NAL PROPOSAL No. 118

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HADRON SPECTRA FROM HIGH ENERGY INTERACTIONS

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ABSTRACT

We propose to study inclusive reactions of the type $a + b \rightarrow c + \text{Anything}$, induced by protons, pions, and K mesons. Measurements will be made over as wide a kinematic range as possible with the use of the NAL Focussing Spectrometer Facility. The objective is to map out the general behavior of these reactions and to test a number of hypotheses based on recent theoretical models.

HADRON SPECTRA FROM HIGH ENERGY INTERACTIONS

Introduction

As the incident energy in a hadron-nucleon collision increases, the total cross-section is approximately constant whereas the contribution of each non-diffractive channel appears to decrease with energy. The constancy of the total cross-section can be accounted for by additional multi-particle channels opening up with increasing energy. Though a major part of the total cross-section is due to these multi-particle channels, the variety and complexity of these final states make it very difficult to measure and interpret them in detail. Perhaps the most amenable processes to study, both experimentally and theoretically, are the so-called "inclusive reactions", in which some final particle or property of the final state is studied without trying to specify what else is happening in the reaction. Such a reaction can be represented by $a + b \rightarrow c$ + Anything. One of the important experimental challenges for the NAL accelerator will be to delineate the regularities of this type of process, which has recently received a good deal of theoretical interest.

We propose to make an exploratory investigation of this process by measuring the momentum spectra of final state hadrons over a range of production angles and incident energies, with the use of the NAL focussing spectrometer[1]. By employing an array of Cerenkov Counters in the spectrometer (differential and threshold) set to be sensitive to different masses, the momentum distributions of protons, π^+ and K^+ can be simultaneously measured. The spectra of final state π^-, K^- and $\bar{P}$ can be simultaneously measured with reversed magnetic fields. With the use of two Cerenkov Counters in the incident beam inclusive reactions resulting from protons, K mesons, and pions can be simultaneously measured over that part of the kinematic range to be covered in this experiment in which the incident intensities are about 10^7 particles per pulse or less.

The simultaneous measurement of the different cross-sections not only saves a significant amount of time but also eliminates part of the systematic error which would normally enter a comparison of these cross-sections, were they to be measured separately. This is especially important since some of the current theoretical interest focusses on the relative behavior of these spectra.

The primary objective of this experiment is to study these spectra over as wide a range of kinematics as possible, in order to investigate the general properties of the kinematic behavior of the cross-sections. Such a study will also provide data for comparison with predictions from various theoretical models: the multiperipheral model[2]; the limiting fragmentation model[3] of Yang and collaborators; and the parton model[4] of Feynman.

The above models provide some interesting predictions and speculations that can be tested by this type of measurement, which are

1. for the process $a + b \rightarrow c +$ Anything, the cross-section in the c.m. system will have the limiting form:

$$\frac{1}{\sigma_{ab}} \quad \frac{d\sigma}{dp_{11}(dp^2_{\perp})/\bar{E}} = f(\bar{X}, P_{\perp}) \text{ in the high energy limit.}$$

The quantity $\bar{E}$ is the c.m. energy of the detected particle, $P_{\perp}$ is its transverse momentum, and $\bar{X} = \bar{P}_{11}/\bar{P}_o$, where $\bar{P}_{11}$ is the longitudinal momentum of the detected particle and $\bar{P}_o$ is the incident momentum, both expressed in the c.m. system. The quantity σ_{ab} is the total cross-section for the interaction of particles a and b.

2. for values of $\bar{X} \approx 1$, the function $f(\bar{X}, P_\perp)$ depends only on the incident and detected particles and not on the target particle.

3. for values of $\bar{X} \approx -1$, the function $f(\bar{X}, P_\perp)$ depends only on the target and detected particles and not on the incident particles.

4. for values of $\bar{X} \approx 0$ the function $f(\bar{X}, P_\perp)$ depends only on the detected particle and not on the identities of the incident and target particles. For small $\bar{X}$, $f(\bar{X}, P_\perp) = g_c(P_\perp)$ where g is related to the average multiplicity of the production of particle c. If the total cross section is constant with s and the limiting distribution $f(\bar{X}, P_\perp)$ is constant as a function of $\bar{X}$ at $\bar{X} \approx 0$, then the average multiplicity $\langle N_c \rangle$ would be given by

$$\langle N_c \rangle = a_c \ln(s) + \text{constant},$$ where s is the c.m. energy, and

$$a_c = \int g_c(P_\perp) dP_\perp^2 .$$

5. when $\bar{X} \approx 1$, $f(\bar{X}, P_\perp)$ is proportional to $(1 - \bar{X})^{1-2\alpha(t)}$ [4,5] where $\alpha(t)$ is the highest trajectory which could carry off the quantum numbers needed to change particle a to c. It is interesting to note that here the Regge trajectory function $\alpha(t)$ appears in the description of an emission process.

Range of Measurements

Since the primary objective of these measurements is the mapping out of inclusive reaction cross-sections, the measurements should cover a wide kinematic range. The kinematic limits are also important in the consideration of what theoretical predictions can be tested by this experiment.

The focussing spectrometer is expected to function well for detected momenta between 200 and 10 GeV/c. It will perhaps function satisfactorily at momenta of about 5 GeV, but this can be determined only after the spectrometer is in operation. For a comparison with past experience, it should be noted that the SLAC 20 GeV spectrometer has operated satisfactorily at 1 GeV/c and could be expected to work well at 0.5 GeV/c, covering the same fractional range of momentum that is desired for this experiment. Taking 10 GeV/c as the nominal cut-off of the detected momentum, we find that this experiment can study particle spectra for the following ranges of $\bar{X}$ given in Table 1:

Table 1

	P_o in GeV/c	$P_\perp = 0$	$P_\perp = 1.0$ GeV/c
protons	200	$0.00 \lesssim \bar{X}$	$0.00 \leq \bar{X}$
	150	$0.00 \lesssim \bar{X}$	$0.00 \leq \bar{X}$
	100	$0.06 \leq \bar{X}$	$0.00 \lesssim \bar{X}$
	50	$0.16 \leq \bar{X}$	$0.10 \leq \bar{X}$
pions	200	$0.05 \leq \bar{X}$	$0.00 \leq \bar{X}$
	150	$0.06 \leq \bar{X}$	$0.01 \leq \bar{X}$
	100	$0.10 \leq \bar{X}$	$0.04 \leq \bar{X}$
	50	$0.20 \leq \bar{X}$	$0.15 \leq \bar{X}$
K mesons	200	$0.04 \leq \bar{X}$	$0.00 \leq \bar{X}$
	150	$0.05 \leq \bar{X}$	$0.00 \lesssim \bar{X}$
	100	$0.09 \leq \bar{X}$	$0.03 \leq \bar{X}$
	50	$0.19 \leq \bar{X}$	$0.14 \leq \bar{X}$

Examples of the dependence of the final laboratory momentum on $\bar{X}$ are shown in Figures 1(a) and 1(b), for incoming protons at 200 GeV/c producing pions (a) and protons (b), in inclusive reactions at two different values of $P_\perp$.

The range of $P_\perp$ that can be covered depends both on the maximum production angle at which the spectrometer can be used and the rate with which the cross-sections decrease with $P_\perp$. In Tables 2A and 2B we show estimates of the maximum values of $P_\perp$ that can be covered in this experiment as a function of $\bar{X}$ for protons (a), pions(b), and K mesons (c) for incident energies of 200 and 100 GeV. Also indicated is whether the maximum value of $P_\perp$ is the result of counting rate or production angle limitations. The assumptions on which these counting rates are based are described in the section which discusses running time estimates. In the regions in which the range of $P_\perp$ is limited by counting rate, we take as a nominal limit 100 counts/hr. The limitations on production angle are discussed in detail in the section dealing with experimental layout.

Table 2A

P_o = 200 GeV/c   Incident Protons 10^{10}/pulse

$\bar{X}$	Final Protons: Max. $P_\perp(\frac{GeV}{c})$	Final Protons: Limitation	Final π^+: Max. $P_\perp(\frac{GeV}{c})$	Final π^+: Limitation	Final K^+: Max. $P_\perp(\frac{GeV}{c})$	Final K^+: Limitation
∿0	1.8	Angle	1.8	Angle	1.8	Angle
0.2	1.8	Angle	1.8	Angle	1.8	Angle
0.4	2.0	Angle	2.0	Angle	2.0	Angle
0.6	3.0	Angle	3.0	Angle	2.5	Rate
0.8	3.5	Rate	2.5	Rate	1.4	Rate
∿1.0	3.5	Rate	0.5 - 1.0	Rate	∿0	Rate

Table 2B

P_o = 100 GeV/c   Incident Protons   2 x 10^7/pulse

$\bar{X}$	Final Protons: Max. $P_\perp(\frac{GeV}{c})$	Final Protons: Limitation	Final π^+: Max. $P_\perp(\frac{GeV}{c})$	Final π^+: Limitation	Final K^+: Max. $P_\perp(\frac{GeV}{c})$	Final K^+: Limitation
∿0	1.2	Rate	1.8	Angle	1.5	Rate
0.2	1.7	Rate	1.8	Angle	1.5	Rate
0.4	1.9	Rate	1.9	Rate	1.4	Rate
0.6	2.2	Rate	1.7	Rate	1.3	Rate
0.8	2.3	Rate	1.4	Rate	0.5	Rate
∿1.0	2.3	Rate	∿0	Rate	∿0	Rate

On the basis of these estimates, we believe the measurements proposed here can provide significant information on a number of questions.

The experiment can determine whether there is a limiting function $f(P_\perp, \bar{X})$, over a wide range of incident energies, 50 - 200 GeV, for a wide range of $\bar{X}$, and moderate ranges of $P_\perp$ for protons, pions, and K mesons produced by incident protons, pions and K mesons.

The hypothesis of target independence can be tested by comparing spectra near $\bar{X} \approx 1$ produced from hydrogen and deuterium targets.

The possible relationship between the behavior of the spectra near $\bar{X} \approx 1$ and Regge trajectories can be investigated by measuring the $\bar{X}$ dependence of a spectrum for various values of t.

Information on the validity of a ln(s) dependence of average particle multiplicities can be provided by these measurements, utilizing the considerations discussed on page 3. Also some direct measurements of particle multiplicities can be made. This is possible because the average multiplicity of particle c produced in an inclusive reaction caused by the interaction of particles a and b is given by

$$N_c = \frac{1}{\sigma_{ab}} \int \frac{d^2\sigma}{dP_\perp^2 dP_c} dP_\perp^2 dP_c$$

where $\frac{d^2\sigma}{dP_\perp^2 dP_c}$ is the cross-section for producing particle c. In p-p collisions, measurements of spectra between $0 \leq \bar{X} \leq 1$ will provide such information because of the symmetry in the c.m. system. This range of $\bar{X}$ is available for proton spectra at $p_0 \gtrsim 150$ GeV/c. For proton spectra at lower values of p_0 and for pion and K meson spectra some extrapolation would be necessary for determining multiplicities because of the unmeasured regions in $\bar{X}$ corresponding to momenta below 10 GeV/c.

This experiment can also provide information on whether near $\bar{X} \approx 0$ the spectra depend only on the particle detected and not on the incident nor the target particles. This would be done by comparing, for example, the spectra of pions produced by incident pions and protons on hydrogen and deuterium targets. The same comparisons would also be made for spectra of detected protons and K mesons.

This experiment has only a small overlap with NAL Proposal #63. For proton induced reactions the present proposal covers a different kinematic range. In addition, it has a broader scope in that it investigates pion and K meson induced reactions and can study the question of target independence.

Experimental Layout

Protons and pions from the 2.5 mr beam will be incident on a 40 cm liquid hydrogen or deuterium target. The NAL focussing spectrometer will be used to measure the spectra of particles produced in the target. A detailed description of the properties of this spectrometer is given in NAL Proposal #96.

The basic arrangement to be used to vary the production angle will employ a number of bending magnets upstream of the target to change the direction of the incoming beam. The system will consist of one 3-meter external beam bend magnet, a drift space of 22 meters, followed by four 3-meter external beam bend magnets placed just before the target. By using 8 cm of the available 8.9 cm apertures of these magnets, and by making small adjustments of the positions of the last four magnets, it is possible to achieve maximum angles of about 25 mr to 100 mr corresponding to incident energies of 200 to 50 GeV respectively.

Table 3 shows the maximum values of transverse momentum of the final detected particle imposed by instrumental limits for various incident and final momenta.

Table 3

Maximum $P_\perp$ in GeV/c

Incident Momenta in GeV/c

		200	150	100	50
Final Momenta in GeV/c	200	4.92			
	150	3.7	4.92		
	100	2.45	3.28	4.92	
	50	1.23	1.64	2.46	4.92
p'	25	.615	.82	1.23	2.46
	10	.245	.33	.49	.98

In all cases, the maximum angles are limited by the magnetic field available, so that an increase of angle could be achieved by using additional bending magnets. As can be seen, the range of $P_\perp$ covered decreases with decreasing final momentum. A different configuration of magnets would be used to vary angles at the lowest values of final momentum in order to enlarge the range of $P_\perp$. This arrangement would consist of one main ring B-1 magnet 20 meters upstream of the target and one 3-meter bend magnet with an aperture of about 10" x 4" located about 3 meters downstream from the target. The maximum values of $P_\perp$ for this system are given in Table 4.

Table 4

Maximum $P_{\perp}$ in GeV/c

Incident Momenta in GeV/c

		200	150	100	50
Final	30	1.80	1.80	1.80	1.80
Momenta	20	1.80	1.80	1.80	1.80
in GeV/c	10	1.15	1.52	1.80	1.80

Cerenkov Counters will be used in the incident beam to tag the incoming particles when necessary. At a secondary beam energy of 200 GeV the incident protons arise from elastic scattering and particle identification is not necessary. At an incident momentum of 150 GeV/c, the expected intensity of protons is about 10^8/pulse, of π^+ mesons 2 x 10^6/pulse, and K^+ mesons 10^5/pulse. A threshold Cerenkov Counter set for pions and a Disc Cerenkov Counter set for K mesons in the incident beam would be able to function well at these rates since they would be insensitive to the protons. At lower incident momenta all particle intensities are expected to be on the order of 10^7/pulse or less, and hence will pose no difficult rate problems for the Cerenkov Counters.

A series of Cerenkov Counters in the spectrometer will be used to distinguish pions, protons, and K mesons; these will be a differential Cerenkov Counter and two threshold counters of the type developed at Serpukhov[6]. Particle separation will only be important at momenta below 150 GeV/c which is well within the capability of the counters being designed for the spectrometer. The spectrometer will have total absorption counters for electromagnetic and strong interaction cascades which will be used to reject electrons and muons. The trigger counters, detector planes, and hodoscopes which are to be part of the facility will be adequate for these measurements.

