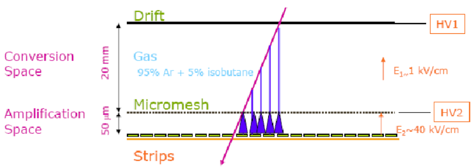
Development and Performance of Microbulk Micromegas Detectors



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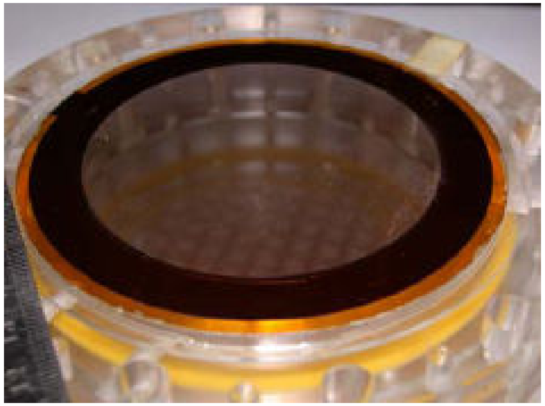
1st International Conference on MicroPattern Gaseous Detectors, MPGD 2009, Kolympari – Crete, Greece

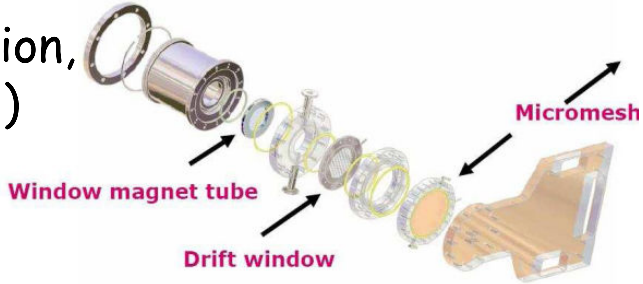
Micromegas development



Conventional Micromegas

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

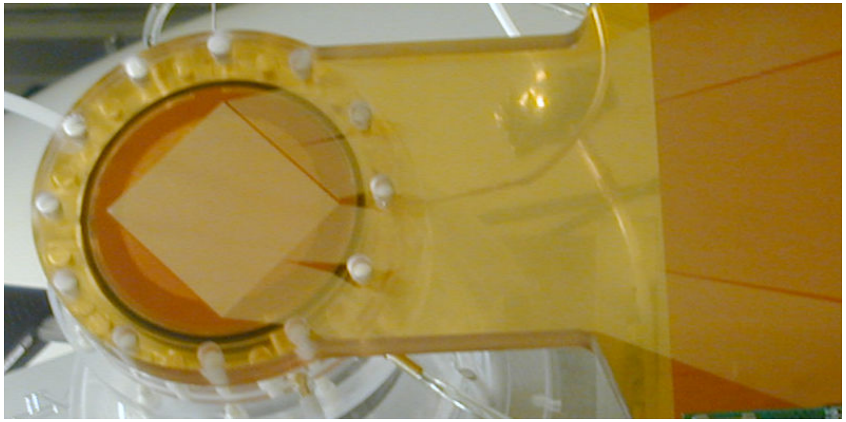
Typical dimensions: mesh thickness 5 μm, gap 50 μm



- ✓ All "Micromegas advantages" (material selection, spatial resolution, field uniformity, stability…)
- ✓ Good energy resolution (mesh quality)
- ✓ Mesh can be replaced easily

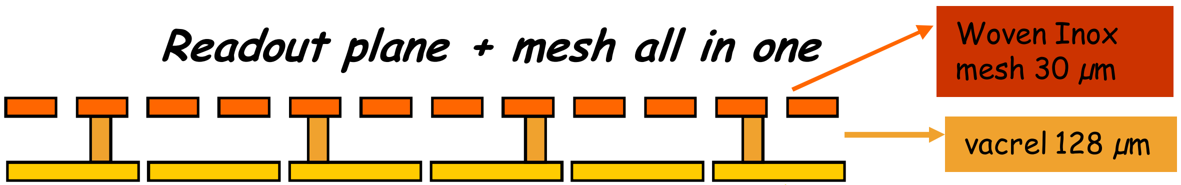
Mesh not attached + support frame:

- × Resolution limitations
- × Dimension limitations / large detectors
- × Large scale production
- × Curved surfaces

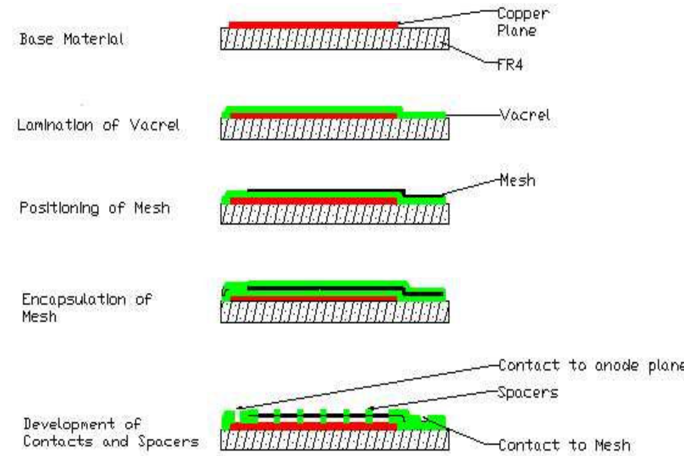


Micromegas development - Bulk technology

Readout plane + mesh all in one



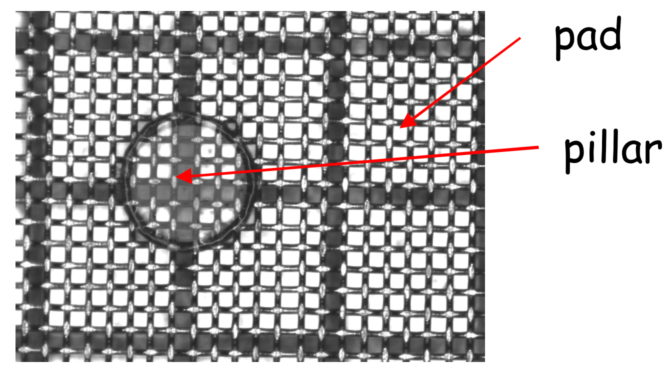
Well established technique



<u>Bulk Micromegas</u>

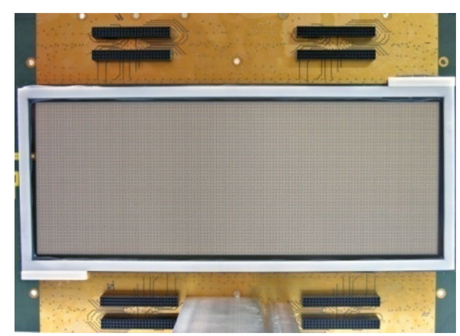
The pillars are attached to a woven mesh and to the readout plane

Typical mesh thickness 30 µm, gap 128 µm



Uniformity, robustness, lower capacity, easy fabrication, no support frame, small surrounding dead region:

- ✓ **Large area detectors**
- ✓ **Curved surfaces**
- ✓ Mass production!

