The HARP RPC time-of-flight system

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Abstract

The time-of-flight system based on thin-gap glass resistive plate chambers (RPCs) for the HARP detector at CERN is described and first experience with the chamber operation and performance is reported. The system consists of 46 chambers, covers an area of 10 m^2 and has 368 readout channels. The chambers are 2 m long, 150 mm wide, and 10 mm thick and have four gas gaps of 0.3 mm each, the glass plates are 0.7 mm thick. The RPCs are operated in avalanche mode with a mixture of 90% $C_2F_4H_2$, 5% SF_6, and 5% C_4H_{10}.

Key words: Gaseous detectors; HARP; resistive plate chamber; RPC; TOF

1 Introduction

The HARP Experiment measures hadron production on targets of different materials and thicknesses by protons and pions with momenta between 2 and 15 GeV/c. It is located in the T9 beam at the Proton Synchrotron at CERN. HARP was approved in February 2000 and data taking started in July 2001.

The detector consists of a large-angle system, with its centre-piece, a Time Projection Chamber (TPC), surrounding the target, and a forward spectrometer comprising tracking and particle identification capabilities. Figure 1 shows a schematic view of the setup. Resistive Plate Chambers (RPCs) are used for particle identification via time-of-flight (TOF) measurement in the large and medium angle regions for momenta in which the $\mathrm{d}E/\mathrm{d}x$ measurement in

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the TPC can not distinguish between electrons and pions (100–250 MeV/c), electrons and kaons (500 MeV/c), or electrons and protons ($\sim$ 1 GeV/c).

The RPC system comprises 46 chambers: 30 RPCs surround the TPC field cage and 16 RPCs form the forward RPC wall. All chambers are identical to each other; their dimensions are 2 m $\times$ 150 mm $\times$ 10 mm chosen such that two layers of RPCs fit into the 25 mm radial free space between TPC and solenoid magnet coil and cover the full length of the TPC field cage, see Fig. 2.

The RPC system was designed to measure TOF for particle momenta in the range of a few hundred MeV with a time resolution of 200 ps which is considered adequate despite the short particle flight distances of 0.5–2 m. In line with the goal to measure differential cross-sections at the 1–2% level, the detection efficiency is required to be $\sim$ 99%. There are no particular requirements on rate capability and spatial resolution given the low event multiplicities in HARP.

2 Chamber design

We opted for a design with four thin gas gaps and glass as resistive plate material.

The glass stack consists of two identical sets of three glass plates and two 0.3 mm gas gaps on each side of a central readout electrode. The glass plates are 0.7 mm thick and made of standard float glass [2] with a specific resistivity of $\sim 10^{13}$ Ωcm. The glass stack is 106 mm wide, 1930 mm long, and 7.8 mm thick. A cross section through its short side is shown in Fig. 3. The gaps are created by four spacers per gap made of 0.3 mm thick fishing line stretching over the full length of the detector.

The two outer glass plates of each set are coated on the outside with graphite tape [3] with a resistivity of 200 kΩ/square. Negative high voltage is applied to the outer glass plate of the set through the graphite coating. The inner glass plate (next to the central readout electrode) is connected to the detector ground. The middle glass plate of each set is electrically floating.

[2] GLAVERBEL S.A., 116, Chaussée de la Hulpe, BE-1170 Bruxelles.
[3] ESD EMI Engineering Corp., Toyo 5-chome, Tokyo 135–0016.

The signal electrode is located in the central plane between the two sets, it picks up the induced signals from all four gas gaps. We have also placed reference electrodes, connected to ground, on the outside of the two outer glass plates of the stack. They are electrically isolated from the HV layer by 175 μm of Mylar. All electrodes are made from 15 μm Cu on a 75 μm Kapton layer; they are segmented into 64 pads of dimensions 29 mm $\times$ 104 mm with 1 mm distance between neighbouring pads, as shown in Fig. 4. Each pad is connected on one side, through a feed-through, to a connector on the outside of the chamber housing.

The glass stack is housed in an aluminium box of dimensions 2 m $\times$ 150 mm $\times$ 10 mm made of a bottom part and a removable cover plate, see Fig. 2a. The bottom part is composed of a 1 mm thick ground plate, two longitudinal, and two end profiles. One of the longitudinal profiles is wider than the other; it contains the signal feed-throughs and provides for the space for the preamplifiers. The signal feed-throughs are printed boards, they carry eight connectors each on the inside and outside. All parts are glued [4] gas-tight together. The box is closed by a 1 mm thick cover plate fixed with screws every 50 mm; gas tightness is provided by an O-ring.

