SOME OBSERVATIONS ON THE BEHAVIOUR
OF MULTIWIRE PROPORTIONAL CHAMBERS

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We present here some measurements that add to our technological knowledge of multiwire proportional chambers:

- A study of the amplification properties as a function of the relative proportions in mixtures of argon-isobutane and argon-carbon dioxide.
- A study of a method for correcting the inefficiency introduced by insulating wires supporting the amplification wires.

1. A STUDY OF GAS MIXTURES

1.1 Introduction

The importance of the mixture argon + isobutane is based on two facts. On the one hand, isobutane is very advantageous because of the relatively high stopping power\(^1\), and the following table indicates the properties of this gas in this respect:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Energy loss in keV per cm at TPN for 1.3 MeV electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>0.34</td>
</tr>
<tr>
<td>He</td>
<td>0.32</td>
</tr>
<tr>
<td>Ne</td>
<td>1.44</td>
</tr>
<tr>
<td>A</td>
<td>2.50</td>
</tr>
<tr>
<td>Kr</td>
<td>4.9</td>
</tr>
<tr>
<td>Xe</td>
<td>10.5</td>
</tr>
<tr>
<td>CO(_2)</td>
<td>3.3</td>
</tr>
<tr>
<td>CH(_4)</td>
<td>1.5</td>
</tr>
<tr>
<td>Isobutane</td>
<td>5.3</td>
</tr>
</tbody>
</table>

On the other hand, chambers with the mixture argon + isobutane work very well in the proportional region.

However, in the long run it may be that isobutane polymerizes, and that oils and carbon are deposited on the wires. This has been observed in the past for different organic additives, and it is very worrying in connection with large and expensive chambers. It may be that this trouble is only important in chambers where the gas is recycled, but we prefer to use continuous flushing because of the low cost of the gases.
Carbon dioxide presents the problem of not having very high stopping power, but it does have advantages that deserve consideration: low cost, no safety problems, no polymerization, and still good operation.

We have made studies of chambers having the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire diameter</td>
<td>$d = 20 \mu$</td>
</tr>
<tr>
<td>Distance between wires</td>
<td>$s = 2 \text{ mm and } 3 \text{ mm}$</td>
</tr>
<tr>
<td>Gap</td>
<td>$L = 7 \text{ mm}$</td>
</tr>
<tr>
<td>Surface</td>
<td>$(10 \times 10) \text{ cm}^2$</td>
</tr>
</tbody>
</table>

1.2 Experimental set-up

The wires were terminated with a resistor $R = 100 \text{ k}\Omega$; we have measured the pulses from the wires with a Tektronix probe, with $R = 10 \text{ M}\Omega$ and $C = 7 \text{ pF}$.

The different gas mixtures were checked by two Rotameter-type flowmeters, with a metric range of 0 to 150 cm$^3$/min, calibrated for air.

1.3 Results

Typical spectra for different mixtures and for chambers of 2 mm and 3 mm are shown in Figs. 1, 2, 3, and 4. Here the figures labelled (a) represent the pulse height versus high voltage; those marked (b) are the same figures but with the pulse height in logarithmic scale.

From the figures in logarithmic scale [curves (b)], one can roughly determine $v_s$, the threshold voltage. The knowledge of $v_s$ is useful for the determination of the radius $r_0$, where the amplification begins$^2$.

Knowing $v_s$ and $r_0$, one can then calculate the collection time, using some simple assumptions$^3$.

We computed the collection time $T$ in the simplest way. For the drift velocity, we take $W = 4 \text{ cm/}\mu\text{sec}$, from a recent result of our group$^4$.

Assuming that the drift velocity is constant in the uniform field region and near the wire, we find for the collection time of electrons liberated at a distance of 50 \m to 7 mm:

$$1 \text{ nsec} \leq T \leq 200 \text{ nsec},$$
Fig. 1
Fig. 2
Fig. 3
(Percentage of CO₂)

Fig. 4
which is verified experimentally and is in agreement with recent measurements of Steffen and Vannucci\(^5\).

We have also calculated the amplification of a chamber with a wire spacing \(s = 2 \text{ mm}\), and a gap \(L = 7 \text{ mm}\) (total capacitance chamber + probe = 47 pF) for the 5.9 keV X-ray of the \(^{55}\text{Fe}\) source. Considering the pulse heights in the range of 0.5 mV to 200 mV, we find

\[10^3 \leq A < 10^6\]

In Fig. 5 we indicate the voltage difference \(\Delta V\) between the end of the proportional region and the breakdown for different concentrations of argon + isobutane, and the same for argon + carbon dioxide in Fig. 6.

The efficiency was measured (Fig. 7 for argon + isobutane, and Fig. 8 for argon + carbon dioxide). The measurements were performed with the \(\beta\)-ray source of \(^{106}\text{Ru}\) and after grouping together ten wires in order to avoid collimation problems. The detection by the monitoring scintillation counter of some bremsstrahlung \(\gamma\)-rays produced in the collimators apparently lowers the efficiency on the plateau, which has in fact been measured to be \(> 99.8\%\).

In order to complete this study of gas mixtures, we measured the arrival time of the first electron liberated in the gas by time-of-flight measurements where the zero time was given by a photomultiplier. We noticed that the fastest pulses in the chamber arrived about 30 to 36 nsec before the pulses from the photomultiplier. The transition time of our photomultiplier chain was estimated to be approximately 40 nsec, confirming that the first pulses from the proportional chamber arrive a few nanoseconds after the passage of the particle. The small fluctuation is due to the different gas mixture, and depends on the high voltage.

