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# Test of the DEP Hybrid Photodiode in 5 Tesla Magnet

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## Introduction

The CMS detector is designed so that the tile/fiber hadronic calorimeter (HCAL) is immersed in a 4 Tesla magnetic field. The Hybrid Photodiode (HPD) will be used as the photodetector. Below we present the experiment data which we obtained on the HPD behavior in a magnetic field.

## The Goal of the Measurements

The degree of alignment required for the multipixel HPD in a magnetic field comparable to that provided by the CMS magnet was the main point of interest. We changed the angle between the HPD axis and the magnetic field direction to see what happens to the signal. Timing of the HPD in the magnetic field was measured simultaneously, along with the pulse shape.

## Setup

A 5 Tesla solenoid magnet[1] was used. The HPD, which was under test, was mounted on a movable nonmagnetic support at the geometrical center of the magnet. The HPD assembly had light signals injected by the use of 2 optical fibers (Fig. 1). One fiber was of 200 um diameter for direct current (DC) measurement and the other was of 1 mm diameter for pulse mode operation. Both of the fibers could be moved across the HPD photocathode in both the X and Y directions (Fig. 1). The fibers delivered the light emitted by light emitted diodes (LED) placed about 10 meters outside of the magnet to the HPD. We could change the HPD angle with respect to the solenoid magnet axis in the range 0 - 45 degrees with a setting accuracy of 0.3 degrees (Fig. 2). The nonuniformity of the magnetic field at the HPD was less than 0.1% in all measurements.

## Measurements

A schematic view of the 7 pixel HPD under test is shown in Figs. 1 and 2. The HPD parameters were measured by using oscilloscopes and multimeters which operated well in the high field enviornment.

Initial measurements were made to define the gains curve of the HPD without and with a 5 Tesla magnetic field oriented parallel to the HPD electric field for the DC mode. The LED light level was chosen to get no more than 1% of the output signal charge spread. The full duration of the signal was 40 ns in the pulse mode, for which data was also taken.

We also scanned the HPD photocathode by moving fibers in both X,Y directions for each set of measurements with and without magnetic field. An example of such data are presented in Fig. 3.

The measurements were also performed for different HV and bias voltages applied to the HPD. We did not see any noticable spatial displacement of the HPD response in any of these cases.

In the next series of measurements the angle between the HPD axis (which we assume coincides with the direction of the HPD electric field) and the direction of the magnetic field was changed (in the X,Y plane). We scanned the HPD photocathode fibers for all sets of angles. Examples of such measurements are shown in Figs. 4 and 5. The first scan in Y shows a clear dependence of the image shift on the tilt of the magnetic field along the Y axis. The same scan along the X axis does not show any displacement of the image. As shown in Fig. 6 the magnitude of the y image shift is proportional to the tangent of the angle θ between the E and B fields.

We noticed no change in the timing of the HPD signal (shape, delay, jitter, etc.) with an estimated 1 ns of accuracy in all sets of measurements

## Discussion

The data obtained are in very good agreement with theoretical calculations[2]. The calculations show that the photoelectron moves along the magnetic field direction in the presence of high magnetic fields (Fig. 7). The experimentally observed tangent dependence is also confirmed by the calculations.

We note that the shift of the image along the X axis is only of the order 10 um[2] in the case where the electric and the magnetic field are not in parallel. This value is less than out spatial accuracy, so we did not observe a displacement along the X axis.

We can conclude now that we can satisfy the CMS[3] requirements on HPD alignment in the CMS magnet. For example 3 mm distance between the photocathode and the silicon of the HPD means 47 um of image shift for 1 degree of misalignment. The accuracy is acceptable given a dead space between the pixels of order 100 um.

We have also observed an increase of the threshold of the gain curve when the magnetic field is included at an angle with respect to the electric field. It appears to be a simple geometrical effect which occurs because the photoelectrons lose more energy penetrating the dead layer.

## Acknowledgments

We appreciate the help of all the personnel responsible for the operation of the 5 Tesla medical magnet. Our special thanks to Bruce Hammer who was a great help with data taking.

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[1] B. Hammer, N. Christensen, B. Heil, Use of a magnetic field to increase the spacial resolution of positron emission tomography, Medical Physics. Vol. 21, 12, December 1994, pages 1917-1920.
[2] D. Green, Fermilab, Technical Memo, FNAL-TM-1992, 1996.
[3] CMS, The Hadron Calorimeter Project, Technical Design Report, CERN/LHCC 97-31, CMS TDR2, 20 June 1997.

