Study and optimization of novel UV photon detectors with resistive electrodes

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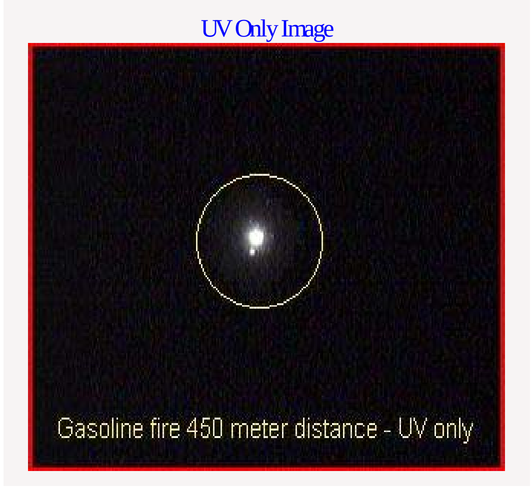
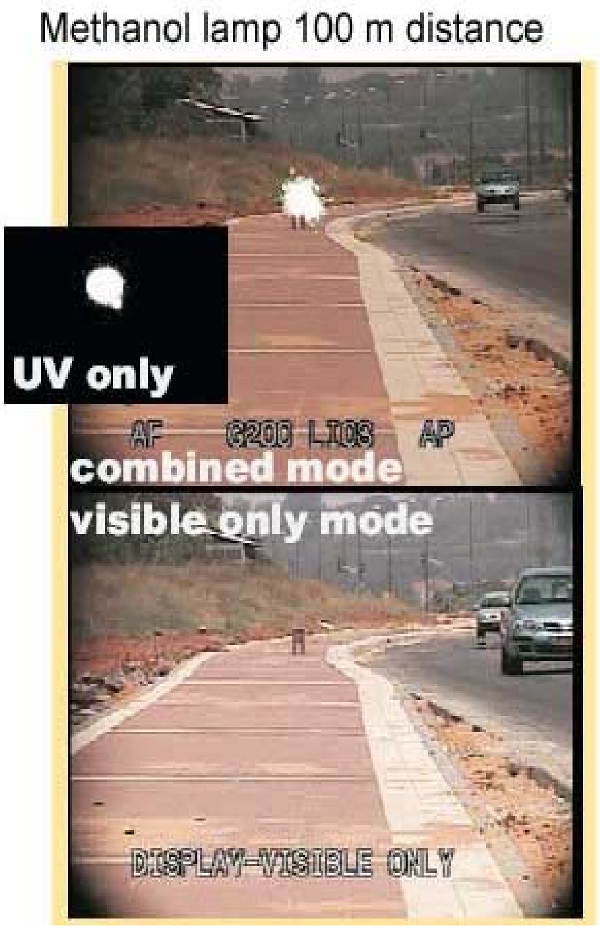
I. Introduction

In the last several year a great interest arise to UV imaging detectors. The main motivation comes from home-land security [1] and the possibilities to detect small forest fires or corona discharges an large distances [2]. It is known the sun light in between 180 and up to 280 nm is adsorbed by the Oson layer in the upper atmosphere and does not reach the earth surface. However, on the ground level the atmosphere is transparent for UV, so one can detect UV emitting objects. The existing UV imaging detectors are image intensifiers combined with bialkali photocathodes and equipped with narrow-band filters transparent in the wavelength interval 240-280 nm [3]. At this wavelength range, called "solar blind", daytime detection of UV signals occurs with practically no background of solar radiation. Thus the UV radiation emitted from the fire or electrical discharges and transmitted through the solar blind filter could be detected with a very high signal to background ratio. For example, a small forest fire can be detected by a such device up to a several kilometers distance [4].

Fire detection with image intensifier combined with a narrow-band UV filer





Example of images of fire in visible (top on the left figure and bottom on the right figure a) and in the UV region (vice versa).

One can see that in the latest case the signal to noise ratio is orders of magnitude higher

Industrial applications: visualisation of corona discharges and sparks at day-light conditions

- Example: a UV image of the HV corona discharge obtained with image intensifies combined with a narrow band filters. During the day time this corona is practically undetectable in the visible region of spectra

In spite of impressive UV images which one can obtain with image intensifiers combined with narrow-band UV filters these detectors have several drawbacks, for example: small size of the MCPs used, high noise (bialkali photocathodes), bad transmission of narrow band filters for UV (typically only 10%)

- Recently we have developed first prototypes of a new detectors of single UV photons- RPCs combined with CsI or CsTe photocathodes [5]. These RPCs operated at high gas gains and resistive electrodes were essential to protect electronics from damage by possible discharges. Because of these detectors were able to detect single photoelectrons with a position resolution of 30 μm they also could be used in UV imaging applications, for example RICH or visualization of discharges or flames in air.

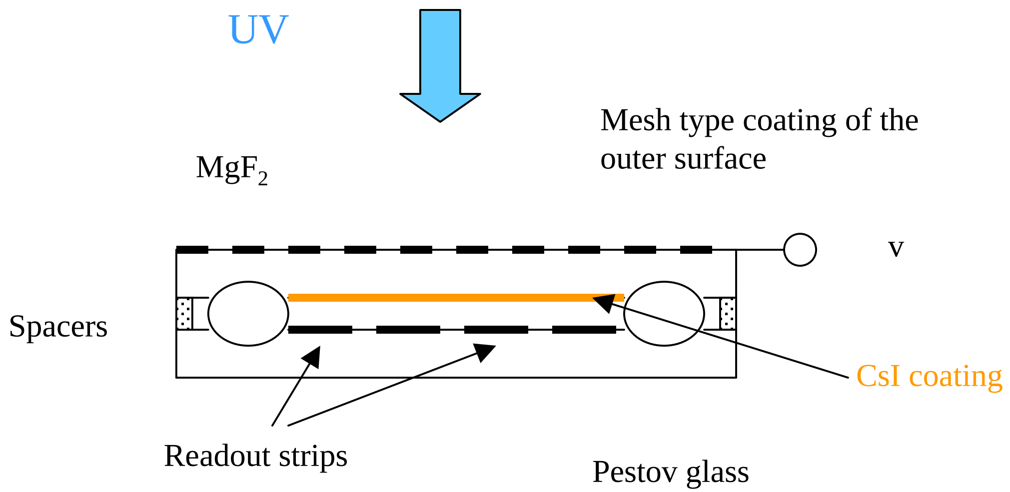
The main advantages of photosensitive RPCs are:

- They are spark protected and can operate at high gains in single photon counting,mode;
- They have very low noise;
- They have excellent position resolution;
- Potentially could be done with large sensitive area. This allows to combine them with high aperture optics, which is an additional way to increase sensitivity.

