

Contributions to the Experiment Mu2e for Direct Muons to Electron Conversion at Fermilab

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1. Introduction

The purpose of the Mu2e [1] experiment at Fermilab is to search for charged lepton flavor violation with unprecedented sensitivity. Its aim is to measure the ratio of the rate of the neutrinoless, coherent conversion of muons into electrons in the field of a nucleus, relative to the rate of ordinary muon capture on the nucleus:

$$R_{\mu e} = \frac{\mu^- + A(Z, N) \rightarrow e^- + A(Z, N)}{\mu^- + A(Z, N) \rightarrow \nu_\mu + A(Z-1, N)} \quad (1)$$

with a sensitivity $R_{\mu e} < 6 \times 10^{-17}$ at 90% CL. This is almost four orders of magnitude improvement over the existing limit. The observance of such a process would be unambiguous evidence for physics beyond the Standard Model.

The Mu2e apparatus is shown schematically in Fig. 1.

The detector consists of a magnetic spectrometer, which is the primary energy measuring device, and an electromagnetic calorimeter, which is used for triggering purposes and for confirming the energy and position measurements of the magnetic spectrometer. It has been designed to ensure that the intense non stopped beam from the production target is transported to the beam stop at the end of the detector solenoid with minimal interaction. It must also minimize the acceptance for electrons from backgrounds, such as muons decaying in orbit and have excellent momentum resolution for 100 MeV/c electrons. It sits in an evacuated vessel inside the 1.0 T field of the Detector Solenoid and must withstand instantaneous rates up to 200 kHz in each individual detector element.

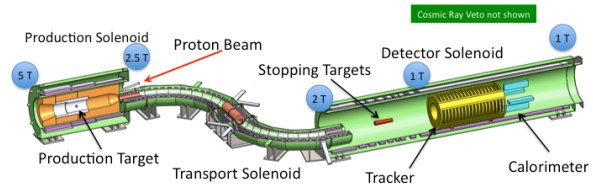


Figure 1. The Mu2e muon beamline showing the positions of the primary proton beam, the three solenoids, the production target, the stopping targets, and the detectors. The coral colored insets in the TS are the collimators that define the aperture. The figure also shows the grading of the magnetic field strength; the blue bubbles give values of B_Z .

2. The Drift Chamber Proposal

The contribution of the Lecce group is centered around the proposal of a tracking detector, alternative to the current baseline choice of a system of thin walled straw tubes, based on a drift chamber. The challenge of such a proposal consists in designing in vacuum, to minimize the interactions of the non stopped muon beam, a chamber which is normally operated at atmospheric pressure and limiting, at the same time, the interactions of the conversion electrons before entering its active volume.

Currently, there exist two different variations of such a proposal. Both are founded on the innovative concept of separating the gas contain-

ment function from the wire supporting one and on the same choice for the light gas mixture, 90% helium, and on the thin wire composition, 40 μ m diameter Al for the field wires and 20 μ m Mo for the sense wires. The electrostatic configuration of the chamber foresees small size drift cells and a full stereo layer structure.

The first variation, more complex in its structure, preserves the baseline scheme for the stopping targets and places the drift chamber downstream of them. This requires entrance walls of the chamber which must be extremely light in terms of energy loss - energy fluctuations increase with the energy losses - and of multiple coulomb scattering of the conversion electrons. Very detailed studies have been performed to optimize the shape of the end plates and to select the best performing composite materials [2], reaching the goal of defining a solution with a total amount of material on the path of a conversion electron entering the active volume of the chamber of less than 0.1g/cm².

The second one, requiring the displacement of the targets inside the volume of the drift chamber to increase the acceptance for conversion electrons, is even more challenging. This, obviously, implies a longer chamber but also an insensitive region around the targets to avoid excessive chamber occupancy. Different solutions are under scrutiny to deaden the middle part of the para-axial sense wires. The advantages of such a scheme are the release of the stringent requirements on the lightness of the end plate walls and an easier strategy for replacing broken wires, even though the constraints regarding the inner cylinder are maintained.

Our current activities within the experiment Mu2e are concentrated on four concurrent streams.

- The studies for defining and testing the optimal composition of the materials constituting the mechanical structure of the end walls of the chamber [3] and on the optimization of the inner cylinder with respect to the buckling problems [4].
- A chamber prototype which simulates a portion of the proposed drift chamber. To this purpose, we have designed and built a wiring robot [5] able to position a full layer of wires in a single operation. The prototype will be completed by the first months of 2012 and, after the initial commissioning under a cosmic ray test stand, will undergo tests first in an electron beam at the Beam Test Facility of the INFN Frascati National Laboratory and then in a 1 Tesla magnetic field on a tertiary beam line which we are designing at the Fermilab site.
- With the aim at designing the lightest possible drift chamber, we are also studying the possibility of operating the gas mixture at pressures lower than the atmospheric value. This possibility has the twofold advantage of minimizing even further the contribution due to the multiple coulomb scattering to the momentum measurement of the conversion electron and of reducing the stress on the chamber walls due to the differential pressure with the surrounding vacuum, thus allowing for an even lighter solution. Precise measurements with a dedicated apparatus are undergoing in the Gas Detector Laboratory at INFN Lecce.
- Coupled with the development of the readout electronics of the proposed drift chamber, there exists the possibility of defining an innovative fast tracking trigger, solely based on the drift chamber itself. It exploits the advantages offered by the method of cluster counting/timing which we propose to adopt for the chamber [5]. The developed numeric algorithms [6], implemented on a Field Programmable Gate Array for the common project of defining the drift chamber readout of the SuperB experiment at the Cabibbo Laboratory, will allow for such a possibility.

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