PMT** (2010)

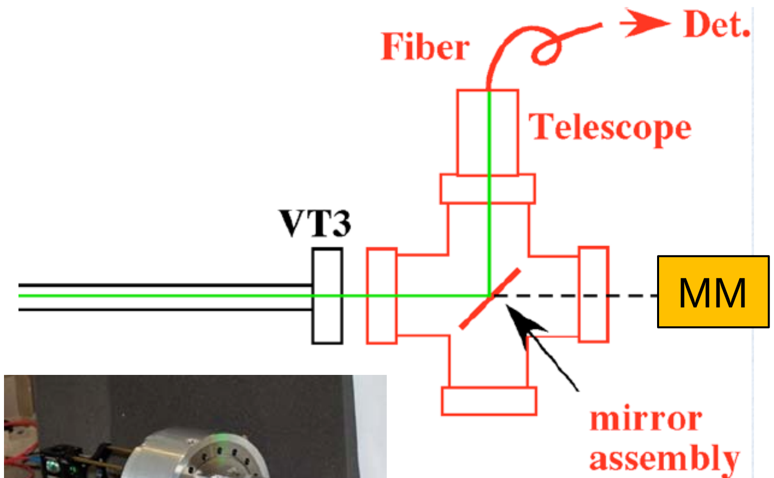
Statistics:

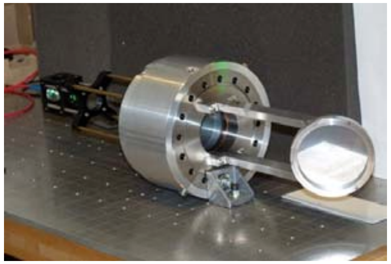
- Sun tracking 3.3×10^5 s
- Background 4.3×10^6 s
- DCR(sun tacking) = (0.42+/-0.03) Hz
- DCR(background) = (0.42+/-0.01) Hz

- On average there is no excess of sun tracking counts over background,
- Detailed analysis in progress

