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 a large, custom built frame, the Integration and Test Tool (ITT). The ITT was constructed to allow the use of custom tooling for all assembly and to allow rotation of the assembled detector to facilitate the assembly and testing. The basic sequence of assembly was, in order: barrel region, beam pipe(with temporary supports), 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 with bi-staves (described in section 7.2). These layers were inserted sequentially into the global support frame by using tooling on the ITT. The Layers 1 and Layer 2 exhaust pipes and capillaries were added only after the shells were clamped and loaded into the support frame on the ITT.

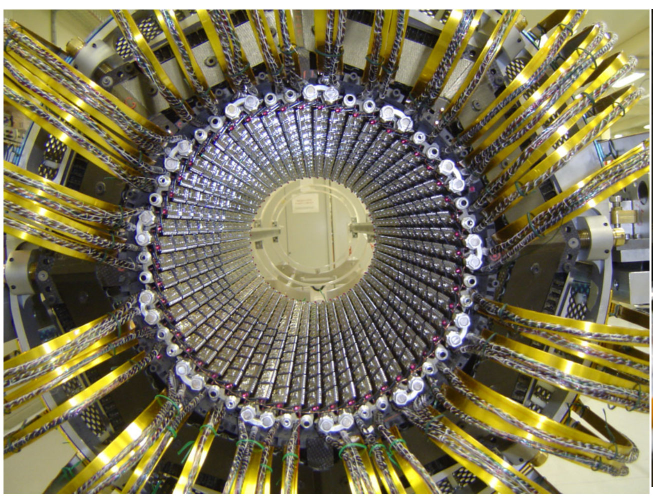

Fig 7.6.2 (a) *Pixel Layer assembled into global frame and held on the ITT as it appears from looking the IP along beam line.*

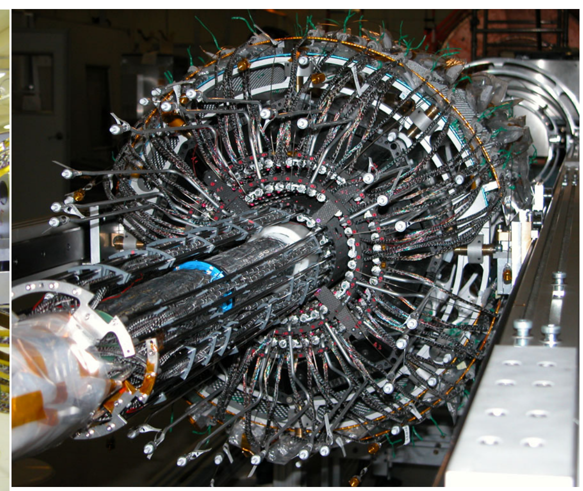

Fig 7.6.2 (b) *The barrel of the Pixel Detector completed. View from the C-side*

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. 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 bolted and pinned for accurate location to the barrel support frame section, again using tooling on the ITT.

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 (described in section 7.4).

The four SQP's per side were mounted directly to their respective BPSS. SQPs were lifted by a small crane and guided by hand onto the BPSS for final connection. Cooling pipes were connected first at PP0, pressurized and leak checked. Electrical connectors were plugged into PP0 and an electrical test performed on each SQP. Figure 7.6.2 shows how the package looked like with the first SQP installed. Figure 7.6.3 is a view of the PP0 area after all the services had been connected.

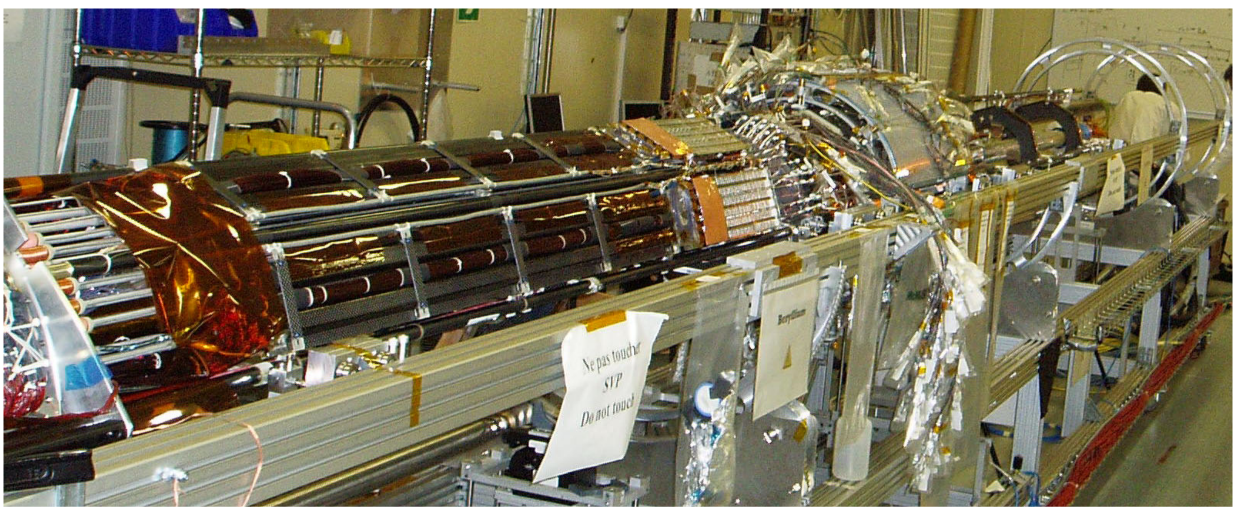

Fig 7.6.4 *Pixel package is loaded with the first SQPs*

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 4 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

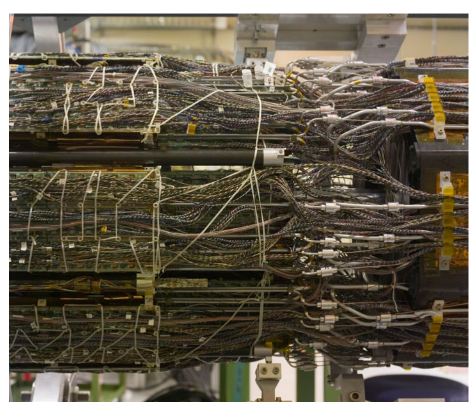

Fig 7.6.5 *View of the services connection at PP0 where the detector is connected to the SQP's*

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.

The integration of a single service panel was also followed by a connectivity test. This was performed using the full readout chain and employed the same services as the system test (section 8). Its general goal was to make sure that the full pixel package was ready for the installation in the ATLAS underground hall. More specifically the module micro-cable mapping was checked, the environmental and electrical connections were exercised and the optical connections were tuned. Note that this test was performed without cooling.

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, 0.2% due to pixel-level failures). 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, both before and after the connectivity test.

	After disk and bistave integration			After connectivity test		
	pixel	Fe or Module	total	pixel	Fe or Module	total
L2	0.29	0	0.29	0.29	0	0.29
L1	0.20	0	0.20	0.20	0.20	0.40
L0	0.07	0	0.07	0.07	0	0.07
D1C	0.12	0	0.12	0.12	0	0.12
D2C	0.11	0	0.11	0.11	2.08	2.19
D3C	0.18	0	0.18	0.18	0.13	0.31
D1A	0.14	0	0.14	0.14	0	0.14
D2A	0.10	0.13	0.23	0.10	0.13	0.23
D3A	0.26	0.13	0.36	0.26	0.13	0.39

Table 7.6.1 Inefficiency in % for barrel and disk layers (1) before final integration and (2) 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.