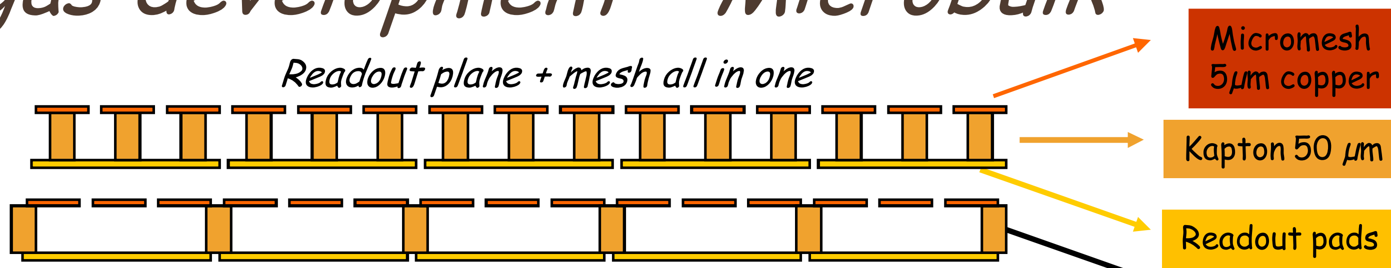


Mesh thickness & bigger gap: some disadvantages in special applications:

- × Good but limited energy resolution (~18% @ 6keV)
- × Restrictions on support material
- × More sensitive to pressure variations

Micromegas development - Microbulk

Readout plane + mesh all in one



Lower capacitance
Under development

An I. Giomataris and R. De Oliveira idea

<u>Microbulk Technology</u>

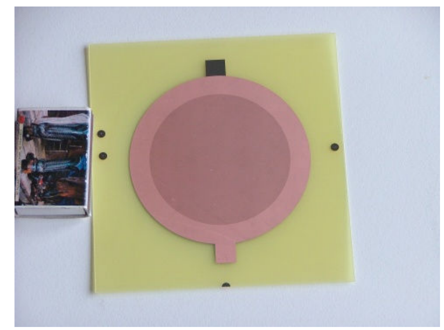
The pillars are constructed by chemical processing of a kapton foil, on which the mesh and to the readout plane are attached. ***Mesh is a mask for the pillars!***

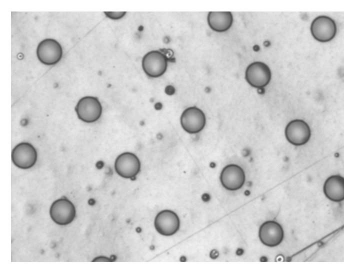
Typical mesh thickness 5 μm, gap 50/25 μm

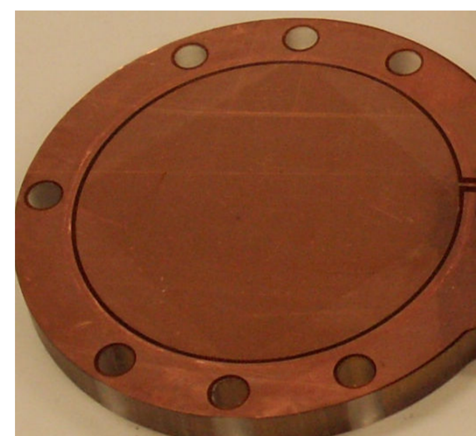
The advantages of a bulk micromegas but with enhanced performance.

In addition: uniformity, clean materials, stability

- ✓ **Energy resolution** (<13% FWHM @ 6 keV)
- ✓ **Low intrinsic background & better particle recognition**
- ✓ **Low mass detector**
- ✓ **Very flexible structure**



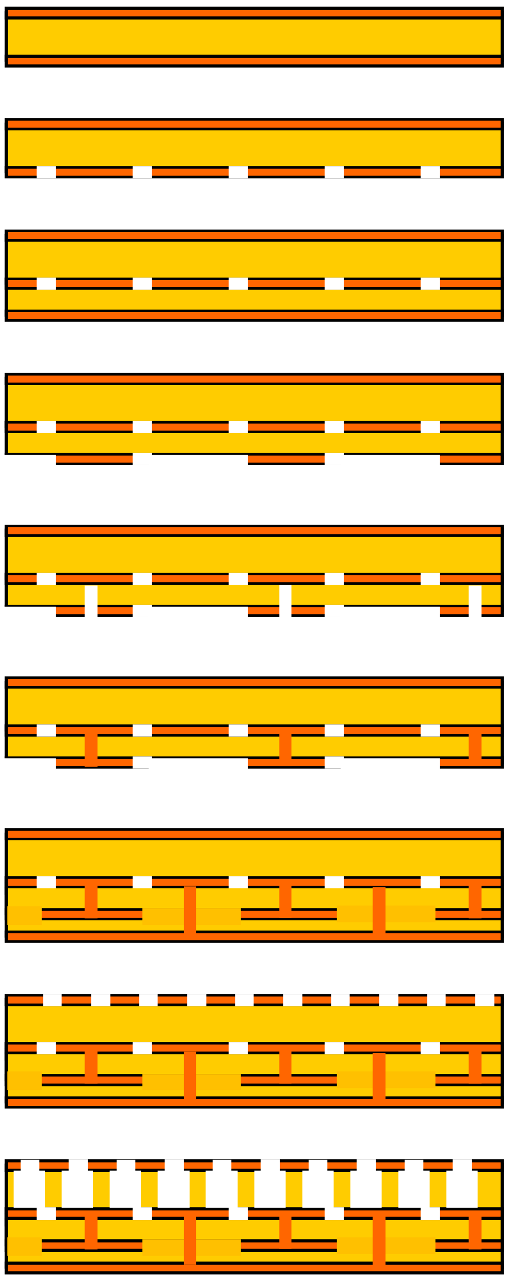




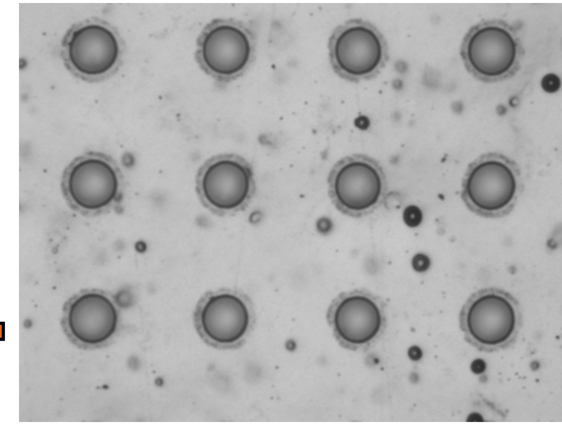
- × Higher capacity
- × Fabrication process still improving
- × Fragility / mesh can not be replaced

