ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Lecce

INFN/AE-90/18
3 Dicembre 1990

E. Gorini:

THE RESISTIVE PLATE COUNTER MUON SYSTEM OF E771

Presented at the
"2nd International Conference on Advanced Technology and Particle Physics"
Como, Italy, 11-15 June 1990

Servizio Documentazione
dei Laboratori Nazionali di Frascati

INFN - Istituto Nazionale di Fisica Nucleare
Sezione di Lecce

INFN/AE-90/18
3 Dicembre 1990

THE RESISTIVE PLATE COUNTER MUON SYSTEM OF E771

Edoardo Gorini
Istituto Nazionale di Fisica Nucleare, Sezione di Lecce, Italy

ABSTRACT

The performances of a "novel" detector, the Resistive Plate Counter, have been studied with particular emphasys to its use in a fixed target high rate experiment. A muon detector made out of RPC is actually operative in the E771 spectrometer at Fermilab. The working characteristics and parameters have been analyzed on a test stand with cosmic rays.

1. INTRODUCTION

Heavy flavour Physics is one of the most interesting field in high energy physics research and, beauty hadroproduction can give confirmation about many unresolved problems (Q.C.D.,standard model etc.).

The primary objectives of experiment E771 at Fermilab[1] are the production of beauty particles and the study their decays using a high intensity (up to several 10^8/second), high momentum (800-900 GeV/c) proton beam on a silicon target. With an estimated cross-section of ≈10 nb, and an interaction rate of 10^7/sec, 8 produced $B\bar{B}$/sec are expected.

The strategy adopted to detect beauty events is to trigger on dimuons coming from J/ψ mesons produced at a secondary vertex, through the decay

$$B \rightarrow J/\psi + \text{anything}.$$

This can be achieved, at the first level, by requiring at least one muon with $p_t > 0.8\text{-}1.0$ GeV/c. Such a request allows also to select semileptonic decays of B mesons with the possibility of enriching the sample and to have a way to "tag" beauty mesons. Montecarlo analysis show that in one year running a few thousand of fully reconstructed events[2] are expected.

2. THE EXPERIMENT E771

The experiment E771 is located in the High Intensity Lab at FNAL and is essentially an upgrade of the former E705 spectrometer. The new setup includes a new beam line, a segmented silicon target, a 24 planes silicon vertex detector, new proportional wire chambers (PWC) with pad readout and 3 planes of Resistive Plate Counters (RPC)[3] for detecting muons and for triggering purposes.

First level trigger is based on programmable logic arrays which form muon coincidences from RPC signals and upstream pads of PWC to select high p_t muons via pre-defined patterns loaded in the trigger logic. A subsequent level trigger (based on associative or content addressable memories) will, in a very analogous way, perform a online tracking of intermediate p_t particles. Third level trigger is implemented in software on a farm of VME based ACP microprocessors and will select events with secondary vertices.

3. RESISTIVE PLATE COUNTERS

RPCs are thin gap devices operating in streamer mode in a very high uniform electric field (40kV/cm).

Their main characteristics are very good time resolution, low cost and large area coverage. A cross sectional view of an RPC module is shown in figure 1. Two large plates ($1 \times 2\text{m}^2$), made of a phenolic polymer (bakelite) with a bulk resistivity of$\approx 10^{11} \Omega \times \text{cm}$, are faced up one another at a distance of 2mm kept constant by PVC disk spacers, and enclosed in a PVC frame to mantain gas thightness. The external surfaces of the plates are coated with graphite where high voltage and ground are applied through metallic contacts.

The counter is filled with a mixture of argon, butane and freon through small gas feed-throughs on both sides of the PVC frame. The charge produced by the streamer process is picked-up by copper pads supported by a polycarbon structure facing the high voltage side. Twisted pair cables are soldered to the pad plane ensuring easy handling of 16 pads at the time.

Each RPC module, equipped with the pad structure, is enclosed in a steel frame for mechanical stability, and for supporting the 32-pins signal connectors, and the high voltage and gas supplies.

The large pulse height (≃300 mV and 20 ns on 50 Ω) of the produced signals allows for very simple and inexpensive electronics: the signals are simply discriminated at a common value of threshold (16 pads per card) and ECL and TTL shaped with a 20 ns width to be sent to the trigger boards and to the acquisition chain.

