Fermilab Proposal # 458

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PHOTOPRODUCTION EXPERIMENT AT FERMILAB

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I. Introduction

We propose to continue and extend the program of photoproduction and pair production studies currently being carried out in Experiment E-87. The goals of the physics program we propose are:

(i) to look for $\mu^{\pm}+e^{\mp}\nu$'s final states.

(ii) to study the mass spectra of hadronic final states which are produced in association with a single charged lepton (electron or muon).

(iii) to determine the properties of a selected number of photoproduced multi-body hadronic final states; in particular:

$$\begin{aligned} \gamma + A &\rightarrow (\bar{p}p\pi^+\pi^-) + A \\ &\rightarrow (\pi^+\pi^-\pi^+\pi^-\pi^o) + A \\ &\rightarrow (K^+K^-\pi^+\pi^-) + A \\ &\rightarrow (K^+K^-\pi^+\pi^-\pi^o) + A \end{aligned}$$

etc., etc.

The need for a heavy lepton pair production experiment is more crucial today than when we first proposed this experiment five years ago. The μe pairs observed recently at SPEAR can be interpreted as arising from the decay of 2 GeV/c^2 heavy leptons. We feel there is a compelling need to demonstrate that such μe pairs are observed in at least one other reaction before such an interpretation can be considered completely satisfactory. To the best of our knowledge, the only independent reaction in which one might expect to observe such events is the pair production of heavy leptons. The broad band photon beam at Fermilab is perhaps the only beam in which such a pair production experiment is feasible. In addition, the probability of mis-identifying two hadrons as a μe pair is extremely small (10^{-6}) at Fermilab energies--several orders of magnitude smaller than at SPEAR.

Our primary motivation for examining the photoproduced hadronic final states such as $\pi^+\pi^-\pi^+\pi^-\pi^0$ and $K^+K^-\pi^+\pi^-\pi^0$ is to search for structure in the mass spectra of these states. We propose to do so by both measuring and identifying these final state particles. We expect to observe hadronic decays of $\psi(3.1)$, $\psi(3.7)$, and other structures at higher masses.

II. Physics Objectives and Rates

All the physics objectives to be described in this proposal are natural extensions and outgrowths of the program begun in Experiment E-87. Indeed the major reason we are convinced the physics proposed here can be completed successfully is because of the experience we have gained in E-87, i.e., we are well aware of the strengths and limitations of both the wide band beam and our own pwerful detection system.

(a) Pair Production of Heavy Leptons

The interpretation of the μe events observed at SPEAR as an indication of the possible existence of a heavy lepton is extremely provocative. We feel that a decisive test of this interpretation requires the observation of μe pairs arising from a different production mechanism; the pair production process is clearly such a mechanism.

We have made detailed calculations of the rates at which heavy leptons would be produced and detected using the basic experimental layout of Experiment E-87. The pair production cross sections we have used in this calculation have been provided by Y. Tsai, and are typically $2(10^{-34})cm^2$ for an incident photon of E_γ = 200 GeV. Integrating the yield over the photon energy spectrum we can determine the total number of heavy lepton pairs produced in the wide band beam. The average detection efficiency of our apparatus for detecting both the electron and the muon arising from the decays

$$\text{heavy lepton} \rightarrow e^\pm + \nu + \bar{\nu}$$
$$\rightarrow \mu^\pm + \nu + \bar{\nu}$$

is large; typically 30% of all such decays are detected if they arise from 2 GeV/c^2 heavy leptons which are pair produced by 75 GeV photons. In a 600 hour run at an average intensity of 5 x 10^{12} protons per pulse, the number of $\mu^\pm e^\mp$ events detected would be 1000 B^2, where B is the branching ratio into the leptonic channel, i.e., $B = \lambda \rightarrow e\nu\nu/\lambda \rightarrow \text{all}$. If B = .2, then the total rate would be 40 events (see Fig. 2 for detail calculation).

The size of the event sample we propose collecting is approximately equal to the number of μe candidates observed at SPEAR. The dominant feature that will make our event sample particularly compelling arises from the phenomenally improved ability one has for identifying electrons and muons at high energy compared to low energy.

In the subset of data from E-87 which we have analyzed thus far, we have observed one μe candidate which is consistent with the hypothesis of heavy lepton pair production. (See talk presented by W. Lee at SLAC Conference 1974.) Although we make no claims for this one event, the relevant point is that by performing this analysis we have been able to <u>measure experimentally</u> our μ/π and e/π rejection ratios. Consequently, we have experimental data that allows us to determine the improvements that need to be made to our detector in order to have adequate rejection of hadrons at the cross section level expected for heavy lepton pair production. The detector improvements are discussed in Section III. Another interesting source of μe events would be leptonic decays of charmed particles. The production and decay of charmed particle pairs is discussed in (b).

(b) The source of single charged leptons in hadron-hadron collisions and of charged lepton pairs in neutrino-hadron collisions is unexplained, although several interesting conjectures have been put forward. We will consider three possible mechanisms for producing a single charged lepton in photon-hadron collisions. For the first one we assume that single charged leptons are a general property of central hadron collisions. Since the photon-nucleon total cross section is dominated by the contribution of vector mesons interacting with the nucleons we would expect that the number of direct produced charged leptons should be $\sim N\pi \times 10^{-4}$ of the total photon-nucleon cross section. The effective cross section for single lepton production would then be of order $10^{-31} cm^2$ per nucleon for an incident photon energy of 100 GeV.

For the second possibility we assume that the single charge lepton could be due to the photoproduction of a charmlike-anticharmlike pair of hadrons, followed by the semileptonic decay of one of these particles.

A speculative estimation of the cross section can be made from the following assumptions

(i) the $\psi(3.094)$ is a $c\bar{c}$ bound state. When the interact with nucleons the dominant inelastic process is dissociation.

(ii) the forward scattering amplitude of the $\psi(3.094)$-nucleon is very nearly imaginary.

(iii) vector dominance is applicable to the photoproduction of the $\psi(3.094)$ on nuclei.

With these assumptions one arrives at a cross section of 10^{-30}cm^2 for $c\bar{c}$ pair production. If the probability for a semi-leptonic decay of a c is 10%, then the cross section for single lepton production by this mechanism would be 10^{-31}cm^2.

A third mechanism for the production of single leptons would be through the production of a pair of heavy leptons, followed by the decay of one of these leptons into a ν plus hadrons while the other decays leptonically as described in (a). If the heavy lepton had a branching ratio as assumed in (a), the cross section for single charged lepton production would be six times that of the $\mu^{\pm}e^{\mp}$ final states. The cross section would be of the order of 10^{-34}cm^2, approximately 10^{-6} of the total photon-nucleon cross section. We would not expect this mechanism to dominate the single lepton final states. Nevertheless there are certain final states which may arise more prominently from this mechanism than the preceding ones. Consider the decays

$$\lambda_1 \rightarrow K^{\pm} + \nu_{\lambda} \qquad\qquad \lambda_2 \rightarrow e + \nu_e + \nu_{\lambda}$$
$$\rightarrow p^{\pm} + \nu_{\lambda}$$
$$\rightarrow K^{*\pm} + \nu_{\lambda}$$

The electron signal will give adequate rejection of hadrons.

