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Outer Tracker

Beam tests of a full-scale prototype of the LHCb Outer Tracker straw tube modules

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Abstract

This note presents the results of beam tests of a full-scale prototype of the LHCb Outer Tracker straw tube modules performed at CERN in April 2001.

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1 Introduction

This note describes the beam tests of a full scale prototype of the LHCb Outer Tracker module performed at CERN in April 2001.

Our previous testbeam studies [1] revealed several problems in the performance of 2 m long straw modules, the most important among them being a too high cross talk level. Extensive laboratory studies of electrical properties of various types of straws were undertaken at the end of 2000 [2]. Good results were obtained using straw tubes with aluminum outer winding, which have good electrical contact to the ground plane along the full length of the chamber.

The new prototype was built at NIKHEF at the beginning of 2001 according to this new design scheme.

2 The prototype

The prototype is 3.2 m long and consists of two 1.6 m long half-modules. A common gas volume surrounding the half-modules is formed by two 10 mm thick NOMEX® panels. Each half-module consists of two staggered planes of 64 straw tubes each. The straw tubes are glued directly on the plate material using STYCAST® glue.

The half-modules are separated by a 2cm wide G10 printed circuit board with independent mounting pads for wires of both planes. The wire mounting pitch is 5.25mm. The straw tubes have an inner diameter of 5.0 mm and a wall thickness of 75 μm, consisting of a 40 μm inner winding of Kapton XC, a 25μm aluminum outer winding and a glue layer of 10 μm in between.

The inner conductive cladding of the plate material is a 25 μm aluminium foil which extends outside the gas volume to serve as a ground connection for the preamplifier boards. The electrical contact between the foil and the outer winding of the straw tubes is provided by silverMEK® conductive paint at intervals of 20 cm.

The 25 μm thick gold-plated tungsten-rhenium wires were stretched at a tension of 70 g. The wire locators of the twister type were installed at the centre of each tube. In addition, wire locators at both ends of the wires, near the central piece and at the readout ends, were installed in all the tubes of both planes of one of the two half-modules (planes 2 and 4 in Fig.1).

The leakage current of each wire was checked by applying a high voltage before the final assembly. The good gas tightness of the module was verified after the assembly.

The signals are read out by preamplifier boards based on ASDBLR chip [3]. These boards are placed at both ends of the module. The anode wire resistance (∼110 Ω/m) causes significant signal attenuation and smearing, which degrades the coordinate resolution. Moreover, during the LHCb operation maximum track density is expected near the beam pipe, i.e. in the regions furthest away from the preamplifiers. In order to optimize chamber performance in that region, it was decided to implement impedance matching only at the preamplifier side and leave the other end of the wires electrically open. In this configuration both the direct and the reflected components of a signal from the far end will arrive at the preamplifier almost simultaneously, doubling the amplitude and thus partly compensating for signal attenuation and making the module performance more uniform. For signals occuring closer to the preamplifier, the arrival time difference will not exceed 20 ns even for the longest straw tubes of the detector. The superposition will lead only to some elongation of the signal and not to double discriminator firing. For better impedance matching at the preamplifiers it was found necessary to install additional serial resistors of 150 Ω at the inputs of each readout channel.

Although this prototype differs from final modules in many details, in particular in the design of the readout endpieces and the central piece, it has the most important features of the final design, and its performance parameters are expected to be close to those of the final Outer Tracker modules.

3 The testbeam setup

As all the previous beam tests of Outer Tracker prototypes [1, 4], these tests were performed with 10 GeV/c pions at the T7 beam area of the PS accelerator at CERN. We used the same gas system, high voltage supplies

