Design Report

BNL AGS E821

A New Precision Measurement of the Muon $(g-2)$ Value at the level of 0.35 ppm

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Cornell University, Fairfield University, University
of Heidelberg, University of Illinois, Max Planck
Institute für Med. Forschung - Heidelberg,
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Preface (Overview, Progress, and Milestones)

The for the muon *(g-2)* experiment, E821 at the Brookhaven AGS, was first proposed to the Brookhaven program committee in September 1985. It was defended for a second time in October 1986, and "first stage approval" was granted on 17 November 1986. A revised proposal was submitted in October 1987. Final approval was granted on 3 March 1988. Originally there was a four-year construction schedule, which began in FY89. This schedule was subsequently changed to a five-year one, which has stretched further. The first beam is now scheduled for early 1996.

This document is the third and last edition of the Design Report for E821. Its predecessors have, by necessity, been a statement of intentions as much as a source of details about the experiment, since at the time of their preparation many of the details were still being worked out.

The situation is much different now. With beam just over a year away, the superconducting coils wound and installed in their cryostats, the storage ring magnet almost completed, this document is much more mature than its predecessors, and only a few details remain to be resolved.

Muon injection now plays a central role in achieving the precision advertised in the experiment's name. A working decision to go with a magnetic kicker has been taken, and the necessary R&D is well along.

The beamline, superconducting inflector, storage ring magnet, shimming of the magnet, field monitoring and control, are all well along in development or construction. The electron detectors are in production and their electronics are in the final prototype stage. The data acquisition system and the slow control system are being designed, and the host computer is already installed in the $(g-2)$ building. The beam dynamics calculations, which were scarcely existent when the previous editions were written, have matured, and have even been carried out independently at several institutions.

A rather detailed management structure has developed, and it is described in detail in Chapter 24. Coordination between the various tasks is crucial to the success of the project, and this is now being overseen seen by a number of coordinators who are listed in Chapter 24.

A number of important R&D tests have been carried out over the past few years, and the results have been reported in *Muon (g-2) Technical Notes.* These notes, which document the R&D program, include the refrigerator acceptance test, shimming studies with the test magnet, detector studies with test beam, and quadrupole and kicker studies, among other topics, may be obtained from the *(g-2)* Secretary, Mrs. Joan Depken, BNL. Only the title and a brief description is given below in the footnotes. [1-23] Additional details are given in the appropriate chapters.

1. #190 *Acceptance test of the g-2 refrigerator*, Authors: R. Meier, A. Esper, and L. Jia, 29 November 1993, Refrigerator test with dummy load.
2. #187 *The performance of the WFD in the summer '93 Testbeam run*, Author: Rob Carey, Date: 9 March 1994, The WFD is the wave form digitizer that will be used to read the electron calorimeters. Results are compared with ADCs and 2.5 ns interleaved reads with two WFDs is tried with the AGS test beam.

3. #178 *High frequency attenuation in 50 ohm cables,* Authors: B. Lee Roberts and Christopher Roof, Date: November 1993,.
4. #177 *July 1993 g-2 test beam results for the calorimeter, FSD, and SSD,* Authors: T.D. Jones, G. Garino, D.W. Hertzog, R. Carey, J. Miller, J. Ouyang, L. Roberts, W. Worstell, K. Arrington, D. Kefford, J. Kennedy, R. Pisani, C. Sanzeni, D.R. Winn, P. Cushman, Date: November 1993, Studies of the electron calorimeter, front and side scintillation detectors with the AGS test beam.
5. #169 *Minutes of the Quadrupole Meeting of August 18, 1993,* Author: Yannis K. Semertzidis, Date: August 28, 1993, Final dimensions, test results, pressure requirements, DC high voltage and resonant frequency of trapped electrons gives electric field to 0.5possibility of pumping between AGS cycles.
6. #168 *Test setup for measuring the magnetic field due to kicker eddy currents,* Authors: Yannis K. Semertzidis, Francis J.M. Farley, Richard Larsen, William M. Morse, Joe Yelk, Date: August 27, 1993, Development of a test setup to measure varying magnetic fields, such as the remnant field from the muon kicker. A 6 mG measurement was made in the test..
7. #161 *Results of the tests of the Heidelberg NMR system at Los Alamos,* Authors: R. Prigl, K. Jungmann, G. zu Putlitz, P. v. Walter, U. Haeberlen, X. Fei, V. W. Hughes, M. Janousch, W. Liu, W. Schwarz, Date: June 1993.
8. #156 *Results of Boston University g-2 Electron Calorimeter June 1992 Beam Test,* Authors: D.H. Brown, R.M. Carey, M.B. Chertok, S. Doulas, C.S. Lin, J.P. Miller, B.L. Roberts, W.A. Worstell, X.F. Zhang, G.T. Zwart, R. Pisani, K. Segall, D. Wall, D.R. Winn, Date: April 18, 1993.
9. #144 *Development of distribution ion pumps (DIPs) for g-2 beam vacuum system,* Author: H.C. Hseuh, Date: March 1993, Tests of proposed DIPs in a test magnet.
10. #139 *Results on the Position Sensitive Detector–Summary of the last 2 years,* Authors: P. Cushman and S. Hou, Date: January 19, 1993, Tests with a source and test beam of the proposed fiber hodoscope.
11. #134 *Progress on the electrostatic kicker,* Author: Zhifeng Liu, Date: December 1992, Tests of insulators for the proposed electrostatic muon kicker.
12. #129 *Progress on the NMR Magnetic Field Measurement System,* Authors: U. Haeberlen, K. Jungmann, R. Prigl, G. zu Putlitz, P. v. Walter, Date: September 1992, Includes studies of NMR in a Heidelberg test magnet.
13. #113 *Tests of Prototype Electrostatic Quadrupoles,* Authors: S. Doulas, F. Krienen, R. Larsen, W. Morse, J. Yelk, T. Zwart, Date: April 1992, Misc: tests on hyperbolic quads.
14. #89 *Response of Photomultiplier Tube to Radiation,* Authors: G. Brown and W. Morse, Date: September 1991, Misc: remarks on tests using a source and tests by AGS E871.
15. #87 *Survey of the Magnetic Field Fluctuations and Perturbations for Muon g-2 Experiment,* Authors: X. Fei, K. Woodle, and S. Dhawan, Date: July, 1991, Fluxgate magnetometers were used to measure magnetic field fluctuations in the g-2 building. A 1 mG field due to AGS cycling was observed.