Our intent here is to first establish the level of direct produced single leptons in photoproduction (if this has not been done in E-87) and second to determine which type of mechanism is most likely. Moreover we would be able to determine whether the particle composition contains unusual amounts of strange particles, neutrals such as η and η', and baryon-antibaryon pairs. It is possible to identify new states with our proposed detector. We estimate our efficiency for detecting all of the decay products of one member of the $c\bar{c}$ pair and at least the lepton from the other member of the pair to be of the order of 10%. The principle assumption which went into this estimation was to assume that multiplicity of a hadronic decay of a c would be the same as the comparable multiplicity in a hadron-hadron collision at a center of mass energy of 2 GeV. On this basis we would expect to detect 10 of these events/day. The number of events stemming from a particular decay mode is, of course, unknown.

The principle limitation in our detector for this experiment is the size of the magnet aperture. The particle identifier and most of the proportional chambers could be used with a much larger magnet as was proposed in the original E-87 proposal. With a magnet of 1000 in^2 it would be possible to detect all of the decay particles resulting from the production of a $c\bar{c}$ pair.

(c) the number of $\psi(3.1)$ decaying into $\pi^+\pi^-\pi^+\pi^-\pi^0$ which we detect in this experiment is expected to be ~500. The purpose of putting this number down is to illustrate the sensitivity of the experiment. The number ~500 is very similar to the number acquired by SPEAR. We know that the ratio $\psi\to\mu^+\mu^-/\gamma\to\mu^+\mu^-|_{m=3.1}$ is considerably larger in our experiment than at SPEAR. We believe that it is possible that some new and therefore, interesting hadronic final states could be detected by us, while they might not be as easily recognized at SPEAR. These final states will also be analyzed in terms of a pair production of charmed particles.

III. Detector Improvement

The detector system which will allow us to carry out the physics program described above is basically an extension and improvement of the magnetic spectrometer and particle identification system used in Experiment E-87. We describe here the modifications and additions we plan to make to the existing experimental layout and we summarize how these detectors will extend and improve the scope of the physics program we will pursue.

(a) Cerenkov Detectors

The two Cerenkov counters shown in Fig. 1 will be used in a conventional fashion to provide detailed information and particle identification on the character of the photoproduced final state. A detailed design and test program is currently in progress to optimize the parameters of these counters for the range of secondary momenta contained by our spectrometer. The precise momentum range over which these counters will provide separation of pions, kaons, and protons, will not be determined until the final design is complete. We estimate that we will be able to achieve π-K-p separation up to ~100 GeV/c. At lower momentum $e^{\pm}$ identification will improve considerably with the Cerenkov detectors.

(b) π^0/γ Detector

The addition of a π^0/γ detector to the experimental apparatus described above will provide us with the ability to do both complete identification and reconstruction of very complicated final state topologies. The existing electromagnetic shower detectors already yield a measure of the energies of both photons and electrons with a precision on $\pm 4\%$ at 16 GeV. We plan to add a new-type of proportional wire chamber that will measure the position of the electromagnetic shower after a depth of 4-6 radiation lengths into the electromagnetic cascade. This depth is large enough to ensure that virtually 100% of the photons have begun to cascade but small enough so that the center of gravity of the shower has not begun to spread significantly in a lateral direction.

The novel feature of the proportional wire chamber we will use to measure the photon conversion point is that it will measure the pulse height and the center of gravity of the electromagnetic cascade with an accuracy of $\lesssim$ 1 cm. The addition of this detector will greatly improve $e^{\pm}$ identification.

We have constructed a prototype proportional wire chamber of the type we plan to use. The signals induced on the cathode plane of the chamber, by the charged particles in the electromagnetic cascade of a converted photon, are detected and pulse height analyzed. We are developing the electronics to provide a measurement of the centroid of the pulse height distribution and plan to test the prototype and associated electronics in the next several months.

Request for Running Time

1) 100 hours of testing
2) 200 hours of low intensity run ($\sim 10^{12}$ ppp) to take data on hadronic and charged leptonic and hadron final states
3) 400 hours of high intensity run ($\sim 5\times10^{12}$ ppp) for $e\mu$ and charged lepton and hadron final states.