4. MUON DETECTOR

The muon detector consists of three layer of RPC modules placed in between the hadron absorbers at the end of the E771 spectrometer. Ten RPC modules are assembled together as in figure 2 to form a detector plane. Slight overlapping of the modules is necessary to recover dead zones along the perimeter of the detectors. The beam plug in the first two muon planes forced the construction of non standard L-shaped modules to cover the complete area. In the same figure is also shown the resulting pad configuration, obtained with pad size of $6\times6, 6\times12$, and 12×12 cm^2.

High voltage is supplied by a computer controlled system equipped with 20 channels which can operate up to 15 kV with 1 mA current limit. Gas is provvided through a 30 lines system. The mixture is controlled by 3 mass flowmeters (one for each gas) assuring 1% stability and precision.

5. TEST STAND RESULTS

Before the installation of the 3 planes, some of the RPC modules have been exstensively tested with cosmic rays to check their characteristics and to tune their working parameters[4]. Two different pad sizes have been examined (6×6 and 12×12 cm^2) and two different bakelite resistivity ($\simeq10^{11}$ $\Omega\times cm$, $\simeq2\times10^{10}\Omega\times cm$). The reason for having different counter resistivity is to achieve a better response to high rates, given that the recovery time of the detector is depending on $\rho\varepsilon$ where ρ is the resistivity and ε the dielectric constant of the bakelite[5].

5.1 Gas Mixture Studies

In figure 3 is shown the dependence on the ratio butane/argon of the efficiency and of the voltage at which the plateau starts, at a threshold of 30 mV for the 12×12 pad. The limiting efficiency of 97% (given by the dead zones around the spacers) is reached at a low content of butane, while freon content does not affect nor the efficiency neither the start of the plateau (at least in the 3-9% range and at such low threshold).

The dependence from freon content of the mean charge and time resolution (trigger folded) at 200 V over the plateau knee is shown in figure 4 for the 12×12 pad detector. One can see that freon is very important for time resolution and it affects the amount of charge in the detected signal in a sensible way: both pulse height and length decrease as freon increases. Butane/argon ratio also affects these quantities even if its main contribution is just in the quenching of the streamer and in the afterpulsing. The choise of the mixture is then a subtle compromise between different requirements which can depend from the particular application.

5.2 RPC Characteristics

Once mixture has been chosen (butane/argon=0.67, freon at 5%) to favorite the highest efficiency and good time resolution, the characteristics of the RPC have been studied. Figure 5 shows further the efficiency plateau, at a threshold of 60 mV, for two detectors equipped with squared pads of 6 and 12 cm and respectively with low and high resistivity, while figure 6 shows their dark currents. One has to stress that the flat top is very long ($\simeq$ 1000 V) and therefore a very high working stability is obtained. Singles rates are at the level of few Khz/m^2 at 8.2 kV with a threshold of 60 mV and reach 10 Khz/m^2 at 9.0 kV. The dependence of the average charge on high voltage is shown in figure 7 for both types of detectors. It is to be noticed that this difference is only due the pad size which affects the pulse height, while the streamer charge is nearly the same for both detectors.

We also separately measured cross-talk to side pads and corner pads, since it mainly depends from the faced surfaces. Even at the maximum voltage reached (9.5kV) the mean cross-talk (with a card threshold of 90 mV) to the side pad does not exceed 2%, while no effects have been found on corner pads. It is then the capacitive coupling between side pads which produces this noise it is in fact delayed by about the risetime of the inducing signal (4-8 ns).

5.3 Time Resolution

Time resolution and signal formation delay have been studied making use of a simple four scintillator telescope for triggering, whose intrinsic time resolution was 1.2 ± 0.1 ns. The results, once the trigger resolution has been unfolded, are shown in figure 8. The very long flat top allows to reach resolutions, given this gas mixture, as good as 500 ps for a single pad. The delay in the formation of the signal (fig.9) also plays an important role, especially for triggering purposes, given its dependence on high voltage and therefore on local disuniformities.

