R&D on a novel polarimeter spectro-imager with Micromegas detectors and a Caliste readout system

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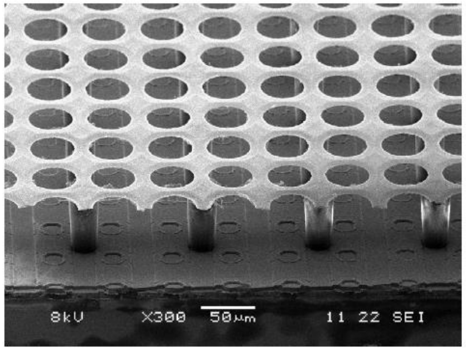
NDIP

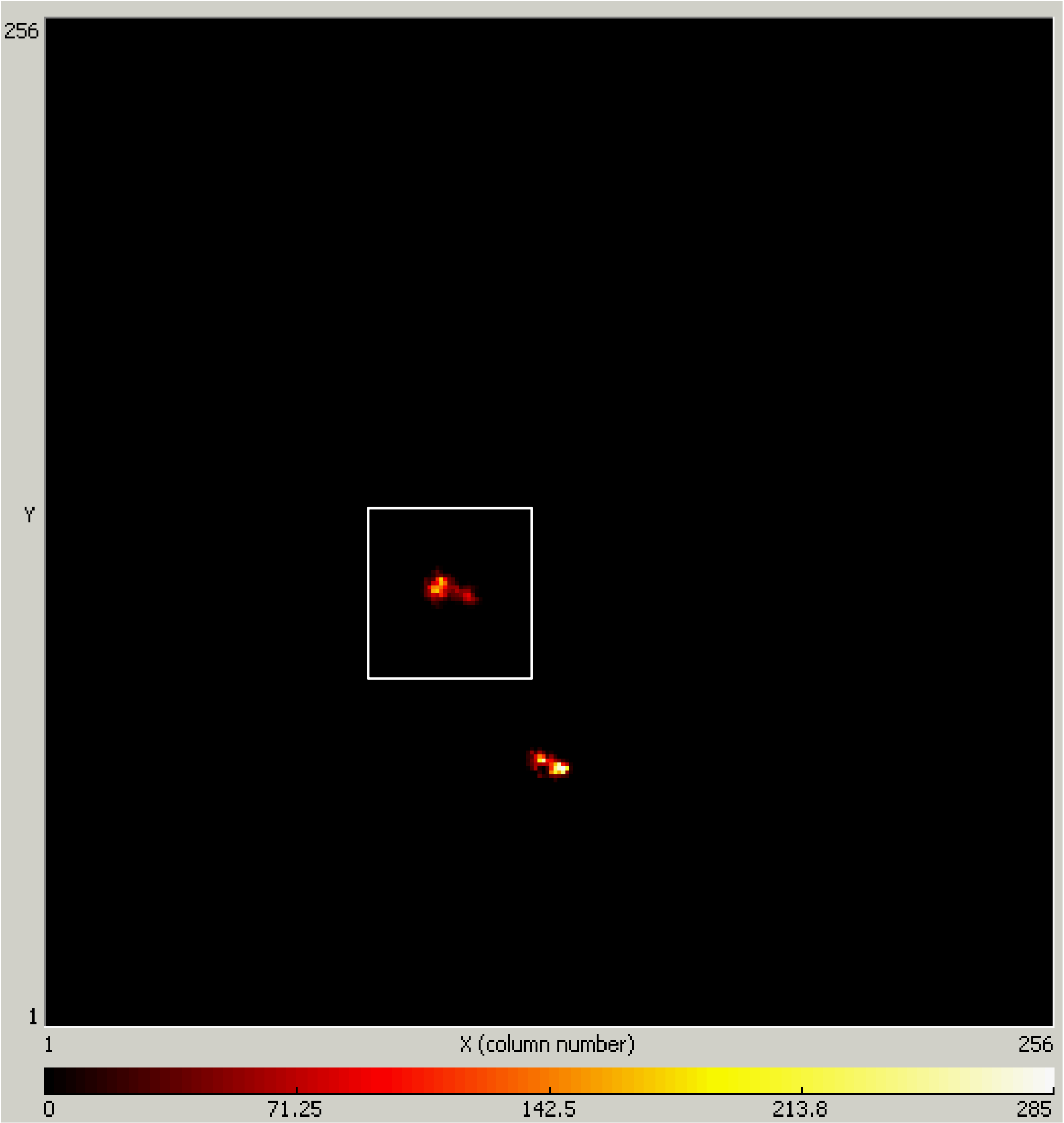
Outline

- Polarimetry capability using Micromegas
- Motivation for a new concept
- The Piggyback Micromegas
- Simulation, experimental set-up and studies with Piggyback detectors
- Towards a sealed chamber
- First result with Caliste readout system
- Conclusions and outlook

Previous Prototype Polarimeter using Timepix/Micromegas

- Timepix chip
  + SiProt 20 µm
  + Micromegas
- Matrix 256×256 pixels of 55×55 µm²
- Chip noise: ~650 e-
- ^{55}Fe source (6 keV)
- Ne/Iso (90:10)
- TOT mode
- Drift distance ~ 5 mm





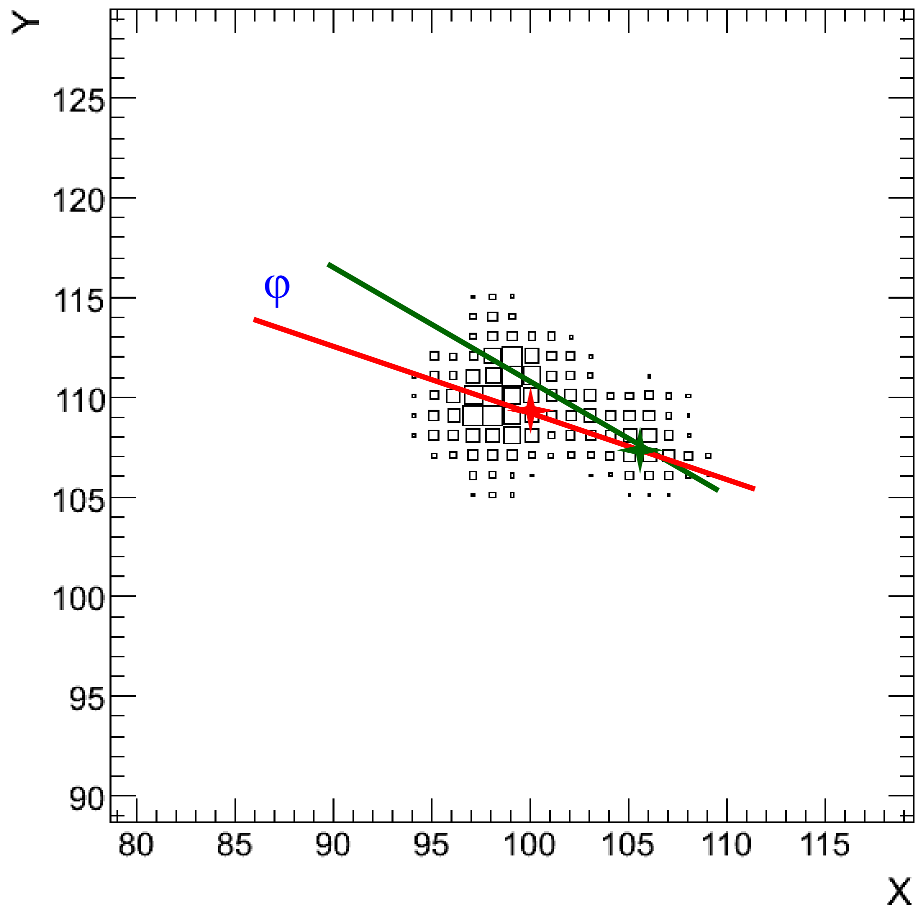
Previous Prototype Polarimeter using Timepix/Micromegas

- Determination of the polarization:
  - ✦ Barycentre & principal axis
  - ✦ Reconstructed absorption point
  - φ photoemission angle

- Low $E_{k\text{-edge}}$ of Neon

  → e_{auger} are isotropically emitted with a small fraction of the photon energy

- In low Z gas mixture tracks are longer so angular reconstruction is easier



Photoelection + e_{auger} track in Neon+10% Isobutane

Attié *et al.*, NIMA 610(2009)178A

Motivation for New Concept

1. Sealed detector needed for space experiment
2. In gaseous detectors: sparks induced by heavily ionizing particles:
   - Limitations on rate during operation
   - Reduction of the detector lifetime
   - Risk of damage of the readout electronics

   ⚠ Most of the time no issue (detector/electronics) using passive protection

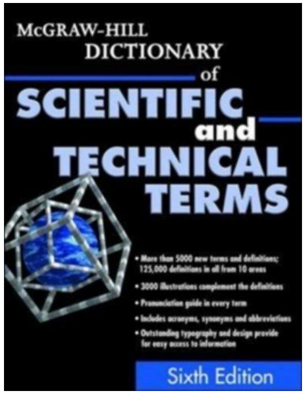
→Possible solutions:

1. Limit usage of outgassing material
2. Spark suppression by using:
   - Resistive strips above readout (ATLAS/NSW Upgrade)
   - Resistive foil on top of anode plane

Piggyback resistive Micromegas

- Attié *et al.* , JINST 8 P05019 (2013)
- inspired by similar work with PPAC by M. Kocsisa *et al.*, NIMA 563 (2006) 172–176
- new approach where a thin resistive layer is desposited on an adequate insulator

