11.12 Prototyping and System tests

11.12.1 Introduction

Although the baseline technical design for the ATLAS SCT exists, a number of prototyping and system level test activities will continue over the next few years. The prototyping activities will be aimed at various optimizations in the detailed design of the silicon detectors, the front end electronics, the module, and the mechanical support structure. A number of these issues will then be studied in a series of beam tests to be held at CERN and at KEK. These beam tests will also serve as a bridge to a second set of activities aimed at optimizing the system aspects of the SCT. System aspects refer to the behavior of sets of modules and the interaction between various subsections of the SCT.

In this section of the SCT TDR a discussion of the future prototyping and system test activities will be presented. Because of different prototyping status for the barrel and forward detectors, many of the planned system prototyping described in this section for the SCT Forward Disks o are considered in Section 11.8.8 for the SCT Barrel.

11.12.2 Detector Prototyping Plans

Section 11.3.4 described ongoing prototype studies of silicon strip detectors for the SCT. These studies have confirmed, on a small number of detectors, the possibility of meeting the ATLAS design specifications during the expected LHC 10 year operating scenario. To meet the ATLAS construction schedule, orders of ~20000 detectors must be placed at the end of 1998. Prior to that, extensive system prototyping is required, using detectors of the final design, and from each potential supplier. Prototype studies will include:

- irradiation of at least 10 detectors from each manufacturer to LHC fluences, and subsequent device measurement as described in Section 11.3.4 with an emphasis on verifying strip robustness at the level of 97%,
- the use of these detectors for module prototyping; in addition to ongoing module prototypes of the current version of the baseline design, at least 50 barrel and forward pre-construction ‘module 0’ prototypes will be constructed in 1998 by the 7 module construction centres, and several of these modules will be exposed to radiation at LHC levels.

Between 25 and 50 detectors from each potential supplier will be delivered in 1997, following the detector design of Section 11.3.2; a second preproduction order will be submitted in 1998. Potential suppliers are listed in Section 11.3.3.

11.12.3 FEE Prototyping Plans

The ATLAS binary readout architecture was described in Section 11.4.4. This architecture is built upon a development process which has been ongoing for several years and upon the application of this approach in a number of high energy physics experiments [11-96], [11-97], [11-98]. These earlier applications provided useful experience with the architecture but did not use chips which meet ATLAS specifications. A number of prototype chips developed and tested in the last two years represent a clearer attempt to meet ATLAS requirements. FInally, the two chip sets that are now under development are full-functionality ATLAS prototypes that could be used in the experiment if they prove to meet all the requirements. These are the CAFE-M/ABC chip pair now being fabricated by Maxim and Honeywell and the ABCD chip scheduled to be submitted to DMILL in late Spring of 1997.

Table 11-41 lists existing and planned ATLAS SCT prototype front end electronics and their purpose. The CAFE and CDP128 chip set has demonstrated a full 128 channel solution with acceptable power, noise and radiation performance. The SCT128B should demonstrate the same acceptable solution in the new DMILL biCMOS process and was designed to use the same data acquisition system as the CAFE/CDP128 system to facilitate testing and comparison. A 32-channel version of the SCT128B has been built in DMILL and was shown to have good performance. In addition to validating the DMILL process, the SCT128B will allow validation of an alternate pipeline design using a shift-register rather than the SRAM pipeline of the CDP128.

The next set of chips, CAFE-M, ABC and ABCD are designed to meet all ATLAS specicifications. The CAFE-M is a transfer of the CAFE design to the Maxim (previously Tektronix) bipolar process along with the added feature of programmable control of the calibration and threshold amplitudes via analogue levels from the companion ABC chip's DACs. The Maxim bipolar process is an evolution of the Tektronix process used already in a binary front end design for ZEUS [11-96]. The ABC builds on the pipeline of the existing CDP128 chip and adds many system features for ATLAS-SCT, for example data compression and DACs to control CAFE-M calibration and threshold amplitudes. The ABCD is designed to be functionally identical to the CAFE-M/ABC chip set in a single biCMOS chip and will have all of the new features that are being introduced in the CAFE-M and the ABC. The details of these new chip sets are described in detail in Section 11.4.4 since they are full ATLAS-SCT readout ICs.

If the CAFE-M/ABC and the ABCD chips meet design specifications, they will be ready for production. Any further further pre-production submissions will fix problems with these full-function chips or merely implement design changes to reduce die area.

11.12.4 Module Prototyping Plans

The baseline modules, centre-tap for the barrel region and end-tap for the forward region have been described in Section 11.5.3. During 1997 well defined objectives exist for the prototype and test programmes, and targets for more ambitious sub-units are given for 1998.

For the barrel region, the centre-tap modules described in Section 11.5.3 will be prototyped to include the current baseline detectors, baseboard materials, hybrids, front-end readout electronics and support structures. As shown in Figure 11-82 of Section 11.8, six modules together with the necessary cabling will be combined into a single barrel structure, for powering and readout. This addresses some system aspects that will be encountered in the larger barrel assemblies needed for the final ATLAS installation.

