

Lawrence Berkeley National Laboratory

Recent Work

Title

EFFECT OF THE PION-PION RESONANCE ON THE NEGATIVE-POSITIVE RATIO IN PHOTOPION PRODUCTION

Permalink

<https://escholarship.org/uc/item/9hz787kk>

Author

Ball, James S.

Publication Date

1960-05-26

UNIVERSITY OF
CALIFORNIA

Ernest O. Lawrence

*Radiation
Laboratory*

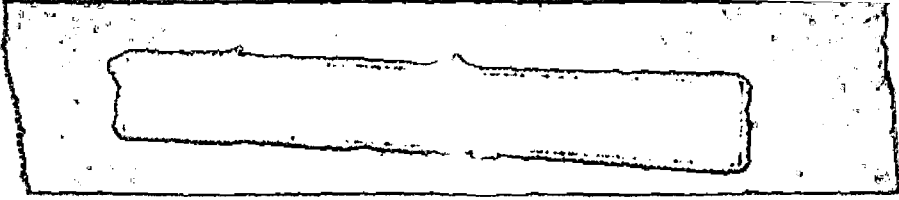
TWO-WEEK LOAN COPY

*This is a Library Circulating Copy
which may be borrowed for two weeks.
For a personal retention copy, call
Tech. Info. Division, Ext. 5545*

BERKELEY, CALIFORNIA

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.



UCRL-9234
Limited Distribution

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California
Contract No. W-7405-eng-48

EFFECT OF THE PION-PION RESONANCE
ON THE NEGATIVE-POSITIVE RATIO
IN PHOTOPION PRODUCTION

James S. Ball

May 26, 1960

EFFECT OF THE PION-PION RESONANCE
ON THE NEGATIVE-POSITIVE RATIO

James S. Ball

Lawrence Radiation Laboratory
University of California
Berkeley, California

May 26, 1960

It has been shown by Frazer and Fulco that a P -wave pion-pion resonance can account for the isotopic vector component of the nucleon electromagnetic structure.¹ The purpose of this note is to show that the contribution of this resonance to photoproduction is capable of producing a large effect in the π^- - to - π^+ ratio at threshold.

It is assumed that the Chew, Goldberger, Low, and Nambu invariant amplitudes,² $A^{\pm 0}$, $B^{\pm 0}$, $C^{\pm 0}$, and $D^{\pm 0}$, satisfy the Mandelstam representation.³ The singularity produced by the 2π state is a branch cut running from $4\mu^2$ to ∞ in the complex plane for the momentum-transfer variable $t = -(q - k)^2 = (\omega_q - k)^2 - (\vec{q} - \vec{k})^2$.⁴ Since G parity allows only the scalar part of the photon interaction in the process $\gamma + \pi \rightarrow \pi + \pi$, the 2π singularities will be present only in the photoproduction amplitudes representing the scalar part of the photon, namely the (0) amplitudes. It should also be noted that the (0) amplitudes have only the $I = 1/2$ pion-nucleon phases in the physical region for $\gamma + n \rightarrow n + \pi$ and $\gamma + \bar{n} \rightarrow \bar{n} + \pi$. The strength of the singularities associated with these two channels is given by the imaginary part of the amplitudes. Therefore, since the $I = 1/2$ phases are small in the low-energy region for photoproduction, it is a good approximation to neglect these singularities.

The (0) amplitudes may now be written in the form

$$A^{(0)}(s, t) = \text{Poles} + \frac{1}{\pi} \int_{4\mu^2}^{\infty} dt' \frac{\text{Im}_2 A^{(0)}(s, t')}{t' - t}, \quad (1)$$

where Im_2 denotes the absorptive part of $A^{(0)}$ for the channel $\gamma + \pi \leftrightarrow n + \bar{n}$. The square of the total energy for this channel is t , and s is the square of the total energy for the photoproduction channel. Since the singularities are neglected for $s > (M + \mu)^2$, the physical region for photoproduction, a polynomial expansion may be used to continue $\text{Im}_2 A^{(0)}(s, t')$ to $s > (M + \mu)^2$.

