New gas mixtures suitable for rare event detection using a Micromegas-TPC detector

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ABSTRACT: The aim of the presented work was to develop further techniques based on a Micromegas-TPC, in order to reach a high gas gain with good energy resolution, and to search for gas mixtures suitable for rare event detection. This paper focuses on Xenon, which is convenient for the search of neutrinoless double beta decay in $^{136}$Xe, and CF$_4$, suitable for dark matter searches and the study of solar and reactor neutrinos. Various configurations of the Micromegas plane were investigated and are described. Gains of $10^5$ and energy resolutions of 35-65\% at 6 keV have been achieved.

KEYWORDS: Micromegas; Time Projection Chamber; rare event detection; charge collection; attachment; CF$_4$; Xe.

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1. Introduction

Low energy neutrino experiments, whether at reactors [1] or with solar neutrinos [2], and in particular searches for double beta decay [3] require high background suppression. Good event signature can contribute significantly. TPCs, thanks to their spatial resolution, allow a good event selection using the event topology. Good energy resolution, of order 1% at 2 MeV or better, is mandatory to separate neutrinoless double beta decay "0νββ" from the allowed two neutrino decay "2νββ". High gas amplification is necessary for optimal performance. The Micromegas technique is highly promising. In addition, Micromegas are found to be reliable, and suited for large size devices. We have conducted tests of Micromegas in various gas mixtures of interest for low energy neutrino physics, optimizing the performance. We have restricted ourselves to pressures up to a few bar, at which electrons above a few 100 keV produce tracks long enough to be identified.

First we investigated mixtures dominated by Xenon, having in mind the search for neutrinoless double beta decay in $^{136}$Xe. We have looked for additives improving drift properties and gas amplification. We have concentrated on CF$_4$ because it is cheap, easy to use, non hazardous, and transparent to light. The latter feature is important if the scintillation light is to be measured in parallel to the ionization. Other additives can be considered, for instance Xe(97)-CF$_4$(2)-isoC$_4$H$_{10}$(1) [4, 5], but to us CF$_4$ appears the best compromise. Second, for experiments on elastic neutrino
scattering off electrons, we have investigated gas mixtures with a large CF₄ component. Pure CF₄ is a high density gas with good drift properties. It has a relatively low Z, with low multiple scattering making tracks smoother allowing for a better reconstruction of the electron direction. We have tried to get around the attachment problem, which limits the amplification at higher pressures in CF₄. Some of the results we obtained are also relevant for dark matter searches. In these experiments high amplification is required to detect the tiny fraction of ionization deposited by a recoiling nucleus.

Both Xenon and CF₄ are good scintillators. This opens the door to combined measurement of the ionization and the light in a TPC, which should further enhance the detector performance. In particular detection of the primary scintillation light may provide a time reference for the absolute drift time, from which the absolute event position in the drift direction can be determined. In the present work however we have concentrated on the gas amplification. Our results are presented in the following.

2. Xenon as a double beta decay candidate

The $^{136}$Xe isotope is a good candidate for the search of $0\nu\beta\beta$. The released energy is relatively high ($Q_0 = 2.479$ MeV), the relative abundance is 8.9%, and it is relatively easy to enrich. It has a rather high density (5.858 g/l). It has been successfully used in the Gotthard experiment with a gas TPC [6]. Xenon gas acts as the source and the detector medium. The EXO collaboration is presently investigating $^{136}$Xe with a liquid TPC, EXO-200 [7], having a much improved sensitivity. But a gas TPC remains an alternative for the final version of the EXO experiment, with still superior sensitivity [3]. Xenon has a high ionization yield ($W = 22$ eV), it is an efficient scintillator (175 nm), it is mono-atomic and it is relatively easy to purify.

In the Gotthard experiment 5% of CH₄ was added as quencher. The energy resolution and calibration was determined from the double escape peak of the 2614 keV $^{208}$Tl line, obtained in an exposure to a $^{232}$Th source illuminating uniformly the gas volume. The resolution at 1592 keV was found to be $\sigma(E)/E = 3.4\%$ scaling to $\sigma(E)/E = 2.7\%$ at 2.48 MeV. This is however a resolution averaged over the entire drift length (70 cm), since the TPC had no absolute time reference.

