Developments for the outer tracking system of the LHCb experiment

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Developments of straw tube modules for the outer tracking system in the LHCb experiment are described.

1. The LHCb experiment

LHCb is a dedicated experiment to study CP-violation and other rare phenomena in B-meson decays. The detector is configured as a single forward arm spectrometer. It consists of the tracking system (vertex locator, inner and outer tracker), the particle identification system (RICH1 and RICH2), the electromagnetic and hadronic calorimeter, and the muon system. As shown in figure 1, the outer tracking system (OT) is made of 3 stations, with an overall size of 6 m $\times$ 5 m. Every station comprises four detecting planes (X/U/V/X) with a double layer of straw tube detectors.
The design value for the momentum resolution is 0,35% for 1 GeV tracks. In the hottest region an occupancy of about 7% is expected.

2. Straw tube modules

The OT is designed as a modular system. The modules have a size of 5m$\times$0,34m and house 256 straw tubes.

2.1. Straw tubes

The straw tubes are winded from two foils. The inner cathode foil is made of 40 μm carbon doped Kapton-XC. The outer foil is a laminate made of 25 μm Kapton-XC and 12.5 μm aluminium. The usage of the laminate guarantees gas tightness of the straws. The aluminium layer is mandatory for the signal transmission and to minimise crosstalk between adjacent straws.
The diameter of the straw tubes is 4.9 mm, the pitch is 5.25 mm. To limit the occupancy they are split midway along the wire. The counting gas is $Ar/CO_2/CF_4$ (75/10/15), the operating point is at a gas gain of 2×10^4.

2.2. Detector modules

Up to 256 straw tubes are mounted in module boxes made of sandwich panels with 120μm carbon-fibre skins and a 10 mm Rohacel core. Side walls are made of 400 μm carbon fibre. The panels and the side walls are covered by a laminated foil of 25 μm Kapton and 12,5 μm aluminium to guarantee gas-tightness of the box and to provide a closed Faraday cage.

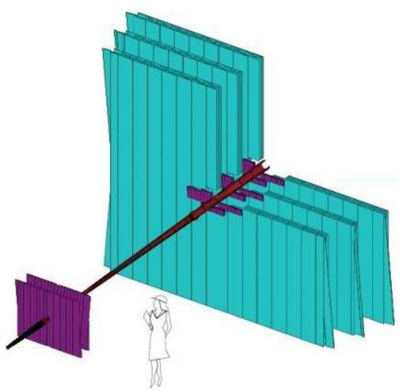

Figure 1. Schematic view of the tracking system at LHCb, divided in the inner and outer tracker. The dimension of the outer tracker stations are 6 m $\times$ 5 m.

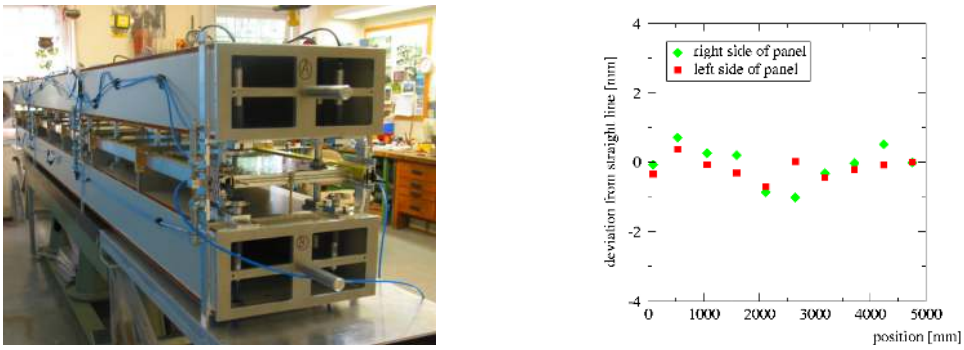

Figure 2. Glueing of a detector module box using the tool described in the text. The straightness of a 5 m long box built with that tool is shown. The rms of the deviation from a straight line is better than 400 μm.

3. Construction of detector modules

To achieve the anticipated detector performance, the straw tubes have to be aligned to a high precision in the detector box. The position of the straw tubes in the wire plane has to be kept within 100 μm. The mounting of the module boxes must guarantee a flatness of the box better than 500 μm.
The positioning of the wire in the centre of the straw is given by means of wire locators and endpieces. They are made of Noryl and produced by injection molding. Wire locators are placed every 80 cm in each straw.
To glue the straw tubes to the sandwich panels, they are positioned in an aluminium template produced with a precision better than 50 μm.
Special care is needed when the 5m long panels with the straw tubes are handled during production, as their intrinsic rigidity is not sufficient. Therefore a special tool has been designed to keep the panels straight within a precision of better than 100 μm. Two of these tools are used, as shown in figure 2, to glue a module box from two half modules equipped with straw tubes.

