ALPS (Any Light Particle Search) II

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1 Goal of experiment

The goal of ALPS is to search for very weakly interacting slim particles beyond the Standard Model (WISPs) which have a tiny coupling to photons, such as axions, axion-like particles (ALPs), hidden sector photons (HPs), mini-charged particles (MCPs), or the like. In particular, ALPS II aims to hunt for ALPs and HPs in previously unexplored parameter ranges in mass and coupling which have been suggested in the context of embeddings of the standard model in string theory and of possible explanations of astrophysical and cosmological puzzles, such as the anomalous transparency of the universe for very high energy photons, the anomalous energy loss of white dwarfs, the extra dark radiation during decoupling of the cosmic microwave background photons, and non-thermally produced cold dark matter. For ALPs, the accessible parameter range overlaps with the one to be explored by the next generation axion helioscope NGAH, for HPs it extends the one to be explored by the solar hidden photon helioscope SHIPS.

2 Experimental setup

ALPS is a light-shining-through-a-wall (LSW) experiment. ALPS-I was completed in the beginning of 2010. Since then research and development towards an extended version ALPS-II are under way. A Technical Design Report will be completed in summer 2012. Compared to ALPS-I the following improvements are aimed for:

- Laser: With the help of an optical resonator ALPS-I achieved a circulating laser power of up to 1.2 kW of 532 nm light in front of the wall separating the two parts of the experiment. We plan to switch to infrared laser light of 1064 nm at ALPS-II (benefiting from the experiences of gravitational wave interferometers which are operated at the same wavelength) and increase the power to about 150 kW. The maximal power is mainly given by the damage threshold of the mirrors defining the optical cavity.

- Magnets: ALPS-I was operated with a single HERA dipole magnet providing a 5 T field at a length of 8.8 m. One half each was used for the generation and re-generation part of the experiment. Considering the aperture of the HERA dipoles and the laser beam optics one could extend the set-up to $4+4$ HERA dipole magnets. At present we study options to straighten some of the HERA dipoles in order to increase their aperture. With straightened magnets ALPS-II could be enlarged to $10+10$ or even $12+12$ HERA dipoles.

- Re-generation cavity: A second optical cavity behind the wall would significantly enhance the sensitivity of a LSW experiment. However, such a set-up is rather complicated and has not been realized so far. At present we study options for the construction and operation of a re-generation cavity.

- Detector: ALPS-I utilized a commercially available cooled CCD where the light was focused on very few pixels. This is also an option for ALPS-II, but in addition we study the performance and applicability of a superconducting Transition Edge Sensor (TES).

3 Accelerator or Lab Facility

The experiment does not require particle beams, but will make strong use of accelerator infrastructure. This is obvious from the usage of HERA dipole magnets. One of the straight sections of the HERA tunnel will harbor ALPS-II.

4 Physics Reach

The physics reach of ALPS-II in the search for axion-like particles is displayed in the lower panel of Fig. 1. ALPS-II will surpass the sensitivity of present-day helioscopes and the indirect limits derived from the lifetime of stars for example (see upper panel of Fig. 1).

ALPS-II will allow to probe a part of the parameter region, where the apparent transparency of the universe to TeV photons or the cooling of white dwarfs might hint at the existence of axion-like particles.

Already in a first phase without magnets (see below) ALPS-II will provide access to yet unexplored hidden photon parameter regions as depicted in Fig. 2. Recent CMBR analyses observe an excess of a relativistic energy component which is usually parameterized as an additional neutrino beyond the three known standard model species. This excess could also be

