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MULTI-STREAMER STUDIES ON GAS MIXTURES FOR THE OPERA RPCs

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Abstract

Resistive Plate Chambers with bakelite electrodes are employed in the spectrometers of the OPERA experiment. The RPCs are operated in streamer mode with the gas mixture $Ar/C_2H_2F_4/i-C_4H_{10}/SF_6 = 75.4/20.0/4.0/0.6$. The studies performed in order to choose the operating gas mixture have been already published. In this note the results of additional tests on the multi-streamer probability are presented.

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1 Introduction

Resistive Plate Chambers (RPCs) interleaved with iron slabs are employed in the magnets of the OPERA spectrometers [1]. Given the very low expected counting rate in the underground Gran Sasso laboratory, high resistivity bakelite electrodes ($\rho > 5 \times 10^{11}$ Ωcm at T=20^{o}C) have been chosen, reducing the detector aging, as suggested in [2]. The streamer operation is preferred because of the high signal amplitude (∼100 mV).

The flushed gas mixture is made of argon (Ar), tetrafluoroethane ($C_2H_2F_4$ also called R134a), isobutane ($i - C_4H_{10}$) and sulfur hexafluoride (SF_6) in the volume ratios 75.4/20.0/4.0/0.6 [3]. This mixture is characterized by low operating voltages (about 6 kV) and currents (the charge released in the gas in each detector count is around 500 pC). The increase of after-pulsing with respect to typical streamer mixtures (like for instance $Ar/C_2H_2F_4/i - C_4H_{10} = 48/48/4$), compensated by the low streamer charge due to the SF_6 addition, is not a problem because of the very low counting rate (~ 20 Hz/m^2).

This note aims to extend the studies published in [3], estimating the multi-streamer probability with mixtures of interest for our experiment.

2 Experimental set-up and measurements description

The set-up, whose sketch is shown in figure 2, is made of three trigger RPCs and other three chambers under test. The trigger RPCs have an area of 50×50 cm^2 and are read out by means of a pad covering the whole detector surface. The charges induced on the trigger chambers read-out pads are acquired by means of ADCs and used to select isolated tracks.

The three chambers under test are: another 50×50 cm^2 RPC read out with a single pad similarly to the trigger detectors and other two 60×70 cm^2 RPCs read out by means of 16 copper strips with 3.5 cm pitch, discriminated and OR-ed by a Timing Board embedded in the strip panel. The Timing Boards are circuits designed by the LNF-SEA for the OPERA experiment; their description can be found in [4]. In addition to the digital OR, the Timing Boards perform also the analog sum of the strip signals, which is acquired by a digital scope with 1 ns sampling.

The efficiency, the single streamer charge and the multi-streamer probability are easily obtained from the induced charge spectrum, as suggested in figure 2.

In order to take into account the different environment conditions during data-taking, the operating voltage reported in the following plots is rescaled [5] [6] to standard temperature and pressure values $T_0 = 293$ K and $P_0 = 1010$ mbar, according to the relationship $V = V_a \times (T/T_0) \times (P_0/P)$, where V_a and V are the applied and the rescaled

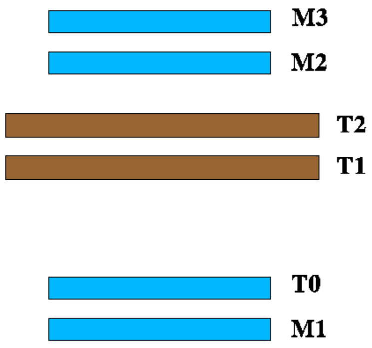

Figure 1: Sketch of the experimental set-up, with the trigger chambers (M1, M2, M3) and the three chambers under test (T0, T1, T2).

