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NAL PROPOSAL No. 295

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A Study of π^+-d Interactions at 200 GeV/c in the 30-inch Bubble Chamber at NAL

Centre de Recherches Nucleaires de Strasbourg
Centre de Recherches Nucleaires de Saclay
Weizmann Institute

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Supplement 2

NAL PROPOSAL No. 204
March, 1973

Proposal for a pd 200 GeV/c BC

Experiment at NAL

(Weizmann Institute High Energy Group)

Identification of coherent d events from recoil particle measurements.

In standard bubble-chamber experiments at a few GeV/c the identification of coherent d-events is usually achieved via complete kinematical solutions of individual events (4c or 1c solutions). Thus in true d-events, for example, $pd \rightarrow pd\pi^+\pi^-$, the spurious (1c) solution $pp_s n\pi^+\pi^-$ usually yields a very narrow d spike in the invariant mass distribution $M(p_s+n)$. At NAL energies complete kinematical solutions are almost impossible and one has to utilize the measurements of the slow particle alone in order to isolate the coherent d-events. We wish to demonstrate that by such measurements one can unambigously identify deuterons in the momentum region of 0.4 - 3.0 GeV/c.

A. Region $p_d = 0.8 - 3.0$ GeV/c. In this region deuterons will have specific ionization less than 6 time minimum ionization and will not stop in the 30" bubble chamber. However, ionization measurements can easily be carried out here and since for the same ionization the d-momenta will be twice the corresponding proton momentum, the particle identification is easy and possible. Note that $p \geq .8$ GeV corresponds to $|t| \gtrsim 0.6$ GeV^2 and thus only very few events are expected in this energy region.

B. Region p_d = 0.4 - 0.8 GeV/c. This region corresponds to $|t|$ = 0.16-0.6 GeV^2 and should contain most of our identifiable d-events. The technique that we shall use here is momentum vs. range measurements, which we find reliable down to d-ranges of 6 cm in the bubble chamber. Because of the extremely steep t-distribution of the coherent d-events it is important to estimate reliably the smallest t value for which deuterium identification is possible. Thus we tested this point experimentally in the following ways:

(1) Reliability of rejection of protons. From a high statistics π^+p experiment in the SLAC 82" HBC stopping protons produced in the reaction $\pi^+p \to \pi^+p\pi^+\pi^-$ where selected and measured on our Spiral Reader. Each track yields 4 "measured" momenta values: $p_p(R)$ and $p_p(C)$, momenta determined from range and curvature respectively, assuming the stopping particle to be a proton, and $p_d(B)$, $p_d(C)$ - the corresponding quantities for a deuteron hypothesis. The errors on p(R) are usually extremely small and thus the quantity

$$x = \frac{p(R) - p(C)}{\delta p(C)}$$

where $\delta p(C)$ is the error of p(C), should have a normal distribution with a mean of zero and unit variance. The distribution of x for the proton hypothesis (x_p) and the deuteron (x_d) are shown in fig. 1, for all events having a range R $\geq$ 6 cm. Clearly a reliable separation is observed and one concludes that very few protons could be mis-identified as deuterons. In Fig. 2(a) and 2(b) we give actual distributions of $p_p(C)$ vs. R and $p_d(C)$ vs. R, assuming the protons to be deuterons. Again, clearly the protons sit nicely on the range-energy proton curve whereas the deuteron hypothesis does not agree with its curve, for R $\geq$ 6 cm.

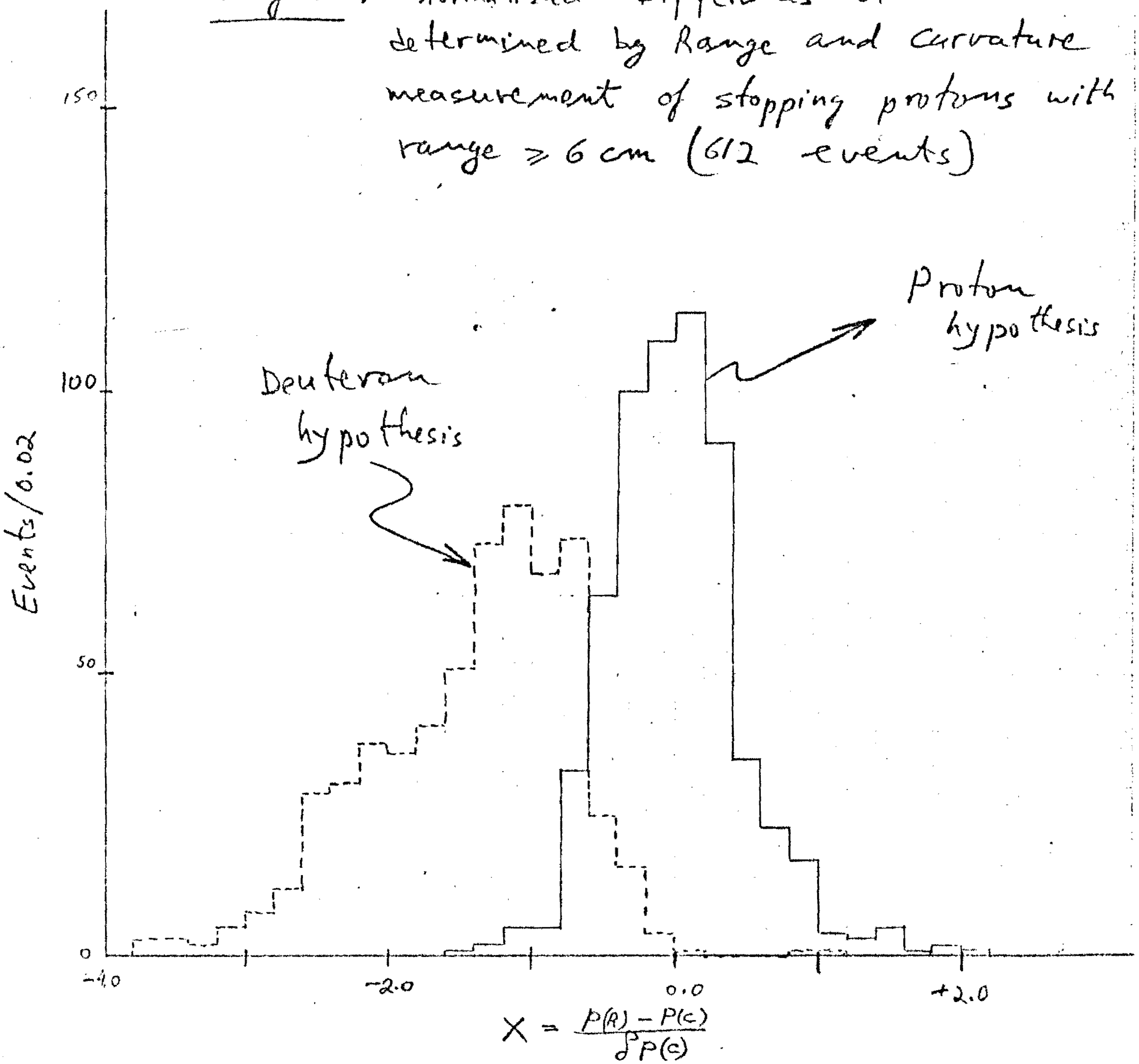
(2) Reliability and efficiency of deuteron detection. From another exposure (pd at 12 GeV/c, BNL) we selected coherent d-events by conventional kinematical methods. These events should be mostly true d-events. We computed also here $p_d(C)$ and $p_p(C)$ and show in Fig. 3 $p_d(C)$ and $p_p(C)$ vs. the true range R. Each event is entered twice in Fig. 3 assuming it to be a proton and deuteron. Again we see from Fig. 3 that for ranges over 5-6 cm in the bubble chamber, reliable and efficient identification of the deuterons is possible and the events scatter nicley around the expected range-energy curve of the deuteron.

