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Muon Accelerator Program
FY11 Additional Funding Request

The FY11 guidance from the DOE for the MAP is $10.3M; this funding level is well below what was requested for Year 2 of the MAP proposal. As a consequence, preparing a FY11 budget compatible with the guidance has involved severe cuts to some aspects of the proposed program. Moreover, at our August review, there were several recommendations to somewhat *increase* our scope. We clearly cannot begin such new tasks with flat-flat funding with respect to FY10, and thus require an augmented budget for this purpose.

This request for additional funds, prepared in consultation with the MAP Technical Board, outlines key areas where additional funds would permit us to make more rapid technical progress and/or reduce technical risk during FY11. The total request for additional funds is $3,075K; *the ordering of the items listed reflects our view of their importance to the MAP R&D program*. In all cases, partial funding would still advance the program. Thus, in the event that we do not get the entire amount requested, we would plan to use the funds to optimize the R&D program based on the budget available. We note that the recent DOE review endorsed our R&D program directions, verified that we are using our funds efficiently, and indicated to DOE the benefits of additional MAP funding to make progress in a timely way.

1) *New 805-MHz Test Cavities for MuCool* ($500K)

At the recent review of the MAP proposal, the reviewers strongly recommended that we fabricate and test additional 805-MHz RF cavities to gain experience with their behavior with multiple samples prior to our down-selection process.[1] To do this in a timely way, we propose to engage SLAC engineers and scientists in this task. SLAC has world-class expertise in the design of normal-conducting RF cavities, and has expressed interest in participating in MAP R&D in this way. The funds would be used to design two cavities, the first a replica of the current pillbox cavity, but designed to permit the sophisticated cleaning techniques developed for our 201-MHz cavity. The second would be roughly a quarter-scale model of the 201-MHz MICE cavity. For the pillbox cavity, the tasks would include:

[1] Nearly all of our current 805-MHz vacuum cavity tests have been carried out on a single pillbox cavity, which is far from being a "representative sample" on which to base our down-selection decision.

1. evaluation of the existing design, with particular attention paid to the power coupler
2. development of a new design, fabrication drawings, and definition of the fabrication and processing steps, and
3. fabrication of the new cavity

This task will allow us to obtain additional information on the maximum stable operating gradient for NCRF copper cavities. It is important to update the original design, implementing improvements that we have developed over the past years of RF testing. If the new design offers relatively inexpensive fabrication, we would consider producing multiple versions of the cavity in order to increase the statistics of our tests and to evaluate cavity performance consistency. For the quarter-scale cavity, only item 2 above would be carried out using the requested funds, with cavity fabrication following the next year. For these tasks we request $400K for engineering of the two cavity designs and $100K for fabrication and processing of the pillbox cavity.

2) *RFCC Module Fabrication for MICE* ($830K)

In order to deliver the two Spectrometer Solenoids for MICE during FY11 with a flat-flat budget, it was necessary to defer a substantial amount of planned expenditures for the MICE RFCC module into FY12 and FY13. This results in significant additional risk to MICE, as MAP must do some $2M worth of work during FY12 and 13 and still try to deliver the last module in late 2013 or early 2014. With additional funds, we would pull some of the deferred RFCC work and purchases forward into FY11, maintaining our original schedule and maximizing the chances of delivering the required MICE modules to RAL in a timely fashion. Given the delays with the Spectrometer Solenoid modules, which we expect to deliver this year, it would behoove us to do all that we can to keep the remaining deliverables on schedule. Items that would be pulled forward compared with the current (flat-flat) plan include fabrication or purchase of the RFCC vacuum vessels, cavity tuner assemblies, RF couplers, RF windows, and Be windows.

3) *201-MHz Coupler Fabrication and Testing* ($220K)

We have recently observed arcing problems in the 201-MHz input couplers of the MTA test cavity, which will necessitate replacing them. These couplers are identical to those we had anticipated for the MICE cavities. Funds are requested here for the redesign and replacement of the MTA couplers, along with a test stand for processing them at high RF power without requiring an actual cavity. We envision using this test stand not only for testing and processing the MTA cavity couplers, but for processing all of the 16 MICE couplers as well. We

request $120K for the replacement MTA cavity couplers, along with two spares, and $100K for developing a processing stand in which two couplers can be conditioned and tested simultaneously.

4) *MTA Diagnostics and Data Acquisition Upgrade* ($200K)

In order to more fully exploit the capabilities of the MuCool Test Area, we request funds to improve and extend our RF diagnostics and our data acquisition system. In addition, we will modify the mechanical support structures for the test cavities to permit more rapid changeover of test setups. All of these changes will make better use of our test facility and improve our overall test efficiency. Such changes are needed to comply with the MAP review committee's desire for more test data from the MTA.

