New developments in Micromegas Microbulk detectors

F.J. Iguaz

on behalf of

IRFU-CEA/Saclay: F. Belloni, E. Ferrer-Ribas, J. Galán, I. Giomataris, F. Gunsing, T. Papaevangelou

CERN: R. De Oliveira

Univ. Zaragoza: T. Dafni, J.A. García, D.C. Herrera, I. Irastorza, A. Rodríguez, A. Tomás

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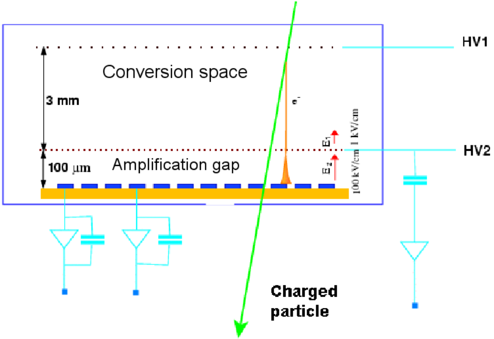
Micromegas and microbulk technology

Micromegas: A Micro-Pattern Gas Chamber detector



I. Giomataris (1992)

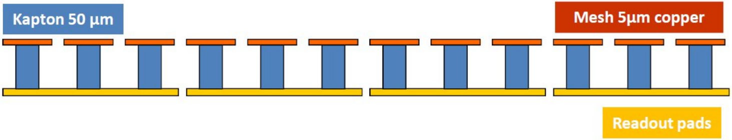
A thin metallic grid and an anode plane, separated by insulated pillars. They define a very little amplification gap (20-300μm).

A support ring or frame adjust the mesh on top of the readout plane, with the help of some screws.

- Good properties: High granularity, good energy and time resolution, stable, easy construction, little mass and radiopure.
- Limitations: Large scale production, dimensions and resolutions.

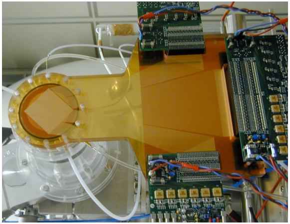
Micromegas and microbulk technology

The microbulk technology

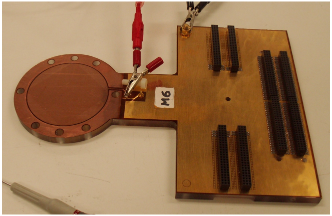


Readout and mesh in one piece: S. Adriamonje *et al.*, *JINST* 5 (2010) P02001

The pillars are constructed by chemical processing on a kapton foil, to which the mesh and the readout plane are attached.



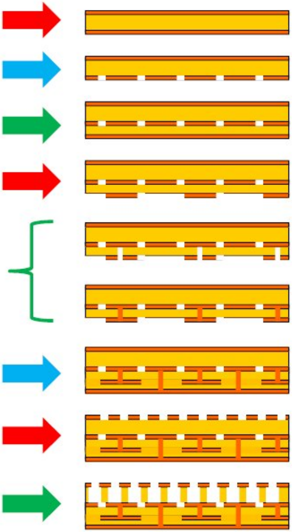
A conventional and a microbulk Micromegas CAST detector



Micromegas and microbulk technology

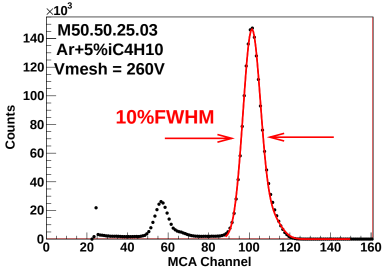
How a microbulk detector is built

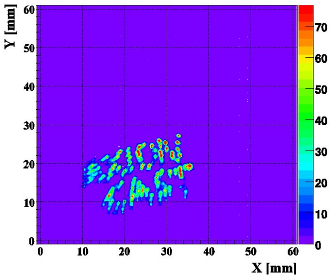
- Kapton foil (50µm), both sides Cu-coated (5µm)
- Construction of readout (strips/pads)
- Added a single-side Cu-coated kapton foil (25/5)
- Construction of one direction readout lines
- Vias construction by etching the kapton
- Construction of the second direct readout lines and vias
- Photochemical production of mesh holes
- Kapton etching and cleaning



Micromegas and microbulk technology

General features of microbulk readouts





Good features

- Excellent energy resolution.
- Low intrinsic background.
- Better particle recognition.
- Low mass and flexible structure.
- Stable gain during long periods.

