"jump of electrostatic potential" and not the term "work function," since the latter should be reserved for the difference of the electrostatic potential energy of an electron outside the metal and its electrochemical potential inside.[6]

The experiment of Witteborn and Fairbank[7] measured the field in vacuum inside a vertical copper tube, i.e., outside the metal. This field was found to be 5.6×10^{-11} V/m, and it just compensates the gravitational force on free electrons, in agreement with the theory of Schiff and Barnhill.[8] To reconcile this measured value with the theory of Dessler et al. we must assume that $\Delta\varphi_{df}$ and $\Delta\varphi_{eg}$ at the top and bottom of a vertical copper bar are not equal and that they are such that the field outside the bar is only about 1/1000 of that inside the bar. [In the notation of Ref. 2 this would mean that in Eq. (32) $\gamma'\ll1$, i.e., that the true work function is practically independent of pressure.] In that case even the vibrating capacitor measurement would have no bearing on the electrostatic field inside the metal.

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SU(3) SYMMETRY, EXCHANGE DEGENERACY, AND LORENTZ-POLE CLASSIFICATION OF CONSPIRATOR FAMILIES*

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A classification of conspiring trajectories according to SU(3) symmetry, exchange degeneracy, and Lorentz symmetry is given. This classification gives rise to numerous experimental consequences. A few of such predictions are indicated.

The purpose of this Letter is to propose the following classification of conspirator trajectory families: The octet of pseudoscalar-meson trajectories and the octet of axial-vector–meson trajectories are taken to be exchange degenerate. Furthermore, each pseudoscalar-meson trajectory (e.g., the pion) conspires with a corresponding parity doublet (A_2') and an axial-vector trajectory (A_1') which has an intercept one unit below the parity doublet (π and A_2'). These trajectories together with their respective even daughters are associated with a single Lorentz pole at $t=0$. Similarly, each member of the axial-vector octet of trajectories (e.g., B meson) conspires with a corresponding parity doublet (ρ') and a third trajectory of opposite signature which has an intercept one unit below B and ρ'. Again these three trajectories together with their respective even daughters are associated with a single Lorentz pole at $t=0$. We call the two Lorentz poles just mentioned "exchange-degenerate Lorentz poles". We are therefore suggesting six octets of conspiring families including their even daughter trajectories. All of these trajectories are associated with two octets of exchange-degenerate Lorentz poles at $t=0$. We do of course allow for SU(3) splittings within an octet of Regge trajectories or Lorentz poles.

Our classification has an enormous number of experimental consequences. Further detailed predictions and phenomenological tests of our proposed model are being studied and will be subject to separate publication. In the following we briefly mention a few of these cases:

(1) π-B trajectory. – From the known masses of the pion and the B meson we obtain an approximate π-B trajectory with possible Regge recurrences. Also similar considerations are made for the corresponding $I=\frac{1}{2}$ octet member.[1]

(2) Polarization phenomena. – The parity doublet conspirator of the B meson trajectory is ρ'. Such a conspiring ρ' trajectory has already been

suggested by Sertorio and Toller[2] to explain the polarization in $\pi^- p$ charge-exchange reaction. Similarly, the parity doublet conspirator to the pion (A_2') would be expected to explain the polarization in the reaction $\pi^- p \to \eta n$. Note that based on exchange degeneracy and the $\pi^- p \to \pi^0 n$ case, we have a pure prediction here.

(3) Crossover phenomena.—Our $I=0$ member of the axial-vector octet has a parity-doublet conspirator with the quantum number of ω. The contribution of this conspirator is expected to explain the difficulties with certain crossover phenomena mentioned by Barger and Durand.[3] Note that again our assumptions of exchange degeneracy and SU(3) symmetry would give certain definite predictions, especially at the t values where the ordinary ω trajectory couplings vanish.

(4) Photoproduction.—In the reaction $\gamma p \to \pi^+ n$ our model includes (in addition to pion conspiracy) the B-meson conspiracy without any additional free parameters. Therefore, if one uses the same parametrization as Ball et al.,[4] one finds[5] only a somewhat different value for the parameter λ in their factor of $[1+\lambda(t-\mu^2)/\mu^2]$.

(5) Total cross sections and forward-direction reactions.—The conspirators mentioned here have no contribution to the nonflip amplitudes at $t=0$. Therefore the total cross sections and the corresponding sum rules based on exchange degeneracy obtained previously[6] are not affected by our present considerations. On the other hand our previous exchange degeneracy of vector and tensor trajectories requires that both the helicity flip and helicity nonflip residues of the ρ trajectory in $\pi^- p$ charge exchange should vanish[6] at $t \simeq -0.6$ where $\alpha_\rho = 0$. There is of course a dip at $t=-0.6$ in $d\sigma(\pi^- p \to \pi^0 n)/dt$. That the differential cross section does not vanish at this point should easily be explained by the contribution of our conspiring ρ'.

(6) np and $\bar{p}p$ charge-exchange reactions.—A detailed calculation of nucleon-nucleon and nucleon-antinucleon charge-exchange reactions in our model consists of exchange-degenerate ρ and R trajectories together with exchange degenerate π and B conspiracies. Now, as is well known, the ρ and R contributions are relatively small at moderately high energies. Therefore, in our model it is mainly the exchange degenerate π and B conspirators which should explain the data. It is a simple matter to show that in our model the exact exchange-degeneracy limit predicts that all the np charge-exchange helicity amplitudes will be real. Now from the equality of the pp and pn total cross sections, it follows that at the forward direction the np charge-exchange helicity amplitudes are in fact real. For nonzero momentum transfers, the reality of the np charge-exchange amplitudes is a prediction of our model. Note that in our case, because of the negative charge conjugation of the B-meson conspirators, the $\bar{p}p$ charge-exchange cross section is automatically different from the np case. Also the various $p\bar{p}$ charge-exchange helicity amplitudes are not real. We expect that in our treatment a parametrization similar to that of Arbab and Dash[7] can be made in which the pion (and also the B meson) residue has a somewhat displaced zero as compared with theirs.

