The Upgraded Performance of CAST.

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CAST (CERN Axion Solar Telescope) is a helioscope looking for axions coming from the solar core to the Earth. The experiment, located at CERN, is based on the Primakoff effect and uses a magnetic field of 9 Tesla provided by a decommissioned LHC magnet. CAST is able to follow the Sun during sunrise and sunset and, therefore, four X-ray detectors are mounted on both ends of the magnet waiting for a photon from axion-to-photon conversion due to the Primakoff effect. During its First Phase, which concluded in 2004, CAST looked for axions with masses up to 0.02 eV. By using a buffer gas, CAST's Second Phase manages to re-establish the coherence needed to scan for axions with masses up to 1.20 eV. This technique enables the experiment to look into the theoretical regions for axions. During the years 2005 and 2006, the use of ^{4}He in CAST has already provided coherence in order to look for axions with masses up to 0.39 eV. At present time, CAST has managed to upgraded its experimental setup to alloy ^{3}He within the magnetic field and data concerning axions of masses up to 0.56 eV have already been taken.

1 Helioscope axion searches

The strong CP-problem of QCD might be solved by the introduction of a chiral symmetry that leads to the existence of a new pseudo-scalar particle [1]. Axions, as the new particles were named [2, 3], can be produced via the so-called Primakoff effect [4] in the presence of strong electromagnetic fields. The solar core is an ideal environment to produce them due to the strength of the solar plasma electric fields. In such conditions, a real photon (X-ray) and a virtual photon might couple and result in an axion that could be able to reach the Earth's surface. Those axions, could be reconverted into X-ray photons in a magnetic field and therefore detected by using a magnet pointing to the solar core and an X-ray detector attached to its end [5].

2 The CAST experiment

Twice per day, CAST (CERN Axion Solar Telescope) points in the direction of the Sun making use of a decommissioned superconducting LHC magnet of 9.26 m length and 9 Tesla field in order to look for a signal of axions according to the expected differential axion flux at the Earth's surface [6].

Four different X-ray detectors are mounted on both sides of the magnet. Each one of them is daily aligned with the solar core during 1.5 hours expecting a photon coming from an axion-to-photon conversion due to the Primakoff effect suitable to happen in the magnet of CAST. The detectors are: two sunset MICROMEGAS that replace the previously used Time Projection Chamber [7], a sunsrise MICROMEGAS [8] and a Charge Coupled Device [9], this last one together with an X-ray telescope that improves the signal to background ratio by a factor of about 200 for this detector.

Due to coherence requirements, during the data taking periods of 2003 [10] and 2004 [11] *(see Figure 1)* CAST was sensitive to axion masses under 0.02 eV. The loss of coherence over the full magnet length that CAST encountered during its First Phase when the magnet bores were under vacuum is restored for the Second Phase of the experiment by filling the magnet with a buffer gas such that the photon acquires an effective mass. By varying the gas and its pressure the search for axions with higher masses is possible.

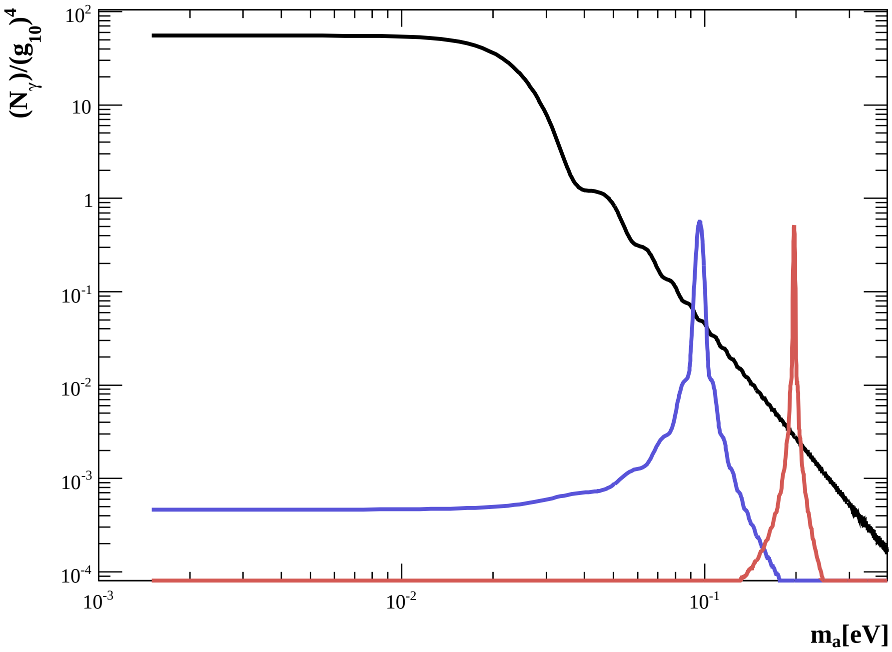

Figure 1: Expected photons arriving CAST for the First Phase (black line) and for two different settings of CAST's Second Phase (red and blue lines). Observe how CAST loss of coherence for axion with masses below 0.02 eV during the First Phase of the experiment is restored during the Second Phase with the help of ^{4}He and ^{3}He as buffer gases.

