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NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

The muon and neutral hadron detector for BaBar

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Abstract

The muon and neutral hadron detector of the BaBar experiment for the PEP-II Asymmetric B-factory at SLAC uses Resistive Plate Counters (RPCs) as active detectors. A large fraction of the total system, which consists of approximately 800 chambers for an overall surface of 2000 m^2, has already been built and tested in cosmic rays. Preliminary results of the operating characteristics with a new non-flammable and environmentally safe gas mixture are reported. © 1998 Elsevier Science B.V. All rights reserved.

1. Introduction

BaBar is the experiment designed to measure *CP* violation effects in the neutral B system at the PEP-II asymmetric B-factory at SLAC. This machine is an e^+e^- collider operating at a center-of-mass energy corresponding to the $\Upsilon(4S)$ mass; the energies of the electron and positron beams are 9.1 and 3.0 GeV, respectively.

The main components of the detector are: a Silicon Microstrip Vertex Detector, a Drift Chamber, a Cerenkov based PID system, a CsI Electromagnetic Calorimeter, a Superconducting Solenoid and a Muon Detector (see Fig. 1). The design of the detector emphasizes particle identification both for reconstructing the B decay final states and for tagging the B-quark flavour. Muon and neutral hadron identification is performed in the Instrumented Flux Return (IFR [1]).

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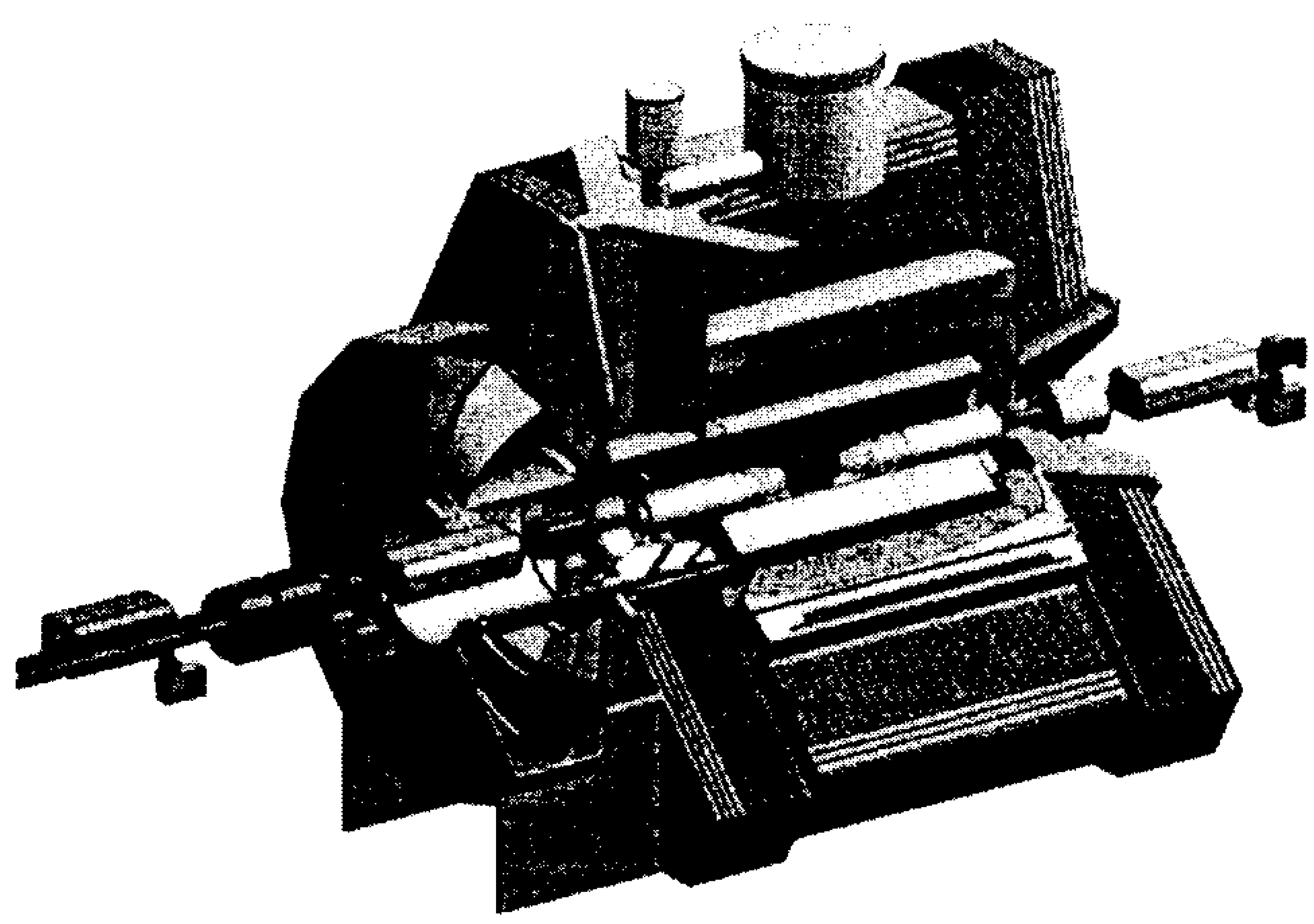