Following the successful production of significant numbers of barrel modules during the current year, the next aim moves to incorporating module-rows into the larger geometry of a cylindrical barrel assembly (see Figure 11-116). Using a prototype barrel cylinder, several rows will be populated, again with modules that possess the necessary electronics, cooling and readout to move to the next level of system testing.

The option of assembling some additional rows of "mechanical" modules, to examine the practical issues of building up a large tiled surface area will allow initial studies of more global mechanical and construction issues. This stage is expected to be completed by the end of 1998.

Table 11-41 Summary of completed and planned prototype chips.

Chip name	Foundry and Process	Features studied and status
CAFE	AT&T CBICV bipolar process	1) Gain and threshold uniformity over 128 channels 2) Efficiency and occupancy after irradiation to LHC levels. *Completed.*
CDP128	Honeywell rad-hard CMOS process.	1) Deadtimeless SRAM pipeline. 2) Acceptable noise generation with simultaneous data cellection and transmission. 3) Acceptable performance to LHC radiation levels. *Completed.*
SCT128B	DMILL radhard biCMOS process	1) Deadtimeless shift-register pipeline with acceotable power dissipation. 2) Noise performance with analogue and digital circuits on same chip. 3) Gain and threshold uniformity over 128 channels. 4) Performance to LHC radiation levels. *Tests underway.*
CAFE-M	Maxim bipolar process	1) Programmable calibration and threshold from companion ABC chip. *In fabrication, due 7/97.*
ABC	Honeywell rad-hard CMOS process	1) Data compression. 2) Full ATLAS-SCT command, data transmission and redundancy protocol. 3) LVDS input/output digital data bus. 4) Programmable calibration and threshold using on-chip DACs. *Design complete, expected 7/97.*
ABCD	DMILL radhard biCMOS process	1) Combined analog/digital system on single chip 2) Data compression. 3) Full ATLAS-SCT command, data transmission and redundancy protocol. 4) LVDS input/output digital data bus. 5) Programmable calibration and threshold using on-chip DACs. *Expected fabrication 6/97.*

In the forward region programme for 1997 a significant number of electrically working modules will be constructed. Unlike the barrel, each radial ring needs a different module with different wafer designs. The aim is to produce examples of each of the three types of module with the total number being of order 6 to 10. These will then be operated individually and then in increasing numbers integrated on to cooling and support structures to form a sector of overlapping modules. The support structure will be a quadrant of a disc populated with a mixture of electrical modules and dummy thermal modules.

With the production of more forward modules during 1998 the aim will be to completely equip the prototype disc quadrant by replacing the dummy modules by electrical modules as these and their readout systems become available (see Section 11.8 and Figure 11-85). This will require 34 modules in total. The operation of this assembly will provide a test both of the electrical sys-

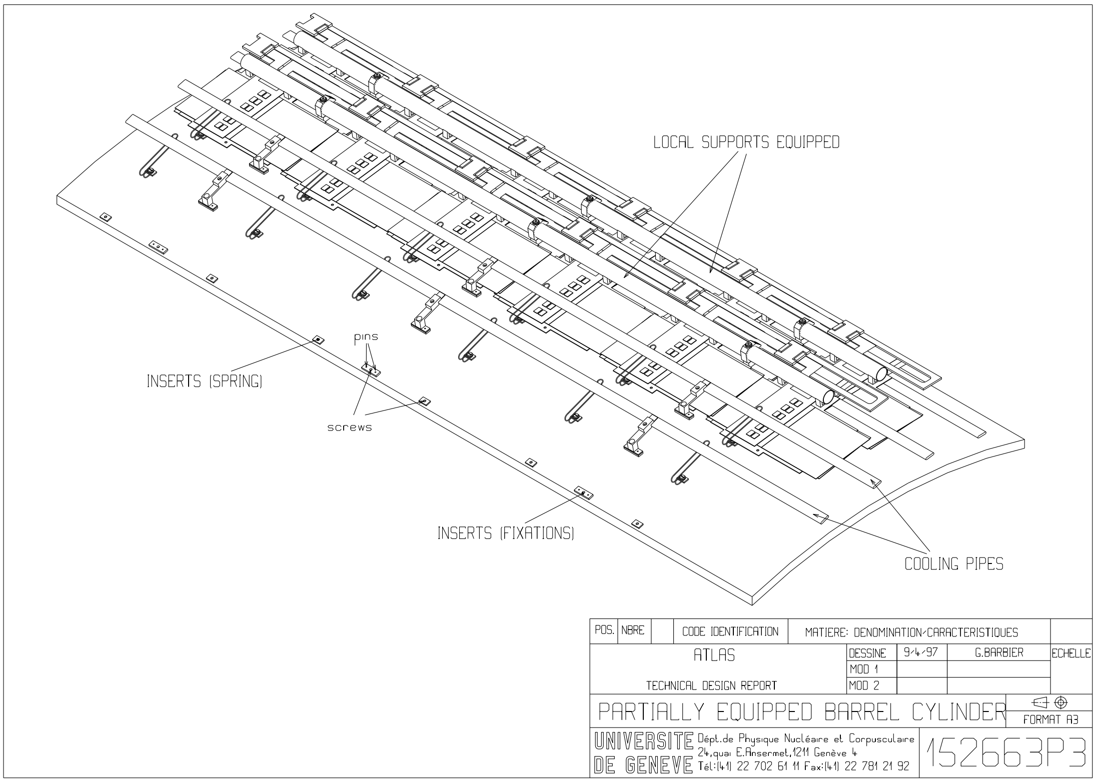

Figure 11-116 A 3D view of a partially equipped barrel cylinder.

tem and readout and of the cooling system. The mechanical and thermal testing of the support structure is described separately in Section 11.12.5 and Section 11.8.