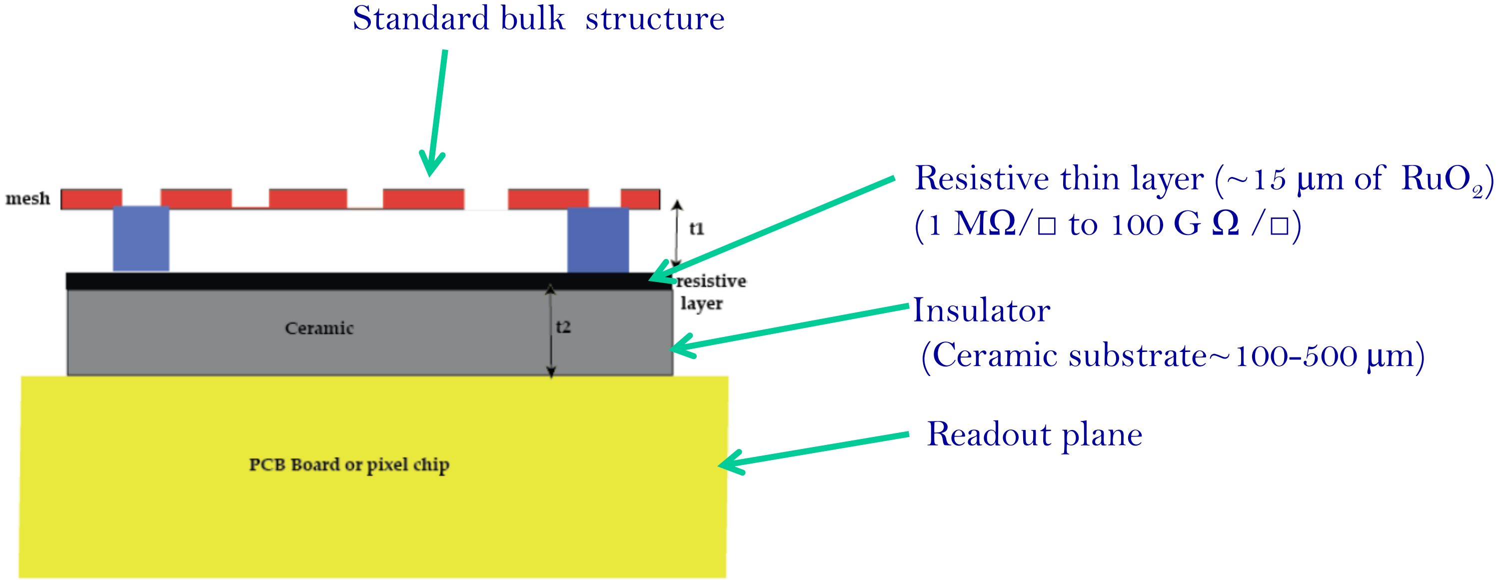
- McGraw-Hill Science & Technology Terms: **piggyback board**



"A small printed circuit board that is mounted on a larger board to provide additional circuitry."

- Piggyback (transportation): something that is riding on the back of something else

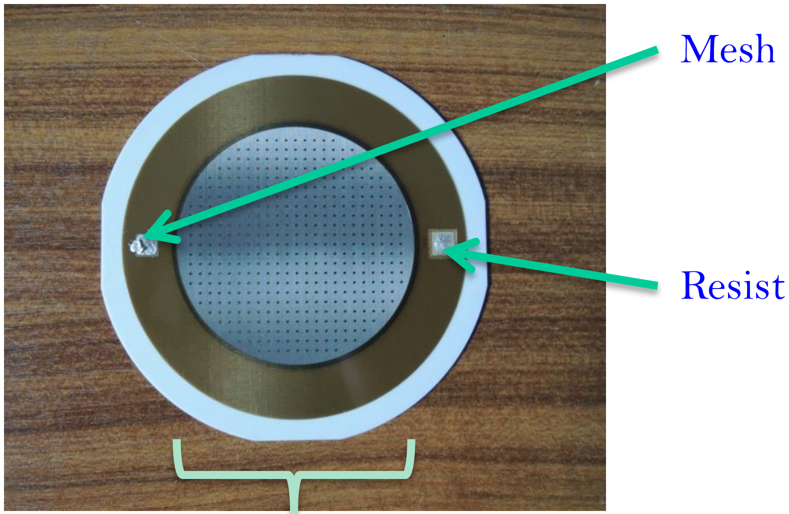
- Separation of the amplification structure and the readout plane



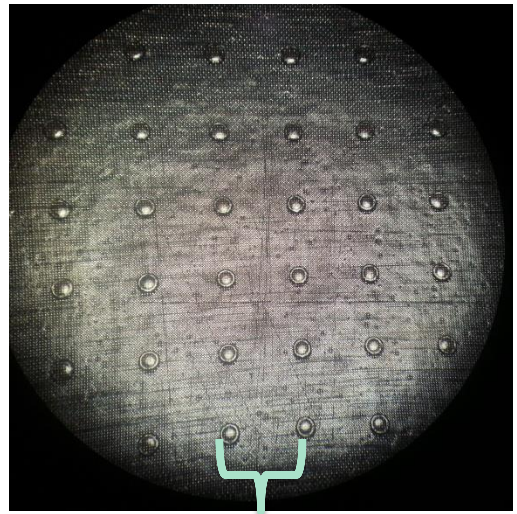
- Signal is transmitted by capacitive coupling to the readout plane
- Optimisation of the induced signals: $t_{insulator} \ll t_{gas} \frac{\varepsilon_{insulator}}{\varepsilon_{gas}}$
- $\varepsilon_{insulator}$ should be as high as possible (first prototype alumina with ε~10)

