GEM-MIGAS optimization for high pressure operation in He/CF_4 mixtures

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Summary

- Overview He/CF_4 properties
- Gas Electron Multiplier with a Micromegas Gap Amplifying Structure
    a) The structure
    b) The properties
- Optimization for high pressure operation in CF_4 and He/CF_4
    a) Optimize Induction region length
    b) Influence of the GEM parameters
    c) Helium Measurements
- Conclusions

Overview

Motivation: Evaluate GEM technology for thermal neutron detection.

^{3}He is a suitable gas for thermal neutrons detection:

- high efficiency
- low gamma sensitivity

$$^{3}He + ^{1}n \rightarrow ^{3}T + ^{1}p + 0.764 MeV \begin{cases} \text{tritium (191 keV)} \\ \text{proton (573 keV)} \end{cases}$$

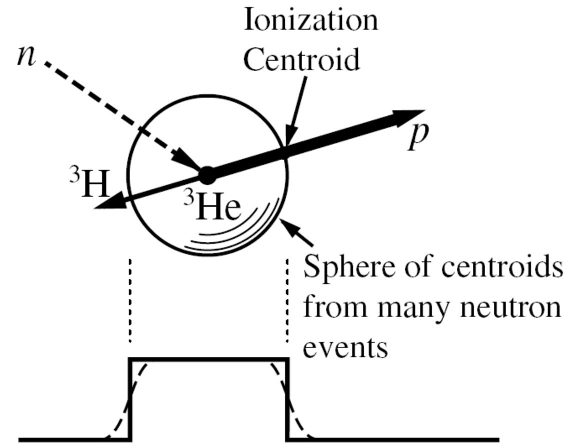

Fig.1- Distribution of centroids projected in one dimension.

T and *p* deposit their energy asymmetrically.

↓

Limit the position resolution (~ 80% from proton range)

Solution:

Add a gas with high collision cross section for fasted charge particles FWHM, such as CF_4.

Overview

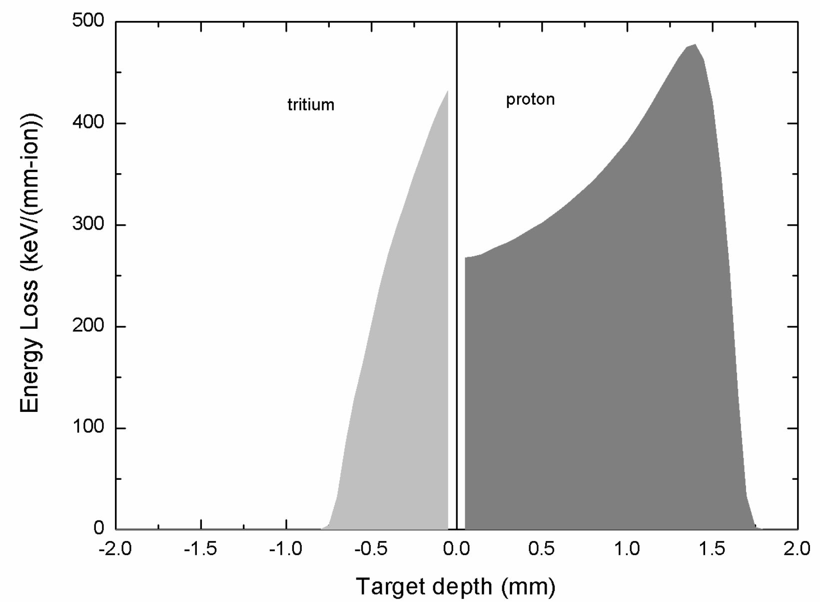

Fig. 2- Energy loss by Proton and Tritium at 2.6 bar of CF_4.

Spallation sources requires a mm position resolution !

SRIM calculations:

- a proton range around 1 mm for 2.6 bar CF_4

The CF_4 pressurization:

- Limits charge gain in GEM based detectors
- Gain performance tend to unity above 2 bars

What is its purpose?

Systematic studies to evaluate the gain performance vs pressure for different GEM-MIGAS configurations in a He/CF_4 gas mixture .

