NEUTRINOS AND MUONS IN AREA 1

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ABSTRACT

Possible expansion of experimental-area 1 to obtain greater utility and flexibility is considered. Neutrino experiments might be performed with spark chambers in that area near the anticipated location of the 25-foot bubble chamber using either a neutrino beam with pulsed magnetic horn focusing or a beam with dc focusing elements generated in a target upstream of the horn target. Muon experiments might be performed with a narrow band ($\Delta p/p \sim 0.1$) muon beam obtained from either a separate target or the same target as the dc focused neutrino beam. A muon channel separate from the highest intensity neutrino beam channel will make available a second high-energy neutrino beam capable of being tagged.

I. IMPROVED UTILITY OF AREA 1

We are of the opinion that a major increase in the utility and flexibility of area 1 can be achieved if consideration is given to the following possibilities:

1. Neutrino experiments--e.g., W- and other particle searches and cross-section measurements--may be performed with spark chambers in an area near that planned for the 25-foot bubble chamber, using either the neutrino beam with pulsed magnetic horn focusing or a beam generated in a target upstream of the horn target with dc focusing elements such as quadrupole magnets or a fresnel lens.

2. Muon experiments--e.g., W- and other particle searches and deep inelastic scattering--may be performed with a narrow band ($\Delta p/p \sim 0.1$) muon beam obtained either from a separate target or from the same target as the dc focused neutrino beam.

3. (a) The muon channel might proceed independently of the neutrino beam channel mentioned in 1 above, in which case a second high-energy neutrino beam

suitable for spark-chamber experiments and capable of being tagged becomes available. This neutrino beam will be several times lower in intensity than the beam described in item 1; this is desirable for ν tagging but not for neutrino experiments in which intensity is at a premium. The parent hadrons for this beam would be generated in the target upstream of the horn target, deflected to one side by an achromatic transport system and allowed to pass through a 500-meter decay tunnel. At the end of this tunnel the hadrons strike a Be hadron shield and the decay muons are deflected to one side, selected in momentum and passed into an experimental area which we envisage as about 20 m wide by 100 m long. Neutrino experiments in this beam would share this area.

(b) Alternatively, the hadron drift space for the muon beam might proceed along the same channel as the high-intensity neutrino beam and be diverted to a muon experimental area before it reaches the main muon shield.

An additional rf separated beam can be accommodated from the same upstream target as the muon-tagged neutrino beam and run simultaneously. (See report on this beam by D. Berley and H. Foelsche.[1])

It is premature to attempt to choose definitively among these possibilities, but we wish here to delineate the alternatives as explicity as possible. The major decision is whether to use a decay channel and muon shield in common with that for the high-intensity, broad-barrel neutrino beam. Initially, this appeared to us to be an attractive scheme and a detailed discussion has been made (see report by T. Kirk[2]). However, the cost saved by using the same tunnel and shield is to be weighed against the following disadvantages:

1. Time Sharing of beam (b) with the bubble chamber and/or spark chambers in the horn-focused beam appears to be impossible. The chief difficulty is caused by the restricted aperture for the quadrupoles and the large size of the horn beam. It appears that the horn must be physically removed to permit the slow-spill muon-neutrino beam, reducing the order of compatibility. This requirement becomes even more evident when one considers the tagging of neutrinos and the necessary absence in this case of a hadron halo.

2. Without delving into the complicated question of whether a magnetic shield would be suitable for bubble-chamber neutrino experiments, we believe such a shield as described by March[3] in this summer study would be adequate for spark-chamber experiments, thus reducing drastically the shielding cost and the need for sharing with the bubble chamber.

3. Access to the decay tunnel seems to be highly desirable for the MNB (muon-neutrino beam). Neutrino tagging will almost certainly be tried in the early stages;

one scheme involves filling the decay tunnel with water (except for the beam volume) to range out the K-decay muons. We prefer not to rely on a schedule in which the beam comes on two years before the 25-foot chamber since this interval is computed as the difference of several numbers having large uncertainties. Horn testing and spark-chamber experiments using the horn neutrinos will undoubtedly proceed at an earlier date in any case.