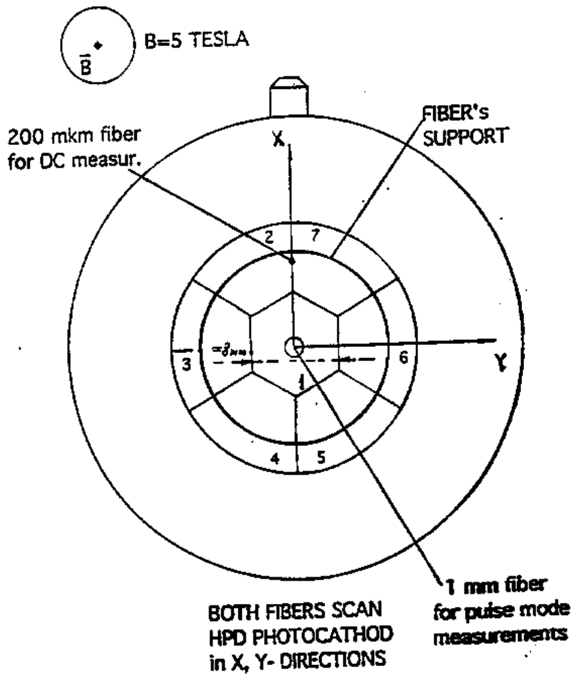


Fig.1.

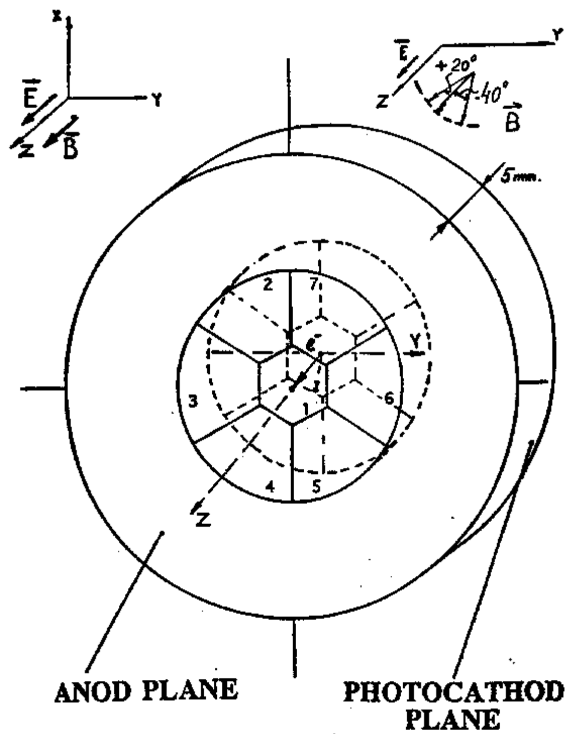


Fig.2.

Fig. 1: The 7 pixel HPD DEP showing the front face view and the two fiber locations.
Fig. 2: A 3D schematic view of the HPD in the magnetic field.