In summary, a co-ordinated and complementary set of prototype module tests with their ancilliary equipment, including cooling and mechanics, is planned for both the barrel and forward projects in 1997 and 1998, within an integrated programme that will provide confirmation by the beginning of 1999 of a successful overall SCT assembly.

11.12.5 Mechanical Prototyping

This section describes the plans for future prototyping of mechanical structures and materials for the SCT. The tests described in this section fall into three categories: material tests, tests of mechanical and thermal properties of prototypes, and tests of processes to be performed with detector components

11.12.5.1 Material tests

Previous material studies are described in Section 11.8.8. Studies which are ongoing or planned in the near future include:

1. An investigation of the properties of a 3 layer carbon fibre (CF) skin. The skin will be layed up with a sequence of 0,-60,60 degrees and each layer will be a 60 micron thick unidirectional tape layer of RS3 impregnated XN50 prepreg [11-99]. Data from these studies will be compared to the results previously obtained with more conservative skins having

a larger number of layers and representing slightly more radiation length. The feature of this skin is that it is not intrinsically symmetric and will not be flat unless it is made part of a sandwhich structure with the same skin on the other side of the sandwhich. Finite element simulations indicate that the above skin could be used to construct the forward SCT disks.

2. A study of the CTE for cooling contact blocks made from CF composites, TPG [11-100] or Carbon-Carbon. They would be compared with Alcontact blocks in terms of radiation length, conductivity, cost, machineability and mechanical stability.
3. Machining of CF skins, blocks and honeycomb structures. These tests are supposed to investigate the following points: precision drilling/reeming in of location holes in CF blocks, machining of CF blocks to shape and the machining of CF-honeycomb structures for buried inserts and integrated channels.
4. A measure of long term creep stability of mounting blocks glued to a carbon fibre skin under shear load in a thermally accelerated creep test and a comparison to similar results for inserted contact blocks.
5. A continuation of adhesive studies for module construction.
6. A study of the radiation hardness of room temperature curing thermal epoxies, and of thermally conductive contact grease to neutrons and charged particles, including thermal conductivity, tensile strength and dimensional changes both pre and post-irradiation.

11.12.5.2 Tests of mechanical and thermal properties of prototypes

The most important planned studies include:

1. An investigation of the properties of cooling channels integrated into the skins of the carbon fibre disks for the forward SCT; if demonstrated, such channels may reduce the material in the cooling system of the forward SCT. Properties under investigation include:
   a. the flow characteristics of several channel types,
   b. thermal contact between the cooling fluid and the top surface of the skins,
   c. the burst pressure of the channels in case of accidental over pressure operation,
   d. the performance of moisture barriers inside the channels in terms of moisture absorption, corrosion resistance, and deflections of channels integrated into sandwich structures.
2. A section of a forward SCT wheel will be instrumented with the baseline external aluminium pipe cooling system to test the deflections of the disk resulting from the stresses building up in the pipe during cool down. Separate corrosion studies of aluminium tubing following long-term irradiation will also be carried out.
3. A complete forward wheel (see Section 11.12.7) will be constructed and measured for load etc, and ultrasonically to establish quality control techniques for the disk and cooling channels. A section of forward space frame (see Figure 11-117) will be used as part of the forward SCT system test.
4. Tests of the barrel interlinking wheels (see Figure 11-118). This wheel will be made from RS3-XN50 CF laminate with skin thicknesses of ~0.2 mm. A section of the wheel is being made and tests will include sector deformation measurements under load and a comparison of deflections to FE-Model calculations.

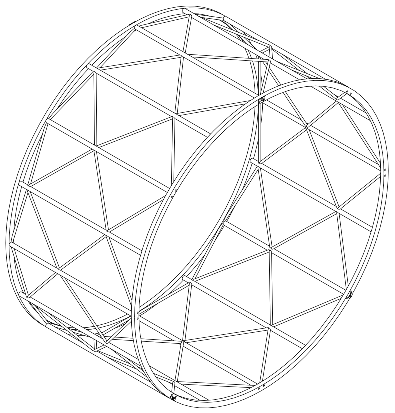

Figure 11-117 Schematic of support space frame for forward wheels.

