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# JRA2 Milestone
# Field Cage Available

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**Abstract**

A Large Prototype (LP) of a Time Projection Chamber (TPC) has been constructed by the LCTPC (Linear Collider TPC) collaboration [1] . It has a diameter of about 750 mm and a length of about 600 mm, which allows to measure tracks with up to 125 space points with pad readout . The LP has started to become operable in the $4^{th}$ quarter of 2008 and will be tested under $e^-$ irradiation in a DESY II testbeam area [2], immersed in a magnetic field of about 1 T. The field cage (FC) of the TPC [3] as well as the test beam facility including a superconducting magnet [4, 5] are provided as EUDET projects.
The field cage as part of the JRA2 efforts was produced in the first half of 2008 and became available in August 2008.

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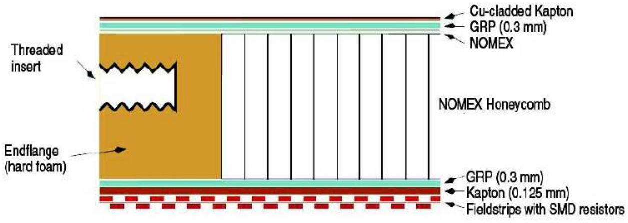


Figure 1: Sandwiched structure for the field cage.

# 1 Introduction

Part of the LP is a field cage (FC), which is made out of composite materials. The materials were chosen such that they guarantee a maximum of stability, though providing a minimum of material for the traversing particles. The homogeneous electrical drift for the electron and ion clouds in the TPC volume will be provided through a series of field strips, which had to be arranged such that the relative distortions of the field are below $10^{-4}$ within the drift volume. This can be achieved with mirror strips that lie on an intermediate potential.

# 2 The Field Cage

## 2.1 Structure of the Field Cage

The FC depicts a large and low mass device, which provides a highly homogeneous electric field throughout its volume. The FC has an inner diameter of 720 mm and a length of 610 mm. This gives a usable detection volume for the TPC of about 0.25 $m^3$. The wall consists of several layers of different materials (Fig. 1) in order to provide the homogeneous electric field, the electrical and gaseous isolation to the outer environment, the stiffness of the wall, as well as the shielding against induced electrical signals. The layer structure starts from the inside with the field strip foil. A series of parallel Cu strips, 35 $\mu$m thick, are arranged on a 50 $\mu$m thick Kapton foil such, that the homogeneity of the electrical field along the axis of the TPC is a maximum. The strips have a width of 2.3 mm and the distance between the strips is 0.5 mm (Fig. 3). A second layer of strips was shown to become necessary in order to compensate for field distortion effects close to the wall. This additional layer is placed at the other side of the Kapton foil and the strips are displaced by half the pitch. They are included in the same resistor chain, being on an intermediate potential. The complete foil has a length of 600 mm, along the axis of the TPC, and a width, which corresponds to the circumference of the TPC. The width comes out to be about 2.3 m. The next layer is an isolation layer, made out of 125 $\mu$m thick Kapton. This layer is followed by a glass-fiber reinforced plastic layer (GRP) with a thickness of 300 $\mu$m. The GRP layer is glued to a 22 $\mu$m thick Nomex layer. This layer has a honeycomb-like (HC) structure, which provides both, the needed stiffness, but with a minimum of material. Due to the honeycomb-like

