Towards sealed GEM-based flame detectors

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In fire safety it is very important to record appearance of a flame on its early stage

There are various commercial flame detectors on the market

EU standard:
The highest sensitivity
Class 1: ~30x30x30cm3 flame
on ~20m in 20sec

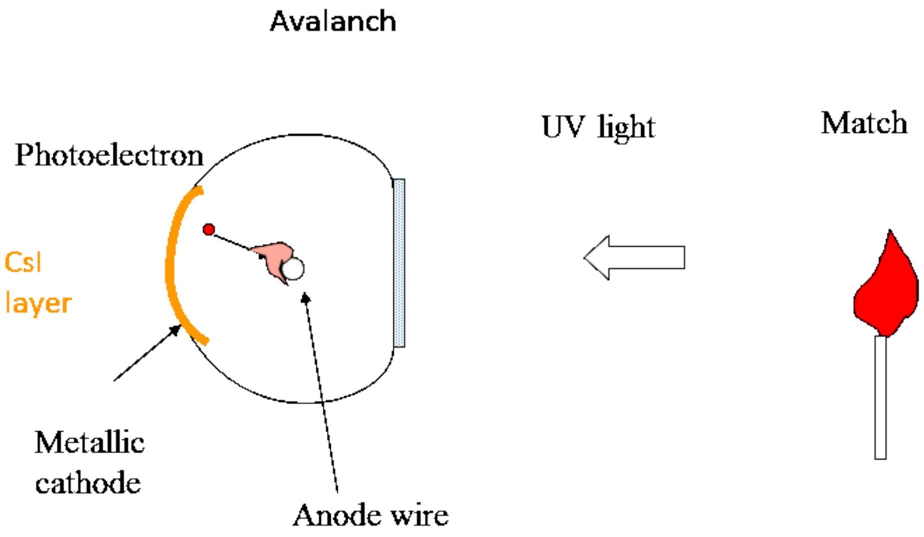
An example of the Class-1 detector

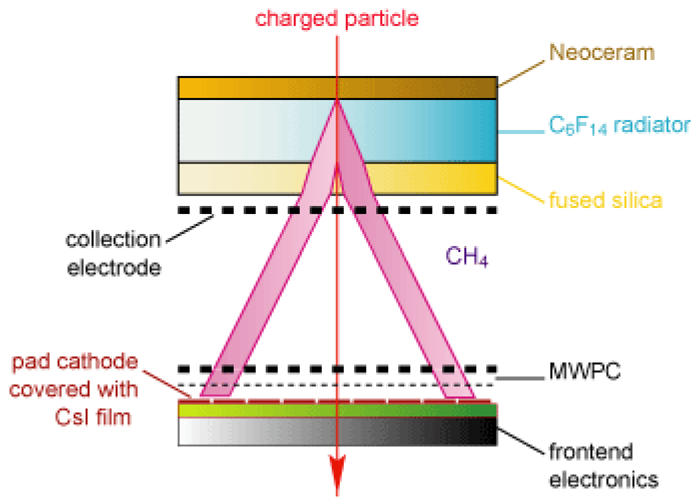
UV light from flames
Create photoelectrons
from the metal cathode
and they trigger a glow
discharge. The latter is
quenched by an external
resistor

Hamamatsu UVtron
is used in some sensors
produced by other
companies

It is a digital device, it cannot distinguish between a single photon and a spark

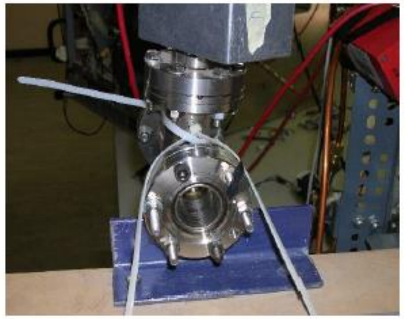
Ours idea-CsI coating to enhance the QE



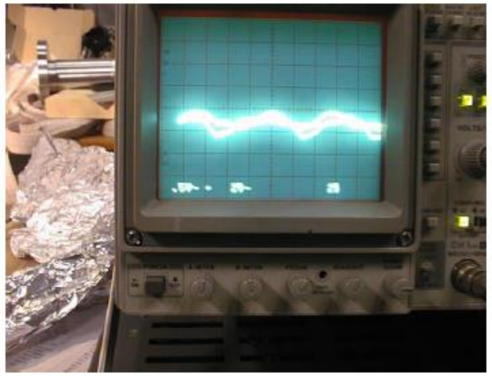


.. the spin of ALICE and COMPASS approach for Cherenkov photons detection

Laboratory prototype



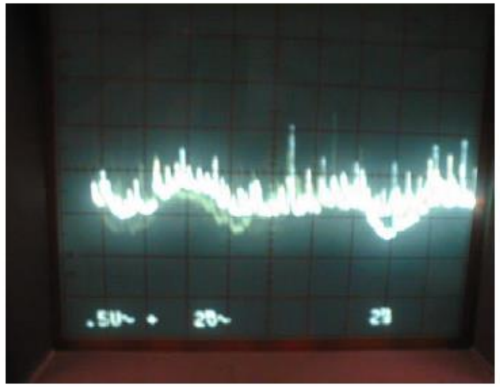
Laboratory prototype



Background in a fully illuminated room (usual+ halogen lamps)

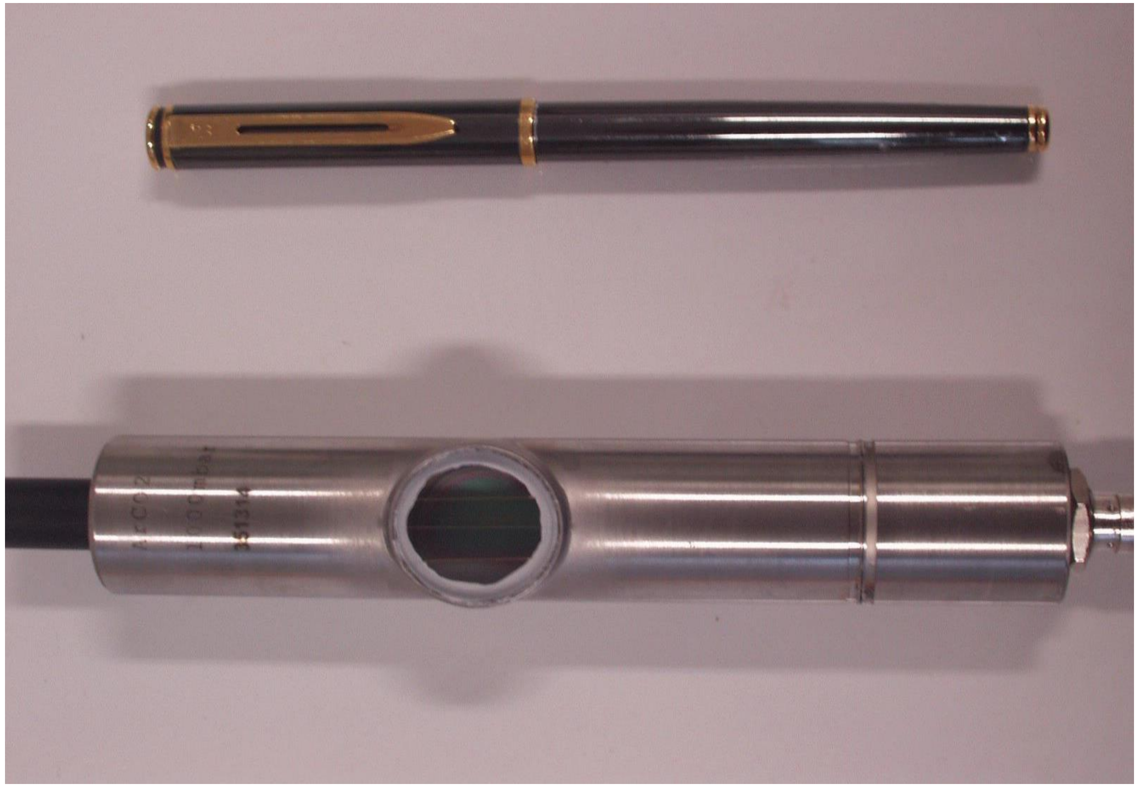
First step-laboratory prototypes. They were 1000 time more sensitive than the class 1commercial detectors.
Can operate in illuminated area

This success triggered our attempts to install contacts with companies and commercialize the detectors



Candle in a fully illuminated room

First sealed detector (industrial prototype)

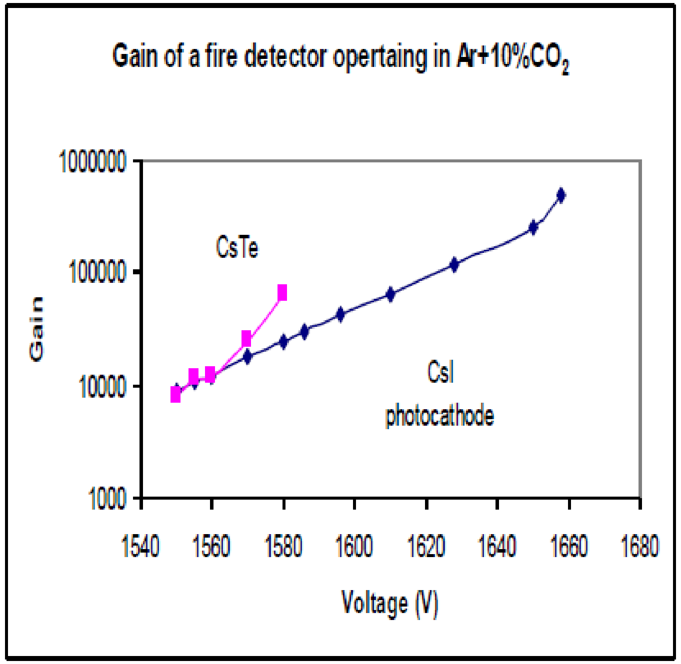


The history of manufacturing:

Miranda evaporated the CsI photocathode at CERN on a inner surface of the tube. It was put then to a plastic bag and sent to Oxford Instr., where the detector was filled with the gas and sealed

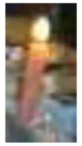
CsI was exposed to air for one week

The detector showed stable operation for 12 years, The sensitivity was 100 times higher than Hamamatsu (the QE loss was due to the exposure to air). The detector was demonstrated in operation at CERN open days



(In collaboration with Oxford Intsr and Reagent, Moscow)

Comparison between our and Hamamatsu UV fire detector



Three UV detectors of fire were compared using the same candle flame:
1.Hamamatsu R2868
2.Our laboratory prototype
3.Our industrial prototype.

