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Resistive Plate Chambers in ATLAS

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Abstract

The ATLAS first level muon trigger is based, in the rapidity region $\mid \eta \mid \leq 1.05$, on fast and finely segmented gaseous detector, Resistive Plate Chambers. A prototype of a small scale RPC trigger tower has been assembled and tested. We present results on efficiency, time resolution, cluster size and collected charge. The detectors, filled with a non-flammable and enviroment safe gas mixture, have been operated in avalanche mode. The measurements have been made at the CERN SPS accelerator in the H8 test-beam area with muon fluxes up to 900 Hz/cm^2. A 14mCi Co^{60} radiactive source has been used to illuminate the chambers with a flux of low energy photons, simulating LHC background conditions.

Talk presented by Anna Di Ciaccio at Beauty '96
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1. Introduction

The ATLAS[1] Collaboration has proposed a general purpose detector for an experiment at the Large Hadron Collider (LHC), recently approved by the CERN management. The muon spectrometer consists of three air-core superconducting toroid magnets, namely a barrel and two identical end-cap toroids, covering the rapidity range $\mid \eta \mid \leq 3$, to insure a high resolution muon momentum measurements over a p_t range from 5 to about 1000 GeV/c. Precision momentum measurements[2] and triggering are done by two dedicated detectors.

2. The first level muon trigger

The first-level muon trigger is based on gaseous detectors, namely Resistive Plate Chambers[3] in the barrel and Thin Gap Chambers[4] in the forward regions, to identify penetrating charged particles pointing to the interaction region. The trigger chambers also provide the second coordinate to the muon tracking system and the time information to relate muon tracks to bunch-crossings. The transverse momentum selection is done with a fast coincidences between strips on different planes. The number of planes is defined by the need to minimize the rate of accidental coincidence due to the high level of random hits in the detector produced by low energy photons and neutrons[5]. To reduce the accidental rate to a level lower than the prompt muon rate, the trigger will operate in two projections, r- z and r- ϕ. The different momentum selection criteria required by the relevant physics processes are met using a low p_t and an high p_t trigger[6]. The proposed trigger scheme uses three stations, two middle stations, each made of two RPC planes, and an outer stations, with three RPC planes. These stations together are called a "trigger tower".

3. Experimental lay-out

A prototype of a muon trigger tower has been tested at the H8 SPS beam line with 180 GeV/c muons fluxes up to 900 Hz/cm^2. The tower consisted of six single gap 50 x 50 cm^2 RPC chambers, organized in three stations of two chambers each (doublet). The doublets were located along the beam line, two at a distance of 40 cm and the third at a distance of 200 cm (to simulate the ATLAS low p_t and high p_t forseen trigger schemes).

The RPC chambers were made by 2 mm bakelite plates interleaved by a 2 mm gas gap and are read-out on both sides by pick-up strips (30 mm wide), ortogonal to each other.

The front-end electronics (192 channels) consisted of two stage voltage amplifier (10 and 30) with a bypolar output signal[7]. The strip signals were send first to the inputs of discriminators with adjustable threshold between 15 and 300 mV. Part of the discriminator outputs were send to two TDCs with 1 ns resolution (for time resolution measurements) and the rest to the inputs of four registers.

In addition to the trigger tower, two RPCs with similar characteristics, were installed on the beam to study the charge distribution as a function of the applied voltage and the transition from the avalanche to the streamer regime. The strips from these chambers were read-out at both ends to study at the same time the avalanche and streamer charge distributions as a function of the voltage. The signal from a strip was directly sent to the input of an ADC module (0.25 pC/ch) within a gate of 250 ns (the streamer charge is big enough not to require an amplifier). The signal from the same strip but seen at the opposite end, was first amplified by a voltage amplifier of gain 300 and then read-out by an ADC (0.25 pC/ch) module with a gate of 70 ns (the avalanche precedes in time the streamer).

