Nuclear Instruments and Methods in Physics Research A235 (1985) 91-97
North-Holland, Amsterdam

SENSITIVITY OF STREAMER MODE TO SINGLE IONIZATION ELECTRONS

G. BATTISTONI, P. CAMPANA, U. DENNI, B. D'ETTORRE-PIAZZOLI, E. IAROCCI, M. MESCHINI and F. RONGA

INFN, Laboratori Nazionali di Frascati, 00044 Frascati, Italy

Received 20 July 1984

Making use of electrons extracted by UV photons on aluminum cathodes, the ionization threshold of the streamer mode has been measured, and a fully efficient operation range for single ionization electrons has been found. Operation conditions have been investigated for Ar–isobutane and He–isobutane gas mixtures, and 50 and 100 μm wire diameters.

1. Introduction

The knowledge of the ionization threshold of streamer mode in wire detectors is of relevance in some experimental applications. Within the design work for an experiment to search for magnetic monopoles [1], we have measured the streamer response to single ionization electrons.

The streamer generation mechanism can be qualitatively sketched as follows. Clusters of ionization electrons drift toward the wire, where proportional multiplication takes place. For proper operation conditions (wire diameter, gas mixture and high voltage), the multiplication factor is so high that recombination becomes relevant. The UV photons emitted in this recombination process are enough to give rise to secondary multiplications in the nearby region. Those avalanches rapidly melt together in an ionization column (streamer) extending radially from the wire to the cathode. With minimum ionizing particles an operation range exists where only streamers are generated. It turns out that the detection efficiency of streamer tubes in that range is not appreciably different from the geometrical acceptance [2]. This is an indication that short segments of tracks (i.e. only few primary electrons) can give rise to a multiplication over the threshold for streamer generation.

The streamer sensitivity to single ionization electrons can be measured by studying the response of streamer tubes to isolated photoelectrons extracted by UV light, either from an aluminum cathode [3], or from the atoms of a photoionizable vapour, such as benzene or TEA [4], added to the gas mixture.

Here we report the results obtained using the first of the above mentioned methodes, for 50 and 100 μm wire diameters, and for Ar–isobutane and He–isobutane gas mixtures. The latter gas mixture has been tested in order to exploit a recently suggested energy loss mechanism for monopoles in light elements, in the velocity range from $10^{-4}c$ to $10^{-3}c$ [5].

2. Experimental results

We have built two test tubes made of extruded aluminum with 1 cm^2 cross section, and 50 and 100 μm wire diameters. On both tubes a 2 mm diameter quartz window is inserted at the center of one side, in order to let the UV light in. The wire pulses are discriminated with a 20 mV/50 Ω threshold and then sent to a scaler.

The singles counting rate as a function of HV has been measured with an uncollimated ^{90}Sr source. The results are shown in figs. 1a and 2a for the two tubes, together with the wire pulses at the knee of the curve. The plateau of these curves is substantially coincident with the efficiency plateau, as measured with minimum ionizing particles, uniformly illuminating the tube [2]. The tubes were exposed to the UV light of a Hg vapour lamp, filtered by a quartz monochromator. The singles counting rate, normalized to the relative intensity of the lamp, is shown in fig. 3 as a function of the wavelength for the 50 μm wire tube at fixed voltage ($\simeq$ 100 V above the knee of the ^{90}Sr singles rate plateau). The lamp intensity was measured by means of a calibrated thermopile. A similar result was obtained for the 100 μm wire tube. The measured photoelectric threshold is consistent with the expected one [6].

We have fixed the wavelength at 2500 Å, near a Hg emission line, to perform the following measurements. In fig. 1b the singles counting rate as a function of HV is shown for the 50 μm wire tube; the cosmic ray and radioactivity background ($\sim 10^{-2}$ Hz per mm of wire) has been subtracted. A plateau is found, showing that an efficient operation range exists for single electrons.