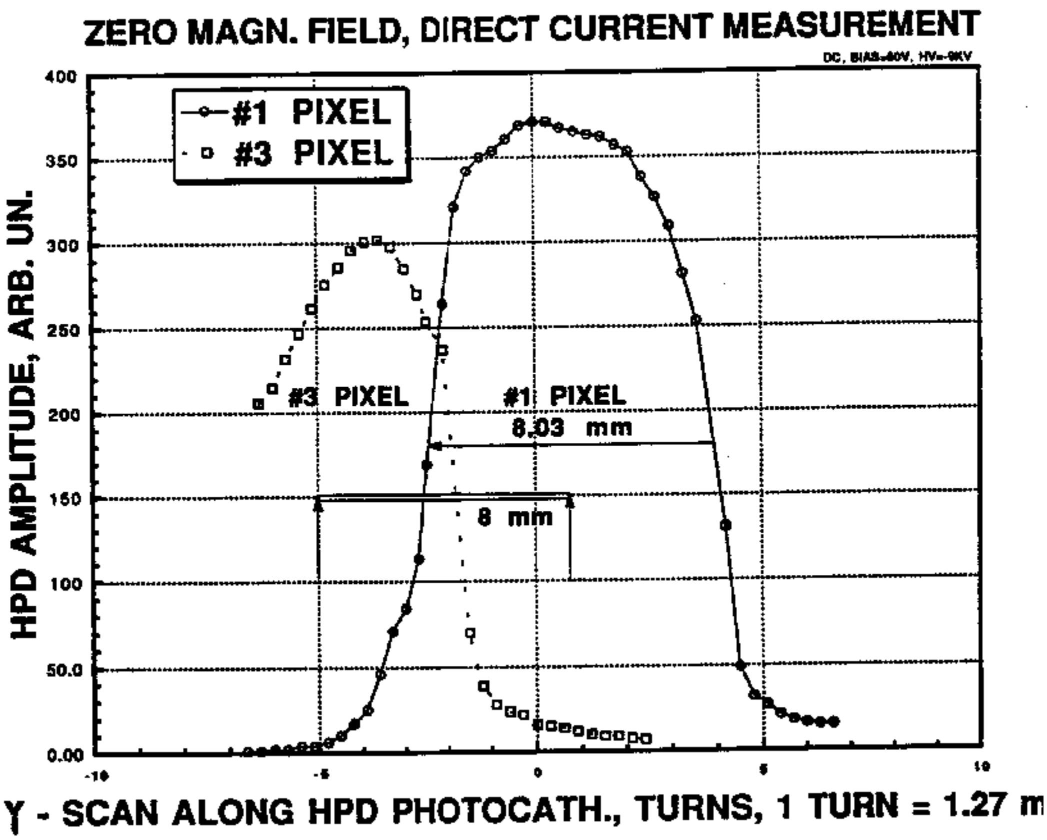


Fig. 3: Y-scan of the HPD photocathode without magnetic field.

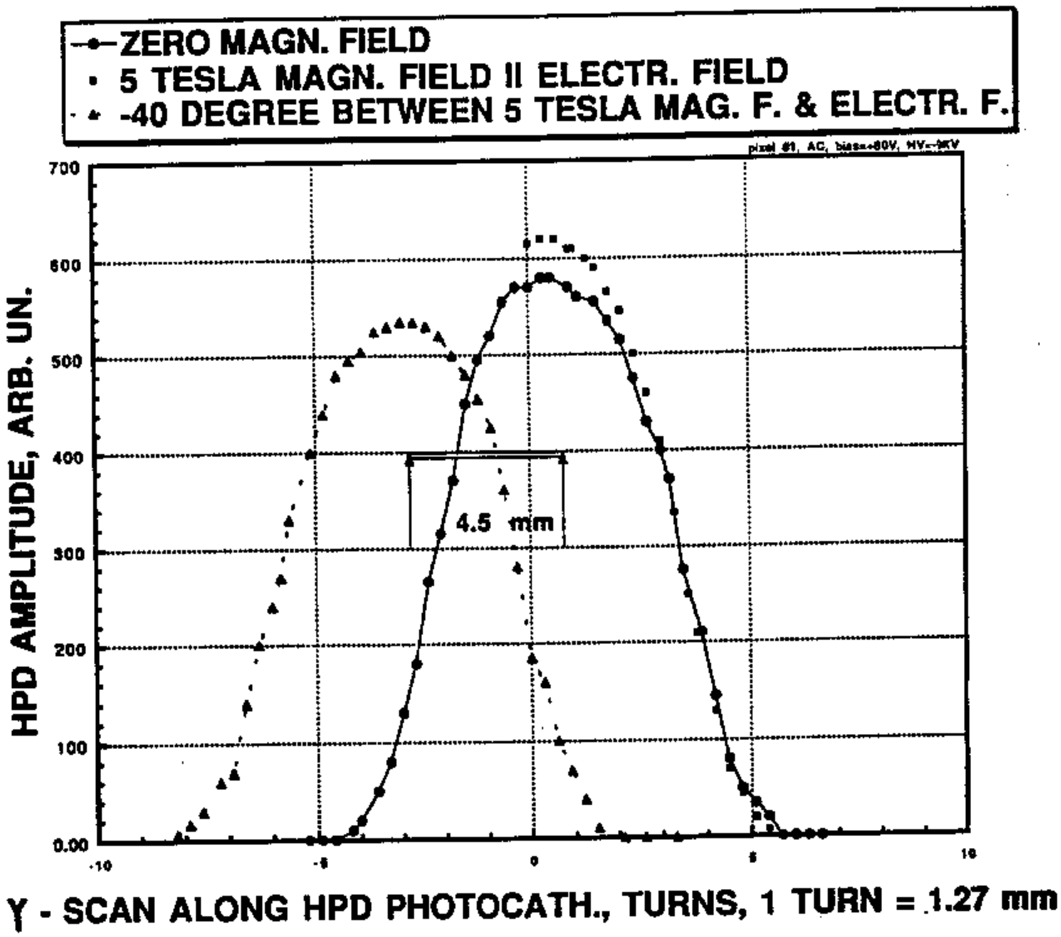


Fig. 4: Y-scan of the HPD photocathode for pixel #1 with and without magnetic field.

