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# A Proposal to Search for Short-Lived Neutral Bosons in a Beam Dump Experiment

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## Summary

We propose to search for hypothetical light (1 - 10 MeV) bosons with short lifetimes ($\sim 10^{-13}$ sec) by doing a beam dump experiment in End Station A. The A-beam photon collimator C-10 will serve as our beam dump. The 8 GeV Spectrometer set at zero degrees will be used as our detector for the electron and positron decay products of such a boson. Incident electron beams with energies of 10 and 20 GeV are required for this survey experiment. We estimate that two weeks running at 50 PPS will be sufficient to do a definitive search.

## Contents

## I. THE PHYSICS

The phenomenon of spontaneous symmetry breakdown is a prominent feature of both strong and electroweak theory. An apparently inevitable concommitant of this dynamical mechanism is the appearance of massless, or nearly massless, spinless Nambu-Goldstone bosons. A natural question emerges as to whether the dynamical forces which (must) exist beyond the strong/electroweak gauge forces also incorporate this symmetry-breaking mechanism. If so, the possibility arises for the existence of additional such bosons.

Indeed, the axion, which was concocted to elude the problem of strong CP violation in the QCD/electroweak Standard Model, is a possible example of such a Nambu-Goldstone boson. The original Peccei-Quinn- Weinberg-Wilczek1) axion has been ruled out experimentally2). However, a plethora of variants is possible; they seem to emerge when there is any stimulation from experiment whatsoever. Irrespective of the theoretical fashions of the day, it is obviously important to search for such bosons — especially because they will be low-energy manifestations of physics at high-energy scales, beyond the Standard Model.

SLAC already has a history of such searches. The original "Black Hole" beam dump experiment E-563) and the more recent E-1374) were sensitive to relatively long-lived axions decaying into $\gamma\gamma$, $e^+e^-$, or $\mu^+\mu^-$ pairs. Those experiments, with detectors placed 55 and 400 meters behind the A-beam dump, employed typically 30 coulombs incident on dump; they were able to rule out axion lifetimes (for $e^+e^-$ decay) down to about $10^{-12}$ seconds. Our proposed beam dump experiment supplements those searches by looking for shorter-lived particles with decay lengths 10 to 100 times less than those for which E-56 was sensitive. Such a short lifetime (down to $\sim 10^{-14}$ sec) implies stronger coupling to $e^+e^-$ or $\gamma\gamma$, and hence much less stringent requirements on electron beam intensity.

An important stimulus for this search is the recently reported experiment of the EPOS collaboration at the GSI in Darmstadt, which observed anomalous pairs of electrons and positrons with laboratory kinetic energies of about 380 keV each[5)]. *If* these pairs are interpreted as decay products of a primary boson, its mass must be about 1.8 MeV and it is probably a pseudoscalar[6)].There are many difficulties with this interpretation. Nevertheless, the appearance of the GSI phenomenon highlights the fact that *were* such a particle to exist, it would have escaped detection elsewhere, provided its lifetime lies somewhere in the range $6 \times 10^{-14}$ to $2 \times 10^{-13}$ sec. The credibility of this lifetime range is enhanced by the recent appearance of several theoretical papers purporting to explain the GSI phenomenon via axion production.

Assuming such a particle "X" is pseudoscalar, its lifetime is related to the Yukawa coupling constant K for $X \rightarrow e^+e^-$ according to the formula

$$\tau_X = \frac{1}{\Gamma_X} = \left[ \frac{K^2}{4\pi} \frac{m_X}{2} \left(1 - 4\frac{m_e^2}{m_X^2}\right)^{1/2} \right]^{-1} \tag{1}$$

This lifetime is constrained from below by measurements of the electron anomalous magnetic moment, which require $K^2/4\pi$ to be less than $1.6 \times 10^{-8}$, or $\tau_X > 6 \times 10^{-14}$ sec[7)]. SLAC expriment E-56 constrains $\tau_X$ to be less than $10^{-12}$ sec. The Fermilab beam dump experiment E-613 appears to place an even more stringent upper limit on this lifetime [8)]. With more than $10^{17}$ incident protons of 400 GeV delivered to E-613 , there are enough electrons generated in the hadronic cascade via the chain $p + N \rightarrow \pi^0 \rightarrow \gamma \rightarrow e$ to produce a large number of high-energy (about 200 GeV) X particles by radiation from these electrons. Some of these would penetrate the 55-meter shield between dump and detector, decaying into an $e^+e^-$ pair inside it. Our admittedly crude estimates indicate that X lifetimes above $2 \times 10^{-13}$ sec can be excluded by the fact that no such high-energy pairs were observed in the E-613 detector. These experimenters are currently reanalyzing their data and should soon provide a more accurate limit, but it is clear that the final result will not change by more than a factor of 2.

It is important to recognize that the above lifetime constraints, $6 \times 10^{-14} < \tau_X < 2 \times 10^{-13}$ sec, apply only to the GSI "particle" of mass 1.8 MeV. At higher boson masses the lifetime window remaining open is considerably wider, as indicated in Figure 1. The upper limit increases because more massive particles are produced less copiously, and they cannot penetrate the thick shield between dump and detector so easily. The lower limit falls by virtue of the fact that heavier bosons can be coupled more strongly to electrons without having much effect upon its anomalous magnetic moment[7]). To repeat, we take the GSI phenomenon to indicate only that something interesting might exist within this range of masses and lifetimes that has so far escaped detection. Thus we have designed an experiment to search as much of this parameter space as possible at SLAC.

Meanwhile the theoretical response to these experimental hints has already been brisk. Most of the new models[9,10]) proposed accommodate the new data and the negative results of earlier searches by postulating an axion with a lifetime of order $10^{-13}$ sec and preferential (or exclusive) coupling to electrons or light quarks. The most notable candidate model has been offered by Krauss and Wilczek[10]). It appears to be consistent with all the data, including the very recent and preliminary constraints imposed by E-613 (especially when supplemented by the model of Brodsky et al[11]). for production of X in a bound nuclear state in heavy-ion collisions). The lifetime of the Krauss-Wilczek axion is predicted to be $1.2 \times 10^{-13}$ sec, inside the open experimental window, and easily accessible in this experiment. Other non-standard axions, with different masses and lifetimes within the open window, can easily be imagined.

The most definitive experiments that search for the GSI particle (and any others like it) will depend only upon the fact that it couples to $e^+e^-$ (and possibly to $\gamma\gamma$), because the hadronic production — as well as the coupling to other lepton and quark species — is model dependent. In this regard SLAC electrons can provide an especially clean source of any such X particles. The bremsstrahlung of X from electrons (Figure 2a) is readily calculable, with the result depending only upon its spin-parity, mass and lifetime. If the branching fraction to $\gamma\gamma$ is appreciable, on the other hand, this would also imply substantial production via the Primakoff process (Figure 2b), again (literally!) rendering the X highly visible.

In either case, the X particles would be produced in a narrowly collimated beam with approximately 1 mrad angular divergence. For light bosons ($\leq$ 10 MeV) the opening angle between the decay electron and positron (or two photons) also remains less than 1 mrad. Bremsstrahlung of a pseudoscalar boson is strongly peaked toward high energies close to the energy of the electron itself. When coupled with the fact that only the highest-energy X particles will penetrate through to the back of the dump, these characteristics require that high-energy electrons and positrons must be observed downstream of the dump, if such bosons exist at all. By searching for this signal, in either a single-arm or double arm experiment, we can make a definitive test of their existence. Similar considerations apply in the case of Primakoff production and decay into $\gamma\gamma$, or $\gamma e^+e^-$.

## II. THE EXPERIMENT

The best way to search for light, neutral, short-lived particles at SLAC is to produce them in a very short dump, of order 1 meter long. For each additional meter thickness, the number of X particles with $10^{-13}$ sec lifetime penetrating the dump drops by a factor of about 30, assuming 20 GeV electrons and holding all other parameters fixed. For lifetimes of $5 \times 10^{-14}$ sec, the counting rate drops by a factor of 1000 per each additional meter. This feature gives us a very sensitive measure of the lifetime of such a short-lived particle, but it limits our search to particles with lifetimes greater than 2 x $10^{-14}$ sec (and masses below $\sim$ 20 MeV). And while the electromagnetic cascades of 20 GeV electrons can readily be absorbed in a meter-long dump, the intense backgrounds of muons and hadrons exiting it cannot be taken as lightly, given typical SLAC duty cycles. Indeed, they threaten to swamp any detector placed directly downstream of the dump.