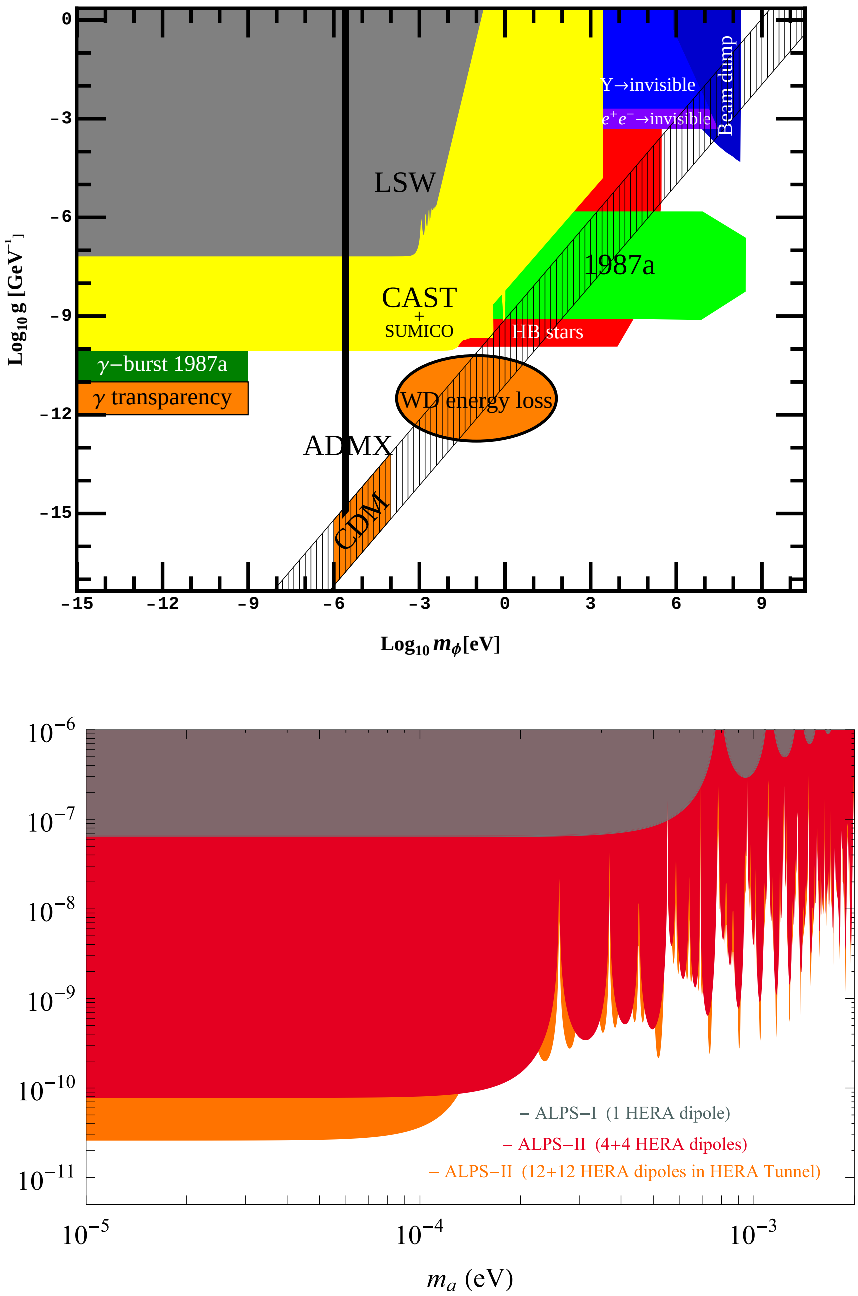

Figure 1: Top panel: Current limits of ALP searches and indications for the existence of ALPs. Bottom panel: Projected sensitivity of ALPS II.

