SCIENCES & BIOENGINEERING SCIENCES

The Research Group
High Energy Physics

has the honor to invite you to the public defence of the PhD thesis of

# Kunal Gautam

to obtain the degree of Doctor of Sciences

Joint PhD with University of Zürich

Title of the PhD thesis:
**Precision Measurement of Strange Quark Asymmetry and Monolithic Pixel Sensors for Vertexing at the FCC-ee**

**Supervisor:**
Prof. dr. Michael Tytgat (VUB)
**Co-supervisor:**
Prof. dr. Florencia Canelli (University of Zürich, CH)

The defence will take place on

**Monday, September 15, 2025 at 2 p.m.**

VUB Campus Etterbeek, Pleinlaan 2, Elsene, auditorium **I.0.02**

The defence can also be followed through a live stream:
https://cern.zoom.us/j/62263723198?pwd=9gxO83Atg64elvK8fghCeOJbQcAPV1.1

## Members of the jury

Prof. dr. Alberto Mariotti (VUB, chair)
Prof. dr. Lea Caminada (University of Zürich, CH)
Dr. Michele Selvaggi (CERN, CH)
Dr. Francesca Carnesecchi (CERN, CH)

## Curriculum

Kunal Gautam graduated with a Master of Science in physics from the University of Copenhagen in 2020. He joined the Vrije Universiteit Brussels as a doctoral candidate in cotutelle with the University of Zurich in 2021. His research contributed to assessing the physics potential of the Future Circular Collider, the planned successor to the LHC at CERN, and the advancement of corresponding R&D on innovative silicon detectors. He has published his work in internationally peer-reviewed journals and has presented at two international conferences as well as several workshops and seminars.

## Abstract of the PhD research


Future $e^+e^-$ colliders, such as the FCC-ee, aim to test the Standard Model to the ultimate precision, requiring synergistic progress in detector technology and data analysis techniques. This thesis comprehensively presents the interlinked efforts targeting these goals, strengthening the next generation of precision measurements at the FCC-ee and beyond.

Jet flavour tagging algorithms allow for the identification of the initiating quark flavour from the spray of detected particles and play a crucial role in maximally exploiting the physics potential of the FCC-ee, particularly in the Higgs and the electroweak sectors. The presented DeepJetTransformer algorithm, exploiting a transformer-based neural network that is substantially faster to train than state-of-the-art graph neural networks, combines particle-flow reconstruction with advanced vertexing and hadron identification. Beyond excellent bottom and charm jet discrimination, a strange jet tagging efficiency of 40% can be achieved with a 10% background efficiency from up and down jets.

A $5\sigma$ discovery significance can be achieved while isolating $Z \to ss$ events from the exclusive decays of the $Z$ boson with less than a second of the FCC-ee run plan at the $Z$ boson resonance. This thesis presents one of the first measurements of the forward-backward asymmetry in the strange decay channel of the Z boson, resulting in an almost three-order improvement.

To support these improvements, ultra-thin, high-resolution, and robust vertex detectors are essential. Recent advancements in the use of ultra-light monolithic active pixel sensors (MAPS), developed in the 65 nm CMOS imaging process for the ALICE ITS3 project, foresee drastic improvements in the vertexing performance. Small-scale analogue prototypes show sub-3 µm spatial resolution and >99% detection efficiency, even under moderate irradiation, satisfying the stringent requirements of ALICE and the future collider environments.