The aim of this work is to further pursue this promising direction

We have studied in detail this photosensitive RPCs and demonstrated experimentally that they have the same sensitivity to fires as UV image intensifiers
In addition we developed and tested new advanced resistive electrode photosensitive detectors allowing better suppression of photon feedback

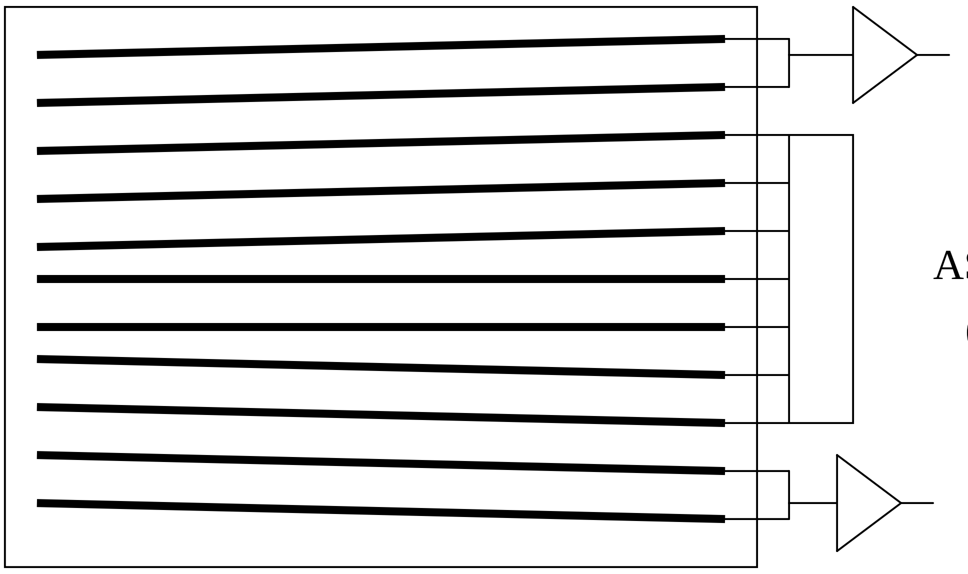
II. Photosensitive RPCs combined with CsI photocathodes



- The cathode was made from a 2 mm thick MgF_2 plate with an area of 40×40 mm^2. The inner surface, facing the anode, was coated by a 20 nm thick photosensitive CsI layer. The outer surface was in contact with a 0.2 µm thick Al mesh, manufactured by a microelectronic technology, forming cells with an open area of 23×23 μm^2 at 30 µm pitch. The anode of the RPC was made of Pestov glass covered by Cr strips placed at 30 µm pitch and the gas gap was 0.4 mm wide.

•This detector allows one at the same time high gains and high position resolutions to be achieved.

Readout plate

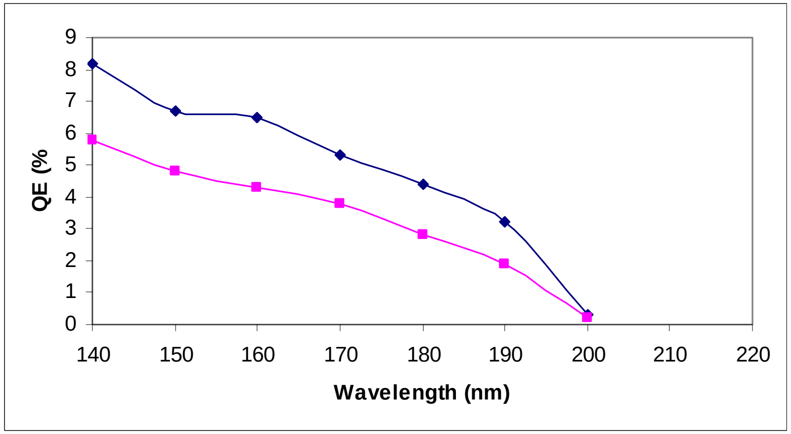


Ceramic plate with Al strips 50µm in pitch

(« focused » on 78 cm distance)

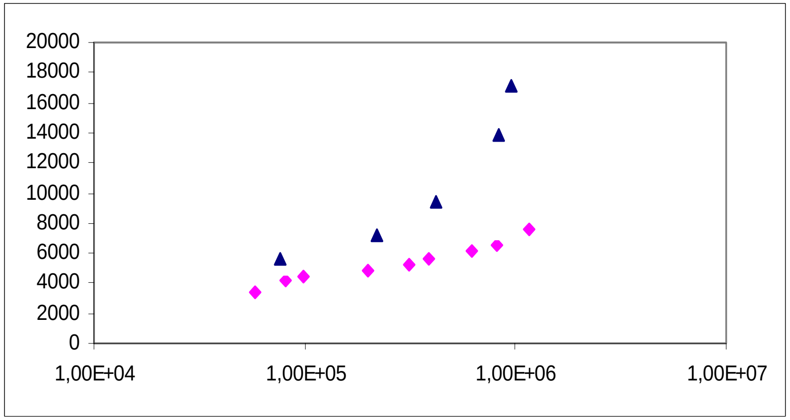
Results obtained in various gas mixtures:

QE:



Blue curve: He+0.8%CH_4+EF;
Rose curve: $C_2H_2F_4$+10%SF_6+5%isob.

