

Lawrence Berkeley National Laboratory

Recent Work

Title

BACKWARD n-p SCATTERING AS A FURTHER TEST FOR REGGE HIGH-ENERGY BEHAVIOR

Permalink

<https://escholarship.org/uc/item/6hg668r5>

Authors

Chew, Geoffrey F.

Stack, John D.

Publication Date

1965-07-26

University of California

Ernest O. Lawrence Radiation Laboratory

BACKWARD π^-p SCATTERING AS A FURTHER TEST
FOR REGGE HIGH-ENERGY BEHAVIOR

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

UCRL-16293
C2

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.

Journal to be determined later

UCRL-16293

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

BACKWARD π^-p SCATTERING AS A FURTHER TEST
FOR REGGE HIGH-ENERGY BEHAVIOR

Geoffrey F. Chew and John D. Stack

July 26, 1965

BACKWARD π^-p SCATTERING AS A FURTHER TEST
FOR REGGE HIGH-ENERGY BEHAVIOR

Geoffrey F. Chew and John D. Stack

Department of Physics and Lawrence Radiation Laboratory
University of California, Berkeley, California

July 26, 1965

Although no experimental conflict with Regge behavior has been observed for reaction amplitudes at lab energies above 4 GeV, in most cases the theoretical predictions at currently available energies (below 30 GeV) are ambiguous because several trajectories simultaneously make significant contributions. Recently there have been studied two reactions, $\pi^- + p \rightarrow \pi^0 + n$ and $\pi^- + p \rightarrow \eta + n$, where only a single trajectory is important.¹⁻⁴ The results provide strong support for the Regge pole hypothesis. We hope that this letter may encourage further measurements in the same class. Experimenters measuring reaction cross sections in the range above 4 GeV lab energy should be constantly aware that any reaction in which a single trajectory stands above its competitors by a full unit of J (or more), if measured accurately with beams currently available at Brookhaven and CERN, is an especially significant test for Regge behavior.

We discuss here one new candidate for this category, backward π^-p scattering, for which preliminary measurements already suggest an energy dependence of the Regge form.^{5,6} To our knowledge, however, the

necessary experimental precision for establishing Regge shrinkage here has not yet been achieved. It is possible to estimate what this rate of shrinkage will be. The predicted rate is substantial and should be accessible to current techniques.

Our argument has three elements: (a) Detailed study of the relevant crossed reaction, elastic π^+p scattering, has shown only one high-level communicating trajectory--that associated with the Δ (33 resonance). (b) The rough energy dependence already observed for backward π^-p scattering is adequate to establish the Δ trajectory intercept at zero crossed energy. That is, we have⁷

$$\frac{d}{d \ln s} \ln \left(\frac{d\sigma^{\pi^-p}}{du} \right) = \alpha_{\Delta}(\sqrt{u}) + \alpha_{\Delta}(-\sqrt{u}) - 2 ,$$

where s is the energy squared in the direct reaction $\pi^-p \rightarrow \pi^-p$, u is the energy squared in the crossed reaction $\pi^+p \rightarrow \pi^+p$, and $\alpha_{\Delta}(\sqrt{u})$ is the Δ trajectory. Recent experiments near $u=0$, at $p_{\text{lab}} = 4$ and $8 \text{ GeV}/c$,⁶ show a decrease by a factor ≈ 6 between these two energies. Thus⁸

$$2[\alpha_{\Delta}(0) - 1] \approx - \frac{\ln 6}{\ln 2}$$

or

$$\alpha_{\Delta}(0) \approx - 0.3 \quad . \quad (2)$$

(c) We may then use this value together with the masses of the $J = 3/2$ (1236 MeV) and $J = 7/2$ (1924 MeV) particles on the trajectory to estimate at $u = 0$ the second derivative of α_Δ with respect to $\sqrt{u}$, which determines the rate of peak shrinkage. Making a simple cubic fit to these three points in GeV units, we find

$$\alpha_\Delta(\sqrt{u}) \approx -0.3 + 0.53 \sqrt{u} + 0.75 u, \quad (3A)$$

while the Pignotti form⁹ gives

$$\alpha_\Delta(\sqrt{u}) \approx -4.0 + \frac{3.7}{1 - \sqrt{u}/3.8}. \quad (3B)$$

These two fits are shown in Fig. 7. In the first case $\alpha_\Delta''(0)$ is 1.5 GeV^{-2} and in the second 0.5 GeV^{-2} . Values in this range have been observed for several different meson trajectories,⁴ and have been obtained by Garcia from N/D calculations of the Δ trajectory.¹⁰ They therefore seem entirely reasonable.