The trigger signal was provided by four scintillator counters of various dimensions. Two trackers, consisting of a 4 x 4 matrix of 3 cm diameter drift tubes, were put just before and after the RPCs to measure the beam spot along the vertical coordinate. The biggest triggered area was 10 x 10 cm^2, outside of this area the chambers could be illuminated by a 14 mCi Co^{60} radiactive source. The source, positioned at a distance of around 70 cm from the closest RPC, was accounting for an extra rate of about 100 Hz/cm^2, produced by 1.2 MeV photons.

4. Experimental results

The chambers were fluxed with a gas mixture of Isobutane, $isoC_4\ H_{10}$ and Tetrafluoretane, $C_2\ H_2\ F_4$. The Tetrafuoretane is a high density and enviroment safe gas, widely industrially employed.

In Fig. 1 the chamber efficiency for a RPC doublet (four strip planes) is plotted as a function of the high voltage for two different gas mixture. The discriminator threshold was set at 100 mV for the y strips and at 200 mV for the x strips. The chambers are fully efficient ($\epsilon > 99$ %) at a voltage of 9.0 KV for the gas mixture with 6% Isobutane and at 9.4 KV with 1.6% Isobutane.

The other measurements presented in this section were all obtained with a gas mixture of 6 % Isobutane, 94 % Tetrafluoretane and a muon flux of about 500 Hz/cm^2 plus the photon flux coming from the Cobalt source.

The time of flight between two RPC chambers is presented in Fig. 2. From a gaussian fit of this distribution we extract a $\sigma = 2$ ns, corrisponding to a RPC time resolution of around 1.5 ns, well below the 25 ns LHC bunch crossing.

Fig. 3 shows the cluster size distributions for the two RPCs of a doublet, namely four strip planes, at a voltage of 9.0 KV.

The RPC charge distributions, plotted in ADC channels, are shown in Fig. 4 for an applied voltage of 8.6 KV, 8.8 KV, 9.0 KV and 9.2 KV. The last three distributions look pretty gaussian, indicating that the chambers are working in a regime of saturated avalanche. The corrisponding signal charges, are about 0.4 pC, 0.8 pC, 1.0 pC at 8.8 KV, 9.0 KV and 9.2 KV respectively.

Fig. 5 shows the charge distributions for signals not amplified at increasing voltage values on the efficiency plateau, namely at 9.0 KV, 9.4 KV and 9.6 KV. The plots show no evidence for streamer signals at 9.0 KV, instead at 9.4 KV and 9.6 KV the streamers produce a clear peak, with an average charge of about 45 pC, well separated from the pedestal. From these distributions the streamer fraction as a function of the high voltage has been measured (see the lower part of Fig. 1). They indicate that the RPCs work at high efficiency with a low fraction of streamers.

5. Conclusions

A RPC trigger tower constituted by six single gap chambers, 50 x 50 cm^2, has been successfully operated in avalanche mode with non-flammable and enviroment safe gas mixture at the CERN H8 test-beam. We have measured an efficiency $>$ 99 % at 9.0 KV with a negligible streamer fraction, a time resolution about 1.5 ns and a cluster size perfectly adequate to the LHC requirements.

6. References

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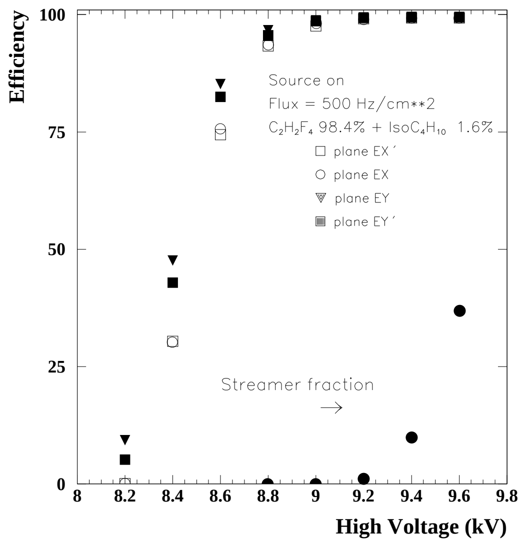

