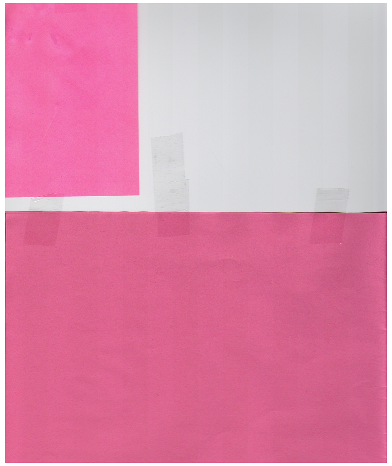
# Part-XIV

## Environmental applications of gaseous detectors

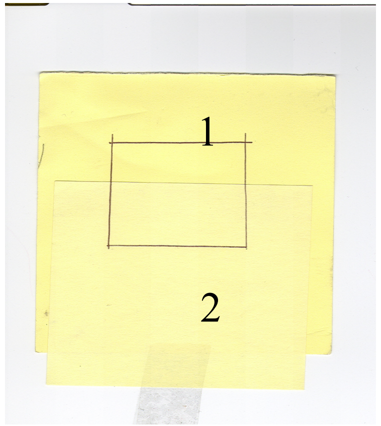
# Hyperspectroscopy

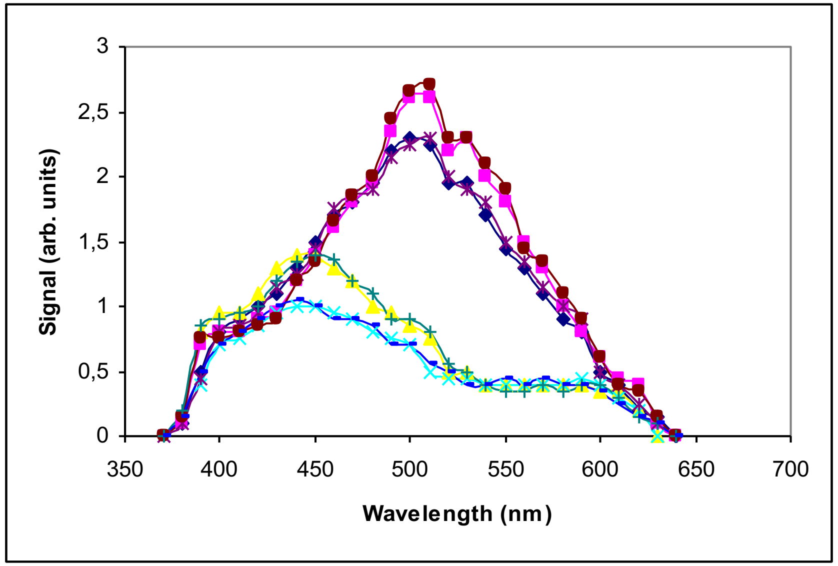
# Traditional spectroscopy

Two rose papers



Two stickers: "light" yellow and "dark" yellow

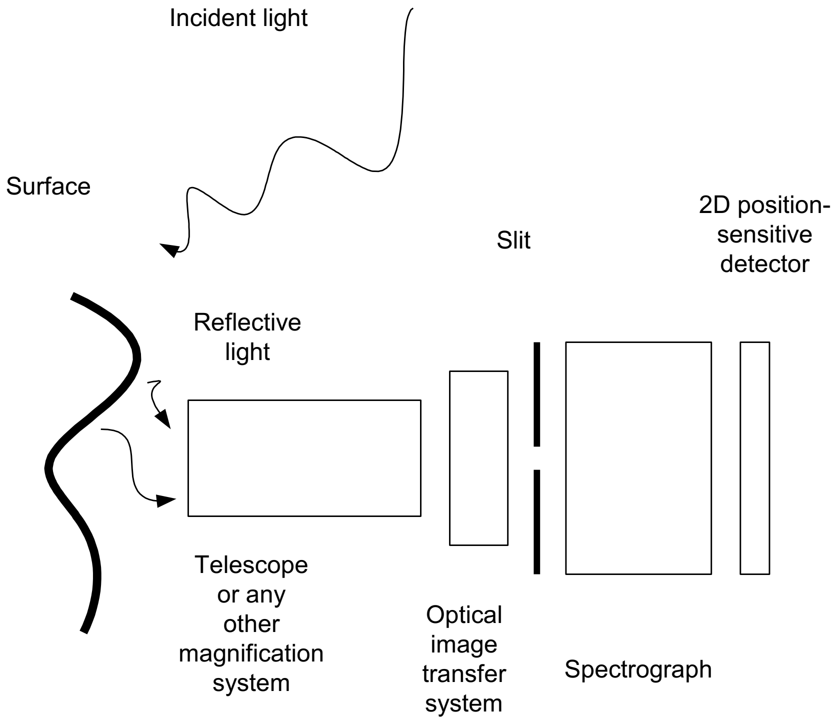


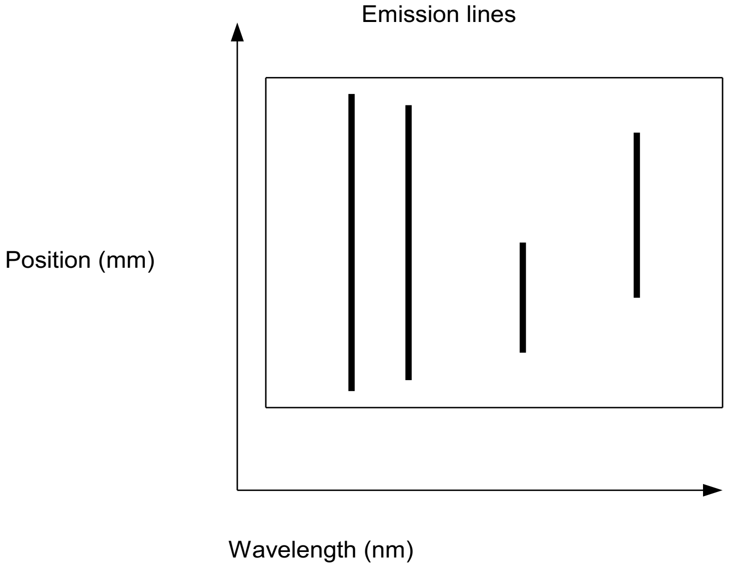

Spectrum of colour papers measured wth a PMT

# Principle of the Hyperspectroscopy

**Schematic view of the device**

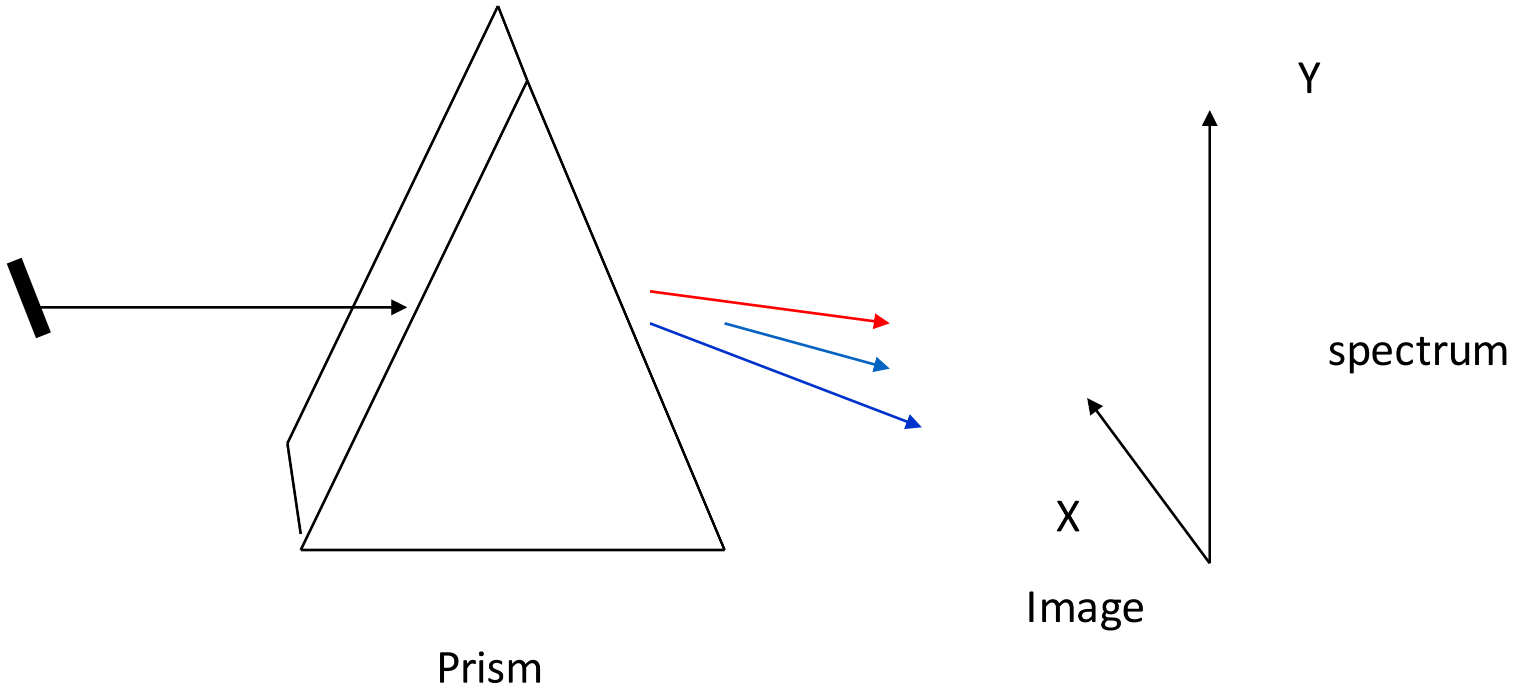



**Example of the image in the focal plane of the spectrograph**

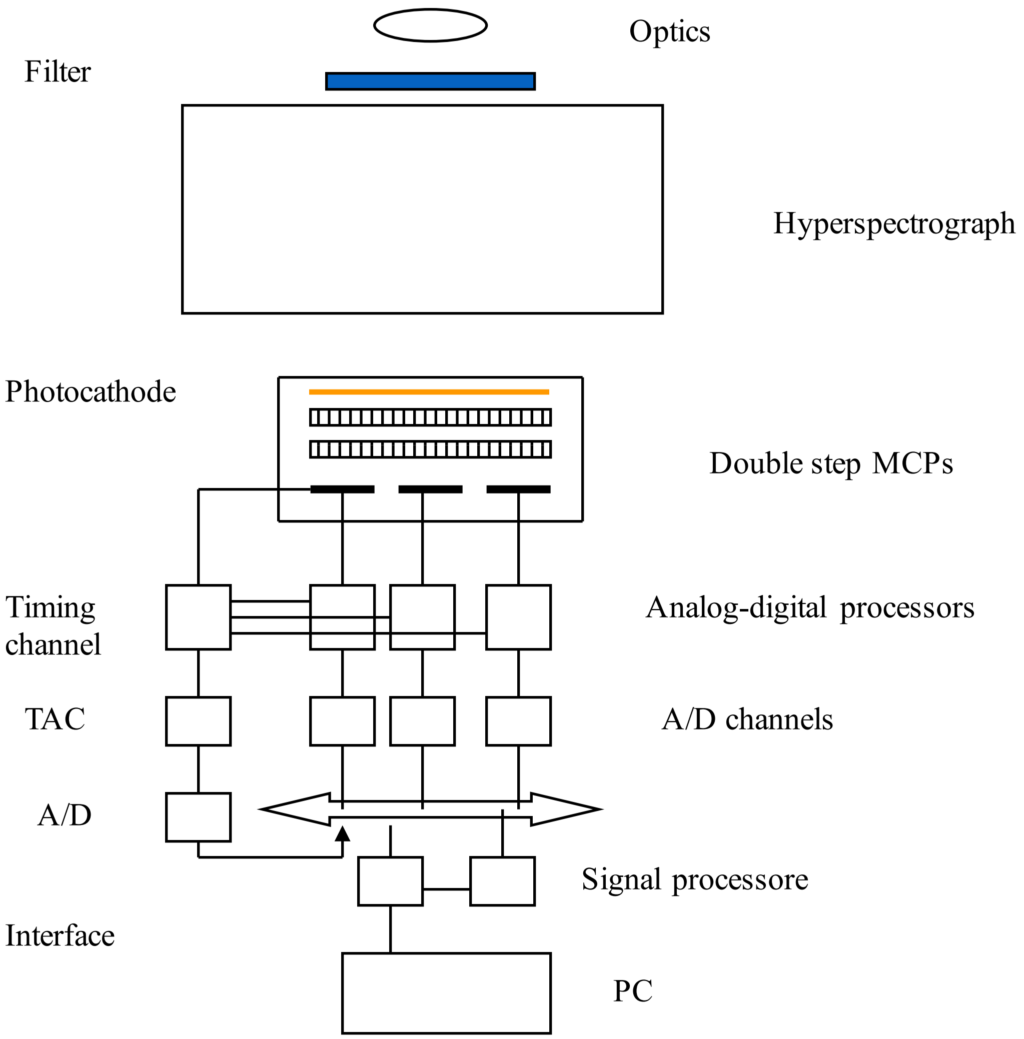



The device contains a telescope (or any other optical magnification system) focusing the surface image (illuminated by daylight or with light having special designed spectra) to a compact spectrograph. In the focal plane of the spectrograph a 2d photosensitive detector is placed. It is allows to get spectra and at the same time an image along the input slit. Scanning with the telescope l allows to obtain a 2d position picture with simultaneous spectra of each point along a line of the surface.

## A simple illustration of the hyperspectroscopy principle

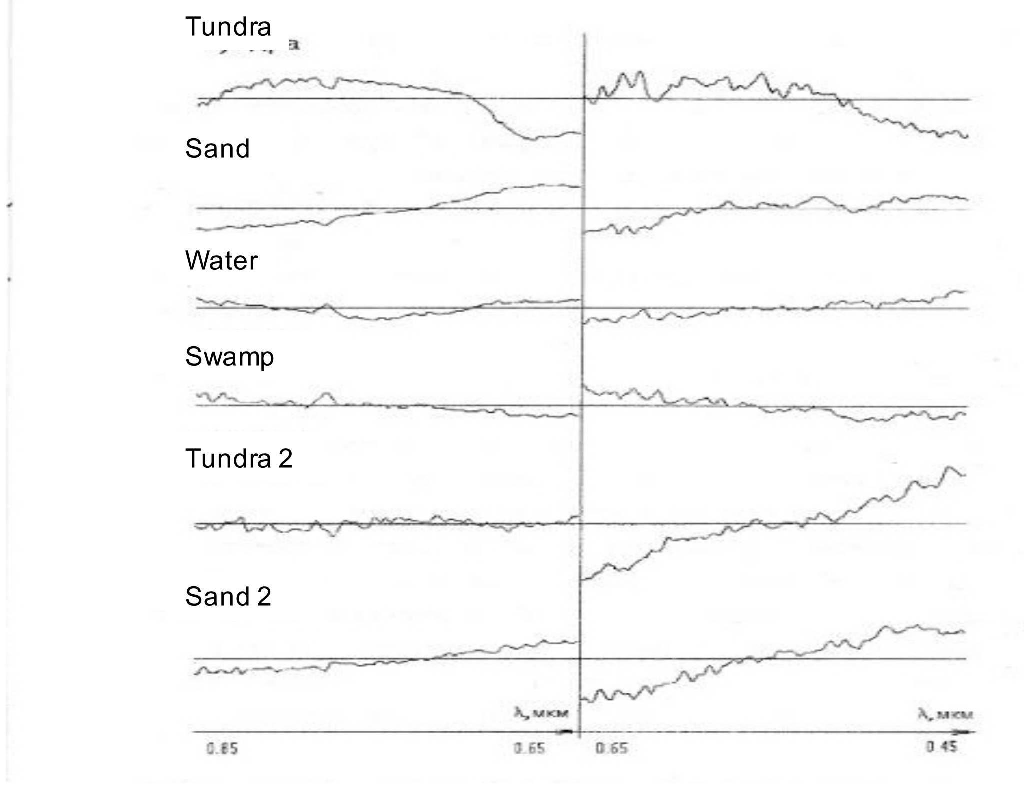


# Advanced detectors and readout technique developed by Reagent Company

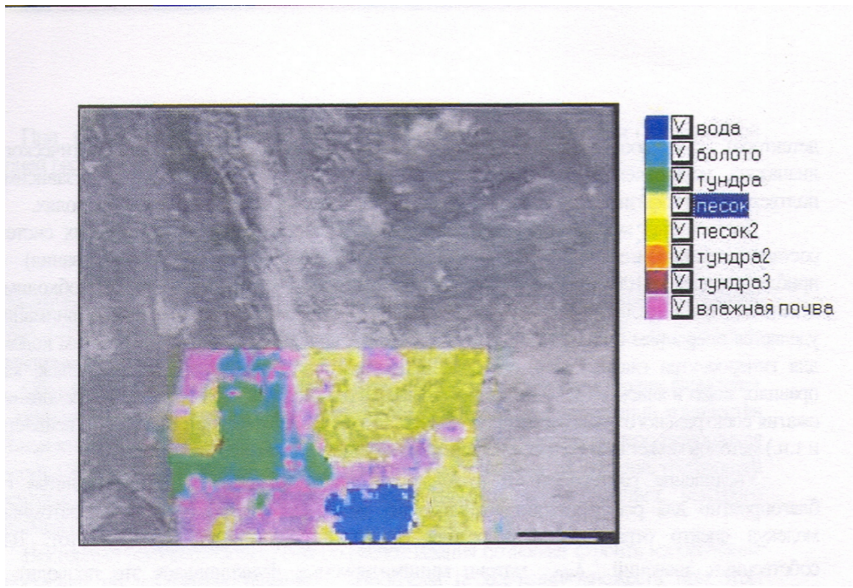


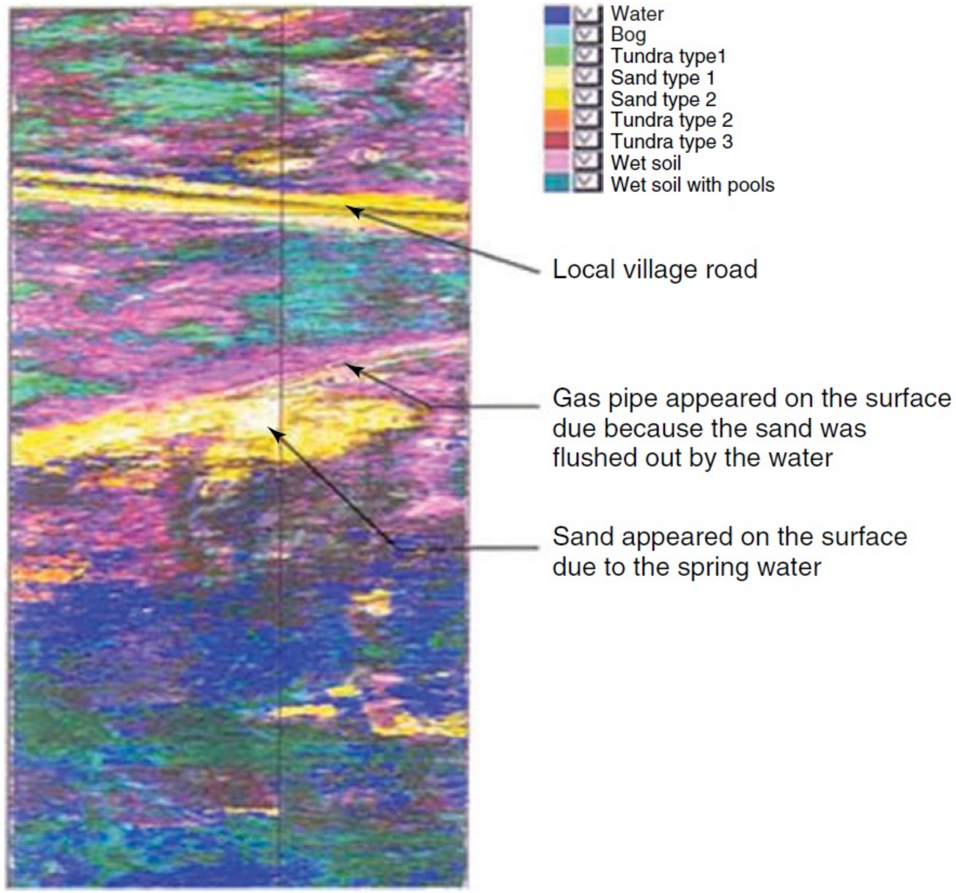
# Emission spectra of some materials

Each material on the earth surface has it's own emission spectra and this allows to recognize materials on the surface images (like water, sand, oils spills, etc.). It is difficult or impossible to obtain the same information without a spectral analysis)



