LETTER OF INTENTION

NEW (g-2) EXPERIMENT WITH THE 14 METRE DIAMETER MUON STORAGE RING

by


CERN LIBRARIES, GENEVA
Letter of Intention

To : Members of the EEC.


Subject: New $(g-2)$ experiment with the 14 metre diameter muon storage ring.

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1. The present muon storage ring has given a 20-fold increase in the accuracy of the muon anomalous moment. Compared with theory the result is $(460 \pm 270)$ ppm (parts per million), that is a discrepancy of 1.8 standard deviations. It appears likely that further measurements will be made to resolve or confirm the deviation. These experiments could well be made at CERN. As a result of a new principle recently discovered (see §3), it now appears certain that the experimental error can be reduced to 20 ppm (an improvement of 10-20 times in accuracy), using a larger storage ring and incorporating special techniques to cure the troubles of the present project.

A $(g-2)$ measurement to 20 ppm is capable of testing QED to $q^2 \sim (15 \text{ GeV})^2$. Alternatively, it could give clear confirmation of the $\sim 500$ ppm discrepancy mentioned above. The error would be of the same order as current estimates of strong interaction contribution (30 ppm or more) and the intermediate boson contribution (-20 ppm) if it exists.

2. In summary, the improvement can be obtained by the following means:

i) Injecting pions with a pulsed inflector, instead of protons. This allows us to remove electron contamination, and so to have low background in the counters even at early times. The muon polarization is increased by a factor $\sim 2$. By matching the pion beam to the ring acceptance, the stored intensity is increased substantially.

ii) Using higher momentum to lengthen the time scale by a factor 2.5.

iii) Increasing the decay electron counting rate per RF bunch of PS by a factor $\sim 10$ (bigger aperture, more counters, pion injection with matching).
iv) Using 6 bunches per cycle instead of 3, and the improved PS cycling rate, gives a factor \( \sim 4 \), leading to an over-all factor 40 in counts per second. We thus gain a factor \( \sim 6 \) in accuracy from the statistics of \((g-2)\) precession, and a factor \( \sim 5 \) from time-scale and muon polarization. This is an over-all factor of \( 30 \times \) if the value of \( \bar{B} \) is well known. (Note that we have high-lighted the main changes responsible for the improvement. In fact the result given comes from a detailed calculation involving also many minor factors.)

v) Decreasing the uncertainty in \( \bar{B} \) by: a) using a uniform magnetic field with electrostatic focusing (see below), so that it is no longer necessary to measure orbit radius; and b) using a laminated magnet.

vi) Eliminating the loss of particles after the first few microseconds by ensuring that the injected particles are far away from all stops and obstacles. This can be accomplished by perturbing the orbit with pulsed electric fields at early times.

Further details are now given.

3. FOCUSING

In a ring with uniform magnetic field (14.7 kG, say) an almost continuous electric quadrupole, focusing vertically, will be mounted. This defocuses horizontally and is equivalent to a magnetic gradient,

\[ n_{\text{effective}} = \left( \frac{P}{\beta B_0} \right) \left( \frac{dE_P}{dP} \right). \]

The radial component of the electric quadrupole field \( E_P \) will in general perturb the spin precession frequency by the factor

\[ 1 + \left( \frac{\beta}{\alpha} \right) \frac{E_P}{B_0}. \]

But the correction becomes zero if \( \beta^2 \gamma^2 = 1/a \), corresponding to \( p_\mu = 3.098 \) GeV/c. Accordingly, it is proposed to work at this momentum (corresponding, for example, to 7 m radius, for \( B_0 = 14.7 \) kG). The vertical component of an electric field inevitably averages to zero for a stored particle, and so does not precess the spin on the average. For a useful aperture of 17 cm horizontally by 5.6 cm vertically, the voltages required are of the order of \( \pm 40 \) kV only, and appear to present no technical difficulty. This is for \( n_{\text{effective}} \sim 0.16 \), a value which seems
the optimum for minimizing losses due to non-linear resonances which have been studied in detail. Note here that n_{\text{effective}} can be varied by changing the applied voltage.

Departures from the condition $\gamma = 29.3$ at the edges of the aperture imply a correction, but averaged over the muon distribution this will be of the order of 4 ppm.

As the magnetic field is uniform, the precession frequency is now independent of muon radius. We still intend as a check to estimate the radial distribution from the rotation frequency, but no particular accuracy is required.

4. **MAGNET DESIGN**

We are studying a design for a 14 m diameter ring magnet with gap $\sim 10$ cm, and horizontal aperture $\sim 30$ cm. The magnet will be laminated to reduce eddy current effects on run-up which are known to give inconsistencies in the field from point to point. Because the field is uniform, the magnet could be a polygon instead of a true circle, possibly simplifying the construction.

5. **PION BEAM**

3.1 GeV/c pions, produced in an external target hit by the fast ejected proton beam, will be inflected into the ring for one turn only using a pulsed inflector. Acceptance at the target of $\pm 16$ mrad (vertically) and $\pm 27$ mrad (horizontally) will be transformed to $\pm 1.6$ mrad (vertically) and $\pm 11$ mrad (horizontally) to fit the ring acceptance. The momentum bite will be $\sim 1\%$, and absorbers will be used to clear the beam of electrons. Using about 20 GeV protons, the injected $\pi$ intensity is expected to be $1.4 \times 10^5$ per r.f. bunch.

It is planned to eject single RF bunches of protons in succession at 3 millisecond intervals during the first part of the flat-top. This enables us to use 6-10 PS bunches in a single PS cycle, but to avoid high counting rates. In effect, the experiment is repeated up to 10 times in each PS cycle. The pulsed inflector must also be capable of cycling at the same rate. We understand (B. Kuiper, G. Plass, private communications) that such a scheme is, in principle, technically possible.
6. ELECTRIC "SCRAPING" TO ELIMINATE LOSSES

Quite modest electric fields will perturb the orbit during the first microseconds after injection, causing muons to be lost on the walls. By adiabatically reducing these fields to zero, the remaining particles are centred in the available aperture. This allows room for moderate beam blow-up due to irregularities in the magnetic or electric quadrupole field without incurring a loss of particles.

7. COUNTERS, ELECTRONICS

As backgrounds are strongly reduced by using π injection we expect to use counters around three-quarters of the ring. The expected total counting rate per RF bunch is only 22 counts (compared with 2 at present), so the digitron can be almost the same as now. A small on-line computer (such as Varian Data 622) should be used to make histograms and generally monitor the experiment.

8. SITE

It is proposed to site the ring in the West area. Shielding round the ring would be much lighter than at present because we do not inject protons.

9. COST, RUNNING TIME, TIME SCHEDULE

The main costs are roughly as follows:

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>Sw.</th>
<th>Fr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generator</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum chamber, inflector</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Counters, on-line computer, electronics</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td><strong>4.3</strong></td>
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The accuracy of 20 ppm should be reached in a data-taking run of four weeks. Appropriate test and tune-up time should be allowed.
The time schedule is roughly as follows:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design of magnet</td>
<td>6 months</td>
</tr>
<tr>
<td>Model tests</td>
<td>3 &quot;</td>
</tr>
<tr>
<td>Tender, plus order</td>
<td>3 &quot;</td>
</tr>
<tr>
<td>Construction</td>
<td>13 &quot;</td>
</tr>
<tr>
<td>Assembly and measurement</td>
<td>6 &quot;</td>
</tr>
</tbody>
</table>

Total from decision to operation = 2 yrs 7 months

This means that we could be running the experiment in the middle of 1971.