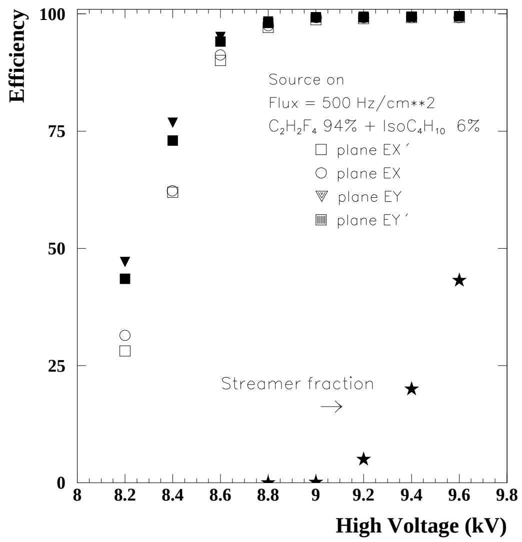

Figure 1: Efficiency and streamer fraction vs high voltage for two different gas mixture.

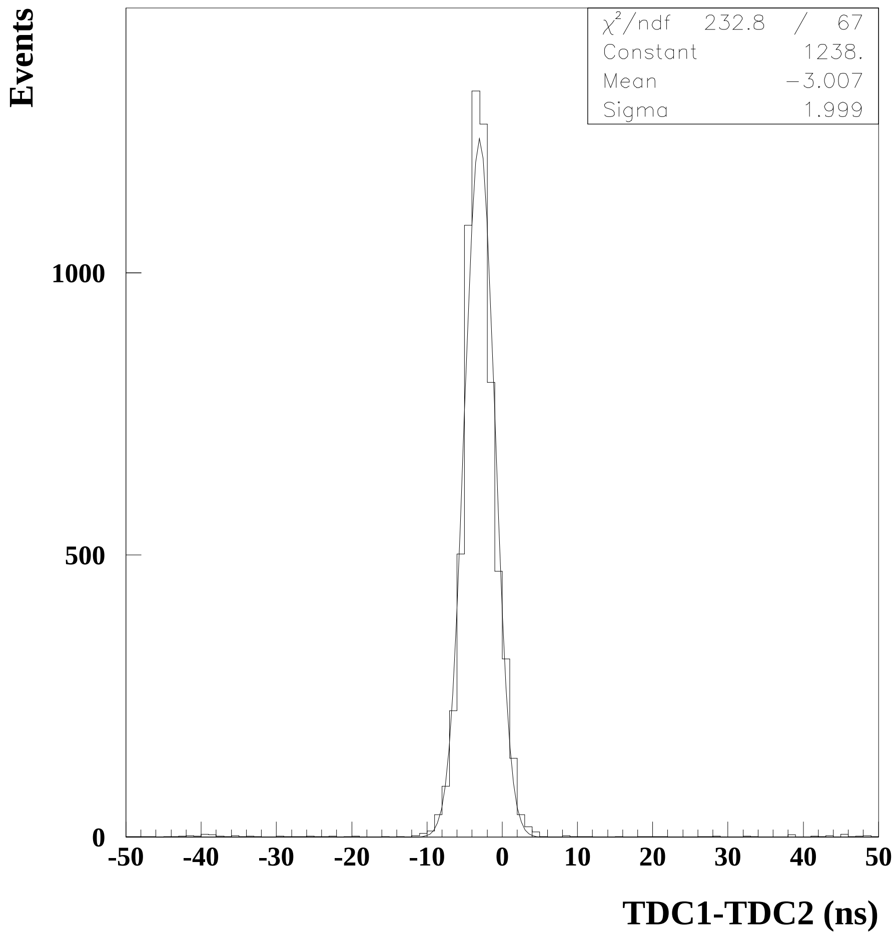

Figure 2: Time of flight between two RPC chambers at 9.0 KV.