Results are summarized in the table below:

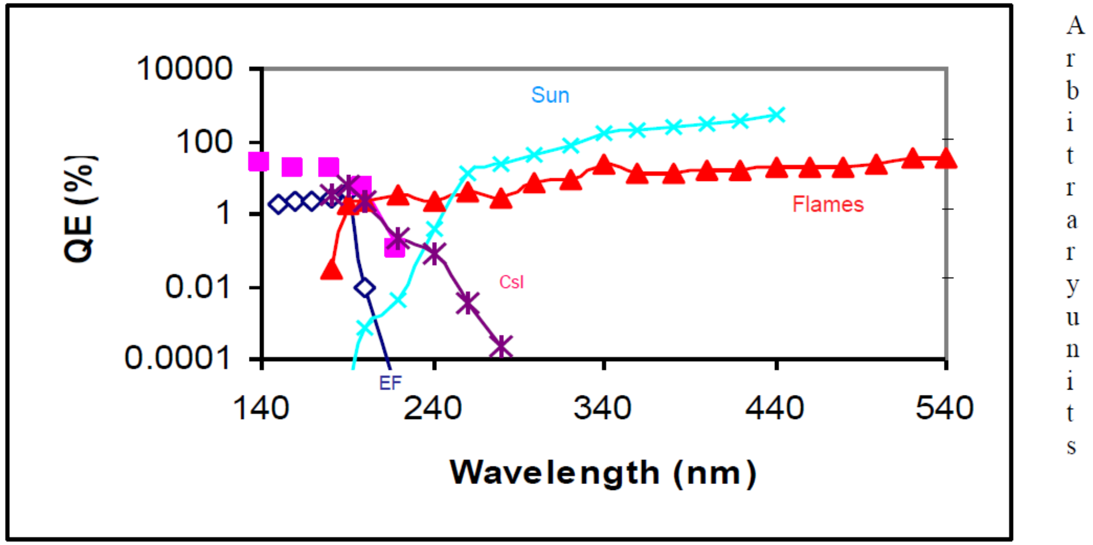
Hamamatsu R2868		Our industrial prototype		Our lab. prototype	
Distance (m)	Mean number of counts per 10sec	Distance (m	Mean number of counts per 10sec	Distance (m	Mean number of counts per 10sec
1		1	81579		
1,1	583				
2,5	99				
3	76	3	9015	3	87574
4,5	28				
10	6	10	811	10	7902
20					
30		30	92	30	876

Conclusion:
Our lab prototype is ~1152 and our industrial prototype is~ 118 times more sensitive than Hamamatsu R2868.

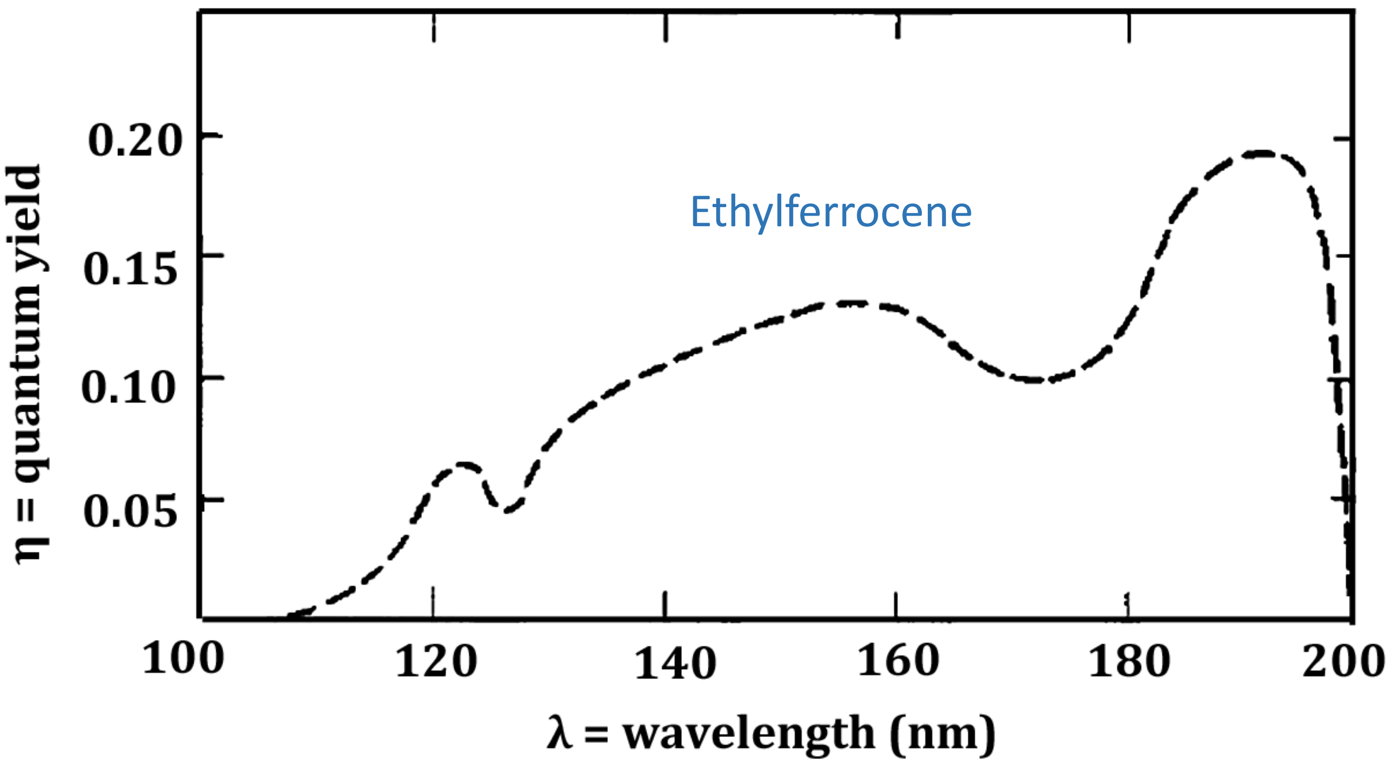
Immediate gain in sensitivity 1000 times

It is excellent for indoor applications, however in direct sunlight ”noise” pulses appear

Results of measurements the CsI and Ethylferrocene QE (%) and spectrum of flame and the sun (arbitrary units)