6. CONCLUSIONS

Parameters and characteristics of the E771 Resistive Plate Counters have been worked out with a pad read-out scheme giving satisfactory results especially for time resolution, efficiency and working stability. A test run with intermediate intensity (up to 4×10^7 protons per second) is in progress. At these intensities particle rates of 10-20Hz/cm^2 are expected.

REFERENCES

1. B. Cox et al., FERMILAB Proposal E771 (April 1986)
2. G Grancagnolo, Studies of B-physics with FNAL E771, INFN-AE/90-07, 10 luglio 1990, Proc. of XXV Rencontres de Moriond, "High Energy Hadronic Interaction", Les Arcs, Savoie, France, March 11-17, 1990.
3. R.Santonico et al., N.I.M., 187 (1981) 377
   R. Cardarelli et al., N.I.M., A263 (1988) 20
4. F. Grancagnolo, "The RPC system of E771, cosmic ray test results", Proc. of the "4th topical Seminar on Experimental Apparatus for high Energy Particle Physics and Astrophysics", San Miniato, Tuscany, Italy, may 28-june 1, 1990.
5. M. Bertino et al., N.I.M., A283 (1989) 654

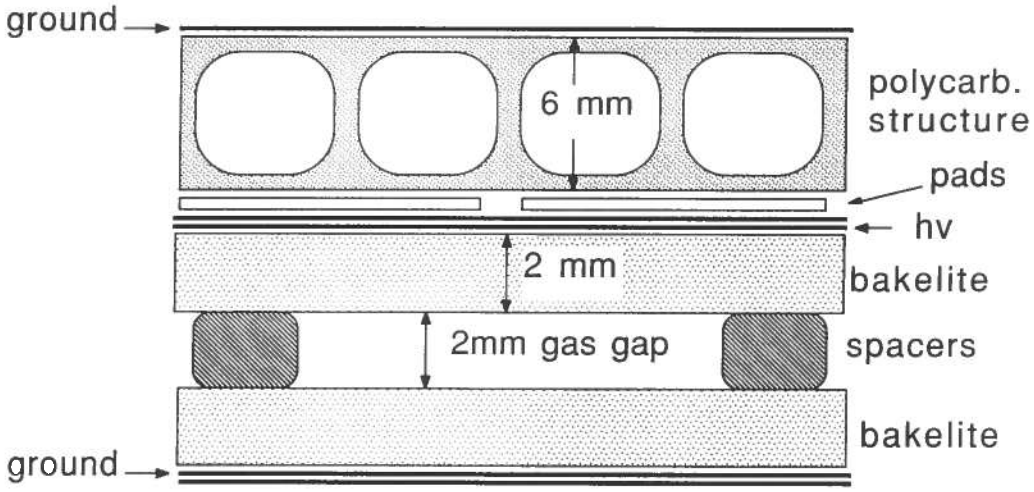

