RADIATION EFFECTS IN PROPORTIONAL CHAMBERS

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We report here the results of some studies on the deterioration of proportional chambers exposed to intense beams and sources. Using the "magic" gas (argon + isobutane + freon)\(^1\), it appears that proportional chambers develop discharges which seriously limit performance after exposure to very large particle fluxes. The construction of the two chambers used in this study is illustrated in Fig. 1. Not shown are the two nylon strings stretched across the middle of the chamber to eliminate the electrostatic instability\(^2\).

The schematics of high-voltage supply, signal extraction, and signal electronics are given in Figs. 2, 3 and 4. One may monitor the total current into the chamber, the total counting rate of pulses above 5 mV, and the counting rate of individual wires at any desired threshold.

For comparison with other chambers, one must account for the fact that three wires are grouped together and that our effective load per wire group is about 5 kΩ.

1. EXPOSURE

   a) Two chambers were exposed to a 0° intense neutral beam at the PS for two days, following a previous charged particle run of several days at relatively low intensity. Enough material was placed in the neutral beam upstream of the chambers for the charged particle rate, as measured by chambers and scintillators, to be 500 kHz integrated over the whole chamber, with a peak flux of about 500/cm² sec.

   b) One chamber was later exposed to a collimated strong strontium-90 source for two days. This β-ray source gave \(5 \times 10^5\) particles/sec into the chamber over an effective area of about 5 cm².

2. EFFECTS

   2.1 Visible effects

   The most striking effect of these exposures is shown in Fig. 5. There are clearly visible discharges in the chamber:

   i) The constellation marked 'G' was produced by smearing a small quantity of silicon vacuum grease over a preselected area of the high-voltage plane, reclosing the chamber, and irradiating with the source for several minutes.
ii) The unlabelled constellations were ignited during the beam irradiation. (They are probably of the same type as the preceding one, with the possibility that some deposit will remain after the mounting of the chamber.) Note that these constellations are not in the vicinity of the centre of the beam.

iii) The constellation 'R' has been created in a clean region after a 50-hour exposure to the strontium source: the large number of discharges due to the crossing of β-rays may induce the formation of a deposit on the high-voltage plane. This deposit could then be responsible for a visible effect such as that described in point (ii).

Independently of their distinct origins, the three types of constellations ultimately share the same general features.

Inspection with a magnifying lens shows that the discharges are dancing, whitish-blue glows on the sense wires. Apart from the movement within the borders, these constellations have fixed and reproducible locations.

2.2 Chamber current

With a gas mixture of about 0.4% freon, 33% isobutane, and 67% argon, and for a working high-voltage value placed 200 V after the beginning of the plateau, the normal "dark" current was about 5 µA and the current for $5 \times 10^5$ charged particles/sec was 50 µA. At the end of the beam exposure ($30 \times 10^5$ particles/cm²) there was a constant current of 50 µA in the chamber, without any beam. The current was strictly correlated to the visible discharges, about 10 µA/constellation. The discharges could be extinguished by decreasing the voltage to less than 4 kV. The ignition could be achieved at lower voltage by a few minutes exposure to the source, thus allowing selective production of the discharges.

2.3 Counting rates

A high counting rate of low-amplitude pulses is found on the wires covered by discharges, as illustrated in Fig. 6. In Fig. 7a is plotted
the counting rate as a function of voltage for a constellation wire. A hysteresis effect is clearly seen. The discrimination curve of Fig. 7b illustrates the amplitude dependence of the noise in 'quiet' wires and in 'hot' wires. The amplitude spectrum of pulses produced by a small source in coincidence with a scintillator is given in Fig. 8 for the two cases. A typical counting rate for a 'quiet' three-wire group is 100 Hz, compared to 100 kHz for a 'hot' wire group (both at 5 mV threshold).

The effect of the high rate can be seen in the coincidence pulse spectrum in which a large fraction of randoms are present.

2.4 Subsidiary effects

i) The discharges, although mainly visible on the sense wires, are sustained by the HV wires. When the chamber was opened, the sense-wire plane was rotated 180°; the constellations remained fixed with respect to the HV plane, and no new discharges were observed in areas fixed with respect to the sense wires.

ii) The discharges grow over long periods of time; in about two weeks of on-time, with no irradiation, the active area doubled itself.

iii) After a certain time, the constellation areas on the HV plane developed a white, powdery deposit. Black powdery deposits were found on both HV and sense wires, but with no correlation with the discharges.

iv) Saturating the gas at 0°C with isopropyl-alcohol reduces the visibility of the discharges by more than one order of magnitude. The current and counting rates, however, are reduced by perhaps a factor of only two.

v) Temporarily reversing the polarity of the chamber has no salutary effect on the discharges. Moreover, the myriad of small point discharges produced on the sense wires at -3 kV in this condition show no correlation with constellation position.

vi) There were indications of an over-all deterioration time of chamber performance as measured by wire group counting rates. A new chamber exhibited a wire group rate of 20 Hz, which progressed to 300 Hz over one month.
3. CONCLUSIONS

A consistent but not compelling hypothesis is that: i) appropriate material on the HV electrode produces discharges; ii) these discharges cause reactions in the gas, which results in a further deposit of appropriate material on the HV electrodes and increases the discharges; iii) intense radiation is sufficient to start the process; iv) it seems that the sense wires have no role in producing or maintaining the discharges; they only serve to make the discharges visible.

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REFERENCES

Figures captions

Fig. 1 : Chamber construction.
Fig. 2 : High-voltage circuit and signal electronics.
Fig. 3 : Test electronics for an individual wire.
Fig. 4 : Group electronics.
Fig. 5 : Photographs of constellations.
Fig. 6 : Counting rate of the wire groups for two different currents (with or without constellations).
Fig. 7 : a) Counting rate as a function of the high voltage.
       b) Spectrum of the pulses coming from a 'hot' wire group or a 'quiet' one.
Fig. 8 : Amplitude spectrum of pulses produced by a small β-ray source for 'hot' and 'quiet' wire groups.
GAS: Argon 72%, isobutane 27%, freon 0.46%
HIGH-VOLTAGE CIRCUIT

μA-meter

2.7 MΩ

2 x 22 groups

4.7 MΩ

4.7 MΩ

220 pF

Group of 32 HV plane wires

d.c. power supply

SIGNAL ELECTRONICS

To amplifier ("Output")

120 Ω

22 nF

22 m cable

Emitter-followers on chamber

-6 V

33 kΩ

-6 V

64 groups of three sense wires each

Fig. 2
GROUP ELECTRONICS (ALL WIRES)

FROM "OUTPUT"

64 lines

I.C. amplifiers
Z_in > 10 kΩ

Gate

Flip-flop

Level inverter

Pattern units

(Held open)

Reset after (200 nsec)

Pilot

Or + shaper

TTL NIM translator

Scaler

Stretched PMT signal

Delay

Coinc.

AMPLIFIER THRESHOLD = 5 mV
DIFFERENTIATION : R = 330
C = 220 pF

Fig. 4
Fig. 7
Fig. 8

○ 'Hot' wire group
● 'Quiet' wire group