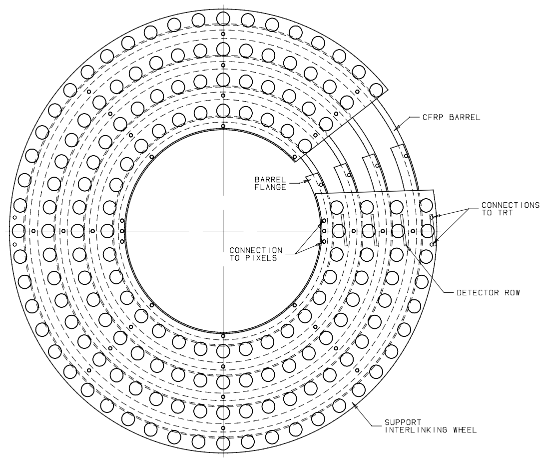

Figure 11-118 Interlink plate for barrel cylinders.

5. The static deflections of a full prototype carbon fibre barrel now under construction (see Figure 11.8.8) will be measured as a function of load and temperature (both ambient and local), and compared with relevant FE analyses. Machining and insert studies will be made with this barrel, with the aim of equipping it in part for full mechanical and electrical tests.

11.12.5.3 Tests of component handling and assembly

Tests in this category will mainly be concerned with the handling, assembly and installation of detector sub-groups (see Section 11.12.7 for the forward wheels).

1. A dummy local support section and a disk will be built along with a substantial number of dummy modules, to study the manipulation of barrel and forward modules, and their associated connections (initial studies have been described in Figure 11.8.8).
2. The mounting of local supports onto a cylinder will be tested. A dummy section of a cylinder, and the full cylinder prototype, will be used to mount several local supports. Tests will require special jigs that allow safe handling of fully equipped local supports. Tests of service connections and their robustness will be made.
3. The filling and draining process of a realistic cooling system will be tested
4. A mechanical and operational compatibility study of the cooling pipe, module, module services, local support and cylinder will be made.

11.12.6 The SCT Beamtest Programme 1997-1999

The performance of prototype SCT modules has been studied in beam tests at KEK and in the H8 beam line at CERN. Since 1996, 12 cm length modules have been assembled using 60 x 60 mm^2 *n-on-n* single-sided detectors with 75 µm pitch, and have been read out at 40 MHz with binary readout electronics with the required shaping time of close to 20ns. A presentation of relevant results is given in Section 11.5.4.

The plan for evaluation of the SCT detector modules in beams during the years 1997-1999 is described below.

11.12.6.1 Overview

Detailed studies of barrel and forward SCT module will take place in the H8 beam line both in 1997 and 1998. At KEK it will be possible to perform similar module evaluations.

The purposes of the SCT beam test program are a systematic performance evaluation of completely irradiated and un-irradiated SCT modules, a study of the operation of many SCT modules simultaneously in a system test, and practical operational experience in an experimental environment (cooling, readout, calibration, control and monitoring, alignment, etc).

A significant milestone towards establishing full operational viability of the ATLAS ID is the successful construction and testing of a prototype sector of the complete barrel tracking system. The H8 beam test area has been arranged to allow combined running of the ATLAS barrel detectors, initially with pixel modules and the TRT for pattern recognition studies, and later with the barrel calorimeters as well.This study of the combined pattern recognition performance, efficiency, and resolutions, will depend upon parameters such as the combined synchronisation, track reconstruction, and alignment, which can only be studied with combined data and readout from all ID systems.

11.12.6.2 The beam parameters and beam area infrastructure

The ID tests will take place in H8 beam at CERN is the presence of a 1.56 Tesla magnetic field. The beam line is well suited to ATLAS ID studies, since it can provide beams comparable with the intensity expected in the position of the ATLAS tracking detectors.

Table 11-42 Particle beams in the H8 beamline.

Beam	Energy (GeV)	Intensity
Electrons	10-300	Up to 10^6/spill
Charged pions	10-300	Up to 10^7/spill
Protons	50-450	Up to 10^6/spill
Jets		Foil in beamline

The Morpurgo [11-101] magnet in the H8 beamline at CERN is a 1.5-2 Tesla super-conducting dipole magnet of length 4 metre and diameter 160 cm. The H8 beam runs down the centre of the cylindrical magnet volume; within 1 metre of the magnet centre the vertical field is uniform to 10%. The ATLAS ID devices are tested in this position. A rail system has been constructed which allows fast access and installation of equipment from both ends of the magnet.

At KEK a 4 GeV pion beam, with intensity 10^3 particles $cm^{-2}s^{-1}$, over a 2 second spill, will also provide conditions for SCT module tests.

The ATLAS SCT groups have developed the necessary infrastructure in the H8 area for the SCT module tests. In particular,

- High precision beam telescope modules provide position measurements to 2-3 μm within a limited aperture (32x32 mm^2). The telescope consists of 8 planes of silicon detectors, organised in 4 modules each providing one x-plane and one y-plane, thus providing high precision measurements of the tracks in front of and behind the modules under test.
- The SCT modules can be rotated and translated in x and y to explore their performance at various impact angles and positions.
- Gas and liquid cooling are available to allow operation of irradiated modules in the beam at temperatures -5 - 15 ^{o}C.

