ATLAS PIXEL PATCH PANEL 1

The requirements and interfaces for the ATLAS Pixel Patch Panel 1 [illegible] described. The status of p[illegible]ype development is presented. The preliminary design and production plan are described.

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Distribution List

History of Changes			
Rev. No.	*Date*	*Pages*	*Description of changes*

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1 Introduction

Patch Panel 1(PP1) is located at the end of the Pixel Support Tube(PST) near the end of the Inner Detector volume – see Figure 1.

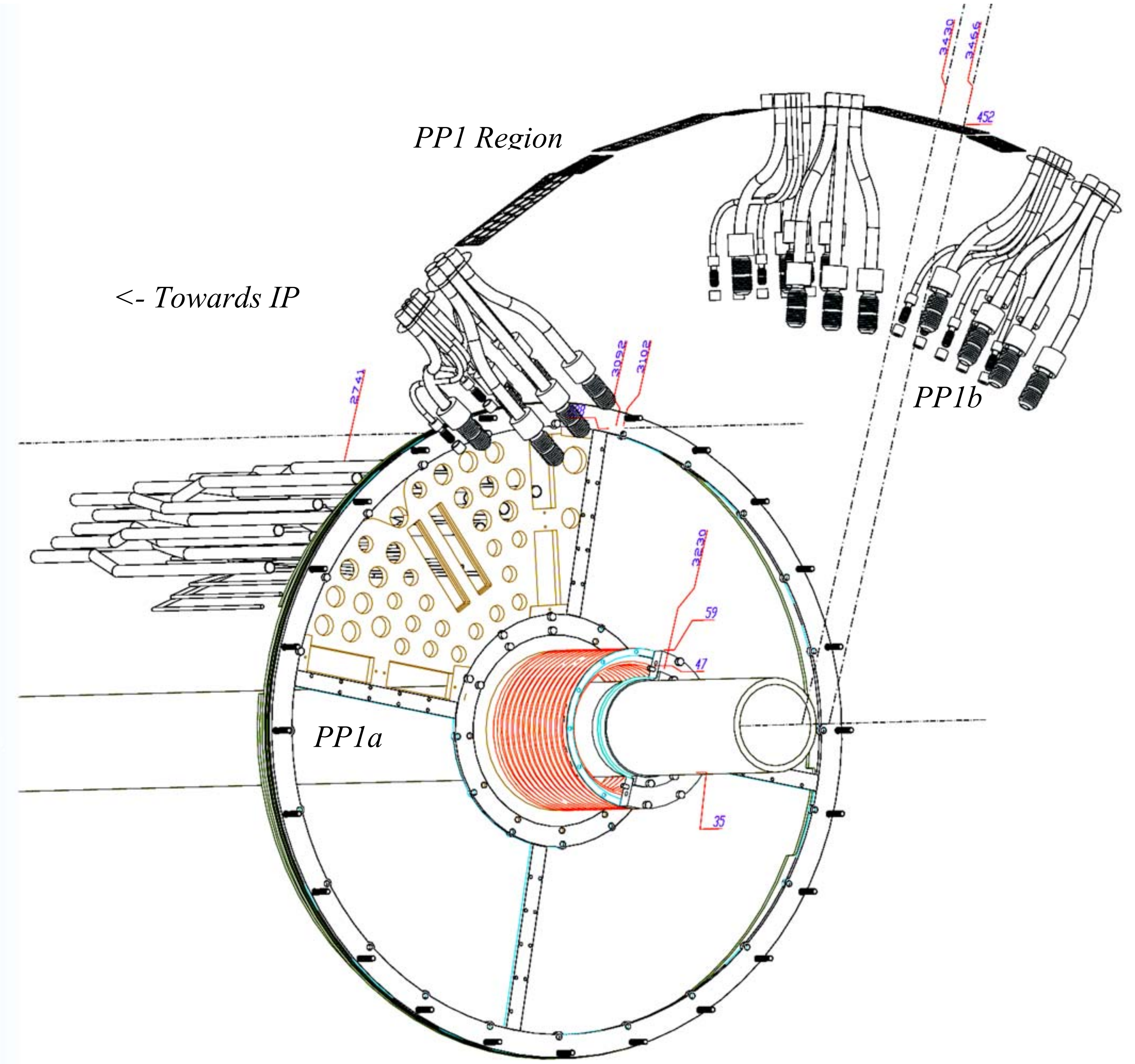

Figure 1. The Patch Panel 1(PP1) region.

Connections for the following items are present at PP1: coolant pipes for the pixel modules and optical interface boards; gas inlets and outlets for dry nitrogen that flows within the PST; power and slow signals for pixel modules and system monitoring; optical fibers; beam pipe support structure inside the PST; and beam pipe support outside the PST. PP1 is a segmented assembly so that it may be attached to the beam pipe/pixel service panel structure on the surface such that the assembled pixel package may roll/slide into the PST from Side C of ATLAS. PP1a refers to the connections at the bulkhead endplate connected to the Pixel Support Tube(see Figure 2). PP1b refers to the connections in the transition region to services routed to PP2 outside of the Inner Detector and along the calorimeter/cryostat wall.

2 Requirements

The barrel part of the ATLAS pixel detector is built up of 3 layers (B-layer, layer 1, and layer 2) and there are 3 disks per endcap (8 sectors per disk). Each barrel layer has a certain number of staves (B-layer 22, layer 1 38, layer 2 52 staves) where the modules are mounted on. There are 13 modules per stave, and 48 modules per disk. The total number of modules is 1456 for the barrel (B-layer 286, layer 1 494, layer 2 676 modules), and 288 modules for the two endcaps (6 modules per sector), i.e. there are 1744 modules for the whole pixel detector.

The initial pixel detector will have Layer 1 and the middle disk on each end absent. We have designed PP1 for the full, 3-hit pixel system.

2.1 Structural and General

The overall requirements on PP1 have been specified in the general "Services" document[1]. Here the aspects related to structural and to geometrical characteristics are listed.

- *Maximum pressure differential is 4mbar;*
- *No heaters are present on the plate to prevent condensation. The volume outside the Pixel envelope is continuously flushed by CO_2 with a dew point below -25C°.;*
- *The penetrations at the two PP1 plates and the seals[2] at the two PST flanges should guarantee a leak rate better than 6 L .mbar/h. Given a total of ~200 penetrations all over the Pixel Package, each single seal should be gastight at less than $3x10^{-2}$ L .mbar/h*
- *The penetration for the cooling pipes should allow the axial motion of the aluminum coolant tubes as they are cooled from room temperature to the operating temperature;*
- *The plate should make accessible the beam pipe adjusters that are located within the Pixel Support Tube volume;*
- *A beam pipe survey is deemed necessary. PP1 endplate must have openings to allow the survey of targets located on the beam pipe at Z ~ ±800mm.*
- *The detector is in a N_2 environment. This gas is provided by a dedicated piping system[3] for a total of four pipes.*

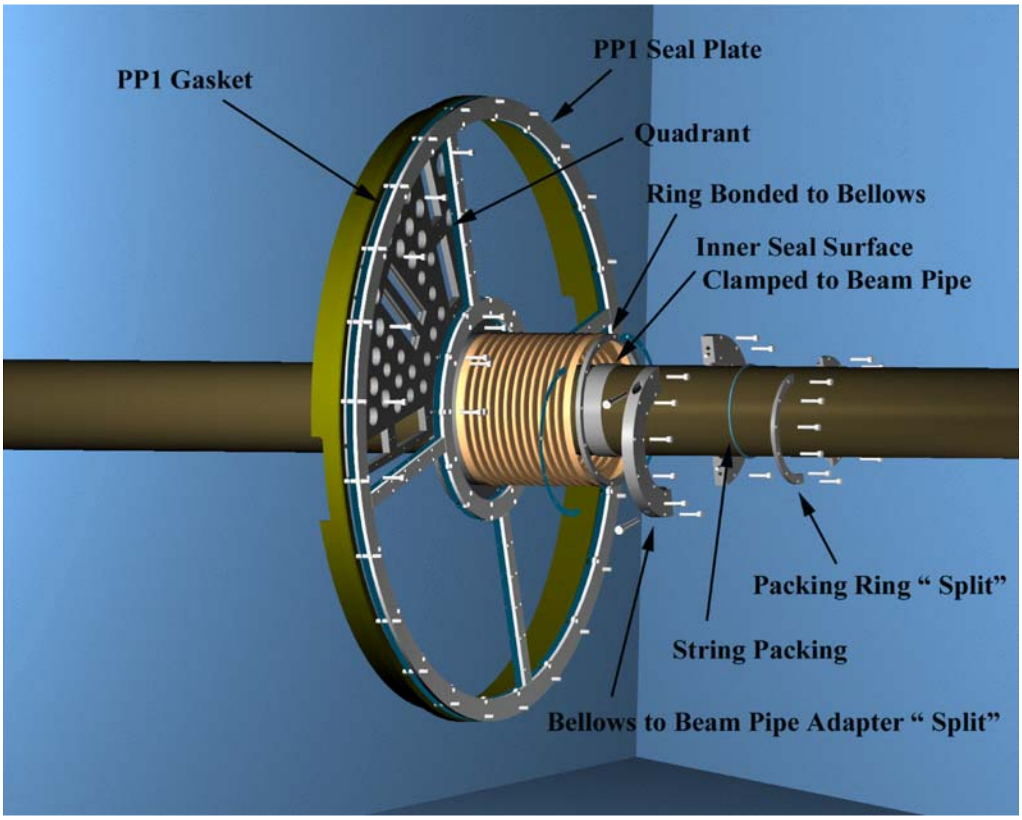

Figure 2. Patch Panel 1(PP1) consists of a bulkead/endplate attached to the Pixel Support Tube and connections for cooling, gas flow, power and signals and fiber optics. The bulkhead also provides a connection to the beam pipe.

