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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 $a + b \rightarrow c + \text{Anything}$. One of the important experimental challenges for the MBL 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 MBL focussing spectrometer¹. 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 model²; the limiting fragmentation model³ of Yang and collaborators; and the parton model⁴ 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 $a + b \rightarrow c + \text{Anything}$, the cross-section in the c.m. system will have the limiting form:

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

quantity \bar{E} is the c.m. energy of the detected particle, P_{\perp} is its transverse momentum, and $\bar{X} = \bar{P}_{11}/\bar{P}_0$, where \bar{P}_{11} is the longitudinal momentum of the detected particle and \bar{P}_0 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

$$\langle N_c \rangle = a_c \ln(s) + \text{constant, where } s \text{ is the c.m. energy, and}$$
$$a_c = \int g_c(P_{\perp}) dP_{\perp}^2 .$$

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_0 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

\bar{X}	$P_0 = 200 \text{ GeV/c}$		Incident Protons		$10^{10}/\text{pulse}$	
	Final Protons		Final π^+		Final K^+	
	Max. $P_{\perp} (\frac{\text{GeV}}{c})$	Limitation	Max. $P_{\perp} (\frac{\text{GeV}}{c})$	Limitation	Max. $P_{\perp} (\frac{\text{GeV}}{c})$	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

\bar{X}	$P_0 = 100 \text{ GeV/c}$		Incident Protons		$2 \times 10^7/\text{pulse}$	
	Final Protons		Final π^+		Final K^+	
	Max. $P_{\perp} (\frac{\text{GeV}}{c})$	Limitation	Max. $P_{\perp} (\frac{\text{GeV}}{c})$	Limitation	Max. $P_{\perp} (\frac{\text{GeV}}{c})$	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 $\bar{X} = 1$ produced from hydrogen and deuterium targets.

The possible relationship between the behavior of the spectra near $\bar{X} = 1$ 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
200	4.92			
150	3.7	4.92		
100	2.45	3.28	4.92	
50	1.23	1.64	2.46	4.92
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 Momenta in GeV/c	30	1.80	1.80	1.80	1.80
	20	1.80	1.80	1.80	1.80
	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 2×10^6 /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 Serpukhov⁶. 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 H₂ and D₂ 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 10⁷ 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} , ΔP_{\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 $P + P \rightarrow P + \text{Anything}$ 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/R/K obtained from calculations using the model of Hagedorn and Ranft⁸. 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 facility for 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

$P_0 = 200 \text{ GeV/c}$ (Incident Momentum)

Intensities:

Protons: 10^{10} /pulse

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

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

Running Time, 150 hours

$P_0 = 150 \text{ GeV/c}$

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 $p' > 30 \text{ GeV/c}$
 0-150 mrad $p' \leq 30 \text{ GeV/c}$ with constraint $P_{\perp} \leq 1.8 \text{ GeV/c}$