By means of the unitarity condition, it is now possible to obtain $\text{Im}_2 A^{(0)}(s, t)$ expressed in terms of the helicity amplitudes for $\pi + \pi \rightarrow n + \bar{n}$, and $\pi + \gamma \rightarrow \pi + \pi$. Since the process $\pi + \gamma \rightarrow \pi + \pi$ contains only odd angular momentum, only the $J = 1$ state is kept, and $J \geq 3$ is neglected. The $\pi + \pi \rightarrow n + \bar{n}$ states that enter into these imaginary parts are the same as those in the nucleon electromagnetic structure problem, and we find

$$\text{Im}A^0 = -t h(t) g_2^v(t), \quad (2.a)$$

$$\text{Im}B^0 = h(t) g_2^v(t), \quad (2.b)$$

$$\text{Im}C^0 = 0, \quad (2.c)$$

and

$$\text{Im}D^0 = g(t) g_1^v(t), \quad (2.d)$$

$$\text{where } h(t) = \frac{3}{8\sqrt{2}e} \frac{m_1^*(t)}{F_\pi(t)},$$

$m_1(t)$ is the $J = 1$ eigenamplitude for $\pi + \gamma \rightarrow \pi + \pi$ and g_1^v , g_2^v are the imaginary parts of the nucleon form factors given by FF. Here $F_\pi(t)$ is the pion form factor introduced by these authors.

H. S. Wong has shown that $m_1(t)$ is well represented for $t > 4\mu^2$ by the form

$$m_1(t) = \frac{\Lambda}{F_\pi(1)} \left(\frac{1+a}{t+a} \right) F_\pi(t), \quad (3)$$

where Λ is the new coupling constant required to describe $\pi + \gamma \rightarrow \pi + \pi$ and a is a parameter that depends on the pion-pion P-wave amplitude. If the FF pion-pion resonance is used, we have $a = 5.7$ and $F_{\pi}(1) = 1.08$.

Because of the simple form of $h(t)$, it is possible by making suitable subtractions in FF's Eq. (1) to write the dispersion-integral parts of A^0 , B^0 , C^0 , and D^0 directly in terms of the nucleon isotopic vector form factors. Since the form factors are approximately linear in the region $-5 < t < 0$, the (0) amplitudes may be expressed in terms of $G_i^V(0)$ and

$$\left. \frac{1}{G_i^V(0)} \frac{dG_i^V(t)}{dt} \right|_{t=0} = \frac{1}{6} \frac{1}{t_r^2} = \frac{1}{t_r^2}$$

where t_r' is approximately the position of the pion-pion resonance. (Frazer and Fulco obtained $t_r' \simeq 12$.)¹

For the (0) amplitudes, we have

$$A^0 = \frac{e_r g_r}{2} \left[\frac{1}{s - M^2} + \frac{1}{\bar{s} - M^2} \right] + \lambda' \left(\frac{\mu_p' - \mu_n}{2} \right) \left[1 + \frac{t-a}{t_r'} \right] \quad (4a)$$

$$B^0 = \frac{e_r g_r}{(s - M^2)(\bar{s} - M^2)} - \lambda' \left(\frac{\mu_p' - \mu_n}{2} \right) \frac{1}{t_r'} \quad (4b)$$

$$C^0 = -\frac{1}{2} g_r \left(\mu_p' + \mu_n \right) \left[\frac{1}{s - M^2} - \frac{1}{\bar{s} - M^2} \right] \quad (4c)$$

$$D^0 = -\frac{1}{2} g_r \left(\mu'_{p_r} + \mu'_{n_r} \right) \left[\frac{1}{s-M^2} + \frac{1}{\bar{s}-M^2} \right] - \lambda' \frac{e}{2t'_r} \quad (4d)$$

where $\bar{s} = -(p_2 - k)^2$ and

$$\lambda' = \frac{3 \Lambda}{8\sqrt{2} e F_\pi} \frac{1+a}{1}$$

Since the (0) amplitudes enter into $d\sigma(\pi^+)$ and $d\sigma(\pi^-)$ with opposite signs, the ratio $d\sigma(\pi^+)/d\sigma(\pi^-)$ at threshold will be quite sensitive to changes in the (0) amplitude. The threshold ratio becomes

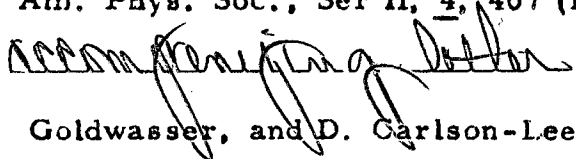
$$R = \frac{d\sigma(\pi^-)}{d\sigma(\pi^+)} = \left(\frac{ef + (\mu_p + \mu_n) f - \lambda' \left(\frac{\mu'_p - \mu'_n}{8\pi} \right) \left(1 - \frac{1+a}{t'_r} \right)}{ef - (\mu_p + \mu_n) f + \lambda' \left(\frac{\mu'_p - \mu'_n}{8\pi} \right) \left(1 - \frac{1+a}{t'_r} \right)} \right)^2 \quad (5)$$

