Proposal E#272 (Revised)

Proposal to Measure Coherent Dissociation of π^-, K^- and $\bar{p}$ into Two-Body Systems at Fermilab Energies

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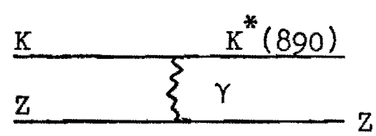
Abstract

We propose to examine at Fermilab energies the coherent excitation of particles impinging on nuclei. Our experiment will probe the interactions of $\bar{p}$, K^- and π^- with the nuclear Coulomb field (Primakoff production) as well as the diffractive dissociation of these elementary particles into two-body systems via Pomeranchukon exchange. The specific objectives of the experiment, which can only be attained at Fermilab energies, are the following: (1) Definitive measurements of the radiative widths of the ρ^-, $K^*(890)^-$, A_2^- and $K^*(1420)^-$. (2) Determination of the Pomeranchukon-exchange contribution to the coherent production of $K^*(1420)^-$ and A_2^- mesons. (3) Survey of the spectroscopy of the as yet unexplored high-mass $\pi^-\gamma$, $\pi^-\pi^0\gamma$, $K^-\gamma$ and $K^-\pi^0\gamma$ systems. To achieve these goals we propose the construction of a new high-resolution forward V-spectrometer, with high data-rate acquisition capacity, and excellent capability for γ detection. We propose to execute our experiment in 900 hours of beam time.

I. Physics Justification

The review of Berlad et al[1] has emphasized the increasing importance of electromagnetic effects in hadron-induced reactions at high energies. Nagashima and Rosen[2], Stodolsky[3], and Berlad et al have stressed the great variety of exciting physics problems which can be probed as a result of the dominance of the one-photon exchange mechanism at FNAL energies. Of particular interest to us is the measurement, through the Primakoff effect[4], of the radiative decay widths of the vector and tensor mesons.

Some of the most straightforward tests of unitary symmetry schemes are available via predictions relating such parameters[5]. Measurements of the radiative widths of the $K^*(890)$ and of the ρ meson have recently been reported from BNL.[6] As was remarked in the initial Proposal #272, these measurements were not expected to be completely definitive due to background sources present at AGS energies. That is, in order to measure the radiative decay width of, for example, the $K^*(890)$, it is essential to extract the Coulomb part of the $K^*(890)$ coherent production amplitude. The diagram of interest for a K-meson impinging on a nuclear target of charge Z is:



At AGS energies a large ω^o exchange amplitude also contributes to coherent $K^*(890)$ production. The presence of this hadronic-exchange process makes it difficult to separate out the Primakoff term required to obtain the rate for the $K^*(890) \rightarrow K + \gamma$ decay.

In Fig. 1 we present a comparison of the recent results for $K^*(890)^o$ production from BNL[6] with those expected at Fermilab (150 GeV/c). At BNL energies the extracted radiative width of the $K^*(890)^-$ is very sensitive to the ω^o-exchange contribution (T_s amplitude), while at 150 GeV/c a measurement of at least ±15% accuracy is expected, independent of the relative phase of the Coulomb (T_c) and strong production amplitude. (The experimental resolution has been folded into the curves for 150 GeV/c.) Consequently, because the ω^o-exchange cross section falls with increasing beam momentum (P_L) as $\sim 1/P_L$, while the Coulomb term grows substantially with P_L, it is clear that measurements of the radiative widths of $K^*(890)$ and ρ mesons far superior to those completed at the AGS are feasible at Fermilab energies. Also, measurements of the radiative widths of the tensor mesons ($K^*(1420)$ and A_2), which cannot be performed at lower energies because of kinematic damping (t_{min}), are possible at FNAL.[7] We wish to point out that the K*(890) and ρ measurements at AGS energies[6], although not definitive, are nevertheless of great interest in that they indicate that the widths are about a factor of three smaller than expected from SU(3) predictions. Consequently, it is even more important at this time to verify these results and perform the experiments with more precision.

The cross section for the electromagnetic production of a resonance of mass M* and spin S* in the Coulomb field of a target nucleus (A) of charge Z is given by:[4]

$$\frac{d\sigma}{dt} = \frac{2S^* + 1}{2S + 1} \, 8\pi\alpha Z^2 \left(\frac{M^*}{M^{*2} - M^2}\right)^3 \Gamma_\gamma |F(t)|^2 \, \frac{(t - t_{min})}{t^2}$$

Here t is the square of the momentum transfer to the nucleus, F(t) is the nuclear form factor, t_{min} is the kinematic minimum for t, and Γ_γ is the radiative width for the process $M^* \rightarrow M + \gamma$. M and S are the mass and spin of the impinging projectile particle.

Using the measured values for the radiative widths of the vector mesons[6], and similar rates for the tensor mesons, we have estimated (Tables I,II) yields from Coulomb-induced sources for the reactions:

$$K^- + Z \rightarrow \left.\begin{matrix} K^{*-}(890) + Z \\ K^{*-}(1420) + Z \end{matrix}\right\} \rightarrow K^0_s \pi^- Z \text{ or } K^-\pi^0 Z \qquad (1)$$

$$\pi^- + Z \rightarrow \left.\begin{matrix} \rho^-(760) + Z \\ A_2^-(1320) + Z \end{matrix}\right\} \rightarrow K^0_s K^- Z \text{ or } \pi^-\pi^0 Z \qquad (2)$$

Other interesting non-resonant processes are also expected to contribute to both reactions. Of particular interest are the photon-meson two-body scattering processes:

$$K^-\gamma \rightarrow K^-\pi^0 \;,\; \pi^-\gamma \rightarrow K^-K^0_s, \;\text{ or } \pi^-\gamma \rightarrow \pi^-\pi^0$$

In addition to probing the symmetry questions discussed above, we also hope to examine, at the same time, a region of physics which has hitherto been largely unexplored. This is the regime of direct $K\gamma$ and $\pi\gamma$ interactions. At Fermilab energies, the nuclear Coulomb field provides the unique opportunity for studying these processes in some detail. The particular reactions we have in mind are the kind which may involve suppressed couplings to hadrons but possibly large radiative widths. (This is, of course, not the case with the known low-mass objects such as $K^*(890)$, ρ, etc.) Although we have no specific models in mind, the color schemes based on the work of Han and Nambu [Phys. Rev. 139, B1006 (1965)] would suggest that an investigation of reactions such as: $K^-\gamma \rightarrow K^-\gamma$, $\pi^-\gamma \rightarrow \pi^-\pi^0\gamma$, $\pi^-\gamma \rightarrow \pi^-\gamma$, etc., namely, reactions which involve purely radiative channels, would be of great importance. If color schemes are applicable to hadrons then narrow-width ($\Gamma \lesssim 1$ MeV) resonant channels might be observable in such reactions at masses in the 2 GeV - 3 GeV range. If the elastic widths of these states are approximately ~~1%~~ 0.1% of the $\pi\gamma \rightarrow \pi\pi$ transition in the region of the ρ mass, then we would detect ~100 event signals in the $\pi\gamma$ mass produced through coherent coulomb processes. The background to these reactions would be due to processes wherein only a single γ from a π^o or η^o materialized in our γ detector. If we use ~5 radiation lengths of Pb in our Pb/Scintillator veto counters, and a γ detector of the kind we envision (see later), we expect that this source of background will be at a level of $\lesssim$0.02 per π^o (in the trigger). This corresponds to an estimated post off-line analysis background of $\lesssim$300 events per full mass-resolution width in the 2-3 GeV $\pi\gamma$ mass range. The yields in the $K^-\gamma$ channels may not be high enough for these studies.

Aside from Coulomb production of objects such as the $J^P = 2^+$ A_2 and K*(1420), we can also envision the strong production of these mesons via Pomeranchukon ($\mathbb{P}$) exchange.(8) Although folklore has it that the coherent dissociation of mesons can only proceed via the "Morrison rule" (that is, $\Delta P = (-1)^J$), this rule has not been tested under favorable - i.e., low background conditions. We note that the question of coherent A_2 production was a somewhat speculative aspect of the original Proposal #272; it now appears, however, that this process has recently been observed at AGS energies(9) and the degree of Pomeranchukon-exchange dominance in coherent A_2 production has therefore become a particularly interesting question in strong-interactions phenomenology.

The observation of coherent A_2 production on large nuclei has been reported(9) in reactions such as:

$$\pi + Z \rightarrow (\pi\pi\pi) + Z$$

These three-body dissociations, however, contain large backgrounds from the A_1, which make the presence of a small $J^P=2^+$ component in the data difficult to discern in an unambiguous way. In concentrating on coherent A_2 or $K^*(1420)$ production, utilizing the two-body decay channels available to these tensor mesons ($A_2^- \to K^- K_s^o$ or $\pi^- \eta^o$ and $K^* \to K^- \pi^o$ or $\pi^- K_s^o$), has the great advantage of reducing A_1^- and Q^- backgrounds to these interesting processes by one to two orders of magnitude. Consequently, examining the coherently produced two-meson mass spectrum at FNAL energies will provide a stringent test of the Morrison rule (away from $t=t_{min}$) and of our ideas concerning the $\mathbb{P}$ trajectory in the inelastic regime. A reasonable estimate of the total amount of A_2 production through this process is 2-5% of the A_1 yield on hydrogen.[9,10]

Consequently, we expect reactions (1) and (2) to contain information pertaining not only the the Coulomb-induced processes but also to phenomena involving $\mathbb{P}$-exchange. The two separate contributions to reactions (1) and (2) will differ significantly in their t- and Z-dependences, and will provide two-body final states which can be analyzed in a straightforward manner to extract radiative widths and relative magnitudes and phases of the two production amplitudes. (In Fig. 2 we provide data from E#27 on neutron dissociation into $p\pi^-$ systems off C and Pb nuclear targets;[11] the t-spectra clearly illustrate the separate presence of the Coulomb and diffraction dissociation contributions, and their dependence on Z.)

It is worth pointing out that because we will measure radiative widths using both the $K_s^o\pi^-$ and $K^-\pi^o$ decay modes of the K^*'s, we will have excellent checks on the systematics of each final state. A similar check will be available for the A_2^- measurements (i.e., $A_2^- \rightarrow K^-K_s^o$ comparison with $A_2^- \rightarrow \pi^-\eta^o \rightarrow \pi^-\gamma\gamma$).

