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A GEM-based detector for detection and imaging of sparks and flames

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Summary. — We have developed and tested a RICH detector prototype consisting in a CsI-coated triple GEM operated in gas flushed mode. In this work, we present a modified version of this detector for a completely different application: fire safety. The detector operates in sealed mode and is combined with an optical system and a narrow band filter. As a photosensitive element, a CsI photocathode coated with a thin layer of ethylferrocene was used. This detector is almost 1000 times more sensitive than the best commercial flame sensor, it has 100 times better time resolution and allows determining the location where the spark, or flame, appears.

1. – Position-sensitive detector for flame imaging

There are several commercial sensors capable to detect small flames. One of the most sensitive among them are those who operate in the UV region: 185–250 nm. In this wavelength interval, all the flames in air emit quite strongly, whereas the sunlight is blocked by the ozone in the upper layer of the atmosphere. An example could be the Hamamatsu R2868 UVtron, which is a gaseous detector with a metallic photocathode. Since this detector operates in digital mode, it cannot distinguish between a single photon, a cosmic ray or a spark. Our idea was to replace the metallic photocathode with a CsI one, which is an order of magnitude more sensitive than the metallic one, and also to use a GEM detector, which has imaging capability. To materialize this idea we used a detector, which we developed earlier for RICH applications. It consisted of a CsI-coated triple GEM operated in gas-flushed mode [1].

The imaging flame detector is a sealed gas chamber with a UV transparent window. Inside the chamber a triple resistive GEM detector is installed, whose top GEM (fig. 1) is coated with a CsI layer 0.4 μm thick. Each resistive GEM has a $10 \times 10\,\text{cm}^2$ active area, 0.45 mm thickness, 0.4 mm hole diameter and 0.8 mm pitch. This GEM has resistive electrodes instead of metallic ones, making it spark-protected [2]. Below the GEM, a pad readout plane is placed (pads size $8 \times 8\,\text{mm}^2$). The gas chamber was filled either with

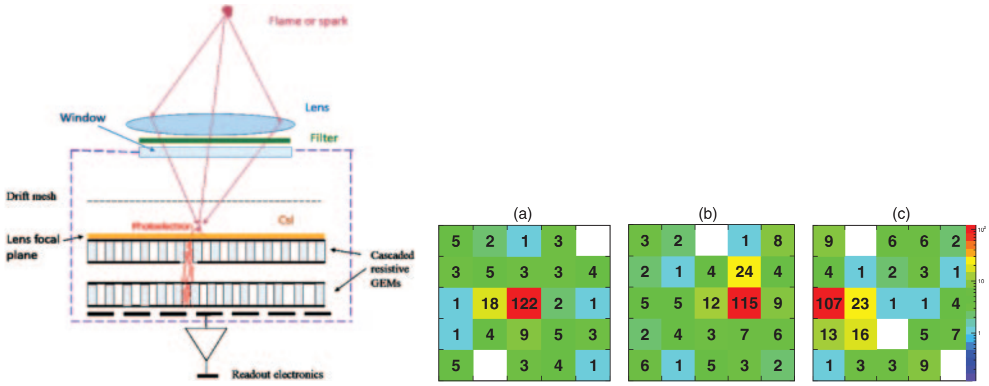

Fig. 1. – (Left) Working principle of a cascaded resistive GEM combined with a CsI photocathode. (Right) Digital images (number of counts per readout pad measured during 10s) of a candle flame placed 15 m away from the detector in three different positions: on the line perpendicular to the window surface and passing through its centre (a); shifted 1.3 m to the right (b); shifted 2.5 m to the left (c).

Ne+10%CH_4 or with Ne+10%CF_4 at 1 atm pressure. In this device, a UV photon can extract an electron from the CsI photocathode that is deposited on top of the first GEM upper surface. The electron is led by the electric field action to the nearest hole, where it experiences the first amplification; then the electrons in the avalanche undergo a second amplification in the following GEM (and more, depending on the number of GEM foils) and they finally induce a signal on the pad-type readout plate. For imaging purpose, in the front of the entrance window a lens is placed, such that the top GEM surface, which is coated with the CsI layer, is in its focal plane. In this arrangement any objects, which are located at a distance much larger than the lens focus, are projected on a CsI surface. Combined with a proper electronics, this detector allows visualization of flames or sparks. During image taking, a triple resistive GEM operated with a reversed drift electric field (around 200 V), to enhance the photoelectron extraction efficiency from the CsI cathode [3] and suppress undesired signals from cosmic or natural radioactivity at an overall gain of $\approx 10^5$. Preliminary tests have shown that such a detector operates perfectly well in fully illuminated buildings and rooms, however may have some noise pulses under the direct sunlight illumination caused by its strong long wavelength radiation with $\lambda > 300$ nm. To adopt this detector for the fire safety applications several important modifications were done: a narrow-band filter was placed in front of the input window; to compensate the sensitivity loss due to the filter, a CsI photocathode was coated with a thin ethylferrocene layer which enhanced its quantum efficiency in the interval 190–220 nm; it operated in proportional mode allowing to detect sparks if analog signals are used [4] or obtain digital image of flames. Thanks to these modifications, this detector is 500 times more sensitive than the best commercial flame sensors, has a much faster response (time resolution few μs), allows to determine the direction where a spark or a flame appears (fig. 1) and is able to operate even in direct sunlight illumination. Moreover, two such detectors, located in different places and operating simultaneously, can accurately determine flame position in 3D. Provided with an appropriate algorithm for pattern recognition, this detector could achieve a high rejection of false signals, making this flame-detection system very robust.

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