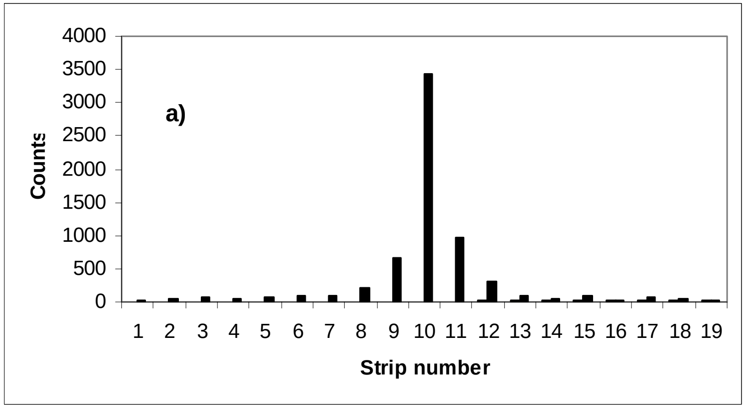
Counting plateau: counts vs. gain

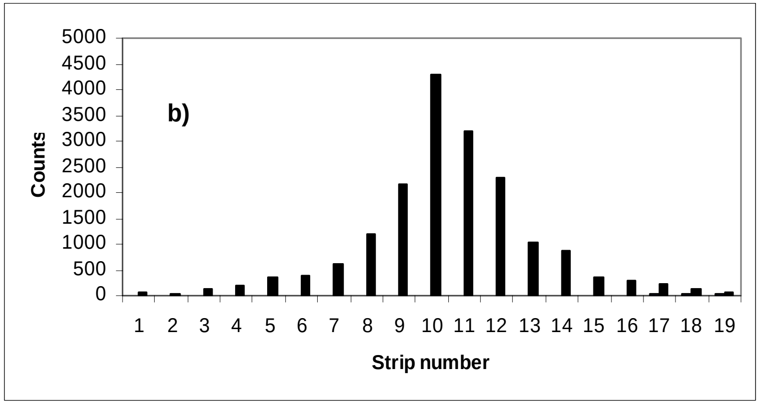


Blue triangles: He+0.8%CH_4+EF;
Rose rhombus: $C_2H_2F_4$+10%SF_6+5%isob

Position resolution measured in various gas mixtures:

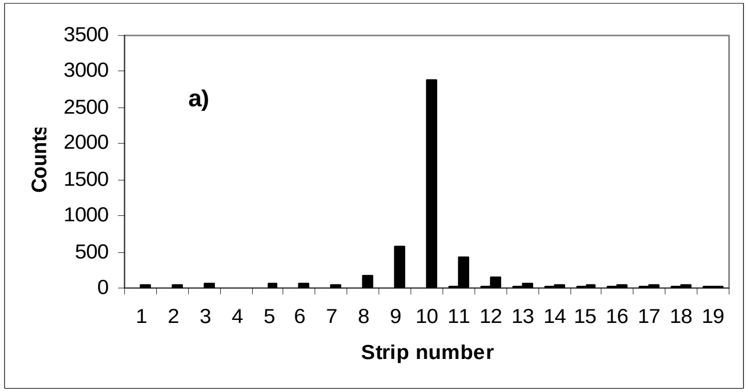
He+0.8%CH_4+EF

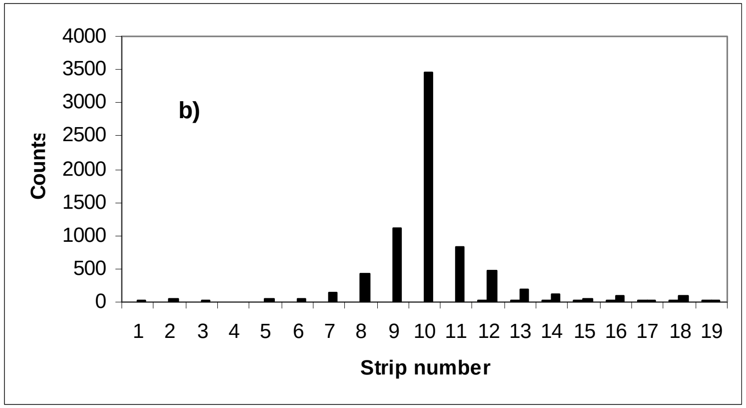




a)gain A=8x10^4, b)A=10^6

$C_2H_2F_4$+10%SF_6+5%isob



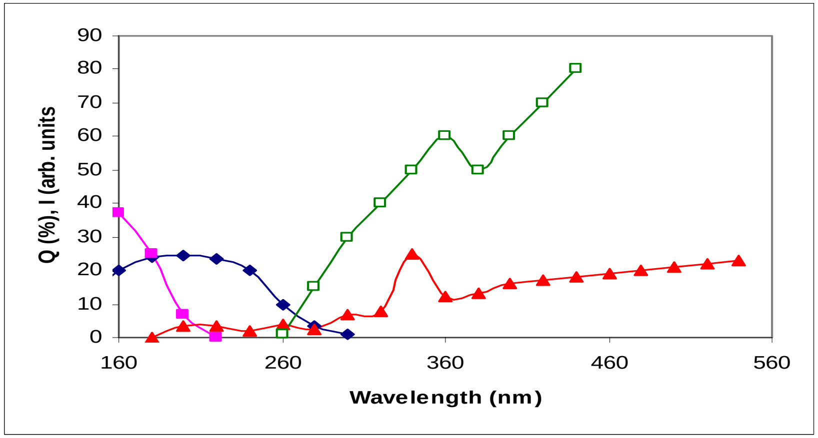


a) gain A=8x10^4, b)A=8x10^5

Comparison with UV image itensifiers

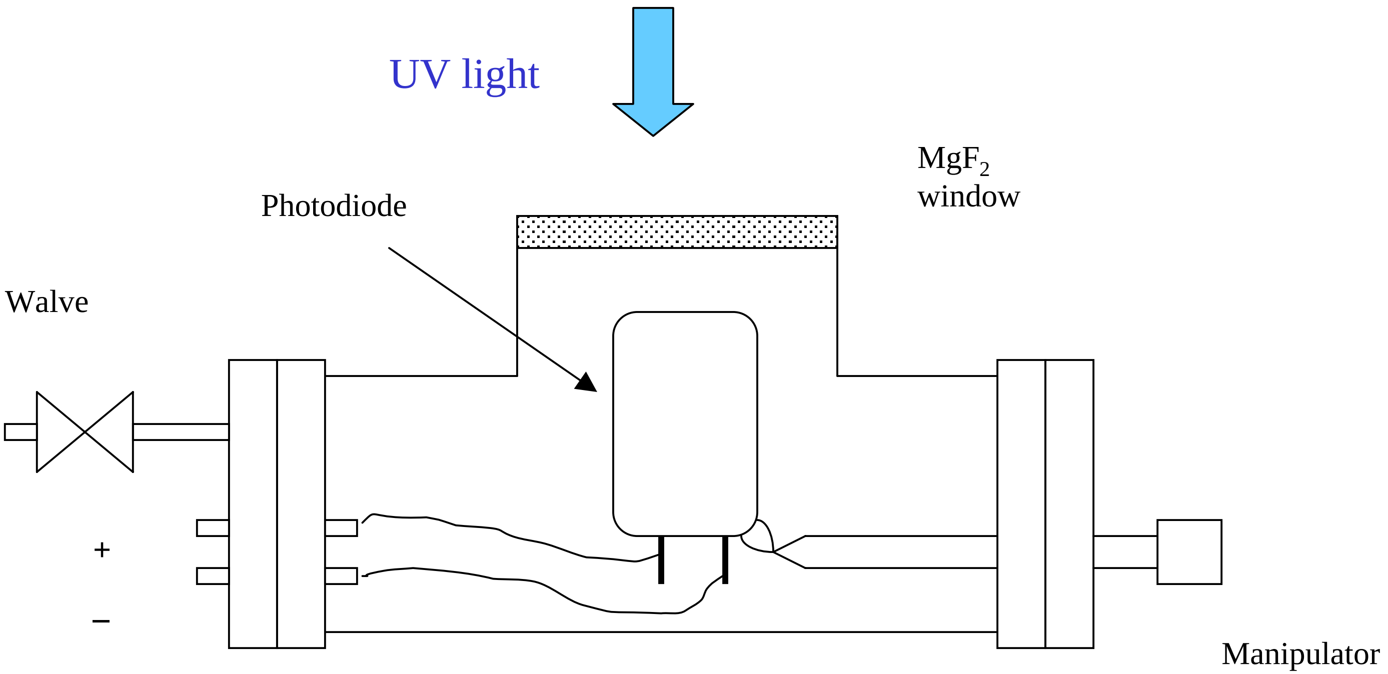
- Measurements performed in Reagen Research Center demonstrated that sensitivity of the UV image intensifier and a gaseous detector with CsI photocathode are almost the same:
- both detectors were able to detect a cigarette lighter on a distance of 30m. Thus in some applications photosensitive RPCs could be cheap and simple alternative to the UV image intensifiers.

Even better sensitivity can be expect in the case of gaseous detectors combined with CsTe photocathodes:



One can see that even CsI with the highest possible QE (rose) [6] poorly overlaps the fire emission spectra (red), whereas CsTe (blue) overlaps quiet well. In this figure a green curve is the sun spectra at the ground level

« Home-made RPC » with CsTe photocathodes:

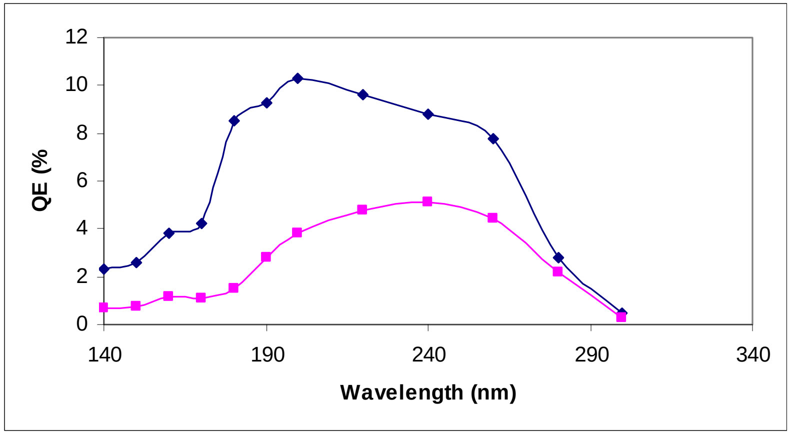


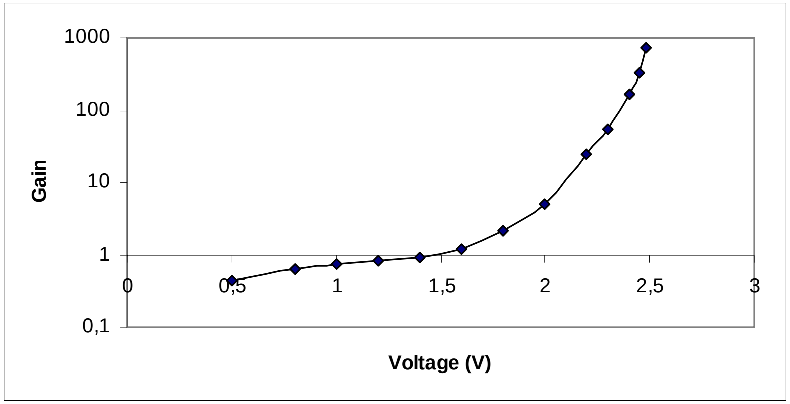
Prototypes of sealed gaseous detectors with CsTe photocathode were manufactured by us from commercial vacuum photodiodes from Hamamatsu Photonics, Japan (types R702 and R1107) and from the Photonic Company MELZ, Moscow. The photodiodes were converted to gaseous detectors by filling with gas via a procedure described in [7].

