Irfu - CEA Saclay
Institut de recherche sur les lois fondamentales de l'Univers

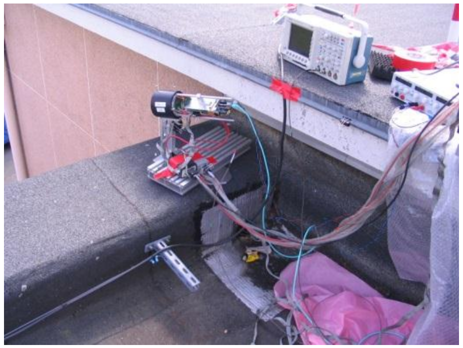
DE LA RECHERCHE À L'INDUSTRIE
cea

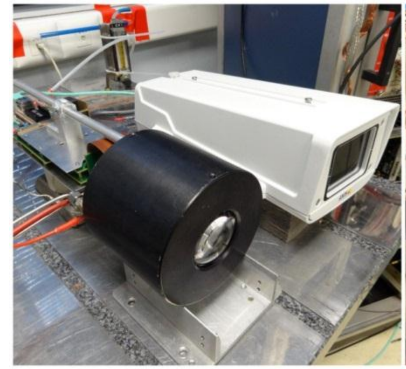
Instrumentation Days on gaseous detectors

25-26 June 2014
IPNO, Orsay

Feedback from Micromegas operation without gas renovation (FORFIRE/Piggyback)

Thomas Papaevangelou
CEA Saclay





The FORFIRE project

The FORFIRE project

Objective: the development of an outdoor fire detection system, using an innovative solar blind camera based on the technology of photosensitive gas and solid state detectors

R&D investment

CEA	475.380
ITAV	443.250
UOA	80.977
Total	**999.607**

Provide a fire detection system capability for:

- ✓ highly reliable
- ✓ cost effective
- ✓ early detection
- ✓ accurate localization.

Beneficiary Number	Beneficiary name	Beneficiary short name	Country	Date enter project	Date exit project
1 – SME coordinator	Irish Precision Optics	IPO	Ireland	Month 1	Month 24
2 – SME	HERON Technologies	HERON	France	Month 1	Month 24
3 – SME	OPTOEL	OPTOEL	Rumania	Month 1	Month 24
4 – SME	PINDIATEC	PINDIATEC	Spain	Month 1	Month 24
5 – End User	Forest Research Institute	FRI	Poland	Month 1	Month 24
6 – RTD	CEA	CEA	France	Month 1	Month 24
7 – RTD	ITAV	ITAV	Spain	Month 1	Month 24
8 – RTD	University of Athens	UOA	Greece	Month 1	Month 24

VUV area of the electromagnetic spectrum (190nm<λ<240nm).

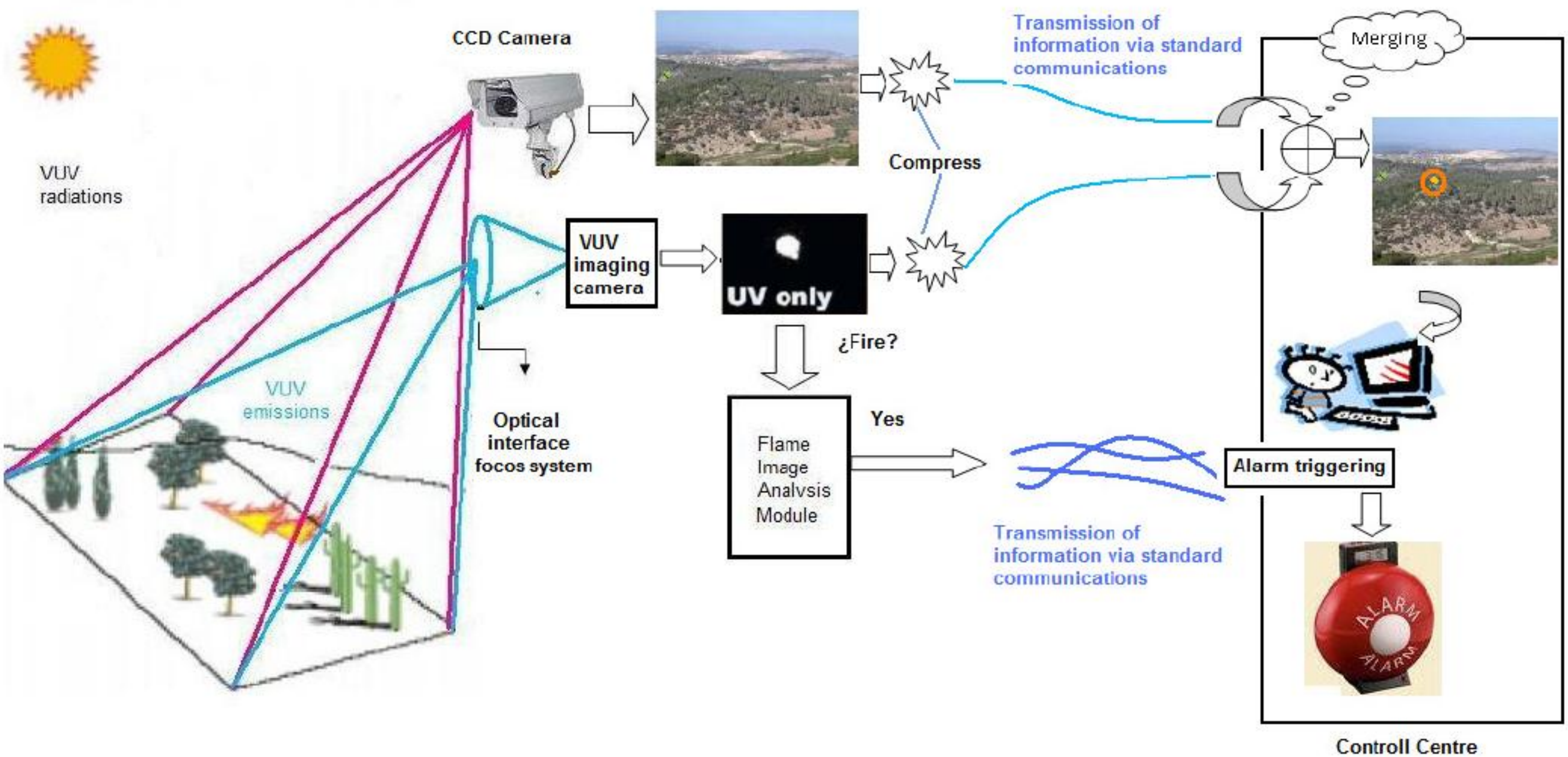
on the Earth surface only fire flames emit in this spectral range avoiding potential cross interferences from other wave sources including the Sun.

The project received a European subsidy of **1.1 million €**

within the framework of the FP7 program- Technology transfer to *Small and Medium Enterprises*.

Fire detection principle

➔ Detection of UV light
➔ Detector Network



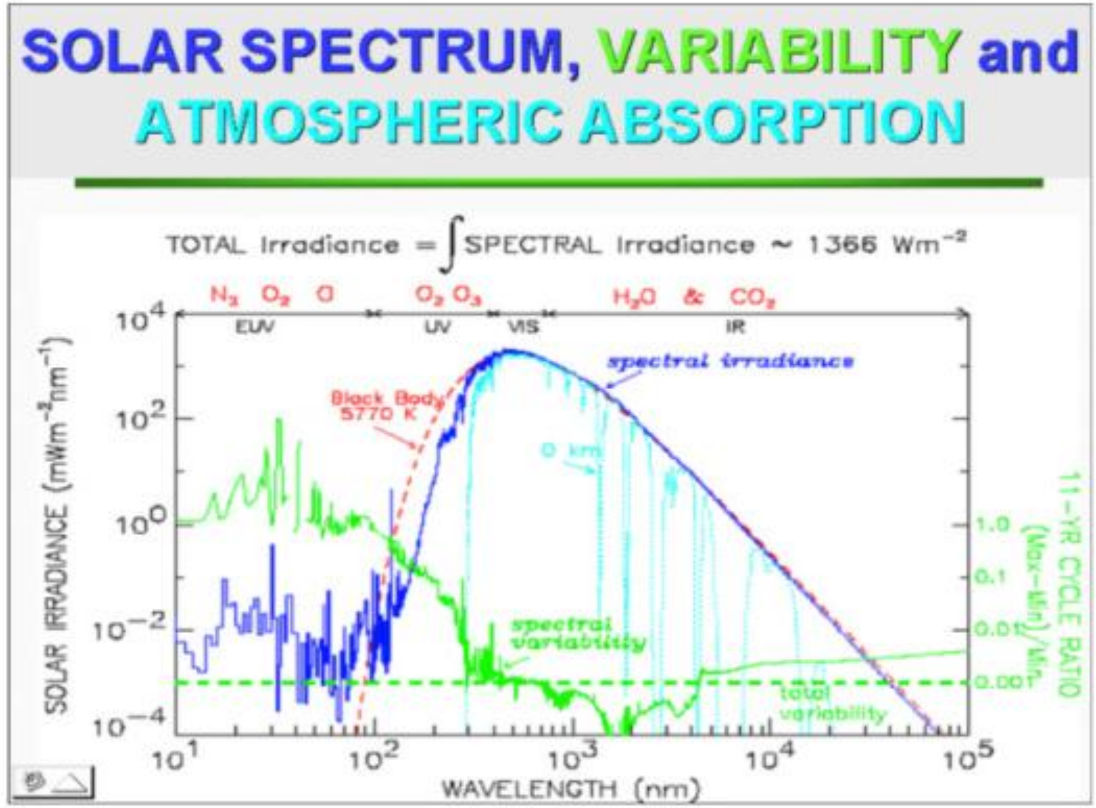
False alarms

Where is the fire ?

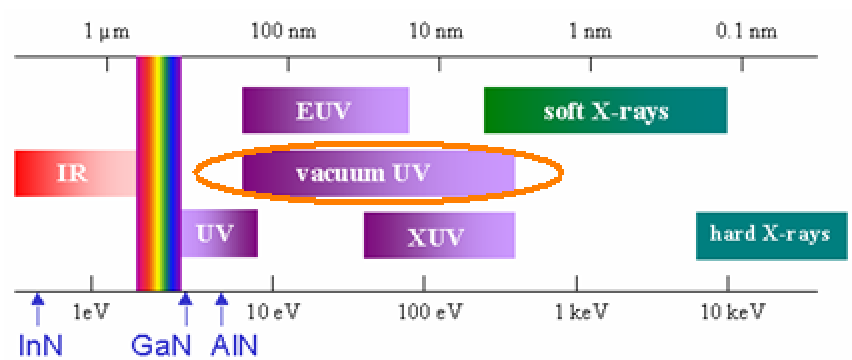
Where is the fire ?

