7.6 Integration

In this section we summarize the final integration of the major detector sub-elements: the barrel half-shells, the endcap units and the internal services and related supports. The integration of these elements was carried out in large clean-room area (nominally about class 10,000) that was used to assemble all of the Inner Detector sub-detectors.

The pixel detector with internal services was assembled on an 8m long,custom built frame, the Integration and Test Tool (ITT). The ITT was constructed to temporarily support each element with high precision until the fully integrated package provided the final support and to allow rotation about the beam pipe axis to facilitate assembly and testing. The basic sequence of assembly was: barrel region outer layers, beam pipe(with temporary supports), barrel B-layer, endcap units, support units for the beam pipe and internal services and finally the internal services. Testing to verify functionality was done as possible in between major assembly steps. The basic assembly sequence is described below.

Barrel Layer 2 and Layer 1 were in turn constructed by clamping together the respective half-shells pre-loaded with bi-staves (described in section 7.2). These layers were inserted sequentially into the global support frame mounted on the ITT. The Layer 1 and Layer 2 exhaust pipes and capillaries were added only after both full shells were in the support frame.

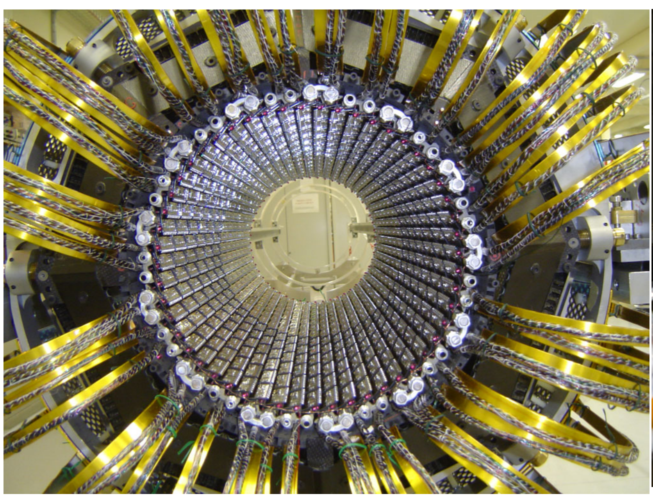

Fig 7.6.2 (a) *Pixel Layer assembled into global frame and held on the ITT as it appears from looking toward the IP along beam line.*

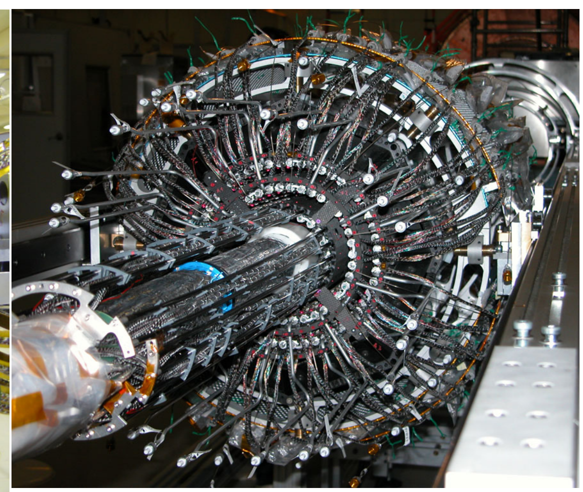

Fig 7.6.2 (b) *The barrel of the Pixel Detector completed.*

For the B-layer, exhaust pipes had to be added prior to clamping the shells because of the reduced access to fittings (at the ends of the bi-staves) due to the proximity of the beam pipe. For this reason all the cooling pipes for the B layer are on the C-side, instead of divided between A and C sides as for the outer layers. The B-layer half-shells were clamped together around the beam pipe after the beam pipe was loaded onto the ITT. Figures 7.6.1 (a) and (b) show, respectively, Layer 2 in the support frame and the full barrel completed with the beam pipe. Electrical services were temporarily folded back onto the frame.

Both endcap units were fully integrated into their respective support frames, including attachment of exhaust pipes and capillaries, prior to transport to CERN and loading on the ITT. Each endcap was moved into position on the ITT and bolted and pinned for accurate location to the barrel support frame section.

The integration of the Beam Pipe Service Support (BPSS) followed the attachments of the endcaps. The BPSS has the dual function to support and adjust the position of the beam pipe and support the Services Quarter Panels (SQP, described in section 7.4).

The four SQP's per side were mounted sequentially on their respective BPSS, and connections to the detector made immediately after mounting. SQPs were lifted by a small crane and guided by hand onto the BPSS for final connection. Cooling pipes were connected first and tested. Electrical connectors were then plugged into the SQP, dressed, and tested. Figure 7.6.2 shows how the package looked with the first SQP installed. Figure 7.6.3 is a view of the detector connector region (PP0) after all the services had been connected.

