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The CAST experiment: status and perspectives

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The status of the solar axion search with the CERN Axion Solar Telescope (CAST) will be discussed. Results from the first part of CAST phase II where the magnet bores were filled with ^{4}He gas at variable pressure in order to scan m_a up to 0.4 eV will be presented. From the absence of excess X-rays when the magnet was pointing to the Sun, we set a typical upper limit on the axion-photon coupling of $g_{a\gamma} \lesssim 2.17 \times 10^{-10}\mathrm{GeV}^{-1}$ at 95% CL for $m_a < 0.4$ eV, the exact result depending on the pressure setting. Our search for axions with masses up to about 1.2 eV using ^{3}He as a buffer gas is in progress in the second part of CAST phase II. Expectations for sensibilities will be given. Near future perspectives as well as more long term options for a new helioscope experiment will be evoked.

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1. Introduction

The CAST (Cern Axion Solar Telescope) experiment is using a decommissioned LHC dipole magnet to convert solar axions into detectable x-ray photons. Axions are light pseudoscalar particles that arise in the context of the Peccei-Quinn[1] solution to the strong CP problem and can be Dark Matter candidates[2]. Stars could produce axions via the Primakoff conversion of the plasma photons. The CAST experiment is pointing at our closest star, the Sun, aiming to detect solar axions. The detection principle is based on the coupling of an incoming axion to a virtual photon provided by the transverse field of an intense dipole magnet, being transformed into a real, detectable photon that carries the energy and the momentum of the original axion. The axion to photon conversion probability is proportional to the square of the transverse field of the magnet and to the active length of the magnet. Using an LHC magnet (9 T and 9.26 m long) improves the sensitivity by a factor 100 compared to previous experiments. The CAST experiment has been taking data since 2003 providing the most restrictive limits on the axion-photon coupling [3, 4] for masses $m_a \lesssim 0.02$ eV. At this mass the sensitivity is degraded due to coherence loss. In order to restore coherence, the magnet can be filled with a buffer gas providing an effective mass to the photon[5]. By changing the pressure of the buffer gas in steps, one can scan an entire range of axion mass values. At the end of 2005 the CAST experiment started such a program, entering its phase II by filling the magnet bore with He gas. From 2005 to 2007, the magnet bore was filled with ^{4}He gas extending our sensitivity to masses up to 0.4 eV. From March 2008 onwards the magnet bore has been filled with ^{3}He and the sensitivity should be increased to sensivities up to $m_a \lesssim 1.2$ eV by the end of the ^{3}He run in 2011. Preliminary results of 2008 ^{3}He data will be presented here up to masses around 0.65 eV.

2. Set-up and results

The CAST set up has been described elsewhere [3, 9]. From 2002 to 2006 three X-ray detectors were mounted on the two sides of the magnet: a conventional TPC[10] covering both magnet bores looking for sunset axions; in the sunrise side one of the bores was covered by a Micromegas detector[11] and in the other bore a CCD detector coupled to a telescope[12] improving the signal to background ratio by a factor 150. In 2006 the TPC started to show a degraded performance due to aging. It was then decided to replace the sunset TPC and the existing Micromegas detector in the sunrise side by a new generation of Micromegas detectors[13, 14] that coupled with suitable shielding would improve greatly their performance. The new detectors were commissioned end of 2007 and are taking data since then. These new generation of Micromegas detectors have shown an improvement in performance that has been translated in a background reduction of a factor 15 compared to the TPC performances and a factor 3 compared to the standard Micromegas detector used without shielding till 2006.

In 2005, the experiment went through a major upgrade to allow operation with He buffer gas in the cold bore in order to increase the sensitivity to higher masses. Special care was needed in order to inject the gas in the magnet bores with precision and to monitor accurately the gas pressure[15, 16] as this is directly correlated to the mass range explored.

Figure 1 shows an exclusion plot in the $g_{a\gamma}$–m_a plane that compiles results obtained up to now. Final results from phase I cover masses $m_a \lesssim 0.02$ eV. The ^{4}He data recorded end of 2005 and 2006 allowed to scan a new axion mass range between 0.02 and 0.39 eV. This parameter space was not previously explored in laboratory experiments. CAST has therefore entered the QCD axion band for the first time in this range of axion masses, excluding an important portion of the axion parameter space. The final results was published in [17]. The preliminary exclusion line for the ^{3}He data acquired during 2008 is also shown. It includes data from three out of the four CAST detectors and covers axion masses up to about 0.65 eV. Analysis is in progress on order to obtained the final combined results with the four CAST detectors. At the end of 2010 we reached sensitivities of around $m_a < 0.8$ eV and by the end of 2011 the CAST initial aim to scan masses up to $m_a < 1.2$ eV will have been reached.

The collaboration has performed by-product analysis of the data taken, to look for other axion scenario to which CAST would also be sensitive. The TPC phase I data has been reanalysed in order look for 14 keV axions coming from M1 transitions[6]. In addition, data taken with a calorimeter during the phase I, were used to search for high energy (MeV) lines from high energy axion conversion [7]. More recently a few days of data were taken with a visible detector coupled to one end of the CAST magnet [8], in search for axions with energy in the "visible" range. A permanent setup has been installed in the experiment in order to take data without interfering with the standard program of CAST.