The GEM- MIGAS - structure

Gas Electron Multiplier with a Micromegas Gap Amplifying Structure

- This alternative configuration was introduced by J. A. Mir, RAL
- GEM directly coupled to a Micromegas amplification stage
- Induction region initially set at 50 μm

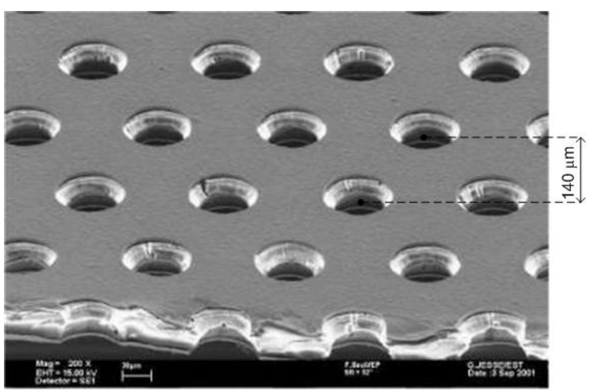

Fig. 3-GEM picture obtained with electronic microscope

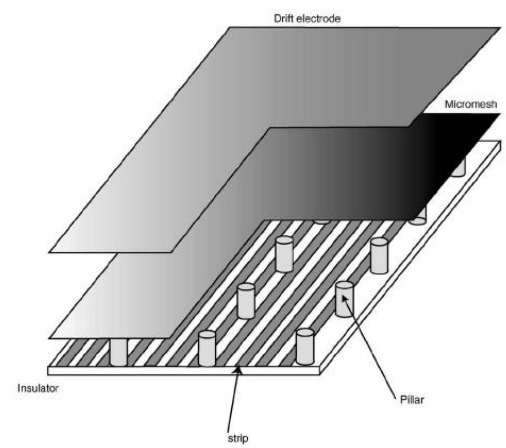

Fig.4-Scheme of Micromegas detector

The GEM-MIGAS-properties

Combine the charge amplification properties of a GEM and Micromegas

Charge multiplication → GEM holes + Induction region

Resulting:

• More efficient charge extraction from the GEM holes

• More efficient charge collection by the anode readout

• Elevated charge gain

• Lower operational voltages in the GEM

• Reduce the sparks rate allowing a longer lifetime of the device.

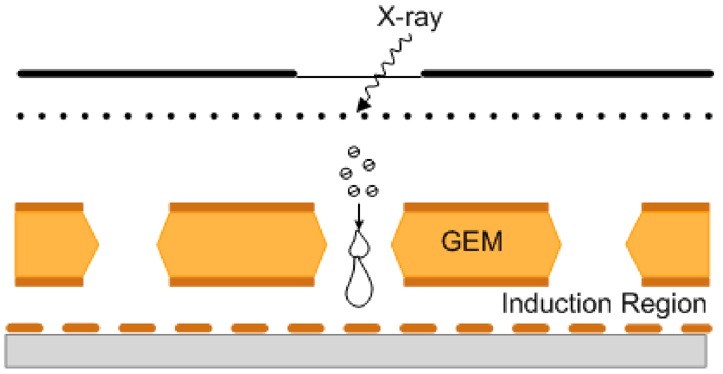

Fig.5-Schematic diagram of GEM-MIGAS detector

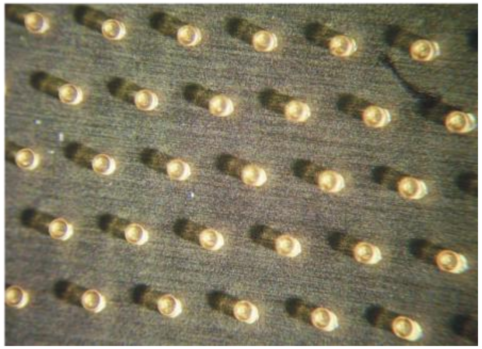

Fig.6-Photomicrograph of the micromesh, detail of the Kapton pillars

Experimental Setup

Pure CF_4 at 1, 2 and 2.6 bar

- Explore the induction region length in 20-250 μm region
- Influence of the GEM Parameters, hole diameters of 30 and 50 μ m