- 128 µm amplification gap, 20 µm of RuO_2 with 100 MΩ/□, ceramic layer 300 µm

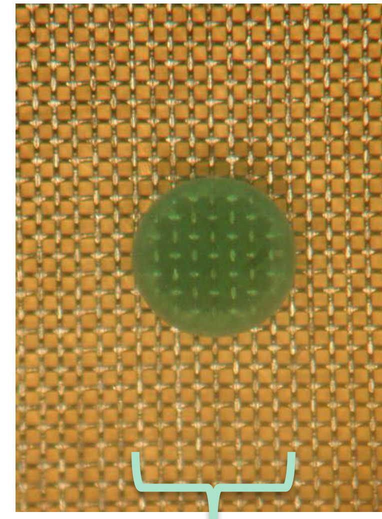
Bulk Micromegas



50 mm

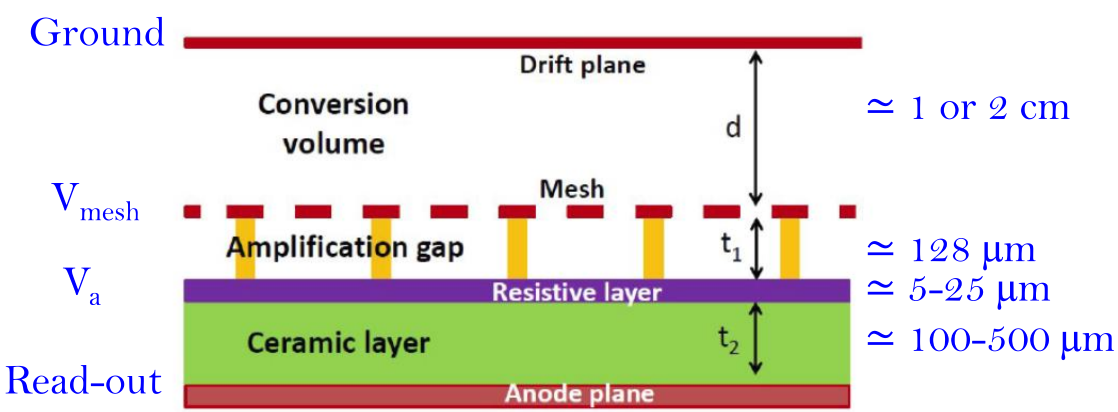


2 mm

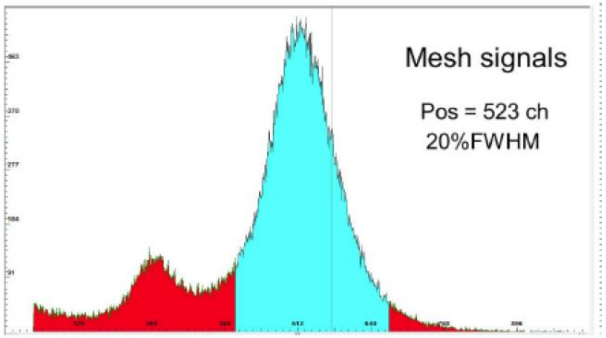


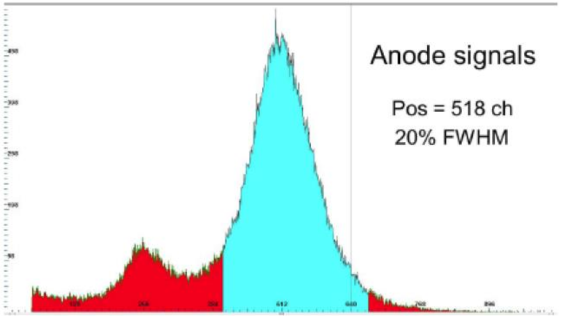
500 µm

« 45/18 » woven mesh

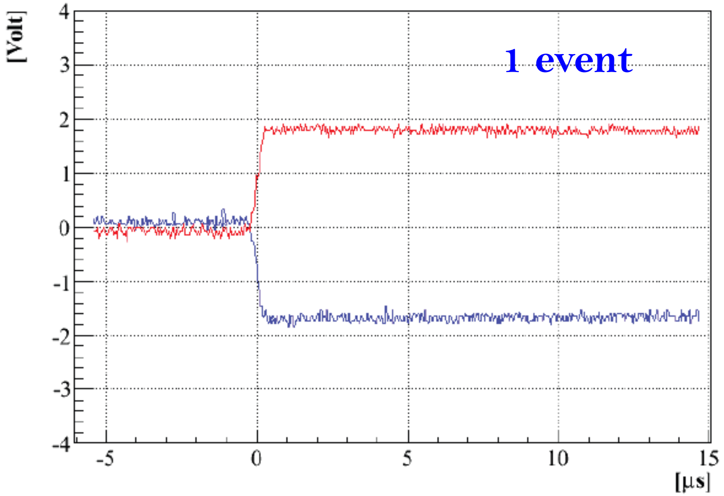


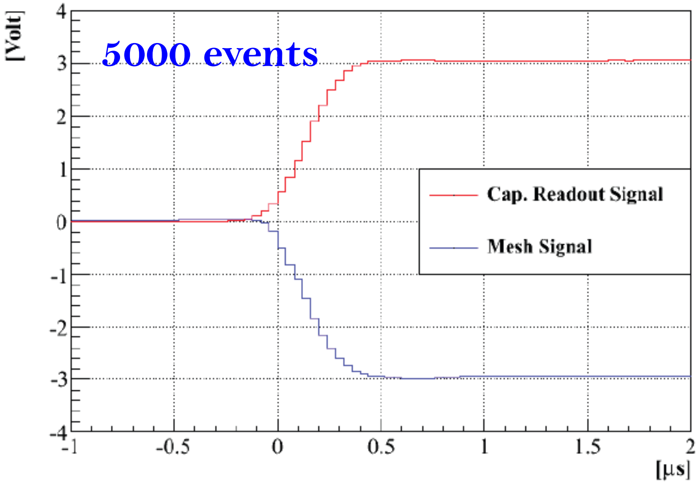
- Checking possibles looses by the ceramic layer: signal entirely transmitted





- Test with a ^{252}Cf (fission fragments signals) reading simultaneously mesh and anode

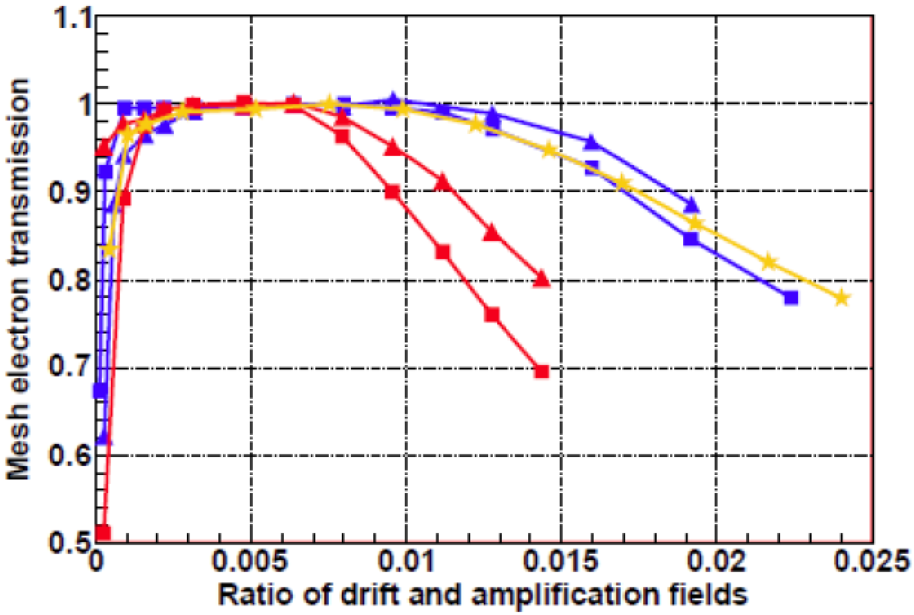


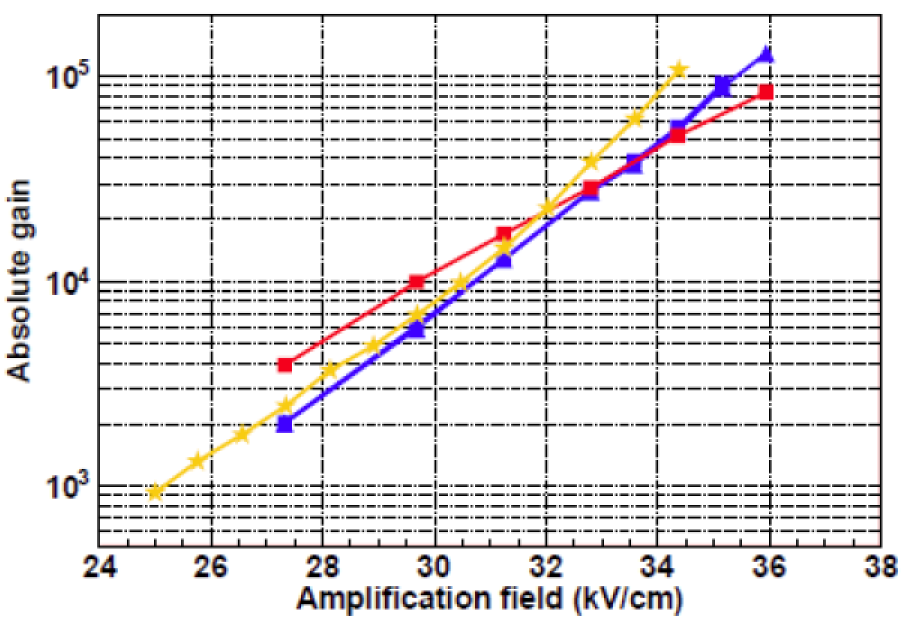


→Amplitude within 5%, same rise time for both polarities

- Electron transparency reach a plateau
- Gain up to 10^5

Ne + 5% Ethane
Argon + 5%Iso
Argon + 5%Iso (Standard Bulk)

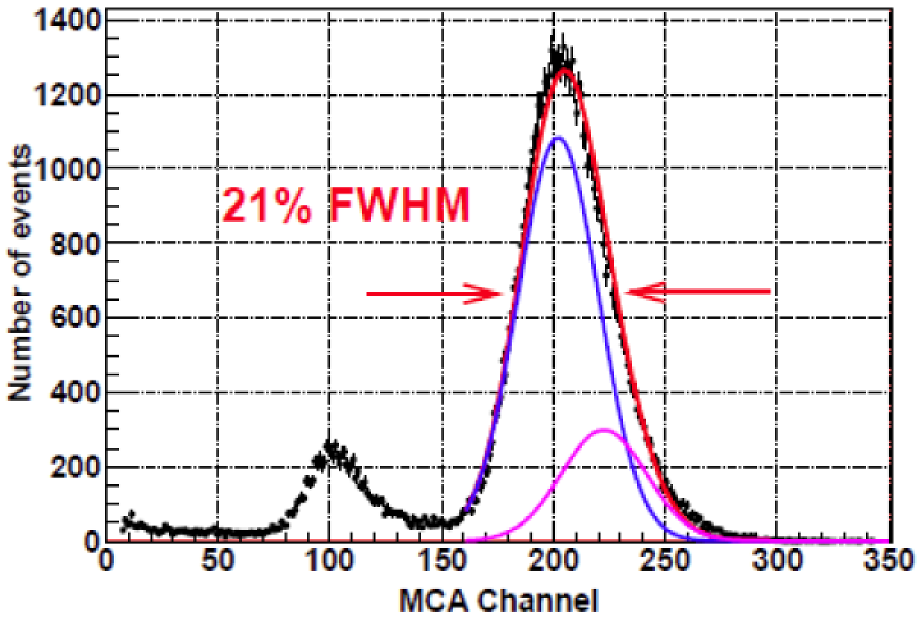




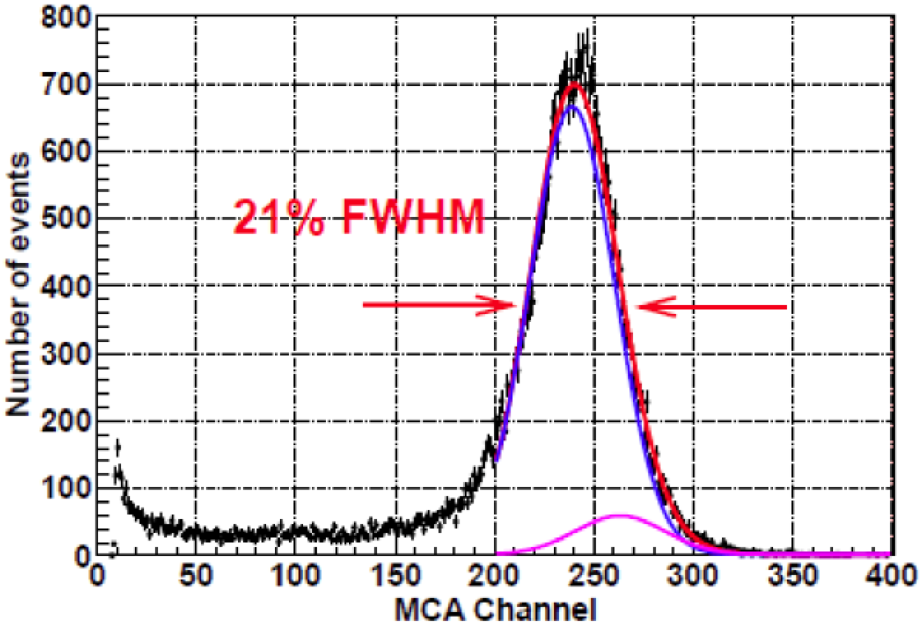
Attié *et al.* , JINST 8 P05019 (2013)