Results with CsTe photocathodes

QE

Gain





Blue curve-vacuum photodiodes ,

Rose curve-photodiode filled with He+0.8%CH_4+EF).

Gain vs. applied voltage for gas–filled photodiode with CsTe photocathode (“home made” RPC) in

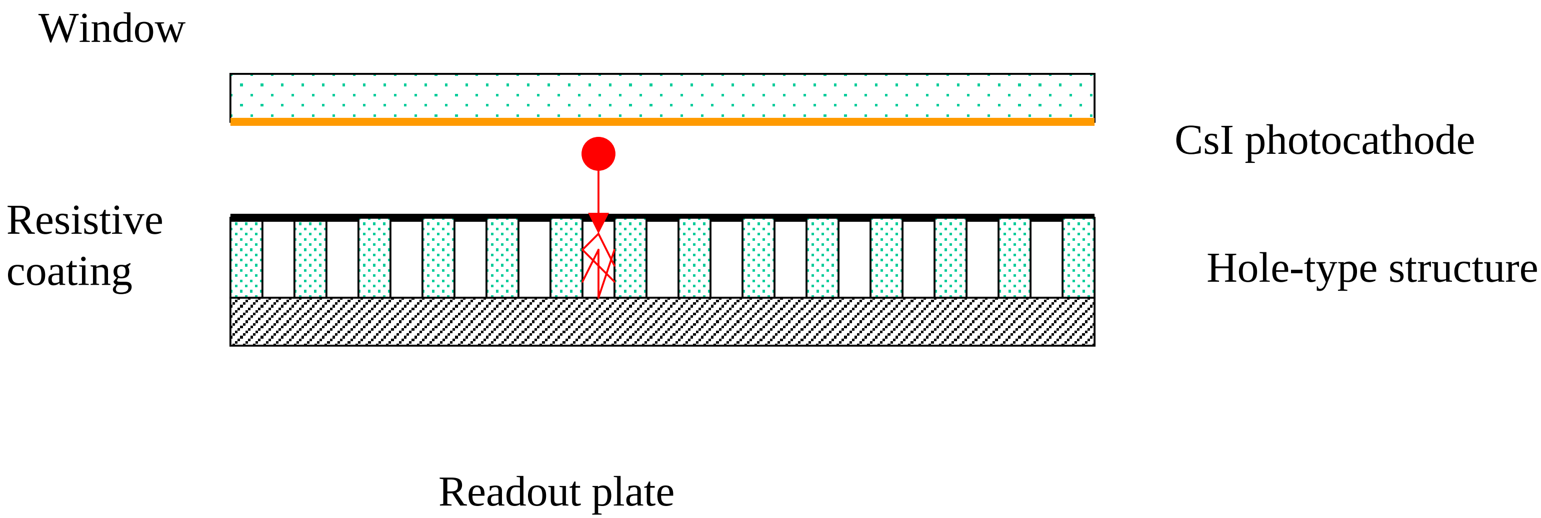
He+0.8%CH_4+EF mixture

The problem however is that due to the feedback one cannot reach high gains with the CsTe photocathodes

III. New developments:hole type gas amplifiers with resistive electrodes

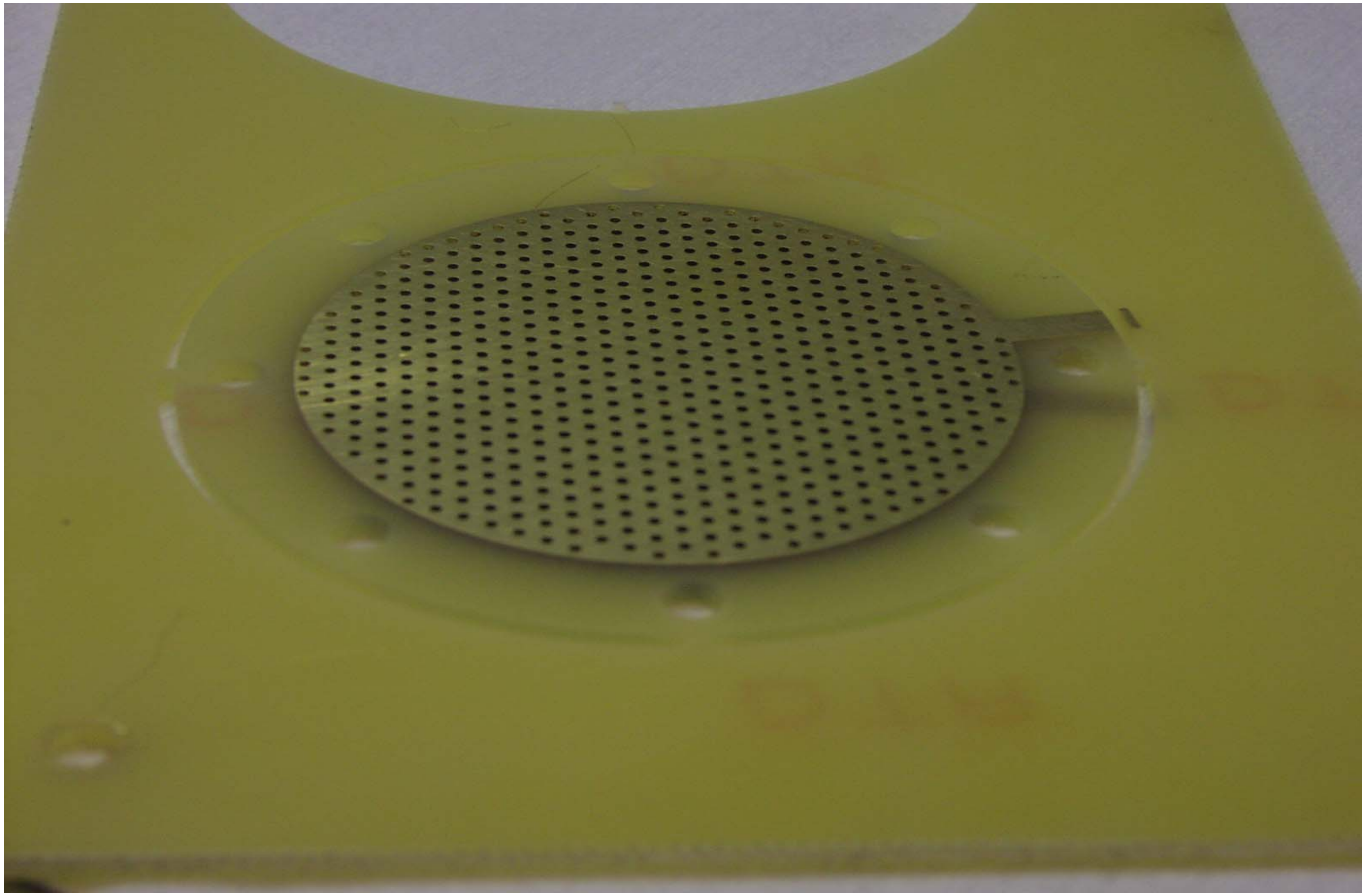
- In attempts to boost the gain achievable with CsTe photocathode (or to be more precise: to suppress better the photon feedback) we also performed first test of a new version of a photosensitive detector with resistive electrode.

