ATLAS project	Pixel Detector Cooling Circuit Requirements		
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Pixel Detector Cooling Circuit Requirements

Abstract

This document describes the basic requirements of the Pixel Detector primary cooling circuit. Power, modularity and system layout are discussed, together with basic system specifications.

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Distribution List

Atlas Collaboration for comments

History of Changes

Rev. No.	*Date*	*Pages*	*Description of changes*
Draft	15/10/99	All	General up-date

Table of Contents

1 INTRODUCTION

The pixel detector is made of an array of sensitive elements whose surface must be kept below –7°C.

The sensitive elements are organised in two main structures: barrel and disk.

The barrel region is made of three coaxial cylinders (B-layer, layer 1 and layer 2) each containing a different number of staves.

One stave is a basic element with 13 modules on and an integrated cooling channel.

The two disk regions, one at each end of the barrel, contain five disks each.

Each disk is made of sectors, one sector supports 6 modules and provides the required cooling.

2 PIXEL DETECTOR HEATING STRUCTURE

The power dissipated by each module is always the same apart from the innermost layer of the barrel region (B-layer).

The following table summarises the cooling requirements of the pixel structure.

	n. of elements	*n. of module per element*	*total n. of modules*	*Baseline power per module (W)*	*Power per element (W)*	*Total power (W)*
B-LAYER	*18*	*13*	*234*	*11*	*143*	***2574***
BARREL						
layer 1	*42*	*13*	*546*	*7.7*	*100.1*	*4204.2*
layer 2	*58*	*13*	*754*	*7.7*	*100.1*	*5805.8*
Subtotal						***10010***
DISCS						
1	*11*	*6*	*66*	*7.7*	*46.2*	*508.2*
2	*11*	*6*	*66*	*7.7*	*46.2*	*508.2*
3	*11*	*6*	*66*	*7.7*	*46.2*	*508.2*
4	*9*	*6*	*54*	*7.7*	*46.2*	*415.8*
5	*9*	*6*	*54*	*7.7*	*46.2*	*415.8*
Subtotal						***2356.2***
BARREL+DISCS						***14722.4***
PIXEL DETECTOR						***17296.4***

3 PIXEL DETECTOR PRESSURE SPECIFICATIONS

Due to the ultra-light design of the mechanical/thermal support of pixel sensitive elements and to reliability requirements the maximum absolute pressure of the refrigerant should never exceed 3 bar in heating structures.

The heating element cooling channels have been designed to achieve at nominal power pressure drops in the range of 100-300 mbar to minimise the temperature non-uniformity over the sensitive elements.

4 MODULARITY AND LAYOUT OF COOLING PIPES

The staves and the disks are cooled with a modularity of two: 1 independent circuit for two elements.

The B-layer is currently assumed to have a modularity of 1 but latest changes in the insertion scheme, show as more convenient to adopt (if consistent with the cooling efficiency/pressure drops) a modularity of two even for the B-layer.

All cooling pipes for disks and barrel layer 1&2 come from the gap barrel/forward Inner Detector and break at PPB1.

The B-layer pipes come from one side only through the gap between the beam pipe and the SCT forward region and break at PPF1.

Due to the routing constraints of services coming out the ATLAS detector and the possible locations of the cooling racks on the platforms, it is convenient to group the pipes of the pixel detector in four bundles manifolding to four cooling units located on racks over the platforms.

The proposed locations of the four units are approximately at 45, 135, 225 and 315 degrees in phi.

The B-layer cooling pipes can be grouped, conveniently, in one bundle going out of the ATLAS detector from only one radial direction, and reaching an independent cooling rack on the platform.

The following table summarise the organisation of the cooling circuits in four group (+1 for the B-layer) and the relevant informations for each group.

	n. of circuits at 1st end	n. of circuits at 2nd end	N. of pipes/connections per end	Power per each of four unit	N. circuits per unit
B-LAYER	9		**18**	(1)	**9**
BARREL					
layer 1	10	11		1051.05	
layer 2	15	14		1451.45	
Subtotal	25	25	50	2502.5	
DISCS					
1	6	6		254.1	
2	6	6		254.1	
3	6	6		254.1	
4	5	5		207.9	
5	5	5		207.9	
Subtotal	28	28	56	1178.1	
BARREL+DISCS	53	53	**106**	**3680.6**	**26.5**
(1) 1 unit @ 2860 W					

5 cooling pipe routing

The Pixel detector is the innermost part of the ATLAS detector and hence it is the hardest reachable by the services.

The cooling pipe layout is therefore extremely complex.

The pipes break at fixed locations for assembly and installation reasons the changes in cross section are therefore permitted only in a few places.