- Energy resolution in two gas mixtures: 21% FWHM

Argon + 5%Iso

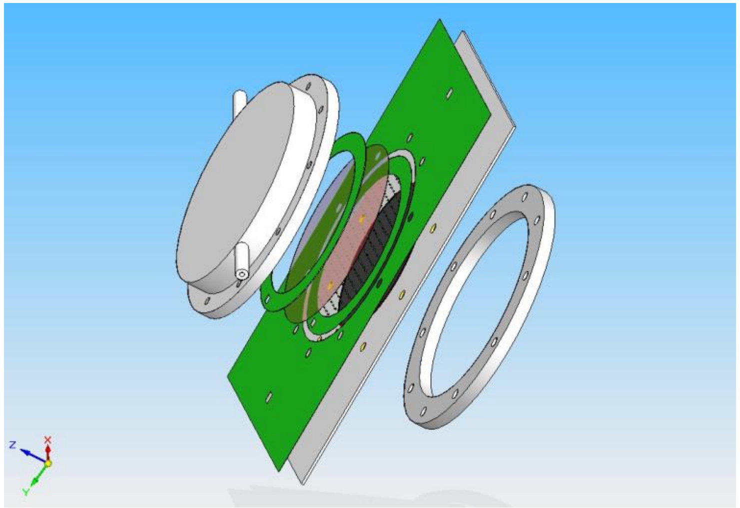


Ne + 5% Ethane



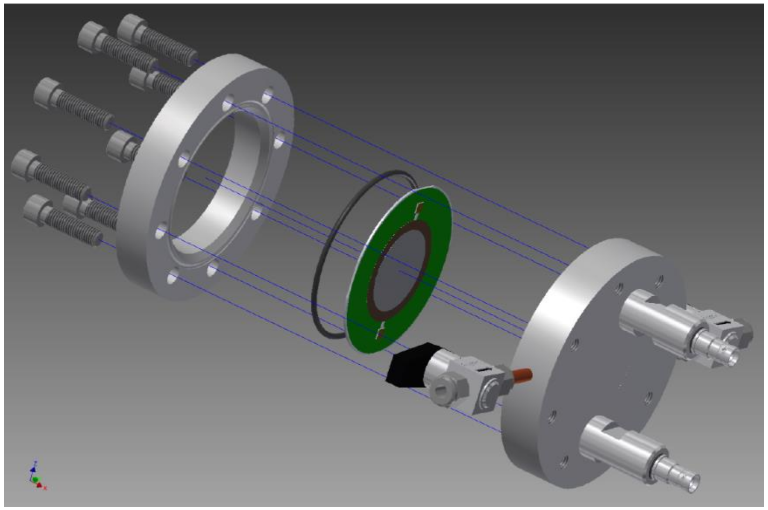
Attié *et al.* , JINST 8 P05019 (2013)

Piggyback Sealed Chamber Evolution



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

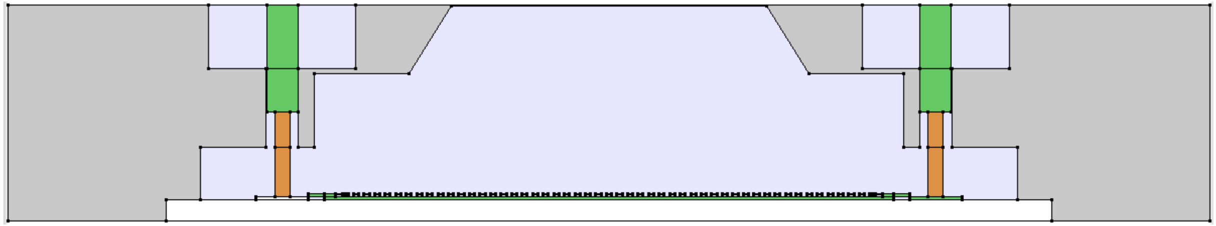
→Verify the resistive layer concept
Good performances in normal mode

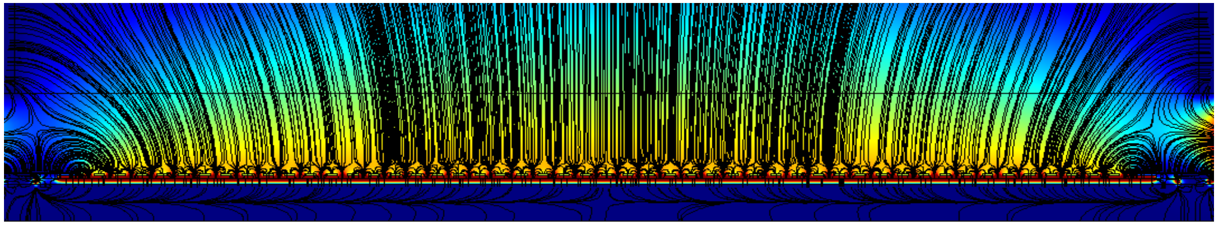


- HV connectors inside
- Ceramic totally inside
- Made in stainless steel
- Uncovered ceramic layer

→ Very low outgassing
Robust and versatile

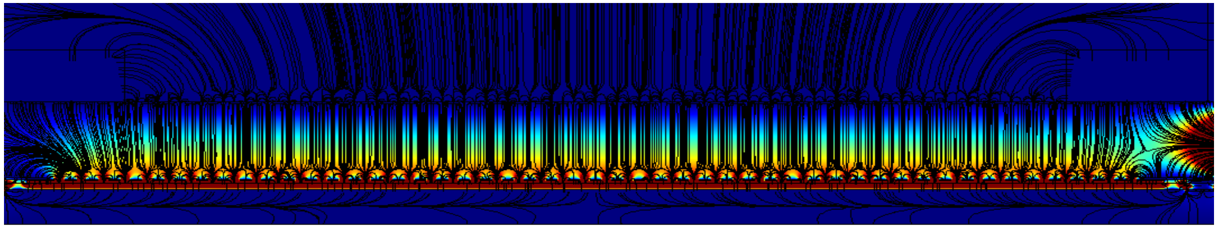
- Problem:
  Bad parallelism of electric field lines

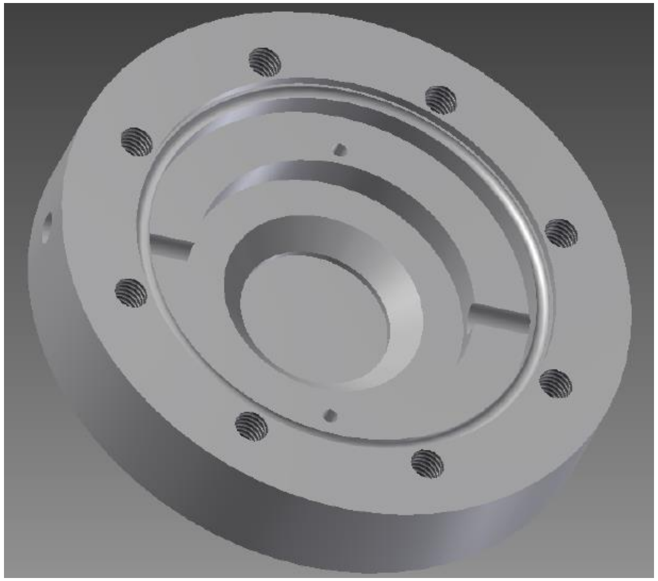


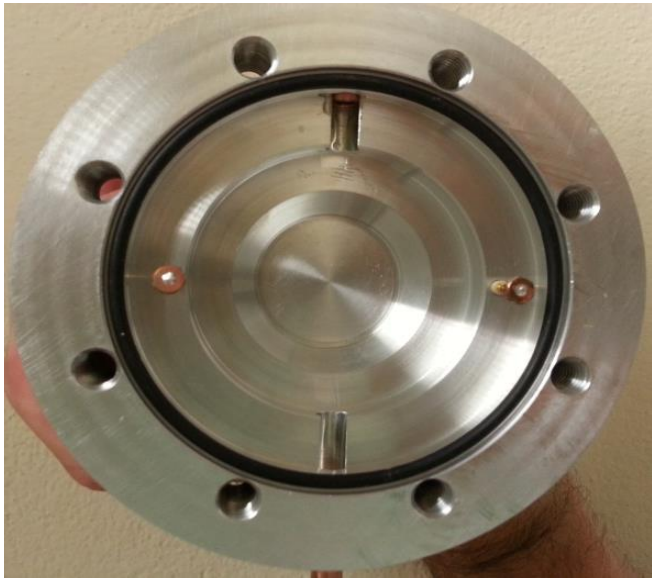


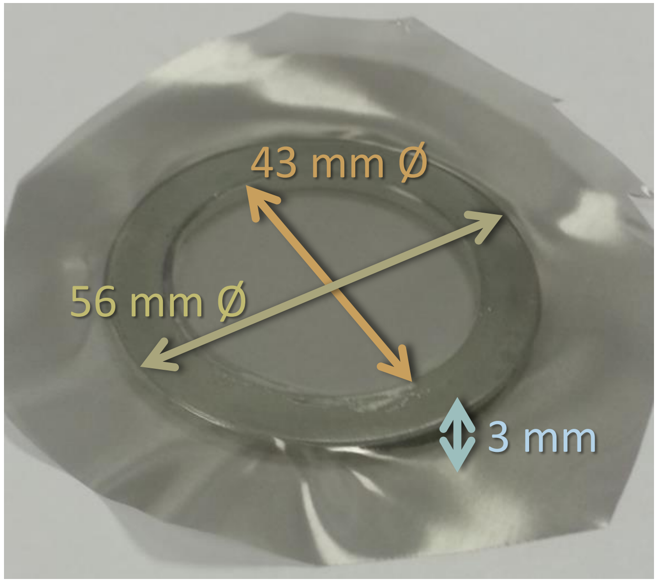
→ <u>Idea:</u> Put a grounded element into the chamber to improve the parallelism

