PiggyBack: sealed MicroMEGAS with external read-out electronics

D. Attié, C. Blondel, L. Boilevin-Kayl, D. Desforges, E. Ferrer Ribas, Y. Giomataris, O. Guevin, F. Jeanneau, O. Limousin, A. Meuris, R. de Oliveira, T. Papaevangelou, A. Peyaud, A. Teixeira

CERN and IRFU (CEA-Saclay)

Outline and statut report

- Motivation and reminder of previous presentation

- Characterization of the new chamber in normal and sealed operation
- Characterization of new bulks

- Set-up with new high-tech read-out electronics
- First results of the coupling to electronics

- Conclusions and outlook

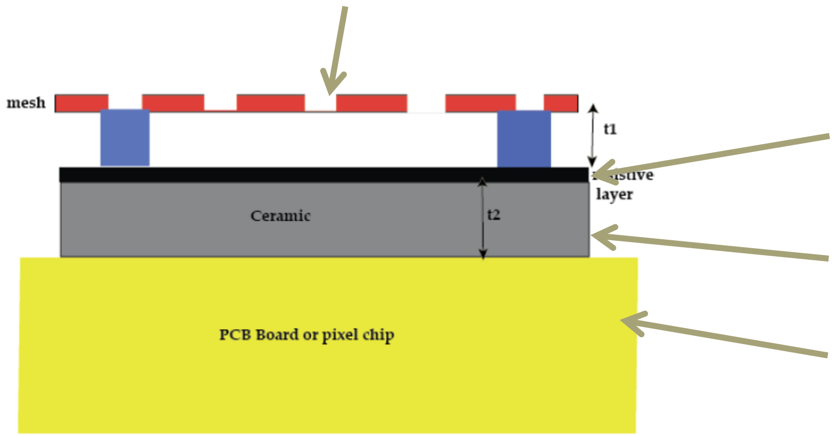
Reminder: resistive MicroMEGAS

Development of PiggyBack resistive MicroMEGAS

Why ? → To reduce sparking and to protect the detector

How ? → Thin resistive layer deposited on an adequate insulator

Standard bulk structure



Resistive thin layer
1MΩ/□ to 100 GΩ/□

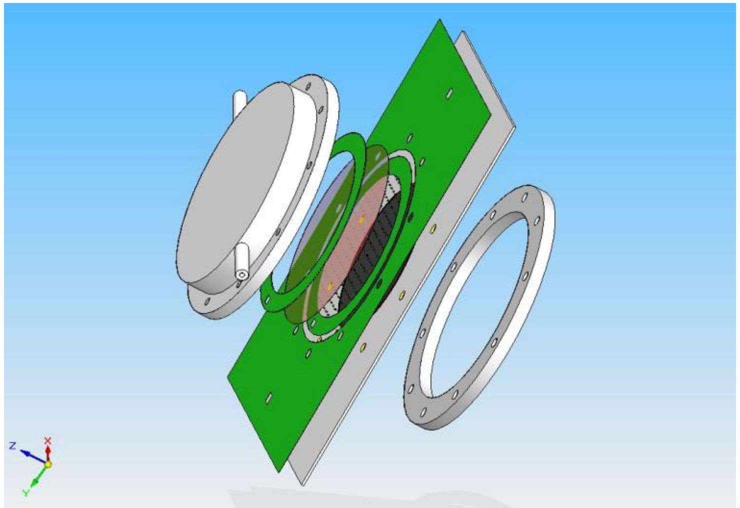
Insulator : Ceramic substrate
thickness ≃ 100-500 µm

Read-out plane

Detector dissociated from read-out plane, so why not :

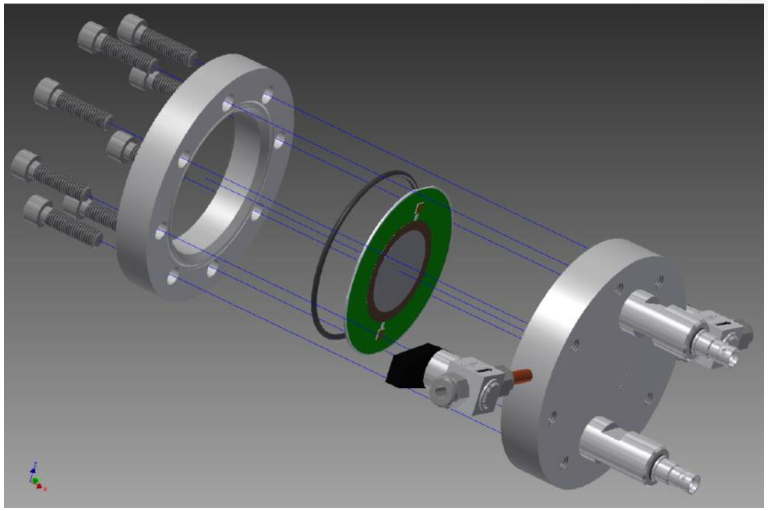
→ Couple it to ≠ electronics ? → Work in sealed operation ?

Reminder: evolution of PiggyBack



- HV connectors outside
- Ceramic partially outside
- Made in aluminium
- PCB Board under ceramic layer

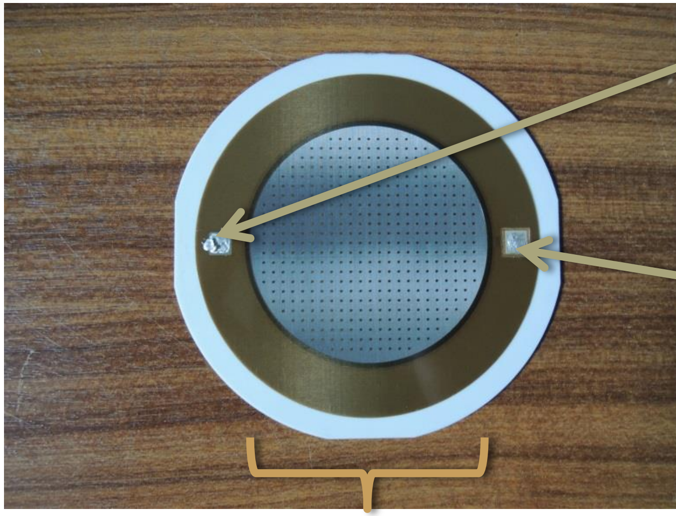
→ Verify the resistive layer concept
→ Good performances in normal mode



- HV connectors inside
- Ceramic totally inside
- Made in stainless steel
- Uncovered ceramic layer

