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Results and prospects of deep under-ground, under-water and under-ice experiments

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ABSTRACT

Astroparticle experiments have provided a long list of achievements both for particle physics and astrophysics. Many of these experiments require to be protected from the background produced by cosmic rays in the atmosphere. The main options for such protection are to build detectors deep under ground (mines, tunnels) or in the deep sea or Antarctic ice. In this proceeding we review the main results shown in the RICAP 2013 conference related with these kind of experiments and the prospects for the future.

1. Introduction

Astroparticle experiments have provided richful physics results for many years. In this conference we have seen many examples of the most recent advances and the prospects for the future, showing that this yield is growing and will continue giving us answers (and new questions) during the following years.

In this paper I will report the results presented which are related to one of the three following topics: dark matter, underground experiments and neutrinos.

2. Dark matter

Evidence for dark matter has been accumulating for almost one century [1]. The experimental hints for its existence include galaxy clusters, the rotation curves of galaxies, structure formation, filaments, the Bullet cluster, etc. The main ingredient of the Universe is dark energy. From the last results of Planck satellite, the dark energy content has been estimated in 68.3%. Dark matter contribution is 26.8% and ordinary matter is just 4.9% of the total. In other words, approximately 85% of the matter in the Universe is dark matter. The basic requirements for a good dark matter candidate are to be stable (or very long-lived), neutral and with an interaction cross-section of the order of the one of the weak interaction. The only viable candidate within the Standard Model would be the neutrino, but since neutrinos are relativistic, they cannot explain the structure formation of the Universe. Therefore, the explanation for dark matter has to be outside the Standard Model.

The question of identifying the nature of dark matter has to be approached from several experimental fronts at the same time. For instance, there are many searches for supersymmetric partners of the Standard Model particles at the Large Hadron Collider. These experiments have succeeded in finding what looks very much like the Higgs boson, but for the moment, only limits on models beyond the Standard Model, like Supersymmetry, have been set (see Fig. 1 for an example). In the mean time, these results are weakening the arguments in favor of naturalness [2]. As an example of model to explain the experimental results, Peiró [3] proposes an extension of the Next-to-MSSM (NMSSM) with right-handed neutrinos, in which the right-handed component of sneutrinos can be a good DM candidate. The coupling of these sneutrinos with the Higgs is of the order of the electroweak scale, making possible the thermal production of these particles. There is a wide range of predictions for both direct and indirect detection of DM experiments for very light sneutrinos. The different predictions are related, generally, to the final state annihilation in the early universe of these light particles.

In any case, a positive signal at LHC will not be enough to claim the discovery of dark matter, since one of the main features that a dark matter candidate has to fulfill, the stability at cosmological scales, cannot be proved in accelerators. The other two fronts which complement this task are the so-called direct and indirect searches. In the first case, the interaction of dark matter particles in the detector is looked for. The experimental effort here is very broad. Three main signatures are used, often combined in pairs in order to improve the sensitivity: scintillation (light), ionization (charge) and phonon (heat). Another technique which is being tested is the superheated liquids (bubbles). Fig. 2 shows a summary of present and future experiments, indicating the techniques used in each case. The present situation is quite puzzling and very interesting. There are positive results (DAMA/LIBRA,

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COGENT, CRESST, CDMS-Si) which are in contradiction, at least for the most simple assumptions, with limits set by other experiments (XENON100, CDMS-Ge). Moreover, the signal regions of the positive results are at least in tension among themselves. In the following subsections we review some of these experiments (see Fig. 3).

Indirect searches look for the particles resulting from the decay or annihilation of dark matter particles. This includes photons, cosmic rays and neutrinos. For a summary of the results presented in this conference for photons and cosmic rays, see [4,5]. As described there, there are several hints which could be compatible with dark matter. However, there are also more standard astrophysical scenarios which could explain these results. Searches for WIMPs in the Sun by neutrino telescopes would not have this problem if a signal is detected, since no astrophysical explanation would compete. In this proceeding we will review the results of the ANTARES neutrino telescope.

