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OPERATING PROPERTIES OF STRAW-TUBE

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The initial results of the study of thin-wall mylar tubes ("straws") made under the laboratory conditions are presented. The maximal avalanche charge allowing the reliable detector operation is ~ 10 pC, the spatial accuracy σ_x near the anode wire at 3 atm of pure isobutane is $\cong$ 45 μm. The good separation of charge signals from electrons and X-rays was obtained with the Xe:iso-C_4H_{10} = 94:6 gas mixture. Tubes 5 mm in diameter withstand the pressure of 8 ÷ 12 atm.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Характеристики цилиндрического счетчика с катодом из алюминизированного лавсана

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Приведены начальные результаты методических исследований тонкостенных лавсановых трубок, изготовленных в лабораторных условиях. Максимальный заряд в лавине, при котором возможна стабильная работа детектора, составляет ~ 10 пКл, оценка координатной точности детектора, наполненного чистым изобутаном при давлении 3 атм, вблизи анодной проволоки $\sigma_x \cong$ 45 мкм. Получено хорошее разделение сигналов от электронов и рентгеновских γ-квантов по заряду на смеси Xe:iso-C_4H_{10} = 94:6. Трубки диаметром 5 мм выдерживают внутреннее давление 8 ÷ 12 атм.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Thin-wall mylar tubes called "straws" are now widely used as an elementary drift cell of tracking systems/1-4/. This is first of all due to the reliability of straw tracking devices as compared with conventional jet chambers as there are no innumerable cathode and field wires. Besides, mylar mechanical strength, combined with a relatively small radiation thickness, allows one to use a gas mixture at high pressure (~ 3 ÷ ÷ 4 atm.), which improves the spatial resolution (see below) even if simple threshold electronics is used. So, it's possible to make a tracking system more compact almost without losses in momentum resolution/5 /.

Straw-tube is a conventional cylindrical small diameter drift tube with an aluminized mylar cathode. The tubes 5 and 10 mm in diameter were studied, their cathodes being manufactured from mylar strips by two different techniques. In one case the joint was made by ultra-sonic welding/6 /, in the other an external mylar layer was glued upon an internal one.

The main characteristics of a straw-tube as a tracking system and transition radiation detector elementary cell are presented below, taking as an example a tube 5 mm in diameter, ≅ 200 mm long, with walls 50 ÷ 60 μm thick (two 12-μm mylar layers and ≅ 30 μm of glue), and with a gold-plated W anode wire 50 μm in diameter. The maximal avalanche charge allowing the reliable detector operation, the spatial accuracy near the anode wire at various pressures, the operation with a Xe mixture, and the mechanical strength at high pressure were studied.

An amplifier/7 / with the equivalent noise level ≅ 100 nA, an 8-bit charge-to-digit converter (type KA006/8 /) and an 8-bit time-to-digit converter (type KA371/9 /) were used in the measurements.

Figure 1 shows the dependence of the average avalanche charge on the operation high voltage for pure isobutane (i-C_4H_{10}) and the

