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

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Introduction

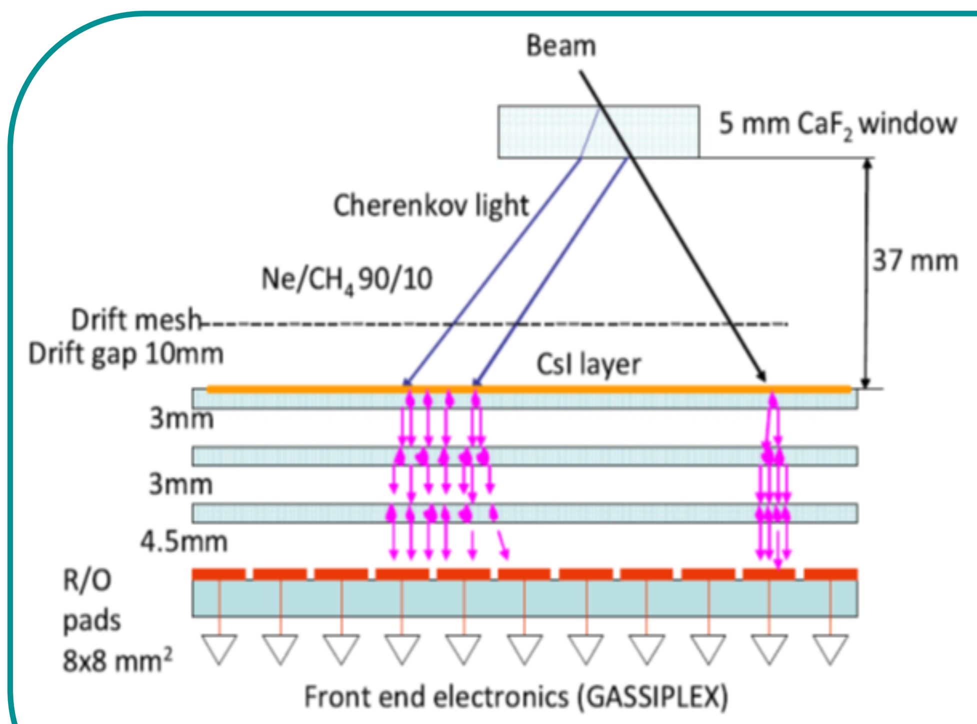


Figure 1: RICH detector.

[1] P. Martinenego et al., NIM A639, 2011, 126.

It is very important to determine a fire hazard on its early stage. There are several commercial sensors capable to detect appearing of small flames. One of the most sensitive among them are those who operate in UV region of spectra: 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. The example could be Hamamatsu R2868 UVtron, which is in fact a gaseous detector with a metallic photocathode. Since this detector operating in digital mode, it cannot distinguish between a single photon, cosmic or a spark. Our ideas were to replace metallic with a CsI photocathode, which is on orders of magnitude more sensitive than the metallic one, and also to use a GEM detector, which has an imaging capability. To materialise these ideas we used a detector, which we develop earlier for the RICH applications. It consisted of a CsI coated triple GEM operated in gas-flushed mode [1].

Figure 2: Schematic views of 3-GEM gaseous photomultipliers with:
(a) Semi-transparent and
(b) reflective photocathode.