Two other two-body processes which we wish to examine are the predominantly hadronic diffractive dissociations:

$$K^- Z \rightarrow \Lambda \bar{p} Z \qquad (3)$$

$$\bar{p} Z \rightarrow \bar{\Lambda} K^- Z \qquad (4)$$

These reactions can also be used to examine the nature of the $\mathbb{P}$ trajectory as well as to search for possible resonance structure[12] in the $\Lambda\bar{p}$ (K*) system.[13,14] We wish to stress that the Λ and $\bar{\Lambda}$ decays will provide us with heretofore unavailable polarization data for diffractive inelastic channels.

We expect the Coulomb induced transitions for reactions (3) and (4) to be comparable to the $\mathbb{P}$-exchange contributions, and consequently, we expect to observe contributions from both the nuclear and the Coulomb processes. (As usual, the Coulomb cross sections will have a steeper t-dependence and will scale like Z^2, while the $\mathbb{P}$-exchange cross section will behave approximately as $|F(t)|^2$, and have a weaker Z dependence[11].)

In addition to the two-body (charged-particle plus V or π^o) decays of coherently produced objects, we plan to study for normalization and comparison purposes the more usual three body decays:

$$\pi^- Z \rightarrow \pi^-\pi^+\pi^- Z \qquad (5)$$

$$K^- Z \rightarrow K^-\pi^+\pi^- Z \qquad (6)$$

$$\bar{p} Z \rightarrow \bar{p}\pi^+\pi^- Z \qquad (7)$$

These data can be obtained easily and rapidly through a minor modification of the trigger in our proposed spectrometer system.

Tables I, II and III enumerate the results of Monte Carlo acceptance and resolution studies for the final states of interest. The yield for Coulomb-induced processes are based on the recent measurements of radiative widths of the $K^*(890)$ and the ρ.[6] Theoretical rates based on the vector dominance hypothesis have been assumed for A_2 and $K^*(1420)$ production.[7] We have also assumed that the diffractive dissociation channels will not exhibit strong energy dependence but will remain at the levels observed at BNL.[9] Resolution and acceptance were calculated using the spectrometer arrangement shown in Fig. 3 (see next section).

The anticipated event rates are $\gtrsim$500 events per hour for the negative-particle beam M-1 of the Meson Detector Building of Fermilab. Because of the low beam-fraction of $\bar{p}$ and K^- particles, most of the yield will be from π^- induced channels. However, the K^- and $\bar{p}$ data will be clean, and the expected number of $K^*(890)$ events, for example, will be ~20,000; a number which is sufficient for the precise extraction of the radiative width. (The yields for $\bar{p} \to \bar{p}\pi^0$ dissociations will, of course, be quite large and can be used for comparison with the results of E 305.)

II. Experimental Equipment

The major hardware items required for the execution of this experiment are indicated schematically in Fig. 3. The elements of importance are described more fully below.

1. The Beam

The Beam is to be a high energy high intensity negative-particle beam such as the M-1 beam, capable of providing $\sim 10^6$ π^- and $\sim 5 \times 10^4 K^-$

over a one second spill time. With the upgrading of the Meson Lab to 400 GeV/c primary proton energy, we request running at 150 GeV/c and 300 GeV/c secondary beam momenta. We require a 1-2 mm beam spot on the target, with a momentum resolution $\frac{\Delta p}{p} \approx 0.3\%$, and an angular resolution for the projectile particle of $\lesssim 0.03$ mr. Consequently, we require the momentum tagging system at the first focus of the M1 beam; we will provide two sets of proportional multi-wire planes preceding the target in the low bay area of the Meson Lab. For particle identification we need the two DISC and one threshold counter presently in the beam.

We are presently investigating the possibility of enriching the K^- fraction in the M1 beam through the use of selective hadron filtering at the triple focus in the beam. Preliminary indications are that the K^- fraction may be increased by about a factor of two without seriously affecting the quality of the beam. The loss in flux can be compensated for by opening the momentum acceptance of the beam.

2. Spectrometer System

We propose to use a high-resolution forward V-spectrometer similar in essence to the one presently operating in the M-3 line. A schematic of the system is given in Fig. 3. The envisioned spectrometer would consist of a mixture of drift-wire (DWC) and multi-wire proportional chambers (MWPC). Although the system design is not yet fully completed, we expect that the major features will be as shown in Fig. 3. The system consists of a total of 650 drift wires spaced at 1 cm intervals, and a total of 2700 proportional wires spaced at 2 mm intervals. (Only the P1 MWPC trigger chamber will have 1 mm wire spacings.)

Trajectories upstream of the bending magnet will be determined utilizing two modules of drift-wire planes. Each module will consist of two sets of x, y and u (or v) planes; the two planes of similar orientation will be off-set relative to each other by 0.5 cm so as to remove left/right ambiguities.[15] In addition to the DWC, we propose to have a MWPC (P1) for triggering purposes immediately downstream of the vacuum decay region.

The DWC system should provide ± 0.2 mm spatial resolution and the ability to locate the vertex of the V decay to <10 cm accuracy along the beam direction. Should these estimates prove to be too optimistic we would lengthen the distance to the magnet by 3 meters thus doubling the lever arm. This would, however, reduce our acceptance for high-mass two-body states.

Downstream of the magnet we propose to have two similar DWC-MWPC modules. The active area of the most downstream module will be 20" × 72" in size. The precision of the DWC elements will provide excellent momentum resolution; the MWPC will provide adequate performance in the vertical direction. Left/right ambiguities will be resolved with the aid of the proportional chambers. A second triggering MWPC (P2) will be located immediately downstream of the bending magnet.

3. Target and Veto Counters

The target (T) and the S trigger counter and some of the veto counters would be located with a 5 meter-long vacuum decay vessel (this length corresponds to one decay length for 100 GeV/c K^o_s mesons). Additional veto counters of lead/scintillator sandwiches will be positioned outside of the decay vessel as well as on the face of the magnet. These veto counters will be arranged to shadow the magnet aperture and consequently assure that no charged or neutral particles emerge from the target in the region outside of the acceptance of the magnet.

Our Monte-Carlo simulations indicate that the ambiguity between K_S^o, Λ^o or $\bar{\Lambda}^o$ decays will be essentially negligible; consequently, we will not require particle identification during data taking (ambiguities will be resolved via Q-value and fitting). We will therefore require only the 5 meter vacuum tank to observe neutral-particle decays in order to establish the correct mass assignments.

The target assembly will have several rotational settings to provide semi-concurrent data taking capability on various nuclei, as well as to measure the background levels for target-empty subtractions. (This is similar to a system recently used for transmission measurements in E#305.) The target thickness will be typically $\lesssim 0.2$ radiation lengths of material so as to minimize measurement errors due to multiple-Coulomb scattering.

4. Photon Detection

The photon detectors γ_L and γ_R are presently envisioned to be of the Caltech variety.(16) Two identical units, each 20 inches × 30 inches in size transverse to the beam will be required. The individual scintillator elements will not be as narrow as those of the Caltech detector. We expect that 30 × 45 elements per unit would suffice for the ±1.5 mm spatial and $\pm \frac{0.2}{\sqrt{E}}$ $(\mathrm{GeV})^{1/2}$ energy resolutions we require to achieve our physics goals. Consequently, the entire device might require 150 phototubes. The photon detectors will be used as part of the trigger logic for the experiment.

5. Magnet

We have planned the present experiment with a BM109 analyzing magnet in mind. Although opening up the gap would increase the acceptance at high mass, it would also worsen the resolution. Furthermore, a larger magnet aperture could only become of value if a larger (and more expensive) γ detector were to be constructed. Consequently, the yields and resolutions, which appear to be quite adequate for the task, have been calculated assuming the standard 8" × 24" aperture and 1 GeV/c transverse kick.

6. On-Line Computer System

Data acquisition will proceed, depending on scheduling restrictions, either through the Rochester DEC PDP-15/CAMAC Control System, presently in the M-3 beam, or through a Fermilab BISON PDP-11 computer system.

III. Technical Details

1. Trigger Modes

We envision running in two trigger modes defined by the following logic requirements:

1) $\check{C} \cdot \bar{A} \cdot S\ (PH<2) \cdot P1R(\geq 1) \cdot P1L(\geq 1) \cdot P2(=3) \cdot \bar{\gamma}$

2) $\check{C} \cdot \bar{A} \cdot S\ (PH<2) \cdot P1L(=1) \cdot P2(=1) \cdot \gamma R \cdot \overline{\gamma L} \cdot \overline{P1R}$

or $\check{C} \cdot \bar{A} \cdot S\ (PH<2) \cdot P1R(=1) \cdot P2(=1) \cdot \gamma L \cdot \overline{\gamma R} \cdot \overline{P1L}$

The first mode corresponds to the conditions of the old proposal E272. Namely, we require the pulse height in the S counter to be that of one minimum ionizing particle and insist that at least one charged particle appear on each side (P1-Right and P1-Left) of the beam center line (in bending plane) at the exit window of the decay region. In addition, we require a total of three charged tracks to emerge from the downstream side of the magnet, and no other particles in any of the veto counters (nor in the beam anti downstream of the apparatus). The photon detectors will be tagged rather than put in as a trigger veto unless the rates become prohibitive.

The second mode of operation requires the γ-detectors. The trigger demands that energy deposited in one of the γ detectors be correlated with a single charged particle traversing the side of the P1 chamber opposite to that of the activated γ-detector. Our plan is also to introduce into the trigger a requirement on the number of separated shower centers in the γ detectors. For 300 GeV/c running we will require only one shower center in the γ-detector (this will eliminate very few single π^o but a major fraction of the $\eta^o \to \gamma\gamma$ events), while at 150 GeV/c we will accept up to two large-pulse-height shower centers. We are confident that using this scheme will provide us with a relatively unbiased sample of single π^o (and single γ) events accompanying single charged-particles produced in the target. This requirement on the number of shower centers may be essential to reduce background (see later).

2. Yields and Detection Efficiency

Figure 4 indicates the mass acceptance of our system. Tables I and II display the envisioned event rates at 150 GeV/c incident momentum for the reactions of interest, assuming a target thickness of 0.2 radiation lengths of Pb. We see that the nuclear coherent-production channels are in general comparable to the Coulomb-production cross sections. Although the expected yields, particularly for reactions (3) and (4) are small, the signals are clean and we do not forsee any difficulty in K_s^o - $\bar{\Lambda}$ separation. (The decays $K_s^o \to \pi^+\pi^-$ and $\Lambda \to \bar{p}\pi^+$ are ambiguous for only a very restricted region of $K_s^o \to \pi^+\pi^-$ kinematics. Our K_s^o mass resolution will be superior to that attainable in the 30-inch ANL/FNAL bubble chamber in which the Λ-K_s^o ambiguity causes no significant problems.)