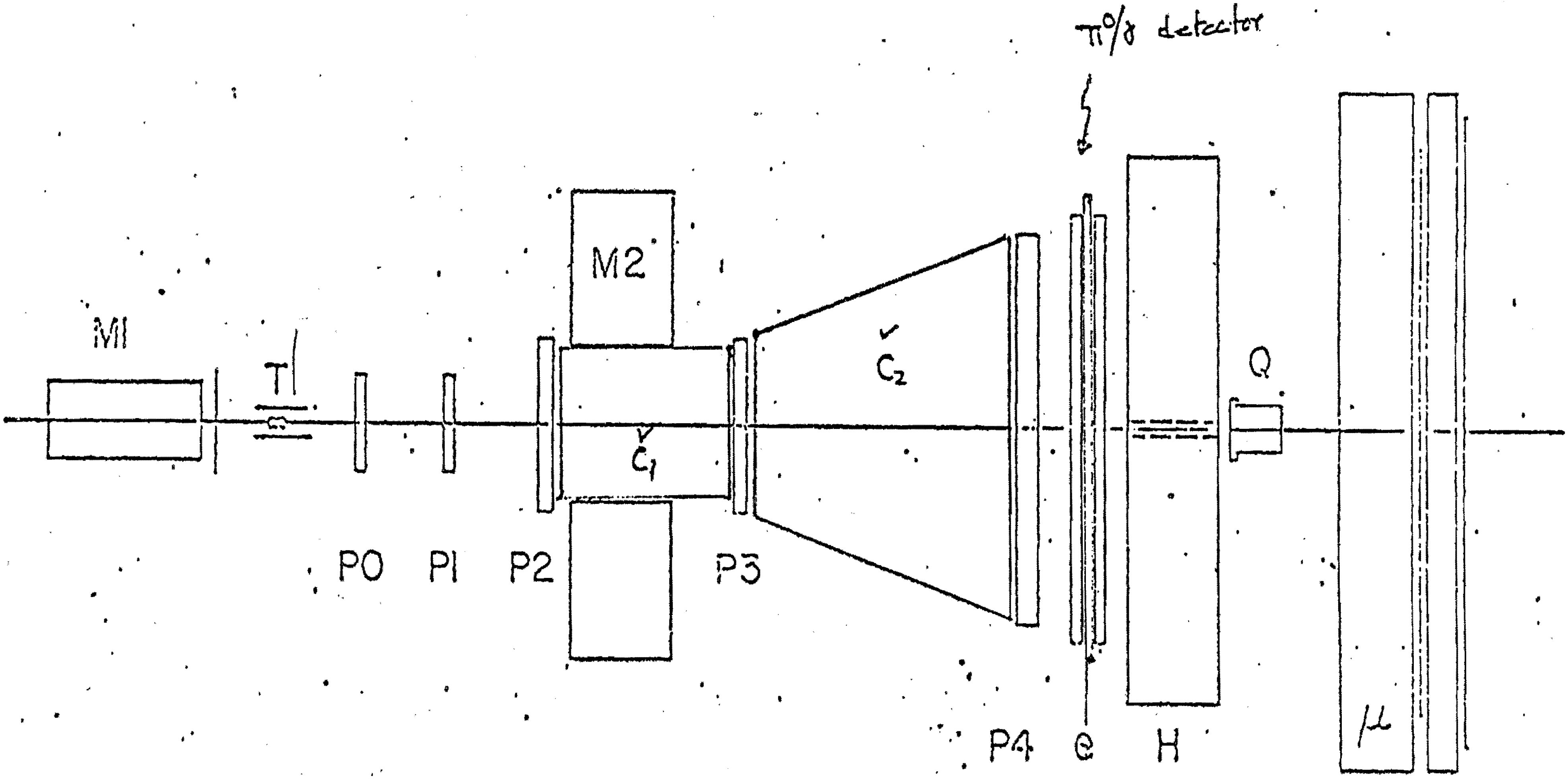
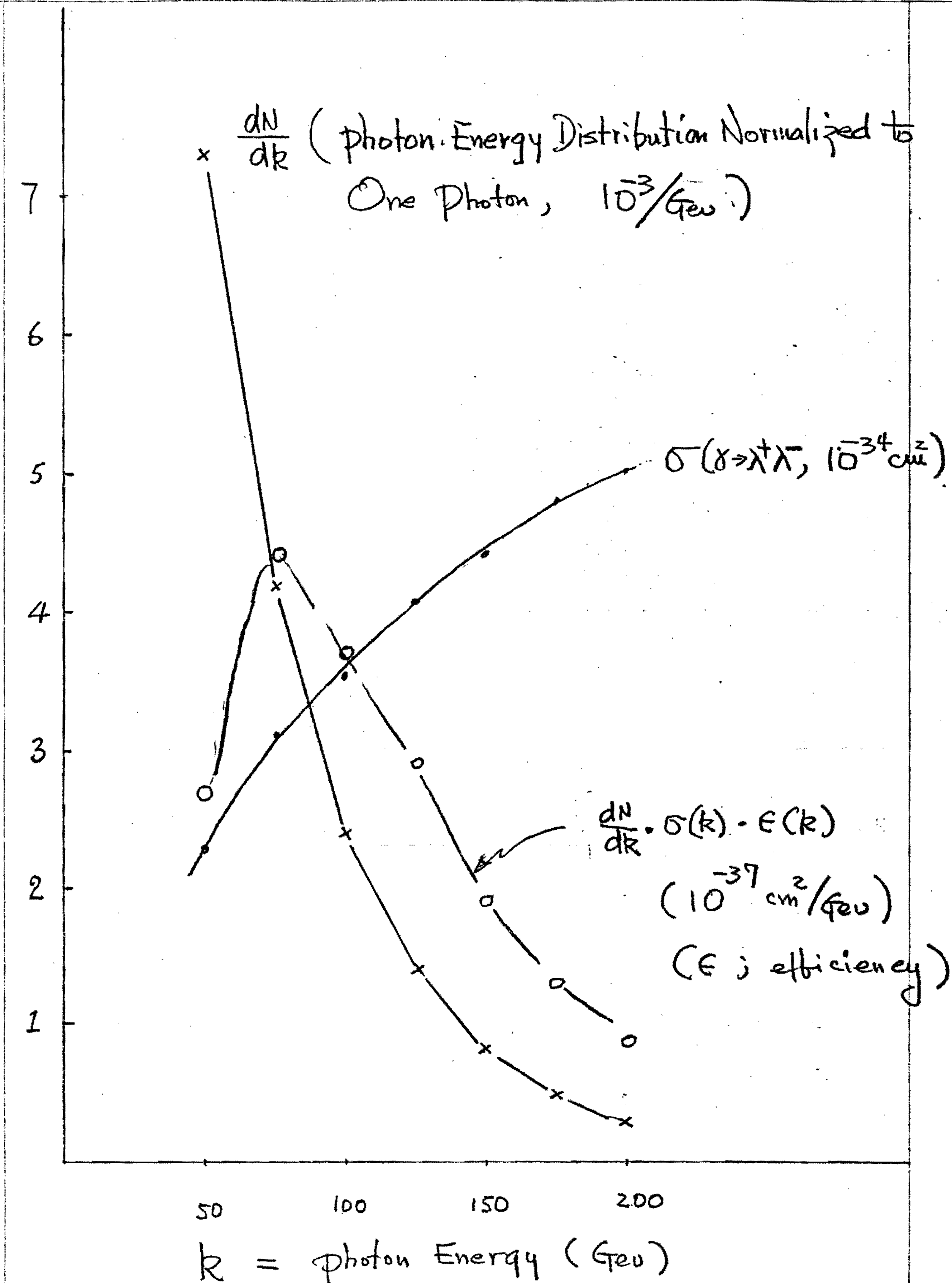


Fig 1



dN/dk (photon Energy Distribution Normalized to One Photon, 10^-3/Gev)
σ(γ→λ+λ-, 10^-34 cm^2)
dN/dk · σ(k) · ε(k) (10^-37 cm^2/Gev) (ε ; efficiency)
7
6
5
4
3
2
1
50
100
150
200
k = photon Energy (Gev)

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I. Introduction

We propose to continue and extend the study of photoproduction of massive 1^- objects and the photoproduction of pairs of new particles with a much improved detector. The main improvements are: 1) the geometric acceptance of the detectors is increased from $\sim \pm 30$ mrad to $\sim \pm 150$ mrad thereby making it possible to momentum analyze charged particled produced at large angles ($\theta > 60$ mr); 2) momentum resolution of high energy tracks has been improved leading to improved mass resolution through the use of drift chambers and a stronger magnetic field; 3) γ ray directions as well as γ ray energies are measured making it possible to measure the mass of states with π^o, η^o, and γ's; 4) the charged particles are separated into $\pi^{\pm}/K^{\pm}/p^{\pm}$ in certain momentum ranges by gas Cerenkov counters.

The larger geometric acceptance of the proposed detector coupled with improved mass resolution allows this experiment to extend the search for vector mesons to considerably higher masses than what was accessible in E-87. The addition of two new detectors, one to measure both the shape and location of a γ ray shower development in space, and the other to identify charged particles, opens the study of many final states which were not accessible in E-87.

The primary objectives of the proposed experiment are: 1) to study the interaction dynamics of the known massive vector mesons, ψ, ψ', and ψ'', and to search for new massive vector mesons; and 2) to search for the photoproduction of heavy lepton pairs. We also plan to improve significantly our previous search for charmed particle pairs.

