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BaBar forward endcap RPCs

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Abstract

The BaBar detector has operated over 2000 m^2 of resistive plates chambers (RPCs) as muon and neutral hadron detectors since 1999. Most of the RPCs of the original production underwent a significant efficiency loss and many are now completely inefficient. During the summer 2002 new RPCs from a recent production were therefore installed to replace the old chambers in the forward endcap. The experience of the first 8 months of operation is described here.

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The BaBar detector [1], operating at the PEP-II B factory at the Stanford Linear Accelerator Center, utilizes resistive plate chambers (RPCs) [2], installed inside the segmented flux return steel as detectors of muons and neutral hadrons (the instrumented flux return or IFR system). The details of the steel design are shown in Fig. 1. The inner steel plates are graded in thickness from the inside to outside to optimize the detection of K_L. Over 800 single gap RPCs ranging in size from 1.5 to 3 m^2 are inserted into the gaps. In the summer of 2002 the forward endcap ($0.3<\theta<1$ rad, detecting 40% of the muons from B meson decays) was upgraded with the addition of brass and steel to increase the thickness of the muon absorber to more than 6 nuclear absorption lengths. With the exception of 4 RPC modules installed in 2000 and retained for ageing studies, all of the RPCs in the forward endcap were replaced.

The RPCs, shown in Fig. 2, consist of two planes of 2 mm thick bakelite (bulk resistivity $\rho_V = 3\text{–}12 \times 10^{11}\,\Omega$cm) separated by 2 mm polycarbonate buttons and fiberglass frames. The inner surface of the bakelite is coated with linseed oil while the outer surface is covered by a graphite paint ($\rho_S \sim 100\,\mathrm{k}\Omega/\Box$) and by an insulating PET film. A sandwich of strips, foam, and insulated ground planes is glued to either side. RPCs are

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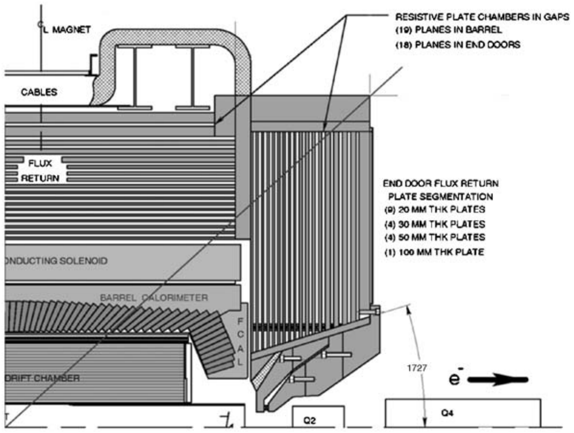

Fig. 1. The BaBar detector showing the details of the flux return steel surrounding the inner detector elements. Single layer RPCs are inserted into the gaps. The forward endcap chambers are made of two RPC high-voltage modules connected together to form a single gas volume and share one view of the readout strips.

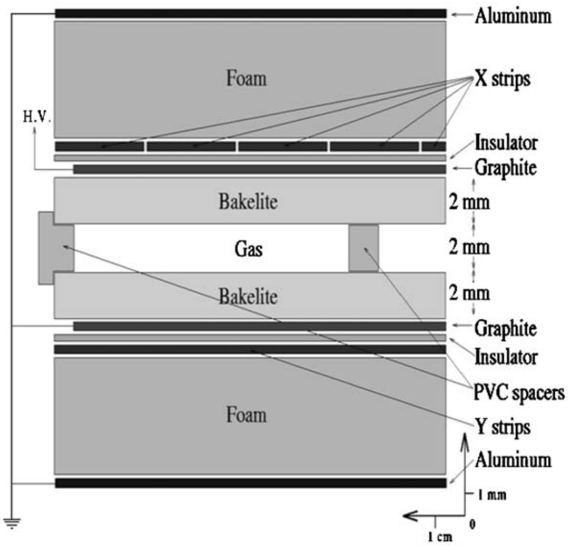

Fig. 2. Cross-section of a typical BaBar RPC.

operated in streamer mode at a voltage of 6700 V, using a gas mixture of 4.5% isobutane, 60.5% argon and 35% freon 134a. The average gas flow is 4 volume changes per day. The signals are readout capacitively by strip electrodes oriented along or orthogonal to the long axis of the RPC.