The target array to be used will consist of 40 cm. liquid hydrogen and deuterium targets, and an empty replica. It is important to have available simultaneously both H_2 and D_2 since in making comparisons of the two cross-sections, an interleaving of the measurements decreases systematic errors.

At small angles, at which the incoming intensity can be reduced to about 10^7 particles a pulse or less, horizontal and vertical hodoscopes in the incident beam will be used to define the angle of incidence to about $\pm$ .2 mr. At large angles, at which maximum intensity is required, the beam spot size will be increased by an amount compatible with the use of the differential Cerenkov Counter, in order to decrease the angular spread in the incoming beam. By arranging to have the spectrometer operate in the mode in which the longer focal length is in the scattering plane, the spot size could be as large as ~ 0.25 cm in this plane resulting in an angular spread of ± 0.2 mr, and still be compatible with mass separation at high momenta. At large angles we take the maximum spread in $P_\perp$, $\Delta P_\perp$, due to an angular spread in the incident beam, to be 0.050 GeV/c. If a trade off between beam spot size and angular spread does not meet this criterion, the solid angle of the incident beam will be decreased.

Plan of Measurements and Running Time Estimates

Our preliminary plan is to collect data at four incident beam energies 200, 150, 100, and 50 GeV. Spectra of protons, pions, and K mesons would be measured from the maximum momenta down to about 10 GeV/c in coarse steps. Spectra of negatively charged particles will also be measured over these ranges of momentum. At incident energies of 200 and 100 GeV, both the hydrogen and deuterium targets will be employed whereas at the other energies only hydrogen measurements will be made. Measurements of the spectra will be made as a function of P'_{lab} for constant $P_\perp$, at a number of values of $P_\perp$. The range of $P_\perp$ covered for various conditions will be determined primarily by where the counting rates run out, except at the lowest values of P'_{lab} where the limit on the production angle that can be measured will impose limits on the maximum values of $P_\perp$. In Table 4 we show the ranges of kinematics, assumed incident intensities, and estimated running times.

In making the estimation of the running time required we have used a parametric fit for P + P → P + Anything from the results of Anderson et al.[7], who measured P-P inelastic scattering for 10,20, and 30 GeV/c protons out to values of $P_\perp$ of 2 GeV/c. The yields for pions and K mesons were obtained by using the ratios of P/Π/K obtained from calculations using the model of Hagedorn and Ranft[8]. We assumed 40 cm. liquid targets, the beam intensities given in Table 4, the specifications of the proposed NAL focussing spectrometer, and statistical accuracies ranging from 1.5% at small $P_\perp$ to about 10% at the largest values of $P_\perp$. On this basis we estimate that 750 hours of running time will be required to carry out this series of measurements. We would expect to give a progress report after about 400 hours of running, along with a reassessment of the additional time needed to complete the experiment.

We also will require at least 200 hours of testing time prior to data taking. Based on a steady use of the beam at desired intensities, we would require an occupancy of the spectrometer facilityfor three months. A one-to-two week interval between the testing period and the beginning of data taking would be useful in order to allow time for any necessary repairs.

Table 4

P_o = 200 GeV/c (Incident Momentum)

Intensities:

Protons: 10^{10}/pulse

Range of Final Momenta, P' 200-10 GeV/c

Angular Range 0-25 mrad $p' \geq 50$ GeV/c
0-95 mrad $p' \leq 50$ GeV/c with constraint $P_\perp \lesssim 1.8$ GeV/c.

Running Time, 150 hours

P_o = 150 GeV/c

Intensities:

Protons: 10^8/pulse

π^+ : 2×10^6/pulse

K^+ : 10^5/pulse

Range of Final Momenta, p' 150-10 GeV/c

Angular Range 0-33 mrad $p' \geq 30$ GeV/c
0-150 mrad $p' \leq 30$ GeV/c with constraint $P_\perp \lesssim 1.8$ GeV/c

Running Time, 200 hours

P_o = 100 GeV/c

Intensities:

Protons: 2×10^7/pulse

π^+ : 5×10^6/pulse

K^+ : 4×10^5/pulse

Range of Final Momenta, p' 100-10 GeV/c

Angular Range: 0-49 mrad $p' \geq 30$ GeV/c

0 -180 mrad $p' \leq 30$ GeV/c with constraint $P_{\perp} \leq 1.8$ GeV/c.

Running Time, 250 hours

$P_o = 50$ GeV/c

Intensities:

Protons: 2×10^7/pulse

π^+ : 4×10^7/pulse

K^+ : 2×10^6/pulse

Range of Final Momenta p', 50-10 GeV/c

Angular Range: 0-98 mrad $p' \geq 20$ GeV/c

0-180 mrad $p' \leq 20$ GeV/c with constraint $P_{\perp} \leq 1.8$ GeV/c.

Running Time, 150 hours

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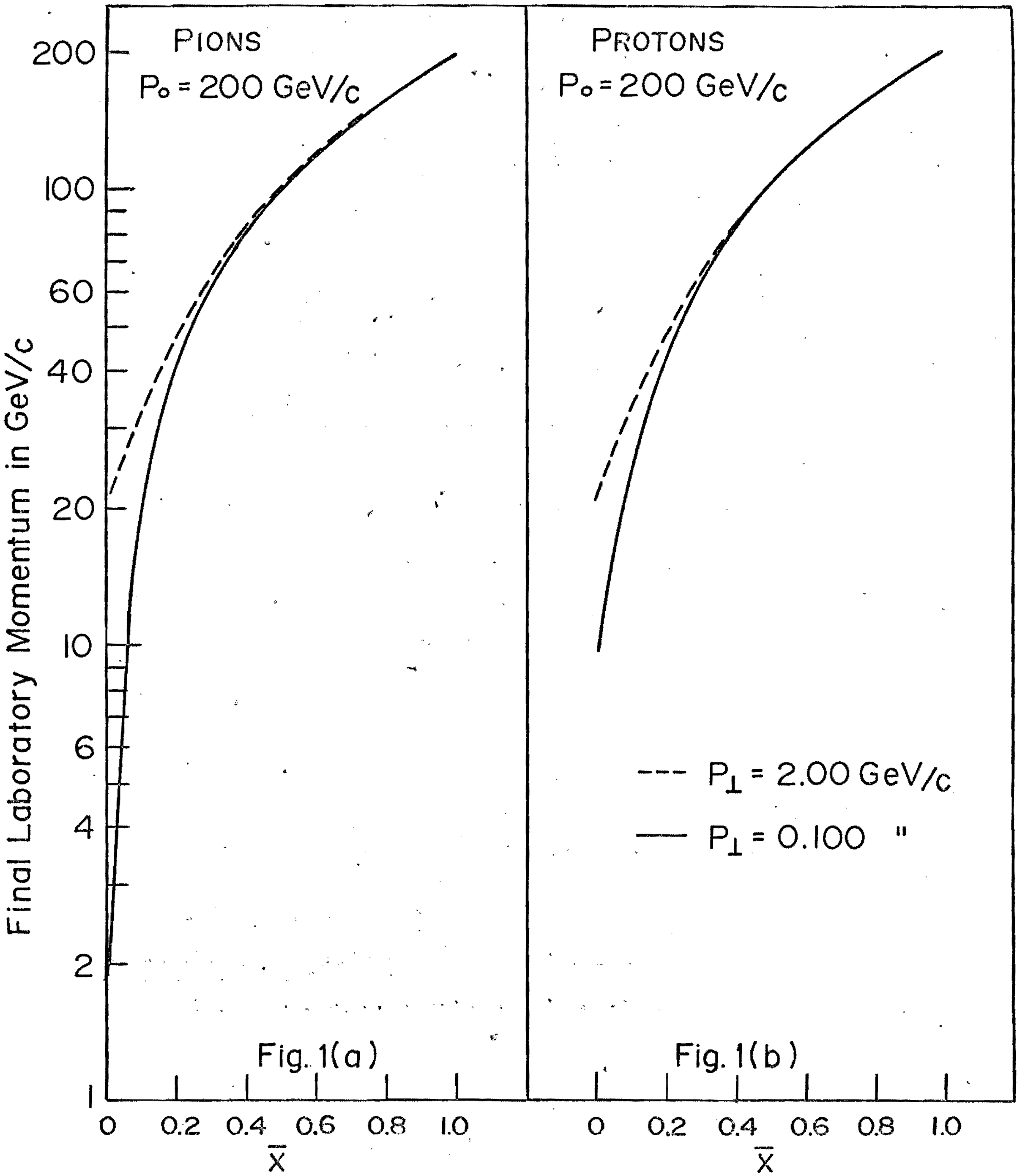

PIONS
P_o = 200 GeV/c
PROTONS
P_o = 200 GeV/c
Final Laboratory Momentum in GeV/c
200
100
60
40
20
10
6
4
2
1
0
0.2
0.4
0.6
0.8
1.0
$\bar{X}$
$P_\perp$ = 2.00 GeV/c
$P_\perp$ = 0.100 "
Fig. 1(a)
Fig. 1(b)

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JUN 18 1973

June 15, 1973

Dr. James R. Sanford
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Dear Jim:

Enclosed you will find an addendum to Proposal 118. We hope that it can be discussed at the July meeting of the Program Advisory Committee if spectrometer proposals are to be considered.

Sincerely,

Jerome I. Friedman

Jerome I. Friedman
Professor of Physics

JIF/pm

ADDENDUM TO PROPOSAL #118

HADRON SPECTRA FROM HIGH ENERGY INTERACTIONS

L. Guerriero (Bari University), R.E. Lanou, J. Massimo (Brown University), W. Busza, J.I. Friedman, H.W. Kendall, L. Rosenson (Massachusetts Institute of Technology) and A.E. Brenner (National Accelerator Laboratory)

In Proposal #118, we proposed to study inclusive reactions of the type a + p(or n) → b + anything where a and b are the incident and detected particles respectively, and a and b can be any of the following particles, in any combination: P, $\bar{P}$, π^+, π^-, K^+, and K^-.

The over-all objective of the investigation proposed in Proposal #118 is to map out the general behavior of these reactions over as wide a range of kinematic variables as possible, concentrating on those reactions which cannot be measured at the ISR. In particular, incident momenta of 50, 100, 150 and 200 GeV/c would be used and the spectra of particle b would be measured from the maximum momentum down to about 10 GeV/c in coarse steps. The range of transverse momenta covered will be determined primarily by counting rate but generally < 2 GeV/c.

It is proposed to use the NAL focussing spectrometer. Statistical errors will range from about 1.5% at small transverse momenta to 10% at large transverse momenta.

While the program described above has substantial interest in itself, we feel that with a modest increase in instrumentation we can significantly increase the physics output and study inclusive reactions in a way that has hitherto been relatively unexplored. We propose to measure the charged particle multiplicity for each event in the inclusive reaction measurements and thus to study the general correlation of the inclusive cross-sections with this multiplicity, both in number and azimuthal distribution. We feel that such information would greatly aid in the attempt to understand the dynamics of high energy hadron processes.

This additional study would be accomplished by placing in the forward hemisphere of the target an array of segmented lucite cerenkov counters and proportional wire chambers. For each event these detectors will provide a measurement of the charged particle multiplicity, and such information will allow a study of the general relationship of the x, $P_\perp$, and S dependence of the cross-section and the charged particle multiplicity. A number of theoretical speculations and predictions can be tested with such results. Among these, for example, are the following:

(1) The field theoretical calculation of Cheng and Wu predicts[(1)] that in the reaction $a + b \rightarrow a + X$ where the outgoing detected particle has roughly half the energy of the incident particle, the $P_\perp$ distribution becomes less steep as the multiplicity increases.

(2) In versions of the fragmentation model[(2)(3)], the assumption is made that the multiplicity is proportional to the excited mass, so that for $a + b \rightarrow a + X$, the average multiplicity is proportional to M_x in the fragmentation region, except for the effects of double fragmentation which are expected to be small. By using events in which there is not extensive clustering of particles around the particle detected in the spectrometer, one can presumably look at the proper class of events to test this assumption.

(3) A model based on diffractive production proceeding through the exchange of a factorizable Pomeron[(4)] leads to the prediction that the average multiplicity of hadrons produced in diffraction dissociation of hadron i into a state M increases as

$$\langle n \rangle = A \ln M^2 + B i(t)$$

for M in the appropriate region, where the coefficient A is independent of s, t, and incident particle type.

(4) To what extent do the semi-inclusive cross-sections

$$\frac{d\sigma_n}{d^3P/E}$$

(the semi-inclusive cross-section for multiplicity n) approach scaling? Scaling behavior would indicate that σ_n has a diffractive part[(5)].

It is also interesting to note that the single-arm spectrometer group at ISR has preliminary results[6] which point up the potential of a spectrometer study of inclusive reactions with associated multiplicity determinations. In particular, in the study of the reaction PP → PX, they find structure in the invariant cross-section as a function of x for the detected proton, and further that there are dramatic changes in associated multiplicity distributions which are x dependent. None of these phenomena have a satisfactory explanation and it is important that they be investigated with incident particles other than the proton.

While a bubble chamber experiment can provide information of this type, the experiment proposed here has some important advantages.
(1) The use of the spectrometer in conjunction with fast detectors permits the measurement of much smaller cross-sections and provides much greater statistics. Thus the cross-sections can be measured over broader kinematic and multiplicity ranges.
(2) Because of the array of cerenkov counters, differential and threshold in the beam line and in the spectrometer, the spectrometer facility provides particle identification for both the incident and detected particles up to the maximum momentum available. This is especially important in testing theories that incorporate Regge exchange, such as in models involving triple Regge exchange.

Charged Particle Multiplicity Detector

In order to measure the number and azimuthal distribution of charged particles produced in association with each hadron detected in the spectrometer, it is proposed to surround the target with a system of detectors consisting of proportional wire chambers and cerenkov counters. Fig. 1 illustrates the proposed multiparticle detector.

Charged particles produced at angles up to about 90° in the lab will be detected in five 50 x 50 cm^2 proportional chambers each consisting of 3 planes of wires at 0°, 60° and 120°. To accommodate the proportional chambers the hydrogen target vacuum vessel used for experiment #96 will have to be slightly modified. Since the forward proportional chamber has neither the time nor the spatial resolution needed for resolving the many particles close to the beam line, the central 5 cm x 5 cm of this chamber will be made insensitive. Particles produced in a forward cone of $\lesssim$ 10° will be detected in a hodoscope consisting of eight 1 cm thick lucite cerenkov counters. Pulse height will be used to give information on how many particles passed through any one hodoscope counter (see Proposal #178 for a detailed discussion of the use of threshold cerenkov counters for the measurement of the multiplicity of interactions at ultra relativistic energies). A cerenkov counter similar in design to one of these hodoscope counters has been tested at BNL. It was found that for n particles the full width at half maximum resolution is

$$\lesssim \frac{70}{\sqrt{n}}\ \%$$

and thus adequate for this experiment.