→ Very low outgassing
→ Robust and versatile

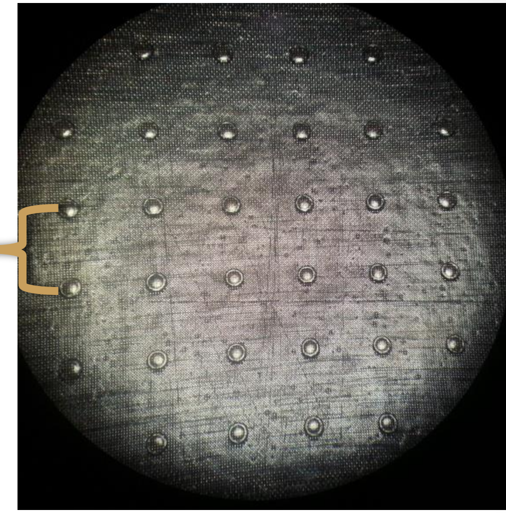
Bulk technology on ceramic



Mesh

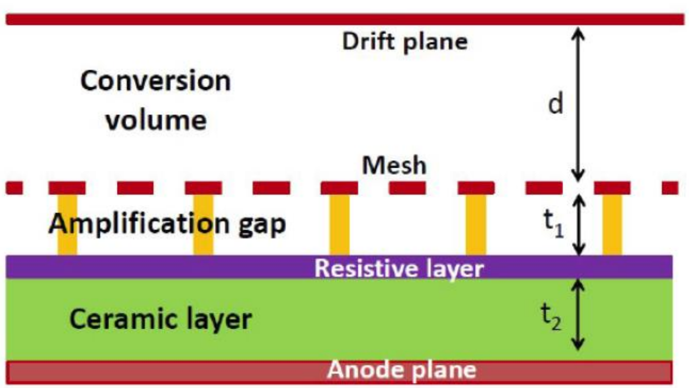
Resist

50 mm



2 mm

Ground



V_{mesh}

V_a

Read-out

$\simeq$ 1 or 2 cm

$\simeq$ 128 µm

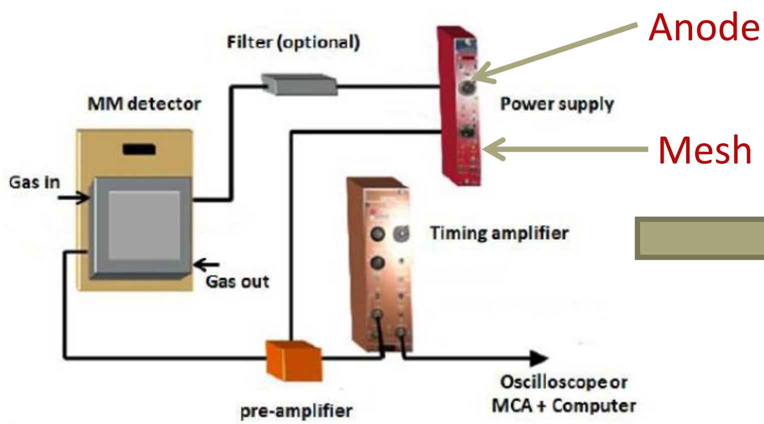
$\simeq$ 5-25 µm

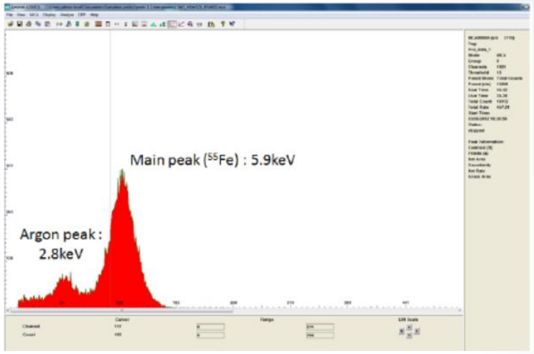
$\simeq$ 100-500 µm

→ Amplification field depends on two voltages!

Set-up

Fe^{55}





Source

Electronics

Data processing

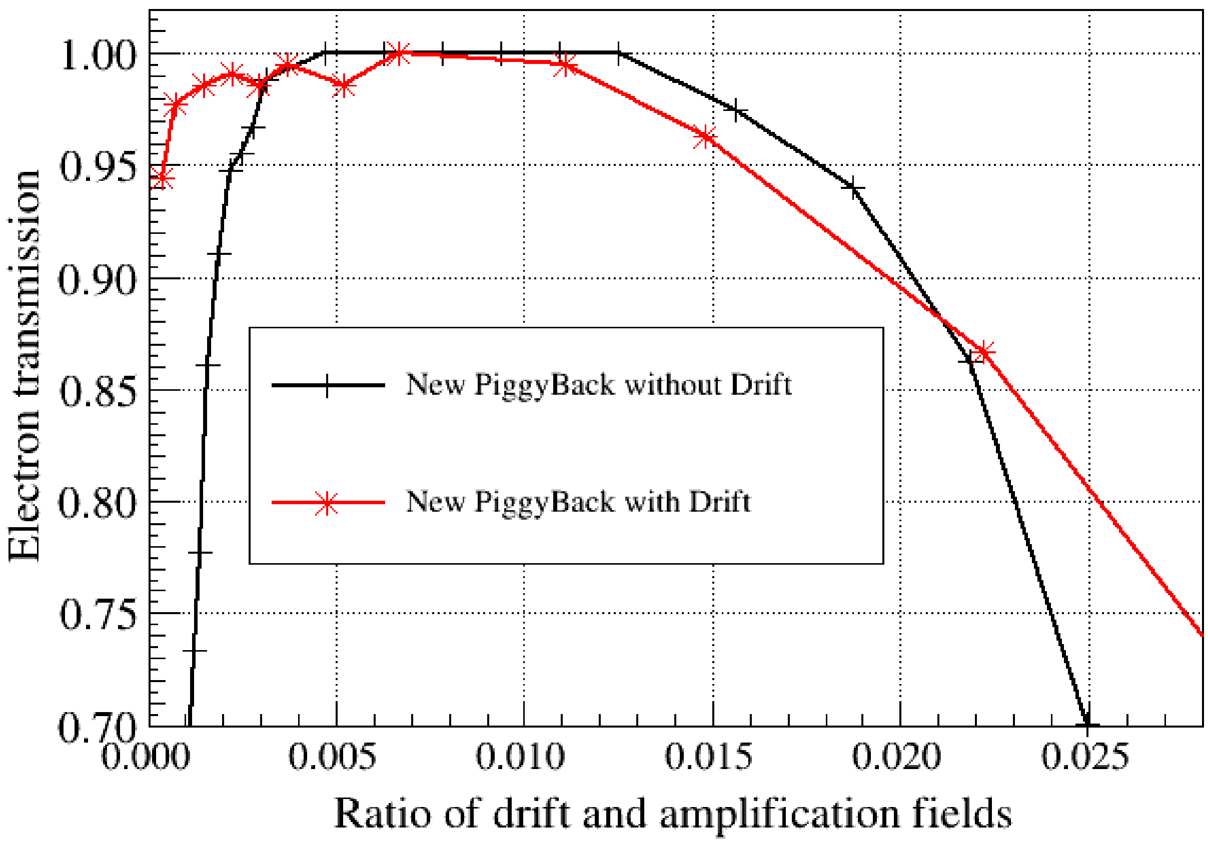
Performance expected:

- Electron transparency: a large flat curve where gain ≥ 95% of max gain
- Gain ≥ 10^4
- Energy resolution: ≃ 20-26% (for 5.9 keV)

And the most important one: good stability of gain for **several days**!!!

