T 5: Methods in Particle Physics I

Time: Monday 16:15–18:15 Location: KH 00.020

T 5.1 Mon 16:15 KH 00.020

Machine Learning Methods for Charged-Particle Identification at Belle II — •Robert Mundzeck[1,2], Martin Bartl[1], Hans-Günther Moser[1], and Stefan Wallner[1] — [1]Max Planck Institute for Physics, Garching, Germany — [2]Technical University of Munich

We present recent advances in charged-particle identification at the Belle II experiment at KEK, Japan. So far, particle identification at Belle II has relied on a likelihood-based method that combines information from six subdetectors to distinguish between different particle species. Recently, a neural-network-based classifier has been developed that complements and improves upon this conventional approach. We report on a study comparing the neural network performance to an alternative classifier based on boosted decision trees. We also present the approaches of further optimization of the neural network, aimed at optimizing particle identification performance at Belle II.

T 5.2 Mon 16:30 KH 00.020

Validation of the Graph Neural Network tracking at Belle II — •Jonas Lotz and Slavomira Stefkova — Physikalisches Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn, Bonn, Germany

A novel end-to-end multi-track reconstruction algorithm based on a graph neural network (GNN) architecture was developed for the Belle II collaboration (Comput Softw Big Sci 9, 6 (2025)). These studies demonstrate substantial improvements in key performance metrics such as tracking efficiency, with particularly strong gains for tracks originating from displaced vertices. In addition, different hit-to-track association provides an opportunity for improved event clean-up, which may be particularly useful for missing energy decays. In this presentation, building on this development, the applicability of this GNN-based tracking algorithm in the context of searches for $B^0 \to K_s^0 \nu\bar{\nu}$ decays will be studied. We will focus on validating the algorithm against established tracking methods and assessing potential benefits for rare decay searches. The talk will present the status of integrating the new GNN tracking framework into the $B^0 \to K_s^0 \nu\bar{\nu}$ analysis.

T 5.3 Mon 16:45 KH 00.020

Towards a Complete Tracking Concept for ILD@FCC-ee — Frank Gaede[1], Daniel Jeans[3], Jenny List[1], Thomas Madlener[1], and •Victor Schwan[1,2] — [1]Deutsches Elektronen-Synchrotron DESY — [2]Universität Hamburg — [3]Institute of Particle and Nuclear Studies, KEK, Tsukuba, Japan

The International Large Detector (ILD) concept was originally conceived for the International Linear Collider (ILC). In-depth simulations benchmarked against the performance of prototype components have shown that ILD in its ILC incarnation is exceptionally well suited to pursuing the physics program of a linear e^+e^- collider at energies from the Z pole to the TeV regime. Recently, the ILD collaboration has begun investigating how the detector concept would need to be modified to operate successfully in the experimental environment of a circular e^+e^- collider, and ILD is now being evaluated as a candidate detector concept for FCC-ee. In particular, the interaction region and the machine-detector interface (MDI) require substantial changes to accommodate accelerator elements and to withstand background levels. This contribution presents recent progress on beam-induced background (BIB) estimates in ILD's tracking systems, along with ongoing developments in adapting ILD tracking and reconstruction to FCC-ee operating conditions. Together, these efforts lay the groundwork for enabling full-simulation physics studies with ILD@FCC-ee and for further optimizing the detector concept for the FCC-ee environment.

T 5.4 Mon 17:00 KH 00.020

Tracking Performance Studies for the Mu3e Experiment — •Elija Engelhardt, Tamasi Kar, and André Schöning for the Mu3e-Collaboration — Physikalisches Institut, Universität Heidelberg, Germany

The Mu3e experiment aims to find the charged lepton flavour violating decay $\mu^+ \to e^+e^-e^+$ at the Paul Scherrer Institute (PSI). Phase 1 of the experiment will reach a single event sensitivity of 2×10^{-15} on the branching ratio, and Phase 2 aims for a sensitivity down to 10^{-16}[1]. In order to reach this level of sensitivity, a high muon stopping rate (2 GHz) and a large track reconstruction efficiency are required. The tracking detector comprises of four pixel detector layers based on the HV-MAPS technology for precise position measurements, scintillating fibres, and scintillating tiles for precise timing. The tracking algorithm used is based on the General Triplet Track Fit (GTTF) [2].

The tracking efficiency, purity, and various parameter resolutions are studied and improved using Monte Carlo simulations and data taken during the June 2025 commissioning run. The track reconstruction efficiency and purity are defined with simulation truth as reference. Various track parameter cuts are investigated to balance fake rate and efficiency. Results from the tracking performance optimisation studies will be presented.

