Friday Afternoon Journal Club:

"Vector-Meson Production by Polarized Photons at 2.8, 4.7, and 9.3 GeV", PRD **7** 3150 (1973).

D. Mack (TJNAF)

6/12/15

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Vector-Meson Production by Polarized Photons at 2.8, 4.7, and 9.3 GeV*

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(Received 13 November 1972)

We present results on vector-meson photoproduction via $\gamma p \to Vp$ in the LBL-SLAC 82-in. hydrogen bubble chamber exposed to a linearly polarized photon beam at 2.8, 4.7, and 9.3 GeV. We find ρ^0 production to have the characteristics of a diffractive process, i.e., a cross section decreasing slowly with energy and a differential cross section with slope of ~ 6.5 GeV^{-2}. Within errors the ρ^0 production amplitudes are entirely due to natural-parity exchange. s-channel helicity is conserved to a high degree in the $\gamma \to \rho^0$ transition. We find evidence for small helicity-flip amplitudes for $\pi\pi$ pairs in the ρ^0 region. Photoproduction of ω mesons is separated into its natural- (σ^N) and unnatural- (σ^U) parity-exchange contributions. The E_γ and t dependence and the spin density matrix of the unnatural-parity-exchange contribution are consistent with a one-pion-exchange process. The natural-parity-exchange part has characteristics similar to ρ^0 production. At 9.3 GeV the ratio of $\sigma(\rho^0)$ to $\sigma^N(\omega)$ is ~ 7. The slope of the ϕ differential cross section is ~ 4.5 GeV^{-2}, smaller than that of ρ^0 and ω production. Natural-parity exchange is the main contributor to ϕ production. No evidence for higher-mass vector mesons is found in $\pi\pi$, $\pi\pi\pi$, or $K\bar{K}$ final states. The s and t dependences of Compton scattering as calculated from ρ, ω, and ϕ photoproduction using vector-meson dominance agree with experiment, but the predicted Compton cross section is too small by a factor of 2.

I. INTRODUCTION

We have studied the photoproduction of hadrons by monochromatic linearly polarized photons at 2.8, 4.7, and 9.3 GeV by exposing the LBL-SLAC 82-in. hydrogen bubble chamber to the SLAC backscattered laser beam. We obtained, respectively, 92, 150, and 275 events/μb at the three energies. Here we present data on vector-meson photoproduction in the reactions

$\gamma p \to p\rho^0$,

$\gamma p \to p\omega$,

$\gamma p \to p\phi$,

counted for, for example, in the vector-dominance model[10] (VDM) by a direct $\gamma \to \rho^0$ coupling, followed by a diffractive scattering of the ρ^0 from the target. Whatever mechanism is postulated, however, the use of polarized photons allows us to study the spin structure of the amplitudes involved by analyzing the ρ^0 polarization.

In Ref. 1 we found that ρ^0 photoproduction proceeds through natural-parity exchange in the t channel. Similar conclusions were reached in counter experiments with polarized beams.[11,12] We showed also that the dominant amplitudes for the γ-ρ^0 transition conserve the s-channel helicity of the photon. In our new data at 9.3 GeV we confirm these observations and also observe small

