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NEUTRINO BEAM DUMP EXPERIMENT AND A POSSIBLE ELECTRON NEUTRINO BEAM IN THE NEUTRINO AREA

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A study of the prompt production of leptons in hadron interactions[1] involves several special experimental problems: The signal is small when compared to lepton production from the decay of charged mesons. (Typically, one hopes to place the detector very close to a beam dump but then muon and hadron backgrounds can be intolerable.) Because the signal is small, its origin (prompt or decay) can be difficult to establish. Recent neutrino beam dump experiments done at CERN[2] show a substantial signal of prompt neutrino production and imply a 100μb cross section for charmed meson production. These experiments, however, do not unambiguously demonstrate that the origin of the signal is the beam dump (there was no attempt made to vary target density, for example). Furthermore, to substantiate the hypothesis that prompt neutrinos originate in the decay of charmed mesons would require a study of the p_T dependence of prompt neutrino production. Again, this was not done in the CERN experiments. A survey of possible neutrino beam dump areas within the neutrino area was made to study the feasibility of these experiments at Fermilab.

Guided by the needs to minimize costs, minimize the lead time for installation and to maximize the solid angle acceptance of the detector, we have found several locations in the neutrino area that meet these requirements. We shall, in this article, summarize our findings for beam dump locations in the neutrino area, and in particular, we will consider Neuhall and the target tube, enclosure 100, enclosure 102 and enclosure 109 for a detector located in the bubble chamber area and in the region of the Wonder Building. Figure 1 shows a physical layout of the neutrino area and the buildings studied.

Several factors must be considered in locating a beam dump and its detector. The solid angle acceptance of the detector relative to the dump should be maximized. (Table I gives the solid angle acceptance for two detector locations relative to four beam dump locations. The acceptances are normalized to units of one for the acceptance of the 15-foot chamber for a beam dump in the target tube.) However, this requires that the detector be located close to the dump, and exacerbates the muon shielding problems and the cost of the installation. For a beam dump located in the target tube or enclosure 100, the costs and the lead time for installation are minimal. However, if we put the dump into enclosure 109, the cost increases by over an order of magnitude.

Active muon shielding will be required if the beam dump is located in either enclosure 102 or 109. The available soil shielding between 102 and the Wonder Building is sufficient to range out 80 GeV muons, and between 109 and the bubble chamber the soil is sufficient to range out 70 GeV muons. However, the source of muons in the dump is well localized and magnetized iron can be used effectively to shield them out. A possible configuration shown in Figure 2 uses a dipole and toroid. The dipole separates μ^+ from μ^-, and the toroid dumps each component into the ground. The configuration shown will provide a relatively muon free region to 4 1/2 feet below beam axis at the detector. The cost of the magnets will be about $150,000.

Current guidelines for radiation safety demand that radiation levels outside enclosures should not exceed 100 mrem on any single pulse[3]. Given this restriction, additional shielding would have to be added to the berm if the dump were to be placed in enclosure 109. Beam line enclosures 105, 106, 107 and 109 would have to be re-enforced to allow earth berm to be piled on top of them. The cost of berm, and construction for enclosures would be about $235,000. If the beam dump were located in enclosure 102, some improvement would be required to enclosures 100, 101 and 102 to moderate leakage through the existing entryways. An only minimal cost would be incurred for these modifications.

A study of the p_T dependence of prompt neutrino production would require the existence of a large bend immediately upstream of the beam-dump This would be the simplest requirement to fulfill, since enclosure 100, 102, and 109 already have large bends in their existing beam lines. It would be most difficult to obtain a large bend angle in neuhall. With the installation of more magnets, a ten mrad bend could be achieved.

A further requirement placed on the beam dump location is that it allow the detector to be isolated from upstream decays. If the detector cannot be so isolated, the signal might be dominated by the decay of charged mesons generated upstream of the beam dump. Only for a detector located in the muon laboratory, and a beam dump in the enclosure 100 or enclosure 102, does such isolation exist in any of the areas. It would be possible to configure such an arrangement in Neuhall, but only with a rearrangement of magnets. The bubble chamber will always look at the primary beam as it traverses the decay pipe and cannot be isolated from upstream decays unless the beam dump is located in the target tube. The conclusions are summarized in Table II.