0168-9002/85/$03.30

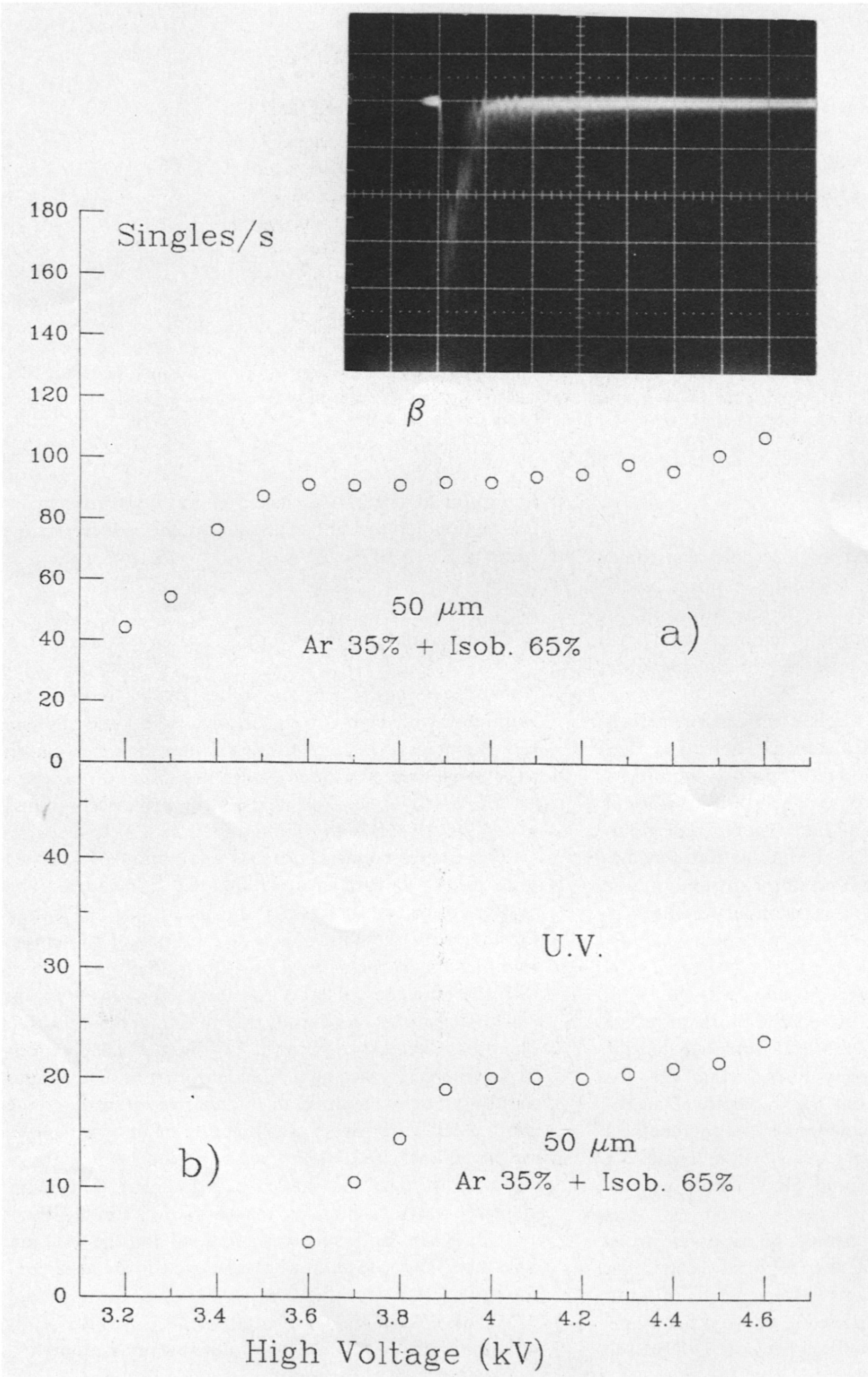

Fig. 1. Singles rate plateaux and wire pulses (at 3.6 kV) for β-rays (a) and photoelectrons (b). Aluminum tube 1 × 1 cm^2 cell size, 50 μm wire, gas mixture: Ar 35% + isobutane 65%. Vertical scale: 20 mV/div.; horizontal scale: 50 ns/div.