some context

The SLAC Polarized Gamma Facility

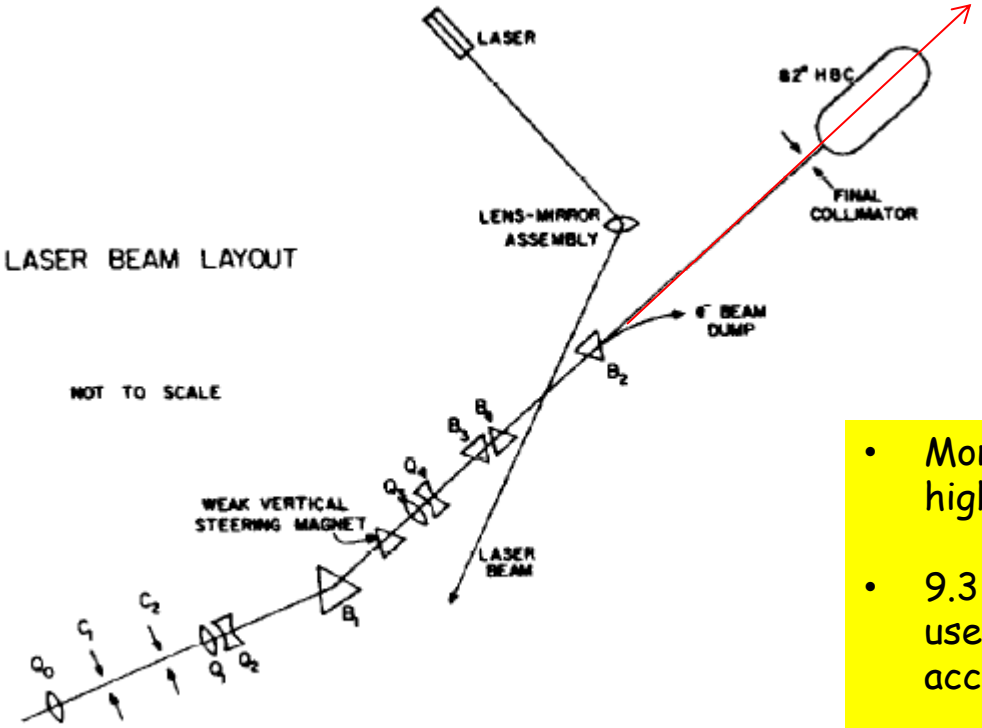

Figure 1

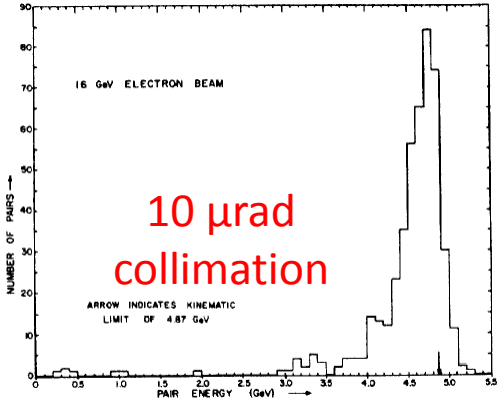

Figure 3

- Mono-energetic (if broad) gamma beam with high linear polarization.
- 9.3 GeV was their technical limit; they had to use a frequency doubling xtal and push the accelerator energy.
- 82" LH_2 bubble chamber detection (hence no photons observed; π^0 by Mx only)

E Ruby Laser	E Primary e-	E Backscatt. Gamma	Polarization
1.78 eV	12 GeV	**2.8 GeV**	**93%**
1.78 eV	16 GeV	**4.7 Gev**	**91%**
2x1.78 eV	19 GeV	**9.3 GeV**	**77%**

•A polarized photon beam for the SLAC 82-inch hydrogen bubble chamber
C.K. Sinclair (Tufts U.), J.J. Murray, P.R. Klein (Stanford U., Phys. Dept.), M. Rabin (UC, Berkeley). 1969.
Published in **IEEE Trans.Nucl.Sci. 16 (1969) 1065-1068**
DOI: 10.1109/TNS.1969.4325441
Presented at Conference: C69-03-05 Proceedings References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
•Full-text at JACoW Server

Where This Talk (Sort of) Fits In

Date/ Lead Paper	Supple-mental Paper	ρ(770)	ω(782)	ϕ(1020)	Excited ρ's	Etc.
5/29/15 Shepherd PRL **53** 751 (1984)	PRL **103** 231801 (2009)				$\pi^+\pi^-$	
					.	
					.	

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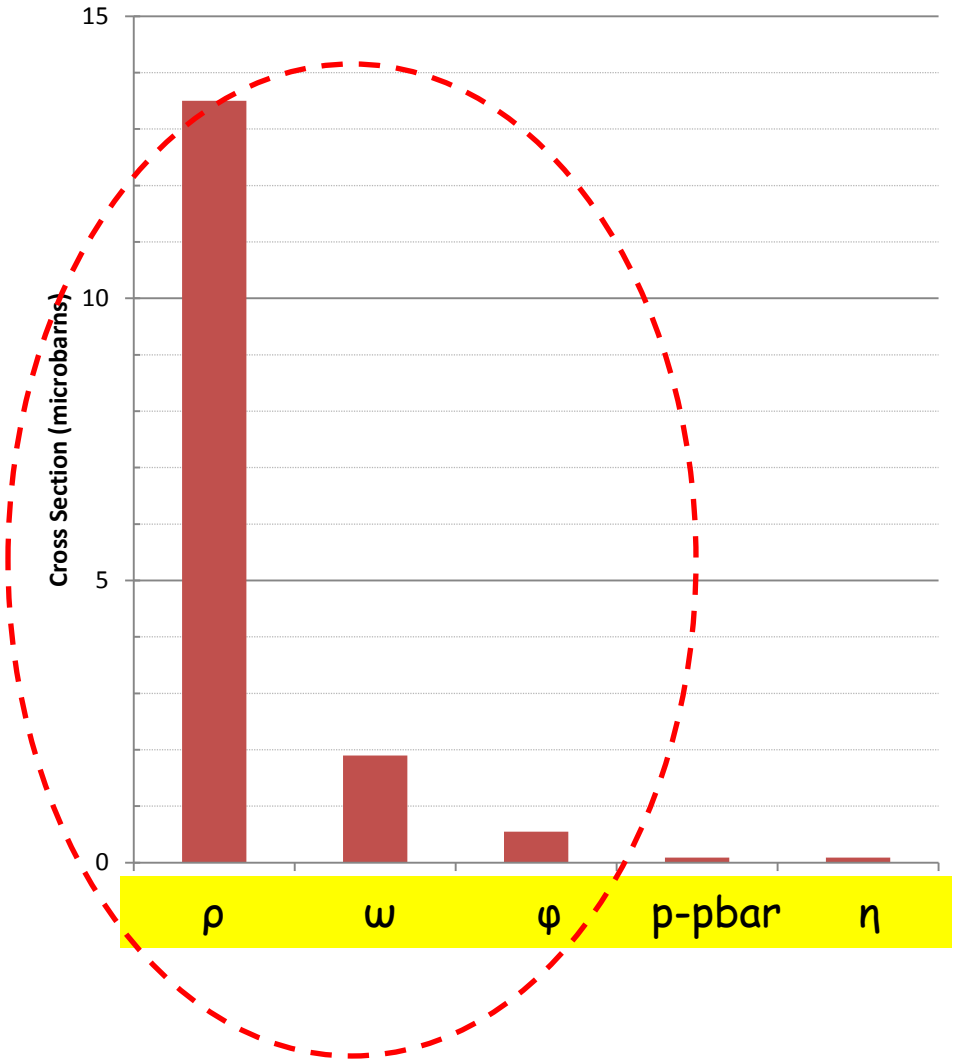
5/29/15 Shepherd PRL **53** 751 (1984)	PRL **103** 231801 (2009)				$\pi^+\pi^-$	
6/12/15 Mack PRD **7** 3150 (1973)		$\pi^+\pi^-$	$\pi^+\pi^-\pi^0$	K^+K^-		
					.	
??? ZPC 33, 407-417 (1987)					4π	

Other than for didactic purposes, I thought this paper (thanks, Justin) might suggest early contributions GlueX could make near 9.3 GeV, e.g., the -t dependence of the asymmetry.