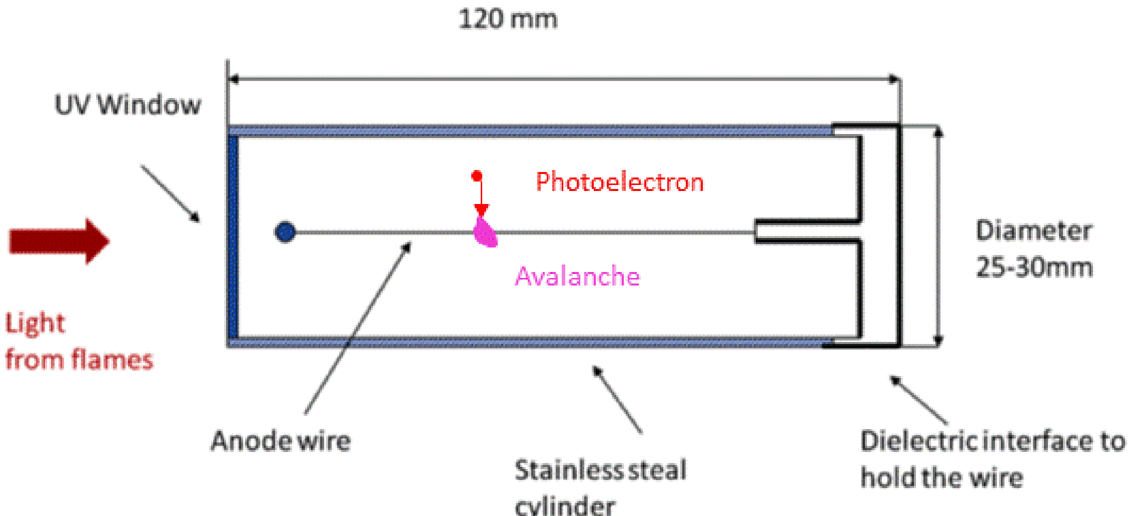


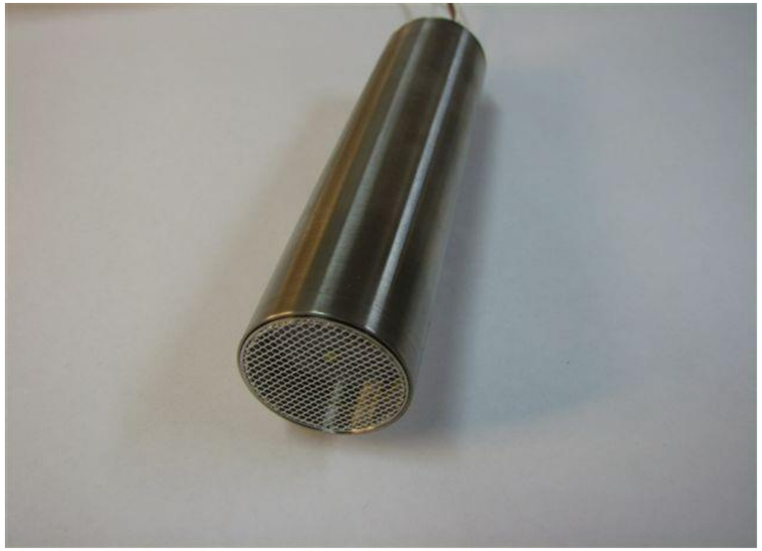
Conclusion: all high-sensitivity solid photocathodes have a “tail” of sensitivity in long wavelengths.
In contrast, gaseous photocathodes have a sharp cut off at $E_v > E_i$



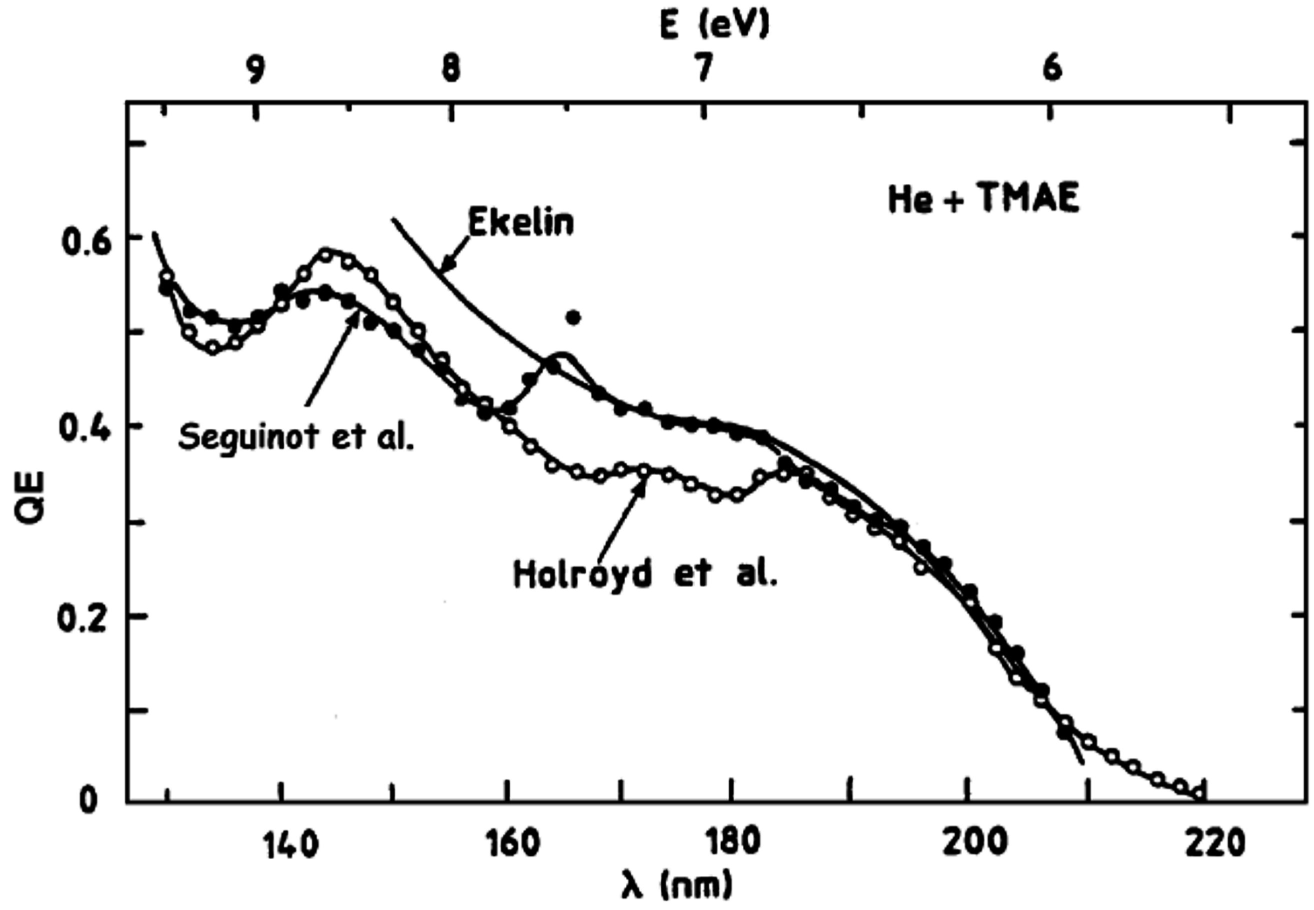
Alternative approach

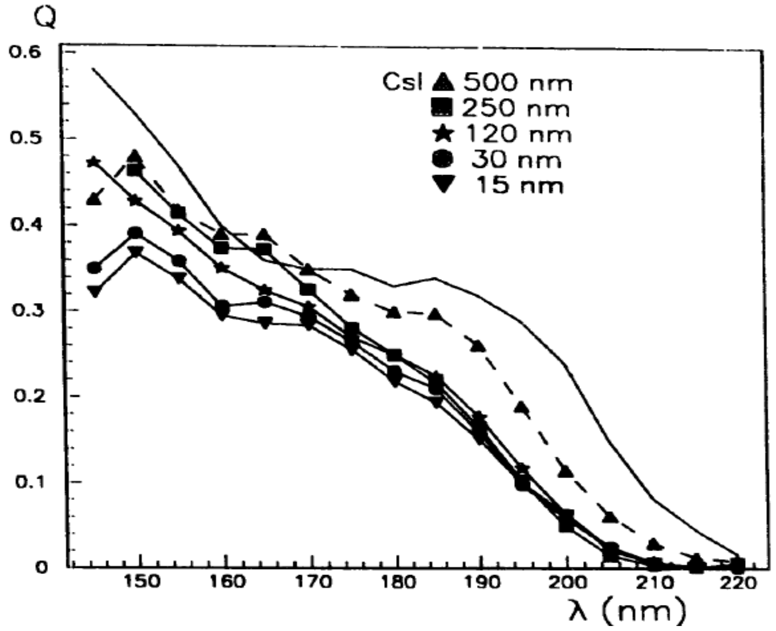
-photosensitive vapour.
In this case the sensitivity to direct sunlight is practically zero





TMAE


E (eV)
9
8
7
6
He + TMAE
Ekelin
0.6
0.4
0.2
0
QE
Seguinot et al.
Holroyd et al.
140
160
180
200
220
λ (nm)


Q
0.6
0.5
0.4
0.3
0.2
0.1
0
CsI 500 nm
250 nm
120 nm
30 nm
15 nm
150
160
170
180
190
200
210
220
λ (nm)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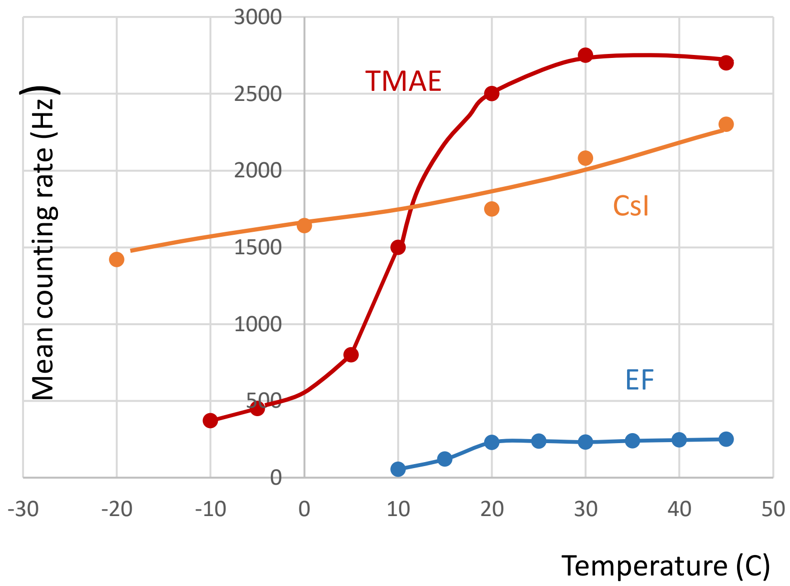
Comparison of TMAE and EF detectors(20°C) with the 1st class flame detectors

