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System test of the ATLAS muon spectrometer in the H8 test area: program for year 2002

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Abstract

The plans for the extension of the system test of the ATLAS muon spectrometer in year 2002 are outlined. A description of the year 2002 scientific program is given. The new components that must be added to the current set-up to accomplish this program and the sharing of responsibility are discussed.

[*] The author list includes people who contributed directly to the proposal or to dedicated meetings and workshops, or committed themselves to a relevant participation in the completion of the program.

1. Introduction

High-momentum final-state muons are among the most promising and robust signatures of physics to the LHC. To exploit this potential, the ATLAS collaboration has designed a high-resolution muon spectrometer with stand-alone triggering and momentum measurement capability over a wide range of transverse momentum, pseudorapidity and azimuthal angle.[1]

To achieve this goal, very demanding requirements on the Muon system as a whole have been placed.

The precision chambers not only have to be built to very high standards of performance, both mechanical and electronic, but their positions in the spectrometer must be known at the level of the resolution of the chambers themselves (~60 μm per station). This requires a sophisticated and precise alignment system.

The large size of the ATLAS muon system also presents a host of technological problems; precision of tens of microns, on a scale of tens of meters, a sophisticated trigger, a complicated magnetic field, a large piece count, intricate structural supports, complex installation procedure, and intricate routing of services to name just a few. We have always expected that a full-scale test of one sector of the muon system would be necessary. It is self-evident that we cannot go from a single or few chambers test to full-scale implementation of the muon system without a meaningful system test on a reasonable scale.

There have been extensive tests of the various components of the muon system already and they have been found to perform adequately. We do not anticipate finding any fundamental error of design or implementation. However, many detailed problems only show up in an integrated system on an adequate scale. To confront these potential problems, we are planning a multi-step program to validate the muon system before installation. The final set-up foresees the installation and the test of a tower of the barrel and of one octant of the end-cap including fully equipped MDT (Monitored Drift Tubes) and trigger chambers, RPC (Resistive Plate Chambers) and TGC (Thin Gap Chambers).

A first document with the general H8 test program was produced in 1999.[2] Since then two workshops have been held at CERN aiming to the organization of the work to be accomplished in the H8 test beam area. The transparencies presented at these workshops can be found in Ref.s 3, 4.

The first phase of this system test started in 2001 for both the barrel and end-cap stands. Section 2of this document gives a brief overview of the current set-up and of the results already achieved. The scientific program for the 2002 run is outlined in section 3. In section 4 the components needed to reach these physics goals, together with the sharing of responsibilities between the different institutes involved in the 2002 test beam activities are discussed.

2. The current setup and the achievements in 2001

The final set-up foreseen for the H8 muon system test is already outlined in Ref. 2. During 2001 part of the set-up has been put in place.

2.1 The barrel stand

The current barrel stand consists of two regions, one dedicated to autocalibration and readout/DAQ studies and the other dedicated to emulate a sector of the ATLAS Barrel; in Fig 1 the barrel sector stand with a BIL and a BML chamber and the rotating stand, with a BIL chamber are shown.

In the first region a rotating support designed to house MDT chambers of BIS, BIL and BOS type was placed on the beam line, and a BIL chamber and a BOS chamber were tested and autocalibrated. In the second region two rails were placed in a way to emulate the position of Inner and Middle chambers of the sector at η=0.06 of the spectrometer. The same BIL chamber that was tested on the rotating support and a BML chamber were placed on the rails and data were taken with the two chambers in this configuration. Each chamber was read-out by four mezzanine boards. The data from the MDT chambers were then sent to an adapter-CSM0 (Chamber Service Module)[5] readout chain and to the data acquisition system via S-Link. More information on the data acquisition structure is given in section 2.3. On the beam line two trigger systems were present, a large area one used to trigger on the beam halo, consisting of two layers of scintillating slabs, covering an area of 60x100 cm^2, and a small area trigger (10x10 cm^2) centered on the beam line. A beam tracker chamber allowing to measure with high precision two orthogonal coordinates on an area of 48x48 cm^2 was operated to check the results obtained on the MDT autocalibration and resolution. The DCS system based on PVSS, allowed recording the temperature of the chambers (8 values for each chamber), the temperature of the gas, the gas flow setting and the gas pressure. The gas system was controlling both the gas composition and the gas pressure with a few per mill precision.

Figure 1: A) The Barrel Sector (BIL & BML chambers), B) the rotating support with a BIL chamber

A) B)

The goals achieved with this set-up are:

- The overall check of the new Module 0 Chambers
- The study of the autocalibration of the RT-relation in different working condition and at different angles between the tracks and the chamber.
- The study of the resolution as a function of the threshold and of the HV.
- The test of the new electronics
- The tracking with more than one chamber
- The study of different gas distribution schemes
- The study of the effect of air contamination on the efficiency and resolution.
- The development of a DAQ system in the framework of the ATLAS DAQ-1 prototype[6] as a first step toward the integration of the detector, its readout electronics and the trigger systems.

