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S.P. Denisov, S.V.Erin, N.N.Fedyakin

FIRST RESULTS ON A PERFORMANCE OF PROPORTIONAL COUNTERS FILLED WITH C_3F_8

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Abstract

Denisov S.P., Erin S.V., Fedyakin N.N. First results on a performance of proportional counters filled with C_3F_8: IHEP Preprint 99-35. – Protvino, 1999. – p. 7, figs. 6, refs.: 3.

The development of gas gain in proportional counters of different anode diameter, and filled with heavy perfluoroalkane C_3F_8 has been investigated. The possibilities of application C_3F_8 in gaseous tracking detectors are discussed.

Аннотация

Денисов С.П., Ерин С.В., Федякин Н.Н. Первые результаты по исследованию работы пропорциональных счётчиков, наполненных C_3F_8: Препринт ИФВЭ 99-35. – Протвино, 1999. – 7 с., 6 рис., библиогр.: 3.

Исследовались особенности развития газового усиления в пропорциональных счётчиках с разным диаметром анода, наполненных тяжёлым перфторидом C_3F_8 и оценивается возможность применения C_3F_8 в газовых трековых детекторах.

Introduction

Heavy perfluoroalkanes C_3F_8 and n-C_4F_{10} have been widely used in a Switching High Power Technique (where after a long accumulation of energy very high power is transmitted to load for a very short time) for their very good transport properties and high dielectric strength. In HEP and nuclear physics, CF_4 was the first that was used as a dopant to standard gas mixtures in proportional and coordinate detectors. Then C_4F_{10} was used as a working gas for RICH detectors, due to very high density and good transparency to optical radiation. And very recently in gas calorimetry, where the main problem is high pressure in a large volume, C_3F_8 is supposed to be used to reduce high pressure of gas, while keeping the same amount of active material. Now attention is drawn to proportional gas detectors, where the requirement to increase ionization in a gas layer and to improve the efficiency is very frequently satisfied at the expense of using flammable and poison gases (DME, etc.). The purpose of the paper is to study the possibility of using C_3F_8 as a working gas for proportional counters applications.

1. Experimental Set-Up

We have investigated four cylindrical proportional counters with cathode diameter 10 mm and anode wires diameters 11 μm, 20 μm, 50 μm and 100 μm, correspondingly. The composition of all the wires with the exception of 100 μm was tungsten with 3% of Re and they have the Au coating. 100 μm wire was manufactured from berillium bronze. Cathode tubes were made from stainless steel and the thickness of their walls was 70μm. HV was applied to cathode tubes and a signal was readout from anode wires with a low-noise preamplifier, implemented by monolithic integrated circuit EL2074 with gain ≈20 and cut-off frequency 75 MHz and noise referred to input $2.2\frac{nV}{\sqrt{Hz}}$. Signal waveforms and pulse height spectra of Fe^{55} and Sr^{90} radioactive sources were measured with a digital oscilloscope TDS724. The film with Fe^{55} has been attached directly to cathode tube and simulated point-like ionization, while a collimated beam from Sr^{90} provided MIP- like ionization with the help of magnetic monochromator. All the tests were made using the "electronical " freon with the stated purity 99.99% (manufactured for microelectronics applications), and usual commercially available freon with stated purity 99%.

2. Results

Counting performance of counters with different wire diameters is shown in Fig.1a. The impact of the freon purity on the counting rate performance is illustrated in Fig.1b, where the results of measurements for the tube with anode diameter 20μm which was filled with "electronical " and industrial graded freons, correspondingly, are presented. It is seen that the counting rate measured with the "electronical" freon exhibits more abrupt transition to plateau. Purification of industrial freon by means of circulation through nitrogen traps is very efficient and allows are to get exactly the same performance as with very expensive "electronical" freon. The efficiency of MIP detection was measured to be about 10%. The average waveforms measured with TDS724 digital scope after MIP (Sr^{90}) and point-like ionizations (Fe^{55}) are presented in Fig.2 for the 11μm wire counter. In both cases the signal duration is about 2-3 ns, while average amplitude to MIP is almost twice compared to that from a point-like source. The dependencies of a collected charge on an electric field strength for all the wire diameters are shown in Fig.3. Maximum gain (charge) before transition to self-sustained discharge was achieved for 20μm counter. The relative widths of pulse height spectra taken after Fe^{55} and Sr^{90} irradiations are shown in Fig.4. It is seen that the energy resolution in the case of point-like ionization (Fe^{55}) is about 50%, while in the case of MIP irradiation the energy resolution is only 30%. The pulse height spectra taken with tubes having different wire diameters can be found in Fig.5.

