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Investigation of double gap resistive plate chambers for BaBar

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1 Introduction

Double gap chambers are one of the options being considered for the replacement of the chambers in the barrel portion of the BaBar IFR. In this document, we report on the construction of a prototype double gap chamber using two ordinary single gap BaBar IFR chambers.

2 Double gap design and construction

Multigap resistive plate chambers have been previously used to improve efficiency and timing resolution. In the BaBar case we are interested in producing a relatively thin chamber which can fit in the 22mm gap between the iron plates in the IFR barrel. Our design calls for 2 gaps which are readout with the same set of orthogonal strips. See figure 1. In order to induce voltages of the same sign on both the top and the bottom strips the electric field in both of the gaps must point in the same direction. The simplest solution is to apply high voltage of opposite sign to the top and bottom chamber.

An alternative solution would be to use a single layer of floating bakelite between the upper and lower gap. This would have the advantage of reducing the amount of graphite between the upper chamber and lower strips (the lower chamber and the upper strips). However, it has the disadvantage that an electrical fault in upper gap could potentially affect the lower gap and vice versa. Given the problems which have been observed with the existing BaBar chambers it is better to consider a design with completely separate high voltage (HV) distribution for the two gaps.

The main challenge in producing a double gap chamber is to develop a chamber which can fit in the gap between Iron plates in the IFR. During the construction of the barrel, a gauge of width 22mm (?) was passed between each of the layers which indicates that the chamber thickness should be no more than about 22mm. The individual gaps in the existing RPC gaps consist of a two pieces of 2mm bakelite held part by spacers of 2mm. The gaps are read out by strips insulated from the ground plane by 4mm foam. If the other elements of the chambers, the mylar insulation, the strips and ground planes, are neglected the thickness of two gaps and two sets of strips would be 2 x 4mm + 2 x 6mm = 20mm. In practice, the mylar, strips and ground planes are all about 1/2mm thick, adding 4mm to thickness of a double gap chamber.

In our initial tests we decided to reduce the thickness of the foam to 2mm. This produces a chamber of 20mm thickness as shown in Figure 1. This leaves at least 2mm on top of the chamber for cables and HV connections.

One disadvantage of the reduced foam thickness is that the characteristic impedance of the strip lines associated with the strips is reduced. For 4mm foam with dielectric $\kappa \simeq 1$ and 4.0cm wide strips, the impedance of a strip line is 39 Ω. This impedance is reduced to 21 Ω for 2mm foam. In order to test the sensitivity of our chamber to this impedance we constructed one side with silicon foam with low dielectric $\kappa \simeq 1$ and the other side with neoprene which had a measured value of $\kappa \simeq 4$, which should reduce the characteristic impedance to approximately 10 Ω.

In our prototype the strips which ran the length of the chamber were salvaged from a BaBar RPC from the first series. The original foam was removed from the 3 cm aluminum strips. On the opposite side, strips were constructed from 1 inch wide copper tape on mylar (see figure 2) with a pitch of approximately 2.9cm. Both the upper and lower ground planes are copper. In both cases the far end of the strips was attached to the ground plane with a 2k resistor.

The HV connections were made to outer graphite surfaces in the same manner as was used for the chambers in the BaBar upgrade. The HV cable used was quite thick and at this point our chamber is

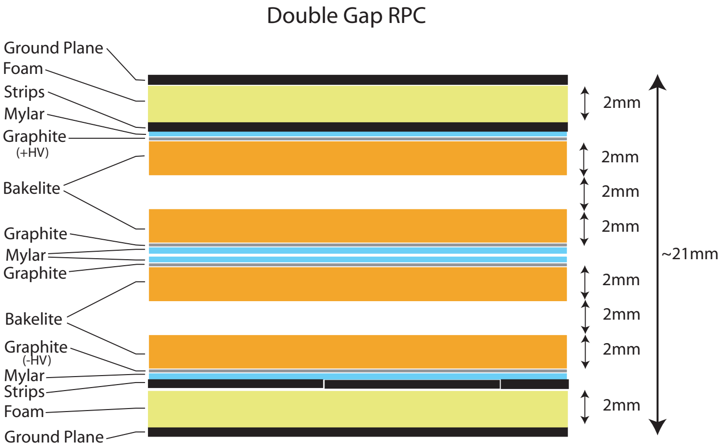

Figure 1: Cross section of double gap chamber as built.