Some of the results obtained in this first test can be found in 7. More details on the barrel stand set-up can be found in Ref. 4.

2.2 The End-cap stand

The current set-up for the end-cap stand consists in three support structures that emulate $1/8^{th}$ of one end-cap of the ATLAS Muon Spectrometer. In Fig 2 a picture of the three end-cap support structures taken in summer 2001 is shown.

On each structure two alignment bars (fully equipped, measured and calibrated) shall be mounted. The two EO and the two EM bars are already in place, and the remaining two (EI) should be installed before the end of February 2002. Two phantom chambers per structure shall also be mounted on the frames. The two EO and the two EI phantom chambers are already mounted, the other two are already at CERN and will be mounted before the end of February 2002.

Each alignment bar[8] is an aluminum tube of 80 mm outer diameter and up to 9600 mm length, equipped with Pt100 temperature sensors to monitor thermal expansion of the bar, in-bar optical devices (RASNIK[9]) to monitor its straightness, and surveyed platforms for mounting optical alignment devices (BCAM[10]). The phantom chambers are equipped with proximity sensors and RASNIK masks to determine their positions with respect to the alignment bars.

The Pt100 sensors are read out with the PVSS SCADA system used at CERN as the agreed common program for DCS[11] The optical devices are driven and read out using a custom VME driver board controlled by a small server program written in C and running under Windows NT on an embedded PC in the VME crate. The server communicates via the DIM protocol[12] (based on TCP/IP calls) with a computer running the PVSS SCADA system. The Seattle and CERN groups wrote the SCADA control and readout software. The optical readout system is controlled using this PVSS computer, which allows for graphical display of results, data archiving and run control, as well as flexible testing of individual sensors and groups of sensors. The optical sensors consist of CCD chips used to take images of either point light sources (BCAM) or coded masks (RASNIK). The images are analyzed by the server program running in the VME crate and the results, consisting of two-dimensional position coordinates and (in the case of RASNIK) the magnification and rotation of the mask image with respect to the mask, are sent to the PVSS computer. These data are then stored both in the PVSS native archive format, which can be used for plotting alignment bar and chamber information online with the PVSS interface, and in the form of simple ASCII text files that are used by the alignment reconstruction code.[13] The alignment bars are calibrated and measured in Freiburg, where a CMM machine precisely measures the positions of the alignment platforms. The EO and EM alignment bars have been measured, the remaining EI ones should be ready in short time. More details about the bar characteristics, calibration and measurement procedure can be found in Ref. 14. From the preliminary analysis of these data it has been shown that the position of the alignment platforms can be predicted with a 20μm RMS by using an analytical model of gravitational deformations, complemented by the in-bar RASNIK and temperature measurements.

Figure 2: The three end-cap support structure EI, EM and EO as seen from the beam. The two phantom chambers installed on EO frame are also visible.

The phantom chambers have been equipped with in-plane RASNIKs, temperature sensors and proximity platforms. A "muon simulator" consisting of one BCAM and two light sources per chamber will be installed in spring 2002.

The goals to be achieved with this set-up are many:

- Get experience on installation of chambers and alignment bars on structures similar to the ATLAS ones
- Verify the consistency of the alignment mounting procedure with the positioning accuracy required by the optical system acceptance
- Gain experience with readout and control of the alignment devices and test the alignment devices and DAQ in an environment similar to the one of the ATLAS experiment (long cables, temperature gradients, time dependent temperature variations)
- Check the capability of the alignment system to correctly reconstruct controlled movements of one component (the lower EO bar has a controlled movement device)

- Use the muon simulator with the phantom chambers to perform a relative test of the proximity part of the alignment system
- Use the redundancy of the alignment system to perform an absolute consistency check of the alignment system

Another important benefit of running the End Cap test stand will be the opportunity to test the alignment devices readout and control system under more realistic conditions in preparation for expanding the hardware and software to the scale needed for ATLAS.

This program is quoted in [2] as the PHASE I of the H8 end-cap test. Only a part of it has been achieved in 2001. This test program should be completed in spring 2002. More details on the actual end-cap set-up can be found in Ref. 4.

2.3 The DAQ system

As outlined in section 2.3, the three barrel-chambers installed in 2001 have been readout using the software developed at Rome3 for the cosmic ray stand.[15] A DAQ system, based on the ATLAS DAQ-1 architecture [], was designed and implemented. It consisted of two VME readout crates (one for the MDT CSM0s and the other for the TDCs of the tracker), mastered by two RIO2 processors that were sending event fragments via S-Link to a ROS PC. Other PCs were used for the run control, the monitoring, the data storage and the DCS. A more detailed description of the DAQ architecture and the use of the DAQ-1 software can be found in Ref. 4.

