MUON INTERACTIONS AT NAL

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ABSTRACT

The recommendations of the committee on muon interactions are summarized. The possible location of the beam is briefly discussed.

I. INTRODUCTION

During the first month of the 1969 Summer Study, a committee consisting of R. Hofstadter, L. Hand, T. Kirk, R. Sard, T. White, and the author reconsidered the question as to whether or not a muon beam was desirable at NAL and looked into the experimental justification for such a beam. A subsection of the group (T. Kirk, L. Hand, and the author) also looked into the ways that the muon beam might be incorporated into areas 1 and 2.

II. PREVIOUS WORK

During the course of the 1968 Summer Study, a great deal of work was done on possible muon experiments, and the following reports were written:

1.	B. 2-68-28	K. W. Lai	Some Speculative Muon Experiments
2.	B. 2-68-32	M. J. Tannenbaum	Muon Tridents at NAL
3.	B. 2-68-4	W. T. Toner	Feasibility of Using High Flux Muon Beam
4.	B. 2-68-38	T. Yamanouchi	A Muon Beam at NAL
5.	B. 2-68-47	M. L. Perl	Inelastic Muon + Proton Experiments at NAL
6.	B. 9-68-54	R. Wilson	Electromagnetic Physics at NAL
7.	B. 2-68-54	L. M. Lederman	Search for Intermediate Bosons Using Muons

In the course of these papers, the following experiments were proposed:

1. Muon Tridents
2. Inelastic Muon-Proton Scattering
3. Wide-Angle Muon Bremsstrahlung

4. Muon-Electron Scattering
5. Muon-Electron Exchange Scattering
6. Muon-Electron Production of Vector Mesons
7. Muon Production of Intermediate Bosons
8. Search for Heavy μ-Type Leptons

III. PRESENT CONSIDERATIONS

The committee reconsidered these experiments in the light of our present knowledge and in the light of what we expect to learn from existing accelerators in the next few years. It was the conclusion of the committee that it was very important to have a muon beam at NAL and that one could do experiments with the muon beam that would be at least as significant as the currently proposed hadron experiments. The committee felt that the following should be first generation experiments:

1. Muon Search for the Intermediate Boson
2. Study of the Deep Inelastic Form Factor for Muon-Proton Scattering as a Function of Energy Loss and q^2
3. Search for Anamolies in the Muon Energy Loss and for Heavy Muons
4. Study of μ - e Universality

The importance of the deep inelastic muon-proton scattering has only become apparent since the 1968 NAL Summer Study. The SLAC data reported at the Vienna Conference indicates that the W_2 form factor for inelastic electron-proton scattering has, for large energy losses, a much weaker q^2 dependence than the form factors for elastic scattering and for the production of resonances. One of the major problems of photon physics is to understand this behavior. With the muons available at NAL, one can extend these measurements to energies and q^2's which will not be available at SLAC unless they increase the SLAC energy to 100 BeV. In addition, because of the good duty cycle available at NAL, one can study the particles produced by the virtual photon and determine the form-factor behavior for some of the channels. Because of the low duty cycle, these experiments are not feasible at SLAC. In a separate report, L. Hand has designed an experiment for making these measurements.[1] This is clearly a first-generation experiment.

The second important experiment is to use muons to search for the intermediate boson. With a properly designed beam, one can obtain a greater flux of high-energy muons than high-energy neutrinos. Thus, muons can be used to search for the coherent production of very high mass intermediate bosons. T. Kirk has re-examined this experiment and has developed a total-absorption method for using high-energy muons to search for W mesons. This experiment is reported elsewhere in these proceedings.[2] During the course of this re-analyzing of the muon experiment, it was realized that the muons that come from the forward decay of pions have the wrong helicity to produce W's. This follows from the fact that the normal pion and kaon decay into muon plus neutrino is helicity-forbidden. One must use the μ's that come from the backward decay of the pion. This must be taken into account in the beam design if one is to make a muon W search. Elsewhere in these proceedings, there is a note by Kirk et al., concerning the muon polarization.[3]

The other two experiments are concerned with the possible detection of a difference between the electron and the muon or the discovery of heavy muons. These are important questions which must be asked whenever possible. The other source of information concerning this is the storage-ring experiments on e^+e^- collisions and e^+e^- production of muons. These experiments and the other electrodynamic experiments should be re-examined when the results from the storage-ring experiments become available.

IV. THE BEAM

For the muon experiments, one wants a beam with 10^7 muons/sec at 100 GeV with as small a diameter as possible. One also wants as good a duty cycle as possible. If the same pion source is to be used to make a high-pass neutrino beam, then it is desirable to collect as many kaons and pions as is feasible.

It developed during the course of the summer study that there was a problem with fitting the muon beam into area two. In order to make a high-intensity muon beam, one must first obtain a high-intensity pion beam and then let the pions decay. The design of the muon beam and the problem of containing the muons has been extensively studied and the results have been reported.[4-6] The best arrangement is a system of quadrupoles in an FODO configuration. One such beam was designed by Toohig. A modification of this beam is given by Yamonouchi in the 1968 NAL Summer Study. Either of these beams is adequate for the proposed muon experiments.