The 5th line





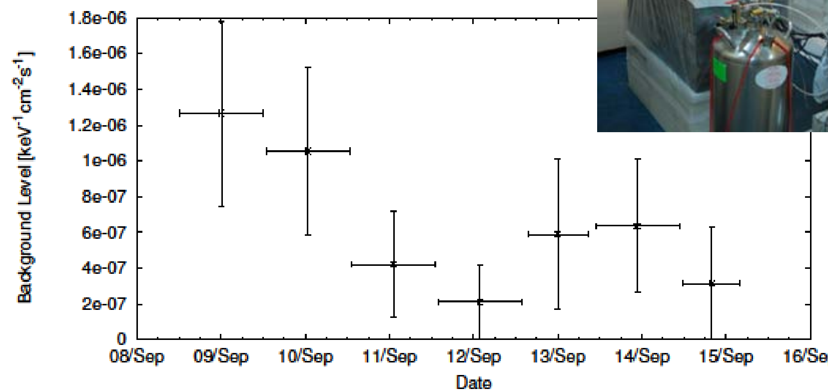


Detector development

Comprehending the background nature

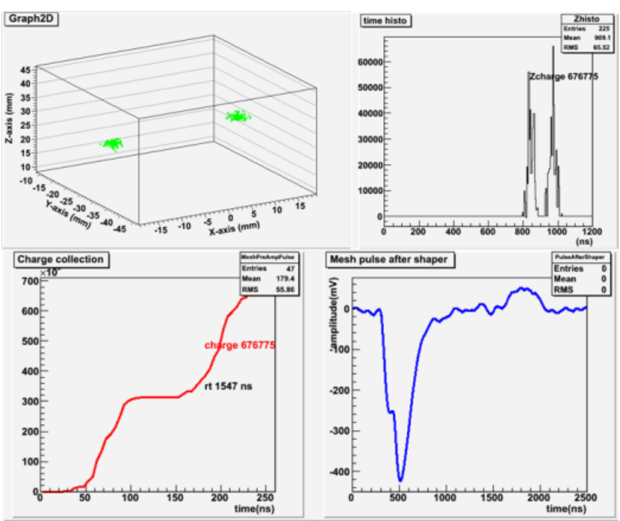
Laboratory tests

Background Studies
in Canfranc



Mean rate ≈ $8{\cdot}10^{-7}$ keV^{-1} cm^{-2} s^{-1}

Monte Carlo Simulations

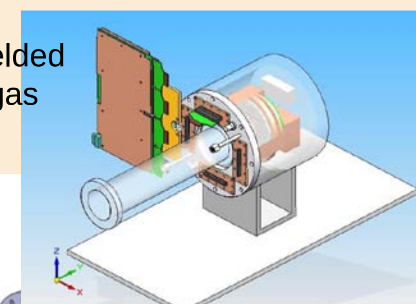


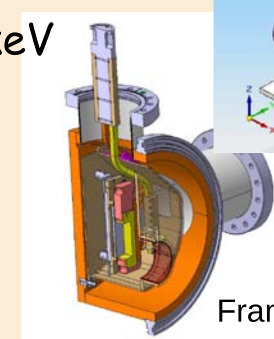
New design

- Very low background
- Low threshold (sub-keV range)

✓ For future physics

Self –shielded Micromegas





Frame store CCD

^{3}He System

"The ^{3}He phase was and is a challenging project which turned out to be far more complex than even the experts had imagined"

Working with a buffer gas…

- **Precise knowledge** and **reproducibility** of each pressure setting is essential
- Gas **density homogeneity** along the magnet bore during tracking is critical
  - ✓ **Superfluid** ^{4}He @ 1.8 K guaranties **temperature stability** along the cold bore
  - ✓ Hydrostatic pressure effects are not critical

However:

- × There are parts of the magnet bores, outside the magnetic field region, that are in higher temperatures. These temperatures **can vary during tracking** and may **depend on the buffer gas density**
- × There is also a volume of pipe work in high temperature directly connected with the cold bores

To face that situation we:

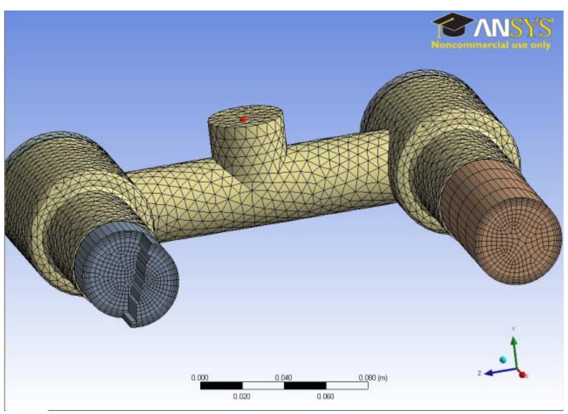
- Measure precisely the amount of **gas injected** into the magnet with a **metering volume** kept at stable temperature (typically 36 °C)
- During ^{4}He phase we kept the **cold windows** that confine the gas **at T=120K**, making the effective “dead volume” **negligible**
- × However at higher densities (^{3}He phase) heat conduction towards the magnet does not allow high window temperatures. Dead volumes become **significant** and more effects appear (**gas convection**) . Comprehending the gas behavior is critical for the data analysis!

Understanding ^{3}He dynamics

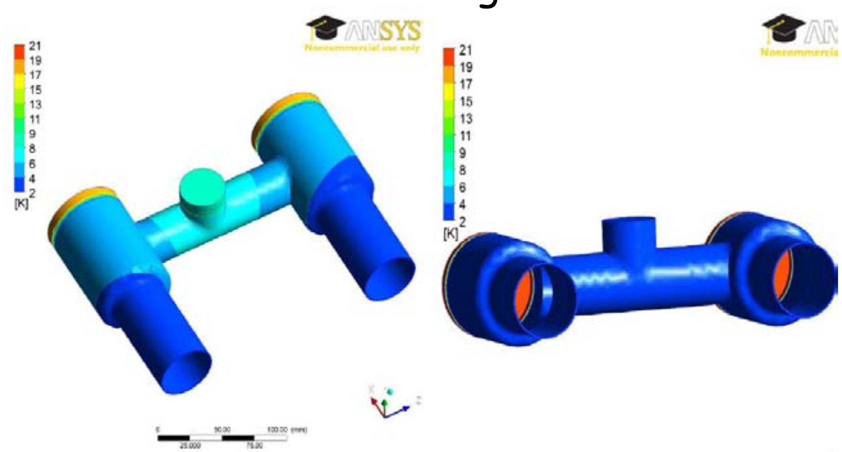
A number of additional **temperature and pressure sensors** have been placed in several points of the magnet and the gas system