Solar blind detectors

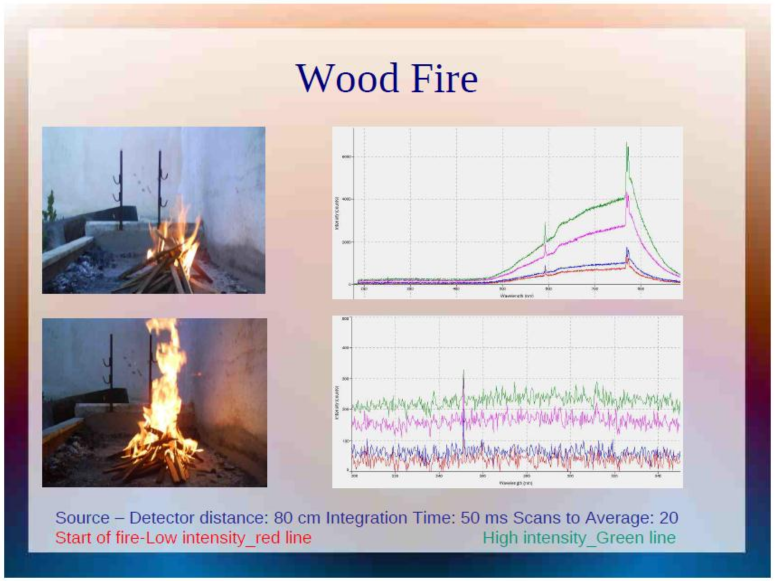
- O_3 layer absorbs solar irradiance below 250–300 nm
- Atmosphere is “transparent” to photons above 200 nm
- Photons between 200–250 nm indicate:
  - Electrical discharge
  - Explosion
  - **Flame**

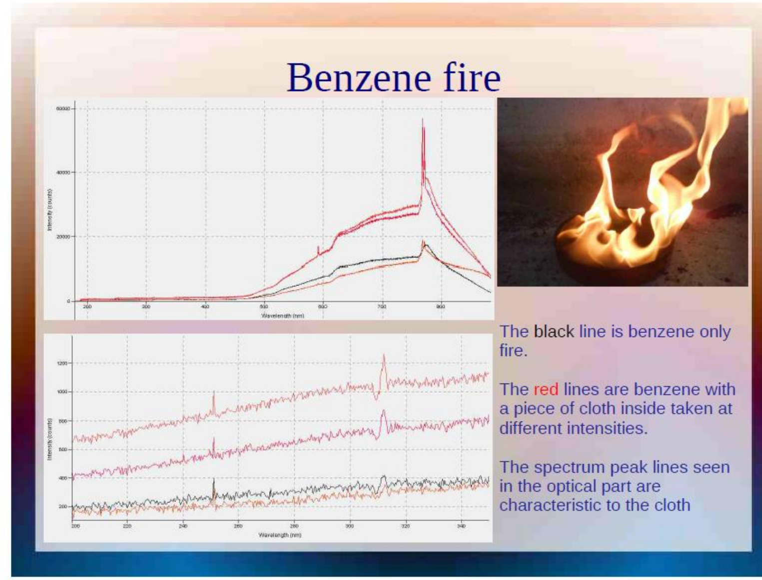


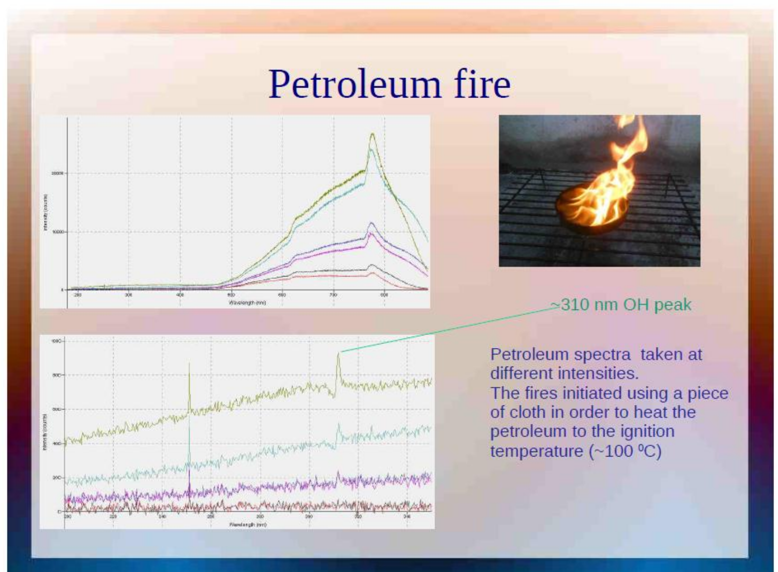
A detector sensitive in the region 200 – 250 nm and insensitive above is solar blind, producing black/white images



Fire spectra (Athens University)







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
- Very fast response (<1μs).
- UV imaging possible

☞ Challenge: Photocathode and gas aging

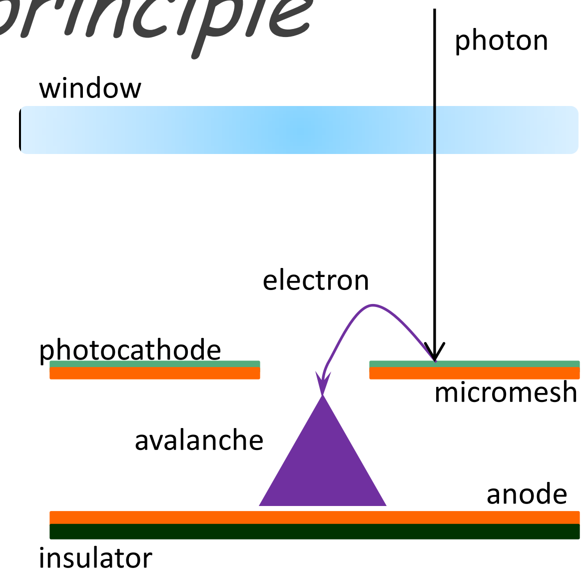
UV photon detection principle

➢ **Reflective photocathode:**

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

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

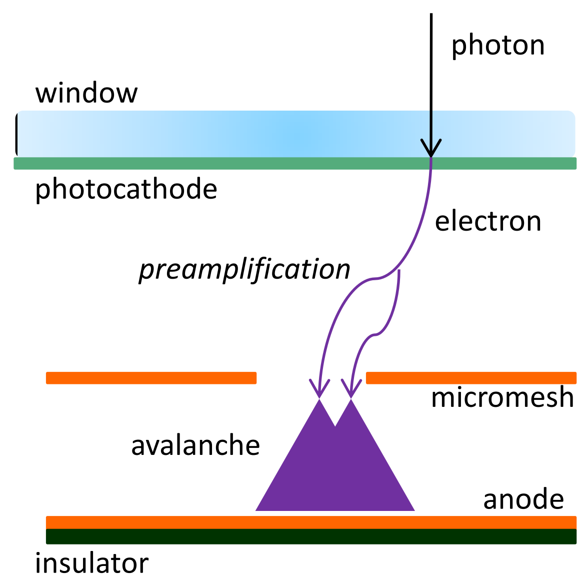
- ✓ The photocathode does not see the avalanche ➔ *no ion feedback effect ➔ higher gain (up to 10^6)*
- ✓ High electron extraction & collection efficiency
- ✓ Field on photocathode 10^4 V/cm



➢ **Semi-transparent photocathode:**

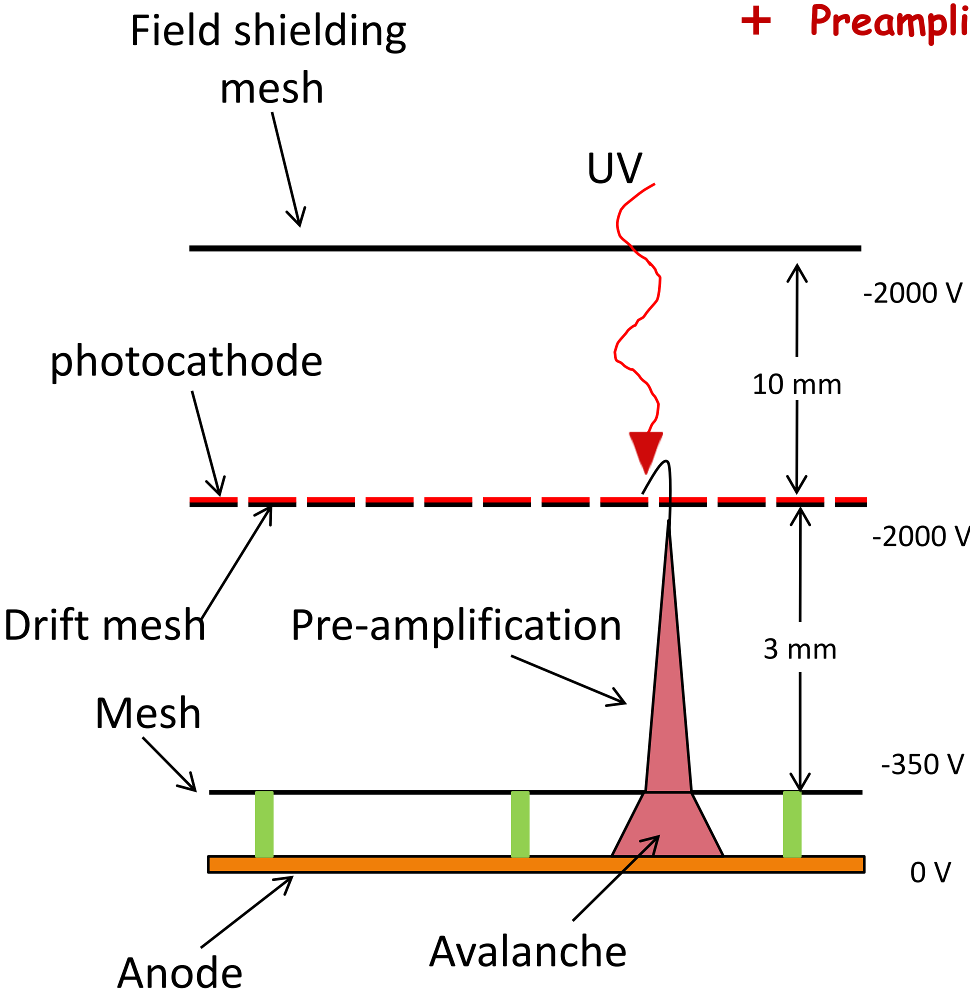
Photosensitive material is deposited on an aluminized quartz window (drift electrode)

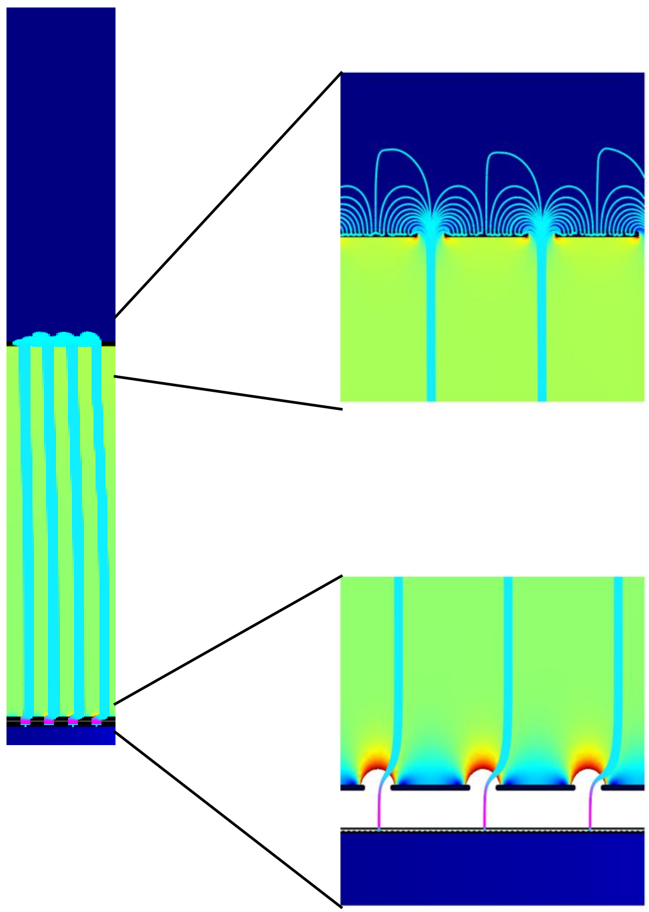
- ✓ Extra preamplification stage ➔ better long-term stability
- × Lower photon extraction efficiency (factor 3)
- × Fragility to sparks
- × Ion feedback ➔ gain limitation