3. CF₄ for solar neutrino and dark matter search

CF₄ has a much lower average Z, and multiple scattering is smaller than in Xenon. It has a high density (3.72 g/l at 1 bar, or $1.06 \times 10^{21}$ e⁻/cm³), leading to a compact detector size. It is more suited for solar or reactor neutrinos. The high spin of fluorine makes it a good candidate for the detection of dark matter with spin interaction. In addition, CF₄ is a scintillator, which emits light in the region from ultraviolet to the visible light [8]. The primary scintillation photon yield of CF₄ is about $16(\pm5)\%$ of that of Xe as cited in the last reference.

Despite its high electron attachment in high electric fields, which can cause electron loss, and ageing effects [4], relatively high gas amplification can be achieved [9]. It was used in several detectors: a gain of $10^6$ was reached with triple-GEM (Gaseous Electron Multiplier) [10] based detector in pure CF₄ [11]. It was used as filling gas in the MUNU experiment with a Multi Wire
Proportional Chamber MWPC [12]. It gave good tracking capability, which was essential in getting results on the electron neutrino magnetic moment [13].

4. Drift properties and diffusion

As a first step, we performed some simulations with the Magboltz [14] program to study the effect of CF₄ as additive in Xe to improve the electron transport properties (drift velocity, diffusions, etc). The ionization potential of CF₄ (15.9 eV) is significantly higher than the excitation energy of Xe (8.4 eV). Comparisons with other quenchers were also made. Calculations showed that an Xe-CF₄ mixture has a higher drift velocity and lower longitudinal and transversal diffusions, compared with Xe-CO₂, Xe-isoC₄H₁₀ and Xe-CH₄. As mentioned in reference [15], the drift velocity is high when the electrons are slowed down into an energy region where the mean scattering cross section <σ_sc> for the gas is small, which is the case for the CF₄ gas.

To give an idea, in Xenon with only 2% of CF₄, assuming a typical drift field of 200 V·cm⁻¹, the drift velocity is 0.5 cm·µs⁻¹, the lateral diffusion for one cm of drift is about 225 µm and the longitudinal diffusion is 285 µm per cm.

We also looked if the properties of CF₄ can be improved by an addition of Xenon. For CF₄ with 2% of Xenon we find 4.2 cm·µs⁻¹ for the drift velocity, 180 µm per cm for the lateral diffusion, 178 µm per cm for the longitudinal diffusion. A more detailed description of these considerations can be found in reference [16]. These simulations guided us throughout our measurements.

5. Experimental set-up

All measurements presented in this paper were carried out with a mini Time Projection Chamber (mTPC) combined with a compact Micromegas micropattern structure [17]. A schematic view of the mTPC with a Micromegas detection plane is shown in the left of figure 1. A full description of the mTPC prototype, instrumented with a MWPC, is given in reference [18]. The drift volume of 10 cm diameter and 20 cm length was delimited by the cathode at the top and the Micromegas at the bottom. To achieve a uniform electric drift field, 9 field shaping rings with 2 cm separation are placed between the cathode and the Micromegas. They are connected with equal value resistors (10 MΩ) and held by spacers made from nonconducting material (delrin). The Micromegas-mTPC is enclosed in a grounded stainless steel vessel, which can be evacuated. This prototype was equipped with various configurations of Micromegas to compare the performance. In particular, woven wire mesh as well as chemically etched structures [19] were studied.

5.1 The Compact Micromegas

The compact Micromegas consists of an anode and a grid, compacted "two in one" and separated with cylindrical pin spacers. The compact Micromegas is shown in figure 1. The anode, developed at CERN, is a plain copper plated board with 9 cm of diameter. Kapton spacers with 250 µm diameter by 100 µm height or more and placed every 1 mm, are laid on it by conventional lithography. The height defines the amplification gap size.
The grid, from the BOPP\(^1\) company, is made of stainless steel wires, with 20 \(\mu m\) of diameter, woven with a pitch of 53 \(\mu m\). It was tensioned delicately and glued with a thin Araldite layer to the outer part of the anode. The glue layer is thin enough to have no impact on the gap depth. The grid is pressed against the spacers.

![Figure 1. A schematic view of the Micromegas-mTPC (left) and a microscopic zoom on a Micromegas grid with a spacer (right). The diameter of the spacer and the opening of the grid are 250 \(\mu m\) and 53 \(\mu m\), respectively.](image)

This grid is cheap, easy to handle, robust (no damages were observed on the grid even after high voltage discharges).