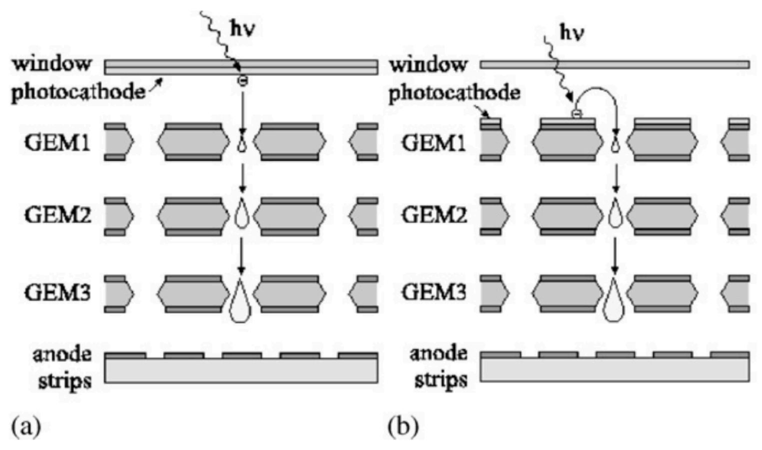
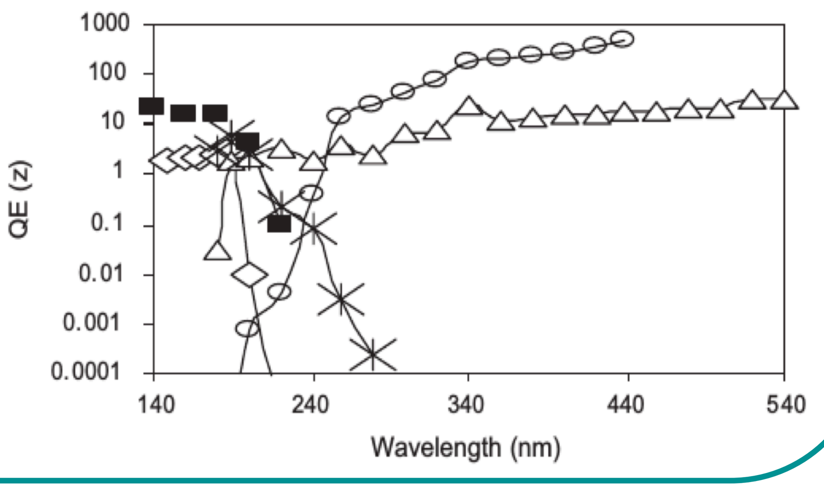


Figure 3: Results of the QE measurements for some materials: stars - the QE of CsI photocathode with the quartz window, filled squares—the QE of the same type of the detector, but with the MgF_2 window, open rhombus - the QE of the detector filled with the ethylferrocene vapours. Typical spectra of flames in air (open triangles) and the spectra of the sun (open circles), both in arbitrary units



