AGS Letter of Intent-Search for an Electric Dipole Moment of Muon at the 10^{-24} e cm level.

R. Carey, E. Efstathiadis, J. Miller, O. Rind, L. Roberts, L. Sulak

Boston University

R. Larsen, D. Lazarus, W. Morse, R. Prigl, Y. Semertzidis*

Brookhaven National Lab

Y. Orlov, J. Rogers

Cornell University

D. Winn

Fairfield University

K. Jungmann

University of Heidelberg

P. Debevec, D. Hertzog, S. Sedykh

University of Illinois

P. Cushman, D. Zimmerman

University of Minnesota

F. Farley

Yale University

October 20, 1997

*Spokesperson, E-mail address: semertz1@bnl.gov

1 Abstract

We propose using the existing g-2 ring to search for an electric dipole moment of the muon with a dedicated experiment. We are confident that we can improve by six orders of magnitude the current sensitivity to the muon EDM, both in statistics and systematics, bringing it down to $10^{-24}\,\mathrm{e\,cm}$. We will be sensitive to several non-standard models of CP violation at this sensitivity and will be extremely competitive to the electron EDM experiments for the first time. A lower energy muon beam, strong magnetic focusing, lithium lens target with modified beam transport and inflector system, placing the detectors above and below the vacuum chamber, and applying a flat radial electric field to cancel the $g-2$ precession, maximize the sensitivity of the proposed experiment to the muon EDM.

Contents

2 Introduction

We propose to search for an electric dipole moment (EDM) of the muon using the existing muon g - 2 ring. [1] The large number of polarized muons necessary for achieving a small statistical error is only possible due to the high intensity primary proton beam available at the AGS. The EDM value expected from the Standard Model is negligibly small, [2] about $10^{-35}\,\mathrm{e\,cm}$ which makes the search of the muon EDM a powerful probe for new physics.

The present experimental limit [3] is $1.05 \times 10^{-18}\,\mathrm{e\,cm}$ (95% c.l.). Super Symmetric (SUSY) models, [4] two and multi-Higgs doublet models predict much larger values from contributions involving Higgs boson exchange. [5, 6] The predicted value for the electron EDM is in the neighborhood of its present experimental limit and for the muon (scaling linearly by the ratio of the masses) near the experimental accuracy claimed in the present letter of intent (LOI). Other, less generic models, predict even larger values, [4] as large [7] as $10^{-21}\,\mathrm{e\,cm}$. Also, left-right symmetric models predict [7, 8] values in the range of low $10^{-23}\,\mathrm{e\,cm}$.

The electric dipole moment upper limits for the electron [9, 10],

$$d_e = (1.8 \pm 1.2 \pm 1.0) \times 10^{-27}\,\mathrm{e\,cm}, \tag{1}$$

and for the neutron [11]

$$d_n = (-30 \pm 50) \times 10^{-27}\,\mathrm{e\,cm}, \tag{2}$$

have already been used to set limits on SUSY models. [12, 13] Even if experimental evidence for an EDM in the electron and/or the neutron existed, the prospects of having available another system where the models could be checked would be very valuable. [7] Since we do not know the mechanism by which electrons and muons might acquire an EDM, it is important to improve the EDM limits of both particles. [14] In various models, the EDM value goes as the second or third power of the ratio of the muon mass to that of the electron mass as, for example, is the case with various multi-Higgs models. [15]

The muon g-2 experiment underway at BNL will probe a wide range of non-standard physics, in particular SUSY models [16, 17, 18] with large $\tan\beta$ (≥ 10). The muon EDM experiment is also sensitive to some of those models and together they explore a larger parameter range. [19]

3 Experimental Overview

The muon spin precession angular frequency (relative to the momentum vector) in the presence of both electric and magnetic fields is given by

$$\begin{aligned}\vec{\omega} &= -\frac{e}{m}\{a\vec{B} - \frac{a\gamma}{1+\gamma}(\vec{\beta}\cdot\vec{B})\vec{\beta} + (\frac{1}{\gamma^2-1} - a)\frac{\vec{\beta}\times\vec{E}}{c} + \\ &\quad \frac{\eta}{2}[\frac{\vec{E}}{c} + \vec{\beta}\times\vec{B}] - \frac{\eta\gamma}{2(\gamma+1)c}(\vec{\beta}\cdot\vec{E})\vec{\beta}\},\end{aligned} \tag{3}$$

where $a = (g-2)/2$ and η is the EDM in units of $\frac{e\hbar}{4mc}$. This simplifies to

$$\vec{\omega} = -\frac{e}{m}\{a\vec{B} + (\frac{1}{\gamma^2-1} - a)\frac{\vec{\beta}\times\vec{E}}{c} + \frac{\eta}{2}(\vec{\beta}\times\vec{B})\}, \tag{4}$$

using the fact that $|E| << |B|$ and assuming the muon velocity is orthogonal to the external magnetic field ($\vec{\beta}\cdot\vec{B} = 0$). η plays a role for the EDM corresponding to the g factor for the magnetic dipole moment. The muon EDM couples to the external magnetic field because in the muon rest frame it looks like an electric field due to the Lorentz transformation. The EDM value in MKS units is given by

$$d_\mu = \frac{\eta}{2}\frac{e\hbar}{2mc} \simeq \eta \times 4.7 \times 10^{-14}\,\mathrm{e\,cm}. \tag{5}$$

From the above equation (4) is apparent why the present $g-2$ experiment uses muons at the “magic” γ, i.e. $\gamma = 29.3$ since at this value the coefficient

$$\frac{1}{\gamma^2-1} - a = 0, \tag{6}$$

and the muon spin precession becomes independent of the electric field present in the lab frame. For the dedicated EDM experiment we propose to use muons with much lower energy so that the radial electric field cancels the $g-2$ precession leaving the EDM precession to operate on its own and accumulate over many microseconds. The required electric field is

$$E = \frac{aBc(\gamma^2-1)}{\beta} = 2\,\mathrm{MV/m}, \tag{7}$$

for $\gamma = 5$, $B = 0.24\,\mathrm{T}$ and a magnet radius of 711 cm. Two parallel plates 10 cm apart with ± 100 KV voltage can create such a field.