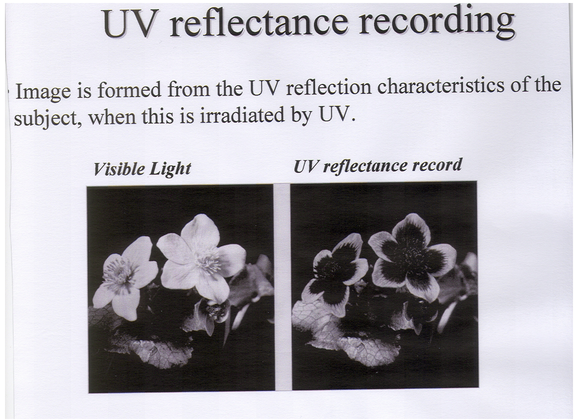
# Environmental applications: results in IR and visible spectra obtained with MCPs

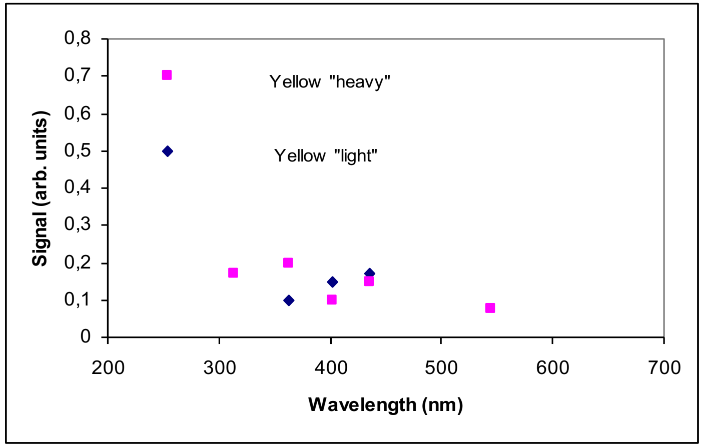


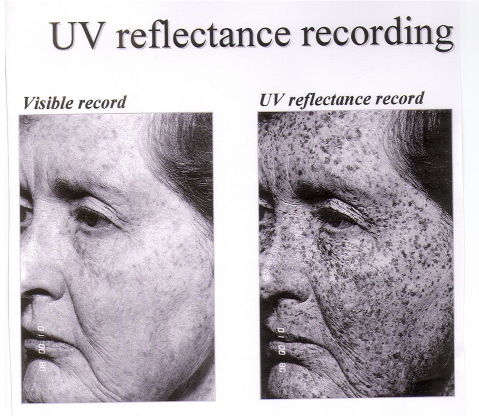

•**The Reagent Research Center in Moscow developed and used this method for the analysis of earth surface. For example, it is used now for Gasprom Inc. tasks: observation of oil pipes and spills from planes and helicopters**

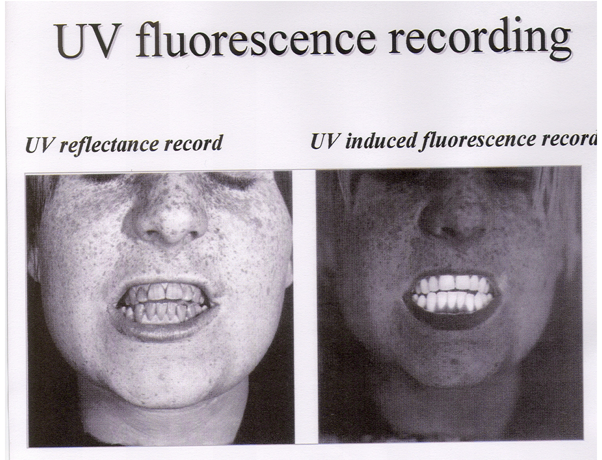
# Necessity for UV



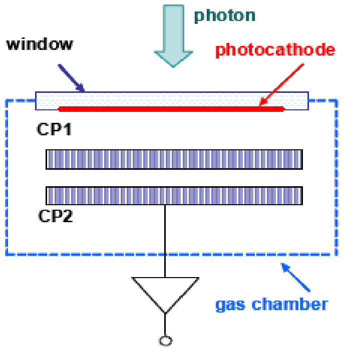

UV spectra of the shown earlier yellow stickers, measured with a PMT



# Gaseous photodetectors sensitive to UV and visible light

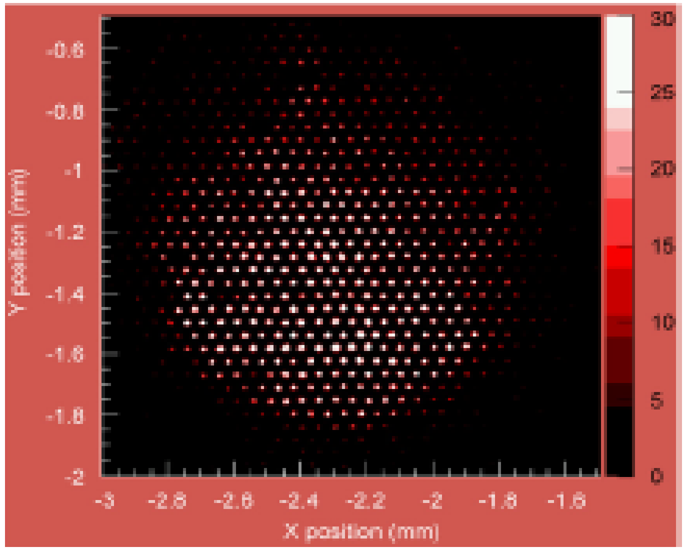
Advantages: large area (no mechanical constrains on window size), high quantum efficiency, practically insensitive to magnetic fields, position resolution is approaching of the best MCPs




V. Peskov, IEEE TNS, 47, 2000,1825

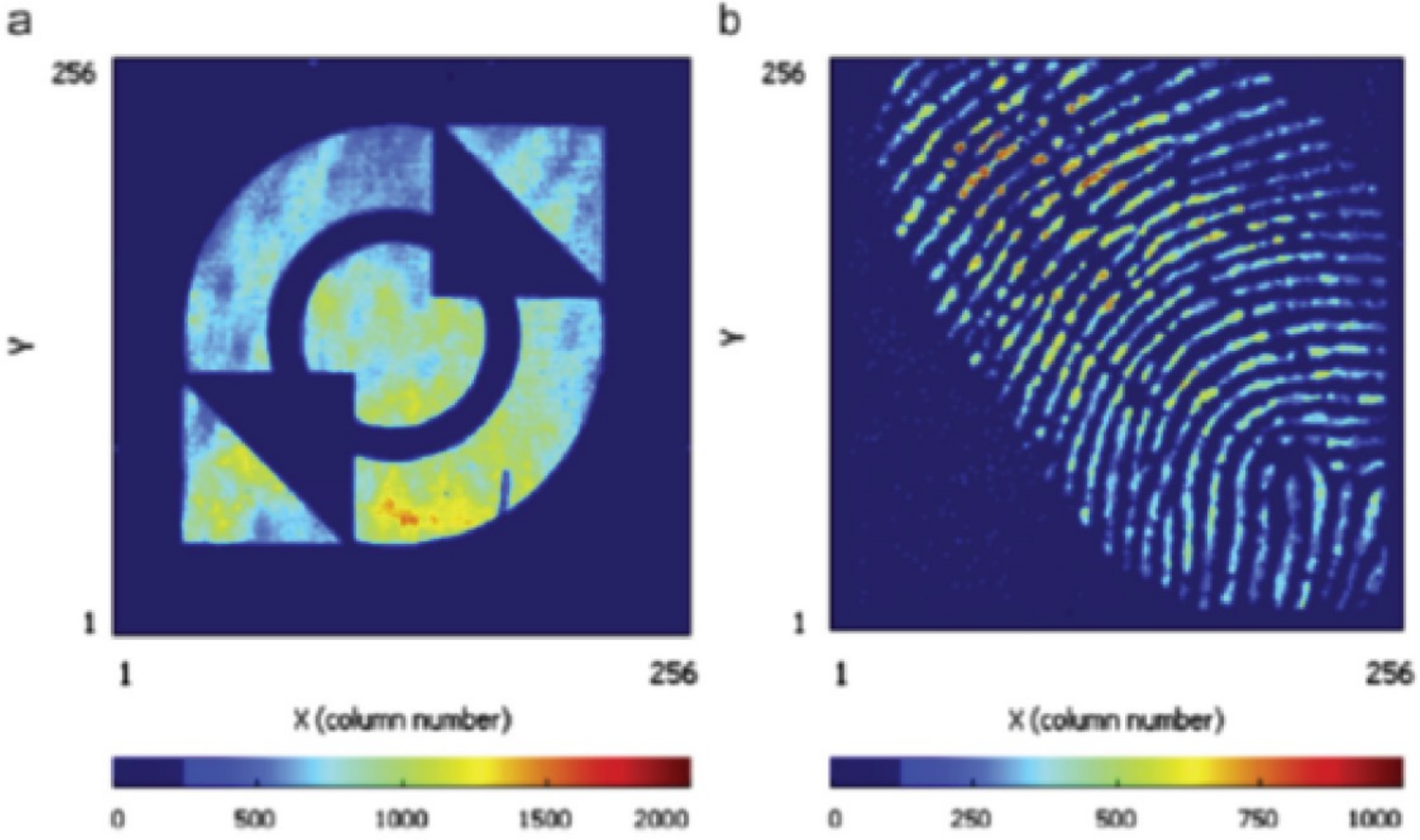
R. Chechik, et al.,

NIM A595, 2008 116




R. Bellazzini et al., NIM, A581, 2007,246

Position resolution much better than 50μm, (approaching 4 μm)


a
256
Y
1
1
256
X (column number)
0
500
1000
1500
2000
b
256
Y
1
1
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X (column number)
0
250
500
750
1000

# Application in environmental monitoring and in health alarm systems

# Flame detection

**Violent forest and bush fires in South Europe, Australia, USA and other countries worldwide bring in danger human lifes, destroy properties, damage the environment**

## The lost of forest due to the fire in Europe in the period of 1971-2000

*(from J. Goldammer et al, presented at the International Conference "Fire and emergency safety", October 202 , Bulgaria)*

| Country | Time period | Average number of fires | Total area burned, ha |
|---|---|---|---|
| Albania | 1981-2000 | 667 | 21456 |
| Algeria | 1979-1997 | 812 | 37037 |
| Bulgaria | 1978-1990<br>1991-2000 | 95<br>318 | 572<br>11242 |
| Cyprus | 1991-1999 | 20 | 777 |
| Croatia | 1990-1997 | 259 | 10000 |
| France | 1991-2000 | 5589 | 17832 |
| Greece | 1990-2000 | 4502 | 55988 |
| Israel | 1990-1997 | 959 | 5984 |
| **Italy** | **1990-1999** | **111163** | **118576** |
| Lebanon | 1996-1999 | 147 | 2129 |
| Morocco | 1960-1999 | n.a. | 2856 |
| Portugal | 1990-1997 | 20019 | 97175 |
| Romania | 1990-1997 | 102 | 355 |
| Slovenia | 1991-1996 | 89 | 643 |
| Spain | 1990-1999 | 18105 | 159935 |
| Turkey | 1990-1997 | 1973 | 11696 |

**Summary:** Europe, up to 10,000 km$^2$ of vegetation are destroyed by fire every year, and up to 100,000 km$^2$ in North America and Russia.

**Du to the scale and the danger forest fires classified as a planetary disaster**

The probability of fires in forests and fields is steadily increasing owing to climate changes and human activities.

The most important in fight with the forest fire is <u>its  early identification</u>

# What is considering/ exists?

- Satellites:Multifunctional satellites such as NOAA and Landsat with CCD- and IR-cameras on board can observe large areas with moderate time and spatial resolution.
- Spy Airplanes (visible images)\IR sensors
- Watch towers :CCD or image intensifiers monitors operating in IER and visible region of spectra

IR detecors (4.4micr)

Laser scattering

- Heat sensors
- Combination of these methods

# A short review of these methods…

Satellites are very expensive, they observe limited areas,
cannot detect small fires.
…Clouds is another problem

## Spy airplanes with visible and IR

In the USA, Canada, Russia, Finland, and other countries with large forest areas an early warning system is planned to be based on aircraft patrolling with visible , but mainly IR-cameras is used.

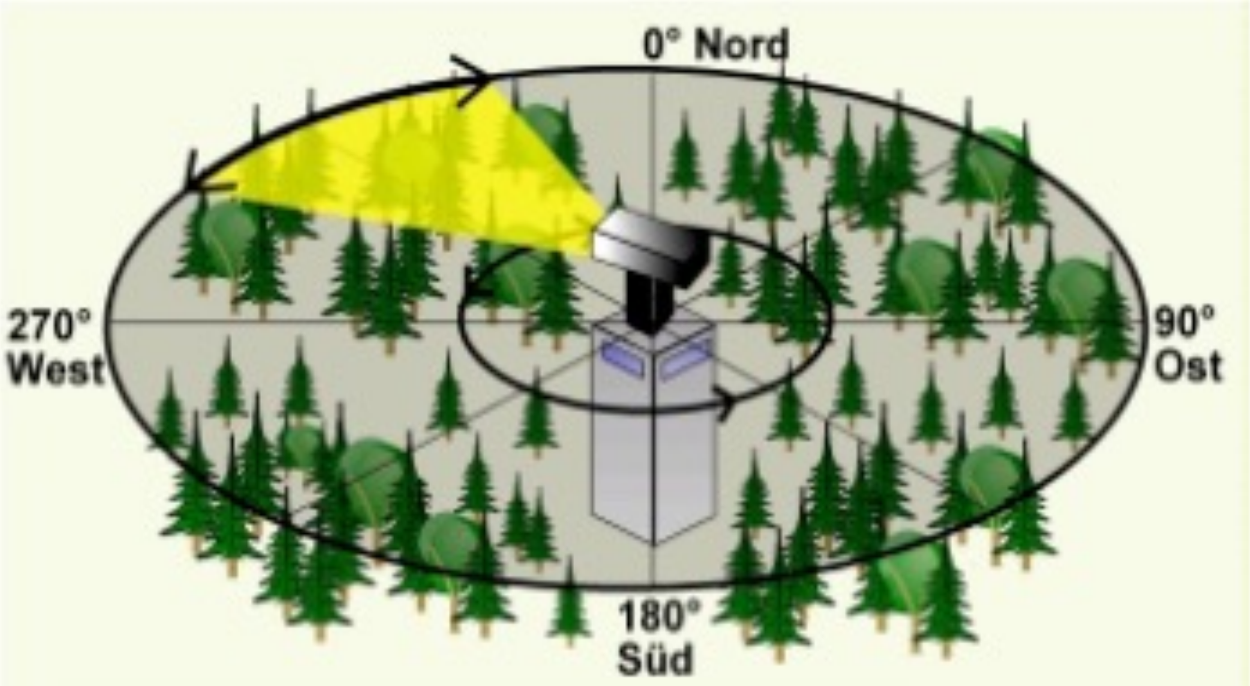
However, this is expensive to operate if quick detection is mandatory

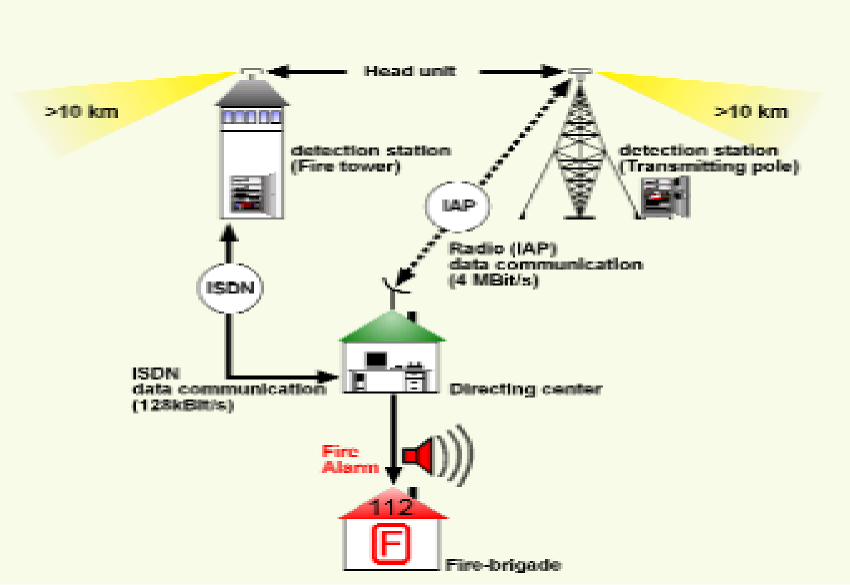
# Watch tower approach

The state's Forestry Department erected a 40-foot forest fire watch tower on the summit of Harts Hill in the spring of 1913 to replace a similar tower on Bear Hill. The four-cornered steel framed tower was supported by four strong steel posts firmly cemented into the ledge at the summit of the hill. The lookout was another seven to eight feet higher, bringing the total height of the structure to nearly 50 feet, or 285 feet above sea level. The forest fire watch tower had glass windows on all four sides that provided an unobstructed view for several miles in all directions, 'as far as the western part of the state and the southern part of New Hampshire.' The first watchman was Henry Fay, the firefighter with the longest years of service. He was selected for the job, and paid, by the state Forestry Department. His equipmen t consisted of powerful glasses, a chart of the country 'round about,' a range finder and a telephone number (512-M). If he spotted a fire, he called the nearest fire department or fire warden. It was reported that he would be able to see a fire 10 to 15 miles away, and when he 'gained complete familiarity with his apparatus, could place it as close as 100 to 200 feet.' The Town voted in 1912 to pay $350 for public access to the tower. An iron stairway at the northwest corner was built so that ladies would not be 'inconvenienced.' On May 1913, over 400 people took advan tage of the public opening." -- Text from calendar by Jayne M. D'Onofrio.

