DESIGN AND CONSTRUCTION OF A CATHODE READOUT PROPORTIONAL CHAMBER FOR THE HPC CALORIMETER

D. Bollini, F.R. Cavallo, A. Cavana, P. Giusti, G. Laurenti,
G. Molinari, F.-L. Navarria and R. Pilastrini

Dipartimento di Fisica dell'Università, I-40126 Bologna
Istituto Nazionale di Fisica Nucleare, Sezione di Bologna

ABSTRACT

A cathode readout MWPC for the High-density Projection Chamber of the Delphi experiment at LEP has been built and tested. In order to decouple both electrically and mechanically the drift volume of the HPC from the readout region, the segmented cathodes are made of brass U profiles, with a 100 micron diameter wire wound around the profile with a 2 mm pitch.

1. Introduction

The use of drift collecting calorimeters or High-density Projection Chambers (HPC) for the detection of electromagnetic and hadronic particles has become popular in the past few years owing to the 3-dimensional information and to the superb granularity which can in principle be reached even with a limited amount of electronic channels [1,2]. Adequate usage of the detailed

information on the e.m. shower development should lead to good tracking capability, optimum multishower separation, as well to an improvement in energy resolution compared to other types of gas sampling calorimeters. An additional feature of the drift collecting calorimeter is the ability to work in a uniform magnetic field, with the electric drift field parallel to the magnetic field, without loss in energy resolution or possibly with a substantial improvement compared to the absence of magnetic field [3]. After several years of successful testing of small scale prototypes [3,4], some large detectors based on this technique are at present being commissioned [5] or have started large scale production [6].

A non-negligible role in the construction and performance of a drift collecting calorimeter is played by the chamber used to read out the charge deposited by the showering process and drifted along the gas. Here we would like to discuss the design criteria, the construction and the test of a prototype of such a chamber which is coupled to a module of the HPC barrel electromagnetic calorimeter being constructed for the Delphi experiment at LEP [5].

2. Design and construction of the pad chamber

The principle of the HPC is shown in Fig. 1 [7]: the electric drift field is provided via lead wires, which are used as well as passive converter, glued onto a thin vetronite substrate and bent to an accordion-like shape, leaving gaps of 8 mm width, where the electrons are allowed to drift over distances of the order of one meter. Since the device is intrinsically slow, it is foreseen to insert near shower maximum a special gap, comprising either proportional tubes or scintillators and fibers, for first level triggering [5].

The design criteria of the readout chamber to be used with the HPC are as follows:

1) the readout should be subdivided into pads which define the granularity of the calorimeter into two dimensions (i.e. longitudinally and one transverse dimension, the other being measured by the drift time);

2) the chamber must be opened on one side to permit the collection of the drifted charge;

3) the chamber field should be decoupled from the drift field, hence the need for a (transparent) grid, which also serves to collect 1/4 of the charge in the open side;

4) the chamber should be as thin as possible to minimize dead spaces;

5) in particular at LEP, where access for repairs is probably difficult, and in any case time consuming, the construction of the chamber should be such that it is able to operate even with one or few broken sense wires, hence each readout channel facing a drift channel should be mechanically and electrically independent and the grid should prevent a broken wire from entering the drift volume;

6) finally a surface of about 0.3 m^2 should be covered by about 100 pads, in order to match an angular resolution of one degree in azimuth with a reasonable longitudinal sampling of the showering processes.

At the prototype level, we have satisfied the conditions 1)2)3) and 5) whilst conditions 4) and 6) will be optimized only in the final production stage. In fact, we have left some flexibility in the pad sizes and grouping, to be able to test various geometries, both by measuring electron and pion beams of different energies and by comparing with detailed Monte Carlo simulations.

For the milestone prototype (made with 1.7 mm thick Pb wires, having a trapezoidal cross-section of the module and totalling 66 cm drift length) we adopted the following solution: the pad elements are cut out of a commercial brass U profile (actually

of the type used to house thick window glasses) and the grids consist of 100 micron diameter Cu-constantan wire wound around the pads with 2 mm pitch. The geometry of the pad elements is shown in Fig. 2a and their layout in the chamber is shown in Fig. 3. The sense wires run in the centre of the pad elements resulting in a series of parallel segmented proportional tubes. The distance between each line of pads is 1.5 mm and the distance between two consecutive pads along the sense wire is 1 mm.

