Streamer phenomenology in streamer-mode RPCs

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March 11, 2016

Two or three things I learned about streamer-operated RPCs.... (personal pick of past results)

Outline:

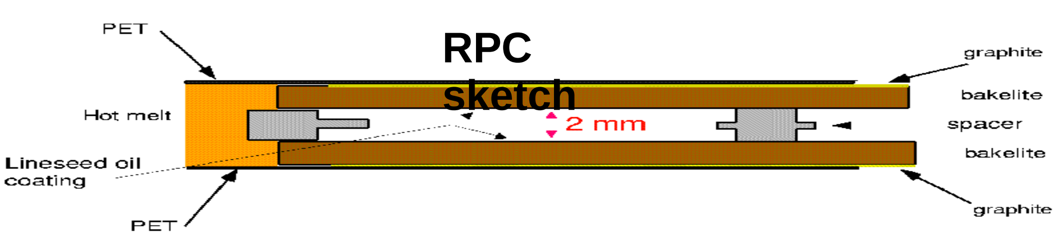
1) OPERA RPC system
2) Streamer formation time
3) Streamer and particle parameters
4) Streamer and gas mixtures

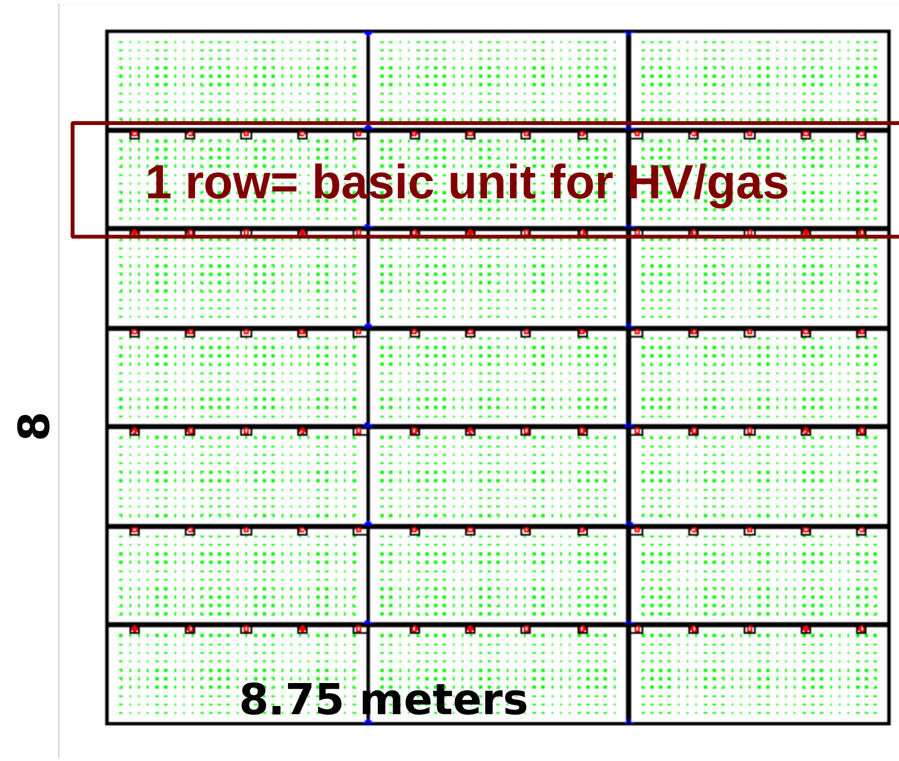
OPERA RPCs

Located in 2 cm gaps between iron slabs:
- **Track reconstruction inside magnet**
- **Shower leakage measurement**
- **Trigger & Timing for the drift tubes**

1 layer = 21 RPCs of size (2.9*1.1) m²
1 spectrometer = 504 RPCs/XPCs

- **High resistivity bakelite electrodes (low rate expected): $\rho > 5*10^{11}$ Ω cm @20°C**
- **Special curved contour chambers**
- **Streamer mode operation (large signals)**
- **Read-out by means of ~8 m strips with 2.6 (3.5) cm pitch for bending (orthogonal) view**



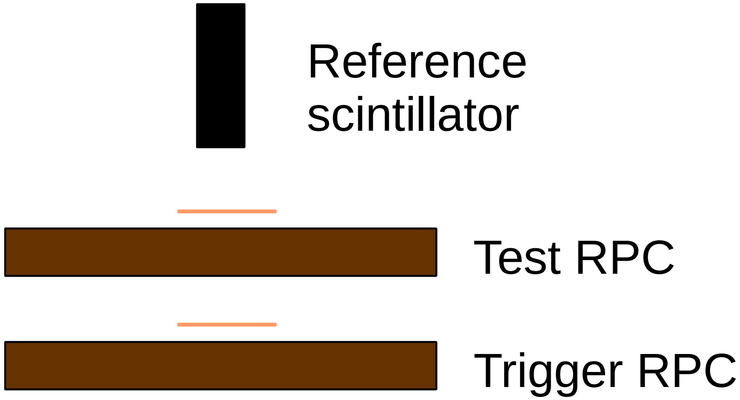


Total surface of the system ~ 3200 m²
Number of digital electronics channels ~ 28000
Streamer operation with $Ar/C_2H_2F_4/isoC_4H_{10}/SF_6$=75.4/20/4/0.6 (5 refills/day, open-flow system).
See JINST4 (2009) P04018 for Front-End discriminators and DAQ.