Fig. 1. The BaBar detector.

This detector makes use of the iron of the magnetic flux return as absorber and Resistive Plate Chambers [2,3] as active devices. The iron structure is divided into three parts: a "Barrel" in the central region and two "End Caps" which cover the region of small polar angles. It is segmented into 18 plates of graded thickness (2,3,5, and 10 cm) for a total of 65 cm in the Barrel and 60 cm in the End Caps.

The chambers are housed in the gaps between the iron slabs covering a total area of about $2000\ m^2$. The RPCs (see Fig. 2) consist essentially of a 2 mm gas gap at atmospheric pressure enclosed between two high-resistivity bakelite plates (10^{11}–$10^{12}\ \Omega$ cm), 2 mm thick. A graphite paint is brushed on the outer face of the plates, so that the HV (about 8 kV) can be applied to the electrodes. The needed planarity and gap uniformity of the two bakelite plates is ensured by a grid of insulating spacers.

External induction electrodes are coupled, with a suitable insulator, to the bakelite sheets. In the BaBar design both sides of the RPC are read-out with strip-shaped electrodes. The strips are orthogonal in the two planes allowing bidimensional read-out. The active volume is filled with a gas mixture based on comparable quantities of Argon and Freon 134A ($C_2H_2F_4$), and a small amount (few percent) of Isobutane. This choice is the result of extensive R&D studies on operation of RPCs in streamer mode with non-flammable and environmentally safe gas mixtures.

2. Results from the cosmic rays test

Prior to shipment to SLAC all RPCs are tested in an experimental set-up for cosmic rays at the

