High sensitivity detectors of smoke/flames and dangerous gases- preliminary results

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CERN

(behalf of the ATTRACT/ SMART project)

https://twiki.cern.ch/twiki/bin/view/SMART/WebHome

What is ATTRACT?

Developing breakthrough technologies for science and society

(including sensors)

SMART (Supersensitive Multipurpose Advanced Radiation Technology)

Supersensitive multipurpose/multifunctional avalanche gaseous detectors for environmental hazard intrusion system

Commercial partners: Finland, Dubna, Spain

Consortium Composition Table

	Organization full name	Organization short name / PIC number	Organization type[1]	Contact person name	Contact person email
Coordinator	European Organization for Nuclear Research	CERN	Research & Technology Organization	Francesco Pietropaolo	francesco.pietropaolo@cern.ch
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The aim of SMART project is to develop a prototype of a high sensitivity integrated system for complex monitoring of indoor environmental conditions: on line Radon detection, flames and sparks detection and visualization, remote smoke detection, detection of appearance of dangerous gases

Flame detection and visualization
Smoke detector
Dangerous gases detector
Rn detector

Four or more detectors combined in one multifunctional battery fed device with Wi-Fi communication

Pilot prototypes of some sensors were developed earlier and the main SMART tasks were to further improve these devices and adopted them to our integrated system

So, let’s briefly review the present status of these developments

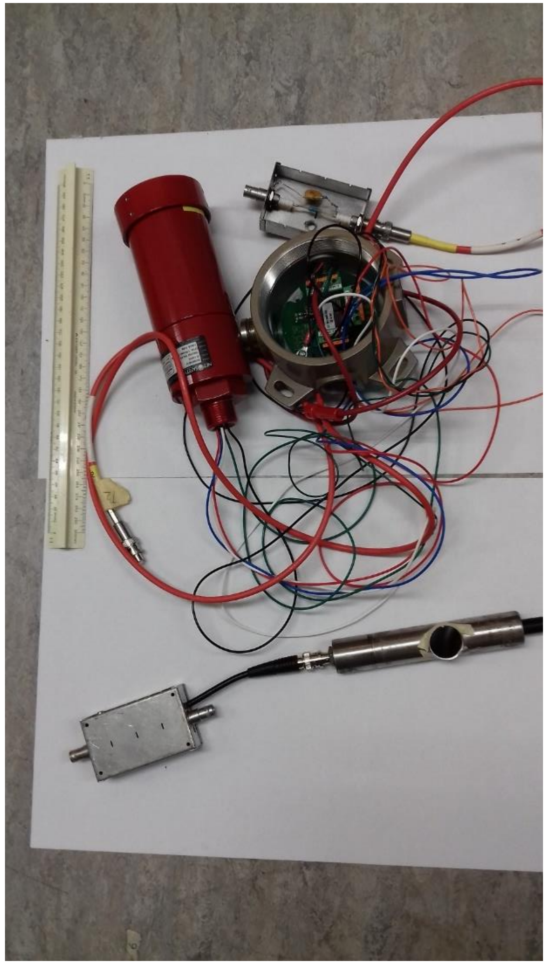
I. Flame detector

for SMART system

I.1. Indoor applications

The RD51 community was already informed about our developments of various flame detectors for indoor applications.

They demonstrated excellent performance and the sensitivity, depending on a particular design, 100-1000 higher the best commercial sensors have

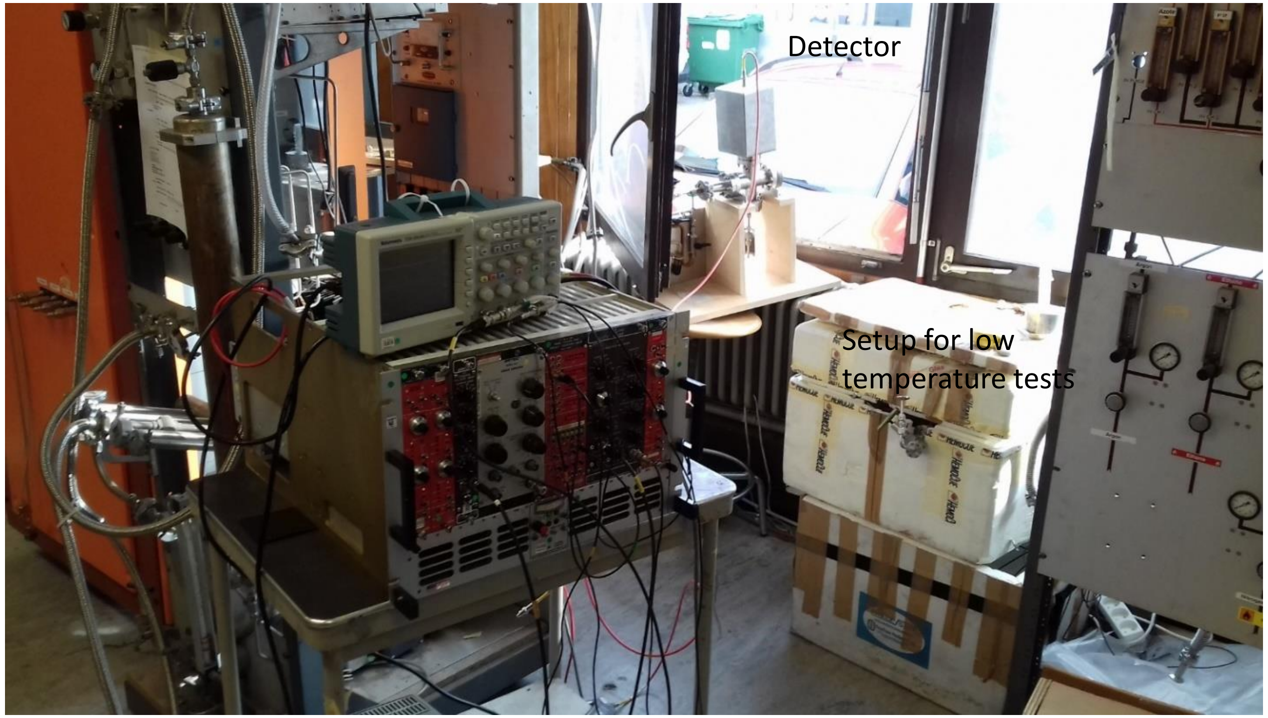


Class-1
The most sensitive commercial detector

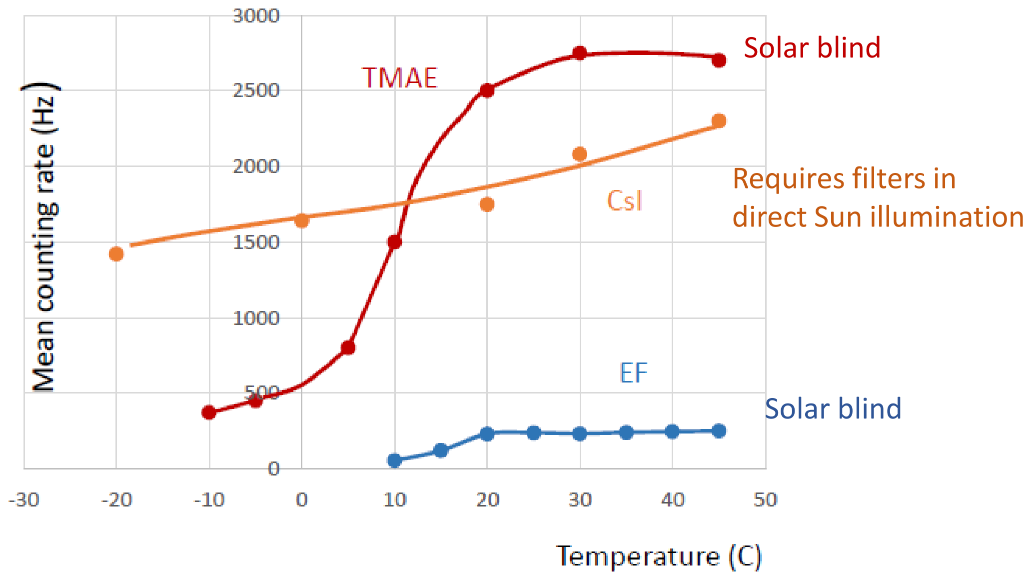
Our detector

In principle, theses detectors fit SMART requirements for indoor applications

However, we keep in mind to extended (*later, of course*) SMART system also for outdoor applications. This put additional constrains on detectors: they should be solar-blind and capable operating in wider temperature interval



Test of detectors operation in direct sunlight



Therefore, one of the specific tasks was to modify our flame detectors in order to adopt them for outdoor conditions

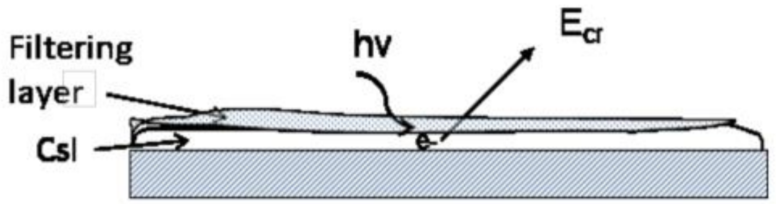
I.2. Flame and spark detectors for outdoor applications

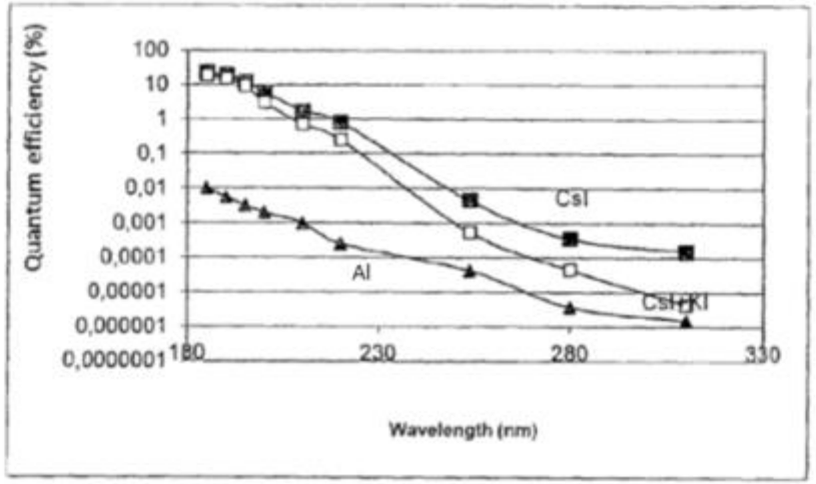
to be integrated in the future to the SMART system

The idea was to use solar-blind solid photocathodes with lower efficiency in the region of interest (185-250 nm) and compensate this by a larger sensitive area

This lead us to flat panel designs

We have tested several photocathodes, for example CsI coated with various this films, serving as a kind of filters for passing through photoelectrons



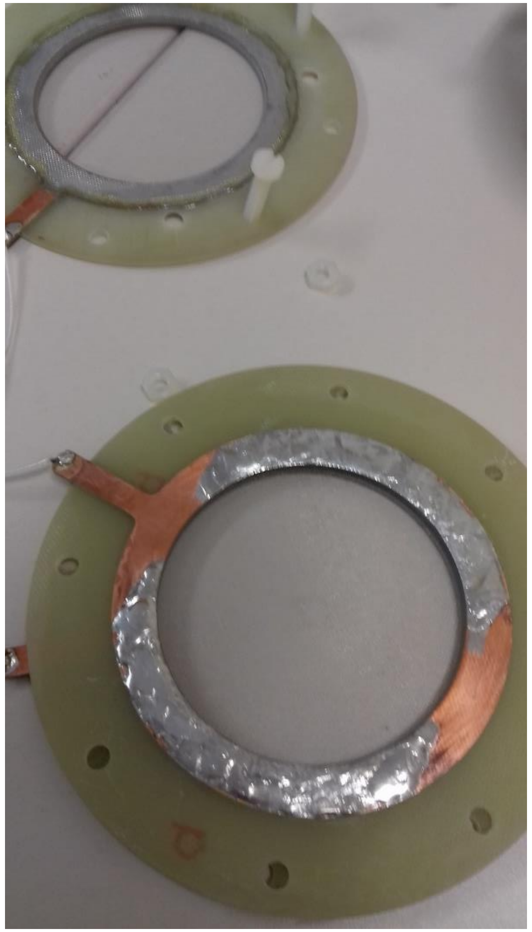


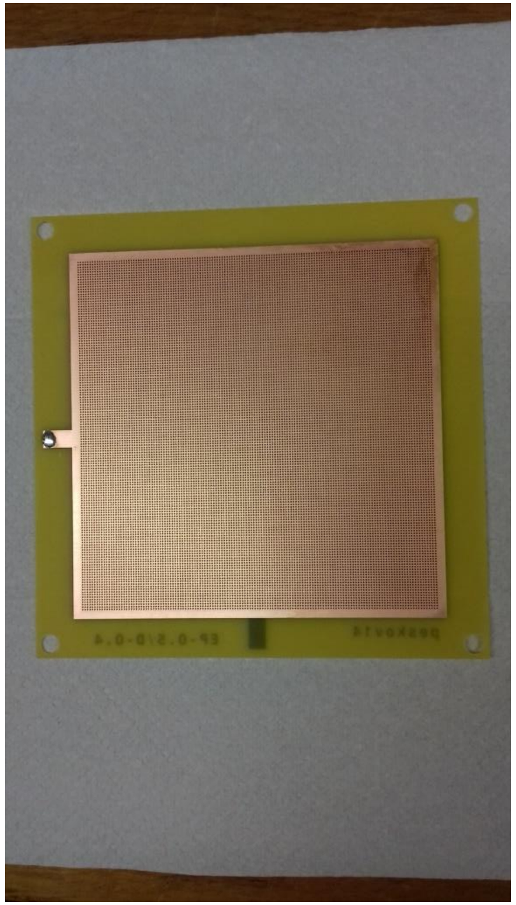
However, it turned out that the best solution is to use something much simpler, e.g.

