1 Commissioning of the ATLAS Monitored Drift Tube Chambers

The Max-Planck-Institut für Physik has built 88 of 1150 Monitored Drift Tube (MDT) chambers of the muon spectrometer of the ATLAS detector. These chambers were installed in the experiment from February to June 2006, after being integrated with their respective trigger chambers and tested at CERN in 2005. The chambers were the first to be mounted on the rail system in the barrel part of the spectrometer and were positioned with an accuracy of about 1 mm, well within the specifications. The barrel part and the middle wheels of endcaps of the muon spectrometer were installed in 2006, the missing inner and outer endcap wheels followed in 2008, completing the muon spectrometer. 10 of 62 additional chambers improving the acceptance in the barrel-endcap transition region have been installed in 2009, the rest will follow in 2012.

The Max-Planck-Institut für Physik has taken a leading role in the commissioning of the ATLAS muon spectrometer and, via a representative in the ATLAS Muon Steering Group, is responsible for the overall coordination of the operation and maintenance of all MDT chambers since beginning of 2008. In addition, our MDT group provides on-call gas system and detector experts, as well as the data quality expert, who is responsible for the final sign-off of the MDT data. The MPI team is also involved in providing training and documentation for the shifters operating the detector in the ATLAS control room.

The commissioning of the MDT chambers should have followed their installation closely, but it was delayed due to the late installation of the final services in the experiment—the routing of the low and high voltage cables, readout fibers, and gas pipes and valves—and the availability of the commercially manufactured power supply boards. Thus, the commissioning phase of the muon spectrometer spanned from the end of 2006—with only 13 MDT chambers operational on temporary services—to September 2008, when the first beam was circulated in the Large Hadron Collider (LHC), and 98.8% of the 350000 channels of the 1088 MDT chambers of the muon spectrometer were operational.

A notable exception to the overall commissioning strategy were the MPI MDT chambers: immediately after their installation and in regular intervals afterwards their gas tightness, HV stability and the stability of the chamber geometry has been tested. As a result, the chambers exhibited less problems than other types when finally taken into operation. The chambers were connected to the ATLAS gas system in 2007 and to the power supplies and read-out chain in 2008 by a teams of 2–3 technicians and 2–4 physicists from MPI. Due to their exposed position at the outside of the ATLAS detector and the hostile environment with cooling and cryogenic stations and electronics racks on the surrounding structures nearby, the MPI chambers showed an increased noise pickup compared to the inner chambers. The situation was remedied by designing additional low-pass filters for the high voltage lines which were mounted on all MPI chambers in 2008. These filters are now also used on other chambers in the muon spectrometer which suffer from high noise rates.

The commissioning of the ATLAS muon spectrometer encompasses the connection of services to the chambers and the electronic racks in the experimental cavern. The MPI team supported this global work with 1–2 technicians and 2–4 physicists during 2007 and 2008. About 50% of all barrel MDT chambers were connected by the team and subsequently integrated in the read-out and debugged. Faulty front-end electronics cards were exchanged and high voltage failures due to a few broken anode wires in the drift tubes or dirt in the Faraday cages—caused by the ongoing installation of other subdetectors—were fixed. The channel mapping of the optical fibers for the read-out and the high and low voltage cabling of the whole spectrometer was verified and corrected. Fig. 1 shows an overview of the number of read-out MDT chambers as a function of time, denoted by periods of either combined muon system cosmic data taking (P-weeks) or combined cosmic data taking of all ATLAS subdetectors (milestones, M-weeks). An event display of one of the first recorded cosmic muons traversing the entire muon spectrometer during the P4 period is shown in Fig. 1.

A major part of the commissioning phase consisted of taking into operation the recirculating MDT gas system—-the largest gas system of any LHC experiment. This effort was coordinated and to a large part executed by the MPI team. The system consists of 15 distribution racks serving 226 individual gas manifolds, each connected to 4–32 MDT chambers. The total gas volume of 2.2×10^6 bar L is exchanged once every 24 hours, and about 10% of the gas is replaced. In addition to the 2.8 million O-ring seals of the on-chamber gas distributions, the systems has about 4500 manual valves and 18000 connections. Stringent requirements

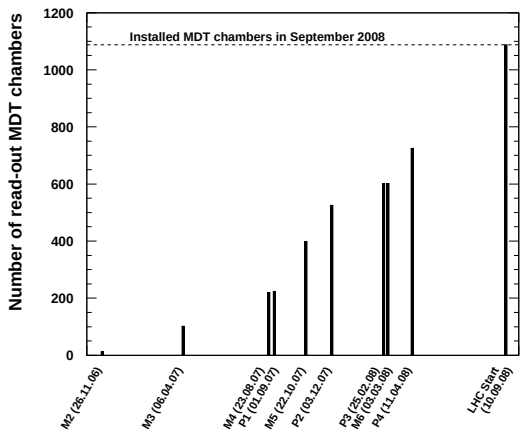

Figure 1: Number of read-out MDT chambers as a function of time from Nov. 2006 to the LHC start-up in Sep. 2008. Pi denotes the ith combined muon data taking, Mi denotes the ith milestone of combined ATLAS data taking.

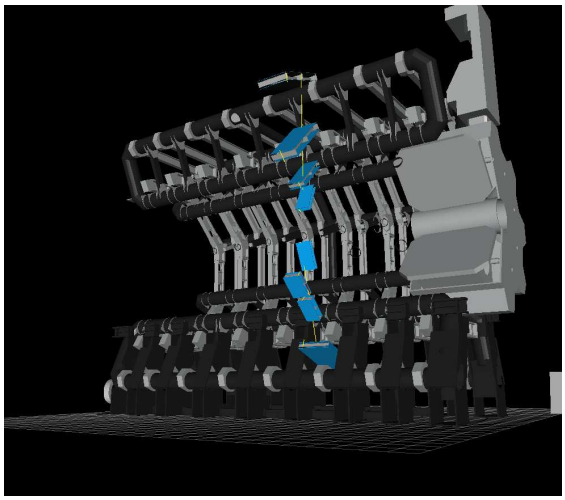

Figure 2: A cosmic muon traversing the ATLAS muon spectrometer, recorded during the P4 period in 2008. Only the MDT chambers with hits close to the reconstructed track and part of the toroid magnet system is shown. The topmost MDT chamber was built at MPI.

exist for the allowed leak rate which should not exceed $2 \cdot 10^{-7}$ bar L/s per drift tube to avoid back diffusion of air into the system which would change the space to drift relation and degrade the drift tube efficiency. The vast majority of all chambers and connections fulfills the tightness requirements after several hundreds of leaks were repaired. At the moment, the total leak rate of the system is about 30% higher than the allowed limit, caused by several larger leaks which will be repaired during the next LHC shutdown when access is possible. No adverse effect of the larger leaks has been observed so far. The purging of all MDT chambers, the leak search and repair, and the adjustment of the distribution system took an estimated manpower of 1.5 man years during 2007 and 2008. Periodic leak tests are still performed to spot new leaks in the system.

As all other subdetectors of the ATLAS experiment, the MDT system has entered routine operation in 2009 and 2010. The power supply system unfortunately still has high annual failure rates of 15–20% of the 345 installed boards. Annual failure rates of the active and passive front-end electronics on the chmabers, the high voltage distribution, and the detector control system are all well below 1%, but the vast amount of about 50000 single components nevertheless requires a constant maintenance of the system to which the Max-Planck-Institut für Physik contributes a major share of manpower and expertise. The MDT system has been operational with 99.7% of all channels taking high quality data for the past two years.