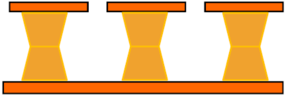
Being improved

- Higher electrical capacity.
- Large area detectors.
- Mass production.

Micromegas and microbulk technology

Classic and pillars types

Standard micromegas



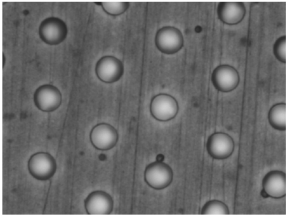
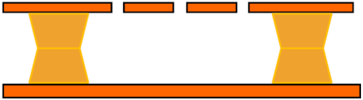
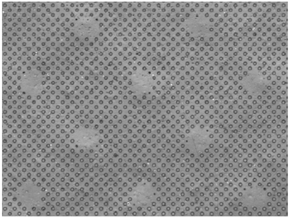


Photo: Gap 50μm / holes 40μm pitch 100μm.

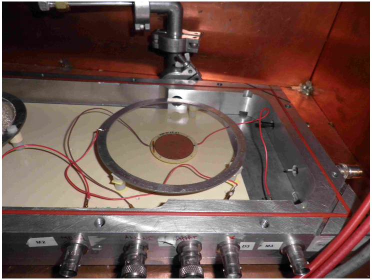
Micromegas with pillars





Areas without holes & full etching underneath normal holes. Lower capacity!!!!

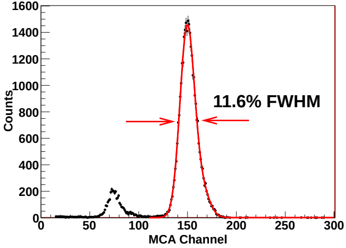
Characterization in Argon-Isobutane mixtures
Setup description

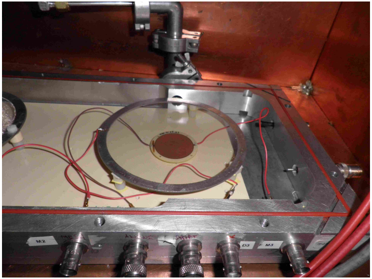


- Setup designed to characterized a maximum of three Micromegas readouts in the same gas conditions.
- A mesh frame is used as drift cathode: drift distance = 10 mm.
- The top cap contains several holes, covered by an aluminized mylar film, used to calibrate the readouts.

Characterization in Argon-Isobutane mixtures

Procedure description

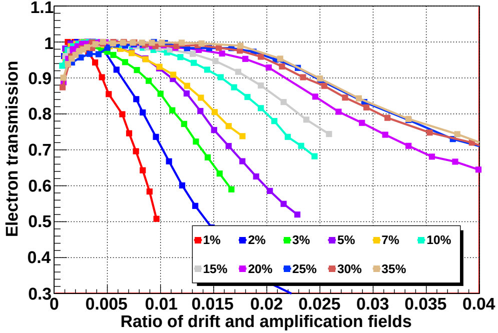




- Two microbulk readouts with a gap of 50μm and built with the two different construction techniques have been tested.
- Calibrated with an iron source (^{55}Fe, x-rays of 5.9 keV) in mixtures of argon and isobutane (1-35%).
- Electronic chain: ORTEC 142C preamplifier + ORTEC 472A amplifier + AMPTEK MCA-8000A.