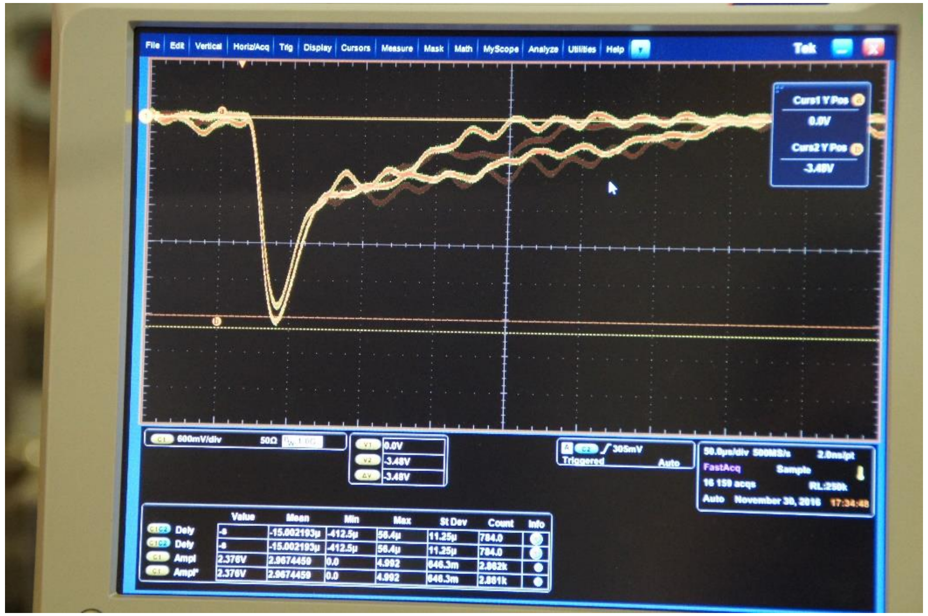
Efficiency vs. temperature

Hamamatsu R2868		Our TMAE detector at 23°C		Our EF detector at 25°C	
Distance (m)	Mean number of counts per 10sec: N_H	Mean number of counts per 10sec: N_{tmae}	Ratio N_{tmae}/N_H	Mean number of counts per 10sec: N_{ef}	Ratio N_{ef}/N_H
1,1	583	690747	1.18×10^3	75613	1.3×10^2
3	76	91013	1.19×10^3	11052	1.4×10^2
10	6	7820	1.30×10^3	643	1.1×10^2
30	0.1	873	8×10^3	68	6×10^2
85		51		4	



Detectors with photosensitive gases are efficient at room and elevated temperatures

All these detectors were exploited in proportional mode, so they can distinguish between single photons and sparks



Signals from invisible sparks

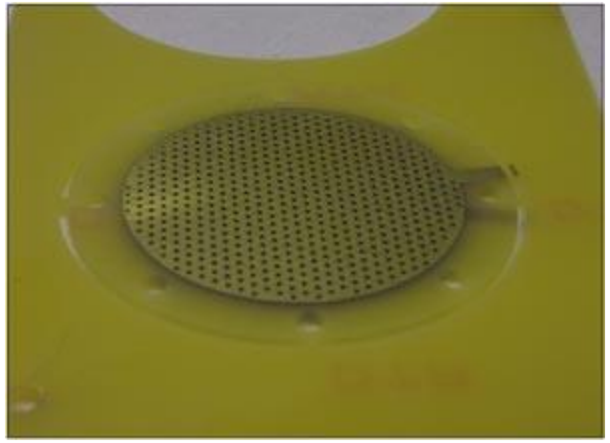
Single wire detectors: in the past the cost of sealed X-ray counter was low, around 100 Euro, (Hamamatsu is around 50 Euro), including HV supply and electronics.
However, nowadays they are not produced anymore (solid state detectors took over)
To start their production is not easy and require a considerable investment

This why we are considering now a GEM-based approach

It offers several advantages, for example:

Compact flat-panel geometry

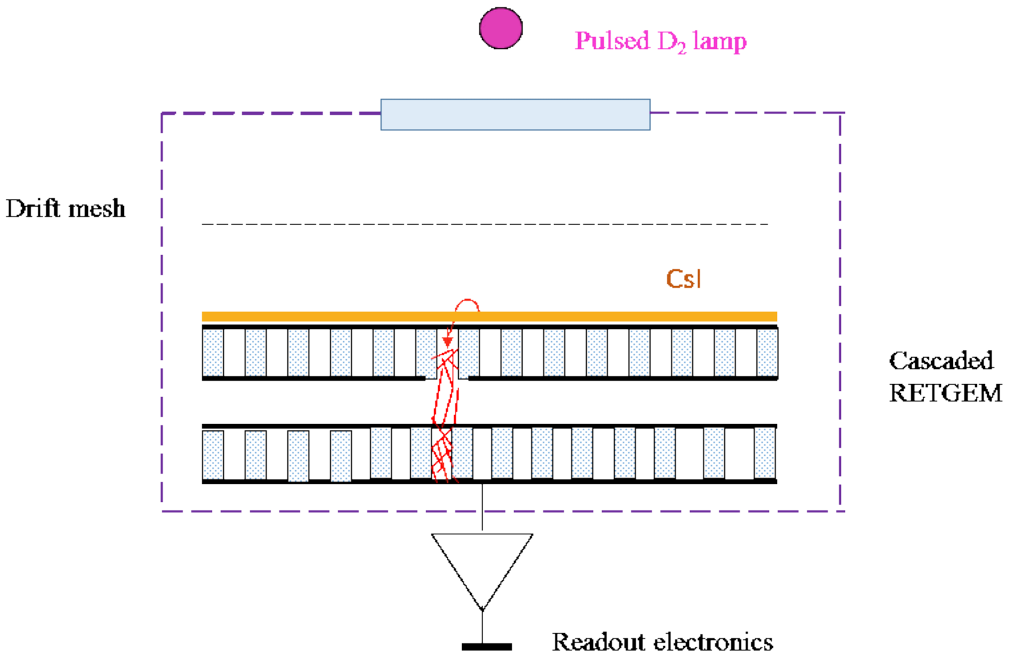
Large area-herefore, higher sensitivity



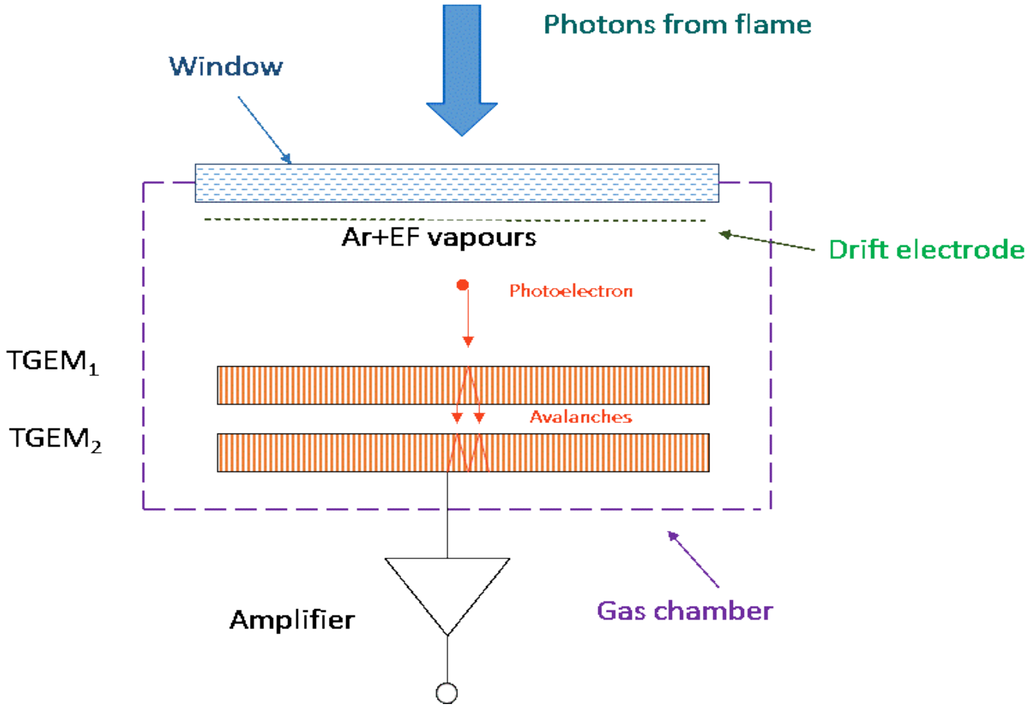
In this work we try to learn the difficulties in this approach

We started of course, with flushed detectors (this part of work was done in collaboration with A. Di Mauro and P. Martinenego and was supported by the CERN Technology Transfer office)

