FNAL Experimental
Proposal 375
Spokesman: Howard A. Rubin

STUDIES OF K^+-MESON COLLISIONS WITH PROTONS AT AN INCIDENT MOMENTUM CLOSE TO 150 GeV/c

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SUMMARY

We propose exposures of approximately 0.5 ev/μb equivalent for K^+ mesons as close as possible to 150 GeV/c in the FNAL 30-inch Bubble Chamber Proportional Wire Hybrid System. We request these exposures as soon as suitably enriched beams of K^+ mesons are available to that facility. For beams with K^+/contaminant ratio R, the exposure will require $\frac{1}{R}$ x 100,000 pictures and will yield approximately 10,000 K^+p interactions for study.

The purpose of these experiments is to carry out a detailed study, with modest statistical accuracy, of kaon-proton collisions at energies significantly above those at which such data currently exists, and to further extend the range of incident channel quantum numbers over which multiparticle production has been explored at FNAL energies. The choice of energy is such as to allow us to make a reasonable cross particle comparison with existing data at 147 GeV/c.

An integral part of this proposal is the development of the K^+ meson beam. We are prepared to explore the techniques described in W. W. Neale's FN-259 2200 Report, either alone or in collaboration with other interested parties. We are also prepared to study alternate K^+ beam producing techniques. We expect this proposal to proceed in two phases. The first phase being a feasibility study of the K^+ beam and the second phase, contingent on the success of the first phase, being the proposed physics exposure.

I. Introduction

This experiment is seen as proceeding in two phases, the first is the development of a K^+ beam and the second is the physics experiment.

The starting point for Phase I will be W. W. Neale's work. This is conveniently summarized in his FNAL Report FN-259/2200, "Enriched Particle Beams for the Bubble Chambers at the Fermi National Accelerator Laboratory", 24 June 1974. In addition to the techniques described in that report we will investigate other possible methods for producing a K^+ beam. We will be pleased to collaborate with other outside groups or individuals who are interested in studying a K^+ beam.

The physics motivation is the study of K^+p interactions in a new energy regime. We would like to perform the study at an energy close to 150 GeV/c so as to make comparisons with π^+, π^-p and $\bar{p}$ interactions. However, this desire will be modified by the K^+ beam we will actually be able to produce. Namely, we will run the experiment at the closest energy to 150 GeV/c that we can produce a beam.

Cross sections for both leading-kaon and leading-proton events will be measured and compared with lower energy kaon data as well as with existing πp and pp collision data at 150 GeV/c. The K^+p total cross section rises by about 10 percent between 10 GeV/c and 100 GeV/c incident momenta. This experiment should determine whether this variation is reflected in, or can be accounted for, by variations in the cross sections for diffractive excitation.

The total cross section for K^+p reaction increases by more than 10% from 30 to 300 GeV/c incoming lab. momentum. In some respects, K^+p reactions at the FNAL and SPS energies can therefore be expected to resemble pp reactions at ISR energies. To investigate whether and to what extent such a similarity does exist, is the first main aim of our experiment.

Insofar as such a similarity to pp reactions will indeed be observed, an advantage of the K^+-beam is that it avoids the symmetry of the pp-reactions.

Over π^+p reactions, K^+p reactions have the advantage that the identity of the beam particle can be traced in the final state.

We intend to perform the comparison to higher energy pp reactions and the exploitation of the asymmetry of the K^+p reactions in several steps. Among the most important of these are:

1. Topological cross sections
2. Elastic cross sections
3. Leading particle peaks at low t
4. Resonance production
5. Central emission
6. Double diffraction dissociation

Phase I: Beam Study

We propose to establish a K^+ bubble chamber beam to the Fermilab 30" Hybrid Bubble Chamber System. This beam should have a $\frac{\Delta p}{p} \leq 1\%$ and a $K^+/(\pi^++p)$ ratio greater than 20%.

We will attempt to make a beam with momentum close to 150 GeV/c. However, the experiment will be run at the highest practical energy. As stated in the introduction, we would start with the concepts developed by W. W. Neale and would welcome other individuals or groups in this phase of the experiment.