Running Time, 200 hours

$P_0 = 100 \text{ GeV/c}$

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

$P_0 = 50$ 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

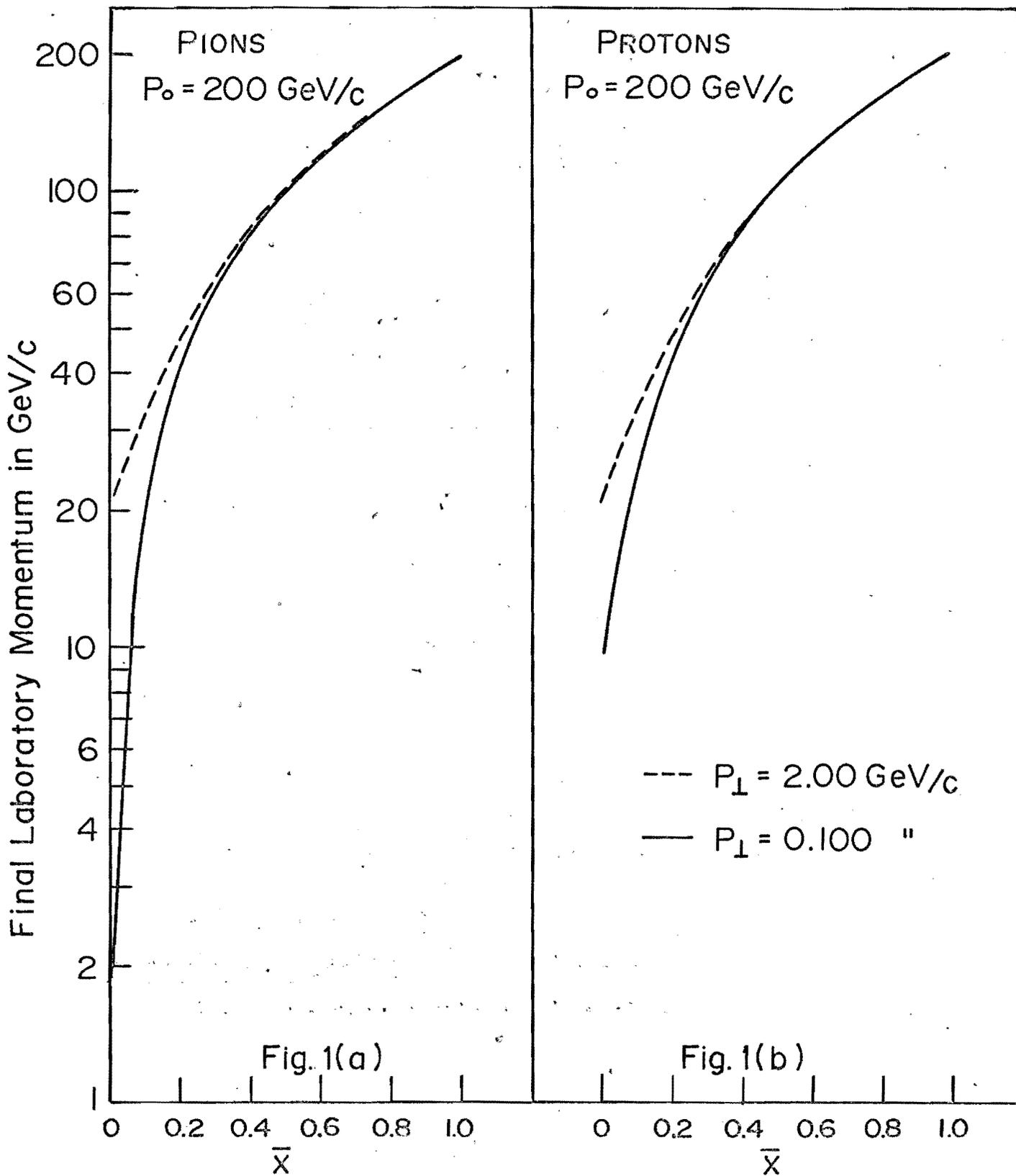
Angular Range: 0-98 mrad $p' \geq 20$ GeV/c

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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ADDENDUM TO PROPOSAL #118

HADRON SPECTRA FROM HIGH ENERGY INTERACTIONS

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In Proposal #118, we proposed to study inclusive reactions of the type $a + p(\text{or } n) \rightarrow b + \text{anything}$ 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 $PP \rightarrow PX$, 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 $50 \times 50 \text{ cm}^2$ 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 $5 \text{ cm} \times 5 \text{ cm}$ of this chamber will be made insensitive. Particles produced in a forward cone of $\leq 10^\circ$ 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

$$\Delta \approx \frac{70}{\sqrt{n}} \%$$

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 ≈ 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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Target surrounded by five
proportional chambers. Each
is $50 \times 50 \text{ cms}^2$ and consists
of three planes of wires.

