Form factors of $S$-wave charmed baryon multiplet $J^P = \frac{1}{2}^+$. 

S.M. Gerasyuta, E.E. Matskevich

Department of Theoretical Physics, St. Petersburg State University, 198904, St. Petersburg, Russia
Department of Physics, LTA, 194021, St. Petersburg, Russia

Abstract

Electric form factors of $S$-wave charmed baryons are calculated within the relativistic quark model in the region of low and intermediate momentum transfers, $Q^2 \leq 1 \text{GeV}^2$. The charge radii of low-lying charmed baryons are determined.

e-mail address: gerasyuta@SG6488.spb.edu
e-mail address: matskev@pobox.spbu.ru

PACS: 11.55.Fv, 12.39.Ki, 12.40.Yx, 14.20.Lq.

The inclusion of relativistic effects in composite systems is fairly important in considering the quark structure of hadrons [1 – 10]. The dynamical variables (form factors, scattering amplitudes) of composite particles can be expressed in terms of Bethe-Salpeter functions or quasipotentials. The form factors of composite particles were considered by a number of authors, using, in particular, the ladder approximation for Bethe-Salpeter equation [11] and ideas of conformal invariance [12]. A number of results were obtained in the framework of three-dimensional formalisms [13]. Apparently, a fairly convenient way of describing relativistic effects in composite systems may be the use of dispersion integrals in the masses of composite particles. On the one hand, the technique of dispersion integration is relativistically invariant and not related to the consideration of any specific coordinate system. On the other hand there are no problems with the appearance of extra states, since in the dispersion relations the contributions of intermediate states are under control. The dispersion relation technique makes it possible to determine form factors for composite particles [14].

In the paper [15] we have constructed a relativistic generalization of the three-particles Faddeev equations in the form of dispersion relations in the pair energy of the two interacting particles. By the method of extraction of the leading singularities of the amplitude we have calculated the mass spectrum of $S$-wave baryons, the multiplets $J^P = \frac{1}{2}^+$ and $J^P = \frac{3}{2}^+$ [15, 16], and we have obtained the electric form factors of nucleons at low and intermediate momentum transfers [17, 18].

In the present paper we calculate the form factors and the charge radii of $S$-wave charmed baryon multiplet $J^P = \frac{1}{2}^+$. We consider electric form factor of the three-particle systems (charmed baryons) shown in Fig. 1.a. We assume that the momentum of the baryon is large ($P_z \to \infty$). The momenta $P = k_1 + k_2 + k_3$ and $P' = P + q$ correspond to the initial and final momenta of the system, and $P^2 = s$, $P'^2 = s'$; $s$ and $s'$ are the initial and final energies of the system. We assume that $P = (P_0, P_\perp = 0, P_z)$ and $P' = (P'_0, P'_\perp, P'_z)$.

Then we have several conservation laws for the incoming momenta:
\[ k_{1\perp} + k_{2\perp} + k_{3\perp} = 0, \]
\[ P_z - k_{1z} - k_{2z} - k_{3z} = P_z(1 - x_1 - x_2 - x_3) = 0, \]
\[ P_0 - k_{10} - k_{20} - k_{30} = P_z(1 - x_1 - x_2 - x_3) + \frac{1}{2P_z} \left( s - \frac{m_{11}^2}{x_1} - \frac{m_{22}^2}{x_2} - \frac{m_{33}^2}{x_3} \right) = 0, \]
\[ m_{i\perp}^2 = m_i^2 + k_{i\perp}^2, \quad x_i = \frac{k_{iz}}{P_z}, \quad i = 1, 2, 3. \] (1)

Similarly, for the outgoing momenta,
\[ k'_{1\perp} + k'_{2\perp} + k'_{3\perp} - q_{\perp} = 0, \]
\[ P'_{z} - k'_{1z} - k'_{2z} - k'_{3z} = P_z(z - x_1' - x_2 - x_3) = 0, \]
\[ x_1' = \frac{k'_{1z}}{P_z}, \quad z = \frac{P'_z}{P_z} = \frac{s' + s - q^2}{2s}, \]
\[ P_0' - k'_{10} - k'_{20} - k'_{30} = P_z(z - x_1' - x_2 - x_3) + \frac{1}{2P_z} \left( \frac{s' + q_1^2}{z} - \frac{m_{11}^2}{x_1} - \frac{m_{22}^2}{x_2} - \frac{m_{33}^2}{x_3} \right) = 0, \]
\[ m_{i\perp}^2 = m_i^2 + k_{i\perp}^2, \quad q_{\perp} = P'_{\perp}, s' = P'^2 = P_0'^2 - P_{\perp}'^2 - P_z'^2. \] (2)