We propose to solve these problems by using the existing A-beam collimator, C-10, as our dump and the 8 GeV Spectrometer as a single-arm electron/positron detector (see Figure 3). Consisting of two sets of 0.5 meter-long jaws, one vertical and one horizontal, C-10 can be fully closed and offset slightly to act as a beam dump able to handle power levels up to 40 kW – far more than ever encountered with a SLED beam. Each set of jaws consists of about 60 radiation lengths of copper and tungsten to absorb the electron showers. Together they also provide about 5 hadron interaction lengths, which can be augmented by inserting additional tungsten absorber plates in a drift space just downstream.

Only particles exiting the dump at angles of a few mrad or less can pass all the way down the beam pipe to the ESA pivot, about 35 meters away. Thus any light X particles (10 MeV or less), and their decay electrons and positrons, will have no problems reaching the pivot. But the vast majority of muons and hadrons, produced at characteristic angles of 1-3 degrees, will be stopped in the thick lead-and-concrete shielding surrounding the beam pipe between 7 and 15 meters downstream of C-10. Still, at typical beam intensities of $10^{10}$ electrons per pulse, we estimate there will be backgrounds of 10-100 muons per pulse at the pivot, far more than our detectors could cope with if placed directly in the beamline.

To avoid this problem without cutting back on the primary electron beam, we intend to station the 8 GeV Spectrometer at zero degrees and search for the electron and positron decay products of a possible X particle. Its detectors – a hydrogen-filled Cherenkov counter, wire chambers, and a lead glass total absorption counter–sit in a shielded cave well out of the way of background particles coming straight down the beam pipe. Based on their performance in the recent experiment E-140, we estimate they provide a combined pion rejection factor of $10^5$ (and still better against muons) while giving us better than 99 percent detection efficiency for electrons. By making our measurements predominantly at secondary engergies between 6 and 9 GeV, we can hold the muon singles rates to manageable levels and reject the pion and other backgrounds.

The 8 GeV Spectrometer has the added advantage that it can be put to work almost immediately, with only a minimum of beam time devoted to checkout. It is fully instrumented at present, with only the wire chambers (which are required for experiment NE-4) needing to be reinstalled. The fast electronic logic assembled for E-140 has been left intact, saving us at least a week of checkout time. Furthermore, the performance characteristics of this spectrometer are extremely well understood at present, so we will not have to spend valuable beam time wondering whether our detector is working properly. It works!! Should we ever need it, this spectrometer offers 0.1 mrad angular resolution and 0.1 percent momentum resolution. We feel it is the obvious choice if we are to run this experiment before the shutdown to commission the SLC. Should we witness a signal that cannot be rejected as background, we can then begin the more difficult and time-consuming task of designing a double-arm spectrometer to detect electron-positron coincidences, an experiment that would probably have to be run in 1987.

We anticipate using incident electron energies of 10 and 20 GeV, and closing one or both sets of C-10 jaws to achieve dump lengths of 0.5 and 1.0 meters. That way we can scan the entire range of X particle lifetimes possible at $m_X = 1.8$ MeV. We would set the spectrometer polarity initially to search for positrons, thus eliminating any possibility that line-of-sight electrons from the incident beam are slipping by our dump. If high-energy positrons are in fact seen at any particular setting, we can quickly reverse the spectrometer polarity and search for a comparable electron signal.

Should both electrons and positrons be seen, we must then reject the possibility of muon- and hadron-initiated backgrounds. This can be done by inserting additional absorbers in the beamline, just downstream of C-10, using the "window changer" shown in Figure 4. Based on existing equipment available in End Station A, this device inserts any one of three different segments of beam pipe into the nominal position. One segment containing no absorber at all will allow us to check beam steering to the pivot; one will contain a 3 r.l. absorber sitting

2.0 meters behind the upstream edge of the front C-10 jaws; the final segment will be designed to allow insertion of up to a meter thickness of additional tungsten absorber. If the electrons and positrons originate from the decay of a short-lived X-particle, then the signal should disappear or be drastically reduced by insertion of the 3 r.l. absorber; the counting rates from background processes, however, should not change noticeably. By interchanging absorbers, and opening and closing the back jaws of C-10, we should also be able to determine the lifetime of any short-lived X-particle we might encounter.

High-energy photons from the $\gamma\gamma$ decay of an X particle can be detected by inserting a 1 r.l. converter into the beam, either at the pivot or just before the opening window of the 8 GeV Spectrometer, which would then be operated at high-energy for both positive and negative polarity. The difference between the spectra seen with and without the converter in place gives us a measure of the possible $\gamma\gamma$ decay channel, although such a signal would be more difficult to interpret because the $e^+e^-$ would apprear at lower energy. Electrons or positrons from any $\gamma e^+e^-$ decay channel would be detected without the use of a converter; but they, too, would appear at lower energies because of three-body decay kinematics.

## III. THE SIGNAL

We have estimated the rate of X particle production using cross-section calculations of Tsai[12) and a version of the EGS shower simulation program modified for our particular purposes[13). The differential cross section for bremsstrahlung production of a pseudoscalar (Figure 2a) X by an electron of energy $E_e$ is written as

$$\frac{d^2\sigma}{dE_x\, d\Omega_x} = \frac{\alpha^2\alpha'}{\pi}\,\frac{E_e}{u^2}\,Z^2 \ln\left[\frac{4E_e^2(1-x)}{u} - 1\right]$$

$$\times\left\{x^3 - \frac{2m_x^2 x^2(1-x)}{u} + \frac{2m_x^2 x}{u^2}\left[m_x^2 x(1-x)^2 + m_e^2 x^3(1-x)^2\right]\right\} \qquad (2)$$

where $\alpha' = K^2/4\pi$,

$x = E_X/E_e$

$$U = m_X^2\left(\frac{1-x}{x}\right) + m_e^2 x + E_e E_X \theta^2$$

This equation includes only the scattering from completely screened atomic nuclei and not from individual atomic electrons; a more accurate expression will include these effects.[12] For $E_e, E_X >> m_X$, this cross-section is very strongly peaked in the forward direction, falling like $1/\theta^4$ for angles greater than 0.1 mrad. In the forward direction the spectrum of produced X particles peaks at high energy close to the electron energy $E_e$. Its approximate shape is given by[12]

$$\frac{d\sigma}{dx} = \alpha^2 \alpha' \frac{1}{U_{min}^2}\left[\frac{2}{3} m_X^2 x(1-x) + m_e^2 x^3\right] \chi_0 \tag{3}$$

where
$$U_{min} = m_e^2 x + m_X^2\left(\frac{1-x}{x}\right)$$

and
$$\chi_0 = 2\left[Z^2 \ln(184 Z^{-\frac{1}{3}}) + Z \ln(1194 Z^{-2/3})\right)$$

To estimate the yield of X particles created in a beam dump, we must fold the differential cross-section with the energy spectrum of electrons (and positrons) in the electromagnetic cascade. This was done by folding equation 2 with spectra generated for 10 and 20 GeV electrons by the EGS shower simulation program at Fermilab.[13] The energy distribution remains peaked at high energies, as indicated in Figure 5 for the 20 GeV case. Almost all the highest-energy X particles are produced in the first radiation length, and their angular distribution is dominated by multiple scattering of the incident electrons, or about 1 mrad on the average. The overall rate of production is about 6 x $10^{-21}/\tau_X$ particles per electron incident on the dump, growing linearly with energy.

To get the counting rate for positrons (or electrons) in the 8 GeV Spectrometer, we multiply the X particle production rate by an attenuation factor and by the 8 GeV Spectrometer's momentum acceptance($\sim$ 10%). Assuming a flat energy distribution of the decay products, we estimate that at least 2 percent of any X particles exiting the dump give us a positron (or electron) within this acceptance. Figure 6 shows the yield of positrons (or electrons) in the spectrometer at 7 GeV, given an incident energy of 10 GeV and dump lengths of 0.5, 1.0 and 2.0 meters. Figure 7 shows the same yields at 20 GeV incident energy.

It is clear that absorption of the $e^+e^-$ pair inside the dump becomes the limiting factor at short lifetimes. A counting rate of $10^{-14}$ per incident electron corresponds to about 20 counts per hour, assuming $10^{10}$ electrons per pulse and 50 PPS; it represents a reasonable lower limit for a quick survey experiment like this one. Thus, to gain access to X lifetimes of 5 x $10^{-14}$ sec needed to close the open window, we need the highest possible incident energies and the shortest possible dump that backgrounds permit.

