Test for upgrading the RPCs at very high counting rate

Lorenzo Paolozzi

Autors:
Giulio Aielli, Roberto Caradarelli, Anna Di Ciaccio, Luigi Di Stante, Barbara Liberti, Lorenzo Paolozzi, Enrico Pastori, Rinaldo Santonico, Marco Toppi

The purpose for the new RPCs

1) To handle rates up to 14kHz/cm^2 without increasing the operating current - which determines ageing and power dissipation of the detector – is necessary:

. Introduction of a new front end circuit, sensible to smaller signals, which determines the most significant contribution to charge reduction for efficient signals.

. Systematic study of the gas gap size and a multi-gap structure, which also contributes to determine the amount of charge delivered for a single avalanche.

2) To have a better time resolution, in order to reject both uncorrelated background and correlated heavy charged particles in the forward region of hadronic colliders.

. Achievable with smaller gaps and multi-gap structure.

How to work at higher rates

$\varepsilon = \varepsilon(V_{gas}) \longrightarrow$ To keep the same efficiency it is necessary to keep the same tension on the gas gap

$$V_{gas} = V_A - R \cdot I = V_A - \rho \cdot d \cdot \Phi \cdot Q(V_{gas})$$

Reduce resistivity

Allows to work at higher rates and depends on temperature, relative humidity of both gas and environment. Does not solve the problem of the ageing (if any).

Reduce average charge/avalanche.

Grants at the same time an higher rate capability at constant current.

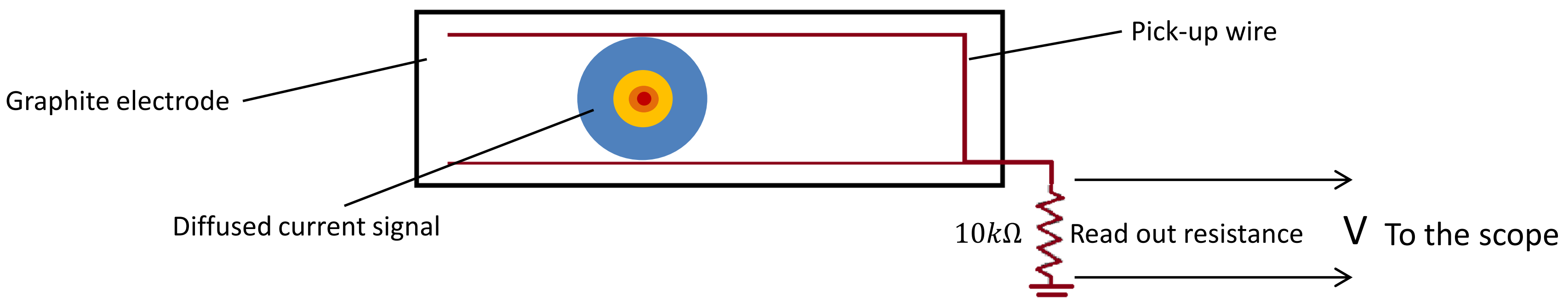
Reduce electrode thickness

The ageing effects were demonstrated to increase with the operating current, that is proportional to the charge delivered into the gas at each count of the detector.

The reduction of the average charge/efficient avalanche is thus the most effective way to work at higher rates without incurring in ageing effects.

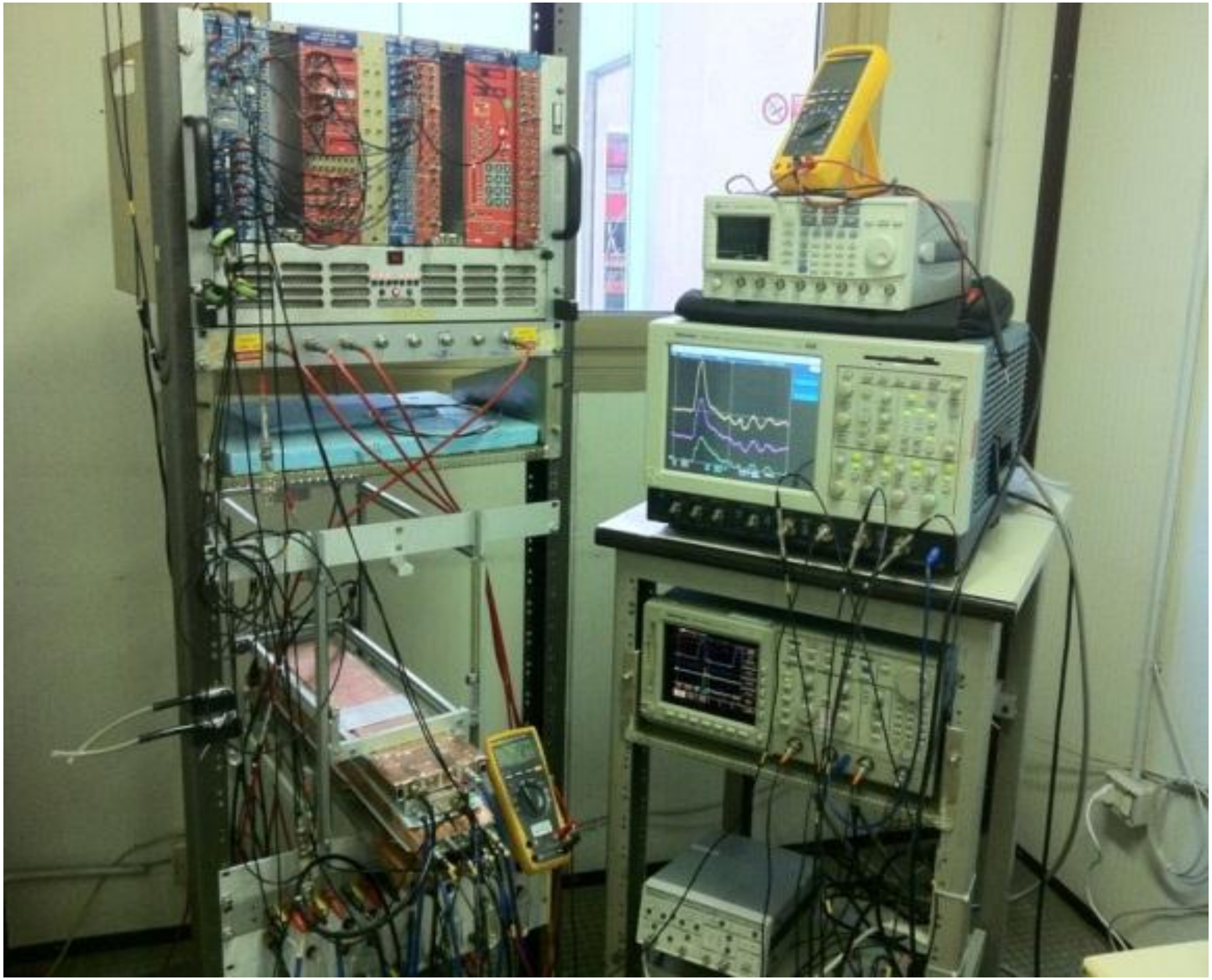
Systematic study of the delivered charge in a cosmic ray test

- It was carried out on small size (8x50 cm2) gas gaps of 2.0, 1.0 and 0.5 mm irradiated with cosmic rays, using a gas mixture of $C_2H_2F_4$/i-C_4H_{10}/SF_6=94.5/5.0/0.5.
- We have studied both “naked” signal and amplified signal using the new FE electronics [1].
- The wave forms of both the prompt signal due to the fast drifting electrons and the signal detectable in the HV circuit (dominated by the ion drift motion) are recorded using a scope of 1GHz analog band and sampling rate of 10 points/ns.
- It has been possible to measure the ionic signal by using a pick-up wire on the graphite. In this way we could evaluate the charge developed in a single event.