2.2 Cooling and Gas Pipes

The number and characteristics of the pipes containing the C_3F_8 coolant and the pipes used to flush nitrogen within the pixel volume(inside the Pixel Support Tube) are given in ref. 1. The number of coolant circuits(side C) is given in Table 1. The table for Side A is given in reference 1. We have required that each quadrant of the PP1 be identical. Hence it must allow penetrations for the maximum number of pipes and cable bundles. This corresponds to 14 cooling circuits for the pixel modules and 2 panel cooling circuits per quadrant.

SIDE C SERVICES FROM PP0 TO PP1										
TOTAL OUTER PANELS	PANEL NAME	PE C1	PE C2	PE C3	PE C4	PE C5	PE C6	PE C7	PE C8	TOTAL
	6 module cable bundles	5	7	5	5	6	6	5	6	45
	7 module cable bundles	6	5	5	7	5	6	5	6	45
TOTAL INNER PANELS	PANEL NAME	PI C1	PI C2	PI C3	PI C4	PI C5	PI C6	PI C7	PI C8	
	6 module cable bundles	3	3	3	3	3	3	3	3	24
	6 B-module cable bundles	2	1	2	1	1	2	1	1	11
	7 B-module cable bundles	1	2	1	1	2	1	2	1	11
COOLING CIRCUITS		6	5	6	5	6	5	6	6	45
PANEL COOLING CIRCUIT		1	1	1	1	1	1	1	1	8
TOTAL AT PP1	Cooling circuits	7	6	7	6	7	6	7	7	53
	6 module cable bundles	8	10	8	8	9	9	8	9	69
	7 module cable bundles	6	5	5	7	5	6	5	6	45
	6 B-module cable bundles	2	1	2	1	1	2	1	1	11
	7 B-module cable bundles	1	2	1	1	2	1	2	1	11

Table 1. Side C coolant circuits and number of cable bundles from reference 1.

Each cooling circuit consists of an inlet pipe and an outlet pipe. There are 53(43) circuits on Side C(Side A). The dimensions of these pipes are given below in Table 2. The dimensions are slightly different for the pipes coming from Patch Panel 0(PP0) at the end of the pixel detector and from PP1a to PP1b. The former correspond to U.S. standards and the latter to metric standards.

	PP0-PP1a		*PP1a-PP1b*	
	ID(mm)	*OD(mm)*	*ID(mm)*	*OD(mm)*
Inlet	*2.07*	*2.78*	*2.5*	*3.0*
Outlet	*7.92*	*8.73*	*8.0*	*10.0*

Table 2. Requirements for inlet and outlet cooling tube diameters.

The dimensions of the coolant circuits for the service panels are the same.

The dimensions of the pipes for flushing of dry nitrogen are given below in Table 3.

Nitrogen system							
Side	*ID (mm)*	*# of pipes*	*material*	*Max P (mbar)*	*From*	*To*	*description*
C	*6*	*1*	*Any*	*4*	*PP2*	*Pixel*	*inlet*
A	*21*	*2*	*Any*	*4*	*pixel*	*PP2*	*exhaust*
	21	*1*	*Any*	*4*	*pixel*	*Bubbler @PP2*	*emergency*
	2	*1*	*Any*	*4*	*pixel*	*US15*	*sensing*

Table 3. Dimensions of the pipes for the dry nitrogen system.

2.3 Electrical

The power and slow signal connections to the pixel modules are made via cable/wire bundles soldered to copper-on-kapton circuits that are captured by PP1. The transition from wires to flat copper-on-kapton circuits is necessary to meet the tight space requirements at PP1. The number of cable bundles for Side C are given in Table 1(and for Side A in reference 1). Again each PP1 quadrant is required to be identical.

Each coolant pipe must be electrically isolated at PP1 ie. there must be an electrical break in the pipes between PP1a and PP1b.

2.4 Fiber Optics

Each module transfers the data information via optical fibres from the detector at PP0 to the electronics in the counting room USA15, while the timing information to read-out a module goes via optical fibres from the counting room to the detector. Only the B-layer reads out the data information with 2 optical fibres and it receives 1 TTC signal per module. All other modules are read-out each by 1 optical fibre and they receive each 1 TTC optical fibre. Inside the ATLAS detector the radiation hard Fujikura SIMM50 optical fibre with a core diameter of 50µm will be used, while ouside the detector till the counting room in USA15 radiation tolerant Draka GRIN62.5 fibres (62.5 µm core diameter) for the data and Draka GRIN50 fibres (50 µm core diameter) for TTC are foreseen. Both fibre types (SIMM50 and GRIN50/62.5) will be spliced together at PP2 just under the first layer of the ATLAS muon detector system.

The total number of single fibres for the pixel detector is 3774. The barrel part has 1742 data single fibres (B-layer 572, layer 1 494, layer 2 676 single fibres) and 1456 TTC single fibres (B-layer 286, layer 1 494, layer 2 676 single fibres). Both endcaps with their 6 disks have 288 data and 288 TTC single fibres (48 single fibres per disk each for data and TTC or 6 single fibres per sector for data and TTC each).

A stave with its 13 modules are read-out in such a way, that 7 modules are read-out on side A of the detector, while the remaining 6 modules of that stave are read-out on side C. The next stave will read-out 6 modules to side A, and 7 modules to side C. In that way it is guaranteed that the same total number of modules is read-out on both sides. The 48 sectors of the 6 endcap disks are read-out in equal parts to side A and side C.

Inside the pixel detector, 8 single fibres will form a so-called 8-way fibre ribbon, which is the basic unit for the optical fibre system. A ribbon has a rectangular cross-section of 3mm x 0.3mm. There are certain criteria to read out the data from and to bring the TTC information to the modules:

- *data and TTC information are handled by different ribbons, i.e. there are data and TTC ribbons,*
- *the ribbons of layers and of disks are separated,*
- *the ribbons of each layer and of each disk are separated.*

In an 8-way fibre ribbon always only 6 or 7 out of the 8 single fibres are actually used. The endcap regions always use only 6 out of the 8 fibres of a ribbon.

The above criteria will become even more important when 8 ribbons will form so-called optical fibre cables. An optical fibre cable has an external diameter of 9.5mm. While the connection inside the pixel detector from PP0 to PP1 will be established by about 3m long 8-way ribbons, PP1 will be connected to the counting room in USA15 by 8x8-way ribbon fibre cables. These cables have the advantage that the fragile fibre ribbons are protected by the plastic mantle of the cable. In order to limit the number of fibre cables it is necessary to put together into one cable ribbons, where 6 OR 7 out of 8 fibres are used.

The total amount of 8-way SIMM50 fibre ribbons for the whole pixel detector is 588. Per side A and side C that are needed for data transfer are:

- *67 barrel ribbons using 7 fibres each (B-layer 22, layer 1 19, layer 2 26 ribbons),*
- *67 barrel ribbons using 6 fibres each (B-layer 22, layer 1 19, layer 2 26 ribbons),*
- *24 endcap ribbons using 6 fibres each (disk 1, disk 2, disk 3 each 8 ribbons).*
- *for TTC transfer:*
- *56 barrel ribbons using 7 fibres each (B-layer 11, layer 1 19, layer 2 26 ribbons),*
- *56 barrel ribbons using 6 fibres each (B-layer 11, layer 1 19, layer 2 26 ribbons),*
- *24 endcap ribbons using 6 fibres each (disk 1, disk 2, disk 3 each 8 ribbons).*

The 588 8-way fibre ribbons will arrive from the PP0 optoboards PP1. The connection of these ribbons to the optoboards will be done by MT8 connectors (1 connector per 8-way fibre ribbon). At PP1 the ribbons have to be connected to the fibre cables coming from USA15 in such a way that an easy disconnection is possible. It has to be pointed out that due to space requirements inside the pixel detector itself there are no spare 8-way fibre ribbons foreseen between PP0 and PP1.

At this point it seems appropriate to describe in detail which and how many fibre cables are needed for the installation in the ATLAS cavern. As the modules of the B-layer need 2 data and only 1 TTC fibre per module the number of cables containing GRIN62.5 fibre ribbons will be slightly higher than the number of cables with GRIN50 fibre ribbons.

The 294 SIMM50 ribbons per side A and side C will be put into optical fibre cables in the following way:

<u>B-layer:</u>

3 cables for 22 data ribbons using 7 out of 8 fibres (reserve: 2 ribbons),

3 cables for 22 data ribbons using 6 out of 8 fibres (reserve: 2 ribbons),

3 cables for 22 TTC ribbons using 6 or 7 out of 8 fibres (reserve: 2 ribbons).

<u>Layer 1:</u>

5 cables for 38 data ribbons using 6 or 7 out of 8 fibres per ribbon (reserve: 2 ribbons),

5 cables for 38 TTC ribbons using 6 or 7 out of 8 fibres per ribbon (reserve: 2 ribbons).

<u>Layer 2:</u>

7 cables for 52 data ribbons using 6 or 7 out of 8 fibres per ribbon (reserve: 4 ribbons),

7 cables for 52 TTC ribbons using 6 or 7 out of 8 fibres per ribbon (reserve: 4 ribbons).