The width of the backward peak, Γ_b , may be defined through

$$\Gamma_b^{-1} = \left[\frac{d}{du} \ln \frac{d\sigma^{\pi^- p}}{du} \right]_{u=0}, \quad (4)$$

so from Eq. (1) and Eq. (3),

$$\frac{d}{d \ln s} (\Gamma_b^{-1}) = \left\{ \frac{d}{du} [\alpha_\Delta(\sqrt{u}) + \alpha_\Delta(-\sqrt{u})] \right\}_{u=0} = \alpha_\Delta''(0). \quad (5)$$

The width (4), as measured roughly at 4 GeV lab momentum,^{5,6} is fairly broad:

$$\Gamma_b(p_{\text{lab}} = 4 \text{ GeV}) \approx 0.3 \text{ GeV}^2 \quad (6)$$

If $\alpha_{\Delta}''(0) = 1 \text{ GeV}^{-2}$, formula (5) shows that such a width would be reduced by 50% in raising the lab energy by a factor ≈ 5 , that is, by going to 20-GeV/c incident pions.

Because a single (real) residue function is involved here, the shape of the backward peak is expected to be simple--not exhibiting the structure possible when spin-flip and non-spin-flip components are independent. Shrinkage of the peak thus should be on even more persuasive phenomenon than in the reaction $\pi^- + p \rightarrow \pi^0 + n$, where a strong spin-flip component leads to a complicated shape for the peak and confuses the definition of "width."^{1,2}

We do not want to convey the impression that the only significant test for Regge behavior lies in peak shrinkage. On the contrary, our opinion is that other aspects, such as energy behavior according to a power that is noninteger and the relation between this power and the phase, are equally important.^{4,11} We also do not wish to suggest that in any absolute sense backward $\pi^- p$ scattering is more crucial than charge-exchange pion-nucleon scattering or other reactions dominated by a single trajectory. It is a fact of life, however, that most high-energy physicists think of peak shrinkage as the decisive criterion for Regge

behavior, and it is also a fact that the psychological impact of any particular experiment depends on whether its theoretical significance is spelled out in advance. Furthermore, the dedicated experimenters who measure precision reaction cross sections deserve a clean swipe now and then at an outstretched theoretical neck.