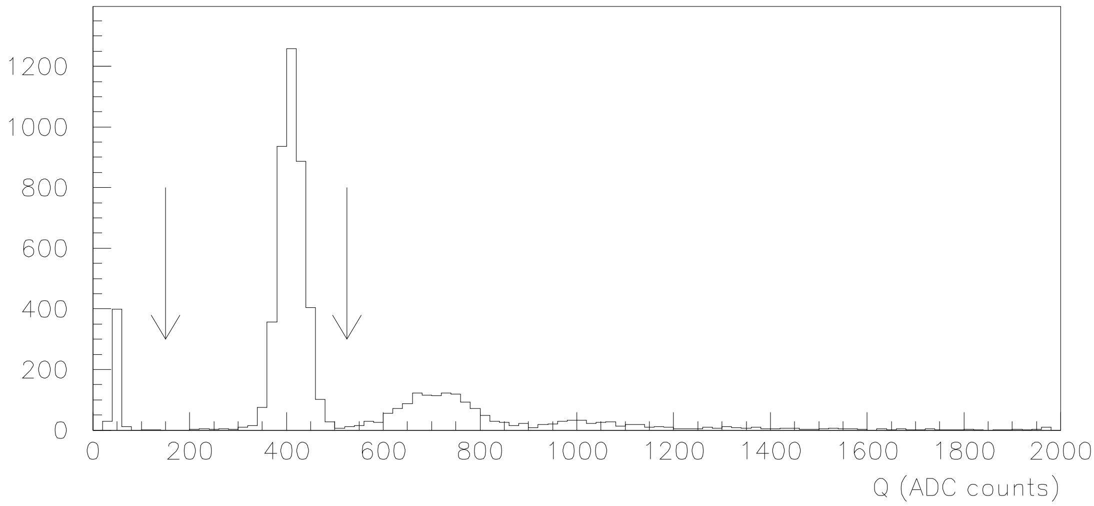

Figure 2: Induced charge for the gas mixture $Ar/C_2H_2F_4/isoC_4H_{10} = 56/40/4$ at V=7.6 kV. One ADC count is .83 pC. The cuts for selecting single streamers are also shown.

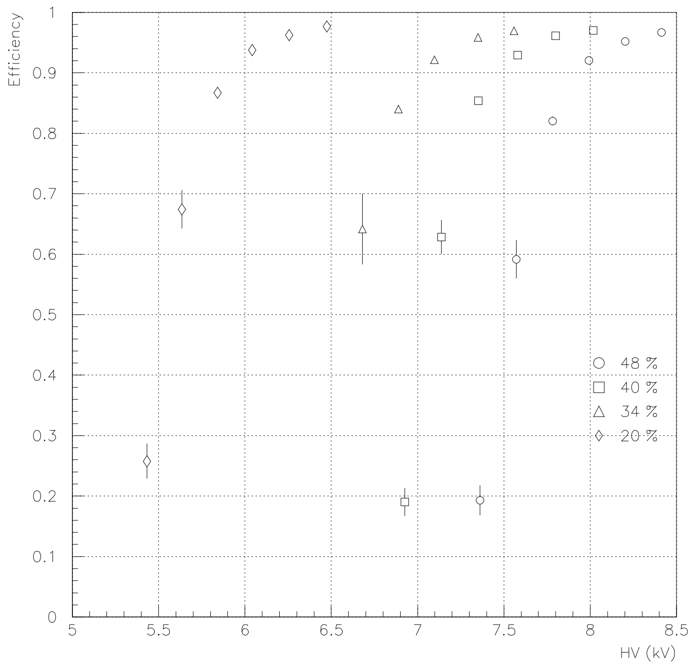

Figure 3: Efficiencies for different R134a concentrations in ternary mixtures with argon and isobutane (fixed at 4%).

voltage respectively. It is worth noticing that operating voltages at the Gran Sasso laboratory are $\sim 10\%$ lower than those shown in this note, because of the lower pressure (900 mbar instead of the considered reference value, 1010 mbar).

3 Multi-streamers and R134a concentration

The measurements described in this section have been performed on the chamber T0, with the read-out pad acquired by an ADC. We considered ternary mixtures made of argon, R134a and isobutane (fixed at 4%).