The hodoscope will be placed 70 cm downstream from the hydrogen target. At this position particles produced by the beam in the hodoscope will not fall into the acceptance of the spectrometer for all spectrometer settings above 10 mr.

The addition of the multiparticle detector will have little effect on the inclusive measurements originally proposed in 118. Although the resolving time of each cerenkov counter is $\approx$ 20 n sec, the pile up rate problem in the cerenkov hodoscope is no more severe than that of the beam cerenkov counters and trigger counters, because the cerenkov hodoscope consists of eight separate counters.

As mentioned above, for all spectrometer settings greater than 10 mr the hodoscope is not a source of background. For settings less than 10 mr it does add to the target empty rate and it will be necessary to spend a small amount of extra running time to check this effect. If necessary the hodoscope will be removed for the small angle inclusive study.

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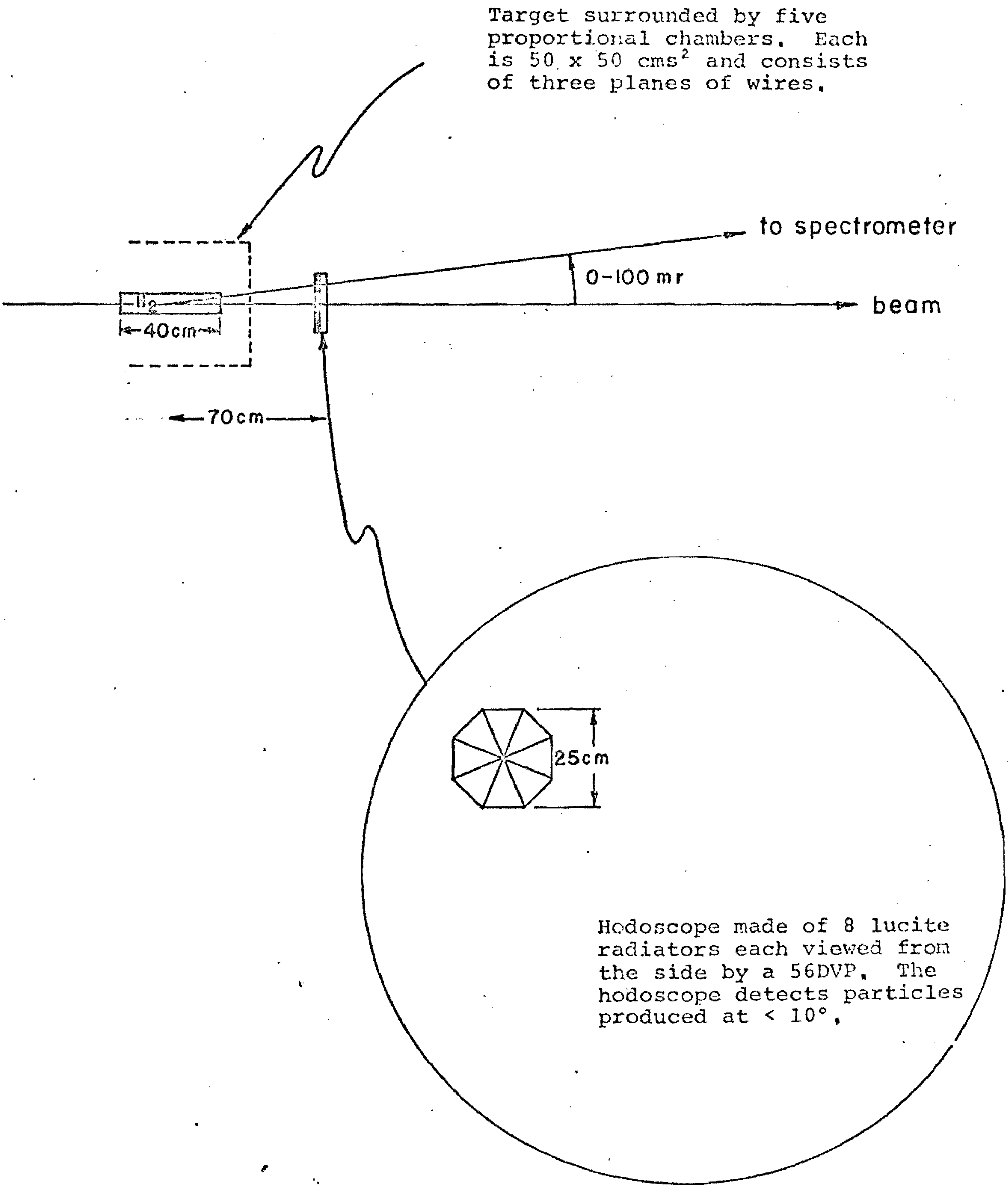

Fig. 1 Detector for measuring the charged multiplicity of the interaction.

national accelerator laboratory

September 24, 1974

TO: Tom Groves

Attached are copies of an update of Proposal 118. Primarily the physics as originally proposed remains the same as in the original proposal. The update primarily addresses itself to the measurement of charged particle multiplicities and also tabulates the expected rates based upon measured properties of the spectrometer and M6 beam line.

Very truly yours,

Jerome I. Friedman

J. Friedman

PROPOSAL # 118
MASTER
DO FILE
ELG
JRS

UPDATE OF EXPERIMENT 118 - September 18, 1974

by

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ADDENDUM TO UPDATE PROPOSAL 118

In February of 1971 we submitted Proposal 118 to the Fermilab, in which we proposed to study inclusive reactions of the type a + p(or n) $\rightarrow$ b + anything. Here a and b are the incident and detected particles respectively, and a and b can be any of the following: p, $\bar{p}$, π^+, π^-, K^+, and K^-.

The overall objective of the investigation in Proposal 118 is to map out the general behavior of these reactions over as wide a range of kinematic variables as possible, concentrating on those reactions which cannot be measured at the ISR. In particular incident momenta of 50 to 175 GeV would be used and the spectra of particle b would be measured from the maximum momentum down to 10 GeV/c in coarse steps. The range of transverse momenta covered will be determined primarily by counting rate and generally is less than 1.5 GeV/c. It is proposed to use the Fermilab focussing spectrometer for this investigation.

While the initially proposed program described above has substantial interest in itself, we subsequently felt that with a modest increase in instrumentation we could significantly increase the physics output and study inclusive reactions in a way that has hitherto been relatively unexplored. Consequently in an addendum to Proposal 118, which we submitted in July of 1973, we proposed to measure the charged particle multiplicity for each event in the inclusive reaction measurements and thus to study the general correlation of the inclusive cross-section with this multiplicity, both in number and angular distribution. We feel that such information would greatly aid in the attempt to understand the dynamics of high energy hadron processes.

While a bubble chamber experiment can provide information of this type, the experiment proposed here has some important advantages. 1) The use of the spectrometer in conjunction with fast multiplicity detectors permits the measurement of much smaller cross-sections and provides much greater statistics. Thus the cross-sections can be measured over broader kinematic and multiplicity ranges. 2) Because of the array of Cerenkov counters, differential and threshold in the beam line and in the spectrometer, the spectrometer facility provides particle identification for both the incident and detected particles up to the maximum momentum available. This is especially important in testing theories that incorporate Regge exchange, such as in models involving triple Regge exchange.

The original version of Proposal 118 was written before the final designs of the Meson Laboratory and the spectrometer were completed. In this document we are revising this proposal in accordance with the known properties of the spectrometer and the M6 beam line. We will discuss the counting rates for various processes that we expect to achieve with the spectrometer facility and bring up to date the physics objectives that are compatible with these rates. A brief discussion will also be presented of the design of the multiplicity detector.

Counting Rate Estimates

We have calculated the expected counting rates for various single particle inclusive reactions using estimates based on known spectrometer and beam properties and certain parameterizations of the inclusive cross-sections, based on existing ISR and NAL data.

A. Spectrometer

As presently employed by NAL-Exp 96, the focussing spectrometer has an angular aperture of 6 micro-steradians and a momentum bite $\Delta p/p$ of 3.5%. We do not propose to bin our data on any finer scale than this except for measurements of diffractive processes at small values of missing mass, so we plan to use the total spectrometer acceptance to obtain the counting rate at a given x and p_t or M_x^2 and t data point. We assume a 40 cm liquid hydrogen target. Using the present configuration of the AVB magnet system, we can obtain a maximum scattering angle of 17 mrad at 200 GeV/c with a maximum corresponding to 25 mrad at lower incident momenta, determined primarily by the apertures of the AVB magnets.

B. Beam

The incident beam intensity has been assumed to be 5×10^6 particles/pulse. This has been attained by Exp 96 and represents a limit due to radiation trips in the Meson Lab. This is still below the rate at which counter sags or beam pile-up problems become serious. Hopefully, this limit can be extended in the near future. The particle ratios in the beam have been taken from the beam survey experiment in the M1 beamline[1]. Although the M1 line is at 3.6 mrad as compared to our 2.5 mrad, there is good agreement between the two beams on the $\pi/K/p$ ratios at 100^+ and 140^-. The primary proton momentum is taken to be 300 GeV/c.

C. Differential Cross-Section Estimates

There are two generic types of reaction that can be studied, namely those in which the incident and detected hadrons are identical and those in which they are different species. As the representative of the former case, we take the reaction $pp \to pX$ at 450 GeV/c from the ISR[2]. This gives the familiar leading particle rise and peak at $x \to 1$. A parameterization of these data[3] has been obtained as a function of x and p_t. The parameters are listed in Table I. The latter case is represented by the fit of Carey et al.[4] for the production reactions $pp \to h^- X$. The normalizations for this fit were taken from $pp \to \pi^- X$ inclusive data[5] at $s = 558\ GeV^2$. The one final class of events includes the detection of a forward proton in $\pi^{\pm} p \to pX$ for example. We have used a simple fit[6]

$$E \frac{d\sigma}{d^3p}\,\pi^+ p \to pX \sim A e^{-bx^2 - cp_t^2}$$

for the continuum proton spectrum.

We take these reactions to give the prototype invariant cross-sections. We define the invariant distribution function

$$f_{ap \to bX} = \frac{E_b}{\sigma_{ap}^{TOT}} \frac{d\sigma}{d^3p_b}$$

and make the following assumptions for the purpose of estimating counting rates:

a. $f_{hp \to hX} = f_{pp \to pX}$ leading particle fit

b. $f_{h^+p \to q^- X} = f_{pp \to q^- X}$ Carey et al. fit

c. $f_{h^-p \to q^+X} = f_{pp \to q^-X}$ Carey et al. fit for $q^+ \neq p$

d. $f_{h^\pm p \to pX} = f_{\pi^+p \to pX}$ Reference 6 .

This involves merely scaling the inclusive cross-sections by the total cross-sections. Jacob[7] presents data indicating that such assumptions as $f_{\pi^+p \to \pi^-X} = f_{\pi^-p \to \pi^+X}$ and $f_{\pi^+p \to \pi^+X} = f_{\pi^-p \to \pi^-X}$ are valid at high energies. The forms a. - d. account for 26 out of the possible 36 incident-detected combinations. The other reactions are estimated using

e. $f_{h^\pm p \to q^\pm X} = R f_{h^\pm p \to q^\mp X} = R f_{pp \to q^-X}$

where R is the appropriate +/- ratio as calculated using the Hagedorn-Ranft statistical model ratios[8]. These ratios are close to those experimentally observed at the ISR[5].

D. Rate Contours

The beam, spectrometer, and cross-section data have been folded together to obtain an estimate of the counting rates for various reactions and energies. The data are presented in the following series of plots Figures 1 to 9 , depicting the contour of a given counting rate as a function of x and p_t of the detected particle. Those plots showing a single interaction, say $\pi^+p \to \pi^-x$ have contours of 10, 100, and 1000 counts/hour. Those comparing reactions such as π^+p or K^+p or $pp \to \pi^-X$ have contours of 100 or 1000 counts/hour indicated. Also included are contours corresponding to the maximum scattering angle limit imposed by the present AVB system, the minimum lab momentum of 10 GeV/c, and the kinematic limit. As can be seen, some reactions such as $K^+p \rightarrow K^-X$ will never have more than 100 counts/hour at 100 GeV/c. With p_t and x chosen to maximize the rate for each reaction, we find that the production reactions

$$K^+p \rightarrow K^-X \text{ or } \bar{p}X$$
$$K^-p \rightarrow K^+X \text{ or } \bar{p}X \quad \text{and}$$
$$\bar{p}p \rightarrow K^+X$$

never give 100 counts/hour even at 175 GeV/c incident momentum. The reactions involving a leading particle however, are always accessible, even for $K^{\pm}$ and $\bar{p}$ incident beams.

Charged Particle Multiplicity Detector

In order to measure the number and angular distribution of charged particles produced in association with each hadron detected in the spectrometer, it is proposed to surround the target with a system of detectors consisting of proportional wire chambers, a Cerenkov counter, and scintillation counter hodoscopes. Figure 10 illustrates the proposed multiplicity detector.

Charged particles produced in the forward cone of <120 mr (half angle 60 mrad) will be detected in a 1 cm thick lucite Cerenkov counter of dimensions 30cm. x 30cm. Pulse height information will be used to determine the number of charged particles that passed through this counter for each spectrometer event. (See Proposal 178 for a detailed discussion of the use of threshold Cerenkov counters for the measurement of charged particle multiplicities at ultra relativistic energies). This technique has been successfully used in Experiment 178 by Busza et al. Proportional chambers H3, V3, W3, (0°, 90°, 135°) with 5mm wire spacing subtend the angular region for 0 to 425 mr with the central region corresponding to the size of the Cerenkov counter made insensitive. In addition to measuring the charged multiplicity in the angular region for 130 to 425 mr the chambers V3 and H3 will provide projected angular distributions of the multiplicity in the scattering plane of the particle detected by the spectrometer and also in a plane perpendicular to this scattering plane. Proportional chambers H2 and V2 (2mm wire spacing) will provide these projected angular distributions in the angular region covered by the Cerenkov counter, except for a small central region of about 5 mr which is made insensitive to allow for the passage of the beam. As the H2, V2, and H3, V3 chambers will be placed about one meter from the center of the target, the target length of 40 cm. will produce about a $\pm 20\%$ spread in the determinations of the projected angles unless the point of origin of the event in the target is known. This information can be obtained for most events by using proportional chambers H1, V1, W1, (5mm wire spacing), and H2, V2, W2 to reconstruct track directions. The central regions of H1, V1,W1 are made insensitive to decrease the problem of ambiguities in track reconstruction. In the angular region between 400 mr and about 135° the charged multiplicity is measured by a crossed scintillation counter hodoscope wrapped around the target vacuum chamber.