CuI or Ni photocathodes

M. Abresscia et al, paper in preparation

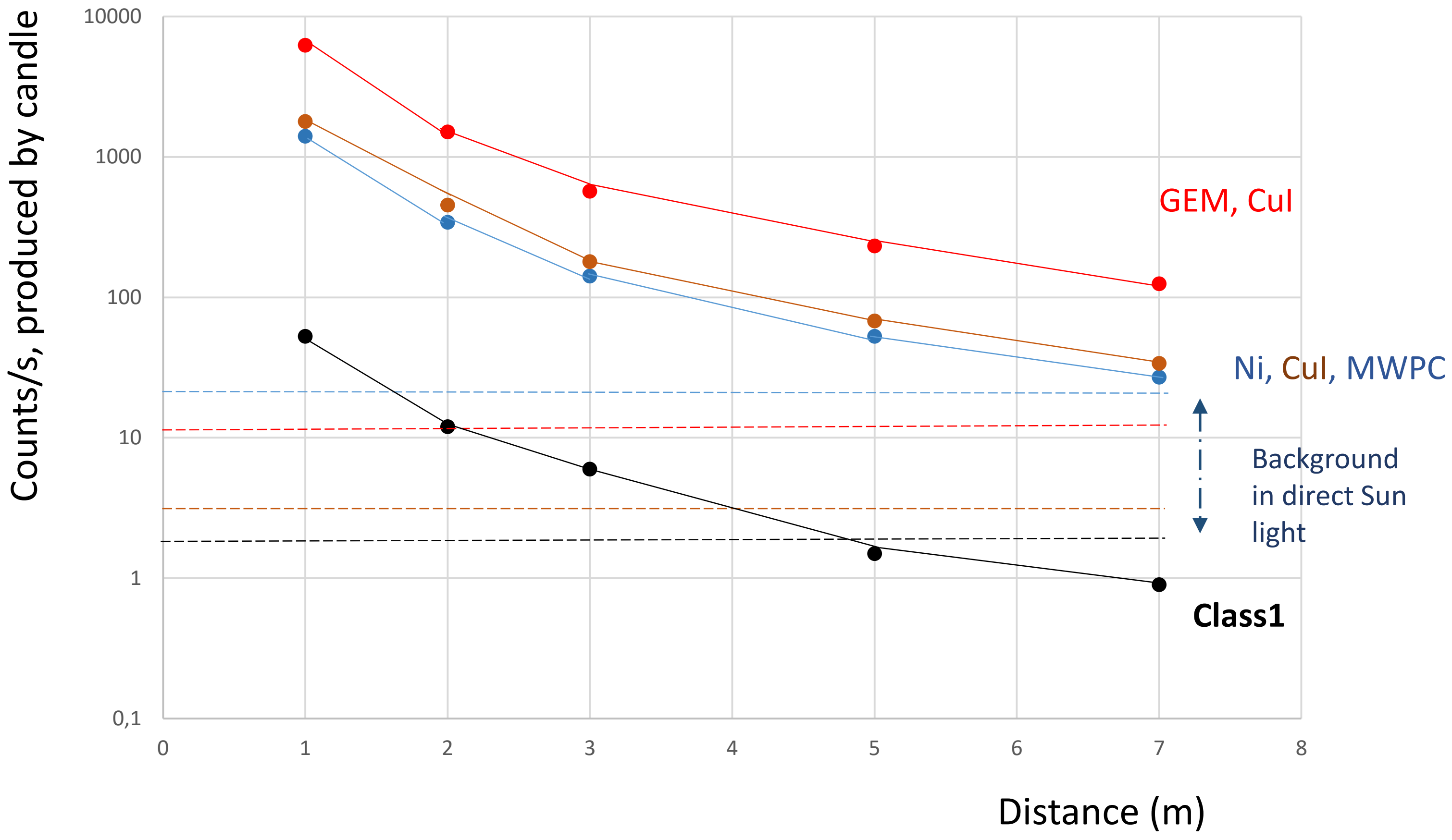
Compact flat panel designs based on MWPC and thick GEM

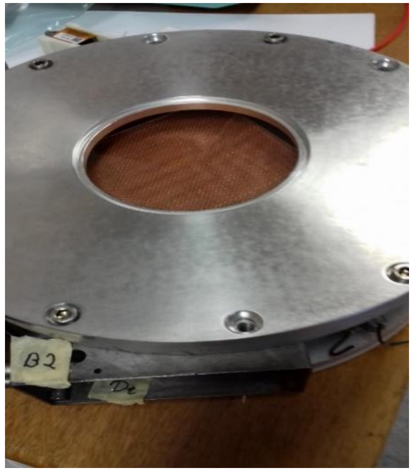




The choice of the multiplication structure depends on an application

Tests of detectors with solar blind photocathodes (preliminary results)

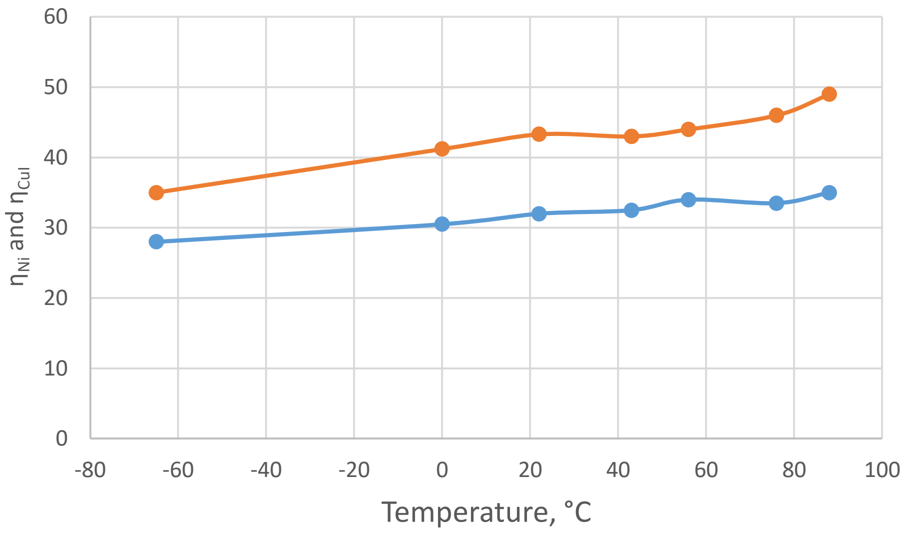




Gas chamber with large window

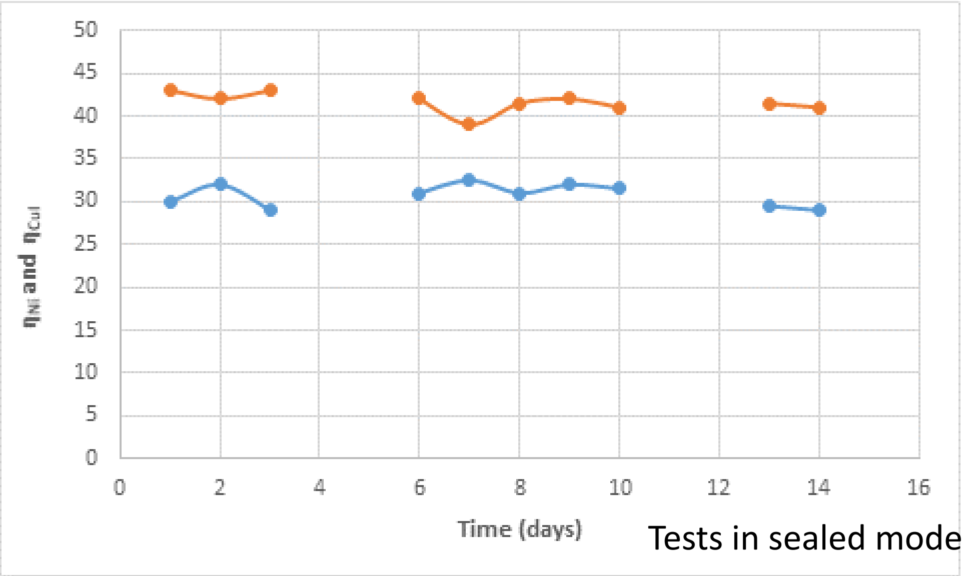
In one test the detector with CuI photocathode was placed on a distance of 15 m from candle, the latter produced counting rate three times higher than background from the direct sunlight (~3Hz)

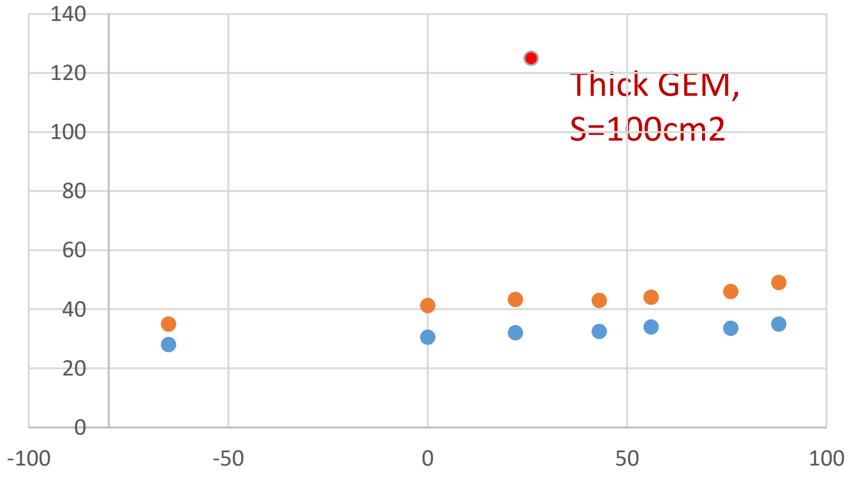
Other preliminary results



CuI

Ni





MWPC, S=33 cm2

Gain 3.5×10^5

Ref. on sealed detectors: https://indico.cern.ch/event/676702/contributions/2811167/attachments/1576152/2488989/RD51_Flame_det.presentation.pdf#search=authors%3Apeskov