Position-sensitive detector for flame imaging

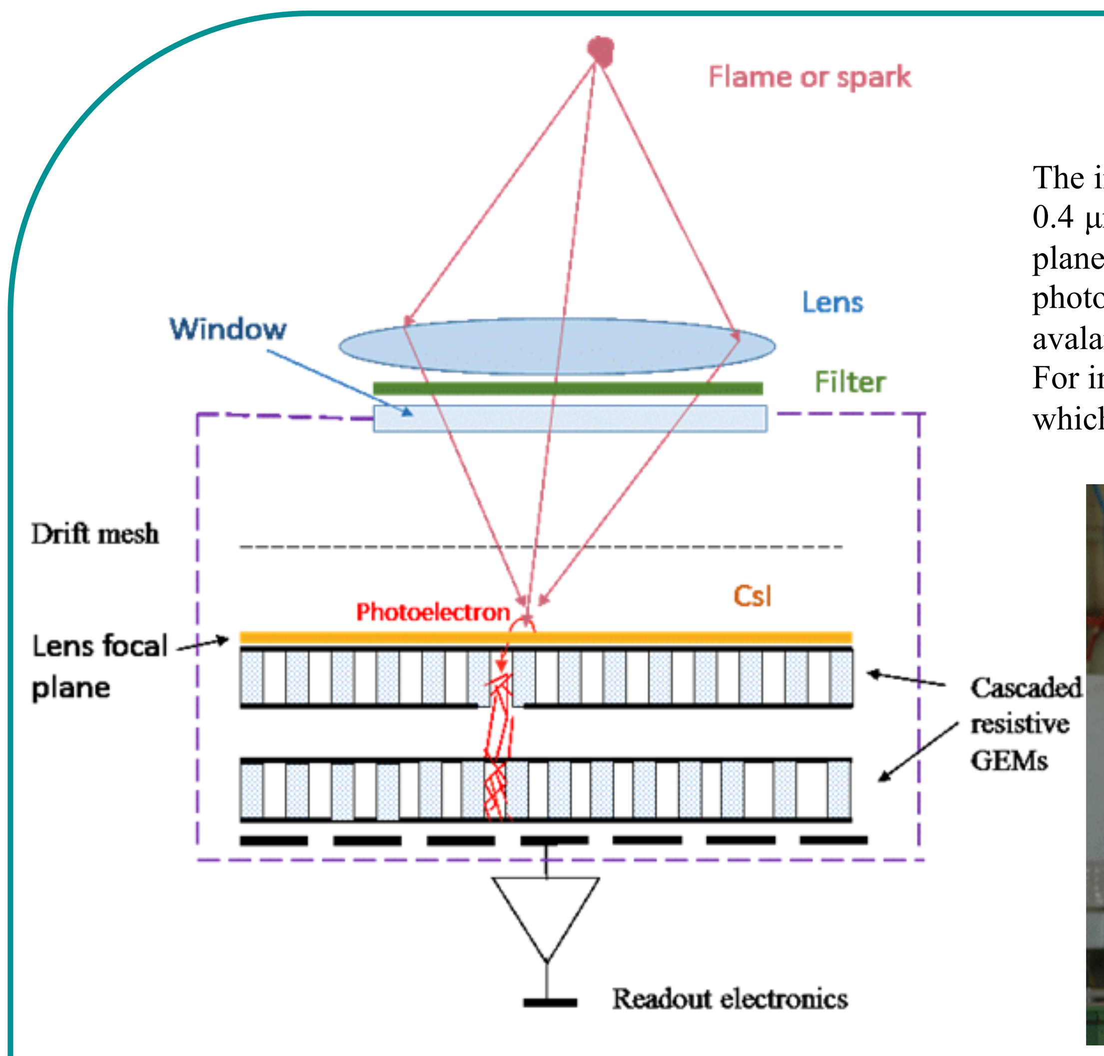


Figure 4. Working principle of a cascaded resistive GEM combined with a CsI photocathode; also the optical system is shown.

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 is coated with a CsI layer 0.4 µm thick (see Figures 4 and 5). Each resistive GEM has a 10x10 cm² active area, 0.45 mm thickness, 0.4 mm hole diameter and 0.8 mm pitch (Figure 6). Below the GEM, a pad readout plane is placed (pads size 8x8mm²). The gas chamber was filled either Ne+10%CH_4 or 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 avalanche electrons 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 widow 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