## IV. THE NOISE

There are four major sources of backgrounds that can pose problems for this experiment:

— electrons and positrons arising from decays of muons and hadrons,

— electron and positrons from pair creation processes

— pions masquerading as electrons or positrons in our detectors

— muon singles rates

The first two constitute the irreducible background below which measurement of a true signal becomes very difficult. The last two can be readily handled by the 8 GeV detectors or by reducing beam currents.

The flux of background particles entering the 8 GeV spectrometer acceptance was estimated for the two beam dump configurations:

— front jaw of C-10 closed (~57 r.l. total)

— both sets of jaws closed (~114 r.l. total)

We have used the measured yields of $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$ produced at zero degrees in interactions of 16 GeV electrons with a 1.8 r.l. thick beryllium target[14)] and assumed that the production of secondaries scales in variable $x_p = E_p/E_0$, the fraction of beam energy carried by the produced particle. The muon flux was also calculated using a program provided by W.R.Nelson[15)], which describes the available data well. Figures 8a and 8b show our estimated rates of background particles entering the 8 GeV spectrometer acceptance, assuming a 1 GeV momentum bite. The most important sources of background electrons and positrons are:

- $\mu \rightarrow e\nu\bar{\nu}$
- $\mu$ bremsstrahlung followed by $e^+e^-$ pair production
- $K^{\pm} \rightarrow \pi^0 e^{\pm} \nu$
- $K_L^0 \rightarrow \pi^{\pm} e^{\mp} \nu$

At higher $x_p$ these contributions to the signal are about $10^{-15}$ per incident electron, with at most a factor of 10 uncertainty. Thus a true signal of $10^{-14}$ per incident electron should be just perceptible above the irreducible background.

Though much higher than these $e^+/e^-$ backgrounds, muons and hadrons can be rejected by measuring at high values of $x_p$ and taking advantage of the $\sim 10^5$ rejection factor of the 8 GeV detector array. This brings their contribution to the signal down to the $10^{-15}$ to $10^{-14}$ range, about equivalent to the irreducible $e^+/e^-$ backgrounds. The drastic reduction of these backgrounds is obtained mainly by the very small solid angle acceptance ($10^{-5}$ steradian) rather than by absorption of secondaries in the dump. The proposed setup assumes that the mass of an X particle is much smaller than the muon mass, and therefore $p_T^X \ll p_T^{\mu}, p_T^{\pi}$. Secondaries emitted at wide angles are merely absorbed in the $\sim$ 7 meters of lead and concrete shielding upstream of ESA. It may help, however, to shield the beam pipe inside ESA, too, and we plan to do so.

In Figure 9 we display the $e^+/e^-$ signal anticipated in a 10 GeV beam from the decays of X particles together with the estimated muon, pion and electron backgrounds at the same x = 0.7. Down to lifetimes of about $2 \times 10^{-14}$ sec, the anticipated signal exceeds background by a factor of 10, especially if we use the 0.5 meter dump. The best sensitivity occurs at $\tau_X \approx 5 \times 10^{-12}$ sec. Figure 10 shows the $e^+/e^-$ signal in a 20 GeV beam together with the backgrounds at x = 0.4. The signal is higher, but so is the noise, and we again can measure down to lifetimes of about 2 x $10^{-14}$sec. Table I gives the lifetime limits accessible in each of our four anticipated configurations.

With $10^{10}$ electrons/pulse on dump, we anticipate about 10 muons per pulse, give or take a factor of 3. Were these spread over a long 1 microsecond pulse, they would present no problems for the 8 GeV detectors. But such a singles rate will make track identification difficult in a ~ 100 nsec SLED beam and impossible in a ~ 1 nsec pulse from the CID injector. If necessary we can reduce the current to ~ $10^9$ electrons/pulse, to bring the singles rates down to manageable levels. We plan to use some of our checkout time to study these rates and find the best possible operating modes under these conditions.

## V. THE PLAN

It is difficult to gauge the exact amount of beam time required for a speculative experiment like this one . But the relatively large counting rates expected from an X particle with a lifetime ~ $10^{-13}$ sec makes our task easier. For counting rates of $10^{-12}$ detected $e^+e^-$ per incident electron, and assuming $10^9$ electrons per pulse and 50 pulses per second (at 50% efficiency factor), it requires about 1 hour to accumulate 100 counts. This fact allows considerable flexibility in the planning of experimental runs.

We would spend a few days checking out the 8 GeV spectrometer and detector, making sure we can detect electrons and positrons properly while rejecting backgrounds. This work could be done by inserting a metal foil into the beamline over the ESA pivot and setting the 8 GeV spectrometer at small, non-zero angle. Here we would also determine optimal data-taking conditions.

Then we anticipate the following core sequence of events, dubbed Phase I:

1. 10 GeV electrons incident on 1.0 meter dump; 8 GeV spectrometer set to 7 GeV to detect positrons and then electrons, photon converter out of beamline. (3 hours)
2. Repeat step 1 with 0.5 meter dump, converter out. (3 hours)
3. Repeat step 1 with 0.5 meter dump, converter in. (3 hours)
4. If no signal witnessed yet, open C-10 completely and recheck electron beam steering using ZnS screens or 8 GeV spectrometer on dark current. Repeat steps 2 and 3. (6 hours)
5. If signal witnessed, proceed to Phase II. Otherwise continue.
6. 20 GeV electrons incident on 1.0 meter dump; 8 GeV spectrometer set to 8 GeV to detect positrons and then electrons, converter out. (3 hours)
7. Repeat step 6 with 0.5 meter dump, converter out. (3 hours)
8. Repeat step 6 with 0.5 meter dump, converter in. (3 hours)
9. If no signal witnessed yet, recheck steering as in step 4 and repeat steps 7 and 8. (6 hours)
10. If signal witnessed, proceed to Phase II.

Including a liberal 6 hours apiece to set up and steer the beam at each energy, we could conceivably complete Phase I in two days. If nothing were seen at all, we might well be finished, but we would probably repeat running of the above configurations, plus others, to make sure we have not made a mistake. But if a null result is all there is to be found, it should take us no more than a week of average beam time to believe it.

If we instead witness a tenative signal at any of the above settings, we will proceed to Phase II, once the core runs at that beam energy have been completed. The intention here is to examine the possibility that the observed $e^+/e^-$ signal is due to muon or hadron backgrounds; it can also set narrower limits on the lifetime of any X particle, should one actually be found. Here we anticipate inserting an additional 3 r.l. absorber into the beam 1.0 meter downstream of C-10, plus any additional tests necessary – like adding more absorbers, or making high-statistics measurements of the variation of signal with spectrometer momentum settings.

Phase II would be repeated for every Phase I setting in which a tentative signal is observed; we estimate each repetition to require no more than one average day of beam time. Thus, assuming the Phase I program to take no more than 2 days, the data-taking phase should be completed within a ten-day period. Including four days of checkout at reduced rates, the entire experiment should require no more than two weeks of running time.

## VI. THE REQUEST

For this proposed experiment, we request that SLAC provide us the following items:

1. Two full weeks of time on the A-beam with at least 50 PPS, or its equivalent, using the full linac at electron energies of 10 and 20 GeV. Momentum-defining slits SL-10 can be set at 1.0%, and pulse widths as long as possible are desirable. Our experiment is compatible with use of the CID injector as the electron source, but we could only use $\sim 10^9$ electrons/pulse from this gun.
2. Use of the photon collimator C-10 in a beam dump mode, together with any engineering or technical support necessary to achieve that end.

3. The engineering and technical support necessary to modify and install the "window-changer" into the beamline just downstream of C-10, including the fabrication of a support structure for this device.
4. The necessary beam monitoring and steering equipment that may have to be added upstream of C-10.
5. The materials and manpower to shield the beam pipe inside ESA.
6. Use of the 8 GeV Spectrometer with its full complement of detectors and fast electronics, plus necessary power supplies and connections.
7. Use of the ESA VAX computer for data-logging purposes during the experiment, and for offline data analysis during a six- month period thereafter. Possible use of the SLAC IBM computer for Monte Carlo studies before, during and after the experiment. (We also anticipate using the University of Rochester VAX and other computers, as we are already doing for E-140.)
8. Adequate office space and equipment for the experimenters through the completion of the experiment and the subsequent offline analysis.

