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ADVANCED FIELD SHAPING DRIFT CHAMBERS FOR SSC MUON TRACKING

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ADVANCED FIELD SHAPING DRIFT CHAMBERS FOR SSC MUON TRACKING

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Abstract

New construction methods are described which can be used to form high-precision drift chambers that are light and strong and have a linear voltage-to-distance relationship over large portions each of the drift cells. Use of resistive sheet film plastics is discussed. Examples are given with respect to a recent version of this sort of detector built for internal forward tracking the AMY experiment at TRISTAN.

Introduction

Muon tracking chambers for detectors at the SSC will have to meet some very stringent requirements for accuracy of alignment, physical size, and intrinsic resolution in order to provide useful input to triggering as well as offline data analysis. In addition they ought to be fairly robust, both in terms of relative immunity from rate-dependent effects and also physical rigidity and strength, and ought to be able to withstand broken wires and similar localized problems without greatly affecting the data-taking abilities of the entire detector subsystem.

These problems are not new, but take on added significance when compounded with the difficulties involved with handling chambers of the size typically needed for a large SSC detector. Spans of several meters in width and up to tens of meters in length are often discussed and have been seriously proposed. In order to meet these challenges it's desirable to have chambers that are light, strong, and rigid and that are constructed in a simple fashion which incorporates an appropriate method of electric field shaping directly into the mechanical design of the device.

We propose an option based on mechanical components that are stress-skin panels formed from a light core with a cladding of resistive or conductively-printed or etched metal-coated sheet plastic, then made into box girder layers by the addition of light side walls to give sets of closed vector- or single-wire drift cells. These can be made with recently available resistive sheet plastics to allow a construction that is light, strong, and economical to assemble.

An example based on AMY Forward Tracking

The AMY Forward Tracking Chambers[1] that were recently built by our group[2] for use at the e^+e^- collider TRISTAN were developed to meet a similar need. These chambers, which consist of approximately 2000 drift cells housed within the magnetic field of the detector, needed to be self-supporting with a minimum amount of material within the interior active volume of the detector and without much space devoted either to dead regions in the form of a support structure; hence they had to be essentially self-supporting, light, and strong. They were built to provide tracking in the endcap regions, approximately the 14° to 35° angular range with respect to the beam line.

Figure 1 shows the mechanical details of a 3-layer subset of the multi-layered construction for the Forward Tracking Chambers (FTCs) at AMY. They were formed from thin (80 μm) sheets of high resistance (10^{14} Ω per square) resistive-Kapton[3,4] plastic, preprinted with parallel lines of conductive epoxy paint, which were then laminated to 2 mm thick panels of nonconductive polymethacrylimide[5] foam.

The conductive traces, which were 2 mm in width, were printed at 1.5 cm intervals directly onto the high resistance Kapton. These corresponded to the centers and the sides of the 3 cm wide cells. Low-resistance side walls, made of a

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high conductivity (200 Ω per square) resistive Kapton laminated to 1 mm thick Rohacell foam, were used to complete the sides of each cell. The conductive traces in contact with the cell walls were placed at negative high voltage, and the center strips were placed at ground potential.

In this design, the high-resistance Kapton acted as a continuous, electrically noise-free sheet resistor between adjacent conductive traces to form a uniform potential gradient from the sides to the centers of the cells. Distortion of the equipotentials within the cell by the sense wires, which were placed at positive high voltage, was minimal, as shown in Figure 2. These cells consequently exhibited a uniform electric field throughout most of their width, which should lead in turn to an extremely linear time-to-distance relationship. Drift paths are shown for an example track in Figure 3. We built several prototypes using other methods of construction, including the multiple parallel strip method which involves the use of an external resistor chain. The resistive kapton method appears to be superior in terms of construction time and effort, as well as overall complexity (since it gets rid of the external voltage divider and field shaping traces or feed throughs), at roughly comparable cost.