2.6 bar CF_4 + Helium (^4He)

- Outermost GEM –MIGAS configuration { Gap thickness / GEM Geometry }

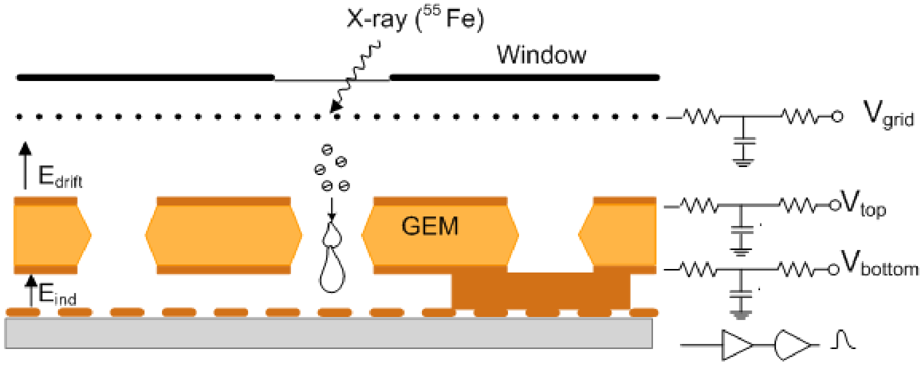

Fig. 8-Schematic diagram of GEM-MIGAS detector

Technical characteristics:

- ^{55}Fe X-ray source
- Active area of 10×10 mm^2.
- Drift region of 5 mm

Influence of Induction region length

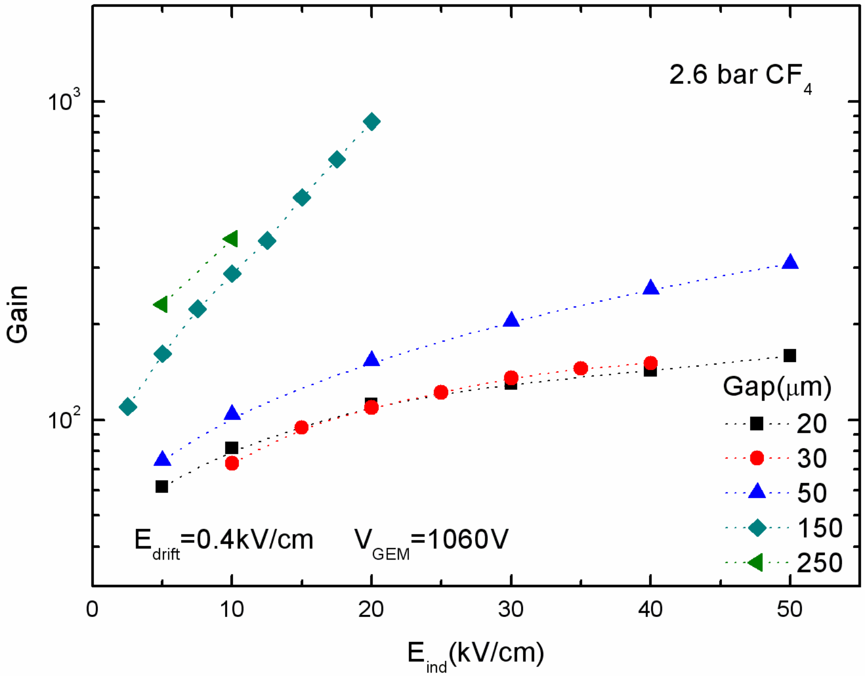

Fig.9-Gain as a function of the E_{ind} with a standard GEM.

- High induction fields the gain increases exponentially with E_{ind}
- Low induction field the gain augment with E_{ind} is steeper
- Gain improve for thicker gaps

Table 1- Higher gain value for each gap.

Gap (μm)	Gain	Eind (kV/cm)
20	160	50
30	150	40
50	300	50
150	865	20
250	370	10

- 150 μm configurations had electrical instabilities due to poor insulation
- Following studies were made with **50 μm gap**.