Best results with good charge collection have been obtained for a gap around 100 \(\mu m\) \(^{[20]}\), which justifies our choice of this height for all measurements at 1 bar. Field non uniformities, including the drift volume (20 cm) and the amplification gap (100 \(\mu m\)), are studied with the Garfield \(^{[21]}\) program as shown in figure \(^2\). The 2D configuration of Garfield was used.

In reality, the grid has a 3D structure, but it can be locally approximated to good precision by a 2D structure. The 3D crossed wires in the micromesh grid are approximated by superposed circles, with 20 \(\mu m\) diameter. One of them is slightly displaced. The wires are repeated every 53 \(\mu m\). The electric field is homogeneous in both the conversion and the amplification region, where the field is highest, which is required for good gain uniformity. There is a bulge in the intermediate opening of the microgrid, which is however of no concern.

Great care has been taken when handling the detection plane, to avoid any gap deformation. Obviously, defects of flatness are the source of gain fluctuations and therefore affect the energy resolution. In all of our tests, the ratio between the amplification and the drift electric fields exceeds 250 for all gas mixtures. This value is sufficient to permit a full electron transmission, with intrinsic ion feedback suppression, leading to nearly total charge collection.

Before installation, the compact Micromegas is washed with isopropyl alcohol and dried with a thin vacuum cleaner brush to remove dusts and scraps from manufacturing and to keep humidity low. Traces of humidity in this narrow gap can adversely affect the energy resolution, while dust

\(^{1}\)www.bopp.ch
Figure 2. Electric field configuration near the grid wires.

particles lead to discharges.

5.2 Electronics and gas systems

The detector was operated with the cathode at a negative potential, the anode at ground and the grid at a negative potential of several hundred Volts.

The signal is taken from the grid. It is collected on a capacitor (C = 10 pF), amplified by a charge-sensitive preamplifier and amplified again and shaped in a gaussian form by a spectroscopic amplifier. A multichannel analyzer sorts the incoming pulses by their height. The mean value of the current is measured with a slow base time oscilloscope via a nanoampermeter.

To achieve good purity, the chamber was evacuated to $10^{-6}$ mbar while heating before each gas filling. The mixing of Xe and CF$_4$ at ambient temperature was done by controlling the partial pressure within the chamber itself.

After filling, the gas was circulated continuously through a purification system. It includes two "oxysorb" filters: one to remove electronegative impurities such as O$_2$ and H$_2$O and the second one in series to monitor the purity. A cold trap maintained at a temperature fluctuating around $-109^\circ$C serves to remove water and possible remaining freon contaminations. Measurements started after one day of gas circulation. Moreover, at regular intervals, the gas composition is controlled with a mass spectrometer mounted near the chamber, analyzing the inflowing and the outflowing gas.

6. Main results

Charge spectra from the grid signal are recorded for each gas mixture with different proportions of the additive, exposing the gas volume to a $^{55}$Fe source (5.9 KeV X-rays). The source was placed on the cathode. All measurements are done under the same conditions. The acquisition time is 100
s for all measurements.
In this section we report on results obtained at atmospheric pressure for various Xe-CF\textsubscript{4} admixtures. The drift field has been maintained constant during all measurements at 200 V cm\textsuperscript{-1} bar\textsuperscript{-1}. The main emphasis was put on the energy resolution of the detector at low energy and the determination of the gas gain. These factors were determined in the following way:

- The effective gain of each gas mixture was measured by comparing the peak of the pulse height distribution generated by the $^{55}$Fe X-ray source with that of a calibrated charge deposited at the test input of the charge sensitive preamplifier. The charge collected on the grid represents the total number of ions created after the amplification and is equal to $CV$, where $C$ is the input capacitance of the preamplifier and $V$ is the voltage at the end of the collection, determined by comparison with the calibration pulses. Thus, the gas gain is given by the relation:

$$G = \frac{CV}{eE/W_i},$$  \hspace{1cm} (6.1)

where $e$ is the elementary charge, $E$ is the deposited energy of the incident photon (equal to 5.898 keV in the case of the $^{55}$Fe source) and $W_i$ is the average energy required to ionize the gas (54 and 22 eV for CF\textsubscript{4} and Xe respectively).

- The relative intrinsic FWHM energy resolution at half height is given by:

$$R_E = 2.35 \frac{\sigma(E)}{E},$$  \hspace{1cm} (6.2)

where $\sigma(E)$ is the standard deviation and $E$ is the average deposited energy.

In these measurements, the electronic noise only leads to a small increase of the total resolution and was neglected.