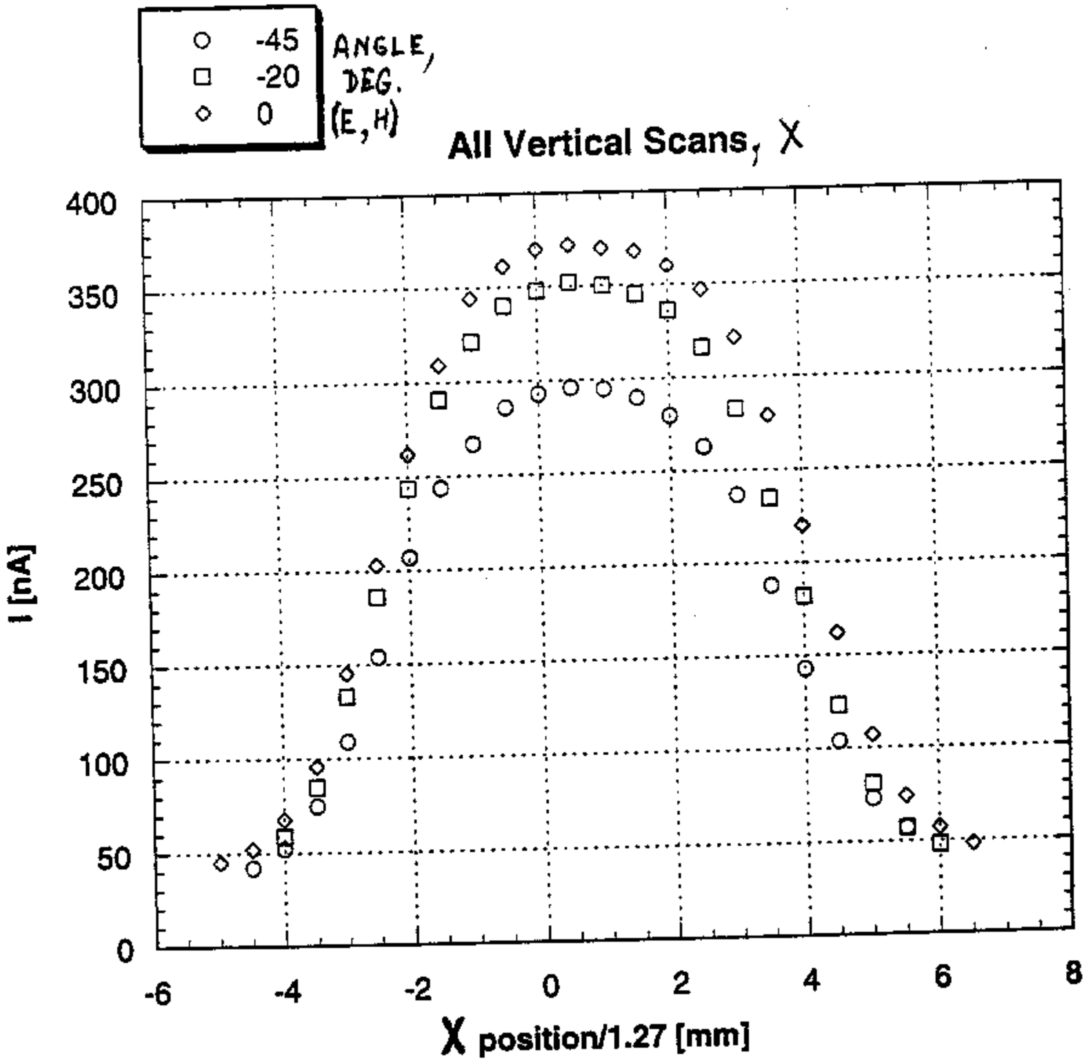


Fig. 5: X-scan of the HPD photocathode for different angles between E and H fields.

