

**Fermilab**DO WE NEED A HORN FOR TEVATRON NEUTRINO PHYSICS?

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INTRODUCTION

In the 1976 Summer Study Report C. Baltay et al. discussed various broad-band neutrino beams for 1,000 GeV protons.¹ In this report I will compare neutrino and antineutrino fluxes for the single horn system² with those for the modified quadrupole triplet beam³ and for the sign-selected bare-target (SSBT) beam.⁴ It should be noted that for 1,000 GeV proton, neutrino and antineutrino fluxes for the single horn system and the old double horn system become essentially identical except for a very low energy range, below 30 GeV.⁵

Neutrino and antineutrino fluxes and wrong sign backgrounds were computed by the Fermilab CDC computer NUADA program⁶ for a detector radius of 1 meter at the 15' Bubble Chamber. The incident proton energy was 1,000 GeV. Stefanski-White's parametrization⁷ was used for particle production throughout the present study.

II. SINGLE HORN SYSTEM²

Computed neutrino and antineutrino fluxes for the single horn system are shown in Figure 1. The horn excitation current was set to the design value, 140 kA. An antineutrino plug was not used. The spectra are strongly peaked below 50 GeV and are possibly disadvantageous in studying neutrino interaction processes which have some energy dependences. Also shown are wrong sign backgrounds for neutrino and antineutrino beams. Wrong sign background for the antineutrino beam are so large that neutral current-type experiments using this beam seem to be impractical. Antineutrino beam and wrong sign background for the single horn system with an antineutrino plug will be discussed in the later section.

Neutrino and antineutrino fluxes for a bare target train which consists of a target are shown in Figure 1.

III. QUADRUPOLE TRIPLET BEAM³

Figure 2 shows computed neutrino fluxes for a modified quadrupole triplet beam with tunes of 200, 400 and 600 GeV/c. Angular acceptances for all the above tunes were assumed to be the same as for the present quadrupole triplet train at 200 GeV/c. They can be attained by using 4Q120 quadrupole magnets.⁸ The quadrupole triplet beam contains both neutrinos and antineutrinos without any sign selection. Figure 3 shows neutrino and antineutrino fluxes for incident proton energies of 400 GeV and 1000 GeV with tunes of 200 GeV/c and 400 GeV/c, respectively. For comparison, neutrino fluxes for the single horn system, quadrupole triplet beam with a tune of 400 GeV/c and dichromatic train with a tune of 700 GeV/c are shown in Figure 4. The hypothetical N-50

was used for the dichromatic beam. Also shown is the neutrino flux for the present quadrupole triplet train in which all the quadrupole magnets were replaced by 4Q120 quadrupole apertures at 200 GeV/c. Except at very low energy, below 50 GeV, neutrino beam intensities for this quadrupole triplet arrangement are as large as for the single horn system. It must be pointed out that most of the counter experiments with large detector volumes prefer neutrino or antineutrino spectra with suppressed low energy peaks.

As seen in Figure 3, energy dependences of neutrino and antineutrino fluxes for the quadrupole triplet beam can be adjusted by changing the tune. It has been proven that the quadrupole triplet beam has very attractive characteristics to study charged current interactions for 400 GeV operation provided that precise data of the total cross sections for neutrino and antineutrino charged current interactions are available from experiments using a dichromatic beam.¹⁰ It has (1) large neutrino and antineutrino fluxes, (2) smoothly varying and adjustable spectra, (3) extremely good operational reliability, and (4) large duty cycle of possible DC operation.

IV. SIGN-SELECTED BARE-TARGET BEAM⁴

Computed antineutrino fluxes and wrong sign background fluxes for the single horn system with an antineutrino plug and sign-selected bare-target (SSBT) beam are shown in Figure 5. The tune of the SSBT beam was 250 GeV/c to optimize magnet acceptance for 1000 GeV incident protons. It was 200 GeV/c for 400 GeV operations. Except at very low energy, below 50 GeV, the SSBT beam is dominantly better than the single horn system with a plug as far as antineutrino intensity and sign selection are concerned.

The SSBT beam can be tuned for a neutrino beam where wrong sign background is significantly small.

The SSBT beam consists essentially of two 10' dipole magnets and a dump. Because of its simplicity it is extremely reliable and requires minimum efforts of maintenance. It can run almost in a DC mode.

V. CONCLUSIONS

In conclusion, any horn focussing system seems to be of marginal use for Tevatron neutrino physics. Search experiments for new phenomena at higher energies and detailed studies of charged current interactions at higher energies can be better performed by a quadrupole triplet beam of conventional magnets. A sign-selected bare-target beam can provide a better and much cleaner antineutrino beam at higher energies compared to any horn system, and it can also be used as a pure broad-band neutrino beam.

