Performance of proportional counter filled with Xe + 5% TMA under high count rate

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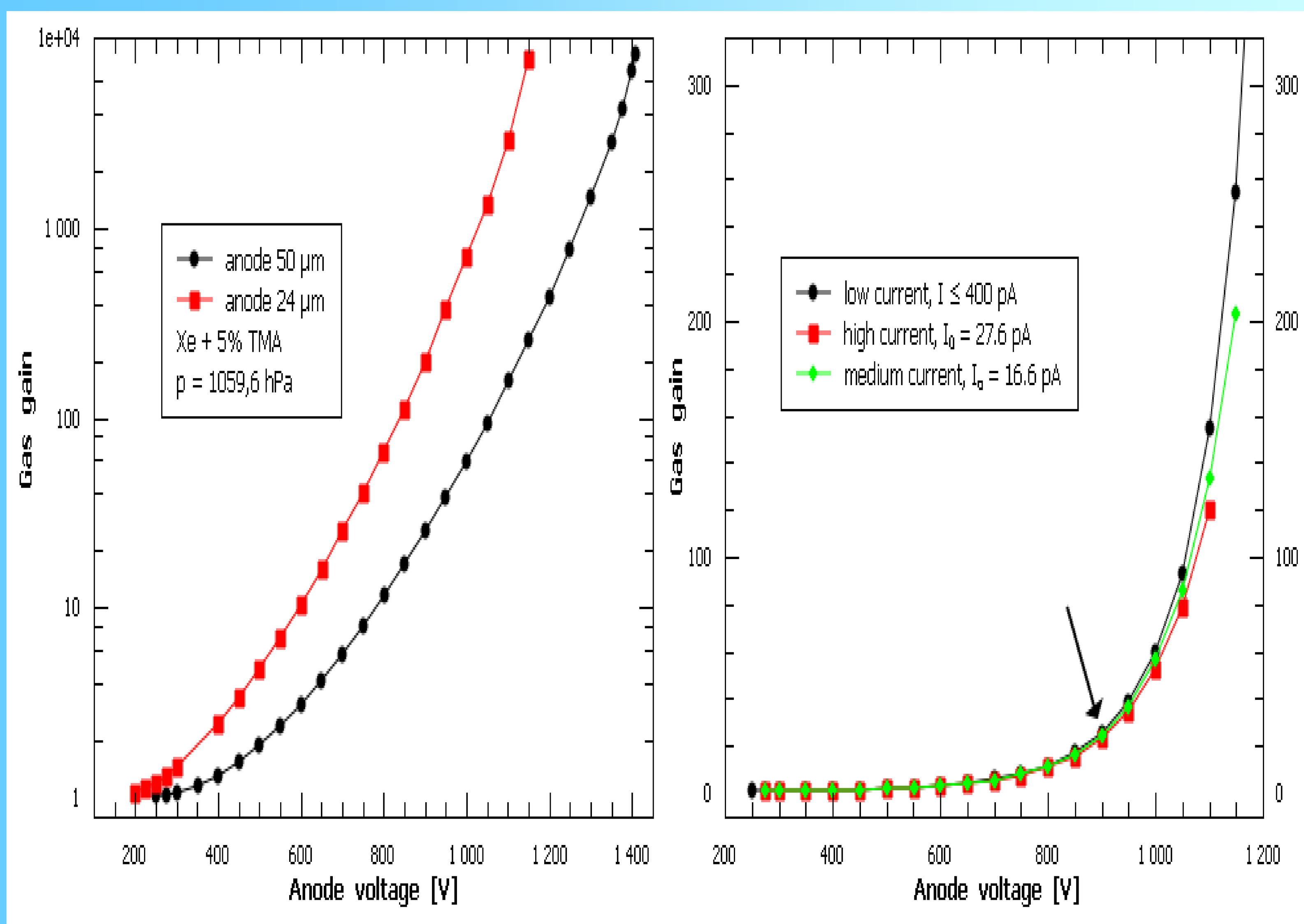