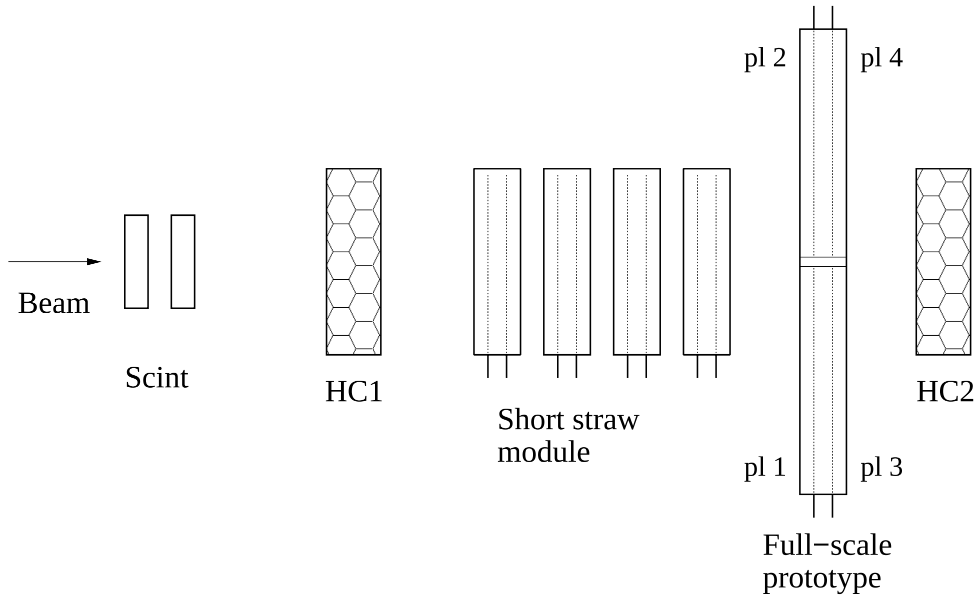

Figure 1: Testbeam layout, top view.

and data acquisition system as before. The problem of unrecoverable data losses in the TDCs reported in [1] was solved by a minor modification of the data acquisition system. The sketch of the testbeam layout is shown in Fig.1. The trigger signal for the data acquisition system was produced by the coincidence of signals from two scintillation counters. The long prototype was installed horizontally, with wire planes perpendicular to the beam. The numbering of its planes is shown in the figure. As our setup does not have an external high precision tracking device (e.g. silicon strip detector), a module of 4 short straw chambers was used for the track reconstruction, as described in [1]. The two honeycomb chambers HC1 and HC2, with vertical wires, were used for rough measurements (with precision of $sim1$ mm) of the horizontal coordinate of tracks.

At these beam tests we used the gas mixture $Ar(75)CF_4(15)CO_2(10)$, as in [1] it was found optimal for use in the Outer Tracker.

The analysis procedure and definition of measured quantities were the same as in [1]. The detailed description of the analysis procedure can be found in [4, 5]. During the tests the performance parameters of the long prototype were measured at 10 points along its length (5 points per half-module).

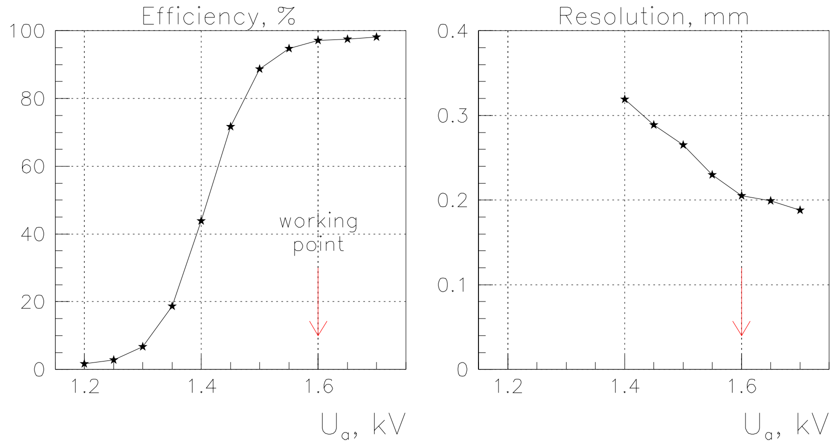

Figure 2: Efficiency and resolution of plane 2 of the prototype at 120 cm from the preamplifiers.

4 Results

The dependence of the efficiency and resolution on high voltage for plane 2 of the long prototype, at a distance of 120 cm from preamplifiers, is shown in Fig.2. The high voltage of 1600 V was chosen as a working point. At this voltage the chamber has 97% efficiency and $\sim 200\mu$m resolution. The short straw chambers at this voltage have a resolution of about 180μm.

The values of the performance parameters of all the four planes of the prototype as a function of the beam position are shown in Fig.3. The origin of the horizontal axis corresponds to the position of the central piece between the two half-modules. The chamber shows high efficiency (96...98%) and good coordinate resolution ($\sim 200\mu$m). The cross talk level was about 5%. The performance is very uniform over the whole module length and validates the decision to have no electrical termination of the wire ends at the split. The slight increase of efficiency and cross talk and slight improvement of resolution towards the centre of the module agree with the expectation that the signal amplitude from the far end of a wire is maximal.

