# T 42: Experimentelle Methoden I

Zeit: Dienstag 16:00–18:35 Raum: ST 1

**Gruppenbericht** T 42.1 Di 16:00 ST 1

**Track reconstruction for the Mu3e experiment** — •Alexandr Kozlinskiy for the Mu3e-Collaboration — Institut für Kernphysik, Johannes Gutenberg-Universität Mainz

The *Mu3e* experiment is designed to search for the lepton flavour violating decay $\mu^+ \to e^+e^-e^+$. The aim of the experiment is to reach a branching ratio sensitivity of $10^{-16}$. In a first phase the experiment will be performed at an existing beam line providing $10^8$ muons per second at the Paul-Scherrer Institute (Switzerland) which will allow to reach a sensitivity for the branching fraction of $10^{-15}$. The muons with a momentum of about 28 MeV/c are stopped and decay at rest on a target. The decay products (positrons and electrons) with energies below 53 MeV are measured by a tracking detector consisting of two double layers of 50 $\mu$m thin silicon pixel sensors. The high granularity of the pixel detector with a pixel size of $80 \times 80$ $\mu$m allows for a precise track reconstruction in the high occupancy environment of the *Mu3e* experiment reaching 100 tracks per reconstruction frame of 50 ns in the final phase of experiment. To deal with such a high occupancy and combinatorics the *Mu3e* track reconstruction uses a novel fit algorithm that in the simplest case takes into account only the multiple scattering, which allows fast online tracking on a GPU based filter farm. The implementation of the 3-dimensional multiple scattering fit based on hit triplets is described. The extension of the fit that takes into account energy losses and pixel size is used for offline track reconstruction. The algorithm and performance of the offline track reconstruction based on a full Geant4 simulation of the *Mu3e* detector are presented.

T 42.2 Di 16:20 ST 1

**Selective background Monte Carlo simulation at Belle II** — •James Kahn and Thomas Kuhr — Ludwig-Maximilians-Universität München

The Belle II experiment, beginning data taking with the full detector in early 2019, is expected to produce a volume of data fifty times that of its predecessor. With this dramatic increase in data comes the opportunity for studies of rare, previously inaccessible processes. The investigation of such rare processes in a high data volume environment requires a correspondingly high volume of Monte Carlo simulations to prepare analyses and gain a deep understanding of the contributing physics processes to each individual study. This presents a significant challenge in terms of computing resource requirements and calls for more intelligent methods of simulation, in particular background processes with very high rejection rates.This work presents a method of predicting in the early stages of the simulation process the likelihood of relevancy of an individual event to the target study using convolutional neural networks. The results show a robust training that is integrated natively into the existing Belle II analysis software framework.

T 42.3 Di 16:35 ST 1

**New formulas to handle uncertainty from limited Monte Carlo statistics** — •Thorsten Glüsenkamp for the IceCube-Collaboration — FAU Erlangen-Nürnberg, Erlangen, Bayern

This talk will discuss new probabilistic approaches to handle the statistical uncertainty from Monte Carlo statistics for Poisson likelihoods. First, it will be shown how five approaches from the last 25 years, starting with Barlow/Beeston in 1993, are related to each other. Then, the approaches are compared in a typical Toy MonteCarlo setting representatative of high-energy particle experiments. The results indicate the advantages of the new formulas over the old ones in terms of speed, interpretability, and ability to mitigate the statistical bias.

T 42.4 Di 16:50 ST 1

**BAT.jl - A new toolkit for Bayesian analysis** — •Cornelius Grunwald, Kevin Kröninger, and Salvatore La Cagnina — TU Dortmund, Experimentelle Physik IV, Deutschland

In all but the simplest cases, performing Bayesian inference can be a computationally challenging task. Performant algorithms and tools are needed to apply Bayesian statistics to the complex problems of modern data analysis. The Bayesian Analysis Toolkit (BAT) is a software package that allows the application of Bayesian inference through the use of Markov Chain Monte Carlo techniques. BAT provides a toolbox of algorithms and statistical methods that facilitate solving user-defined problems in a Bayesian approach. In order to improve its applicability, a complete rewrite of BAT is currently in process. Using the Julia programming language for core development and targeting innovative sampling algorithms, the performance of BAT will be increased and computation times will be reduced. Software dependencies will be minimized and interfaces to commonly used languages and tools are going to be provided. This will enhance the general usability of BAT and allow to extend its applicability to further fields of research. In this talk, the approach for the redevelopment of BAT will be presented and first insights into the current status of the project will be given.

T 42.5 Di 17:05 ST 1

**Pileup mitigation with Constituent Subtraction** — •Peter Berta and Lucia Masetti — JGU Mainz, Mainz, Germany

The ability to correct jet kinematics and substructure for simultaneous proton-proton interactions (pileup) largely determines the precision of measurements and searches at the Large Hadron Collider. In this talk, the Constituent Subtraction method for pileup mitigation in jets will be presented. This method corrects the jet inputs from the whole event before jet clustering based on the average pileup density in the event. Phenomenological studies showed potential for sizable improvements in performance for small- and large-radius jets compared to the previously used methods. Several improvements are presented, along with performance studies for expected pileup conditions at the LHC Run 2 and Run 3.

