Operation and Radiation Damage studies of the ATLAS Pixel Detector

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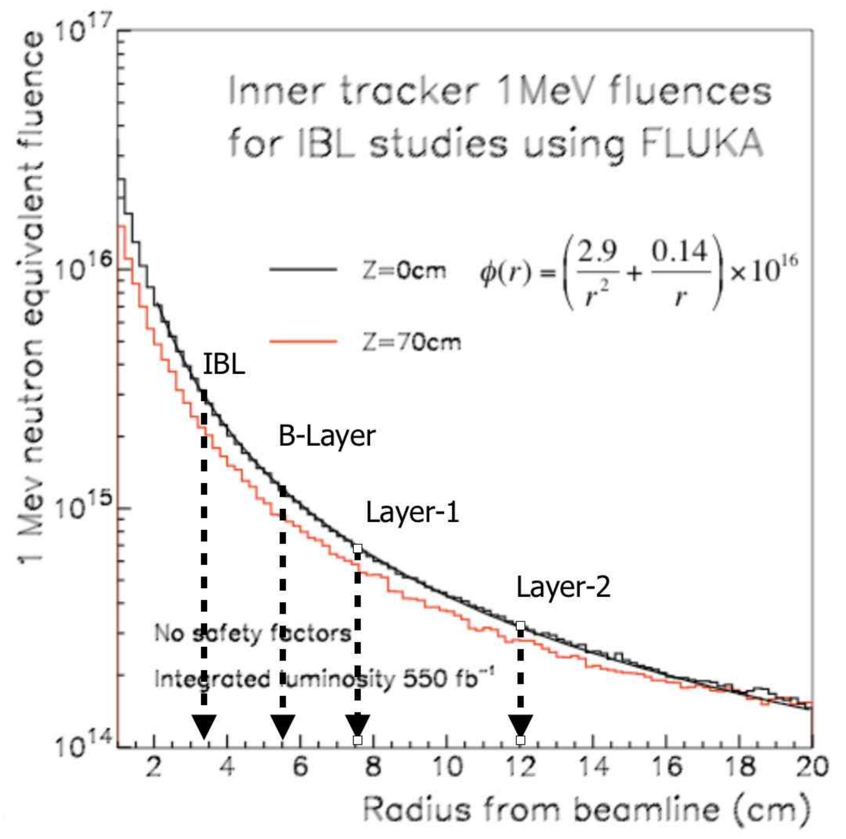
Introduction

The ATLAS pixel detector is the innermost layer of the Inner Detector (ID). Due to its proximity to the collision point the pixel detector has been exposed to considerable levels of radiation during its operation at the LHC, up to $2{\cdot}10^{14}\ n_{eq}/\mathrm{cm}^2$. By the end of Run 3, in 2023, the integrated luminosity and fluence will have increased further by an order of magnitude.

Radiation damage effects are already visible, and they will increasingly affect the detector performance in the coming future. The poster presents a summary of the performance of the Pixel Detector during operation in Run 2. A model to describe the radiation damage effects in MonteCarlo simulation is discussed, and the predictions are compared with data.

