Streamer studies in RPCs

A. Paoloni (INFN-LNF)

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Why streamer ?

Streamer operated RPCs can be used:

- **in low rate experiments (in underground laboratories or at cosmic ray fluxes).**
- **if time resolutions worse than 1 ns are acceptable.**

Examples in neutrino and astro-particle physics: OPERA, ARGO.

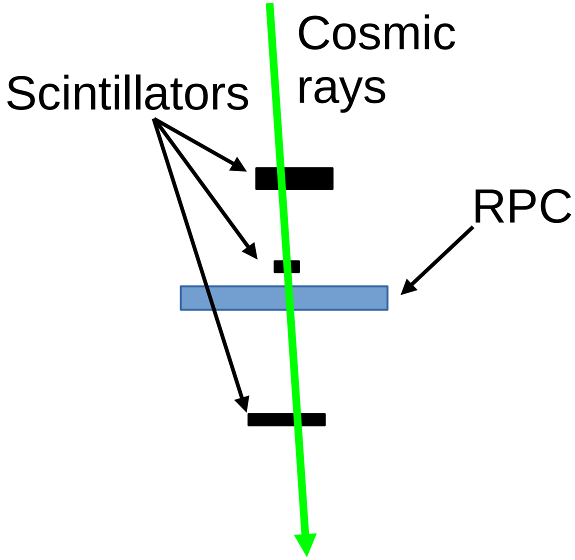
Though antiquated, streamer regime has two advantages:

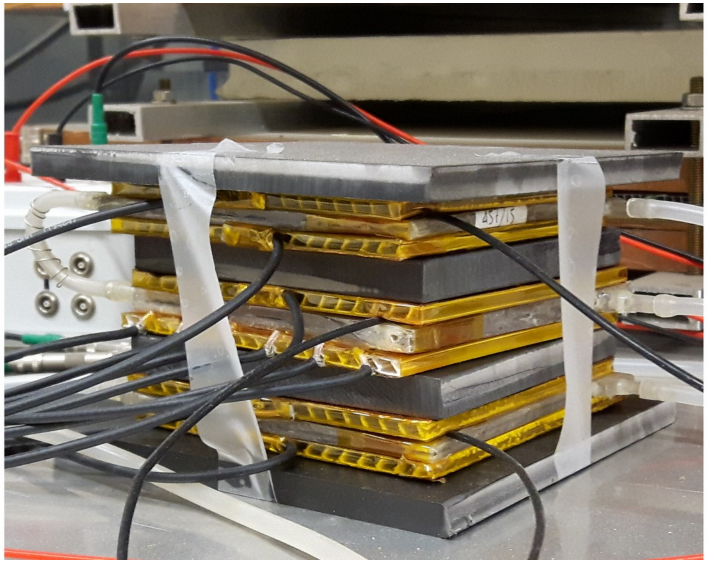
- **FrontEnd electronics simplicity.**
- **Possibility to use mixtures made of Argon and HFO-1234ze (i.e. green and made of not-flamable gases).**

In addition it is possible to study streamer discharges in gas and put benchmarks for models.

Experimental set-up

The measurements described here have been performed using cosmic rays, with different set-ups.
Trigger made by scintillators or other RPCs.
Unless for gas gap studies, all RPCs under test have 2 mm gas gap and 2 mm bakelite electrodes.



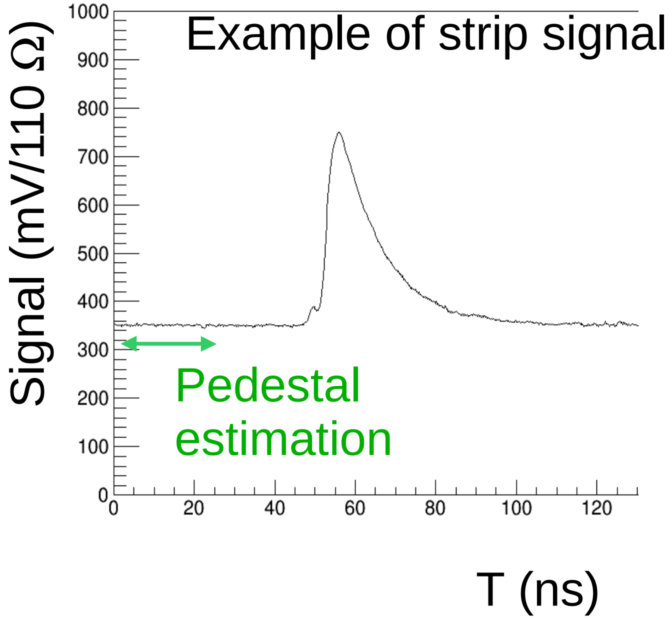


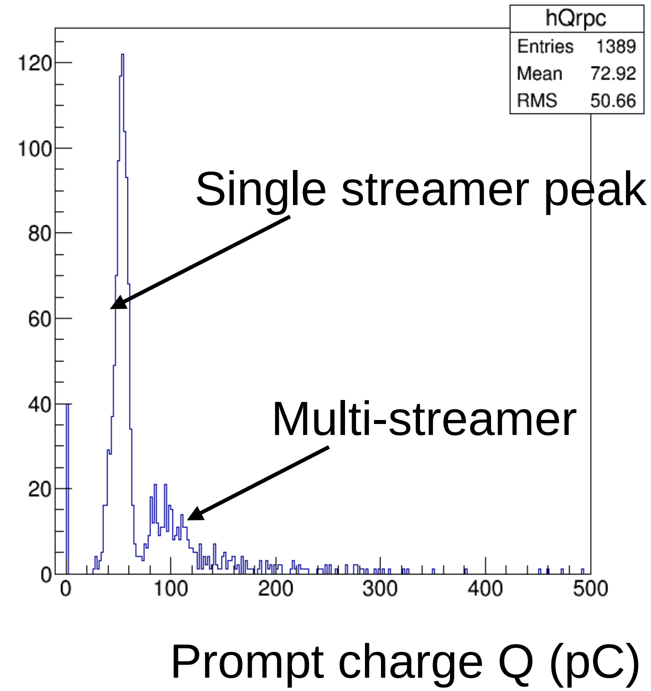
3 10*10 cm^2 RPCs piled-up

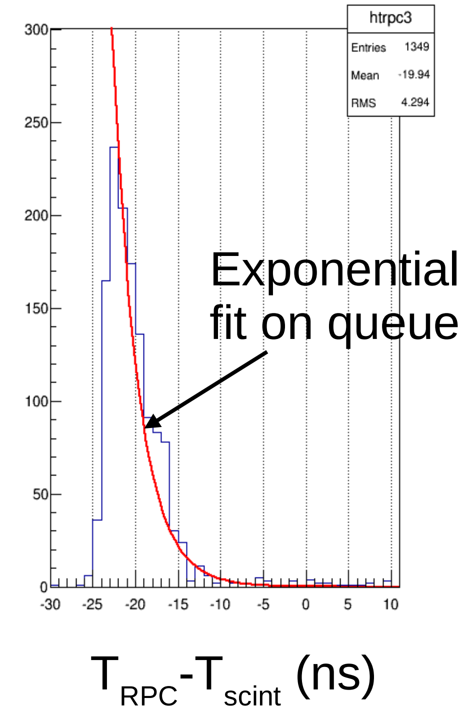
Different set-up read-outs:
CF4 measurements - read-out by 3.5 cm strips terminated on 110 Ω.
Gas gap studies - 10*10 cm^2 wide RPC read-out by a single pads.
Avalanche-to-streamer delay - read-out by 1 cm strips on 50 Ω.
Streamer formation time - read-out by 3.5 cm strips terminated on 110 Ω.