Forward Light Meson Photoproduction Xsects at 9.3 GeV

Values from compilation by A.R. Dzierba, GlueX-doc-835-v1



These are big signals:

up to 10% of the ~125 μbarn total hadronic xsect at this energy.

But is there low-hanging fruit for an early GlueX publication?

on to the paper

ρ: γ + p → p + $\pi^+\pi^-$

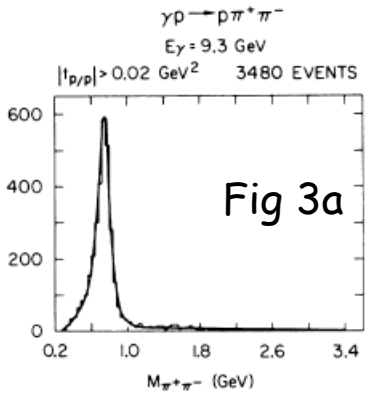


Fig 3a

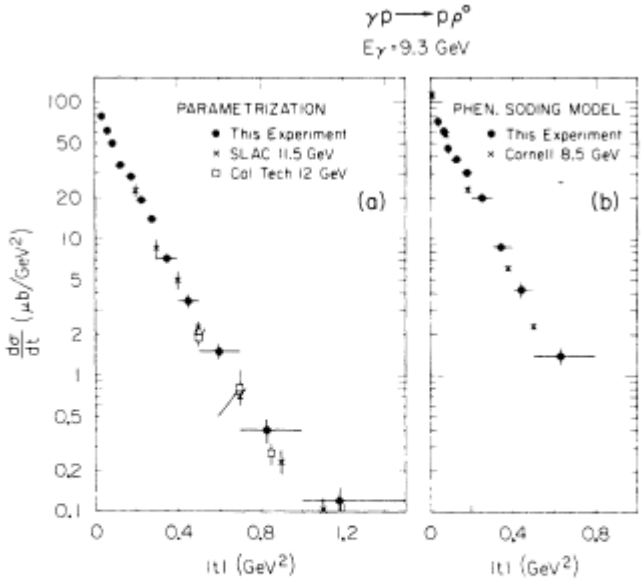


FIG. 9. Reaction $\gamma p \to p\rho^0$ at 9.3 GeV. Differential cross sections from (a) parametrization method and (b) phenomenological Söding model. The points labeled SLAC 11.5 GeV, Caltech 12 GeV, and Cornell 8.5 GeV are from Refs. 8, 30, and 9, respectively.

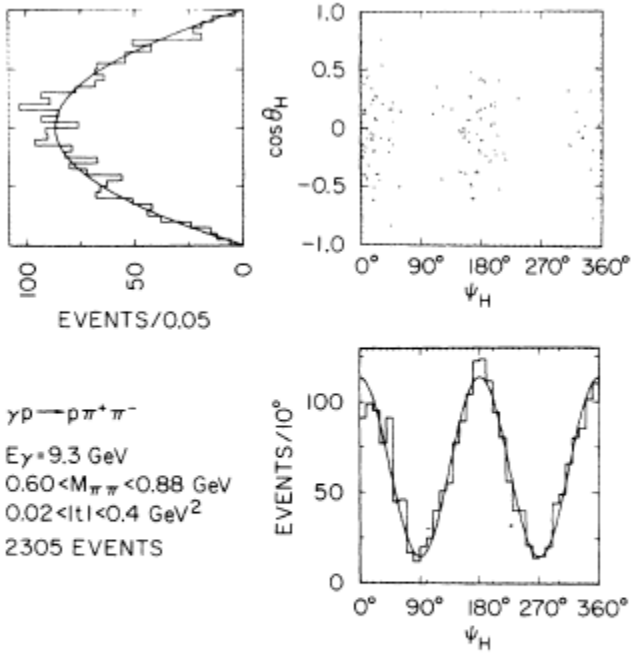


FIG. 7. Reaction $\gamma p \to p\rho^0$ at 9.3 GeV. Decay angular distribution of events in the ρ^0 region in the helicity system. The curves are calculated for an s-channel helicity-conserving $\gamma \to \rho^0$ transition and incident photon polarization of 77%.

ρ′ misc.

This 1973 work didn't have much sensitivity.

The 1984 paper Matt covered last time had higher statistics around $M_{2\pi} \sim 1.5$ and suggested *something* was going on. (I wonder if they made a plot like that on the right.)

The 1987 suggested paper by Ryan found two resonances with the best signatures in 4π.