Influence of the GEM hole diameter

GEM hole Ø 50 µm

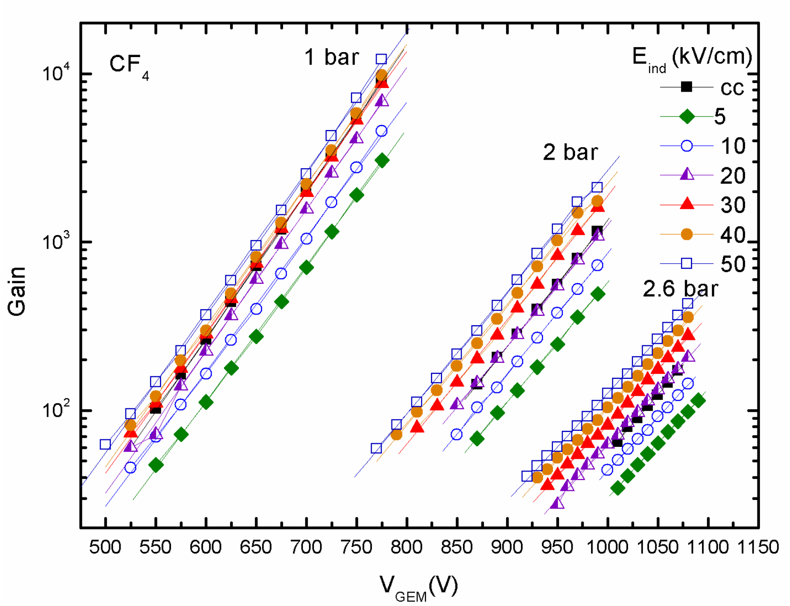

Fig.10-Charge gain as a function of V_{GEM},

GEM hole Ø 30 µm

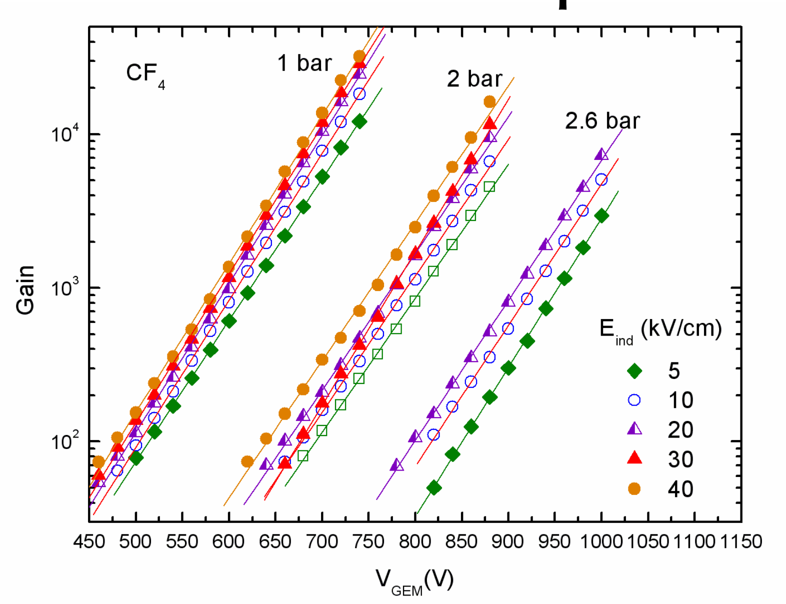

Fig.11-Charge gain as a function of V_{GEM},.

GEM-mode (E_{ind} < 5kV/cm)

10^3 at 1bar decreasing to 10^2 at 2.6 bar

10^4 at 1 bar decreasing to 10^3 at 2.6 bar

GEM-MIGAS mode (E_{ind} > 5kV/cm)