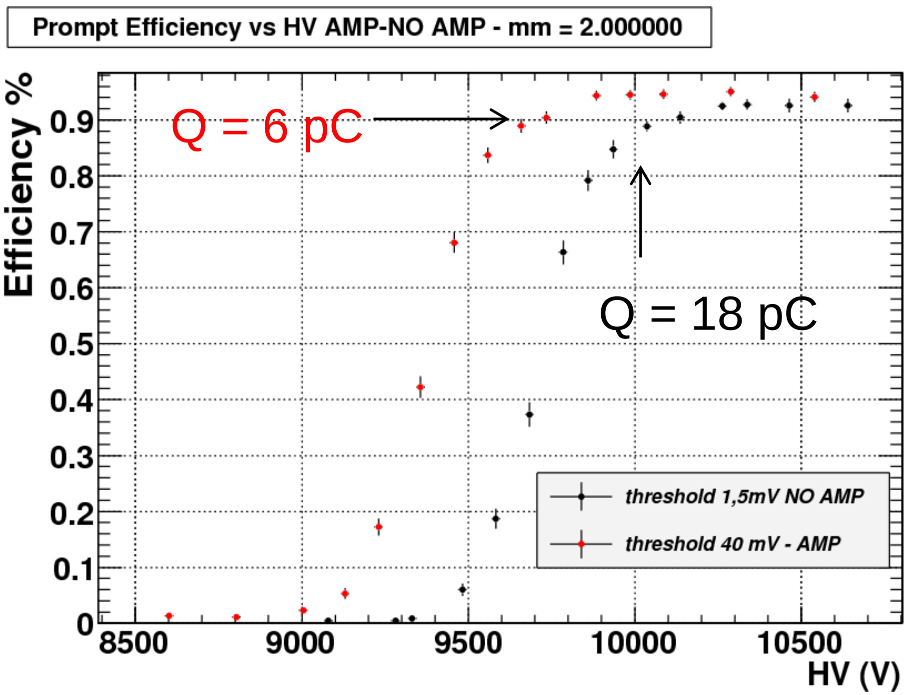


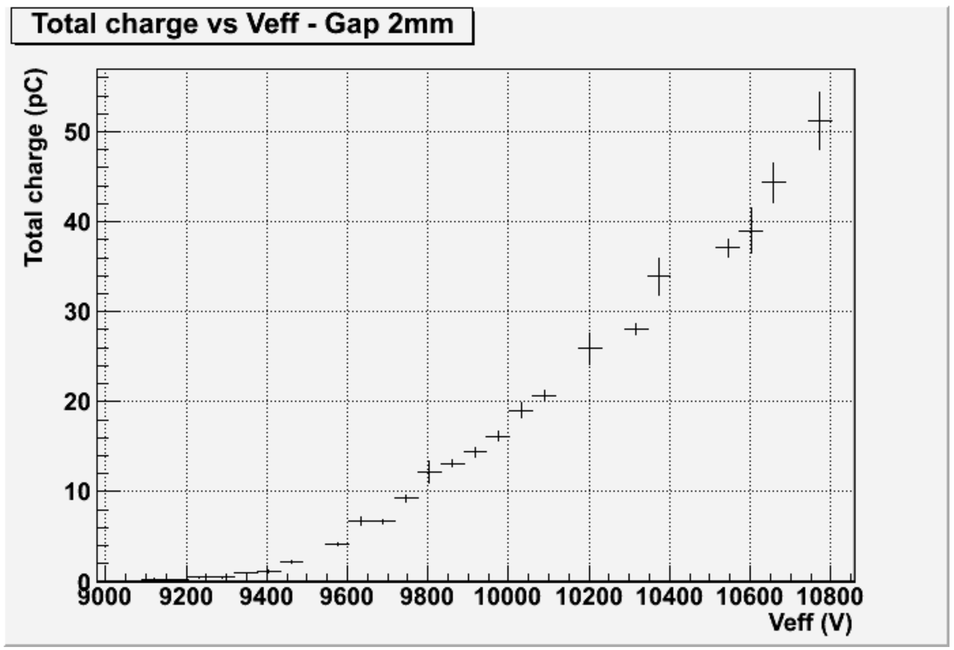
[1] R. Cardarelli, RPC performance vs. front-end electronics, Nuclear Instruments and Methods in in Physics Research A, doi: 10.1016/j.nima.2010.09.136

Experimental setup



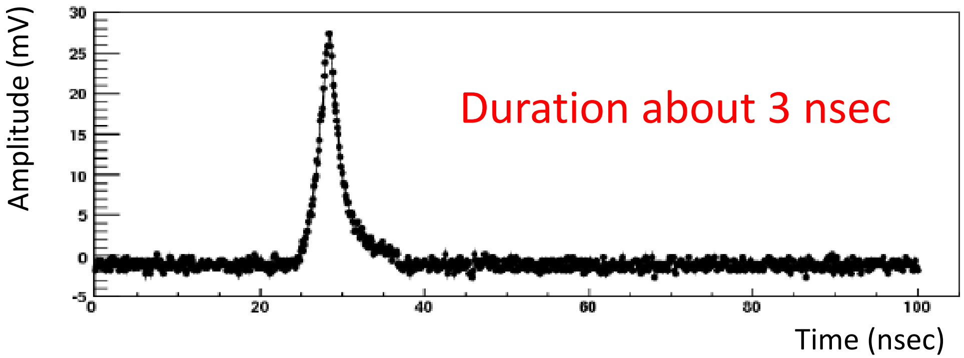
Performance of the new FE electronics on a ATLAS-like 2mm gap



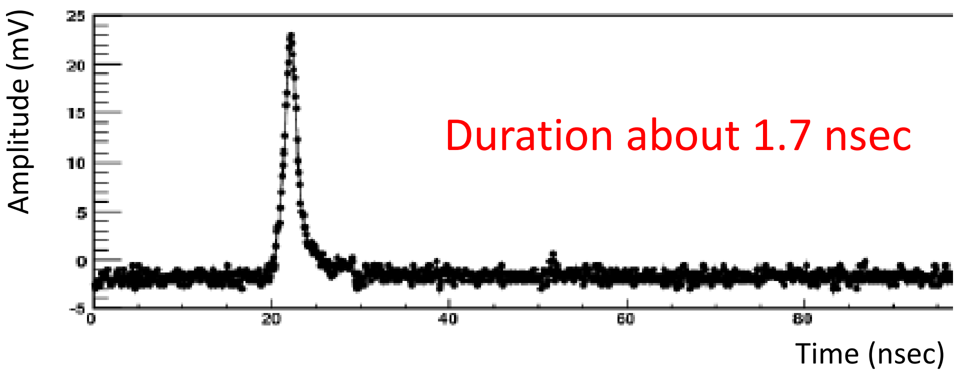


This is one of the many versions of FE electronics that we are testing. Better results are on the way with new FE electronics versions.