At KEK three similar telescope modules and nitrogen gas cooling allow the testing of irradiated and non-irradiated SCT modules.

11.12.6.3 Measurements

The following operating parameters are chosen to simulate the conditions expected during ATLAS operation:

- Magnetic field: 1.56 T.
- Operating Temperature: -7 ^{o}C.
- Rotation Angle: Lorentz Angle (12^o) ±15 ^{o}.
- Bias conditions appropriate to operation after high fluence.
- Beam intensity to obtain mostly single track events in the slow-shaping beam-telescope system (3 x 10^4 /spill) or similar to the expected intensities in ATLAS (3 x 10^6 /spill).
- Simultaneous read/write (data registration) of beam particles by the front end electronics during the readout of previous triggers.

Modules are evaluated by scanning the threshold at each operating condition (bias and detector angle). A typical threshold region for high efficiency is around 1.0-1.4 fC equivalent input charge. The efficiency is determined using the silicon telescope. The noise performance of the detectors is characterized by the "off-track occupancy", which is the number of hits >500 μm from a track divided by the total number of hit strips. The occupancy from electrically noisy channels is measured using beam-off data.

Bias dependence of response

To determine the operating conditions, bias voltage scans are performed with no applied magnetic field and at 0^o rotation angle.

Efficiency and noise occupancy

The parameters having direct application in tracking programs are position resolution, efficiency and noise occupancy. They can be determined in threshold scans for the modules. Using the high resolution beam telescope these parameters can be studies as a function of the track impact point on the SCT modules (i.e. as a function of the distance to the nearest readout strip). For the ID tracking system the same parameters will depend on internal alignment, overall synchronisation and environmental noise and should be measured in a combined run. The presence of all detectors will also provide important tests of the ID performance with a realistic material distribution.

Rotation in a magnetic field

The ATLAS silicon tracker will be operated in an axial magnetic field of 2T. If the detectors are rotated by the Lorentz angle relative to the radial direction, the effective crossing angle at the edges of the 6cm wide modules located at 30cm radius will be $\pm 13^0$ for 1GeV/c particles. Therefore the Lorentz angle must be determined and the angular response of particles has to be measured. Based of measurements of [11-102] in a 1T field, a Lorentz angle of $+12^0$ is expected in the magnetic field of H8. The detectors are rotated between -12^0 and $+27^0$. To measure the efficiency as a function of the inter-strip position, the high resolution telescope is used. For crossing angles $>15^0$, tracks always traverse more than 1 strip.

Position resolution

The position resolution is extracted from the residuals of found hits relative to the extrapolated track positions. The tracks are extrapolated using the high resolution beam telescope or from other SCT modules in the test beam.

Determination of optimal tilt angle

It has been shown that the efficiency and position resolution evaluated at 1fC threshold are nearly independent of the rotation angle. At larger thresholds, the efficiency becomes a function of the angle, and the tilt angle should be optimised. This is close to the Lorentz angle for electrons, given that the readout is on the *n*-side. But at larger tilt angle, the track length and charge deposition are increased, and at 27^0, the largest rotation studied, this was a 12% charge correction. The angular distributions can be corrected for this track length variation by re-scaling the threshold considered by the cosine of the incident angle.

High intensity operation

During LHC operation, the ATLAS SCT will experience an instantaneous rate of $\sim 10^6 cm^{-2} sec^{-1}$. To test the operation of detectors under realistic LHC operating conditions, the H8 beamline rate was increased to 2.6×10^6 cm^{-2} $spill^{-1}$. This is close to the instantaneous rate expected at ATLAS, and ~20% of the sustained rate.

11.12.6.4 The SCT support structure with integrated cooling and installation in the H8 beam

For the beam test in 1997-1999 an improved SCT barrel support structure will be built, to allow the testing of modules in-line or organised in layers with efficient liquid cooling of the modules. The structure models the barrel local support structure as detailed in Section 11.8.4. Several short local supports allow installation of modules with the strips in the correct orientation with respect to the vertical B-field. The cooling is supplied by a binary ice machine, and the entire structure is enclosed in an insulated box that enables flushing by cold nitrogen. Nitrogen is transferred to the H8 SCT setup from the central LAr cooling plant in the beam area. The rail system allows access from both sides of the magnet. Figure 11-119 illustrates the individual pixel, SCT and TRT tests.

The ID barrel detectors can be tested as a system in the H8 beam-area by placing successive detector layers in-line at positions corresponding to radii in the ATLAS barrel detector and in a field close to the ATLAS ID field configuration. The ATLAS calorimeter systems can be placed behind the magnet but the distance between the ID systems and the ATLAS calorimeters will be limited to 2 m. Figure 11-120 shows the combined system test.