In all cases, acquisition by N6742 CAEN digitizer (5 Gsamples/sec).

Analysis techniques description







Signal treatment:
Pedestal subtraction channel by channels using first 100 samples.
Common mode noise estimation using strips without signals.

RPC and streamer properties from measured distributions:
Prompt charge: efficiency, multistreamer probability, single streamer charge.
Single strip events: streamer amplitude, FWHM, risetime (10% - 90% of amplitude).
T_{RPC}-T_{scint}: streamer arrival time (relative to the scint.), time resolution (exp fit on the queue).

Conclusions from previous workshop

New ecological Ar/HFO-1234ze binary mixtures are good for streamer operation of 2 mm gaps (HFO concentration > 30% not to have a high multistreamer probability). HFO-1234yf, the flamable isomer, has similar properties.

Unfortunately no substitute has been found for SF_6, whose addition strongly diminishes the streamer charge.

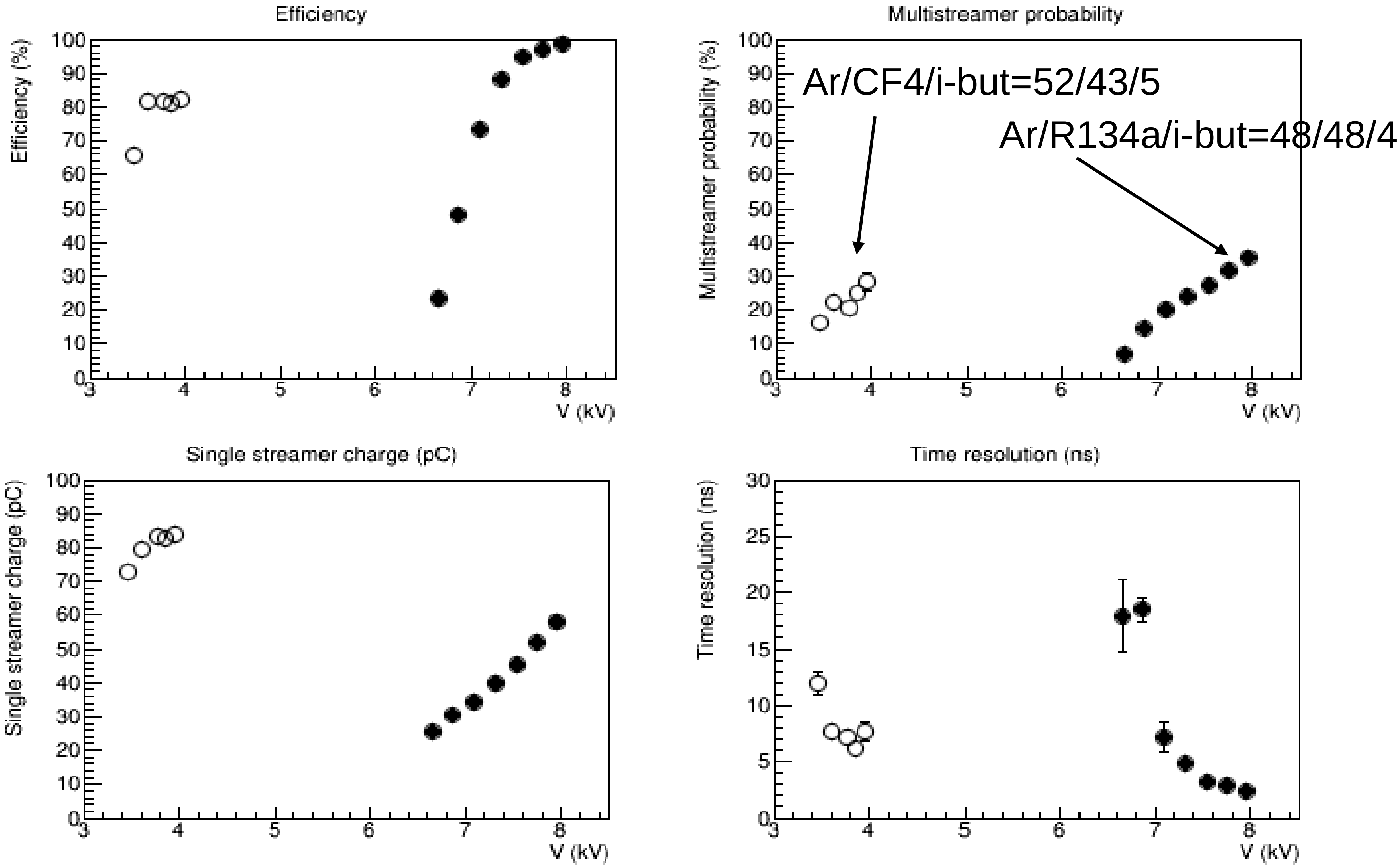
CO_2 neither reduces the charge nor lower the multistreamer probability.

N_2 is even worsening the mixture properties.

Ar replacement with He seems interesting, improving the time resolution.