Cross talk between the two layers of a half-module and between the half-modules was found to be negligible (<0.3%).

The precision of the wire positioning at the prototype was investigated using the method described in [1]. Fig.4 shows the magnitude of the wire

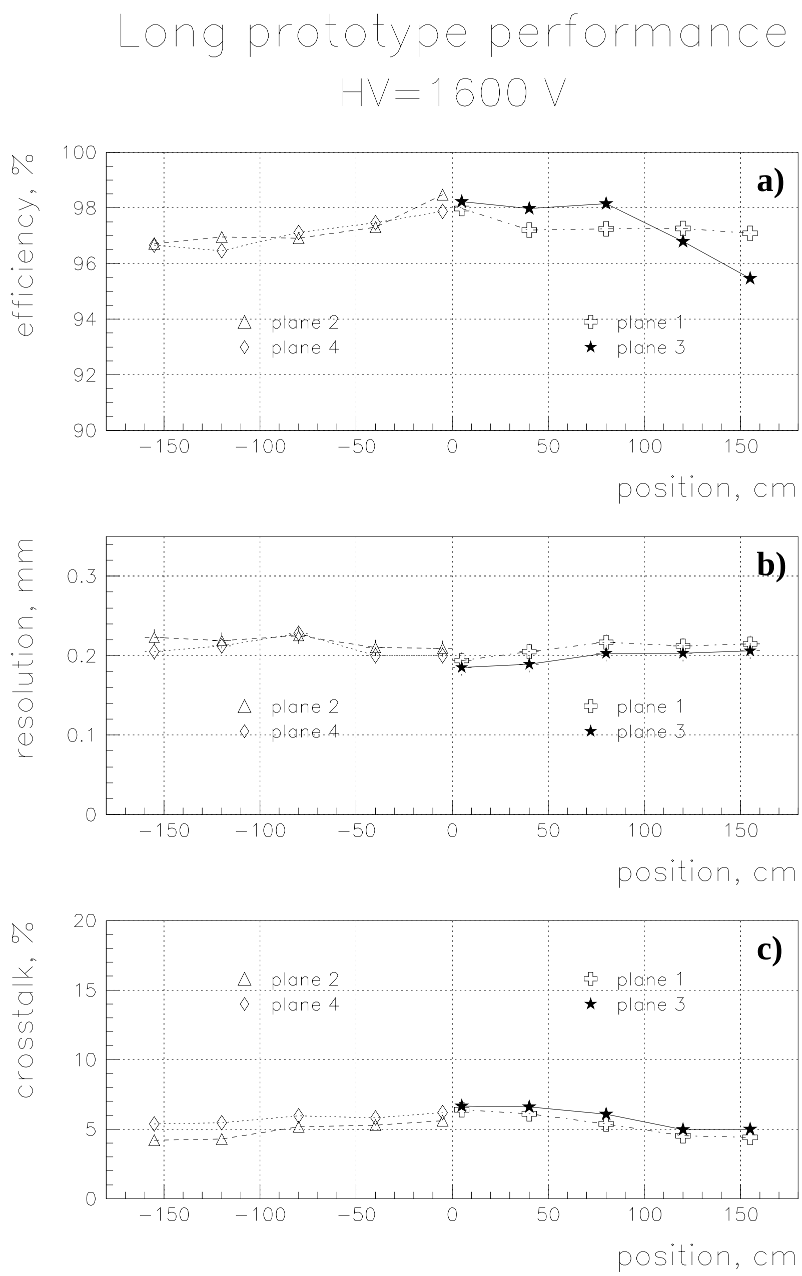

Figure 3: Efficiency (a), resolution (b) and cross talk level (c) of the prototype as a function of the beam position.

