ISSNAF-INFN 2011 Summer Internship
FINAL REPORT

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According to the Standard Model (SM), elementary constituents of matter belong to one of three families: quarks, neutrinos and charged leptons. Unlike quarks or neutrinos, charged leptons (electron, muon and tau) do not transform into one another: Charged Lepton Flavour Violation (CLFV) processes have never been observed, and are indeed theoretically forbidden in the SM.
Although the SM is very well tested in many sectors, it probably is incomplete, and many of its evolutions, such as several supersymmetric models, predict CLVF rates within reach of current and upcoming experiments. CLFV searching would present sensitivity to New Physics comparable or even exceeding those of collider experiments such as Tevatron or LHC, making indirect CLFV measurements an essential tool of discovery in the physics of the near future.

Mu2e is a proposed Fermilab experiment designed to measure the branching fraction of CLFV processes by studying neutrinoless muon-to-electron conversion in the Coulomb field of a nucleus, with a sensitivity of up to 10^{-18}.
8 GeV protons from the Fermilab Booster Ring are used to produce muons, which decay in a solenoidal magnetic field after impacting with an aluminium target. A high-resolution straw tube tracker measures the momentum of the decay products, allowing discrimination between signal electrons from neutrinoless decay (with momentum $p = 104.97$ MeV/c) and background electrons ($p \leq 104.97$ MeV/c) originated in ordinary decays; an electromagnetic calorimeter, made up of four arrays of Cerium-doped Lutetium Yttrium Orthosilicate (LYSO) crystals, provides trigger capabilities and independent confirmation of signal events.

The aim of my Summer Student activity was, under the supervision of S. Miscetti and I. Sarra, to develop and analyse a simulation to study the possibility of using the calorimeter to perform background rejection for a rare but otherwise potentially irreducible background process: if a muon enters the detector region with a momentum $p \simeq 105$ MeV/c, it can mimic a signal electron in the tracker since it has the same momentum and charge. The calorimeter could instead reject the event exploiting the differences in the way electrons and muons deposit energy in the crystals.

The simulation was carried out in GEANT4, a C++-based toolkit for the simulation of passage of particles through matter, widely used in various fields of particle physics to analyse the behaviour of detectors.
The first part of my work has been dedicated to the calibration of the simulation environment. Energy deposit of muons in matter involves several different physical processes that had to be implemented and activated within the code. The inclusion of high-precision physics lists was needed to correctly treat the scattering of neutrons generated by the decay processes. For this purpose, I simulated the interactions of muons with homogeneous slabs of four different materials (aluminium, gold, lead and LYSO) and analysed the secondary particles, using their properties to discriminate the contributions due to different processes, overcoming the intrinsic limitations of the monolithic GEANT4 classes that describe muon decay. The results of the tests were in good agreement with both theoretical estimates and experimental data.
In the second part of my work I studied the interactions of 105 MeV/c muons and electrons on a 5×5 LYSO crystal cell matrix representing a section of the Mu2e calorimeter. The implementation of a simple cut based on charge integration interval confirmed the difference of temporal evolution of energy deposits for muons and electrons, and I studied the rejection factor for different values of calorimeter resolution. The results have shown that even an electromagnetic calorimeter with suboptimal resolution (∼5% at 100 MeV) is able to provide a signal/background rejection of ∼400. The implementation of a charge integration period time cut improves this value by a factor of 4.

The results of my study have been considered valuable, and have been released as an internal note for the Mu2e collaboration.