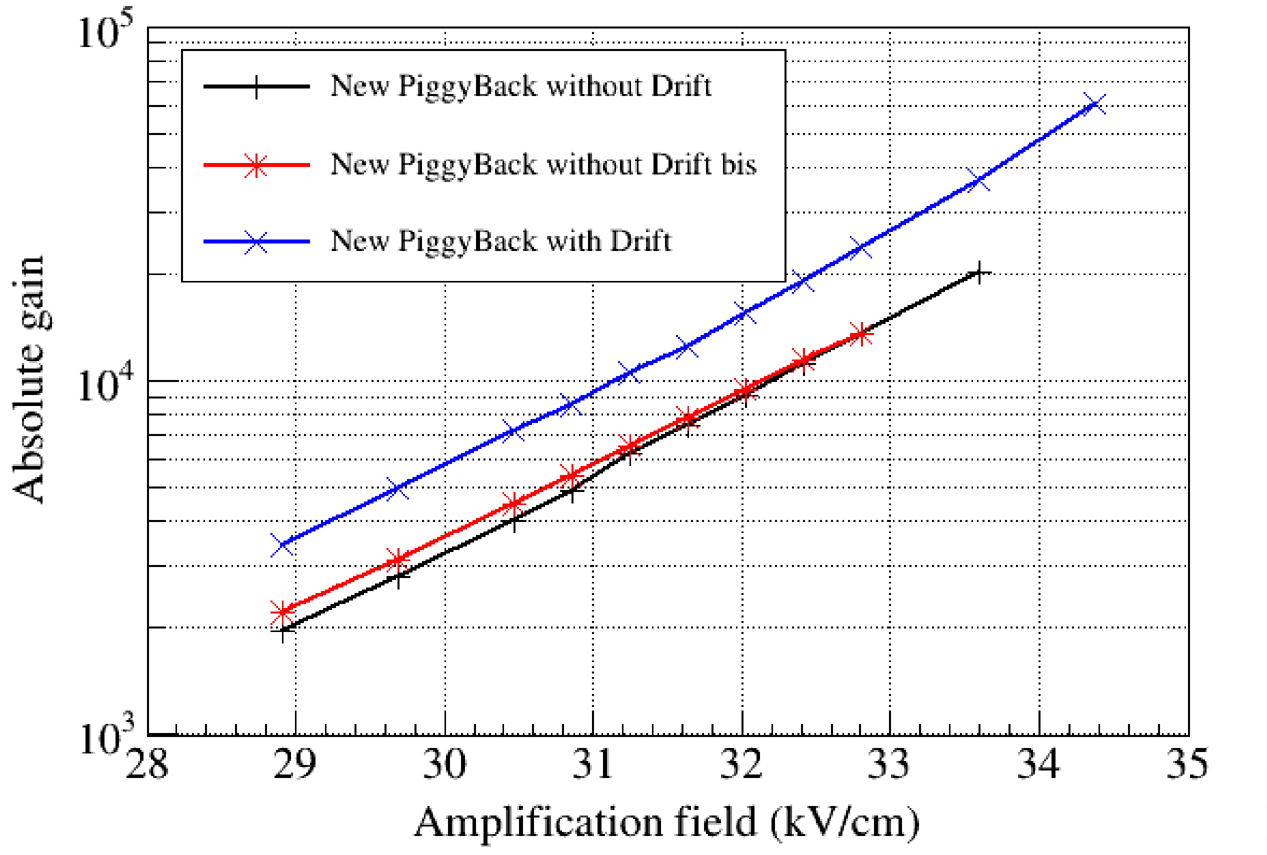
Electron transmission

- Evolution of the position of the main peak with the electrical ratio
- Fixed amplification field, evolving drift field



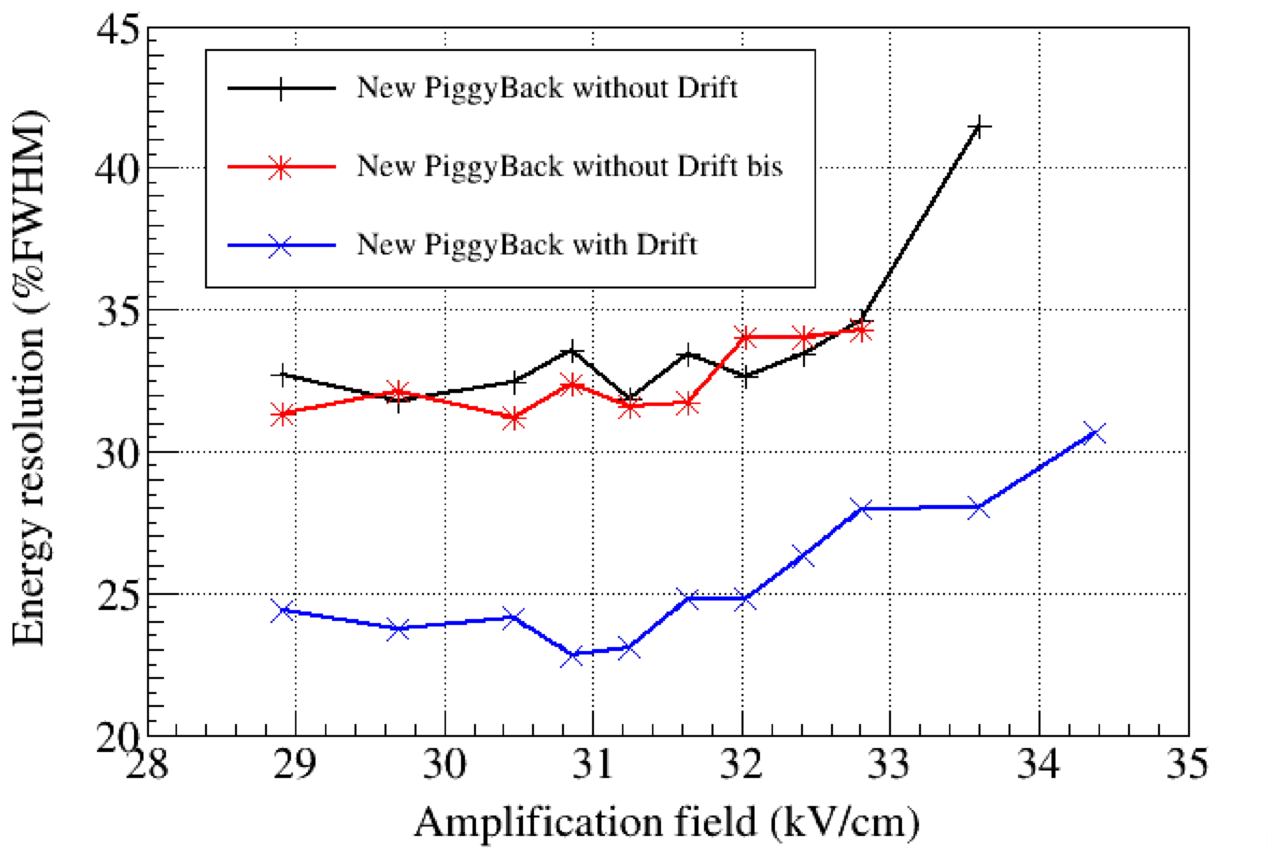
Electron gain

- Keep working with voltages verifying the optimized transmission
- Increase gain until apparition of sparks

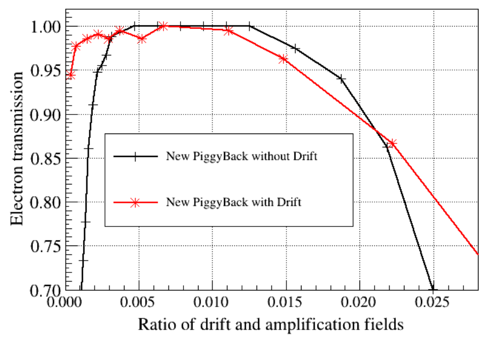
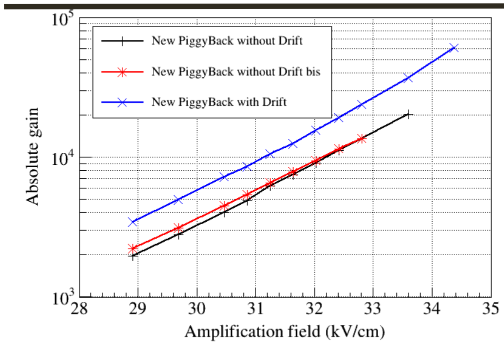
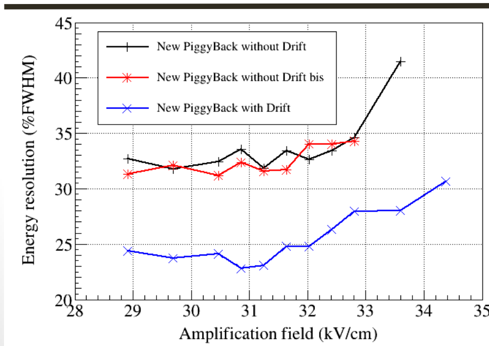