Figure 1: Sectional view of an RPC

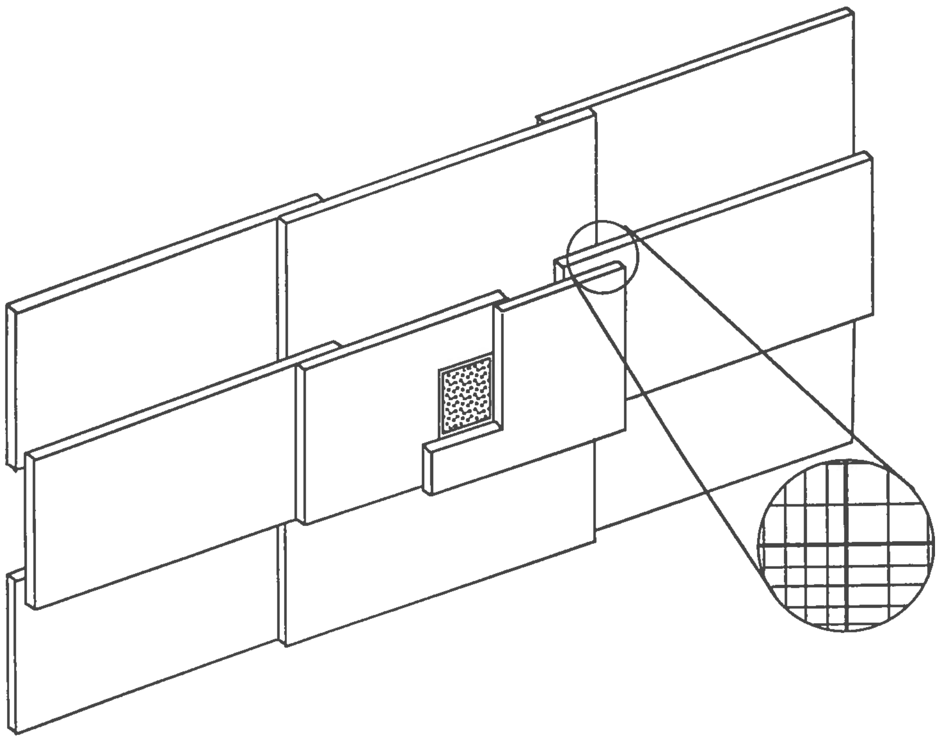

Figure 2: Muon detector plane and pad configuration

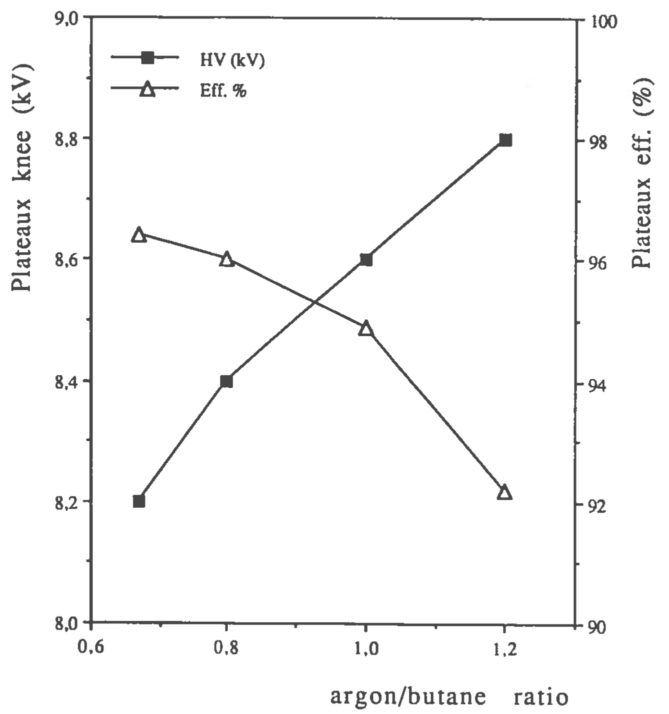

Figure 3: **Efficiency and plateaux knee vs the ratio butane/argon**

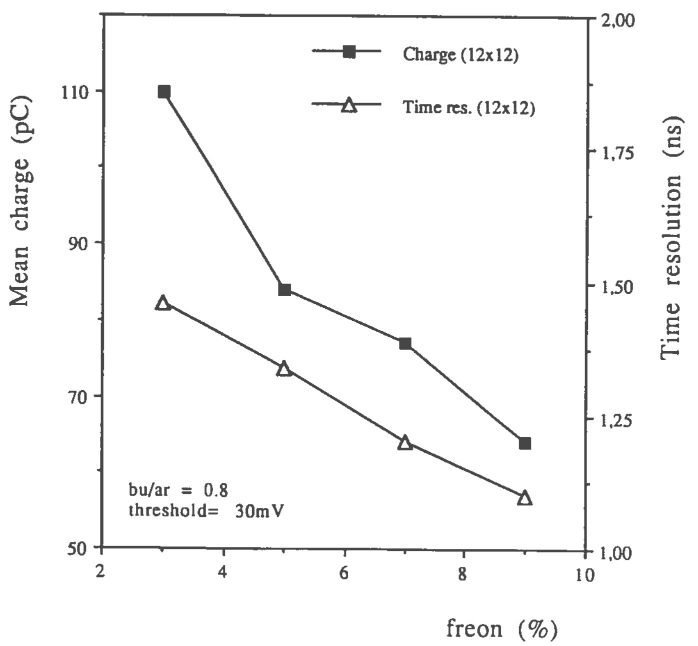

Figure 4: **Time resolution and means charge vs freon content**

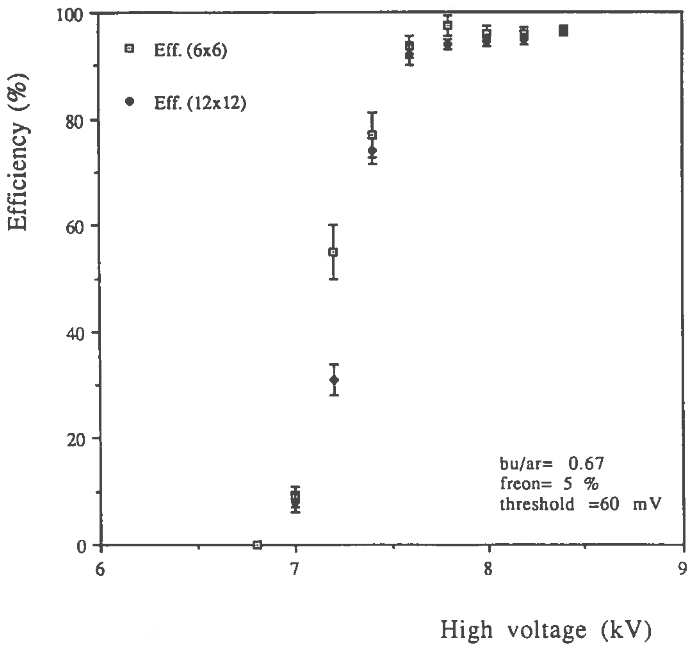

Figure 5: Plateaux curves (both detectors)

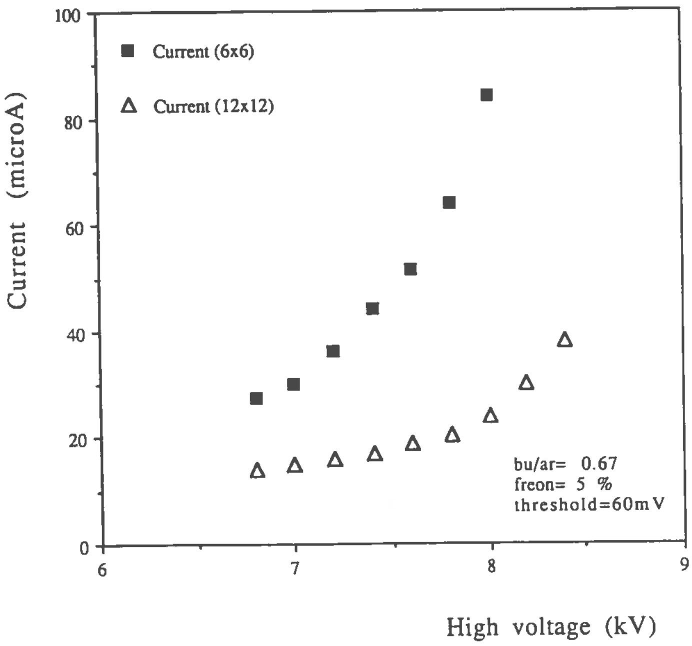

Figure 6: Dark currents (both detectors)