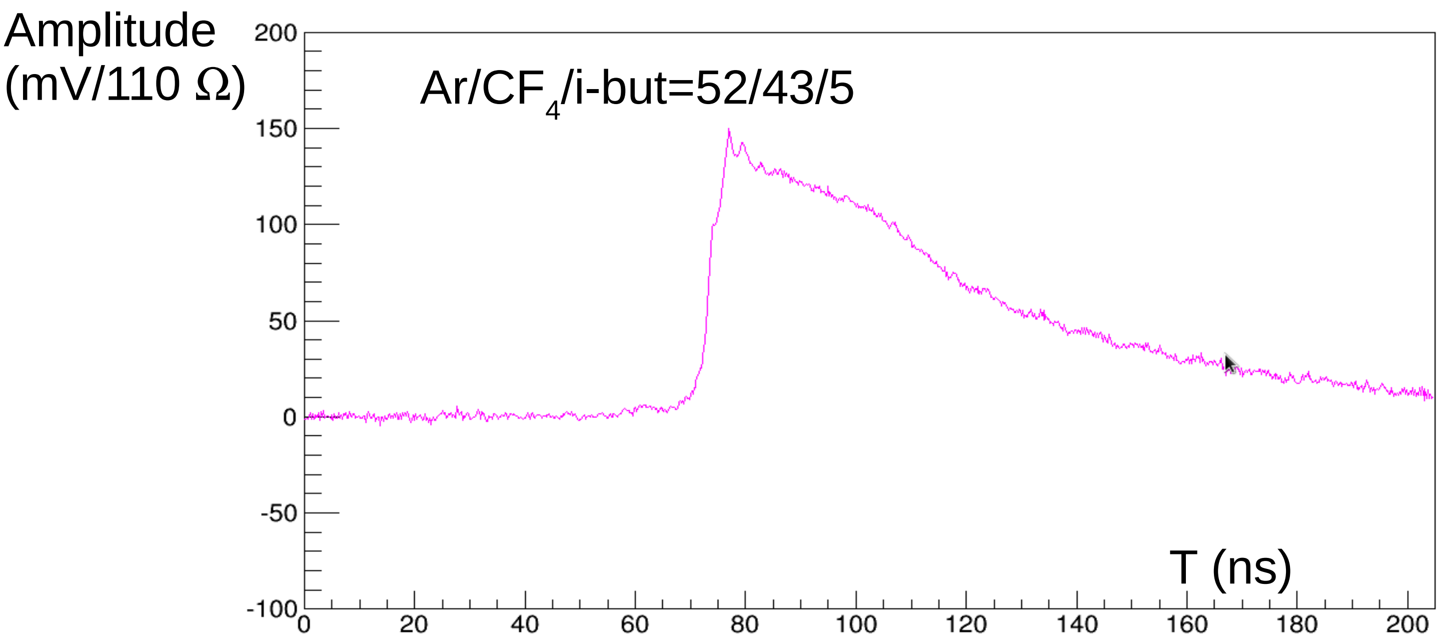
CF_4 tested as a replacement for SF_6, but the question whether could work in mixture with Argon was not answered.

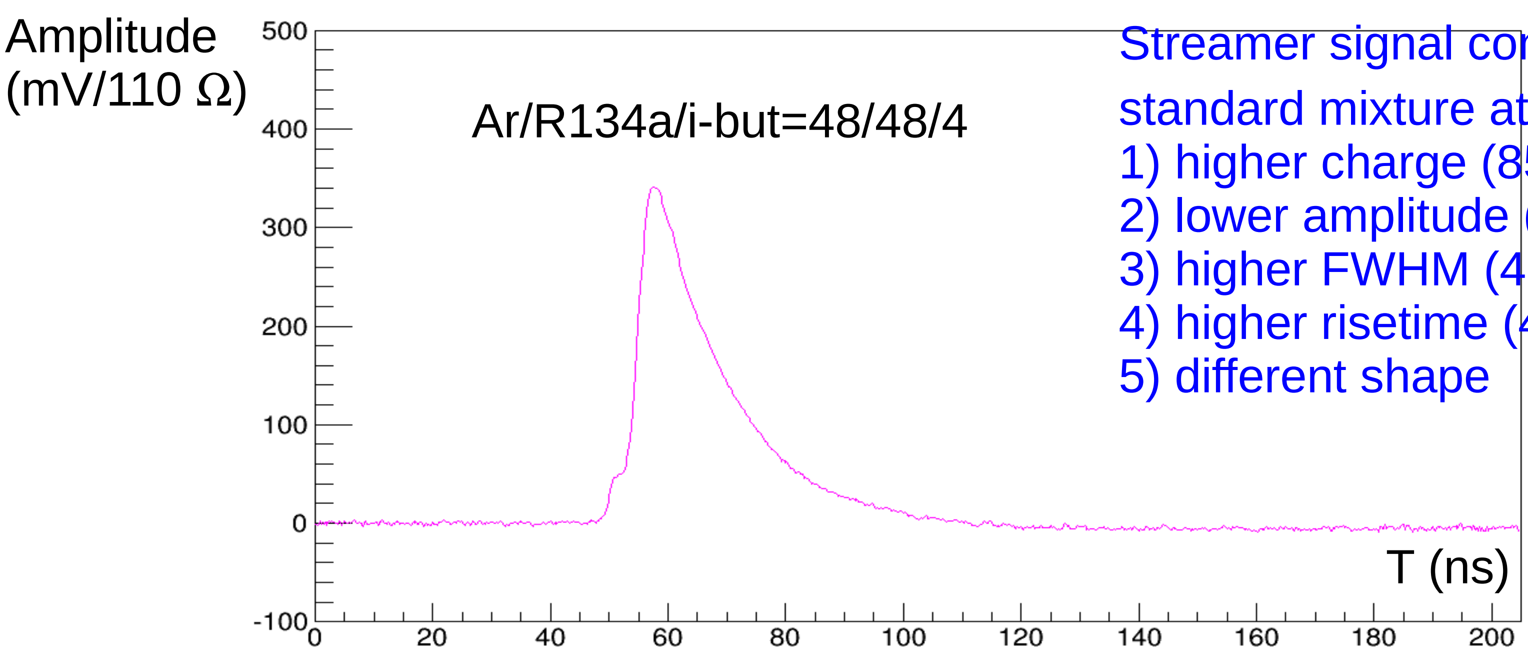
CF4 quenching power measurement



Comparison between Ar/CF4/i-but=40/55/5 and Ar/R134a/i-but=48/48/4 (used in Babar, and very similar in composition but for the presence of CF4/R134a).
Operating voltage with CF4 at 3 kV (5 kV below...) with a higher charge.
Seems typical of a mixture with a low quenching, but multi-streamer probability not very high, probably as a consequence of the dimensions (and time duration) of the discharge.

CF4 quenching power measurement





Streamer signal comparison with CF_4 vs standard mixture at full efficiency :

1) higher charge (85 vs 60 pC)
2) lower amplitude (170 vs 450 mV/110 Ω)
3) higher FWHM (45 vs 12 ns)
4) higher risetime (4 vs 2.5 ns)
5) different shape