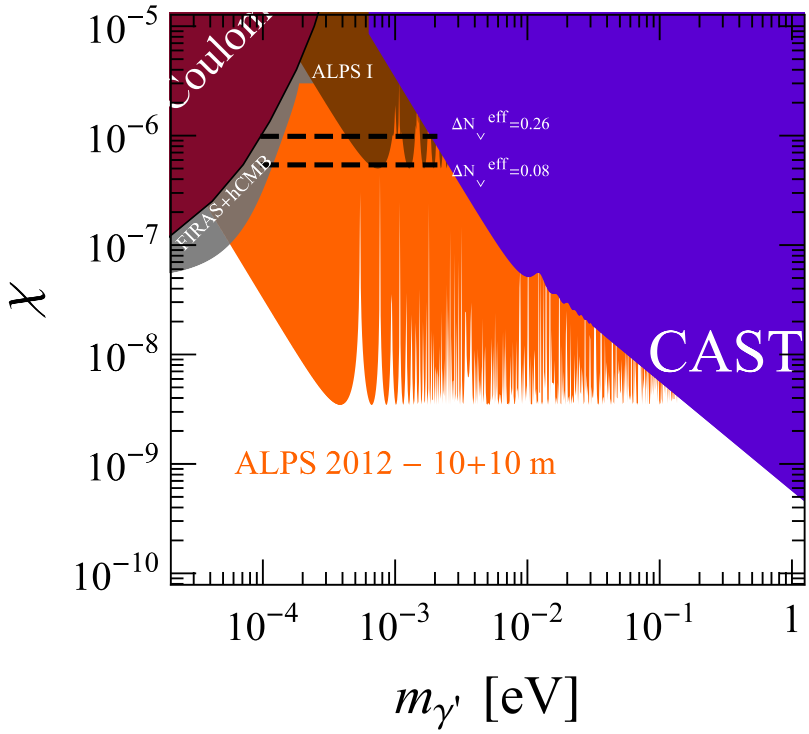

Figure 2: Current limits on HPs and projected sensitivity of ALPS II

related to a hidden photon component in the universe. ALPS-II will allow to experimentally test this hypothesis.

5 Status and Schedule

A formal decision on the construction of ALPS-II is expected for summer 2012. If the experiment is approved, it will be realized in steps. First the optics will be set up in a newly built laser laboratory on a $2\times10\,$m scale without any magnets. Besides studying the performance this first phase will also allow to search for hidden photons in a yet unexplored parameter region. If the first phase is completed successfully, the set-up will be moved to the HERA tunnel to demonstrate its functionality with two 100 m long optical cavities. This is a pre-condition for a "go-ahead" to install the two strings of HERA dipole magnets for ALPS-II. At present the completion of

ALPS-II is expected for the year 2017.

6 Future Plans

At present there are now plans for any LSW experiment at DESY beyond ALPS-II.

7 Collaborating Institutions and Collaborators

The following institutions and persons are members of the ALPS collaboration:

- Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany:
  Paola Arias (now at University of Santiago, Chile), Jan Dreyling-Eschweiler, Samvel Ghazaryan, Reza Hodajerdi, Ernst-Axel Knabbe, Axel Lindner, Dieter Notz, Javier Redondo (now at MPI Munich, Germany), Andreas Ringwald, Jan Eike von Seggern, Dieter Trines.

- MPI for Gravitational Physics, Albert-Einstein-Institute, and Institut für Gravitationsphysik, Leibniz University, Hannover, Germany:
  Robin Bähre, Tobias Meier, Benno Willke.

- Hamburger Sternwarte, Hamburg, Germany:
  Günter Wiedemann.

- Hamburg University, Hamburg, Germany:
  Dieter Horns.

The studies for a TES detector are taking place in collaboration with institutes in Italy, headed by INFN and University in Trieste as well as the University of Camerino, and the PTB in Berlin, Germany.

8 Written Materials (e.g. references)

The results of the ALPS-I experiment have been published in two papers:

- "New ALPS Results on Hidden-Sector Lightweights," Phys. Lett. **B689**, 149-155 (2010), arXiv:1004.1313 [hep-ex].

- "Resonant laser power build-up in ALPS: A 'Light-shining-through-walls' experiment," Nucl. Instrum. Meth. **A612**, 83-96 (2009), arXiv:0905.4159 [physics.ins-det].

The theoretical backgrounds and the physics case are for example described in:

- "Light shining through walls", Contemp. Phys. 52 (2011) 211, arXiv:1011.3741 [hep-ph].
- "The Low-Energy Frontier of Particle Physics", Ann. Rev. Nucl. Part. Sci. 60 (2010) 405, arXiv:1002.0329 [hep-ph].

9 Any other info?

At present we do not have items to be raised here.