Design-1

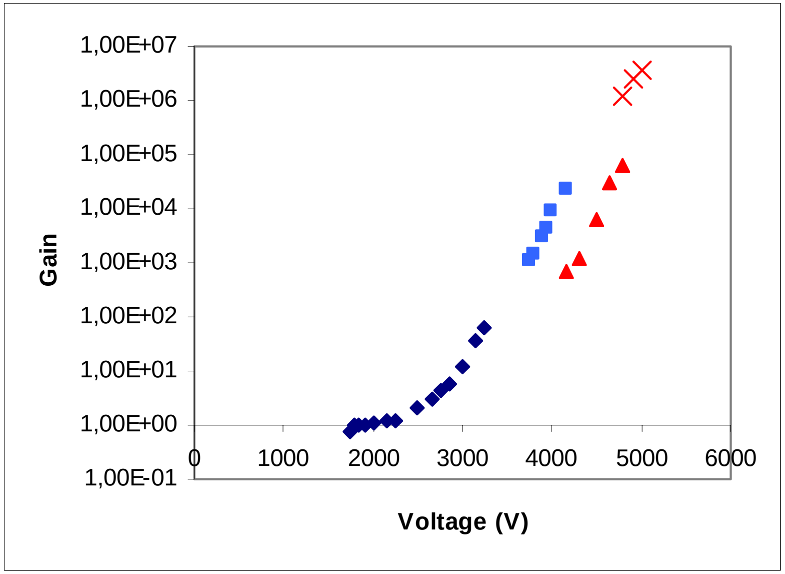


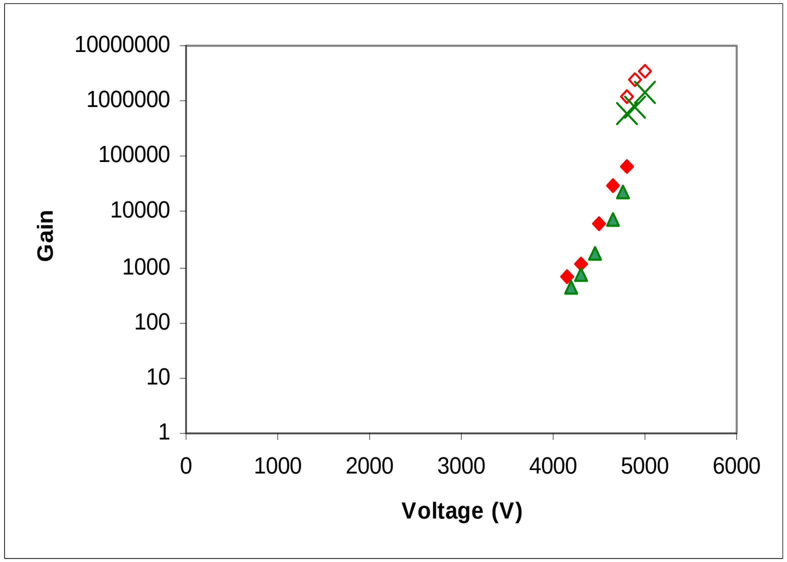
As hole type structures, we tested G-10 plates 1 –2 mm thick with drilled holes (0,3 –1 mm in diameter, depending on design). The Cu coating of the G-10 was almost fully removed and both surfaces were covered with graphite paint used in the usual RPCs [8].