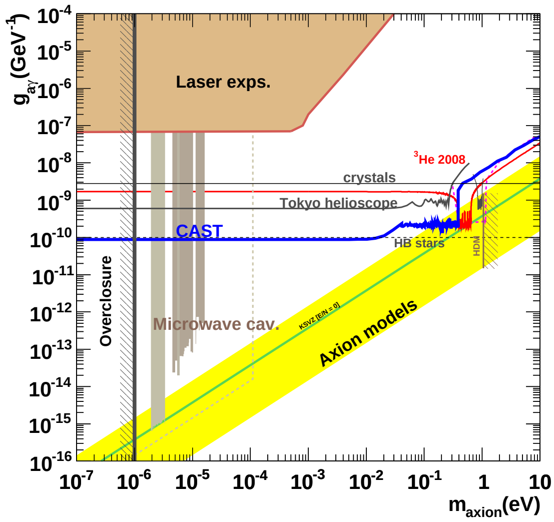

Figure 1: Exclusion plot in the axion-photon coupling versus the axion mass plane for a wide range of parameters. The limit achieved by the CAST experiment (combined result of the CAST phase I and phase II till end 2008) is compared with constraints obtained from the Sumico experiment (the Tokyo helioscope) and HB stars. The red dashed line shows our prospects for final result end 2011. The vertical line (HDM) is the hot dark matter limit for hadronic axions $m_a < 1.0$ eV inferred from observations of the cosmological large-scale structure. The yellow band represents typical theoretical models with $|E/N - 1.95|$ in the range 0.07–7 where the green solid line corresponds to the case when $E/N = 0$ is assumed. Limits from laser, microwave and underground detectors [18] for axion searches have been included.

3. Conclusions and outlook

The CAST experiment has established the most stringent experimental limit on axion coupling constant over a wide range of masses, exceeding astrophysical constraints. The ^{4}He phase has allowed to enter in an unexplored region favoured by the theory axion models. From the absence of excess X-rays when the magnet was pointing to the Sun, we set an upper limit on the axion-photon coupling of $g_{a\gamma} \lesssim 2.17 \times 10^{-10}\,\mathrm{GeV}^{-1}$ at 95% CL for $m_a \lesssim 0.4$ eV, the exact result depending on the pressure setting. At present, with the ^{3}He run we are exploring deeper this region to reach sensitivities of $m_a < 1.2$ eV by the end of 2011. A preliminary exclusion result has been given covering axion masses up to about 0.65 eV.

The Collaboration is looking into developing the new generation of helioscopes in order to reach sensitivities of the order of $10^{-11}\mathrm{GeV}^{-1}$ leading to explore a large part of the QCD favoured model region including the otherwise non-accessible sub-keV range. The sensitivity of helioscope axion searches depends strongly on the magnet's characteristics. Studies are on going in order to find a magnet design that would be optimised for axion searches and would enhance the discovery potential. Different options as well as expected sensitivities were presented in detail in [19].

References

[1] R.D. Peccei and H.R. Quinn, Phys. Rev. Lett. **38**, 1440 (1977).

[2] P. Sikivie, Int. J. Mod. Phys. **D3 S**, 1 (1994) and Phys. Rev. Lett. **51**, 1415 (1983).

[3] K. Zioutas*et al*. (CAST collaboration), Phys. Rev. Lett. **94** ,121301 (2005), arXiv: hep-ex/0411033.

[4] S. Andriamonje*et al*. (CAST collaboration), JCAP **04** 10 (2007), arXiv:hep-ex/0702006.

[5] K. van Bibber,P.M McIntyre,D.E. Morris and G.G Raffelt, Phys. Rev. D **39**, 2089 (1989).

[6] S. Andriamonje *et al*. (CAST collaboration), JCAP 1003, 032(2010).

[7] S. Andriamonje *et al*. (CAST collaboration), JCAP 0912, 002(2009).

[8] G. Cantatore et al., arXiv:0809.4581 [hep-ex] (2008).

[9] K. Zioutas *et al*, Nucl. Instrum. Methods Phys. Res., A **425** 480 (1999), arXiv:astro-ph/9801176.

[10] D. Autiero *et al*., New J. Phys **9**, 171 (2007) arXiv: hep-ex/0702189.

[11] P. Abbon *et al*., New J. Phys **9**, 170 (2007), arXiv: hep-ex/0702190.

[12] M. Kuster *et al*., New J. Phys **9**, 169 (2007), arXiv: hep-ex/0702188.

[13] J. Galán *et al*., Nucl. Instr. and Meth. A **604** 15-19 (2009).

[14] S. Aune *et al*., J. Phys. Conf. Ser. **179** 012015 (2009).

[15] T.O. Niinikoski *et al*., Submitted to Proc. ICEC 22, Seoul (2008).

[16] CAST Collaboration, SPSC-TDR-001, CERN-SPSC-2006-029.

[17] E. Arik *et al*. (CAST collaboration), JCAP 0902, 008 (2009).

[18] Z. Ahmed *et al*. (CDMS Collaboration), Phys. Rev. Lett. **103** 141802 (2009), arXiv: hep-ex/0902.4693.

[19] T. Papaevangelou (CAST collaboration), Presentation at "New opportunities in the Physics Landscape at CERN", http://indico.cern.ch/conferenceDisplay.py?confId=51128.