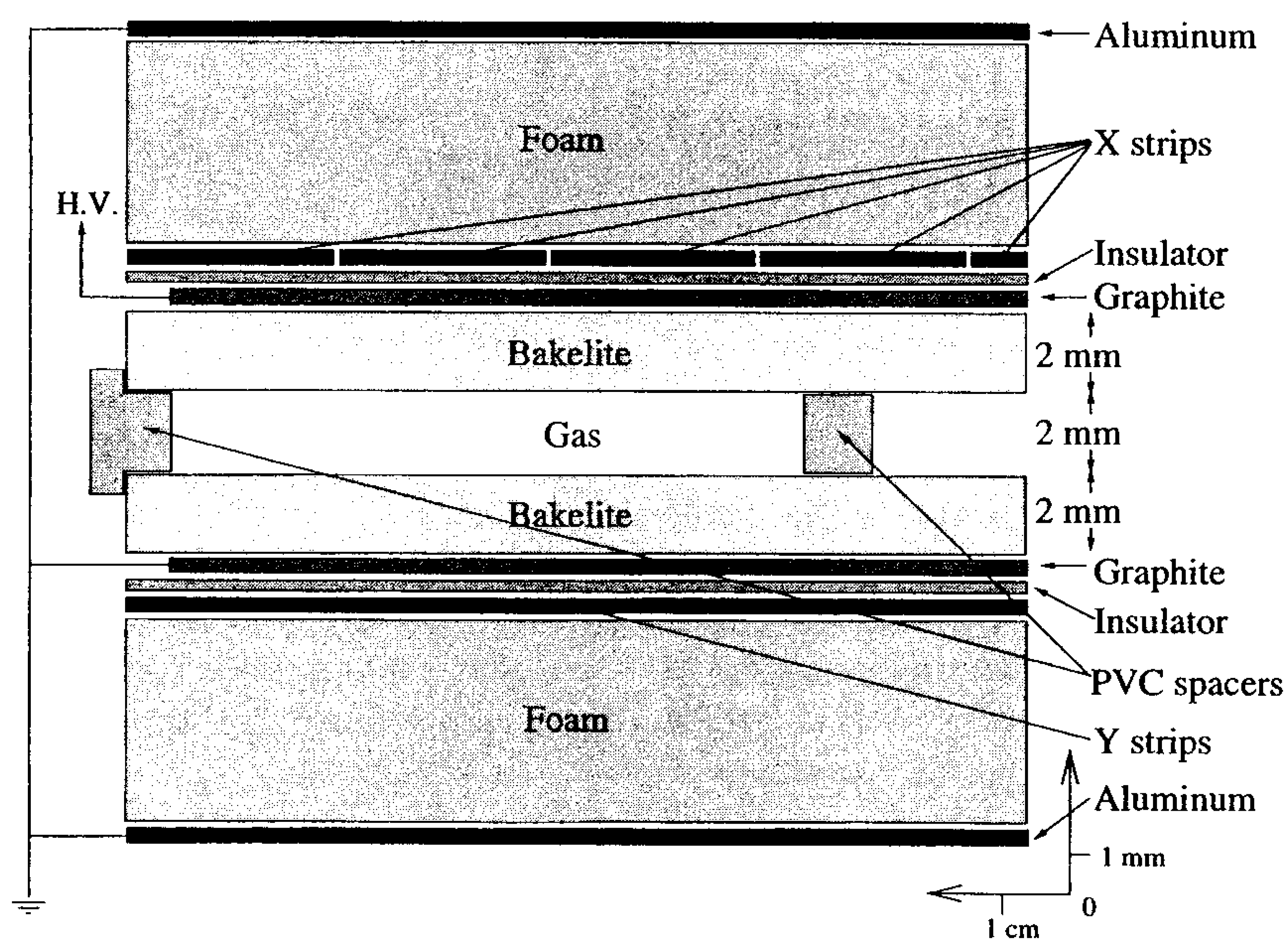

Fig. 2. Schematic view of RPC components.

