PhD course of National Interest in Technologies for Fundamental Research in Physics and Astrophysics

Annual report

Name and surname: Riccardo Pavarani
Cycle and a.a.: XL cycle - 2024-2025
Supervisor: Matteo Cadeddu, Francesca Dordei

- **Research activity carried out during the year**

Describe the aim of the project (very briefly), discuss the research activity carried out during the year mentioning the difficulties encountered until now and the actions taken to face them. 1 page max in total.

The goal of my PhD project is to carry out an R&D program to study new techniques to reduce the background in cryogenic liquid-noble detectors with a particular focus on the operation of the dual-phase time projection chamber (TPC) of DarkSide-50. This could be a fundamental step toward the new phase DarkSide-20k detector, which aims to achieve one of the best constraints on the Weakly Interacting Masses Particle (WIMP) cross section, while also significantly reducing the background.

During my first year I acquired the skills to operate a cryogenic laboratory, starting from the study of the gas connections of the cryostat, and the operation of the vacuum pump, the cryocooler and the PID controller. The first step was to test the cryostat using argon gas, which was condensed inside the cryostat. After condensing 7 liters of argon, we observed the stability of the system. This run was particularly instructive, as it allowed me to develop a solid understanding of the apparatus and to learn how to handle unexpected issues effectively. In parallel, we implemented a temporary slow-control system using Python scripts to regulate the temperature using sensor feedback (RPTs), the heaters, and the pressure inside the cryostat. In the future, we plan to establish a more robust slow-control system using LabVIEW software. We also designed and built the circuit to characterize two different kinds of SiPMs (DarkSide-20k and DArT) at room temperature, outside the cryogenic setup, by studying the IV curves of the sensors. Subsequently, we designed the structure to house them inside the cryostat and modified the gas lines, enabling us to test them under cryogenic conditions (planned for November/December), in conjunction with the development of a dedicated DAQ system.
In addition, I completed the sensitivity analysis of the new CsI and Ar cryogenic detectors, started during my Master's thesis, which will be installed by the COHERENT

collaboration. From this study I learned much more about cryogenic detectors operation and on noble-liquid (argon) detection as well as about the coherent elastic neutrino-nucleus scattering (CEvNS) which, in this case, allows us to measure many Standard Model parameters and to constrain neutrino properties predicted by theories beyond the Standard Model (e.g., the neutrino magnetic moment). It is also an important background for all the dark-matter detectors.

- **List of attended courses and passed exams**
  - DarkSide Young Academy 2025: exam passed on March 7th, 2025. The Academy counts as a course upon approval by the coordinators of the detector curriculum, Salvatore My and Matteo Munari.
  - Rare event search with noble liquids: I have attended the course, and I plan to do the exam by the end of the first year.
- **List of attended conferences, workshops and schools, with mention of the presented talks**
  - TECH-FPA PhD retreat in LNGS, L'Aquila (17-21 February 2025).
  - Incontri di Fisica delle alte energie (9-11 April 2025): presented a poster ("Fisica di precisione con il rivelatore criogenico COHERENT CsI: verso nuove frontiere della diffusione coerente dei neutrini sul nucleo").
  - Multi Aspect Young ORiented Advanced Neutrino Academy (MAYORANA) – International School (19-25 June 2025): presented a poster and given a mini talk ("Toward precision physics test with CEvNS cryogenic COHERENT CsI detector"): exam passed on August 29th, 2025. The school counts as a course upon approval by the coordinators of the detector curriculum, Salvatore My and Matteo Munari.

- Gran Sasso Hands-on 2025 PhD summer school on experimental astroparticle physics (8-19 September 2025).

- **List of published papers/proceedings**
  - **Papers Cagliari group:**
  - M. Atzori Corona, M. Cadeddu, N. Cargioli, F. Dordei, C. Giunti, and R. Pavarani. Toward precision physics tests with future COHERENT detectors, arXiv:2509.04205, 2025.
  - **Papers DarkSide collaboration:**
  - F.Acerbi et al. (DarkSide-20k Collaboration). Production, Quality Assurance and Quality Control of the SiPM Tiles for the DarkSide-20k Time Projection Chamber, arXiv:2507.07226, 2025.

- **Thesis title (even temporary)**

  Background mitigation techniques and sensitivity studies for cryogenic noble-liquid detectors.

Date, 29/08/2025 **Signature**

Seen, the supervisor