Let us now make a few concluding remarks. As shown by Freedman and Wang,[8] in the unequal-mass case analyticity requires existence of an infinite number of daughter trajectories. In the equal-mass case, it is a single Lorentz pole[9] which gives rise to an infinite number of daughter trajectories. To have a finite number of trajectories at $t=0$, Lorentz invariance would require an infinite number of Lorentz poles. This possiblility has not been ruled out. However, we need the infinite number of daughters in the unequal-mass case, anyway. Therefore the whole question of pion conspiracy seems very plausible. Now the same arguments are also applicable to the other conspirator families that we have considered in our model. Then in our opinion we should perhaps accept the existence of all such conspiracies as a fact of life. In that case our classification (if it works) would be very useful. For otherwise we would have to deal with a large number of new parameters. Our optimistic point of view is that exchange degeneracy of the conspirator families would also allow to satisfy exchange degeneracy of the vector and tensor trajectories even better than we have done so far. Thus, for example, in the case of $\pi^- p$ charge exchange we can assume (almost) exact exchange degeneracy and still have a finite value for $d\sigma/dt$ at $t \simeq -0.6$. [See (5) above.]

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USE OF SINGLE-PION PRODUCTION TO REMOVE AMBIGUITIES IN PARTIALLY CONSERVED AXIAL-VECTOR CURRENT AND CURRENT-ALGEBRA PREDICTIONS OF π-π SCATTERING*

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We show that the ambiguities present in the current-algebra and partially conserved axial-vector current model of low-energy π-π scattering are the same as those in the single-pion production amplitude. The experimental data strongly support the Weinberg formulation.

For some time, it has been apparent that there is considerable ambiguity in the prediction of the pion scattering lengths by the hypothesis of partially conserved axial-vector current (PCAC) and current algebra.[1] In Weinberg's original calculation[2] of π-π scattering, he requires that $\partial^\mu A_\mu^\alpha$ form a chiral quadruplet with an isoscalar field. In a later paper[3] he derives a phenomenological Lagrangian that reproduces the same π-π scattering with all pions on the mass shell. Schwinger's Lagrangian[4] differs by assuming a chiral-symmetry-breaking term which implies that $\partial^\mu A_\mu^\alpha$ is proportional to the physical pion field. Schwinger's Lagrangian yields the exact Adler consistency condition[5] on π-π scattering which the Weinberg Lagrangian fails to do. The Schwinger Lagrangian differs also in its prediction of π-π scattering lengths.

The phenomenological Lagrangian technique allows easy reproduction of the current-algebra and PCAC results for the π-π scattering amplitudes and pion-production amplitudes. A further advantage is the ease with which one can isolate and study ambiguities remaining after the application of PCAC and current algebra. We shall show that the most general Lagrangian derived in accordance with current algebra and PCAC introduces a single parameter ξ into the π-π scattering lengths which can be determined only by additional assumptions.[6] However, we shall further demonstrate that ξ is the only parameter that enters the amplitude for single-pion production with external pions on the mass shell. Experimental data favor the value $\xi=0$. This value of ξ yields the Weinberg π-π amplitude on the mass shell; $\xi=1$ yields the Schwinger mass-shell amplitude.

Several techniques exist for generating chiral-invariant Lagrangians.[3,4,7] Our notation is that used by Bardeen and Lee. We assume PCAC in the form $\partial^\mu A_\mu^\alpha = f_\pi \mu^2 \varphi^\alpha(1+h_0\varphi^2+\cdots)$ to break the chiral invariance. Our pion Lagrangian to order φ^4 follows at once[8]:

$$\mathcal{L}(\pi) \equiv \tfrac{1}{2}(\partial_\mu \varphi)^2 - \tfrac{1}{2}\mu^2\varphi^2 + \mathcal{L}_\pi,$$

where

$$\mathcal{L}_\pi = (1/8f_\pi^{\,2})[(\partial_\mu\varphi^2)^2-\mu^2(\varphi^2)^2]-(g_0/f_\pi)[\tfrac{1}{2}\varphi^2(\partial_\mu\varphi)^2+\tfrac{1}{4}(\partial_\mu\varphi^2)^2-\tfrac{3}{8}\mu^2(\varphi^2)^2]-\tfrac{1}{4}\mu^2h_0(\varphi^2)^2.$$

Choosing the two undetermined parameters to be $g_0=1/2f_\pi$ and $h_0=-1/4f_\pi^{\,2}$ yields the Weinberg Lagrangian.[3] The values $g_0=1/2f_\pi$ and $h_0=0$ produce the Schwinger Lagrangian.[4]

Defining[8,9]

$$\frac{\delta^{(4)}(q+l-p-k)}{4(2\pi)^2(q_0l_0p_0k_0)^{1/2}}M_{abcd}(s,t,u) \equiv -\int d^4x\langle\pi^c(l)\pi^d(q)|\mathcal{L}_\pi|\pi^a(p)\pi^b(k)\rangle,$$

we obtain

$$M_{abcd}(s,t,u)=\delta_{ab}\delta_{cd}[As+(A+f_\pi^{\,-2})(t+u)+C\mu^2]$$