Pixel Detector Active Area Layout

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Pixel Detector Active Area Layout

Abstract

This document describes the layout of the active area of detector elements of ATLAS Pixel Detector.
All relevant assumptions are presented and the physical/technological constraints are discussed.
The basic purpose of this document is to provide the required input to those who are in charge of the calculation of the detector performance and to people in charge of finalising the design of the Pixel Detector support structure and services.

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Distribution List

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History of Changes

Rev. No.	*Date*	*Pages*	*Description of changes*
Draft	22/10/99	All	Draft release for comments
1	14/12/99	7-8	Change n. of staves on layer 1 and 2 and relative disk positions
2	14/12/00	All	Major revision due to adoption of fully insertable design
3	28/09/01		Change of B-layer insertion concept
3.1	24/06/2002	9,10,11	Added references to drawing in appendix

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1 INTRODUCTION

The pixel detector is made of an array of sensitive elements organised in two main structures: barrel and disks.

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

The basic element of a barrel layer is a stave with 13 detector elements.

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

Each disk is made of sectors, one sector supports 6 detector elements three on each face.

The layout is driven by many constraints and its final design is a result of a very sophisticated and refined optimisation involving almost all fields of the Pixel Detector project (mechanics, physics, electronics).

The layout drawings as well as this document are stored on EDMS in document ATL-IP-EP-0004 and kept under change control.

2 PHYSICS REQUIREMENTS

The ATLAS Pixel Detector must provide the conditions for excellent pattern recognition and track and vertex resolution in a very demanding high-multiplicity environment.

These general requirements can be translated into a number of practical constraints:

- Three pixel hits over the full rapidity range covered by the Inner Detector ($|\eta|<2.5$), for all tracks generated within $|z| < 11.2$ cm (2σ) of the beam crossing point
- the smallest possible radius for the innermost layer (B-layer)
- the largest possible radius for the outermost layer
- the smallest possible pixel area
- the smallest possible pixel size in the R-ϕ co-ordinate
- good charge collection even after irradiation
- the lowest amount of material in the system, compatible with the requirements of mechanical and thermal stability
- the smallest outer envelope of the pixel system to minimise the impact on end-cap SCT design

A layout that attempts to satisfy all these requirements consists of three concentric barrels and three disks on each side. The innermost barrel layer (B-layer) is positioned just outside the beam pipe and provides complete $|\eta|$ coverage; the two outer barrels together with the 3+3 disks provide the two other space points.

3 LAYOUT CONSTRAINTS

The inner and outer radii of the three barrels are constrained by different requirements.

The B-layer radius is required by physics (impact parameter resolution) to be as small as possible. It is limited by the size of the beam pipe and the surrounding mechanical tolerances.

The radius of the outer layer (layer 2) should be as large as possible, in order to optimise the pattern recognition and the stand-alone trigger performance. As it has to give continuous coverage together with the first disk, the upper bound on its radius comes from the maximum disk radius and the minimum distance between the end of its active area and the position of the first disk in $|z|$.

The radius of the middle layer (layer 1) is constrained by the position of the B-layer and of layer 2.

The barrel staves are tilted by a small angle with respect to the local radial direction in order to partially compensate the effect of the Lorentz angle on the charge collection in the silicon sensors.
Concentrating the electrons into the smallest possible clusters improves the double-track resolution and increases the detector efficiency after irradiation.

The disks are physically constrained in inner and outer radii and z position. The disk outer radius determines the outer envelope of the pixel system and should be minimised. On the other hand, the physical inner radius of the disks should not be less than the physical inner radius of barrel layer 1. This constraint insures that any device that will fit within barrel layer 1 will also pass through the disks. At present these limitations are taken as a minimum physical disk inner radius of 85 mm.

The z positions of the disks are constrained by the necessity to rout barrel services between the physical end of the barrel and the first disk and by the necessity to keep the maximum z extent of the pixel detector less than +/- 780 mm. The requirement of service space between the physical end of the barrel region and the first disk also imposes (as discussed before) a maximum radius constraint on barrel layer 2 since disk 1 approaches the barrel as the radius of barrel layer 2 increases. At present disk 1 is constrained to have an absolute z position of approximately 495 mm or greater. The last or third disk z position is constrained to be no greater than 770 mm from the interaction point to fit within the pixel detector volume.

4 MODULE ENVELOPES

The current baseline for the detector module is based on the flex hybrid technology.

From the layout point of view only the geometrical envelopes of the modules are relevant.

Therefore the definition of realistic envelopes for the module has been a fundamental starting point for the design of the layout.

Drawing ATLAY0001 shows the agreed envelope of the module, it can be found on EDMS document ATL-IP-ES-0003. In the same document a table MOD_ENV shows the breakdown of the assumed module thickness for the envelope definition.

5 BARREL LAYOUT

5.1 Basic assumptions

The barrel azimuthal and z layouts are strongly coupled and both are heavily dependent on module envelopes and stave design.

The layout of the components on modules is constrained by the layout as well.

Therefore the optimisation of the barrel layout is a result of a very long iteration due to such strong cross-links and constraints.

