Future Colliders for Early-Career Researchers

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CERN

Book of Abstracts

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Design and Performance of the IDEA Vertex Detector at FCC-ee in Full Simulation and Related R&D on Monolithic Silicon Sensors

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The FCC-ee is a proposed future e^+e^- collider capable of producing an unparalleled number of Higgs, Z, and W bosons, as well as of top quarks, in very clean experimental conditions. Up to four experiments can detect the collision products, with IDEA being one of the proposed detector concepts. A plethora of measurements at the FCC-ee rely on precise and accurate measurements of bottom and charm quarks and most of the heavy-flavour program crucially depends on efficient hadron and lepton identification and precise flight distance measurements.

This contribution presents the implementation of the IDEA vertex detector in full simulation using the Key4hep and DD4hep frameworks used by all future collider communities as well as the expected detector performance.

All future e^+e^- colliders foresee to use Depleted Monolithic Active Pixel Sensors (DMAPS) in their vertex detectors. This contribution will therefore also discuss the potential of using DMAPS developed in the 65 nm TPSCo process in the context of ALICE ITS3, which features similar requirements as FCC-ee vertex detectors.

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Bottom quark forward-backward asymmetry at the future electron-positron collider FCC-ee

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The Standard Model prediction for the Z-boson pole b-quark forward-backward asymmetry is calculated to be $(A^{0,b}_{FB})_{th} = 0.1030 \pm 0.0002$. From the experimental point of view, A^b_{FB} as measured by the large electron-positron (LEP) collider at the Z-pole is $A^{0,b}_{FB} = 0.0992 \pm 0.0016$, which remains today the electroweak precision observable with the largest discrepancy with respect to its SM prediction. All the A^b_{FB} measurements performed at LEP suffered from both the dominant statistical and different sources of systematic uncertainties. In this feasibility study, we show that the proposed high-luminosity electron-positron collider FCC-ee, collecting orders of magnitude more data at the Z-pole than LEP, will significantly reduce statistical uncertainties on $A^{0,b}_{FB}$. We also have studied and discussed to what extent the newly developed packages and tools, the QCD developments in the last years, and the new official FCCAnalysis framework could improve our understanding of the different sources of systematic uncertainties.

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Future colliders survey: Presentation of first results and live survey

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Concluding remarks

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Machine Detector Interface for $\sqrt{s} = 3\ TeV$ Muon Collider

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Muon collisions are considered a promising mean for exploring the energy frontier, leading to a detailed study of the possible feasibility issues. Beam intensities of the order of 10^{12} muons per bunch are needed to achieve the necessary luminosity, generating a high flux of secondary and tertiary particles that reach both the machine elements and the detector region. A strategy to reduce the beam-induced background to manageable levels at 3 TeV center-of-mass energy will be discussed. The configuration of the interaction region will be presented with particular focus on the absorber design, as well as the overall background-mitigation strategy with the relevant detector parameters in mind.

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Beamstrahlung dump and radiation levels in the experiment IRs

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The Future Circular Collider (FCC) study explores the feasibility of post-LHC colliders with a circumference of almost 100 km. As a first stage, a high-luminosity electron-positron collider (FCC-ee) is envisaged, with a beam energy ranging from 45.6 GeV (Z pole) to 182.5 GeV (ttbar threshold). The most intense radiation source at FCC-ee interaction region (IR) is the production of synchrotron photons in the field of the counter-rotating beam, called beamstrahlung radiation. Dedicated high-power beam dumps must be designed to safely dispose of the two beamstrahlung photon beams emerging from each interaction point (IP). In this work, the Monte Carlo simulation code FLUKA has been used to give a first evaluation of the main quantities related to the dump core and shielding design. A simple simulation model including only the concrete tunnel, the photon extraction line and the dump, has been set up to assess the power deposition and the DPA in the dump core, as well as the radiation levels induced in its vicinity. This study has been carried out for the two operation modes at Z pole and ttbar threshold and investigating two possible materials for the dump core, graphite and liquid lead.