Characterization in Argon-Isobutane mixtures

Mesh electron transmission



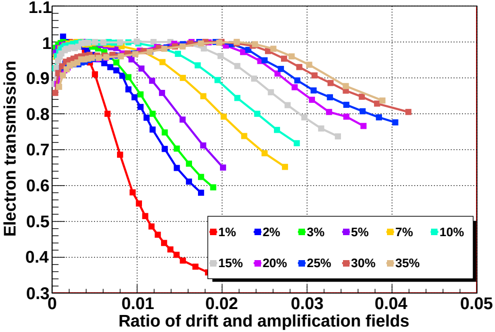
Procedure

The drift voltage is varied for a fixed mesh voltage and the peak position is normalized by the maximum value.

- For E_{drift}/E_{mesh} lower than a specific value, there is a maximum in the electron transmission (A=0.01 for a 5%). For higher drift fields, the mesh stops being transparent for primary electrons.
- The plateau widens with the porcentage of isobutante and seems to be correlated with the diffusion coefficients.

Characterization in Argon-Isobutane mixtures

Mesh electron transmission for the pillars technology



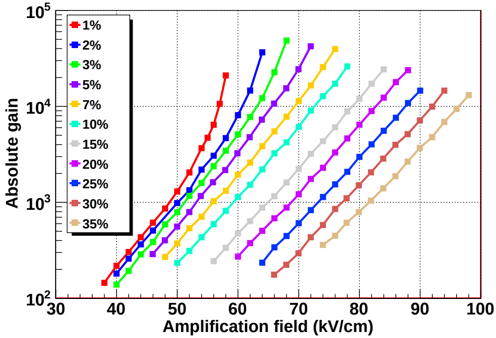
Procedure

The drift voltage is varied for a fixed mesh voltage and the peak position is normalized by the maximum value.

- For $iC_4H_{10} \leq 20\%$, there is a plateau of maximum electron transmission which matches with the classic readout.
- For $iC_4H_{10} \geq 20\%$, there is instead a steady increase of about 5%.

Characterization in Argon-Isobutane mixtures

Absolute gain



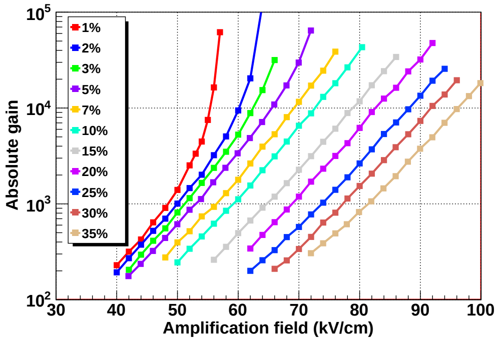
Procedure

The ratio E_{drift}/E_{mesh} is fixed so as the mesh showed the maximum electron transmission. The mesh voltage is varied and the peak position registered.

- An absolute gain greater than 10^4 is reached before the spark limit.
- At low quantities of isobutane, there is an over-exponential behaviour due to UV photons (P. Fonte *et al.*, *NIMA* **305** (1991) 91 and I. Krajcar Bronic *et al.*, *NIMB* **142** (1992) 219).

Characterization in Argon-Isobutane mixtures

Absolute gain in the pillars technology



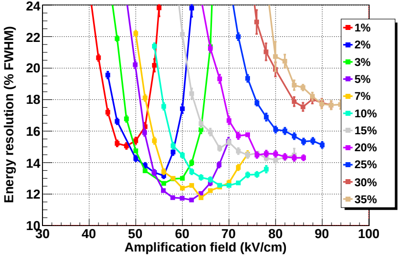
Procedure

The ratio E_{drift}/E_{mesh} is fixed so as the mesh showed the maximum electron transmission. The mesh voltage is varied and the peak position registered.

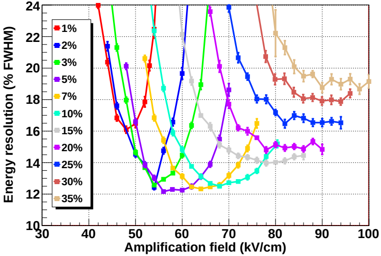
- The gain curves are the same than those of the classic type.
- At low isobutane concentration, the gain curve deviates more from the exponential tendency.