- These sensors revealed a **divergence** from the gas behavior expected by the initial **simple model**.
- ✓ A series of **C**omputational **F**luid **D**ynamics simulations with the sensors' data as bounding conditions was performed and is still going on
  - Static case
  - Dynamic case (magnet movement)

Geometry parameterization



Temperature distribution in the cold window region

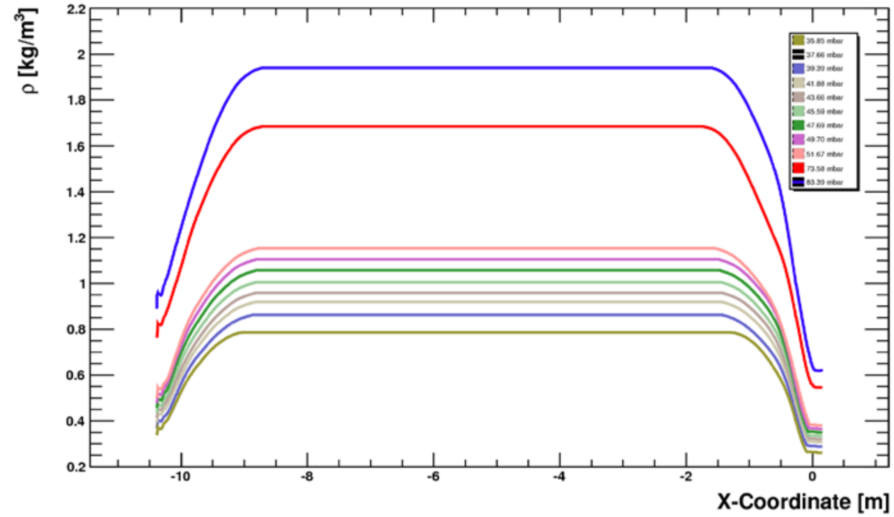


Simulation results

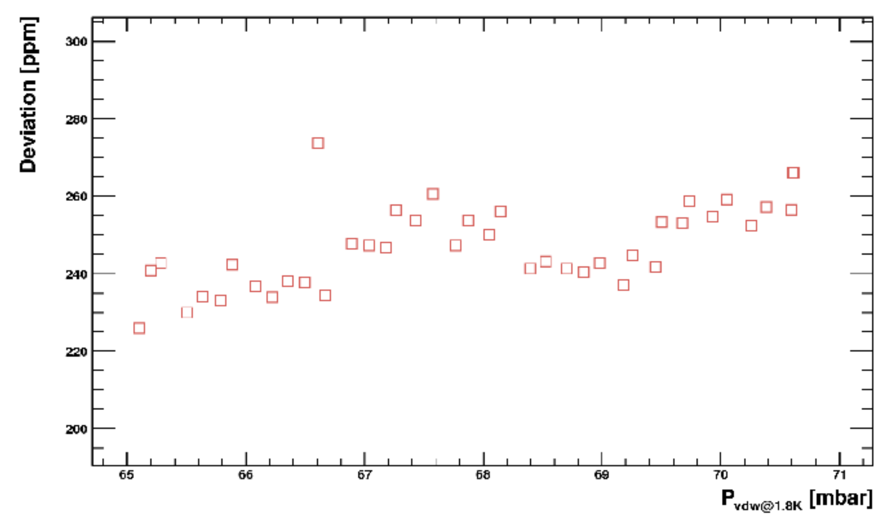
Simulations & new instrumentation have been essential in understanding 3He system

- ➢ in CAST temperature and density conditions ^{3}He is not an ideal gas (Van der Waals forces)
- ➢ convergence between simulation results & experimental data
- ✓ Knowledge of gas density / setting reproducibility possible
- ✓ Gas density stable along magnet bore
- ➔ Coherence length slowly decreases with increasing density