The barrel layout has been studied and optimised on the basis of the following ground rules:

- 1.2 mm min clearance between two adjacent staves
- 0.4 mm min clearance between two adjacent modules on a stave
- 1 GeV min transverse momentum coverage
- 4 mm min clearance between envelopes of layers and support structure
- coverage to infinite momentum tracks up to a max beam offset of 7 mm

The layout of the B-layer assumes an outer envelope of the beam pipe of 36 mm in radius (still provisional) and a nominal radial clearance of 9.5 mm between the B-layer inner envelope and the beam pipe outer one.

The 9.5 mm clearance is the minimum required for a safe B-layer installation taking into account the potential misalignment of the B-layer relative to the beam pipe.

The minimum inner envelope of the B-layer is then set to 45.5 mm in radius.

5.2 Module layout on stave

The layout of the 13 modules on a stave has been arranged in a sequence of shingled steps (tilt angle of 1.1°) symmetric with respect to the stave mid module which is horizontal.

The geometry of the stave stepping sequence is shown on drawing ATLAY0004 (see appendix).

Drawing ATLAY0002 (see appendix) and shows the layout of modules along the stave.

5.3 Stave azimuthal layout

The staves have been organised on three layers overlapping along a tilted sequence.

The tilt angle has been chosen as the minimum to achieve the required coverage with the minimum allowed clearance.

The stave azimuthal layout is shown on ATLAY0003 drawing (see appendix).

The main features of the stave azimuthal layout are summarised in the following table:

	nominal active radius (1)	n° of staves	tilt angle
B-layer	50.5 mm	22	20°
Layer 1	88.5 mm	38	20°
Layer 2	122.5 mm	52	20°

(1) Radius at the centre point of the active area of the non-centre module on the stave.

The constraints on module component layout resulting from the adopted stave layout translate into an allowable volume requirement for the components on the module (see drawing n. ATLAY0001 in appendix).

6 DISK LAYOUT

6.1 Basic assumptions

The pixel disks continue two pixel hit coverage beyond the pixel barrels. The region extends from approximately an $|\eta|$ of 1.8 to an $|\eta|$ of 2.5. Pixel disks are sized in radial extend and positioned in z so that continuous two hit coverage is provided in this region. Since there is no tilting of disk modules there is little or no dependence of coverage on particle transverse momentum.

6.2 Module layout on disk

The physical and active dimensions of disk modules are the same as barrel modules. Modules are attached to both sides of disk structures whose thickness, for the baseline design, is 5 mm. Each disk is divided into sectors of six modules for fabrication and service modularity. The modules on one side of a disk are offset in azimuth by 360/(n. of modules) degrees from the modules on the other side to insure active area overlap. The twelve o'clock position on a disk lies halfway between a module on one side and the other.

All the three disks have the same design with the same number of modules.

The number of modules per disk and their inner active radius is given in the table following section 6.4. Drawing n. 21F3754 (see appendix) shows the layout of the 48 modules on the disk. The inner active radii quoted below are to the centre of the module's active inner radial side. The fact that modules on one face of a disk cannot physically overlap constrains the disk layout such that there are small v-shaped gaps in active coverage of each disk at the outer radii.

6.3 Disk layout in z

The z position of disks 1 and 2 are determined by the ends of acceptance coverage of barrel layers 1 and 2 respectively. Disk 3 position provides the coverage of two pixel hits up to an eta of 2.5. The disk z positions are given for the point midway between the sides of a disk, hence the modules on the side of the disk facing the IP are closer to the IP and those on the opposite side are further from the IP.

Disk	Nr Modules	Active Inner Radius	Disk Centre Z Position
1	48	88.77 mm	495 mm
2	48	88.77 mm	580 mm
3	48	88.77 mm	650 mm

7 ACCEPTANCE LOSSES

7.1 Calculation method

Acceptance losses were estimated with the full GEANT3 simulation using high energy muons with pT=50 GeV with uniform distribution in pseudorapidity. The vertex was centred at x=y=z=0.0 with Gaussian distribution of sx=sy=0.5 cm and sz=5.6 cm, truncated at |z| < 11.2 cm (at two standard deviations).

7.2 Barrel losses

The acceptance losses occur in the barrel mainly in the gaps between the central module and its neighbours at |z| ~ 3 cm and between the next modules at |z| ~ 9 cm. The probability to have less than three hits in the barrel layers with |eta| < 1.5 is 1.6 %.

Low energy muons of one sign can pass through the r-phi gap between the staves. For muons with pT=0.4 GeV the probability to loose one of the barrel layers increases up to 2.1 %.

7.3 Overall losses

There are two sources of the losses in the disk pseudorapidity region:

- Losses due to the small v-shaped gaps at the outer active radii of each disk

- Losses due to the small gap between barrel layer 2 and first disk

The total losses in the acceptance region |eta| < 2.5 expressed in the probability to have less than three hits is 2.5 % for high energy muons. For low energy muons of unfortunate sign with pT=0.4 GeV the losses increase only slightly up to 3.1 %.

8 GLOBAL LAYOUT OF PIXEL ACTIVE REGION

All geometrical information to locate each module active area in the pixel detector volume with respect with ATLAS co-ordinate system is given on drawing n. ATLAY0008 (see appendix).