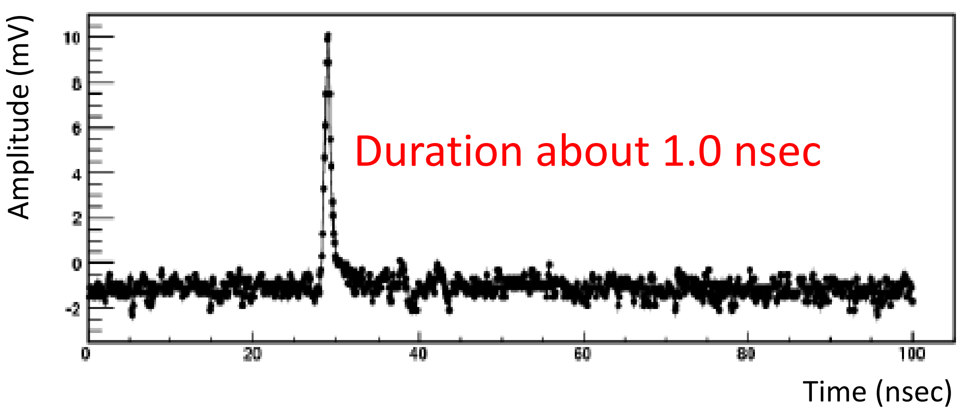
Prompt signal for different gap size



Prompt signal from a 2mm gap RPC



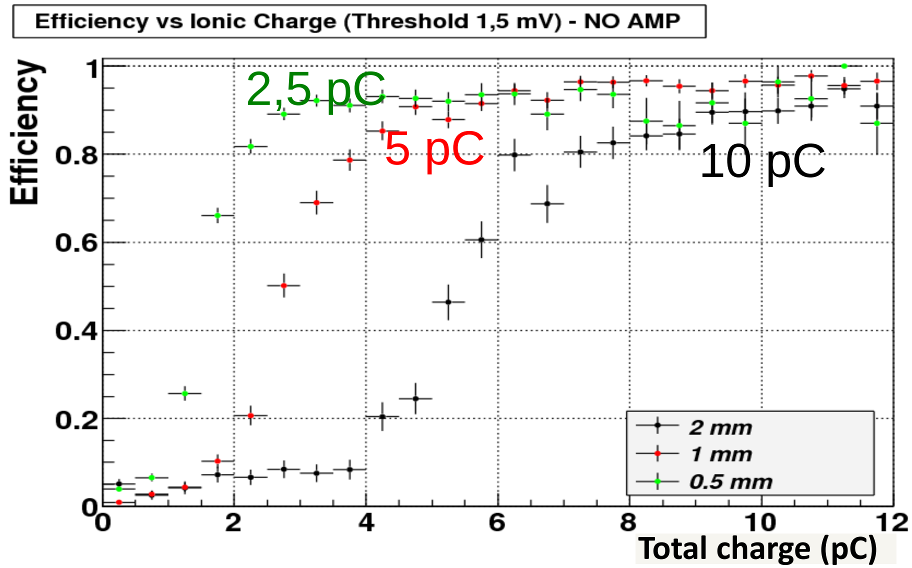
Prompt signal from a 1mm gap RPC



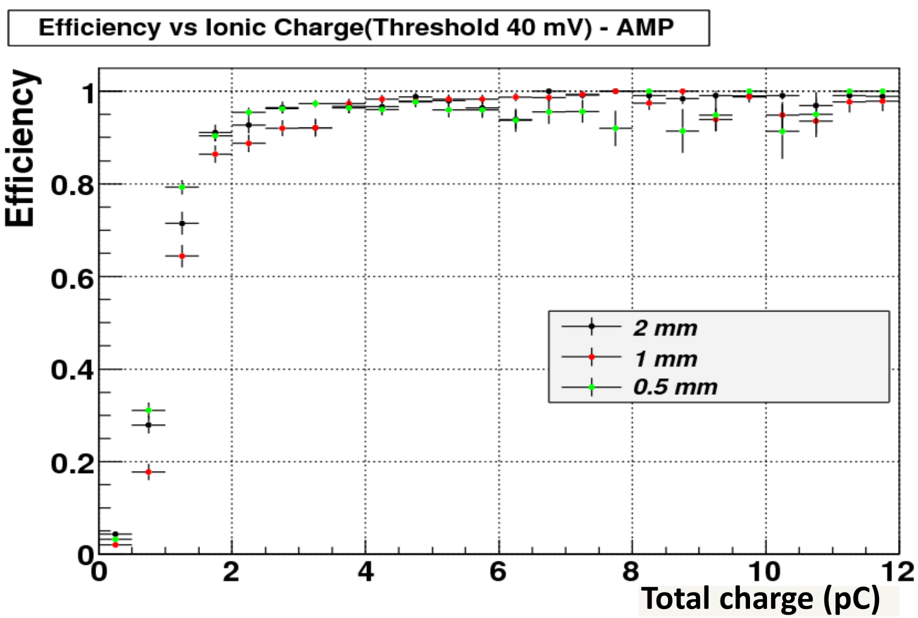
Prompt signal from a 0.5mm gap RPC

Efficiency vs Total charge

Another contribution to the avalanche charge reduction is to work with a thinner gap.

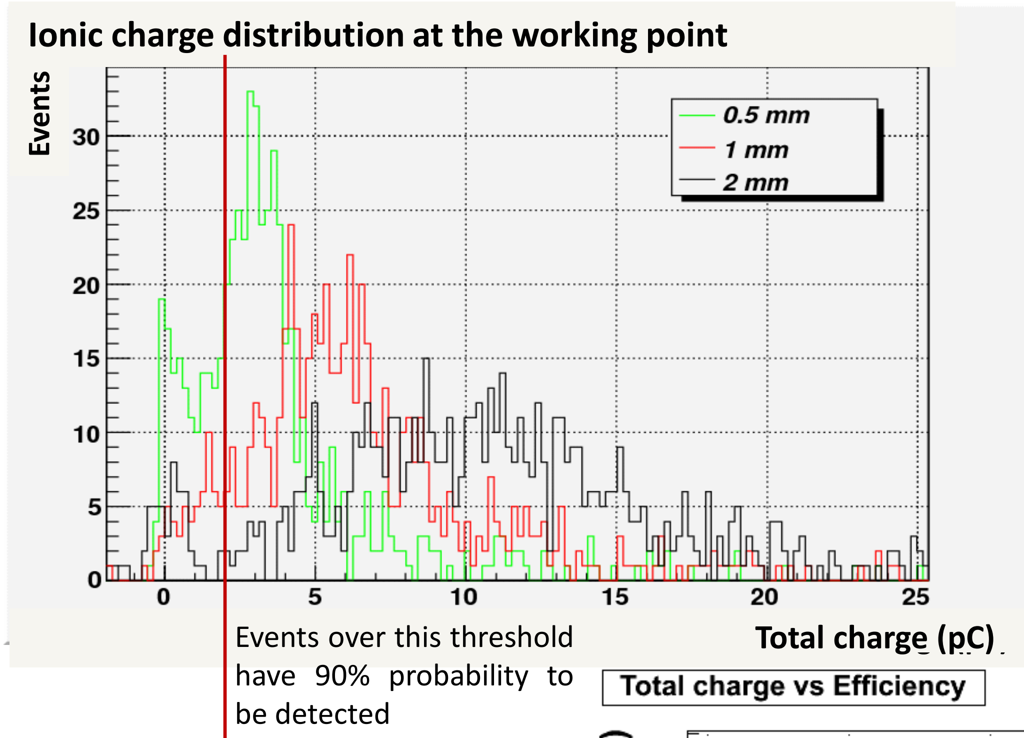


Using a voltage amplifier (scope amplifier) signals with the same amplitude have a lower charge if produced in thinner gaps. This is due to the lower duration of the signal.



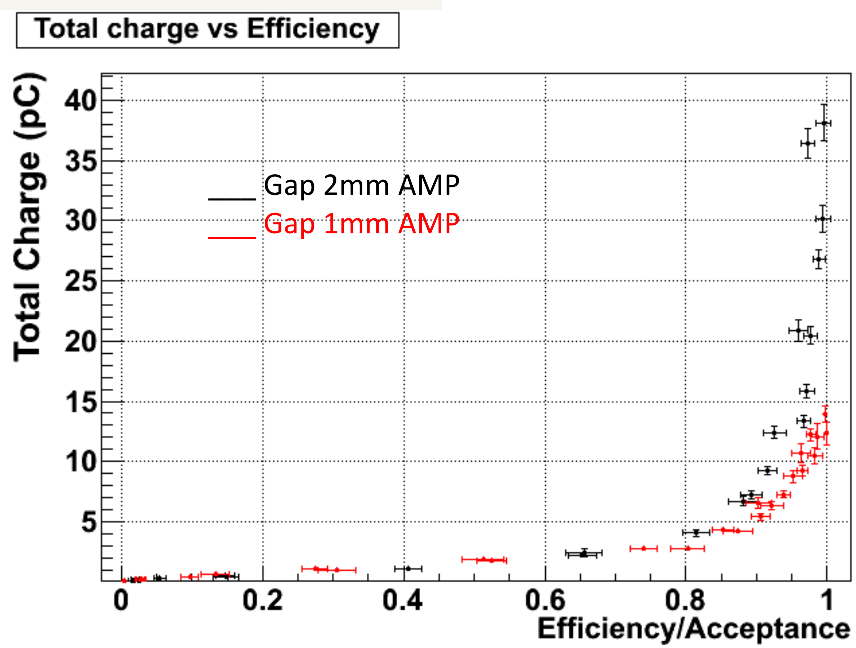
Introducing a charge amplifier most of the difference is lost and the average detectable signal has more than 2pC charge for all the gaps.

Total charge reduction



The reduction of the average charge when reducing the gas gap is a consequence of the fact that the charge distribution itself is less wide.

For this reason you do not need to raise too much the average value to bring most of the events over threshold.