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Proposal on the electromagnetic calorimeter for a muon collider

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In the panorama of future colliders, a muon collider represents a very promising choice that would enable a vast physics program. However, the beam-induced background generated from the decay of the muons along the ring is a challenging aspect both from the hardware and the software side. Indeed, despite the presence of a pair of tungsten absorber cones, that mitigate the flux of particles reaching the detector, there is a component that enters the detector and could limit the performance. For this reason, adequate design of the entire detector and of suitable event reconstruction algorithms plays a fundamental role. This poster presents studies on a proposal of promising electromagnetic calorimeter to respond the requests of physics at muon collider.

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Beam-induced background simulations for a multi-TeV muon collider

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Circular muon colliders offer the exciting potential to collide lepton beams at previously unattained center-of-mass energies. However, a notable technological challenge arises due to the continuous decay of stored muons. This decay introduces significant complexities for both collider and detector design. The secondary radiation fields generated by the decay electrons and positrons can seriously hinder detector performance and may limit the lifespan of its components. Consequently, muon colliders require a sophisticated interaction region design, which combines custom detector shielding with the detector envelope and the final focus system.
Here, we present design studies for the machine-detector interface and quantify the resulting beam-induced background at 10 TeV center-of-mass energy. Starting from the optics and shielding design developed by the MAP collaboration for a 1.5 TeV collider, we propose an initial interaction region layout for a 10 TeV collider. Specifically, we investigate how choices in lattice and shielding design impact the distribution of secondary particles entering the detector. These results are vital for evaluating detector performance and conducting studies on radiation damage.

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The Key4hep software stack: Beyond Future Higgs factories

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The Key4hep project aims to provide a turnkey software solution for the full experiment life-cycle, based on established community tools. Several future collider communities (CEPC, CLIC, EIC, FCC, and ILC) have joined to develop and adapt their workflows to use the common data model EDM4hep and common framework. Besides sharing of existing experiment workflows, one focus of the Key4hep project is the development and integration of new experiment independent software libraries. Ongoing collaborations with projects such as ACTS, CLUE, PandoraPFA and the OpenDataDector show the potential of Key4hep as an experiment-independent testbed and development platform. In this poster, we present the challenges of an experiment-independent framework along with the lessons learned from discussions of interested communities (such as LUXE) and recent adopters of Key4hep in order to discuss how Key4hep could be of interest to the wider HEP community while staying true to its goal of supporting future collider designs studies.

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Exploring the Hidden Sector with two-particle angular correlations at future e+e- colliders

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The analysis of the long-range particle correlations can yield valuable insights into the initial state of matter and potentially reveal the existence of Beyond the Standard Model scenarios, such as the "Hidden Valley"(HV) one. In this work, we are interested in QCD-like hidden sectors in which the production of HV matter would enhance and enlarge azimuthal correlations of final-state particles. We study the observability of the latter at future e^+e^- collider, which provide a much cleaner environment with respect to the LHC one. Specifically, the presence of ridge structures could indicate a possible presence of new physics signals.

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Beam-induced background simulations in calorimeter at a muon collider

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A future high energy muon collider can probe the multi-TeV regime and greatly improve our understanding of the Higgs self-coupling. One of the major challenges to detector performance is the beam induced background (BIB) which comes from muon decays along the beam pipe. The upstream and downstream electromagnetic showers blanket the detector with low energy photons, electrons and neutrons. Powerful BIB mitigation strategies have to be employed to study physics potential at a muon collider environment. We focus on the BIB appearing in the calorimeter and study the

performance of jet reconstruction algorithm. We investigate the effect of various energy thresholds on the calorimeter hits and how it depends on the hit depth inside the calorimeter.

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Calorimeter Clustering at FCC-ee with E(n) Equivariant Graph Neural Networks

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Reconstructing particles from raw detector outputs at the FCC is a challenging task due to complex detector geometries and highly granular, unique shower shapes. Conventional computer vision approaches are typically not suitable for application to the sparse detector outputs, so other methods more suited for unstructured data shall be consulted. We employ E(n) equivariant graph neural networks trained with object condensation loss for ECAL and HCAL calorimeter clustering in a CLIC-like CLD detector. A successful deep learning-based approach for calorimeter clustering in the FCC-ee is proposed and the next steps for improvement are suggested.

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Group photo

In front of the building