We expect relative yields on light nuclei from processes involving other than Coulomb production to be somewhat higher than yields obtained on Pb.(9) Consequently, for a 5 cm Be target the total rates at 150 GeV/c will be similar to those presented in Tables I and II (within a factor of two). At 300 GeV/c the expected K^- flux will be about a factor of three below that at 150 GeV/c. The π^- yield will be approximately unchanged.

3. Resolution

The resolution in transverse momentum we expect for our apparatus is ~15 MeV/c (even without using the constraints in the data, i.e., the mass of the Vee and energy balance at production). This resolution will be adequate for resolving the sharp coherent spike in t, and for distinguishing the Coulomb contribution (peaking at $t \simeq 2t_{min}$) from the less peaked spin-flip $\mathbb{P}$-exchange contribution (peaking at $t \sim 3/R^2$(17), where $|F(t)|^2 = e^{-(R^2/3)t}$ and R is the radius of the nucleus) to the coherent production process. Table III provides an indication of the kind of mass and t resolution we expect for the proposed system. Monte Carlo studies are still in progress to ascertain how fine a grid is required for the γ detectors (the present calculations assume 1.5 cm strips of scintillator and ±1.5 mm spatial resolution). The overall resolution of the proposed system is comparable to that of the E#305 spectrometer and is consequently well suited for the proposed studies.

4. Backgrounds

Because our total transverse momentum resolution for the coherently produced system is expected to be $\lesssim$20 MeV/c, we do not forsee any difficult background problems in off-line analysis. Excellent discrimination against dissociations involving additional unobserved π^o mesons should be straightforward due to the overconstrained nature of the data. Also, as we mentioned earlier, we do not foresee any problem in resolving Vee ambiguities such as between a K_s^o and a $\bar{\Lambda}$. Consequently, the only significant problem we expect from background reactions is their effect on the data-taking rate.

Beam particles not scattered in the target will interact in the thin windows of the vacuum chamber. Although most of these window interactions will involve the production of more than just three charged forward particles and will therefore be vetoed through the requirement of having three and only three tracks in the MWPC downstream of the vacuum chamber, we expect nevertheless 10-20 interactions per pulse of the kind which will have to be recorded as background triggers to Mode 1). These events will subsequently be separated off-line from events of interest.

The backgrounds in the second mode of operation (from $A_1^- \rightarrow \pi^-\pi^o\pi^o$) are large and require special care. For example, using a $\frac{1}{10}$ interaction-length Be target (the worst case) may provide typically 400 possible background triggers per pulse for 10^6 beam particles.(18) Having investigated the resolution of the Caltech detector(16) we believe that a factor of ten suppression in triggering is feasible; thus we feel confident that we can reduce the trigger rate to a managable level. (For K^- beam particles we can afford a far looser trigger.)

We emphasize again that we do not expect any serious background to the signal after performing post-line analysis; the background will be easily separable from the signal, and will only affect the rate at which data can be accummulated. Our calculations, based on production data at 100 GeV/c, indicate that interactions in the windows of the vacuum tank for a beam containing 10^6 particles will be at a manageable level. And, in fact, if the background rates in Experiments #27 and #305 can be used as a guide, then background levels for the present proposal will also not be problematic.

IV. Summary and Running Schedule

We propose to initiate the above described studies with a 300 hour run at 150 GeV/c incident momentum. This time period should be adequate for the full debugging of the apparatus as well as for providing a precise measurement of the radiative width of the ρ^-. (The initial tests of the γ detectors will be performed in a test beam at Fermilab or at another accelerator.) Following the successful execution of the first phase of the experiment we propose to complete our envisioned program with the measurement of the other processes we have discussed in this proposal. We anticipate an additional 600 hours for the completion of our program. This time will be allocated between two energy points, half at 150 GeV/c and half at 300 GeV/c incident momentum. At each energy we plan to take data using $\lesssim$0.2 radiation length Be, C, Al, Cu, Sn and Pb targets, devoting about 50 hours per target per energy in this exploratory investigation of diffractive phenomena. (The three-particle dissociation data will require less than 50 hours of running time.) It is also worth contemplating a future measurement of reaction (1) through (4) on a H_2 target. The H_2 measurements will require the high pressure gas target successfully utilized in E#305.

As for the time schedule for the development of the spectrometer and γ detectors, we believe that we can obtain the required funds and build the proposed system within a two year time period after the formal approval of the experiment.

References

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6. B. Gobbi et al, Phys. Rev. Letters 33, 1450 (1974); W. C.Carithers et al, University of Rochester Report, UR-525 (1975).

7. A large radiative width of ~1 MeV is expected for $A_2^- \rightarrow \pi^-\gamma$. See H. Harari, Phys. Rev. Letters 18, 319 (1967) for the calculation.

8. T. Ferbel, SLAC Report 144 (1972); G. Kane, Acta Physica Polonica B3, 845 (1972).

9. U. Kruse et al, Phys. Rev. Letters 32, 1328 (1974).

10. Because of absorption we do not expect A_2 coherent production to be very sensitive to nuclear mass. This is, in fact, observed to be the case in the data of ref. 8.

11. J. Biel et al, presented at the Washington Meeting of the APS (1975).

12. Because $\mathbb{P}$ - exchange and Coulomb excitation should be the only processes contributint to coherent production at FNAL energies, we can use our data to ascertain the validity of recent conjectures pertaining to the vanishing of the Resonance-Particle - $\mathbb{P}$ coupling as $t \rightarrow 0$. We thank R. Brower for a discussion of this point.

13. Diffractive-like $\bar{\Lambda}p$ systems are produced copiously in K^+p collisions, see, for example, D. Cohen et al, Phys. Rev. D8, 2772 (1973).

14. Concerning possible resonance structure in the $\bar{\Lambda}p$ system, see the review of P. Slattery, University of Rochester Report UR-332 (1971).

15. At the deisred beam intensities we expect some problems with extra tracks in the front DWC's; to avoid these difficulties we may have to space the centermost sense wires closer together and develop methods for deadening areas of high beam flux.

16. We wish to thank Messers Alan Barnes and Art Ogawa for extensive discussions and for providing us with invaluable internal reports from Caltech pertaining to the properties of the γ-detector.

17. For the spin-flip amplitude in $\mathbb{P}$-exchange processes we expect $A \sim \sqrt{t'}\, F(t)\, s^{\alpha(t)-1}$. We thank G. Kane for a discussion of this point.

18. We have used the coherent cross sections for A_1 production on nuclei measured at CERN to estimate background yields at Fermilab. On Be the coherent cross section for $\pi^- \mathrm{Be} \to \pi^-\pi^0\pi^0$ is expected to be ~2 mb, on Pb it is 15 mb. See the CERN report of P. Muhlemann et al (Jan. 29, 1973).

Table I

Estimated Yields at 150 GeV/c on Pb (Mode 1)

Reaction	Mass (MeV)	$\sigma^{strong}_{coherent}$[a] (μb)	$\sigma_{Coulomb}$[a] (μb)	Average[b] Efficiency	Yield[c] per spill	Events 900 hours
$\bar{p} \to K^- \bar{\Lambda}$	$\lesssim$2000	400	200	0.4	0.014	5,600
$K^- \to \Lambda \bar{p}$	$\lesssim$3000	200	100	0.3	0.018	7,200
$K^- \to K^o_s \pi^-$	890	20	160	0.5	0.018	7,200
	1420	50	160	0.2	0.0084	3,360
$\pi^- \to K^o_s K^-$	1310	6	80	0.4	0.138	55,000

Table II

Estimated Yields at 150 GeV/c on Pb (Mode 2)

Reaction	Mass (MeV)	$\sigma^{strong}_{coherent}$[a] (μb)	$\sigma_{Coulomb}$[a] (μb)	Average[b] Efficiency	Yield[c] per spill	Events 900 hours
$K^- \to K^- \pi^o$	890	30	240	0.8	0.043	17,300
	1420	75	240	0.4	0.025	10,000
$\pi^- \to \pi^- \pi^o$	760	40	525	0.8	1.81	7×10^5
$\pi^- \to \pi^- \eta^o$	1320	25	285	0.2	0.25	10^5
$\bar{p} \to \bar{p} \pi^o$	1236	~ 5 mb	~10 mb	0.8	0.7	$\sim 3 \times 10^5$

(a) Contains corrections for all branching ratios.

(b) Contains all corrections for geometrical efficiency assuming a 5 meter decay region for the V.

(c) Assuming 10^6 π^-, 5×10^4 K^- and 1.5×10^4 $\bar{p}$ and a target of 1.3 gm/cm^2 of Pb. The beam composition is based on an extrapolation to 400 GeV/c primary momentum of the measurements of W. Baker et al, Phys. Letters 51B,303 (1974).

Table III

Typical Resolutions*

	Mass Resolution			
Momentum	$K_S^0\pi^-$ Mass (GeV)		$K^-\pi^0$ Mass (GeV)	
	1.0	2.0	1.0	2.0
150 GeV/c	±0.01	±0.015	±0.01	±0.015
300 GeV/c	±0.02	±0.025	±0.015	±0.025

Error in p_T: ~ ± 15 MeV/c at 150 GeV/c

± 20 MeV/c at 300 GeV/c

Effective slope in t for δ-function at t=0:

exp(2000 t) at 150 GeV/c

exp(1200 t) at 300 GeV/c

* Resolutions contain estimates of spatial resolution of ±0.2 mm for the drift chambers and ±1.5 mm for the γ-shower detectors. Energy resolution of the γ-detector is taken as $\pm 0.22/\sqrt{E}$ (ref. 16). Multiple scattering errors included in calculations.