<u>Endcap:</u>

3 cables for 24 data ribbons using 6 out of 8 fibres per ribbon (reserve: 0 ribbons)

3 cables for 24 TTC ribbons using 6 out of 8 fibres per ribbon (reserbe: 0 ribbons).

Hence a total of 39 8x8-way fibre ribbon cables are needed for a connection at PP1. As there are 312 ribbons in these cables, there are 18 ribbons not used, and these 18 ribbons are serving as a reserve NOT being connected to PP1. In order to have more reserve ribbons in case of problems in data or TTC transfer, there are 2 cables with 8 ribbons each per side A and side C (1 spare cable for data and 1 spare cable for TTC transfer) foressen for installation. These 2 spare cables are not connected at PP1. A total of about 10.9% (34/312) of ribbons between PP1 and USA15 are serving as reserve.

The whole pixel detector will have 82 fibre cables for its optical transfer of data and TTC information. On side A the 41 cables will leave through slot A10 and on side C the 41 cables will go through slot C15. The 82 cables consist each of 8 about 9m long SIMM50 ribbons which will then be spliced to 8 about 70m long GRIN50/62.5 ribbons. Therefore PP1 will be connected to USA15 without any further patch panel. The following data SIMM50/GRIN62.5 and TTC SIMM50/GRIN50 fibre cables will be installed per side A and side C:

<u>Data SIMM50/GRIN62.5 cables per side A and side C:</u>

B-layer: 6 cables, Layer 1: 5 cables, Layer 2: 7 cables, Endcap: 3 cables, Reserve: 1 cable => 22 cables

<u>TTC SIMM50/GRIN50 cables per side A and side C:</u>

B-layer: 3 cables, Layer 1: 5 cables, Layer 2: 7 cables, Endcap: 3 cables, Reserve: 1 cable => 19 cables

Per side A and side C, the 294 single 8-way SIMM50 fibre ribbons arriving from PP0 at PP1 have to be connected to the 39 cables coming from USA15 to PP1. Four places (1 per quadrant) are foreseen for this connection on the PP1 endplate. Therefore 74 ribbons coming from PP0 will meet 10 cables arriving from USA15 at each quadrant of PP1.

3 Interfaces

3.1 Pixel Support Tube

A side-view of the PP1 region is shown in Figure 3. The Z location of the end of the PST and thus of the PP1 endplate is preliminary. The final dimension will be set after construction of the PP1 prototype and a mockup of the PP1, including pipes and cables. The interface to the pixel support tube flange is a bolted connection of the PP1 endplate.

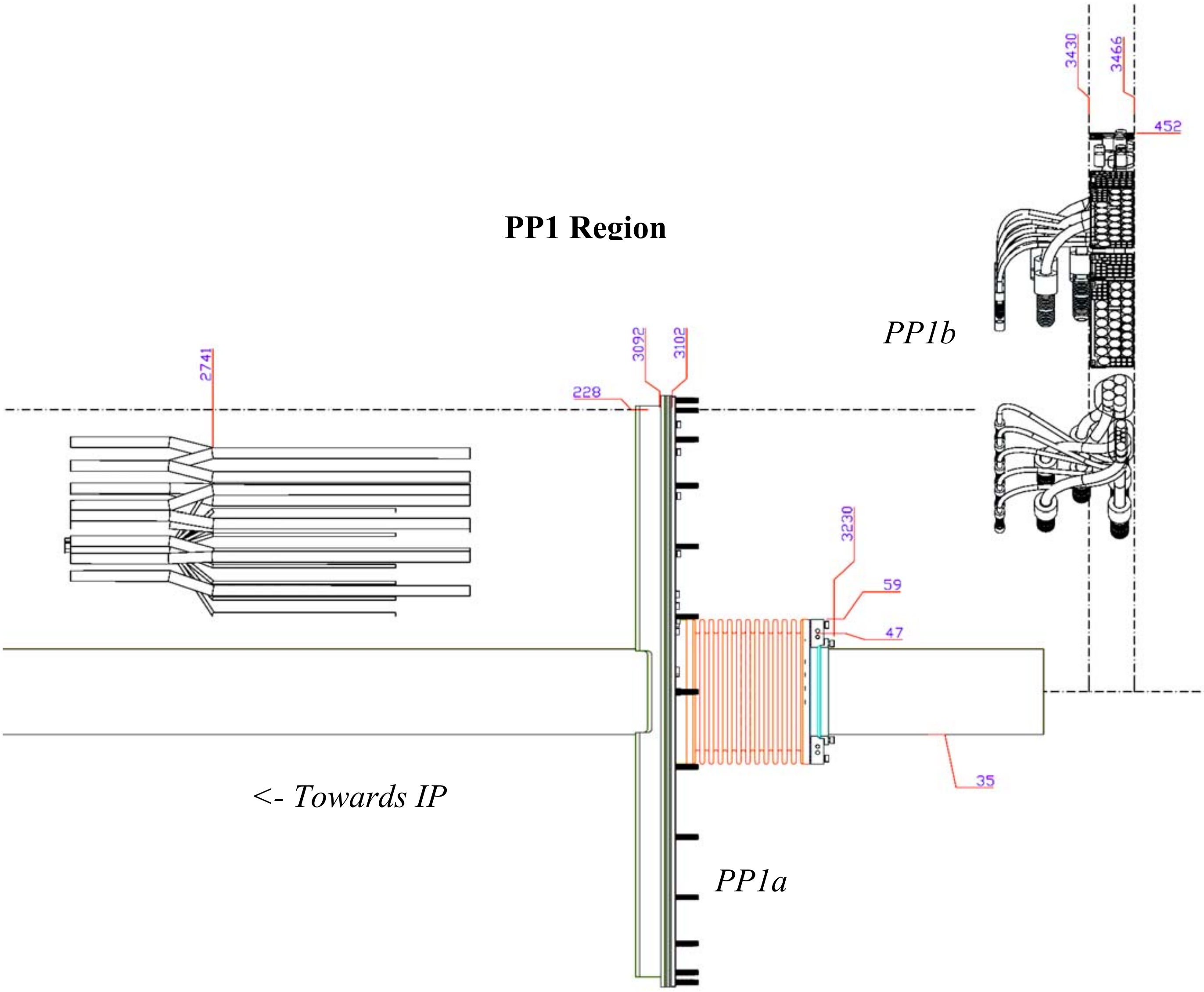

Figure 3. Side view of the PP1 region showing the current Z location of the PP1 endplate.

3.2 Connections to Patch Panel 2(PP2)

The connections at PP1b are determined in part by the routing of services outwards to PP2. We have taken as a requirement the location of services at PP1b as shown in Figure 4.

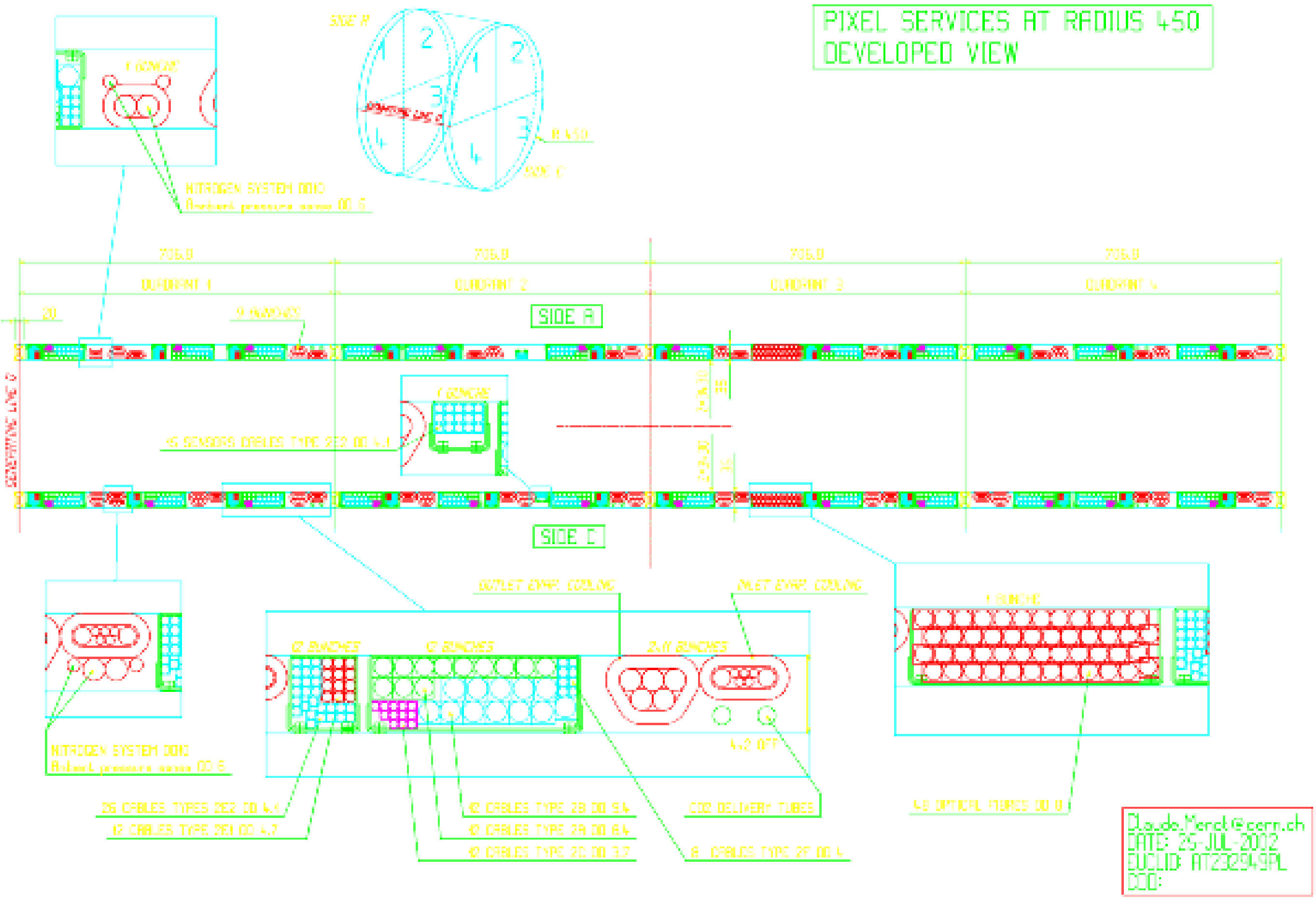

Figure 4. Services layout at R=450mm for routing to PP2.