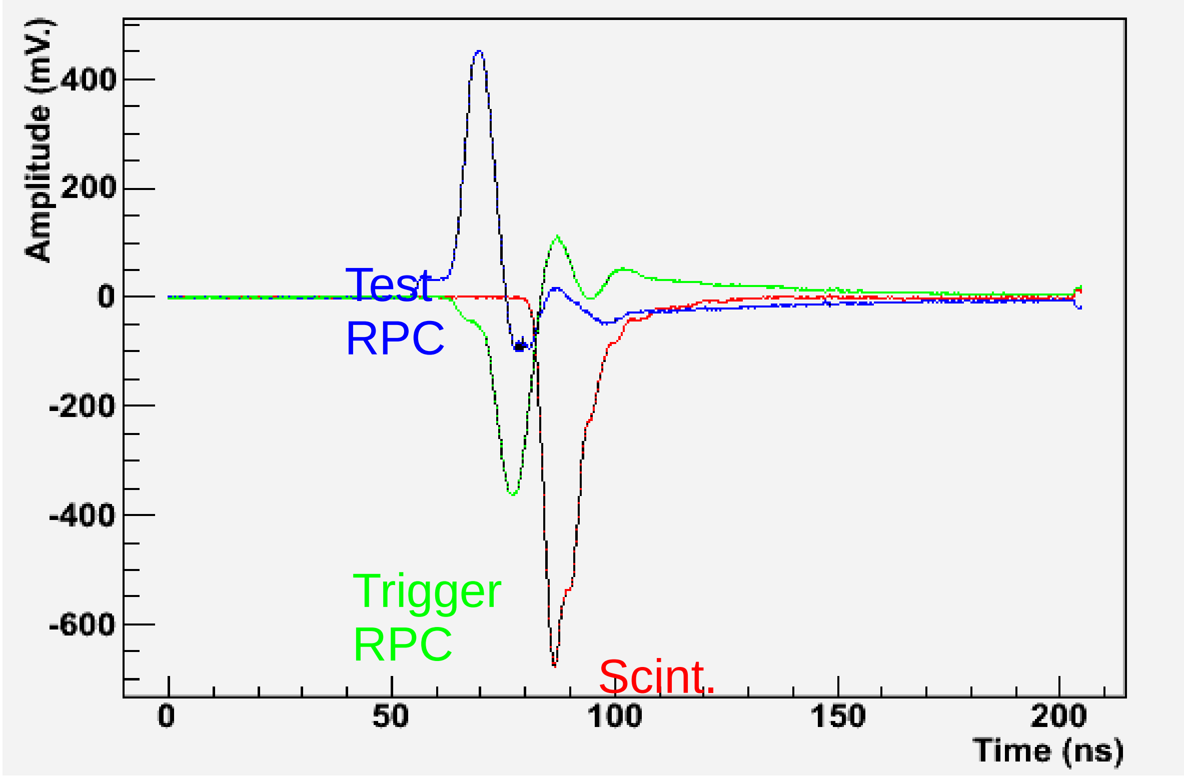
Streamer formation time measurement

At some point in OPERA we needed a precise time calibration....

RPC time response calibration

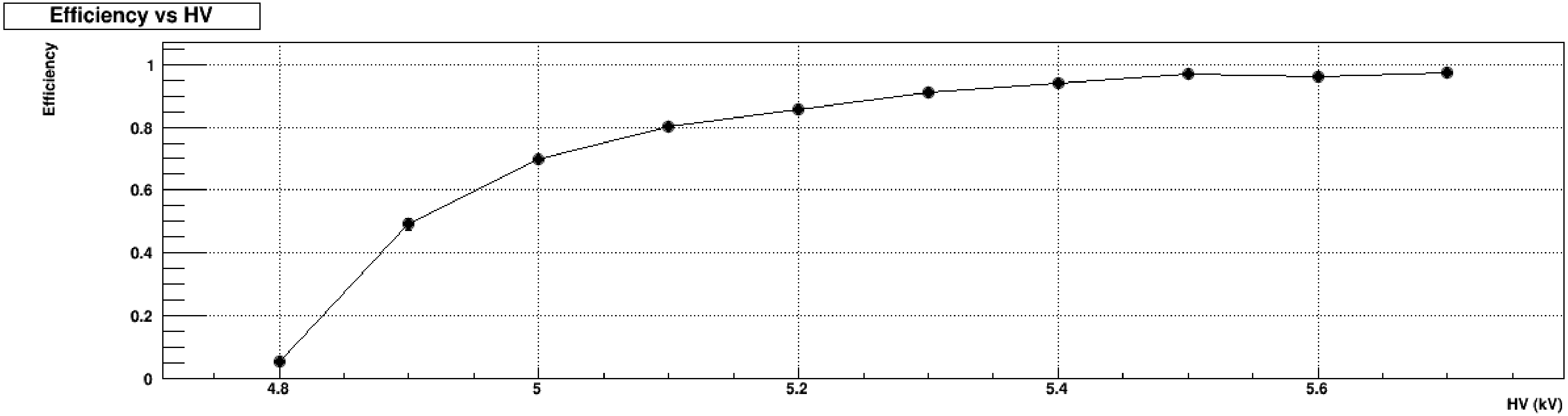


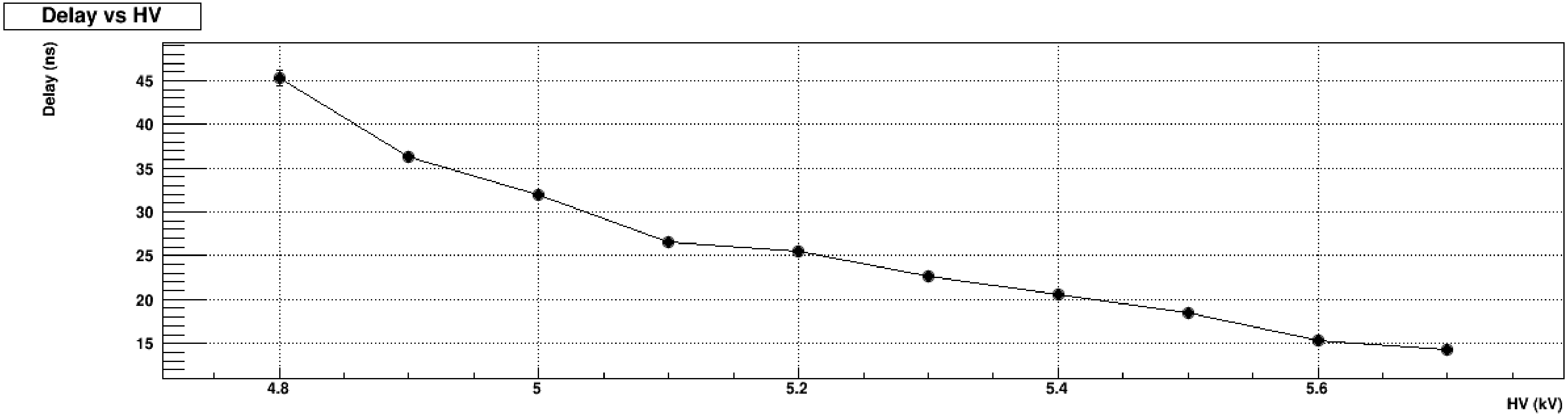
Cosmic rays.
OPERA gas mixture.
Trigger = scintillator and Trigger RPC.
RPCs read-out by means of 3.5*3.5 cm^2 pads.
Scintillator time response calibrated with ps laser.
All other set-up delays calibrated with scope.
Analogic signals acquired with a waveform digitizer (5 Gsamples/s).



