Construction of a High-Resolution Muon Drift Tube Prototype Chamber for LHC Upgrades

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The muon spectrometer of the ATLAS experiment at LHC at CERN uses Monitored Drift Tube (MDT) chambers as precision tracking detectors. These chambers consist of 2×3 (or 4) layers of densely packed aluminum tubes of 30 mm diameter—each equipped with a single central anode wire—mounted on a lightweight aluminum support frame. Operated with an Ar/CO_2 gas mixture at an absolute pressure of 3 bar, the MDT chambers reach a spatial resolution of 40 μm and a tracking efficiency of almost 100% up to counting rates of 0.5 kHz/cm^2. Possible upgrades of the muon spectrometer in the very forward region at pseudo-rapidities of η = 2.0–2.7 and luminosity upgrades of the LHC beyond its design luminosity 1×10^{34} cm^{-2} s^{-1} require muon tracking detectors with a rate capability of up to 10 kHz/cm^2 with the same spatial resolution as the current MDT chambers. The different upgrade scenarios require the construction of a large number of new muon chambers.

The design of new drift tube chambers consisting of 15 mm diameter tubes has been completed. These chambers are operated with the same gas mixture as the original MDT chambers, allowing for the re-use of existing services. The decreased tube diameter allows for higher granularity of read-out channels in the same detector volume, improving the tracking capabilities of the detectors. At the same time, space charge effects are suppressed and the maximum drift time is reduced from 700 ns to about 200 ns, reducing the background occupancy induced by photons and neutron conversions in the tube walls by a factor of 7. First test beam measurements confirm the required spatial resolution and high rate capability.

A full-scale chamber, consisting of 1152 tubes arranged in 2×8 layers and covering an area of 1 m^2, is currently being built (cp. fig. 1 for the layout). It uses 15 mm aluminum tubes with a wall thickness of 0.4 mm. An anode wire of 50 μm diameter is centered within each tube. To achieve the required spatial resolution, the anode wire positions have to known to better than 20 μm within a chamber. The high mechanical accuracy is reached by using precision wire locators on the inside of the tube endplugs (see fig. 2) and reference surfaces on their outsides in conjunction with precision combs for positioning during the gluing of the tube layers. The assembly setup consisting of a stack of jigs (see fig. 3) allows for the gluing of up to 8 layers in one day. Measurements with cosmic rays on a test bundle of 96 tubes yielded an accuracy of 20 μm on the relative anode wire positions.

The high density of tubes necessitates the design of new on-cahmber services as well. A modular gas system using injection molded plastic (Pocan) pieces has been developed. Compact HV distribution and front-end electronics boards have been made possible by integrating passive components into extensions of the signal caps of the tubes (see fig. 4). The drift tubes are produced using a semi-automated assembly facility inserting and tensioning the anode wires and crimping the tubes and wires on the endplugs. Each tube had to pass wire tension, gas leak rate, and HV stability tests before being used in the chamber assembly. We will also report on these test results.

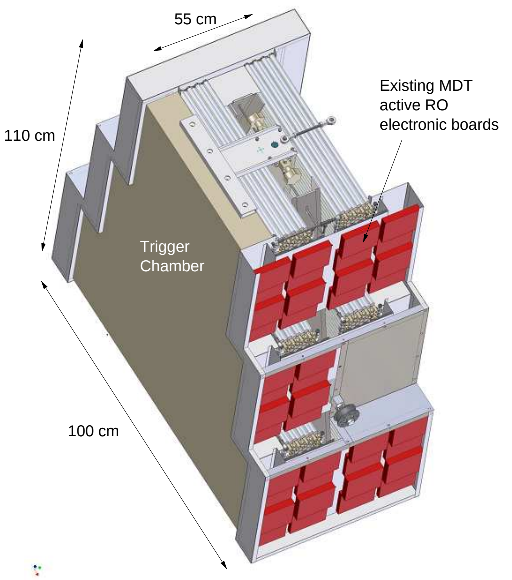

Fig. 1: Schematic drawing of the prototype drift tube chamber. The design allows a piggyback trigger chamber. The increased size of the Faraday cages is due to the re-use of existing read-out electronics.

