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High Magnetic Fields to Probe the sub-eV range of Particle/Astroparticle Physics : From OSQAR experiments up to new projects & perspectives at CERN & CNRS-Grenoble with GrAHal

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Particle physics is not limited to the high energy range. There are unexplored territories at ultra-low energies, i.e. sub-eV to eV, that offer promising opportunities to go beyond the Standard Model and explain the dark matter (DM) of our Universe. The emblematic particle of this physics is the axion, a pseudo-scalar particle predicted independently by Weinberg and Wilczek, to solve the fundamental problem of the apparent non-violation of the CP symmetry by the strong interaction (QCD) through Peccei-Quinn symmetry breaking. Standard axion at the electroweak scale with a mass around 100 keV has been ruled out after extensive experimental searches. This has led the scientific community to consider the case of almost invisible axion, i.e. with a mass and coupling to other particles extremely weak. If the axion mass is in the range 1-1000 micro-eV, this particle could also be responsible for the DM of our universe and constitutes one of the leading non-supersymmetric candidates. On the other hand, various ultra-light and weakly interacting scalar and pseudo-scalar particles are naturally present in string theory without the need of solving the strong CP problem. This new family of particles has coined the name of WISPs for Weakly Interacting Slim Particles in complement to the WIMPs standing for Weakly Interacting Massive Particles. P. Sikivie demonstrated in 1983 that the invisible axion as well as axion like particles (ALPs), a subfamily of WISPs, could be detected via a chiral anomaly that modifies Maxwell's equations. In this context, one of the objectives of the OSQAR experiment at CERN was to detect ALPs from the light shining through wall scheme and the interaction of 20 W CW laser beam with magnetic field lines produced by two spare 9 T LHC dipoles. It will be presented together with last results obtained, which are the most sensitive to date for this type of experiment for axion mass below 0.2 meV, waiting new limits that will be settle soon by ALPS-II at DESY. OSQAR has been extended for the search of Chameleons, a special type of particle with a mass depending on the density of the surrounding medium and which could be responsible for the dark energy. Ongoing developments at CNRS-Grenoble will also be presented to probe axion/ALPs DM particle with GrAHal (Grenoble Axion Haloscopes) that will be housed in the modular hybrid magnet platform soon in operation at LNCMI-Grenoble and producing static magnetic fields ranging from 9 T in 800 mm diameter up to 43 T in 34 mm diameter. The unique opportunities offered by this modular magnet will be highlighted, in particular to probe the 1-3 micro-eV range with unprecedented sensitivity (GrAHal-CAPP, https://doi.org/10.3389/fphy.2024.1358810).

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