Analysis refinements:
Cuts on amplitude of scintillator and trigger RPC signals.
Threshold on test RPC: 26 mV/50 Ohm.

Results





For reasonable efficiency values, there is a 20 ns delay between the passage of the particle and the streamer formation.

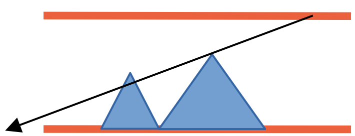
Streamer and particle properties

OPERA data (cosmic and CNGS produced muons) in the first two slides and one test-beam at LNS (parasitic mode).

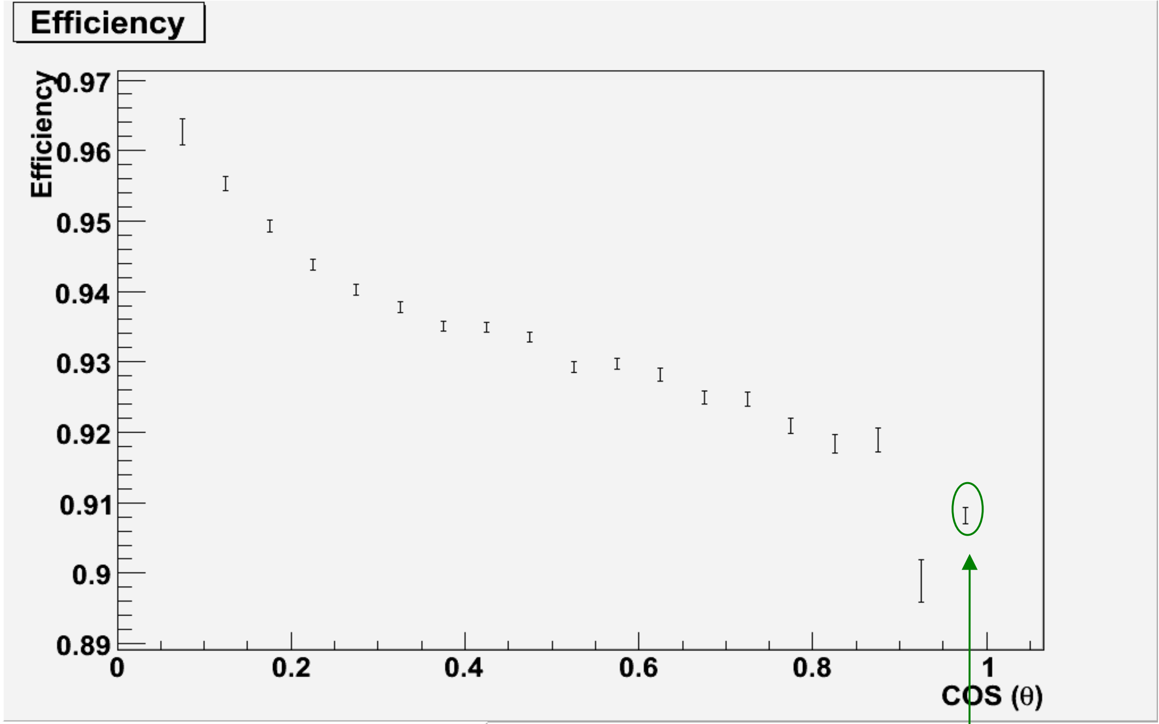
Angular dependence

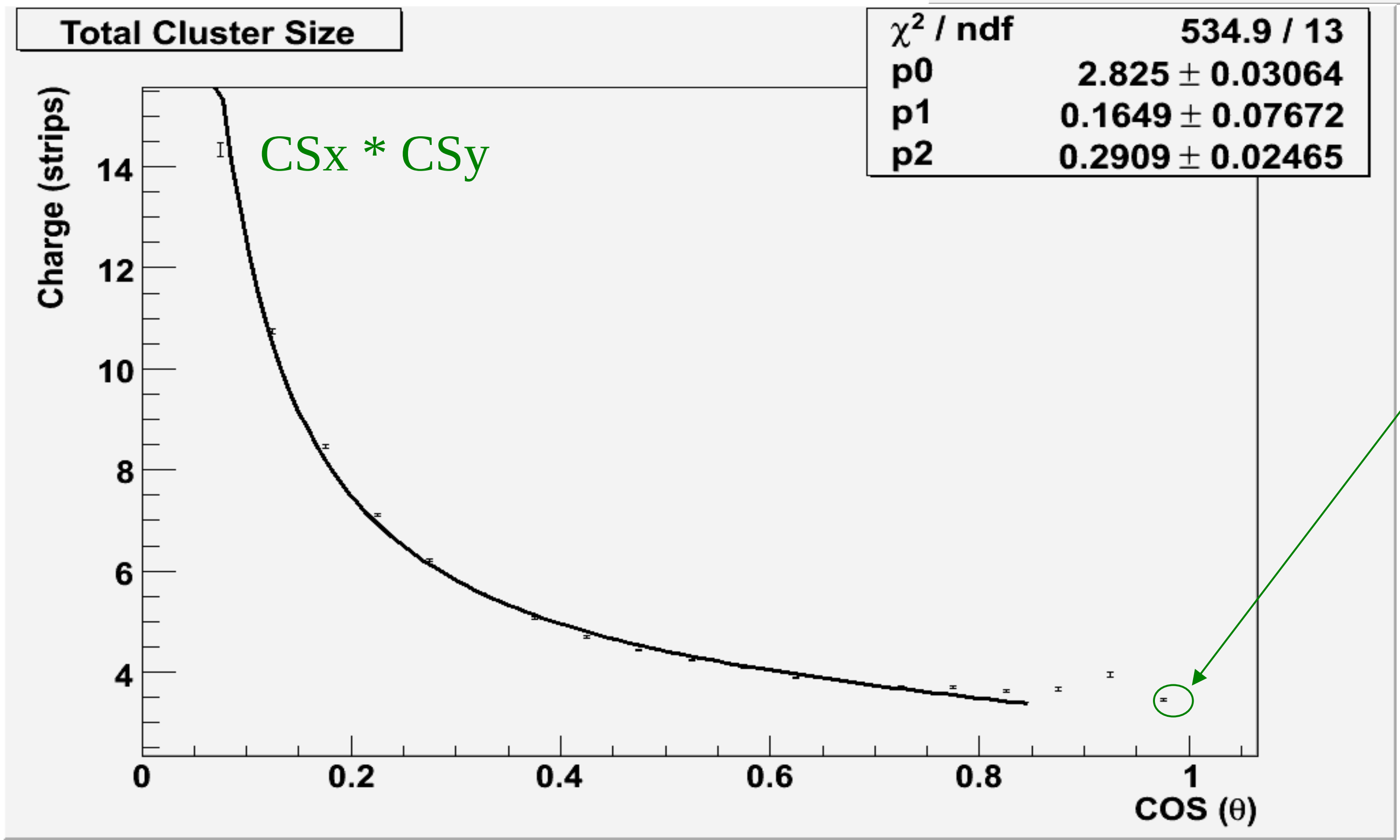
Higher efficiency and cluster size for inclined tracks:

•Geometry effect (more streamers in parallel for inclined tracks)



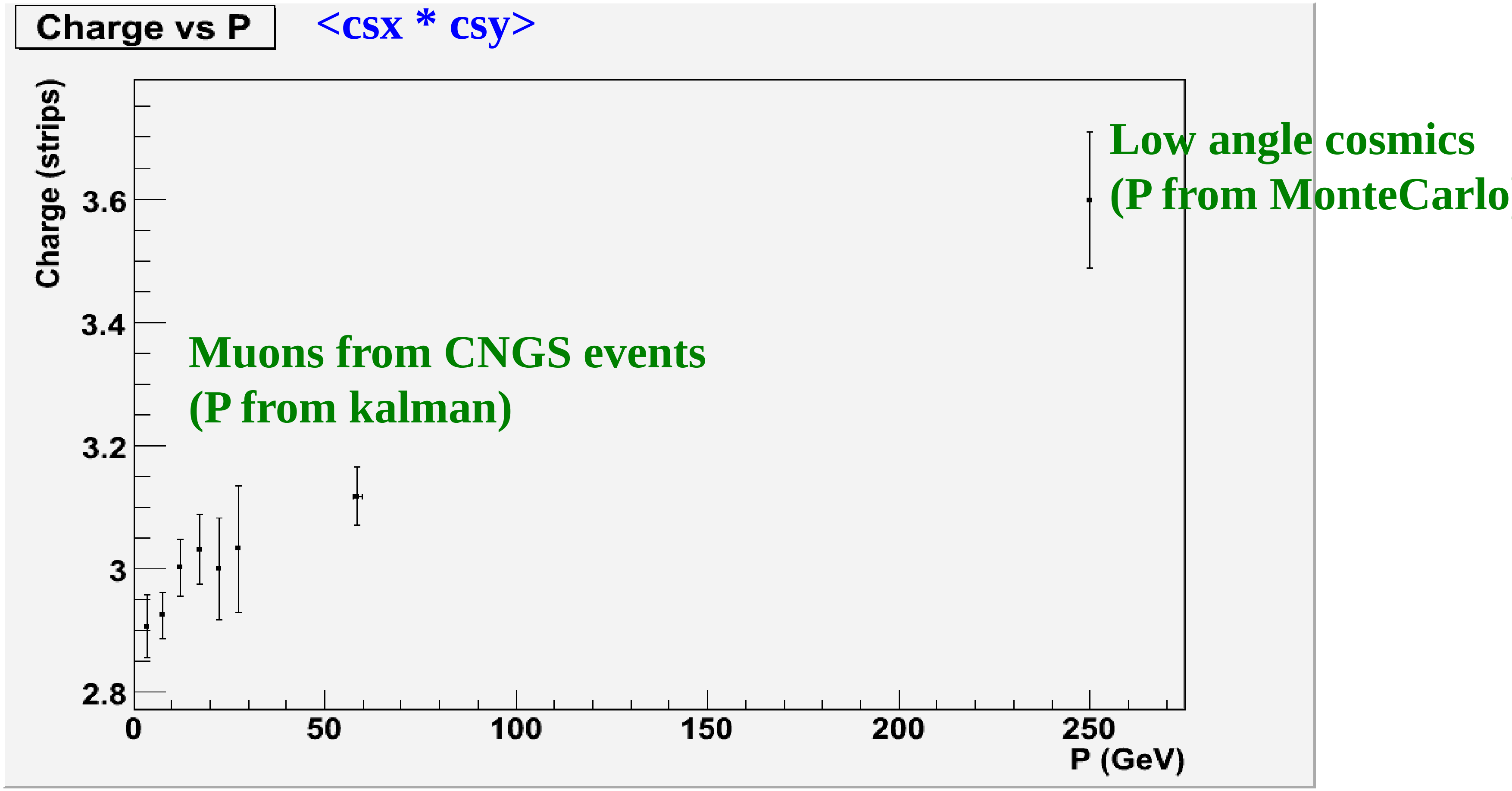
θ=angle wrt to z-axis, normal to RPC layers





Beam events
(p~20 GeV << cosmic muons)

