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3D imaging of the pion off-shell electromagnetic form factors

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The main tools to probe the structure of the hadron in terms of quarks and gluons are the electron elastic and inelastic scattering experiments. In the elastic case, the charge and current distributions of the on-mass-shell target hadron are encoded in the electromagnetic form factors which depend on the virtual photon four-momentum square $q^2 = -Q^2$. For the on-mass-shell spin-zero charged pion,
only one real form factor exists in the spacelike region $Q^2 > 0$ due do the time reversal invariance. Due to the short lifetime of the pion, however, the on-mass-shell elastic electron-pion scattering is not yet feasible and thus one may resort to the pion electroproduction process to estimate the on-mass-shell pion form factor extrapolating the data with one leg off-mass-shell, $t \neq m_\pi^2$, in the limit $t \to m_\pi^2$. On the other hand, the kinematic region of the electroproduction process is intrinsically limited to $t < 0$ and the extrapolation to $t \to m_\pi^2$ involves the disallowed kinematic region of $t > 0$. In this work, we analyze the two off-shell pion form factors appearing in the matrix element of the pion electromagnetic current with one leg off-mass-shell using an exactly solvable manifestly covariant model of a $(3+1)$ dimensional fermion field theory and provide the 3D image of the two off-shell pion form factors as a function of (Q^2, t).

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