The addition of the multi-particle detector will have little effect on the inclusive measurements originally proposed in 118. The pile up rate problem in the Cerenkov counter is no more severe than that of the beam Cerenkov counters and trigger counters. The beam and the particles detected in the spectrometer will pass clear of the four 5" phototubes backing up the Cerenkov counter. Particles produced in the lucite Cerenkov counter will fall into the acceptance of the spectrometer for all angle settings below ∿10 mr. Such events can be eliminated from the class of target induced events by interrogating the proportional chambers, which are upstream of the Cerenkov counter. An absence of all signals in the wire chambers and in particular in H2 and V2, in conjunction with a spectrometer event would indicate that the interaction originated in the lucite. This could be easily checked by spending a small amount of time measuring the counting rate with the target removed.

Physics Objectives:

In the initial investigations of inelastic scattering we intend to concentrate on those processes which have the highest counting rates. From Figures 1 through 9 it is apparent processes of the type $h + p \rightarrow h +$ anything are dominant over those in which the detected hadron is not the same particle as the incident particle. We intend to design the experiment for these dominant processes within the regions defined by the contours of 100 counts/hour. These figures show that the experiment can cover a broad range of X and transverse momenta up to 0.5 to 1.5 GeV/c for various incident particles, except where the transverse momentum is restricted by the limit in the spectrometer angle. In general this limitation sets in for values of X less than .2 to .4, depending on the process. Since the incident beam contains a variety of particles each of which is identified, and the spectrometer can be set to simultaneously detect pions, K, mesons, and protons, various dominant processes can be simultaneously measured. In addition, information on some of the minority processes will be accumulated while the dominant processes are being measured. Significant information on these minority processes will be obtained at the lowest values of transverse momentum.

The singles yields obtained by the spectrometer independent of the data available from the multiplicity detector, will provide information on the inclusive distributions of the processes studied. Since we intend to make measurements at incident energies of 50, 100, and 175 GeV, this data in conjunction with data at lower energies will provide information on the approach to scaling in X (or other scaling variables) of

$\frac{E d^3\sigma}{dp^3}$ for processes initiated by pions, K mesons, and anti-protons in addition to protons. In the region of $X > .9$ we plan also to make comparisons of yields from deuterium and hydrogen targets for incident protons, pions, and K mesons to test the hypothesis of target independence in the projectile fragmentation region.

Since in this experiment, we propose to measure the number of charged hadrons produced in conjunction with a hadron detected in the spectrometer, we may also consider this to be a measurement of the semi-inclusive distribution $\frac{E\,d\sigma_n}{dp^3}$ corresponding to the single particle spectrum for events with n charged prongs. It is of considerable interest to study the s dependence of $E\frac{d\sigma_n}{dp^3}$. For example, the approach to scaling of this quantity would indicate that σ_n has a diffractive part[9]. This experimental arrangement also allows the triple Regge region to be studied in conjunction with multiplicity. It is also of interest to investigate how in that region the particle distribution depends on the multiplicity.

In the process $h + p \rightarrow h' + X$, where X is anything, let us consider the projectile fragmentation region of fairly high x, $x \geq 0.5$ for the detected hadron. We note that $M_X^2 \sim S(1-x_R)$ where $x_R = \sqrt{X^2 + (p_t/p_{max})^2}$ and the momentum transfer is $t = (p - p')^2 \sim -pp'\theta^2$. We measure $\frac{d\sigma_n}{dt\,dM_X^2}$ which is in general a function of M_X^2 and t. Mueller analysis[10] shows that if we calculate the associated multiplicity using the assumption of a factorizable pomeron, we find

$$\langle n(M_X^2,t)\rangle \sim f_{hph'}(t) + g \ln M_X^2$$

a simple logarithmic behavior for the M_x^2 dependence. If this assumption is valid, the coefficient g is independent of t and the incident and detected hadron species. Moreover, the factor g is independent of s and provides the same dependence of the multiplicity on the excitation energy as in the reaction $p + p \rightarrow X$ where we substitute s for M_x^2.

This is precisely the prediction of the limiting fragmentation hypothesis[11], namely that the behavior of the semi-inclusive distributions and the associated multiplicities should be similar at a common M_x^2 and t value for pp, $pp \rightarrow pX$, ep, πp, etc. reactions. This feature is also predicted by the independent emission and short range order models. Any deviation from the simple $\ell n M_x^2$ behavior is attributed to correlations between the produced secondaries[12]. The field theoretic calculation of Cheng and Wu[13] predicts that $\langle n \rangle$ increases as t increases for values of x around 0.5. There exist some bubble chamber data for $pp \rightarrow X$ and $pp \rightarrow hX$[14,15] where the detected hadron is a p, π^-, Λ, K_s^o, π^o. Whitmore and Derrick[14] show that the associated multiplicities in $\pi^- p$ or $pp \rightarrow X$ or pX have quite similar behavior as s or M_x^2 increases. See Figure 11. Similarly, the topological cross-sections appear to follow the same functional form for both the total and associated multiplicities. Recent data[22] has indicated that the $\pi^+ p \rightarrow X$ multiplicity may be slightly higher (5%) than the $pp \rightarrow X$ multiplicity at 100 GeV/c. However, these bubble chamber data are at low t values. The requirement of $p_{lab} \lesssim 1.5$ GeV/c limited the bubble chamber measurements to $|t| \lesssim 1.6 (\text{GeV/c})^2$.

The only data spanning a range of t is that of the Argo Spectrometer Group at BNL[16]. They studied the target fragmentation process $pp \to pX$ at 28.5 GeV/c for $M_x^2 \lesssim 40$ and $|t| \lesssim 7$. They claim a distinct 10-15% difference in the associated multiplicity for high and low t events at fixed M_x^2. They have parameterized their multiplicity as a linear increase[17] with $|t|$ or as a distinct break in two plateaus[18] at $|t| \sim 2.8$, where both the high and low t plateaus are independent of t.

It is interesting to note that the reaction $hp \to hX$ may be mediated by an exchanged pomeron, while the reactions $hp \to h'X$ are expected to be associated with other exchanges. Still the behavior of the multiplicities of X are similar. The corresponding electroproduction multiplicities[19] show an s slope similar to the hadron reactions, but do not show any variation with Q^2, the momentum transfer. In this case, a virtual photon is exchanged. Figure 12 exhibits[20] the electro-, photo- pion-production and e^+e^- and $\bar{p}p$ annihilation multiplicities showing a similar behavior for $s \lesssim 50$. Comparisons of the average multiplicity at various values of M_x^2 and t for the processes $h + p \to h + X$ and $h + p \to h' + X$ can be made in the proposed experiment with the same detecting apparatus. This can provide information as to whether the average multiplicity is independent of the type of interacting particles or the identity and off-mass behavior of the exchanged particle, and depends solely on the excitation energy.

Using the rate data presented in Figures 1 through 9 we see that we can observe more than 100 counts/hour for the reaction $pp \rightarrow pX$ at 175 GeV/c for a range of $x \gtrsim 0.4$ and $p_t \lesssim 1.5$ GeV/c. This gives the M_x^2 and t ranges presented in Table II. Therefore, for $M_x^2 \gtrsim 100$ GeV^2, we can repeat the Argo spectrometer experiment at significantly higher energies and check if this effect is real and continues to apply at higher excitation masses. The low energy BNL data suggest that this t effect increases as M_x^2 increases. Furthermore, we can obtain good statistics for a scan in t at a constant M_x^2. Hence we can check whether the coefficient g (see page 12) has any s or t dependence. This part of the experiment would be complementary to the low t diffractive $pp \rightarrow pX$ experiment about to begin at the ISR[21], which employs a magnetic spectrometer in conjunction with an improved version of the Pisa-Stony Brook hodoscope. In addition, we can study incident $\pi^{\pm}$, $K^{\pm}$, and even $\bar{p}$ reactions at 100 GeV/c and 175 GeV/c at a reduced range of M_x^2 and t to check on the beam independence of average multiplicity.

Plan of Measurements and Running Time Estimates

Our preliminary plan is to collect data at three incident energies: 175, 100, and 50 GeV. The data at 50 GeV will not be as extensive as at the other two energies and will serve to provide some overlap with the Serpukhov accelerator in addition to providing a somewhat wider range in s. Spectra of protons, pions, and K mesons at constant transverse momentum will be measured from the maximum momentum down to about 10 GeV/c in coarse steps, except in the neighborhood of $X \approx 1$ where overlapping steps will be taken to obtain a continuous measured spectrum in this region. This will be done for a number of values of transverse momentum. At about $X \approx 0.6$, for incident energies of 175 and 100 GeV we intend to make a series of measurements as a function of P_t, in reasonably small steps for the purpose of determining the behavior of

$$E\frac{d^3\sigma}{d^3p} \quad , \quad E\frac{d^3\sigma}{d^3p}n$$

, and $\langle n \rangle$ as a function of transverse momentum. The same study as a function of P_t will be carried out in the neighborhood of $X \approx 1.0$. This program of measurements will be carried out with both beam polarities (with the spectrometer having the same polarity as the beam in each case). In addition, we plan to take a limited amount of data with the beam and spectrometer having opposite polarities, for the purposes of comparing such processes with the more dominant processes. As the counting rates for opposite polarities are low, we will concentrate in the region $0 \lesssim p_t \lesssim 0.25$ and $.3 < X \lesssim .5$. Table III gives a summary of the basic plan. We aim for statistical errors of 1.5% at small p_t to about 10% at the largest values of p_t. On the basis of our counting rate calculations, we estimate that about 1000 hours of running time will be required to carry this series of measurement. We would expect to give a progress report after about 500 hours of running, along with a reassessment of the additional time required to complete the experiment. We will also require about 200 hours of testing time prior to data taking.

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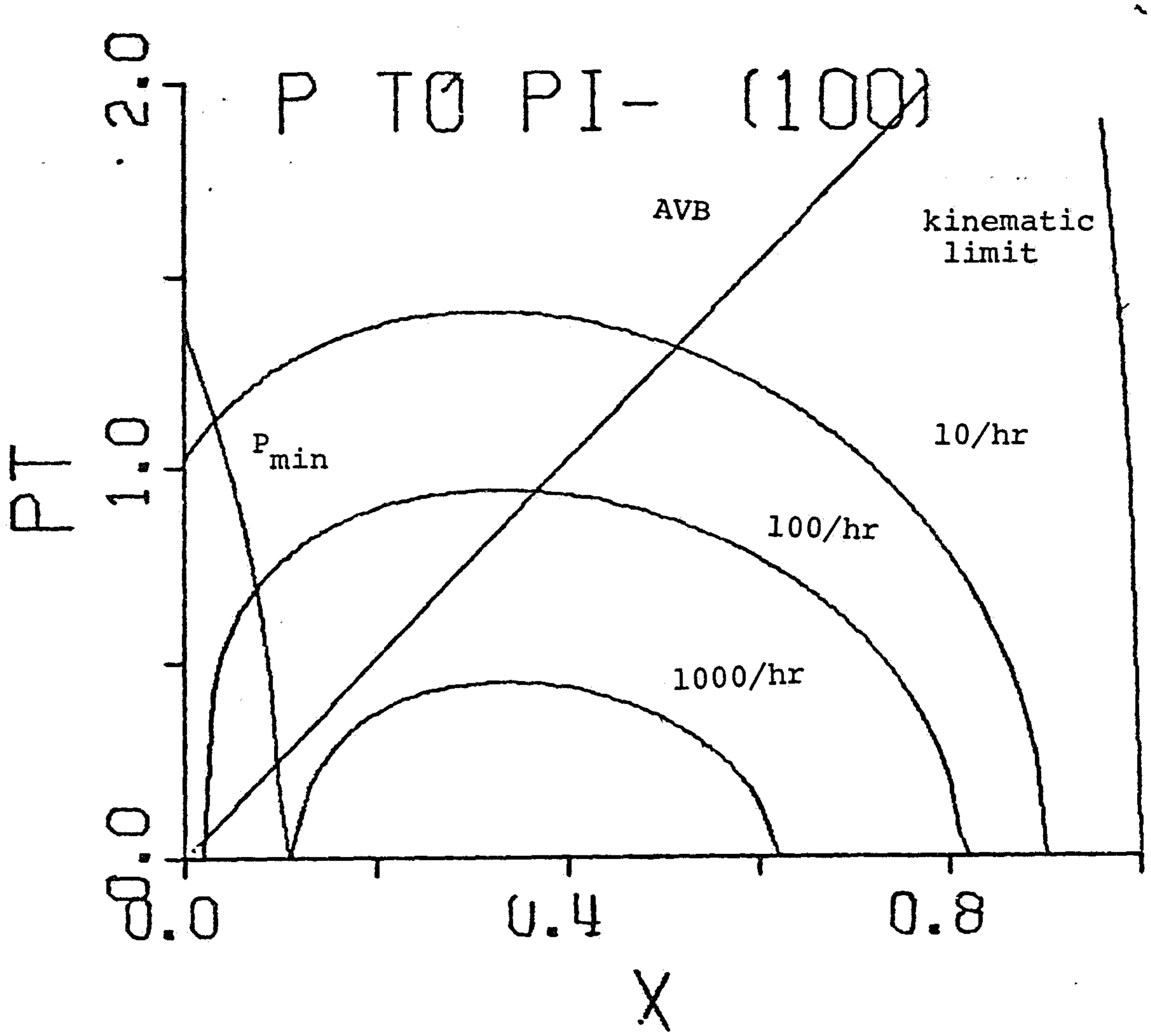


Fig. 1

Contour Plots:

Contours of constant counting rates are presented for a given process and incident momentum.

The kinematic limit is roted. The line marked AVB represents the maximum scattering angle limit in the present AVB system due to field or aperture limitations. The curve marked Pmin corresponds to a lab momentum of 10 GeV/c, a nominal low momentum cut off for the spectrometer. These limits are calculated for a zero mass particle, thereby representing the most severe limits on our kinematic range.