Fluence Levels

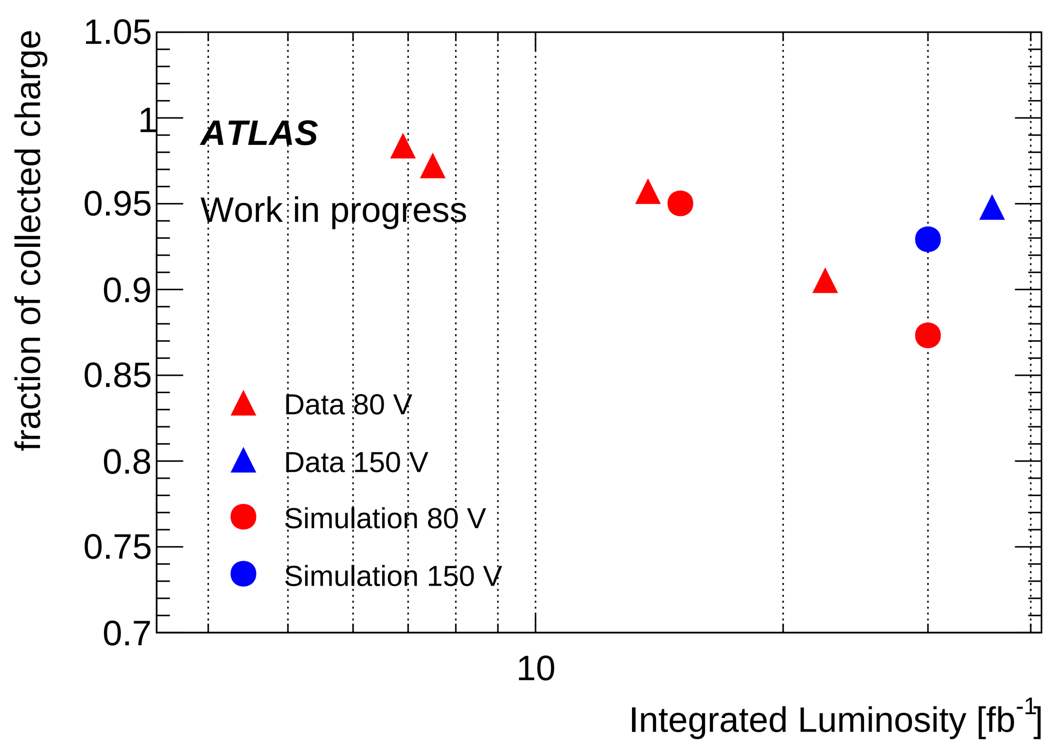
Radiation level as a function of the distance from beam pipe [1] for 550 fb^{-1}. The levels of radiation damage for the IBL are estimated to be $\mathbf{2.4}{\cdot}10^{14}\ n_{eq}/\mathrm{cm}^2$ for **40** fb^{-1}and $\mathbf{1.8}{\cdot}10^{15}\ n_{eq}/\mathrm{cm}^2$ for **300** fb^{-1}(end of Run 3) .



Validation on Run 2 Data

Simulation can be used to predict the Charge Collection Efficiency (CCE): the fraction of charge collected by the sensor with respect to an non-irradiated sensor. In figure is shown the CCE for different models and for data for the IBL sensor.

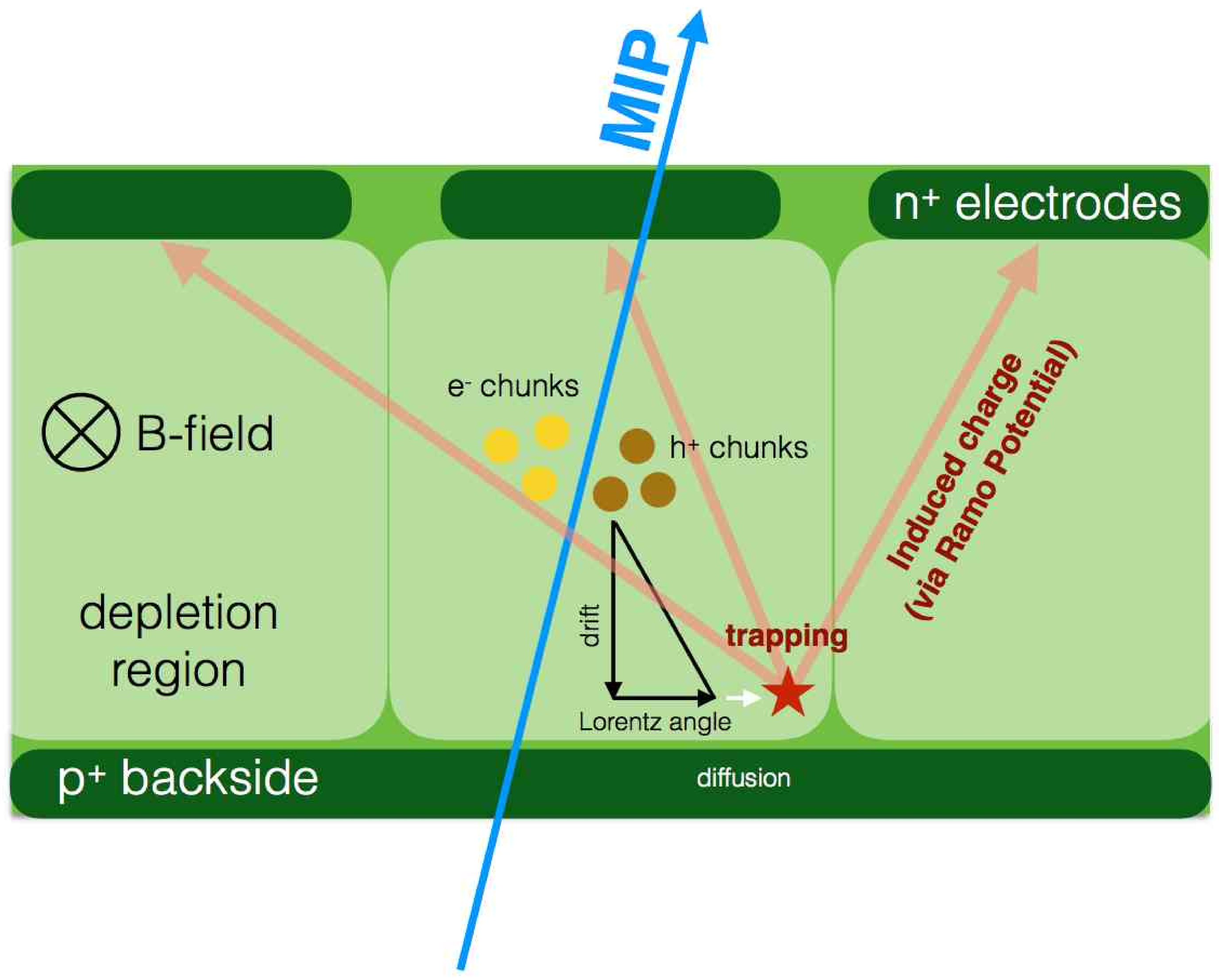
Simulation well describe Run 2 data.



