The active diamond target for the PADME experiment

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The PADME (Positron Annihilation into Dark Mediator Experiment) collaboration searches for dark photons produced in the annihilation $e^+ + e^- \rightarrow \gamma + A'$ of accelerated positrons with atomic electrons of a fixed target at the Beam Test Facility of Laboratori Nazionali di Frascati [1]. The apparatus can detect dark photons decaying into visible $A' \rightarrow e^+e^-$ and invisible $A' \rightarrow \chi\chi$ channels, where χ's are particles of a secluded sector weakly interacting and therefore undetected. In order to improve the missing mass resolution and to measure the beam flux, PADME has an active target able to reconstruct the beam spot position and the bunch multiplicity.

Two active target prototypes of 2×2 cm^2 area and 50 and 100 μm thickness, respectively, were built in Lecce (Fig. 1). The readout strips (1 mm pitch in orthogonal directions on the two sides of the film) were made in the first case with in-house laser graphitization [2], in the second case with Cr-Au thermal evaporation by the supplier.

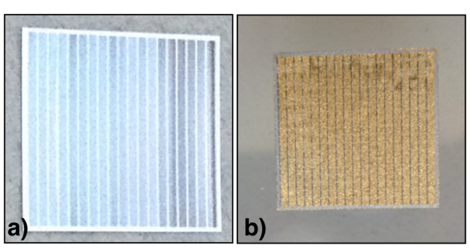

Figure 1. Diamond sensors for the active target: graphite electrodes c) and Cr-Au electrodes d).

The diamond target has 19 strips per view, for a total of 38 channels, and the signals on all these strips, after being amplified, are also digitized. The choice to digitize the diamond signals will allow to follow in details the evolution of the polycrystalline sensor response. Therefore, the electronics based on multi-channel charge sensitive amplifier (CSA), often used for silicon strip detectors, are not an option for the front-end of the active target of PADME, because only the charge information is provided.

In the first test beam we evaluated several single channel charge sensitive amplifier (CSA) with 5mV/fC gain, 100 MHz bandwidth, 2 ns rise-time, 7 ns pulse width and 750 e^- equivalent input noise, together with several single channel voltage amplifier (VA) with gain 100, 2 GHz bandwidth and 25 μV equivalent input noise when terminated with 50 Ω.

In the second test beam, in addition to the previous electronics, the detector was readout also by a multi-channel CMOS chip named AMADEUS from IDEAS. This chip contains 16 CSA with 16 analog outputs and equivalent noise charge of about $1106e^- + 68e^-$/pF. In addition, the nominal shaping time is about 40 ns and it can be increased by adjusting the working point, allowing to match the bunch duration. Finally, this electronics can be placed on the same pc-board of the detector to minimize the noise.

In Fig. 2 the digitized waveforms recorded in beam tests, for comparable beam intensities, using the three front-end electronics described above are shown. The AMADEUS chip, which is the current baseline for the PADME experiment, is slower than the other two but it exhibits the best signal-to-noise ratio. Nevertheless, also the other two front-end electronics perform well and could be used in the experiment. In fact, as discussed in the next section, the detector performance (efficiency, space and time resolution) has been measured with single channels front-end for CSA and VA.

The detector is mounted on a carrier board, which must deliver the bias voltage to all the sensor strips and route the 38 induced signals to the readout chip placed on a mother board. In ad-

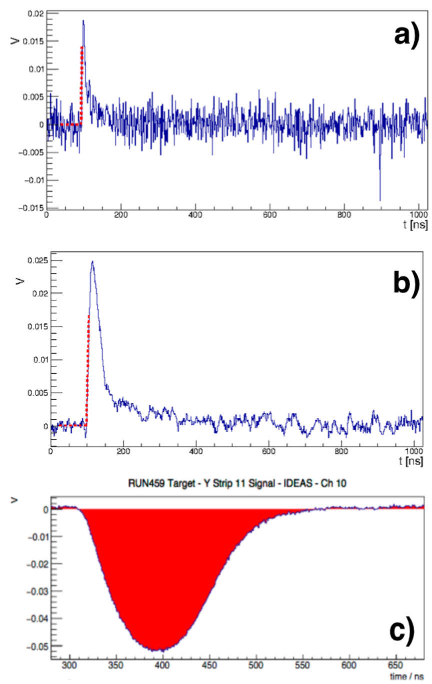

Figure 2. Front-end output signal for three different amplifiers: single channel fast charge sensitive amplifier a), single channel fast voltage amplifier b) and sixteen-channels charge sensitive amplifier c). In these measurements the single channel amplifiers are placed 25 cm far away from the sensor.

dition, the carrier board must hold very rigidly the diamond sensor, to avoid mechanical torsions that could break it.

The electrode strips of both faces must be electrically connected to the carrier board. The most natural solution is to use conductive glue dots for the back-plane which is in contact with the carrier board and also guarantees the mechanical stability, and wire bonding on the front face, as typically done to interconnect silicon sensors to pc-board. In the first test beam we tested both solutions for the graphitic sensor, but we had some failure due to the bad planarity of the pc-boards. Anyway, where a good contact was established the signal didn't show any degradation with time. For the final assembly, two solutions are under evaluation: all conductive glue dots or conductive glue dots in the back-plane and wire bonding in the front-plane, as shown in Fig. 3 a) and b). The reason to bypass the wire bonding is to avoid the risk of damaging the diamond sensor in case of unwanted localized over-pressure during the soldering procedure.

The carrier board and the mother board are connected through a multi-pin connector, in such a way that both, sensors and front-end electronics can be easily replaced for repair or upgrade. The diamond active target with the sensor and the electronics is going to be placed in the va-cuum inside a 4-way cross with four access flanges of 10 cm inner diameter. A linear positioning mechanism in vacuum is placed on a flange to control the horizontal position of the active target, in such a way that it could be also be removed from the beam line outside standard running conditions or for beam calibration (Fig. 3 right). On the second movable flange of the linear position mechanism a multi-pin feed-through connector will allow to deliver high voltage, low voltage, control signal, pulse calibration to the detector and to extract the 38 output signals bringing then to the dedicated input lines of the digitizer.

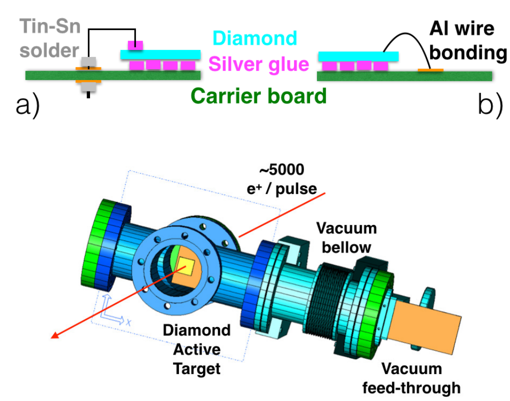

Figure 3. Drawing of two methods under consideration to interconnect the diamond sensor orthogonally segmented on both faces with the printed circuit board (a) and (b). CAD drawing of the mechanics with a horizontal linear shift holding the active target in vacuum is shown in the bottom picture.

REFERENCES

1. M. Raggi and V. Kozhuharov, *Proposal to Search for a Dark Photon in Positron on Target Collisions at DAΦNE Linac*, Adv. High Energy Phys. 2014, 959802 (2014)
2. M. De Feudis et al. *Characterization of surface graphitic electrodes made by excimer laser on CVD diamond*, Diam. Relat. Mater. **65**, 137-143 (2016).