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Proposal to Search for Neutrino Oscillations at CERN- SPS

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The possibility of neutrino oscillations has long been recogized (1) and a recent analysis of the experimental data indicates that oscillations may exist (2).

Phenomenologically neutrino oscillations can be divided into four groups:

1) $\nu_\mu \leftrightarrow \nu_e$
2) $\nu_\mu \leftrightarrow \nu_\tau$
3) $\nu_e \leftrightarrow \nu_\tau$
4) $\nu_{\mu,e,\tau} \leftrightarrow \bar{\nu}_{\mu,e,\tau}$

Recent experiments set upper limits on the mass difference for reactions 1) and 2) which are considerably lower than those for reaction 3).

This has stimulated recent proposals to study $\nu_e \leftrightarrow \nu_\tau$ (3) and additional interest in studying $\nu_\mu \leftrightarrow \nu_e$ oscillations.

For this reasons we have reexamined the proposal submitted by some of us in 1976 (4) and we conclude that the experiment is indeed very timely; in fact the experiment is unique in that

1) The ratio of the path length L over the neutrino energy E is large: $L/E \sim 1.2$ m/MeV
2) The beam purity (i.e. the ratio N_{ν_e}/N_{ν_μ}) is of the order 1/1000 (see Fig. 1)

and

3) The bubble chamber permits the detection of a relatively small ν_e signal in a beam with a high flux of ν_μ.

Because of these reasons the proposed experiment is capable of detecting a mass difference $\Delta m^2_{\mu e} = |m^2_{\nu_\mu} - m^2_{\nu_e}|$ which is two orders of magnitude smaller than the presently existing upper limit.

Assuming the Argonne neutrino spectrum as an input, the relative number of ν_e events is shown in Fig. 2 as a function of the mass difference $\Delta m^2_{\mu e}$. The energy distribution of these events is shown in Fig. 3.

If one assumes a background of the order of .2 per cent, as in Fig. 1, and an exposure corresponding to 1000 ν events, the existence of a ν oscillation can be established at 3 standard deviations level with a.5 per cent effect, corresponding to a $\Delta m^2_{\mu e}$ value of 0.05 eV^2.

This experiment will also be sensitive to $\nu_\mu \leftrightarrow \nu_\tau$ oscillations (reaction 2). The oscillation of ν_μ into ν_τ would result in a change in the ratio of neutral current to charged current events because tau neutrinos of these low energies can only interact through neutral current channels. The ratio of neutral current to charged current events for various values of the mass difference is shown in Fig.4. With the statistics available in this proposed experiment, a mass difference $\Delta m^2_{\mu\tau} > 0.5$ eV^2 should be detectable.

It should be pointed out that the change in the ratio $R = \frac{NC}{CC}$ would show a predictable momentum dependence which would constitute an experimental check of the result.

Conclusion: We are thereby resubmitting proposal CERN/SPSC/76-92 (included as an appendix) and we request a run which would result in a total of 1000 ν interactions.

A continuing study is being made of beam parameters which would maximize the effects of $\nu_\mu \leftrightarrow \nu_e$ oscillation with a minimum background and a maximum detection efficiency.

