A "LEGO" Hybrid Photon Detector - assembled from standard mass-produced vacuum components

Daniel Ferenc [a,b] Eckart Lorenz [b] Razmik Mirzoyan [b]

[a] *University of California at Davis, USA*

[b] *Max Planck Institut für Physik, München, Germany*

Abstract

Motivated primarily by the MAGIC atmospheric cherenkov telescope project, we have developed a "LEGO" Hybrid Photon Detector (HPD) comprising excellent focusing properties and protection against positive ion feedback. LEGO-HPD is supposed to be assembled from standard high vacuum components, which insures simplicity in the assembly procedure and reliability of operation.

Key words: Photon detectors, Photocathodes, HPD

1 Introduction

With the onset of new technologies, Hybrid Photon Detectors (HPDs) became one of the most favorable options for the detection of photons in many applications, as e.g. in large area Ring Imaging CHerenkov (RICH) detectors. In contrast to ordinary Photo Multiplier Tubes (PMT), where a photoelectron initiates a multi-step amplification process in a dynode system, in HPDs (1) a photoelectron undergoes a single-step acceleration from the photocathode towards the silicon sensor. Due to its relatively high energy (5-20 keV) a photoelectron releases a large number of electron-hole pairs upon its impact in the semiconductor sensor.

Recent HPD developments have focused on the following goals: (i) improvement of imaging performance, (ii) reduction of dead area, (iii) improvement of time characteristics, (iv) positive ion feedback protection (2; 3; 4; 5), and the exploitation of a photocathode in reflective mode (2; 6).

A usual way of designing a new device, in our case a HPD, has been to find an optimal solution for the given application and to manufacture optimized components. However, the production and assembly of such new components for an HPD may be very expensive and also risky, since certain high vacuum standards have to be met (surface properties, metal-ceramic joints, possibility to sustain a high bakeout temperature etc.).

In this paper we present a "reversed design" approach: an HPD is combined from the existing reliable mass-produced high-vacuum components which fit together, and its functionality is optimized within the given (market) constraints. This is where the name "LEGO HPD" stems from.

For all electron optics simulations presented, SIMION 3D software (8) has been used. It is assumed that the medium in the tubes is vacuum.

2 LEGO HPD

The LEGO HPD presented in this paper has been composed of (see figures (1,2):

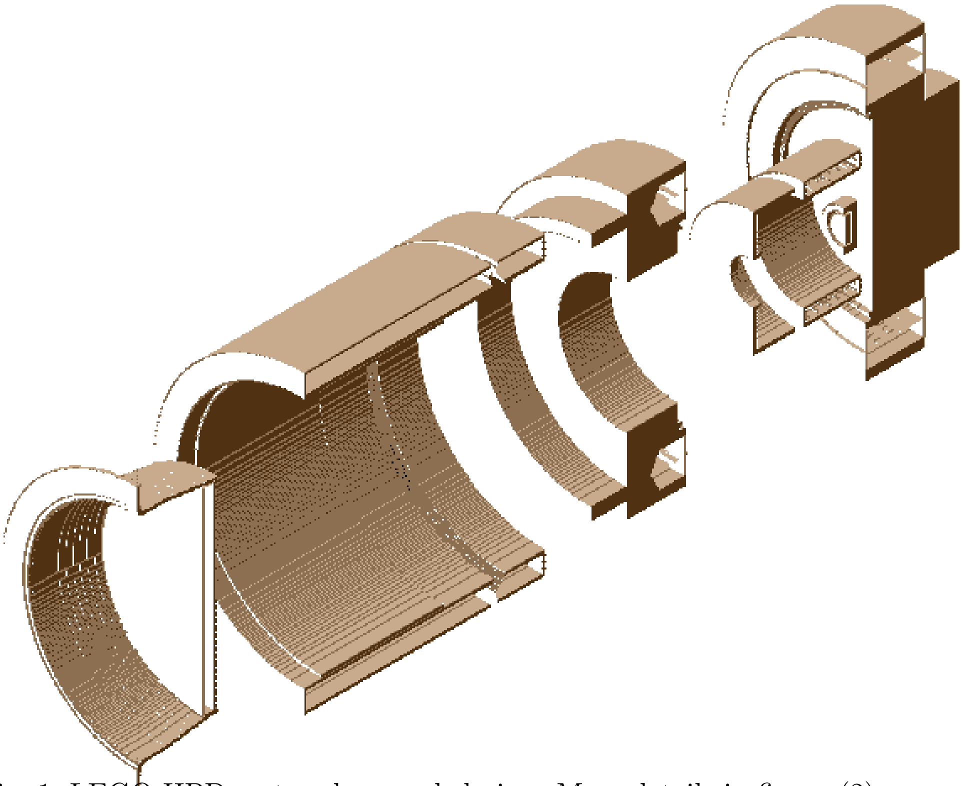

Fig. 1. LEGO HPD, cut and expanded view. More details in figure (2).