The gas connections are through the two end profiles with the gas flow along the length of the detector. The HV is brought into the box through one of the short sides with the HV cable [5] glued into one of the end profiles.

The front-end electronics consists of an on-chamber preamplifier and a discriminator/splitter stage at about 6–7 m distance from the chamber. The preamplifiers are designed as plug-in modules to the chamber housing. Each RPC has eight preamplifiers. Each preamplifier is connected to eight pads and covers an area of 240 mm $\times$ 104 mm. Its eight input lines have equal transit times to the preamplifier chip and are isolated from each other through input transistors. As preamplifier we use the AD8009 chip [6] operated with an amplification factor of $\sim$ 30. Each preamplifier has also a calibration input through which test pulses can be injected.

The amplified signals are transmitted through mini coax cables [7] over a distance of 0.8–2.5 m to a passive connector board and from there over a distance of 5 m through Lemo 50 Ω cables to a custom made discriminator and splitter unit. Each splitter module has 16 inputs and serves two RPCs. Here the signal is again amplified (factor $\sim$ 3, using the same AD8009 chip as in the preamplifier) and split into two signal streams. One of the streams is discrim-

[4] Araldite 2011, Ciba-Geigy, Basel, Switzerland.
[5] Reynolds Industries, part no. 167–2896.
[6] Analog Devices, Inc., Corporate Headquarters, Building Three, Technology Way, Norwood 781–329–4700, USA.
[7] Radiall FILOTEX 50VVMTX.

inated (threshold about 5 mV) and the discriminator output is sent via 80 m of twisted pair cable to a TDC[8]. The other signal part is sent as an analog signal over 80 m twisted pair cable to a QDC[9].

The full system comprises 368 readout channels.

3 Construction

The construction of the RPCs and their corresponding front-end electronics was carried out between December 2000 and April 2001 at CERN by a team from IHEP Protvino and CERN. The machining of the parts for the chamber housing and most of the making of the electronics was contracted to industry. All other steps were performed in-house. Two months were needed for the orders and the preparation of the assembly sites and the tooling. The chamber construction itself lasted from February to April 2001 and involved nine technicians and physicists. Given the small series no sophisticated industrial processes were used.

After being cleaned in an ultrasonic bath, the glass plates were, in a first step, coated with the graphite tape. A tool developed for this purpose guaranteed reproducible results. The same tool was also used to glue either an insulation sheet (Mylar) and/or the electrodes to the self-adhesive graphite layer.

Glass plates of 1930 mm lengths were not deliverable on our time-scale. We therefore joined together two or three shorter pieces using silicon glue[10] as junction material.

Once the glass plates were prepared they were stacked and the HV and ground connections were made. Two end pieces made of Noryl were used to align the plates and to fix the fishing lines serving as spacers between the plates, see Fig. 5. To prevent the two outer fishing lines from slipping out from between the glass plates, small drops of silicon glue were placed at distances of 30 cm at the edge of the glass, outside the detector fiducial volume. Once all six plates were stacked on top of each other they were interconnected with a few drops of silicon glue.

[8] CAEN V775 with 35 ps per count.
[9] CAEN V792 with 0.1 pC per count.
[10] RHODORSIL CAF 4, CERN SCEM 37.40.45.C.

4 Operation and performance

The RPCs are operated in avalanche mode (HV: -6 kV) with a gas mixture of 90% $C_2F_4H_2$, 5% SF_6, and 5% C_4H_{10} at a gas flow of ~ 1 volume change per hour. Two neighbouring RPCs are always connected in series to the same gas line.

The chambers were commissioned in May 2001 and have been operated since then until the end of November 2001 without particular problems.

The operating temperatures were 27–30°C in the barrel (stable) and 20–30°C in the forward chambers (varying with hall temperature).

Typical random noise rates are ≤ 200 Hz per RPC, i.e., ≤ 1 kHz/m^2. In a few RPCs we observed significantly higher noise rates. In all cases the origin of this was traced back to mechanical problems with the glass stack and has been repaired [11].