UV flame detector prototype

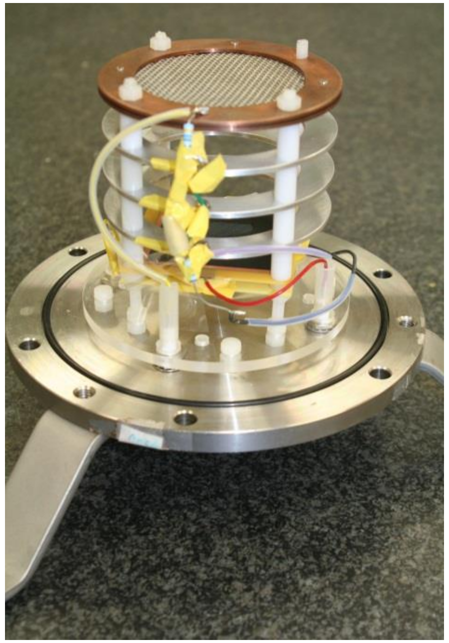


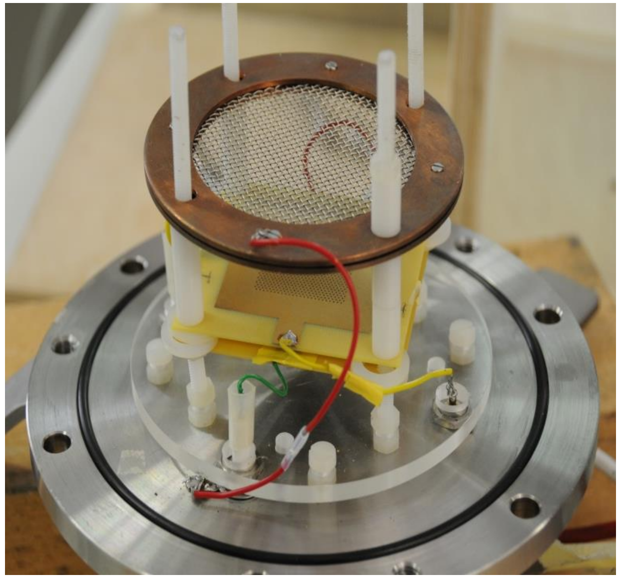
One of the designs



Examples of optimizations made in flush mode:

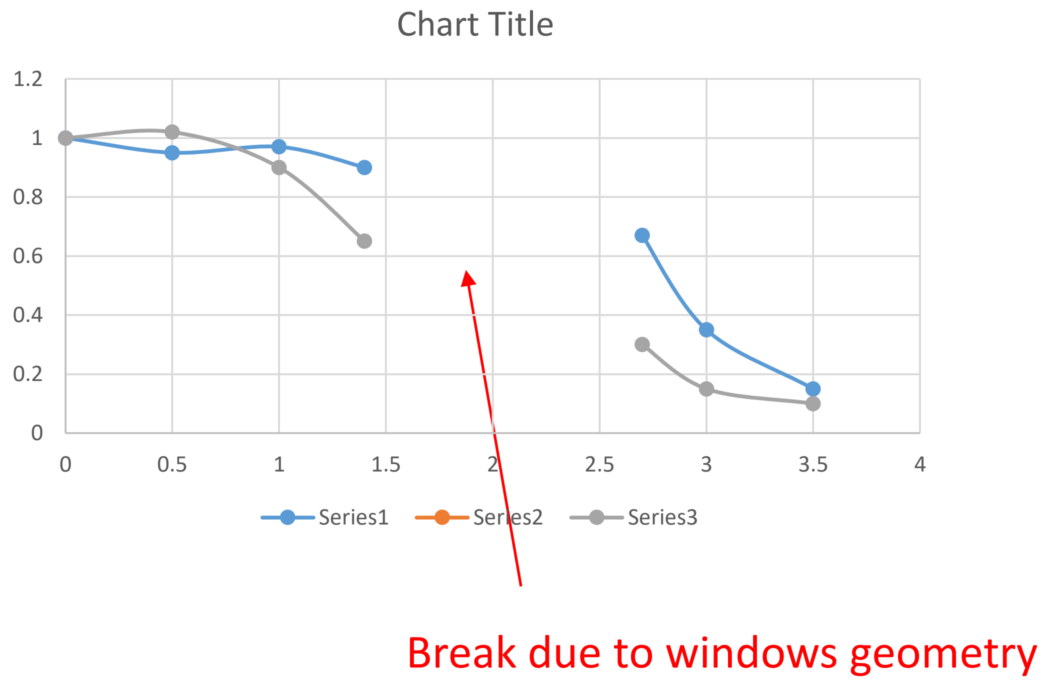
choice grift region geometry





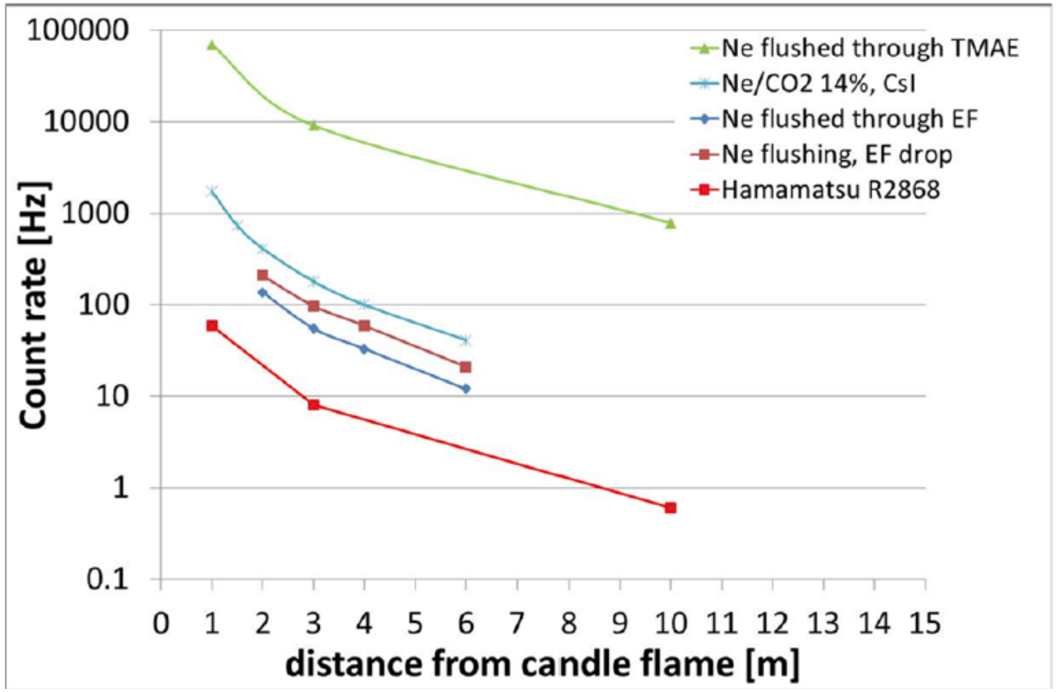
Choice of THGEM and RETGEM geometries: t=0.8, d=0.6, s=1,h=0.1mm
and
t=0.4, d=0.5, s=0.9,h=0.1mm

Example of some results:
efficiency vs radius



Conclusion : there ae some losses, but the construction is simpler

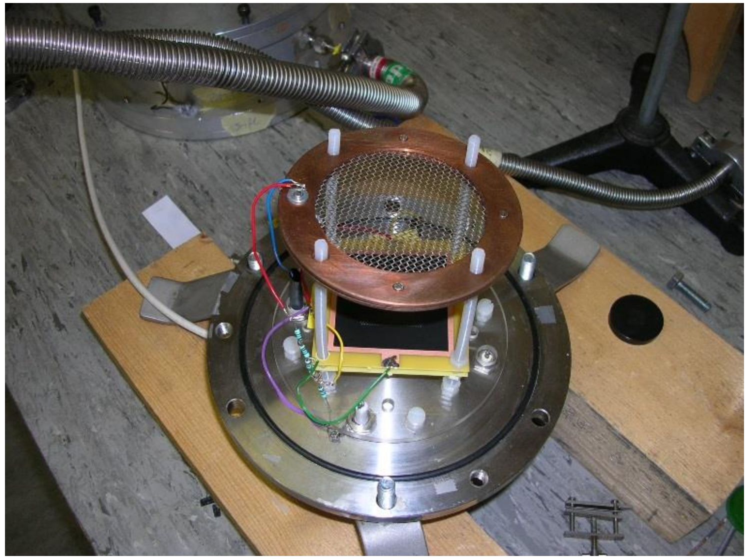
Comparison with Hamamatsu



From:
Di Mauro,
P. Martinego,
V. Peskov
Report to CERN
Tech. Transfer office

In principle, one can gain sensitivity further with the window size increase

Sealed detectors



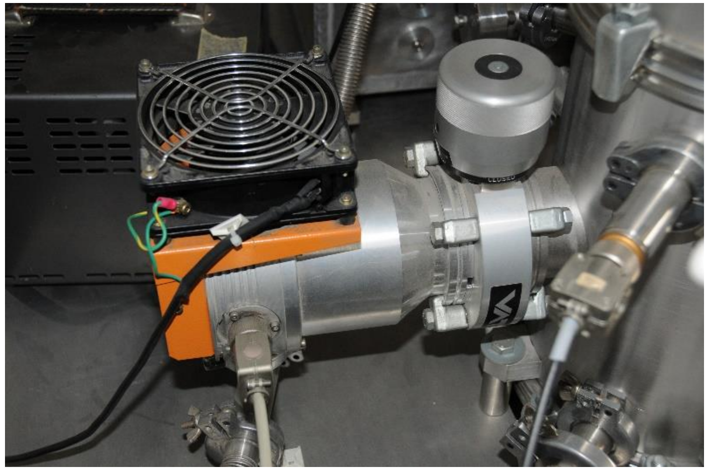
Teflon pieces were changed to ceramics

In the case of CsI the drift was 10 mm
In the case of photosensitive gases it was 80 mm