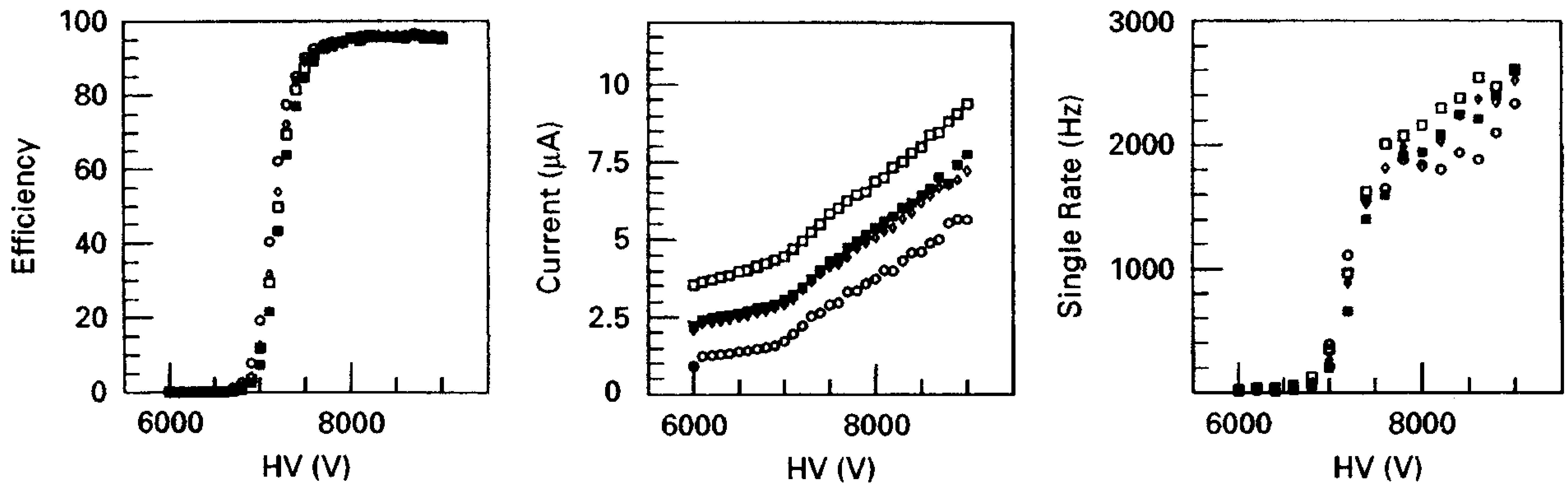

Fig. 3. Efficiencies, currents and single rates versus the high voltage.

LNF (Frascati). The test station consists of a mechanical structure capable of housing up to four boxes, each containing 12 RPC modules (typically, $1.3 \times 2\ m^2$ each).Two RPCs (on top and bottom) provide the trigger. The trigger chambers have a bidimensional strip read-out, while at this test stage the strips are glued only to one side of the modules. During the tests, the Data Acquisition System, records currents, pulse timing, rate of singles and efficiencies. Two different acquisition modes are used: "plateau" run where the high-voltage spans from 6 to 9 kV in steps of 100 V and a longer run at fixed voltage. The first mode of operation provides on line, for each high-voltage step, the efficiency, the single rate and the current drawn by each chamber. All these results are stored in an Excel DataBase [4] together with information related to the construction of each module. Most of the data shown in the following refers to a sample of $\simeq 330$ Barrel modules. Typical examples of efficiencies, single rates and currents as a function of the HV are shown in Fig. 3. A plateau-type behaviour can be readly seen both in the efficiency and in the single rates. The knee of the plateau for the two observables is around 7500 V. Full efficiency is reached just below 8000 V. Typically, the single rate at 90% efficiency is of the order of $1\ kHz/m^2$ and the currents drawn are spread over a range between few μA and 20 μA.