At ~90% efficiency:

2mm gap: 6 pC
1mm gap: 4.5 pC

Study of a 1+1 mm bigap using a cosmic rays test

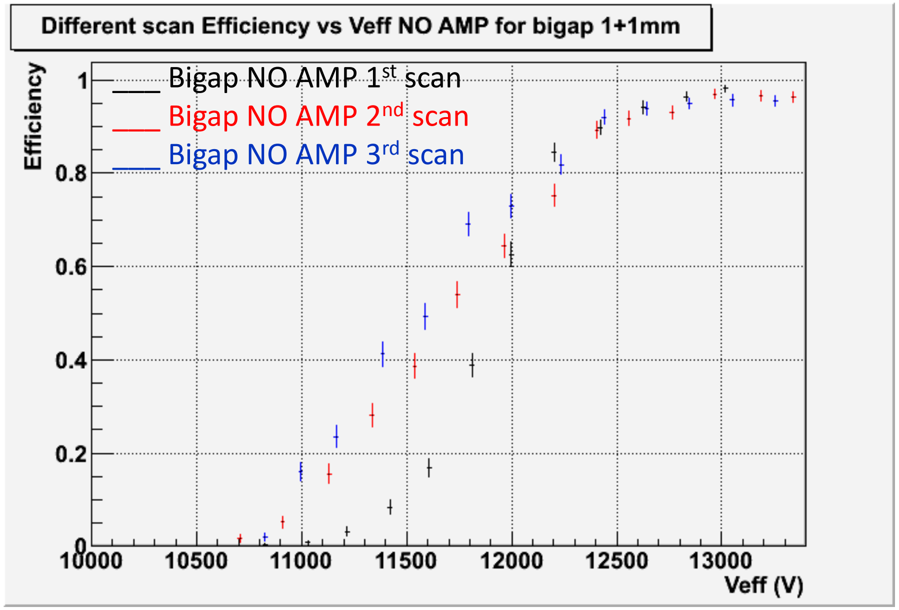
. The study on the bigap was carried out with the same setup used for the comparison between different gaps.

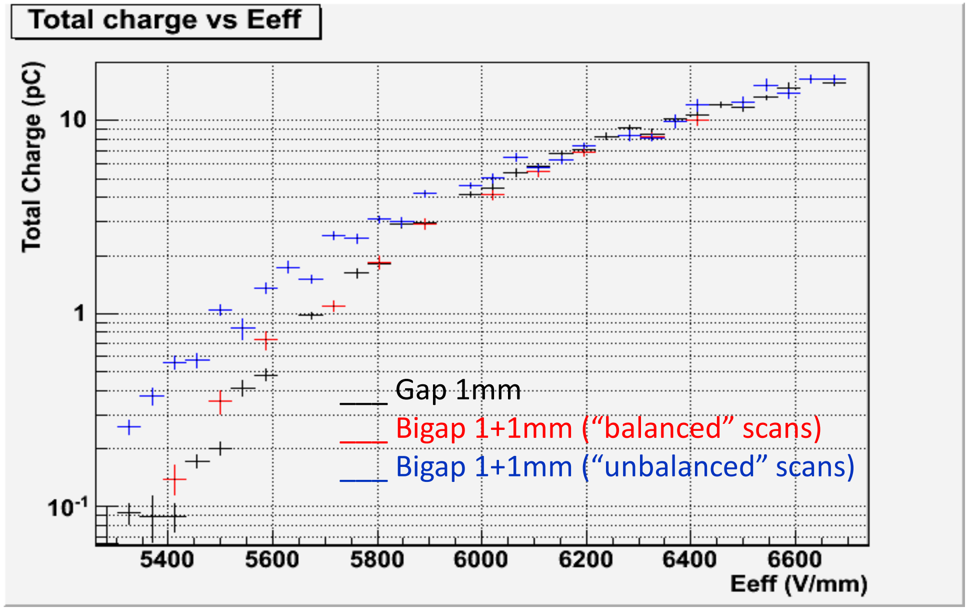
. The chamber has two gaps 1mm wide, separated by a 2mm floating electrode.

. The floating electrode is expected to work properly at high rates, when the gap current itself acts as a controller of the balance of the two gas gaps (the condition is that the physical current must be significantly higher than the Ohmic current). An aim of the test is also to see if the floating electrode realizes the condition of a balanced electric field for the two gaps in a low counting rate regime

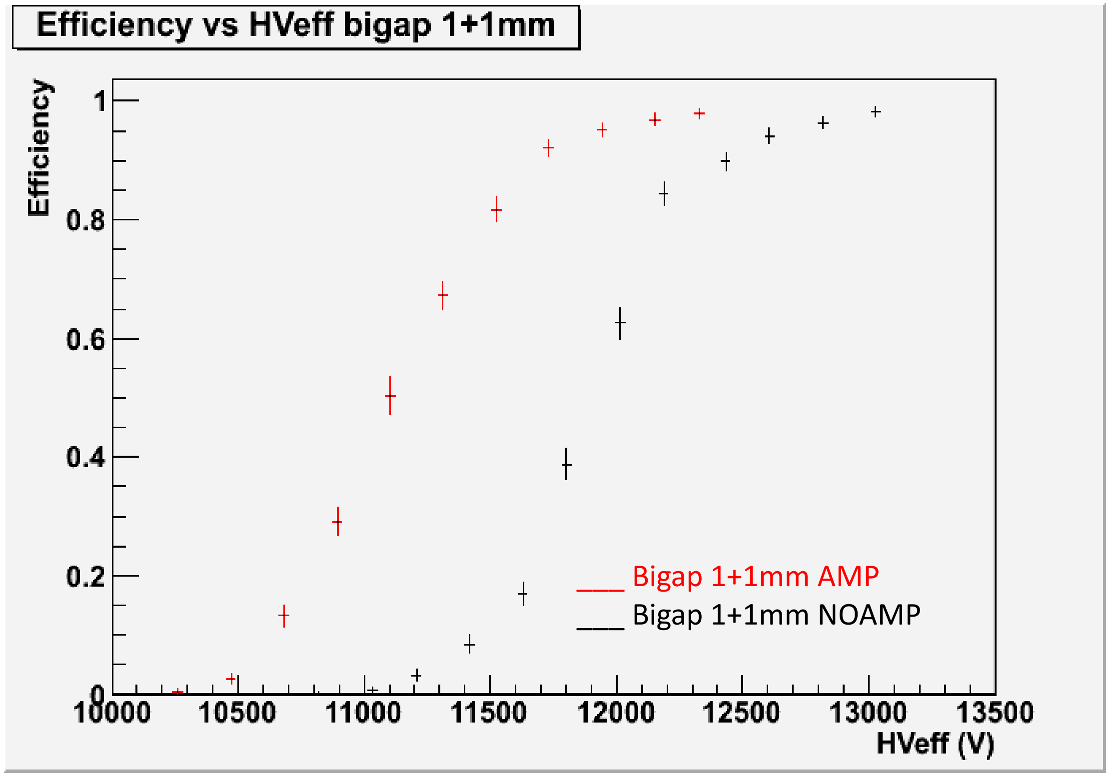
Unbalance of the bigap chamber due to the floating electrode at low rates

- We have observed that bigap chambers with intermediate floating electrode work properly only if the operating current exceeds a proper threshold.
- The compared measurements of efficiency and total charge vs HV supports the interpretation of this effect as due to the unbalance of floating electrode.
- Before the test a long conditioning of the gaps was done, so that the Ohmic current of the two gaps was much lowered and the applied voltage appeared to be almost the same for both the gaps. This condition however may not be long time stable.





Performance of the new FE electronics on the 1+1mm bigap

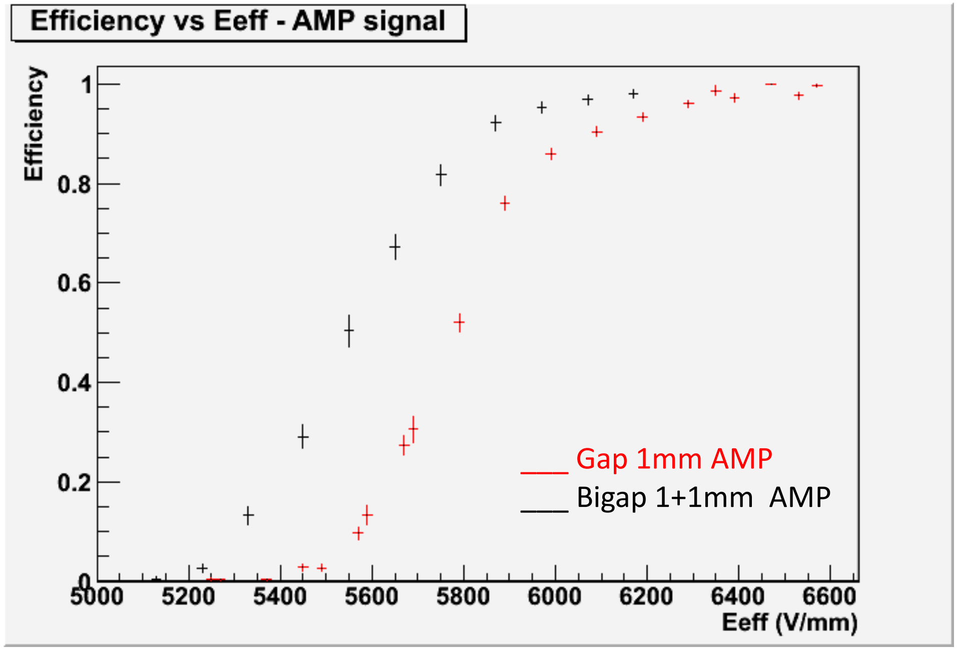


A significant gain comes from the electronics when used on a bigap RPC ($\Delta V \cong 800V$ on efficiency).