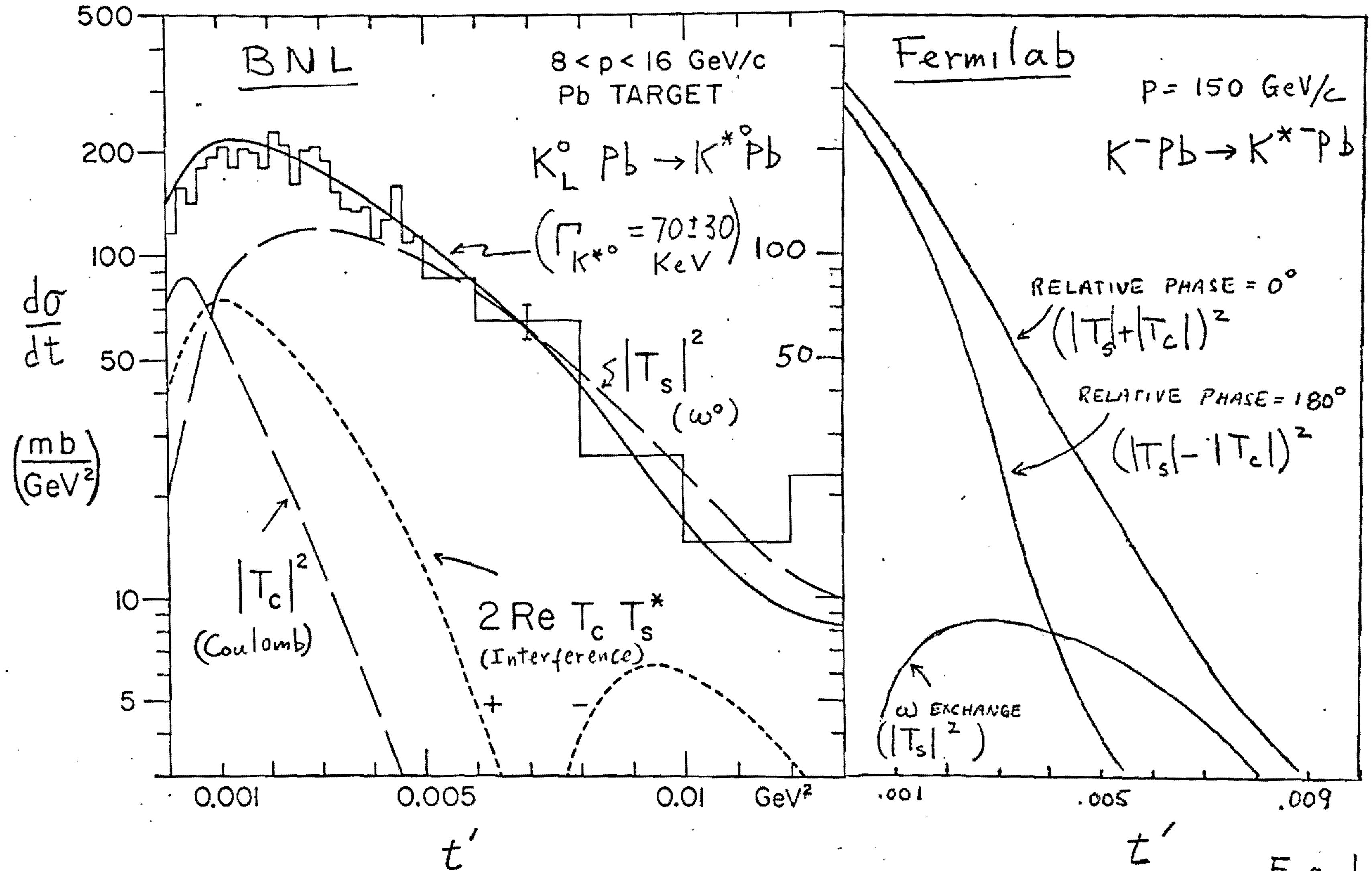
FIGURE CAPTIONS

1. Comparison of the recent measurement of the radiative width of the $K^*(890)^o$ at BNL (Reference 6) with expectations for $K^*(890)^-$ measurement at Fermilab. At Fermilab energies the width measurement should not be sensitive to the relative phase of the Coulomb and strong-production amplitudes. (Information on the relative phase will, of course, be extracted from the data.)

2. Data from Fermilab E27 displaying the dependence of the Coulomb and diffractive process on t, M and Z (Reference 11).

3. Schematic of forward spectrometer proposed for E272.

4. Geometrical Acceptance of the proposed system for a variety of final states. (We have assumed a 5 meter decay region for the Λ and K_s^o particles.)



BNL
8 < p < 16 GeV/c
Pb TARGET
K_L^0 Pb → K^{*0} Pb
($\Gamma_{K^{*0}}$ = 70±30 KeV)
$|T_s|^2$ (ω^0)
$|T_c|^2$ (Coulomb)
2 Re $T_c T_s^*$ (Interference)
+
−
$\frac{d\sigma}{dt}$ $\left(\frac{mb}{GeV^2}\right)$
500
200
100
50
10
5
0.001
0.005
0.01
GeV²
t′
Fermilab
p = 150 GeV/c
K^- Pb → K^{*-} Pb
RELATIVE PHASE = 0°
$(|T_s|+|T_c|)^2$
RELATIVE PHASE = 180°
$(|T_s|-|T_c|)^2$
ω EXCHANGE
$(|T_s|^2)$
100
50
.001
.005
.009
t′

Fig. 1

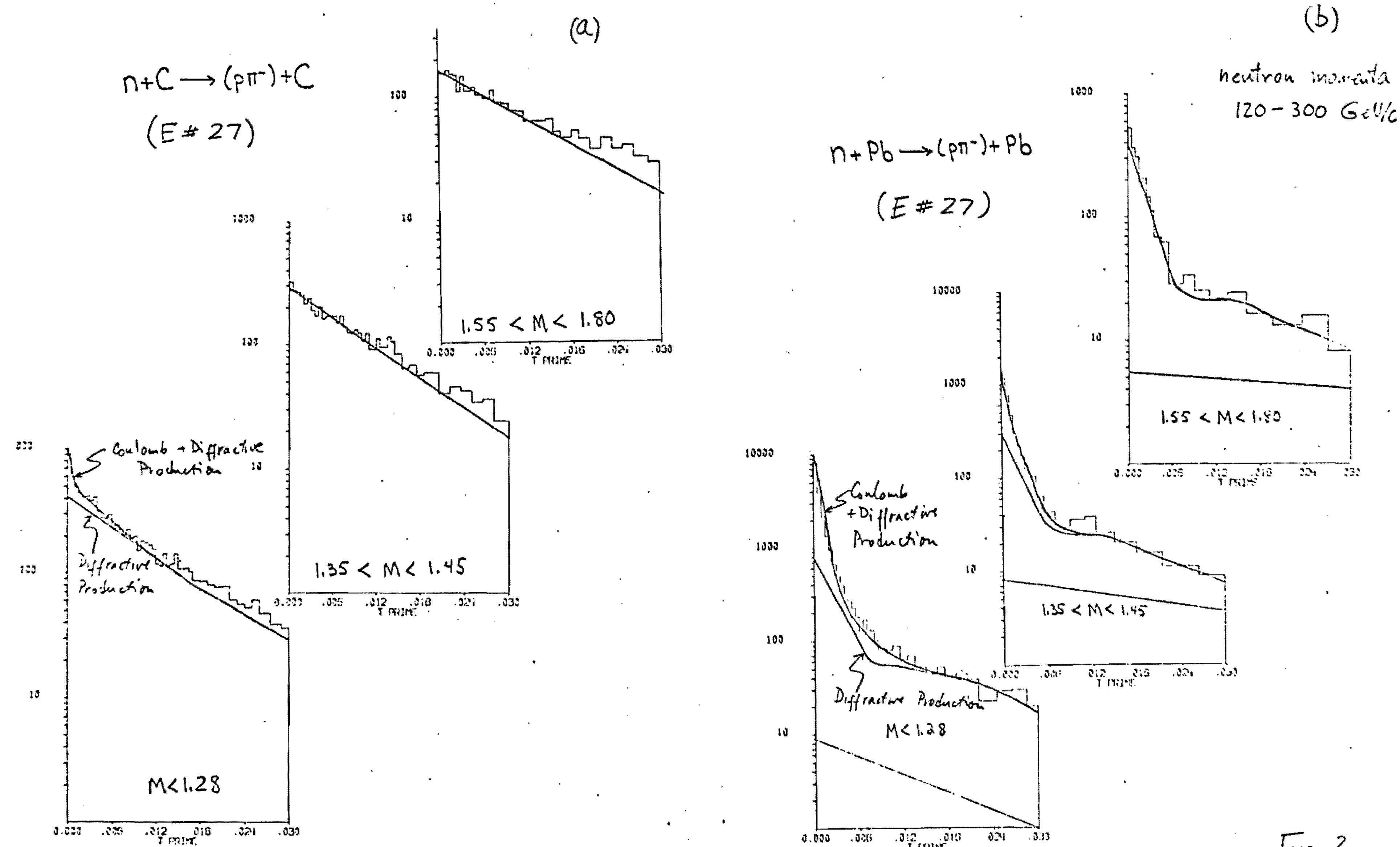
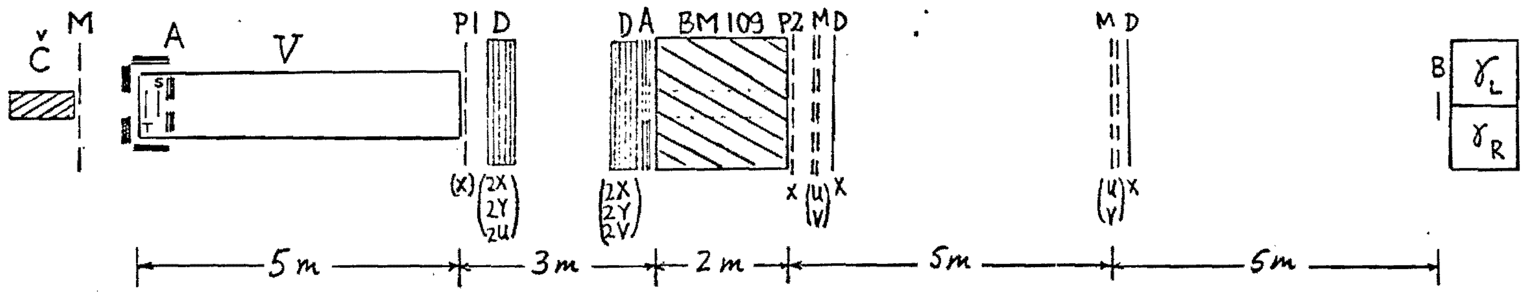

(a)
n+C ⟶ (pπ⁻)+C
(E # 27)
1.55 < M < 1.80
1.35 < M < 1.45
M<1.28
Coulomb + Diffractive Production
Diffractive Production
T PRIME
(b)
neutron momenta
120 - 300 GeV/c
n+Pb ⟶ (pπ⁻)+Pb
(E # 27)
1.55 < M < 1.80
1.35 < M < 1.45
M<1.28
Coulomb + Diffractive Production
Diffractive Production

Fig. 2



D = Drift wires (planes)

M = Multiwire proportional chambers

C = Cerenkov counter in M-1 beam

T = Target

S = Thin trigger counter

A = Veto counters (Pb/Scintillator)

P1,P2 = MWPC used for triggering

γ1,γ2 = Photon detectors

V = Vacuum vessel

B = Beam particle veto

X = Bending plane

Y = Normal to bending plane

u,v = Wires at ±30° with respect to Y.