Form factor for a system of three quarks can be obtained by means of a double dispersion relation:
\[ F(q^2) = \int_{(m_1 + m_2 + m_3)^2}^{A} ds \, ds' \, \text{disc}_{s} \, \text{disc}_{s'} \, \frac{F(s, s', q^2)}{(s - M^2)(s' - M^2)}, \] (3)
\[ \text{disc}_{s} \, \text{disc}_{s'} \, F(s, s', q^2) = G(s, s_{12})G(s', s_{12}) \int d\rho(P, P', k_1, k_2). \] (4)

The integral for the invariant phase-space has the following form (Fig. 1,a):
\[
\int d\rho(P, P', k_1, k_2) = \int (2\pi)^4 \delta^4(P - k_1 - k_2 - k_3) \frac{d^3k_1}{(2\pi)^3(2k_{10})} \frac{d^3k_2}{(2\pi)^3(2k_{20})} \frac{d^3k_3}{(2\pi)^3(2k_{30})} \\
\times (2\pi)^4 \delta^4(P' - k_1' - k_2' - k_3') \frac{d^3k'_1}{(2\pi)^3(2k'_{10})} \frac{d^3k'_2}{(2\pi)^3(2k'_{20})} \frac{d^3k'_3}{(2\pi)^3(2k'_{30})} \\
\times (2k_{20})(2\pi)^3 \delta^3(k_2 - k_2') (2k_{30})(2\pi)^3 \delta^3(k_3 - k_3').
\] (5)

In the presence of a spectator diquark (Fig. 1,b) we obtain:
\[
\int d\rho(P, P', k_1) = \int_{(m_2 + m_3)^2}^{A_{23}} ds_{23} \frac{1}{(2\pi)^2} \int (2\pi)^4 \delta^4(k_{23} - k_2 - k_3) \frac{d^3k_2}{(2\pi)^3(2k_{20})} \frac{d^3k_3}{(2\pi)^3(2k_{30})}
\]
\[
\times \int (2\pi)^4 \delta^4(P - k_1 - k_{23}) \frac{d^3k_1}{(2\pi)^3(2k_{10})} \frac{d^3k_{23}}{(2\pi)^3(2k_{230})} \\
\times (2\pi)^4 \delta^4(P' - k'_1 - k'_{23}) \frac{d^3k'_1}{(2\pi)^3(2k'_{10})} \frac{d^3k'_{23}}{(2\pi)^3(2k'_{230})} (2k_{230})(2\pi)^3 \delta^3(k_{23} - k'_{23}).
\]  

(6)

Upon some transformations, we obtain the form factors of charmed baryons as:

\[
F(q^2) = \frac{1}{8} \left( \frac{1}{(2\pi)^6} \right) (J_3 + J_6),
\]

(7)

here the $J_3$ and $J_6$ are the contributions of Fig. 1,b and Fig. 1,a respectively:

\[
J_3 = I_{23} \int_{0}^{\Lambda_{k_1}} dk_{11}^2 \int_{0}^{2\pi} d\varphi_1 \int_{0}^{1} \frac{dx}{x(1-x)} b \lambda + 1 \left( \frac{1}{b + \lambda f (s - M^2)(s' - M^2)} \right) \times (G(s)G(s'))_3 \Theta(\Lambda_s - s) \Theta(\Lambda_s - s'),
\]

(8)

\[
J_6 = \int_{0}^{\Lambda_{k_1}} dk_{21}^2 \int_{0}^{\Lambda_{k_1}} dk_{21}^2 \int_{0}^{2\pi} d\varphi_2 \int_{0}^{2\pi} d\varphi_2 \int_{0}^{1} dx_1 \int_{0}^{1} dx_2 \left( \frac{1}{x_1 x_2 (1-x_1)(1-x_2)} \right) \tilde{b} \lambda + 1 \left( \frac{1}{\tilde{s} - M^2}(\tilde{s}' - M^2) \right) \times (G(s)G(s'))_6 \Theta(\Lambda_s - \tilde{s}) \Theta(\Lambda_s - \tilde{s}').
\]