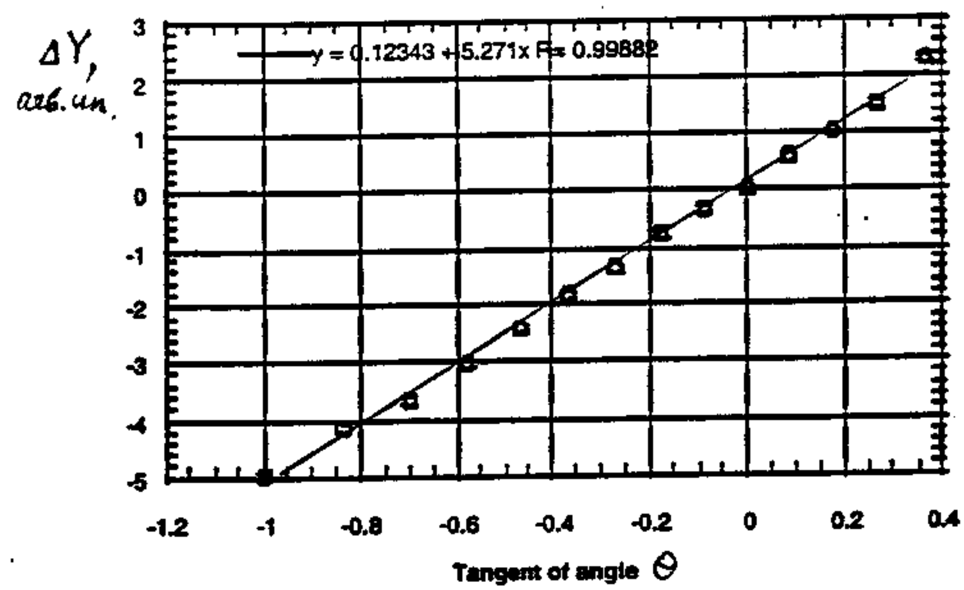


Fig. 6: The dependence of the shift of the center of the image on the tangent θ between E and H fields.

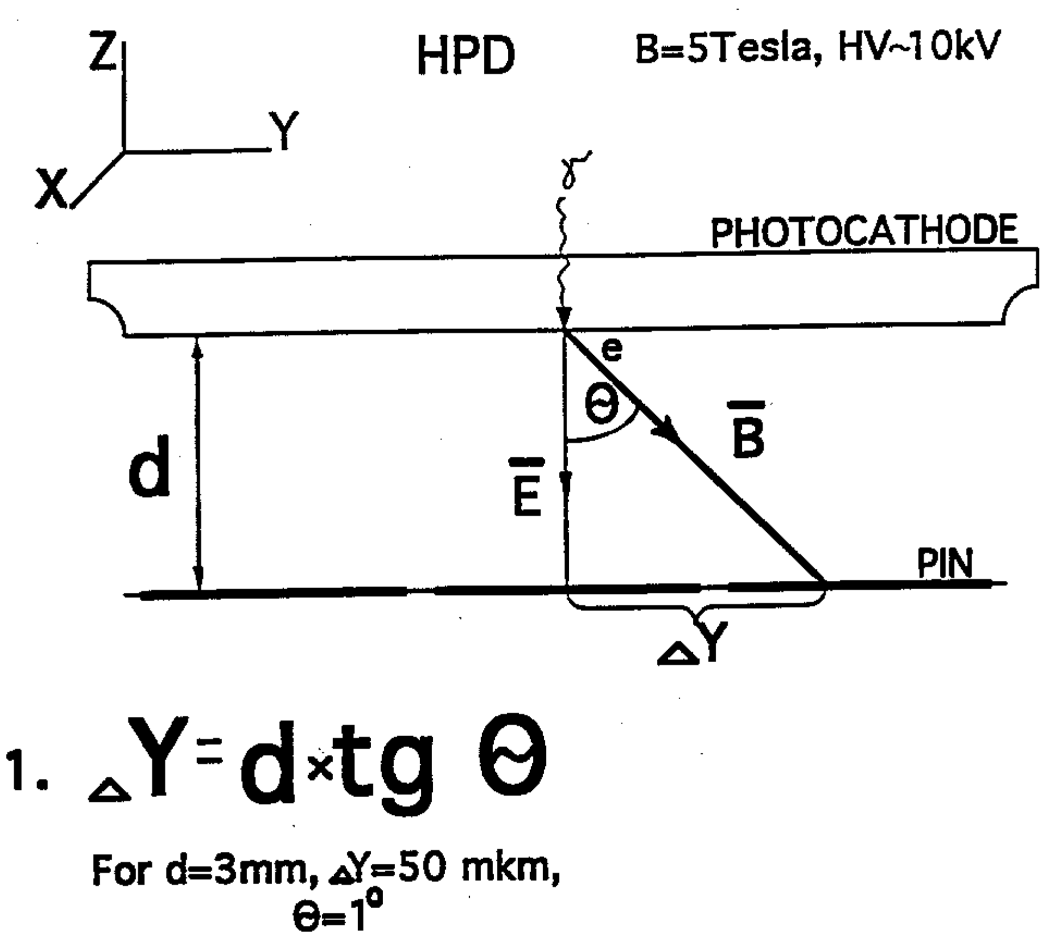


Fig. 7: Schematic defining the geometry of the relevant quantities, E and H fields, the angle between them, and the perpendicular distance d between the photocathode and the PIN diode.