Comparison between 1mm monogap and 1+1mm bigap: efficiency (amplified signal)

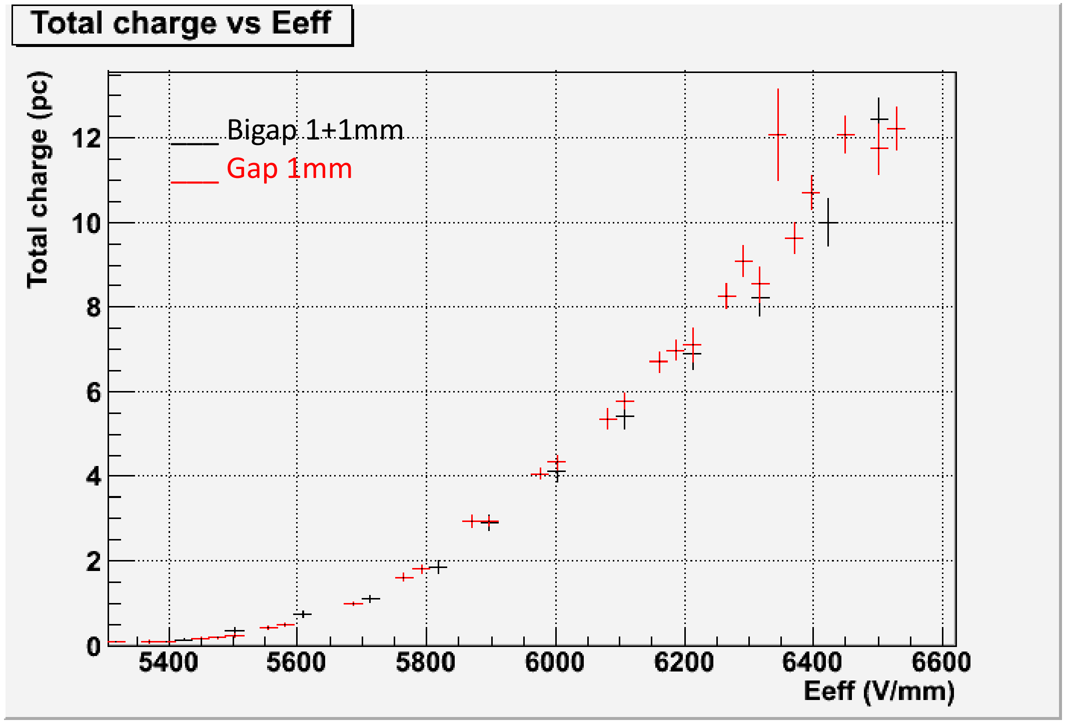
The bigap chamber gives a gain in electric field of $\sim 250\,{}^{V}/_{mm}$ at 90% efficiency with respect to the 1mm single gap.

→



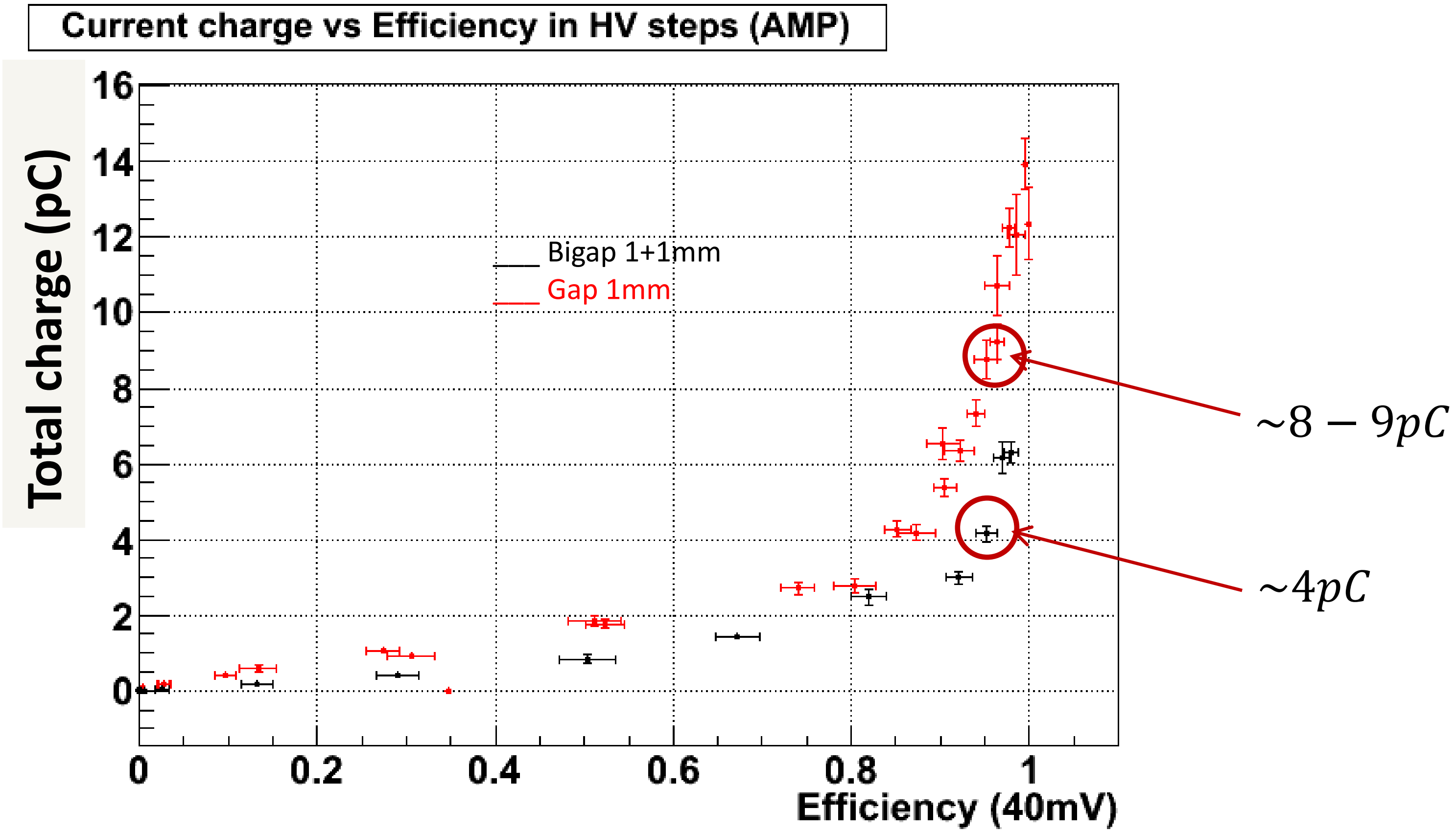
Monogap vs bigap total charge comparison vs electric field

The average total charge is the same for both monogap and bigap as expected.



Average charge vs efficiency for 1mm monogap and 1+1mm bigap

The higher efficiency of the bigap at the same E field permits to work at a lower current.