The length of each pad element varies between 17 and 45 mm. A 1.5 mm diameter brass pin is inserted under pressure at 12 mm from one end of the pads to provide the positioning on a vetronite back plate and the extraction of the signal. The method used for building the pads is visible in Fig. 2b: the Cu-constantan wire is wound around the U-profile on a winding machine, starting and ending at 0.5 mm distance from its edges, microsoldered at the two ends and then epoxied along the external sides in order to hold the wire in place with the right pitch [8]. In this way, given the distance between consecutive pads, the overall pitch of the grid is 2 mm. Several pad elements were scanned with a scanning electron microscope to check for possible cracks in the wire due to the bendings close to 90 degrees. An example is shown in Fig. 2c: no crack or sign of deformation was visible in the tested sample.

The geometry of the readout chamber is shown in Fig. 3. The sensitive area of the chamber is 0.27 m^2 , the dimensions of the sensitive trapeze being $0.5 \times (520 + 637) \times 467 \text{ mm}^2$, with the inclined sides making an angle of 7.5 degrees. The sense wires, not indicated on the figure, are made of gold-plated W wire 20 micron thick, stretched and soldered onto two 4 mm wide printed board strips running along the sides of the trapeze [Fig. 4]. For readout purposes the sense wires are ganged into four groups, to be used for a second level trigger of the detector. A photograph of the chamber is shown in Fig. 4.

Several pad elements have been hard wired together to form 198 pads in total covering the whole chamber surface. The final pad geometry is shown in Fig. 3: notice that the grouping is not regular in such a way as to have more flexibility at the prototype level.

Each pad group is connected via a short wire to a large printed board of the same size as the chamber, which provides the housing of the preamplifiers and of the low voltage busses, as sketched in Fig. 1. The printed board is then fixed onto the vetronite back plate holding the pads.

The electronics consists of the hybrid preamplifiers developed at CERN for the HPC [1,3] on both anodes and cathodes. For the tests of the chamber alone, which have been performed with radioactive sources and with cosmic rays, the anode is inverted, amplified times 18 db using a standard NIM amplifier and then goes to a discriminator in order to provide the gate for the ADC which measures the cathode pulse. The cathode pulse is either fed to the ADC or discriminated via a standard NIM module and sent to a scaler.

In order to have a uniform gas flow along the whole chamber and inside the HPC itself, the gas distribution is made out of several (four) brass U pipes which fan the gas into the chamber volume via 5mm diameter holes drilled into the vetronite back plate in correspondence of the 1 mm gaps between consecutive pad elements. The gas return is realized through the drift channels of the HPC. The gas used is Ar-CO₂ (80-20) at atmospheric pressure. For the tests the open part of the chamber is sealed simply by a 100 micron thick mylar foil to ensure gas tightness and transparency to low energy radiation. To be able to use for calibration a gamma emitter (Fe55) an additional grid made of wiremesh is glued onto the mylar foil and can be powered to a few hundred Volts providing a positive clearing field for the gammas converting in the mylar or in the gas before the chamber volume.

3. Study of the pad uniformity

The measurements of the width of samples of the U profile show differences up to 2/10 mm (from 7.85 to 8.05 mm) between different batches and up to 1/10 mm between the top and the bottom of the profile. The profiles used to build the chamber are selected to be within a factor of two better tolerance, which implies an expected non-uniformity of $\pm 5\%$.

The prototype readout chamber was measured in several positions with a collimated Fe55 source. High voltage plateaus were recorded corresponding to different pad sizes and in particular to the cases where the mechanical differences between different pad elements had been found to be bigger (for the pad numbering see Fig. 3). Plateaus taken on different days were slightly normalized in the counting rates (normalization factors range between 0.9 and 1.1) and show consistency. The results are shown in Fig. 5 for five different pad groups: the onset of the plateau is constant within 10 V, consistent with the readout of the HV power supply (± 5 V); the plateau is ~ 200 V wide and the only characteristic which varies somewhat between the different pads is the slope of the rise after the plateau.

Since the prototype chamber had to be used immediately coupled with the HPC milestone module, a small chamber with 20 pads has been built to test in detail whether the pads cut out of the commercial U profile after the rough inspection have the required accuracy leading to an uniform charge collection along the chamber itself.