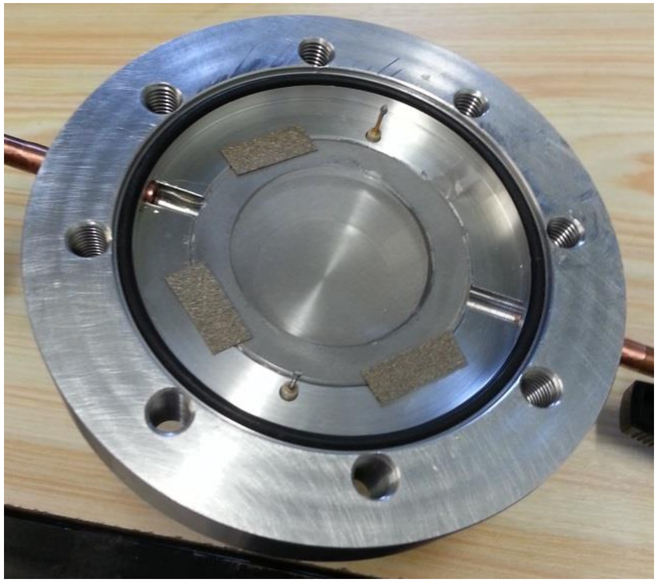
- Solution:
  Install an additional little mesh to make the drift space more homogenous



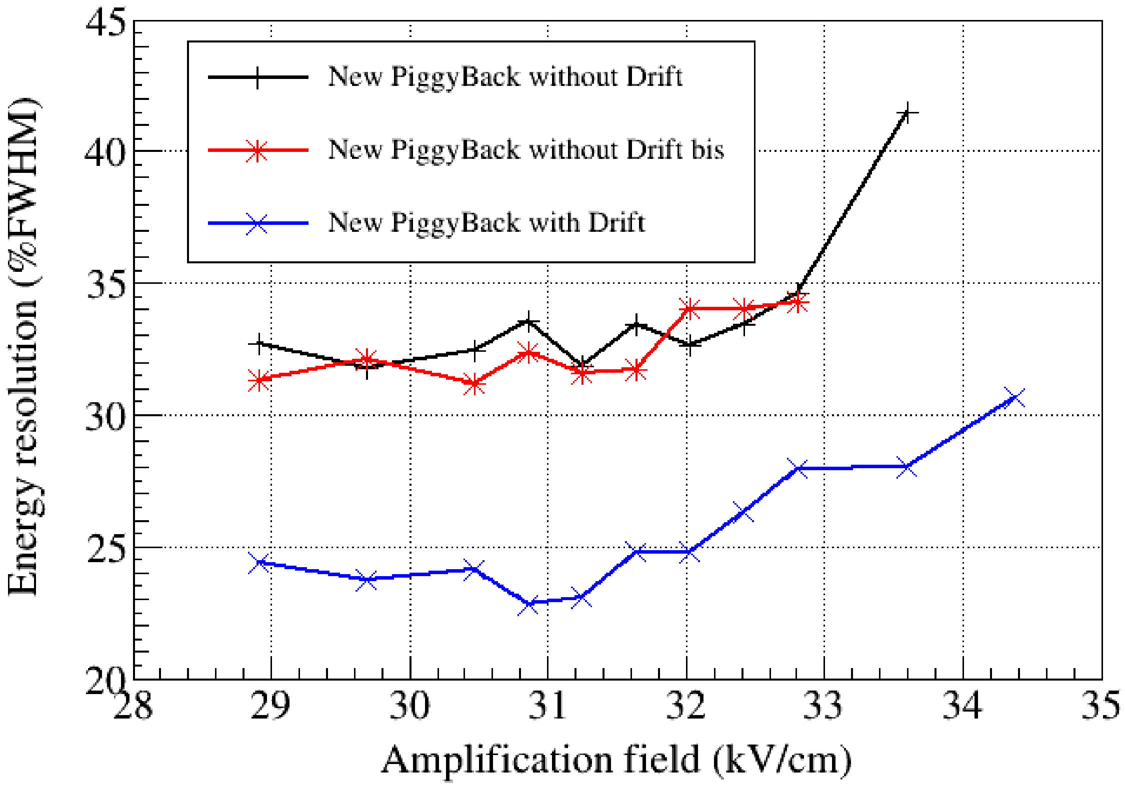





43 mm Ø
56 mm Ø
3 mm



- Electron transmission maximal for: $0.001 < \frac{E_{Drift}}{E_{Amplification}} < 0.015$
- Gain up to 5×10^4
- Energy resolution ≤25% for a large range of amplification fields

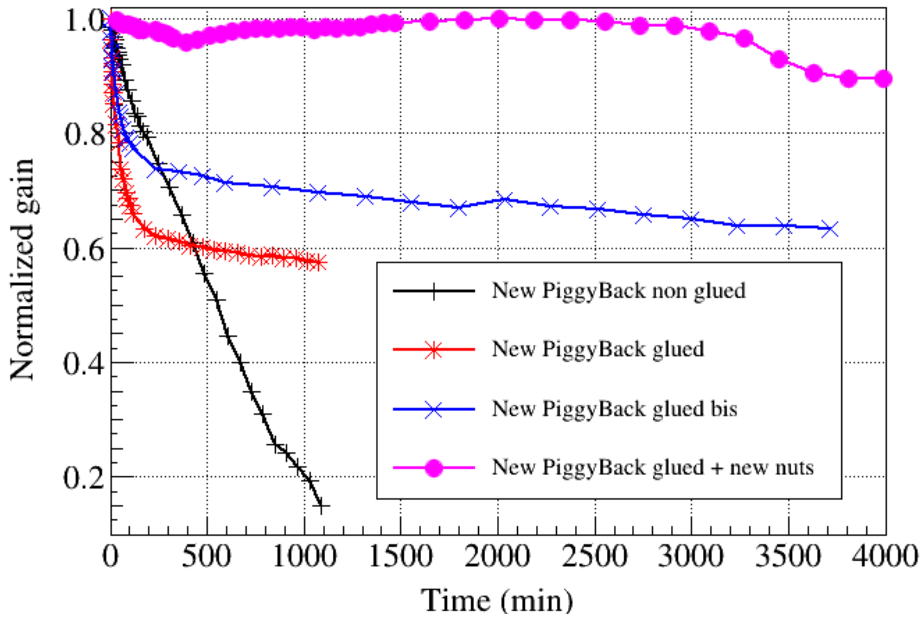


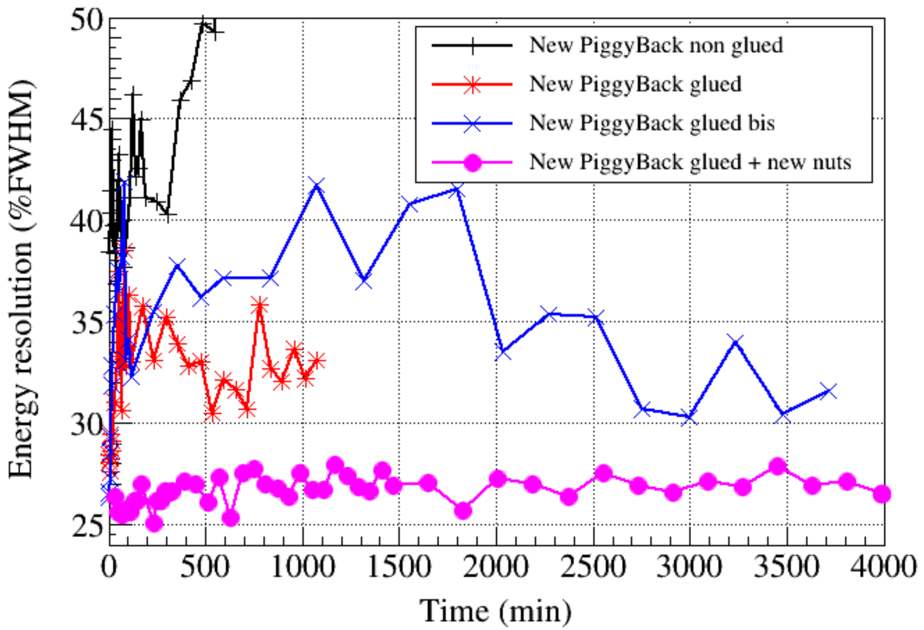
The new chamber meets the expected performance in normal operation

- Evolution of gain and energy resolution during several days:
  → Important gas leaks

- Solutions:
  - Torr Seal glue on HV connectors
  - Improvement of the mechanics

