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A Proposal for a $K^- d$ Exposure at 8.25 GeV/c

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SUMMARY

Diffractive coherent production of Q and L. Diffractive production of $N^*(1470)$ and $N^*(1700)$. Quasi two-body reactions; Reconance hunting; inclusive reactions; search for Ξ, Ω and exotic states.

I. Introduction

1) We have been already involved in a 3 GeV/c K^-d experiment as part of the SABRE Collaboration, and this could be an extension of the previous experiment to higher energy with eventually more statistics and the analysis performed by two groups on one measuring machine and with identical set of programs and computers.

2) As far as we know, there is only one K^-d exposure in the momentum range of 6 - 12 GeV/c with moderate statistics[(1)], while many high statistics exposures have been taken and proposed at this momentum region with K^+p, K^-p and K^+d.[(2)]. In particular there is a large K^-p exposure at 8.25 GeV/c taken at the CERN 2 m bubble chamber.[(3)] A high statistics K^-d exposure at 8.25 GeV/c will be a natural complementary experiment.

3) The choice of 8.25 GeV/c is further motivated by the following argument: This energy is high enough compared to the low momentum (3 - 5.5 GeV/c) exposures[(1)], so that phase-space will generally peak above the interesting resonance structures. Moreover, diffractive channels will be relatively more important at this energy than at lower energies, yielding important information on the nature of the diffractively produced Q, L and N^*(1470) effects. (See next chapter for further details). On the other hand, non-diffractive reactions are still expected to be seen at this region in a high-statistics experiments.[(4)]

4) Energy dependence of various reactions can be found by comparison with existing data[(1)] and with a recently proposed high-statistics K^-d exposure of the JHU Group at around 12 GeV/c.[(5)]

II. Specific Points of Interest.

1) Diffractive Coherent Production: In recent results from a 12.6 GeV/c K^-d experiment[(6)], Q and L production are reported in the coherent final state

$$K^- d \rightarrow K^- \pi^+ \pi^- d. \qquad (1)$$

The signal to background ratio is much higher in this pure $I = 1/2$ $K\pi\pi$ system than in similar KN reactions, allowing a meaningful spin-parity analysis. This analysis is easier in coherent channels at high energy because of the suppression[7] of natural J^P series (1^-, 2^+, 3^-...) and due to the smallness of $d^*(2200)$ overlap which goes down fast with increasing energy.[6] In particular we shall try to solve the puzzle of the L-meson, which has been seen in coherent K^-d[6] but not in coherent K^+d experiments.[8,9] The structure within the Q-region claimed by [illegible] K^+d[9] and K^+p[10] data but not by other coherent states ($K^\pm d$ at 12 GeV/c[6,8]) will also be looked for. We shall also test the assumption[11] that $J^{PC} = 2^{++}$ mesons can be produced via Pomeron exchange by searching for a $K^*(1420)$ shoulder next to the Q peak and by separate spin-parity analyses on both sides of the Q-bump.

Estimated cross-sections and number of visible events above background are given in table 1.

2) <u>Diffractive Non-Coherent Production</u>: a) The nature of the Q and L structures will be further checked in the non-coherent final states:

$$K^- n \rightarrow (K^- \pi^+ \pi^-) n \qquad (2)$$

$$(K^- \pi^- \pi^0) p \qquad (3)$$

$$(\bar{K}^0 \pi^- \pi^-) p \qquad (4)$$

In particular we shall try to find whether the Q effect is consistent with one or several of the following hypotheses: resonance interpretation; non-resonant kinematic effect; dual Regge parametrization[12] in the region of small $M(K^*\pi)$ or $M(K\rho)$. Reactions (3-4) are a decisive test for the kinematical hypothesis (See Ferbel, ref. 11). We shall measure the Q and L density matrix elements as function of momentum transfer in the helicity and Jackson frames in order to test s- and t-channel helicity conservation.

b) The existence of a higher (diffractively produced?) $K^*(2200)$, suggested by reference 13, will be also checked in the final states

$$K^-n \to (K(\pi)^n)N; \quad n=1,2,3... \tag{5}$$

$$K^-n \to (\Lambda\bar{p})n \tag{6}$$

c) The diffractive isobar production will be searched for in the πN and $\pi\pi N$ systems in the final states:

$$K^-n \to K^-(\pi^-p) \tag{7}$$

$$\to K^-(\pi^+\pi^-n) \tag{8}$$

$$\to K^-(\pi^o\pi^-p) \tag{9}$$

and will be compared to the non-diffractive channel:

$$K^-n \to \bar{K}^o(\pi^-\pi^-p). \tag{10}$$

The main interest in this study is in the $N^*(1470)$ since there are contradictory results[14] concerning its width, elasticity, slope of diffraction peak and spin-parity, indicating that the enhancement in production experiments may be different from the P_{11} Roper resonance found in phase-shift analyses. In particular, there are some hints that the diffractively produced low-mass object in production experiments may have spin $J > \frac{1}{2}$.[15] The K^-n system is a good place to study isobars since there is only one combination per event contrary to NN or $\pi^{\pm}N$, and since many charge combinations are detectable (reactions 7-10). The 3-body final state (7) has further the advantage that there are no overlapping meson resonances.