The small test chamber is shown in Fig. 6. It consists of 20 pads each 41 mm long aligned in four parallel rows at a distance of 1 mm longitudinally, the distance between the rows being 1.5 mm, as in the final chamber. The sense wires are made of gold plated W wire 20 micron thick, stretched between precisely positioned pins

inserted in a 1 cm**3 vetronite block closing each row at both ends. All the sense wires are electrically connected together. The decoupling grid is made of 100 micron diameter thick silver plated Cu-Be wire stretched on a thin vetronite frame with a 2 mm pitch. The grid is electrically connected to the pads. The rows of pads are aligned and spaced by glueing the pads on 1.5 mm thick brass strips and eventually all the 20 pads are electrically connected yielding a surface of 93 cm**2, which corresponds to about 1/30 of the total surface of the HPC readout chamber. Since we plan to have finally about 100 electronics channels per chamber, the surface chosen should be large enough to represent the worst case even if a non-uniform pad grouping is adopted.

The small test chamber was scanned with the collimated Fe55 source and the pulse height corresponding to the 6 keV gamma line after the preamplifier was recorded. The collimation should ensure a beam spot of about 1 mm width. A surface scan of the chamber at 1580 V is presented in Fig. 7. The measurements along the sense wires show a flat response constant to $\pm 5\%$ up to ~ 5 mm from the wire ends, no systematic difference is observed when looking at the four different sense wires and there is no evidence of large non-uniformities. The edge effects, i.e. a substantial decrease of the pulse height, start at about 5 mm from the chamber ends. Several ways of reducing the dead region have been tried, following the idea of guard strips developed for other chamber geometries [9]. In our case we have tried various metal rings made of thin wires bent with a diameter of about 5 mm centered around the sense wires and glued onto the vetronite blocks with different glues: in all cases the addition of the guard rings resulted in an improvement of the efficiency near the ends of the chamber. A typical measurement is shown in Fig. 8 : the counting rate with a Cs137 beta source was recorded as a function of the distance from the chamber end for different voltages applied to the guard rings. The smearing introduced by the Cs137 source is such that this figure is not directly comparable to Fig. 7, but the relative effect is nevertheless clearly visible. The conclusion is that the

introduction of guard rings at a voltage of $\sim$ -200 V should decrease somewhat the edge effects to about 2 mm, in rough agreement with the results of Ref [9]. On the other hand it is not clear how the rings which are the natural choice given the geometry of the pads could be easily implemented in the large chamber.

4. Conclusions

We have built a MWPC comprising separate segmented proportional tubes with a transparent side to allow the readout of drifted in charge. Each tube is mechanically independent and can easily be made electrically independent, in such a way that one or few broken sense wires should not prevent the operation of the rest of the chamber. A commercial brass U shaped profile wound with Cu-constantan wire was found adequate to provide the cathode pads. The chamber shows good uniformity over the full surface and high efficiency up to a few millimeters from the end of the sense wires. the chamber has been operated successfully in conjunction with a full scale prototype of the HPC in hadron and electron beams [10].

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Figure captions

- Fig. 1 a) Artist's view of the HPC, showing the lead wire ribbon converter used to produce a uniform drift field and bent to fill a trapezoidal volume.
b) Side view of the readout chamber facing the drift volume of the HPC.
- Fig. 2 a) Geometry of the pads. Dimensions are in mm. The length of the pad elements is variable, between 17 and 45mm.
b) Photograph of two pads showing the wound grid microsoldered at the extremities and after the bonding with epoxy resin.
c) Scanning electron microscope photograph of the bent grid wire (x100).
- Fig. 3 Pad geometry of the readout chamber (right) and grouping of the pads into readout channels (left). The part of the chamber not equipped with pads corresponds to the region, near shower maximum, where the HPC is equipped with a fast device for first level triggering [5].
- Fig. 4 Photograph of the readout chamber.
- Fig. 5 High voltage plateaus measured with a Fe55 source in different regions of the readout chamber. For the pad group numbering see Fig. 3.
- Fig. 6 Top and side views of the small test chamber.
- Fig. 7 Uniformity of the small test chamber scanning along the different rows with a Fe55 source.
- Fig. 8 Counting rate with a Cs137 beta source as a function of

the distance from the chamber end. All the counting rates are normalized at the point at 50 mm from the edge.

Fig. 1

Fig. 2

Fig. 3

Fig. 5

Fig. 6

Fig. 7

Fig. 8