Harts Hill forest fire watch tower, 1913 picture

## Modern approach:



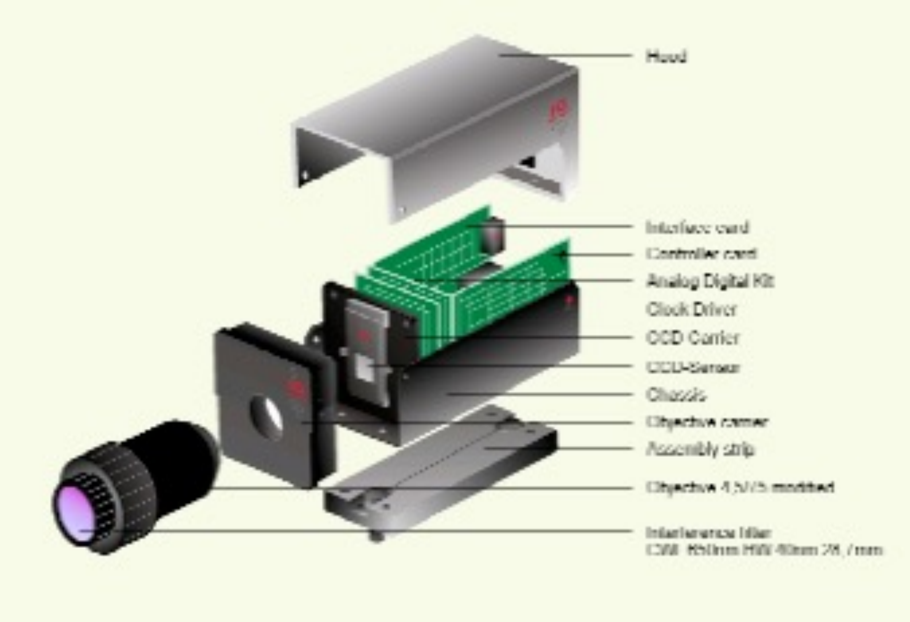

Already functioning in Germany
and will be soon installed in Russia


Smoke detection within the visible spectral region is especially important in densely wooded forests, as open flames (which IR-sensors respond to) give alarm too late. Furthermore, cameras provide the operator in the control center with expressive images and hence make it easier for him to evaluate the situation.

650 nm (CWL) and 400(HW)nm.

Can identify 10x10x10m$^3$ smoke on ~10km

**The entire system is very expensive**

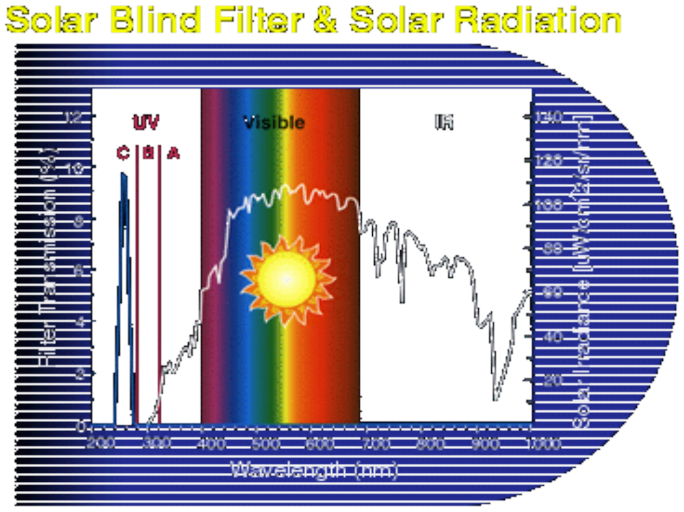


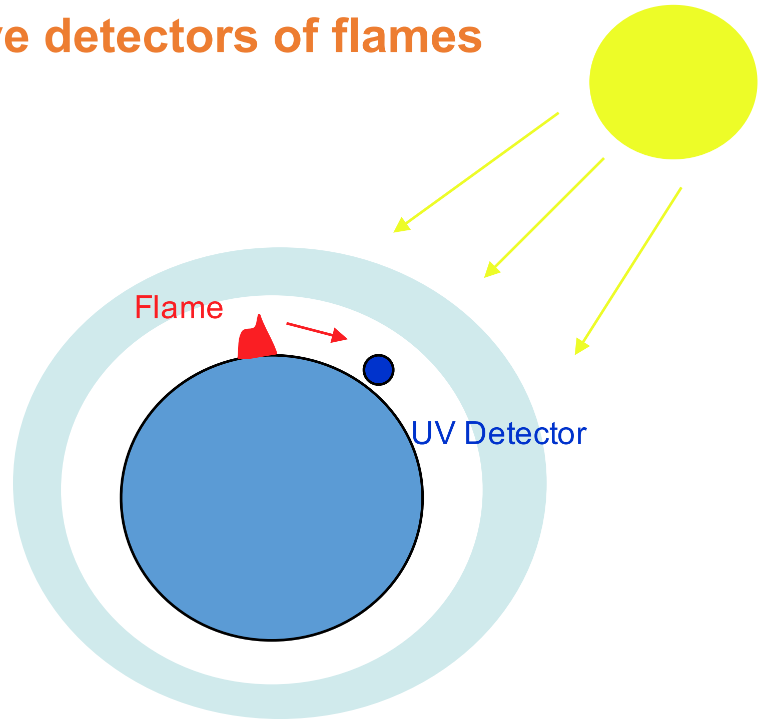
# Heat sensors (Swedish company)

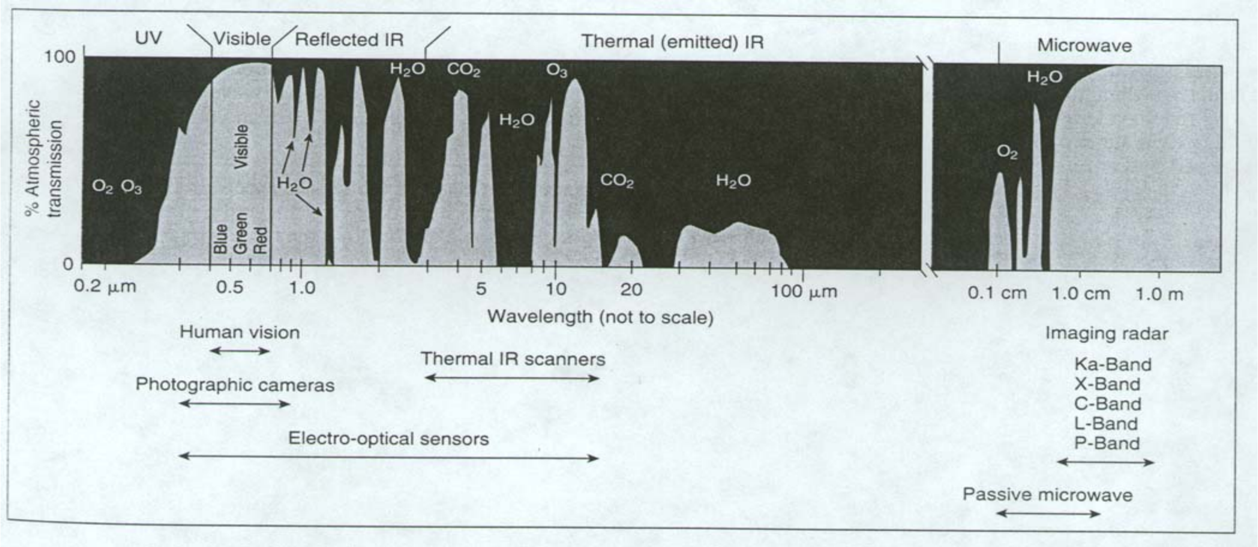
Very cheap (~10Euro), but should be placed each 5-10m, so the <u>total price is high</u>

A new approach: for early fire detection use high-sensitivity UV gaseous detectors

# The basic idea of the UV sensitive detectors of flames




Ozone layer in upper atmosphere blocks the sun radiation in the range 185-260 nm, however on the ground level the atmosphere is transparent in this spectral interval

So a UV detector, sensitive only in the interval 185-260nm is able to detect a UV radiation from the flame, but at the same time is insensitive to the Sun radiation

# Requirements for these detectors (and for any stationary forest fire detectors):

Low price
High sensitivity to flames
Insensitivity to direct sunlight
Low power consumption

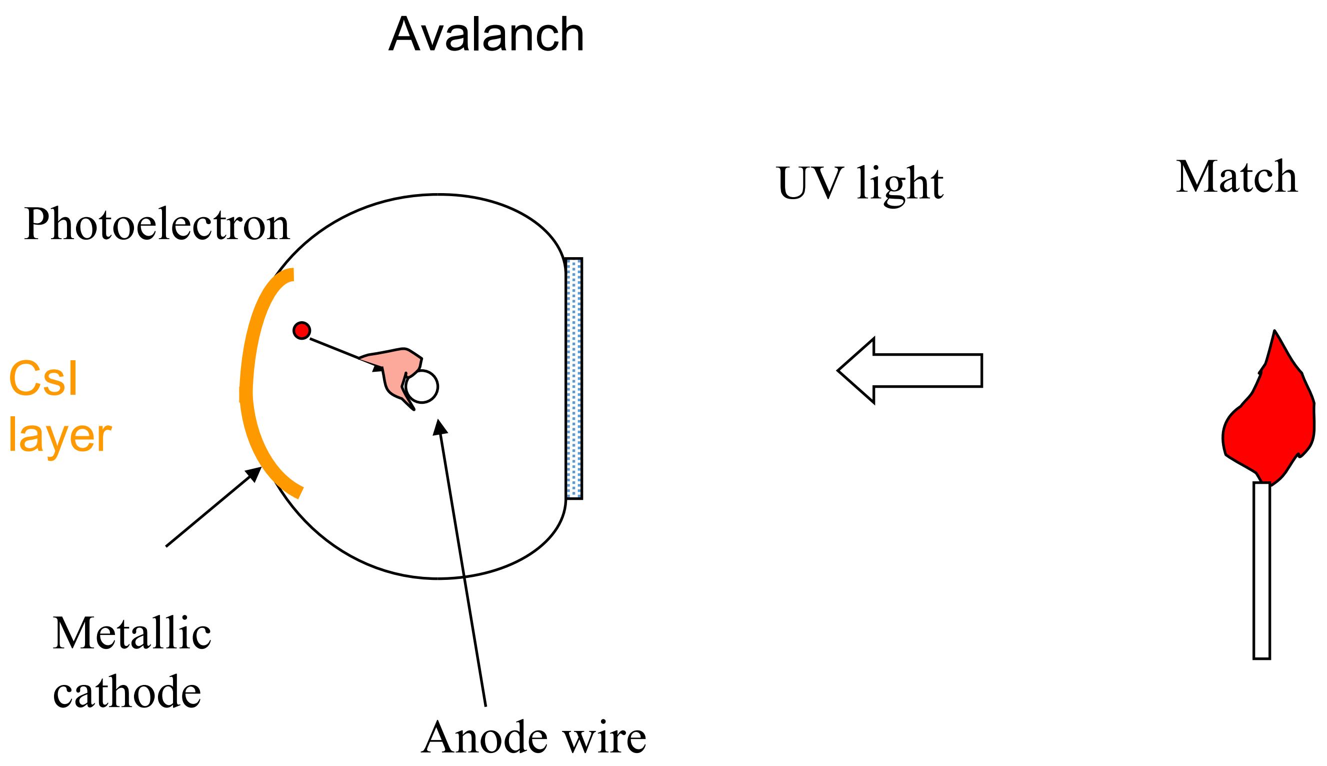
# There are commercial UV detectors of flame, but their sensitivity is insufficient for the forest fire detection


**EU standard:**
The highest sensitivity
Class 1: ~30x30x30cm$^3$ flame
on ~20m in 20sec

An example of the class one detectors is Hamamatsu UVtron

# Indoor flame gaseous detectors (based on ALICE RICH photodetectors)

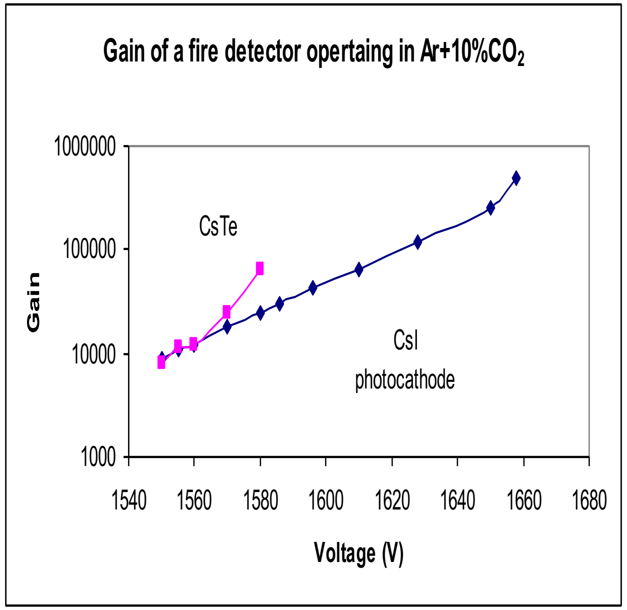
# Modification made by us-simplification




Inside the rooms there is practically no background UV light, so the signal to noise ratio in very high

# Indoor Detector of Flames and Sparks

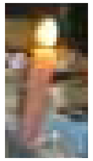
(a sealed single-wire counter with CsI pc)




*(In collaboration with Oxford Intsr and Reagent, Moscow)*

The detector is able to operate in fully illuminated rooms

**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.

# Outdoor flame detectors

The Sun radiation is so strong that high sensitivity *solid-based pc* detectors can operate in direct sunlight conditions *only in combination with filters*

↓

This means an attenuation is at least on a factor of 10 at the peak of the transparency

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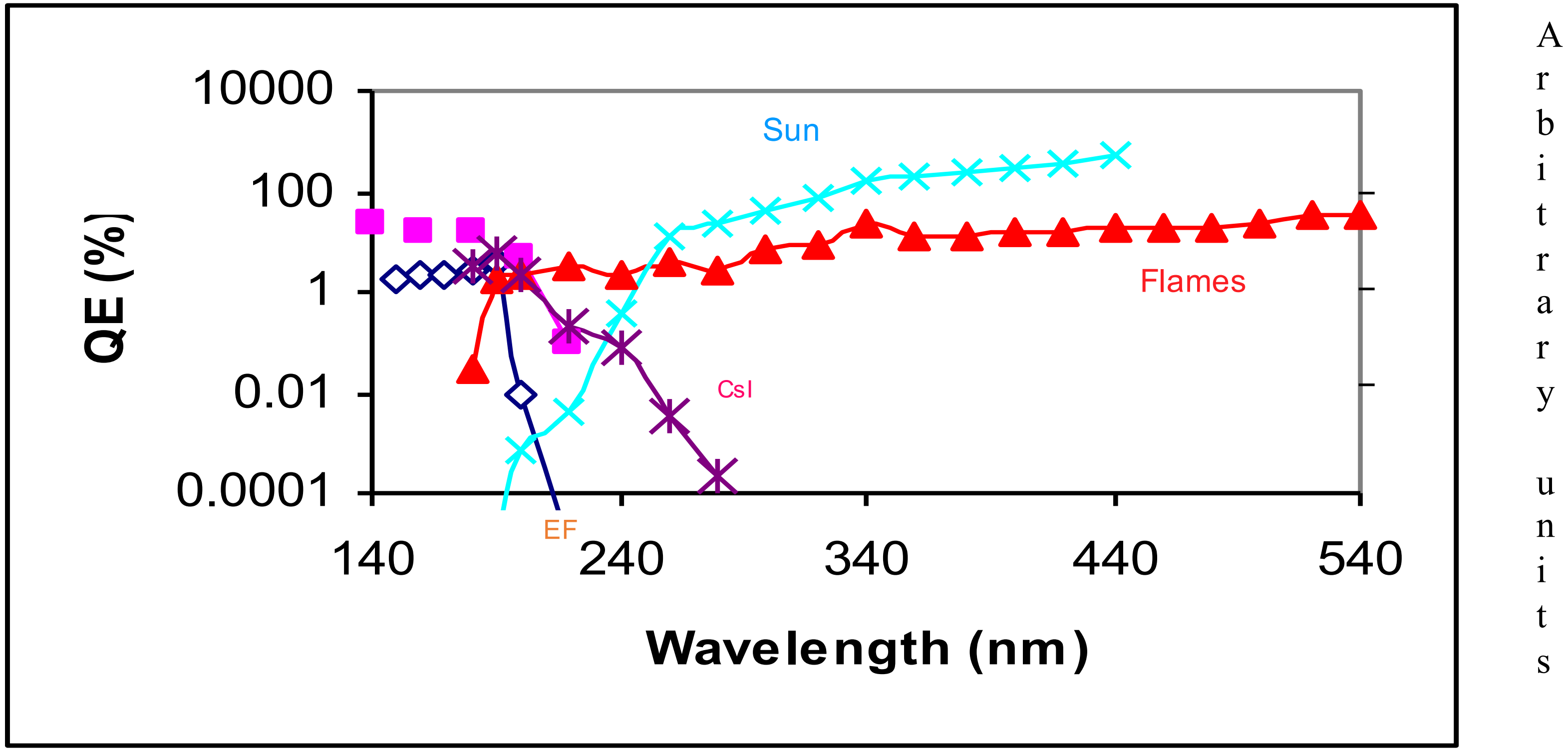
↓

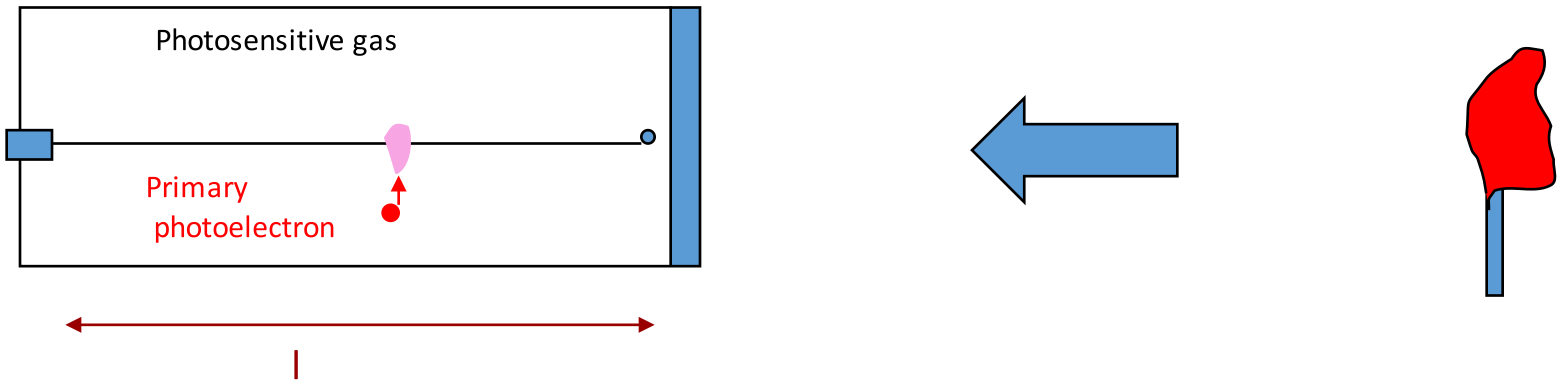
This means an attenuation is at least on a factor of 10 at the peak of the transparency