Due to the weak interaction decay of the muon to an electron, a muon neutrino and an electron anti-neutrino, the electron angular distribution in the muon rest frame is given by:

$$dP(y,\theta) = n(y)[1 + A(y)\,\cos\theta]dy\,d\Omega, \tag{8}$$

with $y = p_e/(P_e)_{\mathrm{max}}$, the distribution function $n(y) = 2y^2(3 - 2y)$ and the asymmetry $A(y) = (2y - 1)/(3 - 2y)$. $d\Omega$ is the solid angle element, and θ the angle between the electron momentum and the muon spin. The number of detected electrons above an energy threshold in the lab frame thus probes the angular distribution of the decay electrons in the muon rest frame. [20] The oscillation frequency in the number of detected electrons is given by equation (4) when the detectors are placed on the inside of the muon storage region. [1] The detector position and the energy threshold in the g-2 experiment is optimized by maximizing NA_L^2, where N is the number of the detected electrons and A_L is the amplitude of the average vector asymmetry given by

$$\vec{A_L} = \int A(y)\,\hat{e}\,dy\,d\Omega, \tag{9}$$

where $\hat{e}$ is the unit vector along the electron direction in the muon rest frame.

From equation (4) (at the muon "magic" momentum) it is apparent that the EDM influence on the spin precession is two-fold: 1) The spin precesses about an axis which is not exactly parallel to the magnetic field but is at an angle $\delta = \tan^{-1}\frac{\eta\beta}{2a}$. The maximum excursion of the muon spin from the horizontal plane, due to an EDM, occurs when the spin is at 90° with respect to the momentum vector. When the spin and momentum vectors are aligned there is no excursion from the horizontal plane. 2) The spin precession frequency is increased by a factor of $\sqrt{(1+\delta^2)}$.

Both of the above methods were used at the last CERN muon g-2 experiment to set a limit on the EDM. [3] They searched for an up down asymmetry in the counting rate with a detector split on the vertical mid-plane. The presence of an EDM induces a difference between the counting rate of the two parts of the split detector at the anomalous spin precession frequency. Due to limited statistics and a comparable systematic error, their final result was $d_\mu \leq 1.05 \times 10^{-18}\,e\,\mathrm{cm}$ at the 95% confidence level. [3] In the current g-2 experiment at BNL, we plan to improve on systematics by a factor of ten by having a finer segmentation in the vertical detector and much greater statistics. The systematics will dominate our error. [1, 24]

Instead, here we are proposing to use a radial electric field to cancel the $g-2$ precession. This together with other improvements will significantly reduce many systematic errors and improve the experimental sensitivity to a muon EDM. The muon spin direction will be “frozen” so that an EDM will induce an asymmetry in the electron counting from early times (shortly after muon injection into the ring) to late times.

Other changes over the present $g-2$ experiment include:

1. Placing the detectors on top/bottom of the vacuum chamber so that the muon spin direction and not the muon's position at the time of muon decay will be the dominant factor in determining whether the electron will end up in the upper or lower detector. This reduces severely the dominant source of systematic error due to the long term instability of the average vertical position of the muon population. [3]

2. Use only strong *magnetic* focusing reducing substantially the long term vertical instability of the muon population. At 0.5 GeV/c using weak electrostatic focusing and same aperture, the number of stored muons are estimated to be 10 times less than at 3.1 GeV/c for the same number of protons on target. The strong focusing in the ring with the modification of the the target and beam transport system, provides about 200 times more stored muons than the present system for the same protons on target. Since there is an anticipated increase in the proton current by a factor of 2.5 by the year 2000 the expected increase in the number of muons per fill at the storage ring is 500. We will obtain 8 bunches every 2 seconds with 1.3×10^7 stored muons per bunch. In 5300 hours of dedicated run one can accumulate 10^{15} stored muons. We have only considered a storage region of 9 cm in diameter, the same as in the g-2 experiment. A 10 by 10 cm area is available for muon storage and is currently being considered.

3. Eliminate all vertical electric fields from the system during normal data taking. Any radial magnetic field in the presence of compensating electric field introduces a systematic limitation. [23, 24] For example, in the g-2 ring, a net radial magnetic

field of 50 ppm of the main field would produce a systematic error in the EDM of 5×10^{-21} e cm. A vertical electric field can be used to calibrate the system sensitivity with high accuracy.

3.1 Target and Beam Line

In order to obtain sufficient muon storage at a momentum of 0.5 GeV/c, it will be necessary to increase the acceptance of both the beam transport and the storage ring. A strong focusing upgrade of the g-2 ring would require replacement of the present pole face of the magnet with 36 alternating gradient poles to give a $\beta^x_{max} = 4.5$ m, $\beta^y_{max} = 4.3$ m and a momentum acceptance of $\pm 3\%$.

A 10 cm diameter by 25 cm lithium lens pulsed at 800 KA with a gradient of 3.2T/cm located 20 cm, center to center behind the production target would capture 0.9 GeV/c secondary pions beyond the maximum production angle of 8-10 degrees indicated in the Sanford-Wang [21] parameterization.

The beam transport upgrade is designed to transport pions of higher momentum than the desired muons. We use 0.9 GeV/c pions in order to take advantage of the steep increase in pion production with increasing pion momentum. Backward emitted (in the c.m. frame) 0.5 GeV/c muons would then be transported to and injected into the g-2 ring.

The design upgrade requires the installation of 20 additional 4Q24 quadrupole magnets in the pion decay region. In addition 3 new quadrupole magnets in the matching section can be employed in order to capture more pions into the beam channel.

Simulations using the Sanford-Wang parameterization of particle production indicate 6.4×10^5 stored muons per bunch of 10^{12} protons on target is a realizable goal (assuming the inflector has 100% injection efficiency) at the present AGS intensity.

