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The analysis strategy of the PADME experiment searching for invisible decays of the dark photon

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Summary. — PADME at the Beam Test Facility of the DAΦNE accelerator complex at the Laboratori Nazionali di Frascati of INFN is a new experiment looking for the gauge boson A' of a $U(1)$ symmetry holding in a secluded sector and acting as a portal between the Standard Model and the new sector. The experiment will start its data taking this year. The results of a recent study of the data analysis strategy, based on a realistic simulation of the apparatus, is summarised in this work.

1. – Description

At the end of 2015, INFN approved the PADME (Positron Annihilation in Dark Matter Experiment) [1] experiment at the BTF facility of the DAΦNE accelerator complex of LNF. The experiment aims at searching for a massive companion of the photon that is postulated in some theoretical models extending the Standard Model (SM) with a secluded sector to account for dark-matter particles non-interating with ordinary matter. The minimal assumption about the gauge structure of the secluded sector is a $U_d(1)$ symmetry with the corresponding gauge boson A' mixing with the SM photon. PADME will use a beam of 550 MeV positrons incident on a diamond target to search for the process $e^+e^- \to A'\gamma$. The missing mass method allows identifying the A' signal over the large electromagnetic background, profiting from the constrained kinematics of the event: $M^2_{A'} = (p^+_e + p^-_e - p_\gamma)^2$. Bremsstrhalung ($e^+N \to e^+N\gamma$) and SM annihilation

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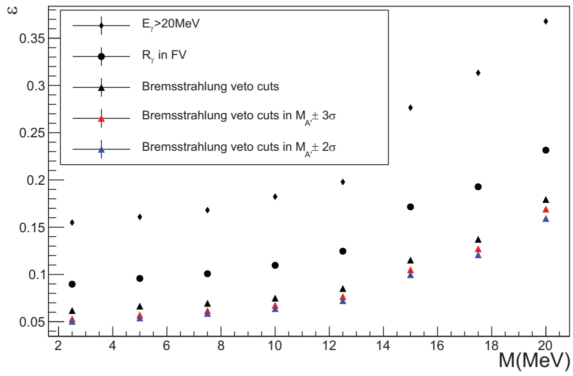

Fig. 1. – Signal selection efficiency as a function of $M_{A'}$ after each cut is applied.

$e^+e^- \to \gamma\gamma(\gamma)$ events are abundant background processes that can easily emulate the signal. A series of vetoes are designed for their rejection. The analysis strategy designated to select the signal was studied on data samples generated with the PADMEMC [2] software using realistic geometry and performance of the detector and emulating a beam intensity of 5000 e^+ in 40 ns long bunches. Several Monte Carlo samples were generated and analyzed for different mass hypotheses of the dark photon, $M_{A'} \in [2.5, 20]$ MeV, and for all relevant background processes. The following selection cuts have been defined as a result of the comparison of features of signal and background events: $E_\gamma > 20$ MeV, where E_γ is the reconstructed energy of the photon; the distance R_γ between the position of the recostructed photon and the beam axis must be in the fiducial region (FV) $[94.5, 262.5]$ mm; events are vetoed if the photon is in time ($\Delta t < 2.5$ ns) with a positron hit in the veto detectors and if the sum of the energies of the photon and the positron is compatible ($\Delta E \lesssim 150$ MeV) with the beam energy. Figure 1 shows the selection efficiency as a function of the mass hypothesis. From the fraction of background events passing the selection with a recostructed missing mass close to the value of the mass hypothesis for A' and from the estimated efficiency for the signal, the expected limit on the mixing parameter ϵ can be derived. For $M_{A'} = 10$ MeV and assuming a total statistic of 4×10^{13} positrons on target, a limit of $\sim 10^{-3}$ is obtained in agreement with the results of earlier studies [1]. Furthemore, a Deep Neural Network (DNN) has been trained to recognize the signal of a $M_{A'} = 10$ MeV A' boson in the PADME data against the background processes. The network features two hidden layers of neurons, each one with 100 nodes and 55 input nodes feed with variables corresponding to ECAL and positron veto signals. For a selection efficiency equal to the value obtained in the cut-based analysis, the DNN accepts only 5% of the background events, while the traditional analysis has a 54% acceptance for backround events. This preliminary study shows the potential improvement of the PADME results.

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