NAL PROPOSAL No. 85

Correspondent: L. J. Gutay
Department of Physics
Purdue University
Lafayette, Indiana 47907

FTS/Off-net: 317-633-7000
749-2961

PROPOSAL FOR AN EXPOSURE OF THE 15 FOOT DEUTERIUM FILLED BUBBLE CHAMBER TO A BEAM OF SEPARATED π^+ MESONS AT 40 GeV/c at N. A. L.

V. E. Barnes
D. D. Carmony
R. S. Christian
A. F. Garfinkel
J. A. Gaidos
L. J. Gutay
S. Lichtman
F. J. Loeffler
R. L. McIlwain
D. H. Miller
T. R. Palfrey
R. B. Willmann
D. Cords
J. Lamsa
K. Paler
K. Rangan
J. H. Scharenguivel
A. C. Ammann
H. R. Barton, Jr.
R. DeBonte
C. R. Ezell
R. F. Holland
S. Kramer
W. J. Miller
T. A. Mulera
J. Tebes

Purdue High Energy Physics Group

July 21, 1970

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Group: Purdue High Energy Physics Group

Person to contact: L. J. Gutay

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ABSTRACT

The purpose of this experiment is twofold.

1. We intend to study production mechanisms and properties of reactions where there are an even number of visible pions and a visible nucleon in the final state. We will use these reactions to obtain information on:
   a) G parity of high mass bosons.
   b) Study the multiperipheral chain in $\pi\pi$ scattering a la Amati-Fubini-Stanghellini and Chew-Goldberger-Low
   c) Study the properties of Pomeron exchange in $\pi\pi$ scattering
   d) Test of the Vector Dominance Model
   e) Spin Parity Determination of Higher Boson Resonances
   f) Search for unexpected new phenomena.
2. We concurrently propose a hybrid system. It is essential to understand the origin of possible biases in such a system. Since no experimental results exist in the 40 GeV region which has bearing on the $\pi\pi N$ final state, it is essential to carry out a large statistics bias free inelastic πN scattering experiment. It is of interest to all counter and spark chamber groups who intend to study the $\pi\pi N$ final state.

We request a <u>separated</u> π^+ beam and a deuterium filled chamber. We will need on the order of 600,000 pictures to obtain reasonable statistics, although this quantity may need modification depending on possible collaboration with other groups who have a scanning or measuring facility comparable to ours.

Names of Experimenters

The Purdue High Energy Group consists of the following members:

Professors:	V. E. Barnes	Doctors:	D. Cords
	D. D. Carmony		J. Lamsa
	R. S. Christian		K. Paler
	A. F. Garfinkel		K. Rangan
	J. A. Gaidos		J. H. Scharenguivel
	L. J. Gutay		
	S. Lichtman	Messrs:	A. C. Ammann
	F. J. Loeffler		H. R. Barton, Jr.
	R. L. McIlwain		R. DeBonte
	D. H. Miller		C. R. Ezell
	T. R. Palfrey		R. F. Holland
	R. B. Willmann		S. Kramer
			W. J. Miller
			T. A. Mulera
			J. Tebes

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This proposal is submitted by L. J. Gutay (Purdue High Energy Physics Group).

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Physics Justifications

The principal aim of the proposed experiment is to study the production mechanism and properties in the full angular region of reactions where there are an even number of pions in the final state. The errors in momentum measurements result in a large uncertainty in the missing mass. Thus it is unlikely that 1C fits in π^+p reactions will be of much value. Therefore we propose to study π^+d reactions, making use of the bound neutron to obtain:

$$\pi^+N \rightarrow n\pi + p + p_s \quad (n \text{ even}) \qquad (1)$$

The type of reaction expressed in Eq. 1 contains an even number of pions and at the same time affords 4C fits.

Our interest in even-number boson final states is many fold. In what follows we detail them in the context of our previous experimental work on $\pi^+\pi^-$ interactions and theoretical importance.