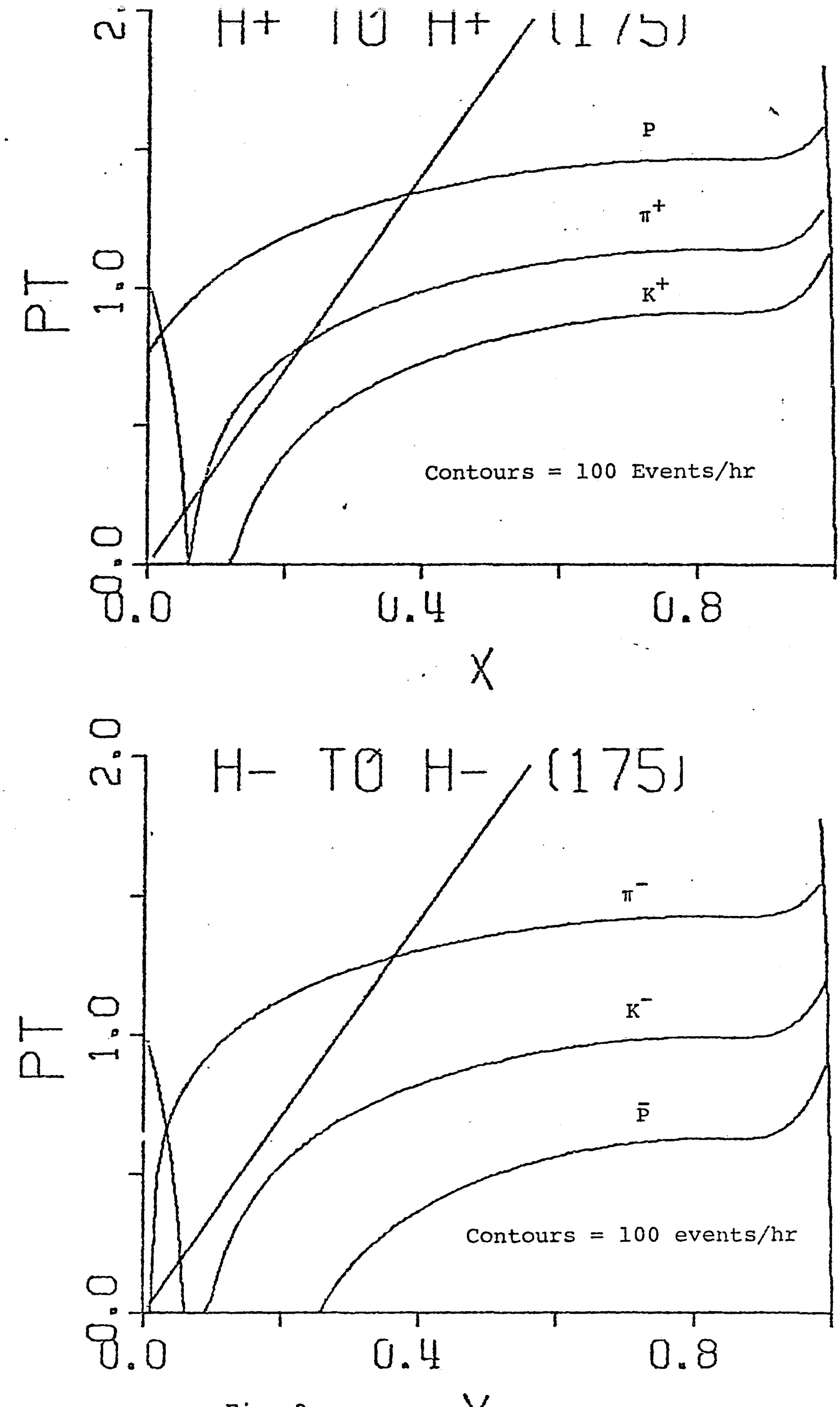
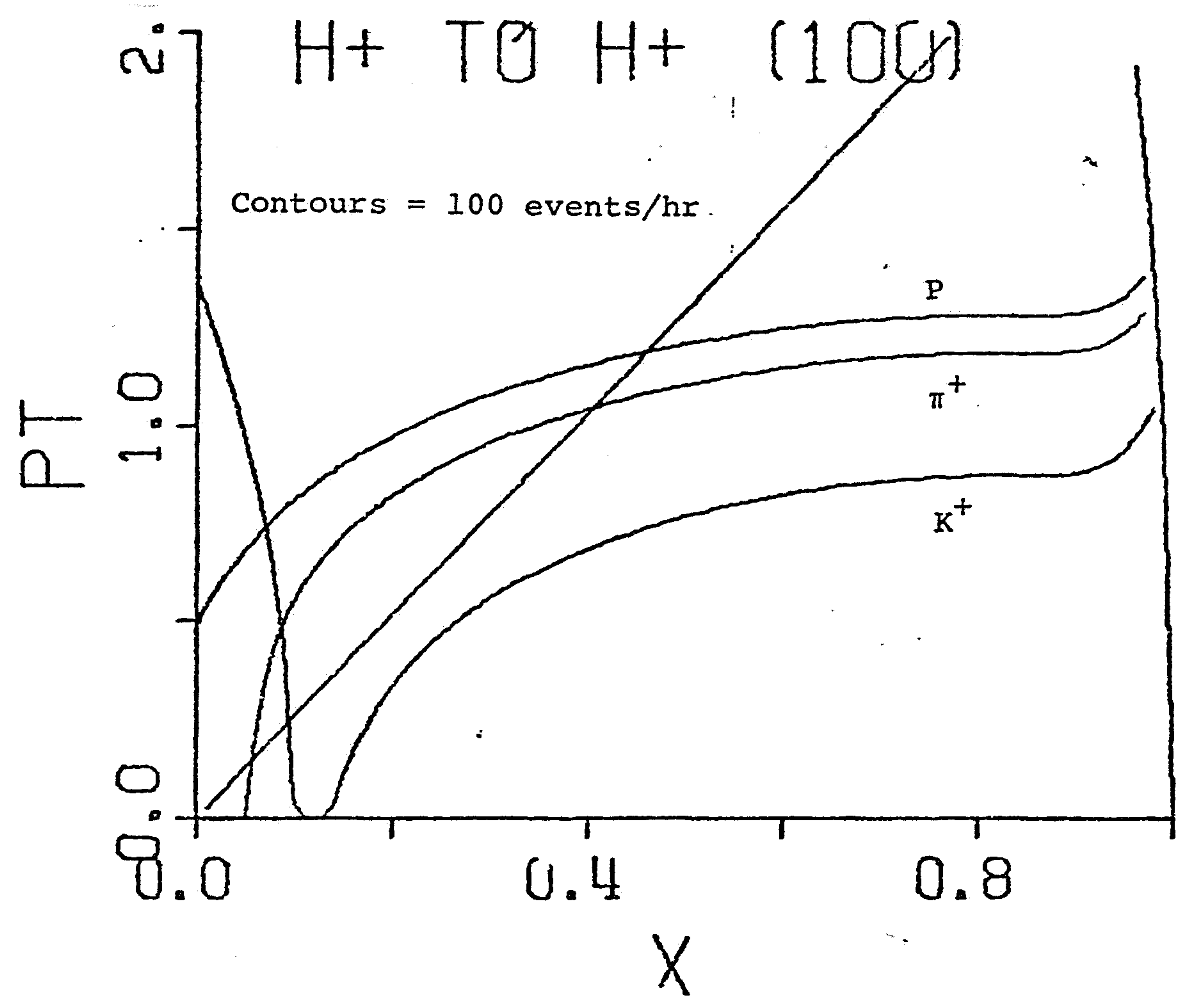
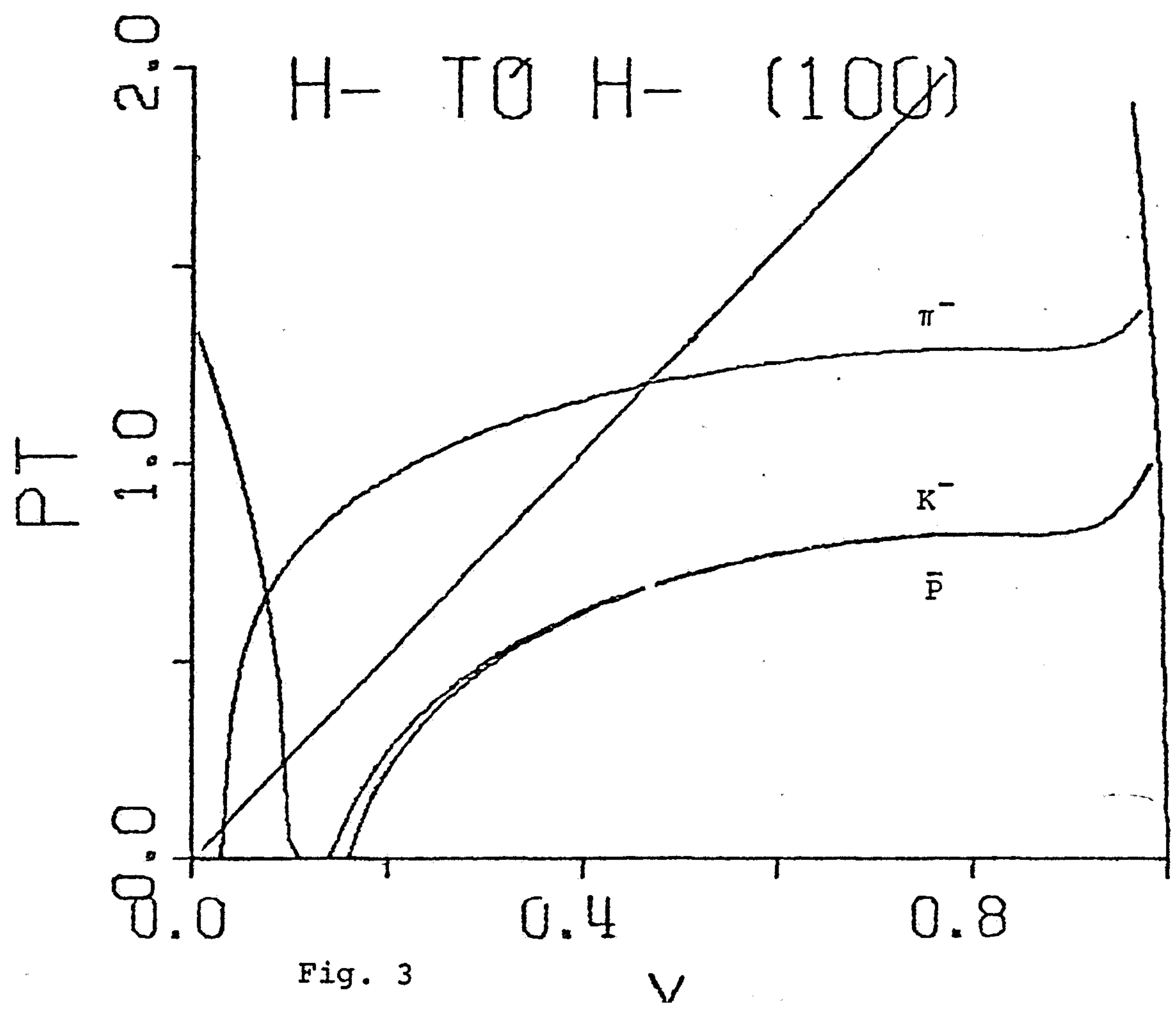

H+ TO H+ (175)
P
π+
K+
Contours = 100 Events/hr
PT
0.0
1.0
2.0
0.4
0.8
X
H- TO H- (175)
π-
K-
P̄
Contours = 100 events/hr
PT
0.0
1.0
2.0
0.4
0.8
X

Fig. 2



H+ TO H+ (100)
Contours = 100 events/hr
P
π+
K+
PT
0.0
1.0
2.
0.0
0.4
0.8
X



H- TO H- (100)
π-
K-
P̄
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0.0
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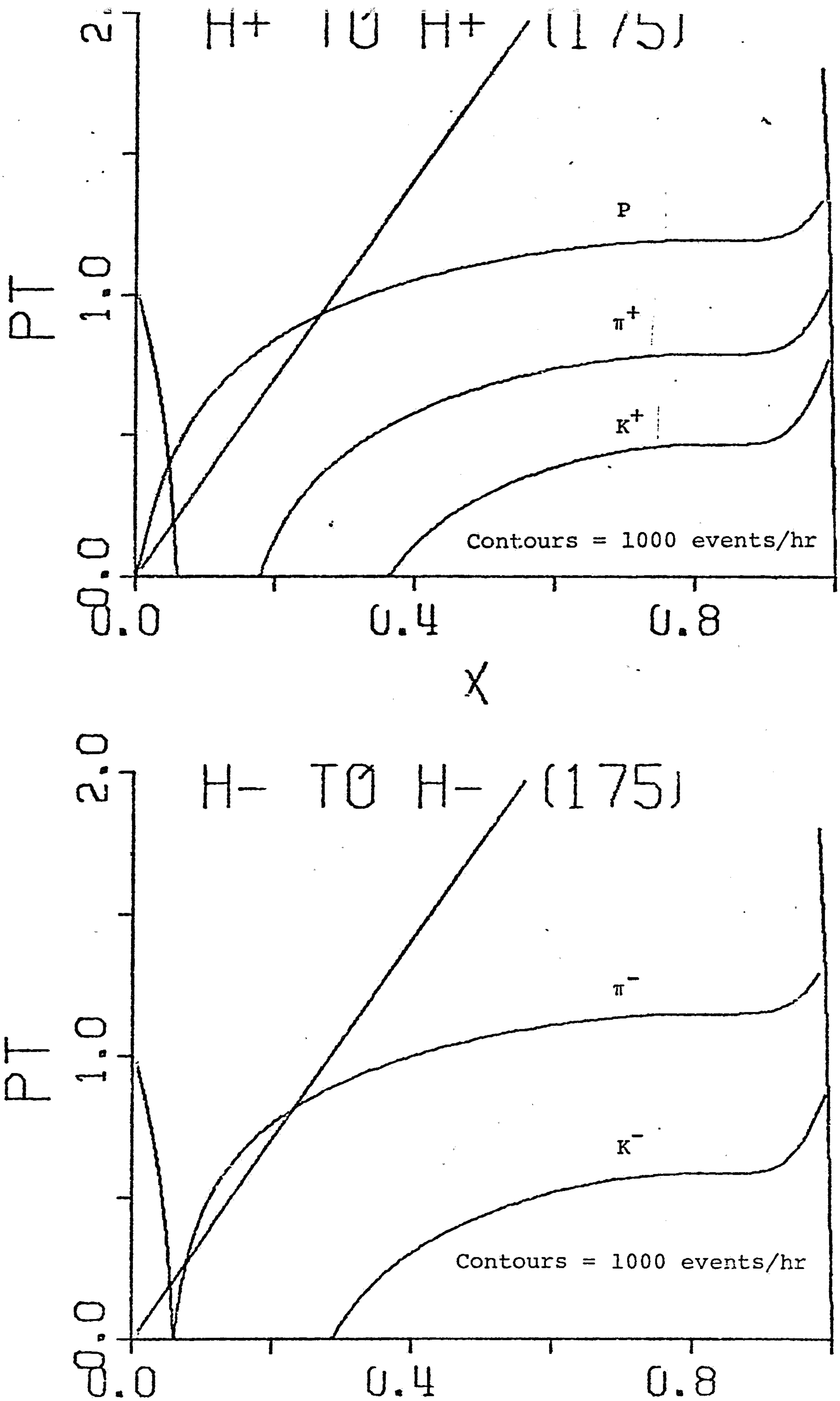
Fig. 3


