# 2 - 4 Nucleon Electromagnetic Form Factors in the Timelike Region*

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Human beings have never stopped exploring the structure of matter, and are going deeper into smaller scales—quarks and gluons[1, 2]. They are decisive for understanding the internal structure of nucleons, the main source of mass of the visible matter in universe[3]. The high-precision experiments of the BaBar and BESIII collaborations recently have found that the one-dimensional structures - electromagnetic form factors - of protons and neutrons are distorted by several local structures of small magnitude, manifesting a sinusoidal periodic oscillation behavior[4–7].

Different theories give completely different explanations for the dynamical origin of this behavior. In particular, do they have anything to do with nucleon structure? In the measurement of time-like experiments, in addition to the contribution of the nucleon structure, there is also the contribution of the vector meson above threshold. The latter is much smaller than the former. We found that at the leading order of the perturbative expansion, the interference between the two contributions leads naturally to an oscillatory behavior of the electromagnetic form factors of the nucleon versus center mass of energy, the oscillation frequency of which is directly related to the lifetime of the vector meson, *i.e.* the decay width[8]. The high-order contribution of this perturbation expansion is within 10%, at the same level of the relative error of the existing experiment data, which makes the experimental data unable to distinguish various theoretical models, as shown in Fig. 1.

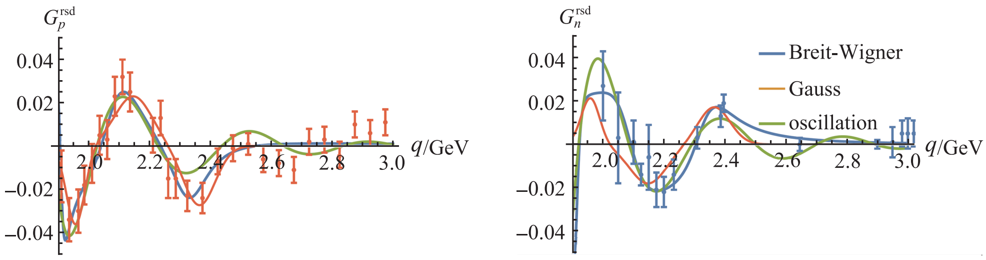


Fig. 1 (color online) The fitting of the Breit-Wigner distribution (blue curve) and the Gauss distribution (yellow curve) to the oscillatory structures (green curve) below center mass of energy 2.5 GeV in comparison with BESIII proton (left panel) and neutron (right panel) data[5–7]. Taken from Ref. [8].

In order to solve this problem, based on the experimental fact that the magnitudes of neutron and proton oscillations are equal, we further confirm that each oscillation period of a specific isospin with the help of isospin analysis, thus confirming that their dynamic origin is the vector meson excitation above threshold. Our theoretical studies have also clarified that the experimentally found phase difference between neutron and proton oscillations originates from the fact that the time-like amplitude is complex. These model-independent analyzes negate the traditional understanding that the oscillation itself is directly related to the nucleon structure, thus solving a long-standing problem in theory.

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