Similarly, the nature of the $N^*(1700)$ will be studied, with particular emphasis on the unresolved questions of the spin-parity (there are at least five

N^* and Δ states in this mass region from phase-shift analyses), $\Delta\pi/N\pi\pi$ fraction and width.(14-16)

Estimated cross-sections and number of visible events above background are given in table I.

3) Coherent Non-Diffractive Production: The production mechanism of the reactions

$$K^- d \to K^{*-}(890) d \quad (11)$$

$$\to K^{*-}(1420) d \quad (12)$$

will be studied as well as the energy dependence of the cross-sections and of the density matrix elements. The advantage of these reactions is that they are produced with pure I=0 exchange mechanism (most probably ω exchange); therefore this is a good tool to study this kind of mechanism.

4) $K\pi$ Spectrum: In addition to the well-known $K^*(890)$ and $K^*(1420)$ resonances, some $K\pi$ structures have been reported by various experiments at 1080(17), 1160(4,18), 1260(17), 1370(19), 1750(20) and 1850(21) MeV. We shall search for such effects in the final state:

$$K^- n \to (\bar{K}^0 \pi^-) n \quad (13)$$

as well as in reaction (7). The asymmetry in the decay distribution of the $K\pi$ system in the $K^*(890)$ region and above will also be studied. At our energy we expect to have low background underneath the resonances and little overlap of resonance bands.

5) Quasi-two-body Reactions: The $K^- n$ system provides many quasi-two-body reactions at medium energies(22) which are produced via normal Regge exchange mechanisms (contrary to diffractive processes produced via Pomeron exchange) and consequently their cross-sections go down with the incoming energy. We

still expect to detect at our energy region the more copiously produced reactions with reasonable statistics (Table 2). Most of the numbers in Table 2 are lower limits since they are obtained by assuming an energy dependence for the forward ($\cos\theta^* > 0$) cross-sections[22] of

$$\sigma = c\, P_{lab}^{-n} \qquad (14)$$

with n=2 (usually the exponent varies between 1 and 2) and by neglecting the backward ($\cos\theta^* < 0$) cross-sections.[22] We shall study the cross-sections, angular distributions, energy dependence and production mechanism of the quasi-two-body reactions and parametrize the results according to various theoretical and phenomenological models (single particle and Regge exchange, quark model, etc.). We shall also compare the cross-sections (total and differential) and density matrix elements with similar KN reactions available at similar energies.[2,3] In particular we shall check the deviation from exchange degeneracy in the reactions $K^+p \to K^o\Delta^{++}$ and $K^-n \to \bar{K}^o\Delta^-$.[23]

6) Resonance Hunting: a) Search for 3π structures (A_1, A_2, A_3, etc.) in the 4c reaction:

$$K^-n \to \Lambda(\pi^-\pi^+\pi^-). \qquad (15)$$

A narrow A_2 and traces of the A_1 were found in reaction (15) at 3.9 GeV/c.[24] The non-diffractive nature of the 3π system may provide a unique proof for the resonance interpretation of the A_1 as well as a clean A_2 signal with small background which will enable a meaningful spin-parity analysis, a study of the A_2 production mechanism and a search for the unknown A_2KK^* vertex by isolating the K^* exchange contribution.

b) Search for $\Lambda\pi$ structures above the $\Sigma(1385)$ in reaction (15) ($\Sigma(1620)$, $\Sigma(1768)$, $\Sigma(1915)$ etc.). The $\Sigma(1620)$ was originally seen in reaction (15) at 3.9 GeV/c[25] and also at 4.5 GeV/c[26], but not at 3 GeV/c.[27]

c) Search for the B meson in the reaction[28]

$$K^-n \rightarrow \Lambda(\pi^-\omega);\quad \omega \rightarrow \pi^+\pi^-\pi^o \qquad (16)$$

d) Examination of non-strange structures in the 1 GeV region, e.g.: $\pi_N(980)$ in the reaction[29-31]:

$$K^-n \rightarrow \Lambda(\pi^-\eta);\quad \eta \rightarrow \pi^+\pi^-\pi^o(\gamma) \qquad (17)$$