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FIGURE CAPTIONS

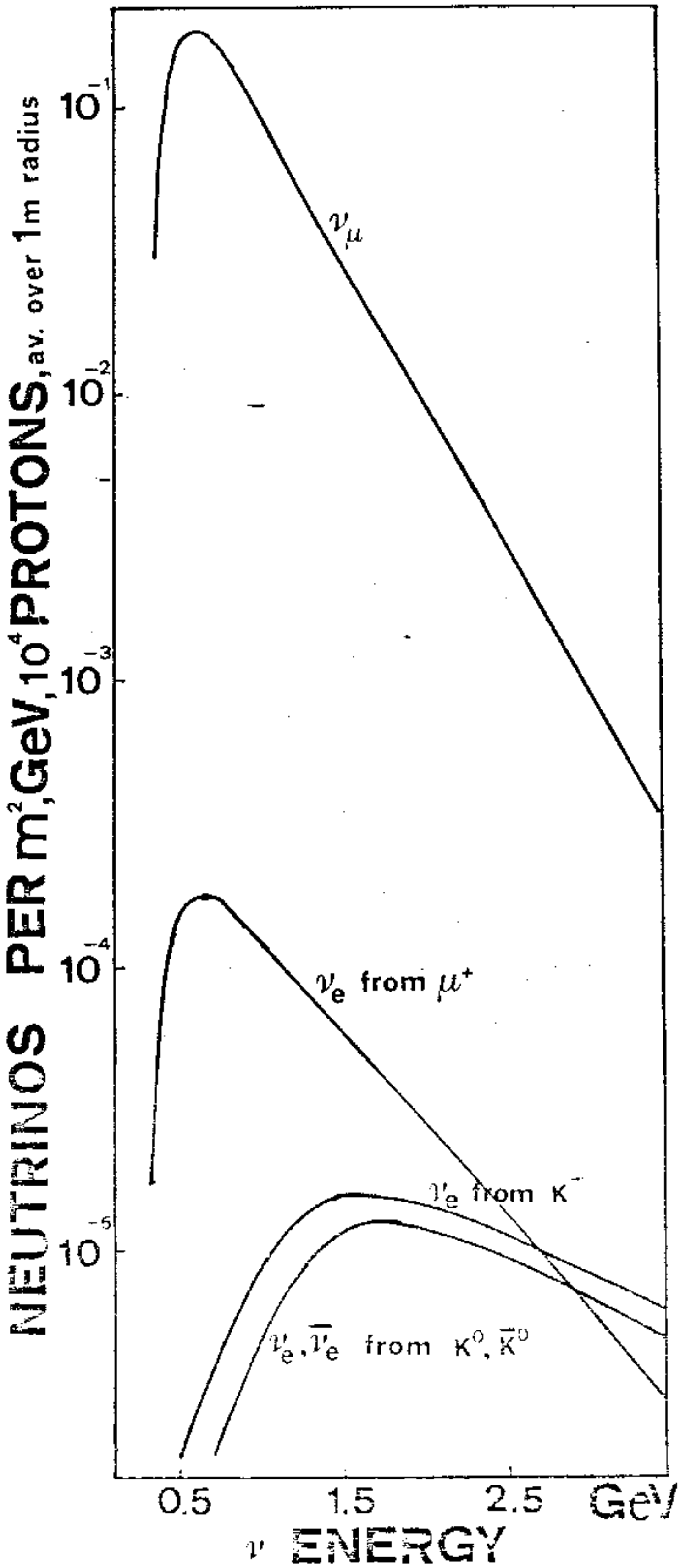
Fig. 1: The calculated ν_μ and ν_e spectra in BEBC are shown as a result of a beam study. These curves were obtained by using H. Wachsmuth's program for the CERN-PS neutrino beam. The energy of the primary protons was assumed 12.5 GeV and the decay tunnel 100 m long. Horn and reflector were located at the same distance as in the old CERN-PS neutrino beam.

Fig. 2: The ratio of ν_e events to all ν events is shown as a function of the mass difference.

Fig. 3: The total yield of events as a function of ν-energy is shown in arbitrary units. Also shown is the yield of ν_e events for various mass differences.

Fig. 4: The ratio of neutral current to charged current events as a function of the mass difference.

FIG. 1



NEUTRINOS PER m², GeV, 10⁴ PROTONS, av. over 1m radius
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
ν_μ
ν_e from μ⁺
ν_e from K⁻
ν_e, ν̄_e from K⁰, K̄⁰
0.5
1.5
2.5
GeV
ν ENERGY