The performance of the RPCs was measured for a few chambers out of the series production in a test beam exposure [12]. Figure 6 shows that over a HV range of 300 V a time resolution of ~ 150 ps and an efficiency of $\sim 99\%$ were obtained. Figure 7 shows that there is neither a strong dependence on the position of the impact point across the 240 mm covered by one readout channel nor significant cross-talk between neighbouring readout channels.

We also studied the dependence of the time resolution as a function of number of pads connected to the preamplifier. While in the standard configuration with eight pads connected to a preamplifier a time resolution of ~ 150 ps was observed, we measured 105 ps when only one or two pads were connected.

Quantitative data on the performance of the RPCs in the HARP experiment can be obtained only after the track reconstruction in the detector has been performed. However, in a special run, one of the RPCs had been exposed directly to a beam of -8 GeV pions. The response of the RPC without any correction for the jitter of the beam trigger (which is of the order of 500 ps and dominates here the time resolution) is given in Fig. 8. It shows the characteristic relation between measured charge and time for which we have to correct.

During this run the RPCs were also systematically moved across the beam

[11] When we opened these RPCs it turned out that some fishing lines had slipped out of their fixations in the end pieces and had come out along the sides. The glass plates were locally no longer kept apart.

[12] We are indebted to the ALICE TOF group which hosted us in the T10 test beam.

to study the response as function of the particle impact point. A comparison of average time measurements as function of the beam impact point confirms the test beam results shown in Fig. 7.

5 Conclusion

A system of 46 RPCs with 368 readout channels, covering an area of ~ 10 m^2, has operated successfully since May 2001 as time-of-flight detector in the HARP experiment. The chambers were designed, constructed, and commissioned over a period of nine months with only little time for research and development. Their performance, as measured in a test beam, shows a time resolution of ~ 150 ps and an efficiency of $\sim 99\%$. Running experience so far shows clean data and stable and easy operation of the system.

6 Acknowledgements

We would like to thank our technical staff, in particular Boris Dybine and Alexandre Golovine from IHEP Protvino and Denis Rotil and Christiane Schillinger from CERN for their dedication and patience in the construction of the RPCs. Claude Millerin and his staff from the CERN EST-DEM assembly workshop were instrumental in sypplying the front-end electronics in such a short time. We thank Jean-Claude Legrand for his important contributions to the design of the preamplifier and Pietro Govoni and Giovanni Franzoni from the University of Milano for their help during the detector prototyping phase. Furthermore we are indebted to our colleagues from the ALICE TOF system, and, in particular, Crispin Williams, for continuous advice and help. And last but not least we tried to follow Paulo Fonte's advice on what to do and what not to do in the chamber construction.