# 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 $E_v > E_i$

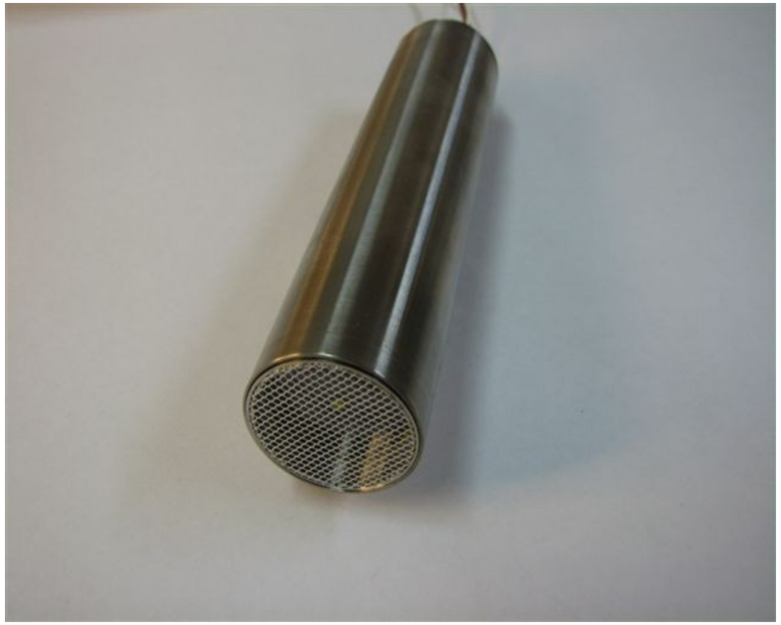
# Principle of the operation:




Gaseous detector filled with photosensitive vapors

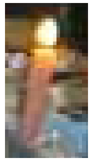
**Efficiency**: $\eta \sim \int_{Ei} Q(E_v)\{1-\exp(-k(p,E_v)l\}dE_v$

The use of photosensitive gases (TMAE and EF) instead of solid photocathodes is the best solution




Detectors filled with photosensitive vapours can operate without any filters and in photon counting mode

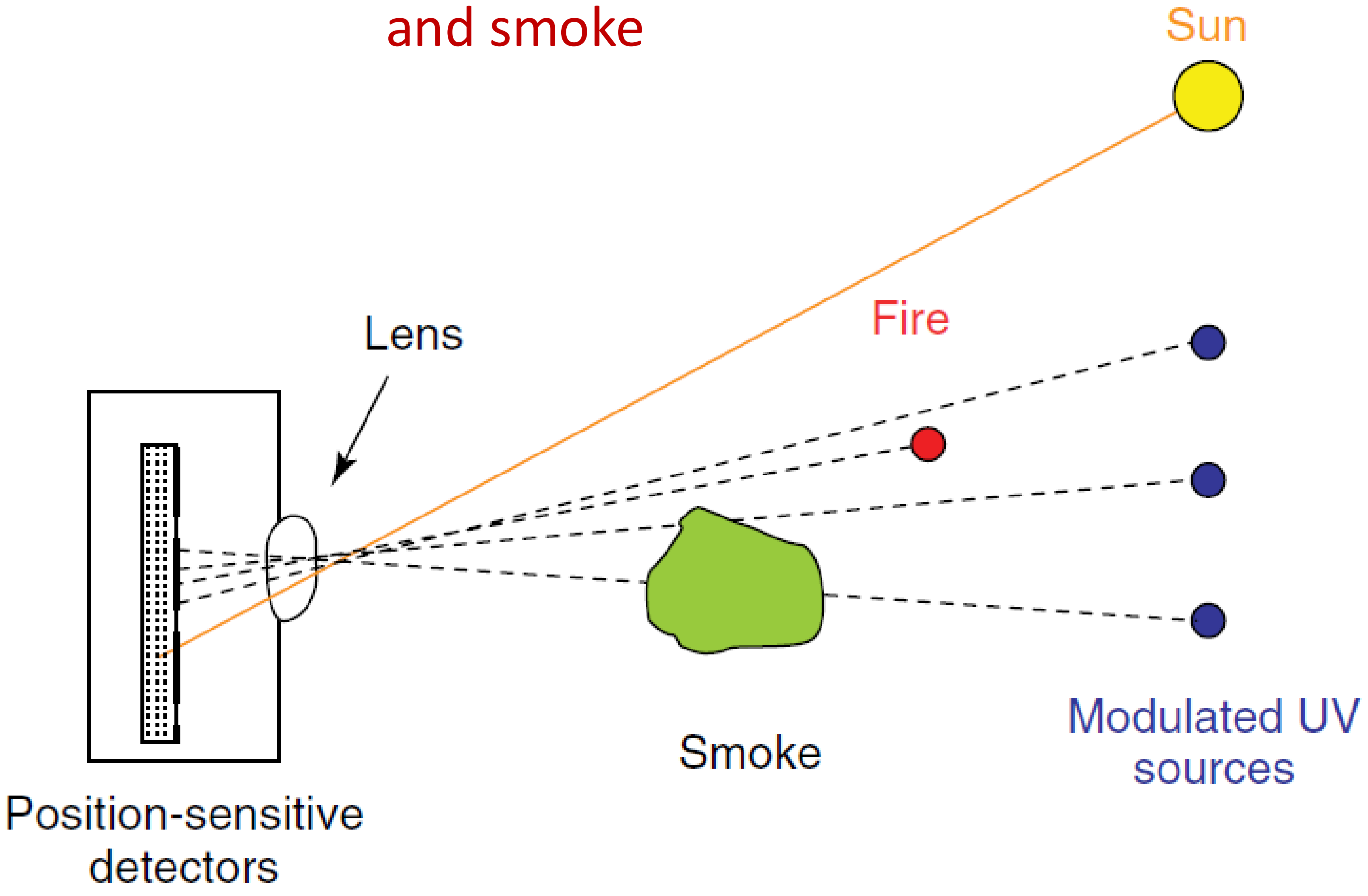
## Comparison of TMAE and EF detectors(20°C) with the 1st class flame detectors

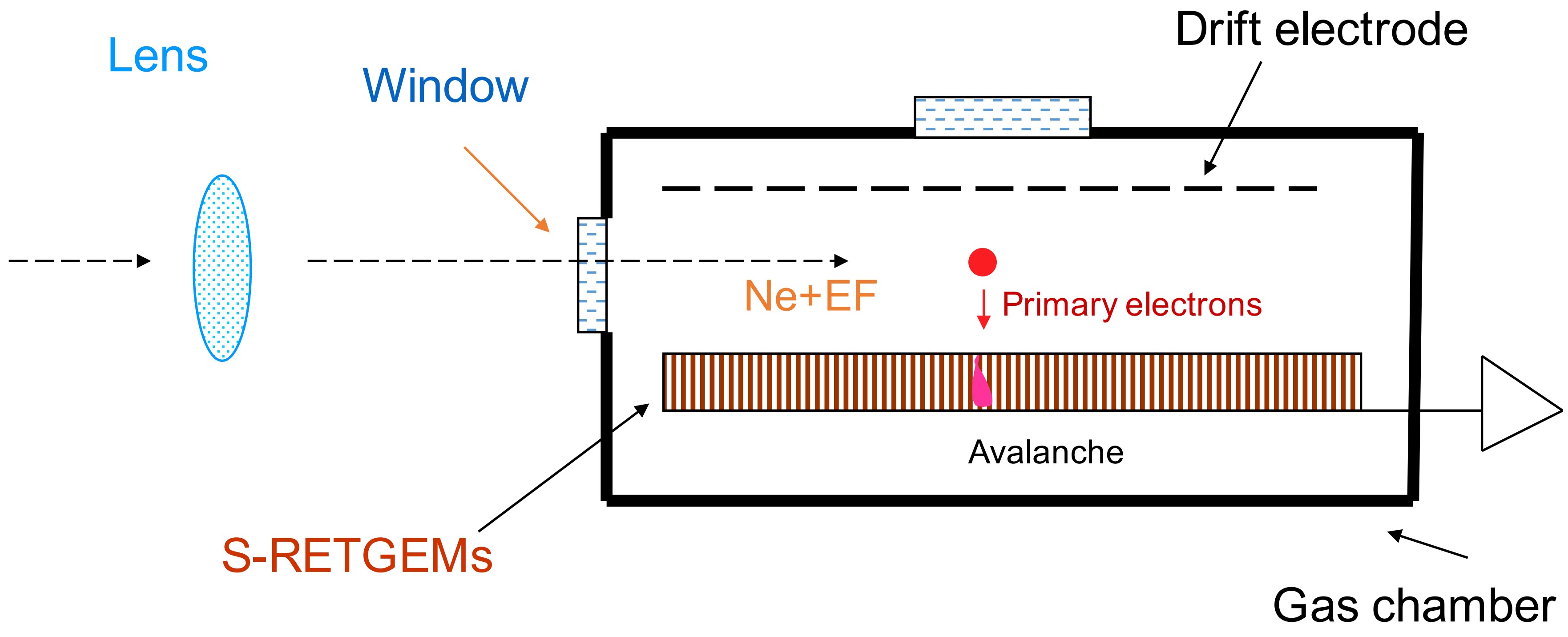


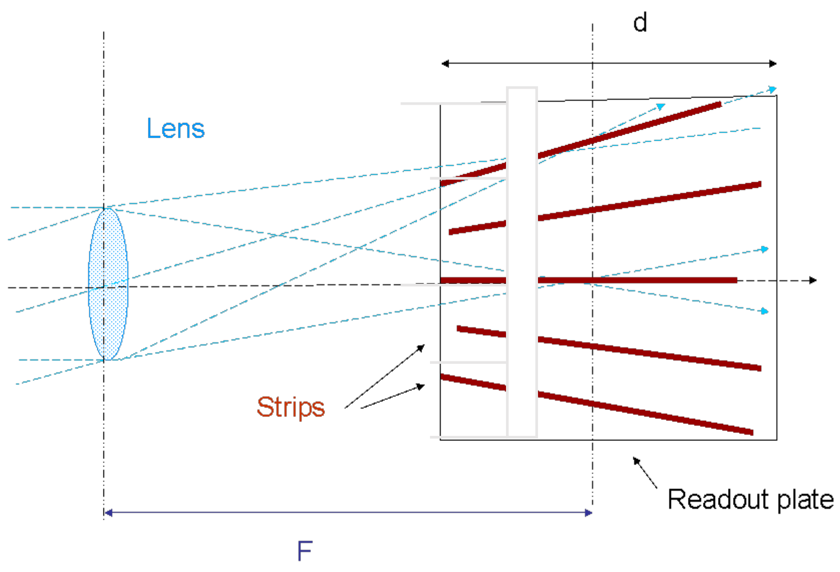
| Hamamatsu R2868 | | Our TMAE detector at 23°C | | Our EF detector at 25°C | |
|---|---|---|---|---|---|
| Distance (m) | Mean number of counts per 10sec: $N_H$ | Mean number of counts per 10sec: $N_{tmae}$ | Ratio $N_{tmae}/N_H$ | Mean number of counts per 10sec: $N_{ef}$ | Ratio $N_{ef}/N_H$ |
| 1,1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

<u>A note</u>: we have a working prototype at CERN; those who are interested are welcome to see it in operation!

# Simultaneous detection of flame and smoke

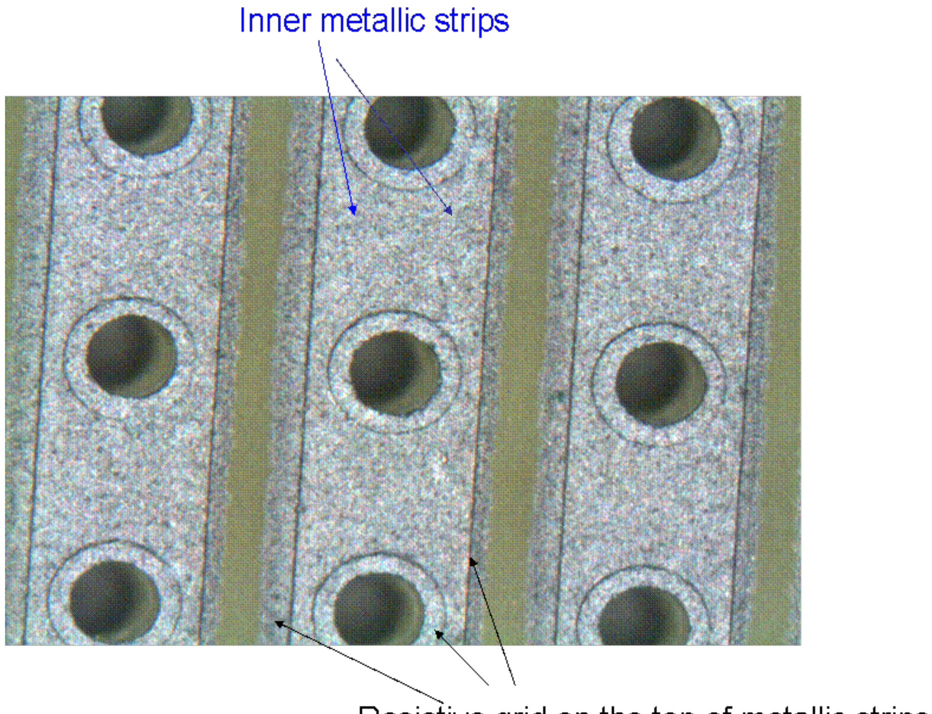





Readout electronics (ASIC or individual amplifiers)

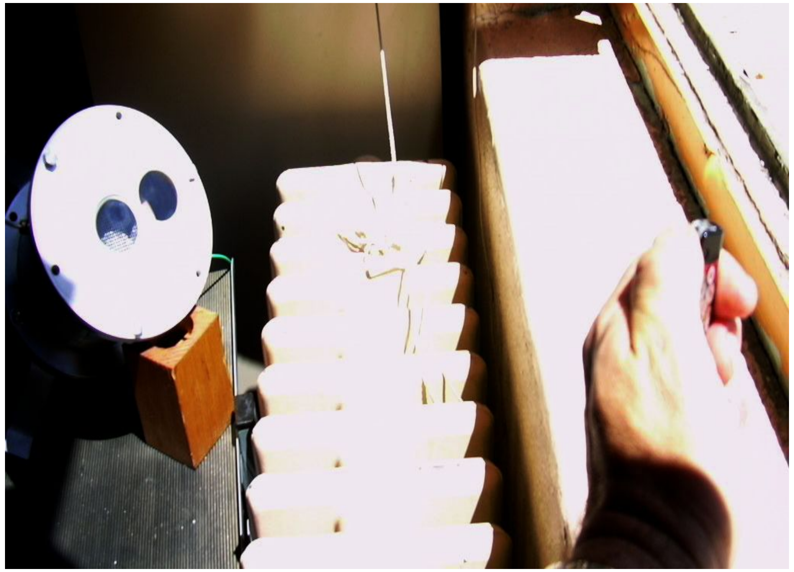
# S-RETGEM detector filled with Ne and EF

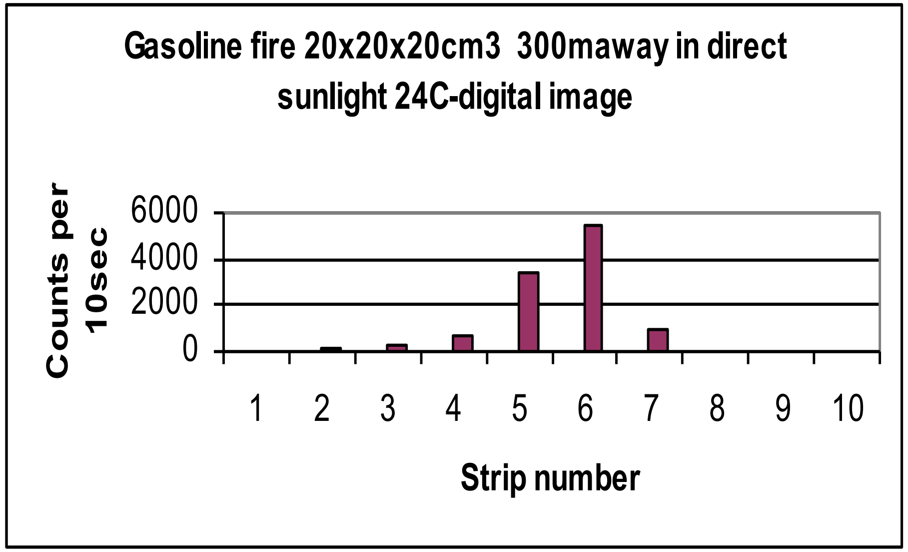



A photo of S-RETGEM developed in R. Olivera Workshop
*(see Di Mauro et al, report at the IEEE Nucl. Sci, Dresden, 2008)*

S-RETGEM flame detector operating in St. Etienne

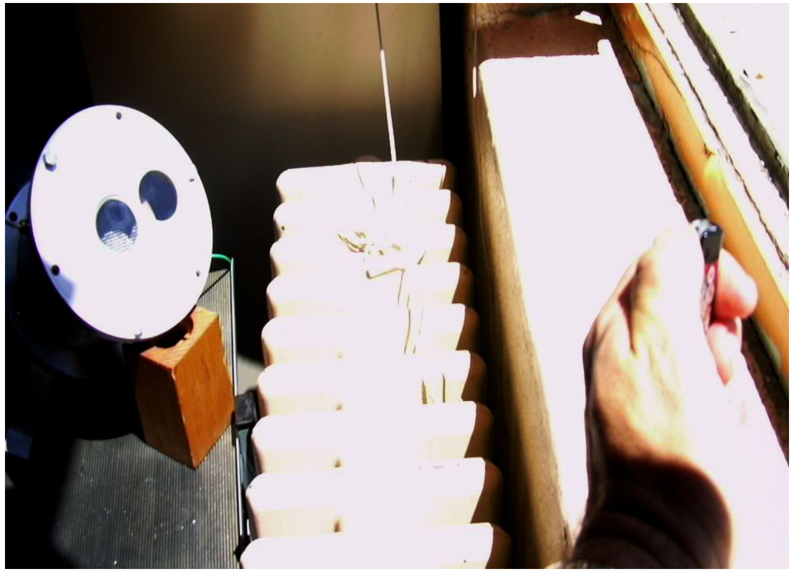
# Operation in direct sunlight and imaging capability-are extremely important

