HIGH PRESSURE PROPORTIONAL COUNTERS
OPERATING IN PURE HYDROGEN

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Construction and operation of high pressure proportional counters designed for pressures up to 92 atm which work in pure hydrogen are described. This type of counter offering track reconstruction as well as energy loss determination will be employed as live-target for low-energy recoil measurements in elastic np scattering.

1. Introduction

For the CERN experiment NA 61) on 'very small angle neutron scattering' a live-target, i.e. a proportional counter operating in pure hydrogen at pressures \( \geq 40 \text{ atm} \) was built. The kinematical variables of the scattering process are determined by the recoil energy, the azimuthal angle of the recoil particle and the scattering angle measured in the neutron vertex detector.

The method of low-energy recoil measurements2) is also of interest at very high energies where small scattering angles require large detector distances to gain sufficient angular resolution.

If the recoil proton is stopped in the sensitive volume its range can be determined through the charge collection time which therefore gives an independent energy determination. Radial nonlinearities in drift time can easily be corrected by computation. Calculations show that by proper choice of potentials the effect of different azimuthal orientations of the proton tracks can be pushed towards 10%. On the analog sector fast sampling techniques as offered e.g. by a 20 MHz Waveform Analyzer3) may give accurate \( dE/dx \) measurements thus determining the proton recoil energy.

In the past several similar high pressure proportional counters have been constructed4-6). No operation with pure \( \text{H}_2 \) gas is so far known, however.

2. Construction

At the moment we operate two high pressure counters to study their properties.

Type I is the multiwire structure for the neutron experiment designed for 40 atm which is presently tested at CERN. Type II is a more simple version which allows pressures up to 92 atm.

Table 1 compares the main features of both counters.

<table>
<thead>
<tr>
<th>Features</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating pressure</td>
<td>40 bar</td>
<td>92 bar</td>
</tr>
<tr>
<td>Gas</td>
<td>( \text{H}_2, \text{A...} )</td>
<td>( \text{H}_2, \text{A...} )</td>
</tr>
<tr>
<td>Number of sense wires</td>
<td>36+1</td>
<td>1</td>
</tr>
<tr>
<td>Diameter of sense wires</td>
<td>5, 20 ( \mu \text{m} )</td>
<td>20 ( \mu \text{m} )</td>
</tr>
<tr>
<td>Sensitive length</td>
<td>1.0 m</td>
<td>1.0 m</td>
</tr>
<tr>
<td>Number of scintillators</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Overall length</td>
<td>1.80 ( \times 10^3 ) mm</td>
<td>2.0 ( \times 10^3 ) mm</td>
</tr>
<tr>
<td>Overall diameter</td>
<td>325 mm</td>
<td>275 mm</td>
</tr>
<tr>
<td>Windows: diameter</td>
<td>20 mm</td>
<td>50 mm</td>
</tr>
<tr>
<td>thickness</td>
<td>0.1 mm</td>
<td>0.4 mm</td>
</tr>
</tbody>
</table>

II. PROPORTIONAL CHAMBERS
drifted towards the outer ring cells and collected there. The pulse shape then gives a time sequence of the energy loss per path length $dE/dx$ modified by the field. Particle identification and total energy measurement is achieved by adding signals from A and C in a proper way. The requirements short response time of the central cell and a large drift potential in B are achieved by choosing the sense wire diameters 20 $\mu$m in A and 5 $\mu$m in C (fixed gas multiplication assumed).

At still higher energies $7 \leq E < 50$ MeV of the recoil proton energy is measured in the ring of scintillation counters.

The construction of the high pressure vessel II (stainless steel DIN No. 1.4571) is shown in fig. 2.

As beam entrance windows we use thin stainless steel rupture discs ($\varnothing$ 50 mm, thickness 0.4 mm). The windows are eccentrically arranged (24 mm off axis) to allow radial beam scans. On both sides near the end flanges four pipes (inner diam. 54 mm) with standard flanges for 100 atm are welded into the vessel shell to accommodate the high voltage feedthroughs and for pump connection.