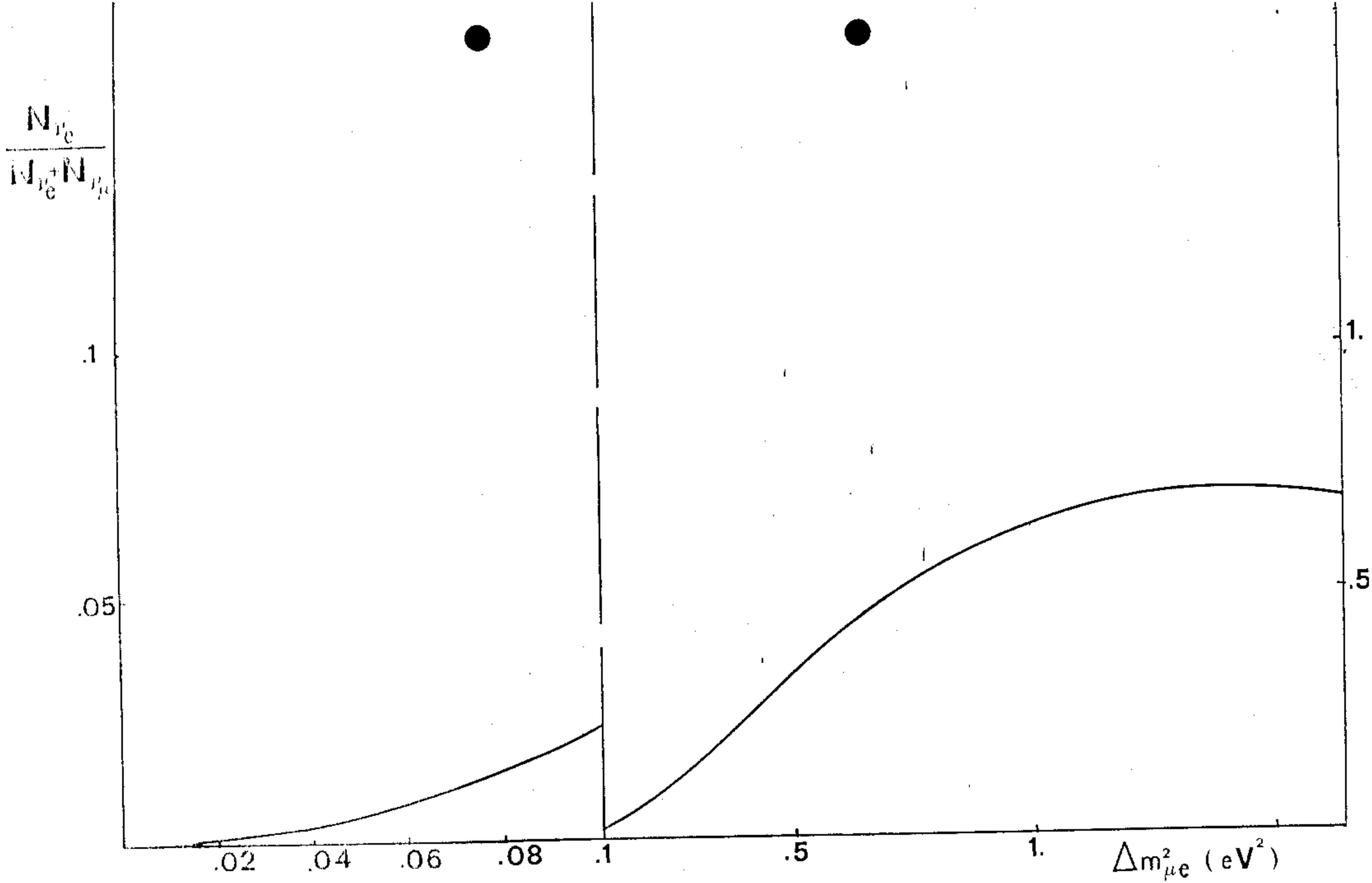


FIG. 2

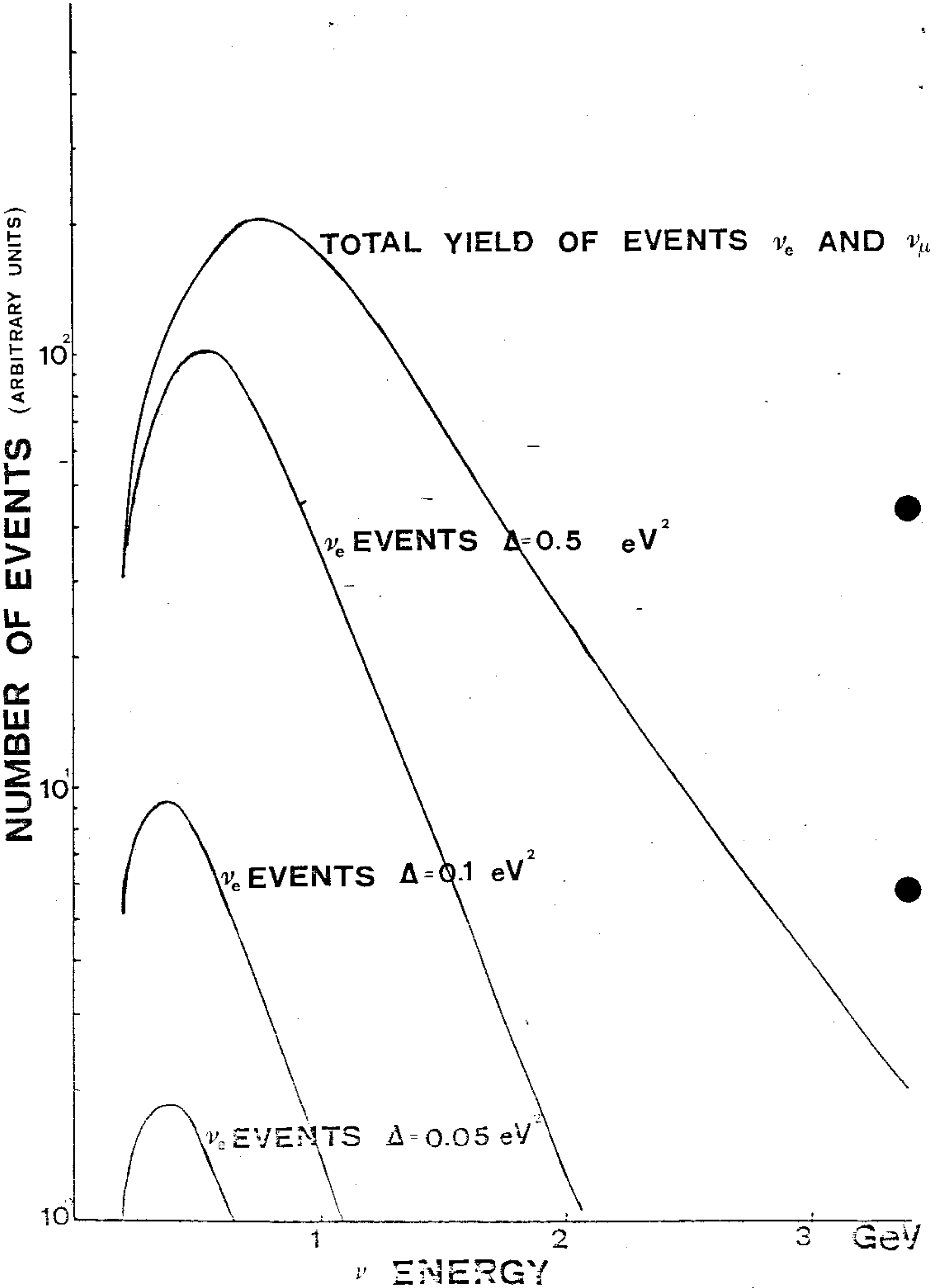

NUMBER OF EVENTS (ARBITRARY UNITS)
10²
10¹
10⁰
TOTAL YIELD OF EVENTS ν_e AND ν_μ