- a standard sapphire viewport, 24 mm in diameter, used as the entrance window (quartz window is also possible),

- a standard ConFlat flange with an builtin SMA connector, as the base plate, and
- a standard ceramic isolator, as the body of the cylindrical HPD tube.

All these components are high-vacuum graded, bakeable to 450 degrees, and have been optimized by industry and proved reliable in numerous applications (7). The number of additional parts needed is very small.

Figure (2) presents the focusing properties of our LEGO HPD design. Photons (not shown) approach the window from the left side, and release electrons from certain points on the internal surface of the photocathode. The photoelectrons are simultaneously accelerated and focused towards the 3 mm diameter Avalanche Photo Diode (APD), shown on the right side. The overall spread in time of flight of the photoelectrons is lower than 250 ps.

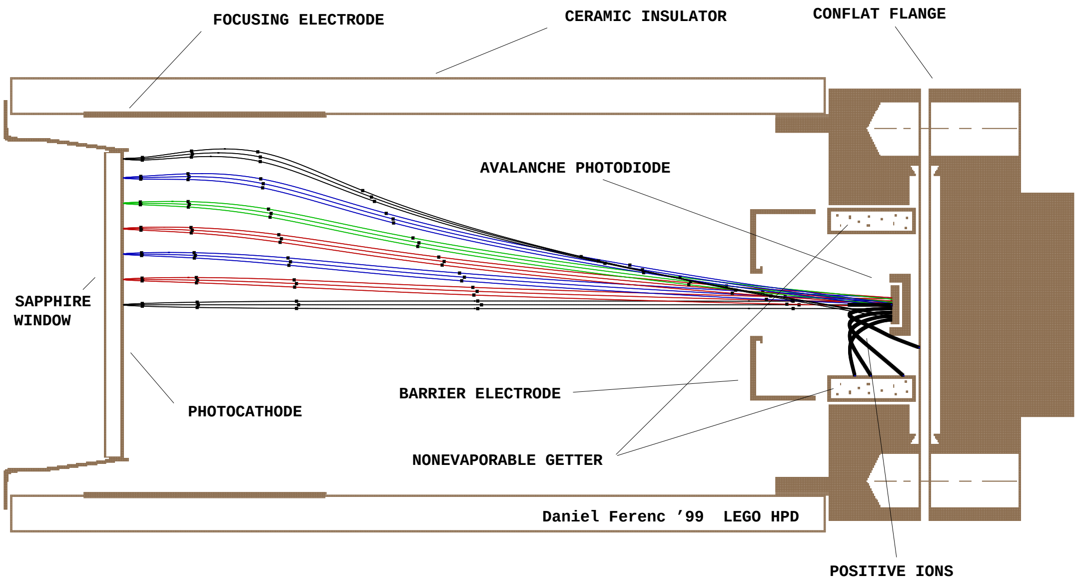

Fig. 2. LEGO HPD with a 24 mm diameter window. One time mark indicates 0.5 ns.

An innovative positive ion feedback protection (5; 4) is established with the use of the "barrier electrode", shown on the right side as enclosing the anode area. Positive ions emerging from the anode surface do not penetrate towards the photocathode, but get swept away from the anode towards the Non-Evaporable Getter (NEG) placed around the anode.

The assembly procedure of the LEGO tube may start with the mounting of the photocathode on the viewport surface, followed by metal-to-ceramic brazing of the isolator tube with the viewport braze adaptor on one side, and the ConFlat flange on the other. The base-plate ConFlat flange, together with previously mounted NEG, barrier electrode and silicon sensor, may be then mounted to the tube by six screws. The ConFlat flange contains a Cu gasket which deforms during that process. Before closing, all the parts may need special cleaning, possibly even bakeout. Since the GaAsP photocathode may be handled in argon atmosphere, all these steps may be carried out in a rather simple way, without a need for a large expensive vacuum chamber equipped with special manipulators. Once the ConFlat flange is closed, the evacuation, the bakeout process, and the activation of the photocathode by cesium may be performed in the so called internal process, where the connection to the vacuum pump and the insertion of the cesium evaporator both run through a narrow pipe attached to a hole in the HPD body on one side. Therefore there seems to be no need to keep the entire tube in high vacuum ever during the entire assembly process.

3 Summary

LEGO-HPD with excellent focusing properties and protection against positive ion feedback has been proposed, to be assembled from standard high vacuum components. The assembly procedure may be carried out with a rather simple set of tools. With a modern epitaxially grown photocathode, as the GaAsP photocathode, LEGO-HPD may become the favorable solution in many high energy physics and astrophysics applications. This work was motivated by one of those experiments, the MAGIC Atmospheric Cerenkov Telescope (9).

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