3. Discussion

The observed performance of counters filled with C_3F_8 may be attributed to a very strong dependence of attachment on electric field strength [3]. Using experimental dependencies of electron attachment and multiplication coefficients, taken from [3], we have calculated the probability for at least one electron after 1mm path in C_3F_8 to survive at atmospheric pressure as a function of electric field strength. This dependence, illustrated in Fig.6, has three quite flat parts, separated by two rather sharp transitions:

- ionization mode and relative weak field, no attachment as well as multiplication.
- transition between ionization and multiplication, attachment dominates over multiplication, so called "dead zone".
- proportional mode, where multiplication exceeds attachment.

The ionization calorimeters filled with pressured gas [2] operate mainly under relative by weak uniform field of the first area. A survival probability of drifting electrons in the second area is quite small, that is why reasonable operation of proportional counters is possible only in the last area. Eventually, the low efficiency of counters filled with freon C_3F_8 can be attributed to losses of electrons, travelling through the "dead zone". Only electrons deposited in a cylinder of few hundreds micron diameter around the wire give the effective contribution to the observable signal, and it explains why their duration is so short. The attachment properties of C_3F_8 must significantly reduce a space charge accumulation around the wire, which allows one to use the counters filled with C_3F_8 for high rate and hard radiation environment conditions, for example, for the measurement of profiles of high intensity particle beams.

4. Conclusions

- We have observed very fast signals with duration as little as 2-3 ns directly on 50Ω input of oscilloscope and the signal waveform does not depend on the type of ionization (extended or point-like),
- The average of signal amplitude depends on the kind of ionization: MIP response is two times higher than to point-like ionization.
- Efficiency for cylindrical geometry was as little as 10%, which can be attributed to the existence of extensive “dead zone”, where the survival probability is practically zero.
- Maximum gain before the transition to a self-sustained discharge was attained using 20μm wire.

There are different ways to increase efficiency :

to use a parallel plate chamber with uniform field exceeding at least 100kV/cm or to decrease the transition between a drift gap and amplification gap (multi-stage approach).

A set of low-efficiency tubes filled with C_3F_8 can be successfully applied to problem of profile measurements of high intensity primary and secondary particle beams.

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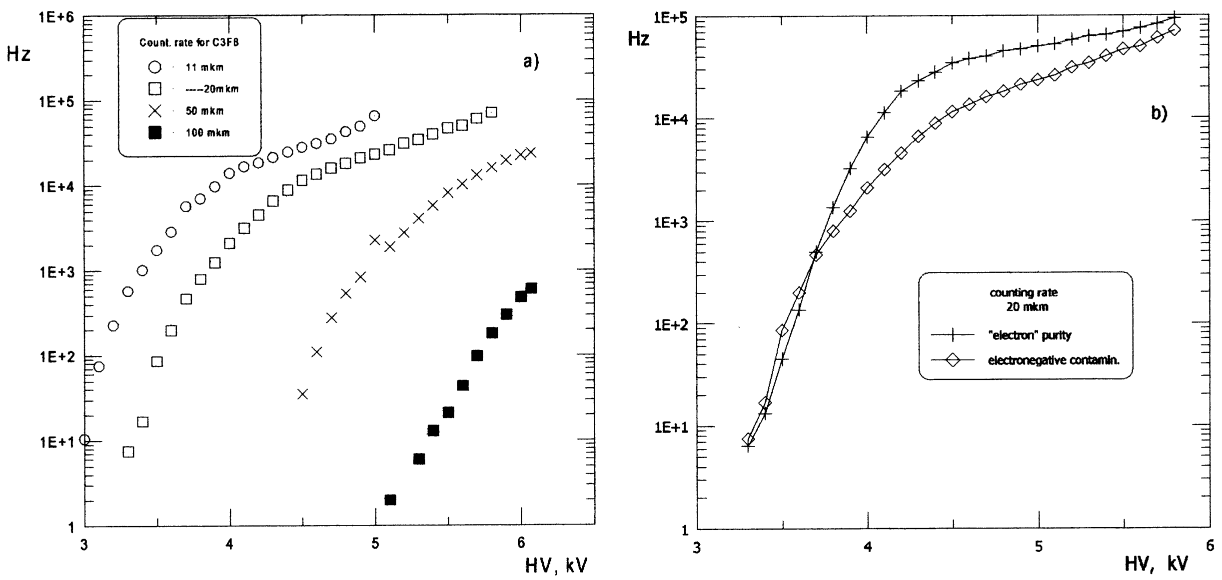


Fig. 1. Counting rates measured a)with “electronically graded” freon -11μm, -20μm, -50μm and -100μm diameter anode wire; b) with “electronical”(...) and commercially available (...) freons, correspondingly.