(9)

The $I_{23}$ corresponds to the diquark phase space. We introduce the following notations:

\[
b = 1 + \frac{m_s^2 - m_{c}\tilde{c}}{s}; \quad f = b^2 - \frac{4k^2\cos^2\varphi}{s}; \quad \lambda = \frac{-b + \sqrt{(b^2 - f)(1 - (s/q^2)f)}}{f};
\]

\[
s = \frac{m_{11}^2 + x(m_{23}^2 - m_{11}^2)}{x(1-x)}; \quad s' = s + q^2(1 + 2\lambda);
\]

\[
\tilde{b} = x_1 + \frac{m_{11}^2}{\tilde{s}}; \quad \tilde{f} = \tilde{b}^2 - \frac{4k_{11}\cos^2\varphi_1}{\tilde{s}}; \quad \tilde{\lambda} = \frac{-\tilde{b} + \sqrt{(\tilde{b}^2 - \tilde{f})(1 - (\tilde{s}/q^2)\tilde{f})}}{\tilde{f}};
\]

\[
\tilde{s} = \frac{m_{11}^2}{x_1} + \frac{m_{21}^2}{x_1} + \frac{m_2^2 + k_{11}^2 + k_{21}^2 + 2(k_{11}^2 k_{21}^2)^{1/2}\cos(\varphi_2 - \varphi_1)}{(1 - x_1)(1 - x_2)}; \quad \tilde{s}' = \tilde{s} + q^2(1 + 2\tilde{\lambda}).
\]

The quark masses and the two-body cutoff are similar to the paper [19]: $m_{ud} = 0.495 \text{ GeV}$, $m_s = 0.770 \text{ GeV}$, $m_c = 1.655 \text{ GeV}$; $\lambda = 10.7$. The dimensional cutoff parameters for the pair energy of nonstrange, strange and charmed diquarks are $\Lambda_{ab} = \lambda^{(m_a + m_b)^2}$/4: $\Lambda_{uc} = 12.4 \text{ GeV}^2$, $\Lambda_{ac} = 15.7 \text{ GeV}^2$, $\Lambda_{cc} = 29.3 \text{ GeV}^2$. The transverse momentum cutoffs are $\Lambda_{k_1} = 1.04$ for the $\Sigma^{++}$, $\Sigma^+_c$, $\Lambda^+_c$; for the $\Xi^{+A}$, $\Xi^{+S}$ $\Lambda_{k_1} = 1.37$; for the $\Omega^{+}_{ccq}$, $\Omega^{+}_{ccq} \Lambda_{k_1} = 2.70$; for the $\Omega^{+}_{ccs}$ $\Lambda_{k_1} = 2.47$. 


The vertex functions \((G(s)G(s'))_3\) and \((G(s)G(s'))_6\) are determined by the wavefunctions of the corresponding charmed baryons (Appendix 1). To find the form factor of the charmed baryons we must include the interaction of each quark with an external electric field by means of the form factor of nonstrange, strange and charmed quarks: for the \(u, d\)-quarks \(f_q(q^2) = \exp(\alpha_q q^2), \alpha_q = 0.33 \text{GeV}^2\), for the \(s\)-quark \(f_s(q^2) = \exp(\alpha_s q^2), \alpha_s = 0.20 \text{GeV}^2\), and for the \(c\)-quark \(f_c(q^2) = 1\).

The equation (7) use for the a numerical calculation of the form factors with the normalization \(G_E^p(0) = 1\). The behaviour of the electric form factor of the \(\Sigma^+\), \(\Sigma^+_c\) is shown in Fig. 2. The calculated value of the charge radii of the charmed baryons are found to be (Table 1):

\[
R_{\Omega^{++}_{cqs}} < R_{\Omega^{++}_{cqq}} < R_{\Xi^{++}_c}, R_{\Lambda^+_c} < R_{\Omega^{++}_{cqs}}, R_{\Xi^{++}_c} < R_{\Sigma^{++}_c} < R_{\Sigma^+_c}. \quad (11)
\]

The charmed radii of the neutral baryons are found to be practically equal to zero.

It is worth noting that we do not use any new parameters here. All of the parameters involved were borrowed from the calculations of the mass spectrum of the \(S\)-wave charmed baryons [19].

**Acknowledgment**

The authors thanks D.V. Ivanov for the assistance with the calculations. The work was carried with the support of the Russian Ministry of Education (grant 2.1.1.68.26).

