FORFIRE

System for highly reliable, cost effective, early detection and accurate localization of incipient forest fires

➔ The objective of the ForFire project is the development of an outdoor fire detection system by using an innovative solar blind camera based on the technology of photosensitive gas and solid state detectors

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in collaboration with

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What exist out there?

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

EU standard:

The highest sensitivity Class 1: ~ 30 x 30 x 30 cm3 flame at ~20m for 20sec - Hamamatsu UVtron

Dräger Flame 5000

Gasoline Fire surface of 0.1 m^2 at 44 m

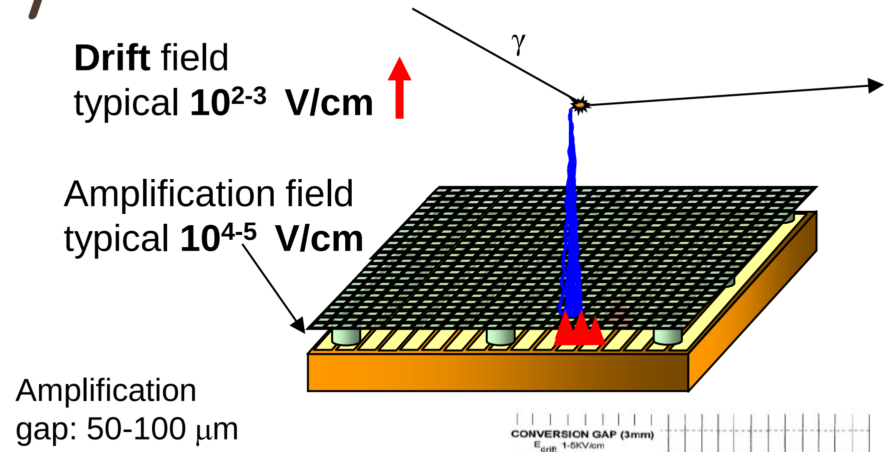
Simtronics MultiFlame DM-TV6-V Dual UV-IR

Range, n-heptane 45m 0.3x0.3m
Range, gazoline 27 m 0.3x0.3 m

The Micromegas Concept

Two-region gaseous detector:

- Conversion region
  - ➢ Primary ionization
  - ➢ Charge drift
- Amplification region
  - ➢ Charge multiplication
  - ➢ Readout layout
    - Strips (1/2 D)
    - Pixels



Separated by a Micromesh

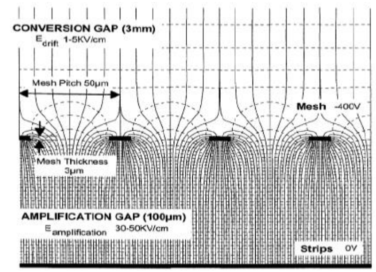
➔Very strong and uniform electric field

- metallic micromesh (typical pitch 50μm)
- sustained by 50-400 μm pillars
- simplicity
- single stage of amplification
- fast and natural ion collection
- discharges non destructive

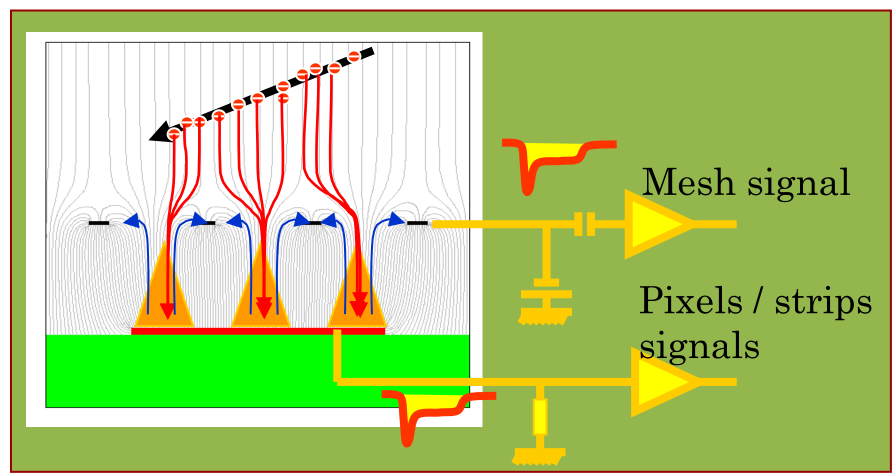
MICROMEsh GAseous Structure

Giomataris, Charpak (1996)

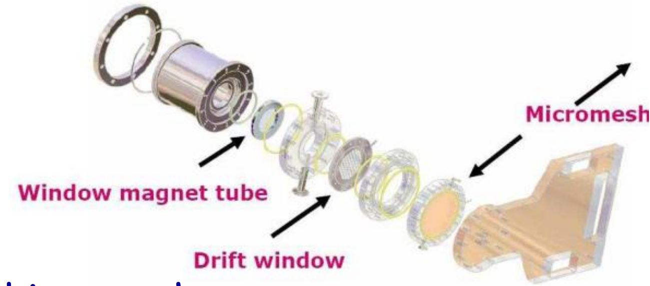
Y. Giomataris *et al.*, NIM A 376 (1996) 29



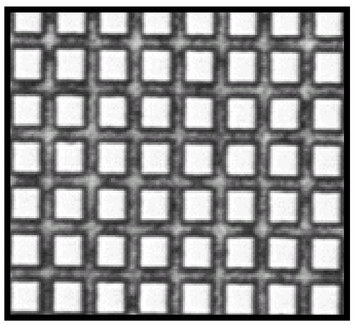
In 1st Micromegas
Fishing line spacers have been used



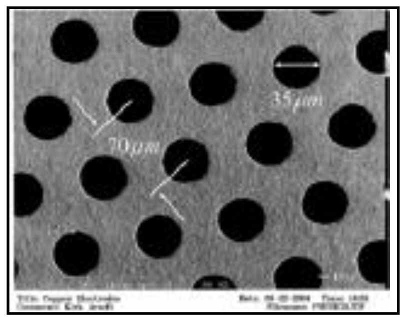
Micromegas elements



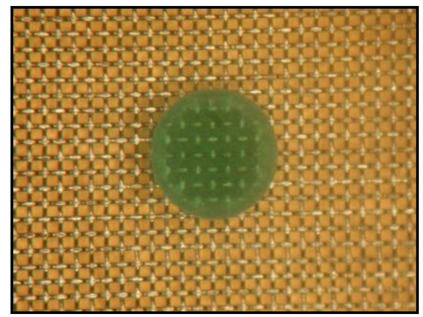
- micromesh
  - Many different technologies have been developed for making meshes (Bopp, CERN, 3M-Purdue, Gantois, Twente…)
  - Exist in many metals: nickel, copper, stainless steel, Al,… also gold, titanium, nanocristalline copper are possible.