The FORFIRE Micromegas concept

Our choice:
- ☞ **Reflective photocathode**
- **+ Photocathode separated from detector**
- **+ Preamplification**





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 detector

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

✓ High purity Ne gas (6.0)

✓ Metallic tubes and components

✓ Quartz lens glued with glue appropriate for ultra vacuum

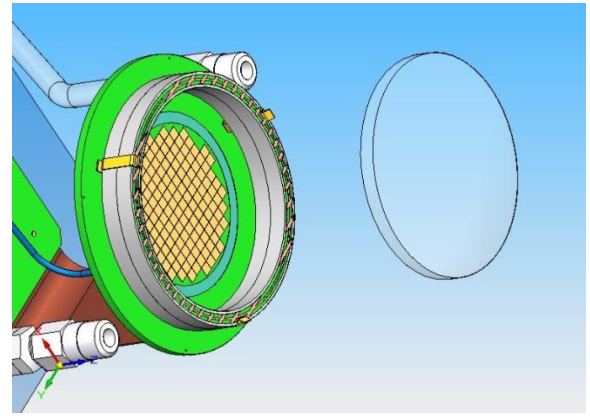
✓ Anodized aluminum chamber

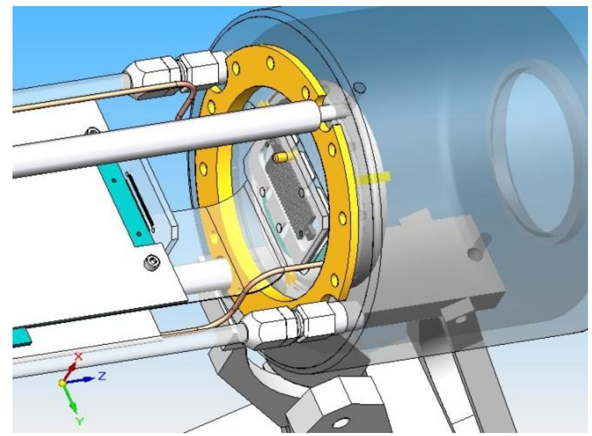
✓ Detector pumped and heated up before sealing

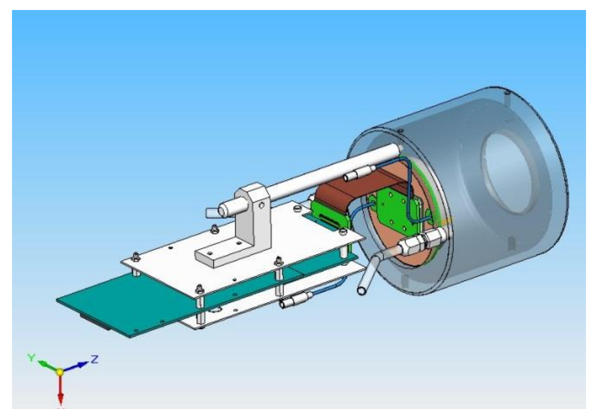
× Gas tube feedthroughs (Stubli) leaky ➔ glued

× PCB outgassing (?)

× O-ring to seal the PCB







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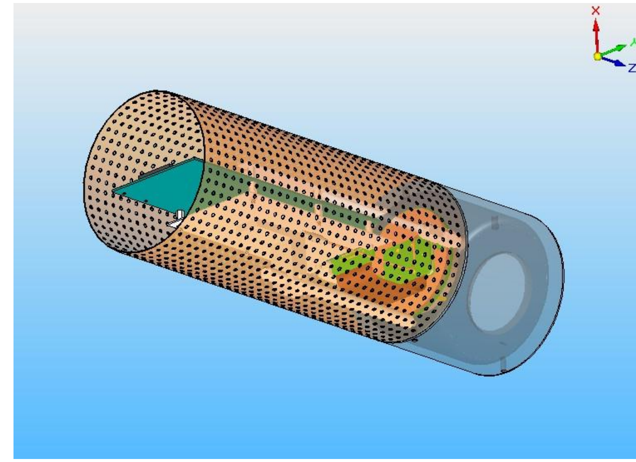

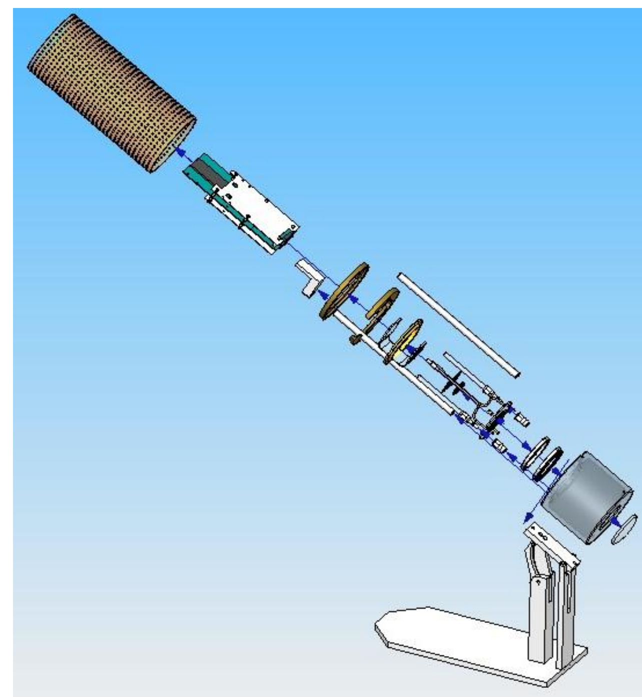

- ✓ High purity Ne gas (6.0)
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Photocathode

Selected Material: **CsI deposited on Ni mesh**.
The photocathode is the drift electrode of the detector

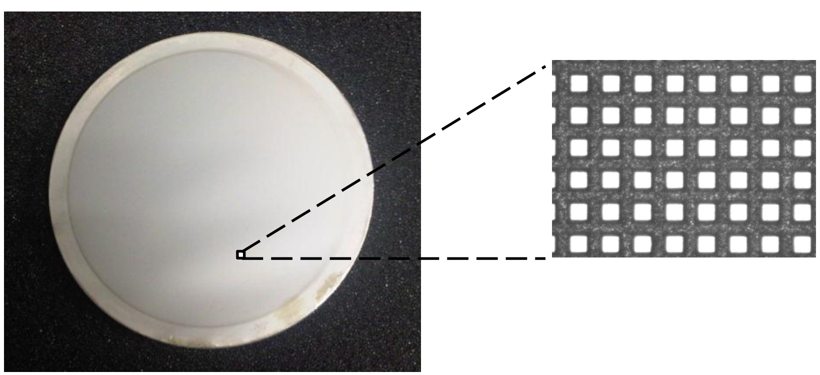
All photocathodes used were fabricated at CERN with CsI evaporation.

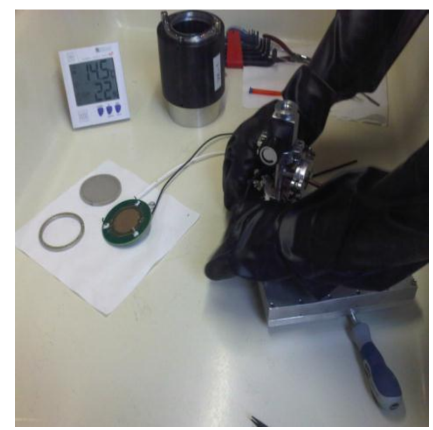
Evaporation facility at CEA: ready to start!

Aging:

- ➔ Photocathodes produced Jan / Apr/ May/Oct 2011
- ➔ Measurements done Feb / May / Jul / Sep / Nov 2011

Similar behavior





General behavior

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

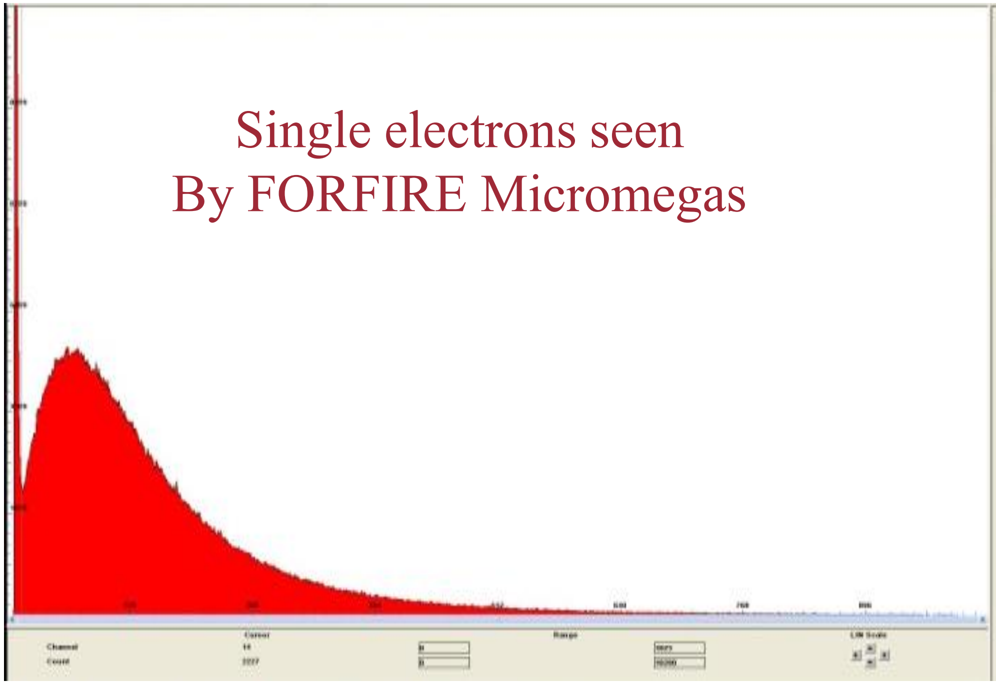
- ☞ Single electron

<u>No ion feedback</u>

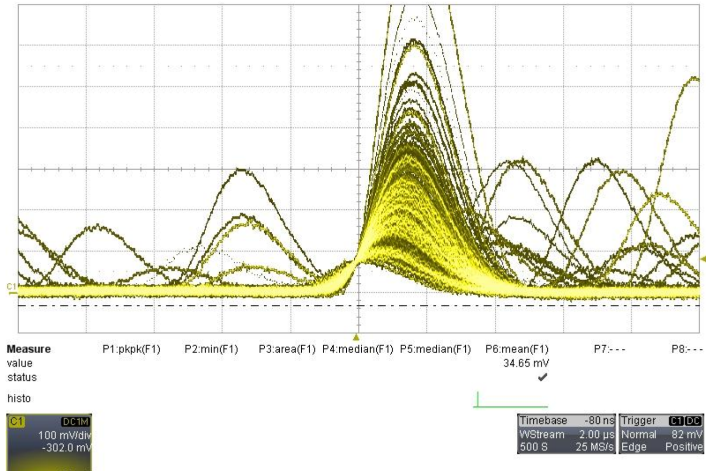
Sealed

Preamplification (>100)

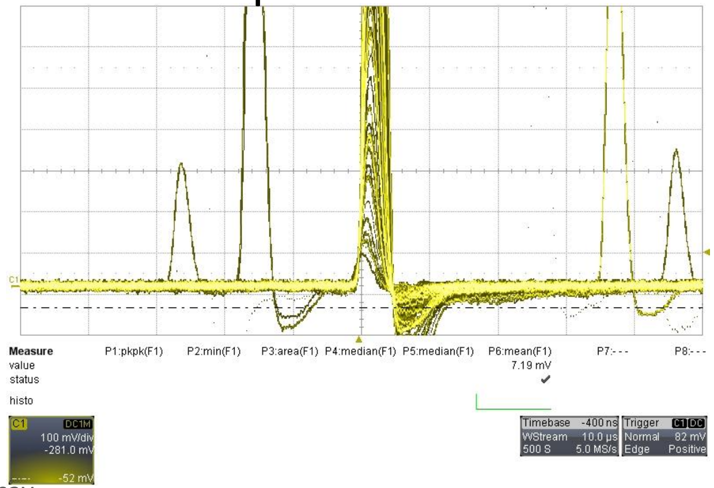
- ✓ Stable operation, far from sparking limit
- ✓ Huge gain (even causing trouble using standard electronics!)