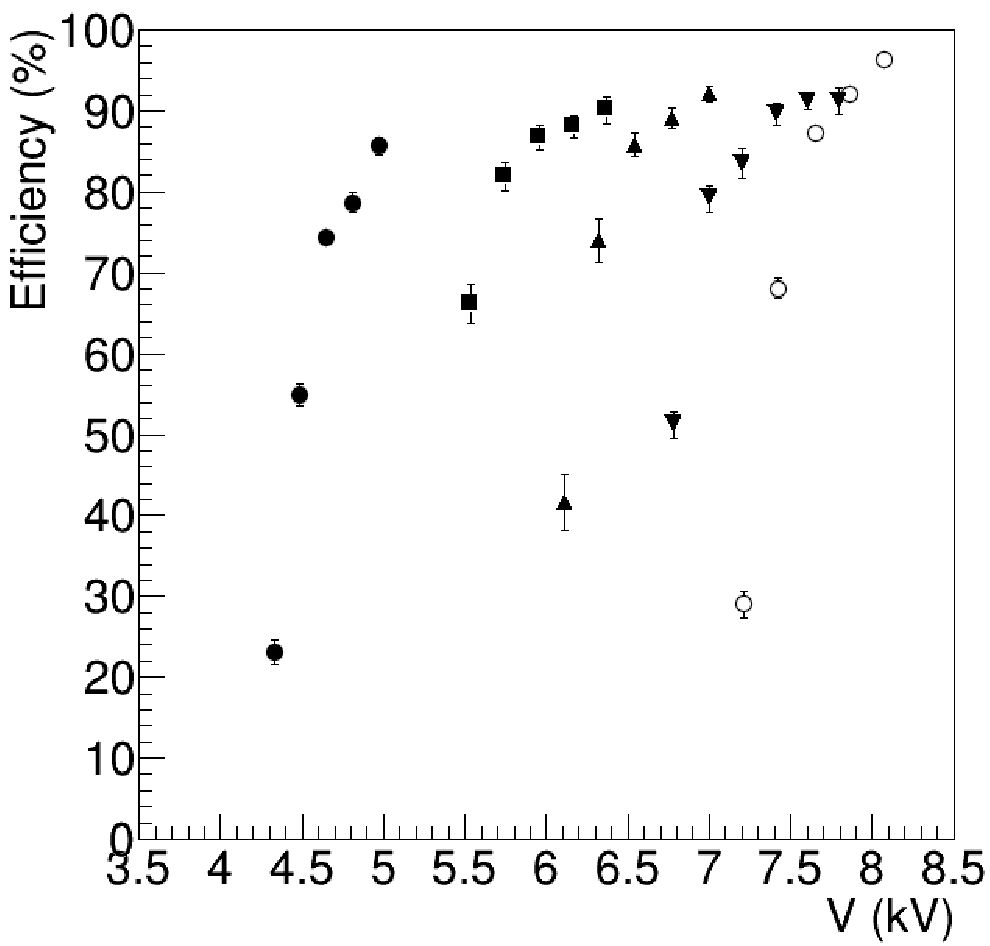
Gas gap studies

Mixture	Ar/HFO-1234ze/SF_6 volume ratios
1	76.8/23.1/0.1
2	65.6/34.2/0.2
3	54.4/45.4/0.2
4	44.3/55.5/0.2

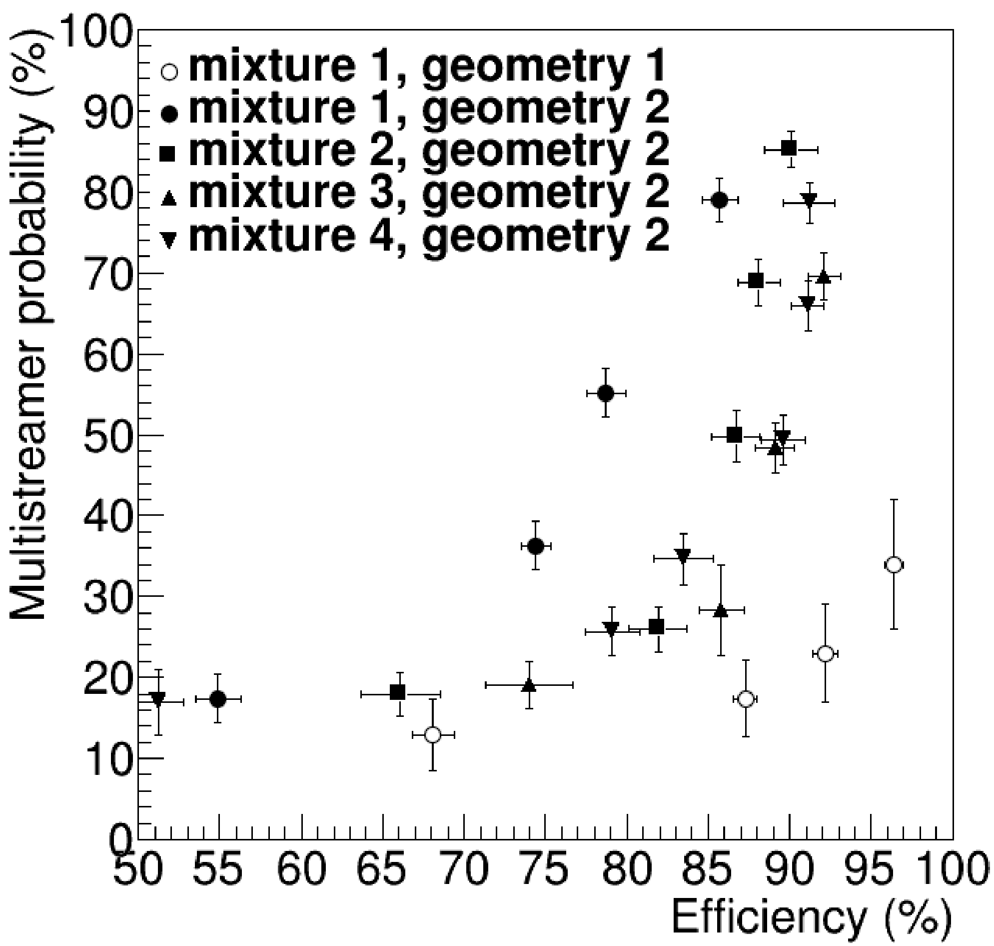
Geometry 1: 2 mm gap, 2 mm electrodes
Geometry 2: 1 mm gap, 1 mm electrodes

Much lower quenching power with 1 mm gap.
Could higher gas gaps increase quenching ?

