**Small Project Quarterly Report**

DOE Office of Nuclear Physics (NP)

Facilities and Project Management Division

**Proposal Name:**

Critical Accelerator R&D for Achieving High Performance of a Polarized Medium Energy Electron Ion Collider (***FY14***)

**Report Date:**

July 31, 2018

**Principal Investigator:**

Yuhong Zhang (***FY14***)

**Work-scope Highlights:**

In this quarterly report, we summarize the R&D work completed during the third quarter of FY18 at Jefferson Lab with funds carried over from FY14. The remaining FY14 funding is used to support A.M. Kondratenko of Novosibirsk, Russia and his colleagues for polarization design of JLEIC (formerly MEIC). In the past quarter, this team studied electron spin matching requirements to increase the electron polarization lifetime in JLEIC.

**Brief summary of activity issues, concerns, successes:**

Work continues on schedule and on budget.

**Task 3 (FY14): Beam Polarization**

**Milestones**

1. *Milestone description*

Continue Spin Matching design for increasing *electron polarization* lifetime

1. *Milestone forecast versus actual date*

This task is completed on schedule and on budget.

1. *Milestone result*

To free up space in the experimental straight, the doglegs for stacking of the electron and ion collider arcs were moved from the ion ring to the electron ring and combined with the universal spin rotator (USR). The USR rotates the spin from vertical in the arcs to longitudinal at the interaction point and returns it to vertical at the exit from the experimental straight. The electron polarization life time depends significantly on the particular design of the USR.

This report presents general requirements, which must be met by the USR design to minimize its contribution to the decrement of the radiative polarization. The depolarizing effect of radiation is determined by a vector function describing spin-orbit coupling. Vector is always perpendicular to . At high energies, when , the main depolarizing factor is the diffusion of the spin rotation angle about the arc fields. When polarization is vertical in the arcs, the diffusion of the spin rotation angle gives no contribution to the polarization decrement. However, lattice errors give rise to a transverse polarization component in the arcs, which must be sufficiently small:

where is the arc’s orbital rotation angle. The greatest danger comes from the roll and vertical misalignment of arc quadrupoles and final focusing quadrupoles.

To maximize the electron polarization life time, the USR should not excite spin-orbit coupling in the arcs. Let us formulate a requirement for making vanish in the arcs assuming that there is no vertical dispersion and betatron coupling in the arcs and the betatron tunes significantly exceed the number of spin precessions in the arcs :

where is a complex unit vector composed of two unit vectors transverse to in the spin reference frame and , , and are the strengths of the dipole and solenoid fields normalized to the magnetic rigidity in the accelerator frame. The integration is done over the whole experimental straight. This condition means that the rotator must be achromatic.

Let us now state the requirements, which must be satisfied by the USR to minimize its contribution to the polarization decrement.

1. The closed orbit must be restored.
2. Betatron coupling must be compensated at the entrance into and exit from the rotator.
3. The rotator must provide vertical polarization direction in the arcs.
4. There should be no vertical dispersion in the arcs.
5. The rotator should not excite the spin-orbit coupling function at the entrance into the arc.

Increase in the radiative decrement in this case is associated only with radiation in the USR. The contribution of radiation to the decrement has a cubic dependence on the rotator’s dipole fields and can be reduced by increasing the dipole lengths.

At the next stage, one should optimize the USR parameters and the electron ring lattice to satisfy the above requirements. One should then numerically verify the spin matched design including alignment errors of the electron ring’s magnetic elements.

**Budget**

**FY14 R&D Funding**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   | **Item/Task** | **Baseline****Total Cost** | **Costed &****Committed** | **Estimate****To Complete** | **Estimated****Total Cost** |
| ID # |
|   |   | (AY$) | (AY$) | (AY$) | (AY$) |
| JSS | Junior scientist support | $180,262  | $180,262  | $0  | $180,262  |
| KS | Kondratenko support | $142,897  | $135,609  | $7,288  | $142,897  |
| MISC | Travel, computers, etc. | $22,841  | $22,841  | $0  | $22,841  |
| Totals:  | $346,000  | $338,712  | $7,288  | $346,000  |

Summary of expenditures:

|  |  |
| --- | --- |
|  | FY 2014 |
| a) Funds allocated | $346,000  |
| b) Actual costs to date  | $338,712  |
| c) Uncosted commitments | $0  |
| d) Uncommitted funds  | $7,288  |

**Details on, or further, issues/concerns**

None.