H+ TO H+ (175)
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π+
K+
Contours = 1000 events/hr
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0.4
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X
H- TO H- (175)
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K-
Contours = 1000 events/hr
PT
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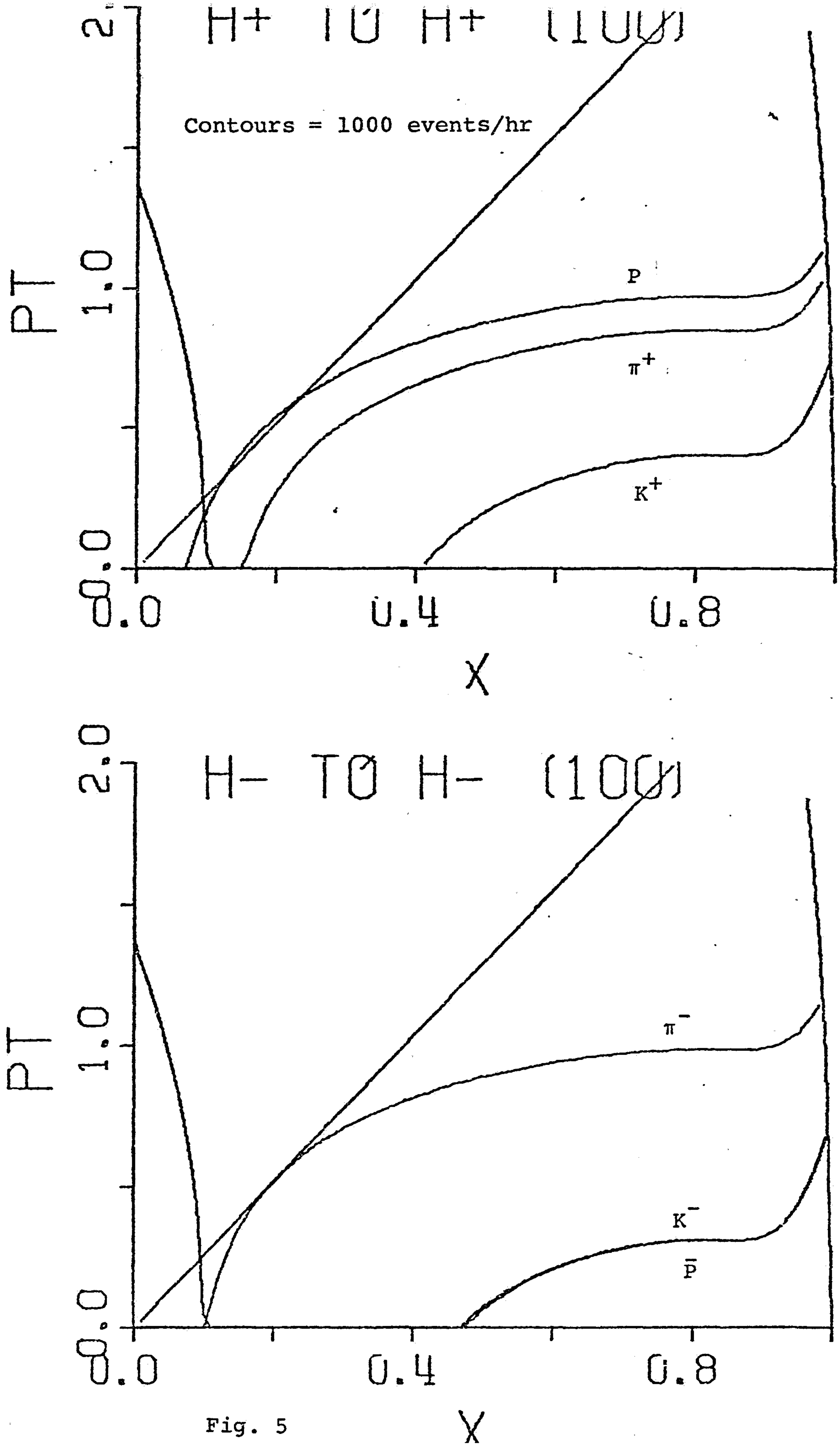
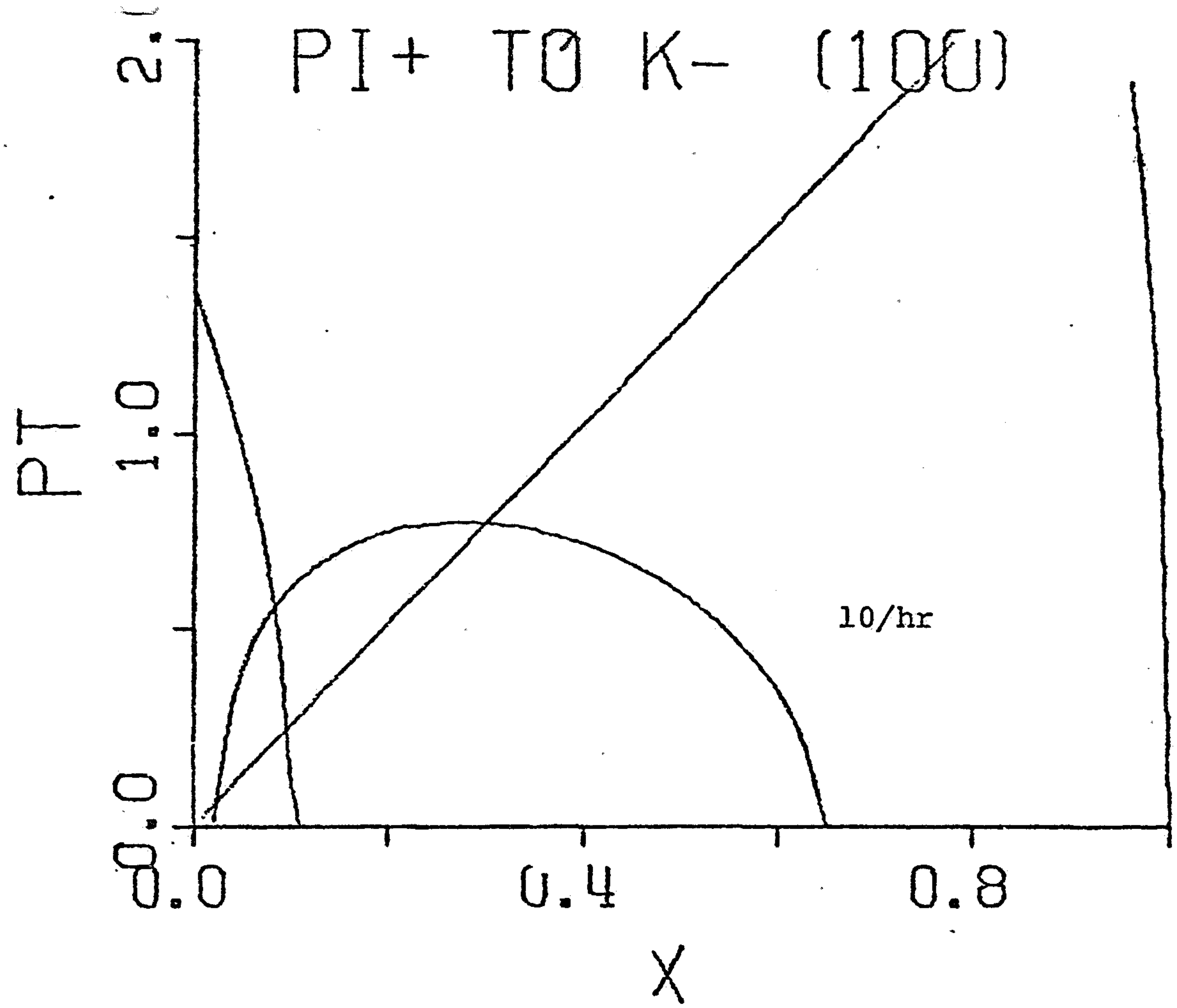
0.4
0.8
X

Fig. 4



H+ TO H+ (100)
Contours = 1000 events/hr
PT
X
0.0
1.0
2
0.4
0.8
P
π+
K+
H- TO H- (100)
2.0
1.0
0.0
0.4
0.8
PT
X
π−
K−
P̄

Fig. 5


PI+ TO K- (100)
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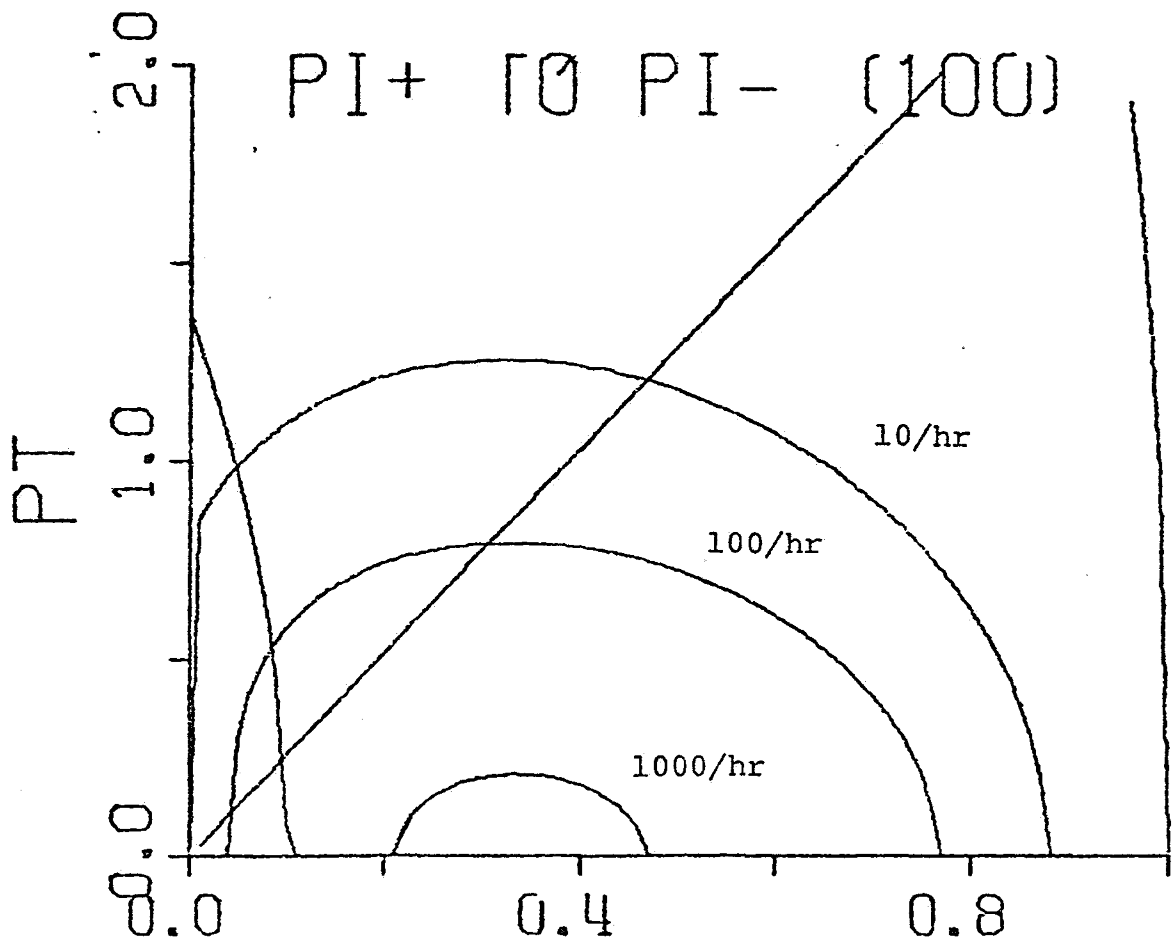
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10/hr
100/hr
1000/hr