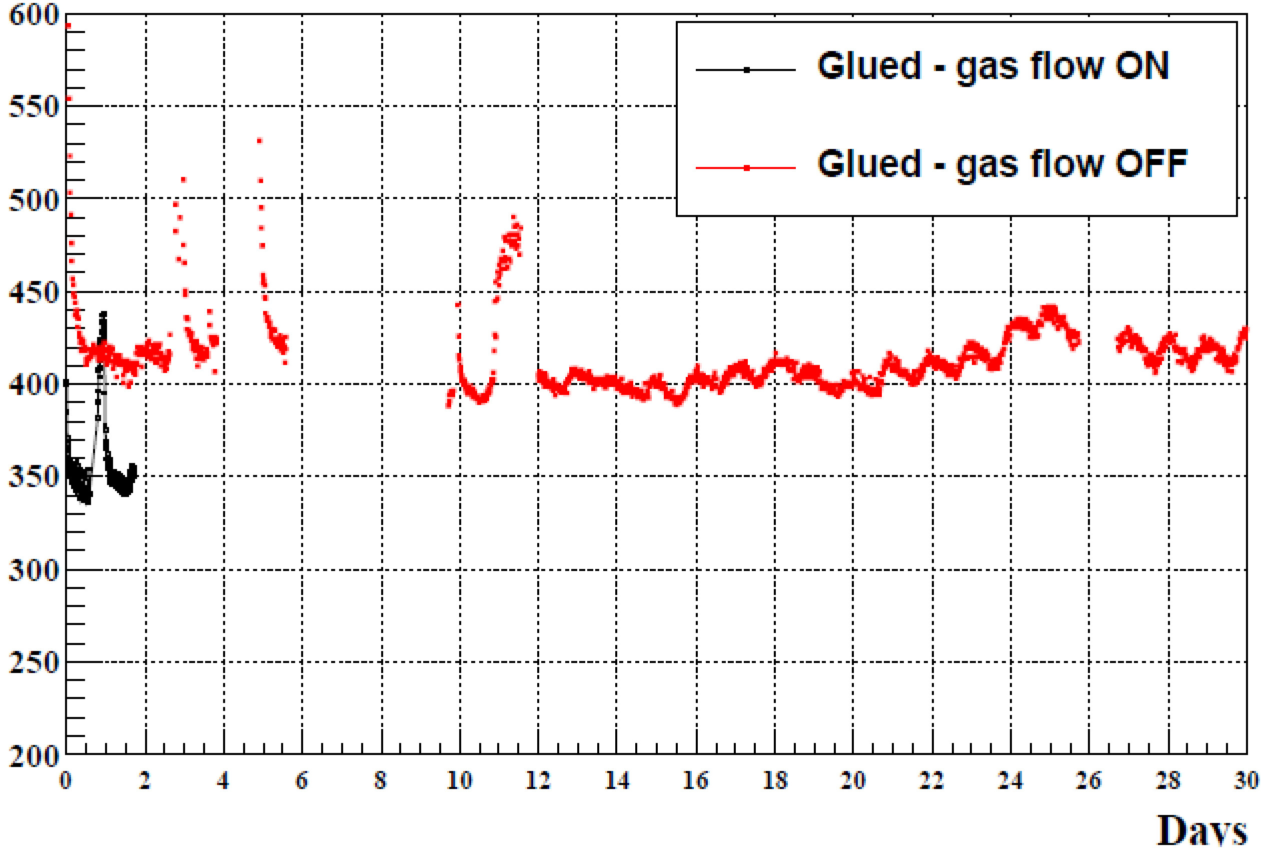
The new chamber is now leak-proof





Sealed Operation

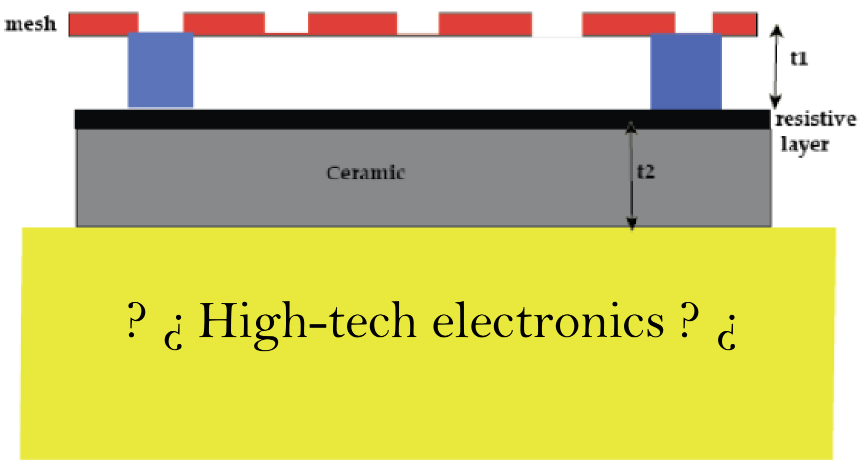
- Stability over 30 days
- Small fluctuations due to day night effects
- Big amplitude fluctuations due to the removal of the source

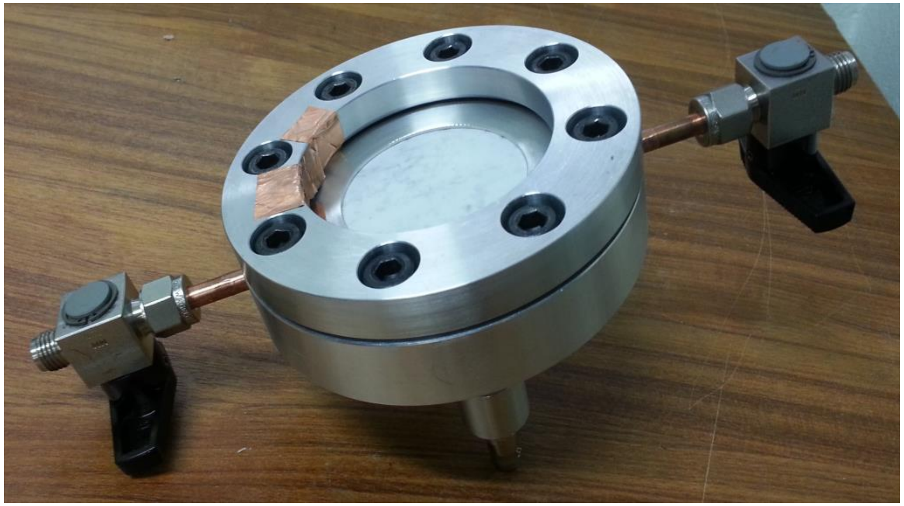


Coupling to Electronics Readout

- Why?
  - Low noise, good energy resolution, radiation hardness, large size, low cost,…
  - Could work at any temperature
  - Improved performance for space missions

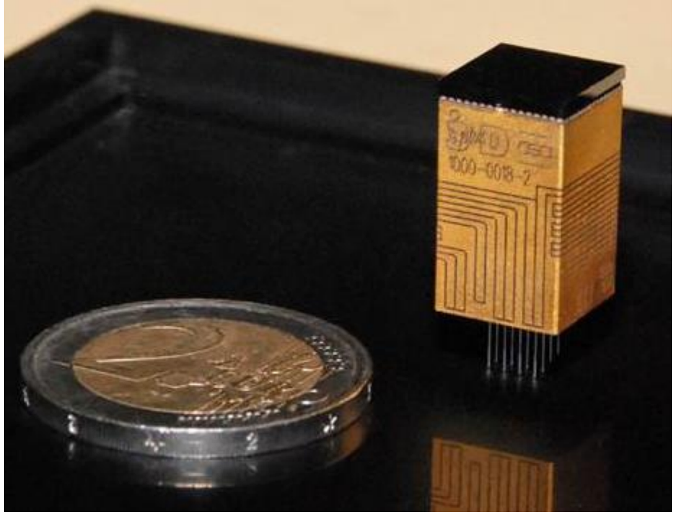
- How?
  - Put the electronics at the bottom of the ceramic layer
  - Signal transmission by capacitive transmission





Fine Pitch Imaging Spectrometer: Caliste HD

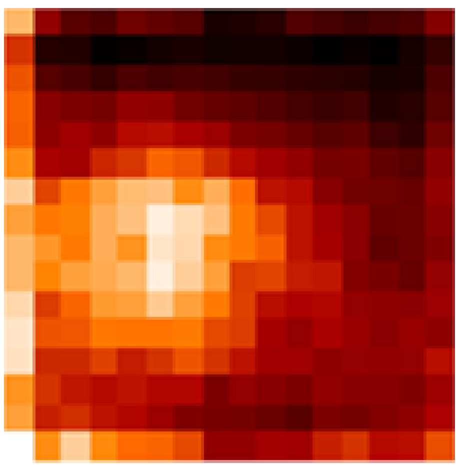
- Space qualified device and optimised for space missions
- Very compact and robuste
- Matrix of 256 pixels of 625 µm²
- No dead-space
- Made of 8 eight programmable ASICs
- Noise e⁻: 25.5e⁻+5.5e⁻/pF
- Spectral resolution: 1.2 keV FWHM@ 60 keV

