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 provide precision measurements of QCD predictions and 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 through a magnetic field; this is achieved by comparing initial and final polarization states of a sample of particles through a fit to 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 $6\,\mathrm{fb}^{-1}$ 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 the discrepancy in z coordinate between the point of closest $p\pi^-$ track distance in the xz (bending) plane and the crossing track point in the yz (non-bending) plane. 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. The reason for the xz-yz inconsistency is currently unknown; however, an observed systematic underestimation of p_z for pion tracks in non-converged events suggests it could be linked to poor momentum measurement at the T tracking stations.

In the second part of my thesis, I 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 $m(J/\psi\,\Lambda^0)$ invari-

ant 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 Λ_b^0 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 θ_p (polar) and ϕ_p (azimuthal) proton production angles in the Λ^0 helicity frame is unbiased net of acceptance effects. Angular resolutions, defined as the root mean square deviation of proton angles from their generated values, span 0.2–0.3 for $\cos\theta_p$ and 1.0–1.2 for ϕ_p; in both cases the results are acceptable, being within roughly one sixth of the allowed variable ranges. Reconstructed signal events have a median 14 cm positive bias on the z component of the $\Lambda^0 \to p\pi^-$ vertex, which negatively affects proton angular resolutions. This bias is mostly attributable to «ghost vertex» events, where $p\pi^-$ tracks are bent by the magnet into a second crossing point misidentified as the apparent production vertex by the algorithm. Ongoing tests with a modified vertex reconstruction algorithm show encouraging results in reducing the number of ghost vertex events; the complete solution of this problem would improve 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 increase expected 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.