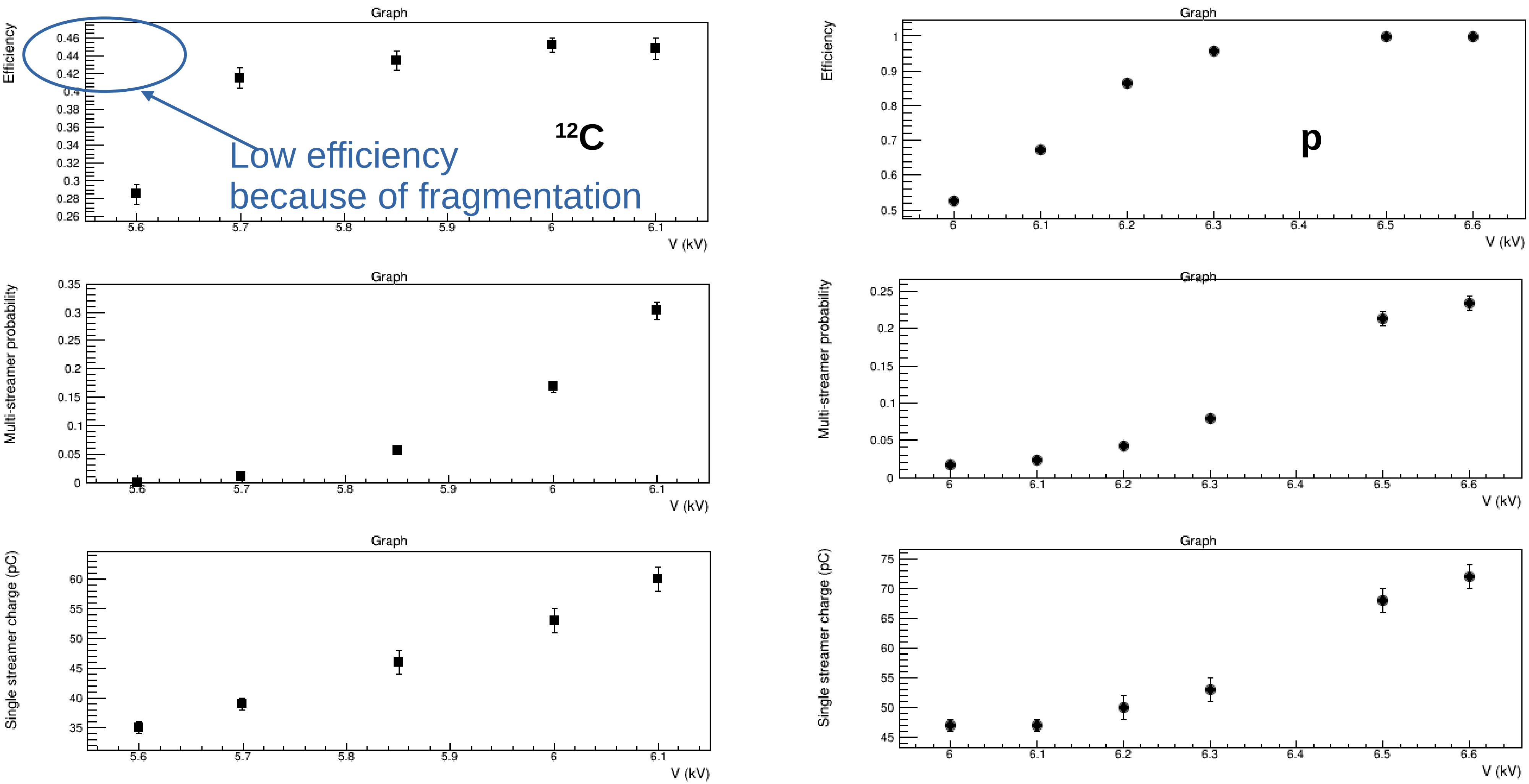
Momentum dependence for perpendicular tracks



For particles impinging with the same inclination, the cluster size increases with the momentum (suggesting a streamer charge dependence on the primary ionization ?)

Highly ionising particles

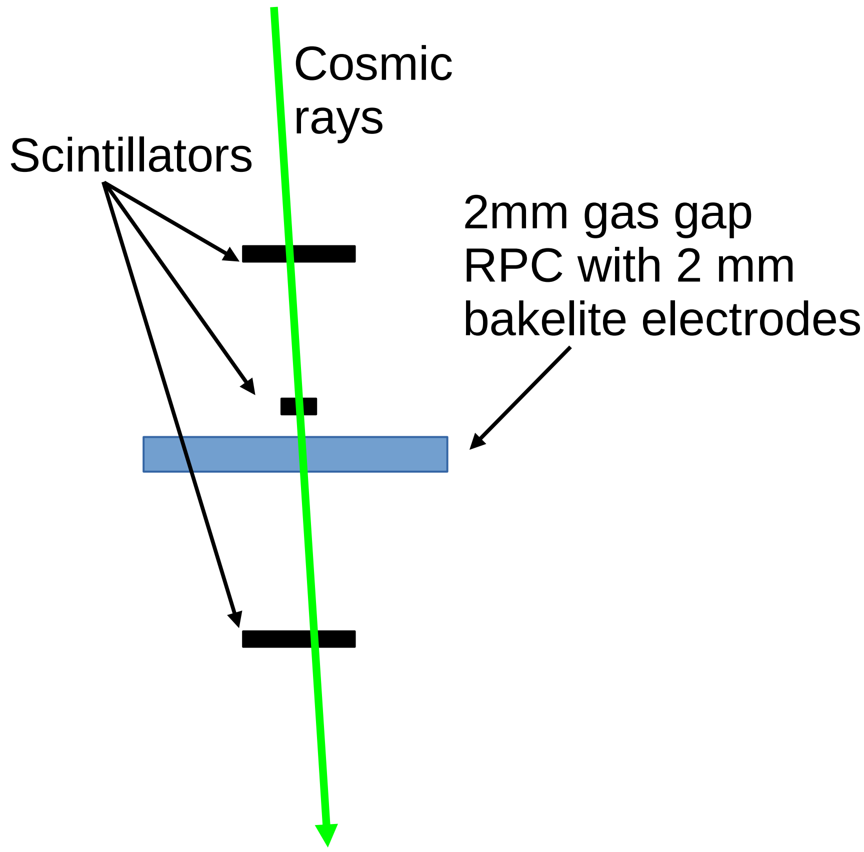
Test-beam in parasitic mode at LNS with 80 MeV/u p and ^{12}C



On ^{12}C ions (36 times more ionizing) streamers develop 500 V lower than on protons.

Streamer and gas mixture

Experimental set-up



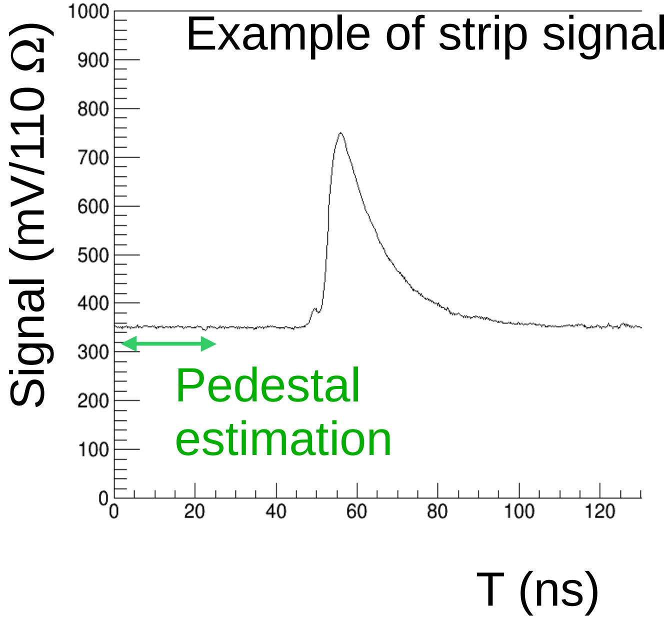
RPC under test read-out by 3.5 cm wide copper strips of 70 cm length. Terminated on 110 Ω on the read-out side, on 25 Ω on the opposite side.