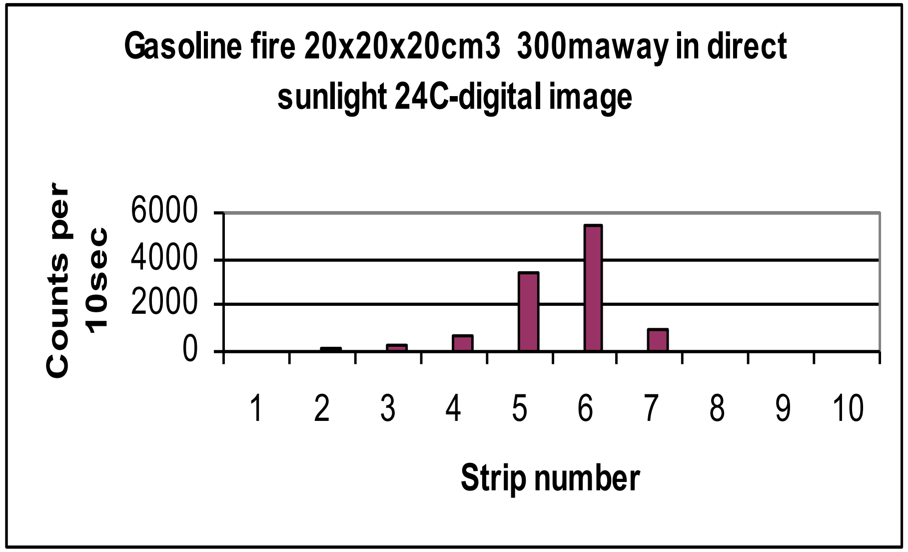





This why S-RETGEMs are essential

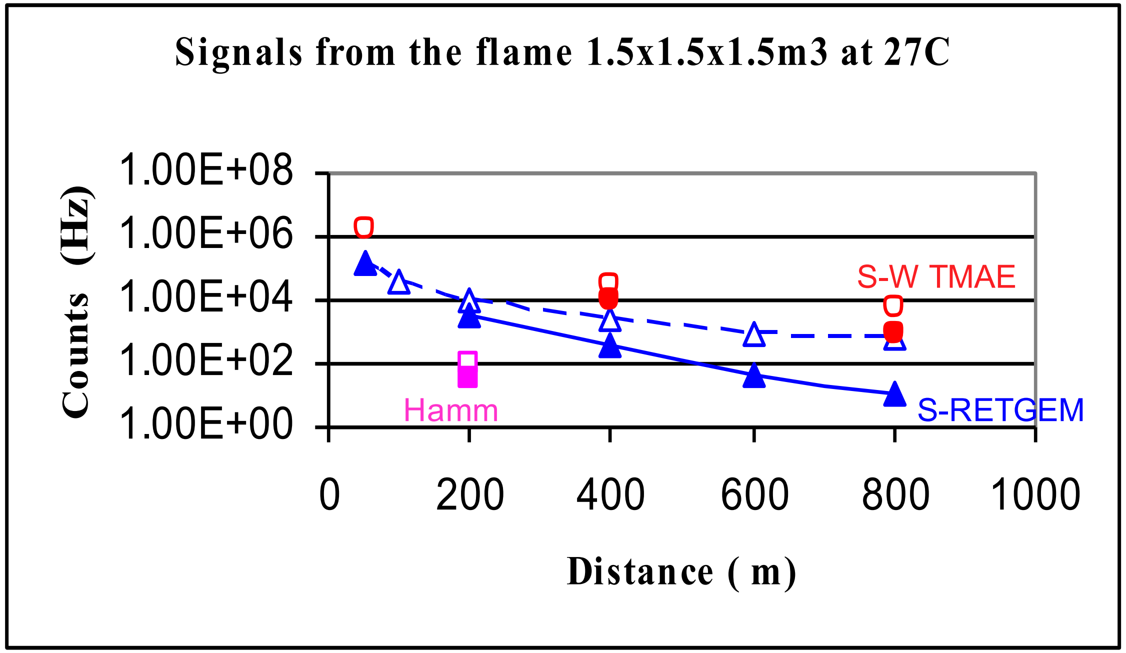
# Operation in direct sunlight and imaging capability-are extremely important






This why S-RETGEMs are essential

# The most important data-long distance tests:




Open symbols-calculations
Filled symbols-measurements

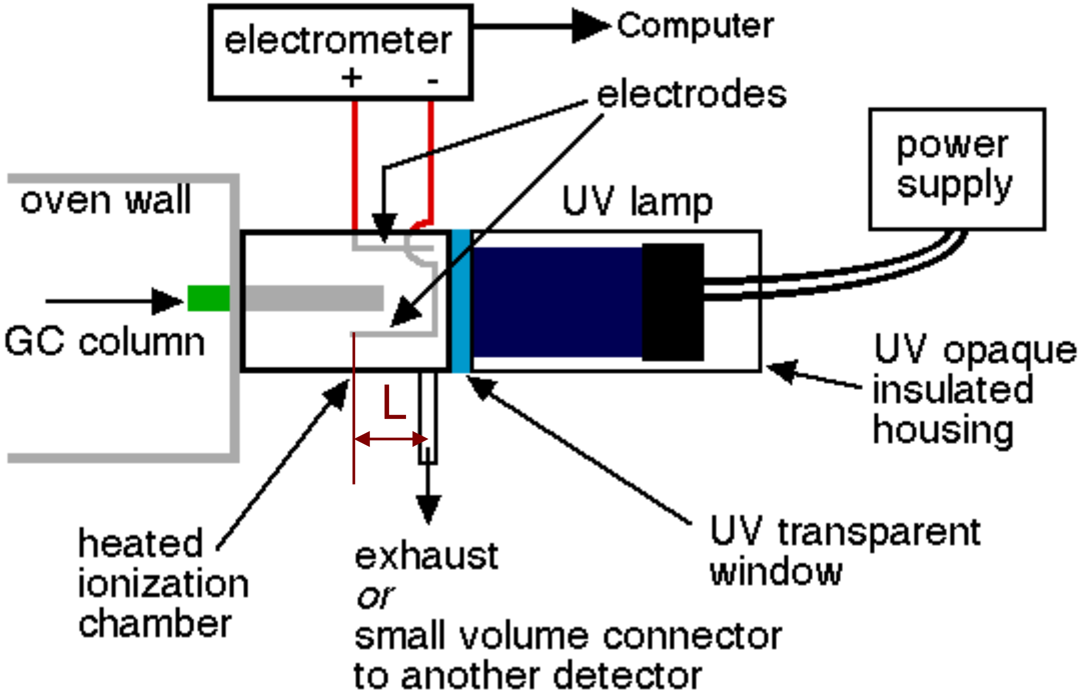
<u>Air absorption:</u> mean free pass for active photons in the case of EF~250m
In the case of TMAE ~400m
*Estimations based on these data show that with EF 5x5x5m$^3$ fire will give 20Hz at 1,5km.With increasing the recording time to 100 sec even higher sensitivity can be reached*

The main conclusion: our detectors can detect flames at large distance

# Detection of dangerous gases

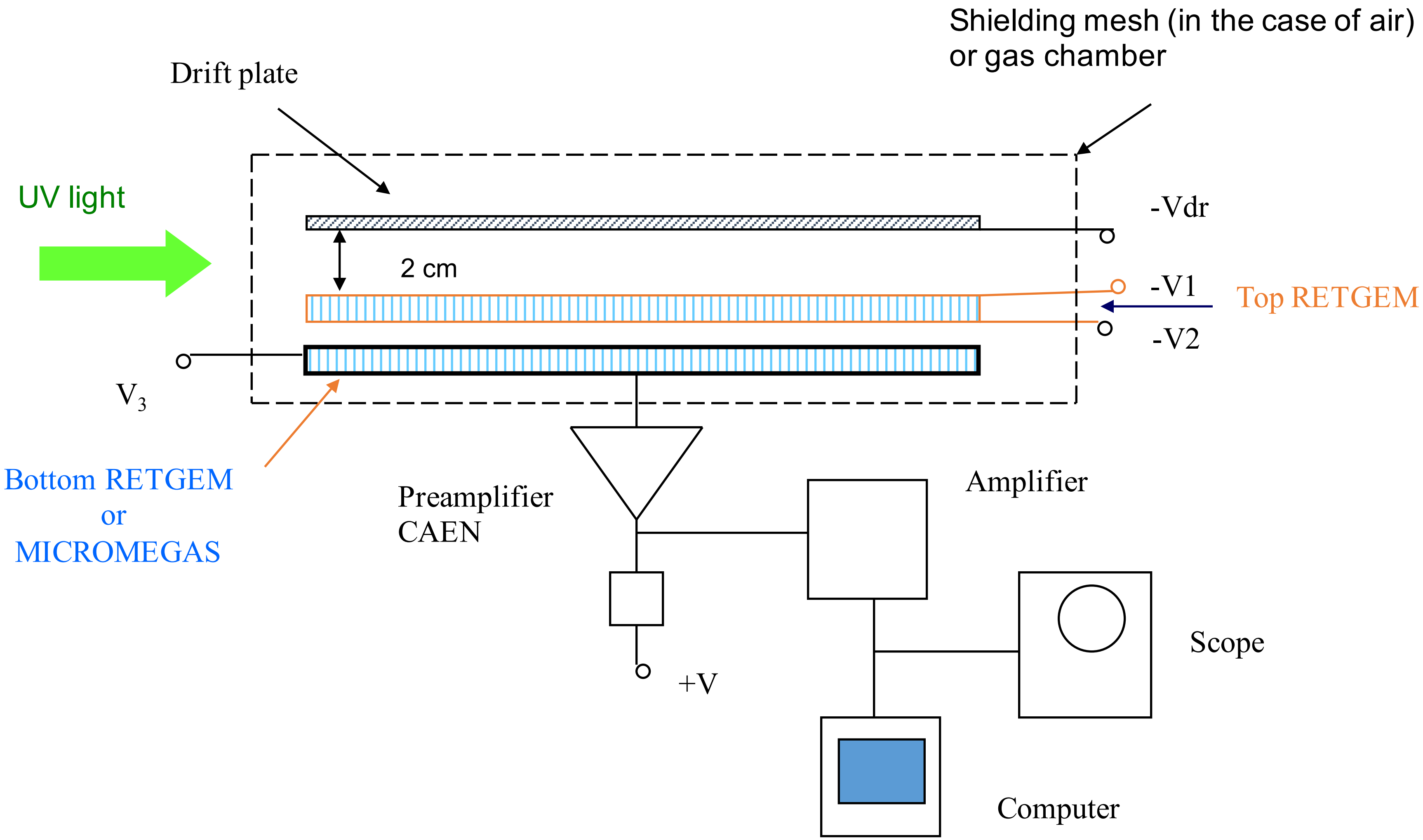
Besides the fire, another thread for the environment and the health is caused by various dangerous gases

## Commercial photoionization detector of dangerous gases /flammable , combustive, toxic):



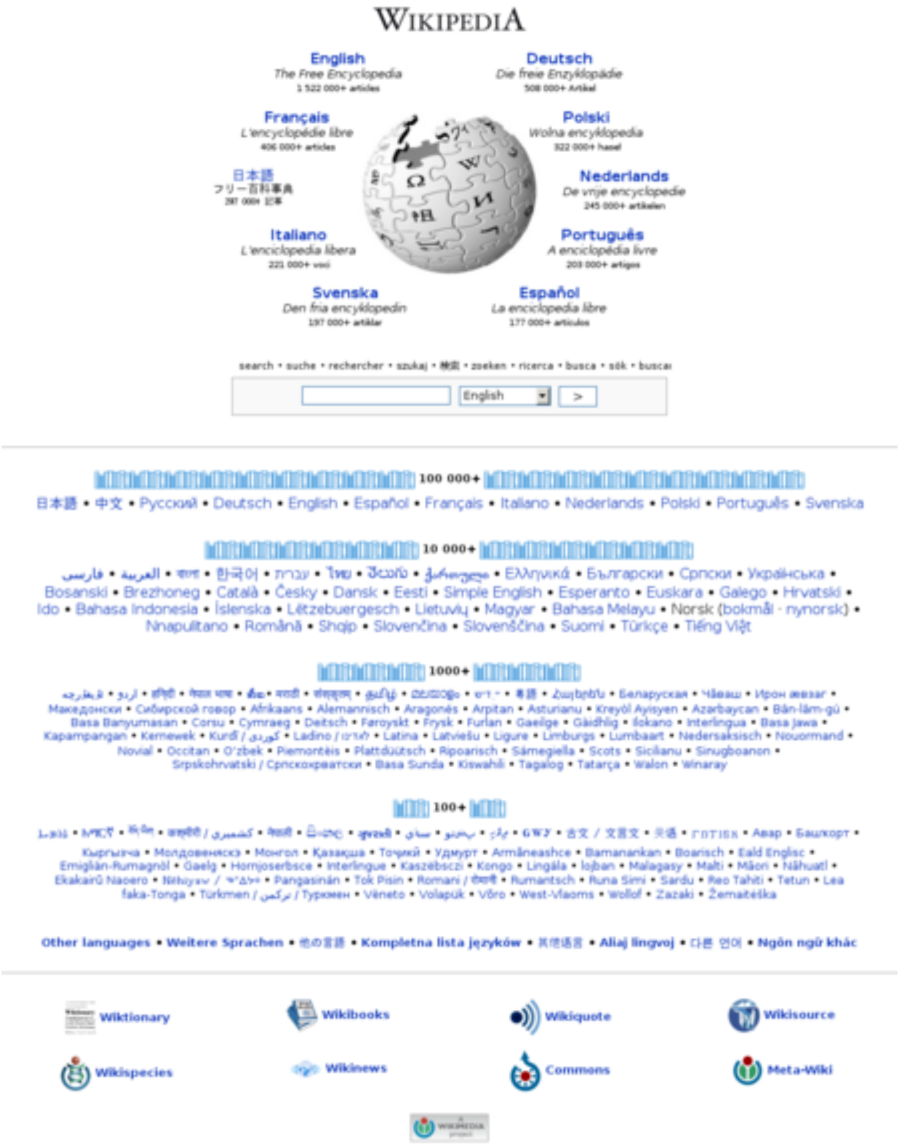

<u>Sensitivity</u>: in some cases up to 100 ppb (stationer devices)
<u>Gases</u>: benzene, toluene and others

# Double RETGEM and RETGEM+MICROMEGAS were also tested




G. Charpak et al., IEEE Trans. Nucl. Sci 55 , 2008 , 1657

# Rn detectors



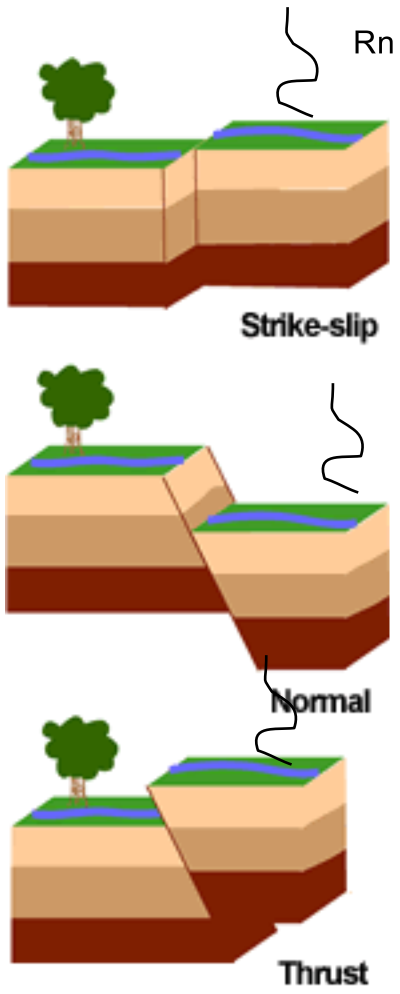

Based on studies carried out by the National Academy of Sciences in the United States, radon is the second most common cause of lung cancer after cigarette smoking, accounting for 15,000 to 22,000 cancer deaths per year in the US alone according to the National Cancer Institute.

In this presentation, however, the main focus will not be on the application to health safety (which is quite well covered with the existing detectors), but on the possibility to investigate the presence of anomalous Radon concentrations in case of forthcoming earthquake events


Haiti Earthquake building damage

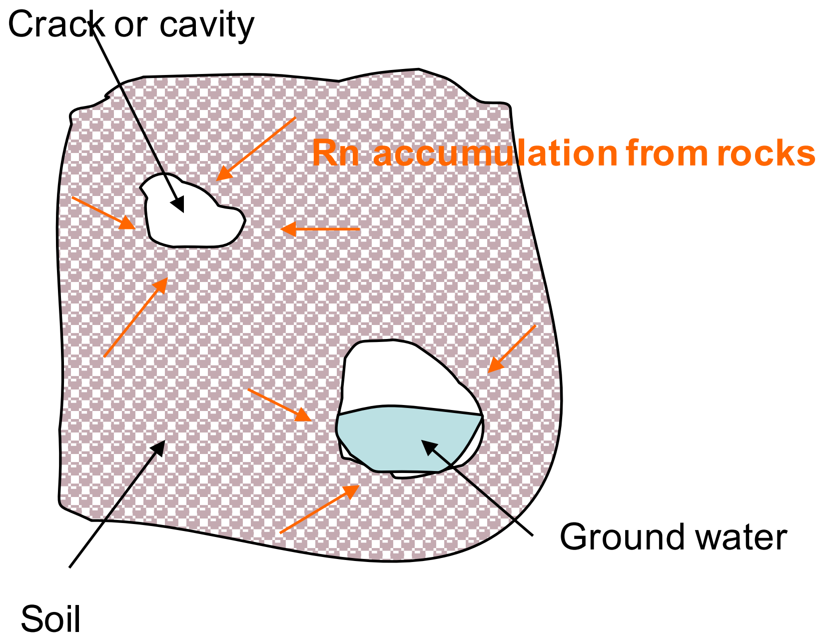
In the last decade, some studies have shown the possibility to correlate elevated concentrations in the soil of gas Rn, or rapid changes in soil or groundwater radon concentration, to the early

prediction of earthquakes



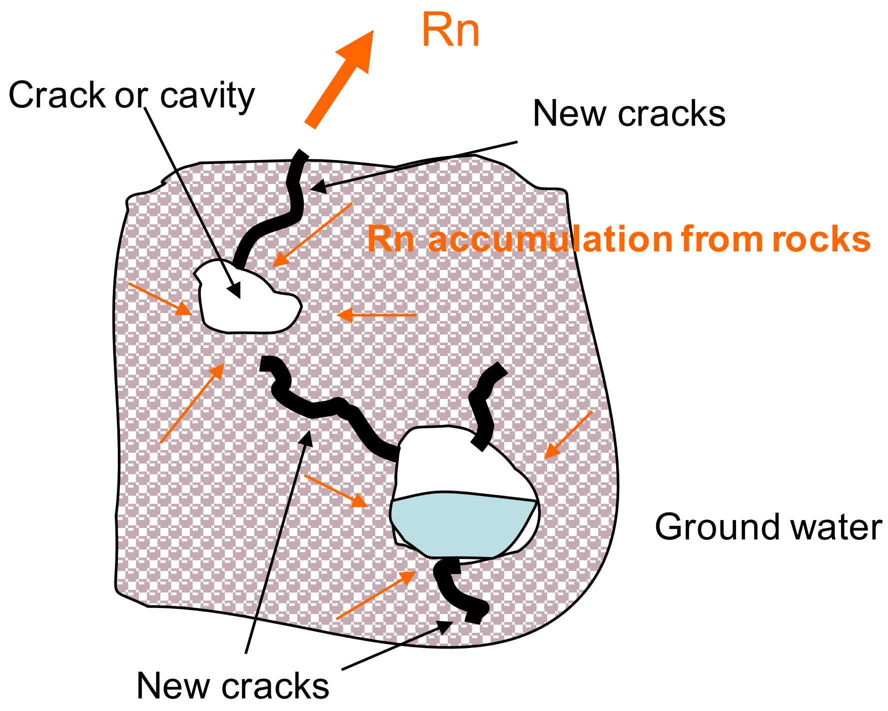
**<u>Normal</u> process of accumulation of Rn in cavities, cracks and ground water**

a)