2.4 The DCS and other common items system

All the temperature sensors positioned in the alignment bars and on the chambers have been read out via the SCADA PVSS system running on a dedicated PC. The SCADA software has been written by the NTUA group. A communication between the DCS and the DAQ system has been established.

3. Set-up and scientific program for 2002

The main goal for the 2002 H8 muon test beam activity is the test of the alignment system for both barrel and end-cap systems. On this purpose a low energy run and the installation of a beam magnet in front of the barrel stand are foreseen. The ATLAS 2002 test beam schedule is shown in Fig 3.The muon group has requested a low-energy beam period. This period is scheduled for the week starting the 8th of August. Another short (1-2 days) low energy run could be scheduled during the week starting the 3 of September (under negotiation with TRT group). During the low energy run particles with momenta down to 10 GeV/c will be delivered in H8. In addition to the runs where the muon group is the main user, parasitic runs are in general also possible when other sub-detectors are taking data on the H8 beam line. The access in the H8(B) muon area will not be possible during the periods dedicated to the Liquid Argon barrel calorimeter, namely from the 19 of June until the 4 of July and from the 24 of July until the 8 of August. This gives strong constraints on the installation of the muon system in view of the low energy run. If possible, the barrel stand installation should be completed before the 19 of June. The open-area period in July should be used to complete the barrel stand commissioning and to install the end-cap chambers. The remaining end-cap installation should be completed in the first part of August. It is important to prepare early enough an accurate schedule of the chamber installation. If the June and July period would not appear sufficient for completing the chamber installation, it is conceivable to delay the installation of some End Cap chamber to August, in parallel with the alignment run for the Barrel. All the information about the proposed schedule for the chamber installation is summarized in Table 1.

The requested low energy run aims to a complete test of the barrel alignment system including projective, axial and in-plane components. The end-cap test has the same goals but they can also be achieved using the high momentum muons that will be delivered during the parasitic run mode.

Figure 3: Preliminary ATLAS test beam schedule for 2002.