Building a Microbulk

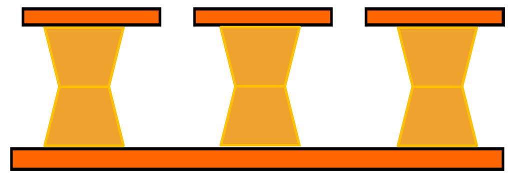
- Kapton foil (50 µm), both side Cu-coated (5 µm)
- Construction of readout strips/pads (photolithography)
- Attachment of a single-side Cu-coated kapton foil (25/5 µm)
- Construction of readout lines
- Etching of kapton
- Vias construction
- 2nd Layer of Cu-coated kapton
- Photochemical production of mesh holes
- Kapton etching
- Cleaning

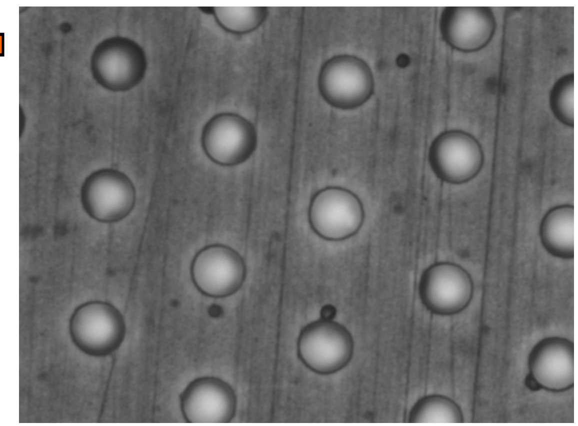


Mesh types

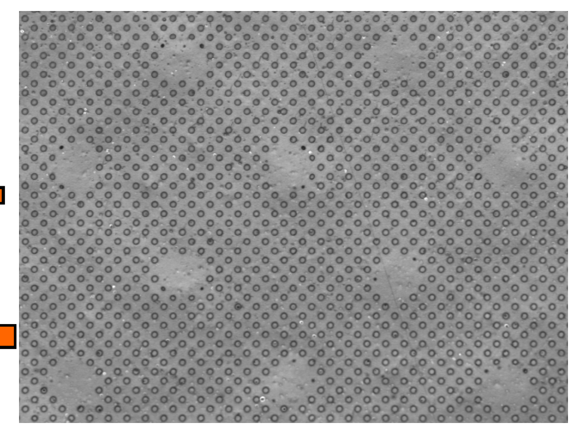


- A “standard for 50 µm gap: 30 µm holes placed in 100 µm pitch

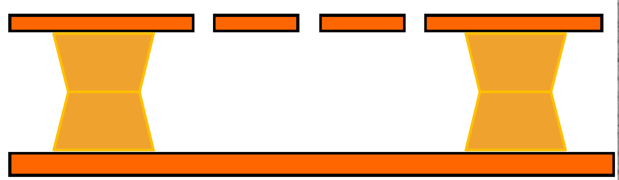




- Alternative: hexagonal arrangement for better optical transparency

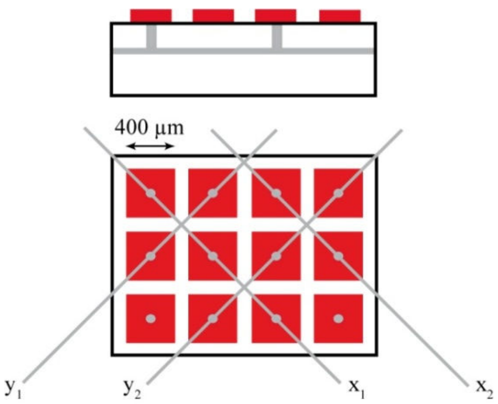


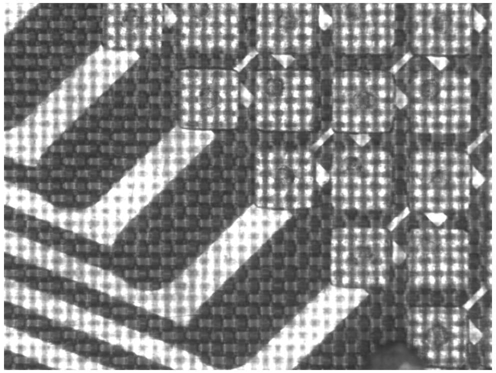
- Pillars: Areas without holes & full etching underneath normal holes
  - ✓ Less material / capacity

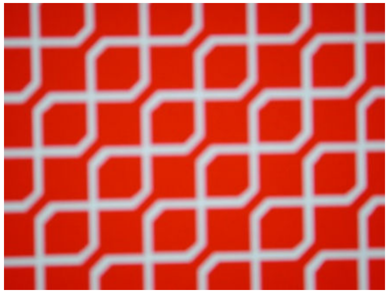


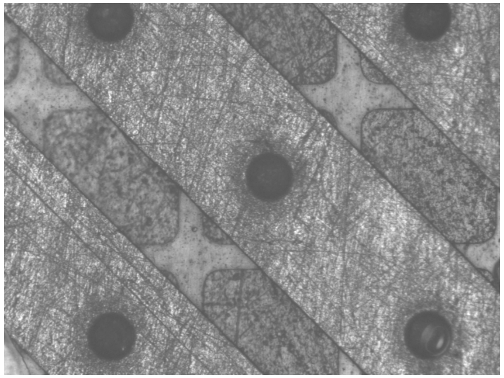
2D Readout schemes

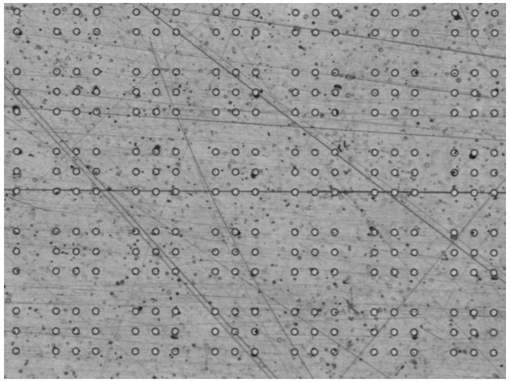
- Square pads connected through 2 extra layers
- Combination of "strips" and pads connected through one extra layer:
  - Detector thickness ~80 μm
  - Simpler process
  - ✓ *Charge distribution in x-y is determined by the hole geometry*
- *Possibility of more etching around holes*











Microbulk performance at

Rare event detection (CAST, NEXT)

