File

(8-89)
EFG (07-90)

United States Government **Department of Energy**

memorandum

DATE: MAR 0 5 1997

REPLY TO ATTN OF: ER-22

SUBJECT: Request for Approval of Justification of Mission Need for the NuMI Project: Neutrinos at the Main Injector at Fermilab, Critical Decision 1

TO: Martha A. Krebs, Director, Office of Energy Research

In accordance with the procedures of DOE Order 430.1, "Life-Cycle Asset Management" (LCAM), we are submitting for your approval the Justification of Mission Need (JMN) for the NuMI Project: Neutrinos at the Main Injector at Fermilab. Comments from other appropriate Energy Research organizational elements have been incorporated into the JMN.

If this JMN meets with your approval, please sign on the appropriate page and return the document to my office. Approval of the JMN constitutes Critial Decision 1 of the LCAM process.

John R. O'Fallon

John R. O'Fallon
Director
Division of High Energy Physics

Attachment

cc:
D. Lehman, ER-65
J. R. Clark, ER-60

OPTIONAL FORM 99 (7-90)

FAX TRANSMITTAL # of pages ▸ 8

To Ron Lutha	From Lowell Ely
Dept./Agency	Phone #
Fax #	Fax #

NSN 7540-01-317-7368 5099-101 GENERAL SERVICES ADMINISTRATION

*U.S.GOVERNMENT PRINTING OFFICE:1990-278-541

21

Justification of Mission Need
for the
NuMI Project: Neutrinos at the Main Injector at Fermilab

Division of High Energy Physics
Office of High Energy and Nuclear Physics
Office of Energy Research

A. Mission Need

1. High Energy Physics Program Mission

The mission of the Division of High Energy Physics (DHEP) is to support the Director of Energy Research in providing effective planning, funding, and management of the Department of Energy's (DOE) High Energy Physics (HEP) program. In doing so, the Division is a principal focus in carrying out the Department's role as the designated Executive agent for the United States HEP program. The mission of the HEP program is to understand the fundamental nature of matter and energy and the forces which govern their behavior. The specific purpose of this project is to measure the mass, if any, of the neutrinos.

2. Project Purpose

The Neutrinos at the Main Injector (NuMI) Project at Fermilab will provide the U.S. HEP program with a world-class facility for studying the physics of neutrino systems in general and, more specifically, addressing the fundamental question of whether or not neutrinos have mass.

Of all the quarks and leptons, only neutrinos have, as yet, no measurable mass. It is a complete mystery how such a particle could lack mass. Understanding this bizarre masslessness would be a window on the nature of matter.

In 1934, when only one kind of neutrino was hypothesized, Enrico Fermi showed that its mass must be either small or zero. Today it is known that there are three kinds, or "generations," of neutrinos: the electron neutrino, the muon neutrino, and the tau neutrino. For each generation, experiments have set an upper limit on the mass, but no experiment has been able to measure a definite non-zero mass. These are difficult measurements. Neutrinos interact so rarely that enormous numbers of them are needed to yield statistically useful data from traditional beam/target experiments. In fact, neutrinos are so elusive that, despite many efforts, it was 1955 before one was even detected, a feat for which Fred Reines of the University of California at Irvine won the 1995 Nobel Prize. Today, as in 1934, the neutrino masses are still "small or zero," and the traditional beam/target techniques for measuring neutrino masses have gone as far as they can go.

A new technique, involving a search for neutrino oscillations, has been proposed. The term "neutrino oscillation" refers to the ability of a neutrino to change its generation in flight. For example, a muon neutrino might change into an electron neutrino, and, later, into a tau neutrino. It is oscillating among different generations. Oscillations can occur in the neutrino system only if the neutrinos have masses. If the observed generation state is a superposition of those mass states, then different generation states will appear as the phases of the mass states evolve. This is a quantum mechanical phenomenon that is quite common. The neutrinos are said to mix, or to oscillate. The observation of any oscillation between any two generations is the most sensitive way known to observe small masses. Slower oscillations correspond to smaller masses, so it is important to have the baseline of the experiment as long as possible in order to see the smallest possible masses. This proposed experiment, with a baseline of 750 kilometers, is sensitive to mass differences down to one-tenth of an electron-volt.

Three additional points are worth mentioning. The first point concerns the enormous impact on the Standard Model that the experiment would have if it measured a non-zero mass for any of the neutrino generations. Neutrinos are unique in several ways. They are the only particles completely decoupled from both the electromagnetic force and the strong force. And, most peculiar, they have a "handedness." All neutrinos are left-handed, meaning that they spin clockwise about their direction of motion. No right-handed neutrinos have ever been observed. (This is parity violation; "right" and "left" are not subjective labels.) The origin of the handedness is not understood, but it is believed that only a massless object could exhibit such behavior. If the oscillation experiment were to measure a non-zero neutrino mass, an enormous edifice of theoretical structures would come crashing down. The ramifications would reverberate throughout the world of particle physics and the present understanding of matter and energy.