Phase II: Physics Proposal

1. Topological Cross sections

Topological Cross sections are predicted for 75, 150 and 300 GeV/c incoming lab. momentum in fig. 1. These cross sections values have been calculated from the K^+p data at 32 GeV/c [1] under the assumption of

1. a logarithmic increase of the total K^+p cross section [2] and average charge multiplicity and

2. a KNO scaling law for K^+p reactions.

These predictions are rough and can be used only for a provisional planning of the layout of the experiment. How the energy dependence of particularly the low multiplicity reactions (diff. diss.) actually contributes to the total cross section will have to be answered from the first step. The multiplicity distribution and its statistical moments can be obtained essentially from the scanning of photographs from the bare bubble chamber.

2. Elastic Cross Section at low t.

Of immediate interest in connection with the increasing total cross section σ_T is the elastic cross section. One usually distinguishes between three regions.

a) very small t ($|t| < 0.05$ GeV^2) for the estimation of the real to imaginary part ratio ρ, The value of ρ can be of interest for the prediction of the further increase of σ,

b) small t ($0.05 < |t| < 0.30$ GeV^2) for the estimation of the slope or the slopes of the forward peak and their shrinkage,

c) large t ($|t| > 0.3$ GeV^2) for the search for diffraction minima.

While this is a priori a typical counter experiment, high quality data have been obtained in particular for point (a) as a "by-product" of bubble chamber K^-p experiments at 4.2, 10, and 14.3 GeV/c [3]. The high measurement precision of low $|t|$ elastic events in bubble chambers comes from the exact measurement of the proton momentum from its range in hydrogen. It does therefore not depend on the incident energy.

3. Leading Particle Peaks at low t

a) leading K^+ may be used to separate proton dissociation,

b) leading backward proton may be used to separate K^+ dissociation.

One dimensional Feynman x- or missing mass distributions contain large overlap of diffraction dissociation and other mechanisms. This overlap makes the estimation of the diffractive cross section as well as a further study of diffraction dissociation a difficult. task. We therefore plan an attempt of separation of diffraction dissociation in two-and more dimensional inclusive distribution. Besides conventional separation methods we intend to make extensive use of newly developing "cluster" searching techniques [4]. We therefore need to know the momenta of leading and as far as possible, also the nonleading particles. After and only after clean separation of diffraction dissociation factorization properties can be meaningfully tested [5]:

$$\frac{\sigma_{K^+p}(\text{elastic})}{\sigma_{pp}(\text{elastic})} = \frac{\sigma_{K^+p}(\text{leading } K^+)}{\sigma_{pp}(\text{leading } p)}$$

$$\frac{\sigma_{K^+p}(\text{elastic})}{\sigma_{\pi^\pm p}(\text{elastic})} = \frac{\sigma_{K^+p}(\text{leading } K^+)}{\sigma_{\pi^\pm p}(\text{leading } \pi^\pm)}$$

4. Resonance Production

4a) Leading resonance production

A predominant feature of kaon-induced final states is the presence of the narrow K^* (890) resonance which, unlike the rho, is relatively easy to isolate even in the face of large combinatorial backgrounds. This feature shou ld allow a more detailed study of two-body resonance formation in multibody final states than is possible in pp and πp collisions.

The mechanism of resonance production at high energies is of great importance. In particular, K^*_{890} production is allowed to proceed by Pomeron exchange from the quark model [6], but forbidden by the Gribov-Morrison rule [7]. Should K^*_{890} production be allowed by Pomeron exchange, we could expect a leading K^*_{890} peak, similar to the K^+ peak (as well as a clear signal in the exclusive 4C channel $K^+p \to K^0\pi^+p$). The partial wave analysis of 3 π system [8] grants a rather flat energy dependence for the $J^P = 2^+$ component. If a similar behavior exists in the $K\pi\pi$ system, one can expect a nonzero amount of K^*_{1420} production at high energies, as well.

While "diffractive" K^* production is an open question, diffractive N^* production is present. The question there is the exact mechanism [9]. We believe that as much information as possible has to be collected. K^+p reactions can contribute to the study of factorization properties.

