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The charged particle veto system of the PADME experiment

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ABSTRACT

The PADME (Positron Annihilation into Dark Matter Experiment) will search for the production of a dark photon from positron–electron annihilation $e^+e^- \to \gamma A'$ using the positron beam of the Beam Test Facility (BTF) of the DAΦNE Linac at Laboratori Nazionali di Frascati (LNF). This paper presents the status of the charged particle veto system which is necessary to tag bremsstrahlung processes which are the main source of background events.

Contents

1. Introduction

The PADME experiment [1] will search for the dark photon A' in the process $e^+e^- \to \gamma A'$ using the missing mass method, which is independent from the new gauge boson decay mode. The missing mass squared is computed by the formula:

$$M^2{}_{miss} = (P_{e^+} + P_{e^-} - P_\gamma)^2,$$

where P_{e^+}, P_{e^-} and P_γ are the 4-momentum of the positron beam, of the target electron and of the emitted photon, respectively. The PADME detector (Fig. 1) is made of a thin diamond target, a magnetic dipole, which bends the beam outside the experimental acceptance, a high resolution electromagnetic calorimeter (ECAL), a small angle electromagnetic calorimeter (SAC) capable to sustain a high rate, and a charged particle veto system. The diamond target and the veto detectors will be hosted in the vacuum vessel [2]. A positron that hits the diamond target could annihilate and produce together a SM and a dark photon; a signal event is represented by a ECAL cluster, due to the hit of a SM photon. The main source of background is represented by the Bremsstrahlung process, which produces only one photon in the final state, in addiction to a positron of energy lower than the beam energy by an amount corresponding to the energy of the photon. In order to suppress this background two kind of positron vetoes are present in the experiment: the Positron Veto (PV), which is 1 m long and covers the left internal vertical wall of the magnetic dipole and a High Energy Positron (HEP) veto, which covers an angular region between the beam dump and the magnet. An Electron Veto (EV), identical to the PV, covers the internal right vertical wall of the magnetic dipole. The PV and the EV will be also used to search for a dark photon in the visible channel.

2. Veto system description and status

The charged particle veto detectors are made of scintillating bars (96 for the PV and the EV, 16 for the HEP). The scintillating bars are positioned with the long side parallel to the magnetic field direction and rotated around their longitudinal axis by 0.1 rad to minimize geometrical inefficiencies. The $10 \times 10 \times 180$ mm^2 scintillating bars,

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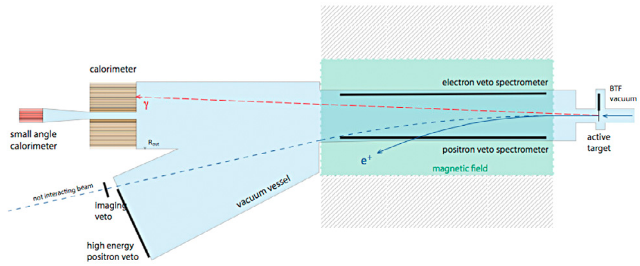

Fig. 1. Drawing of the PADME detector with a bremsstrahlung event, tagged by the charged particle veto system and the bremsstrahlung photon hitting the calorimeter. The positron beam is swept out of the calorimeter acceptance by the dipole magnet.

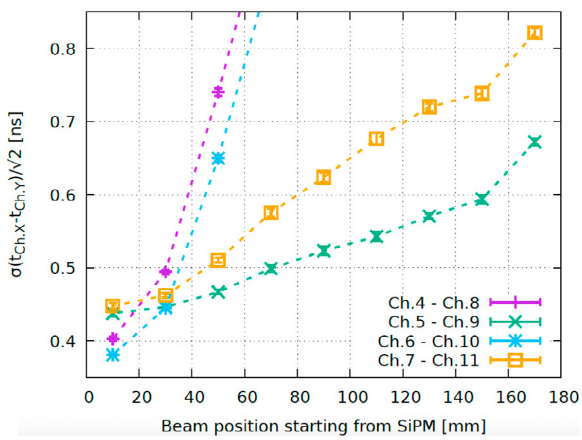

Fig. 2. Time resolution measured from the dispersion of the difference in time between pairs of scintillating bars. The best performance is observed for ch. 5–9 corresponding to scintillators with glued light-guides and readout of both scintillator and fiber; the time resolution increases when the fiber is not glued (ch. 7–11) and when the fiber is not readout (ch. 4–8) or absent (ch. 6–10).

