The Low Energy Frontier of Particle Physics or the Quest for Dark Matter with Experimental Tools of Condensed Matter Physics

Pierre Pugnat[a*]

a. LNCMI, CNRS/UGA, 38042 Grenoble, Cedex 9, France

* Pierre.Pugnat@lncmi.cnrs.fr

Particle physics is not only confined to the high energy range. There are unexplored territories at ultra-low energies, *i.e.* sub-eV to eV, which are also very promising for the identification of the dark matter (DM) of our Universe. The emblematic particle of this physics is the axion, a pseudo-scalar particle predicted independently in 1978 by two Nobel Prize Laureates in Physics, S. Weinberg [1] and F. Wilczek [2], to solve the fundamental problem of the apparent non-violation of the CP symmetry by the strong interaction (QCD). This constitutes one of the remaining sand grains in the gear of the standard model of particle physics. Standard axion at the electroweak scale with a mass around 100 keV has been excluded 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 10^{-6} to 10^{-2} eV, this particle could also be responsible for the DM of our universe and constitutes one of the rare 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 showed in 1983 [3] 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, the OSQAR experiment at CERN aims 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 LHC dipoles. It will be presented in detail together with the last results obtained, which are the most sensitive to date for this type of experiment [4]. More recently this experiment has been extended in the search of Chameleons [5], 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. Other types of WISP search experiments in operation worldwide will also be briefly described as well as future projects. One of them, a new haloscope will be housed in the modular hybrid magnet platform in construction at LNCMI-Grenoble to profit from the static magnetic fields produced, ranging from 43 T in 34 mm diameter down to 9 T in 800 mm diameter [6], and will probe the flow of DM of our galactic halo crossing the Earth [7]. This unique opportunity will also be presented as well as the technological challenges to overcome.

[1] S. Weinberg, Phys. Rev. Lett. 40, 223 (1978).
[2] F. Wilczek, Phys. Rev. Lett. 40, 279 (1978).
[3] P. Sikivie, Phys. Rev. Lett, 51, 1415 (1983); Phys. Rev. D 32 2988 (1985).
[4] R. Ballou, P. Pugnat *et al.* (OSQAR collaboration), Phys. Rev. D 92, 092002 (2015)
[5] https://cds.cern.ch/record/2001850/files/SPSC-P-331-ADD-1.pdf
[6] P. Pugnat *et al.*, IEEE Trans. Appl. Supercond. vol. 28, no. 3 (2018), 4300607.
[7] https://bib-pubdb1.desy.de/record/395493/files/fulltext.pdf