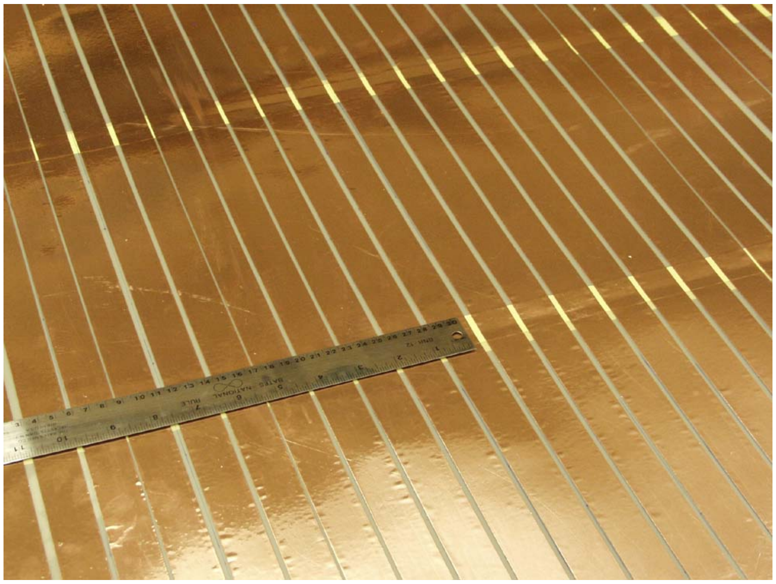

Figure 2: Copper strips.

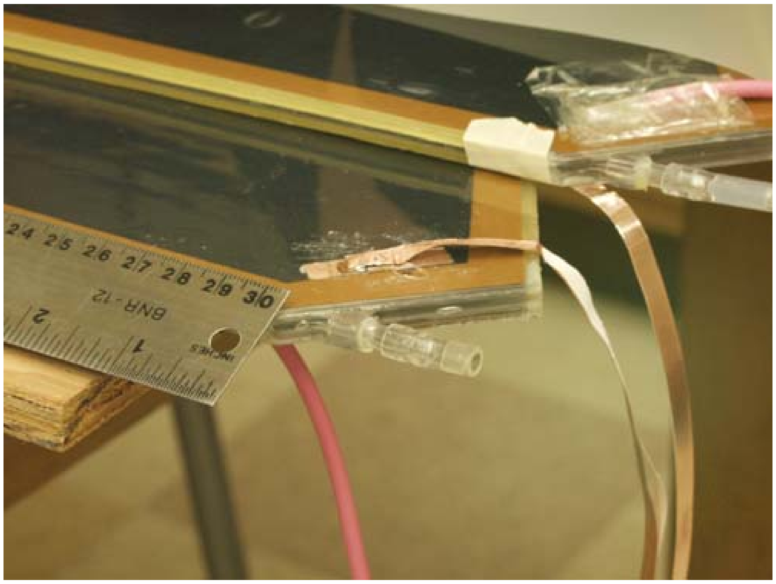

Figure 3: Copper tape used to make the ground connections to the chamber before the mylar was attached. Also visible are the rather thick high voltage cables used for the positive and negative voltage.

wider than 22mm. In a production run this could be solved by using a smaller HV wire, such as those used in the original BaBar production. This detail will have to be followed up for the final design, as the thinner wire may be more prone to shorts.

For the connection to the central graphite electrodes, copper tape and mylar were used. This produced a good electrical contact, but may not be strong enough for use in production. See figure 3.

3 Test Measurements

The first measurements on the double gap chamber were made with the top and bottom gaps powered separately. The chambers were placed on the Oregon test stand which is triggered by a coincidence of two scintillators. In the test the scintillators illuminated the middle third of the chamber. The gas used was the present BaBar mix, 35% Freon, 4.6% isobutane, and balance Ar.

Initially, the strips were connected to standard BaBar FECs with 2 meter long twisted pair cables. The cables have characteristic impedance of approximately 100 Ω which matches the input impedance of the FECs. The time of the common-or signal measured for both the top and bottom set of strips. The time of the first FEC signal relative to the scintillators were recorded by the DAQ system and required to be within approximately 60ns. The efficiency versus voltage is shown in figure 4. Only a small difference is seen between the efficiency of the strips closest to the HV and furthest from the HV.

We have also applied high voltage to both of the gaps in chamber (also shown in figure 4. In this instance the turn on of efficiency is somewhat faster than for a single gap on HV at a time. Notice that overall efficiency has not improved. This is not surprising as the spacers, and hence any dead areas in the top and bottom gaps line up almost exactly.