16. #85 *Energy Resolution, Leakage and Light Yield Studies of the g-2 prototype Scintillating Fiber Calorimeter,* Authors: Detector Group, Boston, Fairfield and Yale Universities, Date: August 1991, Misc: First Results of the May-June 1991 AGS A3 beamline tests.
17. #75 *Pulser for Test of Electrostatic Quadrupoles,* Authors: G. Brown, F. Krienen, R. C. Larsen, W. M. Morse, J. Yelk, Date: April 1991.
18. #61 *Prototype of g-2 digitron,* Authors: William M. Morse, Joseph Yelk, Date: October 1990.
19. #47 *Comments on 1989 flash test,* Author: W. M. Morse, Date: May 1990.
20. #45 *Results of the wire chamber flash test,* Author: W. M. Morse, Date: April 1990, Misc: includes comments on effects of phototubes viewing charged particles.
21. #44 *Status of shimming studies with the BNL test magnet,* Author: K. Woodle, Date: 23 April 1990.
22. #39 *g-2 Building Floor Stability,* Authors: A. Pendzick, F. Karl, J. Mills, J. Sullivan, Date: May 23, 1989.
23. #37 *Results of Flash Tests at BNL, May 17-18 1989,* Authors: P. Cushman, S. Dhawan, B. Kerosky, M. May, J. Miller, B.L. Roberts, D. Winn, K. Woodle, W. Worstell, Date: 6 Feb. 1990.

This document represents a substantial amount of work on the part of the collaboration members. Credit for its success must be spread widely over the membership. John Cumings "cut and pasted" hundreds of figures and several chapters for the final draft and the final version of the third edition. Without his help and good cheer, this edition would have been even later in reaching the collaboration. Mrs. Joan Depkin has been essential both in the preparation of chapters by BNL AGS staff as well as in the reproduction, collating and distribution of past editions of this report. She also continues to be the librarian and distributor for the *(g-2)* technical notes, and her help in this final edition as well as in the earlier ones is gratefully acknowledged. Ms. Pat Fleming at Yale played a major role in putting the previous two editions together, and her contributions both there and to this edition are gratefully acknowledged.

This document was typeset using TEXsis and I am grateful to Frank Paige for help in some of its subtleties.

A draft of the third edition was prepared in time for the DOE review of the experiment in May 1994. It has taken some months to finish the revisions to the manuscript, and the editor appreciates all the help and cooperation he has received from his colleagues in producing this document. In the interest of making this report available in a finite time, the editor has been forced to resist making further editorial and clarifying changes to the chapters submitted by the various teams.

BLR - Boston, March 1995

WBS Correlation with Chapters

The Work Breakdown Structure, while a useful accounting tool, does not correspond chapter by chapter to the presentation in this document. In order to help the interested reader find the sections relevant to a given WBS category, the following key is included.

1.1 Storage Ring Magnet
- 1.1.2 Magnet Yoke and Base - Chapter 8.
- 1.1.3 Coil and Cryostat - Chapter 8.
- 1.1.4 Assembly of Ring - Chapter 8.
- 1.1.5 Refrigerator - Chapter 9.

1.2 Beam Monitoring and Dynamics
- 1.2.2 Injection Into the Ring - Chapters 5, 6 and 15.
- 1.2.3 Particle Orbits/Phase Space - Chapter 5.
- 1.2.4 Primary Beam Monitoring - Chapter 6.
- 1.2.5 Secondary Beam Monitoring - Chapter 6.
- 1.2.6 Pion/Muon Beam in the Ring - Chapter 5, 15.

1.3 Magnetic Field Shims - Chapter 14.

1.4 Ring Vacuum and Quadrupoles
- 1.4.2 Ring Vacuum Chamber - Chapter 13.
- 1.4.3 Quadrupole Electrodes - Chapter 11.
- 1.4.4 Beam Vacuum System - Chapter 6.
- 1.4.5 Pulse Equipment - Chapter 11.
- 1.4.6 Tests - Chapter 13.
- 1.4.7 Inflector Cryostat - Chapters 9, 10.
- 1.4.8 Inflector Power Supply - Chapter 10.
- 1.4.9 Inflector Coil - Chapter 10.

1.5 Detectors - Chapter 16.

1.6 AGS Beam + Experimental Hall - Chapters 6, 7.

1.7 Field Measurement and Control - Chapter 14

1.8 Muon Kicker - Chapter 12

1.9 DAQ and Control
- 1.9.2 Host Computer - Chapter 17.
- 1.9.3 VME-Based DAQ - Chapters 16, 17.
- 1.9.4 Slow Control - Chapter 18.
- 1.9.5 DAQ Integration - Chapter 17, 18.