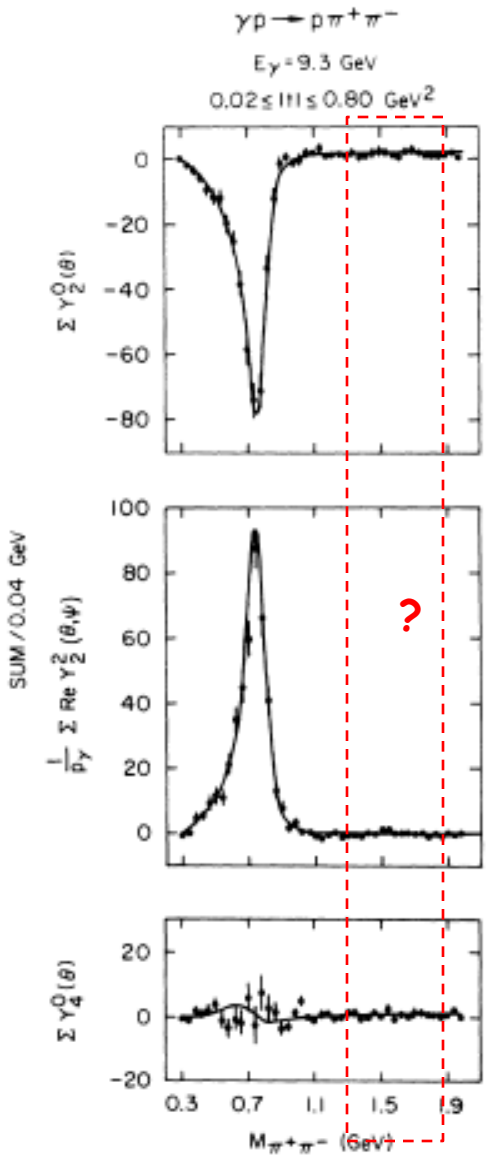


FIG. 8. Reaction $\gamma p \to p\pi^+\pi^-$ at 9.3 GeV. The dipion moments $Y_2^0(\theta, \psi)$, $\mathrm{Re}Y_2^2(\theta, \psi)$, and $Y_4^0(\theta, \psi)$ in the helicity system as a function of $M_{\pi^+\pi^-}$ for $0.02 \leq |t| \leq 0.8$ GeV^2. The curves were obtained from the Söding model.

ω: γ + p → p + $\pi^+\pi^-$ (π^0)

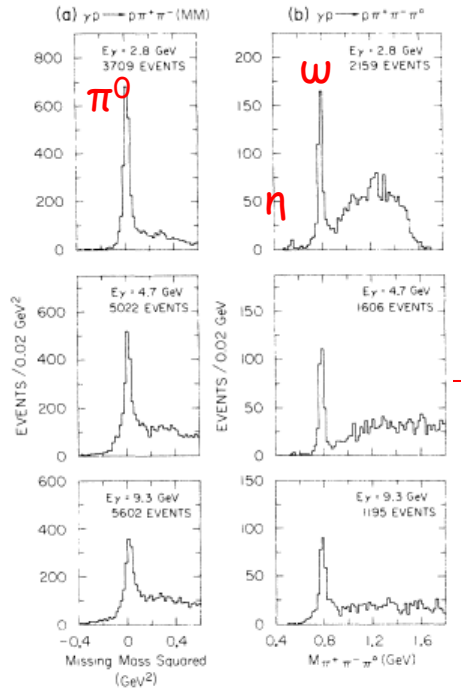
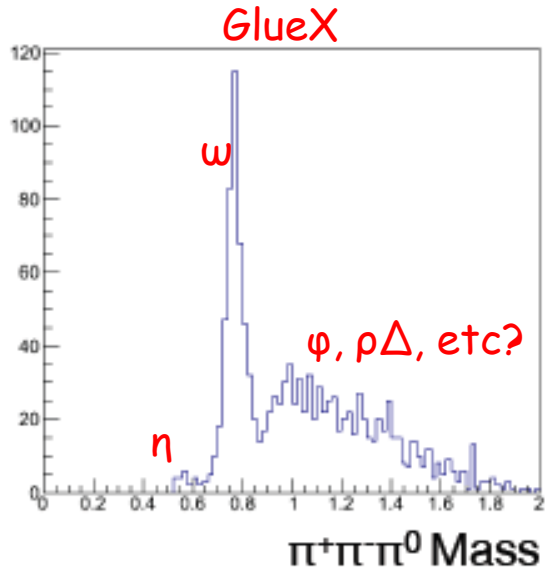


FIG. 16. Reaction $\gamma p \to p\pi^+\pi^-$MM at 2.8, 4.7, and 9.3 GeV. (a) Distribution of the square of the missing mass, MM^2, for 3-prong events not fitting $\gamma p \to p\pi^+\pi^-$, $\gamma p \to pK^+K^-$, or $\gamma p \to pp\bar{p}$ and consistent with $\gamma p \to p\pi^+\pi^-\pi^0$. (b) $\pi^+\pi^-\pi^0$ mass distribution from a 0-constraint calculation for events in (a) with MM$^2 < 0.1$ GeV^2. At 2.8 and 4.7 GeV a selection was also made on the calculated photon energy ($2.4 \le E_\gamma \le 3.3$ GeV and $4.1 \le E_\gamma \le 5.3$ GeV, respectively).



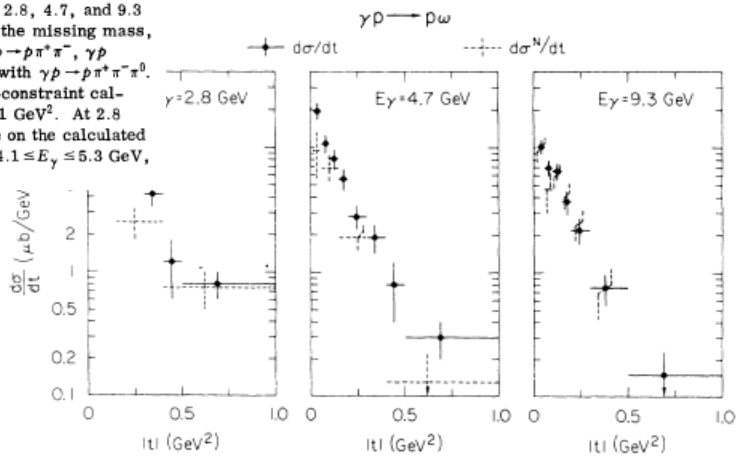


FIG. 19. Reaction $\gamma p \to p\omega$ at 2.8, 4.7, and 9.3 GeV. Differential cross sections (●) and natural-parity-exchange contributions to the differential cross section (---).