### 6.1 Charge collection in Xenon gas

We have done experimental studies of the gas gain of Xe-CF\textsubscript{4} mixtures, going from 2% of CF\textsubscript{4} in 98% of Xe to (50-50)% by volume. A comparison with 2% of IsoC\textsubscript{4}H\textsubscript{10} in Xenon, often given as the best quencher for Xe, was also performed. No amplification was obtained with pure Xe.

A typical preamplifier response to $^{55}$Fe 5.9 keV X-rays in Xe(98)-CF\textsubscript{4}(2) gas at 1 atm, is shown in figure 3. The shaping of the signal allows to catch the entire induced charge. The integrated signal current measured with a nano-ampermeter is very small (few hundreds pA).

We summarized in figure 4 the effective gas gain curves and energy resolutions at 6 keV of energy, obtained in various gas mixtures as a function of the grid voltage. The gain was measured for increasing grid-anode voltages, up to the point where discharges occur. For a given gain, the grid voltage must be increased at higher CF\textsubscript{4} admixtures. Usually, the addition of the quencher gas is meant to decrease the operating voltage and to increase the gain amplification, which is not the case here.

The observed gas gains are large enough to allow the detection of small signals in the ionization mode of the Micromegas-mTPC. They exceeded $10^3$ for all Xe-CF\textsubscript{4} gas mixtures investigated. A remarkable fact is that we obtain the best gain for a given voltage with only 2% of CF\textsubscript{4}. 

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Figure 3. The shape of the preamplifier output (top) and the spectroscopic amplifier (bottom), recorded in the oscilloscope for Xe(98)-CF$_4$(2) gas mixture at 1.00 atm and $-470$ V on the grid voltage.

Figure 4. Gas gain G measurements (left) and $^{55}$Fe energy resolutions $R_E$ (right) versus grid voltages, with Xe-CF$_4$ (full markers) and Xe-IsoC$_4$H$_{10}$ (□) admixtures at atmospheric pressure and 100 µm gap.

The half-width energy resolution of Xe(98)-CF$_4$(2) admixtures is in the range of (35 - 65)% in the working grid voltage region, compared with (25 - 29)% with Xe(98)-isoC$_4$H$_{10}$(2) (see the right of figure 4). However, comparing with the same proportion of isoC$_4$H$_{10}$ quencher added to Xe, the Xe(98)-CF$_4$(2) admixture gives higher gas gain (1.4 times better) at the same grid voltage ($V_g = -480$ V) with same settings and conditions, as shown in figure 5.
Figure 5. The response to the 5.9 keV X-rays from a $^{55}$Fe source with a compact Micromegas in 1 bar of Xe-CF$_4$ (left) and in Xe-isoC$_4$H$_{10}$ (right) gas mixtures at the same proportion (2%) and the same settings. The contribution of the electronics noise to the energy resolution is given by the pulser peak width to the right.

Even under the worst case of the Fano factor $F = 1$, the energy resolution is not as good as expected ($R_E = 2.35 \sqrt{\frac{F}{N}}$) with CF$_4$ addition. This worsening of the energy resolution can be explained by the strong contribution of the electron attachment in CF$_4$ [15].

To conclude this section, we can reach high gains at lower applied voltages, with only 2% of CF$_4$ added to Xe (see figure 4). The Xe(98)-CF$_4$(2) gas mixture is well suited for a search of neutrinoless double beta decay in $^{136}$Xe as a double beta candidate for its good charge collection and good transport properties. The lower gain at higher percentage of CF$_4$, can be explained by the loss of electrons, which inhibits the ionization in the avalanche region. Ageing of the gas was observed and found to be less at low CF$_4$ concentrations [4].

Large and flat (with a small drift volume) Micromegas-TPC filled with Xe(98)-CF$_4$(2) at 4-5 bar of pressure could be convenient for medical imaging and safety control in ports and airports. It may be a good alternative to existing schemes with MSGC’s [22] and with MWPC’s [23]. Micromegas-based gaseous photomultipliers filled with Xe-CF$_4$ admixture could be developed, for the UV and the visible spectral range. Progress in this field with Multi-GEM micropattern cited in reference [24] are very encouraging.