Gas density along the magnet bore



Agreement between measured/simulated pressure



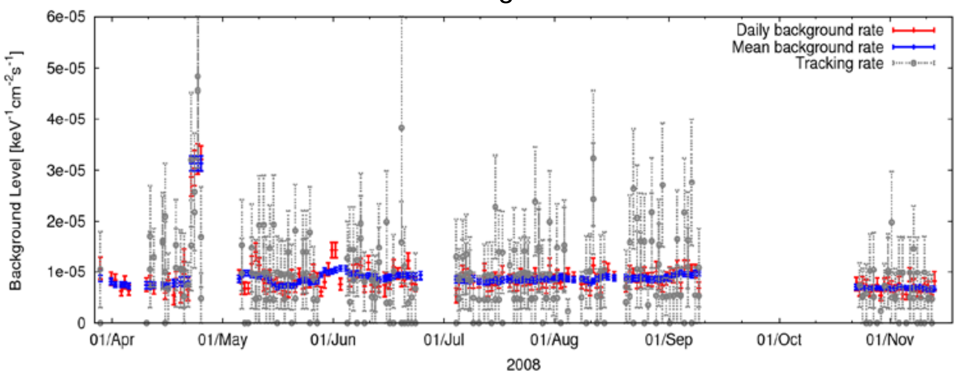
First results from ^3He

A new approach compared to ^4He-phase analysis

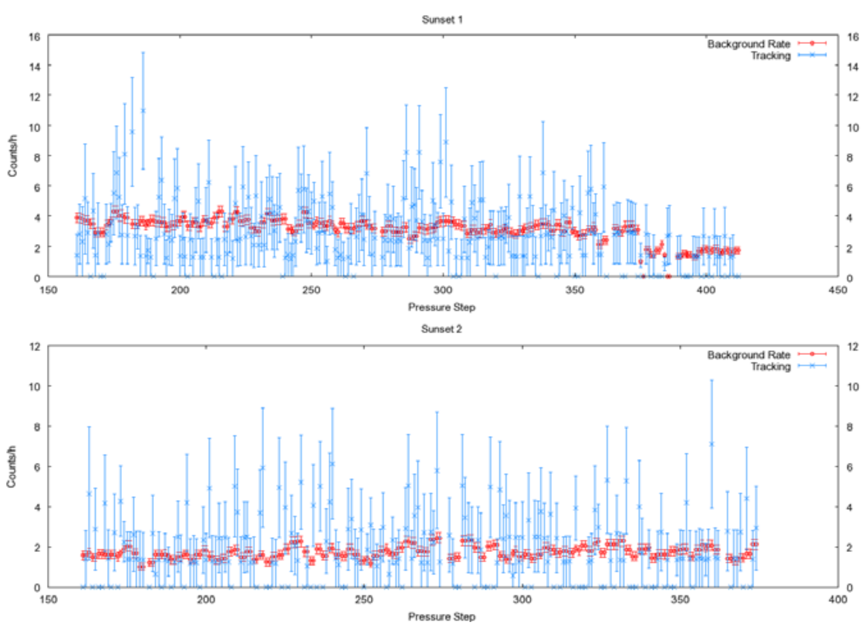
Preliminary ^{3}He result

- Background estimation & systematics
- Counts during tracking as a function of **axion mass**
- Tracking time as a function of **axion mass**

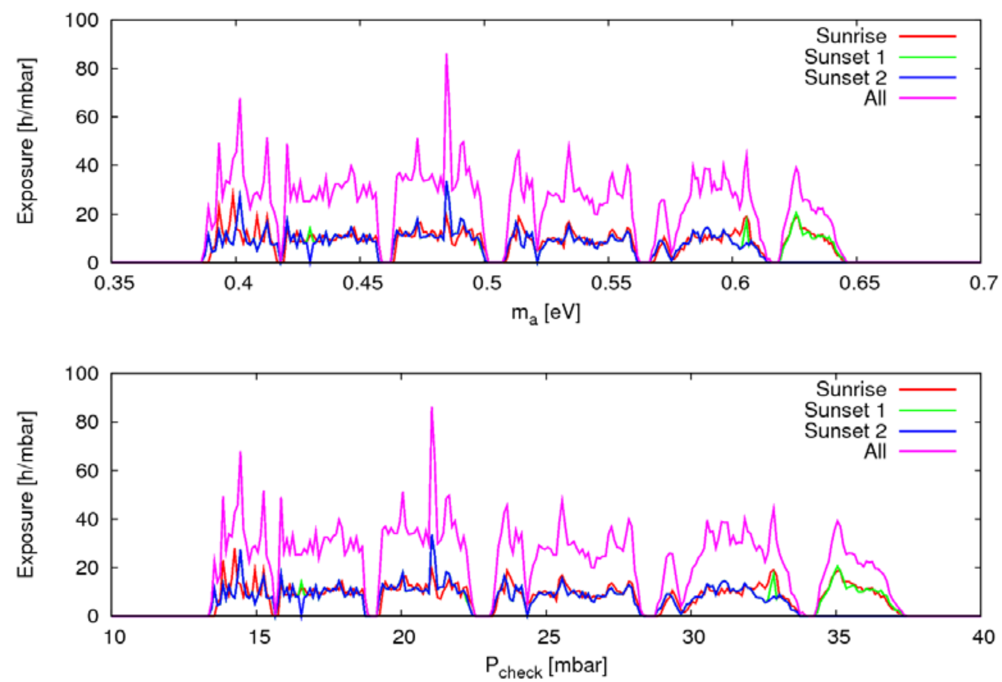
Sunrise Micromegas data in 2008.