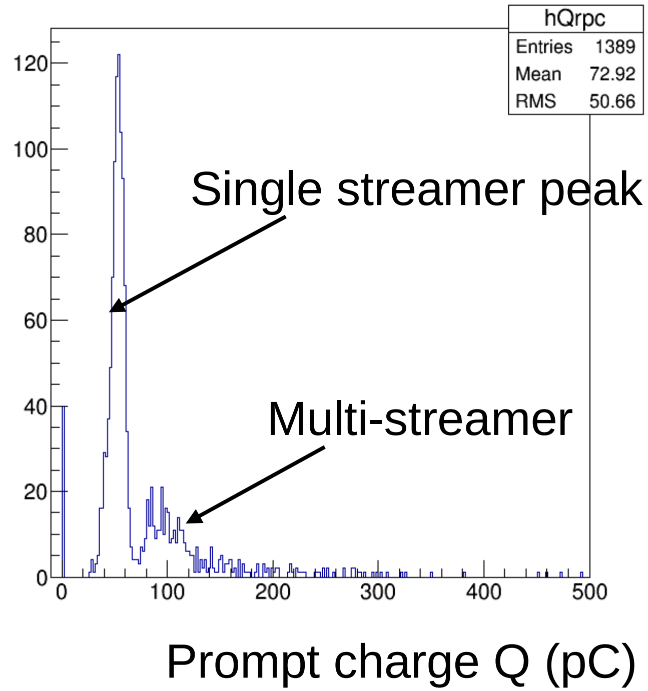
Cosmic ray trigger made by three scintillators coincidence (the central one used also as time reference).

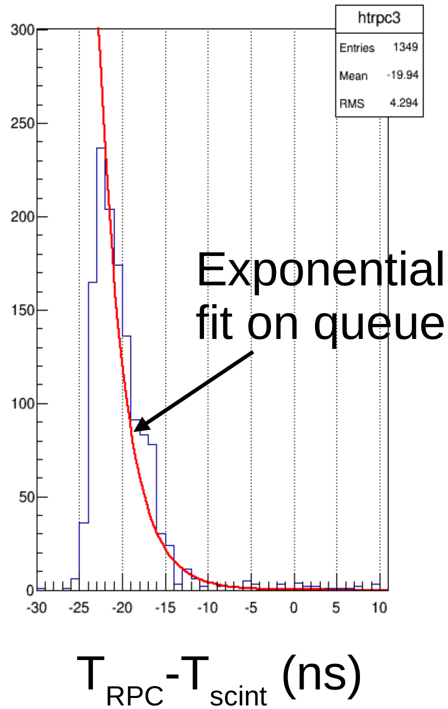
Signals from 11 strips acquired by means of N6742 CAEN digitizer (5 Gsamples/sec).

Strip signals discriminated at 50 mV/110 Ω.

Analysis techniques description



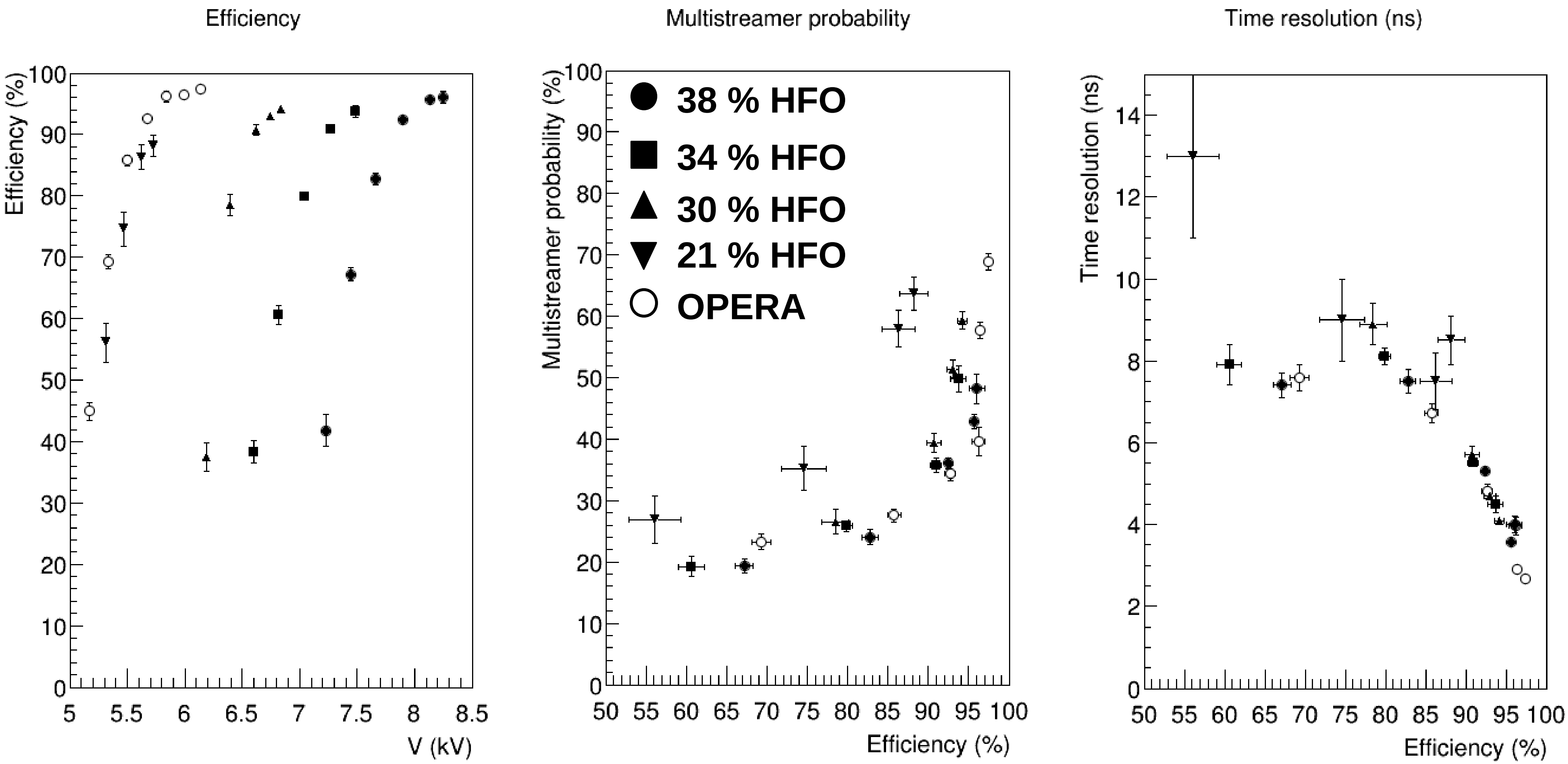




Signal treatment:
Pedestal subtraction channel by channels using first 100 samples.
Common mode noise estimation using strips without signals.