Conclusions

We conclude that practically all deuterons having a range $\geq$ 6 cm can be positively and unambiguously identified in the bubble chambers by measurements performed on the slow particle alone. This would include coherent events with $|t| \gtrsim 0.16\ \mathrm{GeV}^2$. By extra demands on coplanarity and range vs. angle relations, coherent elastic d-events with $|t| \gtrsim 0.12\ \mathrm{GeV}^2$ could also be identified.

$\pi^+ p \rightarrow \pi^+ p \, \pi^+ \pi^-$

Fig. 1 : Normalized Differences between momenta determined by Range and Curvature measurement of stopping protons with range $\geq$ 6 cm (612 events)



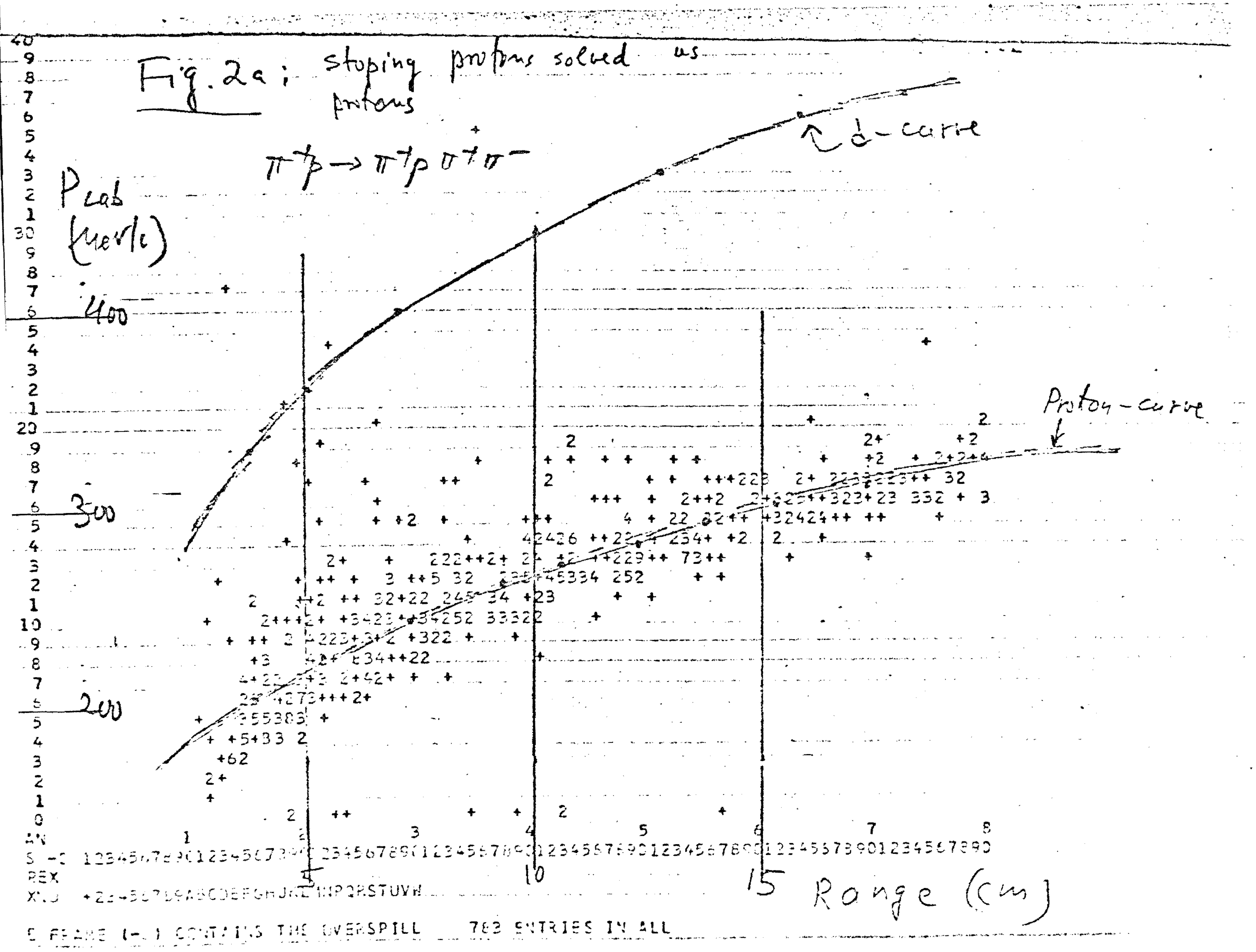
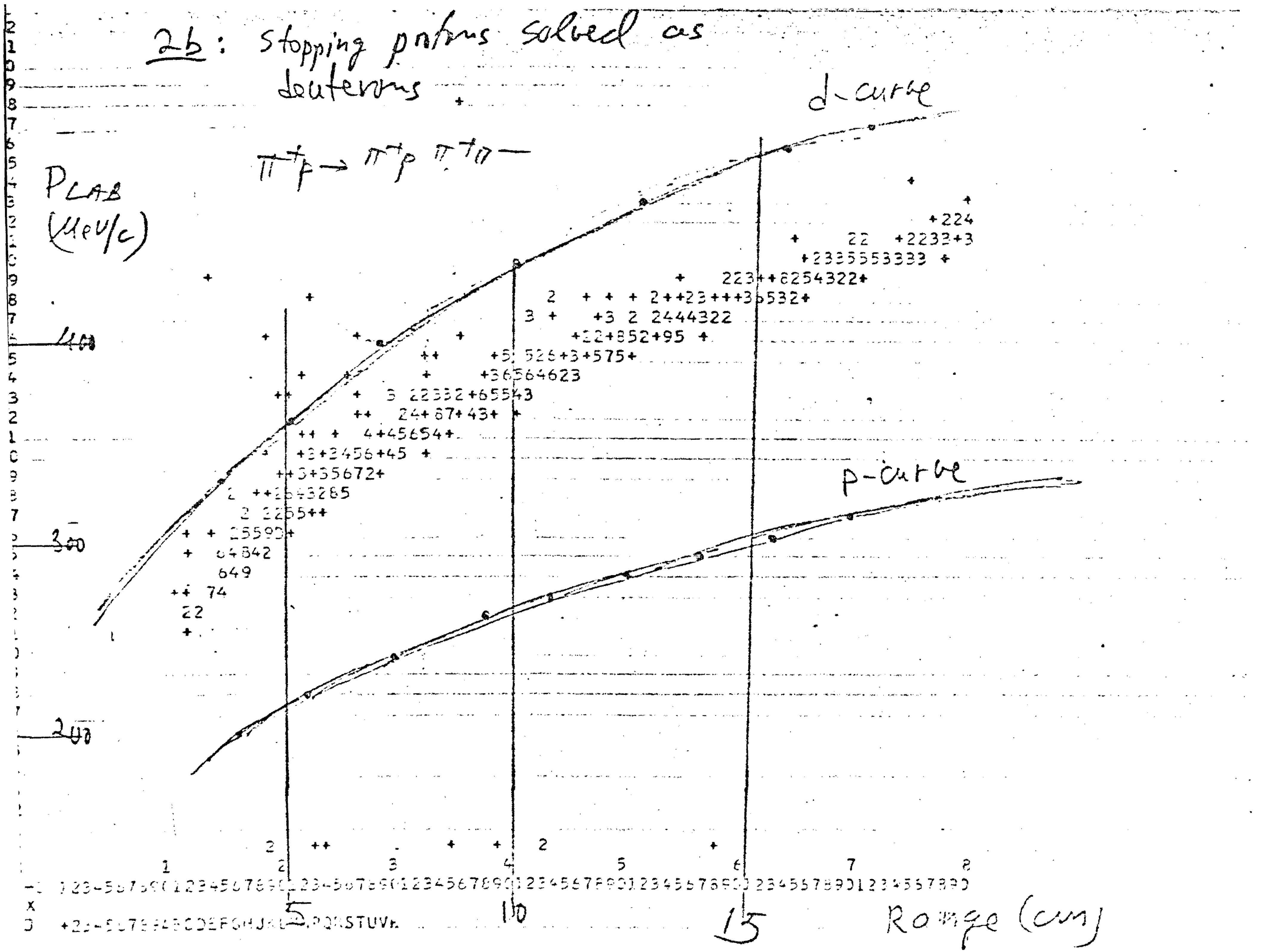
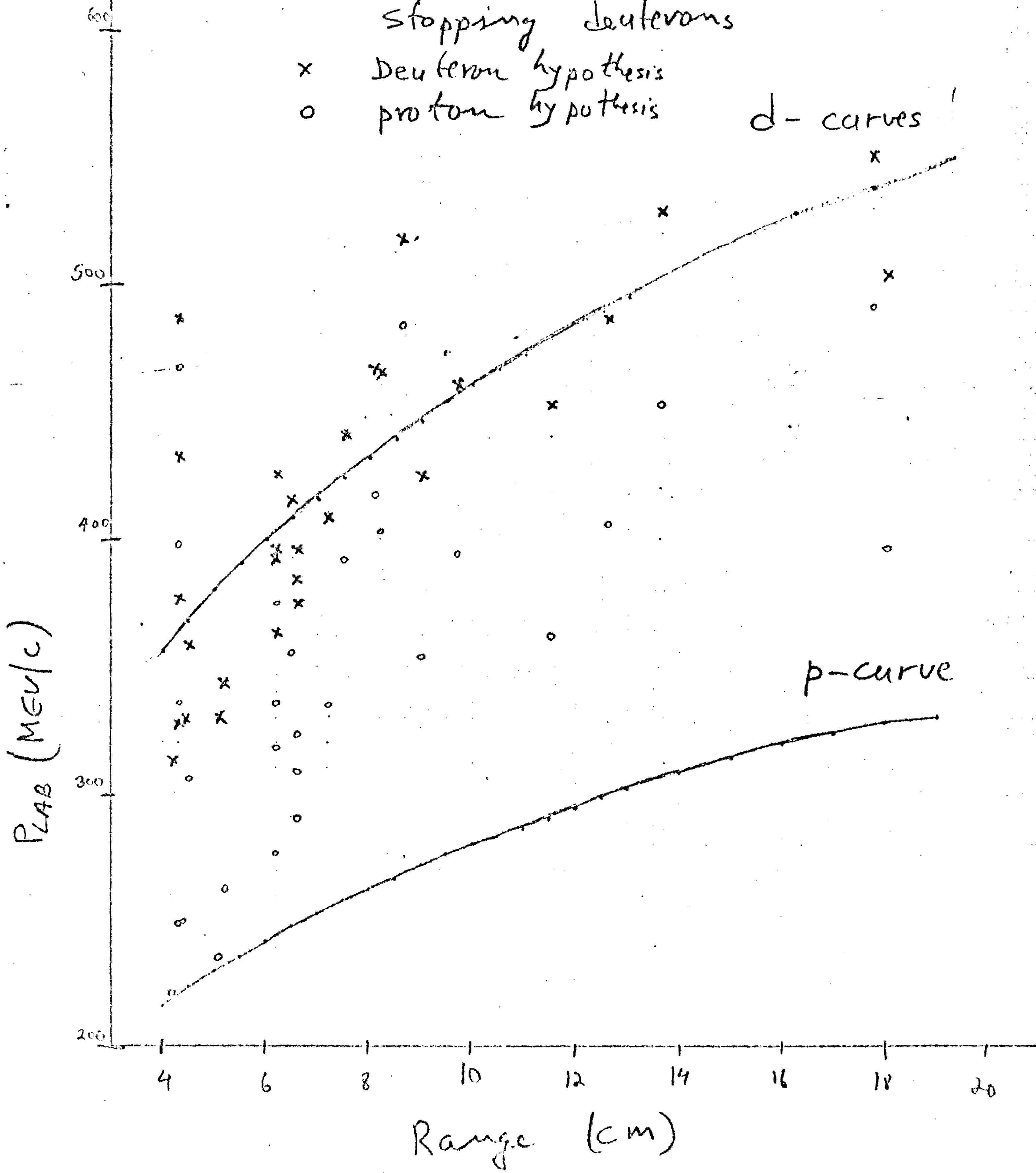