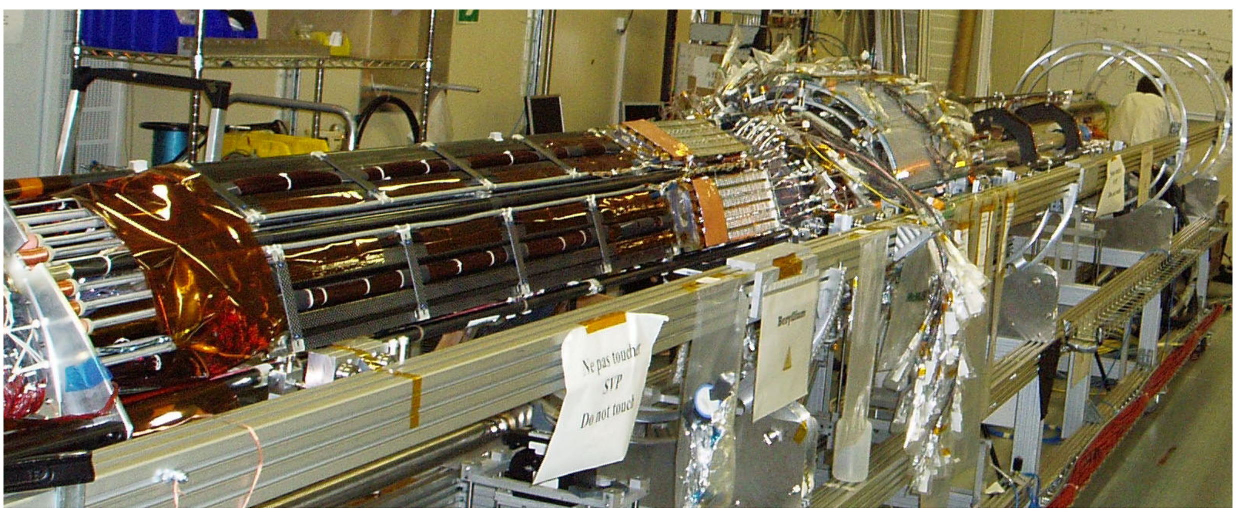

Fig 7.6.4 *Pixel package is loaded with the first SQPs on the ITT.*

Cooling pipe circuits underwent vacuum leak checks after each fitting connection. Within the pixel package, each cooling circuit has a U-link with two fittings ganging staves or sectors, one exhaust tube with two fittings connecting a bi-stave or bi-sector to a service panel heat exchanger exhaust, and one capillary with two fittings connecting to the same heat exchanger. A pressurization test at four bar absolute using dry air was carried out for one minute after the capillaries and exhaust pipes had been added and for 24 hours after the full package had been integrated, always followed by a vacuum leak check. This was the highest pressure for which the local supports (sectors and staves) had been qualified. While this pressure should not be reached in the exhaust circuits during normal operation, all inlet circuits must operate at 16 bar(a), and therefore have not been individually tested at final pressure in the full package. A small number of cooling fittings (4) and one capillary tube failed during the integration process. These were repaired in place and subsequently tested successfully.

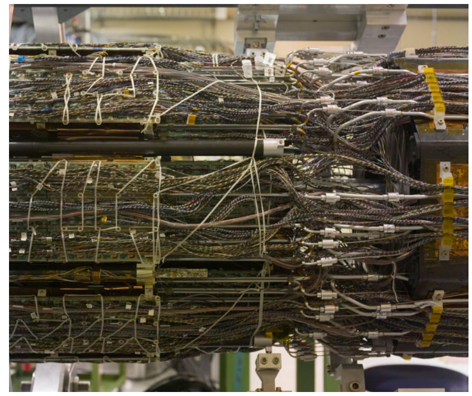

Fig 7.6.5 *View of the services connection at PP0 where the detector is connected to the SQP's*

The integration of each single service panel was followed by a connectivity test. This was performed using the full readout chain and employed the same services as the system test (section 8). This test checked all the electrical and optical connections, the module micro-cable mapping, the environmental sensors, the optical fiber mapping, and the functioning of the opto boards. Note that this test was performed without cooling. Ten micro-cables with broken wires were found by the connectivity test. In six cases the damage was visible, clearly caused by handling, and was repaired. In three cases the damage was not visible but the modules could be recovered by using spare or redundant connections. One module was lost. No broken optical fibers were found. No significant damage to the SQPs was found.