Although horn focussing can provide sign selection, it is very limited at Tevatron energy because high energy secondary particles are produced preferentially in the very forward direction. Precision measurements such as total cross sections and delicate experiments such as neutral current experiments must be made by a dichromatic narrow-band beam which complements broad-band beams.

The above conclusions seem to be more significant for multi-TeV accelerators.

It should be pointed out that a horn system can cause the severest muon background problem when the muon shield cannot be built redundantly.¹¹

REFERENCES

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6. D. C. Carey and V. A. White, Fermilab Internal Report, NUADA, June, 1975.
7. R. Stefanski and H. White, Neutrino Flux Distributions, FN-292, May, 1976.
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10. For example, see A. Benvenuti et al., Measurement of the Energy and x-Dependence of the γ -Distributions in Antineutrino Interactions, October, 1978 (submitted for publication) and Measurement of the x-distributions in Neutrino and Antineutrino Inelastic Interactions, December, 1978 (prepared for publication).
11. J. Wolfson pointed this out to me. Also see S. Mori, Muon Shield for the Tevatron at Fermilab, TM-790, May, 1978.

FIGURE CAPTIONS

- Figure 1. Computed neutrino and antineutrino fluxes and wrong sign backgrounds for the single horn system. The incident proton energy was 1000 GeV. No antineutrino plug was used. Wrong sign backgrounds are indicated curves with W's. Also shown are neutrino and antineutrino fluxes for a bare target train which consists of a target.
- Figure 2. Computed neutrino fluxes for a modified quadrupole triplet beam with tunes of 200, 400, and 600 GeV/c. The angular acceptance of the beam was assumed to be the same as for the present quadrupole triplet train at 200 GeV/c. The incident proton energy was 1000 GeV.
- Figure 3. Computed neutrino and antineutrino fluxes for incident proton energies of 400 GeV and 1000 GeV with tunes of 200 GeV/c and 400 GeV/c, respectively.
- Figure 4. Computed neutrino fluxes for the single horn system, quadrupole triplet beam with tunes of 200 GeV/c and 400 GeV/c, and dichromatic beam with a tune of 700 GeV/c. The quadrupole triplet beam with a tune of 200 GeV/c was obtained by replacing all the quadrupole magnets of the present quadrupole triplet train by 4Q120 quadrupole magnets. The incident proton energy was 1000 GeV.
- Figure 5. Computed antineutrino fluxes and wrong sign backgrounds for the single horn system with an antineutrino plug and sign-selected bare-target (SSBT) beam. The tune of the SSBT beam was 250 GeV/c. The incident proton energy was 1000 GeV.