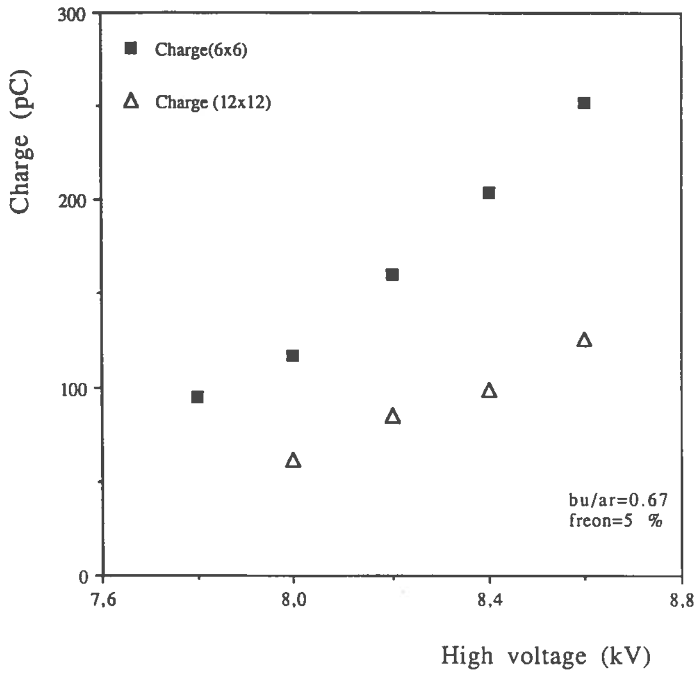

Figure 7: Charge dependence on high voltage (both detectors)

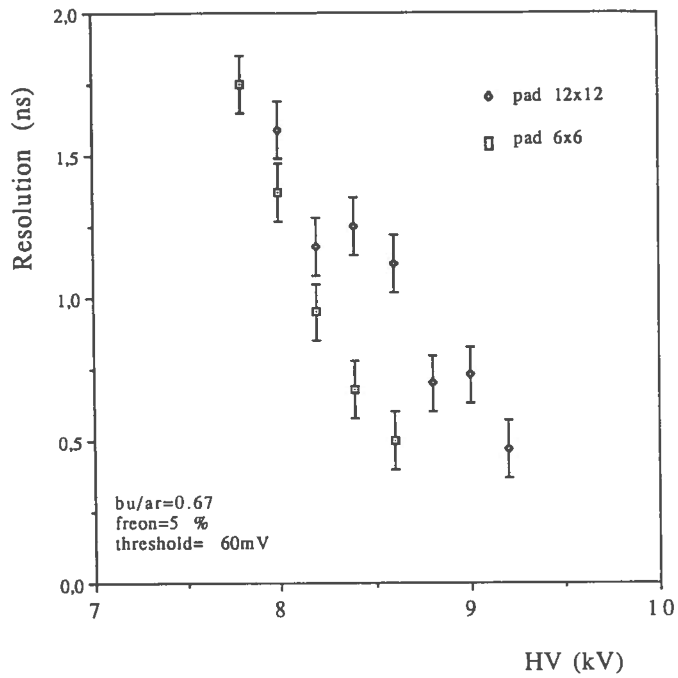

Figure 8: Time resolution (both detectors)

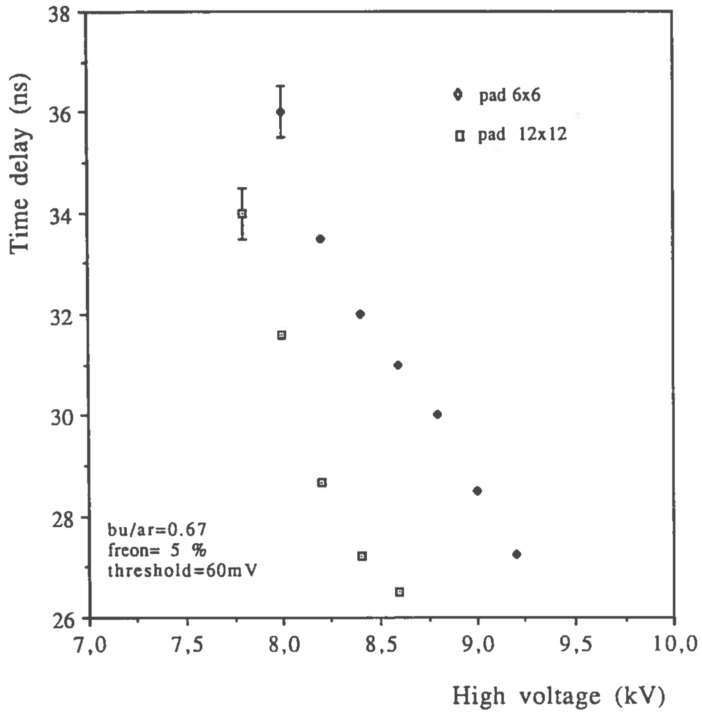

Figure 9: Signal formation delay (both detectors)