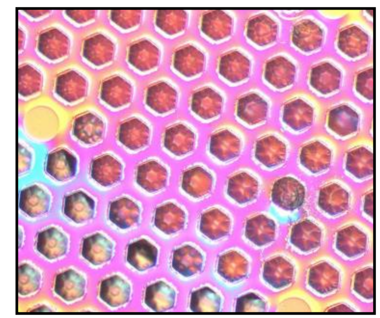
Electroformed



Chemically etched



Wowen

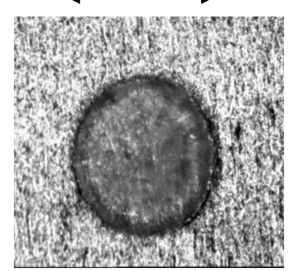


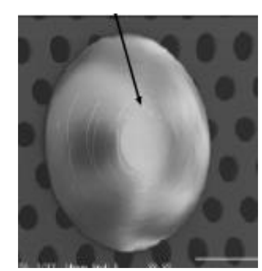
Deposited by vaporization

Laser etching, Plasma etching…

- Pillars
  - Can be on the mesh (chemical etching) or on the anode (PCB technique with a photoimageable coverlay).
  - Diameter 40 to 400 μm

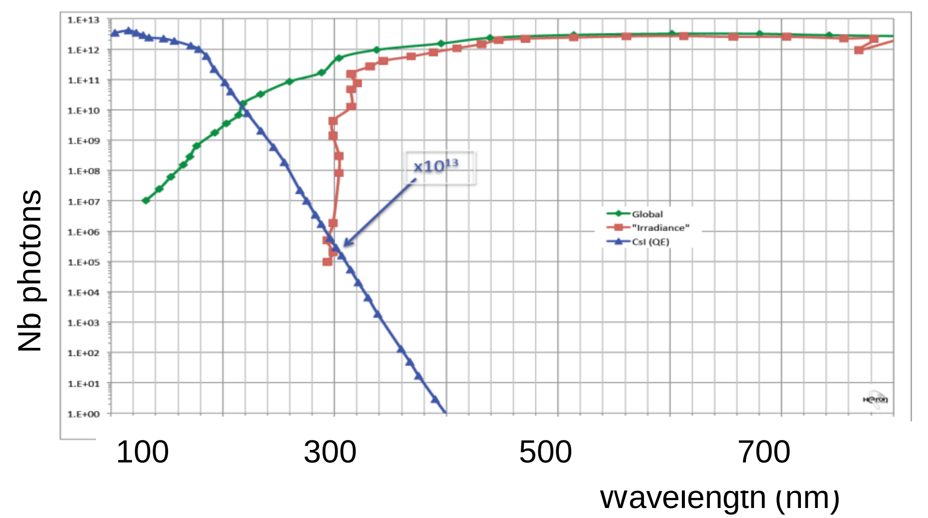
200 μm





A Micromegas for UV is attractive:

- High electron amplification possible (10^6)
  - ➔ Good signal to noise ratio
  - ➔ **High sensitivity**, reaching "***single photon detection***" level.
- Very low power consumption (<< mW)
- Intrinsically "solar-blind":
  the Q.E. of solid photocathodes such as CsI is significant for 200-230 nm and drops by 7 orders of magnitude up to 300 nm
- Very low production cost
- Large scale production possible
- Sealed detector
- Very fast response (<1µs).
- UV imaging possible



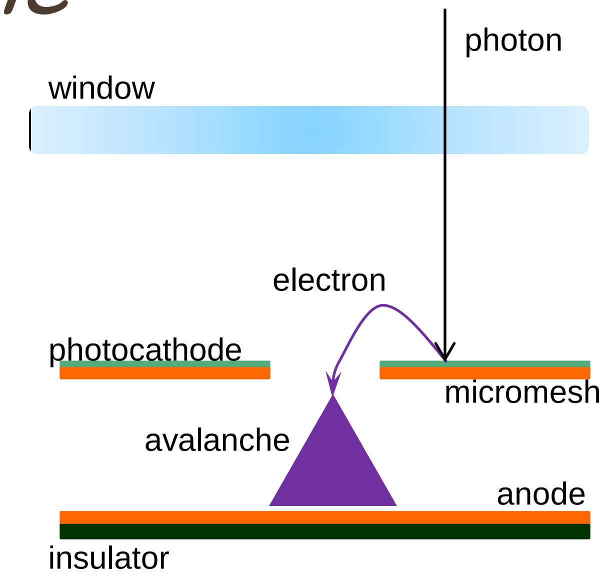
UV photon detection principle

➢ <u>Reflective photocathode</u>:

Photosensitive material is deposited on the top surface of the micromesh.

Photoelectrons extracted by photons will follow the field lines to the amplification region

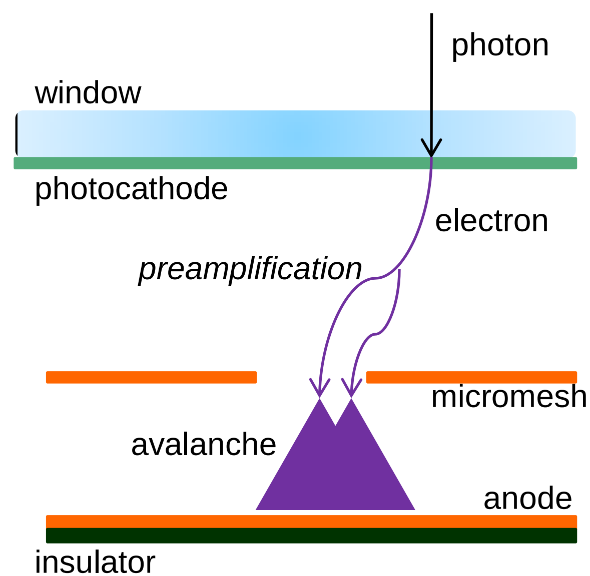
- ✓ The photocathode does not see the avalanche ➔ *no ion feedback effect ➔ higher gain (up to 10^6)*
- ✓ High electron extraction & collection efficiency
- ✓ Field on photocathode 10^4 V/cm



➢ <u>Semi-transparent photocathode</u>:

Photosensitive material is deposited on an aluminized quartz window (drift electrode)

- ✓ Extra preamplification stage ➔ better long-term stability
- × Lower photon extraction efficiency (factor 3)
- × Fragility to sparks
- × Ion feedback ➔ gain limitation



Advantages of the new concept

Combining the advantages of the two modes, while suppressing the disadvantages!!!