The ideal time to run this experiment is as soon as possible. Given the constraints on the Laboratory and conflicts with NE4 over use of equipment and access to ESA floor space, we feel a realistic time is the last two weeks in June for the actual checkout and data-taking period. Before that we would need a week to reinstall wire chambers and other 8 GeV equipment. During that week we will also need two shifts of BSY access to install and test the modified "window-changer" in the beamline downstream of C-10. If some of this BSY work can be done during the March-April shutdown, this access could probably be shortened to one shift.

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## TABLE I

Lower Limits on X Particle Lifetimes That Can Be Measured in E-141*

| | $E_O = 10$ GeV | $E_O = 20$ GeV |
|---|---|---|
| 0.5 m dump | $3.3 \times 10^{-14}$ sec | $2.1 \times 10^{-14}$ sec |
| 1.0 m dump | $7.1 \times 10^{-14}$ sec | $4.5 \times 10^{-14}$ sec |

*assuming $m_X = 1.8$ MeV and requiring that estimated signal be 100 times the estimated $e^+/e^-$ background.

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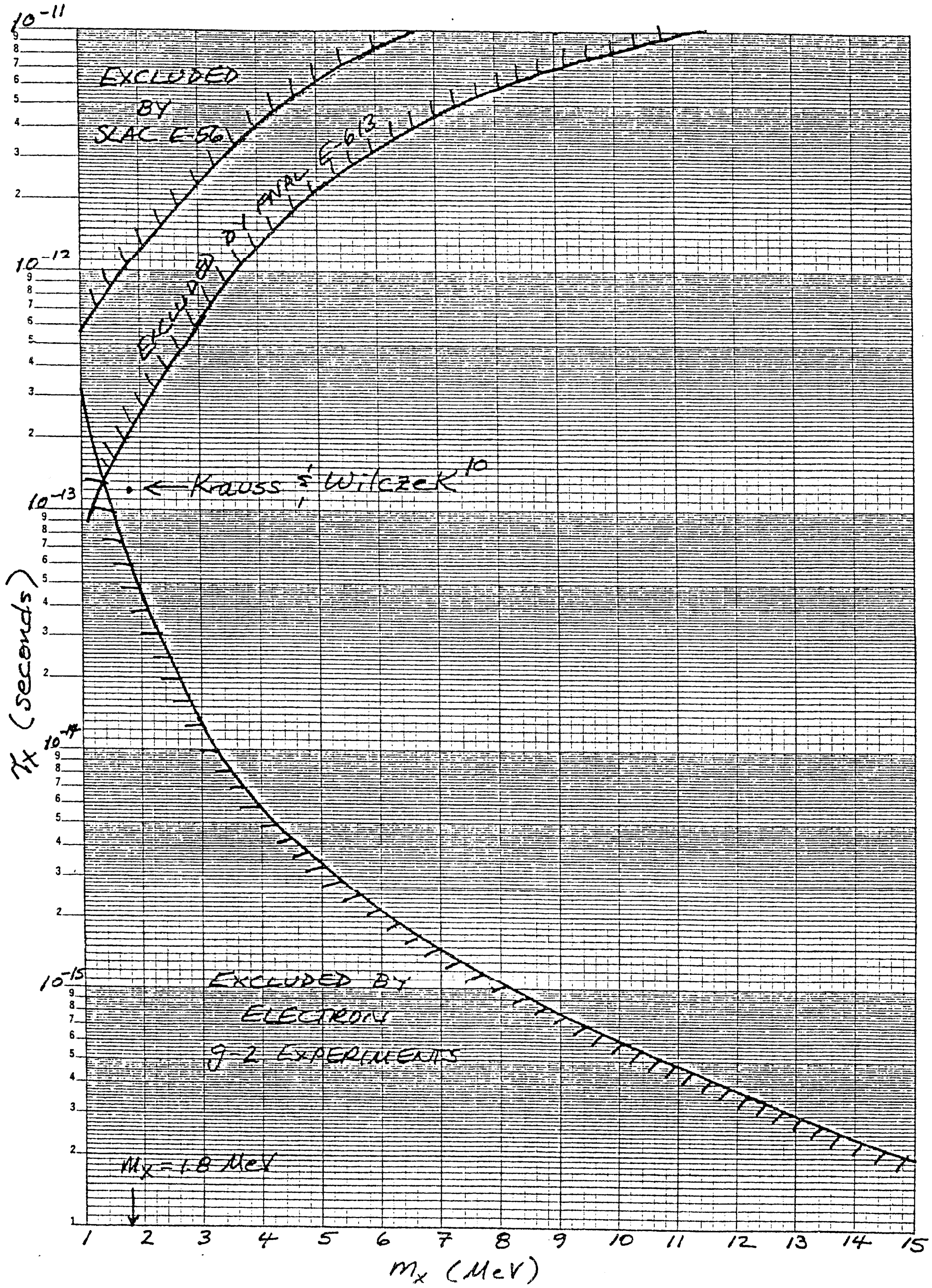
9. Comparison of counting rates and background rates at $E_0 = 10$ GeV, plotted versus X lifetime, assuming spectrometer set at 7 GeV.
10. Comparison of counting rates and background rates at $E_0 = 20$ GeV, plotted versus X lifetime, assuming spectrometer set at 8 GeV.



10^-11
10^-12
10^-13
10^-14
10^-15
1
EXCLUDED BY SLAC E-56
EXCLUDED BY FNAL E-613
← Krauss & Wilczek10
EXCLUDED BY ELECTRON g-2 EXPERIMENTS
m_X = 1.8 MeV
τ_X (seconds)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
m_x (MeV)

FIGURE 1.

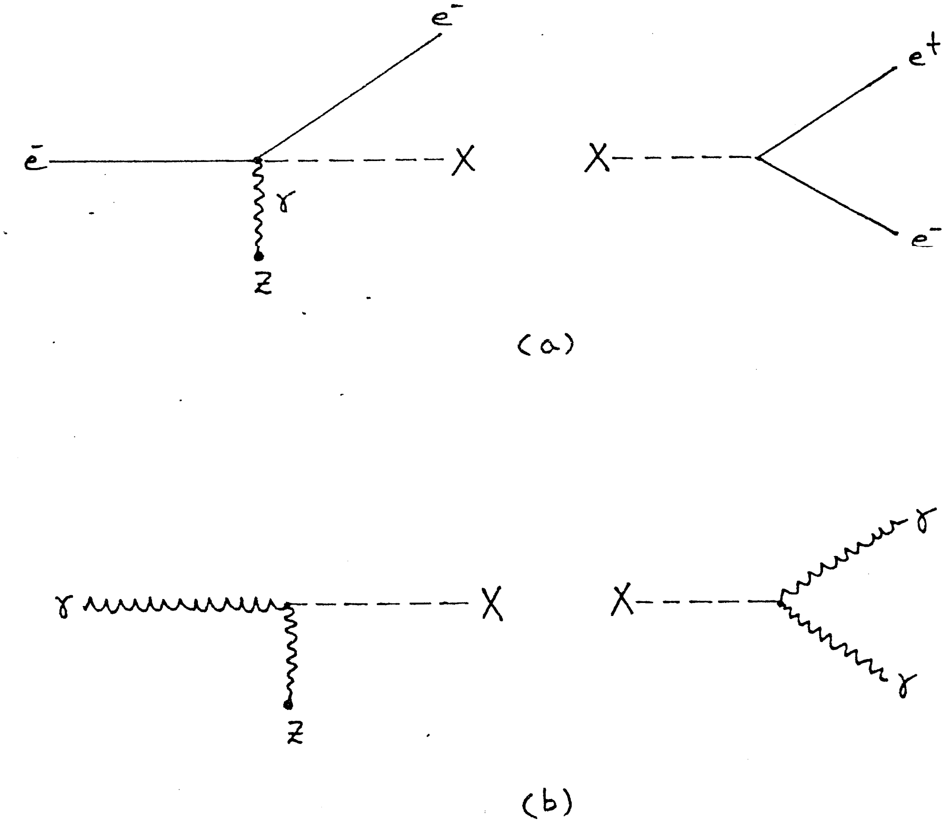
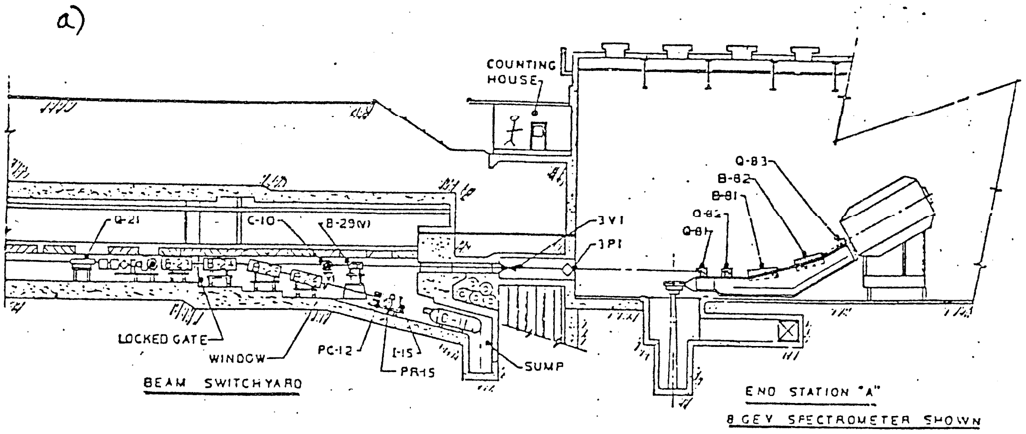