The RPCs were manufactured by General Tecnica[1] in 2001–2002 under a stringent quality assurance (QA) program developed by the IFR group. Particular care was made to keep the inner RPC gap as clean as possible and to ensure that the final linseed oil coating was thin and well cured. The inner surface of the bakelite were coated only once with a mixture of 40% linseed oil and 60% *n*-pentane. Multiple filters were added to the linseed oil filling stations and the oil was periodically analyzed for impurities. New molded corner pieces were designed to replace the drilling previously used to make the gas fittings. Gas tightness and unglued button identification tests were performed on each gap. As a part of the QA program about 5% of the RPCs were opened after construction to inspect the surface quality. Each gap was characterized by measuring the dependence of the current on the applied voltage. Many of the QA improvements in RPC production made by the IFR group have been adopted by the LHC detectors collaborations [3–5] and Opera collaboration [6].

Two modules were assembled into chambers, sharing one view of the pickup strips and one connection to the gas distribution system. The gas connections within a chamber were serial, downstream modules receiving the output of the upstream module. The RPC modules were tested at General Tecnica before shipment to SLAC and then at SLAC with cosmics. After insertion into the BaBar steel, connection to the data acquisition, high voltage, and gas systems the RPCs were tested with cosmic rays. The average efficiencies were greater than 95% with a counting rate of about 0.1 Hz/cm^2.

During the first 8 months of operation we were able to monitor noise rate, current and gas flow of each chamber. Efficiency at operating voltage was continously monitored with collision data using physics process as $e^+e^- \rightarrow \mu^+\mu^-$. Once a month we performed voltage scan to record efficiency plateaux with cosmics. Over the first 8 months of operation the parameters of the fit function describing those plateaux have been stable and

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the RPCs efficiencies in the inner layers have shown no decline as displayed in Fig. 3.

The noise rates in the 2002 RPCs produced by backgrounds from normal BaBar running varied considerably. RPC modules near the bottom of the door were dominated by the cosmic ray rate and never drew more than 2 μA. The current and noise rates of modules closest to the beam line (3rd and 4th module from the bottom) were proportional to the PEP-II luminosity and were typically 1–3 Hz/cm^2 or 30–50 μA. Moreover, the rates in the outermost layers (15 and 16) which are practically unshielded from the beam background, were too high to allow normal operation (>12 Hz/cm^2), while the rates in the next outermost layers, protected by 10 cm of steel, were lower (5–10 Hz/cm^2), depending on the PEP-II backgrounds. A large shielding wall, scheduled for installation in 2004, is planned to reduce these backgrounds by a factor at least 10.

All but the bottommost RPCs see PEP-II induced backgrounds. The charge accumulated by each RPC varied from 1 to 15 mC/cm^2. Several of the RPCs suffered changes to their dark current and noise rates as evidenced by the cosmic ray values in Fig. 4, increasing linearly over time.

In Fig. 5 currents with cosmic rays at 5.0 kV (below the sparking threshold) and at 6.7 kV (normal operating voltage) are shown. The little difference between these currents is suggesting that

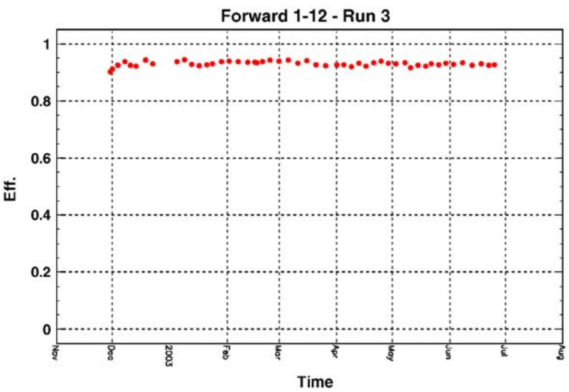

Fig. 3. The average efficiency of RPCs installed in the summer of 2002 in the inner 12 layers of the forward endcap is 93% and is stable in time.