Fig. 2a: stoping protons solved as protons
$\pi^+p \to \pi^+p\pi^+\pi^-$
d-curve
Proton-curve
P lab (MeV/c)
400
300
200
5
10
15
Range (cm)
783 ENTRIES IN ALL


2b: Stopping protons solved as deuterons
π+p → π+p π+π−
PLAB (MeV/c)
400
300
200
d-curve
p-curve
5
10
15
Range (cm)

pd → pd ...

Fig. 3: Measured momenta vs. Range for stopping deuterons



NAL PROPOSAL No. 204

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Proposal for a pd 200 GeV/c Bubble Chamber Experiment at NAL

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Group, Rehovot, Israel

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E. Kogan, G. Mikenberg

February 1973

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Spokesmen for the experiment: Y. Eisenberg and G. Yekutieli

Feb. 1973

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NAL Directors Office

1.0 Purpose

(a) Study of particle production in pp and pn collisions and testing the duality predictions for these reactions.

(b) Study of the fragmentation of the neutron in pn collisions.

(c) Study of particle production and multiplicity distribution in diffractive processes by measuring coherent pd collisions.

2.0 Specifications

(1) 200 GeV protons in the 30 in. bubble chamber filled with deuterium.

(2) 60,000 pictures with 6 protons per picture.

(3) Pictures photographed on 35 mm film.

(4) Magnetic field desired: 27 KG.

3.0 Yield estimates

Based upon existing NAL exposures[1-3], it would seem that an average of 6 protons per frame, in the 30" HBC is a reasonable flux. Assuming $\sigma_T(pd)$ of about 80 mb this would yield, in a fiducial volume of 50 cm along the beam, an average of about 1 interaction per picture, inside the fiducial volume. With a Poisson distribution about 1/3 of the pictures would yield no interactions or more than 3 interactions, which we assume to be then un-analyzable. Thus, in 60,000 pictures we expect about 40,000 good events, namely about 500 events/mb.

4.0 Introduction

Recent pp experiments at 100[1], 200[2] and 300[3] GeV/c in the 30 inch hydrogen bubble chamber at the National Accelerator Laboratory yielded interesting and important results. Moreover, they demonstrated the possibility of studying production of slow charged and neutral particles in bubble chamber at these energies. Following these experiments we propose a pd experiment at 200 GeV/c.

One of the main purposes of the proposed pd experiment is to study and compare the single particle spectra of slow charged and neutral particles in pp and pn collisions. There are several predictions for these spectra[4] and, for example, those of Tye and Veneziano[4], which generalize to inclusive spectra the well known predictions of two-component duality (Harari-Freund, $\sigma(K^+p)=\sigma(K^+n)$ and $\sigma(pp)=\sigma(pn)$), are summarized in table I. Glauber corrections and possible experimental biases are greatly reduced if one considers normalized spectra for inclusive reactions:

$$\rho_p(c) = \sigma(pp \to c) \;/\; \sigma_T(pp) \quad \text{and} \quad \rho_n(c) = \sigma(pn \to c) \;/\; \sigma_T(pn)$$

where $\sigma(pp \to c)$ and $\sigma(pn \to c)$ are the differential spectra of particle c in a given x and p_T range and the $\sigma_T(pp)$ and $\sigma_T(pn)$ respectively are the total pp and pn cross-sections (How pp and pn cross-sections are measured in the pd experiment is described and discussed in the next section).

Table 1: relations predicted by Tye and Veneziano[4]

(1)	$\rho_p(\pi^o) = \rho_n(\pi^o)$
(2)	$\rho_p(\pi^+) + \rho_p(\pi^-) = \rho_n(\pi^+) + \rho_n(\pi^-)$
(3)	$\rho_p(\pi^+) + \rho_p(\pi^-) = 2\rho_p(\pi^o)$
(4)	$\rho_p(\bar{p}) = \rho_n(\bar{p})$
(5)	$\rho_p(K^-) = \rho_n(K^-)$
(6)	$\rho_p(K^+) + 2\rho_p(K^o_{s,L}) = \rho_n(K^+) + 2\rho_n(K^o_{s,L})$
(7)	$\rho_p(\Lambda^o) = \rho_n(\Lambda^o)$
(8)	$\rho_p(\Sigma^o) = \rho_n(\Sigma^o)$

The fragmentation of protons into neutrons in pp collisions was not measured so far. We propose to study the fragmentation of neutrons into protons and to measure the inclusive spectrum of the protons in pn collisions. Comparing this with $p \to p$ might provide an estimate of triple Pomeron and Regge-Regge-Pomeron couplings[5] in inclusive reactions. We shall also study the reaction $pn \to (p\pi^-) + x$ and attempt to observe inclusive production of the $N^*(1470)$ isobar.

We shall also attempt to study the production of particles in the coherent reaction $pd \to$ (fast prongs) + d. In this reaction the incident proton is fragmented presumably by diffraction dissociation into fast particles with no isospin exchange. It will be very interesting to study the multiplicity distribution of this diffractive reaction and thus test the current two-component description of multi-particle production at high energies.

5.0 Discussion of the p and n interactions

(a) pp and pn inclusive cross sections

We expect to have 40,000 good events in the 60,000 proposed pictures. We shall scan for all types of events and record in particular (1) the number of charged prongs, (2) associated stopper protons, (3) associated V^o decays and γ conversions, (4) charged decays of prongs from the primary vertex and (5) recognizeable Dalitz pairs. We shall measure all the low energy tracks ($p \lesssim 1.5$ GeV/c).

According to Charlton et al.[2] in their pp experiment they achieved a scanning efficiency of (99 ± 1)% and there were only 1.4% events with odd or unresolved prong count. We believe that we shall also be able to obtain a similar sample that will be classified as follows:

Class - (I) pp events: pd events with even number of charged prongs with no proton stopper of $P < 300$ MeV.