FIGURE 2.



LONGITUDINAL SECTION

B.S.Y. - E.S.A. AREA

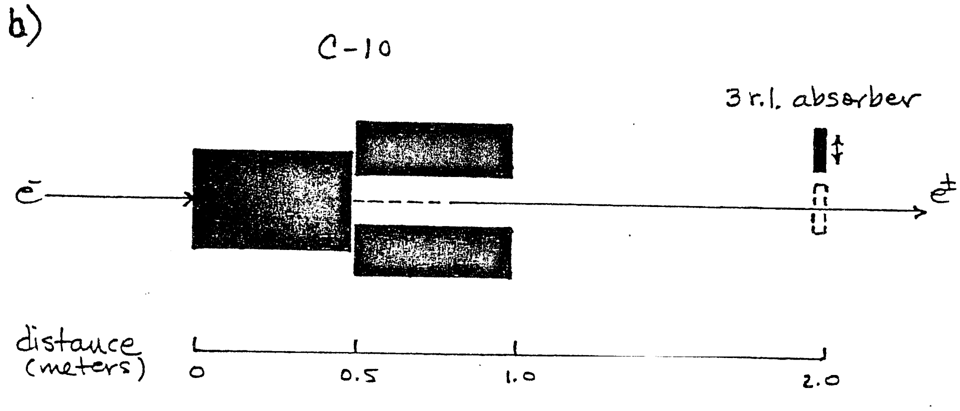


FIGURE 3.

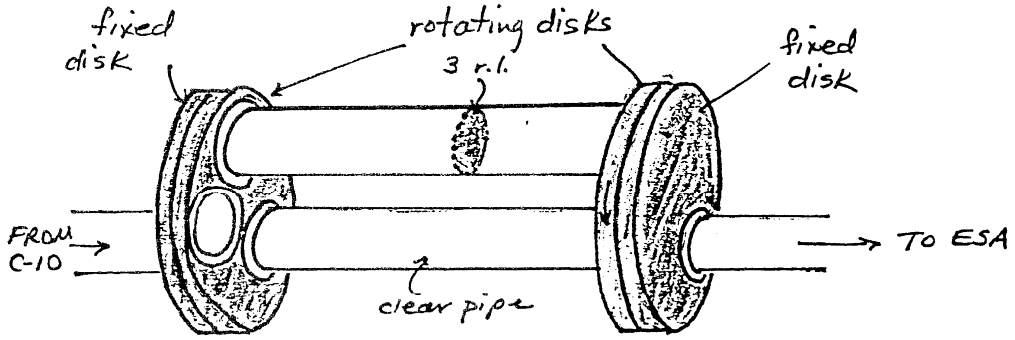

fixed disk
rotating disks
3 r.l.
fixed disk
FROM C-10
TO ESA
clear pipe

FIGURE 4.

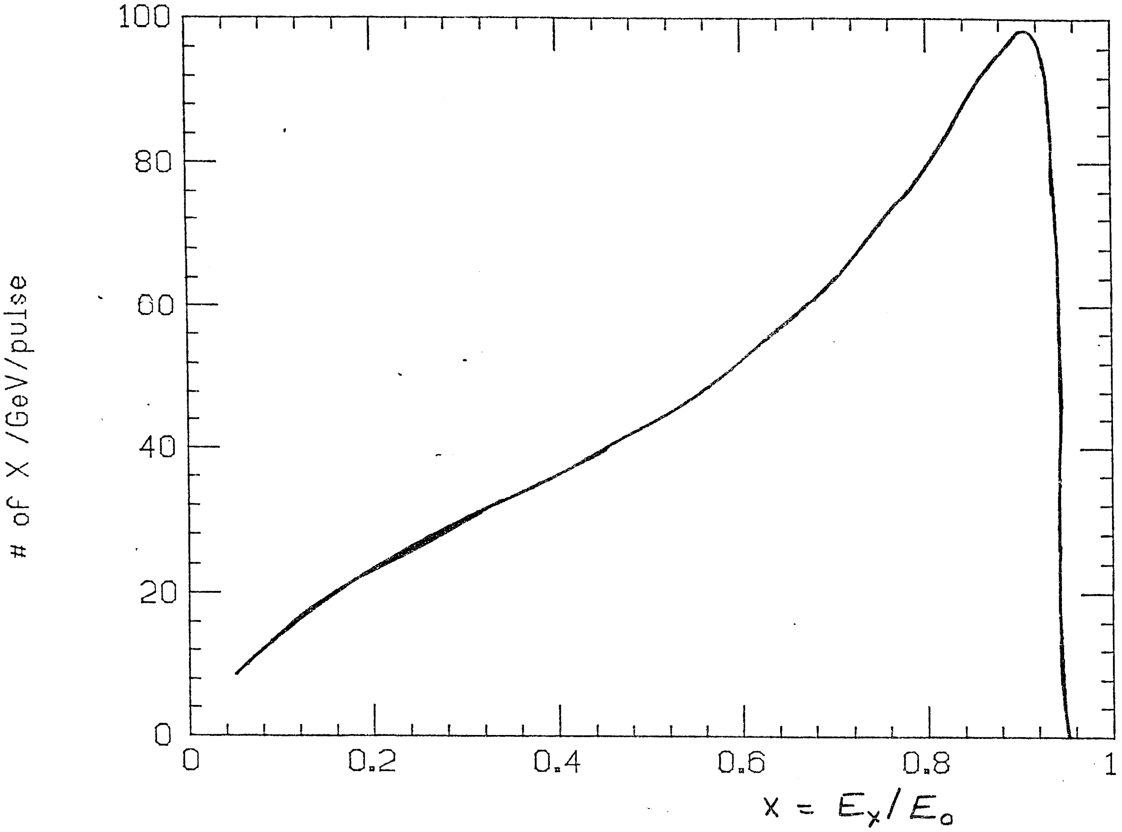


FIGURE 5.