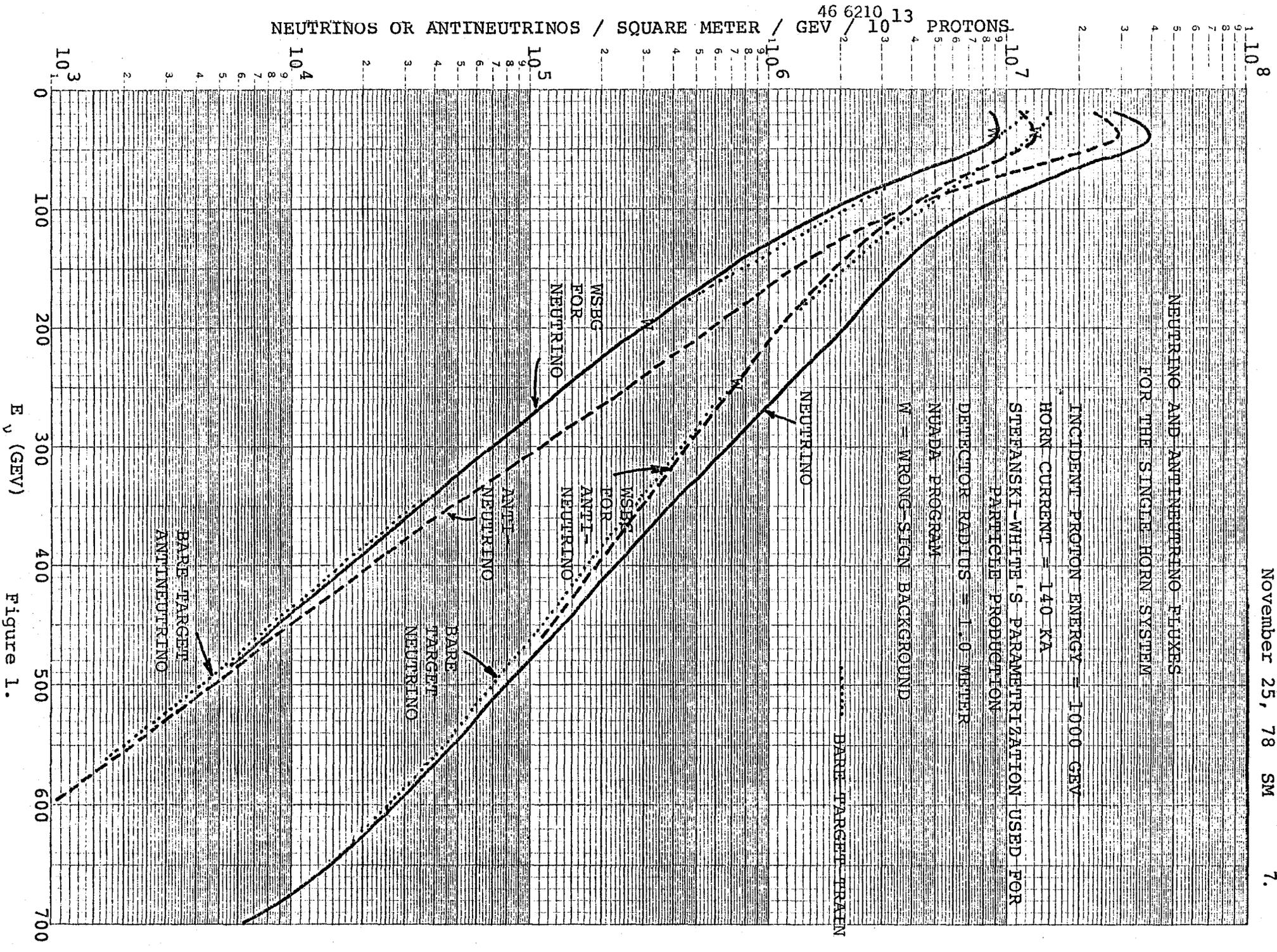


Figure 1.

