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Measurements of the effective depletion voltage in the ATLAS Pixel Detector

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ATLAS Pixel Detector

Pixel Detector:



- Consists of
 - 3 Barrel Layers
 - 6 End-cap disk layers
 - I744 modules in total

Pixel Module:





27/01/12



Cross-talk scan

Before type-inversion, use an interpixel cross talk to determine depletion voltage:

- Sequentially inject charge into pixels
- read out neighbouring pixel
- If not fully depleted, high-ohmic short between pixels. (cross-talk)
- If fully depleted, pixels are isolated from each other (no hits)
- Inject charge 100 times and count pixels with no hits (Dead pixels)



Single module close to VFD White: already depleted pixels with no crosstalk hits.

^oixel Row



Cross-talk scan

- The grid structure is an artefact of the scan.
- Corresponding pixels do not represent depleted/undepleted regions
- Vertical lines parallel to the Pixel Row are created by the long pixels.
- More charge is collected in the longitudinal pixel lines
 - 4 injection pixels are close to the read out pixel



- Exclude long, ganged and inter ganged pixels
- Exclude rows 14-17, 30-33, 46,-49, 62-65,



Plot Voltage vs Dead Pixels for every module

Fit function:



Take 90% of the maximum as the depletion voltage



Several modules show a strange behaviour and have to be excluded.

- Fit has to converge
- Maximum of error function > 20000 dead pixels
- Minimum of error function < 500 dead pixels



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60

80

100

Pixel Column

^oixel Row

250

200

150

100

50

- Increasing number of modules can not be used for the depletion voltage
- Cross-talk of undepleted pixels is reduced
 - Too low for scan
- Failing modules seem to be depleted but they are not

Change in resistance between pixels?



100

90

80

70

60

50

40

30

20

10



Increase of the depletion voltage can be observed after cooling stoppage between 29/06/2011 - 03/07/2011

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Depletion voltage By module in Pixel layer 0 as a function of the luminosity and of the date



- General trend of reduction in depletion voltage
- Beneficial annealing is observed after cooling stoppages



Mean value of the depletion voltage in Pixel layer 0 as a function of the luminosity and of the date



- General trend of reduction in depletion voltage
- Beneficial annealing is observed after cooling stoppages



Depletion Voltage Results

Silicon 1 MeV neutron equivalent fluence, Pixel region



Change in the depletion voltage as function of the Module Position in Z





- Fluence is larger for modules closer to the interaction point
- Reduction in depletion voltage is slightly larger for inner modules



Depletion Depth Measurement



- Type inversion in the ATLAS innermost layer is expected in late 2012
- Cross-talk scans are no longer viable for monitoring the depletion voltage.
- A track based method is being developed to calculate depletion depth
- Using the angle in the long pixel direction
 - Advantage: Parallel to the solenoid field

Track depth:

 $td = \frac{y_0 - y_i}{\tan \alpha}$

30/05/2012

Results of the depletion depth measurement shown for Beam and Monte Carlo Data:

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- Measured Mean Values of the depletion depth (D)
- Expected thickness (S)

-0.5

-1

Depletion Depth Measurement

MC 250 µm $D = (248 \pm 8(\text{stat.}))\mu\text{m}$ MC 200 µm $D = (201 \pm 6(\text{stat.}))\mu\text{m}$ 2011 Data $D = (253 \pm 3(\text{stat.}))\mu\text{m}$ $D = (252 \pm 2(\text{stat.}))\mu\text{m}$ $\sigma_{sus} = 10 \ \mu\text{m}$

Sensor thickness:

0.5

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 $S = (253.7 \pm 0.6) \mu \text{m}$

Active sensor thickness is \sim 3-4 μ m smaller .

-1.5

1.5

 θ_{trk} [rad]



- General trend of reduction in depletion voltage
- Beneficial annealing is observed after cooling stoppages
 - Similar patterns observed for many modules.
- Type inversion is imminent
- Fully Data driven depletion depth method has been developed
- Continuous Monitoring of the depletion depth after type inversion during normal operation



Backup

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Measurements of the effective depletion voltage in the ATLAS Pixel Detector



ATLAS Detector







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