This exposure should yield some 300 events of the 4-constraint reaction $K^+p \to K^+ p \pi^+ \pi^-$, which is dominated at lower energies by the diffractively produced Q enhancement. We should measure the cross sections for both the Q and the L and have sufficiently good statistical precision and mass resolution to determine whether the shape (width) of the Q is significantly different at 150 GeV/c than at 15 GeV/c. Such a change is to be expected if the enhancement seen at lower energies is an interfering mixture of $J^{PC} = 1^{++}$ and 1^{+-} states. At this energy, diffractive excitation of the form $K^+ \to \bar{\Lambda} p$, for which some evidence has been seen in 10 and 13 GeV/c data, may be available for study.

b) Cascade production

The main part of resonance production will probably proceed via cascade decay of peripherally or centrally produced clusters. If we can trace the K^+ (or K^0) in the final state we have the advantage over incoming pions of less identical particles.

5. Central Emission

The possible mechanisms usually summarized as central emission give rise to the largest contribution to the total cross section. They involve high multiplicity reactions which are difficult to study. Therefore relatively little is known here.

The simplest problem is that of "central emission" of a neutral pion pair in a four-body final state via double Pomeron exchange. It is not yet clear whether this mechanism exists. One can expect to get useful information from the (asymmetric) K^+p four or six body final states (4C fit):

$$K^+p \rightarrow K^+ (\pi^+ \pi^-) p$$
$$K^+ (\pi^+ \pi^+ \pi^- \pi^-) p$$

Tests of predictions based on Mueller's generalized optical theorem and the Regge pole model may be carried out for pion production in the fragmentation and central regions by comparing exotic (K^+p) and nonexotic (K^-p) incident channels. It will be important to confirm at this high energy the "early scaling" results which have been reported at lower energies for K^+ induced reactions.

6. Double Diffraction Dissociation

It is expected to contribute to the total cross section with a sizable amount (0.5 - 1.0 mb estimated from factorization). Nevertheless, little is known about it so far.

Monte Carlo calculations [10] for the SFM show that diffraction dissociation almost completely overlaps with central emission even on two-dimensional inclusive X-plots.

We expect that diffraction dissociation can be studied better in medium multiplicity exclusive 4C fits like

$$K^+p \rightarrow (K^+ \pi^+ \pi) \quad (\pi^+ \pi^- p) \; .$$

for which we expect a 20 - 40 μb cross section. At high energies one can expect to separate it from single diffraction dissociation and central emission with multidimensional cluster searching techniques as mentioned in sect. 3 (and useful also for 4).

From factorization we should get as diffractive and double diffractive component in the inelastic topological cross sections [5]

$$\sigma^n = \sigma_{1K^+} + \sigma_{1p} + \frac{1}{\sigma_{el}} \sum_{j=o}^{\frac{n-2}{2}} \sigma_{1K^+}^{n-2j} \sigma_{1p}^{2j+2}$$

with σ_{el} being the elastic K^+p cross sections, σ_{1K^+} the leading K^+ and σ_{1p} the leading proton cross sections.

7. Cross Particle Comparisons

We expect to compare the details from this experiment with data from π^+, π^-, p, $\bar{p}$, and K^- exposures that have already been approved or may soon be approved. A comparison of such a large number of incident projectiles should yield some knowledge about any fundamental differences among hadrons.

REFERENCES

[1] G.A. Akopdjanov et al., Nucl. Phys. B75 (1974) 401.

[2] BNL - Fermilab-Rockefeller Collaboration, XVII Int. Conf. on High Energy Physics, London 1974.

[3] U. Amaldi, IInd. Int. Conf. on Elementary Particles, Aix-en-Provence 1973, page C1-252.

[4] G. Friedman "Data Analysis Techniques for High Energy Particle Physics" Proc. 1974 CERN School of Computing, CERN 74-23, W. Kittel "Treating Multiparticle Processes". Proc. Symposium on Antinucleon-Nucleon Interactions" Liblice-Prague 1974, CERN 74-18.

[5] D.G. Fong et al., Phys. Letters 53B (1974) 290.

[6] P.G.O. Freund, H.F. Jones and R.J. Rivers, "Dynamics versus selection rules in diffraction dissociation", Imperial College preprint ICTP/70/35.