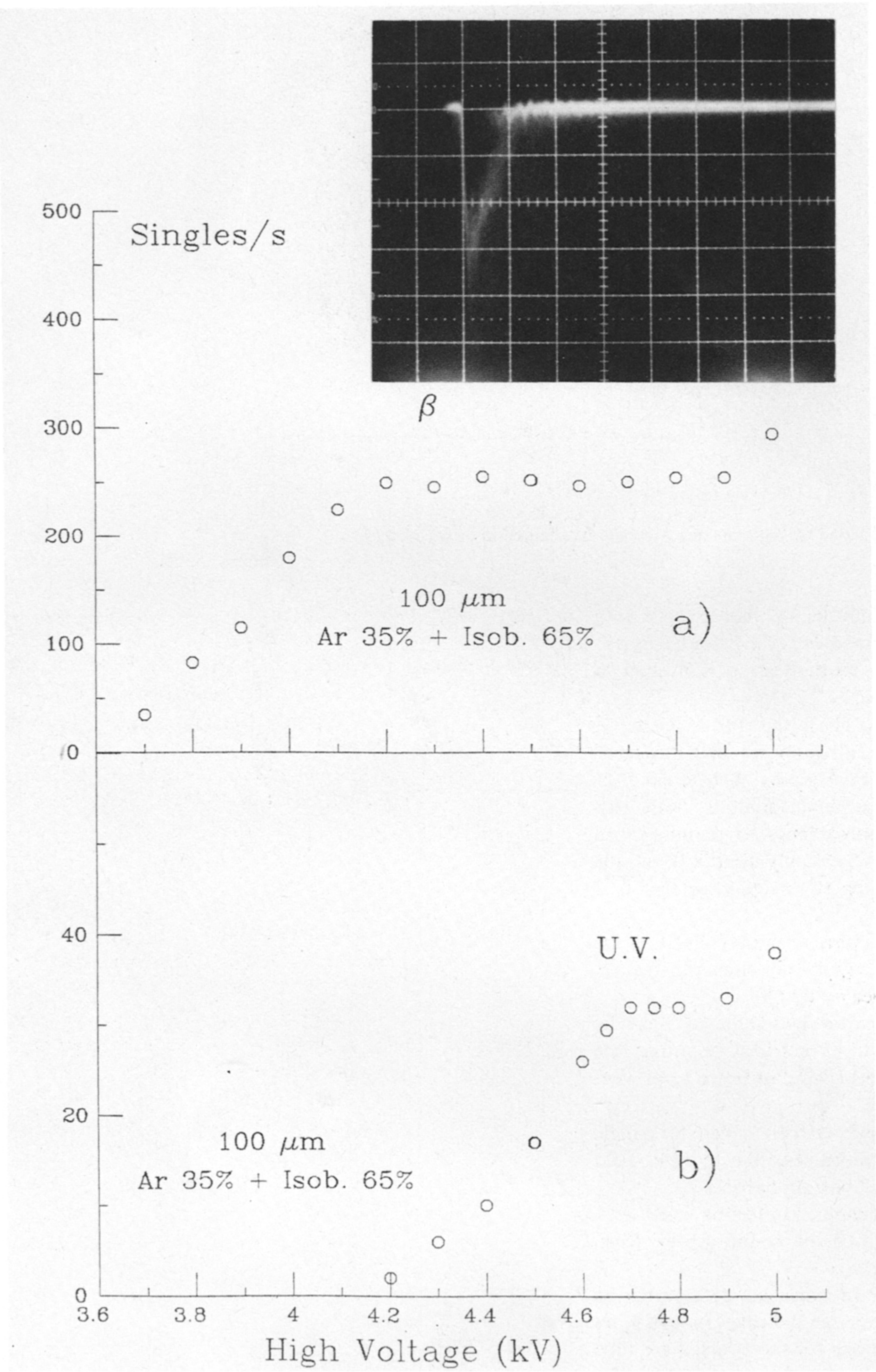

Fig. 2. Singles rate plateaux and wire pulses (at 4.2 kV) for β-rays (a) and photoelectrons (b). Aluminum tube 1 × 1 cm^2 cell size, 100 μm wire, gas mixture: Ar 35% + isobutane 65%. Vertical scale: 20 mV/div.; horizontal scale: 50 ns/div.

