Ph.D. Annual Report

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My Ph.D. activity focuses on the search for Light Dark Matter (LDM) through accelerator-based experiments. In particular, my PhD project is developed in the context of the POKER (POsitron resonant annihilation into dark mattER) experiment. POKER aims to carry out a pilot missing-energy measurement with a 100 GeV positron beam impinging on an active thick target. The beam interaction with the target could produce feebly interacting massive particles, exiting from the detector and carrying away a significant fraction of the primary positron energy. The POKER activity is integrated into the NA64 experimental program, operating at the H4 beamline at CERN, searching for LDM through the same experimental technique, and performing a complementary electron-beam measurement.

During the second year of my Ph.D. activity, I contributed to the NA64 data analysis, studying the first positron-beam dataset collected by NA64 in 2022 with the existing, non-optimised configuration. In parallel, I contributed to the ongoing POKER electromagnetic calorimeter *R&D* program. From March 2022, I got a 1-year Doctoral Student position at CERN. Spending an extended period at CERN allows me to participate effectively in the POKER-NA64 experimental project. I'm actively working with detector experts, planning the measurements, preparing the experimental setup and contributing to the data-taking effort. Moreover, I can personally discuss with NA64 experts about analysis improvement and results studies.

During the last year, in the context of the NA64 data analysis, I studied the intrinsic hadronic contamination of the H4 beam at CERN [1]. A precise knowledge of this observable is required in POKER since hadronic contaminants can result in background events. This analysis, performed using data collected by the NA64-e experiment in 2022, is based on calorimetric measurements, exploiting the different interaction mechanisms of 100 GeV/c electrons and hadrons in the NA64 detector. I determined the contamination by comparing the results obtained using the nominal electron/positron beamline configuration with those from a dedicated setup, in which only hadrons impinged on the detector. This work proved that the possible electron purities available in the H4 beamline can reach up to 99.7% for 100 GeV/c beams. Furthermore, I focused on the first positron-beam, missing-energy search for LDM performed with the NA64 experiment. The analysis was based on a total accumulated statistics of $(10.1 \pm 0.1) \times 10^9$ 100 GeV positrons on target. In particular, I worked on the selection cuts optimisation to maximise the sensitivity to the LDM production signal. After the unblinding, no events were found in the signal

region. This result allowed to set new exclusion limits that, relative to the collected statistics, prove the power of this experimental technique. This measurement was a crucial first step towards the POKER research program with positron beams. The results have been summarised in a dedicated publication [3].

I worked on the $R\&D$ program for the new POKER active target (a $PbWO_4$ electromagnetic calorimeter), by contributing to the crystal testing campaign to assess the radiation damage effects. A set of 135 crystals manufactured by the CRYTUR company was characterized using an intense ^{60}Co radiation source at the facility present in the Strahlenzentrum of Gießen (Germany). This work showed good agreement between the measurements and the specifications stated by the manufacturer. I also participated in the construction of a small $PbWO_4$ calorimeter prototype (POKERINO), preliminarily tested at the H4 beamline during the summer of 2022. I analysed data collected during this first short test, deepening some POKERINO critical aspects. This study indicated the need to improve the power supply performances and the lack of time during our first preliminary test. Consequently, a dedicated on-beam characterization of POKERINO was carried out at the SPS H8 beamline in July 2023. I joined the experimental effort, working on the detector test and data-taking shifts. In the coming months, I plan to analyse the data collected during these measurements.

List of publications:

[1] Andreev, Yu. M. et al. - "Measurement of the intrinsic hadronic contamination in the NA64$-e$ high-purity e^+/e^- beam at CERN" - arXiv 2305.19411, CERN-EP-2023-108. - Corresponding author

[2] Andreev, Yu. M. et al. - "Search for Light Dark Matter with NA64 at CERN" - arXiv 2307.02404, CERN-EP-2023-130.

[3] Andreev, Yu. M. et al. - "Probing Light Dark Matter with positron beams at NA64" - arXiv 2308.15612, CERN-EP-2023-192. - Corresponding author

List of presentations:

- P. Bisio "The NA64-e experiment at CERN" - Talk within the 8th Symposium on Prospects in the Physics of Discrete Symmetries (DISCRETE 2022). November 2022, Baden Baden.

List of attended courses and exams given:

- Particle Physics and Multimessenger Astroparticles (M. Pallavicini, M. Sanguineti)
- Machine Learning for Particle Physics (A. Coccaro, F. Di Bello)

- The Double Trouble of the Missing Matter in the Universe (E. Branchini) - Exam not given yet
- Neutrinos and Nuclear Astrophysics (S. Zavatarelli) - Exam not given yet