SLAC-PUB-12204

EXPERIENCE WITH THE RESISTIVE PLATE CHAMBER IN THE BABAR EXPERIMENT

FABIO BELIINI

University/INFN of Rome
P.le Aldo Moro 2,
00185 Rome, Italy
E-mail: fabio.bellini@roma1.infn.it
on behalf of the BABAR RPC collaboration

The BABAR detector has operated nearly 200 Resistive Plate Chambers (RPCs), constructed as part of an upgrade of the forward endcap muon detector, for the past two years. The RPCs experience widely different background and luminosity-driven singles rates (0.01-10 Hz/cm^2) depending on position within the endcap. Some regions have integrated over 0.3 C/cm^2. RPC efficiency measured with cosmic rays and beam is high and stable. However, a few of the highest rate RPCs have suffered efficiency losses of 5-15%. Although constructed with improved techniques many of the RPCs, which are operated in streamer mode, have shown increased dark currents and noise rates that are correlated with the direction of the gas flow and the integrated current.

1. Instrument Flux Return Overview

The BaBar detector[1], operating at the PEPII B factory of the Stanford Linear Accelerator Center (SLAC), installed over 200 2nd generation Resistive Plate Chambers[2](RPCs) as part of an upgrade[3] of the forward endcap muon and neutral hadron detector (IFR) in 2002. Most of the RPCs were operated nearly continuously for the two years of BaBar data taking covered in this report. The new RPCs were built from bakelite sheets at General Tecnica[a]. A stringent quality assurance (QA) program was developed by the IFR group to keep the inner bakelite surfaces as clean as possible and to ensure that the final linseed oil coating was thin and well cured. New molded corner pieces were designed to replace the drilling method previously used for the gas fittings. Multiple filters were added to the linseed oil filling stations and the oil was periodically analyzed for impurities.

[a]General Tecnica S. r. l., I-03030 Colli (FR), Italy

Contributed to 9th ICATPP Conference on Astroparticle, Particle, Space Physics, Detectors and Medical Physics Applications, 10/17/2005-10/21/2005, Villa Erba, Como, Italy

Work supported in part by the US Department of Energy contract DE-AC02-76SF00515

Chambers are made from two RPC high voltage modules interconnected to form a single gas volume and share one view of the readout strips. The modules are numbered from 1 to 6 counting from the bottom. The gas lines of two high voltage modules are connected in series to form a single gas volume of ~ 8 l. Details of the RPC construction and testing may be found in[3].

1.1. *RPCs operating conditions*

BaBar RPCs operate in limited streamer mode, using a gas mixture of 4.5% isobutane, 60.6% argon and 34.9% Freon 134a. The gas flows in the inner (outer) layers were originally set to 22 (45) cc/min. corresponding to 4(8) volume changes per day. Concern for increased currents in the higher rate middle chambers prompted an increase in the gas flows in these RPCs to 8 volume changes per day (on day 300). During the Christmas 2003 break (day 420), all flows in the forward endcap were reversed.

The streamer rates produced by backgrounds and signals from normal BaBar running varied considerably depending on the layer and position of the chambers. In the inner layers 1-12 the chamber occupancy was highest around the beam line. Signal rates (and occupancy) were proportional to the PEPII luminosity and were typically 30 to 50 kHz per module in layer 1 with peak rates above 10 Hz/cm^2. RPC modules in the bottom of the endcap saw very low rates (little more than the cosmic ray rate) and never drew more than a few microamps.

The rates in the outermost layers (15 and 16) were sensitive to backgrounds from PEPII, which enter the outside of the endcap. These backgrounds were often too high (≥ 12 Hz/cm^2) to allow normal operation. The rates in the next outermost layers (13-14) were lower (~ 4 Hz/cm^2) with typical PEPII backgrounds. Although the rates per module of RPCs in Layer 14 were typically higher than for RPCs in Layer 1, hits were spread over much of the chamber surface, resulting in lower peak rates per unit area.

