Ravera Simone

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Dottorato in Fisica e Nanoscienze - Ciclo XXXVIII - Third Year Report

Tutors

Claudia Gemme: Researcher at *Istituto Nazionale Fisica Nucleare* division of Genova
Fabrizio Parodi: Full Professor at *University of Genova* - Physics Department

Research activity

As a member of the ATLAS collaboration, one of the four large experiments operating at the Large Hadron Collider (LHC), my research activities are mainly driven by the data collected by the experiment and by its operation and upgrades. During my third year, I was mainly involved in the operation and calibration of the ATLAS Pixel detector, search for long-lived particles with the ATLAS Pixel detector and in the Phase-II tracker upgrades that are foreseen to cope with the High Luminosity (HL) phase of the machine. The opportunity to develop my skills in areas that spanned all aspects of the ATLAS experiment allowed me to acquire a broad range of expertise, from developing hardware systems for the characterisation and operation of silicon sensors to advanced software development for the proton-proton collisions data analysis. I carried out all my activities with the ATLAS Genova group.

Calibration and Operation of the ATLAS Pixel detector

The ATLAS Inner Detector (ID) has been designed to provide robust pattern recognition, excellent momentum resolution, and precise measurements of both primary and secondary vertices for charged tracks up to $\eta = 2.5$. Immersed in the 2 T magnetic field generated by the surrounding solenoid, the ID consists of a high-granularity Pixel detector in the region closest to the beam pipe and a Semi-Conductor Tracker (SCT) in the outer layers and a Transition Radiation Tracker (TRT) at central η. During the spring/summer of 2025 (May–August), I was extensively involved in the operation of the ATLAS Pixel detector. My responsibilities included taking on-call shifts to ensure its continuous operation 24/7, as well as contributing to the weekly calibration procedures required to mitigate the effects of radiation damage on detector performance. The experience I gained in detector calibration played a very important role in my understanding of data analysis, as reported in the following section.

Search for Long-Lived charged particles using the ATLAS Pixel detector

The ATLAS experiment is searching for new physics beyond the Standard Model. Long-Lived charged Particles (LLP) are one of the possible hypotheses of new physics. In particular, heavy-charged LLPs could be identified as they would travel much more slowly than the speed of light ($\beta < 1$), implying anomalous high specific ionisation energy losses ($\mathrm{d}E/\mathrm{d}x$), significantly greater than those of Standard Model particles. The $\mathrm{d}E/\mathrm{d}x$ of the LLP track can be measured using the ATLAS Pixel detector; its value is affected by the reduction of the pixel sensors' charge collection efficiency due to the radiation damage from LHC collisions. It is therefore necessary to calibrate this variable to equalise the track $\mathrm{d}E/\mathrm{d}x$ measurements throughout the entire data-taking period. My contribution to this analysis is mainly focused on the calibration of the track $\mathrm{d}E/\mathrm{d}x$ that I performed for the first time by normalising the $\mathrm{d}E/\mathrm{d}x$ value at the cluster level before evaluating the track $\mathrm{d}E/\mathrm{d}x$. The cluster-level is necessary to cope with the complex η-layer dependencies of the radiation damage and avoid biasing the calculation of the $\mathrm{d}E/\mathrm{d}x$. For this task, I was in charge of writing the code for the equalisation that I delivered to the ATLAS collaboration in June 2025.

