CV LORENZO PIETROPAOLI

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Education

SEP 2023 - PRESENT

Master School Student, Sapienza Università di Roma

- Current Average of Grades: 29.6
- Study Curriculum: Fundamental Interactions, Theory and Experiment
- Characterising Courses: Particle Physics, Nuclear Physics, Physics Laboratory (I and II), Neutrinos and Dark Matter, Theory of Fundamental Interactions, Phenomenology of the Standard Model Methods in Experimental Particle Physics, Computing Methods for Physics
- Exams Left: 4

SEP 2019 - NOV 2023

Bachelor School Diploma, Sapienza Università di Roma

- Final Mark: 107/110
- Dissertation Title: *Studio dell'oscillazione di sapore nei mesoni neutri*
- Thesis Advisor: Prof. Shahram Rahatlou

SEP 2014 - JUL 2019

High School Diploma, Liceo Scientifico Statale Vito Volterra

- Final Mark: 100/100 con Lode

Other Qualifications

OCT 2025 - PRESENT

INFN Association

Master student Association at Istituto Nazionale di Fisica Nucleare, Comitato Nazionale Scientifico 2 (CSN2) of Astroparticle Physics. Research Group: DarkSide

Academic Training

The projects that I will list below have allowed me to develop skills in the application of physics models to ~~real problems and~~ experiments, as well as critical thinking, teamwork and leadership in the context of a work group.

- Project for the Machine Learning and Artificial Intelligence course of my Bachelor School: *Jet Flavor Classification in High-Energy Physics with Deep Neural Networks.* (Group project, 2 persons) Lecturer: Prof. Stefano Giagu.
  Description of the project: Development of a Deep Neural Network algorithm for the classification of hadronic jets as "light quark jets" or "heavy quark jets" for high energy collision experiments at LHC. Project results (link), Bibliography (link).
- Project for the Neutrinos and Dark Matter course of my Master School: *Interaction Rate of Dark Matter WIMPs with Ordinary Matter.* Lecturer: Prof. Marco Vignati.
  Description of the project: Development of a Python-based model for calculating the interaction cross section of Dark Matter in the form of Weakly Interacting Massive Particles (WIMPs) with ordinary matter. Bibliography (link).
- Project for the Methods in Experimental Particle Physics course of my Master School: *Signal Reconstruction and Branching Ratio Evaluation for the Decays* $K_S \rightarrow \pi^0\pi^0$ *and* $K_S \rightarrow \pi^+\pi^-$ *in the KLOE Experiment.* (Group project, 2 persons) Lecturer: Prof. Antonio Di Domenico.
  Description of the project: Development of a Python-based algorithm for signal reconstruction from a 200 nb^{-1} dataset from a one-hour run of the KLOE Experiment at the DAFNE e^+e^- collider in Frascati. Cut choice for the reconstruction of the signal of a K_S decaying to two charged or two neutral pions and evaluation of the detection efficiency.
- Project for the Physics Laboratory II course of my Master School: *DREAM: A Measurement of the Cherenkov Light in a BGO Crystal Crossed by Cosmic Muons.* Lecturer: Prof. Gianluca Cavoto. (Group project, 4 persons) Supervisors: Dr. Fabio Cappella, Dr. Filippo Errico.
  Description of the project: Study of the Dual-REAdout Method (DREAM), a technique that improves resolution on calorimetric measurements by focusing on Cherenkov/scintillation light separation in BGO crystals. The project crucially consisted in the implementation of the DREAM in the Sapienza Didactic Laboratory, through an experimental setup mainly consisting of a BGO

and PMTs for trigger and calorimetric measurements. My group carried out a measurement of the Cherenkov to scintillation light ratio, validating the dependence of this quantity on the tilt angle of the crystal. Report and results (link).

Research Activity

Bachelor thesis (link)

My Bachelor thesis (*Studio dell'oscillazione di sapore nei mesoni neutri*) is a study of flavor oscillation in heavy neutral meson systems, with a focus on the B^0 meson system and on the measurements of flavor mixing in the BaBar Experiment. In the first Chapter I give a brief introduction to the Standard Model, as well as a historical outline of the discovery of the first antiparticles. The Chapter concludes with the quark mixing mechanism, which is a pivotal concept in order to understand meson mixing. In the second Chapter I show flavor oscillation in heavy neutral mesons from a quantum mechanical point of view, with a detailed description of the time evolution of a couple particle-antiparticle of heavy neutral mesons. In the last Chapter, I focus on experiments to verify and measure flavor mixing in heavy neutral meson systems, concentrating on the BaBar Experiment oscillation measurements in the beauty meson system.
Thesis Advisor: Prof. Shahram Rahatlou
Thesis Co-advisors: Prof. Gianluca Cavoto, Prof. Piero Rapagnani