Active component failures not caused by handling were encountered at a low level in the integrated package. One front-end readout chip failed in a disk module by developing an internal short. The module functionality except for this chip was recovered by breaking wire bonds to isolating the failed chip. Two optical components failed: one channel of a laser diode array and one channel of a photodiode array. In both cases the failure was confirmed to be internal to the component and could not be repaired. However, in both cases the affected modules were moved to spare service slots. One module was discovered with an unusual defect that prevents it from operating with the final optical communication, yet it operated with a pure electrical readout as used for production testing.

The data from the connectivity test, combined with the detailed production data, tell us that 99.7% of the detector is currently operational (0.1% due to module/optoboard-level failures discussed above, 0.2% due to pixel-level failures already present in the staves and sectors). Table 7.6.1 summarizes the fraction of non-working parts of the pixel detector as a function of the barrel and end-cap layers.

	Fractional loss (%) Pixel From assembly	Fe or Module Before integration	Fe or Module After integration	Total After integration
L2	0.29	0	0	0.29
L1	0.20	0	0.20	0.40
L0	0.07	0	0	0.07
		Barrel Total		**0.28**
D1C	0.12	0	0	0.12
D2C	0.11	0	2.08	2.19
D3C	0.18	0	0.13	0.31
		Endcap C Total		**0.87**
D1A	0.14	0	0	0.14
D2A	0.10	0.13	0.13	0.23
D3A	0.26	0.13	0.13	0.39
		Endcap A Total		**0.25**
		Pixel Total		**0.33**

Table 7.6.1 Inefficiency in % for barrel and disk layers after final integration and connectivity test described in the text. Pixel inefficiencies are those seen in individual module testing(section 6) and are assumed to be the same after final integration as before. The column FE or Module indicates the fraction resulting from inoperative front-end chips or complete modules.

7.7 Installation

Upon completion of the integration of the pixel detector (described in the previous section), the pixel package was transferred from the ITT to a temporary support structure, Dummy Support Tube or DST, for transport from the surface assembly building to the ATLAS detector underground.

The DST was designed to receive the detector from the integration tool on surface and to keep it dry and protected during the transport to the ATLAS pit. The detector support conditions changed during the extraction from ITT to DST. The load was transferred from the supports on beam pipe plane, used during the integration period, to the sliders mounted on the diagonals of the lower two quadrants. A set of V-Flat rails in the DST, replicating the ones in the Pixel Support Tube, provided the new interface to the sliders by which the detector is guided first into the DST and later on, in the pit, into its final location.

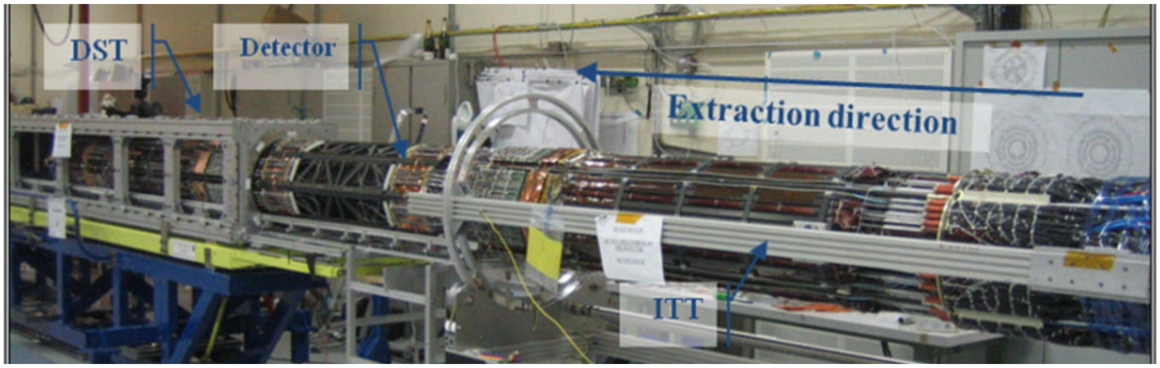

Figure 7.7.1 *The pixel detector leaves the tool on which has been integrated(ITT) and it enters into the transportation tool [DST]. The blue structure underneath is equipped with pivoting and spring loaded wheels for an easy and shock free transfer outside the building.*

The driving force required to move the detector was provided by a winch attached to the far end of the DST that pulled the detector by a metal line attached underneath the detector at the PP0 area.

The detector transfer to the ITT provided important information that was useful for the installation in the ATLAS underground hall. In particular:

- The very limited clearances between the detector and the PST were checked. In some cases, structures of the detector had to be modified to recover from the envelope violation at the PP0 area.
- The impact of the alignment on the clearance at the entrance of the PST was understood and the installation procedures updated accordingly.
- The force required to make the detector slide partially passes through the detector and validation of the estimated friction coefficient with was important.