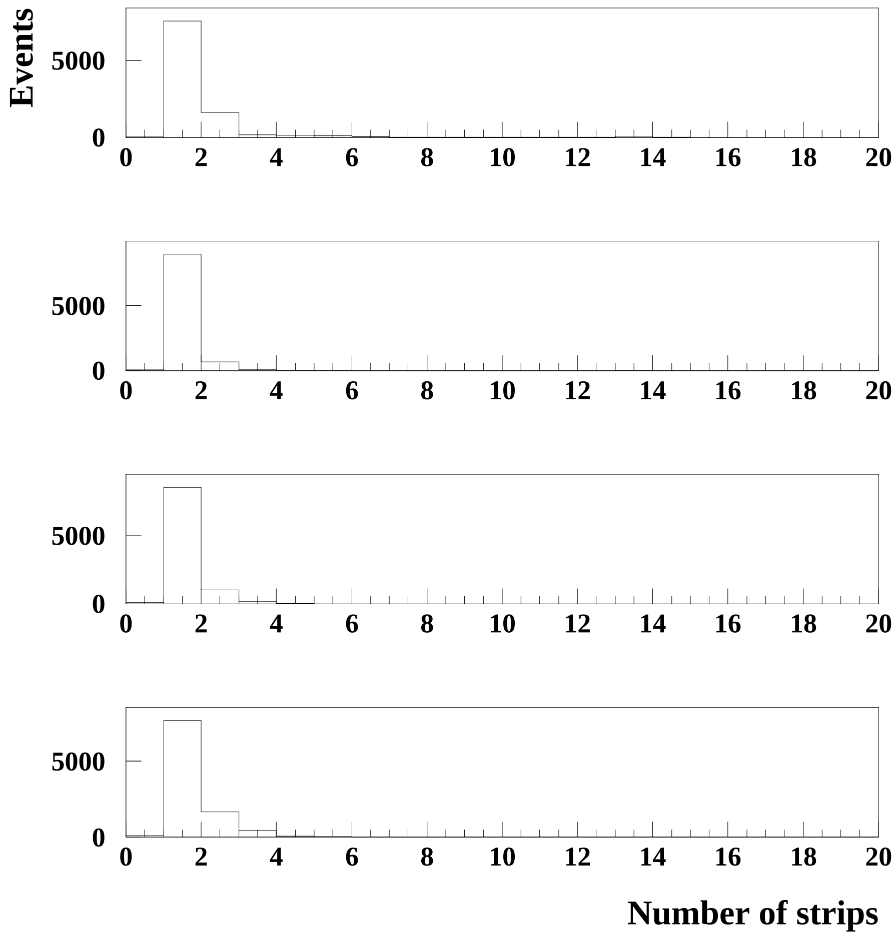

Figure 3: Cluster size distributions of a doublet at 9.0 KV.