Spectrometer Proposed For Revised E272

Fig. 3

Geometrical Acceptance (Using 5 meter decay vessel)

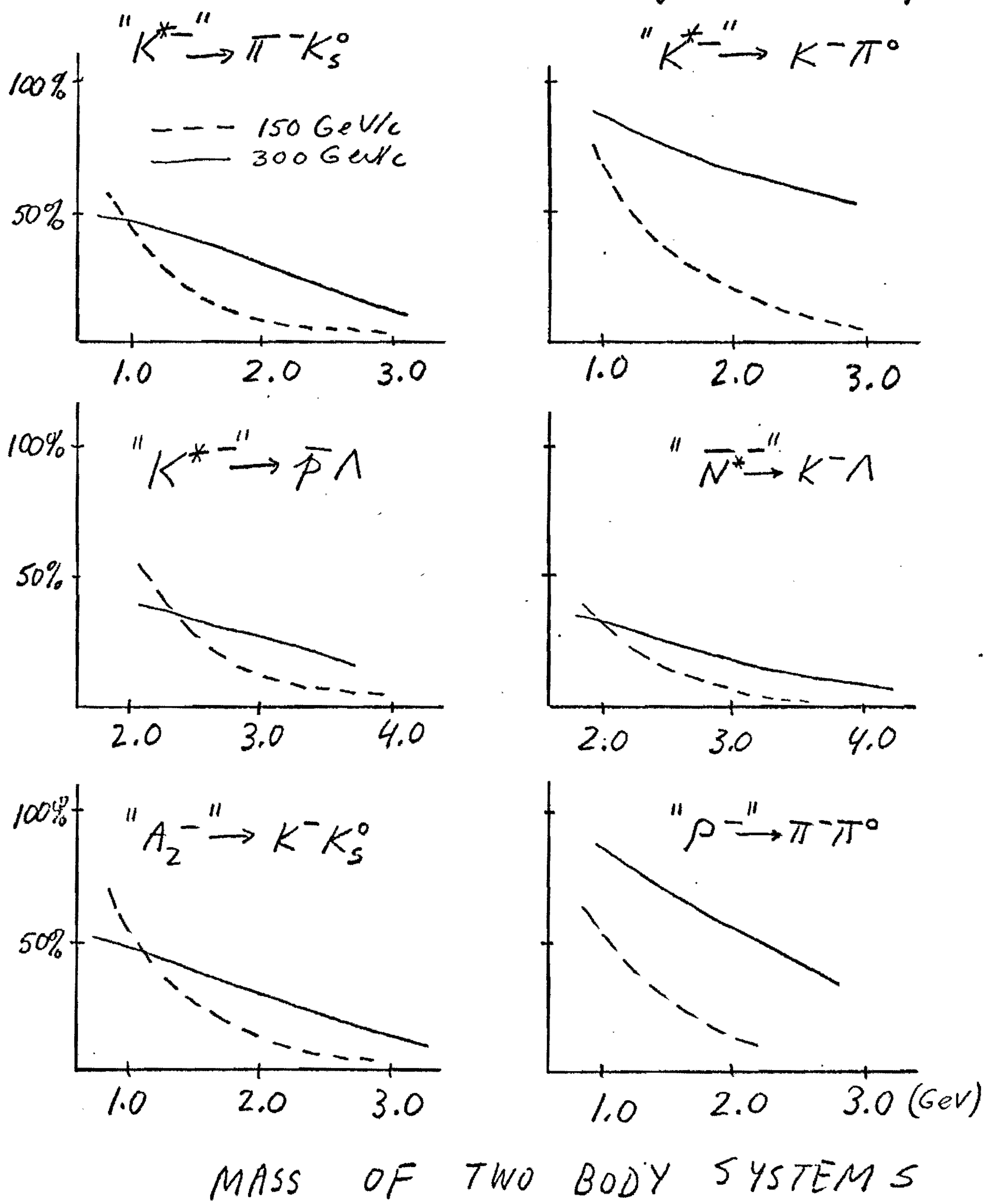


Fig. 4

NAL PROPOSAL No. 272

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Proposal to Measure Coherent Dissociation of π, K and p into Strange Particles at NAL Energies

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November 1973

Abstract

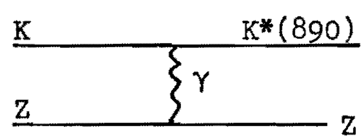
Cross sections for the coherent excitation of particles impinging on nuclei rise dramatically with incident bombarding energy. Two processes are held responsible for these projectile excitations: (1) the interaction of the projectile with the nuclear Coulomb field, and (2) the hadronic interaction between the colliding objects. The first process can be interpreted through an analysis paralleling the Primakoff effect, and can yield valuable information pertaining to radiative widths of resonances produced through Coulomb dissociation. The second process, usually referred to as diffractive dissociation or Pomeranchukon exchange, is not currently understood in any fundamental way. The two separate types of interactions responsible for coherent dissociation are most readily distinguished through their differing dependences on nuclear mass, nuclear charge, scattering energy and momentum transfer. We intend to examine both processes in sufficient detail so as to gain a significant advance in the understanding of the overall dissociation phenomenon.

Specifically, the objective of the experiment is the investigation, with high statistics, of the decay angular distributions for, and the dependence on, mass, momentum transfer, target and energy, of the two-body dissociation reactions: $p \rightarrow \Lambda^{o}K^{+}$, $\pi^{+} \rightarrow K^{+}K_{s}^{o}$, $K^{+} \rightarrow K_{s}^{o}\pi^{+}$, and $K^{+} \rightarrow \bar{\Lambda}p$. The Pomeranchukon contributions to the fragmentation of mesons into two other mesons will be of particular interest. The reactions listed above have not been examined extensively as yet due to their relatively low yields at energies below the range of NAL. The study of these simple transitions will add important information to our knowledge of coherent processes and will probe in detail the nature of the Pomeranchukon trajectory in the inelastic regime. We propose to execute this experiment utilizing a slightly modified form of the Northwestern-Rochester V-spectrometer system.

I. Physics Justification

The recent review of Berlad et al[1] has emphasized the increasing importance of electromagnetic effects in hadron-induced reactions at high energies. Nagashima and Rosen[2], Stodolsky[3], and Berlad et al have stressed the great variety of exciting physics problems which can be probed as a result of the dominance of the one-photon exchange mechanism at NAL energies. Of particular interest to us is the measurement, through the Primakoff effect[4], of the radiative decay widths of the vector and tensor mesons.

Some of the most straightforward tests of unitary symmetry schemes are available via predictions relating such measurements[5]. Radiative widths of the ρ and of the K*(890) are presently being measured at BNL[6], and the results will be of value. However, these measurements may not be definitive due to backgrounds present at AGS energies. That is, in order to measure the radiative decay width of, for example, the K*(890), it is essential to extract the Coulomb part of the K*(890) coherent production amplitude. The diagram of interest for a K-meson impinging on a nuclear target of charge Z is:



At AGS energies a large ω^o exchange amplitude also contributes to coherent K*(890) production. The presence of this hadronic-exchange process makes it difficult to separate out the Primakoff term required to obtain the rate for the K*(890) $\rightarrow$ K + γ decay.

Because the ω^o-exchange cross section falls rapidly with increasing beam momentum (P_L), while the Coulomb term grows substantially with P_L, it is clear that measurements, superior to those being performed at the AGS, of the radiative widths of mesons, are feasible at NAL energies. Also, measurements of the radiative widths of the tensor mesons ($K^*(1420)$ and A_2), which cannot be performed at lower energies because of kinematic damping (t_{min}), are possible at NAL.

The cross section for the electromagnetic production of a resonance of mass M* and spin S* in the Coulomb field of a target nucleus of charge Z is given by:[4]

$$\frac{d\sigma}{dt} = \frac{2S^* + 1}{2S + 1} \; 8\pi\alpha Z^2 \left(\frac{M^*}{M^{*2} - M^2}\right)^3 \Gamma_\gamma |F(t)|^2 \; \frac{(t - t_{min})}{t^2}$$

Here, t is the square of the momentum transfer to the nucleus, F(t) is the nuclear form factor, t_{min} is the kinematic minimum for t, and Γ_γ is the radiative width for the process $M^* \rightarrow M + \gamma$. M and S are the mass and spin of the impinging projectile particle.