In figure 3 the efficiencies are shown for R134a concentrations ranging from 20% to 48%. The operating voltage increases with the R134a concentration, from 6 kV to more than 8 kV.

These mixtures show an increasing streamer charge for lower R134a concentrations, as shown in figure 4. The same behaviour is observed for the multi-streamer probability, displayed in figure 5, indicating that the tetrafluoroethane has some quenching effect. The

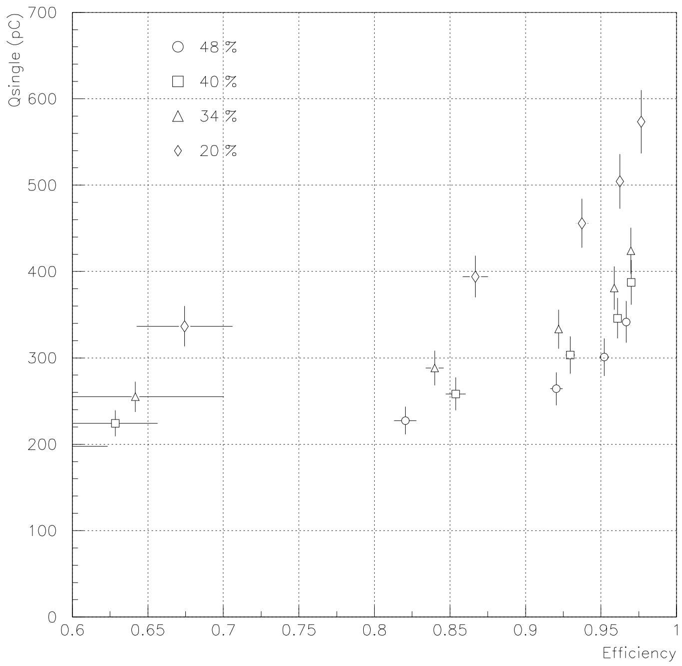

Figure 4: Streamer induced charge as a function of the efficiency for different R134a concentrations in ternary mixtures with argon and isobutane (fixed at 4%).

quenching power is greatly reduced for R134a concentrations lower than 30%.

4 Multi-Streamers and isobutane concentration

The measurements described in this section have been performed on the chamber T2, read out by a panel made of 16 strips, whose analog signals are summed up and acquired by means of a digital scope.

We considered quaternary mixtures with the argon concentration fixed at 76% and a 0.5% SF_6 addition, moving the isobutane quantity from 3% to 8%. Furthermore we tested also the gas mixture $Ar/C_2H_2F_4/i-C_4H_{10}/SF_6 = 64.0/32.0/3.5/0.5$. In table 1 a resume of the mixtures under test is given.

In figure 6 the efficiency is shown as a function of the operating voltage. The working voltage of mixture 4 is 1 kV higher than those of the other three mixtures, contained in a 200 V range.

The four considered mixtures have the same streamer charge (shown in figure 7),

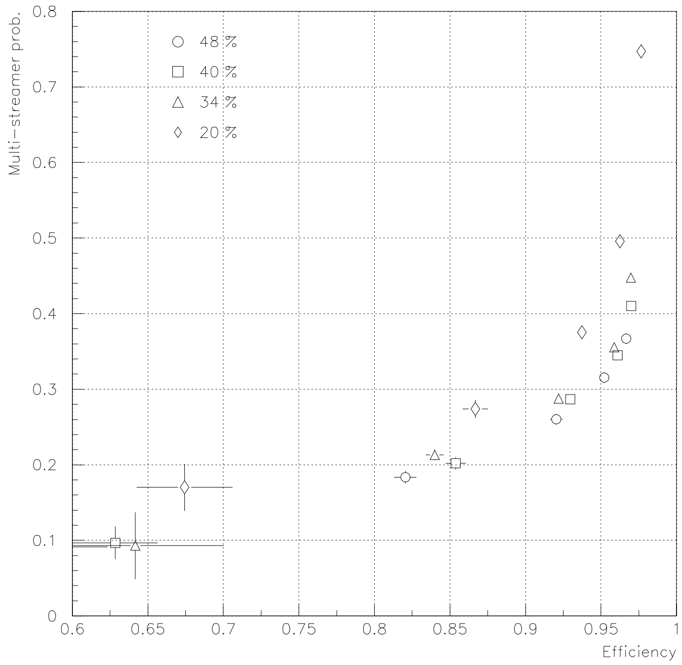

Figure 5: Multi-Streamer probability as a function of the efficiency for different R134a concentrations in ternary mixtures with argon and isobutane (fixed at 4%).

