Title
MULTIPERIPHERAL MODEL WITH PSEUDOSCALAR AND VECTOR MESON EXCHANGE

Permalink

Author
Avalos, Daniel R.

Publication Date
2009-03-26

Submitted to Comments and Addenda
to Phys. Rev.

LBL-1308
Preprint c.2

MULTIPERIPHERAL MODEL WITH PSEUDOSCALAR AND VECTOR MESON EXCHANGE

Daniel R. Avalos and Cristian Sorensen

September 1972

AEC Contract No. W-7405-eng-48

MULTIPERIPHERAL MODEL WITH PSEUDOSCALAR AND VECTOR MESON EXCHANGE*

Daniel R. Avalos† and Cristian Sorensen

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

September 15, 1972

ABSTRACT

Previous work on generalizations of the ABFST multiperipheral model is extended to allow for vector meson exchange. The intercept of the Pomeranchon pole, the magnitude of asymptotic total cross sections and off-shell corrections to them are calculated.

Regge behavior is one of the several attractive consequences of multiperipheral models.[1] However, when simple, but fairly realistic, versions of the model are studied quantitatively, it is found that the intercept $\alpha_P(0)$ of the Pomeranchon pole is too low. The original ABFST model has been the object of such studies yielding a value of $\alpha_P(0) \approx 0.3$.[2] Neglect of interference terms has been established not to be the cause of the unsatisfactory Pomeranchon intercept.[3] In Refs. 4-6, the model was enlarged to include the exchange of the full pseudoscalar meson octet. In particular, it was shown in Ref. 6 that, if implemented with reasonable off-shell corrections, exchange of the complete pseudoscalar meson octet is capable of generating a Pomeranchon trajectory with $\alpha_P(0) \approx 0.6$.

In this note, the model is extended further to allow for ρ and ω exchange in addition to π and K.[7] To simplify the equations, it is assumed, following Hara,[8] that asymptotic total cross-sections are spin independent.[9] Once this hypothesis has been made, the position of the Pomeranchon pole at $t = 0$ and some total cross sections can be obtained by solving the following system of coupled integral equations:

$$A_{i\pi}^{J}(u,v) = V_{i\pi}^{J}(u,v) + \frac{\sum\limits_{k=\pi,\rho,\omega,K}}{16\pi^3(J+1)} \int_{-\infty}^{0} dw \frac{V_{ik}^{J}(u,w)A_{k\pi}^{J}(w,v)}{(w-m_k^2)^2} . \tag{1}$$

In Eq. (1), the subindices i and k label the type of particle, that is $i,k = \pi,\rho,\omega,K$; $A_{i\pi}^{J}(u,\nu)$ denotes the forward-direction absorptive part for $(i\pi)$ scattering projected onto the cross-channel isospin zero angular-momentum (J) plane; u, v, and w are the (off-shell) masses of the particles;[10] $V_{i\pi}^{\ J}(u,v)$ is the low-energy absorptive part;

$$A_{i\pi}^{\ J}(u,v) = \int_0^\infty ds\; e^{-(J+1)\eta(s,u,v)}\, A_{i\pi}(s,t=0;\,u,v), \quad (2)$$

$$A_{i\pi}(s,t=0;\,u,v) = \frac{1}{2\pi i}\,\frac{1}{2(uv)^{\frac{1}{2}}} \int_{c-i\infty}^{c+i\infty} dJ\, \frac{e^{(J+1)\eta(s,u,v)}}{\sinh\,\eta(s,u,v)}$$

$$\times\; A_{i\pi}^{\ J}(u,v) \quad (3)$$

$$\eta(s,u,v) = \cosh^{-1}\left[\frac{s-u-v}{2(uv)^{\frac{1}{2}}}\right] \quad . \quad (4)$$

The projection $V_{ij}^{\ J}(u,v)$ is obtained in the same way from $V_{ij}(s,t=0;\,u,v)$, which is parametrized as a sum of narrow resonances:[2-6]

$$V_{ij}(s,t=0;\,u,v) = \sum_k \beta_k\, g_{ij}^{\ k}\, F_{ij}^{\ k}(q_{off})\, \delta(s-m_k^{\ 2}) \quad (5)$$

where β_k is the appropriate $SU(2) \times U(1)$ crossing-matrix element[4] times a factor of 2 if identical particles require it; $F_{ij}^{\ k}(q_{off}^{k})$ is the form factor for the $(ki\pi)$ vertex normalized so that $F_{ij}^{\ k}(q_{on}^{\ k}) = 1$ with