An increase in the proton current by a factor of 2.5 by the year 2000 is anticipated which would lead to 8 bunches every 2 seconds with 1.3×10^7 stored muons per bunch. In 5300 hours it would be possible to accumulate 10^{15} stored muons. We are investigating the possibility to use a smaller diameter lithium lens by a factor of 3 to further increase the number of captured pions and reduce the required total running time.

3.2 Inflector

The injection of beam into the storage ring is usually done with a septum magnet (inflector), which locally cancels the field of the main magnet, so that the beam enters the storage region nearly tangential to the equilibrium orbit.

A direct current non-ferrous superconducting inflector has been designed and constructed for E821 (muon g-2) experiment [1]. Double cosine function related current density is applied on an arc with a radius of 5 cm. Truncation is carried out along one of the constant vector potential lines, by placing conductors corresponding to certain current density. [22] The dipole field is uniform in the beam channel and there is very low fringe field in the vicinity of the device. E821 required 2850 A current in 88 turns to provide a 1.5 T channel field. For the muon EDM experiment, only one sixth of the current is required. Using the existing E821 SC inflector is one of the options, but the aperture would be limited.

In the EDM experiment the leakage field requirement is much more relaxed and simpler designs are acceptable. We are planning to use a water cooled normal conductor with the geometry shown in Fig. 1 The figure shows the cross section of the inflector (the two parallel plates with the enclosed flux) and the $g-2$ magnet with the pole pieces as shaped currently. Fig. 2 shows the magnetic flux when both the main magnet and the inflector are powered. Fig. 3 shows the vertical component of the magnetic field in gauss over the storage region (from 706.7 to 715.7 cm) with both the inflector on and off. The influence of the inflector at the muon storage area can be further reduced by shimming it to the required accuracy.

3.3 Storage Ring

Since the search for an EDM does not require an accurately known magnetic field, the use of strong magnetic focusing is very advantageous. We plan to use the 36 pole pieces on top and 36 on bottom shaped in such a way that they provide $\frac{\partial B}{\partial R} = 1.45$ T/m of 36 alternating gradient focusing regions. The main dipole field (for the 0.5 GeV/c muon momentum case) is 0.24 T and therefore the regional field focusing index is $n = 43$. The phase advancement is 44.5° per region. Assuming the same muon storage region of 9 cm in diameter, as in the current g-2 experiment, the estimated beta functions are $\beta^x_{max} = 4.5$ m, $\beta^y_{max} = 4.3$ m. The compactification factor is 5.9 giving an overall factor of 50 improvement in the number of stored muons over a comparable system with an electrostatic weak focusing. We are also considering a redesign of the beam storage vacuum chamber to optimize it for the EDM experiment.

There is a need to have a kicker in order to be able to inject muons into the ring. One third in length of the current kicker with two thirds the peak current would suffice. The eddy currents of this kicker would be sufficiently low not to become a source of systematic errors.

3.4 Electrode alignment

The vertical component of the electrostatic field in the muon storage region, averaged over the ring circumference, must be well suppressed. An average component of 10 nrad will induce an effect mimicking an EDM of $10^{-24}\,\mathrm{e\,cm}$. This implies that the electrodes, and the resistive top and bottom plates used to produce a uniform electrostatic field, must be aligned with respect to the horizontal plane with high precision.

Fig. 6 shows a method that may be used to achieve this alignment. The electrodes and top and bottom plates are clamped at intervals with pairs of U-shaped machinable ceramic yokes. The top and bottom plates are made of glass doped to produce a small but uniform conductivity bonded to insulating webbing for support. The outer surfaces of the conductive glass are covered with an antireflection coating so that the parallelism of the inner surfaces of the top and bottom plates may be tested, after clamping, by optical interferometry. Shimming may be necessary to insure that these inner surfaces are parallel.

The conductive glass plates are then referenced to a water surface in hydrostatic equilibrium by means of precision glass rods with lengths that have been tested by optical interferometry. The upper ends of these rods support the lower conductive glass plate. The lower ends are metallized, and are brought within 1 mm of the water surface. The capacitance between each rod and the water surface is monitored, and the position of each rod adjusted continuously by a servo loop to maintain a fixed gap between the rod and the hydrostatic surface. The rods are clamped to a lever driven by a pair of piezoelectric transducers, which are in turn supported by a support beam which runs around the periphery of the magnet. These leveling devices would be positioned at 0.5 to 1 m intervals around the circumference of the ring.

A similar hydrostatic leveling scheme has been used to align magnets in the European Synchrotron Radiation Facility (ESRF)[25]. This system has an analog resolution of better than 2 μm and a digital resolution of better than 0.1 μm, and is used to align the ESRF magnets over its 1 km circumference. If we decrease the gap between the rod and water surface to less than 1 mm from the 6 to 8.5 mm used at the ESRF, the analog resolution will be decreased to 0.3 μm. Further improvements may be obtained by using low-noise front ends and signal averaging, so that the alignment precision will be determined by the precision of the interferometric parallelism measurement ($\pm 0.2 \mu$m) and thermal expansion (0.03 μm for a 0.1°C temperature differential). The local angular error will be approximately $\pm 1 \mu$rad. The angular error, averaged over the ring, will be significantly smaller if the local errors are uncorrelated, i.e. $\pm 0.1 \mu$ rad .

Since the required magnetic field is one sixth of the one currently used, we can open up the magnet gap further and increase the available space for the leveling feedback server. We need to make a prototype and find out the limitations of this technique.

3.5 Detectors

The lower momentum decay electrons need thinner calorimeters than the present ones used for the g-2 experiment. [1] Those can be placed on the top and bottom of the vacuum chamber extending inwards, towards the center of the ring to cover as much solid angle as possible. The location of the detectors is driven by the desire to maximize both acceptance and the asymmetry of the decay electrons. The total acceptance of the detectors corresponds to approximately 65% of the stored muons. [26] The radial location of the decay electrons where they hit the top/bottom detectors is shown in Fig. 4. The vertical asymmetry distribution of the detected electrons is shown in Fig. 5 after applying an electron energy threshold of 100 MeV. The average asymmetry value is 0.3 which can be increased by using the number of electrons separately in (for e.g.) five energy bins.

