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ATLAS Pixel Detector status in Run 2

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Summary. — The ATLAS Pixel Detector had good performance throughout the first operation of the LHC. During the long shutdown of data taking in 2013 and 2014, the services of the detector have been renovated and a fourth layer of pixels, called Insertable B-Layer (IBL), has been placed around new smaller radius beam-pipe. The new layer is closer to the interaction point and has a reduced pixel size. It will mitigate some loss of efficiency of the previous innermost layer when increasing the peak luminosity, scheduled to reach $2\times10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. The modules production has been completed in the first months of 2014. An overview of the used technologies and the expected performance of the Pixel Detector is presented.

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1. – Introduction

The Pixel Detector [1] is the innermost component of the ATLAS experiment [2] and it is therefore located very close to the interaction region. The pixel tracking system consists of three concentric barrel layers (with mean radii of 50.5 mm, 88.5 mm and 122.5 mm) and six disk layers, three disks in each of the forward and backward directions. It provides at least three high accuracy space-point measurements per track for pseudo-rapidity $|\eta| \leq 2.5$, as needed for track and vertex determination. The innermost pixel layer (so-called B-Layer) plays a crucial role for tracking, vertexing, and b-tagging capabilities of ATLAS, especially at high luminosity. The Pixel Detector is composed by 1744 modules in total. Each module consists of a $16.4 \times 60.8\,\mathrm{mm}^2$ planar n-in-n silicon sensor tile, $250\,\mu$m thick, with 47232 pixels (size of $50 \times 400\,\mu\mathrm{m}^2$), connected to 16 front-end (FE-I3) integrated circuits. The detector has been designed to face a total dose of 500 kGy (expected at $300\,\mathrm{fb}^{-1}$), a fluence of $1 \times 10^{15}\ \mathrm{n}_{eq}\,\mathrm{cm}^{-2}$ and a peak luminosity of $1 \times 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. Given the present LHC schedule, the integrated luminosity should reach $340\,\mathrm{fb}^{-1}$ at the end of Phase I (2022) and the peak luminosity could reach 2–$3 \times 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ generating some inefficiency in the B-Layer when the occupancy is higher. For this reason a program of upgrade has been arranged.

2. – ATLAS Insertable B-Layer

The Insertable B-Layer (IBL) [3] is the fourth pixel layer, that has been added to the Pixel Detector between the beam pipe and the B-layer, at a sensor average radius of 33 mm. To make the insertion of the IBL possible, the old beam pipe has been replaced by a new one, with reduced radius (from $R = 29$ mm to $R = 24$ mm), built of beryllium. The IBL consists of 14 staves (64 cm long, 2 cm wide), tilted in ϕ at 14° to guarantee hermeticity and optimize charge collection.

In the IBL two different silicon sensor technologies have been used: planar n-in-n manufactured by CiS (Germany) and 3D with passing through columns manufactured by Fondazione Bruno Kessler (FBK, Italy) and Centro Nacional de Microelectronica (CNM, Spain). Both technologies are equipped with the FE-I4 readout chip [4] in two different format layouts: double chip configuration for planar and single chip for 3D.

The FE-I4 was designed in 130 nm CMOS technology to cope higher radiation levels (750 MRad) and larger occupancies. It has a total size of $20.2 \times 18.8\,\text{mm}^2$ (5 times larger than the FE-I3) and consists of 26 880 pixel cells organized in a matrix of 80 columns (50 μm pitch) by 336 rows (250 μm pitch).

Each IBL stave is populated with planar pixel technology (12 double-chip modules) in the central region and 3D technology ($4 + 4$ single chip modules) in forward region.

3. – IBL modules production and integration

The selected sensor and electronics wafers are sent by the foundries to Fraunhofer IZM Institut (Berlin) to be diced and flip-chipped with SnAg solder bump-bonding. The final assembly is done at INFN Genova and in Bonn laboratories: a flex hybrid with passive components is glued on the back of the sensors and wire-bonds are done to establish the connection to the services. Then modules are qualified and shipped to University of Geneva where the final stave assembly is performed.

ATLAS IBL modules will need to operate for several years at the LHC, in a very harsh radiation environment, with no opportunity to repair channels developing a failure. To ensure good performance, all components follow a strict quality assurance (QA) during the production and all along the module loading, assembly and wire bonding operations.

4. – Conclusion

IBL modules production had good yield (75% for planars and 62% for 3D modules) and the insertion of the IBL will be crucial to maintain excellent performance of the ATLAS vertex detector and compensate possible inefficiencies of the old three layer Pixel Detector. Furthermore after surface repairs several failures in the Pixel Detector have been recovered and 98% of the channels are now operational.

REFERENCES

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