[1] The Mu3e Collaboration. Technical design of the phase I Mu3e experiment. doi: 10.1016/j.nima.2021.165679
[2] A. Schöning. A general track fit based on triplets. doi: 0.1016/j.nima.2025.170391

T 5.5 Mon 17:15 KH 00.020

Vertex Reconstruction Using the General Triplet Track Fit for the Mu3e Experiment — •Thomas Schwartze, André Schöning, Tamasi Kar, and David Fritz for the Mu3e-Collaboration — Physikalisches Institut, Heidelberg University, Germany

The Mu3e Experiment at the Paul Scherrer Institut (PSI) searches for the charged-lepton-flavour-violating decay $\mu^+ \to e^+e^-e^+$. Mu3e aims to improve the sensitivity to the exclusion-limit of this process by four orders of magnitude. It uses a high-intensity muon beam to deliver up to 2 GHz of muons to a stationary target. To efficiently distinguish signal from background, a fast and accurate reconstruction of the common vertex is essential.
In this talk, an extension to the General Triplet Track Fit (GTTF) [1] is presented that is able to reconstruct the vertex of three-track combinations. The GTTF is a track fitting algorithm based on triplets. It is highly parallelizable and therefore, for example, well suited for GPU implementation. It has been extended to reconstruct the position of the decay vertex by treating it as an additional pseudo-hit. The performance of this vertex reconstruction is evaluated using both Monte Carlo simulations and data from the June 2025 commissioning run at PSI.

[1] A.Schöning, A general track fit based on triplets, doi: 10.1016/j.nima.2025.170391.

T 5.6 Mon 17:30 KH 00.020

Improving secondary vertexing for HL-LHC: Algorithm research using ACTS and ODD — •Diptaparna Biswas[1], Markus Cristinziani[1], Margret Keuper[2], Adrian Szymon Kosmala[3], Vadim Kostyukhin[1], and Paweł Swoboda[3] — [1]Experimentelle Teilchenphysik, Center for Particle Physics Siegen, Universität Siegen, Germany — [2]Data and Web Science Group, Universität Mannheim, Germany — [3]Heinrich-Heine-Universität Düsseldorf, Germany

The High-Luminosity Large Hadron Collider (HL-LHC) offers unprecedented discovery potential but introduces extreme pileup conditions that challenge standard reconstruction techniques. Accurate Secondary Vertex (SV) reconstruction is critical for precision flavour physics and BSM searches. This contribution presents research utilizing A Common Tracking Software (ACTS) to develop and benchmark robust SV algorithms tailored for this environment. While ACTS is established for tracking R&D, this work expands its scope to address the distinct complexities of vertexing. Using the Open Data Detector (ODD) for realistic HL-LHC simulations, we evaluate the performance of various algorithmic strategies, ranging from established techniques to novel approaches based on machine learning. We report on the current status in terms of the key metrics including vertex reconstruction efficiency, resolution and fake rates, demonstrating the viability of ACTS as a powerful platform for developing cross-experiment vertexing solutions for the HL-LHC era.

T 5.7 Mon 17:45 KH 00.020

Towards an implementation of ACTS for the Belle II experiment — •Marc-Philipp Thomas, Giacomo De Pietro, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Track reconstruction is a fundamental component of particle physics experiments, relying critically on robust and precise track fitting algorithms that must perform reliably across a wide range of particle momenta. The Belle II experiment at the asymmetric electron-positron SuperKEKB collider presents particular challenges for track fitting. These include particles with momenta ranging from a few tens of MeV to several GeV, and an asymmetric detector geometry.

In this talk, we discuss the integration of the experiment-independent ACTS (A Common Tracking Software) toolkit into the Belle II reconstruction chain. In the proposed workflow, track finding is performed within the Belle II Analysis Software Framework, while ACTS is used solely for track fitting. We will present the current status of this integration effort, including the first results on ACTS track fitting for the Silicon Vertex Detector, and a comparison with the current Belle II track-fitting approach in terms of reconstruction efficiency, parameter resolution, and robustness for low-momentum tracks.

T 5.8 Mon 18:00 KH 00.020

Track Reconstruction with the Pixel Detector for the Phase-2 Upgrade of the CMS High-Level Trigger — •Jan Gerrit Schulz[1,2], Alexander Schmidt[1], Marco Rovere[2], Elena Vernazza[2], Bruno Alves[2], Emanuele Coradin[2,3], Luca Ferragina[2,4], Marco Musich[2], and Felice Pantaleo[2] — [1]III. Physikalisches Institut A, RWTH Aachen University, Germany — [2]CERN, Switzerland — [3]Università di Padova & INFN, Italy — [4]Università di Bologna, Italy

The CMS detector will undergo an extensive upgrade for the upcoming High-Luminosity LHC, which will include the complete replacement of the inner tracking system. Event reconstruction algorithms must be adapted to the new geometry and the planned denser environment of up to 200 simultaneous proton-proton interactions. An important component of this event reconstruction in the High-Level Trigger (HLT) is pixel tracking, which forms the first step in the track reconstruction chain as well as a fast alternative for full tracking entirely. To exploit the full potential of the improved pixel detector, the CMS pixel tracking algorithm has been improved in various respects. This includes an extension of the coverage to parts of the outer tracker, an optimization of the parameters, and a new DNN-based track selection. This contribution provides an overview of these new developments.