6.2 Reducing the CF$_4$ attachment

Pure CF$_4$ was used in the MUNU TPC, and its drifting and gain properties are well known. Gas multiplication was made around thin wires. As mentioned one problem is the electron attachment occurring at higher fields in the avalanche region, which leads to electron losses, gain reduction, and to a deterioration of the energy resolution. In the subsequent studies, we estimated the electron
loss at different CF$_4$ gas pressures with Magboltz and Imonte [14] interfaced to Garfield, under the exact experimental conditions (pressure, temperature, voltages ...).

The electron loss increases with the gas pressure, which is confirmed by experimental results. At 1 bar of pressure, the high electric field (about 400 kV/cm) around the anode wires, causes a serious electron loss and the charge collection efficiency is about 13%. At 3 bar of CF$_4$, only 5% of the electrons survive. This decrease of the collection efficiency contributes to the worsening of the energy resolution. More details for electrons loss calculations are in reference [14].

A comparison between energy resolutions of the MUNU-TPC for 1 and 3 bar is mentioned in reference [25], confirming that the energy resolution at 1 bar is about 1.7 – 2 times better than at 3 bar.

We decided to test whether replacing the MWPC used in MUNU by a Micromegas structure helps in reducing the attachment.

A comparison between $^{55}$Fe pulse height spectra of the compact Micromegas [16] and the MWPC [18] in pure CF$_4$ at 1 bar of pressure and same conditions and settings, gave the Micromegas a clear advantage. The energy resolution is improved by a factor 1.3. A first advantage of the Micromegas structure is that the electric field near the anode is very homogenous. In the case of the MWPC, the electric field around the anode wire is very high compared with the amplification field in the Micromegas gap region. The attachment is therefore less with the Micromegas.

We further considered an additive to improve the properties of CF$_4$. Xe and Ar gases are good candidates to quench CF$_4$ gas. The first one is simply chosen because of its low operating voltage, and the second one has zero attachment.

The first ionization potential of Xe (12.13 eV), compared with the excitation energy of CF$_4$ (12.5 eV) molecules, allows the addition of Xe to CF$_4$. The high electric field in the amplification region leads to the following decomposition of molecules [26]:

\[
e^- + \text{CF}_4 \rightarrow (\text{CF}_3)_2^+ + \text{F}^- + 2e^- \tag{6.3}
\]

\[
e^- + \text{CF}_4^+ \rightarrow (\text{CF}_4^+)_2 + e^- \tag{6.4}
\]

When a stable state is reached, dissociated fragments ((CF$_3)_2^+$ and (CF$_4^+)_2$) emit photons in the UV (peaked at 160 nm) and the visible range (\(\lambda = 620 \text{ nm}\)) [27]. Light signals were also recorded by the MUNU photomultipliers [28].

Measurements are carried out with the same prototype described above using parameters similar to those for the charge collection in Xe study (pressure, amplification height, drift field...).

Results of our measurements are summarized in figure 6. In pure CF$_4$ gas, the working region is around 150 V grid voltage. Adding noble gas decreases the maximum possible gain. It increases the gas gain at a given low operating voltages.

Moreover, this addition decreases the probability of photoeffect on the grid wall, caused by ultra-violet photons from dissociated fragments of CF$_4$. The presence of Xe atoms can prevent or more precisely delay the formation of those fragments, especially dissociative processes, because the operating voltage is lower than before.

A small addition of Xe reduces the working voltage, and increases the gas amplification by more than 10 times. At the same grid voltage, we obtain a gas gain 10 times greater with CF$_4$(98)-Xe(2) than with pure CF$_4$. This can be explained by the decrease of the number of electrons lost in the
avalanche ionization region. At higher pressure the high attachment of CF$_4$ makes the Micromegas less efficient.

As presented in the right plot of figure 6, the energy resolution is not improved when adding Xe or Ar quenchers. It is a consequence of the increase of diffusions, the lowering of the drift velocity and the photoeffect of Xe and Ar in these admixtures. But the lowering of the operating voltages and the higher gains obtained confirmed the good collection efficiency.

7. Use in large size devices for rare event detection

In the envisioned rare event experiments large detector masses are required and background considerations are important. In this context compact Micromegas look promising. They are simple, and can be made from materials with good radiopurity. Mesh grids can be obtained in large sizes (2.5 $\times$ 30.5 m$^2$). A large size Micromegas (50 cm of diameter, otherwise similar to the structures described so far$^2$ was tested in the Gotthard-TPC [6] with 1 bar of P10 (Ar(90)CH$_4$(10)) and CF$_4$ gases. The drift distance was 67 cm and the drift field 200 V/cm. Detailed results are given in reference [29].