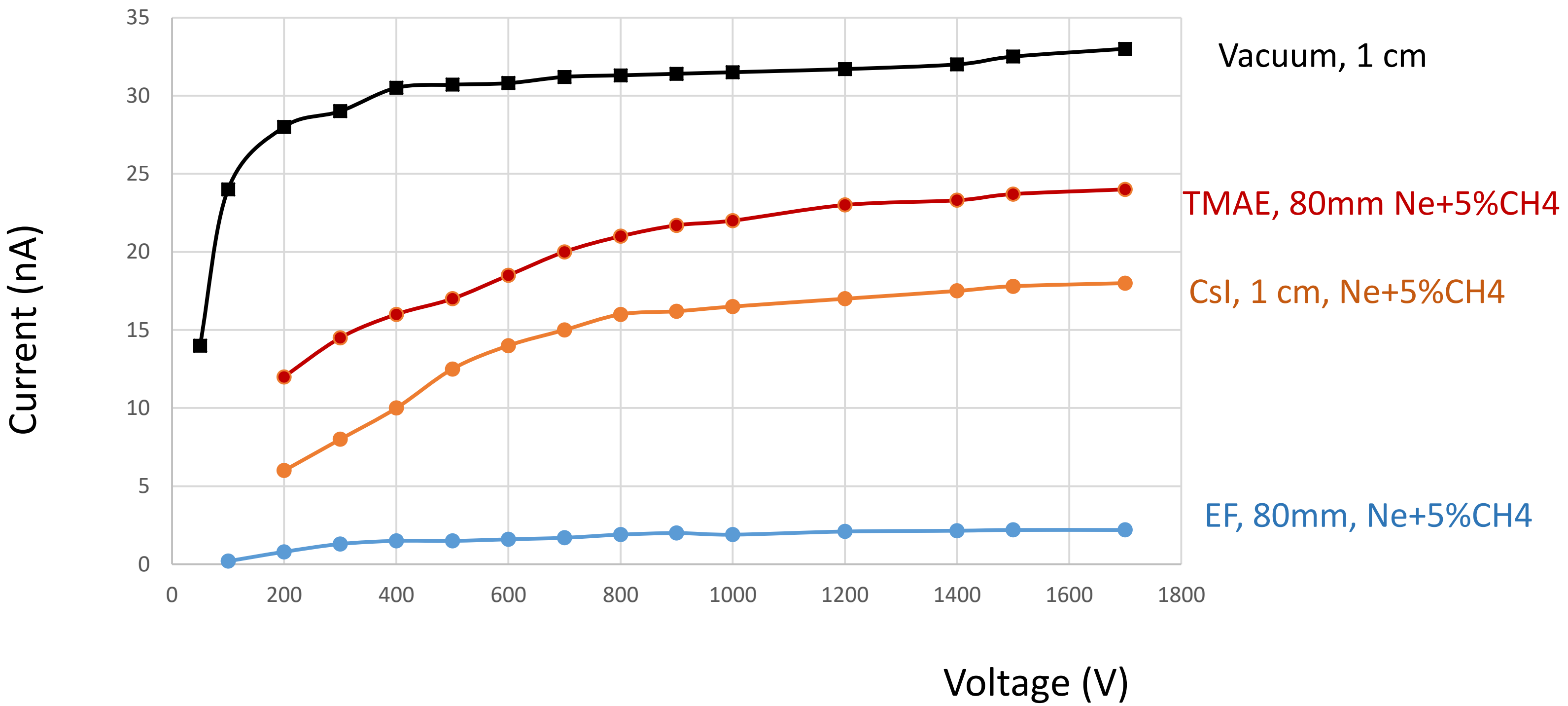
In first experiments we used heating tapes wrapped in Al foil 150-180, pumped for7-10 days, the vacuum was better 10^{-6} Torr

Later a more advanced, more convenient, setup was developed

Heating cabinet
(in collaboration
with A. Di Mauro)

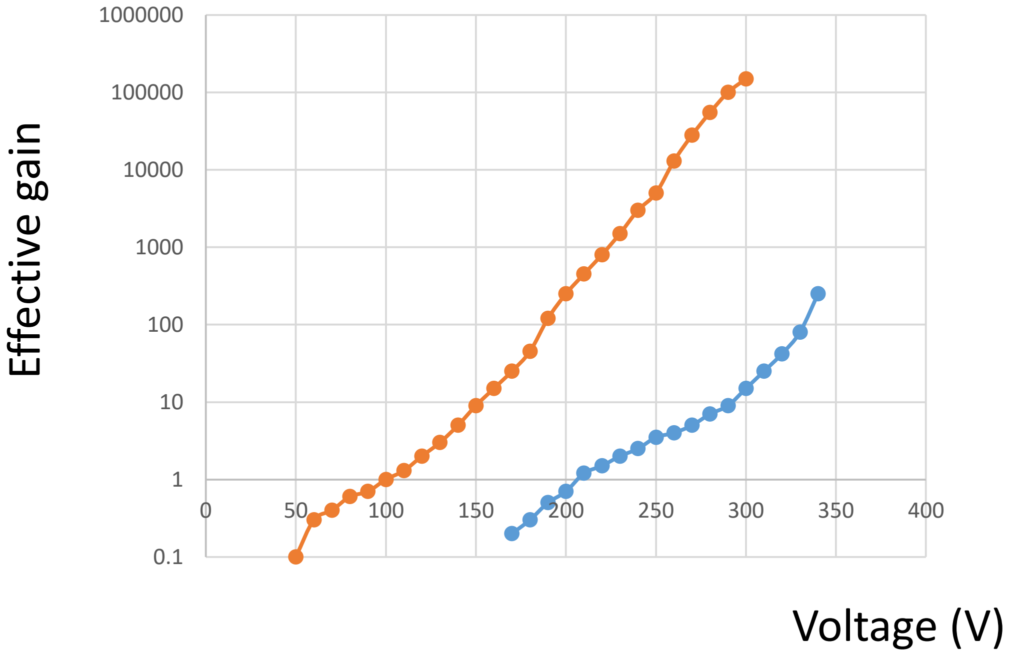


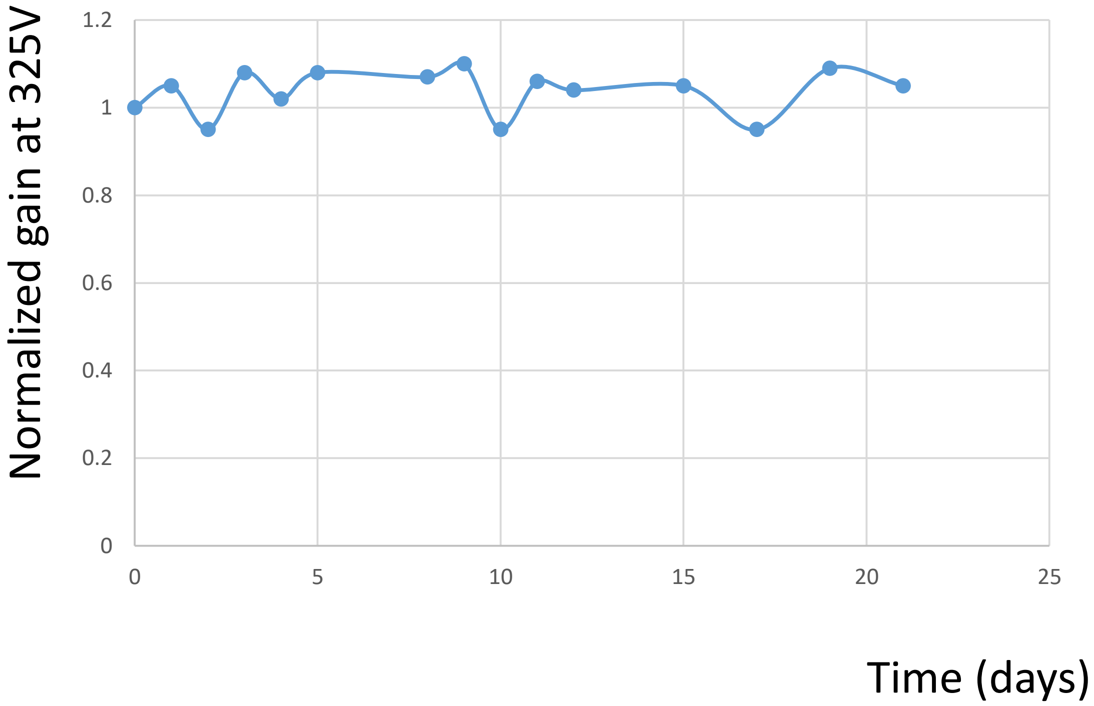
Ionization chamber measurements



Ne as a cleanness probe

Current measurements





Double THGEM

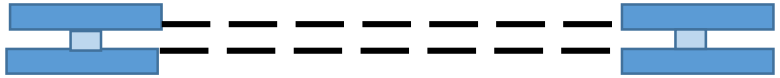
t=0.4, d=0.5, s=0.9,h=0.1mm

In TMAE THGEMs become noisy even if we introduce its vapours below the saturation value

Special THGEM design for TMAE
(to avoid leakage current)