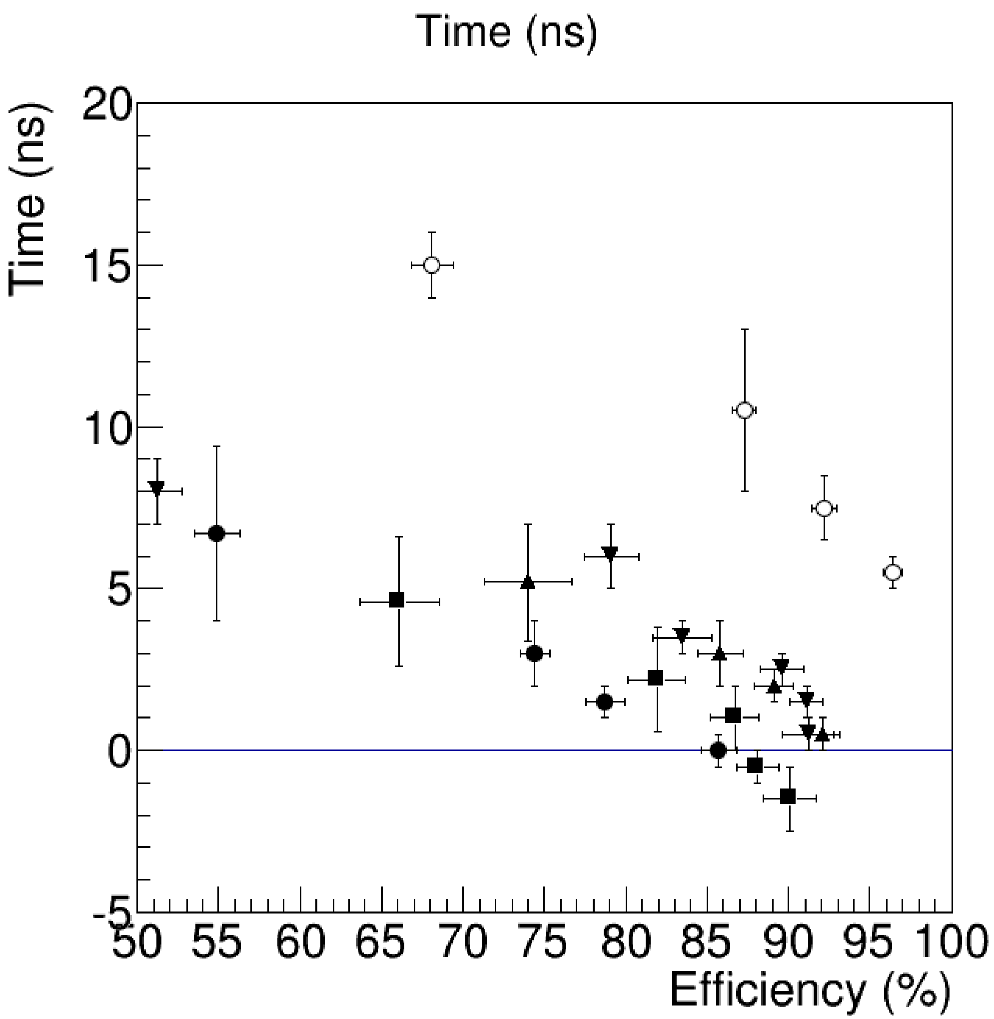
Efficiency

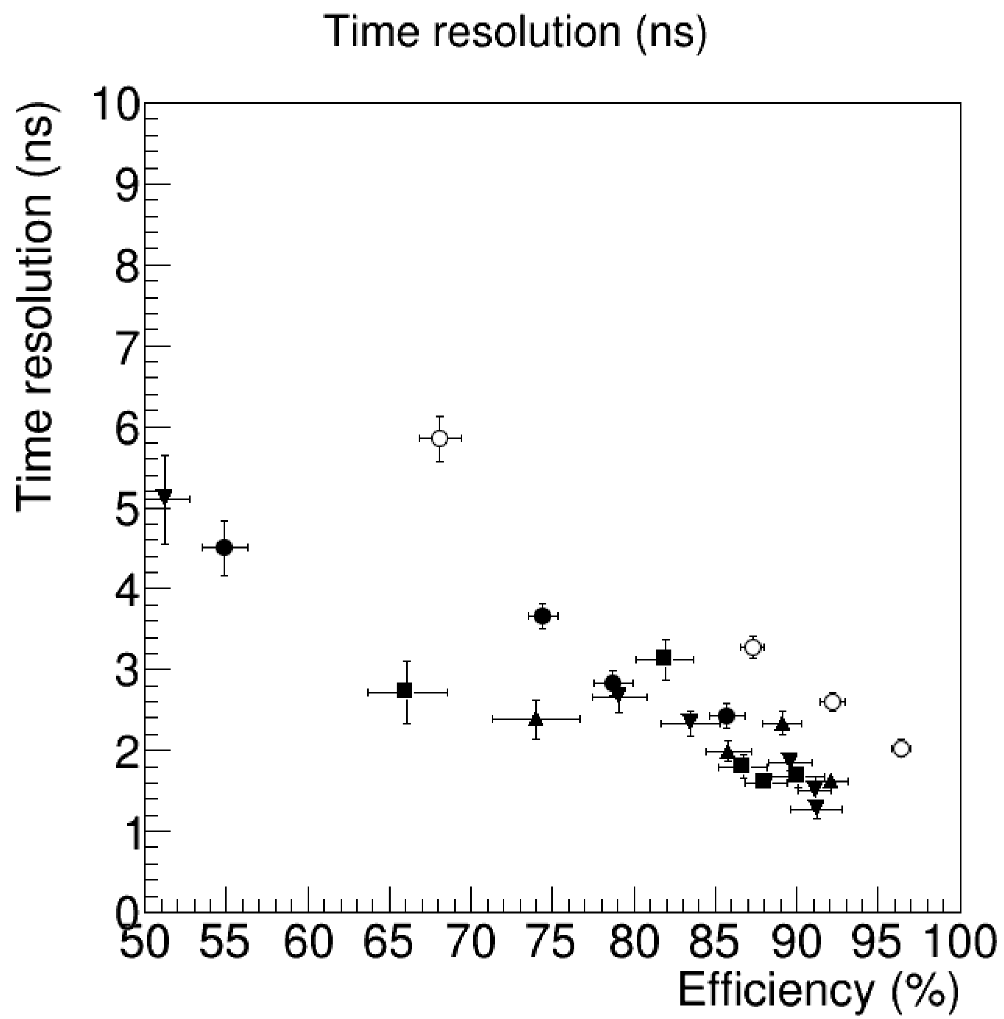


Multistreamer probability



Gas gap studies

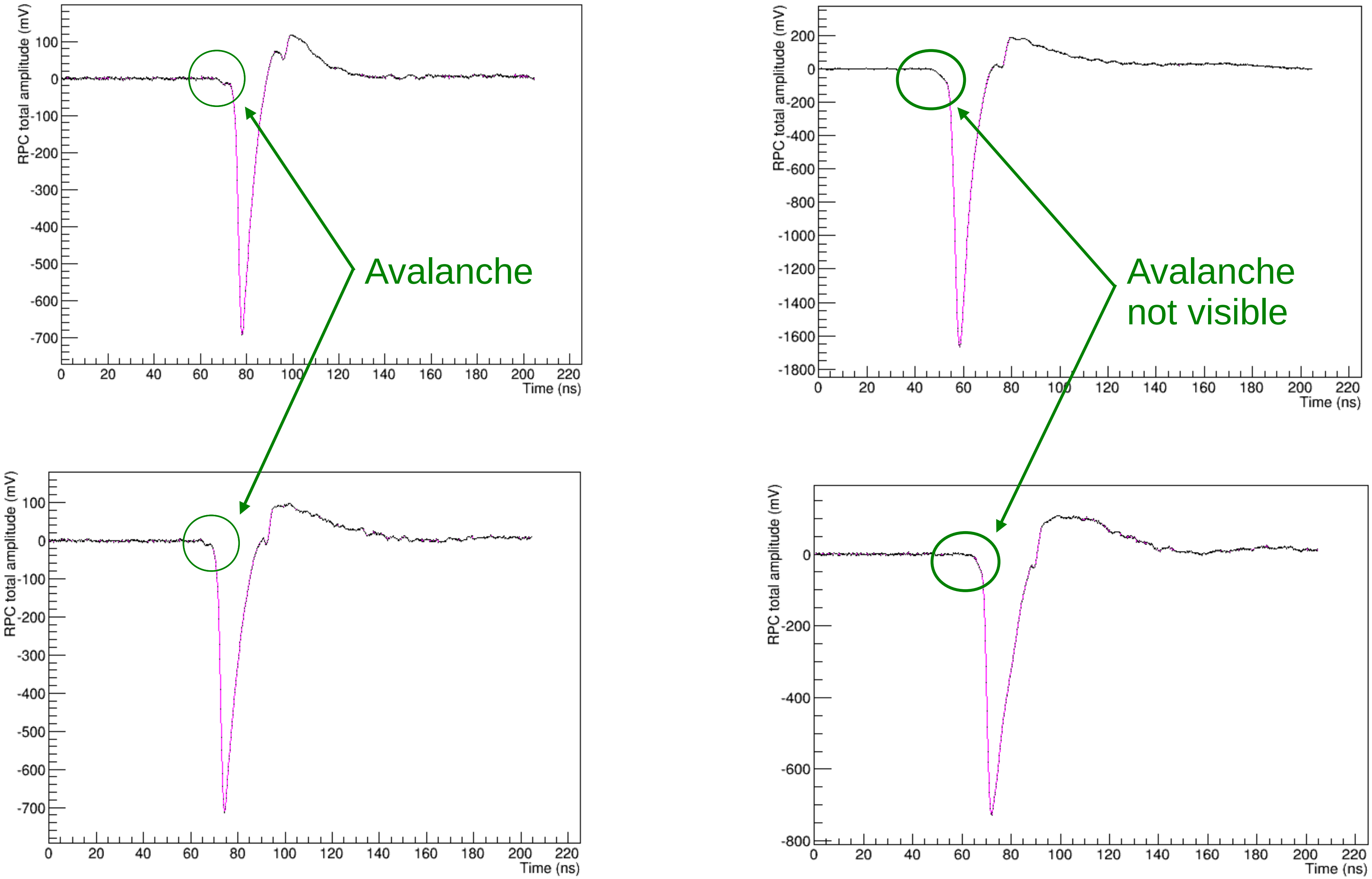