The number of photomultiplier tubes (PMTs) for the calorimeter readout must increase substantially from the present of about 100, in order to have a complete coverage of the ring without compromising in their performance due to increased rates. [3] The issue is being investigated further and it will be facilitated by our experience during muon injection in the g-2 ring.

We think it is advantageous to look at the total charge collected by the detectors rather than at individual pulses, the method known as the "Q" method [27]. Other detection schemes are currently under investigation to increase acceptance and decrease any rate dependent effects of the detectors.

4 Sensitivity Level

The EDM sensitivity is given by (in MKS units)

$$\eta = \frac{2\theta_t}{\beta B t}\frac{m}{e}, \tag{10}$$

with θ_t the minimum transverse spin precession angle which can be detected, m, e the muon mass and charge respectively, B, the average magnetic field seen by the muon, and $t = 55\,\mu$s equal to 5 lifetimes, the total observation time being 10 lifetimes. If one observes 5×10^{14} decay electrons which have an average transverse asymmetry of 0.3 then the error in $\theta_t = \pm 1.5 \times 10^{-7}$ rad, the sensitivity to η of 2.7×10^{-11}, and the EDM of 1.2×10^{-24} e cm.

The sensitivity of the experiment increases as the B field and the lifetime increase. However, the necessary electric field which is canceling the muon $g-2$ spin precession also grows fast as can be seen by equation (7).

4.1 Calibration of Sensitivity

A simple way to calibrate the experimental sensitivity to the muon EDM is to apply a vertical electric field in the muon storage region. The beam will be displaced vertically until the magnetic focusing will compensate with an equal and opposite force. The average radial magnetic field seen by the muons will be such that it compensates the vertical electric field. This non-zero radial magnetic field will induce a non-zero spin precession in the vertical plane mimicking an EDM effect.

The vertical spin precession angle with a vertical electric field E_v, and a vertical B magnetic field present is given by

$$\theta_t = \frac{e}{2m}[g\frac{E_v}{\beta\gamma^2} + \eta\beta B]t, \tag{11}$$

which for $E_v = 5$ KV/m results in 30 mrad vertical spin precession which is easily measurable. This average electric field can be achieved by placing pulsed 25 KV on a pair of electrodes, 10 cm apart, covering 2% of the ring. The average vertical muon population will shift by about 10 μm.

It should be noted that in the absence of an electric field the average radial magnetic field seen by the muons is exactly zero since we are using strong *magnetic* focusing.

4.2 Systematic Errors

Potential systematic errors include the following:

1. Early to late electron counting due to rate effects. With 10^7 muons entering the ring and a good fraction of them decaying within 10 μs the rates are very high. This item we need to investigate further.

2. Proton or pion contamination of the muon beam. During the 1997 run of the g-2 experiment where there were injected about 10^8 pions per spill, the pion flash was the biggest problem. After striking a nucleus they produce secondary neutrons which in turn produce gammas paralyzing the photomultipliers mostly at the first half of the ring for tens of μs. When we tried the muon injection by lowering the accepted particle momentum by about 1.5% the light flash went down by a factor of 50.

   In the muon EDM experiment the secondary beam is 900 MeV/c whereas the muons have half that. One can expect a proton/pion leakage of less than 10^{-4} per muon. If we assume that the lower momentum particles are less likely to produce a neutron by a factor of 2 and taking into account that most of the injected particles (i.e. 90%) are expected to be stored and not get lost, the total particle population in the ring producing a neutron will be 5×10^9 for a total of 10^{15} stored muons. Assuming that they cause a 0.5% asymmetry on top versus the bottom detectors (in the worse case) the effect will be below the sensitivity of the experiment.

3. Due to the cylindrical nature of the electrostatic plates which provide the radial electric field, the E-field decreases as $1/R$ making the cancellation of the g-2 non-perfect as a function of the muon momentum. Also, taking into account that the spin

precession cancellation depends on both the magnetic field and the value of gamma (see equation (7)), one can estimate that at the edge of the aperture, the muons will flip the spin horizontally in $100\,\mu$s. Only a very small fraction of the muons will do that. We are investigating the requirement on the acceptance and detector efficiency uniformity so that this effect is also negligible.

4. The problem with radial magnetic fields present, when electrostatic focusing is used, is eliminated completely because we only use strong magnetic focusing.

We feel confident that we can analyze all sources of systematic errors and greatly reduce them due to the flexibility provided by a dedicated muon EDM experiment.

5 Cost and Schedule

The cost of a dedicated EDM experiment is only incremental over the current g-2 experiment since the bulk of the equipment is going to be used as is. A rough estimate of the extra cost is about 4.5 million dollars with most of the money needed is for the new target with the lithium lens ($800 K), beam transport line ($415 K) and installation ($390 K), detectors ($500 K), vacuum chambers ($400 K), new inflector ($100 K), ring modification ($400 K), and electrostatic plates with feedback system ($500 K). A 30% overall contingency is $1.05 M bringing the total to $4.5 M.

The schedule of this experiment will be determined by progress in the current g-2 experiment. If all goes well, it is anticipated to take data until around the year 2001. In the mean time one can start building and testing the various components for the dedicated EDM experiment.

6 Summary

We have proposed to search for an EDM of the muon by performing a dedicated experiment in the existing g-2 ring. The main differences from the g-2 experiment are that we are going to place the detector calorimeters on top/bottom of the vacuum chambers, use strong magnetic focusing with no vertical electric fields present, lower momentum muons, and a lithium lens target with modified beam transport and inflector system. All of these are described in more detail in the corresponding sections.

The estimated sensitivity is at the level of $1.2 \times 10^{-24}\,\mathrm{e\,cm}$, an improvement of a factor of almost 10^6 over the last CERN muon g-2 experiment, with comparable improvement on the systematic errors. The systematic error analysis is still underway.