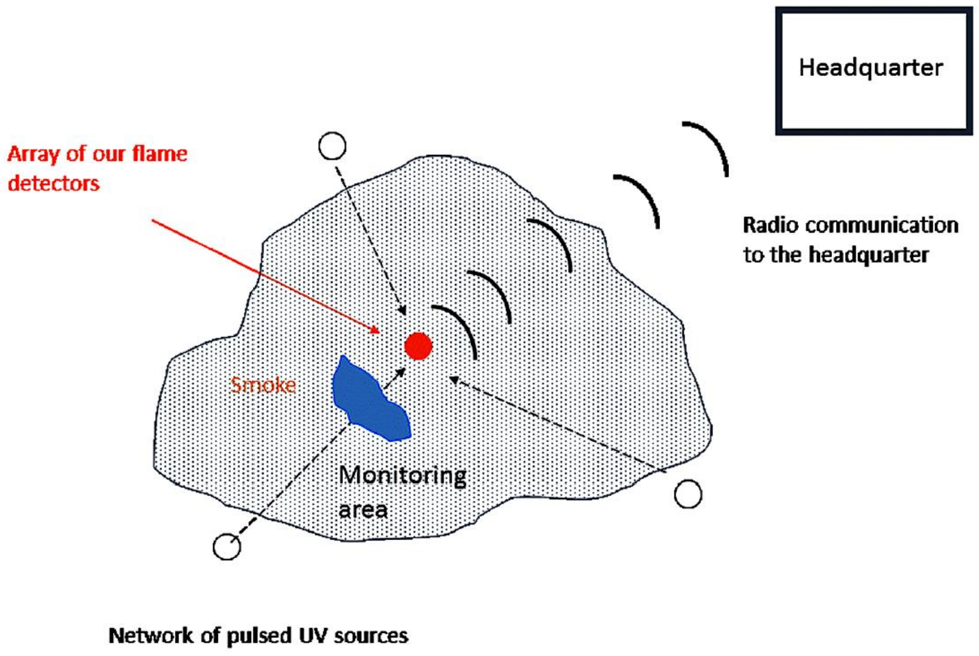
II. Smoke detector

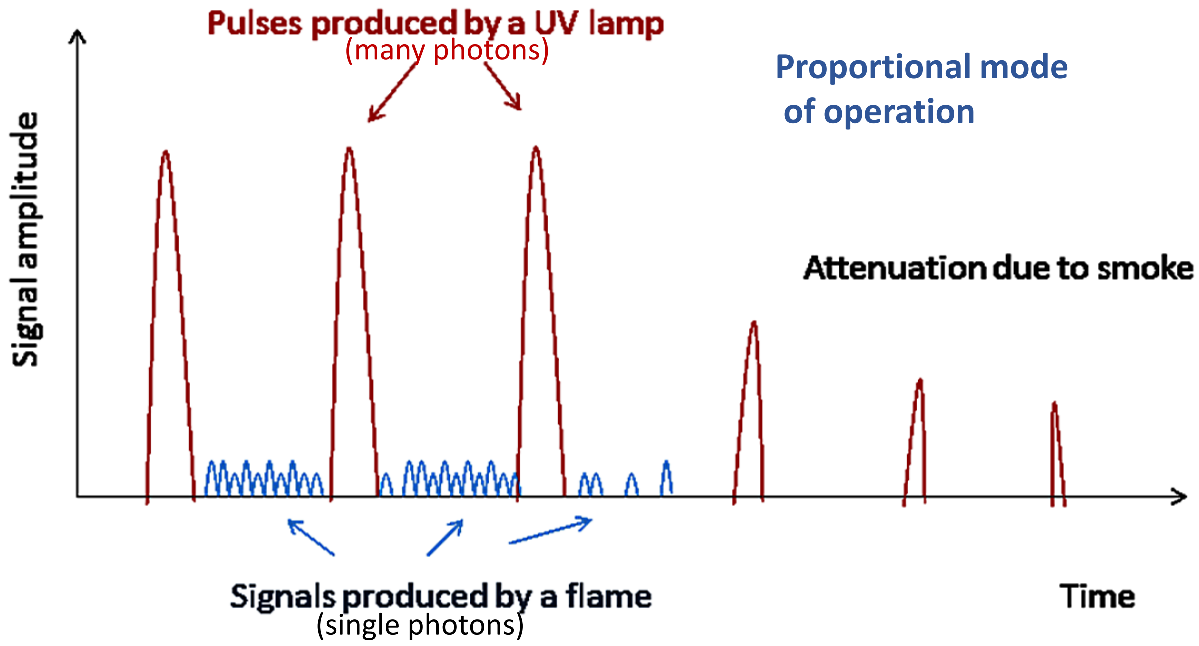
for SMART system

Novelty: simultaneous detection of flames, sparks and smoke

To our best knowledge, commercial high sensitivity smoke and flame detectors, do not exist

One of the features of our detectors is operation in proportional mode (most of commercial devices are digital). This opens new possibilities, for example, simultaneous detection of flames and smokes. The idea is demonstrated below:





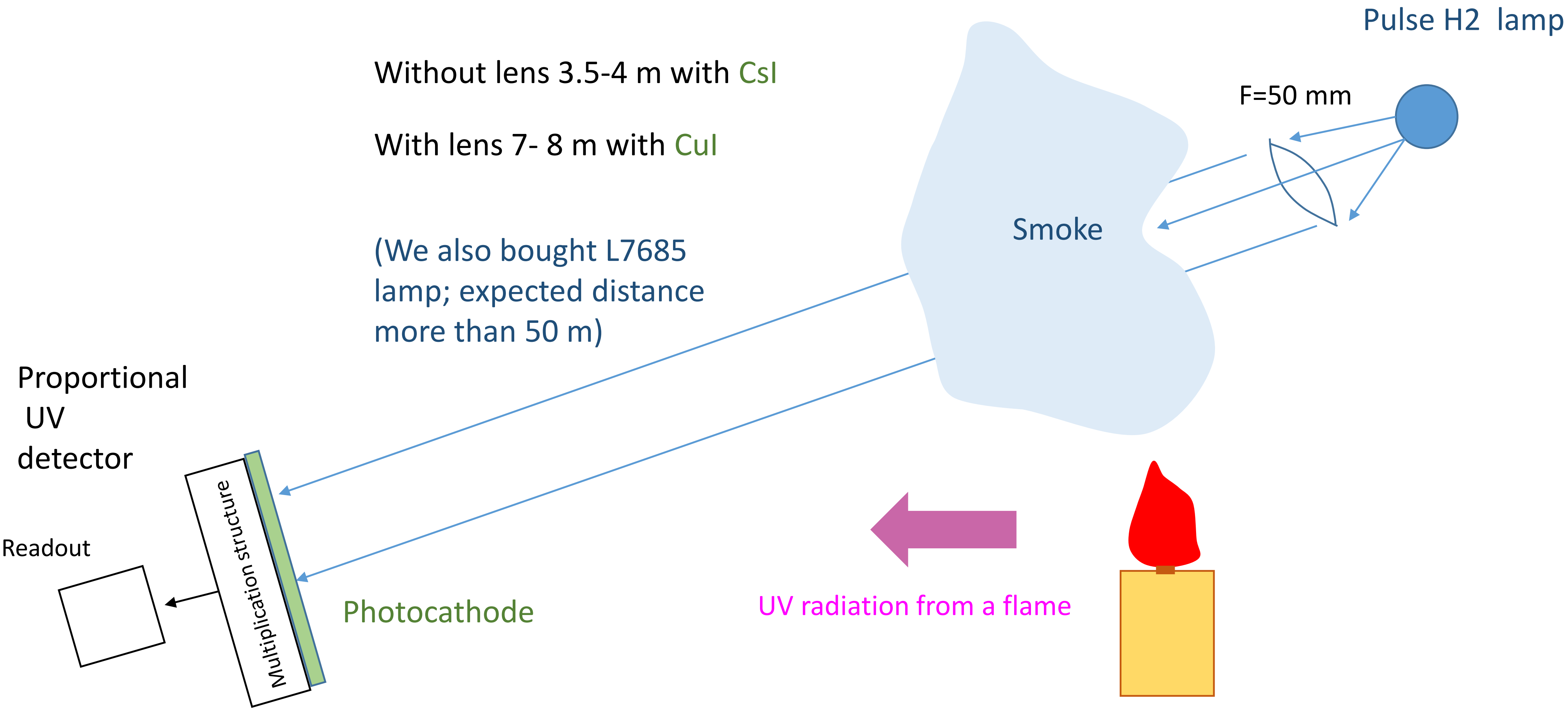
Expected distance of the smoke appearance monitoring is at least 10 times higher than the best commercial detectors have

Schematics of our experimental setup:

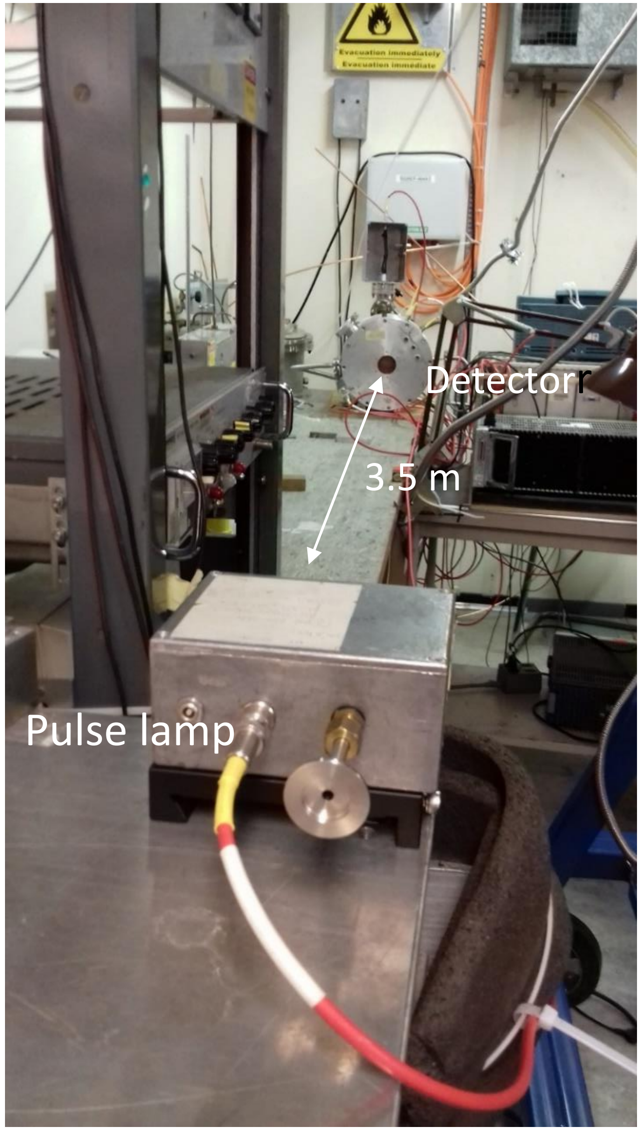
Without lens 3.5-4 m with CsI

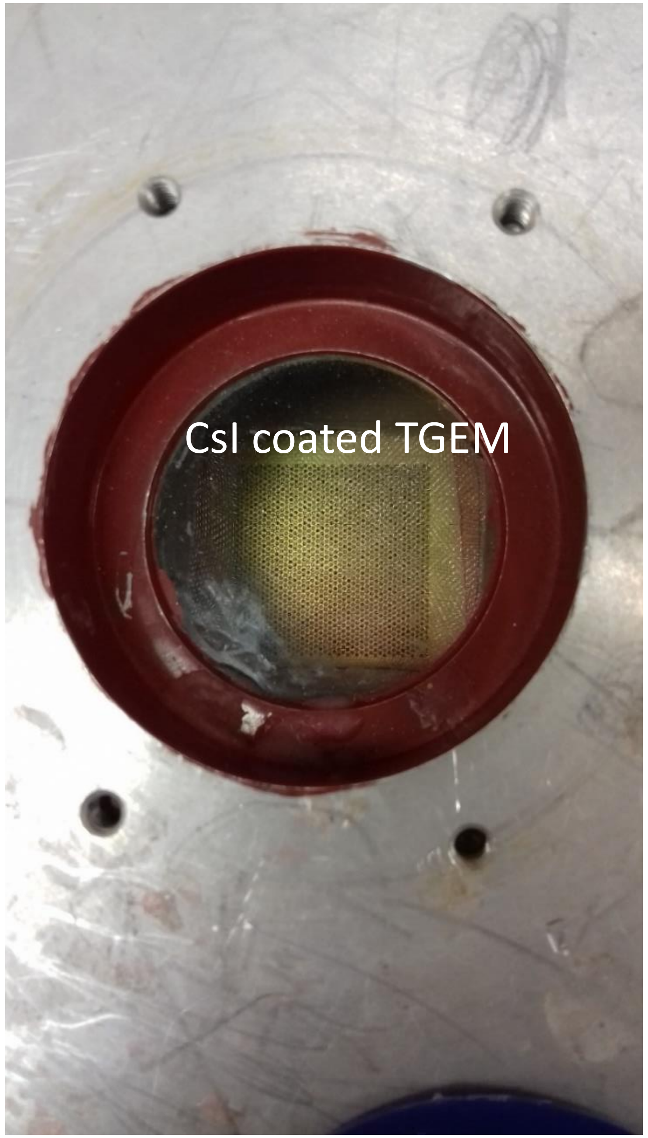
With lens 7- 8 m with CuI

(We also bought L7685 lamp; expected distance more than 50 m)