More details of the signals from the chamber can be obtained by connecting the strips to charge integrating ADC with a 200ns integration time. In this case the behavior of the signals will be modified by the lower impedance of the 50 Ω coaxial cables used for these studies. Since the ADC only works with negative signals, we use 1:1 transformers to couple the strips to the coax cable. For consistency these transformers are used for both positive and negative signals, but the polarity is reversed for the

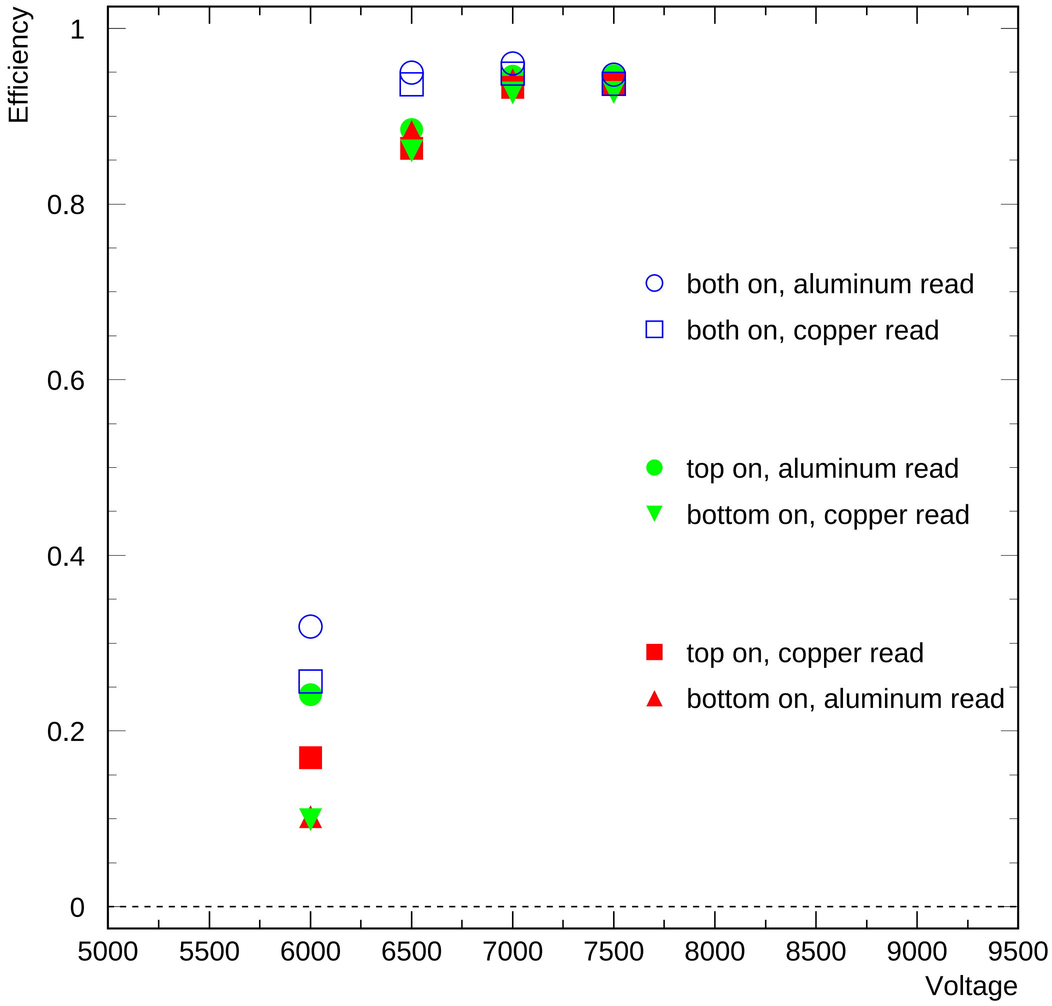

Figure 4: Efficiency versus voltage for different configurations of the double gap chambers. The blue points show the efficiency with both gaps on voltage. The green points show the efficiency with gap closest to the strips on voltage. The red points show the efficiency with gap farthest from the strips on voltage.