II. ALTERNATIVE PROCEDURES

Even if the additional muon and neutrino physics justifies a separate beam line in Area 1, as we believe it does, there are still a number of alternatives which we list here:

1. Hadron Decay Tunnel - Should NAL build a tunnel large compared with the beam size, to permit the later insertion of tagging counters and/or quadrupoles, or a cheaper tunnel essentially identical to the hadron beam size? We think that a cheap tunnel which is essentially a deep trench would be quite adequate in this case. Tagging in this latter tunnel would be achieved by sinking ~50 shafts from the surface or by digging a parallel slit trench which allows access to the decay tunnel. Wilson has suggested the tunnel might be filled with water which could be pumped out when tagging is attempted. We feel it is probably too soon to make this decision (to tag or not to tag). If the initial target, quadrupoles and bends for MNB are installed at the outset, the tagging might be tested (or at least the stray muon and hadron flux measured) before the final decay tunnel construction. In particular, if the tunnel is made by the cheap method of cut and fill, tests could be made before the fill is carried out. We emphasize here that at no time do the primary protons pass along this beam line, thus reducing the shielding and radioactivity considerably below that of the horn decay tunnel.

2. Another suggestion is to bend the beam at an upward angle (10 mrad) in order to emerge at the surface 600 meters away. This avoids the need for excavation of the experimental areas. For discussion purposes, we assume a beam deflected horizontally by 60 mrad and vertically by 10 mrad. The neutrino beam rises 10 cm every 10 meters and of course the muon beam can be straightened out to the horizontal if necessary. A concrete pad for the experimental area with a 1% grade is probably the easiest solution.

Figure 1 shows the MNB configuration using the separate beam line and its relation to the presently planned horn-beam tunnel and bubble-chamber experimental area. Figure 2 shows the "dog-leg" configuration which might be used if a decision is made by NAL to combine the beam lines.

We feel that a separate beam would add considerably to the utility of area 1 and substantially increase the output of neutrino and muon physics from NAL. It is our recommendation that sharing of the beam line with the horn beam be adopted only as a last resort, dictated by economics and possible delays in the bubble-chamber schedule. The economic advantages of a shared beam line may be only an illusion which disappears when the actual running compatibility is considered. However, this would be preferable to having no muon beam available for several years.

III. USE OF OTHER AREAS

The question arises: Why can't a suitable muon beam be built in area 2 or area 3? Use of these areas implies:

1. Competition for beam time with a much larger universe of users with primary interest in hadron physics.

2. Loss of a factor 8-10 in possible solid angle and hence beam intensity. Many significant muon experiments will be able to use the full 10^7 muons/burst; 10^6 muons/burst is a parasitic intensity in the area 1 beam, but requires prime use of the 3.5 mrad beam in area 2.

3. Construction of a long decay path is always required and the necessary 500 meters is not available in area 2. Collimators and shielding must be supplied for this beam.

4. Area 3 would immediately lose much of its anticipated flexibility if a 30 μsr beam was installed at 0°. (Area 2 has difficulty fitting in a 2 μsr and a 3.8 μsr beam at 2.5 and 3.5 mrad respectively.) If separate targets were used, then of course one is back substantially to the proposal for area 1 but several years later. Such a delay can only be ruled out by a high theoretical priority for the muon and neutrino physics made possible by the beams discussed above.

Finally, in conclusion, we wish to emphasize our recommendation that the minimum change in the Nezrick proposal be the inclusion of spark-chamber areas for neutrino work both after the iron shield and beyond the bubble chamber. We fully expect several W searches will be carried out here and other spark-chamber neutrino experiments as well.

Detailed reports dealing with some specific issues raised are listed in Refs. 1-6 below.

REFERENCES

[1] H. Foelsche, A Normal RF Separator With 33% Duty Cycle, National Accelerator Laboratory 1969 Summer Study Report SS-13, Vol. I; RF Separated Beam of Long Cycle, National Accelerator Laboratory 1969 Summer Study Report SS-26, Vol. I.

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

[3] R. H. March, Magnetized Iron Muon Shields, National Accelerator Laboratory 1969 Summer Study Report SS-8, Vol. I.

