

Ph.D. Annual Report

Ph.D. Student: Pietro Bisio

Tutors: Andrea Celentano, Luca Marsicano

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My PhD project is focused on the search for Light Dark Matter through accelerator -based experiments. Specifically, my activity is performed in the context of the POKER (POsitron resonant annihilation into dark matter) experiment. POKER aims to execute a missing energy measurement using a 100 GeV positron beam impinging on an active thick target, searching for feebly interactive massive particles that could be produced by the interaction of the beam with the target material, subsequently exiting from the detector and carrying away a significant fraction of the primary e^+ energy. The ultimate goal of POKER is to perform a pilot measurement at the H4 beamline at CERN to prove the feasibility of this new experimental technique. The POKER activity is integrated into the NA64 experimental program, operating at CERN and searching for LDM with a complementary electron-beam measurement. During the first year of my PhD program, I focused on two main goals. I contributed to the NA64 data analysis and worked on the POKER electromagnetic calorimeter development.

The first aspect I deepened in the NA64 data analysis was the NA64 electromagnetic calorimeter (ECAL) energy calibration. My study showed the effectiveness of using full-energy deposition events, acquired with an appropriate pre-scaled trigger, to perform a better event-by-event ECAL energy calibration. Subsequently, I exploited the dataset collected by NA64 in 2021 operating the H4 beamline in positron mode to study the absolute hadronic contamination in this configuration. In particular, I measured the fraction of hadrons in the positron beam by exploiting the different signatures of these particles in the NA64 electromagnetic and hadronic calorimeters. The knowledge of this fraction is crucial for POKER since the hadronic contamination represents the primary background source of the experiment. Finally, I also tested a new fast digitiser (the INFN WaveBoard [1]) implemented within the NA64 DAQ setup, reading the signals from the NA64-ECAL channels. This work demonstrated how the ECAL energy resolution could be improved using the new WaveBoard. Performing these studies, I had the opportunity to personally work on the experiment, doing my first data-taking shifts at CERN and directly contributing to the experimental effort.

In parallel, I joined the *R&D* program for the new POKER active target (a PbWO_4 electromagnetic calorimeter), contributing to its design, testing and construction. In particular, I worked on the characterisation of the SiPM-board that, coupled to the crystal, allows the scintillation light measurement. Within this study,

I focused on the thermal characteristics of the board, verifying the variation in the signal performance due to SiPM temperature fluctuation. I also optimised the amplifier processing the signal generated by the SiPMs before the digitalisation, and I performed numerous tests of the entire crystal-SiPM-amplifier chain by using both a laser-based setup and a cosmic rays telescope. The results of these studies led to the construction of a prototype called POKERINO (a small PbWO_4 ECAL) that will be tested in the coming months. Within the prototype construction effort, I contributed to the testing of single electronic components and then participated in the overall assembly.

[1] F. Ameli et al. “A low cost, high speed, multichannel analog to digital converter board”. In: Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 936 (2019), pp. 286–287. doi: <https://doi.org/10.1016/j.nima.2018.08.110>.

List of attended courses and exams given:

- INFN School of Statistics 15-20 May 2022, Paestum
- Electronics and data acquisition (F. Fontanelli, P. Musico, S. Minutoli)
- Particle Physics and Multimessenger Astroparticles (M. Pallavicini, M. Sanguineti) - Exam not given yet
- Machine Learning And Data Analysis (L.Oneto, 2 slots from LM Computer Engineering) - Exam not given yet

List of publications:

- Andreev, Yu. M. et al. “Search for a light Z' in the $L_\mu - L_\tau$ scenario with the NA64- e experiment at CERN”. Phys.Rev.D 106 (2022) 3, 032015. <https://link.aps.org/doi/10.1103/PhysRevD.106.032015>
- P. Ilten et al. “Experiments and Facilities for Accelerator-Based Dark Sector Searches”. arXiv (2022) <https://doi.org/10.48550/arxiv.2206.04220>
- Andreev, Yu. M. et al. “Search for a new B-L Z' gauge boson with NA64”. arXiv (2022) <https://arxiv.org/abs/2207.09979>
- P Bisio. “Light Dark Matter search with a positron beam”. Nuovo Cimento C 45 (2022). <https://www.sif.it/riviste/sif/ncc/econtents/2022/045/05/article/2>

List of presentations:

- P. Bisio “DM/DP search with e^+ thick target” - talk at the HPS online collaboration meeting (Nov, 2021). <https://indico.jlab.org/event/496/>