- Energy resolution
- Low background
  - Particle recognition
  - Radiopurity
- Time stability

Neutron x-section measurements (n_TOF)

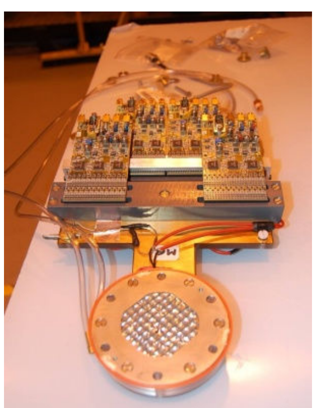
- Low mass
- Radiation resistance
- Detector materials material have low neutron interaction X-sections

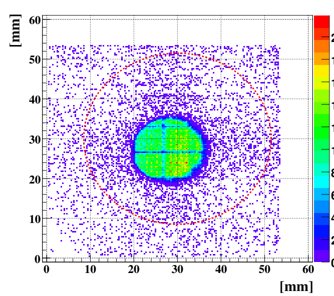
CAST microbulk energy resolution

CAST expected signal:
1-10 keV X-rays

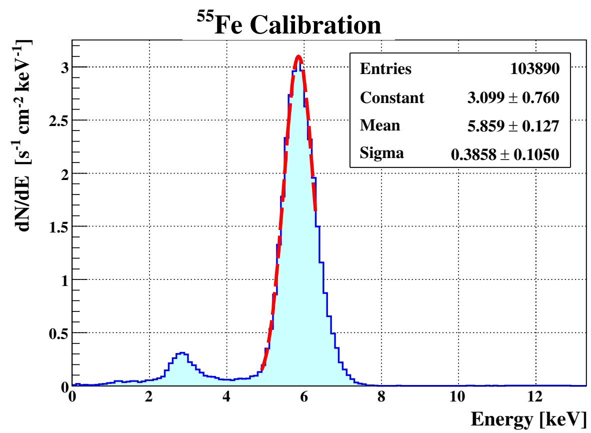
Detector characteristics:

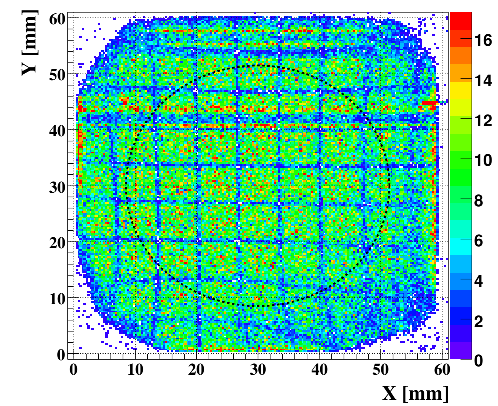
- 6x6 cm^2 active area
- 106x106 strips, 550 μm pitch
- 3 cm drift
- 5 μm mylar window with strongback
- 1.43 bar Ar – 2.3% isobutane (non flammable)



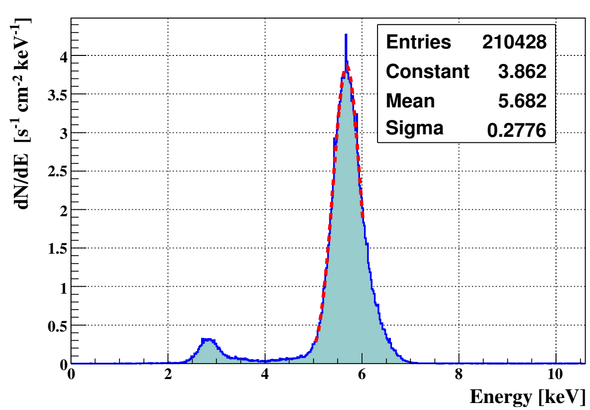


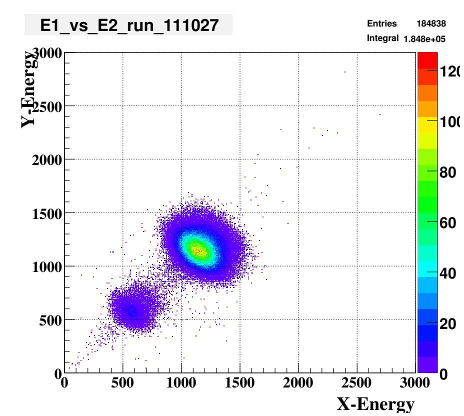
^{55}Fe Calibration with Ar – 2.3% isobutane @ 1.43 bar
Illumination of whole area from ~ 0.7 m distance
FWHM @ 6 keV = 15.5 %





^{55}Fe Calibration with Ar – 5% isobutane @ 1 bar
Collimated source to avoid border effects
FWHM @ 6 keV = 11.5 %