Fig. 6

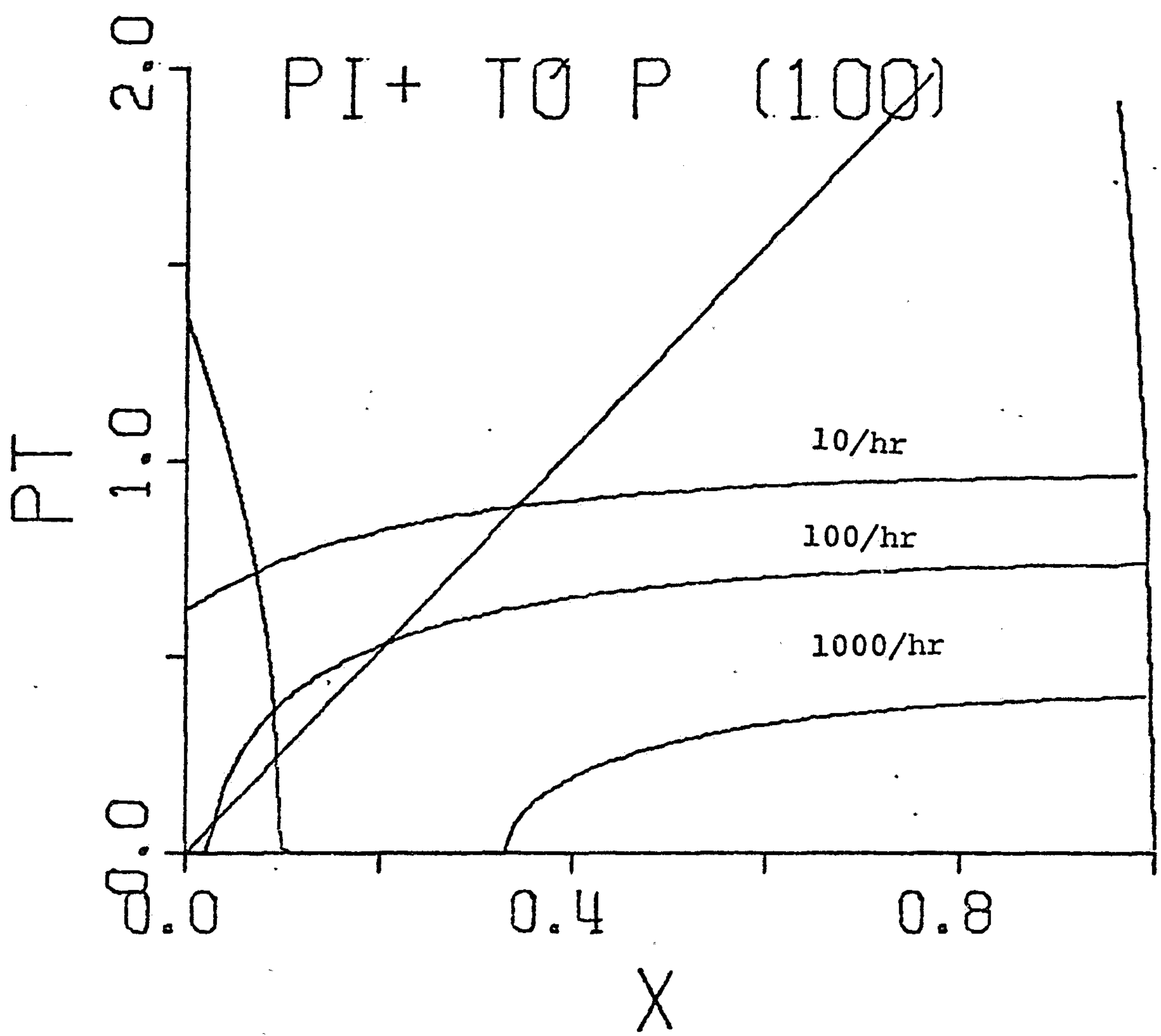
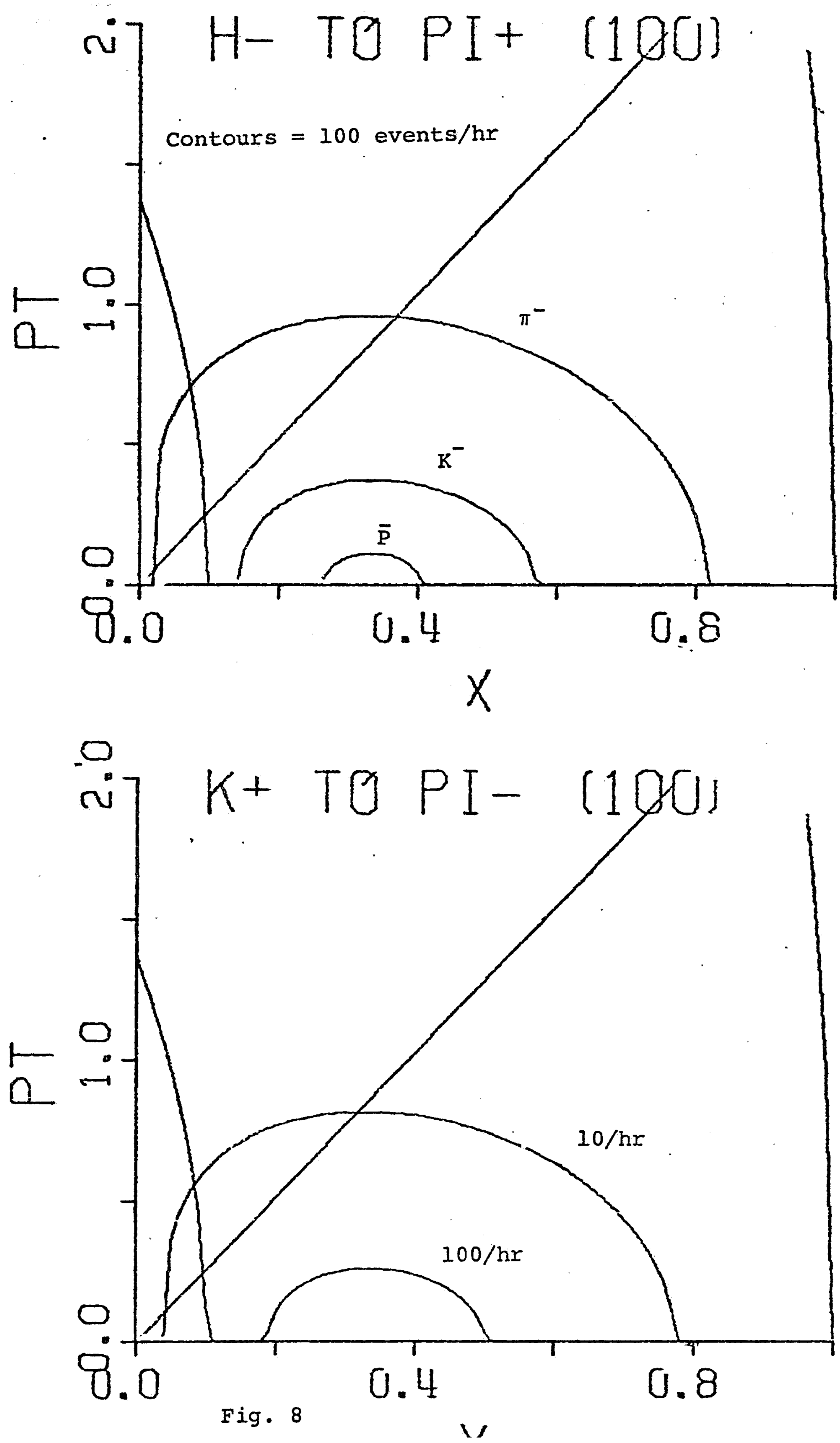
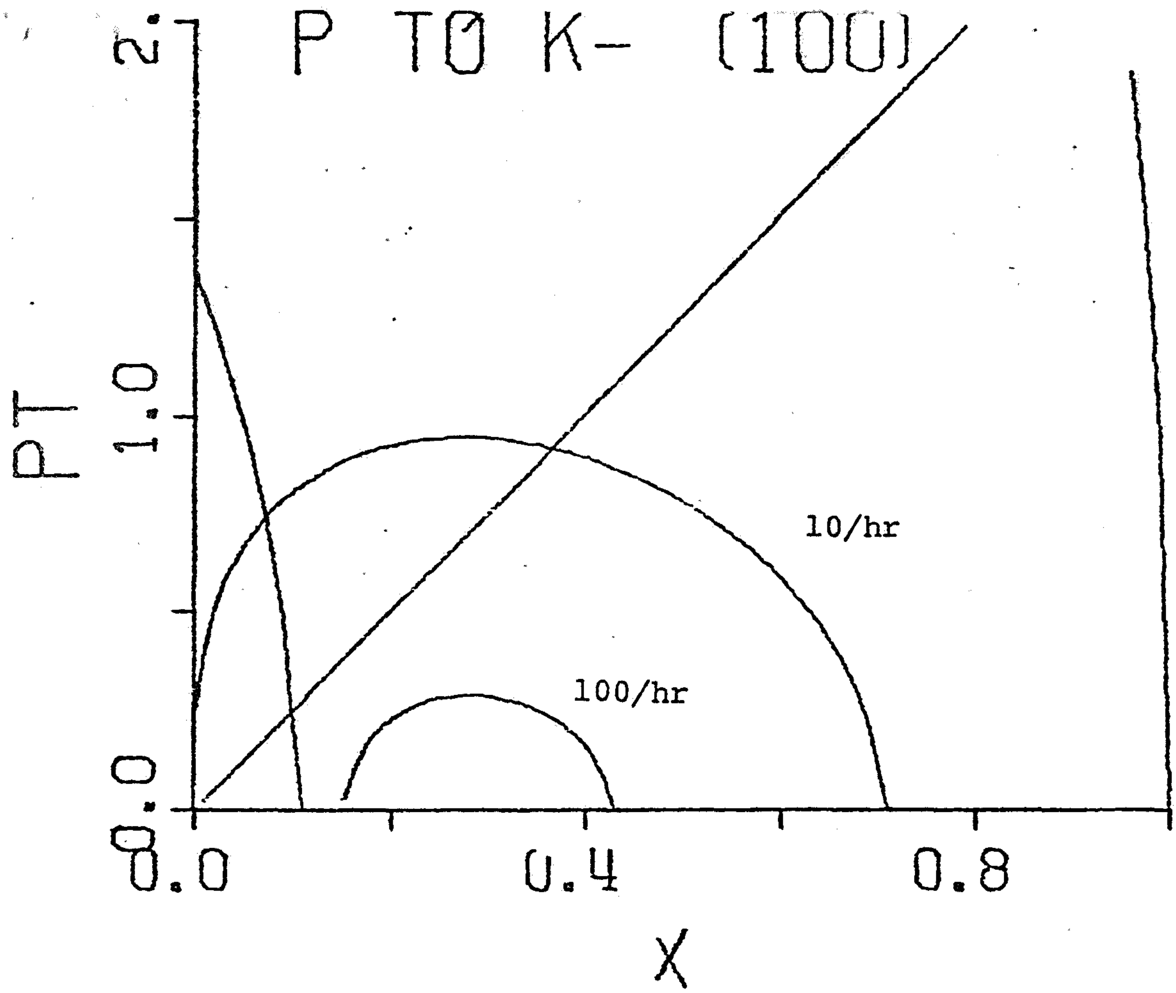


Fig. 7



H- TO PI+ (100)
Contours = 100 events/hr
π⁻
K⁻
P̄
PT
X
2.
1.0
0.0
0.0
0.4
0.8
K+ TO PI- (100)
10/hr
100/hr
PT
2.0
1.0
0.0
0.0
0.4
0.8