Class - (II) pn events: pd events with odd number of charged prongs with either (a) an unseen proton spectator or (b) an observed proton spectator i.e. a backward proton stopper ($p < 300$ MeV) in the laboratory system.

Class - (III) pN events: i.e. either pp or pn events - all the remaining events which are not included in (I) or (II), and are not coherent pd events. (The coherent events are discussed later).

More than 90% of the pp collisions in the proposed experiment will be found in class (I), and 15,000 good events are expected in this group (see table IV). Class (II) will include 80% of all pn collision with total of 13,000 expected events. About 5000 events are expected in class (III) of which about 80% are pn collisions and 20% are pp collisions.

Next we shall measure (whenever possible) the momentum and ionization of all slow particles associated with all the events in the three groups: (I) pp, (II) pn and (III) pN. The information about the measured particles is summarized in table II. In this table we used the results on charged and neutral particles obtained in the NAL pp experiments[2,3] and assumed that two particles with the same momentum and of different mass can be distinguished by ionization if $(I_1/I_2) = 1.5$. The expected number of particles was estimated from NAL[2,3] pp results. We expect similar measuring ability for pn events. It appears from table II that we shall be able to observe in a given P_T and $x = \frac{2P_L}{\sqrt{s}}$ ranges the following particles: p, π^+, π^-, π^o, K^o, Λ^o or Σ^o. We shall use these observations in both pp and pn events to measure the inclusive normalized spectra $\rho_p(c)$ and $\rho_n(c)$ of these particles, and to test the predictions of the various theories, i.e. some of those in Table I. We shall also use the results of the pp experiments[2,3] as another independent test of all available predictions.

(b) Fragmentation of the neutron

The pn events (class II) with measured slow protons ($E_p \leq 1.4$ GeV) will be used to study the inclusive spectrum of protons in the fragmentation region of the neutron: $-1.0 \leq x \leq -0.3$. From cosmic ray estimates(6) one expects over 500 pn events with slow measurable proton in our sample. Furthermore pn events associated with both measurable protons and π^- will be used to study the reaction $pn \rightarrow (p\pi^-)+x$ and to deduct possible inclusive production of the $N^*(1470)$ isobar in pn collisions.

Table II

Expected numbers of observed particles in pp collisions at 200 GeV/c, in 60,000 pd pictures (16,000 pp events)

particle	Expected No. of Particles	P_{max} GeV/c	P_T GeV/c	$\frac{2P_L^*}{s}$
π^+ (a)	1550	1.4	≥ 0.1	$-1.0 \leq x \leq -0.04$
p	4500	1.4	≥ 0.1	$-1.0 \leq x \leq -0.3$
π^- (b)	≥ 5000	15	0-1.5	$-1.0 \leq x \leq 0.07$
π^o	800	20	0-0.6	$-1.0 \leq x \leq 0.10$
K^o	380	20	0-0.6	$-1.0 \leq x \leq 0.09$
Λ	160	20	0-0.6	$-1.0 \leq x \leq 0.07$

(a) K^+ are neglected

(b) K^- are neglected

6.0 The Diffractive Component

(a) Inelastic Coherent Part

Currently there are several fits[7-10] to the high energy multiplicity distribution in which the two component model[11] is being utilized. The various approaches emphasize different theoretical aspects - however practically all of them assume that the diffractive part is energy independent. If such a component indeed exists, measurements of the coherent diffractive D cross-section in the reaction:

$$pD \rightarrow D + \text{anything} \tag{1}$$

could reveal it. Thus, the yield of coherent D events due to this component should remain constant with energy, for each multiplicity separately. The following table III summarizes the expected yields (in mb):

Table III

cross section inelastic	Quigg Jackson[7]	Fialkowski & Miettinen[8]	Frazer et al[9]	Harari & Rabinovici[10]
σ_2	(2.5)*	2.3	2.0	2.0
σ_4	2.4	3.1	2.7	2.2
σ_6	1.1	1.7	1.7	0.9
σ_8	0.6	0.6	0	0.1
σ_{10}	0.4	-	-	-
$\sigma_{D(tot)}$	8.5	7.0	6.4	5.2

(*) In the original calculation $\sigma_{2(elastic)} \simeq 7$ mb was added to σ_2

Tests in some of our current deuterium experiments (pd at 12 GeV/c) have indicated to us that one can distinguish reliably between short proton recoils and deuterons, if the particles have a range of $\geq$ 6 cm in the bubble chamber. This range deuteron corresponds to a momentum transfer of $-t = 0.16\ \mathrm{GeV}^2$. Assuming the diffractive inelastic part to behave like:

$$\frac{d\sigma}{dt} = A\ e^{Bt} \tag{2}$$

with $B \approx 6\ \mathrm{GeV}^{-2}$, we obtain for the coherent deuterium cross section in the single[12] scattering region ($|t| \lesssim 0.4$) :

$$\frac{d\sigma}{dt} = 4 \cdot A\ e^{Bt}\ [F(\tfrac{1}{4}\ t)]^2 + (\text{d. scatt. corrections}) \tag{3}$$

The form factor F(t) can be[12] approximated here by:

$$F(t) \approx \frac{1}{1+60|t|} \cdot \frac{1}{1+5|t|} . \tag{4}$$

The double scattering region ($|t| \gtrsim 0.5$), where the interaction occurs on one of the nucleons and the diffractively dissociated projectile (N^*'s (?)) subsequently scatters elastically on the other nucleon of the deuterium, is characterized by a much flatter[12] $d\sigma/dt$. Roughly, the slope here becomes about half the corresponding slope in pp collision, namely about B/2. At NAL energies the N^* would behave like a stable particle and thus estimates of the double scattering effect can be gotten from $\pi^+ d$ scattering[12]. It is worth pointing out that in principle the double scattering term could lead to determination of the N^*-N scattering, as was done by Anderson et al.[12] in $\rho^o N$ photoproduction.

Expected yield

From table III we take 7 mb as an estimate of the total cross-section in the diffractive component in p-p collisions. Assume the above expression (2) to get $A \simeq \sigma \cdot B \simeq 40\ \mathrm{mb \cdot GeV^{-2}}$. Utilizing now (3) we get about 0.3-0.4 mb for the integrated coherent total cross section for $|t| \geq 0.16$ (namely, deuterons with range $\geq$ 6 cm in the bubble chamber). In an experiment with 500 event/mb this would yield about 150-200 events. Comparison with other energies would give the diffractive multiplicity energy dependence. With this number of events some information on the double scattering region might be gotten ($\sim$ 50 events).

