# Excerpts from Mission Need Statement for the New Muon g–2 Project at Fermilab

Office of High Energy Physics
Office of Science

The primary mission of the DOE Office of High Energy Physics (HEP) is to understand the universe at its most fundamental level through the study of matter and energy, space and time, and the forces governing basic interactions. The Standard Model of particle physics documents the current status of that understanding, which is known to be both stunningly robust, yet necessarily incomplete. An urgent mission of the particle physics community is to complete the Model. The tools required include high-energy colliders, which can directly produce the highest mass particles, and high-intensity accelerators, which can tease out the tiny effects of still unknown interactions in the data through high precision.

One of the more persistent hints of new physics has been the deviation between the measured muon anomalous magnetic moment, (g−2)/2, and its Standard Model expectation, where both are determined to a precision of 0.5 parts per million. This fundamental measurement has been pursued for decades with increasing precision. The discrepancy has been interpreted to point toward several attractive candidates for Standard Model extensions: supersymmetry, extra dimensions, or a dark matter candidate. The Large Hadron Collider (LHC) is now delivering on its promise to explore physics at the highest mass ranges to date, although no new physics has yet been found. A new and more precise muon g−2 experiment offers a strategic opportunity to search for new physics through alternative means, which could lead to a fuller and more coherent picture of the underlying physics.

The search for new physics can be carried out in complementary ways on the different frontiers of particle physics. The measurement of the muon anomalous magnetic moment is sensitive to interactions at the TeV scale, which is also the scale probed by the LHC. The capability gap filled by the new muon g−2 experiment derives from the ability of the measurement to elucidate the underlying physics we hope to discover at the LHC and probe areas of the newly discovered physics that are inaccessible to the LHC experiments.

The current muon g−2 measurement is used as a benchmark for new physics and has been used as input into the parameter space explored in almost all model dependent searches for new physics at the LHC, but the current discrepancy between the muon g−2 measurement and the theoretical prediction could be explained as a statistical fluctuation at the three-sigma level and has only been observed by one experiment. If the discrepancy is false, then this will cause serious confusion in interpreting LHC results. The discrepancy needs to be confirmed and established above the accepted discovery threshold of five standard deviations above a fluctuation.

Should LHC discover new physics at the TeV scale and the g−2 discrepancy is confirmed, a precise determination of g−2 is expected to provide direct measurements of the coupling constants of the new particles responsible for the discrepancy, fundamental parameters of the underlying theory and a window on the underlying symmetries of the new physics. In many cases, it is expected that these parameters will not be measured with adequate precision at the LHC alone.

There are no facilities, equipment, or services currently existing or being acquired within the Department of Energy, other government agencies, public organizations, private entities or international bodies that are sufficient to address these gaps.

A prior muon g−2 experiment at BNL (E-821) ended with a successful, statistics-limited measurement of the anomalous magnetic moment of the muon. By virtue of having run the apparatus for five years, all of the required technology and physics principles have been tested and demonstrated. Additionally, much of the expertise involved with the initial construction of the experiment is still available and remains involved for the new muon g−2 experiment at Fermilab. For these reasons, the technological risk is much smaller than typical of a new endeavor. The largest technical risk may arise from transportation of the storage ring superconducting magnet coils.