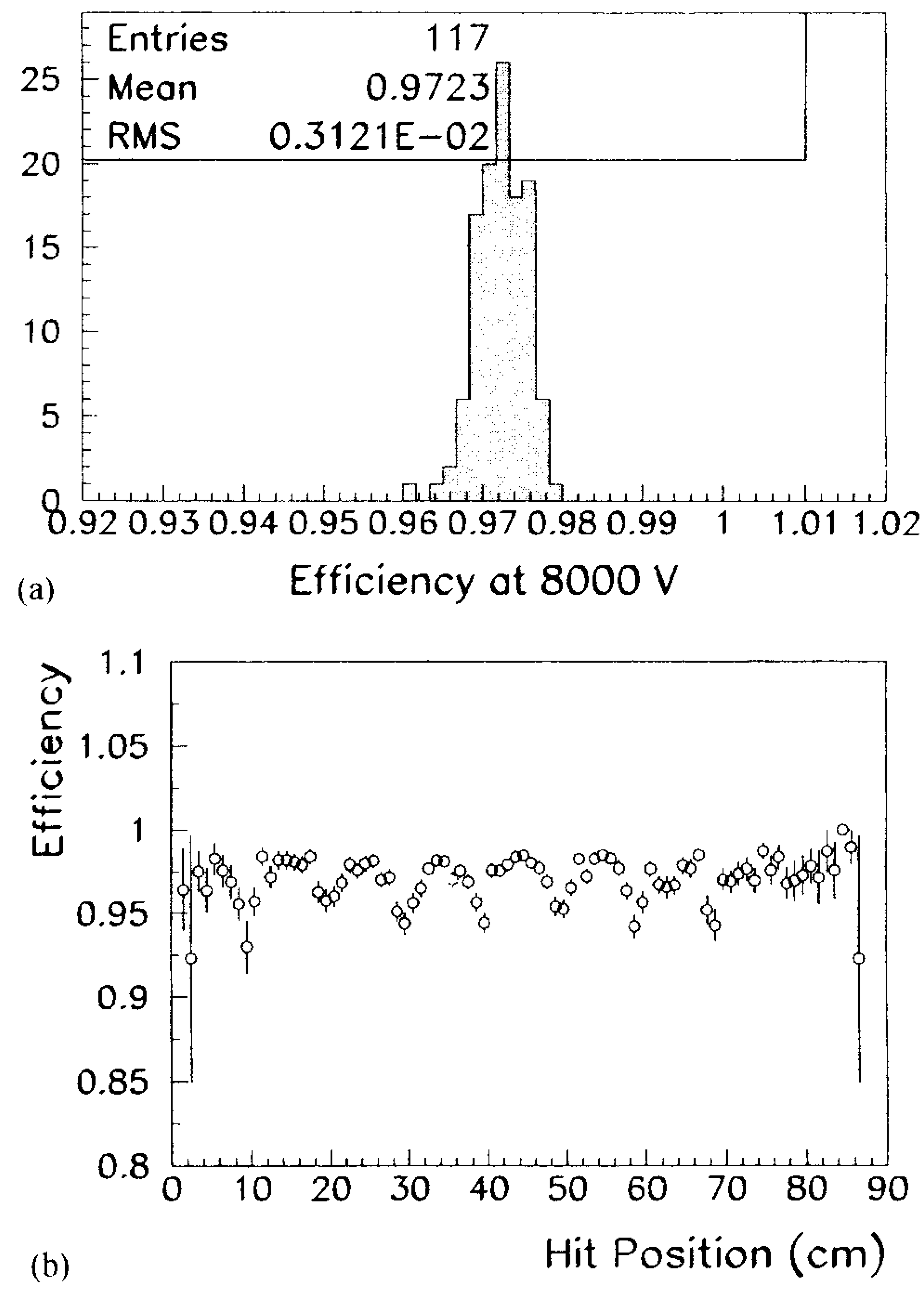

Fig. 4. (a) Plateau efficiency distribution. (b) Local efficiency for one module.

The data collected over a period of several hours at fixed voltage are analysed off-line in a more sophisticated way: full spatial reconstruction and tracking of the cosmic μ's are performed to get a more precise estimate of the efficiency and time resolution of the modules; only tracks within the frame of the modules are considered. As shown in Fig. 4a, the average value of the efficiency is 97.2% at 8000 V. Tracking allows to study the local