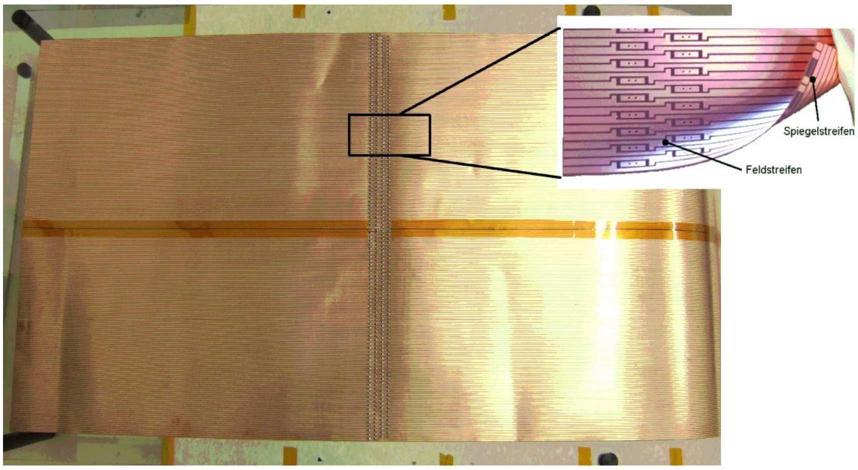


Figure 2: Field strip foil with a zoomed section of the vias.

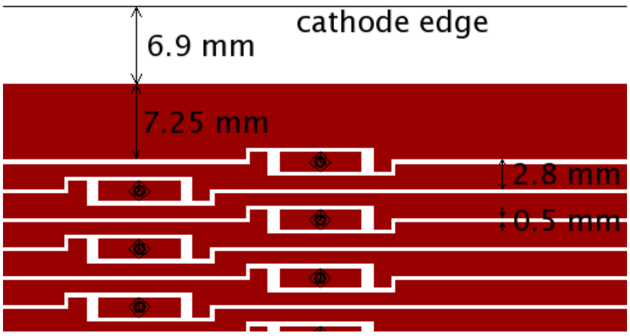


Figure 3: Dimensions of the field strip foil.

structure this layer is virtually empty. The layer is then followed by another layer of 300 $\mu$m thick GRP. Eventually, the wall is terminated with a 35 $\mu$m thick Cu layer for shielding purposes and a 75 $\mu$m thick Kapton layer for isolation. The wall structure constitutes a radiation length of about 1.3 % of $X_0$ (Fig. 4). Sample pieces of the wall structure have been tested according to high-voltage stability and mechanical stability and this confirmed the performed calculations (Fig. 5). Additional tests have been performed in order to guarantee the compatibility with the end plates, in particular the stability of the inserts for the threads and gas tightness. The resistors for the field strip resistor chain have been investigated with respect to their reliability and were included in a calculation concerning the possible inhomogeneity of the electric field. In addition, possible inaccuracies in the production of the FC-wall and thus a further inhomogeneity in the electric field was investigated. All tests have shown that these distortions are

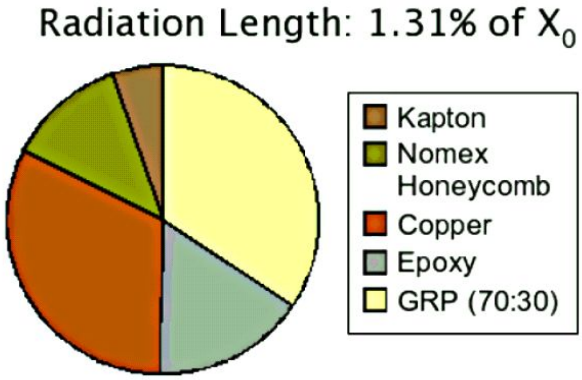


Figure 4: Contribution of the various wall materials to the radiation length.

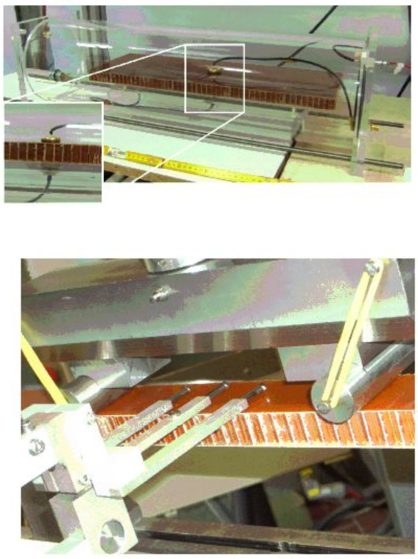

Figure 5: Setups for testing the material properties.

small and correctable.