The complex scenario outside the ATLAS detector and the tortuous path inside, result in possible large variation of pipe length from the pixel detector to the cooling racks on the platforms.

Anyway, it is possible to make each group of pipes fed by one unit of coherent circuits having similar routing/length and hence similar pressure drops.

The following table gives the breakdown of the inlet and return pipe lengths for each relevant section of the system.

It can be observed how different the minimum and maximum lengths are, this is due to the constraints on allowed routings and platform location.

	min length (mm)	*max length (mm)*	*inlet pipe ID (mm)*	*return pipe (ID)*	*n. of 90 elbows*
Detector-PPB1	*990*	*1490*	*1*	*7*	*5*
PPB1-PPB2	*6260*	*9410*	*2*	*9*	*4-6*
PPB2-PPB3	*10200*	*10200*	*3*	*13*	*2*
PPB3-rack	*6000*	*24000*	*4*	*13*	*2*
Total	***23450***	***45100***			

The inlet and return pipe ID are the current envelopes assumed for the layout of services in the gap region.

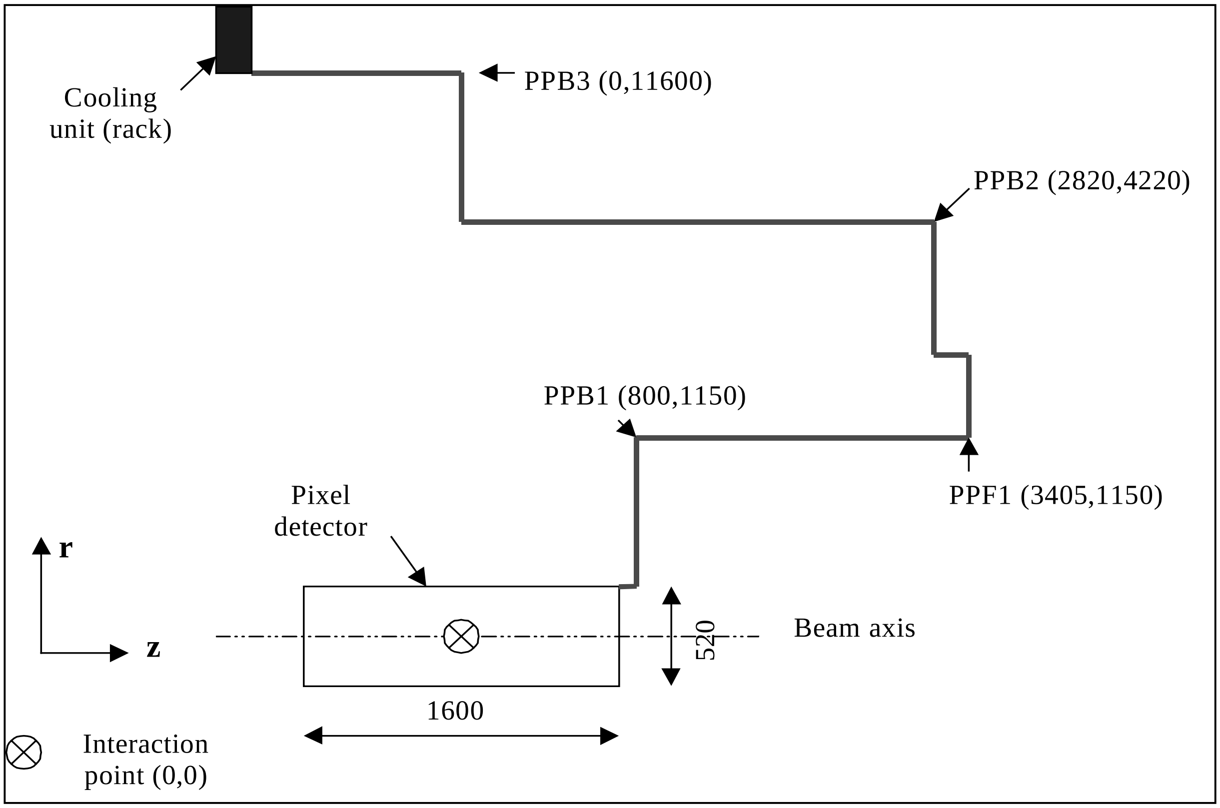
A detailed study of the pressure drops should lead to a more optimised pipe layout: in any case the pipe IDs must never exceed the ones in the table.