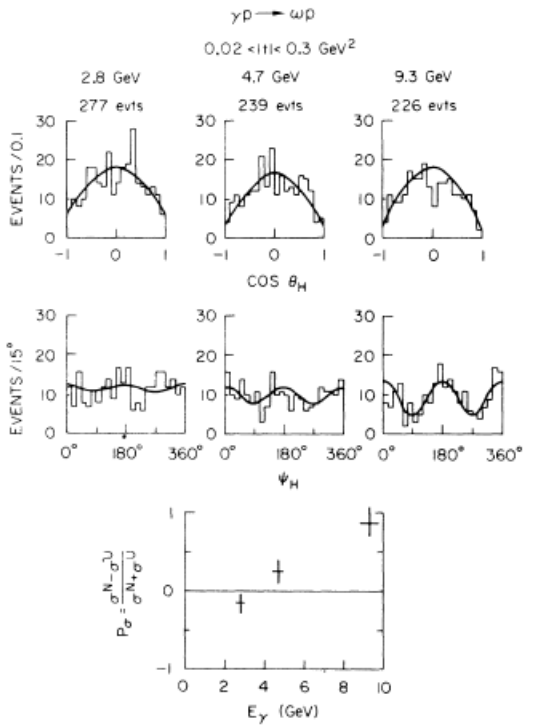


FIG. 21. Reaction $\gamma p \to p\omega$ at 2.8, 4.7, and 9.3 GeV. Decay angular distributions in the helicity system and parity asymmetry P_σ for events in the ω mass region $0.74 \le M_{\pi^+\pi^-\pi^0} \le 0.84$ GeV and in the momentum-transfer interval $0.02 \le |t| \le 0.3$ GeV^2. Curves are calculated from the fitted density matrix elements (see text).

Statistics on xsect and asymmetry look scruffy near 9.3 GeV.
Is this M. Staib's thesis?

ω' misc.

Focus on highest beam energy a la GlueX:

- the lower -tmin makes production by t-channel exchange more efficient
- plus better separation of current and target fragments (next slide)

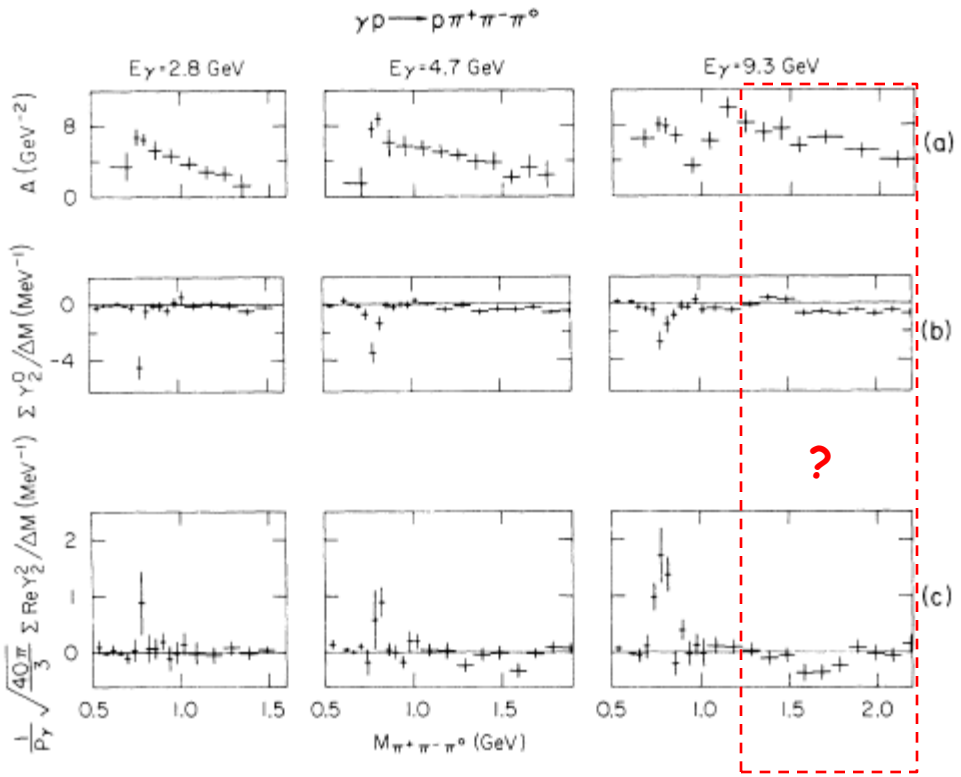


FIG. 18. Reaction $\gamma p \to p\pi^+\pi^-\pi^0$ at 2.8, 4.7, and 9.3 GeV. (a) Slope A of the t distribution of the $\pi^+\pi^-\pi^0$ system as calculated from a fit of the form e^{At} as a function of $\pi^+\pi^-\pi^0$ mass. (b), (c) Moments $Y_2^0(\theta)$, $\mathrm{Re}Y_2^2(\theta, \psi)$ of the $\pi^+\pi^-\pi^0$ system in the helicity system as a function of $\pi^+\pi^-\pi^0$ mass.