**References.**

1. F. Gross, Phys. Rev. Lett. **140**, 410 (1965).
2. H. Melosh, Phys. Rev. D**9**, 1095 (1974).
3. G.B. West, Ann. Phys. (N.Y.) D**74**, 464 (1972).
4. S.J. Brodsky and G.R. Farrar, Phys. Rev. D**11**, 1309 (1975).
5. M.V. Terent’ev, Yad. Fiz. **24**, 207 (1976) [Sov. J. Nucl. Phys. **24**, 106 (1976)].
6. V.A. Karmanov, Zh. Eksp. Teor. Fiz. **71**, 399 (1976) [Sov. Phys. JETP**44**, 210 (1976)].
7. I.S. Aznauryan and L.N. Ter-Isaakyan, Yad. Fiz. **31**, 1680 (1980) [Sov. J. Nucl. Phys. **31**, 871 (1980)].
8. A. Donnachie, R.R. Horgen, and P.V. Landshoft, Z. Phys. **C10**, 71 (1981).
9. L.L. Frankfurt and M.I. Strikman, Phys. Rep. C**76**, 215 (1981).
10. L.A. Kondratyuk and M.I. Strikman, Nucl. Phys. A**426**, 575 (1984).
11. R.N. Faustov, Ann. Phys. **78**, 176 (1973).
12. A.A. Migdal, Phys. Lett. B**37**, 98 (1971).
13. R.N. Faustov, Teor. Mat. Fiz. **3**, 240 (1970).
14. V.V. Anisovich and A.V. Sarantsev, Yad. Fiz. **45**, 1479 (1987) [Sov. J. Nucl. Phys. **45**, 918 (1987)].
15. S.M. Gerasyuta, Yad. Fiz. **55**, 3030 (1992) [Sov. J. Nucl. Phys. **55**, 1693 (1992)].
16. S.M. Gerasyuta, Z. Phys. C**60**, 683 (1993).
17. S.M. Gerasyuta, Nuovo. Cim. A**106**, 37 (1993).
18. S.M. Gerasyuta and D.V. Ivanov, Vest. St. Peterburg Univ. Ser. 4, 2 (11), 3 (1996).
19. S.M. Gerasyuta and D.V. Ivanov, Yad. Fiz. **62**, 1693 (1999).
Fig. 1 a, b. Triangle diagrams the form factors of charmed baryons.

Fig. 2. Electric form factors of the charmed baryons $\Sigma_{c}^{++}$, $\Sigma_{c}^{+}$ at small and intermediate transfers $Q^2 < 1 \text{GeV}^2 (Q^2 \equiv -q^2)$.

Table 1. The $S$-wave charmed baryons charge radii $J^P = \frac{1}{2}^+$.}

| particle | mass (GeV) | charge radius (fm) |
|----------|------------|--------------------|
| $\Lambda_{c}^+$ | 2.284 | 0.34 |
| $\Sigma_{c}^{++}$ | 2.458 | 0.39 |
| $\Sigma_{c}^{+}$ | 2.458 | 0.41 |
| $\Xi_{c}^{+}$ | 2.667 | 0.34 |
| $\Xi_{c}^{+}$ | 2.565 | 0.35 |
| $\Omega_{cqq}^{++}$ | 3.527 | 0.32 |
| $\Omega_{ccq}^{+}$ | 3.527 | 0.35 |
| $\Omega_{ccq}^{++}$ | 3.598 | 0.25 |
Appendix 1. The vertex functions of the charmed baryon multiplet $J^P = 1^+$. 

$\Sigma_{c}^{++}$: 

$$(G(s)G(s'))_3 = \frac{1}{18} \frac{1}{4} \left( A_1^{(c)}(s, s_0) f_q(q^2) e_u (s) 12 + A_0^{(c)}(s, s_0) f_q(q^2) e_u 36 + A_1^{(c)}(s, s_0) f_q(q^2) e_u 24 \right)$$

$$(G(s)G(s'))_6 = \frac{1}{18} \frac{1}{4} \left( A_1^{(c)}(s, s_0) f_q(q^2) e_u (s) 12 + f_c(q^2) e_u 12 \right) + A_0^{(c)}(s, s_0) f_q(q^2) e_u 36 + f_c(q^2) e_u 36 + A_1^{(c)}(s, s_0) f_q(q^2) e_u 48 \right)$$