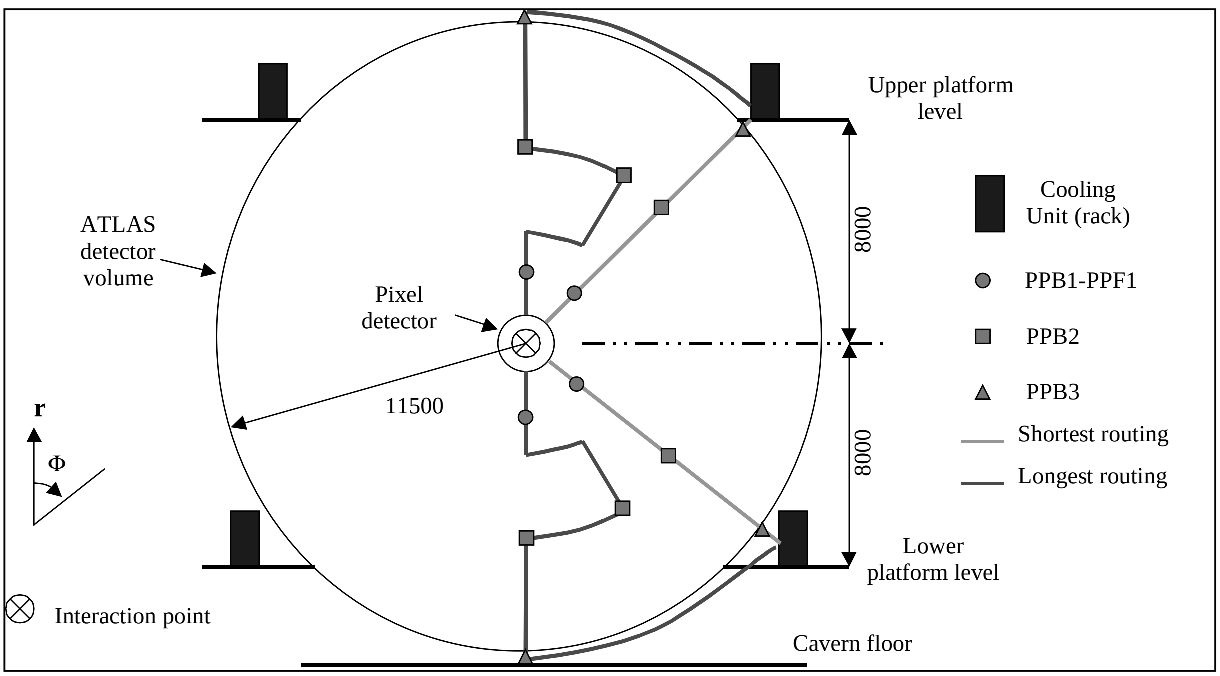
The pipe layout for layer 1&2 and disks should be standardised (same IDs sequence and fitting types) at least to simplify the installation/maintenance.

The B-layer piping can be designed independently due to different routing/installation procedures.

The following drawings show the layout of cooling pipes identifying the longest/more complex routing and the shortest/simplest one.

The locations of the cooling racks are also identified.


Cooling
unit (rack)
PPB3 (0,11600)
PPB2 (2820,4220)
PPB1 (800,1150)
PPF1 (3405,1150)
Pixel
detector
r
z
520
Beam axis
1600
Interaction
point (0,0)


Upper platform
level
Cooling
Unit (rack)
ATLAS
detector
volume
8000
PPB1-PPF1
Pixel
detector
PPB2
PPB3
11500
r
Φ
Shortest routing
Longest routing
8000
Lower
platform level
Interaction point
Cavern floor

6 Thermal design in the gap region

The pixel cooling circuit has to comply the general rule to be thermally neutral in the gap region outside the thermal barrier.

Space constraints show as preferable a solution avoiding insulation on pipes.

This means that the liquid refrigerant has to enter the detector volume at a temperature close to the gap one (20-25 °C) and that the return piping should reach the equilibrium conditions with gap as soon as possible after the thermal enclosure penetration and before the most congested area at PPF1.

Two possible solutions are under study:

- Inlet/return pipe heat exchanger
- Heating strip on the first section of the return pipe

Both solutions require insulation on pipes in the transition region up to the point where the equilibrium conditions are reached.

7 cooling unit specifications

The pixel system will be supplied by 5 cooling units (racks) located on the service platform.

The design of B-layer and barrel layer 1&2 + disks cooling units will be common.

The nominal design power corresponds to the max module dissipation

The design power will be:

- barrel layer 1&2 and disk: 3680 W (for each unit)
- B-layer: 2574 W

An inlet quality to cooling structures of 0,3 (worst case) and an outlet quality of 0,9 should be conservatively assumed.

Each unit will provide an independent control of the flow rate (by controlling the input pressure) of each one of the 27 cooling circuits (8 for the B-layer)

All system components (actuators, control devices, safety valves) have to be located in one or more racks on the platform: (no component is allowed in the detector region).