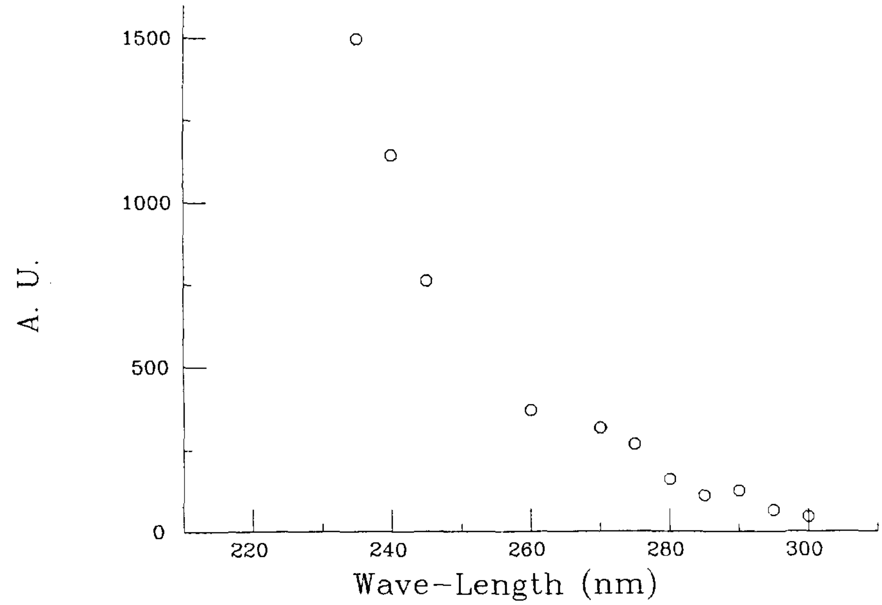

Fig. 3. Singles counting rate divided by relative lamp intensity as a function of wavelength.

The knee of this curve is shifted by about 300 V with respect to the plateau obtained with the β-source, showing that a higher primary multiplication is needed to reach the streamer threshold.

In order to have a direct check that full efficiency is really achieved in the plateau region, we have measured the percentage of proportional pulses at different high voltages by means of pulse height analysis, both with UV lamp on and off. Approaching the photoelectron plateau, proportional pulses gradually disappear and the inefficiency at the beginning of the plateau region is $\leq 2\%$.

The same measurements have been performed on the 100 μm wire tube and the results are shown in fig. 2b. Now the knee shift is higher ($\simeq 500$ V).

It must be noticed that the light intensity must be kept low enough in order to have a local counting rate below ~ 40 Hz over 2 mm of wire, in order to prevent two effects:

1) inefficiency due to space charge, which for single electrons is obviously more sensitive to local field value than for mininum ionizing particles,
2) a sensitization phenomenon manifesting itself as a steady increase in time of the counting rate level, until saturation is reached.

We have compared the streamer charge distribution obtained with photoelectrons and β-rays. In fig. 4 are shown the charge distributions for the 50 μm wire tube at the beginning of the β-rays plateau (3.7 kV), for β-rays (a) and photoelectrons (b). In the latter case single streamers are predominant. It can be also seen that there is a shift of $\sim 20\%$ in the single streamer

