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The calorimeters of the PADME experiment

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ABSTRACT

The PADME experiment is under construction at the Frascati National Laboratories of INFN to explore the coupling between ordinary and dark matter. This will be done through the detection of Standard Model photons produced in the reaction $e^+e^- \rightarrow \gamma A'$. The measurement of the photons 4-momentum allows to reconstruct the missing mass spectrum of this process, where the A' could appear as a peak. To this purpose, two independent electromagnetic calorimeters are used. The layout of the two detectors, and their expected performance measured during prototypes tests, are here presented.

Contents

1. Introduction

The PADME experiment [1,2] will be performed at Laboratori Nazionali di Frascati (LNF) of INFN to look for signals of dark matter [3]. This will be done by detecting the Standard Model (SM) photons produced in the reaction $e^+e^- \rightarrow \gamma A'$. The measurement of the 4-momentum of the SM photon allows to reconstruct the missing mass spectrum of this process, where the dark photon A' could appear as a peak.

Positrons accelerated by the LNF's LINAC at 550 MeV [4] collide with a diamond target [5], possibly producing γ and A', with $M_{A'} \leq$ 23.7 MeV.

2. The PADME calorimeters

In order to detect with high efficiency and precision the photons produced in coincidence with an A' particle, and to reject all the others due to background events, there are two calorimeter units in the experimental setup: the main one is the ECAL, while the second one is the Small Angle Calorimeter (SAC). Fig. 1 shows a CAD drawing of the two units.

The PADME ECAL is a homogeneous crystal calorimeter with an approximately cylindrical shape of diameter 600 mm with a central squared hole 100 × 100 mm^2. It is composed by 616 BGO scintillating units (21 × 21 × 230 mm^3) obtained machining the crystals recovered from one of the end-caps of the electromagnetic calorimeter of the dismantled L3 experiment at LEP [6]. ECAL is placed roughly 3 m downstream the interaction target providing an angular coverage from 20 to 95 mrad. The central squared hole, five units wide, is meant to let the Bremsstrahlung radiation to pass through and to be vetoed by the faster SAC placed behind; this is necessary since the BGO has a long scintillating light decay time (∼300 ns) and would be continuously blinded by this radiation.

According to the tests performed by the L3 collaboration [7], the expected energy resolution for these crystals lies in the interval (1–2)%$/\sqrt{E}$ for electrons and photons with energy < 1 GeV. Early tests aimed at evaluating the best readout technology for ECAL, showed that

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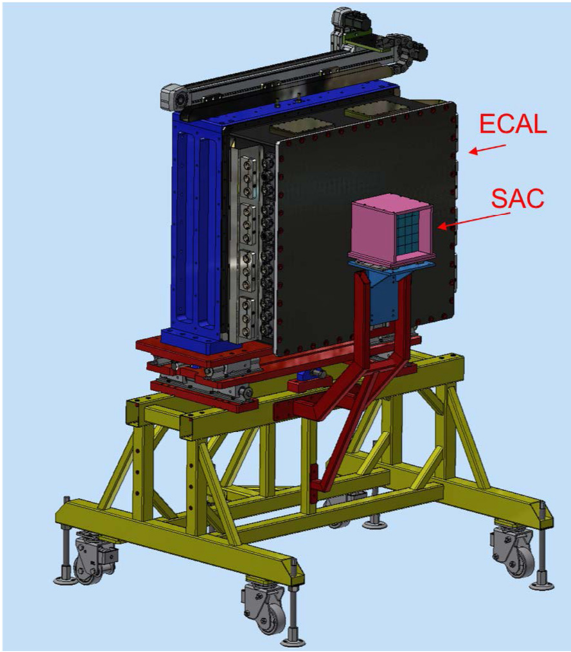

Fig. 1. CAD drawing of the electromagnetic calorimeter units of the PADME experiment: ECAL is the main one, SAC is the small angle calorimeter that has to provide a veto signal for background photons (see text for more details).

