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The MUonE experiment: A measurement of the hadronic contribution to the muon $g-2$ via μ-e elastic scattering

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Summary. — We present the MUonE experimental proposal, which aims to determine the leading-order hadronic contribution to the muon $g-2$ using a novel approach, based on the measurement of the hadronic contribution to the running of the electromagnetic coupling constant in the space-like region.

1. – Introduction

The measurement of the muon magnetic anomaly, $a_\mu = (g_\mu - 2)/2$, presently exhibits a $\sim 3.7\sigma$ discrepancy from the Standard Model prediction [1], representing a possible hint of new physics. On the experimental side, a_μ will be measured in the next years at the remarkable accuracy of $\sim$0.14 ppm by two new experiments at Fermilab and J-PARC, improving by a factor of 4 the precision of the most recent result. An improvement is also required on the theoretical prediction, as its uncertainty can become the main limitation for a test of the Standard Model. The accuracy on the Standard Model calculation is limited by the evaluation of the leading-order hadronic contribution a_μ^{HLO}, which cannot be computed perturbatively at low energies. For this reason, a_μ^{HLO} is traditionally determined by means of a dispersion integral on the annihilation cross section $e^+e^- \to$ hadrons, which is densely populated by resonances and influenced by flavour threshold effects. These aspects limit the final precision achievable by this method. Nevertheless, the calculation of a_μ^{HLO} has reached the accuracy of $\sim$ 0.4%. In order to consolidate the theoretical prediction, it is important to crosscheck this calculation in an independent way.

2. – The MUonE experiment

The MUonE experiment has been recently proposed [2], with the aim to measure a_μ^{HLO} using a completely independent approach. It is based on the measurement of the

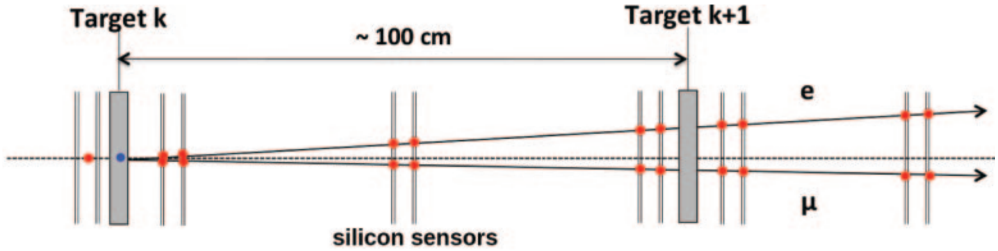

Fig. 1. – Sketch of a single station (image not to scale).

hadronic contribution to the running of the electromagnetic coupling constant ($\Delta\alpha_{had}$) in the space-like region, by means of $\mu^{\pm}e^{-} \to \mu^{\pm}e^{-}$ elastic scattering. The measurement of the shape of the differential cross section provides direct sensitivity to $\Delta\alpha_{had}$, and it is carried out by scattering a 150 GeV muon beam on a beryllium target. The M2 beam available at CERN provides muons with the proper energy and an average intensity of $1.3 \cdot 10^7$ μ/s. It allows to collect an integrated luminosity of 1.5×10^7 nb^{-1} in 3 years of data taking, corresponding to a statistical uncertainty of 0.3% on a_μ^{HLO}. This makes the measurement of MUonE competitive with the dispersive approach.

2˙1. *Experimental apparatus.* – The experimental apparatus consists of a repetition of 40 identical stations. A sketch of a single station is shown in fig. 1. It is made up of a 15 mm thick beryllium target, followed by a tracking system with a lever arm of $\sim$ 1 m, which is used to measure the scattering angles with high precision. The tracking system is composed by 3 pairs of silicon strip sensors. In particular, the sensors foreseen for the CMS HL-LHC Outer Tracker in the so-called 2S configuration have been chosen. A sensor is made up of two layers reading the same coordinate. Each layer is 320 μm thick, with a squared area of 10×10 cm^2 and a pitch of 90 μm, which allows to obtain an angular resolution of $\sim$20 μrad. The apparatus is also equipped with an electromagnetic calorimeter, placed downstream all the stations. Its main role is to provide e/μ particle identification. The final optimization of the calorimeter is still under study. Two options are currently considered: $PbWO_4$ and PbF_2 crystals. A surface of $\sim 1 \times 1$ m^2 will allow to achieve a full acceptance for electrons in the angular region of interest (scattering angles $\lesssim$ 10 mrad).

2˙2. *Systematic uncertainties.* – The main challenge of the MUonE experiment is to reach a systematic uncertainty of the same order as the statistical one. For this purpose, the differential cross section must be measured with a systematic uncertainty $\lesssim$10 ppm. Systematic uncertainties arise both from experimental and theoretical aspects, such as: bad reconstruction of the elastic events, limited control of the experimental conditions, missing contributions in the computation of the theoretical cross section.

2˙3. *Future plans.* – A Letter of Intent has been submitted in June 2019 to CERN SPSC [3]. Studies on detector optimization, simulations and theory improvements will continue in 2020. The detector construction is expected during CERN LS2 and the plan is to have a pilot run of 3 weeks in 2021. A run with full statistics is envisaged in 2022–24.

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