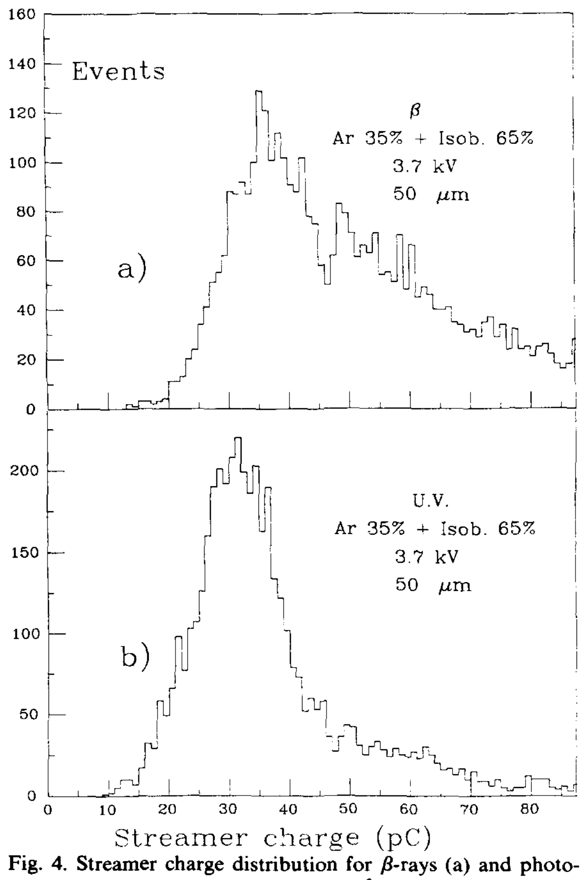

Fig. 4. Streamer charge distribution for β-rays (a) and photoelectrons (b). Aluminum tube 1×1 cm^2 cell size, 50 μm wire, gas mixture: Ar 35% + isobutane 65%, 3.7 kV.

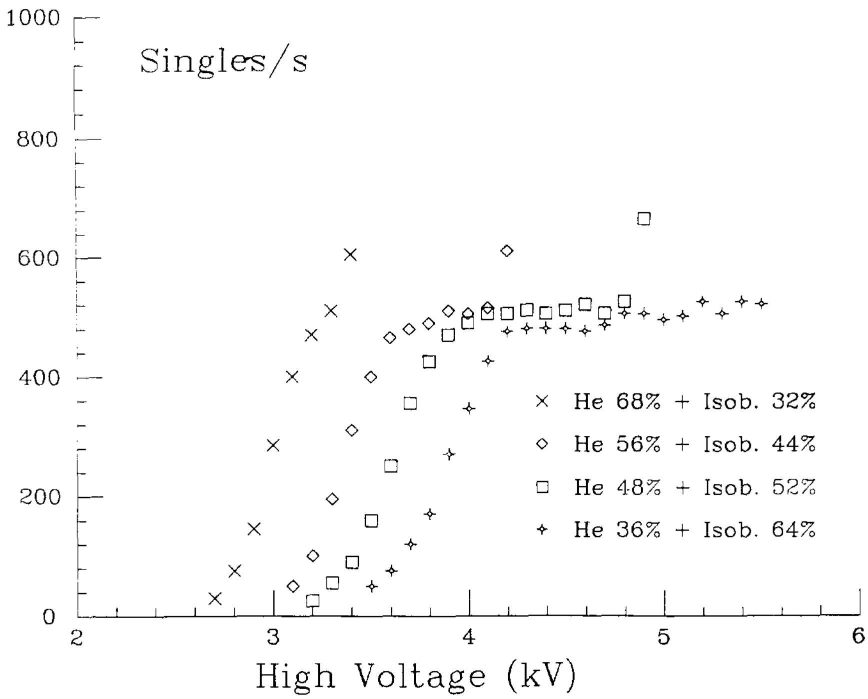

Fig. 5. Singles rate plateaux for β-rays at different He–isobutane fractions. Plastic streamer tubes, 8×8 mm^2 cell size, 100 μm wire.

charge peak value between the two cases. It shows a small dependence of streamer charge on the triggering primary avalanche charge. In this measurement we took care to exclude afterpulses, whose generation is relevant for aliminum cathodes [3], which we have used only to extract photoelectrons easily. Graphite cathodes are planned to be employed in experimental applications.

We have tested helium instead of argon in the gas mixture, for the reason already mentioned. Different fractions have been tested making use of a plastic streamer tube module of the same type used in the Mont Blanc proton decay experiment [7]. Streamer mode is achievable; the singles rate plateaux for β-rays are shown in fig. 5. Now in order to get approximately the same performance (the same plateau width and pulse duration) of the above mentioned argon gas mixture, only 50% of isobutane can be used.