It is apparent that each of the locations considered has some virtues as well as problems with regard to a beam dump experiment. The ultimate choice of location and detector would depend on the goals of the experiment and the level of funding set aside to implement it.

If the production cross section for charmed mesons is indeed about 100 μb for the incident proton energy of 400 GeV, electron neutrinos and antineutrinos from the charmed meson decays can be used as an electron neutrino (or antineutrino) beam. Figure 3 shows electron neutrino and antineutrino fluxes at the 15-Ft. Bubble Chamber from the K_L^0 decay for the ordinary decay pipe arrangement[4] and from the D(1.86) decay in the Enclosure 109 beam dump[5]. Electron neutrino energy distributions from the D decay and the form of production cross section of D's were taken from I. Hinchliffe - C. H. L. Smith[6]. We assumed that the cross sections of the D and $\bar{D}$ are identical and that $\sigma \cdot B$ = 10 μb. The A dependence of D production was assumed to be the same as that of the total inelastic proton-nucleon cross section of 33 mb. The electron neutrino beam derived from D decay would contain the same number of muon and electron neutrinos. As discussed in Reference[5], contributions of electron and muon neutrinos (and antineutrinos) from pion and kaon decays in the dump depends strongly upon the targetting angle of the incident proton at the dump. The electron neutrino and antineutrino fluxes from the charmed meson decay decrease much more slowly with p_T when compared to those from the pion and kaon decays. Therefore, by optimizing the targetting angle an electron neutrino beam of roughly 50% purity with reasonable intensity can be achieved for the beam dump arrangement.

REFERENCES

1. The experimental situation of the prompt production of charged leptons was reviewed by J. W. Cronin, Proceedings of the 1977 International Symposium on Lepton and Photon Interactions at High Energies, Hamburg, 1977, page 579.

2. T. Hansl et al, Phys. Lett. 74B, 139 (1978), P. Alibran et al, Phys. Lett. 74B, 134 (1978), and P. C. Bosetti et al, Phys. Lett. 74B, 143 (1978).

3. L. Coulson, private communication.

4. S. Mori, S. Pruss, and R. Stefanski, TM-725, 1977, and S. Mori, TM-769, 1978.

5. S. Mori, TM-774, 1978.

6. I. Hinchliffe and C. H. Llewellyn Smith, Nucl. Phys. B114, 45 (1976).

Table I

Relative Detector Acceptance for
Various Beam Dump Locations

	Beam Dump Locations			
Detector Location	Target Tube	Enclosure 100	Enclosure 102	Enclosure 109
Wonder Building	2.2	6.6	33	N.M.[+]
15-Ft. Bubble Chamber	1	2	4	30
Cost of Installation	$30K	$40K	$225K	$400K
Maximum bend angle available at 400 GeV (existing magnets)	7 mrad	27 mrad	27 mrad	37 mrad

[+]Not Meaningful, the Wonder Building is upstream of Enclosure 109.

Table II

Detector Can Be Isolated
From Upstream Decays

Beam Dump Locations

Detector Location	Target Tube	Enclosure 100	Enclosure 102	Enclosure 109
Muon Lab	Yes*	Yes	Yes	N.M.+
Wonder Building	Yes*	No	No	N.M.+
15-Ft. Bubble Chamber	Yes*	No	No	No

*Requires a rearrangement of magnets in Neuhall.

+Not Meaningful - the Muon Lab and Wonder Building are upstream of Enclosure 109.

