Note on Muon Collider Detector background

N.Mokhov, S.Geer

Since muons are point-like particles, and do not easily radiate away part of their energy as they see the oncoming beam, the collisions of muons and anti-muons in a high energy muon collider result in "clean events" with a well defined energy. As in all colliders, these clean events occur in the presence of background hits in the detector produced by processes other than the event. In the LHC operating at high luminosity, for example, many other simultaneous interactions are expected to generate substantial backgrounds. In the case of a high energy electron-positron collider, radiation from the incoming electrons creates backgrounds. A muon collider does not suffer substantially from either of these background sources, but has its own unique source of background, generated from the electrons born in muon decays. These high energy electrons are produced at small angles to the beam direction, and stay within the beampipe for many meters before exiting. To protect the events from these backgrounds, well upstream of the detector the decay electrons can be swept into several meters of shielding. Early studies a decade ago showed that with carefully designed shielding the decay-electron-induced background can be reduced by many orders of magnitude. Simulations predicted residual background-hit-densities in the inner detector (the vertex and tracking detectors) that are comparable to (a little smaller than) the expected background hit densities at the LHC when operating at its nominal luminosity (10^34 cm-2 s-1). At that time this was considered good enough since the LHC detectors would be leading the way. Since that time, the LHC detectors have become a reality, and their design and capabilities have exceeded the expectations from a decade ago. In addition, a luminosity upgrade is being planned, and the upgraded LHC inner detectors will have to cope with background levels an order of magnitude greater than currently anticipated at a muon collider. Recently, with increased interest in muon colliders, and increased expectations for detector performance, work has restarted on understanding muon collider backgrounds. Although it is at an early stage, and for a greatly updated muon collider configuration, the recent work gives results for backgrounds in the inner detector that seem consistent with the earlier work. With optimized shielding implemented in the muon collider machine-detector interface, the peak neutron fluence in the inner detector is calculated to be about 10% of that at the LHC at its nominal luminosity. The peak photon fluence and absorbed dose at a muon collider is now estimated as 50% of the nominal LHC. The studies for the outer detectors (the calorimeters) deserve far more study. The early work on the backgrounds in the outer detectors suggested performance that was considered OK at the time, but the estimates were not very detailed, and community expectations for the required performance were less demanding at that time.

In summary, a muon collider produces the "clean events" that go hand-in-hand with mono-energetic lepton-antilepton collisions, and these events are produced in a background environment in the inner detector that appears to be less or comparable to that at the LHC operating at nominal luminosity. This was the conclusion of the studies a decade ago, and is consistent with preliminary results of the renewed studies. The outer detectors deserve more study.