Current research activity

I am currently working on my Master Thesis on direct dark matter search within the DarkSide Experiment. The presence of dark matter (DM) in the universe is supported by many observations based on gravitational effects but its real nature remains unknown. Dark matter may consist of an undiscovered elementary particle. A leading candidate is a Weakly Interacting Massive Particle (WIMP), with a mass ranging from below the GeV/c^2 scale to a few TeV/c^2. This range is extensively searched for via elastic scattering off atomic nuclei. These searches often use underground Time Projection chambers (TPC). The lack of concrete evidence of direct DM detection so far motivates the search for lighter WIMPs, below 10 GeV/c^2, and for light DM candidates interacting

with shell electrons, which may subsequently produce sufficiently large ionization signals.
The DarkSide-20k (DS-20k) Experiment looks to be one of the most promising techniques for direct detection of Dark Matter. DS-20k is the next generation of liquid argon (LAr) dual-phase TPCs, presently in construction at INFN Laboratori Nazionali del Gran Sasso in Italy. It is expected to start taking data in 2027. It is primarily designed to perform a nearly instrumental background-free search for high mass WIMPs. DS-20k aims for < 0.3 nuclear recoil background events with an exposure of 200 ton·year. The detection mechanism relies on the combined observation of the scintillation light (S1) and ionization (S2) signals. DarkSide-50 (DS-50), a first generation LAr dual-phase TPC, already demonstrated the capability of the technology and obtained world best sensitivities to light DM particles using only the S2 signal, when the S1 signal is no longer observable. The scaling from the 50 kg of Ar of the DS-50 TPC to the envisioned instrumented 50 t for the DS-20k TPC bears significant challenges and requires a phased approach in which intermediate-sized detectors are built first, to demonstrate that the technology works. The intermediate steps for the liquid Ar (LAr) detectors on the way to DS-20k are the detectors that are part of the "Proto" program, which includes the Proto-0 and Proto-1 (also called DS-Mockup). The goals of DS-Mockup are manifold but primarily focus on the feasibility of assembling a scaled down version of DS-20k. Innovative technologies that will be tested for future implementation in DS-20k include: a TPC made with radiopure acrylic, electrodes made by coating the acrylic with a resistive polymer, light reflectors, a TPB coating on the electrodes for photon wavelength-shifting (although the detector will not be instrumented with photosensors like DS-20k), argon recirculation in gaseous phase and gas pocket formation inside the TPC. DS-Mockup will then be an important effort to test not only electric field generation and gas pocket formation, but also the techniques that we will use to build DS-20k and to see how the materials perform at cryogenic temperatures. Starting from January 2025, DS-Mockup will be run at cold, using the DS-20k cryogenic system for pure underground Ar (UAr), that has been developed and whose commissioning has had significant contribution from the Rome group. While the DS-Mockup will have served their primary purpose with the completion of runs and collection of useful data, they have the potential to be used as a multi-purpose platform for future Research and Development on LAr detector technology. These could prove useful for testing aspects of future detectors deploying noble liquids. At the moment of writing, the Mockup working group, of which I am a member, is taking care of the final phases of the assembly of DS-Mockup at LNGS.

Master thesis project plan

My master thesis, which is advised by Prof. Sandro De Cecco, can be chronologically divided in three phases:

1. The assembly of DS-Mockup at Laboratori Nazionali del Gran Sasso;
2. The DS-Mockup cold tests and data analysis;
3. The development of on- and off-line event reconstruction analysis.

Current activity and results achieved

Since the start of my thesis (in October 2024), my work mainly refers to a first and immediate participation in the assembly of the DS-Mockup detector. For a total stay at LNGS of five weeks up to now, I have contributed (and will keep doing so) to a series of crucial activities for building the detector, a task which is going on inside Clean Room 2 (CR2), a DS-Mockup dedicated, ISO-6 level clean room of extremely new manufacture at Nuova Officina Assergi (NOA) in LNGS. A brief list of my tasks so far includes: preparation, cleaning and transportation of components for the assembly inside CR2; assembly and metrological characterization of the Wire Grid for the extraction field of the detector; preparation of the High High Voltage (HHV) infrastructure for DS-Mockup and setup of the HHV generators; general upgrades to the layout of utilities inside CR2 in order to ease and improve the assembly procedure. With respect to the metrological characterization of the Wire Grid, I am contributing with a live analysis of the planarity of said grid as we are building it. Our goal is to have a grid which is flat within 100 μm, so that the S2 signal can be generated uniformly over the whole anode surface. I have already presented my first preliminary results on the grid metrology in a meeting within the collaboration.

The next steps of my thesis project plan

The assembly phase of DS-Mockup should be completed by mid-January 2025, and from there on will begin the second phase of my thesis project, which will be twofold. On one hand I will take part as a shifter in the operation of DS-Mockup during its first, underground, cryogenic run in Hall C of LNGS. This will be carried out over a period of at least two months, which will likely extend further . On the other hand, DS-Mockup will provide us with a large variety of data, both for what concerns the monitoring of the detector parameters during its cool-down phase and also in the form of studying crucial features that will be ported to DS-20k, like the gas pocket formation.

A 3 liter Ar gas pocket inside the TPC of DS-Mockup can be created in two ways: by boiling liquid with a resistive electric heater element in situ (the *boiler*), and by feeding gas from an external gas bottle. Excess gas can escape through a so-called *bubbler*. My thesis work, ultimately, will be studying the formation of the gas pocket of DS-Mockup and its analysis as a function of the power of the boiler, with comparison to simulations that I will contribute to develop, as a test bench for DS-20k.

In a third and final period my thesis project will also comprehend a study and development of algorithms for S1 and S2 signal reconstruction on data from the most recent runs of Proto-0, the other small-scale DS-20k detector prototype located at INFN Napoli laboratory, which has been running already for a couple of months. I will in particular concentrate on the S2 reconstruction algorithms validation and development, which are related to the creation and stability of the gaseous gap.

Assergi, 16 December 2024

Lorenzo Pietropaoli