Multi-pion Final States.

a) Recent results of the CERN Boson Spectroscopy Group indicates an unending number of narrow boson states[1]. Since only the recoiling nucleon is detected, no information has been obtained about the G parity of these resonances. At 13.1 GeV/c we have succeeded to identify some of the CBS peaks in the fitted $\pi^+\pi^0$ final state[2], and obtained the G parity of S and T. Thus, we expect to fit the $n(\pi^+ + \pi^-) + p + p_s$ final state at an incident beam momentum of 40 GeV/c, extending the G parity determination to higher masses.

b) We know, that at present accelerator energies pions are the most copiously produced particles. Further, we have spent several years investigating contribution of one pion exchange to the single pion production amplitude. We found that after we incorpprated off-mass-shell[3] and absorption effects[4] into our analysis we could describe single pion production in certain kinematic regions as a result of $\pi\pi$ elastic scattering. Thus, we expect that a

generalization of this model to multi-pion production will be successful as well. But the reaction

$$\pi^+ + \pi_{off} \rightarrow n(\pi^+\pi^-) \qquad \text{(n is an integer)} \qquad (2)$$

can be regarded as an iteration of the process

$$\pi^+ + \pi^-_{off} \rightarrow \pi^+\pi^- \qquad (3)$$

and obtain the multipheripheral chain of the Amati-Fubini-Stanghellini type[5], or its generalization by Chew, Goldberger and Low[6].

c) It is a general feature of this model that the resulting integral equation has a kernel which is the elastic off-shell $\pi\pi$ scattering cross section[7]. We have determined the off-mass-shell dependence of the S-wave $\pi^+\pi^-$ scattering amplitude below the 1 GeV region[3]. Our conclusion is that where the amplitude is mainly imaginary, the off-mass-shell dependence is slight, while it is large in a region where the amplitude is dominantly real. Since at high energies the amplitudes are dominantly imaginary, we hope this will not cause insoluble problems.

d) Combining the theoretical ideas and experimentally accessible results discussed in paragraph b and c, we intend to pursue an extensive study of the reactions that contain $2(\pi^+\pi^-)$, $3(\pi^+\pi^-)$ and $4(\pi^+\pi^-)$ final states. With sufficient statistics accumulated we hope to determine in what kinematic region and to what extent one pion exchange multipheripheral chains approximate physical reality, or perhaps to suggest modifications of the theoretical ideas[4] as was done in the case of $\pi^+_{off} + \pi^- \rightarrow \pi^+\pi^-$.

Two Pion Final States

a) Another rather unclear ingredient of some versions of the model is the Pomeron contribution. In Reference 7 it enters as an input; in Reference 8 it is an output of the model. We propose to study this in the dipion final state. In our 13.1 GeV/c experiment[2] we have already found a clear onset of P contribution to $\pi^+\pi^0$ scattering, resulting in an extremely asymmetric $\pi^+\pi^0$ angular distribution even in the S and T resonance region. We are in

the process of deducing the properties of the P from our $\pi^+\pi^o$ angular distribution. A more accurate value for α_p can be obtained, however, at 40 GeV because of the availability of higher dipion masses.

b) The availability of high energy photon beam revived theoretical as well as experimental interest in the Vector Meson Dominance Model[9]..(V.M.D.). Time reversal invariance and V.M.D. related the

$$\gamma + N \rightarrow \pi + N \qquad (4)$$

$$\pi + N \rightarrow \rho_{tr} + N \qquad (5)$$

reaction amplitudes. First we tested V.M.D. by comparing the asymmetry parameter, obtained in polarized photopion production, with the ρ^o production density matrix elements in the helicity frame[10]. It indicated that if V.M.D. is to hold, mass extrapolation must be taken into account[11]. Sudden rise in the photopion production cross section would imply a similar rise in the transverse ρ^o differential cross section. At low incident beam momentum it is not possible to measure directly the shape of the differential cross section for momentum transfers less than μ^2 because the minimum momentum transfer is large. Thus we relied on the theoretical result that Ball's invariant amplitudes[12] have no kinematical singularities and the experimental fact that the reduced Ball amplitudes, after explicit kinematic factors are separated out, vary smoothly as a function of Δ^2 in the One Pion Exchange frame. Using the above facts and an extrapolation method in the O.P.E. frame we observed a forward peak in the helicity frame[13].

At high energies the minimum momentum transfer is extremely small, and thus the above test can be carried out without relying on extrapolation. We are aware of the problem caused by the deuterium target.

c) Finally, when sufficient statistics are collected, we hope to determine the spin and parity of the higher mass resonances in the dipion final states indicated by the C.B.S.

d) We propose concurrently another hybrid system experiment. Once we learn about the production mechanism in a bias free bubble chamber, we hope

to use this information in a bias free triggered chamber experiment.

e) Finally, we hope to learn some completely new and unexpected phenomenon. Since we do not know what it might be, we do not want to speculate here.

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