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Neutron sensitivity of thin gap chambers

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Abstract

Thin gap chambers (TGC) will be used for triggering forward muons in the ATLAS detector for the LHC at CERN. A large amount of neutron background is foreseen in the ATLAS experiment. This paper describes the measurements of the neutron sensitivities (detection efficiencies) of the TGCs. The sensitivities of both small and real size TGCs to 2.5 and 14 MeV mono-energetic neutrons were measured. For a small size TGC, sensitivities of 0.032% and 0.10% were measured to 2.5 and 14 MeV neutrons, respectively, whereas for a real size TGC, sensitivities of 0.048% and 0.13% were measured. These measured values were in reasonably good agreement with the simulations based on the Geant4.

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Keywords: LHC; ATLAS; Trigger; Thin gap chamber; TGC; Neutron; Geant4

1. Introduction

The ATLAS detector [1] is one of the major detectors for the future 14 TeV proton collider, the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN). The event rate of the ATLAS experiment is expected to be 1 GHz [2] for the designed luminosity of the LHC-$10^{34}\,cm^{-2}\,s^{-1}$. The event trigger is one of the important issues for the experiment. Thin gap chambers (TGC) [3] will be used for triggering forward muons in the ATLAS detector. The structure of TGCs is similar to that of multi-wire proportional chambers and their detection efficiency for minimum ionizing particles (MIP) is more than 99% within a 25 ns time gate [4] (time duration of this time gate is referred to as "time jitter"), that satisfies the requirements of the ATLAS muon triggering.

A large amount of background radiation is predicted in the ATLAS experiment. In the

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installation area of the TGCs, neutrons and photons are the primary components of the background. This may induce a high counting rate in the TGCs, thereby affecting stable operation and causing false muon triggers or the chamber aging. In order to estimate such effects, the sensitivities of TGCs to such background particles must be measured.

The primary energy range in the case of the photon background ranges from 10 keV to 10 MeV according to simulation [5], where photons are primarily generated through the capture of thermal neutrons. The sensitivity was measured in the energy range from 20 keV to 1.8 MeV and was found to be less than 1% [6].

In the case of the neutron background, it originates from the interaction of primary hadrons with the materials of the ATLAS detector and accelerator elements. Its energy spectra ranges primarily from 0.025 eV to 1 GeV with a gentle peak around the 500 keV region obtained from the simulation [5]. Recoil nuclei or fragments from neutron reactions can produce hits in the TGC. Photons generated through neutron reactions can produce electrons that can also be the cause of hits in the TGC.

We performed the first measurements on the neutron sensitivity (detection efficiency) of TGCs for mono-energetic neutrons of 2.5 and 14 MeV. The results of the measurements were evaluated with a Monte Carlo simulation that was based on the Geant4 [7] and a good understanding of the TGC response to neutrons was obtained.

2. Real size TGC and small size TGC

In this measurement, two types of the TGCs were used to get a better understanding through comparing both results. One was a real size TGC, the structure and materials of which were identical to that of the TGCs that will be used in the ATLAS experiment. The other was a small size TGC that had a smaller and a simpler structure than the real size TGC. The structure of the real size TGC is described in Ref. [8]. The cross-sections of both real and small size TGCs are shown in Fig. 1. The anodes are gold-plated tungsten wires—50 μm in diameter—uniformly spaced at 1.8 mm. The gap between the anodes and the cathode is 1.4 mm. The cathode surface is made of a conductive layer of approximately 10 μm in thickness, which primarily comprises graphite and acrylic resin in order to achieve a surface resistivity of approximately 1 MΩ/square. The chamber walls are made of FR4[2]. The TGC is operated in the limited proportional mode with a gas mixture of CO_2 and *n*-pentane, the ratio of which is 55:45.

The real size TGC is trapezoidal in shape—with a height of 1250 mm and a base length of 1529 mm. Approximately 20 wires are grouped together in order to obtain 32 channels for the anode readouts. There are 32 rows of copper strips, each with the thickness of 30 μm on the FR4 boards, which are perpendicular to the wires. Two chambers compose a double layer module (doublet) with a 20-mm thick paper honeycomb between them to maintain mechanical rigidness. In addition, 5-mm thick paper honeycombs with 500-μm thick FR4 skins are glued on both the outer surfaces for protection and rigidness.

The small size TGC is 10 cm in width and 12 cm in length. It is a single layer chamber without cathode strip readouts. Its wire spacing, the wire diameter and the gap between the wire and the cathode are identical to that of the real size TGC. The thickness of one side of the chamber wall is 1.6 mm and that of the other side is 0.2 mm. The thickness of the copper cladding on the wall is 10 μm. There are 16 anode wires, each of which is 8 cm in length. The signals generated at each wire are individually read. The two edge wires are not used in order to eliminate the effect of a higher electric field and a larger drift space corresponding to the edge wires. Accordingly, the sensitive area was 8 cm in length and 2.52 cm in width.

3. Experimental setups

The geometrical and electrical setups for the measurements with both 2.5 and 14 MeV neutrons are described in this section.

[2]Flame retardant glass fabric base epoxy-resin laminate.