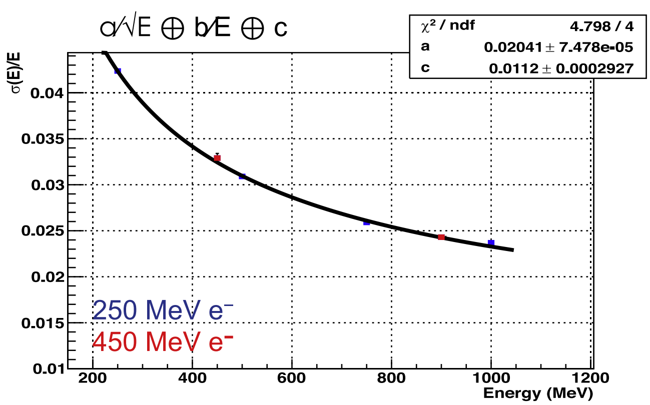

Fig. 2. Energy resolution measured with an ECAL prototype exposed to electron beams of different energies from the LNF's LINAC.

APDs, even with an area of 10×10 mm^2, have a gain not sufficient to reach this energy resolution that is mandatory for the success of the experiment. Then in the end, the final solution adopted for the light collection is based on conventional 19 mm diameter photomultipliers HZC XP1911. The energy resolution measured with a detector prototype irradiated with electron beams of different energies is shown in Fig. 2 [8].

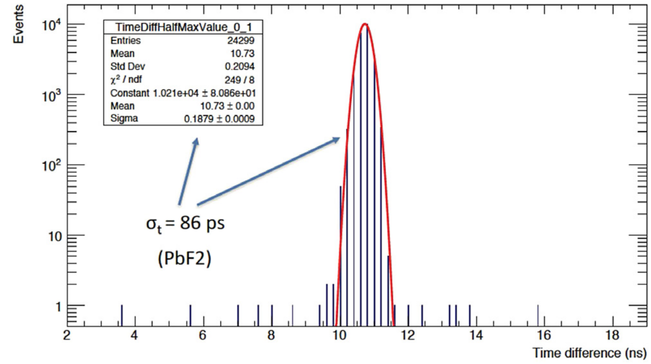

Fig. 3. Time resolution measured with SAC PbF_2 crystals (see text for more details).

The SAC is a squared matrix made of 25 PbF_2 crystals, $30 \times 30 \times 140$ mm^3 coupled to fast Hamamatsu R13748 photomultipliers that covers the angular range below 20 mrad. Being based on Cherenkov counters, it has a short dead time ~3 ns and it is able to stand event rates 10 times higher than the ECAL.

To determine the time resolution of this detector, time-of-flight measurements have been performed in a test beam using a scintillator finger, with a time resolution of 174 ps, as start counter. This combines in quadrature with the intrinsic resolution of SAC crystals that turned out to be < 90 ps (see. Fig. 3).

At present the two calorimeters are being commissioned in the experimental hall.

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References

[1] M. Raggi, V. Kozhuharov, Proposal to search for a dark photon in positron on target collisions at DAΦNE linac, Adv. High Energy Phys. 2014 (2014) 959802.
[2] P. Gianotti, The investigation on the dark sector at the PADME experiment, this proceedings.
[3] B. Holdom, Two U(1)'s and ϵ charge shifts, Phys. Lett. B 166 (1986) 196.
[4] G. Mazzitelli, et al., Commissioning of the DAΦNE beam test facility, Nucl. Instrum. Methods A 515 (2003) 524.
[5] F. Oliva, Searching for a dark photon with PADME at LNF: status of the active diamond target, this proceedings.
[6] B. Adeva, et al., The construction of the L3 experiment, Nucl. Instrum. Methods A 289 (1990) 35–102.
[7] Y. Karyotakis, The L3 electromagnetic calorimeter, in: Beijing 1994, Proceedings of Calorimetry Symposium, Annecy Lab. Part. Phys. - LAPP-EXP-95-002.
[8] M. Raggi, et al., Performance of the PADME Calorimeter prototype at the DAΦNE BTF, Nucl. Instrum. Methods A 862 (2017) 31–35.