3.3 Beam Pipe Support

A 3D model of the connection between the PP1 endplate and the beam pipe support structure inside the Pixel Support Tube is shown in Figure 5. The beam pipe support structure (BPSS) interfaces to PP1 through two structures: the beam pipe position adjustors, which protrude through PP1; and the PP1 support rods, which are parallel to the adjustors and bolt directly to the PP1 quadrants. Since the services are integrated into quadrant structures before attachment to the BPSS, each PP1 quadrant is affixed to the service quadrant "backbone" in order to support it during the assembly process (otherwise the PP1 panel would hang from the attached services). Once a service panel structure is attached to the BPSS, the associated PP1 quadrant can be bolted to it through the support rod. The beam pipe adjustor moves into its open spot in the PP1 quadrant, and is then sealed to the PP1 panel with a small "closeout" piece that forms a gas seal. After more than one service quadrant structure has been assembled to the BPSS, the adjoining PP1 panels are also bolted to each other.

3.4 Beam Pipe

PP1 is attached to the beam pipe directly outside(larger Z) of the PP1 endplate as shown in Figure 2. A bellows is attached to the PP1 endplate to allow for differential motion(up to 30mm) of the beam pipe as it is cooled from room temperature to the pixel operating temperature. The interface to the bellows is through a split clamp that connects to a ring clamped to the beampipe. The details of this interface are under design.

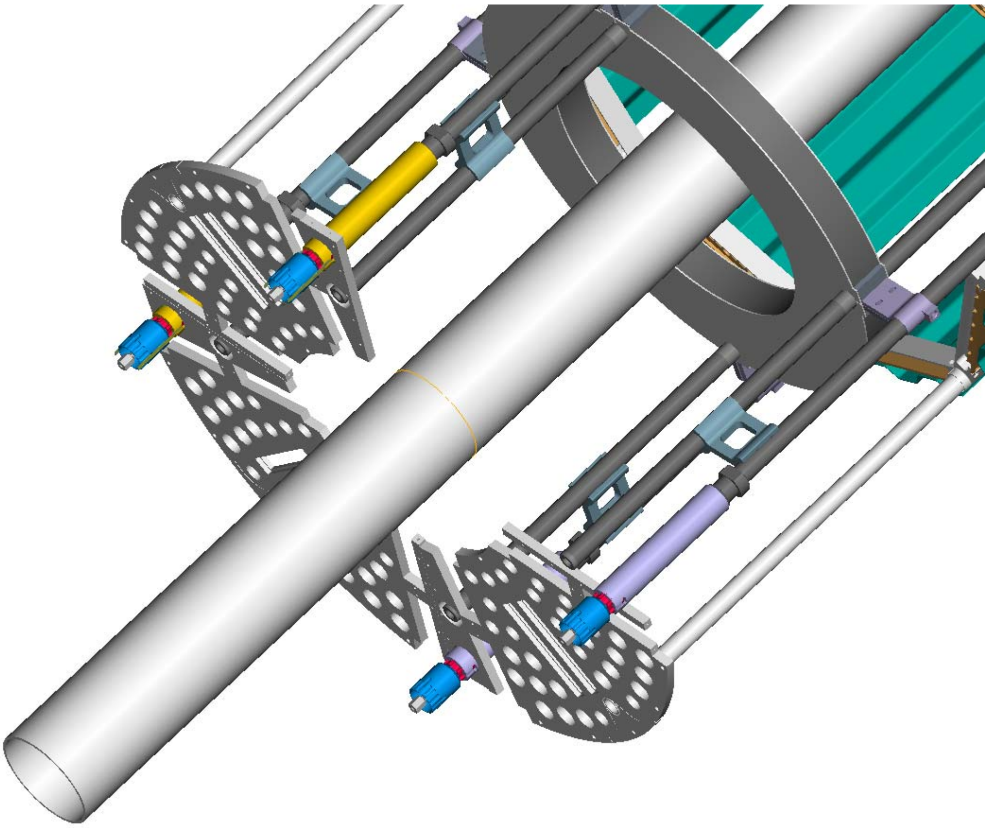

Figure 5. Model of the PP1 region showing the connection to the beam pipe support.

4 Overview of Design and Prototypes

In this section we provide an overview of the principal design elements of PP1. Prototypes of these have either been fabricated or are under fabrication.

5 Mechanical Structure

A prototype of the PP1 endplate is shown in Figure 6. The PP1 endplate will be machined from aluminum. Each quadrant is designed to be identical. Each quadrant will be mounted(along with the various feedthroughs) to a quadrant of the service panel structure that carries the services to PP0. The quadrants of PP1 are joined after the quadrants and service panels are mounted on the beam pipe/service panel support structure. The quadrants are joined and the gas seal is completed by a connection to the PST flange. A drawing of the joining pieces is shown in Figure 7. Gasket material is used to make the low pressure gas seal. Our current design uses paper gaskets

The prototype program includes the fabrication of a complete quadrant. The remaining quadrants are just plates. The prototype endplate will be loaded with prototype pipe and electrical feedthroughs. It will be bolted to a prototype section(30 cm long) of the pixel support tube with end flanges. The other end of the 30cm prototype will be blanked off apart from a fitting to introduce a small known pressure. This will allow us to make leak rate measurements at the level of one quadrant. It will also verify the interface to the pixel support tube as well as the general fabrication and assembly procedures for the endplate..

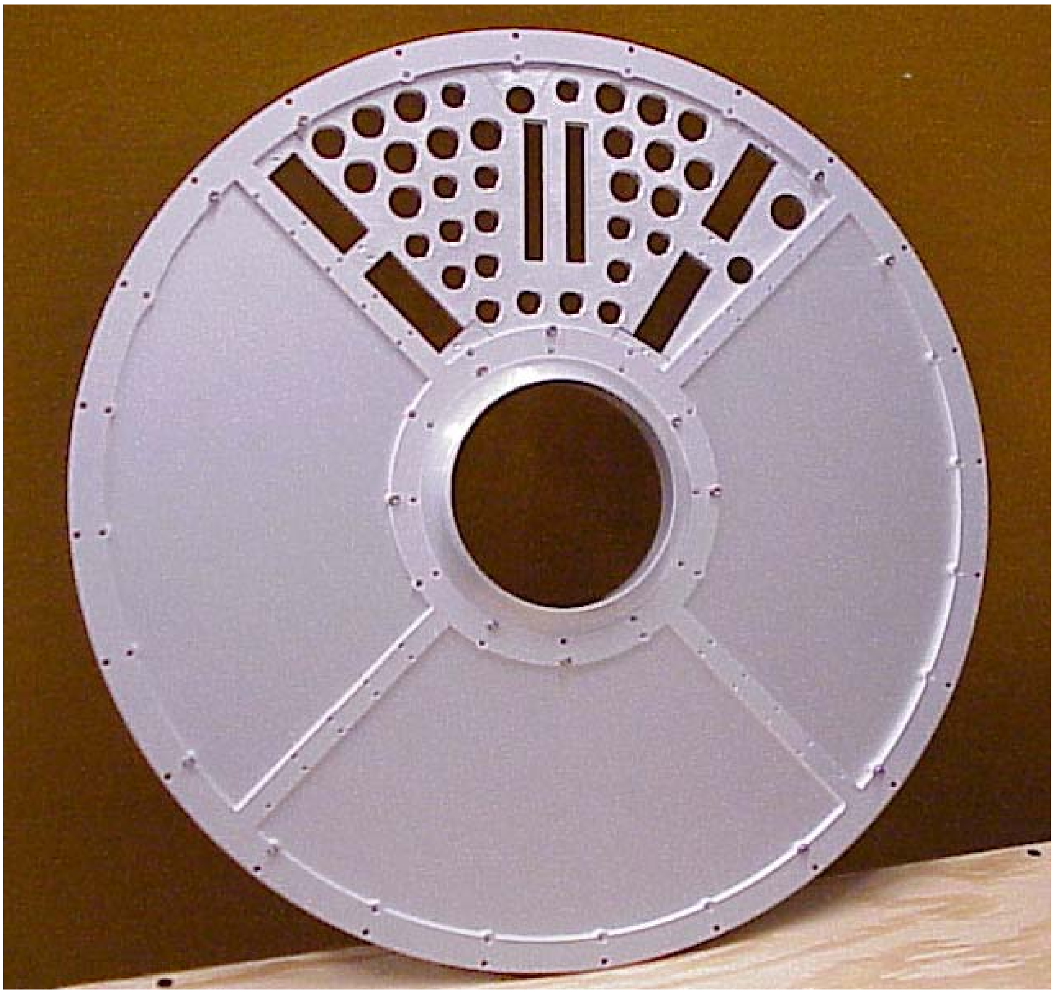

Figure 6. Prototype PP1 endplate.