References

[1] E821 collaboration at BNL. For details see: Design Report, BNL AGS E821, "A New Precision Measurement of the Muon (g - 2) Value at the level of 0.35 ppm".

[2] I.B. Khriplovich and M. Pospelov, Sov. J. Nucl. Phy. **53**, 638 (1991); F. Hoogeveen, Nucl. Phys. **B341**, 322 (1990).

[3] J. Bailey, K. Borer, F. Combley, H. Drumm, F.J.M. Farley, J.H. Field, W. Flegel, P.M. Hatterley, F. Krienen, F. Lange, E. Picasso, and W. von Rüden, J. Phys. **G4**, 345 (1978).

[4] W. Bernreuther, M. Suzuki, Reviews of Modern Physics **63**, 313 (1991).

[5] V. Barger, A. Das, C. Kao, Phys. Rev. **D55**, 7099 (1997).

[6] D. Bowser-Chao, D. Chang, W. Keung, Phys. Rev. Lett. **79**, 1988 (1997).

[7] C.G. Geng and J.N. Ng, Phys. Rev. **D42**, 1509 (1990).

[8] Some of the limits have been updated not to contradict the recently available experimental limits on the electron EDM of $6 \times 10^{-27}\,\mathrm{e\,cm}$.

[9] E. Commins *et al.*, Phys. Rev. **A50**, 2960 (1994).

[10] K. Abdullah *et al.*, Phys. Rev. Lett. **65**, 2347 (1990).

[11] I.S. Altarev *et al.*, Phys. Lett. **B276**, 242 (1992).

[12] S. Dimopoulos, L.J. Hall, Phys. Lett. **B344**, 185 (1995).

[13] R. Barbieri, A. Romanino, A. Strumia, Phys. Lett. **B369**, 283 (1996).

[14] Savas Dimopoulos, private communication.

[15] Frank Paige, private communication.

[16] Jorge L. Lopez, D.V. Nanopoulos, Xu Wang, Phys. Rev. **D49**, 366 (1994).

[17] U. Chattopadhyay and Pran Nath, Phys. Rev. **D53**, 1648 (1996).

[18] Takeo Moroi, Phys. Rev. **D53**, 6565 (1996).

[19] W. Marciano, private communication.

[20] F.J.M. Farley and E. Picasso, "Quantum Electrodynamics", ed. by T. Kinoshita (World Scientific, Singapore, 1990), p. 479.

[21] J.R. Sanford and C.L. Wang, "Empirical Formulas for Particle Production in P-Be Collisions Between 10 and 35 GeV/c", AGS Internal Report JRS/CLW-1 March 1967.

[22] F. Krienen, D. Loomba, W. Meng, NIM **A283**, 5 (1989); F. Krienen, D. Loomba, W. Meng, "Development of Non-ferrous Superconducting Magnets", Muon g-2 Note #63.

[23] Yuri Orlov, "Spin and Beam Dynamics I", Muon g-2 note #279.

[24] J. Miller, R. Carey, and E. Hawk, "Measurement of the Muon Electric Dipole Moment in E821", Muon g-2 note #215.

[25] D. Roux, "The Hydrostatic Levelling System (HLS)/Servo-Controlled Precision Jacks, A New Generation Altimetric Alignment and Control System", Proc. 1995 Particle Accelerator Conf., Dallas, Texas, 2932 (1995).

[26] R. Carey, and A.C. Derre, "Where do the Electrons go?", Muon g-2 note #270.

[27] W.M. Morse, "A new method of Analysis", Muon g-2 note #93.

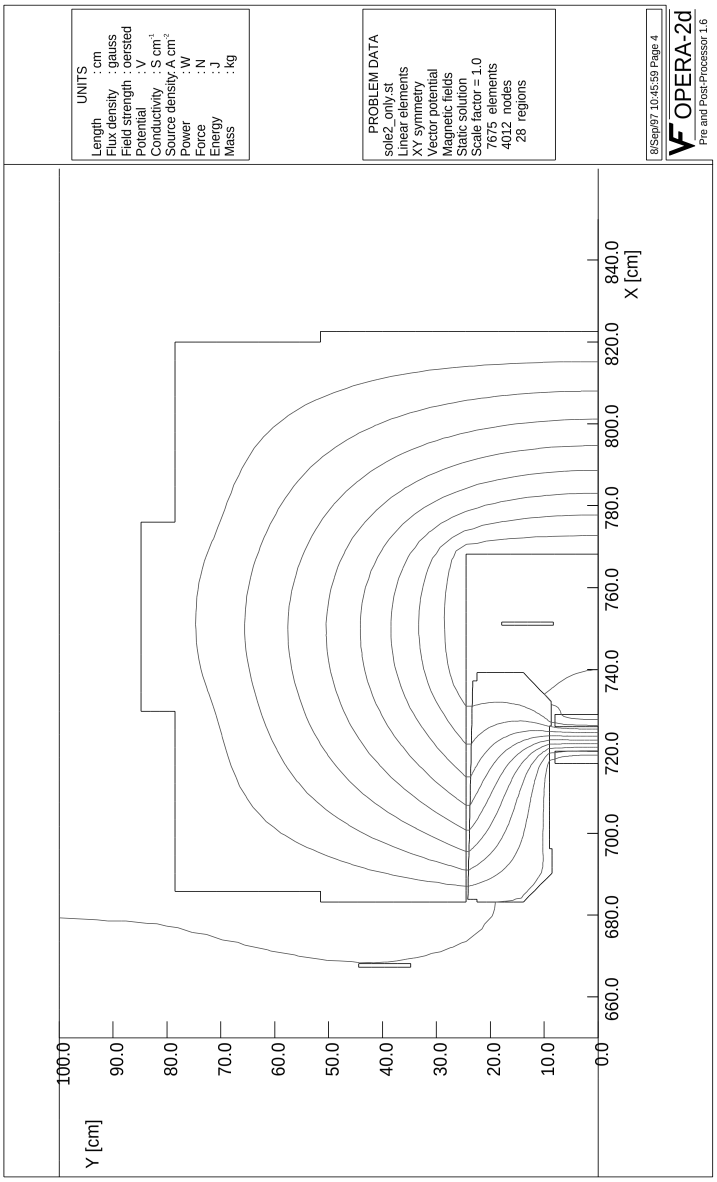

Figure 1: The proposed new inflector design for the EDM experiment located at 723 cm away from the center of the $g-2$ ring. The muon storage center is at 711.2 cm. The magnetic flux lines are shown with only the inflector energized.