Energy resolution

- Relation used : $R = 2.35\sqrt{\frac{w}{E}(F+b)}$ with E = 5.9 keV
- Fit with ROOT, considering the two gaussians from Argon spectrum

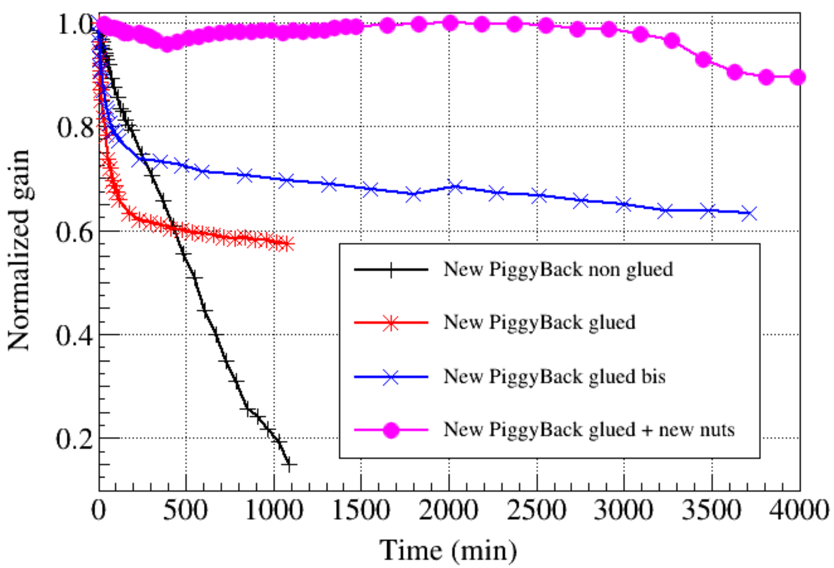


End performance characteristics

<table>
<tr><th>Characterization</th><th>Expected performance</th><th>Achieved performance</th></tr>
<tr><td></td><td>A large flat curve where gain ≥ 95% of max gain</td><td>Width from a ratio of 0.001 to 0.015 ✓</td></tr>
<tr><td></td><td>Gain ≥ 10^4</td><td>Gain ≥ 2.10^4 ✓</td></tr>
<tr><td></td><td>Energy resolution ≤ 26%</td><td>Energy resolution ≤ 25% for a large range of amplification fields ✓</td></tr>
</table>

→ The new chamber meets the expected performance in normal operation

Stability in sealed operation



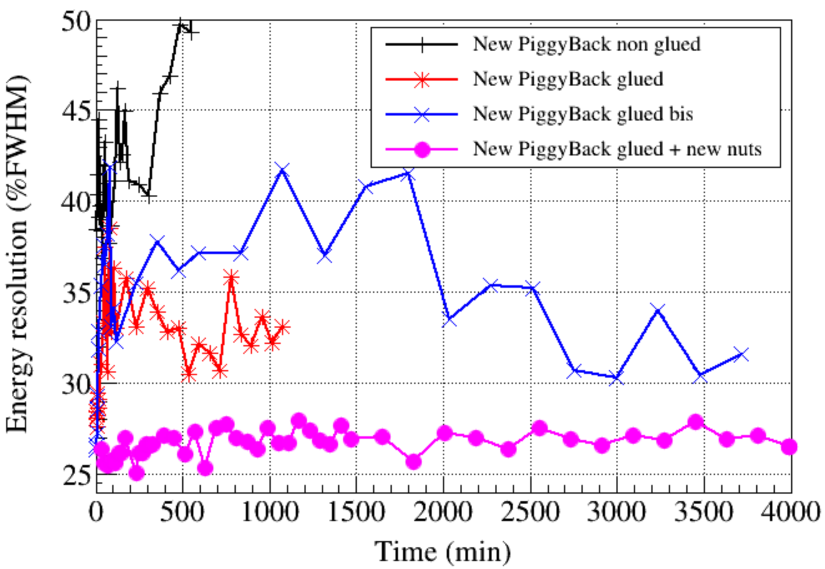
Evolution of gain and energy resolution during several days:

→ Important gas leaks

Solutions:

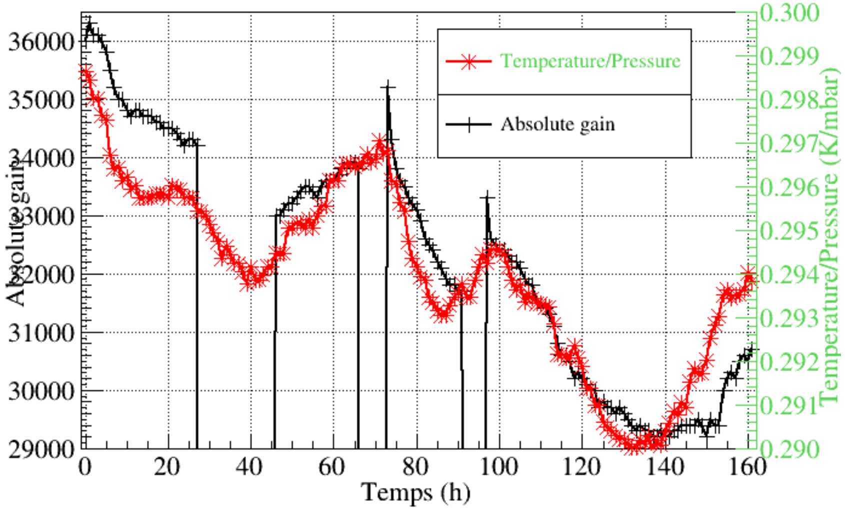
→ Torr Seal glue on HV connectors

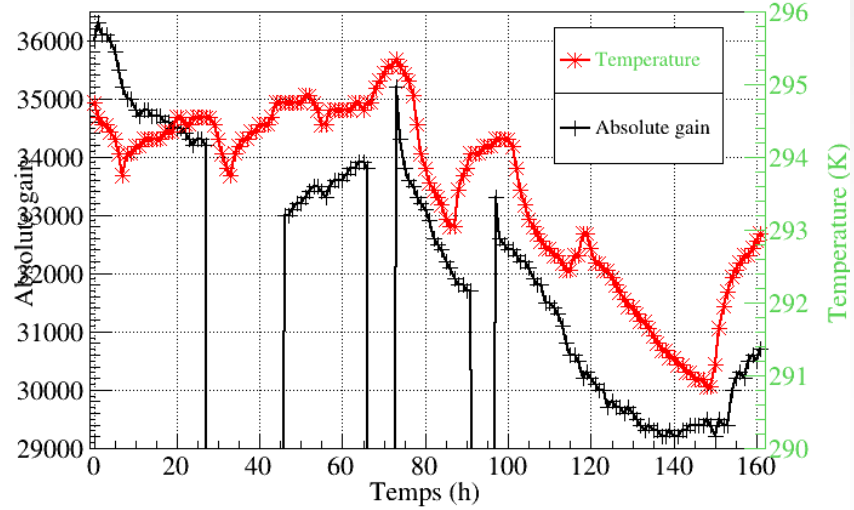
→ New nuts for the mechanics



→ The new chamber is now leak-proof enough

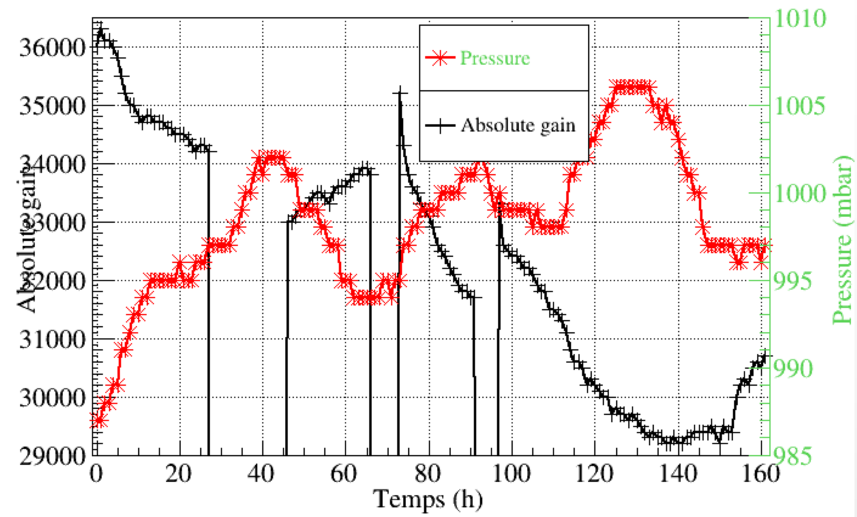
Environmental study





Mixing ratio	C_P (1/mbar)	C_T (1/K)
80/20	-0.46	1.50
90/10	-0.59	1.91
95/5	-0.68	2.18

Adloff et al., Environmental study of a Micromegas detector



→ We cannot neglect the evolutions induced by the environment

Coupling to high-tech electronics

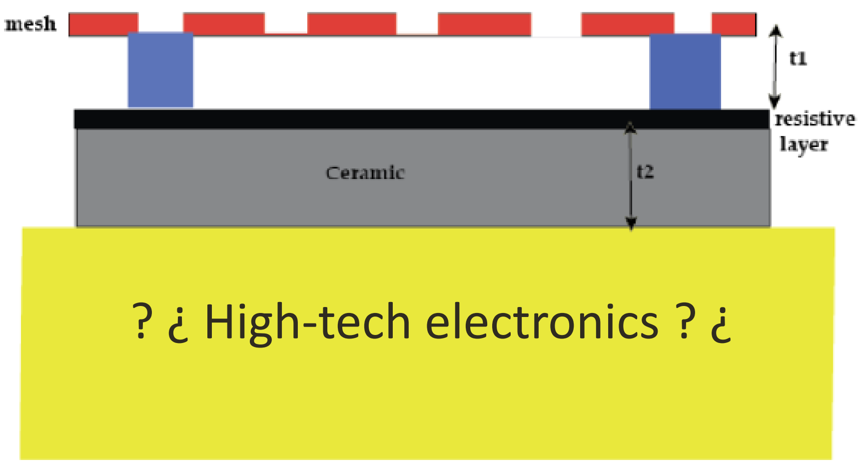
Why?

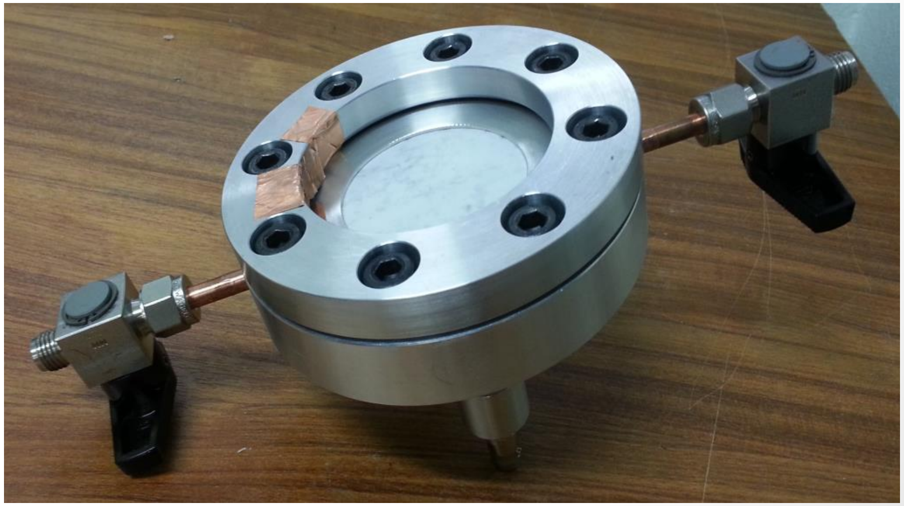
- Low noise, very good resolution, radiation hardness, low cost,…
- Could work at normal and high temperature
- Improved performance for space missions

How?

→ Put the electronics at the bottom of the ceramic layer

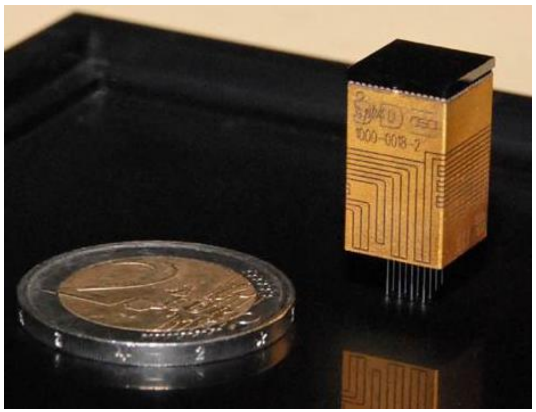
→ Signal transmission by capacitive transmission





A powerful detector camera: Caliste

- Detector above made in CdTe
- Very compact and robuste
- Optimised for space missions
- Read-out in 256 pixels
- No dead-space
- Made of 8 eight programmable ASICs

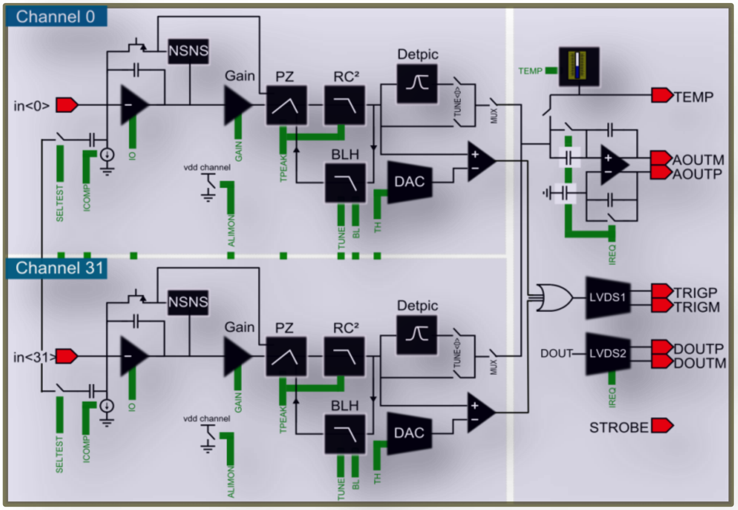


Validation	*Caliste HD*
Noise performance	SIMULATION 25e-+ 5.5 el./pF rms at 13 µs, 1 pA
Spectral resolution < 1.2 keV fwhm @60 keV	SIMULATION <900 eV at 60 keV, -20°C
Low threshold	SIMULATION <2 keV, -20°C
Radiation hardened design	Yes
SEL LETASIC	65 MeV.cm^2.mg^{-1} (TBC)
SEU LETASIC	9 MeV.cm^2.mg^{-1} (TBC)

Features	***Caliste HD***
Dimensions of the 3D block	10 x 10 x 20.7 mm3
Electrical I/F *Pin grid array*	4 x 4 (1.27 mm pitch)
Number of pixels	256 (16 x 16)
Pixel pitch	625 µm
Guard ring width	20 µm
Number of ASIC	8
ASIC version	IDeF-X HD (32 channels)
Slow control	Yes
	3.3V