$$\rightarrow \text{neutrals}$$

and $\pi^+\pi^-\pi^o$ (or γ) effects (M(953), η'(958), H(990)) in the reactions[32,33]:

$$K^-n \rightarrow \Lambda\pi^-(\pi^+\pi^-\pi^o) \qquad (18)$$

$$\rightarrow \Sigma^-\ (\pi^+\pi^-\pi^o)$$

7) <u>Inclusive Reactions</u>: We shall study single particle distributions (p_L, p_T, t, M(X) etc.) in various inclusive reactions, such as:

$$K^-n \rightarrow \bar{K}^o + X^- \qquad (19a)$$

$$\rightarrow \Lambda + X^- \qquad (19b)$$

$$\rightarrow \bar{K}^* + X \qquad (19c)$$

$$\rightarrow \pi^+ + X^{--} \qquad (19d)$$

in order to check the limiting behaviour theoreis of Feynman and Yang[34] while comparing the results with other experiments.[35]

8) <u>Search for Ξ , Ω and Exotic States</u>: In a large statistics K^- experiment one can look for higher Ξ^* resonances as well as for Ω states, although cross sections are expected to be quite low.

a) For each microbarn of the reaction

$$K^-n \rightarrow \Omega^- + \text{anything} \qquad (20a)$$

we expect to have a sample of ∿10 Ω^- with a visible Λ^o in one of the main decay modes

$$\Omega^- \to \Lambda^o K^- \quad , \quad \Xi^- \pi^o \;(\Xi^- \to \Lambda\pi^-) \quad , \quad \Xi^o \pi^- \;(\Xi^o \to \Lambda\pi^o). \qquad (20b)$$

New S=-3 I=0 states can be detected at ∿8 GeV/c up to a mass of ∿2.5 GeV.

b) A search will be done for possible exotic Ω^{--} and $\Xi^{*--}_{3/2}$ states in the final states

$$K^- n \to \Omega^{--} + \ldots \text{ (e.g.: } K^o K^+) \qquad (21a)$$

$$K^- n \to \Xi^{*--}_{3/2} + \ldots \text{ (e.g.: } K^+) \qquad (21b)$$

in the mass range from threshold up to ∿2.5 and ∿3.0 GeV respectively.

c) Higher $\Xi^*_{1/2}$ states will be looked for in the reactions

$$K^- n \to \Xi^* + \ldots \text{ (e.g.: } K \text{ or } K^*) \qquad (22)$$

d) Exotic states of strange and non-strange mesons and S=-1 and S=-2 hyperons will be looked for up to higher mass ranges than before.[36]

III. Experimental Details.

We request at the first stage 300,000 pictures to be taken in the CERN 2 meter deuterium bubble-chamber. For a flux of 10 K^- mesons per picture we expect to get ∿16 events/μb/nucleon which will yield a total of ∿300,000 $K^- n$ events. The measurements will be performed on our Spiral Reader, which is already in full operation and measures 24 hours per day, 50 events per hour (this number will soon be improved by ∿50%). We shall thus be able to finish all measurements in ∿12-18 months. At a later stage we plan to ask for an extension up to a total of one million pictures, provided preliminary results will justify it.

Our computing power includes 2 IBM 370/165 machines, one at the Weizmann Institute and one at the Technion, so we do not anticipate any computer time problems.

Our manpower includes in both groups 8 physicists, 4-5 Ph.D. students, 5-6 programmers and more than 20 scanning and measuring staff. About half the manpower will be working on this proposed experiment.

Table 1. Diffractive Reactions*)

Estimated cross-sections and number of visible events above background for 16 events/μb.

Reaction	Estimated cross section μb	Estimated no. of visible events
$K^-d \rightarrow Q^-d \rightarrow K^-\pi^+\pi^-d$	100	1600
$\rightarrow L^-d \rightarrow K^-\pi^+\pi^-d$	20	320
$K^-n \rightarrow Q^-n \rightarrow K^-\pi^+\pi^-n$	250	4000
$\rightarrow L^-n \rightarrow K^-\pi^+\pi^-n$	40	640
$K^-n \rightarrow K^-N^*(1470) \rightarrow K^-n\pi^+\pi^-$	30	480
$\rightarrow K^-N^*(1.2\text{-}1.6) \rightarrow K^-\pi^-p$	100	1600

*) The diffractive cross-sections are estimated from $K^\pm$ results of adjacent regions, assuming no energy dependence.