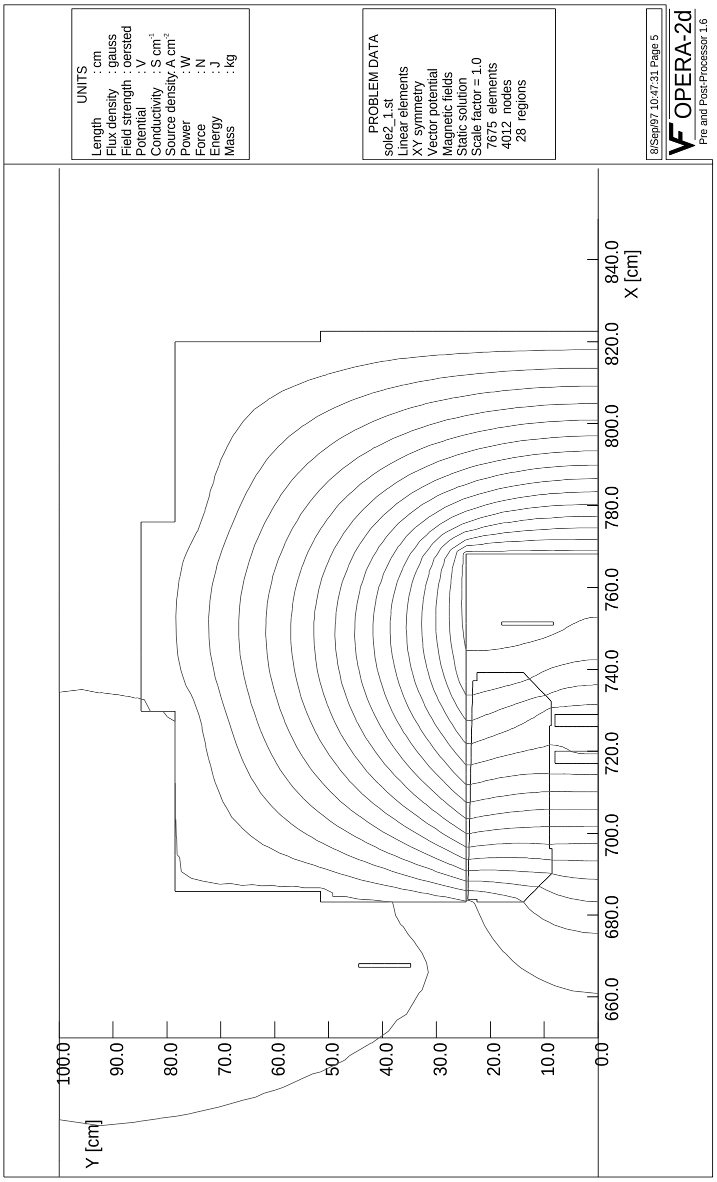

Figure 2: The magnetic flux when both the main magnet and the inflector are powered. The required current density for no magnetic field inside the inflector is 31.7 KA − turn.

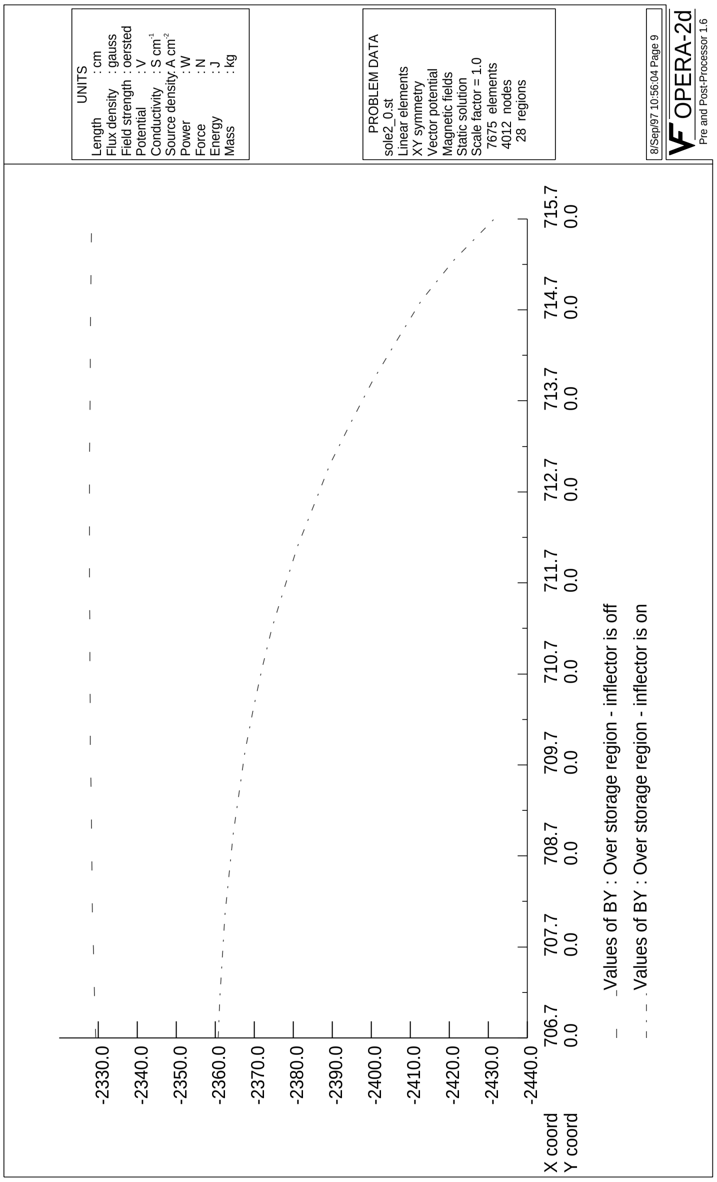

Figure 3: The vertical magnetic field in gauss at the location of the muon storage region with and without the inflector energized.