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).

Ar/HFO-1234ze binary mixtures



The higher the HFO concentration, the higher the operating voltage and the quenching power.
Better to keep HFO concentration to 30%, to limit multistreamers.

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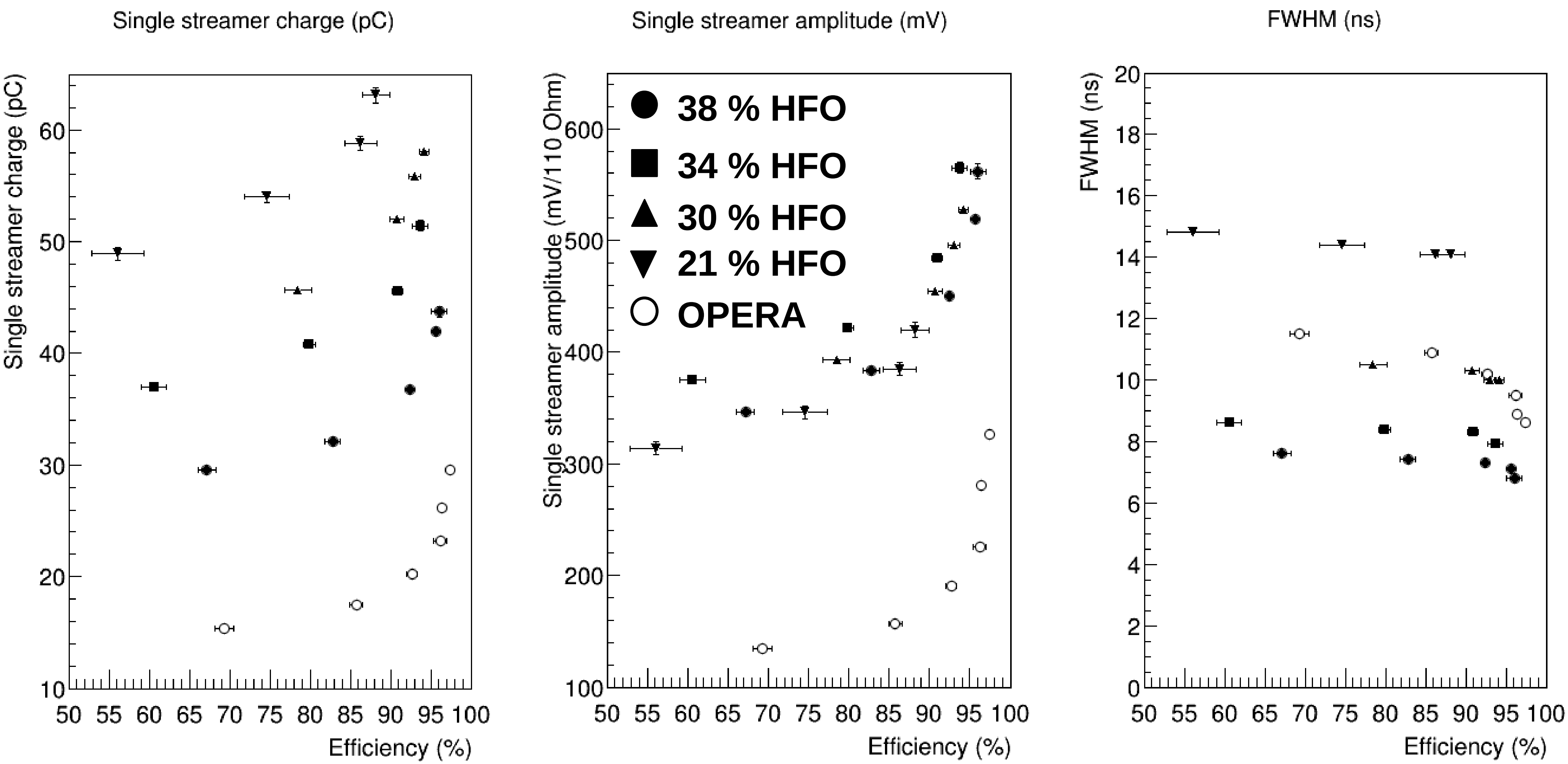


The higher the HFO concentration, the higher the operating voltage and the quenching power.

Better to keep HFO concentration to 30%, to limit multistreamers.

The higher the HFO concentration, the lower the prompt charge (FWHM smaller).

