Abstract – The DarkSide 20k experiment construction at LNGS

The DarkSide-20k experiment is the latest generation dual-phase Liquid Argon-TPC hunting for Dark Matter. In particular, its goal is to discover or to extend the current sensitivity limits on the search for WIMP-like particles. This detector brings together the successful concept of the DarkSide-50 detector, and the experience gained on large volume membrane cryostats developed within the DUNE program. It features large-area, SiPM-based optical planes for light readout, and it exploits a unique target, i.e. argon extracted deep underground (underground argon, UAr) and depleted from its beta-decaying isotope ^{39}Ar, therefore extremely radio-quiet.
Currently, the detector design is being finalized, with construction of the TPC components starting next year. In the meantime, the main cryostat that will contain the detector has been constructed in Hall C of the Laboratori Nazionali del Gran Sasso (LNGS), Italy. At the same time, characterization and production of the SiPM-based photo sensors started in LNGS facility NOA, with the goal of starting assembling the readout planes in late 2025.
This contribution will describe the DarkSide-20k detector, and then it will report on the ongoing activities. At LNGS underground: construction of the cryostat and the atmospheric argon (AAr) cryogenic plant were completed. AAr will provide the thermal bath in which the main detector, filled with UAr, will be operated. At LNGS on the surface: preproduction and characterization of the photon detector units (PDUs), which will then be long-term tested in Napoli and analysed for failures in Pisa. Several other PDU test sites were put into operation across the collaboration, and their activities will be presented.

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The DarkSide 20k experiment (DS-20k) is the current implementation of the dark matter (DM) search physics program carried out by the Global Argon Dark Matter Collaboration (GADMC). It aims at direct DM search in the form of Weakly Interactive Massive Particles, WIMPs. The experiment will be hosted deep underground at the Laboratori Nazionali del Gran Sasso (LNGS). It exploits argon Dual-Phase TPC technology; in particular, utilizing - as target for the interactions - a unique kind of argon, extracted deep underground (underground argon, UAr) from a well in Colorado, and depleted of the beta-decaying isotope ^{39}Ar: this represents an important background for DM searches with argon-based detectors.

Charged particles interacting in liquid argon (LAr) produce 128 nm primary scintillation light (S1) and ionization electrons. The charge can be drifted by a uniform electric field to a gas region, where it is accelerated to produce secondary light emission (S2). The shape of the S1 light pulse, and the relative amplitude S2/S1, together allow identifying the nature of the interacting particle, and therefore rejecting most backgrounds. Scintillation light is collected by arrays of custom SiPMs constructed and assembled in-house, for a total sensitive surface exceeding 20 m^2.
Differently from its predecessor, DarkSide-50, DS-20k will be inserted in a stainless steel (SS) vessel and immersed in a bath of regular atmospheric argon (AAr), which doubles as thermal bath and veto for muon-induced events. In order to do this, membrane cryostat technology is exploited, i.e., an industrial solution conceived for liquid natural gas transport on ships, and exported to astro-particle physics by CERN. This technology is at the base of the cryostats for the upcoming DUNE experiment.

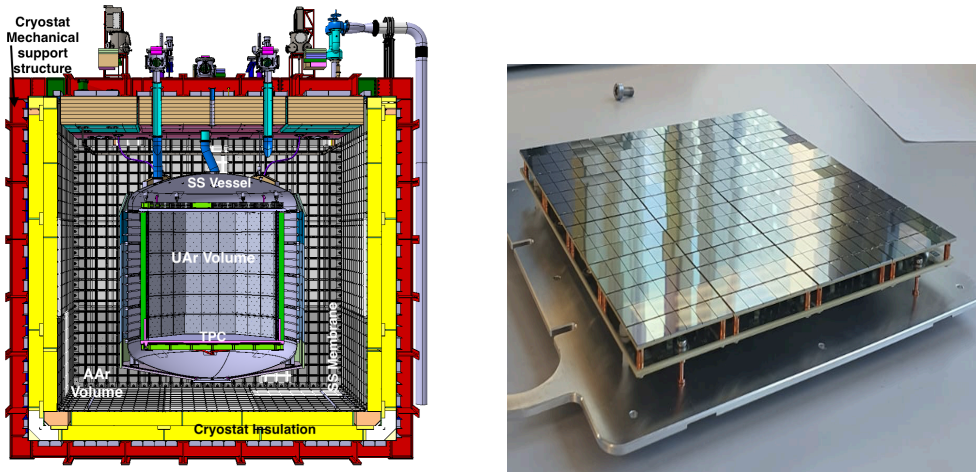

Figure 1: Left: cross-sectional view of the DS-20k detector hosted inside the cryostat, whose insulation is visible in yellow. The detector is inserted in a SS vessel separating UAr (inside) and AAr (outside). Right: basic unit of DS-20k PhotoDetectors, made of SiPM arrays, i.e., the Photon Detector Unit (PDU)

The membrane cryostat is a passive construct, with polyurethane insulation and very thin and elastic inner corrugated SS sheet (membrane), which can contract at cold temperature. In such a cryostat, it is not possible to make vacuum; instead, argon gas is circulated until air is pushed out. The main cryostat will host in its center a SS vessel containing the inner detector. The experiment will feature two different kinds of argon circulated by separate cryogenic plants.

The main cryostat was constructed in Hall C of LNGS in 2023-24, whereas the AAr cryogenic plant will be installed and tested in October-December 2024. Detector components production is set to start in 2025, whereas assembly will happen in 2026 directly inside the cryostat, that will be transformed in a clean room by end 2025. This contribution will present the physics case of the DS-20k detector, it will describe its main design concept together with the key features of the photon detector system, and it will summarize the performance of the preproduction photon detector units (PDUs) built in NOA and tested mainly in the Napoli Cold Test Facility and in Pisa; then, it will describe the membrane cryostat technology and the AAr cryogenic plant.