Normal mode



Preamplification mode



Performance of FORFIRE prototype





Q.E & Sensitivity

Photodiode Q.E.(200nm)≈70%

FORFIRE Q.E.(200nm)≈1%

However

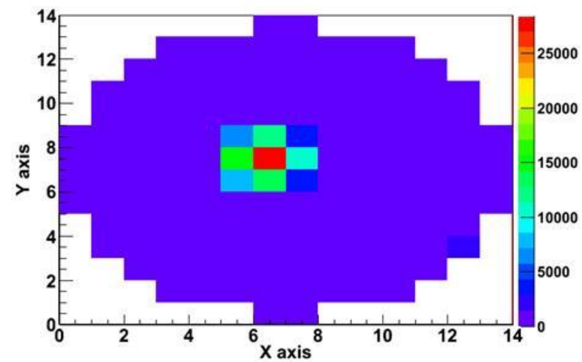
Photodiode minimum signal ≈ 5 pA ➔

Photodiode minimum sensitivity ≈

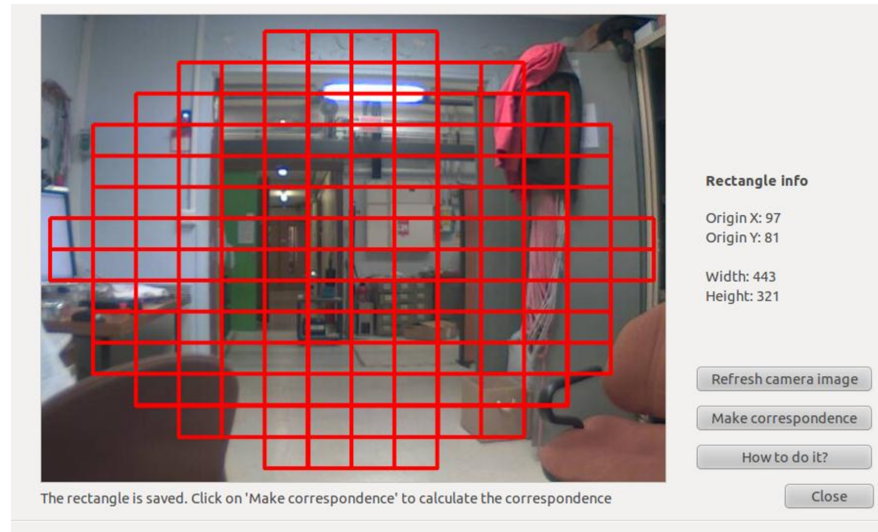
5×10^{7} photons

FORFIRE minimum sensitivity ≈

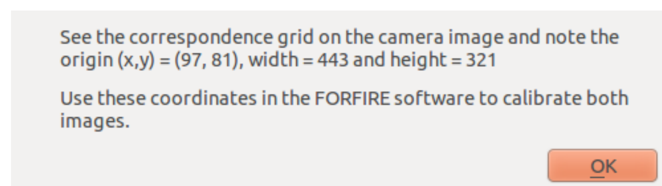
5×10^{2} photons



Imaging - alarms

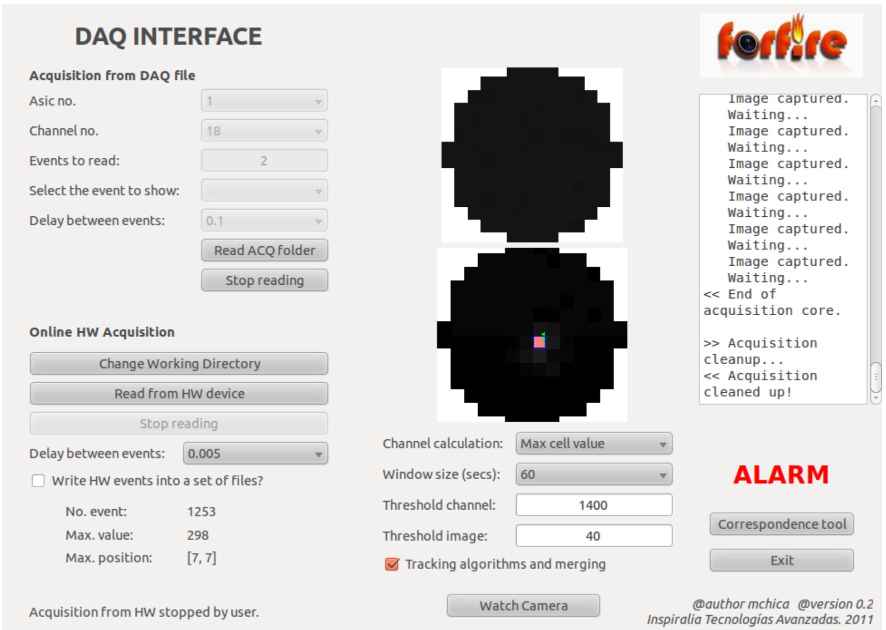


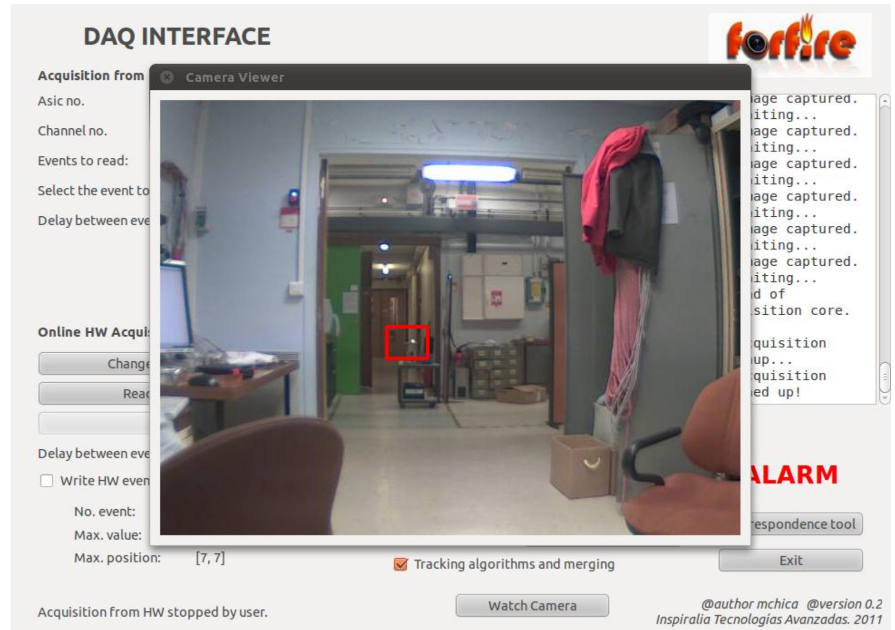
- To mark the square window for merging the camera image with that of the detector.



- ➢ Changing the software values in ImakeT2K.cpp and recompiling
- ➢ Gives the gui the correct dimensions to the pixel mapping image and the IP camera