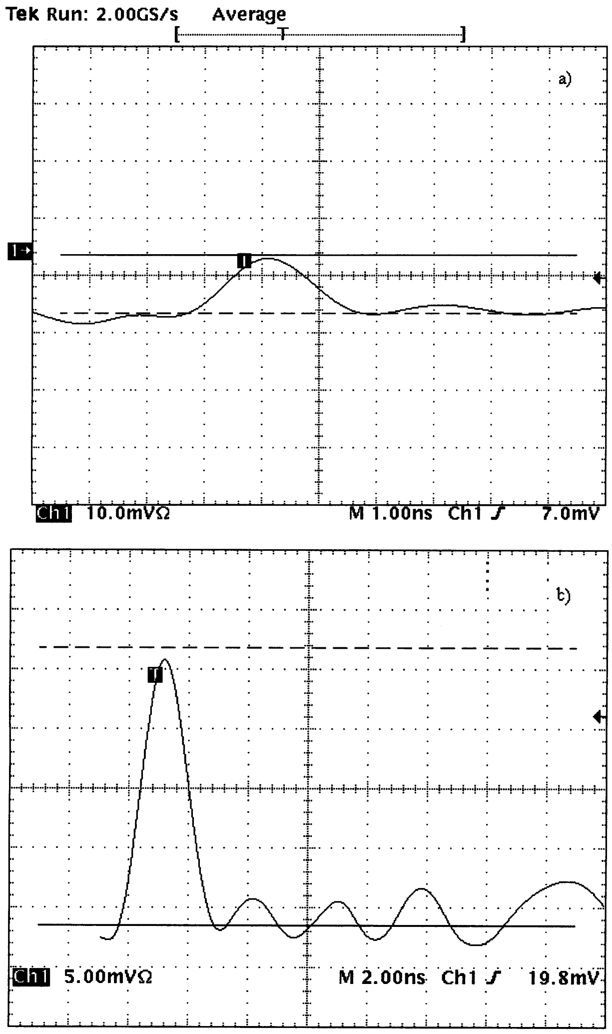


Fig. 2. Average signal waveforms, measured directly on 50Ω inputs of TDS724 oscilloscope: from Fe^{55}(a) and from Sr^{90}(b), radioactive sources, correspondingly.

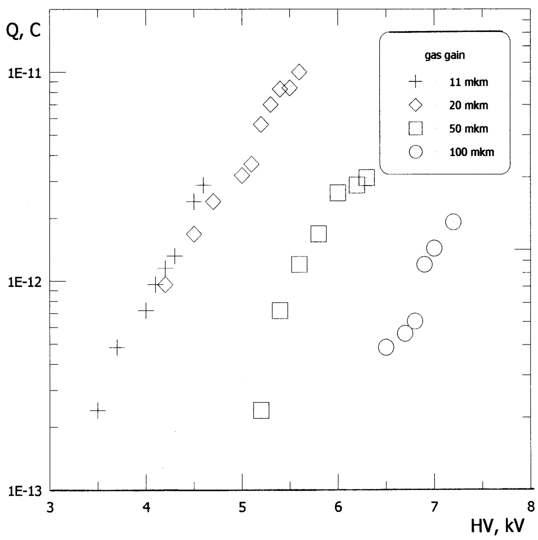
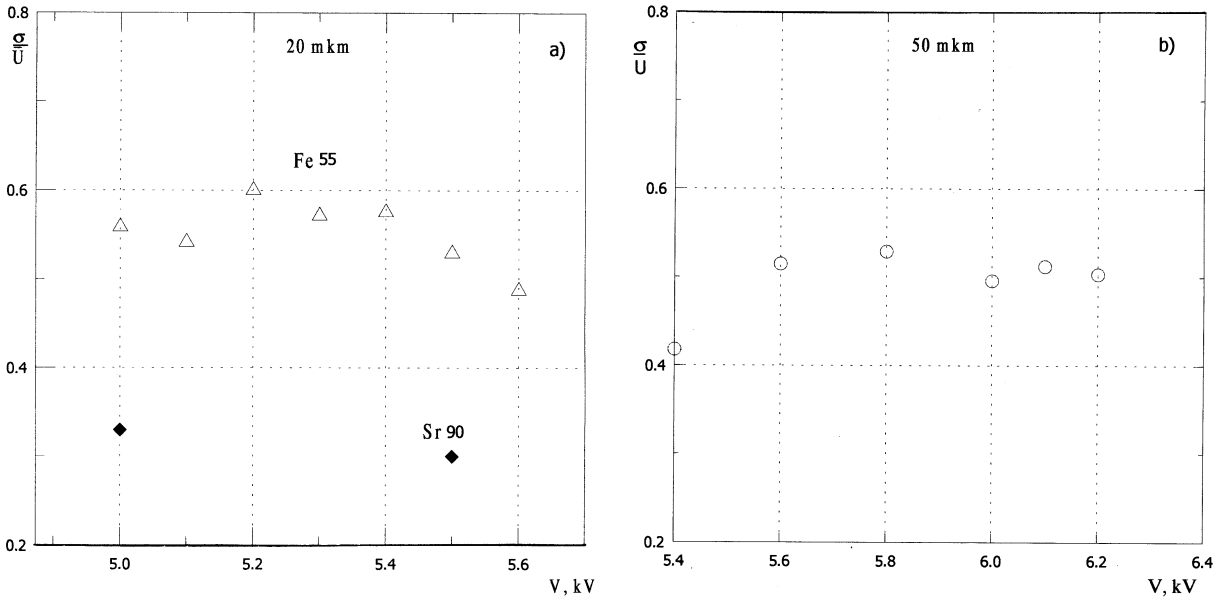