Overlap of Current and Target Fragments in $\gamma + p \rightarrow p + \pi^+\pi^-\pi^0$

A.R. Dzierba,
GlueX-doc-838-v4

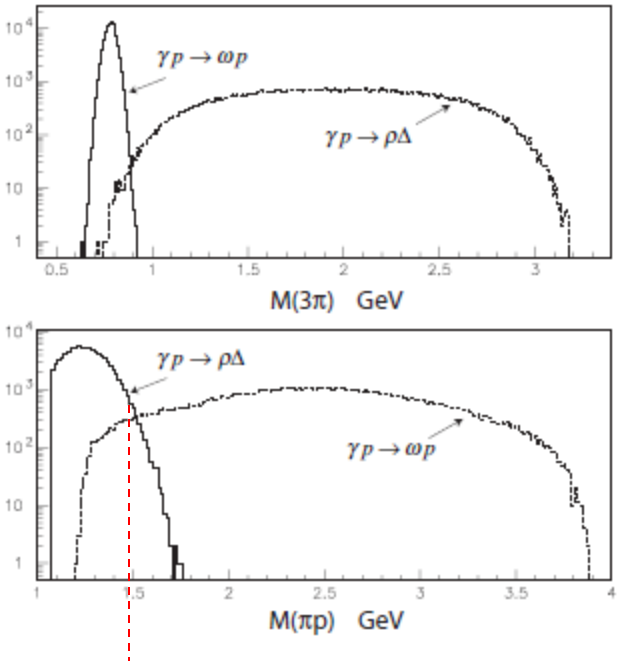


Figure 16: The upper plot shows the 3π effective mass distribution for the ωp final state (solid histogram) and the $\rho\Delta$ final state (dotted). Note the logarithmic scale. The bottom plot shows the πp effective mass for the two final states: $\rho\Delta$ (solid) and ωp (dotted).

There are similar backgrounds for

- ρ photoproduction $\gamma+p\rightarrow\Delta^{++}\pi^- \rightarrow p\pi^+\pi^-$, and possibly
- φ photoproduction $\gamma+p\rightarrow\Lambda(1520)K^+ \rightarrow pK^- K^+$ (see Fig 4 of Anciant et al paper)

Looks small for η photoproduction, but it might be important in a precision $\eta\rightarrow 3\pi$ Dalitz distribution like we hope to measure.

"Phi": γ + p → p + K^+K^-

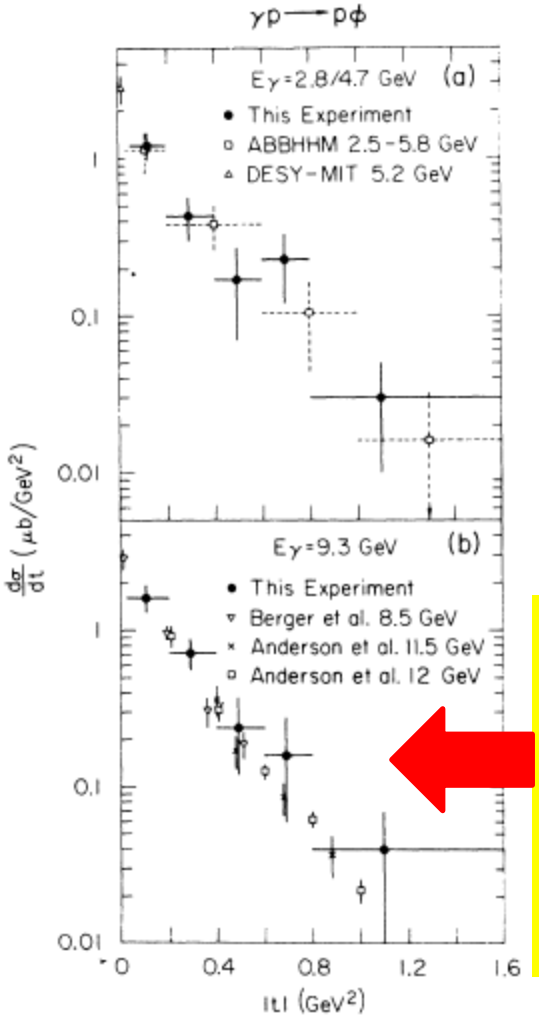


FIG. 27. Reaction $\gamma p \to p\phi$ at 2.8, 4.7, and 9.3 GeV. Differential cross section: (a) 2.8- and 4.7-GeV data combined; (b) 9.3 GeV. The data points labeled ABBHHM, DESY-MIT, Berger *et al.*, and Anderson *et al.*, are from Refs. 5, 42, 9, 8, and 43, respectively.

High statistics φ xsects exist (from a different expt).

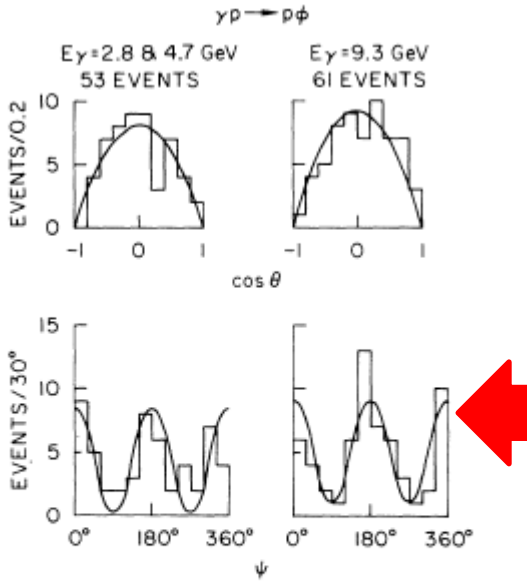


FIG. 29. Reaction $\gamma p \to p\phi$ at 2.8, 4.7, and 9.3 GeV. Decay angular distribution of $K\bar{K}$ pairs in the helicity system in the ϕ mass region $1.00 \le M_{K\bar{K}} \le 1.04$ GeV and in the momentum-transfer interval $0.02 \le |t| \le 0.8$ GeV^2. The curves are calculated for an s-channel helicity-conserving ϕ production amplitude.

