the integro-differential equations Eq. (3) can be formally rewritten as equivalent differential ones,

$$\left[\frac{d}{dr} - \frac{\kappa}{r} - Y_F(r)\right] F(r) - \left[V_+(r) - E\right] G(r) = 0, \tag{5a}$$

$$\left[\frac{d}{dr} + \frac{\kappa}{r} + X_G(r)\right] G(r) + \left[V_-(r) - E\right] F(r) = 0, \tag{5b}$$

where $V_+ \equiv V_+^D + Y_G$, $V_- \equiv V^D + X_F$, and

$$V_+^D \equiv M + \Sigma_S + \Sigma_0, \qquad V^D \equiv \Sigma_0 - \Sigma_S - M. \tag{6}$$

In the above expressions, Σ_S represents the scalar potential from the Hartree terms, Σ_0 is the time component of the vector potential, which contains the contributions from the Hartree terms and the rearrangement terms induced by the density-dependence of the meson-nucleon couplings [21], and X_G, X_F, Y_G, Y_F are the effective local potentials from the Fock terms. The equations Eq. (5) then can be solved self-consistently with the same numerical method as in RMF [27].

From the radial Dirac equation Eq. (5), the Schrödinger-type equation for the dominant component $F(r)$ can be obtained as,

$$\frac{1}{V_+ - E}\left\{F'' + \left(V_1^D + V_1^E\right)F' + \left[V_{\rm CB} + V_{\rm SOP}^D + V_{\rm SOP}^E\right]F\right\} + V^D F + V^E F = EF, \tag{7}$$

where $V_{\rm CB} = \frac{\kappa(1-\kappa)}{r^2}$ and $V_{\rm SOP}$ correspond to the centrifugal barrier (CB) and spin-orbit potential (SOP), respectively. In the above equation, the Hartree and Fock terms for V_1, $V_{\rm SOP}$ and V read as

$$V_1^D = -\frac{V_+^{D\prime}}{V_+ - E}, \qquad V_1^E = X_G - Y_F - \frac{Y_G'}{V_+ - E}, \tag{8a}$$

$$V_{\rm SOP}^D = \frac{\kappa}{r}\frac{V_+^{D\prime}}{V_+ - E}, \qquad V_{\rm SOP}^E = \frac{\kappa}{r}\left(\frac{Y_G'}{V_+ - E} - X_G - Y_F\right), \tag{8b}$$

$$V^D = \Sigma_0 - \Sigma_S - M, \qquad V^E = X_F + \frac{1}{V_+ - E}\left(Y_F\frac{V_+'}{V_+ - E} - Y_F' - X_G Y_F\right). \tag{8c}$$

One may note that the denominator $V_+ - E$ contains a state dependent potential Y_G. However, as the quantity Y_G is around a few MeV and is negligible in comparison with $V_+ - E$ which is of the order of 1 GeV, the Eq. (7) is accurate enough to estimate the Hartree and Fock contributions. Similar argument also holds for the time component of the vector potential Σ_0 which contains the rearrangement term from Fock channels.