Table 1: Summary of the tested mixtures with different isobutane concentrations.

Label	Mixture
mixture 1	$Ar/C_2H_2F_4/i-C_4H_{10} = 76/16/8\ +\ 0.5\%SF_6$
mixture 2	$Ar/C_2H_2F_4/i-C_4H_{10} = 76/20/4\ +\ 0.5\%SF_6$
mixture 3	$Ar/C_2H_2F_4/i-C_4H_{10} = 76/21/3\ +\ 0.5\%SF_6$
mixture 4	$Ar/C_2H_2F_4/i-C_4H_{10}/SF_6 = 64.0/32.0/3.5/0.5$

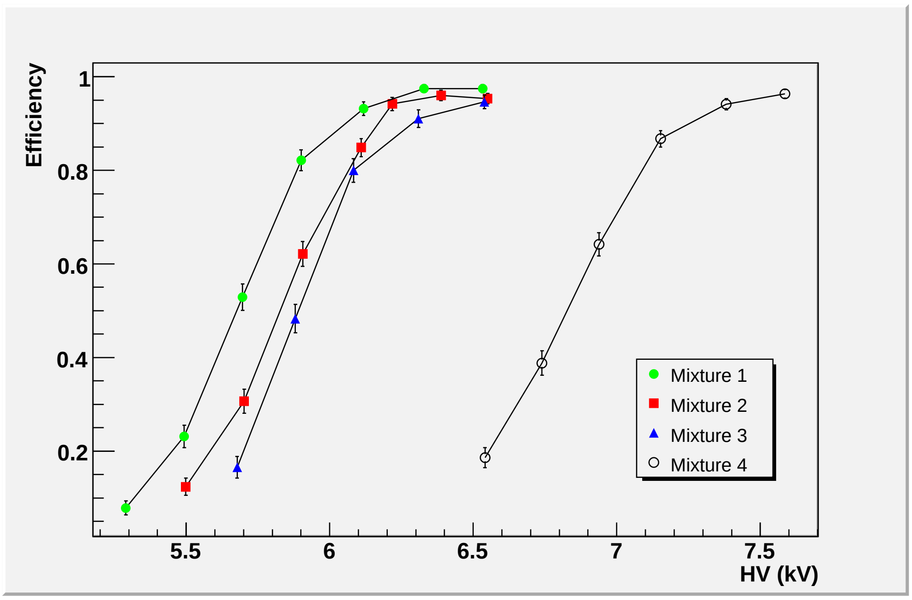

Figure 6: Efficiencies measured for mixtures with different isobutane concentrations.

much lower than the mixtures considered in the previous section, as an effect of the addition of SF_6. It is worth noticing that the charge difference between the mixtures with 20% and 30% R134a concentration is much smaller if SF_6 is also added (compare figures 4 and 7).

Figure 8, displaying the multi-streamer probability of the considered mixtures, suggests that the quenching power strongly depends on the isobutane concentration. Mixture 4 has anyway a good quenching capability, with the low isobutane concentration compensated by the increase of the R134a from 20% to 32%.

5 Conclusions

The mixture presently flushed inside OPERA RPCs is made of argon, tetrafluoroethane, isobutane and sulfur hexafluoride in the volume ratios $75.4/20.0/4.0/0.6$. The low tetrafluoroethane and isobutane concentrations are suggested mainly by economical reasons.

The measurements displayed in this note allow us to make a comparison between the quenching power of these two gases. In particular we have demonstrated how, starting from OPERA-like quaternary mixtures, a 0.5% decrease of the isobutane concentration can be compensated by moving that of the tetrafluoroethane from 20% to 30%.

