Neutrino Factory and Muon Collider Collaboration R&D Program

Michael S. Zisman† – Lawrence Berkeley National Laboratory

Summary:

The Neutrino Factory and Muon Collider Collaboration (NFMCC) began as an informal group of about 100 scientists and engineers investigating the feasibility of building a Muon Collider. It became a formal entity in May 1997 and obtained its first significant funding in Spring 1998. It now has some 135 members from six U.S. national labs, 17 U.S. universities and 14 foreign institutions. The collaboration has a defined oversight and review structure that was negotiated with DOE and the directors of the sponsoring Labs (BNL, FNAL, LBNL). Since 1999, motivated by the exciting discovery that neutrinos oscillate, the NFMCC has focused mainly—but not exclusively—on Neutrino Factory design; this is viewed as a technically simpler option that addresses an area of high scientific interest and priority. There have now been two Neutrino Factory Feasibility Studies, the first sponsored by FNAL and the second co-sponsored by BNL and the NFMCC, along with a significant update of the second study in connection with the recent APS Neutrino Physics Study. The Collaboration also supports a strong R&D program having three main components: target studies, cooling studies, and simulations. The first two topics emphasize component R&D, including tests of a mercury-jet target system and development of liquid-hydrogen absorbers and high-gradient normal conducting RF cavities. Universities participate strongly in the R&D program, especially in the absorber R&D effort. In addition to its own R&D program, the NFMCC has helped launch two international experiments, the Muon Ionization Cooling Experiment (MICE), and a target experiment at CERN (nTOF11), and is playing a key role in the International (Neutrino Factory) Scoping Study (ISS). NFMCC members serve as Spokespersons for the nTOF11 experiment, as Deputy Spokesperson and Chair of the Collaboration Board for MICE, and as Leader of the Machine Working Group of the ISS.

Goals and Organization:

The Neutrino Factory and Muon Collider Collaboration is governed by a formal charter that defines its goals and organization. The goals include:

- Developing theoretical tools unique to the design of Neutrino Factories and Muon Colliders
- Developing simulation tools unique to the design of Neutrino Factories and Muon Colliders

† Project Manager, NFMCC

- Carrying out R&D on the hardware that is unique to the design of Neutrino Factories and Muon Colliders
- Carrying out an extensive experimental program to verify the theoretical and simulation predictions and to gather the necessary data for a future facility

The organization is illustrated in Fig. 1. The NFMCC is run by elected Co-spokespersons, currently Steve Geer (FNAL) and Bob Palmer (BNL), who appoint an Executive Board to deal with policy matters and a Technical Board to deal with R&D planning, priorities, and budgets. Oversight of the Collaboration's performance is provided by the Muon Collaboration Oversight Group, MCOG, with members (S. Aronson, BNL; S. Holmes, FNAL; J. Siegrist, LBNL) designated by the directors of the three sponsoring labs. MCOG appoints a Technical Advisory Committee (MUTAC), currently chaired by Helen Edwards of FNAL, to review the technical accomplishments of the Collaboration annually, and has appointed a Project Manager to be responsible for execution and monitoring of the NFMCC's national R&D program.

Each year, the R&D groups propose a budget to the Technical Board, based on guidance from DOE on the available NFMCC funding. The Project Manager prepares a budget based on this input that is then approved by the Technical Board, the Executive Board, and the Spokespersons. The budget is dictated by the R&D program needs, not by institutional commitments. After the budget is finalized, the Project Manager negotiates milestones—specifying deliverables and dates— with each institution based on the current R&D plan. At the end of the year, a spending summary along with an evaluation of progress toward the R&D milestones are presented to MUTAC, MCOG, and DOE.

The NFMCC interacts closely with corresponding organizations in Europe and Japan to minimize duplication of effort and maximize the effectiveness of the global R&D effort. Although this coordination is done informally, at the grass-roots level, it has been very effective, and has led to three fully international activities, the MICE and nTOF11 experiments mentioned earlier and the recently launched ISS.

<u>Recent Accomplishments</u>:

In the last several years, the NFMCC has carried out two feasibility studies of a Neutrino Factory, participated strongly in the APS Multi-divisional Neutrino Physics Study, developed and validated a simulation tool, ICOOL, specifically designed for muon beam line design, and helped launch the ISS. We have also led the worldwide development of the so-called "non-scaling" FFAG (fixed field, alternating gradient) ring concept, which has potential applications as a high-intensity proton driver and/or a rapid acceleration system for muons.

In the target area, we have carried out proton bombardment experiments at the AGS, using a specially constructed beam line funded by us, with candidate target materials including carbon rods and a mercury jet (see Fig. 2), and done irradiation studies on various target materials to look for changes in mechanical and physical properties. We are currently fabricating a 15-T test magnet to be used in the nTOF11 experiment at CERN (see Fig. 3). A closed-loop mercury-jet system for the nTOF11 experiment is also being designed and built by us.