Missing Mass distribution:

The typical errors at 205 GeV/c lead to a resolution of $\delta_{mm^2} = \pm 1.5\ \mathrm{GeV}^2$ for masses around 1 GeV[2], based on measurements of the recoil particle only. This should enable us to study further the coherent events and to examine if in general they are associated with low missing masses.

(b) Elastic Coherent $pd \to pd$.

The work of Charlton[2] *et al.*, has shown that separating elastic events from inelastic is possible and reliable in the $|t|$ range $|t| \gtrsim 0.05\ \mathrm{GeV}^2$, for $P = 200$ GeV/c. This t corresponds to proton recoil momentum of about 220 MeV/c, or range of 5 cm. The coplanarity and angle vs. P(recoil) tests should be reliable in deuterium also and thus we shall be able to measure elastic coherent $pd \to pd$ for events with $R_d \geq 4 - 5$ cm, or $|t| \geq 0.12\ \mathrm{GeV}^2$. Utilizing expressions (2)-(4) above, for $\sigma_{pp}{}^T(el) \simeq 7$ mb and $B = 10.1\ \mathrm{GeV}^{-2}$, one has $A \simeq 70\ \mathrm{mb\ GeV^{-2}}$ and we get $\sigma_{pd}{}^T(el) \simeq 8$ mb, of which we shall reliably measure about 0.5 mb ($|t| \geq 0.12\ \mathrm{GeV}^2$), corresponding to 250 events. Estimates of $\sigma_T(pd)$ and, by subtraction, also $\sigma_T(pn)$ will thus be possible. This work would extend therefore the small angle pd scattering measurements at NAL[11] to higher $|t|$ - regions.

7.0 The Weizmann Institute Bubble Chamber Group

Our group has been active in bubble chamber work for about 12 years and we have been engaged in many experiments. We are particularly active in deuterium work and have conducted several K^-d, γd, and pd experiments in the energy range of 3-12 GeV/c. Thus our entire personnel is used to working with deuterium and well prepared to handle deuterium problems.

The group at present is composed of 10 physicists, 7 programmers, 6 engineers and technicians and about 20 scanners. Most of our people are experienced and participated already in many experiments.

Our measuring equipment is composed of a Spiral Reader system and 3 film plane manual digitizers. Our measuring capacity is over 300,000 events per year. Thus the relatively small number of measurements involved in the NAL experiment should be completed in a short time, of the order of a few months.

The Institute owns an IBM 370/165 computer and 30-40% of its time is used by the High Energy group. Also, we have worked already with the MURA 30" HBC in the past and thus all the desired programs are readily available.

8.0 Time table and collaboration

The proposed experiment can be done by our group alone in 6-12 months. If it will turn out to be successful and yield important information as outlined in the proposal, we think that it should be repeated at a higher energy and eventually supplemented by measurements of the fast particles in one of the hybrid systems currently under consideration at NAL in conjunction with the 30" HBC. We shall be interested to collaborate with other interested groups in the continuation of such experiments at NAL.

Table IV. Cross-sections and yields estimates

	σ(mb)	No. of events in Fiducial Volume
Total pd cross section	80	40,000
Elastic scattering, $pd \rightarrow pd$ (all)	8	4,000
Inelastic, coherent d (all)	6	3,000
d Break-up events:		
p-p interactions(all)	33	16,500
p-n interactions(all)	33	16,500
$pn \rightarrow p_s$(visible) + odd	10	5,000
$pn \rightarrow$ (p_s - visible, backwards in Lab) + odd	5	2,500
d Coherent events:		
Elastic with $\lvert t \rvert \geq 0.12$ ($R_d > 4.5$ cm)	0.5	250
inelastic, $\lvert t \rvert > 0.16$ ($R_d > 6$ cm)	0.4	200

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Proposal for a pd 200 GeV/c BC

Experiment at NAL

(Weizmann Institute High Energy Group)

Estimates of the expected differences in the inclusive p and n spectra.

In general, the single particle inclusive spectra on protons and neutrons are expected to be different. Typical order of magnitude of the p-n differences can be gotten from total cross-sections differences, $\sigma_T(pp) - \sigma_T(pn)$, π^+p and π^-p, etc. Using recent Serpukhov results[14] and compilations[15] one can extrapolate the effects to 200 GeV/c to find that the expected differences are about 1-2 mb, namely of the order 2-5%. These could barely be detected in the main channels of the present experiment, namely p, π^+, π^- (see table II), because of limited statistics. One can be less certain about the expected inclusive difference $(p \to K^-)$ vs. $(n \to K^-)$, in the target nucleon fragmentation regions. These could be larger and therefore easier and interesting to test in the present experiment. A difference of about 10% in this inclusive spectra could already be detected. Thus some tests of the duality predictions will be possible in our experiment and this would help the planning of more detailed and accurate future experiments, along similar lines.

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NAL PROPOSAL NO. 185

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PROPOSAL TO STUDY pn INTERACTIONS AT 205 GeV/c BY MEANS OF THE 30" DEUTERIUM FILLED BUBBLE CHAMBER

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NAL proposal

PROPOSAL TO STUDY pn INTERACTIONS AT 205 GeV/c BY MEANS OF THE 30" DEUTERIUM FILLED BUBBLE CHAMBER

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Abstract -

We propose to carry out a pd experiment at 205 GeV/c using the 30" deuterium filled bubble chamber. We show that a representative sample of events allowing the study of pn interactions can be obtained. A comparison between pp and pn interactions at 205 GeV/c will then be made and may be helpfull to study the various dissociation models. We plane to measure the various topological cross sections and to study the single particle distribution for the π^- and the p emitted backward in the c.m. system. Results on inclusive $pn \to \pi^- X$, $m\pi^- X$, $\pi^- pX$, $m\pi^- pX$ reactions ($m \geq 2$) and on two particle correlation will also be obtained. Elastic $pd \to pd$ scattering will be studied and in certain cases we may be able to extract some information on other coherent pd channels.

* Scientific Spokesman

1.- INTRODUCTION

Recently data have been reported on pp interactions at 205 and 303 GeV/c incident momenta[1,2]. We are interested in complementing these investigation by studying the pn interactions. Although some pd experiments have already been submitted to N A L it seems that the groups involved have decided to focus first their interest on pp interactions[3]. We propose to carry out a pd experiment at 205 GeV/c allowing us to study the pn interactions and to compare the results with those obtained from the pp data at 205 GeV/c.