Characterization in Argon-Isobutane mixtures

Energy resolution versus the amplification field



Classic readout

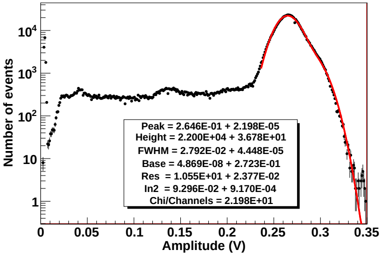


Pillars readout

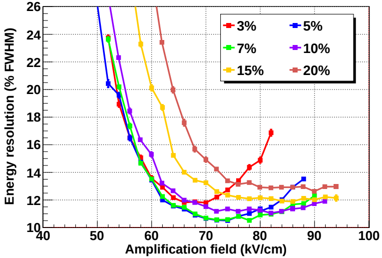
- It is constant for a range of amplification fields.
- For low fields, bad resolution due to the worse signal-noise ratio.
- For high fields, the resolution worsens due to the gain fluctuations. This effects doesn't appear for high quantities of isobutane.

Characterization in Neon-Isobutane mixtures

Energy resolution and threshold



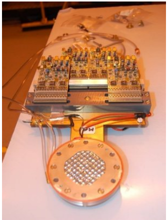
Iron source spectrum

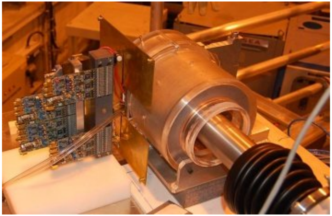


Energy resolution vs Eamp

- Motivation: Application of micromegas in the sub-keV energy range.
- Observed the neon escape peak (870 eV). Threshold at 400 eV!!
- The energy resolution is better than in argon-isobutane mixtures: 10.5% FWHM vs 11.6% FWHM. Should be worse due to primary ionization!!
- $W_{Ar} = 26.3$ eV, $W_{Ne} = 36.4$ eV // $F_{Ar} = 0.22$, $F_{Ne} = 0.17$.

Applications of the microbulk technology
CAST: A solar axion experiment

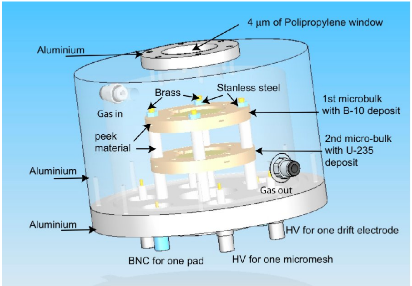


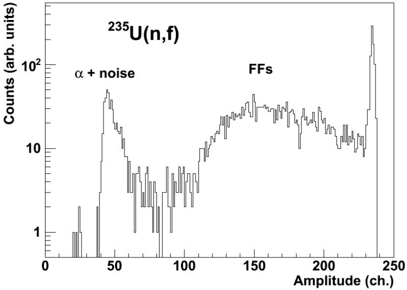


- CAST experiment uses a LHC dipole magnet to detect solar axions.
- Energy range of interest: 1-8 keV.
- 3 Micromegas detectors installed. Readout: 106×106 strips, 550μm pitch. Gas: Ar + 2.3% Isobutane at 1.44 bar.
- References: *J. Phys. Conf. Ser.* **179** (2009) 012015 and the talks: "CAST micromegas background in the LSC", 10th June, A.Tomás and "Background rejection of Micromegas readouts", 13th June.

Applications of the microbulk technology

nTOF: A neutron flux monitor and 2D profiler

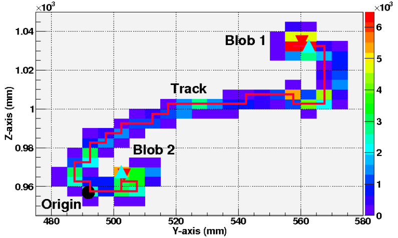


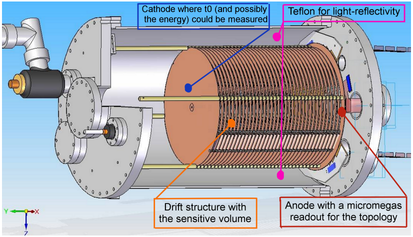


- A thin microbulk detector has been placed in the beam, equiped with a converter (^{10}B or ^{235}U) deposited on the drift electrode.
- Low material budget $\Rightarrow$ Minimum beam perturbation and induced background.
- Wide energy range, high efficiency and accuracy.
- Future: 2D readout microbulk for an online beam profile monitor.