FOOTNOTES AND REFERENCES

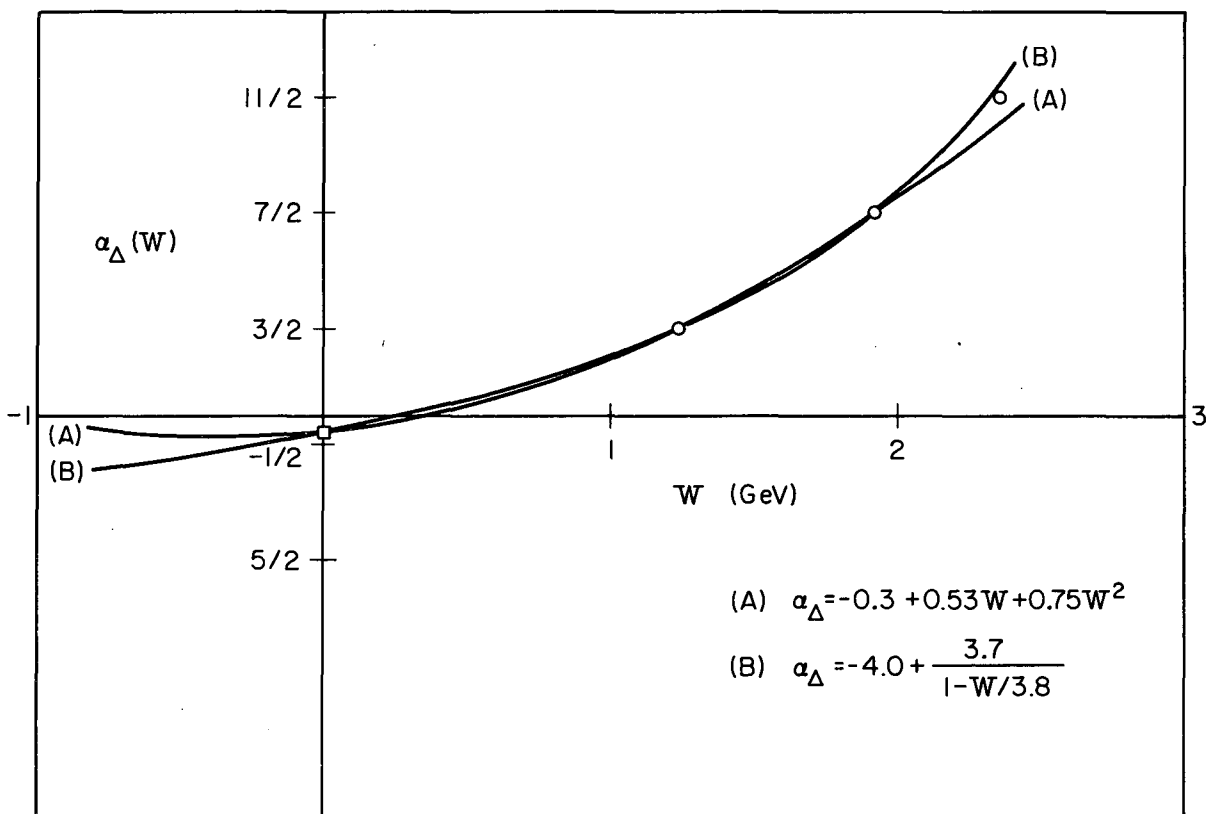
- * Work done under auspices of the U.S. Atomic Energy Commission.
1. A. V. Stirling, P. Sonderegger, J. Kirz, P. Falk-Vairant, O. Guisan, C. Bruneton, P. Borgeaud, M. Yvert, J. P. Guillaud, C. Caverzasio, and B. Amblard, Phys. Rev. Letters 14, 763 (1965), and submitted to Physics Letters (1965).
 2. J. Mannelli, A. Begi, R. Carrara, M. Wahlig, and L. Sodickson, Phys. Rev. Letters 14, 408 (1965).
 3. R. K. Logan, Phys. Rev. Letters 14, 414 (1965).
 4. R. Phillips and W. Rarita, Lawrence Radiation Laboratory Reports UCRL-16033 and 16097, 1965, to be published in Physical Review.
 5. C. Coffin, N. Dikmen, L. Ettlinger, D. Meyer, A. Saulys, K. Terwilliger, and D. Williams, University of Michigan preprint, June 1965.
 6. R. Rubinstein, J. Orear, D. B. Scarl, D. H. White, A. D. Krisch, W. R. Frisken, A. L. Read, and H. Ruderman (Lawrence Radiation Laboratory), private communication, 1965.
 7. Both the trajectory and residue functions for systems of odd baryon number are natural functions of energy, not energy squared, as first pointed out by V. N. Gribov, Soviet Physics-JETP 16, 1080 (1963). Gribov also showed that the power law in s for the unpolarized differential cross section corresponds to Eq. (1).
 8. There has been uncertainty in some of the literature about whether Regge behavior should be expected for backward πN scattering near the point $u = 0$, because the cosine of the crossed-reaction angle

may be small here even when s is large. Maximal analyticity (e.g., the Mandelstam representation), however, assures us that, if the amplitude behaves as $s^{f(u)}$ (more generally, as a sum of powers) for a fixed value of u not equal to zero, it must continue to so behave near $u = 0$. There is no singularity of $A(s,u)$ on the physical sheet in the neighborhood of $u = 0$.

9. A. Pignotti, Phys. Rev. Letters 10, 416 (1963).
10. Andres Garcia (Lawrence Radiation Laboratory), private communication, 1965.
11. R. Phillips and W. Rarita, Phys. Rev. Letters 14, 502 (1965).

CAPTION FOR FIGURE

The Δ trajectory as a function of $W = \sqrt{u}$. The two forms (A) and (B) are both constrained to pass through the particle masses at $J = 3/2$ and $J = 7/2$, as well as $J = -0.3$ at $W = 0$. The 2360-MeV $I = 3/2$ particle of conjectured spin $11/2$ is shown for reference.



MUB-7147

Fig. 1

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.

