matrix elements of $(J^{\rm nc}_\mu)_{V/A}$ are supressed, the nuclear vector and axial-vector NC operators may be written as follows,

$$\left(J^{\rm nc}_\mu\right)_V = \xi_V^{(T=1)} J^{\rm em}_\mu(T=1) + \sqrt{3}\xi_V^{(T=0)} J^{\rm em}_\mu(T=0) + \xi_V^{(0)} V_\mu^{(s)} \tag{12}$$

$$\left(J^{\rm nc}_{\mu 5}\right)_A = \xi_A^{(T=1)} A_\mu^{(3)} + \xi_A^{(T=0)} A_\mu^{(8)} + \xi_A^{(0)} A_\mu^{(s)}, \tag{13}$$

where $J^{\rm em}_\mu(T=1)/J^{\rm em}_\mu(T=0)$ are the isovector/isoscalar EM currents, and $V_\mu^{(s)} \equiv \overline{s}\gamma_\mu s$ is the strange quark contribution in the vector NC current. The operators $A_\mu^{(a)}$ are given by $A_\mu^{(a)} \equiv \overline{q}\lambda^a\gamma_\mu\gamma_5 q/2$, where q represents the triplet of quarks (u,d,s), and the λ^a, $a = 1...8$ are the Gell-Mann SU(3) matrices. The strangeness content in the axial-vector NC current is given by $A_\mu^{(s)} \equiv \overline{s}\gamma_\mu\gamma_5 s$. Finally, the ξ_V's and ξ_A's are couplings determined by the underlying electroweak gauge theory (see Refs. [6, 21]). We use the minimal Standard Model tree level couplings

$$\begin{array}{ll} \xi_V^{(0)} = -1 & \xi_A^{(0)} = 1 \\ \sqrt{3}\xi_V^{(T=0)} = -4\sin^2\theta_W & \xi_A^{(T=0)} = 0 \\ \xi_V^{(T=1)} = 2 - 4\sin^2\theta_W & \xi_A^{(T=1)} = -2. \end{array} \tag{14}$$

Single-nucleon matrix elements of the EM and weak NC currents shown previously are restricted by Lorentz covariance, together with parity and time reversal invariance to the following forms,

$$\langle N(P')|J^{\rm em}_\mu|N(P)\rangle = \overline{u}(P')\left[F_1\gamma_\mu + i\frac{F_2}{2M}\sigma_{\mu\nu}Q^\nu\right]u(P) \tag{15}$$

$$\langle N(P')|\left(J^{\rm nc}_\mu\right)_V|N(P)\rangle = \overline{u}(P')\left[\tilde{F}_1\gamma_\mu + i\frac{\tilde{F}_2}{2M}\sigma_{\mu\nu}Q^\nu\right]u(P) \tag{16}$$

$$\langle N(P')|\left(J^{\rm nc}_\mu\right)_A|N(p)\rangle = \overline{u}(P')\left[\tilde{G}_A\gamma_\mu + \frac{\tilde{G}_P}{M}Q_\mu\right]\gamma_5 u(P), \tag{17}$$

where $u(P)$ and $u(P')$ are the single-nucleon wave functions properly normalized, $Q = P' - P$ is the four momentum transfer to the nucleon and M is the nucleon mass. From Eqs. (12,13) and (15)–(17) one can write,

$$\tilde{F}_a = \xi_V^{(T=1)} F_a^{(T=1)}\tau_3 + \sqrt{3}\xi_V^{(T=0)} F_a^{(T=0)} + \xi_V^{(0)} F_a^{(s)}, \quad a = 1,2 \tag{18}$$

$$\tilde{G}_a = \xi_A^{(T=1)} G_a^{(3)}\tau_3 + \xi_A^{(T=0)} G_a^{(8)} + \xi_A^{(0)} G_a^{(s)}, \quad a = A, P, \tag{19}$$

where $F_a^{(T=0,1)}$ denote the isoscalar and isovector EM Dirac and Pauli form factors of the nucleon, the $G_a^{(3,8)}$ are the triplet and octet axial-vector form factors, and $F_a^{(s)}$ and $G_a^{(s)}$ are the vector and axial-vector strange-quark form factors. In Eqs. (18) and (19) the terms involving τ_3 are isovector while the rest are isoscalar. We will mainly use throughout this paper the Sachs form factors defined as: $G_E = F_1 - \tau F_2$ and $G_M = F_1 + F_2$, with $\tau \equiv |Q^2|/4M^2$. Analogously one can also define $\tilde{G}_E$ and $\tilde{G}_M$ from $\tilde{F}_1$ and $\tilde{F}_2$. Also, as discussed in Appendix A and Ref. [6], the pseudoscalar contributions are absent in PV electron scattering.