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The Pavia–Roma1 ATLAS MDT Quality Control System

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Abstract

The physics at LHC imposes very severe requirements on the ATLAS muon detector, which translates into stringent requirements on drift-tubes wire tensioning, leak current, gas leak and wire positioning. In order to verify all these parameters prior to chamber construction, a dedicated quality control system was completely designed and built by our groups. © 2001 Elsevier Science B.V. All rights reserved.

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ATLAS is one of the two general-purpose experiments that are under construction at the CERN Large Hadron Collider. The ATLAS apparatus comprises a high-resolution muon spectrometer to reconstruct narrow 2- and 4-muon final states from decays of Standard-Model and SuperSymmetric Higgs (and new vector bosons).

Over most of the solid angle, the muon momentum is reconstructed with Monitored Drift Tube (MDT) precision chambers. About 1200 chambers, for a total of 370 000 tubes, will be built in the next 4 years. A MDT is made of a 400 μm thick — 3 cm diameter — extruded aluminium tube closed at both ends by an aluminium/plastic end-plug. A locator inserted in the end-plug centers the wire inside the tube. Gas gain (2×10^4) and mixture (Ar:CO_2 93:7 at 3 absolute bars) were chosen to obtain a 80 μm single-tube resolution and minimize ageing effects.

Physics and budget constraints require that each MDT fulfils the following requirements:

- mechanical wire tension: 375 g $\pm$ 5%;
- leakage current below 2 nA/m at a gas gain of 4×10^4;
- gas leak smaller than 10^{-8} bar l/s at three absolute bars;
- wire off-centering within 10 μm rms in projection.

A specialized Quality Control System (QCS) (Fig. 1) was designed and built by us in order to match the huge construction commitment of the Pavia and Roma1 groups (120 chambers in four years) with the time and manpower limitations. Up to 10 tubes will be automatically and independently tested for mechanical wire tension, leakage current and gas leak, without any operator intervention. Each tube will be inserted in a single and independent vacuum vessel providing both gas and HV connections. Permanent neodymium magnets, mounted close to tube centres, are used

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to induce forced mechanical oscillations of the wires. Finally, on a separate setup, each tube will be tested for the wire off-centering.

The *mechanical wire tension* is reconstructed by looking at the wire forced-oscillations, induced by feeding the wire with a sinusoidal current when it is partially immersed in a magnetic field. A custom board (built by the Roma1 group) is used to supply the current and detect the induced electro-motive force at the wire ends. By varying the period of the sinusoidal current generator the resonance frequency f_0 can be found. The wire tension τ is reconstructed by means of the relation $\tau = \lambda(2Lf_0)^2$, being λ and L, respectively, the wire linear density and its length. The calibration curve (Fig. 2) shows that the systematics can always be kept below 1%, provided that both λ and L are well under control. The reproducibility was found to be better than 0.2%.

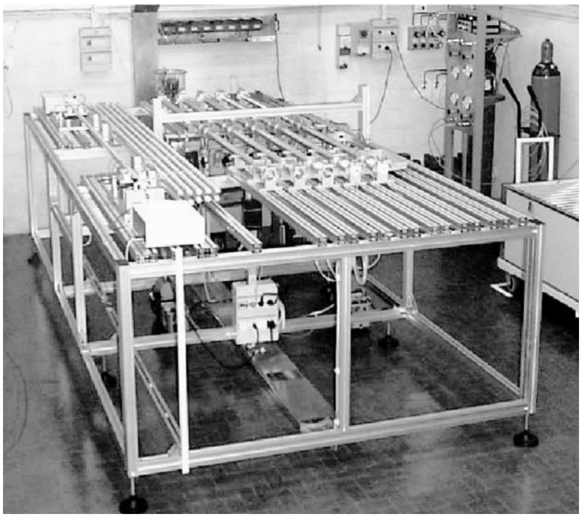

Fig. 1. The Pavia–Roma1 MDT Quality Control setup.

MDTs *leakage current* is measured by means of a high sensitivity (5 pA) HV floating (up to 5 kV) picoammeter, designed and built by the Pavia INFN group. An HV switching box allows the sequential measurement of all the tubes under test. A serial port allows interfacing the picoammeter with a computer. The setup was carefully designed in order to avoid systematics due to relays leakage currents.

The MDT *gas leak* is estimated by looking at the argon partial pressure in a quadrupole mass spectrometer connected to a vacuum vessel through an orifice. At equilibrium, both the pressure in the vessel and in the spectrometer volume are proportional to the amount of gas leaking into the vessel. After background subtraction, the averaging of the argon spectrum over a time period of about 1 min results in a sensitivity