10^4 at 1bar decreasing to 10^2 at 2.6 bar

10^4 at 1bar decreasing to 10^3 at 2.6 bar

Influence of the GEM hole diameter

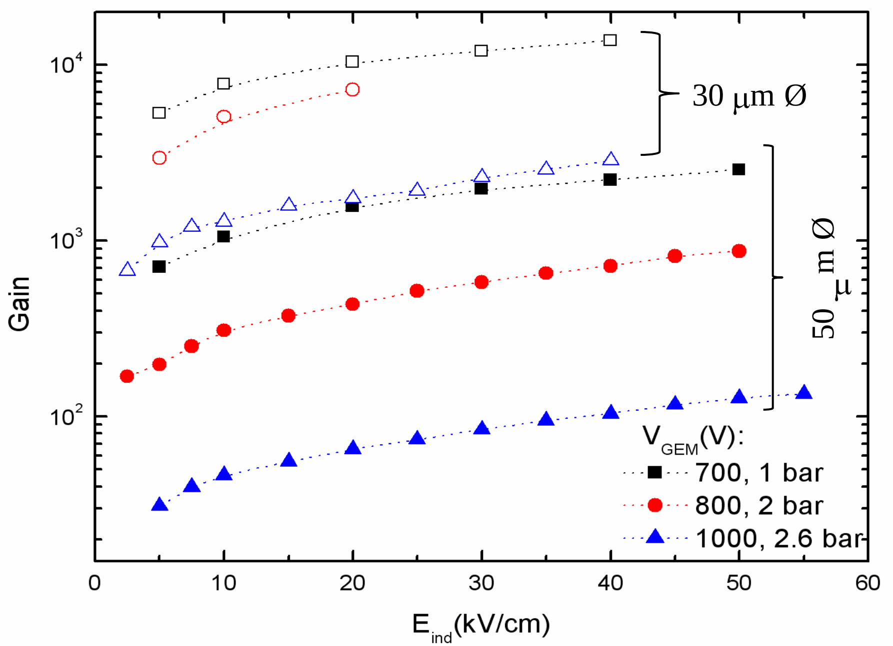

Fig. 12- Gain as a function of $E_{ind.}$ GEMs 50 μm, filled symbols ,30 μm open symbols.

The 30μm GEM gain (~2 10^3) is one order of magnitude higher than the standard GEM(~10^2),

- Augment of E field strength inside the GEM holes
- Reduction on hole diameter profit charge gain enhance

GEM-MIGAS with a 30μm Ø GEM:

- ✓ Efficient approach in view to neutron detection,
- ✓ Lower GEM voltages benefit discharge probability and GEM life time

Helium/2.6 bar CF_4 mixtures

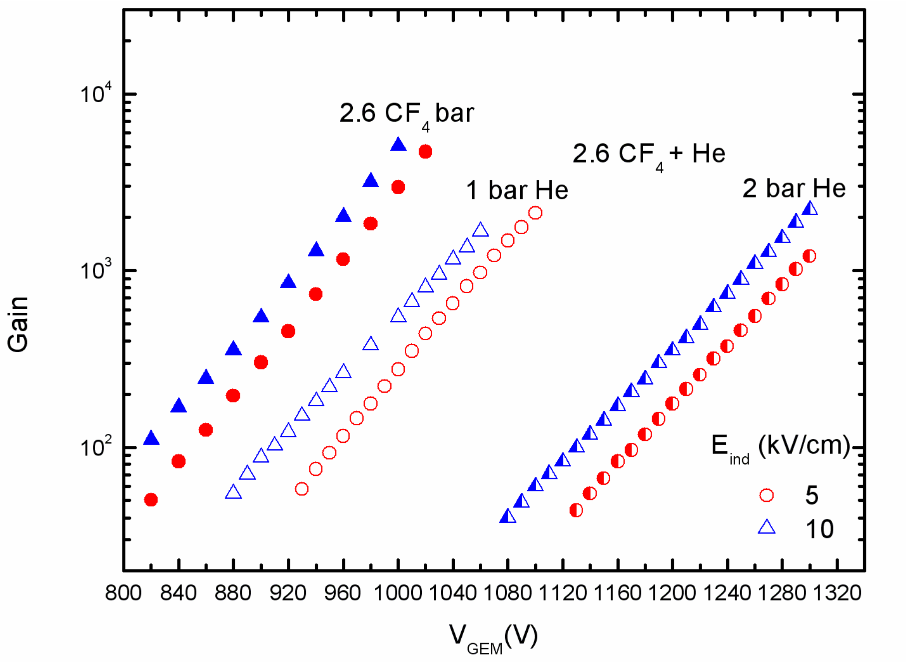

Fig. 13- Gain as a function of VGEM for the 30 µm hole diameter GEM with a 50 um gap.