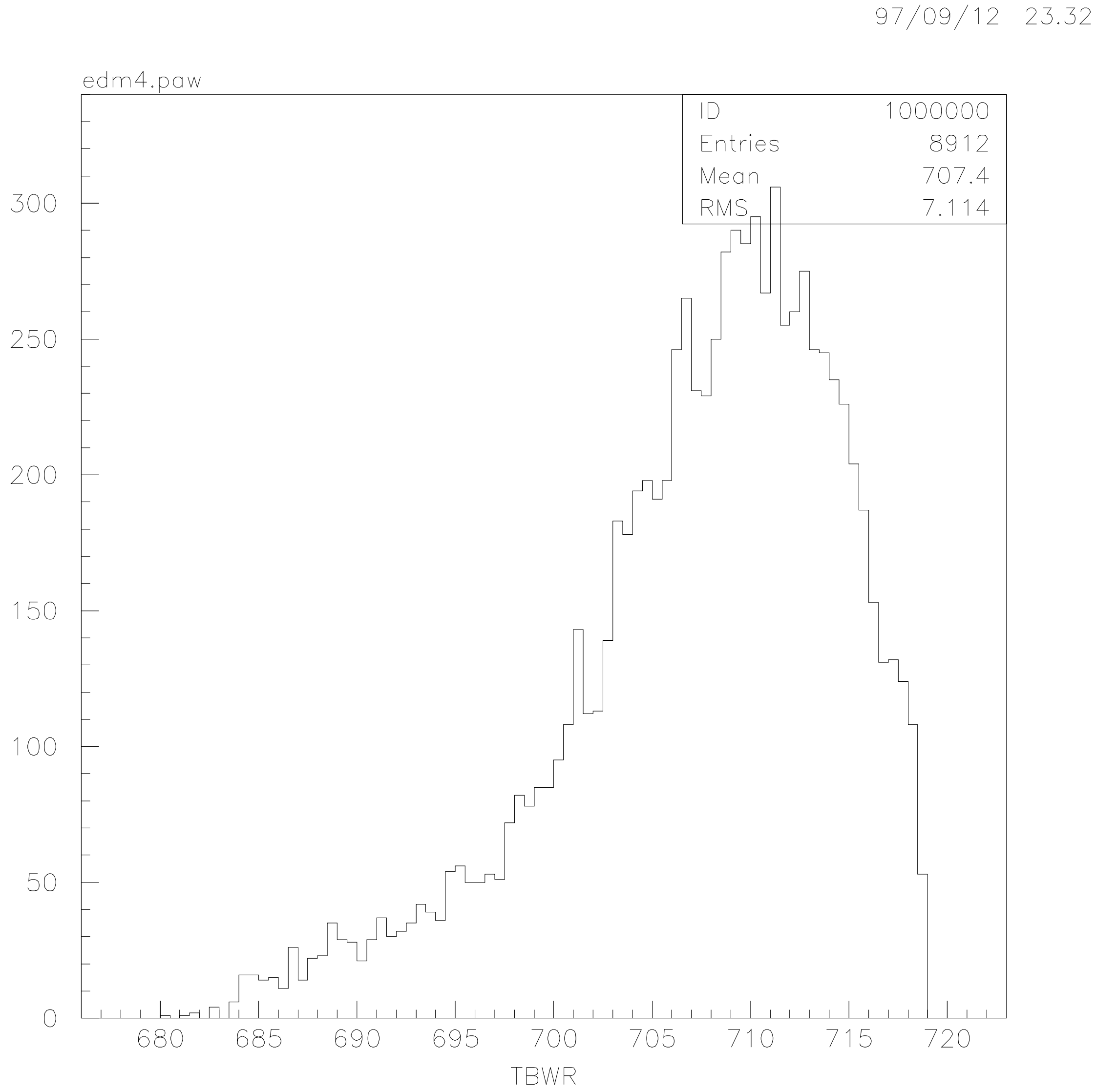

Figure 4: The radial distribution of the decay electrons at the detector location.