5) *Target Facility Design Effort at BNL* ($680K)

The target system is one of the most challenging parts of an accelerator complex requiring multi-MW beams, such as a Neutrino Factory or Muon Collider. Recent work has indicated that the radiation loads in this area are sufficiently high that the feasibility of present designs must be called into question. Thus, the careful and detailed design of this region of the complex is a very high priority in order to demonstrate feasibility and to understand its impact on the cost of a future facility.

Funds are requested for designing and estimating the cost of a continuous mercury-jet target system, including both the circulation system and an optimized nozzle design, to be used for either a Neutrino Factory or a Muon Collider. Funds are also requested for re-evaluation of the 20-T target solenoid design in light of its extreme radiation environment. Recent estimates made for the IDS-NF indicate much higher radiation loads than assessed in Study II, which will necessitate additional shielding and a concomitant change in the size of the target magnet. Total request for the nozzle design is $480K, with $400K being used for the mercury circulation system and $80K being used to support a specialist in fluid dynamics and his graduate student at SUNY-Stony Brook to develop the nozzle design. Magnet design engineering costs will be $200K.

6) *Site-dependent Studies for the Neutrino Factory Reference Design Report* ($200K)

Due to the size (755 m) of the muon decay ring and the steep angle (~30°) at which it must point to aim at the long-baseline (7000–8000 km) detector, the underground engineering aspects of such a design are formidable. One component

of the U.S. contribution to the IDS-NF will be to study the siting of such a facility at Fermilab. To fully develop the underground engineering R&D plan, we will convene an expert panel comprising two senior representatives, one a design contractor and one a construction contractor, along with an independent technical consultant. Although the Fermilab site has some very positive attributes, there are also some significant issues that will need to be addressed in the NF RDR. These include:

- isolating the facilities from the regional aquifer
- limitations due to rock fall occurrence
- enhancing the tunnel floor stability
- identification of "best existing," or development of improved, methods to mine rock on steep slopes

Carrying out the engineering effort outlined here during the early years of concept development of the project will not only help reduce the construction cost, duration and contingency, but will also help limit the number of design iterations. Moreover, it will ensure that the Fermilab option is taken seriously in the international arena if and when there are discussions of possible siting options.

7) *Machine-Detector Interface Simulations* ($185K)

The design of the collider ring interaction region and the design of the muon collider detector are intimately related. The size and location of magnets near the IP and backgrounds from muon decays and other processes constrain the design of detector components. The ability to measure possible physics processes depends critically on the detector and background characteristics. The success of the overall program for muon colliders is thus critically dependent on the development of the parallel effort on physics and detectors.

We request $185K for a person to begin work on developing background and radiation simulation tools that meet the specific requirements of the detector community. We anticipate that this person would work closely with the MAP MDI group and with people working on the physics and detector simulations. We cannot afford to fall too far behind on this effort without a significant risk of losing community involvement in the Muon Collider design.

8) *Proton Driver Design* ($185K)

Our plan for the proton driver is to design facilities that will use beam from the Project X complex being proposed for Fermilab. We assume that a reference design for the baseline version of Project X will be prepared independently of our effort but that MAP will be responsible for determining the modifications that

must be made, and the facilities that must be added, to accommodate the requirements of a Muon Collider and/or a Neutrino Factory. This task is time-critical in that it must keep pace with the Project X design to the extent of ensuring that no fundamental incompatibilities occur between the two designs.

The baseline parameters for Project X currently call for a proton beam power of 1 MW at an energy of a few GeV. Thus, the intensity capability, and probably the beam energy, of Project X must be enhanced to deliver 4 MW for the muon facilities of interest to MAP. In cooperation with the Project X design team, we will add MAP personnel to explore upgrade options beyond the baseline parameters for the complex. Specifically, we request $185K for manpower to begin work on a design for upgrading the output power of Project X to the required 4 MW. We anticipate that this person would work closely with the MAP Proton Driver management, the Project X team, and possibly with experts at Muons, Inc. that recently prepared a conceptual design for the power upgrade.

9) *Additional Vacuum Vessel for Testing MICE RF Cavities at the Fermilab MTA or CERN* ($75K)

The RF gradient limitation in a magnetic field is the most significant technical challenge to be faced in order to successfully design a Neutrino Factory and/or a Muon Collider. The Muon Collider would allow the U.S. to regain a foothold at the energy frontier in particle physics.

Funds are requested for a second MICE-like vacuum vessel that would permit full validation tests of the MICE hardware prior to shipping to RAL. We have already obtained funding for one such special vacuum chamber from FY10 supplemental funds, and its design is under way. It was recently recognized, however, that the ability to mount a second cavity in another chamber while the first is being tested would permit faster turn-around for the important validation tests that must happen prior to the actual installation at RAL. The requested funds ($75K) cover the fabrication of a second half-length vacuum chamber compatible with the test coupling coil. Fabrication work will be managed at Fermilab. In addition to improving throughput on testing the cavities at Fermilab, having a second chamber would potentially allow us to make use of a second RF test area (already having a suitable solenoid) that is being proposed at CERN.