IL NUOVO CIMENTO **41 C** (2018) 50
DOI 10.1393/ncc/i2018-18050-7

Colloquia: IFAE 2017

Dark photon search with the PADME experiment

G. Piperno for the PADME Collaboration(*)
INFN Laboratori Nazionali di Frascati - Via E. Fermi, 40, I-00044 Frascati (RM), Italy

received 21 April 2018

Summary. — The PADME experiment, at the Laboratori Nazionali di Frascati, is dedicated to the search for a dark photon that decays into invisible channels. Its aim is to observe the reaction $e^+ e^- \rightarrow A' \gamma$, by searching for unbalanced final state events (A' undetected), with a missing energy equal to the non-interacting A' mass. With the present beam energy of 550 MeV it is possible to search for masses up to 23.7 MeV, while the foreseen statistics allows to scan coupling constants down to $\sim 10^{-3}$.

1. – The physics case

The Dark Matter (DM) problem continues to be an open issue in contemporary physics: we have many indirect evidences of its existence, but its direct detection is still difficult. A possible solution is to speculate that DM lives inside a dark sector and interacts with Standard Model (SM) particles only by means of "portals". The simplest portal consists of a new $U(1)$ symmetry, which carries its new vector boson, A', generally called the Dark Photon (DP), which could even be massive [1]. SM particles are neutral under this symmetry, but, due to a faint mixing of A' with the SM photon, parametrised by the mixing constant ε, they can effectively couple to the DP with charges $q' = q\varepsilon$, where q is the electric charge.

In addition, a DP with $\varepsilon \approx 10^{-3}$ and a mass from 1 MeV to 1 GeV can explain the discrepancy between the measurements and the expected value of the muon anomalous magnetic moment $(g-2)_\mu$ [2]. Recently, in this simple DP model, the BaBar Collaboration excluded the A' as a possible solution of this discrepancy [3], but in more complex scenarios it is still a viable road.

(*) P. Albicocco, R. Bedogni, B. Buonomo, F. Bossi, A. P. Caricato, G. Chiodini, P. Creti, R. de Sangro, F. Ferrarotto, G. Finocchiaro, S. Fiore, L. G. Foggetta, G. Georgiev, A. Ghigo, P. Gianotti, V. Kozhuharov, E. Leonardi, M. Martino, G. Maruccio, A. Monteduro, F. Oliva, G. C. Organtini, M. Palutan, G. Piperno, M. Raggi, I. Sarra, V. Scherini, B. Sciascia, T. Spadaro, E. Spiriti, S. Spagnolo, L. Tsankov and P. Valente.

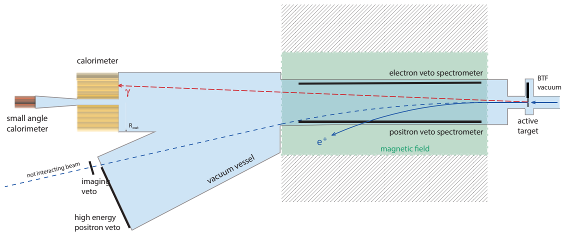

Fig. 1. – PADME detector schematic view. From right to left: active target, veto inside the dipole, electromagnetic calorimeter (3 m from the target) and small-angle calorimeter.

2. – The experiment

The Positron Annihilation into Dark Matter Experiment (PADME), hosted at the Laboratori Nazionali di Frascati (LNF), is devoted to the search of a DP which decays into DM [4, 5]. The A' can be produced, along with a SM photon, by a positron annihilation with an electron,

$$e^+ e^- \to A' \gamma,$$

and then leaves the experiment undetected, resulting into missing energy and momentum. The e^+ comes from the LNF Linac, which accelerates the beam at the nominal four-momentum $|\vec{P}_{\rm beam}| = 550\,\text{MeV}$, while the e^- comes from a fixed target ($\vec{P}_{e^-} = \vec{0}$).

