

# Boccardo Lucrezia

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DOTTORATO IN FISICA E NANOSCIENZE - CICLO XXXIX - FIRST YEAR REPORT

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## TUTORS

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**Andrea Coccaro:** Researcher at *Istituto Nazionale Fisica Nucleare* division of Genova

**Federico Sforza:** Professor at *University of Genova* - Physics Department

## RESEARCH ACTIVITY

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I carry out my research activity in the ATLAS experiment at the Large Hadron Collider at CERN. The ATLAS experiment is at the forefront of particle physics and its efforts focus on the understanding of the fundamental building blocks of our Universe through high-energy collisions of protons and heavy ions. My work focuses on three main areas of research and optimization: Higgs physics, Standard Model precise measurements, and flavor tagging. They will be described in more detail in the following sections.

## FLAVOUR TAGGING

Many analyses in the ATLAS experiment rely on flavor tagging, which is the identification of the quark that originated a particular jet that is reconstructed in the detector. In recent years, flavor tagging has undergone a transformative shift due to the introduction of Graph Neural Networks: the new algorithm, GN2, shows improvements in  $c$ -jet efficiency (the probability of mistakenly tagging a  $c$ -jet as a  $b$ -jet) of almost a factor 4 with respect to the algorithm that was used in Run2. However, this algorithm has been trained on Monte Carlo samples, and its behavior on real, actual data is not guaranteed to be the same: for this reason, it is calibrated through special analyses that are carried out to extract scale factors to reweight tagged jets and take into account this possible mismatch. During my first year, I worked on the calibration and the  $c$ -jet efficiency evaluation of the GN2 algorithm using  $W + c$  events, which are particularly pure in signal and allow for good background rejection. Preliminary results will be presented at the 2024 ATLAS+CMS Flavour Tagging Workshop in Genoa.

## HIGGS PHYSICS

One of the main goals of the Large Hadron Collider was the discovery of the much sought after Higgs boson. This extraordinary feat was achieved in 2012, but much is still to be known about this boson that is responsible for the mass of the other Standard Model particles. Among the many analyses carried out in ATLAS, the  $VHbb/cc$  analysis has the task of precisely measuring the coupling of the Higgs boson to  $b$ -quarks and to  $c$ -quarks. After the recent presentation (<https://atlas.cern/Updates/Briefing/Higgs-beauty-charm>) of the most precise measurements to date on Run 2 data, hopes are as high as ever for future data. For this reason, the analysis framework must be updated with all the recent improvements (for instance, a new, vastly better-performing flavor tagging algorithm) to be in great shape for Run 3. Part of my work in this first year consisted of implementing these updates and checking the performance of the new framework.

## STANDARD MODEL ANALYSIS

The ATLAS experiment also performs extremely precise measurements of already-known quantities from the Standard Model. In order to discover new physics, our knowledge of "what is supposed to happen" needs to be as deep and precise as possible. As part of my Master's thesis, I participated in the measurement of the production cross-section of a  $Z$  boson in association with  $b$ - and  $c$ -jets [1]. My contribution focused on the optimization of kinematic cuts to perform studies on intrinsic charm, which is a theoretical QCD concept that proposes a non-negligible contribution from the charm quark to the proton wave function. This analysis came to an end, was published during my first year of PhD, and was presented by me at the IFAE 2024 conference in Rome, Italy. Its natural follow-up will be an analysis that will exploit the new flavor

tagging algorithms to perform a first-time measurement of the production cross-section of a  $Z$  boson in association with at least 2  $c$ -jets.

## PHD COURSES

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**Machine Learning for Particle Physics (course from the Master's degree in Physics):** *A. Cocco, F.A. Di Bello, R. Torre*

**QCD and Collider Physics:** *S. Marzani* - To be attended in September 2024

**Advanced Statistics for Data Analysis:** *F. Badaracco, F.A. Di Bello, F. Parodi*

## PUBLICATIONS

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[1] The ATLAS collaboration, **Measurements of the production cross-section for a  $Z$  boson in association with  $b$ - or  $c$ -jets in proton-proton collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector**. <https://arxiv.org/abs/2403.15093>

## CONFERENCES AND WORKSHOPS

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**SIF 2023: Congresso Nazionale della Società Italiana di Fisica**, Salerno, 11 - 15 September 2023. Talk: *Search for intrinsic charm in the ATLAS experiment using multivariate techniques*.

**IFAE 2024: Incontri di Fisica delle Alte Energie**, Firenze, 3-5 April 2024. Talk: *Misura della sezione d'urto di produzione per un bosone  $Z$  in associazione a  $b$ - e  $c$ -jet*

**ATLAS+CMS Flavour Tagging Workshop**, Genoa, 9-13 September 2024. Talk: *GN2 calibration and  $c$ -jet efficiency evaluation using  $W + c$  events*, ATLAS Internal Session

**ATLAS Italia Workshop**, Rome, 16-18 September 2024. Talk: *Production of a  $Z$  boson in association with two  $c$ -jets*

## FELLOWSHIPS AND AWARDS

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**Swiss Excellence Fellowship:** one-year fellowship awarded by the Swiss Confederation to conduct research at the University of Geneva, under professor Tobias Golling. The project focuses on the application of innovative machine learning techniques to particle physics, with a focus on flavour tagging.