New developments in Micromegas Microbulk detectors

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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

A conventional and a microbulk Micromegas CAST detector

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

Readout and mesh in one piece: S. Adriamonje et al., JINST 5 (2010) P02001
Micromegas and microbulk technology
How a microbulk detector is built

1. Kapton foil (50µm), both sides Cu-coated (5µm)
2. Construction of readout (strips/pads)
3. Added a single-side Cu-coated kapton foil (25/5)
4. Construction of one direction readout lines
   - Vias construction by etching the kapton
5. Construction of the second direct readout lines and vias
6. Photochemical production of mesh holes
7. 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

Micromegas with pillars

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

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 percentage of isobutane 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 $E_{\text{drift}}/E_{\text{mesh}}$ 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

- 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.
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 // $F_{Ar} = 0.22$, $F_{Ne} = 0.17$. 

Iron source spectrum

Energy resolution vs Eamp

- Energy resolution and threshold

Characterization in Neon-Isobutane mixtures

Energy resolution and threshold
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: $106 \times 106$ strips, $550\mu m$ pitch. Gas: Ar + 2.3% Isobutane at 1.44 bar.
A thin microbulk detector has been placed in the beam, equipped with a converter ($^{10}\text{B}$ or $^{235}\text{U}$) 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 equipped with a Micromegas readout

Feasibility studies in NEXT project

Applications of the microbulk technology

A $^{136}$Xe TPC equipped 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

- 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$_4$H$_{10}$.
Characterization in Neon-Isobutane mixtures

Electron transmission and absolute gain

- 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, \(\lambda_e\) is the electron mean free path, \(I_e\) is the ionization energy threshold and \(E_{amp}\) is the amplification field.

- A microbulk (50\(\mu\)m gap) readout has been tested in pure argon and low isobutane concentrations at high pressure gases with an \(^{241}\)Am source (\(\alpha\) 5.5 MeV).

- The gain curves have been fitted to the Rose-Korff model. A dependence of \(I_e\) and \(\lambda_e\) with pressure has been observed.

Setup description and results in:

In pure argon, the maximum gain before the spark limits decrease with pressure (\(1.5 \times 10^2\) 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

$\lambda_e$ vs pressure: $14.5 \pm 3.6(P - 1)$ (Argon: 15.8 ev).

Similar dependence for Ar-Iso mixtures but with lower slope.

$\lambda_e$ is constant in argon (1.3\(\mu\)m), similar to Ar+0.5\%iC_4H_10.

At higher quantities of isobutane, $\lambda_e$ decrease with pressure.