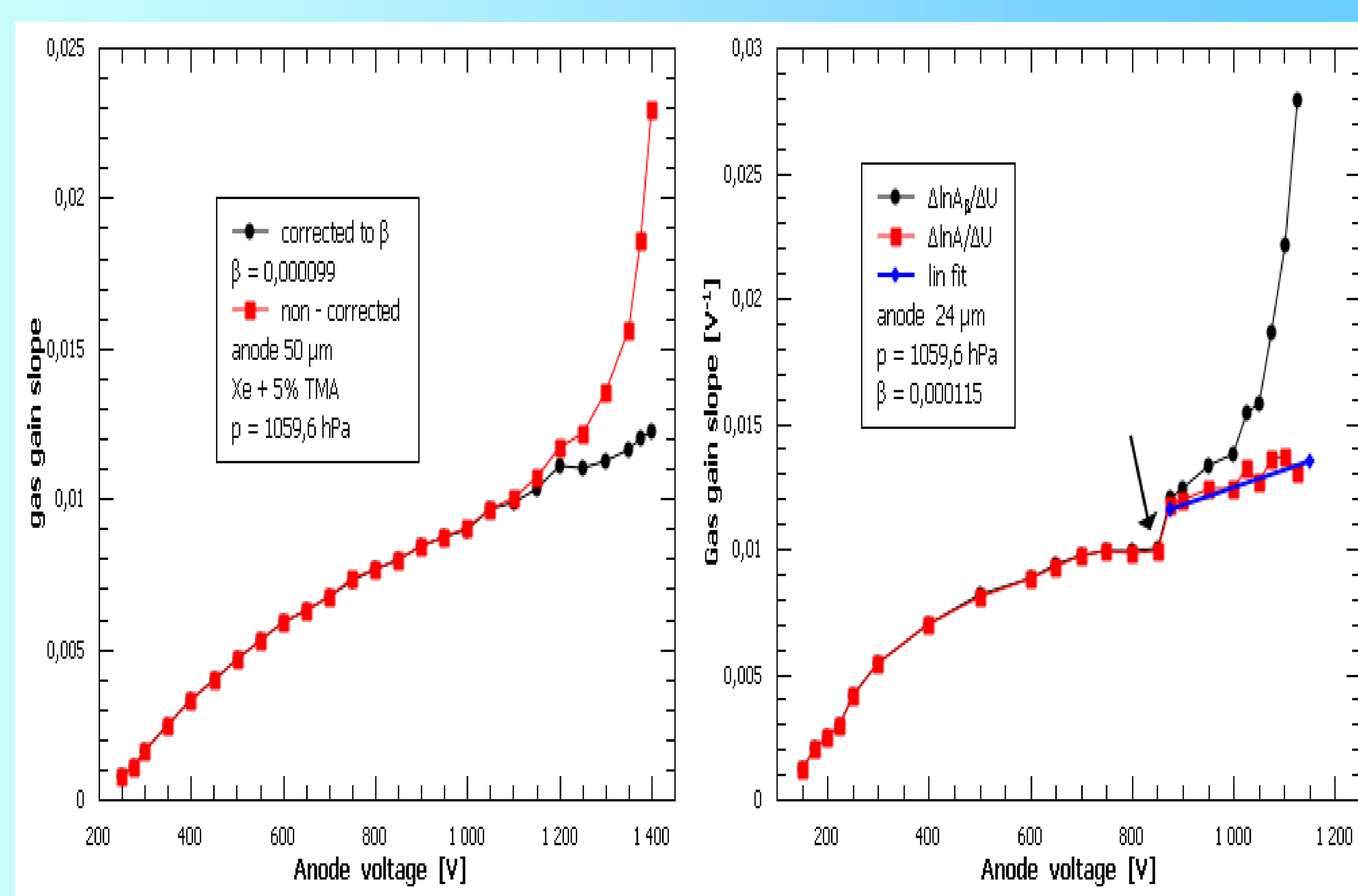
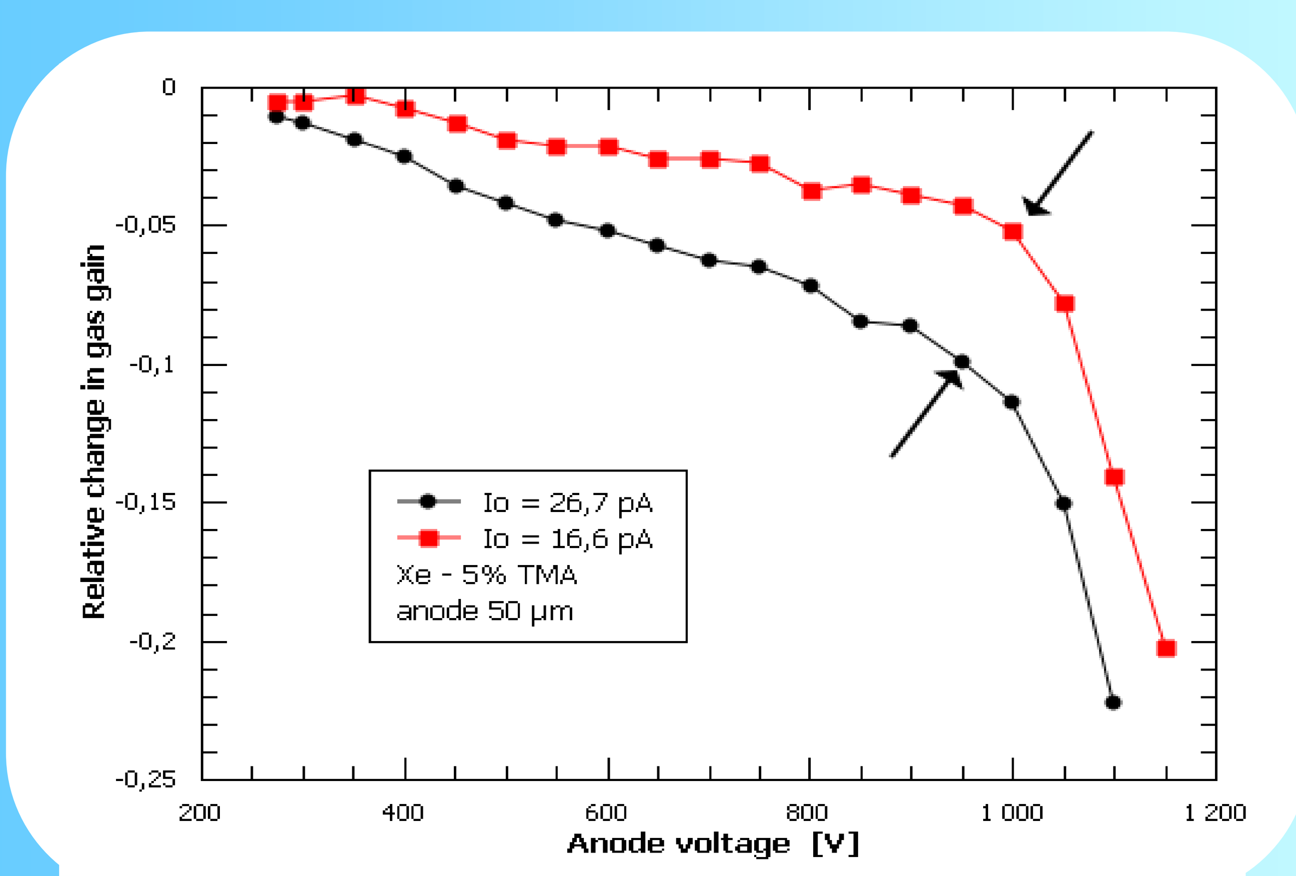