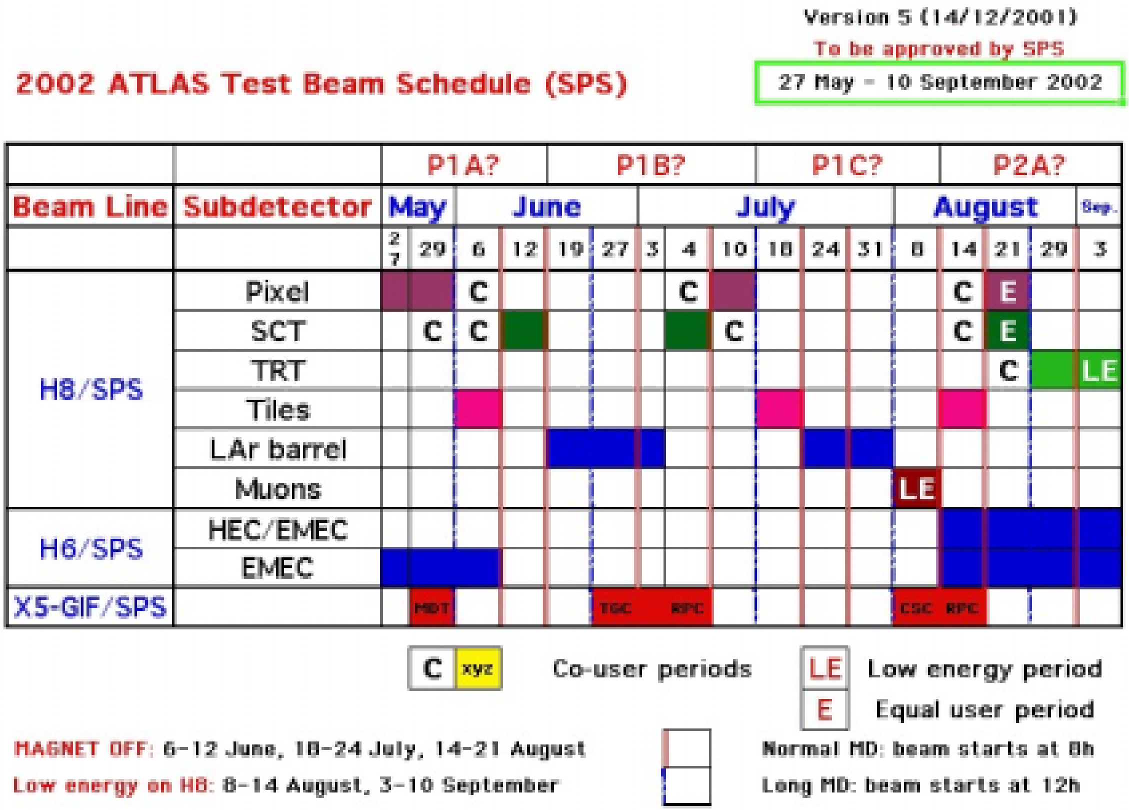


Table 1: Proposed schedule for barrel and end-cap chambers installation

Period	Scheduled operation
15 April – 26 April	Align. Platf. on BML X-tomo measurement
27 April – 24 May	BML installation in H8
1 May – 30 June	EC MDTs preparation in BB5
13 May – 24 May	Align. Platf. on BIL and X-tomo measurement
15 May – 30 June	Installation and operation of BOS MDT
25 May – 10 June	BIL installation in H8
27 May – 11 June	Align. Platf. on BOL and X-Tomo measurement
11 June – 19 June	BOL installation in H8
19 June – 4 July	**H8 area closed**
4 July – 24 July	Barrel commissioning; start EC MDTs installation
24 July – 8 August	**H8 area closed**
8 August – 14 August	**Low energy run**; complete EC MDTs installation
14 August – 3 September	EC MDTs commissioning
3 September – 6 September	**Possible second low energy run**

3.1 The barrel stand

During 2002, the barrel stand shall be completed with 6 new chambers, namely two BILs two BMLs and two BOLs. The BIL and BML rails are already in position while a new rail to place the BOL chambers shall be mounted on the beam line (though also the other rails would need a precise positioning once the final drawings of the barrel stand will be available).

To accomplish the projective alignment in the test beam environment the chambers that should be used are of the following type:

- BIL2 (placed in position 1) and BIL2 provided by Rome1/Rome3 and Pavia,
- BML1 and BML2 provided by LNF,
- BOL1 and BOL2 provided by NIKHEF.

This will reproduce the first two chambers of sector 1A with the exception of BIL1 replaced by BIL2. A more detailed description of the barrel stand can be found in Ref. 4, C.Guyot presentation.

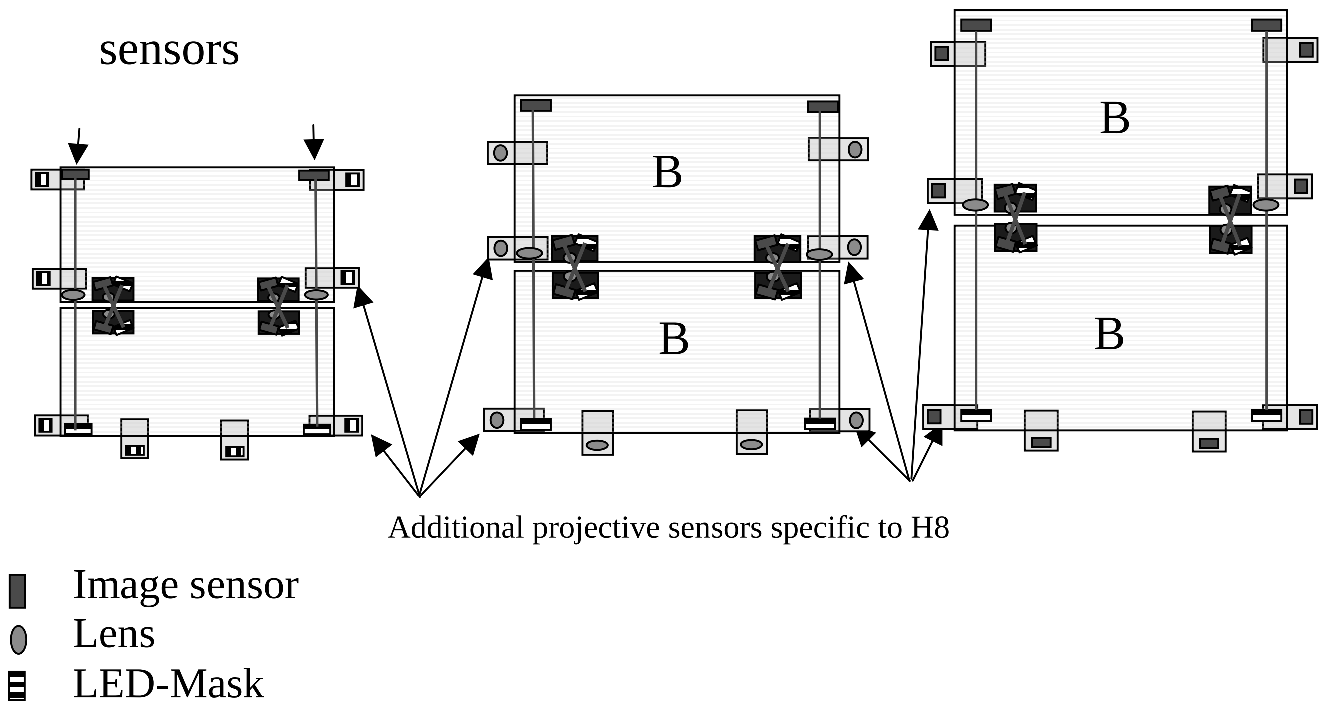
A magnet will be used to fake tracks coming from the interaction region. With a 20 GeV/c muon beams an angular spread of ±0.07 rad could be achieved with available magnets. The characteristics of the proposed magnet are reported in Table 2.