II. Detector and Detector Layouts

Figure 1 shows our detector layout. New additions are clearly labelled. They are:

1) a new magnet M1, which has an aperture of 15 in. x 15 in., a magnetic field length of 40 in., and a field integral of 450 MeV/c;

2) D_1, D_2, and D_3 are 5 ft x 5 ft drift chambers with x-y planes. P_o is a high resolution multiwire proportional chamber (or a drift chamber);

3) E_o is an outer electron/γ ray identifier similar to the present E-87 electron identifier;

4) M2 is a new high field large aperture magnet which has an aperture of 30" x 30", a magnetic length of 60", and a field integral of 1500 MeV/c;

5) C is a gas Cerenkov counter; and

6) P_5 is a multiwire proportional chamber to measure the size and position of showers.

The remaining detectors are the same as those used in E-87 and E-400/E-401.

A. The Magnetic Spectrometers

The detectors consisting of $P_0P_1D_1D_2P_3P_4D_3$ and the magnet M2, which we call the inner detector, subtend a solid angle of ±50 mr. The detectors $P_0P_1D_1$ and the magnet M1, which subtend a solid angle ±150 mrad in both horizontal and vertical planes, are called the outer detector. In the rest of the discussion, the outer detector does not include the inner detector. D_2 is used as a muon identifier in the outer detector and the iron of magnet M2 acts as a hadron absorber. In the case of two track final states, two situations arise: 1) both tracks go through the inner detector; and 2) one of the tracks goes through the inner detector and the other through the outer detector.

If both tracks are in the inner detector, the event can be analyzed in a straightforward manner. In this case, assuming that we can attain a spatial resolution of ±0.15 mm (rms) with drift chambers, then $(\delta p/p)_{inner}$ = 0.014 (P(GeV/c)/100) FWHM. This gives a mass resolution of 50 MeV FWHM for a 5 GeV narrow resonance decaying into charged tracks. The multiple scattering in the target, which is taken to be 10% of a radiation length, is included.

If one track traverses the inner detector, and one traverses the outer detector, the momentum of the track in the outer detector can be determined. The dominant error comes from locating the interaction point in the bending plane with the track that traverses the inner detector. The momentum resolution of the outer detector is then $(\Delta p/p)_{outer}$ = 0.06 (P(in GeV)/25) FWHM. The typical momentum of a particle which traverses the outer detector is between 7 and 30 GeV/c for a 5 GeV object decaying into two charged particles, as shown in Figure 2. For this case, we get a mass resolution of 150 MeV FWHM. These numbers should be compared with the mass resolution of 450 MeV FWHM at 5 GeV in E-87.

The improvement in acceptance at the ψ(3.1) for the proposed detector is a factor of 5 compared to E-87 when we average over the photon spectrum. The increase in acceptance at a 5 GeV object decaying into two muons is 10 times larger and for masses above 5 GeV we have good acceptance in the momentum range 50 to 150 GeV while it was essentially zero in E-87.

There will be three 5 ft x 5 ft drift chambers with anode (signal) wires every 1 cm to deal with very high rates. Field wires will be located halfway between the anode wires and above and below the anode wires. Rssolution is expected to be about 150 μ. The electronics will be the same design as the one developed by W. Sippach at Nevis Laboratory which is being used in an experiment at the ISR. The system posses a least count time resolution of 1.5 ns leading to an excellent least count spatial resolution of 75 μ. The drift times of two signals on the same wire can be measured if they are separated by at least 36 ns. In order to handle a very high rate on the wire the electronics for each wire has a local memory so that many signals can be recorded during the full drift space memory time.

B. Cerenkov Counters

The Cerenkov counter shown in Figure 1 will be used in a conventional fashion to provide detailed information and particle identification on the character of the photoproduced final state. A detailed design and test program is currently in progress to optimize the parameters of these counters for the range of secondary momenta contained by our spectrometer. The precise momentum range over which these counters will provide complete separation of pions, kaons, and protons will not be determined until the final design is complete. We estimate that we will be able to achieve complete π-K-p separation between $\sim$ 10 to 70 GeV/c. Below 10 GeV $e^{\pm}$ identification will be helped considerably by the Cerenkov detectors.

C. γ ray detector

The addition of P_5, a π^o/γ detector, to the experimental apparatus will provide us with the ability to reconstruct the directions of γ, π^o, and η and it will improve our electron identification. The existing electromagnetic shower detectors already yield a measure of the energies of both photons and electrons with a precision on ±4% at 16 GeV. A new type of proportional wire chamber that will measure the position of the electromagnetic shower is placed at a depth of 4-6 radiation lengths into the electromagnetic cascade. This depth is large enough to ensure that 95% to ____ of the photons have begun to cascade but it is small enough so that the lateral deviation center of gravity of the shower has not begun to deviate significnatly from the γ ray direction. The size of the shower is expected to be ∿ 1 cm. We will measure then the shower position to ± 2 mm. The novel feature of the proportional wire chamber which we will use to measure the photon conversion point is that it will measure the pulse height and the center of gravity of the electromagnetic cascade.

III. Rates and Trigger

In Figure 3 we show the momentum spectrum of the broad band photon beam as used by E-87. For $E_\gamma > 50$ GeV, this spectrum is well described by the formula $\left(\frac{dN}{dE_\gamma} = 4.5 \times 10^5 \, e^{-E_\gamma/45} \text{ photon/GeV}\right)$ for 10^{12} 400 GeV protons on target.

We intend to increase the [illegible] of the collimator aperture of the neutral beam by a factor of two area, and to run with an incident proton intensity of 3×10^{12} protons per pulse. This will result in a photon flux which is a factor of 8 more than was used in E-87. We will be able to run at such high rates because of the new M1 magnet, which will sweep all low momentum e^+e^- pairs away from the detectors. Based on our past experience, we will have no trouble in taking this intensity. In particular, the current drawn by the MWPC's, which previously limited our intensity, will remain at quite comfortable levels without the e^+e^- pairs, as we were able to demonstrate in E-87 during short periods of high intensity running with a small amount of lead downstream from the target to absorb the pairs.

The limitations on intensity will be due only to trigger rates. As in E-87, we intend to run with three basic classes of triggers: dilepton triggers (ee, μe, and $\mu\mu$); multi-hadron triggers; and single lepton plus hadron triggers. The new detectors and additional electronics will alow us to make each of these triggers substantially more selective than before, so that we can run with the higher intensity and increased acceptance as proposed and still write less data on tape than in E-87.

Again based on our experience, we expect no problems with the rates of the dilepton triggers, which always represent only a small fraction of our triggers. We intend to add microprocessors to insure that the tracks we trigger on point back to the target and have high transverse momentum, to eliminate accidental and low mass lepton pairs. (Such a system is presently being designed for E-400.) This will be more than adequate for the dilepton events.