Knowing the initial kinematics and measuring the $\vec{P}_\gamma$ of the photon in the final state, it is possible to measure the A' invariant mass as the missing mass $M_{\rm miss}$ in the detector:

$$M^2_{\rm miss} = \left(\vec{P}_{e^-} + \vec{P}_{\rm beam} - \vec{P}_\gamma\right)^2 .$$

As is schematically shown in fig. 1, the detector consists of:

- a diamond active target, to have average information about the beam;
- a 1 m long and 23 cm gap MBP-S dipole that drives positrons that did not interact towards a concrete block and sends those that lost energy for bremsstrahlung to a veto;
- a veto made of plastic scintillator bars ($1\times 1\,\text{cm}^2$ in section), divided into two parts, one inside the dipole and the other near the beam exit, for high-energy positrons;
- an electromagnetic calorimeter (ECAL) of 616 $2.1\times 2.1\times 23\,\text{cm}^3$ bismuth germanate (BGO) crystals arranged in a cylindrical shape ($\approx 59\,\text{cm}$ in diameter, with a central square hole of 10.5 cm side) at 3 m from the target, with energetic resolution $\sim \frac{(1-2)\%}{\sqrt{E}}$ [6], to measure the γ in the final state;
- a fast small-angle calorimeter (SAC), based on Cherenkov counters, for the detection of the bremsstrahlung radiation emitted at very small angle and therefore passing through the calorimeter central hole.

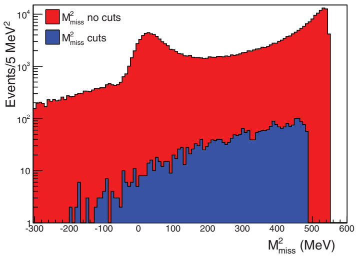

Fig. 2. – PADME foreseen backgrounds without (red) and with (blue) events selection.

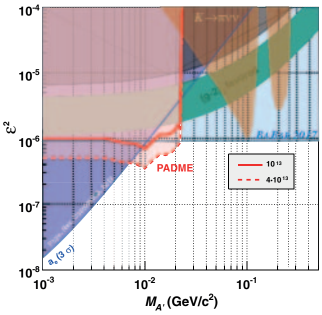

Fig. 3. – PADME sensitivity for different collected statistics for a beam energy of 550 MeV.

The background is mainly due to three phenomena: bremsstrahlung ($e^+ N \rightarrow e^+ N \gamma$), that is relevant for higher values of $M^2_{\rm miss}$; annihilation in 2 γ's with, possibly, an initial state radiation ($e^+ e^- \rightarrow \gamma\gamma(\gamma)$), that spoils the sensitivity for masses close to zero; and the pile-up, that reduces the statistics that can be accumulated without "blinding" the calorimeter, because of the BGO long decay time of 300 ns.

Figure 2 shows the background reduction obtained by requiring only one cluster in the ECAL, no hits in the veto detectors, no γ's in the SAC with energy larger than 50 MeV and an energy of the cluster in a range which depends on the A' mass hypothesis under test.

The detector construction completion and the start of the data taking are planned for 2018. Figure 3 shows the constraints on the DP mass and mixing parameter that can be derived in the absence of a signal, after collecting $\sim 10^{13}$ 550 MeV positrons on target. Values of ε larger than 10^{-3} would be excluded at 68% CL by PADME for DP with masses up to 23.7 MeV.

REFERENCES

[1] Holdom B., *Phys. Lett. B*, **166** (1986) 196.
[2] Pospelov M., *Phys. Rev. D*, **80** (2009) 095002.
[3] Lees J. P. *et al.*, arXiv:1702.03327 (2017).
[4] Raggi M. and Kozhuharov V., *Adv. High Energy Phys.*, **2014** (2014) 959802.
[5] Raggi M., Kozhuharov V. and Valente P., *EPJ Web of Conferences*, **96** (2015) 01025.
[6] Raggi M. *et al.*, *Nucl. Instrum. Methods A*, **862** (2017) 31.