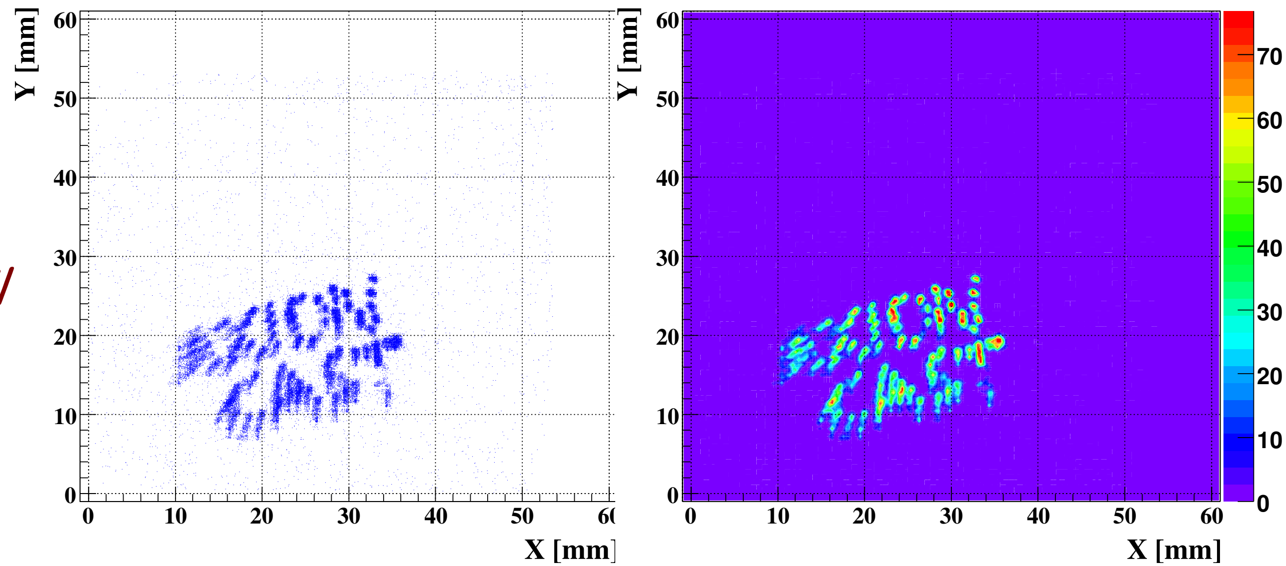


Spatial resolution and stability

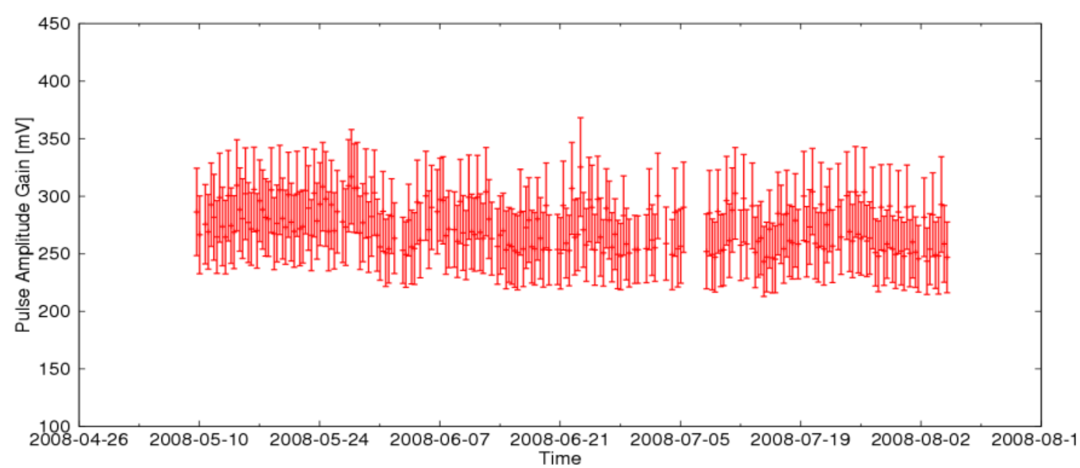
No precise measurement of the spatial resolution of a microbulk…

However an indication:

Illumination of a lead foil with pinholes writing "AXION CAST" laying in front of the entrance window. The holes were made by hand with a common needle..



Gain evolution of a Microbulk installed at CAST during May-August 2009. There was no precise regulation of gas pressure or temperature

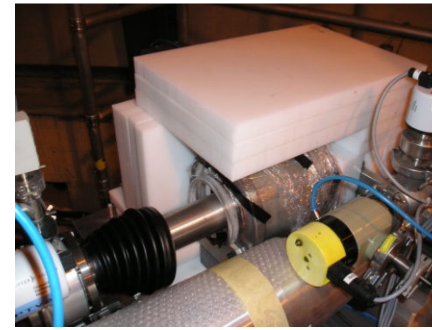


Robustness!

Low background

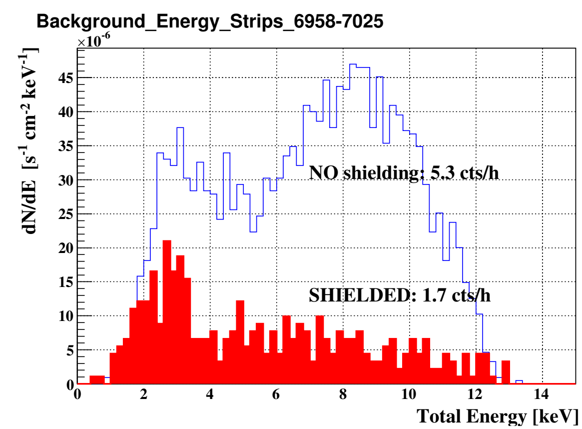
CAST is in phase II since 2005.

- Changing buffer gas density changes axion mass sensitivity
  ➔ new discovery potential for each setting.
- Alignment with the sun for ~1 hour per setting demands *detector background ~0 counts/hour*



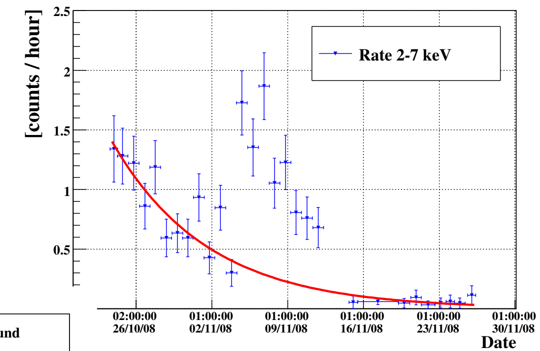
How the low background is achieved:

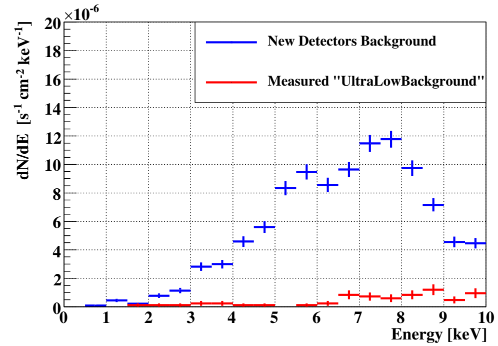
- Offline analysis
  - Particle identification
  - Readout scheme
  - Energy resolution & short signal risetime
- Low radioactivity materials
- Shielding for external radiation (archeological Pb + Cu + Cd + Polyethylene + Nitrogen flushing). *Compact size!*

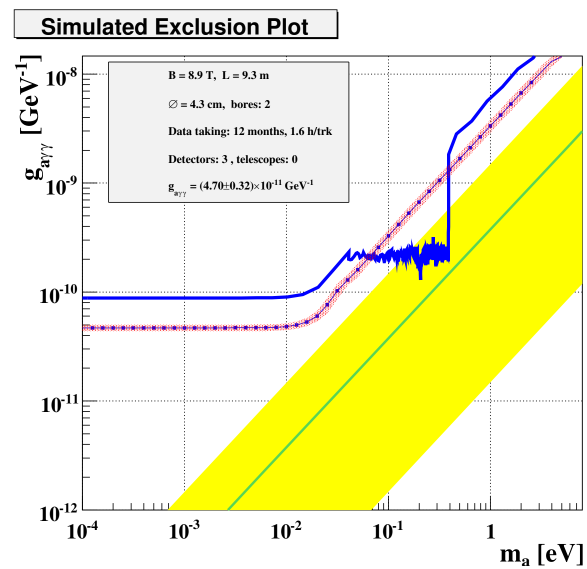


Ultra Low Background with Microbulks

- New microbulk detectors were tested @ CAST since Oct 2008. The background level of the new detector was initially good
  ~1×10^{-5} s^{-1} keV^{-1} cm^{-2}
- The count rate appeared to drop with time, reaching an unexpected low level of **~2×10^{-7} s^{-1} keV^{-1} cm^{-2}** implying **~0.05 counts/hour** for the energy range 1-7 keV
- Same behavior observed for 2 detectors. On going study.
- *New possibilities for CAST!*
- More about Micromegas in CAST at **Javier Galan's talk**