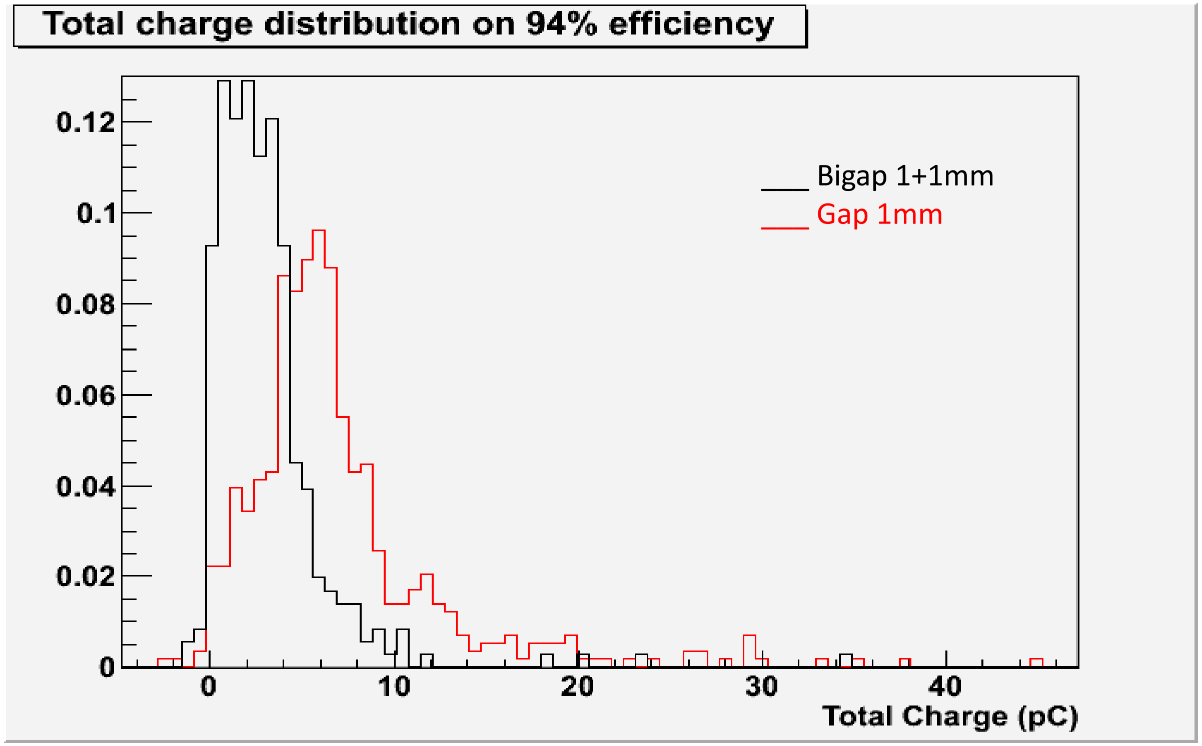
At 94% efficiency the bigap works with an average charge of 4pC.

At 90% efficiency the bigap works with an average charge of less than 3pC.

Note: The gain turned out to be very lower without using the new electronics.

Charge distribution on efficiency for monogap and bigap

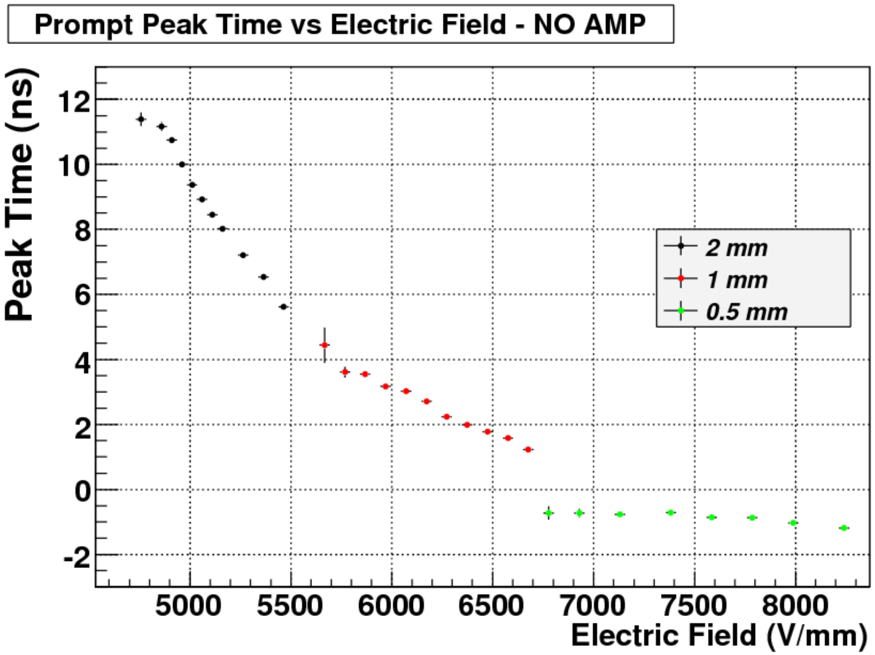
At the same value of the efficiency the distribution of the total charge for the bigap chamber is significantly different: not only the average charge in smaller, but also the RMS is about a factor 2 less than for the monogap.



Bigap: average total charge: $\sim 4pC$

Monogap: average total charge: $\sim 8-9pC$

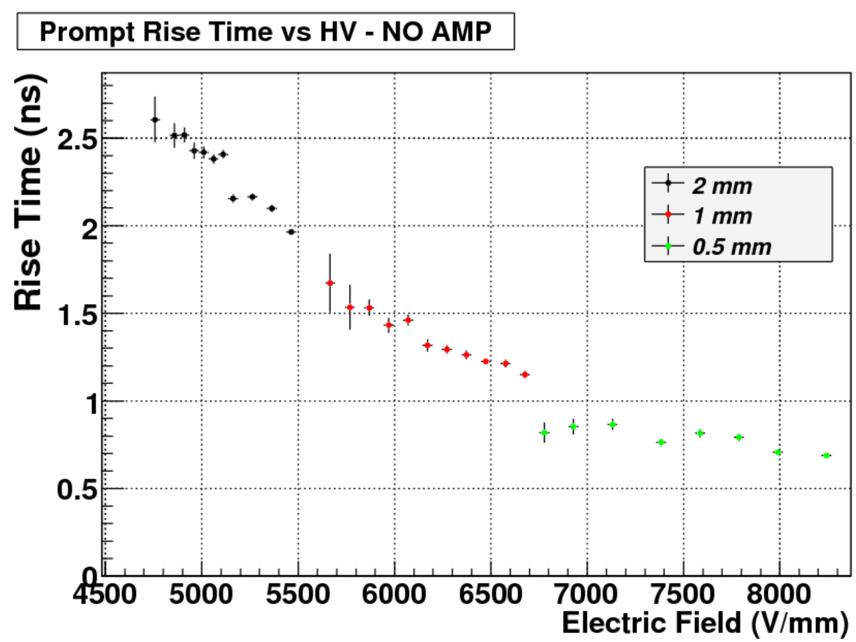
Time performance for different gaps



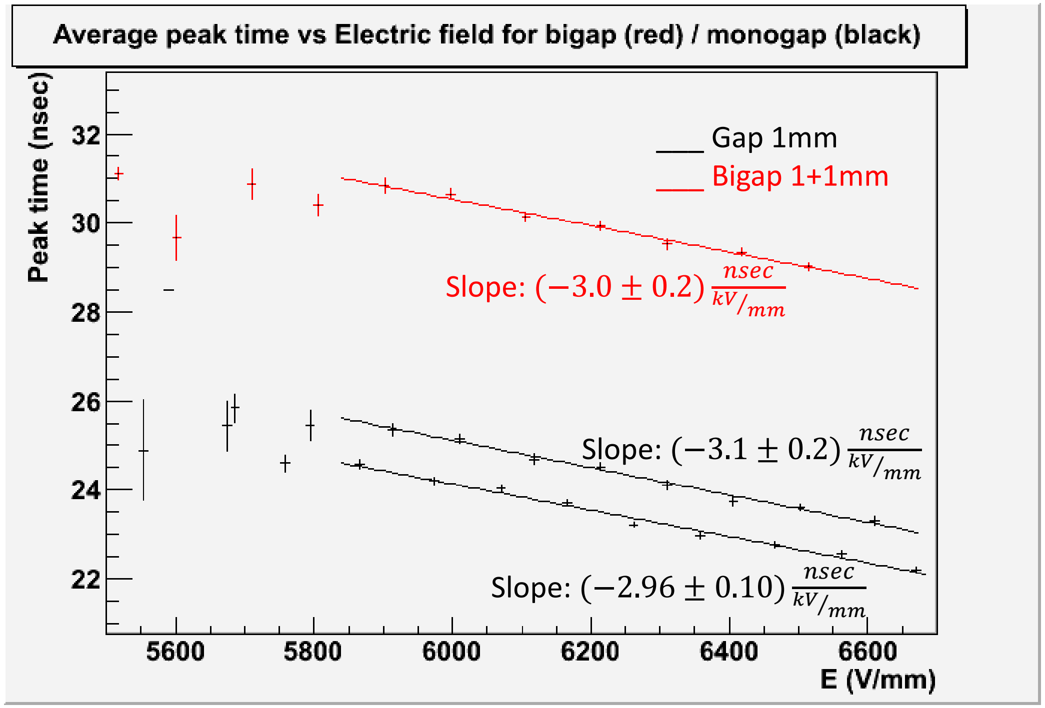
The peak time (with respect to the trigger) decreases as an almost continuous function of the electric field, without a significant discontinuity for different gap sizes.

This is also true for the rise time.

This implies a continuous reduction of the signal duration too.



