The ATLAS Pixel detector

The ATLAS Pixel [1][2] detector is the innermost part of the Inner Detector (ID). 4 Barrel + 2x3 Disk Layers.

Three outer layers
- B-Layer, Layer 1 and 2
- 50 x 250 µm²
- 250 µm thickness
- FEI3 readout - 8 bit ToT

Innermost Layer: IBL (planar and 3D)
- 50 x 250 µm²
- planar: 200 µm thickness
- 3D: 230 µm thickness (n-in-p)
- FEI4 readout - 4 bit ToT
- 3.3 cm from beam pipe

Fluence Levels

IBL is the most sensitive layer to radiation damage, already with a measurable impact on tracking.

Total IBL cumulated fluence and corresponding LHC delivered luminosity. Values referring to 2023 are estimates and correspond to the end of Run 3.

<table>
<thead>
<tr>
<th>year</th>
<th>2016</th>
<th>2017</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluence</td>
<td>2.4</td>
<td>6.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Total LHC delivered luminosity [fb⁻¹]</td>
<td>42</td>
<td>93</td>
<td>300</td>
</tr>
</tbody>
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Results

Simulations based on Allpix have been developed to predict the evolution of the performance parameters of the detector with fluence, such as: charge collection efficiency (CCE), the fraction of charge with respect to the non-irradiated case, and Lorentz Angle, the angle minimizing the transverse cluster size. Comparisons with data from 2016 and 2017 with 80, 150, and 350 V are shown in the figure. Simulation error bars account for radiation damage model parameter variations (trapping constant, introduction rates, and capture cross-sections).

Future Operations

Simulation is also used to predict future operational conditions, allowing to change them in time to maintain a high detection efficiency.

The most probable value of ToT (Time over Threshold) of the IBL pixel clusters as a function of the Bias Voltage working point is shown in the figure.

In order to have the same ToT we will need to increase the Bias Voltage working point.

Simulations Scheme

A software based on Allpix that simulates the charge induced on the electrodes by the deposit of energy in the detector from particles has been developed. The various components are illustrated in the figure below.

Drift and diffusion model have been augmented to include effects such as:
- Modification of the Electric field (Simulated with TCAD technology and with radiation damage effects based on model [4])
- Charge drift
- Lorentz Angle
- Trapping probability
- Ramo Potential to account for induced charge
- Diffusion

Conclusions

Effects of radiation damage are already visible in the pixel detector:
- Simulation is in good agreement with data within the systematic uncertainties on simulation - need to constrain these in the future.
- Predictions allow to set a new working point in order to maintain a high detection efficiency.

Bibliography

[3] Allpix: https://twiki.cern.ch/twiki/bin/view/Main/AllPix