ν_e EVENTS Δ=0.5 eV²
ν_e EVENTS Δ=0.1 eV²
ν_e EVENTS Δ=0.05 eV²
1
2
3
GeV
ν ENERGY

FIG. 3

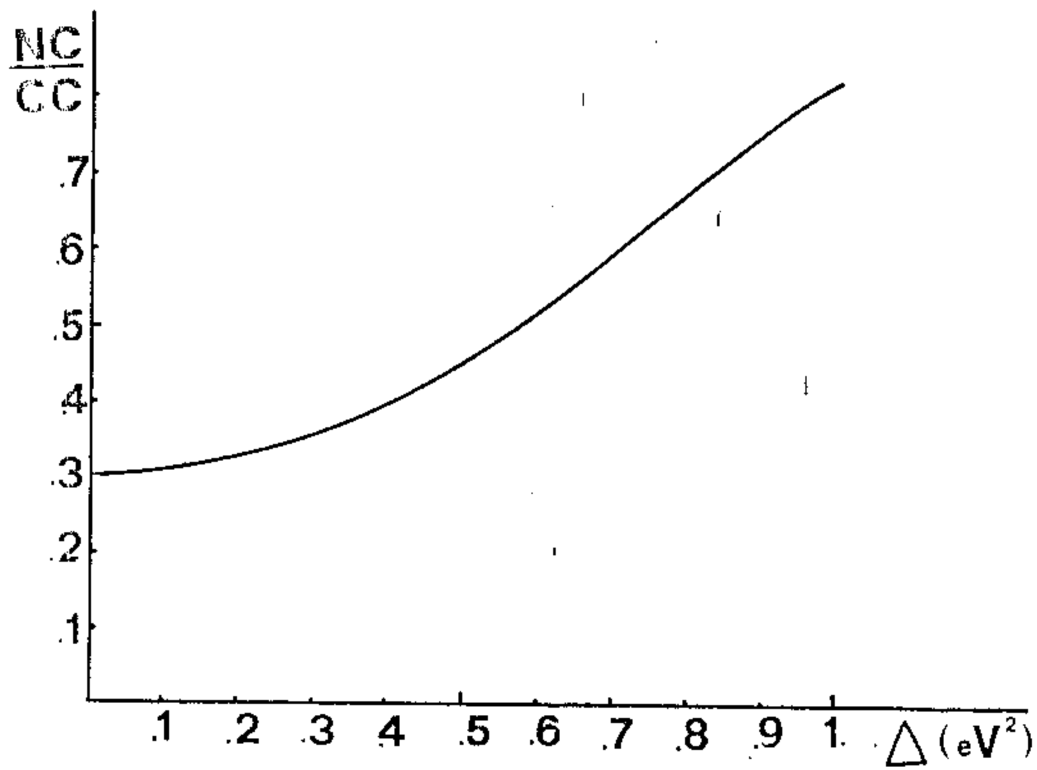


FIG. 4