And its front-end electronics

Architecture of one IDeF-X HD ASIC:



<u>For each channel:</u> low noise/low charge preamplifier + sharper with adjustable peaking time + discriminator to set the low threshold value + peak detector to memorize the pulse height

Signal induced in pixels → trigger set up and sent to SAB.
FPGA begins readout sequence channel by channel : date, adress, energy

Sequel of actions: Event → trigger → Wait & Freeze → Detect ASIC trig. → Readout hit register → Energy mux → Delay & Reset

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+ FPGA card

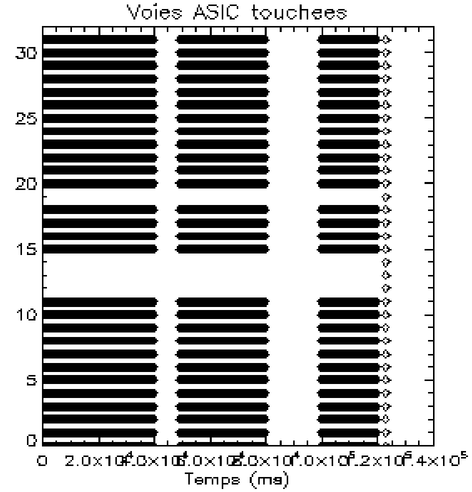
- In permanent reconfiguration with logical gates
- Users communicate with the card by scripts

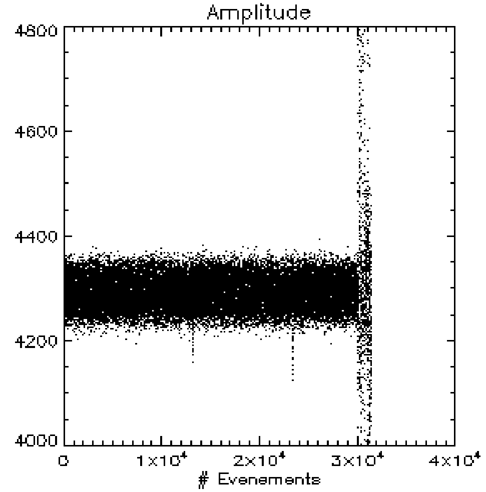
+ SAB card

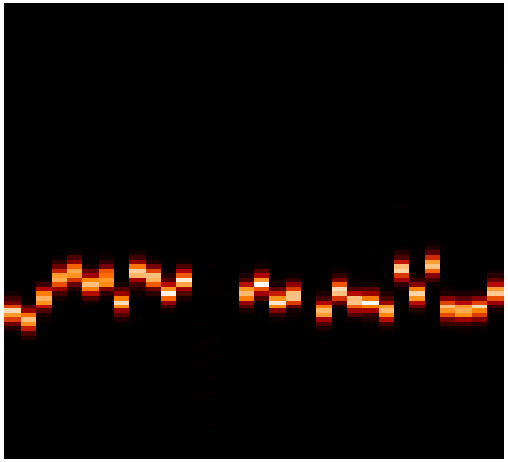
- Communication between the electronics and the computer

Injection of signals in one ASIC

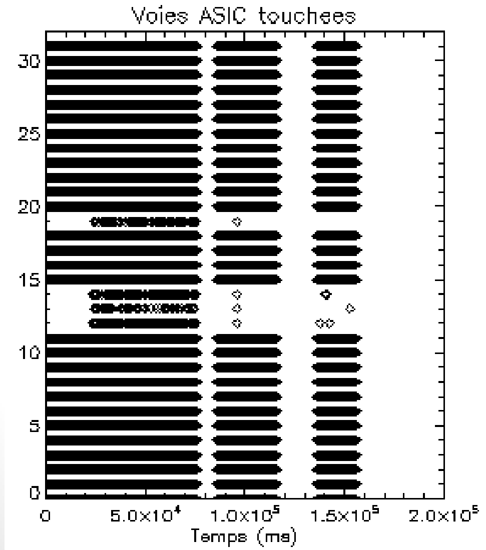
Test with stopped signal: two breaks (40s-50s and 80s-100s) with fixed amplitude (10mV)

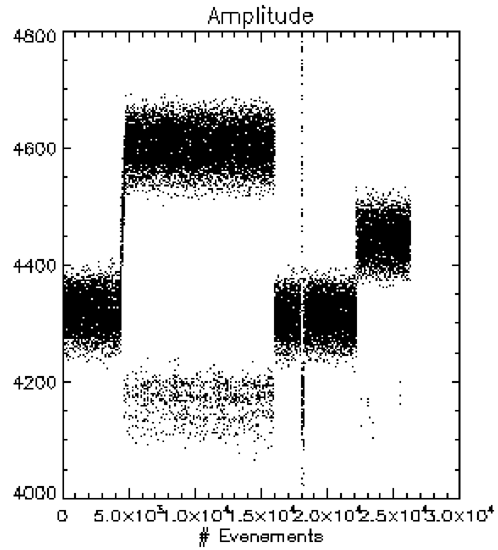


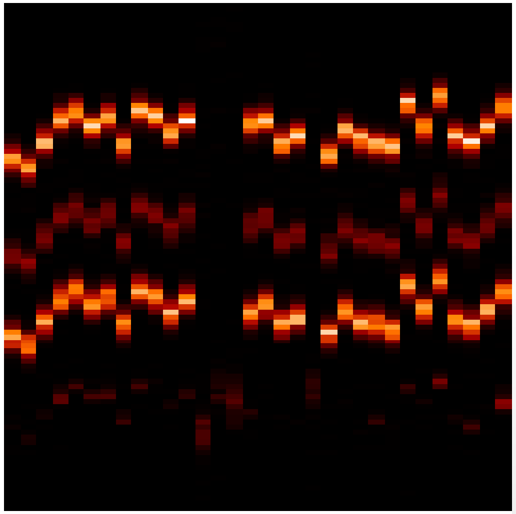




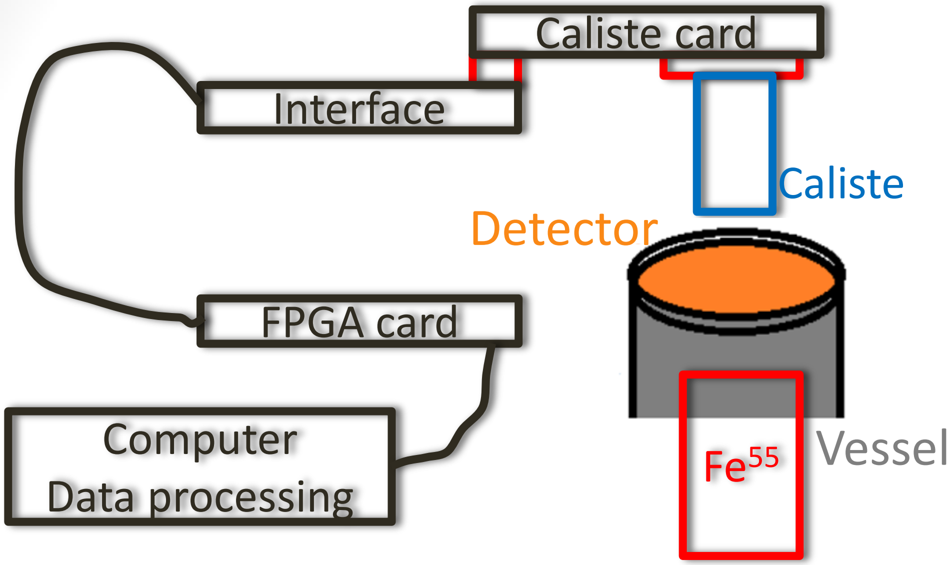
Test with various signal: modification of the amplitude (20, 10 and 15mV) after the breaks