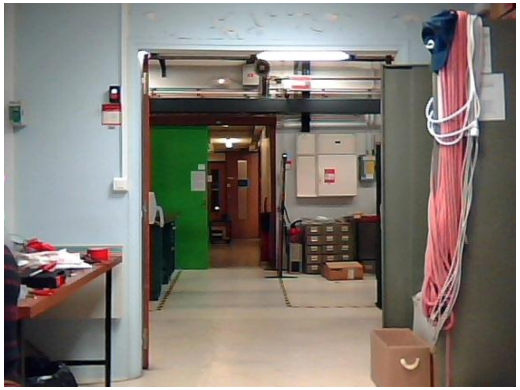
Imaging - alarms

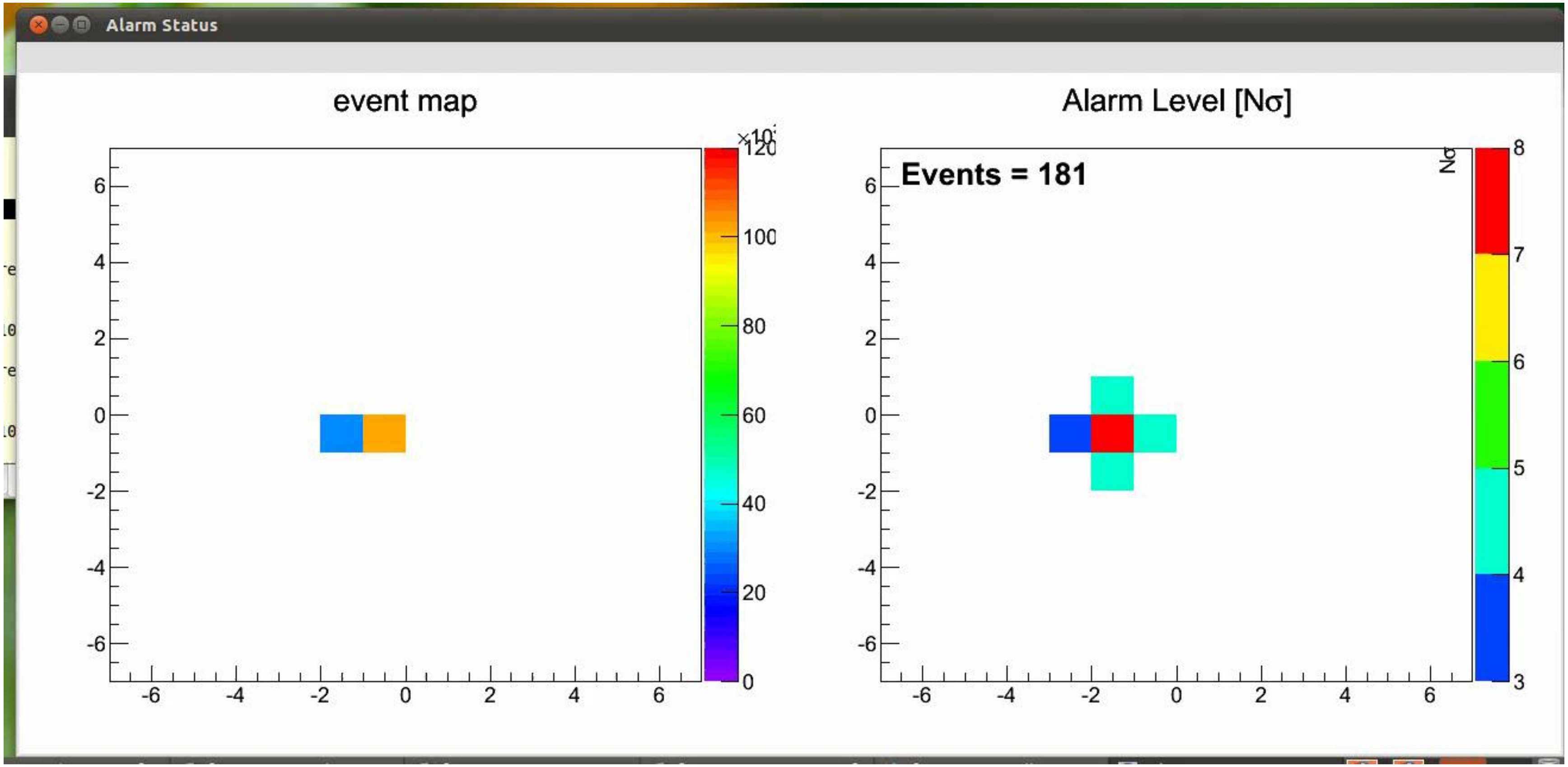




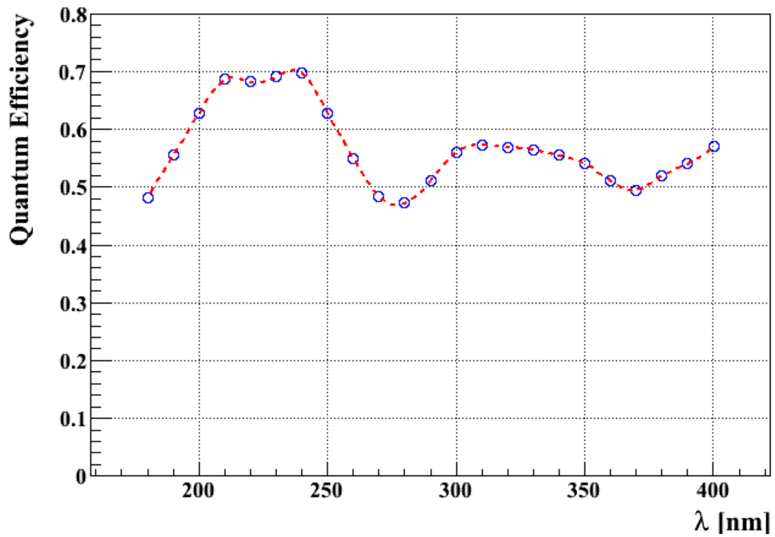
- ➢ Click on Tracking Algorithms and Merging to raise an image on alarm event
- ➢ Imaging software defines the position from the pixel map onto the camera image to pin-point the location of the triggered alarm.

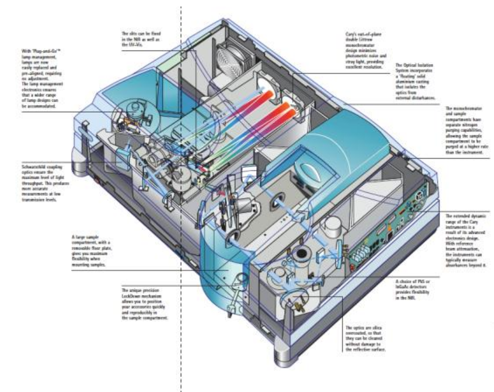
Recording a candle's flame



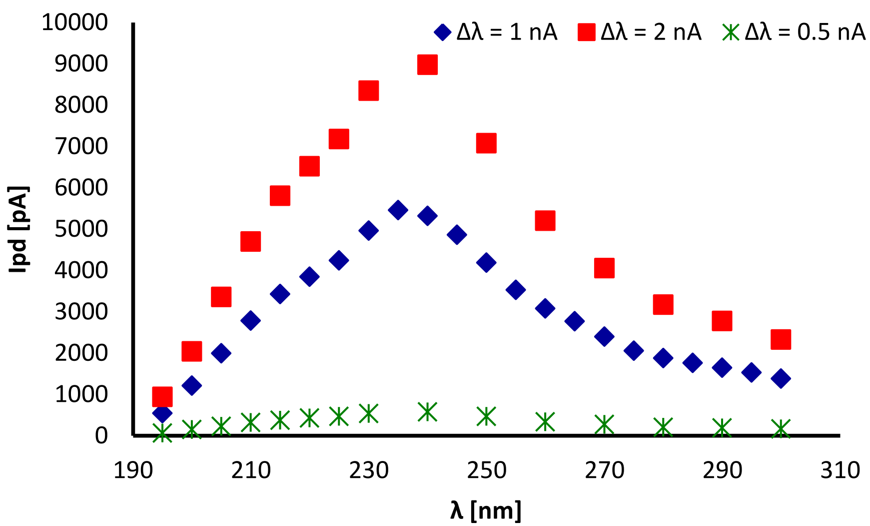


Quantum Efficiency of the FORFIRE detector



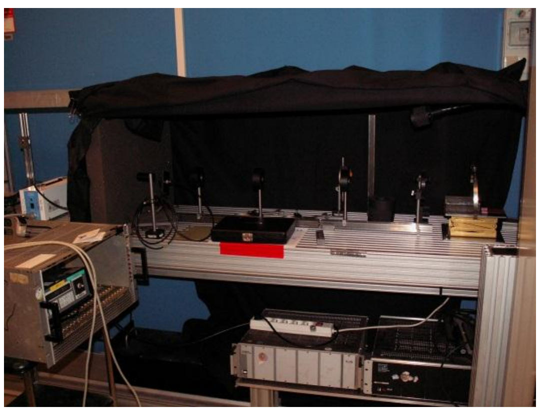


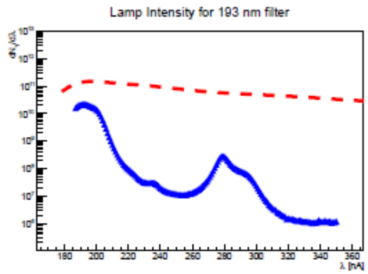
The measurements were performed using the Varian 5000 spectrometer. The photon flux as a function of the wavelength was measured using a calibrated PD222AUV photodiode

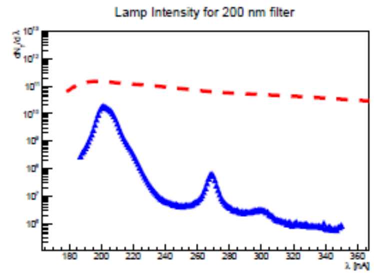


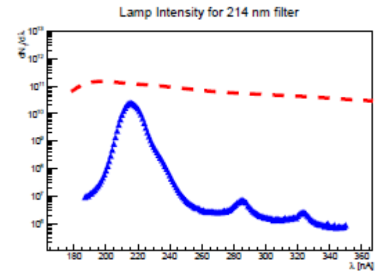
Spectrometer flux for several bandwidth acceptances. Measurements repeated within a period of 1 month revealed stability of the order of few %.

