CAST - Probing Axions from the Core of the Sun

M. Kuster, S. Gerhard, G. Hoffmeister, D. Weber, TU Darmstadt, Darmstadt, Germany
D. H. H. Hoffmann, GSI, TU Darmstadt, Darmstadt, Germany
K. Zioutas, University of Patras, Patras, Greece

The sun provides a deep insight into the physics of fusion, the physics of hot plasmas and is an excellent laboratory for astroparticle physics. As such the sun can be used to probe the existence of novel particles and dark matter candidates like the axion. The axion is a direct consequence (2; 3) of the theoretical solution of the CP problem in strong interactions proposed by (1). Inside the core of the sun axions could be produced by coherent conversion of thermal photons interacting with the electromagnetic field of charged particles of the solar plasma (Primakoff effect).

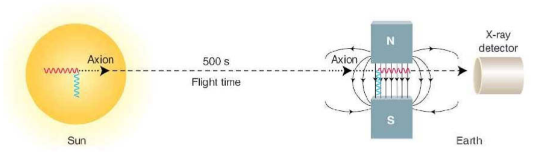

Figure 1: Physical principle of the CAST experiment.

With the *CAST* experiment at *CERN*, we aim to detect such solar axions on earth by "converting" them back to X-ray photons inside a strong transversal magnetic field (inverse Primakoff effect, see Fig. 1). The conversion probability of axions to photons is proportional to the square of the strength of the magnetic field and its length. Thus, a strong magnetic field is essential to achieve a high sensitivity of the experiment.

The heart of CAST is a prototype LHC superconducting magnet providing a dipole magnetic field of $\approx 9\,\mathrm{T}$ in the interior of two parallel pipes over a distance of $9.26\,\mathrm{m}$. On both ends of the magnet X-ray detectors are looking for a potential axion signal as an excess signal over detector background. A TPC detector covers two magnet bores on one end looking for axions during sunset. On the opposite side of the magnet, a micro mesh gas detector and an X-ray telescope with a pn-CCD detector are looking for axions at sunrise. The magnet can be pointed towards the sun for about $1.5\,\mathrm{h}$ during sunrise and sunset, resulting in $3\,\mathrm{h}$ observation time per day. The remaining time is used for systematic background studies. The most sensitive detector system of *CAST* is the Wolter I type X-ray telescope which enhances the signal-to-background ratio by a factor of ≈ 100 by concentrating the potential signal flux on a small spot on the pn-CCD detector.

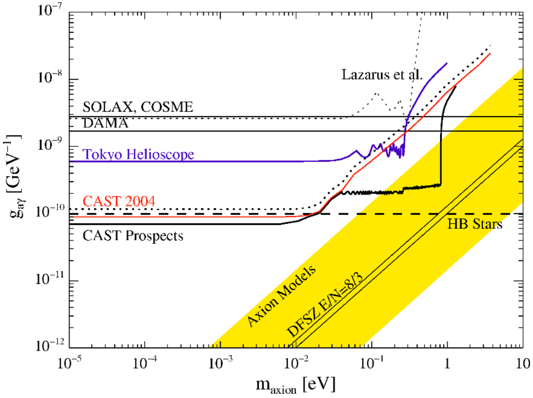

Figure 2: *Preliminary* upper limit (CL 95 %) on the axion to photon coupling $g_{a\gamma}$ depending on the axion mass m_a derived from the data of 2004 exploiting the full sensitivity of the X-ray telescope. The shaded area represents the parameter range of theoretical axion models. The results of earlier experiments *SOLAX*, *COSME*, *DAMA*, and the Tokyo helioscope are shown for comparison. The best astrophysical limit is indicated as "HB Stars".

During the last two years *CAST* was taking data for about twelve months, six months during 2003 and during 2004. The analysis of the data reveals no significant excess signal over background and allows us to set a new upper limit on the axion to photon coupling (4). Fig. 2 shows the preliminary corresponding upper limit for the axion to photon coupling constant $g_{a\gamma}$ derived from the data aquired with the X-ray telescopes during 2004. The analysis of the 2004 data is still in progress and we expect to further improve the upper limit in the *CAST* axion sensitive mass range $m_a < 0.02\,\mathrm{eV}$, although the present preliminary result is already comparable to the best astrophysical constraints (see Fig. 2). Due to coherence effects, the *CAST* helioscope in its configuration during 2004 was sensitive for axions with masses $m_a < 0.02\,\mathrm{eV}$, only. To extend the sensitivity of CAST to $m_a < 0.8\,\mathrm{eV}$, the refractive index of the conversion volume has to be changed using a buffer gas, either $^4\mathrm{He}$ or $^3\mathrm{He}$. Then, the photon acquires an effective mass ($m_\gamma = m_\mathrm{a}$) and the momentum exchange during the Primakoff process becomes negligible (phase II of CAST). During 2005 the CAST magnet has been transformed into its phase II configuration, allowing to be operated with a buffer gas ($^4\mathrm{He}$) inside the conversion volume. First data has successfully been taken with the new experimental setup at the end of 2005 and data taking will be continued at the beginning of this year.

References

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