Sunset Micromegas data in 2008.



Tracking time vs axion mass in 2008.



Preliminary - ^{3}He result

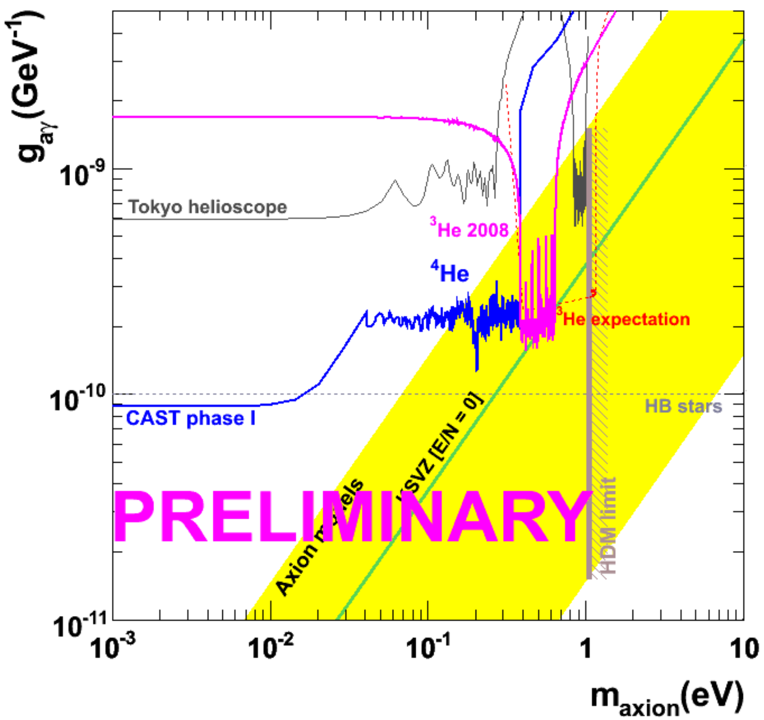
Density variation during a tracking ➔ ^{4}He phase analysis not easy to be used.

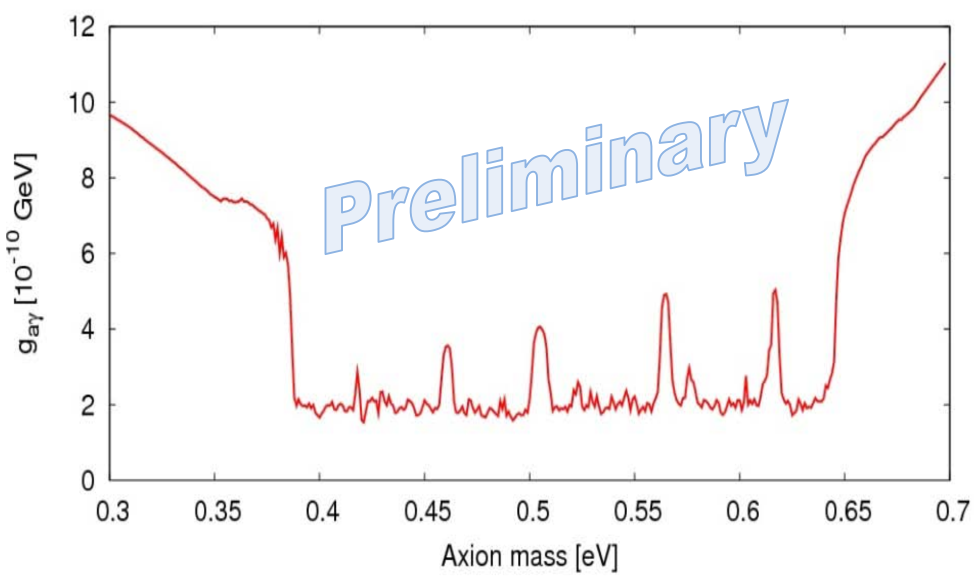
- new formulation of the unbinned likelihood:

