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The CAST Experiment.

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Abstract.

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 three 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 has been looking for axions with masses up to 0.02 eV. CAST's second phase manages to re-establish the coherence needed to scan for axions with masses up to 1.16 eV by using a buffer gas. 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 0.4 eV.

1. Introduction

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. Axions, as the new particles were named, 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 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].

Three different X-ray detectors are mounted on both sides of the magnet and each of them is aligned with the solar core for 1.5 hours per day waiting for a photon coming from axion to photon conversion due to the Primakoff effect in the magnet. The detectors are a Time Projection Chamber [7], a 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 masses lower than 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. Therefore, 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.

The second phase of CAST is planned to be done in two steps :

- **^{4}He step** allowing to look for axions with masses up to 0.4 eV. Completed during years 2005 and 2006.

- **^{3}He step** restoring coherence for axion masses up to 1.16 eV. Years 2007 to 2010.

The need of cooling the super conducting CAST magnet down to 1.8 K by using superfluid Helium while it is moved ±8 degree in vertical direction causes the employed gas in the magnet conversion region to saturate. ^{4}He for instance, saturates for ∼14 mbar at this temperature, which requires the use of lighter gases in order to achieve coherence for higher axion masses. Therefore, while the use of ^{4}He restores CAST's coherence conversion for axions masses up to 0.4 eV, the use of a lighter gase such ^{3}He would allow a further search up to axion masses of 1.16 eV (see figure 1).

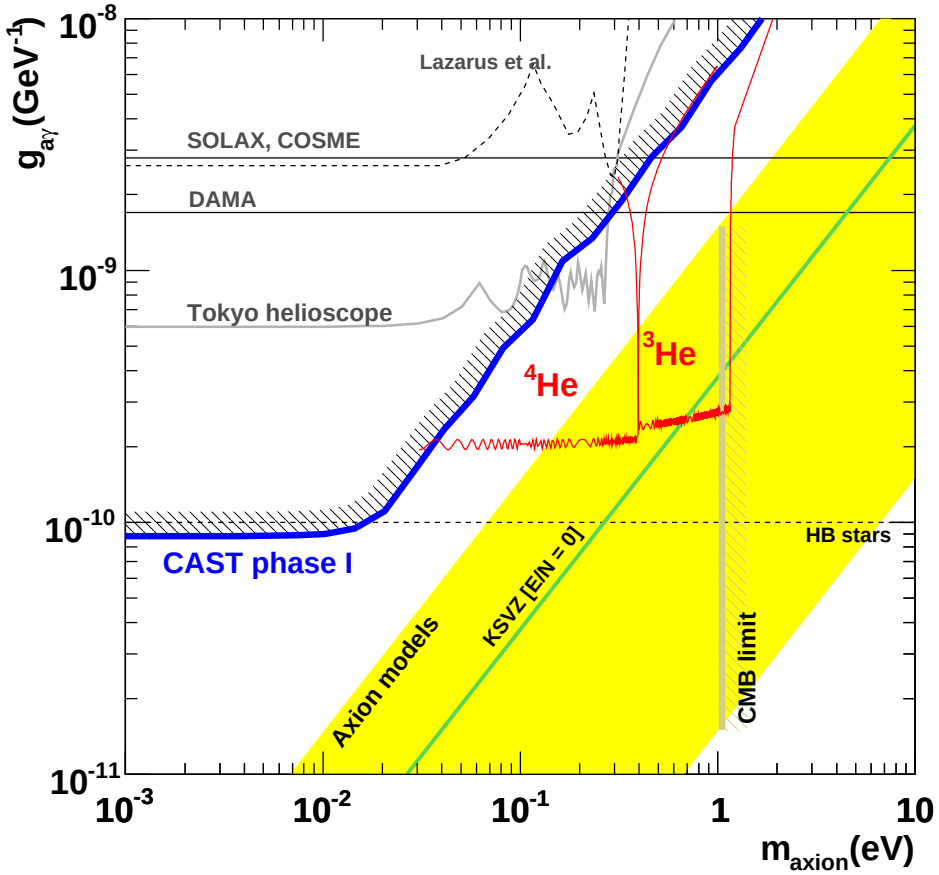

Figure 1. Preliminary CAST exclusion plot for axion mass versus coupling constant to photon in the experimental panorama of the rest of stelar axion search experiments. In the figure, it can be observed the result achieved by CAST during its first phase [11] (thick blue line) and the expected results for the second phase of CAST (thin red lines). The different sectors of the second phase search are divided in ^{4}He and ^{3}He.

The upgraded setup of CAST that allows the use of ^{3}He is being prepared during the year 2007 and the first data is supposed to be taken at the very end of this year.

CAST data taking procedure during its second phase has been choosen in a way such that allows to scan for axion masses from 0.02 eV to 1.16 eV in little steps. The procedure used for

^{4}He during 2005 and 2006 was to daily increase the ^{4}He gas pressure in the magnet bore by a certain amount of atoms which corresponded to a daily increase in pressure of about 0.082 mbar. The overall range of pressure pressure inside the bore went from 0 to 13.43 mbar. This mechanism has allowed CAST to restore the coherence of the axion to photon conversion via the Primakoff effect for axion masses up to 0.4 eV.

3. Conclusion

The first phase of CAST has been looking for axions with masses below 0.02 eV during 2003 [10] and 2004 [11] by having vacuum in the magnet bores where an axion-to-photon conversion via the Primakoff is expected for those axions produced in the plasma of the solar core. CAST's second phase did already start and the extension of sensitivity utilizing ^{4}He gas has been explored by CAST during the years 2005 and 2006 allowing the experiment to enter into the theoretical region of the axion masses. The analysis of ^{4}He phase is ongoing and the expected results can be seen in the figure 1. The extension of sensitivity in CAST up to axions masses of 1.16 eV is planned to be accomplished by using ^{3}He gas and the upgrade of the experimental setup in CAST for the use of this lighter gas is in progress.

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