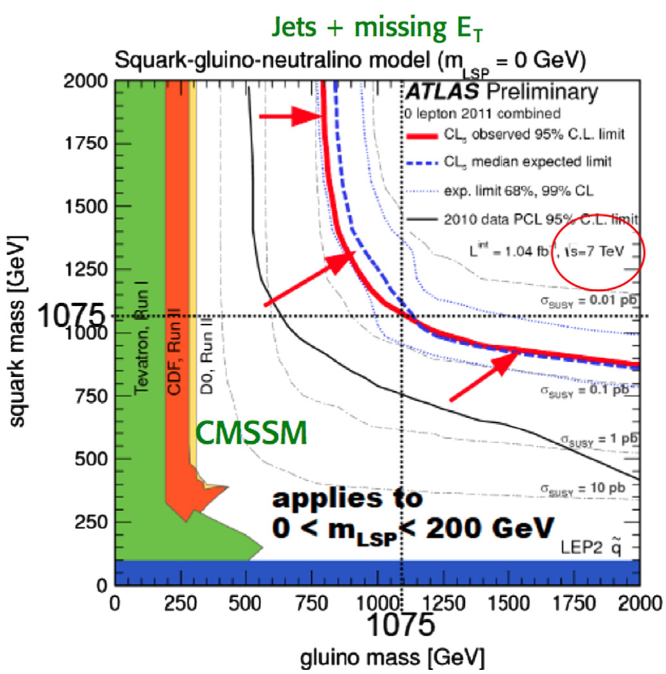

Fig. 1. Example of constraints to CMSSM from LCH results.

2.1. DAMA/Libra

The DAMA/LIBRA collaboration [6] has deployed about 250 kg of highly radiopure NaI(Tl) at the Gran Sasso National Laboratory. They have observed an annual modulation signature which is compatible with the assumption that it is produced by the asymmetry in the expected rates of dark matter particle interactions when the Earth is moving forward or backwards the "wind" of dark matter seen as the Sun moves around the Galaxy. The requirements for such a signal in this scenario are that it has to be modulated according to a cosine function, in a definite low energy

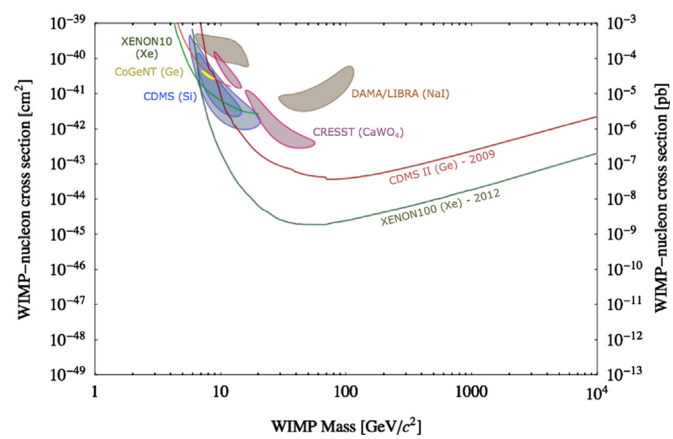

Fig. 3. Experimental limits and signal favored regions obtained from the results of different direct searches of dark matter (source: Particle Data Group).

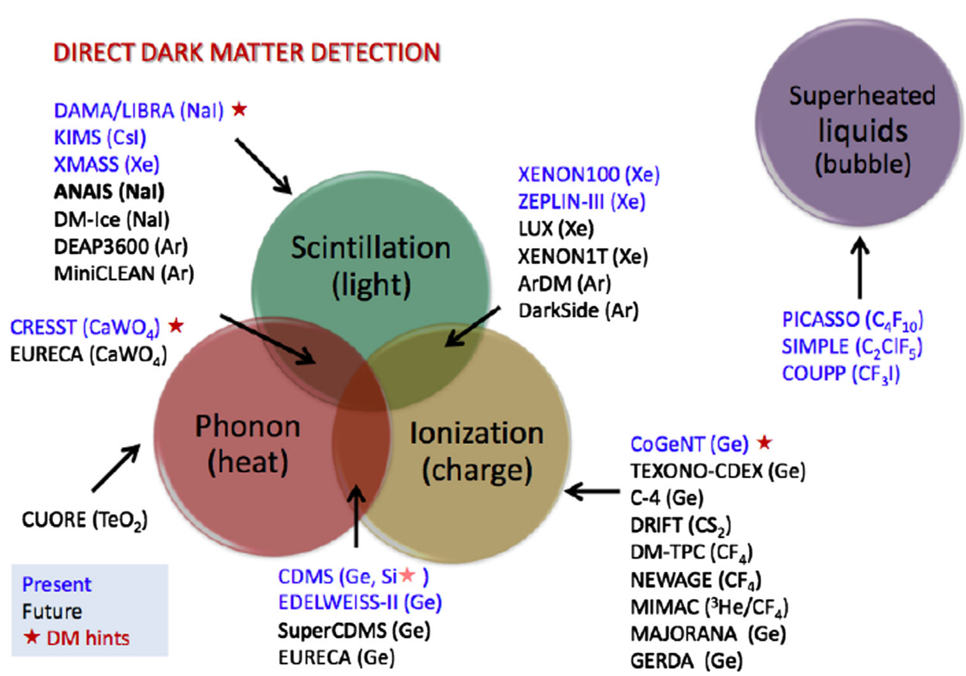

Fig. 2. Experimental approaches for direct dark matter detection. The figure includes both present and future experiments. (From C. Cuesta thesis defense.)