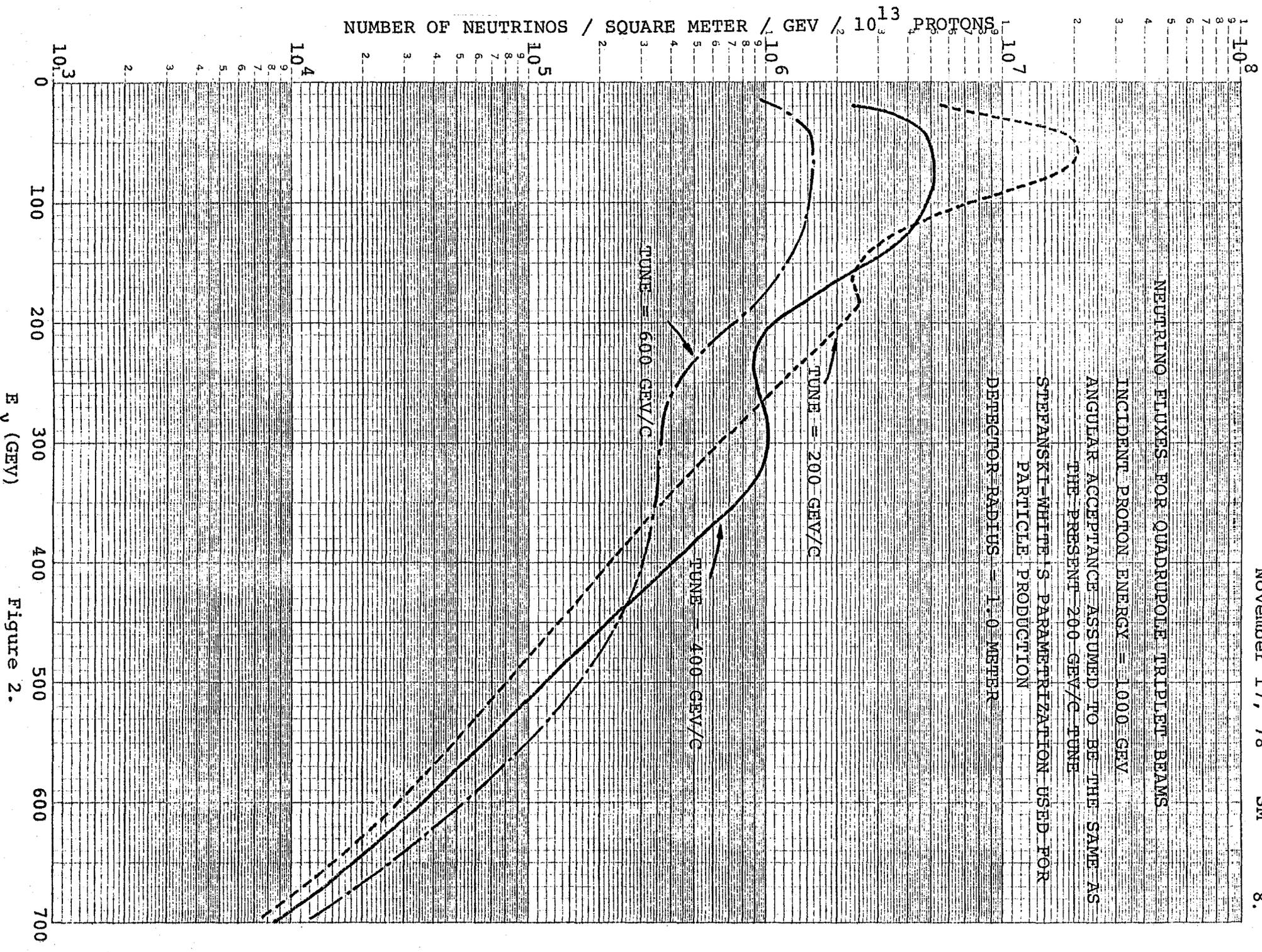
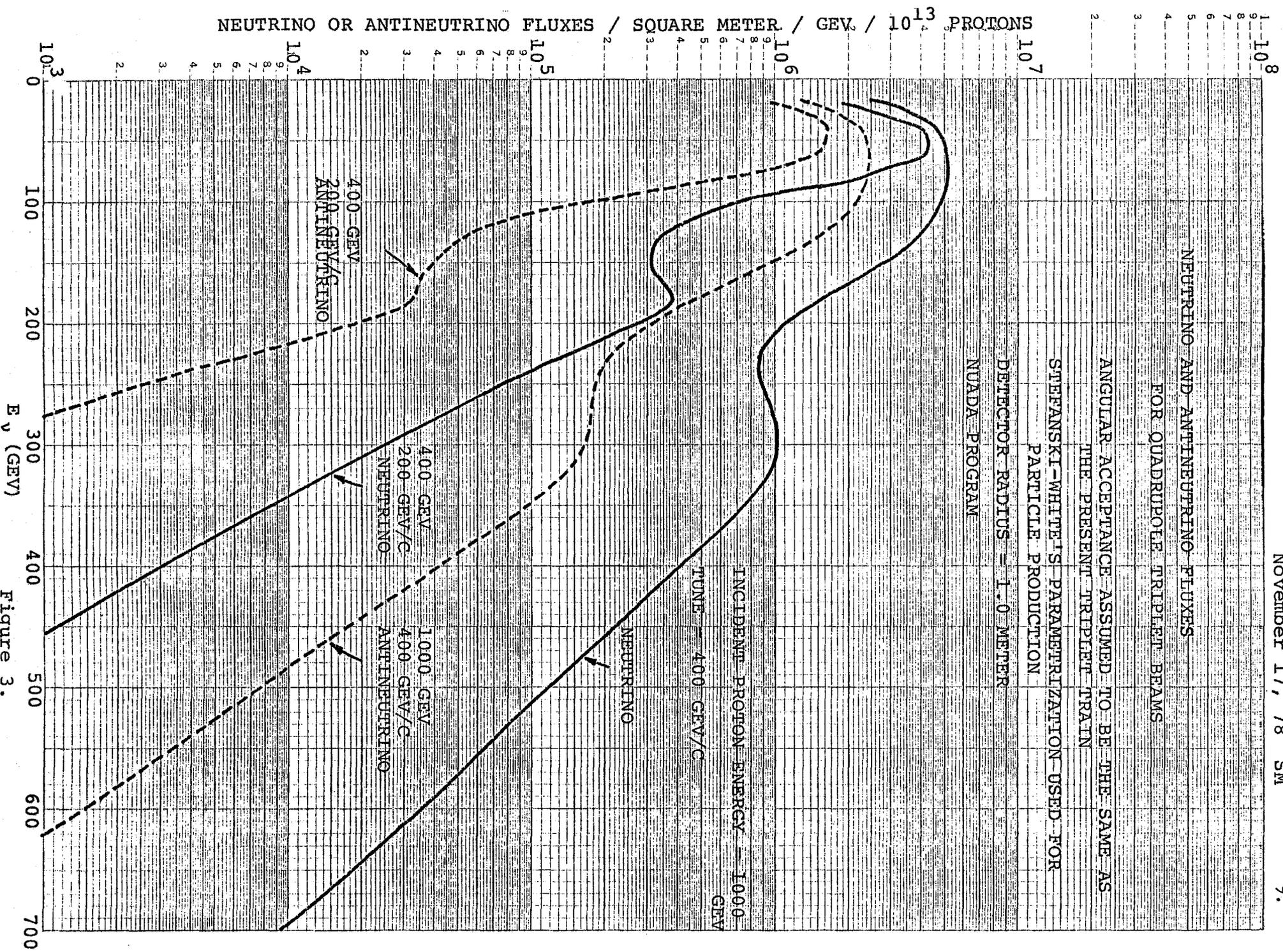


Figure 2.