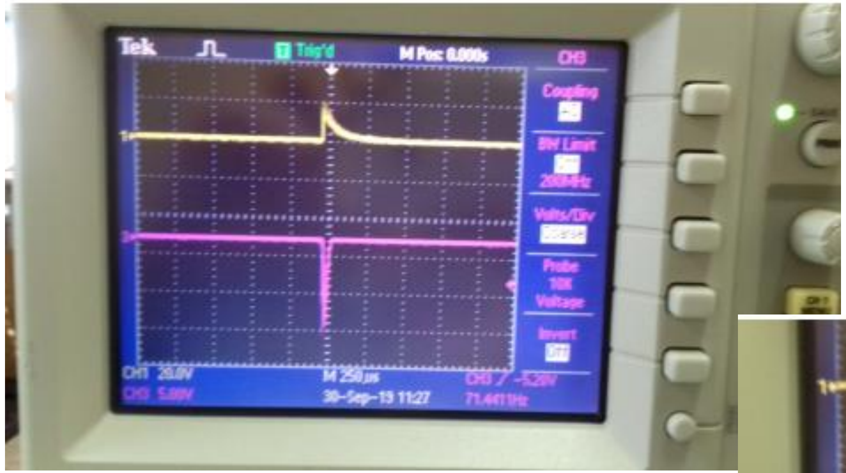
Photos of the setup



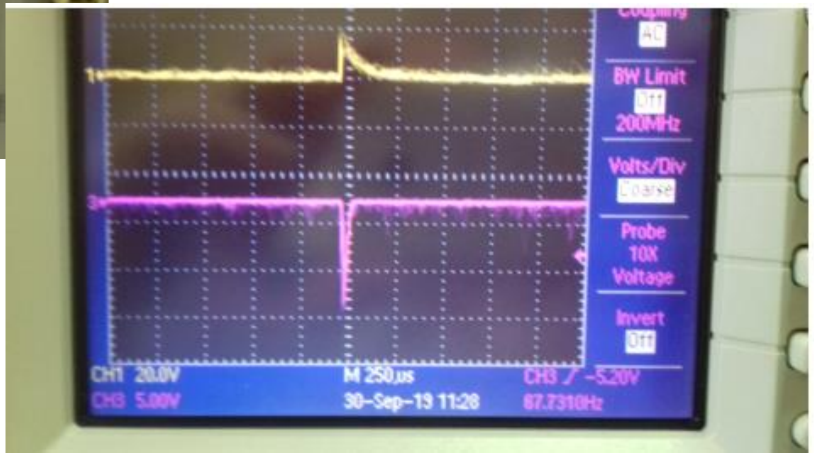


Pulses from the scope

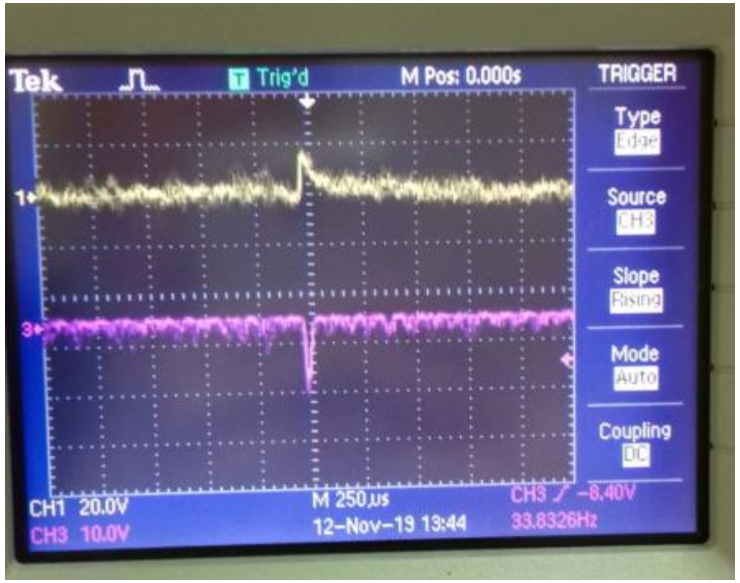
Distance between the lamp and the detector3.5 m,
no lens



Periodical pulses without flame

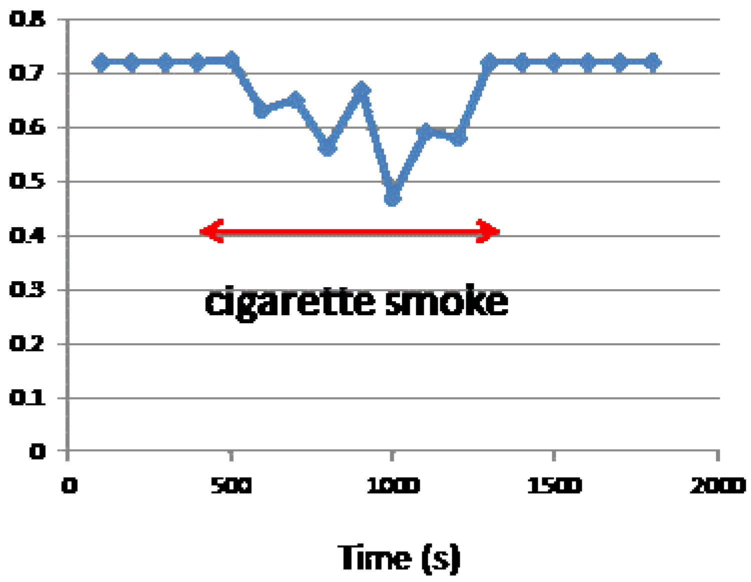


Signals from the lamp and a candle



Lamp signal attenuation due the smoke produced by a cigarette

Typical signal attenuation due to the light in density smoke

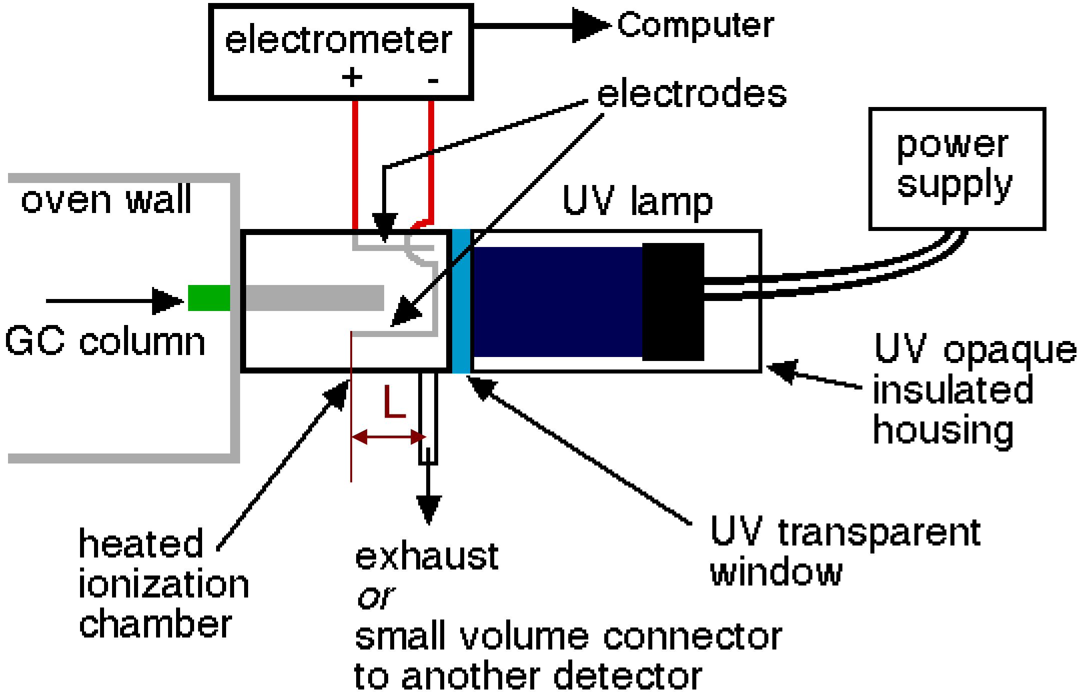


III. Detection of dangerous gases

for SMAR integrated system

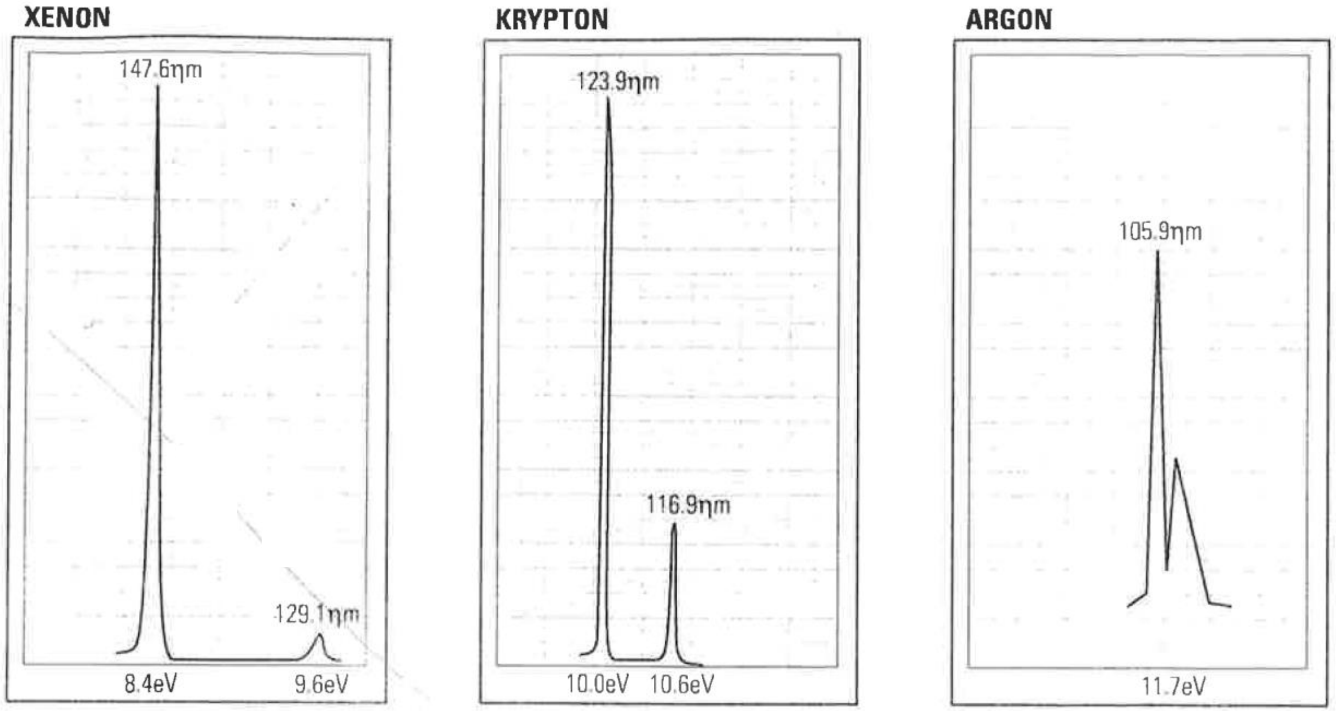
III. 1. Gases with small ionization potentials

What is known: commercial photoionization detectors of dangerous gases /flammable , combustive, toxic):



<u>Gases</u>: benzene, toluene and others
<u>Sensitivity</u>: in some cases up to 100 ppb (stationer devices)

List of used lamps and identified by them gases



1. *Gases detected by 9.5 eV lamp* such as benzene, aromatic compounds, amines. Xe lamp
2. *Gases detected between 9.5 eV and 10.6 eV* such as ammonia, ethanol, acetone. Kr lamp
3. *Gases detected between 10.6 eV and 11.7 eV* such as acetylene, formaldehyde, methanol. Ar lamp

In ionization chamber mode for the given geometry and the lamp power

the minimum measurable concentration is determine by the pA sensitivity

Our suggestion was to explore gas multiplication in air.