We have measured the response to photoelectrons of the aluminum tubes with the He + isobutane (1 + 1) gas mixture. Singles counting rate curve and wire pulses are shown in figs. 6a and 6b for the 50 μm wire tube. The voltage range of operation is shifted down of ~ 200 V with respect to the equivalent Ar + isobutane gas mixture. As far as the single electrons plateau is concerned, the knee shift with respect to minimum ionizing particles is ~ 400 V.

Streamer charge distributions at the beginning of the single electrons plateau (3.8 kV) are shown in fig. 7. In this respect, slight differences between helium and argon gas mixtures are of negligible importance for detector operation.

The same measurements have been performed for the 100 μm wire aluminum tube, confirming the less favoured operation for single electrons detection, the plateau shift becoming ~ 600 V.

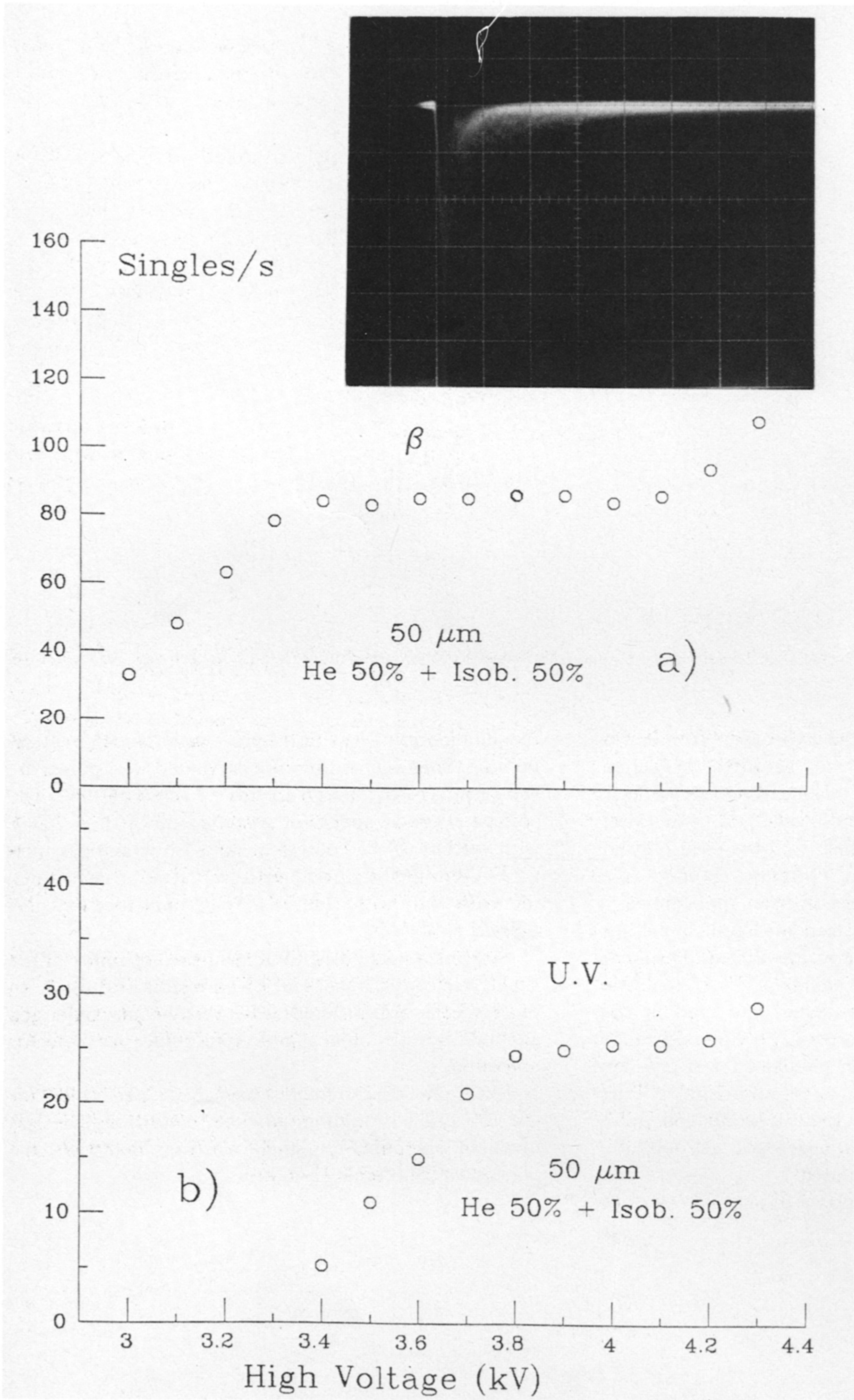

Fig. 6. Singles rate plateaux and wire pulses (at 3.4 kV) for β-rays (a) and photoelectrons (b). Aluminum tube 1×1 cm^2 cell size, 50 μm wire, gas mixture: He 50% + isobutane 50%. Vertical scale: 10 mV/div.; horizontal scale: 50 ns/div.

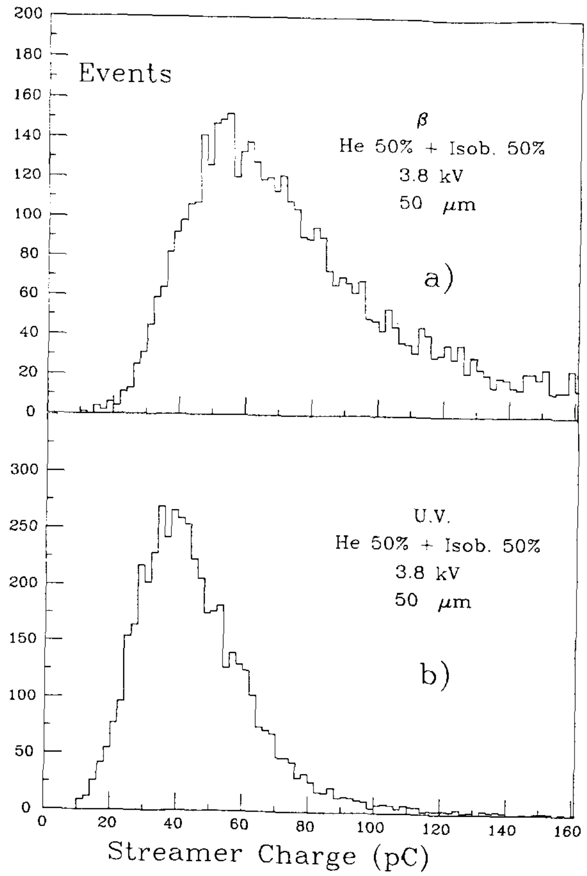

Fig. 7. Streamer charge distribution for β-rays (a) and photoelectrons (b). Aluminum tube 1×1 cm^2 cell size, 50 μm wire, gas mixture: He 50% + isobutane 50%, 3.8 kV.

3. Conclusions