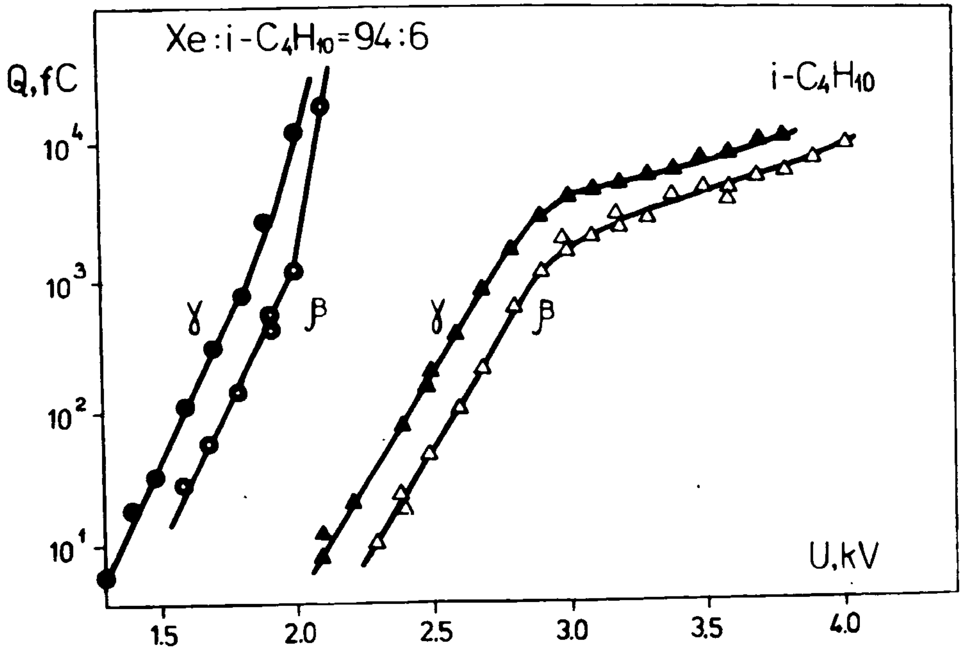


Fig.1. Average avalanche charge vs high voltage for various gases and irradiation sources.

$Xe{:}i\text{-}C_4H_{10} = 94{:}6$ gas mixture, measured at atmospheric pressure and with two types of irradiation used: ^{90}Sr β-particles and X-rays (8 keV). The signal was integrated with a 200 ns gate. It's seen that the tube operates reliably up to the charges $\cong$ 10 pC. The further increase in high voltage causes a sharp rise of dark current ($\cong$ 2 μA) and spark breakdown.

The $Xe{:}i\text{-}C_4H_{10} = 94{:}6$ gas mixture was chosen for the following reasons. Xenon is commonly used in transition radiation detectors/9/ owing to its large X-ray absorption cross-section. On the other hand, its amount is limited by the increase of energy losses dE/dx. The optimal thickness of the gaseous detector providing the effective γ detection and sufficiently small energy losses corresponds to approximately one γ absorption length. The latter is equal to $\cong$ 8 mm for 8 keV γ-quanta in Xe, which is close to the thickness of two 5 mm tube layers (two layers are necessary to provide good efficiency). So, pure Xe is an optimal gas, but we added a small amount of isobutane for stable operation. Figure 2 shows the good separation of charge signals from electrons and

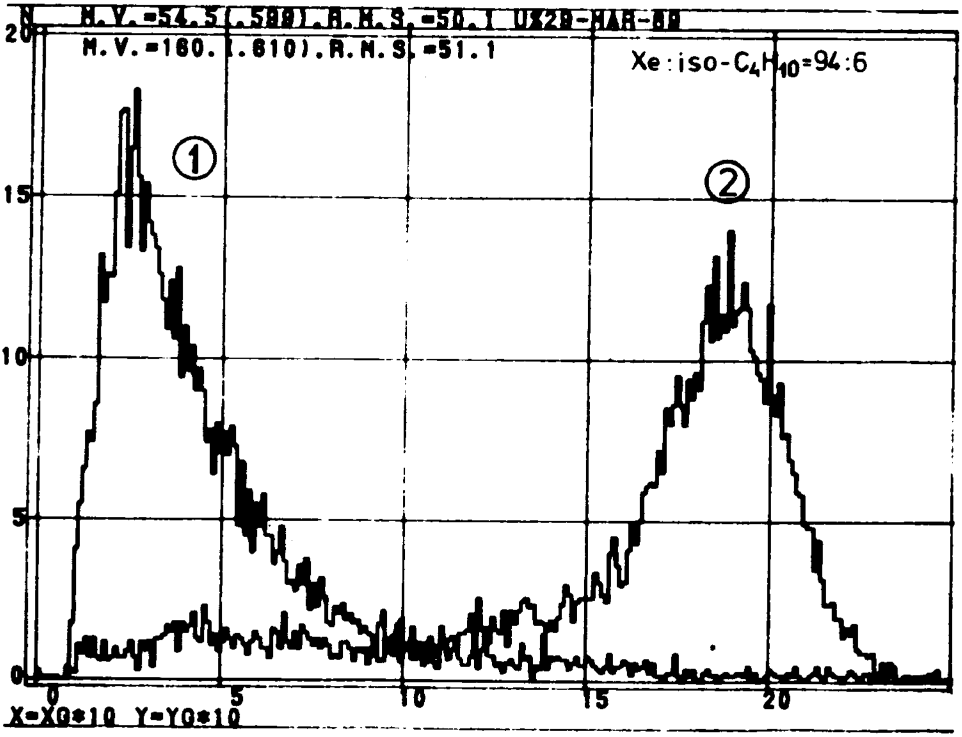


Fig.2. Charge spectra from β-particles and X-rays in $Xe{:}i\text{-}C_4H_{10} = 94{:}6$ gas mixture (high voltage U = 1.7 kV): 1 — ^{90}Sr β-source, mean charge $\bar{Q}$ = 56 fC; 2 — 8-keV X-rays, mean charge $\bar{Q}$ = 282 fC.