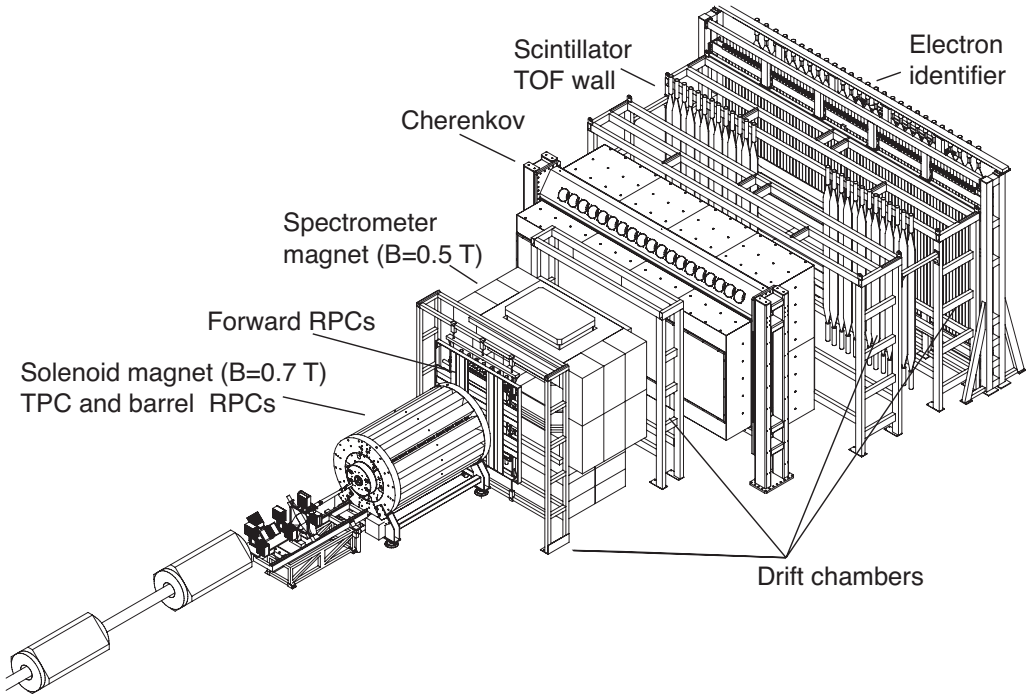

Fig. 1. Layout of the HARP detector; the barrel RPCs are inside the solenoid magnet surrounding the time projection chamber, the forward RPCs are in a plane just downstream of the solenoid magnet

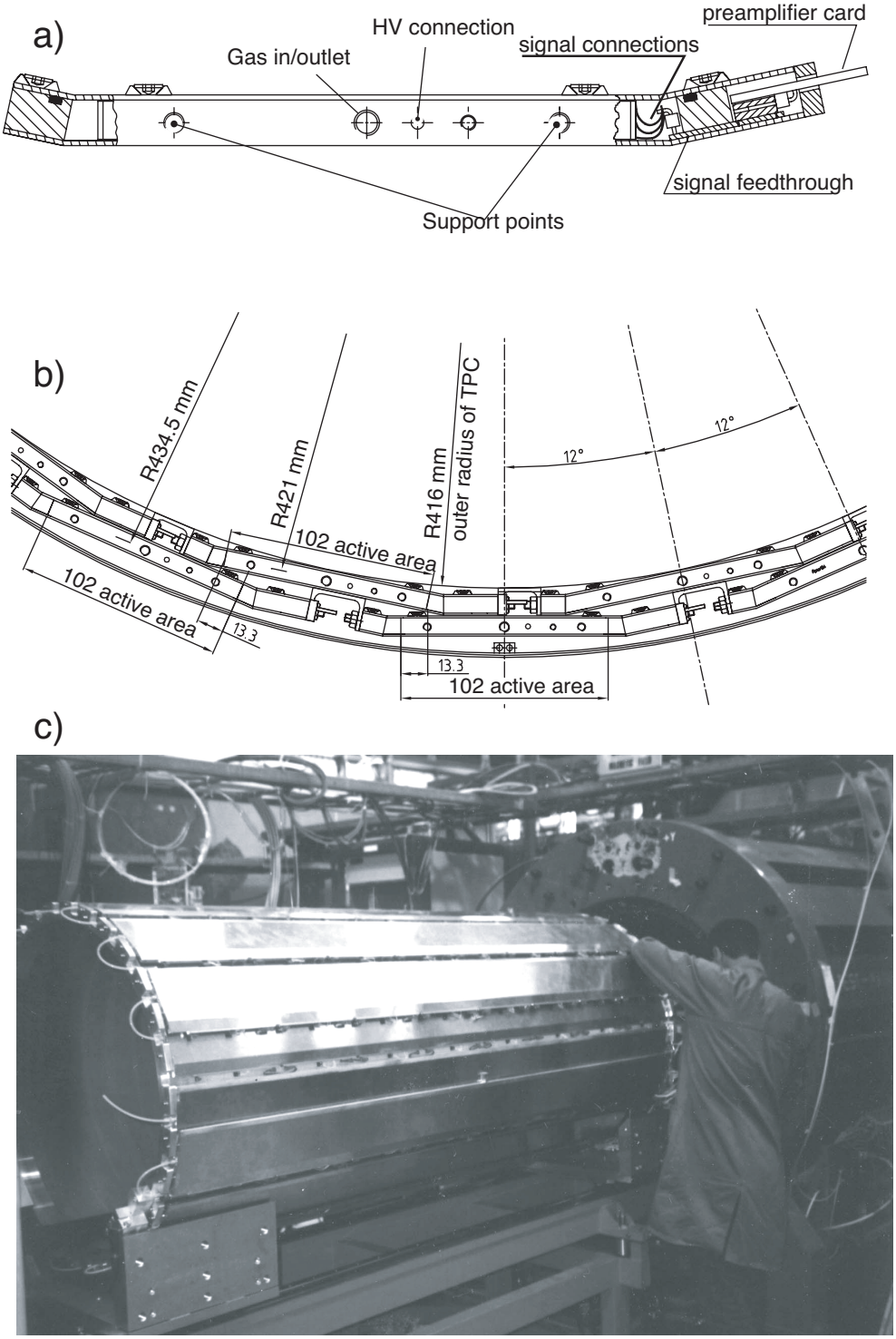

Fig. 2. a) Cross-section through single RPC b) arrangement of barrel RPCs around the TPC and c) photo of the barrel RPCs on the TPC cylinder