For the purely hadronic final states, we will use the MWPC information at the trigger level to require at least four hadron tracks coming from the target. By requiring that at least two tracks have a transverse momentum of more than 400 MeV, the abundant 4π decay of the $\rho''(1600)$ can be supressed. As with the lepton pairs a microprocessor will be used to make a crude measurement of the particle momenta and transverse momenta. With this information and the Cerenkov counter information we will be able to suppress neutron induced events while enriching the sample of events containing K^+, K^- and p, $\bar{p}$ pairs. Furthermore we will require that the minimum hadronic energy exceed a threshold ($\sim$ 50 GeV). We will use the Cerenkov counter to choose final states rich in $K^{\pm}$ and $\bar{p}$.

The single lepton triggers will be reduced in a similar manner to the multi-hadron triggers. Here we will also benefit from the improved electron identification due to the new P_5 chamber. Again we do not forsee any particular problems with the trigger rates.

IV. Physics Objectives

A. Search for New Vector Mesons (Dilepton Decays)

In invited talks at the New York APS Meeting in February and at the Vanderbilt Conference in March, Experiment 87 reported the observation of 11 photoproduced dimuon events which suggest the existence of a new massive vector meson V, with a mass around 4.7 GeV/c^2. If this effect is real, this object V is produced with a cross section times branching ratio relative to the ψ of

$$\frac{\sigma^V \cdot B^V_{\mu\mu}}{\sigma^\psi \cdot B^\psi_{\mu\mu}} \approx 1.5\%$$

Naturally, we are quite interested in making further observations of this state to firmly establish its existence.

With the increased acceptance of the new detector, we expect to observe a total of 500 events of V decaying into $\mu^+\mu^-$. The signal to background ratio will be improved by an order of magnitude due to the improved mass resolution of the new detector (150 MeV FWHM compared to 450 MeV in E-87). We will also detect a similar number of events of V decaying into e^+e^-. This will be adequate to not only confirm the existence of this state, but also to gain insight into its production mechanism and hadronic interaction properties.

We will also search for unknown objects in the mass range of 2.5 to 10 GeV/c^2. In Figure 4 we give relative numbers of high mass vector mesons we could observe. We assume that

1. $\Gamma(V \to \mu^+\mu^-) = \Gamma(\psi \to \mu^+\mu^-)$
2. $\sigma_T(V) = \sigma_T(\psi)$
3. Detection efficiency is calculated for two-body final states.

We find a significant rate for a 10 GeV/c^2 state. This state can be observed if its photoproduction is 0.5% of the ψ photoproduction cross section.

B. Search for New Vector Meson (Hadronic Decays)

If a vector meson width is more than 10 MeV it is likely that its branching ratio into lepton pairs is 10^{-4} or less. A broad width suggests that a hadronic decay mode, such as $\pi^+\pi^-\pi^+\pi^-\pi^o$ $(4\pi^c,\pi^o)$, would be a better final state to use in a search for such particles. As an example of our sensitivity we discuss our ability to photoproduce and detect the $\psi''(4.4\ \mathrm{GeV}/c^2)$ which has a leptonic decay width of 440 eV, and a branching ratio in e^+e^- of only 1.5×10^{-5}.

We write the cross section for vector meson production in terms of the $\psi(3.095)$ photoproduction cross section as follows:

$$\sigma_{\gamma V} = \left(\frac{\Gamma^V_{ee}}{\Gamma^\psi_{ee}}\right)\left(\frac{M_\psi}{M_V}\right)\left(\frac{\sigma^T_{VN}}{\sigma^T_{\psi N}}\right)^2 \cdot \frac{b_\psi}{b_V} \cdot \sigma_{\gamma\psi}$$

where Γ^V_{ee} is the vector meson leptonic decay width, σ^T_{VN} is the total V meson-nucleon cross section, and b_V is the slope parameter of the V meson-single nucleon cross section. Our experience with the ψ showed that the most important contribution to the photoproduction of ψ is the quasielastic photoproduction of a single nucleon (no pion production). If we assume that σ^T_{VN} is equal to $\sigma^T_{\rho N}\left(\frac{M_\rho}{M_V}\right)^2$, that b_ψ equals b_V, and that $B^V_{4\pi^c,\pi^o}$ is .02, then we would expect to detect 200 events decaying into $4\pi^c,\pi^o$ during the run due to the 4.4 GeV/c^2 resonance. This will be a sufficient number of events to determine the hadronic cross section of the 4.4 GeV/c^2 state. On this basis we believe that we can detect any new vector mesons in the region of 2.5 GeV/c^2 to 10 GeV/c^2, provided the product $B^V_{4\pi_c,\pi^o} \cdot \Gamma^V_{ee}$ is greater than 20 eV.

C. Photoproduction of the $\psi(3.095)$ and $\psi'(3.684)$

We expect to have a sample 40,000 of $\psi(3.095)$ decaying into $\mu^+\mu^-$ and a similar sample decaying into e^+e^-. With this large sample it will be possible to study the properties of the ψ-N interaction in considerable detail. For example, the energy dependence in the region of 25 to 250 GeV/c will be well measured. Because of the outer detector it will be possible to measure the momentum and $P_\perp$ distribution of the pions produced in association with the ψ. We will be able to determine whether the particle ratios $K_s^o:\pi^\pm$ and $K^\pm:\pi^\pm$ are the same as in ordinary hadronic reactions.

The photoproduction cross section of the $\psi'(3.684)$ has not been measured above 20 GeV/c. We would have a sample 1000 $\psi'(3.684)$ decaying into $\mu^+\mu^-$ as well as a similar sample decaying into e^+e^-. This sample is sufficient to measure the energy dependence of the cross section in the interval of 25 GeV/c to 250 GeV/c. It is also sufficient to be able to observe inelastic $\psi'(3.684)$ production and compare it to $\psi(3.095)$.

While we do not believe that we can shed any new light on the rare decay modes of the ψ and ψ' beyond what has been provided by the experiments at e^+e^- colliding beam facilities, we may provide insight on the η_c. It has not been observed at SPEAR.

It is possible that η_c exists but $M_\psi - M_\eta$ may be smaller than 100 MeV. If the mass difference is that small, the detection of η_c is very difficult in e^+e^- colliding beam experiments. If $M_\psi - M_{\eta_c} = 50$ MeV, then the average momentum of the photon in our experiment is 2 GeV if the ψ momentum is above 120 GeV. We can clearly detect and identify 2 GeV photons in our shower counters and P_5.

If $\frac{\psi \to \gamma\eta_c}{\psi \to \text{all}} \cdot \frac{\eta_c \to \bar{p}p}{\eta_c \to \text{all}} \geq 10^{-4}$,

then we expect to observe $\geq$ 40 events in 600 hours of running. The proton or/and antiproton is identified by C.

D. Pair Production of Heavy Leptons

The heavy leptons are observed through their decay into $\mu^{\pm}e^{\mp}$ plus neutrinos. The larger acceptance and the improved particle identification makes it feasible to search for this process. There is evidence from SPEAR that a heavy lepton with mass near 2 GeV/c^2 may exist. This experiment can provide an important confirmation.

