

## The DarkSide-50 Experiment: A Liquid Argon Target for Dark Matter Particles

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*Abstract.* The DarkSide-50 experiment, located at the “Laboratori Nazionali del Gran Sasso (INFN)”, is based on low-radioactivity argon double phase time projection chamber, surrounded by an active liquid scintillator veto, designed for the zero background achievement. The liquid argon features sufficient self shielding and easy scalability to multi-tons scale. The impressive reduction of the  $^{39}\text{Ar}$  isotope (compared to the atmospheric argon), along with the excellent pulse shape discrimination, make this technology a possible candidate for the forthcoming generation of multi-ton Dark Matter experiments.

## Introduction

Astrophysical and Cosmological observations suggest the existence of a relevant amount of dark matter in the Universe [1]. According to some theoretical models, such a matter consists of weakly interactive massive particle (WIMP) [2] and interacts with target nuclei of experiments releasing energies of order few tens of keV. The DarkSide-50 experiment, after the promising results of its predecessor DarkSide-10 [3], searches for such nuclear recoils (NR) using a liquid argon double-phase Time Projection Chamber (LAr-TPC), surrounded by a liquid scintillator veto (LSV) located in the middle of a water Cherenkov veto (WCV), both used for rejecting the coincidences in the LAr-TPC induced by cosmic and material radiation (technical details are reported in [4–7]). Two arrays of 19 3” PMTs, facing from the top and the bottom the liquid argon active volume ( $\sim 46.4$  kg), detect the primary scintillation (S1) and the gas scintillation from drifted ionization electrons (S2). Thanks to S1 and S2 it is possible to reconstruct the full 3D position of the events. LAr intrinsic scintillation features allow us to reject electron recoils ( $\beta$  and  $\gamma$  events from background) at the level of  $1.5 \times 10^7$  or even better [6]. The pulse shape discrimination between ER and NR is based on the  $f_{90}$  parameter, i.e. the fraction of S1 detected in the first 90 ns.

The DarkSide-50 experiment exploited two important data taking campaigns: first, the atmospheric argon (AAr) campaign, in which the main features of the detector have been tested [6]; second, the underground depleted argon (UAr) campaign in which the predicted characteristics have been confirmed and the impressive reduction of the  $^{39}\text{Ar}$  has been proven [5]. The main features of both LAr-TPC and LSV detectors have been understood also by means of intense calibration campaigns with internal ( $^{83\text{m}}\text{Kr}$ ) and external ( $\gamma$ , AmBe) sources.

## 1 The Underground Argon

UAr was extracted and purified with an effort lasted many years [8]. Fig. 1 shows a comparison between AAr and UAr spectrum in terms of S1 in a reduced volume (34 kg). The activity of  $^{39}\text{Ar}$  and  $^{85}\text{Kr}$  is determined through a simultaneous Monte Carlo (MC) fit of S1 spectrum (with field on and off) and  $z$ -position distribution of the corresponding events. The  $^{39}\text{Ar}$  activity of

UAr is a factor  $(1.4 \pm 0.2) \times 10^3$  lower than the AAr one, corresponding to  $(0.73 \pm 0.11)$  mBq/kg.

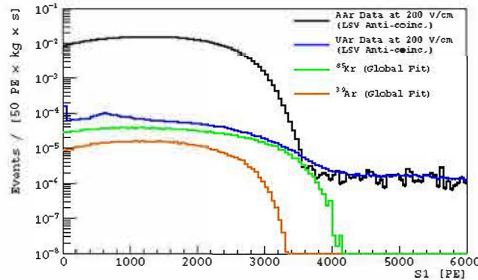


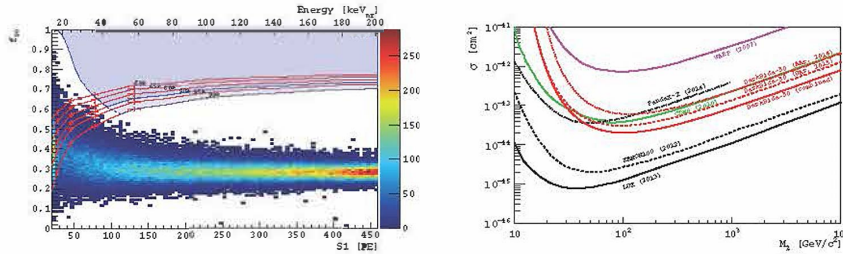
Figure 1: Livetime normalized S1 pulse integral comparison between AAr (black) and UAr (blue) events. For UAr events  $^{85}\text{Kr}$  (green) and  $^{39}\text{Ar}$  (orange) are shown separately [5].

The vetoing efficiency of the LSV, necessary to exclude NR events due to radiogenic or cosmogenic neutrons, during the UAr campaign is estimated to be  $> 99.1\%$ , using the AmBe calibration data and MC simulations.

Fig. 2a shows all UAr events in the dark matter region in the  $S1$ - $f_{90}$  plane after applying all selection criteria (see for details [5]). NR acceptance is based on the median of  $f_{90}$  measured in SCENE experiment [9] combined with a suitable statistical model [10]. Finally, Fig. 2b shows the spin-independent WIMP-nucleon cross section 90% CL exclusion plots for DarkSide-50 AAr and UAr (independently and combined), compared with the most popular dark matter limits [11].

## 2 Future developments

LAr-TPC based on UAr is an excellent candidate for the next generation of dark matter search experiments, thanks especially to: low background, powerful pulse shape discrimination, sufficient self-shielding and good light yield. The DarkSide collaboration is proposing, in the same underground laboratory, the DarkSide-20k with an active mass of  $\sim 20$  t. Yet this scaled version will be surrounded by a LSV inside a cylindrical WCV. Thanks to ultra-low background, this detector will be able to reach the sensitivity of  $\sim 10^{-47}$  cm<sup>2</sup> for WIMP of 1 TeV/ $c^2$  mass. SiPM light sensors will take the place of the usual PMTs, with a consequent increasing of the light collection. In parallel the ‘‘Urania’’ project, an improved extraction plant in Colorado, will guarantee an UAr production rate of  $\sim 100$  kg/day. Finally the ‘‘Aria’’ project, a cryogenic distillation facility for isotopic separation of argon at the Seruci mine in



(a) Event distribution in the  $f_{90}$ -S1 plane. NR acceptance bands are derived from SCENE experiment. Shaded area represents the WIMP search region [5]. (b) Comparison between the DarkSide Spin-Independent WIMP-nucleon cross section 90% CL exclusion plot and the most popular experimental limits [5].

Sardinia will further reduce the  $^{39}\text{Ar}$  content and strongly suppress the  $^{85}\text{Kr}$  presence.

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