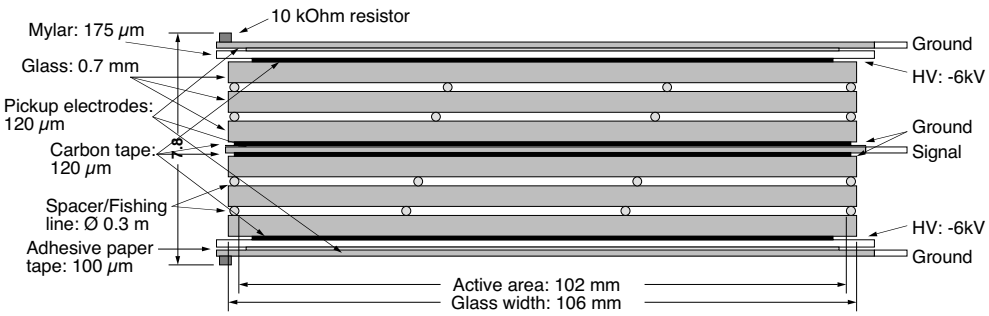

Fig. 3. Cross section through the glass stack

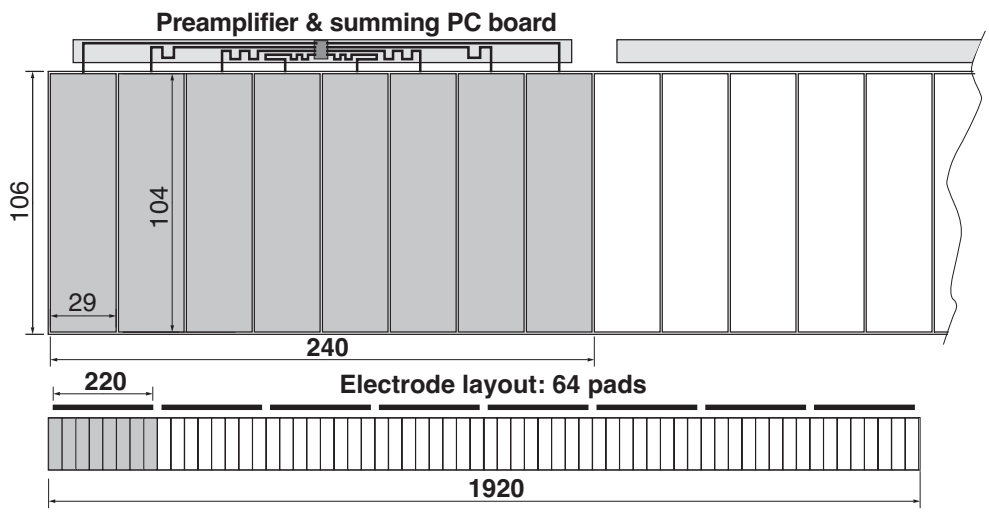

Fig. 4. Layout of the readout electrodes; eight pads are connected to the same preamplifier