In this case the sensitivity is increasing proportional to the gas gain

The proof of principle was already done earlier*

*Charpak et al, NIM 628, 2011, 187
Charpak et al., IEEE Nucl. Sci. 5 , 2008, 1657

Schematic of the apparatus developed for SMART

1)

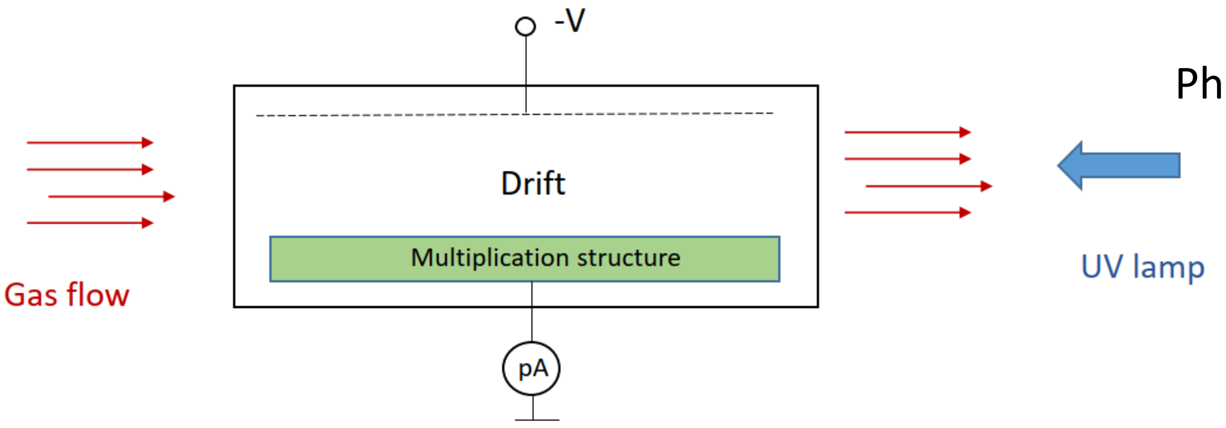
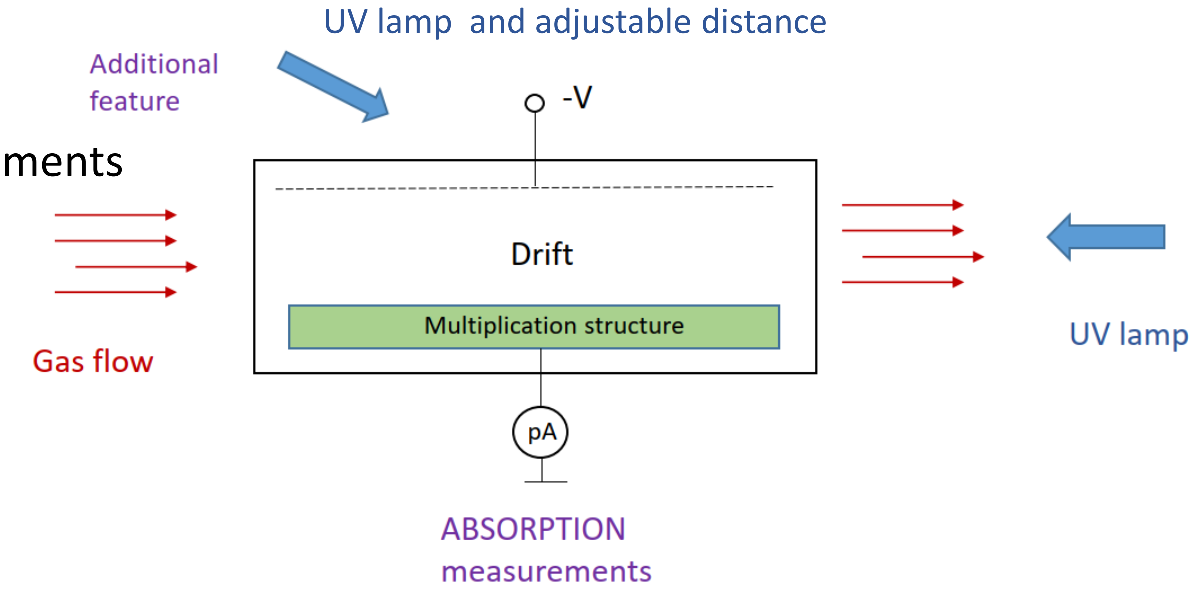


Photo ionization measurements

Absorption and ionization measurements

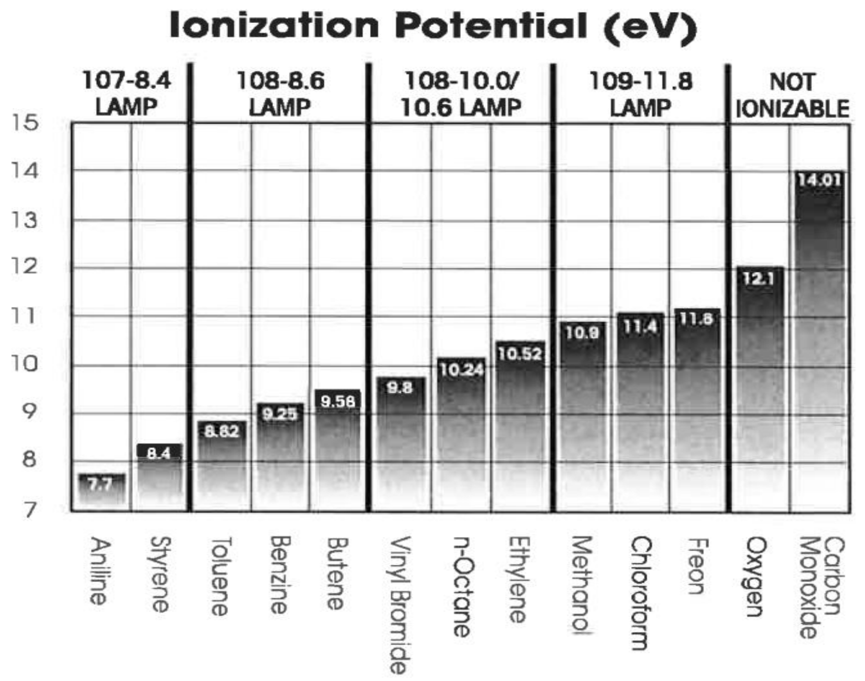
2)

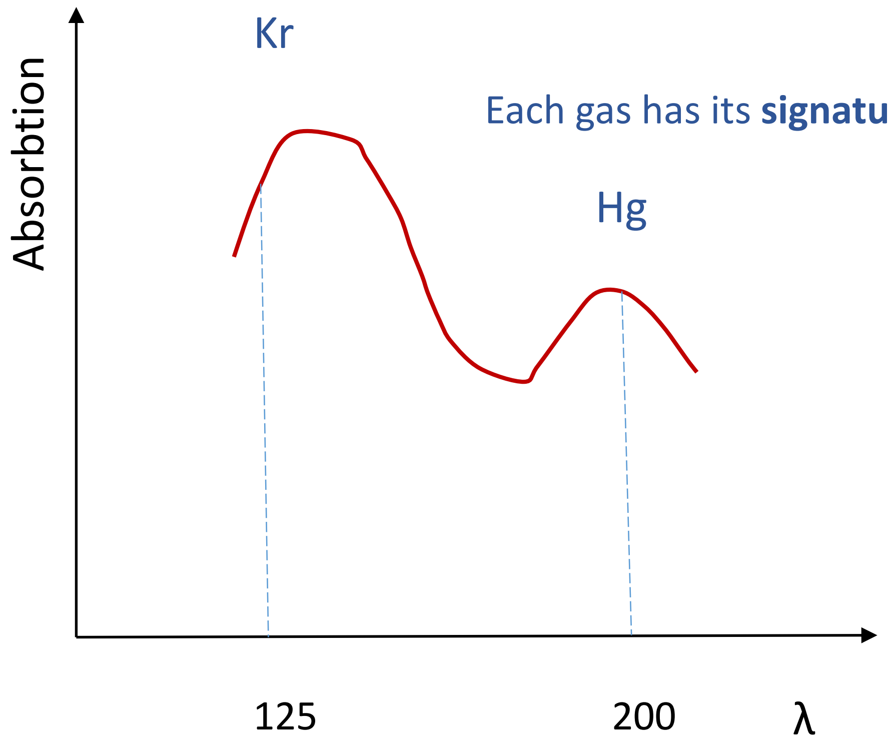


Multiplication structures tested:
GEM, MWPC , single wire

The idea behind the second apparatus was to inreach the known classification by ionization potential with classification by absorption

Example of gases identified by **photoionization**

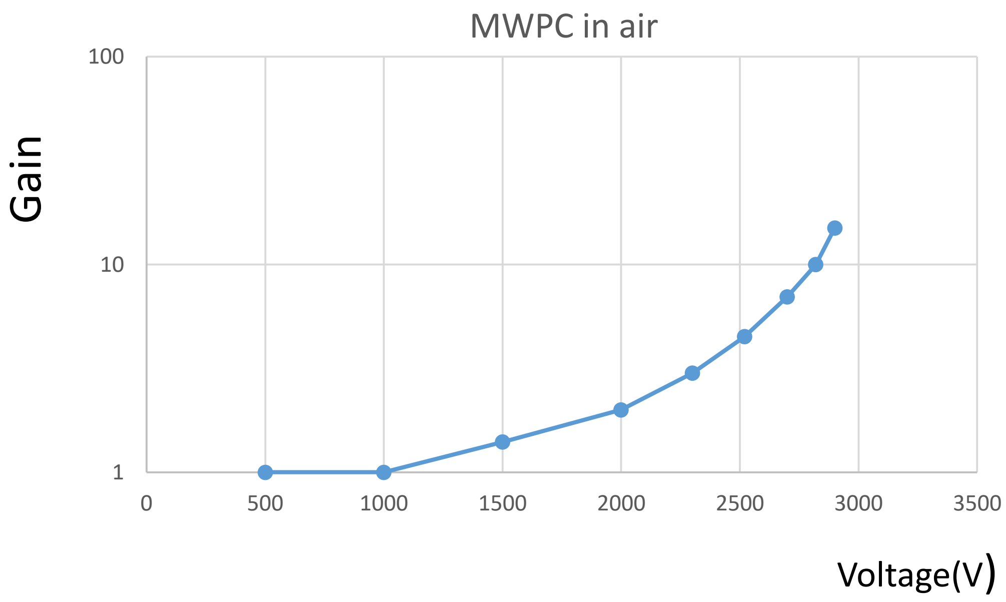


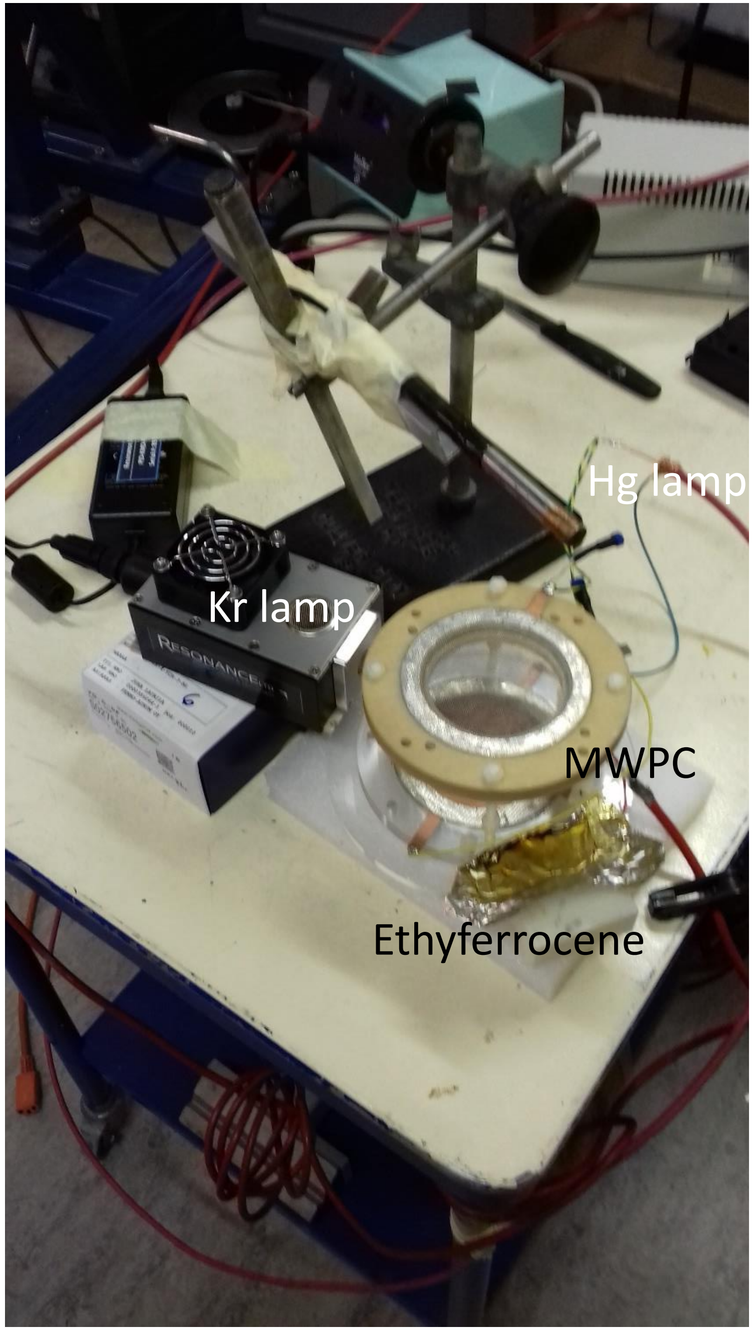


Preliminary results:

Vapuors	Ei (eV)	Ratio Kr/Hg
Methyl alcohol	10.85	1.2
Water vapours	13	14

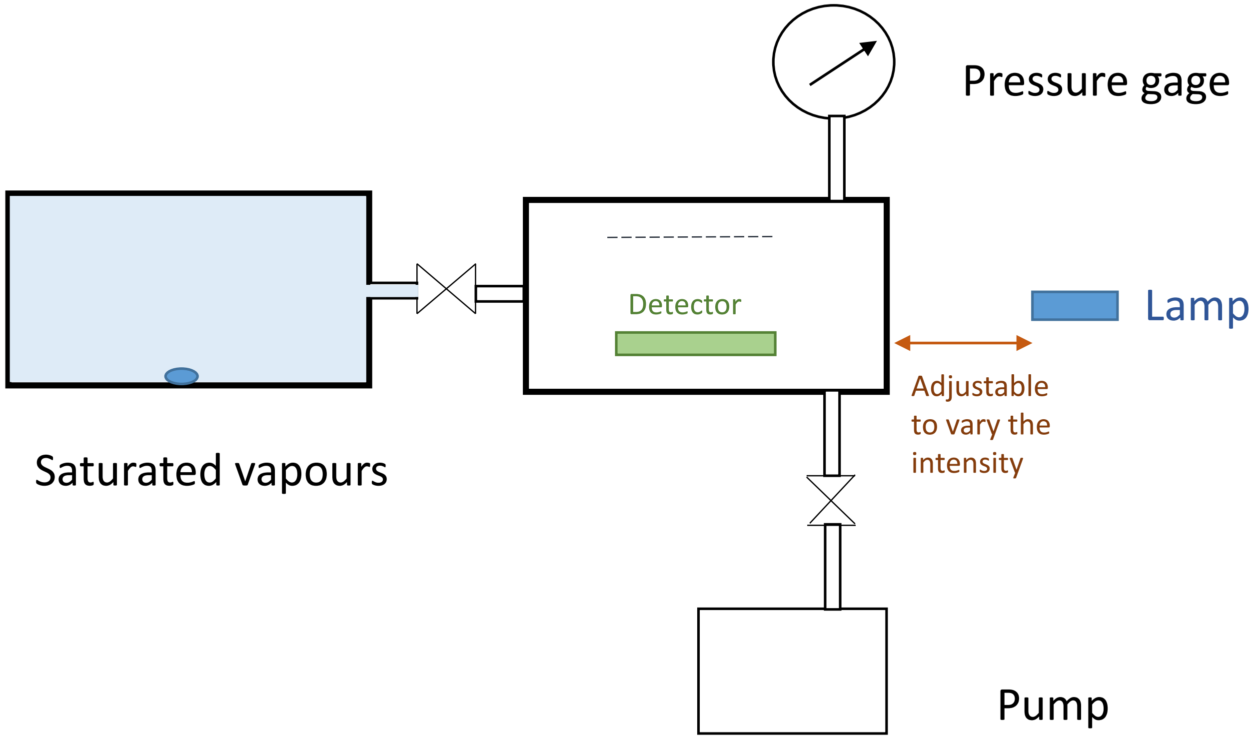
Preliminary tests in open air:





For more photos and videos see:
https://twiki.cern.ch/twiki/bin/view/SMART/WebHome

Setup for calibration:

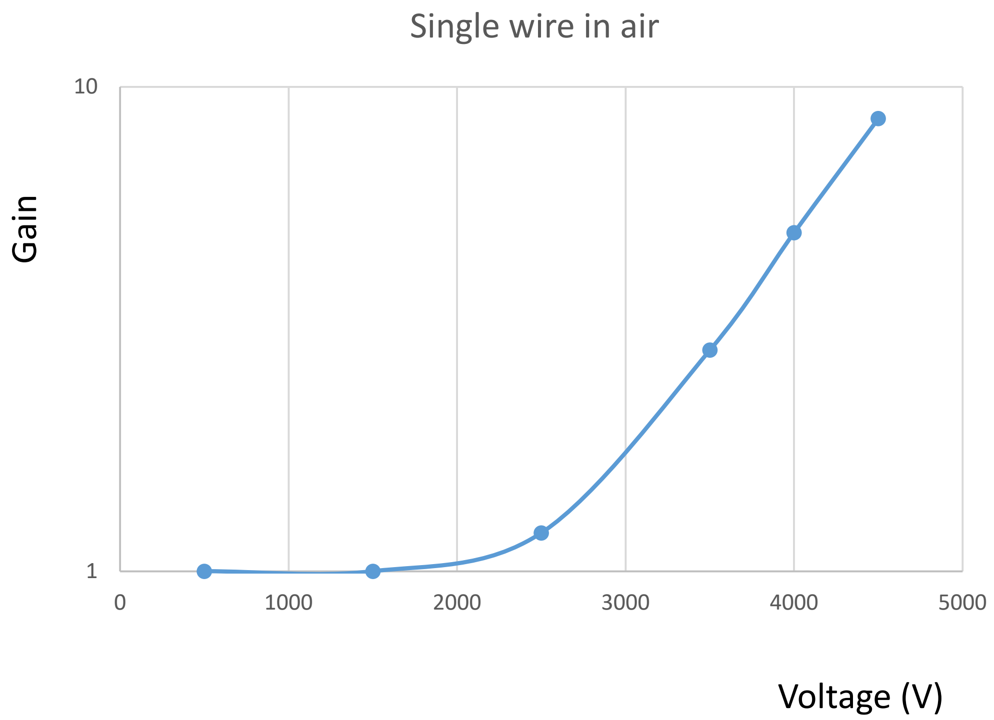


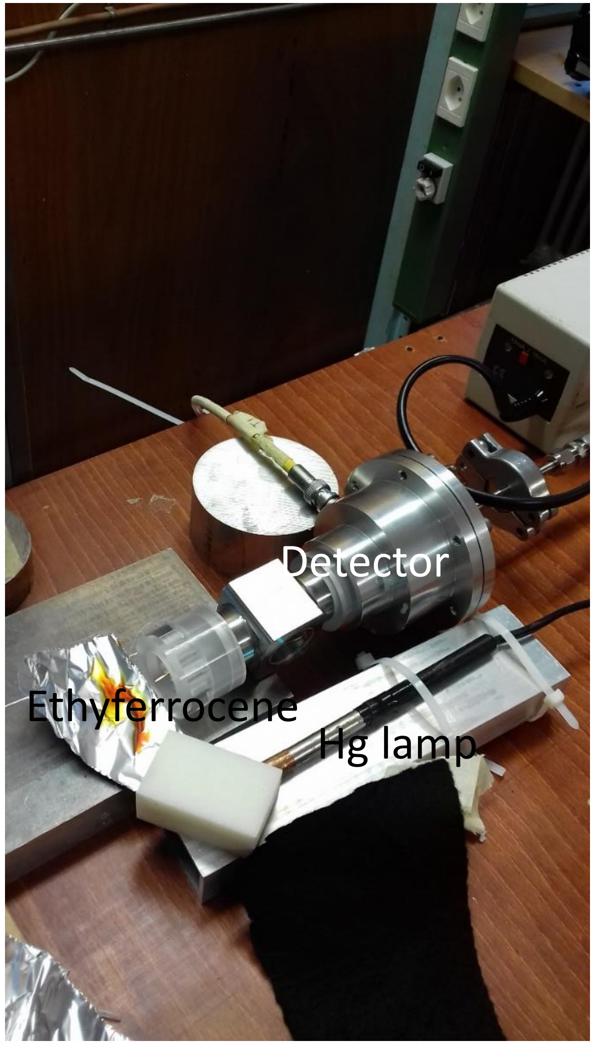
Several gas chambers
were used with
different detectors inside :
GEM,
MWPC
or
single-wire

III.1a. Single-wire option

Why do we need it?

Due to the geometrical feature this detector is capable operating at 100% humidity. Water vapours absorb UV, but cannot be ionized by the standard lamps (Ei=13 eV)

