Abstract

Hard probes are expected to provide crucial input for nuclear parton distribution functions (nPDF), as well as to bring valuable insights into the quark-gluon plasma (QGP). In this thesis, measurements of heavy-ion collisions using top quarks in the ATLAS experiment at the Large Hadron Collider are presented. Analysed data from proton–lead (p+Pb) and lead–lead (Pb+Pb) collisions were collected with the ATLAS detector during Run 2 (2015–2018) at a nucleon–nucleon centre-of-mass energy of $\sqrt{s_{\mathrm{NN}}} = 8.16$ TeV and $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV, respectively.

Electrons play an important role in the top-quark pair ($t\bar{t}$) decay modes, specifically in the ℓ+jets and dilepton channels, which involve electrons in the final state. Electron performance is evaluated in p+Pb and Pb+Pb collisions, using electrons from the $Z \to e^+e^-$ resonance decay. Electron scale-factor corrections are derived in p+Pb collisions and applied in the measurement of $t\bar{t}$ production. Moreover, electron identification is optimised for Pb+Pb collisions and currently serves as the baseline approach in Run 3 (2022–2026).

The $t\bar{t}$ process is studied in the ℓ+jets and dilepton channels in p+Pb collisions. The inclusive $t\bar{t}$ cross-section is measured with the total relative uncertainty of 9%, leading to the most precise $t\bar{t}$ cross-section measurement in heavy-ion collisions achieved so far. The signal significance exceeds five standard deviations separately in the ℓ+jets and dilepton modes, resulting in the first observation of $t\bar{t}$ production in the dilepton channel in p+Pb collisions. The nuclear modification factor for the $t\bar{t}$ process is also extracted for the first time. The results are in agreement with theoretical predictions for various state-of-the-art nPDF sets.

The production of $t\bar{t}$ pairs is also analysed in the dilepton decay mode in Pb+Pb collisions. The inclusive $t\bar{t}$ cross-section is extracted with the total relative uncertainty of 31%, providing the most precise $t\bar{t}$ cross-section measurement in Pb+Pb collisions to date. The observed signal significance amounts to 5.0 standard deviations, establishing the first observation of the $t\bar{t}$ process in Pb+Pb collisions. The obtained result is consistent with the measurement by the CMS Collaboration and theoretical predictions based on the latest nPDF sets.

The conducted studies open a new path for further research on heavy-ion collisions at ultra-relativistic energies. The precise measurement of $t\bar{t}$ production in p+Pb collisions provides valuable input for constraining nPDFs in the high Bjorken-x region. The observation of the $t\bar{t}$ process in Pb+Pb collisions marks the start of the heavy-ion program with top quarks, and in particular, opens a possibility of exploring the time structure of the QGP in the future.

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