Statistics was very thin on the asymmetry.

Presumably there's been no change near 9.3 GeV.

If this is low-hanging fruit, what's the physics?

CLAS Paper from 2000

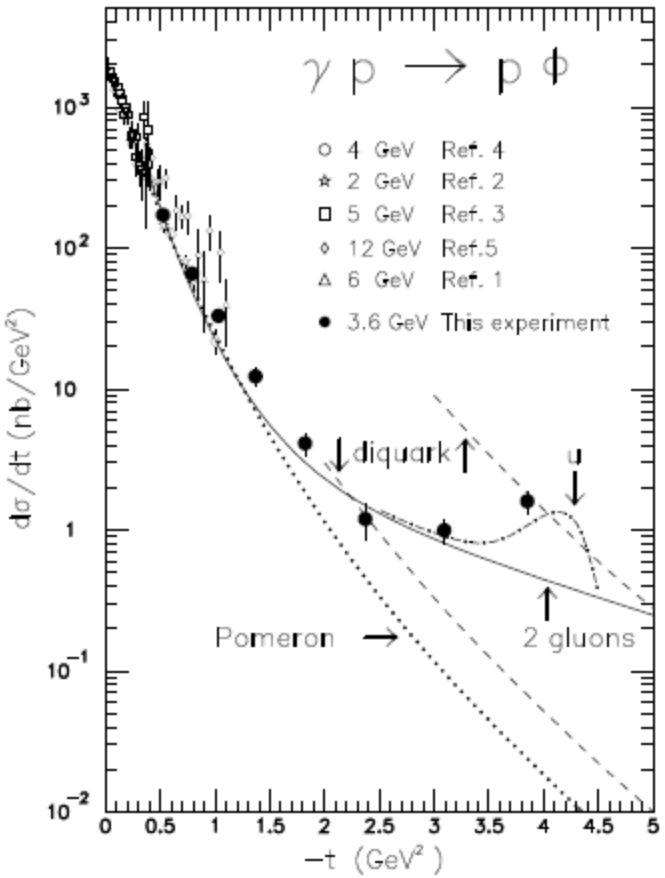


FIG. 6. The differential ϕ photoproduction cross-section versus the four-momentum transfer t (see text for the explanation of the curves). The error bars displayed are the quadratic sum of statistical and systematic uncertainties which include 3% for normalization, 5% for acceptance and 5-15% for background subtraction.

E. Anciant et al., Phys.Rev.Lett.85:4682-4686,2000

Phi photoproduction at large –t is supposed to be easier to model than rho or omega due to suppression of quark exchange with the target.

CLAS saw interesting deviations in the xsect above ~ 2 GeV^2 suggesting 2-gluon exchange.

(See also K. McCormick et al., http://journals.aps.org/prc/abstract/10.1103/PhysRevC.69.032203 which used the same 2-gluon exchange model.)

It's conceivable the asymmetry might show interesting evolution as low as –t ~ 1 GeV^2.

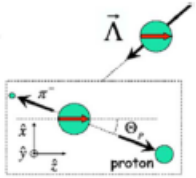
Reinhard's slide from the User's Group meeting:

Pseudoscalar Meson Photoproduction

4 Complex amplitudes: **16** real polarization observables.

Complete measurement with at least **8** suitably chosen observables.

nN has large cross section but in **KY** recoil is **self- analysing**



nN

recoil target γ

KY

γ target recoil

Symbol	Transversity representation	Experiment required	Type
$d\sigma/dt$	$\|b_1\|^2+\|b_2\|^2+\|b_3\|^2+\|b_4\|^2$	$\{-;-;-\}$	S
$\Sigma d\sigma/dt$	$\|b_1\|^2+\|b_2\|^2-\|b_3\|^2-\|b_4\|^2$	$\{L(\frac{1}{2}\pi,0);-;-\}$	
$T d\sigma/dt$	$\|b_1\|^2-\|b_2\|^2-\|b_3\|^2+\|b_4\|^2$	$\{-;y;-\}$	
$P d\sigma/dt$	$\|b_1\|^2-\|b_2\|^2+\|b_3\|^2-\|b_4\|^2$	$\{-;-;y\}$	
$G d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_3^* + b_2 b_4^*)$	$\{L(\pm\frac{1}{4}\pi);x;-\}$	BT
$H d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_3^* - b_2 b_4^*)$	$\{L(\pm\frac{1}{4}\pi);x;-\}$	
$E d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_3^* + b_2 b_4^*)$	$\{C;z;-\}$	
$F d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_3^* - b_2 b_4^*)$	$\{C;x;-\}$	
$O_x d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_4^* - b_2 b_3^*)$	$\{L(\pm\frac{1}{4}\pi);-;x'\}$	BR
$O_z d\sigma/dt$	$-2\,\mathrm{Im}(b_1 b_4^* + b_2 b_3^*)$	$\{L(\pm\frac{1}{4}\pi);-;z'\}$	
$C_x d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_4^* - b_2 b_3^*)$	$\{C;-;x'\}$	
$C_z d\sigma/dt$	$-2\,\mathrm{Re}(b_1 b_4^* + b_2 b_3^*)$	$\{C;-;z'\}$	
$T_x d\sigma/dt$	$2\,\mathrm{Re}(b_1 b_2^* - b_3 b_4^*)$	$\{-;x;x'\}$	TR
$T_z d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_2^* - b_3 b_4^*)$	$\{-;x;z'\}$	
$L_x d\sigma/dt$	$2\,\mathrm{Im}(b_1 b_2^* + b_3 b_4^*)$	$\{-;z;x'\}$	
$L_x d\sigma/dt$	$2\,\mathrm{Re}(b_1 b_2^* + b_3 b_4^*)$	$\{-;z;z'\}$	

