

The Standard Model (SM) is known to be incomplete, and the Effective Field Theory (EFT) approach enables the parametrization of potential subtle deviations from the SM. The EFT relevant to this thesis involves describing anomalous Quartic Gauge Couplings (aQGC) through Eboli operators. I have participated in the first comprehensive statistical combination of ATLAS Vector Boson Scattering (VBS) analysis constraining those operators. In particular, I have estimated the significance of cross-terms in simulations, demonstrating that they cannot be ignored when both pair members belong to the same operator family, but many analyses did not initially include them. I developed a method to insert missing cross-terms by leveraging experimental degeneracy between certain operators. A similar method is utilized if single operators are missing. The insertion method was validated, typically showing less than 10% non-closure.

Another part of this thesis focuses on the migration of the ATLAS forward pileup jet tagger (fJVT) to the updated ATLAS software, which initially resulted in up to 15% performance degradation. Additionally, I calibrated the fJVT using Run-3 data (2022-2023): differences in fJVT efficiency between simulations and real data quantified (typically below 5%) via a set of scale factors (SF), together with SF uncertainty composed of statistical and several systematic ones. SF depends on jet transverse momentum and the number of simultaneous proton-proton interactions (so-called pileup) in the event. Results are now available for use by the entire collaboration. Three working points are provided.

Yet another part of this thesis focuses on the ATLAS Upgrade for the High Luminosity LHC (HL-LHC): pileup would reach 200, creating significant challenges for object reconstruction. To address this, track timing information would be provided by the High Granularity Timing Detector (HGTD). Achieving this requires front-end electronics with excellent time performance called ALTIROC. I analyzed test beam data for ALTIROC1, demonstrating a time resolution of 45 ps. I contributed to the development of ALTIROC2 software and conducted multiple evaluations particularly of the Time of Arrival (TOA) discretization step, the lowest possible threshold, and test beam analysis. Furthermore, I analyzed test beam data for ALTIROC3, showing that calibration performed in the laboratory could not be directly applied to the test beam environment. I identified a method to overcome this miscalibration, achieving an average time resolution of 44 ps across many pixels.