Figures 9 and 10 are the multichannel display of time-to-amplitude converter signals for the two mixtures being studied, visualizing the time delays between chambers and scintillation counters.

2. **INFLUENCE OF NYLON WIRES --- CORRECTION OF THE INEFFICIENCY**

The work of the CERN-Heidelberg Group has shown that the static charge induced on the wires of a proportional chamber by the surrounding HV meshes finally results in a displacement of the wires\(^6,7\). The new equilibrium
Fig. 5

Fig. 6
Fig. 7

Argon + Isobutane
s = 2 mm
d = 20 μ

Fig. 8

Argon + CO₂
s = 2 mm
d = 20 μ
position is different from the coplanarity and will, of course, completely modify the electric field in the chamber. The displacement increases in accordance with the dimensions of the chamber; and with thin 20 μ molybdenum wires of a length exceeding 20-30 cm, a mechanical constraint to the wire mesh is necessary. A possible solution is to fix several insulating wires across the mesh; these should lie orthogonal to the wires of the mesh and be in strict contact with them (they could also be glued to the mesh). In Figs. 11a and 11b, two possible configurations are shown.
A prototype chamber was built, using the geometry of Fig. 11b, with a mean distance of 20 cm between each pair of insulating wires; these wires were made of nylon, 0.5 mm thick. The unwanted displacement of the metal wires in the mesh with the HV applied was reduced to a tolerable figure but, as was observed by an Orsay group*, a new feature occurred which is strikingly visible in Fig. 12a. The efficiency of the proportional chamber in a region near the insulating wire decreases by more than a factor of two. The measurement has been performed using a collimated \( \beta \) source, in coincidence with two scintillator counters, as can be seen in Fig. 12b. The distance of the proportional wires was 3 mm, and the gap 8 mm*).

Of course, owing to the multiple scattering of the electrons on the chamber and to the finite dimension of the collimating counter SCI (2 mm in the x-direction, see Fig. 12), the actual hole in the efficiency could be narrower and deeper; in any case it is surprisingly wide.

Figures 13a and 13c show the time distribution of the pulses given by the chamber, for a region far away from the efficiency hole (a) and in the hole itself (c); it can be seen that the time distribution is not distorted near the nylon wire, but is only depressed in the number of counts. This can, of course, be due to the electrons passing on the sides of the nylon wire, but scattered towards the scintillation counter.

Although at this stage we did not have a quantitative explanation of the effect, from a qualitative point of view one would expect a strong local modification of the field because of the proximity to the high-gradient region of the wire mesh, of an insulating wire with a dielectric constant of \( \varepsilon = 4 \). The proportional multiplication, typical of a well-shaped electric field, does not take place in the critical region. The electrostatic charging-up of the insulating wire can also be responsible for the effect; it has been seen that two different insulators, with essentially the same \( \varepsilon \) but different resistivity, have a different behaviour.

An obvious way of getting rid of the problem is to find some means of restoring the original electric field locally, by "pushing" back the equipotentials. Two possible solutions have been investigated:

a) A "correction" conducting wire, 0.1 mm in diameter, is added, lying parallel to the nylon wire (Fig. 14a) at about 1 mm from the wire mesh.

*) In these measurements five adjacent wires were connected to the amplifier. A gas mixture of 70% A, 30% CO\textsubscript{2} was employed.
Relative efficiency vs Chamber length (cm)

Nylon wire

Fig. 12
Fig. 13
b) The insulated supporting line is a metal wire within an insulating tube (Fig. 14b), the external diameter of the wire being 0.8 mm. The measurement was first carried out using a Teflon insulator, but this failed to cure the defect; the measurement was then repeated, following satisfactory tests by the CERN-Heidelberg group, using vinyl-insulated wire.

A convenient potential applied to the metal wire could rebuild the correct field, or at least an approximation of it, in the critical region.

The results of the measurements, again done with the set-up of Fig. 11, are summarized in Figs. 15a, b, c for the two solutions. It is clear that the first approach is satisfactory, giving full efficiency, within the statistical error, and with a reasonable HV applied on the correction wire. The second approach seems to fail in the case of a good insulator (Teflon), whereas with an insulating material of poorer characteristics the result is satisfactory. This indicates, as was said before, that charge effects do play a role in the physical phenomenon. The vinyl insulator has, of course, a lower resistivity than Teflon, and then the charges that eventually build up on the insulator can be swept away by the internal conductor.

An important parameter is, of course, the time resolution of the chamber in the critical region that could have been modified by the correction potential. This is not the case, as can be seen in the pictures
Fig. 15a
Fig. 15b
Fig. 15c
of Fig. 13. In Fig. 13a the time resolution in a region of normal condition in the chamber is shown; in Fig. 13b the same distribution is given for the critical region over the nylon + metal wire [solution (a) of Fig. 14], the HV applied to the wire being 1.7 kV. Lastly, the time distribution in the critical region, but with the metal correction wire grounded, is shown in Fig. 13c. Similar curves have been obtained for the second solution, and for the vinyl-insulated wire.

These measurements show that the construction of large chambers presents some delicate problems. Different groups are working on these problems, and some of the data used in this paper represent partially the results of their efforts. But clearly, more experience has still to be gained in that field.
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