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Resistive Plate Chambers for hadron calorimetry: Tests with analog readout

Gary Drake, José Repond*, David Underwood, Lei Xia

Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439, USA

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Abstract

Resistive Plate Chambers (RPCs) are being developed for use in a hadron calorimeter with very fine segmentation of the readout. The design of the chambers and various tests with cosmic rays are described. This paper reports on the measurements with multi-bit (or analog) readout of either a single larger or multiple smaller readout pads.

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1. Introduction

Particle Flow Algorithms (PFAs) have been applied to existing detectors, such as ZEUS and CDF, to improve the energy resolution of hadronic jets. The algorithms attempt to measure all particles in a jet (originating from the interaction point) individually, using the detector component providing the best momentum/energy resolution. Charged particles are measured with the tracking system (except for high momenta, where the calorimeter provides a better measurement), photons are measured with the electromagnetic calorimeter (ECAL), and neutral hadrons, i.e. neutrons and K^0_L's, are measured with both the ECAL and the hadronic calorimeter (HCAL). The energy of a jet is reconstructed by adding up the energy of the individual particles identified as belonging to the jet. Additional details on PFAs can be found in Ref. [1].

The application of PFAs at HERA and the Tevatron is limited by the relatively coarse segmentation of the existing detectors. By contrast, detectors for the International Linear Collider (ILC) are being designed [2] explicitly with adequate segmentation to optimize the performance of PFAs. In particular, this optimization imposes the following constraints on the design of the HCAL:

- To effectively identify energy deposits in the calorimeter belonging to charged or neutral particles, the readout needs to be very finely segmented, of the order of $1\times 1\,\mathrm{cm}^2$ laterally and layer-by-layer longitudinally, thus eliminating the traditional "calorimeter towers" of past calorimeters.
- The high segmentation of the readout leads to a large number of channels, of the order of 50×10^6 for the HCAL alone. In order to reduce the complexity and cost of the readout system, the front-end system needs to be located on the detector and be highly multiplexing.
- The favored design for the ILC detectors features a large magnetic field, of the order of 3–5 T, with its direction parallel to the beam axis. The magnetic field is to be provided by a superconducting coil with a considerable thickness, corresponding to one to two nuclear interaction lengths λ_I. To preserve the single particle resolution of the calorimeter, both the ECAL and the HCAL need therefore to be located inside the solenoid. As a consequence, only technologies which operate in high magnetic fields can be utilized.

*Corresponding author.
E-mail address: repond@hep.anl.gov (J. Repond).

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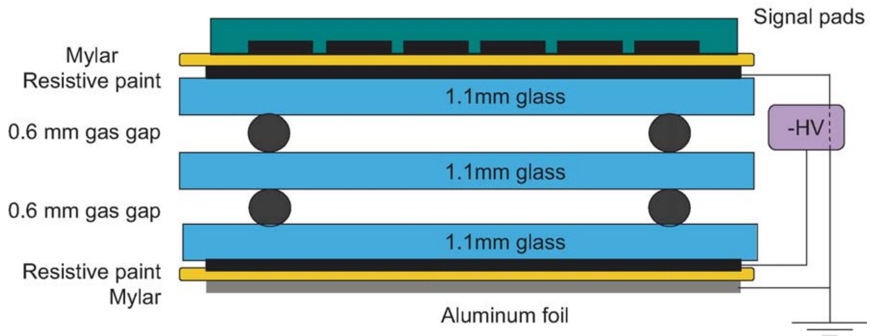

Fig. 1. Schematic of the three-glass chambers. Not to scale.

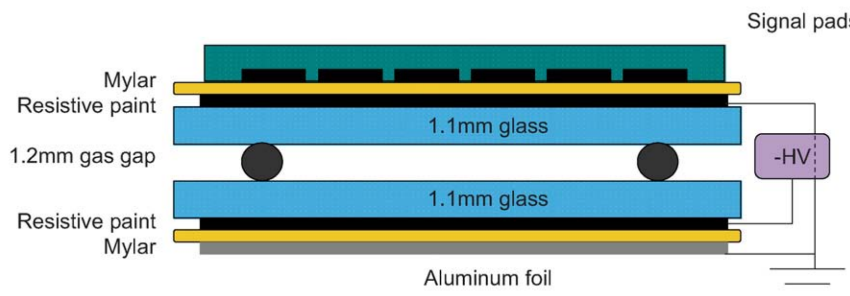

Fig. 2. Schematic of the two-glass chambers. Not to scale.

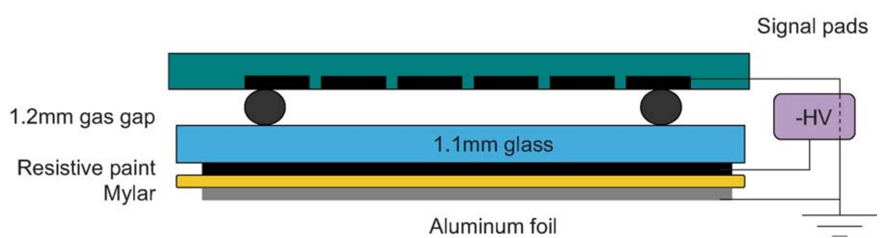

Fig. 3. Schematic of the one-glass chambers. Not to scale.

- To minimize the radius (and the cost) of the coil, the active medium needs to be as thin as possible, of the order of 10 mm or less per layer.
- Given the difficulty to access, the calorimeter in a colliding beam experiment, the active element and its electronic readout system need to perform reliably over the lifetime of the experiment, i.e. 10–20 years.
- To equip the entire active area of the HCAL, estimated at approximately 5000 m^2, a cost-effective medium needs to be developed.

A hadron calorimeter with very fine segmentation of the readout provides additional advantages, beyond the benefits from the application of PFAs to the measurement of jet energies. The fact that this type of calorimeter has no "towers" simplifies certain aspects of the calibration procedure and reduces the effects from possible non-uniformities of the response over different regions of the calorimeter. In general, a finely segmented calorimeter renders the use of pre-shower detectors, shower maximum detectors and possibly muon systems redundant.

This paper reports on the development of Resistive Plate Chambers (RPCs) as active medium of a finely segmented HCAL. Other groups have previously investigated RPCs as candidates for the active element in such calorimeters [3,4]. This paper complements their studies with detailed measurements of the charges as measured in an array of small readout pads.

2. RPCs

RPCs are simple in design, robust, quiet, well understood, reliable and cheap to build [5]. The readout can be segmented to match the need of a variety of applications,