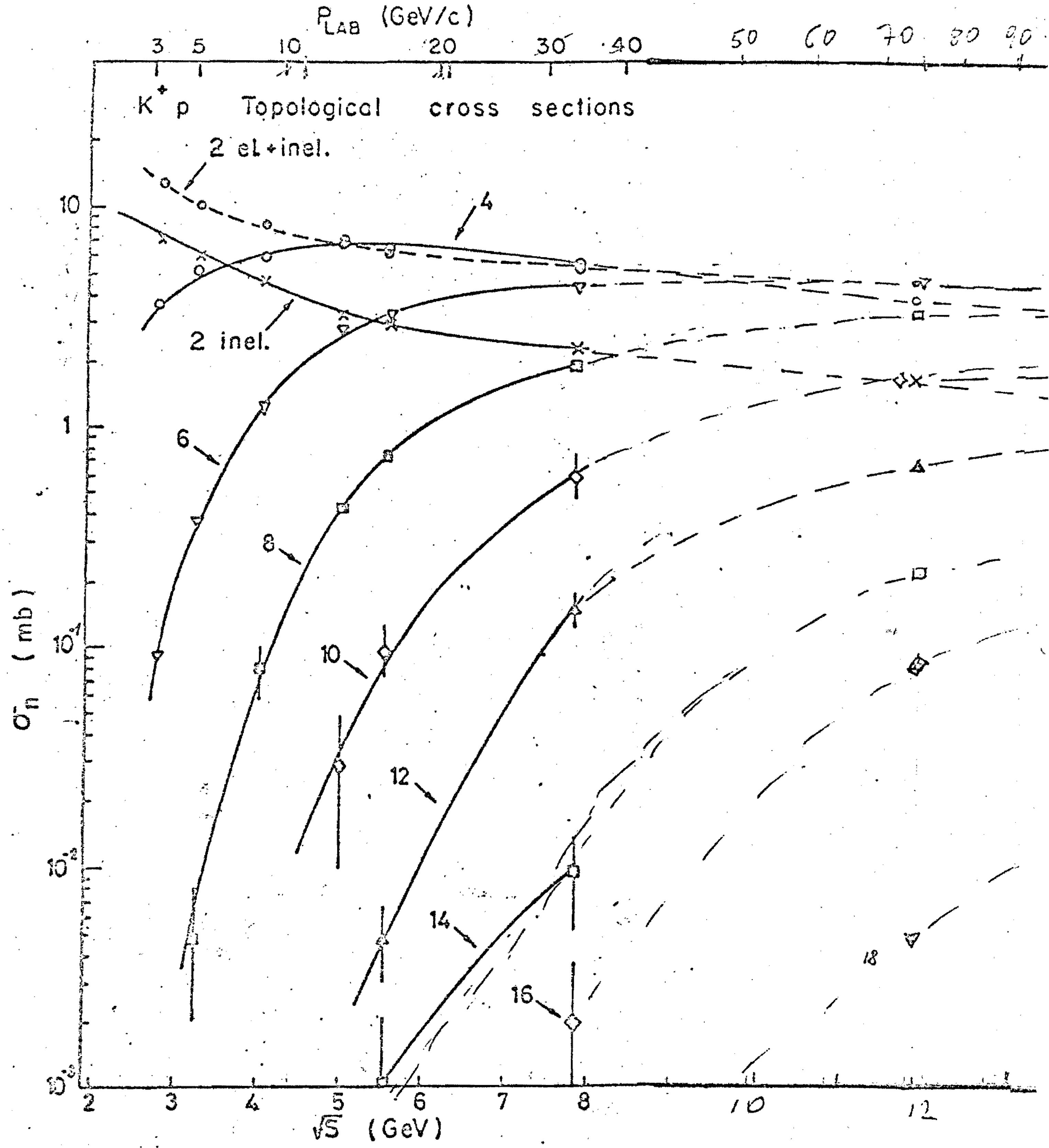
[7] V.N. Gribov, Yadernaya Fiz./U.S.S.R./5 (1967) 197, D.R.O. Morrison, Phys. Rev. 1965 (1968) 1699.

[8] G. Ascoli, "Results on $\pi^{\pm}p \rightarrow \pi^{\pm}\pi^{+}\pi^{-}p$", XVII Int. Conf. on High Energy Physics, London 1974.

[9] G. Berlad et al. Phys. Letters 51B (1974) 187,

E. Nagy et al., "Experimental Results on Inelastic Diffraction Scattering in Proton-Proton Collisions at the ISR".

[10] W. Kittel, W. Schwille and H. Wahl. Internal SFM Group Report, Jan. 1974.