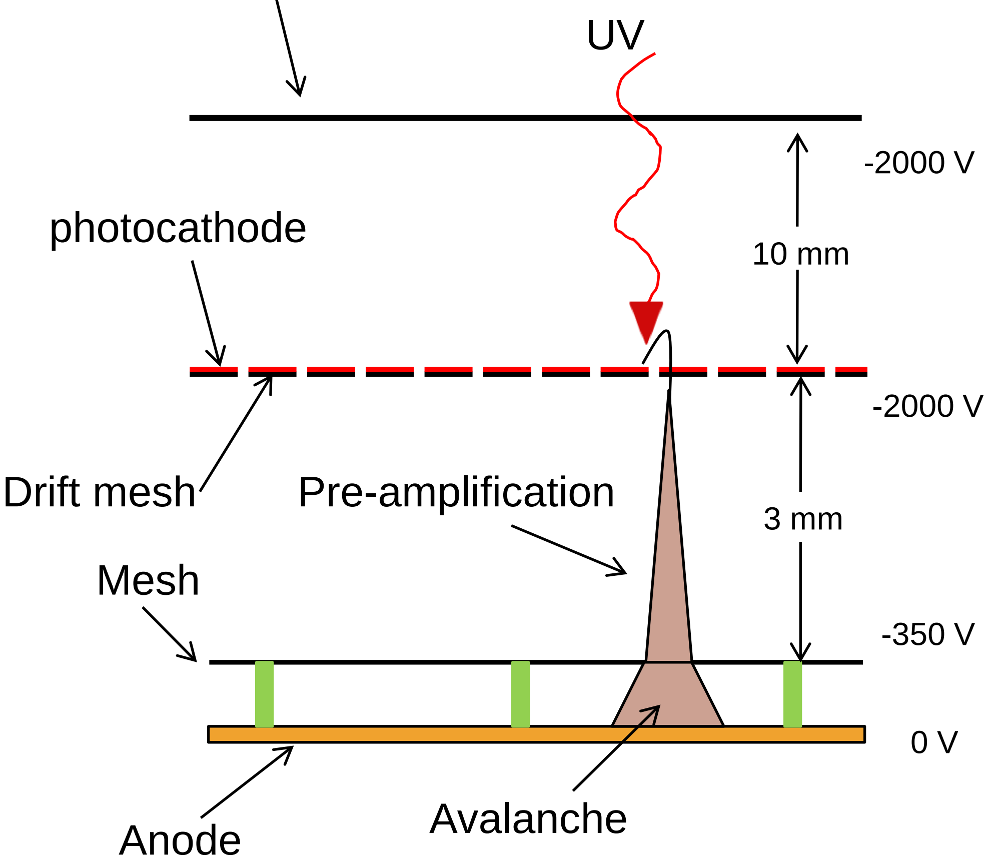
- **Reflective photocathode**
  - ➔ **High electron extraction efficiency**
- **Preamplification**
- **No ion feedback**
  - ➔ **Very high total gain (>> 10^7)**
  - ➔ **Stability in sealed mode**
  - ➔ **Exceptional signal to noise ratio**
- **Photocathode separated from detector**
  - ➔ **Easy fabrication/handling of CsI**

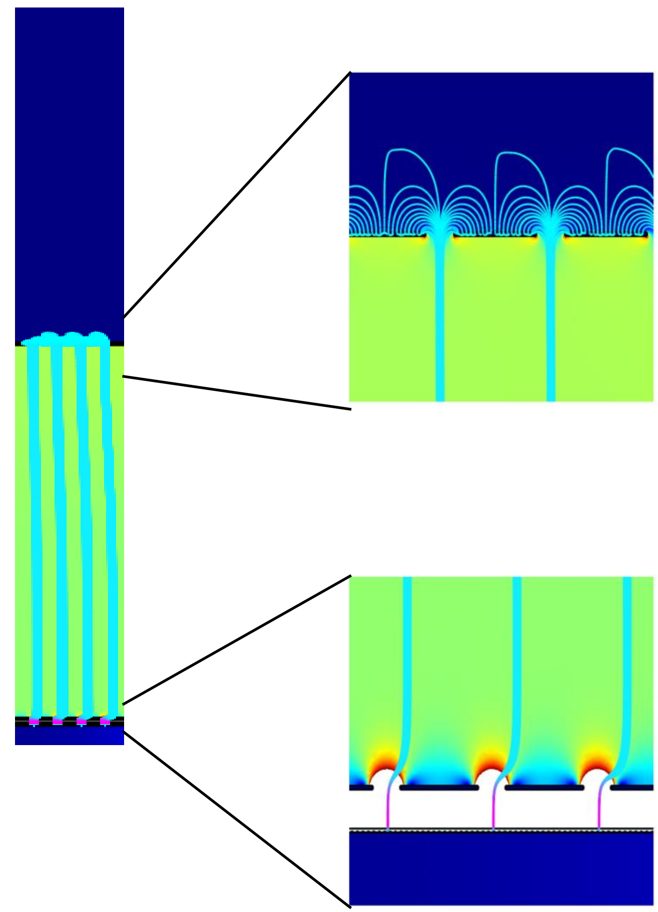
The FORFIRE Micromegas concept

Our choice: ☞ **Reflective photocathode**

+ Photocathode separated from detector

+ Preamplification





Micromegas construction

Conventional technology

The pillars are attached to the mesh. A supporting ring or frame is adjusting the mesh on top of the readout plane

Typical dimensions: mesh thickness 5 µm, gap 50 µm

Bulk technology

The pillars are attached to a woven mesh and to the readout plane

Typical dimensions: mesh thickness 30 µm, gap 100 µm

Microbulk technology

The pillars are constructed by chemical process of a kapton foil, that is attached to the mesh and to the readout plane

Typical dimensions: mesh thickness 5 µm, gap 50 µm

The FORFIRE detector

- Bulk Micromegas
- 144 pixels
- Gas: 90% Ne + 10% Ethane
  - High gain
  - Good electron extraction efficiency
- Photocathode = drift electrode

This design provides:

- ✓ *Production simplification*
- ✓ *Low cost*
- ✓ *Imaging capabilities*
- ✓ *Sealed operation*
- ✓ *Robustness*
- ✓ *Stability with time*
- ✓ *Very high gain*
  ➔ *Single photon detection*