Photo of one of the hole type structures used in our studies



Some very preliminary results of gain measurements:



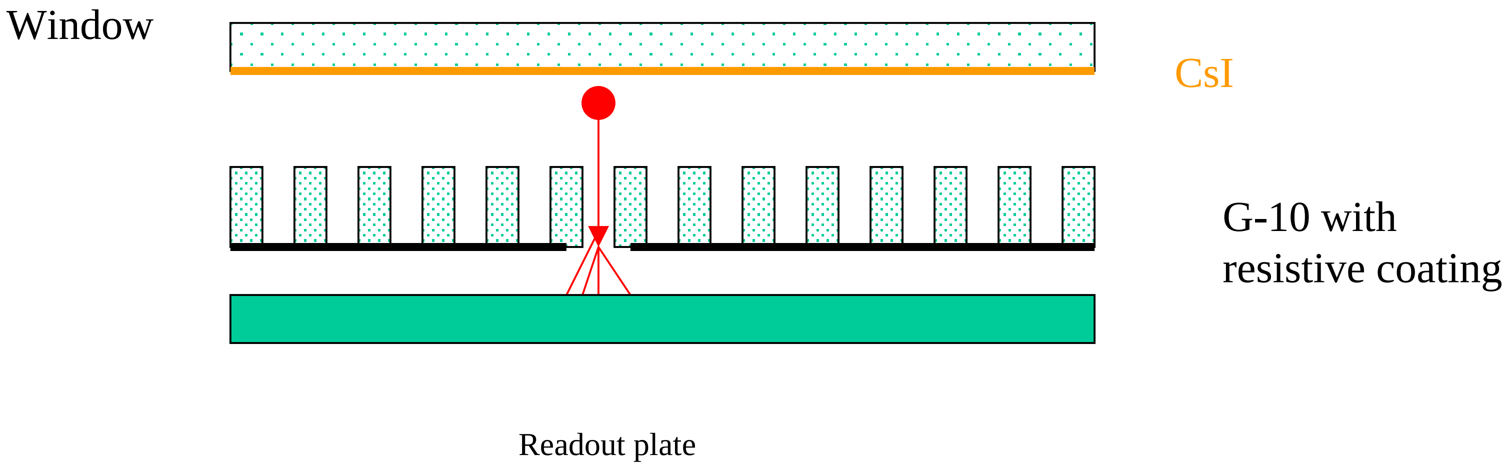


Blue curve-Cu coated G-10;
Red-G-10 with resistive coating.
Gas :Ar+5% isob

Red-G-10 with resistive coating;
Green –the same plate combined with CsI photocathode.
Gas :Ar+5% isob

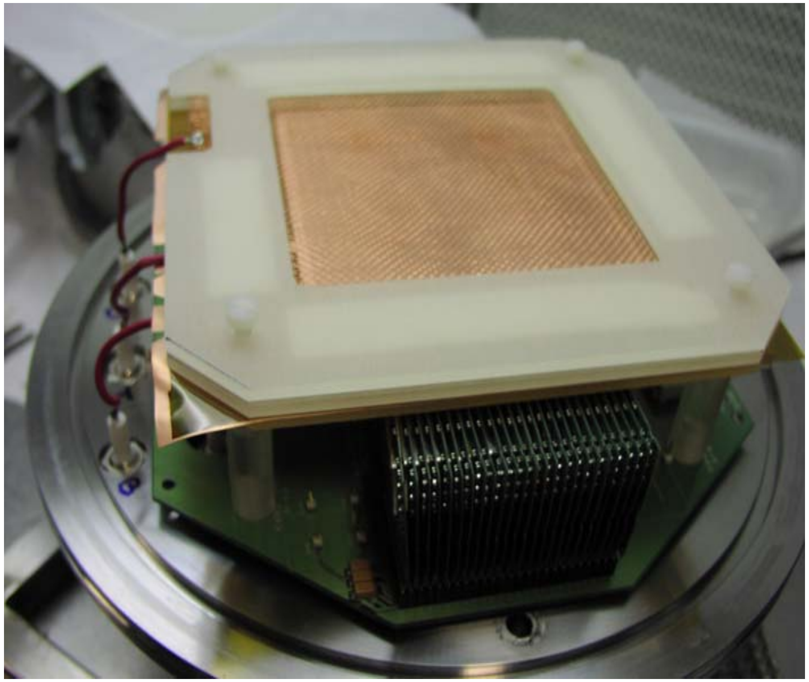
Conclusion: mush higher gains were possible to achieve with resistive coating

Design-2: « Hybrid RPC »