1.2. *Efficiency Trends*

Most of the endcap RPCs have stable efficiencies (Fig. 1)with moderately increasing currents and noise rates. Other RPCs have significantly increased noise rates and currents coupled with significant efficiency losses[4].

At least part of the observed efficiency changes are probably due to increases of the bakelite resistance with time (due to the bakelite drying

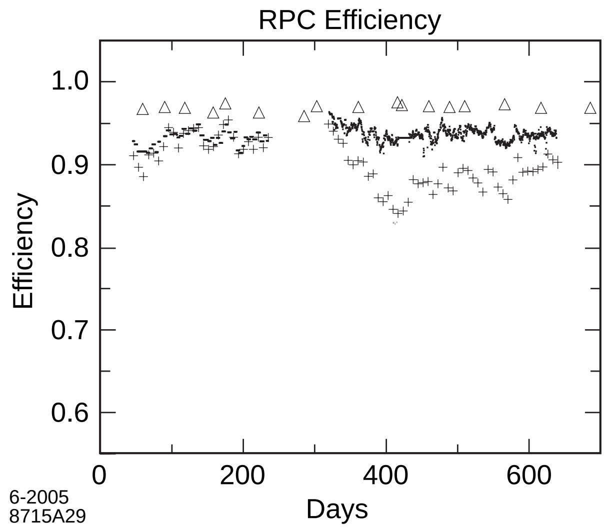

Figure 1. The average RPC efficiency of layers 1-12 was measured with beam using μ-pair (black points) and with cosmic rays (open triangles). The crosses show the efficiency of the 4th RPC in layer 1 of the west door.

out) as has been previously observed by the ATLAS experiment during LHC chamber testing[5]. Initial measurements indicate that the relative humidity of the IFR input gas is $\sim$0% RH, while the exhaust gas from 2 modules in series is 20-30% RH, consistent with the removal of water from the RPCs. This observation suggests the following model. The initially dry gas entering the first module absorbs water from the bakelite as it flows through the module. The removal of water from the bakelite raises the bulk resistivity. When exposed to substantial signal rates, the higher resistance leads to a voltage drop across the bakelite, reducing the voltage across the gap thus lowering the RPC efficiency.

The regions near the gas inlets are exposed to the driest gas at high flows. There is strong evidence in BaBar of high resistance regions developing in the bakelite near the gas inlets. These regions have a much reduced observed noise rate or reduced efficiency. When the gas flows were reversed and gas inlets became outlets, thereby increasing the humidity of the gas in that regions, the efficiency returned to normal. New inefficient regions appeared at the new gas inlet locations.

It is likely that most of the water removed in the exhaust gas is from the first module. Preliminary measurements show that the humidity of the gas from the BaBar belt chambers (about 1/4 the size of the typical layer 1-16 chambers) is already 80% of that measured in the larger chambers. The gas entering the second (downstream) module is therefore more humid and drying effects in the second module are reduced. This may explain why the gas flow reversals also affected the efficency in the region of the high rate ring around the beam-line which is far from the gas inlet/outlets. The efficiencies of the chambers originally first in the gas flow chain increased after the reversal. Humidified ($\sim 30\%$ RH) gas has been supplied from the beginning of 2005 to a sub-sample of the RPCs, a clear efficiency recovery effect showed up (Fig. 2) with no negative effect so far.