Applications of the microbulk technology

A ^{136}Xe TPC equiped with a Micromegas readout



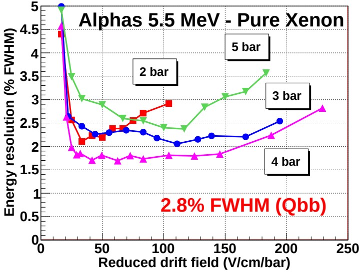


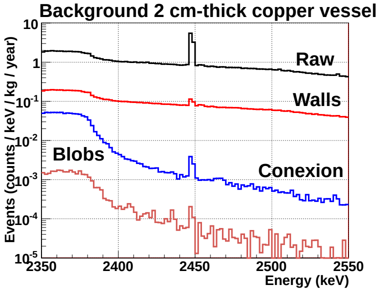
Feasibility studies in NEXT project

- Energy resolution: S. Cebrian *et al.*, *JCAP* (2010) 1010:010.
- Gain: C. Balan *et al.*, *JINST* (2011) **6** P02006.
- Radiopurity: S. Cebrian *et al. Astropart. Phys.* (2011) **34** 354.
- Prototypes: T Dafni, talk at 5th Large TPC Conference, Paris, 2010.
- Background: F.J. Iguaz, http://zaguan.unizar.es/record/5731.

Applications of the microbulk technology

A ^{136}Xe TPC equiped with a Micromegas readout





Feasibility studies in NEXT project

- Energy resolution lower than 3% FWHM at 2458 keV ($Q_{\beta\beta}$ at 10 bar in pure xenon.
- Gains greater than 10^2 in pure xenon.
- Low background level due to the readout.
- High background rejection power.

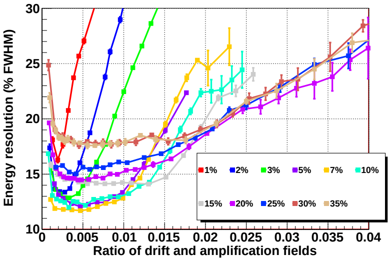
Conclusions

- Microbulk is a Micromegas technology which offers uniform and flexible structures with an excellent energy and time resolution, low background levels and low mass.
- Microbulk readouts have been characterized in argon-isobutane mixtures. The two fabrication techniques (classic and pillars) show similar performances.
- Readouts are being tested in neon-isobutane mixtures for sub-keV energy applications. Good energy resolution (10.5% FWHM at 5.9 keV), gains up to 10^5 and threshold at 400 eV.
- Other gases like Helium and quenchers like cyclohexane will be tested.
- Microbulk technology has been applied in nuclear (nTOF) and astroparticles experiments (CAST, NEXT).

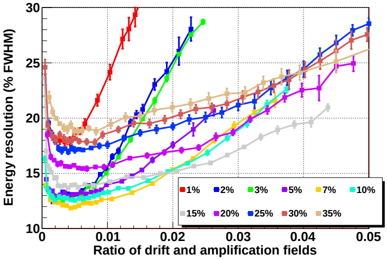
Back-up slides.

Characterization in Argon-Isobutane mixtures

Energy resolution and the electron transmission



Classic readout

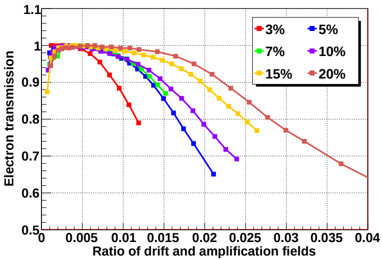


Pillars readout

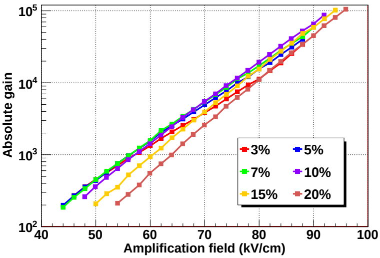
- The energy resolution is correlated with the electron transmission. Best values at the maximum of the mesh transparency.
- At high isobutane quantities, there is a continuous degradation.
- Best values respectively obtained at 5% and 7% iC_4H_{10}.

