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Electro-magnetic meson form-factor from a relativistic coupled-channels approach*

E. P. Biernat[a], W. Schweiger[b], K. Fuchsberger[b], and W. H. Klink[c]

[a] Institut für Physik, Universität Graz, A-8010 Graz, Austria
[b] BE-OP Division, CERN, CH-1211 Geneve 23, Switzerland
[c] Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa, USA

We calculate the electromagnetic form factor of a confined quark-antiquark pair within the framework of relativistic point-form quantum mechanics. The idea is to treat elastic electromagnetic scattering of an electron by a meson as a relativistic two-channels problem for a Bakamjian-Thomas type mass operator [1] such that the dynamics of the exchanged photon is taken explicitly into account.

On the hadronic level the structure of the meson is encoded in a phenomenological form factor which is not known a priori. Similarly, on the constituents level we can consider electromagnetic scattering of an electron by a confined quark-antiquark pair as a two-channels problem. The quark and the antiquark are assumed to interact via a spontaneous confining potential. Elimination of the channel containing the photon gives in both cases an eigenvalue equation for the eM and $eq\bar{q}$ channels on the hadronic and constituent levels, respectively, which contains the one-photon-exchange optical potential. In order to work within the Bakamjian-Thomas framework one has to resort to the approximation that the total four-velocity of the system is conserved at electromagnetic vertices [2]. By comparison of matrix elements of the optical potential on the hadronic and the constituent levels the electromagnetic meson form factor can be read off [3,4].

The form factor obtained in this way depends on all Lorentz invariants of the electron-meson system, i.e. on the momentum-transfer and on the total invariant mass of the electron-meson system. The dependence on the invariant mass is related to the violation of cluster separability. If, however, the invariant mass is chosen large enough this dependence becomes negligible. In the limit of an infinitely large invariant mass the optical potential separates into an electron and a meson current which are connected via the usual photon propagator. The expression for the form factor becomes then [5]

$$F\left(Q^2\right) = \int d^3\tilde{k}'_q \sqrt{\frac{m_{q\bar{q}}}{m'_{q\bar{q}}}}\, \mathcal{S}\, \Psi^*\left(\tilde{\mathbf{k}}'_q\right) \Psi\left(\tilde{\mathbf{k}}_q\right). \tag{1}$$

Here $Q^2 = \mathbf{q^2}$ is the momentum transfer squared with $\mathbf{q} = \mathbf{k'_q} - \mathbf{k_q} = \mathbf{k'_M} - \mathbf{k_M}$ and $m^2_{q\bar{q}} = (E_q + E_{\bar{q}})^2 - \mathbf{k^2_M}$ is the invariant mass of the quark-antiquark pair.

* Talk delivered by E. P. Biernat

Quantities without a tilde refer to the electron-meson center-of-mass and quantities with a tilde refer to the meson rest system. $\mathcal{S}$ is a spin-rotation factor which takes into account the substantial effect of the quark spin on the form factor. By an appropriate change of variables the integral for the form factor Eq. (1) takes the same form as the integral for the pion form factor from front form calculations [6,7]. This remarkable result means that relativity is treated in an equivalent way and the physical ingredients are the same in both approaches.

For a simple two-parameter harmonic-oscillator wave function with the parameterization taken from [6,7] our result for the pion electromagnetic form factor provides a reasonable fit to the data as shown in Fig. 1.

The generalization of this multichannel approach to electroweak form factors for an arbitrary bound few-body system is quite obvious. By an appropriate extension of the Hilbert space this approach is also able to accommodate exchange-current effects.

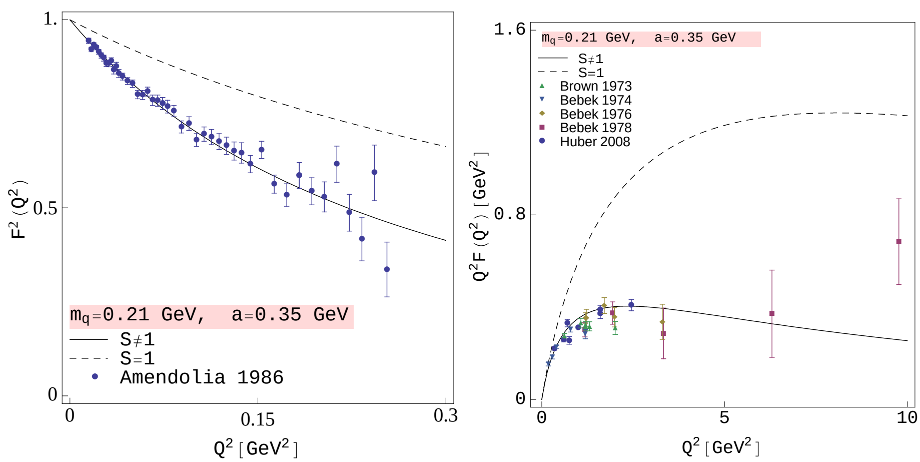

Fig. 1. Q^2-dependence of the pion form factor with (solid) and without (dashed) spin-rotation factor $\mathcal{S}$. Values for the quark mass m_q and the oscillator parameter a are taken from [6,7] and data are taken from [8–13].

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