The early muon scattering experiments at NAL were planned to utilize low intensity, moderate energy muon beams. It was recognized, however, that beams of higher intensity and energy would soon be necessary for the future of muon physics. Recent experience with the first muon beam at NAL has also indicated the need for control of the various muon beam properties that is independent of other beams in the same experimental area. This is required to reach high values of muon production per proton at the highest energies, and to minimize halo and background.

Accordingly, possible improvements of the muon experimental area were considered during the 1973 NAL Summer Study. These have led to the discussion and recommendations that follow.

Recommendation 1

The present muon beam should be upgraded to the extent possible before longer range plans can be implemented. It will be useful to evaluate at least the following non-exclusive possibilities for higher intensity and improved beam optics:

(i) a quadrupole triplet front end

(ii) additional quadrupoles in the hadron decay pipe

(iii) the construction of a direct beam line from enclosure 106 to enclosure 104 as discussed by L. N. Hand in SS-73/233.

Experience with a muon beam at NAL thus far has indicated that compatibility with neutrino beams, although superficially attractive, is illusory. Failure to achieve compatibility in turn leads to wastage of protons and compromised experimental running conditions. Hence
Recommendation 2

Any new improved muon beam should be able to operate at the same time (but probably not during the same beam spill time) as the neutrino beam. An appreciable investment has already been made in facilities and experimental equipment in the present muon laboratory. To relocate that laboratory would be quite expensive in time and money. Moreover, increasing interest in muon physics (see report SS-73/218 by R. Wilson) suggest that the original investment in the muon laboratory will continue to be exploited in the foreseeable future.

It seems therefore that the muon laboratory should be supplied with a high quality, high intensity muon beam capable of being used for a wide variety of experiments. Several possibilities exist for such a beam that would provide for optimization of the parameters and simultaneous running with the neutrino beam, and would also efficiently utilize existing construction.

One attractive suggestion is to split the proton beam to the neutrino area far enough upstream to allow a separate branch of the proton beam to move along a line parallel to but displaced westward from the parent proton beam to the neutrino area. The secondary hadrons and muons produced by the collision of those protons with a heavy target would be carried by an appropriate channel to the muon laboratory. A possible front end of this beam, i.e., the proton split, is discussed in detail in this study (SS-73/243) by L. C. Teng.

There are many approaches to a muon channel which would follow the proton source described by Teng and which would lead to a high quality muon beam in the present muon laboratory. Some of these have been discussed in separate reports by L. N. Hand (SS-73/233), L. W. Mo and A. Skuja (SS-73/209) and T. B. Kirk (SS-73/250), and others exist in earlier literature on the subject. Here it is sufficient to state the more important aspects of such a channel in the form of the following recommendation.

Recommendation 3

It is desirable to design and construct a new high quality muon beam for the present muon laboratory in the near future. The beam should comply with Recommendation 2 above, presumably by having a source of protons separate from the protons for neutrino beams. Consideration should be given to the following specifications of beam properties:

(i) efficient use of protons by achieving a muon yield of order of $10^{-5}$ muon/proton, and thereby a muon flux in the region of $10^7$ - $10^8$ per pulse. This needs to be achieved at $E_\mu = 1/2 E_p$.

(ii) small spot size, i.e., $< 5$ in. square

(iii) low halo, i.e., $< 10^6$/pulse outside central spot

(iv) energy variable from about 50 GeV to about $3/4 E_p$

(v) capability of using incident protons of energy 1 TeV to provide muons of about 0.5 TeV.

It is possible that the construction of a high quality beam for the present muon area may be difficult to implement rapidly for reasons not directly associated with that beam, e.g., interference with other experimental areas or facilities. In that event serious consideration might be given to a muon beam of similar properties in another experimental area, in spite of the disadvantages in relocating the present muon experimental facilities.
Interest in muon physics and the diversity of experiments that become feasible with increased intensity and energy suggest that a second muon beam, probably with different properties, would be of value. In particular, a broad band beam with large Δp/p and very high intensity might make possible certain particle production experiments with muons. Thus we are led to the final recommendation of this report.

**Recommendation 4**

Independently of Recommendation 3 consideration should be given to the construction of a second muon beam in an experimental area other than the present muon area. This might be, for example, in the proton area. A possible design for a high intensity, broad band beam using toroidal magnets is discussed in this study by M. Strovink (SS-73/215). This beam, which might be built in conjunction with a high intensity charged pion beam, would provide additional necessary flexibility for muon physics at NAL.