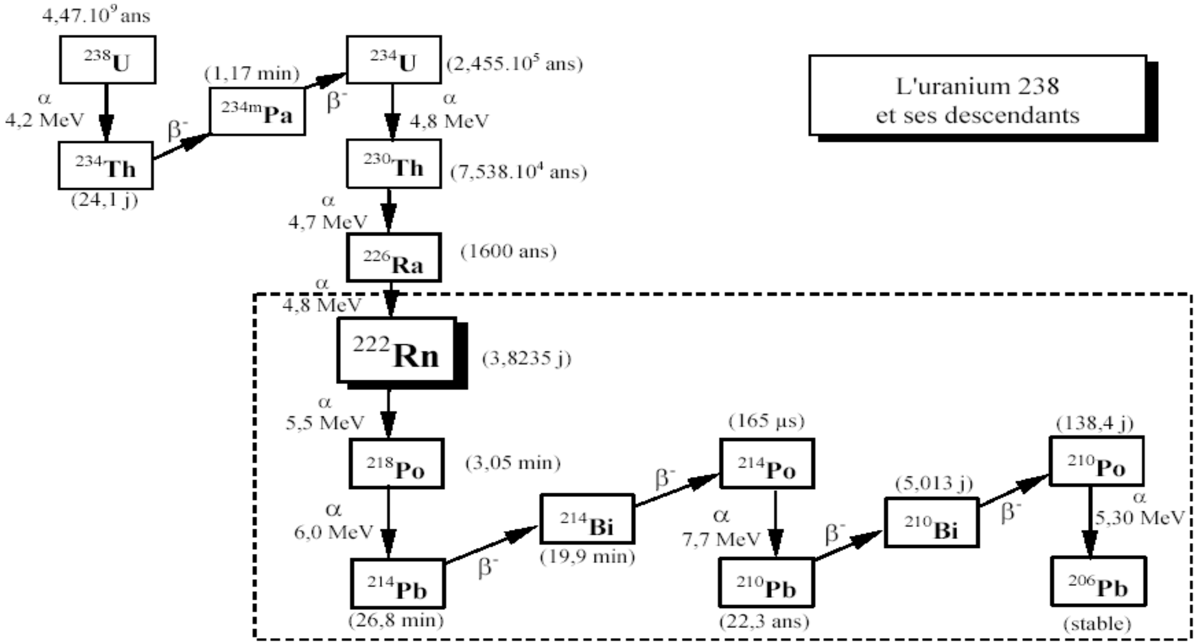

**<u>Before the earthquake</u> the soil and rocks start deforming, cracking and release Rn accumulated in old cracks, cavities ground water**

b)



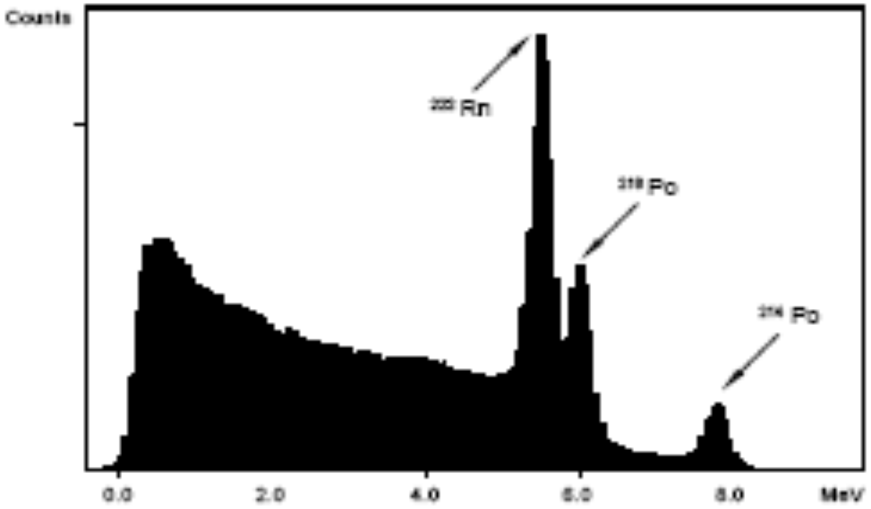
To the aim of verifying such studies on a more solid statistical ground one has to create a wide network of cheap, compact and high sensitivity Rn detectors

# Commercially available Rn detectors are very expensive ~1000Euro



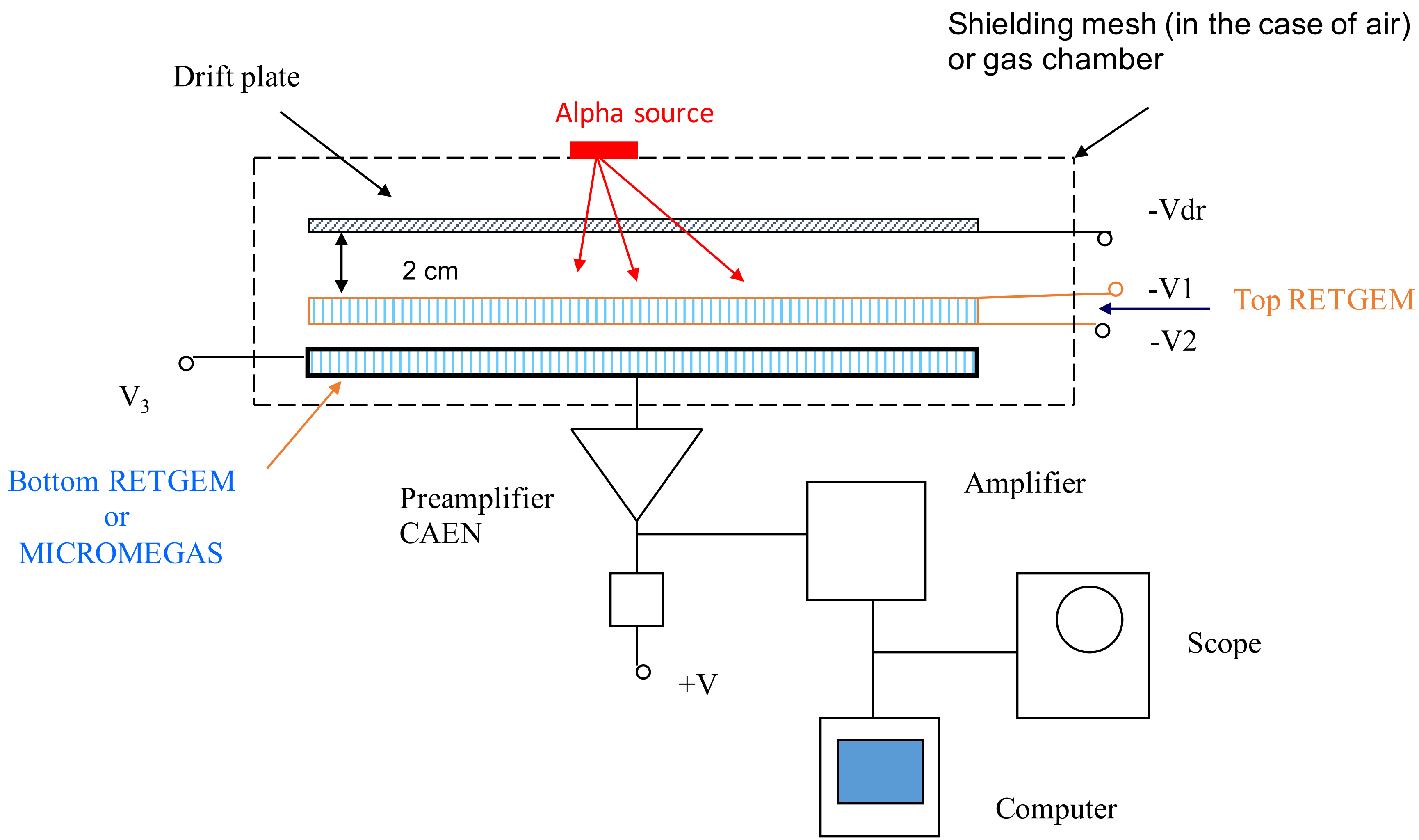


Atmos 12px



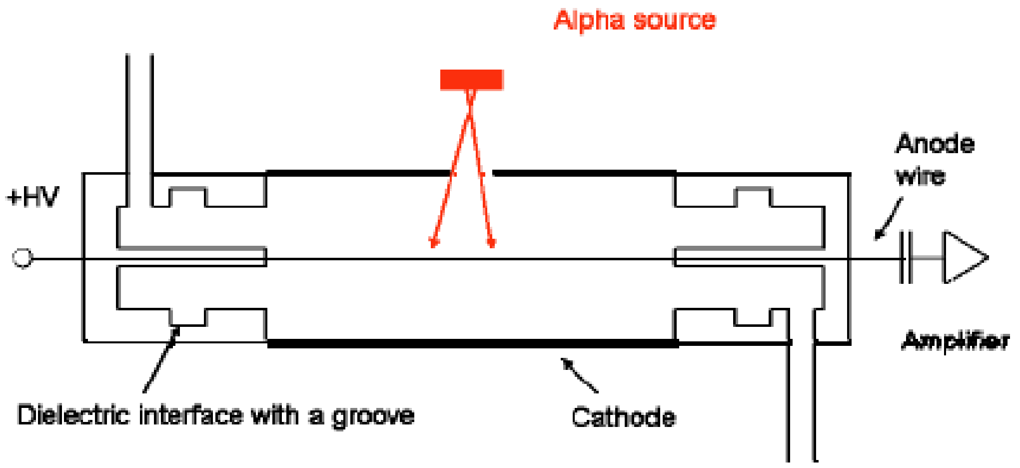

Energy spectrum obtained with the ATMOS 12 DPX.

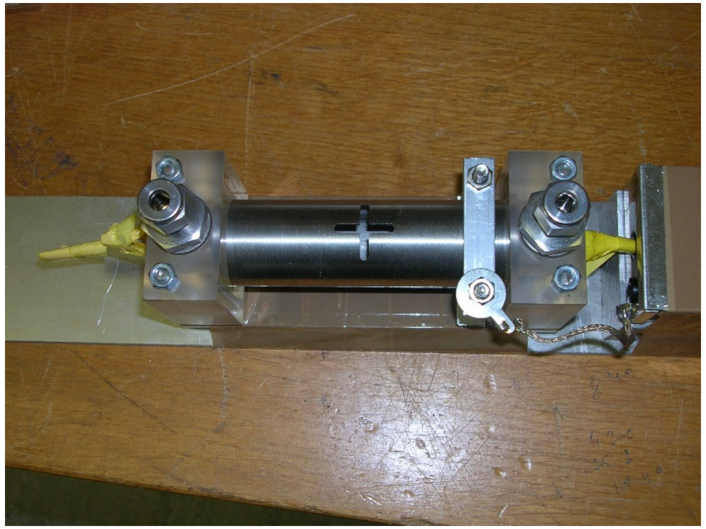
## Double RETGEM and RETGEM+MICROMEGAS were also tested




*G. Charpak et al., [IEEE Trans. Nucl. Sci] 55 , 2008 , 1657*

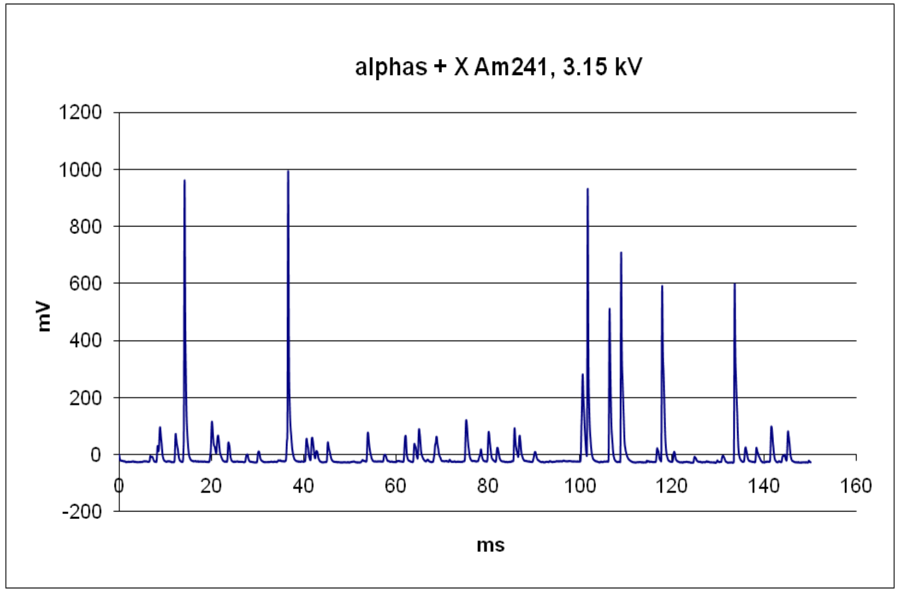
## A simple competitor to commercial devices



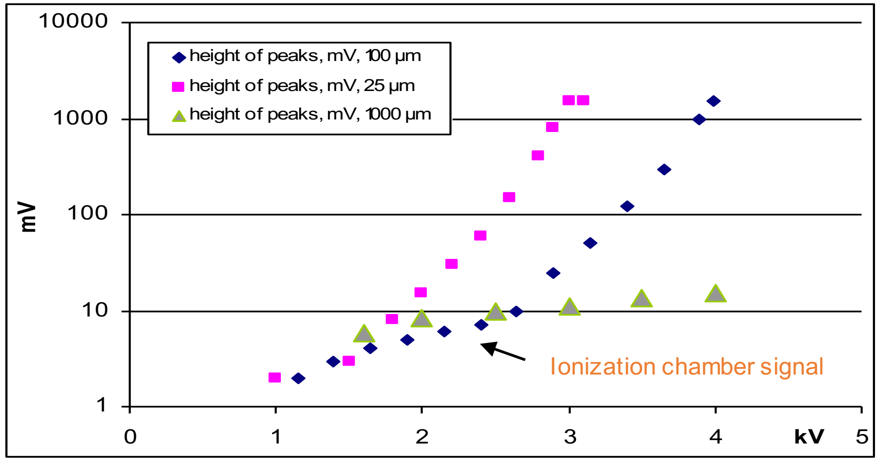



<u>Advantages</u>:
simple,
low cost,
robust,
has sufficient sensitivity for
the earthquake application

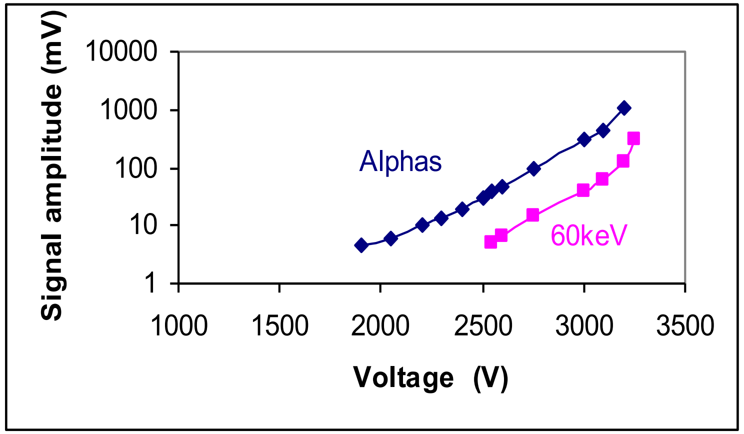
# 1) Results obtained with Am:




Typical signals measured with
a single –wire counter (basic lay-out)
operating in air and irradiated by
$^{241}$Am source

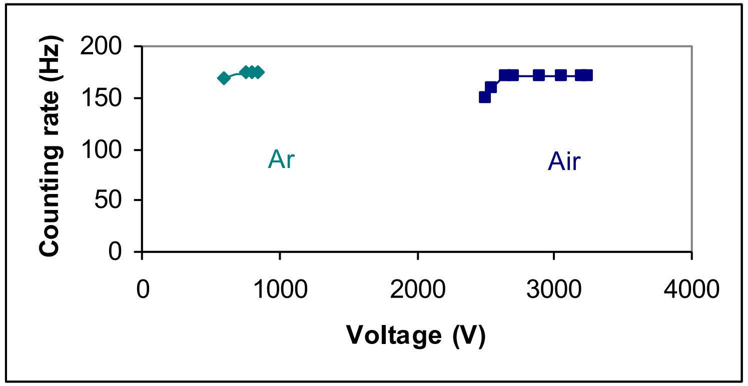



Mean signal amplitude produced by alpha particles vs. the voltage applied to detectors having a cathode diameter of 60 mm and different anode wires