T 42.6 Di 17:20 ST 1

**What can High Energy Physics Tracking learn from 1990s computer graphics?** — •Paul Gessinger[1,2], Andreas Salzburger[2], and Stefan Tapprogge[1] — [1]Johannes Gutenberg-Universität Mainz — [2]CERN

The process of forming particle trajectories from measurements is called track reconstruction. Due to pile-up, this quickly becomes the most resource intensive part of event reconstruction in HEP. In recent runs of the LHC, experiments have successfully used highly optimized software to achieve desirable computational and physics performance. In light of the upcoming increase of luminosity for the HL-LHC, new solutions are being developed. Propagation and navigation of particle trajectories through the detector are particularly CPU intensive tasks. This is essential for fitting tracks, and thus is revisited in the Acts project. In computer graphics, highly performant ray tracing algorithms are used frequently. Using ray-box intersections in hierarchies of boxes, intersections of the assumed direction of a track and the detector geometry can be found efficiently. These algorithms could enable a more robust and flexible alternative to other navigation solutions. The approach could also alleviate some of the sophistication and finetuning required in building geometries which can be navigated easily. Different navigation strategies through HEP detector geometries and their interplay with track reconstruction will be covered in this talk. Benefits and pitfalls of the different approaches will be reviewed. The usage of intersection algorithms for fast navigation will be investigated and applicability to real-world tracking scenarios will be evaluated.

T 42.7 Di 17:35 ST 1

**3D Track Finding in the Preprocessing of the Belle II L1 Neural Network z-Vertex Trigger** — •Sebastian Skambraks, Christian Kiesling, Sara McCarney, and Felix Meggendorfer for the Belle 2-Collaboration — MPI for Physics

Neural networks are going to be used in the pipelined first level trigger of the upgraded flavor physics experiment Belle II at the high luminosity B factory SuperKEKB in Tsukuba, Japan. An instantaneous luminosity of $\mathcal{L} = 8 \times 10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ is anticipated, 40 times larger than the world record reached with the predecessor KEKB. Background tracks, with vertices displaced along the beamline ($z$-axis), are expected to be severely increased due to the high luminosity. Using the hit and drift time information from the central drift chamber, the online neural network trigger estimates the 3D track parameters of single tracks found by the track finder. This robust estimation of the $z$-vertices significantly improves the suppression of displaced background tracks. A machine learning based extension of the conventional 2D Hough track finder to 3D is discussed, which allows to use the stereo sense wire information in the track finding and thus to improve the track finding efficiency. The estimated polar track angle can be used for a further specialization of the following neural networks to phase space sectors.

T 42.8 Di 17:50 ST 1

**Highly performant, deep neural networks with sub-microsecond latency for trigger FPGAs** — •Noel Nottbeck, Volker Büscher, and Christian Schmitt — Johannes Gutenberg-Universität Mainz

Artificial neural networks are becoming a standard tool for data analysis, but their potential remains yet to be widely used for hardware-level trigger applications. Nowadays, high-end FPGAs, as they are also often used in low-level hardware triggers, offer enough performance to allow for the inclusion of networks of considerable size into these systems for the first time. Nevertheless, in the trigger context, it is necessary to highly optimize the implementation of neural networks to make full use of the FPGA capabilities.

We optimized and implemented the processing and control flow of typical NN layers for use within FPGAs, such that they can run efficiently in a real-time context with e.g. the ATLAS data rate of 40 MHz and latency limits of at most few hundred nanoseconds for entire networks. Significant effort was put especially into the 2D convolutional layers, to achieve a fast implementation with minimal resource usage.

A Python-based toolkit has been developed that makes implementing a neural network into an FPGA as easy as executing a few lines of code on an already trained Keras network. Results are presented, both for individual layers as well as entire networks created by the toolkit.

T 42.9 Di 18:05 ST 1

**First Level Neural Network z-Trigger optimization and implementation or the Drift Chamber at the Belle II Experiment** — •Sara McCarney, Christian Kiesling, Felix Meggendorf, and Sebastian Skambraks — Max Planck Institute for Physics, Munich, Germany

For the Belle II experiment at the SuperKEKB asymmetric electron-positron collider (KEK, Japan), a z-trigger for Belle II is required to suppress the dominating background of tracks from outside of the collision point. The concept of a first level track trigger, realized by neural networks, is presented. The Multi Layer Perceptron (MLP) Neural Network, using drift times and a traditional Hough-based 2D track finder as input, reconstructs the origin of the tracks along the beam's z-axis. Training and testing on simulated tracks achieve resolutions below 2 cm in the high Pt region, and below 5 cm in the low Pt region, sufficient for efficient background rejection. The importance of various training parameters and drift time inputs on the optimal spatial resolution of the z-trigger is discussed. Background distributions from first data taking with Belle II are analyzed to optimize suitable z-cuts for an efficient background suppression.

T 42.10 Di 18:20 ST 1

**Data Quality Monitoring for the Neural Network z-Trigger in the Drift Chamber at the Belle-II Experiment** — •Felix Meggendorfer, Sebastian Skambraks, Sara McCarney, and Christian Kiesling for the Belle 2-Collaboration — MPI for Physics

For the drift chamber of the Belle-II experiment located in Tsukuba, Japan, a first level hardware neural network z-trigger is added to the standard 2D track trigger, which is used to identify tracks coming from outside of the interaction region. With this additional condition, a dominating portion of the background is efficiently suppressed and pure 2-track triggers become possible. Since changing background conditions during the first years of SuperKEKB operation are expected, the neural network weightsets will be adapted accordingly. In order to ensure optimal trigger efficiency and background rejection it is important to monitor the performance of the networks over time and retrain and update their weightsets with data from the experiment. An overview of the data quality monitoring system for the neural z-trigger is presented.