$\Sigma_{c}^+$: 

$$(G(s)G(s'))_3 = \frac{1}{36} \frac{1}{4} \left( A_1^{(c)}(s, s_0) f_q(q^2) (s) 12 + e_d 12 \right) + A_1^{(c)}(s, s_0) f_q(q^2) (s) 36 + e_d 36 + A_1^{(c)}(s, s_0) f_q(q^2) (s) 24 \right)$$

$$(G(s)G(s'))_6 = \frac{1}{36} \frac{1}{4} \left( A_1^{(c)}(s, s_0) f_q(q^2) (s) 12 + f_c(q^2) e_c 24 \right) + A_0^{(c)}(s, s_0) f_q(q^2) (s) 36 + e_d 36 + f_c(q^2) e_c 72 + A_1^{(c)}(s, s_0) f_q(q^2) (s) 48 + e_d 48 \right)$$

For the $\Sigma_{c}^{++}$: $A_1(s, s_0) = 0.431$, $A_1^{(c)}(s, s_0) = 2.203$, $A_0^{(c)}(s, s_0) = 2.534$.

$A_{c}^+$: 

$$(G(s)G(s'))_3 = \frac{1}{12} \frac{1}{4} \left( A_1^{(c)}(s, s_0) f_q(q^2) (s) 6 + e_d 6 \right) + f_c(q^2) e_c 12 \right) + A_0^{(c)}(s, s_0) f_q(q^2) (s) 2 + e_d 2 + f_c(q^2) e_c 4 \right) + A_0^{(c)}(s, s_0) f_q(q^2) (s) 8 + e_d 8 \right)$$

$$(G(s)G(s'))_6 = \frac{1}{12} \frac{1}{4} \left( A_1^{(c)}(s, s_0) f_q(q^2) (s) 18 + e_d 18 \right) + f_c(q^2) e_c 12 \right) + A_0^{(c)}(s, s_0) f_q(q^2) (s) 8 + e_d 8 \right) + f_c(q^2) e_c 16 \right)$$

For the $A_{c}^+$: $A_0(s, s_0) = 0.984$, $A_1^{(c)}(s, s_0) = 2.23$, $A_0^{(c)}(s, s_0) = 2.548$. 


\( \Xi^{+A}: \)

\[
(G(s)G(s'))_3 = \frac{1}{12} \frac{1}{4} \left( A_1^{(c)}(s, s_0)(f_q(q^2) e_u 6 + f_c(q^2) e_c 6) + A_1^{(sc)}(s, s_0)(f_q(q^2) e_u 6 + f_c(q^2) e_c 6) + A_0^{(c)}(s, s_0)(f_q(q^2) e_u 2 + f_c(q^2) e_c 2) + A_0^{(sc)}(s, s_0)(f_q(q^2) e_u 2 + f_c(q^2) e_c 2) + A_0^{(c)}(s, s_0)(f_q(q^2) e_u 8 + f_s(q^2) e_s 8) + A_0^{(sc)}(s, s_0)(f_q(q^2) e_u 8 + f_s(q^2) e_s 8) \right)
\]

\( (G(s)G(s'))_6 = \frac{1}{12} \frac{1}{4} \left( A_1^{(c)}(s, s_0)(f_q(q^2) e_u 12 + f_c(q^2) e_c 12) + A_1^{(sc)}(s, s_0)(f_q(q^2) e_u 12 + f_c(q^2) e_c 12) + A_0^{(c)}(s, s_0)(f_q(q^2) e_u 4 + f_c(q^2) e_c 4) + A_0^{(sc)}(s, s_0)(f_q(q^2) e_u 4 + f_c(q^2) e_c 4) + A_1^{(c)}(s, s_0)(f_q(q^2) e_u 12 + f_c(q^2) e_c 12) + A_0^{(sc)}(s, s_0)(f_q(q^2) e_u 12 + f_c(q^2) e_c 12) + A_0^{(c)}(s, s_0)(f_q(q^2) e_u 36 + f_c(q^2) e_c 36) + A_0^{(sc)}(s, s_0)(f_q(q^2) e_u 36 + f_c(q^2) e_c 36) + A_0^{(c)}(s, s_0)(f_q(q^2) e_u 48 + f_c(q^2) e_c 48) + A_0^{(sc)}(s, s_0)(f_q(q^2) e_u 48 + f_c(q^2) e_c 48) \right)
\]