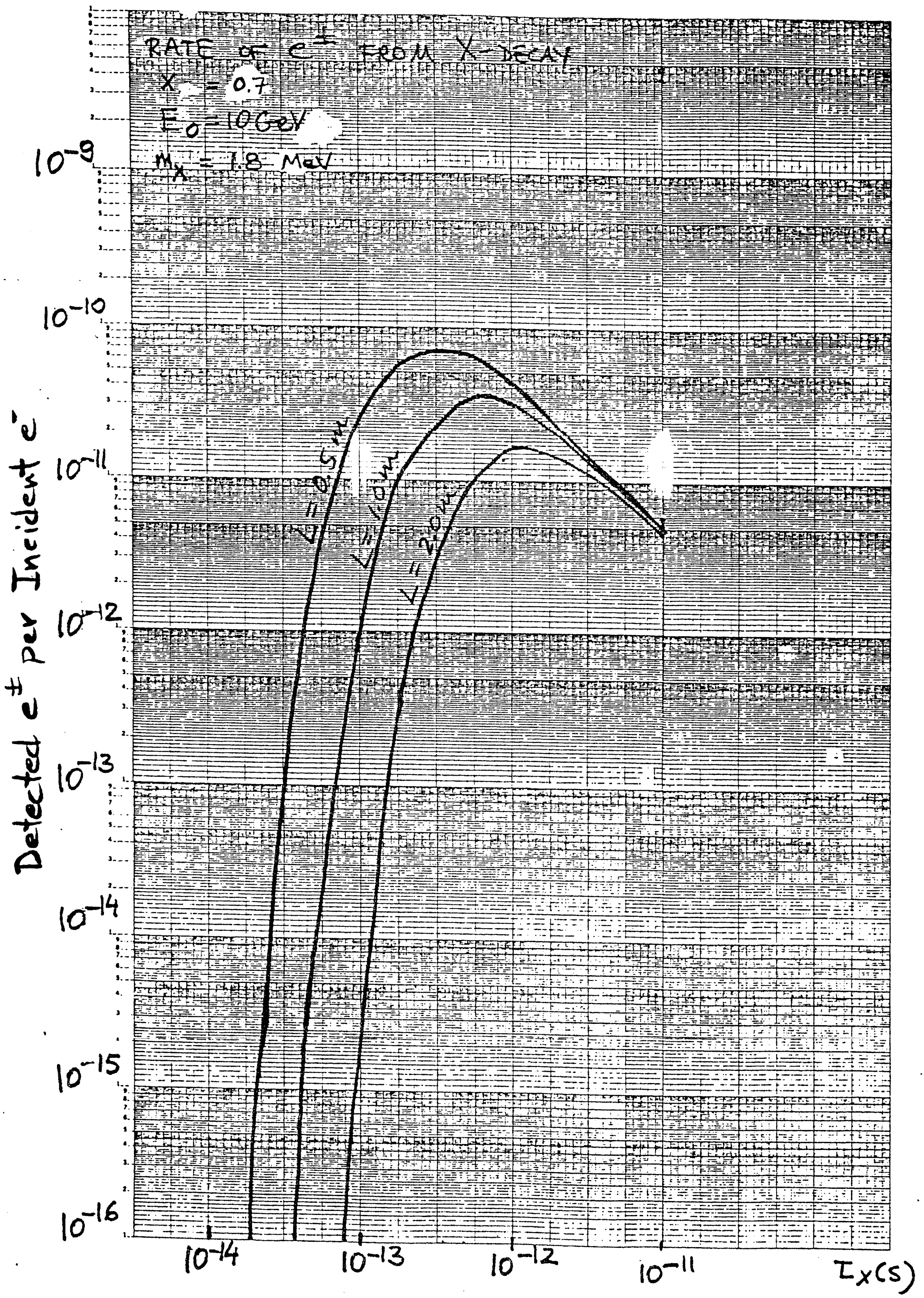

RATE OF $e^{\pm}$ FROM X-DECAY
$x = 0.7$
$E_0 = 10$ GeV
$m_X = 1.8$ MeV
Detected $e^{\pm}$ per Incident $e^-$
$10^{-9}$
$10^{-10}$
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
$10^{-15}$
$10^{-16}$
L = 0.5 m
L = 1.0 m
L = 2.0 m
$10^{-14}$
$10^{-13}$
$10^{-12}$
$10^{-11}$
$\tau_X$(s)

Figure 6.

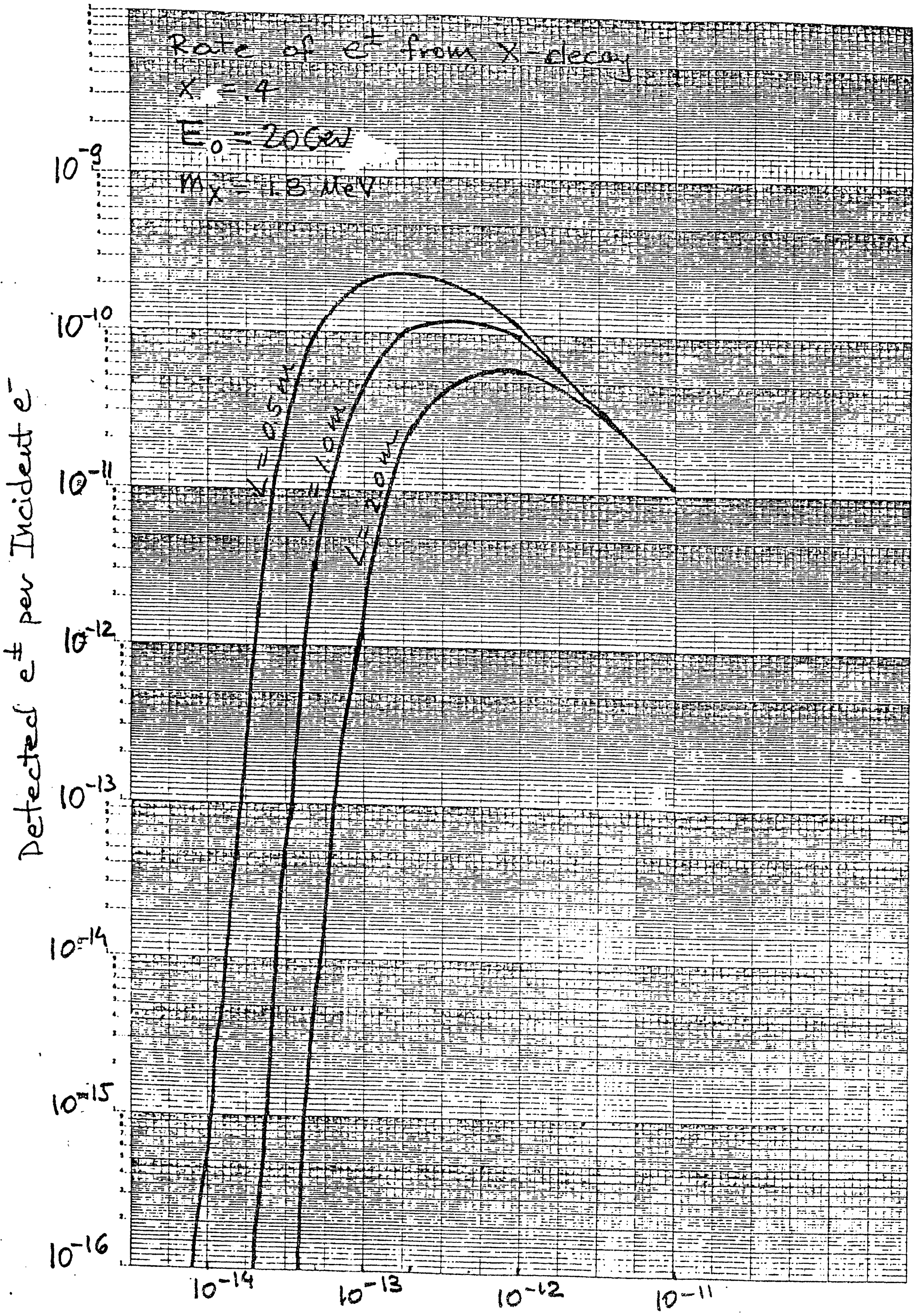
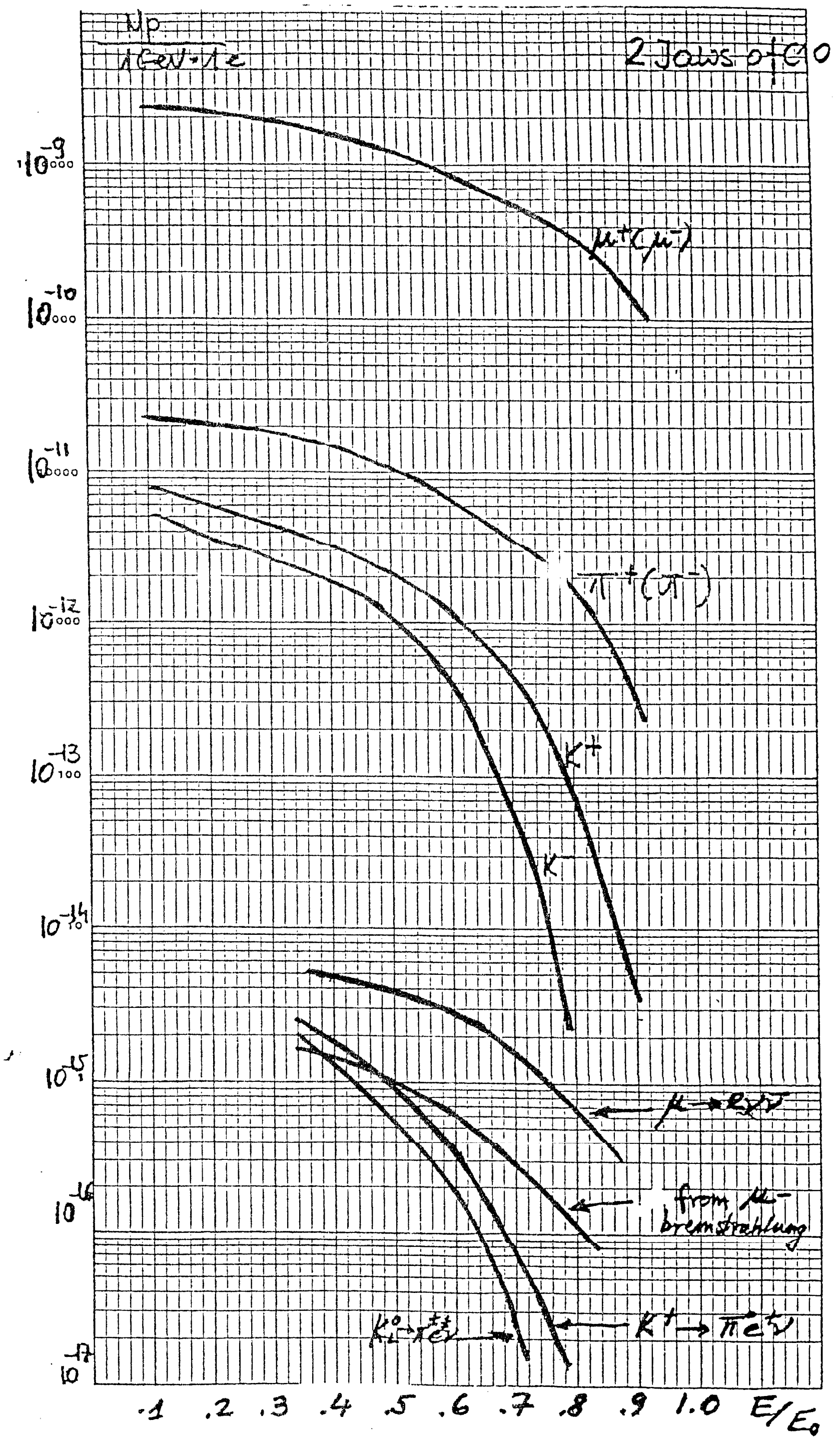

