DarkSide-50 (detector active mass of 50 kg) was designed as a prototype for a ton-scale detector to search for high mass (>50 GeV/c^2) Weakly Interacting Massive Particles (WIMPs) where the critical feature is background rejection. Analysis of a 530 day exposure shows a convincing demonstration of the background events rejection capabilities of the applied techniques. The discrimination achieved between natural radioactivity and nuclear recoils is a strong confirmation of the capabilities of the liquid argon technology. In addition to this achievement, a novel analysis of the ionization signal from low-energy events has been developed which demonstrates that the DarkSide-50 detector had outstanding capabilities in the search for lower mass (< 10 GeV/c^2) dark matter. These results encourage confidence that if a signal is eventually detected in a larger argon-based detector, like the upcoming DarkSide-20k (active target mass of 20 tons), the signal will indeed be from something new in nature.

The heart of the DarkSide-20k apparatus will be a two-phase liquid argon time projection chamber. Unique features of the detector are the active neutron veto, application of low-radioactivity silicon photomultipliers (SiPMs) instead of classical PMTs, and the use of low-radioactivity argon from an underground source. The apparatus will be located in Hall C of the underground laboratory of the Gran Sasso National Laboratories (LNGS) of the Italian National Institute for Nuclear Physics (INFN). The Experiment is a collaboration of institutions from Brazil, Canada, China, France, Italy, Poland, Romania, Spain, Switzerland, UK and the United States of America. From the Polish side groups from the Jagiellonian University, from the Lodz University of Technology and from AstroCent are participating.

Research tasks carried out within the proposed project, mainly construction of ultra-sensitive radon detectors, high-sensitivity screening (alpha, gamma) of DarkSide construction materials and studies of Po surface activity down to ~10 μBq/m^2, which have never been undertaken so far. Obtained results will be of great importance for experiments looking for rare nuclear processes and based on cryogenic gases. They will allow for establishing new techniques for reduction of backgrounds – a crucial parameter for all detectors designed to search for proton decay, neutrinoless double beta decay or cold dark matter interactions. Consequently it will be possible to carry out research with ton-scale experiments (DarkSide-20k).

For particle physics and cosmology successful discovery and characterization of the new particles that most likely explain the non-baryonic cold dark matter, known to comprise the majority of matter in the Universe, would be the most significant advance in physics for a century. What form this matter takes is so far unknown. However, WIMPs, relic particles produced in the early Universe, have emerged as a leading possibility. Such, non-relativistic particles would constitute a cold dark matter population that appears required to explain formation of galaxies and large-scale structures in the Universe.