$$q_{off}^{k} = \frac{\lambda^{\frac{1}{2}}(m_k^{\ 2},u,v)}{2m_k},$$

$$q_{on}^{\ k} = \frac{\lambda^{\frac{1}{2}}(m_k^{\ 2},m_i^{\ 2}m_j^{\ 2})}{2m_k}, \quad \lambda(x,y,z) = (x-y-z)^2 - 4yz; \text{ and}$$

$$g_{ij}^{\ k} = \frac{16\pi^2\, m_k^{\ 3}\, x_{ij}^{\ k}\, \Gamma^k}{\lambda^{\frac{1}{2}}(m_k^{\ 2},m_i^{\ 2},m_\pi^{\ 2})}\,(2J_k+1), \text{ where}$$

J_k, Γ^h, and $x_{ij}^{\ k}$ are the spin, total width, and elasticity (in the $i\pi$ channel) of the resonance k. The form factor $F_{i\pi}^{\ k}$, in the spirit of a barrier penetration correction, has been discussed in Ref. 6, to which the reader is referred for details. In this note, the prescription for $F_{ij}^{\ k}$ has simply been extended to the new resonances encountered, taking into account the appropriate values of the orbital angular momenta and adjusting the root mean square radius of interaction[6,11] to be 0.4 Fermi.[6] The resonances included in the calculation are exhibited, together with their characteristic parameters, in Table I. Bound state vertices, e.g., $\rho K\bar{K}$, were found in Ref. 6 to have very little effect.

In this manner the intercept of the Pomeranchon pole is found to be $\alpha_P(0) = 0.72$. [If off-shell corrections are removed, i.e., $F_{ij}^{\ k} \equiv 1$, one obtains $\alpha_P(0) = 0.32$.] The magnitude of the asymptotic total cross section is given by

$$\sigma_{i\pi}(s,u,v) = \frac{1}{c_i}\,\frac{1}{s}\,A_{i\pi}(s,t=0,u,v) \approx \frac{1}{c_i}\,\frac{16\pi^3\big(\alpha_P(0)+1\big)}{-\left.\frac{\partial\mu}{\partial J}\right|_{\mu=1}}$$

$$\times\; \Phi_i(u)\; \Phi_j(v)\; s^{\alpha_P(0)-1} \quad (6)$$

where c_i is a crossing matrix factor, $\mu(J)$ is the eigenvalue of the integral operator $\left(\mu(\alpha_P) = 1\right)$,

$$\Phi_i(u) = \frac{\psi_i(u)}{[(-u)^{\frac{1}{2}}]^{\alpha_P+1}} ;$$

the eigenvector $\psi_i(u)$ satisfies

$$\left.\begin{aligned} \frac{\sum_{j=\pi,\rho,\omega,K}}{16\pi^3(\alpha_P+1)} \int_{-\infty}^{0} dv\, V_{ij}^{\alpha_P}(u,v)\, \frac{\psi_j(v)}{(m_j^2 - v)^2} &= \mu(\alpha_P)\, \psi_i(u) \\ \sum_{j=\pi,\rho,\omega,K} \int_{-\infty}^{0} du\, \frac{\psi_j^2(u)}{(m_j^2 - u)^2} &= 1 \end{aligned}\right\} . \quad (7)$$

Because $m_\pi^2 \approx -0.02$, the asymptotic $\pi\pi$ cross section can be estimated by setting $u = v = 0$ in (6). One finds $\sigma_{\pi\pi} \approx 27$ mb. The off-shell behavior can be obtained from the u dependence of $\Phi_i(u)$ exhibited in Fig. 1.

The results presented above may be useful for studies of the split Pomeranchon,[12] a multiperipheral mechanism which provides some understanding of diffractive phenomena and allows one to impose self-consistency conditions on the Pomeranchon singularity. In order for the split Pomeranchon scheme to agree with established phenomenological results, one has to have a "low energy" or "resonance" component of the multiperipheral kernel with properties similar to those of the kernel presented in this note, i.e., capable of generating an $\alpha_P(0)$ of approximately 0.7 with an asymptotic $\pi\pi$ total cross section

$\sigma_{\pi\pi} \approx 30$ mb. The split Pomeranchon also requires that diffractive dissociation into high masses be significant but not too large. Quantitatively this is best expressed in terms of the dimensionless parameter[13] $\eta_{PP,P}$. The magnitude of $\eta_{PP,P}$ remains an unresolved problem, both theoretically and experimentally.[13-15] The off-shell behavior of asymptotic total cross sections is important for theoretical estimates[13,15] of $\eta_{PP,P}$, which employ, based on results of simpler multiperipheral models, off-shell corrections that fall fairly rapidly as a function of u. The remarkably flat behavior exhibited in Fig. 1 suggests that a somewhat larger value of $\eta_{PP,P}$ can be expected.