Digitizer Overview

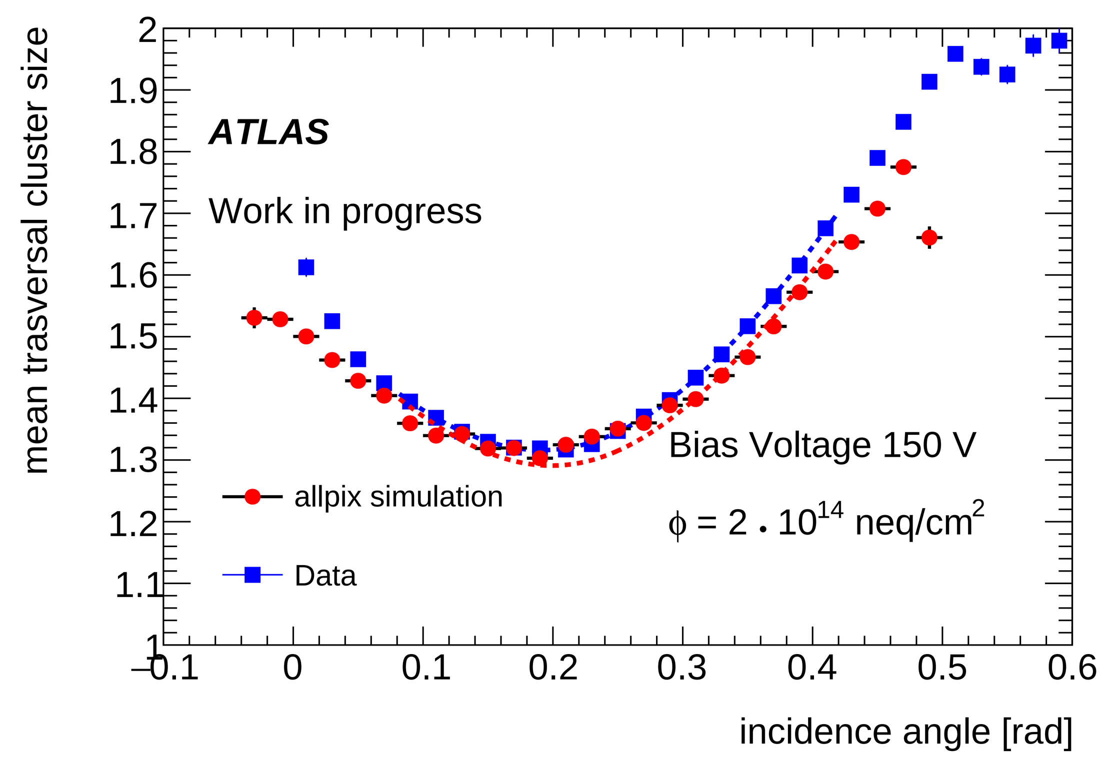
A digitizer, called Allpix, has been developed to simulate the effects of the radiation damage. The input to the digitizer is an energy deposition from a charged particle, produced by Geant4. Electric field maps of the sensor are evaluated with Technology Computer Aided Design (TCAD) using the radiation damage model developed by Chiochia and collaborators [2]. A schematic of the digitizer is in figure. The simulations account for:

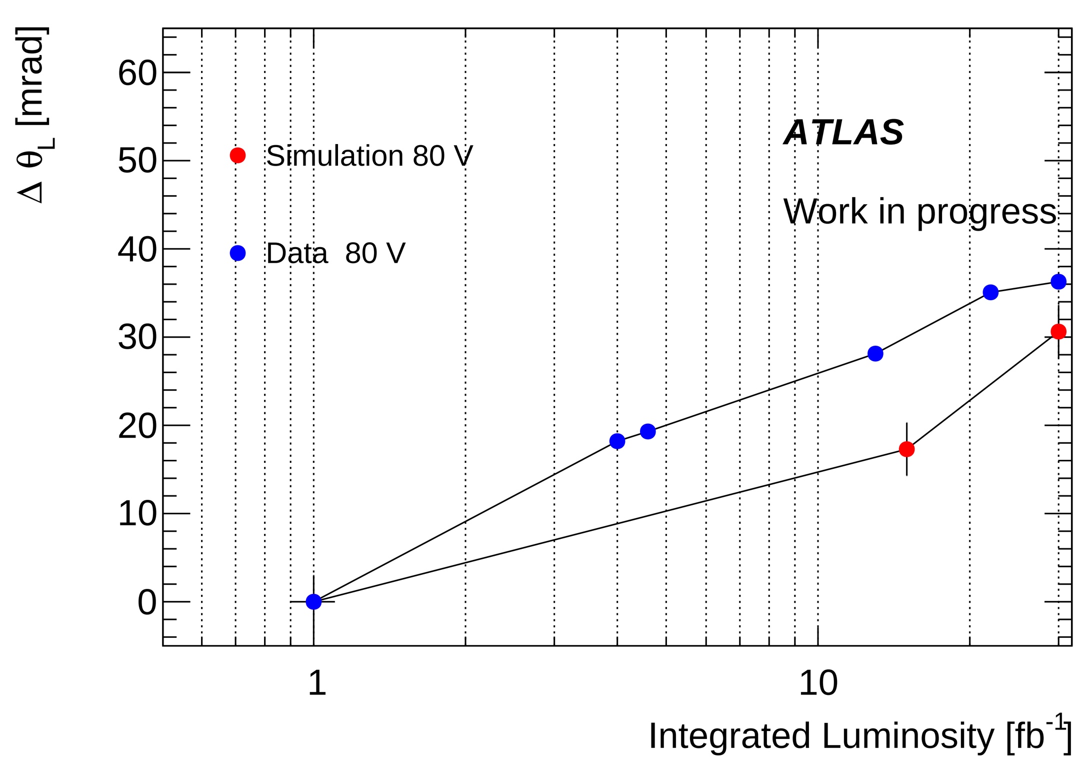
- Charges drift
- E field and B field effects
- Lorentz Angle (function of E field, B field and distance in the detector)
- Trapping probability
- Ramo potential to account for induced charge
- Charge converted in ToT
- Pixels are clustered to compare with collision data



