A Short History and Orientation for RPC's

Steve Dytman*

Univ. of Pittsburgh

(Dated: December 19, 2005)

Abstract

Every time the subject of Resistive Plate Chambers (RPC's) comes up, the nature of the resistive plate and how it was treated becomes important. This is a short orientation to the subject. It becomes clear that the many studies spawned by the failures at BaBar come from timing and aging issues that aren't relevant to Braidwood. When the issues are understood, the outstanding suitability of RPC's to low rate situations is obvious. The Belle chambers are a great place to start for developing a Braidwood design.

PACS numbers:

*Electronic address: `dytman@pitt.edu`

RPC's were invented [1] for applications requiring good timing and low cost, i.e. a replacement for scintillator. These features are readily obtained in a variety of ways, but there were definite growing pains that seem to be solved now. Without an understanding of the differences in design and those initial difficulties, it's difficult to make an assessment of the situation.

The basic picture is shown in Figs. 1 and 2; the gas gap is contained by a resistive material, commonly glass (resistivity of $\sim 10^{13}\Omega cm$) or bakelite ($\sim 10^{10}\Omega cm$). Thus, it is a chamber with no wires! When a voltage (typically $\sim$ 8 kV) is applied across the gap, charge sits on the planes facing the gas volume (Fig. 2left). When a charged particle ionizes gas molecules, the charge on the electrodes is momentarily neutralized (Fig. 2right). This motion of charge induces a pulse on the signal pickup plane which is slightly outside the voltage plane and electrically isolated from it. If the gas is chosen carefully (significant fraction of freon is the easiest way) this loss of charge is localized and the chamber recovers quickly (typically $\sim$ 2-20 ns). Mechanical construction is straightforward since there are no complicated materials and no precision dimensions as in drift chambers. The gap separation (typically 2 mm) is maintained by plastic spacers which create small dead areas. Like all detectors using gas, the output signal size is proportional to the energy loss in the gas at low voltages; this is the basis of multiwire chambers and is called avalanche mode in the RPC community. At higher voltages, the response is larger and the output signal is roughly constant in size; this is normally called a Geiger discharge and is the mechanism in a Geiger-Mueller detector but called streamer mode in the RPC community.

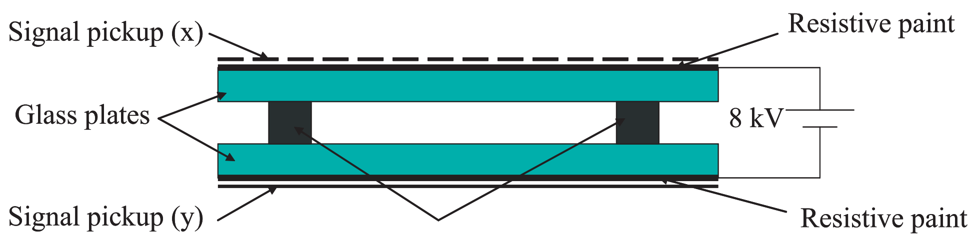

FIG. 1: Typical layout for an RPC. Note that the pickup plane is on the outside of the electrodes separated from the high voltage contact.

The most common usage for RPC's is as muon trigger detectors in collider experiments [3]. The first large applications were at Belle and BABAR; CMS, ATLAS, and ALICE are all installing large arrays. RPC's are also used in ARGO-YBJ, the Tibetan cosmic ray exper-

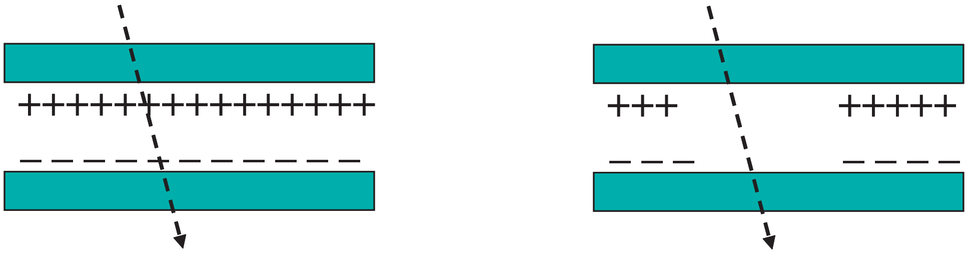

FIG. 2: Movement of charge associated with a track. The key property is that the discharge is localized for appropriate choice of gas. Left diagram shows the charges just before the track passes through and the right diagram shows the charges just after.

iment [7], and OPERA, an underground experiment at Gran Sasso [8] (see ref. [2]). The application is very important because of the high rate at modern collider detectors. They require very fast timing and aging is a strong consideration. Fastest timing comes from use of bakelite rather than glass because the lower resistivity results in faster redistribution of charge. Best lifetimes come from low gain which means running in the avalanche (proportional) mode.

