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Mu2e: A Search for Charged Lepton Flavor Violation in μN $\rightarrow$ eN conversion with a Sensitivity $< 10^{-16}$

G. Pezzullo*†
Yale University, Physics Department, 217 Prospect Street, New Haven (CT), US
E-mail: g.pezzullo@yale.edu

Mu2e will search for coherent, neutrino-less conversion of muons into electrons in the field of a nucleus with a sensitivity improvement of a factor of 10,000 over existing limits. Such a charged lepton flavor-violating reaction probes new physics at a scale unavailable with direct searches at either present or planned high energy colliders. The experiment both complements and extends the current studies at MEG and at the LHC. We present the physics motivation for Mu2e, as well as the design of the muon beamline, tracking spectrometer, and calorimeter. The Mu2e experiment is under design and construction at the Muon Campus of Fermilab. The experiment will begin near the end of 2020 with 3 years of running from 2021 to 2024.

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*Speaker.
†on behalf of the Mu2e Collaboration.

1. Introduction

One way to search for new Physics beyond the Standard Model (SM) is through the search for new interactions that manifest themselves in rare processes forbidden by the SM. This category is usually called "intensity frontier". The Mu2e experiment is part of a worldwide effort to search for Charged Lepton Flavor Violating (CLFV) processes that, if observed, would represent a powerful smoking gun for the presence of new Physics beyond the SM. Among the possible CLFV processes within the muon sector, the μN $\rightarrow$ eN is usually considered "the golden channel" thanks to its clear signature and its discovery potential [1]. The outcome of the μN $\rightarrow$ eN is a monochromatic e^- with an energy slightly below the μ rest mass, E=104.97 MeV, because we need to take into account the contributions from the μ-binding energy and the nucleus recoil [1]. The Mu2e goal is to improve

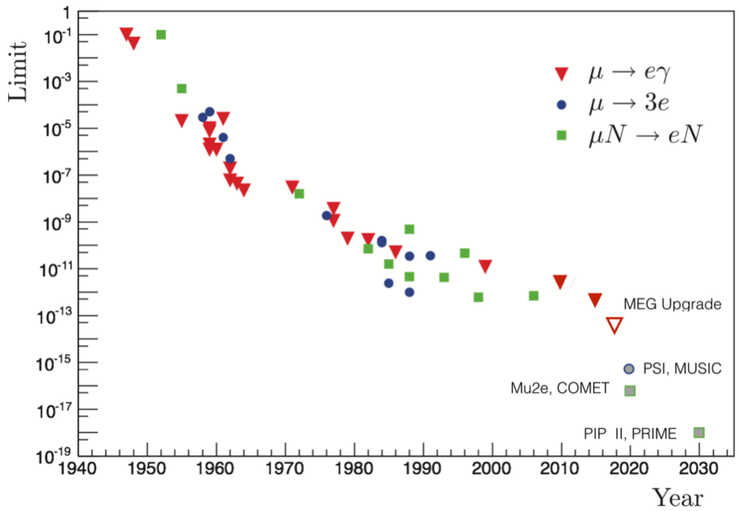

Figure 1: Limit on the branching ratio of CLFV muon decays as a function of the year. The three main clusters correspond to the usage of cosmic ray μ, stopped π beams and stopped μ beams.

the current best limit [2] by four orders of magnitude as shown in Figure 1 [1].

2. Experimental setup

Mu2e consists of three main superconducting solenoidal systems: (i) the production solenoid, where an 8 GeV proton beam, pulsed with a period of about 1.7μs, strikes a W target; (ii) the transport solenoid, which allows the charged π and then selects only low-momenta μ^-; the detector solenoid (DS), which houses the Al Stopping Target (ST) that is used to stop the μ^-, and the detector system. The whole DS and half of the TS are surrounded by a cosmic ray veto system aimed to detect the atmospheric muons that interact in the detector region. Figure 2 shows the schematic representation of the Mu2e experimental setup. The detector system inside the DS consists of a straw-tube tracker and of a crystal calorimeter [3] that are placed downstream the ST in a 1 T magnetic field region and 10^{-4} tor of vacuum. Both detectors have the inner region left un-instrumented in order to be not sensitive to the majority of low energy charged particles. The topology of a conversion electron (CE) event in this setup is represented by a helical trajectory

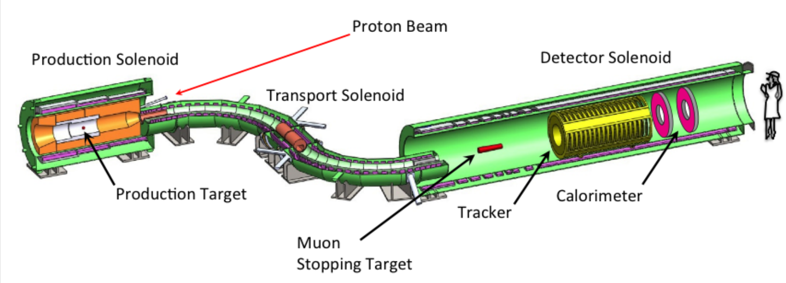

Figure 2: Mu2e experimental setup.

that makes 2-3 loops in the tracking chamber and then hit the calorimeter, producing an electromagnetic shower. The R&D of the sub-detectors is mature [4, 5, 6] and the production phase has already begun in 2018.