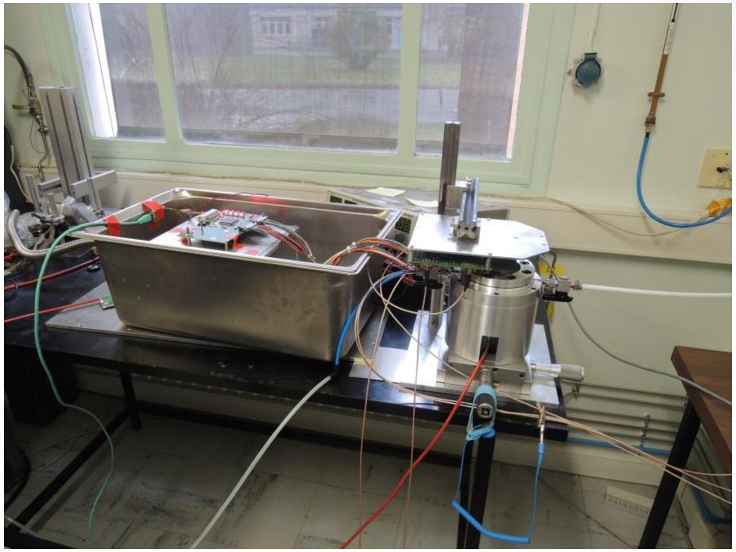


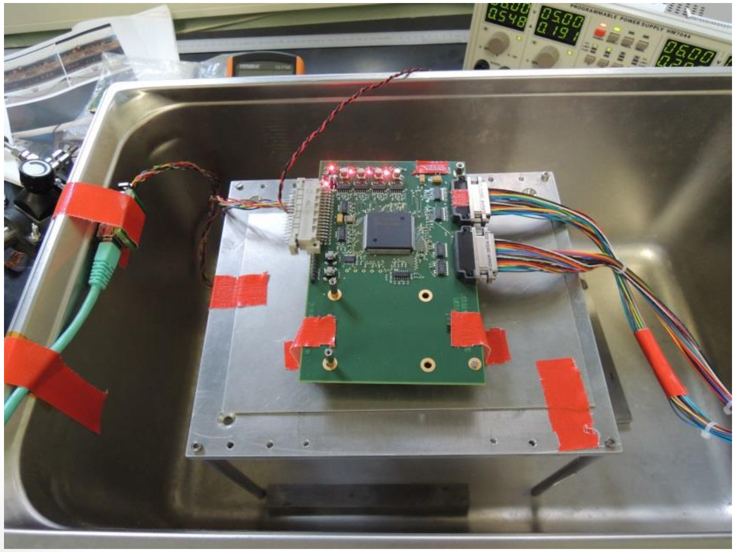


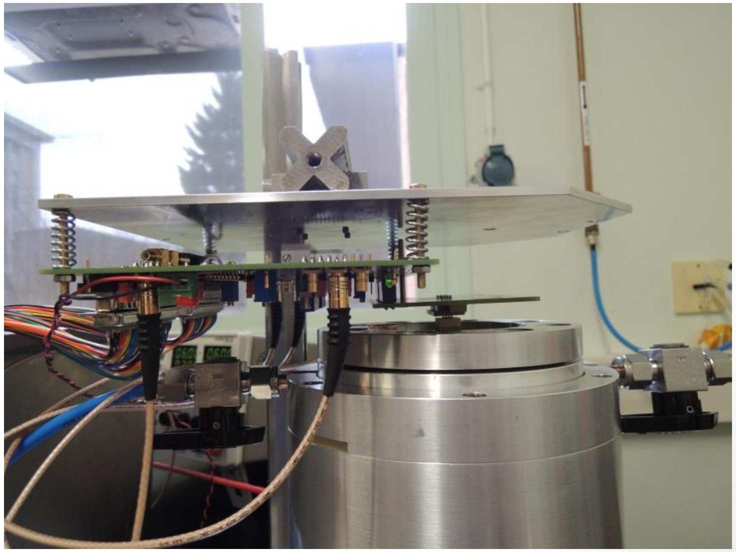


Set up of coupling electronics

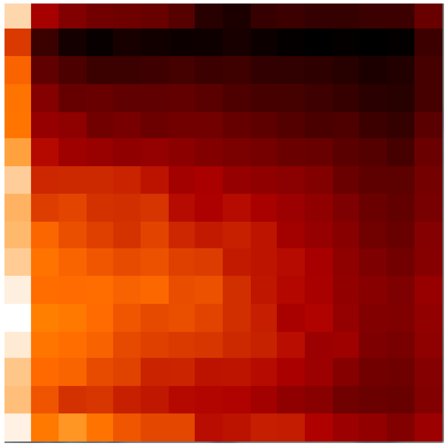


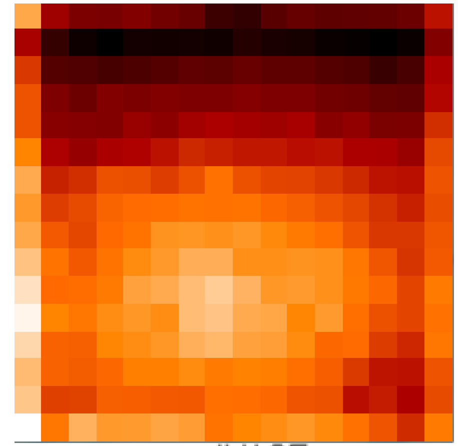




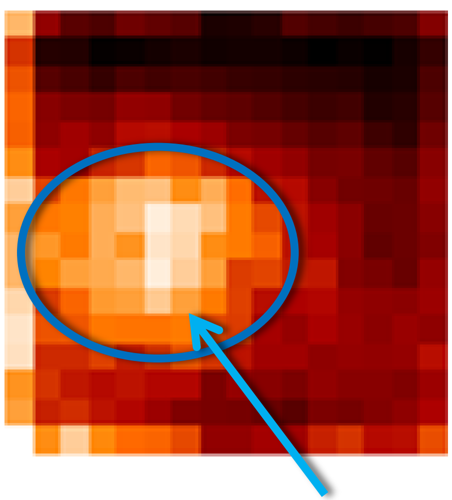


First results on coupled detector

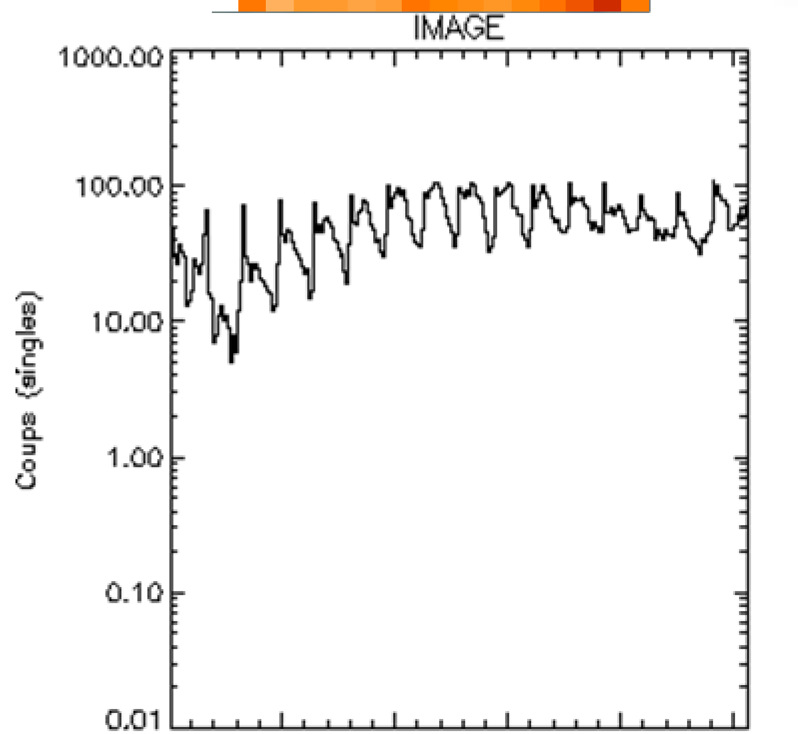




We get the spectrum of the iron source!