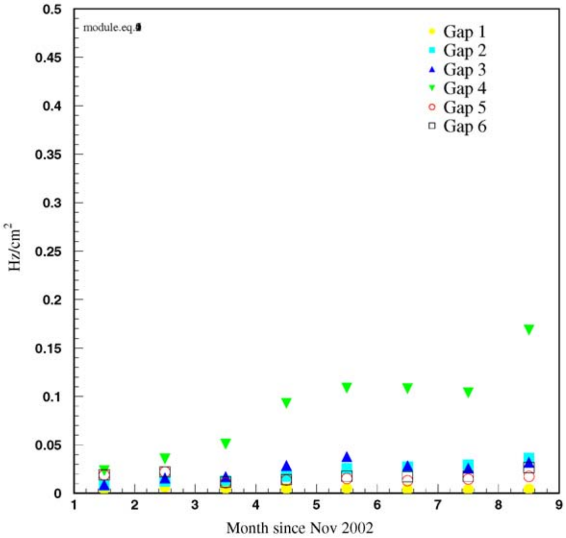

Fig. 4. Forward endcap East door noise rates with cosmic rays as a function of the month of the operations (since Nov 2002). Values are shown for each of the six gaps from bottom (Gap 1) to top (Gap 6) averaged over the inner 12 layers.

the most part of the current at the operational point is not flowing across the gas but rather across the spacers and the frame of the RPC.

We also observed that the largest increases in noise rates and currents were associated to RPCs being the second chamber in the gas flow string. The correlation between increased dark currents, background rates, and position in the gas flow string suggest that the downstream RPCs are being exposed to contaminants in the gas, presumably fluoridric acid, produced in the first RPC. The gas flow in the RPCs exposed to higher background rates has been increased from 4 to 8 volume changes per day for the current 2003–2004 run.

BaBar experience with RPCs constructed and installed in 2001–2002 has been positive so far. No loss of efficiency or shift in the high voltage plateau curves have been seen in the first 8 months of operation. Some chambers have shown a worrisome increase in singles rate and dark current correlated with the integrated charge received and the gas flow. More data is needed before final conclusions can be drawn.

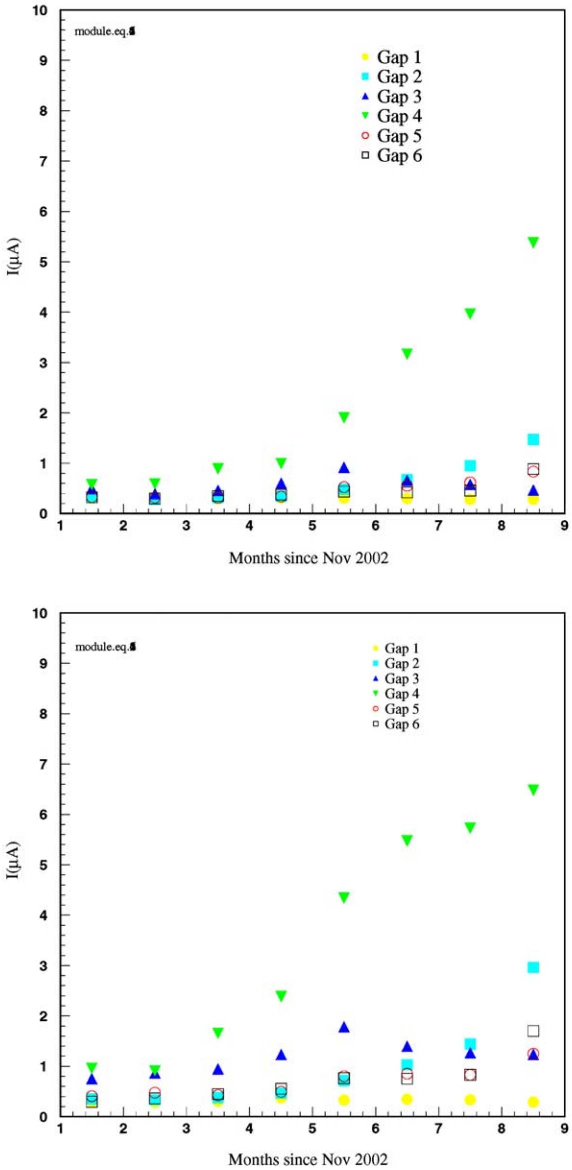

Fig. 5. Forward endcap East door currents with cosmic rays at 5.0 kV (top) and 6.7 kV (bottom). Values are shown for each of the six gaps from bottom (Gap 1) to top (Gap 6) averaged over the inner 12 layers.

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