A Fast High-Resolution Muon Drift Chamber Prototype 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 a pressure of 3 bar absolute, the MDT chambers reach a spatial resolution of 40 μm and have a tracking efficiency of almost 100% up to rates of 1 kHz/cm^{-2}. Planned enhancements of the muon spectrometer in the very forward region at pseudo-rapidities of $\eta = 2.0$–2.7 and luminosity upgrades of the LHC beyond its design luminosity 1×10^{34} cm^{-2}s^{-1} (the so-called Super LHC) 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 would require a large number of new muon chambers, from a minimum 32 to several hundred.

A new design of a drift tube chamber, using 15 mm diameter tubes, is in its prototype phase. These chambers can be operated at the same conditions as the original MDT chambers, allowing the re-use of existing of the services. The decreased tube diameter allows a higher granularity of read-out channels in the same geometrical space, improving the tracking capabilities of the detectors. At the same time, space charge effects are suppressed and the maximum drift time is reduced from 750 ns to 200 ns. 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 inside the tube's endplugs (see fig. 2) and reference surfaces on their outsides in conjunction with precision combs for positioning during the gluing of the tube layers. A stack of jigs and the assembly procedure (see fig. 3) allow 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 16 μm on the anode wire positions. The high density of tubes necessitates the design of new services as well. A modular gas system using injection molded plastic (Pocan) pieces has been developed which can be arranged to accommodate any number of tubes, as e.g. needed for the design of the trapezoidal endcap chambers of the ATLAS muon spectrometer. Compact HV distribution and passive front-end electronics boards have been made possible by integrating part of the components into an extension of the signal cap of the tubes (see fig. 4). The drift tubes are produced with a semi-automatic machine stretching the anode wire and crimping the tube on the endplugs. Each tube has to pass several quality assurance tests—HV stability, wire tension, and gas leak rate—before being used in the chamber assembly. We will also report on these test results and rejection rates.

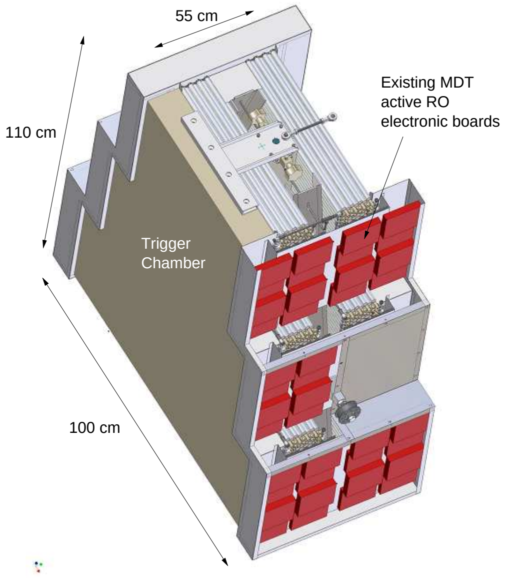

Fig. 1: Schematic drawing of the prototype drift tube chamber. The design allows a piggyback trigger chamber. The increased size of the Faraday cages is due to the re-use of existing RO electronics.

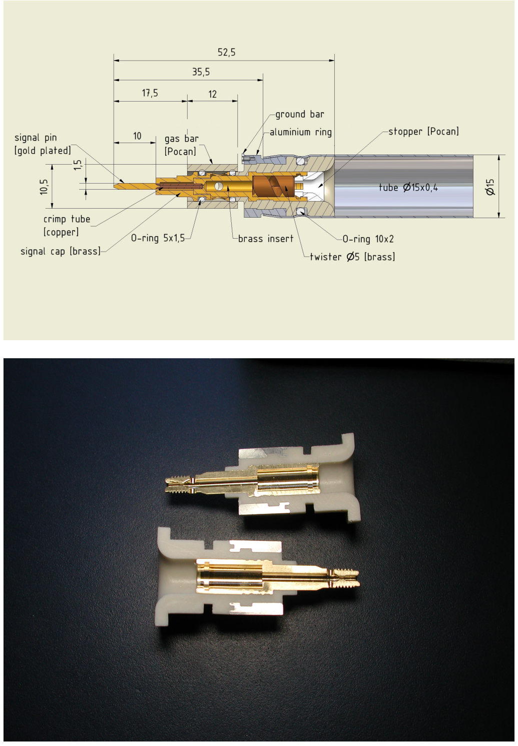

Fig. 2: Schematic drawing of the drift tube and endplug design. Photograph of a cut unmachined endplug.

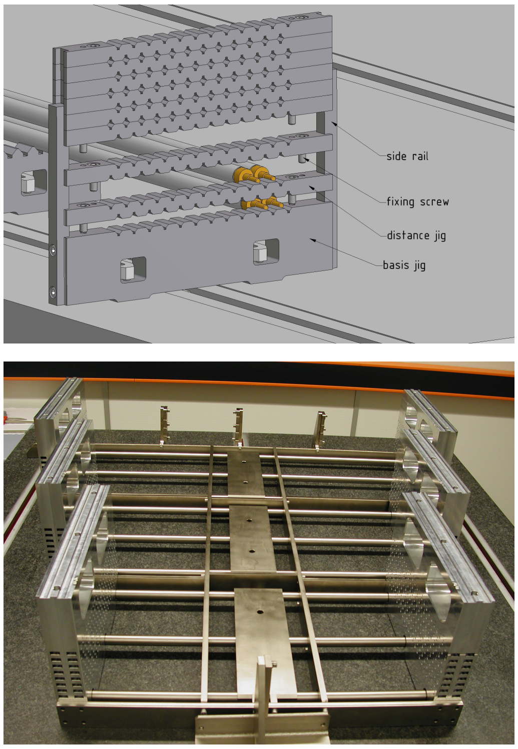

Fig. 3: Schematic drawing of the precision jigs and photograph of the jigs mounted on tghe granite assembly table.

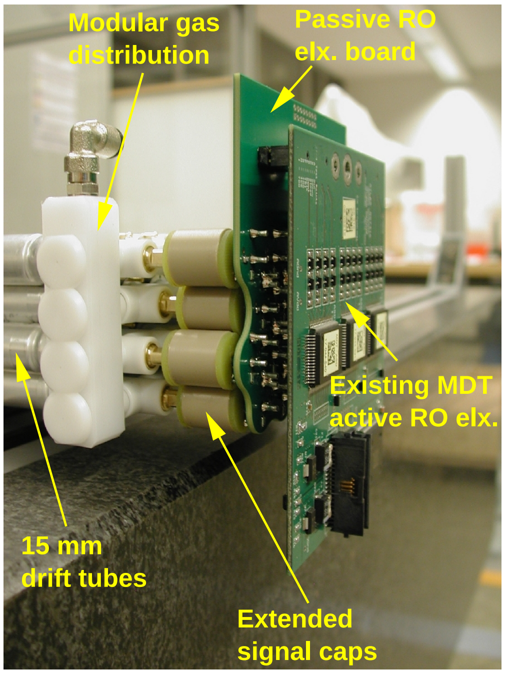

Fig. 4: Photograph of the RO side of a 15 mm drift tube bundle with gas distribution, passive and active RO electronics.