Assuming SU3 values for the radiative widths of the vector mesons[5], and similar rates for the tensor mesons, we have estimated (Table I) yields from Coulomb-induced sources for the reactions:

$$K^+ + Z \rightarrow \left.\begin{matrix} K^{*+}(890) + Z \\ K^{*+}(1420) + Z \end{matrix}\right\} \rightarrow K^o_s \, \pi^+ \, Z \qquad (1)$$

$$\pi^+ + Z \rightarrow \left.\begin{matrix} \rho^+ (760) + Z \\ A_2^+ (1320) + Z \end{matrix}\right\} \rightarrow K^o_s \, K^+ \, Z \qquad (2)$$

(Although the peak of the ρ is about two full widths below the $\bar{K}$ K threshold we expect some contribution from the ρ to reaction (2) due to the Breit-Wigner resonance tails.) Interesting background processes are also expected to contribute to both reactions. The sources of this background are the non-resonant photon-meson two-body scattering processes:

$$K^+ + \gamma \rightarrow K_s^o + \pi^+$$

$$\pi^+ + \gamma \rightarrow K_s^o + K^+$$

Aside from Coulomb production of objects such as the $J^P = 2^+$ A_2 and K*(1420), we can also envision the strong production of these mesons via Pomeranchukon ($\mathbb{P}$) exchange.(7) Although folklore has it that the coherent dissociation of mesons can only proceed via the "Morrison rule" (that is, $\Delta P = (-1)^J$), this rule has not been tested under favorable - i.e., low background-conditions. Thus far there appears to be essentially no evidence for coherent A_2 production on large nuclei in reactions such as:(8)

$$\pi + Z \rightarrow \pi\pi\pi Z$$

However, these reactions contain large backgrounds from the A_1, which make it difficult to discern the presence of a small $J^P = 2^+$ component in the data. Furthermore, if A_2 production proceeds via $\mathbb{P}$-exchange, the cross section must vanish at $t = t_{min}$ (spin-flip is involved, with the production amplitude being proportional to $\sqrt{t_{min}}$); consequently, there is strong kinematic damping of coherent A_2 production at low energies. As the incident momenta increase we expect the $\mathbb{P}$-part of the coherent nuclear amplitude for A_2 production to also rise with energy due to a decrease in t_{min}. (In addition, a small logarithmic rise in the cross section may be expected due to Regge shrinkage of the t-distribution; the finite slope of the $\mathbb{P}$ trajectory will have the effect of shifting the maximum in the differential cross section toward t=0). Consequently, examining the coherently produced two-meson mass spectrum at NAL energies will provide a stringent test of the Morrison rule (away from $t=t_{min}$) and of our ideas concerning the $\mathbb{P}$ trajectory in the inelastic regime. A reasonable estimate of the total amount of A_2 production through this process is ≈ 5% of the A_1 yield.[9]

Consequently, we expect reactions (1) and (2) to contain information pertaining not only to the Coulomb-induced processes but also to phenomena involving $\mathbb{P}$-exchange. The two separate contributions to reactions (1) and (2) will differ significantly in their t- and Z-dependences[10], and will provide two-body final states which can be analyzed in a simple manner to extract radiative widths and relative magnitudes and phases of the two production amplitudes.

Two other two-body processes which we wish to examine are the predominantly hadronic diffractive dissociations:

$$K^+ Z \to \bar{\Lambda} p Z \tag{3}$$

$$p Z \to \Lambda K^+ Z \tag{4}$$

These reactions can also be used to examine the nature of the $\mathbb{P}$ trajectory as well as to search for possible resonance structure[11] in the $\bar{\Lambda}p$ (K*) system.[12,13] We wish to stress that the Λ and $\bar{\Lambda}$ decays will provide us with heretofore unavailable polarization data for diffractive inelastic channels.

We expect the Coulomb induced transitions for reactions (3) and (4) to be comparable to the $\mathbb{P}$-exchange contributions, and consequently, we expect to observe contributions from both the nuclear and the Coulomb processes. (As usual, the Coulomb cross sections will have a steeper t-dependence and will scale like Z^2, while the $\mathbb{P}$-exchange cross section will behave approximately as $|F(t)|^2$, and have a very weak Z dependence $\sim Z^{2/3}$.[10])

In addition to the two-body (charged-particle plus Vee) decays of coherently produced objects, we plan to study for normalization and comparison purposes the more usual three body decays:

$$\pi\, Z \rightarrow \pi\pi\pi Z$$

$$K\, Z \rightarrow K\pi\pi Z$$

$$p\, Z \rightarrow p\pi\pi Z$$

These data can be obtained easily and rapidly through a minor modification of the trigger in our spectrometer system.

We have extrapolated to 300 GeV/c primary momentum the Hagedorn-Ranft estimates given in the report on the Meson Laboratory;[14] the estimated fluxes in the high-resolution beam M-1 for the positive and negative components are shown in Fig. 1. In calculating the expected yields in our proposed experiment, we have assumed "reasonable" radiative widths (SU3 predictions where available and an estimate from photo-production cross sections for reaction (4)). Table I enumerates the results of our Monte Carlo studies, in which we assumed a spectrometer system identical to the Northwestern-Rochester system for NAL experiment 27, (the actual resolution of the equipment, however, may be superior to that assumed due to the overconstrained nature of our event topology.) Figure 2 indicates the mass acceptance of our system. Monte Carlo studies indicate that our mass resolution will be typically 5 MeV and consequently be more than adequate for resonance searches. We will also be able to examine the decay properties of the produced systems with good efficiency when the Λ, K_s^o or $\bar{\Lambda}$ are produced in the forward hemisphere of the dissociated system's rest frame.

The anticipated event rates are $\gtrsim$400 events/hr for positive beam particles and $\gtrsim$200 events/hr for negative beam particles. We propose to initiate these studies with a program requiring 600 hours of data taking. This time will be allocated between two energy points, half at 100 GeV/c and half at 200 GeV/c incident momentum. At each energy we plan to take data using 0.2 radiation-length C, Ag and Pb targets, devoting approximately 100 hours per target per energy in this exploratory investigation of diffractive phenomena. (The three-particle dissociation data will require less than 20 hours of running time.)

II. Experimental Equipment

The major hardware items which are required for the execution of this experiment are available at this time and are indicated schematically in Fig. 3. Details of the target box arrangement are sketched in Fig. 4. The elements of importance are the following:

1. High energy and high intensity beam M-1 (3.5 mr) at the Meson Lab. The high-resolution beam M-6 would also be acceptable.
2. Northwestern-Rochester Spectrometer System, including wide aperture magnet (we assume a BM 109 magnet in calculating rates).
3. Additional proportional wire-plane chambers for trigger logic.
4. Six meter vacuum tank decay chamber.

The above items are discussed below.

1. Positively Charged Beam

We require a positively charged beam at 100 GeV/c and at 200 GeV/c with $\frac{\Delta p}{p} \lesssim 0.15\%$, having a flux of $\leq 10^6$ protons distributed over a one second spill time. We must be able to determine the identity of the projectile particle and its angle to an accuracy of ± 0.02 mr or better.

Consequently, we require the presence of the tagging system which is planned for the front part of the M-1 beam for Proposal #114. In particular, we need the two DISC and one threshold counter in the beam, as well as the two sets of proportional multi-wire planes preceding the target in the low bay area of Meson Lab.

2. Spectrometer System

Our present spectrometer system consists of:

(1) Three 90" × 40" double spark chambers used downstream of the wide aperture magnet; each double chamber has a set of vertical wires, spaced 40 per inch, and one set of diagonal wires at ±15° with respect to the vertical. Chambers have magnetostrictive readout with pickup on both ends of the line.

(2) Three 30" × 60" double x-y chambers, also with magnetostrictive readout. Each chamber, again with 40 wires per inch, has an x and a y readout; one of these chambers is used downstream, while the other two are presently used upstream of the analyzing magnet. These latter two will be replaced for this experiment with proportional-wire chambers of comparable size.

(3) Target box and Vertex chambers. The present target box with associated anti-counters will require only slight modification for our new proposal. The set of proportional high resolution ($\lesssim$0.5mm) vertex chambers will be improved to obtain positional accuracy of $\lesssim$0.2 mm, for an area of ~2 inch^2, through the use of miniature Charpak chambers of the kind being developed at Yale University (we are already proceeding in this direction on a development program of our own).

(4) SAC-MIDAS Digitization system. No changes will be required for the spark chamber system and readout. However, we are considering converting the entire spark chamber system to proportional planes for a second generation version of this experiment. This conversion is dependent largely on availability of funding.

(5) DEC PDP-15/CAMAC Control System. This is a powerful analysis unit which will not require modification for the present experiment.

(6) Wide Aperture Magnet. Our Monte Carlo calculations are based on the availability of a BM109 magnet. We have indicated in several figures by how much a 48D48 would improve the data-taking rate. Although it is clear that a 48D48 magnet is most desirable, it is also unquestionable that a BM109 will suffice for the first stage of our proposed experiment.

3. Large MWPC

We are presently constructing a facility for building multi-wire proportional chambers (MWPC) of the 30" × 60" variety. We are planning to build chambers with vertical and ±15° wires having 2mm spacings. We require two chambers of this size (these will suffice for the 48D48 magnet) to replace the two standard 30" × 60" spark chambers which are upstream of the BM109 magnet in Proposal #27. We have already built chambers of about half this size and feel confident that their construction will not present any difficulty. These two chambers will be used in the trigger logic to establish a "three and only three" charged-tracks condition for coherent production.

4. Decay Vacuum Chamber

Our Monte-Carlo simulations indicate that the ambiguity between K_s^o, Λ^o or $\bar{\Lambda}^o$ decays will be essentially negligible; consequently, we will not require particle identification during data taking (ambiguities will be resolved via Q-value and fitting). We therefore require only a 6 meter vacuum tank for neutral particle decay. Near the windows of the tank we will place anti-counters so as to reduce background rates from beam interactions in the windows which would simulate our trigger. The vacuum tank can be a 6 meter × 0.3 meter pipe (manufactured from 1/4" aluminum) with ≲10 mil mylar windows. Tapering might reduce the required window thickness and the amount of material in the beam. A MWPC in front of the vacuum-tank window will be used as a threshold anti-counter (pulse-height information) to eliminate any three-charged-particle coherent dissociation background (i.e., pulse heights ≳2 minimum will veto the event).

III. Technical Details

1. Yields and Detection Efficiency

Table I displays the envisioned event rates at 150 GeV/c incident momentum for the reactions of interest assuming a target thickness of 0.2 radiation lengths of Pb. We see that the nuclear coherent-production channels are in general comparable to the Coulomb-production cross sections. Although the expected yields, particularly for reaction (3), are small, the signals are clean and we do not forsee any difficulty in $K_s^o - \bar{\Lambda}$ separation. (The decays $K_s^o \to \pi^+\pi^-$ and $\bar{\Lambda} \to \bar{p}\pi^+$ are ambiguous for only a very restricted region of $K_s^o \to \pi^+\pi^-$ kinematics. Our K_s^o mass resolution will be superior to that attainable in the 30-inch ANL/NAL bubble chamber in which the Λ-K_s ambiguity causes no significant problems.)

We expect yields on light nuclei from processes involving other than Coulomb production to be comparable to yields obtained on Pb.(8) Consequently, total rates similar to those presented in Table I should (within a factor of two) also be expected for a 0.2 radiation lengths C target. It is also worth contemplating a future measurement of reactions (1) through (4) on a H_2 target. The H_2 measurements will require detection of the recoil proton.(15)

2. Backgrounds

Because our total transverse momentum resolution for the three charged tracks is expected to be $\lesssim$10 MeV/c, we do not forsee any difficult background problems in off-line analysis. Excellent discrimination against dissociations involving additional unobserved π^o mesons should be straightforward due to the overconstrained nature of the data. Also, as we mentioned earlier, we do not forsee any problem in resolving Vee ambiguities such as between a K_s^o and a $\bar{\Lambda}$. Consequently, the only significant problem we expect from background reactions is their effect on the data-taking rate.

