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Pion off-shell electromagnetic form factors with the light-front approach models

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The pion plays a special role in the understanding of QCD, the main one is its Goldstone boson nature, associated with the origin of the mass from the dynamical chiral symmetry breaking. One of the possible ways to get information about its substructure, in terms of the degrees of freedom of QCD, quarks and gluons, is from the study of the elastic electron-pion scattering. Because the pion has spin zero, we just need one form factor to describe the matrix element of the current operator between the pion states. However, there is no pion targets and one has to rely on the Sullivan process, where experimental cross-section data from the pion electro-production process on a proton is used to obtain information about the form factor. In the Sullivan process an off-shell pion is picked up from the proton cloud and one has to deal with off-shell effects to extract the form factors and extrapolate it to the on-mass-shell point. In the present work, we explore off-mass-shell effects in the pion electromagnetic form factor by computing it within a light front constituent quarks model, where the Bethe-Salpeter vertex function has a Pauli-Villars form which spreads it with a momentum scale of about a GeV, and compatible with the behavior of the running quark mass in the space-like region obtained from Lattice QCD calculations. We compute the electromagnetic off-shell form factors, $F_1(q^2, t)$ and $F_2(q^2, t)$, the cross-sections for thepion electro-production on the proton and compare it with the available experimental data. This work extends a previous study performed with a covariant model where a point-like pion-quark pseudo-scalar vertex was used to calculate the pion off-shell form factors and the cross-sections.

Primary authors: Prof. DE MELO, Joao (LFTC - Universidade Cruzeiro do Sul / UNICID); Prof. JI, Chueng (North Carolina State University); Prof. CHOI, Ho-meoyng (Kyungpook National University); Prof. FREDERICO, Tobias (Instituto Tecnologico de Aeronautica); LEÃO, Jurandi (Instituto Federal São Paulo (IFSP) and LFTC - UCS/ UNICID)

Presenter: LEÃO, Jurandi (Instituto Federal São Paulo (IFSP) and LFTC - UCS/ UNICID)

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