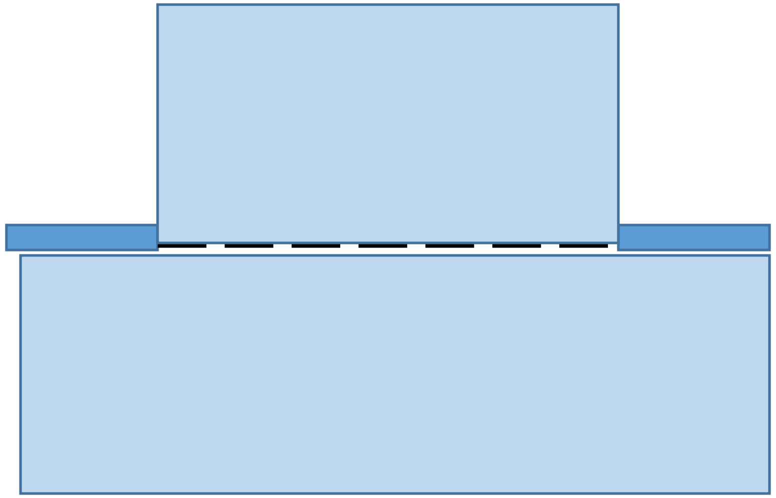
Oxide Cu (0.2 mm thick)

Ceramic



0.4 mm

Hols 0.4mm



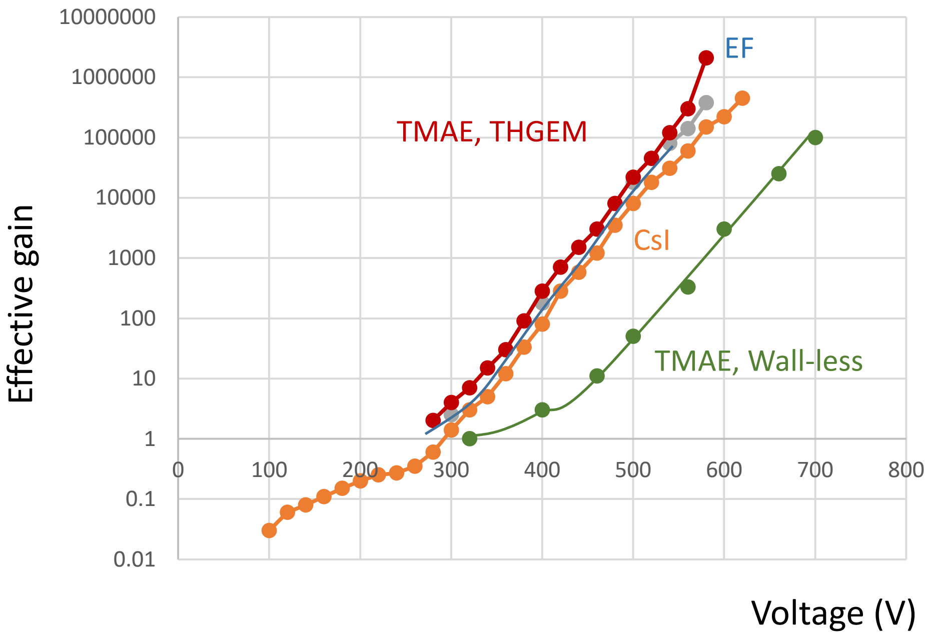
Original idea expressed in CERN Patent Application.
Authors:
R. Oliveira, Di Mauro, P. Breule, V. Peskov

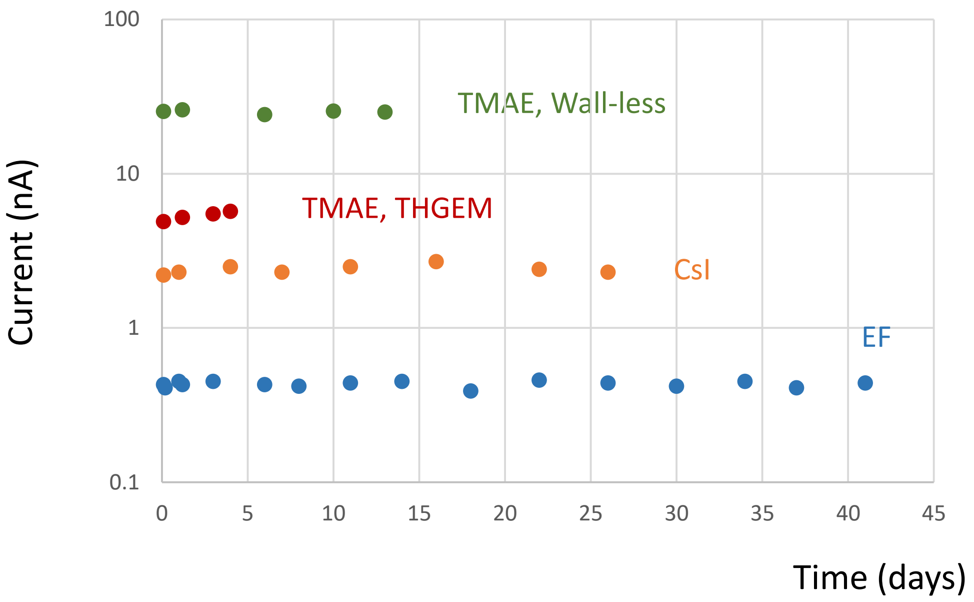
First prototypes were developed by electronic Workshop in Ecole des Mine, St. Etienne, France

Latest prototype-Ragent-
(a photonic branch of the Inst. for Chem. Phys. RAS)

Later a similar detector was developed and successfully tested by the Inst of Nucl. Phys. RAS

Gain and stability in other gases

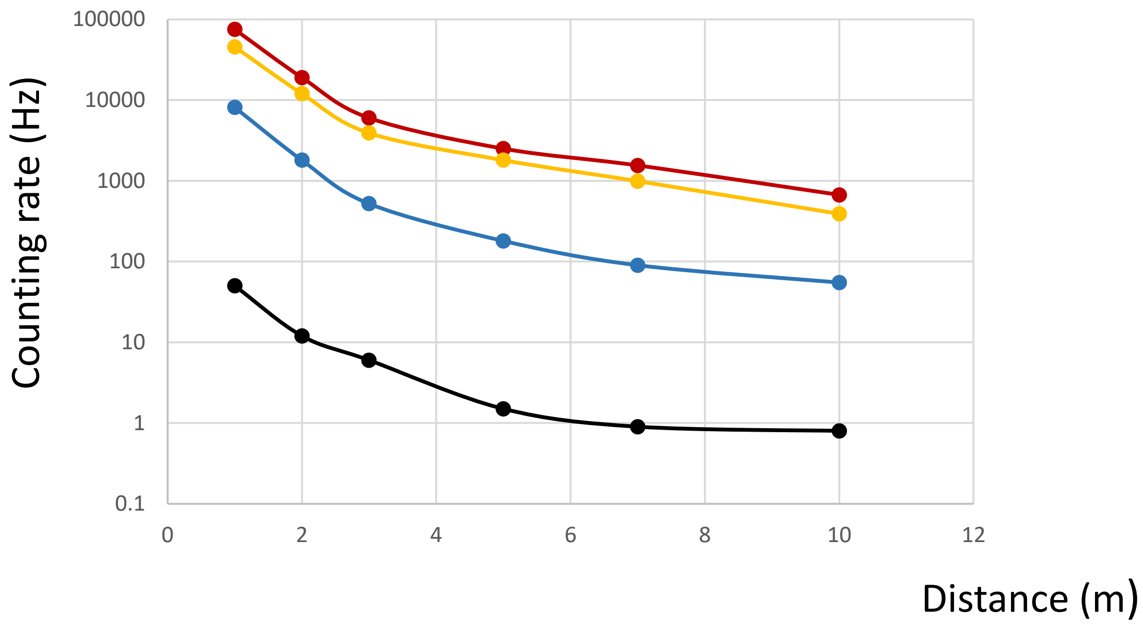




The method:

Stabilization at low gain and step by step increase

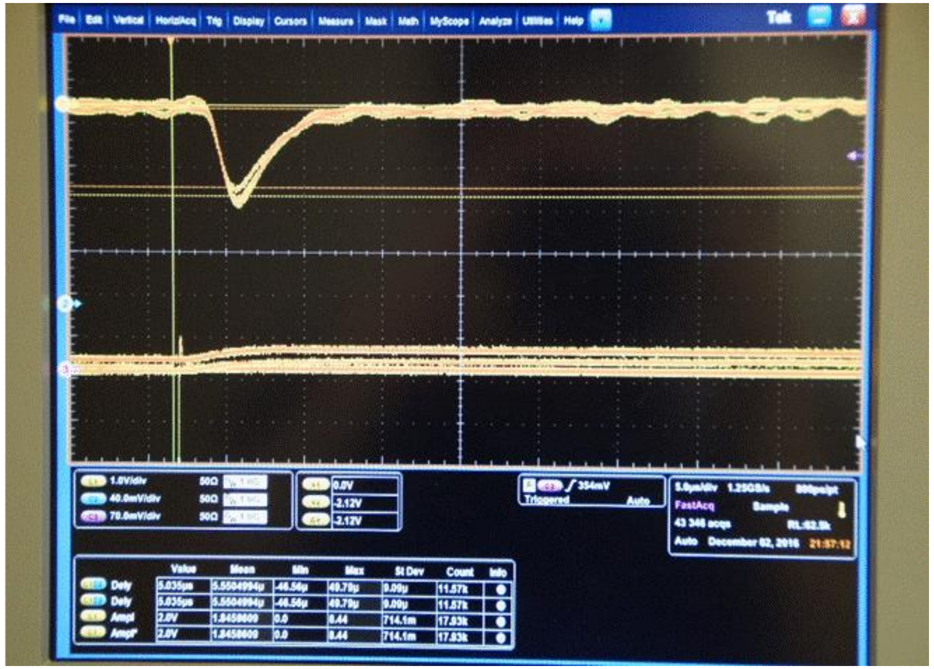
Comparison sealed GEM-based detectors with Hamamatsu



