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Searching for a dark photon with PADME at LNF: status of the active diamond target

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ABSTRACT

PADME (Positron Annihilation into Dark Matter Experiment) is an experiment that will search for the production of a dark photon A' from the annihilation of a positron beam on a thin diamond target. It will use the 550 MeV positron beam of the Beam Test Facility (BTF) of the Laboratori Nazionali di Frascati (LNF) of INFN. According to the PADME design, the region of sensitivity is $M_{A'} \leq 23.7$ MeV/c^2 and $\epsilon^2 > 10^{-6}$, where $M_{A'}$ and ϵ are the dark photon mass and the $A'\gamma$ mixing parameter.

This paper presents the status of the active diamond target, in particular the assembly of two 32 channel targets of polycrystalline Chemical Vapor Deposition (CVD) diamond, one with graphitic strips and another with traditional CrAu strips.

Contents

1. Introduction

The PADME experiment [1] searches for a dark photon produced in $e^+e^- \to \gamma A'$ and decaying to invisible particles. The signal is represented by a peak in the missing mass spectrum in events with a single photon in the final state. The detector is made of an active diamond target, a magnetic dipole, a BGO electromagnetic calorimeter, a small angle Cherenkov calorimeter and a charged particles veto system. The target and the veto system will be placed in a vacuum chamber, in order to minimize the interactions with air molecules. The missing mass is extracted from the photon energy and angle measured by the BGO electromagnetic calorimeter. The choice of an active target improves the missing mass resolution if the beam–target interaction point is measured with a precision < 1 mm. The choice of a low Z material for the target reduces the rate of bremsstrahlung interactions ($\propto Z^2$), main background of the experiment, with respect to annihilation events ($\propto Z$), source of possible signal events via the dark photon–photon mixing mechanism. For these reasons, a target made of electronic grade diamond ($Z = 6$) is a good solution for PADME.

2. Active diamond target description and status

The diamond sensor for PADME is a 100 μm thick and 2×2 cm^2 large CVD polycrystalline diamond, produced by Applied Diamond Inc. (USA), with 19×19 strips on the front and back side in two orthogonal directions. A first diamond sensor prototype with graphitic strips and

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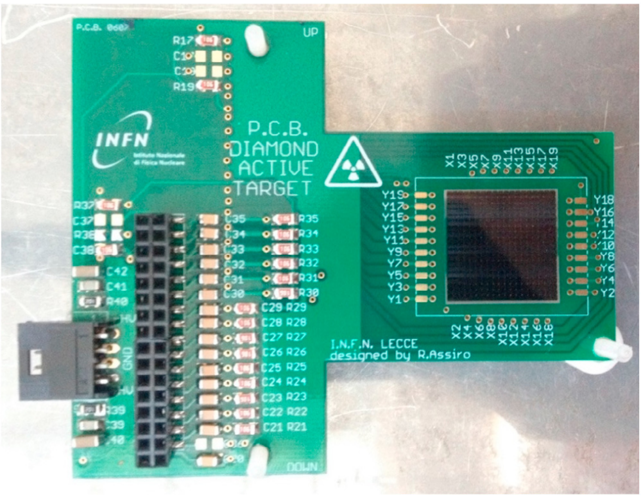

Fig. 1. Diamond sensors with graphitic strip interconnected to the inner board.

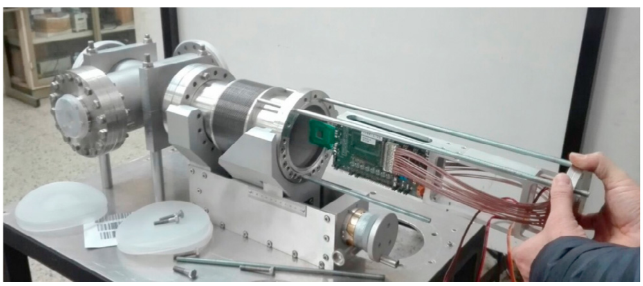

Fig. 2. Diamond active target assembly during insertion tests into the vacuum-cross by the linear positioning system.

same geometrical characteristics but different thickness (50 μm) was tested in November 2015 using the $e^{\pm}$ beam of the DAΦNE Linac. Each strip was readout by single channel diamond amplifiers from CIVIDEC [2]. The graphitic strips were fabricated in the L3 Laser Laboratory in Lecce by means of an excimer laser ArF [3]. The back-side of the prototype sensor was interconnected to a printed circuit board by silver paint conductive glue and the front-side by aluminium wire bonding; both techniques were successfully tested with the prototype, which allowed to demonstrate the good performance of the diamond sensor with graphitic strip: a charge collection distance of about 11 μm and a beam centroid spatial resolution of about 0.2 mm.

Two sensors with different types of electrodes were made: one with graphitic strips and one with metallic strips. The graphitic strips were fabricated in Lecce like for the prototype sensor. The metallic strips were made at Applied Diamond by thermal evaporation of Cr and Au layers. The diamond sensors were precisely positioned with a micrometric XYZ and Θ handling system to a printed circuit board (inner board) and mechanically connected by spots of Araldite glue, previously deposited using a dispensing system equipped with a syringe. The electric contacts between the strips and the inner board were done by filling back-side holes made on purpose with a conductive adhesive and on the front-side by aluminium wire bonding (at INFN Perugia). The electrical resistance of back-side contacts was monitored while the conductive glue was deposited and final values were < 1 Ω. The inner board (see Fig. 1) provides the high voltage to each strip which is AC coupled to the front-end. The front-end consists of two evaluation boards of the AMADEUS chip which are electrically connected to the inner board by two rigid connectors on both sides to readout 16X and 16Y strips. The AMADEUS chip has 16 inputs of charge sensitive pre-amplifiers and 16 single ended voltage outputs, with 20–40 ns adjustable shaping time and equivalent-input-charge noise of about 1100 e^-+68 e^-/pF. Both detectors hold the high voltage up to 150 V with a measured leakage current of about 50 nA. The front-end electronics was turned-on in vacuum with a pressure of 10^{-6} mbar, to verify that the heating produced by power dissipation is limited and it is easily removed by the thermal conductivity of the materials of board and holders. The temperature was monitored with an external thermal imager through a ZnSe window which is transparent to thermal radiation. The highest temperature was observed at the location of a voltage regulator which reached the temperature of 36 °C in vacuum (stable over 3 h of operation), with a time constant of about 45 s, while it was operating at 25 °C in Air. The assembly of one inner board and two front-end boards is rigidly bound to a CF100 vacuum flange by a support frame machined from a single aluminium piece. All electrical services, the calibration signals and the output signals are routed outside the vacuum through a 50-pins vacuum feedthrough connector. The target will be located in the experiment by a linear positioning system and vacuum bellow using a vacuum-cross which intercepts the beam before the PADME vacuum vessel and the magnetic dipole (see Fig. 2). A DCS software based on ROOT has been designed to remotely control by an ethernet-GPIB interface each instrument and automatically calibrate the front-end channels. The DCS is integrated with the DAQ of the experiment and stores detector parameters and run information in MySQL database.

3. Conclusion

The active diamond target of the PADME experiment is equipped with two 16 channels AMADEUS chips and assembled on its final mechanical support frame. Two type of sensors are available for data taking: a full-carbon detector with graphitic strips and a detector with traditional CrAu strips. Both sensors are made of electronic grade 100 μm thin diamond. PADME will be one of the first experiments with an active diamond target with graphitic strips.

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