## 2.2 The Production

The needed materials in order to construct the FC were purchased and tested at DESY. However, the first part in the construction chain of the wall structure, which is the field strip foil could not be delivered as expected due to production difficulties of the primordial manufacturer. The manufacturer had to be changed and consequently the foil delivery experienced a delay. After delivery of the foil the resistors were soldered

Figure 6: Mandrel as a profiling form for the field cage.

in two chains onto the foil, connecting the field strips through the vias to the mirror strips. In the meantime the production of the mandrel for profiling the FC wall had been finished (Fig. 6). It was made out aluminum and had a diameter within 500 $\mu$m according to the inner diameter of the filed cage. The mandrel had two slots in order to leave space for the field strip foil which had to be mounted with the two resistor chains towards the inside of the final field cage volume. The mandrel could be relaxed in diameter so that the drop off for the finalized FC does not experience any problem. The production of the FC started with stretching the field strip foil over the surface of the mandrel (Fig. 7). In the following the layers were successively glued on top of each other (Fig. 8) while before each layer was attached the possible air inclusion was minimized by a pressure treatment (Fig. 9).
The field cage was finished and became available in August 2008. After the production was finished an extensive measurement program was performed in order to verify the dimensional precision demanded by the collaboration.

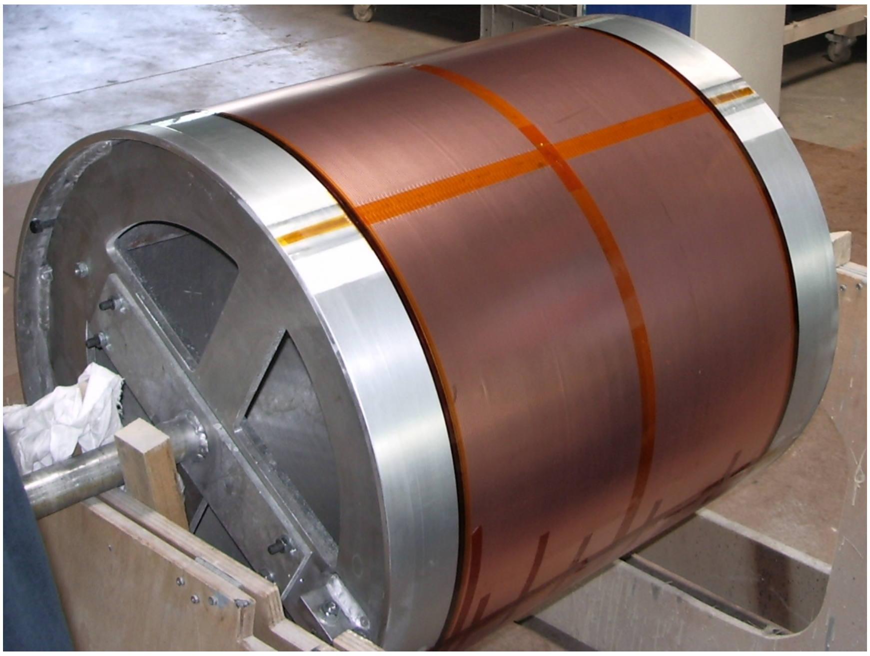

Figure 7: Stretching of the field strip foil onto the mandrel.