ACKNOWLEDGMENT

One of us (D.R.A.) wishes to thank Professor Geoffrey F. Chew for the hospitality of the theoretical group at the Lawrence Berkeley Laboratory.

FOOTNOTES AND REFERENCES

* Work supported in part by the U. S. Atomic Energy Commission.

† Fellow of the National Research Council of Argentina. Present address: Departamento de Fisica, Universidad de La Plata, La Plata, Argentina.

1. L. Bertocchi, S. Fubini, and M. Tonin, Nuovo Cimento 25, 626 (1962); D. Amati, A. Stanghellini, and S. Fubini, Nuovo Cimento 26, 896 (1962).
2. D. M. Tow, Phys. Rev. D2, 154 (1970).
3. D. R. Snider and D. M. Tow, Phys. Rev. D3, 996 (1971).
4. D. R. Avalos, Phys. Rev D4, 2352 (1972).
5. H. W. Wyld, CERN Report No. CERN-TH-1361 (1971).
6. D. R. Avalos and B. R. Webber, Phys. Rev. D4, 3313 (1971).
7. η exchange has been shown not to be important, Ref. 6. K^* and ϕ exchanges, which perhaps should be treated on the same footing as ρ and ω, were ignored to keep the equations tractable. The larger masses of these mesons together with the small number of low mass resonances that couple to them provide some justification for this.
8. Y. Hara, Phys. Letters 23, 696 (1966). See also A. H. Mueller and T. L. Trueman, Phys. Rev. 160, 1296 (1967).
9. Hara's theorem depends, among other things, on having $\alpha_P(0) = 1$. If $\alpha_P(0) \approx 0.7$, spin-independent total cross sections should be viewed as an approximation in the spirit of the perturbative approach of Ref. 12.
10. To obtain the physical amplitude for $(i\pi)$ scattering one would set $u = m_i^2$, $v = m_\pi^2$.