The addition of He:

- Slight decrease on gain
- Increase on V_{GEM}

Table 2- Charge gain compilation for cf4/he mixture.

E_{ind} (kV/cm)		2.6 bar CF_4	+ 1bar He	+ 2bar He
5	Gain	**4700**	**2000**	**1200**
	V_{GEM}	1020	1100	1300
10	Gain	**5000**	**1700**	**2200**
	V_{GEM}	1000	1060	1300

Gain at 2 bar of He is ~ 2 orders above the required for neutron detection!

Helium/2.6 bar CF4 mixtures

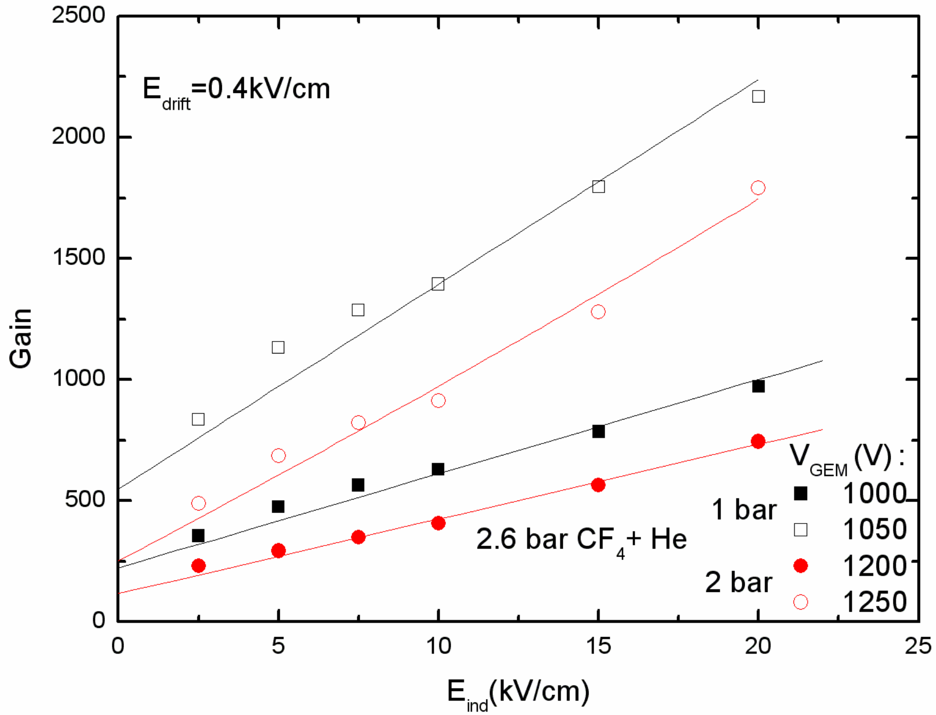

Fig.14- Maximum gain achieved as a function of the induction field.

The increase on E_{ind} results in a gain improvement by a factor ~3.

Detection efficiency can be improved by:

- Increasing drift region depth $\Rightarrow$ Affect the gain performance
- Raise He pressure

Gain presents a slow decrease with the He pressure, it is expected that enough gain will be achieved as the He pressure increases up to several bars! (measurements at higher He pressures are needed)

Conclusions

- The 50 μm gap with 30 μm Ø GEM, is a viable configuration for neutron gaseous detectors based in He/CF_4 mixtures.
- The 30 μm Ø GEM doesn’t suffer a drastic decrease on gain with the pressure augment when compared to the standard GEM.
- The narrower GEM holes provide a proportional gain enhancement, being a suitable alternative for high pressure operation
- The gain measured for 2.6 CF_4+2He, above 10^3, is enough for neutron detection, almost 2 orders of magnitude than required.
- The increase on He pressure is followed by a slight decrease on gain, thus good detection performances are still expected for higher filling pressure.
- Low Helium world wide supplies limit actual use but the study is valid, either to use in an expensive application or in future when He become lesser expensive.

Thank You! ☺