On the basis of the Bethe-Heitler pair production cross section and our acceptance we expect to observe $\sim$ 1000 $\left(B_{\ell\nu\nu}\right)^2$ event in 600 hours of running. If the branching ratio to leptons is .2 then we expect to observe 40 events.

The existence of new massive vector mesons has important consequences for the heavy lepton search. For example, if the 4.7 GeV state is a narrow vector meson, V, its decay into a pair of 1.8 GeV heavy leptons relative to its dimuon decay is:

$$R = \frac{V \to \ell^+\ell^-}{V \to \mu^+\mu^-} = \sqrt{1 - \frac{4M_\ell^2}{4.7^2}} = 0.64$$

This leads to a photoproduction cross section for heavy lepton pairs from the decay of a 4.7 GeV.c^2 state of ½ nanobarn/Be nucleus. The cross section for heavy lepton photoproduction through Bethe-Heitler pair production is 0.2-0.3 nanobarn/Be nucleus. Thus the existence of this state would more than double the rate of heavy lepton production in our experiment. Similarly, the presence of other new massive vector mesons would lead to even further increases in heavy lepton production.

E. New Particle Pair Production

Current folklore has it that the production cross section of a pair of charmed particles is $\sim$ 1 μb per Be nucleus and that the branching ratio of $D^+ \rightarrow \mu^+(e^+) + \ldots$ is $\sim$ 10%. Similar folklore also says that one out of four or five events in e^+e^- collisions above 4 GeV is the production of a pair of charmed particles. One of the reasons that the experimental data do not contradict these hypotheses has to do with the number of the neutral particles involved in the decays of charmed particles. In the proposed experiment, we will be identifying π^o's, η's, and γ's in the final states.

Since the charmed particles are pair produced, we will be looking for e+μ+hadron final states and e(μ)+hadrons. In the single lepton final states, we will be looking for a bump in the mass plot of, for example, $K_S\pi^+\pi^-\eta$ etc. etc. The mass resolution of $K_S\pi^+\pi^-\eta$ is 75 MeV. If the production cross section is indeed 1 μb, then we will be flooded with interesting events. We will, of course, study many different channels.

V. Request from Fermilab

Our requests from the Laboratory are:

1) The use of the broad band photon beam with the additional steel shielding in EE-4 as requested by E-401. The proton beam intensity is required to be between 3×10^{12} and 5×10^{12} protons. We request 300 hours of test time to debug the detector and 600 hours of time for data taking.

2) The use of EE-4 for our detector after the conclusion of E-400 and E-401. The use of the Portakamp assigned to E-400/E-401.

3) Magnet M1, a conventional magnet, with a minimum clear aperture of 15" x 15", a field length of 40" and a peak field of 15 kG. This magnet is essential to the experiment. We estimate that the magnet would require 120 kW of dc power.

4) Magnet M2, a superconducting magnet, with an aperture of 30" x 30", a field length of 60" and a field of 33 kG. This magnet is important for our resolution. We believe that we can start the experiment with the BM109 magnet which is being modified for E-400/E-401. It has an aperture of 20" x 24", a field length of 72", and a maximum field of 17.5 kG. This magnet degrades the momentum resolution by a factor of 1.6 and the inner detector acceptance by a factor of 2. We estimate that the conventional magnet would require 400 kW of dc power. We plan to size our detectors for the larger magnet.

5) The existing muon identifier steel and calorimeter which was used by E-87 and which is being used by E-400 and E-401.

6) PREP equipment which includes the equipment which will be used by E-400 and E-401. The request for new PREP equipment beyond the E-400/E-401 request will be 30% of that request.

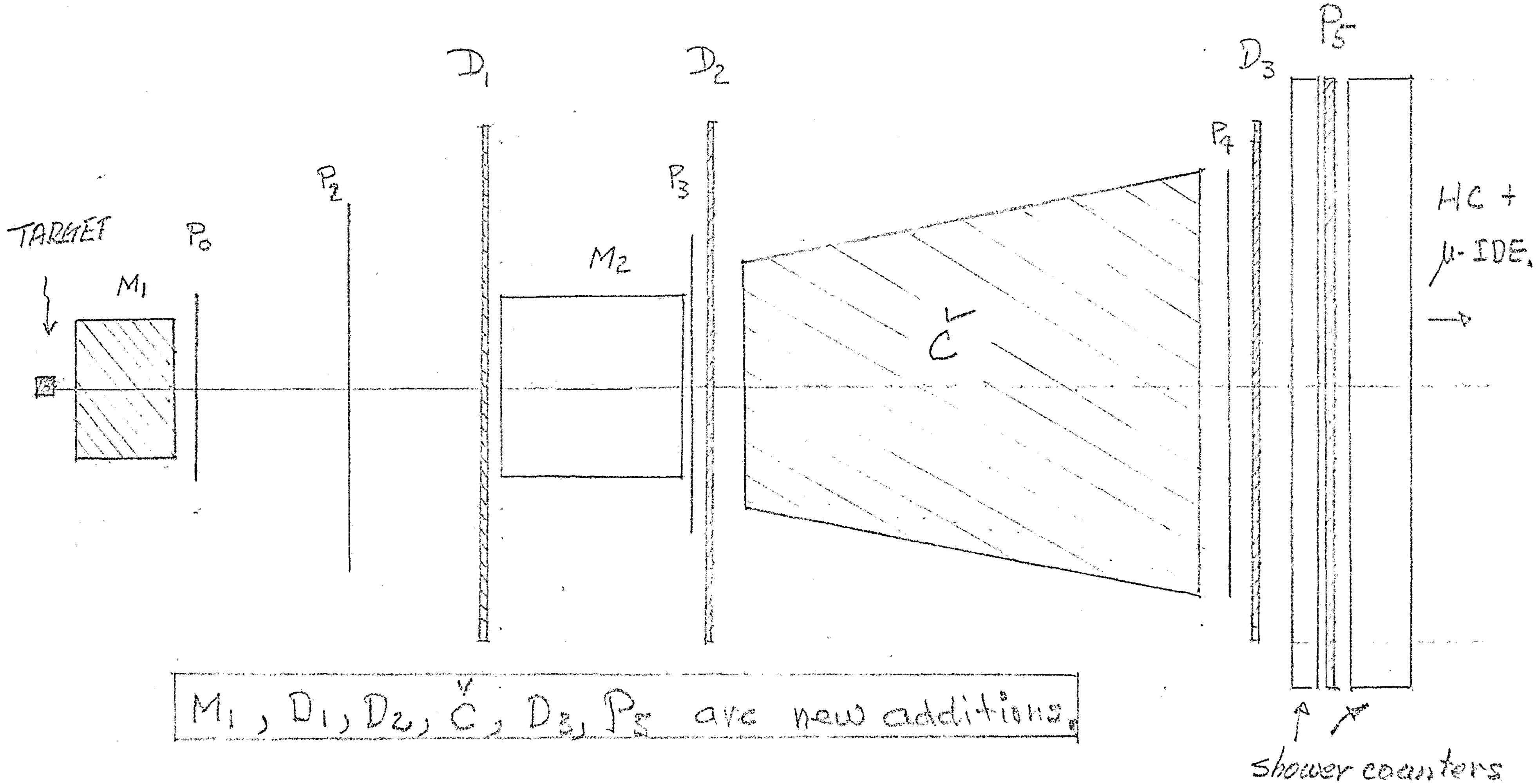
7) A Bison computer or equivalent and a link to the Bison-Net system.