Performance

General behavior

High gain (>> 10^5) in a single stage

☞ Single electron

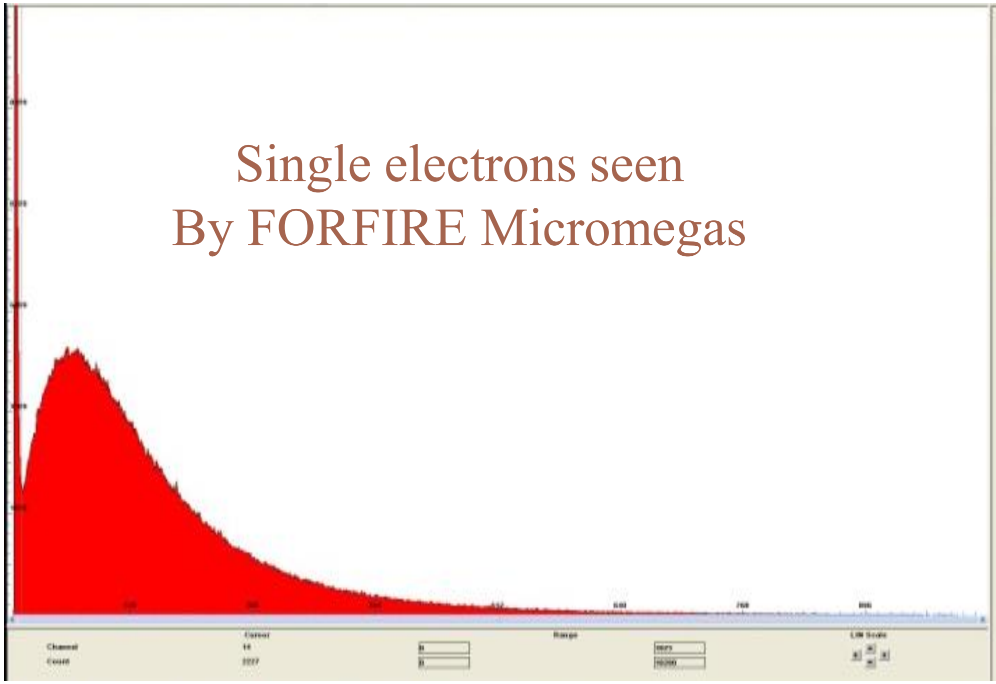
No ion feedback

Sealed

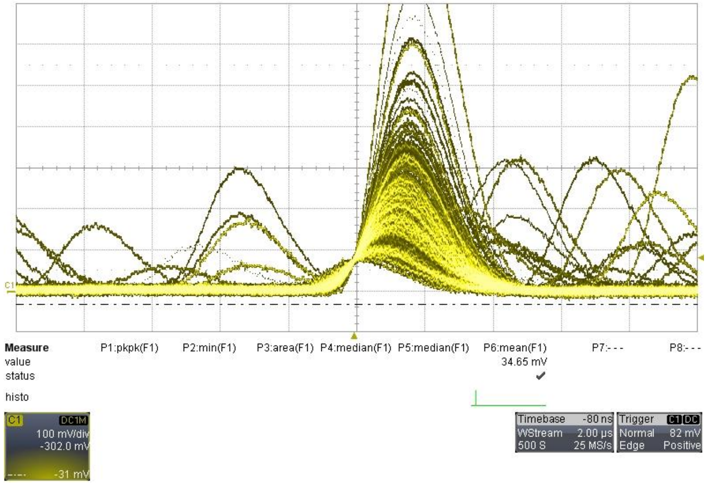
Preamplification (>100)

✓ Stable operation, far from sparking limit

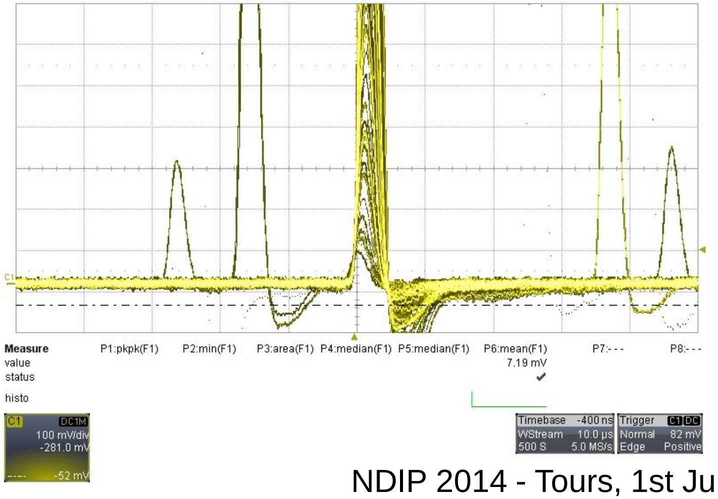
✓ Huge gain (even causing trouble using standard electronics!)



Normal mode



Preamplification mode



Quantum Efficiency measurements

Measurement in the 200 – 300 nm range not easy:

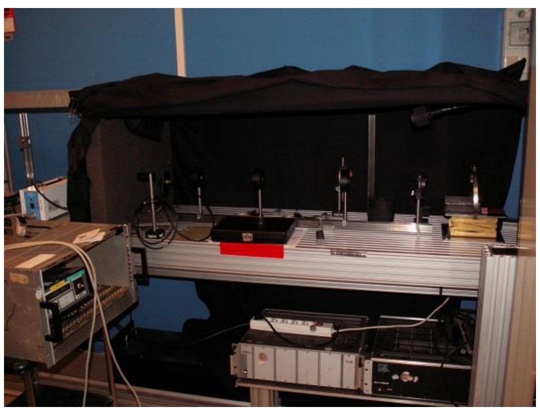
- ✓ Small Q.E.
- ✓ Q.E. drops by > 7 orders of magnitude
- ✓ FORFIRE detector too sensitive! ➔ Reference measurement not easy!!!

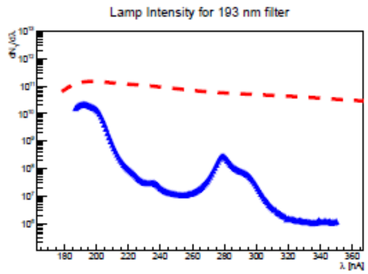
☞ *Use of attenuators*

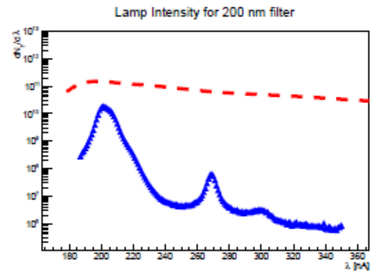
2 systems:

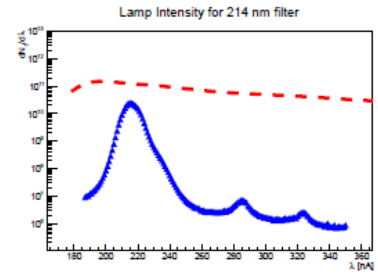
- ➢ UV filters + deuterium lamp
- ➢ Varian monochromator