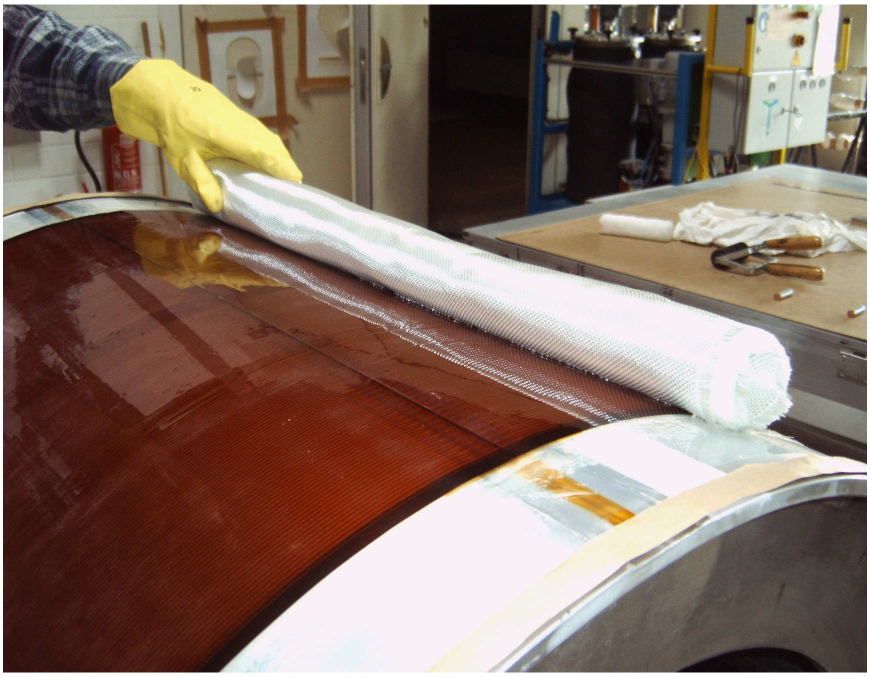

Figure 8: Application of GRP layers.

## 2.3 Process Inspection

In order to verify the dimensions to the required precision (Fig. 10) several measurements were performed. These measurements included the determination of the parallelism and

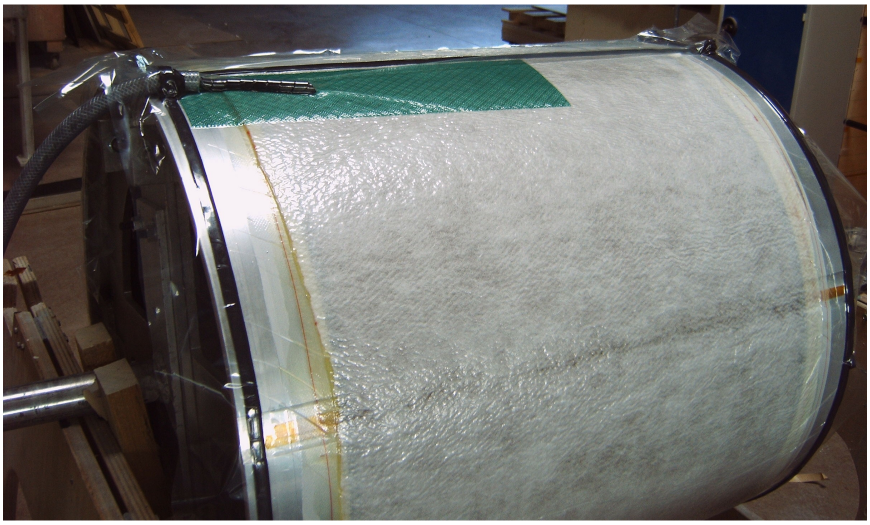

Figure 9: Vacuuming between the layers.

| Quantity | Required | Measured |
|---|---|---|
| Parallelism of Anode and Cathode Surface | $100\mu$m | $(81.1\pm0.11)\times 10^{-3}\mu$m |
| Distance of the end faces | $(610\pm1)$ mm | $(610.362\pm0.004)$ mm |
| Displacement of the central axis | $100\mu$m | $(540\pm 40)\mu$m |
| Roundness | $100\mu$m | $\sim100\mu$m |

Table 1: Required and measured precisions for the production criteria of the FC.

the distance of the end faces, the central axis, the homogeneity of the diameter, as well as the diameters among other things. The required and measured values for the various parameters are listed in Tab. 1. The manufactured dimensions complied with the desired precision except the alignment of the central axis. The central axis is not parallel with the normal axis with respect to the anode or cathode surface within $540\mu$m, which corresponds to a tilting angle of about 1 *mrad*. Consequently, the field strips will be tilted with respect to the anode or cathode surface. This in turn means that one has to distinguish two cases: either the field strips make up planes which are parallel to the anode or they make up planes that are normal to the central axis. The measurements have shown that the latter case is true. Unfortunately, this reduces the field quality by about a factor 10, i.e. the desired homogeneity $\Delta E/E$ of $\sim 10^{-4}$ will become $\sim 10^{-3}$.