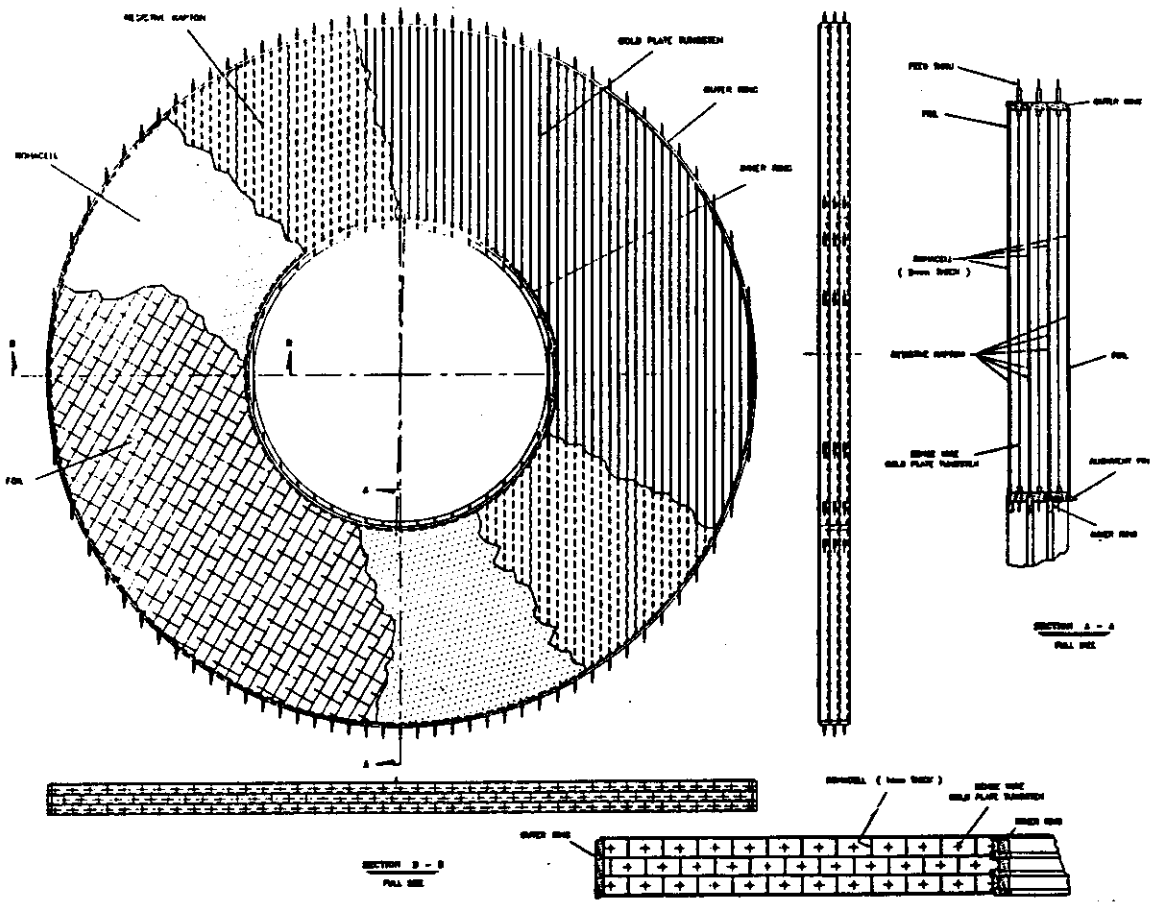

FIG. 1. Physical construction details for the AMY forward tracking chambers. The figure shows 3 of the 15 layers per endcap installed for the initial version of this detector.

Application to SSC Muon Tracking

The main features of the above design were its light weight, achieved by the use of polymethacrylimide foam and resistive sheet plastic, simplicity of field shaping, which allowed the use of comparatively large cells, and self-supporting semi-rigid construction. It is attractive to see whether with modest alterations in design these methods also could apply to the design of large-scale chambers for the SSC.