P_{LAB} (GeV/c)
3 5 10 20 30 40 50 60 70 80 90
K^+p Topological cross sections
2 el.+inel.
4
2 inel.
6
8
10
12
14
16
18
σ_n (mb)
10
1
10^{-1}
10^{-2}
10^{-3}
2 3 4 5 6 7 8 10 12
$\sqrt{s}$ (GeV)

FIG 1

OVER →

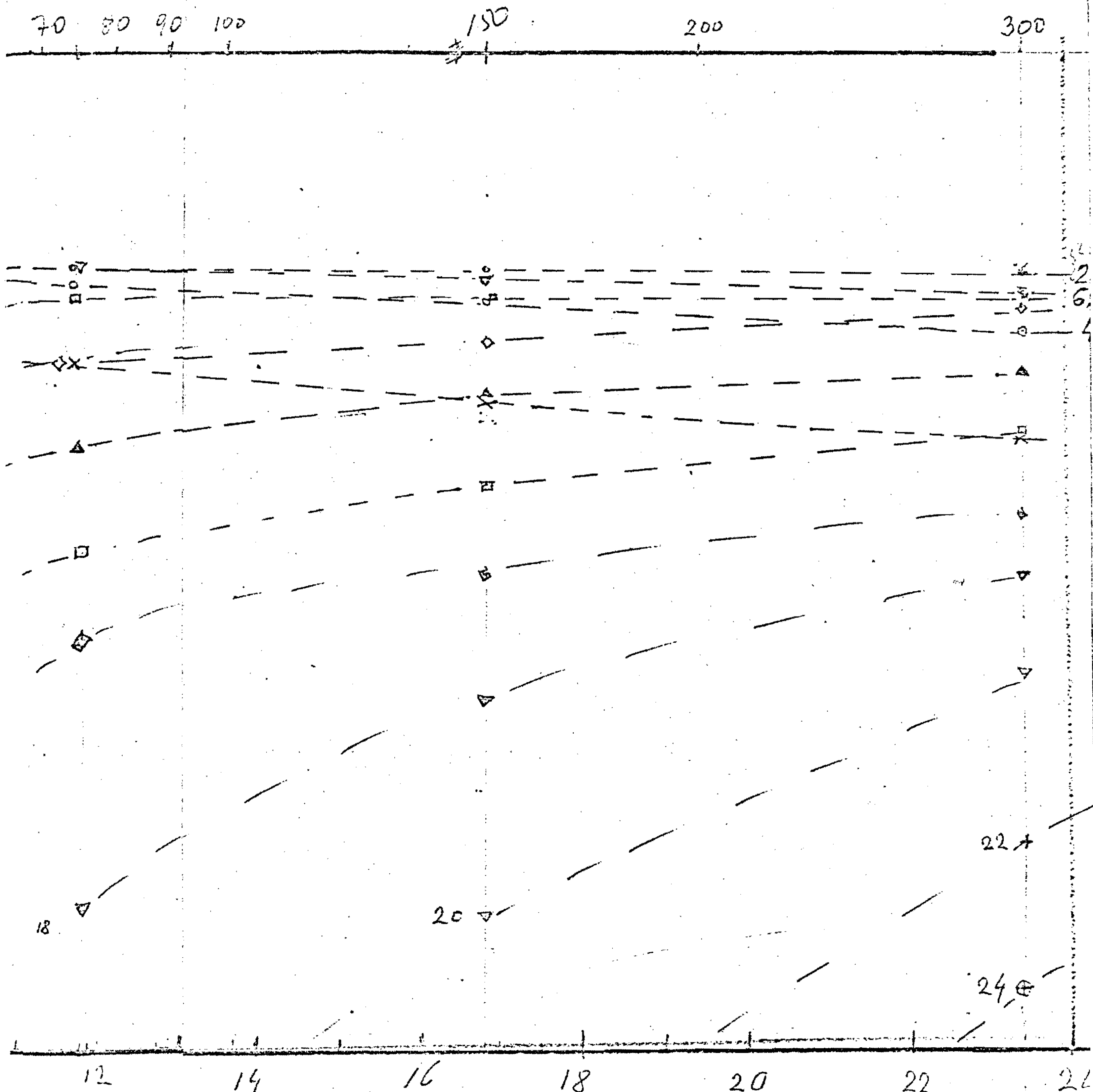


FIG 1 CONT.