The BaBar experience is important because failure was significant. Many of their RPC's developed a large dark current resulting in a catastrophic loss in efficiency and had to be replaced. These used bakelite plates. Almost all bakelite RPC's apply a layer of linseed oil to make the surface smoother and this was the source of the BaBar troubles. The layer was too thick and not properly cured. Thus, the oil formed into beads and made breakdown paths. At the same time, the LHC experiments were anticipating large scale (few thousand m^2) arrays. Needless to say, the effort was made to understand the problems with oil and the solution was found- apply a thinner layer of linseed oil, cure the product, and apply stringent quality controls [2, 3, 6].

This problem with bakelite is a peripheral issue for Braidwood because we are much less concerned with rate and timing issues. We now switch to the Belle experience. They have rate issues similar to those at BaBar but decided to use glass rather than bakelite. The Belle muon trigger consists of 15 double-gap RPC layers covering a total area of 2200 m^2. The overall efficiency is given as greater than 99%. Details of their system will be given in a following note. Although they avoided the breakdown issues because of applied oil, there was an efficiency loss problem soon after the spectrometer was turned on. The problem was traced to water vapor that came in through the polyflo tubing used to take the gas from the mixer to the chambers. This was fixed initially by a large increase in the gas flow rate; the problem quickly disappeared. The gas tubing was switched to copper at a later time and the solution was complete. The original chambers have now been in use for 6 years. With the recent increases in luminosity, the rate capabilities are starting to become an issue.

The Belle chambers are very similar to what is anticipated for the Braidwood veto detectors. Like BaBar, they run the chambers in streamer mode to keep the external electronics simple. This brings a higher dark current ($\sim 500 Hz/m^2$), but still very manageable for them and for us. Note that their experiment is at sea level.

It is a little surprising that few experiments choose glass for the electrodes. (In addition to Belle, STAR and ALICE TOF have made this choice.) Both experiments that are similar to Braidwood (OPERA and ARGO-YBJ) chose to use bakelite for the electrodes, perhaps because of their ties to CERN. OPERA chose avalanche mode because of the very high multiplicity of the PeV cosmic rays they seek to identify. Since ARGO-YBP was initially run in streamer mode, their experience is closest to what can be expected for Braidwood. At an altitude of 4300m, they measure a singles (cosmic rate of 1275 Hz/m^2 [7]. OPERA measures a cosmic ray rate of 300 Hz/m^2 at 1km altitude. They note that the measured rate in Gran Sasso is about a factor of 10 smaller [8].

Efficency of a system depends on many factors- geometry, number of layers ganged together, and spacer size/location. The intrinsic efficiency seems to be $\geq$99%. We can thus project that a multilayer system for Braidwood will be able to get a system efficiency of better than 99%. This subject will be covered in detail in a later note.

We conclude that the low cost and high intrinsic efficiency of RPC's make them a serious design choice for the Braidwood veto detector. Recent experience shows that with careful design and construction, long system lifetimes are also possible.

[1] R. Santonico and R. Cardarelli, Nucl. Instr. Meth. A **187**, 377 (1981).

[2] C. Lu, talk at Snowmass, 2005, http//www-conf.slac.stanford.edu/snowmass05/proceedings/proc/papers/ALCPG1001.PDF

[3] G. Bruno, Eur. Phys. J. C**33**, s1032 (2004).

[4] SLAC Report SLAC-R-95-457, March 1995; F. Annuli, et al., NIM A**508**, 128 (2003); NIM

A**508**, 455 (2003).

[5] Nucl. Instr. Meth. A**479**, 117 (2002); J. G. Wang, NIM A**508**, 133 (2003); D. Marlow, K. Abe, private communication.

[6] J. Va'vra, ICFA Instrum. Bull. **24**, 1 (2002).

[7] C. Bacci, et al., Nucl. Instr. Meth. A**508**, 110 (2003); L. Saggese, T. DiGiacamo, M. Iacovacci, S. Mastroianni, Nucl. Instr. Meth. A**533**, 55 (2004).

[8] G. Barichello, et al., Nucl. Instr. Meth. A**533**, 42 (2004).