Institut national de physique nucléaire et de physique des particules

COLLABORATION AGREEMENT

IN2P3 - COPIN

I. Identification of the laboratories	
Partner	COPIN
IN2P3 laboratories	**APC** / CPPM/LPNHE
Partner laboratories	ASTROCENT, Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences

II. Identification of the collaboration	
Title of the collaboration	Dark matter search with liquid argon
Number of the collaboration	20-152
IN2P3 spokesperson	D. FRANCO
COPIN spokesperson	L. ROSZKOWSKI
Scientific Domain	Astroparticles and Cosmology

Status of the collaboration	
Status	The renewal of the collaboration is requested for the period January 1st - December 31st, 2023

III. Status report for the period January 1st to December 31st, 2022	
III.1 IN2P3 scientists in COPIN	
Total time approved for 2022	12
Total time used for 2022	0
List of scientists	
III.2 COPIN scientists in France	
Total time approved for 2022	12
Total time used for 2022	8
List of scientists	1. M. Wada (5 days) 2. M. Kuzniak (1 days) 3. M. Suchenek (1 days) 4. P. Zackary (1 days)
III.3 Scientific results of the above-mentioned collaboration	
Description	

DarkSide-50 has demonstrated the high potential of dual-phase liquid argon (LAr) time projection chambers (TPCs) in exploring interactions of WIMPs in the GeV/c2 mass range. The technique, based on the detection of the ionization signal amplified via electroluminescence in the gas phase, allows to explore recoil energies down to the sub-keV range. The COPIN Team provided in 2021 the first ever calibration of the LAr ionization response based on DarkSide-50 data (50 kg target mass) to both electronic (ER) and nuclear (NR) recoils in such a low range. This work is the foundation of the new analysis, which also benefited from the extended exposure, improved data selection, a more accurate background model, and a refined treatment of systematics into the statistical analysis. As in the analyses published in 2018, we consider signal models from low-mass (< 10 GeV/c2) WIMPs interacting with nucleons and with electrons. In addition, we included WIMP interactions with nucleons with the Migdal effect, which allows exploring WIMP masses down to a few tens of MeV, solar and galactic axions, and sterile neutrinos. For what concerns WIMPs, this analysis sets the world best limit on the spin-independent dark matter - nucleon cross section for masses below 3.8 GeV/c2 and down to 50 MeV/c2.

In addition, we have established the best direct-detection limits on dark matter-electron scattering in the mass range of 16 MeV/c2 to 56 MeV/c2 for a heavy mediator and above 80 MeV/c2 for a light mediator. We have also placed the first constraints on galactic axion-like particles and dark photons with an argon target. Stronger direct-detection limits are placed on both gAe and κ for masses between 0.03 and 0.2 keV/c2. However, due to the astrophysical constraints set on ALPs using the brightness of white dwarfs, DS-50 data allows for minimal additional exclusion of gAe parameter space from 0.15 keV/c2 to 0.2 keV/c2 and from 0.25 keV/c2 to 0.3 keV/c2. Finally, DS-50 is the first DM direct-detection experiment to set limits on the sterile neutrino mixing angle |Ue4|2. Under the Standard Halo Model assumption, our results improve upon existing direct limits set by a high-precision measurement of the 63Ni beta-spectrum. However, these are well above the indirect detection limits set by the NuSTAR experiment, which looks for anomalous X-ray lines from radiative sterile neutrino DM decays.

IV. Renewal of the collaboration for 2023

IV.1 Proposed scientific program

Description

Last year, the COPIN DarkSide team led the analyses that improved sensitivities to several "light" dark matter candidates with DarkSide-50, with only 50 kg of LAr target . The success of liquid argon technology in this sector is emphasized when compared with liquid xenon experiments such as XENONnT and LZ, with targets about two orders of magnitude more massive. The key of this success is the increasingly refined modeling of the response of LAr to very low energy recoils (10^2 -10^3 eV), a research axis where the the COPIN DarkSide team is playing a leading role. In fact, in recent years, through both the ARIS experiment and the re-analysis of DarkSide-50 (DS-50) calibrations, the COPIN team has been able to characterize the LAr response to electron recoils down to ~80 eV and nuclear recoils down to ~400 eV. As already mentioned, the team then led the analyses, recently released on arxiv, able to set the world's best limits for low-mass WIMPs, axions, dark photons and sterile neutrinos, using DarkSide-50.

In addition to the three recently submitted articles, we are working on three more works based on the same data set and background model, that will be released next year:

- a re-analysis of the DS-50 results exploiting an alternative Bayesian approach, where the analytical electron and nuclear recoil calibration responses are made explicit in the likelihood;

- the dark matter annual modulation analysis with DS-50;

- the search for WIMP-nucleon interactions via non-standard operators with DS-50.

In view of DarkSide-20k (DS-20k), a 50 ton LAr detector that will take data from 2026, the COPIN team is also leading software reconstruction, simulations, and sensitivity studies. Next year will be devoted to include the simulation of the electronics and the reconstruction of the neutron veto detector, which surrounds the TPC.

Finally, prompted by a recent ANR grant that will begin in January, we are discussing a possible collaboration on the characterization of the Xe-doped LAr mixture, both in terms of particle detection and thermodynamics. Both groups have a strong interest in the field because Xe-doped LAr would represent an ideal target for PET, on which Astrocent is already active, and for future large volume detectors for dark matter and neutrino physics.

IV.2 Estimated duration for IN2P3 scientists in COPIN	
Total time requested for 2023	14
List of scientists	1. D. Franco (4 days) 2. T. Hessel (4 days) 3. P. Pralavorio (2 days) 4. M. van Uffelen (2 days) 5. F. Hubaut (2 days)
IV.3 Estimated duration for COPIN scientists in France	
Total time requested for 2023	12
List of scientists	1. M. Wada (3 days) 2. M. Kuzniak (1 days) 3. P. Zackary (3 days) 4. M. Kimura (3 days) 5. T.Hugues (2 days)

Comment Validation	
Unity Director	Antoine KOUCHNER (APC) - 2022-10-20 12:25:19