Time performance for different gaps: single gap and bigap

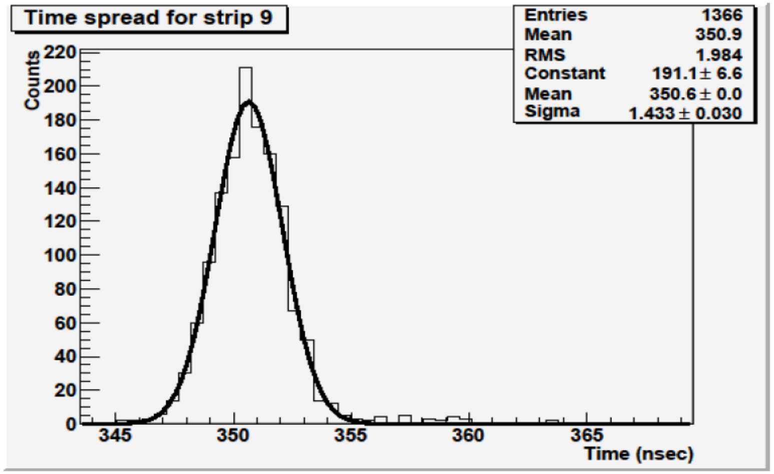


The average peaking time as a function of the electric field has the same slope for both the monogap and the bigap chamber.

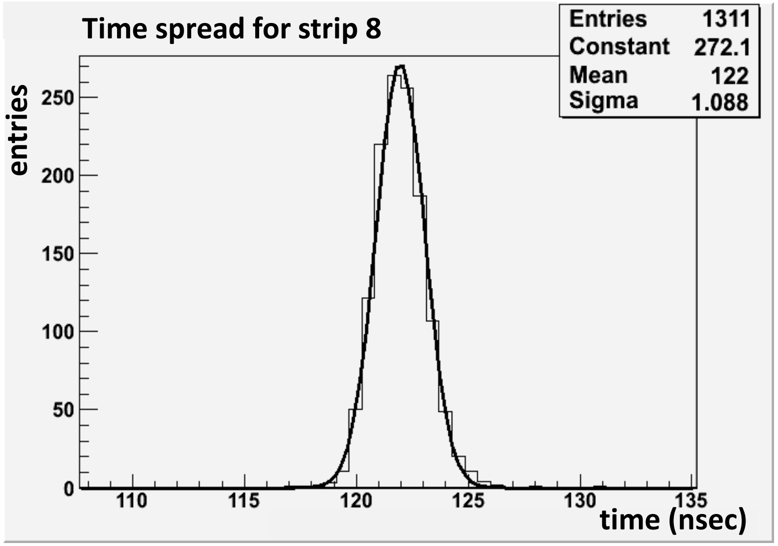
The peak time is measured with respect to the trigger and the difference between the scans is related to a different delay.

Time performance for different gaps: time resolution vs gap size

The time resolution was studied at the H8 test beam facility at CERN.



- 2009 data with 2mm gas gap
- raw time resolution 1.43 ns
- Subtracting the scintillator jitter convoluted with TDC time resolution: →Net result: σ_t=1.14 nsec



- 2011 data with 1mm gas gap
- raw time resolution 1.09 ns
- Subtracting the scintillator jitter convoluted with TDC time resolution: →Net result: σ_t=0.63 nsec

Gap reduction leads to better timing performances

Conclusions

- The improved FE electronics allows to operate at a much lower gas gain with respect to the RPC systems presently working at LHC.

- The study of different gas gaps showed as for fixed efficiency (with respect to the plateau knee) thinner gaps have a sharper charge distribution and a lower average charge/count.

- The bigap structure with respect to the single gap permits to reduce the charge of a further factor of 2.

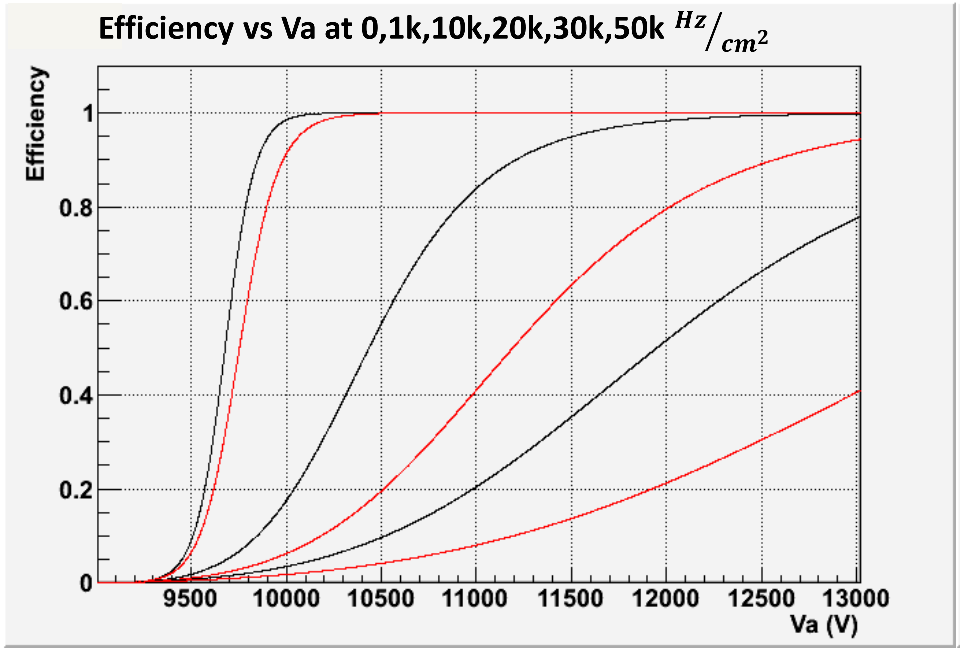
- Reducing the gap we improved the time performance as expected:
    - the signal is faster and the thinner gap (1mm instead of 2mm) strongly improved time resolution.
    - The study of the time performance of the bigap is in progress. In particular the effect of the a counting rate of about 18kHz/cm2 is going to be studied.

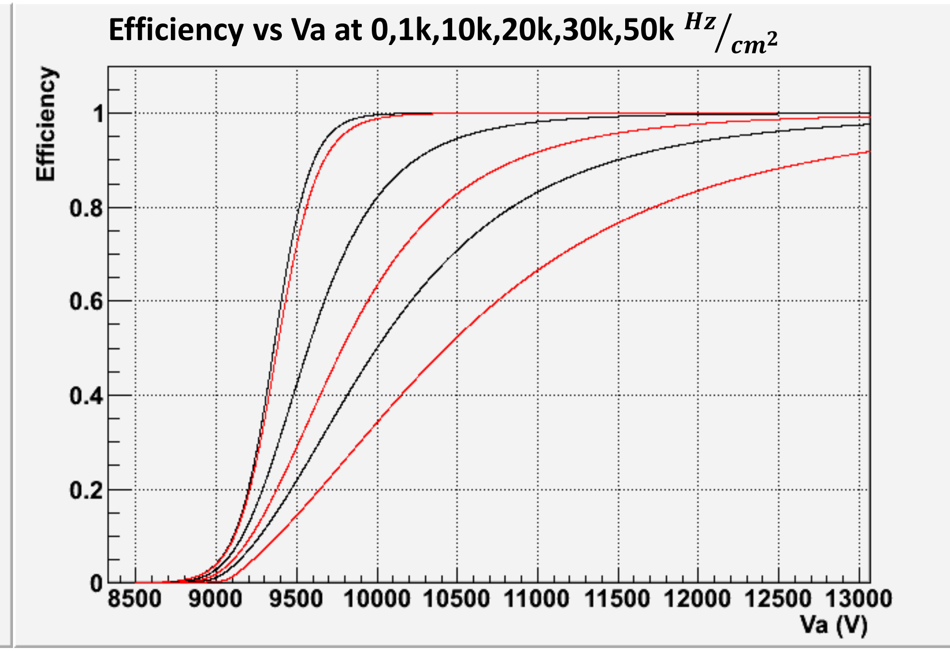
- The performance of 1mm bigap RPCs was studied both at cosmic ray rates and under very heavy irradiation at the Gamma Irradiation Facility at CERN (See Liang Han's and Roberto Cardarelli's talk) with consisting results for the parameters analyzed so far.