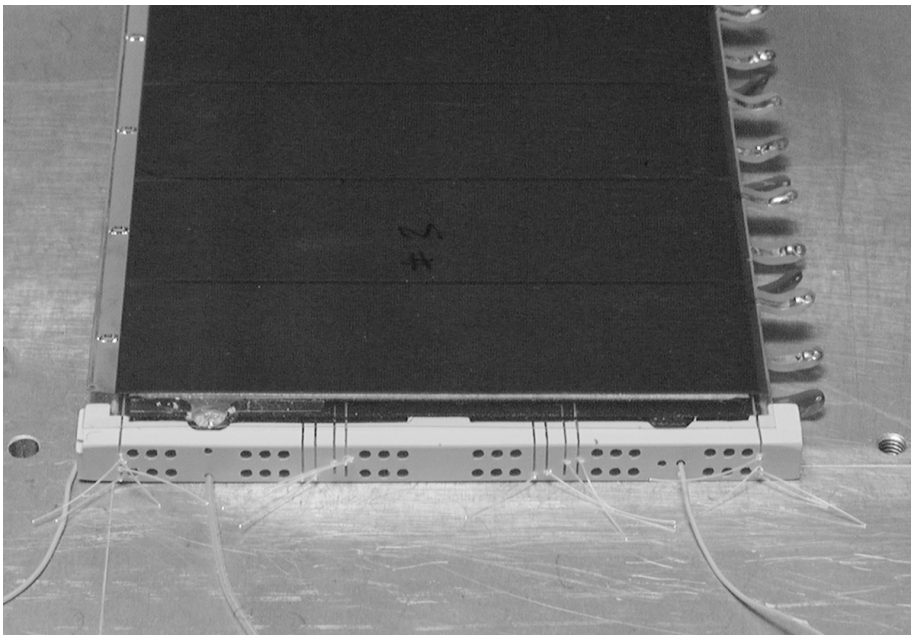

Fig. 5. Photograph of the end of a glass stack with the Noryl end piece. On the right side the signal connections for the individual pads are visible

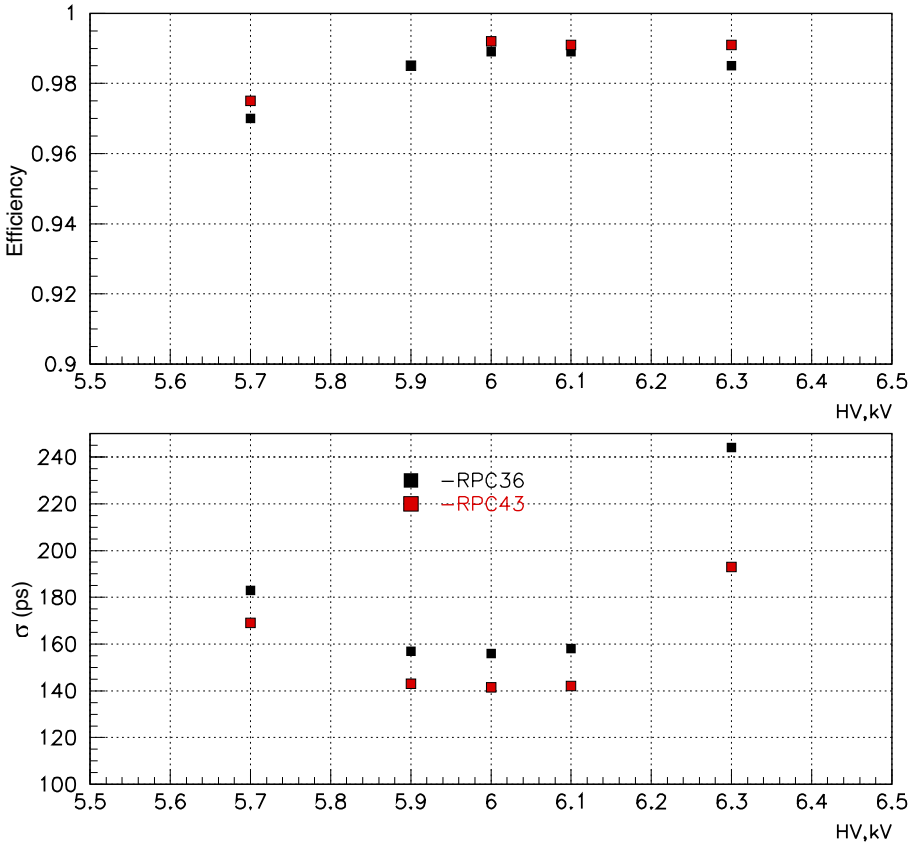

Fig. 6. Time resolution and efficiency as function of HV measured in the test beam

