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Neutron tagging with gadolinium loaded PMMA

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DarkSide-20k is a direct dark matter search experiment, that looks for Weakly Interacting Massive Particles (WIMPs) events. The detector is based on an ultrapure liquid Argon double-phase Time Projection Chamber, which will be located at Laboratori Nazionali del Gran Sasso. In the rare event search experiments (like the DarkSide case), it is crucial to keep under control any background sources. In particular, one of the most dangerous background sources are neutrons, which could

induce nuclear recoils, producing a signal indistinguishable from that of the WIMPs. The strategy adopted in the DarkSide-20k experiment is to build a neutron veto detector, made of a thick plastic layer containing gadolinium, which has a high neutron capture cross section. The construction of 17 cm thick plates made of polymethylmethacrylate (PMMA) doped with a compound containing gadolinium was therefore adopted. The choice of PMMA is due to the high hydrogen content of this polymer, to moderate the neutrons. Then thermal neutrons will be captured on the gadolinium nuclei and will be revealed, exploiting the subsequent emission of an easily-detectable high energy γ ray cascade. All the components of the composite material must be screened to identify any traces of elements (such as uranium, thorium and potassium) whose descendant radioactive isotopes could affect the performance of the experiment. The screening is performed with Inductively Coupled Plasma Mass Spectrometry (ICPMS) and with germanium detectors. The DarkSide collaboration foresees two possible strategies for the realisation of gadolinium doped PMMA sheets, using two gadolinium-containing compounds: gadolinium acetylacetonate (Gd(C5H7O2)3) and gadolinium oxide (Gd2O3) in the form of nanograins. The two candidates have both positive and negative aspects: for instance the gadolinium acetylacetonate is miscible in MMA (the liquid monomer), but its synthesis on an industrial scale is quite complex and requires particular attention in each step to avoid any contamination. On the other hand, it is possible to easily find gadolinium oxide nanograins at a level of radiopurity that meets the standards required by DarkSide (this aspect has been verified through germanium screening and ICPMS). However, the nanograins are not miscible in MMA, therefore they must be treated with a suitable surfactant that prevents their sedimentation, in order to obtain pieces with a reasonably homogeneous gadolinium dispersion. The surfactant concentration must be kept under control, since each additional material represents a possible source of background. Overall, 20 tons of material are required to build the detector. The R&D projects are almost finalized: laboratory scale samples have been produced with both techniques. At the moment, tests on an industrial scale are ongoing.

Primary author: MARINI, Anna (Istituto Nazionale di Fisica Nucleare)

Co-authors: BOTTINO, Bianca (Istituto Nazionale di Fisica Nucleare); CHEPURNOV, Aleksandr (Skobelcyn Institute of Nuclear Physics of Lomonosov Moscow State University)

Presenter: MARINI, Anna (Istituto Nazionale di Fisica Nucleare)

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