Table 2: Characteristics of the proposed magned for the 2002 H8 setup.

Type	Length (mm)	BxL (Tm)	Useful Aperture (mm)
MBPL	2000	4.06-3.11	300 x 110-200

The area illuminated by the core of the beam will be of about 1.5 m , 1 m and 0.6 m wide for the BOL, BML and BIL stations respectively. The total number of read out channels needed to cover the illuminated regions is of about 672; at least 2 CSM0 and 3 CSM cable adapter will be needed to instrument the irradiated area. The use of the magnet will allow the test of the barrel alignment concept with straight tracks, thanks to the produced angular spread. The chamber positions obtained by tracking will be compared with the results of the alignment system. In addition to that the magnetic field will also give the necessary tracks angular spread needed for autocalibration.

Figure 4: Alignment Platforms and sensors for the 6 chambers of the Barrel Stand



All the chambers should be equipped with projective and axial-praxial alignment platforms and sensors. The DCS system should be capable of reading out all the alignment sensors. Specific for the H8 test, eight new alignment platforms should be produced and installed on the chambers as showed in Fig 4 (more details can be found in C.Guyot presentation in Ref. 4).
The purposes of this upgrade of the experimental set up are the following:

- Operate a full barrel sector and accurately position the chamber one with respect to the others.
- Learning the alignment procedure with the barrel chambers
- Testing the results of the alignment system with real track
- Test the calibration of the alignment system with straight tracks
- Complete the DCS system with the reading of the alignment sensors.
- Test the autocalibration procedure with tracks impinging in different parts of the chambers.

The MPI group has requested to install a BOS chamber on a sliding support in the H8 beam. The support, to be designed and built by the MPI group, should be able to slide in order to fully expose the BOS chamber to the muon beam. The aim of this measurement is a homogeneity test of the chamber, possibly with the new ATLAS-like octal-mezzanine, to be performed with a fully equipped chamber. The possibility to have RPCs installed with the BOS chamber is also envisaged. This will allow the test of possible mechanical and electrical interference between the two different kinds of detectors. Due to the limited free space in the H8 muon area the BOS chamber should be installed between the EM and EO frames, in a position that will not interfere with the end-cap polar alignment lines. This test should be performed in the first beam period, which goes from May until the end of June, in order to do not interfere with the end-cap chamber installation (see below).
The alignment platforms, to be installed on the barrel chambers, will be provided by the Saclay group. The complete delivery of the alignment platforms is scheduled for middle of April for the BML chambers and for middle of May for the BIL and BOL chambers. The measurement of all the barrel chambers at the X-ray tomograph facility at CERN is already scheduled (preliminary schedule): BML in the second half of April, BIL in the second half of May and BOL beginning of June. This schedule requires installing the missing alignment platforms at the X-ray tomograph.
The alignment optical devices will be provided by NIKHEF together with the necessary readout electronics (7 Rasmux and 1 MasterMux) and the DAQ software (ICARAS).

3.2 The End-cap stand

The end-cap test performed in 2001/2002 (Referred to as PHASE-I) should evolve to a complete test that includes the alignment of real MDT chambers. At least two chambers per structure shall be mounted and operated. The chambers that are needed (and are illuminated by the H8 beam) are EIS1, EIL1 and EML2 provided by Boston, EML2 provided by Seattle, EOS3 and EOL3 provided by Protvino. The purposes of this upgrade of the experimental set up are the following:

- Learn how to handle and position real EC chambers with the required accuracy
- Test the EC services, electronics and DAQ
- Integration of DAQ and DCS for the EC system
- Learn about track reconstruction with alignment and DCS data
- Full test and validation of the EC alignment system
- Calibration of the alignment system with straight tracks

All the end-cap chambers should be at CERN by the end of April. The commissioning of the chambers is foreseen to happen in the BB5 (UA1) area in Meyrin. The Michigan and the Protvino groups will be in charge of this operation. The chambers from Protvino will also need the installation of the gas distribution bar. The end-cap chambers should be ready for installation by the end of June. The installation in H8 will require a chamber-handling tool that is being developed by the CERN group, based on a modification of the CMS existing tool.[16] This tool will be tested with the EM phantom chambers already in May-June. The complete installation of the six end-cap chambers should happen in the period going from the 4 to the 24 of July. The shortage of the transport personnel at CERN could have a large impact on this operation. For this reason part of the end-cap installation could be delayed to the first half of August (the possibility to ask for a dedicated transport service for the end-cap installation in the July period will be investigated).

The full set of the alignment end-cap components (optical sensors, platforms, electronics) will be provided by the Brandeis group. The presence of calibrated devices for the complete alignment test in 2002 is required. The alignment DAQ has already been developed for the 2001 test by the CERN and by the Seattle groups.

