Small-Strip Thin Gap Chambers for the Muon Spectrometer Upgrade of the ATLAS Experiment

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Abstract

The ATLAS muon system upgrade to be installed during the LHC long shutdown in 2018/19, the so called New Small Wheel (NSW), is designed to cope with the increased instantaneous luminosity in LHC Run 3. The small-strip Thin Gap Chambers (sTGC) will provide the NSW with a fast trigger and high precision tracking. The construction protocol has been validated by test beam experiments on a full-size prototype sTGC detector, showing the performance requirements are met. The intrinsic spatial resolution for a single layer has been found to be about 45 µm for a perpendicular incident angle, and the transition region between pads has been measured to be about 4 mm.

Keywords: Tracking detectors, Thin gap chamber

PACS: 29.40.Cs, 29.40.Gx

1. Introduction

The LHC instantaneous luminosity is expected to increase to 2-7×10^{34}cm^{−2}s^{−1} after the 2018/19 long shutdown. In order to keep the Run 1 and Run 2 ability to trigger on moderate transverse momentum leptons, ATLAS [1] will replace the innermost forward muon-tracking detectors (the so-called Small Wheel) by the New Small Wheel (NSW) [2], which will have excellent triggering and precision tracking capabilities. Figure 1 illustrates how the addition of triggering capabilities to the Small Wheel can improve the identification of tracks pointing to the interaction point. The high precision coordinate measurements provided by the NSW will allow a significant reduction in the rate of fake muon triggers. The two chosen detector technologies for the NSW, MicroMeGas (MM) and small-strip Thin Gap Chambers (sTGC), are complementary. The sTGC is required to reconstruct track segments online with an angular resolution of better than 1 mrad for triggering purposes, as well as a spatial resolution of about 100 µm for tracks reconstructed offline.

The NSW consists of two types of sectors (small and large sectors), and each sector includes eight sTGC detector planes (layers) arranged in two quadruplets (chambers) sandwiching two MM chambers. This layout maximizes the distance between the two main triggering planes and therefore the angular resolution of the track segment measurement.

2. sTGC technology and construction

The structure of a sTGC layer is illustrated in Fig. 2. The 50 µm diameter gold plated tungsten wires are held at a 2.9 kV potential. They have 1.8 mm pitch and are sandwiched between two cathode planes each at 1.4 mm from the wire plane. The cathode planes, made of graphite-epoxy mixture, have a surface resistivity of typically 100-200 kΩ/□. Behind the cathode planes, on one side precision copper strips run perpendicular to the wires, and on the other side there are copper pads, both acting as readout electrodes. Strips have a 3.2 mm pitch (much smaller than the current ATLAS TGC), providing improved angular resolution. Pads have a much larger pitch, of about 80 mm, and are used to identify muon tracks roughly pointing to the interaction point by producing a 3-out-of-4 coincidence, as well as to define a region of interest for which the strips and wires are read out. The chamber is filled with a gas mixture of 55% CO₂ and 45% n-pentane, which has an electron drift velocity of about 3 cm/µs under an electric field of 2.9 kV/cm.

In the construction of the chambers and assembly of the quadruplets high precision alignment is the main challenge. Precise alignment (better than 30 µm) between layers is
achieved by machining together the strips and the precision brass inserts, which can then be externally referenced. The cathode boards are flat and parallel to better than 80 µm. This is achieved by using a 100 µm thinner honeycomb as spacer when gluing the boards together, which allows the glue to be used as a filler and compensate for any small unevenness. Mechanical deformations are avoided by using the same composite material (FR-4) everywhere.

3. Test beam experiments and results

The first full-size sTGC quadruplet detector (of dimensions 1.2×1.0 m²) was built. It was tested in the Fermilab and CERN test beam facilities using 32 GeV pion and 130 GeV muon test beams respectively.

At Fermilab, the prototype was positioned between the two arms of an EUDET telescope (consisting of three 2×1 cm² pixel sensors in each arm) which provided a very precise reference track for the sTGC detector. It was mounted on a movable table which allowed testing the uniformity of the chamber performance. Two analyses are performed to determine the intrinsic position resolution of a single sTGC plane. The position resolution is related to the profile of the induced charge on the strips. The particle position is measured performing a Gaussian fit on strip-clusters with 3, 4 or 5 adjacent strips. The first analysis combines sTGC and telescope data, and compares the measured sTGC position to the expected position from the pixel reference track. The residual is used to extract simultaneously the alignment parameters, the non-linearity corrections and the resolution of each of the layers by fitting it to a Gaussian model. Figure 3 (left) shows the non-linearity correction as a function of the position (relative to the inter-strip gap) applied for the runs under study. Open circles correspond to runs where the beam was crossing a mechanical support in at least one of the layers considered.

At the CERN test beam, the charge sharing between pads was measured by centering the beam in the transition region between two pads as depicted in Fig. 4 (left). The charge fraction (F) is defined using the analog peak values (P) of two neighboring pads as:

\[ F = \frac{P_n - P_{n+1}}{P_n + P_{n+1}} \]  

and is shown in Fig. 4 (right) as a function of the particle position with respect to the center of the transition region. The transition region, defined as |F| < 0.7, is measured to be about 4 mm.

4. Conclusion

The sTGC detectors will provide the Muon NSW with excellent triggering and tracking capabilities. The construction protocol has been validated by test beam measurements on a full-size prototype showing the performance requirements are met.

References