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Simulated performance of a multi-purpose experiment at a Muon Collider

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The future of high energy physics relies on the capability of exploring a broader energy range than current colliders, with higher statistics. The Muon Collider thus provides a unique possibility for combining these two aspects: as a leptonic machine it allows to take advantage of the nominal center of mass energy in the interaction. Moreover, the losses due to synchrotron radiation are negligible with respect to the electron machines, thanks to the muon mass about 200 times heavier than the electron one. For these reasons, studies aimed at designing a muon collider able to reach 10 TeV or higher center of mass energies with luminosity higher than 10^{34} cm^{-2}s^{-1} are currently ongoing. These operational conditions open to an unprecedented physics program, which ranges from high precision Higgs boson studies to Beyond Standard Model (BSM) searches. To mention only a few examples, theoretical studies demonstrate that the direct reach of muon colliders generically exceeds the sensitivity of the High-Luminosity LHC (HL-LHC) when considering several BSM states as Composite Higgs fermionic top-partners T and supersymmetric particles such as stops, chargino, stau leptons e and squarks. Moreover, the muon collider reach exceeds the one of the FCC-hh for several BSM candidates, especially for purely electroweak charged states. In addition, Dark Matter can also be studied at muon colliders in several channels exploiting for example the disappearing tracks produced by charged particles involved in the process.
The interesting possibility in terms of physics reach comes however with not-negligible technological challenges, first of all the ability to produce collimated beams of unstable particles, the muons, for a period long enough to allow high luminosity collisions. From the detector point of view instead, the main challenge is related to the so-called Beam Induced Background (BIB): the muons decay and, together with their decay products, interact with the beam pipe and the surrounding material, producing a huge secondary particle flux, in which the detector must operate. FLUKA simulations show that, at the center of mass energy of $\sqrt{s}$=1.5 TeV, the BIB is mainly composed of low energetic neutrons, photons and electrons/positrons. They deposit energy in a diffused way in all the detector volume, with also a relevant spread in their arrival time with respect to the bunch crossing, thanks to their different velocities. All these characteristics must then be taken into account for a proper detector design.
The existing simulation framework is based on the iLCSoft framework, previously adopted by the CLIC Collaboration and updated for the developments of the Muon Collider. The current configuration foresees a tracking system based on multiple layers of silicon detectors, followed by the electromagnetic and hadronic calorimeters. These three components are contained within a solenoidal magnet, which provides a field of 3.57 T. Out of the solenoid, the muon system extends, based on multiple layers of gaseous detectors, both in the barrel and in the endcap regions.
The purpose of this contribution is to describe the expected performance of a multi-purpose muon collider detector designed to reconstruct the products of collisions at $\sqrt{s}$=1.5 TeV with extreme accuracy. The results presented will include the contribution coming from the BIB particle, in order to face the proper operational condition of the detector.
The main objective of this contribution will be the performance in terms of different objects reconstruction in the various regions of the detectors. Starting from track reconstruction, we will give an overview of the different approaches studied at the muon collider detector, which include a Conformal Tracking (CT) algorithm and a Combinatorial Kalman Filter (CKF) algorithm. The result presented will prove that a robust track reconstruction for charged particles above 1 GeV throughout the detector acceptance can be achieved.
Results of the jets reconstruction, based on a particle-flow approach and a kT-based clustering, will be discussed: reconstruction efficiency, evaluated on samples of light, b− and c−jets, ranging from 82% at $p_T \approx 20$

GeV to 95% at higher p_T will be presented. The jet energy resolution ranges instead from about 50% to about 15%, depending on p_T, with significant improvement expected from the usage of more advanced algorithms. Reconstruction algorithms dedicated to electrons and photons and able to cope with the BIB conditions have been developed as well, resulting in a successful reconstruction of high-p_T electrons and photons with relatively small loss of efficiency and energy resolution. Finally, the muon reconstruction algorithm, which combines the information coming from the hits in the muon system with the reconstructed hits in the tracker, will be discussed: it leads to a reconstruction efficiency in presence of BIB greater than 90% over an extended energy range.
Whenever possible, requirements in terms of detector performance arising from the simulation results presented will also be introduced, together with the proposed technological solutions.

In-person participation

Yes

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