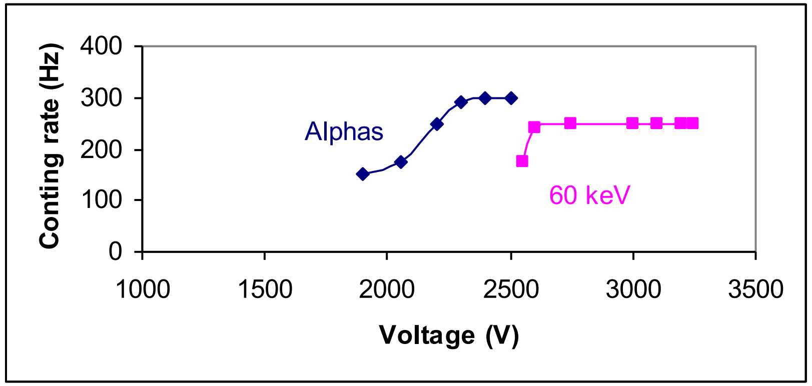



The pulse amplitudes vs. the voltage measures with a single-wire counter having

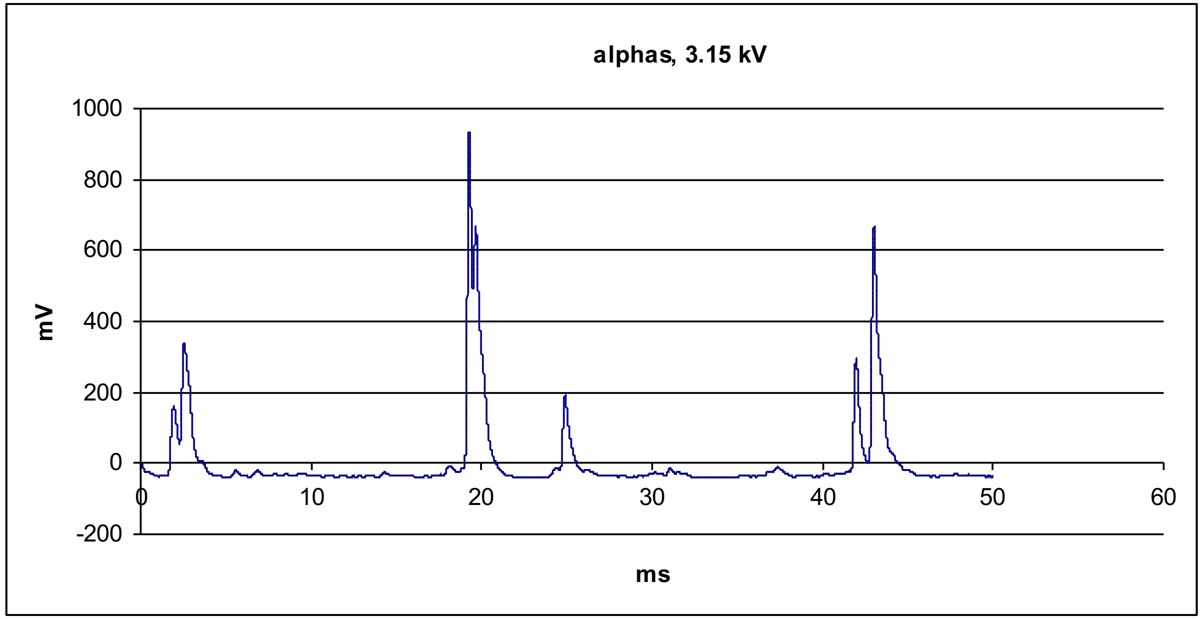
# Efficiency of alpha particles detection is ~100%




Counting rates vs. the applied voltage measured in Ar and in air at the same conditions (alpha particles, D=60mm, da=100 μm)



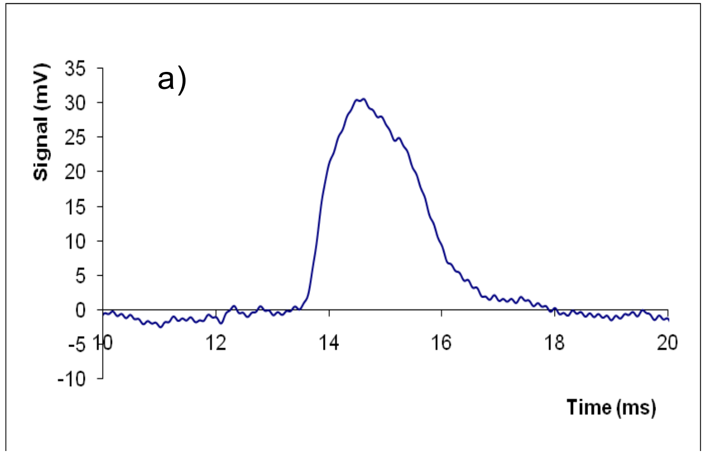

Counting rate vs. Vd for alpha particle (blue) and for 60 keV photons (rose) measured with a basic design of the single wire counter

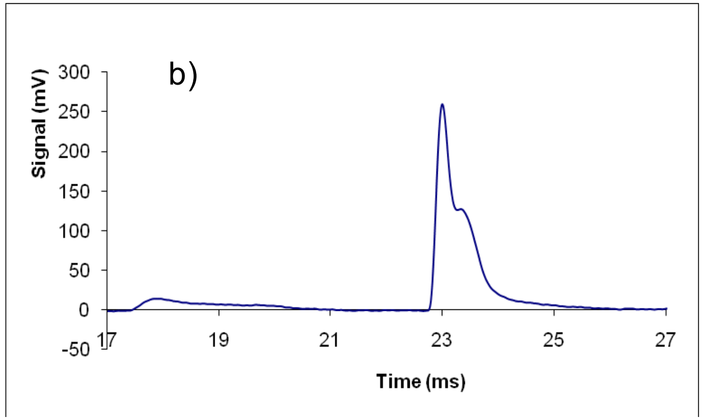



Oscillogramm of pulses produced by $^{241}$Am measured in 100% humid air

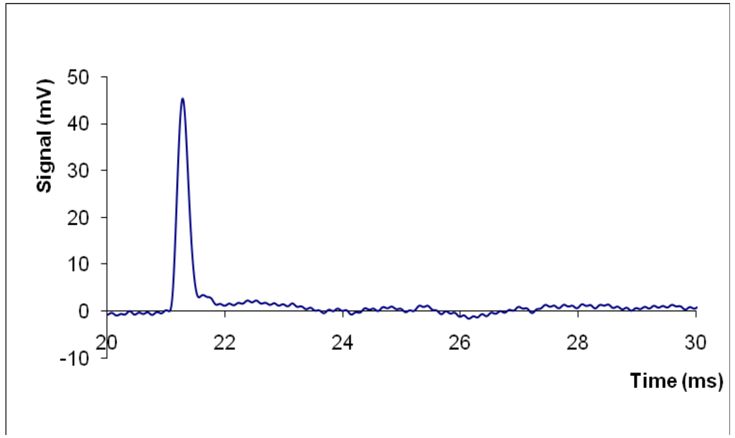
# 2) Basic studies with $^{220}$Rn (Thoron)

High sensitivity can be achieved only if the noise pulses rate is suppressed almost to zero

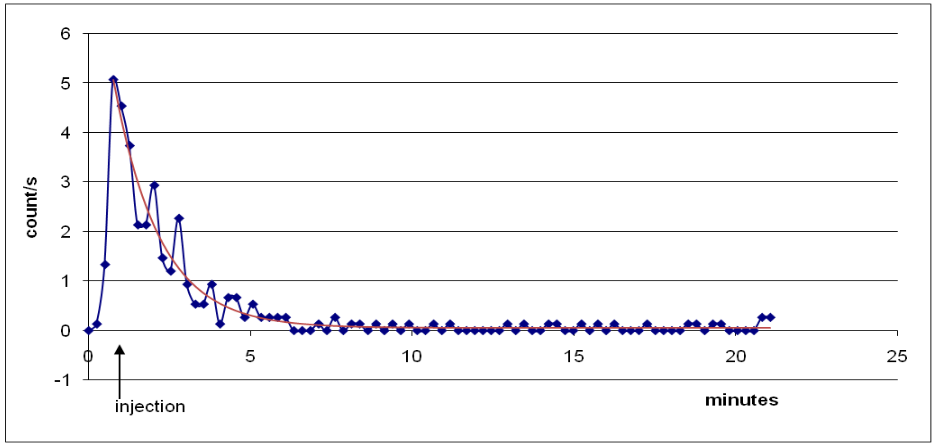



Typical shape of pulses produced in the single-wire counter by Thoron: a) smooth pulses, b) pulses containing 1-2 peaks

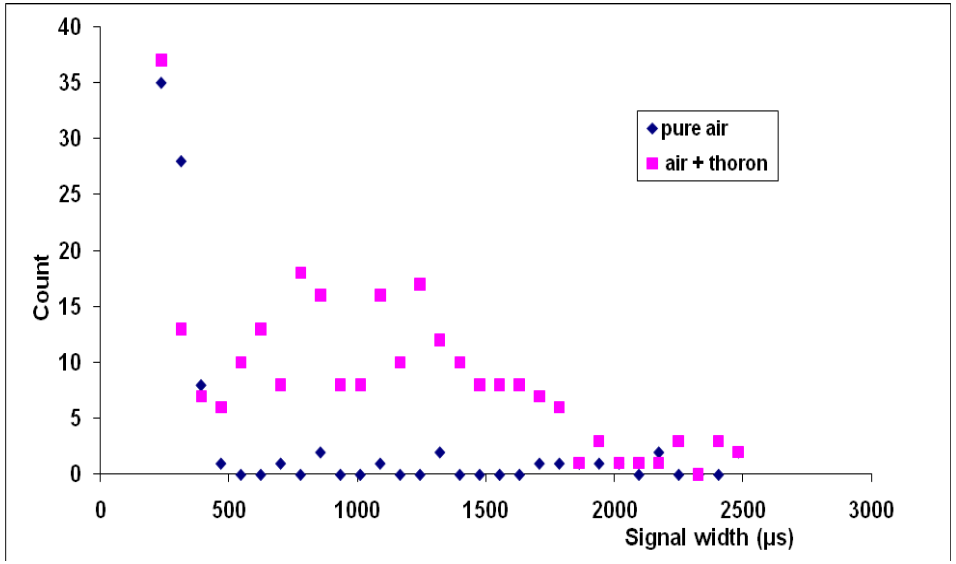



Typical pulse shape of noise pulses



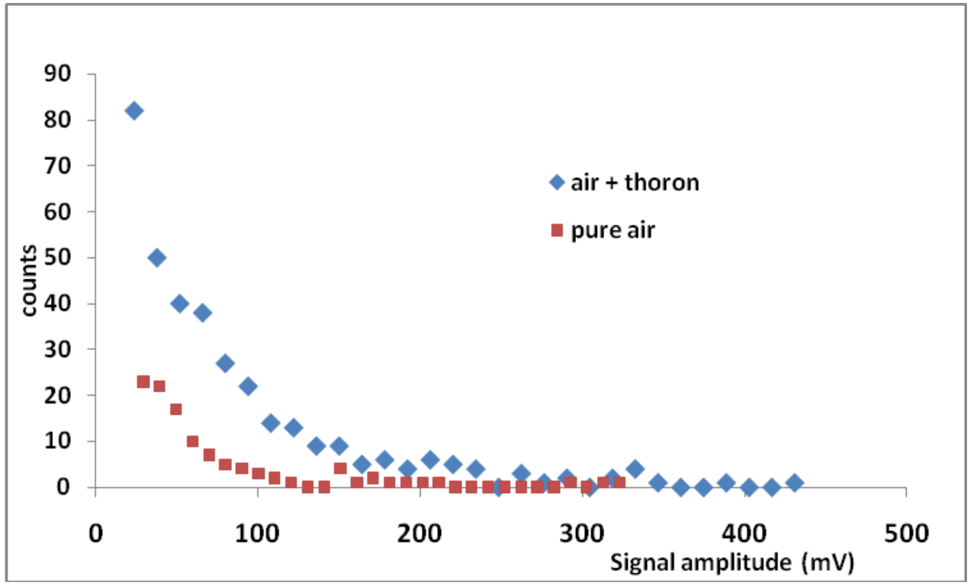

Counting rate vs. time as measured by the single-wire counter in which air contaminated with Thoron was injected($T_0$=56sec).

# Noise pulses rejection technique:

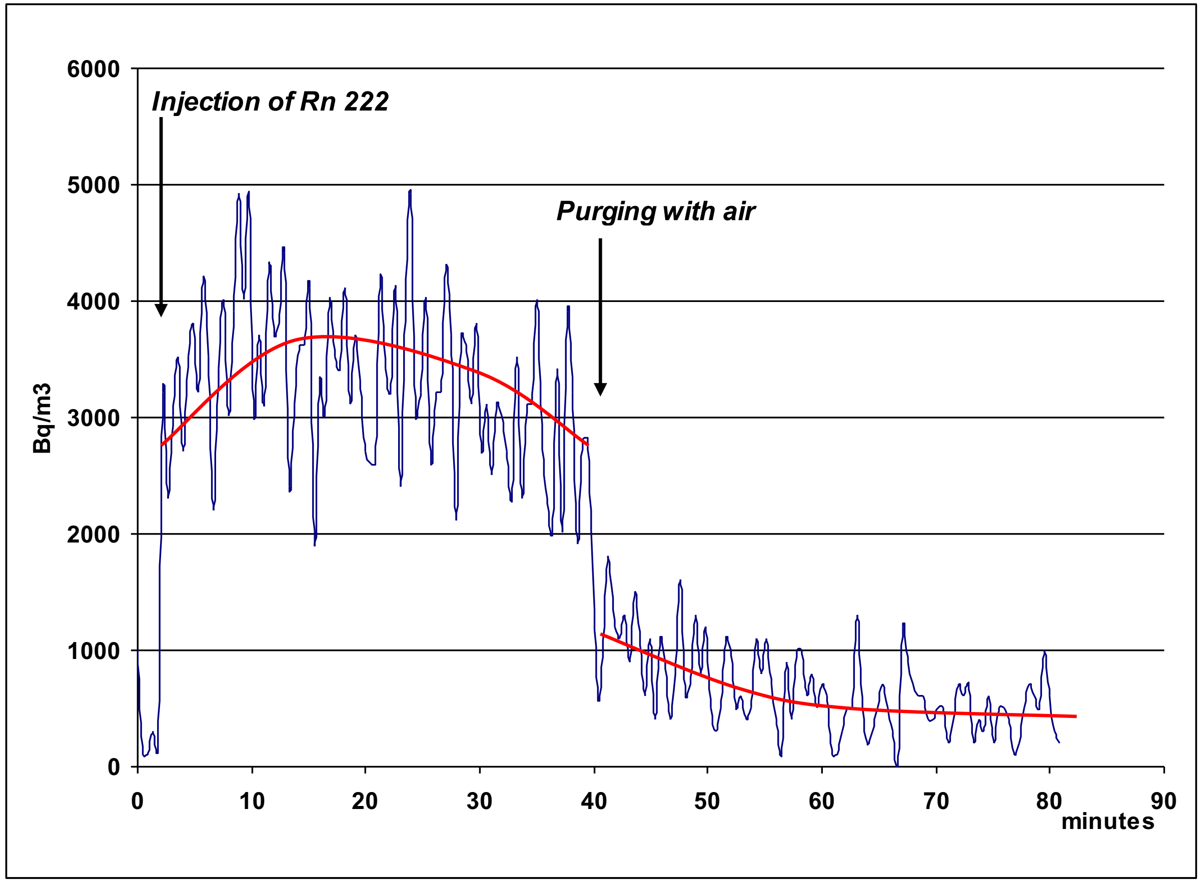



Distribution of the noise width and Thoron induced pulses
(Lab View program)

Pulse height spectrum of Thoron and noise pulses
(Lab View program)



# 3) Measurements with $^{222}$Rn




In case of measurements of the $^{220}$Rn or $^{222}$Rn the air having traces of these radioactive elements was introduce in to the detector.

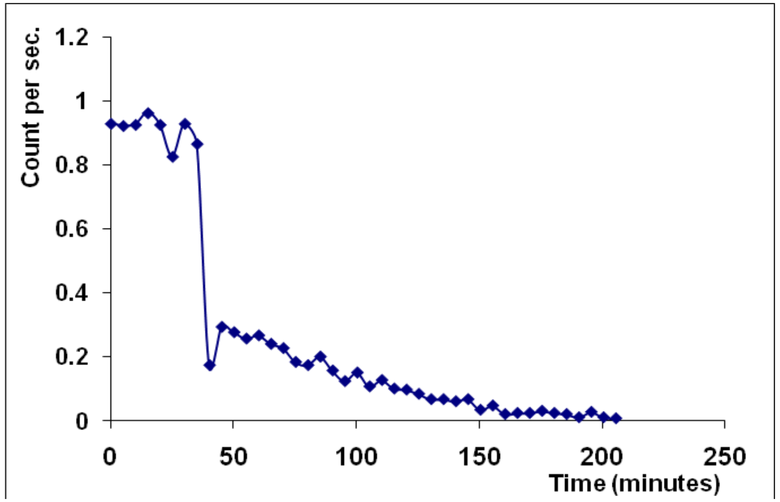
Their concentration was evaluated from the counting rate produced by alpha particles.

samples of air containing Rn were also independently measured by the experts from the French company **ALGADE**

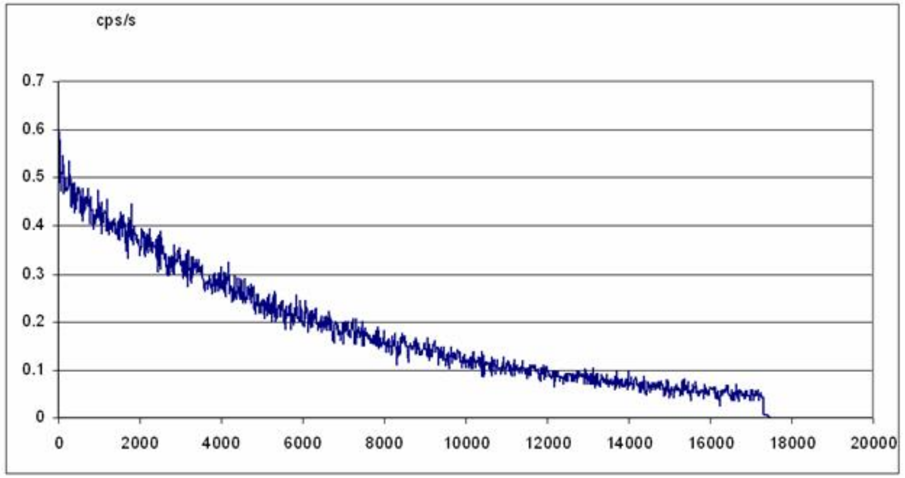
Counting rate vs. time after injection into the basic design (at t=2min) air contaminated with $^{222}$Rn.