$$Log\left(L_{m_a}(g_{a\gamma})\right) = \underbrace{-g_{a\gamma}^4 \int_E \int_{t_k} \frac{d^2 n_\gamma}{dE \cdot dt_k} dE \cdot dt_k}_{\text{Zero counts detected contribution}} + \sum_{kn_i=1} \underbrace{Log\left(b_{ik} + g_{a\gamma}^4 \int_{E_i}^{E_i+\Delta E} \frac{dn_\gamma^k}{dE}\right) dE}_{\text{One count detected contribution}}$$

1st term: expected number of axions. Depends on exposure time

2nd term: Depends on the gas density at the moment a count occured





J. Galan PhD Thesis

Request for running in 2011

^3He data taking overview

Year	Calendar days	Tracking days	Settings covered	Mass Range [eV/c^2]	Comments
2008	201	127	252	0.39-0.65	168 settings @ 1.0dP 85 settings @ 1.2dP Step decreasing with time due to leaks
2009	149	124	247	0.64-0.85	247 settings @ 1.4dP
2010	58 118	53 ~81	105 ~162	0.39-0.65 0.85-0.99	Missing 105 settings 2008 40+122 settings @ 1.4dP (assuming 70% data taking efficiency)
total	**526 (80% original)**	**385 (90% original)**	**766**	**0.39-0.99**	**80% of the proposed pressure settings covered**
2011	~140	~98	196	0.99-1.16	196 settings @ 1.4dP (assuming 70% data taking efficiency)

- End of 2010 run: expect to have reached ~ 87.5 mbar (0.99 eV/c^2), step 1.4dP, data taking 70%
- **The main reasons for not reaching the planned axion mass (1.16 eV/c^2):**
  - **is the 2008 ^3He leak and the consequences it had in 2009 (delay in data taking start due to shutdown intervention for ^3He leak) and 2010 (time spent in covering the missing gaps)**
  - **^3He phase was and is a challenging project for CAST which turned out to be far more complex than even the experts had imagined**
- CAST can reach 120 mbar (1.16 eV/c^2) with 1.4dP step size and 70% efficiency by July 2011

Request for running in 2011

The CAST collaboration strongly desires to continue with the ongoing direct search for solar axions until July 2011 to complete the original scientific objective of searching for axion rest mass up to m_a~1.16 eV/c^2

➔ ***FRC 21st Sept: CAST has the financial resources and manpower to complete the program***

Requests for 2011 ^{3}He running

- CERN
  - Running magnet in 2011
- Continued support from Departments:
  - TE-CRG
    - Continued Cryogenic support
    - Minimal maintenance of cryogenic system before mid February 2011
    - 1.8K by 1 March 2010
    - Operation until July 2011 then warm up to room temperature
  - TE-VSC
    - CAST vacuum systems
  - TE-MPC /EN-ICE
    - Power converter/Power converter controls
  - TE-MPE
    - Quench protection
  - PH-DT
    - Mechanical support & magnet movement
    - Controls & electrical support

Conclusions

10 years of CAST!

- CAST has not observed a direct solar axion signal but has provided **world class limits for axions and axion-like particles**
- The first preliminary results of the ^{3}He data analysis show that high rest mass range (≤ 1.16 eV/c^2) can be investigated with the targeted sensitivity
- Need to run in 2011 to successfully complete the demanding & challenging ^{3}He phase

➔ ***Early November CAST collaboration will submit an addendum (in preparation) for future measurements to be done in 2011, 2012, 2013***

Thank you!