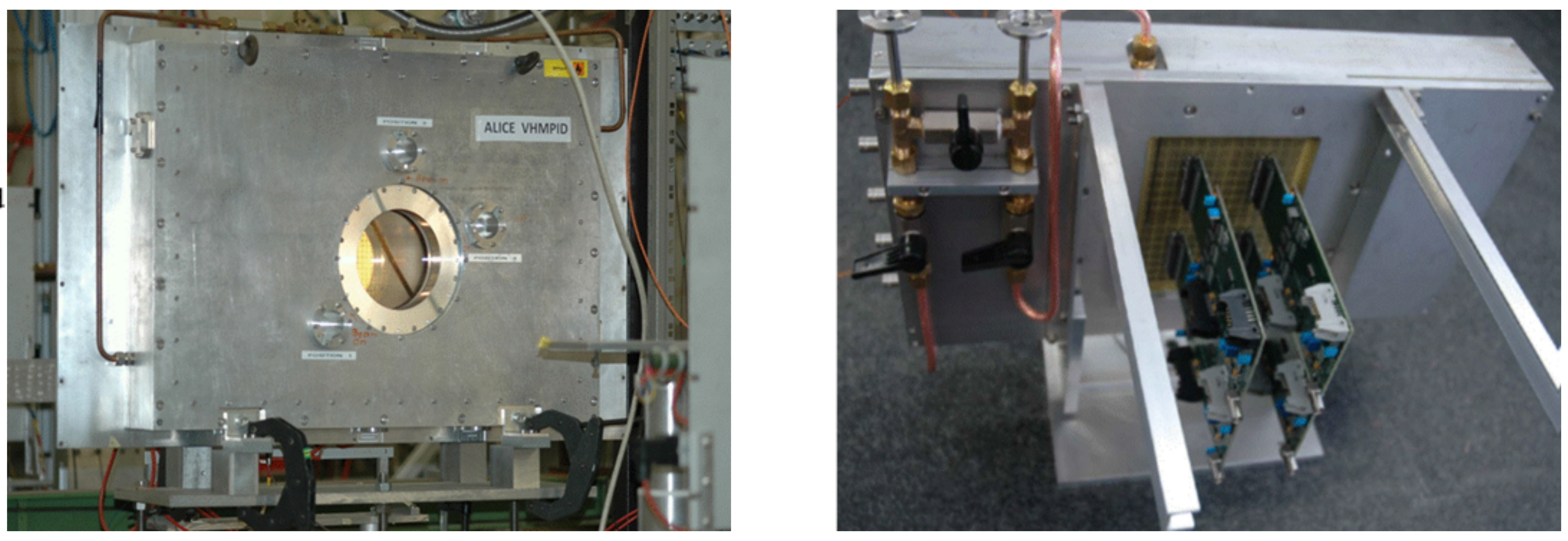


Figure 5: (a) Photographs of the front view of a flame detector, employing triple resistive GEMs, with the top electrode coated with CsI. A CaF_2 window can be clearly seen in the centre of the front flange, facing the particle beam, as well as three windows for radioactive sources used for preliminary tests. (b) Back view of the detectors, showing the front-end electronic connected to the readout pad plane

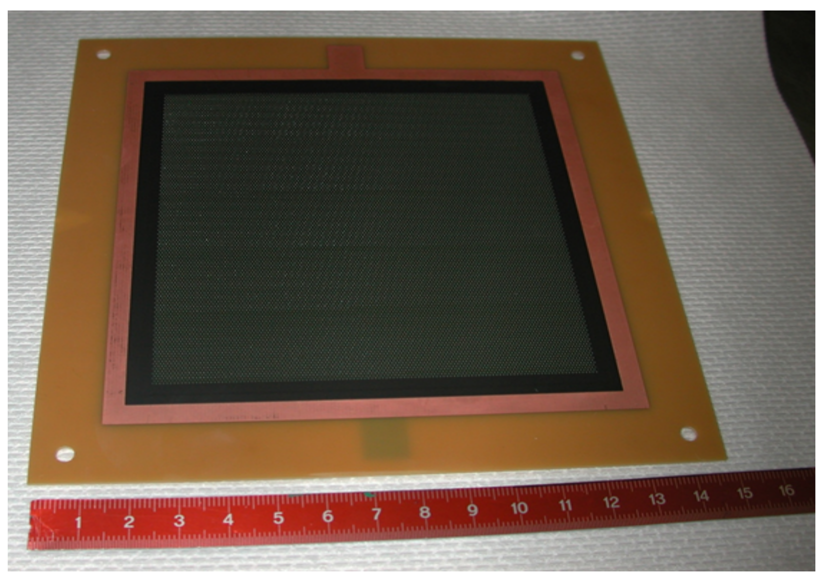


Figure 6. Photograph of a resistive thick GEM

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 at an overall gain of $\approx 10^5$. Preliminary measurements show that such a device can reach a sensitivity almost one hundred times higher and a time resolution 100 times better than the best commercial flame detectors which, in addition, do not have any imaging capability. Moreover, 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.

Preliminary test show that such a detector operates perfectly well in fully illuminated buildings and rooms, however may have some nose pulses under the direct Sun light illumination caused by its strong long- wavelength radiation with $\lambda > 300$ nm
To adopt this detect for the fire safety applications several important modifications were done:

1. A narrow-band filter was placed in front of the input window.
2. 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.
3. It operated in proportional mode allowing to detect sparks if analog signals are used or obtain digital image of flames.

Thanks to these modifications, this detector has superior characteristics: it is almost 1000 times more sensitive than the best commercial flame sensors, has much faster respond (time resolution few µs) , allows to determine the direction, where a spark or a flame appears, is able to operate even in direct sunlight illumination. With two or more such detector, placed in the monitoring area, one can determine the position of the fire

Test results

a) Candle was on the line perpendicular to the window surface and passing through its centre.
b) The candle was shifted 1.3 m to the right.
c) The candle was moved to 2.5 m to the left.

a)

						Scale
5	2	1	3	0		100
3	5	3	3	4		75
1	18	122	2	1		50
1	4	9	5	3		25
5	0	3	4	1		0

b)