Table 2. Non-Diffractive Reactions[†]

Estimated cross-sections and number of visible events above background for 16 events/μb

Reaction	Estimated cross section μb	Estimated no. of visible events
$K^- n \to K^{*-}(890) n \to \bar{K}^o \pi^- n$	70	370
$\to K^{*-}(1420) n \to \bar{K}^o \pi^- n$	30	160
$\to \bar{K}^o \Delta^-(1236) \to \bar{K}^o \pi^- n$	55	290
$\to \bar{K}^{*o}(890) \Delta^-(1236) \to K^- \pi^+ \pi^- n$	110	1760
$\to \bar{K}^{*o}(1420) \Delta^-(1236) \to K^- \pi^+ \pi^- n$	48	770
$\to \pi^- \Lambda(1405)$	11	170
$\to \pi^- \Lambda(1520)$	20	250
$\to \pi^- \Lambda(1815)$	14	150
$\to \rho^o \Sigma^- \to \pi^+ \pi^- \Sigma^-$	10	160
$\to \omega^o \Sigma^- \to \pi^+ \pi^- \pi^o \Sigma^-$	7	110
$\to B^- \Lambda \to \omega \pi^- \Lambda \to \pi^+ \pi^- \pi^o \pi^- \Lambda$	13	140
$\to \Lambda \pi^-$ [††]	10	110
$\to \Sigma^o \pi^-$ [††]	14	150
$\to \Sigma^- \pi^o$ [††]	14	220
$K^- d \to K^- \pi^+ d^{*o} \to K^- \pi^+ \pi^- d$ [†††]	17	270
$\to K^{*-}(890) d \to \bar{K}^o \pi^- d$ [†††]	23	120

[†] Lower limits obtained by assuming a $\sigma \sim P_{lab}^{-2}$ dependence for the forward ($\cos\theta^* > 0$) cross-sections and neglecting the backward ($\cos\theta^* < 0$) cross-sections.

[††] Obtained by extrapolation from ref. 37. In the Σ cases, pure I=1/2 K or K^* exchange is assumed.

[†††] Derived from $\sigma \sim P_{lab}^{-n}$ dependence, where n is estimated in each reaction separately from results of two $K^- d$ existing experiments at different incoming energies.[1]

REFERENCES

1. 3 GeV/c at Saclay 81 cm BC, SABRE Collaboration, 1965 ∿650K pictures;
3.6, 3.9 GeV/c at BNL 80" BC, BNL, 1967 ∿280K pictures;
4.5 GeV/c at ANL 30" BC, Purdue, 1967 ∿400K pictures;
5 GeV/c at ANL 30" BC, Carnegie-Mellon University and others, 1967-1970, ∿400K pictures;
5.5 GeV/c at ANL 30" BC, Northwestern University, 1968 ∿425K pictures;
7.3 GeV/c at BNL 80" BC, Colorado, 1970 ∿126K pictures (additional 74K approved);
12.6 GeV/c at BNL 80" BC, JHU, 1966 ∿120K picture.

2. 9 GeV/c K^+p at BNL 80" BC, LRL 1968 ∿200K pictures;
10 GeV/c K^+p at CERN 2 m BC, CERN 1966 ∿200K pictures;
12 GeV/c K^+p at SLAC 82" BC, LRL 1968 ∿650K pictures;
7 GeV/c K^-p at CERN, BEBC ∿1000K pictures (proposal CERN/TCC/71-25);
10 GeV/c K^-p at CERN 1.5 and 2 m BC, CERN, 1965-1969 ∿750K pictures;
9 GeV/c K^+d at BNL 80" BC, Davis-Purdue, 1969-1970 ∿420K pictures;
12 GeV/c K^+d at SLAC 82" BC, LRL, 1969 ∿500K pictures.

3. 8.25 GeV/c at CERN 2 m BC, 1966 and 1969 ∿270K pictures.

4. V. Gordon Lind, G. Alexander, A. Firestone, C. Fu and G. Goldhaber, Nucl. Phys. B14, 1 (1969); C. Fu, "Resonance Productions in K^+p Interactions at 4.6 GeV/c and 9 GeV/c" Ph.D. Thesis, UCRL-19809 (1970).

5. SLAC Proposal No. BC-34, Johns-Hopkins University (spokesman: A. Pevsner).

6. D. Denegri, et al., Nucl. Phys. B28, 13 (1971).

7. D.R.O. Morrison, Phys. Rev. 165, 1699 (1968).

8. C-Y Chien in Experimental Meson Spectroscopy, Columbia University Press, C. Baltay and A. Rosenfeld, eds. (1970); G. Goldhaber "Selected topics on Boson Resonances", Frice Lecture Notes, July (1971).