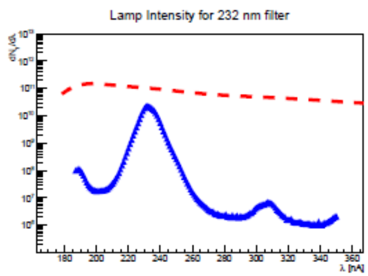
UV filters + deuterium lamp

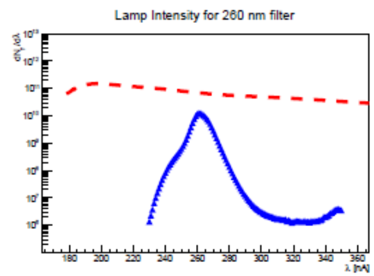


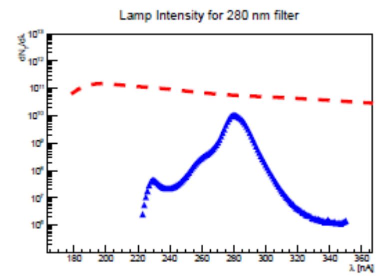


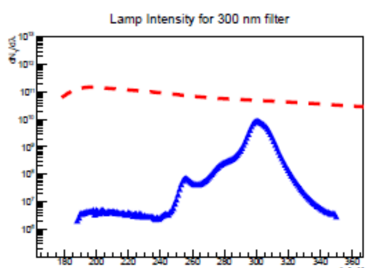


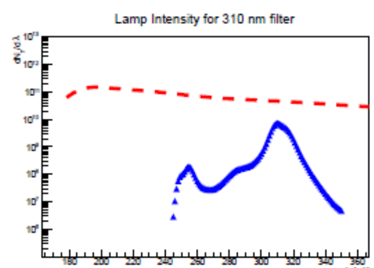








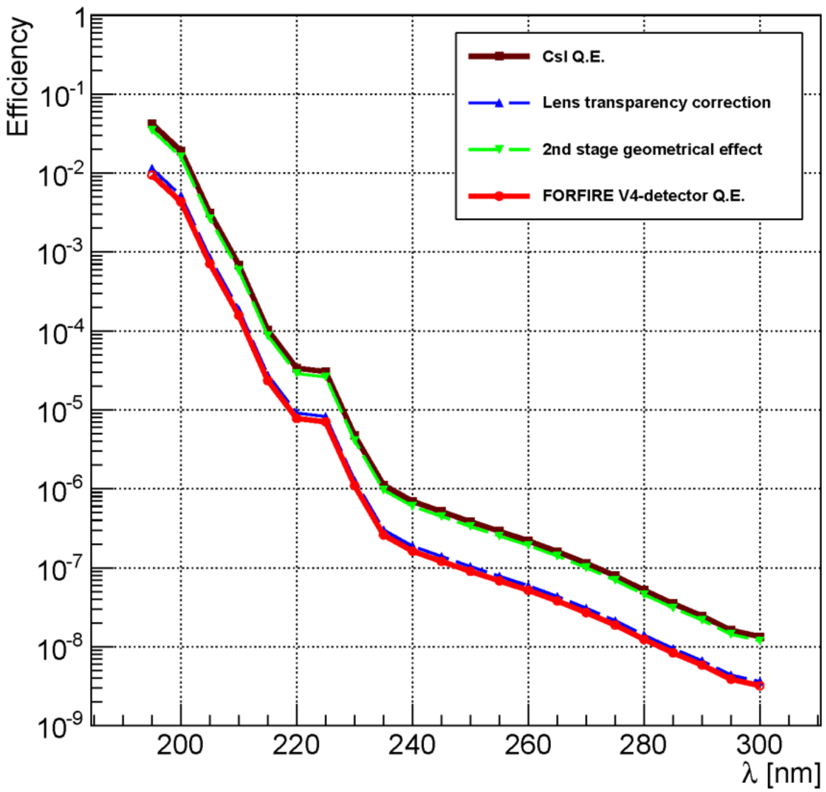




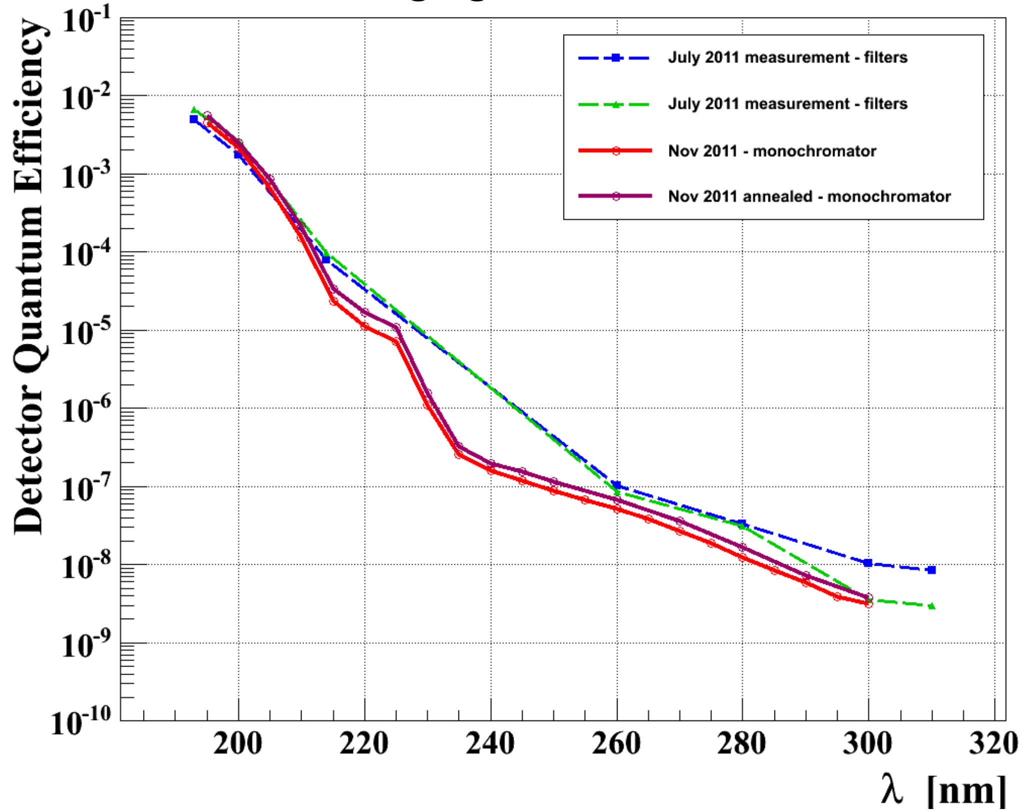
Integrated γ flux at 50 cm	
193 nm filter:	3.202e+11 γ s^{-1} cm^{-2}
200 nm filter:	1.953e+11 γ s^{-1} cm^{-2}
214 nm filter:	2.673e+11 γ s^{-1} cm^{-2}
232 nm filter:	2.440e+11 γ s^{-1} cm^{-2}
260 nm filter:	1.394e+11 γ s^{-1} cm^{-2}
280 nm filter:	1.391e+11 γ s^{-1} cm^{-2}
300 nm filter:	1.139e+11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

Performance of FORFIRE prototype

Q. E



Aging measurements



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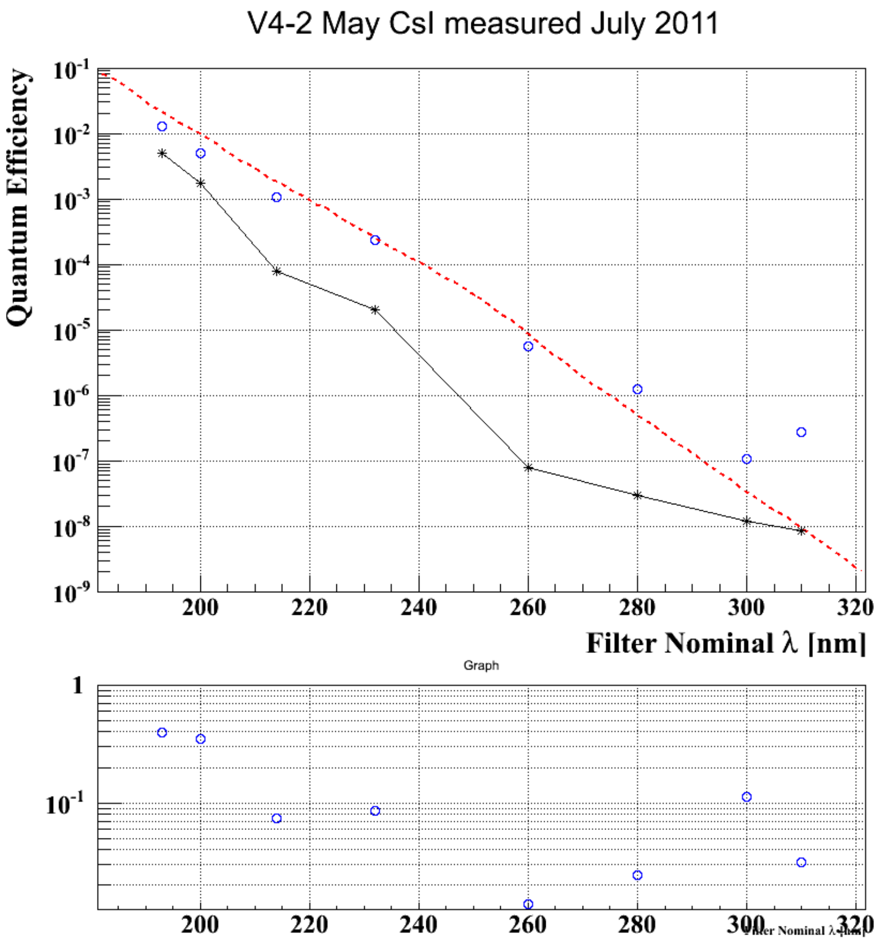
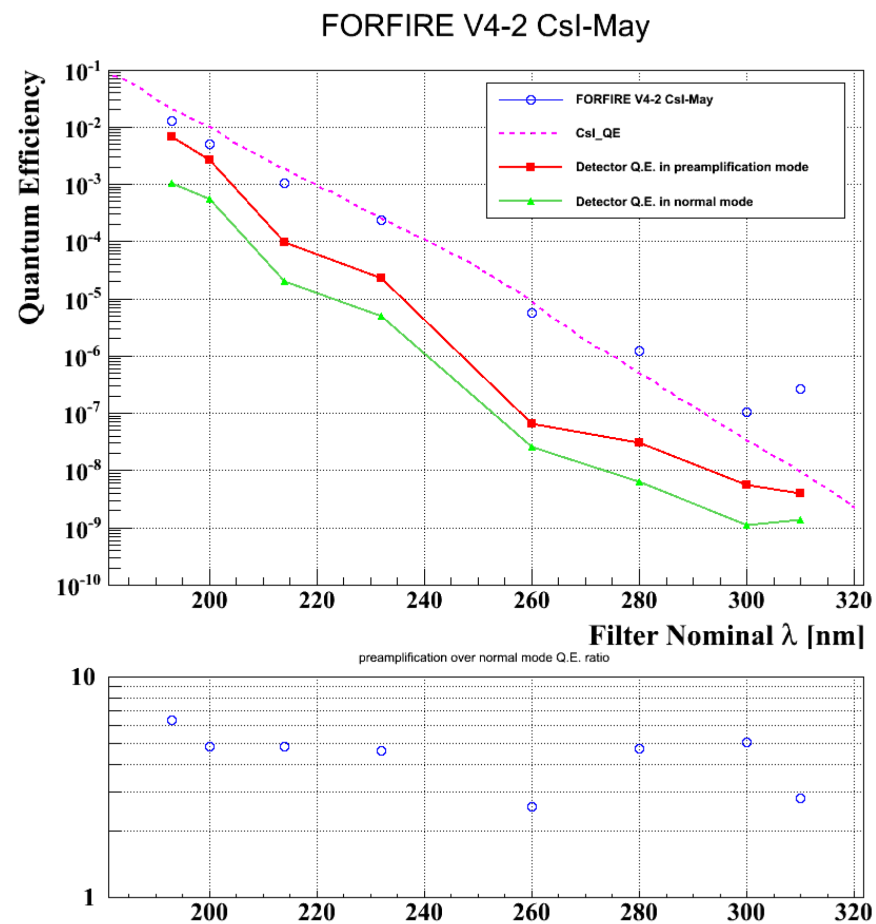




Feedback from the FORFIRE detector

- ✓ Operation in sealed mode possible using standard vacuum technics (baking, gluing etc)
- ✓ Ne – Ethane mixtures have good behavior
- ✓ Stable performance for several weeks
- ✓ Best aging measurement:
  - ➢ Detector filled in April
  - ➢ QE measurements in May
  - ➢ Shipped to Athens for field measurements (June)
  - ➢ Q.E. measurements in July ➔ similar performance

- ➢ No systematic tests done for gas aging ➔ concentrate on photocathode aging
- ➢ Most of problems due to the design: techniques for laboratory prototypes (o-rings feedthroughs etc) are not appropriate for sealed mode operation ➔ Industrial methods should be used (glass, Coca-Cola cans…)
- ➢ Passing voltages & signals through the PCB helps a lot ➔ Piggyback

The Piggyback Micromegas

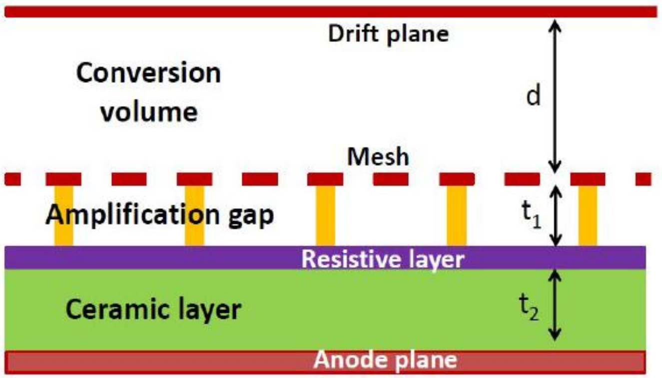
The "piggyback" concept

Micromegas on a ceramic

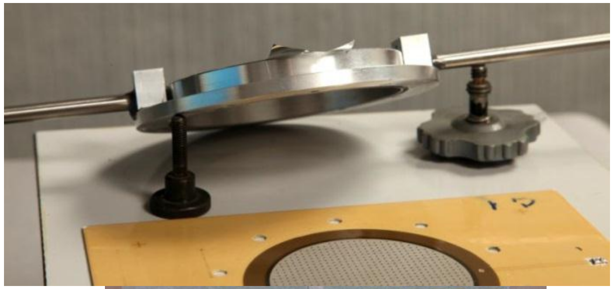
Resistive layer

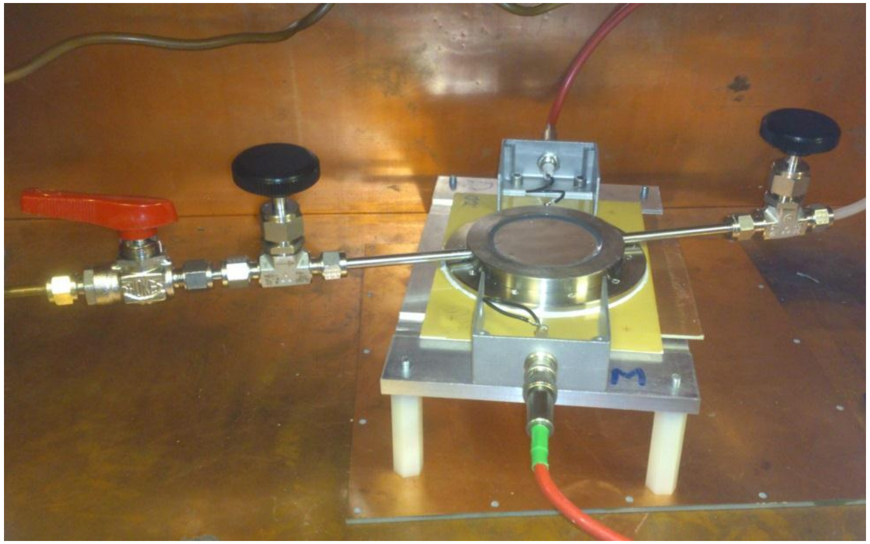
Readout trough capacitance coupling

- ➢ **Detector completely decoupled from readout electronics!**
- ➢ **Readout without fit-throughs**
- ✓ Spark protection
- ✓ Appropriate for sealed operation
- ✓ Window can be grounded