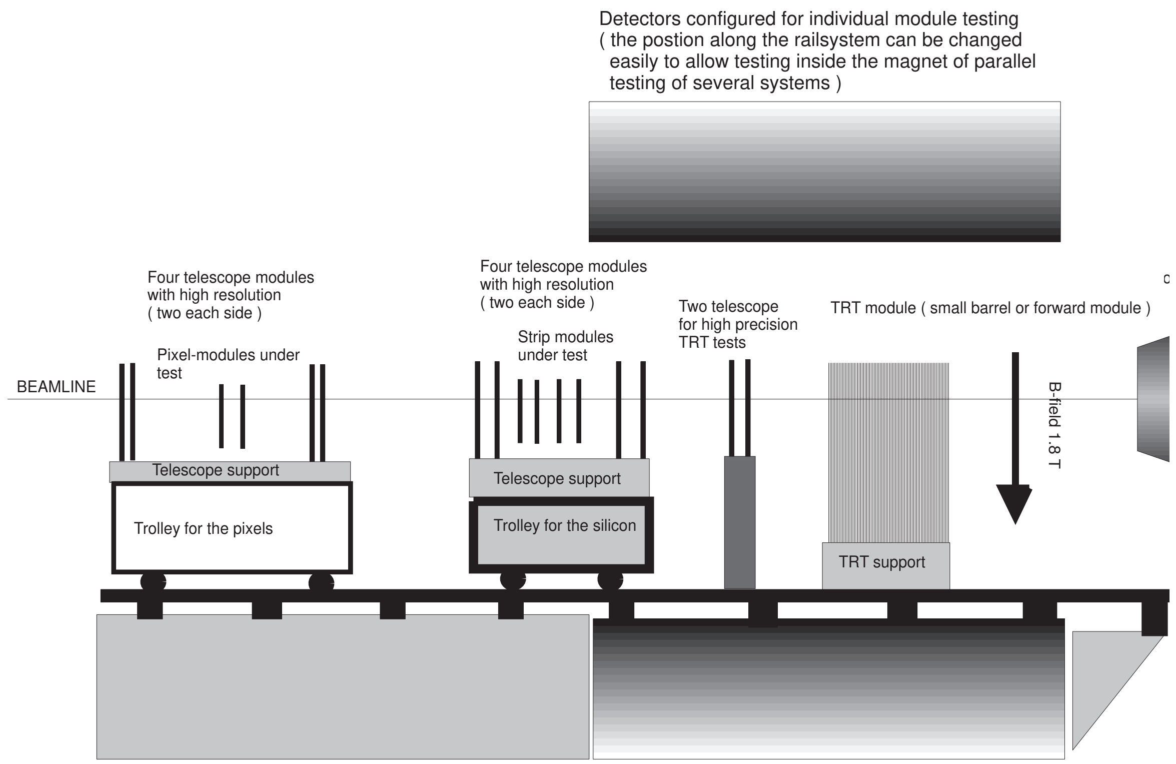

Figure 11-119 Layout of SCT, pixel and TRT prototypes in the H8 beam-line.

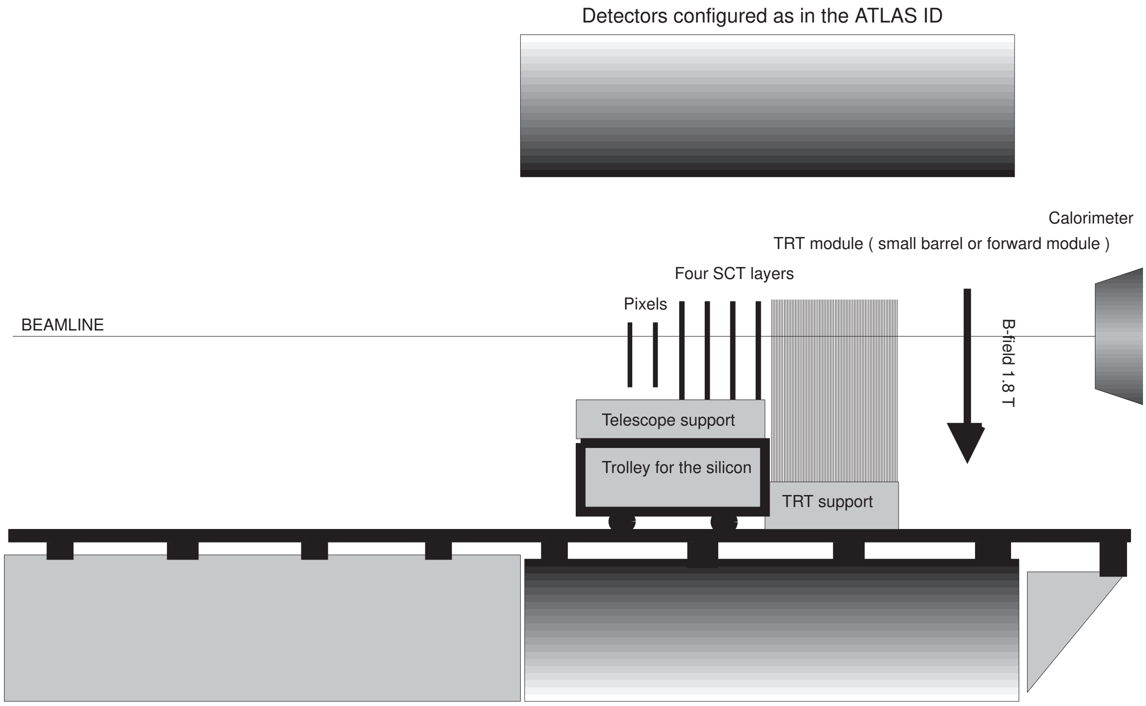

Figure 11-120 Schematic of beam line with system pixel, SCT and TRT tests.