At t=40 min the detector for a few second was flushed with a clean air

## Comparative measurements with a single-wire counter operating at low voltages ( plateau region):



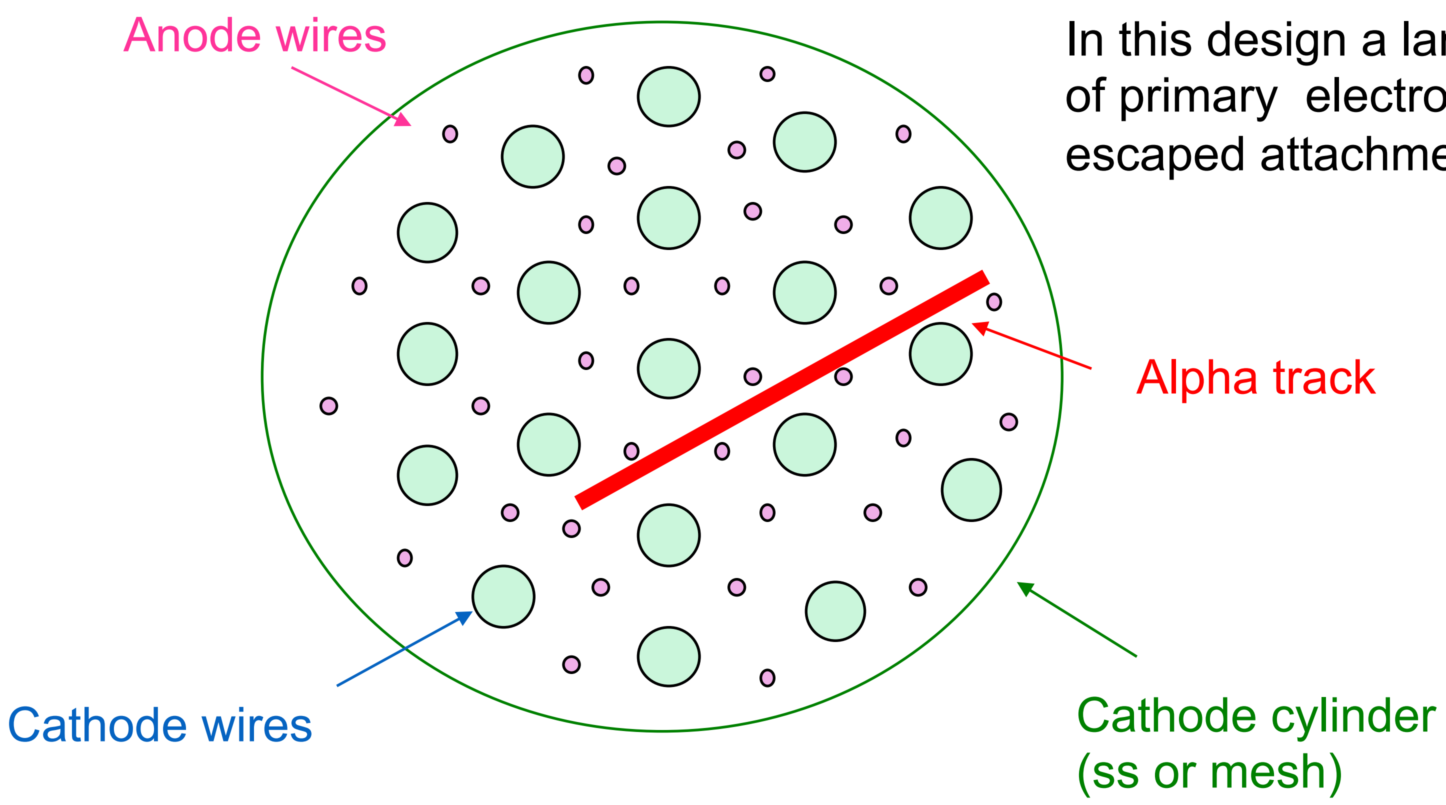

Counting rate vs. time when the radon contaminated air was introduces (at t=0sec) into the ionization chamber and at t=40sec it was flushed with clean air. The fast decrease of the counting rate is mainly due to the Po decay




Long-term measurement performed with the ionization chamber: the counting rate decrease with a good accuracy corresponds to the decay of the $^{222}Rn$ ($T_0$=5500min)

## However, the **most efficient** suppression of noise pulses was achieved with **MWPC**

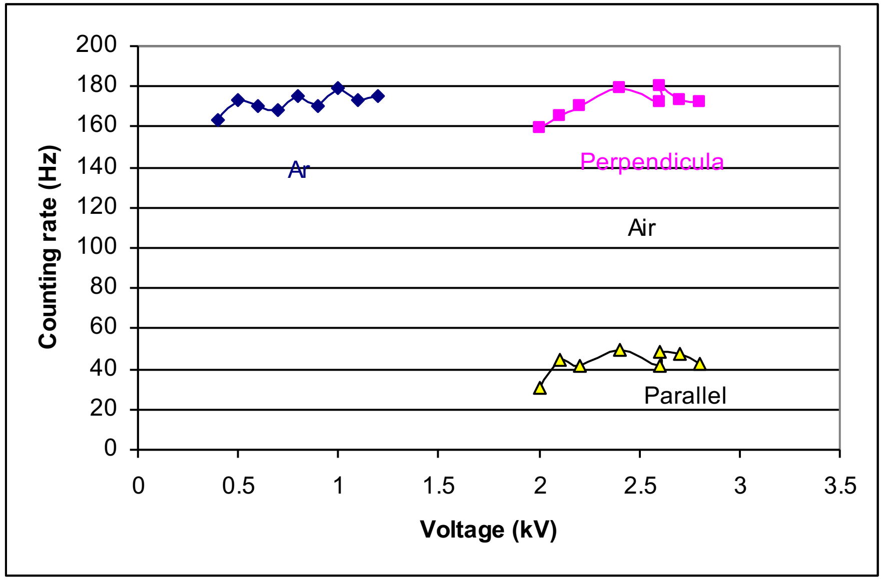
(*a copy of Sauli drift tube**)




In this design a large fraction of primary electrons escaped attachment

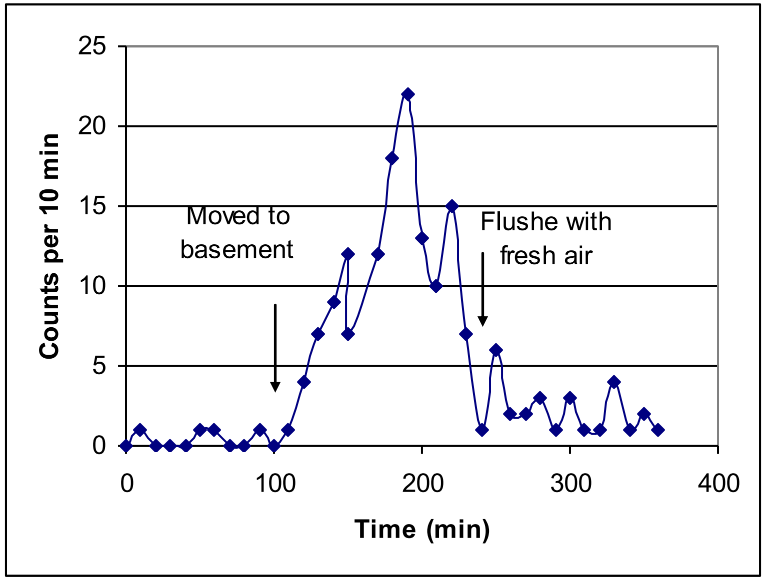
*Standard electronics*: each anode wire was connected to its own amplifier which after the amplitude discrimination produces a standard square pulse 1μs long. These pulses were sent in parallel to a simple "majority" unit which generate an output pulse it there was two or more coinciding input signals. These generated pulses were counted by a standard scaller.
In measurements with alpha particlesonly those event were chosen and counted when two or more wires produce signals within a few μs gate.

**R. Bouclier et al., NIM A2521986,393*




Counting characteristics of the MWPC measured in Ar (all wires were connected to one amplifier) and in air for alpha tracks oriented perpendicular and parallel to the anode wire

Results of detection a small concentration of Rn in a basement. In the time interval of 0-100min the MWPC operated in fresh air. At T=100min it was moved in to the basement. At T=240min the chamber was flushed with fresh air and removed from the basement



# Summary of results:

| | Single -wire proportional counters | Single- wire ionization chamber | MWPC |
|---|---|---|---|
| Noise Bq/m3 | 76 | 24 | 1.2(air from a cylinder)<br>2 (ambient air) |
| Efficiency | 1 | 0.15 | 1 |

Table 1 Noise and efficiency of various types of wire detectors operating in air and tested in this work

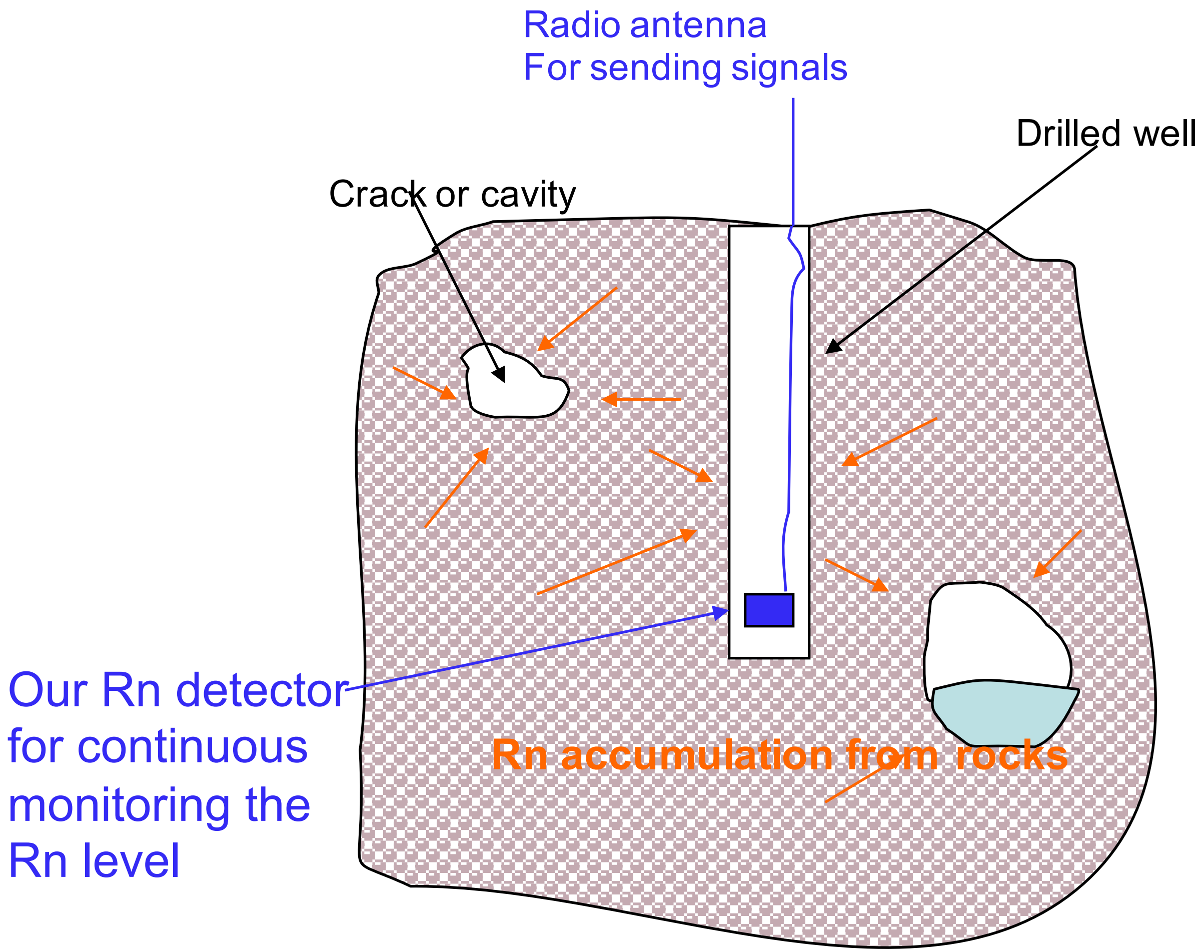
| Time of counting (min) | Single -wire proportional counters MDA | Single -wire ionization chamber MDA | MWPC MDA | **Atmos MDA** (the best on the market) |
|---|---|---|---|---|
| 0.2 | 1300 | 6830 | 625 | |
| 1 | 420 | 1960 | **140** | **150** |
| 2 | 270 | 1200 | 75 | |
| 4 | 175 | 760 | 43 | |

Table 2 Minimum detectable activity of our detectors (in Bq/m3) to Rn alpha particles for various time intervals of measurements Δt

To verify our measurements some samples of air containing Rn were also independently measured by the experts from the French company **ALGADE**

Our detector has sensitivity as high as the best commercial Rn detectors, however *much* simple and cheaper. Its features make it suitable for massive applications, such as  a continuous Rn monitoring for possible earthquake prediction or continuous monitoring of Po contaminations

## How the Rn variations can be monitored in field by our detectors? They should be installed in wells or in cavities and cracks in rocks

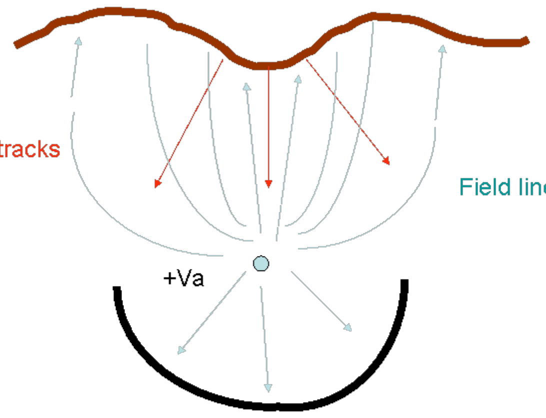


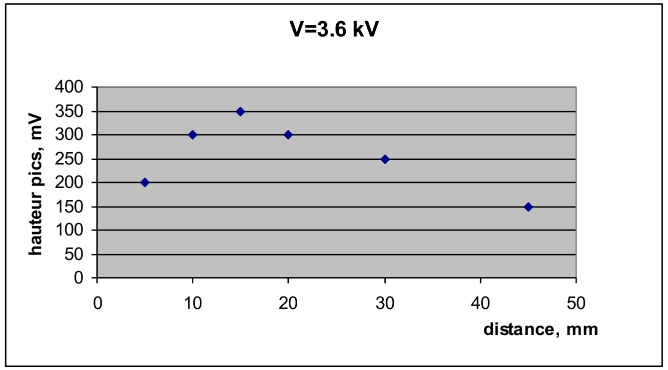

As Prof. F.Romano noted yesterday, our nearest plans are to develop and install a network of such detectors in the region when weak earthquakes are often happen

# Polonium contamination monitoring

# Po detection:

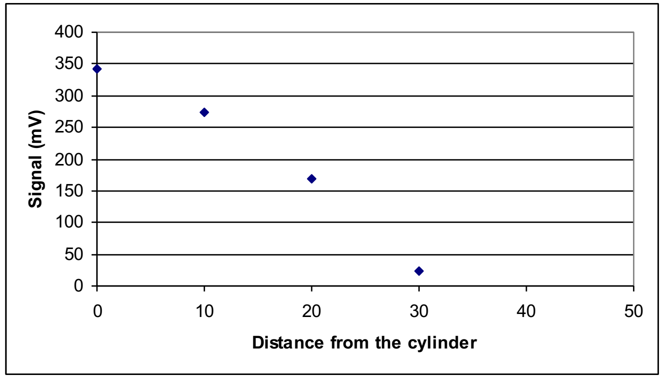
## Single -wire



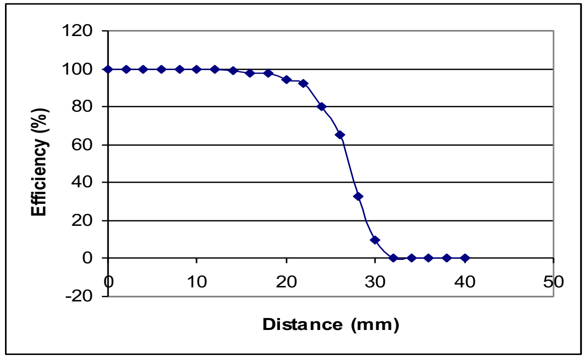




Alpha particles signal amplitude as a function of the distance from the **single-wire counter**

## MWPC




Signal amplitude vs. the distance from the cathode of the MWPC measured with alpha particles oriented perpendicular to the cylinder axis. In these particular measurements all wires were connected to one amplifier




Efficiency of alpha particles detection vs. the distance from the cathode cylinder when MWPC operated in signal coincidence mode

# Conclusions:

● Major applications of gaseous detectors are in high-energy physics and astrophysics

● However, the have many other fields of applications: from medicine and home-land security to environmental monitoring and safety

One of their advantage over existing commercial devise are high sensitivity.

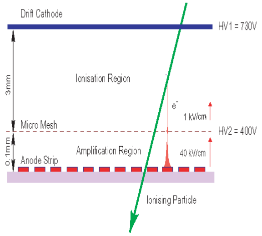
In some cases they are 100-1000 times more sensitive than commercial devices

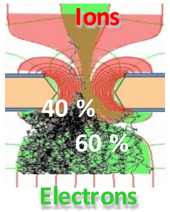
● Special place belongs to micropattern gaseous detectors which represent a new class of imaging detectors

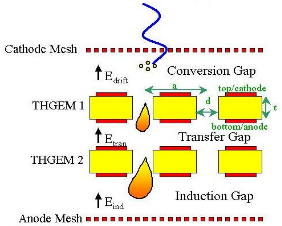
They have potentials for very high energy, position and time resolutions (already approaching or exceeding some solid-state detectors)

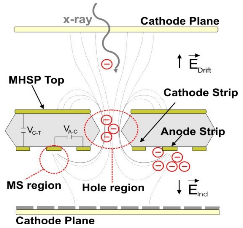
● Their applications is rapidly expanding beyond HEP and astrophysics

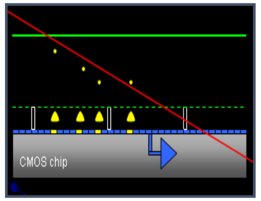
● For these reasons we believe they will have a great future

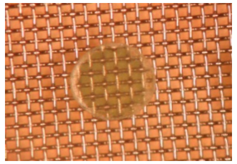


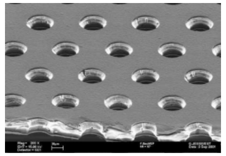



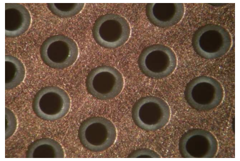



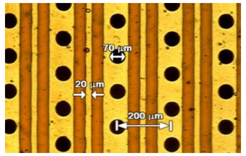



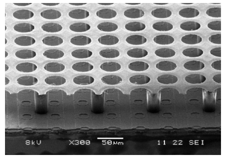





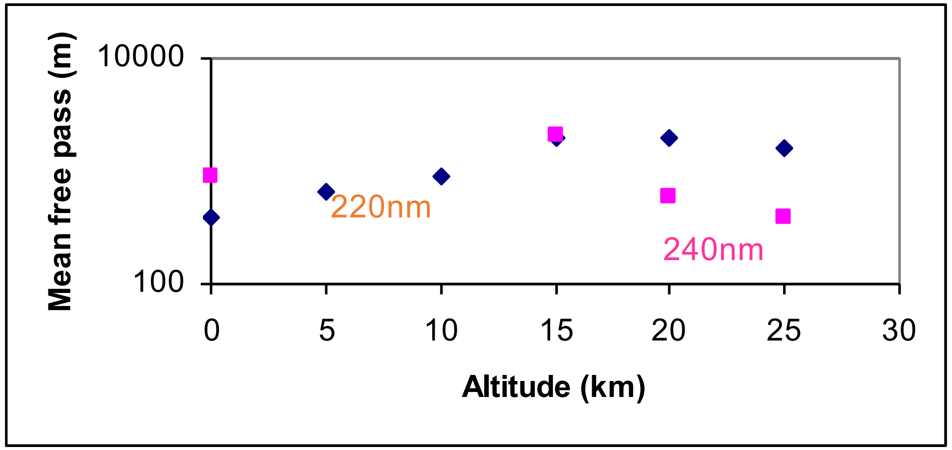




# Bakup slides

# Air transmission at high altitudes:




At 10-15km the UV photons mean free pass increases to km

TMAE -filled gaseous detectors were already successfully used for UV imaging air Cherenkov telescopes