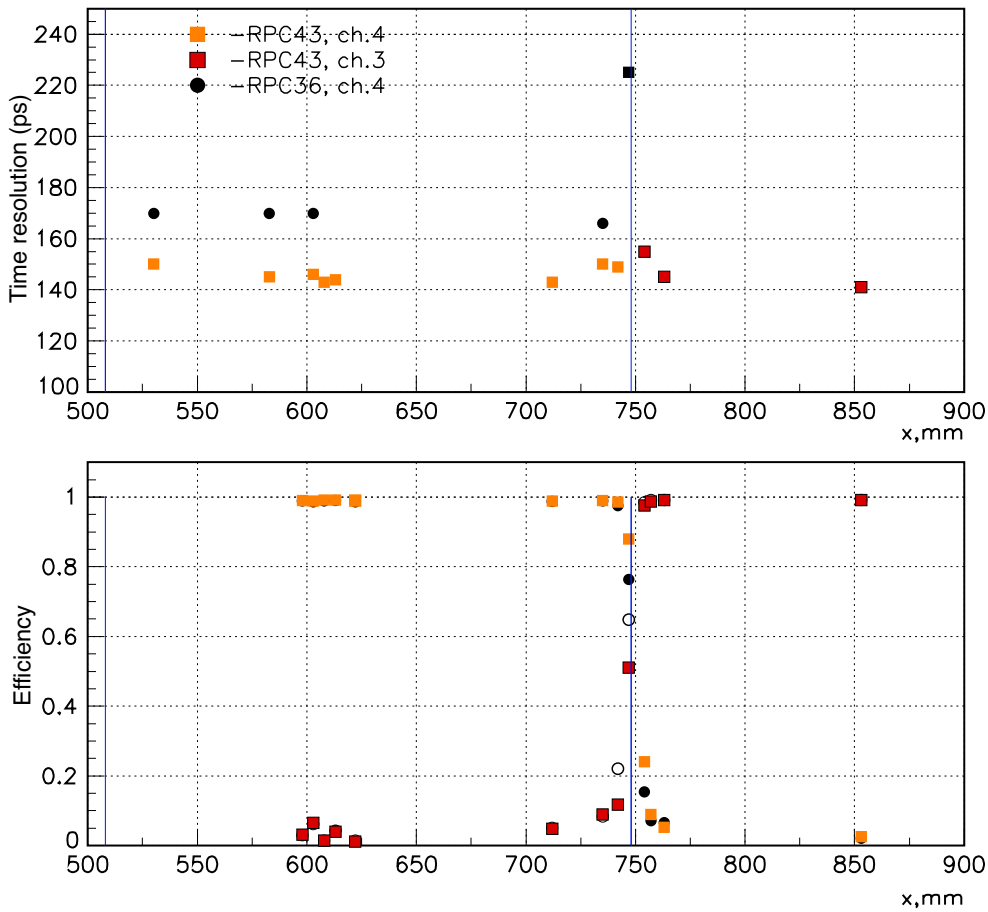

Fig. 7. Time resolution and efficiency as function of the impact point of the beam. The x direction is along the RPC, one readout channel covers 240 mm; the boundary between the pads read out by two different preamplifiers is at x = 750 mm.

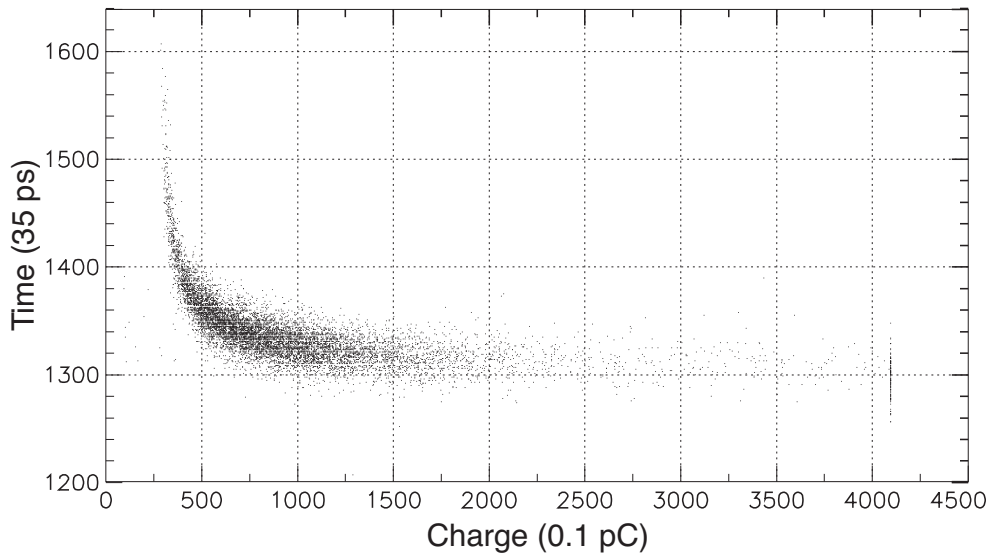

Fig. 8. Time-charge relation for an RPC exposed to a -8 GeV/c beam