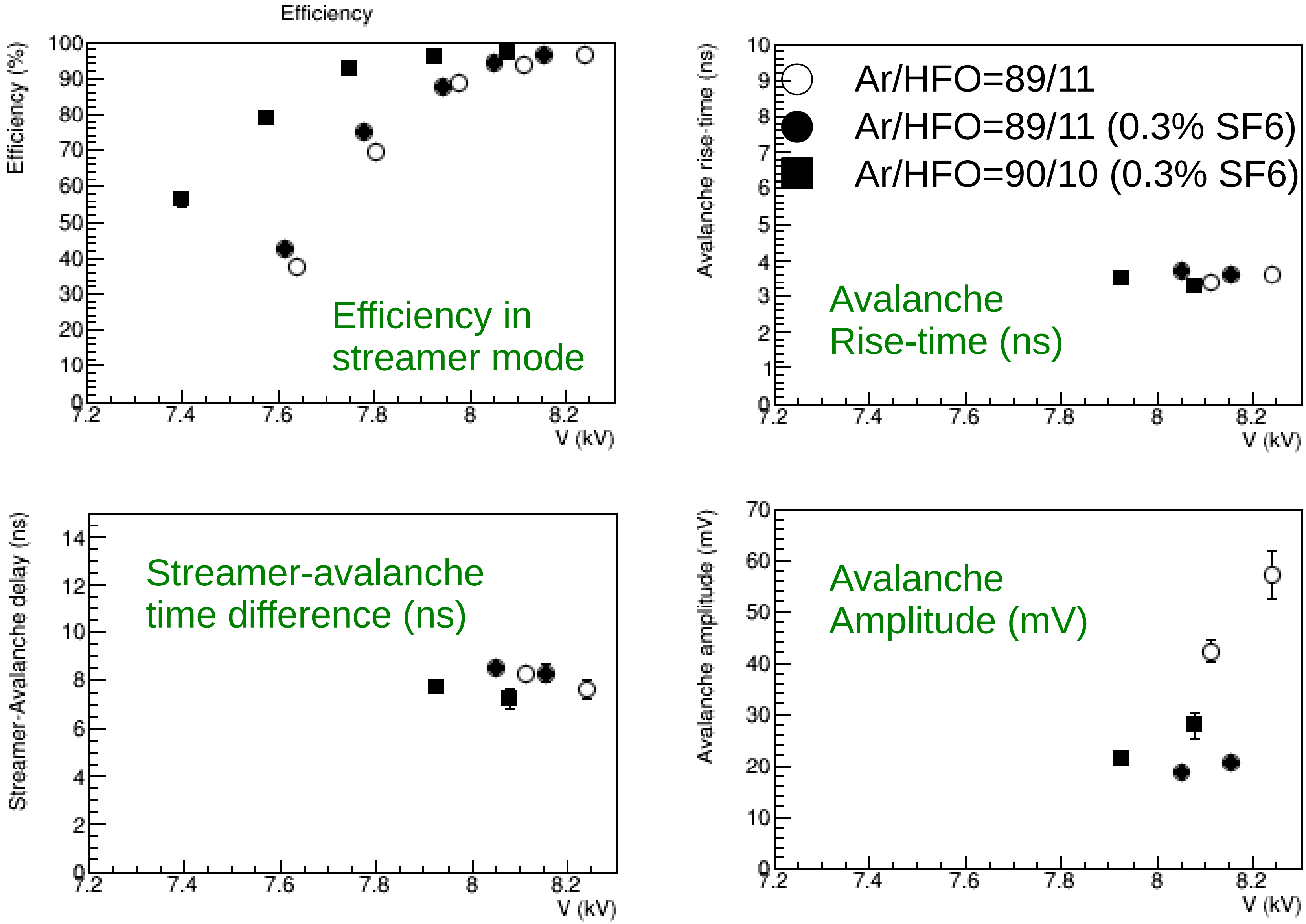
With lower gaps, lower charges, faster streamers and better time resolution.
Quenching however is an issue (increase of HFO precentage in gas needed).