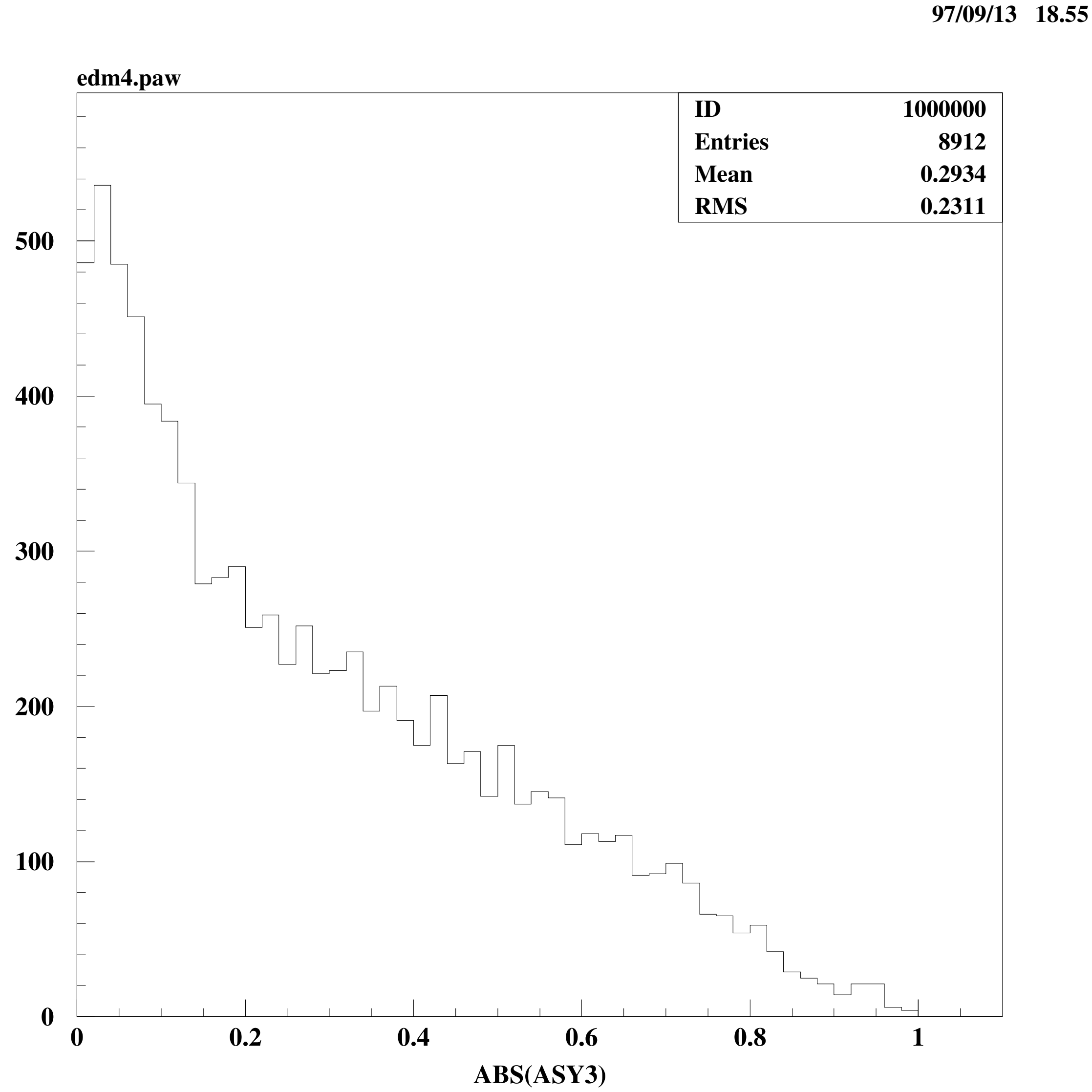

Figure 5: The asymmetry distribution of the decay electrons integrated over the detector locations.

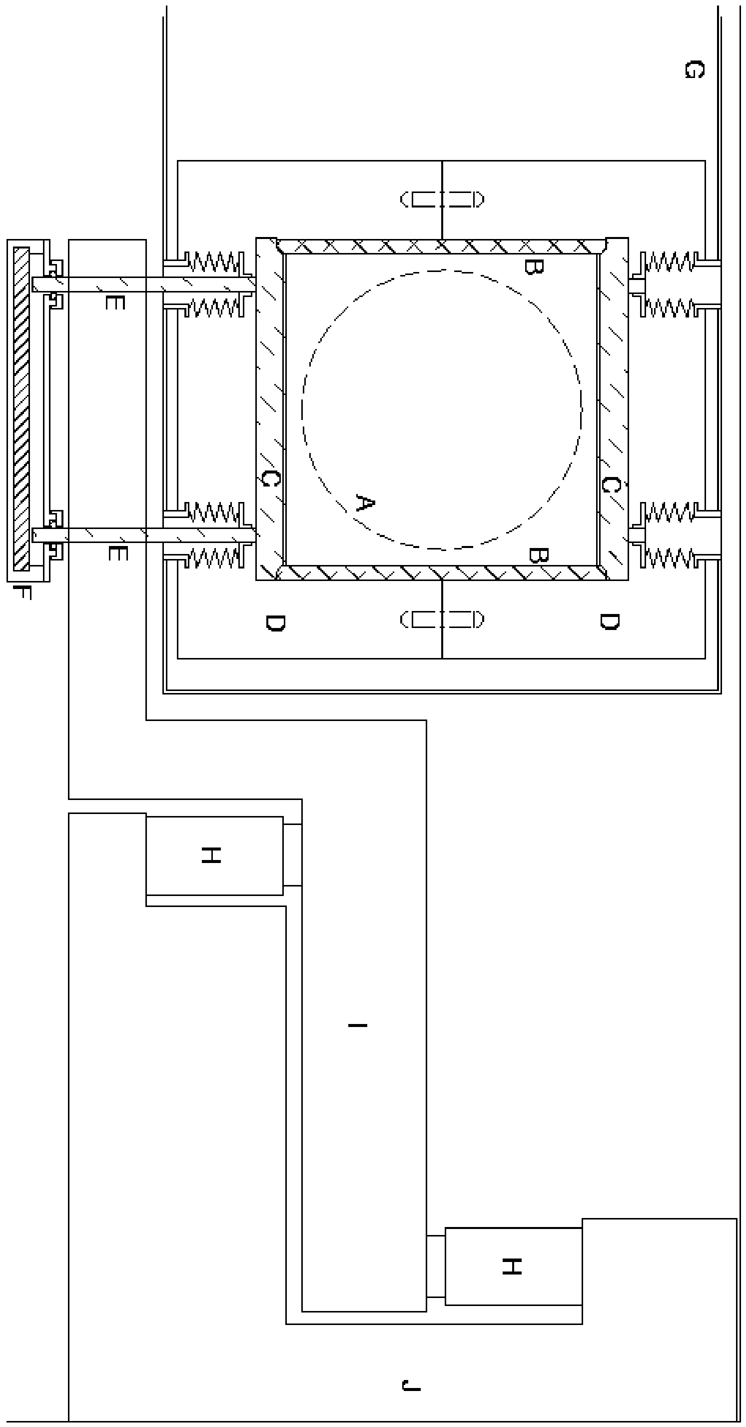

Figure 6: Scheme of electrode alignment showing: (A) muon storage region; (B) electrodes; (C) conductive glass plates with insulating support webbing; (D) ceramic alignment yokes; (E) glass reference rods; (F) hydrostatic reference surface; (G) vacuum chamber; (H) piezo-electric driver; (I) lever; and (J) support beam.