University of Glasgow | Experimental Particle Physics

Depletion Depth Study for the ATLAS SemiConductor Tracker

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I. Introduction

ATLAS is the largest particle detector ever constructed. It is one of the two general-purpose detectors in the LHC, its physics goals range from the discovery of the Higgs boson to physics searches beyond the Standard Model for example extra dimensions and dark matter.

The ATLAS Inner Detector (ID) consists of three sub-detectors (Figure 1): the Silicon Pixel Detector, the **SemiConductor Tracker (SCT)** and the Transition Radiation Tracker (TRT). The purpose of the ID is to identify primary and secondary vertices, accurately measure the momentum of particles and their trajectories, and to provide robust pattern recognition.

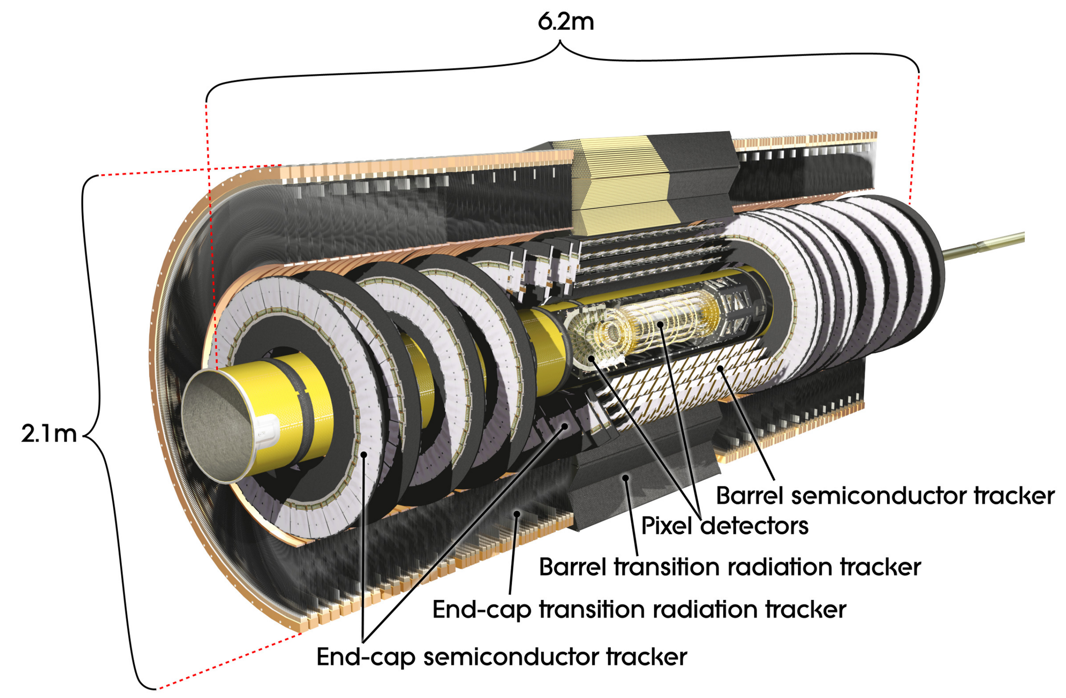

Figure 1: 3D cut-away view of the ATLAS ID showing its three sub-detectors.

The SCT is divided in 4 barrel layers and 9 discs in each of its two endcap regions. An **SCT module** consists of two pairs of single-sided p-in-n silicon microstrip sensors glued back-to-back with a 40 mrad stereo rotation angle. The intrinsic measurement accuracies are 17 μm in the R-Φ plane and 580 μm in the z-plane, this last value arising from the stereo angle.

The **depletion depth** determines the active volume of the detector. It is **important** to measure the silicon depletion depth to evaluate the charge collection efficiency and spatial resolution of the modules and also to monitor the SCT performance while the silicon is being damaged by radiation.

For our analysis, we are using samples from **cosmic ray data** gathered by ATLAS in the Autumn 2008 as well as from Monte Carlo simulated data. This study has only been done for the **barrel section** of the SCT.

II. Methodology and Preliminary Results

Information from particle tracks is used to calculate the depletion depth [1].

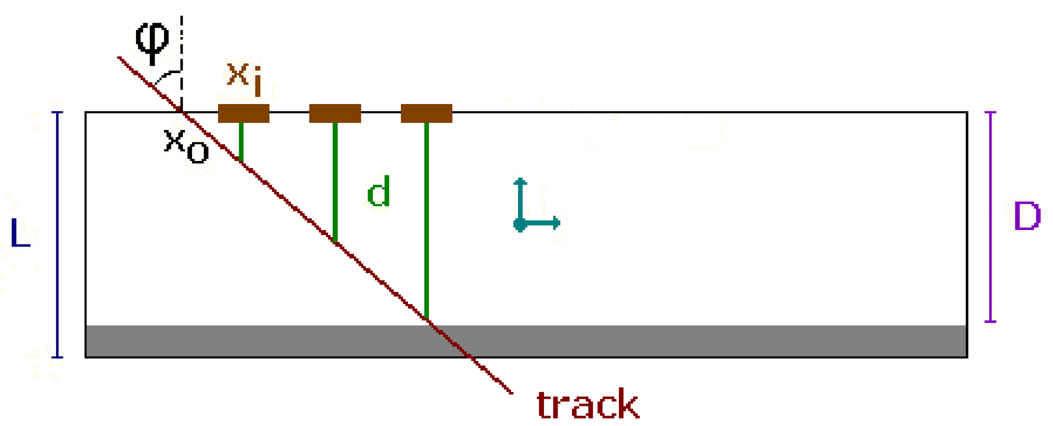

Figure 2: Schematic view of a particle crossing an SCT sensor.