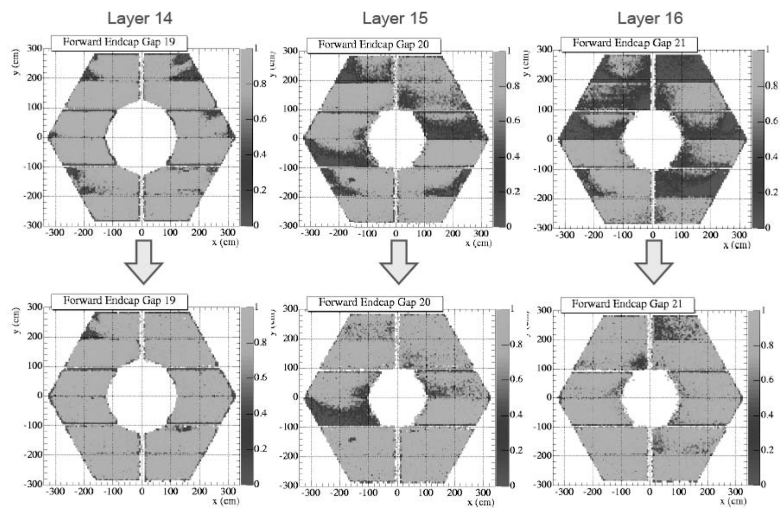

Figure 2. The two-dimensional RPC efficiency of layer 11,15,16 before (upper plots) and after 5 months (lower plots) of $\sim 30\%$ RH gas flow.

1.3. *Increased Noise rates and currents*

The correlation between increased dark currents, background rates, and position in the gas flow string[4] (Fig. 3) suggest that the downstream RPCs are being exposed to contaminants in the gas produced in the first RPC. Several RPC tests[6] have independently measured the presence of HF (hydrogen fluoride) in the exhaust gas presumably from the decomposition of the freon in the avalanche or streamer. High HF levels have been also correlated to increased ohmic currents[7]. Applying the same model to the BaBar

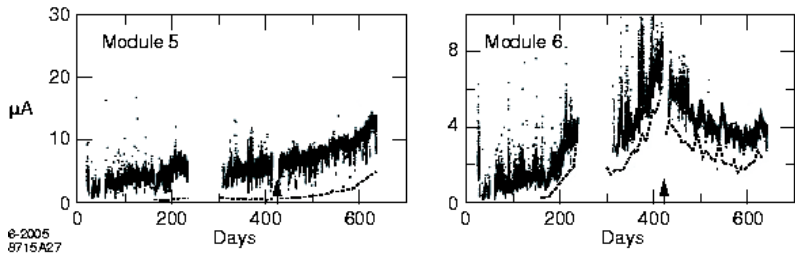

Figure 3. The average current drawn by layers 1-12 in the west door as a function of time. The gas flow was increased on day 280 and reversed on day 425 (arrow). The current with beam (black points) has contributions from streamers and an ohmic contribution (dashed line) which is estimated from the current when the voltage was below the gas gain region (4500V)

chambers would explain the preferential rise of "hot spots" in the high rate regions and in the downstream regions. Extensive HF measurements are on going.

1.4. *Integrated Charge*

The 2002 RPCs in the forward endcap have integrated very different amounts of charge depending on position and background rates. By integrating the current history for each high voltage module, an integrated charge (varying from 10 to 1600 Coulombs) for each module was computed. The modules which have integrated more than 1000 Coulombs are either in the outermost active layer (14) or in the middle chambers of the inner layers. Taking into account the different occupancy, the integrated charge per unit area can be estimated to be ≈ 0.075 C/cm^2 in Layer 14 and ~ 0.3 C/cm^2 in the inner layers[4]. The latter ones start to develop a loss of efficiency at small radii and thereby they will be operated in avalanche mode in the next run.

References

1. B. Aubert *et al.*, *Nucl. Instr. Meth.* **A479** 1-116 (2002).
2. R. Santonico and R. Cardarelli, *Nucl. Instr. Meth.* **A187** 377 (1981).
3. F.Anulli *et al.*, *Nucl. Instr. Meth.* **A539**, 155 (2005).
4. F.Anulli *et al.*, *Nucl. Instr. Meth.* **A552**, 276 (2005).
5. G. Aielli *et al.*, *Nucl. Instr. Meth.* **A533** 86-92 (2004).
6. R. Santonico, *Nucl. Instr. Meth.* **A533** 1-6 (2004).
7. G. Aielli *et al.*, Proceedings of IEEE NSS Roma(2004), to be published.