# Application of passive absorbers for maximizing the beam quality of precision-science experiments

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Following P5 recommendations, the DOE is embarking on a major muon physics program with unprecedented physics potential with the Muon g-2 and Mu2e Experiments. However, both experiments are limited by the large momentum spread of the incoming beam. As a result, nearly 80% of muons produced for the Fermilab Muon g-2 Experiment and more than 60% produced for the Fermilab Mu2e Experiment are not usable for physics analysis. I propose a technique for momentum selection and momentum-spread reduction of muon beams that has direct relevance to precision science experiments such as the Fermilab Muon g-2 and Mu2e experiments. The concept relies on placing a passive absorber at a dispersive point along the beamlines of both experiments, so that to drastically enhance the quality of the downstream beam. Quantitatively, the usable muon flux is expected to increase up to 100% by using this technique.

The Muon g-2 experiment [1] signals the start of an important new research program, one that uses muons as a probe to study physics beyond the Standard Model. The ultimate goal of the Fermilab Muon g-2 Experiment is to measure the anomalous magnetic moment of the muon with an unprecedented precision of 0.14 parts per million in less than 2 years of running time. For the experiment, a polarized muon beam is formed by capturing forward muons from pion decay-in-flight. The muons then are injected into a storage ring with a uniform vertical *B* field. The magnetic moment of the muon causes it to rotate or precess around the central axis of the magnetic field. Measurements of this precession frequency and the strength of the magnetic field are used to extract g-2.

The purpose of the Mu2e Experiment [2] is to make the most sensitive search ever made for the coherent conversion of muons into electrons in the field of a nucleus, which, if detected, would be the first observation of charged lepton flavor violation. The Mu2e Experiment provides an improvement in experimental sensitivity of four orders of magnitude over previous experiments. The observation of charged lepton flavor violation would be a distinct indication of physics beyond the Standard Model. To achieve the sensitivity goal, a high intensity low energy muon beam coupled with a detector capable of efficiently identifying 105 MeV electrons, while minimizing background from conventional processes, is necessary. The muon beam will be created at Fermilab by an 8 GeV pulsed beam of protons striking a production target.

The storage ring of the Muon g-2 Experiment has a very small momentum acceptance for 3.1 GeV/c positive muons, i.e. $\delta p/p = \pm 0.2\%$. On the other hand, the beam transport into the ring has a much larger acceptance, i.e. $\delta p/p = \pm 2\%$. Numerical simulations predict that nearly 80% of the incoming muons have $\delta p/p > 0.2\%$ [3]. As a result, the number of stored muons will be limited by the momentum acceptance. One the other hand, if we could put more beam from the $\delta p/p$ >0.2% range into the < 0.2% region, the useable g-2 beam would increase, substantially. A passive wedge absorber system accomplishes this by reducing the momentum spread of the beam via ionization cooling [4] before injection into the storage ring. The concept relies on placing a wedge at a point with non-zero dispersion along the beam transport system in such a way that the high-energy particles traverse more material that the low energy particles. The improved statistics from delivery of more muons into the storage ring using my proposed wedge absorber system could push the capabilities of the experiment into new regions of parameter space, allowing the measurement of the anomalous magnetic moment with unprecedented precision. Furthermore, the current low production rates of negative muons restrict the measurement to positive muons only. On the other hand, the significant rate increase with my proposed wedge system can open the path for a CPT test with negative muons in a reasonable time frame.

Muons for the Mu2e Experiment are produced from 8 GeV protons hitting a tungsten target in the production solenoid. An S-shaped Transport Solenoid (TS) efficiently selects and transmits the low energy, negatively charged muons, from the Production Solenoid to the Detector Solenoid (DS). The TS empties into the DS, wherein a muon stopping target of thin aluminum disks collects the muon beam. While the momentum distribution of muons reaching the DS ranges from 0 to 100 MeV/c, the distribution of muons that are stopped by the target is only within 0-40 MeV/c and therefore more than 60% of the incoming muons are outside this range [5]. With an appropriately tuned wedge absorber system we could put more beam from the 40-100 MeV /c range into the < 40 MeV/c region and therefore significantly increase the sensitivity of the Mu2e Experiment. The wedge system also plays a key role in improving the quality of the stopped beam in two ways: First, by reducing the number of muons that do not stop, it will decrease neutron background that potentially could spoil the measurement. Second, it could facilitate a thinner target that would allow for a significantly smaller signal window and much less background.

In the first project phase, I will carry out theoretical calculations and computer simulations, in order to determine the needed wedge specifications for both experiments. In this phase, I will also examine available technologies to build such a system. In the second phase, I will build a prototype wedge system and benchmark it for both experiments. This grant would support my work in simulating and designing the system, including constructing prototypes and engineering. I am collaborating with Fermilab engineers who are interested in constructing major components of the final design and Northern Illinois University as well as Illinois Institute of Technology scientists who are interested in different aspects of numerical estimates and data analysis techniques.

**References**

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