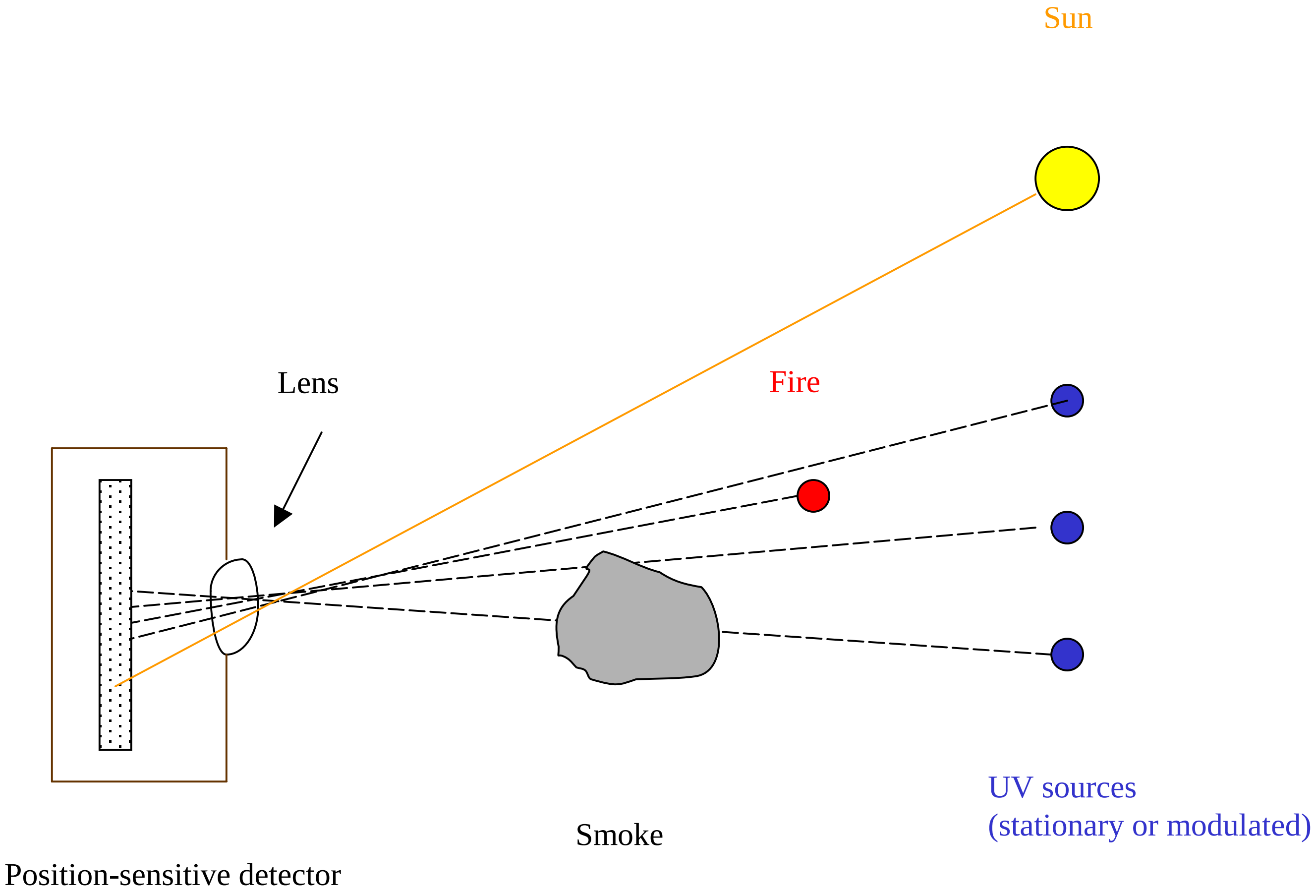
As a readout plate we used either a ceramic plate 40x40 mm^2 covered with Al strips 50 μm in pitch (see above) or a pixelized readout plate (see next fig). The readout plate was placed 0,4 –1 mm below the anode of the G-10. Gas multiplication could take place either in the holes of the G-10 plate or in the gap between the G-10 anode and the readout plate. The advantage of this approach is that the photocathode is geometrically shielded from the light produced by the avalanches and this allows better suppression of feedback pulses and as a result higher avalanche gains (> 10^6) were achieved. The resistive coating in turn protected the device and amplifiers from the occasional discharges.

Photo of some hardware pieces from a portal imaging device



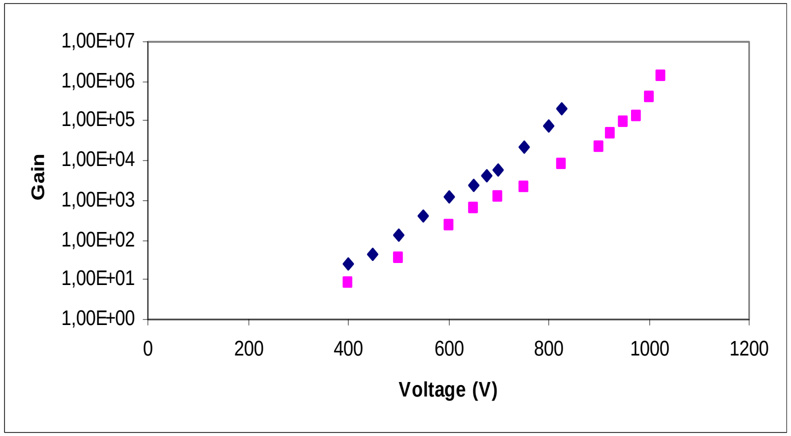
For the pixelized readout G-10 pixelized plate were used originally developed for portal imaging device. In these particular measurements for simplicity pixels in each row were electrically connected together and to the charge sensitive amplifiers.

Layout for flames visualisation



First very preliminary results

Gain



Blue –PPAC combined with semitransparent CsI photocathode;
Rose: “hybrid RPC” combined with Semitransparent CsI photocathode

Flame « image »

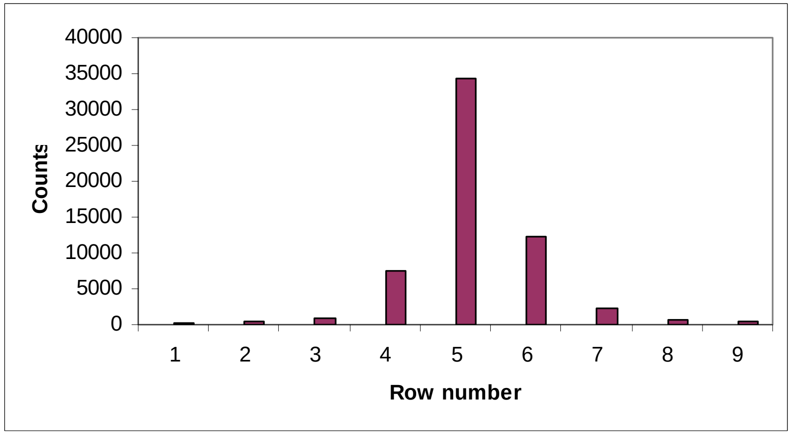


Image of the candle flame
Candle image was focused on the detector window by a quartz lens.
Strips/pixels width was 1,25 mm, pitch ~1,4 mm

Gas mixture: He+1%CH_4+EF

Conclusions

- UV detectors with resistive electrodes are very promising new devices allowing high gains to be achieved. Because these detector were able to detect single photoelectrons with good position resolution they could, after further developments, become compact and simple alternatives to the VUV image intensifiers used today in some applications. Of course, these detectors could be used in high energy physics as well, for example in RICH.

References

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- [8] Supplied by C. Gustavino , Gran Sasso Lab.