Rate of e± from X-decay
x = .4
$E_0$ = 20 GeV
$M_X$ = 1.8 MeV
Detected e± per Incident e⁻
$10^{-9}$
$10^{-10}$
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
$10^{-15}$
$10^{-16}$
V = 0.5m
V = 1.0m
V = 2.0m
$10^{-14}$
$10^{-13}$
$10^{-12}$
$10^{-11}$

FIGURE 7.



$\frac{N_p}{1\,GeV \cdot 1\,sr}$
2 Jaws of C 0
$10^{-9}$
$10^{-10}$
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
$10^{-15}$
$10^{-16}$
$10^{-17}$
$\mu^+(\mu^-)$
$\pi^+(\pi^-)$
$K^+$
$K^-$
$\mu \to e\gamma\bar{\nu}$
from $\mu^-$ bremstrahlung
$K_L^0 \to \pi^\pm e^\mp \nu$
$K^+ \to \pi^0 e^+ \nu$
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
$E/E_0$

FIGURE 8a.

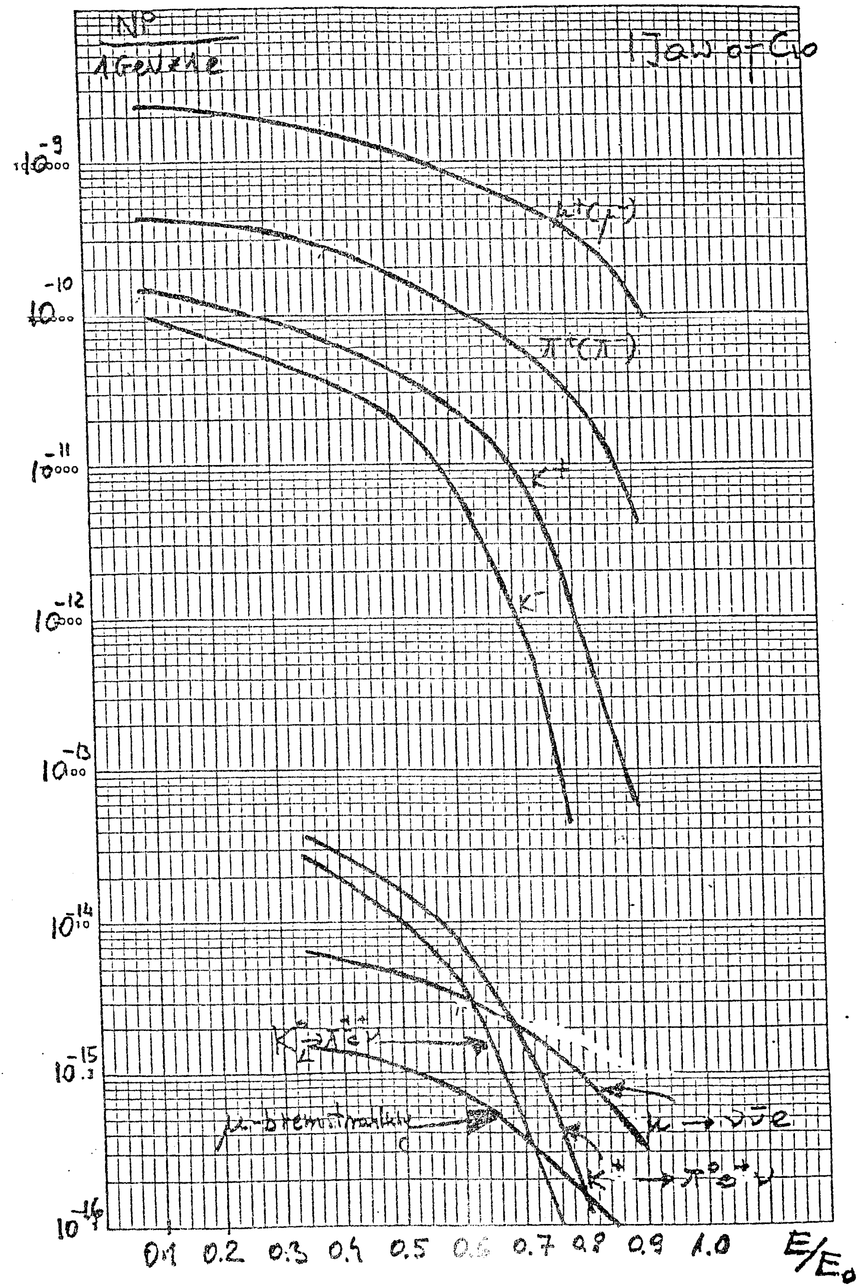

N°
1 GeV × Ne
1 Taw of Cu
$10^{-9}$
$10^{-10}$
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
$10^{-15}$
$10^{-16}$
$\mu^+(\mu^-)$
$\pi^+(\pi^-)$
$K^+$
$K^-$
$K_L \to \pi^{\pm} e^{\mp} \nu$
μ-bremsstrahlung
$\mu \to \nu \bar{\nu} e$
$K^+ \to \pi^0 e^+ \nu$
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
$E/E_0$

FIGURE 8b.