Backup slides

The 2009 – 2010 shutdown

Routine actions / interventions:

- ***Inspection of 13kA magnet power cables***
  - **Bad wear on outer sheath** of a number of cables was found. Modifications to the structure to remove stresses & humidity detection wires for an early alarm in case of leak
  - Cables **could continue to be used in 2010**
- ***Wear on jacks***
  - **Wear on lifting jacks** during 2009 (well within safety tolerances but asymmetric)
  - No adjustments necessary
  - New jacks were bought → in reserve.
  - Jacks can be changed at end of 2010 or after ^{3}He run.
- ***Vacuum***
  - Routine maintenance of residual gas analyzers and pumps
  - Completion of the vacuum interlock system.
  - Torque check and helium leak test of all metal vacuum joints
- ***Survey GRID***
  - Routine annual measurements were done on the 10-12 March 2010
- ***Sun Filming***
  - Measurements were done on the 16-18 March 2010 (magnet cool-down interrupted)
  - September filming is going on
- ***Magnet movement control system maintenance***
  - Maintenance & improvement of EMC shielding on magnet movement frequency inverters.

    ➔ Reduced pickup noise on Micromegas (MM) during tracking.
- ***Slow Control***

The 2009 – 2010 shutdown

Power converter:

- ***Magnet electrical insulation tests (TE-MPE)***
  - proposed by TE-MPE in view of LHC incident.
  - The procedure required the availability of the busy LHC quench protection team and magnet @ 1.8K.
  - Test of the resistance between magnet coil and the ground at 28V was >>1 MΩ → **acceptable**
  - High voltage insulation of quench heaters to the grounded coil → **successful**
- ***Magnet Power Converter improvements***
  - Minimise number of *"infrastructure quenches"* caused by **perturbations & fake quench signals** (electrical network 'glitches', dips in water cooling supply)
  - Current regulation and monitoring crates of the power converter placed on assured power
  - **Soft interlocks on water system** to Slow Ramp down the magnet current
  - **Remote ramp-down facility**
- ***Magnet and Quench Protection System (QPS)***
  - Thorough tests
  - Routine provoked discharge of quench heaters triggered @ 1500A to check out interlocks
  - Magnet was powered to 13050A with no quench (7 April)
  - ➔ **The magnet has operated throughout 2010 so far without a quench**. (a too-low water pressure alarm was incorporated into the slow ramp logic)

The 2009 – 2010 shutdown

^{3}He system:

- Extensive work was done on a ***review of the ^{3}He system and its interlocks***, and later, there were interventions for ***repairs and the installation of modifications*** following the recommendations of the review.

Cryogenics:

- Delayed start of cool down
  - Safety pressure tests in cryo compressor circuit – long overdue
  - Repairs to leaking pipe-work after the pressure testing.
  - Cryo team overload over many experiments. Delayed start of cool-down on 12 March
  - Stoppage due to compressor leak and Sun Filming. Cooling restarted on the 18th March. Magnet at **4.5K on the 22nd March and 1.8K on 24th March**.
- Problems with the Roots pump and its primary pump (~9th April)
  - the source of the oxygen contamination in the returning 4He gas was not found.
  - The pumping system was working under extreme conditions: cold windows operated with heating ON to reproduce the conditions of the 2008 run.
  - The system continued to operate with instabilities and heavy supervision by the cryo group
- Extensive tests after 9th of June led to the discovery of the leaks in the shaft seals of the primary pump.

➔ *CAST decided to continue filling the setting gaps using unheated windows and a larger margin of overlap at the edges of the gap to allow for possible systematic effects.*

Item	CAST/Dept	Units	2008	2009	*2010*	*2011*
Cryogenics M&O (incl gases)	**AT**	**(kCHF)**	**180**	**180**	180	180
Cryogenics power	**TE**	***(hours)***	***7000***	***4653***	*6177*	*4268*
		(kCHF)	**193**	**128**	170	117
Magnet Power Supply	**TE**	***(hours)***	***3527***	***2288***	*3037*	*2099*
		(kCHF)	**25**	**16**	22	15
PS Field Support	**BE**	**(kCHF)**				
	CAST	**(kCHF)**	**5**	**5**	*5*	*5*
Annual Total	**CERN**	**(kCHF)**	**398**	**324**	*372*	*312*
Add No 3			401	358	401	

[1] Calculated assuming 55 CHF/MWhr

Envisaged measurements with upgraded CAST: 2011-2013

- Solar axion & Chameleon search → improve own world best limit / most sensitive search
  - → low noise MM
  - → low thresshold detectors

- CAST as paraphoton helioscope → state-of-the-art

- Low energy axions or other WISPs from the Sun ($E \gtrsim 2eV$)
  - + linear polarization
  - + Fabry-Perot resonator

- Observation of stellar X-ray sources with CAST ?