made of a plastic polystyrene-based material with 1,5% concentration of POPOP, are produced by UNIPLAST. An optical wavelength shifter (WLS) fiber BCF-92 is housed in a longitudinal 1.3 × 1.3 mm^2 groove. The fiber has a maximal emission wavelength at 492 nm and maximal absorption wavelength at about 400 nm (matching the POPOP emission spectrum). The scintillating light is collected from one side by silicon photo-multipliers (SiPMs) Hamamatsu 13360, which are able to work in vacuum and in magnetic field. The Front-End Electronics (FEE) cards serve up to 4 counters. A first veto detector prototype was assembled with 16 bars and the same geometrical parameters of the final detector but different SiPMs (Hamamatsu S12572). This prototype was tested in April 2017 with a 500 MeV single electron beam of the DAΦNE LINAC at the BTF (the same location as the final experiment). The array of scintillators was aligned with the beam line, so that the beam crossed all bars. The first and the last group of four scintillators were used as offline trigger, to assure the passage of a particle through the two remaining groups of four scintillators placed in the middle. In the beam test, the front-end signals were digitized by a CAEN module V1742 at the rate of 5 GS/s. Two properties are crucial for the vetoes: the time resolution and the efficiency. In order to identify a Bremsstrahlung event

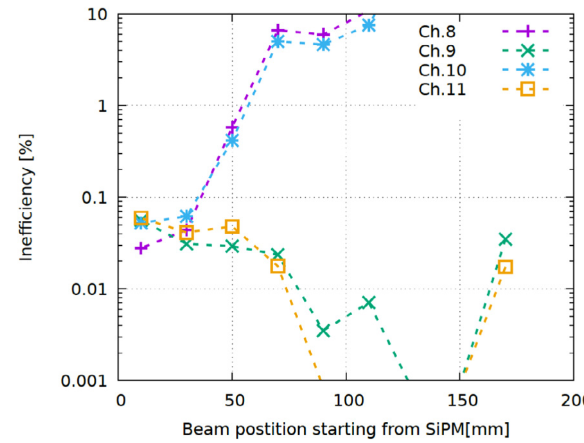

Fig. 3. The measured inefficiency of the scintillating bars as a function of the distance between the beam impact point and the readout side. See Fig. 2 for the legend. The counter is declared efficient for signals above 10 photo-electrons.

a time coincidence between the photon in ECAL and the positron in PV is needed with a resolution < 1 ns. These parameters were studied varying the distance between the impact point of the beam with respect the photodetectors, from 10 mm to 170 mm, and using different light collection configurations [3]. As shown in Fig. 2 the time resolution is under 1 ns in any case and the inefficiency is below 0.1% for scintillators with glued (ch.9) or not glued (ch. 11) light-guides and readout of both scintillators and fiber (Fig. 3), in agreement with the purpose of the experiment. These results were used to choose the design of the veto for the final layout of the experiment, made of scintillators with glued fibers and readout of both scintillators and fibers.

3. Conclusions

The PADME veto system has been tested with electrons at the DAFNE BTF. A time resolution of ∼ 500 ps and an inefficiency lower than per mille have been measured. The PADME charged particle veto system has been already assembled and certified to work in the vacuum. Currently, the veto system is under integration in the vacuum vessel of the experiment in order to be ready for data taking.

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