11. G. Wolf, Phys. Rev. 182, 1538 (1969).

12. G. F. Chew and D. R. Snider, Phys. Rev. D1, 3453 (1970); Phys. Rev. D3, 920 (1971). See also Ref. 13.

13. H. D. I. Abarbanel et al., Phys. Rev. Letters 26, 675 (1971) and Princeton University report, 1971 (unpublished).

14. R. Rajaraman, Phys. Rev. Letters 27, 693 (1971).

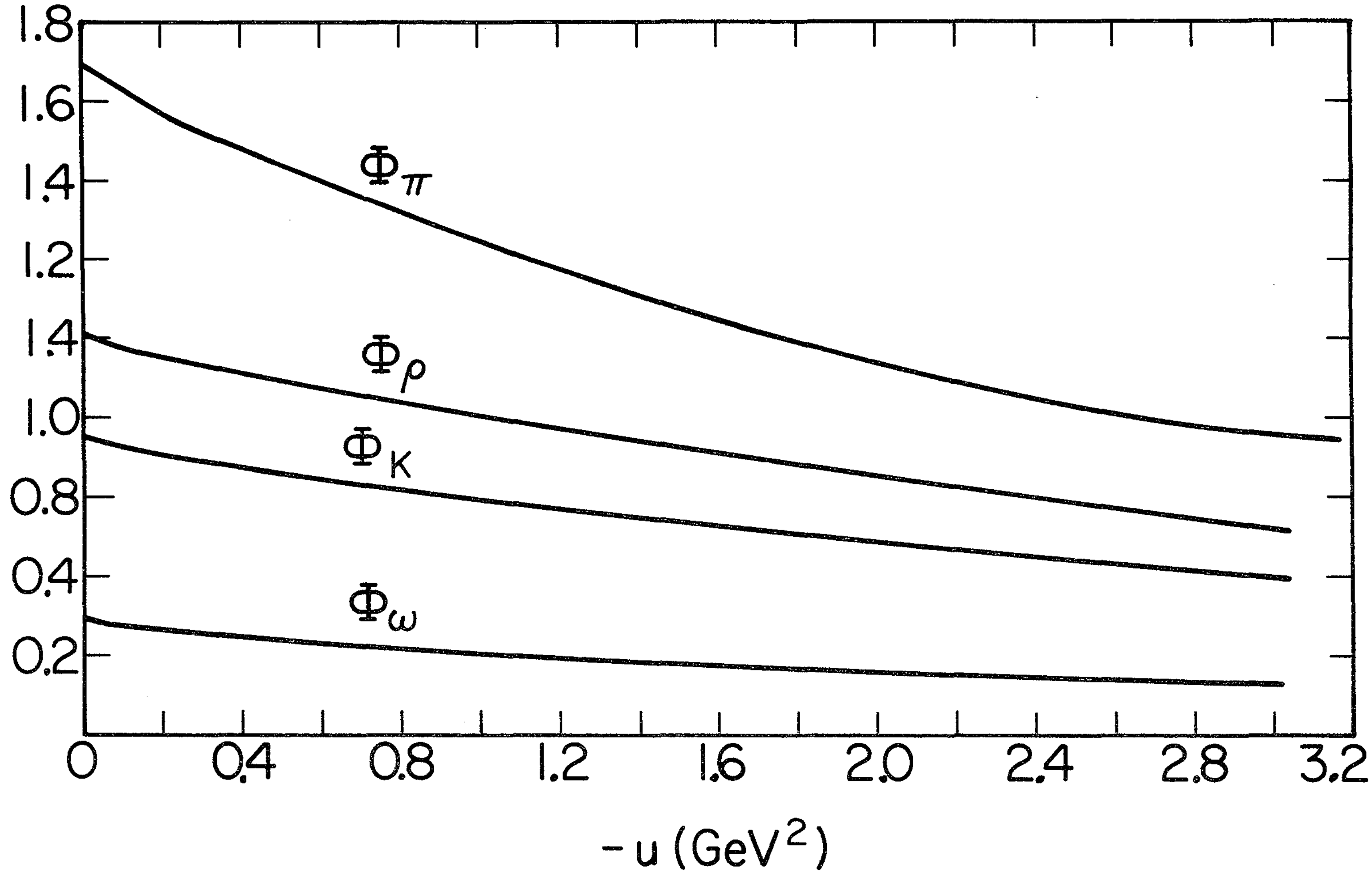
15. C. Sorensen, Phys. Rev. D, in press.

Table I. Characteristic parameters of the resonances included in the calculation.

Particle	$I^{(G)},Y$	m (MeV)	Γ (MeV)	J^P	$x_{ij}{}^k = \frac{\Gamma_{ij}}{\Gamma^k}$
ϵ	$0^{(+)},0$	765	450	0^+	$x_{\pi\pi} = 1$
ρ	$1^{(+)},0$	765	125	1^-	$x_{\pi\pi} = 1$
K^*	$\frac{1}{2}, \pm 1$	892	50	1^-	$x_{K\pi} = 1$
ϕ	$0^{(-)},0$	1019	4	1^-	$x_{K\bar{K}} = 0.8$, $x_{\rho\pi} = 0.2$
A_1	$1^{(-)},0$	1070	100	1^+	$x_{\rho\pi} = 1$
B	$1^{(+)},0$	1220	100	1^+	$x_{\omega\pi} = 1$
f	$0^{(+)},0$	1260	150	2^+	$x_{\pi\pi} = 1$
A_2	$1^{(-)},0$	1300	80	2^+	$x_{\rho\pi} = 0.80$, $x_{K\bar{K}} = 0.05$
K_N	$\frac{1}{2}, \pm 1$	1410	96	2^+	$x_{K\pi} = 0.5$
f'	$0^{(+)},0$	1514	73	2^+	$x_{\pi\pi} = 0.1$, $x_{K\bar{K}} = 0.8$
g	$1^{(+)},0$	1670	170	3^-	$x_{\pi\pi} = 0.92$, $x_{K\bar{K}} = 0.08$

FIGURE CAPTION

Fig. 1. Behavior of $\Phi_i(u)$ [see Eq. (6)] as a function of u. The normalization is arbitrary.



1.8
1.6
1.4
1.2
1.4
1.0
0.8
0.4
0.2
Φ_π
Φ_ρ
Φ_K
Φ_ω
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
$-u$ (GeV^2)

XBL729-4031