Thank you for the attention

Backup Slides

Simulation of the efficiency at different rates for the various gaps





Gap 2mm Atlas like threshold

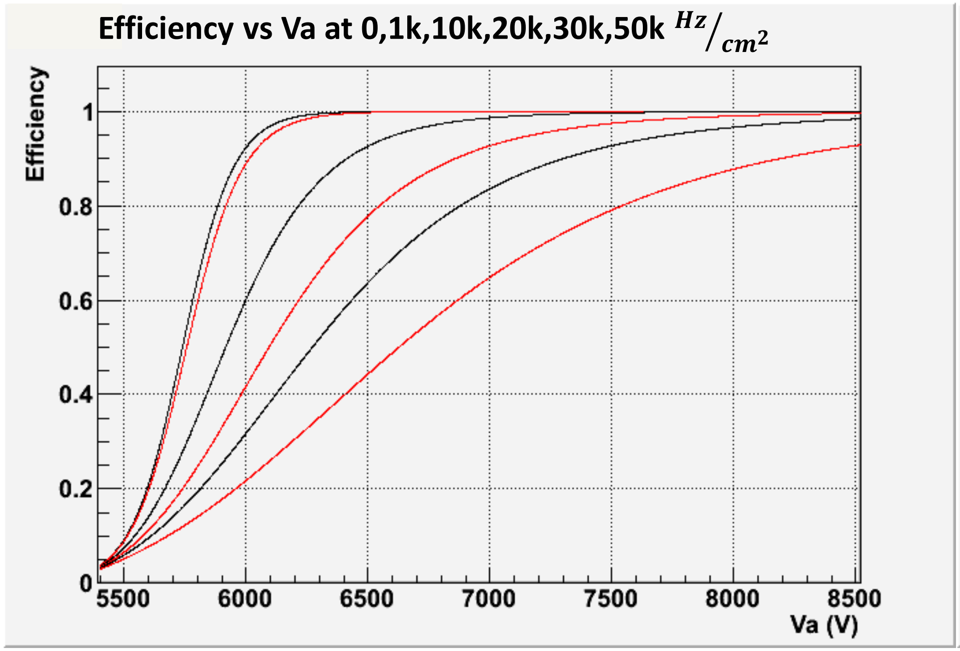
Resistivity: $3 \cdot 10^{10}\Omega \cdot cm$

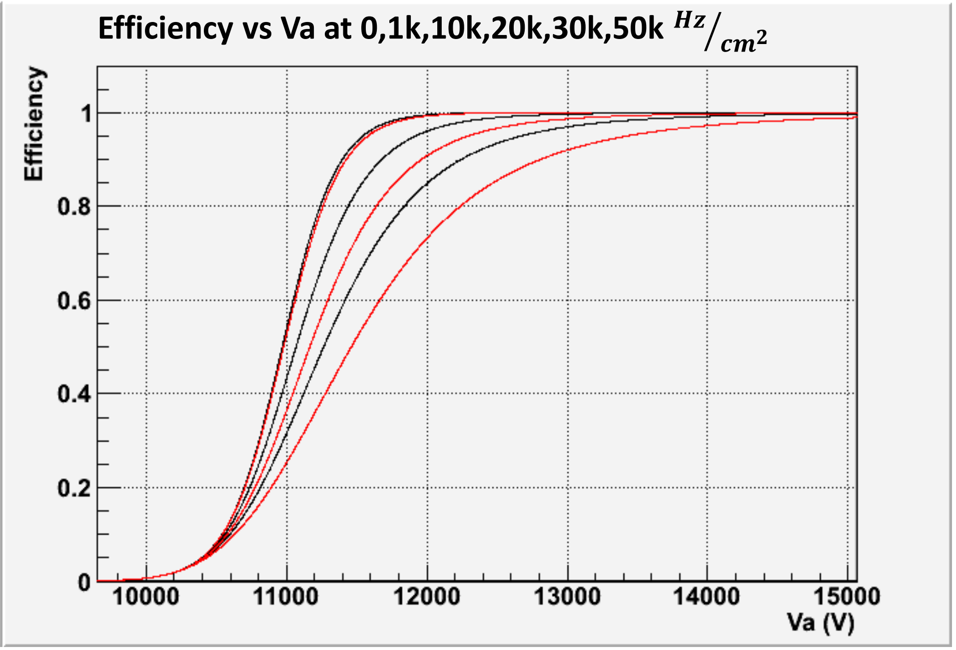
Gap 2mm new Front End electronics

Resistivity: $3 \cdot 10^{10}\Omega \cdot cm$

BACKUP SLIDES

Simulation of the efficiency at different rates for the various gaps





Gap 1mm new Front End electronics

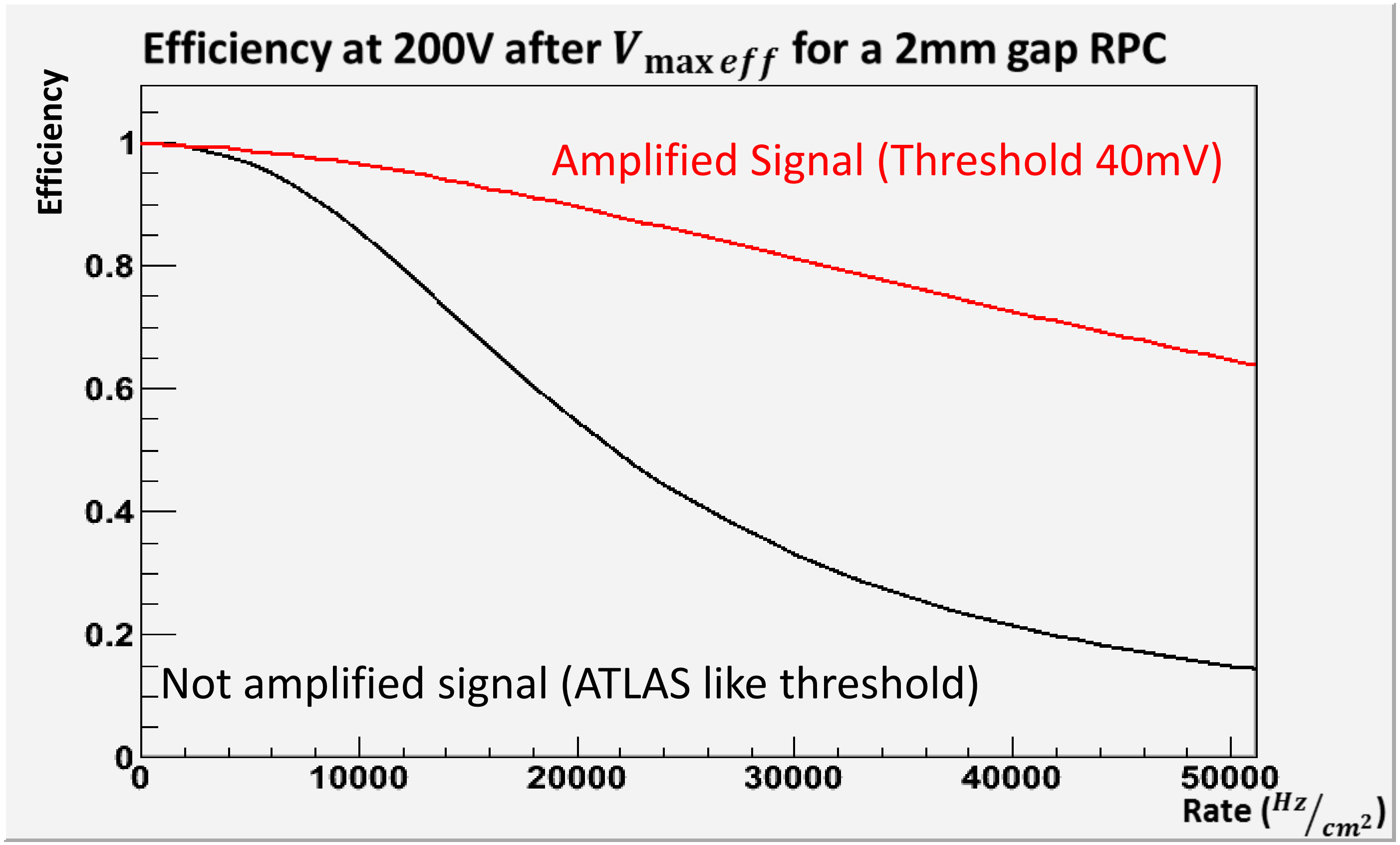
Resistivity: $3 \cdot 10^{10}\Omega \cdot cm$

Bigap 1+1mm new Front End electronics

Resistivity: $3 \cdot 10^{10}\Omega \cdot cm$

BACKUP SLIDES

Simulation of the efficiency at different rates for the various gaps



Resistivity:
$1 \cdot 10^{10} \Omega \cdot cm$

BACKUP SLIDES

Simulation of the efficiency at different rates for the various gaps