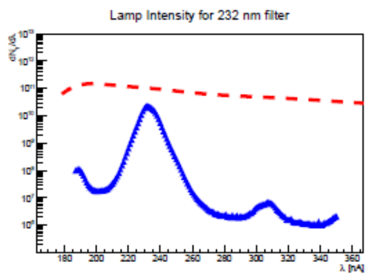
UV filters + deuterium lamp

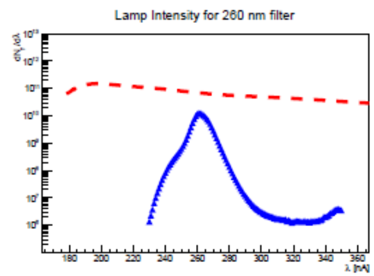


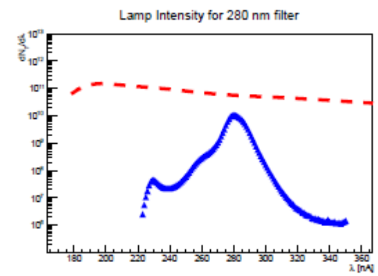


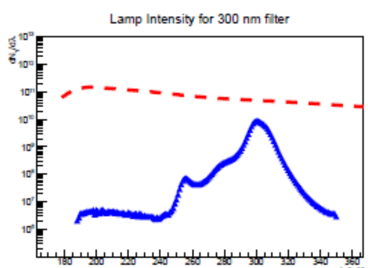


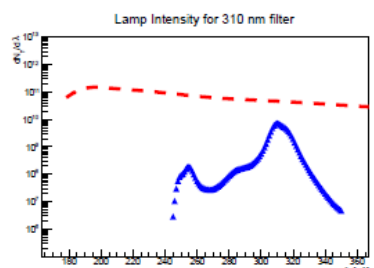






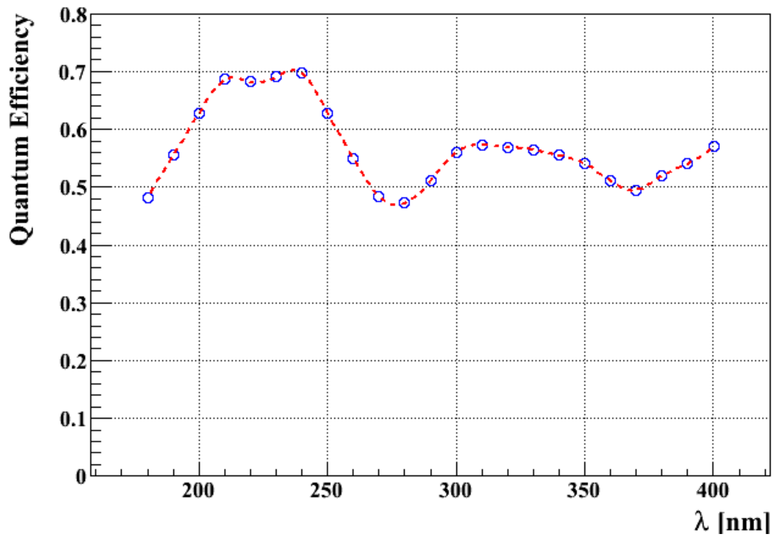


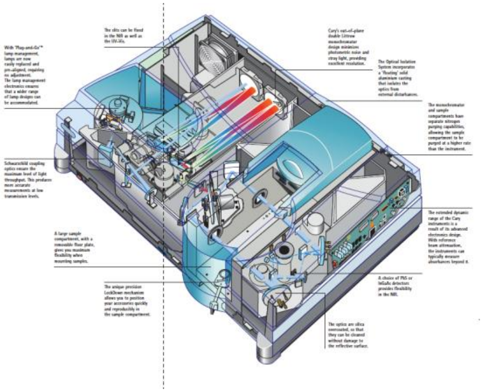




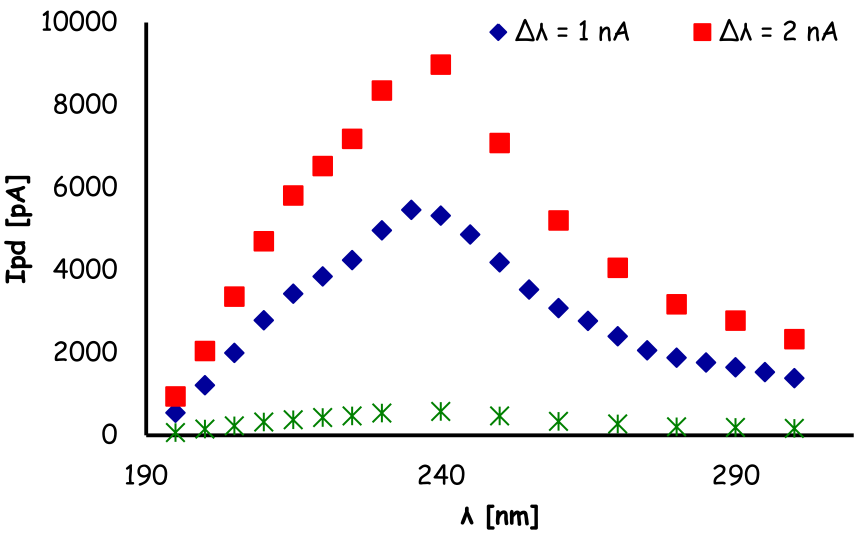
Integrated γ flux at 50 cm	
193 nm filter:	3.202e+11 γ s^{-1} cm^{-2}
200 nm filter:	1.953e+11 γ s^{-1} cm^{-2}
214 nm filter:	2.673e+11 γ s^{-1} cm^{-2}
232 nm filter:	2.440e+11 γ s^{-1} cm^{-2}
260 nm filter:	1.394e+11 γ s^{-1} cm^{-2}
280 nm filter:	1.391e+11 γ s^{-1} cm^{-2}
300 nm filter:	1.139e+11 γ s^{-1} cm^{-2}
310 nm filter:	9.430e+10 γ s^{-1} cm^{-2}

Quantum Efficiency of the FORFIRE detector





The measurements were performed using the Varian 5000 spectrometer. The photon flux as a function of the wavelength was measured using a calibrated PD222AUV photodiode



Spectrometer flux for several bandwidth acceptances. Measurements repeated within a period of 1 month revealed stability of the order of few %.

Quantum Efficiency of the FORFIRE detector

The detector quantum efficiency is the convolution of the CsI QE, the lens transparency and the a geometrical factor from the photocathode

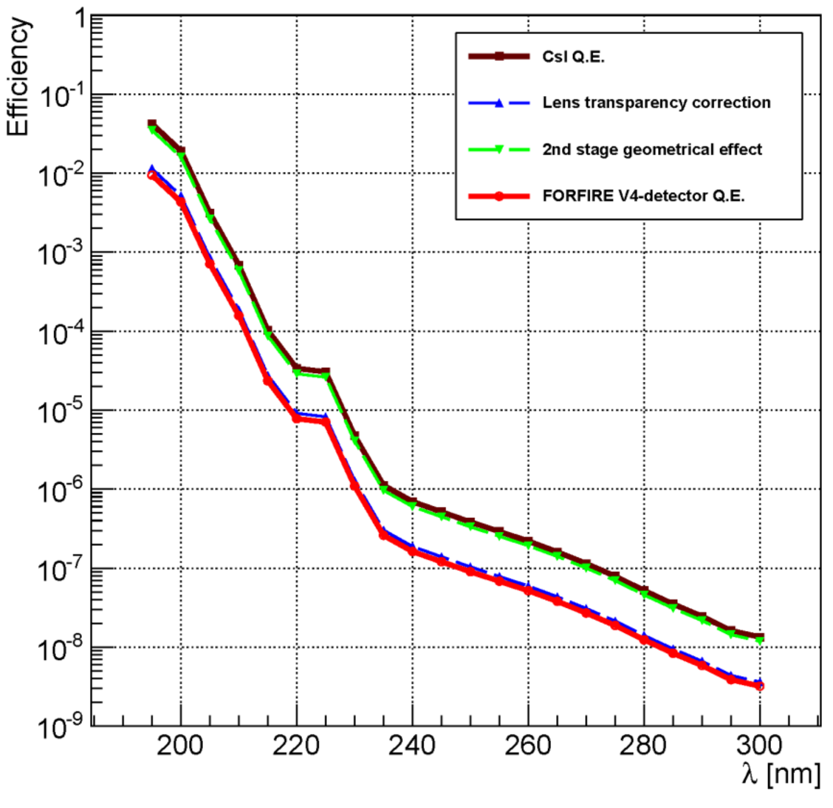
$$QE_{detector} = QE_{CsI} \times T_{lens} \times f_{geom}$$

The geometrical factor has two components:

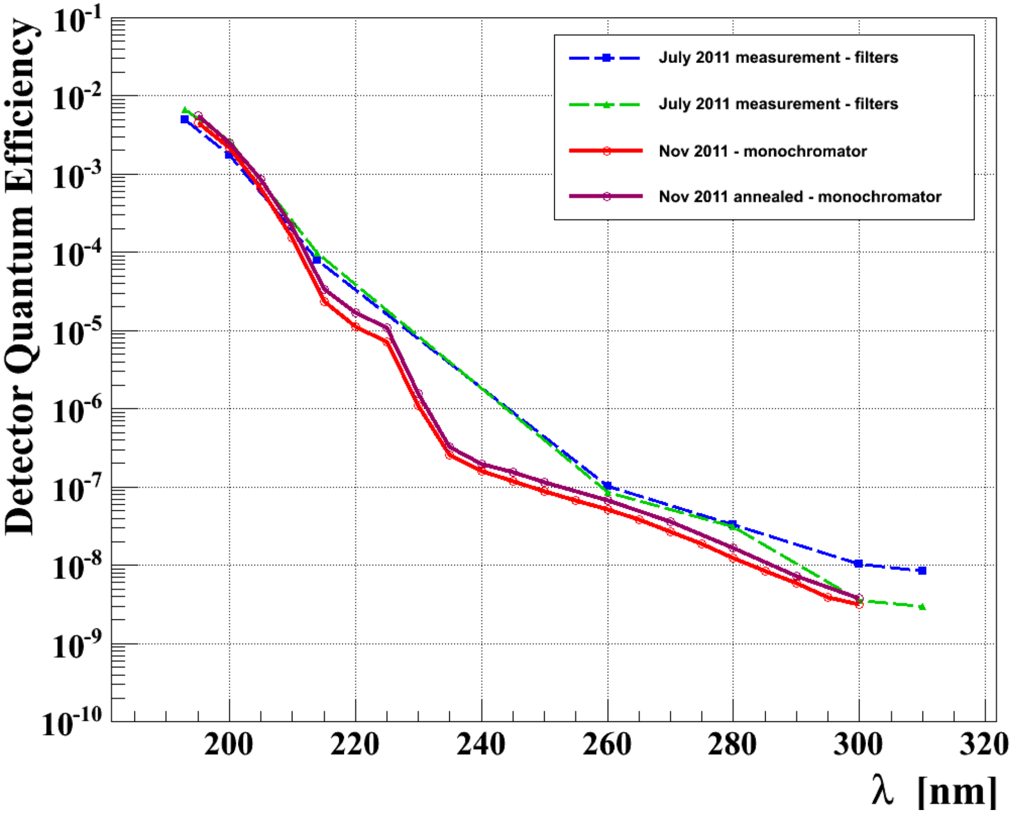
- the photocathode mesh opacity, which is 75%.
- the combination of the photoelectron extraction efficiency, and of their probability to arrive into the drift gap.

Performance of FORFIRE prototype

Q. E



Aging measurements



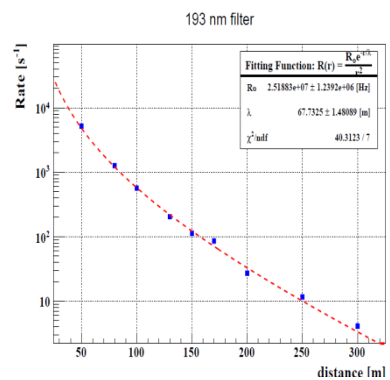
Long range measurements

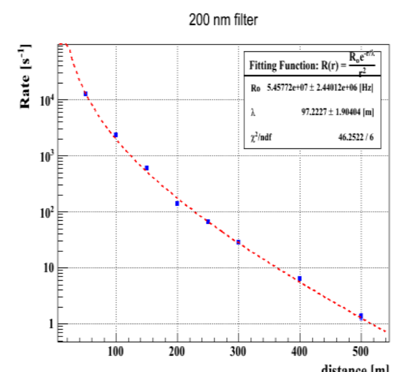
Outdoor measurements using a deuterium lamp and the 193, 200, 214 nm UV filters

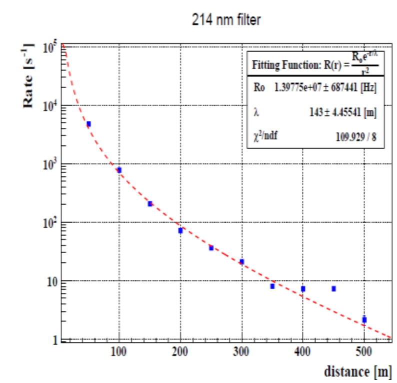
These filters cover the region of interest for fire detection, from where most of the signal is expected.

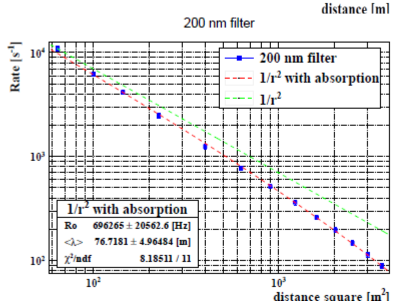
- Smaller wavelengths are strongly absorbed by the atmosphere
- For larger wavelengths the QE drops rapidly.

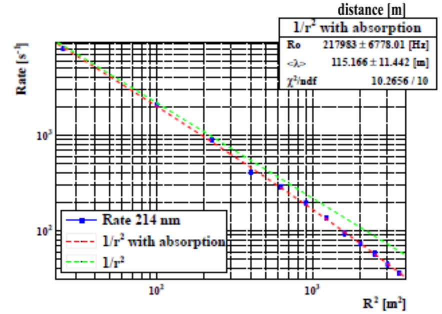
The absorption length of the atmosphere has been derived to be between 100 to 150 m in that region.