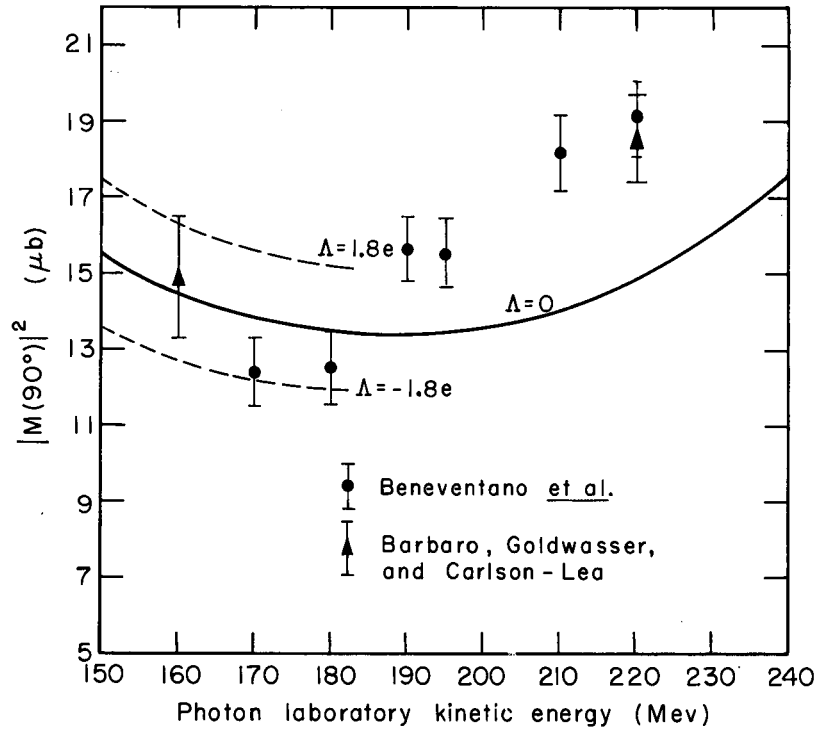
An upper limit on the magnitude of Λ can be obtained by considering π^+ production separately. It is observed that a change in f^2 of ± 0.01 (which is roughly the current uncertainty) can be compensated for in the threshold π^+ cross section by giving Λ a value of $\pm 1.75 e$. The experimental errors in the present π^+ data, with $f^2 = 0.08$, would seem to allow $-1.8 e < \Lambda < 1.8 e$ (see Fig. 1). When combined with the uncertainty in f^2 , this would constrain $|\Lambda|$ to be less than $2.5e$.

Wong⁵ has estimated the size of Λ from the π^0 lifetime. His results are $|\Lambda| \approx e$. For $|\Lambda| = e$, formula (5) leads either to $R = 1.16$ or $R = 1.44$, depending on the sign of Λ .

The author is greatly indebted to Professor Geoffrey F. Chew for suggesting this investigation and for his constant advice throughout the course of this work. The author would also like to thank Dr. How-sen Wong for making some of his results available prior to publication.

FOOTNOTES

1. W.R. Frazer and J.R. Fulco, Phys. Rev. 117, 1609 (1960) (hereafter denoted FF).
2. G.F. Chew, M. L. Goldberger, F.E. Low, and Y. Nambu, Phys. Rev. 106, 1345 (1957) (hereafter denoted CGLN).
3. S. Mandelstam, Phys. Rev. 112, 1344 (1958); Phys. Rev. 115, 1741 (1959); and Phys. Rev. 115, 1752 (1959).
4. The notation of CGLN is used throughout.
5. H.S. Wong, Bull. Am. Phys. Soc., Ser II, 4, 407 (1959) and ~~private communication.~~ 
6. A. Barbaro, E. L. Goldwasser, and D. Carlson-Lee, Bull. Am. Phys. Soc., Ser. 2, 4, 273 (1959); M. Beneventano, G. Bernardini, D. Carlson-Lee, G. Stoppini, and L. Tau, Nuovo cimento 4, 323 (1956).



MU-20370

Fig. 1. The matrix element squared for π^+ photoproduction at $\theta = 90$ deg. The solid line represents the prediction for $\Lambda = 0$; the dashed lines, for $\Lambda = \pm 1.8e$. The experimental points are those of Barbaro et al. and Beneventano et al. (see reference 6).

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.