We would like to obtain 50,000 photographs (we prefer the 35 mm format) using the 30" deuterium filled bubble chamber. By requiring that the proton spectator has to be visible in the chamber, the statistics of the proposed experiment will be of the same size as the data given in reference (2). We will thus be able to measure partial cross sections with an acceptable statistical accuracy[2]. In fact, as shown below, the situation is slightly better because we can also use the events having an odd number of prongs(i.e. those where the track lengths of the proton spectator are too short to be detected) for studying the pn interactions.

The way of selecting the events and the main physics interests of the proposed experiment will be discussed in the next sections.

2.- SELECTION OF pn EVENTS

In order to study the pn interactions we have to identify an outgoing track of low momentum as being a proton spectator. Since the kinematical fit to the production, as made in the usual bubble chamber analysis, cannot be carried out at this high energy, the identification of a proton spectator may present some difficulty. We distinguish essentially two cases :

(1) The positive track has a length too small to be detected in the chamber (events with odd number of prongs)

(2) The track has a length which can be measured, giving then a measurement of the momentum through a range-energy relation if a mass assignement can be made (events with even number of prongs)

In what follows we do not consider the one or two prong events which are difficult to handle although information about elastic pd → pd scattering can be obtained from the two prong events as will be discussed in Section 3 f.

(1) The sample obtained in the first case contains mainly events with unseen proton spectator and a small contribution from coherent pd events. An estimate of the percentage of coherent events can be made by a Monte Carlo calculation using the steep t dependence of the coherent production mechanism, t being the four momentum transfer between the incident and outgoing deuteron. Indeed the sample of coherent events having nonvisible outgoing deuteron tracks in the chamber corresponds to events for which $|t| < 0.025(\mathrm{GeV/c})^2$. This t cut is reflected in the $t' = |t - t_{min}|$ distribution where $|t_{min}|$ is the smallest possible t value obtained with the effective mass value of the system recoiling against the deuteron. Low energy data[4] indicate that the t' distribution is of an exponential form even for low t', which is the region affected by the t cut. Therefore the knowledge of the slope (b) of the t' distribution, and of the partial coherent pd cross sections will allow us to estimate the number of coherent events with non visible outgoing deuteron and hence those which will be classified in the odd prong events. In fact a Monte Carlo calculation shows that to a good approximation this number is practically independent of the inelastic coherent pd channel.

There exist of course no value for the pd → pdmπ cross section at 205 GeV/c. However based on low energy data we consider that 20 % of the total pp cross section is an upper limit for the total inelastic cross section for coherent processes. Using then the measured value of σ_{pp} at 205 GeV/c and assuming $b \sim 18(\mathrm{GeV/c})^2$, we obtain that less than 3 % of the odd prong events will be due to inelastic coherent channels.

(2) Among the even prong events we can increase the ratio of pn to pd coherent events by only taking events for which the cosine of the laboratory emission angle of the stopping track is less than 0.7. Using the same estimate as above a Monte Carlo calculation shows that we then obtain a sample containing about 85 % pn events.

Although the estimations made above are rather crude they seems to indicate that we will be able to collect a representative sample of pn events.

3.- PHYSICS OBTAINED FROM THE STUDY OF pn INTERACTIONS

a). Topological cross sections

The proposed experiment will allow us to measure σ_n, the topological cross section for n charged particles in the final state. These results in addition to those obtained from the pp experiment at 205 GeV/c will give a better estimate of the variation of σ_n as a function of n. In particular, one could see wether or not $\sigma_n \sim 1/n^2$ for large n, as predicted by the various fragmentation models[5]. Also the measurement of the second moment $f_2 = \langle n(n-1)\rangle - \langle n\rangle^2$ for an odd number of charged particles will be of interest because of its sensitivity to the production mechanism[6].

b). Single particle distributions

By using the Mura bubble chamber and our measuring devices we expect to be able to measure tracks having momenta up to 15 GeV/c[7]. Due to the limited transverse momenta of the secondaries ($p_T^2 \lesssim 0.2(\mathrm{GeV/c})^2$) we see from Fig. 1 that even with this 15 GeV/c cut we will obtain an unbiased sample of π emitted in the backward c.m. hemisphere ($q_\ell^* < 0$). As the negatively produced particles are mainly pions, we will be able to study the single π^- distributions for π^- emitted in the backward hemisphere. From Fig. 1 one also sees that we can measure $d^2\sigma/(dq_\ell^* dp_T^2)$ around $q_\ell^* \sim 0$ which is a rather useful quantity. Indeed, if scaling is valid this $[d^2\sigma/(dq_\ell^* dp_T^2)]_{q_\ell^*=0}$ should be independent of $\sqrt{S}$, the c.m. energy. In addition a study of the shape of the $d^2\sigma(dq_\ell^* dp_T^2)$ can be made as function of the multiplicity.

In Fig. 1 we also indicate which part of the $x = 2q_\ell^*/\sqrt{S}$, P_T scatter plot is accessible to protons having momenta smaller than 15 GeV/c. In fact the situation is better than shown by this graph because of the expected peripherality of the pn reaction at 200 GeV/c. Then the outgoing baryon associated with the target neutron vertex has a small laboratory momentum and can then be identified if it is a proton. This can be seen more precisely by using a Monte Carlo method to generate $pd \to p_s p N m\pi$ ($m > 2$) events according to a $e^{bt_1} \times e^{bt_2}$ momentum transfer dependence. Here t_1 (t_2) is the four momentum transfer between the initial p (n) and the outgoing p (N). We took the value of $b = 5(\mathrm{GeV/c})^{-2}$ which is assumed to give a realistic description of the peripherality. (At 7 GeV/c[8] one obtains a slope of $6.1 \pm 1.0(\mathrm{GeV/c})^{-2}$ from the $pn \to pp\pi^-$ reaction).

The laboratory momentum distributions obtained from this Monte Carlo generation for different values of m show that if N is a proton it essentially always has a laboratory momentum less than 1.2 GeV/c and may thus be measured and identified. We will then be able to study the single particle distribution associated to the proton emitted in the backward c.m. frame.

c). Diffraction dissociation

Several attempts have been made to describe high energy production by means of single and double diffraction dissociation of the incoming particles[6,9]. The ratio of the cross section of double to single diffraction dissociation (D/S) is a parameter of the model which may be determined from the experimental data[6]. In particular the n/p production rate, which depends directly on this D/S ratio, can be measured here for the diffraction dissociation of the incoming n. As stated above the emitted baryon has then a small momentum and a proton can only be recognized among the low momentum tracks. The number of neutron events are simply those in which a low momentum proton was not identified.