Center of the source



→ First time that MicroMEGAS are successfully coupled to space electronics!

Conclusions and outlook

- Resistive MicroMEGAS were compatible with read-out electronics
- This coupling is working thanks to capacitive transmission
- Signals from a pulser have been successfully injected and observed
- First picture of the iron source acquired!

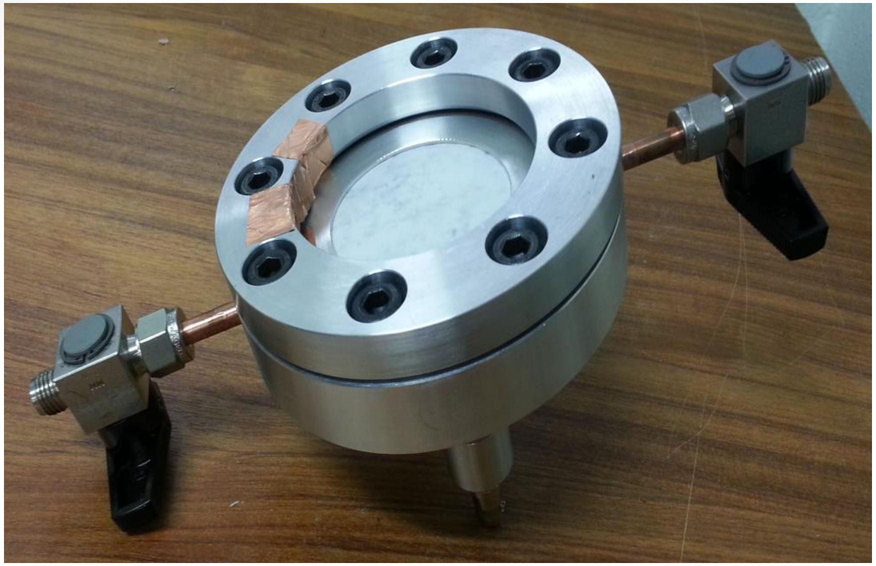
Possibility to build up an imaging spectrometer in the soft X-ray domain!

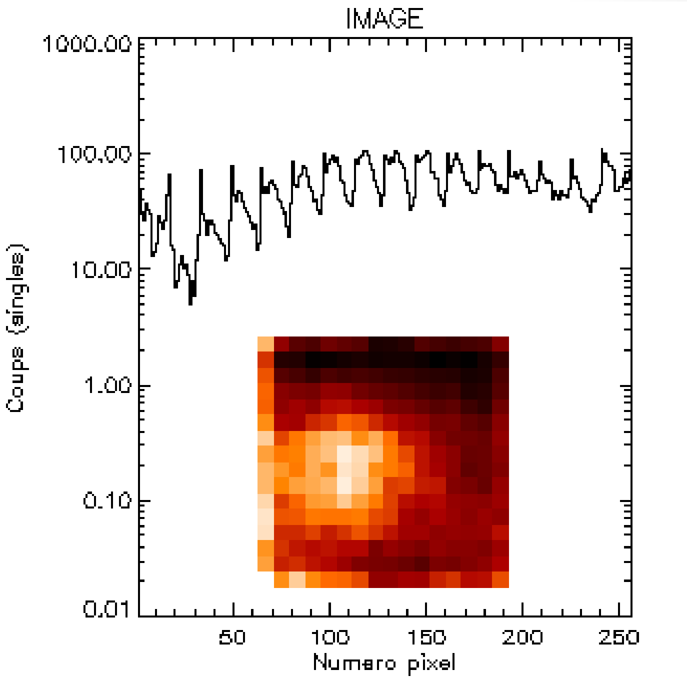
So, maybe, in the future,…

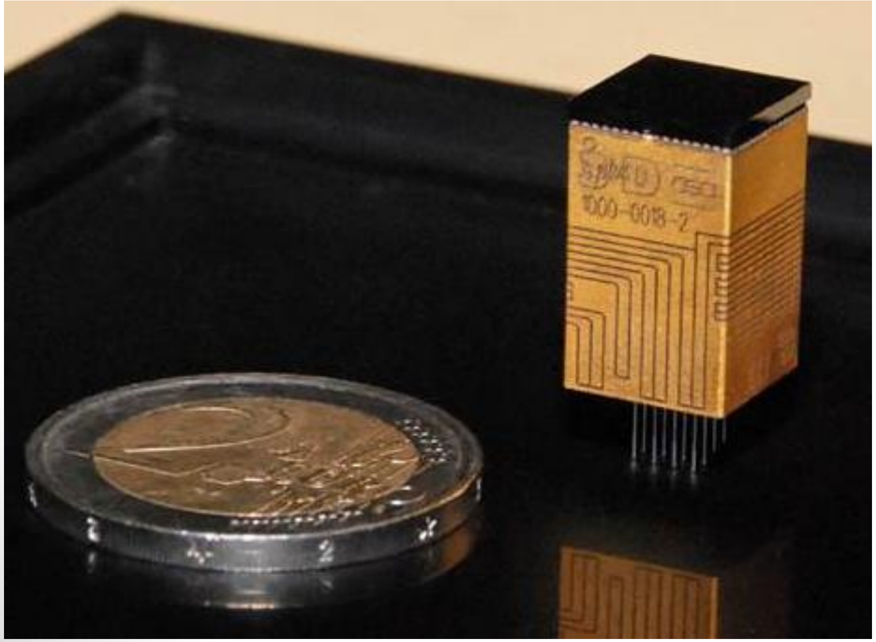
World of detection

Physics of detectors + Development of electronics

Thank you for your attention







Any question?

References

- Resistive MicroMEGAS and PiggyBack:

A Piggyback resistive Micromegas
Attié, D.; Chaus, A.; Colas, P.; Ferrer Ribas, E.; Galan, J.; Giomataris, I.; Iguaz, F.J.; Gongadze, A.; De Oliveira, R.; Papaevangelou, T.; Peyaud, A.
JINST (2013) 8 C11007

- Environmental study:

Environmental study of a Micromegas detector
Adloff, C.; Chefdeville, M.; Espargilière, A.; Gaglione, R.
LAPP-TECH-2009-03

- Caliste HD:

Caliste HD: A new fine pitch Cd(Zn)Te imaging spectrometer from 2 keV up to 1 MeV
Meuris, A.; Limousin, O.; Gevin, O.; Lugiez, F.; Le Mer, I.; Pinsard, F.; Donati, M.; Blondel, C.; Michalowska, A.; Delagnes, E.; Vassal, M.-C.; Soufflet, F.,
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- IDeFX-HD:

IDeF-X HD: A low power multi-gain CMOS ASIC for the readout of Cd(Zn)Te detectors
Michalowska, A.; Gevin, O.; Lemaire, O.; Lugiez, F.; Baron, P.; Grabas, H.; Pinsard, F.; Limousin, O.; Delagnes, E.
IEEE NUCLEAR SCIENCE SYMPOSIUM - CONFERENCE RECORD, 2010