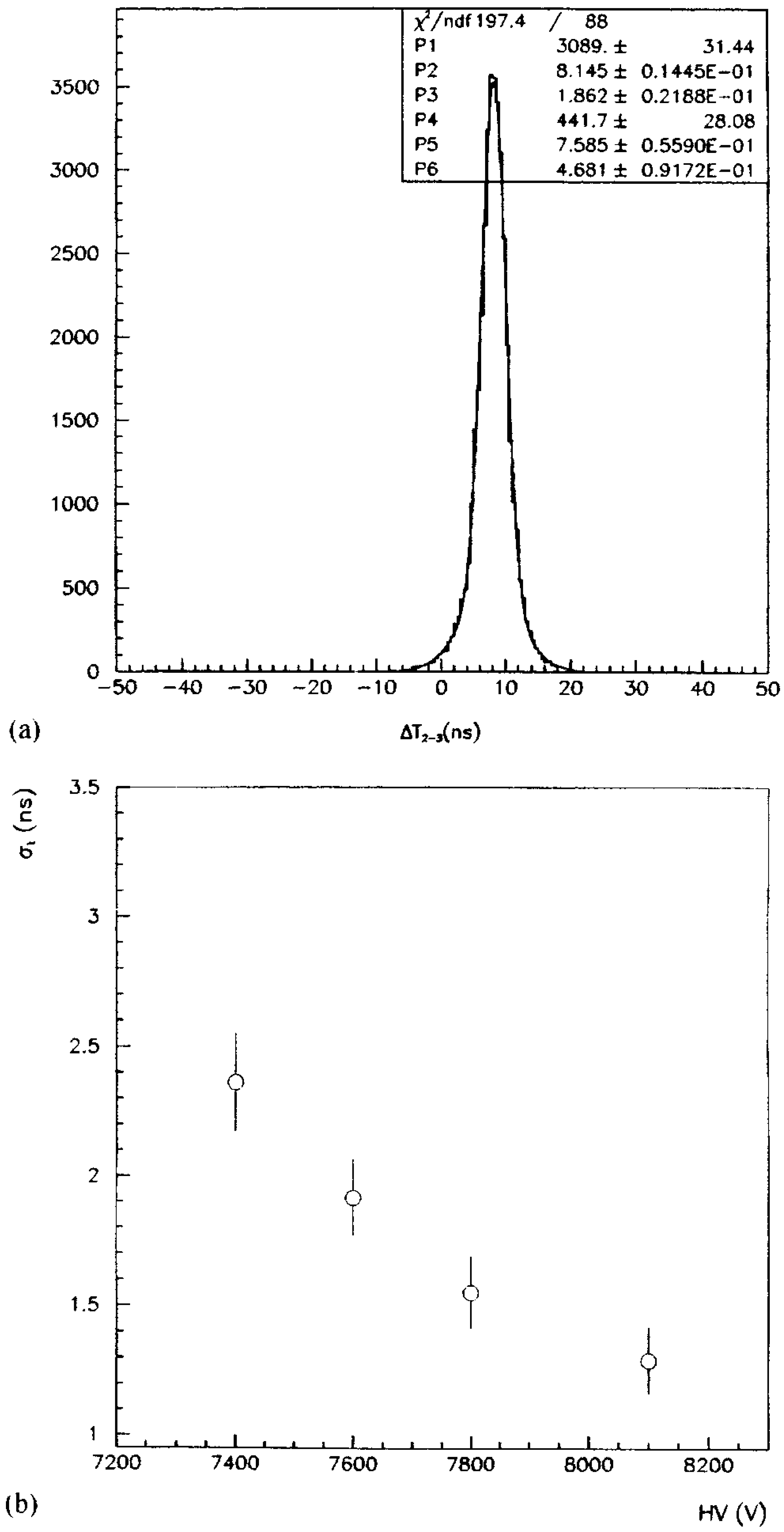

Fig. 5. (a) Time difference distribution for two modules. (b) Time resolution versus HV.

behaviour of the efficiency. As an example, in Fig. 4b the efficiency is plotted against the transverse coordinate. The regular spatial distribution of the dips corresponds to the presence of the plastic spacers, which have a circular sectional area 1 cm in diameter and are located on a 10 cm square grid. The higher values of the efficiency shown in Fig. 4b, allow to set the probability of producing a streamer with the chosen gas mixture for minimum ionizing particles at 98.2%. The difference with respect to the absolute efficiency of Fig. 4a matches nicely the fraction of the area occupied by the spacers.