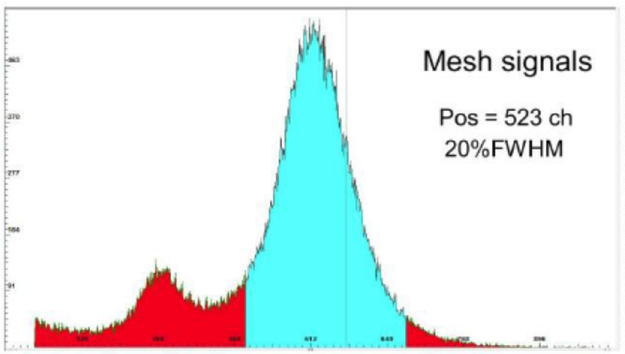
arXiv:1208.6525 [physics.ins-det]

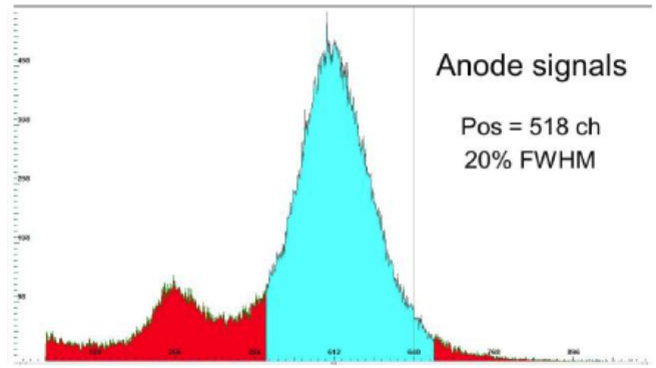




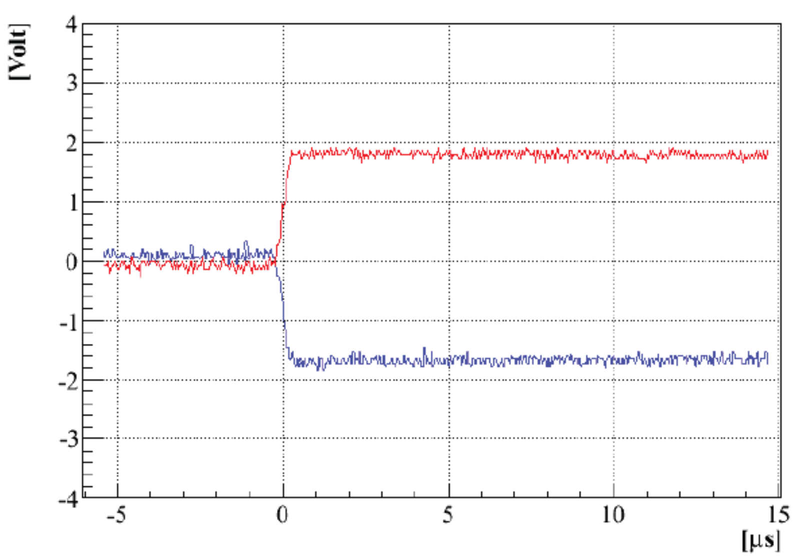
The "piggyback" concept

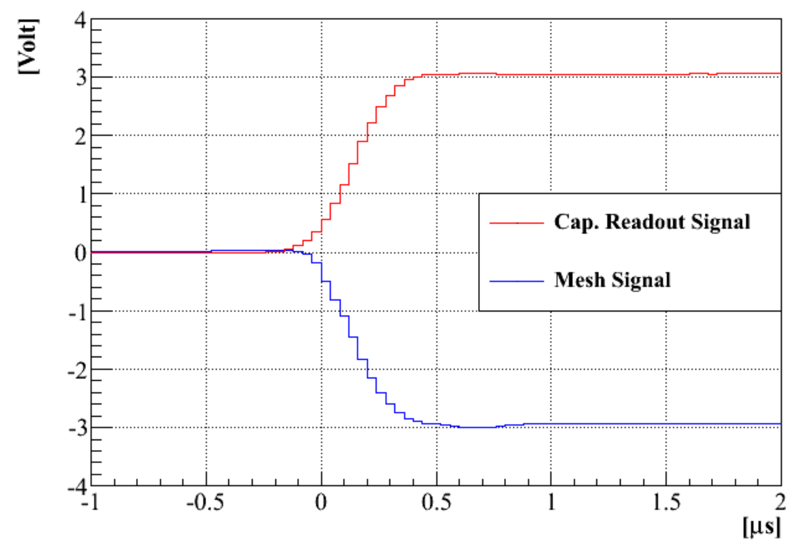
Checking possible looses by the ceramic layer: signal entirely transmitted





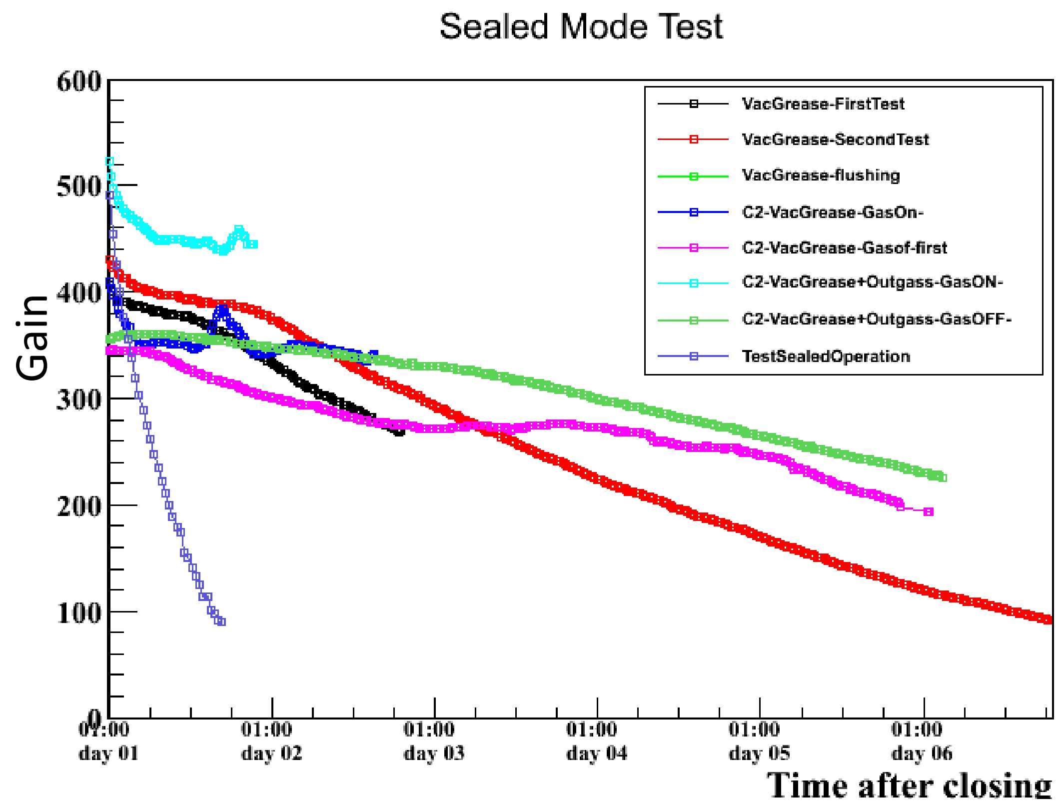
Test with a 252Cf (fission fragments signals) reading simultaneously mesh and anode





First attempts for a "sealed" Piggyback

- Piggyback closed with a metallic chamber + Al window
  - ➔ Use standard o-rings
  - ➔ Improve with standard vacuum grease
  - ➔ Improve by pumping for few hours
- Close the chamber with ultra vacuum glue + outgas by heating and pumbing
  - ➔ Wrong manipulation of the valves blew up the window. Tests just restarted…
- Design of new chamber (by an expert…)

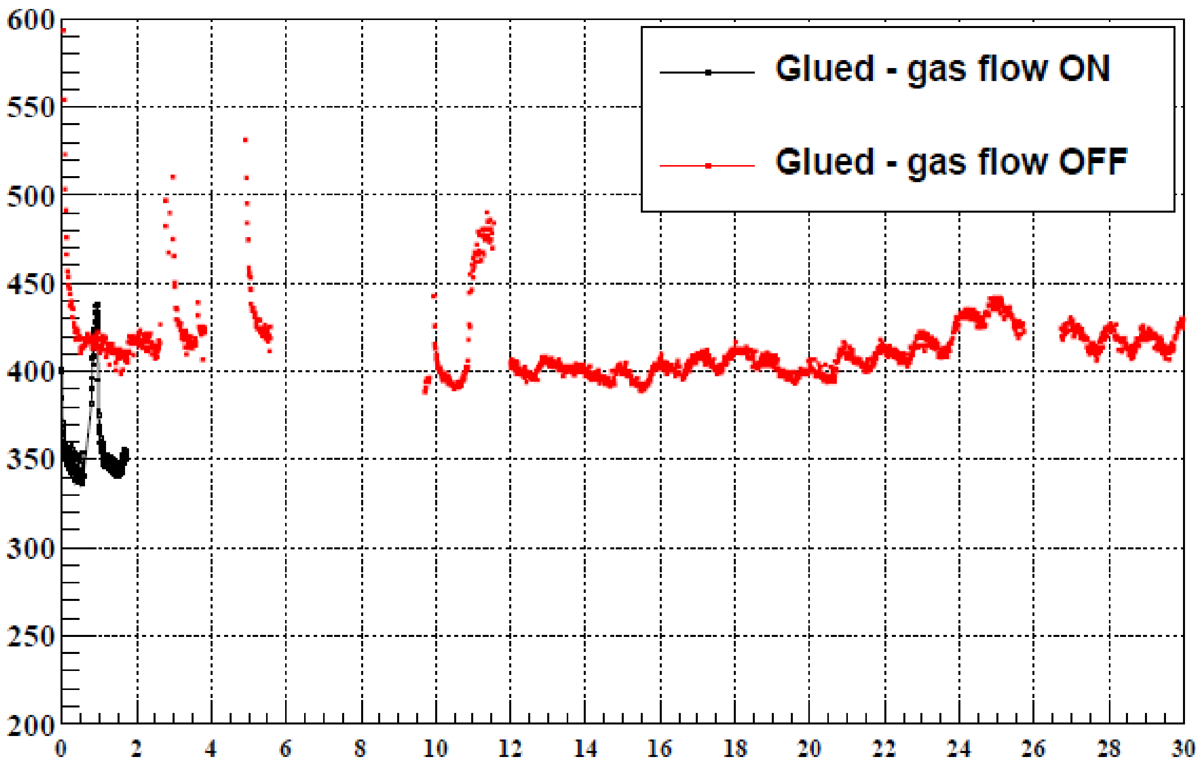


- *Another approach: Microbulk*
  - ✓ *Can heat up to > 300 °C*
  - ✓ *More robust*

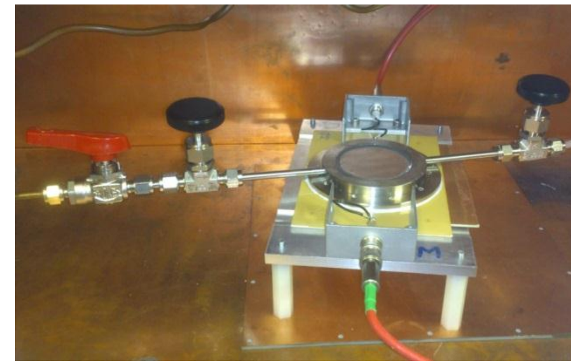
Is it due to leaks from the detector or material outgassing?