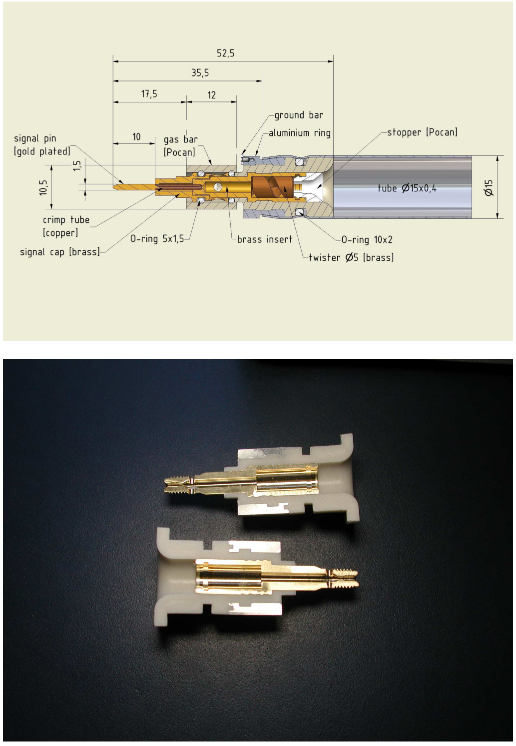

Fig. 2: Schematic drawing of the drift tube and endplug design. Photograph of a cut unmachined endplug.

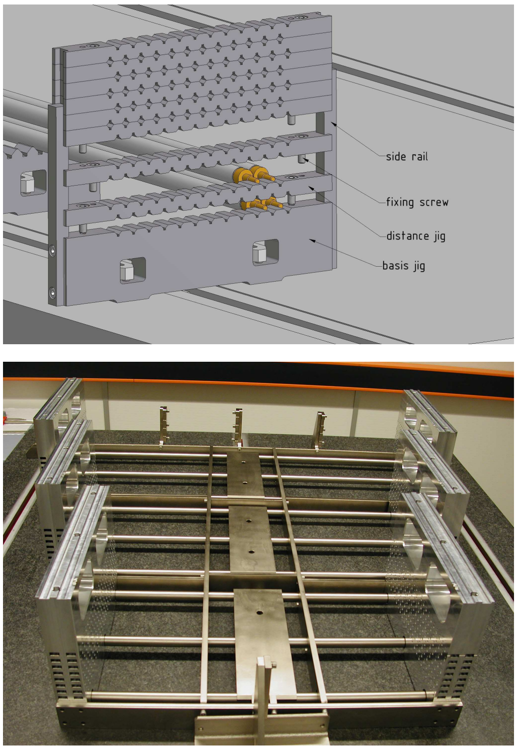

Fig. 3: Schematic drawing of the precision jigs and photograph of the jigs mounted on the granite assembly table.

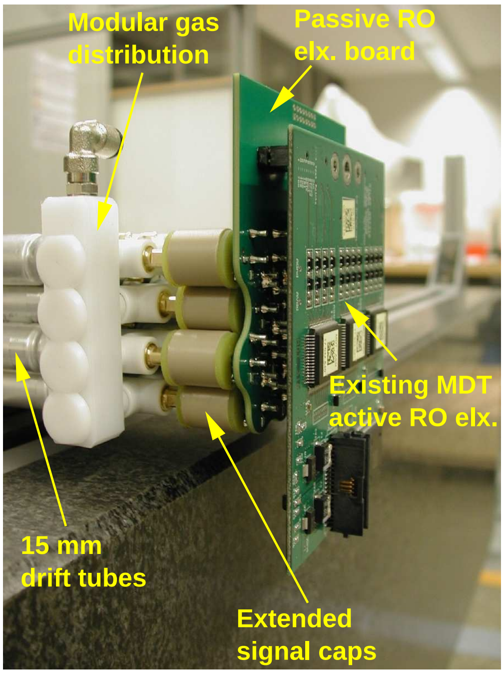

Fig. 4: Photograph of the read-out side of a 15 mm drift tube bundle with gas distribution, passive and active read-out electronics.