We have shown that with simple devices like streamer tubes, one can have localized and efficient detection of single electrons, with 1 mA signals, no noise, and uncritical voltage and gas settings.

Beyond the application in experiments to search for low ionizing particles, we want to mention the possibility of using drift tubes operated in streamer mode. Here the first electron sensitivity could give an improved space accuracy [8], with a cheaper readout electronics due to the big and fast signals. Furthermore, streamer tube devices flowed with TEA, or other photoionizable compounds, could find applications as UV detectors also outside particle physics.

We want to thank R. Habel for helpful discussions and the PULS group of LNF for providing us with part of the equipment. We are grateful to G. Mazzenga who built the test tubes.

References

[1] Letter of intent for a large area detector at the Gran Sasso laboratory, INFN-CNR-CERN, unpublished.
[2] G. Battistoni et al., Nucl. Instr. and Meth. 164 (1979) 453.
[3] G. Battistoni et al., Nucl. Instr. and Meth. 217 (1983) 433.
[4] E.P. de Lima et al., IEEE Trans. Nucl. Sci. NS-30 (1983) 90.
[5] S.D. Drell et al., Phys. Rev. Lett. 50 (1983) 644.
[6] See for instance R. Suhrmann and J. Pietrzyk, Z. Physik 122 (1944) 600.
[7] G. Battistoni et al., Phys. Lett. 133B (1983) 454.
[8] J. Va'vra, SLAC PUB 3131 (1983); MAC group, private communication.