Fig. 3. Gain versus electric field strength for:11μm, 20μm,50μm and 100μm diameter anode wires.



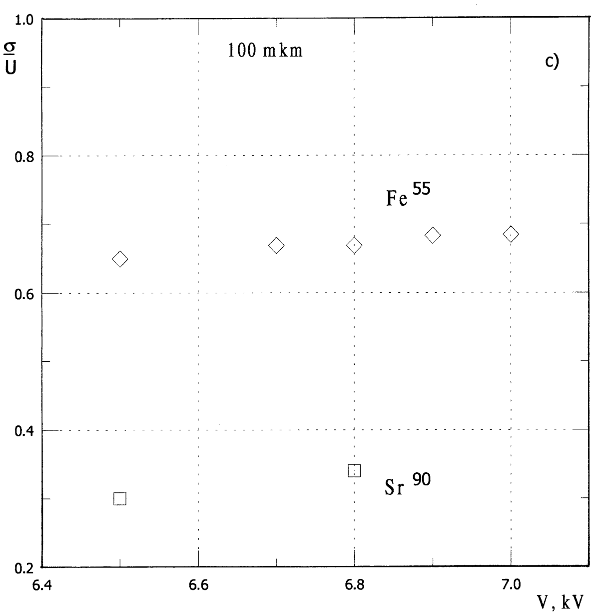


Fig. 4. Relative spectrum widths after Fe^{55} and Sr^{90} irradiations taken with 20μm (a), 50μm (b) and 100μm (c) anode wire diameter counters, correspondingly.