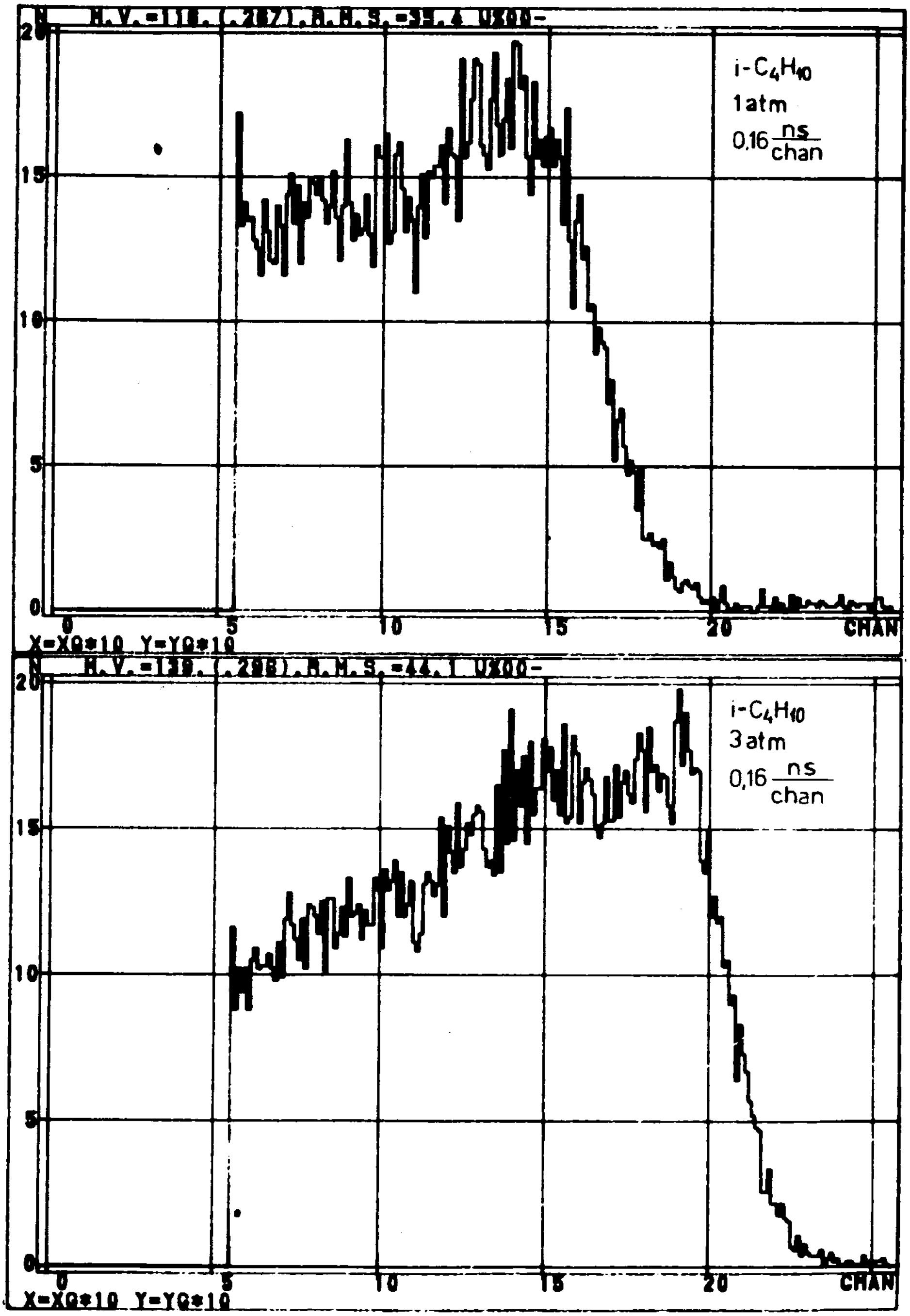


Fig.3. The edge of the time spectrum, giving the information about the spatial resolution. Pure isobutane. Mean charge $\bar{Q}$ = 500 fC. Time scale — 0.16 ns/chan. 1 — gas pressure 1 atm.; σ_x = 110 μm. 2 — gas pressure 3 atm.; σ_x = 45 μm.

