Abstract

Electric and magnetic dipole moments (EDMs and MDMs) of elementary and composite particles are a powerful tool to probe physics beyond the Standard Model: permament EDMs are a potential signature of new sources of CP symmetry violation, while MDMs can be used to test the validity of the CPT theorem.

One approach to study EDMs and MDMs is to exploit the precession of the particle's spin they trigger when flying through a magnetic field; this is achieved by comparing initial and final polarization states of a sample of particles through a fit of the angular distribution of their decay products. This technique is ripe for application at LHCb, a single-arm spectrometer designed to study heavy-flavour physics using proton-proton collisions at the Large Hadron Collider. In this thesis, I analyzed long-lived Λ^0 baryon decays from the exclusive $\Lambda_b^0 \to J/\psi\ (\to \mu^+\mu^-)\ \Lambda^0\ (\to p\pi^-)$ channel in preparation of the first measurement of Λ^0 electromagnetic dipole moments with the $6\,\text{fb}^{-1}$ LHCb Run 2 dataset.

The first part of my thesis was dedicated to the vertex reconstruction of Λ_b^0 and Λ^0 decays: vertexing efficiency falls consistently below 50% for long-lived Λ^0 decaying after the LHCb dipole magnet, halving the potential signal yield. Through topological studies of the events, I found this to be a result of a conflict of track information in xz (with track bending due to the magnet) and yz (without bending) planes, with the leading explanation being a systematic underestimation of p_z in pion tracks. To mitigate the problem, I built and deployed an alternative vertex fitting algorithm that increases the weight of specific track propagation planes. Refitting $\Lambda^0 \to p\pi^-$ decays with the new algorithm results in a +26.4% increase in signal statistics, recovering a quarter of the previously non-converging events.

In the second part of my thesis, I developed and finalized a three-step signal selection process based on loose preliminary filters, rejection of $B^0 \to J/\psi\ (\to \mu^+\mu^-)\ K_S^0\ (\to \pi^+\pi^-)$ physical background, and discrimination of $\Lambda_b^0 \to J/\psi\,\Lambda^0$ events with a histogram-based gradient boosting classification tree. The $m(J/\psi\,\Lambda^0)$ invariant mass fit after all steps shows excellent agreement with data, estimating a signal (background) yield of 3590 ± 60 (2420 ± 50)

in the $\pm 3\sigma$ region around the resonance peak.

Finally, I performed a first analysis of the angular distribution of Λ^0 decay products from $\Lambda_b^0 \to J/\psi\,\Lambda^0$ events. Angular reconstruction of polar and azimuthal proton production angles in the Λ^0 helicity frame is unbiased net of acceptance effects. Absolute resolutions span 0.2–0.3 for $\cos\theta_p$ and 1.0–1.2 for ϕ_p, both roughly one sixth of the allowed variable ranges. Resolutions heavily worsen as function of the bias on the z component of the $\Lambda^0 \to p\pi^-$ vertex. The observed median 14 cm bias in reconstructed decays is mostly attributable to «ghost vertex» events, where $p\pi^-$ tracks are bent by the magnet into a second crossing point misidentified as an apparent production vertex by the algorithm. Removal of this class of events, motivated by encouraging early results with changes to the vertex seeding process, improves proton angular resolutions by a factor 2–3 across the full range of values.

Identified issues in this analysis do not compromise the prospective measurement of Λ^0 electromagnetic dipole moments. On the contrary, the achieved signal yield and absence of bias in proton angular distributions confirm that competitive results with long-lived Λ^0 baryons are possible with Run 2 data. Given the upcoming statistics surge projected for Run 3 and the boost in yield and resolution an improved vertexing algorithm would provide, the outlook is promising for a first measurement of Λ^0 EDMs and MDMs at LHCb.