Beam particles not scattered in the target will interact in the thin windows of the vacuum chamber. Although most of these window interactions will involve the production of more than just three charged forward particles and will therefore be vetoed through the requirement of having three and only three tracks in the MWPC downstream of the vacuum chamber, we expect nevertheless 10-20 interactions of the kind which will have to be recorded. These events will subsequently be separated off-line from events of interest. In NAL Experiment #27 we will be able to ascertain more fully the nature of this sort of background and, if required, we will place additional anti-counters near the mylar windows near and inside the vacuum tank.

We emphasize again that we do not expect any serious background to the signal after performing post-line analysis; the background will be easily separable from the signal, and will only affect the rate at which data can be accummulated. Our calculations, based on production data at 100 GeV/c, indicate that interactions in the windows of the vacuum tank for a positive beam containing 2×10^6 particles will be at a manageable level. However, if background rates for Experiment #27 are larger than anticipated, we are prepared to replace the present large spark chambers with equivalent proportional planes.

3. Resolution

As discussed in NAL Proposal #27, the resolution in transverse momentum we expect for our apparatus is ~10 MeV/c (even without using the constraints in the data, i.e., the mass of the Vee and energy balance at production). This resolution will be adequate for resolving the sharp coherent spike in t, and for distinguishing the Coulomb contribution (peaking at $t \simeq 2t_{min}$) from the less peaked spin-flip $\mathbb{P}$-exchange contribution (peaking at $t \sim 3/R^2$ [16], where $|F(t)|^2 = e^{-(R^2/3)t}$ and R is the radius of the nucleus) to the coherent production process.

References

1. G. Berlad et al, Technion Preprint (1971).

2. Y. Nagashima and J. Rosen, Univ. of Rochester Report-UR-875-295 (1969).

3. L. Stodolsky, Phys. Rev. Letters 26, 404 (1971).

4. G. Morpurgo, Nuovo Cimento 31, 569 (1964); S. Berman and S. Drell, Phys. Rev. 133, 791 (1964); A. Halprin, C.M. Anderson and H. Primakoff, Phys. Rev. 152, 1295 (1966); G. Fäldt, Nuclear Phys. B43, 591 (1972).

5. S. Okubo, Phys. Letters 4, 14 (1963); C. Becchi and G. Morpurgo, Phys. Ref. 140B, 687 (1965). Thus far the only measured vector meson radiative widths are $\Gamma(\omega \to \pi^{o}\gamma) = 930 \pm 50$ KeV and $\Gamma(\phi \to \eta\gamma) = 126 \pm 45$ KeV. For a detailed review of the subject see G. Morpurgo, Lectures at E. Majorana 1971 Summer School (Erice).

6. J. Rosen et al, Experiment 531 at BNL; W. Carithers et al, Experiment 620 at BNL.

7. T. Ferbel, SLAC Report 144 (1972); G. Kane, Acta Physica Polonica B3, 845 (1972).

8. P. Mühlemann et al, CERN Report (1973).

9. We thank G. Kane for a discussion of this point.

10. See the discussion provided in T. Ferbel, et al, NAL Proposal 27.

11. Because $\mathbb{P}$-exchange and Coulomb excitation should be the only processes contributing to coherent production at NAL energies, we can use our data to ascertain the validity of recent conjectures pertaining to the vanishing of the Resonance-Particle – $\mathbb{P}$ coupling as $t \to 0$. We thank R. Brower for a discussion of this point.

12. Diffractive-like $\bar{\Lambda}p$ systems are produced copiously in $K^{+}p$ collisions, see, for example, S. Stone et al, University of Rochester Report UR-421 (1973).

13. Concerning possible resonance structure in the $\bar{\Lambda}p$ system, see the review of P. Slattery, University of Rochester Report UR-332 (1971).

14. Meson Laboratory Report.

15. A high-pressure H_2 gas target serving as the atmosphere for a cylindrical pwc is presently being developed. The successful completion of this project will permit the measurement of the proton recoil angle in the reactions of interest. Measurement of the recoil proton is essential for full exploitation of the H_2 data.

16. For the spin-flip amplitude in $\mathbb{P}$-exchange processes we expect $A \sim \sqrt{t'}\, F(t)\, s^{\alpha(t)-1}$. We thank G. Kane for a discussion of this point.

TABLE I

ESTIMATED PRODUCTION RATES WITH A 150 GeV/c BEAM

Reaction	Resonance Masses	$\sigma_{\text{Strong Coher.}}$ (Pb) [a]	$\sigma_{\text{Coul.}}$ (Pb) [a]	Nuclear Coherent Events per 10^6 Beam [b]	Coulomb Coherent Events per 10^6 Beam [b]	Expected Beam Positive + Charge	Expected Beam Negative − Charge	Total Events Per Spill (+ Beam)
$P \to K\Lambda$	≲2000	~200μb	~200μb	0.1	0.1	10^6	2×10^5	0.2
$K \to \bar{\Lambda}P$	≲3000	~100μb	≳100μb	0.05	0.05	3×10^4	10^4	0.003
$K^{\pm} \to K^{0}\pi^{\pm}$	1420 890	~ 70μb –	~ 2mb ~ 2mb	0.05	3.0	3×10^4	10^4	0.1
$\pi^{\pm} \to K^{0}K^{\pm}$	1300	~ 20μb	~200μb	0.02	0.2	10^6	10^6	0.2

(a) Contains all branching ratio corrections.

(b) Positive beam yields containing all efficiency corrections.