# 3 Summary

The field cage for a large prototype has been manufactured and is now being used as the drift barrel for a TPC. This project as part of the EUDET efforts towards the research and development of a TPC for the use as a central tracker within an ILC detector has been successfully accomplished. This large prototype TPC has been already assembled and successfully operated with a Micromegas [6] readout, magnetic field,

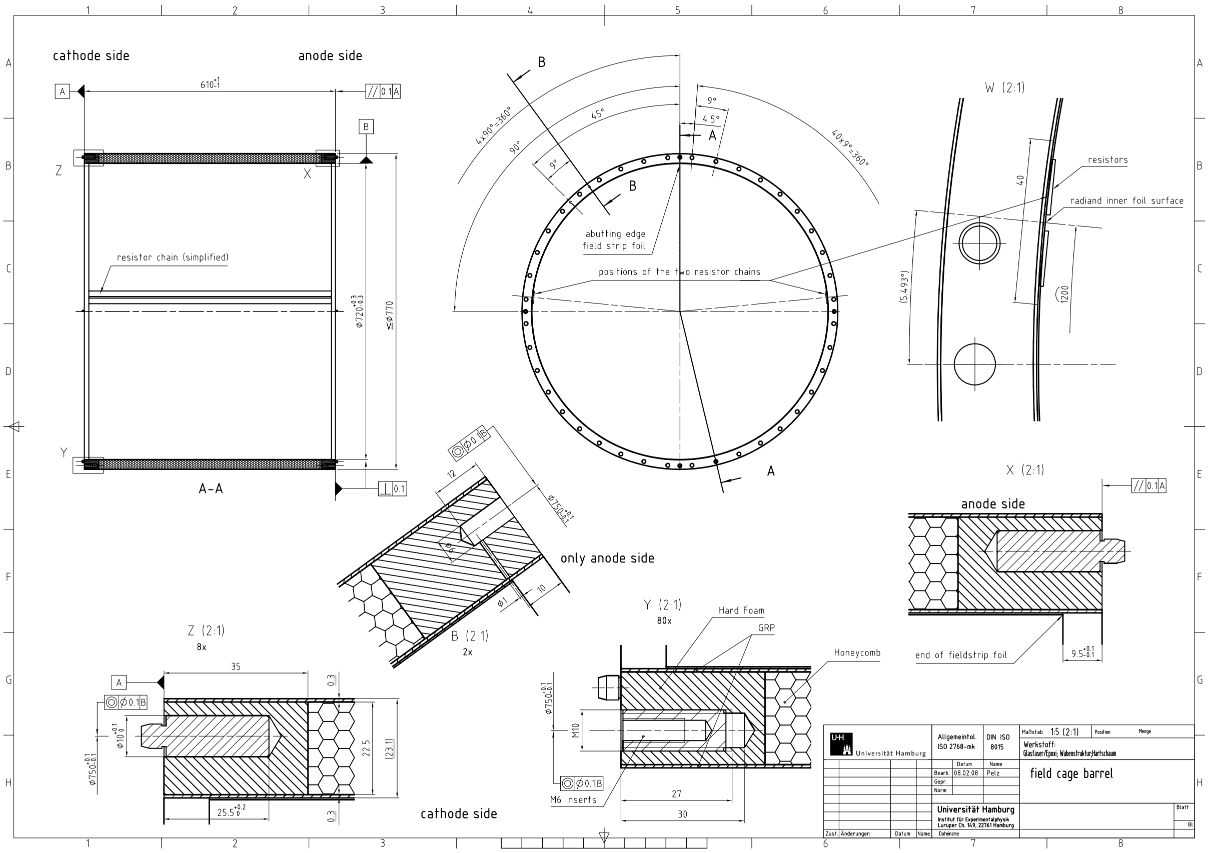

Figure 10: Technical drawing for the production of the FC.

and beam electrons from DESY. In the next future the field cage will be used to test further developments for different readout techniques [7, 8] and a large number of readout channels.

# Acknowledgment

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