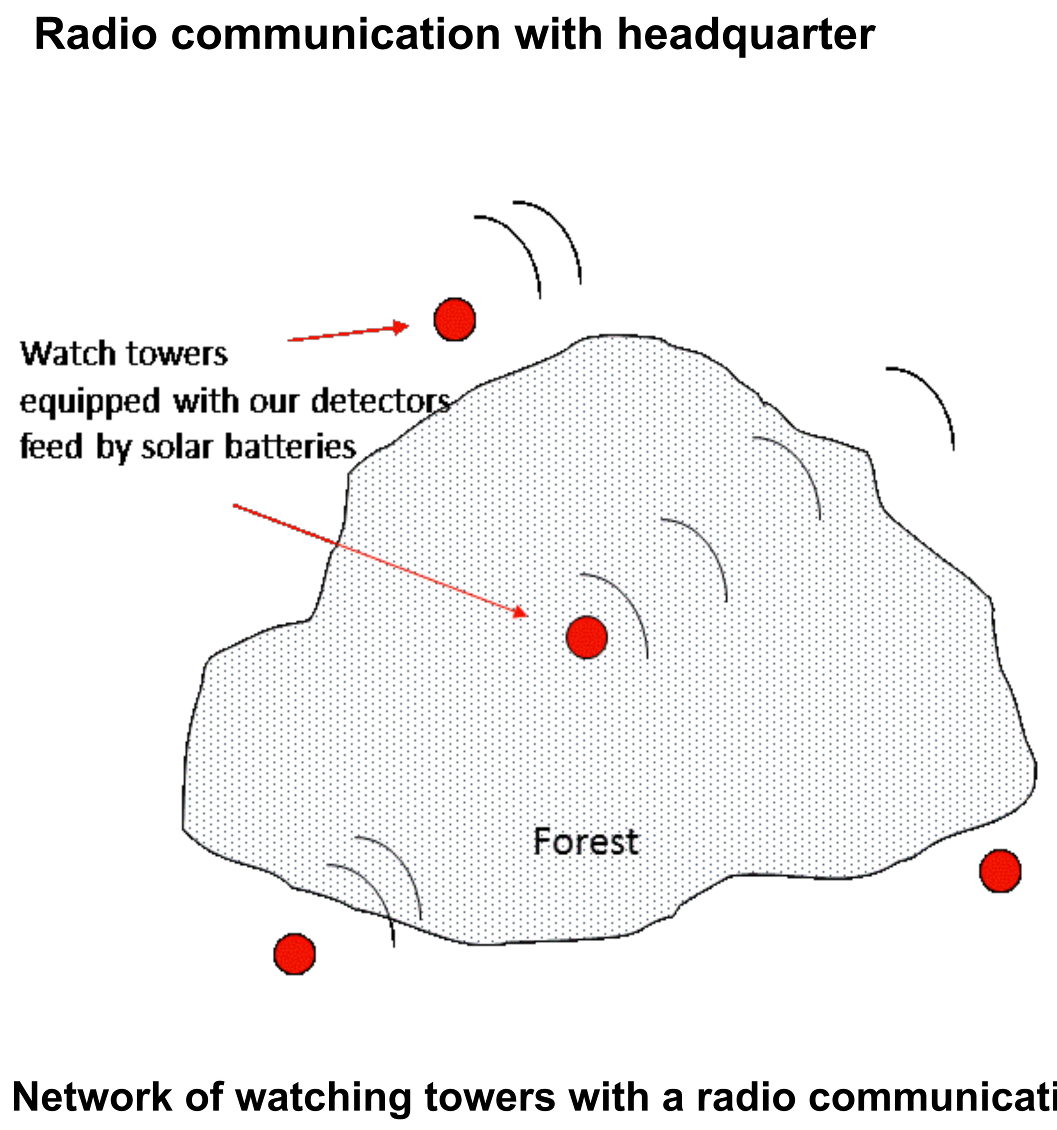
						Scale
3	2	0	1	8		100
2	1	4	24	4		75
5	5	12	115	9		50
2	4	3	7	6		25
6	1	5	3	2		0

c)

						Scale
9	0	6	6	2		100
4	1	2	3	1		75
107	23	1	1	4		50
13	16	0	5	7		25
1	3	3	9	0		0

Figure 7. 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.

Possible arrangement of flame imaging detectors



Headquarter

With two or more such detector, placed in the monitoring area, one can determine the position of the fire.

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