T 59: Neutrino Astronomy III

Time: Wednesday 16:15–18:30 Location: KS H C

T 59.1 Wed 16:15 KS H C

Extending the Advanced Northern Tracks Selection with Energy Uncertainty Estimation — •Lasse Düser, Shuyang Deng, Sönke Schwirn, Philipp Soldin, Christopher Wiebusch, and Marco Zimmermann for the IceCube-Collaboration — RWTH Aachen University

The IceCube Neutrino Observatory is a cubic kilometer-sized detector located at the South Pole. It uses more than 5000 photomultipliers (PMTs) to detect particles via their Cherenkov radiation including muons induced by atmospheric and astrophysical neutrinos. Using a graph convolutional neural network that encodes the spatial geometry of the PMTs, the Advanced Northern Tracks Selection (ANTS) identifies these events and reconstructs important event features like the neutrino energy. Extending the existing ANTS framework allows for the simultaneous, event-based estimation of the uncertainty on the reconstructed energy. In this talk, we discuss the network's performance in terms of resolution and calibration. The reconstruction is compared to established methods and evaluated across different event topologies.

T 59.2 Wed 16:30 KS H C

Event reconstruction for different detector geometries in a toy simulation of water-Cherenkov neutrino telescopes — •Franziska Kirchner for the IceCube-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander-Universität Erlangen-Nürnberg

Water-Cherenkov neutrino detectors are typically built with instrumentation strings placed on a triangular grid. Next-generation detectors such as P-ONE or IceCube-Gen2 are planned as less ordered structures so that no charged particle can pass through the detector without approaching any detector string. However, it is not fully understood which detector geometries result in an optimal resolution of event energies and event positions. The talk will present a toy simulation of various detector geometries and corresponding cascade and muon track event reconstructions, which is used to investigate the corresponding resolutions.

T 59.3 Wed 16:45 KS H C

Approximating Photon Propagation in Ice Using Generative Neural Networks — •Amith Ashwath Narayan for the IceCube-Collaboration — Technical University of Munich

The Precision Optical Calibration Module (POCAM) is an isotropic, self-monitored calibration device. As part of the IceCube upgrade an extension of the IceCube detector located at the geographical South Pole, POCAMs are being installed to tackle existing optical detector systematics with higher precision. Estimating these detector systematic uncertainties requires parsing a multidimensional parameter space, which is computationally intensive, therefore it is infeasible. Since an analytical approximation with sufficient precision does not exist, we employ machine learning: by sparsely sampling the parameter space and using a neural network to interpolate between simulated points. In this project, the focus is specifically on scattering coefficient, training the network to generate the corresponding detection optical module (DOM)-response histograms and total photon counts. The talk will focus on the neural-network architecture and its performance in generating DOM-response histograms and photon counts for the scattering coefficient, with the method being in principle extendable to the remaining detector systematics.

T 59.4 Wed 17:00 KS H C

Advanced Northern Tracks Selection using a Graph Convolutional Neural Network for the IceCube Neutrino Observatory — •Philipp Soldin, Shuyang Deng, Lasse Düser, Sönke Schwirn, Christopher Wiebusch, and Marco Zimmermann — RWTH Aachen University

The IceCube Neutrino Observatory is a large neutrino detector located in the ice at the geographic South Pole. It detects atmospheric and astrophysical neutrinos via Cherenkov radiation emitted by secondary charged particles, recorded by more than 5,000 digital optical modules equipped with photomultiplier tubes (PMTs). A central challenge for IceCube analyses is the efficient separation of muons produced in neutrino interactions from the dominant background of muons from cosmic-ray air showers. To address this challenge, the Advanced Northern Tracks Selection (ANTS) employs a two-stage, machine-learning-based event selection. A transformer-based autoencoder first performs dimensionality reduction of the time-resolved sensor data, followed by a deep graph convolutional neural network (GCNN) that explicitly exploits the irregular, node-like geometry of the IceCube detector. Compared to established selection methods, ANTS achieves a significant improvement in classification performance. This presentation examines the ANTS network architecture, training strategy, background-rejection capability, and computational efficiency.

T 59.5 Wed 17:15 KS H C

Adapting the Advanced Northern Tracks Selections Neural Network for the IceCube Upgrade — •Sönke Schwirn, Shuyang Deng, Lasse Düser, Hasti Maghsoudipour, Philipp Soldin, Christopher Wiebusch, and Marco Zimmermann for the IceCube-Collaboration — III. Physikalisches Institut B, RWTH Aachen

The IceCube Neutrino Observatory is a neutrino detector located at the South Pole, consisting of over 5000 Digital Optical Modules (DOMs), each containing a single photomultiplier tube (PMT). In winter 2025/26, the IceCube Upgrade was deployed, including around 400 newly developed multi-PMT modules (mDOMs). Each mDOM contains 24 PMTs, providing in-module directionality information and increased effective area. A denser spacing of the modules also enables the detection threshold to be lowered to a few GeV. These new modules require modifications to existing event reconstruction methods. The Advanced Northern Tracks Selection (ANTS), developed for the original single-PMT DOMs, uses a multi-stage neural network approach that utilizes the full event information as measured by the DOMs for event selection and reconstruction of event parameters such as the particle direction and energy. This talk presents modifications of the ANTS network architecture to include the mDOMs of the IceCube Upgrade and discusses reconstruction performance at low energies.