ILLINOIS INSTITUTE OF TECHNOLOGY

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DEPARTMENT OF PHYSICS

May 19, 1975

Dr. Tom Groves, Secretary
Program Advisory Committee
Fermilab
P.O. Box 500
Batavia, Illinois 60510

Dear Tom:

I would like to submit the enclosed materials as revisions and addenda to FNAL Proposal 375, Studies of K^+-Meson Collisions with Protons at an Incident Momentum Close to 150 GeV/c.

The revised cover sheet acknowledges the addition of a group from Cambridge University to the proposal. Members of this group have had extensive experience in the development and testing of enriched beams at FNAL.

Also enclosed is a copy of a letter recently sent to FNAL requesting a test run to begin preliminary studies of an enriched K^+ beam. The details outlined in the letter can serve as an addendum to our very brief description of our proposed "Phase I: Beam Study" on page 2 of the original proposal.

Sincerely,

Howard A. Rubin
Scientific Spokesman, E375

HAR/elh
Enclosures

PROPOSAL # 375
MASTER
DO FILE
ELG
JRS

FNAL Experimental
Proposal 375
Spokesman: Howard A. Rubin

STUDIES OF K^+-MESON COLLISIONS WITH PROTONS AT AN INCIDENT MOMENTUM CLOSE TO 150 GeV/c

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Yale/Fermilab: D. Bogert, M. Johnson, H. Kraybill, D. Ljung, T. Ludlam, H. Taft.

Revised

19 May 1975

Yale University *New Haven, Connecticut 06520*

PHYSICS DEPARTMENT
217 Prospect Street

May 9, 1975

Dr. R. Lundy
Fermilab
P.O. Box 500
Batavia, Illinois 60510

Dear Dick:

This letter is to request 3 shifts of beam time in the N3 beam during the month of June. As we discussed with you on May 7, the purpose of this run would be to perform a systematic study of yields of positive particles at the 30-in. bubble chamber at 150 GeV/c with various targetting modes and with varying amounts of polyethylene absorber in the beam at enclosure 103. Specifically, we wish to study the feasibility of an enriched K^+ beam as required for proposal no. 375.

The data to be obtained would be a series of Cerenkov readings for particles at the bubble chamber for absorber lengths from 0 to 8 feet in increments of 2 feet, and for production angles from 0 to 10 milliradians. We will measure absolute as well as relative particle yields for a fixed number of protons on target. A tungsten target will be used. If time permits, some points might be obtained for other target materials and varying target lengths.

For this short test we propose placing the absorber in Enclosure 103, rather than Enclosure 100, since it may then be accessed several times during a short running time, and alignment of the absorber material is not critical in this location. If possible, a comparison run with absorber in enclosure 100 would also be useful, since this would be the optimal location for minimizing muon background in an actual experimental run.

With $\sim 10^{10}$ protons on target, the time required to record each data point is very short -- of the order of a minute or less. The production angle is varied by remote control and requires only a few minutes between angles. More time is required to change absorber lengths, which will be done manually in enclosure 103. Taking into account the time required for beam tuning and calibrating the Cerenkov counter, we feel that 3 shifts of beam time will be adequate to carry out the tests described here.

It is understood that this test would be part of a coordinated study of enriched beams being undertaken by Fermilab and other users. This particular data will be important for assessing the enrichment possibilities for positive beams, and for planning more extensive tests which might take place after the summer running period. The systematic study we propose here would complement data from our experiment no. 299 in which a filter consisting of 100 inches of water and 18 inches of polyethylene was employed at 0 and 1.5 milliradian production angle.

In making this request, we represent the experimenters listed on FNAL proposals no. 375 (K^+ at 150 GeV/c) and no. 376 (K^- at 150 GeV/c). The necessary manpower for conducting the test will be provided by these groups. In preparing this test and analyzing the results we will, of course, work closely with the interested Fermilab personnel.

With best regards,

Thomas W. Ludlam
Yale University

Howard A. Rubin
Illinois Institute of Technology

cc/ J. Peoples
J. Sanford
L. Voyvodic