- R&D towards *New Generation Axion Helioscope* (detectors, optics, magnet)

- more?

→ upgraded / new detectors
→ extensive interventions

Next generation Helioscope

Coupling constant dependence: $$g_{\alpha\gamma} \propto \underbrace{(BL)^{1/2} \times A^{1/4}}_{magnet} \times \underbrace{b^{1/8}}_{Detector} \times \underbrace{t^{1/8}}_{tracking\ system}$$

Detector improvements

Dependence $\propto$ 8th root but big margins:

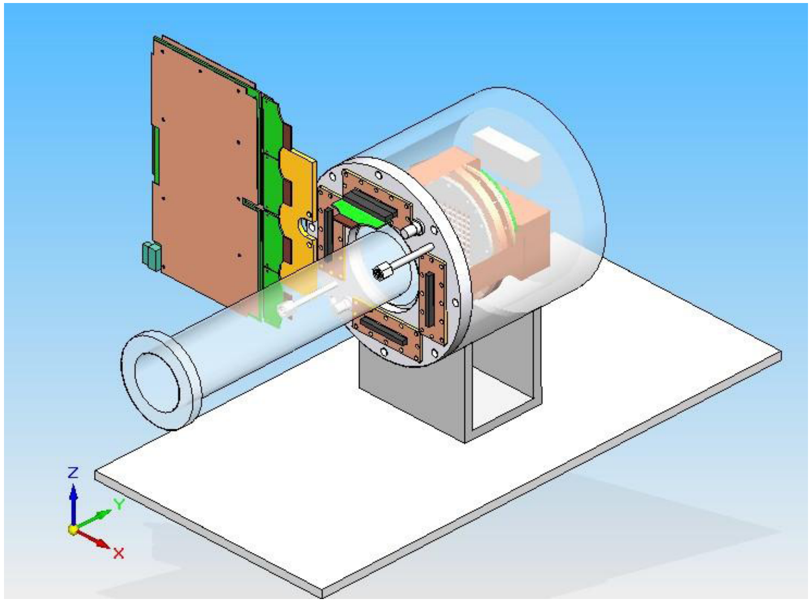
✓ Ultra-Low-Background periods (>1 week each) have been observed with 4 different detectors

Not fully understood yet but:

- Ongoing simulations by Zaragoza group
- Ongoing background measurements in a controlled environment (Canfranc)
- Optimized detector design

✓ New X-ray optics feasible

- Cover big aperture
- High efficiency (>50%)



Next generation Helioscope

Coupling constant dependence: $$g_{\alpha\gamma} \propto \underbrace{(BL)^{1/2} \times A^{1/4}}_{magnet} \times \underbrace{b^{1/8}}_{Detector} \times \underbrace{t^{1/8}}_{\text{tracking system}}$$

Magnet improvements

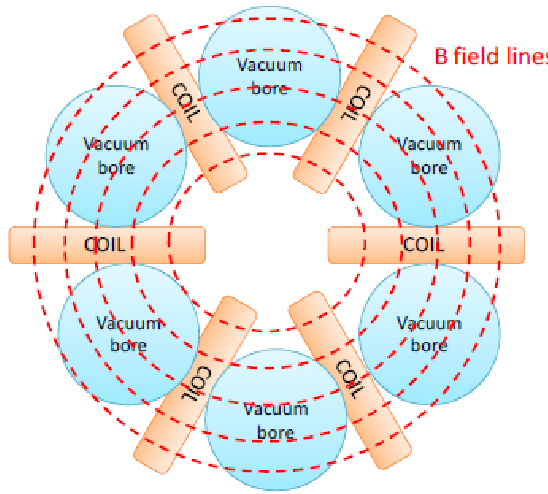
Strong dependence with B,L but small improvement margins for next decade

Increase of tracking time helps but big technical difficulties

Magnet bore's aperture!

Meetings with CERN magnet experts ➔ alternative configurations

- ✓ In an axion Helioscope field homogeneity is not as important as in accelerators
- ✓ An "ATLAS – like" configuration proposed by S. Russenschuck and L.Walckiers is the most promising
  - ➢ Big aperture (~1 m) / multiple bores seem possible
  - ➢ Big magnetic field possible (new superconductive material)
  - ➢ Lighter construction than a dipole



Feasibility studies have started