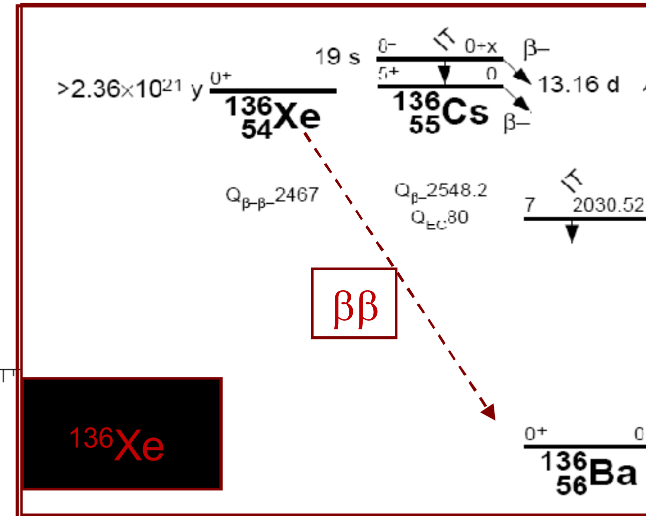
NEXT: a gas Xenon neutrino TPC

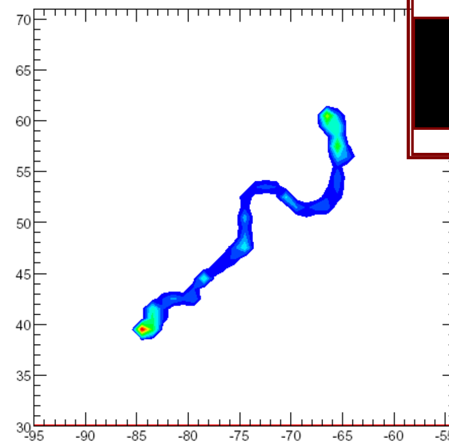
Neutrinoless double beta decay:

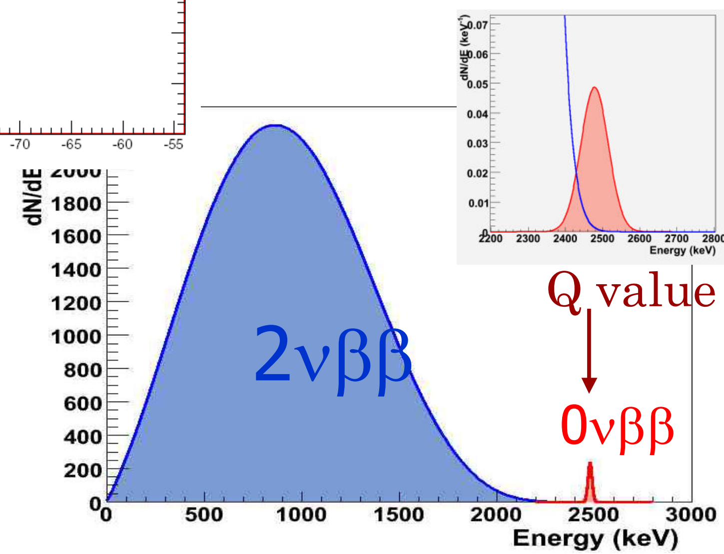
Precious information on neutrino properties (mass scale, Majorana/Dirac nature,…)

Use of a high pressure, gas Xe TPC:

Background reduction from event topology







Observable:

the energy of the two β:

Continuum for the 2ν

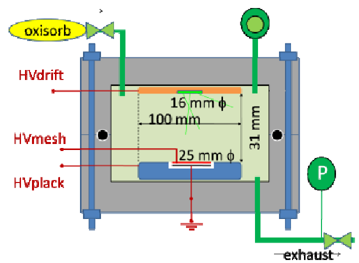
A narrow peak for the 0ν

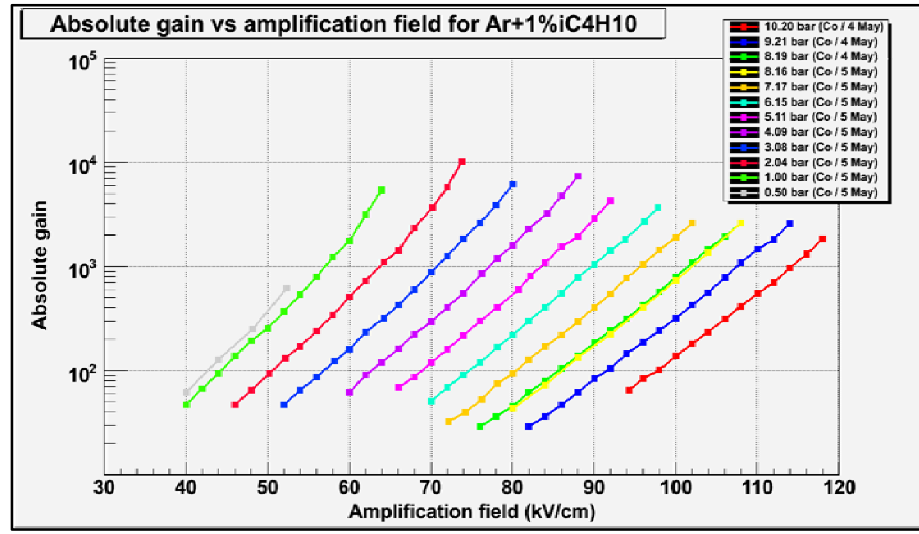
Good energy resolution is essential!!!