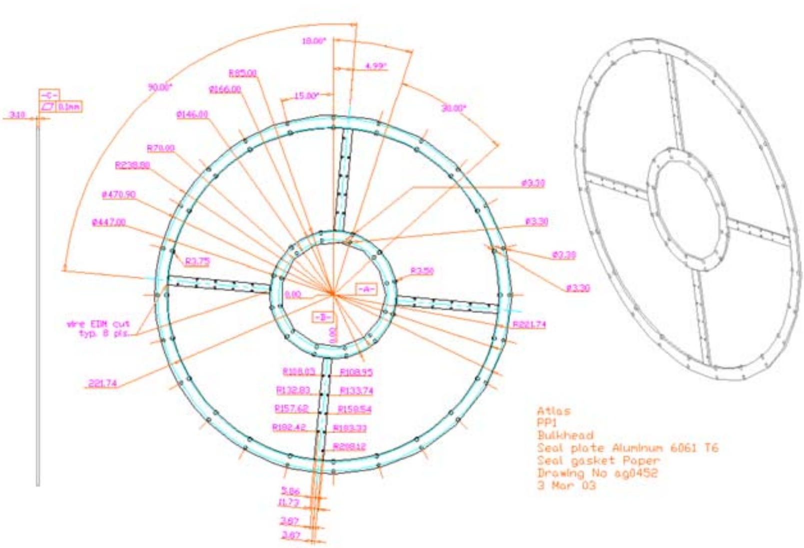

Figure 7. Sealing sections for the PP1 endplate.

6 Electrical Feedthroughs

The constraints of limited space and the need for a gas seal at the support tube end plates make it impossible to have bulkhead-mounted connectors for electrical services through PP1 with existing connector technology. Directly continuing the Type 1 wires(those wires inside the PST) through the endplate with cable-to-cable connectors further away is also not possible because of the need to make a gas seal, and because the Type 1 wires are not compatible with standard connector technologies (copper clad aluminum wires in the case of power and very fine copper wire -AWG42- in the case of sense lines). The proposed solution uses printed copper-on-kapton feedthroughs, which can be tightly bonded in a gas-tight plug to pass through the bulkhead using minimum area. The Type 1 wires are soldered to these feedthroughs on the inside of the bulkhead. On the outside conventional copper cables are soldered to the feedthroughs and terminated in standard connectors at PP1B.

Each octant has an outer and an inner feedthrough. Each feedthrough is a stack of copper on kapton printed circuits bonded in an aluminum stopper that fits into a bulkhead slot, making a gas seal. Each feedthrough will be fully soldered and connectorized before inserting into the bulkhead. Table 1 shows the parameters of the individual printed circuit and the maximum load of the inner and outer feedthroughs. The outer feedthroughs serve Layer 1 and Layer 2 staves, while the inner feedthroughs serve B-layer and disks. shows the staggering and arrangement of the power flex circuits in each feedthrough.

Circuit name	*Length (mm)*	*Cu Mass (g)*	*R/T res. (mΩ)*	*Type 2 bundles served*	*Number inner*	*Number outer*
Power 1	*12.0*	*3.0*	*38*	*2(2A) + 2(2B)*	*1*	*1*
Power 2	*15.2*	*3.9*	*48*	*2(2A) + 2(2B)*	*1*	*1*
Power 3	*19.1*	*4.9*	*61*	*2(2A) + 2(2B)*	*1*	*1*
Power 4	*22.4*	*5.8*	*71*	*2(2A) + 2(2B)*	*1*	*0*
Power 5	*25.6*	*6.6*	*82*	*2(2A) + 2(2B)*	*1*	*0*
Power 6	*29.2*	*7.5*	*94*	*2(2A) + 2(2B)*	*1*	*0*
HV	*35*	*0.1*	*N/A*	*2(2E1)*	*6*	*3*
Signal	*35*	*2.5*	*N/A*	*3(2C)+3(2E2)*	*4*	*2*

Table 4. Printed flex circuits and feedthrough composition.

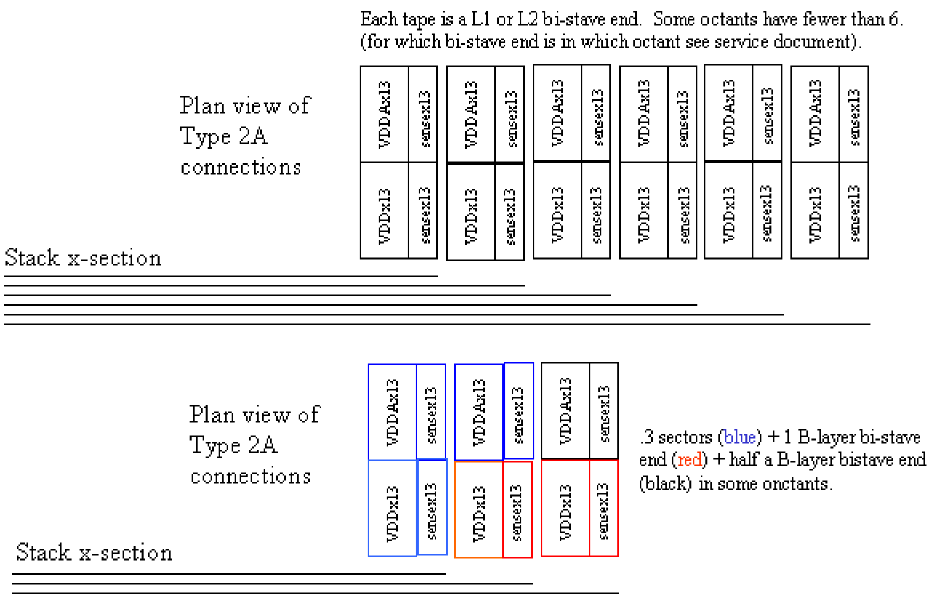

Figure 8. Arrangement of power flex circuits in inner and outer feedthroughs and the number of modules served.

Figure 9 shows a prototype of the outer feedthrough with type 2A cables. The plan for these prototypes includes:

- *Optimization of assembly sequence.*
- *Packing test of wires in corrugated support and assembly of facesheets*
- *Thermal test with full current load for panels as well as PP1feedthroughs*
- *Electrical test with real modules once type 2B cables and connectorsare available.*
- *Development of continnuity test box for production.*
- *Mechanical plugging and unplugging tests*
- *High voltage isolation tests*

In addition, the prototypes will be included in the PP1 mockup under fabrication at CERN.

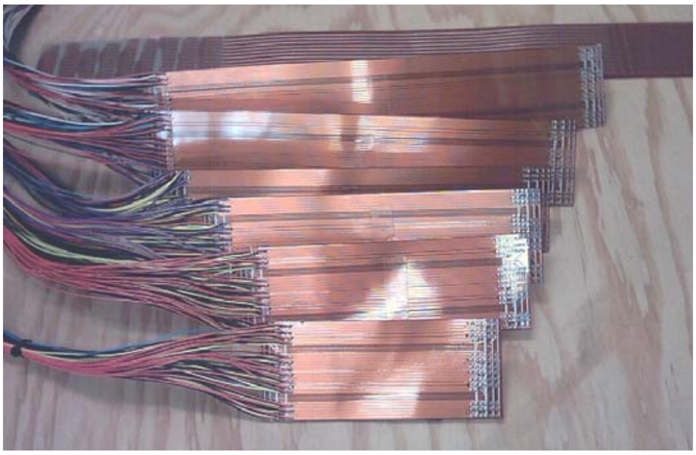

Figure 9. Prototypes of the electrical feedthroughs. The picture on the right shows the feedthroughs gathered as they would be in a clamp that attaches to the PP1 endplate.

7 Coolant Pipes, Feedthroughs and Connectors

7.1 Coolant Pipes

Liquid C_3F_8 is used to cool the pixel detector, which then evaporates and returns to the cooling plant. Thus the narrow supply pipes carry liquid C_3F_8, and the larger return pipes carry gaseous C_3F_8. The aluminum coolant pipes from PP1A to PP1B have the dimensions given in Table 2 and are about 90cm in length to meet the requirements for the routing to PP2 given in Figure 4. The pipes have to travel radially, axially and azimuthally to get from PP1A to PP1B, and this accounts for their long length. The length has not been optimized yet.

The C_3F_8 in the supply coolant pipe is at a pressure up to 16 bar (absolute). A pressure drop device between PP1b and PP1a will reduce the pressure to about 8 bar(abs) at the entrance to the pixel volume.

There will be 55 supply pipes and 55 return pipes on side C, and 45 supply pipes and 45 return pipes on side A, since all the B-layer cooling pipes come out on side C only. These numbers include 2 spare supply pipes and 2 spare return pipes on each side.

7.2 Feedthroughs

Figure 10 shows the parts for a coolant pipe feedthrough for the PP1 bulkhead, Figure 11 shows how these parts are assembled in the bulkhead, and Figure 12 shows more detail of the coolant pipe coupling (using the 3 pieces on the right in Figure 10).