9. A.F. Garfinkel, et al., Phys. Rev. Letters 26, 1505 (1971).

10. G. Alexander, A. Firestone, G. Goldhaber and D. Lissauer, Nucl. Phys. B13, 503 (1969).

11. T. Ferbel "Diffraction Production of Bosons", UR-875-337 Preprint (1971); P.G.O. Freund, H.F. Jones and R.J. Rivers, Phys. Letters 36B, 89 (1971).

12. E.L. Berger, Phys. Rev. Letters 21, 701 (1968).

13. D. Lissauer et al., Nucl. Phys. B18, 491 (1970); P. Slattery, "A Review of Strange Mesons", Report Number UR-875-332, University of Rochester (1971).

14. Particle Data Group, Rev. Mod. Phys. 43, S1 (1971).

15. J.I. Rhode, R.A. Leacock, W.J. Kernan, R.A. Jespersen and T.L. Schalk, Phys. Rev. 187, 1844 (1969); E. Colton, P.E. Schlein, E. Gellert and G.A. Smith, Phys. Rev. D3, 1063 (1971); J. Mickenberg, "$N\pi\pi$ enhancements in K^-d interactions at 3 GeV/c", M.Sc. Thesis, Weizmann Institute, (1971), unpublished; see also R. Morse et al., Phys. Rev. D4, 133 (1971).

16. D.R.O. Morrison, Rapporteur's Talk at the 15th International Conference on High Energy Physics, Kiev (1970);
K. Boesebeck et al., Nucl. Phys. B33, 445 (1971).

17. W.P. Dodd, T. Joldersma, R.B. Palmer and N.P. Samios, Phys. Rev. 177, 1991 (1969).

18. D.J. Crennell, U. Karshon, K.W. Lai, J.S. O'Neall and J.M. Scarr, Phys. Rev. Letters 22, 487 (1969).

19. A. Firestone, G. Goldhaber and D. Lissauer, Phys. Rev. Letters 26, 1460 (1971).

20. D.D. Carmony et al., Bull. Am. Phys. Soc. 16, 826 (1971).

21. A. Firestone et al., Phys. Letters 36B, 513 (1971).

22. SABRE Collaboration (J.C. Scheuer et al.), "Experimental Study of Two-Body and Quasi-Two-Body Reactions in K^-n Interactions at 3 GeV/c", Nucl. Phys. B33, 61 (1971).

23. K.W. Lai and J. Louie, Nucl. Phys. B19, 205 (1970); C. Fu, J. Macnaughton and G.H. Trilling, Nucl. Phys. B28, 528 (1971).

24. D.J. Crennell, U. Karshon, K.W. Lai, J.S. O'Neall and J.M. Scarr, Phys. Rev. Letters 22, 1327 (1969).

25. D.J. Crennell et al., Phys. Rev. Letters 21, 648 (1968) and BNL 13681 preprint (May 1969).

26. A.C. Ammann, A.F. Garfinkel, D.D. Carmony, L.J. Gutay, D.H. Miller, and W.L. Yen, Phys. Rev. Letters 24, 327 (1970).

27. SABRE Collaboration (R. Barloutaud et al.), Nucl. Phys. B16, 201 (1970).

28. SABRE Collaboration (W. Hoogland et al.), Phys. Letters 33B, 631 (1970).

29. D.J. Crennell et al., Phys. Rev. Letters 22, 1398 (1969).

30. W.L. Yen et al., Phys. Rev. 188, 2011 (1969).

31. R. Ammar et al., Phys. Rev. D2, 430 (1970).

32. SABRE Collaboration, "Study of a Neutral Three-Pion Enhancement Near 1 GeV in K^-n Interactions at 3 GeV/c", submitted to the Kiev Conference (1970) and Weizmann 70/37 HEP report.

33. M. Aguilar-Benitez et al., Phys. Rev. Letters 25, 1635 (1970).

34. R.P. Feynmann, in High Energy Collisions, ed. C.N. Yang et al. Gordon and Breach (1970); J. Benecke et al., Phys. Rev. 188, 2159 (1969).

35. See for example: P. Chliapnikov, O. Czyzewski, J. Finkelstein and M. Jacob, Phys. Letters 35B, 581 (1971); R. Blokzyl and J.C. Kluyver, Amsterdam preprint (1971); S. Stone, T. Ferbel, P. Slattery and B. Werner, UR-875-439 preprint (1971).

36. SABRE Collaboration (G. Giacomelli et al), Phys. Letters 33B, 373 (1970) and Bologna Internal Report INFN/AE-70/9.

37. E. Flaminio et al. (High Energy Reactions Analysis Group), CERN/HERA 70-6 (1970).