Streamer-avalanche delay

Waveform examples for Ar/HFO1234/SF6 mixture

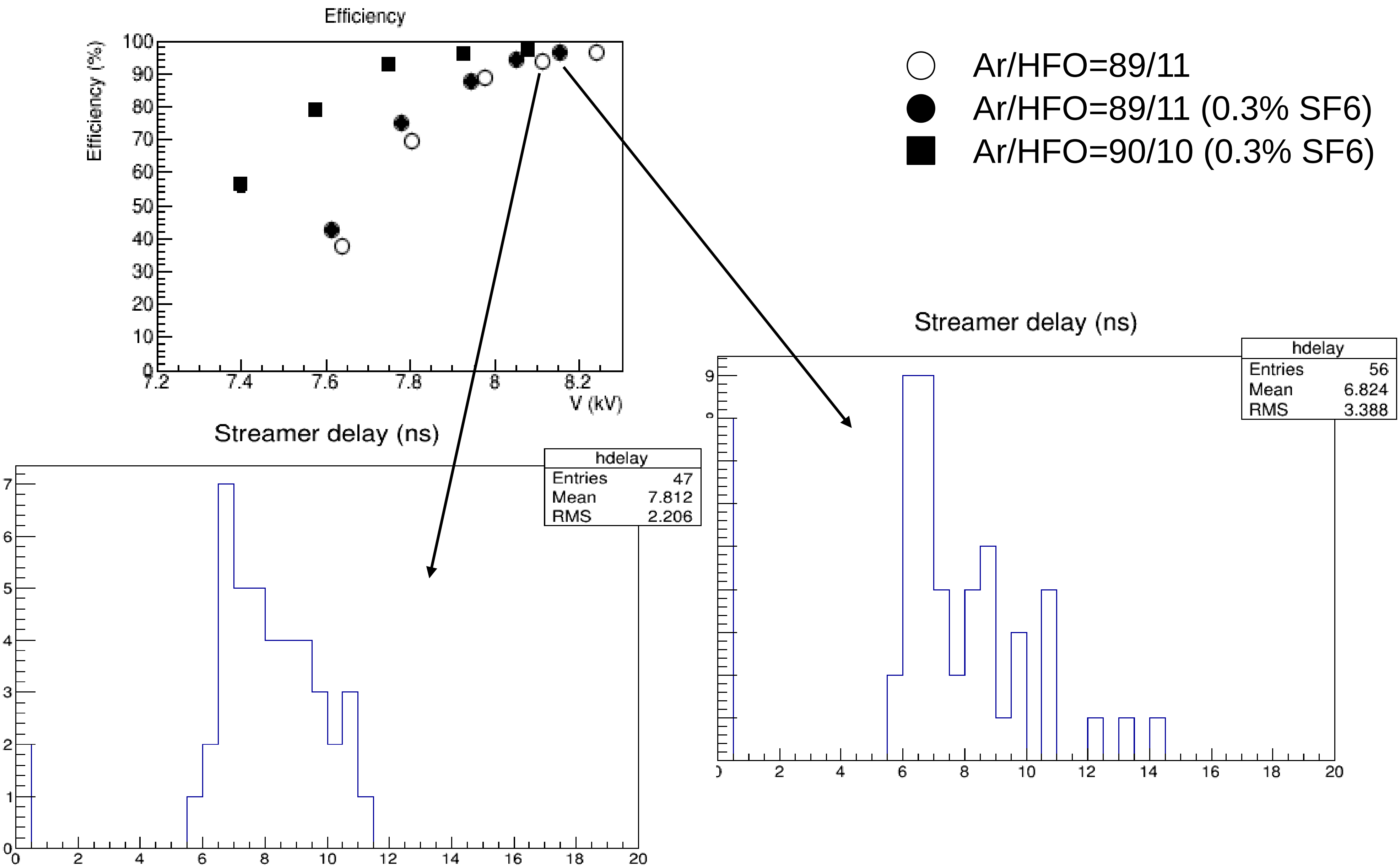


Streamer-avalanche delay



Avalanche time = time @ maximum avalanche signal (when visible)
Streamer time = time @ maximum streamer signal