As discussed in the section on Coolant Pipes, there will be 55 supply pipe feedthroughs and 55 return pipe feedthroughs on side C, and 45 supply pipe feedthroughs and 45 return pipe feedthroughs on side A. However, for ease of design and fabrication, the C-side and A-side PP1 bulkheads are identical, and also the 4 quadrants of the PP1 bulkhead are identical. The number of holes in the bulkhead for the feedthroughs is determined by the busiest quadrant, which requires 16 supply holes and 16 return holes. Thus each PP1 bulkhead has space for 64 supply pipe feedthroughs and 64 return pipe feedthroughs. The unused holes will be plugged.

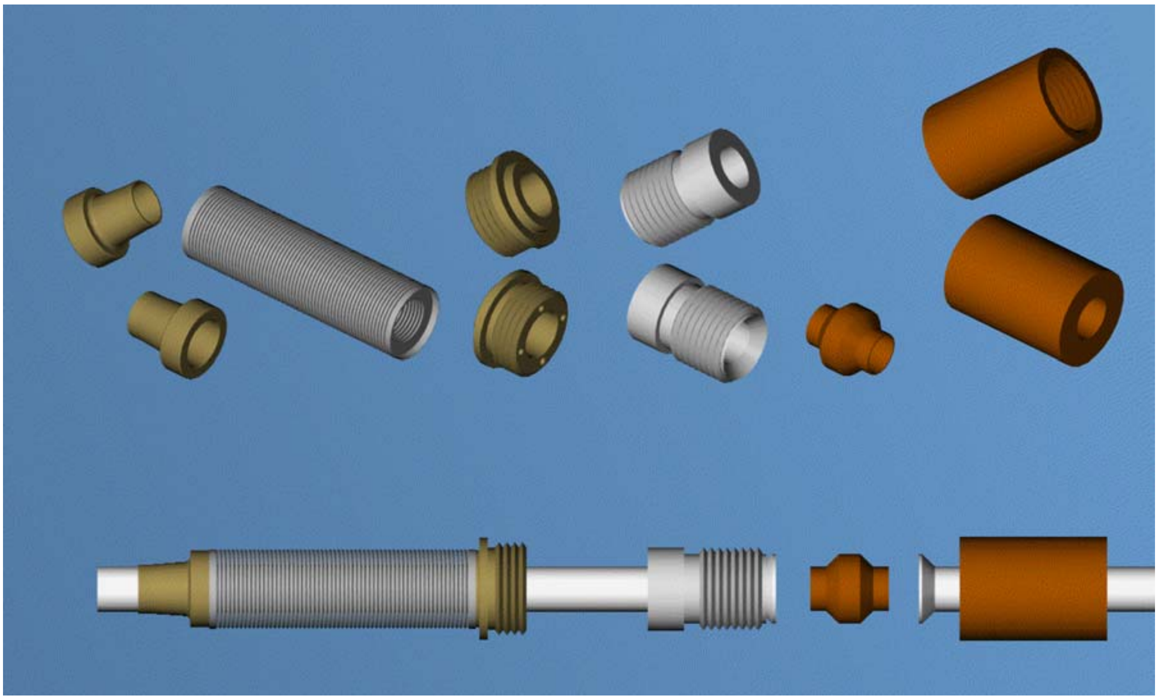

Figure 10. Coolant Pipe Feedthrough for the PP1 Bulkhead.

From left to right in Figure 10 we have the following six pieces:

1) *Sliding Seal: This PEEK piece provides a gas seal to the coolant pipe, and is glued to the bellows. It slides on the pipe, to accommodate the bellows movement. A prototype test (at room temperature) yields a leak rate of < $5x10^{-4}$ liters/(mbar-hr) for one such seal. Tests with many seals will be done as part of the prototype program.*

2) *Bellows: This nickel bellows allows for axial movement of the coolant pipes relative to the PP1 bulkhead.The aluminum pipes shrink as they are cooled from room termperature to the operating temperature. Its length is 54.8 mm when relaxed, and it has a spring rate of 0.53 pounds/inch.*

3) *Bellows to Bulkhead: The bellows is glued to this PEEK piece, and then this piece is screwed into the PP1 bulkhead. This piece might be made of aluminum instead of PEEK to reduce cost.*

4) *Inner Flair Connector: This aluminum piece is at the flared end of the coolant pipe, and is one half of the coolant pipe coupling.*

5) *Flare Bushing: This PEEK piece forms the actual seal between the flared ends of the coolant pipes. It also acts as an electrical break in conjunction with item (6).*

6) *Flare Outer: This PEEK piece screws onto the Inner Flare Connector, and is the other half of the coolant pipe coupling. It is made of PEEK to provide an electrical break.*

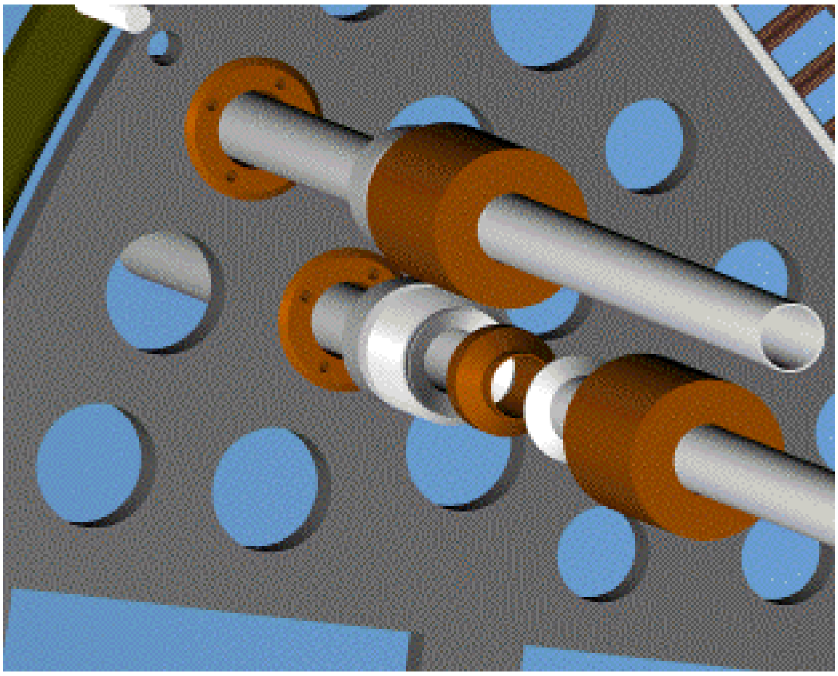

Figure 11. Coolant Pipe Feedthroughs in the PP1 Bulkhead.

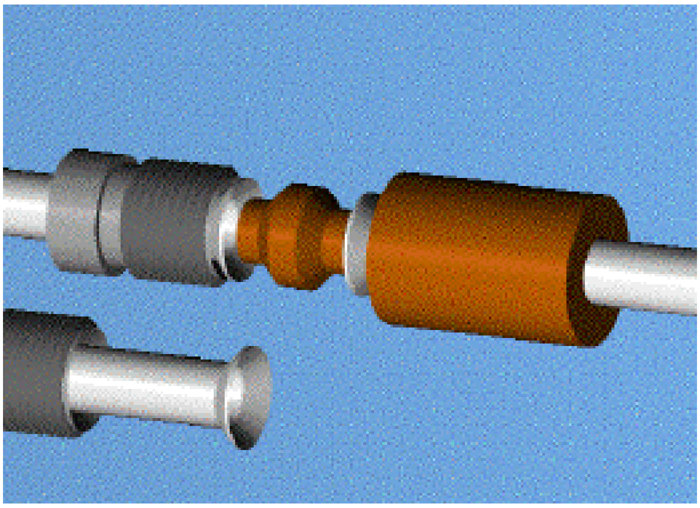

Figure 12. Coolant Pipe Coupling.

There will also be a stainless steel filter-screen/pressure-drop device to reduce the pressure of the C_3F_8 from 16 to 8 bar. This piece will either be a part of the coolant pipe coupling or part of the PP1b fitting. It is under design, and is not shown in the above Figures. The PP1b fittings are expected to be commercially available fittings(unlike those described above) but these have not yet been selected. An alternative would be to use fittings similar to those described above but of slightly different dimensions without the need for an electrical break.

The return coolant pipe couplings are undergoing tests to insure that they do not deteriorate under thermal and pressure cycling, and that they can withstand the nominal pressure. Previous versions of the couplings have passed similar tests. The supply coolant pipe couplings might also be tested. The current testing of the latest version of the return coolant pipe couplings (as shown in Figure 3) involves the following steps (all pressures are gauge pressures):

1. *Helium vacuum leak check (measure leak rate).*
2. *Proof test at 10 bar (this is a 1 minute visual check, to make sure the fitting stays intact, and that there are no large leaks). This will be repeated at a higher pressure, perhaps 20 bar.*
3. *Helium leak check of coupling at 4 bar, 0 °C.*
4. *Helium leak check of coupling at 1 bar, -35 °C.*
5. *Helium vacuum leak check (measure leak rate).*
6. *Thermal cycle coupling: 50 times, between 20 °C and -35 °C.*
7. *Pressure cycle coupling: 50 times, between 1 bar and 4 bar.*
8. *Helium vacuum leak check (measure leak rate).*
9. *Helium leak check of coupling at 16 bar, 0 °C.*
10. *Helium leak check of coupling at 1 bar, -35 °C.*
11. *Helium vacuum leak check (measure leak rate).*

Results for testing 4 samples of return coolant pipe couplings are below (units for helium leak measurements are torr-liter/sec). Leak rates are all well below specs.