In Figure 2:

- x_o = entry point
- x_i = local position of strip
- L = sensor thickness
- D = depleted depth
- d = track depth (distance from track to the readout strip)
- φ = incidence angle

The track depth is given by:

$$d = \frac{x_i - x_0}{\tan\varphi} \qquad \text{where,} \qquad x_0 = x_c + \frac{D}{2}\tan\varphi$$

x_c = extrapolated cluster position (centre of cluster minus residual from track)

At a biasing voltage of 150 V, D = L = 285 μm ⟶ $x_0 = x_c + \frac{L}{2}\tan\varphi$

The track depth is computed for every strip and the values stored in a histogram. Figure 3 shows the distributions obtained for both Cosmic Data and MonteCarlo with the magnetic field on (a) and off (b).

◇ Track quality cuts ◇

- # Silicon Hits ≥ 8 -OR- # TRT Hits ≥ 30
- $p_T \geq 1$ GeV → Only for B-ON samples
- Transverse impact parameter: $d_0 \leq 500$ mm
- -10 ns < TRT event phase < 40 ns (not 0) → only for Data
- $-60° < \varphi < 60°$
- -25 mm $< x_0 < 25$ mm

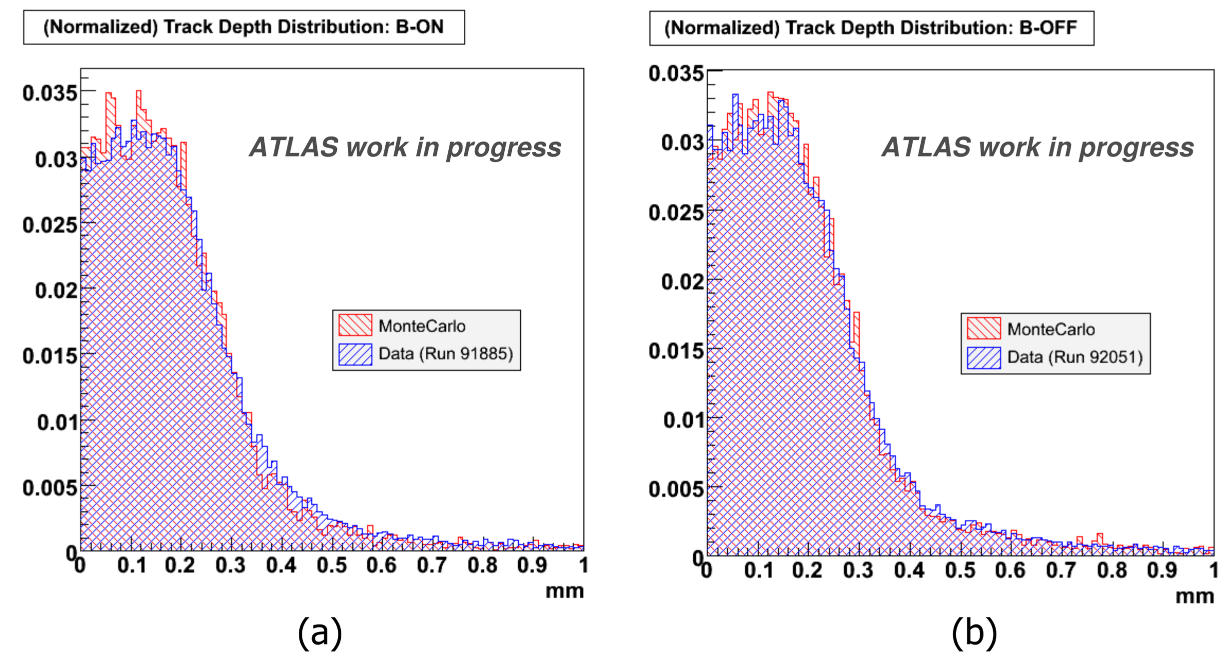

Figure 3: Normalized track depth distributions for Data and MC: (a) with and (b) without magnetic field.