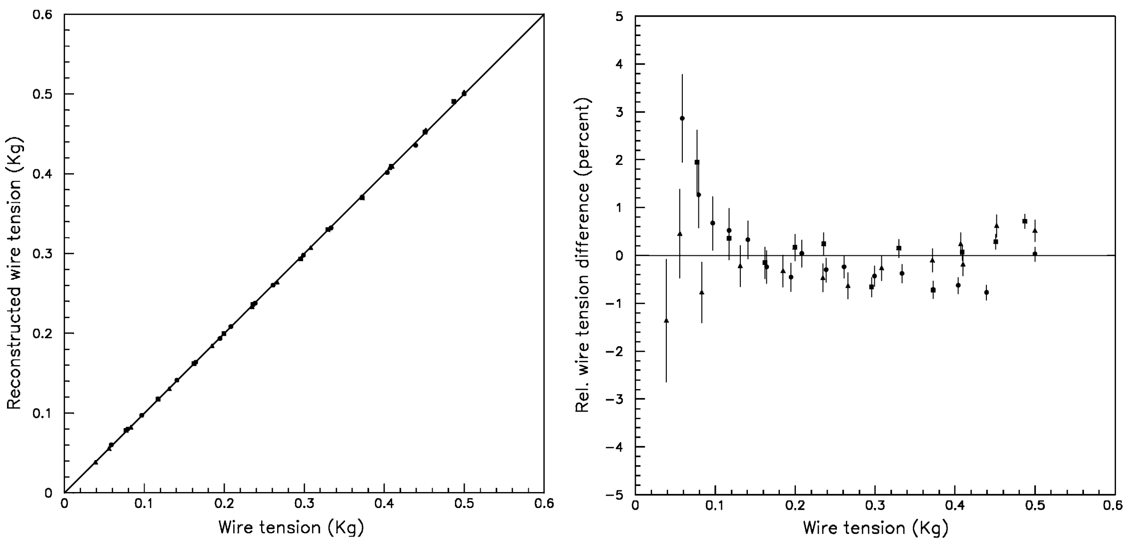

Fig. 2. Calibration curve for the mechanical wire tension measurement (left) and percentage deviation from the true value (right).

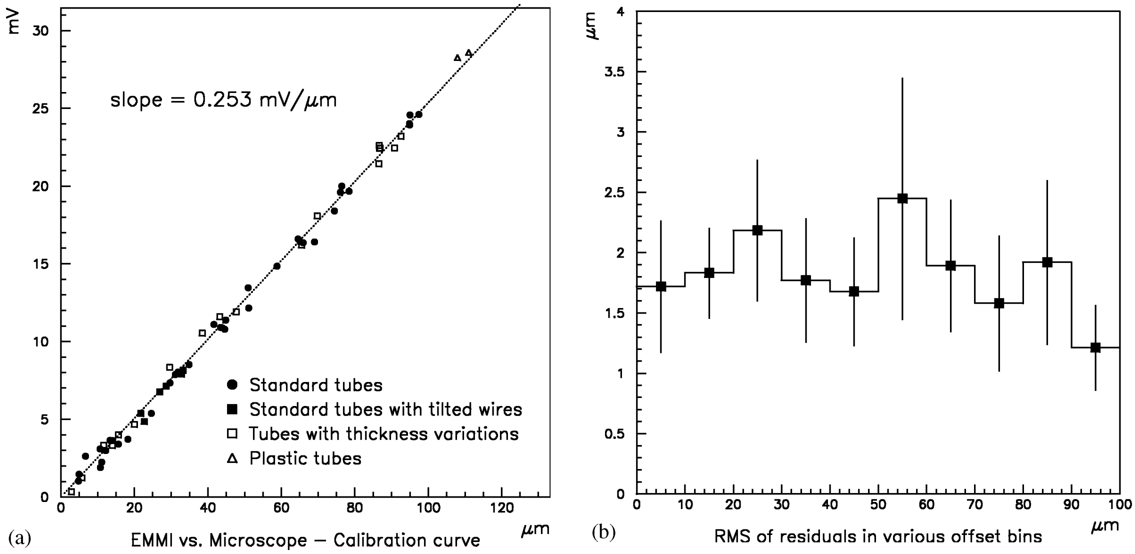

Fig. 3. EMMI calibration curve (left) and rms of residuals in various offset bins (right).

of 10^{-9} bar l/s. A set of electrovalves allows the sequential measurement of all the tubes. A stable leak source, built with a glass capillary and measured with a capacitive pressure gauge, is used to monitor and calibrate the system.

The *wire off-centering* is measured with a new device [1], the ElectroMagnetic MIcrometer (EMMI), especially designed and built by the Pavia and Roma1 groups. The wire position inside the tube is reconstructed by measuring the difference between the electromotive forces induced in two coils symmetrically placed on both sides of the tube when a small sinusoidal current is circulating on the wire. By rotating the tube around its axis (using as a reference the very precise cylindrical surface of the two endplugs), a wire off-centering produces a modulated variation of the signal, which is largely independent of the absolute tube position in the setup (related with the average value of the signal). Operator intervention is required to rotate the tube at four predefined azimuthal positions, in four step of 90° each. The device (see Fig. 3) is highly linear, has a very high sensitivity (2 μm), very good reproducibility (1 μm) and a short measuring time (about 10–20 s/ tube). Within the ATLAS collaboration EMMI has been largely preferred to other methods based on X-ray imaging because it is easy to use, has an equivalent resolution, no safety problems and a lower cost.

The QCS described above is currently in use to test the drift tubes needed for the first muon chamber that will be built by the Pavia and Roma1 laboratories. The QCS was shown to be reliable, easy to operate and quasi-completely automatized by means of a dedicated program running on a PC (developed in the National Instruments Bridge-View environment).

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References

[1] M. Cambiaghi et al., Proceedings of the 1999 IEEE Nuclear Science Symposium, IEEE Trans. Nucl. Sci. 47 (3) (2000).