The second point worth mentioning is the existence of hints pointing toward a possible non-zero mass for neutrinos. Four different experiments have measured the neutrino flux from the sun. All of these experiments measure the flux to be between one-quarter and one-half of what is predicted by standard solar models. The principal theoretical explanation for this "solar neutrino deficit" requires that neutrinos have a small mass causing oscillations among the generations. There are other experiments which measure the numbers of muon neutrinos and electron neutrinos in the earth's atmosphere. Several of these experiments have measured the ratio of muon neutrinos to electron neutrinos to be lower than predicted. Again, the theoretical explanation is that neutrinos have a small mass and oscillate among the generations.

The third point is that the discovery of neutrino masses would have a big impact on cosmology and astrophysics. The "Big Bang" left behind a sea of relic neutrinos, of all three generations, much like the Cosmic Microwave Background Radiation. If these neutrinos have even small masses they would play much different, and generally more significant, roles in galaxy formation and closure of the universe. Neutrinos also play important roles in supernova explosions and other astrophysical phenomena.

3. Relation to Program Strategy

In January 1995, at the request of the Director of the Office of Energy Research, the High Energy Physics Advisory Panel (HEPAP) established the Subpanel on Accelerator-Based Neutrino Oscillation Experiments to evaluate the priority of such experiments in the context of the U.S. HEP Program. The Subpanel report, which was unanimously approved by HEPAP, recommended that "the search for neutrino oscillations with accelerator experiments, including a single long-baseline beam, should form an important segment of the U.S. HEP program." The report went on to recommend that "the Main Injector Neutrino Oscillation Search (MINOS) experiment at Fermilab should be supported; the E-889 experiment at Brookhaven should not be supported." The cover letter that transmitted the HEPAP report to the Director of the Office of Energy Research contained the following statement reflecting the HEPAP consensus:

> "We believe that the program of neutrino oscillations, to be carried out at Fermilab as recommended by the subpanel, is an important component of the future national program. The beam at Fermilab will be the most intense high energy neutrino beam in the world and will provide the greatest reach in the study of neutrino oscillations at accelerators. Discovery of neutrino oscillations accessible to accelerator experiments would revolutionize particle physics."

Fermilab is the site of the world's highest energy proton synchrotron, the Tevatron. The Main Injector is an accelerator which is replacing Fermilab's 25-year-old Main Ring as the intermediate stage in the accelerator complex. It is designed to accelerate protons or anti-protons from 8 GeV to 150 GeV. Construction is scheduled for completion in late 1998.

One of the purposes of the Main Injector was to provide a 120-GeV proton beam for a fixed target program operating independently of Tevatron operations. This plan envisioned a fixed target program of specialized beams, such as neutrino beams, Kaon beams, and photon beams. These specialized probes can provide insights at the frontiers of physics in ways that are not available in the proton-antiproton collider environment. From the beginning, the strategy behind the Main Injector included conceptually something like the NuMI Project as a component of the Main Injector's stand-alone fixed target experimental research program. (Note: the NuMI Project includes the MINOS experiment and the associated neutrino beam.)

4. Alternatives

The charge to the HEPAP Subpanel on Accelerator-Based Neutrino Oscillation Experiments asked it to review the status of ongoing and proposed oscillation experiments in the U.S. and abroad. At that time, DOE was looking at two major proposals to do neutrino oscillation experiments, one from Brookhaven National Laboratory and the other from Fermilab. The Subpanel studied eight different experiments and proposals, at both accelerators and reactors worldwide. The conclusion was that the MINOS experiment at Fermilab is the best way to search for neutrino oscillations.

B. Technical Objectives

The NuMI Project has two distinct components: the beamline, which is underground, and the MINOS experiment, which consists of two underground detectors, one in Minnesota and one at Fermilab. The technical objectives of the NuMI Project are to construct the new high flux beam of neutrinos (in the energy range of 1 to 40 GeV) and the two new detectors. The far detector will be located 700 meters underground in a mine, 730 kilometers from Fermilab. The mine, located in Soudan, Minnesota, is presently the home of an underground laboratory that contains a 1000-ton detector operating to measure the fluxes of ambient neutrinos and to search for evidence of proton decay. The near detector will be located on-site at Fermilab, at about 80 meters depth, at the end of the new beamline. The new beamline will be 900 meters long; it takes protons from the Main Injector and delivers neutrinos to the near detector and beyond to the far detector.

All of the technical objectives can be achieved using proven technology. For the detectors, the mechanical structures and the magnets are simple and conventional. The active elements, including the electronics, data acquisition, and gas systems, all follow designs that are known to work reliably. Neutrino beamlines similar to the one envisioned for this experiment have been built and operated at Fermilab before.

C. Schedule

The schedule objectives for the NuMI Project are summarized below:

FY 1997	Continue R&D and Conceptual Design Activities
FY 1998	Start Engineering and Detailed Design Activities
FY 1999	Start Construction Activities (Assumes FY 1999 Construction Funding)
FY 2002	Begin Operations

This schedule delivers the Project in as short a time as is technically feasible. This is manifestly the most cost-efficient way to proceed, no matter what the start date. The pay off from the quick start is in the substantial operational savings achieved by operating the NuMI program simultaneously with the Tevatron collider. The incremental operating costs of such synergistic operation would be basically only the electrical power costs. Operating the NuMI program when the collider is not in operation would cost considerably more. The collider will most likely operate for most of FY 2000 - 2004.