Fig. 8


P TO K- (100)
PT
2.
1.0
0.0
10/hr
100/hr
0.0
0.4
0.8
X

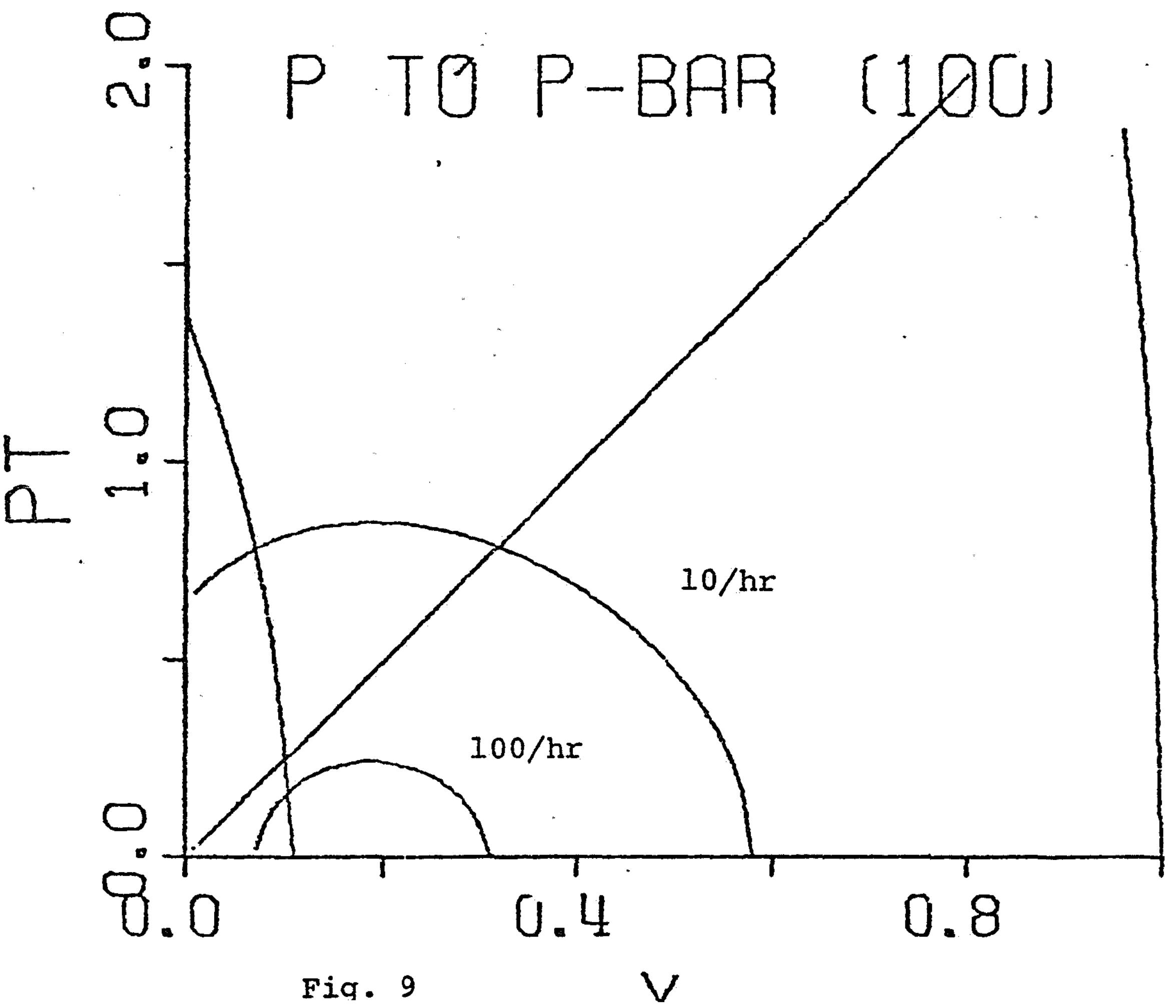

P TO P-BAR (100)
PT
2.0
1.0
0.0
10/hr
100/hr
0.0
0.4
0.8

Fig. 9

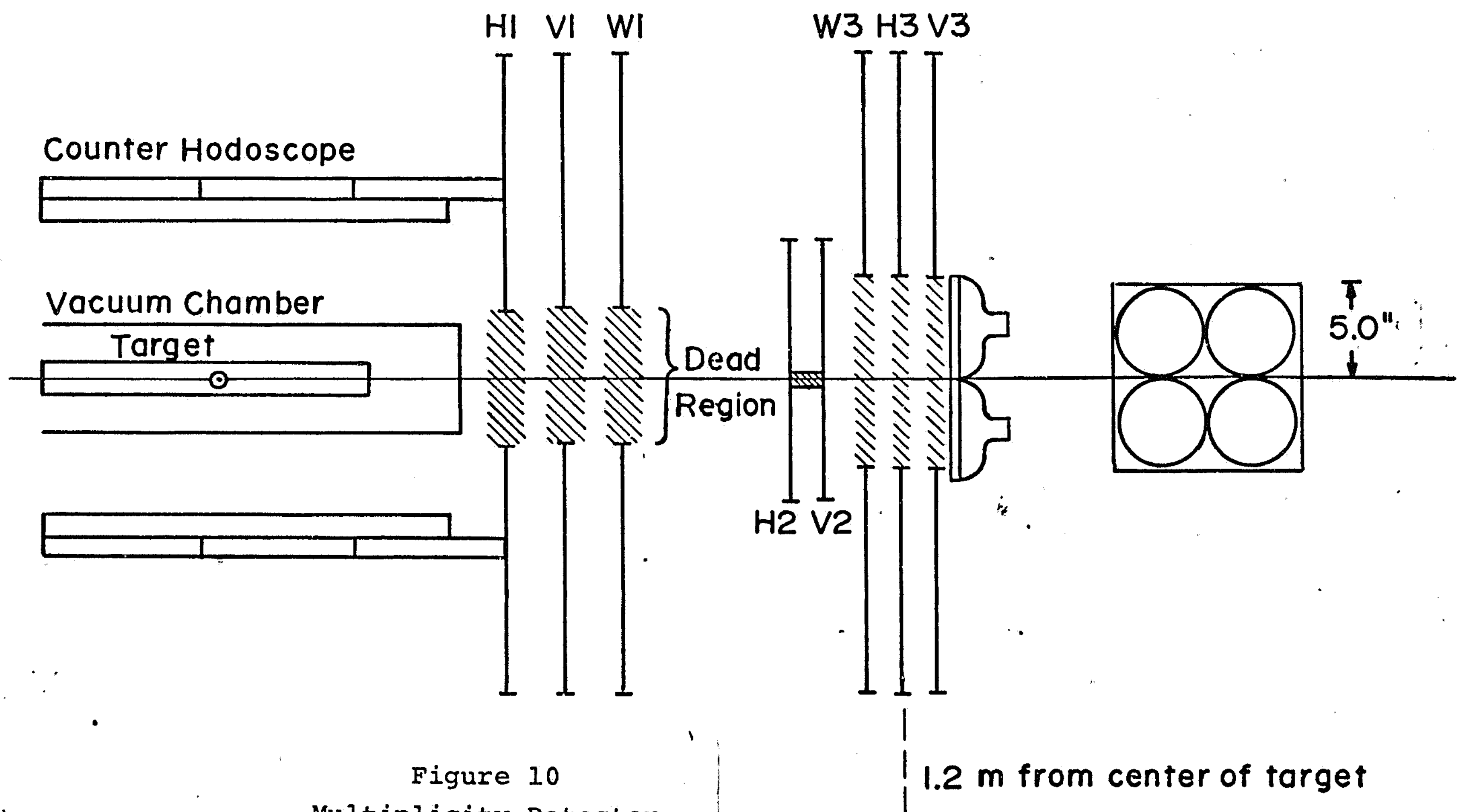


Figure 10
Multiplicity Detector

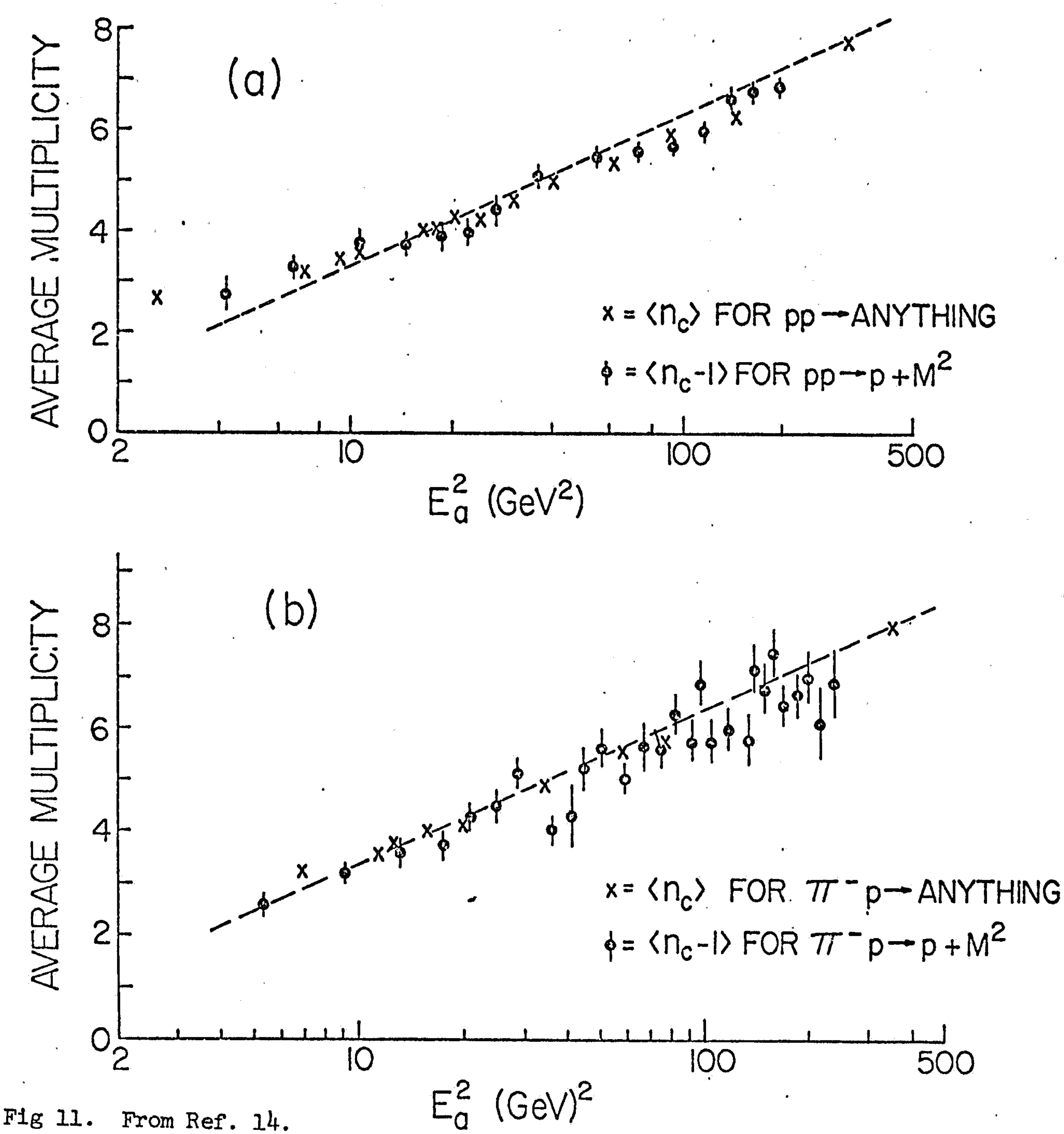


Fig 11. From Ref. 14.

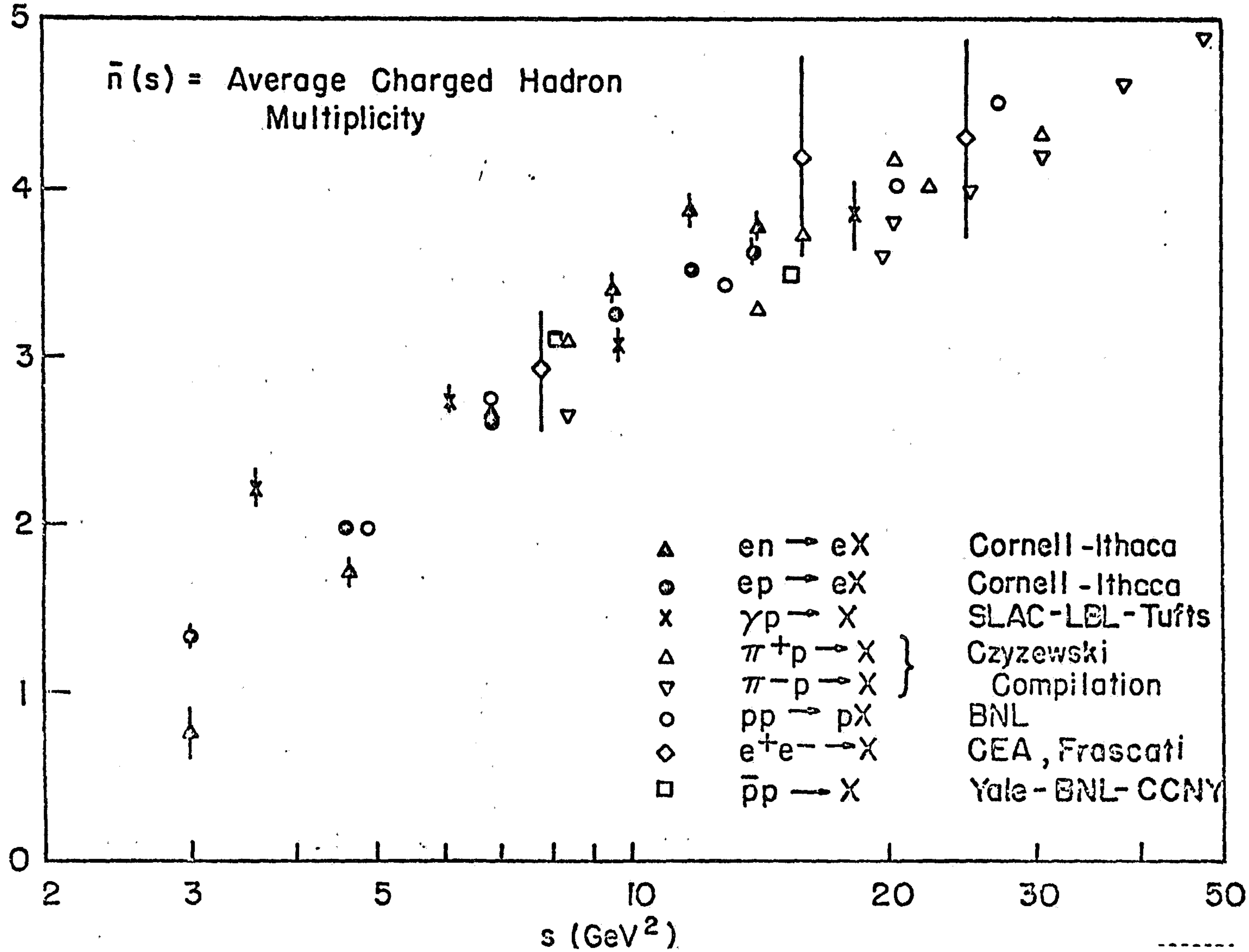


Fig 12. From Ref. 20. Comparison of Average Charged Hadron Multiplicities for Different Initial Hadronic States.

TABLE I

Parameterizations

a. $pp \rightarrow pX$ at 450 GeV/c from Reference 2.

$$E \frac{d\sigma}{d^3p} = \frac{(c_0 + c_1 x + c_2 x^2 + c_3 x^3)}{(b_1 - x)^{b_2}} \exp -(a_1 p_t + a_2 p_t^2)$$

where

$a_1 = 1.529$ /GeV	$c_o = 12.854$ mb/GeV^2
$a_2 = 2.645$ /GeV	$c_1 = 10.829$ "
$b_1 = 1.044$	$c_2 = -63.08$ "
$b_2 = 1.58$	$c_3 = 39.85$ "

b. $\pi^+ p \rightarrow pX$ at 22 GeV/c from Reference 5.

$$E \frac{d\sigma}{d^3p} = C\, e^{-(a x + b p_t^2)}$$

where

$a = 1.75$

$b = 6.0$ /GeV^2

$C = 5.7$ mb/GeV^2

TABLE II

pp → pX at 175 GeV/c

M_x^2	x	$\lvert t_{max}\rvert$ (at P_t=1.5GeV/c or AVB angle limit)
10 GeV^2	.972	2.31 GeV^2
25	.927	2.43
50	.851	2.64
100	.700	3.21
150	.548	4.11
200	.417	5.40
250	.245	3.12

Rate Estimate Tables III - V

Tables III:A through III:D : contain the number of expected events for a proposed run schedule

Table IV: contains the fraction of events initiated by an incident beam particle

Table V: contains the ratios of leading to leading and production processes

EXAMPLE: to find the number of events of the type $K^-P \rightarrow K^-X$ at 175 GeV/c with x = .3, p_t = .25

a. find total number of (175^-, .3, .25) events from III:A = 20.6K

b. find fraction of K^- induced reactions from IV = 0.07

c. find ratio of leading particle/total events from V = .974

d. multiply ______

e. answer 1.3K events

TABLE III:A

X Scans

	p_t/x	.1	.2	.3	.4	.5	.6	.7	.8	.9
50^+	.5					20.6		21.8		19.3
	.25			21.9		21.5		21.3		23.6
50^-	.5					10.2		9.9		11.2
	.25			10.1		12.7		9.8		11.1
100^+	.5		19.0	22.8	26.2	24.3	15.7	18.8	20.1	20.9
	.25		29.6	27.2	21.0	31.4	38.2	45.6	49.0	51.0
100^-	.5		9.8	11.2	15.3	11.9	11.0	13.5	14.7	15.3
	.25		9.8	13.2	12.0	25.1	26.3	32.4	35.3	36.9
175^+	1					10.4	10.9	10.6	11.2	11.6
	.5		12.1	21.3	31.7	43.2	55	66	70	73
	.25	9.9	27.9	50.2	75.4	104	132	158	169	175
175^-	1					9.8	11.2	9.7	10.5	10.9
	.5		11.1	13.0	15.9	24.9	34.5	43	46	49
	.25	10.3	12.9	20.6	38.0	60	83	103	112	117

Number of Events in Units of 1000

TABLE III:B

PT Scan

p_t	$x = .6$				$x = .9$			
	beam = 100^+	100^-	175^+	175^-	100^+	100^-	175^+	175^-
.05	60	42	209	132	80	59	278	186
.1	55	38	191	119	73	53	253	168
.25	38	26	133	83	51	37	175	116
.40	23	16.2	82	51	31	23	107	72
.50	15.7	11.0	55	34	21	15.4	72	49
.60	15.0	10.6	35	22	13.3	9.9	47	31
.75	18.5	9.9	16.5	10.4	12.2	11.5	22	14.5
1.0	5.0	3.6	10.9	11.2	6.5	5.0	11.6	10.9
1.25	.82	.56	3.0	1.8	1.0	.75	3.6	2.4
1.5	.10	.06	.43	.20	.11	.09	.40	.27

NUMBER OF EVENTS IN UNITS OF 1000

TABLE III:C

Beam - Spectrometer Polarity Mixes

$x = .3$

	Beam	Spectrometer	p_t = .05	.01	.25
100	+	+	20.5	19.0	20.4
	+	-	23.3	22.4	23.0
	-	+	13.1	12.6	9.4
	-	-	10.4	14.1	9.9
175	+	+	75	70	50
	+	-	28	27	21
	-	+	20	19.5	15
	-	-	33	30	21

Number of Events in Units of 1000

TABLE III:D

Triple Regge Region

Beam	p_t/x	.90	.92	.94	.96	.98
175^+	1	11.6	10.0	12.0	12.4	13.8
	.5	73	79	93	129	216
175^-	1	10.9	10.1	10.1	11.1	14.1
	.5	49	53	63	87	146

Number of Events in Units of 1000

TABLE IV

Beam Particle Induced Ratios

These are the fractions of events initiated by a given incident beam

Beam	π	K	P
50^+	.51	.04	.45
50^-	.91	.06	.03
100^+	.30	.03	.67
100^-	.90	.07	.03
175^+	.06	.01	.93
175^-	.92	.07	.01

TABLE V

Leading Particle Ratios

Ratio of events with a leading particle detected to all events with a hadron detected in spectrometer.

$$R^{\pm} = \frac{h^{\pm} p \to h^{\pm} X}{n^{\pm} p \to q^{\pm} X}$$

x	R^+	R^-
0.1	.30	.905
0.3	.53	.974
0.5	.79	.994
0.7	.94	.999
0.9	.97	∿1.000

These Ratios Are Fairly Independent of P_{beam} and P_t