T 59.6 Wed 17:30 KS H C

The Pacific-Ocean Neutrino Experiment Design Optimization with Machine-Learning — •Kristian Tchiorniy and Lukas Heinrich for the P-ONE-Collaboration — Technische Universität München, Physik-Department, James-Frank-Str. 1, Garching bei München, D-85748, Germany

The geometrical layout of any experiment or detector can have a large impact on its ability to produce meaningful outcomes for physics. Oftentimes we see that optimal geometries can be unintuitive. Studying and optimizing this is therefore essential. This has become a relevant topic for the optimization of cubic-kilometer-scale neutrino telescopes, in particular, the Pacific Ocean Neutrino Experiment (P-ONE), which is planned to be constructed in the coming years. With more than 70 lines across multiple kilometers of seafloor, the P-ONE geometry is yet to be finalized and studies on how to place these lines can inform crucial design decisions. In this presentation, the possible geometric optimization of such an experiment will be discussed, in particular, how it will employ machine-learning techniques to apply end-to-end optimization.

T 59.7 Wed 17:45 KS H C

Neural Network-based DAQ System for in-ice Radio Detection of Neutrinos for RNO-G and IceCube-Gen2 — •Adam Rifaie for the RNO-G-Collaboration — Bergische Universität Wuppertal, Wuppertal, Deutschland

Detecting astrophysical neutrinos at energies above 10 PeV is challenging due to their extremely low flux. The state-of-the-art detectors, such as RNO-G, and the planned IceCube-Gen2 Radio Array, exploit radio emissions via the Askaryan effect. The km-scale attenuation length of radio signals in ice enables large-scale detectors spanning several tens or hundreds of kilometres.

High trigger rates of such large-scale detectors demand efficient trigger systems and high data purity, such as Neural Network (NN)-based triggers. Previous simulation studies estimate an increase in the detection rates of astrophysical neutrinos by up to a factor of 2 at energies of 10 PeV, doubling the effective detection volume of the detector for no additional costs.

This presentation briefly describes the NNs we will be testing. Followed by the first lab measurements using the new DAQ system, NuRadioDAQ, and compares them to projected estimates based on simulated data.

T 59.8 Wed 18:00 KS H C

Neural Network Tools for the IceCube-Gen2 Optical Array — •Francisco Javier Vara Carbonell and Alexander Kappes for the IceCube-Collaboration — Universität Münster, Institut für Kernphysik

IceCube-Gen2 is a planned extension of the current IceCube neutrino observatory that will increase the in-ice instrumented volume by roughly a factor of eight and introduce 9600 new optical sensors with multiple photomultiplier tubes (PMTs) designed to provide nearly full solid-angle coverage. In this new configuration, neural networks are particularly strong candidates to replace or complement traditional algorithms in key tasks such as event reconstruction, topology classification, noise cleaning, and simulation, as they naturally exploit the additional information provided by the new sensors and can process large data volumes efficiently, especially when run on graphics processing units (GPUs). This talk will provide an overview of these methods, summarize their current performance in the IceCube-Gen2 context, and discuss their possible physics implications.

T 59.9 Wed 18:15 KS H C

Combined Likelihood Analysis for Supernova Hunting — •Thilo Birkenfeld, Achim Stahl, and Christopher Wiebusch — III. Physikalisches Institut B, RWTH Aachen, Germany

The Combined Likelihood Analysis for Supernova Hunting (CLASH) is a software framework for the search for faint Supernova (SN) signals in various kinds of experimental data streams. Supernovae are frequently observed via optical telescopes. Observations via neutrinos and/or gravitational waves are highly anticipated, as they will provide valuable insights into the nature of the explosion onset. However, the observation of neutrinos from an SN has succeeded only once so far, for SN 1987A. The chance of such an observation is given by the SN rate in Earth's vicinity and the limited detection range of individual experiments. We developed a likelihood-ratio test comparing the persistent signal hypothesis with a background-only model as a function of time. It can be applied to individual experiments of various kinds or multiple detectors in combination, increasing the observable range. In this talk, I present CLASH, its underlying methodology, and discuss its use for pertinent detectors such as JUNO and Hyper-K.