The initial MINOS experiment calls for 10^{21} protons from the Main Injector, which will take about two years of operation. If no positive oscillation signal is seen, that experiment will rule out the tentative oscillation signals that have been reported from studies of ambient neutrinos. If the MINOS experiment does see a positive signal, further operations will be requested.

D. Total Project Cost (TPC)

The preliminary TPC for the beamline and both detectors, including technical components, civil construction, project management, contingency and overhead, is about $120 million. The preliminary funding profile for this TPC extends over the 5 years FY 1998 - FY 2002. The preliminary TPC is based on the MINOS collaboration cost estimate for the NuMI Project, based on a "proof-of-principle" proposal, that was developed and delivered to the HEPAP subpanel that reviewed the two competing experimental proposals in the summer of 1995. In addition, a Cost Review Committee, under the direction of the ER Construction Management Support Division, conducted an independent evaluation of this cost estimate for the HEPAP Subpanel. The TPC for this project will be finalized after a project review in 1998.

Funding is being sought from the University of Minnesota and the State of Minnesota to expand the existing Soudan mine laboratory to accommodate the far detector. Minnesota has been a major supporter in the development of the existing laboratory at the Soudan mine. The possibly obtainable state contribution is estimated at $3.4 million. Also, it is quite likely that significant components of the 2 detectors will be built by foreign collaborators in Europe.

Incremental operating costs are not an issue with the NuMI Project. The DOE is constructing the Main Injector at Fermilab with the intention of operating a fixed-target experimental program simultaneously with the collider program. The MINOS experiment has been selected as the highest priority experiment to initiate this new mode of operation, and it will use the funds designated for operating the Main Injector fixed-target program.

E. Acquisition Strategy

Universities Research Association, Inc. (URA) will be responsible for accomplishing the NuMI construction project under the terms of its prime contract with DOE for the operation of Fermilab. The procurements and construction work will be accomplished to the extent feasible by fixed-price subcontractors selected by Fermilab on the basis of competitive bids.

F. Risk Assessment

The risk of failing to achieve the technical objectives of the NuMI Project is very low. This assessment is based on two considerations. One is the extensive success that Fermilab has had in designing and building neutrino beamlines similar to the one required by the NuMI Project. The other is the extensive success that collaborators in the MINOS collaboration have had in building and operating the neutrino detector that now exists in the Soudan mine in Minnesota. The HEPAP subpanel that reviewed the proposal in the summer of 1995 expressed high confidence that the technical and performance goals could be met. The risk of failing to achieve the cost and schedule objectives is also considered to be low based on extensive experience gained in the above mentioned activities. However, it should be mentioned that there is a small element of risk identified in that the state of Minnesota has agreed to provide a majority of the funding for expansion of the underground laboratory that is part of the Soudan Mine, and a formal agreement to this effect has not yet been finalized.

G. Preliminary NEPA Strategy

The Department will comply with the requirements of the National Environmental Policy Act (NEPA) and its implementing regulations (10 CFR 1021 and 40 CFR 1500-1508) prior to taking any action on the proposed project that would have adverse environmental effect or that would limit the choice of reasonable alternatives. In accordance with the June 1994 Secretarial Policy Statement on NEPA and the August 11, 1994, letter from DOE Assistant Secretary for Environment, Safety and Health Tara J. O'Toole (Delegation of Authority), the DOE Chicago Operations Office Manager has determined that an Environmental Assessment (EA) should be prepared for the proposed action. It was determined that the proposed action is encompassed with C11 of Appendix C to Subpart D of the Department of Energy NEPA regulations (10 CFR 1021) classes of actions that normally require EA's, but not necessarily Environmental Impact Statements (EIS's).

H. Project Organization

The Office of High Energy and Nuclear Physics in the Office of Energy Research has responsibility for the programmatic and technical overview of the project, and the Director of the DHEP will be the Headquarters Program Manager. The Area Manager of the on-site Fermi Group of CH will have primary responsibility to ensure that the project is properly managed by Fermilab and that its technical objectives are met within the baseline cost and schedule.

APPROVAL

This Justification of Mission Need for the NuMI Project is satisfactory, Critical Decision 1 (CD-1) is approved, and the project is recommended for inclusion in the DOE FY 1999 budget request for initial construction funding.

Submitted by:

John R. O'Fallon   2/24/97

John R. O'Fallon
Director
Division of High Energy Physics
Office of Energy Research

Date

S. Peter Rosen   3/4/97

S. Peter Rosen
Associate Director for
High Energy and Nuclear Physics
Office of Energy Research

Date

Approved by:

Martha Krebs   3/17/97

Martha A. Krebs
Director
Office of Energy Research

Date