The total space charge effect includes the cumulative effect of positive ions created from many different avalanches. The presence of slowly moving positive ions in the avalanche multiplication region reduces the electric field simultaneously decreasing the gas amplification factor. The gas gain has been measured as a function of the applied voltage for a low (Fig. 1) and high (Fig. 2) count rate by means of the current method for sealed cylindrical proportional counters of radius b = 12,5mm with an axially placed anode of radius a = 24 and 50 µm, respectively. The gas gain curves covered the whole gas gain region from the ionisation chamber to that close to continuous discharge. Gas gain as the function of the applied voltage was determined for 5,9 keV X-rays (^{55}Fe radiation source) of varying intensity (the current was always below 400 pA) (Fig. 1) and of constant high radiation intensity, (Fig. 2). For any count rate there is always a critical voltage indicated by the arrow in Fig. 2, which divides the operation range of the counter into two regions. In the region below the arrow no changes in the gas gain with a count rate are observed. Above the arrow there is already an influence of the space charge of positive ions in the avalanche multiplication region, which reduces the gas gain.

Fig. 3 and 4 show the tangent of the angle of inclination of the gas amplification curve, i.e. the expression $\Delta \lg A / \Delta U$ as a function of the voltage between the anode and the cathode. Characteristic is a strong increase in the slope of the gas amplification curve above the 1100 V, which is associated with the occurrence of secondary effects, described by the second Townsend ionization coefficient, β. The slope of the gas gain curve corrected due to β coefficient is also shown. Figure 3 shows the slope of the properly measured gas gain curve. On Fig. 4 the arrow indicates the voltage at which the reduction in radiation source intensity was made. A jump on the gas gain curve is observed. To the left of the arrow, the slope of the gas gain curve is too low, this is due to the space charge deforming the electric field around the anode. The current flowing through the counter at this voltage before the reduction of radiation intensity was 1.46 nA. Summing up, calculation of the slope of the gas amplification curve can be an indicator of correctness of the gas gain measurements





The values of applied anode voltages over which a reduction in gas gain due to space charge effect is observed are marked by the arrows in Fig. 2 and 5. The current, *I*, flowing through the counter can be expressed by the following expression :

$$I = (\Delta E/W) \times A \times R \times e, \qquad (1)$$

where *ΔE* is the deposited energy by a single registered particle, *W* is the energy required to produce an ion-electron pair, *R* is the count rate in cps and *e* is the elementary charge. Thus, *R* can be calculated from equation (1)

$$R = (I \times W)/(\Delta E \times A \times e) \qquad (2)$$

and

$$R_{max} = (I_{cr} \times W)/(\Delta E \times A \times e) \quad \text{here} \qquad (3)$$

R_{max} is the maximal count rate not affected by the space charge effect and I_{cr} is the highest current that can flow through the detector without deforming the electric field (current corresponding to anode voltage shown by the arrows in Fig. 5).

Short summary

The gas gain has been measured as a function of the applied voltage for a low and high count rate by means of the current method for sealed cylindrical proportional counters of radius b = 12,5mm with an axially placed anode of radius a = 24 and 50 µm, respectively, from the ionisation chamber to that close to continuous discharge for Xe + 5% TMA mixture. The second Townsend ionization coefficient β is equal to $9,9 \times 10^{-5}$ for a = 50 µm and $1,15 \times 10^{-4}$ for a = 24 µm. The β coefficient determines directly the maximum stable gas gain and for a = 50 µm it is A ~ 600 and for a = 24 µm is A ~ 450 (the ratio $A_\beta/A \sim 1,06$ was the criterion). For both counters the critical current over which the reduction in the gas gain due to space charge manifests itself is ~ 900 pA. The R_{max} calculated from Eq. (3) is ~ 30 kcps for deposited energy of 5,9 keV (^{55}Fe radiation source) and gas gain A ~ 500. It is absolutely enough for some measurements like X-rays fluorescence analysis or in searching of the neutrino-less double beta decay (the NEXT Experiment) but absolutely not enough for the HEP application.