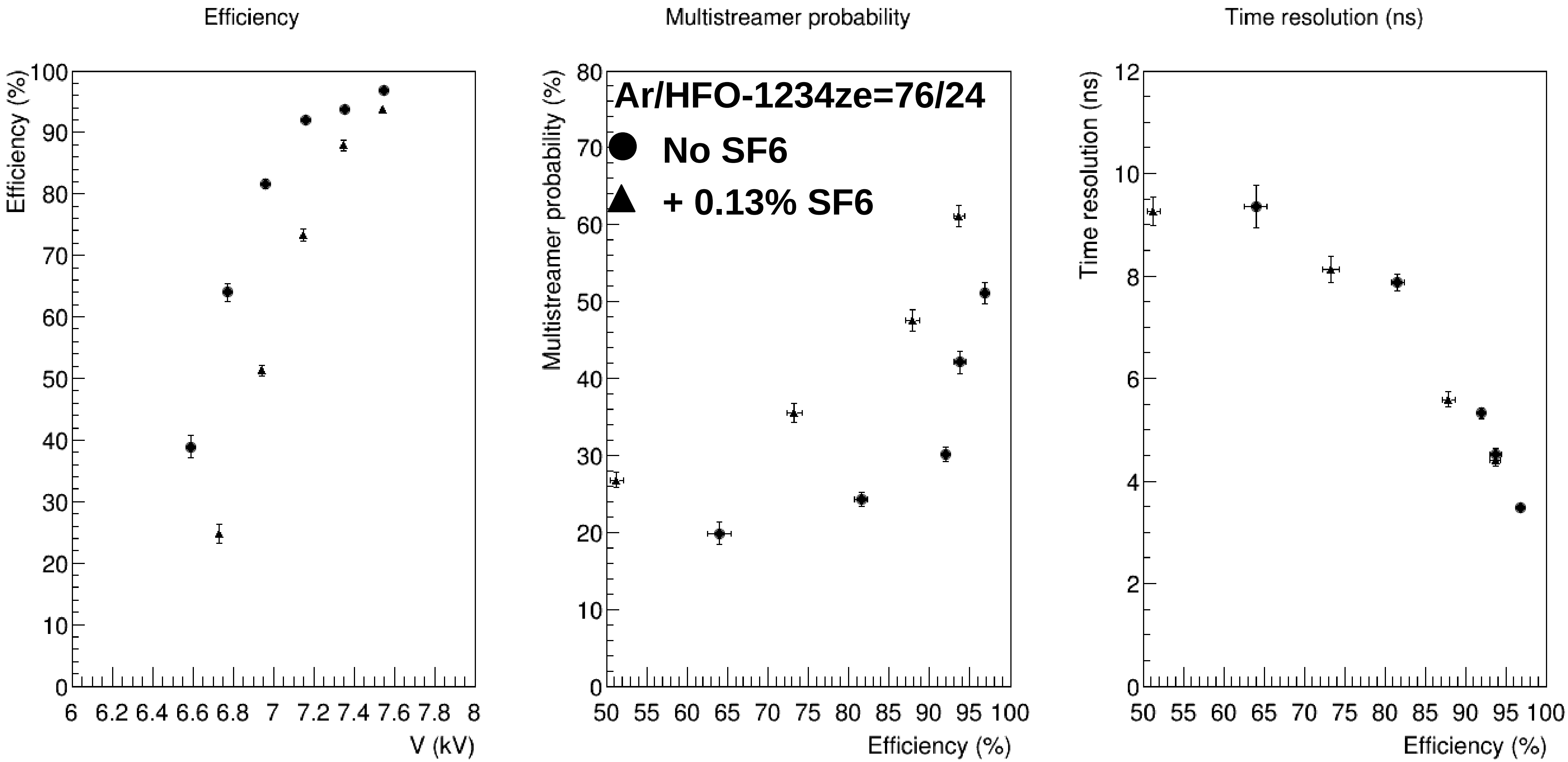
Gas mixtures for streamer RPCs

Typical mixture is composed of Argon/Quencher.

Quencher can be: R134a+Iso-butane, HFO-1234ze, HFO-1234yf, Iso-butane

Quencher cannot be: CO_2, CF_4 .

SF_6 addition



Similar to "standard" mixtures. Even with small additions
Strong charge suppression (both in signal amplitude and FWHM).
Observed also an increase of multistreamer probability.
Tested also on Ar/HFOyf=74/26,70/30 Ar/HFOze=70/30 Ar/HFOyf/ibut=63/34/3.

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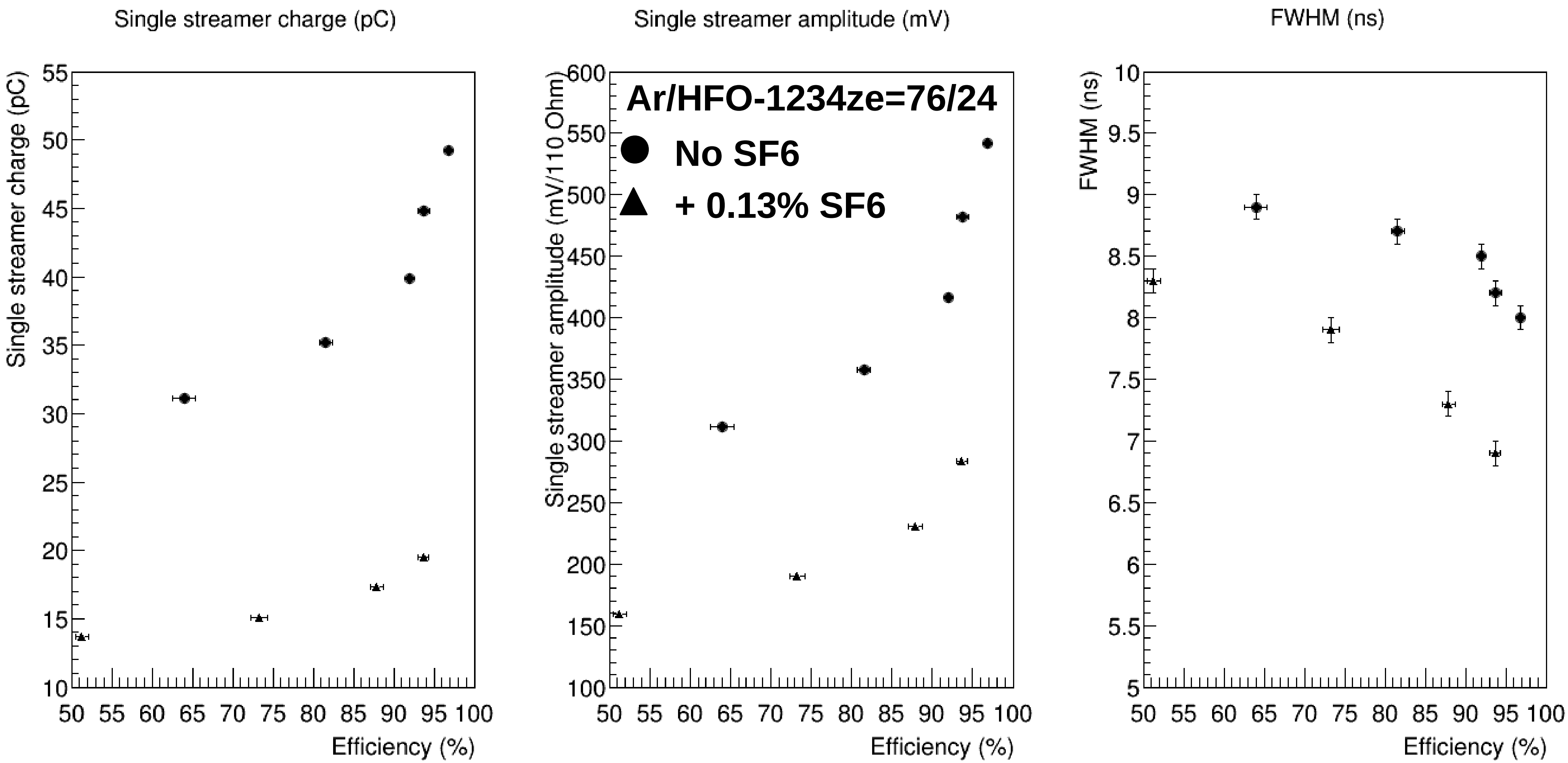

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SF_6 addition

SF6 is used in avalanche operated RPCs as a streamer suppressor.

In streamer mode it suppresses the streamer charge, making stable economic mixtures with low concentrations of quenching gases.

The streamer charge suppression with SF6 is believed to be due to its high attachment coefficient at small electron velocities.