3. Physics backgrounds

The experimental setup has been designed in order to minimize and/or keep under control the expected source of backgrounds. Electrons from the μ decay-in-orbit (DIO) in the ST occurs about 39% of the times a μ is stopped in Al and their momentum spectrum extends up to the CE energy. About 10^{-16} of its spectrum is within the last 1 MeV [1]. This is why in Mu2e we need low-mass tacking system capable to reconstruct the CE momentum with a resolution better than few hundreds of keV/c. Cosmic rays interacting in the detector region are also a source of background; Atmospheric muons can either be trapped in the DS magnetic field and be reconstructed as a CE track or can produce an e^- mimicking the CE. A cosmic-ray veto system with $\varepsilon \geq 1 - 10^{-4}$ that surrounds the whole DS and half of the TS has been designed to mitigate this background. Another source of background is represented by the π^-'s that reach the ST. Radiative π -capture processes where the photon undergoes via asymmetric conversion and produce an e^- mimicking the signal could be problematic for the experiment. This is why Mu2e will use a pulsed beam with a beam line that was designed to provide an extinction factor, which is defined as the ratio of out-of-time protons over the in-time protons, better than 10^{-10}. The Mu2e Offline software [7] implements a detailed description of the experimental setup and it has been used to evaluate the expected performance of the experiment. Figure 3 shows the expected momentum distribution, normalized assuming 3 years of data taking, for the background overlaid with the CE signal, assuming a conversion rate $R_{\mu e} = 2 \cdot 10^{-16}$.

4. Summary

The Mu2e experiment will search for the $\mu N \rightarrow eN$ conversion in the field of an aluminum nucleus with a single event sensitivity of $2.9{\cdot}10^{-17}$. This will improve the current best limit by 4 orders of magnitude, probing new physics at scales up to 10,000 TeV. The detector system consists of a low-mass straw tube tracker that will measure the signal momentum with an expected resolution better than 200 keV/c, and a crystal calorimeter. The design of the apparatus is mature and the construction of several components is underway to start data taking at the end of 2020.

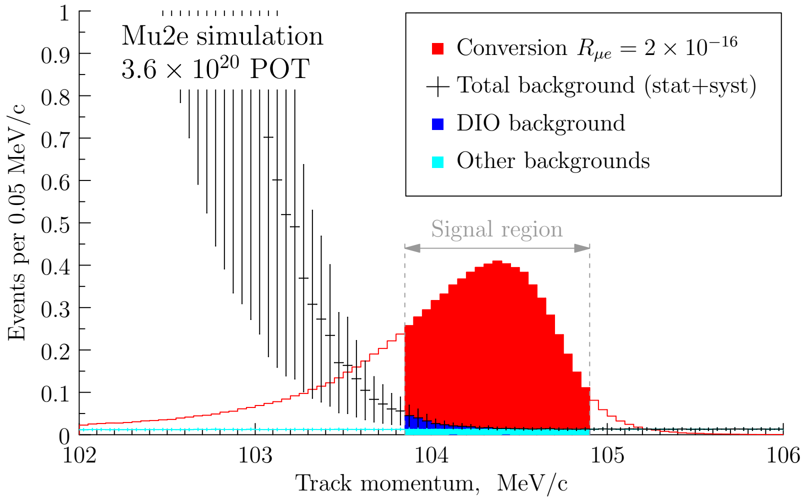

Figure 3: Plot of the expected probability density functions of the momentum distribution for the background and the signal.

Acknowledgements

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References

[1] Bernstein, Robert H. *et al*, Charged Lepton Flavor Violation: An Experimenter's Guide, Phys. Rep., 532, 2, 27-64, 2013

[2] Bertl, W. *et al*, A search for μ- e conversion in muonic gold, EPJ C, 47, 337âĂŞ346, 2006

[3] Bartoszek, L. *et al*, Mu2e Technical Design Report, arXiv: 1501.05241 [physics.ins-det], 2014

[4] Bono, J.S. *et al*, The stress relaxation (creep) rate of Mu2e straw tubes, NIM A, 902, 95-102, 2018

[5] Atanova, O. *et al*, Measurement of the energy and time resolution of a undoped csi + mppc array for the mu2e experiment, JINST, 12(05), P05007, 2017

[6] Artikov, A. *et al*, Photoelec- tron yields of scintillation counters with embedded wavelength-shifting fibers read out with silicon photomultipliers, NIM A, 890, 84, 2018

[7] Kutschke, Robert K., Offline Software for the Mu2e Experiment, JOP, 396, 2, 022028, 2012