Step	*Spec*	*Sample 1*	*Sample 2*	*Sample 3*	*Sample 4*
1	$<2x10^{-5}$	$3x10^{-10}$	$3x10^{-10}$	$3x10^{-10}$	$3x10^{-10}$
2	Pass	Pass	Pass	Pass	Pass
3	$<7x10^{-5}$	$3.5x10^{-10}$	$7x10^{-10}$	$20x10^{-10}$	$200x10^{-10}$
4	$<2x10^{-5}$	$2x10^{-10}$	$7x10^{-10}$	$32x10^{-10}$	$300x10^{-10}$
5	$<2x10^{-5}$	$4x10^{-10}$	$2x10^{-10}$	$3.2x10^{-10}$	$2x10^{-10}$
6	50 cycles	done	done	done	done
7	50 cycles	done	done	done	done
8	$<2x10^{-5}$	$4x10^{-10}$	$4.5x10^{-10}$	$2.8x10^{-10}$	$2.5x10^{-10}$
9	$<7x10^{-5}$	$160x10^{-10}$	$7x10^{-10}$	$40x10^{-10}$	
10	$<2x10^{-5}$	$200x10^{-10}$	$10x10^{-10}$	$70x10^{-10}$	
11	$<2x10^{-5}$	$140x10^{-10}$	$45x10^{-10}$	$30x10^{-10}$	

Note that these prototypes of the exhaust pipes that are larger in diameter than the inlet pipes, which will subject to the highest pressures. We are in the process of extending the maximum pressure range beyond 16 bar(abs) but results are not yet available.

8 Optical Fibers

As PP1 is a very crowded area, the Swedish firm Ericsson made a study in order to indicate a possible solution to minimize the space for the connectors without jeopardizing the fibre life-time, their handling or installation. Industrial proven backplane technology was guiding this study.

The available area per quadrant amounts to 77mm x 35 mm and 4mm around and 50mm above towards the PP2 side of the PP1 endplate. Space for the connectors towards the PP0 side of the PP1 endplate is not directly limited. The pixel detector is kept on a slightly higher pressure (about 4mbar from pure Nitrogen) in comparison to its air surroundings in order to avoid condensation on its elements, which implies that the connectors at PP1 towards PP0 will be made leak-tight by a radhard soft silicon glue (Dow Corning SE4445). The 5 picture below in Figure 13 indicate a space saving lay-out. The left hand side of the firs tfour pictures show the bare ribbons arriving at PP1, while the 5th picture shows the arrangement of the 10 cables with their connectors. A 16 fibres ferrule (MT16 connector) is used by arraying this with two layers, i.e. two 8-way fibre ribbons are going into each ferrule. In the PP1 endplate a housing is foreseen into which the connectors will glide.

In order to save material especially inside the pixel detector, bare ribbons (not ruggedized) are preferred between PP0 and PP1. As the connectors on the PP0 side of the PP1 endplate have to be leak-tight, spring-loaded ferrules for these connectors have to be excluded. Therefore these connectors still need to be redesigned and then to be tested.

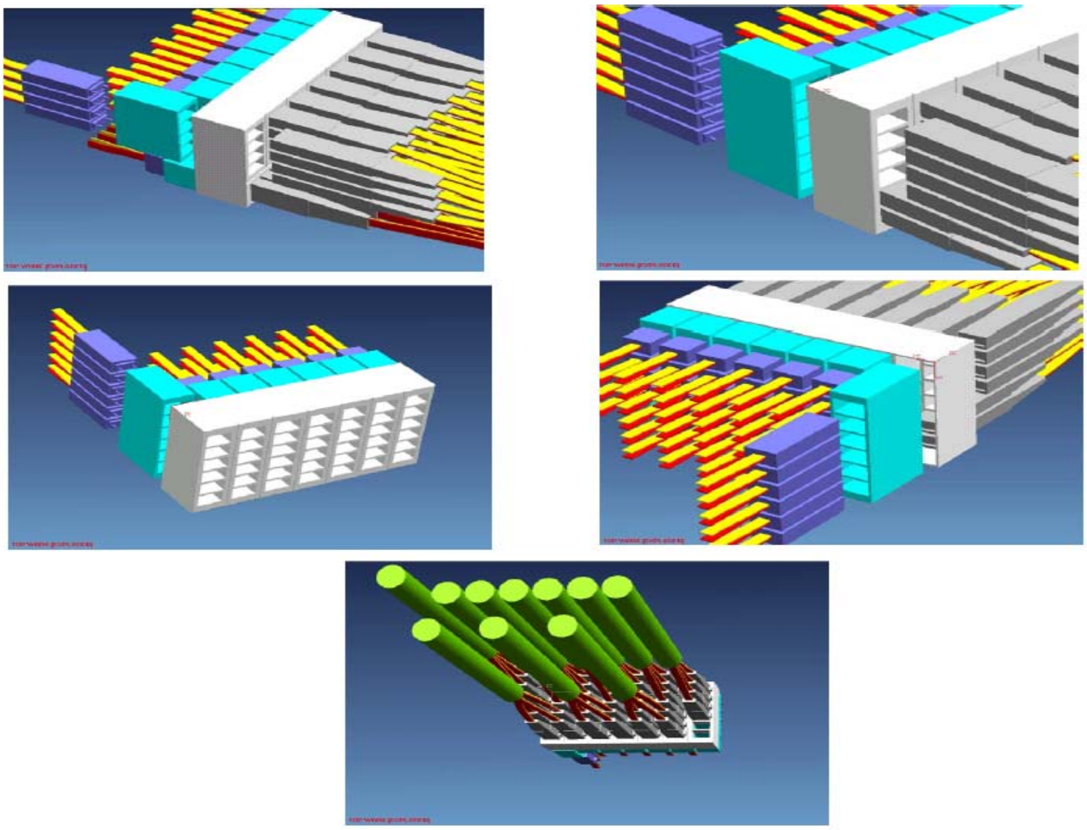

Figure 13. Conceptual design for the fiber optic feedthrough at PP1. See text for description.

The 8 ribbons of each cable coming from USA15 will be hanging out of the cable for about 50cm towards the PP1 side. The length of these ribbons will not differ by more than about 50mm, depending on the exact opening of the end of the cable. Ribbons assembled to the same connector have the same length within 5mm. A cable consists then of a module of 4 connectors which will find their counterpart of 8 nude ribbons with their 4 connectors coming from PP0. A final fixation of the connectors by screws will guarantee an optimal light transfer through the fibres from both sides of the PP1 endplate. All ribbons coming from PP0 to PP1 will be finally fixed to the endplate PP1 region already in the surface SR1-building before the installation of the pixel detector in the ATLAS cavern. The 78 optical fibre cables coming from USA15 will then be connected one by one to both PP1 regions. Because of the very limited space it may turn out to be impossible to exchange one particular cable after having connected all other cables to PP1. Therefore it is necessary to test each connection before continueing to connect the next optical fibre cable to PP1.

As PP1 also is a place of high radiation all materials used in the connectors, housings, and adapters must be radiation hard. Aluminum and PEEK are excellent candidates here. Ericsson is going to make a prototype of the above PP1 optical fibre connector lay-out in the coming weeks.

9 Mockup

The region of the PP1 endplate is very crowded by a huge amount of different electrical cables, optical fibres, cooling and gas integrity pipes. In order to have a better understanding of the implementation and integration of all these different items around PP1, it was decided to build a 1:1 mock-up of one quadrant of one PP1 endplate. The fabrication of this mockup is in progress at CERN – see Figure 14.

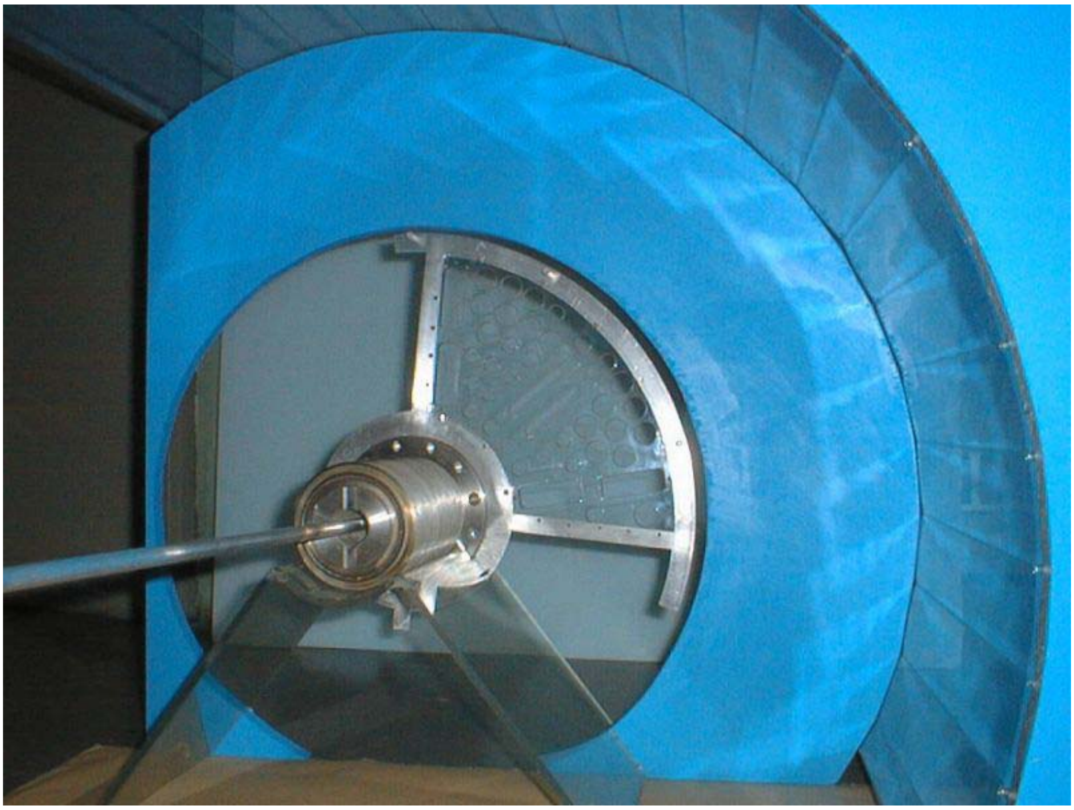

Figure 14. Mockup of the PP1 region under construction at CERN.