For cooling R&D we have fabricated and tested two different styles (open-cell and pillbox) of 805-MHz normal conducting RF cavities, and have almost completed fabrication of a 201-MHz cavity (see Fig. 4) that will be tested in the newly constructed MUCOOL Test Area (MTA) at Fermilab, a facility constructed with NFMCC funds. The 201-MHz cavity will serve as a prototype for the cavities planned for use in MICE. We have also designed a liquid-hydrogen absorber in collaboration with colleagues at KEK, and have successfully test-filled it with liquid hydrogen in the MTA. In collaboration with colleagues at University of Oxford, we have developed very thin (125 μm) aluminum windows (see Fig. 5) suitable for containing the liquid hydrogen, and have verified finite-element analysis estimates of their strength.

<u>Selected Publications</u>:

N. Holtkamp and D. Finley, eds., "A Feasibility Study of a Neutrino Source Based on a Muon Storage Ring," Fermilab-Pub-00/108-E (2000), http://www.fnal.gov/projects/muon collider/nu-factory/nu-factory.html

S. Ozaki, R. Palmer, M. Zisman, and J. Gallardo, eds., "Feasibility Study-II of a Muon-Based Neutrino Source," BNL-52623 (2001). http://www.cap.bnl.gov/mumu/studyii/FS2-report.html

J. Gallardo, S. Geer, and M. Zisman, eds., "Report on Neutrino Factory and Beta Beam Experiments and Development," LBNL-55478 (2005). http://www.aps.org/neutrino/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=58766

M. Alsharo'a, et al., "Recent Progress in Neutrino Factory and Muon Collider Research within the Muon Collaboration," Phys. Rev. ST Accel. Beams, 6, 081001 (2003). http://prstab.aps.org/abstract/PRSTAB/v6/i8/e081001?qid=5c54379a8cd1be3b&qseq=2&show=10

MC notes listing: http://www-mucool.fnal.gov/notes/notes.html

MICE notes listing: http://mice.iit.edu/notes/notes.html

<u>Current Staff</u>:

Co-Spokespersons: Stephen Geer (FNAL); Robert Palmer (BNL)
Project Manager: Michael Zisman (LBNL)

Complete membership list: http://www.cap.bnl.gov/mumu/cgi-bin/membership.cgi

Contact Information:

Michael Zisman
MS 71R0259
Lawrence Berkeley National Laboratory
One Cyclotron Road
Berkeley, CA 94720
PHONE: 510-486-5765
FAX: 510-486-7981
Web: http://www.cap.bnl.gov/mumu/mu_home_page.html

