Small Project Final Report, April, 2012

DOE Office of Nuclear Physics (NP)
Facilities and Project Management Division

Proposal Name: Simulation and Optimization of the Spin Coherence Time for the Proton EDM Measurement at BNL. OSP Number: 62355/A001

Report Date: April 10, 2012

Principal Investigator: Richard Talman, Professor of Physics, emeritus, Cornell

Work-scope Highlights:
This is the final report under the grant. Work during this quarter has concentrated on (1) lattice development of an "all-in-one" storage ring lattice for measuring the EDM's of protons, deuterons, and helium-3 nuclei. (2) COSY EDM precursor experiments; especially using an electric bend element borrowed from the Fermilab Tevatron. (3) establishing benchmark lattices for comparing beam evolution codes. My responsibilities have been to design or alter lattices for these storage ring experiments and to guide the development of the UAL/ETEAPOT, enabling it to simulate beam and polarization evolution and survival in these experiments.

Brief summary of activity issues, concerns, successes:

(1) For theoretical reasons it is considered essential to measure the EDM of the deuteron and helium-3 as well as the proton. Deuterons and helium-3 measurements require a storage ring lattice considerably more complicated than is required for the proton measurement. My COSY, Juelich report, "All-In-One Storage Ring Lattice for Baryon EDM Measurements", February, 2012, describes such a lattice. The report describes an ``all-in-one" lattice and various of its electric and/or magnetic bending configurations. The lattice optics for the ring (or rather rings, since separated beam channels are needed for electric plus magnetic bending) is otherwise designed to be as close as possible to the optics for the proton EDM ring.

(2) With David Rubin and Bruce Dunham from Cornell, and William Morse from BNL, we have generated a proposal to refurbish a Tevatron electrostatic separator as a prototype electric bend for a proton EDM Lattice. My COSY internal report, "A Magnetic-Electric-Magnetic Spin Tune Jumper Chicane for COSY Using a Tevatron Electrostatic Separator" describes one way in which the electric bend element prototype can be tested, and another "A Proton EDM Measurement at COSY Using an MDM-Transparent Chicane" shows how the electric bend element, as part of a net-bending chicane, can be used to measure the proton EDM using the COSY storage ring at Juelich. This measurement can be more accurate than the present day upper limit for the proton EDM, but will still be two orders of magnitude less accurate than is expected to be possible with an eventual dedicated storage ring, such as described in the 2011 BNL

proposal.

Under this proposal a Fermilab Tevatron electric separators is to be delivered to Cornell for refurbishment by the high pressure water rinsing process. The requirement for the electrostatic device for this project is to support an electric field of 10 MV/m across a 5 cm gap. This implies applying voltages of +/-250 kV between long electrodes with a 5 cm gap. Stuart Henderson, associate director for accelerators at Fermilab has approved this transfer. Professors Hans Stroeher and Rudolf Maier, co-directors of the Institut fur Kernphysik, (IKP), COSY accelerator laboratory, have written a letter supporting a test of electric bending in COSY using the modified Fermilab electric separator.

(3) The UAL/ETEAPOT code and other tools are to be used for designing and analyzing compensation schemes, including spin coherence time (SCT), for the EDM storage ring. To acquire confidence in lattice designs it is important to use more than one analysis code. The various codes have various capabilities, but there is an essential core of essentials on which they must agree before their special features can be trusted. Benchmark electric lattices, stripped down to their bare essentials, are needed, to simplify benchmark comparisons of various simulation codes.

An important parameter, whose optimal value has not yet been established, is the field index *m* of the electric bend field. Benchmark comparisons are required for various values of *m*. This will be a significant task to be performed under this topic of the grant. These benchmark comparisons are to be reported in an invited talk by Mei Bai and me at the Workshop on Storage Ring Measurement of Baryon Electric Dipole Moments, in Trento, Italy from October 1 - 5, 2012. Parameters for the benchmark lattices are given in the following table.

Table 1: Parameters of benchmark all-electric EDM lattices

file name	variable name	unit	E_BM_M1.0.sxf	E_BM_Z.sxf	E_BM_P1.0.sxf
cells/arc	NCellPerArc		20	20	20
bend radius	r0	m	40.0	40.0	40.0
half drift length	Ldh	m	1.0	1.0	1.0
half bend per cell	Thetah	r	0.078539816	0.078539816	0.078539816
half bend length	Leh	m	3.141592	3.141592	3.141592
circumference	circum	m	331.327	331.327	331.327
inverse focal length	q	1/m	-0.002019	-0.00005960	0.0019075
field index	m		-1.0	1.0e-10	1.0
horzizontal beta	betax	m	35.9237	36.1018	36.1910
vertical beta	betay	m	264.182	263.620	262.237
horzizontal tune	Qx		1.4605	1.4578	1.4588
vertical tune	Qy		0.20024	0.20004	0.20047

Milestones, Completed

1. An all-in-one, iron-free proton/deuteron/helion storage ring lattice has been designed.
2. An exact analytic orbit formulation (based on work of Munoz and Pavic) has been coded into operative UAL/ETEAPOT computer code.

3. Benchmark lattices have been established for benchmarking by UAL/ETEAPOT and other simulation codes.
4. UAL/ETEAPOT documentation file “ETEAPOT-expanded.pdf” has been updated.

Future Milestones

1. Supervise the benchmarking of EDM lattices using UAL/ETEAPOT, including comparisons with theoretical calculations.
2. Participate in the inclusion of spin tracking in ETEAPOT.
3. Produce a special purpose method for calculating SCT with ETEAPOT.
4. Simulate the performance of SCT compensation schemes using ETEAPOT.
5. Participate (in collaboration with the COSY group) in the design, performance and analysis of EDM precursor experiments.
6. Continue to update UAL documentation, including resurrection of 2005 US Particle School tutorials.

Budget: To be submitted by Cornell University Administration
Summary of total expenditures: To be submitted by Cornell University Administration
Summary of expenditures by fiscal year (FY): To be submitted by Cornell University Administraton

Details on, or further, issues/concerns:

I will give a seminar at Fermilab in late April on EDM storage rings, including the possibility of performing such an experiment in what used to be the Tevatron accumulator tunnel. I will give a half hour invited talk describing “Lattice Design and Beam and Spin Dynamics for Baryon EDM Storage Ring Experiments” at the upcoming, New Orleans, May 2012, International Particle Accelerator Conference.