Validation on Run 2 data

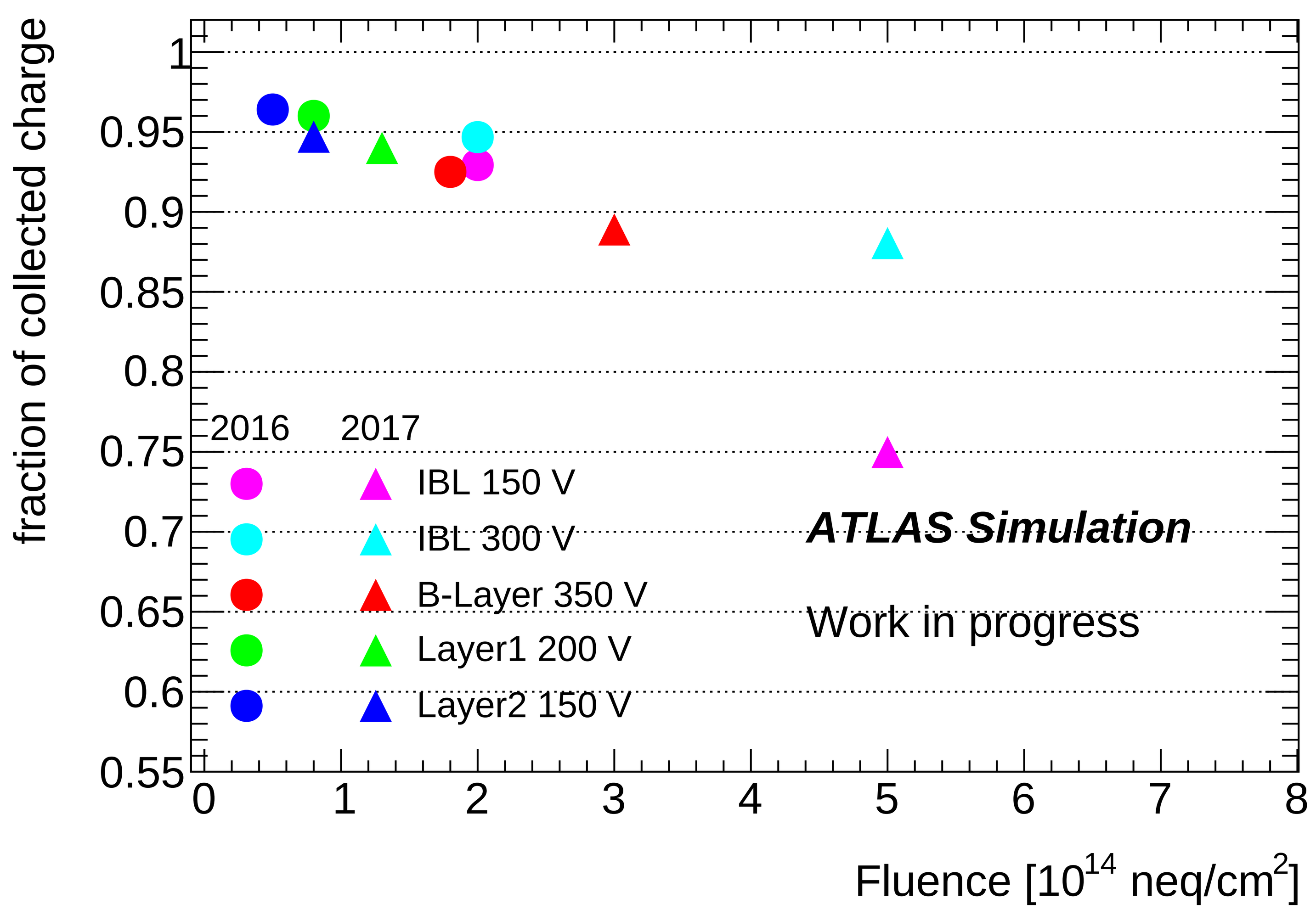
Check the results on data. Compare mean transversal cluster size as a function of the incident angle of the particles (left plot) and the variation of the Lorentz Angle with the increase of the fluence (right plot). Simulation reproduces the mean transverse size, and the increase of Lorentz angle.





CCE prediction

Simulation can be used to predict the CCE of the different barrel layers of the pixel detector for the fluences corresponding to the luminosity collected up to 2016 and up to the expected luminosity estimated for 2017. Layers have been simulated with different parameters:



Conclusions

Radiation damage effects are already visible in the pixel detector

- Simulations are in good agreement with data
- For the innermost layer an increase in the Bias Voltage will reduce the loss in CCE to a level **comparable** with the other layers

References

[1] M Capeans et al. ATLAS Insertable B-Layer Technical Design Report. Technical Report CERN-LHCC-2010-013. ATLAS-TDR-19, Sep 2010.

[2] V. Chiochia et al. A Double junction model of irradiated silicon pixel sensors for LHC. *Nucl. Instrum. Meth.*, A568:51–55, 2006.