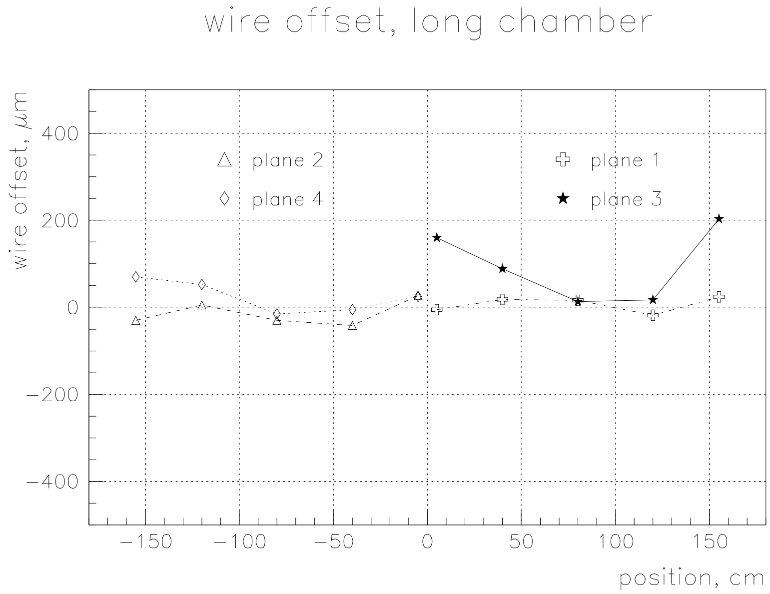

Figure 4: Wire offset with respect to straw centres as a function of position on the prototype.

offset with respect to the straw axis in the four planes of the prototype, averaged over several illuminated wires per plane, as a function of the position. The offset does not exceed 200 μm, which can be considered as satisfactory, given that the resolution of the chamber is also $\sim 200\mu$m. However in the planes 2 and 4 of the prototype, where each straw tube has two additional wire locators at the ends, the values of the offset are much better than this and do not exceed 70 μm. This can be an argument in favour of installing additional wire locators at the ends of the tubes in the mass production of the Outer Tracker modules.

The precision of the relative positioning of the wire planes was also investigated. Fig.5 shows the value of the shift between the two wire planes of each half-module (staggering) as a function of the position along the prototype. This value was defined as a difference between vertical coordinates of the first wires of downstream and upstream planes, obtained by the geometry calibration procedure for each point along the prototype. The nominal value of this shift is supposed to be one half of the wire pitch, i.e. 2.625 mm. The measured shift significantly differs from the nominal value. It

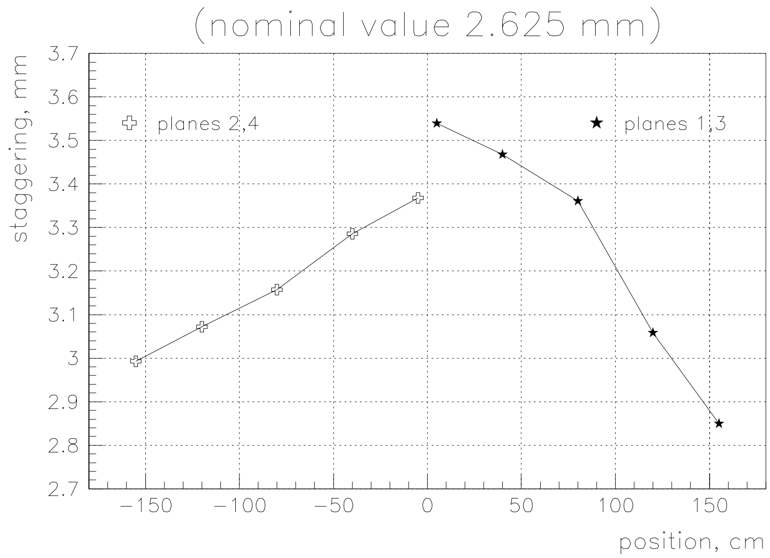

Figure 5: Transversal shift between downstream and upstream wire planes, as a function of position on the prototype.

also noticeably depends on the position along the prototype, which means that the wire planes of each half-module are not strictly parallel. Actually, no special procedure for the relative positioning of wire planes was used in the construction of this prototype, but one is being developed for the mass production of the Outer Tracker modules.

5 Conclusions

A full-scale prototype of the LHCb Outer Tracker straw tube modules was assembled at NIKHEF and tested in the beam of the PS accelerator at CERN. The tests showed good performance parameters of the prototype, which are uniform over its whole length: high efficiency (>96%), coordinate resolution of $\sim 200\mu$m and an acceptable cross talk level of $\sim 5\%$. It has a satisfactory precision of the wire centering in the tube; installing of two additional wire locators at the ends of tubes improves the precision of the centering to $\pm 70\mu$m. The planes of the prototype are not precisely positioned with respect to each other; a special procedure of relative positioning should be applied in the mass production of the Outer Tracker modules.

6 Acknowledgements

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