The ATLAS Inner-Tracker Phase-II upgrade

To cope with the increased luminosity and harsher conditions in terms of radiation hardness and electronic performance during the HL-LHC, the ATLAS experiment will be equipped with a completely new all-silicon tracker, the so-called Inner Tracker (ITk), replacing the ID. The ITk will consist of a Pixel detector at a smaller radius, close to the beam pipe, and a large area Strip detector surrounding it. The ITk Pixel detector will be instrumented with 5 layers of hybrid pixel modules, consisting of a pixel sensor for signal detection, Front-End electronics (FE) for readout and discrimination and an electrical flex to distribute power and collect data. Planar pixel sensors have been chosen as the baseline for the ITK Pixel outermost layers; however, due to the extremely high radiation level in the innermost layer, planar sensors can not be efficiently operated in the innermost layer. Therefore, pixel sensors implemented with the 3D technology will instrument it. The 3D technology consists of direct drilling of the electrodes in the silicon substrate, which allows the sensor thickness to be decoupled from the inter-electrode distance and makes it possible to realise extremely radiation-hard pixel detectors. During my third year within the group, the main goal of my activities was the qualification of the final version of the readout chip, the ITkPixV2 that has been delivered to the collaboration in January 2025. Several chip tiles have been hybrized to 3D pixel sensors, I personally took care of the qualification of the parts in the Genova laboratory and later I joined the installation of several modules at the IRRAD facility at CERN, where the sensors have been irradiated up to a fluence of $1.7 \cdot 10^{16}$ n_{eq}/cm^2, which is the expected sensors' end-of-life fluence at the end of the HL-LHC program. After the irradiation, I joined the beam test activities at the CERN beamlines, participating in the installation of modules and in the data taking, and analysis, mainly focusing on the charge collection efficiency that has been measured for the very first time with the ITkPixV2.

PHD SCHOOLS

ESHEP 2025 European School of High Energy Physics, October 2025, Benasque (Spagna).

COURSES TAKEN

Teorie di Gauge non Abeliane: *N. Maggiore*

PUBBLICATIONS

Ravera, S. **Assembly and electrical characterization of 3D-pixel modules for the ATLAS ITk Pixel detector**, PoS **Nuovo Cim. C** (2025), volume 48, numero 3. doi:10.1393/ncc/i2025-25151-9

Tian, Yusong *et al.* **Characterization with test beams of ITk pixel detectors for the upgrade of the ATLAS Inner Detector**, PoS **ICHEP2024** (2024), doi:10.22323/1.476.0938

Ø. Bergsagel, G. Calderini, T. I. Carcone, J. I. Carlotto, P. Chabrillat, O. Dorholt, C. Gemme, A. Grigorev, T. Heim and S. Hassan, *et al.* **Test Beam Results of SINTEF 3D Pixel Silicon Sensors**, PoS **VERTEX2023** (2024), 076 doi:10.22323/1.448.0076

M. A. A. Samy, G. Calderini, T. I. Carcone, J. I. Carlotto, P. Chabrillat, G. F. Dalla Betta, C. Gemme, A. Grigorev, T. Heim and L. Meng, *et al.* **Qualification of irradiated 3D pixel sensors produced by FBK for the pre-production of the ATLAS ITk detector**, PoS **VERTEX2023** (2024), 072 doi:10.22323/1.448.0072

S. Ravera [ATLAS], **Results of multi-module system test for the ATLAS ITk Endcap detector**, Nuovo Cim. C47 (2024) no.3, 134 doi:10.1393/ncc/i2024-24134-8

G. Calderini, F. Crescioli, G. F. D. Betta, G. Gariano, C. Gemme, F. Guescini, S. Hadzic, T. Heim, A. Lapertosa and S. Ravera, *et al.* **Qualification of the first pre-production 3D FBK sensors with ITkPixV1 readout chip**, PoS **Pixel2022** (2023), 025 doi:10.22323/1.420.0025

TEACHING

Tutor Fisica Generale 1 - Classe L-30, Corso di laurea triennale in Fisica (42h).

CONFERENCES

PIXEL2024 The Eleventh International Workshop on Semiconductor Pixel Detectors for Particles and Imaging, Strasbourg, November 2024. Poster: Towards the construction of the ATLAS ITk Pixel innermost layer.

IFAE 2025 The 21th Incontri di Fisica delle Alte Energie, Cagliari, Aprile 2025. Poster: Tracks of new physics: calibration of the dE/dx measured at the ATLAS experiment looking for long-lived particles.