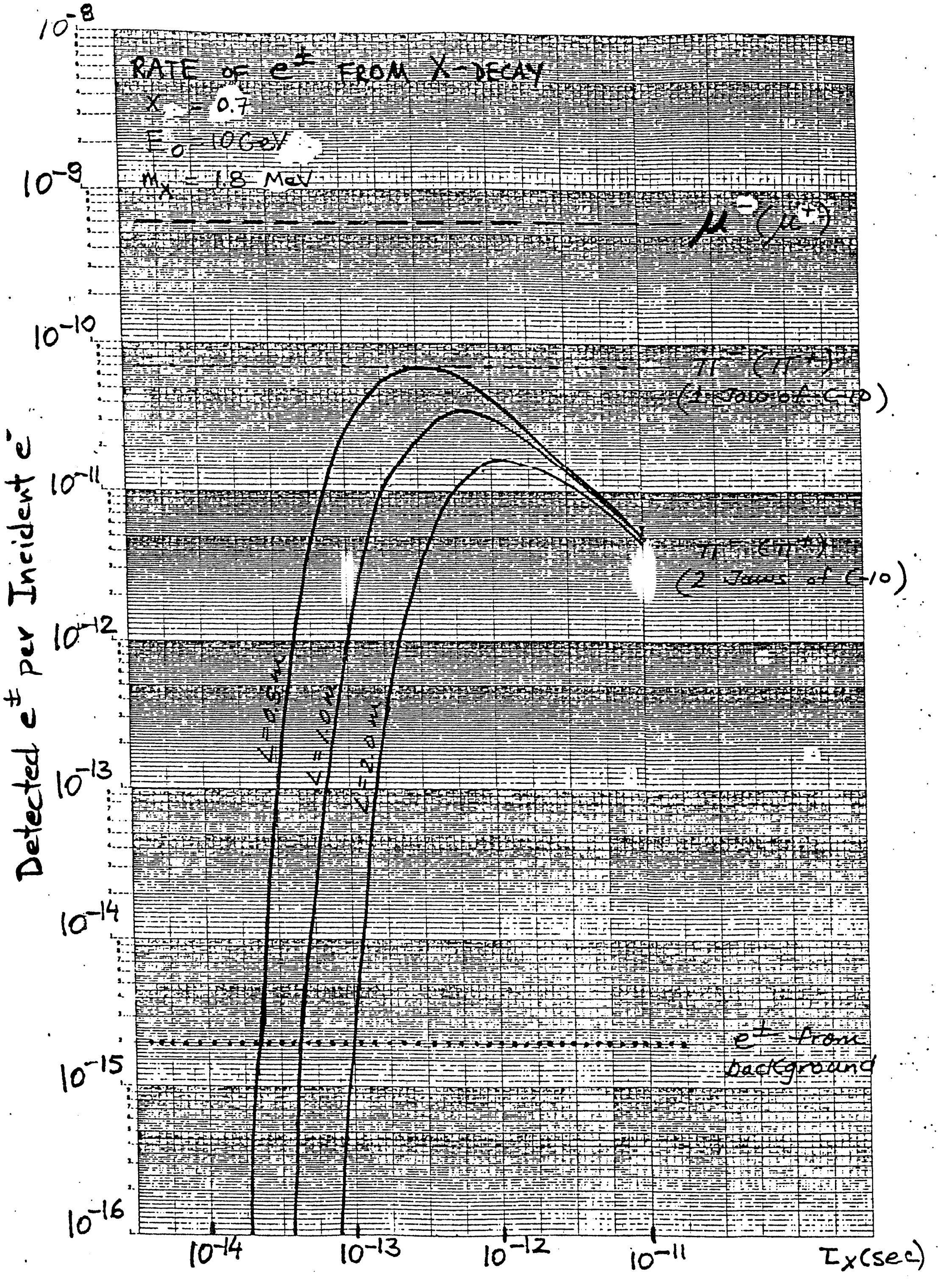

RATE OF $e^{\pm}$ FROM X-DECAY
$x = 0.7$
$E_0 = 10$ GeV
$m_X = 1.8$ MeV
$\mu^-(\mu^+)$
$\pi^-(\pi^+)$
(1 Jaw of C-10)
$\pi^-(\pi^+)$
(2 Jaws of C-10)
$e^{\pm}$ from background
$V = 0.5$ m
$V = 1.0$ m
$V = 2.0$ m
Detected $e^{\pm}$ per Incident $e^-$
$10^{-8}$
$10^{-9}$
$10^{-10}$
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
$10^{-15}$
$10^{-16}$
$10^{-14}$
$10^{-13}$
$10^{-12}$
$10^{-11}$
$\tau_X$(sec)

FIGURE 9.

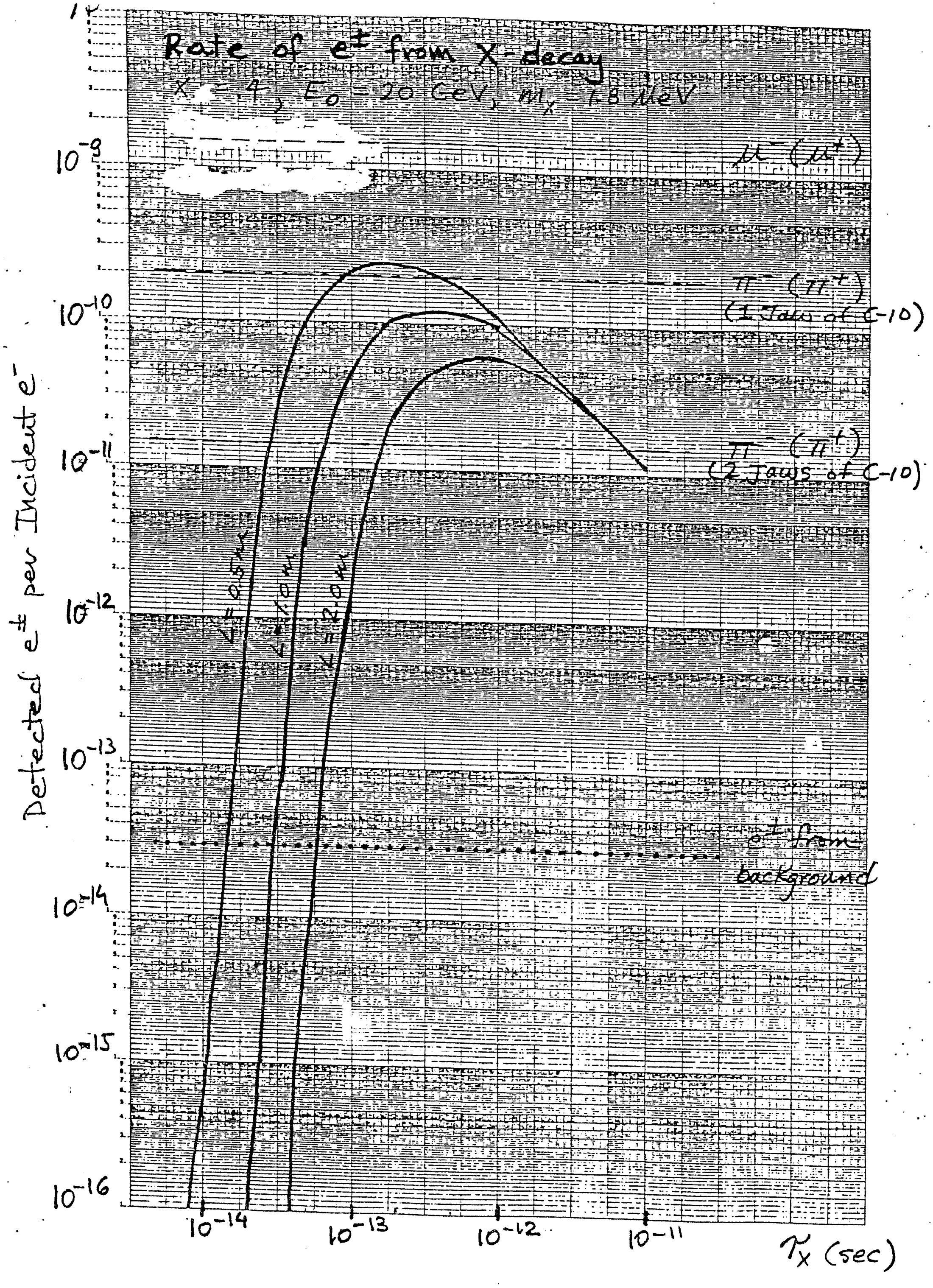

Rate of $e^\pm$ from X-decay
$x = .4$, $E_0 = 20$ GeV, $m_X = 1.8$ MeV
$\mu^-$ $(\mu^+)$
$\pi^-$ $(\pi^+)$
(1 Jaw of C-10)
$\pi^-$ $(\pi^+)$
(2 Jaws of C-10)
$\ell = 0.5$ m
$\ell = 1.0$ m
$\ell = 2.0$ m
$e^\pm$ from background
Detected $e^\pm$ per Incident $e^-$
$10^{-8}$
$10^{-10}$
$10^{-11}$
$10^{-12}$
$10^{-13}$
$10^{-14}$
$10^{-15}$
$10^{-16}$
$10^{-14}$
$10^{-13}$
$10^{-12}$
$10^{-11}$
$\tau_X$ (sec)

FIGURE 10.