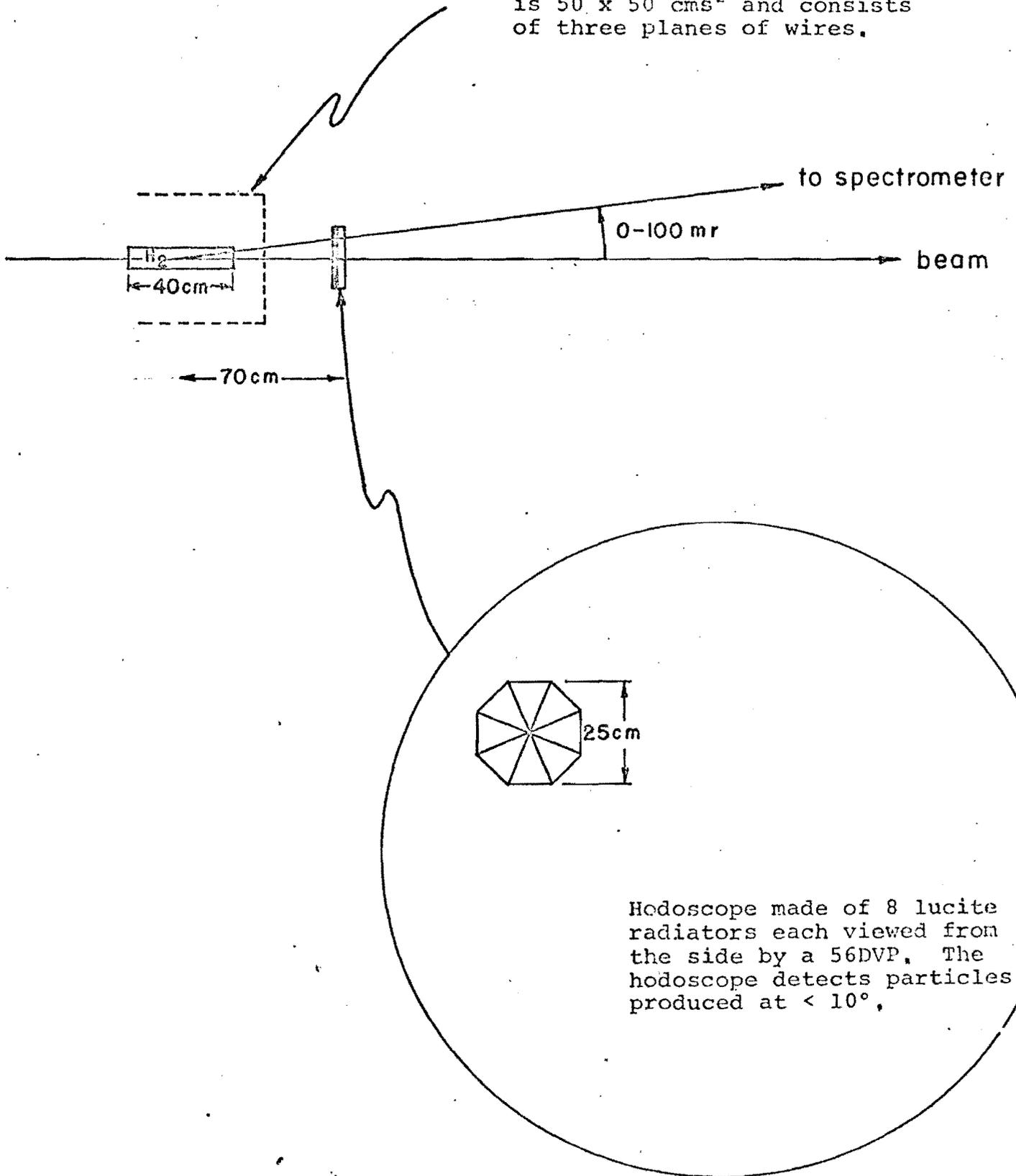


Fig. 1 Detector for measuring the charged
multiplicity of the interaction.