I. S. Barker, A. Donnachie, J. K. Storrow, Nucl. Phys. B95 347 (1975).

circ polarized photons

linearly polarized photons

longitudinally polarized target

transversely polarized target

JLab Users Meeting 2015

R. A. Schumacher, Carnegie Mellon University

9

Xsect ~ $b_1^2 + b_2^2 + b_3^2 + b_4^2$

Σ ~ $b_1^2 + b_2^2 - b_3^2 - b_4^2$

PERHAPS the asymmetry for φ photoproduction would make a stronger case for the two-gluon exchange.

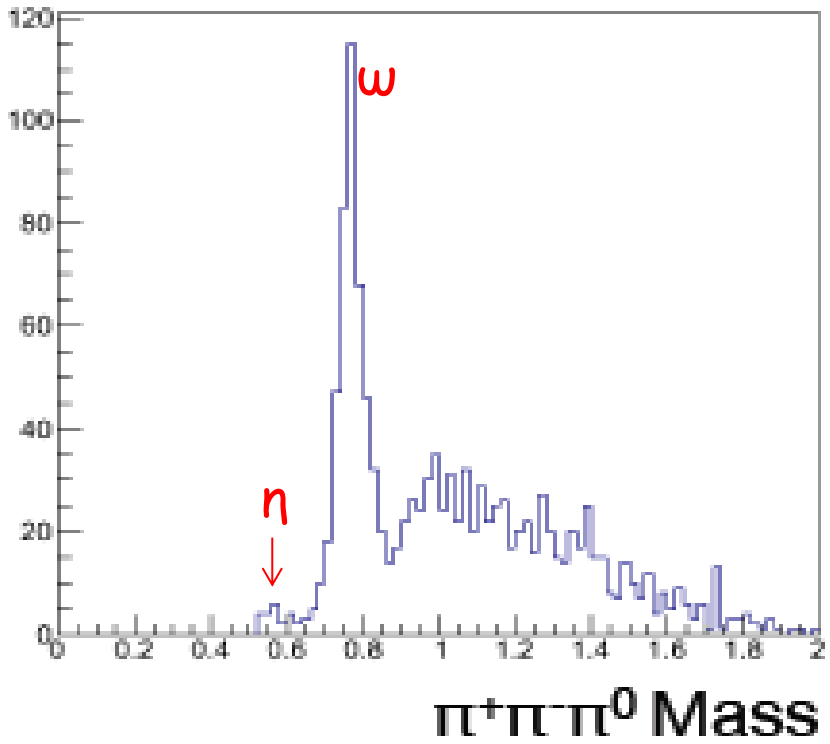
end

Exclusive γ + p → p + $\pi^+\pi^-\pi^0$

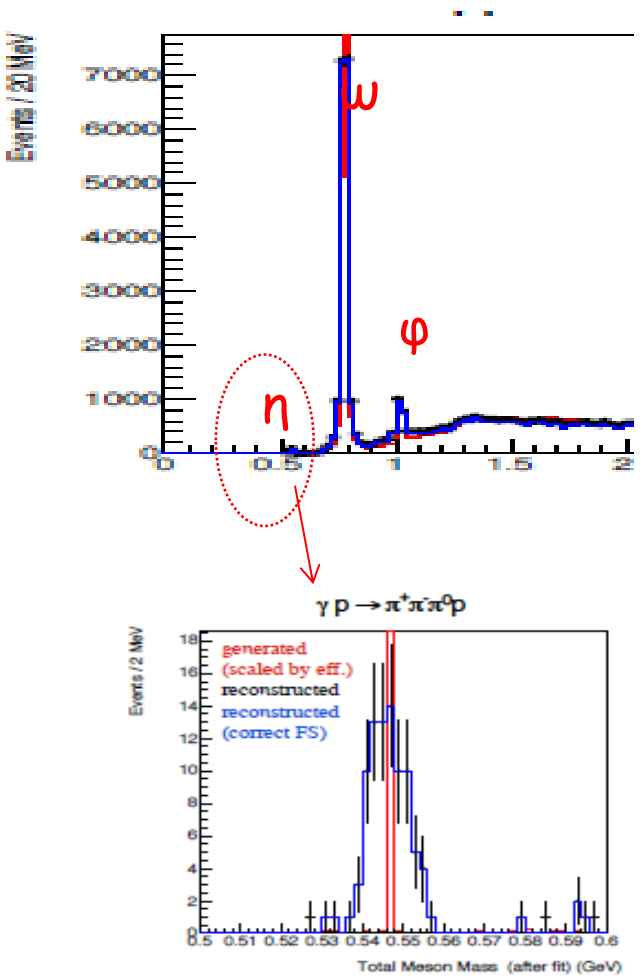
$\omega \rightarrow \pi^+\pi^-\pi^0$ combines charged particle and photon reconstruction (xsect still large, but 10x smaller than ρ)

Calibrations now good enough to see a hint of η→3π!

Data



Simulations



Completed calibrations should result in a well-isolated η peak. (above)

Data figures by J. Stevens