Unveiling anomalies at the Large Hadron Collider with cutting-edge precision calculations

Harnessing the combined strength of CPU- and GPU-accelerated computing infrastructure, this project will develop an automated tool chain that delivers unparalleled coverage of Standard Model predictions to facilitate direct comparisons with published collider measurements, ensuring that even the most subtle variations in the data are not overlooked. Get ready to uncover the anomalies that may redefine our understanding of the universe.

In the pursuit of deeper insights at the high-energy frontier, where the Large Hadron Collider (LHC) continually yields a wealth of measurements, the use of open-source tools, notably HepData [1], Rivet [2], and Contur [3] plays a key role. These tools not only serve as custodians for the preservation of published collider analyses but also form the bedrock for the exploration of uncharted territory within the existing datasets, seeking indications of potential extensions to the Standard Model.

At the same time, contemporary Monte Carlo event generators represent the cutting edge in modelling the experimental data, serving the dual purpose of providing realistic detector simulations and providing the final-state particle prediction to compare to the data. In this project, we seek to establish an automated tool chain that creates—and continuously updates—a pool of state-of-the-art Standard Model calculations by exploiting heterogeneous computing architectures on High-Performance Computing (HPC) resources in order to confront the full suite of published collider measurements available in the Rivet analysis framework with the most precise Standard Model predictions available at any point in time.

Data Intensive Techniques and Innovations relevant to the project

Automated Data Generation
: Develop novel algorithms for automating the generation of Standard Model calculations, ensuring they remain up-to-date and precise as new tools get released. This innovation streamlines public open-source access to cutting edge Standard Model predictions and allows for rapid adaptation to emerging new technologies.

High-Performance Computing and GPU Acceleration
: Implement cutting-edge CPU- and GPU-acceleration techniques to expedite the generation of Standard Model predictions on HPC resources. This approach not only enhances current computational efficiency but also allows for more in-depth analysis and exploration of a broader parameter space.

Machine Learning and Anomaly Detection
: Opportunities to employ machine learning algorithms for anomaly detection within collider measurements. This will help identify deviations from the Standard Model, potentially indicating the presence of new physics. Such techniques can improve the sensitivity of the research to subtle anomalies.

Parallelized Data Analysis
: Develop parallel processing algorithms to analyse the vast amount of data produced in the project efficiently. This enhances the speed of data processing and enables real-time feedback, accelerating the research cycle.

Data Visualization and Interpretation Tools
: Create advanced data visualisation and interpretation tools to provide intuitive representations of complex datasets. These tools will aid researchers in identifying patterns, trends, and anomalies within the data, improving the overall quality of research insights.

Experience and suitability of the supervision team in this area

Dr Christian Gutschow (UCL ARC) and Professor Jonathan Butterworth (UCL HEP) are both members of the ATLAS collaboration where they have many years of experience in making precise model-independent measurements with maximal reinterpretation potential. They are core developers on the Rivet, YODA and Contur packages and have an interest in sustainable software development and reducing the computational cost of data-intensive research at CERN's Large Hadron Collider.

[1] HEPData: a repository for high energy physics data, J.Phys.Conf.Ser. 898 (2017) 10
[2] Robust Independent Validation of Experiment and Theory: Rivet version 3, SciPost Phys. 8, 026 (2020)
[3] Testing new physics models with global comparisons to collider measurements: the Contur toolkit, SciPost Phys. Core 4, 013 (2021)