10 Material Estimate

The material in the PP1A-PP1B region can be approximated by nine disks of material located at:

Disk	*Name*	*Inner Radius (mm)*	*Outer Radius (mm)*	*Average Z (mm)*
1	*Flange Assembly and Studs*	*230.0*	*239.5*	*3094*
2	*Bulkhead Seal*	*70.0*	*238.8*	*3099*
3	*Bulkhead and Feedthroughs*	*80.0*	*227.5*	*3094*
4	*Bulkhead Center Support*	*56.8*	*77.0*	*3103*
5	*Center Bellows*	*46.7*	*58.8*	*3150*
6	*Bellows to Beam Pipe*	*34.7*	*62.3*	*3210*
7	*Pipes, Fiber Optics, & Cables*	*91.0*	*250.0*	*3230*
8	*Pipes, Fiber Optics, & Cables*	*250.0*	*330.0*	*3250*
9	*Pipes, Fiber Optics, & Cables*	*330.0*	*435.0*	*3350*

The contents and description of each disk are:

Disk 1, Flange Assembly and Studs
The flange assembly, which is a narrow ring of carbon fiber, attaches to the PP1 bulkhead with the studs. LBNL drawing 2500053.
Disk 2, Bulkhead Seal

This aluminum pieces provides the gas seal for the PP1 bulkhead quadrants, and is very non-uniform in phi. LBNL drawing ag0452.

Disk 3, Bulkhead and Feedthroughs

- *PP1 Bulkhead itself. LBNL drawing ag0450.*
- *Coolant Return Pipe Feedthroughs (6 pieces)*
- *Coolant Supply Pipe Feedthroughs (7 pieces, including Filter/Pressure Drop)*
- *Fiber Optic Cable Feedthroughs (4 pieces)*
- *Copper Striplines and Feedthroughs*
- *Beam Pipe Adjusters*

Disk 4, Bulkhead Center Support
This aluminum ring connects the PP1 bulkhead to the bellows around the beam pipe. LBNL drawing ag0451.

Disk 5, Center Bellows
This nickel bellows allows for axial movement between the PP1 bulkhead and the beam pipe. LBNL drawing ag0451.

Disk 6, Bellows to Beam Pipe
This plastic pieces connects the center bellows to the beam pipe.

Disk 7, Coolant Pipes, Fiber Optic Cables, and Electrical Cables (R=9.1-25 cm)
The electrical cables go axially about 5 cm to Z=325 cm, and then radially about 10 cm to R=25 cm. For simplicity, the same is assumed for the coolant pipes and fiber optic cables (which have much less mass than the electrical cables). The length of the pipes, fiber optics and cables are 15 cm in this region. The electrical power cables were changed from AWG 22 to AWG 26 in order to reduce the amount of material. Included in this disk are:

- *Coolant Return Pipes*
- *Coolant Supply Pipes*
- *Fiber Optic Cables*
- *Electrical Cables (AWG 26 Power, AWG 26 Sense, AWG 30 HV/Temp)*

Disk 8, Coolant Pipes, Fiber Optic Cables, and Electrical Cables (R=25-33 cm)
The coolant pipes, fiber optic cables and electrical cables go radially 8 cm to R=33 cm, at Z=325 cm. Their length is 8 cm in this region. Included in this disk are:

- *Coolant Return Pipes*
- *Coolant Supply Pipes*
- *Fiber Optic Cables*
- *Electrical Cables (AWG 26 Power, AWG 26 Sense, AWG 30 HV/Temp)*

Disk 9, Coolant Pipes, Fiber Optic Cables, and Electrical Cables (R=33-43.5 cm)

The coolant pipes, fiber optic cables and electrical cables go radially ~5 cm, axially 20 cm, and azimuthally ~42 cm, for a total of 67 cm in this region. The azimuthal routing follows from the layout of the PP1B region provided by others. One might be able to reduce this length of 67 cm, but not before a more detailed study is made. Disk 9 approximates a cylinder of delta_R=10.5 cm (R=33 to 43.5 cm), L=20 cm (Z=325 to 345 cm), in which the pipes, fibers and cables are mainly axial and azimuthal, and which contains electrical cable and cooling pipe connectors. The copper electrical cables, since a lot of their length is concentrated in this radially narrow disk (10.5 cm), contribute a lot of material to this disk. The electrical cable connectors also contribute a lot of material to this disk.

Included in this disk are:

- *Coolant Return Pipes*
- *Coolant Supply Pipes*
- *Coolant Return Pipe Connectors*
- *Coolant Supply Pipe Connectors*
- *Fiber Optic Cables*
- *Electrical Cables (AWG 26 Power, AWG 26 Sense, AWG 30 HV/Temp)*
- *Electrical Cable Connectors (from Mauro Citterio, May 5, 2003)*

In the calculation of the material for each disk, the following assumptions were made:

- *All material is averaged over phi, so the results are given for disks of a specified inner and outer radius. The normalization area used is the area of the disk.*
- *The amount of material is that seen by particles perpendicular to the disks.*
- *The coolant pipes, fiber optic cables and electrical cables go from PP1A to R=435 mm, Z=3450 mm, and are each 90 cm in length.*

The amount of material in the nine disks is calculated to be (Version 6 of the Excel spreadsheet, May 27, 2003):

Disk	Name	Inner Radius (mm)	Outer Radius (mm)	Radiation Lengths (%)
1	Flange Assembly and Studs	230.0	239.5	3.5
2	Bulkhead Seal	70.0	238.8	1.2
3	Bulkhead and Feedthroughs	80.0	227.5	17.1
4	Bulkhead Center Support	56.8	77.0	7.5
5	Center Bellows	46.7	58.8	19.8
6	Bellows to Beam Pipe	34.7	62.3	3.5
7	Pipes, Fiber Optics, & Cables	91.0	250.0	8.0
8	Pipes, Fiber Optics, & Cables	250.0	330.0	5.0
9	Pipes, Fiber Optics, & Cables	330.0	435.0	50.3

The chemical composition of each of the nine disks was also calculated. For the chemical composition calculation we assumed: peek is C, plastic is C, BeCu is Cu, solder is Pb60Sn40 by weight, and we ignored the glass fibers. The densities used were:

Element	Density (g/cm3)	Element	Density (g/cm3)
C	2.200	Cu	8.960
Fe	7.874	Pb	11.350
Al	2.699	Sn	7.310
Ni	8.902		

The chemical composition of the nine disks is calculated to be (Version 6 of the Excel spreadsheet, May 27, 2003):

	C		Fe		Al		Ni		Cu		Pb		Sn	
	Total Equiv t (mm)	**Wt Frac**	Total Equiv t (mm)	**Wt Frac**	Total Equiv t (mm)	**Wt Frac**	Total Equiv t (mm)	**Wt Frac**	Total Equiv t (mm)	**Wt Frac**	Total Equiv t (mm)	**Wt Frac**	Total Equiv t (mm)	**Wt Frac**
Disk 1:	3.280	**0.708**	0.377	**0.292**										
Disk 2:			0.071	**0.229**	0.699	**0.771**								
Disk 3:	6.911	**0.363**	0.170	**0.032**	6.555	**0.422**	0.325	**0.069**	0.419	**0.090**	0.054	**0.015**	0.056	**0.010**
Disk 4:			0.152	**0.070**	5.910	**0.930**								
Disk 5:							2.808	**1.000**						
Disk 6:	10.480	**1.000**												
Disk 7:	1.443	**0.232**			0.749	**0.148**			0.948	**0.620**				
Disk 8:	0.899	**0.232**			0.467	**0.148**			0.591	**0.620**				
Disk 9:	16.464	**0.297**			22.245	**0.493**			2.857	**0.210**				

11 Preliminary Production Plan

The design responsibilities for the PP1 region(including prototypes) are given below in Table 5. In general the fabrication responsibilities will follow from the design responsibilities.

Item	*Institution(s)*
PP1 endplate	*LBNL*
PP1a coolant fittings and seals	*LBNL*
PP1a gas fittings	*LBNL*
PP1b coolant fittings	*CERN*
PP1b gas fittings	*CERN*
PP1a to PP1b pipes	*CERN*
Electrical feedthroughs	*LBNL, Milano*
Fiber feedthroughs	*Wuppertal*
Functional prototype	*LBNL*
Mockup at CERN	*Wuppertal*

Table 5. Overview of fabrication responsibilities for PP1.

12 Appendices

Detailed drawings as needed

[1] ATL-IP-ES-0007 Requirements for Pixel Detector Services
[2] ATL-IC-EN-0009 Inner Detector Thermal Management and Environmental Gas
[3] ATL-IC-EN-0009 Moisture Management in the ATLAS SCR and Pixel Tracker Using Dry Nitrogen Flow