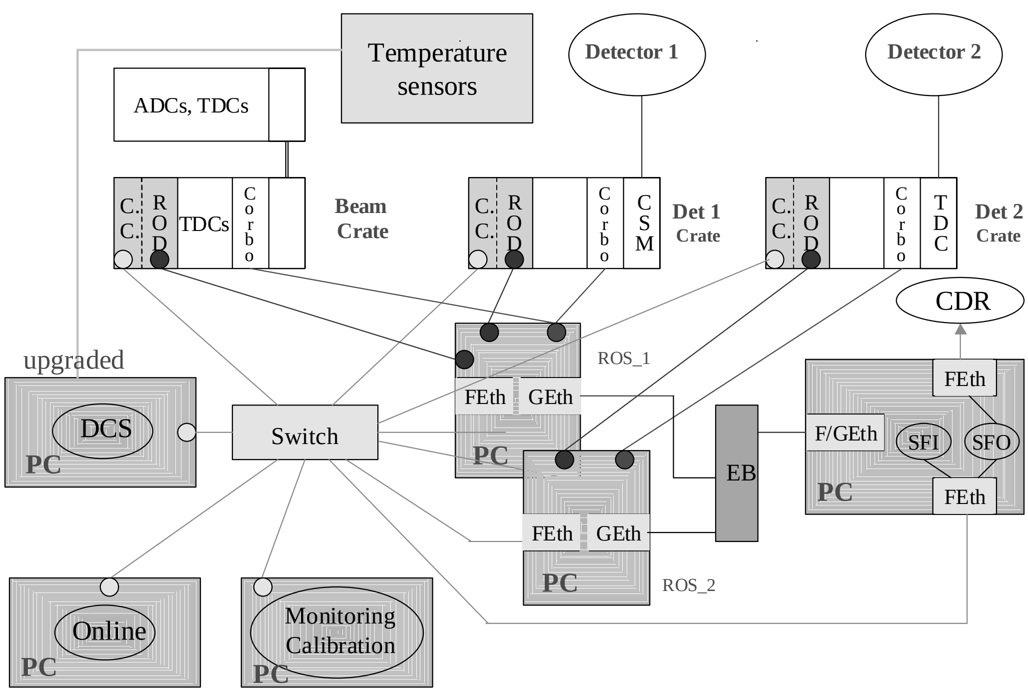
3.3 FE electronics

The minimal set of Front-End components needed for the barrel and end-cap stands is listed in Table 5. The Institutes responsible for the construction of this boards are: Rome 3 for the 4x6 signal hedgehogs, Boston U. for the 3x8 signal hedgehogs, Harvard for the mezzanines, Pavia for the HV hedgehogs.
The FE electronics components needed for the program are listed in Table 5, and will be collected from spare modules made available from some institutes and from a dedicated additional production for the test beam program G.Brandenburg is coordinating the distribution of FE modules. For the barrel MDTs the chamber-provider institutes should already have received the FE electronics components needed for the H8 test beam. The installation and commissioning of the FE electronics on the chambers is under the responsibility of the chamber-provider institutes (help from the electronics builders will be welcomed).

3.4 DAQ

The DAQ system developed in 2001 should be upgraded to permit the reading out of several MDT chambers (six for the barrel and six for the end-cap), TGCs and RPCs. The MDT readout will require a second VME crate.[†] The reliability of the operation of more CSM0s per crate should be tested before the H8 test beam period. The long distances between the CSM adapters and the VME crates in the end-cap stand will probably require the use of signal repeaters. A VME crate wiould be needed for the TGC readout, and another one for the RPC readout. Each new crate will be connected to the central DAQ via S-Link. The upgrade of the readout configuration will require a new ROS system, still based on PC, to accommodate the new links. Then a switch, having the Event Building functionality, will be necessary. This new functionality is already foreseen in the DAQ-1 prototype. A possible setup is shown in fig. 5.

Figure 5: Proposed implementation of the DAQ system for the 2002 test beam.



[†] A less practical alternative requires longer cables and four CSM0 in the same VME crate.

In addition, the system has to be upgraded to the new version of the DAQ software and the muon specific part is being improved to overcome a few problems encountered in 2001 data taking and to allow easier reconfiguration. More details on the proposed set up can be found in Ref. 4.
The Rome1 group will be responsible for the DAQ system. Each institute participating to the testbeam will provide a DAQ person who will participate to the setting-up and data taking, thus allowing for a smooth integration of all the detector components in the DAQ system. Rome1 will organize an H8 DAQ tutorial in spring 2002. The upgrade of the DAQ system is scheduled for May-June 2002.
The NIKHEF group has expressed interest to test in H8 the MROD (MDT Readout Driver) and the ROB (Readout Buffer) prototypes, if available by July. The possibility to integrate the MROD, and then the ROB, in the present DAQ setup has to be studied. As the MROD integration will represent the test of the full MDT readout chain, particular emphasis will be given to this implementation.
The Rome3 group will take care of the MDT monitoring programs, possibly based on the data analysis made with the CALIB package.[17] The possibility to perform online autocalibration will be also investigated.
Due to the number of groups willing to integrate their detectors, some rules are needed to efficiently manage the installation of different pieces.