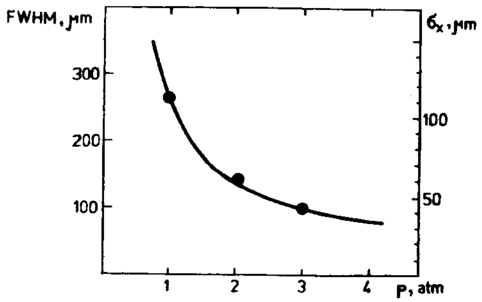
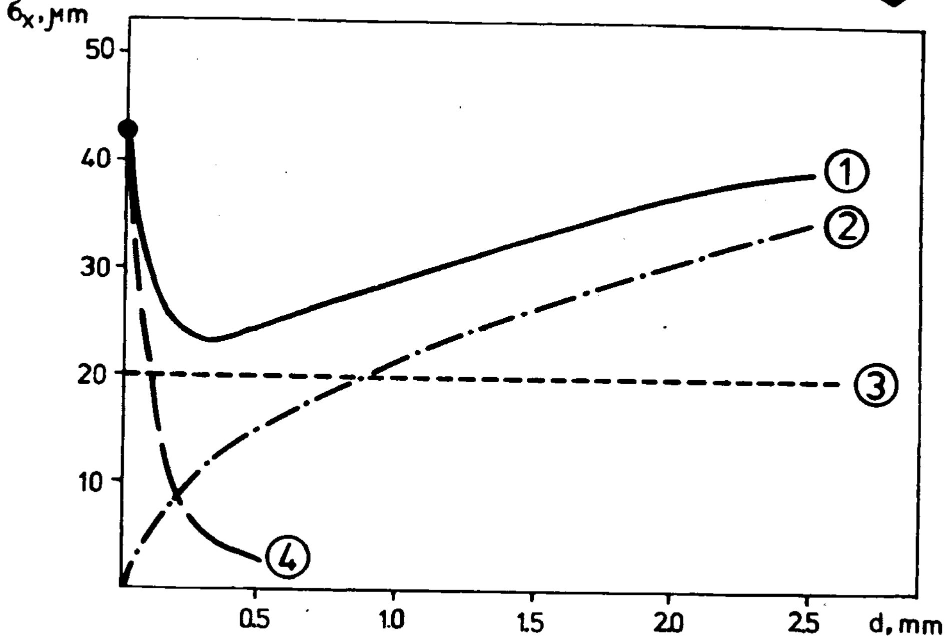


Fig.4. Full width at half-maximum and spatial accuracy σ_x near the anode wire vs isobutane pressure.

Fig.5. Spatial accuracy σ_x vs drift length under isobutane pressure p = = 3 atm: 1 — resulting curve; 2 — electron diffusion; 3 — electronic noise and signal amplitude instability; 4 — primary ionization statistics.



γ-quanta in the Xe:i-C_4H_{10} = 94:6 gas mixture, which confirms the detector rejection properties.

To evaluate the spatial accuracy near the anode wire the tube was filled with pure isobutane, which guaranteed the most reliable operation under hard loading conditions with the ^{90}Sr β-source. The average charge ~ 0.5 pC was maintained irrespective of pressure, while the discriminator threshold was ~ 0.005 pC. The interesting part of the time spectrum, corresponding to particle passage near the anode wire, is shown in figure 3 for 1 and 3 atm. The saturated drift velocity was estimated from the full width of the time spectrum. The resulting value, 53 μm/ns, is in agreement with the data from/10/. The right edge of the spectrum was differentiated, the standard deviation of the obtained curve multiplied by the drift velocity was considered to be the estimation of the spatial accuracy. Figure 4 presents the full width at half-maximum (FWHM) and the spatial resolution σ_x, obtained by this technique, at a pressure of 1, 2 and 3 atm. The estimated dependence of σ_x on drift length d at 3 atm is shown in figure 5 (contributions from statistics of primary ionization on the track and its diffusion, and electronic noise are taken into account). It is seen that the result of our measurements ($\sigma_x = 45\ \mu m$), when d = 0, is in agreement with the estimations and is upper limit for accuracy.

The mechanical strength testing of tubes with different cathodes showed that

— the welded cathode 10 mm in diameter withstands the pressure $\cong$ 2 atm.;

— the glued cathode 5 and 10 mm in diameter withstands the pressure $8 \div 12$ atm., and then breaks near the end-plug.

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