Characterization in Neon-Isobutane mixtures

Electron transmission and absolute gain



Electron transmission



Gain vs Eamp

- The classic readout was characterized in neon-isobutane mixtures.
- Similar electron transmission curves are observed.
- Gains as high as 10^5 are reached.
- For $iC_4H_{10} \leq 15\%$, the gain curve remains almost constant.

Micromegas and the Rose-Korff model

Description of the Rose-Korff model

- The gain of a Micromegas detector is described by this simple model of the avalanche multiplication:

$$ln(G) = \frac{d}{\lambda_e} \exp\left(\frac{I_e}{\lambda_e \, E_{amp}}\right)$$

  where d is the gap distance, λ_e is the electron mean free path, I_e is the ionization energy threshold and E_{amp} is the amplification field.

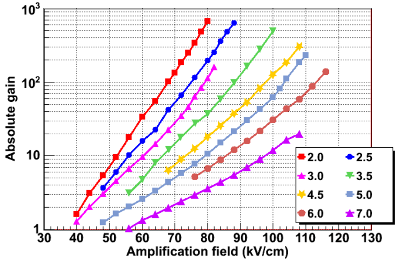
- A microbulk (50μm gap) readout has been tested in pure argon and low isobutane concentrations at high pressure gases with an ^{241}Am source (α 5.5 MeV).
- The gain curves have been fitted to the Rose-Korff model. A dependence of I_e and λ_e with pressure has been observed.

Setup description and results in:

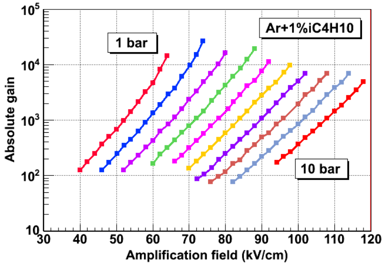
- T. Dafni *et al.*, *Nucl. Inst. Meth. A* **608** (2009) 259-266.
- F.J. Iguaz, PhD thesis, http://zaguan.unizar.es/record/5731.
- S. Cebrian *et al.*, *JCAP* (2010) 1010:010.

Micromegas and the Rose-Korff model

Gain measurements in argon-isobutane mixtures



Pure Argon

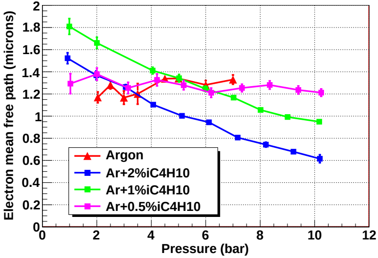


Ar+1%iC_4H_{10}

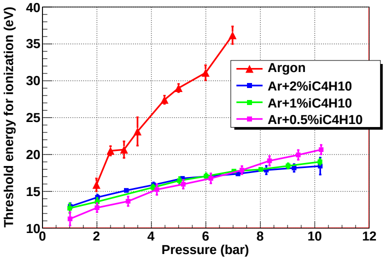
- In pure argon, the maximum gain before the spark limits decrease with pressure (1.5×10^2 at 6 bar). For pressures below 3 bar, the maximum gain is not reached ($> 7 \times 10^2$).
- In argon-isobutane mixtures, a gain $\geq 10^4$ is reached. It also decreased with pressure but in less proportion.

Micromegas and the Rose-Korff model

Results and discussion



Electron mean free path



Ionization energy threshold

- I_e vs pressure: $14.5 \pm 3.6(P-1)$ (Argon: 15.8 ev).
- Similar dependence for Ar-Iso mixtures but with lower slope.
- λ_e is constant in argon (1.3μm), similar to Ar+0.5%iC_4H_{10}.
- At higher quantities of isobutane, λ_e decrease with pressure.