First, the resistive plastic would have to be chosen to allow for fast dissipation of excess accumulated charge from within the chamber at high rates. This would imply a larger conductivity (lower surface resistivity) than the 10^{14} Ω/square used in the top and bottom surfaces in the AMY chambers. As the conductivity is raised, the amount of power dissipated within the gas and carried away by the internal support structure will have to go up as well, leading to a situation in which a tradeoff exists between heat transfer and the intrinsic antistatic nature of the resistive plastic. The expression which gives this power dissipation is $P = 4V_F^2 N_{\rm cells} l/(w\sigma)$ where l and w are the length and width of each cell, V_F is the field shaping difference in potential between the central and side conductive stripes, σ is the surface resistivity in terms of ohms per square, and the factor of 4 derives from the fact that there are four such long strip resistors per cell. In the case of AMY this gives approximately

$$P = \frac{4\ (2\times 10^3\ \mathrm{V})^2\ (2\times 10^3)\ (50\ \mathrm{cm})}{1.5\ \mathrm{cm}\ \sigma} = \frac{10^{12}}{\sigma}\ \mathrm{W}$$

or about 10 milliwatts for $\sigma = 10^{14}\Omega$/square. This is acceptable in the AMY case at low rates since the conductive central traces and low-resistance side walls should provide ion clearing sufficient to the task in the e^+e^- environment. It is substantially beyond the 10^5 to 10^6 Ω/square values usually needed to provide antistatic surfaces, however, and the above equation shows the difficulty of reaching such low values in any chamber with long thin cells. With hexcell panels of intrinsically higher heat conductivity than the extremely insulative foam used in AMY, it may be possible to allow up to several tens or even hundreds of watts to be dissipated within the entire support structure of a layer of cells, and surface resistivities approaching 10^8 Ω/square could be reached. The performance of such chambers in terms of ion clearing with respect to rate dependence will have to be checked by explicit tests.

Second, the mechanical properties of the support substrate and of the sidewalls will have to be improved to achieve such large spans. Possibilities include hexcell, graphite-reinforced composites, and extruded thin I-beams for the side walls. The solution could be a cross between the resistive plastic techniques used in the AMY chambers and those from several earlier I-beam-type chambers, such as those used by CDF and several other experiments. The results would have the advantages of being relatively strong and light compared to extrusions, and more alignable and rigid than all-wire field shaping chambers, which would require massive end plates to achieve similar accuracy in placement.

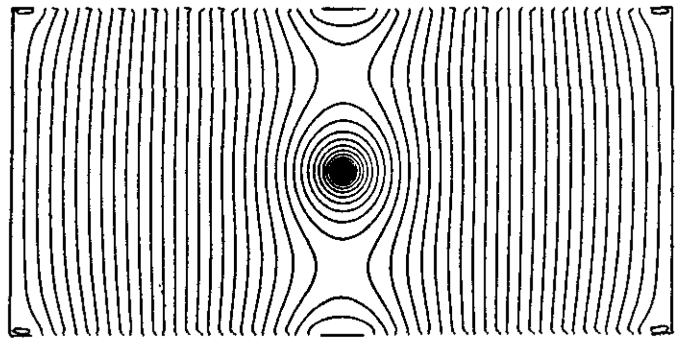

FIG. 2. Equipotentials for the example of the AMY drift cells described in the text.

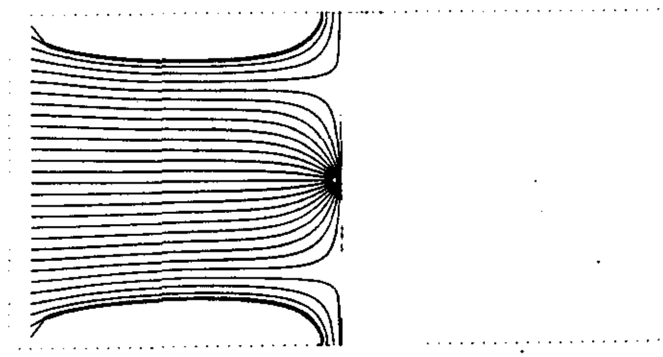

FIG. 3. Electron drift paths for the graded potential drift chamber cell shown in the previous figure.

References

1. A. Sill, Proceedings of the Meeting of the Division of Particles and Fields of the American Physical Society, Rice University, Houston, TX, Jan. 5-9, 1990.
2. The group involved physicists from Rochester, Louisiana State University, and KEK.
3. XC series resistive Kapton™ polyimide film, DuPont Corporation, Wilmington DE 19880.
4. The desired value of resistivity in the AMY case had been two orders of magnitude lower, but DuPont was only able to supply this material within the time (and budget) limitations of the project.
5. Rohacell™ polyimide/acrylic alloy foam, Röhm GmbH Chemische Fabrik, Darmstadt, W. Germany

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