8) 250 hours of rapid turn around computing at the 6600.

9) The Fermilab Physics Department will provide one third of funds for the construction of the new detectors and the analysis of the data. The University of Illinois and Columbia University will provide the remaining funds.

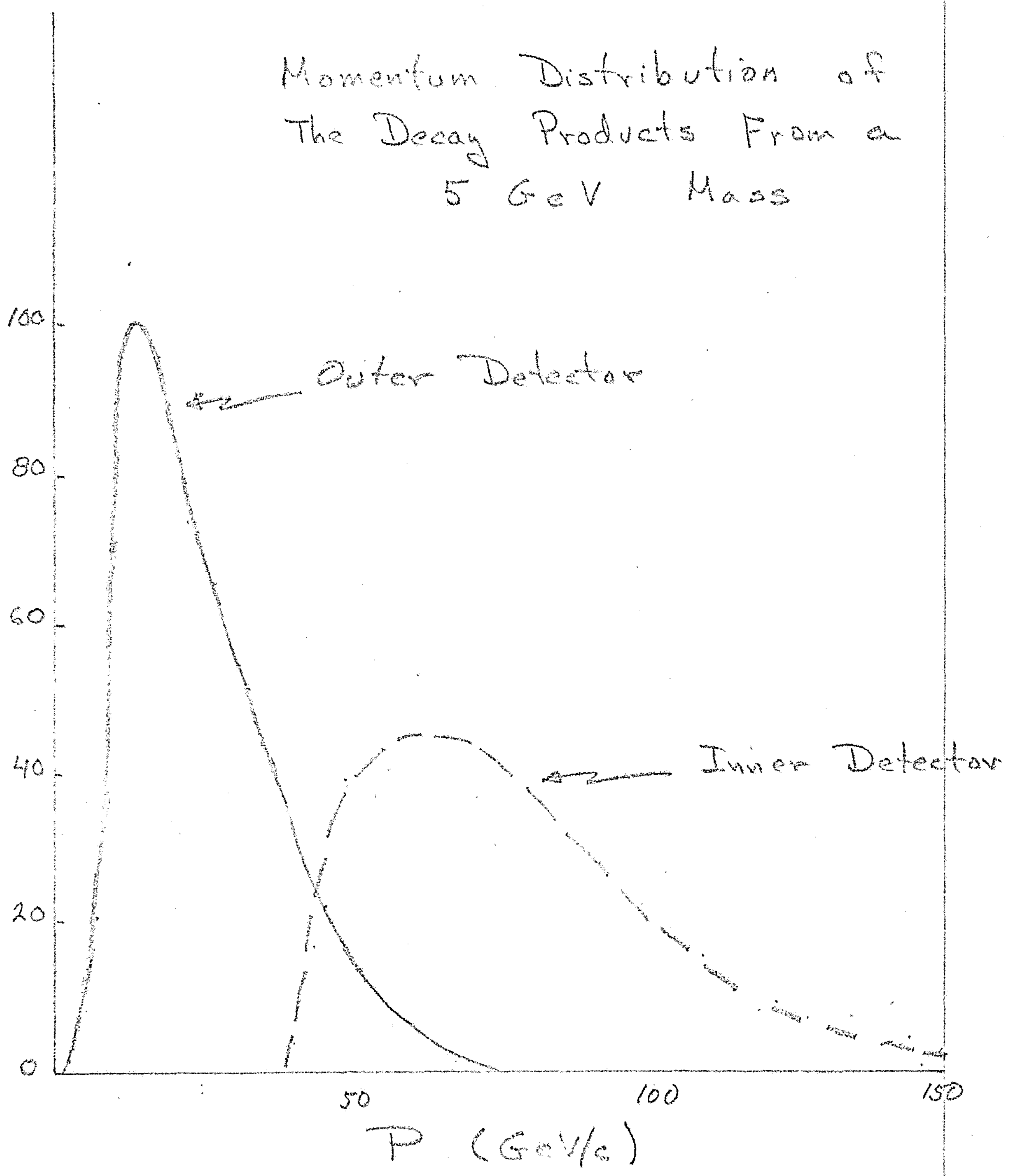
Running Schedule:

We are prepared to install the new detectors at the conclusion of E-400 and E-401. We will need access to the EE-4 pit for a period of one to two months in order to install the new detectors. We will be prepared to execute a 300 hour test immediately after the installation is complete and we would be prepared to take data two months after the 300 hour test was complete.



