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Future Dark Matter Searches with Low-Radioactivity Argon

We present the case for the DarkSide-Argo program for direct dark matter searches with low-radioactivity argon.

The immediate objective is the DarkSide-20k two-phase liquid argon detector, currently under construction at the Gran Sasso laboratory (LNGS). DarkSide-20k will have ultra-low backgrounds, with the ability to measure its backgrounds in situ, and sensitivity to WIMP-nucleon cross sections of 1.2 × 10−47 cm2 (1.1 × 10−46 cm2) for WIMPs of 1TeV/c2 (10TeV/c2) mass, to be achieved with a 5 yr run and an exposure of 100 t × yr. This projected sensitivity is a factor of >50 better than currently-published results above 1TeV/c2, and covers a large fraction of the parameter space currently preferred by supersymmetric models. With 100 t × yr exposure 1.6 NR events are expected from the coherent scattering of atmospheric neutrinos, making DarkSide-20k the first ever direct dark matter detection experiment to reach this crucial milestone. The sensitivity would further improve to 7.4 × 10−48 cm2 (6.9 × 10−47 cm2) for WIMPs of 1 TeV/c2 (10 TeV/c2) mass for a decade run with exposure of 200 t × yr. DarkSide-20k is foreseen to start operations in 2022 and will either detect WIMP dark matter or exclude a large fraction of the favored parameter space.

In parallel to DarkSide-20k, a second and important element for this program will be a detector of the order of 1 t in mass: DarkSide-LowMass (DS-LM), which we will propose to be installed at LNGS and specifically optimized for the observation of the electroluminescence signal below 10 GeV/c2 with strong restriction of electron recoils background through careful detector design. Based on demonstrated ultra-low threshold and world-leading sensitivity achieved with DarkSide-50, and coupled to additional 39Ar reduction by distillation in Aria and the use of a massive liquid argon veto, this dedicated search would display an excellent discovery capability, reaching through the so-called "neutrino floor"in the low-mass search region.

The crowning objective, towards the end of the next decade, will be the construction of the ultimate Argo detector with a 300 t fiducial mass to push the sensitivity to the region where neutrino background will be a limitation in detectors without directional capability. The WIMP detection sensitivity will only be limited by systematic uncertainties in nuclear recoil background from Coherent Neutrino Scattering of Atmospheric neutrinos. The strong electron recoil rejection will eliminate background from solar neutrinos and some residual internal backgrounds such as radon. This unique property of argon extends the sensitivity with respect to technologies with more limited electron recoils discrimination. The throughput of the Urania argon extraction system would enable 400 t of underground argon to be extracted and purified in the Aria facility over a period of about 6 yr. SNOLAB would be strong potential site for this detector motivated by the dark matter search, but also possibly enabling the observation of ultra-rare solar neutrino sources (CNO, hep).

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