The straw tube technology for the LHCb outer tracking system

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Abstract

For the outer tracking system of the LHCb spectrometer 53.760 straws of 2.5 m length will be used. They are arranged in detector modules of 5 m length and 0.34 m width. The envisaged spatial resolution over the entire active area is 200 μm resulting in stringent requirements on the accuracy for the module construction.

In this paper we discuss the optimisation of the straws, design and construction of detector modules. The long term operation properties of straws in two different counting gases, Ar/CO_2 (70/30) and $Ar/CO_2/CF_4$ (75/10/15), is compared.

1 The LHCb experiment

Scope of the LHCb experiment is to study CP-violation and other rare phenomena in B-meson decays. The experiment is designed as forward spectrometer to match the preferable polar angle of $b\bar{b}$ production. 10^{12} $b\bar{b}$-pairs will be produced per year in 14 TeV pp-collisions. This allows to reconstruct ~216.000 $B^0 \rightarrow J/\Psi K_s$ events and ~26.000 $B^0 \rightarrow \pi^+\pi^-$ events per year.

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Preprint submitted to the Xth VCI 2004 *16 April 2004*

The LHCb detector consists of the tracking system, including vertex locator, inner and outer tracker, the particle identification system (RICH1 and RICH2), electromagnetic and hadronic calorimeter, and the muon system.

The outer tracking system (OT)

Task of the tracking system is to reconstruct the trajectories of charged particles and measure their momenta. The expected momentum resolution is 0.35% for 1GeV particles.

The OT is designed as modular system. Detector modules have a size of up to 5 m $\times$ 0.34 m. They house 256 straw tubes with an inner diameter of 4.9 mm. 3 stations with a total size of 6 m $\times$ 5 m are constructed from the modules. A station comprises four detecting planes (X/U/V/X). The OT consists of 264 detector modules with 53760 straws, part of them are half size modules.

To reach the envisaged momentum resolution a spatial resolution for the straws of 200μm is needed. The baseline gas mixture of $Ar/CO_2/CF_4$ (75/10/15) meets that requirement. It also provides a fast charge collection needed due to the 25ns bunch crossing time at LHC [1]. Ar/CO_2 (70/30) is studied as alternativ counting gas.

Figure 1 shows the components of a detector module. A double layer of straws is closed by two panels made of a Rohacel core and carbon fibre laminates. The inner side of the panel is covered by a Kapton-aluminium laminate. The straws consist of a double layer of Kapton XC and Kapton-aluminium laminate. The inner conductive Kapton XC layer serves as cathode. The outer Kapton-aluminium layer guarantees gas tightness and electrical shielding.

To reach the resolution of 200 μm the alignment of the straws in a module has to be done better than 100 μm over the entire module length. This is reached by high precision templates used to position the straws when they are glued to the panel. The straws are equipped with endpieces and wire locators defining the position of the wire in the centre of the straw. Two panels with straws are glued to each other. To guarantee the straightness of the final module box a dedicated support tool is used to hold the panels. The material of a detector module corresponds to 0.7 % of a radiation length. The accuracy of the straw positioning in a 5 m module is shown in figure 2.

2 Aging in straw tube detectors

A study to compare the aging of straws operated in $Ar/CO_2/CF_4$ (75/10/15) and Ar/CO_2 (70/30) has been performed. It includes the impact of water on possible aging phenomena. It is motivated by the observation of wire ruptures in preceeding aging tests using CF_4 based gases. CF_x and F radicals and HF can be formed in the avalanche, the latter in case of the presence of hydrogen,

e.g. from H_2O. They may be capable to attack the gold coating of the wire. Gold damage effects in CF_4 based gases have been reported also elsewhere[2,3].
A set-up for a long-term irradiation of straw tube modules with X-rays has been built. It allows to add a defined amount of water to the gas. The set-up and the operational parameters are shown in figure 3. Before, during and after irradiation the pulse height variation along the wires are measured using an ^{55}Fe source. To cancel pressure and temparature effects the ratio of the pulse heights from irradiated and non-irradiated straws is measured.
After irradiation up to an integrated charge of ∼2 C/cm the modules are opened and inspected by an optical and a scanning electron microscope. Deposits of carbon and heavier elements can be detected by the EDX technique. Figure 4 shows selected results of the measurements. The results of all measurements are summarized in the following table:

Ar/CO_2 (70/30)	**Ar/CO_2/CF_4 (75/10/15)**
- carbon deposits observed for all levels of water content, but no gain variations in dry gas.	- carbon deposits observed for all levels of water content.
- For wet gases 'classical aging' in irradiated regions, i.e. deposits of C and O and gain drops up to ∼30%.	- gain variations at ≤50 ppm and 500 ppm.
- no indications for wire etching.	- at ≤50 ppm and 500 ppm: gain drop and deposits in non irradiated sections.
	- at 3500 ppm: deposits of C and O in irradiated section but no gain drop, tungsten from wire observed: hint for wire etching.

A remarkable difference between both gases is that aging phenomena in Ar/CO_2 occur only in presence of water and are restricted to the irradiated area. For the CF_4 based mixture they occur also in the dry gas and even in regions not irradiated. Presumably they are caused by the creation of stable compounds removed from the irradiated region and deposited outside the irradiated region on the wire.

3 Conclusion

First full size detector modules for the LHCb OT have been built. It has been shown that the stringent constraints on the mechanical accuracy can be fullfilled during construction.
Aging studies with Ar/CO_2/CF_4 reveal a variety of aging phenomena. With Ar/CO_2 the same phenomena are not observed. It is therefore a promising alternative as counting gas for the usage at LHCb. The impact of that choice on the physics performance of the OT is under study.

4 Figure captions

Fig. 1: a) Components of a half module. A detector module is made by gluing two half modules to each other. b) Straw tube made of Kapton XC (inner layer) and Kapton-aluminium laminate (outer layer). c) End block, wire locator and middle block, made of Noryl and produced by injection molding.

Fig. 2: Assembly accuracy for a 5m module. The spread of the wire pitch around the nominal value of 5.25 mm is shown.

Fig. 3: Set-up and operational parameters used for the irradiation tests.

Fig. 4: Selected results from the irradiation tests in $Ar/CO_2/CF_4$ (75/10/15).

References

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