The energy calibration was performed with an internal $^{241}$Am source (37 kBq) and two external gamma ray sources ($^{241}$Am and $^{133}$Ba with 370 kBq activity each). The spectra with the internal source alone and, in addition, the external sources, are shown in figure 7.

The Compton edge at 207 keV and 228 keV of the Ba lines at 356 and 382 keV is clearly visible in the right plot of the figure, as well as the 81 keV full energy peak. Better containment with the

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$^2$Compass detections planes: GEM and Micromegas are about (31 $\times$ 31) and (40 $\times$ 40) cm$^2$. 
Figure 7. The response to the internal $^{241}$Am source and the external $^{241}$Am (left) and $^{133}$Ba (right) sources, with the 50 cm diameter Micromegas in the Gotthard TPC with 1.03 atm of CF$_4$. The cathode is set at -13.8 kV.

larger Micromegas is thus obvious. The energy resolution is 10% FWHM at 228 keV, averaged over the Micromegas.

Moreover to have a large target or source mass without unmanageable volume requires working at high pressure. Reasonable electron tracks, with identification of the increased ionization at the end, can be observed up to say 10 bar of pressure in a TPC. All of our measurements reported so far were performed at a pressure of 1 bar. But we varied the pressure and found that the maximal achievable gain decreases with pressure. The same effect was observed with a triple-GEM detector $^{[30, 31]}$, operated at different pressures of argon, krypton and Xenon. We have shown however that it is possible to work at higher pressure if the Micromegas gap is increased.

We have studied the dependence of the gas gain of the Micromegas detector as a function of gap. Two different gaps were investigated: 75 and 225 µm at various gas pressures extending from 1 bar to the highest achieved pressure 4 bar. Figure 8 shows measurements of the gas gain versus the grid potential obtained for P10 at (1, 2, 3) bar for 75 µm and (1, 2, 3, 4) bar for 225 µm gaps. With the larger gap value (225 µm), gas gains greater than $10^4$ are comfortably achievable. The collection efficiency is higher with the 75 µm gap, but the dynamic range is smaller. One can reach the same gain as with a higher gap with a lower applied voltage. With a 225 µm gap, much higher voltages are needed to reach the same gain, but the working region is much larger, and much higher gains are achievable. This makes it possible to work at higher pressure. Moreover with higher gaps, the relative gap variations over the entire area is reduced. This insures better gain uniformity in the avalanche over larger detection plane surfaces.

The energy resolution at 6 keV is slightly better at lower pressure of P10 (22% and 26% at 1 and 4 bar respectively), with approximately the same gains. This is not the case for CF$_4$, where the energy resolution is remarkably worse when increasing the pressure. The energy resolution at 1 bar (36%) is about 1.5 times better than at 2 bar (54%) $^{[16]}$. 

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Figure 8. Gas gains measured in P10 gas, with 75 μm (▲) and 225 μm (•) gap heights at different pressures as a function of the grid voltage, using a $^{55}$Fe source.

The Micromegas with 225 μm gap was also successfully operated in Xe(98)CF$_4$(2) at pressures up to 4 bar. Gain of $10^3$ and energy resolution of 50% at 30 keV have been achieved at 4 bar of pressure [29].

8. Conclusions

TPCs have shown to be powerful instruments in low energy, low count rate, neutrino physics. A tight event selection is possible exploiting the imaging capability of these devices. We have investigated the properties of various gas mixtures in view of future experiments, amplifying the charge in Micromegas structures, which are reliable and suited for large size devices. For double decay searches, we conclude that a mixture of Xenon (enriched in $^{136}$Xe) with a few percent of CF$_4$ is an attractive possibility. It gives a large drift velocity, and allows to reach high gas amplification, essential factors for a successful experiment. For the study of neutrino electron scattering, where it is important to have a light gas to minimize multiple scattering, we showed that CF$_4$, with a few percent of Xenon reducing the attachment, also gives high gains. All these gas mixtures are transparent to light, so that a simultaneous measurements of the scintillation is possible. Neutrino experiments require large detector masses. To avoid excessive dimensions, it is necessary to work at pressures of a few bar. This can be done, with the Micromegas, by suitably adapting the amplification gap. In a next phase we want to investigate more precisely the spatial resolution which can
be achieved in gas TPCs filled with these gas mixtures, as well as the energy resolution at energies up to 2 MeV.

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