Note: adding a sun-blocking filter reduce the efficiency of the CsI THGEM four times

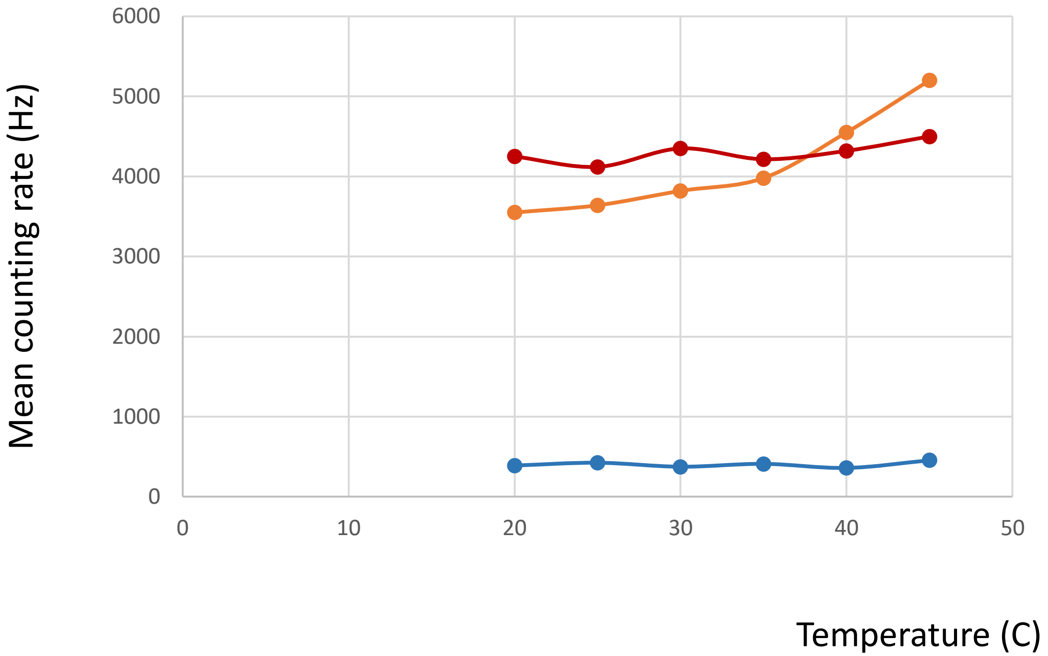
In contrast to Hamamatsu GEM-based detectors are capable to detect sparks

Сигнал с формирователя



Сигнал с предусилителя

Stability with temperature



The most attractive are GEM-based detectors with CsI photocathodes:

they operate stably in wide temperature interval

However, the necessity to use filters create some problems,e.g:

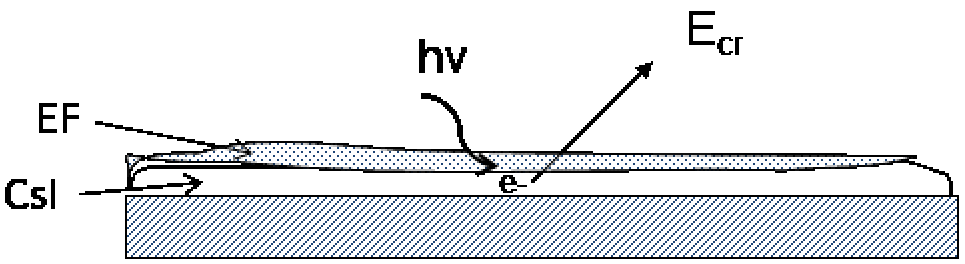
size,

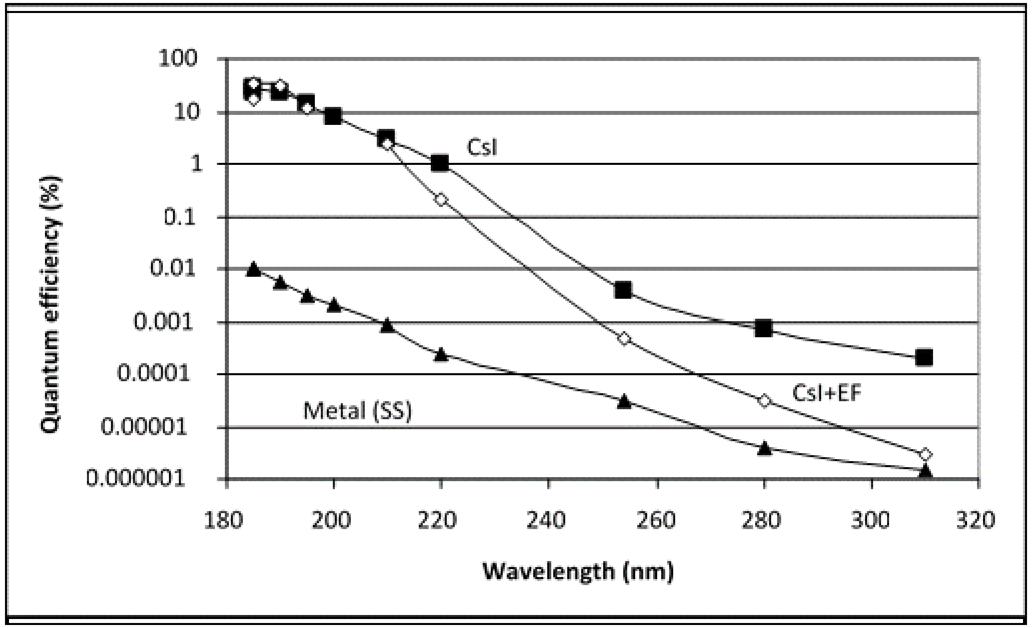
price

Pilot studies progress:

CsI surface coating as an incorporated filter

(in collaboration with Di Mauro, P. Martinengo and P. Breul)





CERN Techn.Transfer office filed a patent application

Conclusions

- GEM approach offers the possibility to manufacture compact ,but large area, high sensitivity flame detectors
- CsI detectors the most attractive , but require filters for outdoor applications

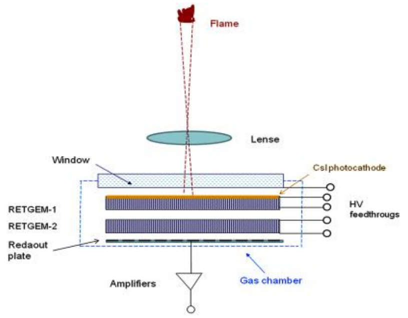
This increase the cost

- GEMs with photosensive vapours practically are not sensitive to the direct Sunlight, but have high QE only at temperatures more than 15C. So they are good either for indoor application or for outdoor applications in warm countries (Greece, Israel, Italy, California etc)
- It will be attractive to coat CsI with a incorporated filter

Our nears effort will be focused on optimization of these layers

- We are also working on imaging version of GEM-based flame detectors

Probably we will be able to present some results on one of the RD51 meetings



Backup

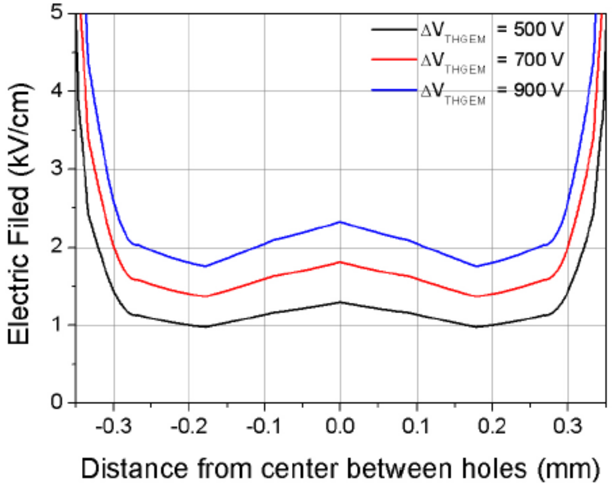


Figure 8. The electric field on THGEM top surface used in this work, $E_{surface}$, as calculated by MAXWEL along the line interconnecting two hole centers.

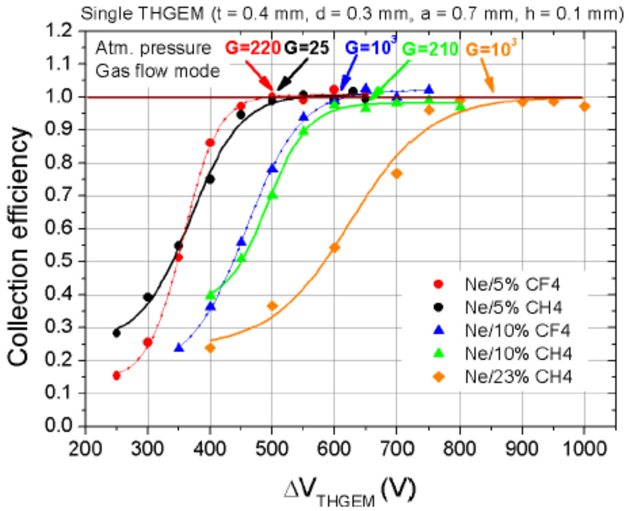


Figure 9. Single-photoelectron collection efficiency in Ne/CH_4 and Ne/CF_4 mixtures, measured in pulse-counting mode, versus the voltage across the THGEM; the threshold gain values for reaching full collection efficiency are indicated for each mixture.