Also the sense wire feedthroughs are mounted on the cylinder to leave the end caps free and allow a fixed wiring to the inner cage. Up to 80 read-out feedthroughs are foreseen in two circles at each end of the vessel. Pressure tightening is made with Cu-seals everywhere. The overall leakage rate at 92 atm He measured with a He sniffer probe is $\leq 10^{-7}$ torr-l/s.

The cage of counter II consists of a central wire as sense wire (stainless steel, $\varnothing$ 20 $\mu$m) and a ring

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Fig. 1. Cross section of target type I. Region A: central cell, region B: drift space, region C: outer cells, SC: scintillators.

Fig. 2. Total view of pressure vessel for target type II.
of 72 potential wires (Cu–Be wire, $\varnothing$ 100 $\mu$m). As in counter I the support of the central wire is made with a thin mylar foil which is thermally shaped such as to serve as a spring load to the wire. The support rings for the potential wires are made of glass fiber epoxy (Stesalit).

The presence of large quantities of plastic material such as scintillator, plexiglass Stesalit and others within the proportional counter gas volume requires a continuous purification of the gas. Measurements of the outgassing of these materials show that a circulation speed of $\sim$1–101 is necessary to remove possible electronegative impurities to a level $\leq$1 ppm.

A nitrogen-cooled carbon adsorber column was connected in closed circuit to the target vessel. The circulation is forced through the density change of the H$_2$-gas in the purification column. All cross sections of the pipes were calculated taking into account the pressure drops in the carbon and filters to maintain the necessary circulation speed. Care must be taken to avoid local turbulences in the pipes which can effectively clog the system.

![Drift time measurements in target type I](image)

Fig. 3. Drift time measurements in target type I. Solid line results from computer calculations, open circles are measurements at 11.2 atm H$_2$, dots at 19.8 atm H$_2$.

![55Fe, 5.9 keV line measured in target type II in pure hydrogen at various pressures](image)

Fig. 4. $^{55}$Fe, 5.9 keV line measured in target type II in pure hydrogen at various pressures: (a) 10 atm, (b) 25 atm, (c) 40 atm. The narrow line at the right is a test pulse.
3. Measurements and conclusions

First drift time measurements were performed with a $\beta$-source in the target type I at CERN. A coincidence between the central wire, an outer cell and the scintillation counters ensured that the particle traversed the whole radius of the counter. An analysis of the charge pulse yields the drift time of the electrons across region B. In fig. 3 the measurements are compared with calculations based on the potential distribution.

Measurements with target type II were devoted to the study of resolution and gas gain in the lowest recoil energy range envisaged in the experiment (lower limit 5 keV). The spectra shown in fig. 4a, b and c were taken with $^{55}$Fe 5.9 keV photons at different pressures (10, 25 and 40 atm). Conditions and results are summarized in table 2.

The theoretical limit for the resolution of 5.9 keV photons in H$_2$-proportional counters is about 19% \(^{7,8}\). This value was not quite achieved here, at best 22% at 10 atm. Electronic noise, some uncertainties in the Fano factor and avalanche statistics have to be taken into account. The increase of the line width at higher pressures is here connected with the lower gas multiplication which could be achieved due to the relative increase of electronic noise. The relatively early onset of high voltage breakdown in the counter made it impossible to reach the voltage necessary for an increased gas gain. It is unlikely to be a principal cause, since at 10 atm a gas gain of almost $10^4$ was reached. We are therefore presently rebuilding the high voltage system in the counter.

<table>
<thead>
<tr>
<th>Pressure (atm)</th>
<th>hv (kV)</th>
<th>Resolution (%)</th>
<th>Gas gain</th>
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<tbody>
<tr>
<td>10</td>
<td>9.7</td>
<td>22</td>
<td>$7 \times 10^3$</td>
</tr>
<tr>
<td>25</td>
<td>14.7</td>
<td>25</td>
<td>850</td>
</tr>
<tr>
<td>40</td>
<td>19.9</td>
<td>27</td>
<td>600</td>
</tr>
</tbody>
</table>

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References
1) CERN proposal CERN/SPSC/76-74/SPSC/P76 14 (Sept. 1976).
2) T. Ekelöf, CERN 76-23 and references therein.
3) Manufactured by Le Croy CAMAC Model 2256.