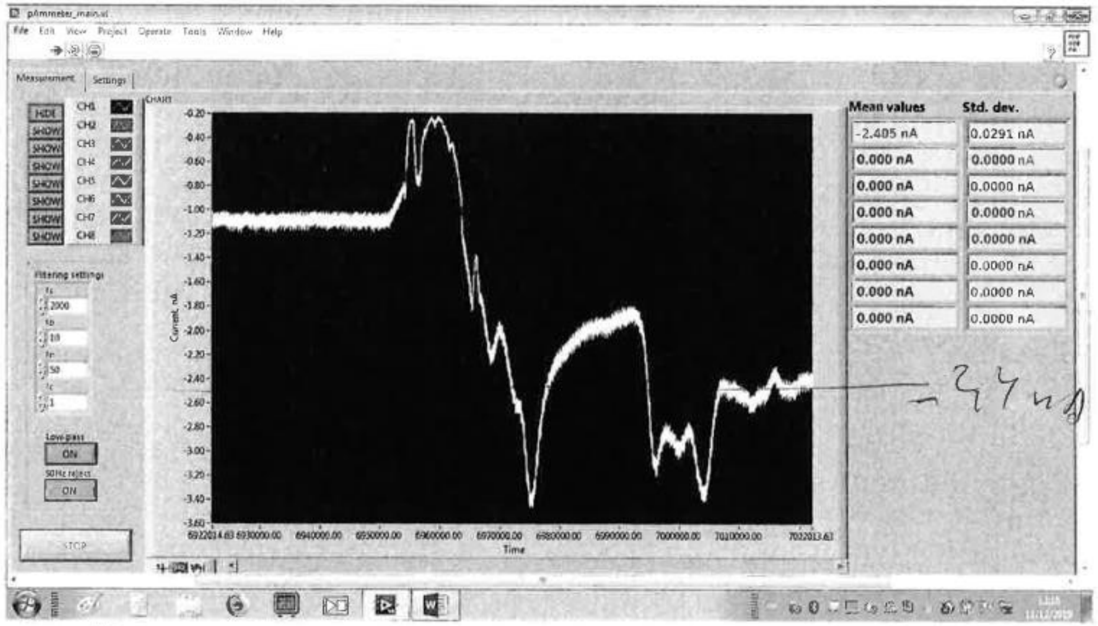


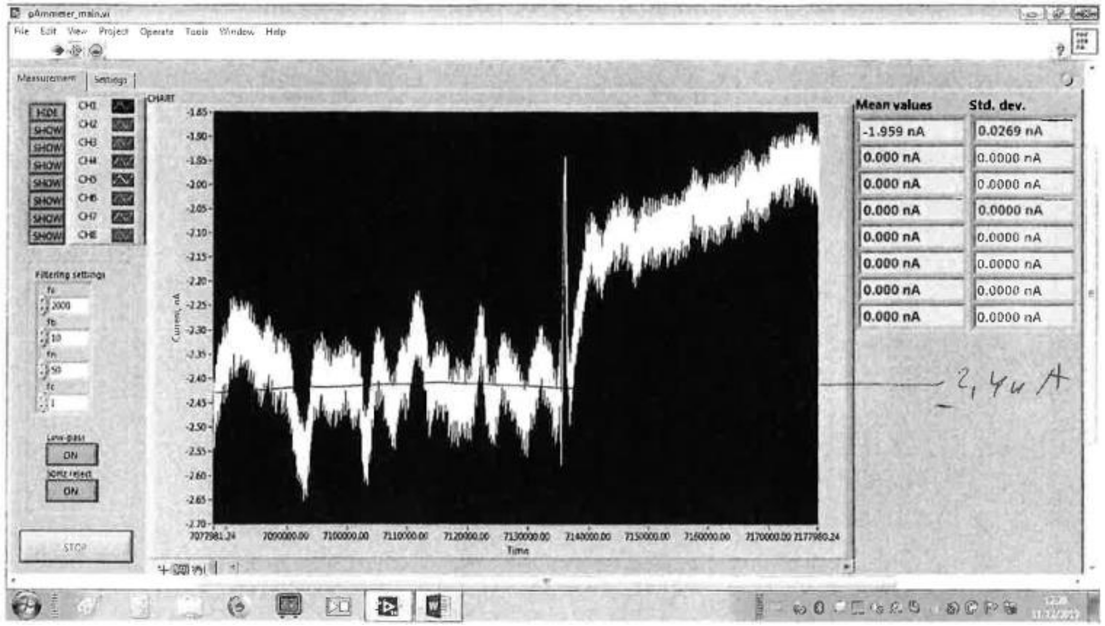


Hg lamp

Kr lamp

For voltages below 3.5 kV Zagreb floating pA was used





Examples of some preliminary results:

Two (they are very time consuming!) independent measurements with each vapours a

Ethylferrocene, Hg lamp

Gain	GEM*/ppm	MWPC/ppm	Single wire/ppm
1		0.4 ppm	2.5 ppm
8			0.03-0.04 ppm
10		0.06-0.08	
300	~ 0.1		

Typically at gain 10 background current due to the surface photoeffect was around 0,1-03 nA in air and minimum 1-2 nA with vapours

Kr lamp, Hg lamp

Gain	MWPC/ppm	Single wire/ppm
1	0.16	0.5
8		0.07
10	0.04	

There is no real statistics yet, however, qualitatively the trend/effect of gas gain clearly seen

Ethanol, Kr lamp

Gain	MWPC/ppm	Single wire/ppm
1	0.015-0.02	0.03-0.02
8		0.01-0.02
10	0.003-0.007	

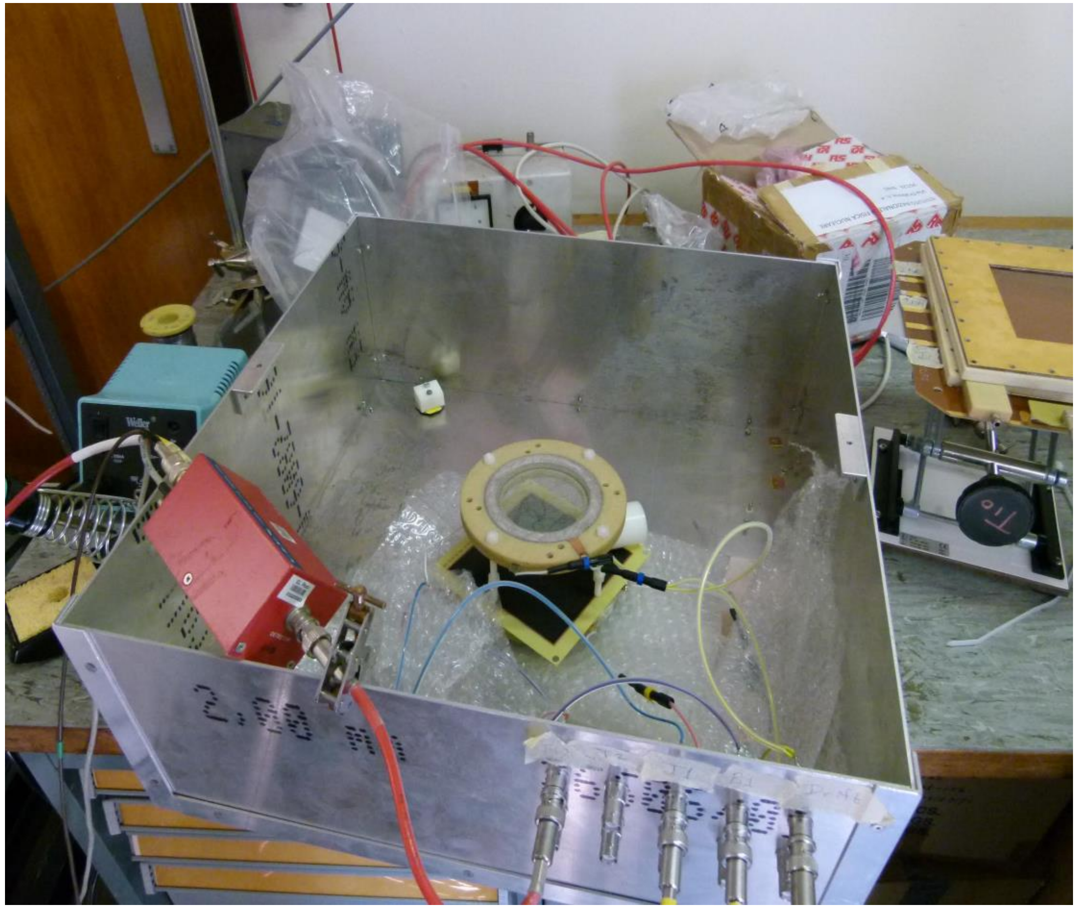
III. Detection of dangerous gases

III. 3. Rn

To the category of very dangerous gases falls also Radon

GEM-based Rn detectors were already tested by us earlier*

With RETGEM and special designed MWPC the minimum detection activity (MDI) achieved was ~50% of the best commercial devices (their cost is about 10-20 kEu!) and at least 10 times lower price



*Charpak et al, NIM 628, 2011, 187
Charpak et al., IEEE Nucl. Sci. 5 , 2008, 1657

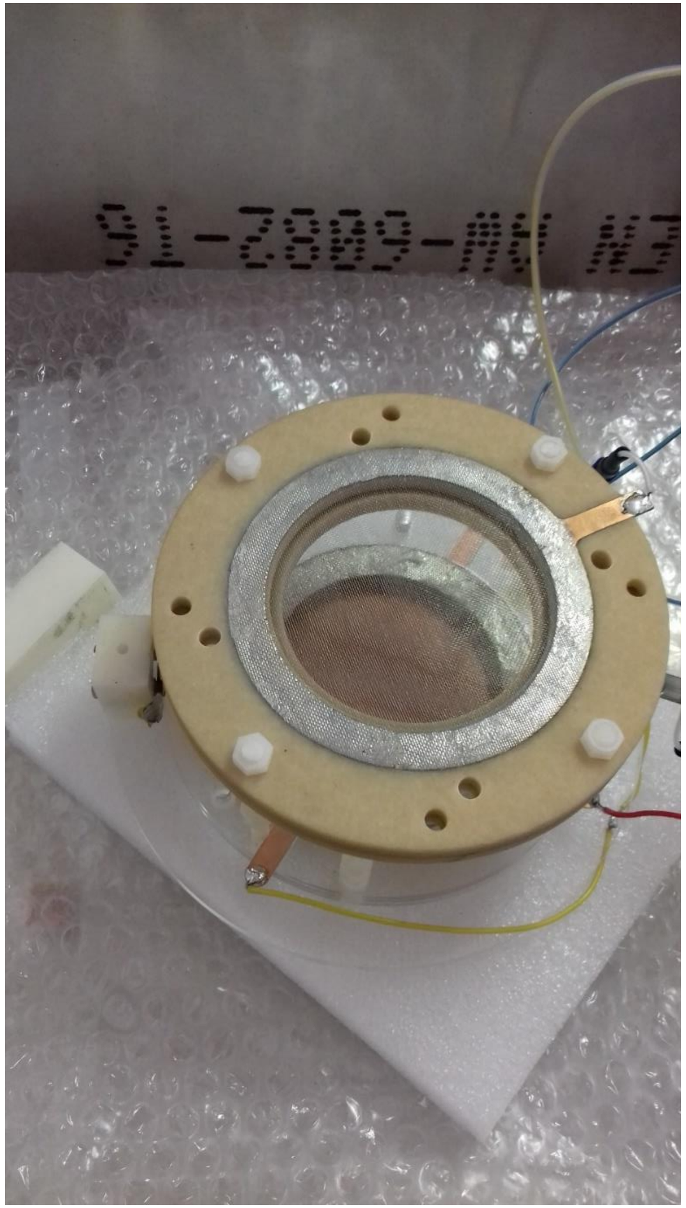
For SMART we also study Rn detection with standard MWPC

Advantages:

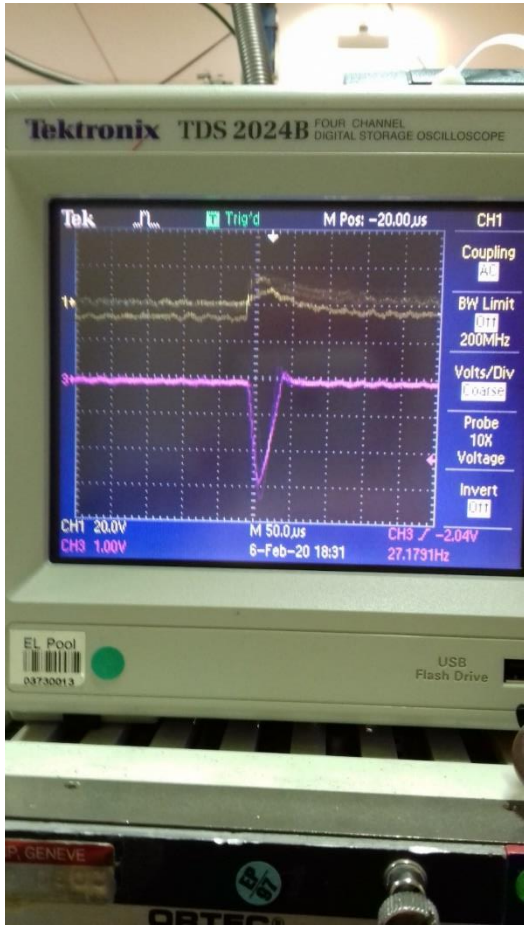
Relatively easy to build

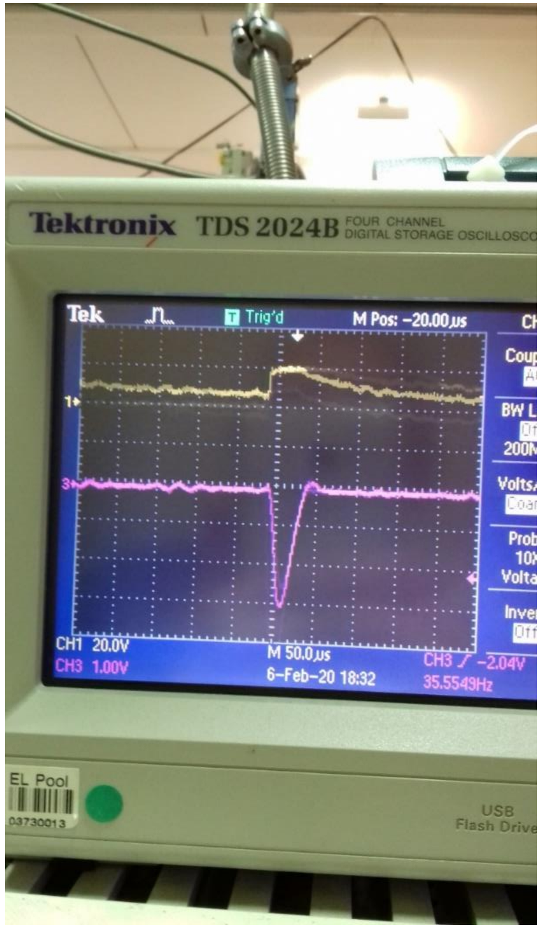
Does not requires RETGEM selection or wall-less TGEM