NEXT : Microbulk Micromegas studies

Tests at Zaragoza & Saclay with microbulk prototypes:

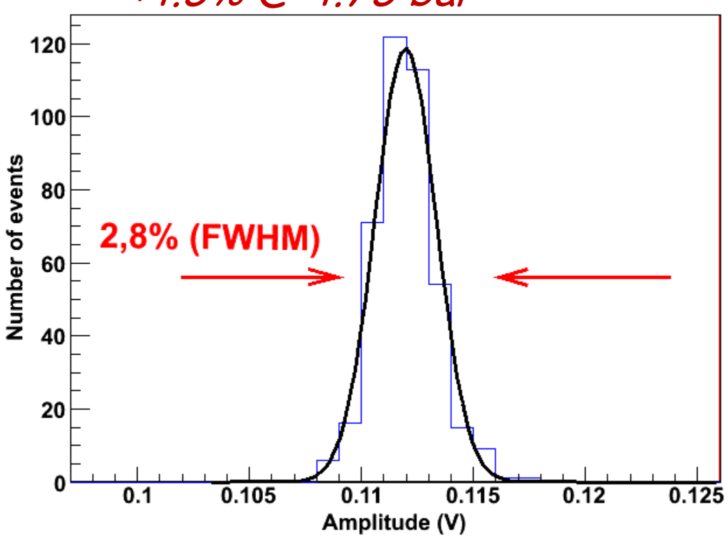
- **Operation at high pressures**
- Very good energy resolution





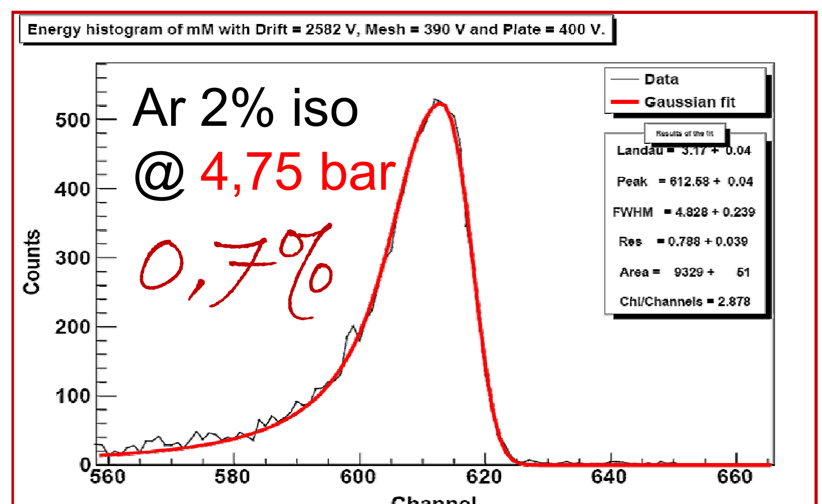
Test with Xe @ 2 bar

✓ *<4.5% @ 4.75 bar*



See poster by A. Tomas!

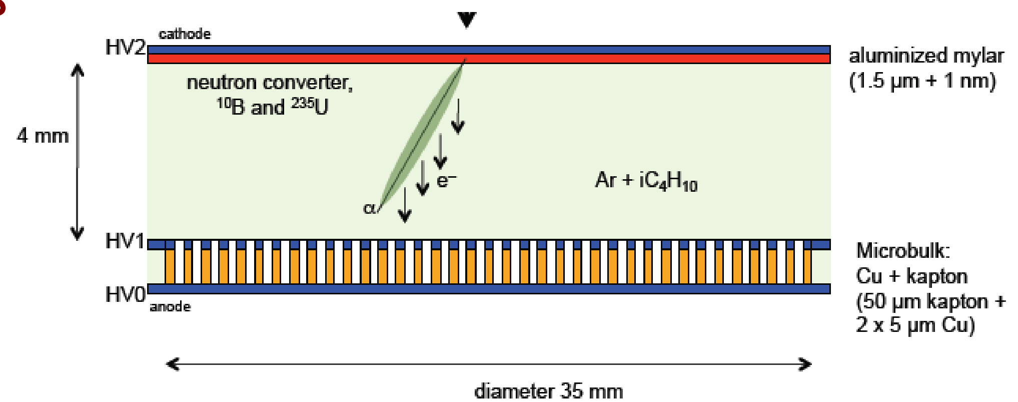
Test with ^{241}Am alpha source:
0.7% FWHM @ 5.4 MeV

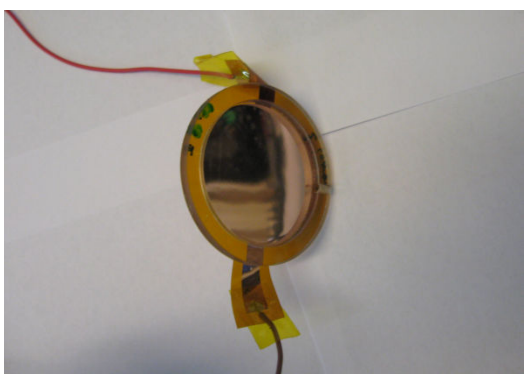


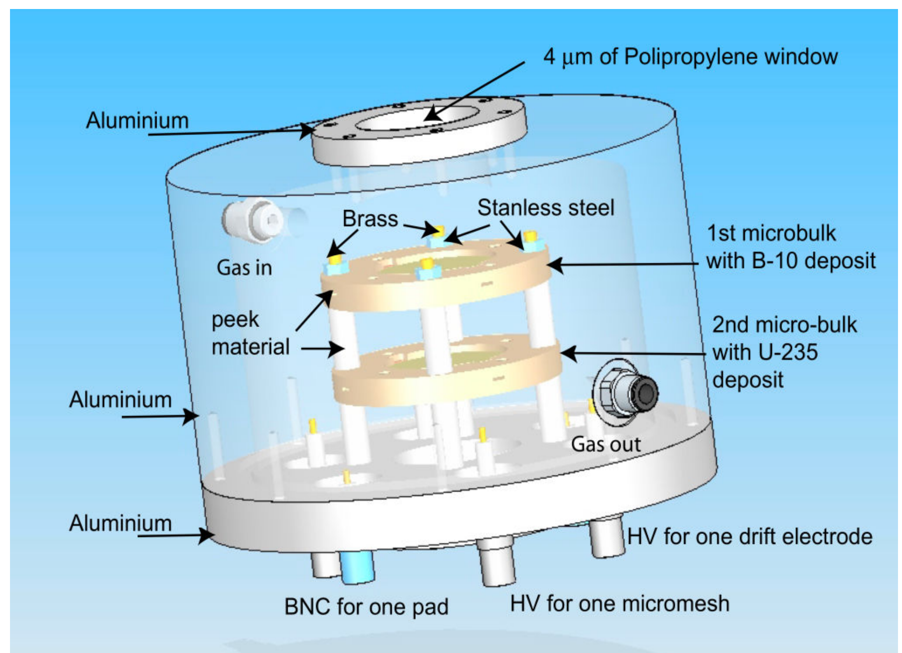
Neutron flux monitors @ n_tof

An online neutron flux monitor is essential for cross-section measurements. Main demands:

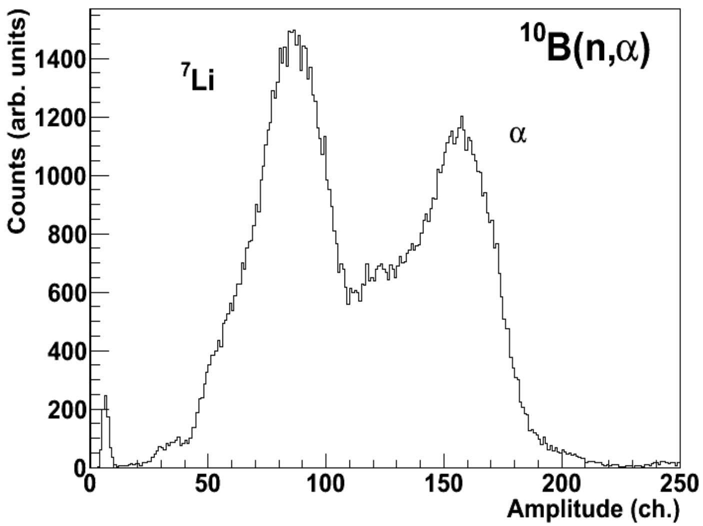
- Minimize beam perturbation and induced background
- Cover a wide energy range
- ☞ Solution: **a thin microbulk** placed *in the beam*, equipped with appropriate converter (^{10}B, ^{235}U) deposited on the drift electrode

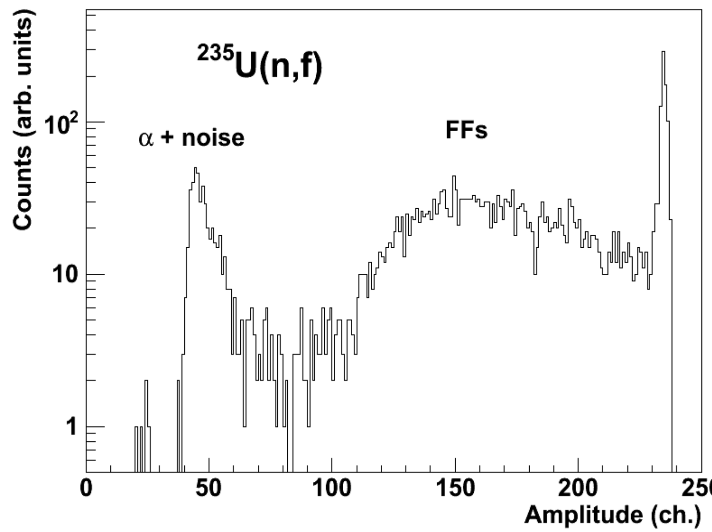






Detector first tests*





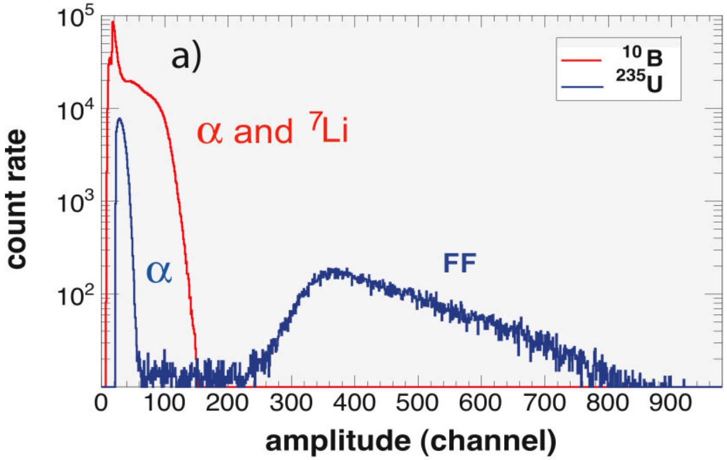
Neutron reaction product spectrum from ^{10}B measured at n_TOF

Use of the premixed gas of Ar + CF_4 + C_4H_{10} allows to distinguish clearly the contribution of the two components (1.47 MeV alpha and 0.83 MeV ^{7}Li) of the reaction products of the neutrons on ^{10}B

Neutron reaction product from ^{235}U measured at n_TOF

(the peak at ch. ~240 is due to the saturation of the flash-ADC).

Same spectra from a test @ GELINA facility



(*) S. Andriamonje & F. Gounsing

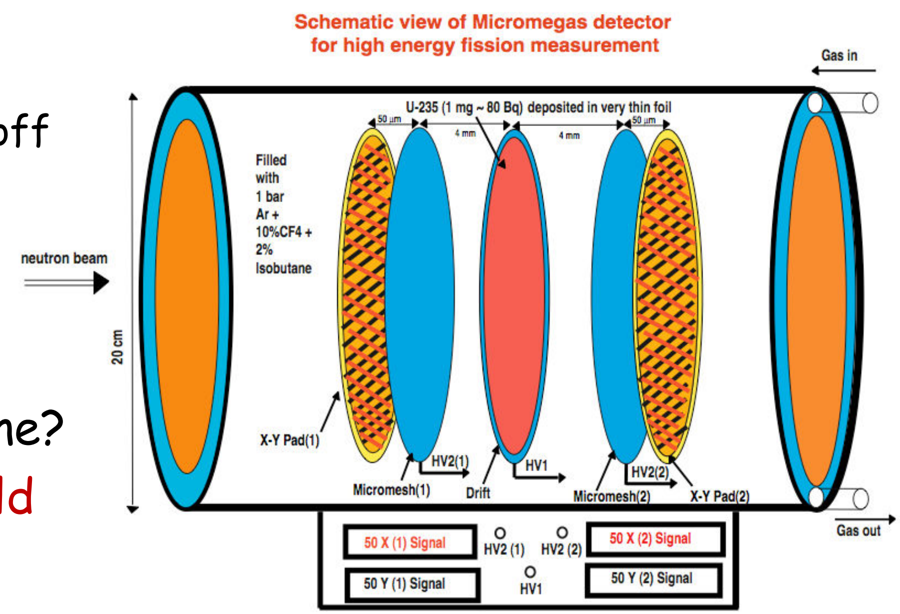
Detector performance & prospects

During the first test the detector proved its potential to be used as neutron monitor

- Higher efficiency & accuracy than any system sample in the beam / detector off the beam
- Low mass in the beam
- Low cost

What other measurements could be done?

- A 2D readout microbulk can be build to be used for online beam profile monitoring
- X-Section & *fission fragment angular distribution*
- Fission TPC



Summary & Prospects

Microbulk technology is a state-of-the-art development on Micromegas detectors offering:

- ✓ Advantages of Bulk Micromegas
  - ➢ Uniformity
  - ➢ Flexible structures
  - ➢ Stability
- ✓ Excellent energy resolution
- ✓ Low background
- ✓ Low mass

These characteristics are important for a wide range of experiments, from rare event detection to nuclear physics

Ongoing research on

- ✓ Resistive layers
- ✓ Capacitance reduction
- ✓ Optical transmission increase
- ✓ Further material decrease

Optimization of the manufacturing technique would allow standardized production.

- ✓ Large area detectors
- ✓ Mesh segmentation
  - ➢ Spark protection
  - ➢ New "**real**" X-Y structure
- ✓ *Mass production (?)*