The CAST experiment has been upgraded in order to be able to have gases at various pressures in the magnet bores. Four cold windows have been developed and placed inside the magnet in order to keep the gas under the conditions needed. A complete gas system has been designed and built to deal with the buffer gas and control its pressure with the needed accuracy.

Cooling the super conducting CAST magnet down to 1.8 K by using superfluid Helium causes the employed gas in the magnet conversion region to saturate. ^{4}He for instance, is able to restore CAST's coherence for axions masses up to 0.39 eV but it saturates at ∼16.4 mbar. In order to achieve coherence for higher axion masses the use of lighter gases is required. ^{3}He allows a further search for axion masses up to 1.20 eV *(see figure 2)*. The Second Phase of CAST consists then of two different stages:

- ^{4}**He run:** allowing to look for axions with masses up to 0.39 eV. Completed during years 2005 and 2006.
- ^{3}**He run:** restoring coherence for axion masses up to 1.20 eV. Years 2007 to 2010.

CAST data taking procedure during its Second Phase has been chosen in a way such that allows to scan for axion masses from 0.02 to 1.20 eV in little steps.

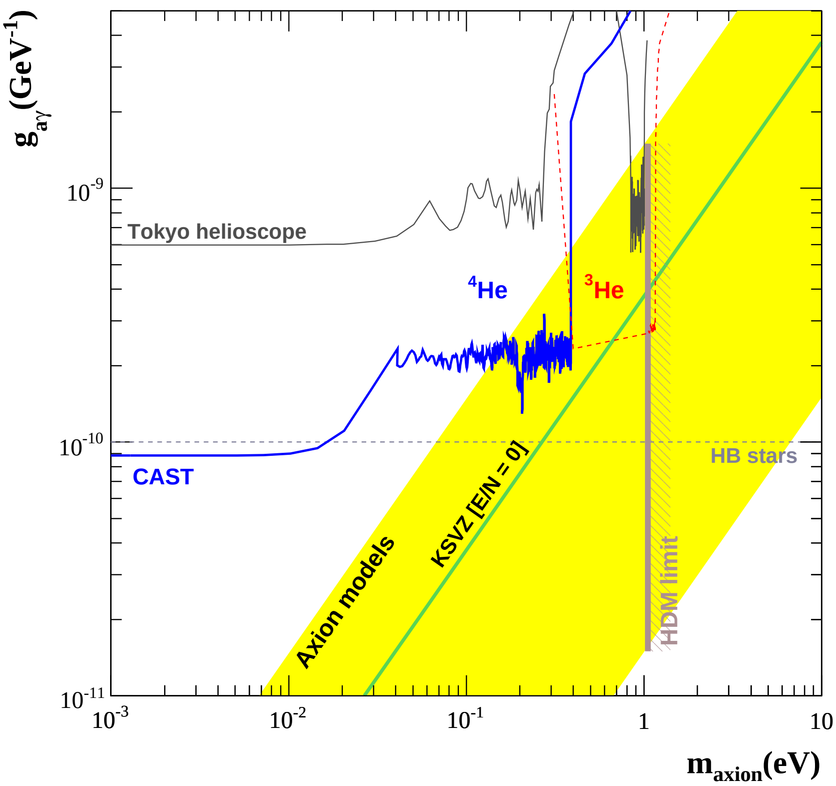

Figure 2: Preliminary CAST exclusion plot for axion mass versus coupling constant to photon in the experimental panorama of the rest of stelar axion search experiments. In the figure, it can be observed the result achieved by CAST during its first and the ^{4}He run of Second Phase [11] (thick blue line). The thin red line is the expectation for the ^{3}He run of CAST's Second Phase.

The procedure used for the ^{4}He run during 2005 and 2006 was to daily increase the ^{4}He gas density in the magnet bore by a certain amount of atoms. The overall range of pressure pressure inside the bore went from 0 to 13.43 mbar. This mechanism has already allowed CAST to restore the coherence of the Primakoff axion-to-photon conversion axion masses up to 0.4 eV *(see Figure 2)*. The ^{3}He run of CAST's Second Phase is ongoing and the Primakoff coherence condition has already been fulfilled for axions of masses up to 0.56 eV.

3 Conclusion

During its First Phase, while having vacuum in the magnet bores, CAST looked for traces of axion-to-photon conversions via the Primakoff effect for axions coming from the solar core. However, coherence restrictions constrained the axion mass search up to 0.02 eV [10, 11].

CAST's Second Phase has already started and the extension of sensitivity using ^{4}He gas has been explored by CAST during the years 2005 and 2006. The analysis of ^{4}He run is at its final stage and the preliminary results can be seen in the figure 2. The extension of sensitivity in CAST up to axions masses of 1.20 eV is being accomplished by using ^{3}He and the Primakoff coherence condition has already been fulfilled for axions of masses up to 0.56 eV.

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