The pixel detector inside the DST was transferred from the surface assembly building to a staging area above an access shaft to the ATLAS underground cavern. A combination of a custom-wheeled cart (see the blue structure in Figure 7.7.1) and a portable crane were used. Once in the staging area, the DST was picked up by an overhead crane and slowly lowered into the ATLAS underground hall (Figure 7.7.2a), coming to rest on a platform at the end of the ATLAS ID volume, with the ATLAS endcap calorimeter retracted to provide sufficient room (Figure 7.7.2b)

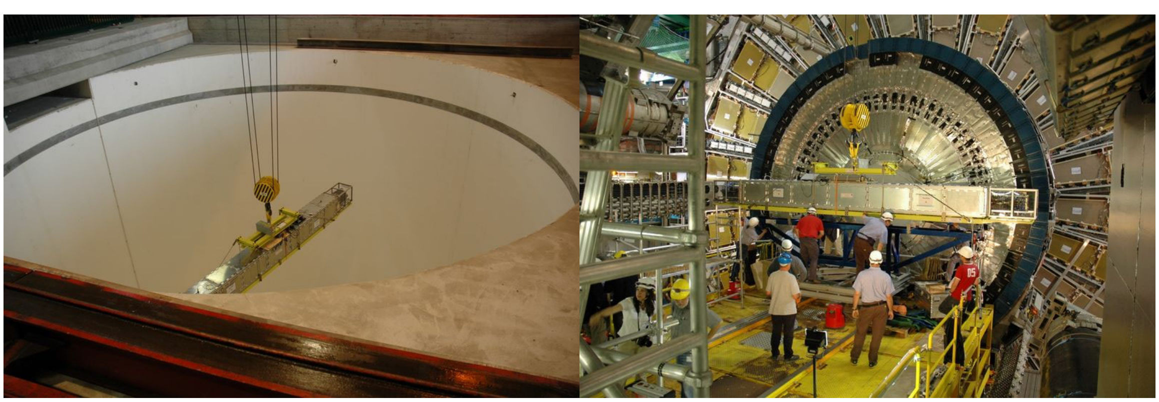

Fig. 7.7.2 (a) *the pixel detector in the Dummy Support Tube (see text) being lowered into the ATLAS underground hall and (b) the Dummy Support Tube and pixel detector on a platform between the Inner Detector area and the endcap calorimeter.*

The DST was rotated and carefully aligned with the PST, already installed within the Inner Detector. The pixel package was slowly pulled into the PST over about a two day period. The clearance between the pixel package and the PST was very small (by design) in a number of positions along the package, requiring very careful monitoring and small last-minute adjustments. This process is illustrated in Figs. 7.7.3a and 7.7.3b.

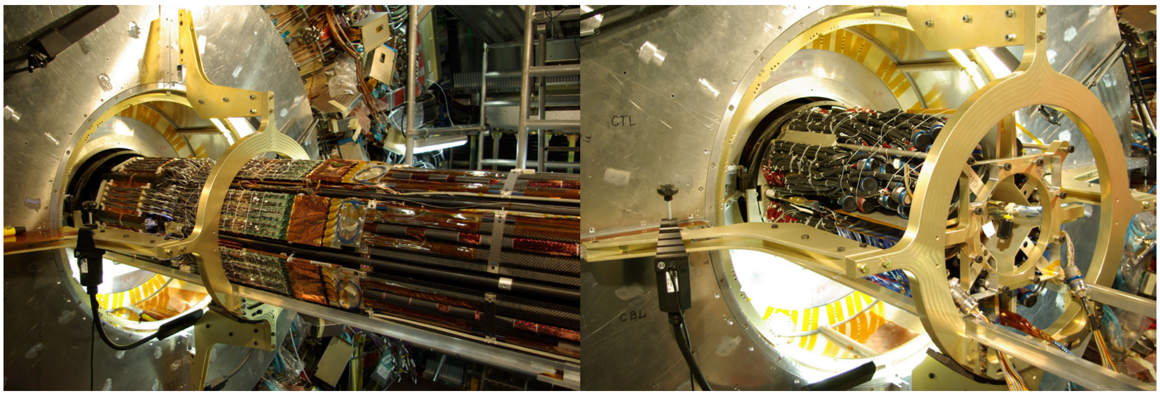

Fig. 7.7.3 (a) the pixel package during transfer from the DST to the PST showing the region at the end of the inner detector and (b) just before completion of the insertion showing the temporary support of internal services at the end of the package.

The mounts attached to the pixel detector global support frame engaged the mating mounts within the PST with excellent alignment (viewed by TV cameras) on June 29, 2007 and the basic installation process of the pixel package completed shortly thereafter.