For the \( \Xi^{+A}: \) \( A_0^{(s)}(s, s_0) = 1.032, A_1^{(c)}(s, s_0) = 1.80, A_0^{(c)}(s, s_0) = 1.888, A_1^{(sc)}(s, s_0) = 0.953, A_0^{(sc)}(s, s_0) = 1.147. \)

\( \Xi^{+S}: \)

\[
(G(s)G(s'))_3 = \frac{1}{36} \frac{1}{4} \left( A_1^{(c)}(s, s_0)f_s(q^2) e_s 12 + A_1^{(sc)}(s, s_0)f_q(q^2) e_u 12 + A_0^{(c)}(s, s_0)f_s(q^2) e_s 36 + A_0^{(sc)}(s, s_0)f_q(q^2) e_u 36 + A_1^{(c)}(s, s_0)f_s(q^2) e_s 48 + A_0^{(sc)}(s, s_0)f_q(q^2) e_u 48 \right)
\]

\( (G(s)G(s'))_6 = \frac{1}{36} \frac{1}{4} \left( A_1^{(c)}(s, s_0)(f_q(q^2) e_u 12 + f_c(q^2) e_c 12) + A_0^{(c)}(s, s_0)(f_q(q^2) e_u 4 + f_c(q^2) e_c 4) + A_1^{(c)}(s, s_0)(f_q(q^2) e_u 12 + f_c(q^2) e_c 12) + A_0^{(sc)}(s, s_0)(f_q(q^2) e_u 36 + f_c(q^2) e_c 36) + A_1^{(sc)}(s, s_0)(f_q(q^2) e_u 48 + f_c(q^2) e_c 48) \right)
\]

For the \( \Xi^{+S}: \) \( A_1^{(c)}(s, s_0) = -0.373, A_1^{(sc)}(s, s_0) = 1.281, A_0^{(c)}(s, s_0) = -1.173, A_1^{(sc)}(s, s_0) = -2.954, A_0^{(sc)}(s, s_0) = 1.042. \)
\( \Omega_{ccq}^{++} \):

\[
(G(s)G(s'))_3 = \frac{1}{36} \frac{1}{4} \left( A_1^{(c)}(s, s_0) f_c(q^2) e_c 24 + A_0^{(c)}(s, s_0) f_c(q^2) e_c 72 + A_1^{(cc)}(s, s_0) f_{q}(q^2) e_u 48 \right)
\]

\[
(G(s)G(s'))_6 = \frac{1}{36} \frac{1}{4} \left( A_1^{(c)}(s, s_0)(f_c(q^2) e_c 24 + f_{q}(q^2) e_u 24) + A_0^{(c)}(s, s_0)(f_{c}(q^2) e_c 72 + f_{q}(q^2) e_u 72) + A_1^{(cc)}(s, s_0)f_{c}(q^2) e_c 96 \right)
\]

For the \( \Omega_{ccq}^{+} \): \( e_u \to e_d \).

For the \( \Omega_{ccq}^{++} \): \( A_1^{(cc)}(s, s_0) = 0.478, A_1^{(c)}(s, s_0) = 2.116, A_0^{(c)}(s, s_0) = 2.433 \).

\( \Omega_{ccs}^{+} \):

\[
(G(s)G(s'))_3 = \frac{1}{36} \frac{1}{4} \left( A_1^{(sc)}(s, s_0) f_c(q^2) e_c 24 + A_0^{(sc)}(s, s_0) f_{c}(q^2) e_c 72 + A_1^{(cc)}(s, s_0) f_{s}(q^2) e_s 48 \right)
\]

\[
(G(s)G(s'))_6 = \frac{1}{36} \frac{1}{4} \left( A_1^{(sc)}(s, s_0)(f_c(q^2) e_c 24 + f_{s}(q^2) e_s 24) + A_0^{(sc)}(s, s_0)(f_{c}(q^2) e_c 72 + f_{s}(q^2) e_s 72) + A_1^{(cc)}(s, s_0)f_{c}(q^2) e_c 96 \right)
\]

For the \( \Omega_{ccs}^{+} \): \( A_1^{(cc)}(s, s_0) = 0.51, A_1^{(sc)}(s, s_0) = 1.686, A_0^{(sc)}(s, s_0) = 1.95 \).