SCHEMATIC LAYOUT OF THE NEUTRINO AREA

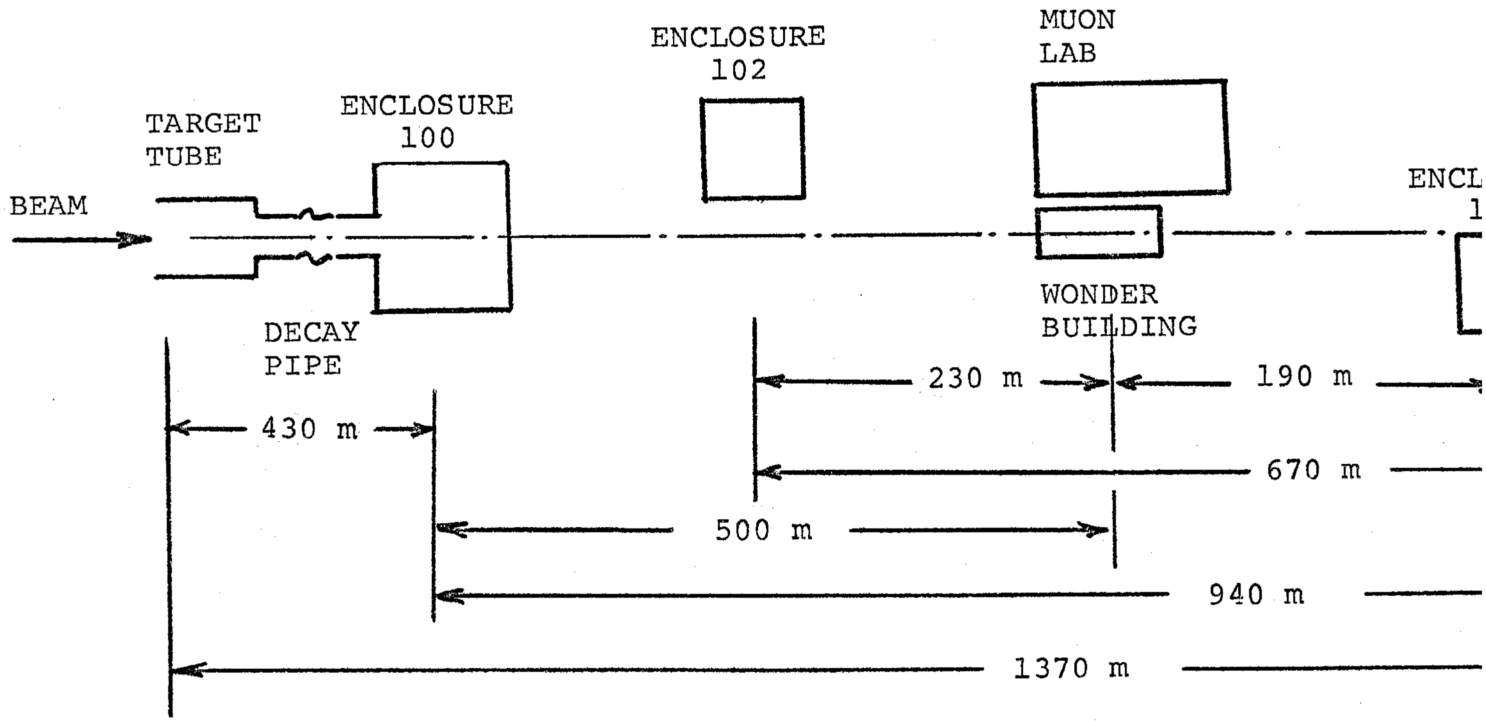


Figure 1

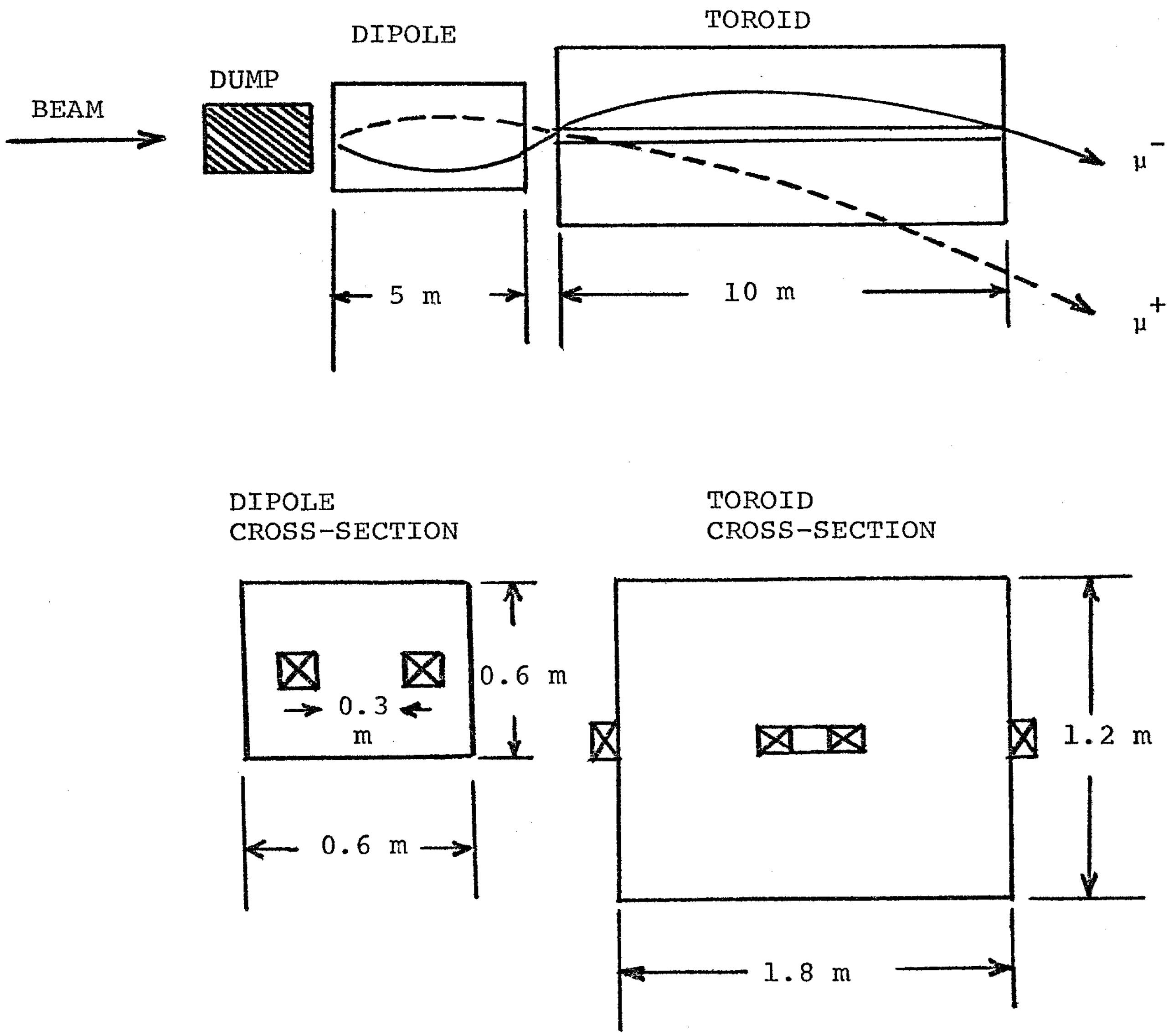
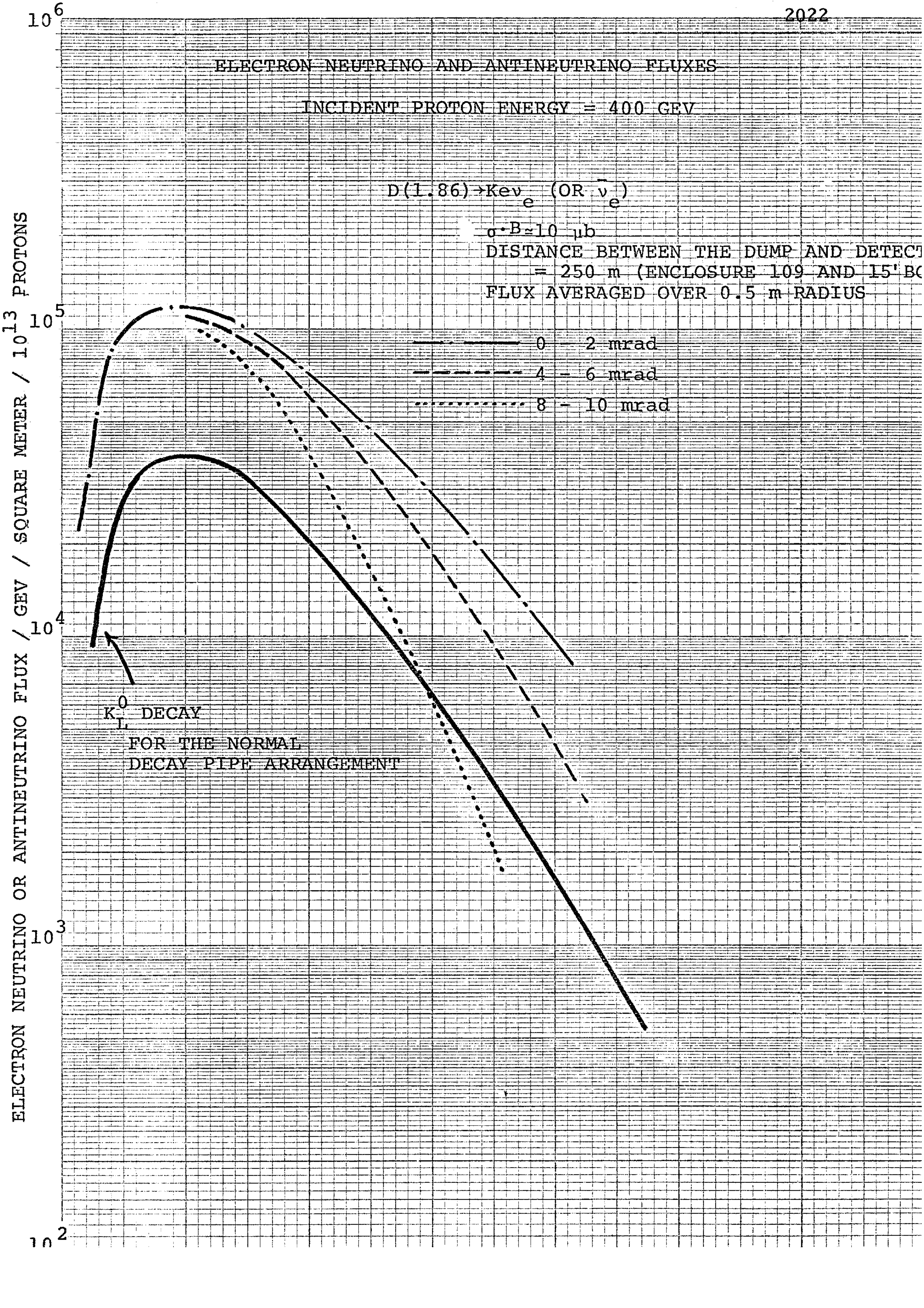

DIPOLE
TOROID
DUMP
BEAM
μ^-
μ^+
5 m
10 m
DIPOLE
CROSS-SECTION
TOROID
CROSS-SECTION
0.6 m
0.3
m
0.6 m
1.2 m
1.8 m

Figure 2


ELECTRON NEUTRINO AND ANTINEUTRINO FLUXES
INCIDENT PROTON ENERGY = 400 GEV
D(1.86) → Keν$_e$ (OR $\bar{\nu}_e$)
σ·B ≈ 10 μb
DISTANCE BETWEEN THE DUMP AND DETECT
= 250 m (ENCLOSURE 109 AND 15' BC
FLUX AVERAGED OVER 0.5 m RADIUS
0 - 2 mrad
4 - 6 mrad
8 - 10 mrad
K_L^0 DECAY
FOR THE NORMAL
DECAY PIPE ARRANGEMENT
ELECTRON NEUTRINO OR ANTINEUTRINO FLUX / GEV / SQUARE METER / 10^{13} PROTONS
10^6
10^5
10^4
10^3
10^2