The fact that the front end of the muon beam must have a large solid-angle acceptance for 0° pions makes it incompatible with the hadron beams designed for area 2. A more natural place to locate the muon beam is in area 1. Area 1 is now being used only for the neutrino beam. This is wasteful and is an inefficient use of a very expensive undergound gallery. L. Hand, T. Kirk, D. Berley, D. Frisch, and the author have studied various ways in which one could bring out a muon beam in area 1. The best way is to put a second target in the gallery and to use a bending magnet to bring out a 0° high-intensity pion beam which after bending makes an angle of roughly 30 mrad with respect to the incident proton beam. This would then bring the muon beam out into an area adjacent to the neutrino shielding. It would provide both a muon beam and a second neutrino beam which could be a tagged neutrino beam. Figure 1(a) shows a general layout for this beam. In a separate report L. Hand has given a more detailed description of this beam.[7]

The second method for obtaining a muon beam [Fig. 1(b)] is to put a quadrupole system in front of the horn and to bring the muon beam out along the same beam line as the bubble-chamber neutrino beam. Then just in front of the muon shielding, the muon beam would be bent so as to emerge beside the neutrino iron shield. This beam could not be run simultaneously with the bubble-chamber beam and it would require a great deal of work to transform it into a tagged neutrino beam. A separate report by T. Kirk gives a more complete description of this beam.[5]

SUMMARY

It is clearly important to obtain a muon beam at NAL, and it should be made available soon after turn-on. The most logical place to put the beam is in area 1. Every effort should be made to obtain a beam in this area. This will require some modification of the present beam 1 plan.

REFERENCES

[1] L. N. Hand, Large Momentum Transfer Muon and Electron Scattering at NAL, National Accelerator Laboratory 1969 Summer Study Report SS-48, Vol. IV.

[2] T. Kirk, A Search for the W Boson with High Energy Muons, National Accelerator Laboratory 1969 Summer Study Report SS-11, Vol. IV.

[3] T. Kirk, F. Pipkin, and J. Sculli, Polarization Effects in Muon Production of W's, National Accelerator Laboratory 1969 Summer Study Report SS-34, Vol. IV.

[4] T. E. Toohig, Parameters of a Muon Facility at the 200-BeV Accelerator, Lawrence Radiation Laboratory UCID-10180, Feb. 25, 1966.

[5] D. D. Jovanovic, The Neutrino-Muon Facility at the 200-BeV Accelerator, Lawrence Radiation Laboratory UCRL-16830.

[6] T. Yamanouchi, A Muon Beam at NAL, National Accelerator Laboratory 1968 Summer Study Report B.2-68-38, Vol. II, p. 1.

[7] L. N. Hand, A Study of 40-90 GeV Neutrino Interactions Using a Tagged Neutrino Beam, National Accelerator Laboratory 1969 Summer Study Report SS-151, Vol. I.

[8] T. Kirk, Long Spill Muon and Neutrino Beams in Area 1, National Accelerator Laboratory 1969 Summer Study Report SS-43, Vol. I.

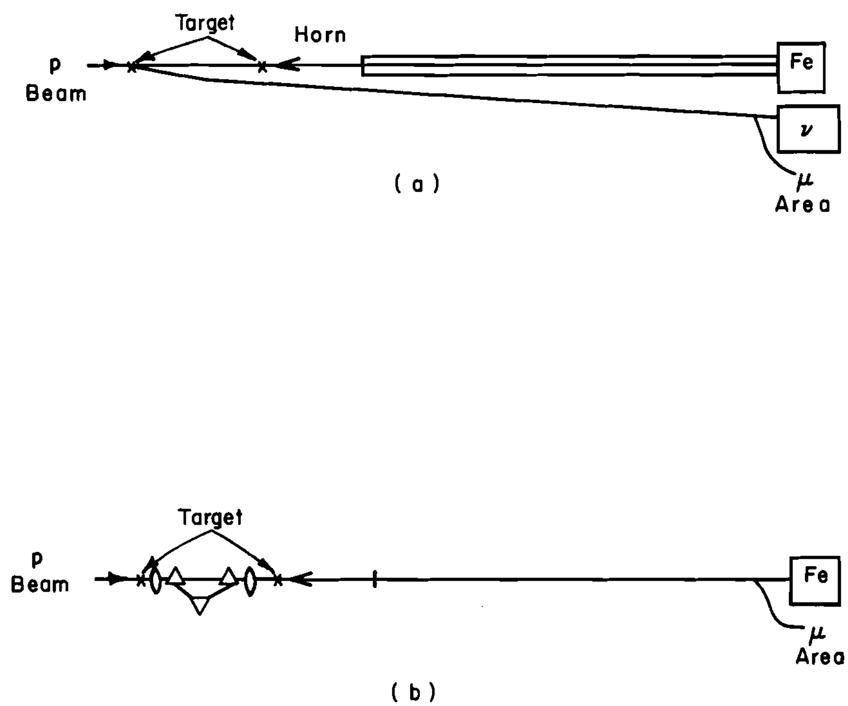

Fig. 1. (a) Proposed muon beam using a transmission target and a modification of the Yamanouchi beam. (b) Proposed muon beam using the same beam line as the 25-ft bubble-chamber neutrino beam.