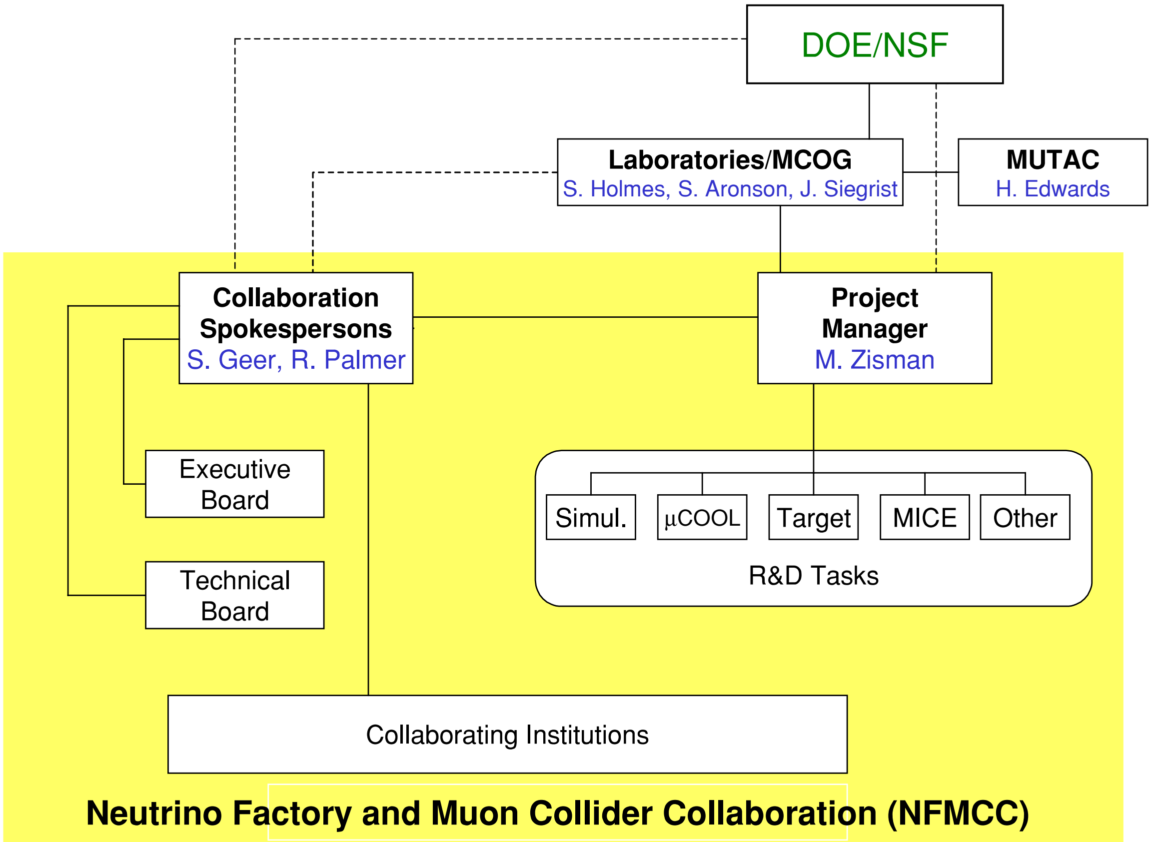

Fig. 1. Organization chart for NFMCC.

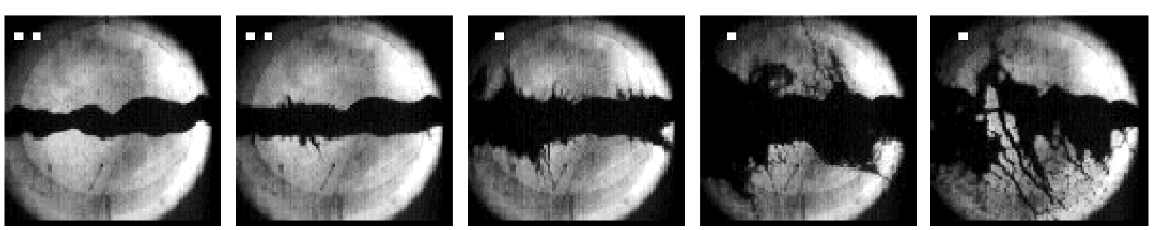

Fig. 2. (top) Mercury-jet apparatus under test at Princeton; (bottom) jet response to interaction with proton beam at AGS at t = 0, 0.75, 2, 7, and 18 ms.

Fig. 3. (left) Solenoid coils that will be nested to produce a 15 T field for the nTOF11 experiment; (right) cryostat into which the coils will be placed. The magnet operates at liquid-nitrogen temperature to reduce demands on the power supply.

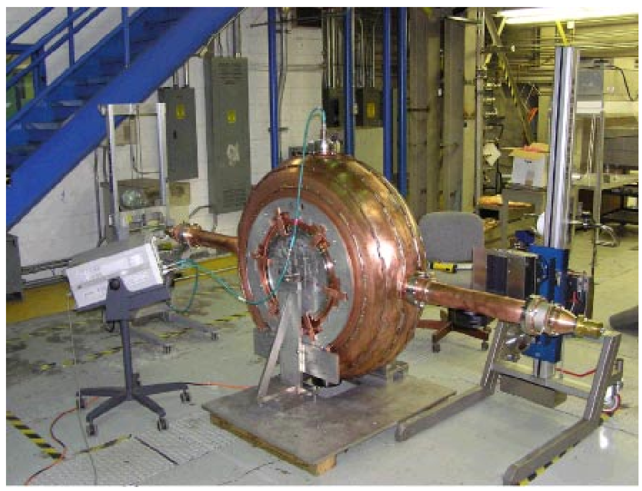

Fig. 4. Prototype 201-MHz RF cavity during low-power testing at Jlab.

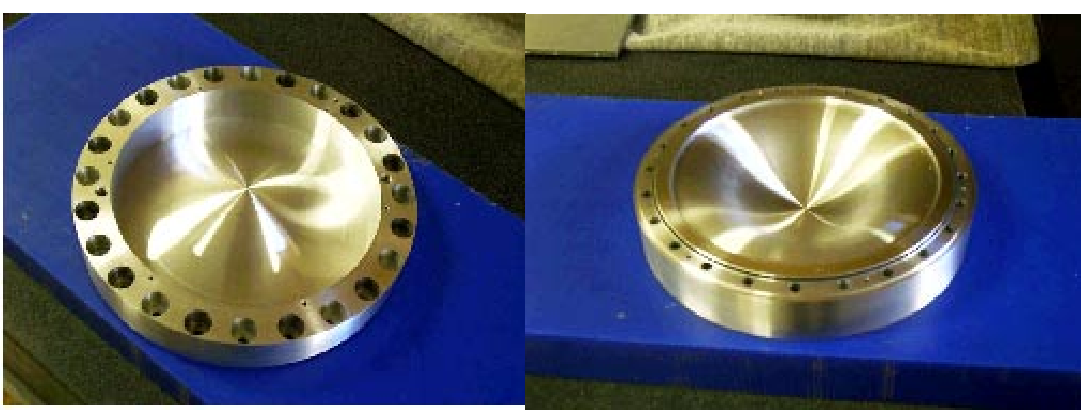

Fig. 5. Thin aluminum window for liquid-hydrogen absorber, fabricated at University of Mississippi. Both front view (left) and back view (right) are shown.