11.12.6.5 DAQ

The SCT modules are read out by prototype DSP custom VME readout and control modules. These modules are used in laboratory tests as well as in the test beam. Software to perform basic functions on the modules, and to communicate with the host VME processor, has been provided.

VME bias cards have been developed and are mounted on a standard 6U card, within a standard EUROcrate. The cards provide the low voltages needed for the modules. The detector bias is generated separately and is fed through the same card to the modules.

In the test beam, a RAID Real-Time Unix processor runs the DAQ software. The data are recorded on an NFS mounted local disk and are accessed there across Ethernet for monitoring and transfer to central storage.

The DAQ is being developed further and will be compatible with the central ATLAS beam test DAQ from 1997. This will allow the SCT system to participate in a combined run with all other ATLAS sub-detectors. The central DAQ [11-103] provides event building functions, parameter data bases and monitoring interfaces.

Stand-alone running by separate systems will nevertheless be the most common operational mode.

11.12.6.6 Items and time schedules

Table 11-43 Beamtest Milestones.

Barrel test beam program	
August 1997	Beam test.
	Inline module tests in H8. Binary modules on support cooled in a realistic way by local supports with integrated cooling.
	Use of available electronics (LBIC+CDP and SCT128B), both with HAC's and support cards.
	Some detectors available and built into modules but most detectors will be available late summer (marginally ready for this test beam period).
Febuary 1998	KEK testbeam.
July 1998	Beam test in H8.
	Modules built from CAFE-M+ABC and ABCD and the detector batch from spring 1997. Modules irradiated as complete modules.
August 1998	System tests with pixels, TRT and calorimeters in H8 with SCT modules (same SCT hardware as above).
Summer 1999	System tests in H8 with the calorimeters, using module-0 batch.
Forward test beam program	
August 1997	Testing of in-line modules in H8.
August 1998	Testing of modules in H8.

All the SCT tests in H8 and at KEK are based on the construction of two generation of modules:

The beam tests in 1997 and 1998 will be based on the readout electronics currently available or being developed and the detectors currently being designed and processed (the barrel and forward detectors). The hybrids for these modules are presently being designed. The intention is to construct and irradiate some modules as complete units before evaluating them in a beam.

The module-0 batch, based on pre-construction batches of electronics and detectors being developed for the autumn of 1998 will be used in the 1999 beam test.

To efficiently test these modules in a beam several components must be developed:

- Low mass cables and connectors are being developed which can be used in the beam tests.
- Fibre optic readout or alternatively STP cables will be available on the time-scale of the beam tests.
- HV and LV biasing units are being developed for the beam test.
- New module VME bias-cards are being constructed.

11.12.7 System Tests

11.12.7.1 Barrel system tests

Progressive systems tests of the barrel modules and assemblies will take place between 1997 and 1999 through the programmes already described for the beam tests (see Section 11.12.6) and for the barrel module prototyping (see Section 11.12.4).

11.12.7.2 Mechanical forward system tests in the period 1997-1998

A mechanical system test of all essential forward SCT components will be carried out during 1997 and 1998. The test will focus on an evaluation of the forward tracker disk design, and its influence on tracker performance. The aim is to fully test an optimised disk design before the start of production in 1999. This includes:

- Studies of the thermal and mechanical performance of the system, including quality control.
- Integration issues such as service routing, access and installation.
- Studies of the FSI alignment system.
- Development and organisation of the assembly process for the attachment of modules to the disks.

To create realistic operational conditions at least two disks will be equipped on support rails, in a known gas volume. The list of items given below is considered to be essential to fulfil the above purpose.

- Both sides of the disks will be equipped with dummy modules to study the mechanical and thermal properties of the disks themselves. The disks will carbon fibre structures close to the final design.

- Dummy versions of all services from modules, cooling, alignment and the DCS will be implemented on both disks to study the routing of services and the assembly of modules and other components onto the disks.
- Lines of sight for FSI alignment, and associated gas conditions, will be monitored.
- A prototype space frame and associated rail support structure designed to meet the SCT specifications will be studied for its stability.
- An active heat insulation of the SCT volume against heat influx from the TRT will be studied.
- A full binary ice cooling system will correctly simulate the SCT conditions.
- A small number of operating modules will be implemented in the setup. This will allow a study of pick up and crosstalk as a function of cable routing and operating conditions by simple pedestal measurements.