Streamer-avalanche delay

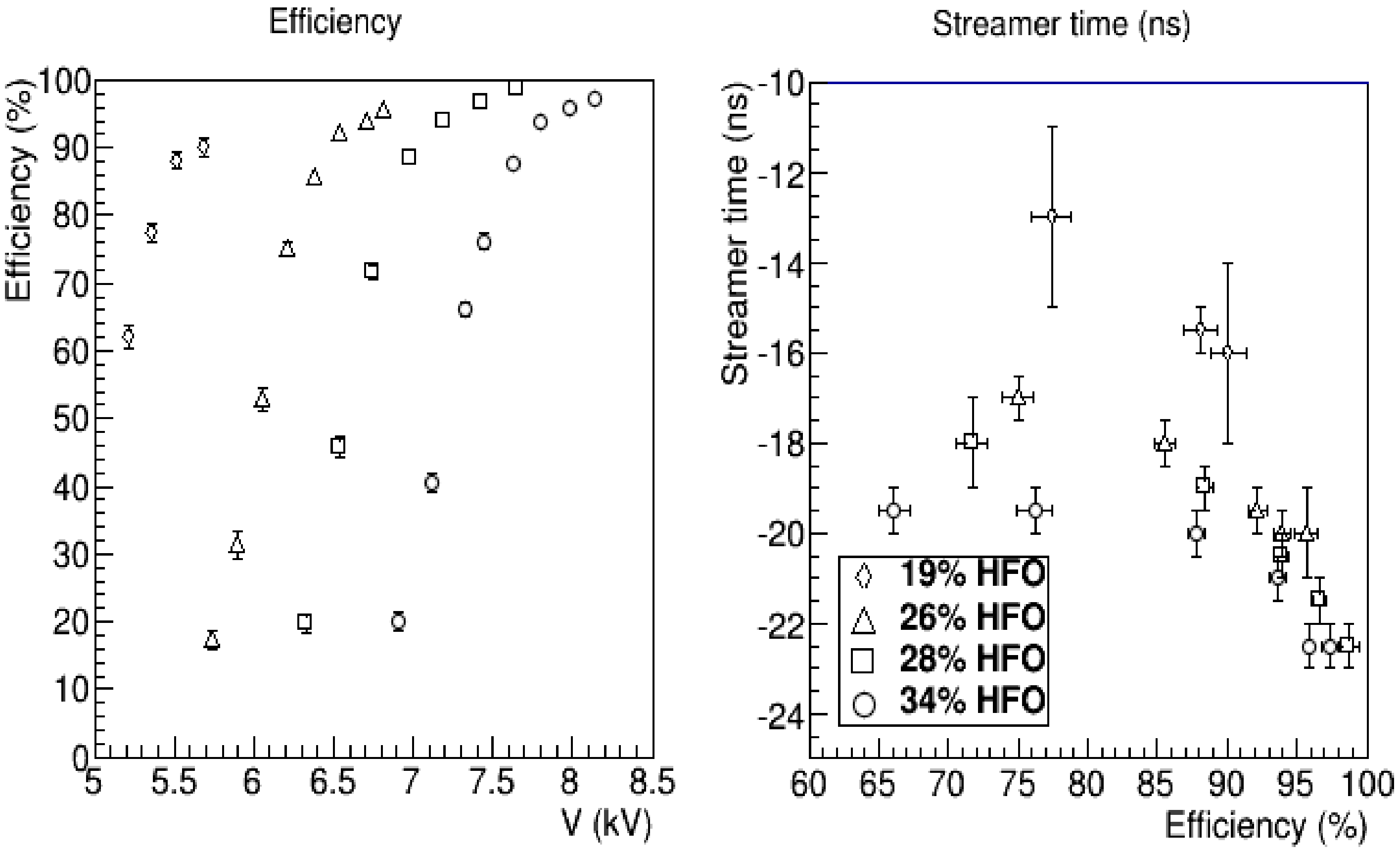


Avalanche time = time @ maximum avalanche signal (when visible)
Streamer time = time @ maximum streamer signal

Streamer-avalanche delay

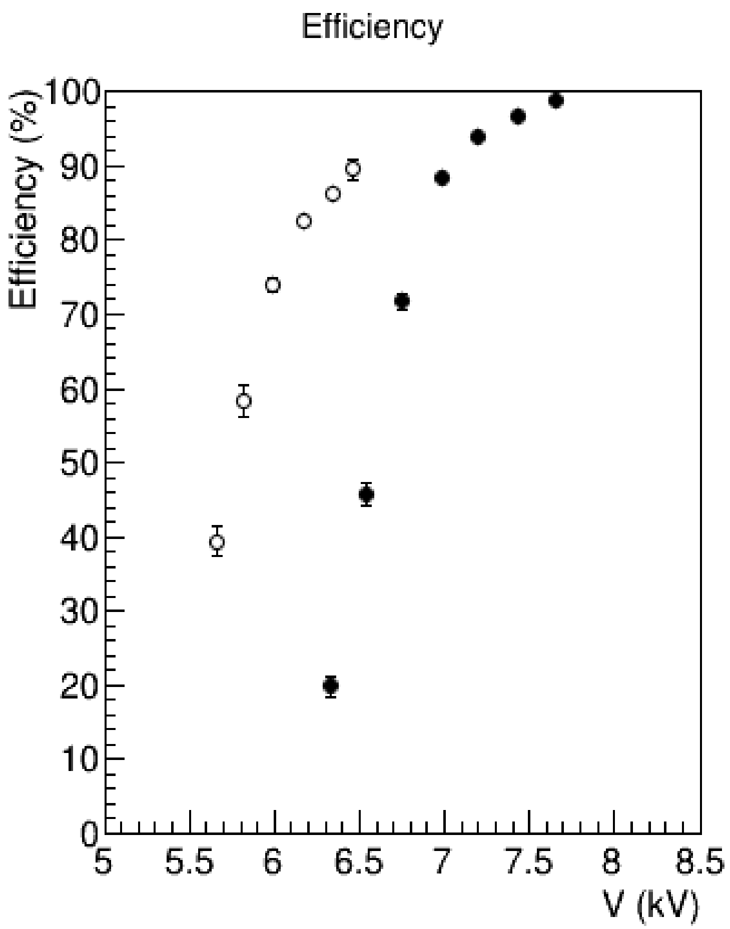
Assuming that the avalanche is contemporary to the passage of the particle, comparing the absolute time of the streamer between different mixtures it is possible to derive qualitative informations about the avalanche-to-streamer delay.
Absolute streamer time here is defined as discrimination time at 50 mV/110 Ω. It is measured with respect to a scintillator used as a reference.

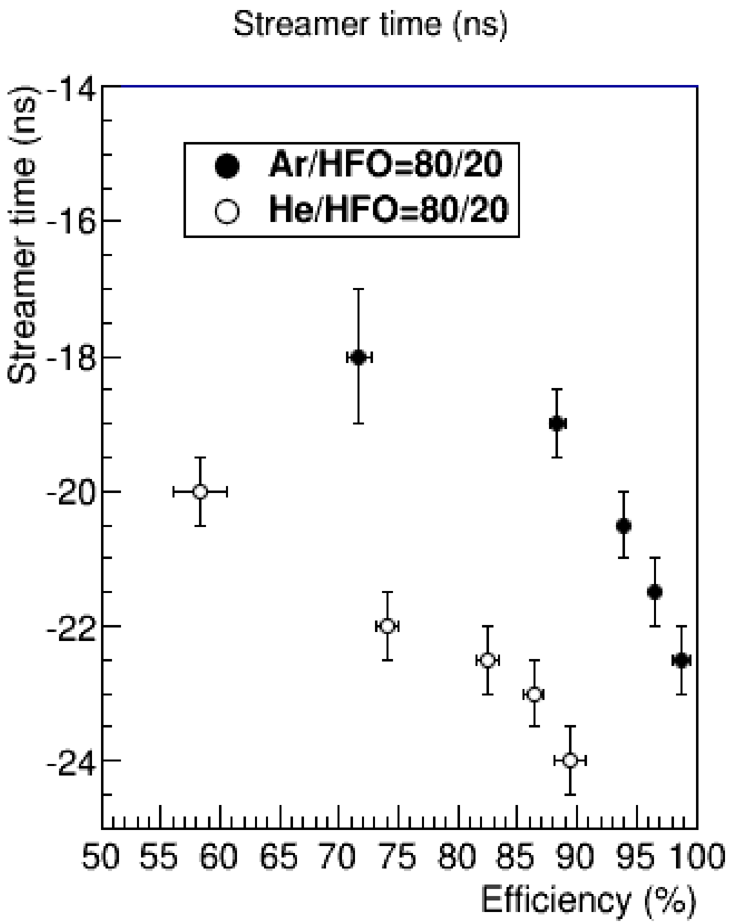
Ar/HFO-1234yf binary mixtures



At full efficiency the streamer time seems almost independent of the quencher (HFO) percentage in the mixture.

Streamer-avalanche delay





Argon replacement with Helium anticipates the streamer formation.

Conclusions

The tests presented here deals with different aspects of atreamer operation of RPCs.

Gas mixtures: CF4 not a good quencher. Not suitable for use in RPCs.

RPC gap: 1 mm gaps increase multistreamers. Usable only with high quencher concentrations.

Streamer mode: possible to define a standard, 2 mm gas gap and Ar/HFO mixture.

Streamer-to-avalanche delay: Around 10 ns, with exponential queue. It decreases replacing Argon with Helium.