The results of the proposed experiment and those obtained from the pp data will permit a direct comparison of the n and p diffraction dissociation.

d). Inclusive reactions

As discussed in b). we will be able to measure the π^- and the proton emitted backward in the c.m. system. In this region of phase space we study the following inclusive processes :

$$pn \to \pi^- X$$

$$pn \to k\pi^- X \qquad (k = 2 ; 3 , \ldots)$$

$$pn \to \pi^- pX$$

$$pn \to k\pi^- pX$$

where X means anything while k represent the number of recorded π^-.

e). Correlations

The study of the two particle correlation in the rapidity space can be carried out if one uses the $y' = \ln tg(\theta_{lab}/2)$ variable which for fast particle reduce to the usual rapidity variable $y = 0.5 \ln[(E + q_\ell)/(E - q_\ell)]$. ($E$ and q_ℓ are respectively the energy and the longitudinal momentum of the particle which is considered while θ_{lab} is its emission angle). As the negatively charged particles are assumed to be mainly pions we will be able to collect some $2\pi^-$ correlation information by measuring only the θ_{lab} values. However for π^- emitted in the backward c.m. hemisphere, for which the momentum can be determined, additional information can be obtained by using other kinematical variables. In the same manner it will also be possible to study the $p\pi^-$ correlation for the p being emitted in the backward c.m. hemisphere.

f). Coherent events

Based on the momentum measurement of the recoil particle it was possible as shown in reference (1) to collect a sample of elastic $pp \rightarrow pp$ events. By a similar method we will study the elastic $pd \rightarrow pd$ scattering for which there is no information at all in the 205 GeV/c region.

A crude estimate of the coherent cross section can be obtained by comparing the number of events having their stopping track greater and smaller than $\cos\theta = 0.7$ (See 1.2).

4.- SCHEDULE OF THE ANALYSIS

If the proposed experiment would be carried out all the effort of both groups would be devoted to this experiment. The collaboration will be able to utilize 6 scanning tables and 5 conventional measuring machines. This is sufficiant to analyse the films in a very short time. Thus we plane to obtain the topological cross section about six weeks after we get the film. On the other hand the events needed for studying the physics described above will be measured within two months.

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P_T VERSUS $x = 2q_L^*/\sqrt{s}$ FOR FIXED LABORATORY MOMENTUM

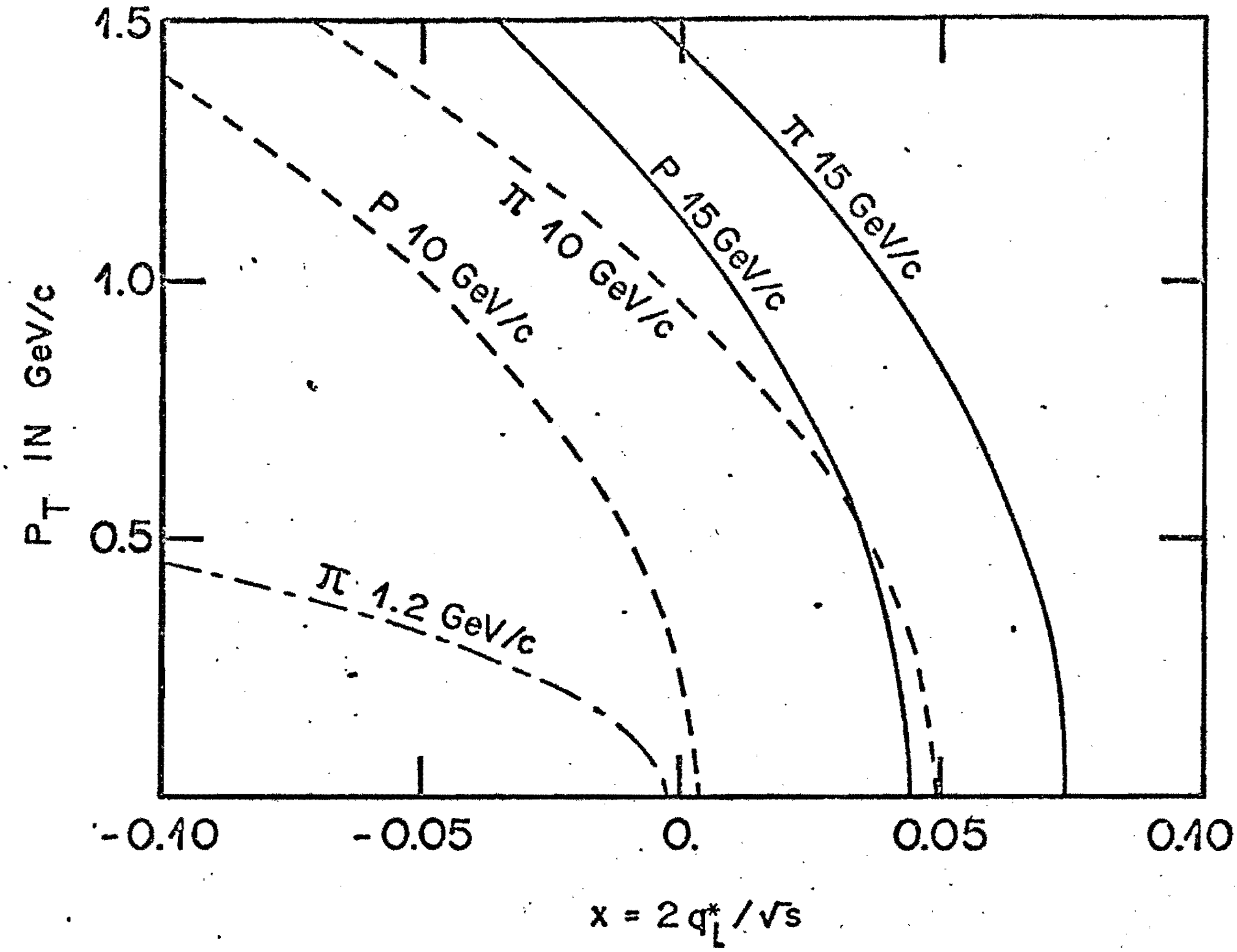

Figure 1