4. Straw tube performance

To cope with the high bunch crossing rate at the LHCb the usage of a counting gas with a high drift velocity is mandatory. This lead to the choice of $Ar/CO_2/CF_4$ (75/10/15) as baseline gas mixture. The presence of the CF_4 in the gas guarantees a fast charge collection, as shown in figure 3. Its electronegativity deteriorates the spatial resolution, but it has been shown that this gas fulfils the requirements for the LHCb outer tracking system [1]. The rate capability of the detectors is not affected by the usage of CF_4.
To study the impact of CF_4 on ageing, straw tubes are irradiated by 9 keV X-rays. A controlled amount of water can be added to the gas. No drop of gas gain or resolution has been observed up to an integrated charge of 2 C/cm, corresponding to 10 years of operation at LHCb, see figure 3. The measurements are not concluded. After completion of the irradiation the wire will be inspected optically and with an electron microscope.

REFERENCES

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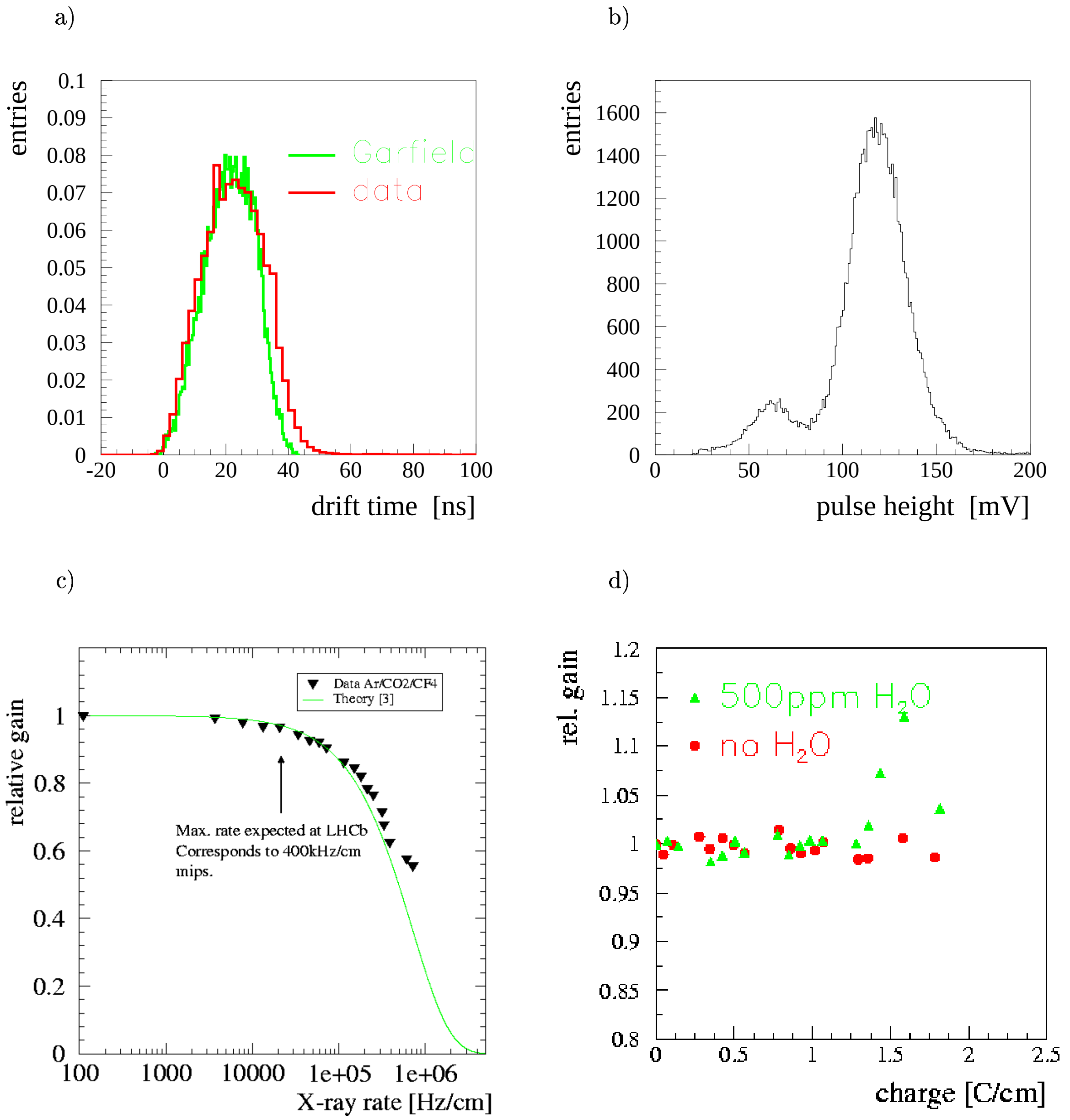

Figure 3. a: Drift time spectra for 5mm straw tubes. The measurement is compared to calculations using the simulation program Garfield [2]. b: Energy resolution for photons from an Fe^{55} source. c: Measured rate capability compared to the prediction of a model described in [3]. d: Stability of gas gain of a straw tube irradiated with 9keV photons. The integrated charge expected for a 10 year operation in the LHCb environment corresponds to 2C/cm. The counting gas for all measurements shown is $Ar/CO_2/CF_4$ (75/10/15).