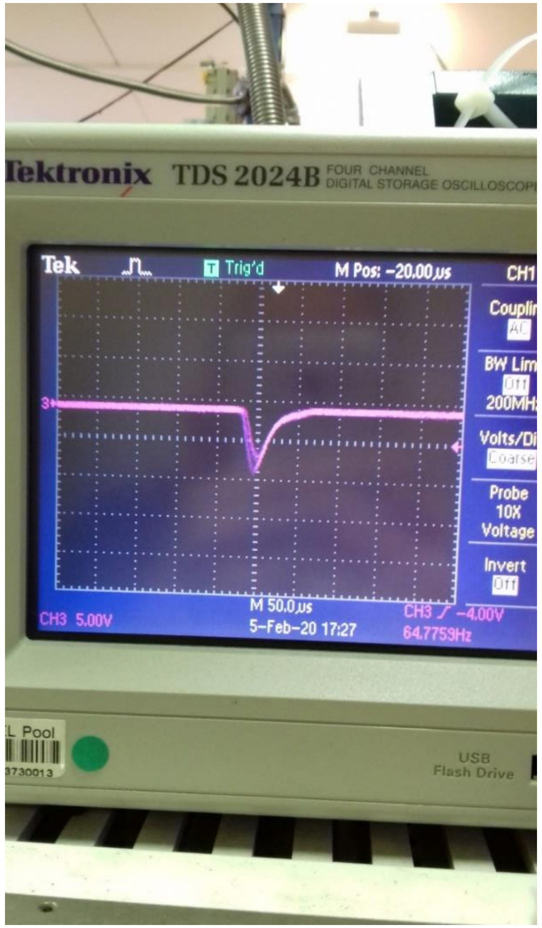
Offers lower operational voltage



In this work we tested another (compared to earlier work) MWPC option: with larger drift and with the possibility to remove progeny







Proportional mode
(up to Gain=3)

V

Saturated mode
(Gain > 7)

Conclusions

1. **High sensitivity** flat panel solar blind detectors of flame capable operating in wide range of temperatures were developed. They can detect candle light in direct sun illumination at a distance up to 15m
2. These detectors can record periodic UV pulses and this allows to detect simultaneously flames , sparks and smokes on a distance (currently) about 8 m
3. We progressed further with our avalanche detectors of dangerous gases. By combining avalanche mode with absorption measurements and after geometrical optimization sensitivity more than 10 times higher were achieved compared to commercial sensors
4. All our detectors have the same basic multiplication structure , but are multifunctional. This was one of the goals of SMART. The choice of the multiplication structure depends on a particular application
5. We developed prototypes of detectors of dangerous gases capable, in contrast to best commercial sensors, operate outdoor in 100% humidity air.
6. Commercial versions of some of these detectors with compact battery fed electronics and HV modules are under the developments by the Finish company Fenno-Aurum

Therefore, **prototypes of all sensors**, fitting the requirements of the SMAR integrated system, **were developed and are under the tests now**.

For more information see: *https://twiki.cern.ch/twiki/bin/view/SMART/WebHome*
There are some photos and videos

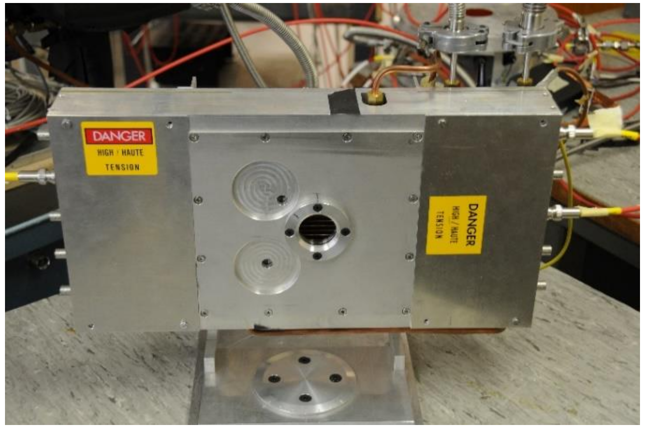
Nearest plans:

1. Flame and smoke visualization using chamber with RETGEMs, (which earlier recorded Cherenkov rings)

(ATTRACT collaborators from CERN and Bari University will take care about electronics updates)

2. Integration our detectors to the CERN REMUS sensors network

(ATTRACT collaborators from CERN and Bari University are working on it)



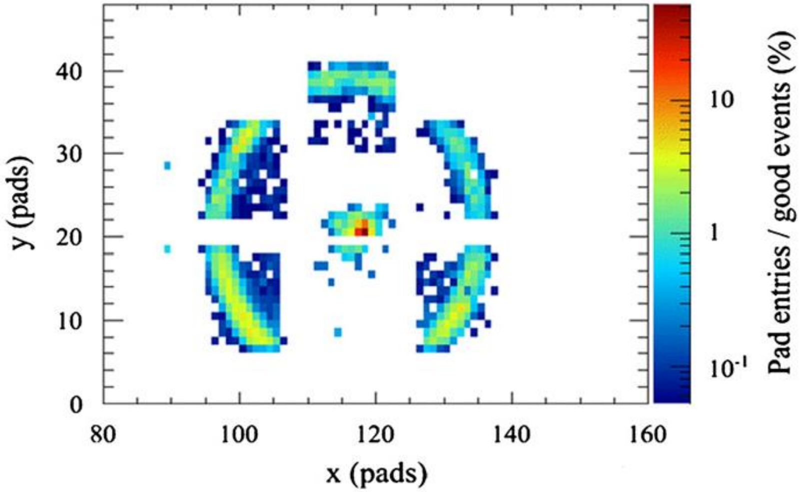


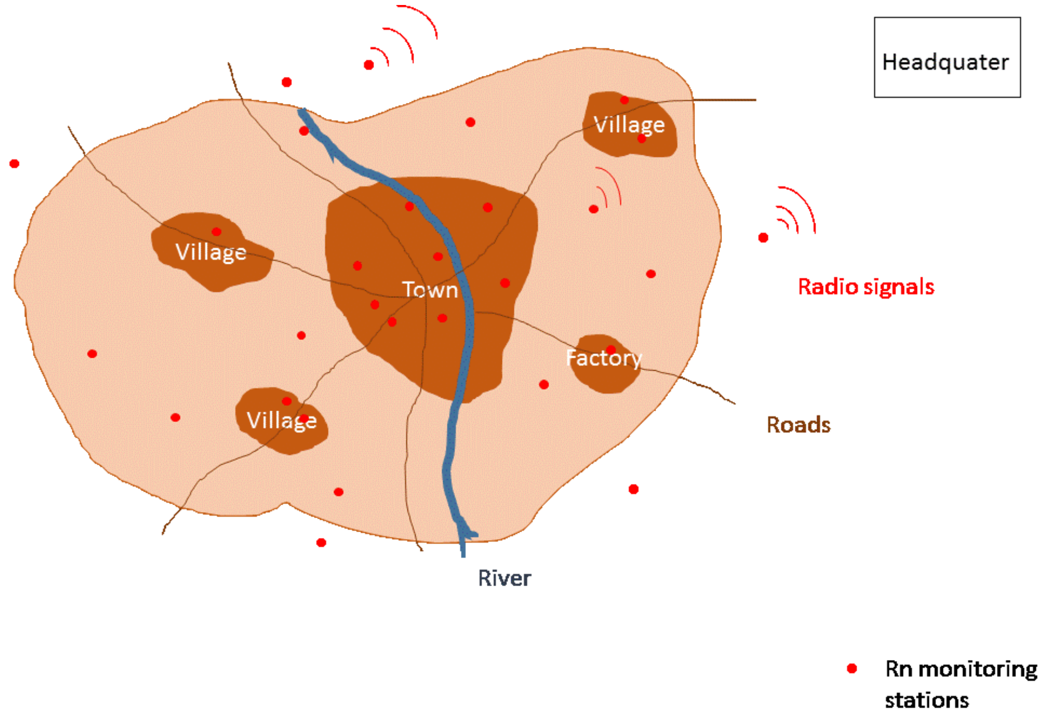
Fig. 3. Detected Cherenkov ring (integrated events) in the recent November 2010 beam test at CERN in Ne+10%CH_4. The “spot” in the center represents MIPs (6 GeV/c pions) detected by the central TGEM.

Peskov et al., NIM A695, 2012, 154

We also consider some related outdoor applications,

in particular earthquake prediction with the help a network of low cost Rn detectors

Rn detector for earthquake prediction
Fire detection and visualization
UV Hyperspescroscopy

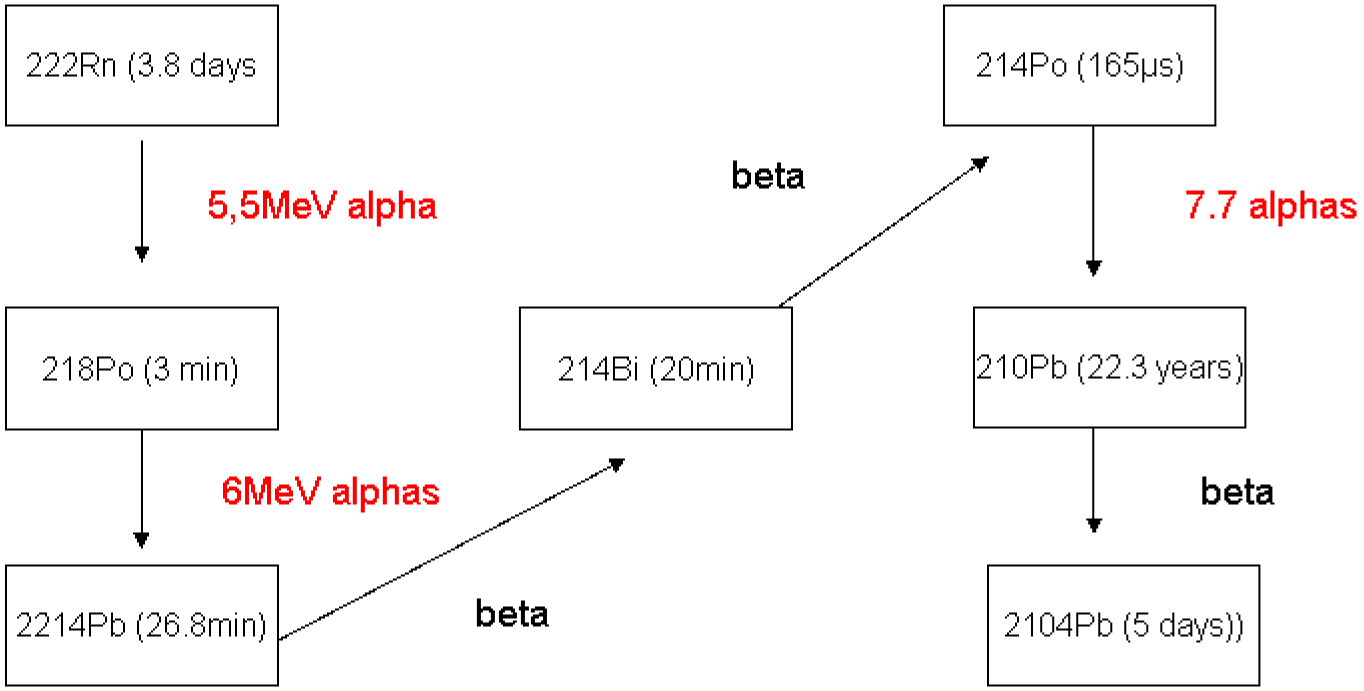


Backup

General Conclusions

1. Prototypes of all sensors fitting the requirements of the integrated system were developed and are under the tests now.
2. Preliminary results prove their high sensitivity
3. All sensor could have one basic flat panel designs-MWPC or GEM bases-, which is attractive in the case of their mass production
4. We stat working on their integration

For more informationsee our Twiki page https://twiki.cern.ch/twiki/bin/view/SMART/WebHome
.There are some photos and videos


222Rn (3.8 days
5,5MeV alpha
218Po (3 min)
6MeV alphas
2214Pb (26.8min)
beta
214Bi (20min)
beta
214Po (165µs)
7.7 alphas
210Pb (22.3 years)
beta
2104Pb (5 days))