Each group must:[18]

- Provide a detailed plan for DAQ integration, based on design and implementation of ROD crates, specifying number and type of modules and connections, schedule for hardware availability;
- Provide clean libraries and diagnostic programs running on unix machines and following "standard muon daq rules";
- Be ready to run at the beginning of July (electronics, ROD crate and detector already tested well in advance) (in June for the BOS MDT chamber)
- Provide a DAQ responsible from tutorial to data taking.

Experts must be present at CERN during data taking. The muon DAQ group should check everyone's integration feasibility and system modifications.

3.5 DCS and other Common items

The DCS for the barrel stand includes the control and the monitoring of the temperature probes, of the gas system and of the HV suppliers (in the actual set up the LV and the thresholds are provided via the CSM adapters). In 2001 part of the DCS system have been developed by the NTUA group. The extension in 2001 will be under the responsibility of the NTUA, NIKHEF and Seattle groups.
The gas system developed in 2001 for the barrel MDTs is sufficient to serve the full set of barrel (including BOS) end-cap MDTs (though the flow is marginal for the 13 chambers flushing). The chamber providers will be responsible for making the connections between the gas distribution line in the H8 hall and the chambers themselves.
The HV module used for the 2001 test (CAEN SY127) could be extended to provide HV to all the chambers. There is some interest to test and control via DCS the SY1527 module that is more "ATLAS like". The Pavia group will be responsible for the HV system.

3.6 Software issues

The alignment test will request the following software items: chamber calibration (including autocalibration), alignment reconstruction, track reconstruction, alignment and tracking simulation, chamber database and alignment database. In 2001 the track reconstruction has been performed with the CALIB [17] software developed by the Rome 1 and Rome 3 groups and with the MT_OFFLINE software developed by the LMU group. In 2002 an improved version of the CALIB program able to reconstruct tracks across three chambers and to integrate the alignment system data will be provided.
The end-cap alignment reconstruction and simulation software ARAMIS[14] has been developed by the CERN group. The barrel alignment reconstruction will be under the responsibility of the Saclay group (code ASAP[19]). The reconstruction of test beam data with "ATLAS like" tracking packages, like

MUONBOX[20] and Moore,[21] will be very interesting exercises; both the Saclay group and G. Stavropoulos have shown interest in following this project. In addition, S. Goldfarb is interested in investigating the possibility of providing access to the data via the ATLAS offline framework, Athena, for future analysis by the existing reconstruction packages.
The developing of a consistent geometry database of the MDT chambers will be another important task. The integration between the alignment and the reconstruction software is mandatory to perform the alignment test. The simulation of the test beam will be performed with GEANT4; the Pavia group has expressed interest to cover this work. The coordination of the software part is a difficult item that will require a dedicated person assuming this responsibility.

4. Sharing of responsibilities for the 2002 test activities

It is important to define the share of responsibilities and costs between the different institutes participating to this second phase of the H8 test. A physicist responsible for the general coordination of the H8 muon test beam activity should be appointed by the collaboration.
In the following subsections the missing components needed to achieve the goals described in section 3 are detailed together with the list of the institutes that are responsible for these items.

4.1 The barrel stand

The components, needed for the completion of Barrel test, are:

- 2 BOLs, 2 BMLs and 2 BILs
- Rails for the BOL chambers (30 mm)
- Gas lines for the new chambers
- Alignment platform and sensors for all the chambers, 8 special alignment platform specific for the H8 test
- DCS readout of the alignment sensors and expansion of the existing set-up to 6 chambers.
- 8 mezzanine for the BILs chamber, 10 mezzanine for the BMLs and 12 mezzanine for the BOLs + spares, (same numbers for signal HedgeHog and HV HedgeHog boards).
- 2 CSM0 and 3 CSM cable adapter + 1 spare of each
- More HV channels or HV fan out.
- Magnet with adequate field integral

The full list of components needed for the barrel stand completion in 2002 is detailed in Table 3. A more detailed list, including the sharing of responsibilities for each component is reported in Table 5

Table 3: List of components needed for the 2002-barrel test program as explained in the text.

General Item	Component
Alignment	Optical sensors /alignment platforms
	DCS/Electronics
	Readout software
	Reconstruction software
Chambers	2BILs 2 BMLs 2BOLs
	30 (Mezzanine, signal hedgehog and HV hedgehog) + spares
	2 CSM0 + spare
	3 CSM Adapters + spare
	Gas Lines
	Cabling
	HV
Calibration software	Autocalibration
Data analysis	Track reconstruction, DCS, chamber geometry and alignment

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4.2 The End-cap stand

The components needed to complete the EC test are listed below.