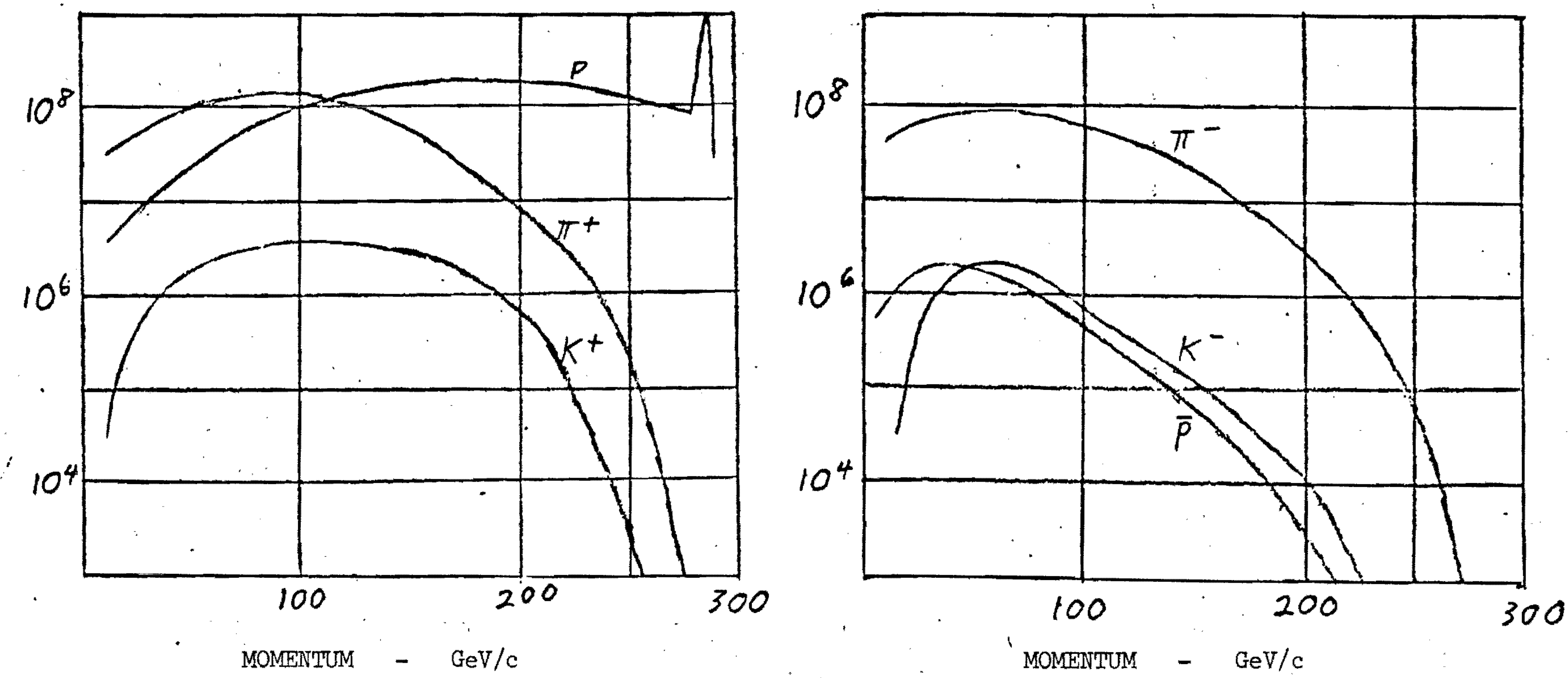


Figure 1

Beam M1 Fluxes / 10^{13} Protons

Hagedorn - Ranft Model Extrapolated to 300 GeV/c

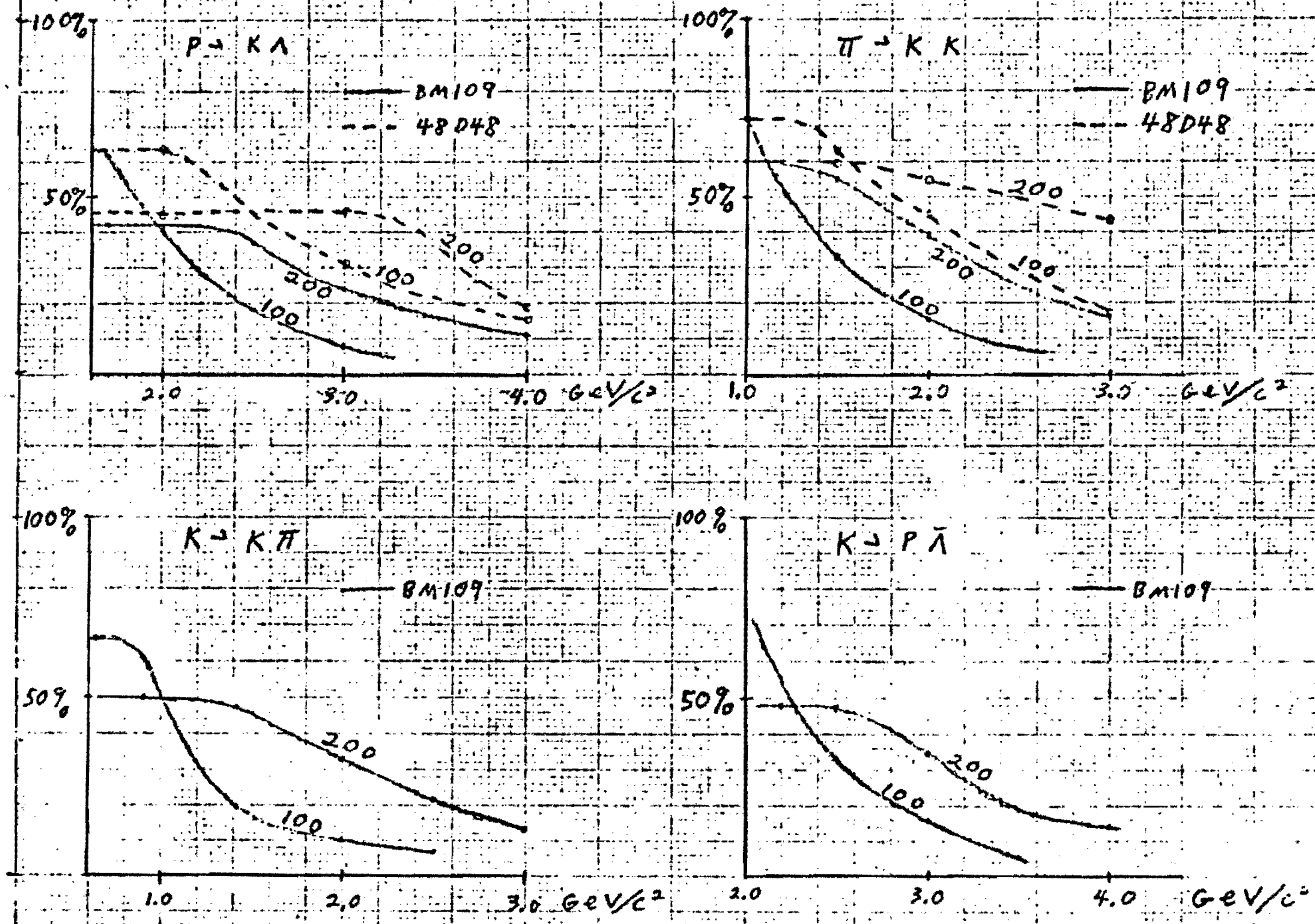


Figure 2

Geometrical efficiencies vs. Effective mass from Monte Carlo calculations assuming production on a Pb target and isotropic decay. (V-decay region of 6 meters).

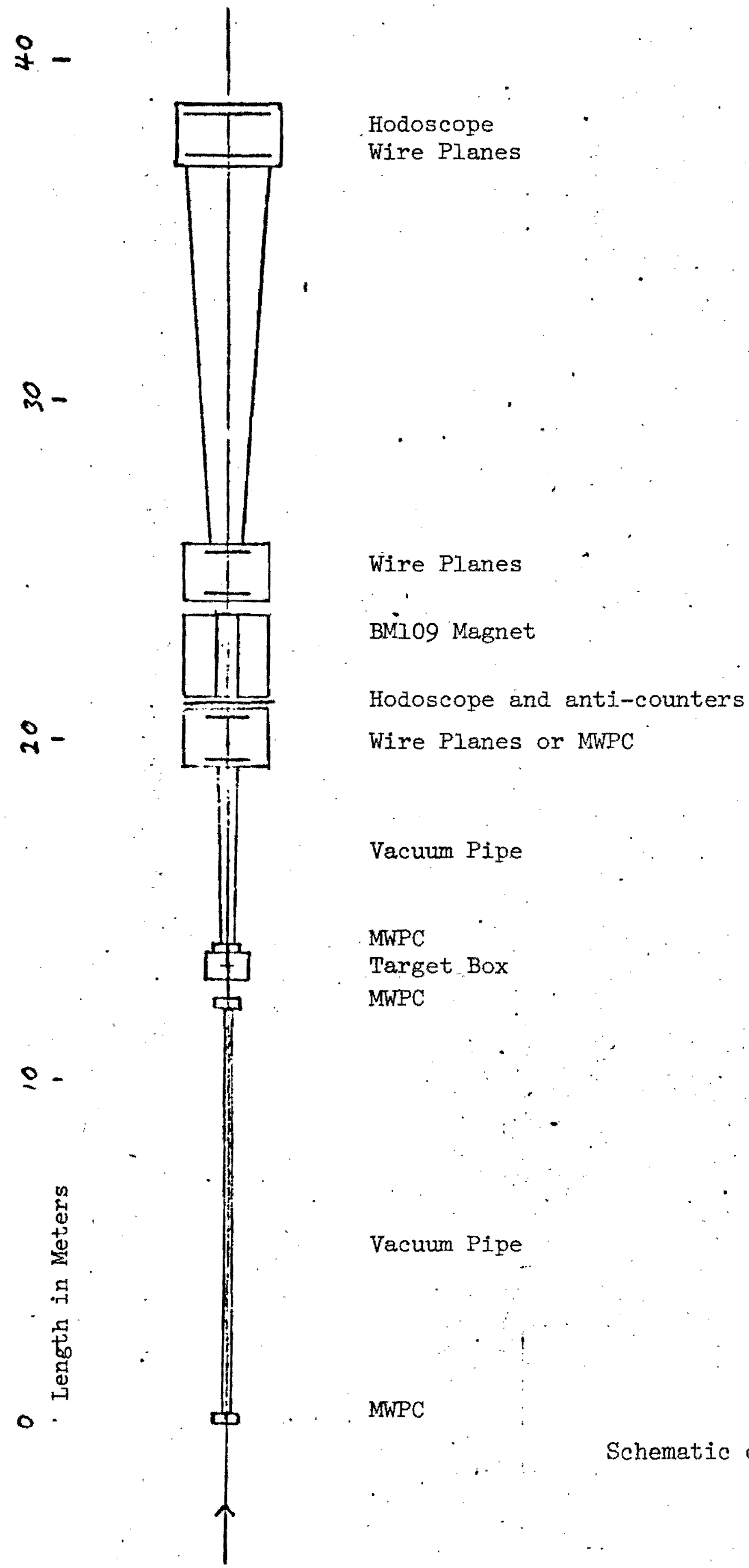


Figure 3

Schematic diagram of apparatus

TARGET COUNTERS

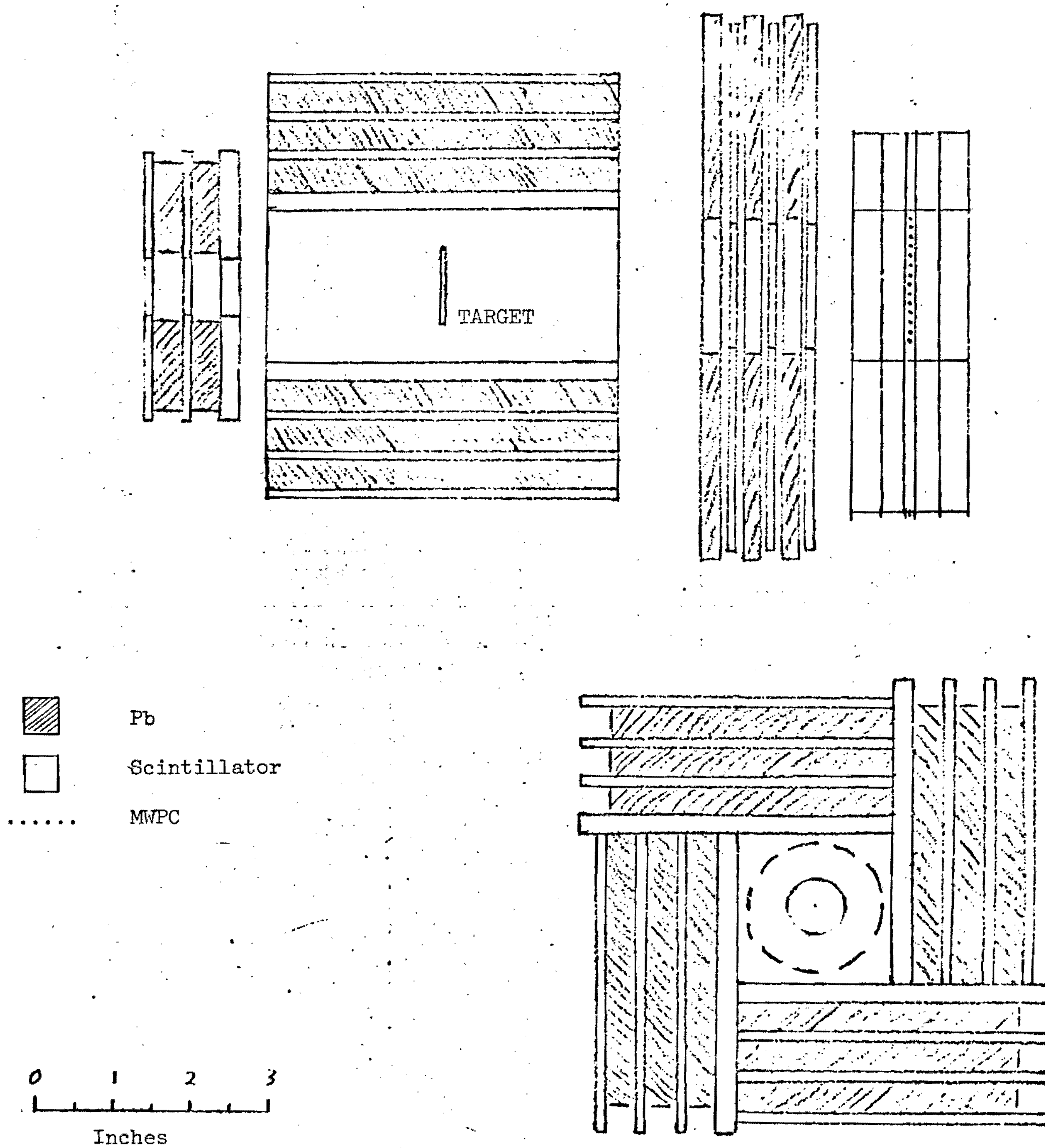


Figure 4