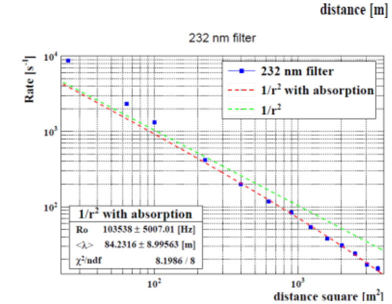




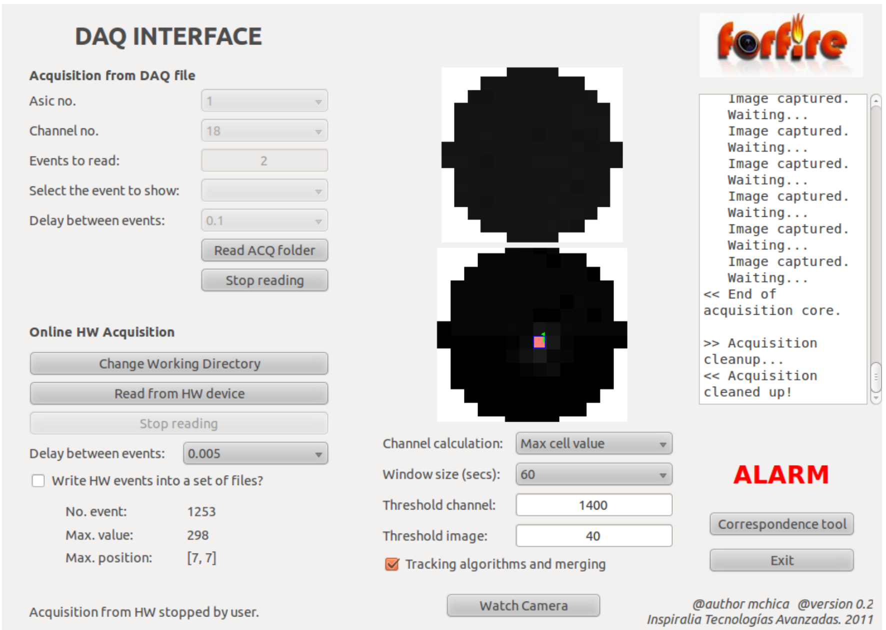


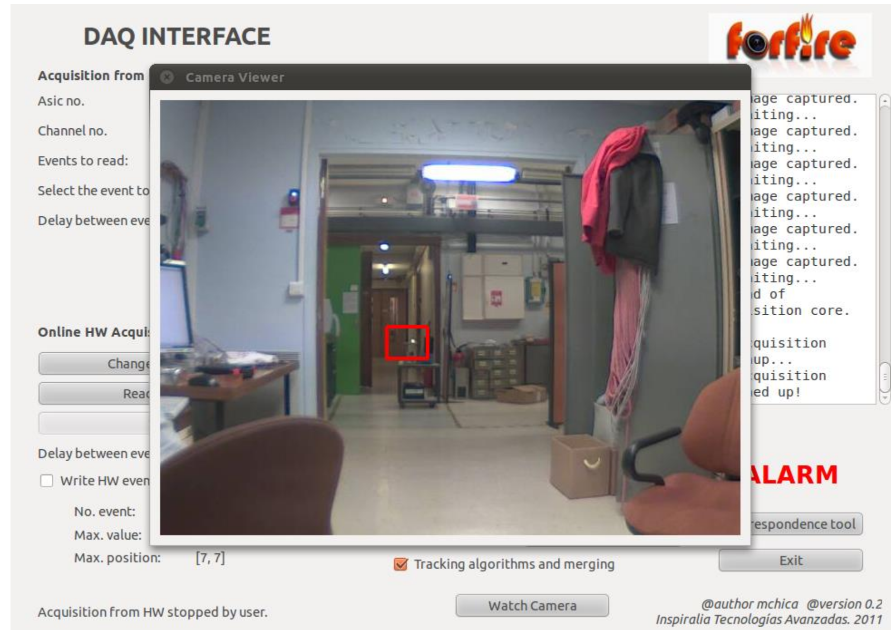






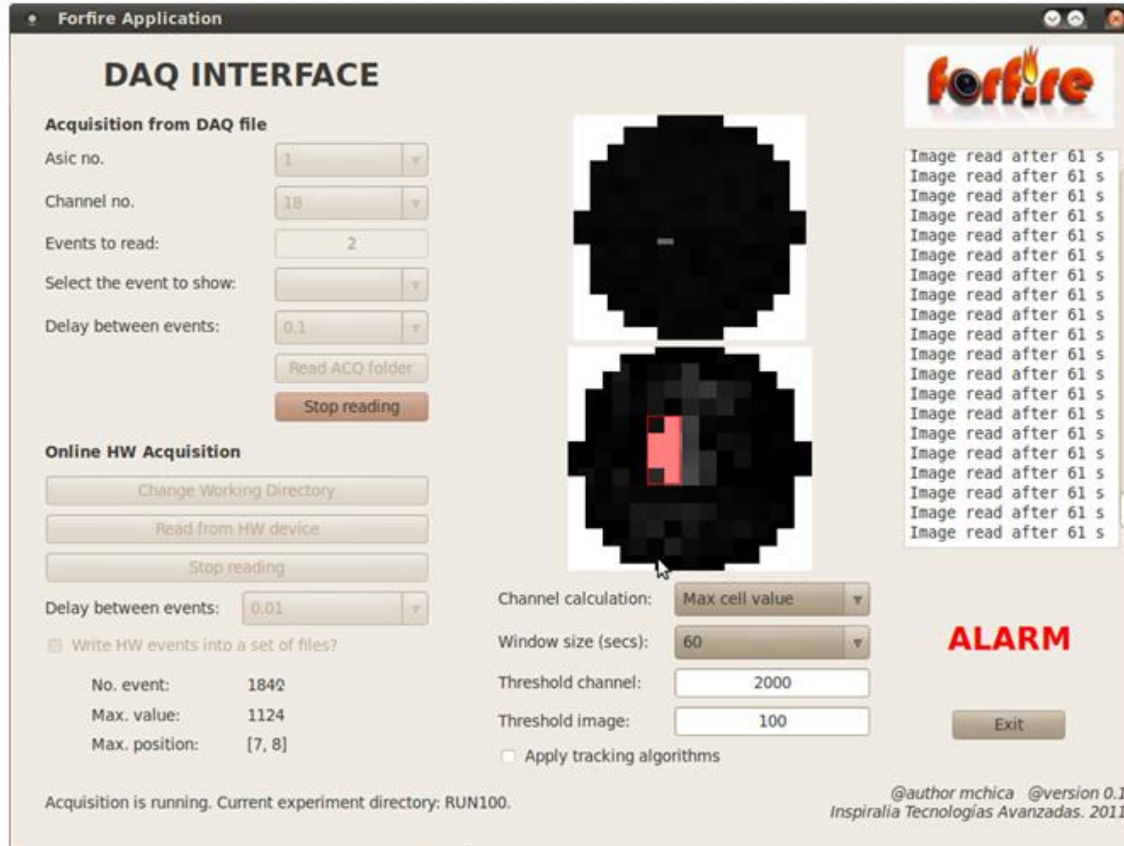
ForFire Software

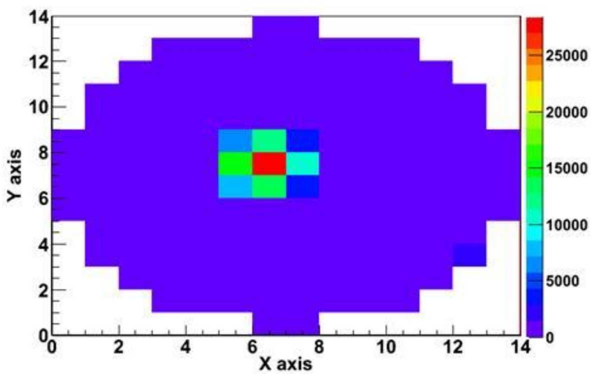




- Click on Tracking Algorithms and Merging to raise an image on alarm event
- Imaging software defines the position from the pixel map onto the camera image to pin-point the location of the triggered alarm.