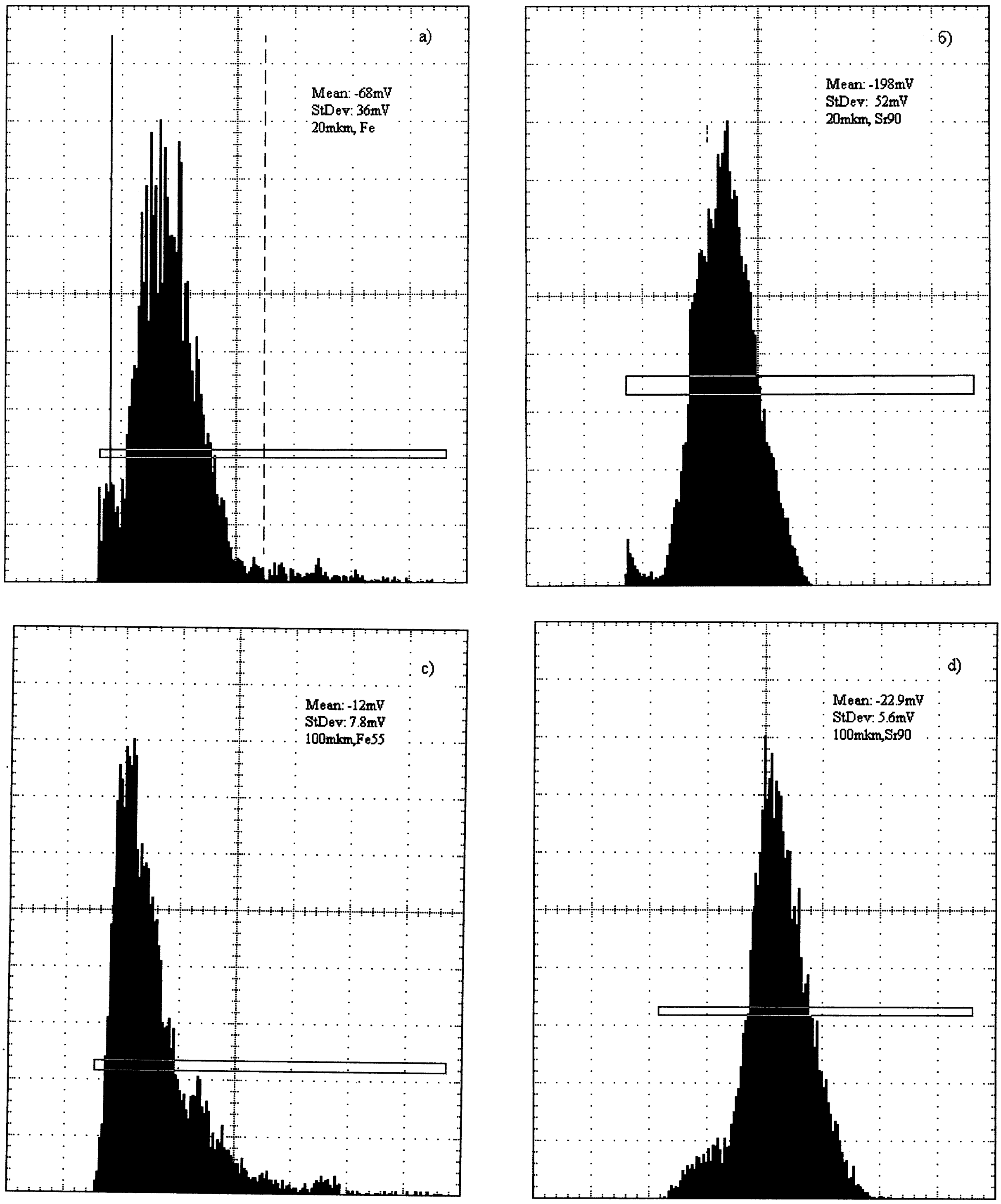


Fig. 5. Pulse height spectra, measured from Fe^{55} and Sr^{90} irradiations for 20μm and 100μm anode wires.

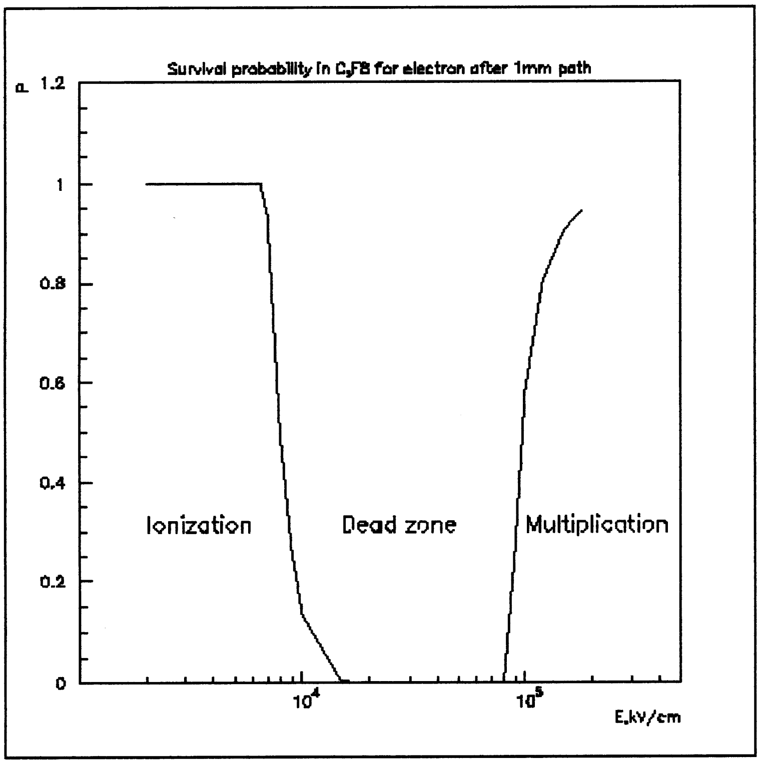


Fig. 6. The survival probability to survive for at least one electron after 1mm path in C_3F_8 at atmospheric pressure as a function of electric field strength.

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