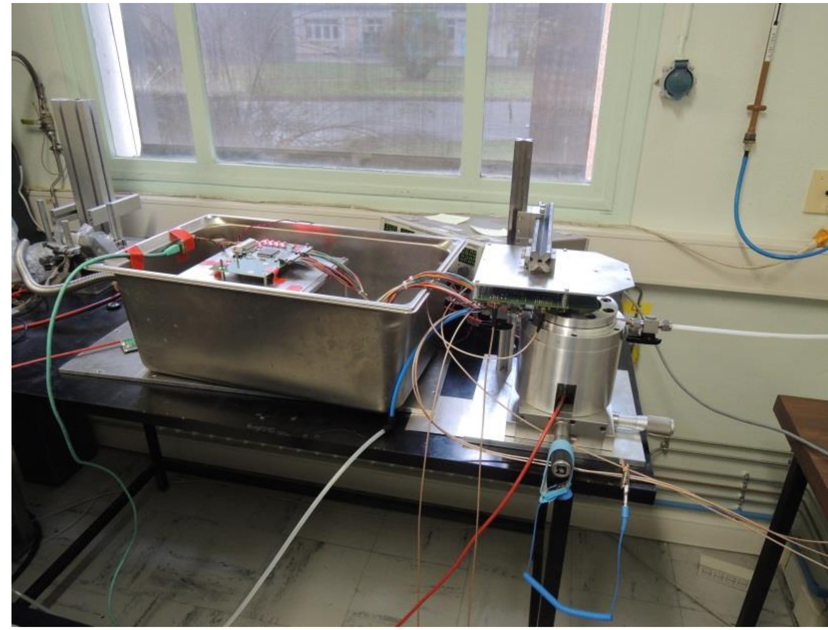


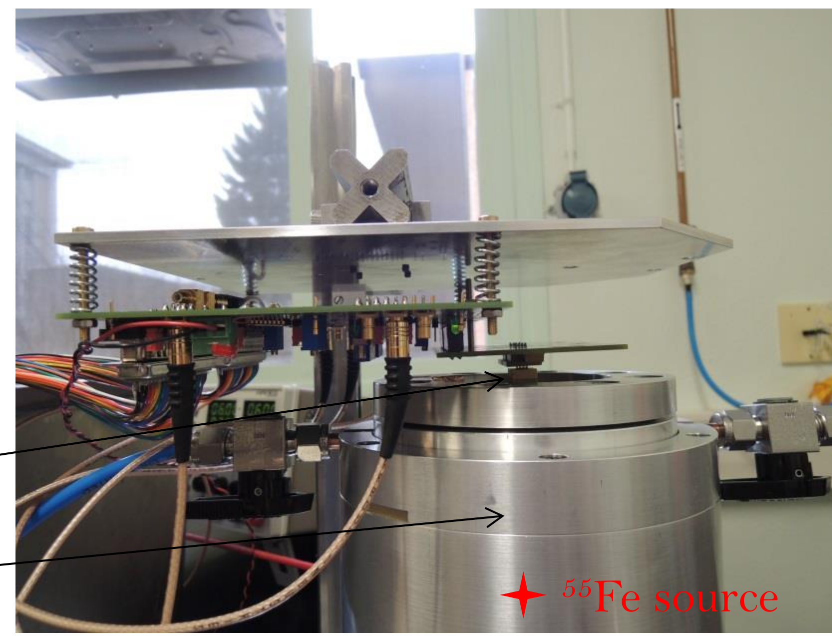
Features	*Caliste HD*
Dimensions of the 3D block	10 x 10 x 20.7 mm3
Electrical I/F *Pin grid array*	4 x 4 (1.27 mm pitch)
Number of pixels	256 (16 x 16)
Pixel pitch	625 µm
Guard ring width	20 µm
Number of ASIC	8
ASIC version	IDeF-X HD (32 channels)
Slow control	Yes
	3.3V

A. Meuris *et al.*, NSSMIC(2011)4485-4488

- Distance between Piggyback and Caliste readout: 0.5 to 1 mm!!!
- Micrometric moving support
- Data taken with ^{55}Fe