Figure 11-121 shows a 3D schematic of the suggested setup. The disks are mounted in the space frame which itself hangs on the support rails of the dummy cryostat with its arms reaching through the dummy TRT ring. The dummy cryostat will be made of transparent perspex to allow optical inspection of the inside of the setup. The dummy TRT is a space holder element representing the physical boundaries of the real TRT. It will be equipped with heater foil on its inner radius to simulate changes of the TRT temperature. The main external functional elements of the system test are:

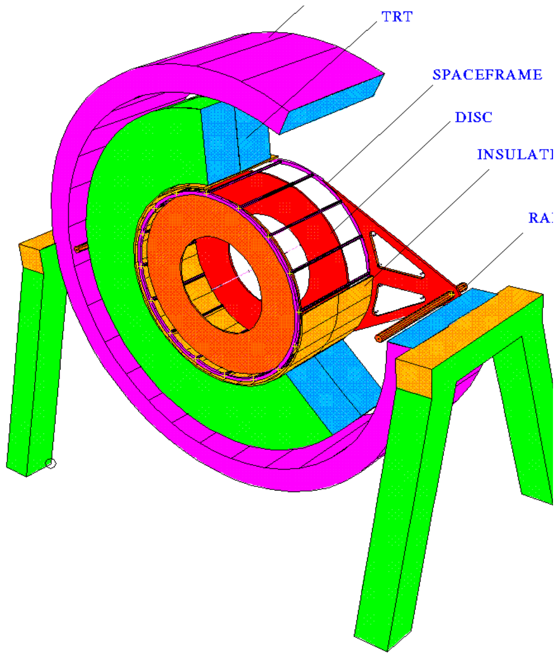

Figure 11-121 3D schematic of the Forward System Test setup.

- binary ice cooling system (40 KW under DCS control),
- module power supplies for dummy silicon modules (1.3KW under DCS control),
- module power supplies for real silicon modules under DCS control,
- back-end DCS (Detector Control System) responsible for control of subsystems and sensor readout,
- sensors in the setup and the auxiliary system include PT-100 platinum resistance thermometry, pressure sensors for fluid and gas, humidity sensors, strain gauges for deflection measurement, DCS control,
- DAQ readout for real silicon modules.

In addition to the functional elements described above, the following infrastructure will be implemented:

- an IR-scanning system with a resolution of approx. 0.5 ^{o}C viewing the full disk area,
- a 3D coordinate measurement machine covering a volume of approximately 1.2 x 1.2 x 0.6 m^3 with an accuracy of 4 x 4 x 20 μm^3 ,
- Clean rooms of class 100.000 with temperature stability of 0.5 ^{o}C and humidity control of ±10 % .

The 3D-coordinate measurement system will be used to survey all components prior to and after each step of the assembly and installation procedure. It will also be used to measure the disk positions when installed inside the space frame. During all tests the temperature distributions on the disks and on the dummy detector modules as well as all parameters of the atmosphere and wherever possible the distortions of the disks will be monitored. The tests can best be summarised in five groups:

1. Variations of module power: The influence of global and local variations of the power consumption inside the detector modules will be studied. Scenarios include a general increase of power consumption for all modules simulating the effect of radiation damage, and extreme increases of single module power consumption due to localised damage or malfunction.
2. Variations of external temperature: The power dissipated in the TRT will vary considerably with particle flux. This will be simulated in the tests by changing the temperature of the dummy TRT with a heater blanket on its internal perimeter. Both active and passive insulation of the SCT will be studied.
3. Changes of cooling parameters: The parameters of the cooling system to be studied in this group are the ice concentration, the overall coolant flow and the incoming coolant temperature.
4. Noise and crosstalk: The service routing and grounding scheme will be optimised to reduce the amount of pickup.
5. Operation procedures: During all the above tests the procedures necessary during the normal operation as well as installation and commissioning will be repeatedly exercised. These procedures include connection and disconnection of all services on the level of modules and disks, filling and draining of the coolings system of a complete disk or a quadrant of a disk and connecting and disconnecting a disk to the space frame.

The major milestones for the forward SCT system test are listed below with their expected dates:

- end of generic RD on disks - June 1997
- delivery of disk - November 1997
- end of tests on "naked" disks - January 1998
- disks assembled with dummy modules - April 1998
- disks installed in space frame and surveyed - May 1998
- space frame with disks installed in the setup - June 1998
- end of tests - December 1998

4.5.6.2 Electrical forward system tests in the period 1997-1998

The readout of individual modules has been accomplished as described in Section 11.5.4. As for the barrel, increasing numbers of modules must simultaneously be read out with the modules and services in the final geometrical configuration. The tests will investigate the effect of pick-up, crosstalk and common mode noise as functions of the module location, service routing and grounding and neighbourhood module configuration.

There will be an ongoing programme studying groups of modules with increasing numbers. The setup uses a 90^{o} sector of a forward disk equipped with a cooling system, all necessary, full length services for the modules in any location on the sector and sufficient low and high voltage power supplies. Several sets of shorter cables will allow the measurements of coherent noise as a function of cable length. It will require a readout system capable of reading out and controlling up to twelve modules. The aim is to progressively populate a sector with fully functional modules. The intended size of the sector is four consecutive modules per ring because this will be a fully populated environment for each geometrically different position on a disk in terms of nearest neighbour modules and services.

11.12.8 References

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