[4] D. Berley and L. Hand, Secondary Beam for Muons and Neutrinos for Area I, National Accelerator Laboratory 1969 Summer Study Report SS-51, Vol. I.

[5] R. H. March and D. Frisch, Problems of Magnetic Shielding for Neutrino Beams Requiring Detailed Study, National Accelerator Laboratory 1969 Summer Study Report SS-27, Vol. I.

[6] Y. W. Kang, The Muon Shielding In The Neutrino Beam Design, National Accelerator Laboratory 1969 Summer Study Report SS-156, Vol. I.

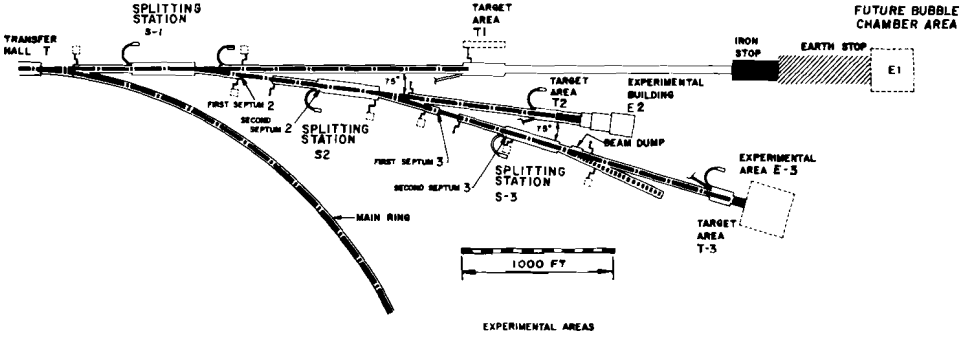

Fig. 1. Plan view of experimental area. Muon-neutrino beam to be added at target-area T1 (see Fig. 2).

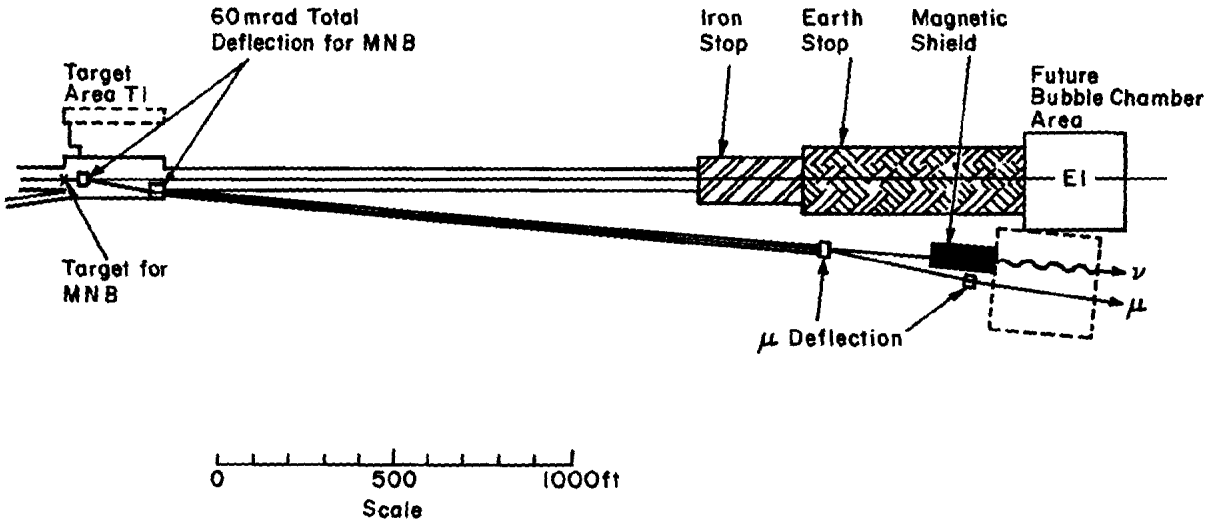

Fig. 2. Proposed addition of muon-neutrino beam in area 1.