SCIENCES & BIOENGINEERING SCIENCES

The Research Group
High Energy Physics

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

Dieder Van den Broeck

to obtain the degree of Doctor of Sciences

Title of the PhD thesis:

Signal Propagation in the Simulation of Radio Emission from Particle Cascades

Supervisor:
Prof. dr. Stijn Buitink (VUB)
Co-supervisors:
Prof. dr. Krijn de Vries (VUB)
Prof. dr. Tim Huege (VUB)

The defence will take place on

Tuesday, July 1, 2025 at 16:00

VUB Etterbeek campus, Pleinlaan 2, Elsene, auditorium D.2.01
The defence can be followed Online
(Meeting ID: 821 4199 2134 Passcode: 593496)

Members of the jury

Prof. dr. Nick van Eijndhoven (VUB, chair)
Prof. dr. Sophie de Buyl (VUB)
Prof. dr. Frank De Proft (VUB)
Dr. Katharine Mulrey (Radboud Universiteit Nijmegen, NL)
Prof. dr. Christian Glaser (Uppsala University, SE)

Curriculum vitae

Dieder obtained his MSc. in Physics and Astronomy from the Vrije Universiteit Brussel (VUB) in 2020. For his master's thesis, he worked on simulating radio signals from particle cascades in ice within the context of the RET project.
His doctoral research focused on signal propagation for radio signals originating from particle cascades in natural materials.

As a PhD student at the VUB-IIHE institute, Dieder was involved in the RNO-G and RET experiments. In addition, he completed teaching assignments where he was a teaching assistant for bachelor level courses at VUB, supervised bachelor students on their theses, and presented his results multiple times to the scientific community at international conferences.

Abstract of the PhD research

Astroparticle physics relies on accurate measurements of cosmic messengers at ever higher energies. Probing beyond 1018 eV, cosmic rays are the most energetic particles that we can observe. The measurements performed by the Pierre Auger Observatory and Telescope Array offer scientists a perspective into the highest energy processes in the universe. For neutrinos, IceCube has measured a diffuse flux around 10^{15} eV, and many detection efforts aiming to detect even higher energy neutrinos are currently under construction.

Nowadays many experiments use radio techniques to detect cosmic particles, which is expected to be especially useful due to the high-duty cycle and good angular resolution. An ongoing challenge is the accurate description of radio signal propagation in natural, non-uniform media. Many simulations implicitly assume straight-line signal propagation when calculating emission from extensive air showers. However, refractive effects change the received signal and associated reconstruction. The error associated with the straight-line approximation of the signal is currently not completely understood for the most inclined air shower geometries. The problem of signal propagation is expected to be of even greater importance inside the layered structure of polar ice. Raytracing predicts a shadow zone for each receiver position, where no signal from an emitter can reach the receiver. However, observations have since indicated that it is possible for a signal to originate from the shadow zone, possibly caused by local over-densities in the ice.

This thesis presents the results of a numerical ray tracer study based on Fermat’s principle. The prediction of an over-density in a layered ice structure allowing horizontal propagation is verified. Also presented is a study regarding the validity of straight-line signal propagation when simulating emission from very inclined air showers by improving the parametrization of the geometric boost factor. We find negligible errors of up to a few percent in radiation energy and O(0.01◦) for directional reconstruction for frequencies up to 600 MHz and zenith angles up to 88◦, confirming that the current implementations remain usable at these frequencies and zenith angles.