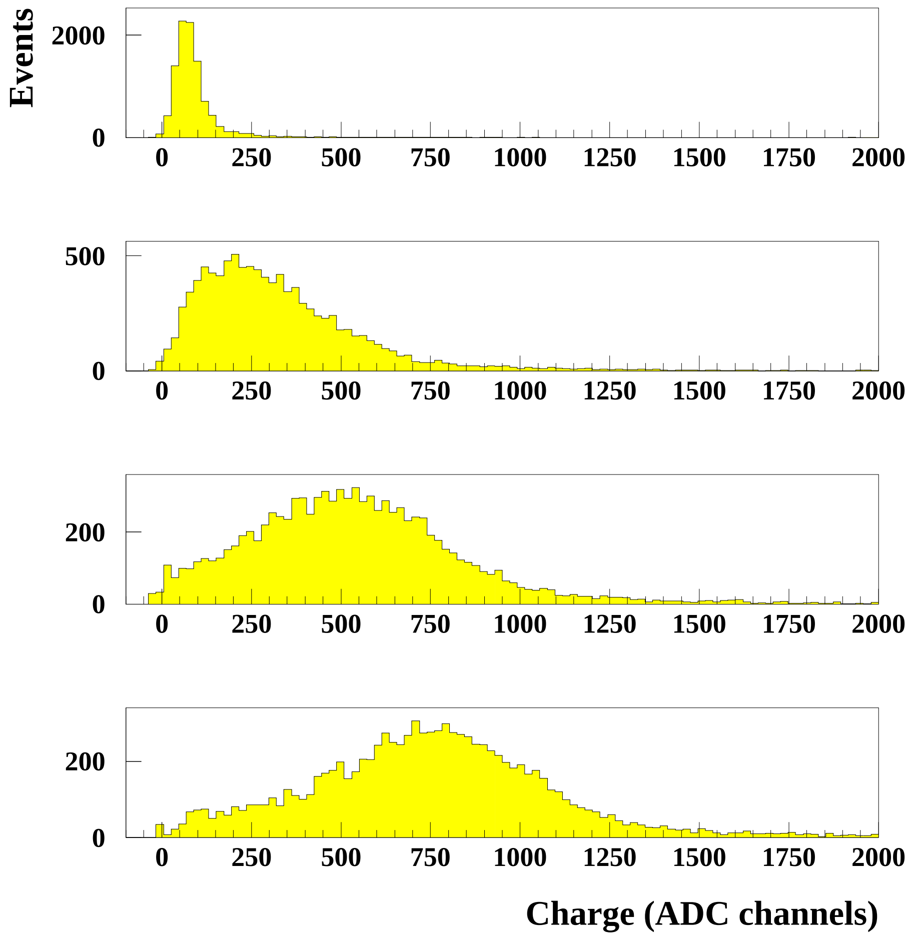

Figure 4: Charge distributions at 8.6 KV, 8.8 KV, 9.0 KV and 9.2 KV.

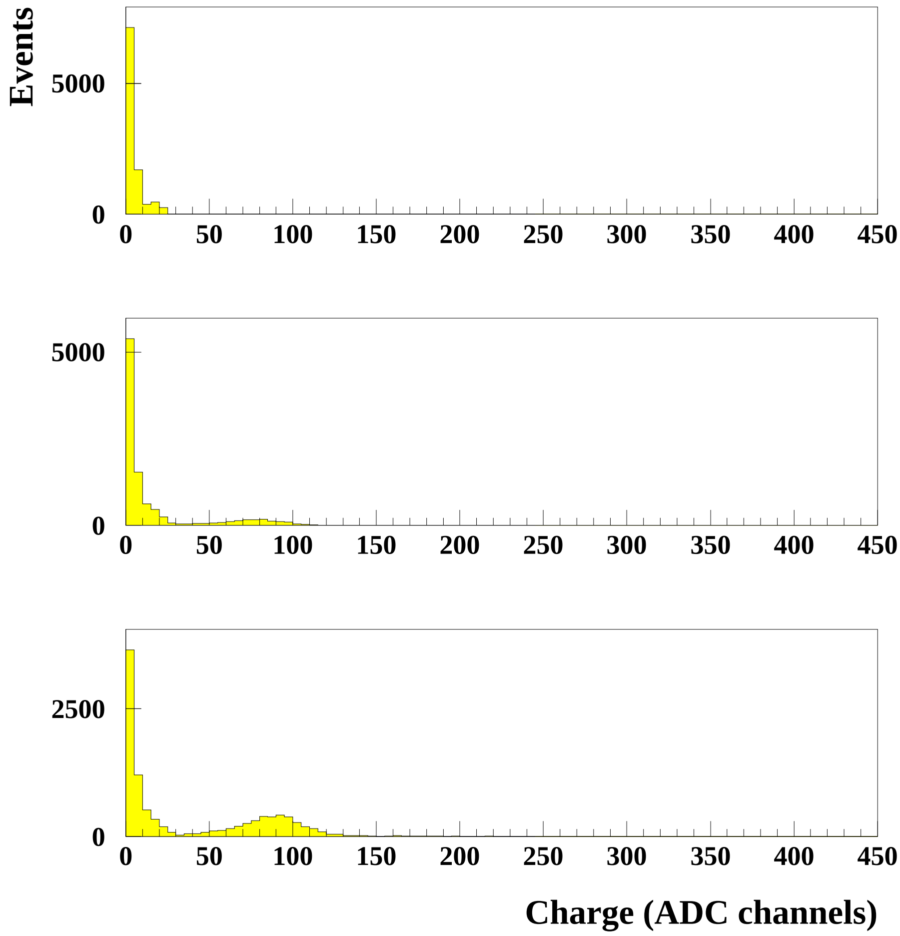

Figure 5: Charge distributions (without signal amplification) at 9.0 KV, 9.4 KV and 9.6 KV.