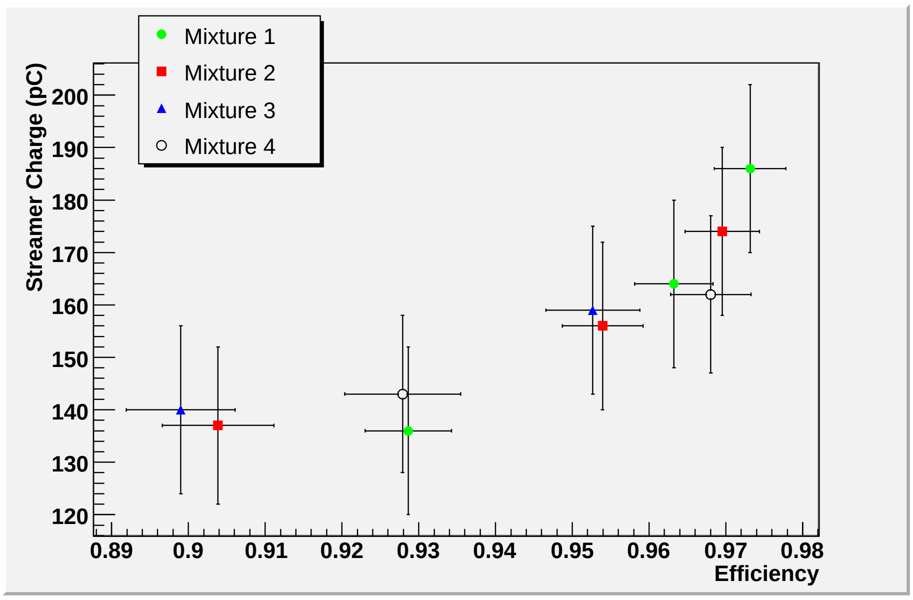

Figure 7: Streamer induced charge as a function of the efficiency for mixtures with different isobutane concentrations.

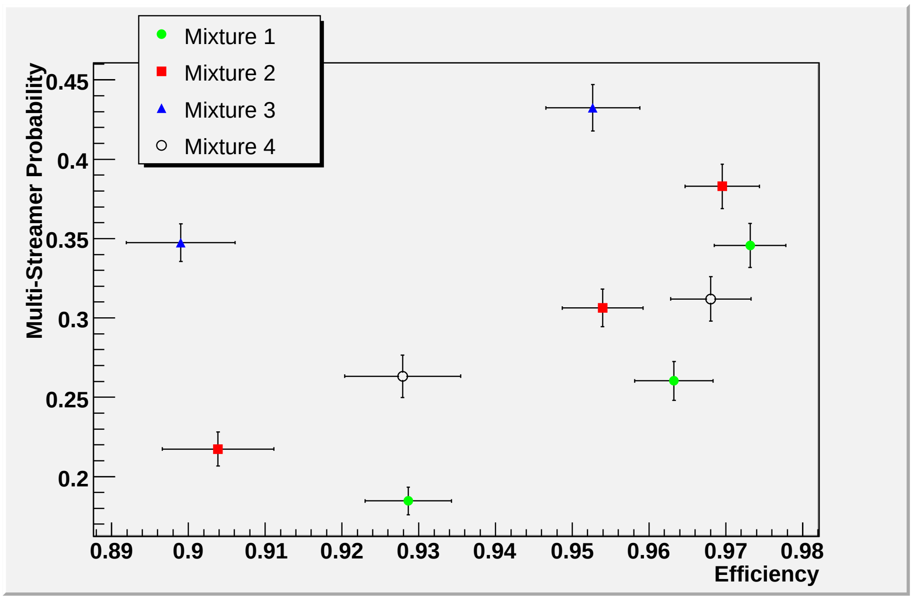

Figure 8: Multi-Streamer probability as a function of the efficiency for mixtures with different isobutane concentrations.

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