The time difference distribution for two consecutive detectors in the same box operating at 8100 V is shown in Fig. 5a. A fit to this distribution with two gaussians of different σ's reproduces well the non-Gaussian tails. The narrow one has a $\sigma = 1.3$ ns (per module) and the areas ratio of narrow to wide Gaussians is $\simeq 2.5$. The behaviour of the time resolution as a function of the operating voltage is shown in Fig. 5b.

Given the relatively large number of modules to be produced, good uniformity of the performances is requested; one of the possible sources of disuniformity is the value of the bakelite resistivity. The plots in Fig. 6 show that no correlation is present between the average resistivity of the two electrodes and the main operational characteristics of the RPCs, at least within the resistivity range accepted for our production ($0.8–8 \times 10^{11}$ Ω cm).

3. Conclusions

The set of RPCs modules already produced for the BaBar Instrumented Flux Return is the largest built so far; the cosmic rays test performed at Frascati has provided good understanding of the operational features of these detectors. The results of the test lend us confidence that the production process results in detectors whose performances and uniformity match the needs of a large system which will operate for many years as BaBar.

No obvious dependence of any relevant feature of the chambers on the resistivity of the bakelite plates has been found. An absolute efficiency larger than 97% and a time resolution of 1.3 ns at the nominal operating voltage (8100 V) have been measured. The rate of singles is below 1 kHz/m^2.

Presently, the insertion of the first chambers inside the iron has begun. We expect to complete the Barrel installation by July 1997, while the full detector will be in place before the end of the year.

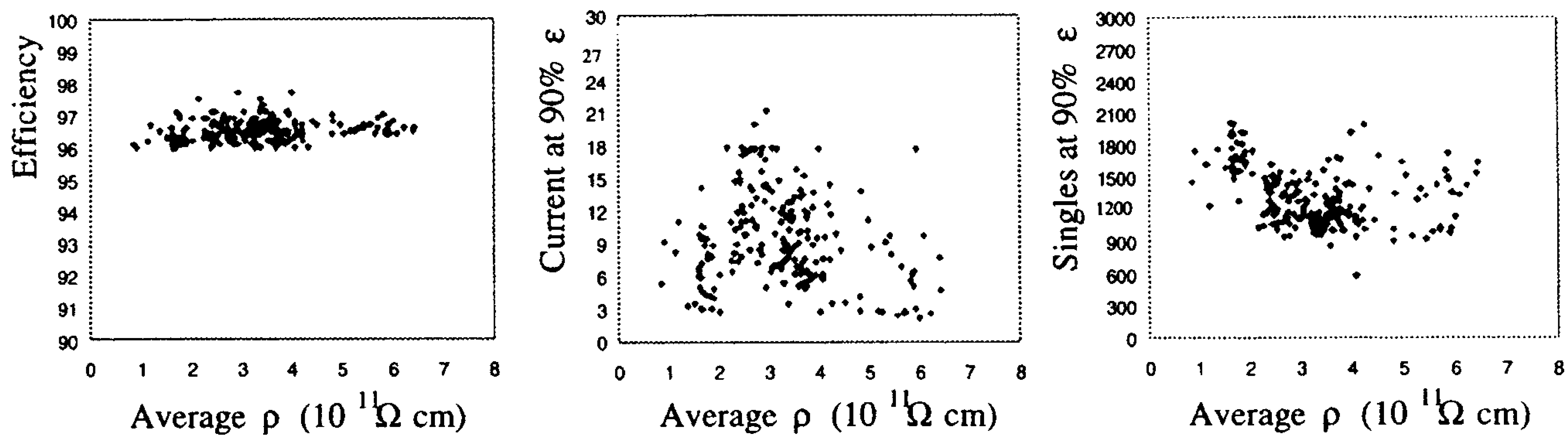

Fig. 6. Efficiency, current and rate of singles versus the average resistivity value of the two bakelite sheets.

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