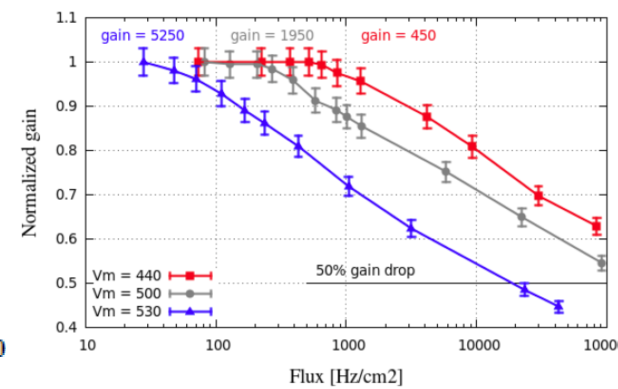
Using lots of Torrseal glue + bake-out

Gain evolution after one month sealed mode!

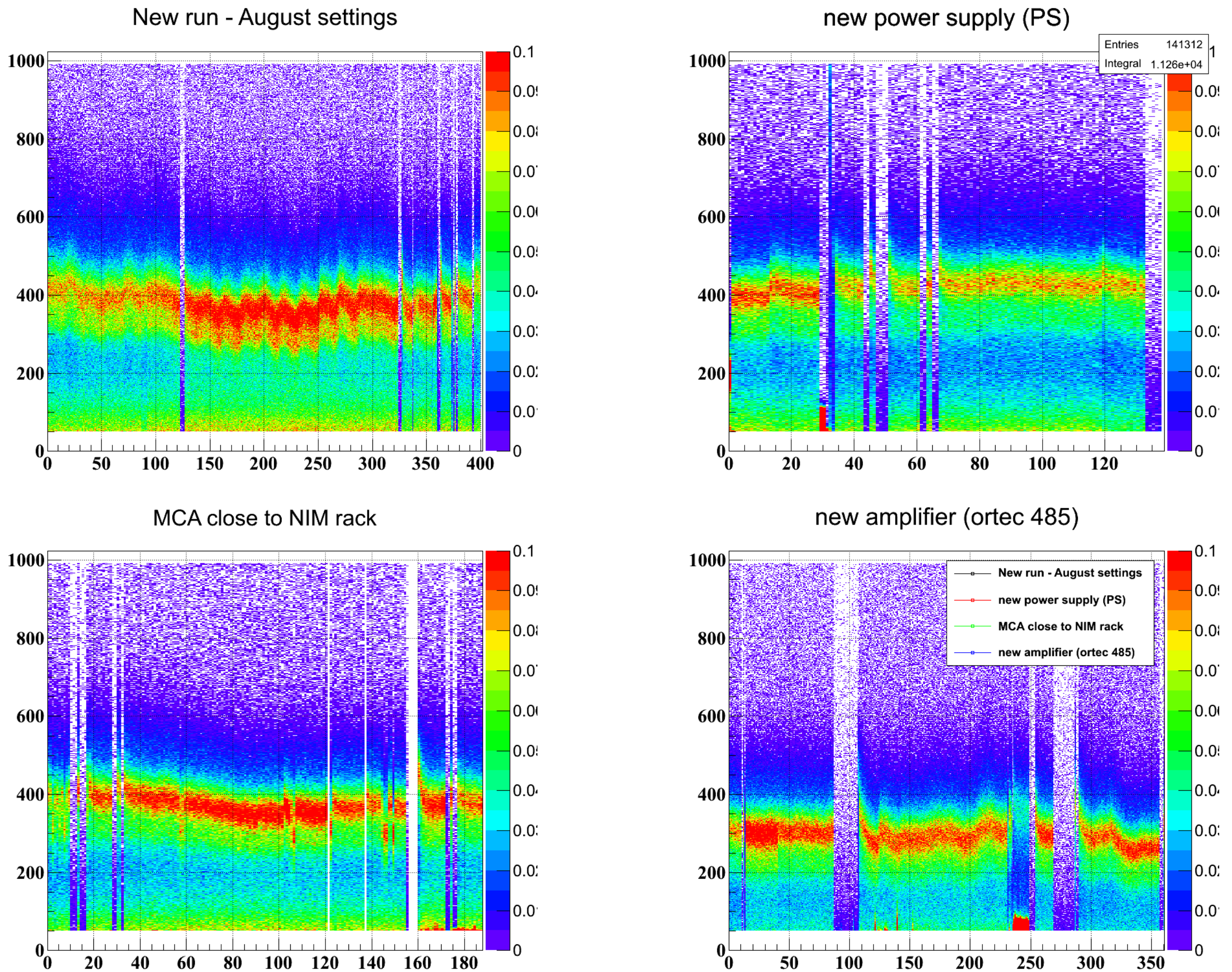


D. Attié et al., JINST 8 (2013) C11007

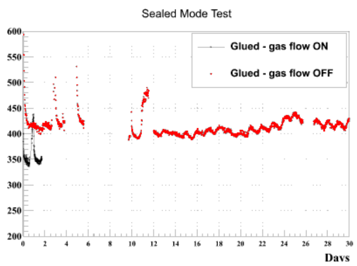


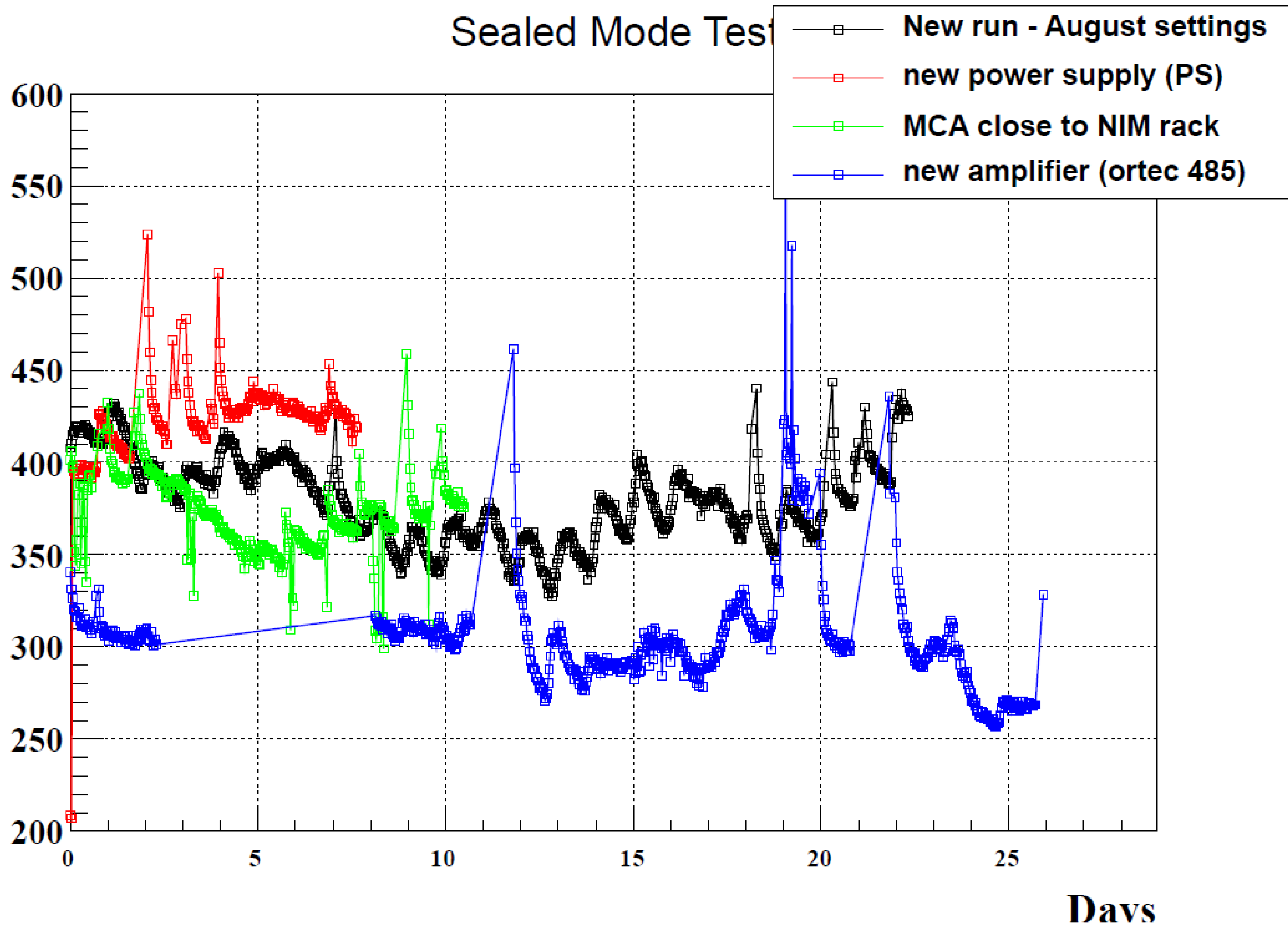


Exploring the variations



June - November 2013

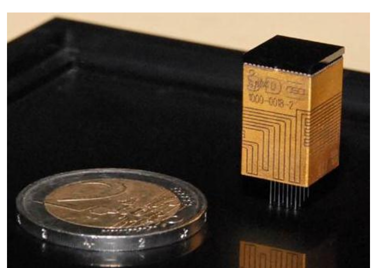
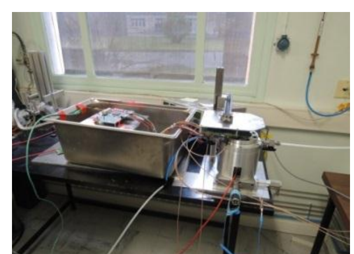
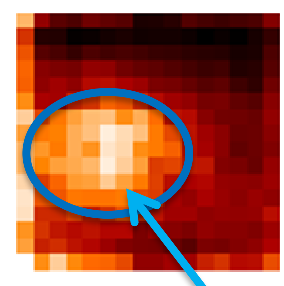




Feedback from the FORFIRE detector

- ✓ Similar techniques with the FORFIRE detector
- ✓ Same gas system
- ✓ Ceramic → excellent for signal extraction
- ✓ **Operation in sealed mode possible for at least 6 months**
- ✓ Ne – Ethane mixtures better behavior than Ar mixtures
- ✓ Detector is still sealed since last year (to be tested!)

- ➢ Verified that o-rings are not good for sealed mode. **Industrial methods should be used**
- ➢ The thin window is a potential leak source. Best operation with a 25 μm aluminum foil over a ø 2mm hole (+some glue on the hole…)
- ➢ A second attempt was not so successful. Gluing should be done by experts…
- ➢ Tests stopped in order to concentrate to signal readout with a chip

Center of the source

Thank you!