- Completion of the alignment system for real EC chambers: at least two additional device driver boards, 18 multiplexers, proximity sensors and masks for all chambers, 6 BCAMs per bar, cables to connect sensors to multiplexers
- Six EC chambers equipped with gas bars, Faraday cage, Proximity platforms, in-plane RASNIKs, Pt100 sensors
- Additional ELMB's
- Mounting tool to handle the EC chambers
- Other services for the EC chambers: gas system, HV
- The readout and high voltage electronics for the EC chambers: ≥24 mezzanine cards (at least 4 per chamber), >24 HV hedgehog boards, >24 signal hedgehog boards, ≥2 CSM0, ≥3 CSM adapters
- The DAQ for the EC chambers
- The DAQ for alignment devices
- The DCS for alignment bars and EC chambers (temperature, gas, LV, HV)
- The DCS-DAQ communication

The full list of components needed for the end-cap stand completion is detailed in Table 4. A more detailed list, including the sharing of responsibilities for each component is reported in Table 5.

Table 4: List of components needed for the 2002 end-cap test program as explained in the text.

General Item	Component
Alignment	Optical sensors (the few ones still missing)
	DAQ/Electronics
	Readout software
	Reconstruction software
Chambers	EOS3, EOL3
	EIS1, EIL1, EMS2, EML2
	24 (Mezzanines, signal HedgeHog, HV HedgeHog) + spares
	CSM0s 2 (+1) +Adapters 3
	Cabling
	HV
	Chamber handling tool
DCS	ELMBs
DAQ-1	S-Link, VMS crate
Calibration software	Autocalibration
Gas system	Gas connections
Data analysis	Track reconstruction, DCS, chamber geometry, and alignment

Component	number of items	complete/provide component	mechanical installation	connections (gas, electrical)	commissioning
End-Cap					
support structures	*3*	CERN/Brandeis	CERN	-	CERN/Brandeis
chamber mounting tool	*1*	*CERN*			CERN
EOL3, EOS3 mdt	2	Protvino	CERN/Protvino	Protvino	
EML2, EMS2	2	Seattle, Boston	CERN/USA	Michigan	
EIL1, EIL2	2	Boston	CERN/USA	Michigan	
Mezzanine+hedgehog(signal and HV)	8 EI 4x6	Mez.=Harvard,signal hh=Rome3,HV hh=Pavia	USA		
"	8 EM 3x8	Mez.=Harvard,signal hh=Boston,HV hh=Pavia	USA		
"	8 EO 3x8	Mez.=Harvard,signal hh=Boston,HV hh=Pavia	USA		
adapters	3	USA			
CSM0	2 (+1 spare)	Michigan			
DAQ		INFN + expert from Chamber providers			
alignm. Components		Brandeis/CERN/Freiburg	CERN/Brandeis		
alignm. DAQ		Brandeis/CERN/Seattle		Brandeis/CERN/Seattle	
DCS components		CERN		NTUA	
DCS DAQ		NTUA/ NIKHEF / Seattle			
Barrel					
layout design coordination		Saclay/CERN			
support structures (rails)	3	CERN			
BIL(2), BIL(2)	2	Pavia/Rome1/Rome3			
BML(1), BML(2)	2	LNF			
BOL(1), BOL(2)	2	NIKHEF			
Mezzanine+hedgehog(signal and HV)	8 BIL 4x6	INFN/Rome 3			
"	10 BML 3x8	INFN	INFN		
"	12 BOL 3x8	NIKHEF			
adapters	3 (+1 spare)			USA/INFN	
CSM0	2 (+1 spare)			USA/INFN	
DAQ		INFN		INFN	
alignm. Components		NIKHEF/Saclay			
alignm. DAQ		NIKHEF			
DCS components		NIKHEF			
DCS DAQ		NTUA / NIKHEF / Seattle			
auxiliary components					
magnet		CERN			
hodoscope					LMU
trigger counters					INFN
trigger					INFN
beam tracking chambers					INFN
services					
low voltages		CERN/USA			
high voltages				INFN	
gas general distribution					CERN/NTUA
gas and other supplies					CERN
offline					
alignment reconstruction		CERN/Saclay			
tracks reconstruction		INFN/Saclay			
simulaton alignment		CERN/Saclay			
simulation detectors		INFN/CERN			
database detectors		Michigan			
database alignment		CERN/SACLAY			
database DCS		NTUA/Saclay/Seattle			
BOS+RPC					
layout design coordination		MPI			
support structure	1	CERN/MPI			
BOS	1	MPI			
BOS electronics		MPI			
DAQ		INFN + expert from Chamber provider			

Table 5: Detailed list of the components needed for the H8 muon test beam program together with the sharing of responsibilities.

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