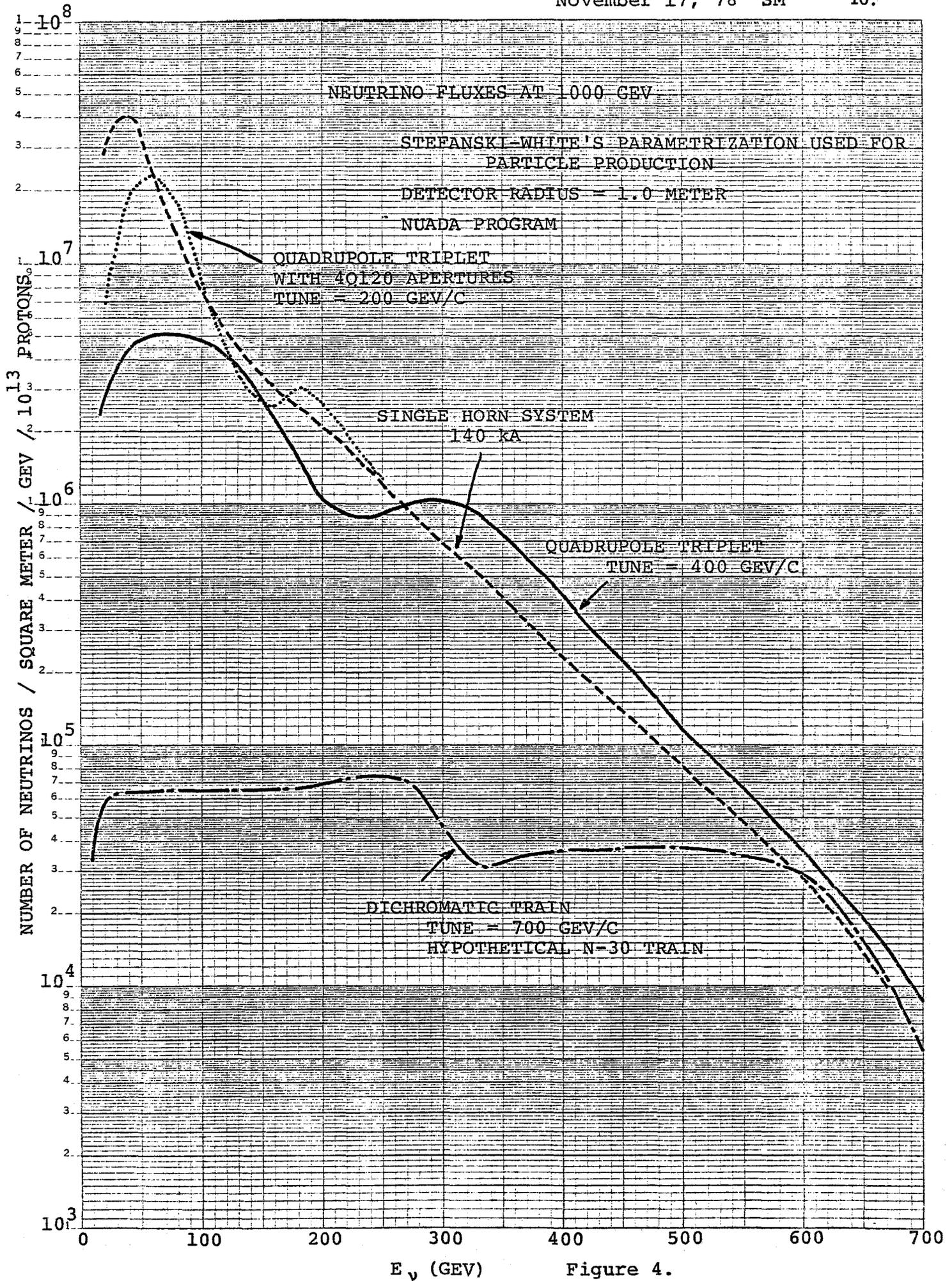


Figure 4.