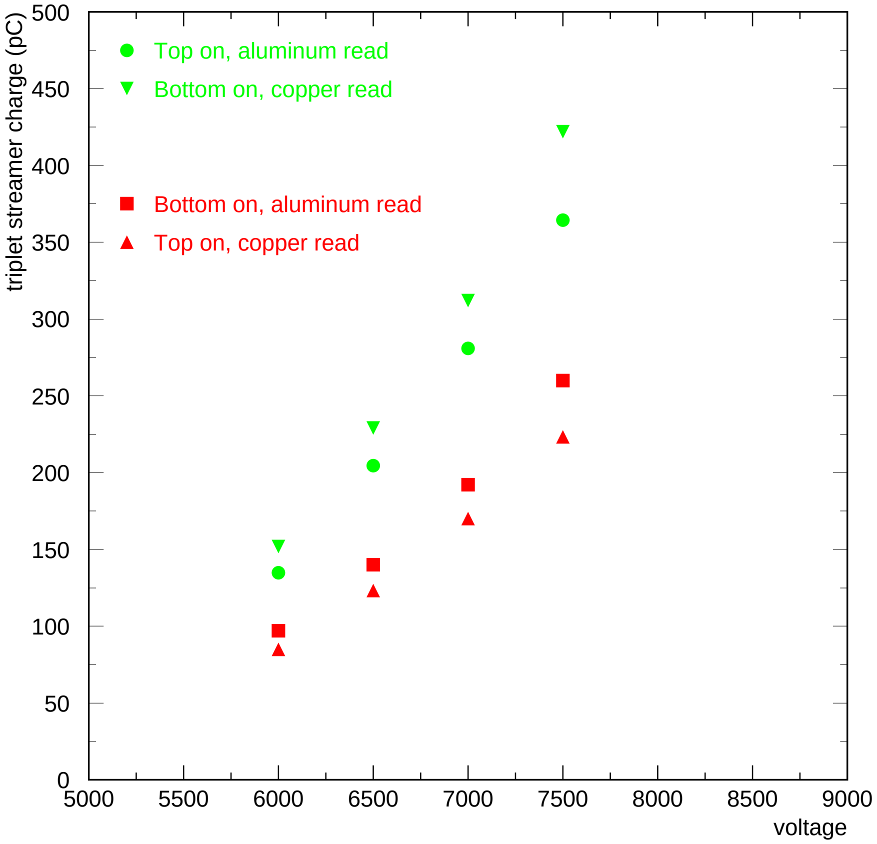

Figure 5: Streamer charge from the largest triplet of strips. The green points show the efficiency with gap closest to the strips on voltage. The red points show the efficiency with gap farthest from the strips on voltage.

positive signals to give a negative input to the ADC.

The integrated charge in the single streamer peak versus voltage is show in figure 5. As expected, more charge is observed when the gap closest to the strip is turned on. We do not have good data on the total charge with both chambers on as this exceeds the dynamic range of our ADC system.

Finally, we have investigated the average number of strips hit for both the upper and lower strips. The results are shown in figure 6. Somewhat counter intuitively the mean number of strips hit is smaller when both gaps are on voltage then when the gap opposite the strips is on voltage. This may be explained by the fact that the strips on either side of the streamer often have an induced negative signal. A large negative signal from the near gap could interfere with the wide signal from the opposite gap.

Two thresholds have been used for the study. In BaBar, the charge associated with the nominal 40mV threshold is close 40pC. This study indicates that when both chambers are operating properly the cluster sizes will not be significantly larger than is in the present BaBar IFR setup.

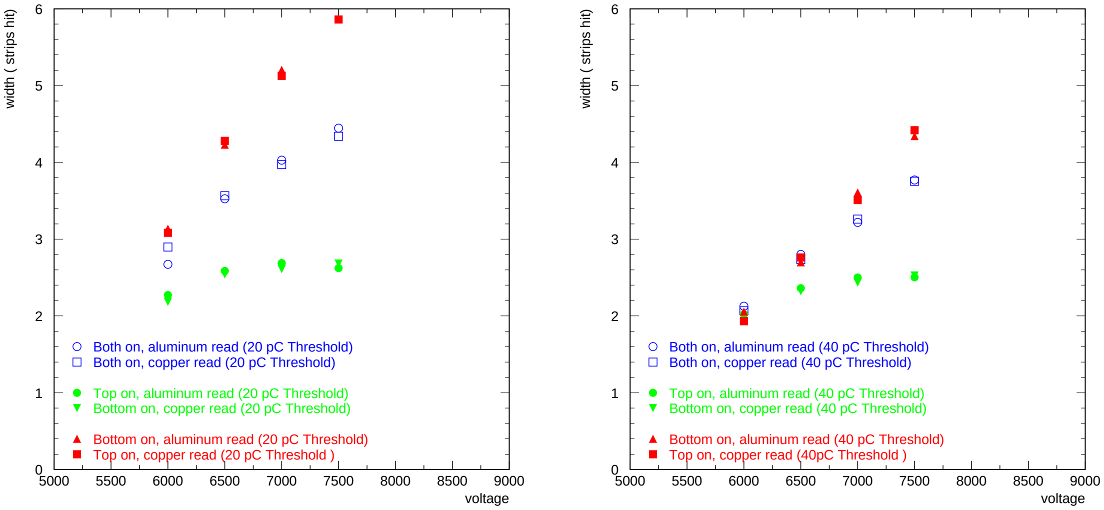

Figure 6: Number of strips above a 20 pC threshold (left plot) and 40 pC threshold (right plot) as a function of voltage.

4 Conclusion

We have shown that a double gap chamber of width 20mm (excluding cables) has performance equal or better than the present BaBar single gap chambers. Such a chamber would be more robust against failure than the present single gap chambers. The double gap chambers require that a thinner strip line is used in the readout which could lead to impedance matching problems. In our setup the present FEC discriminators are sensitive to streamers in a gas of 35% Freon, 5% Isobutane and 60% Argon, even when one of the two gaps is off. Because of aging effects, it may be desirable to run with much higher fractions of freon which give streamers with smaller charges. In this case the threshold in the FEC discriminators may no longer be low enough to ensure efficiency when only one of the two chambers in the double gap is working.