IMAGERY


Forfire Application
DAQ INTERFACE
forfire
Acquisition from DAQ file
Asic no.
1
Channel no.
18
Events to read:
2
Select the event to show:
Delay between events:
0.1
Read ACQ folder
Stop reading
Online HW Acquisition
Change Working Directory
Read from HW device
Stop reading
Delay between events:
0.01
Write HW events into a set of files?
No. event: 1842
Max. value: 1124
Max. position: [7, 8]
Channel calculation:
Max cell value
Window size (secs):
60
Threshold channel:
2000
Threshold image:
100
Apply tracking algorithms
Image read after 61 s
ALARM
Exit
Acquisition is running. Current experiment directory: RUN100.
@author mchica @version 0.1
Inspiralia Tecnologías Avanzadas. 2011


Y axis
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Summary

A Micromegas prototype with solid photocathode has been constructed for the FORFIRE project.

It can be used efficiently for UV detection:

- ➢ The capability for *"single photon detection"* allows to maximize sensitivity & reduce reaction time
- ➢ Fulfils the requirements for "solar-blindness" and offers imaging capabilities

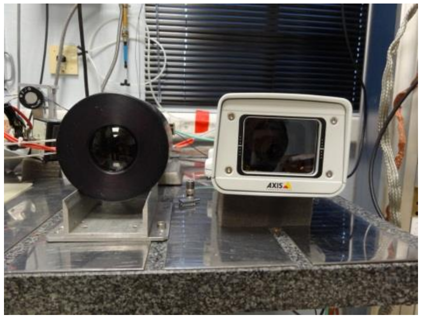
The adopted design:

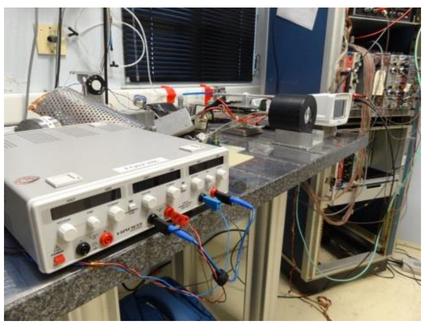
- ✓ has the advantages of reflective mode operation
- ✓ allows the usage of bulk technology
- ✓ allows easy fabrication and
- ☞ efficient mass production

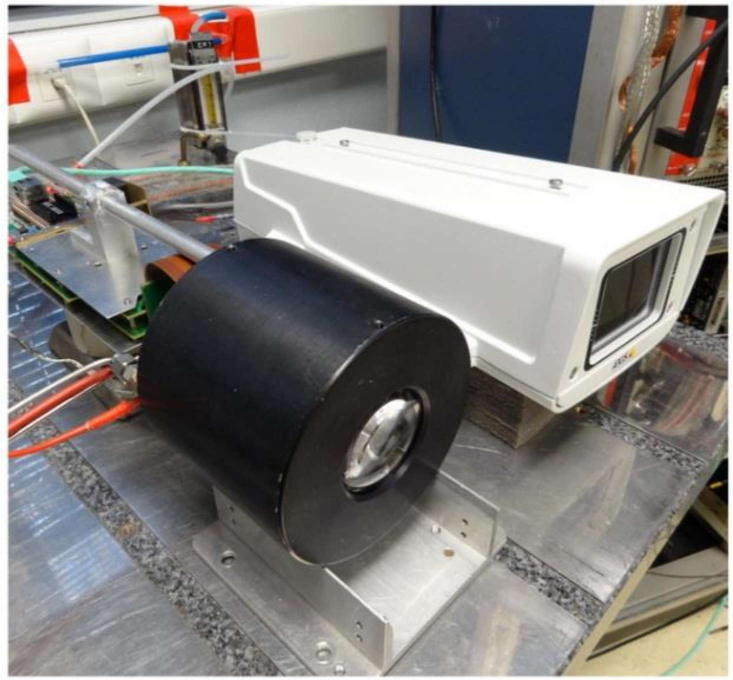
- ➢ The performance of the laboratory prototype meets the expectations.
- ➢ More applications: industrial & home security

Measurements done at various places…

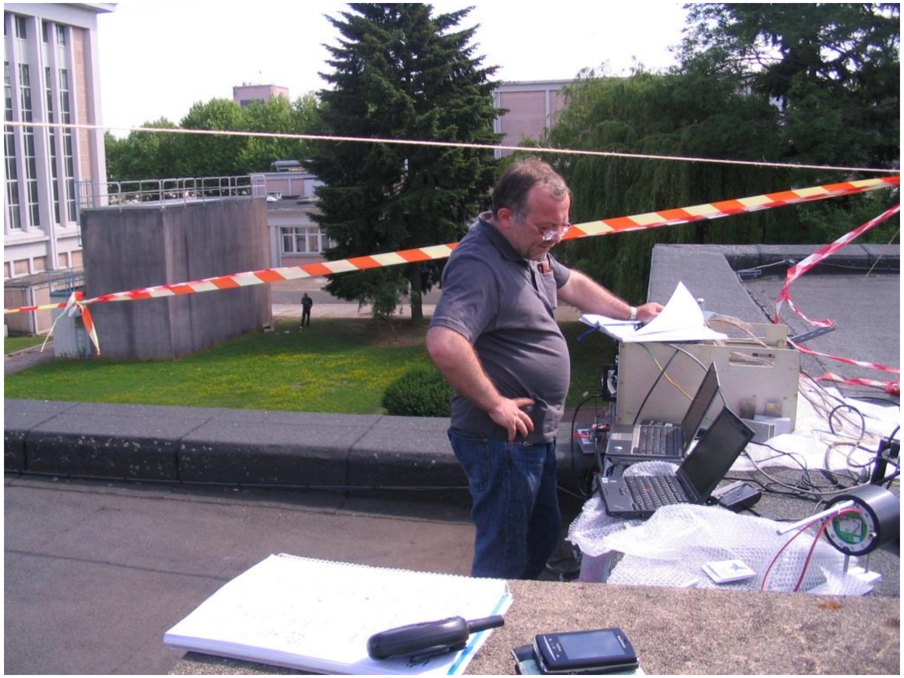
In the Lab

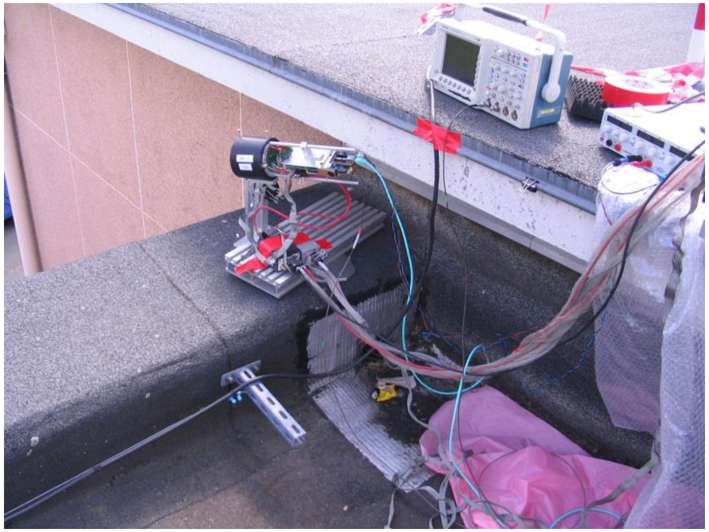






On the roof of building 534...





At Athens University...