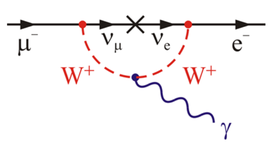
Search for Charged Lepton Flavor Violation at the Mu2e Experiment

Markus Röhrken

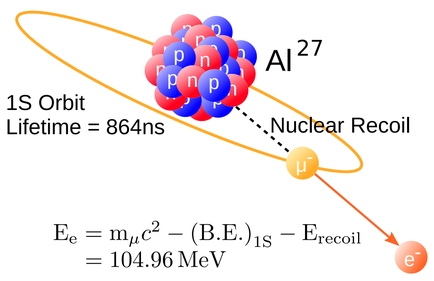
The Mu2e experiment being constructed at Fermilab will search for the coherent neutrino-less conversion of muons to electrons in the field of an atomic nucleus. Mu2e will probe for this charged lepton flavor violating process at a sensitivity of a few parts in 10^{-17}. This sensitivity is an improvement of four orders of magnitude compared to previous experiments and provides a unique probe for physics beyond the Standard Model up to the $10^4\,\mathrm{TeV}$ scale.

Charged Lepton Flavor Violation

In the Standard Model (SM), charged lepton flavor violation (CLFV) can emerge by the intermediate mixing of massive neutrinos. Due to the tiny finite mass of neutrinos, the SM rates of CLFV processes are negligibly small, i.e. <10^{-50} for both $\mu^+ \to e^+\gamma$ and $\mu^-\mathrm{N} \to e^-\mathrm{N}$. Many models of physics beyond the SM predict significantly enhanced CLFV rates. Any experimental detection of a CLFV signal would point to new physical phenomena.



Conversion of Muons to Electrons



$$E_e = m_\mu c^2 - (B.E.)_{1S} - E_{recoil} = 104.96\,\mathrm{MeV}$$

The conversion of muons to electrons in the field of an atomic nucleus is a coherent process and has the kinematics of a two-body decay. The conversion electron is mono-energetic with an energy slightly below the muon mass. Corrected for the nuclear recoil and the binding energy in aluminum, the experimental signature is a single 104.96 MeV electron.

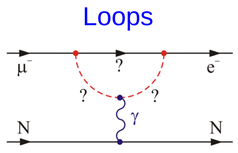
Sensitivity to Charged Lepton Flavor Violation

Effective Lagrangian:

$$\mathcal{L}_{CLFV} = \frac{m_\mu}{(1+\kappa)\Lambda^2}\bar{\mu}_R\sigma_{\mu\nu}e_L F^{\mu\nu} + \frac{\kappa}{(1+\kappa)\Lambda^2}\bar{\mu}_L\gamma_\mu e_L\left(\sum_{q=u,d}\bar{q}_L\gamma^\mu q_L\right)$$

Two types of amplitudes contribute to CLFV:

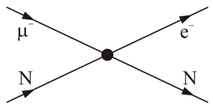
Loops



$\mu \to e\gamma$

$\mu N \to eN$

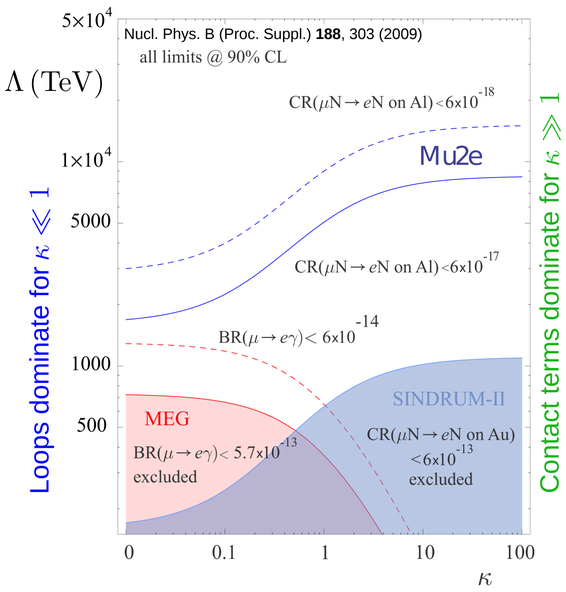
Contact Terms



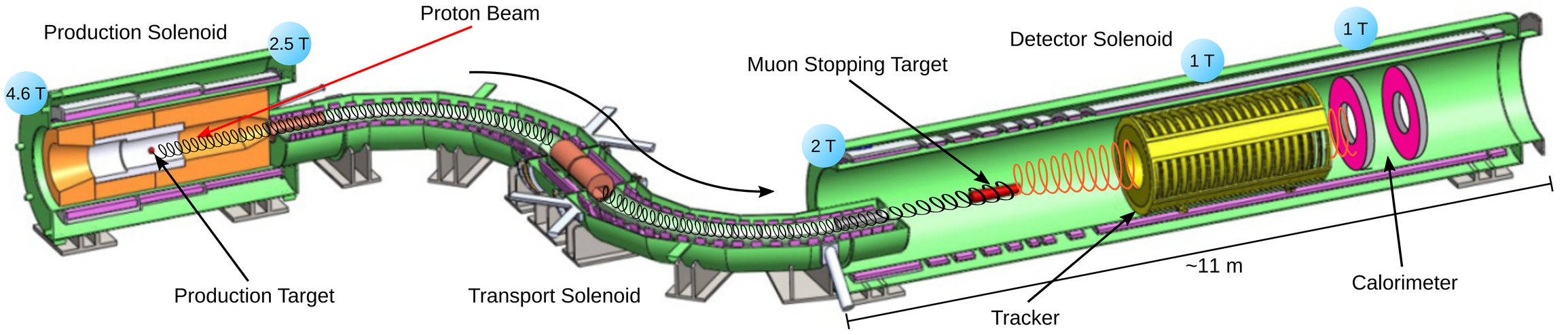
~~$\mu \to e\gamma$~~

$\mu N \to eN$

The $\mu N \to eN$ and $\mu \to e\gamma$ processes have complementary sensitivity to physics beyond the SM. It is important to experimentally search for both CLFV processes to be able to disentangle the underlying physics.



Experimental Apparatus

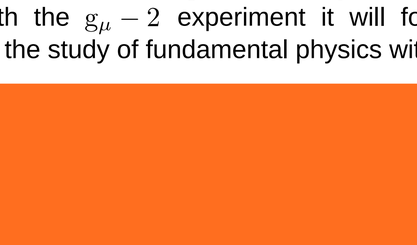


Cosmic ray veto and beam monitoring systems not shown

Main Background: Muon Decay in Orbit

The dominant irreducible background originates from the decay of bound muons. The spectrum of the decays in orbit (DIO) falls rapidly, approx. as $(E_{Endpoint} - E_e)^5$, close to the endpoint.

Detection of the Conversion Signal



Reconstructed simulated momentum spectra for DIOs (blue) and conversion electrons (red) assuming $R_{\mu e} = 10^{-16}$ for the final luminosity of Mu2e. The detection of the signal requires an excellent momentum resolution of a few hundred keV/c.

Tracker

The tracker consists of a low mass array of 21600 straw drift tubes in 18 tracking stations to measure the trajectory of charged particles in a uniform magnetic field of 1T.

Calorimeter

The calorimeter consists of two disks, each composed of ~900 BaF_2 scintillating crystals each read out by two avalanche photodiodes. The calorimeter contributes to the PID and trigger, and can independently confirm measurements by the tracker.

The Muon Campus at Fermilab

Mu2e detector building cut-away view

The Mu2e detector building is currently being constructed. Together with the $g_\mu - 2$ experiment it will form a campus dedicated to the study of fundamental physics with muons.

Prospects of CLF Violation Searches

Further information is available at:

[1] http://mu2e.fnal.gov
[2] Mu2e Technical Design Report, arXiv:1501.05241

www.caltech.edu