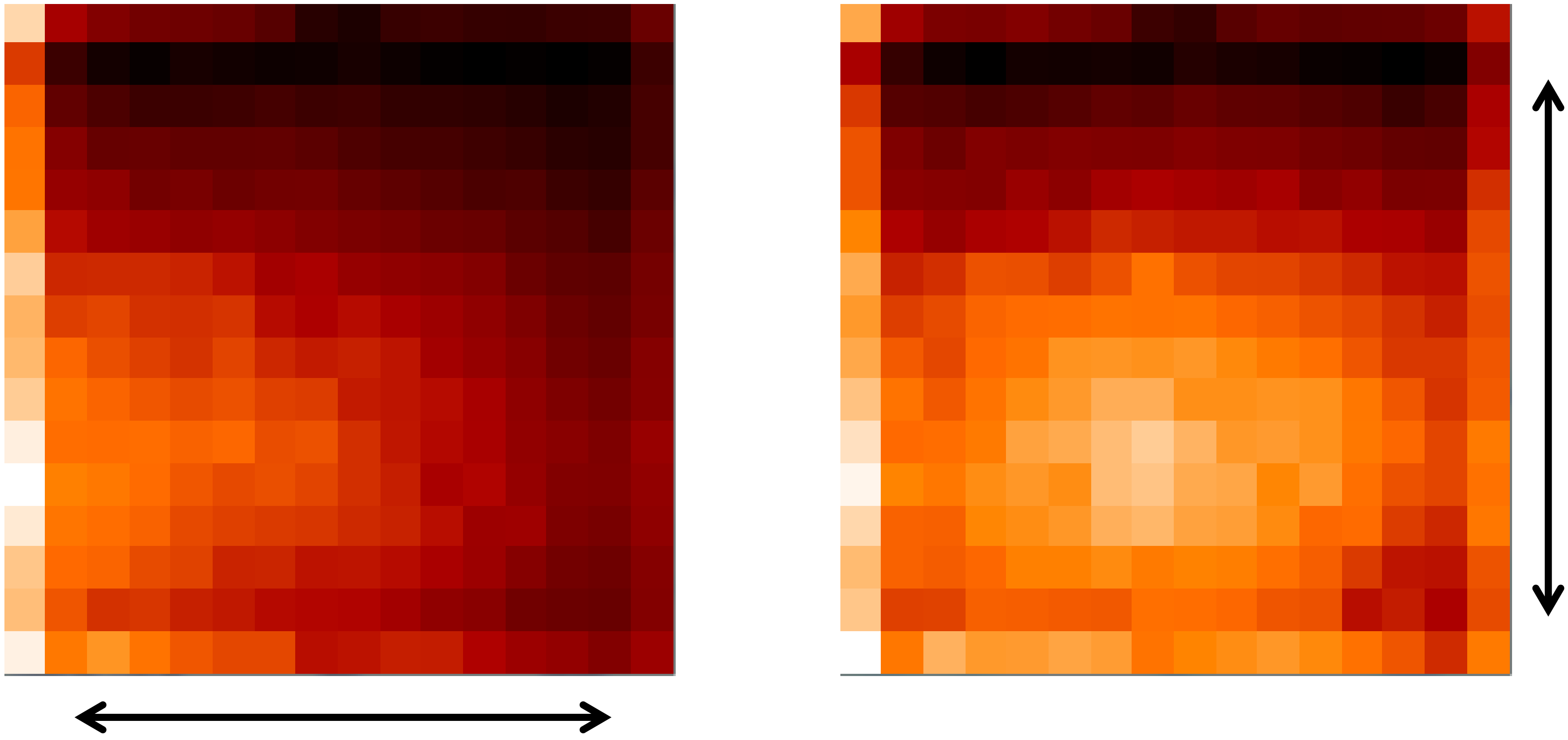




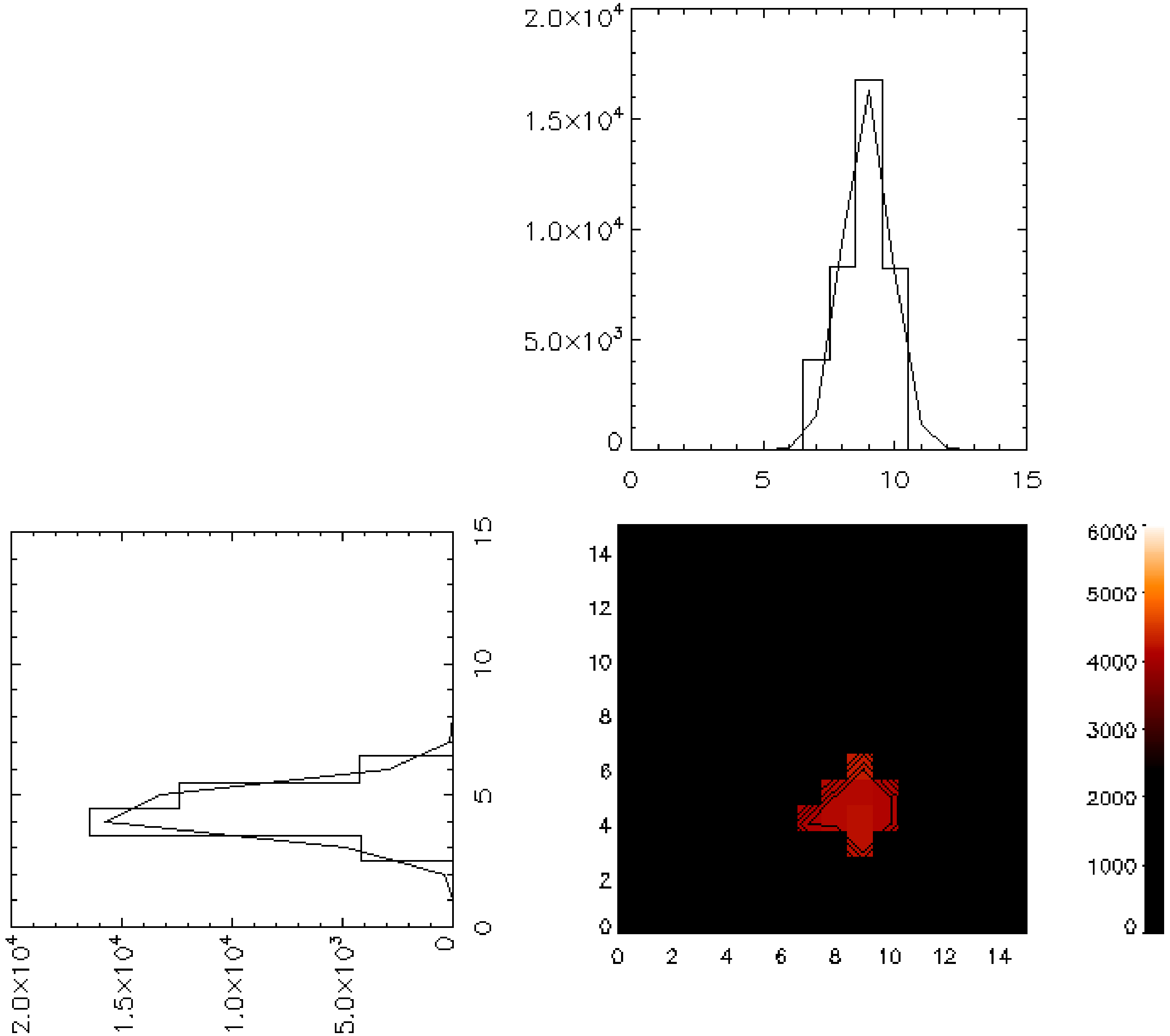
Caliste readout

Piggyback detector

- Integral of many events while moving the source

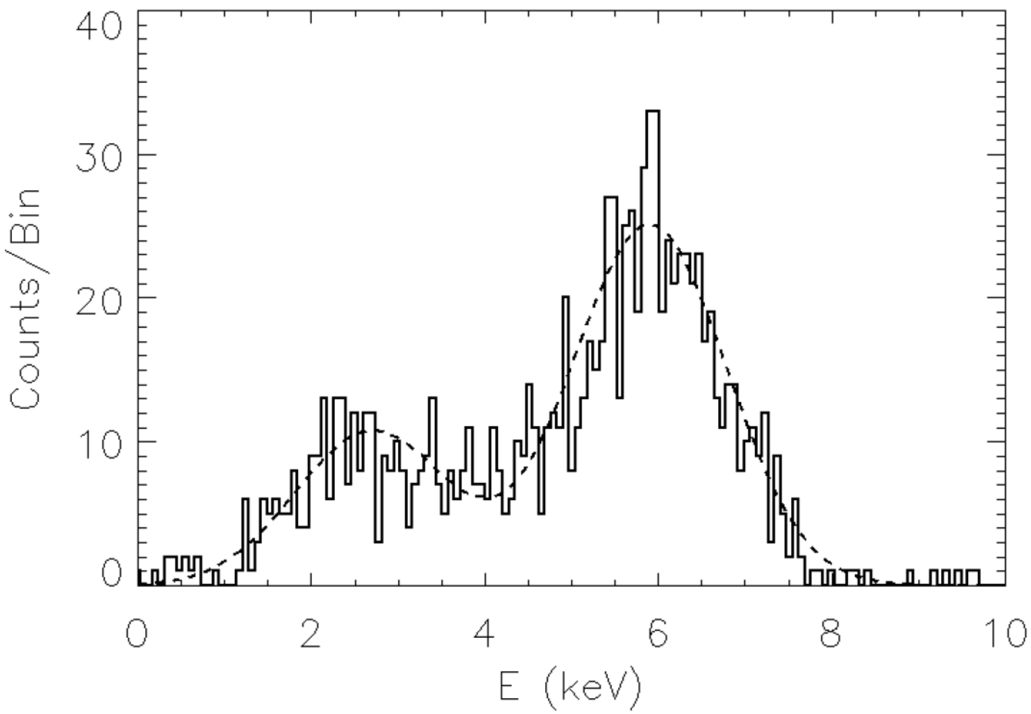


First time that MicroMEGAS are successfully coupled to space electronics!


2.0×10⁴
1.5×10⁴
1.0×10⁴
5.0×10³
0
0
5
10
15
6000
5000
4000
3000
2000
1000
0
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14

- **No calibration** (offset or gain correction per pixel): FWHM=35% @ 5.9 keV
- Selection:
  - event where spots are complete
  - spots diameter > 2.3 pixels rms
- histogram of total charge (29 pixels)
- Fit by two gaussian with identical width at 2.7 (5.9-3.2) keV and 5.9 keV

Very Preliminary!



Conclusions and Outlook

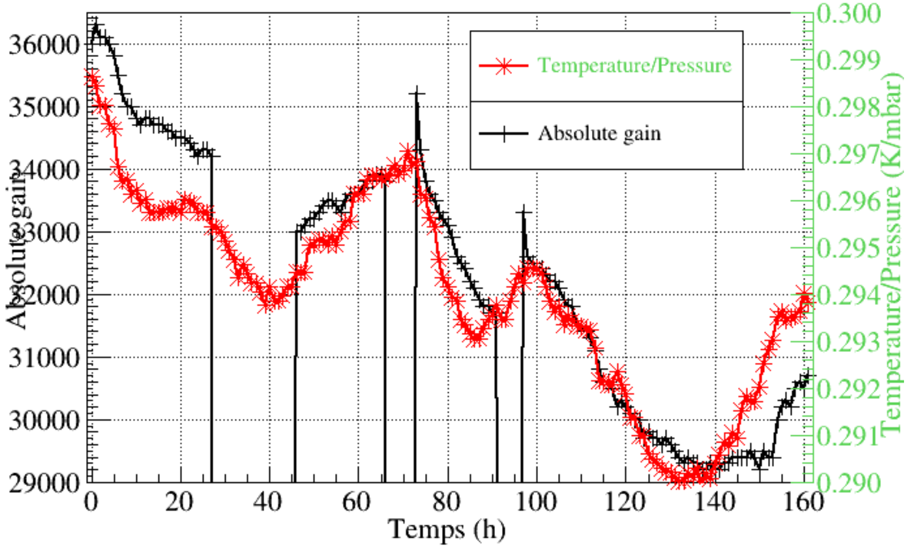
- New resistive Micromegas concept (Piggyback) brings:
  1. - Material compatible with space operation
     - Extensible to larger volume/area gas detectors for polarimetry at higher energy (1 MeV-1 GeV range)
  2. - Electronics coupling using capacitive transmission fully spark-proof
     - Compatible with very low noise (30 e^-) electronics readout (Caliste readout)

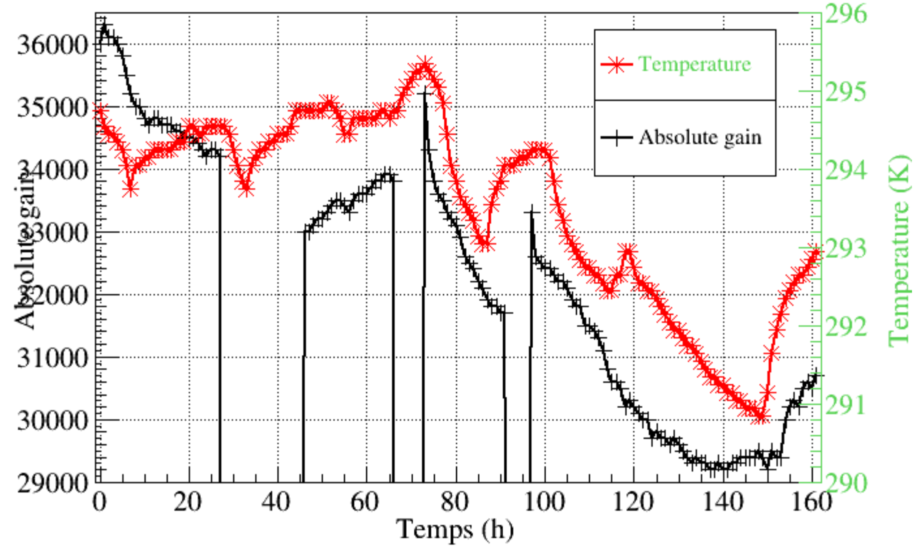
- First try, but further studies will be done

- Toward a new gas-based imaging spectrometer/polarimeter in the soft X-ray domain!

Thank you!

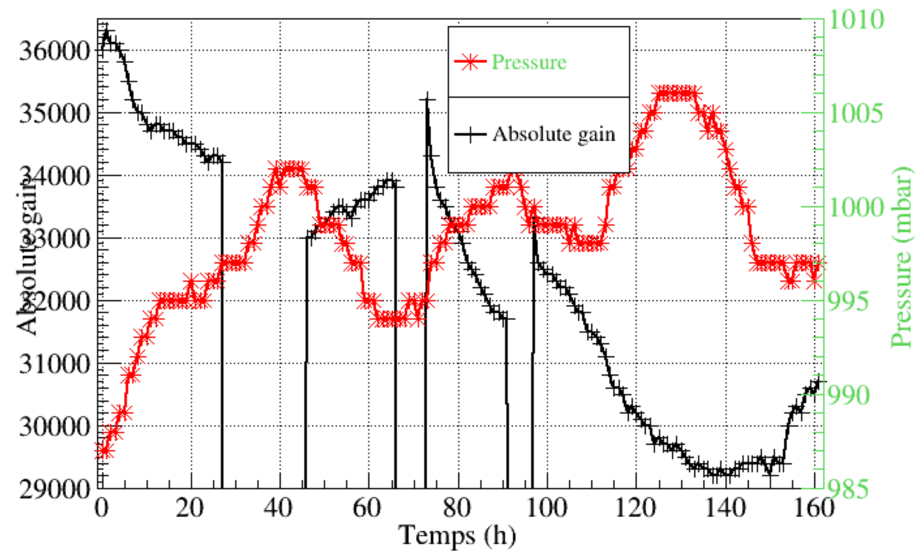
Back-up Slides





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

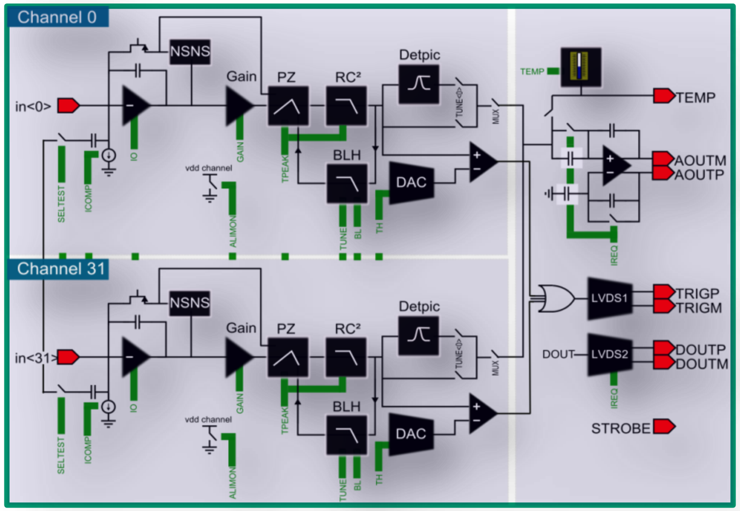
Adloff et al., Environmental study of a Micromegas detector



Evolutions induced by the environment have to be taken into account

And Its Front-End Electronics

Architecture of one IDeF-X HD ASIC:



For each channel: 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

+ FPGA card

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

+ SAB card

- Communication between the electronics and the computer