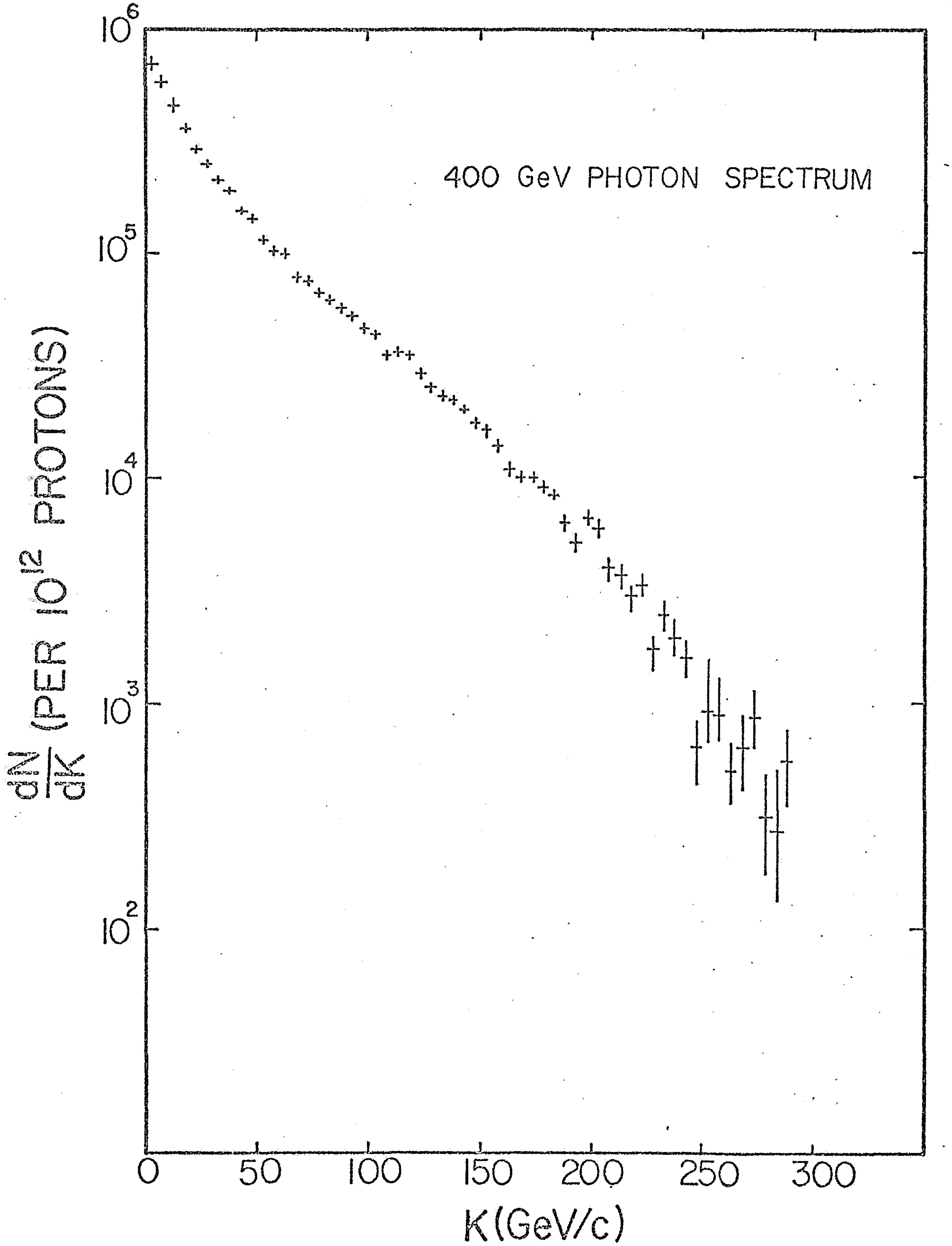
TARGET
M_1
P_0
P_2
D_1
M_2
P_3
D_2
Č
P_4
D_3
P_5
HC + μ-IDE.
M_1, D_1, D_2, Č, D_3, P_5 are new additions.
shower counters

Fig. 1



Momentum Distribution of
The Decay Products From a
5 GeV Mass
100
80
60
40
20
0
Outer Detector
Inner Detector
50
100
150
P (GeV/c)

Fig. 2



400 GeV PHOTON SPECTRUM
$\frac{dN}{dK}$ (PER 10^{12} PROTONS)
10^6
10^5
10^4
10^3
10^2
0
50
100
150
200
250
300
K(GeV/c)

Fig. 3

Assume $\sigma(\gamma + Be \to 1^{-} + \cdots) = const$

$$A = \frac{\int_{20} \frac{dN_\gamma}{dE_\gamma} \cdot \epsilon(1^{-} \to \mu^+\mu^-)\, dE_\gamma}{\int_{20\,GeV} \frac{dN_\gamma}{dE_\gamma}\, dE_\gamma}$$

$\epsilon(1^{-} \to \mu^+\mu^-)$; Efficiency of detecting both μ^+ and μ^- in the detector

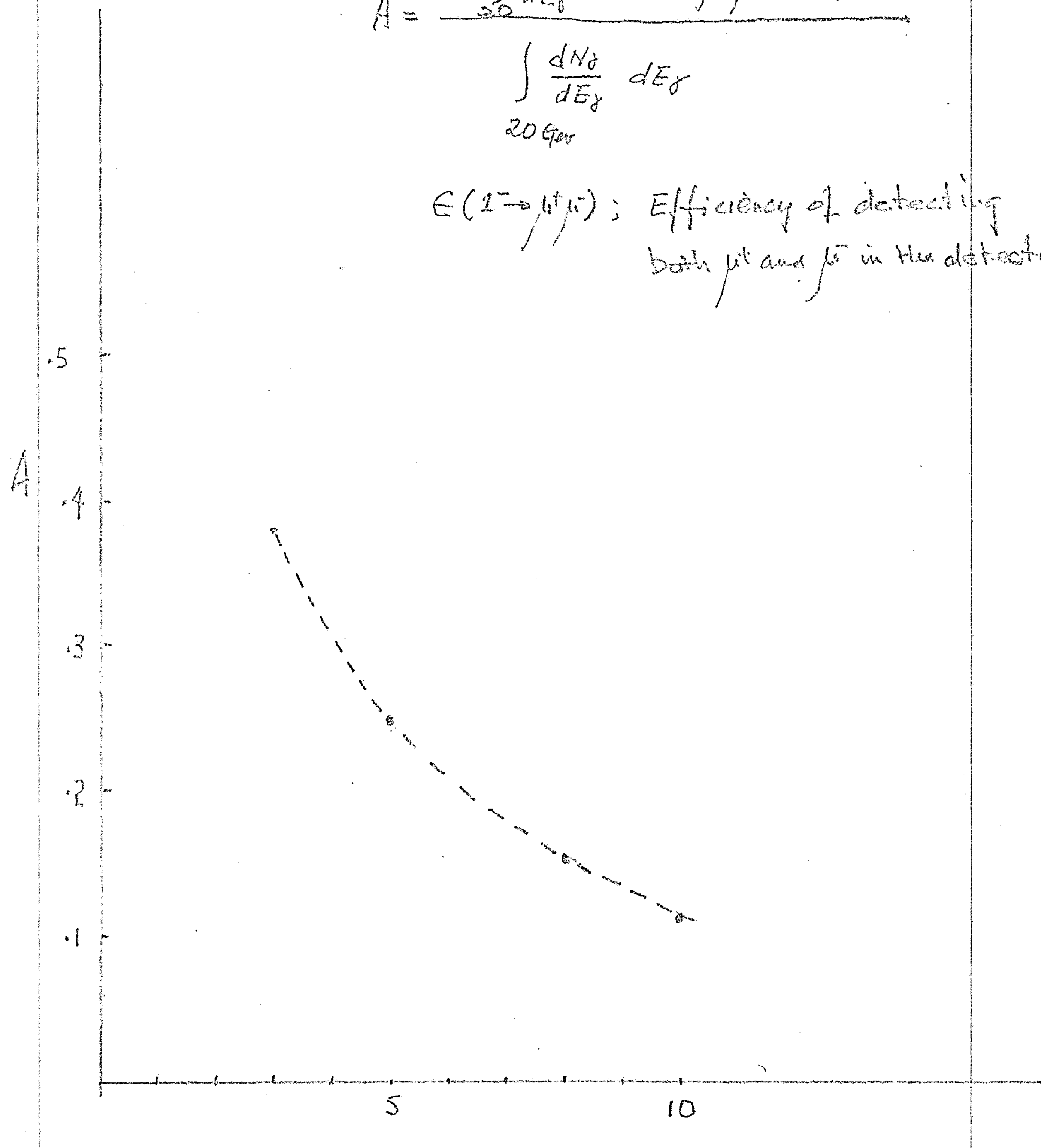


Fig. 4