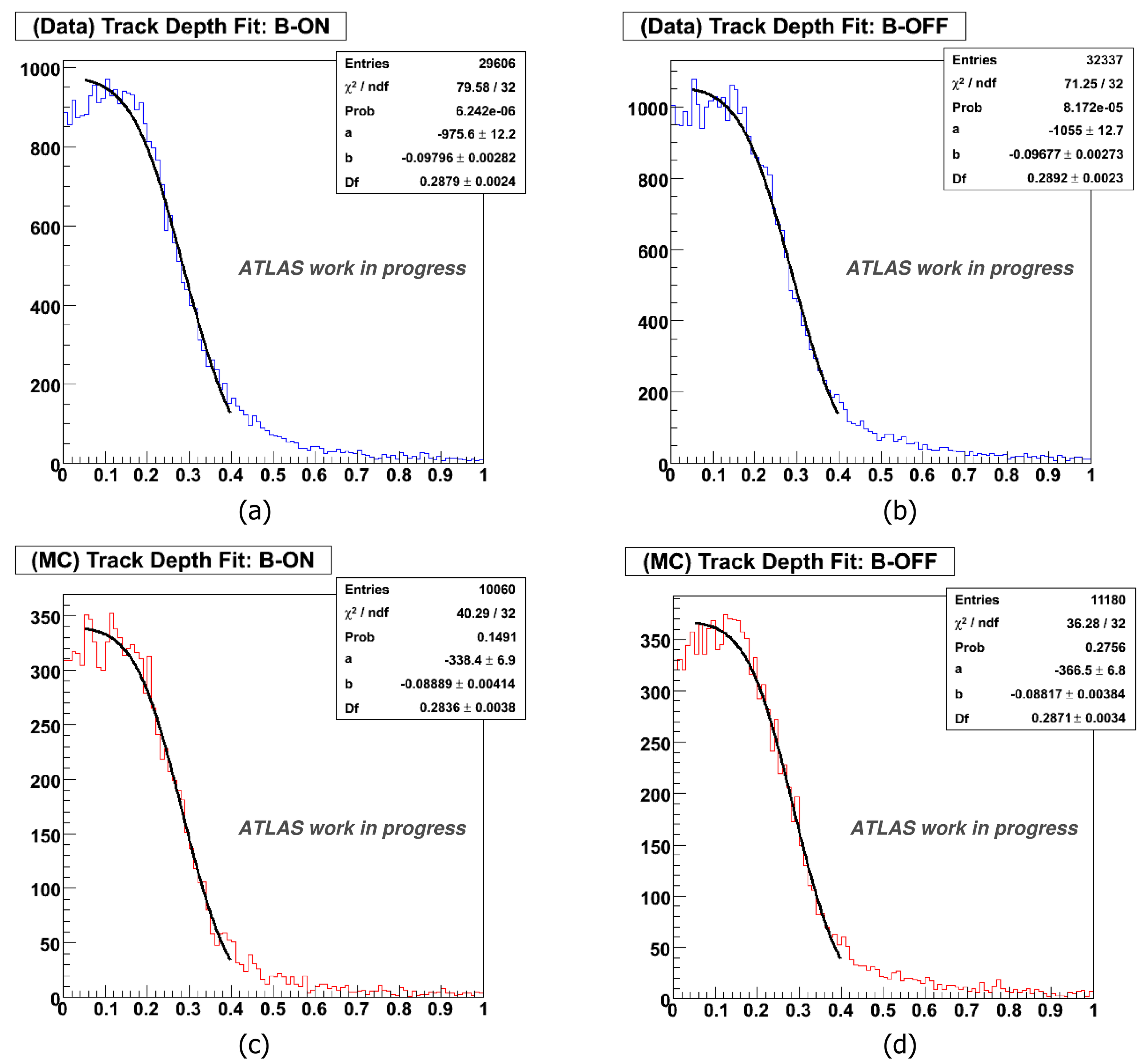

Figure 4: Fit to the track depth distributions of Data (a) with and (b) without magnetic field, and MC (c) with and (d) without magnetic field. The extracted parameter Df corresponds to the depletion depth of the sensors: (a) 287.9 ± 2.4 μm, (b) 289.2 ± 2.3 μm, (c) 283.6 ± 3.8 μm and (d) 287.1 ± 3.4 μm. All calculated values agree with the design sensor thickness.

In order to obtain a preliminary value for the depletion depth, we fitted the following error function to the falling edge of the track depth distributions:

$$f(D_f - x) = 1 - \frac{a}{2} Erfc\left(\frac{D_f - x}{b\sqrt{2}}\right)$$

where a, b and D_f are extracted from the fit. D_f is the inflection point of the curve and is defined as the depletion depth.

From Figure 4, we can extract the following **conclusions**:

✓ MonteCarlo samples reproduce the input sensor thickness of 285 μm.

✓ Data and MonteCarlo depletion depth values agree with each other.

✓ Depletion depth for data agrees with the expected value.

III. Future Work

- Correct for dependence on incidence angle and threshold by dividing the samples in angle slices to find value for which measurement is most sensitive. Correct for uncertainty in entry point calculation.
- Study variations in bias voltage, threshold, track p_T cut.
- Include endcap regions.
- Perform this analysis with first collisions data.

References

[1] “Measurement of Lorentz angle and depleted depth in the ATLAS Pixel Detector with cosmic data”, Draft Note – Pixel Group.